

Imperfect crystal-liquid separation processes

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Log-log-log plots. Plots of the logarithm of the relative concentration achieved in the liquid (or solid) phase as a function of the logarithms of the mass fraction of melt formed and of the distribution coefficient are used to display and explore the features of a variety of liquid-crystal separation processes.

Assumption of ideal trace element behaviour and modal melting throughout. At this stage ideal trace element behaviour, perfect modal melting and hence constancy of crystal-liquid distribution coefficient throughout the progress of melting has been assumed in the interests of simplicity.

Equilibrium partial melting and partial crystallisation as a reference surface. The resulting surface for the composition of the liquid developed in equilibrium partial melting (EPM) or crystallisation (EPC) is shown in Fig. 1.

Extreme contrasts between products of perfect fractional and equilibrium processes. Comparable surfaces for products of perfect fractional melting and perfect fractional crystallisation differ dramatically from that for EPM, showing dramatic depletions in highly incompatible elements at high mass fraction of melting or dramatic depletion in

highly compatible elements as mass fraction of melt declines in fractional crystallisation. Products of accumulated perfect fractional melting differ little from those of EPM.

The petrogenetic problems. The actual partial melting process in the mantle is likely to be closer to a perfect fractional process than an equilibrium process in terms of its physics. The actual partial crystallisation processes of magmas in magma chambers are likely to be closer to perfect fractional crystallisation than to an equilibrium process in terms of its physics. Yet erupted liquids, residues of partial melting and cumulates having the extreme depletions characteristic of the perfect fractional processes are in general lacking from the geological record – in fact much of the geochemical variation seen can be explained in terms of equilibrium partial melting of some appropriate source material.

Imperfections in fractional processes rapidly reduce the above contrasts and potentially resolve some of the petrogenetic problems. Imperfections in the fractional processes resulting from failure to separate liquid and crystals instantly (stepwise, small increment, melting or crystallisation); failure

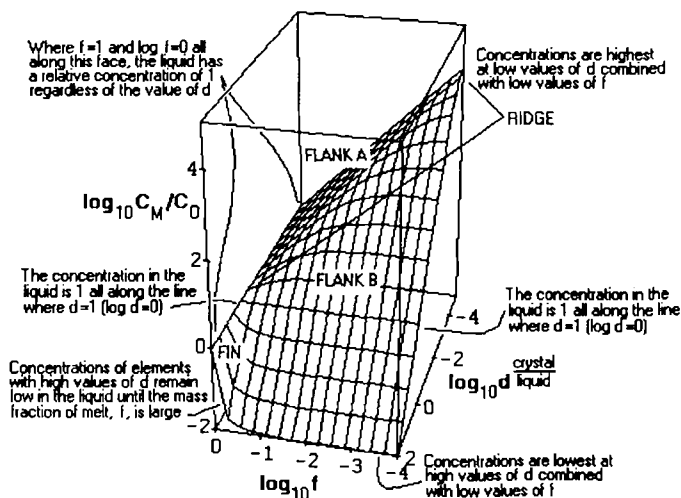


FIG. 1.

Displayed in a box which "chops" the surface where the difference exceeds +58% or -37% of the concentration on the EPC surface.

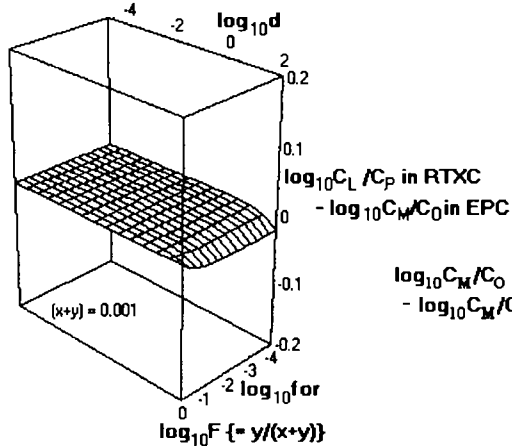


FIG. 2

Displayed in a box which "chops" the surface where the difference is 1 million times greater or less than the concentration on the EPM surface

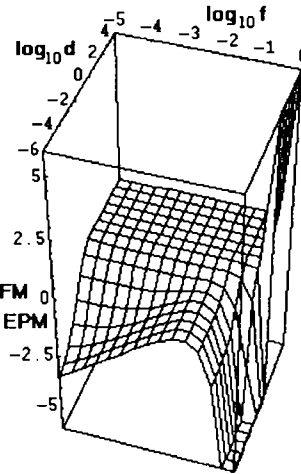


FIG. 3.

to separate liquid and crystals completely (dynamic melting with trapped liquid, fractional crystallisation with suspended crystals); and flow of source material into, and of liquid and solid products out of the 'box' during the fractional process (refilled, tapped and fractionated magma chambers, melting of convecting mantle) have been explored using plots similar to Fig. 1. Introduction of quite small imperfections rapidly reduces the contrasts between the liquid products of potentially 'more realistic' processes and those predicted by the equilibrium processes, flow of source material being by far the most influential in this respect. There need be no serious discrepancy between the observed geochemistry of magmas and the implications of studies of field petrology in basalts and peridotites or the physics of the melt extraction process.

The EPM/EPC surface as a reference surface. Given that many 'more realistic' processes produce liquid products relatively close in character to the EPM/EPC liquids, it is convenient to use the surface of Fig. 1 as a reference

surface, plotting the difference between the logarithms of relative concentration on that surface and that yielded by the process under consideration as a function of the same variables as before – i.e. plotting values effectively normalised against those of the equilibrium process operating under the same parameters of melt fraction and distribution coefficient. Fig. 2 is an example for a refilled, tapped fractionated magma chamber while fig. 3 is an example for a case of dynamic melting. The technique is used in other abstracts in this volume and has been explained in greater detail elsewhere (O'Hara, M.J., 1993)

Reference

- O'Hara, M.J. (1993) Trace element geochemical effects of imperfect crystal-liquid separation. In Prichard, H.M., Alabaster, T., Harris, N.B.W. and Neary, C.R. (eds) *Magmatic Processes and Plate Tectonics*. Geol. Soc. London Spec. Publ. 76, 39–59.