

## Geometry and lithofacies of sediment bodies in a tidally influenced alluvial area. Middle Eocene, Southern Pyrenees, Spain\*

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### Abstract

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Four types of sedimentary macroforms are described from well exposed Eocene deposits in the Tremp-Graus Basin, Spain: channel deposits, depositional lobes, sheet deposits and composite forms of lobe and channel origin. The channel deposits comprise sediment bodies either formed by lateral accretion or by vertical aggradation. Mixed forms also occur. The form of the channel base is used for further subdivision of the channel bodies.

The association of the sedimentary macroforms indicates deposition on distal parts of alluvial fans. Influence of tides is suggested by the bipolar cross-stratification, reactivation surfaces and mud drapes occurring in some of the channel deposits and depositional lobes. At some locations intensive burrowing suggests marine conditions.

### Introduction

The dominance of fluvial processes over tidal ones during sedimentation may conceal the evidence of tidal action in the resultant deposits. In ancient deposits this is stressed by the destructive influences of diagenesis.

A description and classification are given of sediment bodies deposited in a tidally influenced alluvial regime. Moreover, criteria for the recognition of tidal influence in such deposits are discussed.

The Capella Formation is of Middle Eocene (Lutetian) age (Crusafont et al. 1966; Garrido

Megías 1968). Sediments were deposited in the South Pyrenean foreland basin (Tremp-Graus, Provs. Lérida-Huesca), northern Spain. During the Lutetian the central part of the Tremp-Graus basin was an embayment, protected from the open sea in the west by a barrier island system (Nijman & Nio 1975; Donselaar & Nio 1982). The alluvial sedimentation in the embayment was influenced by tidal action (Capella Formation, Cuevas Gozalo 1985).

The Capella Formation consists of terrigenous mudstones with interbedded conglomerate and sandstone bodies. The high proportion of mud allows individual geometries of the sediment bodies to be clearly recognized.

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The present study is based on the exposures of the Capella Formation around the Isabena River and the Esera River valleys (fig. 1). The studied region presents many advantages for the comparative study of sediment bodies since many kinds of sediment morphologies occur in a small area (20 km × 5 km) with a large sediment thickness (up to 1000 m in the Isabena valley). Paleo-geographically, the studied sediment bodies belong to the same basin. They do not form isolated examples of different origin, but were deposited under comparable – if not similar – sedimentary conditions. A number of different types of sediment bodies are spatially related, some of them being the lateral or distal equivalent of each other.

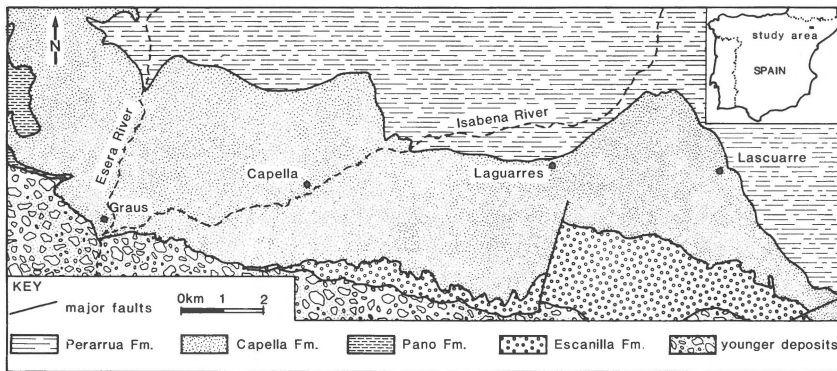


Fig. 1. Geographical and geological setting of the Capella Formation in the study area. The sedimentary formations are of Eocene age and young from left to right in the key.

### Mud deposits

Mud deposits form the bulk of the Capella Fm; they represent about 75% of the total volume. Individual mudstone intervals reach thicknesses of more than 20 m. They are brownish and commonly mottled; bluish-grey mudstones occur in the western part of the study area. The intraformational body-fossil content is generally poor. The deposits are, however, intensely bioturbated; vertical cylindrical burrows are predominant and can be observed at the boundaries with coarser grained deposits (fig. 2). The vertical burrowing suggests, together with other criteria to be mentioned later, intertidal conditions where organisms are frequently exposed to fluctuations in temperature, salinity and/

or desiccation (e.g. Rhoads 1967, 1975; Crimes 1975; Basan & Frey 1977).

Recent examples of fluvial deposits suggest that the proportion of mudstones in the Capella Formation is too high to be interpreted as only the product of channel overbank deposits in an alluvial plain (cf. Wolman & Leopold 1957). Massive mudstone deposits in a purely continental Tertiary basin have been interpreted as the result of high suspension flows, generated as a consequence of general flooding in a humid alluvial fan (Diaz Molina 1979). Besides the alluvial processes mentioned, processes connected with the tidal environment, such as settling lag and scour lag, as well as the production of fecal pellets by benthic animal

populations may be responsible for the accumulation of large amounts of fine grained sediments (Van Straaten & Kuenen 1957; Postma 1967; De Mowbray 1980; Anderson et al. 1981).



Fig. 2. Vertical cylindrical burrows in mudstone deposits; upper deposits are fine sandstones. (Decapod burrows?). Pencil length is 16 cm.

## Geometry and facies of the sediment bodies

In this study sediment bodies are defined as morphological entities, consisting of conglomerate, sand or coarse silt. The sediment bodies can be easily differentiated from the interbedded mudstone deposits.

The Capella Formation is characterized by a large variety of sediment body geometries; four major macroform types are distinguished:

- Channel deposits
- Depositional lobes
- Sheet deposits
- Composite forms

A further differentiation of these macroform types into various subtypes can be made as shown below.

### Channel deposits

A channel is an elongate feature with negative relief, and is defined by a continuous erosive surface cutting into the underlying material; the erosive surface is present at any cross section. A continuous erosive lower surface and a general difference of lithofacies between channel deposits and substratum permit the channel deposits to be recognized.

Based on the internal organization, three types of channel deposits are recognized: bodies created by lateral accretion, by vertical aggradation and by both lateral and vertical aggradation. Vertical aggradation bodies can be subsequently subdivided into bodies with a single concave base, with a multiple concave base or with a base of low erosional relief.



Fig. 4. Lateral accretion body. Note the lateral accretion units in the left and the channel unit in the right. Scale length is 4,5 m.

### (1) Lateral accretion bodies

The lateral accretion bodies found in the Capella Formation are typically 3-10 m thick. They are characterized by epsilon cross-bedding over a clearly erosive basal surface (A in fig. 3; fig. 4) (cf. Allen 1963). The epsilon cross beds fine upwards from medium sand to silt. Trough and planar cross-stratification are found at the base of the epsilon units; the cross strata often show long, well developed bottomsets (fig. 5). The upper part of the units commonly shows bioturbation and motting. Where exposures afford a plain view of the units, a scroll-bar topography can be seen (fig. 6) (cf. Sumborg 1956; Puigdefabregas 1973).

Epsilon cross-bedding alone is not sufficient evidence for lateral accretion; examples have been found in depositional lobes where they were formed as a result of lobe progradation and reworking by tidal currents (Cuevas Gozalo 1985). In the deposits described here, however, the association of epsilon cross bedding with an erosional base, an upward fining in texture, the scroll-bar topography, and the presence of cross-stratification oriented parallel to or upslope the epsilon

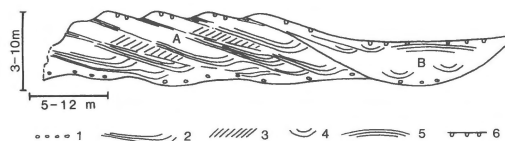


Fig. 3. Lateral accretion body. A: lateral accretion units. B: channel fill unit; 1: lag deposit; 2: trough cross-stratification with well developed bottomsets (oblique section: o.s.); 3: planar cross-stratification (o.s.); 4: trough cross-stratification (transverse section: t.s.); 5: avalanche foresetting and low-angle cross-stratification (t.s.); 6: vertical cylindrical burrows.



Fig. 5. Lateral accretion body: Trough cross-stratification with very well developed bottomsets at the lower part of the lateral accretion units.



Fig. 6. Scroll bar morphology at the upper part of the lateral accretion units of a lateral accretion body.

units provides strong evidence for lateral accretion on a channel point bar.

In addition, the channel relief is sometimes preserved next to the lateral accretion units (B in fig. 3; fig. 4). The channel is commonly filled with sandy deposits. A lag deposit is overlain by trough cross-stratification, avalanche foresetting or low-angle cross-stratification. Bioturbation is well developed, either as hypichnial burrows in the channel floor or as cylindrical vertical burrows at the upper surface of the fill (cf. Martinsson 1970).

Bipolar cross-stratified sandstones associated with reactivation surfaces, and mud drapes at regular intervals are found at the base of the lateral accretion units of some of the bodies (cf. De Raaf & Boersma 1971; Visser 1980; Terwindt 1981; De Mowbray & Visser 1984). Main paleocurrent direction is toward the land – in the northeast. The

sediment bodies with these characteristics are interpreted as meandering tidal channel deposits.

(2) *Vertical aggradation bodies with a simple concave base*

These bodies show a simple concave lower surface and lateral wings (fig. 7 A, B and fig. 8 A).

In most cases, the sediment bodies consist of homogeneous, well sorted medium or fine sand, suggesting that vertical aggradation took place as a single event. Occasionally, low-angle and convex-upward cross-stratification can be observed, but often the deposits appear structureless. The channel depths, inferred from the thickness of the fills and the occurrence of banks covered and fossilized by overflow deposits, varied from 3 to 5 m. The lower surface of the channel deposit is covered with hypichnial burrows (fig. 8 B). The upper surface of the body is perforated by vertical, 1 cm wide cylindrical burrows.

In a few cases, the sediment bodies show evidence of repeated aggradation episodes. The differentiation of aggradation episodes is based either on the occurrence of lag deposits with large mudstone clasts or on the presence of silt or clay deposits at the top of medium to very fine sandy units (fig. 7 B). Individual aggradation units may be up to 2 m thick, the whole sediment body showing thicknesses of up to 8 m. Typical sedimentary structures are, from bottom to top, crescent

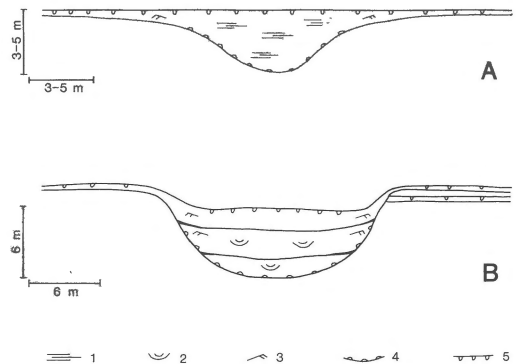


Fig. 7. Vertical aggradation bodies with a simple concave base. A: single filled. B: multifilled. 1: low-angle cross-stratification; 2: trough cross-stratification; 3: ripple-cross-lamination; 4: hypichnial burrowing at the lower surface of the channel; 5: vertical cylindrical burrows.

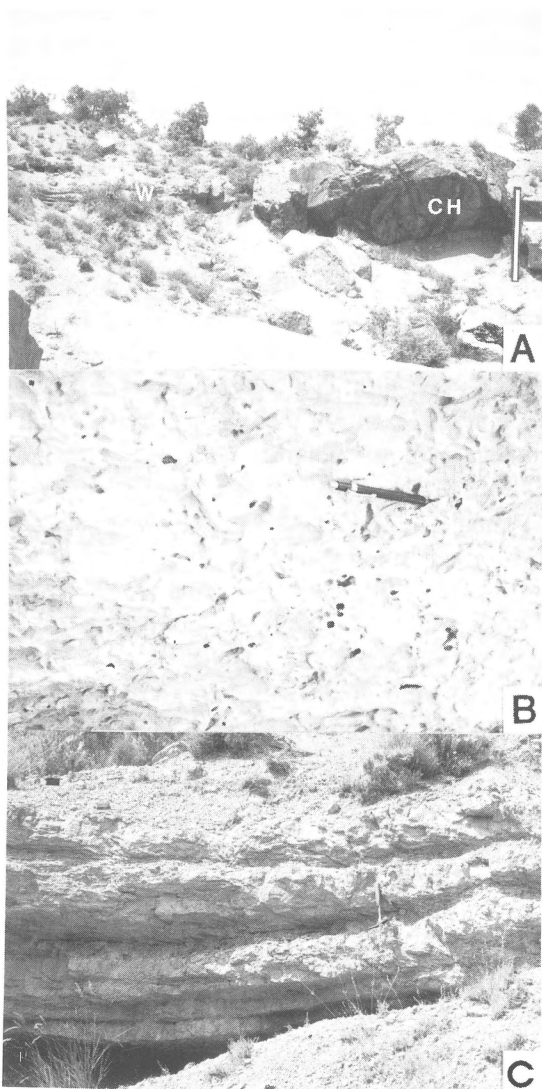


Fig. 8. Vertical aggradation body with a simple concave base. A: Single filled channel body (ch) with lateral wing (w); scale length is 4 m. B: Detail of the hypichnial bioturbation at the channel floor; view is looking at the external part of the channel deposit; pencil length is 14 cm. C: Detail of the multibedded lateral wing; hammer length is 28 cm.

casts at the lower surface, cross-stratification, scour and fill structures, low-angle cross-stratification, parallel lamination and ripple lamination. A textural fining and a transition to small-scale structures occur laterally towards the channel banks.

The lateral wings are 0.5 - 1.2 m thick wedges of fine sand and silt deposits connected to the main channel fill; they pinch out away from the channel

axis. The wings consist of one or more intensely bioturbated beds (fig. 8 C); occasionally, ripple cross-lamination is preserved. The wings are the result of flow expansion over the banks, produced when the water discharge could not be confined in the channel. This situation may be caused by a reduction of the hydraulic radius after deposition within the channel; in this case the wings represent the lateral expansion of the flow prior to the final abandonment of the channel (Reading 1978, pag. 55; see also fig. 7 A). A lateral expansion of the flow can also be produced during flood periods; in this situation wing-like, overbank deposits are formed; these wings are topographically higher than the last channel sandy fill and represent the levee deposits (fig. 7 B).

The bodies described correspond to the simple and multi-storey ribbon bodies of Friend et al. (1979). Moody-Stuart (1966) interpreted similar sediment bodies as being the product of low sinuosity channels. However, there is a similarity of geometry and facies between the bodies with concave base and the channel units associated to the lateral accretion bodies described above (B in fig. 3). This similarity between both channel types suggests that the bodies with concave base may also represent straight sections of meandering channels.

### *(3) Vertical aggradation bodies with a multiple concave base*

These bodies are characterized by a multiple concave basal surface (fig. 9 A, B, C). This surface has an irregular shape and consists of deeper and shallower parts with a difference of depth up to a few meters. The dimension of the channel relief is comparable to the above-mentioned bodies with a simple concave base. The channel fill consists of fine to very fine grained sands with a maximum thickness of 4-6 m. The channel fill consists of several composite cosets over a lag deposit of mud clasts. Observed sedimentary structures are cross-stratification and ripple cross-lamination; opposite paleocurrent directions are occasionally observed in a single body. Bioturbation, burrowing and mottling are very intense in some of the examples. Different types of channel fills are shown in figure 9.

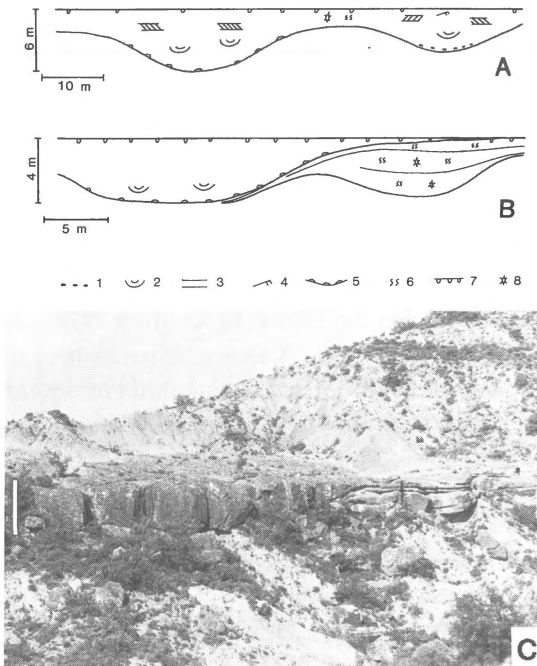


Fig. 9. Vertical aggradation bodies with a multiple concave base. The basal surface has an irregular pattern, consisting of deeper and shallower parts. The filling of the different depressions took place either simultaneously (A) or in different stages (B). In B the channel depression to the right was first infilled by very fine sandy deposits, and then highly bioturbated and mottled. The channel depression to the left was infilled in a later stage by fine sandy deposits. 1: mud lag deposits; 2: trough cross-stratification; 3: angular cross-stratification; 4: ripple cross-lamination; 5: hypichnial burrows; 6: intense bioturbation; 7: vertical cylindrical burrows; 8: mottling. C: Example of channel deposit represented in 9 B; scale length is 4 m.

The configuration of the lower surface suggests that at low water stages some islands of muddy substratum emerged between the deeper parts of the channel; in this situation the channel belt consisted of an anastomosing system.

(4) *Vertical aggradation bodies with a base of low erosional relief.*

The third type of vertical aggradation channel fill is represented by bodies associated with the coarsest textures, i.e. conglomerates and coarse to very fine sands. These bodies have thicknesses ranging from 3 to 11 m, with lateral extents of several hundreds of meters. The basal surfaces of the bodies are erosive, but the erosional relief of the base has a low amplitude with respect to the body thicknesses

(fig. 10). Within the sediment bodies, imbricated scours are observed; they correspond to the bases of smaller subordinate channels. The lower part of a complete sequence consists either of massive conglomerates with sand wedges or of planar cross-stratified conglomerates laterally associated with cross-stratified sands. Higher in the sequence cross-stratified medium sand and low-angle cross-stratified very fine sand with parting lamination occur. The upper part consists of ripple cross-laminated very fine sand, and parallel-laminated silt and clay; mottling is common. The massive conglomerates with sand wedges represent the active part of the channel belt, where probably more sand was deposited, but poorly preserved. The smaller subordinate channels were separated by coarse grained bars. Two types of bars are observed. The first type is erosional, formed by the incision of lateral channels into the previously deposited sediments. The internal structure of the bar is not conformable with the external geometry (fig. 11). The second type consists of a depositional

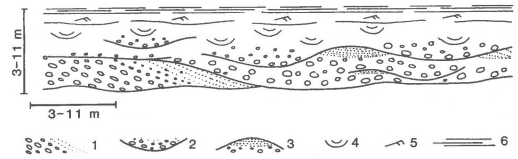


Fig. 10. Vertical aggradation body with a base of low erosional relief. 1: avalanche laminae in coarse-grained depositional bars; 2: imbricated, subordinate channels; 3: coarse grained inter-channel bars; 4: trough cross-stratification; 5: ripple cross-lamination; 6: parallel laminated silt and clay deposits.



Fig. 11. (Vertical aggradation body with base of low erosional relief). Erosional sandy bar bounded by subordinate-channel conglomerates.

bar formed by avalanching over a slip face; the internal structure in this case is conformable with the external geometry.

The well developed textural and structural sequence of the bodies indicates a progressive and general abandonment of the channel belt. The coarse grained bodies are interpreted as braided channels in an alluvial fan system; they are restricted to the eastern part of the studied area.

#### (5) Vertical and lateral aggradation bodies

These are coarse to very fine sand bodies with a maximum thickness of a few meters (fig. 12). The erosive lower surface of such a body is concave and slightly asymmetric. The channel deposit consists of several units. Each unit is characterized by a subordinate erosive concave lower surface formed by the partial erosion of the older channel deposits. The arrangement of the units within the channel body reveals a lateral migration of erosive and depositional activity. The scouring depths of the lower surfaces of the successive units decrease in the direction of lateral migration; the last unit splays over the channel margin.

Such a body represents the progressive abandonment of a channel by reduction of the width and depth of the thalweg. The reduction of the cross sectional area is due to a high deposition/erosion ratio in the channel. Deposition occurs mainly as vertical aggradation during lateral migration of the channel. Prior to the final abandonment, the active channel is not deep enough to confine the flow. Thus it expands beyond the channel and invades the adjacent plain.



Fig. 12. Vertical and lateral aggradation body. The channel deposit consists of several units with erosive base: the units are obliquely arranged within the main channel.

#### Depositional lobes

The lobes are bodies with a positive relief; they are not confined to channels. A description and classification of the lobes was made on the basis of geometry and lithofacies (Cuevas Gozalo 1985).

The lobes have thicknesses between 1-10 m; they are characterized by a wedging-out in longitudinal sections. The transverse section geometries range from tabular to plano-convex. The lower contacts of the lobes are either gradational with the muddy substratum, erosive to gradational, or only erosive. Two main lithofacies types are: *lithofacies A with horizontal bedding* and *lithofacies B with inclined bedding*. In transverse sections lobes with lithofacies B may display either a trough bedding pattern or a concentric convex-upward bedding pattern. Primary sedimentary structures include low and high-angle cross-stratification and ripple cross-lamination. The paleocurrent directions as derived from the sedimentary structures, are usually oriented in the dip direction of the inclined beds. Cross-stratification and ripple cross-lamination with countercurrent directions occur in some lobes, together with structures oriented downdip. The countercurrent structures form a ridge and swale morphology in the upper part of the lobes. They are interpreted to be the product of flood tidal currents. Vertical burrowing and mottling are common on the upper surface of the lobes.

Different interpretations are suggested from the different types of lobes: overbank splay lobes, channel terminal lobes, small delta lobes and spillover lobes, i.e. depositional forms in front of a tidally influenced channel (Cuevas Gozalo 1985).

#### Sheet deposits

The sheet deposits are sediment bodies with a relatively large lateral extent (tens to hundreds of meters), and thicknesses from a few centimeters to about one meter. The sheet deposits consist of fine sand to silt. They occur either as isolated bodies embedded in mudstone deposits or as vertically stacked and amalgamated bodies (fig. 13). The

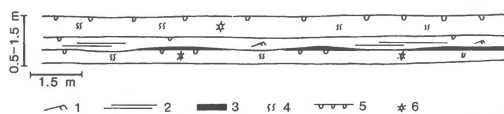


Fig. 13. Vertically stacked sheet deposits. The lower contact of the sheet deposits may be scouring or not. 1: ripple cross-lamination; 2: parallel lamination; 3: intercalated mud deposits; 4: intense bioturbation; 5: vertical cylindrical burrows; 6: mottling.

lower surfaces of the sheet deposits are horizontal; the lower contacts are either gradational with the substratum, or irregular and slightly erosive. The upper parts of the bodies grade into the overlying finer sediments. Sedimentary structures are rarely present; ripple cross-lamination is occasionally observed. Bioturbation and mottling are very intense.

The sheet deposits are suggested to be the result of unconfined water flows moving down a slope. The sheet deposits as described here correspond to the sheetflood deposits of Hogg (1982) and Friend (1983). According to Hogg the hydraulic characteristics of the flow change from place to place on the slope, and also in time. Consequently, erosion and scouring at the sheetflood base either may occur or not; a sheetflood may end in a mudflow. These factors explain the variability of characteristics of the sheet deposits of the Capella Formation.

Sheetfloods are events of intermittent nature: they typically occur across fans, with erosion on the upper slopes and deposition in the lower parts (Hogg 1982). Sheetfloods occur at the downstream ends of channels (Bull 1972). It is assumed that the sheet deposits of the Capella Formation represent distal alluvial fan deposits.

From the point of view of the geometry, the sheet deposits have to be considered as a distinct macroform, occurring independently from the other macroform types. Nevertheless there is a strong similarity of features between sheet deposits, horizontal bedded lobes and the wings of the channel deposits with a simple concave base (compare fig. 8 C and fig. 13).

In the extreme case, the sediment bodies with coarser texture, large lateral extent and irregular, scouring basal surface can be considered as sheet deposits. The body thicknesses are from some decimeters up to 1 m. Occasionally preserved relicts of cross-stratification suggest that stream-flood conditions occurred (cf. Hogg 1982).

#### *Composite forms*

The composite forms are defined by an association of two of the earlier described geometrical types,

channels and lobes. An interpretation of the relationships between channel and lobe forming processes is necessary to describe the composite geometries. The succession or the alternation of both sedimentary processes generates relatively simple forms in which the identification of lobe and channel geometries is possible. However, if both sedimentary systems are simultaneously active, a body with mixed geometry is generated.

The following three relationship types can be recognized:

a) Lateral infilling of a slightly active channel by a lobe. The channel geometry is preserved; the channel deposits are fossilized by the lateral influx of sediment (fig. 14).

b) Alternate episodes of lobe and channel activity in front of the lobe. The lobe sedimentation generates a morphology that determines the position of the channel. In turn, the channel relief controls further progradation of the lobe (fig. 15).

c) Simultaneous activity of lobe and channel. The resulting form is more complex. There are no boundaries between channel and lobe; the sediment supplied by the lobe is immediately transported along the channel. The lobe progradation provokes the lateral migration of the complex channel-lobe (fig. 16).

The composite forms represent the association of a lobe and a channel fill showing paleocurrent directions oblique to perpendicular with respect to each other. The lobe may have relatively little importance in relation to the channel (fig. 14); then it is interpreted either as an overbank splay lobe or a small terminal lobe derived from an adjacent channel. Whenever the amount of sediment laterally supplied into the channel is large, the channel can be plugged and backfilling occurs.

In other cases (fig. 15 & 16), lobe and channel are of comparable size and their deposits are laterally related. Lobe forming processes and channel forming processes are closely related to the extent that both geometries cannot be distinguished individually (fig. 16). The model of spillover lobes (terminal lobes in front of a tidally influenced channel) with marginal channels may be applied to these composite forms (fig. 16 in Cuevas Gozalo 1985).

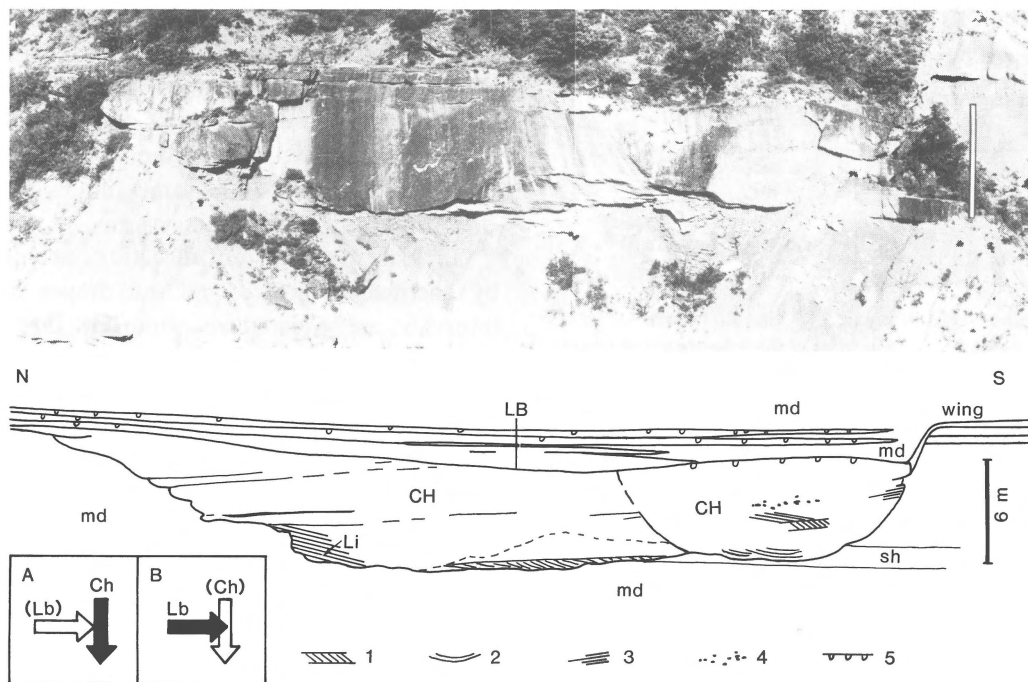


Fig. 14 A & B. Composite form produced by lateral infilling of a slightly active channel by a lobe. The channel deposit (CH) was formed during an active channel period (site A, Ch.). The channel deposit is covered by a horizontally bedded lobe (LB) coming from the north (left) (site B, Lb). The lobe beds wedge out before reaching the southern (right) channel bank. Initial lateral infilling (Li) of the channel can be observed at the northern lower channel bank; the lateral fill consists of avalanche cross-laminae. Sedimentary structures of the channel deposit are planar (1), trough (2) and low-angle (3) cross-stratification. Lag deposits consisting of mud clasts (4) occur in the channel fill. The lobe deposits are highly bioturbated and burrowed (5). md: mudstone deposits; sh: sheet deposits. Scale length is 6 m.

## Conclusions

The sediment bodies of the Capella Formation are classified on the basis of the external geometry and the internal organization. Four major types can be recognized: channel deposits, depositional lobes, sheet deposits and composite forms of lobe and channel. A further differentiation of these groups is based on similar criteria.

The understanding of the relationship between the geometrical properties and the internal organization of the sediment bodies provides information on the mechanism of their formation.

The morphology of channels was considered to be controlled by the bank strength (Schumm, 1968; Friend et al. 1979). The banks of most of the channel deposits of the Capella Formation have similar lithology (mudstones), but different morphologies are inferred. The morphology of the channels was influenced by factors as the hy-

drology, lithology and tectonic activity of the source area, the relative proximity of the channel to the source area and the position of the channel with reference to base level and flow strength.

The deposits of the Capella Formation, channel deposits, depositional lobes, sheet deposits and composite forms were deposited either from confined or unconfined flows. The results of both types of flow are spatially associated: depositional lobes and sheet deposits (unconfined flow) are related to the channel deposits (confined flow) either as lateral products (overbank splay lobes) or as distal products (sheetflood deposits, terminal lobes). Both confined and unconfined flow and their resulting products may be integrated in a model of deposition on the lower, tidally influenced, part of an alluvial fan system.

Among the channel deposits two main textural groups are observed. The first group is coarse, conglomeratic and is associated with braided chan-

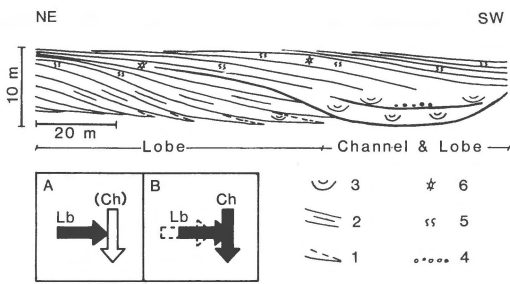


Fig. 15. Composite form created by the alternation of lobe activity and channel activity in front of the lobe. In a first phase (A) the lobe (Lb) progrades from NE to SW (left to right); the channel ([Ch]) is practically inactive and only manifested by some reworking structures at the base of the lobe. In a second phase (B) the channel is highly active and erodes the base of the prograding lobe. Lobe (Lb) and channel (Ch) are simultaneously active; the lobe ends in the channel; the channel fill consists partially of lobe deposits. 1: transition to finer deposits; 2: inclined stratification; 3: trough cross-stratification; 4: lag deposits; 5: intense bioturbation; 6: mottling.

nel deposits. The second group is represented by fine to medium sandy deposits. It includes most of the channel deposits described, comprising me-

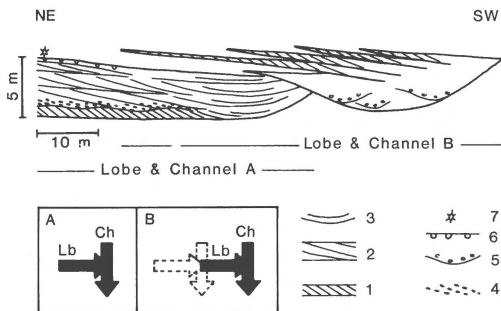


Fig. 16. Two composite forms as the result of lateral migration. Phase A: The simultaneous activity of a lobe (Lb) and a channel (Ch) creates a composite form. The lower contact of the composite form is erosive in response to the channel scouring. Paleocurrents in the composite form exhibit two main directions: the first one is from left to right and corresponds to the lobe deposits (Lb); the second one is perpendicular to the picture and corresponds to the channel deposits (Ch). A thinning of the lobe deposits towards the channel can be discerned. The lobe-channel complex (A) is active in the position A until the channel relief is infilled. As a consequence of progradation of the lobe to a new position; a new phase B starts. 1: angular an 2: low-angle cross-stratification in longitudinal section; 3: low-angle cross-stratification in transverse section; 4: low-angle cross-stratification in mud pebbles (bottomsets; long. sect.); 5: subordinated channels with lag deposits; 6: vertical cylindrical burrows; 7: mottling.

andering, straight and anastomosing channels. In general they are of less lateral extension than those of the first group. The textural and morphological separation of these two groups of channel deposits suggests that they belong either to different areas (proximal to distal) of the same alluvial fan system or to different alluvial fan systems.

Opposite paleocurrent directions accompanied by reactivation surfaces and mud drapes at regular intervals are present in some of the channel deposits and depositional lobes. These features are interpreted to be the result of tidal influence during sedimentation. The vertical burrowing of the mud deposits suggests that the mud plain in which channel deposits and lobes were formed was also affected by intermittent subaquatic conditions. An intertidal environment is inferred from these deposits; supratidal and subtidal conditions could be locally dominant in respectively elevated or deeper parts.

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