High-pressure granulite event in the Filali Unit (Beni Bousera Massif, Morocco): implications for an early Variscan metamorphic evolution

Metamorfismo granulítico de alta-presión en la Unidad de Filali (Macizo de Beni Bousera, Marruecos): implicaciones para una evolución metamórfica Varisca

A.M. Aghzer y F. Haissen

Laboratoire de Géodynamique, Département de Géologie, Faculté des Sciences, Université Chouaïb Doukkali , El Jadida 24 000, Morocco
aghzer@ucd.ac.ma; fhaissen@ucd.ac.ma

RESUMEN

Los paragneises migmatíticos basales de la unidad de Filali (Rif Interno, Marruecos) contienen inclusiones de granulitas básicas de alta-presión. Tres episodios metamórficos que documentan una descompresión isotérmica han sido distinguídos en estas litologías: (1) un episodio granulítico de alta-presión (810-890°C, 13.3-15.7 kbar); (2) un episodio transicional entre las facies de las granulitas y anfibolitas (712-832°C, 10.3-13 kbar); y (3) un estadio anfibolítico (690-770°C, 7.7-9 kbar). Esta descompresión isotérmica está probablemente asociada a un colapso extensional tardi-Varisco.

Key words: Rif belt, Variscan belt, Alpine belt, high-pressure basic granulites.

Geogaceta, 38 (2005), 267-270
ISSN: 0213683X

Introduction

Among the tectonic units of the internal Rif belt, the Filali Unit (Fig. 1b) is considered to have experienced a barrovian-like metamorphism which culminated in the upper amphibolite-facies (Kornprobst, 1974). Recently, we have found garnet-bearing metabasic rocks intercalated within the basal migmatitic gneiss of the Filali Unit. These metabasites display mineral assemblages typical of the high-pressure (HP) mafic granulites. The aim of this study is to elucidate the P-T history of these metabasic rocks based on textural relations and thermobarometric calculations. The combination of the P-T path extracted from these rocks with some available radiometric data provides constrains for the early metamorphic evolution of the Filali Unit.

Geological setting

The Betic and Rif Cordilleras and Alboran Sea (Fig. 1a) were formed by lithospheric Alpine collision attributed to the convergence between the Eurasian and African plates. The Internal Rif belt consists of three nappes, from top to bottom, the Dorsale calcaire, the Ghomaride nappe complex and the Sebtide complex Unit (Kornprobst, 1974) (Fig. 1b). At the Beni Bousera Massif (Fig. 1b), the Sebtide complex is made up by an extensionally thinned units that have been grouped into the pre-Permian lower Sebtide and the Permian-Triassic upper Sebtide (Michard et *al*., 1997). The pre-Permian lower Sebtide includes the Beni Bousera peridotites and an overlying crustal metamorphic section which includes a basal granulitic Unit (kinzigites) overlain by cordierite-sillimanite migmatitic gneiss of the Filali Unit, which is in turn overlain by a thick monotonous section comprising garnet-Al silicate-staurolite-biotite-bearing micaschists (Fig. 1b). The basal unit of the Permian-Triassic upper Sebtide preserves HP-LT assemblages which are typical of eclogite-facies conditions; this HP metamorphic event is related to Alpine-subduction (Michard *et al*., 1997).

Basic granulites

The Filali Unit essentially comprises pelitic schists and micaschists grading downward to paragneiss and migmatitic gneisses (Fig. 1b). We recently found two lenticular bodies of mafic granulites intercalated within the migmatitic gneiss. The metabasic granulites occur as dark to dark green, meter-sized boudins. Their margins are sheared parallel to the regional gneissic foliation (S_2). They contain garnet, clinopyroxene, quartz, plagioclase, ilmenite and hornblende. Garnet porphyroblasts are normally rimmed by symplectites of green hornblende + plagioclase which are confined to the contact between garnet and clinopyroxene. This symplectite texture could have been formed by the following reaction :

Garnet + clinopyroxene + H_2O = hornblende + plagioclase.

Clinopyroxene occurs as subidioblastic to xenoblastic porphyroblasts and contains quartz, ilmenite and abundant plagioclase inclusions. Plagioclase has an idioblastic shape and consists of small polygonal grains with 120° triple junctions. It is an abundant inclusion phase in clinopyroxene and is associated with green hornblende as replacement product after garnet. Ilmenite occurs as an accessory phase in the matrix and as inclusions in the various porphyroblasts of the rocks. Quartz is a minor phase in these rocks and may be present in the

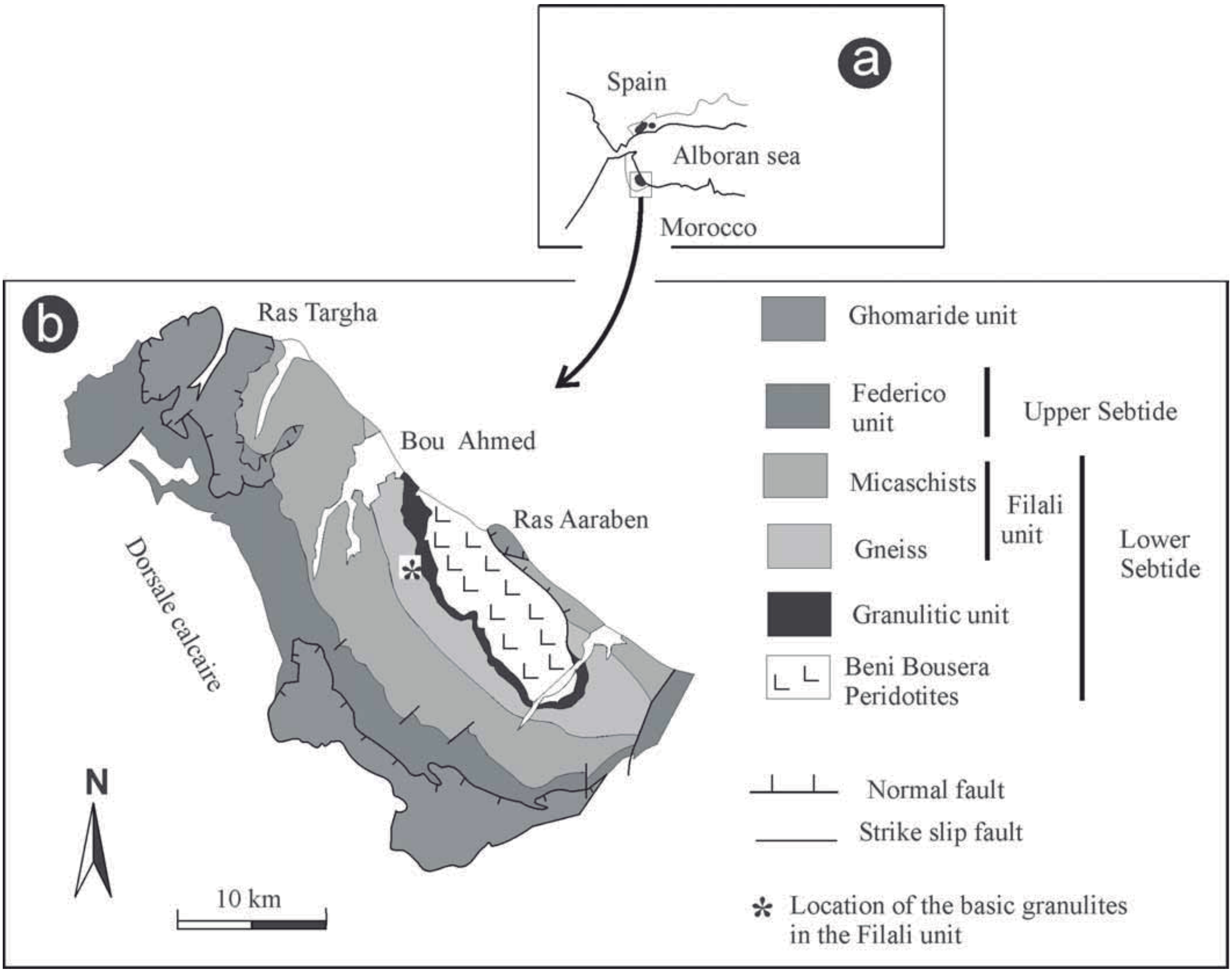

Fig. 1. - Geological sketch map of the Beni Bousera Massif . (a) Location of the Beni Bousera Massif in the Betic-Rif belt. (b) Sketch map of the Beni Bousera area showing the different tectonic Units and the location of the basic granulites in the migmatitic gneiss of the Filali Unit.

Fig. 1.- Mapa geológico esquemático del Macizo de Beni Bousera. (a) Localización del Macizo de Beni Bousera en el cinturón Bético-Rifeño. (b) Mapa esquemático de la región de Beni Bousera que muestra las diferentes unidades tectónicas y la localización de las inclusiones de granulitas básicas en los gneises migmatíticos de la Unidad de Filali.

matrix and as inclusions in garnet and clinopyroxene porphyroblasts. In sheared rocks, the preferred orientation of clinopyroxene forms the S_2 foliation, together with ilmenite and secondary hornblende.

Mineral chemistry

The mineral analyses described here were made using the Cambax SX 50 at the Université Catholique of Louvain (Belgium), with 15 KV accelerating voltage, 20 nA beam current and 15-10 s counting time .

The garnet porphyroblasts are pyrope-rich with relatively high grossular contents. Their cores and inner rims show average compositions of Alm_{27-28} Prp_{40-42} Grs_{29-30} and Alm_{33-35} Prp_{34-36} Grs_{28-30} respectively. Zoning is limited to the rims, which show an increase in almandine and a decrease in pyrope and $Mg/(Mg+Fe^{2+})$ ratios. This garnet composition is typical of high-grade garnets affected by volume-diffusion at peak temperature and diffusive re-homogenisation during retrogression (Spear, 1988). Three plagioclase types are distinguished according to their mineralogical textures: (a) plagioclase inclusions in clinopyroxene range from An_{36-40} in clinopyroxene cores to An_{45-48} at clinopyroxene rims; (b) matrix plagioclase in contact with clinopyroxene have rim composition ranging from An_{50-60}; (c) symplectitic plagioclase which shows the more calcic composition (An_{82-91}). Clinopyroxene has a composition ranging from aluminian diopside ($Enstatite_{41}$ $Ferrosillite_{10}$ $Wollastonite_{49}$) to aluminian wollastonite ($Enstatite_{39}$ $Ferrosillite_{9}$ $Wollastonite_{52}$). It reveals significant Al(t) zoning; the Al(t) zoning profiles decrease gradually towards the outer cores and abruptly decrease at the outer rims (Fig. 2). The drop of XFe towards the rims (Fig. 2) reflects the effect of post-thermal peak, cooling-driven Fe-Mg exchange with garnet. The symplectitic amphibole is pargasite and magnesian-hastingsite.

Thermobarometry

The garnet-clinopyroxene-plagioclase-quatz assemblage is used to estimate the metamorphic peak and the earliest post-peak P-T conditions. The former conditions can be estimated by combining the composition of the clinopyroxene core, their plagioclase inclusions

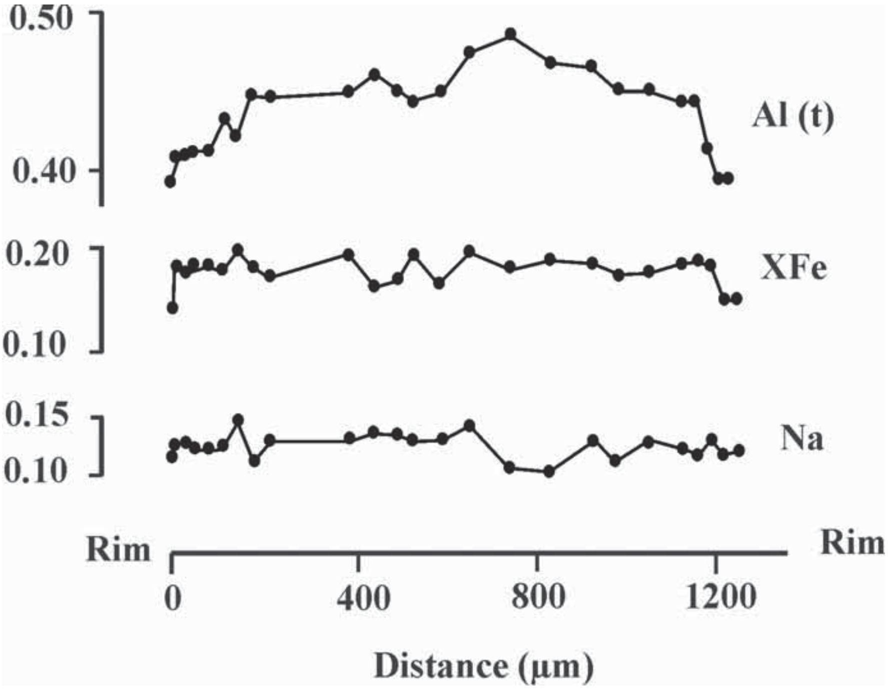

Fig. 2. -Selected zoning profiles of clinopyroxene.

Fig. 2.- Perfiles composicionales representativos del zonado químico de los clinopiroxenos.

and the garnet cores. Post-peak metamorphic conditions are inferred from the clinopyroxene inner rims, the inner garnet rims and the plagioclase inclusions in clinopyroxene inner rims. The temperature estimates obtained on the clinopyroxene and garnet cores by using the calibrations of Råheim y Green (1974) range between 820-890°C. Temperatures calculated with the same thermometer on the clinopyroxene and garnet inner rims range between 712-832°C. The pressure estimates for metamorphic peak conditions obtained by garnet-clinopyroxene-plagioclase-quartz barometer of Perkins y Newton (1981) range between 13.3-15.7 kbar. The pressure calculated for the earliest post-peak conditions with the same barometer is in the range 10.3 - 13 kbar. In order to estimate the P-T conditions of the final metamorphic event recorded in the mafic granulites, the garnet-hornblende thermometer (Graham y Powell, 1984) and garnet-hornblende-plagioclase-quartz barometer (Kohn y Spear, 1990) were applied on garnet outer rims-symplectitic hornblende and plagioclase-qtz assemblage. The calibration of Graham y Powell (1984) yields temperature estimates in the range 690-770°C. The pressure estimates corresponding to the calculated temperatures range between 7.7-9 kbar.

Conclusions

The mafic granulites preserved in the basal migmatitic gneiss of the Filali Unit reveal the existence of an early HP tectonometamorphic event. The granulitic peak metamorphic conditions are 820-890°C and 13.3-15.7 kbar. The early retrograde P-T conditions range from 712-832°C and 10.3–13 kbar. According to petrographic features and estimated P-T conditions, this earliest retrograde event took place at an upper amphibolite to amphibolite-granulite facies transition. The development of plagioclase and hornblende symplectites after garnet

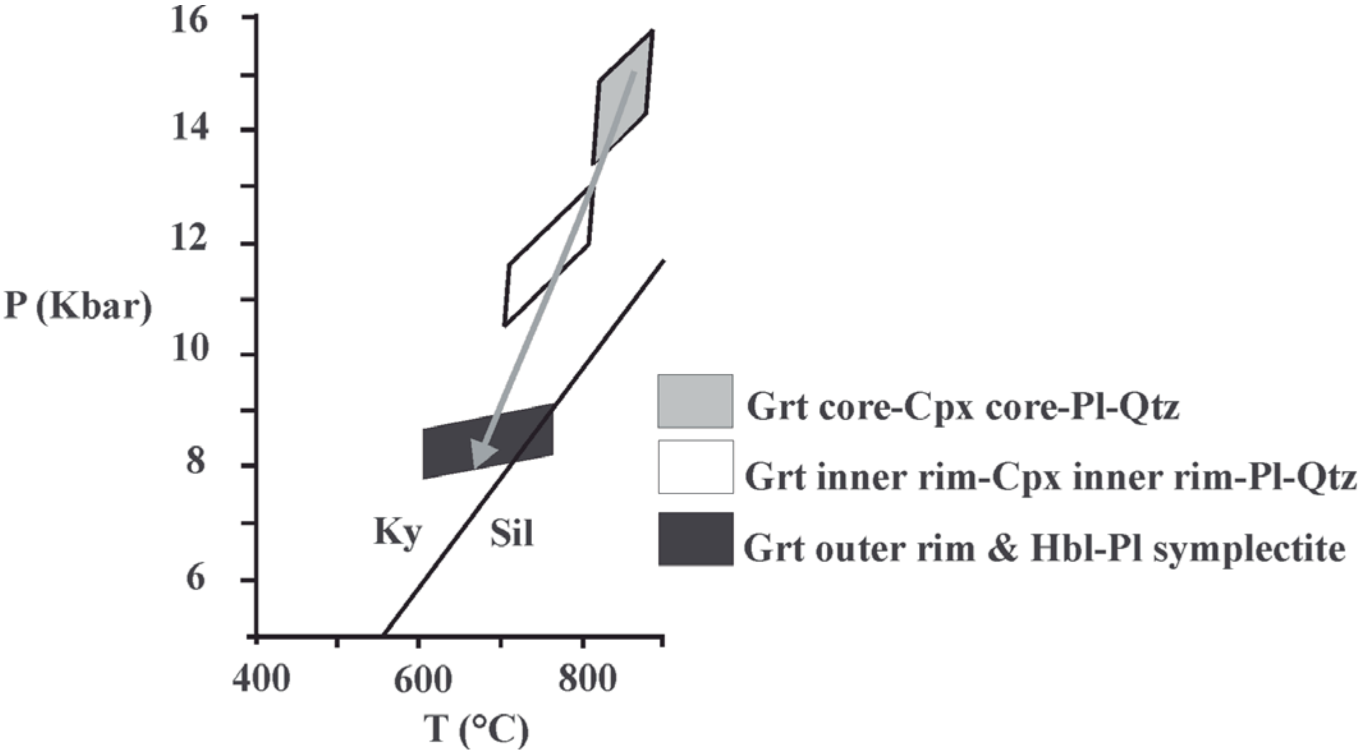

Fig. 3.- P-T diagram showing the thermobarometric results and the P-T path deduced for the basic granulites.

Fig. 3.- Diagrama P-T mostrando los resultados termobarométricos y la trayectoria P-T deducida para las granulitas básicas.

corresponds to the final retrograde P-T conditions established in the upper amphibolite facies (690–770°C and 7.7-9 kbar). The P-T path deduced correspond to an isothermal decompression (Fig. 3) suggesting, as have been identified in many other lower Sebtide Units, that the exhumation of the Filali Unit is essentially controlled by extensional tectonics. The Carboniferous ages obtained for the high and medium-pressure-medium to high-temperature metamorphic events (Montel *et al*., 2000; Zeck and Williams, 2001) suggest that the isothermal decompression path from granulite to amphiblite-facies conditions is probably associated to the late Variscan extensional tectonics that affected a Variscan thickened crust corresponding to the lower Filali crustal section.

Acknowledgements

Many thanks to Ricardo Arenas for his careful reading and to Maria José Huertas for editorial help.

References

Graham, C.M. y Powell, R. (1984). *Journal of Metamorphic Geology*, 2, 13-21.

Kohn, M.J. y Spear, F.S. (1990). *American Mineralogist*, 74, 77-84.

Kornprobst, J. (1974). *Notes et Mémoires du Service Géologique, Maroc*, 251, 256 p.

Michard, A., Goffé, B., Boubaouène, L. y Saddiqi, O. (1997). *Terra Nova*, 9, 171-174.

Montel, J.M., Kornprobst, J. y Vielzeuf, D. (2000). *Journal of Metamorphic Geology*, 18, 335-342.

Perkins, D.III. y Newton, R.C. (1981). *Nature*, 292, 144-146.

Råheim, A. y Green, D.H. (1974). *Contributions to Mineralogy and Petrology.*, 48, 179-203.

Spear, F.S. (1988). *Contributions to Mineralogy and Petrology*, 98, 507-517.

Zeck, H.P. y Williams, I.S. (2001). *Journal of Petrology*, 42, 1373-1385.