Excursion Guidebook

PERMIAN AND TRIASSIC FLUVIAL SYSTEMS IN CENTRAL SPAIN

By

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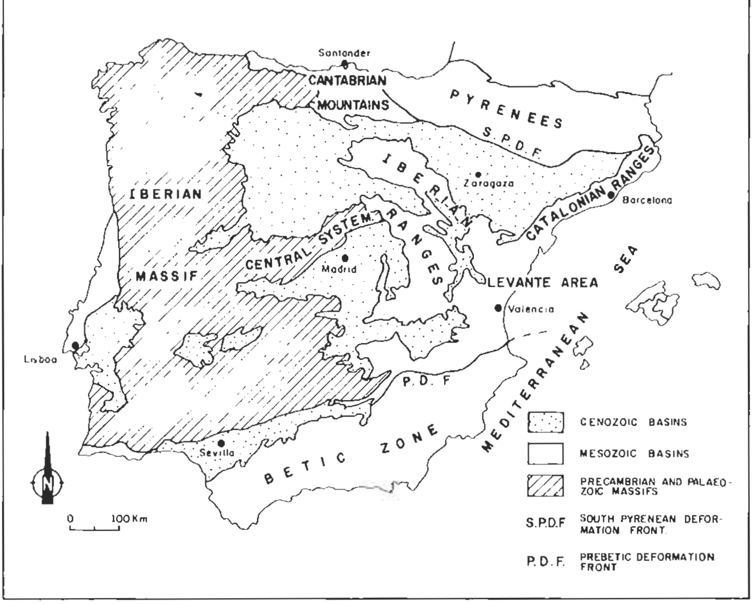
Introduction

The Iberian Range is a chain of intermediate type, Alpine in age. It extends from the Cantabrian Mountains in the northwest to the Mediterranean sea in the southeast, with an elongation of about 400 Km. and an average width of 150 Km. *(fig. 1).*

The Iberian Range can be longitudinally divided into two branches *(fig. 2):* the Aragonese Iberian branch and the Castilian Iberian branch. Both of them are separated by the Daroca and Teruel Tertiary basins, and join in the Levante area. The range consists predominantly of Permian and Mesozoic sediments that rest unconformably on a basement of Hercynian metamorphic rocks. The Iberian Range is a good example of the inherited late Hercynian structures that influenced Permian and Mesozoic sedimentation.

It is commonly accepted that severe fracturing during late Hercynian was a principal factor influencing the Mesozoic evolu-

Figure 1
Main tectono-sedimentary units of the Iberian Peninsula



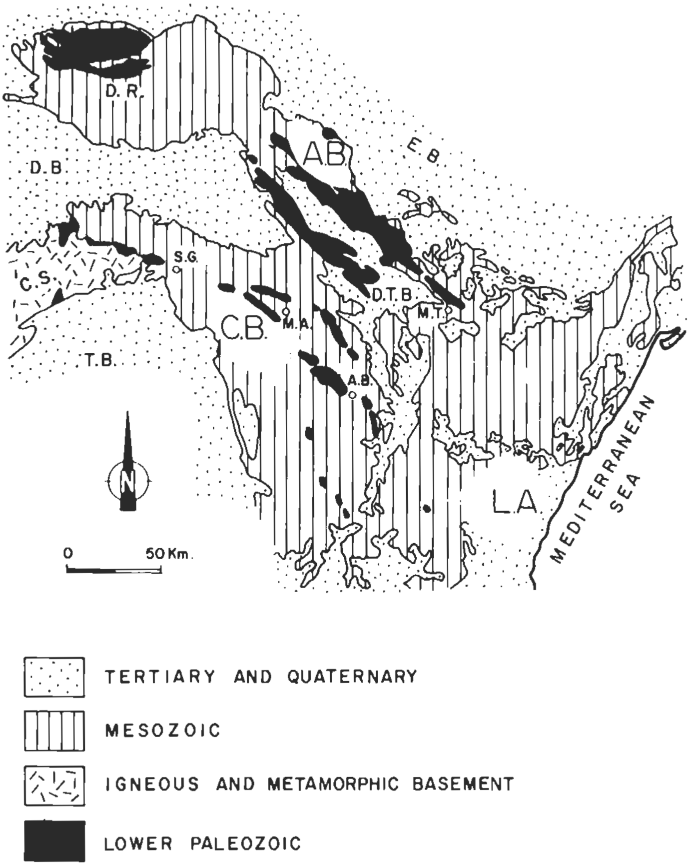
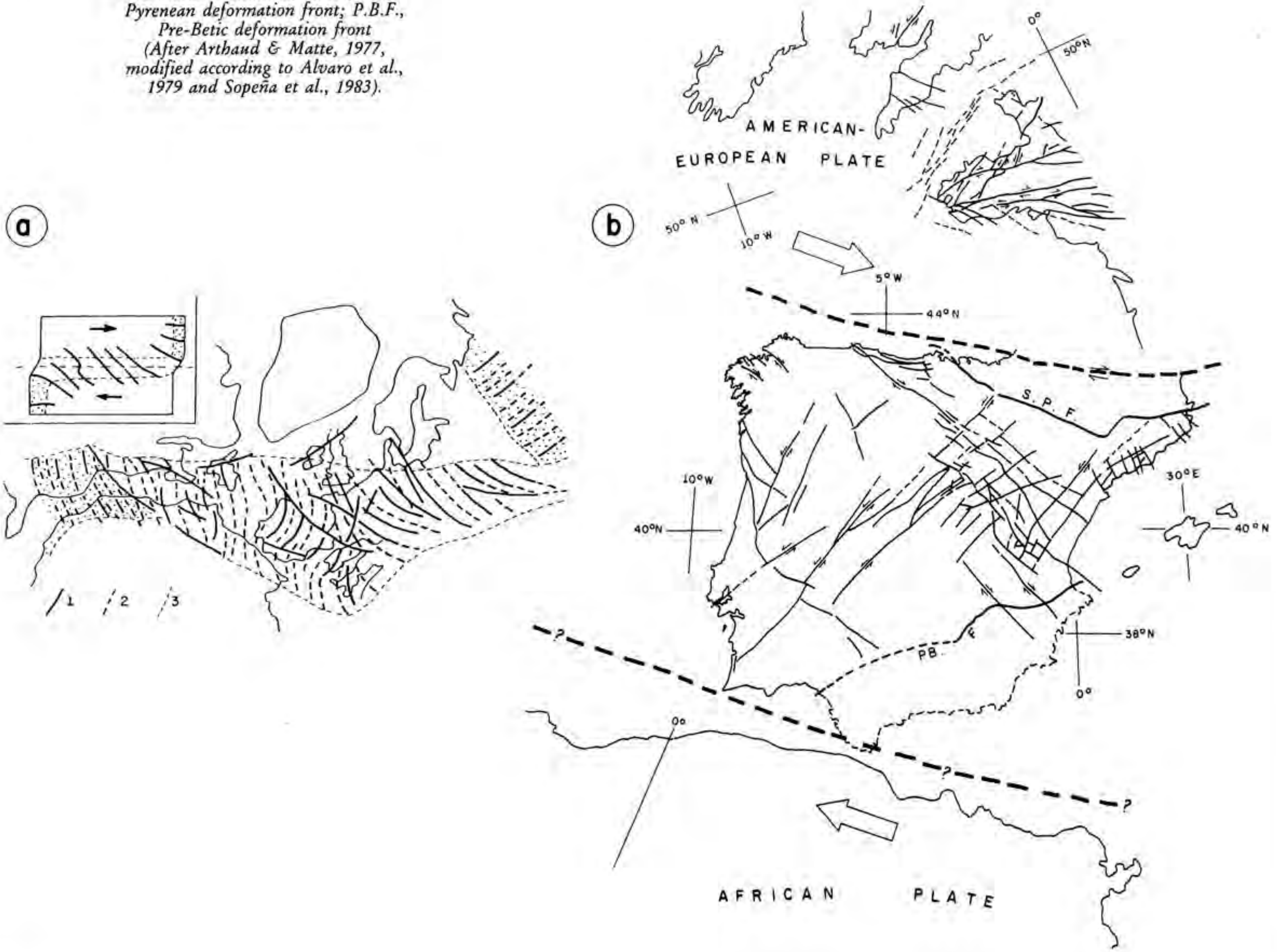


Figure 2
Main units of the Iberian Range

D.R. - DEMANDA RANGE
D.B. - DUERO TERTIARY BASIN
E.B. - EBRO TERTIARY BASIN
T.B. - TAJO TERTIARY BASIN
A.B. - ARAGONESE BRANCH
C.B. - CASTILIAN BRANCH
C.S. - CENTRAL SYSTEM
L.A. - LEVANTE AREA
D.T.B. - DAROCA - TERUEL TERTIARY BASIN

S.G. - SIGÜENZA
M.A. - MOLINA DE ARAGON
A.B. - ALBARRACIN
M.T. - MONTALBAN

Figure 3
a) Dextral megashear zone between the Appalachians and the Urals: 1, main stress trajectories; 2, hypothetical trajectories; 3, boundaries of deformed areas.
b) Late Hercynian wrench-fault systems in southwestern Europe. The Bay of Biscay and the Gibraltar Faults limit the Iberian Peninsula, S.P.F., South Pyrenean deformation front; P.B.F., Pre-Betic deformation front (After Arthaud & Matte, 1977, modified according to Alvaro et al., 1979 and Sopeña et al., 1983).



tion of the Iberian Peninsula. A complex half graben system, evolving along these fracture systems, was filled by hundreds of meters of red beds during the Permian and Triassic.

At the end of the Hercynian orogeny (Late Carboniferous-Early Permian), the Iberian Peninsula underwent a complex wrench faulting process *(fig. 3)* with two main east-west systems (the northern Pyrenean-Bay of Biscay system and the Gibraltar system). An important NW-SE and NE-SW fault system developed in the interior of the Iberian Plate, and associated volcanic rocks were accumulated (Autunian). Tectonic activity decreased during the Permian with the deposition of Saxonian facies.

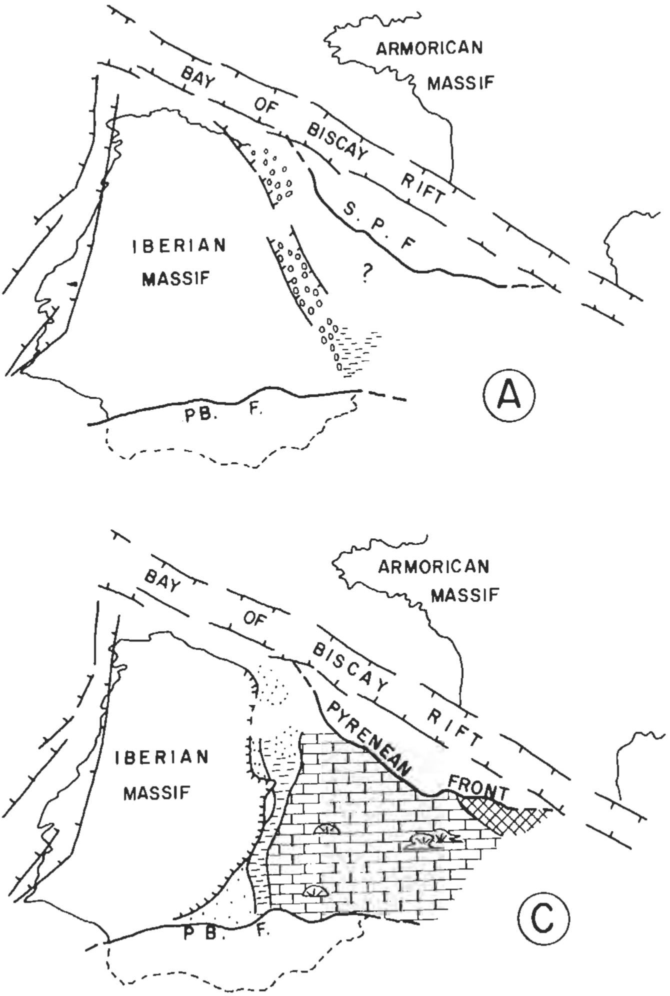
During Late Permian-Early Triassic, the older wrench fault-systems were first reactivated as normal faults which resulted in a series of basins (Sopeña et al. 1988). The basins show a comparable evolution *(fig. 4):* opening with continental (Buntsandstein facies) evolving to shallow marine carbonates (Muschelkalk facies) followed by evaporites and red clays (Keuper facies), the classic Triassic Germanic facies, but clearly diachronous in the different basins.

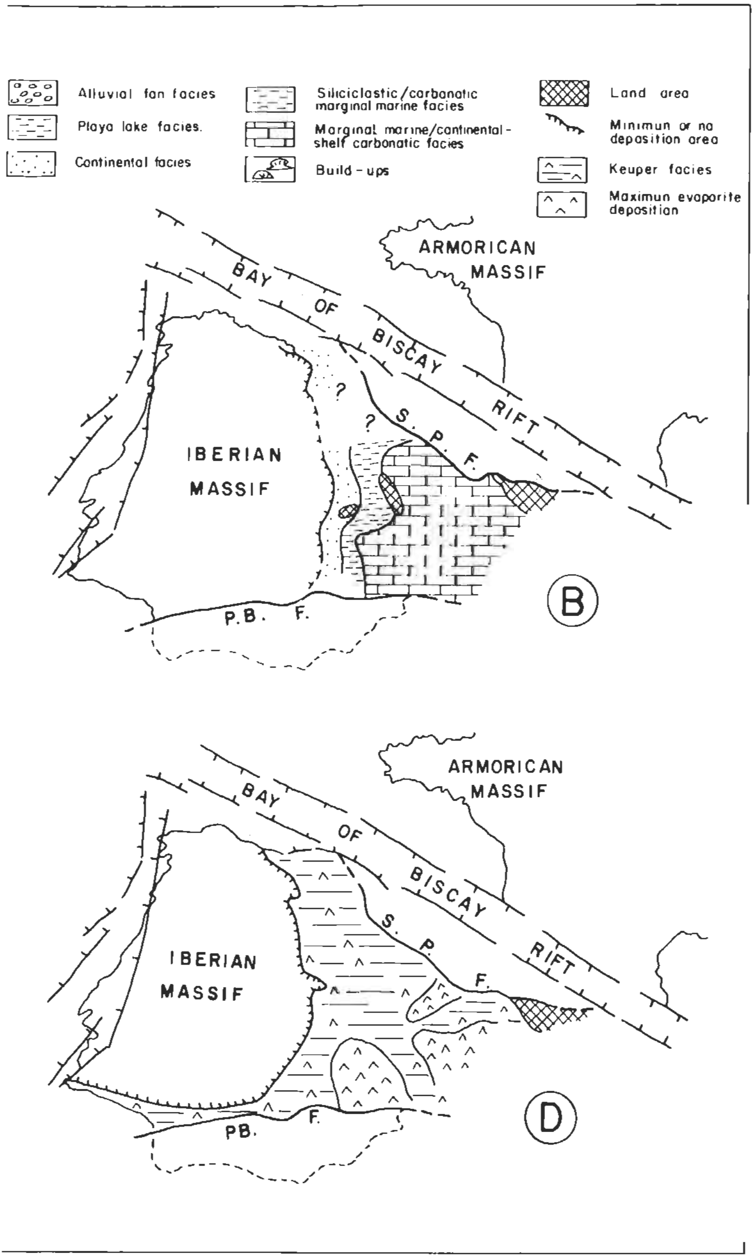
Permian and Triassic sedimentation in the Iberian Ranges, took place in a cratonic area inside the Iberian Plate. This Plate was undergoing an extensional regime because of its location between two broad rifting areas, the Tethys and the Protoatlantic. The evolution of these two major geotectonic realms resulted in the development of a complex multidirectional system of grabens and troughs, which transected the Variscan fold belt and its European foreland (Ziegler, 1988). In the framework of the southward-propagating Arctic-Atlantic rift system and the westward propagation of the Tethys rifts, a progressive regional extension took place with some Late-Hercynian fault systems being reactivated.

Concerning the Iberian Peninsula, this fracture system showed some peculiarities as this microplate lies between the African and American-European plates *(fig. 3)*. Two large fault zones formed the boundaries of the Iberian microplate: The Pyrenean-Bay of Biscay fault system, which evolved and joined the Baffin transform system, and the Gibraltar fault system, which became connected to the Chedabucto wrench-fault system.

It is accepted that the relative dextral movement between the

Figure 4
Evolution of the Late Permian and Triassic sedimentation in the Iberian Peninsula. A) Formation of the Iberian trough and continental sedimentation (Late Permian). B) First advance of the Tethys Sea (Anisian). C) Marine carbonate and mixed facies extend to most of the Iberian Peninsula except in the northern and southern extremes (Ladinian). D) Evaporite and sebkha deposits (Karnian).




Alluvial fan facies
Playa lake facies.
Continental facies
Siliciclastic/carbonatic marginal marine facies
Marginal marine/continental-shelf carbonatic facies
Build-ups
Land area
Minimun or no deposition area
Keuper facies
Maximun evaporite deposition
ARMORICAN MASSIF
BAY OF BISCAY RIFT
IBERIAN MASSIF
S. P. F.
P.B. F.
?
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B
ARMORICAN MASSIF
BAY OF BISCAY RIFT
IBERIAN MASSIF
S. P. F.
PB. F.
D

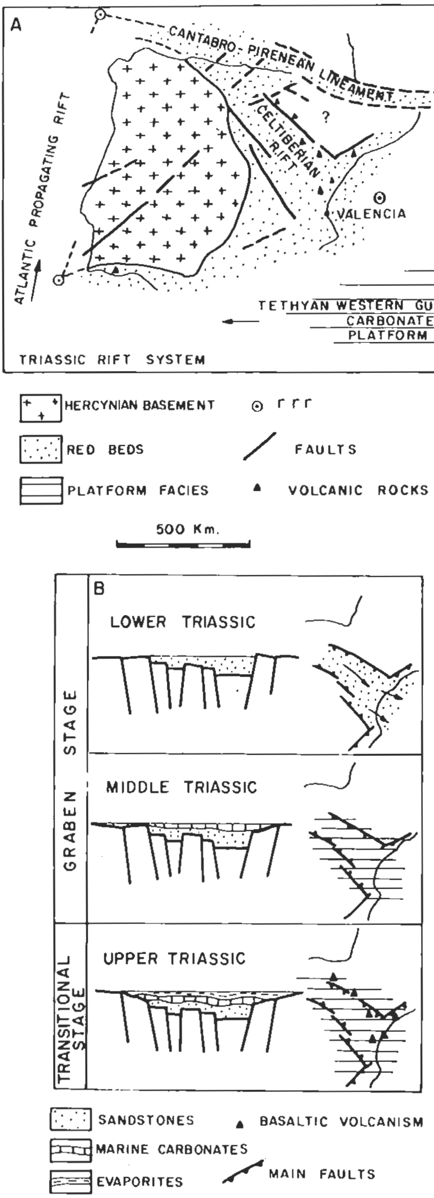
two large African and Euro-American plates resulted in a mega-shear stress, producing two fracture systems: a NW-SE dextral system and a NE-SW sinistral one. Those movements were accompanied by several magmatic events: the late-Hercynian granites and the volcanic rocks (Late Carboniferous-Early Permian andesitic-dacitic rocks, Castilian Iberian Range). Those faults were reactivated as normal faults during the extensional stage or as reverse faults during the compressive ones (Alpine Orogeny), thus controlling the structural style.

Alvaro et al. (1979) described the evolution of the Iberian Range as an aulacogene (Celtiberian rift in *fig. 5A*). They distinguished three stages of evolution:

- Graben stage *(fig. 5B);* this consists of the continental and marine sedimentation that took place during the Early and Middle Triassic. It is an extensional stage, during which a system of horsts and grabens developed. This system was controlled by a NW-SE and SW-NE fault system.
- Transitional stage *(fig. 5B);* this stage must have developed during the Late Triassic with evaporitic Keuper sedimentation. The volcanic and subvolcanic rock emplacement took place during this stage too.
- Flexure stage; this must have consisted of the Jurassic and Cretaceous shallow marine carbonates, also including some important continental events during the Late Jurassic-Early Cretaceous.

Nevertheless, the above described evolution shows some steps that are not so clearly explained. Thus, according to Alvaro et al. (1979), a hot spot must have been located in the upper matle, near Valencia, where a rrr-type junction was also located *(fig. 5A).* The Iberian Range would be one of the rifting arms, the other two corresponding to the Betic-Balear geosyncline. Consequently, a crust doming would take place for the Valencia area, during Late Carboniferous and/or Permian, creating a centrifugal drainage system and probably some important volcanic eruptions. However, none of the above described events are registered in this area. First of all, no Caboniferous sediments have been recognized in this area, and secondly, the sedimentological studies for the Late Permian sediments show a general paleodrainage towards the SE.

Figure 5
A) Triassic rift system (after Vegas & Banda, 1982)
B) First stages of evolution of Celtiberian aulacogene (after Alvaro et al., 1979).



Therefore, the rifting is more probably the response to extensional stress originated at the Iberian plate boundaries accompanying the Pangea breakup and its location between two areas (the Atlantic and the Tethys) that would later suffer oceanic spreading. According to Royden & Keen (1981) and Beaumont et al. (1982), that process generally generates volcanism during the first rift evolution stages but the sedimentation precludes the first volcanic eruptions over a time span of about 30 million years. If the base of the Buntsandstein is taken to be the beginning of the general sedimentation infilling the Iberian rift, the volcanic rocks related to the Keuper facies would therefore be the first volcanic emplacement as predicted in the above described model. This emplacement would have taken place about 30 m. y after the beginning of the sedimentation.

The post-Triassic evolution does not follow the simple aulacogene model either, as there is a new rifting stage from Late Jurassic to Early Cretaceous with continental and/or transitional sedimentation over some areas in the Iberian Range. This new stage of vertical movements and fast subsidence was related to the anticlockwise rotation of the Iberian plate and the opening of the Biscay Bay (Alvaro, 1987). The subsidence curves compiled by Alvaro (1987) show the two different rifting and tectonic subsidence events superimposed *(fig. 6)*. The first event took place during the Late Permian-Triassic and Jurassic, and the second one during the Cretaceous. Both of these events were related to a crustal stretching and thermal subsidence as a result of the extension suffered by the lithosphere.

As a result of the above described evolution during the Late Hercynian movements, the Iberian Peninsula was configurated as complex fracture systems controlling the sedimentation of the Permian and Triassic continental sediments that will be visited during this field trip. Sedimentation was controlled not only by tectonics but also by the eustatic sea-level rise that resulted in the Muschelkalk carbonate platform, the first transgressive event affecting the whole peri-Mediterranean realm.

Figure 6
Subsidence curves in the Iberian Range
(after Alvaro, 1987).
St: tectonothermic subsidence; ST: total subsidence.
A) Castilian branch.
B) Aragonese branch.

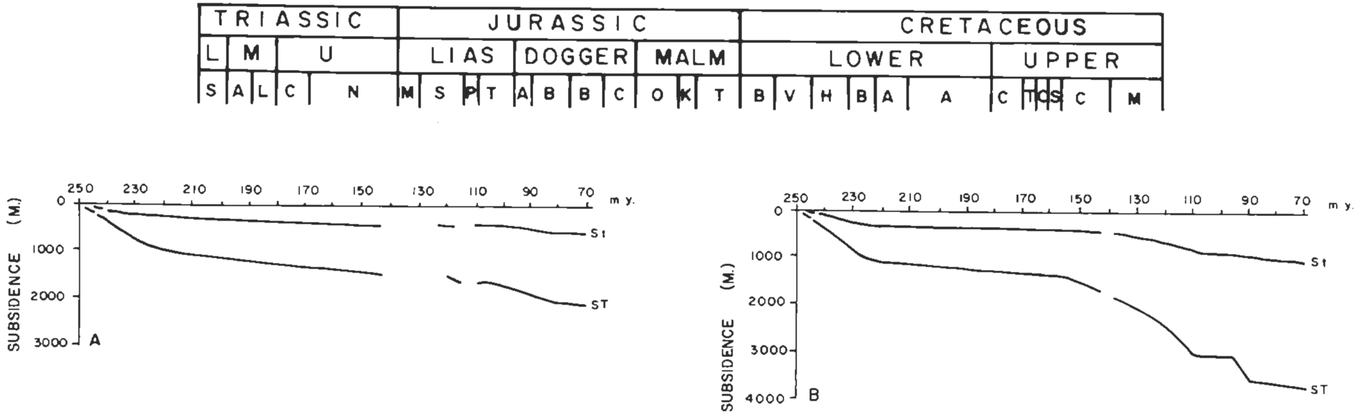
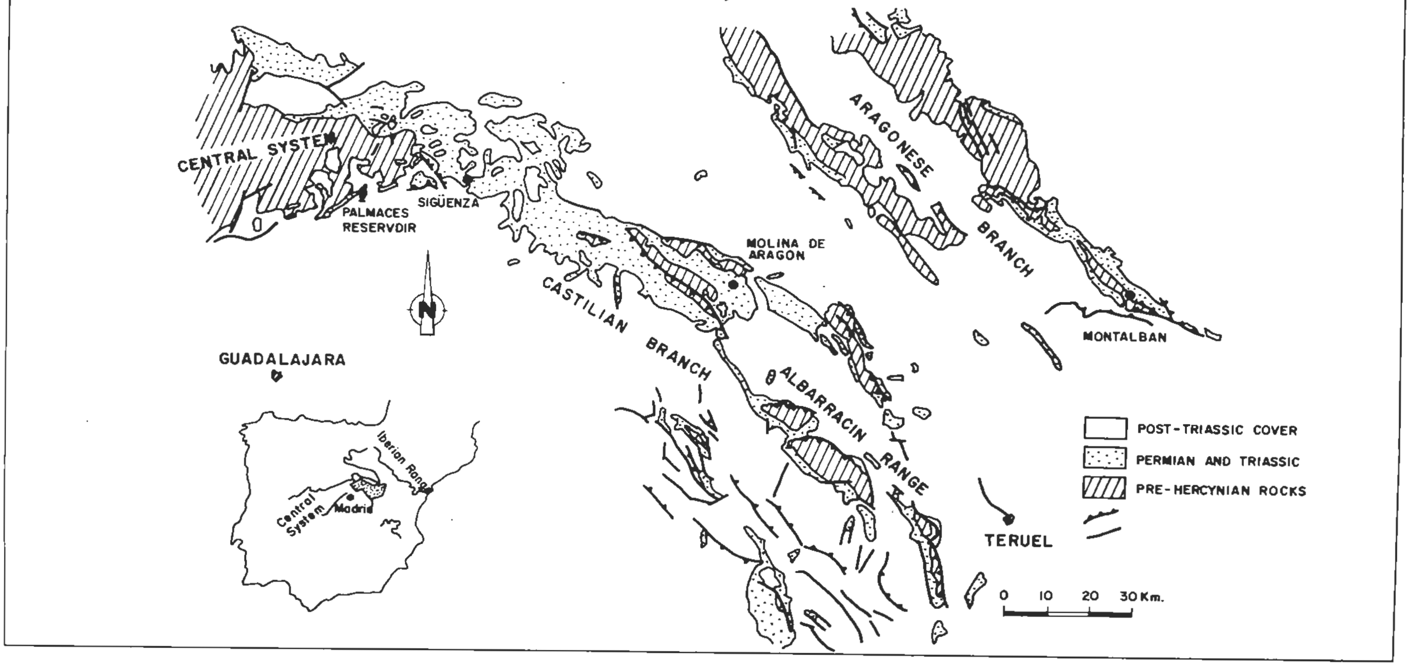


Figure 7
Main structural units of the Iberian Range at the intersection with the Central System.



Evolution of the Western Iberian Range

The area to be visited lies in the western part of the Iberian Range in Central Spain *(fig. 7)* and comprises rocks ranging in age from Early Permian to Late Triassic. The Lower Permian (Autunian) always lies unconformably on Hercynian basement and is also covered unconformably by Saxonian or Buntsandstein red beds. Sedimentation began in some areas (Molina de Aragón), with a volcanoclastic calc-alkline sequence of tuffs, ash flows and ignimbrites of lahar type (Muñoz et al. 1985) or with scree and colluvial debris as in Pálmaces de Jadraque.

The Saalian movements and subsequent erosion greatly modified the regional paleotopography. Continental red beds («Capas de Montesoro» of Saxonian facies), consisting mainly of red mudstones with intercalated breccias of quarzite, sandstones, conglomerates, and thin carbonate beds of mainly alluvial origin, indicate a climatic change to more arid conditions. A number of small alluvial fans came into being in which the distinction between proximal and distal facies is hardly possible. There are no biostratigraphical data for the Saxonian facies, which may reach a thickness of approximately 45 m in this area.

Buntsandstein sediments unconformably overlie all previous rocks and began with a period of extensive continental sedimentation on older Paleozoic massifs in the Iberian Peninsula. Traditionally the basal unconformity has been considered to be the Paleozoic-Mesozoic boundary, but the age of the lowest sediments is variable, ranging from Late Permian to Middle or Late Triassic. A Thuringian microflora has been recovered in our area from the lowest Buntsandstein unit («Conglomerados de la Hoz del Gallo») (Ramos & Doubinger 1979). Tectonics and sedimentation were clearly related. The basin was affected by a series of horsts and grabens with some areas of major subsidence, forming internal unconformities in the border of the basin *(fig. 8)* (Sopeña et al. 1988). The area studied is a major zone of subsidence, where Buntsandstein facies exhibit thick development. The Buntsandstein has been subdivided into six units (Ramos 1979),

Figure 8
Section showing the geometry of the basins and the lateral changes from the margins of the Iberian massif to the Mediterranean Sea. CH: «Conglomerados de la Hoz del Gallo», ARG: «Areniscas de Rillo de Gallo», NP: «Nivel de Prados», ARA: «Areniscas del río Arandilla», LAR: «Limos y areniscas de Rillo», LAAT: «Limos y areniscas abigarrados de Torete»

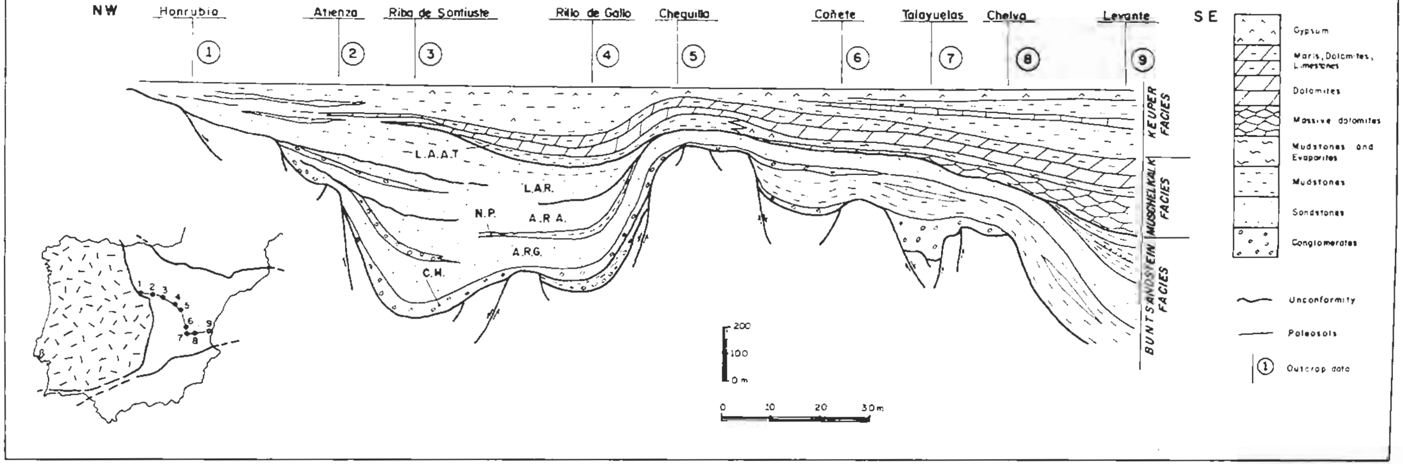
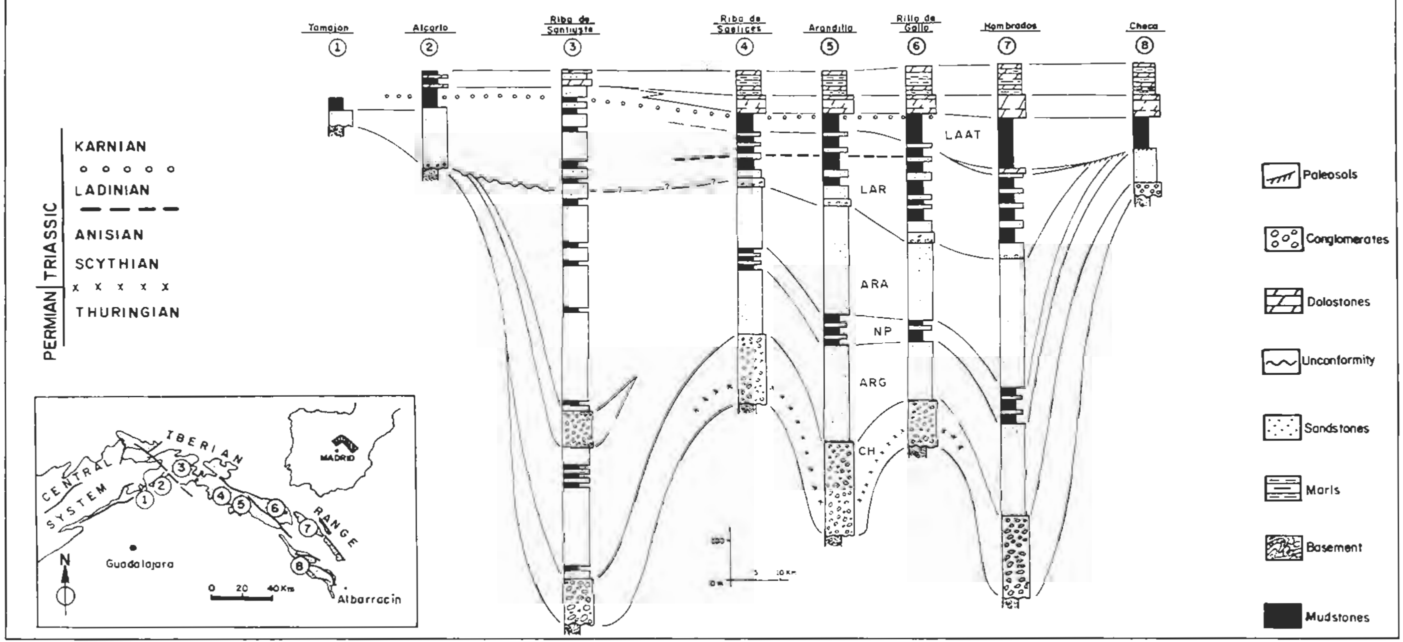


Figure 9
Correlation of selected sections along the Iberian Range (see figure 8 for unit names)



ranging in age from Thuringian to Ladinian *(fig. 9)*. The Buntsandstein facies mainly consists of conglomerates and sandstone red beds. The lower siliciclastic complex «Conglomerados de la Hoz del Gallo» (CH), «Areniscas de Rillo de Gallo» (ARG), «Nivel de Prados» (NP) and «Areniscas del Rio Arandilla» (ARA), is closely related to tectonic events (Ramos et al. 1986, Sopeña et al. 1988). A noteworthy alluvial complex related to late Hercynian faults developing during the sedimentation. The «Conglomerados de la Hoz del Gallo» (CH) onlap «Capas de Montesoro», the result of fan-lobe progradation produced by low-sinuosity streams (Ramos & Sopeña 1983) with a NNE trend. The overlying unit («Areniscas del Rio Arandilla», ARA) accumulated as the result of braided fluvial systems producing transverse or linquoid bars that change upwards into channel fill deposits (Ramos et al. 1986). The «Nivel de Prados» (NP) unit was deposited by higher-sinuosity streams with a new reactivation for the «Areniscas del Rio Arandilla» (ARA) (lower sinuosity, coarse-grained) related to tectonic movements. The «Lutitas y Areniscas de Rillo» (LAR) unit displays evidence of evolution from a distal fluvial environment to one of tidal influence, that probably took place during the late Anisian as indicated by a palynological assemblage in the upper part (Ramos 1979). This marks the beginning of the Tethyan trasgression over this area of western Europe. The «Lutitas y Areniscas abigarrados de Torete» (LAAT) unit, with several palynological assemblages of Ladinian age, shows clear evidence of a supratidal environment in a semiarid climate with algal lamination and evaporite precipitation. The Muschelkalk carbonate facies represents the development of a more homogeneous marine environment, with more general subsidence and widening of the basin. These last events took place in this area during Late Ladinian-Early Karnian as proved by palynological assemblages (Ramos 1979).

Fluvial Style Evolution

The Permian and Triassic continental red beds of this area show a variety of fluvial styles related to the basin evolution.

Late Hercynian molasse occurs along the northeast and southeast margins of the Central System and within the Castillian branch of the Iberian Range *(fig. 10)*. One of the most representative of these basins is the Pálmaces halfgraben, located at the southeast margin of the Central System. Sedimentation began in that area during the Autunian, with the deposition of breccias and volcanoclastic rocks, followed by the development of a near 700 m thick coarsening-upwards sequence of mudstones, sandstones and conglomerates. Sedimentation was influenced by a wrench fault located at the eastern border of the basin. A large vertical throw is reflected by several prograding alluvial fan cycles, including boulder conglomerates at the top.

The post-Hercynian sedimentary record in the Castillian branch of the Iberian Range consists of continental red-beds of Permian age and Saxonian facies type. These sediments are heterochronous and are related to asymmetrical basins bounded by NW-SE and SSW-NNW fracture systems. These systems are commonly late-Hercynian wrench-fault systems that were reactivated as normal faults. These continental red-beds rest unconformably over a Lower Paleozoic basement or over volcanic and volcanoclastic older Permian rocks.

In the Molina de Aragón area, the sedimentation took place as flood-dominated alluvial fans with paleocurrents towards the NE related to the main NW-SE fracture system. More to the southeast, in the Albarracin area, more organized alluvial fan systems were developed with a transition between proximal and distal facies *(fig. 11)*. A major prograding event resulted in a coarsening-upwards sequence from mudstones to sandstones and conglomerates. The relative stability of alluvial channels was higher here than in the northern area.

A general reactivation of the NW-SE fracture system *(fig. 12)* resulted in a larger area of sedimentation and the lower Buntsandstein sediments onlapping the Saxonian facies. The three

Figure 10
Early Permian basins of the Central System and the northwest Iberian ranges.

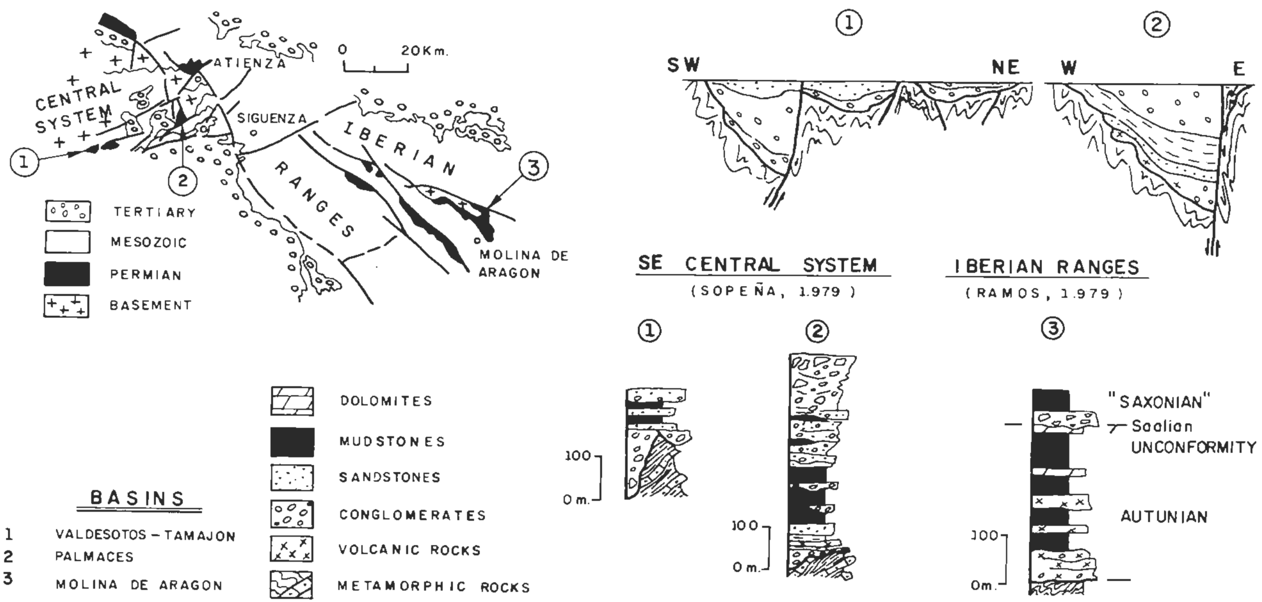


Figure 11
A) Schematic block diagram showing «Lutitas y areniscas de Tormón» depositional facies. B) Palaeocurrents for «Lutitas y arenisas de Tormón» unit.

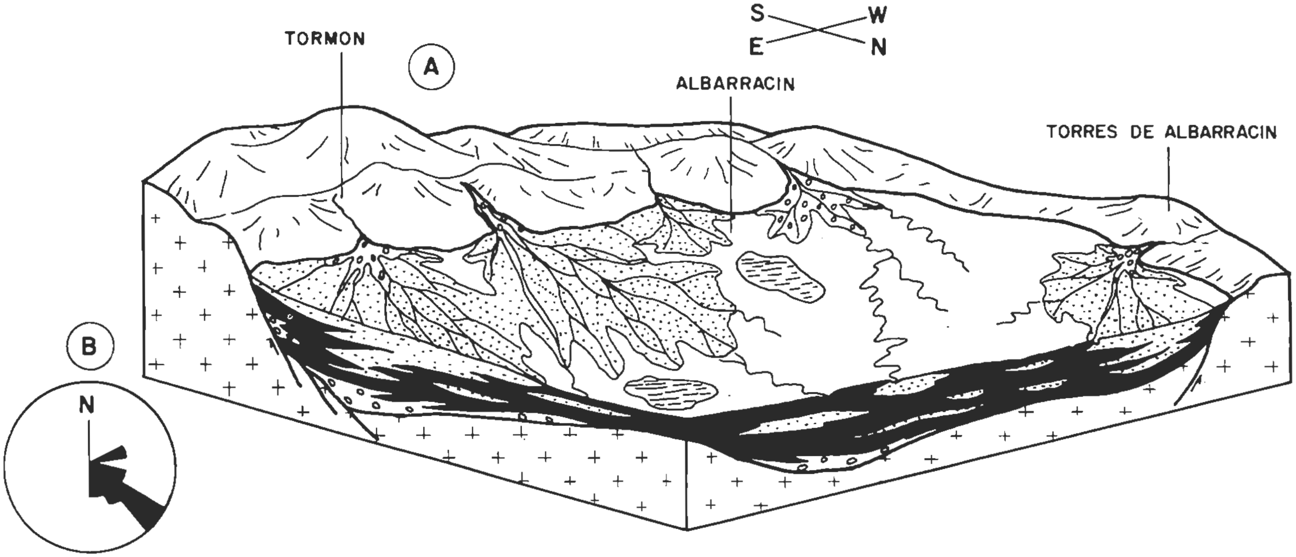
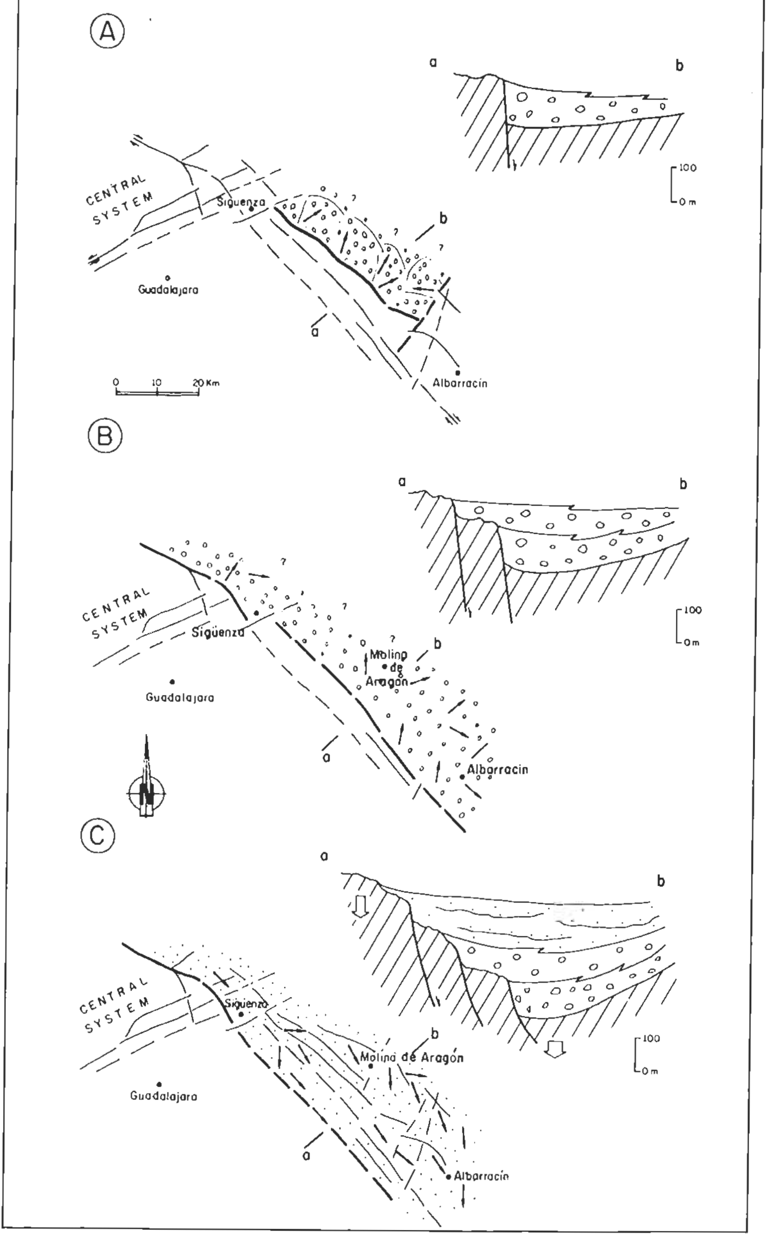


Figure 12
Palaeogeographic model and basin-margin settings for the «Conglomerados de la Hoz del Gallo» (A, lower cycle; B, upper cycle) and the «Areniscas del Rillo de Gallo» (C). See figure 14 for legend.



lowest Buntsandstein units («Conglomerados de la Hoz del Gallo», «Areniscas del Rio Arandilla» and «Nivel de Prados») configurate a fining-upwards megasequence with a distintive evolution in the fluvial style.

Considering firstly the conglomerates («Conglomerados de la Hoz del Gallo»), there were two major cycles in the complete sedimentary sequence that correspond to different physiographic models *(fig. 13)*. The lower cycle was formed mainly by relatively small channels and bars compared to the upper cycle. Three coarsening-upward sequences may be recognized in the conglomerates *(fig. 14)*. These sequences are between 40 to 50 m thick. The two lowest sequences, that form the lower cycle conglomerate, are interpreted as an alluvial fan system and reflect fan lobe progradation across the alluvial plain related to tectonic movements *(fig. 12A)*.

The uppermost sequence (upper cycle conglomerate) displays a greater uniformity of facies and palaeocurrents *(fig. 12B)* that point to a more distant source complex with no control by local relief. This alluvial system flowed across a larger area than the lower one, as shown by the palaogeographic distribution of this cycle, which sometimes rests on the lower conglomerate, and sometimes directly on the basement. This upper cycle conglomerate probably accumulated on a braidplain, transitional from coalescing alluvial fans upslope (the lower cycle conglomerate) similar to those described by Rust (1984).

The conglomeratic units pass upward into the «Areniscas de Rillo de Gallo». Transitional facies are scarce, with very rare mixed lithologies. Units averaging 90% conglomerates commonly give way to units with 90% sandstones.

The paleogeography of the sandstone facies, together with paleocurrents (perpendicular to the conglomerate paleocurrents) point to the deposition from a separate dispersal system that extensively overlaid the previous one *(fig. 12C)*. Where they exist, the mixed facies may have resulted from reworking of the upper conglomeratic beds by the new sandy fluvial system, generating a mixed braided environment with conglomerates and sandstones. The «Areniscas de Rillo de Gallo» represents a more extensive alluvial system spreading over larger areas. The general paleogeo-

Figure 13
Schematic block diagram illustrating «Conglomerados de la Hoz del Gallo» depositional facies. A) Lower cycle, B) Upper cycle.

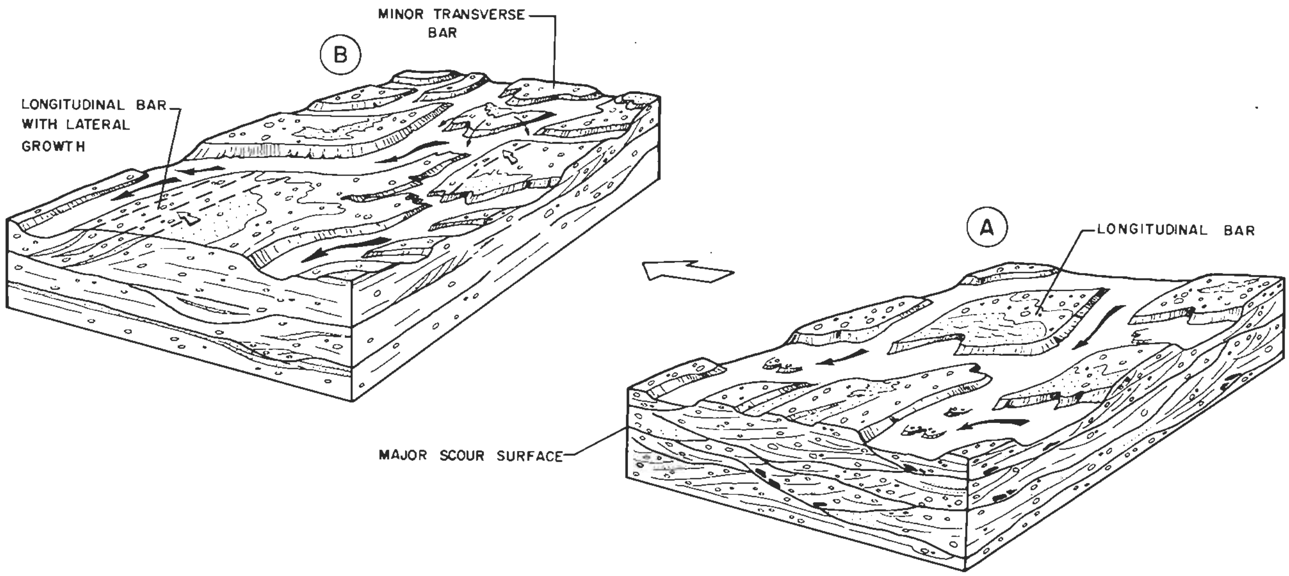
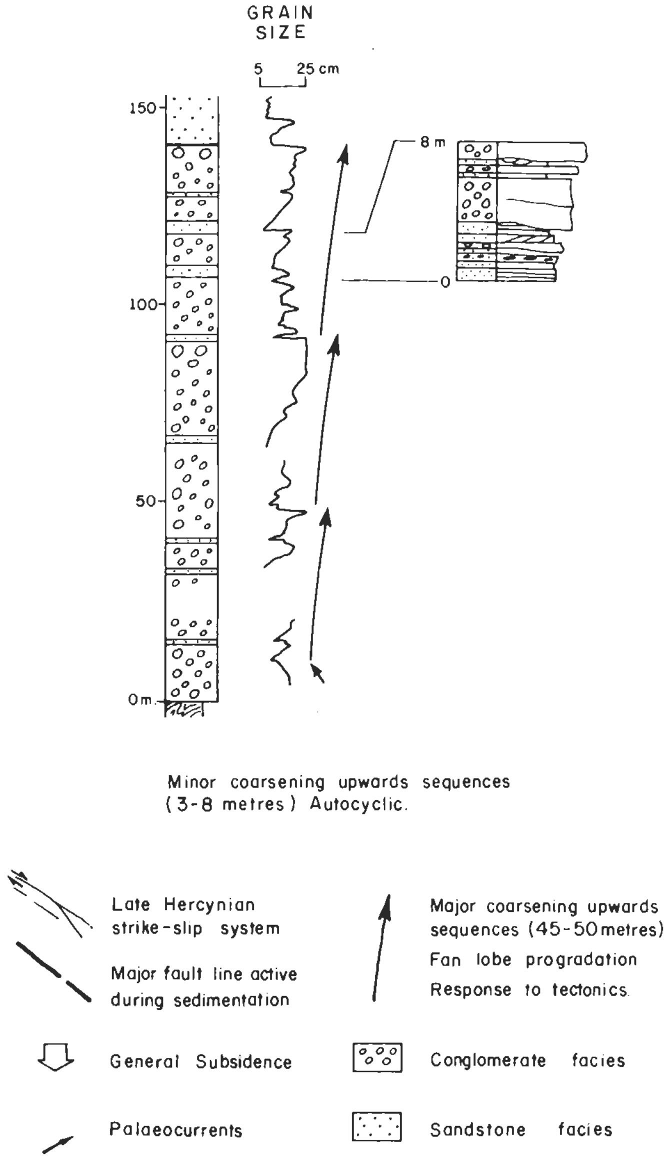


Figure 14
Vertical profile through the «Conglomerados de la Hoz del Gallo» showing the dominance of major coarsening-upwards sequences.



graphy (Sopeña et al., 1988; Perez-Arlucea & Sopeña 1985) shows that this unit can be followed extensively not only in our area, but also over most of the Iberian Ranges and even outside the Iberian Ranges. This unit represents the growth of a fluvial braidplain over a large area of Iberia during the Early Triassic.

The paleocurrents for the sandstone units are directed from north-northwest to south-southeast, nearly perpendicular to the conglomerate paleocurrents. This distinctive fluvial system was first dominated by broad channels with very high width/depth ratios and with major sandy transverse bars extending across them *(fig. 15A)*. This environmental association resembles the Platte type of Miall (1977, 1978, 1982). The sequence passes upward into coarser-grained sandstone with a change in bedforms *(fig. 15B)*. They are minor bedforms compared with the major bars of the lower part of this sandstone unit and consist mainly of trough cross-beds. They represent the infilling of channels in a braided system similar to the south Saskatchewan type of Miall (1977, 1978, 1982), and Cant and Walker (1978).

The «Nivel de Prados» unit represents the upper part of the basal fining upwards megasequence. Sandstone and mudstones alternate in this unit with a fining upwards arrangement. Calcrete horizons in mottled mudstones commonly occur. The characteristics of this unit suggest an evolution into a higher sinuosity alluvial system with relatively small channels and distinctive overbank deposits. Paleocurrents change dramatically in this unit with a range of directional variability of more than 180°, between NNW and SSW. During the sedimentation of this unit, the areas occupied by the fluvial system are restricted to areas in the E-NE. The basin was restricted to a smaller trough where the subsidence continued actively.

The new tectonic activity resulted in a different environment with a coarser grained braided system («Areniscas del Rio Arandilla»). The tectonic movements did not generate backfaulting, and the sedimentation did not cover the southwestern margin. The «Areniscas del Rio Arandilla» is a new fining upwards megasequence with coarser grained low sinuosity streams evolving upwards into high sinuosity meandering streams.

A new reactivation follows marked by the «Limos y Areniscas

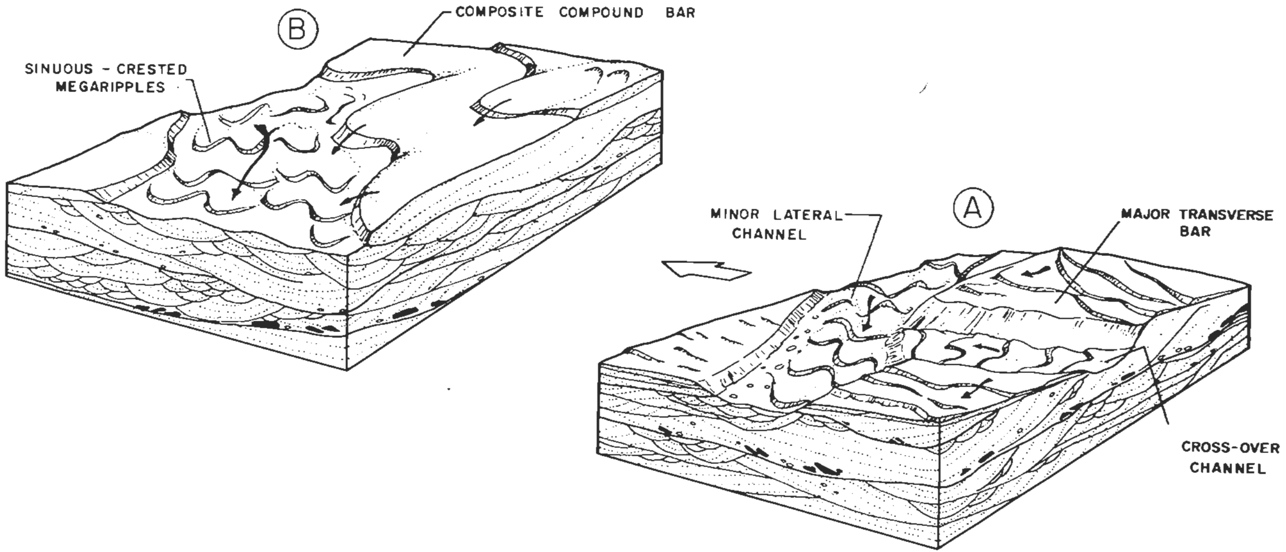


Figure 15
Schematic block diagram illustrating «Areniscas de Rillo de Gallo» depositional facies. A) lower part, B) upper part.

de Rillo» and the «Limos y Areniscas abigarrados de Torete». The first of these two units displays a complete evolution from a broad shallow low sinuosity streams with mixed bed load (gravels and sands), to a distal sandy braidplain with ephemeral run-off into a meandering stream system that displays a variety of channel deposits with lateral accretion surfaces alternating with overbank deposits that include evidence of subaerial exposure. The «Limos y Arenicas de Rillo» marks the end of the alluvial sedimentation over this area.

The «Limos y Areniscas abigarrados de Torete» unit consists of thin-bedded mudstone and sandstone alternating; with flaser, lenticular and wavy bedding. Salt pseudomorphs are the most common feature in this unit with occasional thin dolomitic beds that include algal laminae. This features indicate that a marginal marine environment extended over this area, local evidence of the transgression of the Tethys, from the east over the Iberian Peninsula.

FIRST DAY

Madrid-Pálmaces de Jadraque-Sigüenza

Figure 16
Itinerary and location of stops 1-12.

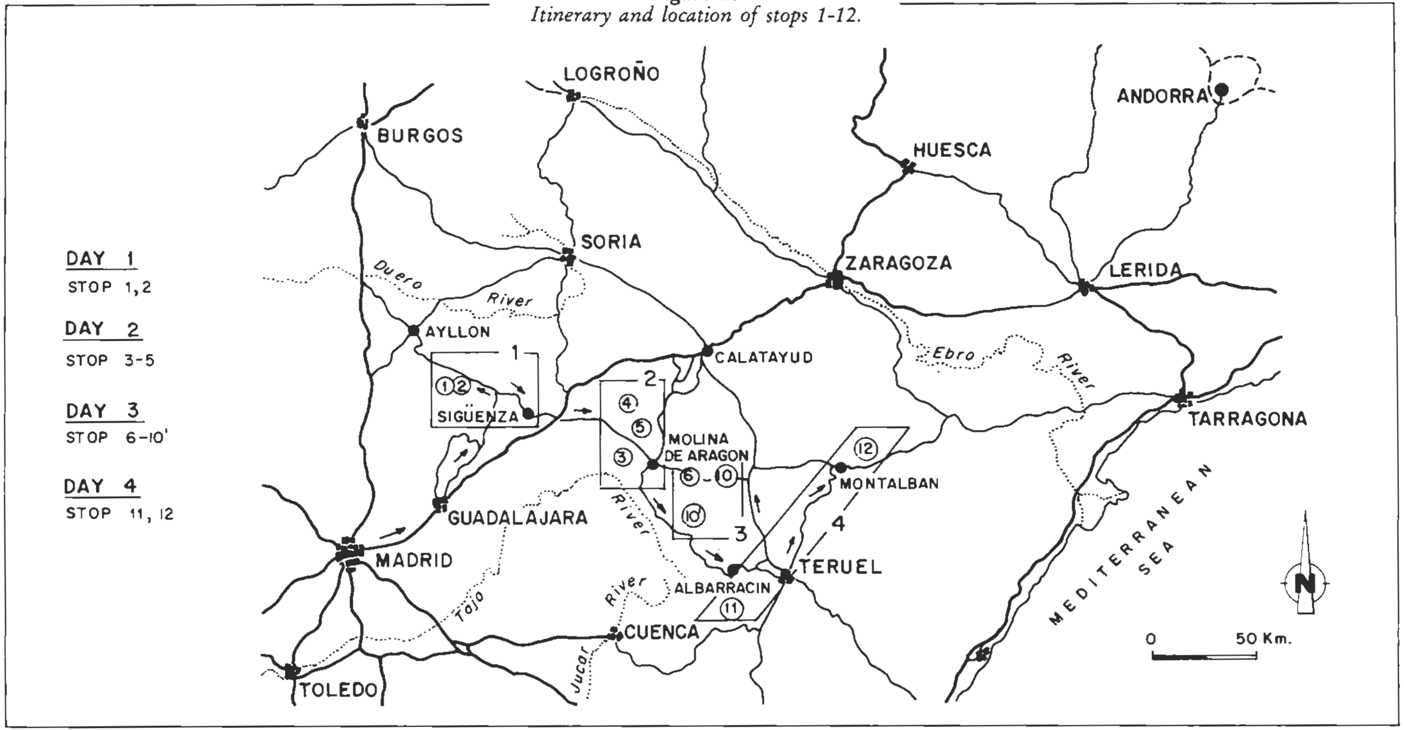
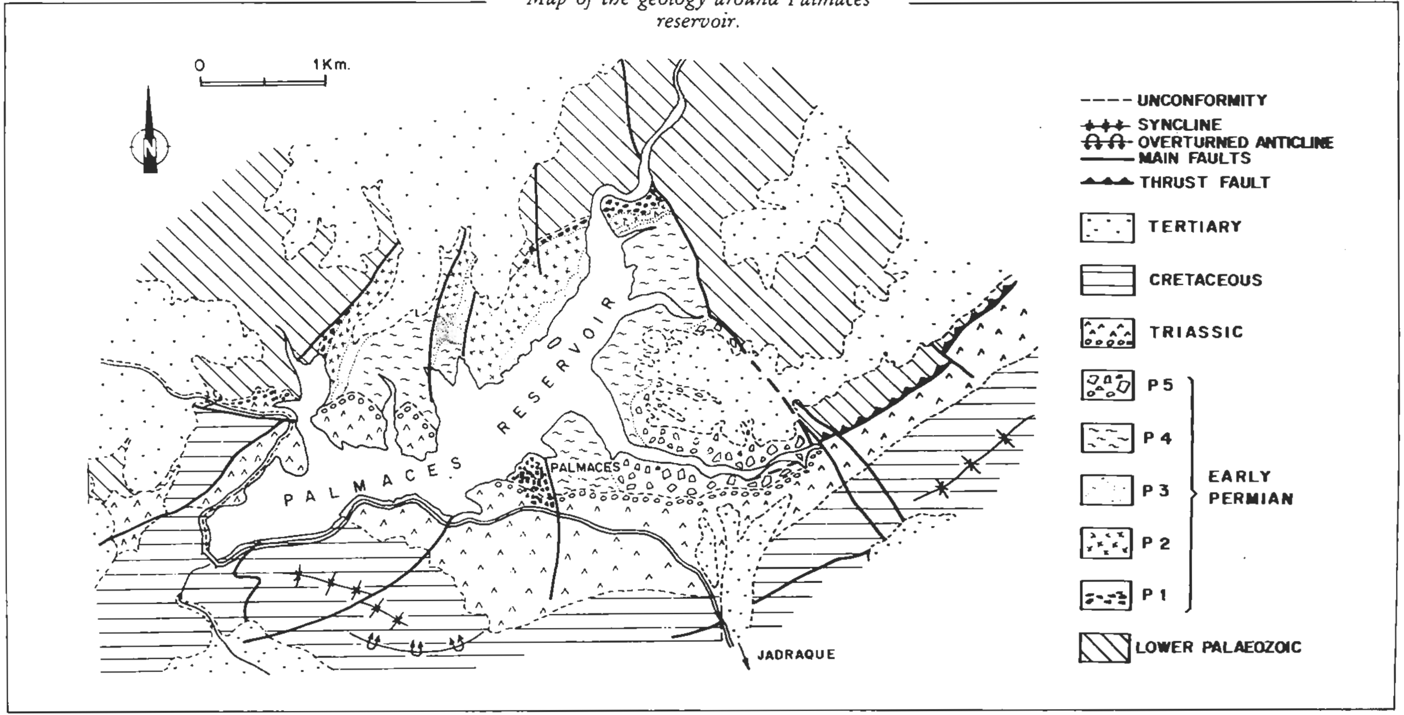


Figure 17
Map of the geology around Pálmaces reservoir.



STOP 1

Lower Permian. Distal alluvial fan facies

Cross-section north of Pálmaces de Jadraque reservoir. Parking site at the track to Hiendelancina, 1.5 km after crossing the Pálmaces reservoir.

The Lower Permian volcanoclastic and alluvial sediments filled a half graben basin with a NNW-SSE fracture system to the west. The actual outcrop is less than 5 km^2 large *(fig. 17)*. In spite of the small exposure, the thicknesses reach more than 670 m. Five lithostratigraphic units have been distinguished, recording the sedimentological evolution of the basin *(figs. 18, 19)*. The basal unit («Conglomerados inferiores de Pálmaces») consists of up to 50 m of breccias and thin-bedded sandstones. These deposits are always directly related to the basal Lower Paleozoic unconformity. The breccia deposits are polymodal, badly stratified and usually lack any fabric. They show clast or matrix support, consisting of fine to medium grain sandstones. These deposits are the base of the halfgraben fill and are interpreted as scree and/or colluvial debris.

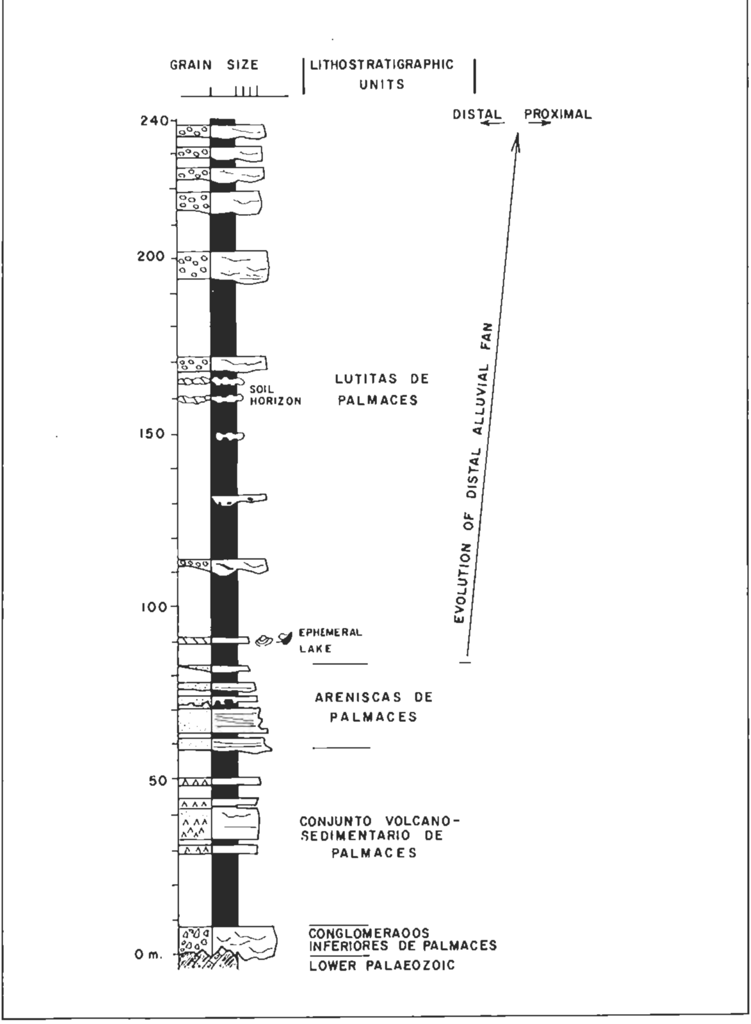
The calc-alkaline volcanic rocks apparently emplaced along the Late-Hercynian fracture systems, are locally both pyroclastic and volcanosedimentary deposits («Conjunto volcano-sedimentario de Pálmaces»). They consist of green, gray and red tuffs, pyroclastics and mixed-lithology breccias, that include metamorphic rock fragments. The volcanic material was partially reworked by alluvial streams.

Small sandy channel fill deposits are the main elements in the «Areniscas de Pálmaces» unit. Mudflow and debris-flow deposits are also common in this unit. They were probably formed by sediment gravity flow and sheet flood events.

The overlying units «Lutitas de Pálmaces» and «Conglomerados superiores de Pálmaces», of which the latter will be visited in the next stop, form a coarsening upwards megasequence (600 m thickness) resulting from an alluvial fan, prograding from the east. The «Lutitas de Pálmaces» unit marks the beginning of the evolution of that alluvial fan and consists mainly of red mudstones with scattered distributed channels. Channel width ranges from 2 to 100

m. They are simple or multistorey channel-fill with sandstone and conglomerates. Carbonate concretions and rootlet beds are commonly in the red mudstones. They are probably a product of soil-forming processes. Thin lenses of carbonates with abundant crustaceans (**Estheria tenella** Jordan) and macerated plant remains

Figure 18
Vertical profile trough Pálmaces Permian basin.

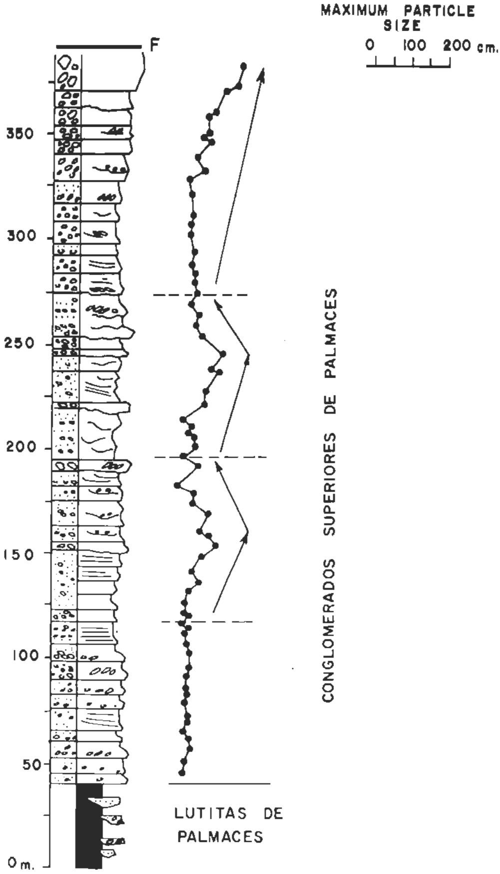


are interpreted as the deposits of short lived ponds covering the floodplain.

The fluvial architecture shows a poorly defined coarsening upwards sequence as due to fan progradation and aggradation *(fig. 18).*

Fluvial Buntsandstein deposits unconformably overlie the Early Permian sequence.

Figure 19
Detailed vertical profile through a complex coarsening-upwards alluvial fan sequence from the upper part of Pálmaces Permian basin.



STOP 2

Lower Permian. Proximal and medial alluvial fan facies

Cross-section 300 m west of Pálmaces de Jadraque, along the «Arroyo del Castillo de Iñesque»

The «Conglomerados superiores de Pálmaces» unit consists of proximal and medial alluvial fan facies.

The coarsening upwards macrosequence (400 m.) begins with sandstones that evolved upwards into conglomerates that include 2 m. boulders. That macrosequence includes three smaller coarsening-and-fining-upward sequences. These sequences are related to fan lobe progradation and gradual abandonment as a result of tectonic activity. Stream-flow and mass-flow deposits are the most characteristic features of these sequences.

To summarize the evolution of the two uppermost Early Permian units («Lutitas de Pálmaces» and «Conglomerados superiores de Pálmaces»), they resulted from the evolution of alluvial fans, related to tectonic uplift that generated the small segmented basin, with at least three stages in faulting activity.

SECOND DAY

Sigüenza-Hoz del Gallo-Rillo de Gallo-Albarracín

STOP 3

Upper Permian-Lower Triassic. Alluvial fan-sandy braidplain architecture

Kms 9-11 Corduente-Torete local road, following the Gallo river. Small «climb» from the «Ermita de Nuestra Señora de la Hoz».

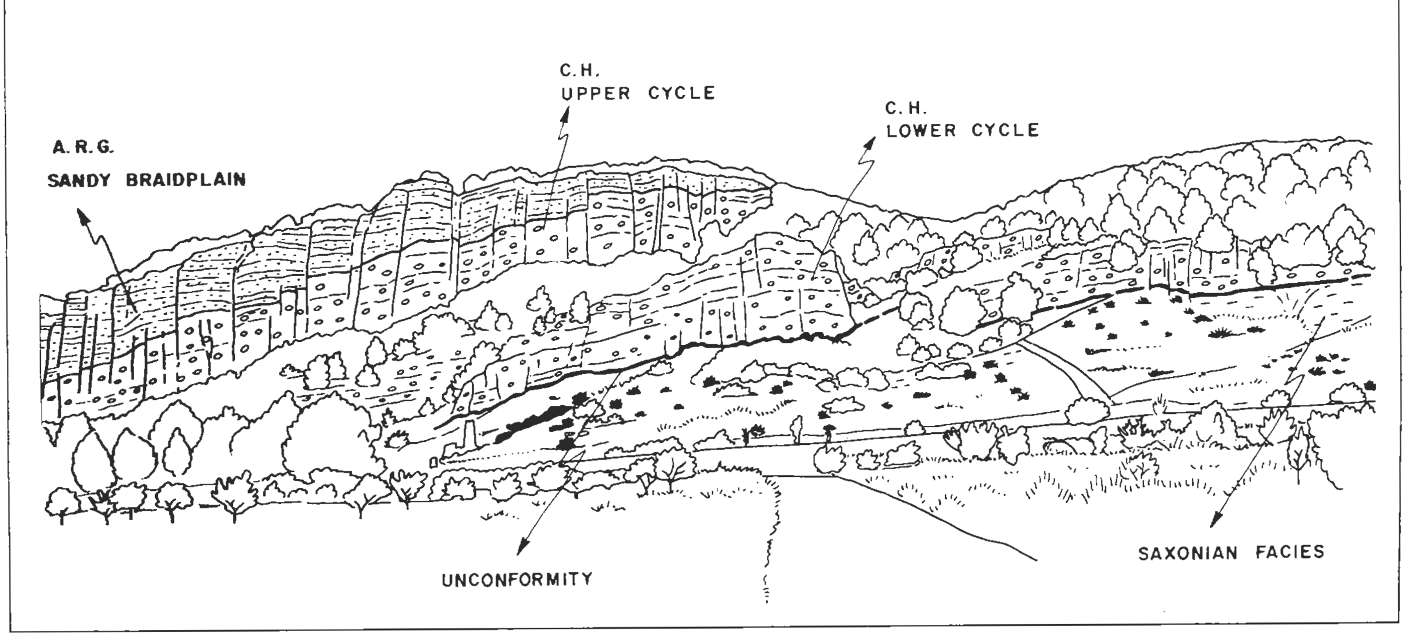
This section shows the alluvial architecture of the two lowermost Buntsandstein units («Conglomerados de la Hoz del Gallo» and «Areniscas de Rillo de Gallo»).

The lower conglomerates rest unconformably on Saxonian (Permian) red beds *(fig. 20)*. Two big cycles may be seen in the complete sedimentary sequence of these lower Buntsandstein conglomerates. They differ in the frequency, distribution and preservation of different physiographic models *(Fig. 13)*. The lower cycle was mainly formed by smaller channels and bars than the upper cycle. Fast migration and filling of channels may have been due to quick, frequent flow-stage fluctuations, together with a slightly higher slope. The clast size is larger, and clasts are less rounded in the lower cycle than in the upper one. Occasionally some major coarsening-upwards sequences are preserved in these conglomerates. The low sinuosity channels and the bar system that formed the lower Buntsandstein cycle may have been part of a north-northeastward-flowing major alluvial fan system. The coarsening-upward sequences were probably the result of fan lobe progradation across the alluvial plain, related to tectonic movements.

The upper cycle overlies the lower one and extends over a larger area *(fig. 12B)*. This upper cycle was mainly formed by longitudinal bars with little complex internal organization.

The lateral growth that can be seen indicates higher stability for the bars, together with higher sinuosity. The upper conglomerate clasts are more rounded and their size is smaller compared with lower-cycle clasts. The most important vertical features are the episodic, large scoured surfaces (also present in the lower cycle) that can be followed laterally across hundreds of meters. They may be related to episodic tectonic activity, reflecting intervals of domi-

Figure 20
Sketch of the relationships between Saxonian, «Conglomerados de la Hoz del Gallo» and «Areniscas de Rillo de Gallo». (Hoz del Gallo, Guadalajara).



nantly lateral movement of the basin floor with respect to the source areas as described by Steel and Gloppen (1980) for the Hornelen Basin (Norway).

The fluvial architecture of the overlying «Areniscas de Rillo de Gallo» exhibits third order contacts (Allen 1983, Miall 1985) defining groups of elements (channels, major transverse bars and minor channels with smaller bed forms) of complex and usually well-defined erosion surfaces (they will be studied in detail on day 3 of field-trip). These surfaces are subhorizontal and are traceable throughout most of the exposure. These surfaces are interpreted as broad and shallow mobile channel-fill, complexes with high width/depth ratio. Internally, minor subhorizontal erosion surfaces were probably generated by almost unconfined sheet-like channels.

Occasionally, fine grained sediments with sheet-like geometry can be seen. They display a well preserved root horizon here. These sediments are interpreted as overbank fines resulting from vertical aggradation.

STOP 4

Lower Triassic?. Relatively high sinuosity fluvial system

2.5 m north of Rillo de Gallo village (km 191, N-211), following the track from Rillo de Gallo to Prados.

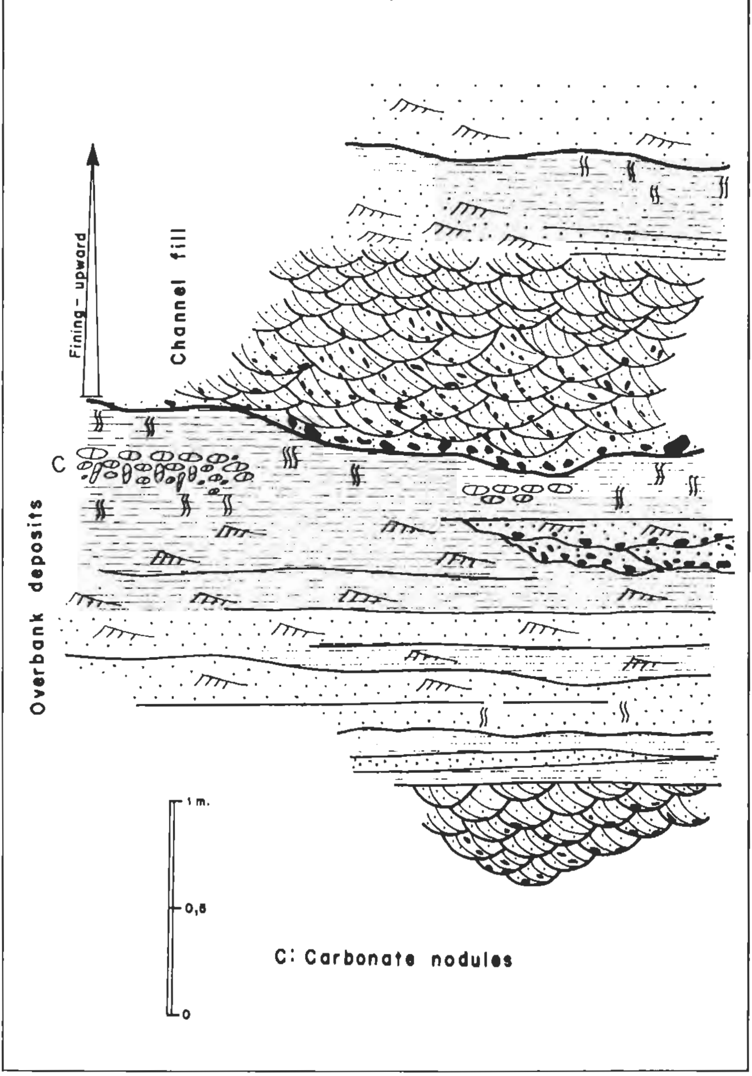
The «Nivel de Prados» unit consists of thin-bedded, micaceous sandstone and mudstones *(fig. 21).* Fining upward sequences alternate with thick mudstone units. Fining upward sequences consist of a basal mud clast conglomerate overlying an erosion surface. Large-scale cross strata (20-50 cm thickness) are abundant in the lower part, whereas small-scale cross-strata are characteristic of the upper part. Mud clasts are common along the foresets. The sandstones pass upwards into red mudstones interbedded with thin fine grained sandstones. Burrows are common especially in the fine grained sandstones and mudstones. Extraordinarily well preserved crescent-casts, formed around an obstacle, are exposed on some sandstone beds. Irregular carbonate concretions related to pedogenic horizons are scattered throughout the mudstone beds.

Measurements of trough cross-stratal azimuth and crescent-casts suggest a high divergence in paleocurrent trend.

The characteristics of the above described sequences point to a low energy fluvial system with a relatively high ratio of channel to overbank deposits ratio. This ratio together with the high divergence in paleocurrent trend may suggest moderately high sinuosity channels. Nevertheless, no clear lateral accretion structures or point bar deposits has been observed here.

When studying this unit («Nivel de Prados») together with the two underlying units («Conglomerados de la Hoz del Gallo» and «Areniscas de Rillo de Gallo», that were studied in stop 3) a general fining upward macrosequence emerges. The evolution marks a transition from a low sinuosity gravelly system («Conglomerados de la Hoz del Gallo») into a sandy braidplain («Areniscas de Rillo de Gallo») and finally, a relatively higher sinuosity system with overbank deposits. The evolution must have been controlled by the tectonic evolution of the area related to a basin-margin setting of back faulting, connected to a graben or half graben similar to those described by Heward (1978). The «Nivel de Prados» unit probably represents a stage when the tectonic activity decreased generating lower relief and slope.

Figure 21
Main facies associations of «Nivel de Prados» unit. (Rillo de Gallo, Guadalajara).



STOP 5

Middle Triassic. Fluvial-litoral transitional facies.

600 m south of stop 4, following the same track.

This outcrop illustrates the transitional facies between fluvial and litoral deposits area that marks the beginning of the Tethys transgression over this area.

The «Limos y Areniscas de Rillo» unit begins with poorly defined fining upward sequences with flat or irregular erosive bases. These sequences consist of massive or crudely bedded gravels with horizontal bedding passing upwards into trough or planar crossbedded gravelly sandstones. Horizontally laminated sandstones may cap the sequence. These sediments were laid down by broad shallow, low sinuosity streams, with mixed gravel-sand bed load.

Upwards in this unit, laminated sand sheets are the dominant elements. Tabular sandbody geometries are characteristic here. The main lithofacies assemblage consists of flat-bedded sandstone followed by ripple-cross bedding and/or occasionally trough-crossbedded sandstones. These deposits were laid down on a distal braidplain, with ephemeral run off forming poorly defined channels. Flashy discharge alternated with long periods when no major currents reached the area, so floodplain facies alternate with sandstone sheet geometries. These facies include thoroughly bioturbated muds, with calcretes and desiccation cracks.

High in the «Limos y Areniscas de Rillo» unit a variety of muddy and sandy facies can be studied. The sedimentary architecture has been analysed in detail in figure 22 (Muñoz-Recio 1987, Muñoz-Recio et al. 1989). Low in this outcrop, lateral accretion elements are composed of fine sandstones and mudstones. Ripple-cross-bedding is the main structure. Trough-cross-bedding may also be present. Fining upward sequences are occasionally observed. The lateral accretion element ends in an abandoned channel, filled with thin sand and mud beds as a result of

Figure 22
Sedimentary architecture of «Limos y areniscas de Rillo» unit showing detailed sketchs of some of the main elements. (Rillo de Gallo, Guadalajara).

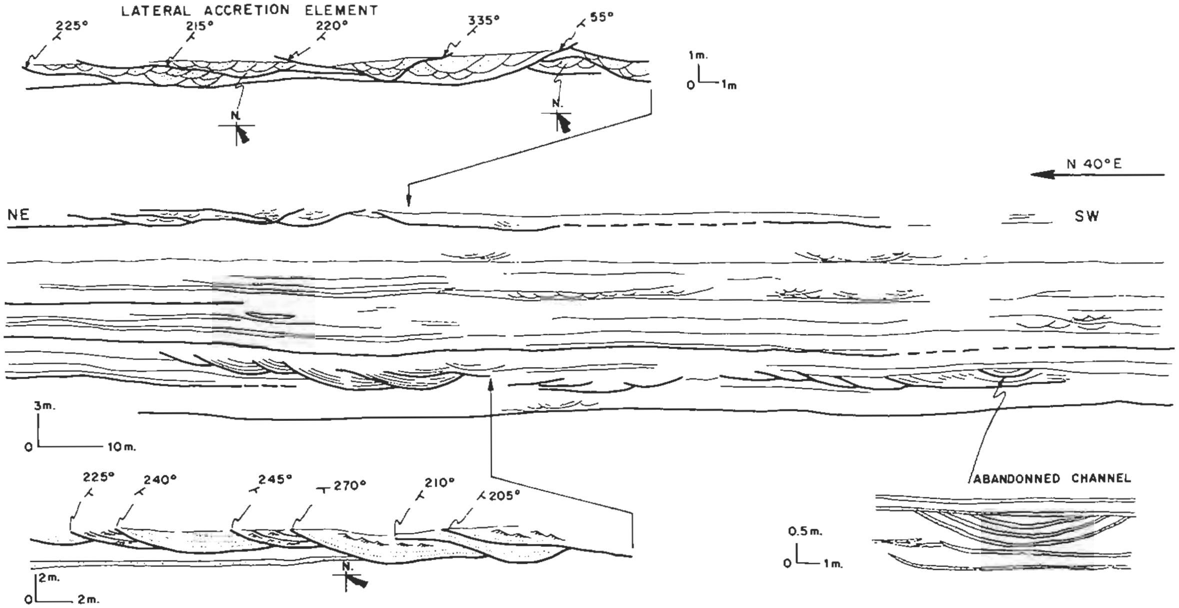
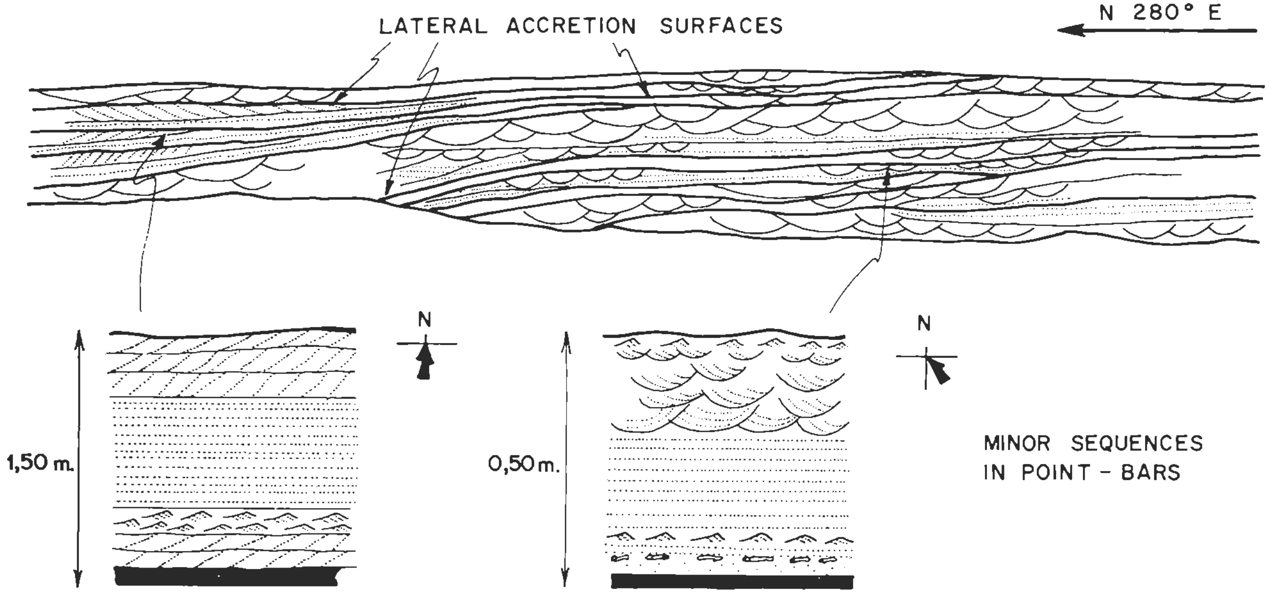


Figure 23
Detailed sketch of point-bar of «Limos y areniscas de Rillo» unit. (Rillo de Gallo, Guadalajara).



alternation between high energy events and vertical accretion, during stand-still periods. Two other lateral accretion sandstone bodies can be studied, more to the west in this outcrop *(fig. 22)*. Both of them consist of gentle dipping surfaces separating units with trough, ripple or flat-bedding sandstone units. They are interpreted as the result of changes in the energy of discharge events in a fluvial system with relatively small high sinuosity channels.

High in the outcrop, a major sandstone body has been analysed in detail *(fig. 23)*. This body can be followed over an extensive area. Its geometry and detailed internal structure indicate that a larger high sinuosity channel system was located in this area.

Fine overbank deposits, with a sheet-like geometry, alternate with the above described channels. Ripple-cross-bedding, bioturbation, desiccation cracks and vertebrate footprints are common in these fine grained facies. Salt pseudomorphs, nodular gypsum after anhydrite, flaser and lenticular-bedding and thin dolomitic beds with algal laminae are not uncommon in these deposits. These features are interpreted as a result of the first marine influences preceeding the Tethys transgression from the east.

THIRD DAY

Albarracín-Hombrados-Chequilla-Albarracín

STOP 6

Upper Permian. Gravelly alluvial fan facies. (Lower cycle)

2 km north of Hombrados (km 214, N-211), following the track from Hombrados to Campillo de Dueñas, near of the «Ermita de San Segundo».

Five fluvial facies are the main component of the lower cycle conglomerate. Sheets of massive conglomerates and massive channel-fill conglomerates are the main group of facies with only small amounts of multi-storey channel-fill conglomerates, units of tabular cross-stratified conglomerates, and flat, low angle or trough cross-bedded sandstones.

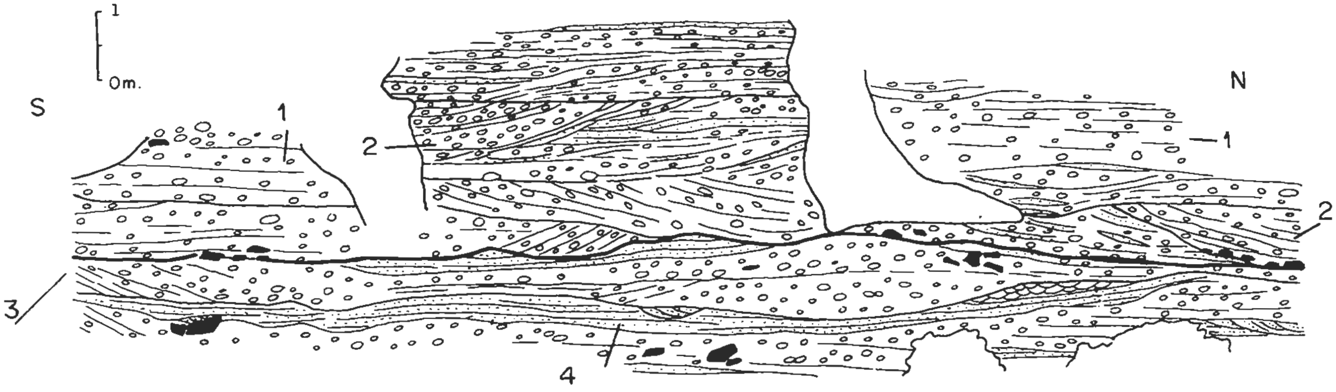
Sheets of massive conglomerates *(fig. 24)* consist of clast supported conglomerates with a very high width/height ratio. Occasionally crude horizontal-bedding is related to alternation of beds of different clast size. Imbricated clasts are not uncommon. These facies represent longitudinal bars accumulated by multiple depositional events.

Massive and multistorey channel-fill conglomerates *(fig. 24)* consist of concave up erosional base bodies with massive accumulations of pebbles and cobbles, or of stratified gravels, sandy gravels or sandstones. Large mudclasts from the rarely preserved fine overbank deposits, may have been incorporated with the channel lag. Sometimes internal concave-up secondary erosion surfaces generate a complex multistorey fill.

Units of tabular cross-stratified conglomerates *(fig. 24)* are erosive fiat base conglomerate bodies with flat or convex tops. They are the result of simple transverse bed-form migration. Outstanding large bedforms, more than four meters thick, with complex internal arrangement, can be studied here.

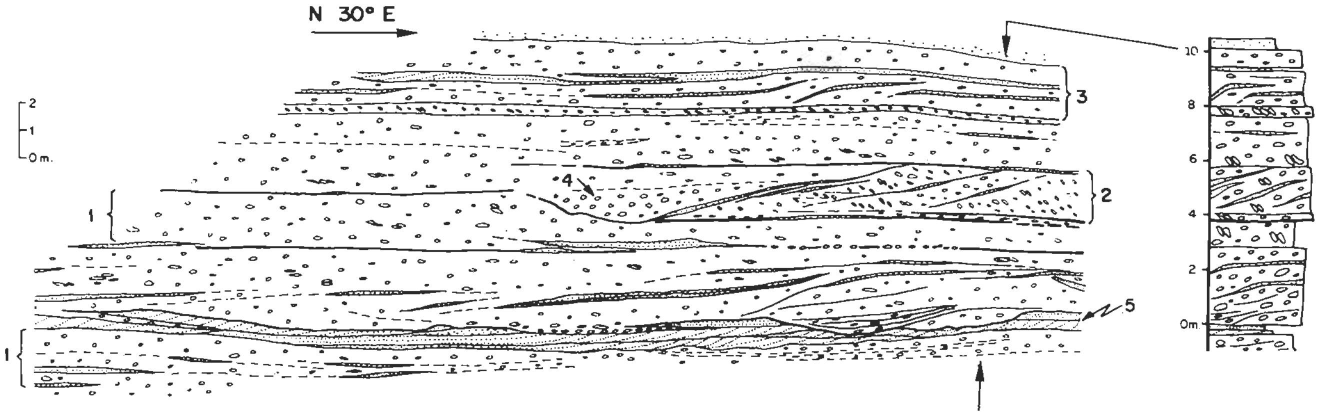
They have erosive bases with large mudstone clasts. Reactivation surfaces with dips ranging from 15° to 30° are not uncommon. The thick individual foresets display a fining upward trend. These large bedforms are interpreted as the result of peak-flood events when the depth of water and the streamflow energy are extreme in some confined channels.

Figure 24
Detailed sketch of «Conglomerados de la Hoz del Gallo» (lower cycle). (Hombrados, Guadalajara). 1: Sheets of massive conglomerates, 2: massive and multistorey channel-fill conglomerates, 3: units of tabular cross-stratified conglomerates, 4: flat, low angle or trough cross-bedded sandstones.



Flat, low angle or trough cross-bedded sandstones *(fig. 24)* form thin tabular or lenticular units that extend laterally from a couple of meters to several tens of meters. They have flat bases or are moulded over the beds underneath. They are probably the result of high flood stage when water spread from the main channels flowing with high velocity as described by Boothroyd & Ashley (1975).

Figure 25
Detailed sketch of «Conglomerados de la Hoz del Gallo» (upper cycle). (Hombrados, Guadalajara). 1: Sheets of massive conglomerates, 2: units of lateral accretion conglomerates, 3: units of lateral and vertical accretion conglomerates, 4: channel-fill conglomerates, 5: flat, low angle or trough cross-bedded sandstones.



STOP 7

Upper Permian-Lower Triassic. Gravelly-alluvial fan facies (Upper cycle)

Short walking (100 m) NW of stop 6.

The upper cycle shows some common facies if compared with the lower cycle, but they differ mainly in the frequency, distribution and preservation of different depositional units (Ramos & Sopeña, 1983). Concerning the textural features, clast roundness is higher in this upper cycle.

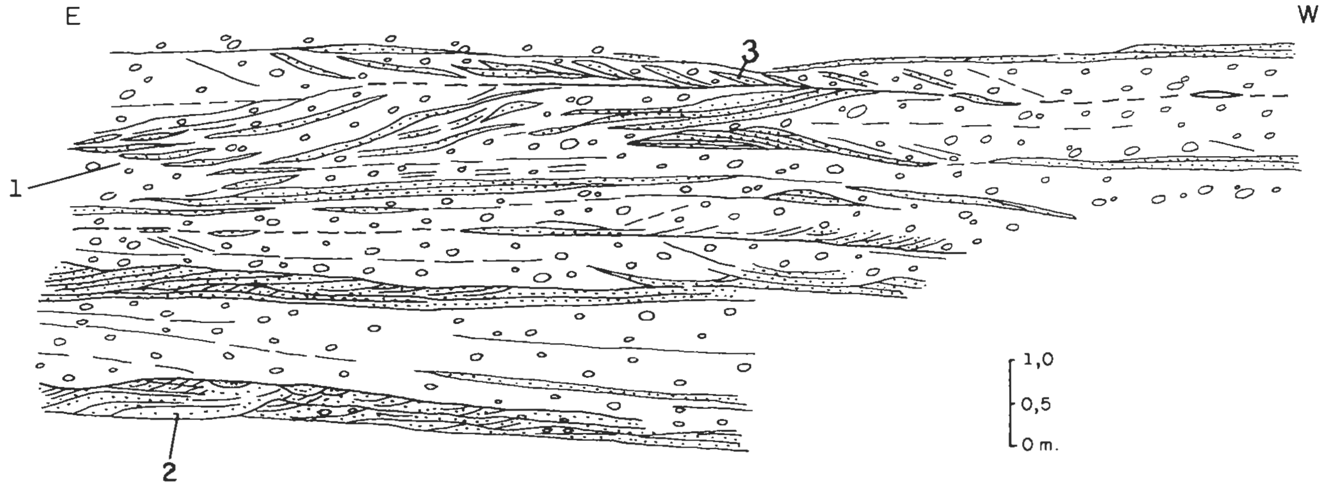
Sheets of massive conglomerates *(fig. 25)*, generated by longitudinal bar accumulation, are the main component of this cycle. Imbricated clasts, that form the main body of these bars, are specially well developed in this outcrop. They show a NE trend, that is quite constant along the different outcrops.

Units of lateral or lateral and vertical accretion conglomerates *(fig. 25)*, are the lateral component of the above described sheets. Internal surfaces dipping between 8° and 15° can be seen inside these units. Thin sandstone drapes along those surfaces, make the lateral accretion units obvious. Occasionally not only lateral but also vertical accretionary surfaces can be distinguished. These surfaces have a sigmoidal shape, moulding the convex up bar form. These units of lateral accretion conglomerates are interpreted (Ramos & Sopeña, 1983) as longitudinal bar modifications, during waning flow when this flow was strong enough only to move clasts laterally along the bar margins, in a similar manner to that described by Costello & Walker (1972) and Smith (1974). Vertical accretion was probably controlled by the water depth.

Channel-fill conglomerates may pass into bars, by transition into lateral accretionary units *(fig. 25)*. Massive clast supported conglomerates with well rounded pebbles, are the main structure in the channel-fill.

Flat, low angle or trough cross-bedded sandstones, (described in stop 6) have also been also studied in detail here *(fig. 25)*.

Figure 26
Detailed sketch of «Conglomerados de la Hoz del Gallo» (upper cycle). (Hombrados, Guadalajara). 1: Sheets of massive conglomerates, 2: units of lateral and vertical accretion conglomerates, 3: channel-fill conglomerates.



STOP 8

Upper Permian-Lower Triassic. Gravelly alluvial fan-sandy braidplain transition.

3.5 km NNW of Hombrados, following the track from Hombrados to Campillo de Dueñas.

The upper cycle conglomerates pass upward here into the «Areniscas de Rillo de Gallo» unit. Transitional facies are scarce with very rare mixed lithologies. Sheets of massive conglomerates with units of lateral accretion conglomerates and channel-fill conglomerates, are the main elements of the upper cycle here *(fig. 26)*. As the channels were filled the lateral bar grew, though there was a decrease in bar height *(fig. 26)*.

Four fluvial sandy facies are the main component of the «Areniscas de Rillo de Gallo» unit in this outcrop; units with tabular cross-bedding; mixed sandy-gravelly bars; complex channel-fill and units of massive mudstones.

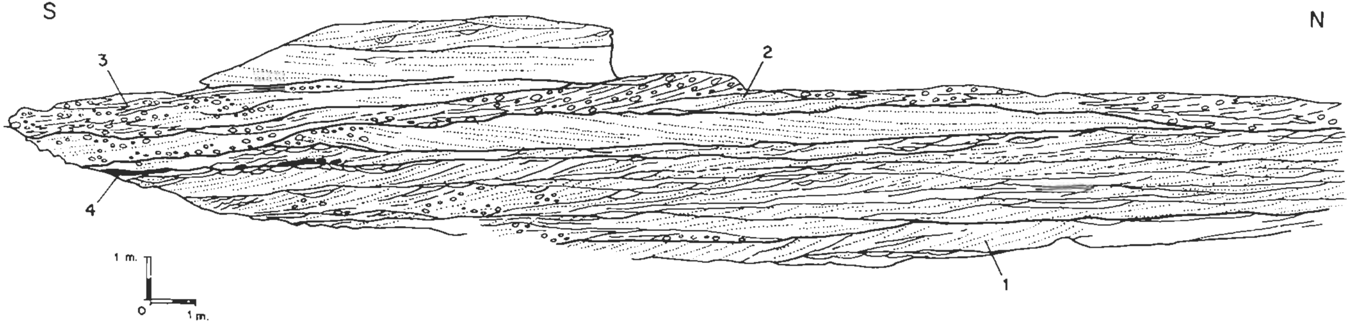
Units with tabular cross-bedding *(fig. 27)* have scoured bases and show multiple reactivation surfaces with smaller bedforms (ripple- or trough-cross-bedding). Each bedform normally thickens downstream. They are interpreted as complex transverse or linguoid bars resulting from important changes in flow stage, that modified the original bedforms.

Mixed sandy-gravelly bars *(fig. 27)* consist of tabular cross-stratified conglomerates with gravel foresets dipping 10 to 20° and interfingering with coarse grained low angle sandstones. They are interpreted as bars with discontinuous avalanching events having well sorted coarse-head and finertail (Bluck 1979, Steel & Thompson 1983).

Complex channel-fills consist here of massive or trough-cross-bedded conglomerates and sandstones *(fig. 27)*.

Units of massive mudstones *(fig. 27)* are very thin here, but large blocks up to 1.5 m are related to the large scoured surfaces. They are the remains of fine overbank deposits with very low preservation rate.

Figure 27
Detailed sketch of «Areniscas de Rillo de Gallo». (Hombrados, Guadalajara). 1: Units with tabular-cross-bedding, 2: mixed sandy-gravelly bars, 3: complex channel-fills, 4: unit of massive mudstone.



STOP 9

Lower Triassic. Sandy braidplain.

300 m SE of stop 8, following the same track, below the medieval castle.

Units with tabular-cross-bedding, units with trough-cross-bedding, units with wavy trough-cross-bedding and ripple or flat-bedded fine grained units are the main fluvial elements that have been studied here.

The units with tabular-cross-bedding are large tabular bedforms with reactivation surfaces *(fig. 28)*. Occasionally some of the foresets continue upward into the horizontal topset. This has been interpreted as vertical accretion taking place simultaneously with the forward progradation of the bedform, generated in the transition between lower and upper-flow regime as described by Sauderson and Lockett (1983).

The units with trough-cross-bedding *(figs. 28, 29)* are the result of megaripple migration. They may have filled channels lateral to the macroforms or they may have modified the tops of macroforms.

The units with wavy trough-cross-bedding *(fig. 29)* consist of large sets of trough-cross-bedding with scoured and wavy bases. Foresets are roughly concordant to the base with concave-up laminae passing laterally into convex-up ones. There are some reactivation surfaces with minor trough cross-bedding on them. These bedforms may have formed as sinuously crested complex bars during flood stabe in a way similar to that described by Allen (1983) as compound and composite-compound bars.

Ripple or flat-bedded fine grained units are occasionally preserved in this environment *(fig. 28)* with bioturbation and soft sediment deformation structures caused by the overlying channel load. They represent low-regime stage or vertical accretion deposits, related to final infilling of abandoned channels.

Figure 28
Detailed sketch of «Areniscas de Rillo de Gallo». (Hombrados, Guadalajara). 1: Units with tabular-cross-bedding, 2: units with trough-cross-bedding, 3: ripple or flat-bedded fine grained units.

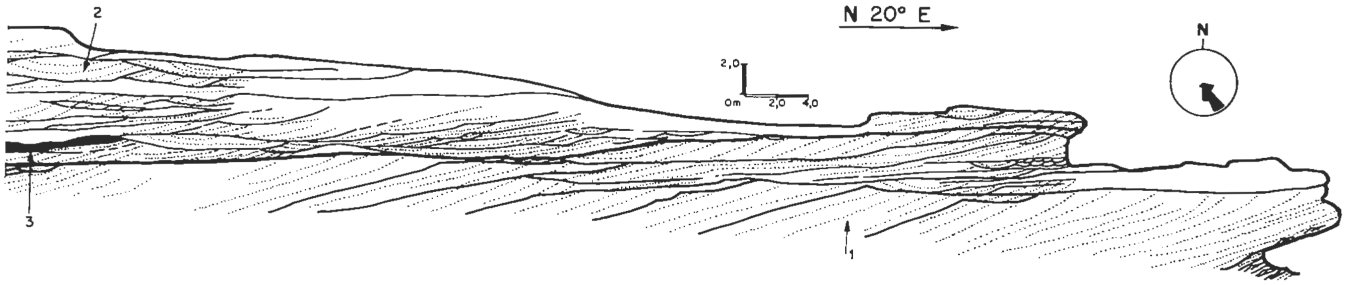
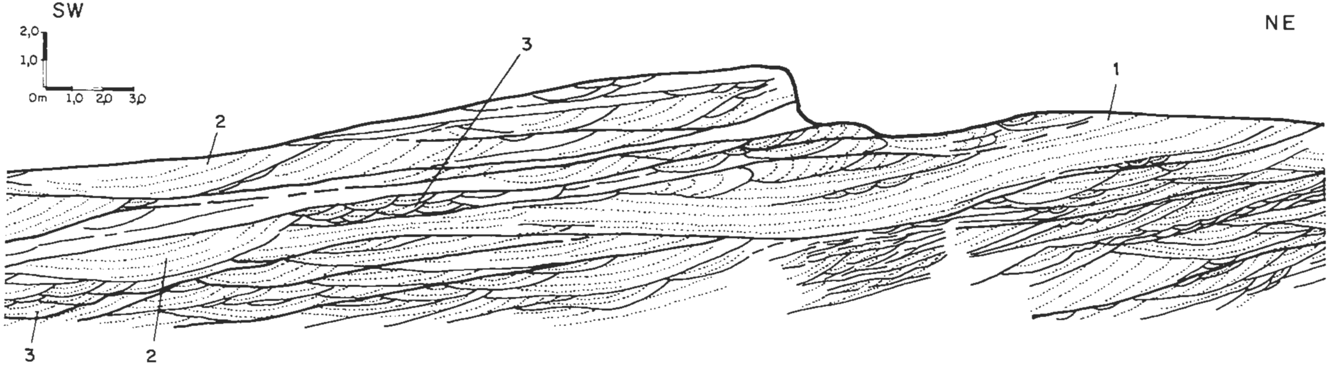


Figure 29
Detailed sketch of «Areniscas de Rillo de Gallo». (Hombrados, Guadalajara). 1: Units with wavy trough-cross-bedding, 2: large trough-cross-bedded bedform, 3: units with trough-cross-bedding units.



STOP 10

Lower Triassic. Sandy braidplain

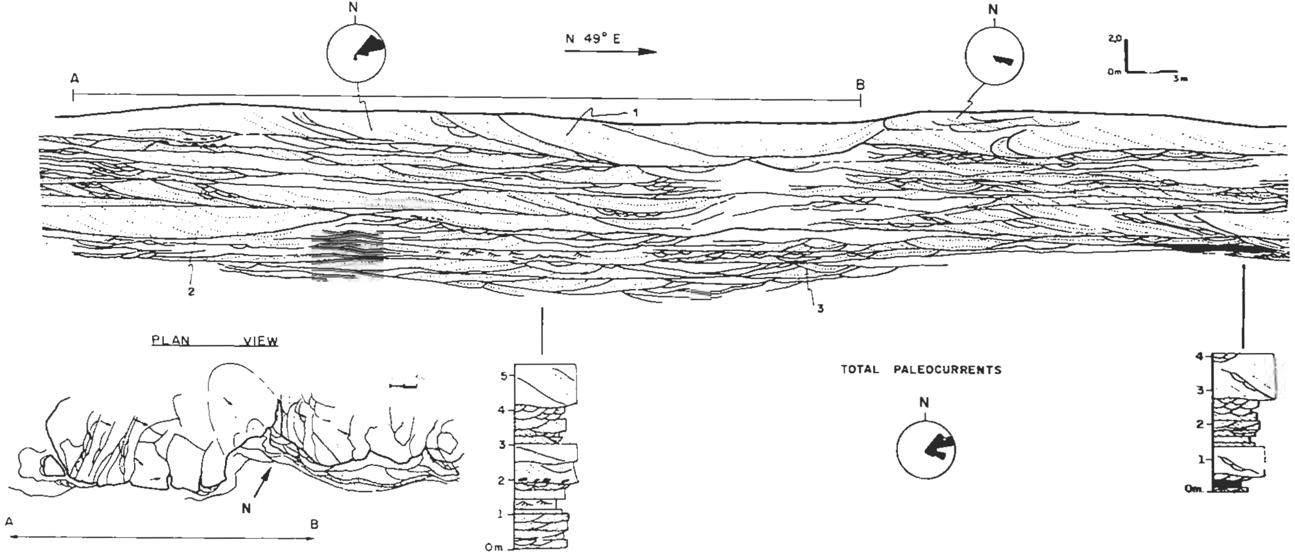
1 km SE of stop 9, following the same track.

Units with tabular-trough cross-bedding, large trough-cross-bedding bedforms and units of small trough-cross-bedded sandstones are the main components of «Areniscas de Rillo de Gallo» exposed here.

Units with tabular-trough cross-bedding *(fig. 30)* have two main subfacies that form a characteristic compound bar. The two subfacies are a) sets of tabular-cross-bedded sandstone up to 2.5 m high and b) sets of trough-cross-bedded sandstones up to several meters wide. Sets of tabular-cross-bedded sandstone have many reactivation surfaces, sometimes with minor forms along these surfaces. The complete bedform may be studied in detail not only laterally but also in plan view *(fig. 30 A-B)*. Tabular-cross-bedded forms can be followed laterally for up to 200 m. These bedforms are related downstream to large troughs *(fig. 30)*. The palaeocurrents in the troughs are oblique to the palaeocurrents in the planar-cross-bedded foresets. These compound bars initially developed as transverse (or linguoid) bars with slipfaces essentially perpendicular to flow. The reactivation surfaces were formed by variation of flood stage or when minor bedforms moved down the main slipface (Collinson 1970; Haszeldine 1983; Crowley 1983). The trough-cross-bedding associated with the tabular-cross-bedded sets might be due to distinctive channels (oblique channels on paleocurrent evidence), but as there was no erosion between them we reject this idea. We suggest that when tabular bedforms grew to a certain size or when a tabular bedform reached another one that acted as an obstacle, the slipface stopped migrating and an oblique trough developed.

Large trough-cross-bedded bedforms have scoured bases and troughs are up to 2 m high and 20 m wide *(fig. 30)*. They are interpreted as large megaripples moving in the channels during flood stage. Units of small trough-cross-bedded sandstones are the result of megaripples moving along secondary channels.

Figure 30
Detailed sketch of «Areniscas de Rillo de Gallo». (Hombrados, Guadalajara). 1: Units with tabular-trough cross-bedding, 2: large trough-cross-bedded bedforms, 3: units of small trough-cross-bedded units.



STOP 10 bis

Lower Triassic? Fluvial sediments related to Chequilla high

Chequilla village, 42 km from Molina de Aragón, following the road to Oribuela del Tremedal.

Chequilla is located on a high between two troughs: the Molina de Aragón-Hombrados trough to the NW and the Albarrac in trough to the SE *(fig. 8)*. Buntsandstein fluvial sedimentation only covered the Chequilla high during some periods («Conglomerados de la Hoz del Gallo» and «Areniscas de Rillo de Gallo»). The rest of the Buntsandstein units and the Permian, wedge out towards this area as can be seen in figure 8.

The «Conglomerados de la Hoz del Gallo» unit is here only between 10 to 40 m thick and their characteristics point to a correlation with the upper cycle conglomerate in the Rillo de Gallo and Hombrados *(fig. 9)*.

The «Areniscas de Rillo de Gallo» unit consist of fluvial sediments whose characteristics are comparable to the ones studied in Hombrados (stops 9 and 10). Nevertheless, channel fill more often include fine grained deposits with ripple or flat-bedding structures and massive mudstones. They are probably the result of channel abandonment and complete infilling of channels, which have been completely preserved. Thin units of fine overbank deposits are also more common here.

The most outstanding feature here is the unconformable relationship between the «Areniscas de Rillo de Gallo» and the overlying «Limos y areniscas abigarrados de Torete» unit. Several meters of fluvial sediments have been strongly altered, displaying high iron and carbonate content. Thus, the Chequilla high was active at least during the Early Anisian to Early Ladinian and the sedimentation only covered it again when the marine Tethys transgression reached this area.

FOURTH DAY

Albarracín-Montalbán-Albarracín

STOP 11

Permian. Distal and medial alluvial fan facies

Kms 6-8 following the road from Albarracín in to Bezas.

The «Lutitas y areniscas de Tormón» unit (Permian, Saxonian facies type) unconformably overlies the Early Paleozoic on the volcanoclastic Lower Permian.

Distal and medial alluvial fan facies can be studied in detail here. A coarsening upwards megasequence has been distinguished from the general section. This is probably the result of fan lobe progradation during the first basin infilling events. Some minor (5 to 25 m thick) coarsening upward sequences are also apparent.

Distal alluvial fan facies consist of massive or laminated mudstones with isolated small channels *(fig. 31).* The channels have a complex multi-storey fill that consist of flat or trough-cross-bedding sandstones and/or conglomerates. Bioturbation is also common related to these channels. Sand bodies consisting of some channels has been detailed studied *(fig. 31).* The individual shape has been partially preserved so they have been probably produced by successive jumps in the channel migration process (Friend et al. 1983). Carbonate nodules with a high iron content are interpreted as soil horizons and may be related to root casts.

Medial alluvial fan facies is made of larger channels *(fig. 32)* with coarser grain sediments. The fluvial architecture consists of closely stacked sandstone bodies with high channel to floodplain deposits ratio. The basal channel scour surface has a lag deposition on it that includes quartzitic pebbles, mud clasts and fragments of eroded soil horizons. Complex channel-fill consists of sandstones with high energy flat-bedded, trough-cross-bedding and ripple-cross-bedding structures

Figure 31
Distal alluvial fan facies, «Lutitas y areniscas de Tormón». (Albarracín, Teruel).
1 to 3: evolution of channel position in time.

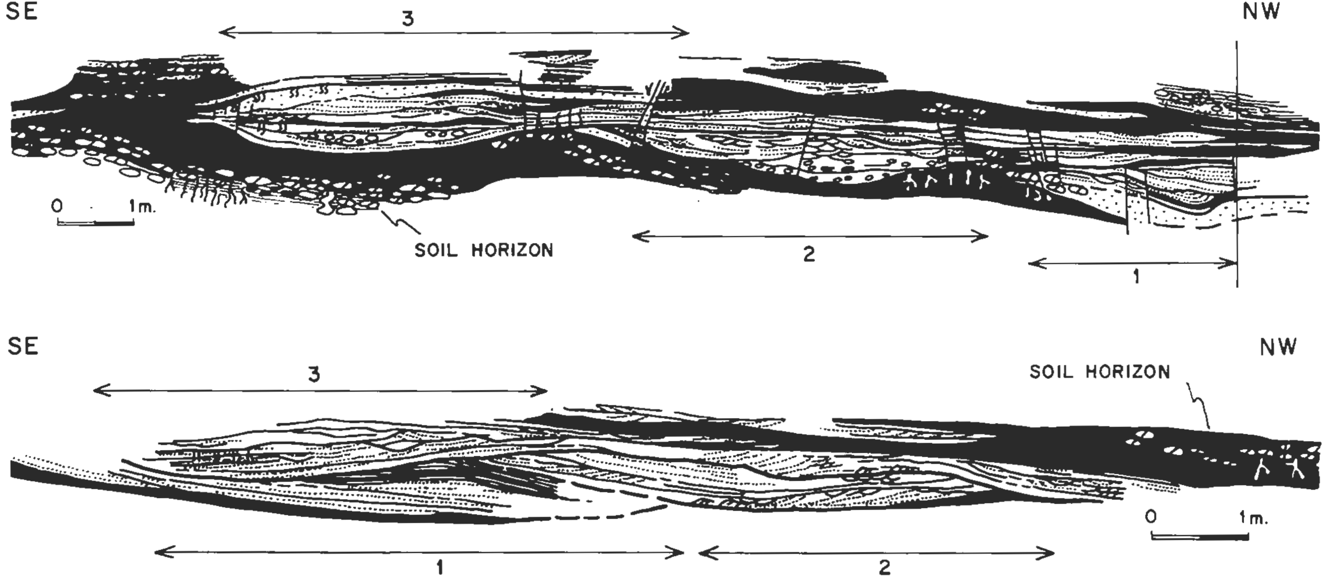
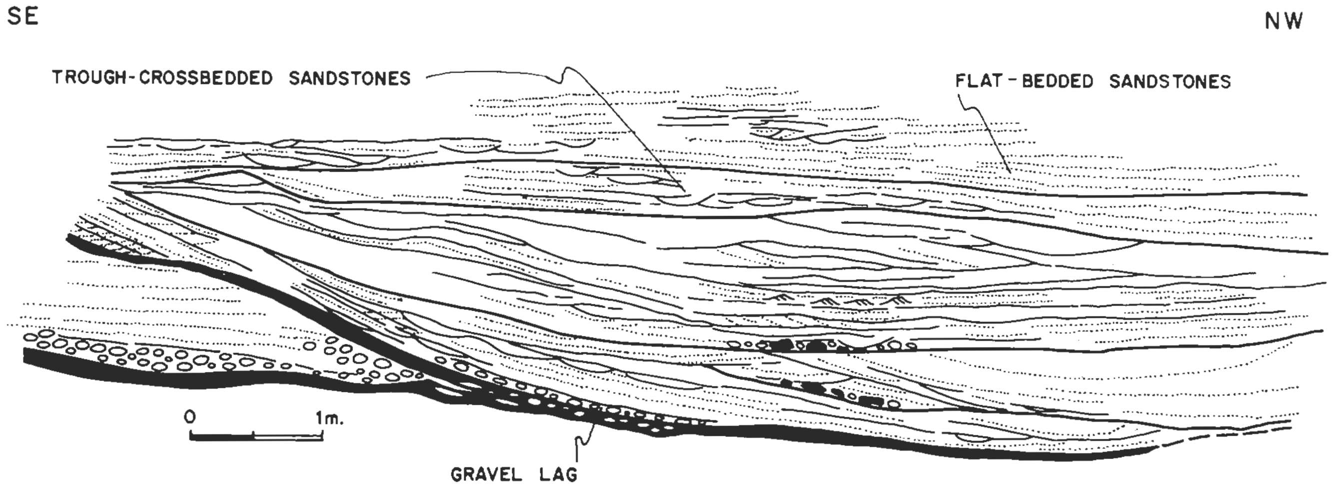


Figure 32
Medial alluvial fan facies, «Lutitas y areniscas de Tormón». (Albarracín, Teruel).



STOP 12

Lower Triassic. Buntsandstein fluvial evolution

Cross-section following the local road from Castel de Cabra (km. 80, N-420) to Torre de las Arcas; 1.200 km before Torre de las Arcas.

This outcrop lies on the SE border of the Aragonese branch of the Iberian Range *(fig. 7)*. The Buntsandstein facies rests here on metamorphic Lower Palaeozoic rocks and displays some peculiarities when comparing it the previously visited locations.

Three lithostratigraphic units have been recognized whose sedimentalogical characteristics will be described below.

The lowermost unit consist of badly organized conglomerates. Some channels can be occasionally distinguished with a complex fill, consisting of massive or trough-cross-bedded conglomerates. The top of this unit has been extensively calcretised in some areas, displaying carbonate nodules and root casts. Here, only some leached zones are observed. This has been interpreted as a major soil horizon that has developed all over the area.

The middle unit displays three different facies associations with thinly interbedded fine grained sandstones being the most common (fig. 33). They show flat-bedding, ripple-bedding (symmetrical, asymmetrical, flat-topped and double-crested) and desiccation cracks. Bioturbation is quite common and vertebrate footprints occasionally appear.

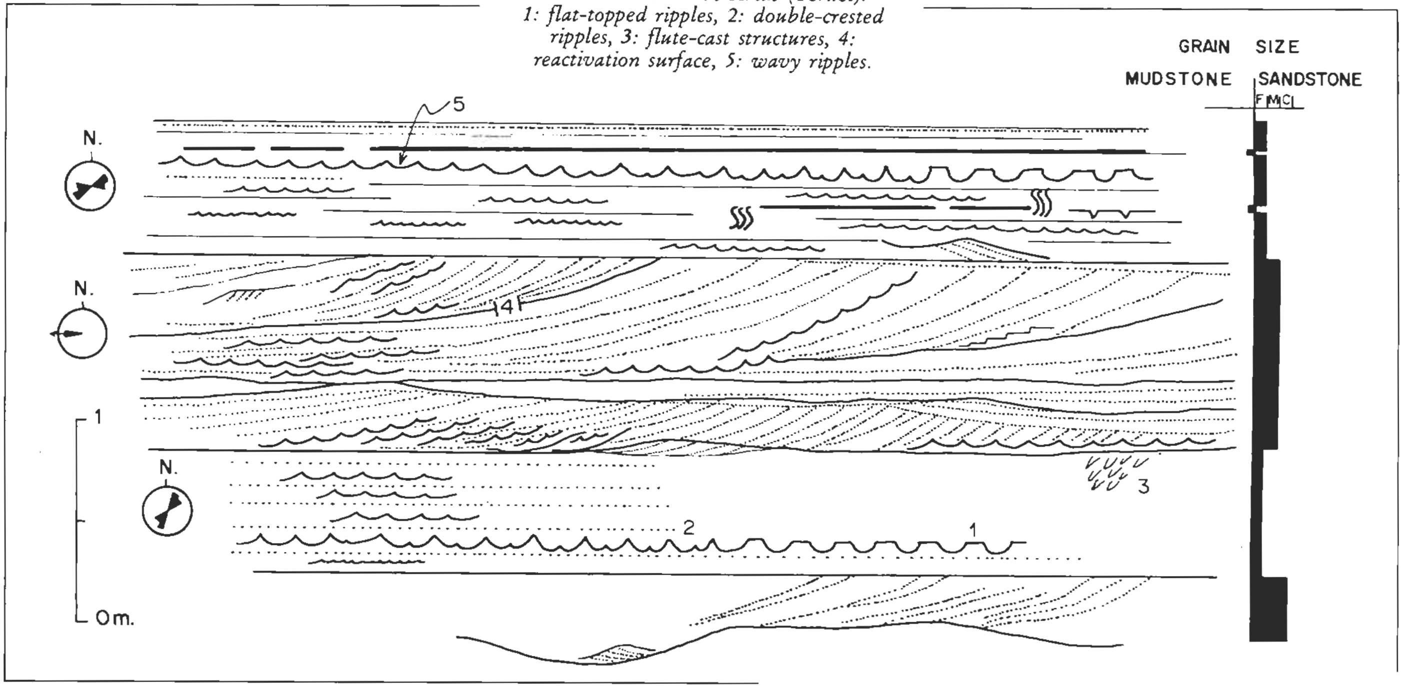
Planar-cross-bedded sandstones with reactivation surfaces and ripples along those surfaces, are also a common facies association in this unit *(fig. 33)*.

The third facies association consists of channelized bodies with channel lag deposit formed by quartzite clasts and mud-clasts and infilled with trough-cross-bedded sandstones.

Occasionally, the facies associations described above are organized in coarsening upwards sequences *(fig. 34)*.

This unit may be tentatively interpreted as an extensive flat lying area (flood-basin-lacustrine?) where only weak currents or

Figure 33
Main facies of middle Buntsandstein unit at Torre de las Arcas (Teruel).
1: flat-topped ripples, 2: double-crested ripples, 3: flute-cast structures, 4: reactivation surface, 5: wavy ripples.

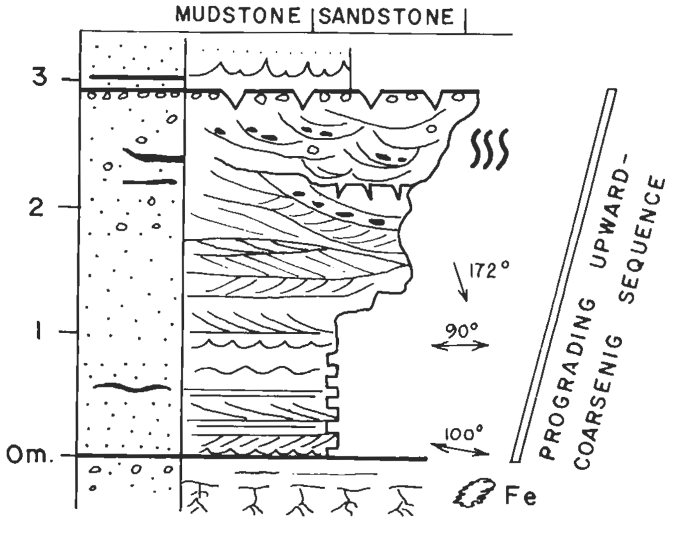


waves generated low regime bedforms. Some areas were occasionally desiccated and living organisms extensively colonized part of the area. Major bedforms (planar-cross-bedding and channel-fill deposits) may be the remains of major input events carrying sediments to this area and generating coarsening upwards sequences as a result of these prograding events.

The upper unit consists of roughly equal amounts of channel and overbank deposits.

Channels have erosive bases with intraformational conglomerates consisting mainly of carbonate mud-clasts, resulting

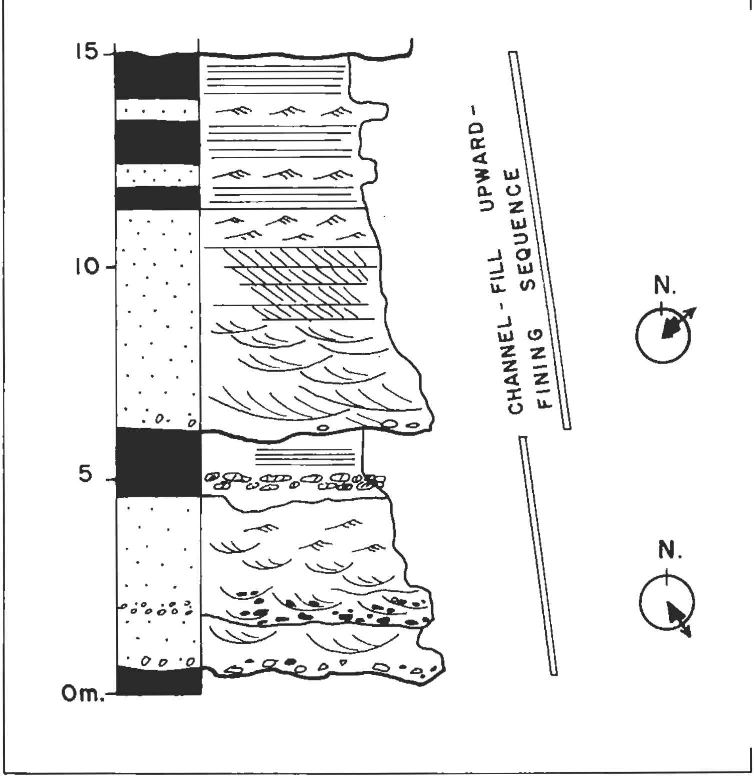
Figure 34
Details of the sequence of progradation over flood-basin deposits, middle Buntsandstein unit, Torre de las Arcas (Teruel).



from the erosion of some soil horizons. Fining upwards sequences *(fig. 35)* with trough-cross-bedded sandstones and ripple-bedding on top are common in channels. Lateral accretion surfaces have been only occasionally observed.

Overbank deposits consist of interbedded mudstones and fine grained sandstones. Flat-bedding, ripple-bedding, bioturbation, desiccation cracks, and carbonate nodules are the most characteristic structures in these sediments.

Figure 35
Channel-fill deposits and related overbank fines in upper Buntsandstein unit, Torre de las Arcas.



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References

ALLEN, J.R.L. (1983)
Studies in fluviatile sedimentation: bars, bar-complexes and sandstone sheets (low sinuosity braided streams) in the Brownstone (L. Devonian), Welsh borders.
SED. GEOLOGY, 33: 237-295.

ALVARO, M. (1987)
La subsidencia tectónica en la Cordillera Ibérica durante el Mesozoico.
GEOGACETA, 3; 34-37.

ALVARO, M. CAPOTE, R. & VEGAS, R. (1979)
Un modelo para la evolución geotectónica de la Cadena Celtibérica.
ACTA GEOL. HISPANICA, 14; 172-177.

ARTHAUD, F. & MATTE, P. (1975)
Les décrochements tardy-hercyniens du Sud-Ouest de l'Europe. Géométrie et essai de réconstruction des conditions de la déformation.
TECTONOPHYSICS, 25; 139-171.

BEAUMONT, C., KEEN, C.R. & BOUTILIER, R. (1982)
On evolution of rifted continental margins. Comparison of models and observations for the Nova Scotia margin
GEOPHYS, J.R. ASTRON, SOC., 70; 667-715.

BLUCK, B.J. (1979).
Structure of coarse grained braided stream alluvium.
TRANS. R. SOC. EDIMB., 70; 181-221.

BOOTHROYD, J.C. & ASHLEY, G.M. (1975)
Process, bar morphology and sedimentary structures on braided outwash fans, North-eastern Gulf of Alaska.
In: Glaciofluvial and Glaciolacustrine Sedimentation (Edited by A.V. Jopling & B.C. Macdonald).
Spec. Publs. Soc. Econ. Paleont. Miner, Tulsa, 23; 193-222.

CANT, D.J. & WALKER, R.G. (1978)
Fluvial processes and facies sequences in the sandy braided South Saskatchewan River, Canada.
Sedimentology, 25; 625-648.

COLLINSON, J.D. (1970)
Bedforms of the Tana River, Norway.
Georg. Annaler, 52; 31-55.

COSTELLO, W.R. & WALKER, R.G. (1972)
Pleistocene sedimentology: Credit River, Southern Ontario: a new component of the braided river model
J. Sed. Petrol., 42; 389-400.

CROWLEY, K.D. (1983)
Large-scale bed configurations (macroforms), Platte River Basin, Colorado and Nebraska: primary structures and formative processes.
Geol. Soc. America Bull., 94; 117-133.

FRIEND, P.F., MARZO, M., NIJMAN, W. & PUIGDEFABREGAS, C. (1983)
Fluvial sedimentology in the Tertiary South Pyrenean and Ebro Basins, Spain.
In: «Field guides to modern and ancient fluvial systems in Britain and Spain» (T. Elliot, Ed.), Proc. II Int. Conference on Fluvial Sediments, Keele, 441-450

HASZELDINE, R.S. (1983)
Descending tabular cross-bed sets and bounding surfaces from a fluvial channel in the Upper Carboniferous coaldfield of northeast England.
Spec. Publs. Int. ASS. Sedinment., 6; 449-456.

HEWARD, A.P. (1978)
Alluvial fan sequence and megasequence models with examples from Westphalian D-Stephanian B coalfields, northern Spain.
In: Fluvial sedimentology (Edited by A.D. MIALL). CAN. SOC. PETROL. GEOL. MEM., 5; 669-702.

MIALL, A.D. (1977)
A review of the braided river depositional environment.
EARTH SCI. REV., 13; 1-62.

MIALL, A.D. (1978)
Lithofacies types and vertical profile models in braided rivers: a summary.
In: Fluvial sedimentology (Edited by A.D. Miall). CAN. SOC. PETROL. GEOL. MEM., 5; 597-604

MIALL, A.D. (1982)
Analysis of fluvial depositional systems.
AMM. ASSOC. PETROLEUM GEOLOGISTS,
EDUCATION COURSE NOTE SERIES, 20; 1-75.

MIALL, A.D. (1985)
Architectural-element analysis: A new method of facies analysis applied to fluvial deposits.
EARTH. SCI. REV., 22; 261-308.

MUÑOZ, M., ANCOCHEA, E., SAGREDO, J., PEÑA, J.A., HERNAN, F., BRANDLE, J.F. & MARFIL, R. (1985).
Vulcanismo Permo-Carbonífero de la Cordillera Ibérica.
C.R. INT. CARBONIFEROUS CONGRESS, 3; 27-52.

MUÑOZ RECIO, A. (1987)
Analisis sedimentológico de la parte superior del Buntsandstein en Rillo de Gallo (Guadalajara)
Tesis de Licenciatura (unpubl.) Universidad Complutense. Madrid, 177 pp.

MUÑOZ-RECIO et al. (1989)
Architectural elements in fluvial «Limos y Areniscas de Rillo» Fm. (Triassic. Central Spain).
4TH INTERNATIONAL CONFERENCE ON FLUVIAL SEDIMENTOLOGY. BARCELONA-SITGES.

PEREZ-ARLUCEA & SOPEÑA (1985)
Estratigrafía del Pérmico y Triásico en el sector central de la rama castellana de la Cordillera Ibérica (Provincias de Guadalaja y Teruel).
ESTUD. GEOL., 41; 207-222.

RAMOS, A. (1979).
Estratigrafía y paleogeografía del Pérmico y Triásico al oeste de Molina de Aragón.
SEMINARIOS DE ESTRATIGRAFIA, SERIE MONOGRAFIAS, 6; 313 pp.

RAMOS, A. & DOUBINGER, J. (1979).
Découverte d'une micriflore thuringienne dans le Buntsandstein de la Cordillère Ibérique (Spagne).
C.R. ACAD. SCI. PARIS, 289; 525-528.

RAMOS & SOPEÑA (1983).
Gravel bars in low sinuosity streams (Permian and Triassic, central Spain).
SPEC. PUBLS. INT. ASS. SEDIMENT., 6; 301-313.

RAMOS, A., SOPEÑA, A. & PEREZ-ARLUCEA, M. (1986)
Evolution of Buntsandstein fluvial sedimentation in the Northwest Iberian Ranges (Central Spain).
JOURNAL OF SEDIMENTARY PETROLOGY, 56; 862-875.

ROYDEN, L. & KEEN, C.E. (1981)
Rifting processes and termal evolution of the continental margin of Eastern Canada determined from subsidence curves.
EARTH PLANET. SCI. LETT., 51; 343-361.

RUST, B.R. (1984).
Proximal braidplain deposits in the Middle Devonian Malbaie Formation of Eastern Gaspé, Quebec, Canada.
SEDIMENTOLOGY, 31, 675-695.

SAUNDERSON, H.C. & LOCKETT, F.P.J. (1983)
Flume experiments on bedforms and structures at the dune-plane bed transition.
SPEC. PUBLS. INT. ASS. SEDIMENT., 6: 49-58.

SMITH, N.D. (1974)
Sedimentology and bar formation in the upper Kicking Horse River, a braided outwash stream.
J. GEOL., 81; 205-223.

SOPEÑA, A., LOPEZ, J., ARCHE, A., PEREZ-ARLUCEA, M., RAMOS, A., VIRGILI, C., HERNANDO, S. (1988)
Permian and Tiassic rift basins of the Iberian Peninsula. In: Triassic-Jurassic Rifting. Continental Breakup and the Origin of the Atlantic Ocean and Passive Margins.
(Edited by W. MANSPEIZER), Part B. DEVELOPMENTS IN GEOTECTONICS, 22, 757-786.

STEEL, R.J. & GLOPPEN, T.G. (1980).
Late Caledonian (Devonian) basin formation, western Norway: signs of strike-slip tectonics during infilling.
SPEC. PUBL. INT. ASS. SEDIMENT., 4, 79-103.

STEEL, R.J. & THOMPSON, D.B. (1983).
Structures and textures in Triassic braided stream conglomerates («Bunter» Pebble Beds) in the Sherwood Sandstone Group, North Staffordshire, England.
SEDIMENTOLOGY, 30; 341-367.

VEGAS, R. & Banda, E. (1982).
Tectonic framework and Alpine evolution of the Iberian Peninsula
EARTH EVOLUTION SCIENCES, 4, 320-343.

ZIEGLER, P.A. (1988).
Post-Hercynian plate reorganization in the Thetys and Arctic-North Atlantic domains.
In: Triassic-Jurassic rifting, continental breakup and the origin of the Atlantic ocean Passive Margins.
(Edited by W. MANSPEIZER) Part B. DEVELOPMENT IN GEOTECTONICS, 22, 711-755.

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