Migmatization of the basal paragneisses of the Filali Unit (Beni Bousera Massif, Morocco) during polyphase extensional tectonics

Migmatización de los paragneises basales de la Unidad de Filali (Macizo de Beni Bousera, Marruecos) durante una tectónica extensional polifásica

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RESUMEN

Los paragneises basales de la Unidad de Filali registran dos episodios migmatíticos: (a) un episodio de media-presión (710-810°C y 6.6-9 kbar) relacionado con el colapso extensional tardi-Varisco que afectó a la sección litosférica de los Sebtides inferiores; y (b) un episodio de baja-presión de edad Alpina, que produjó cordierita durante una descompresión casi isotérmica (640-760°C y 4.5-5 kbar), asociado a la apertura durante el Oligoceno superior-Mioceno del dominio de Alboran.

Key words: *Betic-Rif Belt, Beni Bousera Massif, migmatite, polyphase extensional tectonics.*

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Introduction

The geological setting of the Rif belt have already been commented in this same volume by Aghzer and Haissen. Among the tectonometamorphic units of the lower Sebtide of the Beni Boussera Massif, the Filali Unit experienced a barrovian-like-metamorphism culminating in the high-T part of the amphibolite-facies (El Maz, 1989). It is composed of migmatitic gneiss overlain by a monotonous thick sequence of garnet-Al silicate-staurolite-biotite-bearing micaschists. Most of the details on the tectonometamorphic history of the Filali Unit have only been established from the micaschists. Little is known on the metamorphic evolution of the migmatites; in this paper we investigate the P-T history of these high-grade rocks by combining textural reaction and thermobarometric studies. The integration of the resultant P-T path with available chronological data provides some constraints for a new regional tectonometamorphic model for the entire lower Sebtide section.

Migmatitic paragneisses

The migmatitic gneisses are separated from the underlying granulitic Unit by an extensional detachment. They enclose lenses of leptynites, pyroxenites and a high-pressure (HP) mafic granulites. The migmatitic textures correspond to veins and felsic segregations which are commonly parallel to the regional S_2 foliation.

The migmatitic gneisses consist essentially of the mineral assemblage quartz + plagioclase ± K feldspar ± kyanite + fibrolite + biotite ± cordierite ± andalusite. The leucosomes include minor amount of garnet, biotite, fibrolite, cordierite and andalusite. Garnet porphyroblasts are pre to syn-S_2 foliation and show resorbed edges by oriented biotite and sillimanite aggregates. Garnet is replaced by cordierite porphyroblasts wich in turn are partially to completely pinitized. Subhedral crystals of kyanite are oriented parallel to S_2 foliation and show undulose extinction and kink banding indicating pre kinematic growth. Their edges are often resorbed by sillimanite. The regional planar fabrics are mainly defined by prefered orientations of fibrolitic sillimanite, biotite, biotite-sillimanite intergrowth and, in minor amounts, ilmenite. In some instances, this later mineral enclose relics of rutile. Some cordierite porphyroblasts preserved from retrograde replacements to white mica and biotite include planar fabrics consisting of biotite and sillimanite; these inclusions being parallel to slightly oblique to the external foliation suggest syn to tardi-kinematic growth. Andalusite shows ellipsoidal shape parallel to slightly discordant to the mesosome foliation. Some andalusite porphyroblasts include biotite and needles of sillimanite oriented parallel to S_2 foliation. These microstructural features indicate that andalusite grew tardi to post-kinematically with respect to S_2 foliation. White mica occurs both as plates arranged oblique to the gneissic foliation and as replacement products after kyanite, andalusite, K-feldspar, cordierite and plagioclase.

Interpretation of reaction textures

The absence of primary muscovite and orthopyroxene at respectively low and high temperature suggests that early metamorphic evolution of the migmatites in the kyanite stability field occurred between the following dehydration melting reactions (Fig. 1):muscovite+quartz=K-feldspar+Al-silicate+H_2O and biotite+quartz=orthopyroxene+K-fedspar +liquide. The occurrence of garnet and K-feldspar in the leucosomes with evidence of melting

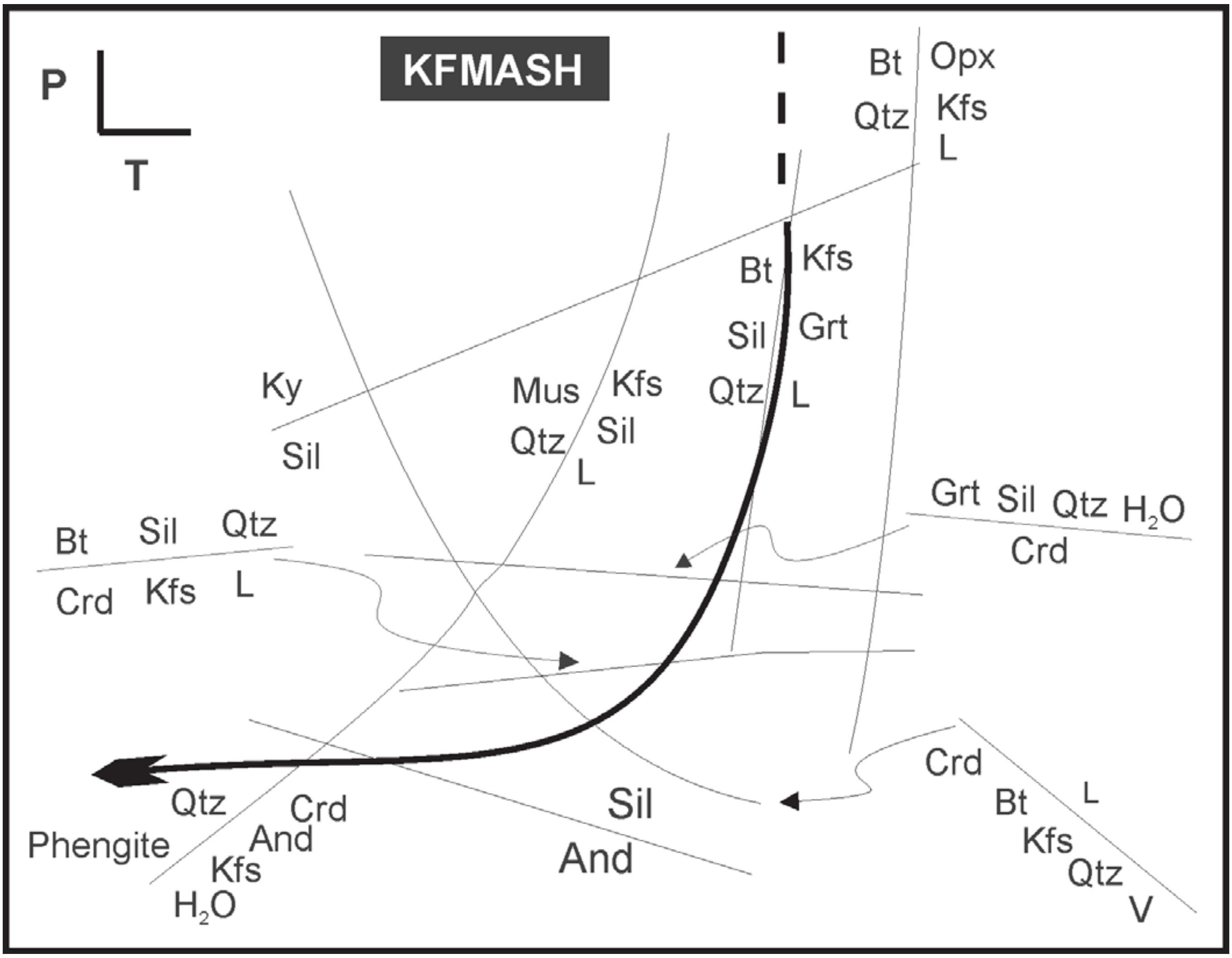

Fig. 1.- Qualitative petrogenetic grid in the KFMASH system for metapelites of intermediate bulk composition (Vielzeuf and Holloway, 1988).

Fig. 1.- Red petrogenética cualitativa en el sistema KFMASH para metapelitas de composición intermedia (Vielzeuf y Holloway, 1988).

in the sillimanite stability field suggests dehydration melting of biotite by the reaction: biotite +sillimanite+quartz=garnet+K-feldspar+liquide (Fig. 1). The reverse of this later reaction took place during cooling at lower pressure giving rise to replacement of garnet by biotite, sillimanite and quartz in the presence of K-feldspar. Replacement of garnet by cordierite which include fibrolitic sillimanite is attributed to the reaction (Fig. 1): garnet+sillimanite+quartz+H_2O=cordierite. The occurrence of cordierite in the leucosomes resulted from crossing the reaction: biotite+sillimanite+quartz=cordierite+K-feldspar+liquide (Fig. 1). These two cordierite-producing reactions suggest metamorphic decompression. White micas grew probably in the andalusite stability field as a result of the reaction with a residual hydrous fluid rising from the melt crystallization (Fig. 1): cordierite+K-feldspar+andalusite+H_2O=phengite+quartz .

Mineralogy

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 cores do not show any significant compositional zoning; the average composition is almandin $_{75}$ pyrope $_8$ spessartine $_{12}$ grossulaire $_5$. Their rims are zoned and show a decrease of pyrope toward the outer rims accompanied by an increase in almandin and XFe ratios. These compositional characteristics are typical of high-grade garnets affected by HT-re-equilibration and diffusive re-homogenization during retrogression (Spear, 1988). Biotite has composition with Al = 1.73-1.77 a.f.u., Ti = 0.21, 0.24 a.f.u. and XMg= 0.32. Cordierite shows higher XMg values (XMg = 0.42) than biotite. Plagioclase ranges from An $_{46-48}$ and are essentially unzoned. Fe-Ti oxides has relatively high ilmenite (ilménite = 74-77 mol%) and low rutile (1-2 mol%) contents.

Thermobarometry

The high P-T conditions of the migmatitic rocks are recorded by the assemblage garnet+silimanite/kyanite/biotite+plagioclase+Fe-Ti oxyde+quartz. These conditions were estimated by using the garnet core compositions in garnet-biotite thermometer and GASP barometer. Reasonable temperature estimates (710-810°C) (Fig. 2) were obtained by the thermometers of Thompson (1976), Ferry and Spear (1978) and Hodges and Spear (1982). The

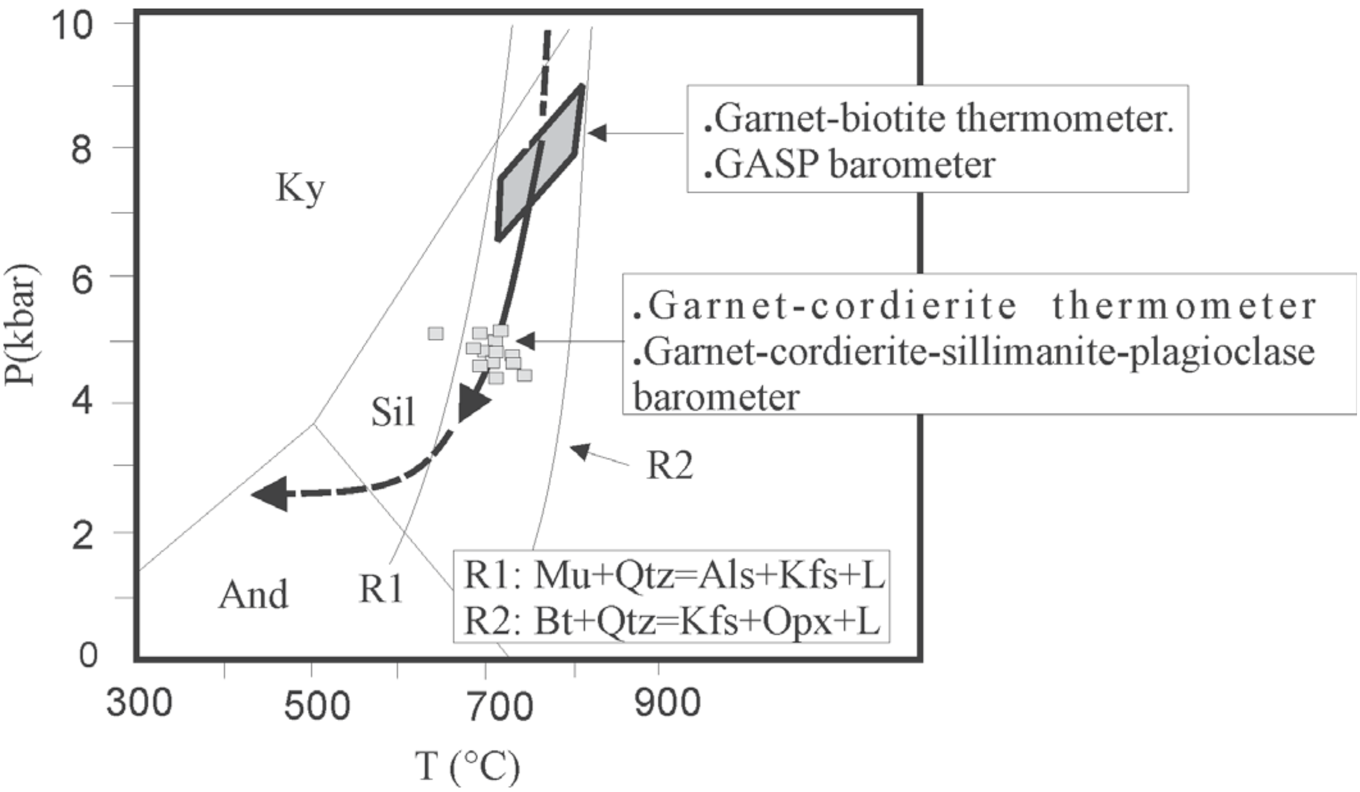

Fig. 2.- P-T diagram showing thermobarometric results and the P-T path deduced for the migmatitic paragneisses. Solid and broken lines represent segments of P-T path deduced respectively from thermobarometric estimations and textural analysis.

Fig. 2.- Diagrama P-T mostrando los resultados termobarométricos y la trayectoria P-T deducida para los paragneises migmatíticos. Las líneas continuas y discontinuas de la trayectoria P-T representan segmentos deducidos respectivamente a partir de estimaciones termobarométricas y de análisis textural.

GASP barometer of Newton and Haselton (1981), Hodges and Spear (1982) and Koziol and Newton (1988) yielded reliable pressure estimates (7-9 Kbar) (Fig. 2) by using sillimanite in the different calibrations. The same pressure estimates were obtained by considering kyanite in the same calibrations; these results, as they plot in the sillimanite stability field, suggest that kynaite is not in equilibrium with garnet. The rim compositions of garnet were combined with those of cordierite for estimating retrograde P-T conditions. Temperature calculated by the garnet-cordierite thermometer of Perchuk and Lavrent'eva (1981) ranges between 640-740°C (Fig. 2). The garnet-cordierite-sillimanite-quartz (Holdaway and Lee, 1977) yielded pressure ranging between 4-5 Kbar (Fig. 2).

Conclusions

The garnet-bearing metabasic intercalations within the basal migmatitic gneiss of the Filali Unit preserve a HP granulitic event (Aghzer and Haissen : this volume). These metabasic rocks show an isothermal metamorphic decompression from HP granulite to MP amphibolite-facies conditions. These HP and MP metamorphic events correspond respectively to an early Hercynian thickening and a subsequent exhumation by late Variscan extensional tectonics (Aghzer and Haissen: this volume).

The MP metamorphic event is recorded in the pelitic migmatites as a regional re-equilibration at the upper-amphibolite-facies conditions (710-810°C et 6.6-9 kbar) (Fig. 2); this is coeval with the first migmatization phase which produced garnet by dehydration melting of biotite in the sillimanite stability field. The second migmatization phase occurred at low-pressure (LP) during nearly isothermal decompression (4-5 kbar and 640-740°C) (Fig. 2) which produced cordierite. Subsequent pinitization of cordierite at sub-solidus conditions is associated to the final isobaric cooling. This LP metamorphic stage is classically related to Late Oligocene-Miocene thinning of the Alboran domain..

Similar isothermal decompression paths, showing the HP, MP then LP transition, are recorded by the underlying granulitic Unit (Haissen *et al.*, 2004) and the Beni Bousera peridotites. Furthermore, some available chronological data show evidence for: (a) Carboniferous high and medium-pressure-high and medium temperature metamorphic events (Montel *et al.*, 2000; Zeck and Williams, 2001); (b) pre-Alpine emplacement of the peridotites (Sanchez-Rodriguez and Gebauer, 2000). The integration of the P-T paths with these chronological data suggests that prior to Late Oligocene-Miocene thinning of the Alboran domain, the lower Sebtide, including the tectonic emplacement of the Beni Bousera peridotite, were affected by a polyphase extensional tectonics related to : (a) a gravitational collapse of the previously Hercynian thickened crust and ; (b) a later episode of rifting during an opening of the Ligurian-Atlantic seaway.

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References

Aghzer, A.M. y Haissen, F. (2005). *Geogaceta*, in press.

El Maz, A. (1989). Thesis de Doctorat, Univ. of PM.Curie, 259p.

Ferry, J..M. y Spear, F.S. (1978). *Contri-*

butions to Mineralogy and Petrology, 66, 113-117.

Haïssen, F., Garcia-Casco, A., Torres-Roldan RL y Aghzer, AM. (2004). *Journal of African Earth Sciences*, 39, 375-383.

Hodges, K.V. y Spear, F.S. (1982). *American Mineralogist,* 67, 1118-1134.

Holdaway, M.J. y Lee, S.M.(1977). *Contributions to Mineralogy and Petrology*, 63, 175- 198.

Koziol, A.M. y Newton, R.C. (1988). *American Mineralogist,* 73, 216-223.

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

Newton, R.C. y Haselton, H.T.(1981). En: *Thermodynamics of Minerals and Melts* (Newton, R.C., Navrotsky, A. y Wood, B.J. Eds). Springer-Verlag, 129-145.

Perchuk, L.L. y Lavrent'eva, I.V.(1983). En: *Kinetics and Equilibrium in Mineral Reactions* (S.K. Saxena, Ed.). Springer-Verlag, 199-239.

Sanchez-Rodriguez, L. y Gebauer, D. (2000). *Tectonophysics*, 316, 19-44.

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

Thompson, A.B. (1976). *American Journal of Science,* 276, 425-454.

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

Vielzeuf, D. and Holloway, J.R. (1988). *Contributions to Mineralogy and Petrology*, 98, 257-276.