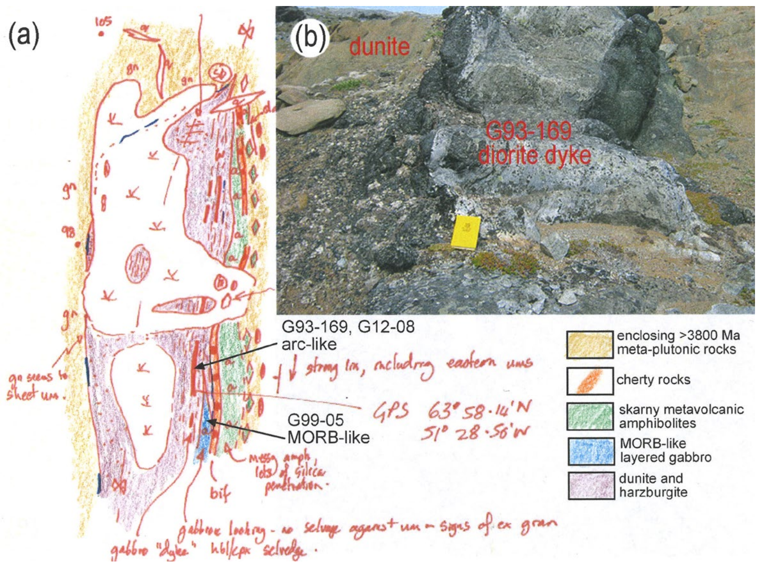
MORB and an ophiolite at the dawn of time

By Allen Nutman

Contemplating Earth's largest surviving chunk of Eoarchean mantle (>3,750 million years old)

Despite over half a century of research on Earth's Eoarchean rock record (4,000 to 3,600 Ma) there has been no convincing record of basalts or gabbros with MORB-like (mid-ocean-ridge-basalt) geochemical features. This, and dispute over evidence for ancient ophiolites, is a remaining gap in accepting the Wilson Cycle as shaping evolution of the earliest-preserved crust.

On the headland Narssaq near Greenland's capital Nuuk, the Eoarchean gneiss complex contains a 500 m long body of depleted-mantle-like peridotite (above), cut by a diorite dyke and associated with which is a sliver of layered gabbro, all in tectonic contact with (meta)cherts and skarny amphibolites of volcanic origin (below).

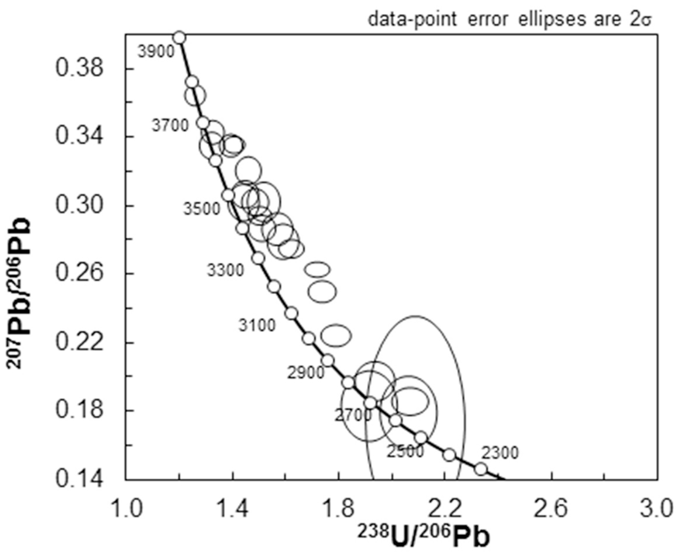


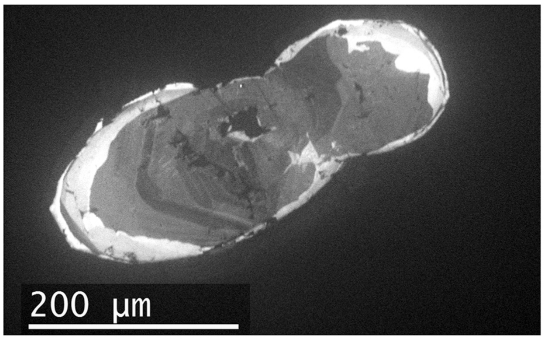
Hand-rendered 1999 sketch map by Allen Nutman, and the diorite dyke cutting mantle peridotite

Analysis of a gabbro collected in 1999 reveals a MORB-like composition, *unique* for the first billion years of Earth's geological record. The GeoQuEST 2019 grant allowed the opportunity, whilst in the Nuuk region on NASA business, to revisit this site. This site was first mapped by me in 1977 during my PhD regional contract mapping for the Geological Survey of Greenland, and I have revisited it on a couple of occasions in the ensuing decades (sketch map above).

The GeoQuEST grant covered the cost of access (chartered boat from Nuuk) to collect more samples, undertake zircon U-Pb dating of a diorite dyke cutting the mantle peridotites, plus whole rock geochemical analyses of the expanded sample suite.

Zircon dating of the diorite sheet indicates a magmatic age of 3768±20 Ma (below-left), with a strong metamorphic recrystallisation event in the Neoarchean. Cathodoluminescence images indicate very strong partial recrystallisation and pitting of zircons (below-left) – typical of zircons from granitoid rocks cutting lower sections of ophiolites in younger epochs.





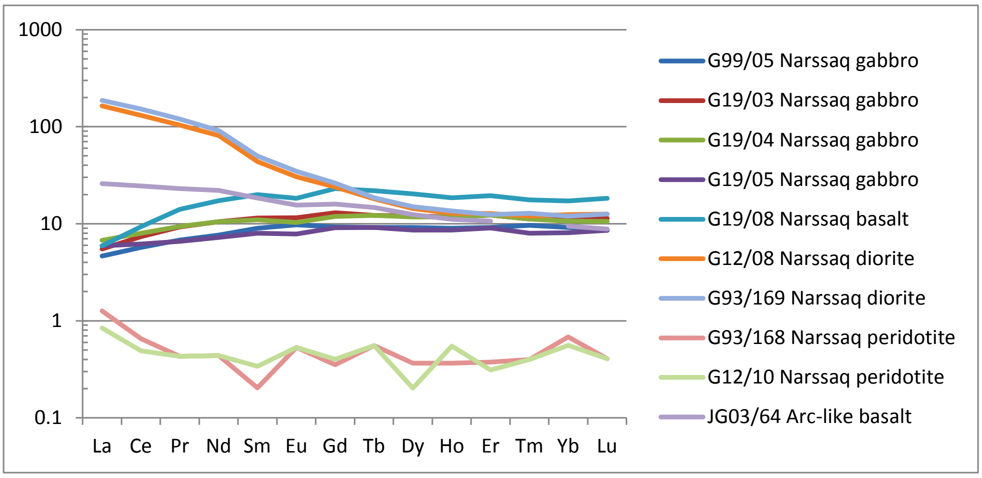
Diorite sheet dating. Left, concordia plot of data, right, typical partly recrystallised igneous zircon

Apart from the diorite being very old, and showing the great age of the mantle peridotite it cuts, what is the greater significance of this result? The >3750 Ma diorite has the chemistry of andesite/diorite produced at convergent plate boundaries by water driven off 'subducted' crustal rocks causing fluxing of the mantle. This adds to the growing evidence for subduction-like processes and the operation of plate tectonics in deep time.

What about the gabbros, the most important target of this GeoQuEST grant? These occur with the mantle peridotite, but to their east an Eoarchean shear zone separates them from (meta)chert and skarny amphibolites derived from altered basalts. Thus in the Eoarchean, mantle and lower crustal rocks were tectonically juxtaposed with upper crustal volcanic and sedimentary rocks – again, a very ophiolite-like scenario (below).

Mantle peridotite (right) in tectonic contact with (meta)chert centre with skarny basalt (left)

More samples of the layered gabbro have reconfirmed the reconnaissance analysis, as shown on the chondrite-normalised rare earth element (REE) plot below, by the depletion of the light REE Nd to La. Also shown is a typical (meta)basalt from the Eoarchean and the diorite, showing arc-like signatures with enrichment of the light REE.



So, on Narssaq there are very ancient mantle peridotites cut by subduction-zone-like diorite sheets, with MORB-like gabbro, in tectonic contact with (meta) cherts and basalts – clearly an ophiolite-like scenario.

What next? Given the global uniqueness of these ancient gabbro samples, radiogenic isotope studies are underway on them, conducted by my colleague of 30 years, Prof. Vickie Bennet of ANU. In particular, integration of the long half-life ^{147}Sm-^{143}Nd and the short half-life ('extinct') ^{146}Sm-^{142}Nd system data she is acquiring (so rudely interrupted by Covid-19), is providing new insight on the first 50 million years of planetary differentiation. All this work will result in a paper in a high profile journal.