IGNEOUS AND METAMORPHIC PETROLOGY OF LAVAS AND DYKES OF THE MACQUARIE ISLAND OPHIOLITE COMPLEX.

by

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This thesis contains no material which has been accepted for the award of any other degree or diploma in any university, and to the best of my knowledge and belief, contains no copy or paraphrase of material previously published or written by another person, except where due reference is made in the text of this thesis.

B. J. Griffin

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May, 1982.

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ABSTRACT

Macquarie Island is an emergent part of the Macquarie Ridge, which runs south from New Zealand to join the Indian-Pacific ridge system, and marks the boundary between the Indian-Australian and the Pacific plates.

Most of Macquarie Island is composed of fault-bounded blocks of volcanic rocks that are commonly basaltic pillow lavas with rarer massive flows and minor sediments. The sediments range from *Globigerina* oozes and red siltstones through coarser lithic wackes to agglomerates. Dolerite dyke swarms, gabbroic masses including a layered complex, and serpentinized peridotites also occur in the northern part of the island, where an oceanic lithosphere section has been recognized.

. . . .

The basalts and dolerites are usually porphyritic, carrying plagioclase (An_{87}-An_{80}) as the dominant phenocryst phase with less abundant olivine (Fo_{89}-Fo_{85}), chrome spinel and rarely clinopyroxene ($Ca_{45}Mg_{50}Fe_{5}$-$Ca_{38}Mg_{50}Fe_{12}$). Normatively the rocks range from ne- to Q-bearing, with most falling near the critical plane of normative silica undersaturation. Dykes tend to be more iron-rich than lavas, and include the more di-poor rocks. The rocks also range in composition from typical ocean-floor basalts through varieties relatively enriched in some incompatible trace elements, particularly Nb (20-73 ppm) and the light rare earth elements, that otherwise retain ocean-floor basalt phenocryst assemblages, major element compositions and Ti, Ni, Cr and Zr contents. These latter varieties closely resemble the ocean-floor basalts from the "abnormal" ridge segments near 45°N and 36°N (FAMOUS) on the Mid-Atlantic Ridge.

Mixing calculations using phenocryst and rock compositions suggest that much of the compositional variation in the volcanics could have arisen by low-pressure crystal fractionation. However, low-pressure fractionation processes cannot alone account for all of the variations in concentration in the incompatible elements: some may also arise from different degrees of partial melting of a possibly inhomogeneous source.

Four grades of alteration and metamorphism have been distinguished in the lavas and dykes. The lowest grade of alteration produced smectite-carbonate dominated assemblages, principally affecting olivine and glass. Lavas that have suffered this ocean-floor weathering alteration have been shown to retain the magnetic properties of typical oceanic crust, and were probably at the top of the pile, in the uppermost 200 m. Underlying these is a complex zone of zeolite alteration defined by the development of Ca and Na zeolites, principally natrolite, thomsonite, analcite, wairakite and at the bottom of the zone, laumontite. The degree of alteration is variable: fresh glass has been found within a few metres of intensely zeolitized lavas. Beneath these zeolite facies assemblages are albite-chlorite-epidote-sphene assemblages of the lower greenschist facies, present at the base of the lava pile where up to half of the outcrop is composed of basaltic dykes. In contrast, the dykes of the dyke swarms have suffered a distinctive actinolite amphibole alteration and replacement of the primary mafic minerals that has left the plagioclase little altered. This "uralitization" reflects the attainment of conditions of the upper greenschist facies grade of metamorphism, and sporadically at the base of the dyke swarm unit, where veins of hornblende are present, the lower amphibolite facies grade of metamorphism.

It is argued that the observed progression of secondary assemblages arose from hydrothermal alteration under varying temperature and pressure conditions, which affected the oceanic crust section to the base of the dyke swarm unit. Field relationships suggest that on Macquarie Island this corresponds to a depth of approximately three kilometres. Preliminary oxygen and carbon isotope studies show that sea water was the initial fluid and that the fluid became substantially modified with depth through rock interaction. Fluid movement was concentrated along fracture systems in the lavas.

The major effects of geochemical alteration of the massive rocks, away from the fracture zones, are increases in the H_2O^+ content and Fe^{3+}/Fe^{2+} ratio. The magnitude of the changes is dependent on stratigraphic position: both decrease with depth. Gypsum deposits, containing minor amounts of sulphides, are present in the top of the dyke swarm unit. Pyrite-dominated sulphide-quartz-carbonate assemblages are present in veins in the base of the lava pile and upper part of the dyke swarm unit. A large stockwork deposit, with the same mineralogy, is also present in the base of the lava section. It is suggested that the gypsum-rich deposits reflect temperature-induced sulphate saturation of the descending fluid whereas the sulphide-bearing vein assemblages have been precipitated from cooling upwelling fluids.

Many of the grassland slopes contain small terraces or terracettes (plate 1b). These are commonly misnamed "sheep tracks" throughout rural mainland Australia and on Macquarie Island some workers have similarly misinterpreted these features as due to rabbit tracks or squats. Actually these features are usually a result of creep processes, solifluction and or occasionally small scale slumping.

Wind is another erosive agent on Macquarie Island; during the three month 1975/6 summer the average wind speed was 26 km per hour. However because of the moist surface environment wind deflation effects are drastically reduced relative to those in drier environments. Moist clay has strong interparticle adhesion so that only during the rare dry periods if ever, are the clays deflated. Coarser material is more susceptible and fossil aeolian dunes deposited along the natural wind 'funnel' between Sandy Bay on the east coast and Bauer Bay on the west coast are being eroded through wind deflation. Observations suggest that this was initiated by rabbits burrowing on the windward side of the dunes. Erosion of raised marine ridges on the coastal terraces is probably also a result of similar rabbit activity. These areas are very small relative to the whole island and insignificant in terms of the overall erosion processes.

It has also been suggested that rabbits have increased the incidence of landslips by weakening an area through burrowing. No evidence has been presented on this and a visual comparison of the island today with photographs taken at about the time of introduction of rabbits would suggest that the rate of occurrence has not significantly altered. Furthermore areas of burrowing petrel colonies, which have a higher burrow density than rabbits, are not obviously more eroded than adjacent areas.

In summary, the major processes active on Macquarie Island are various forms of mass movement. Although rabbits may have severe botanical effects on the ecology, they have had little effect on the erosion of Macquarie Island. It is invalid to compare Macquarie Island with mainland Australia because of the major climatic differences and such comparisons are misleading.

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