

# Combining reversed and subdued discrimination with high relative concentrations of incompatible elements

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*The requirement for reversed discrimination in basalt genesis.* N-type MORB in particular display reversed discrimination (in which the more incompatible element, e.g. Rb, is less enriched relative to the concentration (assumed  $2 \times$  chondritic) in the original source material than is a less incompatible element, e.g. Sr). The simplest way in which to produce reversed discrimination is to extract the liquid from a source which has previously been depleted by a partial melting event (which in favourable circumstances leaves a residue with in-built reversed discrimination which is then transmitted to the next extract of melt which forms).

*Subdued discrimination.* Other natural basalts exhibit subdued discrimination, in which the relative concentration of the more incompatible element is not as great, when compared with that of the less incompatible element, as would be expected during simple equilibrium melting of the original source material. This effect is readily produced by less extreme depletion of the source than is required for generation of reversed discrimination in a previous melt extraction event, again followed by renewed melt extraction. An important requirement in the generation of both reversed and subdued discrimination is that the liquid extracts derived initially from the

original source should not be allowed to mix in any way with the later liquid extracts, otherwise the effects are overwhelmed by the normal discrimination and very high relative concentrations of all incompatible elements in the early liquids. Thompson *et al.*'s (1984) model proposes generation of MORB sources from broadly chondritic-ratio initial compositions by fractional melting, with isolation of early melts in the crust.

*Relationship between equilibrium, dynamic and fractional melting.* Fig. 1 displays the surface of relative concentration of an incompatible element of distribution coefficient  $d = 0.001$  in the next drop of melt to be produced during imperfect separation fractional melting (perfect fractional melting with mass fraction,  $t$ , of the residue being trapped liquid and mass fraction,  $f$ , of the original source system having been extracted as melt - ISFM of O'Hara 1993). Fig. 2 presents a contour map of this surface. In the upper left half of Fig. 2 effects can barely be distinguished from equilibrium partial melting of the original source with  $t$  (not  $f$ ) as the extracted melt fraction; in the lower right half of fig.2 effects are very similar to those of pure perfect fractional melting with  $f$  as the extracted melt fraction; along the lower left-upper

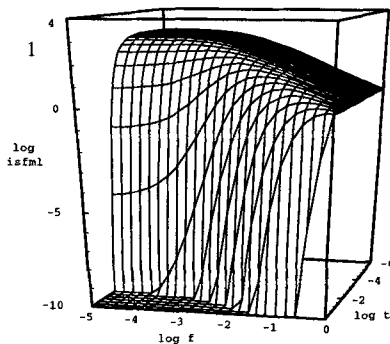


FIG. 1.

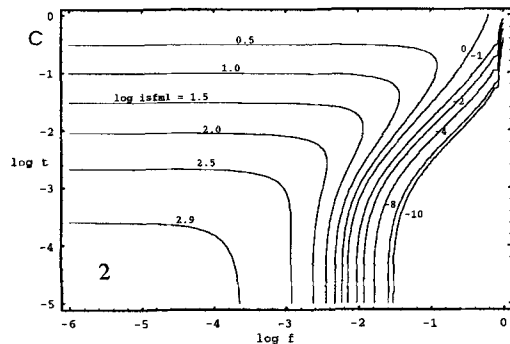


FIG. 2.

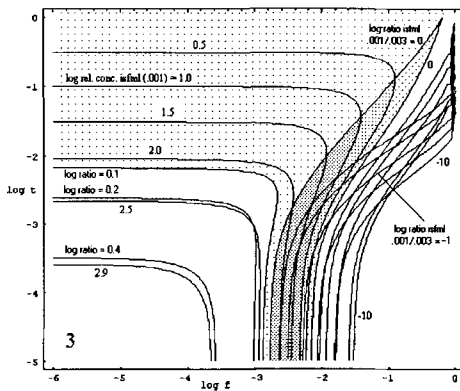


FIG. 3.

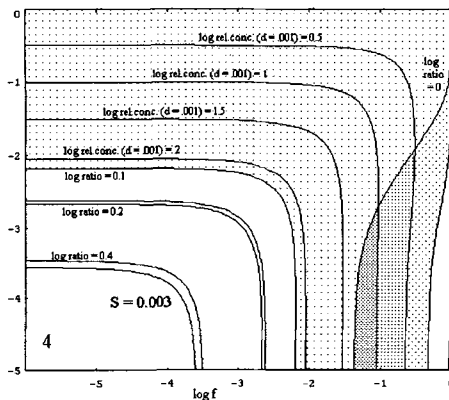


FIG. 4.

right diagonal of Fig. 2, where trapped melt fraction is approximately equal to the mass fraction of melt previously extracted, is the domain of the distinctive effects of dynamic melting (Langmuir *et al.*, 1975, and see O'Hara 1993, Figs. 12–14).

*Generating subdued and reversed discrimination of highly incompatible elements with high relative concentration – extremely restricted combinations and very low values permitted for trapped and extracted melt fractions.* Plots similar to Fig. 2 may also be developed for less incompatible elements (e.g.  $d = 0.003$ ) or for the ratio of relative concentrations of elements with  $d = 0.001, 0.003$ ; Fig. 3 shows the latter plot superimposed upon that of Fig. 2 and shaded to show the ranges of conditions under which the next melts will display, for two such elements, subdued discrimination (lightest stipple, high  $t$ , low  $f$ ); or reversed discrimination but with relative concentration of the more incompatible element still greater than that of the original source (light stipple, rel. conc.  $1-3 \times$  original source; medium stipple, rel. conc.  $3-10 \times$  original source; heavy stipple, rel. conc.  $10-100 \times$  original source). Extremely restricted conditions ( $f$ -previous  $< 0.03$ ;  $0.01 < t < 0.1$  or  $f \sim 0.0015$  at  $t < 0.01$ ) will yield melts with subdued discrimination and relative concentration  $> 10$ ; still more restricted conditions are required ( $0.0015 < f$ -previous  $< 0.015$ ;  $t < 0.03$ ) for reversed discrimination combined with relative concentration  $> 10$ . In each case  $f$ -new must be kept small ( $\sim f$ -previous) or the desired characteristics in the next melt are severely modified towards those of

liquids to the right in Fig. 3.

*Role of mantle flow through the melting regime in relaxing the constraints.* Fig. 4 shows the plot equivalent to Fig. 3, drawn for the case of replenished extracted mixed melting with trapped melt in the residues under conditions where  $S$ , the mass fraction of the melting 'box' which is replaced in each cycle, is 0.003 (REXM of O'Hara 1993, but with equ. 19 developed with the use of the PFM relationship as  $g_1(f)$ ,  $d$  modified as in equ. 16, and all recast in the form of equ. 25 to yield the compositions of component melt extracts). The ranges of mass fraction of previous melt fraction extracted, after which the next melt to be formed will be characterised by subdued or reversed discrimination combined with high concentration relative to the original source - and the mass fraction of such melt which may now be extracted without destroying these characteristics, has been enormously enlarged. Reversed discrimination with relative concentration  $> 3$  may now be displayed when  $0.05 < f < 0.25$ , a prediction which can be far more readily reconciled with field evidence of substantial major element depletion in the harzburgites of ophiolite complexes than the extremely restrictive predictions from the static melting model. The problem of what to do with the earliest melt fractions (which must not be allowed to mix with the derived melts) can be resolved if the source material for the melting process has previously been depleted - and if depleted by a similar process, much higher mass fractions of melt extraction are also permitted for that earlier process.