Geodynamic evolution of the genetic setting of the pre-Alpine orthoderived rocks from the Mulhacén Complex (Betic Cordilleras, SE Spain)

Evolución geodinámica del ambiente de génesis de las rocas ortoderivadas prealpinas del Complejo del Mulhacén (Cordilleras Béticas, SE España)

E. Puga (*), J.M. Nieto (**), A. Díaz de Federico (**), E. Jagoutz(***), P. Monié (****) y M. Portugal (*****)

(*) Instituto Andaluz de Ciencias de la Tierra. CSIC - Univ. Granada.
(***) Dept. of geochemistry. Max-Planck-Institut für Chemie, Mainz.
(****) Dept. of Geochronology, Geochemistry and Petrology. Univ. Montpellier.
(***** Dept. of Earth Sciences, Univ. Corrba.

RESUMEN

Se ha realizado un estudio petrográfico, geoquímico y geocronológico de las rocas ortoderivadas originadas entre el final de la orogenia Hercínica y el comienzo de la Alpína. Los resultados nos permiten deducir una evolución en el contexto geodinámico de génesis de los magmas originarios de estas rocas, que pasa desde: Un ambiente sin-collisional al final del ciclo Hercínico a un contexto de rifting en el Triásico, el cual evolucionó gradualmente hasta un ambiente de dorsal oceánica a lo largo del Jurásico.

Key words: Orthogneisses, ophiolites, isotope geochemistry, Mulhacén Complex, Betic Cordillera.

Geogaceta, 20 (3) (1996), 609-612
ISSN: 0213683X

Introduction and geological setting

The Mulhacén Complex forms part of the Internal Zone of the Betic Cordilleras (SE Spain) and crops out in the central-eastern part of this zone as a series of tectonic windows below the Alpujárride and Malagüide Complexes and above the Veleta Complex (Fig. 1). The Mulhacén Complex is formed by a pile of thrust nappes of continental crust origin (Caldera below and Sabinas above), composed of Paleozoic basement and Mesozoic cover series, between which a Jurassic-Cretaceous nappes of oceanic floor provenance is tectonically intercalated (Fig. 2). Overlying these ophiolitic and continental nappes occurs a discontinuous, volcano-sedimentary formation of continental and evaporitic origin, named the Sopordar Formation (Puga et al., 1984), which was deposited between the eo-Alpine (upper Cretaceous) and the meso-Alpine (Oligocene) metamorphic events (Puga et al., 1996).

The aim of this paper is to elucidate the geodynamic evolution of the Mulhacén Complex between the end of the Hercynian Orogeny and the beginning of the Alpine Orogeny, based mainly on the genetic

Fig. 1. Geological sketch map of the central-eaetern sector of the Betic Cordilleras showing the limits between the Veleta, Mulhacén and Alpujárride Complexes

Fig. 1.- Mapa geológico sintético del sector centro-oriental de las Cordilleras Béticas, mostrando los límites entre los Complejos del Veleta, Mulhacén y Alpujárride.
environment of its orthodextrous rocks, originated throughout this period, deduced from their Nd isotopic signature, their trace element composition and radiometric ages.

**Petrology and geochemistry**

Intercalet at different levels within the nappes of continental crust provenance (Caldern and Sabinas) appear igneous rocks of granitic s.i. composition, transformed into orthogneisses and locally to meta-granites as a consequence of the polyphase Alpine metamorphism. These orthodextrous rocks mainly form either lens-shaped outcrops up to several kms long, derived from plutonic bodies intruded into the graphite-bearing micaschists of the basements (type 1), or banded orthogneisses derived from acidic to intermediate volcanic rocks, making up centimeter-to-meter layers intercalated mainly within the metasediments of the covers (type 2).

These two groups of rocks are also different from a geochemical point of view, as shown in Figs. 3 and 4. The meta-granites and orthogneisses corresponding to type 1 show a lower REE content, higher fractionation index (La/Yb)$_n$ and higher negative Eu anomaly than the orthogneisses from type 2 (Fig. 3). The Nd isotopic signature of these gneisses (eNd = -6.5) indicates a clear crustal origin for the granitic magmas from type 1, and a crustal origin with variable mantel influence for those from type 2 (eNd = -2 to +4). The relationship between Rb and Y+Nb in these rocks (Fig. 4) indicates that the tectonic setting in which the type 1 magmas were developed is syn-collisional, while the type 2 magmas would have formed in a within-plate environment.

The ophiolitic nappe is made up of all the elements of a dismembered ophiolitic sequence, known as the Betic Ophiolitic Association (Puga, 1990). It is composed of metres-to-km sized lenses of basic, ultramafic and sedimentary rocks, affected by ocean-floor and orogenic polyphasic metamorphism. In spite of the deformation and metamorphism that attain eclogite facies, the basic rocks partly retain their igneous textures (cumulates, variolite, porphyric) and the pillow and flow structures in the volcanic sequence (Puga et al., 1989, 1993). Some meta-basalts also locally preserve a high-gradient brown amphibole filling millimetric veins, typical of ocean-floor metamorphism and generally overgrown by different types of amphiboles that developed during the orogenic metamorphism. The plutonic sequence is made up of meta-gabbro, with cumulitic levels, in which the igneous paragenesis (Ol, An±Cpx) is locally preserved as relics in the variously amphibolitized eclogites (Mortet et al., 1987; Puga, 1990). The ultramafic sequence is formed by serpentinized lherzolites showing gradual transition towards secondary nodal harzburgites. The latter are constituted by brown Ol and Opx (frequently with pseudo-spinifex textures), which developed during the orogenic HP metamorphism from serpentine formed in the original oceanic environment (Bodinier et al., 1993). The ultramafic rocks contain abundant boudinated dykes of dolerites, with different degrees of transformation in rodolites, formed by grossularite and diopside, which were later locally transformed in the almandine-omphacite eclogite paragenesis. The CaO-enrichment of the basic dykes, characterizing the roditization process, was contemporaneous and complementary with the CaO-leaching originated by the Cpx-breakdown of their hosted lherzolites during the oceanic serpentinization (Puga et al., 1993).

Fig. 5 shows the REE patterns, normalized to chondrites, of the different types of rocks forming part of the ophiolitic nappe. The similarity between the REE average patterns corresponding to basic rocks, constituting the volcanic and plutoic sequences, and those of the dolerite dykes forming part of the ultramafic sequence, in spite of the interelement mobilization due to the roditization process, suggests a common mantle source for their originating magmas. The N-MORB and V-shaped REE patterns of the serpentinized ultramafites might
The ophiolitic metagabbros from Sierra de Filabres, containing pseudomorphs after clastolite xenocrysts indicative of crustal assimilation, have been dated by Ar/Ar to the Triassic-Jurassic boundary (Puga et al., 1995). Other meta-gabbros and meta-basalts from Sierra de Filabres have been dated by Rb/Sr and K/Ar as middle and upper Jurassic (Hebeda et al., 1980; Portugal et al., 1988; Puga et al., 1991, 1995). While the brown amphibole filling veins in metabasalts, formed during the oceanic-floor metamorphism, has been dated by Ar/Ar to the upper Jurassic (Puga et al., 1991, 1995). These basic rocks, dated up to the upper Jurassic, are overlain by metasediments, from the ophiolitic sedimentary sequence, which locally contain remains of Cretaceous foraminifera (Tendero et al., 1993).

Conclusions

The preceding geochronological and geochemical data corresponding to the orthodcrrect acidic, basic and ultramafic rocks, forming part of the different nappes correspond to the residual protoliths, after extraction of a reduced degree of melting that would have originated the associated LREE enriched basic rocks. The pyroxenite REE pattern corresponds to scarce centimetric veins with mantel Cpx relics contained in the serpentinites. Fig. 6 shows the geochemical affinity of the basic, variously rodingitized rocks from the ophiolitic nappe with E-MORB type magmas currently erupting in the mid-oceanic ridges, and their notable differences with basalts originated in other tectonic settings, such as continental crust within plate, island arcs or oceanic islands. Moreover, the Nd isotopic signature of these magmas, ranging from $e^{Nd} = +6.5$ to $+9.8$, indicates a mantle origin with some crustal influence for the lower values and an oceanic-floor tectonic setting for the upper values. The lower $e^{Nd}$ values correspond to metabasalts containing Al-silicate xenocrysts resulting from the assimilation of basement micaschists (Puga et al., 1989; Gomez-Pagon & Muñoz, 1990).

Radiometric ages

The type 1 orthogneisses from Sierra de Filabres have been dated by Sm/Nd to the upper Carboniferous (Nieto, 1996) and by Rb/Sr to the lower Permian (Andriessen et al., 1991), while the type 2 from Sierra Nevada and Sierra de Filabres have been dated by Rb/Sr to the middle Triassic (Puga, 1976; Andriessen et al., 1991).

Fig. 3.- Chondrite-normalized REE patterns of mean values of type 1 meta-granites and orthogneisses and type 2 orthogneisses, compared with granitoids from known geodynamic settings in: et al., (1984) and Albuquerque (1978).

Fig. 4.- Diagram Rb vs. Y+Nb for the geodynamic classification of granitoid rocks (Pearce et al., 1984). Symbols: circles = type 1 meta-granites and orthogneisses; triangles = type 2 orthogneisses.

Fig. 5.- Chondrite-normalized REE average patterns of basic rocks, rodingites, pyroxenites, lherzolites and pseudo-Harzburgites forming the ophiolitic nappe.

Fig. 6.- Valores medios de REE normalizados a condritos de rocas básicas, rodingitas, pyroxenitas, lherzolitas y pseudo-Harzburgitas, constituyentes del manto ophiolítico.
Fig. 6.- Spidergram of trace elements normalized to N-MORB for the average meta-basalts and rodingites, compared with continental tholeiites from Columbia River in Govindaraju (1984), E-MORB and OIB in Sun and McDonough (1989), and IAT in Pearce (1982).

constituting the Mulhacén Complex, allow us to deduce the following evolution in the geodynamic environment of their precursor magmas: a) Type 1 granitic magmas would have originated in a syn-collisional context at the end of the Hercynian Orogeny, while type 2 acidic volcanism developed in a post-collisional within-plate environment, below an increasing influence of mantle material indicating crustal thinning preceding, or accompanying, a rifting tectonic setting during the Triassic. Some intrusive basic rocks dated to the Triassic-Jurassic boundary could have intruded into the thinned continental crust during the rifting environment, assimilating some of the pelitic rocks it passed through. Finally, the tectonic setting evolved throughout the Jurassic to a drifting environment, causing the accretion of the oceanic floor from which the basic and ultramafic rocks forming the ophiolitic nappe derive.

Acknowledgements

Financial support from the Spanish Project PB-92.0952 and the Research Group of the Junta de Andalucía 4072 is acknowledged.

References


Geol., 91, 33-48.


