Revista de la Sociedad Geológica de España 30 (1)

ISSN (versión impresa): 0214-2708
ISSN (Internet): 2255-1379

THE STRATIGRAPHIC RECORD OF THE LATE JURASSIC-EARLY CRETACEOUS RIFTING IN THE ALTO TAJO-SERRANÍA DE CUENCA REGION (IBERIAN RANGES, SPAIN): GENETIC AND STRUCTURAL EVIDENCES FOR A REVISION AND A NEW LITHOSTRATIGRAPHIC PROPOSAL

El registro estratigráfico del rifting Jurásico Superior-Cretácico Inferior en la región del Alto Tajo-Serranía de Cuenca (Cordillera Ibérica, España): Evidencias genéticas y estructurales para su revisión y nueva propuesta litoestratigráfica

Marian Fregenal-Martínez[1*], Nieves Meléndez[1,3], M. Belén Muñoz-García[1], Javier Elez[2] and Raúl de la Horra[1]

[1] *Departamento de Estratigrafía. Facultad de Ciencias Geológicas. Universidad Complutense de Madrid, Spain. mariana@ucm.es, nievesml@ucm.es, mbmunoz@ucm.es, rhorraba@ucm.es*
[2] *Departamento de Geología. Facultad de Ciencias. Universidad de Salamanca, Spain. j.elez@usal.es*
[3] *Instituto de Geociencias (UCM-CSIC), C/ José Antonio Novais 12, 28040, Madrid, Spain.*

Abstract: *The Southwestern Iberian Domain (Southiberian Basin) corresponds to one of the five palaeogeographic domains into which the Iberian Basin was divided during the Late Jurassic-Early Cretaceous rifting stage. Although it was already known that this domain was clearly separated into two sub-basins, Cuenca and Valencia, the same lithostratigraphic scheme was assumed to be applicable to the whole domain. In the last decades, new data have been incorporated to the knowledge of the Serranía de Cuenca and the Alto Tajo region, showing that this area underwent a separated palaeogeographic evolution and developed a different stratigraphic record. Evidences of such independence are, among others, the development of a Late Jurassic-early Barremian unconformity with unique features in the Iberian Basin and herein described for the first time. Syn-rift sedimentation was controlled by an intricate extensional geometrical and kinematic pattern of multiple and small half-graben basins, and it is represented by just two unconformity-bounded units, late Barremian and Aptian in age respectively. This work reviews, clarifies, and simplifies old and confusing stratigraphic nomenclatures and proposes a specific lithostratigraphic scheme for the Alto Tajo-Serranía de Cuenca region. It includes the new upper Barremian Tragacete Formation and the redefinition of La Huérguina Formation in terms of lithofacies, lower boundary, age and environmental interpretation.*

Key-words: *Southwestern Iberian, Tragacete Formation, La Huérguina Formation, upper Barremian, Aptian; continental sedimentation.*

Resumen: *El Dominio Ibérico Suroccidental (Cuenca Suribérica) corresponde a uno de los cinco dominios paleogeográficos en los que se ha dividido la Cuenca Ibérica (actual Cordillera Ibérica) durante el ciclo de rifting intracontinental Jurásico Superior-Cretácico Inferior. Aunque se sabe que el Dominio Ibérico Suroccidental estuvo compartimentado en dos sub-cuencas diferentes, Cuenca y Valencia, hasta la actualidad se ha asumido que el relleno sedimentario de ambas era asimilable y se ha aceptado un único esquema litoestratigráfico para ambas. Varias décadas de estudio e integración de datos estructurales, estratigráficos, sedimentológicos y paleontológicos del área de la Serranía de Cuenca y el Alto Tajo (Cuenca y Guadalajara) han revelado que esta región sufrió una evolución paleogeográfica independiente y posee un registro estratigráfico particular, que no se refleja en los esquemas estratigráficos disponibles para el Dominio Suroccidental. Evidencias de esta singularidad son (1) el desarrollo de una discontinuidad estratigráfica Jurásico Superior-Barremiense inferior con características únicas en el contexto de la Cuenca Ibérica y descrita por primera vez en este trabajo; (2) el registro más tardío (Barremiense superior) del comienzo de la sedimentación sinrift en la Cuenca Ibérica. La sedimentación sinrift estuvo muy condicionada por el desarrollo de un complejo patrón extensional y cinemático que compartimentó la cuenca en múltiples cubetas de tipo graben y semi-graben, y está representada por dos unidades limitadas por discontinuidades. La primera unidad es Barremiense superior y está compuesta* *por dos unidades litoestratigráficas con rango de formación constituidas por sedimentos continentales que se superponen y presentan cambio lateral de facies: la Formación Tragacete, que se define formalmente por primera vez en este trabajo, y la Formación La Huérguina, que se redefine formalmente aquí en términos de litofacies, límite inferior, edad y ambientes sedimentarios. También se descarta la presencia y validez en el área de estudio de la Formación El Collado, hasta la actualidad considerada cambio lateral de facies de la Formación La Huérguina en su definición inicial. La segunda unidad es Aptiense y está compuesta por la Formación Contreras que cambia lateralmente de facies al Miembro Malacara (Formación El Caroch), y por el Miembro El Burgal (Formación El Caroch). Sobre ambas unidades limitadas por discontinuidades se apoya discordante el Grupo Utrillas (Albiense), no existiendo registro en esta cuenca de otras unidades aptienses y albienses recogidas en los esquemas estratigráficos tradicionales del Dominio Suroccidental. Además, en este trabajo se revisan y clarifican las diversas nomenclaturas que se han venido usando en las últimas décadas en trabajos publicados y mapas geológicos nacionales de la serie MAGNA correspondientes a esta región.*

Palabras clave: *Ibérica Suroccidental, Formación La Huérguina, Formación Tragacete, Barremiense Superior, Aptiense, sedimentación continental.*

Fregenal-Martínez, M., Meléndez, N., Muñoz-García, M.B., Elez, J. and de la Horra, R. (2017): The stratigraphic record of the Late Jurassic-Early Cretaceous rifting in the Alto Tajo-Serranía de Cuenca region (Iberian Ranges, Spain): Genetic and structural evidences for a revision and a new lithostratigraphic proposal. *Revista de la Sociedad Geológica de España*, 30(1): 113-142.

The stratigraphic architecture of rift-related basins is largely constrained by the specific features of the main tectonic structures that define the basin and their evolution. Complex rift-related basins, with elaborate internal compartmentalization at several scales, also show complex stratigraphic architectures; their depiction can be hindered when tools to classify such record are not adequate, and structures that control the stratigraphic and palaeogeographic evolution are not properly known. Lithostratigraphy is the most traditional, essentially descriptive, method to classify the stratigraphic record of any kind of basin, and it should still be the basis for such classification as far as it is supported by the genetic analysis.

In this sense, the Iberian Basin has been extensively studied for many decades. However, the lithostratigraphic schemes proposed for certain areas and stratigraphic intervals were developed before genetic basin analysis had been accomplished, and before the structural patterns and kinematics were well known. Hence, it might be adequate to carry out a thoroughly revision of the basic stratigraphic scheme of the basin whose knowledge has been recently improved in terms of structural, stratigraphic and palaeogeographic constrains and evolution.

The Iberian Basin was an intracratonic rift-related basin characterized by a complex and multi episodic evolution that started in Early Permian times and underwent two major rifting cycles separated by periods of post-rift thermal subsidence (Sopeña *et al*., 1988; Salas and Casas, 1993; Van Wees and Stephenson, 1995; Arche and López-Gómez, 1996; Van Wees *et al*., 1998; Salas *et al*., 2001; Sopeña, 2004). The first main rift cycle developed from Early Permian to Middle Triassic. The second main rift cycle lasted from Late Jurassic to Early Cretaceous (Álvaro *et al*., 1979) and divided the basin into several paleogeographic domains (Soria *et al*., 2000; Salas *et al*., 2001): Northwestern (Cameros Basin), Central, Eastern (Maestrazgo or Maestrat Basin) and Southwestern (Southiberian Basin) (Vilas *et al*., 1982; Soria *et al*., 2000; Salas *et al*., 2001; Mas *et al*., 2004; Liesa *et al*., in press) (Fig. 1). All of them underwent several discrete episodes of extension during this rifting cycle and, as a result, developed thick and complex sedimentary successions.

The Southwestern Domain has long been recognized to be separated in two main sub-basins during the Early Cretaceous, at least, until the Aptian. The paleogeographic reconstruction that Mas *et al*. (1982) carried out for the Berriasian to Aptian time span in the Valencia and eastern Cuenca provinces, already revealed the presence of two well-defined depocenters, one located in Valencia and another in Cuenca. In this line, Meléndez *et al.* (1994) defined the Serranía de Cuenca Basin as a basin separated from the Valencia Basin by the Landete-Teruel transfer fault (Poyato-Ariza *et al*., 1998; Soria *et al*., 2000, Liesa *et al*., in press). Nevertheless, and up to now their similitude and/or equivalence in terms of stratigraphy and palaleogeographic evolution has been assumed without any further discussion. In this sense, the original lithostratigraphic classification of the successions of the Southwestern Domain (Vilas *et al*., 1982; Mas *et al*., 1982) into formal lithostratigraphic units has been maintained without relevant modifications for more than thirty years. The most recent review and scheme provided by Mas *et al*. (2004), maintains the original proposal with some minor modifications. The scheme was still assumed to be valid for both sub-basins, Cuenca and Valencia, and it does not recognize the existence of stratigraphic differences between them (Fig. 2).

Since the seminal works of Vilas *et al*. (1982) and Mas *et al*. (1982) on the regional stratigraphy of the Southwestern Iberian Domain, the ongoing works on the Serranía de Cuenca and its northwestwards prolongation into the Alto-Tajo region have deepened the knowledge on this region in stratigraphic, structural, sedimentological, and palaeontological terms (Gómez Fernández, 1988; Meléndez *et al*., 1989; Gómez Fernández and Meléndez, 1991; Gierlowski-Kordesch *et al*., 1991; Fregenal-Martínez, 1994, 1998; Meléndez *et al*., 1994; Fregenal-Martínez and Meléndez, 1993, 2000, 2016; Poyato-Ariza *et al*., 1998; Buscalioni *et al*., 2008; De Vicente and Martín Closas, 2013; Fregenal-Martínez *et al*., 2014a,b).

The genetic analysis carried out in the Alto Tajo-Serranía de Cuenca region, has shown that it underwent a separated palaeogeographic evolution during the Late Jurassic-Early Cretaceous rifting cycle. In addition, recent results of a comprehensive structural analysis of the area (Fregenal-Martínez *et al*., 2014a; Elez *et al*., 2015) indicate that the stratigraphic succession is constrained by the development of multiple and small half-graben like basins that, in turn, create severe differences in the spatial distribution of the thickness and facies of the deposits. One of the results and the evidence of such independent evolution is a stratigraphic succession unique to this region, which is not reflected by the stratigraphic scheme currently available for the entire Southwestern Domain proposed by Mas *et al*. (2004).

Thereafter the aim of this work is to review, classify and discuss the Upper Jurassic-Lower Cretaceous syn-rift stratigraphy of the Alto Tajo-Serranía de Cuenca region, using traditional lithostratigraphic tools as a basis for the ongoing genetic analysis. Furthermore, an updated stratigraphic scheme appropriate to this area will be generated. The absence of Upper Jurassic sediments in this area and hence the development of an unconformity with unique features in the Iberian Basin are herein described for the first time. Syn-rift sedimentation is represented by two unconformity-bounded units, late Barremian and Aptian in age, respectively. The lithostratigraphic scheme proposed for this area includes a new upper Barremian lithostratigraphic unit named Tragacete Formation and the redefinition of La Huérguina Formation in terms of lithofacies, lower boundary, age, and environmental interpretation. Therefore, this work aims to clarify and simplify the diverse and confusing nomenclatures that have been used for the last decades in the literature and geological maps of the

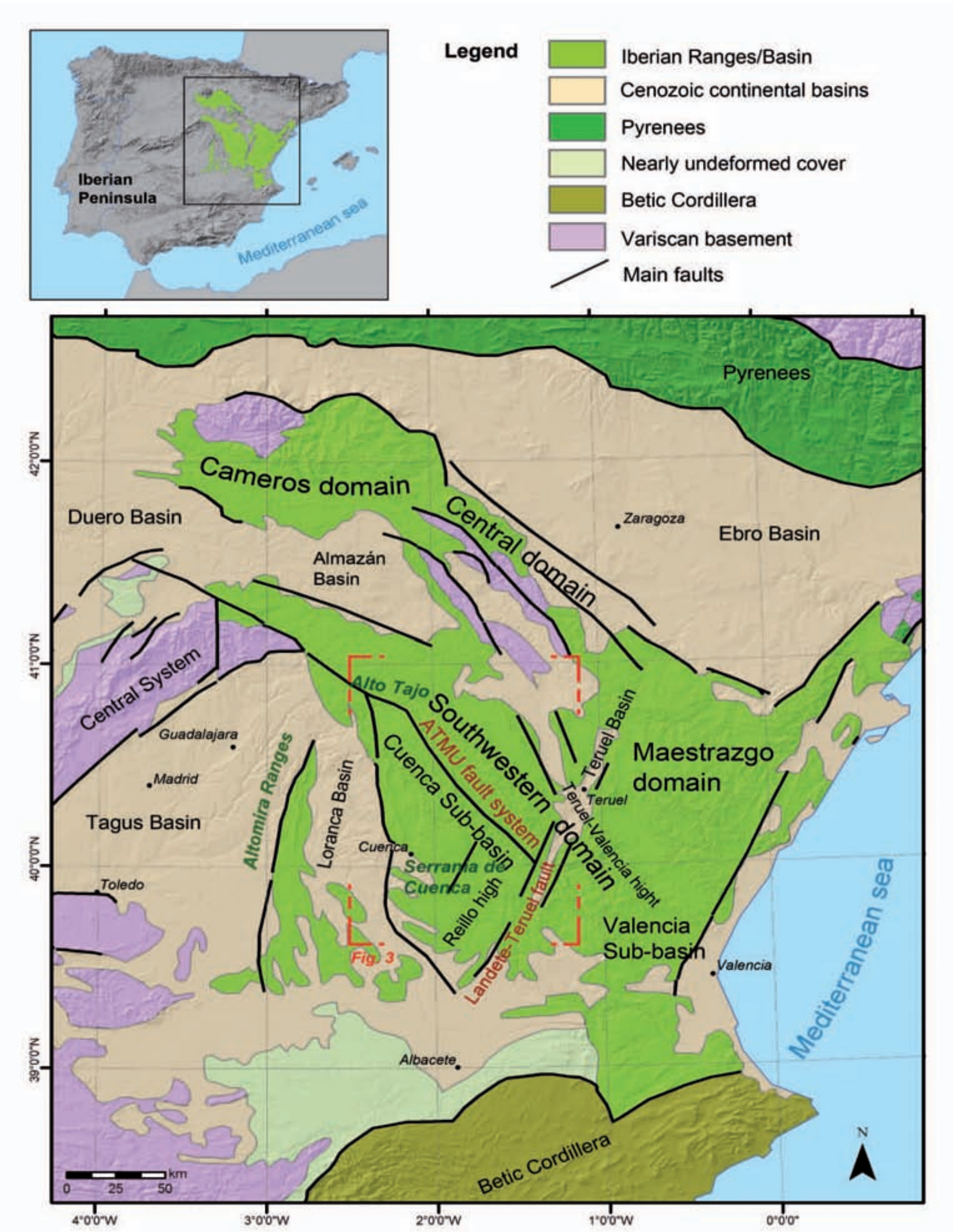

Fig. 1.- Location of the Iberian Basin/Ranges and the main domains and structures. Modified from Vera (2004). The frame encloses the studied area (see Fig. 3). ATMU: Alto Tajo-Montes Universales.

National Geological Mapping Program (MAGNA) for this region, due to the poor knowledge on the stratigraphy of this area and its peculiarity in the structural framework of the Southwestern Iberian Domain.

Area of study and geological framework

This study concentrates on the Upper Jurassic-Lower Cretaceous successions outcropping in the southern part of the Guadalajara province, and all along the Cuenca province, in east-central Spain (Fig. 1). The area of study (Fig. 3) occupies twenty 1:50.000 geological maps of the MAGNA Plan and is fairly coincident with the two contiguous geographic regions known as Alto Tajo and Serranía de Cuenca. This area occupies two thirds of the total extension of the Southwestern Iberian Domain (Vilas *et al*., 1982; Soria *et al*., 2000; Liesa *et al*., in press) at its northwestern area, following the typical NW-SE Iberian trend (Fig. 1). To the NE and E, it is limited by the Teruel-Valencia High (Meléndez *et al*., 1994; Soria *et al*., 2000; Liesa *et al*., in press), which separates the Southwestern Domain from the Central and Eastern (Maestrazgo) Iberian domains, also following a NW-SE trend. To the S and SE, the Landete-Teruel Fault separates it from the Valencia Subbasin (Meléndez *et al*., 1994; Poyato-Ariza *et al*., 1998). To the W and SW the limit is defined by the absence of Lower Cretaceous outcrops which are covered by uppermost Cretaceous and Cenozoic successions. The north-westernmost outcrops are located around the village of Abánades in the Guadalajara province.

At present, the study area is located in the Iberian Ranges. This mountain chain, broadly NW-SE oriented (Fig. 3), was generated by the Alpine tectonic inversion of the previous rift related Iberian Basin (*e.g.,* Salas *et al*., 2001; De Vicente *et al*., 2009). The entire history (extension and later inversion) and general trend of the basin are strongly constrained by the inherited Variscan fabrics (*e.g.,* Álvaro *et al*., 1979; Arche and López-Gomez, 1996; Salas *et al*., 2001; Sopeña, 2004; De Vicente *et al*., 2009). Among them, the broadly oriented NW-SE and NE-SW to N-S structural anisotropies are the most relevant ones (*e.g.,* Alvaro *et al*., 1979).

The first main rifting cycle (Early Permian-Triassic) is represented in the whole Iberian Basin by the so-called Triassic Germanic facies. Extension is interpreted to occur under triaxial conditions, with a main extension direction NE-SW oriented (De Vicente *et al*., 2009). The progression of the stretching led to the development of NE-SW oriented transfer faults (Arche and Lopez-Gómez, 1996). Sedimentation from the latest Triassic to the Middle Jurassic took place in a thermal subsidence dominated regime and is re-

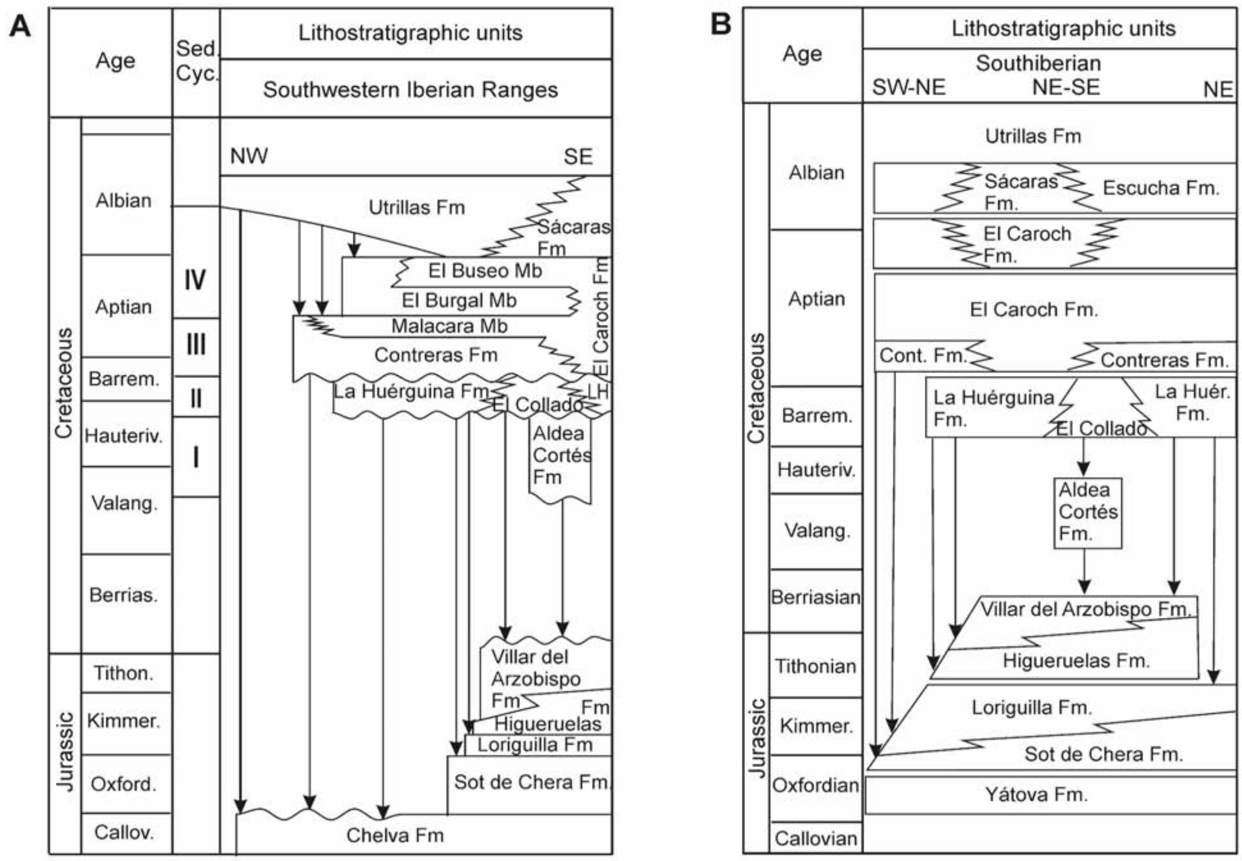

Fig. 2.- Lithostratigraphic schemes which involve the study area, previous to this work. Both schemes were designed according to the geologic time scales that were valid at that moment and they have been maintained as in their original edition. A. Formal lithostratigraphic units and cycles defined by Vilas *et al.* (1982) and Mas *et al.* (1982) for the Upper Jurassic-Lower Cretaceous stratigraphic record in the Southwestern Domain, as modified and redrawn by Fregenal-Martínez (1998). This chart already included some of the main stratigraphic differential features of the Serranía de Cuenca region discussed in this paper. B. Lithostratigraphic scheme of the Upper Jurassic-Lower Cretaceous record in the Southiberian Basin according to Salas *et al.* (2001) and Mas *et al.* (2004).

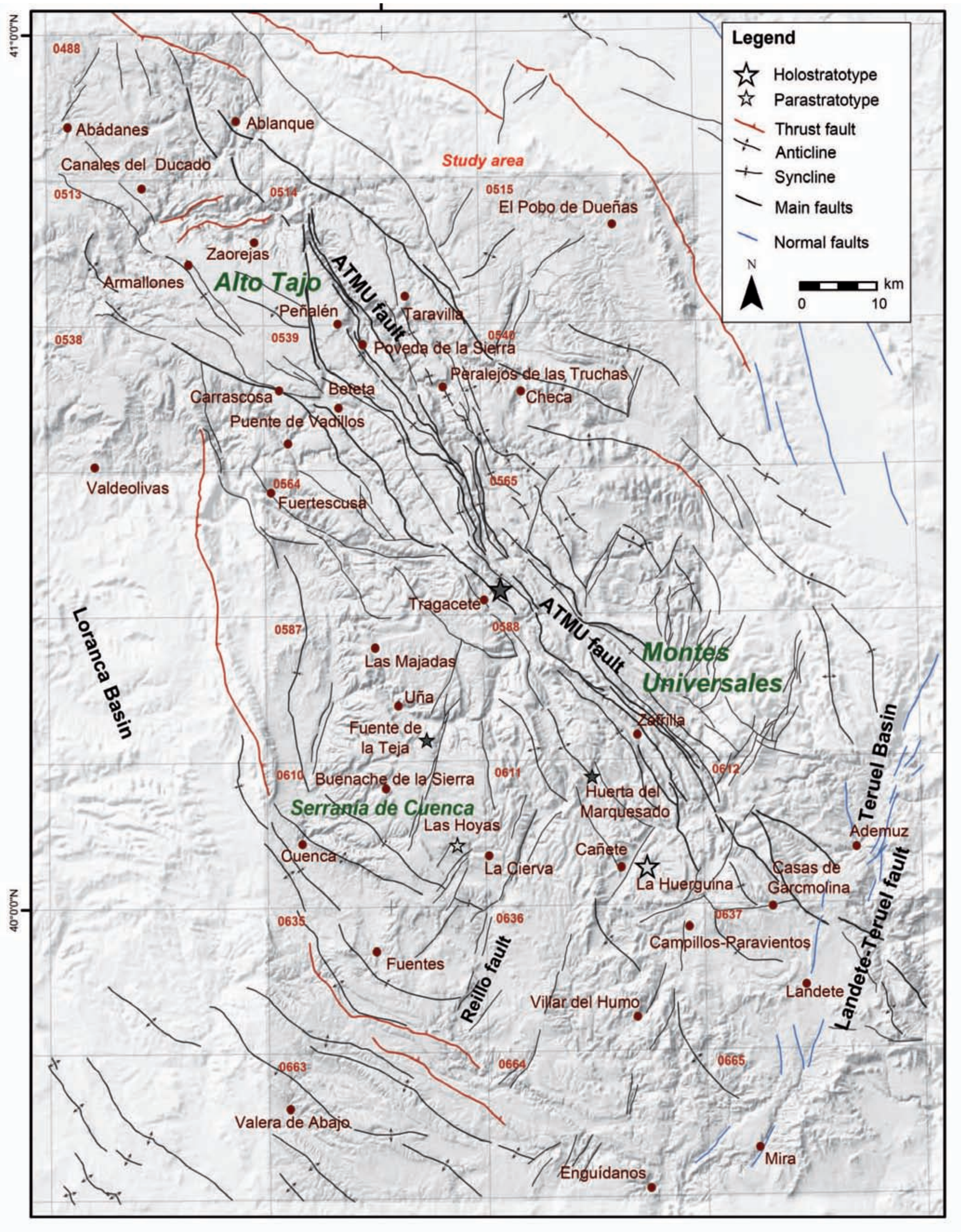

Fig. 3.- General map of the study area showing the main structural features, as well as the distribution of the revised 1:50,000 geological maps of the MAGNA Plan (488 Ablanque; 513 Zaorejas; 514 Taravilla; 515 El Pobo de Dueñas; 538 Valdeolivas; 539 Peralejos de las Truchas; 540 Checa; 564 Fuertescusa; 565 Tragacete; 587 Las Majadas; 588 Zafrilla; 610 Cuenca; 611 Cañete; 612 Ademuz; 635 Fuentes; 636 Villar del Humo; 637 Landete; 663 Valera de Abajo; 664 Enguidanos; 665 Mira). The location of the reference sections for the defined lithostratigraphic units are also included (dark grey stars for Tragacete Formation and light grey stars for La Huérguina Formation). Main structural grain redrawn from Rodríguez-Pascua *et al.* (1994), De Vicente *et al.* (2009), and 1:50,000 geological maps of the MAGNA Plan. ATMU fault: Alto Tajo-Montes Universales fault.

presented by a relatively thin and homogenous succession of shallow marine carbonates (Gómez *et al.,* 2004).

From the regional point of view, the second rifting cycle spanned from the Late Jurassic until the Early Cretaceous (Kimmeridgian-middle Albian; see Liesa *et al*., in press). It was coeval with the northwards progression of the Atlantic Rift System to the W, the aperture of the bay of Biscay to the N, the opening of the western Tethys to the E and a strong anticlockwise rotation of Iberia (*e.g.*, Ziegler, 1988; Rosembaum *et al*., 2002; Vissers *et al*., 2013; Tugend *et al*., 2015). The inherited structural fabrics were reactivated and the Iberian Basin resulted divided into the above-mentioned palaeogeographic domains (*e.g.*, see Liesa *et al*., in press, and discussion therein), including the Southwestern Domain studied in the present work. For the entire Iberian Basin the amounts and rates of subsidence were not evenly distributed and relevant variations in the thickness and timing of the deformation are recorded (*e.g.,* Van Wees *et al*., 1998). Broadly speaking, the basin main trend is NW-SE oriented with transfer faults ranging from NE-SW to N-S directed. However, the complex geodynamical context of this basin does not allow a simple interpretation about the kinematic, the general stress vectors or its spatial and temporal evolution (see discussion in Liesa *et al*., in press).

In detail, the evolution of the region is highly constrained by the Alto Tajo-Montes Universales fault system (near NW-SE directed, ATMU in Fig. 3) and the NE-SW Landete-Teruel fault (LT fault), both classically interpreted as successive reactivations in extension (and later inversion) of the Variscan fabrics (*e.g.*, Álvaro *et al*., 1979). The Alto Tajo-Montes Universales fault system is a relatively narrow complex deformation zone broadly responding to overall dextral transpression during the Alpine inversion (see Rodríguez-Pascua *et al*., 1994 and De Vicente *et al*., 2009 and discussion therein). Nowadays, this structure is approximately 10-20 km wide, can be followed more than 150 km and is interpreted as a major crustal-scale anisotropy in the Iberian Peninsula. Previous authors proposed this fault to be one of the main extensional faults of the Iberian Basin during the existing rifting cycles (*e.g.*, Alvaro *et al*., 1979; Arche and López-Gómez, 1996; Sopeña, 2004; Liesa *et al*., in press). During the Late Jurassic-Early Cretaceous rifting cycle this fault clearly constrained the basin main trend, NW-SE oriented (*e.g.*, Álvaro *et al*., 1979; Sopeña, 2004; De Vicente *et al*., 2009; Liesa *et al*., in press). This fault broadly coincides with the western limit of the Teruel-Valencia High, representing the northeast and east limits of the study area respectively (Fig. 3). In the same manner, the LT fault, more than 100 km long, nowadays shows a half-graben like geometry filled with continental Cenozoic sediments, shaping the Teruel Basin (*e.g.*, Anadón *et al*., 2004). This fault and similar parallel ones (Fig. 3) such as the Reíllo fault (Ramírez de Pozo *et al*., 1974; Meléndez, 1983) are clearly identified to be active during the Later Jurassic-Early Cretaceous as transfer faults (see Liesa *et al*., in press, and discussion therein).

As mentioned above, the main structural trend in this region is similar to that of the Iberian Basin (NW-SE), but the main set of identified extensional faults in the study area is broadly N110 directed with steep and relatively long (more than 20 km), NE-SW to N-S directed transfer faults (Fig. 3) (Fregenal-Martínez *et al*., 2014a; Elez *et al*., 2015). Individual half-graben like basins bounded by these faults are small (< 10 km in length), but the combination at broader scales of complex half grabens, relay ramps, transfer zones and identified local shoulder uplift phenomena points to an overall elaborated extensional geometrical pattern. In this scenario, the palaeogeographic distribution of accommodation space was quite heterogeneous, with scattered depocenters separated by local paleogeographic highs both evolving along time, and thus generating relevant variations in the thickness of the deposits and the timing of the deformation (*e.g.*, Van Wees *et al*., 1998; Fregenal-Martínez *et al*., 2014a; Elez *et al*., 2015).

Methods

This work combines:

(1) The revision of twenty 1:50 000 geological maps of the MAGNA Plan as well as the reinterpretation of their accompanying reports (see location in Fig. 3). The cartographic revision was performed also in a GIS-based environment using the Digital Geological Map 1:50.000 (GEODE project; www.igme.es) from the Spanish Geological Survey (IGME), an improved and digitized version (in shape format) of the MAGNA Plan. All modifications and re-assignation of cartographic units after fieldwork were incorporated successively in the analysis.

(2) A thoroughly revision of the literature about the Middle-Upper Jurassic and Lower Cretaceous of the Southwestern Iberian Ranges (most of it published previously to the formal lithostratigraphic proposal of Vilas *et al*., 1982).

(3) Fieldwork consisting of thorough geological mapping of key areas, extensive sampling, and stratigraphic, sedimentological, structural and palaeontological analyses of the Upper Jurassic-Lower Cretaceous stratigraphic record in the Alto Tajo-Serranía de Cuenca area. Partial results have been published by the authors during the last decades (Meléndez, 1982, 1983; Mas *et al*., 1982; Meléndez *et al*., 1989; Gómez-Fernández and Meléndez, 1991; Gierlowski-Kordesch *et al*., 1991; Fregenal-Martínez, 1994, 1998; Fregenal-Martínez and Meléndez, 1993, 2000, 2016; Buscalioni *et al*., 2008; Buscalioni and Fregenal-Martínez, 2010; Fregenal Martínez and Muñoz-García, 2010; Muñoz-García *et al*., 2012; Fregenal-Martínez *et al*., 2014a,b; De la Horra *et al*., 2014; Elez *et al*., 2015; Muñoz-García *et al*., 2015).

The lithostratigraphic units proposed in this study and their stratotype localities have been defined and described following the procedure and terminology recommended by the International Subcommission on Stratigraphic Classification of IUGS Commission on Stratigraphy (Hedberg, 1976; Salvador, 1994; Murphy and Salvador, 1998; International Commission on Stratigraphy, 2016).

Previous regional works and foundations of this study

The presence of Lower Cretaceous sediments in the Serranía de Cuenca and Alto Tajo regions is known since the late 1960s, and there are a large number of studies dealing with those successions in different localities (Viallard, 1966, 1968, 1969; Curnelle, 1968; Menéndez Amor, 1970; Meléndez Hevia, 1971, 1972, 1974; Ramírez del Pozo and Meléndez Hevia, 1972; Viallard, 1973; Brenner and Wiedman, 1974; García Quintana, 1977; Meléndez Hevia *et al*., 1974a, b; Ramírez del Pozo *et al.*, 1974). In such early studies, what is currently known to be an ensemble of different and mostly siliciclastic lithostratigraphic units, in some cases separated by unconformities, were included as a whole under the term Weald. However, most of the carbonate successions of the uppermost Hauterivian-lower Barremian (La Huérguina Formation) were not recognized and thus, those successions were not included into the Weald and remained usually attached to the underlying Jurassic substrate. Currently the term Weald is not longer formally used to refer to the Lower Cretaceous successions of the Iberian Basin, although it is still used in colloquial terms. The term Weald is present in the oldest publications and in the reports accompanying the 1:50,000 geological maps of the MAGNA Plan. It is also used by the palaeontological scientific community to denote some Lower Cretaceous characteristic fossil associations well known all around Europe that contain dinosaur faunas (Holtz *et al*., 2004).

Vilas *et al*. (1982) and Mas *et al*. (1982) defined the lithostratigraphy and interpreted the palaeogeographic evolution of the area, mostly considering the known outcrops in Valencia and southern Cuenca provinces, at that moment (Fig. 2A). These authors separated the Lower Cretaceous of the Southwestern Domain into four sedimentary cycles tectonically controlled by the rifting process. The lithostratigraphic units that composed such cycles were formally defined by Vilas *et al*. (1982) and derived from the studies carried out in Valencia by García-Quintana (1977) and Mas (1981), and in Cuenca and Rincón de Ademuz (Valencia) by Meléndez (1983). The four cycles defined are (Fig. 2A):

(1) Valanginian-lower Hauterivian Cycle I: This cycle developed just in the Valencia Sub-basin and is composed of the Aldea de Cortés Formation that overlies unconformably the Upper Jurassic Villar del Arzobispo Formation.

(2) Uppermost Hauterivian-lower Barremian Cycle II: Composed of El Collado and La Huérguina formations, related by a lateral change of facies. La Huérguina Formation shows an expansive trend over El Collado Formation. Meléndez *et al*. (1994) later established that El Collado Formation would occupy and crop out at the northern and marginal areas of the Serranía de Cuenca, while La Huérguina Formation would be widespread at its central area, expanding progressively over the marginal areas and overlying El Collado Formation. Both units unconformably overlie different Upper Jurassic lithostratigraphic units.

(3) Upper Barremian-lower Aptian Cycle III: Composed of the Contreras Formation, whose upper part changes laterally to the Malacara Member (El Caroch Formation).

(4) Upper Aptian Cycle IV: Composed of El Burgal and El Buseo members (El Caroch Formation), both related by a lateral change of facies.

Until now this is the formal lithostratigraphic scheme used in the studies on the Lower Cretaceous in the Southwestern Domain. However, there is still a notable confusion in the units mapped in the 1:50,000 geological maps of the MAGNA Plan of the area, due to: 1) Misidentification of the stratigraphic units and unconformities; 2) Use of different lithostratigraphic schemes, in such a way that some maps edited after 1982 adopted the lithostratigraphy proposed by Vilas *et al*. (1982), while others maintained older proposals or developed their own criteria; and 3) The features of the Upper Jurassic-Lower Cretaceous in the Alto Tajo-Serranía de Cuenca do not exactly meet the defining parameters of Vilas *et al*. (1982) and Mas *et al*. (1982), which makes difficult the use of the scheme in many of the outcrops and localities.

More than thirty years have gone by since the formal lithostratigraphy of the Lower Cretaceous was established for the Serranía de Cuenca. The outcomes of the works carried out during these three decades, and the studies developed on some unexplored areas of the Alto Tajo-Serranía de Cuenca region, have determined the need of updating and developing a new proposal. Chiefly, five criteria support this revision:

(1) The absence of Upper Jurassic record in the Alto Tajo-Serranía de Cuenca region (Fregenal-Martínez and Muñoz-García, 2010; Muñoz-García *et al*., 2012; Fregenal-Martínez *et al*., 2014a). The Lower Cretaceous overlies marine limestones that belong to the Middle Jurassic Yémeda Formation (Gómez and Fernández-López, 2004a, b), as well as older Middle and Lower Jurassic stratigraphic units in the northern part of the study area. The presence of such unconformity is unique to the Alto Tajo-Serranía de Cuenca region. Opposite, the earliest episodes of rifting that occurred during the Late Jurassic are well represented in the rest of the Iberian Basin (Gómez, 1979; Mas *et al*., 1984; Liesa *et al*., in press).

(2) The formal definition of La Huérguina and El Collado formations (Cycle II of Mas *et al*., 1982), assigned them a late Hauterivian-early Barremian age (Fig. 2). However, these units have been repeatedly dated in the Alto Tajo-Serranía de Cuenca region from charophyte associations, as belonging to the late Barremian all over the study area (De Vicente and Martín Closas, 2013).

(3) El Collado Formation was defined as a lithostratigraphic unit chiefly composed of dominant sandstones at its lower part and clays becoming dominant towards the top (Vilas *et al*., 1982). Mas (1981) and Mas *et al*. (1982) interpreted this unit as the result of sedimentation in braided fluvial systems, with fluvial meandering channels in some areas, and mostly in coastal alluvial to deltaic alluvial and tidal plain systems with marine fauna such as oysters and foraminifera. However, neither the lithological composition and facies, nor the sedimentological interpretation of the unit correspond at all with the observed features of the sedimentary unit that interfingers laterally with La Huérguina Formation in the study area. On the contrary, the unit is instead chiefly composed of claystones, with quartzitic, carbonatic, mixed and oncolitic conglomerates, arcosic and mixed sandstones, and calcarenites, as well as a variable amount of intercalations of sandy, biomicritic and oncolitic limestones. Such a lithological composition together with the depositional architecture observed are rather similar to: 1) those described for unit C-IIa or "clayey member of La Huérguina Formation" by Meléndez (1983), and by Vilas *et al.* (1982) in the formal definition of La Huérguina Formation; 2) to the "lower part of Cycle II" of Mas *et al*., (1982); and 3) to the unit defined as Rambla de Las

Cruces I Sequence by Fregenal-Martínez (1998). Therefore, the evidence collected in this work no longer supports the presence of El Collado Formation in the Alto Tajo-Serranía de Cuenca region.

(4) In the formal definition of La Huérguina Formation, oncolitic and biomicritic charophyte-rich limestones are described as the main lithology of the unit, although subordinated lithologies such as marls, clays, calcarenites and some sparse arkosic and bioclastic sandstones are also recognized (Vilas *et al*., 1982). However, successive studies on this unit in the Serranía de Cuenca have shown a conspicuous internal complexity in terms of its noticeable vertical and lateral lithological and facies variability, as well as of its stratigraphic architectural patterns (Meléndez, 1983; Gómez-Fernández, 1988; Gierlowski-Kordesch and Janofske, 1989; Meléndez *et al*., 1989; Gierlowski-Kordesch *et al*., 1991; Fregenal-Martínez, 1998; Fregenal-Martínez and Meléndez, 2000; Buscalioni *et al*., 2008; Fregenal-Martínez *et al*., 2014a). This fact has led to propose the internal division of this unit into separated stratigraphic units, some limited by local minor unconformities. Such is the case of the sequences proposed by Fregenal-Martínez (1998) and Fregenal-Martínez and Meléndez (2000) for the record of La Huérguina Formation, in the central Serranía de Cuenca, in the multiple graben and half-graben sub-basins created by rift stretching (Fregenal-Martínez *et al*., 2014a; Elez *et al*., 2015).

In particular, thick successions of what has been considered La Huérguina Formation in the Alto Tajo-Serranía de Cuenca region are in fact mostly composed of clays, marly clays, quartz, carbonate, arkosic and mixed conglomerates, sandstones, and a variable proportion of biomicritic and oncolitic limestones. Those successions correspond to unit C-IIa of Meléndez (1983), and to what Fregenal-Martínez (1998) and Fregenal-Martínez and Meléndez (2000) defined as Rambla de las Cruces I Sequence in Las Hoyas half-graben, which can be recognized in similar depocenters in the Central Serranía de Cuenca including the stratotype locality (*e.g.*, Buscalioni *et al*., 2008; De Vicente and Martín-Closas, 2013). On the contrary, some relevant and characteristic lithofacies such as cross-bedded slabby limestones, and finely laminated limestones rich in exceptionally well-preserved fossils, were not included in the original definition of La Huérguina Formation by Vilas *et al*. (1982).

Moreover, concerning the environmental interpretation of La Huérguina Formation, Mas (1981), Mas *et al*. (1982) and Vilas *et al*. (1982) recognized a noticeable marine influence in the Valencia Sub-basin. Mas (1981) found ostreids, miliolids and rare lituolids in several Valencian localities. The environments interpreted by Mas (1981) for the facies association of La Huérguina Formation in Valencia comprise: mixed coastal paralic plains, both fluvio-palustrine with strong marine, tidal influence; and fluvio-lacustrine environments with more sporadic marine influence. On the contrary, neither the facies associations, nor the palaeontological content reveal such marine influence in the lithosome of La Huérguina Formation in the Serranía de Cuenca (*e.g.*, Buscalioni *et al*., 2008; De Vicente and Martín-Closas, 2013; Poyato-Ariza and Buscalioni, 2016).

In conclusion, it seems to be clear that the original definition of La Huérguina Formation has been being applied to two separated lithosomes with different features, and hence the assignation to it of the different known localities and outcrops should be revised.

(5) The total sedimentary record in the study area just consists of two Lower Cretaceous unconformity bounded units, Upper Barremian, and Aptian in age, scarcely 600 m-thick. On the other hand, the record in the Valencia Sub-basin (Salas *et al*., 2001; Mas *et al*., 2004) is composed of more than 2,000 m-thick Upper Jurassic-Lower Cretaceous successive sequences, spanning from Oxfordian to Lower Albian, all of them fully marine or with remarkable marine influence (Fig. 2B). The development of these two distinctive sedimentary successions points to an almost complete palaeogeographic separation of the two sub-basins during most Late Jurassic-Early Cretaceous rifting.

Upper Jurassic-Lower Cretaceous stratigraphic record in the Alto Tajo-Serranía de Cuenca region

The stratigraphic record of the Late Jurassic-Early Cretaceous rifting in the study region is characterized by: 1) A regional unconformity that in general spans at least from late Callovian to early Barremian in most of the area; 2) Two sedimentary unconformity-bounded units, upper Barremian and Aptian in age, respectively, and overlaid by Albian post-rift sediments.

Unconformity-bounded units (UBU) are objective stratigraphic units bounded above and below by significant unconformities, whose use is advised by the International Stratigraphic Guide only where and when they can fulfill a need that other kinds of stratigraphic units cannot meet (Section 6.E in Murphy and Salvador, 1998, and International Commission on Stratigraphy, 2016).The use of this type of units serves well to the descriptive purposes of this work, because: 1) They are objective and the whole studied record can be easily classified using them; 2) The bounding unconformities of the herein defined units are angular unconformities of regional extent and can be easily identified; 3) It simplifies the description of the studied record, since each defined UBU is composed of several lithostratigraphic units; 4) The lithostratigraphic units with rank of formation that composes each UBU do not meet the conditions to define a lithostratigraphic unit with rank of group; and 5) Other concepts such as sequence can be ambiguous due to the multiple uses that have been given to it in different frameworks and at different scales. Such is the case of the two Upper Jurassic-Lower Cretaceous large-scale syn-rift sequences defined in the Iberian Basin (Liesa *et al*., in press) that do not correspond with the stratigraphic units identified in the present work, which in fact are part of Sequence 2 of Liesa *et al*. (in press); hence the use of the sequence concept in this work might create confusion.

In our case, each UBU is interpreted to represent sedimentation in two successive rifting episodes that involved the structural reorganization of the area during the Late Jurassic-Early Cretaceous rifting cycle. Unconformity-bounded unit 1 (UBU 1) is late Barremian in age, and it is composed of two units (Tragacete and La Huérguina formations) that are formally defined in this work. Unconformity-bounded unit 2 (UBU 2) is Aptian in age and is composed of three lithostratigraphic units, Contreras Formation, and Malacara and El Burgal members (El Caroch Formation) (Vilas *et al*., 1982).

The Late Jurassic-earliest Cretaceous unconformity

The base of the Lower Cretaceous succession in the studied area corresponds to a major regional unconformity (more than 5000 km^2 and at least 27 My, Fig. 4) that is absent in other areas of the Iberian Ranges. Its main features are the total absence of Upper Jurassic rocks (except locally in the southernmost part of the study area, around the localities of Monteagudo de las Salinas and Enguidanos, Fig. 3) and the occurrence of an outstanding alteration surface on top of the Middle Jurassic materials where preserved (Fig. 5A). This diachronic surface presents different features at a regional scale:

(1) In the northern part (geological sheets 488, 513, 538, 539, 564 and western halves of 514 and 565: Fig. 3), the discontinuity is characterized by an important erosional paleorelief (Fig. 4B). In this area, the Barremian sediments overlie different Jurassic units, from basal Lower Jurassic (“Lias” in the cited literature) to Bajocian (*i.e.*, Adell Argilés *et al*., 1978, 1979), although most often they range between Toarcian and Bajocian (Del Olmo and Álvaro, 1985) (Fig. 4). At outcrop scale, the discontinuity usually corresponds to an erosive surface on fresh Jurassic materials although, in some rare cases, where the upper part of the Middle Jurassic materials has been preserved from erosion, a thin alteration surface occurs, characterized by outstanding red and ochre colors, brecciation, and ubiquous presence of boxwork.

(2) In the central area (geological sheets 587, 610, 611 and westernmost parts of 588 and 612: Fig. 3), the discontinuity is a very stratiform surface (Figs. 4B and 5B), usually on top of the Middle Jurassic limestones and dolostones of the Yémeda Formation (Gómez and Fernández-López, 2004a). In this area, the Yémeda Formation usually keeps a constant thickness at local scale despite the overlying discontinuity. Some minor paleorelief can be present at outcrop scale, associated to erosion in the shoulder of the upper Barremian normal faults (Fig. 5C). In these rare cases, the Jurassic materials appear fresh or stained with a yellowish color. However, in most areas the paleorelief is absent and the discontinuity on top of the Yémeda Formation displays very outstanding features (Fig. 5D-G) such as a remarkable diagnostic red color induced by the occurrence of abundant red bauxitic clays, brecciation, ubiquous boxwork and local karstification (Fregenal-Martínez, 1998; Fregenal-Martínez and Muñoz-García, 2010; Fregenal-Martínez *et al*., 2014b). The identification of the local karst can be problematic, since the karstic features are usually blurred by later pedo-

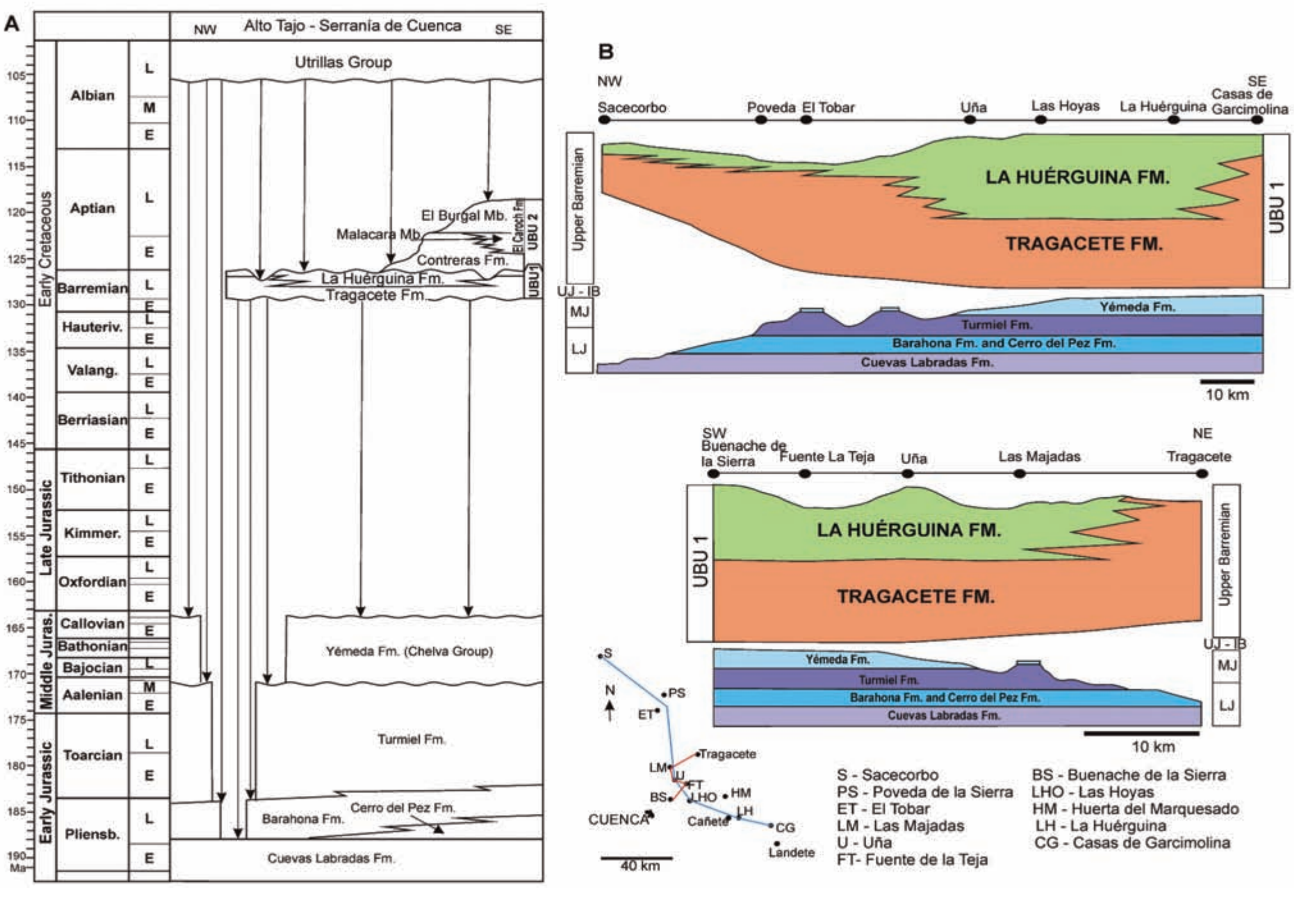

Fig. 4.- Lithostratigraphic scheme proposed in this work for the studied sedimentary succession in the Alto Tajo-Serranía de Cuenca region. Time scale and absolute ages after GTS2016 (Ogg *et al.*, 2016). B. Cross sections of the upper Barremian Unconformity Bounded Unit 1, showing the overall internal geometry and relationships between the Tragacete and La Huérguina formations. LJ – Lower Jurassic; MJ – Middle Jurassic; UJ-lB – Upper Jurassic-lower Barremian.

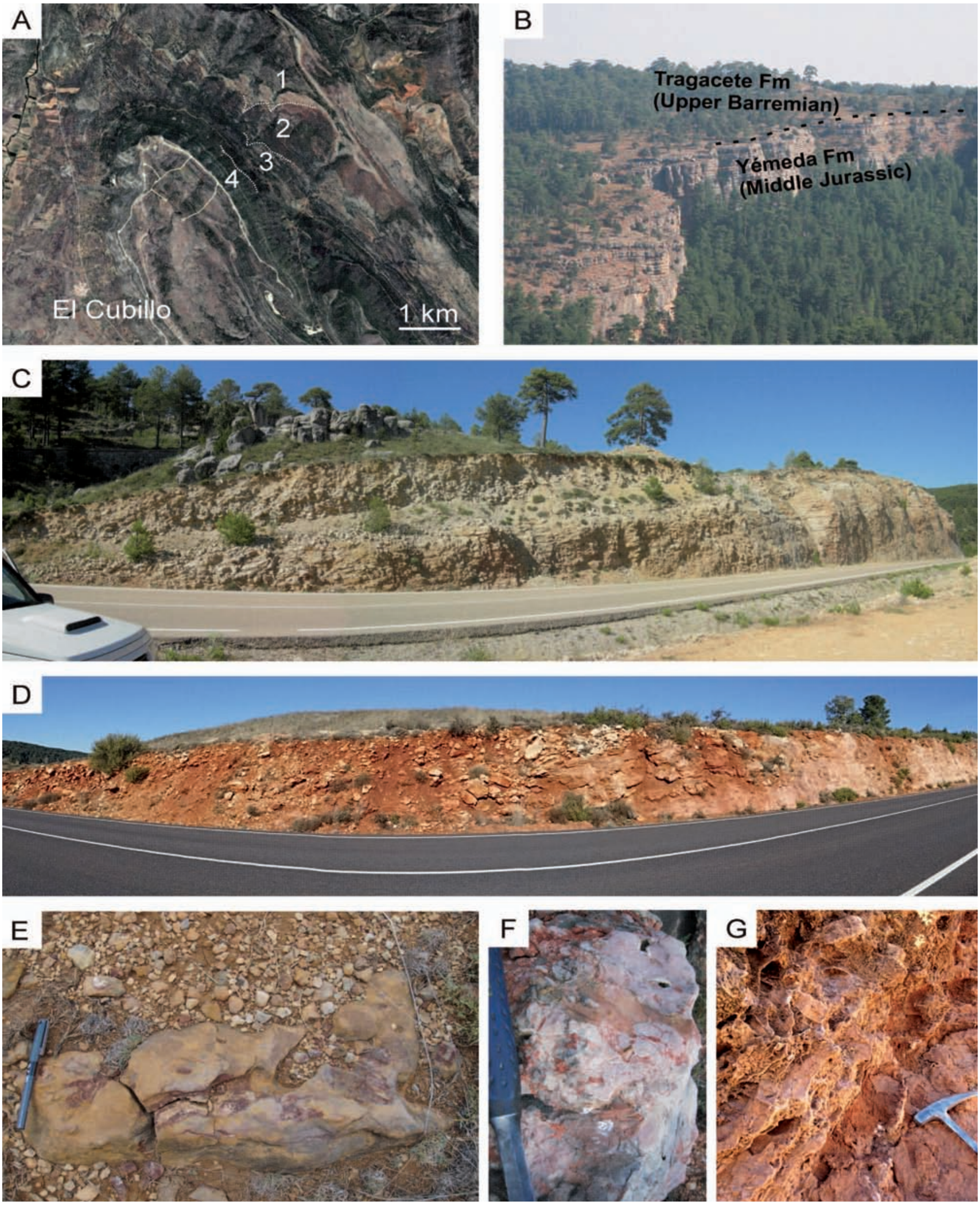

Fig. 5.- A. Landsat image of the Upper Jurassic-lowermost Cretaceous regional unconformity in the surroundings of El Cubillo, Cuenca province (1-Middle Jurassic carbonates; 2-Red alteration surface and associated residual deposits developed on Middle Jurassic carbonates; 3-Lower Cretaceous mixed, siliciclastics and carbonates; 4-Upper Cretaceous carbonates. B. In the central part of the study area, the unconformity surface on top of the Yémeda Formation is always parallel to Middle Jurassic bedding planes. This unit keeps a constant thickness at local scale (Uña village, Cuenca). C. Local erosion and yellowish alteration on top of the Yémeda Formation associated to shoulder-uplift of upper Barremian faults in the road from Uña to Las Majadas (Cuenca). D. Chaotic breccia with red bauxitic clays associated to the unconformity on top of dolostones of the Yémeda Formation in Monteagudo de las Salinas (Cuenca). E. Pedogenic features (root traces and marmorization) commonly associated to the Upper Jurassic-Lower Cretaceous unconformity. F. The occurrence of karstic breccias is the most common karstic feature associated to the unconformity. G. Close-up view of boxwork produced by differential dissolution of host rock, a ubiquitous feature of the deposits and alteration profiles associated to the unconformity.

genic processes (Fig. 5E) (Muñoz-García *et al*., 2015). Both processes contributed to dissolve the upper part of the Yémeda Formation with a table-like geometry (Fig. 5B). These alteration processes can affect a noticeable thickness of the limestones and dolostones of the Yémeda Formation (up to 15 to 20 m), transforming them into chaotic breccias (Fig. 5D). Bauxites and bauxitic clays are relatively abundant in this area associated to this discontinuity (the oldest bauxitic deposits in the Iberian Ranges), either in karst sinkholes (Muñoz-García *et al*., 2012) or as a filling in joints and fissures (Gómez-Fernández, 1988; Gierlowski-Kordesch *et al*., 1991).

The recognition of this alteration surface in previous works could have been hampered by two main reasons: 1) The classic assumption of the occurrence of erosion associated to the Neokimeric tectonic phase in this area (*e.g.*, Ramírez del Pozo and Meléndez Hevia, 1972; Fonollá *et al*., 1974; Morillo-Velarde and Meléndez Hevia, 1979) was progressively abandoned. Later, the idea of an important phase of pre-Cretaceous mechanical erosion has been assumed to be the main cause for the absence of Upper Jurassic deposits in this area (*e.g.*, Mas *et al*., 2004; Bádenas and Aurell, 2001). However, the geometry of the lithosome and the homogeneity in the ages of the younger Jurassic sediments present in such a wide area (Yémeda Formation, Fig. 4), suggest that the stratigraphic gap is due mainly to non-deposition rather than to erosion (although some stratiform chemical erosion of the Middle Jurassic deposits can be present). Further research is needed to clearly establish the origin and evolution of this complex discontinuity; 2) The punctual occurrence of azoic dolostones in the upper part of Yémeda Formation, usually altered and brecciated, has hampered the correct chronostratigraphic assignation of some cartographic units. In some classic works these brecciated dolostones were assigned to the Upper Jurassic and interpreted as litoral Purbeck facies (Ramírez del Pozo and Meléndez Hevia, 1972). Besides, correlation with similar facies found in the Upper Jurassic deposits in nearby areas (Morillo Velarde and Meléndez Hevia, 1979) has also contributed to this confusion. However, the occurrence of diffuse dolomitization on Middle Jurassic rocks was already noticed by Berasategui Batalla and Ramírez Merino (1982) and is very clear in other continuous stratigraphic successions located in the south of the study area (geological sheets 663 and 664; Gabaldón *et al*., 1974a, b).

(3) In the southern area (geological sheets 635, 636, 637, 663, 664 and 665: Fig. 3), the discontinuity is also characterized by the preservation of the whole Middle Jurassic series (up to Callovian, Fig. 4) including the red alteration surface (Fig. 5) described in the central area, although in this case this surface is locally overlaid by disperse outcrops of reduced Oxfordian and Kimmeridgian marine and littoral sediments (Ramírez del Pozo *et al*., 1973; Fonollá *et al*., 1974; Portero García *et al*., 1975) not comparable to any of the known Upper Jurassic lithostratigraphic units formally defined to date.

Therefore, the unconformity located at the base of the Lower Cretaceous succession corresponds to a major discontinuity caused by a combination of non-sedimentation and erosion that comprises at least 27 My in the southern part of the study area (from Tithonian to early Barremian), and could reach 34 My in the northern part (from late Callovian). The stratigraphic gap can be longer (up to 50 My) due to erosion and exhumation of Lower Jurassic rocks, especially towards the northernmost area of the Alto Tajo-Serranía de Cuenca region (Fig. 4).

Unconformity-Bounded Unit 1 (UBU 1): Late Barremian rifting episode

Overlying the Late Jurassic-earliest Cretaceous unconformity there is a continuous upper Barremian sedimentary succession (De Vicente and Martín-Closas, 2013) that corresponds to the UBU 1. This succession crops out all along the study area and is composed of two lithostratigraphic units related by a lateral change of facies (Fig. 4): Tragacete and La Huérguina formations. The Tragacete Formation is herein formally defined for the first time and it is characterized by the dominance of clays and marls, with intercalated lenses of siliciclastic to mixed and carbonate composition, in turn comprising all the possible range of grain sizes, from very fine arenites to conglomerates and breccias. Coal lenses and bauxites are also locally present. La Huerguina Formation is going to be formally redefined. It is essentially composed of a wide spectrum of limestones facies, as well as minor amounts of marls, sandy limestones and locally sparse coal beds.

In general, both units are characterized by a remarkable vertical, as well as lateral, regional, variability in terms of the relative abundance of facies. This fact has urged the need of designating some auxiliary reference sections in addition to the type section or holostratotype. In the case of Tragacete Formation its holostratotype shows quite well the characteristic diversity of this unit, and the two selected parastratotypes exemplify the most common biases from the standard description, at regional scale: 1) dominance of clays where bauxites and bauxitic clays with conspicuous paleosols (Fregenal Martínez and Muñoz García, 2010; Muñoz-García *et al*., 2012, 2015) and any other lithology is usually absent; and (2) abundance of carbonate, that is, successions dominated by marly clays and marls with intercalation of limestone. In the case of La Huérguina Formation the holostratotype exemplifies well the typical facies of the unit; however it lacks the emblematic finely laminated and cross-bedded limestones facies which contain world-wide known palaeontological assemblages of *Konservat-Lagerstatte* type, such as those of Las Hoyas fossil site (Poyato-Ariza and Buscalioni, 2016). That is the reason that supports the proposal of Las Hoyas section as a parastratotype for this unit.

The formal definition included below follows specific recommendations of the International Stratigraphic Guide for definition of new stratigraphic units and redefinition of previous units (Murphy and Salvador, 1998; International Commission on Stratigraphy, 2016).

Tragacete Formation

Main Lithology: Clays, sandstones and limestones.

Stratotypes

Holostratotype: Umbría de la Virgen-Tragacete stratigraphic section (Tragacete, Cuenca province) (Fig. 6).

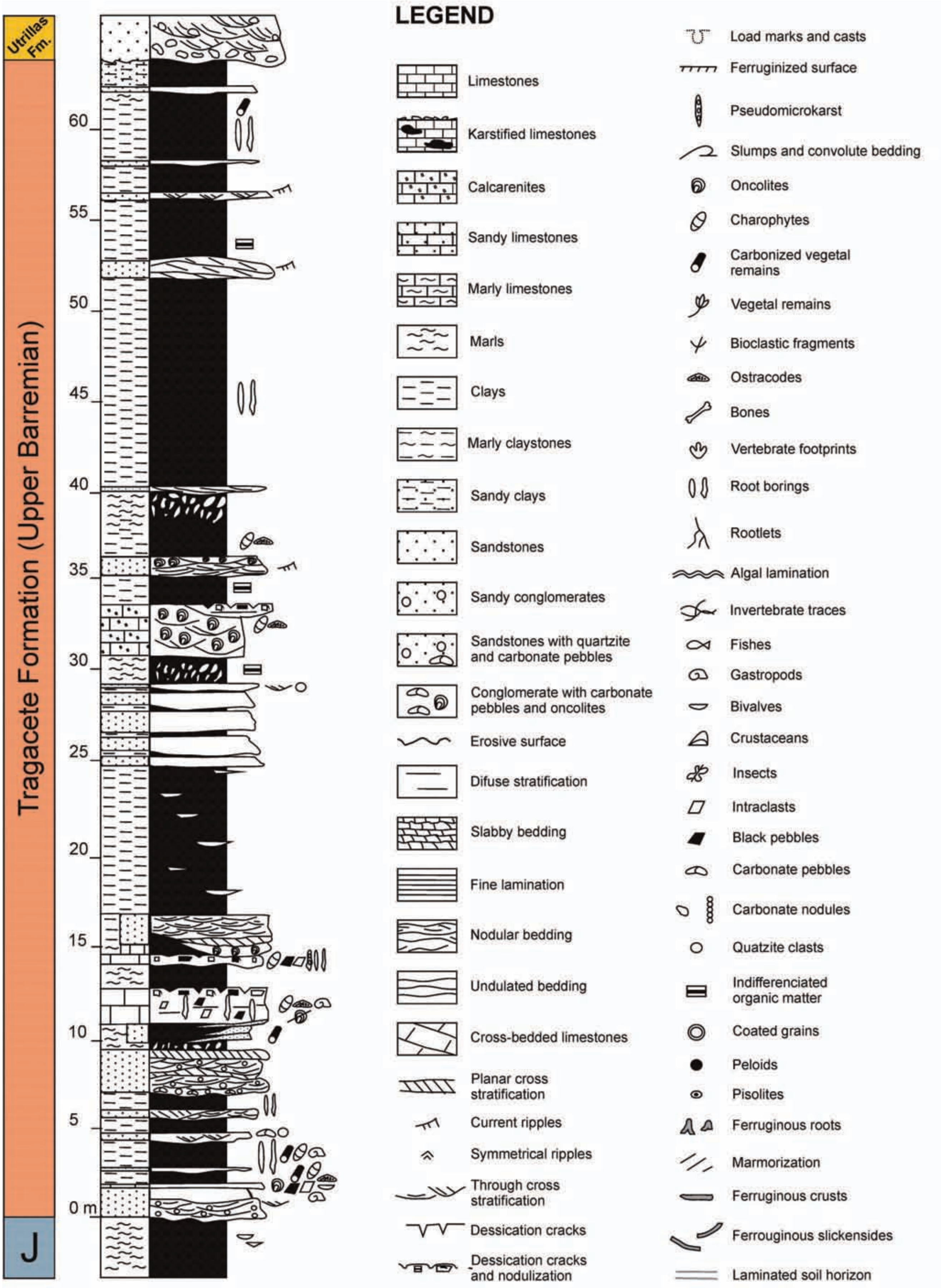

Fig. 6.- Stratigraphic log of the Tragacete Formation at the holostratype locality. B. General legend for stratigraphic logs in figures 6, 7, 8, 11 and 12.

Base: Erosive unconformity. Bioclastic limestones and marls with rhynchonellids that belong to the Barahona Bioclastic Limestones and Cerro del Pez Marls formations (Lower Jurassic). Coordinates: 40°21'50.22"N; 1°49'44.16"W.

Top: Erosive unconformity. Utrillas Group (Albian). Coordinates: 40°21'55.45"N; 1°49'38.98"W.

Parastratotype 1: Fuente de la Teja stratigraphic section (Cuenca, Cuenca province) (Fig. 7).

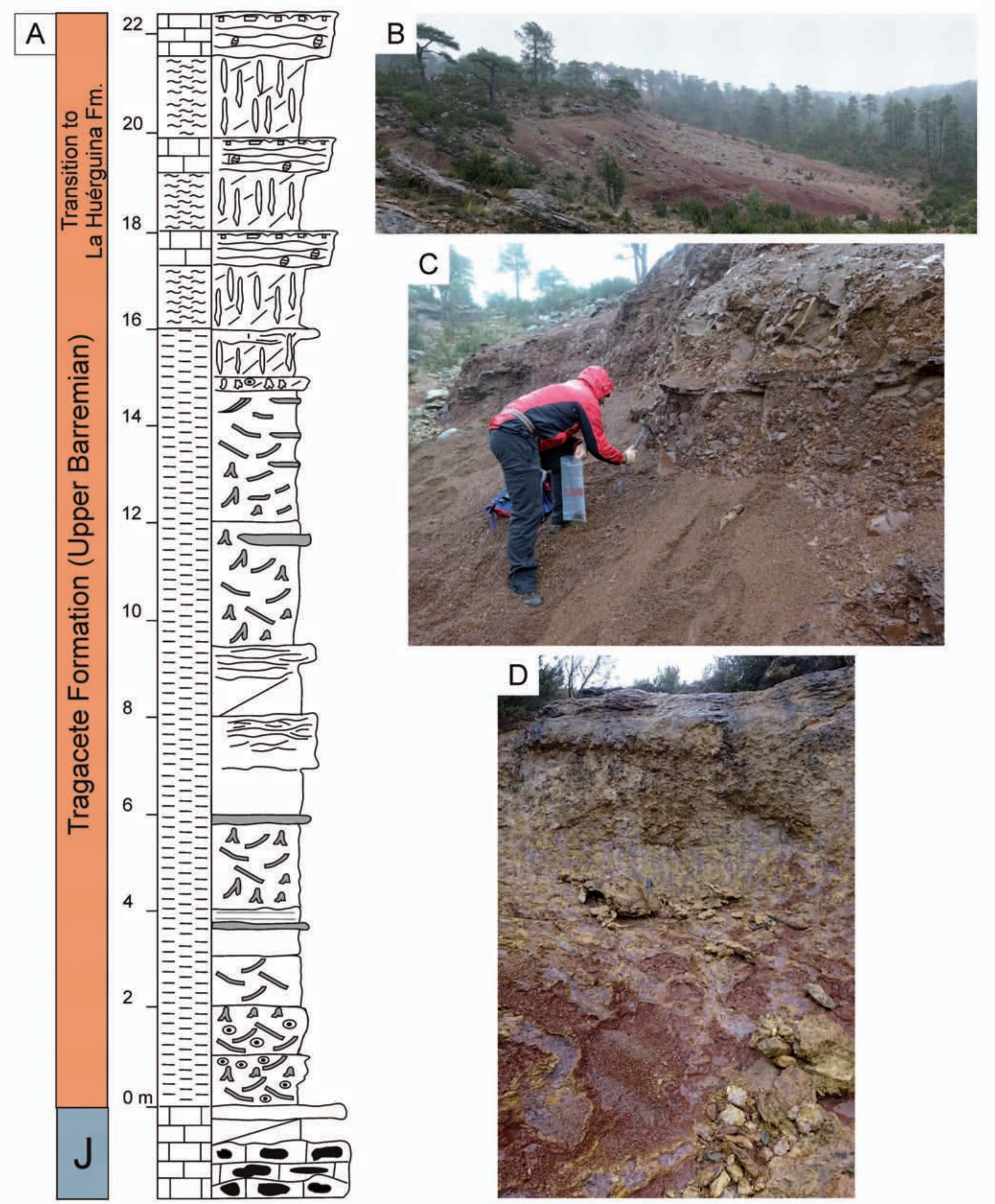

Fig. 7.- A. Stratigraphic log of the Tragacete Formation at Fuente de la Teja parastratotype locality, characterized by the occurrence of bauxite deposits. B. General view of the parastratotype locality. C. Cemented bauxites in the lower part of the section. D. Gradual transition between the Tragacete and La Huérguina formations consisting in several sequences of red bauxitic marls with marmorization overlaid by palustrine limestones with charophytes (see legend of symbols in Fig. 6).

Base: Unconformity on top of an alteration profile developed on the Yémeda Formation (Middle Jurassic). Coordinates: 40°11'25.27"N; 1°56'23.15"W.
Top: Conformable. Gradual change to La Huérguina Formation (upper Barremian). Coordinates: 40°11'25.79"N; 1°56'18.86"W.
Parastratotype 2: Huerta del Marquesado stratigraphic section (Huerta del Marquesado, Cuenca province) (Fig. 8).
Base: Unconformity on top of an alteration profile developed on the Yémeda Formation (Middle Jurassic). Coordinates: 40° 8'19.75"N; 1°41'16.15"W.
Top: Conformable. Gradual change to La Huérguina Formation (upper Barremian). Coordinates: 40° 8'14.29"N; 1°41'20.19"W.

Description

Lithological description: Clays are the dominant lithology (Fig. 9). They may contain variable amounts of silt, sand, carbonate and organic matter, resulting in silty, sandy, marly and carbonaceous clays, and marls (Fig. 9A–D). Most are red and reddish, but pinkish, ochre, yellowish, grayish, and greenish colors as well as mottling and variegation are also common. Bauxitic clays are present at the basal part of the succession in some localities (*e.g.*, Parastratotype 1, Fig. 7). Well developed paleosols and palustrine features are widespread (Fig. 9B, C, E).

In some localities clays are the bulk of the succession of the Tragacete Formation (Fig. 7) (*e.g.*, Parastratotype 1), but usually lenses of varied lithologies alternate or are interfingered with clays: quartzitic, carbonatic, oncolitic and, mixed conglomerates; quartzitic and arcosic sandstones; mixed arenites and calcarenites; sandy, marly and carbonaceous limestones; oncolitic and biomicritic limestones; coal beds. Components of the clastic lithologies include: quartz, feldspars, mica flakes, Jurassic pebbles, intraclasts, black pebbles, mud clasts, oncolites and bioclasts (Fig. 9E–H). These lenses range from a few decimeters to meters in thickness, and from tens to hundreds of meters in lateral extension (Fig. 10). Their geometries are also variable, from convex-up base and flat tops, to lobes and sheets geometries. They may appear as massive beds or show grading, cross bedding at different scales, ripples and parallel laminations.

There is an overall lateral tendency to the enrichment in carbonatic lithologies towards the south central areas of the study area (Parastrotype 2, Fig. 8). Siliciclastic sediments coarser than clay are more abundant in the northwestern half and in a narrow fringe, which occupies the east, southeast and southern edges of the region.

Palaeontological content: Cyanophycean algae, charophytes, ostracods, bivalves, gastropods, pollen, vegetal remains, fish scales and bones, skeletal remains of tetrapods (frogs, turtles, lizards, crocodiles, non-avian dinosaurs and mammals), invertebrate trace fossils, and tetrapod footprints and trails.

It is noticeable the presence of Bone Beds, localities extremely rich in macro and micro skeletal remains of vertebrates, *e.g.*, Buenache de la Sierra (Buscalioni *et al.*, 2008). The presence of dinosaur's remains and other vertebrates has been cited in localities such as Abánades and Canales del Ducado (Comas-Rengifo *et al.*, 1975), Puente de Vadillos (Curnelle, 1968; Lapparent *et al.*, 1969), Carrascosa de la Sierra and Beteta (Francés and Sanz, 1989) and Masegosa (Sanz, 1985). Localities extremely rich in plant's remains are also characteristic, *e.g.*, Uña (Gierlowski-Kordesch *et al.*, 1991; Gómez *et al.*, 2001).

Mineral ore: Coal (lignite) seams, iron concentrations and bauxites.

Regional aspects

Lower boundary: (1) Unconformable on Lower and Middle Jurassic lithostratigraphic units: Cuevas Labradas, Barahona, Cerro del Pez, Turmiel and Yémeda formations (Goy *et al.*, 1976; Gómez *et al.*, 2004). (2) Unconformable on deposits and alteration profiles associated to the Oxfordian-early Barremian discontinuity (Figs. 4 and 5A, C).

Upper boundary: (1) Conformable, abrupt or gradual change to La Huérguina Formation. (2) Erosive unconformity. Overlying stratigraphic units: Contreras Formation (lower Aptian); El Burgal Formation (upper Aptian); Utrillas Group (Albian) (Vilas *et al.*, 1982; Rodríguez-López *et al.*, 2010) (Fig. 4).

Extension and lateral relationships: It crops out all along the Alto Tajo-Serranía de Cuenca region, from north-westernmost area around the locality of Abánades (Guadalajara province) to the south-easternmost area around the locality of Casas de Garcimolina (Cuenca province). To the E and SE, it disappears by no deposition beyond the LT fault. The northeastern limit partially coincides with the NW-SE trending ATMU fault system. It disappears westwards under outcropping Upper Cretaceous and Cenozoic successions, and southwards by erosion and/or non sedimentation.

The unit changes both vertically and laterally to La Huérguina Formation. The vertical change can be gradual or abrupt depending on the specific sub-basin where it occurs (Fig. 4). The lateral change is defined by the increasing presence and relative abundance of marls and carbonatic lithologies from the edges towards the central areas of the study region.

Thickness: It ranges from 170 to 10 m. Such extremely variability is due to the compartmentalization of the area into many small grabens and half-grabens. It can be also deeply eroded by the overlying unconformities.

Age

Late Barremian: 126.3 – 129.4 Ma. (GTS2016, Ogg *et al.*, 2016).

Age determination is based on charophyte associations which are composed of *Atopochara trivolvis* var. *triquetra, Globator maillardi* var. *trochiliscoides*, *Globatormaillardi* var. *biutricularis* var. nov., *Clavator harrisii* var. *reyi*, *Ascidiella cruciata*, *Ascidiella iberica* var. *iberica*, and *Mesochara harrisii* (De Vicente and

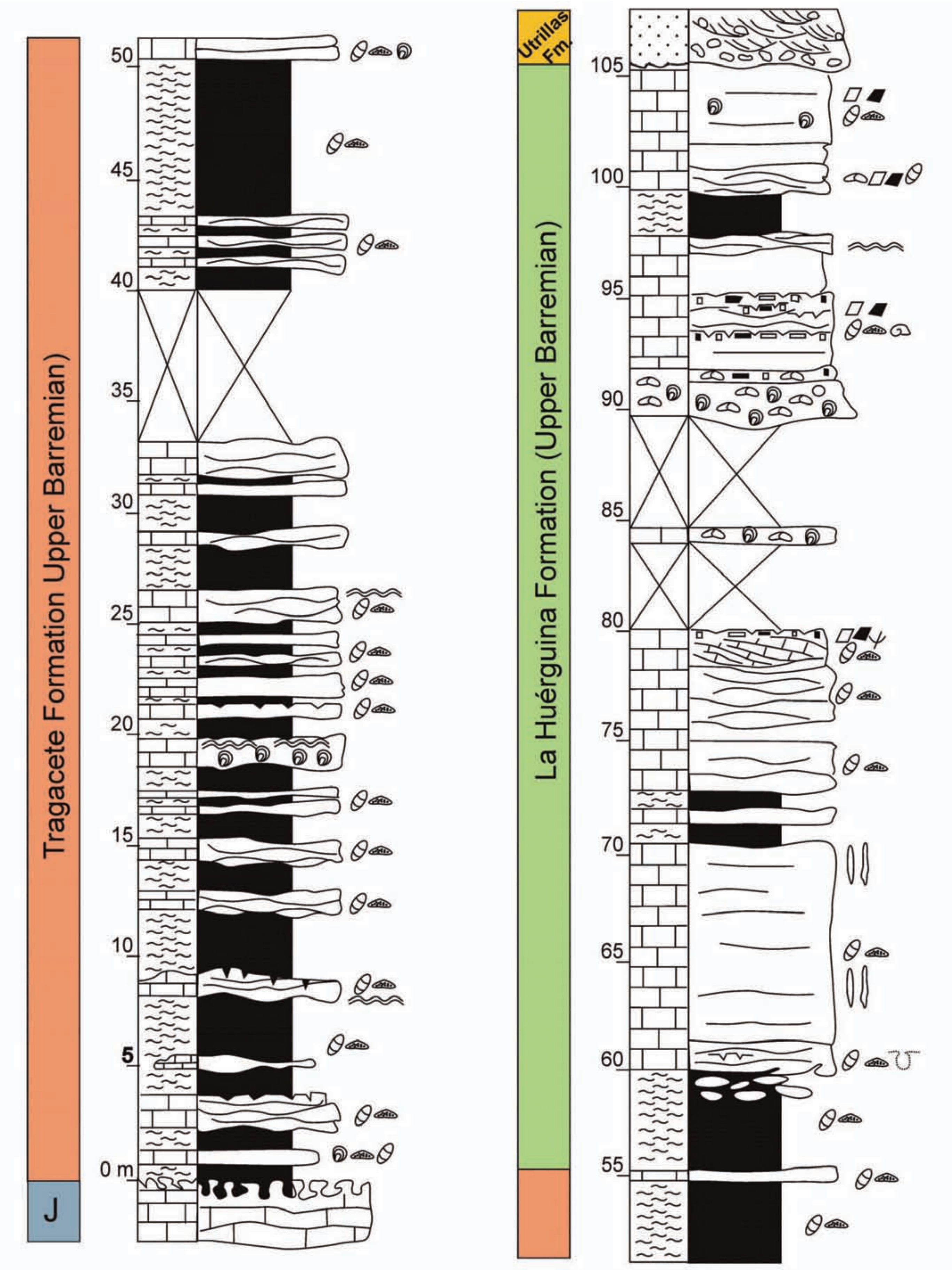

Fig. 8.- Stratigraphic log of the Tragacete Formation at Huerta del Marquesado parastratotype locality, characterized by the relative higher abundance of marls and limestones compared to the holostratotype (see legend of symbols in Fig. 6).

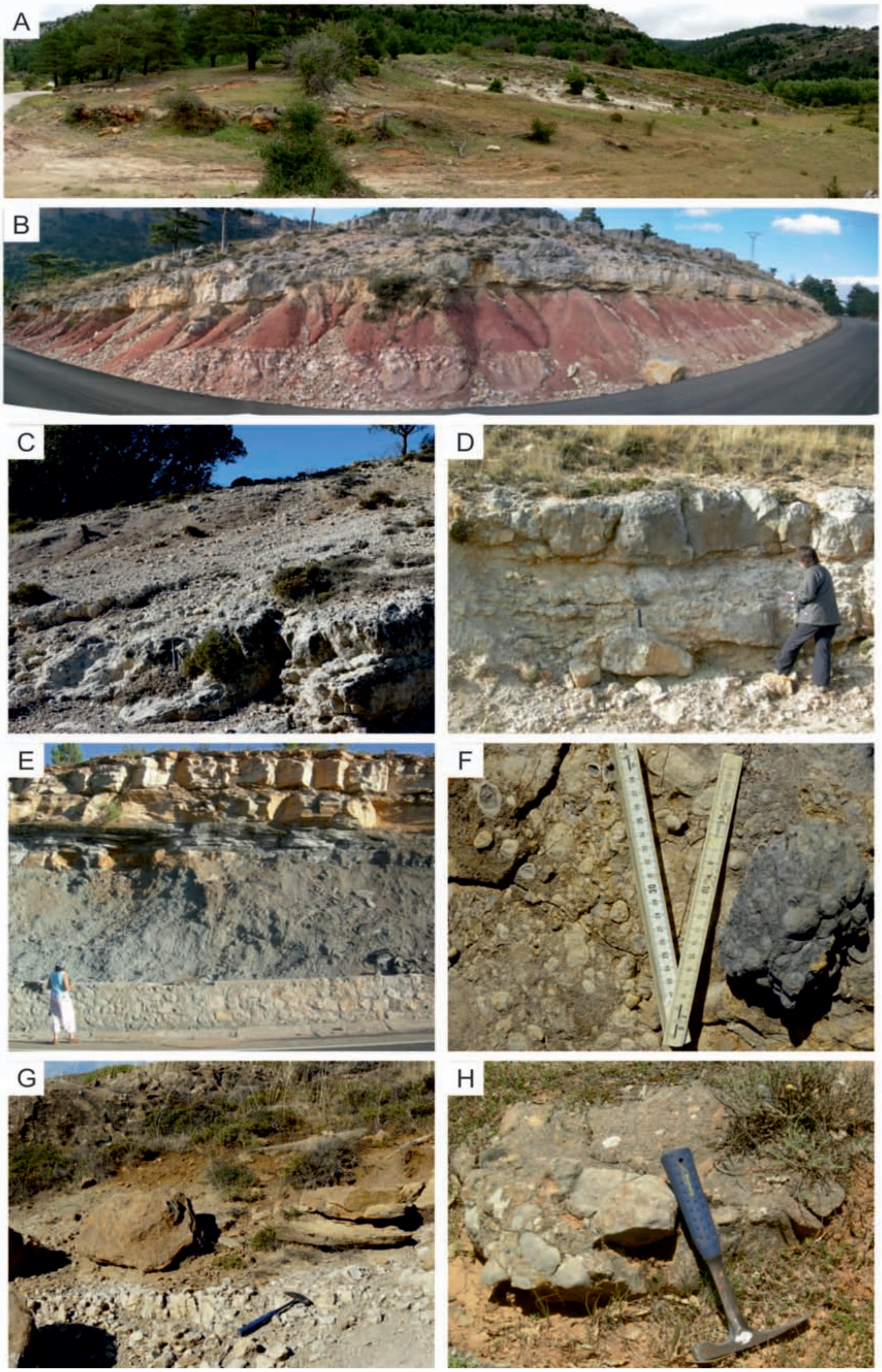

Fig. 9.- Field images of the Tragacete Formation. A. General view of the holostratotype locality. B. Red clays and marls with marmorization interfingered with palustrine limestones and carbonate paleosols in the road to Las Majadas (Cuenca). C. Ochre, grayish, and greenish marls interfingered with palustrine limestones in the Huerta del Marquesado parastratotype section. D. Black, carbonaceous clays with coal seams in Uña (Cuenca). E. Grey marls interfingered with palustrine limestones in Las Majadas (Cuenca). F. Oncolitic limestones, very rich in organic matter. This facies is very common and widespread in this formation. G. Ochre alluvial sandstones and white palustrine limestones. H. Hybrid breccias with large floating jurassic pebbles in a mixed matrix. F, G and H near Poveda de la Sierra (Guadalajara).

Martín-Closas, 2013). This association belongs to the upper Barremian-lower Aptian *Ascidiella cruciata – Pseudoglobator paucibracteatus* Biozone (Martin-Closas *et al*., 2009). The age is restricted to the upper Barremian by the accompanying ostracods assemblages (Schudack and Schudack, 2009; De Vicente and Martín-Closas, 2013).

Genesis

Depositional system: Continental. Alluvial, lacustrine and palustrine facies associations. Regional scale inland freshwater system of wetlands.

Equivalences and References

Wealdian (Curnelle, 1968; Viallard, 1973); Weald Facies (Meléndez Hevia, 1971; Meléndez Hevia *et al*., 1974; Ramírez del Pozo *et al*., 1974); Unit CI and C-IIa (Meléndez, 1983); El Collado Formation (Vilas *et al*., 1982) in the Serranía de Cuenca; Lower part of La Huérguina Limestones Formation (Vilas *et al*., 1982); Rambla de las Cruces I Sequence (Fregenal-Martínez, 1998).

La Huérguina Formation

Main lithology: Limestones.

Stratotypes

Holostratotype: La Huérguina stratigraphic section (La Huérguina, Cuenca province) (Fig. 11).

Base: Conformable, gradual change from the Tragacete Formation (upper Barremian). Coordinates: 40°2'50.98"N; 1°36'39.17"W.

Top: Unconformable, overlaid by the Contreras Formation (lower Aptian). Coordinates: 40°2'35.32"N; 1°36'29.76"W.

Parastratotype: Rambla de Las Cruces-Las Hoyas stratigraphic section (La Cierva, Cuenca province) (Fig. 12).

Base: Conformable on the Tragacete Formation (upper Barremian). Coordinates: 40°5'35.85"N; 1°53'25.19"W.

Top: Recent erosional surface. Coordinates: 40°5'14.53"N; 1°53'58.25"W.

Description

Lithological description: Whitish, light to dark grey and beige limestones with exceptionally abundant charophytes and ostracods is the most conspicuous lithology (Fig. 13). Oncolitic conglomerates, oncolitic and stromatolitic limestones as well as bioclastic and intraclastic calcarenites which are also very abundant. They may appear as several m-thick massive beds, tabular layers, showing cross bedding at different scales (Fig. 13D), or as lenticular beds a few m-thick. Calcarenites usually appear as irregular slabby beds and preserve ripple and cross lamination. Dark grey to black, stinking, slabby, silty to marly limestones extremely rich in plants remains are also present (Fig.13F). Development of features such as brecciation, nodulization, pseudo-microkarstification, vertical voids and marmorization at the limestone bed tops is quite common (Fig. 13C, E). The presence of fossiliferous finely laminated limestones with diverse and rich associations of exceptionally well preserved fossils is a remarkable feature of this unit (Las Hoyas parastratotype, Fig. 13G). Although in variable amounts depending on the specific locality, marls are also present (Fig. 13B). Rarely, sparse beds of sandstones and sandy limestones are found.

Palaeontological content: Cyanophycean algae, charophytes, ostracods, bivalves, gastropods, pollen, vegetal remains, worms, crustaceans, insects, fish scales and bones, skeletal remains and articulated fossils of tetrapods (frogs, turtles, lizards, crocodiles, non-avian dinosaurs, birds and mammals), invertebrate traces, and isolated footprints and trails of tetrapods.

It is noteworthy the presence of *Konservat-Lagerstatten* type (Seilacher *et al*., 1985) localities, being the most outstanding Las Hoyas fossil site characterized by the extreme diversity and abundance of exceptionally well preserved fossils (Poyato-Ariza and Buscalioni, 2016). This fossil site is a worldwide famous palaeontological locality by yielding a biota containing key groups in the base of the lineages involved in the Cretaceous Terrestrial Revolution (angiosperms, modern insects, teleosts, lizards and crocodiles, pterosaurs and birds) and the most complete record of a Mesozoic seasonal subtropi-

Fig. 10.- General view of the Tragacete Formation outcropping near Las Hoyas (Cuenca) that exemplifies the typical depositional architecture of this unit, with lenses of varied lithologies intercalated with dominant clays.

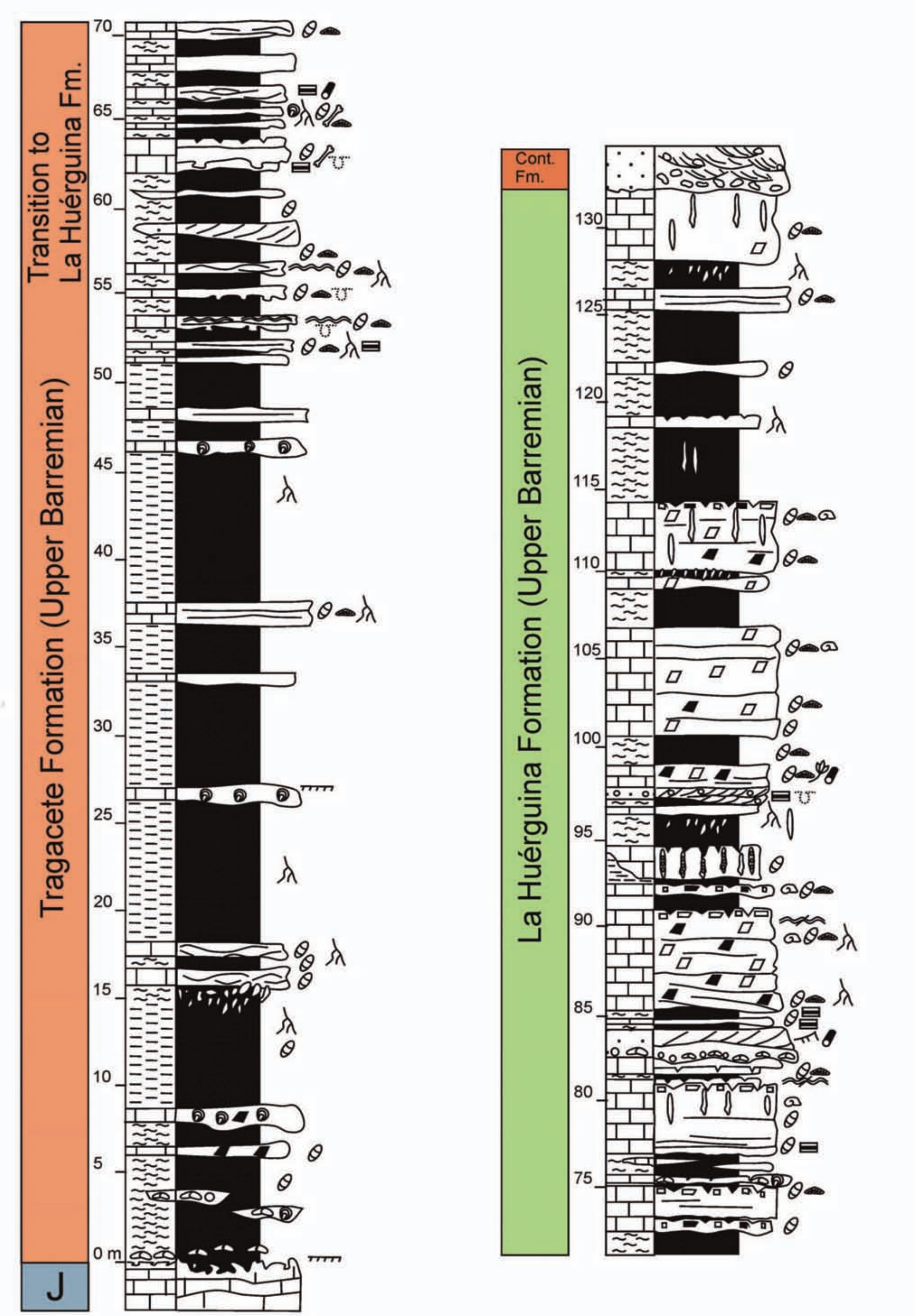

Fig. 11.- Stratigraphic log of the La Huérguina Formation at the holostratotype section (see legend of symbols in Fig. 6).

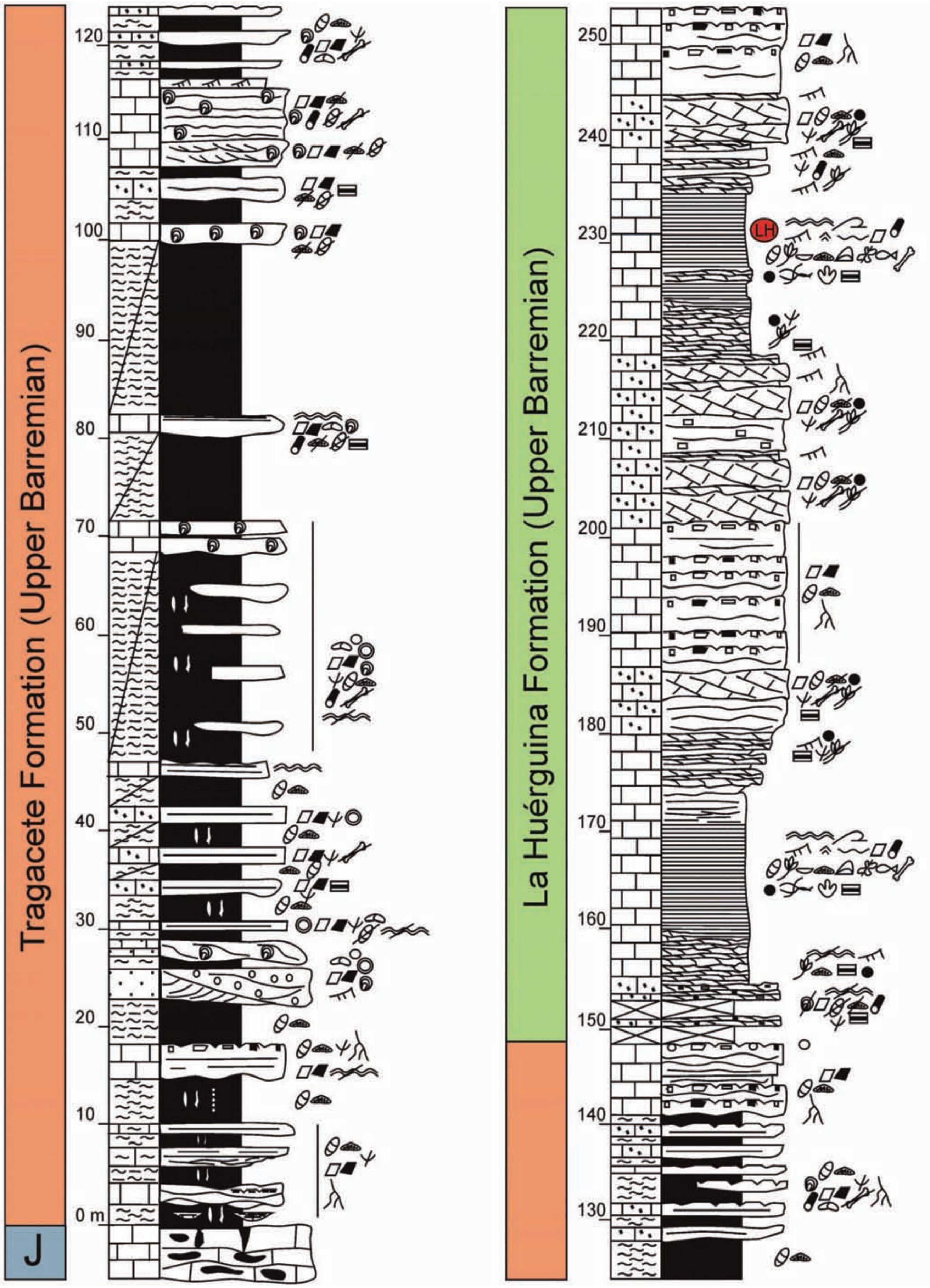

Fig. 12.- Stratigraphic log of the La Huérguina Formation at Las Hoyas parastratotype section characterized by the presence of fossiliferous finely laminated limestones that enclose the *Konservat-Lagerstatte* of Las Hoyas (see LH). See legend of symbols in Fig. 6.

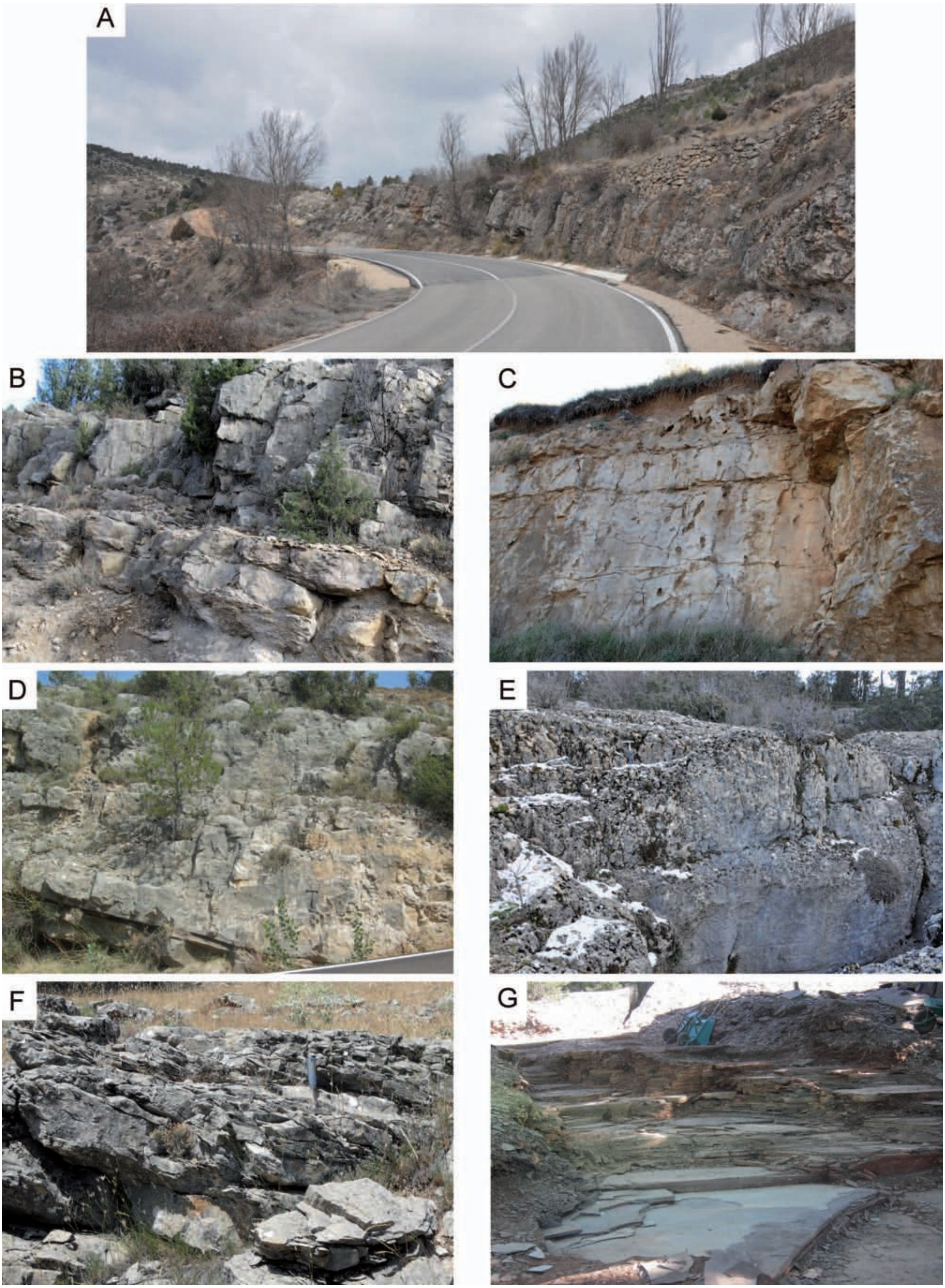

Fig. 13.- Field images of La Huérguina Formation. A. General view of holostratotype section. B. Lacustrine facies succession. C. Root traces as voids on massive charophyte-rich lacustrine limestones facies. D. Cross-bedded limestones deposited in a lake bench. E. Brecciation and nodulization features at the top of massive lacustrine to palustrine facies. F. Cross-bedded irregular slabby limestones. G. Fossiliferous finely laminated limestones at Las Hoyas *Konservat-Lagerstätte* (La Cierva, Cuenca). A, B, C and D in La Huérguina (Cuenca). E and F near Las Hoyas.

cal wetland ecosystem rather similar to Recent large tropical and subtropical inland wetlands (Buscalioni and Fregenal-Martínez, 2010; Fregenal-Martínez and Meléndez, 2016; Buscalioni *et al*., 2016). It is also worth mentioning other associations of vertebrate fossil remains such as those found in the Uña coal mine, in Cuenca province (Henkel and Krebs, 1969; Rauhut and Zinke, 1995). Localities very rich in plants remains with exceptional preservation are also characteristic, *e.g.*, Armallones, in Guadalajara province (Rey Marcos, 1982; Giménez and Rey, 1982).

Mineral ore: Coal (lignite) seams.

Regional aspects

Lower boundary: (1) Unconformable on Lower and Middle Jurassic lithostratigraphic units: Cuevas Labradas, Barahona, Cerro del Pez, Turmiel and Yémeda formations (Goy *et al*., 1976; Gómez *et al.,* 2004). (2) Unconformable on deposits and alteration profiles associated to the Oxfordian-early Barremian discontinuity. (3) Conformable, abrupt or gradual vertical change with the Tragacete Formation (Fig. 4).

Upper boundary: Erosive unconformity (Fig. 4). Overlying stratigraphic units: Contreras Formation (lower Aptian); El Burgal Formation (upper Aptian); Utrillas Group (Albian) (Vilas *et al*., 1982; Rodríguez-López *et al*., 2010).

Extension and lateral relationships: It crops out all along the study area from north-westernmost area around the locality of Abánades (Guadalajara province) to the south-easternmost area around the locality of Casas de Garcimolina (Cuenca province). To the E and SE, it disappears by no deposition beyond the LT fault. The north-eastern limit partially coincides with the NW-SE trending ATMU fault system, in turn western edge of the Teruel-Valencia High (De Vicente *et al*., 2009; Liesa *et al*., in press). It disappears westwards under outcropping Upper Cretaceous and Cenozoic successions, and southwards by erosion and/or non sedimentation.

This unit overlies and is related to the Tragacete Formation by a lateral change of facies. This change can be gradual or abrupt depending on the specific sub-basin where it occurs (Fig. 4). La Huérguina Formation expands progressively from the central and southern areas towards the NW, and in all directions towards the edges of the region.

Thickness: It ranges from 100 to 10 m. Such extremely variability is due to the compartmentalization of the sedimentation area into many small grabens and half-grabens. It can be also deeply eroded by overlying unconformities.

Age

Late Barremian: 126.3 – 129.4 Ma. (GTS2016, Ogg *et al*., 2016).

Age determination is based on charophyte associations which are composed of *Atopochara trivolvis* var. *triquetra, Globator maillardi* var. *trochiliscoides*, *Globator maillardi* var. *biutricularis* var. nov., *Clavator harrisii* var. *reyi*, *Ascidiella cruciata*, *Ascidiella iberica* var. *iberica*, and *Mesochara harrisii* (De Vicente and Martín-Closas, 2013). This association belongs to the upper Barremian-lower Aptian *Ascidiella cruciata – Pseudoglobator paucibracteatus* Biozone (Martin-Closas *et al*., 2009). The age is restricted to upper Barremian by the accompanying ostracods assemblages (Schudack and Schudack, 2009; De Vicente and Martín-Closas, 2013).

Genesis

Depositional system: Continental. Lacustrine and palustrine facies associations. Regional scale inland freshwater system of wetlands.

Equivalences and References

Wealdian (Viallard, 1973); Weald Facies (Meléndez Hevia, 1971; Meléndez Hevia *et al*., 1974; Ramírez del Pozo *et al*., 1974); Unit CII (Meléndez, 1983); Upper part of La Huérguina Limestones Formation (Vilas *et al*., 1982); Rambla de las Cruces II Sequence (Fregenal-Martínez, 1998).

Unconformity Bounded Unit 2 (UBU 2): Aptian rifting episode

In the Serranía de Cuenca region, the Aptian sedimentary record (UBU 2) is chiefly composed of continental (alluvial) siliciclastic deposits belonging to the Contreras Formation, and minor shallow marine and transitional sediments belonging respectively to the Malacara and El Burgal members of El Caroch Formation (Vilas *et al*., 1982; Mas *et al*., 1982) (Figs. 2 and 4). These units overlie unconformably the sediments of the late Barremian rifting episode (Meléndez, 1982, 1983) (Fig. 14A, B). Due to later erosion, these units crop out discontinuously in the S and southeastern half of the Alto Tajo-Serranía de Cuenca region, and are absent by erosion in the northern and northwestern area.

The Contreras Formation is composed of sandstones, claystones and subordinated oncolitic limestones. Its maximum thickness is 60 m, almost disappearing in the localities where it has been deeply eroded. From NW to SE the continental deposits of the Contreras Formation change laterally to mixed, shallow coastal and marine deposits of the Malacara Member (Fig. 14C).

The Malacara Member is characterized by mixed lithologies, with dominant siliciclastic heterolithic tidal facies at its base, that gradually pass upwards to mixed and carbonatic coastal facies, commonly bioturbated and containing abundant algae, benthic foraminifera, gastropods, oysters, rudists and scarce corals (Fig. 14C). The transition from Contreras to Malacara occurs all along a NE-SW trending tectonic structure called Reíllo High (Fig. 3) (Ramírez de Pozo *et al*., 1974; Meléndez, 1983) which limited, towards the NW, the maximum extension of the early Aptian marine transgression

The early Aptian marine encroachment had to overcome NE-SW trending tectonic highs that were still active (Fig. 3); besides the Reíllo High, which limited the marine advance, the Teruel-Landete High limited the extension of carbonate facies deposition of the Urgonian platforms developed towards the SE, in the Valencia Sub-basin (Me-

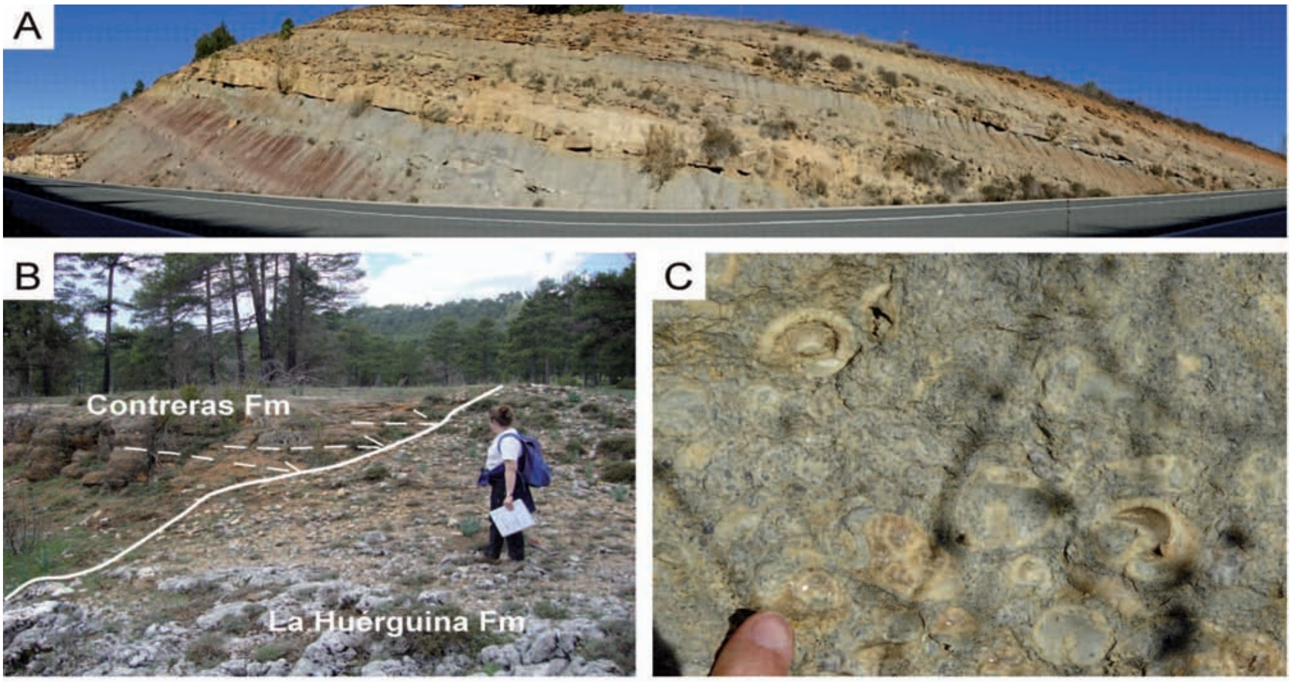

Fig. 14.- A. The Contreras Formation (lower Aptian) unconformable overlying red clays of Tragacete Formation (upper Barremian) in Campillos-Paravientos (Cuenca). B. The Contreras Formation onlapping La Huérguina Formation in Buenache de la Sierra (Cuenca). C. Marine fauna, rudists and ostreids in calcareous sandstones of the Malacara Member in Campillos-Paravientos (Cuenca).

léndez, 1983). This resulted in a very thin sedimentary record (20 m as much for the Malacara Member) in comparison with the Urgonian platforms developed in the Valencia Sub-basin (García Quintana, 1977; Mas, 1981).

The Contreras Formation and the Malacara Member are separated by a sharp ferruginous surface from the overlying El Burgal Member, late Aptian in age. El Burgal Member is composed of siliciclastic deposits, mostly white sandstones with local coal lenses, that deposited in coastal environments (Vilas *et al.*, 1982; Meléndez, 1983; Meléndez and López-Gómez, 2003). El Burgal Member was deposited during the regressive period that followed the early Aptian transgressive pulse represented by Malacara Member (Fig. 2). The maximum thickness of El Burgal Member is around 30 m since it underwent strong erosion. Therefore it outcrops discontinuously, chiefly in the southeastern part of the studied area.

After a period of non sedimentation and erosion, post-rift deposition started over during Albian, in continental arid systems to coastal environments corresponding to the siliciclastic deposits of the Utrillas Group (Chamizo *et al.*, 2016). This sedimentary unit has an extensive character in the Alto Tajo-Serranía de Cuenca region, as it rests unconformable on different Lower Cretaceous sedimentary units and even on the Jurassic substrate.

Discussion

The rift cycle that affected the Iberian Basin during the Late Jurassic-Early Cretaceous divided it into several major domains (Fig. 1) that underwent separate palaeogeographic evolutions reflected by noticeable differences in their recorded sedimentary successions (Mas *et al.*, 2004; Liesa *et al.*, in press). Vilas *et al.* (1982) and Mas *et al.* (1982) developed the lithostratigraphic scheme and carried out the palaeogeographic reconstruction of the so-called Southwestern Domain (Fig. 2). Although the Southwestern Domain is known to be divided into two sub-basins, Valencia and Cuenca, the lithostratigraphic scheme proposed by Vilas *et al.* (1982) has been homogeneously applied to the record of both sub-basins up to the present (Salas *et al.*, 2001; Mas *et al.*, 2004). However, the increasing knowledge on the Serranía de Cuenca and its prolongation northwestwards into the Alto Tajo region has shown that the validity of the original scheme is rather limited, as it does not describe the stratigraphic record and actual evolution of this area during the Later Jurassic-Early Cretaceous rifting. That is the reason of the revision and updating of the previous scheme proposed in this work (Fig. 4).

Palaeogeographic context

The Late Jurassic-Early Cretaceous evolution of the Alto Tajo-Serranía de Cuenca region represents the most outstanding difference compared to other Iberian rifting domains. The limitation of the affected area by the well-known ATMU fault system and LT transfer fault support that the Alto Tajo-Serranía de Cuenca region underwent a distinct, separate palaeogeographic evolution (Fig. 3). The ATMU fault system delimitated the Internal Castilian Platform during the Middle Jurassic, characterized by the frequently dolomitized oolitic and restricted facies of the Yémeda Formation (Gómez and Fernández-López, 2004a, 2006). This restricted shallow-marine area was emerged by the latest Callovian-earliest Oxfordian, coevally with the regional discontinuity also recognized in the rest of the Iberian Ranges, and usually represented by condensed sections, iron crusts and iron oolites included in marine sections (*e.g.*, Morillo-Velarde and Meléndez Hevia, 1979; Aurell *et al.*, 2003; Gómez *et al.*, 2004; Gómez and Fernández-López, 2006). However, in the Alto Tajo-Serranía de Cuenca area, most of the Middle Jurassic platform remained exposed until the late Barremian for *c.* 30 Myr. As a result, a complex stratigraphic discontinuity was generated by the superposition of different sedimentation and alteration processes, mainly the arrival of alluvial bauxitic material from the Iberian Massif, the development of lateritic soils, and finally, karstification and erosion (Fregenal-Martínez and Muñoz-García, 2010; Muñoz-García *et al*., 2012, 2015; Fregenal-Martínez *et al*., 2014b) (Figs. 4 and 5). The late Barremian rifting episode induced important erosion of the Middle Jurassic sediments in the northern part of the region, where upper Barremian sediments overlie different Middle and Lower Jurassic stratigraphic units. On the other hand, most features associated to this discontinuity (table-like dissolution of the upper part of the Yémeda Formation, pedogenic marmorization, karstic breccias, karstic bauxites…) were preserved either under the upper Barremian succession in the central part of the study area (Fig. 5A, C) or under the Upper Jurassic succession in the southernmost parts (*e.g.*, Monteagudo de las Salinas, Fig. 5D). The lateral variability and the diversity of signals left by the complex palaeogeographic evolution during this non-subsident stage have caused several types of mistakes in the identification and definition of stratigraphic units in the literature and geological maps (Table I). The deposits and features left by karstification and pedogenesis have been traditionally mistaken with brecciated Middle Jurassic dolostones or Upper Jurassic units.

Syn-rift sedimentation

Syn-rift sedimentation did not occur in the study region until the late Barremian (De Vicente and Martín Closas, 2013; Fregenal-Martínez *et al*., 2014a; Elez *et al*., 2015; Fregenal-Martínez and Meléndez, 2016). From the late Barremian, two unconformity bounded units record sedimentation in the Alto Tajo-Serranía de Cuenca area, until transition and onset of post-rift (Albian) sedimentation of the Utrillas Group which extended all over this and contiguous areas (Fig. 4):

(1) The upper Barremian unconformity bounded unit (UBU 1) is by far the best represented, and the most complex in terms of lithological variability and architectural patterns. Such lithological variability is the major obstacle in classifying the sedimentary record in lithostratigraphic units (Fig. 4). Its late Barremian age has been determined by De Vicente and Martín-Closas (2013) all over the study area on the basis of charophyte and ostracods assemblages. This episode would correspond to the former uppermost Hauterivian-lower Barremian Cycle II of Mas *et al*. (1982), who considered it composed of two lithostratigraphic units related by a lateral change of facies: El Collado and La Huérguina formations (Fig. 2) (Vilas *et al*., 1982). However, El Collado Formation cannot be recognized in the Alto Tajo-Serranía de Cuenca region and hence its presence is discarded. Furthermore, there is not Hauterivian-lower Barremian sediments recorded in the area. The alternative lithostratigraphic scheme herein proposed (Fig. 4) is composed of two laterally related units, Tragacete and La Huérguina formations.

The Tragacete Formation here defined allows the accommodation of all those successions whose common feature is the overall sedimentation of clays and marls, with intercalated lenses of siliciclastic to mixed and carbonate lithologies. This new unit contains the deposits of what had been attributed to El Collado Formation (Vilas *et al*., 1982) in the Serranía de Cuenca, as well as the lower part of the former La Huérguina Formation defined by Vilas *et al*. (1982), which is in turn equivalent to Unit C-IIa of Meléndez (1983) and to Rambla de las Cruces I of Fregenal-Martínez (1998).

The definition of two parastratotypes has allowed us to emphasize the presence of bauxites and bauxitic clays with conspicuous paleosols (Parastratotype 1, Fig. 7) (Fregenal Martínez and Muñoz García, 2010; Muñoz-García *et al*., 2012, 2015), and to exemplify the noticeable regional variability of this unit (Parastratotype 2, Fig. 8). In this sense, these parastratotypes also facilitate its identification in the field keeping the number of formally defined stratigraphic units to a minimum.

La Huérguina Formation is herein redefined, but maintaining its original name because: 1) Its original definition by Vilas *et al*. (1982) proposed as holostratotype the succession recognizable in La Huérguina locality, which is located in the Serranía de Cuenca, and this section is still fully accessible and the best locality to exemplify the features of the redefined unit; 2) The abandonment of well-established and known names is not recommended by the International Stratigraphic Guide. La Huérguina is a very well and internationally known stratigraphic name, by being the unit enclosing the *Konservat-Lagerstatte* of Las Hoyas fossil site (Poyato-Ariza and Buscalioni, 2016) with literally thousands of international references. Therefore, the change of the name of the lithosome that contains Las Hoyas fossil site might have a strong impact and create undesirable confusion. Instead, the succession including Las Hoyas fossil site is herein proposed as a formal parastratotype for La Huérguina Formation (Fig. 12) to strengthen and make even more visible the link between the stratigraphic unit and its worldwide known palaeontological record. Furthermore, this parastratotype includes lithofacies that had not been considered in the original description of this stratigraphic unit by Vilas *et al*. (1982), such as fossiliferous finely laminated and cross-bedded limestones, highly representatives of the environmental and sedimentary dynamics of this unit.

Therefore, La Huérguina Formation is herein redefined in most aspects and new sedimentological and palaeontological data have been added to its description. Mixed lithologies, thick beds of clays and marls and siliciclastic beds coarser than clays recognizable at the lower part of the former La Huérguina Formation (Vilas *et al*., 1982) are now included in the Tragacete Formation. Therefore, La Huérguina is now exclusively composed of diverse facies of limestones and marls (Figs. 12 and 13). This scheme follows more accurately the criteria to define lithostratigraphic units. Moreover, it facilitates the recognition of the units in the field and the assignation of the outcrops to the units.

After its redefinition the name of La Huérguina Formation should not be used out of the palaeogeographic boundaries defined by ATMU and LT faults and hence, the supposedly equivalent sedimentary record and up to now so-called La Huérguina Formation in other areas of the Iberian Basin should be revised and properly renamed and defined.

From the environmental point of view, La Huérguina Formation has been also reinterpreted. The original environmental interpretation of this unit as deposited in coastal deltaic plains, coastal wetlands and lacustrine coastal plains (Vilas *et al*., 1982), was proposed for the uppermost Hauterivian-lower Barremian limestone lithosome recognized in the Valencia Sub-basin, which experienced a noticeable marine influence from the Tethys Sea (Mas, 1981; Mas *et al*., 1982). However, the Alto Tajo-Serranía de Cuenca La Huérguina lithosome lacks such marine influence which had been limited by the LT transfer fault (Fig. 3) during the late Barremian, and is characterized by alluvial, palustrine and lacustrine facies deposited in continental freshwater environments (Meléndez, 1983; Gómez-Fernández, 1988; Gierlowski-Kordesch and Janofske, 1989; Gierlowski-Kordesch *et al*., 1991; Fregenal-Martínez, 1994, 1998; Fregenal-Martínez and Meléndez, 2000, 2016; Fregenal-Martínez *et al*., 2014b; Muñoz-García *et al*., 2015, among others). This is also supported by the presence of biotas that inhabited freshwater aquatic and terrestrial environments and fossil assemblages that show the typical ecological composition of Recent large inland seasonal, tropical and subtropical, wetlands (De Vicente and Martín Closas, 2013; Buscalioni *et al*., 2008; Buscalioni and Fregenal-Martínez, 2010; Buscalioni *et al*., 2016; Poyato-Ariza and Buscalioni, 2016). It is worth highlighting that De Vicente and Martín-Closas (2013) found that the diversity of the charophyte assemblages in different outcrops of Tragacete and La Huérguina formations are constrained by the exclusive development of freshwater environments. The assemblages lack the presence of brackish-water taxa, and are rather monotonous and low diverse compared to coeval basins in southern Europe and in other Iberian Domains such as the Maestrazgo Basin that underwent marine influence. The freshwater origin and complete isolation from marine influence is also supported by geochemical data (Talbot *et al*., 1995a,b; Poyato-Ariza *et al*., 1998; Fregenal-Martínez *et al*., 2014b). The strontium isotopic composition of rocks and fossils collected in La Huérguina Formation, around Las Hoyas fossil site, clearly indicate a non-marine origin, and confirms that its water budget must have been dominated by inflow from the Middle Jurassic limestones (Talbot *et al*., 1995a, b). Moreover, the values and covariance of $\delta^{13}C$ and $\delta^{18}O$ indicate the existence of lacustrine conditions in a groundwater-dominated, hydrologically closed basin (Talbot *et al*., 1995a, b).

Concerning facies and environments, the Tragacete and La Huérguina formations correspond to two environmental belts of the same depositional system, with a large patchy mosaic of subenvironments (ponds, small lakes, channels, waterlogged soils, marshy and swampy inundated plains, and soils in hummocks of vegetation, among others), reflecting the typical landscape of large inland subtropical and tropical wetlands, poorly drained and strongly controlled by seasonal climate (Fregenal-Martínez and Meléndez, 2016). In general, the Tragacete Formation represents sedimentation in the best drained areas that received inputs of allochthonous sediments, while La Huérguina Formation records sedimentation in poorly drained areas where lacustrine conditions prevailed with minor influx of allochthonous sediments. The resulting depositional architecture is extremely complex and characterized by a large diversity of facies and a remarkable lateral variability. Such variability has hindered the design of a simple and still accurate lithostratigraphic scheme.

The seemingly simple stratigraphic architecture (Fig. 4) at regional scale is more complex by far when observed at local scale, because tectonics largely controlled the remarkable internal compartmentalization of the Alto Tajo-Serranía de Cuenca region in many small grabens and half-grabens. Figure 15 shows a synthetic sketch where the commonest stratigraphic position and relationship of the Tragacete and La Huérguina formations in the compartmentalized substrate are depicted. Sedimentation occurred on a substrate that consisted of a mature flat landscape that was rejuvenated by the late Barremian stretching creating a complex and smooth extensional topography. Early stages of sedimentation occurred in well defined depocenters that enlarged as the extensional fault linkage occurred and the sedimentation expanded (Fig. 15) (Fregenal-Martínez *et al*., 2014a; Elez *et al*., 2015). The consequences are multiple: 1) The Tragacete and La Huérguina formations are onlapping the substrate at local scale (Fig. 15); 2) The geometry and orientation of the lateral change of facies between both units may differ from each graben/half-graben to the next; 3) Some grabens/half-grabens are only filled by deposits of La Huérguina Formation, due to either their palaeogeographic position and structure, which maintained them apart from the regional drainage pathways thus favoring lacustrine conditions, or their late development. The chronology of development of the different grabens and half-grabens is also a remarkable constrain on distribution and stratigraphic architecture of the Tragacete and La Huérguina formations. At regional scale sedimentation progressed from the southcentral areas towards the NW and the boundaries of the region. Therefore this might explain the deeper erosion of the Jurassic substrate northwestwards (Fig. 4B), as it had remained exposed for a longer period than the central areas.

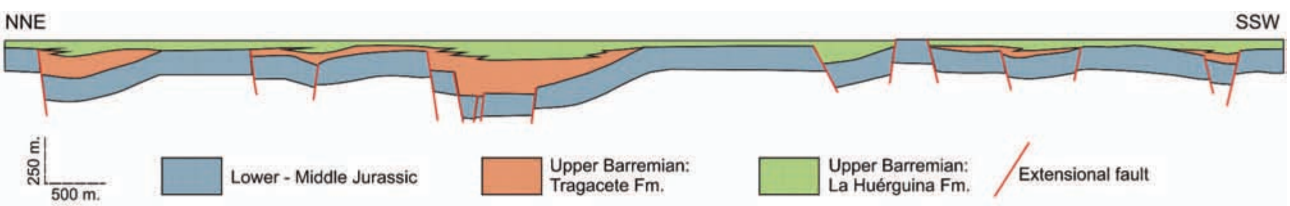

Fig. 15.- Synthetic sketch perpendicular to the main set of extensional faults, N110 directed, identified in the Alto Tajo-Serranía de Cuenca region. The commonest stratigraphic position and relationship of the Tragacete and La Huérguina formations upon the compartmentalized Jurassic substrate can be observed.

The top of the upper Barremian rifting episode is partially eroded and corresponds to an unconformity that developed during the structural rearrangement of the subsident areas at the onset of the following syn-rift episode (Figs. 2 and 4).

(2) The unconformity bounded unit UBU 2 records one more episode of sedimentation in the region during the Aptian. It is poorly recorded when compared to UBU 1, and most outcrops are located in the central and southern areas. At the northwestern area this unit either was not deposited, or it was completely eroded prior to post-rift Albian sedimentation represented by the Utrillas Group. The Aptian UBU2 is composed of the Contreras Formation and the Malacara and El Burgal members (El Caroch Formation). These lithostratigraphic units were originally defined for the entire Southwestern Domain by Vilas *et al*. (1982), and their stratotypes are located in the Valencia Sub-basin, excepting the Contreras Formation whose formal definition included an auxiliary reference section in Campillos-Paravientos (Cuenca province). Nevertheless, and opposite to the case of the late Barremian rifting episode, the best option for the Aptian episode is to maintain the original scheme.

Progressive rise of sea level during early Aptian finally overcame the LT transfer fault, which to that moment had kept the Alto Tajo-Serranía de Cuenca region palaeogeographically separated from other sedimentation areas. The Contreras Formation shows an increasing marine influence southeastwards as it changes laterally to the Malacara Member, which was deposited in the southern area of the Serranía de Cuenca, between the LT fault and Reíllo High (Fig. 3) (Meléndez, 1983). The Malacara Member is composed of coastal and marine facies as it is in Valencia Sub-basin. On the contrary, the late Aptian marine transgression that occurred in the Valencia Sub-basin (El Buseo Member, El Caroch Formation, Vilas *et al*., 1982) did not overcome the LT fault and did not reach the study area, although El Burgal Member shows marine influence. The following early Albian rifting episode recorded in the Valencia Sub-basin (Sácaras and Escucha formations) is not represented in the study area (Fig. 2). It is worth mentioning that the formal definition of the Contreras Formation by Vilas *et al*. (1982) assigned to it an early Barremian-earliest Aptian age. Such age is not compatible with the late Barremian age of the underlying Tragacete and La Huérguina formations (Fig. 4). Hence, the Contreras Formation should be considered early Aptian as already acknowledged by Salas *et al*. (2001) and Mas *et al.* (2004).

The resulting complexity of the described and discussed stratigraphic architecture is behind the confusion in the literature and the 1:50,000 MAGNA sheets (Table I). For instance, usually all of these Lower Cretaceous units appear in the geological maps grouped in a single unit under the name Weald or Weald Facies. Depending on the localities that single unit comprises just one, or two of the Lower Cretaceous successions separated by unconformities. Sometimes Weald Facies corresponds just to the units with siliciclastic lithology (Tragacete, Contreras and El Burgal formations). The Lower Cretaceous carbonatic deposits (mostly La Huérguina Formation and some outcrops of the Tragacete Formation) may have been identified as: 1) Middle or Upper Jurassic marine deposits; 2) grouped with the deposits and alteration features associated to the Upper Jurassic-lowermost Cretaceous discontinuity; 3) ig-

Units

Number of the 1:50 000 geological sheets	Middle Jurassic	Upper Jurassic	Upper Barremian		Lower Aptian	Upper Aptian
	Yémeda Fm.	*Unconformity related deposits*	*Tragacete Fm.*	*La Huérguina Fm.*	*Contreras Fm. and Malacara Mb.*	*Burgal Mb.*
488	J_{14-22}		C_{w14}	C_{w14}		
513	J_{14-22}		C_{w14}	C_{w14}		
514	J_{14-22}					
538	5		6	6		
539	11		12	12		
564	6		7 9	7 9		
565	17		21			
587	6	7	8	8	8	8
588	12		16	17	16	16
610	4 5	5	5 6	5 6	6	
611	12	12	13 14 15	13 14 15	14 15	14 15
612	J^{3-0}_{14-2}	J^{2-0}_{24-31}	$J_{p32}-C^{1}_{w15}$	$J_{p32}-C^{1}_{w15}$	$J_{p32}-C^{1}_{w15}$ C_{15} C^{2-1}_{15-21}	C^{2-1}_{15-21} C_{15}
635	J_{2}	J_{32-33}	C_{w14-15}	C_{w14-15}	C_{w14-15}	
636	J_{2-31}	J_{32-33}	C_{w14-15} C_{w14}	C_{w14-15} C_{w14}	C_{15} C_{w14-15}	C_{16}
637	J^{3-0}_{14-31}		$C^{0-2}_{w\,13-15}$		$C^{2-2}_{w\,15-16}$ $C^{0-2}_{w\,13-15}$ C^{2-3}_{15-15}	
663	J^{d}_{2}	J^{d}_{2}	C_{14-15}		C_{14-15}	
664	J^{d}_{2}		C_{14-15}		C_{14-15}	

Table I.- Equivalences between the stratigraphy proposed in this study and the stratigraphic units mapped in the geological sheets of the National Geological Mapping Program (MAGNA Plan) of the studied area.

nored; or 4) included in the Weald Facies. This is explicable given that different units may show resemblances in their lithology and facies, for example the Tragacete and Contreras formations contain abundant red clays and interspersed beds of conglomerates and sandstones.

The described stratigraphic complexity is linked to genetic aspects which, obviously, cannot be fully articulated in a lithostratigraphic scheme. Lithostratigraphy is basically a descriptive tool to classify the stratigraphic record and facilitates regional geological mapping. The lithostratigraphic scheme provided in this work is thought to be the best solution to clarify and describe thoroughly in a simple manner the stratigraphic record of the Late Jurassic-Early Cretaceous rifting at the Alto Tajo-Serranía de Cuenca region. Although it is aimed to describe the regional stratigraphy, it can still be a useful guide at local scale, and it is thought to be simple and accurate enough to avoid hindering the forthcoming genetic and palaeogeographic analyses.

Conclusions

A revision, updating and new lithostratigraphic proposal for the record of the Late Jurassic-Early Cretaceous Iberian rifting in the Alto Tajo-Serranía de Cuenca region has been accomplished.

The Late Jurassic and earliest Cretaceous are represented by an unconformity, which corresponds to a complex diachronous discontinuity that spans at least from Oxfordian to early Barremian in most of the study area. The unconformity is the result of a long period of non-sedimentation, pedogenesis, table-like dissolution of the substrate, karstification, and minor mechanical erosion. In the northernmost area, a noticeable paleorelief was formed by erosion that affected Lower Jurassic successions. This unconformity is unique to the Alto Tajo-Serranía de Cuenca region in terms of duration, genesis and evolution, as it cannot be recognized at any other area of the Iberian Basin.

Sedimentation did not occur in the Alto Tajo-Serranía de Cuenca region until late Barremian, the latest onset of syn-rift sedimentation in the Iberian Basin. It is represented by two successive unconformity bounded units (UBU 1 and 2) that in turn correspond to two successive rifting episodes. These units have a complex stratigraphic architecture, and show a noticeable spatial variation in lithology and thickness. This is largely the result of the internal structural compartmentalization of the basin into a myriad of grabens and half-grabens with moderate subsidence rate, and their reorganization for each following rifting episode, which in turn caused development of the corresponding periods of erosion and subsequent unconformities.

The currently acknowledged upper Barremian UBU 1 had been traditionally considered to be composed of El Collado and La Huérguina formations. This lithostratigraphic scheme has been proven to be no longer valid for the study region. El Collado Formation is not recognizable in the Alto Tajo-Serranía de Cuenca region and should not be longer used in the area. A new lithostratigraphic unit named Tragacete Formation is proposed to enclose the successions traditionally attributed to El Collado, and to include, in addition, successions that up to now had been included in the lower part of La Huérguina Formation. The Tragacete Formation is characterized by its lithological diversity although clayey lithology account for more than 50% of the total thickness of all its outcrops. Intercalations of lenses of siliciclastic to mixed and carbonate composition are common. Two parastratotypes have been designated to include the extreme cases of the observed lithological variability, which is represented by successions dominated by bauxitic clays and bauxites, and with dominance or marls and abundant carbonate intercalations.

La Huérguina Formation is maintained although it is herein redefined in terms of lithofacies, lower boundary, age and environmental reconstruction. This unit corresponds to a discrete limestone lithosome consistently dated as late Barremian. Some of the lithofacies up to now included in the former La Huérguina Formation are no longer part of it, while some new lithofacies have been incorporated to its definition and description. Concerning environments, La Huérguina Formation had been originally interpreted as deposited chiefly in coastal environments, as it occurs in older deposits recorded in the nearby Valencia Sub-basin. On the contrary, in the Alto Tajo-Serranía de Cuenca region, La Huérguina Formation has been repeatedly proven to lack any marine influence and its sediments were deposited in continental, fully freshwater environments, and in the framework of a regional inland subtropical system of wetlands. Las Hoyas locality, which encloses the homonymous worldwide known *Konservat-Lagersttate,* is proposed as a parastrotype because it contains a facies succession that had not been included in the original definition of La Huérguina Formation and is highly representative of the environmental and sedimentary dynamics of this unit.

The upper Barremian sediments in the Alto Tajo-Serranía de Cuenca region are also characterized by its extraordinary palaeontological record; there are a large number of fossil sites with diverse and abundant continental flora and fauna. All known fossil sites described in the literature have been revised and reassigned to the new lithostratigraphic units in their formal description.

The herein defined La Huérguina Formation is applicable inside the palaeogeographic boundaries defined by the ATMU and LT faults. The formerly interpreted as the equivalent record and up to now so-called La Huérguina in other areas of the Iberian Basin should be properly defined and renamed.

The traditional lithostratigraphic nomenclature used for the Aptian episode (UBU 2) has been maintained, although the age of the corresponding lithostratigraphic units should be considered younger than the original attribution in the formal definition of the Contreras Formation and the Malacara and El Burgal members (El Caroch Formation). The presence of lower Aptian marine deposits represented by the Malacara Member, points to the occasional connection of Cuenca and Valencia sub-basins during major transgressions, which would overcome the LT fault. Otherwise this tectonic structure kept both areas separated and undergoing different palaeogeographic evolution during the entire Late Jurassic-Early Cretaceous rifting cycle.

The revision and updating carried out in this work was also intended to clarify and simplify the diverse nomenclatures that have been used in the geological maps of the National Geological Mapping Program (MAGNA Plan) all along several decades, as well as to serve as a basis for any geological work to be developed in the herein studied area from now onwards. In that line, twenty 1:50,000 MAGNA geological maps have been revised and the correspondence between the cartographic units used in the maps and the units described and defined in this work has been established.

Acknowledgements

This work is a contribution to project CGL2013-42643 of the Spanish Ministry of Economy and Competitiveness. We acknowledge Dr. José López-Gómez (IGEO-UCM) for his comments and suggestions on an earlier version of this manuscript. Dr. Marcos Aurell (University of Zaragoza) and Dr. Alberto Pérez-López (University of Granada) are acknowledged for their rigorous and thoroughly review of the manuscript that clearly improved it. Dr. Beatriz Bádenas is also acknowledged for her careful and helpful editorial work.

References

Adell Argilés, F., Martínez Álvarez, F., Bascones Alvira, L., Martín Herrero, D. and Lamoneda González, E. (1978): *Mapa Geológico de España 1:50.000, hoja nº 488 (Ablanque)*. IGME, Madrid.

Adell Argilés, F., Lendínez González, A., Martínez Álvarez, F., Tena-Dávila Ruiz, M. and La Moneda González, E. (1979): *Mapa Geológico de España 1:50.000, hoja nº 513 (Zaorejas)*. IGME, Madrid.

Abril Hurtado, J. and Rubio Navas, J. (1977): *Mapa Geológico de España 1:50.000, hoja nº 612 (Ademuz)*. IGME, Madrid.

Álvaro, M., Capote, R. and Vegas, R. (1979): Un modelo de evolución geotectónica para la Cadena Celtibérica. *Acta Geológica Hispánica*, 14: 172–177.

Anadón, P., Alcalá., L., Alonso-Zarza, A.M., Calvo, J.P., Ortí, F. and Rosell, L. (2004): Cuenca de Teruel. In: *Geología de España* (J.A. Vera, Ed.), *SGE-IGME*, Madrid, 656–657.

Arche, A. and López-Gómez, J. (1996): Origin of the Permian–Triassic Iberian Basin, central-eastern Spain. *Tectonophysics*, 266: 443–464.

Aurell, M., Robles, S., Bádenas, B., Rosales, I., Quesada, S., Meléndez, G. and García-Ramos, J.C. (2003): Transgressive-Regressive cycles and Jurassic palaeogeography of northeast Iberia. *Sedimentary Geology*, 162 (3-4): 239–271.

Bádenas, B. and Aurell M. (2001): Kimmeridgian palaeogeography and basin evolution of northeastern Iberian. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 168 (3-4): 291–310.

Bascones Alvira, L. and Martín Herrero, D. (1979): *Mapa Geológico de España 1:50.000, hoja nº 515 (El Pobo de Dueñas)*. IGME, Madrid.

Bascones Alvira, L., Lendínez González, A., Martín Herrero, D. and Tena-Dávila Ruiz, M. (1979): *Mapa Geológico de España 1:50.000, hoja nº 514 (Taravilla)*. IGME, Madrid.

Bascones Alvira, L., Lendínez González, A., Martín Herrero, D. and Tena-Dávila Ruiz, M. (1980): *Mapa Geológico de España 1:50.000, hoja nº 540 (Checa)*. IGME, Madrid.

Berasategui Batalla, J. and Ramírez Merino, J.I. (1982): *Mapa Geológico de España 1:50.000, hoja nº 611 (Cañete)*. IGME, Madrid.

Berasategui Batalla, J. and Ramírez Merino, J.I. (1982): *Mapa Geológico de España 1:50.000, hoja nº 588 (Zafrilla)*. IGME, Madrid.

Brenner, P. and Wiedmann, J. (1974): Nuevas aportaciones al conocimiento del "Weald" Celtibérico Septentrional y sus relaciones paleogeográficas. In: *Primer Simposio Cretácico de la Cordillera Ibérica, Cuenca*, 123–134.

Buscalioni A.D. and Fregenal-Martinez M.A. (2010): A holistic approach to the palaeoecology of Las Hoyas Konservat-Lagerstätte (La Huérguina Formation, Lower Cretaceous, Iberian Ranges, Spain). *Journal of Iberian Geology*, 36 (2): 297–326.

Buscalioni, A.D. and Poyato-Ariza, F.J. (2016): Relevance of Las Hoyas as a Mesozoic *Lagerstätte*. In: *Las Hoyas: A Cretaceous wetland. A multidisciplinary synthesis after 25 years of research on an exceptional fossil deposit from Spain* (F. Poyato-Ariza and A.D. Buscalioni, Eds.). Verlag Dr. Friedrich Pfeil, Munich, 13.

Buscalioni, A.D., Fregenal-Martínez, M.A., Bravo, A., Poyato Ariza, F.J., Sanchíz, B., Baez, A.M., Cambra Moo, O., Martín-Closas, C., Evans, S.E., and Marugán-Lobón, J. (2008): The vertebrate assemblage of Buenache de la Sierra (Upper Barremian of Serranía de Cuenca, Spain) with insights into its taphonomy and paleoecology. *Cretaceous Research*, 29: 687–710.

Buscalioni, A.D., Poyato-Ariza, F.J., Marugán-Lobón, J., Fregenal-Martínez, M.A., Sanisidro, O., Navalón, G. and De Miguel, C. (2016): The wetland of Las Hoyas. In: *Las Hoyas: A Cretaceous wetland. A multidisciplinary synthesis after 25 years of research on an exceptional fossil deposit from Spain* (F. Poyato-Ariza and A.D. Buscalioni, Eds.). Verlag Dr. Friedrich Pfeil, Munich, 238–253.

Chamizo-Borreguero, M., Meléndez, N. and De Boer, P.L. (2016): Tidal-bore deposits in incised valleys, Albian, SW Iberian Ranges, Spain. In: *Contributions to Modern and Ancient Tidal Sedimentology: Proceedings of the Tidalites 2012 Conference.* (B. Tessier, J-Y. Reynaud, Eds.), *I.A.S., Special Publication*, 48: 93–115.

Comas-Rengifo, M.J., Goy, A. and Pérez-González, A. (1975): Identificación del Cretácico inferior en facies "Weald" en la región comprendida entre Canales del Ducado y la Fuentesaviñán (Provincia de Guadalajara). *Estudios Geológicos*, XXXI: 369–373.

Curnelle, R. (1968): Etude geologique dans la Serranía de Cuenca de Priego a Beteta (Chaînes Ibériques Occidentales-Province de Cuenca. Tesis Doctoral, Universidad de Bordeaux.

De la Horra, R., Muñoz-García, M.B., Fregenal-Martínez, M. and Elez, J. (2014): Paleoenvironmental interpretation of paleosols and palustrine carbonates of the Lower Cretaceous earliest terrestrial ecosystems in the Serranía de Cuenca, SE Iberian Ranges, Spain. In: *STRATI 2013, First International Congress on Stratigraphy At the Cutting Edge of Stratigraphy* (R. Rocha, J. Pais, J.C., Kullberg and S. Finney, Eds.), Springer, Berlin, 1191–1195.

De Vicente, A. and Martín Closas, C. (2013): Lower Cretaceous charophytes from the Serrania de Cuenca, Iberian chain: Taxonomy, biostratigraphy and palaeoecology. *Cretaceous Research*, 40: 227–242.

De Vicente, G., Vegas, R., Muñoz-Martín, A., Van Wees, J.D., Casas-Sáinz, A., Sopeña, A., Sánchez-Moya, Y., Arche, A., López-Gómez, J., Olaiz, A. and Fernández-Lozano, J. (2009): Oblique strain partitioning and transpression on an inverted rift: The Castilian Branch of the Iberian Chain. *Tectonophysics*, 470 (3–4): 224–242.

Del Olmo, P. and Álvaro, M. (1985): *Mapa Geológico de España 1:50.000, hoja nº 539 (Peralejos de las Truchas)*. ITGE, Madrid.

Del Olmo Zamora, P. (1986) *Mapa Geológico de España 1:50.000, hoja nº 610 (Cuenca)*. IGME, Madrid.

Diéguez, C., Martín-Closas, C., Meléndez, N., Rodríguez-Lázaro, J. and Trincao, P. (1995): Biostratigraphy. In: *Las Hoyas, a lacustrine Konservat-Lagerstätte (Cuenca, Spain),* (N. Meléndez, Ed.). Universidad Complutense de Madrid, 29–32.

Elez, J., Fregenal-Martínez, M.A., Muñoz-García, M.B. and De la Horra, R. (2015): Stratigraphic architecture of rift-related continental basins at the onset of stretching: Examples from the syn-rift Upper Barremian of the Southwestern Iberian Basin, east-central Spain. In: *31st IAS Meeting of Sedimentology, Kraków (Poland)*. Abstracts: 165.

Fonollá, F., Goy, A., Meléndez, F., Robles, F. and Talens, J. (1972): *Mapa Geológico de España 1:50.000, hoja nº 665 (Mira)*. IGME, Madrid.

Fonollá, F., Goy, A., Meléndez, F., Robles, F. and Talens, J. (1974): *Mapa Geológico de España 1:50.000, hoja nº 637 (Landete)*. IGME, Madrid.

Francés, V. and Sanz, J.L. (1989): Restos de dinosaurios del Cretácico inferior de Buenache de la Sierra (Cuenca). In: *La fauna del pasado en Cuenca. Actas del I Curso de Paleontología en Cuenca.* Instituto "Juan Valdés" del Excmo. Ayuntamiento de Cuenca. Serie Actas Académicas, 1: 125–144.

Fregenal-Martínez, M.A. (1994): *El sistema lacustre de Las Hoyas (Cretácico inferior, Serranía de Cuenca): Estratigrafía y Sedimentología.* Publicaciones de la Excma. Diputación Provincial de Cuenca, Serie Palaeontología, nº 1, Cuenca, 181 p.

Fregenal-Martínez, M.A. (1998): Análisis de la cubeta sedimentaria de Las Hoyas y su entorno palaeogeográfico (Cretácico Inferior, Serranía de Cuenca). Sedimentología y aspectos tafonómicos del yacimiento de Las Hoyas. Tesis Doctoral Universidad Complutense de Madrid, 354 p.

Fregenal Martínez, M.A. and Meléndez, N. (1993): Sedimentología y evolución paleogeográfica de la cubeta de Las Hoyas. *Cuadernos de Geología Ibérica*, 17: 231–256.

Fregenal-Martínez, M.A. and Meléndez, N. (2000): The lacustrine fossiliferous deposits of the Las Hoyas sub-basin (Lower Cretaceous, Serranía de Cuenca, Iberian Ranges, Spain). In: *Lake basins through space and time,* (E.H. Gierlowski-Kordesch and K. Kelts, Eds.). *AAPG Studies in Geology*, 46: 303–314.

Fregenal-Martínez, M.A. and Meléndez, N. (2016): Environmental reconstruction: an historical review. In: *Las Hoyas: A Cretaceous wetland. A multidisciplinary synthesis after 25 years of research on an exceptional fossil deposit from Spain,* (F. Poyato-Ariza and A.D. Buscalioni, Eds.). Verlag Dr. Friedrich Pfeil, Munich, 14–28.

Fregenal-Martínez, M. and Muñoz-García, M.B. (2010): Upper Jurassic-Lower Cretaceous subtropical karstification in the South-western Iberian Ranges, Spain: characterization of the deposits associated to a regional unconformity and their paleoclimatic implications. In: *18th International Sedimentological Congress, Mendoza, Argentina*. Abstracts: 367.

Fregenal-Martínez, M., Elez, J., Muñoz-García, M.B. and De la Horra, R. (2014a): The stratigraphy and rifting evolution of the Oxfordian-Upper Barremian (Upper Jurassic-Lower Cretaceous) in the Serranía de Cuenca (Southwestern Iberian Ranges, Spain). In: *STRATI 2013, First International Congress on Stratigraphy At the Cutting Edge of Stratigraphy* (R. Rocha, J. Pais, J.C., Kullberg and S. Finney, Eds.), Springer, Berlin: 655–658.

Fregenal-Martínez, M.A., Muñoz-García, M.B., Élez, J., de la Horra, R. (2014b): The karstic habitat of spelaeogriphacean from Las Hoyas fossil site (Upper Barremian, Serranía de Cuenca, Spain). In: *STRATI 2013, First International Congress on Stratigraphy At the Cutting Edge of Stratigraphy* (R. Rocha, J. Pais, J.C., Kullberg and S. Finney, Eds.), Springer, Berlin: 1175–1180.

Gabaldón, V., Olivier, C. and Sánchez Soria, P. (1974a): *Mapa Geológico de España 1:50.000, hoja nº 663 (Valera de Abajo)*. IGME, Madrid.

Gabaldón, V., Olivier, C.and Sánchez Soria, P. (1974b): *Mapa Geológico de España 1:50.000, hoja nº 664 (Enguídanos)*. IGME, Madrid.

García Quintana, A. (1977): *Jurásico terminal y Cretácico inferior en la región central de la provincia de Valencia y noreste de la provincia de Albacete.* Seminarios de Estratigrafía, 1. Editorial de la Universidad Complutense, Madrid, 334 p.

Gierlowski-Kordesch, E. and Janofske, D. (1989): Paleoenvironmental reconstruction of the Weald around Uña (Serranía de Cuenca, Cuenca province, Spain). In: *Cretaceous of the Western Tethys. Proceedings 3rd. International Cretaceous Symposium, Tübingen,* (J. Wiedmann, Ed.), E. Schwiezerbart'sche Werlagsbruchnand-lung, Stutgart, 239–264.

Gierlowski-Kordesch, E., Gómez-Fernández, J.C. and Meléndez, N. (1991): Carbonate and coal deposition in an alluvial lacustrine setting: Lower Cretaceous (Weald) in the Iberian Range (East-Central Spain). In: *Lacustrine Facies Analysis* (P. Anadón, Ll. Cabrera and K. Kelts, Eds.). *I.A.S. Special Publication*, 13: 111–127.

Giménez, R. and Rey, L. (1982): El Cretácico entre Villanueva de Alcorón y Villar de Cobeta. *Cuadenos de Geología Ibérica*, 8: 391–410.

Gomez, B., Martín-Closas, C., Méon, H., Thévenard, F. and Barale, G. (2001): Plant taphonomy and palaeoecology in the lacustrine Uña delta (Late Barremian, Iberian Ranges, Spain). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 170: 133–148.

Gómez, J. (1979): *El Jurásico en facies carbonatadas del sector levantino de la Cordillera Ibérica.* Seminarios de Estratigrafía, 4. Editorial de la Universidad Complutense de Madrid, 683 p.

Gómez, J.J. and Fernández-López, S. (2004a): Las unidades litoestratigráficas del Jurásico Medio de la Cordillera Ibérica. *Geogaceta*, 35: 91–94.

Gómez, J.J. and Fernández-López, S. (2004b): The Middle Jurassic Eastern margin of the Iberian platform system (Eastern Spain). *Riv. Ital. Paleontol. Stratigr*., 110: 151–162.

Gómez, J.J. and Fernández-López, S.R. (2006): The Iberian Middle Jurassic carbonate-platform system: Synthesis of the palaeogeographic elements of its Eastern margin (Spain). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 236: 190–205.

Gómez, J.J., Fernández-López, S.R. and Goy, A. (2004): Primera fase de post-rifting: Jurásico Inferior y Medio. In: *Geología de España* (J.A. Vera, Ed.), Sociedad Geológica de España-Instituto Geológico y Minero de España, Madrid, 495–503.

Gómez Fernández, J.C. (1988): Estratigrafía y Sedimentología del Cretácico inferior en "Facies Weald" de la región meridional de la Serranía de Cuenca. Tesis de Licenciatura. Universidad Complutense de Madrid, 228 p.

Gómez Fernández, J.C. and Meléndez Hevia, N. (1991): Rhythmically laminated lacustrine deposits in the lower Cretaceous of la Serranía de Cuenca basin (Iberian Ranges, Spain). In: *Lacustrine Facies Analysis* (P. Anadón, Ll. Cabrera and K. Kelts, Eds.). *I.A.S. Special Publication*, 13: 247–258.

Goy, A., Gómez, J.J. and Yébenes, A. (1976): El Jurásico de la Rama Castellana de la Cordillera Ibérica. Mitad norte I. Unidades litoestratigráficas. *Estudios Geológicos,* 32: 391–423.

Hedberg, H.D. (Ed.) 1976: *International stratigraphic guide. A guide to stratigraphic classification, terminology and procedure.* International Subcommission on Stratigraphic Classification of IUGS Commission on Stratigraphy John Wiley & Sons, Nueva York, 220 p.

Henkel, S. and Krebs, B. (1969): Zwei Säugetier-Unterkiefer aus der Unteren Kreide von Uña (Prov. Cuenca, Spanien). *Neues Jahrbuch für Geologie und Paläontologie*, Mh. 8: 449–463.

Hernández Samaniego, A. and Lendínez González, A. (1986): *Mapa Geológico de España 1:50.000, hoja nº 564 (Fuertescusa)*. ITGE, Madrid.

Holtz, T.R., Chapman, R.E. and Lamanna, M.C. (2004): Mesozoic Biogeography of Dinosauria. In: *The Dinosauria* (D.B. Weishampel, P. Dodson and H. Osmólska, Eds.), University of California Press, Berkeley, CA, 627–642.

International Comission on Stratigraphy (2016): *Stratigraphic Guide.* http://www.stratigraphy.org/index.php/ics-stratigraphicguide

Lapparent, A.F. de, Curnelle, R., Defaut, B., Miroschedji, A. de and Pallard, B. (1969): Nouveaux gisements de Dinosaures en Espagne centrale. *Estudios Geológicos,* 25: 311–315.

Lendínez González, A. and Tena Dávila Ruiz, M. (1985): *Mapa Geológico de España 1:50.000, hoja nº 538 (Valdeolivas).* ITGE, Madrid.

Liesa, C., Soria, A.R., Casas, A., Aurell, M., Meléndez, N., Bádenas, B., Fregenal-Martínez, M., Navarrete, R., Peropadre, C. and Rodríguez-López, J.P. (In press): The Late Jurassic–Early Cretaceous rifting stage at the central and eastern Iberian Basin: The central and eastern Iberian Basin. In: *Geology of Iberia: a Geodynamic Approach* (C. Quesada, Ed.), Springer, Berlin.

Martín-Closas, C., Clavel, B., Charollais, J. and Conrad, M.-A. (2009): Charophytes from the Barremian-lower Aptian of the Northern Subalpine Chains and Jura Mountains, France: correlation with associated marine assemblages. *Cretaceous Research,* 30: 49–62.

Mas, J.R. (1981): *El Cretácico inferior de la región noroccidental de la provincia de Valencia.* Seminarios de Estratigrafía, 8. Editorial de la Universidad Complutense, Madrid, 408 p.

Mas, J.R., Alonso, A. and Meléndez, N. (1982): El Cretácico basal "Weald" de la Cordillera Ibérica Suroccidental (NW de la provincia de Valencia y E de la de Cuenca). *Cuadernos de Geología Ibérica*, 8: 309–335.

Mas, J.R., Alonso, A. and Meléndez, N. (1984): La Formación Villar del Arzobispo: un ejemplo de llanuras de marea siliciclásticas asociadas a plataformas carbonatadas. Jurásico terminal (NW. de Valencia y E. de Cuenca). In: *Publicaciones de Geología* 20 (A. Obrador Turudi, Ed.), Universidad Autónoma de Barcelona: 175–188.

Mas, R., García, A., Salas, R., Meléndez, A., Alonso, A., Aurell, M., Bádenas, B., Benito, M.I., Carenas, B., García-Hidalgo, J.F., Gil, J. and Segura, M. (2004): Segunda fase de rifting: Jurásico Superior-Cretácico Inferior. In: *Geología de España* (J.A. Vera, Ed.), Sociedad Geológica de España-Instituto Geológico y Minero de España, Madrid, 503–510.

Meléndez, N. (1982): Presencia de una discordancia cartográfica intrabarremiense en la Cordillera Ibérica Suroccidental (provincia de Cuenca). *Estudios Geológicos*, 38: 51–54.

Meléndez, N. (1983): *El Cretácico de la región de Cañete-Rincón de Ademuz (provincia de Cuenca y Valencia).* Seminarios de Estratigrafía, 9. Editorial de la Universidad Complutense, Madrid, 242 p.

Meléndez, M.N. and López-Gómez, J. (2003): Control eustático y tectónico durante una etapa regresiva de corta duración: Miembro El Burgal, Aptiense, Cordillera Ibérica, España. *Journal of Iberian Geology*, 29: 29–54.

Meléndez, N., Meléndez, A. and Gómez-Fernández, J.C. (1989): *Los sistemas lacustres del Cretácico inferior de la serranía de Cuenca, Cordillera Ibérica. Guía de campo de la IV Reunión del Grupo Español de Trabajo del IGCP-219.* Editorial de la Universidad Complutense, Madrid, 70 p.

Meléndez, N., Meléndez, A. and Gómez Fernández, J.C. (1994): La Serranía de Cuenca Basin (Lower Cretaceous), Iberian Ranges, central Spain. In: *Global Geological Record of Lake Basins, I.* (E. Gierlowski-Kordesch and K. Kelts, Eds.), Cambridge University Press, 215–219.

Meléndez Hevia, F. (1971): Estudio geológico de la Serranía de Cuenca en relación con sus posibilidades petrolíferas. Tesis Doctoral, Universidad Complutense de Madrid, 245 p.

Meléndez Hevia, F. (1972): El sinclinal Cretácico del Alto Tajo-Valdecabriel (Serranía de Cuenca). *Boletín Geológico y Minero*, LXXXIII: 211–220.

Meléndez Hevia, F. (1974): Correlación del Cretácico de la Serranía de Cuenca con el sondeo Villanueva de los Escuderos I (Cuenca). In: *Primer Simposio Cretácico de la Cordillera Ibérica, Cuenca*, 86–95.

Meléndez Hevia, F., Villena, J., Ramírez, J., Portero, J.M., Olive, A., Assenz, J. and Sánchez, P. (1974a): Síntesis del Cretácico de la zona Sur de la Rama Castellana de la Cordillera Ibérica. In: *Primer Simposio Cretácico de la Cordillera Ibérica, Cuenca*, 189–205.

Meléndez Hevia, F., Meléndez Hevia, A., Ramírez, J., Portero, J.M. and Gutiérrez, G. (1974b): Guía de las excursiones geológicas a Tragacete-Las Majadas y Cañete-Landete. In: *Primer Simposio Cretácico de la Cordillera Ibérica, Cuenca*, 253–257.

Menéndez Amor, J. (1970): Primera contribución al estudio esporo-polínico de los lignitos de Uña (Cuenca). *Boletín de la Real Sociedad Española de Historia Natural (Geol.),* 68 (3-4): 275–281.

Morillo-Velarde, M.J. and Meléndez Hevia, F. (1979): El Jurásico de "La Alcarria"-"La Mancha". *Cuadernos de Geología (Universidad de Granada),* 10: 149–166.

Muñoz-García, M.B., Coruña Llopis, F. and Fregenal Martínez, M.A. (2012): Caracterización de los depósitos bauxíticos de la base de la Formación Calizas de La Huérguina en el surco de Uña-Las Hoyas (Barremiense, Serranía de Cuenca, Cordillera Ibérica Suroccidental). *Geo-Temas,* 13: 238–241.

Muñoz-García, M.B., Fregenal, M.A., Elez, J. and de la Horra, R. (2015): The hidden face of the karst or the hidden karst phase in the Lower Cretaceous of the Serrania de Cuenca basin (east-central Spain). In: *31st IAS Meeting of Sedimentology, Kraków (Poland).* Abstracts: 367.

Murphy, A. and Salvador, A. (Ed.) (1998): International Stratigraphic Guide. An abridged version. *Episodes*, 22 (4): 255–272.

Ogg, J.G., Ogg, G. and Gradstein, F.M. (2016): *A concise Geologic Time Scale,* Elsevier B.V., Amsterdam, 234 p.

Portero García, J.M., Olivé Davó, A. and Ramírez del Pozo, J. (1975): *Mapa Geológico de España 1:50.000, hoja nº 636 (Villar del Humo)*. IGME, Madrid.

Portero García, J.M., Meléndez Hevia, F. and Riba Arderiu, O. (1981): *Mapa Geológico de España 1:50.000, hoja nº 565 (Tragacete)*. IGME, Madrid.

Poyato-Ariza, F.J. and Buscalioni, A.D. (Eds.) (2016): *Las Hoyas: A Cretaceous wetland. A multidisciplinary synthesis after 25 years of research on an exceptional fossil deposit from Spain.* Verlag Dr. Friedrich Pfeil, Munich, 262 p.

Poyato-Ariza, F.J., Talbot, M.R., Fregenal-Martínez, M.A., Meléndez, N. and Wenz, S. (1998): First isotopic and multidisciplinary evidence for nonmarine coelacanths and pycnodontiform fishes: palaeoenvironmental implications. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 144: 64–84.

Ramírez, J.I. (1986): *Mapa Geológico de España 1:50.000, hoja nº 587 (Las Majadas)*. ITGE, Madrid.

Ramírez del Pozo, J. and Meléndez Hevia, F. 1972. Nuevos datos sobre el Cretácico inferior en "facies weald" de la Serranía de Cuenca. *Boletín Geológico y Minero*, LXXXIII-IV: 569–581.

Ramírez del Pozo, J., Portero García, J.M. and Olivé Davó, A. (1973): *Mapa Geológico de España 1:50.000, hoja nº 635 (Fuentes)*. IGME, Madrid.

Ramírez del Pozo, J., Portero, J.M., Olive, A. and Meléndez Hevia, F. (1974): El Cretácico de la región Fuentes-Villar del Humo: Correlación y cambios de facies. In: *Primer Simposio Cretácico de la Cordillera Ibérica, Cuenca*, 189–205.

Rauhut, O.W. and Zinke, J. (1995): A description of the Barremian Dinosaur fauna from Uña with a comparation to that of Las Hoyas. In: *International Symposium on Lithographic Limestones (Lleida-Cuenca)*, Universidad Autónoma de Madrid (Ed.), Extended abstracts: 123–126.

Rey Marcos, L. (1982): El Cretácico del Alto Tajo entre Canales del Ducado y Villar de Cobeta (Provincia de Guadalajara). Tesis de Licenciatura, Universidad Complutense de Madrid, 161 p.

Rodríguez-López J.P., Meléndez, N., De Boer, P.L. and Soria, A.R. (2010): The action of wind and water in a Mid-Cretaceous subtropical erg-margin system close to the Variscan Iberian Massif, Spain. *Sedimentology*, 57, 1315–1356.

Rodríguez Pascua, M.A., de Vicente Muñoz, G. and González Casado, J.M. (1994): Cinemática y dinámica de las deformaciones en la zona del alto Tajo (Guadalajara). *Cuadernos do Laboratorio Xeolóxico de Laxe,* 19: 163–174.

Rosembaum, G., Lister, S.G. and Duboz, C. (2002): Relative motions of Africa, Iberia and Europe during Alpine orogeny. *Tectonophysics* , 359(1): 117–129.

Salas, R. and Casas, A. (1993): Mesozoic extensional tectonics, stratigraphy and crustal evolution during the Alpine cycle of the eastern Iberian Basin. *Tectonophysics*, 228: 33–56.

Salas, R., Guimerà, J., Mas, R., Martín-Closas, C., Melendéz, A. and Alonso, A. (2001): Evolution of the Mesozoic central Iberian Rift System and its Cainozoic inversion (Iberian chain). In: *Peri-Tethyan Rift/Wrench Basins and Passive Margins* (P.A. Ziegler, W. Cavazza, A.H.F. Robertson and S. Crasquin-Soleau, Eds.), *PeriTethys Memoir*, 6: 145–185.

Salvador, A. (Ed.) (1994): *International stratigraphic guide: a guide to stratigraphic classification, terminology, and procedure.* 2nd Ed. International Subcommission on Stratigraphic Classification of IUGS International Commission on Stratigraphy. Geological Society of America, 210 p.

Sanz, J.L. (1985): Nouveaux gisements de dinosaures dans le Crétacé espagnol. In: *Les Dinosaures de la Chine à la France.* Museum d´Histoire Naturelle de Toulouse, 81–88.

Seilacher, A., Reif, W.-E., Westphal, F., Riding, R., Clarkson, E.N.K. and Whittington, H.B. (1985): Sedimentological, Ecological and Temporal Patterns of Fossil Lagerstatten [and Discussion]. *Philos. Trans. R. Soc. B Biol. Sci.,* 311: 5–24.

Schudack, U. and Schudack, M. (2009): Ostracod biostratigraphy in the Lower Cretaceous of the Iberian chain (eastern Spain). *Journal of Iberian Geology*, 35: 141–168.

Sopeña, A. (Ed.) (2004): Cordilleras Ibérica y Costero-Catalana. In: *Geología de España* (J.A. Vera, Ed.), Sociedad Geológica de España-Instituto Geológico y Minero de España, Madrid, 465–528.

Sopeña, A., López-Gómez, J., Arche, A., Pérez-Arlucea, M., Ramos, A., Virgili, C. and Hernando, S. (1988): Permian and Triassic rift basins of the Iberian Peninsula, In: *Triassic-Jurassic Rifting, Part B* (Manspeizer, Ed.), Elsevier, Amsterdam, 757–786.

Soria, A.R., Meléndez, A., Aurell, M., Liesa, C.L., Meléndez, M.N. and Gómez-Fernández, J.C. (2000): The Early Cretaceous of the Iberian Basin (Northeastern Spain). In: *Lake basins through space and time,* (E.H. Gierlowski-Kordesch and K. Kelts, Eds.). AAPG Studies in Geology, 46: 257–262.

Talbot, M., Meléndez, N. and Fregenal Martínez, M.A. (1995a): The waters of the Las Hoyas lake: sources and limnological characteristics. In: *Las Hoyas. A lacustrine Konservat-Lagerstätte, Cuenca, Spain. Field trip guide book. II International Symposium on Lithographic Limestones, Cuenca,* (N. Meléndez, Ed.), Editorial Complutense, Madrid, 11–16.

Talbot, M.R., Meléndez Hevia, N., Fregenal Martínez, M.A., Poyato Ariza, F.J. and Wenz, S. (1995b): Hydrology of the Las Hoyas paleolake (Lower Cretaceous, Cuenca, Spain): An integrated strontium and stable isotope study. In: *First International Limno-geological Congress*, Abstracts, Copenhagen, 133.

Tugend, J., Manatschal, G. and Kusznir, N.J. (2015): Spatial and temporal evolution of hyperextended rift systems: Implication for the nature, kinematics, and timing of the Iberian-European plate boundary. *Geology*, 43: 15–18.

Van Wees, J.D. and Stephenson, R.A. (1995): Quantitative modeling of basin and rheological evolution of the Iberian Basin (Central Spain): implications for lithospheric dynamics of intra plate extension and inversion. *Tectonophysics*, 252: 163–178.

Van Wees, J.D., Arche, A., Beijdorff, C.G, López-Gómez, J. and Cloetingh, S. (1998): Temporal and spatial variations in tectonic subsidence in the Iberian Basin (eastern Spain): inferences from automated forward modelling of high-resolution stratigraphy (Permian–Mesozoic). *Tectonophysics*, 300: 285–310.

Vera, J.A., Ancochea, E., Barnolas, A., Bea, F., Calvo, J.P., Civis, J., De Vicente, G., Fernández-Gianotti, J., García-Cortés, A., Pérez-Estaún, A., Pujalte, V., Rodriguez-Fernández, L.R., Sopeña, A. and Tejero, R. (2004): Introducción. In: *Geología de España* (J.A. Vera, Ed.), Sociedad Geológica de España-Instituto Geológico y Minero de España, Madrid, 3–17.

Viallard, P. (1966): Sur le Crétacé de la chaine ibérique castillane entre le Rio Turia et la haute vallée du Rio Jucar (province de Valencia et Cuenca, Espagne). *Comptes Rendus del'Académie des Sciences,* 262: 1997–2000.

Viallard, P. (1968): Le Crétacé inférieur dans la zone marginale sud-occidentale de la Chaine Ibérique. *Compte Rendu Sommaire de la Soc. Geol. France,* 9: 321–323.

Viallard, P. (1969): Le Neocrétacé de la Chaîne Ibérique castillaine à SW de la Serranía de Cuenca. *Compte Rendu Sommaire de la Soc. Geol. France*, 6: 211–212.

Viallard, P. (1973): Recherches sur le cycle alpin dans la Chaîne Ibérique Sud-Occidentale. Tesis Doctoral, Université Paul Sabatier de Toulouse, 445 p.

Vilas, L., Mas, R., García, A., Arias, C., Alonso, A., Meléndez, N. and Rincón, R. (1982): Ibérica Suroccidental. In: El Cretácico de España. Editorial de la Universidad Complutense, Madrid, 457–513.

Vissers, R.L.M., Van Hinsbergen D.J.J., Meijer, P.Th. and Piccardo, G.B (2013): Kinematics of Jurassic ultra-slow spreading in the Piemonte Ligurianocean. Earth and Planetary Science Letters, 380: 138–150.

Ziegler, P.A. (1988): Evolution of the Arctic-North Atlantic and Western Tethys. *AAPG Memoir*, 43: 1–198.

Manuscrito recibido el 1-2-2017
Recibida la revisión el 17-3-2017
Aceptado el manuscrito revisado el 29-3-2017