

**A RECONNAISSANCE OF DELTAIC ENVIRONMENT
IN THE MIDDLE EOCENE
OF THE SOUTH-CENTRAL PYRENEES, SPAIN**

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ABSTRACT

A regressive sequence of Eocene sediments is exposed in an area West of Tremp (South-Central Pyrenees, Spain). The sequence forms part of deposits formed in the Upper Cretaceous-Eocene marginal basin south of the Pyrenees. Insignificant amounts of continental and littoral deposits are preserved on the north coast of this marginal basin. In the studied areas, however, on the eastern margin of the basin, a variety of continental environments is found.

Three formations are distinguished within the Eocene deposits. At the base is the Roda Formation with a regressive marine series of limestone, marl, and sandstone. Partly overlying this formation and partly laterally transitional to it is the Montaña Formation, with continental and littoral deposits. The Santa Liestra Formation, formed after a major regressive phase, is the youngest. The distribution of these formations on the geological map and their main sedimentary facies are presented in figure 1.

The Montañana Formation is regarded as a deltaic association. Two major sedimentary environments are distinguished: (1) a flood-plain environment with fluvial sandstones, conglomerates and finer sediments of the inter-distributary lagoons and swamps, and (2) a transitional environment with channel mouth, bay, tidal flat, and delta-front deposits, containing marine fauna.

Two types of large-scale cross-bedding, with different origins are compared. One is interpreted as river sub-deltaic formations in lagoons, while the other has been formed by lateral deposition in a migrating river channel. Several small sedimentary structures occur, of which "current crescent marks" and "longitudinal furrows-and-ridges" are discussed in some detail.

Excellent exposure of the Montañana Formation provided the opportunity for an almost complete paleogeographic

interpretation. The paleogeographic pattern of the flood-plain is not that of the ideal delta, in which one major stream forms a fan-shaped deposit. Instead there is a concentration of supply from the north and east by several small rivers, caused by the configuration of the upland area.

INTRODUCTION,

Eocene formations west of the "Basin of Tremp" display marine and continental deposits. Because of the interesting foraminifera and algae fauna of the marine units, previous geologic research has been done mainly by paleontologists. Where fossils are abundant, stratigraphic division is complete and detailed, but the continental deposits have never been described in any detail. The continental and littoral deposits have the highly differentiated lateral pattern that is characteristic of deltaic sediments.

The deposits are part of a sequence formed in Upper Cretaceous-Eocene marginal basins, the position of which is shown on the inset-map of Figure 1. The development of this marginal basin on both sides of the Pyrenees began after the first period of Alpine folding during Lower Cretaceous (de Sitter, 1965). During a simultaneous subsidence of the basin and rising of the axial zone of the Pyrenees, the western part of the southern marginal basin was filled with marine flysch deposits. Generally along the northern coast of the southern marginal basin no differentiated coastal sediments are preserved. Owing to the subsidence of the basin and subsequent uplift of the borders, sediments were rapidly buried in deeper parts, while most of the deposits along the coast were removed by erosion in later stages.

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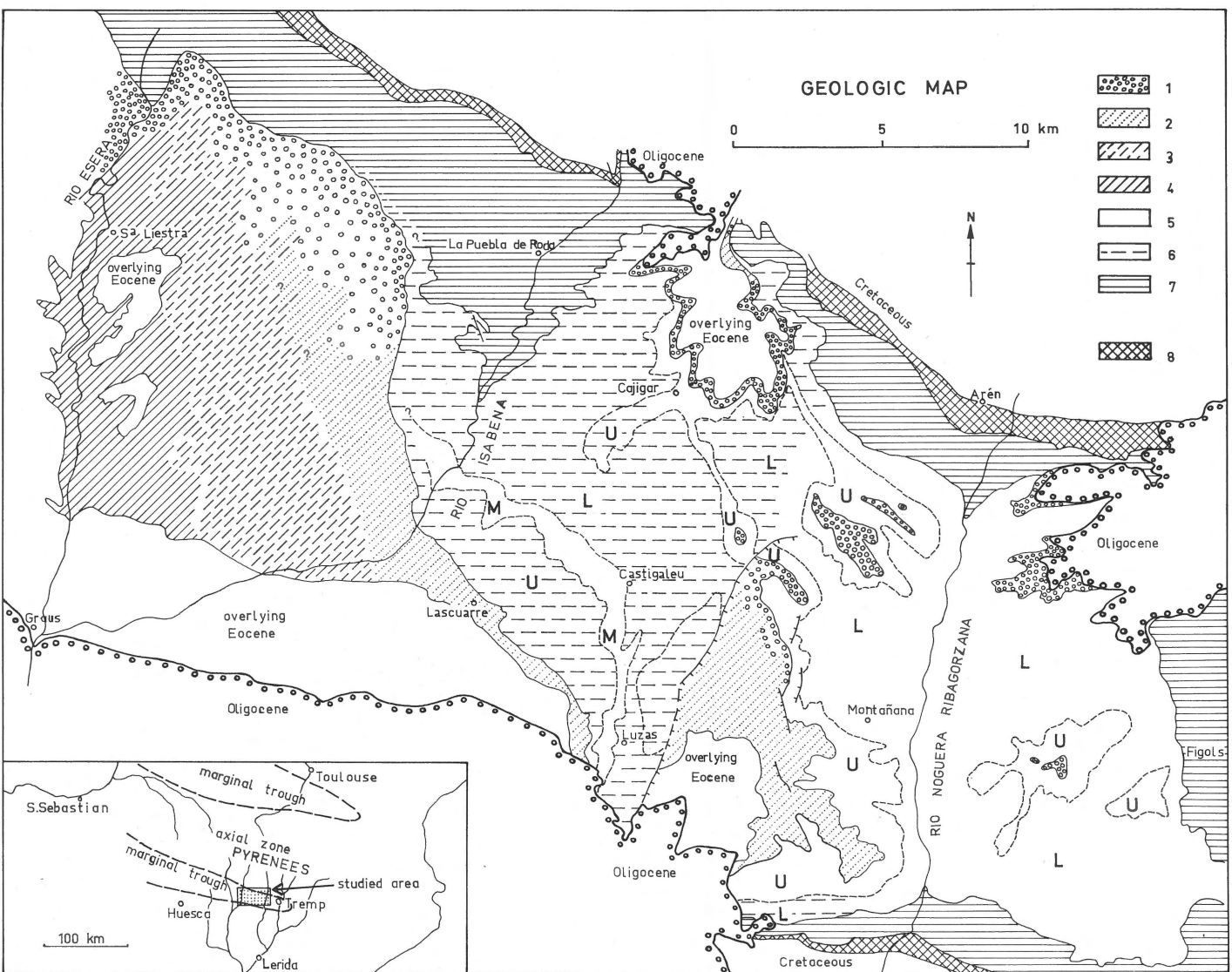


Figure 1

Geologic map.

Santa Liestra Formation, (1) clastic wedge and fluvial environment conglomerates, (2) flood-plain environment, (3) transitional environment, (4) marine environment.

Montañana Formation, (U) Upper, (M) Middle, (L) Lower, (5) flood-plain environment, (6) transitional environment. *Roda Formation*, (7) marine environment. Paleocene, (8) mostly red continental sediments.

STRATIGRAPHY

However, the Eocene sea gradually decreased in depth towards the East and formed a relatively stable and wide-spread shallow area towards the eastern margin of the basin, just west of the small town of Tremp. The general coastline of the early-Eocene sea is indicated by a broken line on the inset-map of Figure 1. In this shallow and relatively stable part of the basin, a variety of littoral and continental environments were developed. The gentle folding and excellent exposures permit the same stratigraphic unit to be followed over an extensive area. This provides an opportunity to study the lateral change in facies from continental to marine. The geologic map of Figure 1 shows the situation of particular sedimentary environments within the stratigraphic units.

This paper is based on the author's M. Sc. thesis, which forms part of a larger regional study of the sedimentary geology carried out by the students and staff of the geology department of Leiden State University. The fieldwork for the present study was executed during the summer months of 1964, 1965, 1966.

Detailed work on the stratigraphy has been done and some age determinations have been made in several locations near the area studied, in the lower Eocene marine deposits, such as those near Figols (Hottinger, 1960). However, in the present study only relative age relations between the units will be mentioned.

Red coloured, continental sediments of Paleocene age occur in the eastern part at the base of the Eocene. The overlying Eocene unit, part of the Roda Formation, is composed of Alveolina-limestone and marls that were deposited after a transgressive phase. The time-stratigraphic boundary between these two formations is easy to recognize.

The Roda and Montañana Formations have a complex relation, which cannot be defined by simple time-stratigraphic boundaries. As shown in the stratigraphic section of Figure 2, young Eocene sediments soon lose their marine characteristics in the eastern part of the studied area, where continental environ-

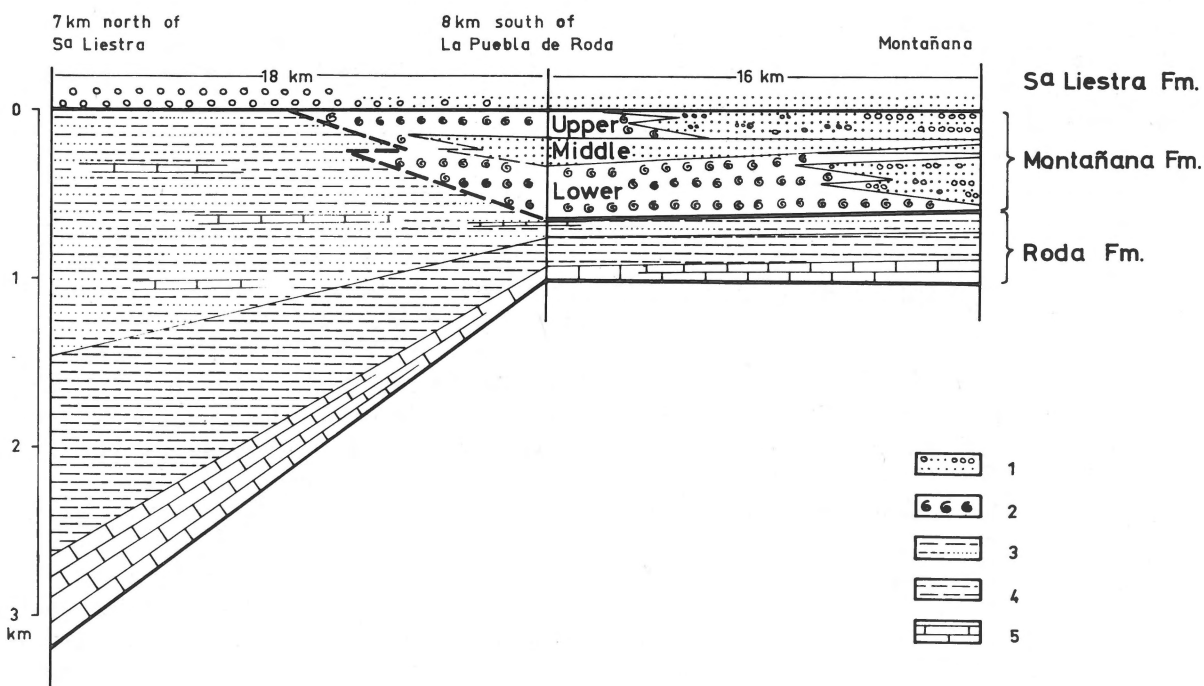


Figure 2

Generalized cross section, showing facies units within the Roda and Montañana Formations.

(1) Continental deposits: sandstone, conglomerate, light coloured mudstone. (2) Littoral deposits: sandstone, dark coloured mudstone, marine shell fauna. (3) Pro-deltaic marine deposits: sandstone, marl, limestone, foraminifera fauna. (4) and (5) marine deposits: respectively, marl and bioclastic limestone.

ments predominated. In the western part, however, marine sedimentation continued. The marine deposits are called the Roda Formation, while the transitional and continental deposits are included in the Montañana Formation. The abundance of foraminifera in the marine sediments and their absence in the transitional and continental sediments has been used to differentiate between the Roda and Montañana Formations. Division of the Montañana Formation into Upper, Middle and Lower is mainly based on a remarkably continuous white sandstone which will be discussed later. This sandstone, called White Sandstone, has been of major importance in correlating the highly variable sedimentary environments.

Overlying the Montañana Formation is the Santa Liestra Formation, which was formed during a regressive phase and is easy to recognize in the northern part of the basin, where it consists of thick red-coloured conglomerates.

RODA FORMATION

General

At the base of the Roda Formation, blue-grey, mostly nodular limestones are found (Alveolina-limestone, — M i s c h, 1934 —). The limestone layers alternate with, and are progressively replaced by marls. The limestone and marl were formed in a

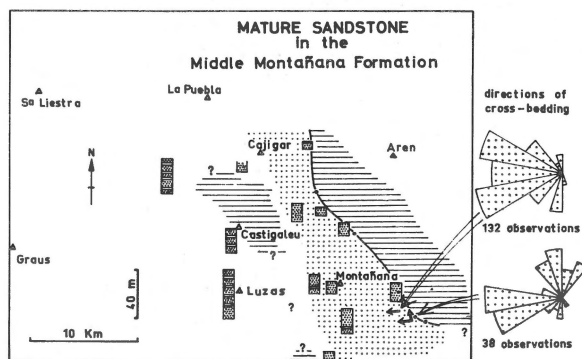


Figure 3
Distribution of the mature sandstone of the Middle Montañana Formation.

The dotted area shows the presence of the Montañana Sandstone; the dashed area indicates its absence. The eastern boundary line is approximately parallel to the ancient coastline. The total thickness and number of the layers of mature sandstone for some locations are given in columns.

shallow sea where the foraminifera and algae fauna can give us a detailed picture of the environment (H o t t i n g e r, 1960; H i l l e b r a n d t, 1962). In the continuous regressive sequence, the sand content increases towards the top. The sandstones consist of coarse shell debris, limestone fragments, quartz and occasionally some mica, embedded in calcilutite. Quartz percentages vary between 10 and 45 percent. The more quartzose sandstones are probably derived from the mature sand deposits that were formed in the high-energy zone along the coast. Layering has a remarkable lateral continuity, which is in contrast to the irregular bedding in the littoral deposits of the Montañana Formation. This sandy marine deposit at the top of the Roda Formation merges towards the east into the transitional and continental deposits of the Montañana Formation, as is illustrated in Figure 2.

Beach-barrier complex

Several kilometers south of La Puebla de Roda, the river Isabena breaks through a relatively hard sandstone complex forming a narrow cleft. This sandstone overlies the marls and forms the base of the sandy top-part of the Roda Formation. The sandstone unit is 20 meters thick. The stratification is very regular, has a constant primary dip of 6° , and can be followed over several tens of meters in the direction of dip. A high-angle cross-stratification can be found in the bottom part of the sandstone unit. Here the primary dip direction is contrary to that of the low-angle stratification. The sandstone is a calcarenite with a somewhat higher quartz content than normal sediments in this area. The sub-horizontal beds have a typical laminated structure with good sorting within the laminae, but a great difference in composition. Quartz percentages can vary from 10 to 40 percent in adjacent laminae.

The extensive sub-horizontal layering and laminated structure are common in fore-beach and similar deposits (T h o m p s o n, 1937; M c K e e, 1957). The high-angle cross-bedding with a contrary dip direction may also indicate an origin as a beach-barrier deposit (W e r n e r, 1963). Lateral transition of the pure sandstone in sandy marls with an abundant marine fauna on both sides, indicates an off-shore barrier.

M a n g l i n (1959) remarks that the Cuisien ends in a detritic period that has a different development

from place to place as a result of tectonic activity. Slight folding caused broad ridges (anticlines) in a direction parallel to the northern coast. The development of the deposits near La Puebla de Roda is parallel to the axial zone. The pure, well-sorted, sandstone of the barrier complex could have been formed on a locally shallow part of the sea, above such a tectonic ridge.

MONTAÑANA FORMATION

General

The transitional and continental deposits of the Montañana Formation are the top-part of a regressive series that started at the base of the Roda Formation. The stratigraphic relation of the Montañana Formation to other formations is shown in Figure 2. Two major sedimentary environments may be distinguished within the Montañana Formation: (1) a floodplain environment with fluvial sandstones, conglomerates and light coloured mudstones, and (2) a transitional environment with littoral sediments, dark coloured mudstones and a shell fauna. Both environments are indicated on the geologic map of Figure 1 and will be described separately.

Flood-plain environments

Lithology — Almost all sediments in the area are clastic, and mainly consist of limestone fragments. The limestone fragments were derived from Cretaceous rocks that must have been exposed towards the north-east. Other rock fragments and quartz grains may make up as much as 30 percent of the rock, but most sediments of the flood-plain environment contain much less. In a few locations sandstones with a higher quartz content are present; they will be discussed separately. Minor occurrences of micritic limestone in thin lenses and very fine layers of gypsum are of local importance. Thin layers of carbonaceous material may be found within the fluvial sandstones.

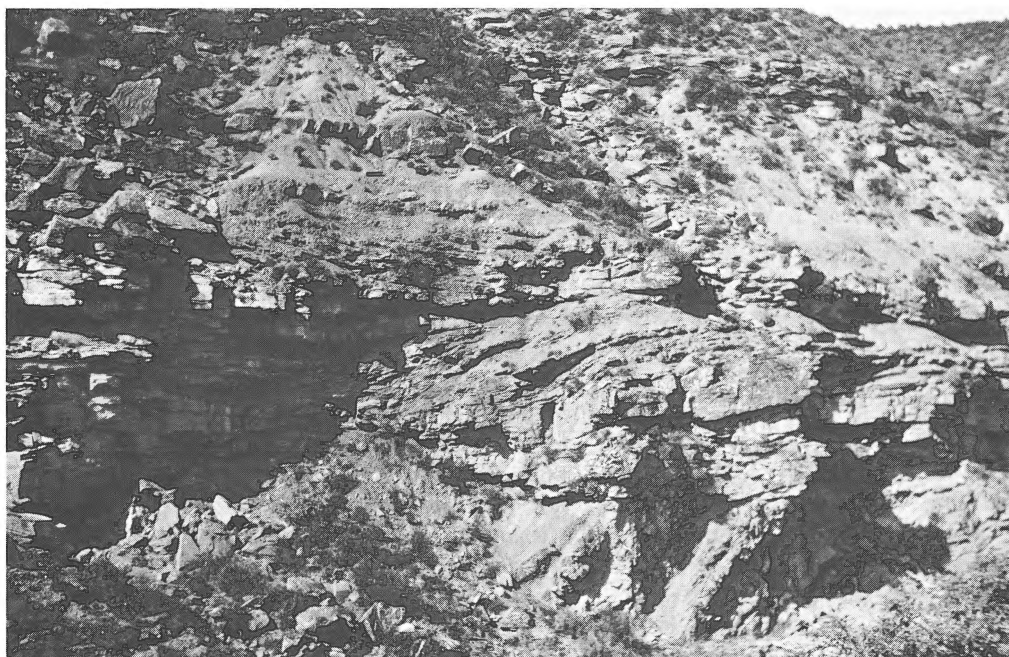
Very fine sandstone and siltstone, which are subsequently referred to as mudstone, have a high clay content, while the coarser sandstones are relatively clean. Original lamination in the mudstone has disappeared by homogenization caused by burrowing animals and probably plant roots. Randomly oriented

worm tracks are preserved in a few places, and irregular vertical structures occur. The concretionary and sometimes red coloured mudstone is indicative of pedogenesis, but no organic remains are found in situ.

Distribution and geometry — Conglomerate, sandstone, and siltstone give a broad picture of decreasing grain-size in a southwesterly direction. No conglomerates occur near the margins of the flood-plain. The sandstone has the typical characteristics of fluvial channel deposits, such as (1) longitudinal bodies of clean, cross-bedded, sandstone several hundred meters wide and 5 to 20 meters thick, (2) an erosional base and numerous conglomerate lenses in the bottom-part, and (3) towards the top of the sandstone a gradual transition to fine sand and mudstone. Fine mudstone alternates with thin layers of somewhat coarser mudstone, at distances of several meters. This indistinct layering sometimes has a pronounced regularity over a distance of a few kilometers, which suggests a deposition in lagoons. The coarser mudstone layers are laterally transitional to the coarse channel-sands; this indicates an origin as natural levees.

Large scale cross-bedding — Thick cross-bedded units are developed in many of the fluvial deposits. Two different types can be distinguished: a) cross-bedding produced by lateral sedimentation in a migrating channel, and b) cross-bedding of a deltaic origin.

a) Photograph 1 shows an example of irregular cross-bedded layers, which are formed by a migrating channel. The sediment often varies from fine sand to conglomerate in different layers of the same channel deposit. Directions as well as the thickness of the foresets are highly variable, some deposits having a rather chaotic appearance. Internal erosive surfaces indicate alternating periods of sedimentation and erosion, due to variable water supply and shifting of the main flow in the channel. Slump structures occur and they probably originated on the steep eroded side of a channel. The lower part of Photograph 1 shows steeply inclined layers, due to slumping. Several cross-bedded units occurring on top of each other were probably formed by the same migrating channel. b) Photographs 2 and 3 show unilateral large-scale cross-bedding. This type of structure is often found in the flood-plain deposits around Montañana. The



Photograph 1

Cross-bedded units, formed by a migrating channel. Just below these units occur steeply inclined layers, due to slumping.

Photograph 2

Unilateral, large-scale cross-bedding (subdelta), in the flood-plain deposits.

Photograph 3

Detail of Photograph 2. The thickness of the cross-bedded unit is approximately 4 metres.

thickness of the sedimentation units is 2 to 5 meters. The foresets have angles of dip less than 20° and are tangential to the underlying horizontal beds. Layers which can be followed in exposure over about 100 meters in the direction of dip, show a homogeneous composition of medium or fine sandstone and have an even thickness. The cross-bedded units have an isolated position within the horizontally bedded mudstones, and consist of one cross-bedded unit only. They do not contain any (marine) fossils and belong to the fluvial deposits.

The homogeneous sediment, the less chaotic appearance, the constant direction of the foresets, the even thickness of the units and their isolated position are remarkably different from the characteristics of the migrating channel deposits, and provide enough evidence to assume a "deltaic" mechanism of deposition.

Russell (1939) and Hill & Webb (1958) have described recent subdeltas, which were constructed by rivers in coastal lagoons. The conditions are probably similar to those under which these deposits have formed.

Erosional structures — A great variety of erosional structures can be seen on the base of sandstone beds. These include channels with a depth of several meters and a width of tens of meters, as well as small-scale dragmark and flute-cast structures. Two types of lesser known structures, "current crescents" and "longitudinal furrows-and-ridges", are discussed in more detail.

"Current crescents" are semicircular depressions, which are commonly excavated on the up-current side of an obstacle by the flow of water, particularly in water of very shallow depth (Potter and Pettijohn, 1963, p. 121). The crescent-shaped depression is preserved on the underside of the sandbed as a cast, forming a so-called "current crescent cast". In these deposits one may find small structures only a few cm. wide, or larger ones up to 50 cm. wide and 6 cm. deep (Photograph 4). The size of the larger structures indicates rather big obstacles, but these are never present. Later transport of such large obstacles would probably have destroyed the cast. If the obstacles are still in place they must have had a similar composition as the underlying mudflat. Plant roots may locally have indurated the soil, and the so-formed mudlumps may have acted as obstacles to the running water. The presence of several crescent

casts on the same exposed bed also suggests rather a local characteristic than an occasional object from outside the environment.

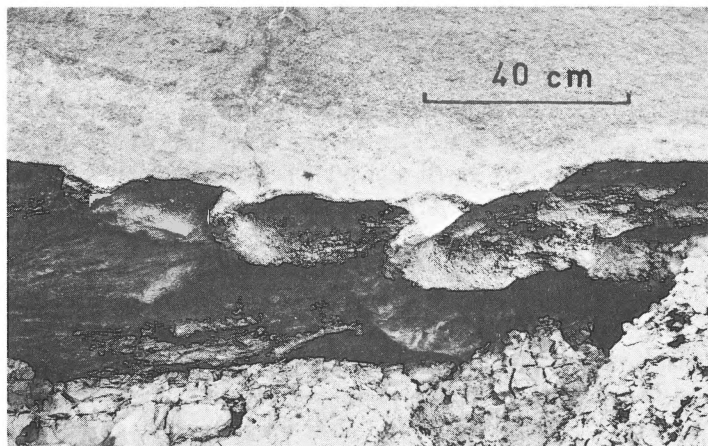
"Longitudinal furrows-and-ridges" is the second type of erosional structure which is preserved on the base of fluvial sandstone beds. Many parallel gullies, with a sharp V-form cross-section, must have been eroded in the mud and preserved as casts on the base of overlying channel sands. Photograph 5 shows the underside of a sandstone bed with a pattern of furrows-and-ridges.

The casts are not more than 6 cm deep and their mutual distance is about 20 cm. Over several square meters of a bedding plane the gullies have a consistent direction, whereas in somewhat larger exposures considerable changes in direction are noticeable. The individual casts can be followed over several meters and at their up-current end they often join in crescent-like casts. As with the "current crescent casts" the kind of obstacles and conditions which have initiated this erosional pattern can only be guessed at. Vegetation may have prevented larger scour phenomena and caused the refined pattern of erosion. Thin layers of running water are probably involved, which could be separated into many current lines to form the regular erosion pattern of parallel gullies. Such conditions are easily realized on a natural levee during overflow of the river. Erosional structures of multi-directional eddies and currents, created by plants and levee-relief are known from the natural levees in recent sediments (More, 1966).

Transitional environment

The sediments of this area are distinguished from those of the flood plain by their dark-coloured mudstone, the absence of conglomerates and the presence of the marine fauna, which consist mainly of pelecypods and gastropods. The light, and sometimes reddish, colours of the flood-plain sediments suggest an exposure to air for longer periods, during which oxidation could take place. The dark-coloured sediments in the transitional area have most likely been covered by water most of the time. Three main types of environment can be distinguished: (1) distributary channels near the delta front, (2) inter-distributary bays, tidal flats, small tidal channels, and (3) the high energy delta front.

Distributary-channel deposits near the delta front — Longitudinal bodies of



Photograph 4

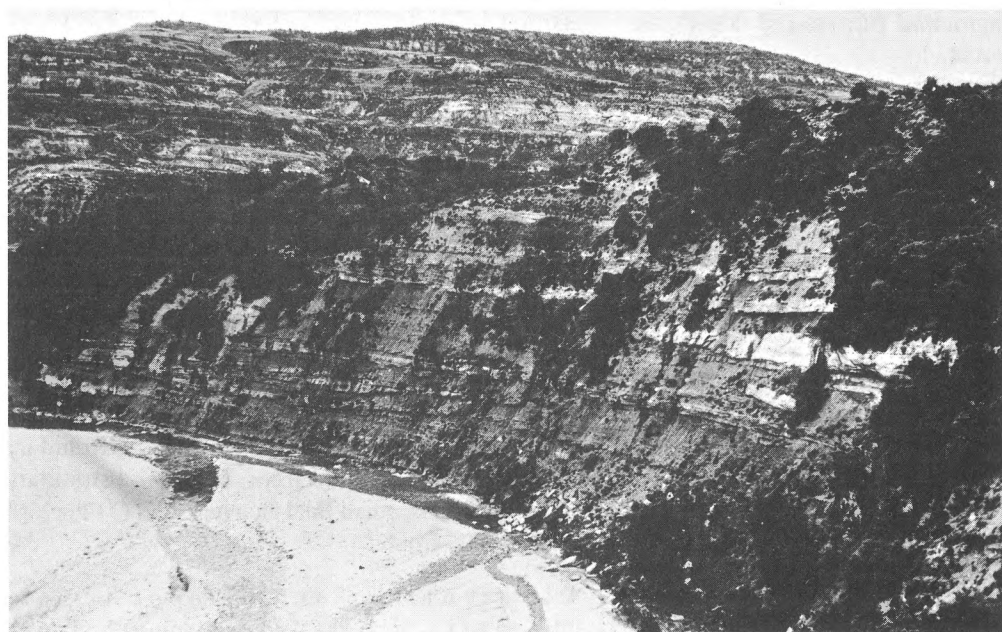
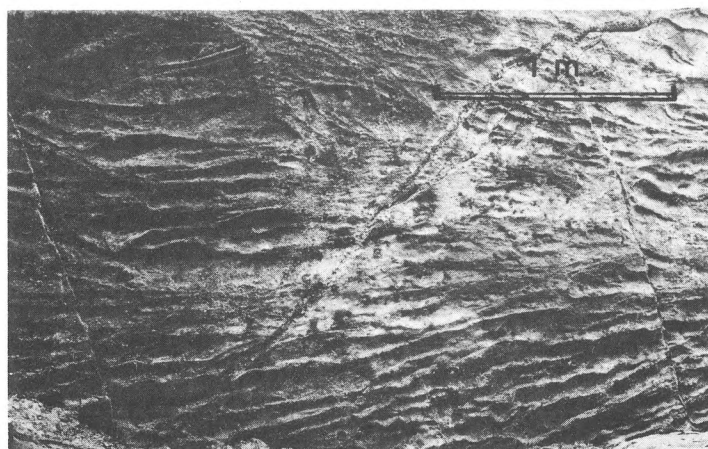
Current crescent casts. The semicircular casts are 40 cm wide.

Photograph 5

Longitudinal "furrows-and-ridges" on the underside of a sandstone bed.

Photograph 6

Distributary channel deposits in the transitional environment of the Montañana Formation, near the delta front.



coarse, rather clean sandstone, alternating with dark-coloured sandy mudstone are exposed along the Rio Isabena. Photograph 6 shows the channel deposits in section. The composition of the sandstone here is similar to that of the sandstone in the fluvial channels, but some layers have a high percentage of shell debris. Coarse shell fragments (often *Ostrea*) are mostly found in the central bottom part of the channels. The sandstone deposits are fairly homogeneous in composition and have fewer internal erosion planes than the fluvial channel deposits of the flood-plain area. The bodies are several meters thick and about 100 meters wide. Most of their cross-bedding is of the trough-type indicating a current direction parallel with the long dimension of the channel deposits, towards the southwest or west.

Large-scale unilateral cross-bedded units with a thickness of several meters occur. The low-angle foresets mostly dip towards the ancient area. These structures are interpreted as tidal deltas.

Bay and tidal-flat deposits — Sediments of these environments are very poorly sorted, most of the deposits give the impression of being thoroughly mixed by burrowing organisms. The sandstones consist of coarse shell detritus, limestone fragments and quartz grains in a calcilutite matrix, sometimes making up more than 50% of the rock. The layering is very irregular. In the vertical sequence this is reflected by a strongly varying bed thickness, and in the horizontal direction by rapid wedging-out layers and many wash-outs and channels. Alternation of coarse- and fine-grained layers is often indistinct. Finely laminated clay and siltstone with very thin carbonaceous intercalations are sporadically found, but in most deposits all laminations and minor structures have disappeared. The organic content of this deposit is higher than that in the flood-plain sediments.

In an area within a radius of 2 or 3 km from Castigaleu the fauna consists almost entirely of *Ostreas*. This abundance of *Ostreas* indicates a brackish-water environment probably derived in a part from the isolated sea bay.

Minor channels have a typical sequence of several types of laminated beds. In the bottom part, the coarse sandstone contains mud-pebbles and large shell fragments, which are derived from the underlying eroded mudstone. This cross-bedded sandstone in the bottom part of the channel is 1 or 2 meters thick. It is often overlain by massive sand layers with parallel

lamination. This type of lamination originated in the higher flow regime, where the supply of sand was abundant. Towards the top of the sequence the sand supply diminished and more quiet conditions returned. This sandy layers and lenses show poorly developed cross-bedding. The transition from the channel sequence into the deposits of the bay facies with their abundant shell fauna is gradual.

Delta-front deposits — A remarkable white sandstone, with a relative high quartz content of up to 60% was probably formed by reworking of the calcareous sediments along the agitated coastal areas. The sandstone is cross-bedded and has a sparse fauna of marine character. The position of these clean sandstones on the seaward margins of the sub-aerial delta environment and their alignment parallel to the coast defines them as delta front sand sheets or beach deposits.

White Sandstone

This sandstone body has a special site within the deposits of the Montañana Formation. It is composed of the same mature sandstones that have been mentioned above in the delta-front environment and it forms an exceptionally extensive sheet-like body in the eastern part of the area studied. It is an important marker-bed between the discontinuous continental and deltaic deposits and it is the stratigraphic boundary between the lower and upper part of the Montañana Formation.

Its elongate shape and its position parallel to the presumed coast is shown in Figure 3. On the eastern boundary it changes to a normal fluvial sediment. The White Sandstone lies almost entirely between the continental flood-plain deposits. Towards the southwest, it splits up into several clean sand layers which are enclosed by sediments of the transitional-coastal environments. Occasionally the sand layers have sparse marine faunae.

The White Sandstone (10 to 15 metres thick) often has an erosional base that shows longitudinal channels in parallel directions similar to the channels in nearby fluvial deposits. Large-scale cross-bedded units that are 0.5 to 1 metre thick have irregular wavy boundaries and steep-dipping (to 30°) foresets that often have remarkably constant direction. They resemble eolian cross-bedding, and the paleocurrent

pattern and the channels at the base give the impression of blown-out river sands. But regular small lenses of conglomerate, aqueous current ripples and small wash-outs point to a predominantly aqueous deposition, and the regional distribution of the bodies, and their relation to the deposits of coastal environment suggest an origin as sandy coastal plains.

It is possible that during the Middle Montañana phase erosion of the sea could dominate over the prograding activity of the delta. In this destructional phase the coastal plains might be covered with mature sands of the delta front. The wide extension of the deposits towards the east over the flood-plain depo-

sits, could be the result of occasional floods or wind action.

SANTA LIESTRA FORMATION

This formation overlies the Montañana and Roda Formations. Its most characteristic facies is a thick red-coloured limestone conglomerate. The conglomerates are exposed over an extensive area north of the place Santa Liestra and can locally be found on topographic highs towards the east; their distribution is shown on the geologic map of Figure 1.

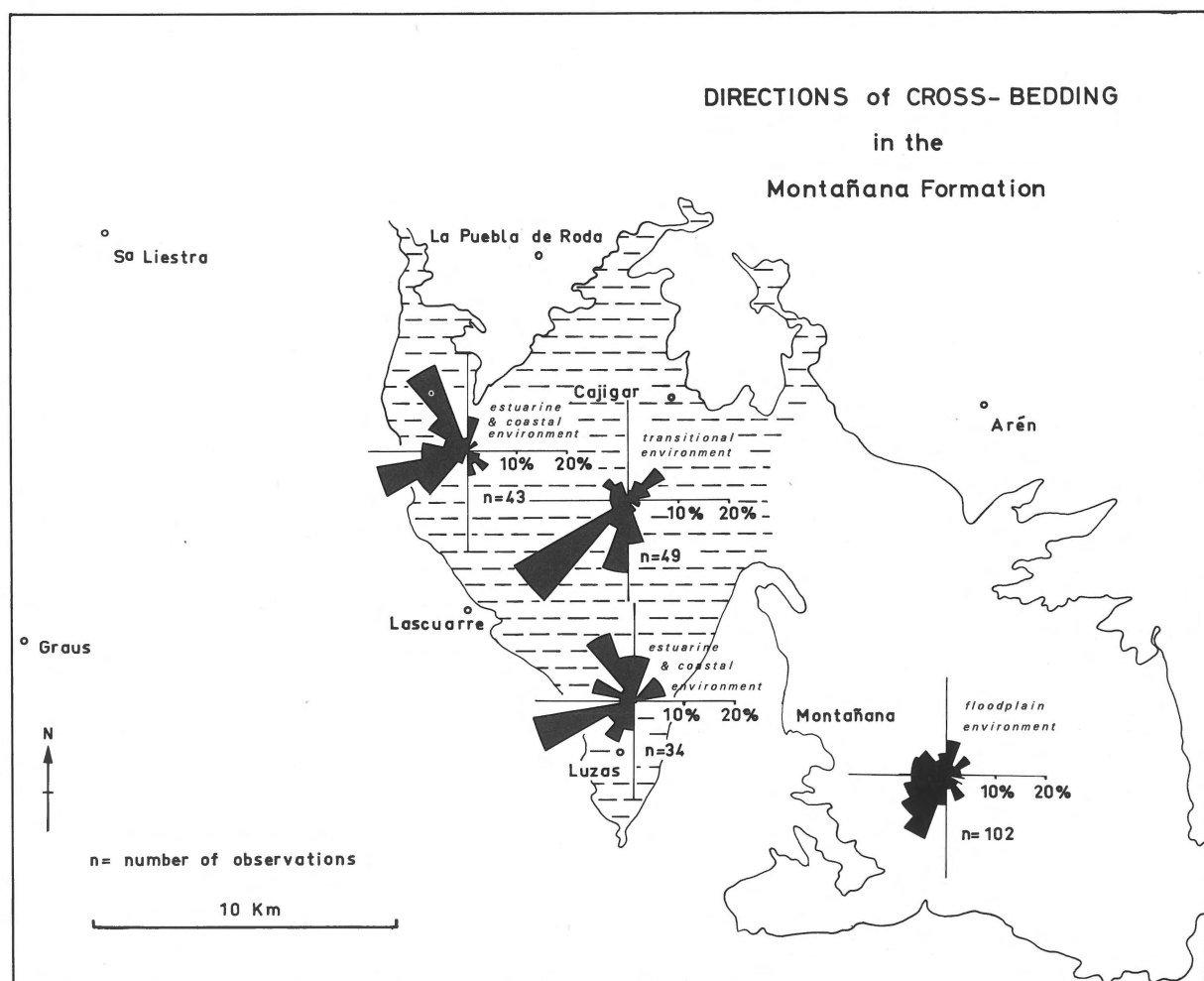


Figure 4

Paleocurrent pattern of the Montañana Formation.

Directions measured in the estuarine and coastal environments have a bicomponental distribution. The northwestern direction is parallel to the assumed coast.

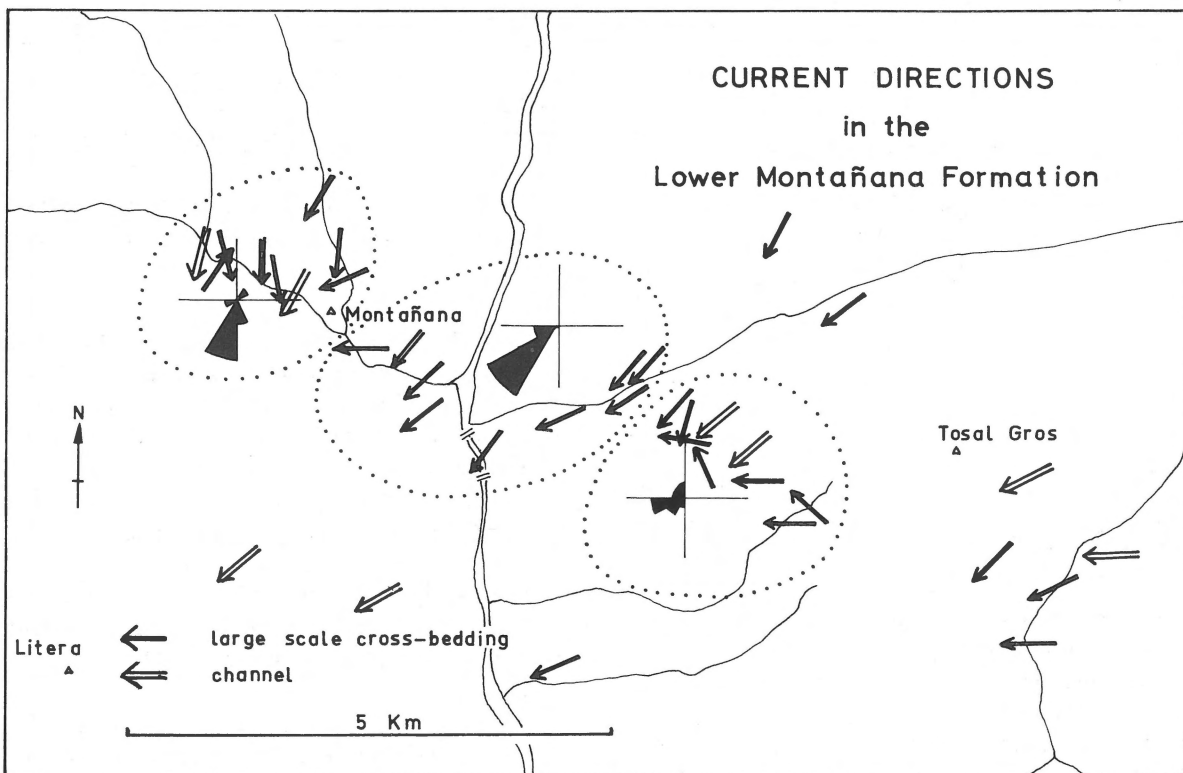


Figure 5

Paleocurrent directions in the area around Montañana.

Directions of large-scale cross-bedding (subdeltas) and fluvial channels. Note the convergent pattern with directions towards the south and west in the areas west and east of Montañana, respectively.

In the eastern part of the area the conglomerates are gradually transitional into sandy and silty fluvial deposits and still further in the direction of transport there is a change to the transitional and marine environment. The facies of this part of the formation is very much the same as that of the Montañana and Roda Formations.

North of Santa Liestra there is an abrupt change from the unsorted, red-coloured conglomerates into marls and sandstones, which contain abundant foraminifera. The conglomerates must have been transported over a short distance and deposited along a relative steep coast, where no transitional environments could be developed.

Between the villages Luzas and Montañana, clastic sediments have intensive red colours. Micritic limestone lenses have locally a total thickness of 6 m. This, together with the occurrence of gypsum and

plant remains, suggests aerial exposure of the sediments and a relative warm and dry climate.

PALEOGEOGRAPHY AND CONCLUSIONS

Lower Montañana Formation — The pattern of environments that can be recognized in the Montañana Formation is shown on Figure 6. The general paleocurrent pattern of the floodplain does not have the characteristics of an ideal delta, where one major stream will split up into several branches near the shore. Instead, the configuration of the basin caused a certain concentration of supply from the north and east by several small rivers. The convergence of paleocurrent directions is most clear near Montañana; west of this village current directions towards the south prevail, while eastwards a pre-

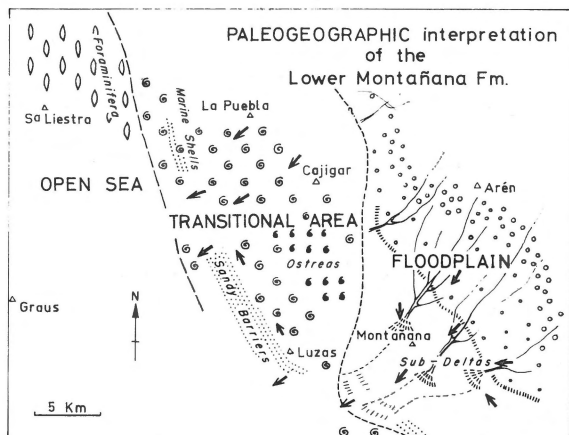


Figure 6
Paleogeographic interpretation of the Lower Montañana Formation.

dominant current direction to the west can be observed (Figure 5).

The limestone composition of the pebbles points to a nearby source and to a rapid uplift with fast erosion of the source area. The size of the pebbles decreases rapidly towards the southwest, in the direction of transport. In the area around Montañana coarse sand was deposited in distributary channels, finer sand on natural levees and mudstone in the inter-levee swamps and lakes. The previously discussed longitudinal furrows-and-ridges indicate multidirectional currents on levees that probably were caused by local relief and vegetation. Subdeltas were constructed by the river channels in lakes and lagoons.

A brackish-water bay with abundant *Ostreas* extended south of Cajigar. This bay was partly isolated from the sea by sandy barriers on the delta front. Channel mouths, bays, lagoons and tidal flats are transient environments, and their preserved deposits alternate and intermingle.

Middle Montañana Formation — The reduced sediment supply caused a domination of erosion over the constructing activity of the delta. A coastal plain of mature sand was formed and its extension is indicated as a dotted area in Figure 3. The sandstone has covered the topographic lower parts of the floodplain and can be traced to the west in a small zone along the coast, overlying the sediments of the transitional environment of the Lower Montañana Formation.

Upper Montañana Formation — Renewed uplift and extension of the tectonically active areas southwards from the axial zone caused a strong sediment supply and a rapid progression of the continental deposits over the transitional deposits of the Middle and Lower Montañana Formation. Deltaic deposits similar to those of the Lower Montañana Formation were thus developed further to the south-west.

Santa Liestra Formation — The major units of the Santa Liestra Formation are shown in Figure 7. The formation was deposited during a rapid regression of the sea, during which thick conglomerates have advanced over the northern part of the continental and marine deposits of the Montañana Formation. These conglomerates, which merge into the marine deposits without the development of any transitional environments, do not belong to the deltaic complex, but can be described as a "clastic wedge" deposit (Krumbein and Sloss, 1963, p. 542).

In the conglomerates north of Cajigar, Alveolina-limestone pebbles of the Lower Eocene age have been found. These pebbles indicate that a strong uplift occurred at the northern border of the basin, making the erosion of the Lower Eocene formations possible.

The paleogeographic picture can be completed by mentioning the remains of the flora and fauna. Fragments of tortoises, crocodiles and mammals have been found, mostly in the flood-plain deposits above the White Sandstone. Crusafont (1964) describes

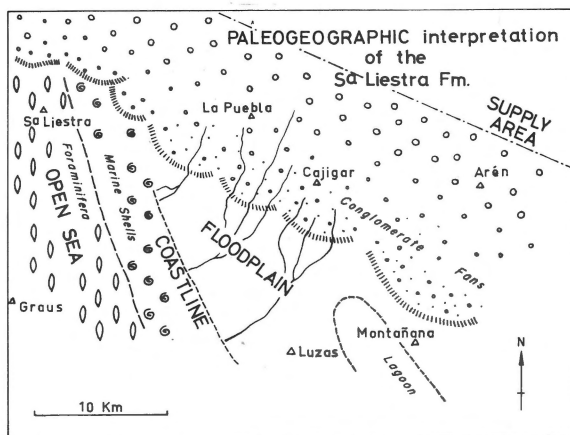


Figure 7
Paleogeographic interpretation of the Santa Liestra Formation.

specimens from nearby locations east of the studied area. Large wood and leaf fragments have been found in all flood-plain deposits and a few impressions of palmleaves have been observed in the Upper Montaña and Santa Liestra Formations.

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