Neotectonics in the Tabernas Desert (Almeria, Betic Cordillera, Spain)

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Key words: Betic Cordillera, Neotectonics, Active Tectonics

Introduction

The Tabernas Desert is an upper Neogene basin situated within the Betic Internal Zone, in the SE of Spain (figs. 1 and 2). In this area, the Betic Internal Zone is formed by the Nevado-Filabride and Alpujarride complexes, both constituted by metamorphic rocks. These rocks form the basement where were unconformably deposited Tortonian to Quaternary sediments infilling the Tabernas Basin.

From the late Miocene (Tortonian) the Betics are submitted to a NNW-SSE to N-S compression linked with a near perpendicular extension that in many cases is even more active than the compression. In this time the sierras Nevada, Filabres, Alhamilla, Gádor etc, were uplifted and formed the main basins of the region as the Alpujarran Corridor (long E-W depression situated between the sierras Nevada and Gádor) and the Tabernas Desert, its eastward prolongation (fig. 1).

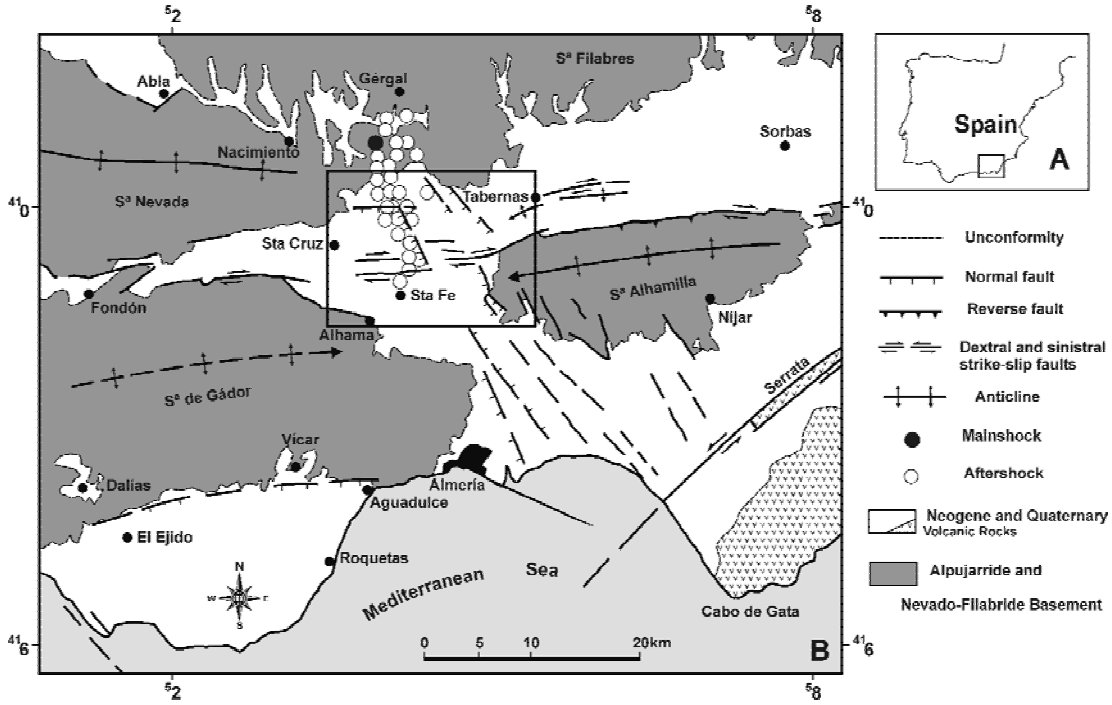

Fig. 1. General setting of the studied area: A — Iberian Peninsula contour, indicating the position of B; B — Part of the central and eastern Betic Cordillera. The Gergal Earthquake and its aftershocks are situated in it (according to IGME, 2004 and referred from the 4th day to the 11/02/2005). The position of the studied area is indicated by a square.

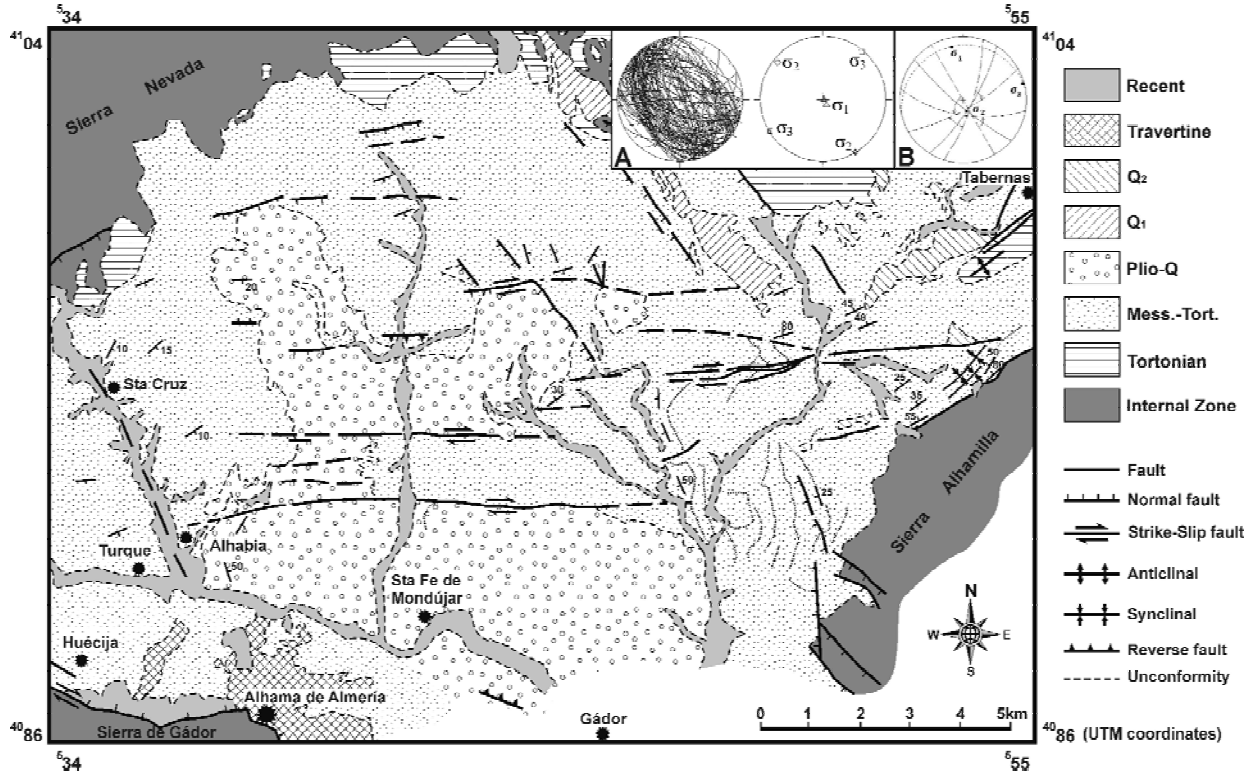

Fig. 2. Geological map of the study area (with the main faults an folds).
Tectonic stress field reconstruction from:
A — striations on slickensides (lower hemisphere projection)
B — measurements of shear joints in Plio-Quaternary and Quaternary sediments (lower hemisphere projection)

In the Alpujarran Corridor and also to the north of Sierra Alhamilla, there are important E-W dextral strike-slip faults clearly visible as consequence to the great contrast existing between the rocks of the basement and those of the upper Neogene. These faults were described by Sanz de Galdeano et al. (1985), Martínez Díaz (1998) and Martínez-Martínez en al. (2006). Nevertheless, in the Tabernas Desert, the basement is only situated in its corners and the existence of these faults in the Neogene and Quaternary sediments was not well known till present, although Pascual (1997) mapped some of them. Moreover, other NNW-SSE faults are also developed. The upper Neogene, Tortonian and Messinian sediments are formed by breccias, conglomerates and sands, continued by silts and sands. In the silt beds there are spectacular slumps, probably seismites, indicating the tectonic instability existing in the area during the upper Neogene times. The Pliocene-Quaternary is formed by red conglomerates, sandstones and silts. Younger Quaternary deposits correspond to different fluvial terraces, generally formed by conglomerates and sands.

The aim of this note is to explain the interplay of the two systems of faults and the antiforms constituting the sierras Nevada, Alhamilla and Gádor and to present the neotectonic and even the active character of some of the faults in the Tabernas Desert.

Structures of the Tabernas Desert

The high mountains dominating this basin correspond to the E-W antiforms of sierras Nevada and Filabres to the north, and Gádor and Alhamilla to the south (figs. 1 and 2). The fault of the north border of Sierra de Gádor greatly controls its uplift. To the east, the north border of Sierra Alhamilla is limited by an E-W dextral strike-slip fault, in some places with reverse, north verging character (Sanz de Galdeano, 1989). There appears an E-W anticline, but unlike the previous antiforms affecting the basement, this one is formed on Neogene sediments (Ott d'Estevou, 1980). There are many other folds affecting the Neogene sediments, but generally with small sizes.

In the Tabernas Desert, the E-W dextral strike-slip faults ensure the prolongation of these faults existing to the north of the sierras of Gádor and Alhamilla (fig. 2), giving in several places spectacular outcrops, especially where the Pliocene-Quaternary sediments are situated in a side of the surface of the fault and the Messinian in the another one, owing

to the contrast of colour. The fault surfaces are generally well exposed, some times anatomized and with many horizontal or nearly horizontal striae. They form parallel echeloned lines, disposition that facilitates the dextral displacement (according our observations the displacement is mainly horizontal, but in some cases there are also important vertical component).

The NNW-SSE faults form another important set. These last faults also affect the Pliocene-Quaternary sediments and are especially present in the central and southeastern part of the studied area. To the south, these faults are very abundant, forming the west border of Sierra Alhamilla; southwards also affect very young sediments forming well conserved fault scarps (Marín Lechado, 2005). In the studied area, these faults dip predominantly to the SW, but there are others conjugated faults dipping to the NE.

Minor faults are very abundant and generally are easily visible due to the very good conditions of outcropping of the whole area. They mainly correspond to E-W, NNW-SSE and even NNE-SSW sets. Near 200 measurments, distributed in several points, have been completed to obtain the paleostress that, briefly, shows a NNW-SSE compression combined with an ENE-WSW extension. Locally, there are some differences and in some cases the positions of σ_1 and σ_2 are interchanged (fig. 2A, B).

Seismicity

The seismic records of the studied area do not present very important earthquake activity but it is important to analyse the relationship of the data from the Gergal Earthquake occurred the on 04/02/2002 at 20 h, 9 min, 30 sec, with a **Mb** (Lg) = 5.1 that had more than 30 aftershocks during a month. The hypocentral depth of the main shock was evaluated at 3 km (IGN, 2004), but according to Rodríguez (2004) the depth was 10 km. Cesca (2005) indicates a possible magnitude **Mw** = 4.6. The focal mechanism is still under discussion, but perhaps the more interesting aspect of these earthquakes is their epicentral distribution (fig. 1) that clearly marks a near N-S (NNW-SSE) orientation in a good coincidence with some NNW-SSE faults existing in the studied area and in the surrounding sectors. This indicates that these faults are nowadays actives. In fact, to the south, in the proximities of Almeria, there are many of these faults cutting Quaternary sediments. By the contrary, the E-W faults, although affect even Quaternary sediments, do not present so clear features of active tectonics.

Discussion and conclusions

The formation of the E-W faults, the E-W folds and the NNW-SSE and NNE-SSW faults can be related to the main features of paleostress obtained. This stress fits well with the existing in the Betics from the upper Neogene: a near N-S to NW-SE compression and a near perpendicular extension. Sometimes the extension is more important than the compression.

The dextral strike-slip E-W faults cut longitudinally the Betic Internal Zone helping to its progressive westward displacements of its internal zones located in the southern part. The E-W folds are something oblique to the present ellipsoid of stress but probably they are forced by the previous existence of the E-W faults. For this reason we interpret that they respond to the same state of compression.

The formation of the NNW-SSE faults, and with less importance NNE-SSW faults, is consequence of the approximately ENE-WSW extension. In this case it is necessary that the position of σ_1 (fig. 2B) change to a vertical position (fig. 2A). This fact has happen in many cases in the Betic Cordillera (Galindo-Zaldívar et al., 2003). The Gergal earthquake and its aftershocks clearly indicate that these faults are active at present. One possible interpretation of the position of these earthquakes is that the NNW-SSE faults are propagating northward to the Sierra de Filabres, while to the south formed previously, although the existence of young morphologic features indicate that they are still active there.

Aknowledgement. Project 2004BG0015 between the CSIC and the Bulgarian Academy of Sciences.

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Неотектоника на пустинята Табернас (Алмерия, Бетска кордилера, Испания)

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Резюме. Пустинята Табернас е източно продължение на коридора Алпухария (южно от планините Невада и Филабрес, Вътрешна зона на Бетската кордилера). Пресичат я големи дясно-отседни разломи с направление И-З, ограничаващи значими антиформи, проследяващи се главно по фундамента. Разломи с направление ССЗ-ЮЮИ разсичат плиоценските и кватернерните седименти. Тяхната съвременна активност се изявява при Жергалското земетресение и неговите афтършоци, както и чрез някои млади морфоложки черти. Всичките тези структури биха могли да се образуват при ССЗ-ЮЮИ компресия и ИСИ-ЗЮЗ екстензия. Структурно-тектонските изследвания показват, че в някои от случаите екстензията има значително по-силни прояви от компресията.