NP115030 L114665

N89-22238 p. 3

TECTONIC IMPLICATIONS OF ARCHEAN ANORTHOSITE OCCURRENCES

W.C. Phinney, D.A. Morrison, Johnson Space Center and D.E. Maczuga, LEMSCO, Houston, TX 77058.

Introduction

Anorthositic complexes occur in essentially all Archean cratons and contain large equidimensional plagioclase crystals (up to 30cm. diam.) with highly calcic compositions (An_{80} to An_{90}). Several occurrences have been described in India [1],[2],[3],[4]. Because the anorthositic complexes represent cumulates, the composition and source of parental melts has been a longstanding problem. Plagioclase having the same composition and texture as that in anorthosites also occurs as megacrysts in basaltic flows, dikes, and sills in which the crysts may be scattered or concentrated in lenses or trains. We suggest that the anorthosites and megacrystic basalts are petrogenetically related. However, the tectonic settings for these occurrences appear to be quite variable suggesting that several environments may be represented. A brief outline of the regional settings of these anorthosites and petrogenetically related basalts follows.

Archean Occurrences of Megacrystic Anorthosites

1. Cumulate crystal segregations in anorthositic to gabbroic complexes associated with volcanic sequences typical of low to middle metamorphic grade greenstone belts [5],[6].
2. Cumulate crystal segregations in thick anorthositic to gabbroic sills that intrude volcanic sequences typical of greenstone belts [7].
3. Cumulate crystal segregations in anorthositic to gabbroic complexes associated with high grade metamorphic terrains containing marbles, quartzites, quartzofeldspathic gneisses, and amphibolites [3],[8].

Archean Occurrences of Megacrystic Basalts

1. Flows, dikes, and sills in volcanic sequences typical of greenstone belts [9],[10].
2. Dike swarms in stable cratonic areas forming parallel to subparallel patterns over hundreds of thousands of square kilometers intruding both high grade granitic gneisses and low to middle grade supracrustal belts [10].

Younger Occurrences

Similar occurrences of megacrysts in basalts of early Proterozoic age are known in cratonic dikes of the Bighorn Mountains of Wyoming [11] and the Beartooth Mountains of Montana [12] and in volcanic flows of the Bell Island Group of the Northwest Territories [13]. Recent occurrences of similarly calcic plagioclase phenocrysts are known in oceanic volcanic flows at spreading ridges, hotspots, aseismic ridges and fracture zones [14]. However, these normally involve only small phenocrysts up to a few millimeters in size and usually are more lathy than equidimensional in shape. In contrast to these common oceanic occurrences, volcanic flows over the Galapagos hotspot display more equidimensional calcic crysts up to 3cm. across [15]. In essentially all of the Archean and Proterozoic occurrences the distribution coefficients for REE's indicate equilibrium between the megacrysts and their matrices of Fe-rich tholeiites [16]. However, use of the same distribution coefficients in the more recent occurrences indicates substantial disequilibrium between the crysts and their tholeiitic matrices. Thus, the more recent occurrences of calcic plagioclase crysts require an additional stage of evolution before reaching their current environment, thereby providing a bit more uncertainty about their petrogenesis than the older occurrences and making direct comparison with ancient tectonic environments untenable.

Melts and Magma Chambers

Utilizing experimental petrologic studies of the basaltic matrices and distribution coefficients with trace element analyses of plagioclase it seems clear that all of the above-listed megacryst occurrences are associated with similar parent melts for both the anorthosites and megacrystic basalts [16]. The melts are relatively Fe-rich, tholeiitic basalts that exhibit a significant range of Fe-enrichment (50-70% on an AFM plot) in association with the megacrysts. The basalts of the cratonic dikes are more enriched in K, Na, and light REE than their greenstone counterparts but follow a parallel Fe-enrichment trend. Furthermore, the fractionation trends and formation of the crysts occurred at relatively shallow levels (<5Kb) [16]. The megacrysts in all of the occurrences are quite uniform in composition (±1 to 2 An units) over several centimeters except for very thin rims (~100-200μm). This suggests nearly isothermal crystallization at a nearly constant melt composition over substantial periods of time. Geochemical modeling of trace elements and subtle cyclic compositional trends in the plagioclase indicate multiple influxes of melts into the magma chambers during evolution of the melts and growth of the megacrysts. The widespread occurrences of the megacrystic units in both greenstone belts and huge cratonic dike swarms further suggests extensive development of magma chambers in which tholeiitic melts produce calcic plagioclase as a major liquidus phase under both cratonic and oceanic Archean crusts. In essentially all occurrences where adequate preservation of initial igneous textures and structures exists, there is evidence for at least two stages of plagioclase formation. In the anorthositic complexes there are bimodal units in which very large crysts are mixed with smaller, but still large, crysts. In the basalts the calcic megacrysts have thin sodic rims that match the composition of the lathy plagioclase in the matrices. Both situations indicate formation of the large crysts at locations other than their final position of emplacement, probably indicating a complex series of magma chambers in the crust.

Crustal Levels
The anorthosites appear to have intruded at various crustal levels. In many of the low-grade supracrustal (greenstone) settings the preservation of primary sedimentary and volcanic structures and textures indicate that the regions have always been at low grade and that the anorthosites intruded at very shallow levels. In the higher grade occurrences it is not always clear whether the anorthosites intruded at the higher grades or at low grade and were later upgraded. In Manitoba there is a clear case of anorthosites initially intruding low grade supracrustal units but later a regional metamorphic gradient produced a continuous sequence from low greenschist to granulite grades in all of the units [17]. In the granulite grade Shawmere anorthosite complex of Ontario [18], however, there are some nearly undeformed enclaves where the more mafic units contain well preserved olivines and pyoxenes with well preserved exsolution texture. Furthermore, some plagioclase contains well preserved polysynthetic twinning that looks like original igneous twinning. Such preservation seems unlikely if the anorthosite were intruded at low grade and underwent progressive metamorphism to granulite grade, unless the system were essentially dry during metamorphism which also seems unlikely in view of the biotite- and amphibole-bearing units adjacent to the intrusion and amphibole-bearing pegmatitic zones within the complex.

Effects of Fluids at High Grades
Several petrographic observations in high-grade anorthositic complexes indicate the infiltration of substantial amounts of fluid. Recrystallized plagioclase ranging from strained patchy areas to polycrystalline areas may occur as irregularly distributed zones, vein-like stringers, or rims around relict cores. Generally these areas display elevated values of Na and REE's in the plagioclase. Inclusions of tiny amphibole needles are common in non-recrystallized plagioclase of upper greenschist and higher grades. Concentration of the inclusions is highly variable even within a single crystal. Many plagioclase crysts contain 10% or more by volume of these inclusions. The initial FeO content of the plagioclase is in the .4-.6% range and the FeO content of inclusion-rich plagioclase is ~.1%. However, microprobe analyses of the amphiboles indicate 15-20% FeO which for 10% inclusions requires several times more FeO than was present in the initial plagioclase. Similarly the heavy REE contents of these plagioclase separates are

substantially increased over the initial values reflecting the heavy REE enrichment in amphiboles. Clearly there must be flow of fluids through the plagioclase in some manner to add Na, Fe, heavy REE, and H_2O.

Conclusions for Archean and early Proterozoic Megacrystic Units

1. Segregations of plagioclase may occur at various depths in the crust to form anorthosite.
2. Anorthosites may occur in oceanic volcanic crust and in cratonic or shelf environments.
3. Megacrystic basalts may form in oceanic or stable cratonic environments.
4. Plagioclase megacrysts in Fe-rich tholeiites indicate relatively shallow magma chambers.
5. Large uniform crysts require extensive periods of isothermal growth at nearly constant melt composition and almost certainly formed in fractionating magma chambers that are periodically replenished.
6. Megacrystic tholeiitic dike swarms indicate widespread replenishing magma chambers under stable cratons.
7. It is not clear what oceanic environment is represented by megacrystic units in greenstones but it does require magma chambers for substantial time at similar temperatures and melt compositions over extensive areas.
8. Petrogenetic conditions for formation of megacrystic anorthosites and basalts in the Archean and early Proterozoic were not the same as in younger times.
9. Substantial flow of fluids accompanied by exchange of components can occur in anorthosites at high grades of metamorphism with little more effect on the plagioclase than formation of amphibole inclusions and scattered recrystallization.

In summary, megacrystic anorthosites and basalts can occur in a variety of geologic settings and by themselves are not definitive. Only with additional field, petrologic and geochemical data can the settings be understood.

REFERENCES

[1] Leelanandam,C. and Reddy,M.N. (1985) Neues Jahrb. Miner. Abh., **153**, p.91-119.
[2] Ramakrishnan,M. et al (1978) Jour. Geol. Soc. India, **19**, p.115-134.
[3] Ramadurai,S. et al (1975) Jour. Geol. Soc. India, **16**, p.409-414.
[4] Naqvi,S.M. and Hussain,S.M. (1979) Can. Jour. Earth Sci., 16, p.1254-1264.
[5] Ashwal,L.D. et al (1983) Contr. Miner. Petrol. **82**, p.259-273.
[6] Myers,J.S. (1986) Bull. Gronl. Geol. Unders. **150**.
[7] Bell,C.K. (1962) Geol. Surv. Can. Pap. **61-22**.
[8] Barton,J.M. et al (1979) Amer. Jour. Sci. **279**, p. 1108-1134.
[9] Green,N.L. (1975) Can. Jour. Earth Sci. **12**, p.1770-1784.
[10] Phinney,W.C. et al (1987) Preprint.
[11] Miller,J.D. (1980-81) Wyo. Geol. Assoc. Earth Sci. Bull. **13-14**.
[12] Prinz,M. (1964) Bull. Geol. Soc. Amer. **75**, p.1217-1248.
[13] Reichenbach,I. (1985) Geol. Surv. Can. Pap. **85-1B**, p.151-160.
[14] Hekinian,R. et al (1976) Contr. Miner. Petrol. **58**, p.83-110; Donaldson,C.H. and Brown,R.W. (1977) Earth Planet. Sci. Lett. **37**, p.81-89; and Blanchard,D.P. et al (1976) J. Geophys. Res. **23**, p.4231-4246.
[15] Cullen,A. et al (1987) Preprint.
[16] Morrison,D.A. et al (1987) This Abstract Vol.
[17] Hubregtse,J.J.M.W. (1980) Manitoba Dept. Ener. Mines, Geol. Surv. **GP80-3**.
[18] Riccio,L. (1981) Ont. Min. Nat. Res., Ont. Geol. Surv., Open File Rpt. **5338** and Percival,J.A. (1983) Amer. Miner. **68**, p.667-686.