Focussed fluid flow during subduction

A. C. Barnicoat *Department of Earth Sciences, University of Leeds,*
Leeds LS2 9JT, UK.
I. Cartwright *Department of Earth Sciences, VIEPS, Monash University,*
Clayton 3168, Australia.

Introduction

It is clear that substantial dehydration of subducted metabasic ocean crust occurs, but the fate and behaviour of the liberated water has been the subject of much debate. It is the purpose of this study to present new data from subducted oceanic crust in the western Alps which has a bearing on this ongoing debate.The western Alps is an ideal place to examine subduction zone processes, as ophiolitic material metamorphosed to high-pressure conditions from <1GPa to >2GPa have been returned to the Earth's surface.

Detailed investigations of ophiolites and ocean crust means that the pattern of alteration and $\delta^{18}O$ values prior to subduction can be estimated (e.g. Shiffman and Smith, 1988; Gillis and Robinson; 1990)

Regional Geology. The ophiolites of the Piemonte zone of the western Alps represent the former ocean floor that once separated the European and Apulian (Italy, etc.) plates. These ophiolitic relics now form the , sandwiched between European and Apulian (also known as Austroalpine) basement. Both basement units and the Piemonte zone contain high -pressure metamorphic assemblages. The samples used in this study come from two areas. At Pfulwe (near Zermatt), a wide range of lithologies are present in an area *c.* 500 × 500m, including eclogite, chloritoid eclogite, blueschist and epidosite. Common metabasalts have eclogitic mineral assemblages, and other parageneses are cofacial; ~~with~~ the variation in mineralogy due to variation in bulk composition due to the effects of sea-floor hydrothermal alteration (Barnicoat and Bowtell; submitted). Conditions of metamorphism were estimated as 1.7–2.0GPa, 550–600°C by Barnicoat and Fry (1986). Servette (on the south side of the Val d'Aosta) is the site of a disused copper mine, and again, a wide range of lithologies is present. The area is one of eclogite-facies metamorphism, although blueschists dominate the immediate area. Also present near the mine are talc-chloritoid rich rocks and talc-cummingtonite assemblages. Quartz-pyrite rich material represents the ore material. Servette is interpreted as the upflow zone of a mid-ocean-ridge hydrothermal system, now metamorphosed to high-pressure assemblages. Metamorphic conditions have been estimated as 550 ± 20°C, 1.2–1.6GPa (Martin and Tartarotti; 1986*b*).

Analytical Method. Oxygen extraction was undertaken using standard techniques with ClF_3 as reagent. Isotopic analysis was done on Finnigan Mat Delta E and 252 mass spectrometers.

Results

There is a remarkable similarity between the isotopic composition of the Alpine samples and unaltered ocean floor and ophiolitic material, especially if the fractionation due to dehydration (estimated at <0.5‰) is taken into consideration. The eclogitic samples, representing essentially unaltered basaltic compositions, possess $\delta^{18}O$ values of 5.5 ± 0.3‰, within error of ocean-floor basalts at 5.7‰. The blueschists, representing material altered at low temperatures in the down-flow zones of hydrothermal systems, have $\delta^{18}O$ values of $6.3 \pm 0.$‰. Altered ocean-floor and ophiolitic samples also have elevated values. Material from proximal alteration zones to high-temperature upwelling pathways in the Alpine samples have $\delta^{18}O$ value of 4.6‰, again similar to ophiolitic material. Quartz-sulphide rocks from Servette have $\delta^{18}O$ values of 8.0 ± 1.0‰, suggesting a comparatively low temperature of formation, as do analogous samples ophiolites (Zierenberg *et al.*, 1988). Thus the metamorphosed ophiolitic material has retained the stable isotope signatures it developed on the ocean floor, and resetting has not occurred during high-*P* metamorphism.

Discussion

A $1m^3$ metabasalt liberating 1 wt% H_2O would yield a fluid flux of 1.9×10^4 mol m^{-2} m^{-3} of source. If this fluid migrates uniformly through overlying rock maintaining equilibrium with its surroundings (i.e. if the Damköhler number was high), it can be shown that the oxygen isotope signature of the source will be transported a distance200m per km thickness of source per

1wt% of water lost. The water content of subducted oceanic crust is conservatively estimated at 1–2 wt%, and typical thicknesses are 8–10km, these results suggest that if the fluid generated by dehydration migrated pervasively through and maintained isotopic equilibrium with overlying rocks, the oxygen isotopes should be homogenised on a scale of > 1km. The data presented here show that the oxygen isotope and bulk compositional heterogeneities developed on the sea floor can not have been displaced or separated by more than a few metres.

Two explanations are possible. The amount of water in the subducted Alpine oceanic crust may be considerably less than 1wt%. or alternatively, the water loss may have been strongly focused. Given the likelihood that the metamorphism of oceanic crust to eclogite releases substantial amounts of water, the conclusion that fluid escape was focused along presumably structurally-controlled pathways appears inevitable. However, while veins with high-pressure mineralogies are present in several west Alpine ophiolites oxygen isotope and fluid inclusion studies suggest that they represent only the local redistribution of limited packages of fluid, and are probably not the pathways along which large amounts of water have passed. The channelways along which the fluids produced by dehydration escaped from Alpine oceanic crust during subduction have thus not yet been identified.

References

Barnicoat, A. C. and Bowtell, S. A. (submitted) Sea-floor hydrothermal alteration in metabasites from high-pressure ophiolites of the Zermatt-Aosta area of the western Alps.

Barnicoat, A. C. and Fry, N. (1986) *J. Geol. Soc., London*, **143**, 603–18.

Gillis, K. M. and Robinson, P. T. (1990) *J. Geophysical Res.*, **95**, 21,523–48.

Martin, S. and Tartarotti , P. (1986) *Ofioliti*, **15**, 135–56.

Schiffman, P. and Smith, B. M.. (1988) *J. Geophysical Res.*, **93**, 4612–24.

Zierenberg, R. A., Shanks III, W. C., Seyfried Jr., W. E., Koski, R. A. and Strickler, M. D. (1988) *J. Geophysical Res.*, **93**, 4657–74.