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MIOCENE EXTENSIONAL DEFORMATIONS IN THE REGION OF AGUILAS-MAZARRON (EASTERN BETIC CORDILLERAS)

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RESUMEN

Algunos contactos de superposición entre unidades tectónica de la Zona Bética en la región de Aguilas-Mazarrón son debidos a fallas normales de bajo ángulo que desarrollan estructuras extensionales de carácter dúctil-frágil y frágil y que producen, a partir del Mioceno Inferior, una importante reestructuración en la pila de mantos. Del análisis cinemático de estas estructuras se deduce la existencia de, por lo menos, dos direcciones de extensión: (a) Una hacia el SSW, que dio lugar a la mayor parte de las fallas extensionales que se observan en la región, y (b) otra hacia el ESE, probablemente posterior y menos acusada.

Palabras clave: *estructuras extensionales, fallas normales de bajo ángulo, adelgazamiento cortical, Cordilleras Béticas.*

ABSTRACT

Some of the contacts between the superimposed tectonic units in the region of Aguilas-Mazarrón, in the Betic Zone, are normal low-angle faults. They are associated with ductile-fragile and fragile extensional structures, which, from the Lower Miocene onwards, extensionely restructured the original pile of nappes. An analysis of these structures points to at least two directions of extension: one to the SSW, which gave rise to most of the extensional faults to be seen in the region and a later, weaker one to the ESE.

Key words: *extensional structures, low-angle normal faults, crustal thinning, Betic Cordilleras.*

Introduction

Various geological aspects of the Aguilas-Mazarron region, in the southwest of the province of Murcia (figs. 1 and 2), have been studied (see Durand Delga *et al.*, 1962; Fernex, 1964 a & b; Corbella-Martí, 1969; Kozur *et al.*, 1985, for example).

Bearing in mind both structural and metamorphic stratigraphic criteria, Alvarez & Aldaya (1985) and Alvarez (1987 b) have distinguished several tectonic units belonging to the three complexes of nappes that make up the Betic Zone: from top to bottom, the Nevado Filabride, Alpujarride and Malaguide (Egeler & Simon, 1969) (fig. 2).

The materials have undergone complex tectonic nappe deformations (Alvarez, 1987 a and b), followed, from the lower Miocene, onwards by an important extensional tectonic stage, which we deal with in this work. An even later strong transpressional deformation, which is still taking place, has resulted in most of the present-day contacts between the units, being subvertical faults with a significant strike-slip component. Some of these faults separate distinct groups of units, although they were not produced by the earlier deformations that originally brought those groups together, which are now obscured by the more recent faults. Thus, the units are piled up in three distinct groups, separated by EW and EWE-WSW dextral strike-slip faults and corresponding to three geographic domains, known as the Septentrional, Central and Meriodional Realms (Alvarez & Aldaya, 1985; Alvarez, 1987 b) (fig. 2).

Although certain evidence exists for a shearing episode in a compressional regime, synkinematic to the main deformation phases, which caused some ENE movement (Alvarez 1987 a and b), the majority of the superimposition surfaces between the units are younger than these shear displacements and are due

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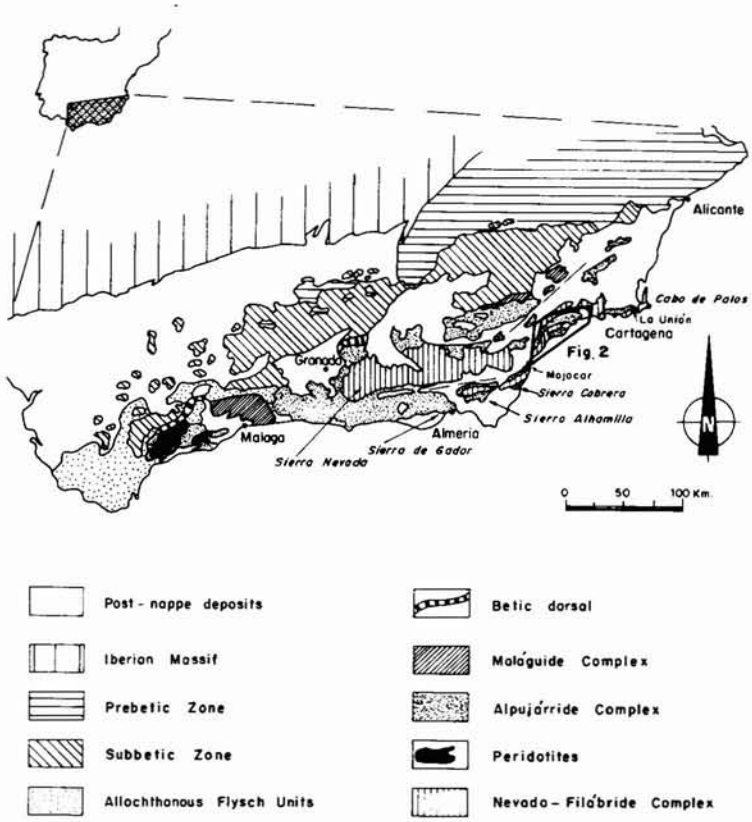

Fig. 1.—Scheme of the Betic Cordillera including the locations of the area studied.

to tangential northward movements. Other contacts, however, are extensional, low-angle normal faults, with the upper block sinking south-southwestwards, and are also previous to the more recent transpressional phase.

The importance of extensional tectonics in the present-day Central Betic Cordillera has recently become clear recently, since Aldaya *et al.* (1984) reinterpreted the contact between the Alpujarride and Nevado-Filabride to the southwest of the Sierra Nevada as being a low-angle normal fault («Mecina Fault»), with the upper block sinking southwards.

Later works have described this type of structure in other parts of the central sector at the contact between the Alpujarride and the Nevado-Filabride (García-Dueñas *et al.*, 1986; García-Dueñas & Martínez-Martínez, 1988; Galindo-Zaldívar *et al.*, in press) and also in the southern sector, where they modify the contact between the Alborán Domain and the Southern Iberian Domain (Balanya & García-Dueñas, 1986).

The aim of this study is to describe the main tectonic structures caused by extensional deformation in the Aguilas-Mazarrón region. The data which we have accumulated so far has allowed us to establish the overall kinematic characteristics of the region and put forward an explanation as to the nature of some of the contacts between the various tectonic units. We have also made a model to justify the anomalous contact between two ensembles of units in the Central and Meridional Domains (Alvarez, 1987 b), which vertically would have been far removed from each other before the extensional phases.

The geometry of the extensional structures studied leads us to the conclusion that at least two such phases took place, one in a SSW direction and a later, weaker one to the SSE.

The SSW movements

The contact between the Alpujarride and the Nevado-Filabride in the septentrional domain

The only contact between units that can be considered with complete certainly as being a low-angle normal fault related to SSW movements is that which separates the Talayon Unit (Alvarez & Aldaya, 1985), in the Septentrional Domain, from the Mulhacen Nappe, which crops out here as the Sierra Almenara. Its outline on the map, despite being

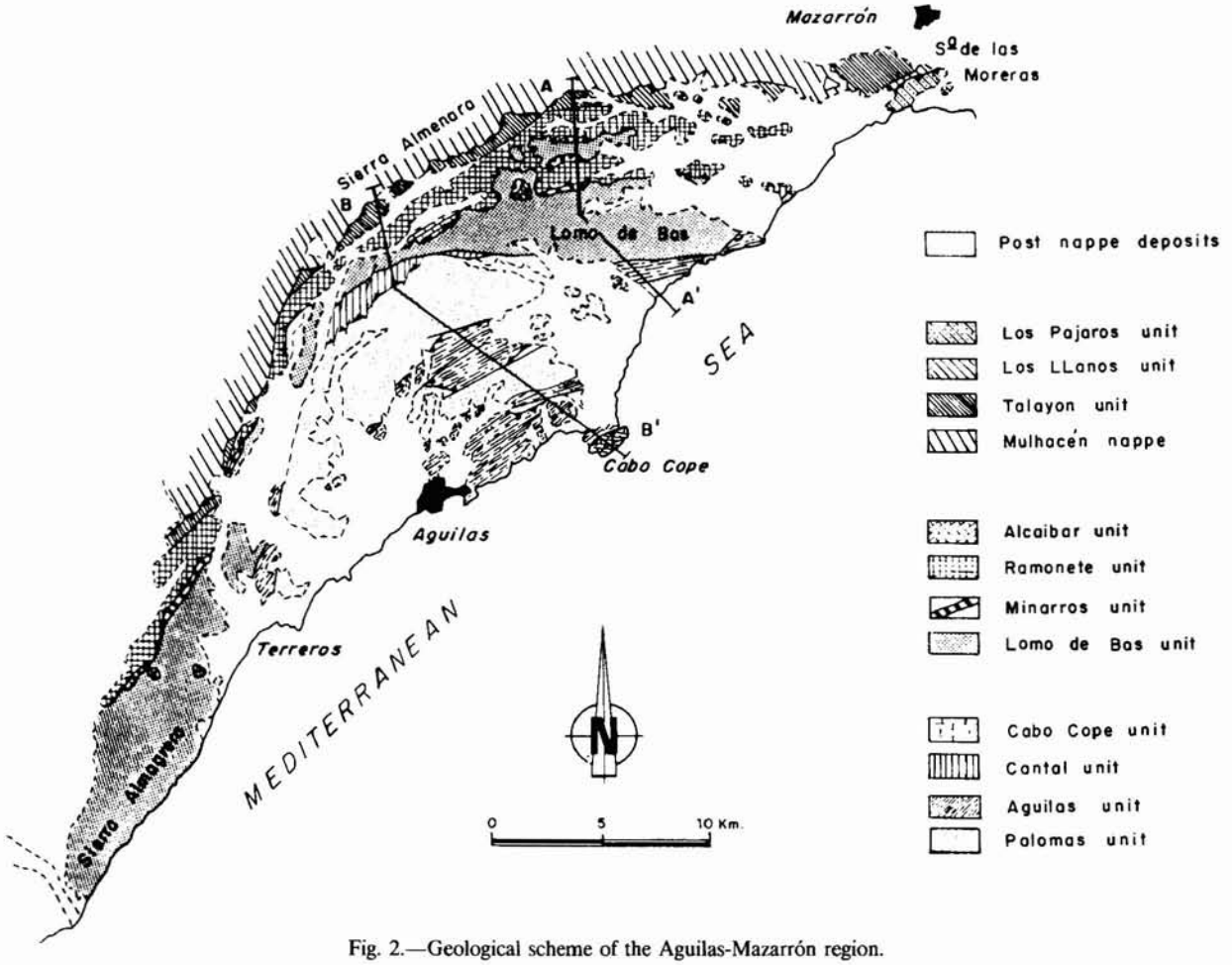

Fig. 2.—Geological scheme of the Aguilas-Mazarrón region.

broken by later deformations and obliterated by more recent deposits reveals clearly that the fault represents an almost flat surface dipping slightly to the south and continuing for more than 60 km. (fig. 2). The cleavages of the rocks on either side are oblique to the contact but become parallel in its proximities.

The outcrop where the extensional structures associated with the fault are best to be seen is in the Rambla Honda (Sheet of Mazarrón E: 1:50.000, U.T.M. 337-822). Here the carbonate formation makes contact with the phyllites in the Talayón Unit and further northwards these meet the materials of the Nevado Filabride. The fault runs N110°E and dips southwards between 20° and 30°. The phyllites have been turned into fault gouge and contain numerous almond structures (*), slickensides and dragging that clearly indicate that the upper block moved south to south-southwest wards; there are also Riedel fractures and the subvertically dipping Alpujarride limestones of the sunken block appear to have undergone a tilting congruent with the listic geometry of the fault.

The Nevado —Filabride rocks to the north of the fault zone show a decimetric— to metric-sized system of extensional structures, including low-angle normal faults, almond structures, Riedel fractures, etc., all of which are congruous with the upper block's having moved south-southwestwards.

The coming together of the ensembles of units belonging to the central and meridional domains

The contact between the Central and Meridional ensembles is a subvertical dextral strike-slip fault some tens of kilometres long. Both ensembles continue together westwards in a similar way to the south of the Sierra Cabrera (Navarro-Vilá *et al.*, 1984) (fig. 1).

At the present-day erosion level, the fault delimits northwards Nevado-Filabride material that can be

(*) The term «almond structure» is used to denote sigmoid bodies included between shear and cleavage surfaces but not generated during the same process; they are not, therefore, the C-S structures of Lister & Snooke (1984).

correlated with the Veleta Nappe (Lomo de Bas Unit) and southwards Alpujarride units (Palomas unit and Cantal unit, Alvarez & Aldaya, 1985), which according to their stratigraphic and metamorphic characteristics can be correlated with those high up in the pile Nappes (Aldaya *et al.*, 1979).

The vertical displacement, deduced from the initial positions of these two nappes on either side of the fault, is one of various thousands of metres: taking into account only the thicknesses to be seen in the units cropping out in the Meridional Domain, it can be calculated that the upper block has sunk 2.500 m to which we must be added the thickness of the materials between the sequence known as the Palomas Unit and the rocks of the Veleta Nappe, which is presumibly the relative autochthonous unit of this ensemble (Alvarez, 1987 b) (fig. 3, section B-B').

It would seem unlikely that a strikeslip fault could be responsible for a vertical displacement of several thousand metres and in our opinion it is more reasonable to conjecture that the vertical proximity of both ensembles is due to the low-angle normal fault which at present separates them. It is worth noting here that such faults, with a southern sense of displacement have also been found above the Veleta Nappe in the Sierra Alhamilla (fig. 1) (García-Dueñas *et al.*, 1986).

The structures to be seen today are no more than pointers to the movement of the strike-slip fault. It can only be presumed that to the south of the strike slip fault the extensional fault is located below the outcropping units of the Meridional Domain and to the north it has been eroded away from above the remaining materials of the Central Domains (fig. 3).

In this context, the existence of southward facing extensional structures in the schists of the Lomo de Bas Unit and to a lesser extent in those of the Palomas Unit are consistent with this fault. Thus, on the southern slopes of the Lomo de Bas and, above all, the Sierra Almagrera, there are smallish extensional faults, normally separating different lithological terms within the same unit. These fault zones may be up to 2 or 3 metres in width with development of extensional crenulation cleavage (as Platt and Visser defined the term in 1980) and almond structures of up to 1 metre, generally contained within a thin matrix of fault gouge.

In the shear surfaces that delimit them, there are slickensides trending approximately N-S. The structural relationships between the shear surfaces and the pre-existing foliation indicate that the upper block moved southwards; locally within the almond structures there are southward-facing folds, the axes of which run from east to west.

The ESE movements

At several points in the region extensional structures are to be seen consistent with the upper block's having moved east-southeastward, but no large surfaces or contacts between units which may be associated with these displacements have yet been found. On the Lorca to Aguilas road, the Alpujarride and Nevado Filabride materials have local deformation bands with extensional crenulation cleavage and very stretched normal faults pointing to ESE movements and, occasionally, to the conjugate WNW displacements.

These types of structure related to a WSW-ESE extension are not in fact very widespread in the Aguilas-Mazarrón region but they are somewhat better

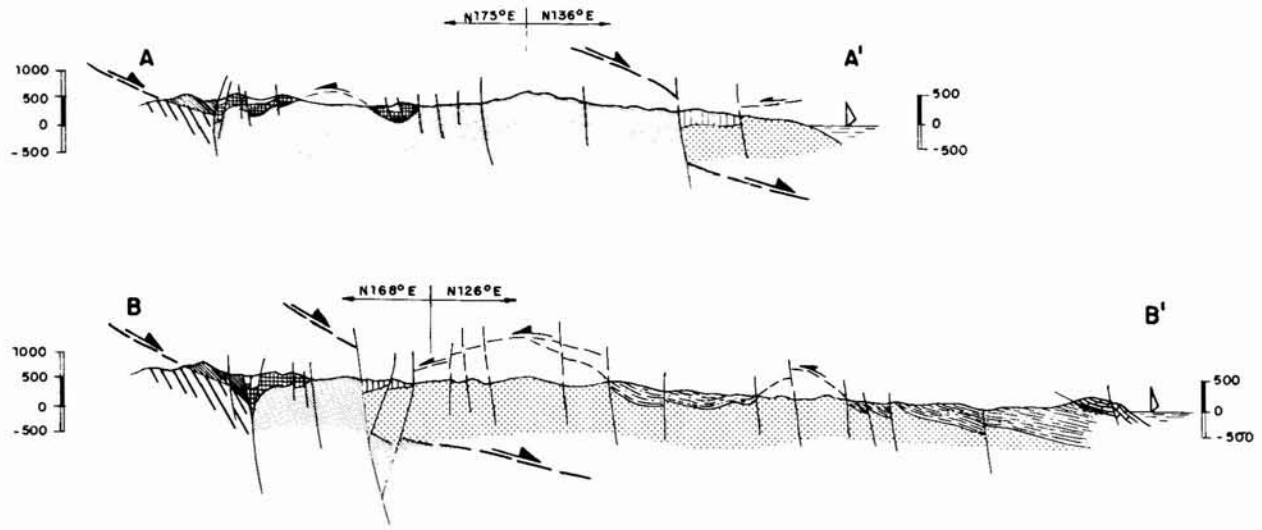

Fig. 3.—Sections showing the direction of movement of contact surfaces between the units; the location and explanation of which appear in figure 2.

developed to the east of Cartagena and they are also to be seen around Mojácar and in the eastern part of the Sierra de Gádor (fig. 1). It is significant that in the two latter regions we have faund ESE extensional structures affecting Tortonian rocks and Larouziére (1985), in a work on the Neogene basins close to Mazarrón, describes an approximately E-W distensive regime in direction and contemporany to the uppermost Tortonian and later sediments, which may have been related to these movements.

The age of the extensional deformations

Although up to now we have not observed any intersections between the two extensional systems mentioned above and thus have not been able to establish any direct temporal relationship between the two, there are good reasons for believing that the SSW extension took place before the ESE one.

The former probably occurred between the Burdigalian and the Langhian, as it is later than the original piling up of the units, a process that was completed during the Oligocene; its most important structures, on the other hand, are fossilized by the Serravallian. Nevertheless (Galindo-Zaldívar, 1986) has shown that this extensional regime did persist after the Serravallian and we have confirmed that Serravallian materials in the «La Sultana» quarry to the east of La Unión shoe C-S structures, indicating south-southwestward displacement.

The latter system can be dated at least in part to a post-Tortonian age, as in the eastern sector of the Sierra de Gádor the structures altered Tortonian sediments, but precisely when the ESE extension began and to what extent it affected the SSW extensional structures remains to be determined.

Conclusions and discussion

From the lower Miocene onwards there began an extensional regime which severely restructured the pile of nappes making up the Betic Zone; low-angle normal faults were produced, generally at the contact between the Alpujarride Nappe and the Nevado Filabride below it. The extensional faults in the Aguilas-Mazarrón region are associated with ductile-fragile/fragile deformation structures, such as almond structures, slickensides, drag structures, etc. and they form two principal directional groups: one south-southwestward, which includes most of the faults in question, and a later, weaker east-southeastward one.

It was the former system that give rise in other regions to the great SSW extensional accidents such as the Mecina Fault (Aldaya *et al.*, 1984) and the Torres Cartas Fault (García Dueñas *et al.*, 1986), among others. Galindo-Zaldívar *et al.* (in press) have reported the prolongation of the Mecina Fault along the western and northwestern edge of the Sierra Nevada and, basing their conclusions on the centrifugal movements that they deduce from the structures in the fault, they propose a core complex model. At present we find it difficult to reconcile our data with such a model, which would have to hold good for the whole Betic Cordillera, although at the moment we are investigating this hypothesis over a much wider area. It still has to be decided, for example, whether there is any causal relationship between the two systems studied here and those that took place during the final piling up stage of the Alpujarride Units, the characteristics of which may be indicative of gravitatorial expansion mechanisms (Platt, 1982; Cuevas, 1988) but whose NNW movement remains constant throughout the whole Betic Cordillera (Aldaya, 1969 a and b; Navarro-Vilá, 1976; Alvarez, 1987 a and b; Cuevas, 1988, Simancas *et al.*, 1988). It is noteworthly as far as this last point is concerned that at the contact between the Alpujarride and the Nevado-Filabride in the Central Domain, in the Aguilas region, there is a very thin, mylonitized unit, the Miñarros Unit (see fig. 2), the lithological and tectonic characteristics of which described by Alvarez & Aldaya (1985) y Alvarez (1987 a and b) resemble the mylonitic carapace (as defined by Hamilton, 1987), but whose structure always points to northwest movement. The formation of this carapace may be related to the final stage of the piling up of the Alpujarride Units, as Tubia *et al.* (in press) suggest, or else the Miocene extensional movements. If the latter were proved to be the case, the Miñarros Unit would have to be considered in terms of a mylonitic carapace correlatable with that described by Galindo-Zaldívar *et al.* (in press) in the southwestern part of the Sierra Nevada and thus the possibility of divergent extensional movements, such as those that have occurred in the core complex in the western United States (Wust, 1986; Malavielle, 1987, etc.), would have to be admitted. Nevertheless, the fact that within the contact between the Alpujarride and the Nevado-Filabride in the Septentrional Domain, which stretches for some kilometres to the north of the Miñarros Unit, the carapace is nowhere to be seen and that the extentional structures there all indicate movement to the south-southwest, implies serious difficulties for the proposition of a core-complex model.

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