

Aeolian dune development in an Albian arid coastal braidplain system in Serranía de Cuenca (Iberian Basin, Spain)

Desarrollo de dunas eólicas en un sistema de braidplain árido costero de edad Albiense en la Serranía de Cuenca (Cuenca Ibérica, España)

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ABSTRACT

The Utrillas Sandstone Group is an Albian to Cenomanian clastic succession which is widely spread along most areas in the Iberian Basin. In the Southwestern sector (Serranía de Cuenca) an arid braidplain was developed and connected to the Tethys towards SE, thus some facies associations present tidal features. Aeolian dune development within the arid braidplain system was possible, although as a minor feature. This paper aims: 1) to describe the facies associations of the arid braidplain regarding their different origin, and 2) to study and interpret aeolian dune accumulations based on the granulometric study of 5 samples and on the outcrop study of the geometry and surfaces hierarchy.

Key-words: Utrillas Group, Iberian Basin, arid braidplain, Albian, aeolian dunes.

RESUMEN

El Grupo Utrillas es una sucesión clástica Albiense-Cenomaniense la cual se encuentra ampliamente extendida en todo el contexto de la Cuenca Ibérica. En el sector Suroccidental (Serranía de Cuenca) un sistema de braidplain árido fue el principal paleoambiente. Este sistema de braidplain árido estuvo conectado con el Tethys hacia el SE. El desarrollo de dunas eólicas en el sistema de braidplain fue posible aunque no son una facies muy abundante. Este artículo tiene como objetivo: 1) describir las asociaciones de facies del sistema braided árido, y 2) estudiar e interpretar las dunas eólicas sobre la base del análisis granulométrico de 5 muestras y del estudio de la arquitectura estratigráfica del afloramiento.

Palabras clave: Grupo Utrillas, Cuenca Ibérica, Braidplain árido, Albiense, dunas eólicas.

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Introduction

The Utrillas Sandstone Group is a well-known, mostly Albian to lower Cenomanian heterolithic but mainly detrital group, which is widely spread all over the Iberian Basin, Spain (Sopeña, 2004). This detrital group has paramount importance in the development of the second rifting stage of the Iberian Basin, which spanned from Upper Jurassic to latest Cretaceous (Sopeña, 2004), since its onset marks the transition from the syn-rift to the post-rift stage. Hence, the Utrillas Group can be considered the first unit of the second post-rift stage of the Iberian Basin in many localities (Rodríguez-López *et al.*, 2008).

The Utrillas Group was originally considered as a fluvial depositional system (Pardo, 1979). However it has been recently

studied and reinterpreted as a subtropical erg system (Rodríguez-López *et al.*, 2010). In the Serranía de Cuenca area, the Utrillas Group overlies either the Aptian El Bungal Fm. or the Barremian La Huerguina Fm. (Fregenal-Martínez *et al.*, 2017).

This paper aims to study the Utrillas Group in the Serranía de Cuenca, Southwestern Iberian Basin, Spain (Fig. 1), an area where its sedimentological traits still remain little studied (Chamizo-Borreguero *et al.*, 2016). The present work comprises a granulometric analysis and outcrop study of 3 different aeolian accumulations within the context of a coastal arid braidplain in Serranía de Cuenca, Spain. Aeolian dune accumulations are not rare phenomena in arid braidplains (Mountney, 2004).

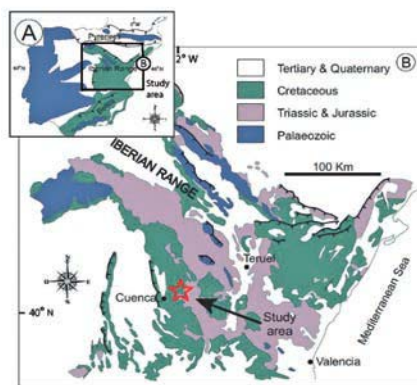


Fig. 1.- A) Location of the study area in the Iberian Basin. B) Close up of the Iberian Basin. A hollow red star indicates the study area (Modified from Sopeña, 2004). Ver figura en color en la web.

Fig. 1.- A) Localización del área de estudio en la Cuenca Ibérica. B) Detalle del área estudiada. Una estrella hueca roja indica la localización del área de estudio (Modificado de Sopeña, 2004). See color figure in the web.

Methodology

5 sedimentary columns have been logged in several adjacent ravines in the surroundings of Buenache de la Sierra, a locality where the outcrops are well exposed. The logs were later digitalized by using a SED LOG 3.1 software (Zervas *et al.*, 2009). Figure 2 shows the most representative logged section.

By means of this procedure up to 9 facies associations (f.a.) have been identified, which are classified into 3 groups of facies associations according to their origin.

Likewise, 5 samples of aeolian dune sandstone were collected from the outcrops. Such samples were smashed and sieved in up to 10 grain size intervals. Later, cumulative weight percentages were calculated and plotted in a semi-logarithmic sheet for each sample.

Facies associations groups

Three groups of facies associations have been interpreted and described from the logged outcrops: alluvial, aeolian and coastal to shallow marine.

Alluvial Facies associations group: (EA, EO1, EO2 and EO3 f.a.)

EA (Ephemeral alluvial): white to red heterometric sandstone, either bioturbated or not, with high feldspar content, medium-coarse to granule grain size, although medium-fine size can be locally found. Scattered faceted pebbles are common. The geometry of the bodies is generally tabular to lenticular, usually presenting erosive or sharp basal contacts. Main structures observed are dm- to dam- planar and trough cross beddings. This facies association is interpreted as ephemeral fluvial channels that remained dry and were occasionally flooded during the wet season. Indicators of a depositional arid climate are: high feldspar content, which indicates a lack of chemical weathering; and the presence of scattered ventifact pebbles (Knight, 2008).

EO1, EO2, EO3 (overbank deposits): EO1 consists of intense red mottled to yellowish mudstones and siltstones with some minor proportions of sand particles. EO2 is a grey to greenish color claystone to siltstone with minor sand proportions. In general EO2 and EO1 show similar geometrical and depositional characteristics. In both facies associations lower contacts are usually

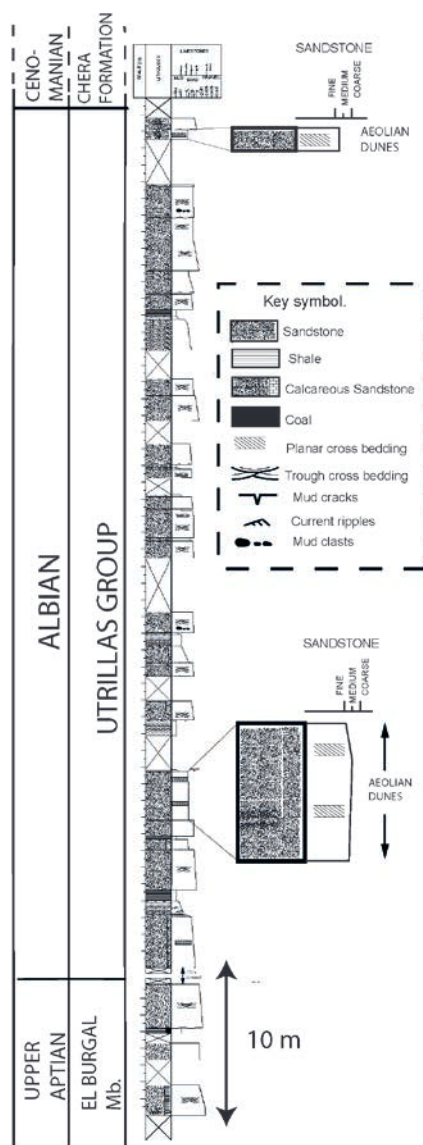


Fig. 2.-Compound logged section for the Utrillas Group in Buenache de la Sierra. Two sampled aeolian dune accumulations are enlarged.

Fig. 2.- Columna estratigráfica compuesta para el Grupo Utrillas en Buenache de la Sierra. Dos tramos de arenas eólicas muestreados han sido ampliados.

sharp, however upper contacts show some degree of transition in many cases, between EO1 and EO2.

EO3 consists of poorly sorted sandstones with variable mud proportions, which are arranged in lenticular thin sand bodies. It appears encased in facies EO1 and EO2.

This three EO of facies associations are closely related to EA facies association and are interpreted as overbank deposits. EO1 and EO2 are interpreted as deposited in a flood plain. The difference between them lies in that EO1 indicates an oxidizing environment due to its intense red mottling and frequent soil development, whereas EO2

grey to greenish color is an indicator of reductive processes in the same depositional sub environment.

EO3 is interpreted as crevasse splays, which spread into the ephemeral flood plain as sandy lenses.

Aeolian Facies associations group: (AD1, AD2, ASS and DL f.a.)

AD1 and AD2 (aeolian dune and aeolian pods): both facies associations consist of fine to fine-medium grained sandstone. They are composed by cm- to dm- scale trough and planar cross bedding sets that stacked all over the facies. AD1 and AD2 are interpreted as complex aeolian dune sandstones due to its cross beddings, compositional and textural maturity and lack of coarser grains in a sedimentary setting where coarser material is predominant. AD1 represents well developed aeolian dunes whereas AD2 represents smaller aeolian dune bodies, which remained preserved encased within coarser fluvially or tidally influenced facies association.

ASS (aeolian sandsheet): fine to medium grained sandstones arranged in tabular sets (20 to 40 cm thick each set), with high clay contents. This facies association also can contain coarse to granule grain size particles. Yellow mottling is a common feature.

Therefore this facies association, which frequently appears associated with EA and EO deposits, is interpreted as an aeolian sandsheet, which keeps great resemblance with other sandstone bodies interpreted as aeolian sandsheets in the Utrillas Group (Rodríguez-López *et al.*, 2010).

DL (Deflation lags): it consists of one flat-lying pebble thick layer that extends for several tens of meters. Pebbles are usually sub rounded and some ventifacts have been found as well. They are interpreted as lags of pebbles formed by wind deflation when wind eject finer particles and pebble size or coarser particles remain *in situ* producing lags. It is a clear indicator of wind reworking in an arid environment (Rodríguez-López *et al.*, 2010).

Coastal Facies associations group: (TSF f.a.)

TSF (Tidal sandflat): coarse to very coarse grain sandstone, in some cases even granule size grains. Occasionally scattered pebbles and mud pebbles can be observed in this facies association. Although it is not very common, carbonate cement can be present. This

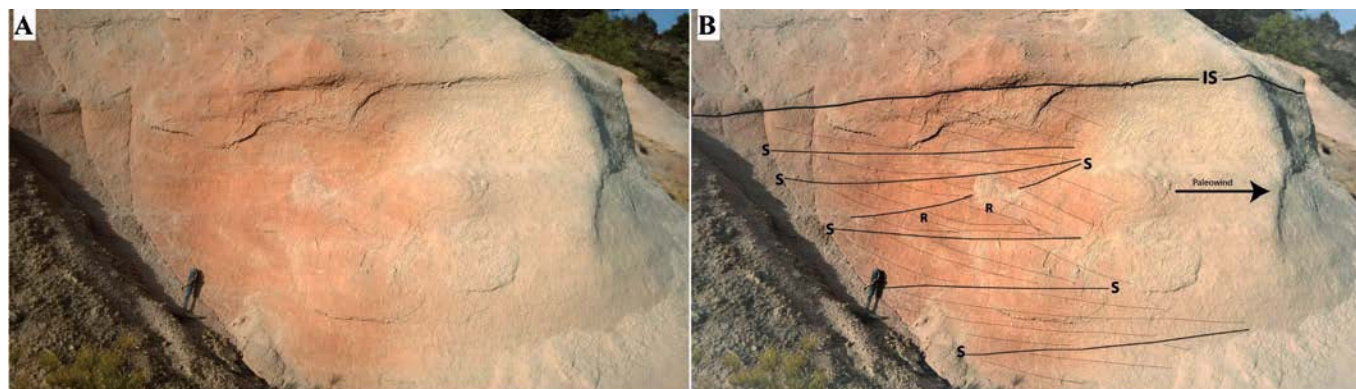


Fig. 3.- A) Photograph of complex aeolian dunes with dry interdunes. B) Line drawing of A. The hierarchy of bounding surfaces is highlighted (see text for explanation). Main paleowind direction is towards the right (NNE). Hammer for scale is 30 cm long. See color figure in the web.

Fig. 3.- A) Fotografía de dunas eólicas complejas con interdunas secas. B) Interpretación de A. En la fotografía se indica la jerarquía de las superficies eólicas (ver texto). La dirección de paleo-viento principal es hacia la derecha de la imagen (NNE). El martillo usado de escala mide 30 cm. Ver figura en color en la web.

f.a. consists of more or less tabular bodies of great lateral continuity (tens of meters). They present trough cross beddings and planar cross bedding although the latter is less common. The main feature is that the lee sides of the cross beddings are reworked in a direction opposed to the main current, showing a "curly" appearance. Therefore, we interpret this facies as a tidal facies in which the curly appearance would have been produced by the flow current (flood), while the main foresets correspond to the ebb current in a tidal sandflat setting.

Aeolian dune granulometry, geometry and interpretation

Granulometric analysis

The granulometry study shows that the population of clasts with ϕ between 1 and 4 is 90.6 % (mean cumulative percentage in weight of the five granulometries), which corresponds to medium to very fine grain size clasts (Fig. 4). Likewise, mean cumulative percentage in weight of clasts with $\phi > 4$ is 3.61% averaged for the five samples. In addition the mean cumulative percentage value for clasts with $\phi < 1$ has also been included (5.79 %).

Hence 90.6 % of the weight of the sampled sandstones ranges between medium to very fine grain size, which agrees with previous studies of aeolian dune sands (Folk, 1971 ; Lancaster, 1986), but especially Sharp (1966), since this author identified medium grain size sandstones in aeolian dunes in the Mojave Desert, California. This allows us to deduce that the clasts in most of our samples are in the field of saltation, and therefore wind transport would have been possible (Rodríguez-López *et al.*, 2006).

Regarding grains with $\phi > 4$, they represent the suspension load fraction, which is wind laid in minor proportion in the aeolian system. On the other hand, those clasts with $\phi < 1$ (5.79 %) represent the traction load population, which could not be transported by the wind (Rodríguez-López *et al.*, 2006). The best explanation for this minor amount of coarser clasts is that they were incorporated by the action of ephemeral alluvial systems, fact that would have not been uncommon in arid braidplain system with associated aeolian dunes.

Dune geometry

3 aeolian outcropping accumulations have been found in the 5 sedimentary logs (both AD1 and AD2 facies associations are represented). The geometrical study of the dune bodies has been tackled based on the best preserved and exposed aeolian accumulations (Fig. 3).

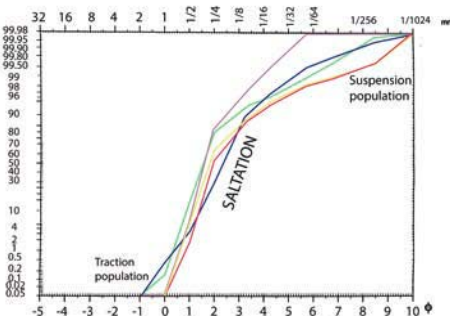


Fig. 4.- Granulometric curve for the 5 collected samples from the Aeolian dunes. Traction, saltation and suspension populations indicated. See color figure in the web

Fig. 4.- Curva granulométrica para las 5 muestras recogidas en las dunas eólicas. Se indican poblaciones de tracción, saltación y suspensión. Ver figura en color en la web.

The outcropping aeolian succession studied here is a 3 m thick well preserved aeolian body bounded at its base by coarse to granule size sandstones from EA facies associations and at its top by greenish to red clays, which belong to EO1 and EO2 facies associations, respectively. It spans laterally for 10 to 15 meters.

Geometrically, 3 different aeolian surfaces have been identified in the outcrop, which have been drawn in figure 3B. These surfaces depict the hierarchy of aeolian processes as follows:

First order surfaces (IS in figure 3B) represent interdune surfaces and can be traced all along the outcropping accumulation. These interdune surfaces represent the migration of larger aeolian forms over the stoss slope of former dunes. In this case the lack of interdune deposits in the IS (see figures 3 A and B) indicates a dry interdune and hence a dry aeolian system (Mountney, 2004). They are represented by flat and sharp surfaces that literally cross the outcrop and cut any other lower order surfaces.

Second order surfaces, interpreted as superimposition surfaces (S in figure 3B), have also been described in the outcrop. The observed superimposition surfaces are sub-parallel surfaces, which usually describe low angle downwind dipping beddings and cut dune foresets and minor third order surfaces (Fig 3B). Superimposition surfaces are the result of the migration of dunes over another larger dune body (Mountney, 2004).

Third order surfaces have been identified and interpreted as reactivation surfaces (R in figure 3B). They are surfaces bounded by either second or first order surfaces, which are more or less concordant, but slightly steeper, with the cross strata of the dunes foresets (see figure 3).

Reactivation surfaces are the result of erosion of the lee face of the dune as a consequence of a change in wind direction. When sedimentation resumes a reactivation surface is generated in the erosive surface (Rodríguez-López *et al.*, 2008, Mountney and Thompson, 2002).

Taking into account the complex geometry defined by the aforementioned surfaces, we identify the aeolian bodies as complex aeolian dunes in an arid braidplain aeolian system for the Utrillas Group. The present outcrop shows great similarity with the complex dune facies association described by Rodríguez-López *et al.*, 2008 (in his figure 14) in a dry aeolian system. The main difference resides in that in the Serranía de Cuenca area these dune bodies are minor and genetically associated with an arid braidplain, instead of being part of a proper erg as in Soria-Zaragoza-Teruel where they are much more abundant (Rodríguez-López *et al.*, 2006, 2010).

Conclusions

The Utrillas Group in the Serranía de Cuenca area has been interpreted as an arid coastal braidplain with minor aeolian record. The prevalence of ephemeral alluvial systems with occasional tidal influence reveals the existence of an arid braidplain, which was at some point affected by tides due to its nearness with the paleo-Tethys.

This work has allowed us to study how dunes develop, as minor features, in an

arid braidplain from the Cretaceous (Albian) of the Southwestern sector of the Iberian Basin.

Both granulometric and outcrop studies were carried out. Granulometric studies show that 90.6 % of the grains sampled are in the field of saltation, hence it would have been possible their transport and deposition by wind, producing aeolian dunes.

Likewise an outcrop study reveals the existence of a typical aeolian dune bounding surface hierarchy, which includes: first order surfaces (IS), second order surfaces (S) and third order surfaces (R). The stacking pattern of the dune foresets and the way in which superimposition surfaces (S) cut them have led us to interpret them as complex aeolian dunes with dry interdunes acting as minor feature within an arid braidplain.

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