Anomalously old Ar-Ar ages in high pressure metamorphic terrains

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Introduction

An increasing number of Ar-Ar ages for phengites in blueschist and eclogite terrains are in conflict with peak metamorphic ages determined by other geochronological techniques (Rb/Sr, Sm/Nd and U/Pb). The Ar-Ar ages are generally much older than the 'true' metamorphic age, and despite the fact that such samples yield apparently acceptable stepped-heating plateaux, the high apparent ages are most probably the result of excess argon.

Recent laser microprobe Ar-Ar studies of within crystal age variations and the distribution of argon components between mineral phases confirm the widespread preservation of excess argon in minerals from high pressure eclogite/blueschist metamorphic terrains. In the light of these uncertainties, should we abandon phengite Ar-Ar ages despite their importance in the construction of T-t profiles models for high pressure terrains?

Background

The large discrepancy between phengite Ar-Ar ages (877–943 Ma) and Rb/Sr and Sm/Nd ages (in the range 219–228 Ma) in the Dabie Shan UHP metamorphic belt, China (Li *et al.* 1994), has highlighted an enigma seen in the high pressure rocks of the Dora Maira Massif in the western Alps where ca. 100 Ma phengite Ar-Ar ages conflict with ca. 40 Ma U/Pb ages on zircon (Monie and Chopin 1991, Tilton 1991). White micas from the high pressure Eclogite Micaschist Complex of the Sesia Zone also yield a wide range of K-Ar and Ar-Ar plateau ages from 60 Ma to 90 Ma ages, while Rb-Sr ages are generally around 60 Ma. Further, a recent Sm-Nd age of 52 ± 18 Ma for high pressure metamorphism in the Zermatt-Saas ophiolite underlying the Sesia zone is younger than had been indicated by earlier Ar-Ar and K-Ar ages on white micas and glaucophane (Bowtell *et al.* 1994). Similar excess argon problems have been detected in many blueschist terrains including the Tavsanli Zone in northwestern Turkey where Ar-Ar ages range from 65 Ma up to 120 Ma which is older than the metamorphic sole of the associated ophiolite complex (108 Ma, Harris *et al.* 1994).

In summary, high pressure metamorphism, whether eclogite or blueschist facies, is consistently associated with excess argon. The implication is that deep crustal fluids present during such metamorphic events did not exchange with surface derived fluids prior to closure of the minerals to argon diffusion. Rapid cooling and exhumation which are an essential part of the preservation of high pressure mineral assemblages, also promote the preservation of deep crustal fluids and thus high argon concentrations and high $^{40}Ar/^{36}Ar$ ratios within the minerals.

Laser Studies

Despite the complexities, phengite Ar-Ar ages have yielded meaningful chronological and thermal information in high pressure metamorphic zones such as Sifnos, Greece (Wijbrans *et al.* 1990). However, it seems that stepped-heating and laser spot analysis of mineral separates do not provide reliable methods to distinguish true cooling ages from ages affected by excess argon. Recent work using a combination of stepped heating and *in-situ* analysis of various mineral phases, using both IR laser extraction and a new ultra-violet laser extraction technique (Kelley *et al.* 1994), seem to provide a reliable method of studying Ar-Ar ages in high pressure rocks.

An undeformed Hercynian metagranite from the Dora Maira Massif, metamorphosed to eclogite grade with amphibolite retrogression, has been studied using a combination of K-feldspar stepped-heating and *in-situ* UV laser extraction techniques (Arnaud and Kelley, 1994). The results demonstrate the frequent occurrence of excess argon ($^{40}Ar/^{36}Ar$ 1000–10000) and a strong relationship between apparent ages and metamorphic textures. It seems likely that excess argon incorporated in all phases during the high pressure event, mixed progressively with an atmospheric component during rapid cooling and retrogression, producing a wide range of apparent ages.

Laser spot analyses of large phengite grains in a phengite/garnet/quartz/omphacite rock from the Eclogite Micaschist Complex in the Sesia Zone of the western Alps also yielded a strong relationship between apparent ages and microtextures. In this case, high apparent ages close to the grain boundaries indicate concentrations of excess argon at the grain boundary increased during deformation associated with rapid cooling.

Laser spot analyses of phengites in a phengite/jadeite/quartz rock from the Tavsanli blueschist zone, Turkey have yielded a cooling age of 88 Ma (Okay and Kelley 1994). UV laser microprobe analyses of all phases indicate low concentrations of excess argon and hence confirm the cooling age close to that previously determined for these rocks.

Conclusion

A combination of stepped-heating and *in-situ* laser spot analyses provides the most reliable technique to study Ar-Ar ages in high pressure metamorphic rocks. Future work centred upon understanding the partitioning of argon between mineral phases may provide not only thermochronological information but also some constraints on the behaviour of argon in the fluid phase.

References

Arnaud, N.O. and Kelley, S.P. (1994) *Contrib. Mineral. Petrol.*, submitted.

Bowtell, S.A., Cliff, R.A. and Barnicoat, A.C. (1994) *J. Metamorphic Geol.*, **12**, 187–96.

Harris, N.B.W., Kelley, S.P. and Okay, A.I. (1994) *Contrib. Mineral. Petrol.*, (in press).

Kelley, S.P., Arnaud, N.O. and Turner, S.P. (1994) *Geochim. Cosmochim. Acta*, (in press).

Li, S., Wang, S., Chen, Y., Lui, D., Qiu, J., Zhou, H and Zhang, Z. (1994) *Chem. Geol. (Isot. Geosci. Section)*, **112**, 343–50.

Okay, A.I. and Kelley, S.P. (1994) *J. Metamorphic Geol.* (in press).

Monié, P. and Chopin, C. (1991) *J. Mineral.*, **3**, 239–62.

Tilton, G.R., Schreyer, W. and Schertl, H.P. (1991) *Contrib. Mineral. Petrol.*, **108**, 22–33.

Wijbrans, J.R., Schliestedt, M. and York, D. (1990) *Contrib. Mineral. Petrol.*, **104**, 582–93.