Structure and kinematics of the Aljibe Unit, north of Cádiz Province (Flysch Trough Complex, Betics)

Estructura y cinemáfica de la Unidad de Aljibe en el norte de la provincia de Cádiz (Complejo del Surco de los Flyschs, Béticas)

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RESUMEN

La unidad de Aljibe es la más extensa de las unidades del Dominio del Surco de los Flyschs en el Norte de la provincia de Cádiz. Esta unidad, formada por rocas de edad Paleógeno a Mioceno inferior, está estructurada según un sistema imbricado de cabalgamientos de edad post-Aquitaniense. Estos son vergentes hacia el W o WNW en el sector oriental del área estudiada y retrovergentes en el sector occidental. En este último, se observa además como los cabalgamientos están plegados por pliegues de gran radio, de dirección aproximada N-S y E-W y de probable edad Mioceno superior a Plioceno, formando así patrones de interferencia en domos y cubetas.

Key words: *Gibraltar Arc, Flysch Trough, Aljibe unit, fold-and-thrust system.*

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Introduction

The Gibraltar Arc is a tightened orogenic arc which formed during the Miocene by the superposition of various crustal domains (Balanyá and García-Dueñas, 1988), which are, from bottom to top: a) the Alboran Domain, formed by continental metamorphic rocks and structured during polycollisional tectonics (Azañón *et al.*, 1997), b) the Flysch Trough Domain, formed by rocks which proceed from a basin with thinned continental crust, eventually oceanic crust (Martín-Algarra, 1987), c) the South Iberian and Maghrebian Domains which derive from the Iberian and African paleomargins, respectively.

From lower Miocene, the westward migration of the Alboran Domain obliterated the Flysch Trough. Below and in front of a main thrust, the so-called Gibraltar Crustal Thrust, an accretionary prism developed (Balanyá and García-Dueñas, 1987, 1988). In the Betics, this prism is mainly constituted by the Flysch Trough units, lower Cretaceous to lower Miocene in age, and by the Iberian paleomargin units (Subbetic units), Triassic to lower Miocene in age. The geometry of the prism can be described as a fold-and-thrust system, mainly W or NW-vergent.

North of Cadiz province, two main units have been distinguished in the Flysch Trough Domain (Fig. 1): the Aljibe unit (Didon, 1960, 1964; Chauve, 1960) and the Algeciras unit (Didon, 1960, 1969). Moreover, some isolated slices of Cretaceous marly limestones appear. They have been attributed to Almarchal unit, which represents the Maghrebian paleomargin (Didon *et al.*, 1973).

The aim of this paper is to describe the structure and kinematics of Aljibe unit north of Cadiz province (1 :50.000 Geological sheets Algar-1063 and Cortes de la Frontera-1064). We describe a westvergent fold-and-thrust system, associated with backthrusts, which produced an EW shortening. Late open folds affected the previous structures.

Lithostratigraphy of the units

The main units of the Flysch Trough which outcrop in the study area are, from bottom to top, the Almarchal unit (Didon, 1969) -equivalent of the Algarrobo unit of Chauve (1968)- and the Aljibe unit (Didon, 1960). This latter occupies most of the mapped area (Fig. 1).

The Almarchal unit is formed by an upper Cretaceous and Paleocene alternation of bioclastic limestones, marls with levels of microbreccias and mudrocks (García de Domingo *et al.*, 1991). The Aljibe unit is composed by two well differentiated terms. The lower one includes two Eocene to upper Oligocene formations, that can intercalate laterally and vertically: the Jimena formation (Didon, 1960), formed by green to red siltstones, and the Benaiza formation (Didon, 1960), composed by calcareous turbidites alternating with siltstones. The upper term is represented by the Aljibe formation (Gavala, 1924) -Numidian of north Africa-, composed by sandstones (around 90% of quartz grains, García de Domingo *et al.*, 1991) with scarce intercalations of claystones, dated as Aquitanian (Esteras et.al. 1995). In the study area, the thickness of this formation can reach 1000m. Sedimentary structures in the Aljibe unit formations, such as laminations (convolute, cross-stratified and trough-cross), flute and groove casts, ripples and load struc-

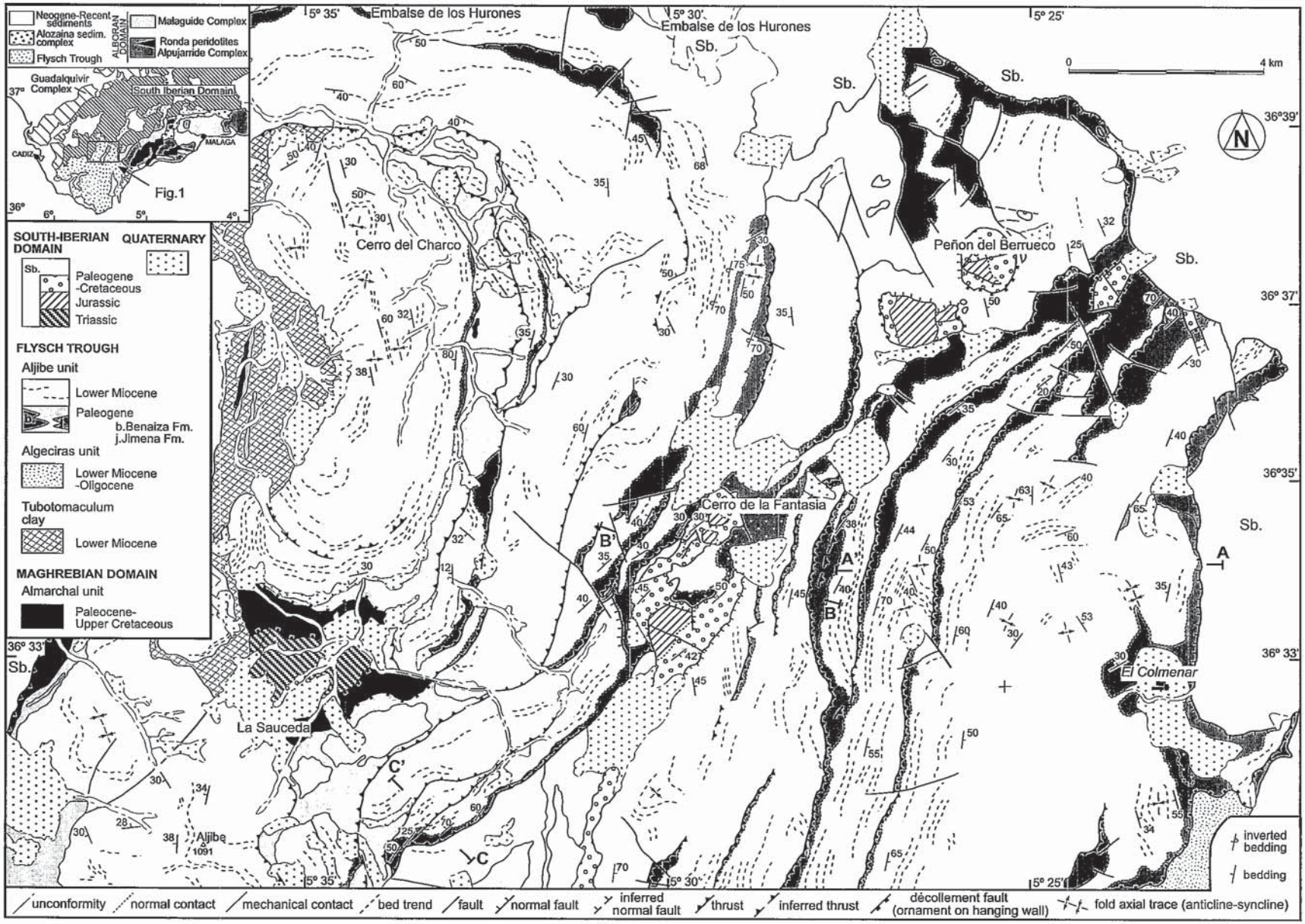

Fig. 1: Geological map of the study arca, based on own data, Del Olmo et. al. (1987) and García de Domingo *et al.* (1991).

Fig. 1: Mapa geológico del área de estudio, basado en datos propios, Del Olmo* et al. *(1987) y García de Domingo et al. (1991).

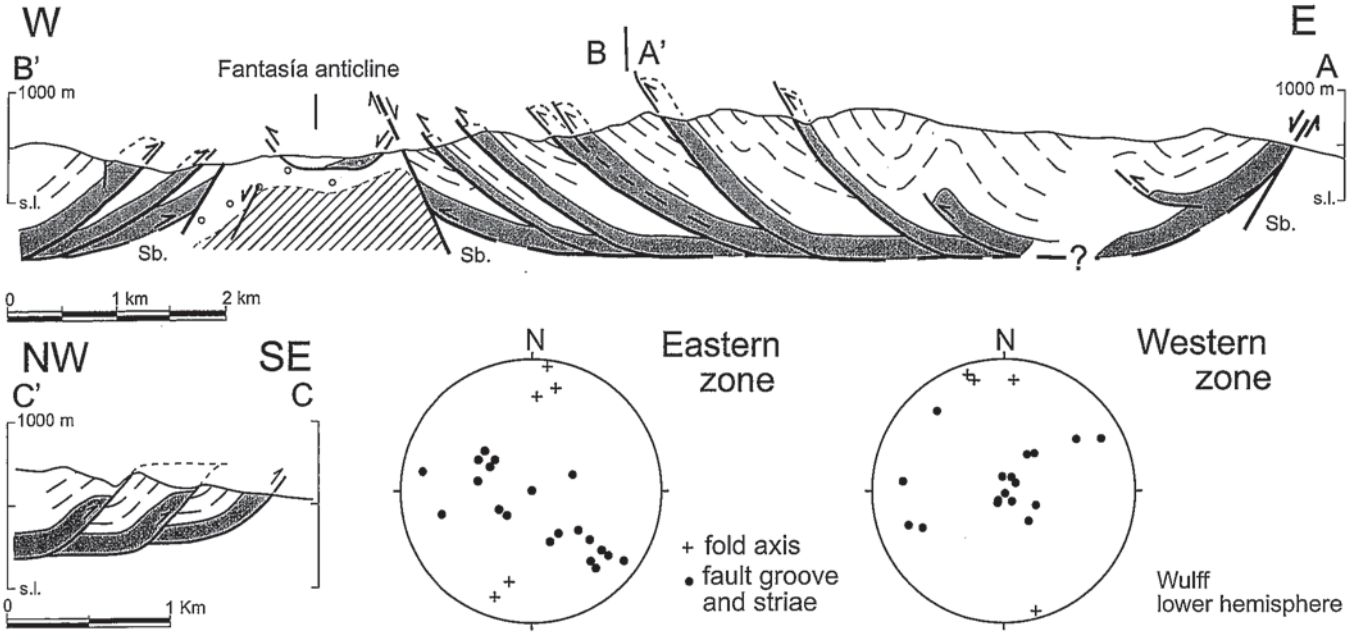

Fig. 2: Cross-section illustrating the imbricate thrust system of the Aljibe unit. Localization on Fig.1. Same legend as in Fig. 1. Stereoplots: Relationships between axes of thrust related folds and striae on bedding due to flexural slip.

Fig. 2: Cortes geológicos que ilustran el sistema imbricado de cabalgamientos en la unidad de Aljibe. Localización en Fig. 1. Misma leyenda que en la Fig. 1. Proyecciones esterográficas: Relaciones entre ejes de pliegues en relación con los cabalgamientos y estrías de deslizamiento flexural sobre los planos de estratificación.

tures permit to have a good control over the strata polarity. An unconformity separates the Aljibe sandstones from the Tubotomaculum clayey formation, which is composed by red and green mudrocks and includes blocks of various lithology and age (among others: Aljibe sandstones, Microcodium limestones and bioclastic limestones of Almarchal unit). In the study area, this formation has been dated as lower Miocene (García de Domingo *et al.*, 1991).

Structure and kinematics of the Aljibe unit

The Subbetic units are structurally below and surround the Aljibe unit (Fig. 1). The Subbetic units also appear as tectonic windows in the western part of the study area (La Sauceda) and in the central part, along an alignment from Peñón del Berrueco to Cerro Fantasía (Fig. 1). This alignment corresponds to an antiform and divides the study area into two zones slightly different concerning the outcropping lithological formations and the vergence of the structures, reason for which they will be described separately. In both zones, no penetrative structures which would reflect internal deformation have been observed.

Eastern Zone

In this zone, the Aljibe unit is composed by an imbricate thrust system (Figs. 1 and 2AB'). Individual thrust faults curve asymptotically downward to a common basal sole thrust within Benaiza formation. Cutoff, branch and tip lines of the thrusts are N-S to NNE.SSW directed. The cut points between the bedding of the sandstones and the thrusts show that the fault ramps ascend towards the W to WNW, as illustrated in the eastern part of cross-section AB' (Fig. 2). The internal structure of the slices is tabular or forms hecto- to kilometric scale folds, W to WNW-vergent. Some folds are fault propagation folds meanwhile others developed within footwall ramps. The axial traces of these folds are drawn in map of Fig. 1 and their axes are approximately NNE-SSW-directed (stereoplot of Fig. 2).

Evidences of slip parallel to the bedding within Aljibe sandstones are frequent. Striae and groove marks show a poorly defined maximum with a N60°W direction, subperpendicular to the folds axes (Fig. 2). Together with opposite shear senses in the fold limbs, this observation is coherent with a mechanism of flexural slip during the fold evelopment.

The minimum shortening can be asumed in the eastern part of cross-section AB' (Fig. 2). The values of the final length (<8 km) and the minimum initial length (>17km) give a negative extension of approximately 0.54.

Western zone

This zone is characterized by a backthrust system. For example, SE of La Sauceda, a duplex shows that the fault ramps ascend towards the E (Fig. 1 and 2C). In this duplex, within the Benaiza formation, reverse faults of metric to decimetric slip associated with the main thrusts show ENE-WSW directed striae.

In the Cerro del Charco slice, various folds which affect the Aljibe sandstones but not the Benaiza formation can be observed (Fig. 1). Their axial traces have been drawn in the geological map and their axes are approximately N-S directed (stereoplot of Fig. 2). Flexural slip within the Aljibe sandstones are also frequent in this zone and show movement striae subperpendicular to the folds (Fig. 2).

In this zone, the fold and backthrust system is affected by more recent folds. For example, observe how, south of the Embalse de los Hurones, the thrust surfaces draw a synform with a high plunge (equal to or more than 40°) towards the south and how, north of la Sauceda the same synform plunges 30° towards the north. This basin-like structure seems to result from the interference of two generations of late open folds, approximately

N-S and E-W directed, whose age is yet not known.

Discussion and conclusions

The imbricate thrust system described in the eastern zone of the study area shows that the Aljibe unit has a coherent structure of folds and thrusts in sequence, rooted in clayeys formations (Benaiza and Jimena formations), more plastic than the Aljibe sandstones. Tectonic transport directions indicate that the first shortening is E-W to ESE-WSW-directed and produced westvergent thrusts in the eastern zone, meanwhile backthrusts are characteristic of the western zone. Similar results can be found in García de Domingo *et al.* (1994). Both systems are post-Aquitanian. The most outstanding structures superposed to the thrust system are two generations of open folds, approximately N-S and E-W trending, although their relative chronology has not been yet established. It must be stressed that similar open folds, have been described in the units belonging to the Flysch Trough Complex near of Bolonia, 60km south of the study area (Balanyá *et al.*, 1995). These authors proposed an upper Miocene to Pliocene age for these folds.

According to Bourgois (1978), the Flysch Complex would be composed by sedimentary megaklippes included in a matrix of Burdigalian age. The type of organization of the Aljibe unit described in this paper does not agree with ourgois's interpretation. It is also not coherent with the "rabotages basals" evoked by Didon (1969), whose geometry of descending ramps towards the W would leed to consider the boundaries between units as extensional faults. Nevertheless, it must be stressed that E and NE of the study area, the boundary between the Aljibe unit and the Subbetic units corresponds with a normal fault which cut the thrust system and which is slightly folded (Fig. 1). Then, this boundary does not correspond with the sole thrust of the imbricate system described in the eastern zone.

Acknowledgements

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References

Azañón, J.M., Crespo-Blanc, A. and García-Dueñas, V. (1997): *J. Struct. Geol.*, 19: 1055-1071.

Balanyá, J. C. and García-Dueñas, V. (1987): *C. R. Acad. Sci., Paris,* 304, Série II: 929-932.

Balanyá, J. C. and García-Dueñas, V. (1988): *II Congr. Geol. España, v. Simposios*: 35-44 pp.

Balanyá, J.C., Esteras, M., García-Dueñas,V. and Izquierdo, J. (1995): *IV Coloquio Internacional sobre el enlace fijo del Estrecho de Gibraltar, SECEG,* Madrid, 2: 3-7.

Bourgois, J. (1978): *Ann. scientifiques Univ. Besançon* (France), 30: 1-445.

Chauve, R (1960): *Livre Mém. Prof. Fallot. Soc. Geol. France,* 1: 257-264.

Chauve R (1968): *Mem. I.G.M.E.*, 69: 1-377.

Del Olmo Sanz, A., De Pablo Macía, J.G., Aldaya Valverde, F., Campos Fernández J., Chacón Montero, J., García Dueñas, V., García Rossell, L., Sanz de Galdeano, C., Orozco Fernández, M., Torres Roldán, R. (1987): *Mapa geológico de España. 1/50.000 serie MAGNA. Hoja n° 1064. Cortes de la Frontera.* IGME

Didon, J. (1960): *Bull. Soc. Géol. France* (7) 2: 352-261.

Didon, J. (1964): *C. R. Somm. Soc. Géol. France* 1: 32-33.

Didon, J. (1969): *Thése Doct. Univ. Paris*: 1-523.

Didon, J., Durand-Delga M., et Kornprobst, J. (1973): *Bull. Soc.Géol. France,* 15: 121-127.

García de Domingo, A., Hernaiz Huerta, P.P. and González Lastra, J. (1991): *Mapa geológico de España. 1:50.000 serie MAGNA. Hoja n° 1063, Algar.* ITGE.

García de Domingo, A., Hernaiz Huerta P.P., Balanyá J. C. and García Dueñas V. (1994): *Mapa geológico de España. 1:200.000. Hoja n°87 Algeciras.* ITGE

Gavala, L. (1924). *Mapa geológico de la provincia de Cádiz. 1:100.000,* Inst. Geol. Min. España.

Martín-Algarra, A. (1987): *Thesis,* Univ. Granada: 1 - 1271.