Field Notes: McMurdo Dry Valleys, Antarctica

of

Bruce D. Marsh

1993-2008

These are my raw, unedited field notes, with only some confusing misspellings fixed due to the typist's misinterpretations. Some parts of them have been referenced in the manuscript. For the first two seasons, the base camp was at Solitary Rocks, on the upper valley (Simmons Valley) shelf. The next season Base Camp was in the center-east area of Bull Pass near the small frozen ponds. For the remaining years, the Base Camps were all at the south edge of Bull Pass, with a subsidiary camp in Beacon Heights (Valley) for a short time. All present additions are in bold italics, additions entered at the time of the notes are in [brackets].

Chapter 1—1992

1/11/93
Helo recon from McMurdo; overcast, 30°, breezy, leaving at 9:20 a.m.

Beacon Valley:
Thin sills, most all at higher elevations, much scree down low. The west side is rather messy.

Areana Valley:
Some thin and irregular sills at higher elevations, not much down low, smooth scree.

Solitary Rocks:
Excellent
Looks like one thick sill on the south side and 2 on the north side? Better view back from south side of Kukri Hills it is 2 sills, the lower one dips beneath ice on the south wall of solitary rocks.

New Mountain:

Sill is only well exposed on the wall facing solitary rocks and only for a short distance. It may be possible to sample.

North Knobhead area is all smooth scree.

Basement Sill on south side of Kukri Hills dips markedly to the west and can be sampled about 2 miles east of west end of Kukri Hills.

Solitary Rocks
13 January 1993, clear, wind ~ 5-10, 40°F, 2 p.m.
Left camp at ~2650' and slowly made our way upward on the west side of Solitary Valley through the Basement sill. Our camp rests exactly on the lower contact of the sill and the Irizar granite. The sill is almost exactly 1000' thick here and the Irizar granite is also the roof rock. About 500' higher is the Peneplain sill. The sill itself is diabase and fairly uniform until one reaches the upper 200 - 300' or so. Here there are coarse lenses of more felsitic rock. Some are as thick as 1 - 2 meters and 30 - 40 m long. They are often irregulars and snake around somewhat at the contact. Although they are overall coarse grained, they seem coarser grained at the top than at the bottom. They are, nevertheless, sometimes splotchy in grain size as if parcels were locally emplaced within the lense itself. The upper contact is knife sharp. And fairly horizontal although there is a regional tilt to the body, but it is slight. There is an occasional block of granite contained in the sill just below the contact. These show chilled diabase all around them and no sign of recrystallization or fusion.

14 January 1993, 3:30 p.m., partly cloudy, some breeze ~ 30°F
West side of Solitary Valley; midway up the sill is a thick opx-norite cumulate with numerous thin, horsetail stringers of white anorthositic layers. Overall the rocks is massive with opx generally fining upward from the massive cliff-forming zone. The opx layer is 50 - 75 m thick or more and has some internal structure. Other than the plag. wisps, there are large blocks? (2m x 20 cm) of grey, finer grained opx rock with fine internal laminations. They are hap-hazardly arranged and have a leudocratic _____. These blocks are scarce, but are obvious when present. They may have been in the body upon injection, perhaps from the walls of an early conduit.
The plag. wisps seem like normal sedimentalogical features as demonstrated by Coats in 1935.

17 January, sunny, clear, wind mod. 28°F.
On opx band SW of camp in Gunn Valley. The opx is large and v. abundant here relative to that of the same horizon in Pearse Valley to the NE, which we visited yesterday. The coarse grained segregations are always in the upper ~200' of sill. They start with some small blotches (from the bottom) and quickly (~10m) grade into large coarse lenses (1m x 20 - 30 - 40 m). The coarsest xtals are clearly at the top (2-3 cm cpx) and finest at the bottom. Their edges undulate irregularly, but they are roughly horizontal. With increasing height the lenses become smaller and more numerous such that the hillside is a series of small cliffs made up of these interleaved lenses. They grade down, over a height of ~ 100-150', to irregular splotches here and there.

18 January 1993, sunny and clear, south wind 5 - 10 mph, ~ 35°
SW side of Valley of Solitary rocks: Here we have found a thick (2m) granophyre layer immediately above a coarse, pegmatitic layer of the usual kind. The layer is find grained, massive, and grey. It is about 150' long and disappears under rubble. Once seen it can followed easily. It is about 50 - 60' from the upper contact. Near the upper contact there is a series of horizontal bands where this whole process is seen on a small scale. Each band consists of a fine granophyre (1/4 - 1/2 inch) followed beneath by a coarse layer of similar thickness. These bands are about 1' apart and they increase in spacing and strength with distance into the body. These bands are about 35-40' below the upper contact.
The next question is whether these massive granophyres are found below this level. It's 7:10 p.m., it has been a long, productive day.

19 January 1993
Pandoras Spire, Peneplain S.V.

B-1	4260 contact
B-2	4275' near vein
B-3	4320
B-4	4375 massive
B-5	4470
B-6	4500 granite veins this high
B-7	5480 - 20' below summit
B-8	5440 Pegmatoid
B-9	5850 Turnagin
B-10	5820
B-11	5760
B-12	5720
B-13	5660
B-14	5540
B-15	5490 edge of glacier

perhaps 100-150' above basal, covered 2:25 p.m. contact

21 January 1993, clear, slight breeze from south
opx horizon: There is a 5 cm wide granite dikelet at this level cutting the diabase. It strikes SE-NW and is vertical. It has a 5 mm chilled margin on its edge and sometimes massive feldspar (bluish) with large intermingled quartz grains. The granite is medium grained and light pink in color.
Near upper contact, SW side of valley, almost directly west of camp: About 40 - 50' inward starts the coarse segregations as distinct lenses, first ~ 1", then 2", then up to 6" over a distance of about 10' vertical. The grain size is about twice as coarse as the usual diabase, lighter in color, and both upper and lower contacts are fairly sharp. Often a 1/4" band of light granophyric rock occurs along the upper contact. These lenses pinch and swell horizontally and are spaced about 18" apart.

Chapter 2 -- 1994

McMurdo
6 Jan. 1994

David Brenahan et al.
8:15 Sunday (Galley)
Science/Lectures

Julie Palais - 110 room
xt. 4110

Box request

Pam Hill
Day Trip Request Close support: requests can be put in early and modified late

Recon Tomorrow. Camp put in on Saturday

9 January 1994
Sunny and bright, gentle northwind 10 mph. 30°F

Solitary Rocks: 11:45 a.m.
2500 ele. west shoulder of valley, near head of lower valley. I saw from a distance a tan, odd object, which turns out to be a desiccated seal. Yes, a seal some 5.5' long, head north and upper part of body strongly sand blasted. The skull is bare although the eye is mostly remaining. It is lying on its side, right side and its left flipper can be thoroughly seen to the bones. How it got here is a real mystery since we are some ~50 km from McMurdo Sound. We walked by here many days last year and it was not here. They have been known to migrate into the interior, oddly enough, but this is up on a shelf with rough country between here and the Taylor glacier. The girls are all excited about it, but they may well have walked right by without noticing it.

Upper contact of Basement Sill and irizar granite (3675'): Can sight across exactly to contact on opposite side of valley. Here, near mouth of valley on West Solitary Rocks the segregations begin in earnest at ~150' below the upper contact. Below this horizon are only scattered bread loaf to watermelon size blobs of segregation material. But they have the usual characteristics of sharp upper contact with coarse cpx crystals growing downward into a milky matrix. The cpx get as large as 7 or 8 cm x 1/2 cm. Above this a layer lens (near 150' below contact) begins with a thickness of about 20 - 30 cm and a length of 8 - 10 m. Continuing upward shows larger segregation lenses and an anastomosing complex of large - horizontal segregations connected by more vertical tears and patches. The lenses overall are still dark in color and there is no way they could ever be seen from the air. Still there is a strong felsic component and they might be detachable by remote sensing in a detailed survey.

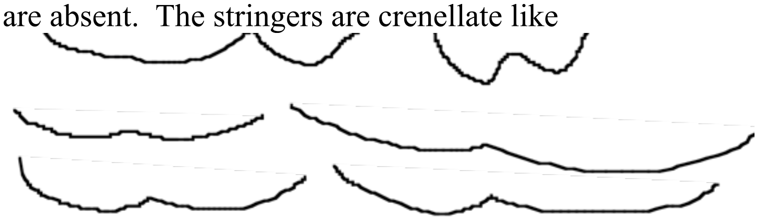
At the upper contact there is no strong, obvious alteration (melting or otherwise) noticeable in the granite, which must have been hot since the Peneplain Sill is only some 600 - 800 ' above.

The lenses themselves begin in earnest ~ 75' from the contact and carry on downward to ~150'. The main lenses are clearly horizontal, but overall it is an anastomosing sequence of tears filled with late stage melt. And these are places where sharp fine grained layer of light color diabasic rock, which is exactly like we saw last year as "andesitic" brows on the lenses. Here this example separates two lenses, each about 8 - 10' thick. The upper lens grades down into the band (which is ~ 3' thick) while the contact is sharp with the lower lens. We have taken massive block samples through both lenses and band also.

10 January 1994
Monday, clean and bright, gentle (5 - 12 mph) s wind, 32°F.

East side of Solitary Rocks Valley in the opx cumulative zone near camp.

The first cliff is the opx layer. The layer begins fairly abruptly over a vertical distance of about 50 feet with the opx gaining in proportion to cpx. There is plenty of pyroxene around before opx became abundant. The presence of plagioclase stringers signals the beginning of opx. The stringers are pervasive and very regular locally, but in some areas are absent. The stringers are crenellate like



locally and are subhorizontal ~ 1 cm thick and up to 2 m long. In rare places they are 3 - 4 cm thick and ~ 1-2 m wide. They often appear as apron like layers with the cumulate. They are often nearly 100% plagioclase, and appear as a result of local segregations in a sedimenting thick suspension. The opx zone ends with the wispy plagioclase zones and the rock becomes much lighter in color - gray like andesite with very few opx and smaller cpx and much more of a felsic component. This felsic zone is ~ 100 ' thick and the rock gets progressively darker and here, oddly enough, the segregations so common elsewhere are here diffuse irregular and dark but still coarse. The upper chill is normal with no apparent affect on the granite and an occasional veinlet (qtz - ose) downward into the sill. The sill is also ~ 1000' thick here.

11 January 1994

Bright sun, wind 15 mph gusting to 30-35; air ~ 25°F with wind <0°F, but okay working.

Below camp on lower contact with Irizar granite for Pearse pluton. The contact is generally clean, there are small chips and pieces of granite in the sill, but nothing that has floated inward. The chips, etc., are generally where the sill seems to be searching for its direction of emplacement. The granite itself is massive, coarse, and pink. It contains numerous dark inclusions of basic rock often contaminating large (1 cm) pink kspar phenocrysts, although the inclusions themselves are fine grained. There are some 2-10 cm aplite stringers running ~ E-W, and there are some purplish zones up to 1 m wide where the granite has been partly recrystallized.

We have taken three samples in the first 50' below the contact.

Hel. S 77°33.49
E 160°54.53

14 January 1994 Friday
Solitary Rocks

Yesterday we took the helicopter to the Labyrinth sill in the Wright Dry Valley, west end, and sampled the sill from top to bottom. It is a massive sill with no obvious segregations, but plenty of fresh rock and contains sparse opx, but no obvious high concentration band. The rock is weathered in some places, but fresh samples can be readily found. The sill has a weak banding near the upper 1/4 of it - its thickness is about 700' or so and it is at the elevation of the sill upon which I now sit - the Basement Sill. On the day before yesterday we hiked up through the Basement Sill and its overlying granite to the overlying granite to the overlay sill the Peneplain sill and found a thin slice (~ 100') of Beacon sandstone between the granite and the sill. This sandstone cannot be seen from afar as it is covered by the debris from the sill. The granite is massive, fairly uniform and with inclusions of dark - kspar bearing rock. The granite does not look much deformed or metamorphosed, but is fresh and clean. It is wonderfully sculpted by the wind in many places.

Today (14th) we went up the SW side of Valley here to the area we studied last year containing segregations. In general, the area is laced with small scale, blotchy and patchy coarse segregations with horizontal lens-like segregations only over a specific horizon of say, 10 m vertically. Some of these lenses (at least 1 here) are spectacular in having a knife sharp upper contact with large (1 - 10 cm) cpx's growing downward. The lenses themselves seem not more than 1 m thick and 20 m long. It is clear that the detailed nature of the segregation zone changes from place to place. In some areas lenses are prominent and in other areas (east of camp) lenses are scarce.

There is also a clear sign that the rock above the opx horizon is more felsic than elsewhere in the sill. This appears as a lighter colored rock, but still of the usual diabase texture.

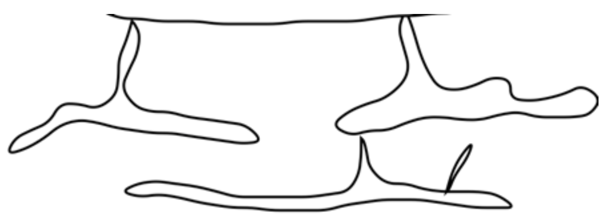
The opx concentration does not seem to get over about 25 - 30% and it certainly does not appear to have been a highly concentrated suspension or slug flow of crystals.

16 January 1994
overcast, windy, chilly, 30°F
SW cliffs of Solitary Valley

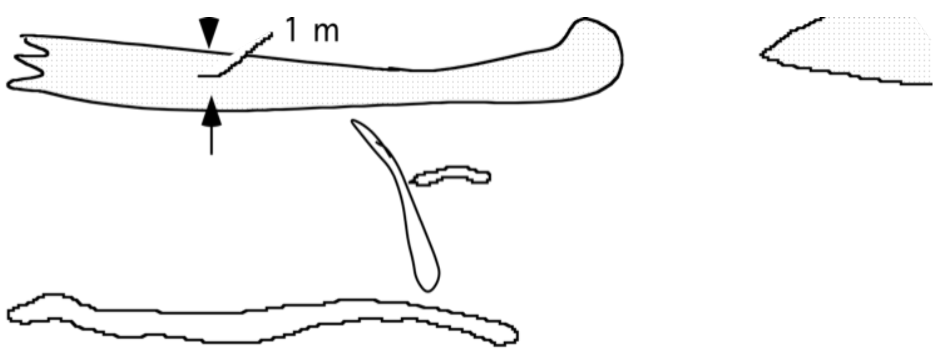
The segregations here are of many kinds. Some are very well formed lenses 10 cm - 10 m and curving upward and horizontal. Others esp. in the splotchy horizon give the impression of bulbous or pillow like masses of many sizes interwoven; the cliff faces sometimes show breadloaf size holes where segregations have been weathered away. These individuals also have, most often, thin stronger like upper contact 1 - 2 mm thick.

Other segregations are lens felsic, broad 50-70 cm and steeply inclined 75-80°, but still seem lens like. The well formed longer lenses invariably have a knife sharp upper contact with 1-3mm fine grained leucocratic selvage. The lower contacts are gradational??? always.

Further SE we saw a splendid set of exposures showing the full set of lens relationships.



And often there is a simple massive lens up to 1 m in thickness with smaller irregular connectors running nearby.



and the horizon runs more or less continuously through interdigitation The textures of the lenses are invariably coarsest at the tops, but the thickest (1m) lenses seem nearly uniform throughout in medium coarse grained cpx and plagioclase, with cpx up to about 1 cm in length and fairly nondirectional in growth habit.

The region itself is about 100' beneath the upper contact. It is clear that these segregations are fracture related fillings, with connectors and small climbing lenses, but overall the whole system is one of horizontal lenses.

Hike to the Lake at Front of Valley.

(Near the end of the season, on a reconnaissance flight into lower Wright Valley, I was impressed by the excellent outcrops at SW Bull Pass and, upon landing and looking at the rocks, I was struck by the massive concentrations of Opx. We made a rough sampling of the area, and from this sampling planned to base future work in this area.)

Chapter 3 – 1996
Central Bull Pass, near frozen Lakes

- 1996 -
Antarctic Field Season

6 Jan. 1996 - 10:15 p.m., cold, overcast, snowy

After setting up camp at 1 - 3 p.m., we took a hike east of here through the Basement Sill. Our camp is ~ 1 mile from the lip of the descent to Wright Dry Valley and we sit pretty much in the middle of the Valley.

Our camp is on granite coarse, with lamprophyre dikes and some large kspar phenos. Our hike took us to the top of the sill, which is 980' above the camp which is at or near the lower contact, which is not seen but abundant chilled phase ventifacts tell its presence. The entire sill is dominated by very coarse ortho pyroxenite - some opx crystals reach as large as 1 cm, but most are 2-6 mm. In some places it is massive in opx. In others it is 75% opx and 25% plag. The plag. crystals are not as coarse as the opx. Wispy plag segregations are abundant, and in the upper part of the sill there is a clear tendency to form cryptic horizontal layering of plag., but it is not well developed.

In the upper 25% of the sill, the sill becomes more felsic and the feldspar forms almost a chicken wire network connecting larger plag. crystals in a mass of large opx. In the upper 150', segregation veins start and some are rather coarser with the snow, however, it is difficult to tell the geometry, but they are very much like all the others we have studied in years past.

SAMPLES:

ABP(Antarctic Bull Pass)	1 upper chilled margin chilled against granite
ABP-2	Plag. vein, unusually large, with some opx phenos
ABP-3	Felsic, opx bearing med. grained diabase from rib above valley mouth ~ 600 ' above camp
ABP-4	dark similar fractured diabase near #3 <u>but</u> from between

<u>7 July 96</u> - cold, (26°F) no sun; Temp is 18°F at 3,600'
The ribs here are erosional with only a slight difference in the diabase. the ribs themselves are more felsic and more massive. The interribs are less felsic, but mainly more fractured and weathered. This all is <u>much</u> finer grained than the opxite of yesterday and across the valley to the SW.

Continuing on up at ~ 1500' the contact is with a coarse grained granite containing 1-5 cm kspar mega-crystals. This granite is cut by a fine grained quartz diorite, which forms wide dikes (2-3 m) forming low smooth ~E-W ribbons. The granite forms rough interdike rock and would appear as a dike on the photo. The granite is somewhat dark in its matrix.

The diabase below is fine at the base an coarsens upward and then fining some before a hard chill at about 1350' ele. Just below the chill the diabase is obscure.

SAMPLES DOWNWARD:

ABP-5	Upper chill 1500
ABP-6	1400'
ABP-7	1300'
ABP-8	1200'
ABP-9	1100'
ABP-10	1000' from between septa or ribs - this is a coarse cpx/opx rock
ABP-11	900'
ABP-12	800', plag strings
ABP-13	665', massive below ribs by 200'

ABP-14 med. grained near bottom

The actual contact is obscured in scree but I would estimate we are well within 200' of the contact.

This section is coarse grained, but not as coarse as the other side of the Pass or as coarse as that near camp. But it is still some of the coarsest rock I have ever seen in this region. There are occasional (rare) patches where the opx are 3" long, and 5 mm wide. The coarsest areas are also clearly where the rock is most felsic. This may be somewhat deceptive because where the rock is blackest and also very fresh it is difficult to clearly discern all the pyroxenes.

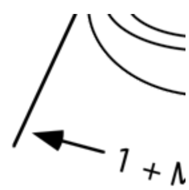
Overall the ribbed structure seems to be due to a slab like weathering of more highly jointed rock, which also seems always wetter and darker. These regions form low topography and the less jointed, more massive and more resistant. They could also be more felsic - this will have to wait for thin sections.

8 Jan. '96 Clear and nice 25F, 5 mph SE wind

Starting from camp going east up sill.

Here rock is also ribbed although less distinct on photos, but clear in field Gully's are more altered and jointed.

A-15 sample of plag bands in concentric vertical layering area



This section of the Basement Sill (east wall Bull Pass, halfway through the pass) is coarse grained through most of its thickness which is near 1000' thick, the bottom is not exposed and the exposed thickness is about 900'.

Near camp there is a circular outcrop (100' dam.) that is coarse and even shows segregation veins, which is highly unusual for any lower contact region - it may well be a vent area or the top of deeper sill, which is unlikely because the basal region of the Basement Sill is nearby and below it.

The sill itself is almost all cumulate opx although the size and abundance vary considerably. The lower half commonly has 2-5 mm opx, but near 400' it becomes coarser to 2-8 mm even occasionally a 1 cm crystal. There are wispy plag. segregations throughout the lower 2/3 of the body. Above this part the rock becomes more felsic and more equigranular.

The lower ribbed and jointed part gives way distinct to more massive rock near ~ 400' where the crystals become coarser. There is a distinct change in slope here and the rock is much more prominent; it is rather subdued in outcrop below. This may be where the upper and lower sets of cooling cracks or joints meet.

A-16 sample of dike cutting granite at upper contact.

The lower half is also more altered and jointed, whereas the upper half is fresher with no apite dikes, some of which are 10 cm thick in the lower half.

We will begin sampling at the upper contact, which is with granite. The contact is clean and dipping to the north.

A-1	920' is chill from 1/6/96
A-17	800', segregation zone - the upper 150 of the sill contains abundant segregations. First patches then lenses then patches again
A-18	700' equigranular dolerite
A-19	600' felsic cpx dolerite - not much opx. Opx begins at ~450 but at 400' the opx is large and the rock very felsic
A-20	500' opx - plag rock. This is an anorthositic zone opx up to ~7-8 mm
A-21	400' opxenite massive
A-22	300', massive zone opxenite
A-23	200' much finer grained cumulate

The transition from the massive to thin flatter rock is at 280' elevation.

A-24	100' finer grained dolerite
A-25	0' opx rich med-coarse granite, heavy concentration of pyroxene

9 Jan. '96 Tuesday

Peneplain Sill
Pandora's Spire

Starting - 200' below where last sample was taken in saline pit area in 1994.

PPS-96-1	at -200' This is about 50' above contact which is obscured here [Actually this may be very near contact and lower rock is scree.]
PPS-96-2	-150'
PPS-96-3	-100'
PPS-96-4	-50'
PPS-96-5	0' top of cliff level with previous sampling (1994) on 300 m east of there

Then at the opx cumulate cliffs on the east side of Solitary Rocks Valley - our old homestead - where we spent from noon to 4 looking for and at plag. layers in the opx cumulates. See a whole series of pictures from roll #9. [The plag. layers here are more cuspate and "truncated" than in some other areas where layers continue without being cuspate or "crossbedded."]

10 Jan. '96 Wednesday

Overcast & cool - snow last evening is gone

11 Jan. '96 Thursday

Clear, nice, SW wind, nice. North rim Wright Valley

Tracing out Basement Sill towards the sea. About 0.75 mile east of Bull Pass Sill is ~200' thick and thins east to nothing. Sill is dark, fine grained diabase throughout.

A-26	upper chill
A-27	50' down
A-28	100' down
A-29	150' down run but 20' above contact
A-30	small 1' thick sill below contact

~1/2 mile east of Bull Pass near sharp cleft in sill. Samples from top. Center is coarse material.

A-31	chill fine grained [top]
A-32	50' lower fine grained
A-33	transition to coarser central material
A-34	another transitional sample some 4m west
A-35	20 cm above A-34
A-36	30' below A-34
A-37	the lower fine grained dolerite just below the inner coarser material

The contrast between these two rock types is clear in the field. The outer rock is almost ceramic like and forms stiff, platy outcrops; whereas the coarse grained rock (inner unit) is friable and subdued, forming poor exposures.

The contact itself is fairly sharp, but not an intrusive contract as it is intimate and irregular on a very small (cm) scale, not planar and sharp in the essence of a second intrusion. The rock texture coarsens over a distance of about 1m or less.

<u>12 Jan. '96</u>
Sun, partly cloudy, with south wind, 5-10 mph

Contact at mouth of valley, east [actually west] side

Chill is hard and very fine. Within 10m it does not ring like a bell, then rock <u>slowly</u> coarsens and contains more pyroxene. At 125' up it contains 2-4 mm cpx and opx.

There are some xenoliths of granite at ~ 60' from the base. Some of the few I have seen.

<u>13 Jan. '96</u>
West Ridge Bull Pass, snowing (27°F)

Sampling down the ridge at 50' intervals.

Upper contact is irregular and confused between dolerite and granite, both are most often altered, but a few areas are fresh.

There is a good zone of segregations thickening downward, many do not seem to show good fining of crystals downward.

Some of the dolerite close (~2m) to the contact is coarse gray dolerite - odd. It is not the opx cumulate phase but it is 2 mm in grain size. This seems to be a circular region running down the slope to Wright Valley.

A-38	at 710' above camp, or about 900' above lower contact
A-38	upper chill
A-39	The coarser diabase as mentioned above

Segs Starting

A-40	dolerite at 660'
A-41	at 610', segs in full bloom
A-42	at 550'
A-43	at 500'
A-44	at 450'

Segs gone

A-45	at 400' coarse opx
A-46	at 350'
A-47	at 300'
A-48	at 250'
A-49	at 200'
A-50	at 150'
A-51	at 100'
A-52	at 40'
A-53	at -10'
A-54	at -60'
A-55	at -110'
A-56	at -170'
A-57	at -220'
A-58	at -270'
A-59	at -320'
A-60	at -360' lower contact

End of sampling this section. 5:20 p.m. Start home at 5:45, home at 6:45.

14 Jan. '96 Sunday
Occasional sun, stiff North breeze

East of camp on sill, comparing grain size on a detailed scale and tracing out big joints and aplite dikes

at bottom	2 mm grainsize (larger)
100'	3 mm - largest hand samples
150'	4-5 m - largest hand samples
250'	5-6 mm – largest hand samples
300'	1-2 cm on big face also here solidified granitic xenolith 20 x 10 cm - not at large crystal location
360'	there is a thick plag. zone anorthosite with disseminated opx up to 8 mm in length but these are slender almost needle-like crystals. Almost no cpx in these zones of plag. The plag. zone is 50 cm thick and 2 m or more wide
425'	rock is generally felsic with coarse grained, blocky pyroxene 6-8 mm

I can follow the aplite dikes from the lower contact to almost 400' elevation. Beyond this level a new set of well formed joints meet these but come down from the top. These upper joints never seem to contain aplites.

500' rock is still felsic, but the diabase texture is developing as opposed to the cumulate textures of individual blocky pyroxenes stuffed together. Now the pyroxenes are more in small clots and crystals are less distinct.

550' there are still places where crystals are individual and blocky, but the diabasic texture is also more apparent although not fully developed

Snowing on me in sunshine

680'	diabasic texture well developed, and rock is also felsic in overall appearance
750'	all diabase but felsic
780'	beginning of silicic segregations
840'	heavy silicic segregations ~ 50% of rock
880'	segregations are clotty and dying out
930-940'	upper contact fine, crystal free, brown-black diabase - not ceramic style

15 Jan. '96 Victoria Valley

Overcast, cold (~15F) NE wind ~ 10 mph South of Lake Vida starting at top of sill, which is obscured here by granite scree; altimeter zeroed at tent

A-61	1075' This is the top of the segregation zone; real contact is within 100' vertically
A-62	975' Still in segregations
A-63	at 875' Segs getting small, rock becoming diabasic
A-64	775' felsic diabase
A-65	675' coarser felsic diabasic, little or no opx.
A-66	575' felsic with large (5-6 mm) opx
A-67	at 475' coarse felsic opx cumulate
A-68	475' (also) plag. rich area with opx. plag stringers
A-69	375', felsic opx and cpx cumulate, heavy plag stringers
A-70	360' plag layer (10 cm thick) with opx layer
A-71	275' opx cumulate more basic
A-72	175' pyroxene cumulate, dark
A-73	75' med grained pyrox cumulate 2-4 mm grains
A-74	25' less opx
A-75	-125' less opx and getting finer grained
A-76	-225' fined grained diabase
A-77	-325 chill zone of lower contact

A cold, windy snowy afternoon as we wait for the pickup helo

Altimeter 0' at camp is at 1900'

16 Jan. ' 96 Sunny & bright NE wind 0-10 mph

N East end of Dais of Wright Valley. Upper contact of Basement Sill altimeter set to 0' elevation. The real elev. is -300 below camp.

A-78	piece of med. grained granitic rock from above contact. Whole contact here is confused and overlying granite seems to have been remelted perhaps injested. The dolerite contact although chilled, is not extremely chilled.
A-79	at 0' dolerite chill
A-80	at -80' dolerite here is coarsening and is laced with clotty segregations
A-81	-180', med. grained gray dolerite, coarse lenses of segregations here, some ~ 1m thick. Seems to be a zone just below coarsest segregations
A-82	-290' Med. grained dolerite not much opx yet, although few plag. stringers are showing up.
A-83	-380' med. grained, gray dolerite with some opx
A-84	-490' med. grained dolerite opx getting larger (2-3 mm) and blocky
A-85	-590', coarse opx (4 mm) cumulate
A-86	-690' coarse granular opx cumulate

Between here and the next highest spot there is excellent plag layering

A-87	-700' plag.-anorthosite layer in opx cumulate
A-88	-740 two wide (8-10 cm) anorthosite bands (see photo) Contains only opx
A-89	-800' med - coarse opx cumulate
A-90	-880' here there are two ~ 20 cm thick layers of anorthosite each 4 or 5 m long pinching out and then starting again off and on for 50 - 75 m. This is a large oriented block from the upper layer and the lower layer is A-91
A-91	block from the lower anorthosite layer
A-92	-920' plag fabric dolerite
A-93	-980' last outcrop still coarse rest covered.

Helo waiting

17 Jan. '96 Wednesday
NW corner of Kukri Hills along Taylor Glacier

Overcast, no wind, 25F
Basement Sill: (-250' rel. to camp) At the western most exposure the plag. stringers dip sharply to the NW but continuous outcrop 50 m east shows more normal (i.e., horizontal) stringers. The opx cumulate appears near the chill, prob. within 50', and coarsens rapidly. Hamilton talks of faulting near here, but no sign of this in outcrop.

A-94	near lower margin of sill - prob. within 20 - 30' of contact - fine grained dolerite

~ 1/4 mile east along Taylor Glacier at large columnar jointed walls of Basement Sill. Rock is fairly fine grained. (~ 1mm) but has some small opx (~ 1-1.5 mm) showing up already. Columns here are 6-8 ' in diameter (elevation is -500' from camp)

A-95	at -500' fine grained, gray dolerite with few opx and feeble plag stringers from above walls.
A-96	at -400' opx cumulate, felsic diabase 1 mm opx, but more frequent. Many plag. stringers here. Many nice plag stringers here, see end of photo rolls 18 and beginning # 19
A-97	at -300', opx not increasing much in size. Plag stringers are done
A-98	at -180', med. grained felsic dolerite, possibly some segregation clots showing up
A-99	at +40' within upper part of segregation zone, gray dolerite

At -180' the segregation zone begins and is well developed. The opx cumulate zone never becomes as well developed as anywhere north of here in the Bull Pass area. The zone of plag. stringers, however, is very well developed. It's snowing - and we are at the top of this mother climb of rock

18 Jan. '96 Friis Hills/Pearse Valley - looking for Peneplain Basement contact - not much luck, too much scree and snow

Sample Boxes:

Box	Samples
1	pp. 2. 2-5
2	6-16
3	17-27
4	28-41
5	42-48
6	49-57
7	58-65
8	66-77
9	78-87
10	88-99
11	Dave's
12	90, 1, 2 & JP; also my ventifacts
13	aplites
14	ventifacts
15	McMurdo xtals & nodules

Chapter 4 – 1997

- 1997 -

Antarctic Field Season

Camp Site: On sand shelf near small, deep fresh pond; elevation ~ 1800'; all elevations reported below are relative to camp.

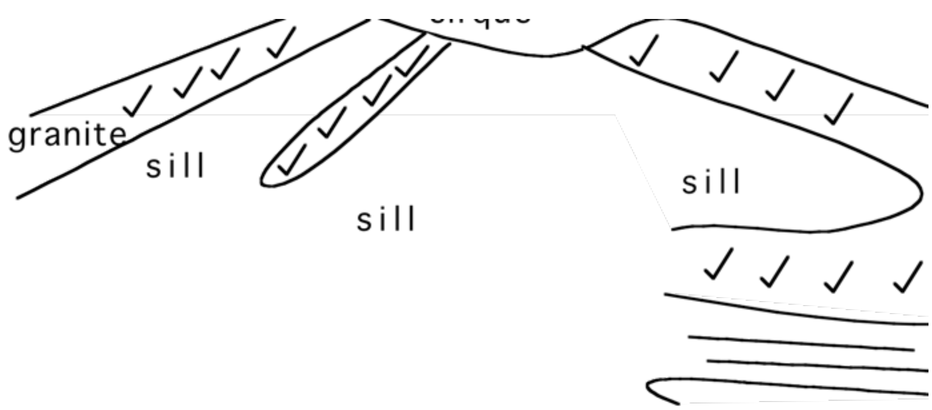
7 Jan. 1997 [Tuesday]

On Basement Sill east of Bull Pass to study tongue contact

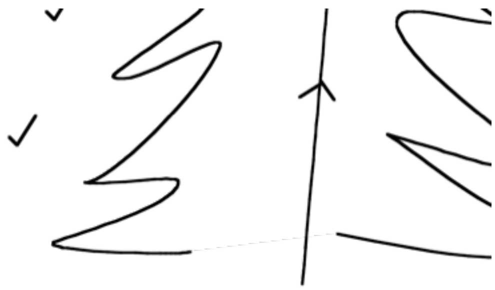
A-100	2 pieces showing apparent transaction from fine to coarse rock with black band. Internal contact or weathering front. Elevation here is 630', about 2 1/4 miles east of camp

8 January, 1997 - [Wednesday] partly sunny, chilly, scattered snow flakes. 28°F, wind variable - alone, beard frozen

West Bull Pass area up through hay stack part of sill to N of dune area near Wright Valley. Several observations: (1) There are abundant plagioclase stringers throughout this area (now at ~ 450' up sill), but they are very steeply dipping at lower elevations nearer middle of Bull Pass (see pictures). They are closer to vertical on average than even 45°. Higher up sill to the west they become more horizontal, but are irregular and often highly contorted. (2) Looking across at the east side of Bull Pass the sill structure is like:



Could be a Christmas tree intrusion



which would suggest this is a vent

(3) The last observation is that up here on the lower N dune area is a set of crossing aplite dikes running N-S and E-W. They are up to ~ 20 cm wide.

Upper Contact West Bull Pass Basement Sill

Contact is irregular as it is climbing under upper granite; contact is chilled good in places, although not hard, and in other places it is apparently not chilled - although exposure was not good. Where contact turns and goes west along Wright Valley there is a 2 foot granite dike in the sills although it could be septa - it cannot be visited. Granite contact rock in places could have been partially fused as it shows segregation - like bodies within it.

5 p.m. and time to head down to camp - an hours walk.

9 January 1997 [Thursday] No helos flying. Toured haystack area of sill and on up the valley to the algea ponds with Bill and Zach.

10 January 1997 - [Friday] cloudy, E wind, chilly

5 p.m. N. rim Wright Valley at the Tongue internal contact exact same location as sample A-33 of last year.

A-101 two largish angular pieces showing undulate opx internal contact; distinct change in grain size and opx contact. "Contact" is clearly a hot one and is apparently undulate on a 10 cm scale.

A-102 Sample (2 pieces) at ~ 20' below start of Tongue

A-103 Sample (2 pieces) ~ 15' below previous sample and this is about 25' above last year's sample A-36

A-104 Sample 20' below last year's A-36

A-105 Sample 50' below last year's A-37

A-106 Sample lower chill. About 75' below last sample

11 January 1997 [Saturday] Cathedral Rocks: clean & sunny 30°F; 3300' above camp

Peneplain Sill [later realized this is Basement Sill].

A-107 gray fine grained diabase, prob. ~ 30' above scree-covered contact

A-108 sample 100' above previous

A-109 100' above previous sample

A-110 Sample 100' above last one

A-111 Sample 100' above last one

A-112 Sample 100' above last one
Plagioclase. stringers here and there)

A-113 sample 100' above last, I have altimeter at 4000' relative to camp

A-114 sample 100' above last one ~ 4100'

A-115 500' below top

A-116 400' below top

A-117 300' below top

A-118 200' below top

A-119 100' below top

A-120 top chill

12 January 1997 [Sunday] Took Michael Parfit [National Geographic] on a tour of sill contacts and haystack area west of camp.

13 January 1997 [Monday] Don Juan Pond, clear at first, little wind, now high overcast

Basement Sill

A-121 upper contact with granite segregations

A-122 sample 100' below top
segregations here are blotchy irregular but very abundant

A-123 sample 100' lower than previous

A-124 sample 100' lower than last

A-125 sample 100' lower than last

A-126 sample 100' lower than last
Rock is homogeneous here, free of segregations, opx is small, but clearly present

A-127 sample 100' lower than last

A-128 sample 100' below last, 700' below chill at top

A-129 sample 100' below last, 800' below chill at top

A-130 Sample at 100' below last, 900' below top

A-131 sample ~ 180' below last and ~ 80' above Don Juan Pond
The full section is about 1160 feet thick.
There is also a drill hole here from the Dry Valleys drilling project. The plaque says (see my pictures).

D.V.D.P. Borehole 13
Don Juan Pond
Lat 77.33.339S
Long. 161°10.798°E
Completion Date 13 Jan. 1975
Total Depth 74.98 M
(exactly 22 years ago)

14 January 1997 [Tuesday]
NE Victoria Valley, NE of Lake Vida
Basement Sill - upper & lower contact exposed

The entire [upper part of the sill here, about 200'] (almost) is intermingled with the overlying granite - there are pieces of granite at all stages of ingestion. Although the evidence is not obvious everywhere. The sill contains biotite pervasively. There are places with big plagioclase crystals scattered.

~1/4 mile behind ridge on steep slope

A-132	black fine grained upper contact
A-133	sample 140' below last
A-134	sample 100' below last
A-134A	sample of sill with granite debris, plagioclase crystals
A-135	sample 100' below last
A-136	sample 100' lower than last

starting on ridge above dunes [that are near Lake Vida]

A-137	sample 100' below last
A-138	sample 100' below last
A-139	sample 100' below last
A-140	sample 100' below last
A-141	sample 100' below last
A-142	sample 100' below last
A-143	sample 100' below last - very large pyroxenes up to ~ 1 cm long
A-144	sample 100' lower
A-145	sample 100' lower
A-146	sample 100' lower v. large opx & stringers
A-148	sample 100' lower
A-149	sample 100' lower (steep)
A-150	sample 100' lower

A-151 sample 100' lower

Vida NE [continuing sampling section]

A-152 sample 100' lower

A-153 sample 100' lower

A-154 sample 100' lower

A-155 sample 100' lower

A-156 sample 100' lower

5:30 at helo.

This sill is very thick, perhaps 2500' thick or about 770 m. The top 200 + feet has many granite blocks and much debris. The bottom 700' or more is coarse opx with poorly developed and chaotically arranged [plagioclase stringers].

15 January 1997 [Wednesday}
East Nose of Dais

Sunny & bright, strong west wind, but not up on rocks.
Studying layering

Layering is well developed here and there and distinctly horizontal.
Most layers are plagioclase rich and some contain pyroxene up to 5 cm long rods. Some are ~ 1 cm equant.

There are also 3-5 cm pyroxene layers. The pyroxene is generally much finer in these layers

A-157 sample of dark layer of massive gray plagioclase and clots of opx

A-158 sample of dense pyroxene-rich pod like blob

A-159 Sample of same pod as above with purple mineral clots Cu-sulfides?

These pods have a vertical bloby structure 2-3 m tall and 1/2 m wide at most.

The layering on the SE side of the nose is vast and varied. At the lower levels, the white plagioclase banding is more apparent and it seems to fade out about 200' up and here the layers are of many types. One type that is distinctive is the 10 cm layers of massive opx and plagioclase. The plagioclase, is not granular like elsewhere but is massive gray with interspersed massive clots of opx - like shown in sample A-157.

No layer is larger than about 20-30 cm, but the rocks is banded to some degree, however, faint, almost on every face.

A-160 sample of fine grained plagioclase rich - possibly annealed?

A-161 sample of thin plagioclase layer for sectioning

Northside of Dais down last year's sampling profile

Layering here seems often to dip SE but is also often flat.

A-162 large sample through fine grained layers area with 6" black layer underneath (see photo)

A-163 lower sample of very fine grained, sandy anorthosite

A-164 sample of dark coarse rock inter-layered with fine grained anorthosite
This section (~200' from bottom in smooth area is coarsely layered - this area has ~ 20' of varied layering

A-165 fine grained anorthosite sample

Unable to find very thick anorthosite layers from last year.

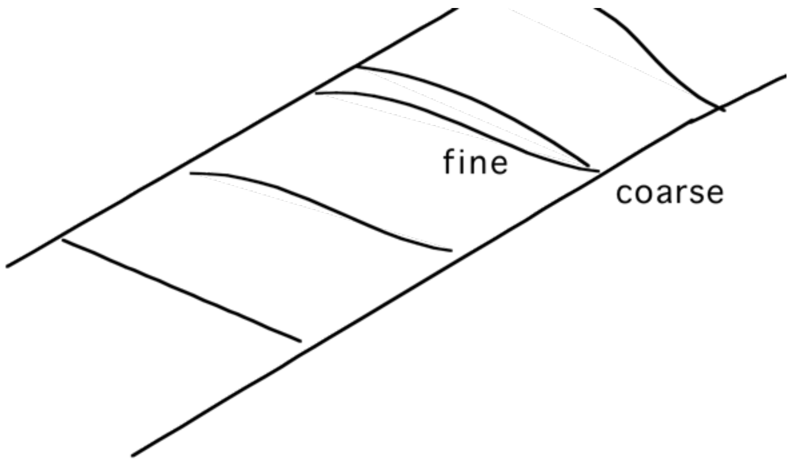
16 January 1997 [Thursday] Sunny, mostly, 30°F, wind from south, mostly nice

Solitary Rocks
Flew over to Solitary rocks via the Labyrinth and Devron 6 Icefall.

There are sills up as high as one can see in the Asgards - very likely two above the Labyrinth, and sills continue out onto the polar plateau, which is high in elevation about 10,000 feet - although I'm not sure of its elevation beyond Devron 6 Icefall. With careful study, these may be sampled. But it won't be easy.

At Solitary Rocks we visited the seal I found in 1994 and took a tissue sample for a seal biologist. The seal is a good deal more eroded away than it was in 1994. Although underneath [on the protected ground side] he is still mostly in tact.

Then after lunch we walked along the opx cliff on the west side of the Valley. Here the plagioclase stringers are of the fluted - horizontal variety and dip most often to the south - although the attitudes are in many places chaotic. Often they, the plagioclase stringers, seem to show the following relations:



As if a slumping pile of crystals also deformed between the slip planes to allow plagioclase segregation.

Then we traversed on to the SW wall area to see the very good segregations seen several years ago, but I could not find the really good ones.

Then we went down to the lake and walked across it to the glacier. The lake ice is now very smooth - glassy for the most part, but everywhere quite cloudy.

The glacier is receding quite rapidly and it has left a large pile of gravel and boulders. It is a very active area and one can hear rock falls and gravel slides if one sits and waits for 15 - 20 minutes. Water runs from the glacier under the ice and the melt water is cloudy or milky.

17 January 1997 [Friday]

Friis Hills, clean blue, icy, S wind 0° with wind chill.

Contact of Basement and Peneplain Sill high up on hill above saddle

A-166	chilled Basement sill
A-167	chilled Penneplain Sill
A-168	pieces of contact - excellent

The contact between the two sills is found high on the Friis Hills above the low, granite absent, slough into the cliff immediately south and a little west of House Lake. The contact can be found by tracing the sandstone remnants and the small pieces of fine grained chill zone rocks on the surface to an elevation of about 1350 m.

The chill zone is clear. Basement sill is chilled hard against the Peneplain Sill. The Basement sill has clearly elevated the typically flat Peneplain sandstone contact rather abruptly, lifting it some 300m. The best exposed contact is at the highest elevation at the contact near a small cliff and the altitude appears near vertical and also highly irregular vertically and horizontally. This cannot be seen unless there is essentially no snow cover. The Basement Sill shows good segregation development at the proper position within the sill. [The fact that the Basement Sill has apparently entered the Peneplain sill easily and pushed the contact rocks (i.e., sandstone + sill) upward within the Peneplain Sill, but the overall Peneplain sill does not seem deformed, leads me to think that the Peneplain sill was still mushy in the interior when he Basement Sill intruded. This is highly significant.]

18 January 1997 [Saturday]

Crystal clear day.

Comrow glacier section of Basement Sill. Directly across from Bull Pass

A-169 sample at top of exposed sill - this is not chill, which is not apparent anywhere here, but on the segregation horizon

A-170 sample 100' lower, now out of segregation section

Coarse grained gray rock - massive

A-171 sample 100' lower, med. grained, gray diabase, may be some very small opx's but not much sign of opx yet

A-172 sample 100' lower

Rock here is massive and has abundant weak plagioclase - anorthosite stringers. This could be one of the apparent stringer horizons we see from across the valley

A-173 sample 100' below last massive, not as many plagioclase stringers, excellent opx phenocrysts

A-174 Sample 100' lower, large opx stringers here and occasional nice 2" layer - and all are in apparent horizontal orientation, little sign of chaos in the stringers

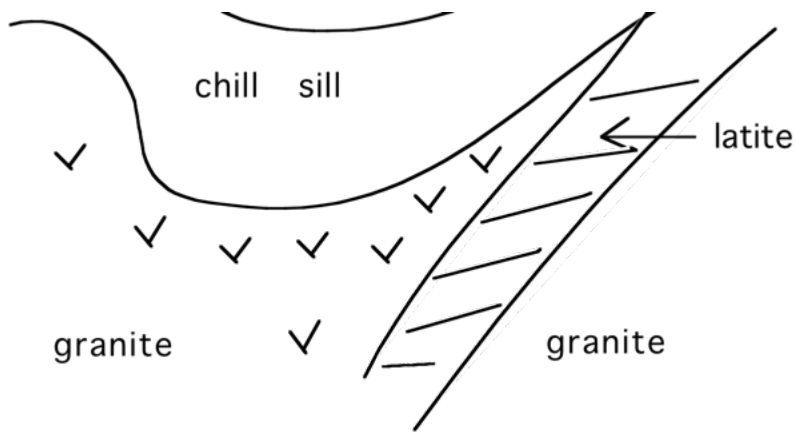
A-175 sample 100' lower. Pyroxene crystals seem smaller, ~2-3 mm. well formed plagioclase layers locally

A-176 sample 100' lower pyroxene-rich-friable still some horizontal plagioclase stringers

A-177 Bottom chill zone sample, 100' below last, granite below

The lower contact dives down slope along a pink latile dike of which there are many in the Valley. This is not remelted granite as fresh granite is also along the sill here and there.

The lowest point of the contact is ~ 300' vertical and about 1/4 mile horizontal [from our sampling transect]



19 January 1997 [Sunday]

High overcast, 5 mph S wind.

Bull Pass NE of camp; there is a septa of granite in the ascending sill section. I have mentioned this previously by this season. We (Bill & I) hiked to this area and diabase is soft quenched about the granite. But following Basement Sill up to higher ground it ascends easterly and forms a large fissure that enters the upper sill in a plexus of fissures area near Mt. Cererus and may continue to the S. to Mt. Peleus. The climbing sill is coarse all the way to Cererus but the opx dies out and its sparse in the rock. This area clearly feeds the upper sill, which should be called the Labyrinth Sill since it may be distinct from the Peneplain Sill of Solitary Rocks.

A-178 is a sample from the area between the two cirques W. of Cererus and on the climbing fissure taken at 3300' above camp

Also the boys climbed NW to the summit near Mt. Jason and took the following samples down the upper (Labyrinth) sill

A-179 top of peak at 4460'

A-180	at 3920'
A-181	at 3820'
A-182	at 3720'
A-183	at 3650'
A-184	at 3530'
A-185	at 3440'
A-186	Lower chill, 3310'
A-187	3920' on Mt. Jason
A-188	nice example of segregation

20 January 1997 [Monday] Helo photo close support

good sampling section upper sill (Labyrinth Sill) upper N rim of Wright Valley opposite Dais-easy

The Basement Sill at NE Lake Vida seems to climb to the NE and we may have sampled a thicker section due to the dip, but this cannot have caused a doubling in thickness as the rise is gentle.

In the Miller glacier area [north of Victoria Valley] the Basement Sill (?) is still present in the basement rock, but only this one sill.

No sills are apparent in the Olympus range buttes, only the two we have in Bull Pass.

Near Devron Six Ice Fall there are higher sills, 2 of them, making 4 in all, but the upper two will be hard to sample.

The Sills at Solitary Rocks, other than the Basement Sill, may represent a new or second injection center, as distinct from the Bull Pass Center.

21 January 1997 [Tuesday]

Dais, Sunny and bright.

Tracing White Layers

A-189	sample of anorthosite layer ~ 6" thick

We can trace the plagioclase layers horizontally for 200-300 m covering the entire nose - see also serial photos. The layers pinch and swell but are horizontal, except where chaotic locally, and maintain their horizon. At last years A-90 & 91 sample location the most distinctive feature is the fineness of the grain size in the layers - the opx is abundant, but it is small in size. Just above the layer the opx is large and highly concentrated. The upper contact is abrupt. The lower contact is splotchy and more transitional and often has very large rod-like opx crystals lying flat and up to 3-4 cm in length locally and lying flat in the layer. Just to the east of here (~100') is a pod about 2 1/2' thick. They seem to be channel fill deposits with fine crystals on top, covered by a dense opx current. The layers definitely fine upwards in opx.

A-190 sample showing layering from ~75' above this level

A-191 Sample of upper transition at the A-90 & 91 location

Sandy anorthosite area now see earlier Dais notes; interspersed with coarse pyroxene layers (thin)

A-192 sandy anorthosite layer

A-193 miscellaneous pieces from here showing various layers; loose pieces not oriented

The "sandy" anorthosite is actually fine grained anorthosite is massive and continuous for 50m or more; it can be seen from afar and is ~ 100' above the lower 2 thick anorthosites where A-90&91 come from. These are nearer the nose and down low, ~50' above the last outcrop, whereas the very fine anorthosite is ~ 100 m west and 100' higher. It is this layer and others that can be seen from a distance and from the air. Overall, the layers here appear to be scour and fill type with a period of quiescence for fines settling followed by another avalanche or input of coarse opx.

22 January 1997 [Wednesday, camp pull out]

End of 1997 field season - EXCELLENT

23 January 1997 [Thursday] trips to Cape Evans and Cape Royds

Cape Evans

A-194 anorthoclaise basalt near Scott's Hut, Cape Evans

A-195 Anorthoclaise basalt from Cape Royds, near Shackelton's Hut

Chapter 5 – 2000

- 2000 -
Antarctic Field Season

4 Jan. 2000 (I'm 53 today) Cloudy, chilly, 2:30
East Bull Pass (3,060') camp at 1500' Ribs Area diabase

At east end contact shows diabase on top of granite with a dip slope altitude. Sill seems to be penetrating easterly from across the valley. The lower ribs contact is crenulated with the granite.

It is the penetration front or leading edge at or laterally penetrating sill. Good chills here and there.

The rib structure is as curious to me as it was in 1996. They still seem to be eroded columnar jointing or erosion along a joint set.

Further north, almost to the large ravine aluvial fan, the basal contact is sharp against the granite. It is irregular, strongly with a wave-length locally on a 30-40m scale. Here there are granite areas isolated in the sill near the contact. It is difficult to see their geometry. The diabase seems to be chilled against it vertically. There may be large (5m X 10m) inclusions. Here the sill above is massive.

Hiking back to camp we crossed the lowest arm of the Basement sill, we noticed coarse plagioclase and cpx rich pipes and pods - small several cm in diameter. The rock below is a sample of the biggest one we found.

First Sample

A-200	sample of pipe-like coarse cpx phyric rock in the middle of opx tongue in Basement Sill on east side of Bull Pass above camp.

5 Jan. 2000 Cold and windy, some sun
East side Bull Pass N of yesterday near north end of granite wedge in sill.

A-201	faint layering at ~3300' sill becomes felsic and strong vertical pegmatic splotches are common. Associated also is a fine and very regular vertical rhythmic layering with ~ 2cm layer thickness. Near bottom of area some sweeps off to south. Altitude of layers ~ E-W strike and steep dip north.

To the north the rock becomes progressively fine grained and flakey in weathering. It is like a hot chill. Then over the next 50 yards north it coarsens strongly and the large cliff running diagonally up the face is the coarse opx tongue rock. It is massive and homogeneous. This starts a wide zone running north for 100m or more.

Here also is a 1 m wide porphyritic latite dike, tan to pink, cutting the coarse opx zone and strikes ~ E-W and vertical in dip. Phenos. seem to be kspars.

On the granite wedge:
There is a good chill on the north side with the opx tongue starting within 10m - first fine and then very coarse ridge only 20 m away.
On the south side the chill has been disrupted into a breccia. The granite is mushy and the chill pieces are scattered in it. The granite seems thin with the sill beneath it. The breccia regions is ~ 20m wide.
The wedge thins downhill and has a ragged bottom where sill is underneath it.

Basil area of granite - [fingers freezing]

A-202 segregations
A-203 granitic/sill breccia (2 pieces, 1 small and 1 large)

The sill seems to split around the granite rather than forming two separate injections, but simultaneous.
At the base of the granite wedge is a wide area of asorbed segregations. Mainly vertical and blobby, they sometimes seem associated with granite xenoliths. Also the faint, inch scale vertical layers here and there up to 1 m thick.
At the base of sill in valley the contact shows that the sill overlies the granite.

Return to camp at 5:45.

6 January 2000 Cold, overcast, East Dais Intrusion

Starting on southside near scree and moving north. There is a 20m thick felsic horizon where layering of all kinds is common.

A-204 coarse pyroxenite from near base of felsic horizon
A-205 coarse mottled plagioclaise-opx lens. Opx in quarter-size splotches and gray massive plagioclase.

As we go to the lower elevations the whole unit becomes more mafic and darker. The most mafic area is the base, and there is where the thickest anorthosite layers are found - they are largest ~ 50 + m [this either refers to the length or if thickness then it should be 50 cm—need to check original notes for clarification] near the most mafic - but are thicker and less continuous, more lens-like deeper into the body.

The uppermost part is massive gabbro with little layering. The mid-zone is layered with many discontinuous features. The most prominent is the "sandy" looking opx/plagioclaise layers than run for ~ 110 m at one point. The thickness never more than about 4m.

7 January 2000 Cold, some snow, south wall Wright Valley 2 km SE of Dais

Basement Sill - good exposure, but also many signs of extensive layering. Not as well developed anorthosite, but good horizons of medium to fine grained buff diabase and some very fine "sandy" diabase.

Sample showing relations - layers can be 2 m thick and in contact with very coarse (2-5 m) diabase.

A-206 small scale relation of "sandy horizons.

Sill structures upper half of sill

The layering here has the same flavor as at the Dais, except there is no well formed anorthosite of major note. There are many small ones, up to about 10 cm X 1 m, but not much. A lot of stringers (plagioclase), but little well developed anorthosite. What is well developed and extensive is the medium-fine to very fine grained "sandy" plagioclase-opx rock. <u>And</u> the fine material or grams can be seen (clearly) to be sieving from the pyroxenite into layers. Some of the layers are 1-2 m thick and more or less continuous for 150 m. In some places there is a very dark layer in contact with a felsic opx rich zone. The pyroxenes are coarse, up to 3-4 mm generally. The blackness seems to be from a lack of plagioclase and (perhaps) more augite. The upper 1/4 - 1/5 is a vast field of splotchy pegmatitic segregations that culminate downward in a well formed 1-2 m thick layer of segregations, then they are mostly absent.

Samples taken by Michael and Riley:

A-207 Felsic opx cumulate grading upward to anorthositic layer (arrow showing up) 180 m below contact. (another piece from this area is a flat one large but it is not this description)

A-208 Small sample as above, but laterally next to 207.

A-209 mottled coarse cpx-plag rock at 200 m below contact

A-210 Porphyritic latite dike cutting most of the sill section here; about 15 m from upper contact. These are all common in the sill around here. They seem to be from melting of the country rock.

A-211 Coarse segregation with splay of 5 cm needles of cpx. A large specimen (~30 cm) from ~ 100 m from upper contact. Plagioclase and cpx form a honey-comb typical texture of segregations. Also showing is a contact with the coarse opx cumulate.

8 January 2000 Mt. Orestes Feeder, Cold (14° F) overcast, snow and S. wind.

Sampling across feeder every 100' on divide

A-212 Chill margin

A-213 27 m east

A-214 20 m E, coarse cpx? phase, 2 pieces

A-215 10 m E plagioclase wisps are vertical

A-216 25 m E

A-217 20 m E

Aplite dike

A-218 30 m E in pass

A-218 30 m E in pass

A-219 30 m E

There is a series of granite (remelted) blobs here, most interesting. 30-40 cm in diameter and fine grained with ghost of original texture in places. Mafics or needles and sometimes concentrated at base. Small dikelets radiating outward. (See photos). Lunch here, we are cold but doing well.

A-220 28 m East of last sample

A-221 28 m east massive

A-222 32 m East massive

A-223 30 m east

A-224 33 m East now see horizontal plagioclase sortings

A-225 30 m East, last sample in this series

There is a patch of black lichen here on a flat rock fully exposed to all elements on ridge top.

On the way back we traversed the entire feeder. It is medium grained opx-phyric diabase. The upper half has an abundance of segregation material scattered throughout. Upper contact is well chilled.

10 January 2000 Monday, crystal clear, biting west wind, but nice in lee areas.

Mr. Grendall near Camrow Glacier Area 5700’

Contact between Basement Sill and Labyrinth sill – the Basement sill is chilled against the Labyrinth, but the chill is only about 30 cm thick and the Basement Sill coarsens downward rapidly to unusual coarse texture with splotchy segregations in less than ~ 5m.

The Labrynth Sill here is a medium grained diabase with scarce opx.

Samples of Chill Margin.

A-226 chilled margin of Basement Sill against Labyrinth Sill

A-227 Another piece of chilled margin as above

There are two 1 m wide dikes also cutting the Labyrinth Sill here. They are ~ 30 m above chilled margin and dip slightly (10°) to the west.

A-228 middle of lower dike

A-229 chill of lower dike

A-230 middle of upper dike

Dikes are separated by 2 m.

Across this cirque and down (i.e. NE) the Basement Sill is massive medium grained and felsic. It is free of segregations and is generally featureless and extends down valley wall a long way.

A-231 sample of massive felsic diabase is described above 5,230 ft.

This whole wall is very massive and homogeneous. Grain size increases downward.

A-232 Sample of massive diabase at 5300 ft.

East and below there is a wide fine grained phase 50 m thick, partial chill, then a hard chill at base into massive medium grained granite. Further below at 5300 ft. is a bulbous mass of Basement sill – irregular – but trending up hill to SE. It is medium fine grained with abundant small opx.

A-233 Sample of the rock as described above.

Continuing down the Basement Sill bursts out near the valley floor cutting across and old dike and the granite. An irregular body 50 m in width and heading uphill. A sample of this is – 234.

A-234 Fine opx cumulate phase of Basement Sill.

11 January 2000 Pandora's Spine of Solitary Rocks Crystal clear occasional gusty S wind, ~ 20°F

Looking at layers of segregations and sampling through one 50 cm segregation layer very well formed.

From top to bottom

A-235 large block from upper contact upwards 20 cm x 20 x 20

A-236 upper half of segregation layer. 30 cm x 20 x 20 cm

A-237 next 1/8 of segregation layer 15 x 20 x 10 cm

A-238 lower 3/8 of segregation 10 x 10 angular block

A-239 contact region small piece just above lower contact 5 x 8 x 8 cm.

A-240 just below contact, brown piece 15 x 10 x 6 m

A-241 large piece below segregation but to normal rock 15 x 15 x 10, A=top, B=bottom, broken big piece

A-242 large piece of the upper contact of another segregation deeper in body. Piece for Michael containing upper contact

Lunch time and no wind!

A-243 Plagioclase band 1 cm from 5 m thick section of thinly banded region about 1/3 down in Peneplain sill

The bands themselves are ~ 1 " apart and the plagioclase in the stringer is about 1 cm thick

Most of our time was spent looking at the segregation layers near the summit, especially just above the large flat area, where landing is possible. Here after getting used to the rocks, we can recognize at least several good segregation bands. Some undulate up and down but generally run fairly horizontal and are about 60-80 cm thick. They are clearly felsic, but the large opx are not abundant, but they are seen. Our large samples include a full segregation layer from top outside to rock beneath the segregation. Below this horizon there are smaller, splotchy segregations in some places, but layers are still seen and within about 50 ft. lower there is no sign of segregation.

13 January 2000 SE Lake Vida Bulbous tip of Basement Sill

Crystal clear, 20 mph wind from east inland; 25°F, -4 F with wind

Walked out contact between end of Basement Sill and wall rock. Contact is sharp and commonly shows two important features. (1) The edge of the sill is thin (~25 cm), which undulates up and down into the wall rock. The sill itself thickens greatly to perhaps 50 m or more within about 10-20 m of the edge. This may mean that the final sill has followed the path of an earlier, contemporaneous, thin leading propagating magma - filled fracture. So the thin leading edge was probably formed much in advance of the mass of magma, was quenched and stifled and then the main sill mass advanced up this lead. (2) The wall rock accommodates the sill by being deformed along myriads of small rigid blocks. A typical block is a parallelepiped and is slightly jostled relative to its neighbors. This is easy to see at the easternmost contact where the rock is a heterogeneous and thinly banded gneiss.

The contact is remarkably clean and free of metosomatic effects. No effects, of hydrothermal alteration and any melting. It appears very dry, and the contact itself - or chilled margin is not more than 1 or 2 m thick. This may mean that the wall rock was hot - deep in the crust or that the bulbous approaching tip kept the region hot for a relatively long time.

On the north side of the sill along Lake Vida is a massive, coarse and homogeneous, and even grained granite.

15 January 2000 Miller Glacier/Wheeler Valley Area

Basement Sill sampling section. Sill appears normal at top with pervasive segregations and no opx tongue. Samples at 100' intervals in elevation, upper contact not exposed with granite, but plenty of chill on ground where the first sample comes from.

A-244 Upper chill - float

A-245 50 ' below chill sample

A-246 100' below last sample, massive and felsic, medium grained, with a hint of stringy segregations. Poorly developed, some big splotchy segregations also.

A-247 100' lower, medium grained and massive

A-248 100' lower, felsic diabase

A-249 100' lower, felsic diabase

A-250 100' lower, felsic diabase

A-251 100' lower felsic diabase

A-252 100' lower, felsic diabase

A-253 100' lower, felsic diabase

A-254 100' lower, lower chilled margin

A-255 chilled contact - float

The base is a coarse grained granite with 1-2cm orthoclase and slight gneissic fabric.

So the sill is about 700' thick. It looks like the Basement Sill, but without the opx tongue. I see little sign of any opx concentration. This is interesting. This is, evidently the northern limit of the tongue.

17 January 2000 Clear and no wind, above Comrow and Bartley Glaciers at 5800', 25F

Granite on top of sill with strings of granite melt into sill

A-256 contact (top)

A-257 100' lower

A-258 100' lower medium grained, felsic, diabase

A-259 100' lower opx phenocrysts here and plagioclase stringers here

A-260 100' lower opx rich with stringers

Good clear stringers, some are vertical.

A-261 100' lower, opx phyric

A-262 black fine grained chilled dike, cuts sill, strikes SE and vertical. Dike divides here with small 1m off shoot making 2 right angles from main 3m dike and continues on same strike

A-263 100' below A-261

Stringers heavy in places

A-264 100' lower, grey, medium grained opx scarce

A-265 100' lower grey, medium grained diabase with small opx

A-266 100' lower medium grained grey massive diabase

A-267 100' lower medium fine grained grey diabase

A-268 100' lower medium fine grained grey diabase

A-269 ~100' lower chilled lower contact

Still chilll is with beacon sandstone but lower country rock is granite. Must be thin sliver and sandstone (2 p.m.)

18 January 2000 Dais, sunny and clear, no wind until 2 p.m., lovely day ~ 30°F

Samples 270-300 are taken every 5 m going upward from lowest outcrop.

In sandy, pyroxenite area

A-301 white and brown ss phase, bands are ~ vertical arrow = up

A-302 massive feldspar and white anorthite arrow = up

19 January 2000 Mt. Freya, very cold, S wind 25

A-303 top of Mt. diabase

Segregations layers here

A-304 50' lower

A-305 50' lower

A-306 50' lower

A-307 50' lower

A-308 50' lower

A-309 50' lower

A-310 50' lower

A-311 50' lower

A-312 lower contact with Beacon. Not a cleanly exposed contact

Samples are dark grey massive diabase. No opx.

We bivouacked in the Beacon for 2 hours with all our gear waiting for the helo. An exciting day!

20 January 2000 Mt. Fleming, clear and windy and cold -10°F (-45° in wind)

A-313 near lower contact, within about 50' of contact

A-314 30' higher, dense medium grained, massive diabase

A-315 30' higher

A-316 15' higher

A-317 20' higher

A-318 20' higher

A-319 20' higher and about 40' below contact

Dais samples collected on last day by Riley

A-320 coarse opxite with plagioclase layers from elevation of 95.5 m at nose, showing rhythmic layering

All below at SS Trough

A-321	fine to medium grained opixite just above ss trough and above host pyroxenite
A-322	fine to medium opixite in a thinly bedded rock of opx and plagioclase
A-323	same as 322 but with less layering
A-324	fine grained ss phase - tan, just below massive plagioclaise
A-325	a tan ss with a few fine layers of plagioclase
A-325b	white ss phase
A-326	coarse opxite intermingled with tan and white ss phase of trough series
A-327	dark coarse opxite at top of trough, has a plagioclase concentration in it.

End of trough samples

A-328	at 40m level large block showing plagioclase layer 4 cm thick.

Last sample.

Chapter 6 – 2003

Bruce Marsh
Antarctica, Bull Pass
2003 Season

January 8, 2003

Alt. 2400
To west section of Basement Sill

Full day up section with students and Mike [Weiss] from lower hill to upper figure, dipping, digested and partially melted granite contact.

January 9, 2003

At. 2250
Wind 5.5

To Central Bull Pass

Central Bull Pass – hiking N up the pass

On solid outcrop alongside the drainage. The BS sill gets progressively coarser in opx just as normal. Then in the central part of the Pass just east of the small cyanobacteria pond (elev. 2600') there is a curious granite pod, several acres in size, that seems to be surrounded by the sill. The sill gets fine grained around it. Chilled evidently, but not hard, and then at a distance of 20-30m the sill gets very coarse again. The granite pod seems totally remelted and is generating aplitic dikes within it. The geometry of the whole complex here is confusing. There is also a serious question as to if the sill is continuous along the West Wall of Bull Pass.

PICTURE – pg 4

January 10, 2003

Alt. 2245 – 11 P.M.
2185 – 10 A.M.
40ºF

Dais Intrusion
A-239 [*this is very likely mislabeled and should be A-329*], a piece showing layering (up indicated) from first big band center (E-W) of N slope.

The higher one goes on this face, the more lichen found. A black/blue type from full to half dollar in diameter.

The third (upper most) felsic band is at 2040' and is ~20' thick. It has good, but not very good or excellent sortings – some sandy horizons and coarse opx. But whole body is more felsic with height.

Upper contact is not a hard chill and is hard to find in granite scree. Some thick segs. Clm, within 20' of contact. Sill is dark and is coarse (same to the contact). Medium grained. Upper contact at 2500' relative to camp this A.M. The granite is disaggregated everywhere and coarse and knobby mixed or infiltrated by dolerite – the entire area is rotten.

The upper half of the sill is massive with decreasing opx and increasing felsic content.

There is the light brown volcanic ash on many parts of the scree slope to the west and the same as is common in Bull Pass.

We hiked as high as we could go in the granite and were stopped by a 300' vertical drop off and 50' cliff above on the East side. Not good way to go – we had to retreat and wait 2 hrs in 28ºF for the helo and a stiff East Wind.

January 12, 2003

Sunday
Temp. 30ºF
Wind 10 mph – South
Alt. 2310’

Ribs Area East of Camp, Lower contact 1200’ above camp.
Across the valley, W wall of Bull Pass, there is a marked change in slope near the upper contact with the Basement Sill and it is continuous to the north and through Bull Pass and matches up with the Basement Sill after contact in Victoria Valley. It looks like West Wall Bull Pass.

PICTURE – pg 10

The contact relations in this area are subtle:

The lower sill, the one that goes a long distance east in the wall of Wright Valley, has an upper chilled margin that climbs strangely up the slope and the lower chill of the Ribbs Sill climbs down the dip slope. It is likely that the 3-D geometry of these two sills is as shown here:

PICTURE – pg 11

Or it may be like this:

PICTURE – pg 12

January 13, 2003

Unsettled weather
T = 30ºF
Alt. 2255’
Wind – 10 mph, S

To Solitary Rocks – Pandora’s Spire – Put in at 12:00 and plucked out at 4 due to bad weather. Took series of samples through a major segregation.

January 14, 2003

T = 24ºF
Alt. 2160’
Wind – S at 10-15 mph
Thick overcast – cold day, Some new snow up pass on West Wall.

At Dais on upper band (topmost?) on East face. Elev. due 1785’

Sampling going up at 5m intervals starting at A-354 – the 115 m level of season 2000, which is just about 25 m above the rhythmic layering horizon.

A-354 – coarse opx felsic rock
A-355 – 5 m higher
A-356 – 5 m higher
A-357 – 5 m higher, beginning of layering of upper band.
A-358 - in middle of upper right band
A-359 – 5 m above previous
A-360 – (two pieces) 5 m above previous and break off here until another day – as it is 7:30 P.M
Actually last sample is:
A-363 – 5 m above 360, massive felsic rock no structure.

8:15, loaded to camp in Bull Pass by 8:45 P.M. Cold - 22 ºF in shade.

A-365 is now here, and may be missing as only a remble.

A-366 is missing WO a rock.

January 15 2003

Dolerite Dikes in granite block east central Bull Pass above 2 frozen ponds.

Cold, 18 ºF, 10-15 mph wind off Polar Plateau. Nippy, have to keep moving.

Starting on N end of block.
A-364 – dolerite dike 70 cm wide, 2 pieces. Overlapping elastic tips.

PICTURE – pg 16

A-366 – dolerite dike, of ~ 1 m dike, similar to last one. A black fine grained dolerite. *Missing in final count.

Both these dikes are in the first ¼ mile of the ridge. We traversed up the ridge all the way to the summit and viewed the feeder region at the pass and the arête ridge leading to the summit of Mt. Peleous ?

The granite ridge where the dikes are changes to dolerite of the Peneplain Sill about half way up it to the South. There is also a small section of Beacon sandstone here on top of the granite. The Peneplain lower contact slopes upward to the summit area. As it also does to the North on the other ridge.

The feeder area of arêtes may have a large dike there of Basement Sill and the main part of the feeder, where it goes upward strongest, is apparently near where it first reached the elevation of the base of the Peneplain Sill. Here the feeder is 100m wide or more, and here on the South contact there is distinct and pervasive inch scale layering, vertical in attitude as is all other segregation material in this region. It is much like a marginal border group.

The ridge of arête leading to Mt. Peleous? has a block of Beacon sandstone about half way up I have not noticed this before as it was always in snow.

Returned to camp via the Ribs at ~ 3 P.M.

A very good day.

<u>January 16, 2003</u>

7:30 A.M.
DV list.

1st 08 Helo – 1315'
45 mph
7 onboard – Berg, Aiken, Lampsen, Weinner, Gilles, Turner, Smith

2nd – 11:10
45 mph
Bresnahan, Boehlert, Smith, Roscoe Bartlett, Wayne? Gilcrest, Palmer, Rita Colewell

<u>January 17, 2003</u>

Dais – continue sampling upward from previous day here-

A-367 – 5 m above A-361 and this continues to A-389 (inches)

Observations to the 95 m band starting at corner on rich/scale layering going first West along layer took a series of pictures of ss layers with some close-ups. Stringers lead to layering which leads to ss layers and lenses.

Next series of pictures of black bands and massive fsp layers is in the 95 m band just above previous zone in 95m band. The whole layer is felsic and the dark layers with the frie textures are of the normal felsic dolerite texture, while the thick melted layers (~10") are massive clotty fsp and opx clusters. The S & Dip here is SE-NW with a 3º S dip.

115 m layer or band – pictures of long and slender opx's on bed face – jackknife for scales – opx ~2.5" long.

The 140 m Band – This band is clear but is weaker than others. That is, it seems felsic overall, but usual individual layer cents are weakly developed, e.g. very little ss type layers, and more medium grained felsic – dolerite layers. There are also, in the middle to west area of band coarse segregation like regions – lenses – that must be melt segregations.

A-390 , sample of 115 m band of layering

January 23, 2003

Cold, high overcast, not sun

Granite dikelets on B-Sill feeder above camp at 5500' on ridge and ¼ mile West of arête leading to NW Orestes.

On North contact of feeder zone, Taber had dug out the contact relations between the dikelet and the source in the wall rock.

PICTURE – pg 23

A-394 – Sample of granite and melted granite
A-391 – granite dikelet
A-392 – granite dikelet
A-393 – granite/melt/chill
A-394 – as above
A-395 – granite/melt/chill, dolerite
A-396 – dikelet 6 m from contact
A-397 – dikelet 20 m away
A-398 – dikelet 70 m away
A-399 – granite hill rock 2 m away from contact

January 24, 2003

Elev. Bull Pass 2200'
On the Dais east nose
Sunny and bright, East wind 0-10 mph. Temp ~30 ºF
Helo spot elev. 1750' which is about ¼ way up the body

There is a real tendency for the opxite above the major bands to be more massive and stripped of plag. And within the bands the plag. layers of every irregularity locally such as peanuts reflecting into a sieve sorting.

A-400 – sample of plag. Xmas tree sorting

PICTURE – pg 26

The entire body becomes increasingly felsic upward to a point, then it becomes massive medium coarse opxite. At about 200 m the area feeding on the east changes from the hollowed out rock (massive opx rock) to a sheer buttress that is laced with thick 1-5 m zones, anastomosing, of segregation – like material. This continues upward into the upper contact region which is a digested type or gradational with overlying crumbly granite.

The segregation are excellently exposed on the East side in the North facing cliffs. The textures are uniformly coarse (opx, plag.) up to ~2-3 cm opx and stubby. But the host rock is a medium fine grained felsic grey rock, very distinctive. The form of the segments clearly show that this was a sagging SF of mushy material.

January 25, 2003

Solitary Rocks

Pandora's Spire, cold and overcast

Note on sill stratigraphy in the Inland Forts region.

The Peneplain still continues from the Friis Hills under the ice and is marked probably by an icefall a half mile or so. Above this in the Inland Forts is a thick and continuous Asgard Sill (~350m) and above that the Mt. Fleming Sill, which is quite large.

January 26, 2003

Heavy, overcast, snowing in the Asgards across the way.
Elev. At camp 2225'
30 ºF
3-5 mph wind from the S

West Bull Pass, upper contact with Wright Valley – hiking up with Sarah Fowler

~300' up in the sill, plag. stringers are getting vertical, but there are both here (see 1997 notes also).

Chapter 7 – 2005

(The entire field season of 2005 was dedicated to leading a Magmatic Field Laboratory field camp or workshop, centered in Bull Pass, involving 25 invited geologists, sponsored by the U.S. National Science Foundation. The full final trip report along with an explanation of the full program, including the pre-workshop program and the post-workshop reports etc., are given as an Addendum at the end of these Field Notes. At the close of the workshop we did do a little field work for ourselves.)

Bruce Marsh
Antarctica
January 2005

Dais – Segregation section below large face on NE corner –

PICTURE – pg 1

Seg. forms layers then pods and pipes as it enters fine grained sill rock.

January 22, 2005 Taber's Notes

Samples of Basement Sill and Peneplain Sill on West Ridge and SW ridge just southeast of Mt. Orestes

West Ridge
A-403, Summit (1,788 m, ~6,000') Peneplain Sill
A-404, 1753 m, Peneplain Sill
A-405, 1716 m, Peneplain Sill
A-406, 1676 m, Peneplain Sill
A-407, 1652 m, Peneplain Sill

1st sandstone block, 1642 m, Dolerite in contact with top of Peneplain? Sandstone block – 1635 m dolerite in contact with lower contact of sandstone block.

A-408, 1621 m, Basement Sill
A-409, 1305 m, Basement Sill

2nd sandstone block, 1626 m, dolerite in contact with second sandstone block, 2 meter thick block

3rd sandstone block, 1618 m, upper contact with sandstone and Basement Sill
1582 m, lower contact of sandstone and Basement Sill

January 26, 2005

SW Ridge – which is about ¼ mile S of West Ridge

A-410, 1606 m, Peneplain Sill
A-411, 1587 m, Peneplain Sill, chilled margin.
A-412, 1587 m, Basement Sill, soft chill against Peneplain Sill.
A-413, 1513 m, Basement Sill
A-414, 1422 m, Basement Sill

Chapter 8 –2007

Antarctica Field Notes 2007

Bruce Marsh
Bull Pass Camp Antarctica
January 2007

January 10, 2007

Clear and slight W wind – Kukri Hills, just west of Mt. Coates

Cinder Cone area
Vented dike ~ 1 km long
Mostly all agglutinate

Xenoliths of dolerite – sample 1 – There are, in places, on the west edge of the crater abundant angular pieces of dolerite caught up in the basalt. The sill is only 10- 50 m beneath the crater elevation so their presence is no surprise. The basalt also only weakly adheres to the dolerite, suggesting the dolerite-basalt contact was probably fairly cool.

On the N. side of the Kukri Hills, in Taylor valley, there are more late basalt cones – or remnants of cones. These are all at the foothill part of the Kukri range and are not well developed, but are in various remnant states.

The largest one on the western end of the field has a well exposed wall showing what may be a dike injected into the agglutinate and cinders and scoria. It shows a chilled margin on the bottom, free of vesicles, which come in a short way above. Here also are areas that present a knobby appearance, where the whole rock has cherry size lumps – quite distinctive.

The flows associated with these cones are not well developed and may have mainly been avalanching agglutinates.

Further east on Nussbaum Riegel is a close rosette of feeder dikes that clearly fed a cinder cone, which is still here in remnants.

What strikes me at all these cones is the extreme localness of the feeder dikes – they appear small in width – a meter or 2, and short in length 50-100 m, and in places, especially high on the Taylor valley side, the tears are very local and there is 100% exposure of country rock.

Up in this area is also a small couloir or cleft in which are two small domes of basalt. They are lump like and maybe 50 – 100m long, 5-10 m wide, and 5 – 10 m high. They are rounded like camel humps and the lower, largest one, shows a vertical bladed or platy structure – all obs. from the air.

January 13, 2007

Sunny and Bright - me, Dean [Peterson], Paul [Morin], Ziggy [Zibigniew Malolepsczy] & Liz [Elizabeth Miller] – Central Bull Pass

Tour of Central Bull Pass region showing the area of partially melted granite near active pond in drainage. There are two large felsic dikes coming from the granite and entering the dolerite. The dolerite, normally coarse, is medium-fined grained here and has penetrated and formed a breccia within certain areas of the granite. The granite thoroughly melted over a wide area and has a characteristic pock marked appearance.

Continuing on the dolerite is even coarser and richer in opx. It has plagioclase clots as in the most massive basal section of the Dais. This is in the central highest part of the Pass where the terrain turns over into Victoria Valley. There are scattered areas of concentric rings of plagioclase stringers or schlieren – on vertical faces they are vertical concentric cylinders. Some are as large as 5 m in diameter, most are 1-2 m in diameter. These plug, ring structures seem to me to be "sink holes" where the slurry has settled back, downward, in plumes of granular material, within a grain-supported, medium where concentric shearing has produced the plagioclase rings.

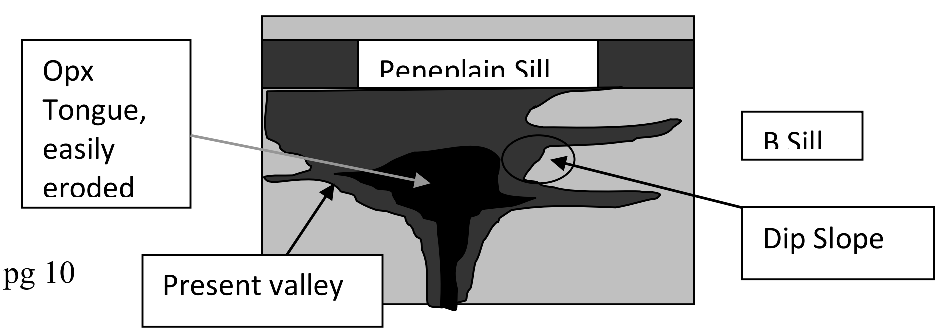
The presence of these, the position of the massive opx-ite means to me that this is a vertical feeder zone that supplied the Basement Sill – the partially melted granite is the wall area of the feeder.

January 14, 2007

East Wall Bull Pass – Ribbs Section

I have seen in past that both Ribbs and lower sill have contacts on the dip slope – and now I see that this is also same to the N across the large alluvial fan – Magma essentially, coated the walls of present Bull Pass – rising from below and making an upward funnel that coated the flow walls and formed the sills

PICTURE - pg 10



January 15, 2007

West Shoulder - Mt. Odin
~1550 meters
Overcast, cold, SE wind 8-10,
BM, MZ, LM, RC, KP
[Although initially thought, because of its high elevation, that this would be the Peneplain Sill, after looking at the rocks this is an upper lobe of the Basement Sill, carrying Opx tongue material.]

Sample A-440
Med. Grained dolerite with small opx –prob. Peneplain Sill – 1550 m
Sample A-441
Chilled margin sample at 1525 m in float – much here but prob. local dike
Sample A-442
Dolerite at 1500 m – massive med. grained and dark – from outcrop ledge
Sample A-443
Opx.-phyric dolerite with local 1-3 cm plag. lenses.
Elev. 1460 m
No apparent contact above–whole slope continuous with original sample 440
Sample A-444
Coarse grained felsic dolerite at 1610 [1410?]m – appears to me mainly cpx phenos. At elev. of 1394 m the rock is finer grained but laden with opx of ~ 1-2 mm in dian. Also, abundant plagioclase clots as in base of Dais.
Sample A-445
1383 m. Med grained opx rich dolerite with plag. clots.
Sample A-446
1343 m. Med grained grey dolerite. No plag. clots. Low amount of opx.
Sample A-447
Med. fine grained grey dolerite – 1270 m
Sample A-448
Fine grained grey dolerite. Elev. 1235 m.
Sample A-449
1210 m. Fine grained dolerite at lower contact – actual contact not seen. But it is clearly within several feet of this spot followed along and down edge of saddle and it continues around slope sub-horizontal. From the helo, it may be that the apparent contact and dolerite distribution on valley wall –appearing vertical – is a thin veneer of dolerite with a chilled margin. The center part appears eroded away revealing granite beneath.

January 16, 2007

Sunny then overcast

South wind 5-10, cold -5ºC or about 20ºF w/o wind chill.

Helo – close support

Inspected scalloped – valley at [East] central Bull Pass where many dikes are seen in granite turtle-back – looking for dolerite on dip slope to indicate a high angle fracture and formation of valley. Saw no dolerite on east slope – still this block may have been formed during emplacement of sill upward to feeder area. Very likely. And the Ribbs body may have been simultaneously accommodated by hinging of the nose of the Ribbs body.

The nose of Basement Sill SE of Lake Vida climbs strongly uphill to meet feeder region on the other, Bull Pass, side. We were unable to follow it to the top of the ridge due to scree. It thins strongly as it climbs, making it difficult to discern, but it climbs over 1000'-

The N-S contact at west end of Victoria Valley of Basement Sill and country rock. Contact is sharp, but chill is hard only locally and is thin, less than 1 m. Chill is generally medium-fine grained. The country rock is laced with basaltic dikes and is golden-brown coarse quartzite (?). In places the B.S. appears to be intruding upward in insolated spots beyond the contact – these are 1-2 m diam areas with strong chill.

Within the B.S., it is massive and seems to show a normal sequence of silicic segregations and a massive felsic horizon with areas of strong opx –rich rock. But the segregations and the plagioclase stringers dip steeply outward, west, at ~ 75º and strike parallel, more or less, to the ~ N-S contact. There is at least one well developed granite dikelet (~ 20 cm wide) and striking normal to contact – we only looked within 1/8 mile of our landing spot, which was due east of the prominent mesa in the valley capped by the Peneplain Sill.

Here also <u>within</u> the dolerite, is what may be the remains of a late cinder cone neck. The rock is fine-grained black, porphyritic basalt – the conspicuous large crystals and clots are ~ 1cm K-feldspars, round bleached white pieces of quartz (that appear, due to radial-fanning fractures, to be zeolites) and also small clots of medium grained granitic rock. It forms a knob 6-8 m wide and perhaps elongated parallel to dolerite contact – perhaps 10 – 15 m long. Although I have seen broadly similar dikes in the country rock – the distinctive placement of this <u>within</u> the dolerite, some 100m east of the contact makes it curious.

We then traced B.S. to the North where it climbs, dividing into two fingers and then dies. It appears across the small valley to the east and can be easily followed east in the hills north of L. Vida through the area where I sampled in 1997, where it seemed unusually thick (~750m). I can see now this is partly due to a ramping up of the sill. Following it further NE it goes into the next range and forms a massive ridge, but it is limited in extent. In this sector it appears less sill-like and more climbing, but still massive with good columns.

Since returning at ~3 p.m. it has been strongly overcast and cold, but now a bright sun hits the tent from the North – spilling good cheer and a promise of better weather – perhaps-

We then headed NW to the Debenham glacier, Miller Valley area and flew along Killer Ridge, which has a sill on top – this may be the continuation of the B.S. on the S side that I previously sampled in 2000? And the Peneplain sill may be at higher elevations to the South here. But there is a massive sill complex in the Convoy range to the west and this PP [Peneplain] sill may be from there.

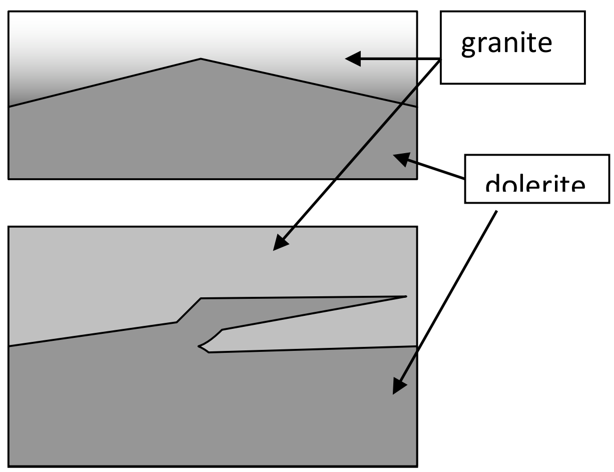
We returned to Victoria Valley and traced upper contact of B.S. along S side of Victoria. It is a climbing contact with apparent internal chills. Followed into Bull Pass and along the granite sliver area just before the scalloped valley [where] we started at. It definitely appears as a slice of granite has been cut from the wall rock by the dolerite, which has formed a second thin sill. All dolerite contacts seem steep and we will go here tomorrow on foot to more carefully observe this.

We then followed the upper contact at the Ribbs to the N. It is sharp and angular in places and migrates strongly up slope to meet the "feeder" area.

We then went to the west side of Bull Pass to follow the contact (upper) of B.S. It is not there to the N, it slopes down-hill strongly into Central Bull Pass.

We then headed higher to follow P-P. sill around Mt. Jason and into Marsh Cirque. Then into Wright and along N wall to see upper contact of B.S., which is irregular here in places.

PICTURE – pg 24



End of Survey.

January 17, 2007

No helos due to weather

Looking over photos of area – realized that large block on east side of Central Bull Pass is a stoped block falling into B-Sill in which the whole Orestes block was floating – very neat. A clean, downward arcuate contact unlike the other aggressive contacts to the North.

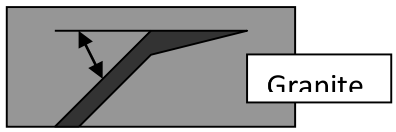
January 18, 2007

Thursday, Sunny and Bright
~20 ºF, 10 ºF in shade

East, Upper Central Bull Pass – on double contact of B.S. and granite

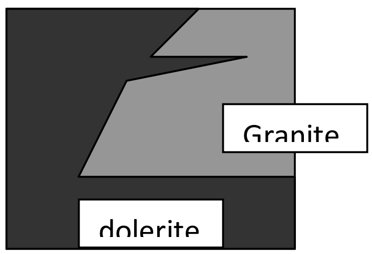
Climbing contact 47º dip to west, this is a sheet-like dike, upper that flattens locally into a small sill, or beginning of a small sill.

PICTURE – pg 26



This upper dolerite section forms a sill in the fashion of near camp. The dolerite climbs and coats the slope and pushes inward forming a sill. The upper contact is crenulate along joints in the granite with small, delicate dikes shooting off in many places.

PICTURE- pg 27

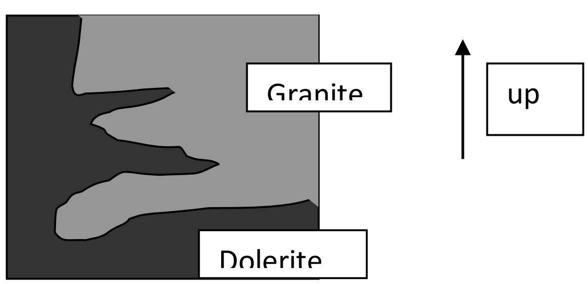


Beneath the upper sill body is granite, but it is fully re-melted and has entirely lost its original coarse texture – samples of before and after.

Sample A-450
 Original un-melted coarse granite above this complex.
Sample A-451
 Re-melted granite from between these two units – i.e. the granite wedge in between.

There are also spots on the lower sill of patches of granite of the re-melted form, and it is on the dip slope, showing that this lower sill has a steep upward climbing character. So the overall nature of the area is below:

PICTURE – pg 29

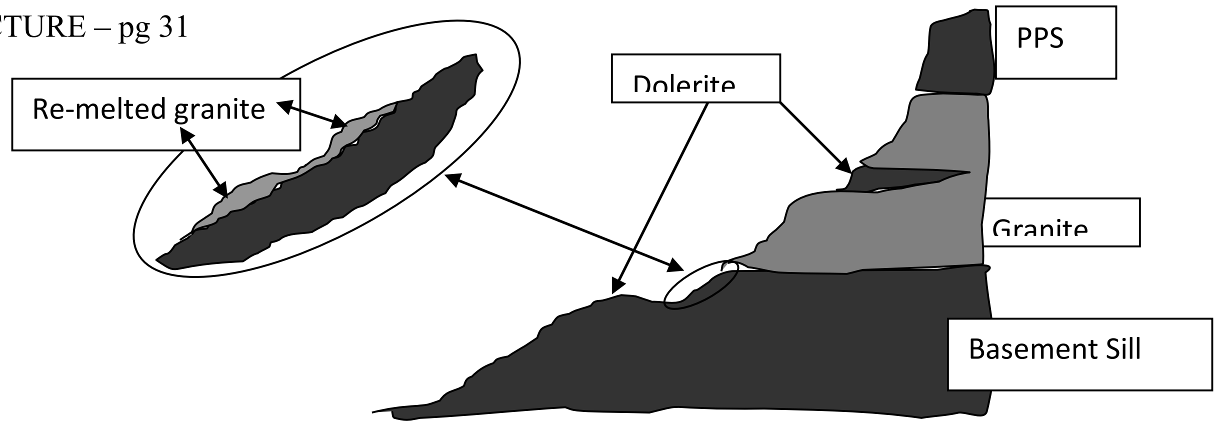


Today the upper contact of the lower sill is the topographic slope and high points are granite (re-melted). The dip of the slope is 31º W.

The tongue or wedge of granite between the two sills is fully re-melted and is now fine grained and contains clots of coarser minerals – 2 cm diameter clots.

So the slope today is as on the next drawing:

PICTURE – pg 31



Dolerite on dip slope is, as expected, not strongly chilled-

Moving South up [on East Valley Wall] from 2 frozen ponds across large rock (glacier) fan. There is a single sill here but with two clear internal contacts below the upper dip-slope contact.

Above the obvious dark contact, the slope is, for long distances (300m), underlain dolerite that has fused the granite and over large areas digested it as at the Dais and NE Lake Vida. The picture is similar to that further North as seen this morning. The dolerite is dark greenish, crumbly and where chilled is medium grained and it is also back-veined with 1-cm wide coarse granite melt – see pictures.

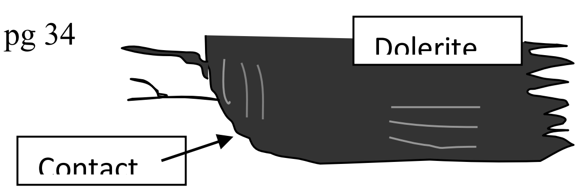
January 19, 2007

Victoria Valley – High Overcast, SW wind to 25 mph. T ~20 w/o wind.

Basement Sill here filling valley. On the west abuts and invades a tan marble with coarse calcites.

The contact here is as elsewhere, all sorts of invading sheets and dikelets –

PICTURE – pg 34

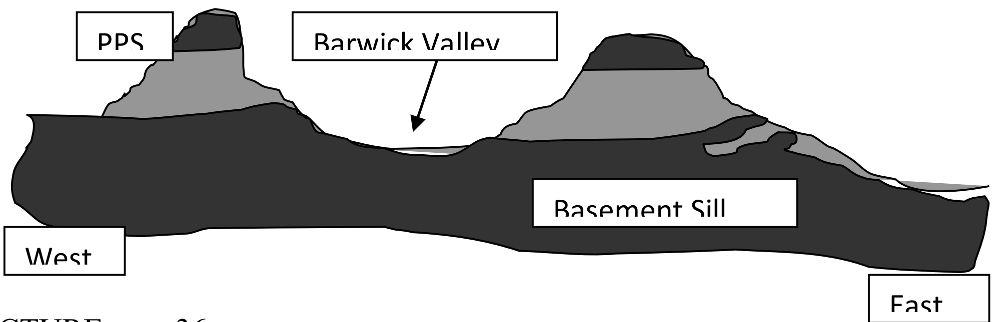


Near the contact there are vertical features and deeper or with distance east all internal features become more horizontal.

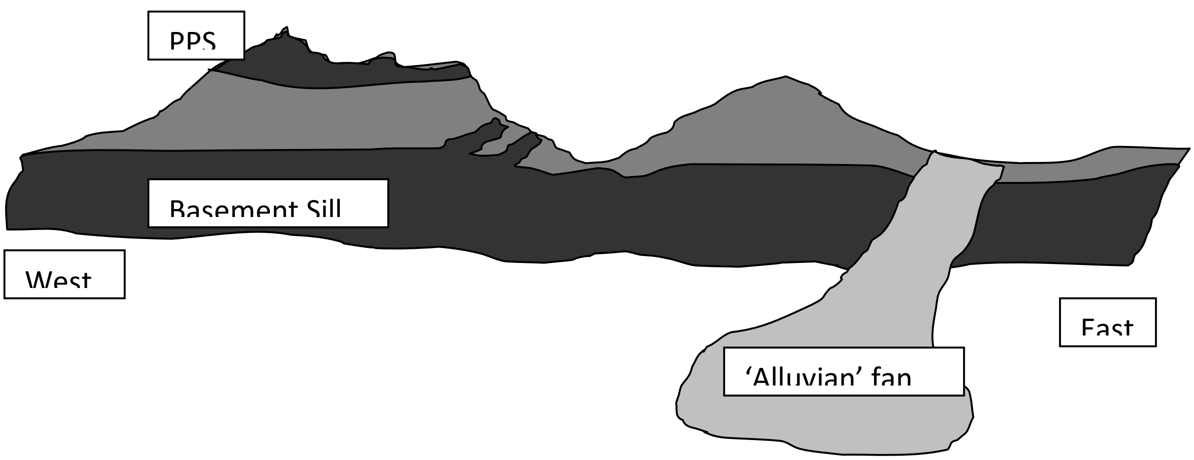
So the sill geometry here is :

This top wraps up into the Barwick Valley and across and over to our NE Lake Vida section. And the lower contact is near the west end of Lake Vida.

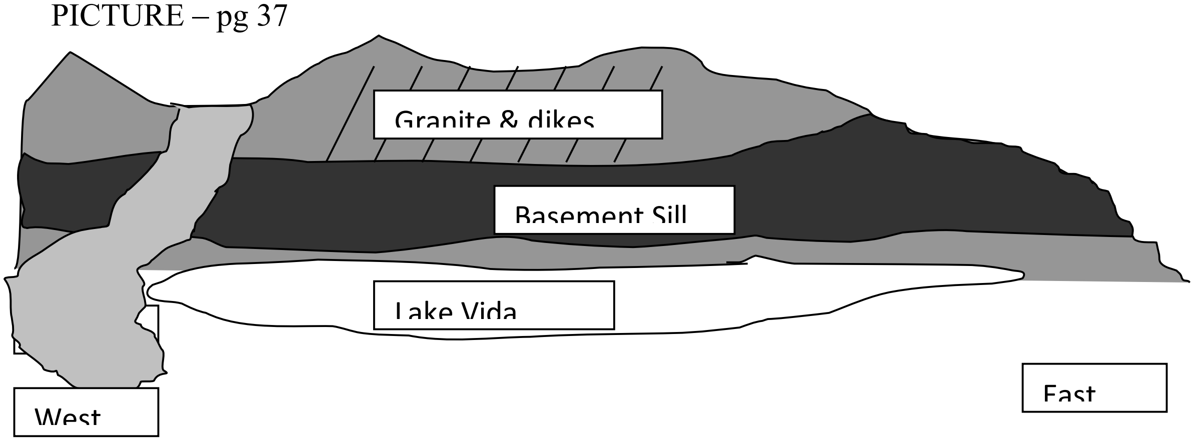
PICTURE – pg 35



PICTURE – pg 36



PICTURE – pg 37



Near the lower part of the sheet [Sill] here (the lower contact is covered by a large fan) there are some large conical mounds of exotic mineralogy – The dolerite is silicified and other minerals may be idocrase, epidote, smithsonite? and other areas that are skarn-like. These mounds are as large as 25m x 40m and light brown areas from a distance. They may be due to hydrothermal systems related to de-carbonization of the underlying marble by dolerite heating – these may have been fumarole vent areas. The dolerite outside the immediate area is unaffected.

Sample A-452

Solidified rock from a large "mound" near the massive alluvial/ glacial fan in the dolerite.

Waiting for helo in little basin near fan edge – cold and overcast but cheerful in the days work.

<u>January 24, 2007</u>

[These are samples of dikes that cut the Beacon 'Sandstone' series in the Wright valleys area. Collected by helo. Stop and go.]

Dolerite Dikes in Beacon Section

Sample A-453

Dike in Beacon near Marsh Cirque – to the west [North shoulder of Wright.]

Sample A-454

Dolerite Dike on upper slopes near Mt. Freya [South shoulder of Wright]

Sample A-455

Dolerite dike, north of Labyrinth in Beacon section between two large buttes

Sample A-456

Dolerite dike cutting Beacon & <u>PP sill</u> North of Dais.

Sample A-457

1m thick dolerite dike - ~3.5km east of A-456 [i.e., near Marsh Cirque?]

These are all dolerite dikes in the Beacon super group section – each is 1-2m wide and long and continuous. They are remarkably similar in appearance on a fresh face. They are black, medium fine grained chilled material, but no super hard chilled. They are long and straight and strike more ~N-S than the strong SW-NE than those that pervade the granitic basement rocks, although they do not strike precisely N-S.

PPS in vicinity of Marsh Cirque does seem to have an edge to the North in the Beacon – it does not appear strong as the N side of the Olympus Range.

The material, B. sill at Mt. Odin appears to chill against PPS cap at summit and below the sill <u>does clearly</u> cascade down the face to low level that shows good layering –

NOTES FOR FUTURE

Cellophane Tape on boxes not good

Stake – too small

Field training, boots
Digging

Propane is good
radios much better
Latrine buckets good

BFC bags, no water
And fluids? Propane?

Boots [need to have known standards for field boots certification for helo use]

Chapter 8 – 2008

Antarctica Field Notes
2008

Bruce Marsh
Bull Pass Camp Antarctica
January 2008

<u>January 6, 2008</u>

Sunny and bright, 35 degrees F.

~1 mile from Camp [to the North], east side of drainage

At base of fine-grained dolerite is melted granite that forms a breccia with med-fine grained dolerite as the invader. The transitions are gradual in grain size and the granite is disaggregated. In other areas the dolerite is chilled. The area is small, some 20 m long and a few m wide with dolerite apparently above and maybe below the granite although the lower area is alluvium (see pictures).

Just west of 2 frozen Ponds

The coarsest opx region, marked by splotchy opx-ite has abundant concentric rings of plag. stringers [[insert p. 2 sketch of concentrically ringed plag. stringers]] that range from 2 m to 10 m in diameter, and they are vertically oriented as concentric cylinders. This area is perhaps ~2 acres in size and may well be a (the) feeder location. To the S is another somewhat similar area, but with no cylindrical concentric stringers – instead there is a large field (~7-10 acres) of chaotic plag. stringers and layers, many of which are steeply oriented at 45-90 degree dips. This could be another feeding location [[insert p. 2 sketch of Y shaped feeder]]
or it could be a ponding location that was repeatedly disrupted.

<u>January 8, 2008</u>

Overcast, cold and wind S

Upper East Central Bull Pass

Upper Slope at Granite Slice N of Ponds ~3000’

Sample A-458
    Piece of fully melted granite with boxy quartz.

This whole region shows extensive melting along the upper contact of the dolerite with the granite – along the upper contact. The amount of melting is extensive with dolerite in a confused intimate contact. The granite is fully melted with the quartz forming at curious globular cluster bounded by black – Cpx? – acicular crystals. In places the dolerite is intimately mixed with the granite such that it is literally impossible to distinguish between dolerite and the fully melted granite. Just South of the alluvial fan in this area starting from the camp on from Mt. Orestes, there is an arc of full granite melting spread over a ~100 m area where the degree of melting varies from complete to 0% in a distance of ~100 m. These are all sill relations vein as delineated in last year’s field notes.

Me, Michael Zieg, Dean Peterson, Today

Found a Geologic Hammer today along the contact that looks like it has been there 30 – 40 yrs.

January 9, 2008

Low Clouds, filling Wright Valley, gentle snow falling
28 degrees – sporadic wind.

North wall of Wright Valley at basal contact of Basement Sill.

Lower contact is highly irregular with large downslope aprons of amplitude ~ 120m. The aprons define the dip slope but also local vertical fronts such that overall is a down-dip, stepping apron of dolerite.

[[insert p. 6 sketch of stepped dolerite aprons and Basement Sill]]

Granite country rock is unmelted.

January 10, 2008

Overcast, snow, 28 degrees F
S. wind 0-10 mph

Central Bull Pass just west of the two frozen Ponds (where I camped in '96)

Mapped the outcrop area here, several acres, where large vertical concentric ring structures are. (see map) – roughly

[[insert p. 7 sketch map showing ring structures and variation in grain size in adjacent areas]]

The coarsest area has the rings and where there are no rings there are the plag. splotches as at the lower Dais. Then in the coarse, as opposed to very coarse, there are plag stringers, subhorizontal up to 30 - 40 degrees dip and chaotic. Then grading to the S to medium grained rock.

Continuing 1 km S to Pond the rock is mainly coarse (not v. coarse) but there is a long beginning piece (on N side nearest ring area) where it is medium grained. The coarse rock has abundant stringers and tends in places to small anorthosite layers.

Good day – bad weather all around – snow everywhere in mtns – bare here and no helos for second day.

January 11, 2008

Friday

East Central Bull Pass

Up to look at the granite window area SE of the two frozen ponds. The dolerite is on top of granite, which is not melted. The mounds have dolerite on top and granite below with clear contacts. There is also examples of local vertical contacts on the edge of large flat areas of contact

[[insert p. 9 sketch of dolerite sill overlying granite with local vertical contact]]

This is much in the style of what we saw two days ago on the South wall of Wright Valley, where the B. Sill formed aprons on the dip slope. It seems as the dolerite follows the joining as it pushed through the granite. Contacts can be locally vertical, but overall it has a long distance dipping (flattish) character.

<u>January 12, 2008</u>

High Overcast, E. wind 0-5 mph. ~32 degrees F.

On South Wall of Wright Valley beneath Mt. Odin

Set down opposite mouth of Marsh Cirque and just to east of tongue of glacier coming from valley west of Mt. Odin. Walked diagonally up to west across layered basement sill rocks. The layering is at distinct horizons and is well developed in places into 5 - 20 cm thick anorthosites that dip into the valley 5 - 8 degrees. There are many other features similar to the Dais except not as well developed.

Three of us (BM, MZ & RC) continued on up to see the upper contact, especially where it goes vertical upward, connecting with the higher Basement Sill just below Mt. Odin. From the air this contact, the vertical one, looks hard chilled and well defined. From the ground it is not well defined, but is a zone 10 - 15 m wide of not hard quenched magma that is on the slope or just beneath the granite country rock. The dolerite is, at best, medium grained and free of opx – so contains none of the opx tongue and seems to be migrating upward. We traversed the contact area – that is also bursting up within the granite area – and went east across the whole feature. (There are some areas of hard chill in the granite areas to the west.) The central area is medium grained and all cpx and plag. To the E there is a lot of Beacon float from above and we went down on this material.

Spent rest of time tracing out large plag-anorthosite horizons in the lower section of B. S. – they run more than about 1.5 - 2 km.

Very satisfying work overall.

January 14, 2008

Sunny and bright, strong S. wind
gusting to 25 mph

On South Wall of Wright Valley directly across from Bull Pass

Landed at top and working our way down slope. The B. S. forms a massive lobe that meshes with another lobe, just to the west. But above the sill proper, dolerite runs uphill under granite – now mostly weathered away and forms a dip slope running from the sill proper to the crest of the valley wall. This is much like we found on Sat. near Mt. Odin. This dolerite is devoid of opx and is medium to med. fine grained, but is hard quenched only in a few places.

The B. Sill here contains all sorts of messy – chaotic segregations near the top and gives way rapidly to much opx.

Continuing down, in the bluff ridge at the sill center the opx tongue is coarse and there are many plag. stringers and some 2 – 4" layers of anorthosite at a specific horizon that continues along for ~200+ meters. It seems that where the plag layers are most common the rock is richer in opx as opposed to the usual mix 80/20 of opx/cpx.

Further down the opx tongue is massive with intense, finely laminated plagioclase stringers on the order of 1 cm thick and of high frequency. The whole package dips at 8 – 10 degrees to the South, into the hillside. Just above here we found a 2 or 3 bushel area of anorthosite surrounded by black dense pyroxenite – the top and side boundaries are sharp against the anorthosite with possibly a narrow vertical zone stretching upward ~2 m. This resembles a pod of anorthosite.

January 15, 2008

Tues. Sunny & Bright, South wind 0-15 mph

Close support air research all day 10:30 – 4:15 p.m.
Chris Dean pilot.

From Bull Pass South to Wheeler Valley, Miller Glacier.
Killer Ridge area.

Stopped on sill above Wheeler Valley and it is typical Peneplain Sill – no opx, just plag and cpx with medium grain size. To the North is Killer Ridge and stopped here to find a clear opx presence in abundance, which is the Basement Sill – it forms the ridge-top here and all other ridges to the NE (probably). Then flew to Queen Mtn. and PegTop and then back to Marble Pt. for fuel. Then to Solitary Rock and Simmons Valley for lunch at foot of glacier at mouth of valley. Stopped then in center of PPS beneath Pandora's Spire to show Holly grain size. Then toured Finger Mtn, Turnagain Valley, Beacon Valley, Arena Valley and saw where our satellite camp of MZ, RC, and BS are. Then down Taylor Valley from Pearse Vally, where B. Sill seems to go high in the Asgards. It may be from the high lobe here above the Ribbs area. Then to Victoria Valley (after fuel) and followed upper contact of B.S. to Camp – in places 3 internal contacts.

Sample A-459
Piece of Peneplain Sill from ridge above Wheeler Valley.
Sample A-460
2 pieces from top of Killer Ridge – opx-bearing Basement Sill.

January 16, 2008

Weds. Still high overcast, warm, up to ~38 – 40 degrees F

No helos – snowing in McMurdo – waited until after lunch to go out then went up to study grain sorting in the avalanching opx/plag sands on the west ridge face. Made some movies and watched plag. stringers form around the edges of the avalanches. Opx is not especially coarse to cause kinetic sieving, but it seems to occur with opx brought to the surface. And ripples appear on the longer lasting avalanches and sort the plag and opx into bands.

Also saw some large granite dikes there up to ~10" wide with some well exposed delicate contacts with the dolerite.

Sample A-461
~2 gallons of the opx/plag sand from the West Ridge of Bull Pass.

January 17, 2008

Thurs. Sunny, bright, warm, 38 degrees F. Variable wind 0 – 5 mph

At NE Corner of Bull Pass at Victoria/McKelvey Valley

From air appears as multiple contacts internal to the dolerite with granite windows here and there. On the ground the whole dip slope is apparently a mix of dolerite and granitic melt, making it look much like silica segregations. At the lower-most edge is a pink strip of granite against which the dolerite is chilled – look for this on air photo. Up hill to the distinct break in slope of the massive granite is a root of heavily melted granite. The melting goes through several phases from slightly melted in patches, to melted where quartz is globular rimmed by cpx and then where whole rock is fine grained with acicular cpx needles up to 1 cm long.

The whole surface running down to a slice of granite to the NW is the heterogeneous dolerite with chicken-wire clots of plag – here and there are more massive, normal felsic dolerite. The granite slice at the bottom has dolerite quenched against it and I read the field relations as:

[[insert p. 20 sketch of cross-section showing dolerite/granite contact capped by PPS]]

So the surface of dolerite is probably near the original contact with the granite. And overall this reads as the lateral edge of the Basement Sill as it goes North into Victoria Valley, which we looked at last year and it, too, shows an edge on the west side. This is all consistent with the B. Sill spreading outward to the NE from this general area.

Continuing Southerly there is a long section 1 – 1.5 mile where the sill/granite contact is covered with alluvium. Then when it does appear it is, again, similar to that described above except there is granite here often roofing it, and to the west, in the deeper part of the Pass, there is the more massive opx-rich part of the B. Sill.

The granite throughout this region is heavily and extensively melted – nowhere else in the whole region have I seen such melting. As noted before, there are many phases of this granite melting process. The granite starts as a coarse, normal granite with a texture of crystals ~1 cm in size. The most abundant phase after melting is a fine grained, white sandy-textured rock with conspicuous globules and clusters of quartz rimmed by a fine black phase, probably cpx. At the most extensive degree of melting these globular clusters are gone and the whole rock is fine-grained on a 1 mm scale, whitish and now with acicular needles of cpx up to ~1cm long. The globular quartz rocks are the most curious as the quartz seems to have accumulated into these clusters of anhedral round blobs.

The fine grained variety of melted granite seems to be a granophyre and it seems to be mobile. The evidence for this is in the disappearance of a basaltic dike as it approaches the dolerite/granite contact. Near the sill doublet area is East Central Bull Pass.

January 18, 2008

Friday. Sunny and bright, 44 degrees F at camp.

Evening flight around Orestes area and through Asgards to Taylor Valley to trace upper level of Basement Sill and onto Kukri Hills – see photos extensive number.

January 19, 2008

Sunny and bright – in Olympus Range –[BM & MZ]

Sampling of Peneplain Sill in first valley (west wall – to North slope) West of Bull Pass and that empties into McKelvey Valley.

Samples 100' apart going downward from top

Samples A-462 → A-473

Each good dolerite fairly coarse with distinct plag-stringers and 1 – 2" layers in middle to lower section – limited vertical extent. And also silicic segregations near top –

Asgard Sill (Mt. Electra)

Second sampling section in first solo mountain east of Polar Plateau and North of Labyrinth – just east of saddle which has a small peak to west capped by thin section of Beacon Sandstone. True elevation at top about 6500'.

Sample A-474

Fine-grained dolerite from east summit.

Samples A-475, A-476 – A-477, A-478, A-479

Each sample 30' apart.

January 20, 2008

High thin overcast, S wind 5 – 8 mph, 35 degrees F

Central Bull Pass – North

Mapping outcrops in valley center – North of 2 ponds for ~1.5 miles.

Massive coarse (not very coarse) opxite – with conspicuous lack of plag. stringers.

Some well developed anorthosite horizons

Sample A-480

Sample of anorthosite layer ~2" thick, not part of a larger zone – layer ~1.5 m thick.

This whole section, which is about 1.5 miles long is massive with 2 -3 mm opx and abundant plagioclase – it is fairly felsic, but there is precious little development of plag stringers. Instead the rock is splotchy with plag, but also continuous. The areas of anorthosite development are thin and long and distinctive horizons – somewhat like what has developed at lower Mt. Odin and at the Dais. But the general lack of plag. stringers indicated no motion. When this magma emplaced here it underwent some reorganization to make the anorthosite layers, as this is a "coming to rest" process, but the stringers reflect motion – and none here mean no shearing – this must be close to the feeder of the system.

A curious geomorphic feature in NE Bull Pass is a deeply incised cut on the east side. It is ~100' deep on the east and ~ 1/4 mile long, cut into massive dolerite. The oddest aspect of this is that it is free of debris – only a deposit of sand now lives at the very bottom. It is as if cut by a deluge – but from where? All I can see here is a cirque directly to the west above the Peneplain Sill in the Olympus Range. This would mean that the deluge came down the Olympus Range and poured down into Bull Pass, cutting this cleft and then going South down through the deep cut in Bull Pass near camp where there is a larger hogback in the middle of the drainage (~1 km N of camp) – curious. The arroyo here is filled with debris - medium size – and it, too, must reflect this deluge. I can't think of anything that could otherwise make this feature. It is bewildering to think if what may have happened here and to realize that it probably carved these features in a day or two and cleaned out the haystacks just west of the camp site. We are of too small a mind to see this as it is intended to be seen and imagined.

January 21, 2008

Sunny and bright – high thin cirrus – wind 0-20 mph at Camp from N.

Close support – NW of Lake Vida in pan to N where B-Sill splits into two fingers on E-facing hillside. Landed here –

Upper lobe ~15 – 20 m thick, good chills, hint of opx tongue. Lower lobe thicker (20 – 30 m) and shows more of Tongue, but fairly fine grained – good upper chill, poor lower chill with extensive melting of granite and thick zone of contamination into felty-messy dolerite.
Also thick granite dike in middle (20 – 30 cm) running along strike of lobe with good (excellent) content exposure on side.

Also – chilled margin rock heavily pitted from aeolian blasting.

Bartlett Glacier
mtn to west

Sample A-481
    Ferrar dike in Beacon – 1 m wide and striking ~E–W and vertical.

Flying back and forth in this area and on over to Taylor Valley

There is massive PPS to the West higher in section and only a little to the east, but most all to the east is Basement Sill – and the Basement Sill is high – and dips to the west sharply. This is also seen in the Kukri Hills where the BS on the west is at Ice Level and rises strongly eastward. At the western end of the Kukri Hills the BS and PPS bodies touch and the interaction is somewhat complex – this is all opposed to at the Friis Hills and at Solitary Rocks where sills are flat and, by and large, flat and smooth. It may be that the BS in N Taylor may combine from 2 lobes – 1 high lobe from above camp here that goes South and a lower lobe from below Mt Odin to Solitary Rocks and these lobes meet perhaps East of Pearse Valley along wall of Taylor or Kukri Hills.

<u>January 22, 2008</u>

Tuesday – Overcast mostly, winds from E then W and E again, 10 – 25 mph – cold while waiting for helo – which was 1 hr late.

At Dais – whole group

Ascended slowly whole section

Lowermost rocks are very coarse suggesting a great deal (maybe 1/2) of the body is buried – this is also suggested by the MgO profile when compared to a full section as at West Bull Pass.

The "sandstone" section of the layered rocks is at the "inch-scale" layering horizon. It is ~100 m long and is massive in form with many varieties of the fine-grained rocks. These appear to me as a package laid down in response to massive settling of the lower opxite – coarse-grained rocks, sweeping the fine crystals upward into "open" magma with the co-precipitation of orthopyroxene. And then, when this deposit was like a mortar in constitution, additional avalanches from ensuing inputs deformed and rolled over the sequence. The massive plag lenses seem to be late recrystallization features.

The largest well developed silicic segregations at the root could have a metasomatic element to them, but they also are well developed as accumulations of late stage melt along pores and fractures – they could be the final final result of a combination of processes.

<u>January 23, 2008</u>

Mt. Fleming Day

Clear, Bright, cold – 22 degrees F at Camp, -and- 15 degrees F on Mt. Fleming and a 30 mph wind off Polar Plateau.

Sampled Sill Vertically starting at the summit from Top down

Sample A-482 – upper contact
Sample A-483 – 10 m down
Sample A-484 – 10 m down
Sample A-485 – 10 m down
Sample A-486 – 10 m down
Sample A-487 – 15 m up and (10 m down)
Sample A-488 – Lower Contact

Sample A-489 – 1 m dike below sill

Sample A-490 – Coal Sample

The sandstone at the top is cross-bedded in a delicate fashion with ~0.5 m scale and is silicified to almost a quartzite.

The sandstone at the lower contact contains coal seams (samples of this A-490). Near the coal seam (~8 cm thick) is a marble-ized conglomerate that may have been metamorphed using calcite cements by the heat of the sill and dike. And some of the coal is now a tufa-type material that is frothy and very crumbly. It may have been cooked using hydrothermal fluids –
All sampling was away from the square end contact seen to the south.

(end of raw field notes)

Addendum

Magmatic Field Laboratory in the McMurdo Dry Valleys

January 2005

The Final Report to the National Science Foundation

Magmatic Field Laboratory Workshop

in the

McMurdo Dry Valleys, Antarctica:

A Final Report

by

Bruce Marsh

M. K. Blaustein Dept of Earth & Planetary Sciences
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November 2005

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Front row (L to R): Drew Fuestel, Dennis Geist, Tom Fleming, Alan Boudreau, David Elliot, Jill van Tongren, Justin Durel,, Amanda Charrier. 2nd Row: Jenifer Cooper, Ron Fodor, Scott Paterson, Ed Mathez, Jon Davidson, Sam Mukasa, Dougal Jerram, Taber Hersum. 3rd Row: Karen Harpp, Jean Bedard,, Michael Garcia, Dick Naslund, Adam Simon, Bruce Marsh. (Not pictured: George Bergantz, Stu McCallum, Michael Manga, Simon Kattenhorn)

Introduction

In the Antarctic summer of 2005 a group of twenty-five geologists participated in a two-week event to study an unusually well exposed unique magmatic structure in the McMurdo Dry Valleys, primarily in Wright Valley, Bull Pass, and Victoria Valley. The uniqueness of this area is in the exceptional exposure of a magmatic-volcanic plumbing system exhibiting in great detail the fundamental connection between deep-seated magmatic and sub-aerial volcanic processes. That is, here the physical and chemical connection between volcanism and its deep-seated source can be followed on foot vertically from one regime to the other. No other place on Earth is this connection so well exposed. Moreover, the magmatic system itself shows a richness of internal structure that reveals other connections of truly fundamental importance linking, for example, the mechanics of ascension and emplacement of crystal-laden magma to the sorting and deposition of crystals leading to exotic layering in the final rock, which bears directly on the genesis of massive layered intrusions found worldwide. That the deepest exposures reveal a chemically primitive, mantle-like, composition and the uppermost exposures are much more compositionally refined, almost continental-like, bears directly on the processes under which the terrestrial planets differentiated into what we know of them today.

Although the occurrence of these magmatic rocks was known from the first visit here by Robert F. Scott's expedition in 1902, and a great deal of subsequent background geologic mapping had been done by primarily New Zealand geologists, very little was known of the overall nature of the full magmatic system itself until systematic detailed petrologic work was carried out over the past ten years (Marsh, 2004). And although this ongoing work was much appreciated as presented at national meetings, the deeper fundamental value of this system to understanding long-standing problems in planetary magmatism could not be appreciated through simply pictures and data. For an intimated understanding of the processes governing magmatic systems geologists have to see the rocks themselves. The rocks in context are the ultimate court of appeal. To serve this end, field trips are key ingredients of many geologic meetings. But the remoteness of the Dry Valleys made a standard field trip improbable. This dilemma was posed in a conversation with Drs. Scott Borg and Simon Stephenson who responded with: "Try us."

After much thought, the idea was not to come all this distance to have a standard field trip, but to bring together the crème de la crème of workers in a spectrum of overlapping fields from volcanology to layerd intrusions to mechanics of emplacement to actually perform real-time field-based research on this magmatic system. The hope was that in this way not only would the whole concept of this system be scrutinized, but also that new discoveries would be made to flesh out in greater detail the power and fundamental value of this system to science. Besides bringing the leaders in various fields, a certain number of younger scientists were also include to expose them to the cutting edge and high value of field-based science. Moreover, the opportunities for geologic research in Antarctica would be discovered by a class of exceptional scientists.

In short, this undertaking was (and continues to be) an enormous success. This venture has changed the scope and course of petrologic science.

Organizational Structure

The main parts of this endeavor involved 1) having enough people around me to allow a smooth flow of information and objective planning without getting bogged down in endless detail, 2) choosing the participants, 3) having a pre-expedition orientation meeting to acquaint everyone with all participants and, especially, with the science, field practices, clothing, and aircraft and field safety, 4) the expedition itself, and 5) post-expedition presentation of results. I will cover these in sequence. A key aspect of the event involved the coordination of transporting people by helicopter each day to and from specific locations of geologic interest and to and from the base camp and McMurdo.

1. Participants and Personnel

The following call for applicants was published in EOS of the American Geophysical Union during the Autumn of 2003.

Magmatic Workshop in the McMurdo Dry Valleys, Antarctica
January 2005

A field-based workshop, involving real-time research, will be held to study the field relations and fundamental magma dynamics of the Magmatic Mush Column of the Ferrar Dolerites of the McMurdo Dry Valleys.

> A two-week field and laboratory event involving 25 researchers will take place to study the magmatic processes of the McDV magmatic system as a centerpiece to understanding the fundamental mechanics and development of magmatic systems in the most general sense. A working conference is envisioned with sessions split between discussions and laboratory work at McMurdo Station in the Crary Laboratory and fieldwork in the Dry Valleys. Four specific processes will be considered: 1. Magma Differentiation in a Mush Column; 2. Crystal Transport and Sorting in Flowing Magma; 3. Solidification Front Instability (SFI) in Sills; and 4. Mechanics of Sill Emplacement.

The McMurdo sessions will involve rock-cutting, study of thin sections, and map analysis so that discussion and work can center on real time field observations. To provide the widest possible impact both in real time and in the long term, it is desired to include in the expected mix of participants researchers working on other parts of the Ferrar system, researchers of layered intrusions and basaltic sills, researchers studying magmatic processes, researchers of ocean ridge magma chambers and impact melt sheets, and graduate students in igneous petrology.

All major equipment, transportation, food and lodging will be provided by the National Science Foundation Office of Polar Programs, Geology and Geophysics Program through a grant to Johns Hopkins University under the direction of Bruce Marsh. Successful applicants will be required to pass a strenuous physical examination and undergo training in field and aircraft safety.

Applicants should send a persuasive letter stating professional accomplishments, research interests relative to above processes, and field experience along with a detailed resume or curriculum vitae to Prof. Bruce Marsh, Dept. Earth & Planetary Sciences, Johns Hopkins University, Baltimore, MD 21218 (bmarsh@jhu.edu).

Approximately fifty applications were received, although many more contacted me during the latter stages of planning to see if they still could be considered. From this group a list of participants was selected along with a reserve list to serve as fill ins for those who drop out for any reason. The final participants were:

Magmatic Field Laboratory Participants

Name		
1. Bedard, Jean	Dr.	Geolological Survey of Canada
2. Bergantz, George	Prof.	University of Washington
3. Boudreau, Alan	Prof.	Duke University
4. Cooper, Jennifer	Grad. Student	University of Missouri
5. Davidson, Jon	Prof.	Durham University, England
6. Elliot, David	Prof.	Ohio State University
7. Fleming, Thomas	Assoc. Prof.	University of Southern Connecticut
8. Feustel, Drew	Astronaut	NASA, Houston
9. Fodor, Ron	Prof.	North Carolina State University
10. Garcia, Michael	Prof.	University of Hawaii
11. Geist, Dennis	Prof.	University of Idaho
12. Harpp, Karen	Prof.	Colgate University
13. Jerram, Dougal	Lecturer	Durham University, England
14. Kattenhorn, Simon	Assoc. Prof.	University of Idaho
15. Manga, Michael	Prof.	University of California, Berkeley
16. Mathez, Ed	Chair	American Museum of Natural History, NY
17. McCallum, Ian	Prof.	University of Washington
18. Mukasa, Samuel	Prof.	University of Michigan
19. Naslund, Howard	Prof.	State University of New York, Binghamton
20. Paterson, Scott	Prof.	University of Southern California
21. Petford, Nick	Prof.	Kingston University, England
22. VanTongeren, Jill	Undergraduate	University of Michigan & ODP
Field Guides		
23. Charrier, Amanda	Graduate Student	Johns Hopkins University
24. Hersum, Taber	Graduate Student	Johns Hopkins University

25. Durel, Justin*	Admin. & Res. Asst.	Johns Hopkins University
26. Marsh, Bruce	Prof.	Johns Hopkins University
27. Simon, Adam	Postdoctoral Fellow	Johns Hopkins University

Reserves

Humphries, Madeleine	Graduate Student	Bristol University, England
Feustel, Drew	Dr., Astronaut	NASA Houston
Ross-Simon, Pierre	Graduate Student	University of Otago, New Zealand
Wilson, Charles	Postdoctoral Fellow	Stanford University

*Mainly in McMurdo

As it turned out, the thin section technician, Sandy Dillard from ODP, at the last minute did not pass the medical checks and he was replaced by Dr. Drew Feustel (more below). Pierre Ross-Simon was already in McMurdo with the New Zealanders, and he also dropped out at the last minute for reasons of graduate school pressures. Charles Wilson also dropped out to take a full time academic job. Right up until the time of departure all of the Reserves were included in all activities. In the end only Madeleine Humphries remained.

In discussions with those who had run biology workshops in McMurdo, I was strongly urged to have a Postdoctoral Fellow to help with the daily correspondence and sundry other chores. The advertisement below produced Dr. Adam Simon from the University of Maryland, who worked out exceedingly well. His salary was split 75-25 between the NSF and Johns Hopkins University.

> **Postdoctoral Fellow in Magma Dynamics, Johns Hopkins University.** A highly motivated and innovative individual is sought for a two-year position to assist in magma dynamics research and, principally, to assist in organizing and leading a Field Workshop on Mush Column Magmatism to take place in the McMurdo Dry Valleys, Antarctica in the Austral summer of 2004/05. The Workshop will involve 25 people and will last 2 to 3 weeks in January 2005. A significant amount of time will also be available for personal research throughout the period of the Fellowship. Individuals liking hard work, long hours, spectacular geology and petrology, and great adventure should apply. Antarctic field experience is desirable, but all applicants will be carefully considered. Johns Hopkins University is an Equal Opportunity/Affirmative Action employer. Women and minorities are encouraged to apply. Application letters and two letters of reference should be sent to: Prof. Bruce Marsh, Morton K. Blaustein Dept. of Earth & Planetary Sciences, Johns Hopkins University, Baltimore, MD 21218 (bmarsh@jhu.edu).

A part time administrative assistant was also hired to handle payments, etc. and his (Justin Durel) salary was split 50-50 between the NSF and Johns Hopkins. Help also came from two graduate students (Amanda Charrier and Taber Hersum) who had both previously been to Antarctica on this research venture.

2. Orientation Meeting

In late October of 2004 a three-day event was held at Johns Hopkins to thoroughly immerse everyone in all aspects of the event itself, from the science to the choice of food and clothing to field safety to life in Christchurch and McMurdo, and the facilities available in the Crary Laboratory. Everyone attended and the nuts and bolts of everything were discussed. Our liaison person, Jesse Crain from Raytheon Polar Services (RPS), also attended, brought examples of the all the ECW (Emergency Cold Weather) gear and offered commentary on any number of issues from housing in McMurdo to the availability of petrographic microscopes. Drs. Scott Borg and Thomas Wagner also visited, as did Prof. William Brody, President of Johns Hopkins. A better idea of the event itself can be gained from the agenda and the agenda preface. A strong underlying theme of this endeavor was to encourage each individual to examine and discover the science on his/her own terms. Although plenty of background information was given, there was a deliberate attempt *not to put forth a 'party line' of thinking to which all work must adhere.* Moreover, *there was no attempt during the event itself to have organized group discussions to consolidate points of view that might snub budding and incomplete fresh ideas spawned from the field observations.*

A field guide to the state of the ongoing research on the magmatic system was supplied to each person containing maps and detailed chemical and physical geological results.

Magmatic Field Laboratory Workshop: McMurdo Dry Valleys, Antarctica

Pre-Expedition Workshop

Johns Hopkins University

Baltimore, Maryland

23 – 26 October 2004

Agenda

The main objective of this meeting is to acquaint everyone with one another and especially with the overall geology and petrology of the Ferrar magmatic system so that each person can make realistic plans on what to see and do while in the field. Once acquainted with the geology and landscapes, each person will want to make detailed plans on how to accomplish the research objectives. This may entail, for example, pulling together additional information on locations of certain field relations and resources (maps, photos, etc.) between now and January to make the field effort meaningful and effective. It is also intended to acquaint everyone with the overall process of travel to Antarctica, clothing, field safety, aircraft safety, camp operations, and life at McMurdo Station.

The overall theme is to provide a creative and cordial atmosphere for the free exchange of ideas, questions, and cutting edge educational insights.

Saturday, 23 October: Afternoon and evening: Arrival of participants and lodging check-in at the Broadview Apartments (at the corner of University Ave. and San Martin Drive).

6:30 PM: Greetings and Social time at the Dept. of Earth & Planetary Sciences (5-7 min. walk directly south across JHU campus to Olin Hall on San Martin Drive); movie on Shackleton Expedition.

Sunday, 24 October: 8 AM: Coffee, tea, bagels, fruit, and juice in E&PS lobby (Dept. of Earth & Planetary Sciences).

8:30 AM: Introductions: "Magma in Context"

The concept of a Magmatic Field Laboratory Workshop. Real time, individually-based research on a unique magmatic system.

Participant introductions- a few minutes from each (w/wo one or two slides or transparencies) on research interests.

Support Personnel: Jessie Crane, Raytheon Polar Services.

10- 10:15 Coffee Break

The field research theme groups: Intrusion Mechanics, Layering Processes, Geochemistry, Petrology & Geology.

11:45 – 1 PM—Lunch in Rocky Run bar & grill.

1 PM: The Ferrar Dolerites of the McMurdo Dry Valleys.

2:15 – 2:30 PM: Coffee Break.

2:30-3:15 PM: Tectonic & Geologic History of Antarctica and Dry Valley Region—

David Elliott, Ohio State Univ.

3:30-4 PM: The Kirkpatrick flood basalts—Thomas Fleming, Southern

Connecticut Univ.

4- 4:30 PM: General discussion and logistics for evening.

5:30-6 PM: Meet at home of Bruce & Judy Marsh (12420 Falls Rd., Hunt Valley,

MD) for dinner and evening lecture on History of Antarctic Exploration.

Monday, 25 October: 8 AM: Coffee, tea, bagels, fruit, and juice in E&PS lobby (Dept. of Earth & Planetary Sciences).

8:30 AM: The Details: Going to and from Antarctica.

In New Zealand:

- The NSF Clothing Distribution Center (CDC)-getting the right clothing, baggage limits.
- How to stay warm.
- Personal items to take.
- Field Gear.

In McMurdo:

- Accommodations (lodging & eating).
- Field training—snow ('survival') school.
- Helicopter safety. Radio operation.
- Crary Science Center:
- Rock Saws, thin-section capabilities, and petrographic microscopes.
- Computer facilities.

10-10:15 Coffee Break.

Field Operations.

- Safety.
- Camp Life and Duties (cooking, cleaning, latrine)
- Sampling.
- Flow Chart of subgroup movements.

11:15AM: Greeting of Visitors from Washington: Scott Borg (NSF), Thomas Wagner (NSF), Brian Stone (RPSC).

11:45 – 1:30: Lunch at JHU Faculty & Alumni Club.

1:30- 3 PM: Research Theme subgroups planning sessions (each group needs a moderator and a recorder).

3-3:20 PM: Coffee Break.

3:20-5 PM: Full Group Discussion on subgroup plans and tentative objectives.

5:30 PM: Ambassador Dining Room (Indian cuisine).

Tuesday, 26 October: 8 AM: Coffee, tea, bagels, fruit, and juice in E&PS lobby (Dept. of Earth & Planetary Sciences).

8:30- 10AM: Overview of Scientific Objectives in light of subgroup plans.

10-10:15AM: Coffee Break.

10:15- 11:45AM: Subgroup revised discussions on field objectives.

11:45 – 1:30: Lunch in Levering Hall cafeteria.

(Throughout this period, individuals with special needs, questions and concerns are encouraged to meet individually with any of the leaders.)

Afternoon: Departures.

The Expedition: Operational Layout

Overall Philosophy: The basic plan decided early on, but which in the end changed drastically, was to establish a Base Camp at Bull Pass for the whole group and to shuttle people in and out of camp by helicopter to key geologic areas. Once a person gained enough rock samples or map information to warrant laboratory work, he/she would be shuttled to McMurdo where facilities were set up to carry out actual research that would decide the next round of field work. Due to environmental concerns this plan was modified, and we were limited to having a smaller camp footprint than originally planned such that a maximum of only fifteen people could be kept at Bull Pass-at least two of these people (camp manager and me) would be in steady residence. There was a suggestion and some discussion of having everyone at McMurdo or part at Marble Point, but from the start a deep philosophical objective was to keep as many people as possible together among the actual formations being studied to allow for maximum critical discussion and exchange of ideas twenty four hours a day. The plan settled on thus involved half of the group at any one time being in Bull Pass and the other half being shuttled in on a daily basis from McMurdo, each group would spend three nights at a stretch in the Bull Pass Base Camp. The group in McMurdo would also stay there for part of their three-day stretch using facilities at the Crary Laboratory for making maps, using the petrographic microscopes, cutting rocks, studying aerial photography, and engaged in discussion.

An important part of the early planning was a division of the participants into four integral groups that would be scientifically cohesive and transportable as groups in and out of the field. These groups were designated: A1- Petrology, A2-Geochemistry, B1- Geology, B2-Mechanics of Intrusion. It was expected that these groups would be shuttled around together as integral units to field locations and in and out of Base Camp at Bull Pass. And for field safety, each person was teamed up with a partner each day in the field and each overall group would have a guide with Antarctic experience and each group would have someone experienced in basic field medicine including CPR. This whole plan changed due to five situations.

First, as the whole group became more and more acquainted with the field relations and the nature of the magmatic system, everyone wanted to spend as much time as possible in the field. Second, many people wanted to be either paired with certain people in other groups or with new people each day so that they could experience the perspective of as wide a group as possible. In this way, for example, a volcanologist could gain the views of a mechanics of intrusion person, which otherwise would be an uncommon occurrence. Third, many people wanted to see almost all the prime field locations and others wanted to spend most of their time at only a few locations critical to their interests. Four, at the last minute our master thin section maker failed the physical exam and we decided that we could each make our own thin sections with guidance from a few among the group who were already experts. Fifth, when the main group was all staged in Christchurch, McMurdo experienced an eight-day whiteout with no travel in or out. This squeezed all the scheduling at Crary, helicopter operations, McMurdo housing, including the time when some of the participants were to return to teaching duties. Given these conditions, a new system was developed to maximize the overall success.

The Cafeteria Science Concept: The group designations were dissolved and everything was centered on the science at the field locations, which is the critically unique aspect of the whole undertaking. That is, each participant was asked on a daily basis what she/he wanted to study for the following day, regardless of whether they were staying at Bull Pass or McMurdo. They were given the following options.

Field Options

Emplacement
Victoria Valley
Ribs and Southeast Edge
East tip Basement Sill (B.S.)
Climbing contact
Granite wedge
Opx tongue and contacts and tip
B.S. pods Southeast Wright Valley
Granite Dike
Contact dikelets B.S.
South wall Wright Valley B.S.

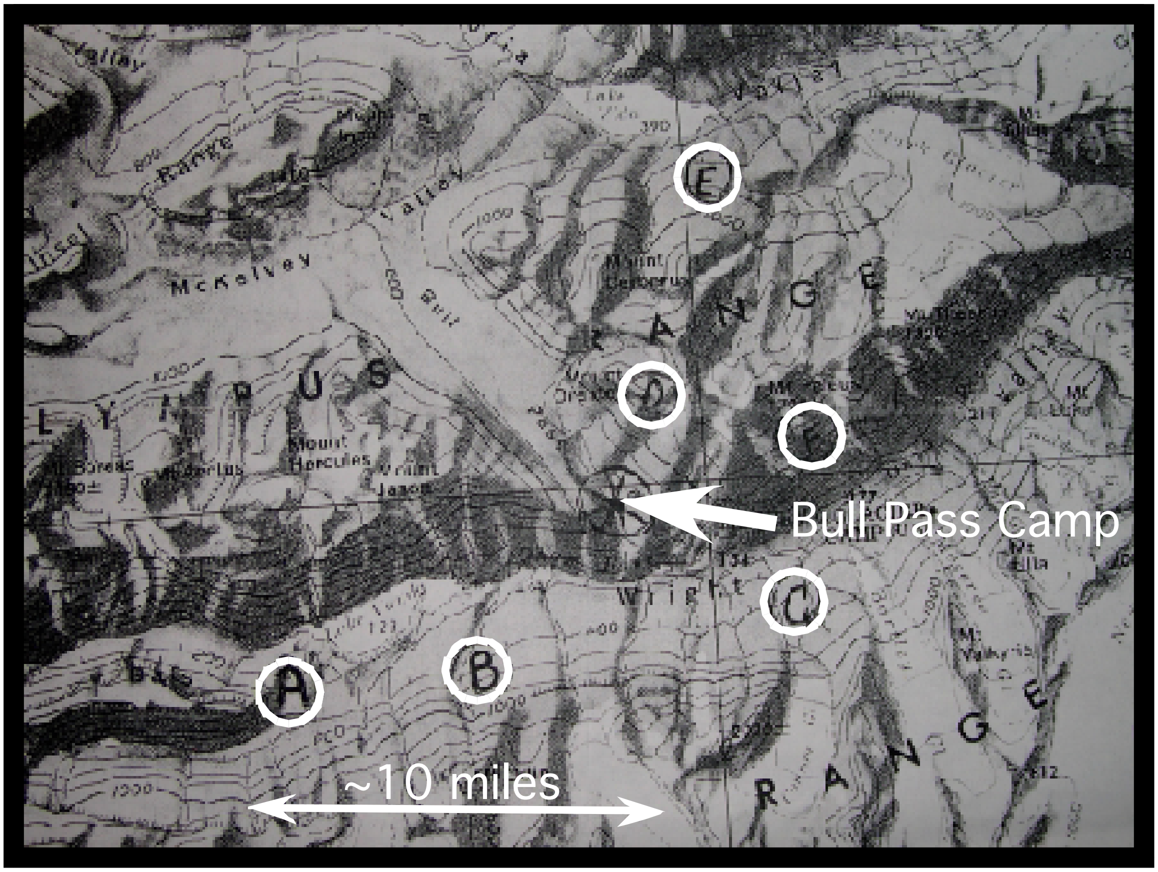
Crust Interaction
Granite Wedge
Aplite dies
Porphyritic dikes
Climbing contacts west Bull Pass (B.P.)

Layering
Dais
West B.P.
South Wall Wright valley
Directional growth in feeder

Solidification Front Instability – Segregations
Dais
West Bull Pass
Central Bull Pass

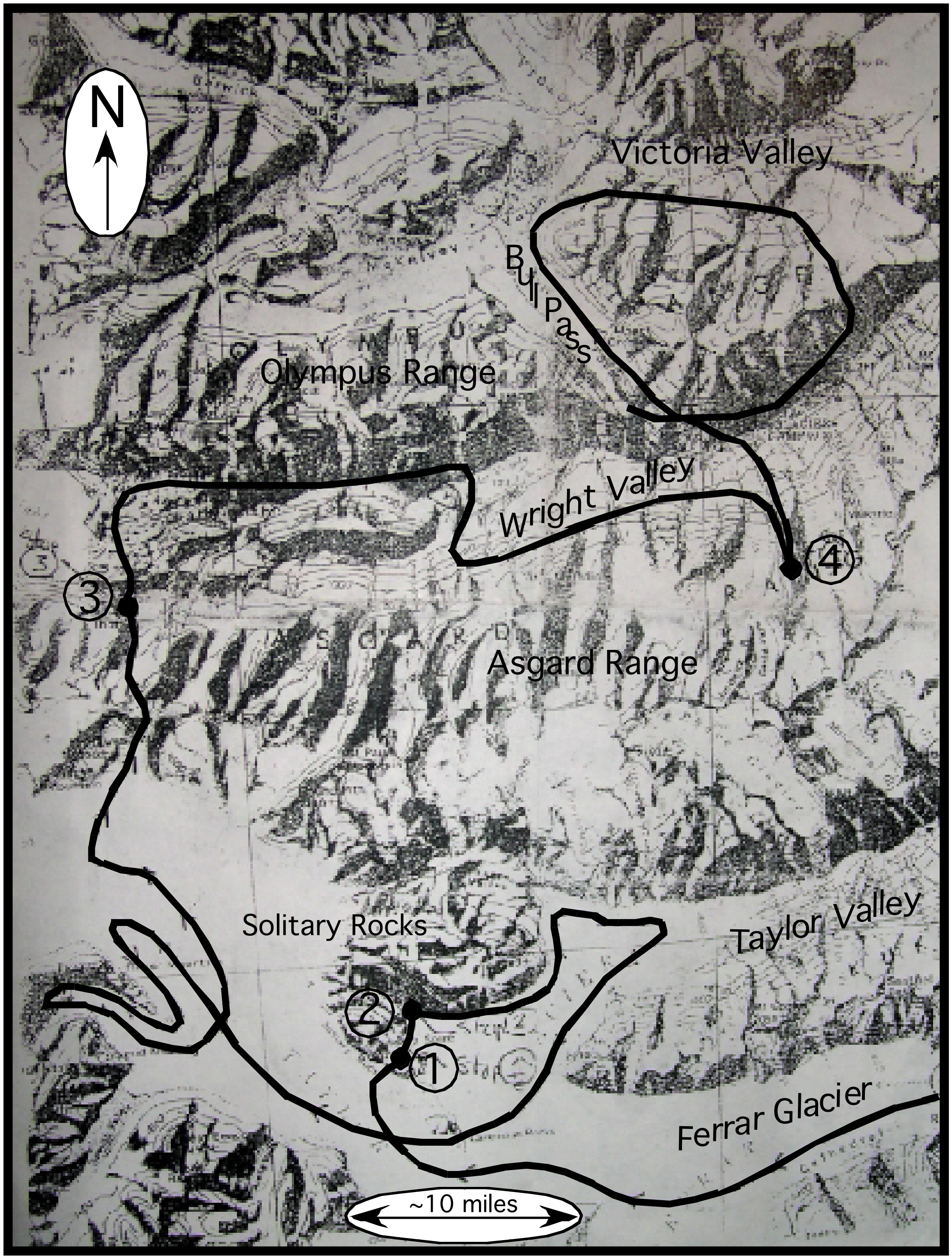
Dikes
East Bull Pass
Central B.P. swarms
South wall Wright Valley
North wall Wright Valley

And since some of these sites are in the same general location, to facilitate helo-operations and minimize confusion over the exact locations, specific scientific sites or landing spots were given designations as A, B, C, D, E, F, and G (see figure 1). These were marked on maps and widely distributed to helo-operations, all pilots, and all participants. Each person, then, simply signed up for a specific location for the following day or days. This information was relayed to helo-operations as “seven packs to site G, four packs to A….etc.” and weights were measured at Bull Pass using scales. Because groups commonly contained mixes of people from both Bull Pass and McMurdo, generally everyone was amassed each morning in Bull Pass and then recombined and shuttled to the various field locations. Although largely unknown to the participants, each field party was also selected to always include a seasoned Antarctic field person and a person possessing advanced medical training. (Participants were each queried at the outset on their medical training (e.g., CPR, etc.) and were encouraged to acquire additional medical skills.) Times for periodic radio checks were set up for each party and the VHF ‘Science Net’ frequency band was used intensively for communication amongst and between groups. People could also work in small groups on foot from Bull Pass or in McMurdo. This worked very well; everyone was able to see as much science as possible and to interact with as many people as possible.



Landing-work sites

In addition to this system, each participant was taken on a half-day helo-geologic tour of the entire Dry Valley geologic system. This was a marathon day from mid-morning to well after midnight involving three separate tours, two with one helicopter and one tour with two helicopters (all Bell 212s) each tour involving four stops. This was intended to develop in each participant a deep geologic impression of the complete magmatic system and to give the pilots and support people a true sense of science and philosophy behind this endeavor. It went very well and was exceedingly well received on all fronts.



Aerial Geologic Tour Flight Path and Landing Sites

The Final Result: *The overall success of the endeavor, as measured in terms of impact on individual careers and in influencing the course of science, is overwhelming. (Personal remarks regarding these issues, from each of the participants are given below.)*

This system did, however, put unexpected strains on the helo-operations and housing. Instead of handling only half the full group each day, they were being asked to handle the full group. This was not an issue of helo time, for we had enough hours, but simply adding a lot more daily complexity to the helo-operations. There were occasional mild mix-ups and strains on both ends, but nothing serious. Given more lead-time for planning with this final operations system, helo-operations would have been more comfortable about the whole procedure.

To alleviate housing confusion, Housing assigned us a block of rooms that we rotated people into and out of, keeping the same pairs of people in each room so that when they were staying in Bull Pass their other gear was in the room (under the bed) where they would return to on the next cycle. To keep the room keys available, each person getting on a helo in McMurdo could only get a bag lunch in exchange for a room key.

In retrospect, the ideal setup would have been to have everyone based in Bull Pass and each day the groups shuttled to the field locations and returned in the evening. This would have greatly minimized helicopter time, wear and tear on all personnel, and the pressure on housing in McMurdo. The environmental concerns of having a bigger camp at Bull Pass will be addressed later.

The facilities in McMurdo set up specifically for this endeavor were excellent. About 100 thin sections were made, probably significantly fewer than would have been made had the master thin-section maker been on board. And the microscopes and mapping facilities were also used less than expected. This is, however, mainly the result of two things: First, with the strained schedule due to the McMurdo Whiteout, people were anxious to see as much in the Dry Valleys as possible. Second, once the outstanding exposures and deeply significant field relations were seen, each participant simply could not see enough of them. They rightly looked upon this time as the chance of a lifetime to see as much of the critically important field relations as possible.

Post-Expedition Impressions and Outcomes

The true success of this endeavor is perhaps best measured by the impact it has had on the scientific perspectives and research agendas of the participants themselves. Each person came to the Expedition with a personal expectation of what he/she wanted to achieve. These expectations were formulated from limited understandings of the science and the actual geologic exposures. In many ways, the following personal impressions tell a multifaceted story of the expectations and outcomes of the Expedition. I have edited them very little, only removing overly congratulatory remarks directed to me.

Impressions of Participants
(alphabetical)

Jean Bedard (Geologist, Geologic Survey of Canada):

Fieldwork was very successful, with good weather overall, after an initial 1-week delay. All of the original research objectives were attained, there were many exciting discussions and a coordinated research effort is now underway. All of the target objectives should be achievable.

[This is only a very brief part of a much more extensive report summarizing the field research observations and overview of impending research, partly in coordination with other members of the Expedition. The full report is given in Appendix I.]

George Bergantz (Professor, University of Washington):

The meeting was absolutely incredible. Everyone said so. I will remember that episode all my life. Many said that. Who could foresee the logistical (weather) complications? But in the end it was stunning. What a tremendous opportunity. I have been kicking around a few thoughts about 'down there' but needed to talk with you more. As I told Jean [his wife], "my mind is blown, constantly."

Jennifer Cooper (Graduate Student, University of Missouri):

The workshop was an excellent idea. I am surprised by how much I got out of the workshop. I learned about the current state of knowledge related to igneous processes in a way that cannot be done by reading a textbook or even journal articles. The opportunity to listen in on so many different debates and ask questions has really helped me develop my thinking on how to approach a scientific problem. In addition, the opportunity to talk with everyone and find out about their research backgrounds has really helped me refine my own interests. I am very fortunate to have had such an opportunity at an early stage in my career.

Bull Pass was a perfect setting for this type of workshop. It was great to see such a well-exposed example of a magmatic system. As you have mentioned the extent of exposure really does make it an ideal system to study. Considering how much information a well-studied magmatic system can add to the field of igneous petrology, I am excited to see what will develop as a result of collaborative research on this system. This workshop has certainly encouraged some excellent scientists to begin work in the area.

The timing of the workshop as a student was perfect. It was an excellent chance to step away from my own research and take a look at the bigger picture. It has definitely influenced my current research, allowing me to see some of the broader applications of the work I am doing. I am sure it will guide me in developing future research ideas.

I hope that more workshops like this one will occur in the future. I also hope that more students will get the chance to participate in something like this. It really has been an incredible experience for me!

Jon Davidson (Professor, Durham University, England):

Dougal [Jerram] and myself (and Nick [Petford]) are working on an article for Geoscientist, which I think nicely sums up our experiences - he may have sent you a copy already.

As you know, I had a great time. It was incredibly smooth considering the logistical hurdles, which had to be surmounted. I enjoyed everyone's company - and was surprised that there were not more tantrums and tears...but again that’s probably because there were minimal frustrations to bring out that kind of thing.

The geology itself was all I expected from the photographs, and more. I admit to not being enticed into detailed sampling, I was rather more tempted to luxuriate in generalities and get a "feeling" for everything, on the basis that my layer of science can be put on top of what's already been carefully laid in place by your work (and I have left my "requests" for samples accordingly with you and Taber).

We had the local press round last week - one of the realisations that I hadn't made before was that this workshop has actually given me a better understanding of magmatic processes than I had previously held - and that’s before I have done any real analyses and data collecting. In response to general questions we ended up talking about continental breakup, storage and transport of magmas and even about volcanic hazards.

Bruce we all owe you (and our benefactors at NSF) an enormous thanks for your efforts.

David Elliott (Professor, The Ohio State University):

The magma field workshop was a rewarding experience. It has been invaluable from the point of view of my understanding of the Ferrar, having never before set foot in the Dry Valleys other than at the Meserve Glacier in 1968. I have, of course, known that the Dry Valleys sills are an exceptionally well-exposed portion of the intrusive component of the Ferrar and important from the perspective of sill geometry and emplacement, let alone geochemistry. There is no substitute for actual field observation. I am incorporating some of those observations in a review paper I am writing at the moment on the volcanology of the Ferrar large igneous province.

The provocative ideas put forth by the PI will change how I present aspects of magma dynamics and crystal accumulation in advanced petrology classes. The processes of crystallization and re-equilibration in large igneous bodies have been puzzling and at best are not well understood, or maybe even poorly understood. The range of expertise at the field workshop provided a unique opportunity for collaborative field observation and collection of common samples, to be followed by lab analyses and interpretation. Insights from the Basement Sill are going to advance understanding of magmatic processes regardless of any one researcher's perspective.

Drew Feustel (Astronaut, NASA, Houston):

I am still trying to formulate my impressions of the trip value...as you can imagine mine will be significantly different from anybody else's. However, I will have some comments for you once I pull together a summary presentation of the trip for the Astronaut office here.

Bruce, thank you so much for the opportunity of a lifetime...you cannot imagine how lucky I feel for having been given the chance to see Antarctica. I hope that I was able to contribute in some way to the adventure for everybody, it definitely had a lifelong impact on me.

Thomas Fleming (Associate Professor, Southern Connecticut State University):

I want to express my thanks for allowing me the opportunity to participate in the Magmatic Field Laboratory this past January. It was a real pleasure to be able to see first-hand the impressive work that you and your students have been doing over the last ten years. The exposure of intrusions in the Dry Valleys segment of the Ferrar Province is unparalleled and clearly this is one of the best places in the world to develop the type of integrated view of magmatic systems that you have been working toward.

The group of specialists you brought together for this workshop/expedition has a terrifically broad range of expertise and the working environment you created in Antarctica facilitated a tremendous free exchange of ideas. I am certain that this group will have a profound impact on our understanding of magmatic processes and will generate significant future interest in Antarctic geoscience.

On a personal level, the opportunity to examine these rocks this past field season was particularly fulfilling because of my long standing history working on a broad range of scientific issues associated with the Ferrar. In particular, being able to observe the dolerite intrusions in Dry Valleys, in light of your observations, has provided an important context for my own work on the Ferrar Dolerites and the Kirkpatrick Basalt in other areas of the Transantarctic Mountains. As a result of observations and discussions made possible during the field season, my thoughts have rapidly evolved regarding many aspects of Ferrar magmatism. I am looking forward, with anticipation, to our gathering this autumn to exchange ideas that have developed from data collected in the laboratory. Also, please extend my thanks to Adam Simon for his efforts in coordinating the logistics for the trip, and to your students Tabor, Amanda, and Justin for all their hard work in supporting the field program. They have all played an important part in making this workshop a tremendous success. Once again, thanks for taking the initiative to put this innovative workshop together and thanks for allowing me to be apart of it.

Ronald Fodor (Professor, North Carolina State University):

I have been wanting for some time to re-connect and thank you...and thank you profusely, if I may, for providing me (us) with such a rewarding trip from so many perspectives. ..petrologically, certainly at the top of the list, but not to ignore the values in the outright and sometimes challenging field experience ('eye-opening' and physical, too), the camaraderie, and the emotional and 'cultural', so to speak, impacts.

I must remark on something you made point of more than once – that the Dry Valley field exploration offers the opportunity to see and sample snapshots of petrologic processes in their largest forms and exposures that are free from the normal obstructions of soil and vegetation and alteration. Up until the trip, I could only imagine the reservoirs beneath, for example, shield volcanoes, and any segregations therefrom --but here were the opportunities to see, touch, photograph, and collect what were until recently only descriptions about how magmas crystallize and processes involved.

I know that for me the immediate application...as I think I'd mentioned to you...are to how I view Hawaiian sub-shield magma environments. In particular, I am now reshaping some of my thinking for my re-writing of a manuscript. I must say […….] I feel that after Antarctica I am much closer to the truth about these Mauna Loa rocks than before.

I have already put my trip insights and slides to good use with a presentation the to geology club in our department, as the students were eager to hear of my experiences and have some vicarious Antarctica experiences themselves.

It's hard to describe all the feelings and individual 'points' of education from the workshop, as you can imagine, but the overriding feeling for me is that a trip of this magnitude is how petrology should be taught and experienced -- to get right there on site with 'perfect' outcrops that one can walk across for hundreds of meters, if not some kilometers, to examine from the finest to the grandest igneous features with ease. (And, of course, contributing to that 'ease' by which we got from here-to-there was the fantastic helicopter service; I'm amazed at how much personal attention those folks offered to accommodate each and everyone's desire to see particular places an geologic features.)

All us attendees are so very aware of all the time, work, planning that you did to get us to the Dry Valleys to share with you what you discovered and have enjoyed for so many years...and I won't touch on the money aspect, because that, I know, was a world unto itself, and maybe a demon at times, as you worked through the years of planning.

I could go on and on about the other aspects, too, like the glaciers and glaciation features -- I really enjoyed those a lot and learned a lot from observing them -- and just the magnitude and enormity of everything around us down there, including having to adjust to estimating distances; I really got a kick out of those enlightenments.

In conclusion, I will add that you are indeed blessed to have such a great group of students (and post-doc) working with and around you. Adam, Amanda, Taber, Justin -- what wonderful people, and all, I can judge, with promising futures. And you, too, Bruce -- it was such a pleasure to be in your company, as you are so incredibly generous and caring. I can't imagine anyone else or any other personality having created and successfully completed such a 20+ person, extremely remote field program as you did.

As for my research: I have some chips I carried back in process to for thin sectioning, and I await the arrival of my crate of rocks. For detailed studies, at this time I will say that I will limit myself to the segregations, largely because that aspect is of special interest to me, and I hope to be contributing when we all decide the place and venue for such. Meanwhile, take care and, for sure, a grande muchas gracias for all and everything.

Michael Garcia (Professor, University of Hawaii):

This note is to thank you for organizing the Antarctica Magma Workshop. This was a remarkable experience. It allowed me to see classic outcrops and to engage in fruitful debates on these sensational outcrops with some of the leading experts in igneous petrology and structural geology. This was indeed, a unique experience.

It all starts with the rocks. Nowhere else in the world are sills so beautifully exposed and accessible. I have been to many corners of the world, but the Dry Valleys of Antarctica provide a unique opportunity to examine the feeder system for ancient volcanoes. The massive sills in these valleys document a wide range of magmatic process from crystallization to melting of country rock. I was also stuck by the remarkable exposure of dikes in the underlying basement granites. I have never seen dikes so dramatically exposed with such details of their structure.

I expect to continue research on two problems related to this workshop: Origin of pegmatites in thick sills (in collaboration with Dennis Geist, Alan Boudreau and Ed Mathez) Petrology of Basement sills (in collaboration with Ken Harpp and Dennis Geist)

I may also examine some of the young volcanic cones in the McMurdo area as a possible future research endeavor. I would never have considered this if I had not gone to Antarctica with this workshop.

Thank you for opening my eyes to the joys and wonder of Antarctica geology.

Dennis Geist (Professor, University of Idaho):

The magmatic field workshop led by Bruce Marsh made a number of impressions on me, both scientifically and personally. The Ferrar sills proved to be everything that Marsh has been presenting over the past decade: they are one of the world's premier examples of crystal-liquid sorting by entrainment and segregation, mostly caught in action and little overprinted by the annealing that plagues larger intrusions. The origins of some of the most basic relationships I saw still confuse me, particularly the irregular distributions of crystal sizes and how those relate to flow and deposition and post-depositional crystal growth. The processes that are clearly exemplified by the Ferrar rocks are already providing food for thought on my own work on lavas that formed by similar processes. Intrusion through pre-existing mush must be one of the most important petrogenetic processes on our planet, and now the goal is to ascertain the extent to which the process governs mass-balance and crustal growth in a variety of tectonic settings.

The opportunity to immerse ourselves in the unique environment of the Antarctic is an experience that will make a permanent impression on every participant. One of the main topics of conversation among groups in the field was "let's figure out a way to initiate our own study down here." Many email conversations have already taken place on this very topic, since our return. I envision a flurry of proposals to Polar Programs, although we all recognize that it is tough to find an unfilled niche because of the Hopkins group's thorough efforts.

Marsh is to be congratulated for assembling this team for the workshop. The group had exceptionally diverse perspectives on the rocks, which kept the scientific banter constantly engaging. A camaraderie among the entire team quickly developed, partly driven by the scientific opportunity and rocks, but mostly because it was an extraordinary group of people.

I especially appreciate the opportunity to have worked with Bruce Marsh. He performed a remarkable service to our field by organizing and executing this workshop. The level of stress presented by the logistics and expectations must have been overwhelming, but it never showed. His knowledge of the rocks and setting were crucial to the expedition's success, and although he is one of the leading theoreticians in our field, he promotes alternative and divergent explanations.

Karen Harp (Associate Professor. Colgate University):

First and foremost, a heartfelt thanks for all your hard work, as well as that of your graduate students and Adam. This was a trip that I keep calling a once in a lifetime experience, but I hope to make that a false statement by bringing students back to Antarctica for research of our own.

This was an exciting and beneficial experience in innumerable ways for me. As a faculty member at Colgate University, an exclusively undergraduate institution, we are, by definition, “one of a kind” in terms of our research specialties. This means that while on campus, there are no other faculty working on research projects similar to my own and I have to reach beyond the walls of the institution for collaborative opportunities. Consequently, it is extremely valuable to me to be able to spend extended time with scientists such as the Antarctica participants, a group of respected and dynamic leaders in their field. Such experiences always allow me to learn a great deal, especially in the field (having come from a chemistry background, I’m still playing catch up on that front!).

Our teaching schedule at Colgate is intense, and does not always allow for us to be up-to-date on the literature as much as we care to be; simply chatting with the distinguished group of participants is an invaluable education in itself. This trip was particularly beneficial because of the length and intensity of the interaction, both in the field and between field excursions, basically talking all the time about geology. You allowed us the great luxury to explore on our own, pursuing our specific interests in the field.
I have spent the bulk of my research career studying volcanic systems, but have had few opportunities to examine and contemplate their internal plumbing networks. The Dry Valleys are a unique location that allows us to delve into fundamental magmatic process questions, as you and your colleagues and students have done over the years. This workshop, in turn, provided both a learning experience as well as a solid grounding on which to base further work.

Another benefit of this experience has been to illustrate that it is not logistically difficult to get into the field in Antarctica, thanks to the resources in place in the Antarctica Program. During the next year, I intend to try to write a proposal to NSF polar programs to initiate a small-scale, geochemically-based research program, beginning, potentially, with the sequence of dikes that I sampled during the workshop. My proposal will, as always, include Colgate undergraduates who will carry out projects focused on specific aspects of the questions I end up posing. In the past, I have included Colgate students in research in the Galapagos Islands and Iceland, which have usually led to the students presenting their work at AGU or other comparable conferences. Most students get involved in undergraduate research primarily because of the draw of the area, and Antarctica will no doubt have an indescribable attraction to many students (as it does for me). They will, subsequently, become involved in the science; most end up pursuing careers in graduate school because of their research experiences.

Dougal Jerram (Lecturer, Durham University, England):

That will go down as one of the most enjoyable experiences both as an overall trip and from a science perspective. I think much will build from this venture and we owe a lot to yourself and to the help from the Johns Hopkins team and the folks on the ice.

I am working on the Geoscientisit article and should have a draft to you over the next few days. I have contacted the editor and in principle he can see no problems and is looking forward to seeing it.

it will be a good way of advertising the NSF grant. It is likely to be about 1500 words with lots of figures and hopefully a front cover picture.

I will be looking to fine time for a short trip over to get images of thin-sections and to make a plane with the 3D model.

Simon Kattenhorn (Associate Professor, University of Idaho):

I would like to extend my eternal gratitude and appreciation to you for allowing me the opportunity to visit your field area. As I mentioned to you once before, I have long dreamed of seeing the sill intrusions in the Dry Valleys, not only to have the opportunity to see intrusion mechanics at a scale much larger than I have ever experienced, but also to simply visit a location of unparalleled magnificence that few scientists would ever get to appreciate. I too have that explorer mentality that drives me to visit the far-flung places of the planet and just feel so appreciative of having been able to visit Antarctica.

The Dry Valleys sills were an eye opener, for sure. The shear scale of them simply blew my mind! I have worked almost exclusively in intrusions into sedimentary rocks, and so really appreciated being able to see a deeper crustal equivalent in granites. Seeing the contrasting higher level sills at the ice falls was particularly breathtaking. I have simply never seen such incredible field examples of brittle intrusion as I did in that region. Although time limitations prevented me from accomplishing some of the tasks I would really have liked to accomplish in terms of analyzing the intrusion mechanics, I found myself constantly taken aback by my observations in Wright Valley and Bull Pass. The OPX tongue continued to impress and confound me until the day I left in terms of its emplacement mechanics.

As well as being able to satisfy my obvious curiosity about the intrusion mechanics, I have to say that the experiences I had interacting with my fellow expedition participants were also greatly appreciated. Just having the opportunity to stand beside a gaggle of petrologists and listen to contrasting views on layering and petrogenesis being "banded" about was an educational experience in itself. I learned so much from the whole experience. I participated in another NSF-funded workshop prior to the Antarctica workshop, and I must say that the magmatic processes workshop was by far the more rewarding experience from a scientific point of view. I felt that your choice of participants covered a range of expertise, experiences, and personalities that worked on so many levels.

Thank you again, and I wish you continued success with you work down there. I hope I can examine some of the data I collected in more detail at some point, and if I do, I will be sure to drop you a line.

Michael Manga (Associate Professor, University of California, Berkeley):

The exposure of the sills was phenomenal and the scale impressive. Compared to other sills and dikes I have seen, I found it much easier visualize the emplacement dynamics because the top, bottom, front and interior were all exposed and in context. Based on what we saw, and the small number of samples I brought back, I have started some lab experiments with analog materials combined with numerical modeling to understand the role of the high crystallinity of the opx tongue on the emplacement dynamics and formation of internal structures. If these preliminary projects turn out not to be dead-ends I will be back in touch with you and Amanda.

Even more valuable to me was the chance to see a wide range of geological processes and phenomena. Two examples have been inspirational.

First, I am currently interested in patterned ground on Mars and the constraints it provides on Martian climate. Seeing real examples of classic patterned ground in a Mars-like setting has made me change a bit the way we are approaching the problem.

I was also very impressed with the hydrology in the "dry" valleys. Rivers have unusually large aspect ratios. Groundwater recharge also seemed to dominate the input to the river at the base of the valleys. I am not yet familiar with the literature and past work on Antarctica hydrology and groundwater-surface water interaction. It must differ significantly from temperate climate hydrology because of the presence of ice and the heat exchange between water and subsurface ice. This academic term I am teaching a class on hydrology (EPS 105) and for the second half of the class we will probably focus on subsurface hydrology in regions with permafrost to see if we explain some of the features we saw on our trip.

Edmond Mathez (Curator, American Museum of Natural History):

I'm happy to summarize what I feel I got out of the Dry Valleys experience. And I do mean experience, but the way. This was no mere field trip. We had the opportunity to study the field relations in detail, to converse at length, to reflect, and, of course, to make new friends. The most important elements I came away with are as follows.

1. I gained significant insight into my own research on layered intrusions. These rocks experienced a substantial geochemical and textural evolution during their slow cooling, making it particularly difficult to understand the igneous differentiation processes. The Ferrar dolerites mostly avoided that fate, yet some of the sills do display a poorly developed layering. I've actually become to believe your own assertion that the presence of crystals has an important influence on the development of layering. Whether or not this is true is irrelevant; the fact is that I am thinking differently about layering in layered intrusions.

2. I've never seen a hypabyssal plumbing system as well exposed in the vertical dimension as it is in the Dry Valleys. This perhaps is the only real basis for a conception of the crustal plumbing system below flood basalt provinces and above layered intrusions, so that's a new insight that I had not had before. Ultimately one starts making connections to imagine what other systems might look like and what the consequence might be. The one that occurs to me is Noril'sk.

3. The Dry Valleys are one of the most exotic places on the planet, and anyone interested in nature has to be fascinated by the place, from its glaciers to its microbes. The fascination appeals to the imagination; it's what makes our science so exciting. This excitement motivates us to tell our natural audience, which in my case includes the public as well as students. It is the intellectual nourishment that feeds the human spirit and helps us be effective educators and ambassadors of our field. As you know, I am taking advantage of the experience and my position to be both as best I can.

Samuel Mukasa (Professor, University of Michigan):

As I already expressed in person at McMurdo, let me once again thank you for providing the opportunity for us to see the world-famous dolerite sills of the Ferrar magmatic province, and to learn so much from each other. For me, having worked primarily on the Dufek layered mafic intrusion at the Weddell Sea terminus of the Transantarctic Mountains, it was very instructive to see other expressions of Ferrar magmatism. I did not realize how truly differentiated "dolerite sills" are until you showed us the western ridge of Bull Pass and the Dais, both parts of the Basement Sill. Moreover, I did not appreciate the textural complexities of silicic segregations until I saw them in the field for the first time during the Dry Valleys magma workshop. They would make a fantastic topic for a comprehensive geochemical and petrologic study [.......]

Also very important to me are the contacts I made with the layered mafic intrusion community. Because I am a jack of all trades with some of my work being in the areas of U-Pb geochronology, mantle geochemistry, arc petrogenesis and tectonics, I did not know the layered mafic intrusion community very well. The Dry Valleys magma workshop provided me with the opportunity to meet some of the key players in the field. Some of these contacts might even result in collaborations on Ferrar materials and possibly even beyond that.

If you want some feedback about my own observations with respect to dynamics within the group, I think that everyone got along with everyone else very well. Nevertheless, there was a tendency for some clicks to develop -- not so much at Bull Pass, but certainly back in town. Some of this may have been due to prior strong associations between the two or three people in each cluster. [.........]

H. Richard Naslund (Professor, State University of New York, Binghamton):

I am writing to thank you for all of your efforts in organizing and implementing our recent workshop in Antarctica. I think that this trip will become a milestone in the careers of many of the scientists who went along. The beauty of the exposures available in the Antarctic Dry Valleys is unsurpassed in the world, and the complexity of the geology exposed in the Basement and Peneplain sills is truly shocking. I have spent many years working on layered intrusions and have seen igneous layering in many different intrusions, in many parts of the world, but I was unprepared for the variety of layering features exposed in the Basement sill and the intensity with which layering has been developed in such a shallow, relatively rapidly cooled body. Those of us who work on the mechanisms for igneous layer formation have a lot of rethinking to do as a result of these Basement Sill features. The contact relationships between the sills and host rock exposed in the walls of the Dry Valley were also phenomenal in their clarity and variety. Calling them "textbook examples" doesn't do them justice. You described the Dry Valley sills as a natural laboratory for examining intrusive processes; I think you were right on the mark.

I shook my head in disbelief at the original price tag for this expedition, but it is clear that it was money well spent. This workshop will have a profound influence on scientific thinking about sills, layered intrusions, and intrusive mechanisms for the next generation of petrologists and structural geologists. Those who were fortunate enough to participate will reference it constantly, those who missed this opportunity, will still be forced to consider the implications of these rocks because their description and photographs will certainly become an integral part of the scientific literature. I can't thank you enough. Please extend my sincere thanks to all of your Antarctic "team".

Scott Paterson (Professor, University of Southern California):

Now that our Sierra meeting is over, I wanted to respond to you regarding my thoughts regarding our Antarctic trip. In general the trip was amazing and an experience I feel very lucky to have experienced. Below I will list a number of thoughts in the order that the occurred on the trip.

1. The Johns Hopkins meeting was very helpful, although I did hope we could have had time to talk science a bit more. The two things that would have helped would have been to hear more about what research each person was doing (beyond the 5 minute introductions we did), and to have a chance to talk more about the "state of knowledge" of sill systems.

2. Staying in Christchurch for 9 days was really unfortunate and not all that much fun. We could have used this time to give our PowerPoint presentations and continue discussions about our research and sills. If the Antarctic center could have a room and multi-media projector available this would have been useful for any delayed group.

3. McMurdo facilities were excellent and much appreciated. However, most of us would have preferred to stay out in the Dry Valleys once the fieldwork started. I don't buy the environmental arguments of reducing the group size. The extra helo fuel, landings, reduced research time in the field, etc. more than offset the above.

4. The camp organization, helo planning, etc in general were great although having a more aggressive person at McMurdo to help would have been useful. If we hadn't lost so much field time in Christchurch I also would have enjoyed mixing the field groups up a bit more to force us to work with other individuals.

5. The experience of seeing the Dry Valleys and the sill system was amazing. It will have the following influence on me:

a. I now understand the logistics of working in the Antarctic and certainly will consider working there in the future.

b. I have already completed one and have two more PowerPoint presentations underway that will give (1) an overview of research in the Dry Valleys, (2) Antarctic research logistics, and (3) the geology of the sill system. I have already given several talks at different universities using these PowerPoint's and will certainly incorporate them into my teaching in the future.

c. Obviously this sill system is a spectacular example of a magmatic plumbing system and being able to see it adds a much greater depth to our understanding of your papers and ideas. Clearly this is fast becoming a world-class study and one that could greatly influence our community for some time to come. My one concern remains the degree to which the different groups will collaborate and address each other's data sets. Jean Bedard's nice summary is an example of this. This is essentially a petrologist's view of the sills and does not incorporate a structural/mechanics view. To truly make this a world-class "community-changing" study, I think this needs to happen.

6. A final comment concerns something that I became very aware of on the way home. Many of us ended up traveling together, some all the way to LA. And there was clearly a camaraderie and bonding between people that did not even know each other before the Antarctic trips. We had made new friends, colleagues and acquaintances, some of which I hope to pursue research with in the future and others that I am already keeping in touch with. As you know our "magma community" can sometimes be a bit fractious. Maybe if we got the whole community to go through the snow camp together in the Antarctic, we could get along better and do better science!

Bruce, thanks again to you and your group for this trip. It is and will certainly send ripples out into our community.

I am slowly making a structure/mechanics summary to go along with Jean's and will send this along at some point.

[This detailed summary or agenda of research needed to solve the emplacement problem is given in Appendix I.]

Nicolas Petford, (Professor, Kingston University, England):

The Dry Valleys exposure is world class. The contact relationships within the sill complex, and in particular the geometry and structure of the Basement Sill and Opx tongue, are generally outstanding. To me a critical feature of the outrcrop is that the detailed internal structure, including layering and local melt segregation processes, appear amenable to analysis using theory and experiment from granular mechanics. Having worked on this problem in magmas from a mostly theoretical perspective, actually seeing structure in the rocks that match those from prediction, and being able to test our ideas in some detail, is priceless.

The experience has also convinced me that some, perhaps many, of the textbook explanations for the origin of structure in intrusive igneous rocks based on classical treatments (equilibrium thermodynamics and phase petrology) might be blinding us to a much richer set of processes that are strongly rate dependent and rely on particle-rich suspensions as an initial condition. This is petrology for the 21st century - informed by rapid progress in allied fields (notably chemical engineering, but also computer science and scientific visualisation), but constrained and ultimately tested in the field.

Jill Van Tongeren (Undergraduate, University of Michigan):

I just wanted to quick write and say thanks for everything this past month. I had an absolutely unforgettable experience and I learned a lot. You put together a great group of people. Thanks so much for including me on the list!

Resulting and Ongoing Research

At the close of the field work, while the group was still in McMurdo, there was a widespread consensus that a symposium or special session at a national meeting should be held to further discuss and present the research findings from the field and ensuing laboratory research. The title suggested was *Magmatic Systems: An Antarctic Perspective*. This was proposed and accepted by the Volcanology, Geochemistry, Petrology section of the American Geophysical Union and 29 abstracts were submitted for presentation at the annual (2005) December meeting in San Francisco. Papers were also contributed by others working in the general area of the Dry Valleys and also by researchers who became involved with the project through contact with the participants. For example, Prof. Peter Larson (Chair, Washington State University) heard about the trip from Prof. Dennis Geist, a participant from the nearby University of Idaho, and contacted me to say that he had performed oxygen isotope analyses on samples from the Ferrar dolerites some 20 years ago and did not know the value of these data. He shipped this important data to me and I found them to cover the very same sections of rock in the Basement Sill that we have been studying. We immediately entered in a mutual research project, which involved sending him another suite of samples, each of which is independently well characterized, and he has completed a suite of oxygen isotope analyses on the whole rocks and on the individual constituent minerals.

Another important example is the involvement of Paul Morin, Dean Peterson (University of Minnesota) and Zbigniew Malolepszy (University of Silesia, Poland) who are each experts in geologic visualization using the most advanced techniques of 3-D visualization. For many years we have tried in vain to construct a 3-D digital geologic model of the McMurdo Dry Valleys, which will enable us to understand the magmatic plumbing system that fed this magnificent magmatic system. An accidental meeting with Paul Morin showed that we, and almost all others, were on the wrong path and in a matter of about four months we were able to develop a true 3-D interactive model of the geology of the Dry Valleys. This has opened up a whole new area of research. Moreover, it was also discovered during this interaction that Dean Peterson is an expert on the plumbing system of the Duluth Gabbro, which is much older (> 1 Ga) but similar in overall nature to the Ferrar Dolerite system. The funnel-like magmatic deep feeder system found for the Duluth Gabbro matches almost exactly the nature of the deep feeder independently inferred for the Ferrar System.

The titles and authors of the abstracts for this Special Session are listed below in the order of presentation (Asterisks denote author groups primarily containing people not participating in the actual field workshop).

Magmatic Systems: An Antarctic Perspective

The McMurdo Dry Valleys Magmatic Laboratory Workshop of 2005 in Antarctica
B D Marsh, A Simon, A D Charrier, T G Hersum, E Eschholz

Development of Three-Dimensional Geologic Model as Spatial Framework for Study of the Ferrar Magmatic System, Dry Valleys, Antarctica
*Z Malolepszy, P Morin, B D Marsh, B J Souter, D Peterson

Lavas and Sills in the Ferrar Large Igneous Province: Field and Geochemical Evidence for the Order of Emplacement.
D H Elliot, T H Fleming

Small-scale modal layering in the Dais section of the Basement Sill, Ferrar Province, Antarctica
H R Naslund, J H Bedard, A Simon, S B Mukasa

Slurry flow and structures formation in a magma mush: the Basement Sill, McMurdo Dry Valleys, Antarctica
N Petford, D Jerram, J Davidson

On the Mechanism of Layering in the Dais Intrusion, McMurdo Dry Valleys, Antarctica
E A Mathez, I S McCallum, B D Marsh

3D crystal packing variation through a 99hythmic layer in the Dais Intrusion, Dry Valleys Antarctica: Initial insights through 3D micro CT analysis.
D A Jerram, A Mock, J Davidson, N Petford, B Marsh

Pyroxene thermometry in the OPX Tongue of the Basement Sill, McMurdo Dry Valleys, Antarctica
A C Simon, B Marsh

*The Transantarctic Mountains between South Pole and Scott Glacier area: a geophysical perspective
M Studinger, R E Bell, W Buck

Geographic Variations in Chilled Margin Chemistry of Jurassic Dolerite Intrusions in the Dry Valley Region of South Victoria Land, Antarctica
T H Fleming, D H Elliot, A Calhoun

Discovery of a Funnel-like Deep Feeder Zone for the Ferrar Dolerites, McMurdo Dry Valleys, Antarctica
B D Marsh, T G Hersum, A C Simon, A D Charrier, B J Souter

Textural Gradients in Antarctic and Canadian Sills: Evidence for Episodic Filling History
*M J Zieg, C J Forsha

Evidence for Channelized Transfer of Residual Melts and Fluids in the Basement Sill, Ferrar Province, Antarctica
J H Bedard, T Fleming, T Hersum, B Marsh, E Mathez, S B Mukasa, H R Naslund, A Simon

Crystallization and Degassing in the Ferrar Sills, Antartica
A E Boudreau, A Simon

Origin of Mafic Pegmatoids in the Dais Intrusion, Wright Valley, Antarctica
D Geist, A Boudreau, M Garcia, K Harpp, E Mathez, B Marsh

Basement Sill of the Jurassic Ferrar Large Igneous Province, Antarctica: Constraints from its PGE Abundance Patterns on Magma Source Characteristics and Crystallization Processes
S B Mukasa, G Ravizza, J Bedard, T Fleming, A Boudreau, B D Marsh

Rheology of Suspensions and the Emplacement of Tongues Crystal-Rich Magma Within Sills
I Sumita, M Manga

Using micro-isotopic approaches to evaluate the origin and emplacement mechanism of the Basement Sill, Dry Valleys, Antarctica
J P Davidson, D Jerram, N Petford, B Marsh

3D Visualization of “Frozen” Dynamic Magma Chambers in the Duluth Complex, Northeastern Minnesota
*D M Peterson, S A Hauck

Petrologic Consequences of the Magmatic Death of a Continental Arc: Vanda Dike Swarm, Dry Valleys, Antarctica
K S Harpp, B C Christensen, D J Geist, M O Garcia

Silicic Melt Generation, Segregation, and Injection by Dolerite Partial Melting of Granitic Wall Rock, McMurdo Dry Valleys, Antarctica
T G Hersum, A C Simon, B D Marsh

Magnetic Anisotropy in Ferrar Sills from the Upper Taylor Glacier Region, Southern Victoria Land, Antarctica
*A M Grunow, T H Fleming, J Priest, A Calhoun, S Marshak, A Whittington

Evidence for Extended (5-10 Ma) Emplacement of Ferrar Dolerite from 40Ar-39Ar Geochronology
*K B Knight, P R Renne

Ferrar Dolerite Sill Emplacement Styles, Dry Valleys, Antarctica
S A Kattenhorn

Sill Emplacement Dynamics: Experimental Textural Modeling of a Pulsing, Cooling, Particle-laden Magma as Applied to the Basement Sill, McMurdo Dry Valleys, Antarctica
A D Charrier, B D Marsh

Visualization Methods for Three-dimensional Mapping Techniques Used in the Dry Valleys
*P J Morin, Zbigniew Malolepszy, B Souter, D Peterson, B Marsh

Profiles of 87Sr/86Sr and 143Nd/144Nd as Indicators of Magma Dynamics in the Ferrar Dolerite Magmatic System, McMurdo Dry Valleys, Antarctica
K A Foland, B D Marsh

Oxygen Isotopes of Orthopyroxene and Plagioclase from the Dais Layered Intrusion of the Ferrar Dolerite Magmatic System; McMurdo Dry Valleys, Antarctica
P B Larson, B D Marsh

Cracking the Lid – Dike Emplacement Above Large Sills of the Ferrar Province, Antarctica
*J D White, T Thordarson, M M McClintock, P Ross

Critical Overview

That this undertaking was an unqualified enormous success is due mainly to the exceedingly professional and unmatched logistical and material support furnished by the National Science Foundation by way of Raytheon Polar Services (RPS). No other scientific expedition of this nature and magnitude has accomplished more at this level of expertise. Handling scientific expeditions of this general nature is, clearly, the routine job of the RPS staff, but the expedition size, weather delays, and desire to do real-time research within a relatively narrow time window added a level of complexity and challenge new to McMurdo. There were ample opportunities for the system to break down. That it did not was due to some simple, but key, ingredients in the operation.

First among these is the assignment of a liaison person (Jesse Crane) from RPS to work with us in the planning from the earliest conceptions of the entire endeavor. Because we also had not put together any similar expedition of this magnitude, and because this group of high-profile academics each had distinct research needs and styles of field work our plans evolved or shifted as the effort took form. The core idea, however, of taking world-class scientists into the field, showing them key areas, and letting them take to the rocks in their own ways with a minimum of proctoring and preaching on what the rocks they were seeing meant never changed. Adherence to this key idea, in a very real way, carried the whole effort and lead to success. Crane understood this philosophy early on and came on her own to understand what we were driving towards. Her geologic background and personal approach to solving problems as they appeared without forcing our plans to mutate into something less desirable were critical aspects of this planning process. Her attendance at the Pre-expedition Workshop solidified her understanding of the whole effort. That is, through her efforts to understand what the endeavor was all about, she solved many smaller problems to our satisfaction with a minimum of contact with us. Also, instead of us dealing with many people in each of the various areas of this effort, Crane handled most of this for us. All the critical decisions and considerations were left to us, but Crane often spelled out the possibilities and gave us advice on how to move and solve major issues.

A downside to this excellent administrative structure came when we got to McMurdo. Crane was not there and we were then left to deal with any number of local department heads on a one to one basis. This was overly time consuming at a time when all the day-to-day details of the field program were also ramping up. I strongly recommend that the liaison structure be carried through to McMurdo and the completion of the project, preferably involving the same RPS staff.

Second was the assignment of a Camp Manager (Erika Eschholz) to help with the daily communications, helo-scheduling, re-supply, and sundry other details of running the Bull Pass Base Camp. Like Crane, Eschholz also quickly came to know and appreciate the philosophy of what this endeavor was all about and she rapidly adhered to the spirit of the whole effort. She also easily came to know exactly what I would want done and would proceed with conviction without having to bother me about many details—she would routinely, however, run through what she was doing so that I could change things if necessary in future moves. Her mindset also covered the very same concerns at the same instants that I sometimes had about late returning field parties on foot from Bull Pass. We would immediately come to a sensible common course of action with a minimum of conversation and all situations were quickly resolved.

Eschholz came to us with a certain amount of apprehension on what we were all about. This may have been based on reports from other camps in the past. She presented us at the start with a clear and sensible description of what she saw as her duties and what she saw as not her duties. She was quite guarded, although impressively professional, in her early dealings with us in McMurdo. I think she thought we would run roughshod over her once in the field and ask her to do custodial work. It would have been good to also have had Eschholz attend the Pre-expedition Workshop at Johns Hopkins so she would have known the group from the very start, and seen that we had clearly laid out the ground rules for running the Bull Pass camp. This involved each person taking turns in cooking, making lunches, and in cleaning the camp, which worked well. Eschholz caught on very quickly and immediately realized that there was no need whatsoever for any concern. She was, I think, very pleased and impressed by the high level of family-communal spirit that pervaded the Camp. She was not only the Camp Boss but she was also Camp Mom; she took care of us to a person on a professional individual basis. Reminding people not to forget sun screen and lunches to attending to persistent sore throats, cuts, hammered thumbs, and giving advice on what might be a good meal or how a certain hike might be more safely made.

Third, the facilities made available at the Crary Laboratory were excellent, not only in the usual ways of supplying paper and pencils, but also in host of more technical aspects. The usual saws for cutting rocks were conveniently arranged and in top shape and the Logitech thin sectioning machine was in peak condition and a person had been trained to help train our users. All necessary supplies were on hand and our production of thin-sections was perfectly satisfactory, although the final number of sections was less than we had anticipated due to the absence of our master thin-section maker. This need was also alleviated by bringing a large supply of existing thin-sections of the Dry Valleys rocks from my laboratory at Johns Hopkins. Thin-sections are useless without good petrographic (i.e., polarizing) microscopes and these were supplied along with a video setup to allow projecting thin-section images on a screen. The value of this setup in a large room with room for discussion and gathering cannot be over emphasized. It was as good as the best facilities at any university. And the nearby IT group handled a myriad of individual computing issues with a level of ease and efficiency enviable to all the university professors. They also, on a moment's notice, printed out large color figures and posters used in discussion and research. Due to the long whiteout at the start, the Crary facilities were stretched by the serious time delay, but this was accommodated with grace and good will.

Fourth, perhaps the only area that did not go as smoothly as it could have gone was in planning for the location and operation of the Base Camp in Bull Pass. Due to environmental concerns about having a camp at Bull Pass, It was suggested by RPS that there be no camp in Bull Pass at all, but that each day the scientists be brought in from McMurdo. After some discussion, it was suggested that a part of the group might be housed at Marble Point and the others in McMurdo. I carefully explained that a deep philosophical basis for the whole endeavor was to have the participants living with the rocks and rock formations that they would be studying during the day and remaining as a group for discussions throughout the evening and on into the following day's field work. Although this made good sense, there was deep concern over the environmental aspects of having a large camp of people at Bull Pass. Questioning on my part about the nature of these concerns revealed that this area had apparently been designated on a map as a sensitive drainage area by biologists and ecologists. A difficulty in the discussion, which was done by conference call among about eight people, was that no one except me had ever been to Bull Pass; there was serious confusion over the exact nature of the terrain and just exactly, to the foot, where the camp would be placed. I carefully explained that I had camps there in 1996, 1997, 2000, and 2003 and had as many as nine people in the group. I also explained that the camp area is about a 10-acre gravel plain and there is virtually no chance for any environmental problems. Although this did not seem to be particularly convincing, on the grounds of having the scientists living with the rocks being studied, it was agreed that perhaps a camp of ten people would be okay. I explained that for logistical ease in handling the group and completing our objectives we needed to have at least 15 people at Bull Pass. This was finally agreed upon and we were approved for about a 16 by 16 meter campsite (see the Record of Environmental Review in Appendix II).

> *The area where the camp will be located is an 8094 square meter loose, but firm, gravel plain. The campsite itself will occupy approximately 16 meters by 16 meters. The structures will consist of 6 Scott Tents (1 latrine, 5 sleeping tents for 10 people); 3 Alpine tents (3 people); and one Endurance tent (21 foot, for kitchen and workshop sessions).*

A problem cropped up as the camp was about to be put in when it was discovered by Eschholz that the footprints of the tents would not fit into the allocated space; stakes for one tent would have to be underneath neighboring tents. We appealed to have our allocated ground space enlarged and the camp footprint was enlarged to 32 by 32 meters. Although still small, this did suffice.

It would have been much more convenient, economical, and environmentally wise to have the whole group in Bull Pass with an A-Star helo assigned to us each morning and afternoon to shuttle people to and from the work sites. This would have saved an enormous amount of fuel (and exhaust into the atmosphere), helo-time, lodging strains in McMurdo, and allowed the full group to form a tighter scientific cohesiveness, allowing a much greater time in the field overall. The largest potential down side would be the need for twice as much re-supply and retro-ing of human waste; since we used no fuels, except propane, there would have been no increased risk of fuel spills.

In retrospect, it seems essential for the environmental officer at RPS to visit the potential campsite, preferably with the PI, and go over the proposed camp footprint and operation or, at the very least, visit the PI and go over aerial photos of the area. It is also important when designating areas as sensitive to one science group (e.g., biologists, geologists, ecologists) that other groups be consulted to get their input. It is too easy to include a larger than necessary area as being sensitive simply because it is ‘barren rock wasteland.’

Fifth, the PHI pilots furnish a core of expertise and skill that is, truly, unparalleled in field geological operations. Of the many aspects of this operation that make it invaluable, perhaps the most important to me is their personal understanding of the objectives of the scientific effort. They take the time to understand what and why we want to do what we are doing in the field. They offer useful advice on how field objectives might be met safely and efficiently, and they always have a sensible, constructive, and supportive attitude. It is very important that they be included in all stages of planning of the field operation of endeavors of this type. Not just in the usual fashion of being informed of the flight needs, but in the details of how the staging and overall scientific operation. I have found that it is the pilots themselves who have valuable insight into how to setup a convenient, safe, and efficient operation. And in this respect it is essential that the transition from the helo-coordinator to the pilots be as seamless as possible. This is especially so when running two shifts of flying. We had some problems in having evening communications passed intact to the day people, and also at the outset in getting established a general plan of day to day operation. Jack Hawkins and Christopher Dean of PHI were instrumental in overcoming these hurdles in a clean and direct fashion.

Because of the initial eight-day whiteout, the schedules among the participants and the McMurdo operations, changed radically as the program commenced. Yet through helpful McMurdo staff in many sectors, each scientist was accommodated and enjoyed a highly productive field season. The final impressions of the participants, which are included below, are, to a person, exceedingly complementary of all aspects of the endeavor.

Summary: An endeavor of this style and magnitude involving participants of this caliber, carrying out real-time research and learning, has perhaps never before been attempted on this scale in the Earth Sciences. The mix of people, the richness of the field relations, and the high caliber and professionalism of the support staff made this endeavor uniquely successful.

Appendix I

Detailed Research Reports

Through field observations and discussions among the participants, many ideas for further research were generated. The majority of the participants outlined agendas for further research. Two of the more extensive research plans are included below. These are intended to give an impression of the level of detail in observation and thinking attained by the more seasoned participants; one report is mainly geochemical and the other is geomechanical.

A. Jean Bedard (Geological Survey of Canada):

1- Overview.

Fieldwork was very successful, with good weather overall, after an initial 1-week delay. All of the original research objectives were attained, there were many exciting discussions and a coordinated research effort is now underway. All of the target objectives should be achievable.

2- Sampling and preliminary field observations.

Two sample sections were collected in the layered rocks of the Basement Sill, in collaboration with Sam Mukasa of U. Michigan: 24 samples from the Dais intrusion, and 22 from the West Bull Pass lobe. Results will be integrated into existing geochemical profiles. A few samples were also collected from the south wall of Wright Valley (Basement Sill) and one from a higher sill.

A) **The Dais**. This is the thickest section of the Basement sill (450 m exposed) and occupies the center of Wright Valley. It was suggested during the discussion that this may be some type of Lopolith, with a thick section at the Dais, and thinning of layers with onlapping to either flank. Some of the observations (C, below) suggest that the valley walls may actually reflect an original contact, with some type of high-temperature subsidence effect (paleo-normal faults?) Moving in towards the sill/valley axis. Although it has yet to be formally subdivided into internal units, an informal nomenclature is suggested here.

The base of the sill is not exposed. The 1st rocks are Lower Zone orthopyroxenite, which is characterized by abundant, euhedral, stubby prismatic orthopyroxene, locally with a well-developed layering-parallel foliation. A poorly developed flow lineation may be present. Variable quantities of feldspar-rich material (10-50%) occurring either interstitially, or as schlieren or ovoid pipe-like structures. More rarely, a facies characterized by 0-15%, 5-10mm sized feldspar clots is seen. The feldspar clots are generally ragged-looking, but some appear to be euhedral, and may represent phenocrysts. Some of the feldspathic schlieren are anastamozing and appear deformed, others are regularly-spaced and could be described as rhythmic layers. The feldspathic schlieren may represent porosity waves, or some other type of structure related to compaction and melt percolation. Alternatively, they may represent sorting of primocryst plagioclase and coprecipitated orthopyroxene. The better-organized feldspar-rich pipes are up to 1-2m wide. They may contain m/g gabbro or gabbro-noritic facies that appear identical to those of the upper part of the intrusion. Others are more complex, with anorthositic or very fine-grained margins. These pipes may represent fossil melt channels.

Isolated feldspathis layers could represent internal sills of this migrating melt, or represent true depositional feldspathic cumulates.

The orthopyroxenite appears to grade up through a feldspathic websterite unit, characterized by upwardly increasing abundance of acicular clinopyroxene, to gabbro-norite and then into a 20-30m thick, complexly-layered, gabbro-norite/gabbro/anorthosite, which I will refer to as the Lower 'Critical' Zone. Clear evidence for movement of residual,volatile-enriched melt fractions and metasomatic overprints were observed in the LCZ. The background lithology is a feldspathic gabbro-norite,characterized by stubby orthopyroxene prisms, and more acicular clinopyroxene; typically with a well-developed bedding-parallel foliation. Beds vary from cm, to 2-3 m scale thicknesses. Whether the feldspar-rich nature of this rock is due to a phase equilibrium control, or whether these rocks are due to large-scale sorting of buoyant plagioclase derived from below, remains uncertain. Some of the rocks in the feldspathic LCZ are pegmatoidal gabbro-norite layers and pipes that clearly truncate the existing fabrics and bedding. Thin (1-5cm), f/g gabbro-norite rhythmic interbeds with lower proportions of plagioclase are developed in spatial association with the pegmatoidal layers, and are inferred to have a post-cumulus origin. Similarly, isolated pyroxene clots or rosettes (see C below) are developed in the background gabbro-norite in the vicinity of these metasomatic bodies. More mafic (pyroxenite) facies appear to replace feldspathic rocks, and could be a metasomatic component complementary to the supra-cotectic proportions of feldspar seen in the LCZ. Both metasomatic types were sampled to provide constraints for the investigation of meltexpulsion and migration.

The Middle Zone cycle (c 30m) appears to begin with a meso-gabbro-norite and again grades up into a complexly-layered, feldspathic unit, the Middle Critical Zone, very similar to the LCZ. The Upper Zone begins with gabbro-norite and rapidly grades up into a more nassive gabbro, with abundant pegmatoidal pods in its upper half, some of which were sampled. In places, the gabbro is spotty, with incipient development of coarse pegmatoidal facies.

B) **West Bull Pass.** This section is c. 380m thick and was also investigated in some detail. The lower chilled margin was sampled so as to provide an internal standard. The chill lacks orthopyroxene phenocrysts, but has plagioclase and clinopyroxene microphenocrysts. A priori, it cannot have crystallized the orthopyroxenitic Lower Zone at emplacement pressure. Phase equilibria experiments will be developed at Johns Hopkins by Adam Simon to constrain this. The Lower Sheeted Sill Zone was discovered to be a composite unit, with emplacement of at least two seprarate 10-50m thick sills with internal aphanitic chilled margins (2 samples), and downward-coarsening zonation to micro-gabbro-norite. The existence of these internal chills suggests that the Basement Sill was emplaced as several pulses, separated by extensive cooling.

The main body of the Basement Sill here is gabbro-noritic at its base (Lower Marginal Series) and grades up into the Lower Zone orthopyroxenite, which is essentially identical to the Dais intrusion Lower Zone. The weathering pattern in the Lower Zone is characterized by erosive-resistant haystacks, up to 5m high, surrounded by concentric fracture patterns that may represent a larger-scale version of columnar jointing. Near the upper part of the orthopyroxenite, some of the feldspathic pods were sampled and mapped more systematically. As for the Dais, these have textures that resemble the gabbros and gabbro-norites above, and could plausibly represent an ephemeral melt-drainage event. On average, these pods are c. 10-20m apart, and have a characteristic number density that may be high enough to have allowed channelized drainage of pore melt from the orthopyroxenites. This aspect will be modeled in collaboration with Bruce Marsh. A well-developed Critical Zone is not found at West Bull Pass, but gabbro-norites, gabbros and anorthositic facies occur together, interlayered on various scales. Whether or not a systematic cryptic zonation exists remains to be seen. Near the top of the section, gabbroic rocks become dominant, with significantly less orthopyroxene and more acicular clinopyroxene. Several laterally-impersistent, 1-3m thick brown-weathering, magnetite-bearing gabbro layers were observed, perhaps indicating arrival of cumulus Fe-Ti-oxides? The upper part of the intrusion is characterized by abundant pegmatitic pods, which plausibly represent volatile-enriched material expelled from the underlying gabbro-norites.

C) **South Wall of Wright Valley**. Like West Bull Pass, this represents a thinner, less well-developed facies of the Basement Sill. These rocks appear to be close to the edge of the sill, and may have been characterized by faster cooling rates? In collaboration with HR Naslund, a series of pyroxene rosettes were sampled from 3-4 sites. The rosettes are concentrated along planar surfaces (at least 3 sets) oriented sub-parallel to the valley wall, and possibly, to the sill contact? Rosettes are c. 5-8mm thick, and in their more primitive variants, occur as globular-shaped pyroxene grain-aggregates scattered randomly along the preferred surface. Larger rosettes develop by preferential growth along this same plane, giving them a more discoidal appearance. The rosette-forming mineral is a black clino(?)pyroxene, and does not show a characteristic cleavage flash, suggesting that these are grain aggregates, not single oikocrysts. They contain inclusions of prismatic brown orthopyroxene and acicular clinopyroxene. Plagioclase inclusions are uncommon, occurring either near rosette edges, or along inclusion-rich concentric zones. The textures imply that rosettes grew, replaced plagioclase, and coagulated. The distribution of the rosettes on some surfaces is extremely suggestive of radial dendrite growth. Another example showed a large rosette surrounded by a halo of smaller ones, suggesting some type of diffusion-controlled nucleation effect. Another example had larger rosettes on the periphery, and a 10-20cm wide core zone with smaller rosettes; possibly reflecting some type of 'Ostwald' ripening effect on the marginal rosettes, where they could grow using nutrients from the surrounding medium, while those in the center were starved? These rosettes are interesting because they seem to record rapid diffusion-controlled growth at high (magmatic) temperatures, suggesting that these may be high-porosity zones. The planar orientations suggest a fracture control, and high-temperature joints may be the closest analog structure. No evidence of a plane-parallel fabric was observed, however, indicating that these cannot be shear zones. In conjunction with fractal analysis, and gothermometry and trace element analyses, it may be possible to constrain cooling rates for these environments, and get some idea of what role they may have played in draining the cumulate mush. Similar rosettes were observed near the metasomatic pipes in the Dais Lower Critical Zone.

3- Collaborations.

My tentative commitment to the group research effort involves:

a) crushing 50 samples; $1K
b) analyzing these 50 samples for trace elements via ICPMS; c $5K
c) mineral-chemical analysis of these samples with the electron probe; c $4K
d) point-counting or image analysis modal calculations; c $ 1K
e) Nomarski imaging; c $1K
f) geothermometry, trace element modeling, percolation/fractionation modeling.

Extensive collaboration with other researchers will cover many analytical costs and will assist in performing some of the modeling. The most pertinent are:

a) major and conventional trace elements by XRF: Tom Fleming of Southern Connecticut State University;
b) Platinum Group elements: Sam Mukasa of the University of Michigan;
c) in-situ trace element and isotopic (Pb) analyses of minerals: Edmond Mathez of the American Museum of Natural History (NY);
d) in-situ Sr isotopic analyses: Jon Davidson of U. Durham (UK);
e) probe work and Nd-Sr isotopic analyses of mineral separates: Richard Naslund of SUNY Binghampton;
f) crystal fabric and tomographic analyses: Dougal Jerram of Durham (UK);
g) numerical percolation and trace element modeling: Alan Boudreau of Duke University;
h) compaction modeling: Nick Petford of Kingston University (UK);
i) calculating diffusion / nucleation effects and intra-conduit flow rates: Bruce Marsh (Johns Hopkins);
j) phase equilibrium experiments on Ferrar lavas: Adam Simon (Johns Hopkins).

4- Research Objectives

The material collected will allow the processes by which the Basement sill differentiated to be investigated in detail.

A) Detailed petrographic (transmitted light, backscattered and Nomarski interference imaging) and mineral-chemical (elemental mapping and trace element ion-probe analysis) comparison of suspended phenocrysts and equivalent minerals in the cumulates, fabric and modal analysis, and thermometric calculations, will constrain how early crystals formed and evolved after accumulation. More specifically: are the feldspathic schlieren in the orthopyroxenite melt escape structures, a trapped melt component, or variably sorted co-precipiotated material (kinetic sieving)? Are the large gabbroic pods in the orthopyroxenite fossil melt channels? Are the plagioclase-rich critical zones above the orthopyroxenite simply suspended plagioclase that had originally coprecipitated with orthopyroxene? Or are they fractionation residua? Comparison with phase equilibrium data is essential to resolution of this issue. Furthermore, are the obviously metasomatic pyroxenites and pegmatoidal gabbro-norites mineralogically distinct from the more common facies?

B) By comparing lava compositions to model liquids calculated by trace element inversion from cumulates, pinned by mineral chemical constraints, it will be possible to model porosity evolution in the cumulates; i.e. did melt expulsion occur rapidly, at near-liquidus temperatures, followed by total entrapment of pore melt, or was the pore melt expelled progressively as cooling proceeded? Several complementary approaches will be used. Trace element models of coexisting liquids based on whole-rock approaches will be compared to models based on in-situ mineral trace element analyses. Mismatches in the extremely incompatible element budgets between these two approaches should provide evidence of late-stage (low-temperature) melt expulsion. Taken in conjunction with modal data, these models will constrain co-evolution of the residual melt porosity and texture. By linking the calculated porosity, initial and calculated melt compositions, and mineral-chemical transformations (trapped melt effect), it should be possible to track pore-melt evolution of trace elements and precious metals and provide conceptual models for PGE genesis.

C) Melt Expulsion Structures, rates, and models. Detailed sampling of structures that may be associated with channelized melt escape (gabbroic pods in orthopyroxenite), in conjunction of measurements of their spatial organization, should allow fluid dynamical modeling of the rate of melt transfer through such structures. These rates can then be compared with the cooling rate calculated from thermal diffusion of the sill as a whole, to see if this is a plausible hypothesis. If correct, then the fractionation modeling for the sill as a whole will need to take such effects into account. The trace element models associated with a diffuse porous flow (A.Boudreau), does not consider the effects of rapid, channellized, melt escape. The ongoing parameterization of trace element partition coefficients will be merged with the Boudreau algorithm, in order to develop a more precise trace element model for such mixed-process fractionation scenarios.

D) Metasomatic Effects. Several obviously metasomatic facies were sampled. Comparison of trace element results and models from these pegmatitic rocks with those of the surrounding (proximal-distal) facies may help to constrain how expelled extremely incompatible elements, including the PGEs, travel up into, and metasomatize overlying rocks. Again, the PGE data will help develop models for fluid-mediated PGE mineralization.

B. Scott Paterson (Professor, University of Southern California):

I. Alan's [Boudreau] specific question [relating to understanding a detailed history of emplacement and cooling] is obviously one that we would like to be able to answer - but if you want to truly be realistic then is not so trivial. David Okaya (also at USC) and I have run many thermal-mechanical models (largely unpublished so far) looking at various scenarios for the incremental growth of magma bodies. We can handle any size, scales down to meters, complex shapes, any number of pulses, various geothermal gradients, latent heat of crystallization, etc. We can't yet handle cooling by advection and/or a fluid circulation system in the host, although others have modeled this. So the rub is that to answer Alan's question we need to know all of the above fairly accurately. What is the initial T of the magma and host rock? How many pulses do you want to emplace to build up these large sills? What is the time increment between pulses? Do we want a majority of the conductive cooling to occur out the top of the sills (as is suggested by field relationships)? Is each pulse truly a dike in the mechanical sense so that the width of the dike is controlled by the flow rate of the magma in the dike? Or could inner pulses be something in between a dike and diapir where it may be buoyantly ascending as a big plug of crystals, maybe even with a yield stress, and doing so by having the previously emplaced magma flow around it. Do you want pulses to be emplaced symmetrically with the younger always in the center of the older?

If we can begin to answer all these questions, then we can begin to place some constraints on the growth and crystallization rates of these sills.

II. Solving the Mechanics of Ferrar Sill Emplacement

Need to know (and how we can begin to determine):

1. Geometry and growth of sills:
    a. Construct maps.
    b. Relative timing of different parts of system.
    c. Determine extend of each internal pulse (need help from geochemists)
    d. Determine flow kinematics.
    e. Use host rock markers to examine displacements across sills. With luck may be able to track emplacement of internal pulses and growth of sill system.

2. Nature of Contacts (helps with above and emplacement processes)
    a. Intrusive verses tectonic.
    b. Faults, tips, process zones, corners.
    c. Small dikes, steps, degree of chills, etc.

3. Far-field stress:
    a. Regional syn-sill dike orientations.
    b. Regional syn-sill fault orientations and kinematics.

4. Near-field stresses as magma emplaced:
    a. Dikes, veins, faults within a few meters of contacts.

   b. Internal features, particularly along margins of internal pulses.

5. Role of host rock anisotropy:
   a. Make maps showing geometry.
   b. What is important scale of anisotropy?
   c. Look at fracturing in host rocks and relationship(s) to anisotropy.

6. Importance/role of secondary processes:
   a. Does stoping occur during sill growth or late once sills are formed?
   b. Melting, mostly upper contact, during sill growth or late as crystalllizing?

7. What is significance of tips and corners? How do they form?
   a. Bluntness of and fractures and faults at tips.
   b. Chemistry of tips verses main sills.
   c. Geometries of host and sills at corners. Why often get batches of dolerite outside of main sills at corners?
   d. Chemistry at sills and in outliers any different? Any signs of internal contacts at corners?

8. Use the above to complete some fairly extensive mechanical-thermal modeling of the growth of individual sills and eventually a sill system.

III. Initial Report:

1. Unlike the petrologists and geochemists, it is difficult for the mechanics folks to collect much of the needed data without extensive field work. So we really have done nothing more than some reconnaissance work. But all is not entirely hopeless.

2. Presumably Bruce Marsh and his group can give us a general pattern of the sills and some relative timing relationships.

3. Tom Fleming has started to work on emplacement kinematics.

4. Simon Kattenhorn and I (and I suspect others) have fairly extensive photo mosaics of some of the sills. These can be used to construct some initial maps – but more detailed mapping of contacts, kinematics, etc. would still be necessary. I will point out that there is a wonderful "grid system" in the host rock, often with the general foliation and contacts at high angles to pre-sill dikes, thus forming two planes at high angles.

5. Some information is available on regional fault and regional dike studies, although my impression is that a much more complete study would be useful. Maybe Tom Fleming, Dave Elliott, or Bruce could fill us in on existing data?

6. Certainly mechanical and thermal models of dikes/sill systems exist and much is known about the growth of simple sill systems (nice summary by Corry, C.E. 1988. Laccoliths; mechanics of emplacement and growth. Geol. Soc. Am. Special Paper 220). But there is still much we could do. Most existing models don't incorporate many of the complications we see in these sills (corners, steps [except by linking], stoping, thermal effects). Nor do they incorporate multiple pulses.

Appendix II

TRACKING # _____

RECORD OF ENVIRONMENTAL REVIEW (ROER)

Scope/Type of Activity: **Establishment of a Temporary Field Camp for a Geologic Research Workshop in Bull Pass, McMurdo Dry Valleys**

Stage of Action: Initial Decision X SIP ___ Revised Scope __ In-the-field change __

Group sponsoring activity (i.e.; event #, proposal #, WBS#) Event # G-056

Principal contact(s) Dr. Bruce Marsh, Principal Investigator

Activity location(s): field camp at Bull Pass with Dry Valley day trips

Intensity and Scope

Duration of activity (approximate dates): Jan. 1 through Jan 20, 2005 (field camps only)

Activity will occur in an area with special environmental and/or scientific management standards? Yes X No __

If yes, the site is located in: ____________ sector of the South Pole Station.

Bull Pass area of the Dry Valleys

____________ (name) rookery/colony

____________ (name) SSSI or SPA

____________ (name) other special area

Is the activity consistent with current operations or long-range plans in terms of size, personnel, and/or footprint? Yes X No __

Are complex, cumulative, large-scale, or irreversible effects likely? Yes __ No X

Is activity likely to preclude or conflict with other foreseeable activities? Yes __ No X

Activity is expected to create no significant effects on the following environments/resources:

Air _X_ aquatic _X_ marine _X_ terrestrial _X_ glacial _X_
historic _X_ aesthetic _X_

Are there EMI or EMR issues associated with this project? Yes __ No _X_

Environmental Documentation

ACA permit required for: Flora/Fauna __ SSSI/SPA __ Not required _X_

Activity fits into a category of exclusion Yes __ No _X_

If yes, which one? Small scale collection of geological __ and/or biological specimen(s) __

Routine, laboratory-based research __
Seismic research utilizing explosives __
Renovation and/or remodeling of existing facilities __
Deployment of retrievable instrumentation __
Use of weather/research balloons __
Use of radioisotopes (in compliance with applicable laws) __

If no, is additional assessment required? Yes __ No _X_

If yes, for which activities? ____

Do existing environmental document(s) adequately describe likely effects?
Yes __ No _X_

If yes, list file name(s) of environmental document(s): ________________________________

This Environmental Review was prepared by Judy Foy, RPSC Assistant Environmental Specialist, July 2, 2004

Signature Block

The action cited above is expected to have less than minor or transitory impacts or there is environmental documentation that adequately describes the impacts of this activity. This Environmental review for the stage of the action is adequate for the action to proceed as noted.

Yes __ Yes, with mitigation (attached) __ No __ If no, why? ___________________

Recommending Official: /s/ ________________________
Date: _____________

Approving Official: /s/ _____________________
Date: _____________

Establishment of a Temporary Field Camp for a Geologic Research Workshop,

Bull Pass, McMurdo Dry Valleys

A team of 20 geologists from a variety of American and foreign institutions will meet for a workshop in Antarctica in January, 2005 to study, collaborate, and perform real-time research in and around Bull Pass (77.5177S, 161.8547E). The location was chosen for its unique magmatic features associated with a large ancient volcanic system in the Dry Valleys. The central objective of this workshop is to immerse the group in the geological setting, while providing as much opportunity as possible for discussion during and after daily field excursions. Key fundamental questions are expected to arise from these encounters, leading to future collaborations and research.

Establishing the workshop camp in Bull Pass is preferred to meet science objectives, for at least two reasons: 1.) A camp on-site will help to ensure that no field days will be lost to weather, owing to the ability to travel via foot within the study area when helicopters are grounded; 2.) On-site camping and foot travel will also allow time for more in-depth analysis of the local geological features, instead of time-constrained trips via helicopter. Occasional day trips will be made via helo to other locations in the Dry Valleys, including Victoria Valley, East Wright Valley, Pandora's Spire, and the Dais Intrusion.

The field camp will be located in an area of Bull Pass where up to nine people have camped, temporarily, over the past six years to conduct similar geological investigations. To minimize the overall scope of the camp and needed infrastructure for cooking and sleeping, two main teams of ten workshop participants will rotate time spent at the field camp. Two instructors will lead each field team, with one Raytheon Polar Services (RPSC) staff member accompanying each team, and frequent stays throughout the two-week period by the principle investigator. In total, the field camp will support 13 to 14 people at any one time during the workshop. This camp will be kept light in infrastructure and as close as possible to what has occurred in the past at this site.

The area where the camp will be located is an 8094 square meter loose, but firm, gravel plain. The campsite itself will occupy approximately 16 meters by 16 meters. The structures will consist of 6 Scott Tents (1 latrine, 5 sleeping tents for 10 people); 3 Alpine tents (3 people); and one Endurance tent (21 foot, for kitchen and workshop sessions).
To mitigate environmental effects, no fuel besides that used for cooking will be used at this camp. Potable water for cooking, cleaning, and drinking will be flown in as needed. All waste generated at the camp will be contained and returned to McMurdo Station for disposal. Fuel storage and handling will be carried out in a manner that prevents release to the environment, and any accidental spills or releases will be reported immediately as required by the USAP

Master Permit. As per normal training procedures, all workshop attendees will be briefed on the Dry Valley Code of Conduct prior to deployment to the field.

Potential environmental impacts as a result of this project can be characterized as less than minor or transitory. No releases to the environment are expected. All elements of the camp will be removed following the workshop. Long-term physical disturbance is unlikely given the effects of wind and the nature of the surface materials, and previous seasons at this location have shown that all traces of habitation are completely erased by the wind within one week of departure.

Appendix III

An Essential Antarctic Reading List

by

Bruce Marsh

Historical

There is virtually no end to Antarctic literature; it comes in many layers. The most abundant are popular books that retell the stories of the Scott and Shackleton expeditions based on the original accounts. Many of these derivative works are exceptionally well done and valuable for an overview of this era (1900-1920) of Victorian exploration. There is no substitute, however, for the original works, which includes diaries and scientific reports, often including insightful detailed observations replete with photographs and maps. There are various reprints (generally not contemporary) available for most of these books. These below are in an order of regional importance to understanding the nature of the McMurdo Sound-Ross Island area and the discovery and exploration of the Dry Valleys.

McMurdo Region:

Discovery of McMurdo Sound and Ross Island

James Clark Ross first visited this area with specially made ships in 1841. He named Mts. Erebus and Terror after his two ships. (John Franklin subsequently used these ships (after they were refitted with steam engines and propellers) in his mysteriously ill-fated attempt on the Northwest Passage; Capt. Crozier, who had been with Ross (a la Cape Crozier), was lost with Franklin.) Ross had the good fortune to head south along 170° Longitude and, in an unusually mild season, reached wide seas of open water near Cape Adare. Thinking that this region may be similar to the Arctic, where he had previously explored finding islands interspersed in ice, he went southeast into McMurdo Sound. Here he may have witnessed the only lava eruption of Mt. Erebus. In trying to circumnavigate Ross Island they discovered the Ross Ice Shelf, then and through Scott;s time called the Great Ice Barrier.

Ross, Sir James Clark, 1847, A Voyage of Discovery and Research in the Southern and Antarctic Regions. John Murray, London.

See also,

Ross, M.J., 1982, Ross in the Antarctic. Caedmon of Whitby, Whitby.

There are also compendiums of the entire history of Antarctic exploration a particularly useful one is by the National Geographic Society (out of print).

The original works of R.F. Scott and Ernest Shackleton give the most pertinent detailed descriptions of land-based discovery and exploration of the Dry Valleys.

Scott, Robert F., 1905, Voyage of the 'Discovery.' London, Macmillan (2 vols.).

This is a detailed account of the first wintering-over expedition to McMurdo. This includes the discovery of the southern Dry Valleys (Ferrar Glacier, Kukri Hills, Solitary Rocks, Finger Mountain, Taylor Valley, etc.) and overviews of the general geology, glaciology, and physiography. The freshness of their observations in finding their way up the Ferrar and Taylor Glaciers and into Taylor Valley are exceptional.

Shackleton, Ernest, H., 1909, The Heart of the Antarctic. William Heinemann, London (2 vols.).

This is the account of Shackleton's 1907-1909 *Nimrod Expedition* to McMurdo, including the discovery of the Beardmore Glacier and his near attainment on the Pole. This too contains exceptionally fresh observations, some conflicting with Scott's, on the geology and physiography of the Dry Valleys.

Scott, Robert. F., 1913, Scott's Last Expedition. Smith Elder, London (2 vols.).

Scott's diary (vol. 1) of his preparation, march southward and attainment (after Roald Amundsen) of the Pole and the subsequent loss of his party on the return march is must reading. Volume 2 contains overviews of the science reports and local sledging journeys. There is a very good inexpensive recent reprint of Volume 1 (Scott's Journal):

Tragedy and Triumph: The Journals of Captain R. F. Scott's Last Polar Expedition. Konecky & Konecky, 150 Fifth Ave., New York, NY 10011.

For scholarly, thorough and engaging accounts on the Amundsen and Scott so-called race to the Pole and on the life of Earnest Shackleton:

Huntford, Roland, 1980, Scott and Amundsen (The Last Place on Earth), G. P. Putnam's Sons, 663 p.

Huntford, Roland, 1985, Sahckleton. Fawcett Columbine, NY, 774 p.

There are diaries and general accounts available by many of the principals in these expeditions that offer slightly contrasting views of the exploration and personalities. (For example: Cherry-Gerrard, Evans, Gran, Ponting, Taylor, Wilson, Wright, and there are also biographies on most of these men and others like Lawrence Oates). Undoubtedly, still the best contemporary account is that by Apsley Cherry-Gerrard, *The Worst Journey in the World*, (various presses beginning in about 1920).

Shackleton's Endurance Expedition: McMurdo Men

Although the world mainly knows this expedition (1914-1917) through the epic story of the crushing of the long icebound Endurance in the Weddell Sea, the intent of the expedition was to transverse Antarctica. Central to this effort was the laying of depots from McMurdo to the Beardmore Glacier to support the Weddell Sea Party as they descended from the polar plateau. The McMurdo Party was also waylaid by a series of crippling disasters the most grievous of which was the loss of their ship before the bulk of the supplies could be unloaded. Since they are hardly ever mentioned in any account, these men have become known as Shackleton's Forgotten Men. Their story of successful depot laying and survival against the longest odds is, indeed, as epic as those on the Endurance. Shackleton's own account in '*South*' does cover their plight, but the more recent work by Bickel does more justice (a further even more detailed account by Kelly Tyler is in the works).

Shackleton, Ernest, H., 1919, South: The Story of Shackleton's Last (1914-1917) Expedition . William Heinemann, London.

There are good cheap recent reprints available in cloth and soft covers.

Bickel, Lennard, 2000, Shackleton's Forgotten Men: The Untold Tragedy of the Endurance Epic. Thunder's Mouth Press, 841 Broadway, 4th floor, New York, NY.

Of the many accounts of the Weddell Sea Party (Endurance crushing), the best is still that by Alfred Lansing.

Lansing, Alfred, 1959,Endurance, Shackleton's Incredible Voyage. McGraw Hill, New York, NY 274 p. (A good reprint is by the Adventure Library, 1994).

A fine contemporary treatment with abundant, excellent, and hitherto unpublished photographs by Frank Hurley is by Caroline Alexander.

Alexander, Caroline, 1998, The Endurance, Shackleton's Legendary Antarctic Expedition.

Alfred A. Knopf, New York, NY, 212 p.

Reopening of McMurdo IGY 1955-1958:

McMurdo Station as we know it today was established during the International Geophysical Year, which was an attempt to geophysically characterize Earth simultaneously and globally, including the most remote regions, for an eighteen month period, 1 July1957 until 31 December 1958. (The idea was spawned at a dinner party on 6 April 1950 for Sydney Chapman at the home of James Van Allen in Silver Spring, Maryland; J. Tuzo Wilson was also there.) The highly cooperative spirit of the IGY led to the establishment of the Antarctic Treaty, still in effect today, that set up the basic rules of conduct in Antarctica. The U.S. IGY effort in Antarctica was facilitated mainly by the Navy (the Army and Marines were also involved), which called this Operation Deep Freeze (I & II). (The Naval operations were authorized on 17 September 1954.) The icebreaker USS Atka was sent to reconnoiter the state of the Antarctic coast for locations of possible support bases. It found that the Bay of Whales feature in the Ross Ice Shelf, where Roald Amundsen had based his operations, no longer existed. (Parts of the structures erected there during R.E. Byrd's Little America expeditions could be see in the new ice face.)

The icebreaker USS Glacier entered McMurdo Sound in December of 1955 and established a Naval Air Facility where McMurdo Station is today. (A facility was also established at Cape Adare.) On 31 October 1956 Admiral George J. Dufek flew from McMurdo and landed at the South Pole; the first people since R. F. Scott to stand at the Pole. Admiral Dufek was in charge of the military aspect of the operation and Dr. Paul Siple was in charge of the science; Admiral Richard E. Byrd was in overall charge. (Paul Siple was the Boy Scout chosen as a member of the Richard Byrd Expedition (1928-1930) that established Little America near the Bay of Whales, during which Byrd flew over the Pole (see more on Byrd's expeditions below).

Accompanying the American operation in McMurdo was a similar arrayed New Zealand contingent that, after searching to find good ground across the Sound near New Harbor, settled at their present location southwest of McMurdo Station. Bernard Gun (the petrologist) was with this group as were Edmund Hillary and Vivian Fuchs. Fuchs and Hillary combined to complete

Shackleton's idea of traversing Antarctica from the Weddell Sea to McMurdo. Fuchs met Hillary at the Pole.

Lewis, Richard S., 1965, A Continent for Science: The Antarctic Adventure, Viking Press, New York, 300 p.

Dukert, Joseph M., 1965, This is Antarctica. Coward-McCann. New York, 192 p.

Siple, Paul, 1959, 90° South: The story of the American South Pole Conquest. G.P. Putnam's Sons, New York, 384 p.

Fuchs, Vivian, 1958, The Crossing of Antarctica. Cassell, London.

Nearby Regions:

Bernacchi's First Winter-Over

The first wintering-over expedition to this part of Antarctica was lead by Louis G. Bernacchi (1898-1900), which was based near Cape Adare, northwest of McMurdo Sound proper. His own account is:

Bernacchi, Loius, G., 1901, To the South Polar Regions. Hurst and Blackett, London.

There is also a new volume on this expedition edited by Bernacchi's grand-daughter:

Crawford, Janet, 1998, That First Antarctic Winter: The Story of the Southern Cross Expedition of 1898-1900 as told in the diaries of Louis Charles Bernacchi. South Latitude Research, Christchurch NZ, 270 p.

See also the hard to find:

Cook, Frederick, A., 1901, Through the First Antarctic Night. William Heinemann, London.

(Yes. This is Robert E. Peary's North Pole nemesis.)

South Magnetic Pole

The attainment the South Magnetic Pole was made by Edgeworth David, Douglas Mawson, and Alistair Mackay as members of Shackleton's Nimrod Expedition (1907-1909), and Mawson, a petrologist, later mounted his own (epically tragic) expedition to the South Magnetic Pole (in lieu of joining in Scott's Terra Nova Expedition (i.e., 2nd)), which was based at Commonwealth Bay on Cape Denison.

Mawson, Sir Douglas, 1915, The Home of the Blizzard. William Heinemann, London.

A popular engaging account of the 1911-1912 expedition is:

Bickel, Lennard, 1977, Mawson's Will: The Greatest Survival Story Ever Written. Stein and Day,

New York, NY, 237 p.

Little America Expeditions of Richard E. Byrd

Beginning in 1928, Admiral Richard E. Byrd established four bases in the Bay of Whales with the intent of exploring West Antarctica and making aerial exploration over vast areas including the South Pole. The bases were called Little America I (1928-193), II (1933-35), III (1939-1941), and IV (1947). Byrd's books are of special interest in marking the transition from the era of dog and man hauling to the extensive use of tractors and aircraft, and where the mainline raison d'etre of the expedition is government-funded science.

Byrd, Richard E., 1930, Little America: Aerial Exploration in the Antarctic; the Flight to the South

Pole. G.P. Putnam's Sons, New York, 422 p.

The account of Byrd's near fatal attempt to winter over alone in a small hut at some distance from Little America is particularly revealing and engaging.

Byrd, Richard E., 1938, Alone. G.P. Putnam's Sons, New York.

Geological Literature

There is an enormous scientific literature on Antarctic. Not as large as the historical literature in sheer numbers of pages as geologic reports are generally of the type that is demanded by present day journals. They are almost universally short detailed works on an overly narrowly defined problem or involve a limited examination of a relatively small set of samples. This is a serious problem. There are few truly comprehensive reports that cover any significant region thoroughly in terms of basic geology and to a satisfyingly sufficient degree of detail. The exceptions to this are in the geomorphologic evolution of the Dry Valleys, which is nicely covered, including basic tectonics and geology, in:

Denton, G.H., Sugden, D.E., Marchant, D.R., Hall, B.L., Wilch, T.I., 1993, East Antarctic Ice Sheet sensitivity to Pliocene climatic change from a Dry Valleys perspective. Geografiska Annaler, 75A, p.155-204.

Also, see this entire issue of Geografiska Annaler for the history of the East Antarctic Ice Sheet. This has been a controversial subject with one group suggesting that the uplift of the mountains is recent (within about the past 3 Ma) and thus the erosional surfaces of the Dry Valleys would also be recent. From a magmatic point of view, the fact that there are numerous young alkali basalt cinder cones (~1.5 to 4 Ma) draped over the terrain in the area of Taylor Valley showing no eruptive signs of involvement with water suggests these surfaces are old. See, e.g.,

Wilch, T.I., Lux, D.R., Denton, G.H., McIntosh, W.C., 1993, Minimal Pliocene-Pleistocene uplift of the Dry Valleys sector of the Transantarctic Mountains. A key parameter in ice-sheet reconstructions: Geology, v. 21, p. 841-844

Cosmic ray exposure dating of surfaces as in Bull Pass show them to be ~ 10 Ma or older. Dating of tan to buff fine volcanic ash just below the surface in many sheltered pockets in SE Bull Pass (you will know it when you step into these) show this to be Mid-Miocene ash (David Marchant, pers. comm., 2003). Similar layers here and there on the upper ledges of the Dais Intrusion are presumably the same ash. As surprising as it may seem, with a continental ice cap merely a day's walk away to the west, this terrain has never suffered a continental glaciation. It was cut by rivers and wind in a more temperate climate in the early Tertiary. The terrain most closely resembles that of parts of the Colorado Plateau, with upland buttes similar to those of Monument Valley.

Ferrar Dolerite Petrology:

Because of the unusual age and quality of exposure of the Dry Valley terrain, much of which is igneous rock, it is common to encounter a steady stream of unusually fine classical geologic problems during the course of routine field work. This sometimes makes it difficult to stay on track in identifying and addressing those problems of truly fundamental importance. Yet given the work by the early explorer geologists (e.g., H. Ferrar, R. Priestley, D. Mawson, etc.), the first modern petrologists to visit this area associated with the settling of McMurdo during the International Geophysical Year 1955-1957 did a remarkably good job of recognizing the basic nature of the magmatism represented by the Ferrar Dolerites.

The overall geology of the region is well described in an early reconnaissance fashion by:

Gunn, B.M., and Warren, G., 1962, Geology of Victoria Land between the Mawson and Mulock Glaciers, Antarctica. New Zealand Geological Survey Bulletin, v.71, 157 p.

And because Bernard Gunn is an avid igneous petrologist, there is special attention paid to the igneous rocks in terms of their nature and field relations. For a more up to date treatment on the whole of Antarctic geology, on a paper by paper basis, see:

Ringey, R.J., 1991, The Geology of Antarctica. Oxford University Press, NY.

The USGS Professional paper by Warren Hamilton shows excellent photographs of the dolerite sill sequences and he studied in detail some chemical profiles through the Basement Sill in Pearse Valley of Solitary Rocks.

Hamilton, W., 1965, Diabase Sheets of the Taylor Glacier Region Victoria Land, Antarctica. U. S. Geological Survey Prof. Paper 456-B.

Bernard Gunn of the New Zealand party made a more regionally comprehensive petrographically and chemically based study of the sills. He divided them into hypersthene-bearing sills and pigeonitic or non-hypersthene-bearing sills. He also recognized that the large Opx crystals of the Basement Sill did not grow in situ, but were contained in the initial magma, and that the internal structure was mainly due to these phenocrysts.

Gunn, B.M., 1966, Modal and element variation in Antarctic tholeiites. Geochimica et Cosmochimica Acta, v. 30, p. 881-920.

Gunn showed chemical profiles through both the Basement and Peneplain Sills at a significant number of localities. He found modal and cryptic layering and sometimes an upward increase in the felsic nature of the dolerite. His earlier papers on the same sills and using much the same data used later have more engaging titles, but this mostly reflects the enthusiasm of the time for layered intrusions. (The Dais Intrusion was not found until 1996.)

Gunn, B.M., 1962, Differentiation in Ferrar Dolerites, Antarctica. N.Z. J. Geol. Geophys., v.5, p. 820-863.

Gunn, B.M., 1963, Layered Intrusions in the Ferrar Dolerites, Antarctica. Mineralogical Soc. of America, Spec. Paper 1, p. 124-133.

Context of Ferrar Dolerites:

The Ferrar dolerites are the result of Mesozoic (~175-200 Ma) global rifting during the breakup of Gondwana that produced dolerites worldwide (e.g., eastern U.S., south Africa, etc.). The Kirkpatrick flood basalts are directly associated with the Ferrar magmatism and on the edge of the nearby Polar Plateau dike offshoots from the uppermost sill (Mt. Fleming Sill) can be followed upward continuously as the dolerite transitions into tephra.

The age of the Ferrar dolerites is considered in some detail by:

Heimann, A., Fleming, T.H., Elliot, D.H., Foland, K.A., 1994, A short interval of Jurassic continental flood basalt volcanism in Antarctica as demonstrated by $^{40}Ar/^{39}Ar$ geochronolgy. Earth and Planetary Science Letters, v. 121, p. 19-41.

They find an age of about 180 Ma for the dolerite sequence with little indication of any significant duration (<~1 Ma) of emplacement of the full sequence. Field relations where the Basement Sill touches the Peneplain Sill, suggest that the timing between sills was probably on a scale of 100's of years.

The overall nature, context, and chemical character of the Kirkpatrick flood basalts has been delineated by David Elliott and Thomas Fleming:

Fleming, T.H., Foland, K.A., Elliot, D.H., Isotopic and chemical constraints on the crustal evolution and source of Ferrar magmas, north Victoria Land, Antarctica. Contrib. Mineral Petrol., v. 121, p. 217-236.

Fleming, T.H., Heimann, A., Foland, K.A., Elliot, D.H., 1997, $^{40}Ar/^{39}Ar$ geochronolgy of Ferrar Dolerite sills from the Transantarctic Mountains, Antarctica: Implications for the age and origin of the Ferrar magmatic province. GSA Bulletin, May, v. 109, no. 5, p. 533-546.

Elliot, D.H., 1992, Jurassic magmatism and tectonism associated with Gondwanaland break-up: an Antarctic perspective. in: Storey, B.C., Alabaster, T., Pankhurst, R.J. (eds), 1992, Magmatism and the Causes of Continental Break-up. Geological Society (London) Spec. Pub. No. 68, p. 165-184.

Elliot, D.H., Hanson, R.E., 2001, Origin of widespread, exceptionally thick basaltic phreatomagmatic tuff breccia in the Middle Jurassic Prebble and Mawson Formations, Antarctica. J. Volcanlogy and Geothermal Research, v. 111, p. 183-201.

For the interesting geology of the transition from dolerite to tephra see:

Grapes, R.H., Reid, D.L., McPherson, J.G., 1974, Shallow dolerite intrusion and phreatic eruption in the Allan Hills region, Antarctica. N. Z. J. Geol. Geophys., vol. 17, no. 3, p.563-577.

Pyne, A.R., 1984, Geology of Mt. Fleming area, South Victoria Land, Antarctica. New Zealand Journal of Geology and Geophysics, V.27, p. 505-512.

The occurrence of the voluminous Dufek Layered Intrusion at the other end of the Trans-Antarctic Mountains, which may be as large as the Bushveld Intrusion (~ 500, 000 km^3), and the suggested global association of plumes, global rifting, large igneous provinces, and regional dike swarms has generated suggestions on a possible linkage for the emplacement of the Ferrar system:

Elliot, D.H., Fleming, T. H., Kyle, P.R., Foland, K.A., 1999, Long-distance transport of magma in the Jurassic Ferrar Large Igneous Province, Antarctica. Earth and Planetary Science Letters, v. 167, p. 89-104.

Elliot, D.H., Fleming, T.H., 2004, Occurrence and Dispersal of Magmas in the Jurassic Ferrar Large Igneous Province, Antarctica. Gondwana Research, v.7, no. 1, p. 223-237.

Dufek Layered Intrusion:

The Dufek Intrusion (~500, 000 km^3) is of the same age, character, and basic nature as the full Ferrar Dolerite package in the Dry Valleys. The Ferrar has all the ingredients to have formed a layered intrusion, but it has, instead, been emplaced in piecemeal fashion as separate aliquots of magma. It is thus interesting to gain an appreciation of the massive Dufek body so that the units with the tiny Dais layered body can be appreciated for their importance to understanding the dynamics of texture formation and annealing.

Ford, A. B., and Himmelberg, G.R., 1991, Geology and Crystallization of the Dufek Intrusion. In, The Geology of Antarctica, R.J. Ringey (ed.), Oxford University Press, NY.

Ford, A.B., 1970, Development of the layered series and capping granophyre of the Dufek Intrusion of Antarctica. Geol. Soc. of South Africa, Spec. Pub. No. 1, p. 492-510.

Sam Mukassa has also worked there and he will be able to offer on the spot insight for comparisons between Dufek and Dais.

Earlier Work on the Geology of the Dry Valleys:

The early mapping of this region during the discovery phase of the Wright Valley-Victoria Valley area is useful to appreciate:

Webb, P.N., McKelvey, B.C., 1959, Geological Investigations in South Victoria Land, Antarctica, Part 1—Geology of Victoria Dry Valley. N. Z. J. Geol. Geophys., v. 2, p. 120-136.

McKelvey, B.C., Webb, P.N., 1959, Geological Investigations in South Victoria Land, Antarctica, Part 2—Geology of Upper Taylor Glacier Region. N. Z. J. Geol. Geophys., v. 2, p. 718-728.

McKelvey, B.C., Webb, P.N., 1962, Geological Investigations in South Victoria Land, Antarctica, Part 3—Geology of Wright Valley. N. Z. J. Geol. Geophys., v. 5, p. 143-162.

Also, do not forget Gunn and Warren mentioned earlier.

Gunn, B.M., and Warren, G., 1962, Geology of Victoria Land between the Mawson and Mulock Glaciers, Antarctica. New Zealand Geological Survey Bulletin, v. 71, 157 p.

Geology of Ross Island:

Living on Ross Island at McMurdo Station is much like living on the big island of Hawaii. Everywhere underfoot is volcanic rock from Mt. Erebus. Being an alkalic volcanic center, ultramafic nodules are commonplace in the lava and tephra; freshly dug trenches and newly graded roads are excellent locations for collecting. The large, nicely faceted anorthoclase crystals common on the summit can be gained from anyone who routinely goes there.