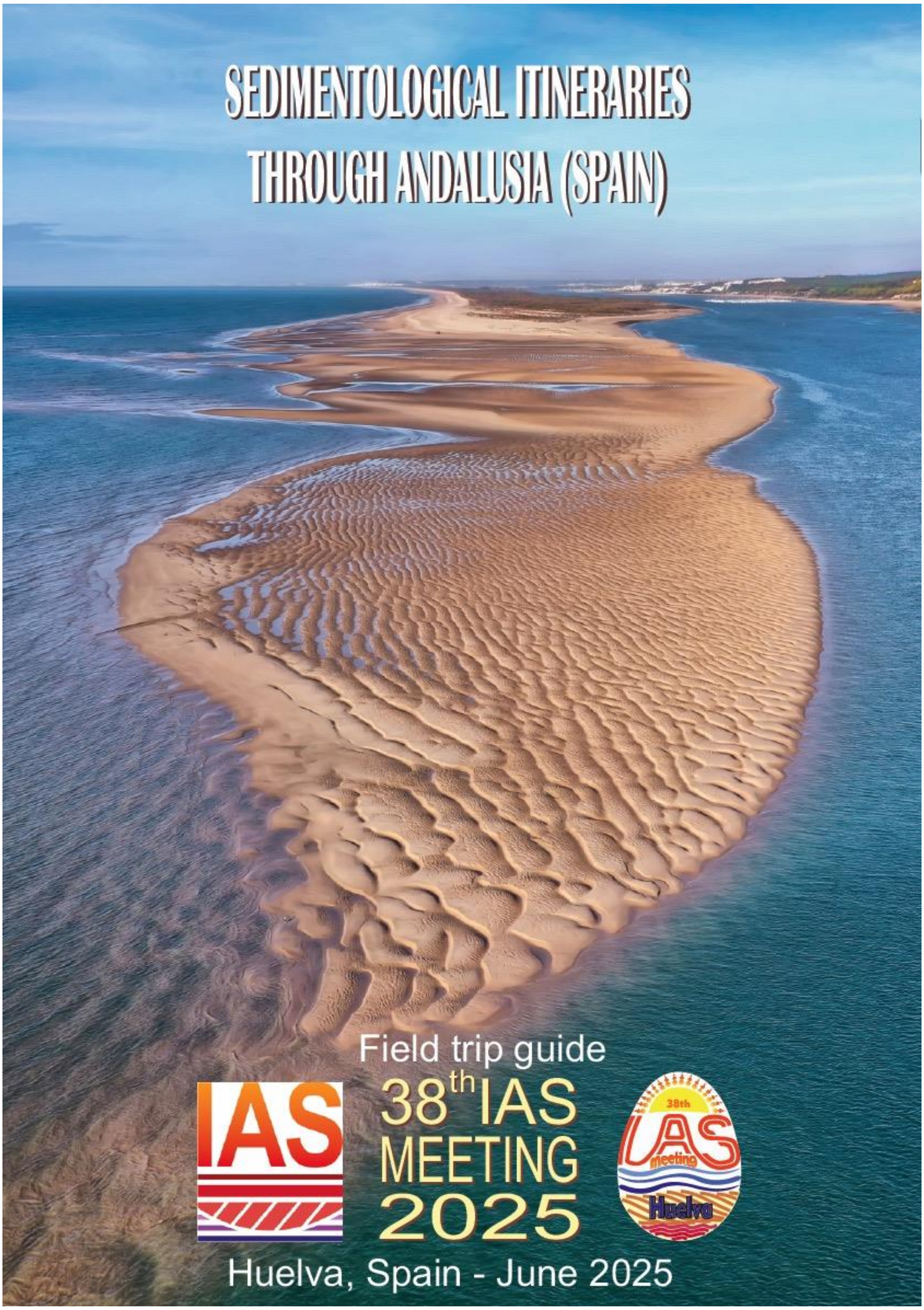
SEDIMENTOLOGICAL ITINERARIES THROUGH ANDALUSIA (SPAIN)



Field trip guide

38th IAS MEETING 2025

Huelva, Spain - June 2025

Cover picture: Piedras spit and ebb-tidal delta system.
Kindly provided by José Antonio Portero
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INTERNATIONAL ASSOCIATION OF SEDIMENTOLOGISTS

SEDIMENTOLOGICAL ITINERARIES THROUGH ANDALUSIA (SPAIN)

38[TH] IAS MEETING

HUELVA-SPAIN

26-28 June 2025

FIEL DRIP GUIDE

Edited by:

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38TH IAS MEETING

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Carbonate sedimentology in the External Zones of the Betic Cordillera

Carbonate sedimentology in the External Zones of the Betic Cordillera

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Introduction

The Betic Cordillera is the geological unit that extends across the S and SE of the Iberian Peninsula (Fig. 1). Together with the Rif and Tell Mountain ranges to the northern of Morocco and Algeria, constitutes the westernmost part of the peri-Mediterranean Alpine Orogen. Discordantly disposed over the Betic Orogen are successions of Upper Miocene, Pliocene and Quaternary deposits that form the post-orogenic basins. Among these is the Guadalquivir Basin, which separates the Betic Cordillera from the Iberian Massif to the North.

Three main geological units can be distinguished in the Betic Cordillera: the Betic Internal Zones, the Campo de Gibraltar Complex and the Betic External Zones (Vera, 2004; Ruiz-Ortiz et al., 2019). They are all composed of stacked tectonic units, para-autochthonous in the more external areas (i.e. closer to the foreland), and gradually more allochthonous towards the more internal sectors (to the south-west).

The Betic External Zones outcrop south of the Variscan Massif and the Guadalquivir Valley, representing the foreland and the foreland basin, respectively (Fig. 1B). Two tectonostratigraphic domains can be distinguished, the Prebetic to the north and the Subbetic in the south. Both are composed of successions of sedimentary and volcanic rocks ranging in age from the Triassic to the Miocene. The deformation is significant; however, Alpine metamorphism is absent, indicating that deformation affected to the superficial levels of the crust (Vera, 2004).

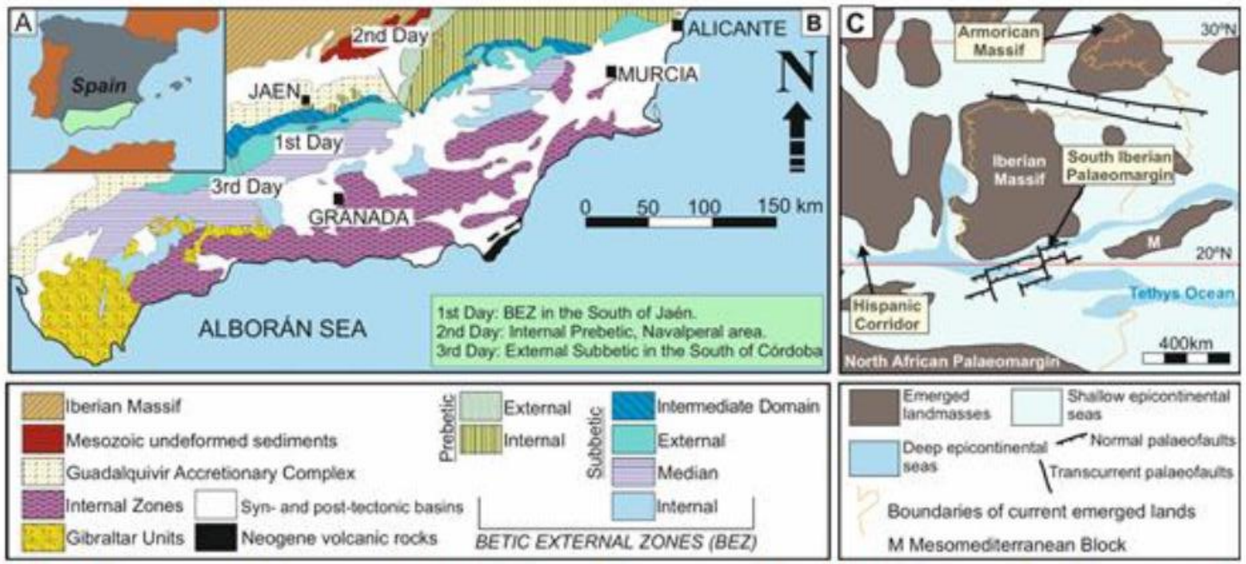

Figure 1. A: Geographic position of the Betic Cordillera in the Iberian Peninsula. B: Geological sketch of the Betic Cordillera with indications of the areas visited in the fieldtrip. C: Paleogeographic sketch of the South Iberian Paleomargin during the Early Jurassic.

Pre-FT2. External zones of Betic Cordillera

The Prebetic domain comprises para-autochthonous (External Prebetic) and moderately allochthonous (Internal Prebetic) units. West of the Tíscar Fault (Fig. 1B), isolated outcrops attributed to the Internal Prebetic, known as the Prebetic of Jaén, are present. Further the west of the city of Jaén, there are no outcrops attributed to this domain, since they are covered by materials of the Guadalquivir Basin or by Subbetic units (Fig. 1B). The Prebetic is primarily composed of mixed carbonate-siliciclastics deposited on a shallow marine platform attached to the continent. Two subdomains can be differentiated, the External and Internal Prebetic. The External Prebetic outcrops are predominantly Jurassic in age and they were deposited in very shallow environments with intercalations of continental rocks. The Internal Prebetic is mainly composed of Cretaceous materials; however, uppermost Jurassic sediments are also recorded in some units of this subdomain (Castro, 1998; Castro et al., 2008). These sediments were deposited in shallow carbonate platforms and hemipelagic environments further away from the continent. These last environments mark the transition to the deeper marine areas of the Subbetic. Some intercalations of sediments generated in coastal and continental environments, such as marsh, pedogenic and even fluvial environments can be recognized within the Cretaceous succession of the Internal Prebetic (García-Hernández, 1978; García-Hernández et al., 2001; Vera, 2004; Ruiz-Ortiz et al., 2019; Nieto et al., 2022). The Prebetic is characterised by NW-SE oriented fault systems interpreted as transfer faults associated with multiple rifting episodes (Vilas et al., 2001; Ruiz-Ortiz et al., 2019). These faults are perpendicular to the main listric faults, parallel to the paleomargin, which controlled the paleogeography of the South Iberian Paleomargin (Fig. 2).

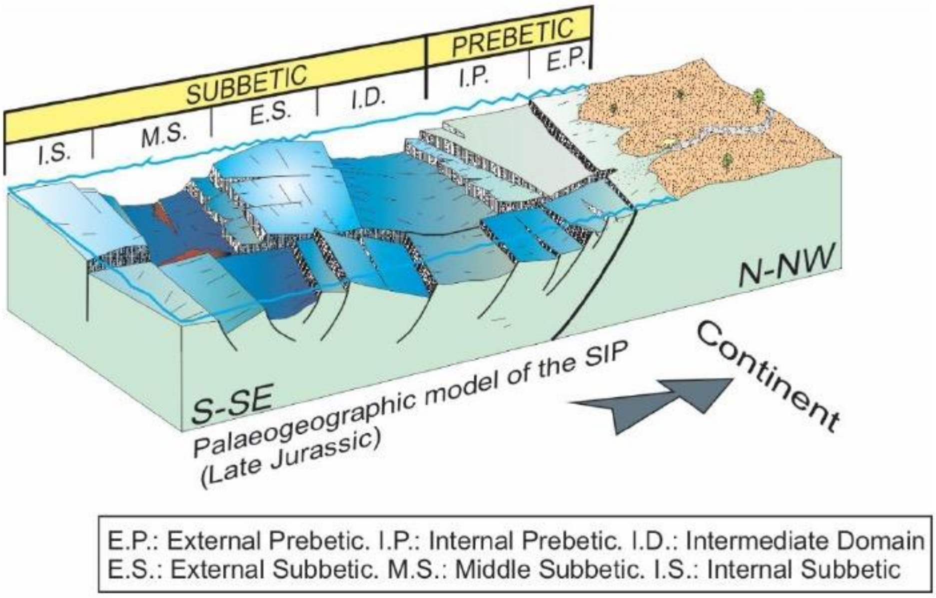

Figure 2.- Paleogeographic model of the South Iberian Paleomargin (SIP).

The Subbetic thrusts on the Prebetic and is thrusted by the Betic Internal Zones (Vera, 2004) (Fig. 3). The Subbetic units exhibit a more complex deformational history than the Prebetic, and they are characterized by a very high degree of allochthony. From north to south, four paleogeographic units can be distinguished within the Subbetic, named as the Intermediate Domain, External Subbetic, Middle Subbetic and Internal Subbetic, from internal to external positions within the margin (Fig. 1B). Each of these units is successively thrusted by the one immediately to the South (Fig. 2). The Subbetic is composed by a succession of sedimentary units ranging in age from the Triassic to the Middle Miocene, mainly deposited in hemipelagic and pelagic environments, with some intercalations of shallow carbonate platform units, and submarine volcanic and subvolcanic rocks. Based on the different facies and facies associations present in the Middle and Upper Jurassic and Lower Cretaceous materials in the different subdomains considered in the Subbetic, it has been possible to reconstruct subsiding troughs (Intermediate Domain and Middle Subbetic) and pelagic swells (External and Internal Subbetic; Fig. 2).

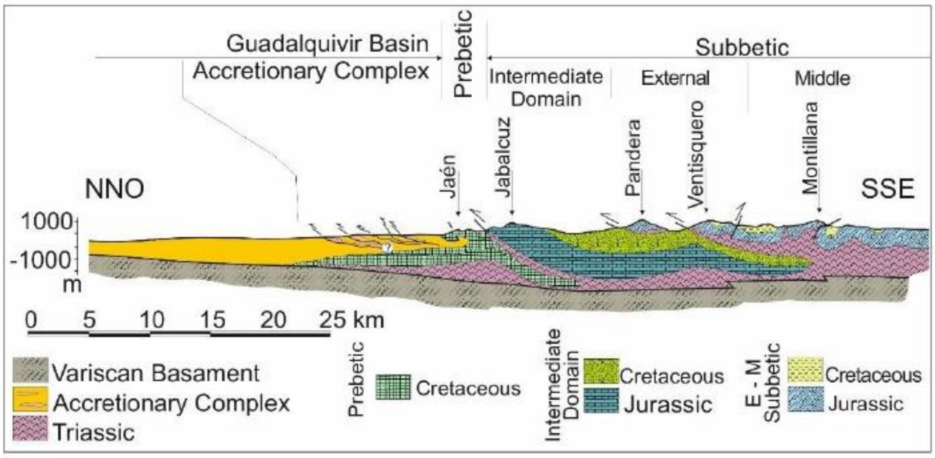

Figure 3.- Geological cross-section of the External Zones. E-M Subbetic: External and Middle Subbetic.

The most pronounced differentiation between troughs and swells occurred during the Late Jurassic (Vera, 2001; Ruiz-Ortiz et al., 2019). The Intermediate Domain is characterized by the presence of Upper Jurassic calcareous turbidite facies (Toril Fm.; Ruiz-Ortiz, 1980; 1983), while the Middle Subbetic contains radiolarian-rich marl limestone facies (Jarropa Fm.; Molina et al., 1999) and tempestite facies (Milanos Fm.; Molina and Vera., 1996; Pomar et al., 2019), both of Upper Jurassic age. Furthermore, the Middle Subbetic contains several intercalations of submarine volcanic rocks with basaltic affinity in materials from the upper part of the Lower Jurassic and from the rest of the Jurassic and

Cretaceous (Molina and Vera., 1999; Molina and Vera, 2001; Vera et al., 1997). The pelagic swells, represented by the External and Internal Subbetic, are characterized by the presence of Jurassic *ammonitico rosso* condensed facies, with abundant hiatuses and iron oxide crusts (Molina, 1987; Nieto, 1997; Vera, 2001; 2004; Jiménez-Millán and Nieto, 2008). The Cretaceous units in the Subbetic are generally more homogeneous (Ruiz-Ortiz et al., 2019). Lower Cretaceous successions are dominated by alternations of marly limestones and marls. In the Aptian-Albian, dark marly facies are observed in specific areas of the Subbetic linked to the record of OAEs (de Gea et al., 2008; Castro et al., 2019), while Barremian to late Albian siliciclastic turbidites are recorded in the Intermediate Domain (de Gea, 2004). In the Upper Cretaceous, pelagic white and pink marly limestones and marls rich in planktonic foraminifers (Capas Rojas Fm; Vera and Molina, 1999) were deposited.

GEOLOGICAL ITINERARIES AND STOPS

Day 1: A transect of the Betic External Zones from the Prebetic Carbonate Platform to the pelagic Subbetic Basin (Jaén-Valdepeñas de Jaén)

Stop 1.1

Santa Catalina Castle and cross. Introduction and landscape explanation.

Objective: Recognize the regional geology and the relationships between the different geological units.

Pre-FT2. External zones of Betic Cordillera

Description and interpretation

From the Santa Catalina Castle, to the north and east, the contact between the Betic External Zones and the Guadalquivir Basin can be seen in the first term (Fig. 4). Further north, the accretionary complex and the autochthonous materials, which are arranged horizontally, can be distinguished. In the background, towards the north, the relief of the Variscan massif can be seen.

Figure 4.- Panoramic view from the Santa Catalina Castle of the Guadalquivir Basin and some areas of the Betic External Zones (Mágina and Pandera from the External Subbetic and Jabalcuz from the Intermediate Domain).

The Santa Catalina Castle and the Peña de Jaén are attributed to the Internal Prebetic, specifically to isolated units without lateral continuity. These units predominantly consist of Upper Cretaceous carbonates that exhibit facies typical of a external carbonate platform. Consequently, these units have been named the Prebetic of Jaén (see Vera, 2004). Other sierras of this subdomain are the Serrezuela de Pegalajar, the Aznaitín de Albanchez and the Sierra de Bedmar-Jódar.

The geological section in Figure 5 shows how the materials of the Intermediate Domain, represented by the Jabalcuz, are overlaid on the Prebetic of Jaén (Santa Catalina Castle and Peña de Jaén) by a thrust, observed in the Reguchillo ravine. This tectonic superposition is the responsible for the intense deformation of these Prebetic units (Sanz de Galdeano, 1973).

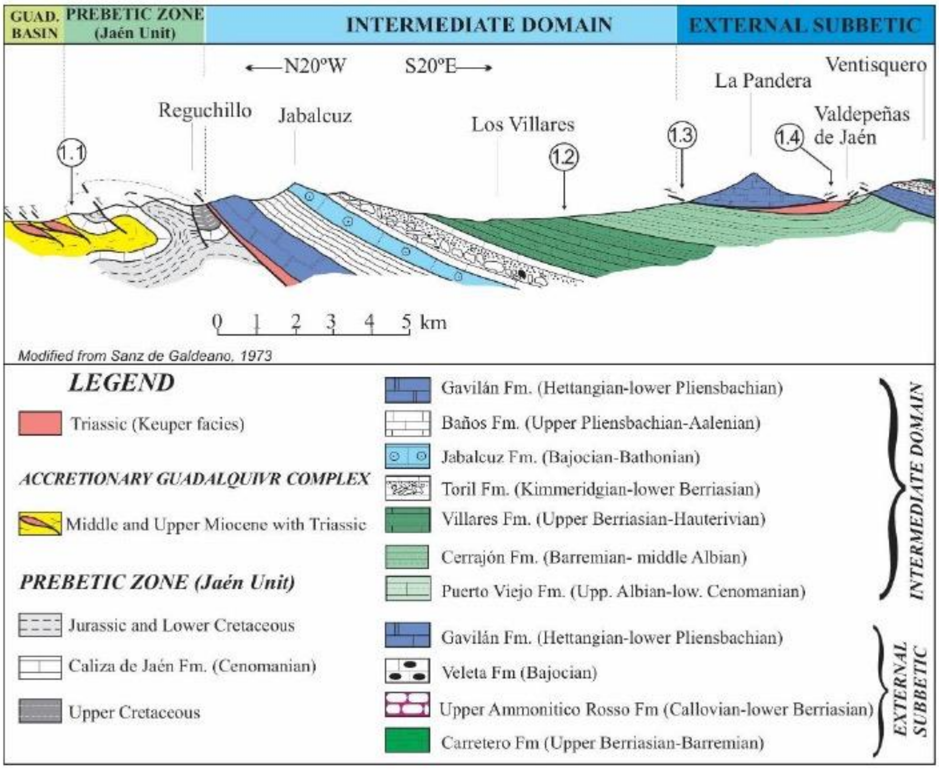

Figure 5.- Geological cross-section of the Betic External Zones in the Jaén-Valdepeñas de Jaén section, with the location of the stops.

Stop 1.2

Los Villares-Valdepeñas de Jaén road section. Cerrajón Fm (lower Cretaceous siliciclastic turbidites). Basal section (km 11.3 on the road A-6050 from Jaén to Castillo de Locubín).

Objective: To observe the contact between Villares Fm and Cerrajón Fm (Lower Cretaceous pelagic units).

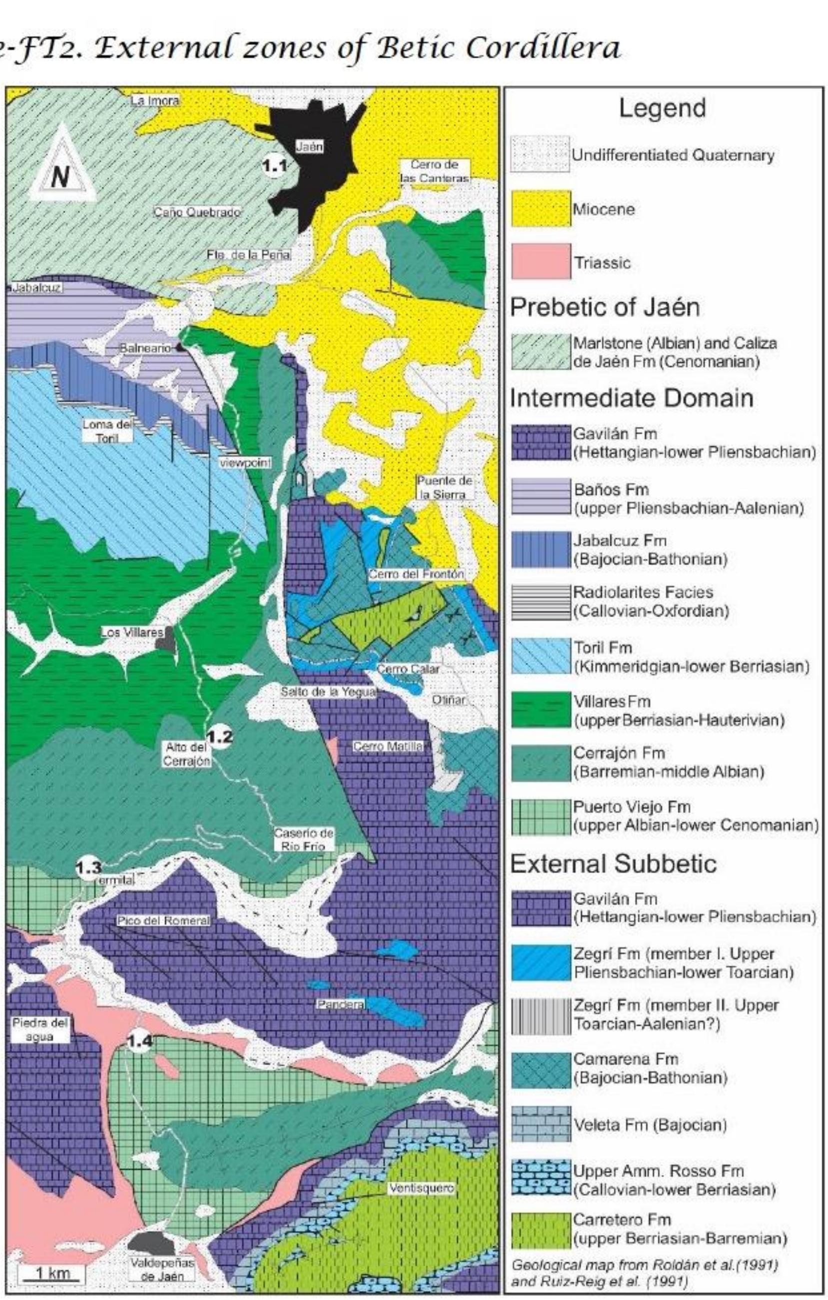

Figure 6.- Geological map for the stops 1.1 to 1.4.

Description and interpretation.

South of Jaén, a succession of carbonate turbidite facies of the Upper Jurassic and marls and terrigenous turbidites of the Lower Cretaceous, attributed to Intermediate Domain of the Jabalcuz unit outcrop. Three formations are differentiated in the Lower Cretaceous: (1) The Los Villares Formation (lower part of the Upper Berriasian - Hauterivian) that is made up of alternating marly limestones and marls, with facies typical of pelagic environments; (2) The Cerrajón Formation (Barremian-Middle Albian; de Gea, 2004), characterised by terrigenous turbidites intercalated with dark marls, occasionally black. Small wood fragments are present in both lithologies and coated quartz grains (cortoids) are common in the terrigenous beds. It has been established that these terrigenous materials originate from the Iberian continent, where they were reworked in shallow marine carbonate environments and finally deposited in pelagic contexts. At kilometre 11.3 on the road from Los Villares to Valdepeñas de Jaén, we can observe the contact between both formations with slumps.

The Cerrajón Fm of latest Hauterivian–earliest Late Albian age can be defined as a turbidite complex with three distinct intervals where turbidites are recorded (turbidite systems; Fig. 7A): latest Hauterivian–Barremian p.p., Late Aptian p.p. and Middle to middle-late Albian age (Ruiz Ortiz et al. 2006). The Cerrajón Fm in these outcrops is made up of thin-, medium- and thick- (more than 1 m) bedded turbidites, arranged in non-channelized sequences (Fig. 7B, C and D). These are intercalated in background deposits composed of rhythmically alternating marly limestones and marls, with ammonites, planktonic foraminifera and nannofossils. A significant NW–SE direction of flow for the turbidite currents and a concentration of the measured paleocurrents between 230° and 310° occur. The Los Villares outcrops represent the most distal turbidites of the turbidite systems. The abundance of slumps in the Cerrajón Fm, coinciding with the beginning of the turbidite sedimentation, has been explained by reference to tectonic events triggering the gravity flows.

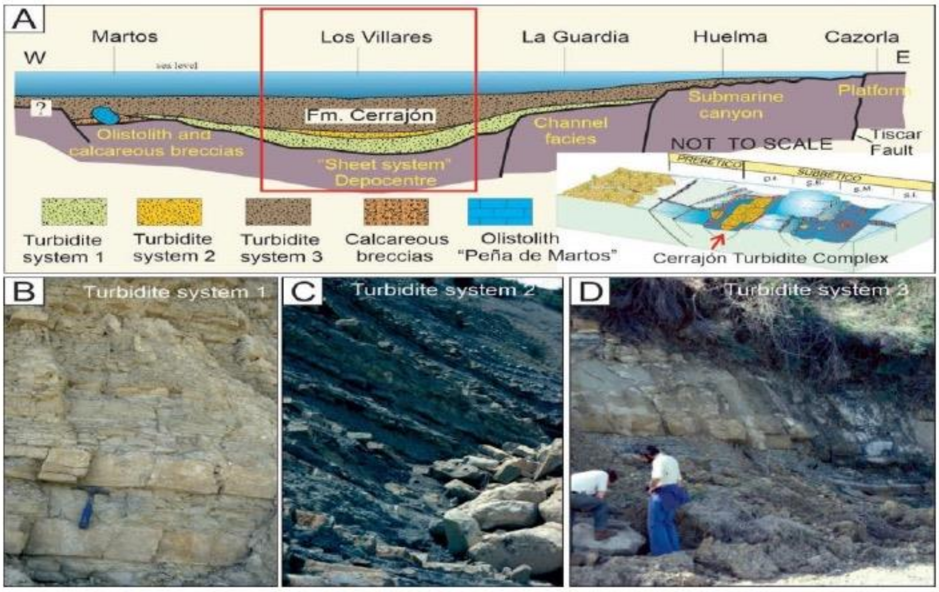

Figure 7.- Early Cretaceous turbidite complex of the Cerrajón Fm. A. Interpretative longitudinal cross-section through the Intermediate Domain, extending from the platform margin (Prebetic Zone) near Cazorla to the distal basinal areas around the Martos region. The red box highlights the palaeogeographic location of the Los Villares outcrops within the turbidite complex of the Cerrajón Fm. Three turbidite systems have been differentiated. B. Sandstone beds interbedded with marls and marly limestones from system 1 (base of the Cerrajón Fm). C. Thin-bedded turbidites from system 2. D. Thick-bedded turbidite from system 3.

In the Los Villares outcrops, outer fan facies, fan fringe and basin plain turbidites are present (Ruiz-Ortiz, 1980; 2006) (Fig. 3B to D). The whole group is envisaged as a basinal lobe or "sheet system" in which it is difficult to carry out a detailed differentiation of outer fan from basin plain deposits. Ruiz-Ortiz et al. (2006) propose a longitudinal or axial clastic distribution model, parallel to the basin margin, which is relatively common in extensional rifting basins.

Stop 1.3

Los Villares-Valdepeñas de Jaén road section. Puerto Viejo. Cerrajón Fm. Top section. Landscape explanation.

Objective: To observe the contact between the Cerrajón and Puerto Viejo formations (upper Albian-Cenomanian), as well as to analyse the landscape related to the thrust of the External Subbetic on the Intermediate Domain.

Description and interpretation.

The last Lower Cretaceous formation is the Puerto Viejo Formation, represented by marly limestone and white marls. Continuing along the Jaén-Castillo de Locubín A-6050 road, at 19.4 km, the contact between the Cerrajón and Puerto Viejo formations (Middle/Upper Albian-Lower Cenomanian; de Gea, 2004) can be observed. It is also possible to observe outcrops of the Subbetic units overlying the Intermediate Domain.

Stop 1.4

Los Villares-Valdepeñas de Jaén road section. Thrusting the External Subbetic on Intermediate Domain and tectonic window. Stratigraphy of the External Subbetic.

Objective: To observe the tectonic window of Valdepeñas de Jaén, making a spectacular view of the thrust of the External Subbetic on the Intermediate Domain.

Description and interpretation.

This stop is made at kilometre 23.7 of the Jaén-Castillo de Locubín (A-6050) road, near the latter town. Here, we can see a valley where the Lower Cretaceous materials of the Intermediate Domain of the Jabalcuz Unit (Los Villares and Cerrajón Fm) are exposed, surrounded by Lower Jurassic materials of the External Subbetic, belonging to the Pandera unit in the northern part and to the Ventisquero unit in the southern part. Along the road we can see the strongly deformed Triassic materials (gypsum, clays, siltstones, sandstones and ophites), which form the base of the External Subbetic thrust.

Stop 1.5

Valdepeñas de Jaén-Castillo de Locubín road section. Unconformity at the top of the Gavilán Fm (Lowermost Jurassic), neptunian dykes and facies association.

Objective: To observe the Lower Jurassic carbonates of the External Subbetic and the neptunian dykes embedded whithin them with different types of sedimentary fills.

Description and interpretation.

Between kilometres 39.3 and 39.8 on the road A-6050, from Jaén to Castillo de Locubín we can see the upper part of the Gavilán Formation (Hettangian-lower Pliensbachian). These are dolostones of secondary origin, formed from limestones deposited on shallow platforms. These dolostones present a network of neptunian dykes parallel (type S dikes) and oblique (type Q dikes) to the bedding, with widths between the walls ranging from a few millimetres to 0.5 m. Three types of fills have been distinguished. 1) Wackestone of filaments, locally mudstone, stained with iron oxides. Crinoids and 'protoglobigerines' are also observed. 2) Very homogeneous mudstone without textural elements. 3) Calcite cements, interpreted as speleothems, forming crusts in which there are two types of textures: on the one hand, grey sparite with many impurities, a few tenths of a millimetre thick, covered by another layer with a columnar texture, of colourless calcite, with thicknesses varying between 1 and 5 mm. From the road in this stop, we can see a quarry fro the explotation of aggregates in Middle-Upper Jurassic amnonítico rosso facies.

Day 2: Early Cretaceous carbonate platform development in the margins of a rifted basin: Navalperal and Segura de la Sierra sections (Internal Prebetic, Sierra de Segura)

Stop 2.1

Facies, facies associations, sedimentological and paleogeographic features of the uppermost Jurassic and Lower Cretaceous in the Navalperal section, as example of the most external record of the deposition in the Internal Prebetic.

Stop 2.2

Panoramic view from the Mirador de Peñalta (Segura de la Sierra) of the Jurassic-Cretaceous section.

Objective: To analyse a stratigraphic succession of the outermost part of the Internal Prebetic, where Upper Jurassic and Lower Cretaceous shallow carbonate platform and mixed siliciclastic coastal sediments are exposed.

The Prebetic is divided into the External Prebetic and the Internal Prebetic (Vera, 2004), according to the thickness of the Mesozoic cover, the composition of the stratigraphic sequence in certain time intervals and the tectonic style (Figs.8, 9). The External Prebetic is the northernmost and outermost sector of the Betic External Zones. In the region visited, it is represented by the Beas de Segura and Sierra de Cazorla units (Fig. 8). In these units, Jurassic rocks predominate over Cretaceous materials, with the latest Jurassic and Lower Cretaceous being poorly developed or absent. The first of these (Beas de Segura unit) lies on the undeformed sediments known as the tabular cover of the Meseta. To the SE, the External Prebetic is overlain by the Internal Prebetic; the boundary between the two domains has been established at the Yelmo (Fig. 8).

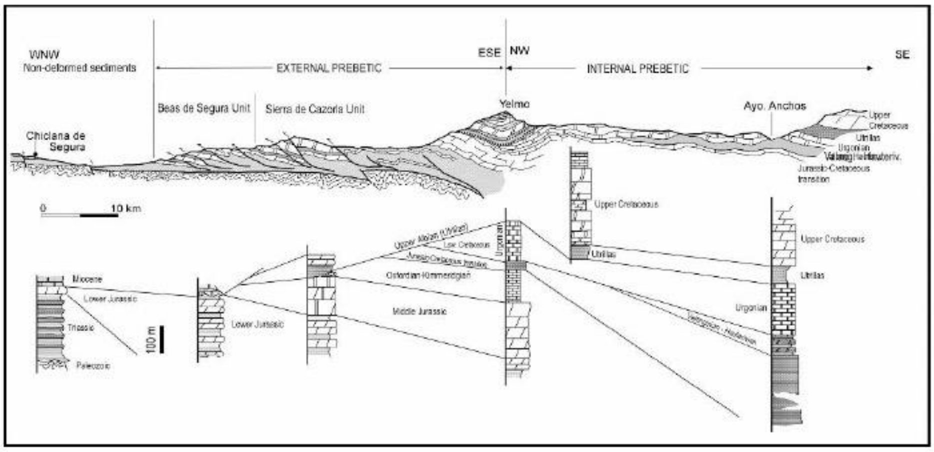

Figure 8.- Geological cross section of the Prebetic considering the Beas de Segura, Sierra de Cazorla and Segura de la Sierra Units. Also a stratigraphic correlation of each units is shown.

The Internal Prebetic corresponds to the innermost sectors of the Betic External Zones. The Mesozoic materials of this domain are characterised by a good development of Upper Jurassic and Cretaceous sediments. An example of a transitional series between the two can be found in the area of Segura de la Sierra.

Description and interpretation.

During the lowest Cretaceous up to the end of the Aptian, the Prebetic experienced the largest phase of compartmentalisation of the entire Mesozoic due to the important development of North Atlantic rifting (e.g. Vilas et al., 2001; 2004). Most of the Lower Cretaceous material was deposited in the Internal Prebetic, characterised by important lateral changes in thickness and facies. In contrast, the External Prebetic underwent considerable uplift. Vilas et al. (2004) identified five sedimentary episodes in the interval between the Valanginian and the Aptian, which can be correlated with the depositional sequences Ci1 to Ci7b of García-Hernández et al. (2001), illustrated in Figure 8. In the same figure we can see the correlation with the transgressive (T)-regressive (R) cycles of Castro et al. (2008) from the Prebetic of Alicante, and with those of Hardenbol et al. (1998).

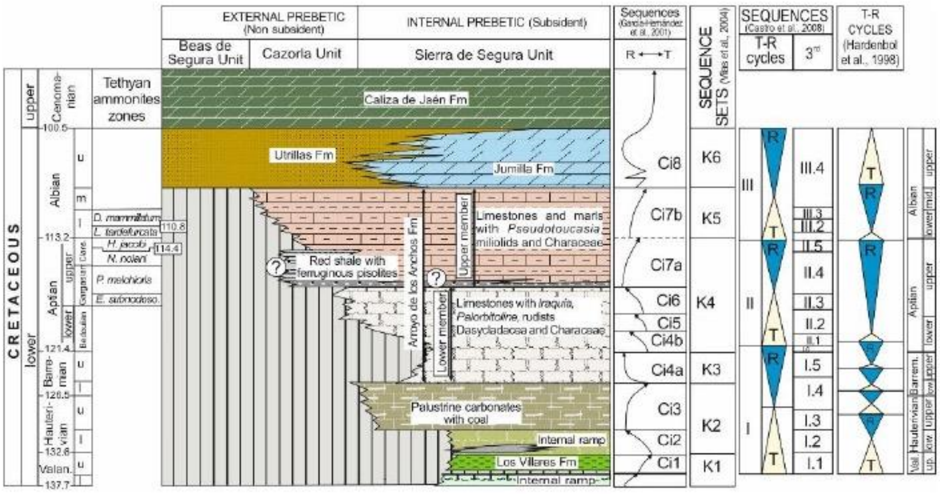

Figure 9.- Chronostratigraphic chart for the Cretaceous from the Cazorla and Segura outcrops, with the correlation of several sequences proposed by different authors.

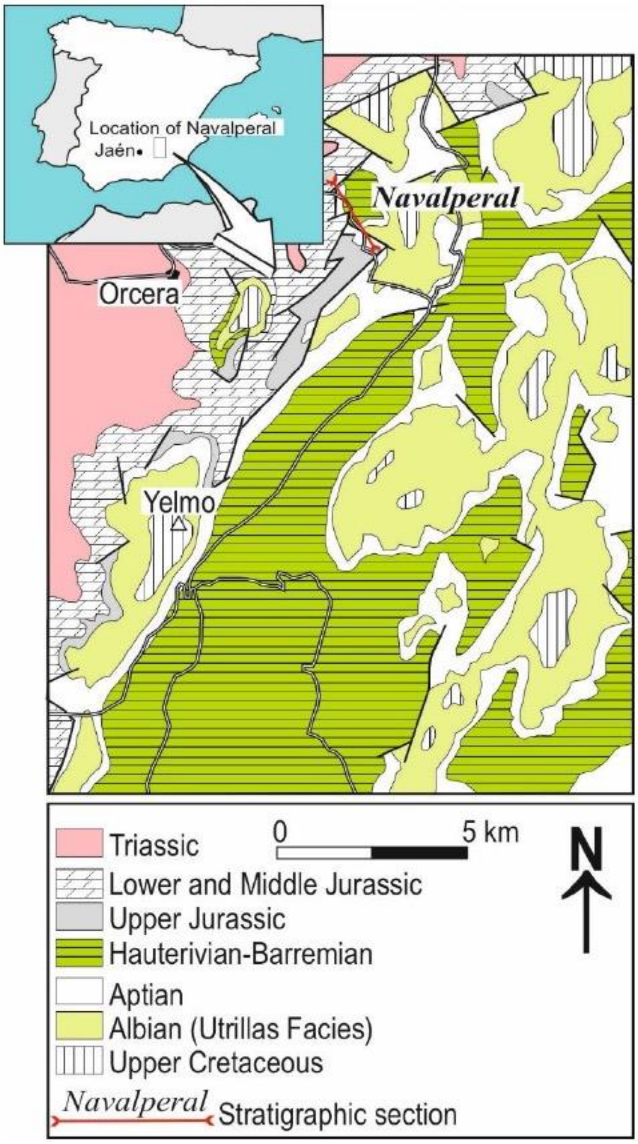

Figure 10.- Geological sketch with location of Navalperal Section

Pre-FT2. External zones of Betic Cordillera

The Navalperal section is located in the outermost sector of the Internal Prebetic (Figs. 9, 10). It begins with a lower stratigraphic unit of dolomites, dolomitic marls and Jurassic limestones, which ends in a discontinuity with an associated hiatus spanning from the Upper Kimmeridgian to the Hauterivian *p.p.* (Figs. 9, 11 to 14).

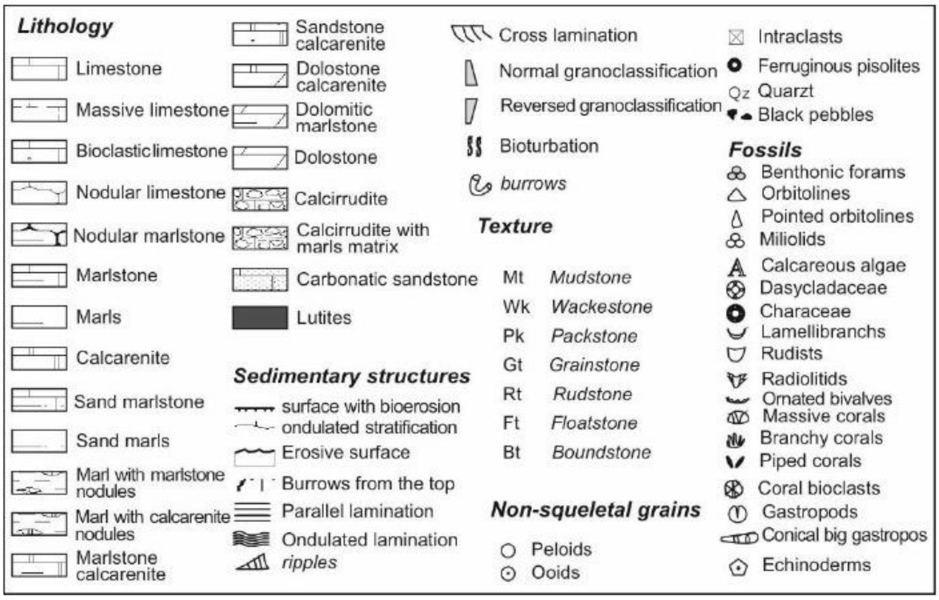

Figure 11.- Legend to stratigraphic sections of figures 12, 13 and 14.

The Aptian-Albian sedimentary sequence is exceptionally well-preserved in this stratigraphic section. From bottom to top, the Ci3 sequence is a succession of calcretes with occasional intercalations of limestones with characeae mudstone microfacies and limestones with lignites and black pebbles. The top of this sequence is marked by a discontinuity that encompasses part of the Barremian and the base of the Aptian sequence (Ci4b; Fig. 12). Overlying this follows the sequence Ci5 (Fig. 12), characterised by littoral facies, which include calcarenites with *Palorbitolina lenticularis*, sandstones and sands. In these facies, various current structures can be observed, ranging from cross-stratification to ripples.

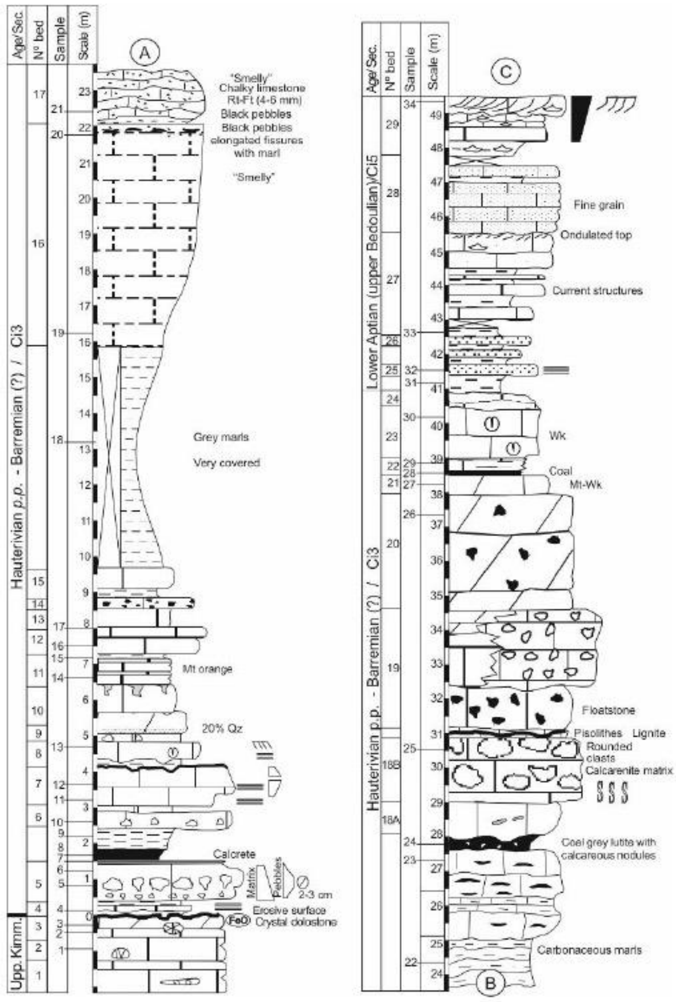

Figure 12.- Navalperal section. Jurassic-Cretaceous boundary and Ci3 and Ci5 depositional sequences.

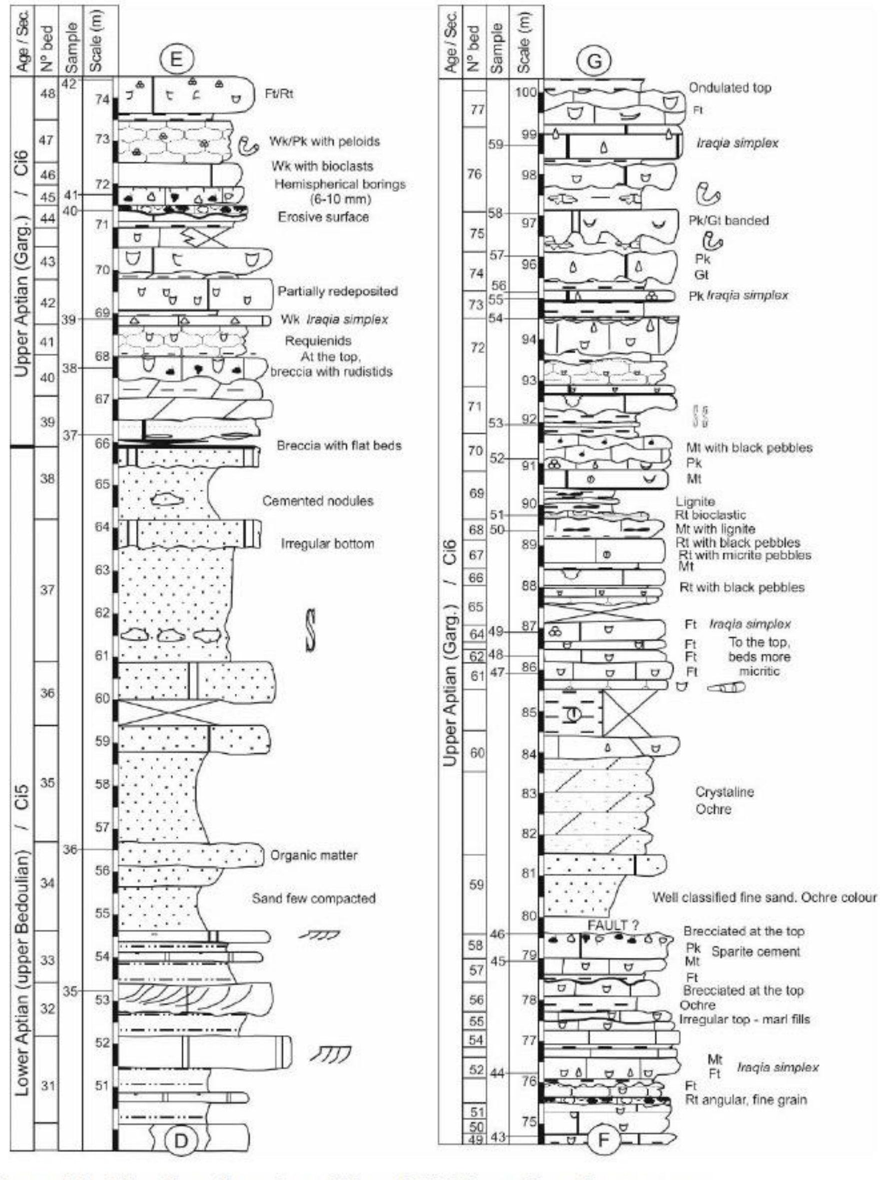

Figure 13.- Navalperal section. Ci5 and Ci6 depositional sequences.

The microfacies of the calcarenite beds are grainstones of orbitolinids. This sequence (Ci5) marks the maximum Aptian transgression, which begins in the most distal sectors of the platform with the Ci4 sequence, which is absent in the Navalperal. The subsequence Ci6 (Upper Aptian; Fig. 13) is characterised by the presence of rudists and orbitolines (*Iraqia simplex*). This sequence exhibits significant thickness in this stratigraphic section. The top of the elementary sequences that can be distinguished in it is characterised by hardground features, with abundant bioerosion imprints. Overlying the Ci6 sequence is the Ci7a (Fig. 14) sequence, which represents the highest stratigraphic level of the Aptian. This sequence is composed of supratidal micritic limestones interbedded with black pebble breccias, indicating evidence of regression at the end of the Aptian. The Albian materials are of poorly exposed, tectonised and partly covered. The Ci7b sequence is characterised by a lower terrigenous division and an upper dolomitic unit (Fig. 14). The top of the latter sequence is a hardground surface, covered by a thick dolomite unit, possibly of Upper Albian age.

From the same point of view, but to the northeast, we can observe the Jurassic-Cretaceous sequence of Segura de la Sierra, considered as a transitional sequence between the two Prebetic subdomains in this area. The Jurassic materials are well developed (Figs. 15, 16); on top of the Lower and Middle Jurassic dolostones crop out carbonates of the Middle-Upper Oxfordian, the Lower Kimmeridgian hemipelagic rhythmite and the Tithonian-Berriasian dolostones. These are overlain by the Upper Albian Utrillas sandstones, which increase in thickness towards the south. Finally, on top of the Utrillas unit, it lies the Upper Cretaceous dolostone formation (base of the Segura de la Sierra castle; Fig. 16).

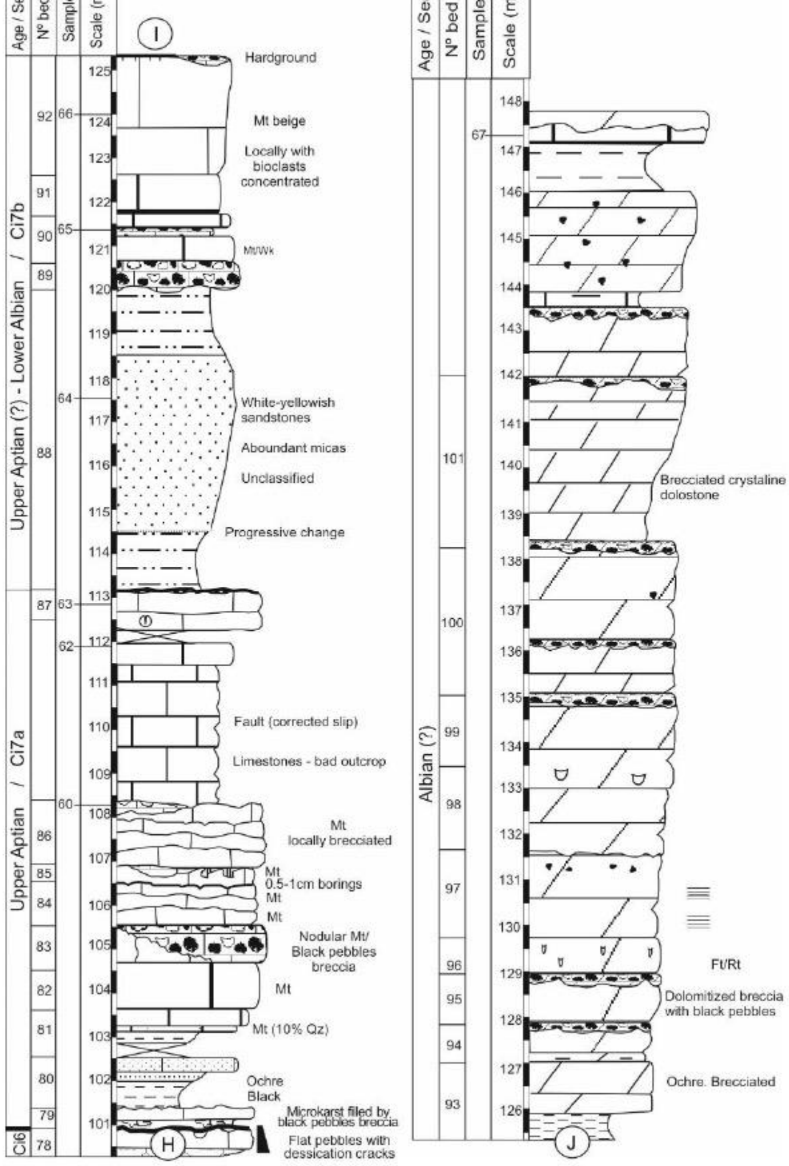

Figura 14.- Navalperal section. Ci7a and Ci7b depositional sequences and Albian rocks.

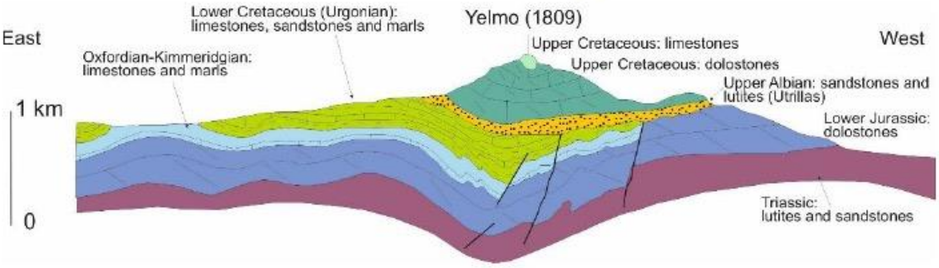

Figure 15.- Cross-section of the Yelmo area that shows the lateral changes in the thickness of the lithostratigraphic units from the East (Internal Prebetic) to the West (transition to External Prebetic).

Figure 16.- Panoramic view of the Jurassic-Cretaceous section from the Peñalta Mirador. Segura de la Sierra.

Day 3: External Subbetic in the province of Córdoba (Priego-Sierra de Cabra). Paleokarst and paleofaults

Objective: To analyse the regional geology, stratigraphic sequences, facies and paleokarst features of the External Subbetic in the Priego-Cabra area (Córdoba province).

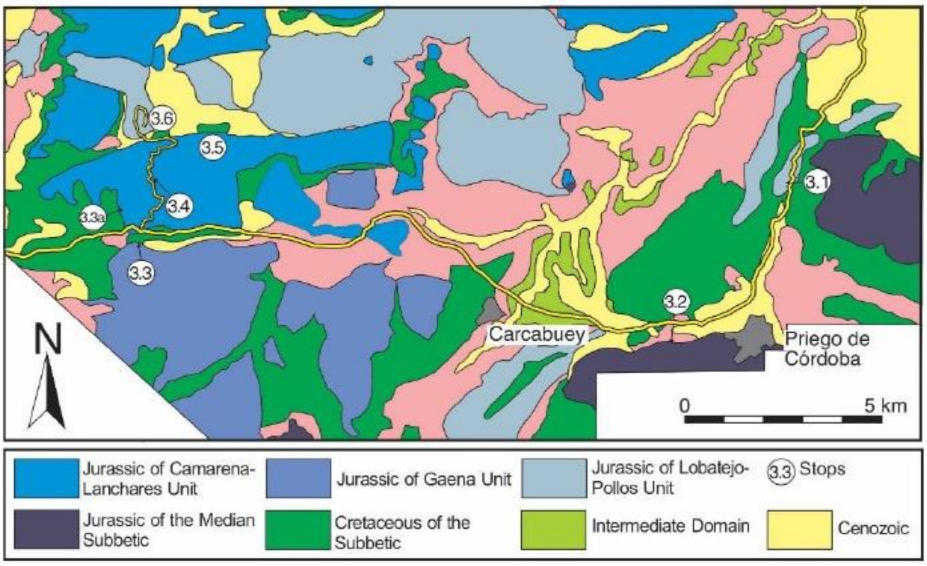

Figure 17.- Geological scheme of the Subbetic in the South of Córdoba province with indications of the stops of the third day.

Stop 3.1

Las Angosturas paleokarst. Top of the Gavilán Fm (Lowermost Jurassic). Paleodoline on shallow platform covered by hemipelagic and *pelagic rocks of the Veleta Fm (Middle Jurassic) and Upper Ammonitico Rosso Fm (Upper Jurassic).*

Description and interpretation.

In the area of Las Angosturas (Río Salado ravine, km 14 of the A-333 road) we can observe the irregular top of the Gavilán Fm (Lower Jurassic; Fig. 18), where we find limestones with chert from the Upper Bajocian. This irregular morphology, with a vertical section of at least 20 m, has a stepped geometry, with vertical steps of several metres. As a whole, it has been interpreted as a paleosinkhole, which in turn was karstified prior to the deposition of the hemipelagic materials of the Veleta Fm (Fig. 18).

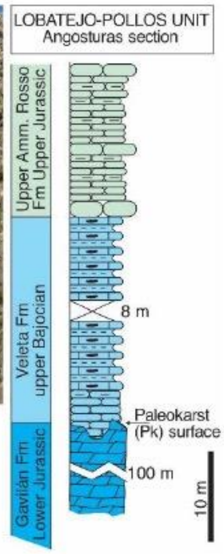

Figure 18.- Interpretation of the paleokarst at the top of Gavilán Fm in Las Angosturas. In the right a simplified stratigraphic section in Las Angosturas.

This paleokarstic surface is the main cause of the important changes in thickness and facies, the heterochrony of the base of the overlying materials and the slumps observed in them. In this area, in a horizontal distance of less than 250 m, the cherty marly limestones of the Veleta Fm change their thickness from 28 m to their disappearance. The greatest thicknesses of this formation are measured in the deepest paleosinkholes. In this sector, the Upper Ammonitico Rosso Fm (Upper Jurassic) overlies the Veleta Fm, although in other areas of the same tectonic unit (Lobatejo-Pollos Unit) the latter lithostratigraphic unit may be directly overlying the Gavilán Fm.

Stop 3.2

Panoramic view. Subbetic regional geology and stratigraphy to the West of Priego.

Description and interpretation.

On the road from Priego de Córdoba to Cabra, near the La Milana recreational area, there is a panoramic view of the three tectonic units of the External Subbetic, located in the southern part of the province of Córdoba: Lobatejo-Pollos, Gaena and Camarena-Lanchares. The latter unit overthrust the Intermediate Domain outcrops (Fig. 17). In turn, the Lobatejo-Pollos and Gaena units overlie the Camarena-Lanchares unit by thrusting. A minor overthrust has been observed in the latter unit (Sierra de Pelpitre; Fig. 19).

Figure 19.- Panoramic view from stop 3.2.

Stop 3.3

Arroyo Jarcas neptunian dykes (in front the Venta de Los Pelaos) and roman quarry in Ammonitico Rosso Fm in the Fuente de los Frailes.

Description and interpretation.

On the road from Priego to Cabra, in front of the "Venta Los Pelaos", flows the creek Jarcas. In the ravine it has created, we can observe the contact between the oolitic limestones of the Camarena Fm and the red nodular limestones of the Ammonitico Rosso Superior Fm. In the highest part of the limestones of the Camarena Fm we can observe numerous examples of neptunian dykes, some parallel to the bedding (S-type dykes) and others approximately perpendicular or slightly oblique to the bedding (Q-type dykes), which are less numerous. Regardless of the type, the size is variable, ranging from millimeters to dykes over 1 m. The most common size ranges from a few centimeters to several decimeters.

Two types of fills have been recognized, a) yellow mudstone and b) reddish or yellowish wackestone with 'filaments' and 'protoglobigerinids'; they may also contain crinoids, ammonites and gastropods. The first of these fills has been dated as Callovian by comparison with others of similar facies in which ammonites of this age have been collected. Locally they can be very bioturbated. The second type of fill can be observed in dikes near the top of the Camarena Fm. Beds with similar microfacies have been dated with ammonites as Callovian-Oxfordian. Locally, collapse breccias with angular clasts of oolitic limestones have also been observed in some dikes.

The walls of the neptunian dikes are net and irregular, with truncated bioclasts and no prefill cement development. In some dikes, thin speleothems (less than 0.5 mm thick) stained by thin patinas of Fe oxides have been observed coating the dikes. Their appearance is similar to that of microstalactitic vadose cements.

The area of the "Fuente de Los Frailes" (stop 3.3a, near to the Venta de los Pelaos by the road of San Marcos to Cabra, 4 km to the west of this city; Fig. 17) is a site of great tradition for the study of ammonites by prestigious paleontologist since the middle of the 19th century. It is included in the Andalusian Inventory of Georesources and next to the Fuente there is a quarry of Roman origin on the Upper Jurassic nodular and brecciated limestones of rosso ammonitico facies.

Stop 3.4

Los Lanchares outcrops. Paleokarst controlled by paleofaults at the top of Camarena Fm (Middle Jurassic) with hardgrounds and crinoidal facies associated. All is convered by Upper Ammonitico Rosso Fm (Upper Jurassic).

Description and interpretation.

About 2.5 km from the "La Venta los Pelaos" crossroad (Fig. 20), the discontinuity surface between the Camarena Fm and the Ammonitico Rosso Superior Fm can be observed. The uppermost meters of the former are represented by crinoidal limestones with herring-bone crossbedding. The most striking features of this surface are the paleokarst morphology and the presence of hardgrounds. The paleokarst morphologies are varied, and have been interpreted as the result of dissolution processes. The development of this paleokarst was clearly controlled by paleofaults, which is easily observed in some outcrops. In this area, no paleosols have been found immediately above the paleokarst surface.

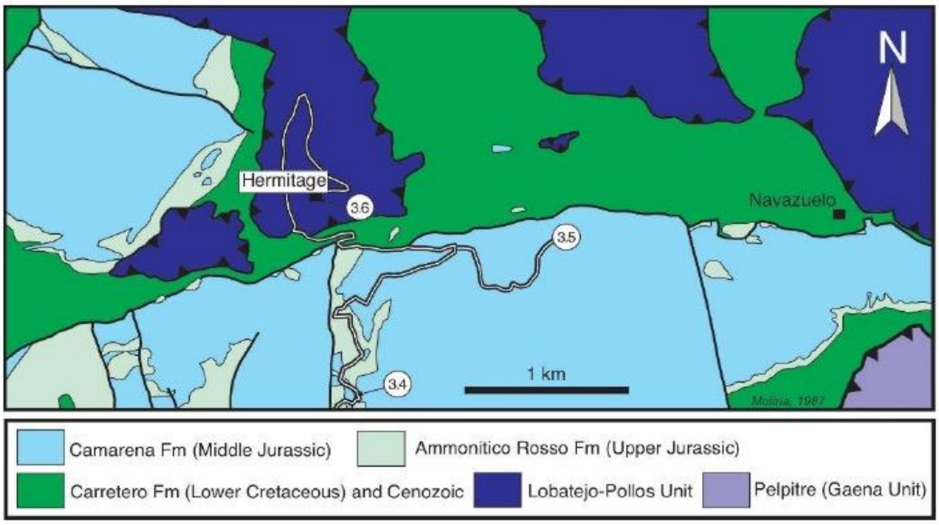

Figure 20.- Geological sketch of the Lanchares área (Camarena-Lanchares Unit, External Subbetic).

Hardgrounds are covered by crusts of Fe and/or Mn oxides, varying in thickness from a few millimeters to a few centimeters. They are usually brown or black in color, with borings, quartz grains and glauconite. Partially dissolved ammonites, belemnites, fish teeth, serpulids and stromatolite structures may also be observed.

The gap associated with the discontinuity may include part of the upper Bathonian and lower Callovian. In some parts SE of the Lanchares, this gap may be wider, encompassing the Callovian and Oxfordian, so that the hardground is the only sedimentary record for about 15 Ma.

Stop 3.5

Quarries in the oncolitic limestones of the Camarena Fm (Middle Jurassic).

Description and interpretation.

The intersection of the road to the now abandoned quarries is about 4.3 km from 'La Venta los Pelaos' (Fig. 20). In the upper part of the Camarena Fm, which consists mainly of white oolitic limestones (commercially known as 'Crema capri'), oncoids are abundant. These carbonate particles have an average diameter of 1.5 cm, although they can reach up to 4 cm. Other carbonate grains accompanying these particles are peloids, intraclasts, aggregates, foraminífera (*Trocholina, Protopeneroplis, Pseudocyclammina*, …), corals, brachiopods, gastropods, crinoids, serpulids, and other bioclasts, usually coated with micrite (cortoids). It was possible to recognize shallowing elementary sequences characteristic of shallow tropical marine environments, with tidal bars, channels and delta (Navarro et al., 2012).

Stop 3.6

Panoramic view from the Picacho de Cabra of the Subbetic Geopark. Subbetic units location and regional geology of an extensive area of the Betic Cordillera.

Description and interpretation.

From the Picacho de Cabra (next to the Ermita de la Virgen de la Sierra, Figs 17 and 20) there is a wide panoramic view of the Cordillera Betica. On days with good weather, the reliefs of the Sierra Nevada (Internal Zones) can be seen to the south, while to the north the reliefs of the Variscan Massif (Paleozoic) can also be observed. This site was one of the stops of the XIV International Geological Congress in 1926 (Fig. 21).

Figure 21.- A memorial plaque to the participants of the XIV International Geological Congress of 1926. It is located in the courtyard of the Hermitage.

Pre-FT2. External zones of Betic Cordillera

The hermitage and viewpoint are located on a klippe of the Lobatejo-Pollos Unit (External Subbetic), formed by Lower Jurassic dolostones. This klippe thrusts on materials of the Camarena-Lanchares Unit (Fig. 20). The tectonic arrangement of the Subbetic units, especially the overthrusting of the Gaena Unit over the Camarena-Lanchares can be seen to the south. There are also very nice views of the poljes of La Nava to the north and est.

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