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Regional implications of a Palaeozoic age for the Nevado-Filábride Cover of the Betic Cordillera, Spain

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Abstract

The Rb/Sr whole-rock age of granitoid gneiss interlayered with marbles at the top of the Nevado-Filábride Complex cover is 247 ± 11 Ma (Permian-Triassic boundary). Tourmaline-rich metasediments were metasomatized by B-rich fluids from the igneous body. Hence the igneous rocks were emplaced in the sedimentary rocks that now host the gneiss body, precluding a later tectonic emplacement. Therefore, the entire Nevado-Filábride Complex is Palaeozoic or older and may have been the stratigraphic basement of the immediately overlying Alpujárride units, which include younger rocks. The consistent evolution of the Alpine high-pressure metamorphism in the Nevado-Filábride and Alpujárride complexes might therefore be due to their original stratigraphic relationship.

Keywords: Betic Cordillera, Nevado-Filábride Complex, gneiss, Rb/Sr isochron, Palaeozoic.

Introduction

A Permo-Triassic/Mesozoic age is traditionally attributed to the cover of the Nevado-Filábride Complex (NFC) in the Betic Cordillera (S Spain) on the basis of its lithological correlation with biostratigraphically dated sections of the overlying Alpujárride Complex and on the radiometric age of metabasite intrusions. This assumption is found in most if not all the reports, models and interpretations of the geological evolution of the NFC and of the Betic Cordillera in general.

We demonstrate here, however, that the NFC cover (NFCC) is Palaeozoic, although still of an imprecise, unknown age, and therefore older than the Alpujárride cover units. This provides for a very different interpretation of the relationships between the Betic complexes and the geological evolution of the westernmost Alpine cordillera.

Geological setting

The Nevado-Filábride is the lowermost tectonic complex of the Internal Zone of the Betic Cordillera (Fig. 1). This complex underlies the Alpujárride Complex which in turn is overlain by the Maláguide Complex. The NFC consists of a lower, thick, monotonous series of black micaschists alternating with graphite-bearing quartzites, locally containing intrusive metagranite bodies. A Precambrian-to-Palaeozoic age has been attributed to the lower black series on the basis of a) very local occurrences of Rifean (Gómez-Pugnaire et al., 1982) and Middle Devonian (Lafuste and Pavillon, 1976) fossils; and b) the age of emplacement of metagranites, which has been established radiometrically at 269 ± 6 Ma (Rb–Sr whole-rock isochron, Priem et al., 1966) and 307 ± 34 Ma (Sm/Nd method, Nieto et al., 1997).

In some tectonic units of the NFC the lower black series is overlain by light-coloured metase-

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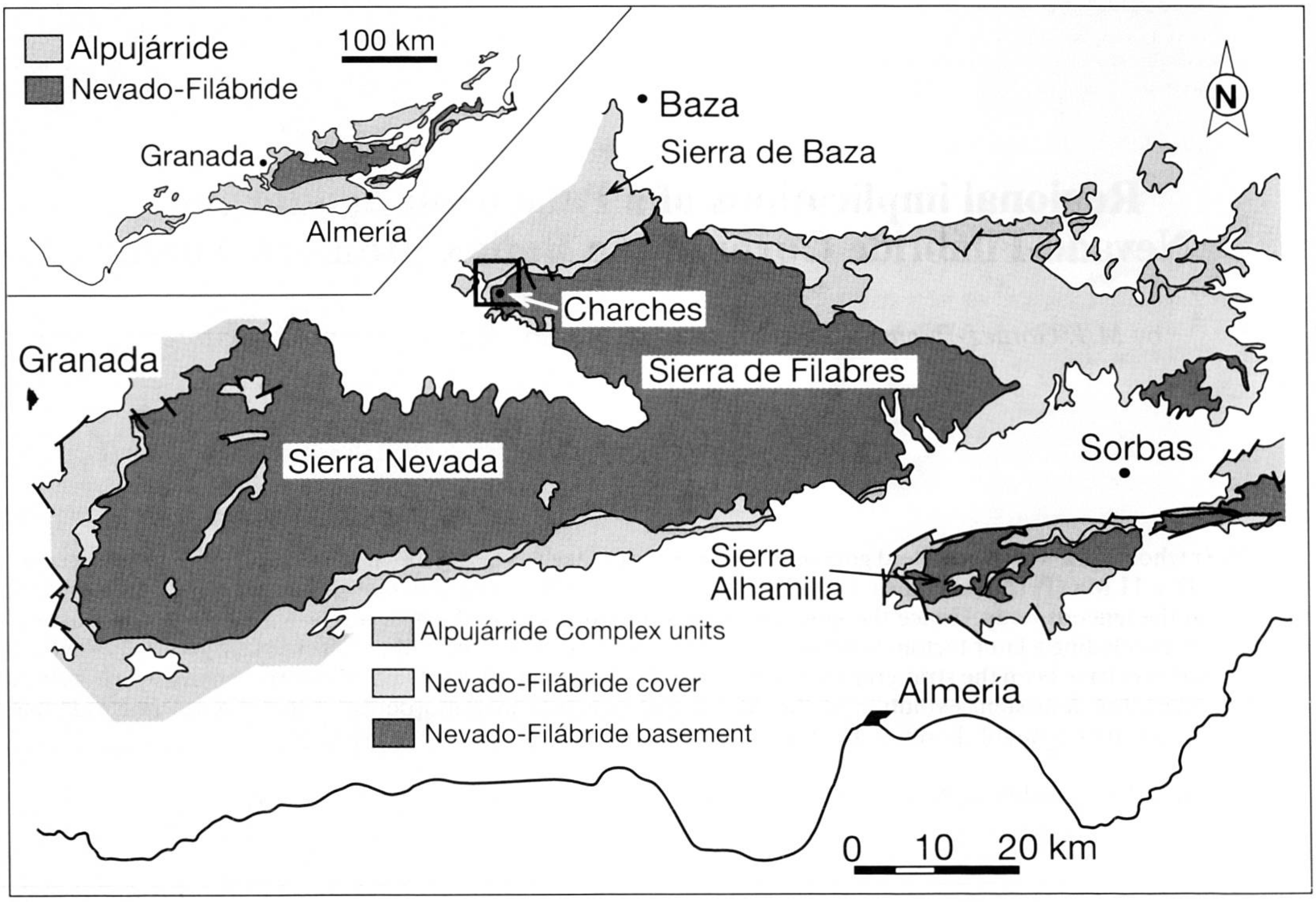

Fig. 1 Nevado-Filábride Complex and immediately overlying Alpujárride units in SE Spain (modified from LÓPEZ-SÁNCHEZ-VIZCAÍNO, 1994). Black frame shows location of map in figure 3 (locality of the dated gneisses).

diments consisting of quartzites, micaschists, metaevaporites and marbles, and minor meta-igneous rocks (Fig. 2A). This upper series, formerly called the "Mischungszone" (BROUWER, 1926), has been interpreted as being a stratigraphic cover (NFCC) of the black-series basement because of: 1) the local occurrence of a metaconglomerate at the contact between the two units (EGELER, 1963); and 2) evidence in the black series of a metamorphic event older than the first metamorphic event found in the upper series (PUGA, 1976; GÓMEZ-PUGNAIRE and SASSI, 1983).

The NFCC consists of three units; from bottom to top (Fig. 2A):

1) *Tahal Schists* (NIJHUIS, 1964); they are light-coloured feldspatic quartzites with interlayered metapelite beds.

2) *Metaevaporitic Formation* (GÓMEZ-PUGNAIRE et al., 1994); this is a thin (< 20 m), carbonate-rich formation with evaporite relics.

3) *Marble and Calcschist Formation* (VOET, 1967); comprising calcitic and dolomitic marbles.

These metasediments are intruded by dykes of basic composition most of which are transformed to eclogite and/or amphibolite (MORTEN at al., 1987; FRANZ et al., 1988).

Discontinuous sheets of quartz-feldspar gneiss, 1 to 20 m thick, are included in the upper part of the NFC.

Ultramafic rocks, typically transformed to serpentinite, occur as lens-shaped bodies less than 500 m thick. They probably represent portions of a serpentinized subcontinental mantle tectonically emplaced in their present position (TROMMSDORFF et al., 1998).

The Alpujárride units directly overlying the NFC consist of Permo?-Triassic metasediments. Phyllites, quartzites, and metaconglomerates pass upwards to Anisian and younger Triassic carbonates (FALLOT et al., 1954) (Fig. 2B). Tectonically higher Alpujárride units include graphite-bearing metapelites, quartzites, gneisses and migmatites. These black series, up to 1000 m thick, have been traditionally considered to be the Alpujárride Palaeozoic basement (EGELER and SIMON, 1969).

The age of the Nevado-Filábride cover

FORMER INTERPRETATIONS

Lithological similarities between the NFCC and certain sections of the overlying Alpujárride Complex were the reason for attributing a (Permo)-Triassic age to the NFCC (FALLOT et al., 1961). In both cases a siliciclastic lower part passes upwards to carbonates, with gypsum at the transition. This change in the NFCC reflects the evolution from shallow-marine siliciclastic deposits (DE JONG and BAKKER, 1991) to marginal-marine or continental evaporites (Metaevaporite Formation, GÓMEZ-PUGNAIRE et al., 1994) to marginal or shallow-marine carbonates (Marble and Calcschist Sequence, VOET, 1967). In the dated Alpujárride sections, however, the change from siliciclastics to carbonates is the result of a transition from fluviatile deposits to shallow-marine carbonates (DELGADO et al., 1981). There was a substantially different sedimentary evolution from siliciclastic to carbonate deposits in the Alpujárride Complex compared to the NFC, and therefore any direct correlation based upon their lithostratigraphic similarity alone is questionable.

TENDERO et al. (1993) interpreted some "ankeritic objects" that occur in the NFCC marbles as being Cretaceous planktonic foraminifers. However, although the profiles of some of these objects may be reminiscent of foraminifers, most have no particular morphology and cannot be attributed to fossils. Even if a trochospiral coiling was responsible for these "planktonic-foraminifer profiles", such coiling is common in benthic foraminifers from a wide geological time span.

The occurrence of dykes of gabbros radiometrically dated as Upper Triassic (213 ± 2.5 Ma, NIETO et al., 1997) and Jurassic (146 ± 4 Ma, HEBEDA et al., 1980) has been used to attribute a Mesozoic age to the NFCC but obviously the host sediments may be much older than the intruding rocks. Basic rocks of unequivocal volcanic origin (PUGA et al., 1995) are of unknown age, and they occur only adjacent to black basement rocks at a site some 100 km away from the dated gabbros.

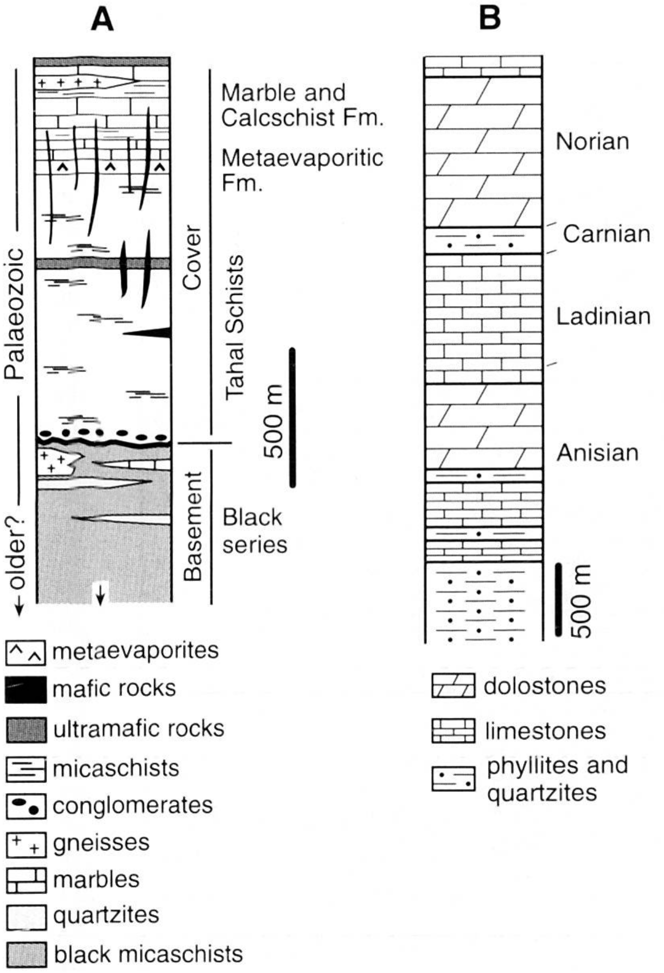

Fig. 2 (A) Lithological column of the Nevado-Filábride Complex (modified from LÓPEZ-SÁNCHEZ-VIZCAÍNO, 1994). (B) Stratigraphic column of the Alpujárride unit immediately overlying the Nevado-Filábride in Sierra de Baza (after DELGADO et al., 1981).

Radiometric data from gneiss in the Charches area

Rb–Sr isotope analyses to estimate the radiometric age of acidic gneiss from five outcrops in the Charches area (Sierra de Baza) have been carried out (Fig. 3). The studied rocks are tourmaline-rich acidic gneisses interlayered with tourmaline-bearing schists and tourmalinites in the marbles at the top of the NFCC, immediately beneath the lowermost Alpujárride Complex unit. Gneiss layers up to 20 m thick display a planar foliation conformable with that of the host metasediments. The igneous nature of the acidic gneisses is unanimously accepted (NIETO, 1996).

Ten fresh gneiss samples were selected. They have a very uniform mineralogical composition that essentially consists of alkali feldspar, quartz and tourmaline together with epidote, white mica, green biotite, zircon, and rare garnet as accessory minerals. K-feldspar is the most frequent alkali feldspar and occurs as relatively large porphyroclasts (up to 3 cm long), commonly showing mortar texture with small fragments around them. Small crystals of K-feldspar appear in the matrix together with quartz. Albite coronas of metamorphic origin developed around the porphyroclasts. Albite also occurs as euhedral crystals of igneous origin locally enclosed by K-feldspar porphyroclasts, and as small granoblastic crystals in the matrix. The modal content of alkali feldspar is highly variable, from 20 to 50%. Tourmaline (up to 10%) occurs as isolated crystals with unzoned, anhedral igneous cores that rarely display metamorphic euhedral rims. White mica is scarce but always present in the matrix, generally associated with green biotite. Large crystals of igneous white mica are commonly included in K-feldspar porphyroclasts.

The normative composition of the samples corresponds to monzogranites (Tab. 1). Major elements indicate that they are alkaline-rich and CaO-poor ($Na_2O + K_2O > 7$ wt%, $K_2O/Na_2O > 1$, $CaO = 0.43–0.85$), with a peralkaline character ($A/KN = 0.9–1.2$).

In the studied outcrops, as in many other locations in the NFCC, gneisses and interlayered and/or underlying micaschists are very rich in tourmaline. Lenses, nodules and folded tourmalinite layers, a few millimetres thick, consisting of tourmaline (more than 50%) and quartz are common in both types of rock. The tourmaline contents in the micaschists gradually decrease away from the gneiss. Although the tourmaline recrystallized during metamorphism, previously formed cores can be observed. Their chemical composition, zoning, and textural features exclude a detrital origin. All these features clearly indicate that the tourmaline was produced by metasomatic replacement of the igneous and sedimentary rocks by hydrothermal, B-rich fluids derived from the magmatic evolution of the igneous body. This implies that the igneous rocks were emplaced in their present metasedimentary host rocks and precludes their later tectonic emplacement.

The low chemical variability and the granitic textures of the porphyroclasts support a plutonic origin of these gneisses, but a volcanic origin cannot be excluded (PUGA, 1976).

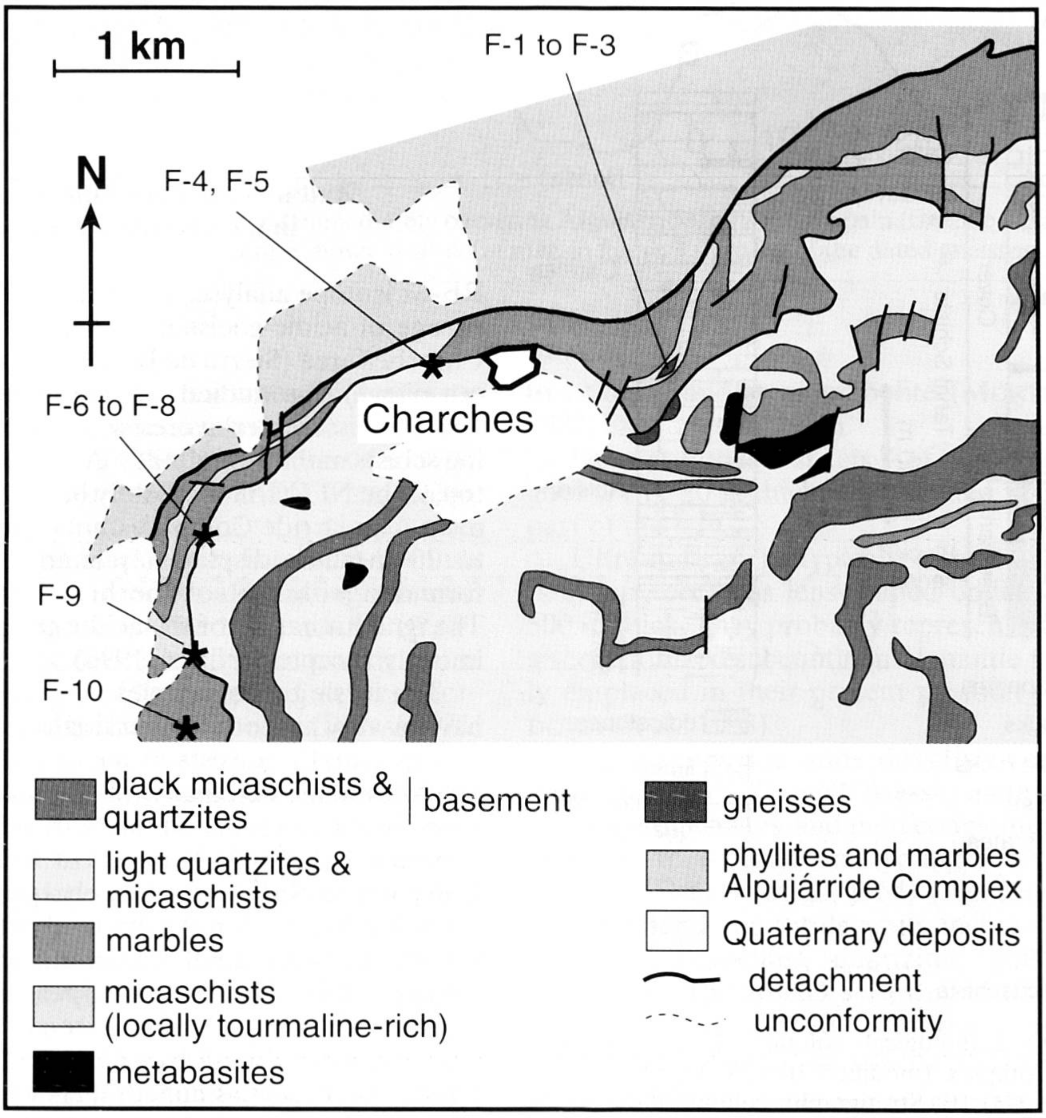

Fig. 3 Geological map of the Charches area; asterisks indicate small gneiss outcrops (after JABALOY, 1993).

Tab. 1 Major element and Rb/Sr isotopic data of selected samples of the Charches gneisses.

	F-1	F-2	F-3	F-4	F-5	F-6	F-7	F-8	F-9	F-10
SiO_2	73.70	75.20	74.00	74.40	73.60	73.70	75.10	69.70	73.20	73.60
TiO_2	0.11	0.08	0.08	0.08	0.09	0.10	0.09	0.10	0.09	0.10
Al_2O_3	13.60	12.40	13.50	12.90	13.90	13.50	12.70	14.20	13.40	14.00
Fe_2O_3	0.55	0.60	0.50	0.50	0.60	0.80	0.70	0.75	0.50	0.55
FeO	1.05	1.10	1.05	1.10	1.15	1.65	1.20	1.70	1.15	1.10
MnO	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.04	0.02	0.02
MgO	0.92	1.33	0.71	0.72	1.01	0.74	0.83	0.99	0.70	0.62
CaO	0.58	0.64	0.43	0.55	0.42	0.66	0.58	0.85	0.49	0.43
Na_2O	4.27	3.23	3.17	3.87	4.08	3.58	3.21	3.96	3.40	3.40
K_2O	4.20	4.17	5.68	4.98	4.26	4.52	5.54	6.70	6.10	5.62
P_2O_5	0.02	0.04	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.02
L.O.I.	0.71	0.61	0.75	0.66	0.60	0.68	0.70	0.70	0.60	0.58
Total	99.73	99.43	99.92	99.80	99.75	99.97	100.70	99.72	99.67	100.00
Rb ppm	341	444	561	328	446	414	490	598	670	653
Sr ppm	49.5	45.3	39.3	62.8	53.1	58.0	67.0	45.7	40.2	37.3
$^{87}Rb/^{86}Sr$	20.02	28.63	49.53	15.18	24.49	20.72	21.32	38.32	49.97	51.59
$^{87}Sr/^{86}Sr$	0.7749	0.7986	0.8807	0.7611	0.7859	0.7731	0.7849	0.8389	0.8797	0.8891
$\pm 1\sigma$	0.0005	0.0002	0.0002	0.0003	0.0004	0.0002	0.0002	0.0002	0.0004	0.0003

The Rb/Sr data obtained from the Charches gneisses (Fig. 4 and Tab. 1) yield a whole-rock isochron giving an age of 247 ± 11 Ma. This value indicates that the Rb–Sr isotopic system in these gneisses or in their protoliths closed near the Permo/Triassic boundary (from about 245, ODIN and ODIN, 1990, to 248 Ma., GRADSTEIN et al., 1995).

A more definite interpretation of this age depends upon the plutonic vs volcanic nature of the protoliths. In any case, the wall-rocks of the hypothetical plutonic protolith, or the footwall of the hypothetical volcanic protoliths, were older that the Permo/Triassic boundary.

Therefore, because these gneisses occur at the top of the NFCC, the entire NFC must be older than 247 ± 11 Ma.

Regional implications

The radiometric data discussed above indicate that the NFC is older than the Alpujárride carbonates (Fig. 2B). It may also be older than the Alpujárride phyllites and quartzites, which are generally considered to be Permo-Triassic, although there are no biostratigraphic or radiometric constraints for an age older than Anisian (Middle Triassic).

The main regional implication of this result is that the NFC may be the stratigraphic basement of the overlying Alpujárride units. The Alpujárride units immediately above the NFC in areas such as Sierra Nevada and Sierra de Baza-Sierra de los Filabres (Fig. 1) consist of basal phyllites and quartzites followed by well-dated Triassic (Upper Anisian-Rhaetian) carbonates (MARTÍN and BRAGA, 1987) with no materials attributable to an Alpujárride basement in the traditional sense (Fig. 2B). Therefore, the succession from the NFC (including its cover) to the Alpujárride phyllites and quartzites may originally be a stratigraphic succession even though at present the contacts between the two complexes are low-angle normal faults (GALINDO-ZALDÍVAR et al., 1989), and the units are displaced from their original position.

The Alpine metamorphic evolution in the two complexes is expected to be consistent with their respective crustal locations. Any comparison of metamorphic evolutions must be restricted to rocks that underwent only Alpine recrystallization in order to avoid mineral assemblages remaining from earlier metamorphic processes. In fact, recent radiometric data indicate a Hercynian age for most of the metamorphic assemblages of the Alpujárride basement (ZECK et al., 1999; SÁNCHEZ-RODRÍGUEZ, 1999). For this reason, data from pre-Mesozoic Alpujárride rocks are not included in the following comparison.

During the continent-continent collision phase, the NFC experienced fast burial with increasing pressure and temperature to a peak in the high-pressure metamorphic stage of 12 kb and 550–600 °C (GÓMEZ-PUGNAIRE and FERNÁNDEZ-SOLER, 1987; BAKKER et al., 1989, Fig. 5), although higher-pressure conditions have been locally found (about 20 kb, CÁMARA and GÓMEZ-PUGNAIRE, 1993, TROMMSDORFF et al., 1998). High-pressure metamorphism also affected the Alpujárride cover units directly overlying the NFC, although the maximum pressure and temperature conditions were lower: 8–12 kb and 450–480 °C

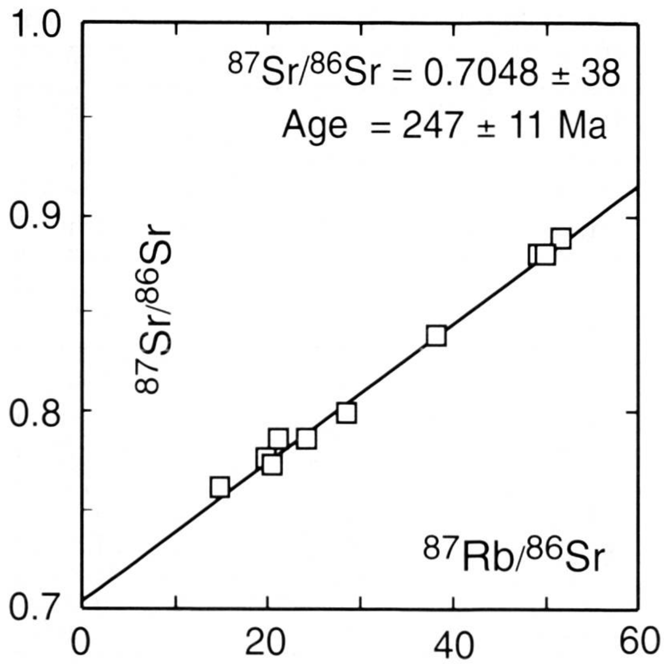

Fig. 4 Whole-rock isochron diagram of gneisses from Sierra de Baza.

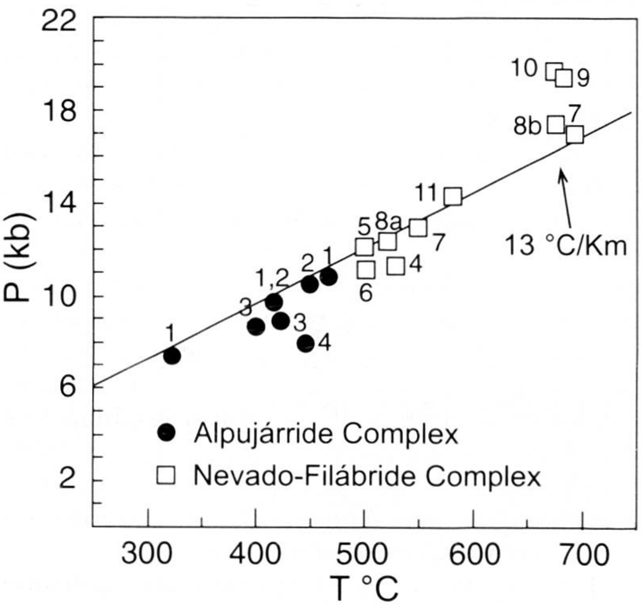

Fig. 5 P-T conditions for the peak HP events from the Alpujárride and Nevado-Filábride Complexes. Only P-T data of Permo-Triassic rocks of the Alpujárride Units overlying the Nevado-Filábride Complex are included in the figure. 1: AZAÑÓN and GOFFÉ (1997), 2: AZAÑÓN et al. (1998), 3: BALANYÁ et al. (1997), 4: BAKKER et al., (1989), 5: VISSERS (1981), 6: LÓPEZ-SÁNCHEZ-VIZCÁINO (1994), 7: NIETO (1996), 8a: GÓMEZ-PUGNAIRE and FERNÁNDEZ-SOLER (1987), 8b: GÓMEZ-PUGNAIRE et al. (1994), 9: PUGA et al. (1995), 10: CÁMARA and GÓMEZ-PUGNAIRE (1993), TROMMSDORFF et al. (1998), 11: CÁMARA (1995).

(VISSERS, 1981; BAKKER et al., 1989; AZAÑÓN and GOFFÉ, 1997). These differences in P and T are consistent with a shallower burial of the Alpujárride cover. In spite of the imprecision of the geobarometric methods and the bias introduced by data from different areas, the PT-data representative of the peak HP events of the Alpujárride and Nevado-Filábride plot along a line that may represent the metamorphic field gradient (about 13 °C/km) deduced for the underthrusting stage (Fig. 5). This PT-array is the consequence of a higher crustal location of the Alpujárride units during the metamorphic overprint. DE JONG (1991) and BALANYÁ et al. (1993) interpreted the relative position of the two complexes as being the result of an early tectonic stacking during the collision process. The higher location of the Alpujárride units may, however, simply reflect their original stratigraphic position above the NFC.

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