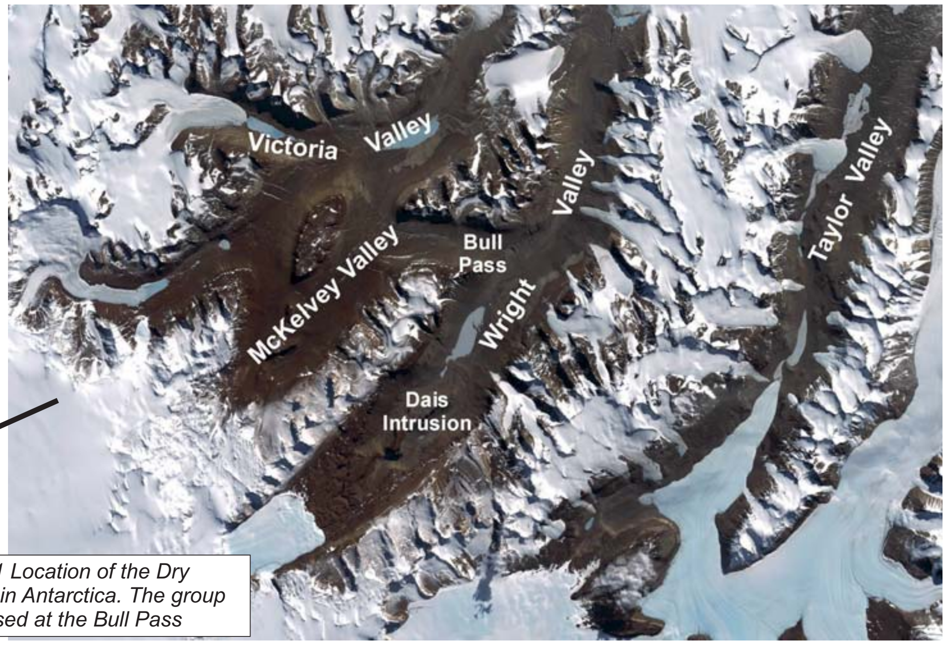
Hot and cold in the Dry Valleys

Antarctica - A window into the plumbing system of a Large Igneous Province.

Three British geologists are involved in a unique NSF funded 'Magma Workshop' run by Professor Bruce Marsh of Johns Hopkins University. Here Dougal Jerram, Jon Davidson and Nick Petford report on the project after the initial field-workshop held in the Dry Valleys, Antarctica Jan 2005………

The great white continent of Antarctica is possibly the last place on earth one would expect to find a continuously exposed and exceptionally well preserved igneous sill complex. But, due to a lucky set of environmental circumstances, and a major geological event that happened some 180 million years ago, it turns out that the Dry Valleys area of Antarctica is one of the coolest places to look at a once active plumbing system that helped feed the massive outporings of flood basalts accompanying the break-up of Gondwanaland.



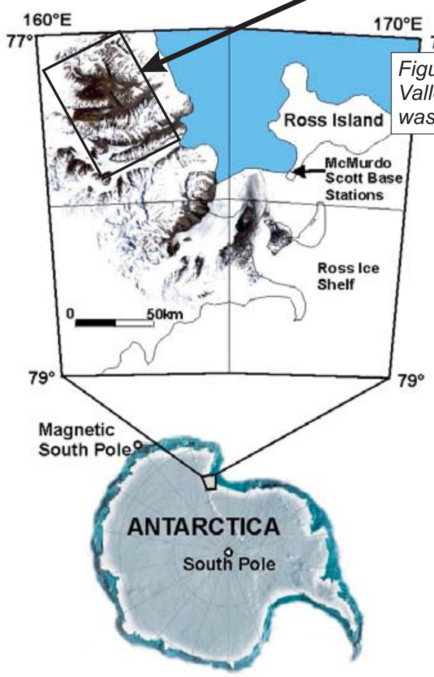


Figure 1 Location of the Dry Valleys in Antarctica. The group was based at the Bull Pass

The Dry Valleys - a geological wonderland

With virtually no precipitation per annum and the Transantarctic Mountains damming the advance of ice, the Dry Valleys form a series of east-west major ice free valleys about 100 km from the McMurdo/Scott Base stations (fig 1). The valleys were carved by water and wind erosion in the Early Tertiary, and have only been lightly retouched in places by glaciers. Cosmogenic dating of the surface suggest it is ancient, perhaps as old as 14 million years. The main ice sheets in Antarctica which developed in the Oligocene around 30 million years ago have only made it to the heads of the Dry Valleys. The great exposure in the valleys has been further aided by occasional floods of water from subglacial lakes within the ice sheets which have swept through the valleys further removing erosional debris.

A Magmatic Workshop in the Dry Valleys!

For the past 13 years, Professor Bruce Marsh of Johns Hopkins University has been working the ground in this harsh remote environment, slowly building up a detailed geological picture of the intrusive sequence of the sill complex preserved so remarkably in the Dry Valleys. Our job was to flesh out this basic framework in more detail by focussing on a number of fundamental questions including magma emplacement mechanisms, geochemistry, rock textures and the development of igneous layering, all in the wider context of flood basalt eruption and the break-up of Gondwanaland. To accomplish this, an international team of 23 specialists with a diverse range of backgrounds and experience, including field mappers, isotope geochemists, numerical modellers and volcanologists were selected to take part, assisted by Bruce and the Johns Hopkins team, and co-ordinated by the McMurdo ground support teams. With the opportunity to cut thin sections, make maps, and perform petrographic analysis, this was a real-time field laboratory workshop. The event was funded entirely by the US National Science Foundation.

Just how do you get there?

Getting to Antarctica can be a tricky business, as we found out. Our route to the great continent was via Christchurch, New Zealand, on C-141 to McMurdo station, courtesy of the US 101 National Air Guard. The weather in McMurdo Sound has been known to delay outward bound flights and can also result in aircraft returning to New Zealand in mid flight (a manoeuvre known as a boomerang), should the weather deteriorate on route. This year was quite exceptional, and we experienced seven failed flights (including one memorable boomerang) before we finally got to Antarctica a full week behind schedule. On arrival in McMurdo you are briefed about the camp, the environment and helicopter safety before being sent to 'snow school' - a training camp where you learn basic survival skills and radio handling before spending the night out on the Ross Ice Shelf.

Figure 3 Following arrival in Antarctica via C141 plane, the group overnights on the Ross Ice Shelf during a two day snow camp.

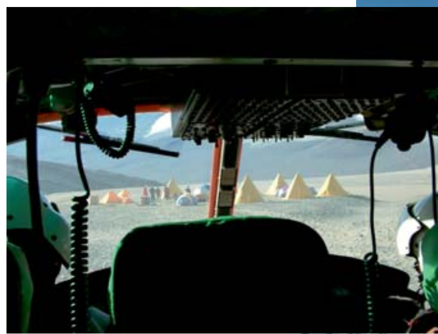


Figure 4 Travel to and from the field area and logistical support was via helicopters with a tent base camp at Bull Pass.

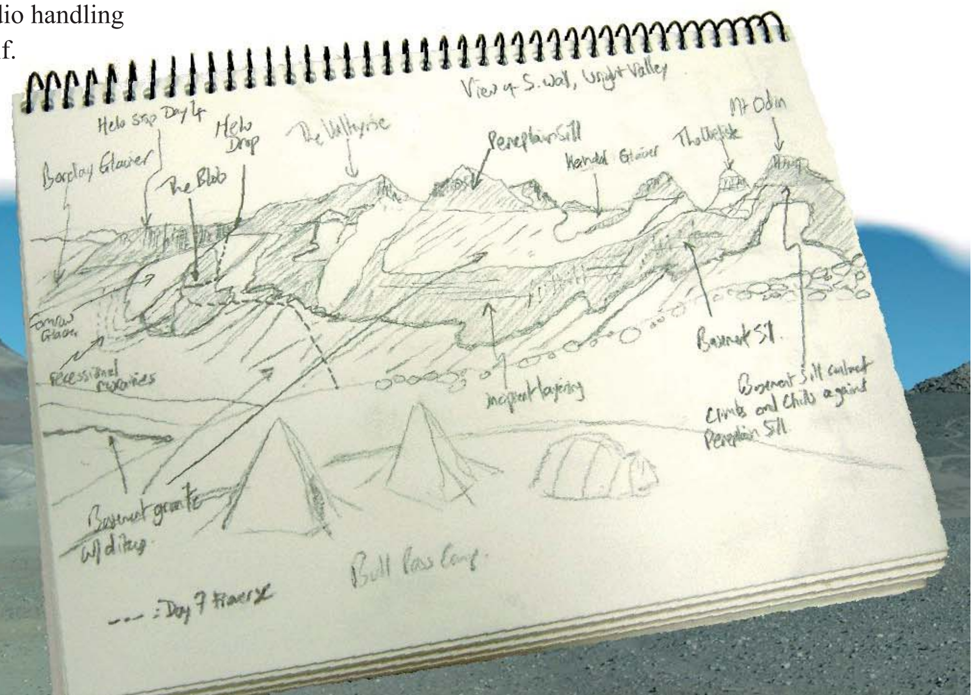


Figure 2 Panoramic view of Bull Pass looking over to the Wright Valley. Inset of sketch from field notebook.

How the magma plumbing system works!

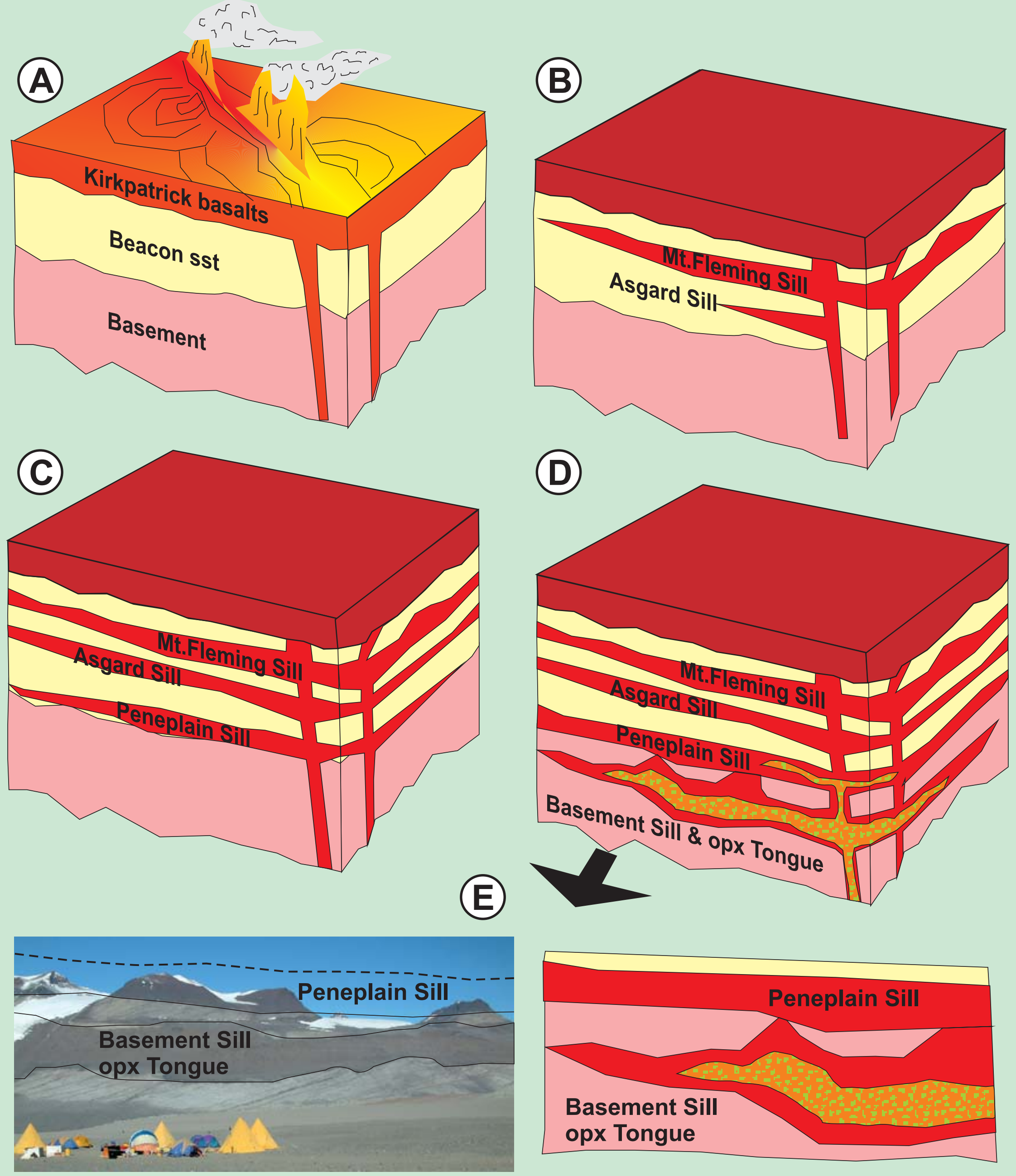


Figure 5. Schematic representation of how the magma plumbing system developed in the Dry Valleys 180 million years ago. A) Onset of flood volcanism with the outpouring of the Kirkpatric Basalts. B) Initial sills start to form close to the sediment lava contact, first with the meeting Fleming Sill then with the Asgard Sill. C) The Peneplain Sill comes next and it intrudes along the Kukri Peneplain between the basement and the Beacon Supergroup. D)Finally the Basement Sill is intruded into the basement granites with an irregular contact. During its emplacement a magma laced with opx crystals invades the base of the plumbing system producing the opx Tongue. E) Present day erosion levels expose the Basement Sill and Peneplain sill in the Wright Valley.

Geological setting

Karoo age (180 Ma) intrusions in the Dry Valleys fed the Kirkpatrick Flood Basalts which are found to cap many of the mountains in the Victoria Mountain Range and all long the Transantarctic Mountains. They are part of a series of sill complexes and associated intrusions which form the plumbing system to this Large Igneous Province. The pre-existing geology prior to the eruption of the lavas and emplacement of the sills, consists of two main lithological units, separated by a major Devonian erosion surface - the Kukri Peneplain. Above the unconformity lie sediments of the Beacon Supergroup, a mix of sandstones, conglomerates and occasional coal measures. Below this, granites and gneisses cross cut by a series pre-Devonian dykes form the basement rocks, dated at 400-500 Ma.

How do the sill complexes develop?

Initial observations suggest that the sill complexes build from the top down, with the first sills developing around the contact between sediment and lava. Similar relationships are seen in other flood basalt provinces, including the British Tertiary on Skye. Sills are emplaced successively at lower levels in the Beacon Supergroup, ending with the Basement Sill, intruded into the older granites and gneisses (fig 5). An intriguing part of the emplacement story relates to the intrusion into the basement sill of a crystal charged slurry made up almost entirely of orthopyroxene crystals. Termed the opx tongue, this crystal mush zone marks the final stage in the development of the Sill complex. Exactly how the opx tongue squeezed itself, toothpaste like, into the Basement Sill remains a mystery. In one part of the Basement Sill known as the Dais Intrusion, the 'opx tongue' is remarkably well developed, and complex igneous layering on a variety of scales is present throughout the sill (fig 6).

Figure 6 Examples of igneous layering and textures from the OPX Tongue in the Dias

Figure 7 Desiccated seal in the dry Valleys, Scotts 1902 Discovery Hut at McMurdo

Figure 8 Views of sills intruding country rock.

Ongoing research

Without doubt the massive logistical task of getting everyone out into the field and back safely is a success in itself. The detailed field observations and sampling undertaken by our group, when pooled with earlier data collected by the Johns Hopkins team, will provide a world class resource with the potential to address a range of fundamental issues relating to magma transport, layering and geochemical development in subvolcanic igneous systems. The plan is for the group to present their initial results during a specially organised 'Dry Valleys' session at a major international conference towards the end of 2005. British involvement in this research effort will look at specifically at improving our understanding the province of crystal populations comprising the basement sill, modelling the emplacement of the opx tongue, and assessing the degree of melting and contamination of the magma by the country rocks. To this end, Dougal Jerram (University of Durham) will be examining the textural development of the sills, in particular how the crystal mush developed and how the crystals are packed together in the different layers of the magma system. At Kingston, Nick Petford's main interests lie in understanding better the magma dynamics and magma emplacement mechanisms, especially the role of dilatancy that accompanies the flow of magmatic slurries. Isotopic evidence for the evolution of the plumbing system will be the focus of Professor Jon Davidson's work at Durham, who will be interrogating individual crystals using innovative micro-analysis techniques. It is hoped that interactions within the group will lead to new international collaborations and further detailed projects in Antarctica.

We applaud the National Science Foundation foresight in sponsoring this endeavour (grant OPP-02 29306 to Bruce Marsh), and appreciate all the help from the Hopkins group (Adam Simon, Amanda Charrier, Taber Hersum, and Justin Durel), the McMurdo support staff, and especially the PHI pilots.The NASA Earth Observatory is thanked for satellite images. This article was compiled by Dougal Jerram (dougal@dougalearth.com).

Further reading/links .....

Bruce Marsh 2004. A Magmatic Mush Column Rosetta Stone: The McMurdo Dry valleys of Antarctica, EOS, Transactions, American Geophysical Union, vol. 85, no. 47, p. 497-502.

http://www.nsf.gov/ - National Science Foundation website, follow links to Polar research programs

http://www.antarctica.ac.uk/ - British Antarctic Survey

http://silvermagma.eps.jhu.edu/ - website for the Dry Valleys Magma Workshop

http://www.enchantedlearning.com/explorers/antarctica.shtml - information about Antarctic explorers