

Meaning of synsedimentary shortening tectonic structures along the Northern limb of the Aït Attab syncline (Central High Atlas, Morocco)

Significado de las estructuras tectónicas sinsedimentarias contractivas a lo largo del flanco norte del sinclinal de Aït Attab (Alto Atlas Central, Marruecos)

Hassane El Makrini¹, Ibrahim Ivanof Régis Mahamat¹, Bennacer Moussaid², Sara Torres-Lopez³, Belen Oliva-Urcia⁴, Juan José Villalain³ and Hmidou El Ouardi¹

¹ CartoTec group, UMI, Faculty of Sciences, PB. 11201 Zitoune, Meknes, Morocco. h.elmakrini@gmail.com; ibrahim2brazza@yahoo.fr; h.elouardi@fs-umi.ac.ma

² Laboratoire de « BGIM », Ecole Normale Supérieure, Université Hassan II, Ghandi Casablanca BP: 500 69, Morocco. bnmous@hotmail.fr

³ Departamento de Física. Escuela Politécnica Superior. Universidad de Burgos. Avd Cantabria S/N, 09006 Burgos, España. storres@ubu.es, villa@ubu.es

⁴ Dpto. de Geología y Geoquímica. Universidad Autónoma de Madrid. Ciudad Universitaria de Canto Blanco, 28049 Madrid, Spain belen.oliva@uam.es

ABSTRACT

This work describes several structures located in the northern limb of the Ait Attab syncline, Central High Atlas, Morocco. The studied structures consist of E-W trending folds affecting the marine terms of the Bajocian, constituted by an alternate succession of marls and limestones and an angular unconformity of Bathonian sandy limestones above the Bajocian series. Taking into account recent works based on AMS and paleomagnetism, considering the presence of an early contractional episode during Bathonian time at Ait Attab or pre-Cenomanian at Imilchil area, we suggest that these folds can be explained as linked to fault or diapiric synsedimentary activity during extensional stage of basin borders, or as shortening structures in Bathonian series, although our structural analysis needs to be further refined.

Key-words: Synsedimentary deformations, Bajocian-Bathonian, Ait Attab syncline, High Atlas, Morocco.

RESUMEN

En este trabajo se describen varias estructuras geológicas observadas a lo largo del flanco norte del sinclinal de Ait Attab, Alto Atlas Central, Marruecos. Las estructuras estudiadas consisten en pliegues de dirección aproximada E-W situados en la parte intermedia de la secuencia marina del Bajociense, constituida por una alternancia de calizas y margas, y una discordancia angular de calizas arenosas del Bathoniense sobre la anterior serie.

Teniendo en cuenta los resultados obtenidos por nuevos trabajos utilizando datos de ASM y paleomagnetismo que muestran la presencia de un episodio de contracción temprana durante el bathoniense en Ait Attab o pre-Cenomaniense en la parte central de la cadena (zona de Imilchil), sugerimos de forma preliminar que los pliegues que afectan a los materiales del Bajociense son el resultado de la actividad sinsedimentaria de la fallas normales o del diapirismo en los bordes de estas cuencas, y los pliegues que afectan a la serie Bathoniense están ligados a un evento de acortamiento durante el bathoniense.

Palabras clave: Deformaciones sinsedimentarias, Bajociense Bathoniense, sinclinal de Ait Attab, Alto Atlas, Marruecos.

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Introduction

The Ait Attab syncline, affecting Jurassic and Cretaceous rocks, is located at the northern border of the Central High Atlas of Morocco (Figs. 1 A and B). This intracontinental belt has been well studied, particularly regarding sedimentological, stratigraphic and magmatic aspects (Haddoumi, 1988; Laville and Piqué, 1991; Ibouh, 1995; Beauchamp *et al.*, 1996; Gomez *et al.*, 2000; Bensalah *et al.*, 2013). Despite this

evidence of a Jurassic-Cretaceous contractional and/or transpressional phase, the spectacular curved shape of this syncline and neighboring structures (Figs. 1B and C) has attracted the attention of several geological studies. Recent works, based on AMS and paleomagnetism (Moussaid *et al.*, 2015) have proposed that this curved shape is inherited from the Ait Attab basin geometry. These authors interpreted the E-W magnetic lineations in this area as the result of N-S convergent context, or linked to sinis-

tral transpression occurred during the Jurassic and Cretaceous periods (Moussaid *et al.*, 2013). Despite this, geological arguments and field data have failed to support this hypothesis. The objective of our research in this area of Ait Attab, is to look for structures and microstructures that can support this interpretation (Jurassic/Cretaceous folding). We have focused our field works on the northern limb of the Ait Attab syncline formed of Jurassic-Cretaceous red beds series, first because the series are complete

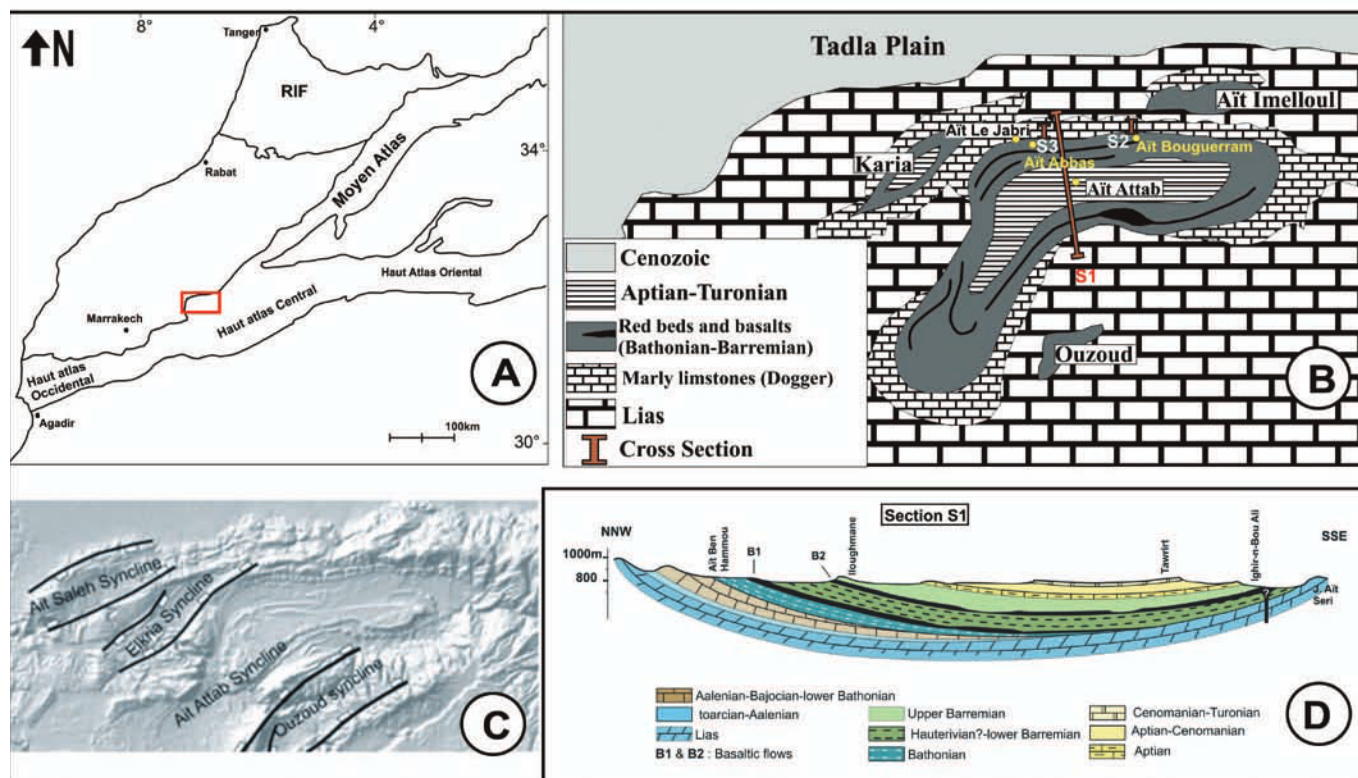


Fig. 1.- A) Location of study area North of High Atlas. B) Geological map of the Ait Attab syncline with location of the studied sites: Ait El Jabri, Ait Abbas; Ait Bouguerrame. C) The main synclines of the Northern border of the High Atlas with continental red beds cropping out in their hinge zones (after Moussaid *et al.*, 2015). D) Geological cross section of the Ait Attab syncline (See section S1, Fig. 1 A, in Haddoumi *et al.*, 2010). Ver figura en color en la web.

Fig. 1.- A) Localización del área de estudio en el norte del alto Atlas. B) Esquema geológico del sinclinal de Ait Attab con la localización de los afloramientos estudiados: Ait El Jabri, Ait Abbas, Ait Bouguerrame. C) Principales sinclinales en el borde norte del Alto Atlas, en cuyos núcleos afloran las capas rojas continentales (a partir de Moussaid *et al.*, 2015). D) Corte geológico del sinclinal de Ait Attab (ver corte S1, fig. 1 A, de Haddoumi *et al.*, 2010). See color figure in the web.

and thick (Fig. 1D) and also, because the transition between the marine Jurassic series and the continental red beds presents significant tectonic structures.

Geological field data

Along the northern limb of the Ait Attab syncline, the Bajocian and Bathonian series (Haddoumi, 1988; Haddoumi *et al.*, 2010) correspond to marls, marly limestones and sandstones. These series decrease in thickness gradually from west to east, along the northern limb of the syncline, and are considerably reduced at its southern limb (Haddoumi, 1988). Therefore there is a significant structural control on sedimentation mainly expressed by thickness changes.

In our field investigations along the northern limb of the Ait Attab syncline, we describe folded structures and unconformities in Ait El Jabri, Ait Abbas and Ait Bouguerrame sites. These structures can be interpreted as the result of syndimentary tectonic events.

Site 1: In the village of Ait El Jabri, along the road Beni-Mellal to Ait Attab,

we noted the presence of shortening syndimentary structures at the base of Bathonian red clays (Fig. 2). They are NW verging reverse faults and E-W trending sealed folds. These structures are sealed by red clay levels showing variation in thickness (Fig. 2 B and C). These folds and faults are affected by the Cenozoic folding.

Site 2: North of the Ait Abbas town, we have described a succession of folds affecting the Bajocian limestones. Fold axes are oriented N076/20°W (Fig. 3).

Site 3: At Ait Bouguerrame, the Bajocian limestones are folded and unconformably overlain by the Bathonian sandy limestones (Fig. 4). The Bathonian strata dip approximately 25°S, and show a progressive unconformity onto the Bajocian deposits dipping 50°S. This progressive unconformity is marked by a lenticular conglomeratic bed. On the other hand, the Bajocian calcareous series shows several metric to decametric folds and drag-folds, trending E-W, and parallel to the main axis of the Ait Attab syncline. These folded calcareous series are capped by the

well marked "Rynconelles bar" (Rolley 1978) dated on the base of Brachiopods as Upper Bajocian (Haddoumi, 1988).

Discussion and conclusion

Tectonic structures observed along the northern limb of the Ait Attab syncline, corresponding to metric and decametric folds, trending E-W, and parallel to the main axis of the syncline, together with the unconformity between the marine Bajocian series and upper Bathonian red beds, militate in favor of a tectonic instability during this period. These structures have been associated with different tectonic settings (i) slumps related to Jurassic extension/transension widely demonstrated at the Atlas basins (Gratier, 1981; Laville and Piqué, 1991; Ibouh, 1995), (ii) Jurassic-Cretaceous shortening deformation events (Moussaid *et al.*, 2013, 2015) or recently, (iii) salt tectonics and gabbroic intrusions associated with the main faults observed in Central High Atlas (Saura *et al.*, 2014, Torres-Lopez *et al.*, 2016). With the data presented in this work, we cannot distinguish their origin.

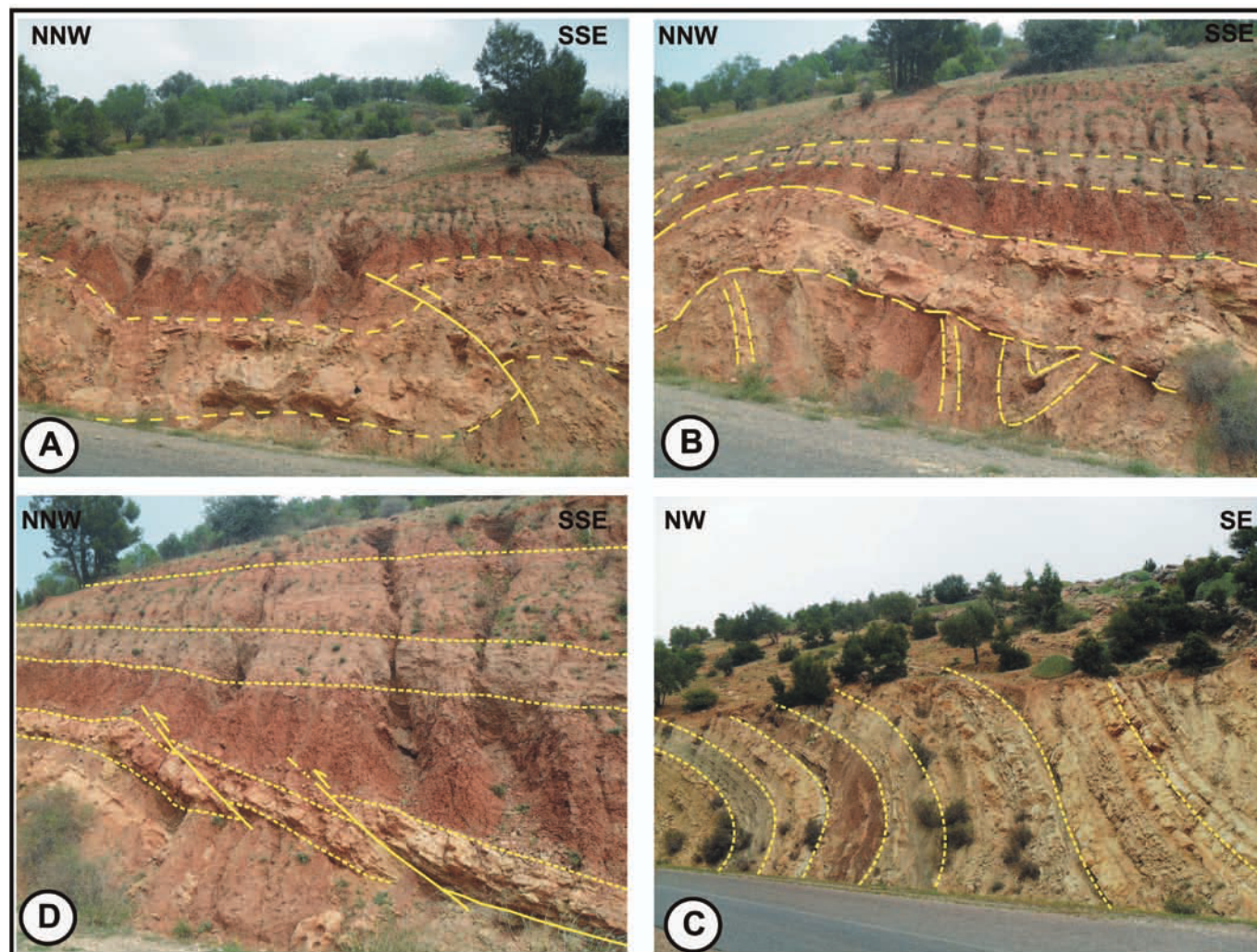


Fig. 2.- Photographs of some structures observed in the Bathonian deposits, Northern limb of the Ait Attab syncline. (A) Metric reverse fault, (B) Synsedimentary sealed folds, (C) Synsedimentary reverse fault, (D) Aspect of the main Cenozoic folding. Ver figura en color en la web.

Fig. 2.- Aspecto en campo de algunas estructuras observadas en los depósitos del Bathoniense, en el flanco norte del sinclinal de Ait Attab. (A) fallas incisas de escala métrica, (B) pliegues sinsedimentarios fosilizados por capas superiores, (C) fallas inversas sinsedimentarias, (D) capas afectadas por el plegamiento principal cenozoico. See color figure in the web.

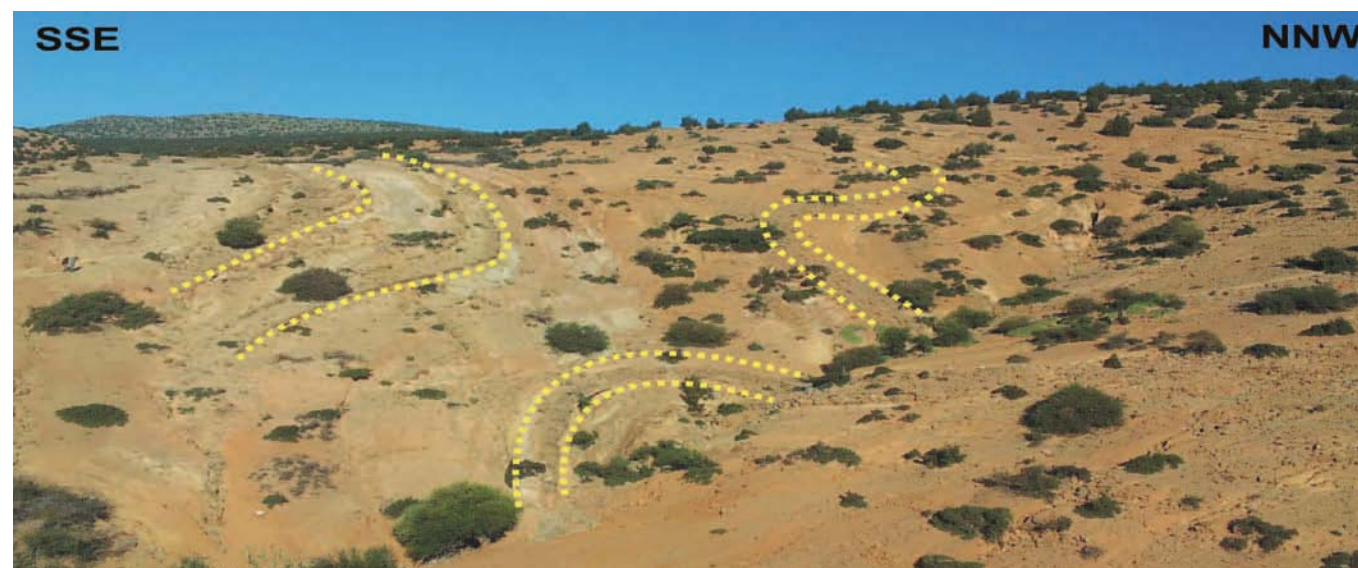


Fig. 3.- Geometry of folds observed at Ait Abbas site. Ver figura en color en la web.

Fig. 3.- Geometría de pliegues en Ait Abbas. See color figure in the web.

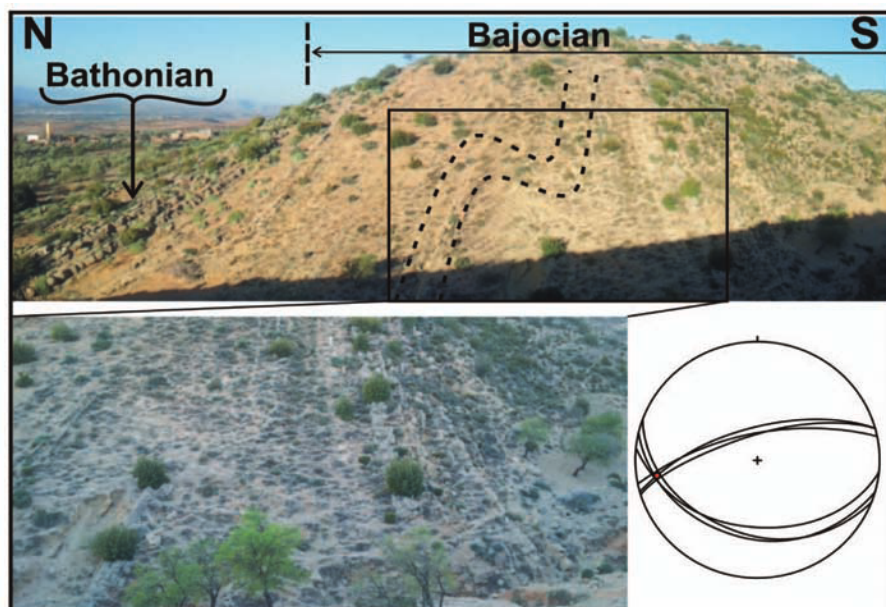


Fig. 4.- Photograph showing the progressive unconformity between Bajocian and Bathonian series at Aït Bouguerrame. Ver figura en color en la web.

Fig. 4.- Discordancia progresiva entre las series Bajociense y Batoniense en Aït Bouguerrame. See color figure in the web.

With respect to the Lower Jurassic and Bajocian series, similar unconformities are widely found near main faults and have been considered as linked to diapiric activity, gabbroic emplacement or distortion related to synsedimentary normal fault reactivation (Laville and Piqué, 1991; Ibouh, 1995; Ettaki *et al.*, 2007; Michard *et al.*, 2011). In our studied area, these deformations have been observed in the Bajocian series located close to basin boundaries without evidences of diapiric nor plutonic activities, and in this case, these structures can be related to an early N-S shortening deformation event.

However, sites studied in Bathonian red beds that are situated far from basin borders, display evidences of a contractional event that are consistent with N-S shortening also attested by the E-W trending magnetic lineation in primary magnetic fabric (Moussaid *et al.*, 2013) and the pre-Cenomanian folding event dated by paleomagnetic data in the Aït Attab area (Moussaid *et al.*, 2015). We can favor the presence of early shortening events, responsible for the change of sedimentation regime since Bathonian time. The general regression in

the Atlas belt, and the abrupt change of sedimentation conditions from marine deposits to the continental red beds since Bathonian time, is probably accentuated by these early tectonic shortening phases.

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References

Beauchamp, W. (1996). *Bulletin American Association of Petroleum geologists* 80, 1459-1482.
 Michard, A., Ibouh, H. and Charrière, A. (2011). *Terra Nova* 23, 5: 314-323.
 Bensalah, M.K., Youbi, N., Mata, J., Madeira, J., Martins, L., El Hachimi, H., Bertrand, H., Marzoli, A., Belleini, G., Doblas, M., Font,

E., Medina, F., Mahmoudi, A., Beraouz, E., Miranda, R., Verati, C., De Min, A., Ben Abbou, M., and Zayane, R. (2013). *Journal of African Earth Sciences* 81, 60-81.
 Ettaki, M., Ibouh, H. y Chellai, E.H. (2007). *Estudios Geológicos* 63 (2), 103-125.
 Gomez, F., Beauchamp, W. and Barazangi, M. (2000). *Geological Society of America* 28, 775-778.
 Gratier J.P. (1981). *Notes et mémoires Service Géologique Maroc* 42, 308 : 195-212.
 Haddoumi H. (1988). *Les couches rouges Bathonien-Barremein du Synclinal des Aït Attab (Haut atlas central, Maroc) étude sédimentologique et stratigraphique*, Thèse du 3^{ème} cycle, Univ. Nancy I, 133 p.
 Haddoumi H., Charrière C. and Mojon P.O. (2010) : *Geobios* 43, 433-451.
 Ibouh, H. (1995). *Tectonique en Décrochement et Intrusions Magmatiques au Jurassique. Tectogenèse polyphasée des Rides Jurassiques D'Imilchil (Haut Atlas Central, Maroc)*. PhD thesis, Univ. Cadi Ayyad, Marrakech, Morocco, 225 p.
 Laville, E. and Piqué, A. (1991). *Bulletin de la Société Géologique de France* 162, 1161-1171.
 Michard, A., Ibouh, H. and Charrière, A. (2011). *Terra Nova* 23 (5), 314-323
 Moussaid, B., El Ouardi, H., Casas-Sainz, A., Villalain, J.J., Román-Berdiel, T., Oliva-Urcia, B., Soto, R. and Torres-López, S. (2013). *Journal of African Earth Sciences* 87, 13-32.
 Moussaid B., Villalain, J.J., Casas-Sainz, A., El Ouardi, H., Oliva-Urcia, B., Soto, R., Román-Berdiel, T. and Torres-López, S. (2015). *Journal of Structural Geology* 70, 65-77.
 Rolley, J.P. (1978). *Carte géologique du Maroc au 1/100.000: feuille d'Afouzer. Notice explicative*. Notes et Mémoires du Service Géologique du Maroc, Rabat, 247 and 247 bis, 1-103.
 Saura, E., Verges, J., Martín-Martín, J.D., Messager, G., Moragas, M., Razin, P., Grelaud, C., Joussiaume, R., Malaval, M., Homke, S. and Hunt, D.W. (2014). *Journal of the Geological Society of London* 171, 97-105.
 Torres-López S., Casas A., Villalain J.J., El Ouardi H. and Moussaid B. (2016). *Terra Nova* 28 (2), 110-119