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112 THE PETROGENETIC SIGNIFICANCE OF PLAGIOCLASE MEGACRYSTS IN ARCHEAN ROCKS.

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Introduction: Plagioclase-megacryst bearing rocks occur in all Archean terrains as basalts, as hypabyssal units, including sills which appear to have transitions to extrusive rocks, as large scale anorthositic intrusives, and as dikes forming post-tectonic swarms emplaced over very large areas [1]. All of these occurrences are characterized by the presence of equant plagioclase megacrysts of homogeneous An content, typically greater than An80. The volcanic and hypabyssal units occur in greenstone belts and are associated generally with supracrustals. Some anorthosite complexes are associated with volcanics and supracrustals. Dikes with megacrysts form large swarms cross-cutting both greenstone and granite-gneiss terrains. Geochemical data suggest that the parent melt and the processes which generate the megacrysts and their host rocks are the same in all tectonic settings.

Parent melt of anorthosites: Archean anorthosite complexes are cumulates composed of plagioclase megacrysts in a mafic matrix and range in mode from anorthositic to gabbroic. The Bad Vermilion Lake complex of Ontario [2] is a representative of such complexes. Parent compositions corresponding to large scale anorthositic cumulates are not directly observable, however, estimates can be made through mineral-melt relationships because the megacrysts represent equilibrium and isothermal crystallization conditions. Individual plagioclase megacrysts from two anorthositic intrusives, but particularly from the Bad Vermilion Lake intrusive, were analyzed in detail via a multiple aliquot technique [3]. The multiple aliquot technique helps to sort out the effects of alteration allowing better estimates to be made of indigenous trace element abundances. Results show that the megacrysts crystallized in equilibrium with a parent liquid depleted in light rare earths and with abundances comparable to those commonly observed in basalts (if the plagioclase/melt partition coefficients of McKay [4] are employed). The possibility that light rare earth depleted basalts may be parental liquids for Archean anothosite complexes is further suggested by the presence of plagioclase megacrysts in basalt flows and basaltic sills and dikes.

The major element compositions of megcryst-bearing volcanic rocks which are likely to represent liquids fall in a cluster corresponding to tholeiites. The average composition of Archean megacryst-bearing tholeiites from the Canadian Shield is shown in table 1. This composition is olivine normative. The Mg* number ($Mg^*=MgO/MgO+Fe+0.9(2Fe_2O_3+FeO)$ where $FeO/Fe_2O_3=8.1$) is 0.54 indicating a relatively evolved composition. In all of the megacryst-bearing basalts, iron contents are relatively high (11 to 13% FeO_t) and Na_2O contents cluster around 2%. In relatively unaltered flows, the An content of lathy, zoned matrix plagioclase is lower than that of the megacrysts but megacryst rims, typically a few hundred microns thick, reflect the compositional ranges of the matrix plagioclase.

Rare earth abundances in megacryst-bearing volcanics and associated sills are invariably light rare earth depleted and range from approximately 10 to 15 times chondrites. These are the characteristics predicted by the rare earth data from the anorthosite cumulates. Rare earth contents of megacrysts in the flows (determined for plagioclase separates) allow equilibrium between megacrysts and matrix but there is some variation in the heavy rare earths, probably as a result of alteration, resulting in some ambiguity.

Parent melts of dike swarms: Megacryst bearing dikes from the Matachewan swarm of Ontario have been analyzed using multiple aliquot techniques. Chilled margins of the dikes are tholeiitic but distinctive from the volcanics. An average composition, representing 36 dikes from the swarm is shown in table 1. This composition is marginally quartz normative, however the dikes vary from olivine to quartz normative. The Mg* number of the averaged composition is 0.46, and dike rocks tend to have a higher alkali component than megacryst-bearing volcanics. In relatively unaltered rocks, plagioclase megacrysts show wave like fluctuations in An content of a few (+/-2) An units, as is also observed in cumulates of the Bad Vermilion Lake type. Groundmass plagioclase laths are more sodic and progressively zoned. Rims of megacrysts (5 to 6% of the total volume) reflect groundmass plagioclase compositions.

Rare earth abundances in these dike rocks are somewhat higher than in the basalts. The dikes can be divided into three groups, 1.) depleted, 2.) enriched, and 3.) highly enriched, based on the rare earth abundances. All three groups have similar major element abundances. Both depleted and enriched dikes occur in greenstone terrains, but only enriched dikes occur in granite-gneiss terrains. Plagioclase megacryst/matrix rare earth abundance ratios equal the partition coefficients determined experimentally by McKay [4] for plagioclase/lunar basalt compositions crystallizing over approximately the same temperature range. This agreement, also observed in the flows and sills, indicates equilibrium between megacrysts and matrix, strongly suggesting that the matrix represents the parent liquid of the megacrysts.

Given the above observations, it appears that the parent liquid from which plagioclase megacrysts in intrusives, sills, flows and dikes are generated is represented by megacryst-bearing sills and flows and at least some dikes. This hypothesis has been tested experimentally. Powders prepared from megacryst-bearing sills from the Bird River area of Manitoba were crystallized at one atm under FMQ conditions. The results show that plagioclase megacryst-bearing basalts could produce the megacrysts they contain and that plagioclase of the appropriate An content is on the liquidus for approximately 25^0 C before cpx appears. For an An content of 80, the plagioclase/mafic ratio is 7/3 approximately, and about 10% of the melt is transformed to plagioclase of megacryst composition. Preliminary experiments at 10 kbs show that this composition crystallizes augite before plagioclase and that the first plagioclase to appear is more sodic than An80. The experimental data support the proposition that tholeiites of the type shown in table 1 could represent a parent liquid for various plagioclase megacryst-bearing rocks including Archean anorthositic intrusives. Compositions cluster around the one atm co-tectic on the Pl-Di-Ol pseuodoternary and the experimental data limit the process to moderate to low pressures. If this hypothesis is correct then limits can be placed upon the crystallization conditions.

<u>Crystallization Conditions</u>: The homogeneity typical of Archean plagioclase megacrysts requires growth in a nearly isothermal environment. Crystallization takes place in mid to upper crustal-level chambers. Individual megacrysts from large scale intrusives (e.g. the Bad Vermilion lake mass) and from Matachewan dikes have smooth oscillations in An content from their cores to within a few hundred microns of their much more sodic rims. These oscillations suggest replenishment of the parent liquid during crystallization of the megacrysts. In addition, rare earth abundances and slopes in dike rocks vary greatly for approximately constant major element composition. The rare earths are de-coupled from the major elements. This characteristic, together with the indications of rejuvenation of the parent liquid shown by the megacryst An content, is typical of magma replenishment during crystallization and the establishment of perched major element compositions in an otherwise evolving liquid. Most, but not all, of the incompatible element de-coupling and enrichment observed in the dike rocks can be accounted for through replenishment processes. However replenishment processes cannot account for the range in slope and abundances observed between depleted (MORB-like) dikes and those with highly enriched patterns ($La/Sm > 1.8$). In these cases, source differences, and/or variation in amounts of partial melting of a single source may be required. (Assimilation partially resolves differences but the amount of assimilated material required is large).

Anorthosite complexes such as at Bad Vermilion Lake place further limits on crystallization conditions. The Bad Vermilion Lake complex is layered on a large scale [5]. Individual units, hundreds of meters thick, vary in their mode and in the size frequency distribution of their megacrysts. Some units have distributions indicating sorting of megacrysts during cumulate formation. Contacts between units which differ in degree of sorting are observable. Flow and sorting during cumulate formation appear to have been important. The density of the liquid is equal to that of the plagioclase at the temperature of crystallization (about 1200^0 C.), consequently the megacrysts are neutrally buoyant in the liquid from which they crystallize. In addition, the large size of the megacrysts suggests few and scattered nuclei during crystallization and little or no supercooling. The Bad Vermilion Lake intrusive and other large scale cumulates suggest the presence of large periodically replenished magma chambers, through which very large amounts of liquid were moved to become volcanics. The cumulates represent 10 to 15% of the parent liquid volume.

Summary: Archean plagioclase megacryst-bearing rocks form in mid to upper crustal level magma chambers which are repeatedly replenished. Crystallization is nearly isothermal and is an eqilibrium process. Cumulates are formed, probably in marginal zones of the chambers, and liquids bearing megacrysts are extracted to appear as volcanics. Flows and some intrusives occur in arc-like environments in greenstone belts. Dikes represent large volumes of melt. The areal extent of dike swarms like the Matachewan swarm suggests multiple sources of like composition. Primitive liquid(s) evolve to Fe-rich tholeiite compositions (and acquire contaminants) then move to mid- to upper crustal levels where megacrysts are formed. Complex sequences of ponding and melt migration are probable and involve large amounts of liquid.

TABLE 1: AVERAGED COMPOSITIONS OF MEGACRYST-BEARING FLOWS AND DIKES

	SiO_2	Al_2O_3	TiO_2	FeO	MgO	CaO	Na_2O	K_2O	LOI
Aver. Flow	48.8	15.4	1.02	11.6	6.9	11.7	1.97	0.18	1.97
Aver. Dike	50.7	13.6	1.34	13.5	5.8	9.4	2.45	0.68	1.45

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