Interference pattern of Miocene extensional systems in the Alpujarride Complex (N of Sierra Nevada, Betic Cordillera)

Interferencia de sistemas en extensión miocenos en el Complejo Alpujárride (N de Sierra Nevada, Cordillera Bética)

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ABSTRACT

During the Miocene rifting of the Alboran Domain, various extensional systems developed. North of Sierra Nevada, in the Sierra de Baza region, two low-angle normal fault systems with subperpendicular extension directions, middle Miocene in age, dismembered the Alpujarride complex into extensional units with the geometric pattern of a chocolate-tablet mega-structure.

Key words: *Betics, Alboran basement, middle Miocene rifting, subperpendicular extensional systems, low-angle normal fault, chocolate-tablet mega-structure.*

RESUMEN

Durante el adelgazamiento mioceno del Dominio de Alborán, se desarrollaron varios sistemas extensionales. En la región de Baza, al norte de Sierra Nevada, dos sistemas de fallas normales de bajo ángulo con direcciones de extensión subperpendiculares desmembraron el complejo alpujárride en unidades extensionales cuya distribución geométrica es de una megaestructura en tableta de chocolate.

Geogaceta, 17 (1995), 140-142
ISSN: 0213683X

Introduction

In the Betic chain, early and middle Miocene crustal thinning of the Alboran basement is well established, as extensional low-angle normal fault systems developed in brittle-ductile and brittle conditions (García-Dueñas *et al.*, 1992). A current study of the Betics as a whole attempts to reinterpret the contacts previously attributed to thrusting. In the Sierra de Baza area, north of Sierra Nevada, all the contacts of the Alpujarride complex attributed to nappe contacts (MAGNA geological maps: Navarro and Velendo, 1979; Comas *et al.*, 1979; Aldaya *et al.*, 1980; Delgado *et al.*, 1980) are shown to be low angle-normal faults (LANF) and detachments belonging to two successive extensional systems, the Contraviesa (Crespo-Blanc *et al.*, 1994) and the Filabres (García-Dueñas *et al.*, 1992) normal fault systems, respectively Langhian and Serravallian in age.

Alpujarride nappe stack

The alpine HP/LT metamorphic assemblages of the Alpujarride units indicate crustal stacking of the Alpujarride complex (see review in Azañon *et al.*, 1994) followed by an episode of ductile flattening accompained by an almost isothermal pressure decrease (Balanyá *et al.*, 1993). This initial pre-Miocene extensional event is followed by north-vergent recumbent folding of the thinned metamorphic sequences (Balanyá *et al.* 1987; Simancas and Campos, 1988). The resulting stack is affected by the lower and middle Miocene rifting that produced the Alboran Basin. Finally, during the upper Miocene, the developed extensional detachments undergo folding (large-scale E-W directed folds) and faulting (Weijermars *et al.*, 1985).

On the basis of their present position and HP/LT metamorphic conditions, Azañon *et al.* (1994) defined five major allochthonous units of the Alpujarride complex in the central Betics related with the pre-Miocene Alpujarride nappe stacking. In the Sierra de Baza area, only four of them are present. Although these units —in ascending order, Santa Bárbara, Quintana, Blanquizares and Hernán Valle— are well differentiated by Delgado in the MAGNA geological maps (op.cit.) as "thrust nappes", we interpret them as the extensional sheets attributed respectively to the Lújar-Gádor, Escalate, Salobreña and Adra units in Azañon *et al.* (1994).

Extensional fault systems in the Sierra de Baza area

The Alpujarride unit boundaries were carefully revised to determine the geometry and kinematics of the tectonic contacts. The tectonic map of Figure 1 shows transport direction and shear sense observed in the fault rock bands that formed in a brittle regime. Two main transport directions can be seen: a NNW-SSE one and a E-W to NE-SW one. The cross-sections of Figure 2, which run parallel to each of the transport directions, illustrate the extensional character of the contacts, as they reveal substraction along low-angle structures, with severe thinning or omission of some of the units. Small ondulations of these LANF are due to upper Miocene folds.

Cross-section AA' (Fig.2) shows how the carbonated sequence of Lújar-Gádor unit is limited by two LANF with SSEward transport direction. The lower LANF produced the progressive northward tilting of the limestone stratification, and a roll-over structure developed. This structure is cut by another SSEward LANF, which limits the Escalate unit and causes the tilting of its phyllites. As in the Lújar-Gador unit, the contact between the carbonated sequence and the phyllites of the Escalate unit is a SSE ward LANF which cut the axial plane of a post-metamorphic recumbent fold in the middle of cross-section AA'. NNWward antithetic movements can be observed in the field, being particularly evident in the Adra unit (Fig.1).

Cross-sections BB' and CC' (Fig. 2) illustrate NE-SW extensional structures. A drastic thinning or even omission of the units takes place in the southwestern part of the sections due to a fan of listric normal faults that tend to coalesce with the sole detachment of this extensional system, the Filabres detachment (García-Dueñas and Martínez-Martínez, 1988), which separates the Alpujarride from the Nevado-Filabride complex. This high extension geometry is evidenced by a detached rider (Gibbs, 1984) of the uppermost Alpujarride unit, the Adra unit, that nearly

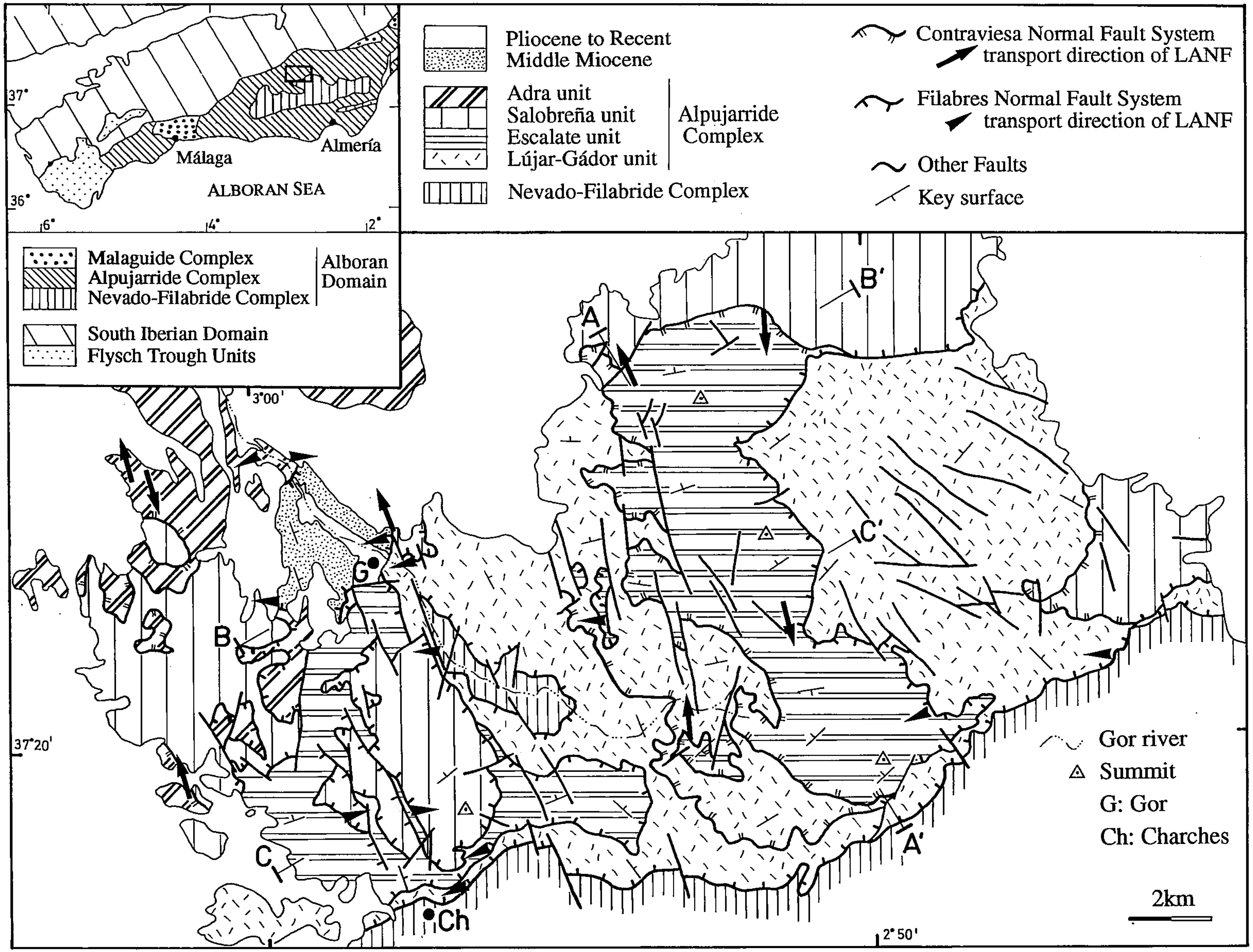

Fig. 1.- Tectonic map of the Sierra de Baza area (modified from MAGNA geological maps). The Alpujarride units are named according to Azañon et al. (1994). Rectangular inset shows the studied area. LANF: low-angle normal fault. Key surface: phyllites or schists main foliation, stratification. A-A', B-B', C-C': localization of cross-sections of fig. 2.

Fig. 1.- Mapa tectónico de la Sierra de Baza (modificado de los mapas geológicos MAGNA). Nombres de las unidades alpujárrides según Azañon et al. *(1994). Rectángulo: área estudiada. LANF: falla normal bajo ángulo. Superficie de referencia: foliación de filitas o esquistos, estratificación. A-A', B-B', C-C': localización de los cortes de la fig. 2.*

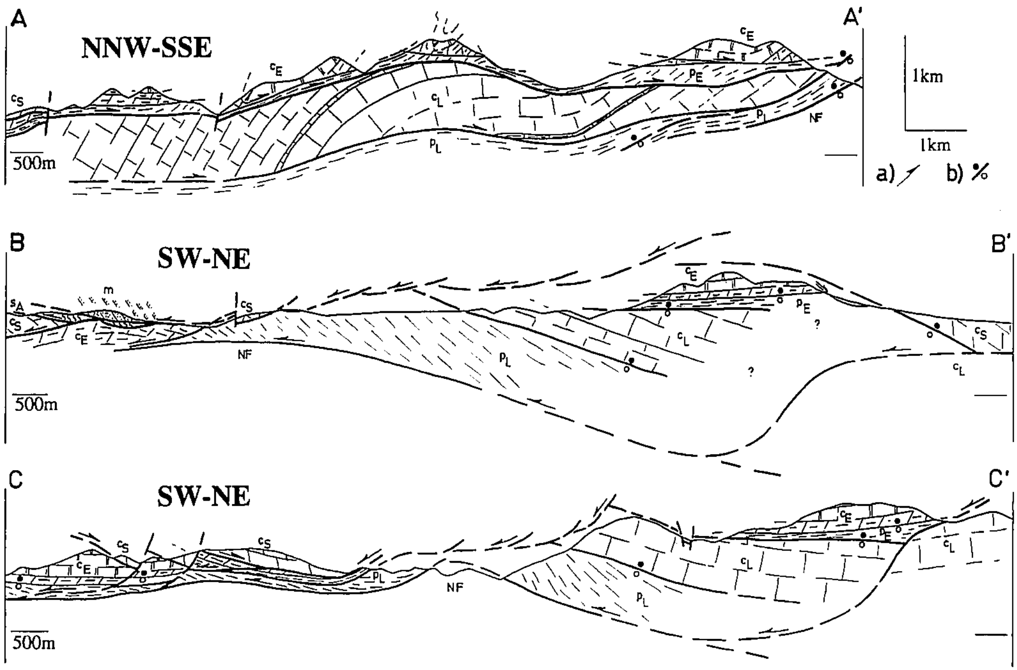

Fig. 2.- Geometry of the Alpujarride extensional units in the Sierra de Baza area, from cross-sections parallel to the fault movement directions. The dips (foliation, stratification and low-angle normal fault) were calculated with vertical scale exaggeration. A, Adra unit; S, Salobreña unit; E, Escalate unit; L, Lújar-Gádor unit; c, Triassic carbonate rocks; p, Permo-triassic phyllites; s, Palaeozoic schists. a) and b) movement sense (open and solid circles indicate motion away from and towards the observer, respectively). Localization on Fig. 1.

Fig. 2.- Geometría de las unidades alpujárrides en extensión en la Sierra de Baza, en cortes paralelos a los movimientos de las fallas. Los buzamientos (foliación, estratificación y falla normal de bajo ángulo) han sido calculados con exageración vertical. A, unidad de Adra; S, unidad de Salobreña; E, unidad de Escalate; L, unidad de Lújar-Gador; c, rocas carbonatadas triásicas; p, filitas permo-triásicas; s, esquistos paleozoicos. a) y b) sentido de movimiento (los círculos blancos y negros indican el movimiento desde y hacia el observador respectivamente). Localización en la Fig. 1.

superposes the Nevado-Filabride complex (Fig.2BB'). Antithetic eastward LANF can be observed to the N of Charches (Fig.1) and to the WSW of section CC' (Fig.2).

Figures 1 and 2 also show that many of the LANF with SSEward transport direction are cut by those associated with the Filabres detachment. For example, the LANF separating the Salobreña unit from the Escalate unit (NE of section BB', Fig.2) is cut and tilted by a SWward LANF of the Filabres extensional system. Striae measured on the fault planes indicate that most of the LANF asociated with SSE-NNW extension were re-used during the NE-SW extensional episode. In the Gor area (Fig.1), E-W striae post-date the NNW-SSE ones.

The middle Miocene deposits in this area constrain the age activity of these extensional systems (Fig.1): a) the contact of the "Gor marls", lower to upper Langhian in age (Martín-Pérez and Viseras, 1994) with the Alpujarride complex is marked by a LANF; b) only E-W striae are observed in the marls, whose stratification planes are systematically tilted towards the E (Fig.1 and 2BB'). Therefore, the E-W to NE-SW extensional system of this area can be considered post-upper Langhian, while the SSE-NNW extension can be interpreted previous to or simultaneous with the Langhian deposits.

Discussion and conclusions

Two extensional systems are observed in the Sierra de Baza area: the Filabres system, post-upper Langhian with a W to SW transport direction, and a previous one, having a mainly SSE transport direction. This previous one is considered to be conjugated with the Contraviesa normal fault system described south of Sierra Nevada (Crespo-Blanc *et al.*, 1994). The Alpujarride extensional units are individualized in the Contraviesa area by listric normal faults with NNWward transport that were active during the upper Burdigalian and Langhian. The Contraviesa extensional system and the SSEward listric fault fan described in Sierra de Baza, both developed in brittle regime during the middle Miocene, produce approximately N-S extension in the present day position. In Fig. 1, the SSEward LANF (eventually the antithetic NNWward ones) are attributed to the Contraviesa normal fault system.

The interference pattern of these two successive extensional systems, the Contraviesa system, mainly Langhian in age, and the Filabres system, mainly Serravallian in age, superimposed on a stack of tectonic nappes resulted in a chocolate tablet mega-structure and the outcropping of a varying number of extensional units within the Alpujarride complex. The described structures fit the geometric model for extension developing in more than one direction, and can be considered representative of the early and middle Miocene tectonics of the entire Alboran Domain, in the Betics and in the Rif.

Acknowledgements

We thank F. Delgado for the beautiful geological map of the Alpujarride Complex in Sierra de Baza area. Se agradece la colaboración del personal del Parque natural Sierra de Baza (AMA - Junta de Andalucía). This study was supported by grant CICYT nº PB92-0020-C02-01. The English version of the manuscript was corrected by J. L. Sanders.

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