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New structural data on the Tertiary of the External Tanger Unit (Intrarif, Morocco)

Nuevos datos estructurales sobre el Cenozoico de la Unidad Tánger Externa (Intrarif, Marruecos)

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ABSTRACT

A tectonic study has been carried out in the Cenozoic of the External Tanger Unit. This parauthocthonous unit, characterized by open SW-vergent folds, overrides by mean of a thrusting the Intrarif Loukkos Unit and it is located at the footwall of different external tectonic units of the Maghrebian Flysch Basin Domain. The tectonic pile is unconformably covered by Upper Miocene-Lower Pliocene postorogenic deposits. The External Tanger Unit experienced a cenozoic polyphasic tectonic deformation generating ENE-WSW, NE-SW, NNE-SSW and NW-SE oriented fracture systems.

Key-words: *Structural analysis, tectonic evolution, Cretaceous-Miocene, External Rif, Morocco.*

RESUMEN

Se ha realizado un estudio estructural en el Cenozoico de la Unidad Tánger Externa. Esta unidad parautóctona, caracterizada por pliegues suaves de vergencia SO, cabalga a la Unidad Loukkos del Intrarif y es cabalgada por diferentes unidades tectónicas del Dominio de la Cuenca de los Flyschs Magrébides. La pila tectónica es recubierta discordantemente por depósitos postorogénicos del Mioceno Superior-Plioceno Inferior. La Unidad Tánger Externa experimentó una deformación tectónica polifásica terciaria generando sistemas de fracturas de orientación ENE-OSO, NE-SO, NNE-SSO y NO-SE.

Palabras clave: *Análisis estructural, evolución tectónica, Cretácico-Mioceno, Rif Externo, Marruecos.*

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Introduction

The Rif Cordillera constitutes the western branch of the Maghrebian Chain (Guerrera and Martín-Martín, 2014; and references therein). Its origin is due to the Miocene fragmentation and migration toward the Africa-Iberia-Adria margins of a Mesomediterranean Microplate placed between the European and African Plates since the Jurassic times (Guerrera *et al.*, 2005, 2012). Other models propose the AlKaPeCa term (Bouillin, 1986). This chain is composed of three main tectonic nappes complexes of nappes: Internal Zones, Maghrebian Flysch Basin (MFB) and External Zones (Guerrera and Martín-Martín, 2014; and references therein).

The Internal Zones are characterized by Hercynian basement crystalline nappes with

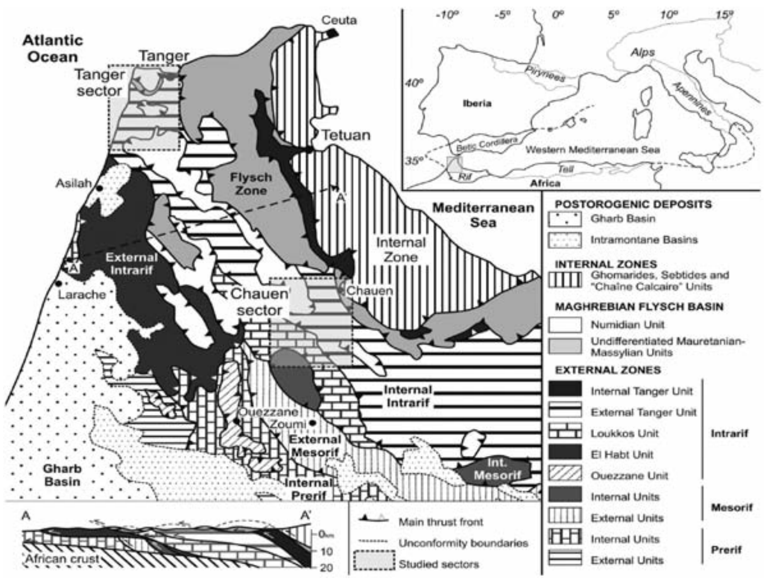


Fig. 1.- Geological sketch of the central-western Rif Chain. Location of figure 2 is marked.

Fig.1.- Esquema geológico de la Cadena del Rif centro-occidental. Se marca la localización de la figura 2.

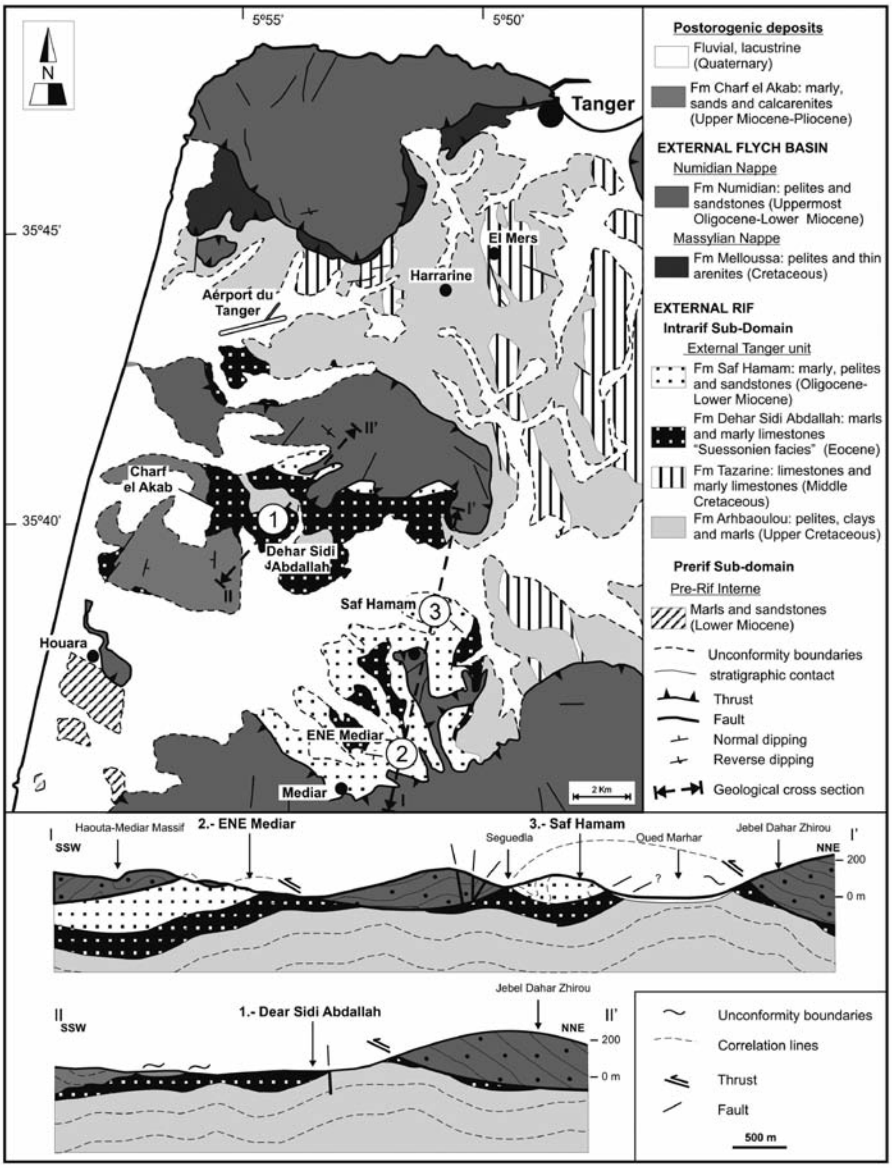


Fig. 2.- Detailed geological map (located in Fig. 1) and cross sections of the Tanger sector with the location of the selected key areas for microstructural analysis.

Fig.2.- Mapa (localizado in Fig. 1) y cortes geológicos detallados del sector de Tánger con la localización de las áreas seleccionadas para los análisis microstructurales

Mesozoic-Tertiary carbonate covers, strongly deformed and frequently affected by Alpine metamorphism, overriding the basinal units of the MFB. These latter consist of Cretaceous-Miocene sedimentary clayey and terrigenous successions that thrust onto the External Units. The External Zones are represented by different nappes of Mesozoic to Cenozoic successions of the African continental margin. The External Rif Zones (ERZ) show high tectonic complexity of nappe structure (Fig. 1) subdivided into tectonic sub-zones (Suter, 1980; Chalouan *et al.*, 2008). This paper presents a structural study (relationships of involved tectonic units and fracturing analysis) of the Cretaceous-Cenozoic of the External Tanger Unit (ETU) of the ERZ (Michard *et al.*, 2008)

Previous knowledge

The ERZ are constituted of allochthonous and parautochthonous units (El Mrihi, 1995; Morel, 1989; Frizon de Lamotte *et al.*, 1991; Chalouan *et al.*, 2001; Zakir and Chalouan, 2003; among others) and was divided into Intrarif, Mesorif and Prerif (Suter, 1980; Tejera de Leon and Duée, 2003; Bargach *et al.*, 2004). The ERZ are related to the passive North African Margin constituting the SW border of the southern branch of the Tethys Ocean (Kuhnt and Obert, 1991; Guerrera and Martín-Martín, 2014) that experienced Mesozoic extension, Paleogene gentle deep folding (Ciszak *et al.*, 1986; Asebriy *et al.*, 1987) at the beginning of the tectonic inversion (from extension and subsidence to contraction), and Miocene thrusting (Chalouan *et al.*, 2008). The Intrarif sub-domain was subdivided into the Internal and External Intrarif. The internal Intrarif comprises the Tanger Unit and the Loukkos Unit (Michard *et al.*, 2008; Chalouan *et al.*, 2008). The External Tanger Unit is characterized by Cretaceous pelites, Paleocene-Eocene limestones and Burdigalian (or younger) terrigenous deposits (Durand Delga *et al.*, 1985; Zaghloul *et al.*, 2005; Chaoulan *et al.*, 2008).

Structural analysis

The Tanger and Chaouen sectors have been selected for this study (Fig. 1). Both sectors show a SW-vergent gentle folding (Figs. 2 and 3). The Cenozoic stratigraphic formations usually crop out in the cores of the synclines where they are still preserved from erosion. Moreover as above mentioned, the Mellousa Unit and the Numidian Nappe (Massylian sub-domain) override the ETU. The External Tanger unit is unconformably overlain by post-orogenic deposits (Upper Miocene-Lower Pliocene) and overthrusts the Loukkos unit (Trias to Upper Cretaceous).

Three key areas mainly affected by abundant syntectonic joints have been selected in the Tanger sector (Fig. 2): 1) Dehar Sidi Abdallah, 2) ENE Mediar and 3) Saf Hamam. This study focuses on fractures affecting the Cenozoic successions at the three sites. It consists of analyzing different families of joints and their relative chronology. Joint orientations are represented through stereographic projections and rose diagrams, using Stereonet program, to display the preferential directions (Fig. 4).

1. In the Dehar Sidi Abdallah area (Fig. 2), three joint directions have been determined: NW-SE (main system), ENE-WSW and NE-SW (subordinate). The NW-SE and ENE-WSW oriented joints are tensional but in some cases they could be considered as hybrid tensional-shear joints. The NE-SW system is considered as a shear system whereas the NW-SE joint system cuts and displaces the ENE-WSW one.

2. The ENE Mediar area (Fig. 2) shows a dominant NNE-SSW joints orientation. A secondary (subordinate) NE-SW oriented system has been observed.

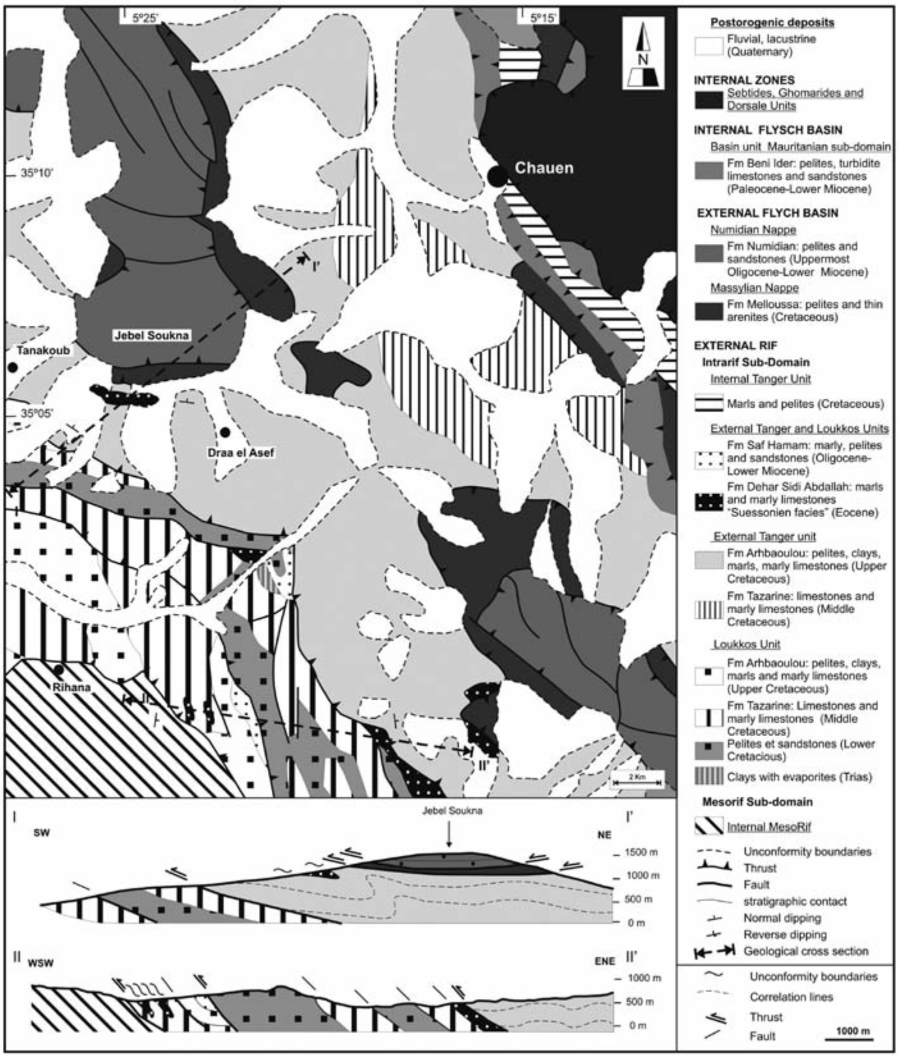
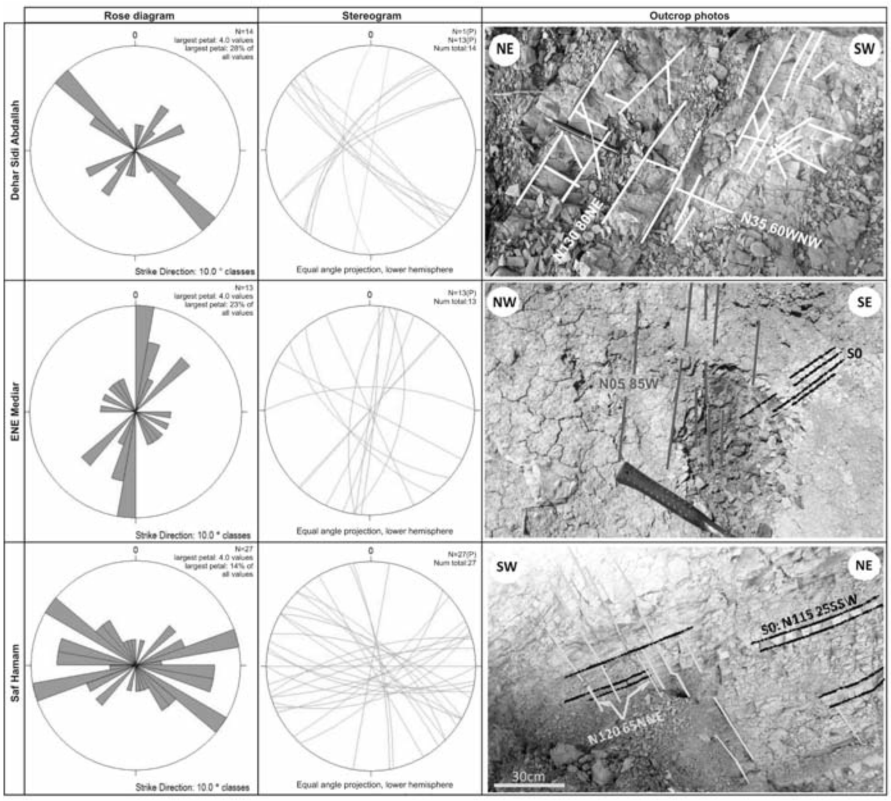


Fig. 3.- Detailed geological map (located in Fig. 1) and cross sections of the Chauen sector.

Fig.3.- Mapa (localizado in Fig. 1) y cortes geológicos detallados del sector de Chauen



3. In the Saf Hamam area (Fig. 2) the joints observed show a more heterogeneous distribution with two preferential joint systems: N110-140E (N1 20E average orientation) and ENE-WSW. The N120E system consists of hybrid joint (tensional-shear) whereas the ENE-WSW system is characterized by shear-type joints.

Discussion and conclusion

The Cenozoic successions of the ETU, corresponding to limestones and detrital deposits, are affected by NW-SE, ENE-WSW, NE-SW and NNE-SSW oriented joint systems. The joint systems from the Dehar Sidi Abdallah area are interpreted through the occurrence of two main contraction phases oriented ENE-WSW and NW-SE. The joint systems observed in the ENE Mediar area are tensional and probably related to a NNE-SSW shortening, while the joint systems from the Saf Hamam area are interpreted as generated by a NE-SW shortening. This deformation is related to the N-S Iberian-African convergence and the westward displacement of the Alboran Block (see also Sanz de Galdeano, 2003; Tejera de Leon and Duée, 2003; Hlila, 2005; Bargach, 2011). In a first stage the migration of the Alboran Block would be also responsible for the closure of the MFB during the Paleogene-Early Miocene and for the development of the Betic-Rifian Arc during the Middle Miocene (Chalouan *et al.*, 2001; Guerrera *et al.*, 2005; 2012; El Kadiri *et al.*, 2006; Guerrera and Martín-Martín, 2014; among others). A change in the shortening direction during the Iberian-African convergence occurred in successive times (Aït Brahim, 1991): NE-SW (Tortonian), NNE-SSW (Late Tortonian) and NW-SE (Late Messinian-Quaternary).

Fig. 4.- Stereoplots, rose diagrams and outcrop photos showing the orientation and frequence of joints recognized in key areas.

Fig.4.- Proyecciones estereográficas, diagramas rosa y fotos de afloramiento mostrando la orientación y la frecuencia de las diaclasas reconocidas en las áreas clave estudiadas.

The analyzed joint systems, affecting Cenozoic successions, occurred therefore after the Mesozoic extension/subsidence and the Paleogene gentle shortening early orogenic (pre-paroxysmal) period, being related to the Oligocene-Miocene *p.p.* syn-orogenic shortening foredeep evolution (ENE-WSW), or to the latest-orogenic evolution (NE-SW, NW-SE and NNE-SSW) tectonic phase (Sanz de Galdeano, 2003; Hlila, 2005; Bargach, 2011).

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