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Phase diagram constraints on magma mixing in “underplated” magma chambers

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Underplating (or better intraplating) of mantle-derived magmas at the base of the crust is a commonly invoked petrogenetic process. It may account for a variety of phenomenon resulting from the interaction of hot basaltic magma with lower crust material and particularly with anatectic melts. Large-scale magma chambers (e.g. the MASH model of Hildreth & Moorbath (1988) may involve mixing of basic and acidic material to produce intermediate magma composition through hybridization and/or assimilation. The plume model, as synthesized by Ashwal (1993), may also give rise to huge quantities of intermediate lithologies of the AMCG plutonism. Paradoxically, however, mafic microgranular enclaves (MME) are evidence that mingling between mafic and acidic melts is more frequent than mixing.

Recent experimental studies in the basaltic tetrahedron olivine – clinopyroxene – plagioclase – quartz in dry conditions and at intermediate pressure (Longhi, et al. 1999) throw new light on the feasibility of magma mixing in deep-seated magma chamber. In the olivine – quartz – plagioclase projection, the classical reaction point at 1 bar, liquid + olivine → orthopyroxene + plagioclase moves towards lower quartz content with increasing pressure and becomes an eutectic point at about 5 kb. At higher pressure (from 8 to 12 kb) it moves out of the plagioclase – orthopyroxene – quartz triangle and becomes again a reaction point involving spinel and an undersaturated liquid. This variation in the phase diagram thus creates a thermal barrier between, on the one hand, the understaturated reaction point and, on the other hand, the liquid – plagioclase – orthopyroxene – quartz eutectic, which can be taken as an equivalent of granitic (charnockitic) melt. The presence of such a thermal barrier between basaltic and granitic domains considerably limits mixing processes between the two melts. When basaltic liquids are on the olivine-saturated surface, mixing with granitic melt compositions will drive the basaltic liquid composition towards the olivine – orthopyroxene cotectic, which will simply hasten normal crystallization. When the melts are on the orthopyroxene-saturated surface, mixing is not possible without an increase in temperature. Only mixing of highly superheated melts (rapidly decompressed) might produce hybrid liquid compositions that reach the liquidus surface on the high-silica side of the thermal divide. Isotopic re-equilibration between the two liquids is however not precluded.

These data are only valid in dry conditions because if water is added to the system the thermal barrier collapses and mixing becomes possible. Such dry conditions normally prevail when granulite facies lower crustal rocks are put in contact with underplated basalts.

References

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