2.4 Non-channelized fan environments

Three primarily non-channelized, sand-dominated depositional zones within the fan were selected for detailed studies (fig. 2.10). The selection was based on their location within the fan system as well as on the degree of exposure and accessibility. These zones were classified according to their facies characteristics, the recognition of their elemental building blocks (components) at different hierarchies of scale and their position within the fan system. A channel-lobe transition zone, a proximal lobe zone and a relatively distal (intermediate) lobe zone were identified as distinctive fan depositional environments within the sandy basin-fill of the E-Fan (fig. 2.10: localities 4 to 6).

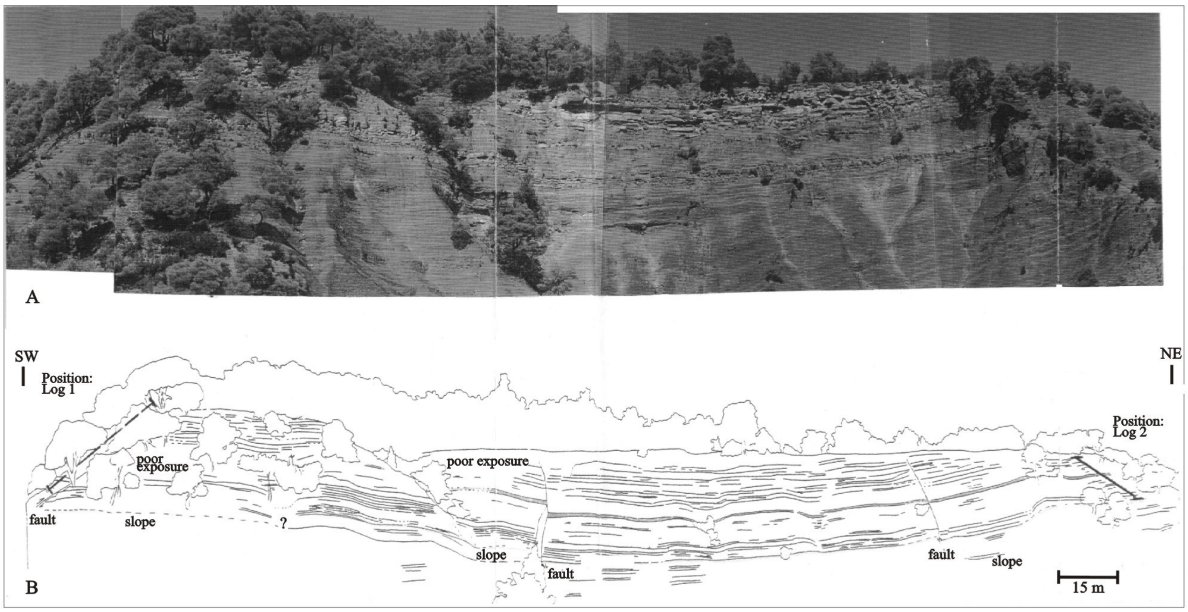

Figure 2.15: A) Photomosaic showing lobe and lobe fringe deposits onlapping a low-angled slope sediments in a SW-NE trending cutbank north of Egner, northeastern margin of E-Fan. The deposits dip to the NWN (340°) and the palaeocurrent directions point obliquely towards the slope. The underlying slope sediments form largely undeformed, monotonous successions.
B) Line drawing depicting the position of logs (fig. 2.14).

2.4.1 Channel-lobe transition zone

Thick successions of primarily non-channelized, coarse-grained sediments are exposed in the very north of the field area (fig. 2.10 [#4]). They stratigraphically succeed the feeder channel 1 complex and the associated overbank deposits. Sourced by feeder channel 1 in the north, palaeocurrent indicators point to a S-SW-ward transport direction (fig. 2.10). Neither the upstream, contemporaneous channel-fill deposits nor the corresponding downstream deposits are preserved and/or exposed. This unit is overlain by distinctly finer-grained and thinner-bedded lobe-like deposits (*chapter 2.2*; fig. 2.11).
Three overview logs were taken covering 150 m vertical extent (fig. 2.16), the stratigraphic top (80 m) is not exposed. Only limited lateral control can be exerted with a maximum of 300 m of continued tracing of selected beds. The geographic eastern margin is not exposed and/or inaccessible. No 3-D sections are present, therefore it is not possible to record downcurrent changes within this zone. Within the lower, better exposed part more detailed studies were carried out to obtain information about facies to mesoscale geometric variations.
Ancient channel-lobe transitions *sensu* Mutti & Normark (1987, 1991) are characterised by i) extensively scoured and amalgamated sandstone and pebbly sandstone facies ii) coarse-grained and lenticular, cross-stratified sandstone beds, iii) abundant out-sized rip-up mudstone clasts and iv) a variety of scours and cut-and fill-structures.This channel-lobe transition zone (CLTZ; plate 4.1) is sand-dominated and contains the coarsest material of the sandy basin-fill of the E-Fan. Laterally extensive, coarse-grained to pebbly

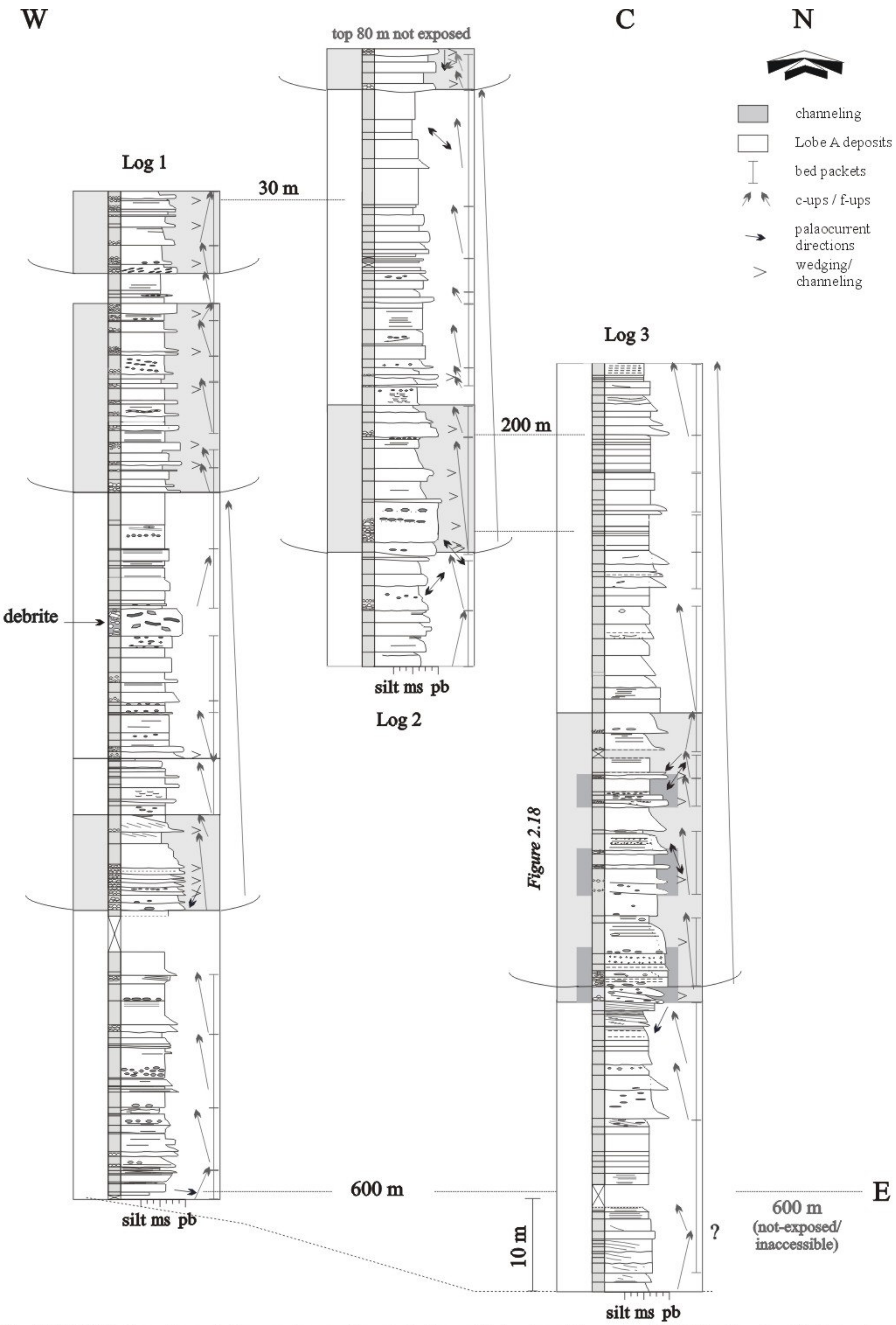

Fig. 2.16: Main logs through the western and central channel-lobe transition zone (CLTZ), showing the lateral and vertical distribution of Lobe A and channeling components. The CLTZ is sourced from the N, transport is towards the SSW-SSE. Log 1: Lobe A deposits aggrade onto mass-flow deposits made up of slope facies. Log 3: Lobe A deposits transitionally overlie channel mouth and overbank facies.

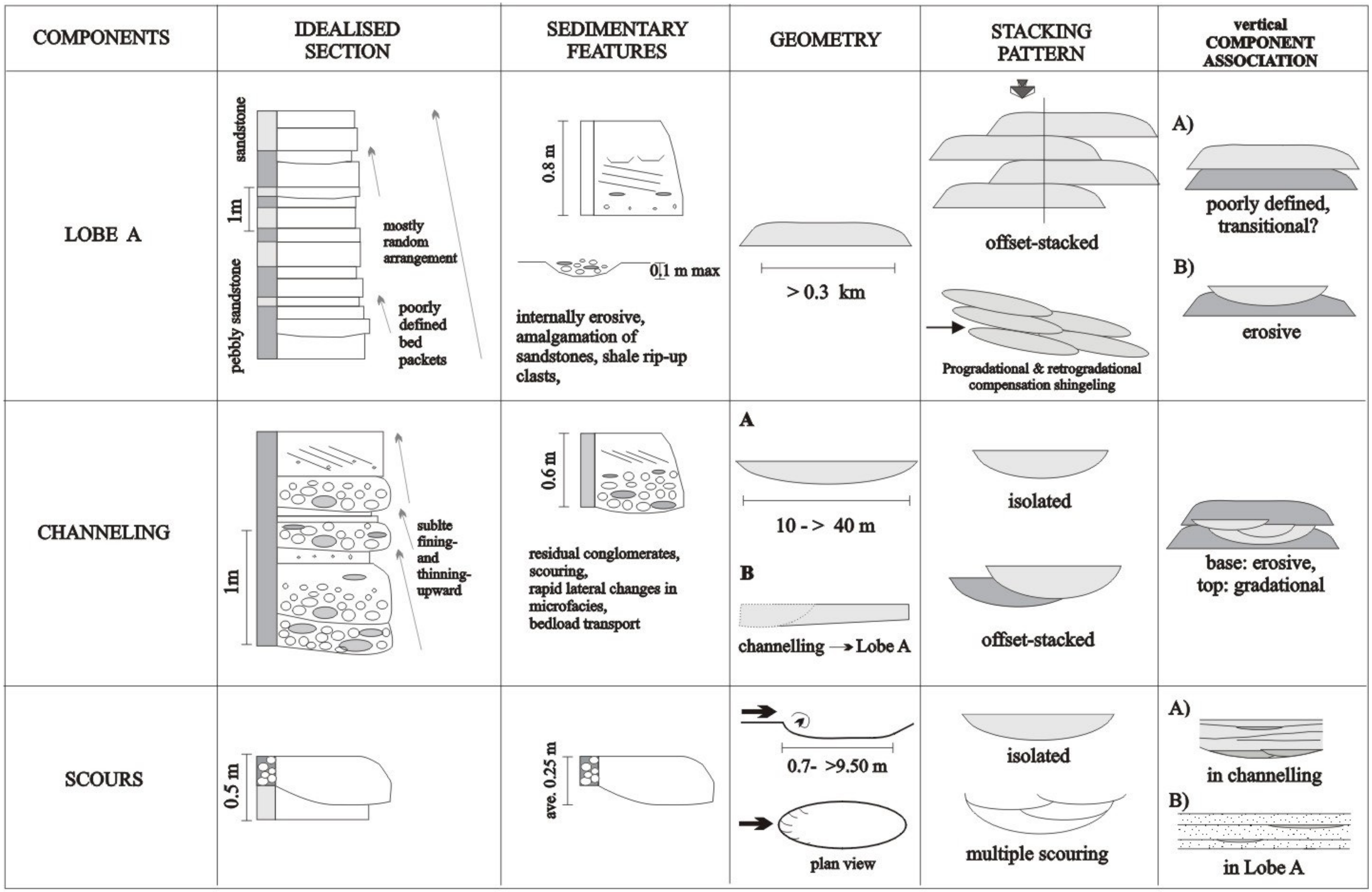

Fig. 2.17: Facies, geometry and association of differentiated components of the channel-lobe transition zone, E-Fan.

sandstones (84 %) dominate, while pebbly to cobbly conglomerates (15 %) and shale beds (1 %) are subordinately present. An abundance of erosional bedding surfaces exist (32 %). The reworking of sediments is characteristic while fine sediment is bypassed and deposited further down-system. The deposits are arranged in distinctive packages which are attributed to discrete components.

2.4.1.1 Component analysis: internal organisation and geometry

Channeling

Up to 20 m thick, discrete conglomerate-dominated successions (fig. 2.16) are forming 30 % of the section (table 2.5). These successions are mainly composed of highly erosive pebbly to cobbly, matrix-supported conglomerates mostly interbedded with pebbly sandstones. The average ratio is 1.3:1 (conglomerates : pebbly sandstones). These units erosively cut into moderately-defined sand-rich packets* and transitionally pass upward into these (fig. 2.16). The conglomerate-dominated units are laterally persistent and can be traced for up to 40 m (exposure limit).

The conglomerates can be classed as R1-3 deposits (Lowe 1982), exhibiting massive bases and crudely stratified tops (plate 4.3; fig 2. 17). Normal grading and non-grading are common, inverse grading rare. The conglomerates display rapid lateral and vertical changes in thickness (thickness: 0.1 - 1.6 m) and facies (conglomerate to pebbly sandstone; fig. 2.18). Some mud-supported conglomerates with outsized, floating clasts are randomly interbedded. The interbedded pebbly sandstones (R3 to S1-2 of Lowe 1982) show abundant traction features. The sediments result from deposition by coarse sandy to gravelly high-density turbidity currents and debris flows (Lowe 1982; Mutti & Normark 1987; Shanmugam 2000).

The amalgamation of sediments is persistent, shale partings were not observed. Fine-grained and shaly deposits are absent within the channeling component. However, reworked shale clasts are common throughout. Poorly rounded mudstone clasts are mostly concentrated within the lower parts of beds suggesting rapid erosion of underlying hydroplastic muds and short transport distances (Kano & Takeuchi 1989; Johansson & Stow 1995).

No actual channel geometries were observed. Channel margins with i.e. multiple onlapping infill geometries which form clear identification criteria for channels (Mutti & Normark 1987) are absent at outcrop scale. The channeling geometry is inferred by means of depositional characteristics. Smaller-scale lensing (up to 10 m in length), wedging beds and abundant cut- and fill structures are present (plate 4.2, 4.3). The at times rapid lateral facies change of individual beds (fig. 2.18) may indicate the progressive change towards marginal areas of the channelized area (Mutti & Normark 1987). The lack of steep-sided erosional channel margins suggests that the channels may have been fairly shallow features which could not necessarily contain the whole flow volume (Weimer 1989) and sheet-sand deposition outside the channelized area was probable, partly forming Lobe A deposits.

In the lower CLTZ, the channeling component is composed of three distinctive sub-packets (figs 2.16, 2.18), their individual bases marked by erosion (1st order bounding surfaces after Pickering *et al.* 1995) and conglomeratic lags. These up to 2.6 m thick sub-packets typically consist of 5 - 8 beds, defined by subtle 2 - 4 bed asymmetric sequences (58 %), while 42 % of the measured beds display random organisation. 3 - 4 bed thinning-upward sequences dominate (54 % of sequences; fig. 2.19) suggesting gradual channel abandonment or backfilling (e.g. Mutti & Normark 1987; Chen & Hiscott 1999a). The grain size trends largely reflect the bed thickness trends, however, fining upward was even observed in conjunction with distinct thickening upward (fig. 2.16, e.g. log 2: 20 - 28 m). The randomness and asymmetric sequences may result from variations in flow volume, concentration and/or flow path (Chen & Hiscott 1999a).

The stacking of 2 or more erosive bed packets within a channeling component (fig. 2.18) implies repeated episodes of increased activity resulting in erosion and deposition of coarse facies within this fairway suggesting it to be a more persistent feature.

* bed packets *sensu* Chen & Hiscott (1999a) are defined as groups of beds sharing similar facies characteristics and an overall grain size distinct from strata immediately above and below corresponding to, for example, channel-fill and lobe deposits. 'Bed packets' correspond to 'bed packages' of Normark *et al.* (1993). Sub-packets is used here to describe subtle but recognisable differences in grain size and bedding pattern within the individual component / bed packet / package.

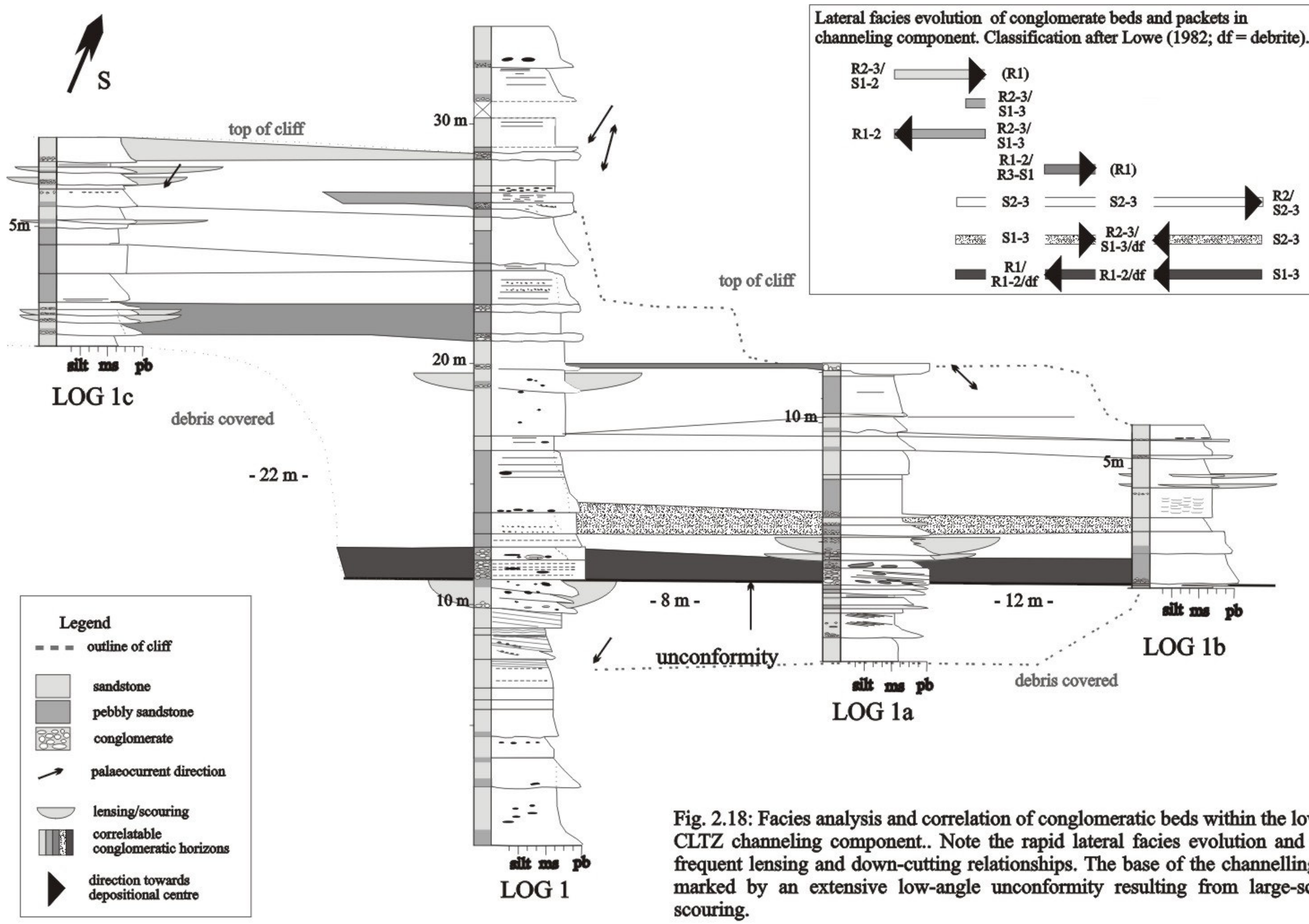

Fig. 2.18: Facies analysis and correlation of conglomeratic beds within the lower CLTZ channeling component.. Note the rapid lateral facies evolution and the frequent lensing and down-cutting relationships. The base of the channelling is marked by an extensive low-angle unconformity resulting from large-scale scouring.

The base of one of the lowermost channeling components is marked by a subtle, low angle unconformity which can be traced for a minimum of 40 m (fig. 2.18; plate 4.1 & 4.3). It is believed to result from mega-scale scouring (Mutti & Normark 1991; *see below: scours*).
Within the channeling components of the CLTZ an upward decrease in pebble size was observed perhaps related to an overall decrease in flow competence (Chen & Hiscott 1999a) and/or denudation of the hinterland in connection with increased transport distance through rising sea level.

Component	Total %	Magnitude components (v:lat in m)	Magnitude sediment beds (v:lat in m)	Constituents ratio (ave) (C/S/SH)	Sedimentology	Cycles
Channeling	30 %	< 20 : > 40	C: 0.4 – 2.5: < 10 - > 40 ave. 0.40 S: 0.5 : > 25	1.3/1/0	R1-3; R3S1-3 debrites	subtle asymmetric cycles and randomness
Lobe A	70%	5 - 33 : > 300	C(ave): 0.2 : > 1 S(ave): 0.6: >300 SH: 0.05: > 10	1/17/0.2	S1-3, rare R1-3, rare Td,e sandy debrites	random, some subtle f-up
Scours	5 % of channeling	? : > 40 : ? (d/w/l)	0.5 : 2.5 : 8 (d/w/l)	1/0/0	R1	non

(Abbreviations: v=vertical, lat=lateral, d=depth, w=width, l=length, C=conglomerate, S=sandstones, SH=shales)

Table 2.5: Hierarchy of scales of components in channel-lobe transition zone. Note that lateral extent is limited by degree of exposure.

<u>Lobe A deposits</u>

70 % of the unit are made up of between 5 - 33 m thick successions of coarse- to very coarse-grained sandstones, pebbly sandstones and occasional conglomerates, characterised by a high net sand content (> 90 %) (fig. 2.16, 2.17; table 2.5). The sandstones are thick-bedded (0.6 to 3.0 m), laterally extensive (traceability up to 300 m) and highly amalgamated (plate 4.4) resulting in some composite beds of up to 14 m thickness with poorly distinguishable amalgamation surfaces. Basal scouring is common but beds appear mostly parallel bedded. Sorting is generally poor to moderate. Individual beds either display normal grading with unstratified basal parts and crudely stratified tops (45 % of beds), or are structureless and ungraded (55 %). The deposits can be classified as Lowe's (1982) S1-3 division (~Bouma Ta, Tab) and deep-water massive sands (DWMS of Johansson *et al.* 1998; Stow & Johansson 2000) suggesting deposition from gravelly to sandy high-density turbidity currents and sandy debris flows. Inclined traction structures indicate bedload transport (Mutti & Normark 1987; plate 4.5). Rippled tops are rarely observed, they exhibit abundant plant debris and coalified material (plate 4.6). Parting lineation, indicating high flow velocities (Tucker 1996), is occasionally present. Trace fossils were not observed.

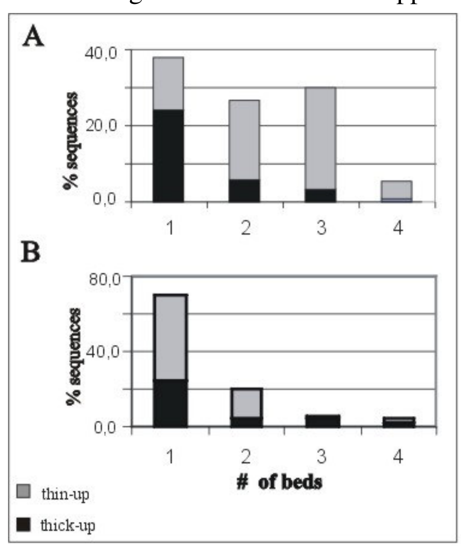

Fig. 2.19: Bedding sequences within A) channeling and B) Lobe A deposits of the channel-lobe transition zone, Cingöz Formation (2-bed moving-average smoothing technique after Heller & Dickinson 1985). Vertical ordering in A) comprised 58% and in B) 40% of the total beds; remainder are randomly organised.

Internally, the lobe deposits are composed of poorly defined, up to 6 m thick bed sub-packets. They occasionally feature coarser sediments and sometimes erosive bases (10 %), showing subtle fining upward at sub-packet and lobe scale. Coarsening upward is rarely observed (fig. 2.16). Beds are arranged in crude 2-5 bed asymmetric bed thickness sequences (40 % of measured beds) with 2-bed thinning- and thickening-upward sequences the most striking ones (total: 70 % of ordered beds; fig. 2.19). However, random vertical organisation prevails. Random, disordered vertical bedding organisation and smaller asymmetric trends reflect irregularities in the volume of flow, concentration, grain size and the pathways of turbidites, compensating pre-depositional relief such as subtle topographic depressions

("compensation cycles"* of Mutti & Sonnino 1981; Millington 1995; Chen & Hiscott 1999a).
Within the Lobe A deposits fine-grained sediments and shales are rare (1 %). They are thin bedded and laterally inextensive (10s of metres), often erosionally cut-off by succeeding flows. Despite the paucity of preserved shale beds, pebble- to small cobble-sized shale clasts are common. They are often associated with coarse-grained to pebbly sandstones with erosive bases.

Scours

Concave-upward scours (*sensu* Mutti & Normark 1987; Pickering *et al.* 1995) produced by intense turbulence are common within the channeling- and lobe deposits, however, they are present at different scales. The smaller scours, micro-scale (cm-dm), are primarily associated with the Lobe A deposits while

scour	length (cm)	width (cm)	l/w	minimum depth (cm)	infill	shape	strike
1	350	240	1.45 : 1	20	CLC	elongate	160 - 340
2	70	60	1.16 : 1	60	CLC	sub-rounded	
3	800	250	3.2 : 1	18	CLC	elongate	35 - 215
3a	250	120	2.08 : 1	?	CLC	elongate	
3b	130	70	1.85 : 1	?	CLC	elongate	
6	950	250	3.8 : 1	30	CLC	elongate	0 - 180

Table 2.6: Scours in the channeling component of the channel-lobe transition zone. Data obtained from scours exposed in plan view. CSC = clast-supported conglomerate.

meso-scale scours (dm-m) are typically found with channeling (fig. 2.16). In the latter, they amount to approximately 5 % of the total component. Here they form isolated, shallow cut-and fill features indicating erosion and subsequent depositional fill. They are typically infilled by pebbly to cobbly, clast-supported conglomerates and pebbly sandstones (plate 4.7). While the lobe and channeling components are 10s of metres thick and 100s of m in lateral extent, these scours appear an order of magnitude smaller (fig. 2.17; table 2.5).
Their elongate, flute-like geometries (high length/width ratios, table 2.6) are interpreted to embody the early development of a scour (Allen 1971), which Millington (1995) ascribed to immaturity, assigning them to an unstable depositional environment. Mature scours approach ratio values of 1:1

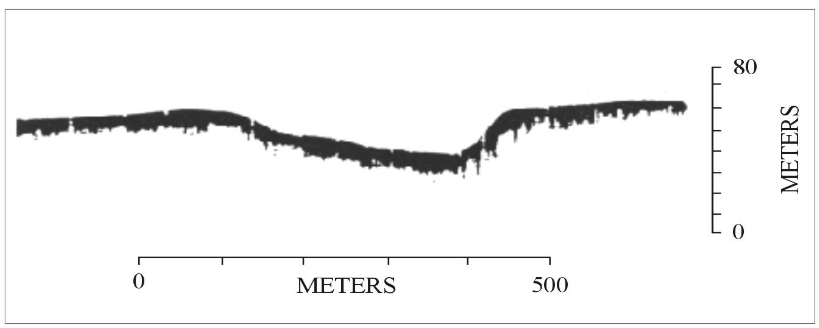

Figure 2.20a : Large-scale scours on Navy fan as observed with deep-tow side-looking sonar. Profile is a dip section showing the steep headwall scarp and that the relief is cut below an otherwise fairly uniform fan surface slope (from Mutti & Normark 1991; adapted from Normark *et al.* 1979).

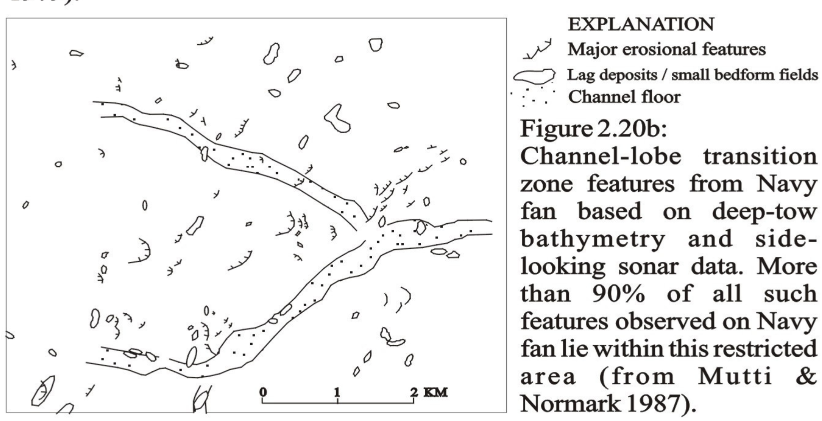

Figure 2.20b: Channel-lobe transition zone features from Navy fan based on deep-tow bathymetry and side-looking sonar data. More than 90% of all such features observed on Navy fan lie within this restricted area (from Mutti & Normark 1987).

* compensation cycles: a set of turbidte beds that collectively fill in low areas created by earlier turbidite depostion that had resulted in local aggradation of the surfaces (Normark *et al.* 1993).

(Allen 1971). The conspicuous absence of mud-drapes suggests that the scour and its infill may be produced by the same flow or that a mud-drape was eroded by a later flow (Mutti & Normark 1991).
Macro-scale scours in the order of 100s of metres could not be observed, however, a subtle, low angel unconformity is present in the lower CLTZ (fig. 2.18; plate 4.3). Although no direct reference is made to low angle unconformities being a feature of transition zones, the large shallow scours seen in modern fans must produce some localised discordances at outcrop scale. Scours observed in transition zones of modern fans (fig. 2.20a,b) may reach depth of up to 100 m and 1 km across (Laurentian Fan: Shor *et al.* 1990) and may occur as groups of scours (5 – 30 m across / 1 – 2 m deep: Navy Submarine Fan: Normark *et al.* 1979). Cazzola *et al.* (1981) suggest that by increasing depth, the infill of large scours may grade into channel-fill deposits.

2.4.1.2 Channel-lobe transition zone: processes, facies and controls

The study area displays characteristics of both the channelized and lobe depositional environments. This is typical of channel-lobe transition zones (CLTZ) which are defined as regions within any turbidite system which separate well-defined channel-fill deposits from well-defined lobe facies (*sensu* Mutti & Normark 1987). CLTZs are regarded as poorly understood sectors of subaqueous fan systems and only few outcrop studies exist (e.g. Marnoso Arenacea: Ricci Lucchi 1981; Rocchetta Formation: Cazzola *et al.* 1981; Hecho Group: Mutti *et al.* 1985; Hecho Group/Morillo system: Millington 1995; Charo-Arro System: Millington & Clark 1995; Peary Land Group/Merqujoq Formation: Surlyk 1995; Macigno costiero: Cornamusini & Sandrelli 2002). Wynn *et al.* (2002) suggest that channel-lobe transition zones should be a common feature worldwide and studies of modern fans include, for example, the Crati Fan (Ricci Lucchi *et al.* 1985), Navy Fan (Normark 1970; Normark *et al.* 1979), Laurentian Fan (Shor *et al.* 1990) and Petite Rhone Fan (Millington 1995). CLTZs have also been recognised in "subseismic"-scale as areas with great relief dissected by numerous low-relief channels, e.g. the Paola Basin systems (Trincardi *et al.* 1995).
The classification of the study area as a channel-lobe transition zone is supported by its position within the fan framework, deposition resulting from turbidity currents undergoing hydraulic jump conditions, the presence of both channeling and lobe deposits and reworked sediments.
The CLTZ is located at the termination of the northernmost feeder canyon (channel 1). The adjacent shelf carbonates and slope (fig. 2.21a) indicate partial areal confinement and thus a more gradual opening up of the basin towards the south. Therefore, the initially confined and channelized flows undergo non-radial flow expansion before becoming completely unconfined (Mutti & Normark 1987, 1991; Millington 1995).
The study of modern fans shows that transition zones are commonly underlain by breaks in slope, creating

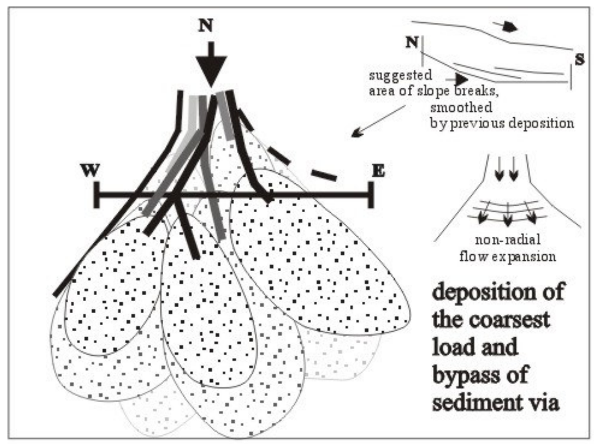

Fig. 2.21a: Conceptual sketch showing channeling and lobe development in the CLTZ. The confining margin allows for a gradual opening up into the basin. Channellised flows are poorly confined and develop laterally into Lobe A deposits. Darker colours indicate youngest deposits.

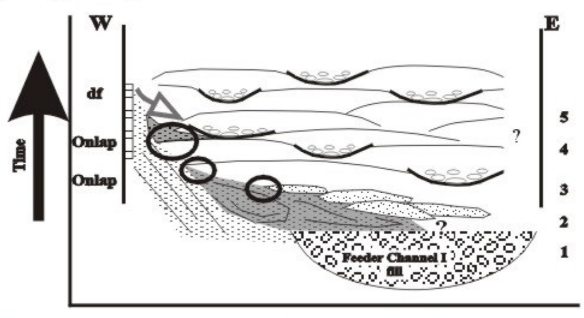

Fig. 2.21b: Cross-section of the CLTZ illustrating the development of the northernmost fan area. Abandoned (?) segments of feeder channel 1 (1) are overlain by collapsed slope deposits (2). Channel mouth and overbank deposits (3) onlap in more central location, indicating renewed channel activity. The channel system is backfilled by the mixed shingled-compensational stacked Lobe A (4) and channeling deposits (5) forming the sand-rich CLTZ. Poorly confined channelized flows may laterally develop into Lobe A deposits. Towards western margin, CLTZ deposits aggrade against collapsed slope debrite.

rough morphological expressions (Navy Fan: Normark *et al.* 1979). However, the apparent backfilling of the feeder channel 1 system by the CLTZ deposits (fig. 2.21b) indicates that previous deposition has probably smoothed slope breaks, giving rise to reduced slope angles (Millington 1995). Nevertheless, as a result of the change in gradient and/or flow expansion (Millington 1995) and/or the flow volume with regard to distance travelled along the longitudinal profile (Mutti & Normark 1987) turbidity currents may undergo hydraulic jump causing increased internal turbulence, enlargement and dilution of flow and a marked increase in erosion (Normark & Piper 1991). As a result of these major changes in flow condition, a highly dynamic erosional-depositional environment with sediment bypass marks the CLTZ. Scouring and amalgamation, rapid deposition of the coarsest sediment faction, reworking of sediments as well as winnowing and bypassing of the finer sediment load are the result.

Millington's (1995) study of the Hecho Supergroup shows that flow bypassing should either erode sediment or rework surface deposits with little to no new net deposition. Scours are located where flow stripping most commonly occurs and the recorded elongate, flute-shaped scours point to immaturity and unstable depositional conditions (Allen 1971; Millington 1995). In this dynamic environment even the creation of large scours can be a matter of minutes rather than hours (Shor *et al.* 1990). Mud-draped scours as typical bypass features (Mutti & Normark 1991) are lacking which may be due to subsequent erosion.

The CLTZ contains the coarsest facies of the sandy basin-fill of the E-Fan (*chapter 2.2*), the deposits often showing inclined traction (bedload) structures indicative of bedload transport (Mutti & Normark 1987) or are thick structureless sediment bodies. Winnowing and bypass of the finer-grained fraction is typical of transition zone (Mutti & Normark 1987, 1991; Millington 1995). The overall paucity of fines is in stark contrast to the relatively high abundance of shale rip-up clasts within the channeling and Lobe A deposits. The large size and angularity of the shale clasts point to short transport distances (Johansson & Stow 1995), suggesting that shales were either deposited within the CLTZ possibly as interchannel or interlobe deposits or slightly further upstream and were subsequently eroded by successive flows. Along the western margin, shale beds and reworked clasts are especially common (fig. 2.16), suggesting that more tranquil conditions favoured shale deposition and preservation in the marginal area. Millington (1995) demonstrated that deceleration in flows exiting a confined environment is not uniform but that the flanks of an expanding flow decelerate much more rapidly than the centre, giving rise to a zonation in facies associations; the centre being erosive in nature resulting in scour- and fill structures, while the flanks are more likely to deposit, for example, thick structureless sandstones (e.g. fig. 2.16, log 1: m 50-60).

Although well-defined channels *sensu* Mutti & Normark (1987) are conspicuously absent, the sedimentary nature of the deposits and the geometric features observed suggest that the conglomerate-dominated areas are associated with channeling. Cazzola *et al.* (1981) studied the channel-lobe transition zone of the Tertiary Roccetta Formation (Piedmont Basin, NW Italy) and found that “channeling” is the product of scouring rather than true channeling. Their differentiation is based on i) the relatively shallow erosional depressions infilled by the same flow that was responsible for the erosion and ii) by the one-bed infill of erosional structures instead of the progressive multiple bed infill clearly onlapping onto channel walls which is characteristic of "proper" channel-fill deposits. However, with increasing depth of a scour, the number of beds infilling a scour will also increase and may eventually grade into channel-fill deposits (Cazzola *et al.* 1981), while through progressive flattening of a scour, gradation into parallel-sided sandstones may take place. Surlyk (1995) and Millington & Clark (1995) found abundant cut-and fill features and small channels filled with relatively few medium- to thick-bedded turbidites to represent the respective channel-lobe-transition zone. Their interpretations are supported by the position of the CLTZ with respect to the mid-fan channels and lobe deposits.

Stratigraphically, the CLTZ is located between well-defined channel-fill deposits up-system and lobe deposits in a down-system position. According to Ricci Lucchi (1985), this suggests an attachment between channel and lobe deposits, typical of sand-rich, low efficiency turbidite systems (*sensu* Mutti 1979). The resulting downcurrent geometry would typically be wedge-like (Millington 1995).

The overall lateral geometry of the channel-lobe transition zone (fig. 2.21a,b) is strongly controlled by the presence of the confining margins (*see above*) at least during the early stages of the CLTZ development. In its geographic centre, the CLTZ is at its thickest, thinning towards the western margin (fig. 2.18, 2.21b). Underlying chaotic slope deposits, thought to have collapsed into the basin margin forming a depositional wedge, are most likely aggraded on to by the CLTZ. Contacts are not exposed, however, onlapping and/or infilling the topography with localised erosion is most likely. Shelf/slope-derived debris flows presumably triggered by seismic activity and/or slope oversteepening or overloading have been recognised elsewhere in

the E-Fan (*chapter 2.3*) and are occasionally found interbedded within the Lobe A and channeling deposits (fig. 2.21a) forming localised topographic obstacles.
The crude fining-upward sequences of 60 to 80 m thickness throughout the CLTZ are created (fig. 2.16) by the highly erosive channeling components at the bases which transitionally fine upward into Lobe A deposits driven by channel abandonment and relocation. In conjunction with the overall fining observed within the channeling component throughout the CLTZ a continued gradual landward shift in the depositional focus is suggested as already indicted by the backfilling of feeder channel 1. This may be driven by the general rise in sea level in conjunction with denudation of the hinterland (Ericella *et al.* 1998).
As demonstrated, the unique development of the CLTZ is controlled by a variety of parametres. These systems may mature through time with continued deposition smoothing out the initial irregular profile and thus display less typical transition zone features (Millington 1995).

2.4.1.3 Lobe A accumulation

The identified Lobe A deposits are unlike the classical lobe deposits *sensu strictu* Mutti & Ricci Lucchi (1972) and Mutti & Normark (1987, 1991). The Lobe A deposits of the channel-lobe transition zone are characterised by an abundance of erosional surfaces, high sediment amalgamation and a conspicuous lack of fine-grained material in an environment marked by its erosional-deposition style and sediment bypass. Associated channeling components appear to pass laterally and vertically into Lobe A deposits.
The clear lack of vertical organisation at sub-packet and lobe scale in conjunction with dominantly crude fining upward suggests an overall aggradational mode in lobe accumulation (e.g. Ricci Lucchi 1985; Shanmugam & Moiola 1988; Chen & Hiscott 1999a), while locally distinctive thickening upward indicates lobe migration into these particular areas (i.e. basal sequences at western margin and central section; fig. 2.16). The presence of channeling indicates sediment-bypass and thus some degree of fan progradation.
Internal cross-current variations in Lobe A facies, i.e. the presence of preserved interbedded fines and abundant shale clasts at the marginal CLTZ position versus the central CLTZ, is probably related to different rates of flow deceleration of the expanding flows with the resulting lateral variation from an erosional-depositional to a more depositional nature (*see above*).
Individual lobe geometries cannot be observed in outcrop and can only be inferred by circumstantial evidence. Field observations indicate that the high concentration turbidity currents were locally erosive, but amamlgamated to form tabular, laterally extensive packages. However, the Lobe A bodies are not believed to form "basin-wide" features, i.e. across the total W-E extend (fig. 2.21a,b), as channeling is i) present at more or less all stratigraphic levels and ii) believed to be relatively shallow and not deeply erosive features. Therefore the Lobe A geometry is rather believed to be driven by the upstream switching of the distributary channels, shifting lobe accumulation into depositional depressions resulting in relatively narrow (maximal width: 600 – 1200 m), elongate, sheet-like bodies (fig. 2.21a).
The component distribution also suggests that channeling is a mostly isolated, relatively short-lived features marked by the frequent lateral and vertical relocation throughout the CLTZ. This observed channel migration may result from i) fairway plugging, ii) topographic lobe build-up and/or channel avulsion due to bifurcation not far upstream (Normark *et al.* 1979; Kneller 1995). Only the observed multistory stacking pattern in the lower CLTZ suggests repeated episodes of increased activity within a more persistent fairway.
The distribution of Lobe A and channeling components and their downcurrent and cross-current relationships suggests an offset-stacked pattern akin to a mixed shingled-compensational stacking of Bouma (2000) rather than a simple vertical stacking of the lobes (fig. 2.17). Mixed retrogressive shingling due to a progressive landward shift mixed with occassional progradation is likely (fig. 2.17)

2.4.1.4 Channel-lobe transition zones associated with feeder channels 3 and 4

Channel-lobe transition zones were identified in the NW of the E-Fan but of much poorer exposure (study area 3; fig. 2.10). Transsection and offsetting by multiple faulting prohibits a detailed analysis. They appear to be associated with feeder channels 3 and 4 respectively, passing into lobe deposits located to the south and east. Here, the transition from channelized, conglomeratic deposits to sandstone-dominated, non-channelized deposits can be observed (fig. 2.22).
Just like the CLTZ associated with feeder channel 1, laterally extensive, very coarse- to coarse-grained, amalgamated sandstones dominate, while occasional conglomerates and pebbly sandstones are confined to

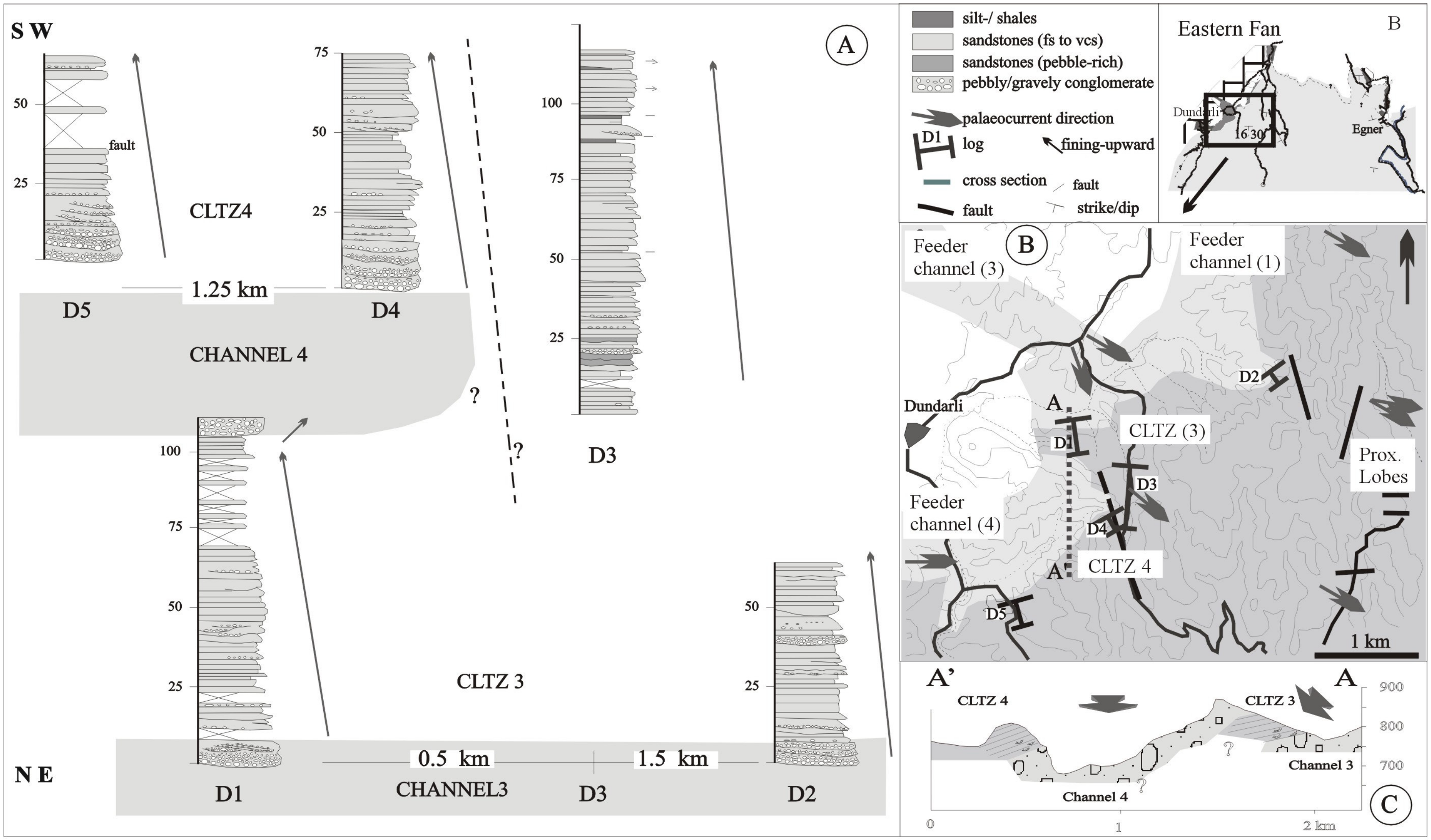

Fig. 2.22: A) Facies of transition zones associated with feeder channels 3 and 4 are located in the NW of the E-Fan. B) Location map indicating position of logs and cross-section as well as the relationship with proximal lobe section to the east. C) Cross-section through CLTZ and channel fill deposits showing the position of the respective fan environments (channel-fill mapped by N. Satur).

small-scale cut- and fill structures (fig. 2.22). Scouring and traction structures are common. The large overall fining-upward sequences are believed to have been generated by upward-passing into Lobe A deposits, upstream channel switching or forced migration due to topographic build-up of Lobe A deposits.
In contrast to the northern CLTZ, no areal confinement of the zone appears to be present thus flow expansion must have been more rapid than at the CLTZ associated with feeder channel 1 resulting in more pronounced "typical" transition zone features described in literature (e.g. Mutti *et al.* 1985; Millington 1995). It is believed that the lower proximal lobe zone is the downcurrent equivalent of CLTZ associated with channel 4 and/or of the possible (?) confluence of channel 3 and 4, if channel 3 was still active at this time. However, the exact relationship cannot be conclusively established.

2.4.2 Proximal Lobe Zone

In the north-western fan area an approximately 300 m thick coarse-grained, sandy complex stratigraphically succeeds the channel-lobe transition zone to the west (*chapter 2.2*). Overlying sediments gradually thin and fine upward into distinct lobe packages interbedded with increasingly thicker interlobe and/or lobe fringe and fan fringe deposits in a distal, basinward direction.
The top 230 m are well exposed in a N-S, near dip-parallel section along a deforested hillside, roughly perpendicular to the palaeocurrent direction (fig. 2.23). The palaeocurrent indicators point to SE-E transport directions suggesting that this area was sourced from the west, from feeder channels 3 (?) and/or 4 (fig. 2.10). The up-stream, contemporaneous channel-fill deposits are not preserved, deposits of the top CLTZ associated with feeder channel 4? may correspond to the lowermost proximal lobe zone, however, relationships are obscured by abundant faulting. The down-stream deposits are not exposed.

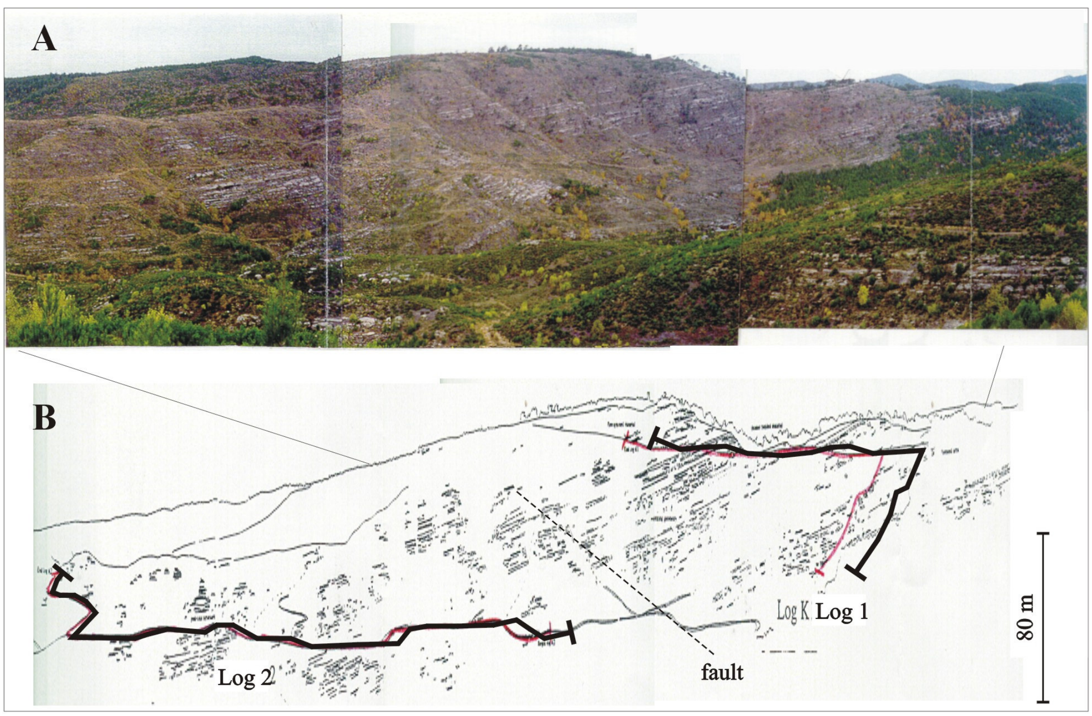

Figure 2.23: A) Aerial photograph showing the northern part of the proximal lobe zone. The hillside faces east, feeder channels 3 and 4 are located approximately 3 km to the west, behind the hill. Palaeocurrents point to SE-E transport direction. Beds dip 15° to south (left).
B) Line drawing of the northern and central proximal lobe zone with 2x hight exaggeration. Position of Logs 1 and 2 are indicated.

Three logs were recorded, essentially covering the lateral development within these deposits (fig. 2.24). Generally, the outcrop quality is limited by i) at times poor exposure and ii) the sediments having undergone deep weathering and pervasive coating by lichens. Individual sandstone bodies can be traced for a maximum distance of 1.2 km before being displaced by faulting. Faulting is abundant (fig. 2.24), offsetting deposits of

mostly unknown vertical and lateral extent. The geometry of the lobe sequence was distinguished by means of photomosaics and linedrawings.
This complex is characterised by a very high sand/shale ratio (32:1). Thick-bedded, laterally extensive, coarse-grained sandstones and pebbly sandstones are arranged in discrete units (fig. 2.24) which are occasionally cut into by shallow channelized components or overlain by fine-grained fringe components. Conglomeratic beds and shale beds are rare, predominantly confined to the channel and fringe deposits respectively. Overall, distinctly pebble-rich and finer-grained sections are present, depicting 4 subtle fining-upward trends (log 1; fig. 2.24) in an overall fining-upward sequence.

2.4.2.1 Component analysis: internal organisation and geometry

Lobe B deposits

90 % of the proximal lobe zone are made up of 8 - 50 m thick lobe deposits characterised by a high net sand content (> 95 %), very coarse bases and an overall fining upward (fig. 2.24; table 2.7). Individual lobe bodies commonly succeed each other, their basal boundaries marked by sharp grain-size increases (fig. 2.25) while the tops are occasionally erosively cut into by distributary channels or transitionally or abruptly pass upward into finer-grained lobe fringe deposits.

Component	Total %	Magnitude components (v:lat in m)	Magnitude sediment beds (v:lat in m)	Constituents ratio (C/S/SH)	Sedimentology	Cycles
Lobe B	90 %	8 - 50: > 1200; downcurrent extend: ~ 2400 - 4800	S: 0.6–2.5: > 1200	0/20/1	pebbly S & S1-3, rare SH, sandy debrites	crude f-ups, rare c-ups asymmetric & random bedding organisation
Distributary channels	8 %	1 – 5 d : 20 w	S: 0.1 – 1.3 : 20 C: 0.1 - 0.5: 1.5	1/10/1	R3,S1-3, pebbly S, rare C (R1)and SH, sandy debrites	subtle f-up, thin-ups
Lobe fringe	2 %	2-8 : >700	S: 0.05 - 0.2: > 700	-/3/1	Tc-e	thin-ups

(Abbreviations: v=vertical, lat=lateral, d=depth, w=width, l=length, C=conglomerate, S=sandstones, SH=shales, f-up=fining upward, c-up=coarsening upward)

Table 2.7: Hierarchy of scales of components of the proximal lobe zone.

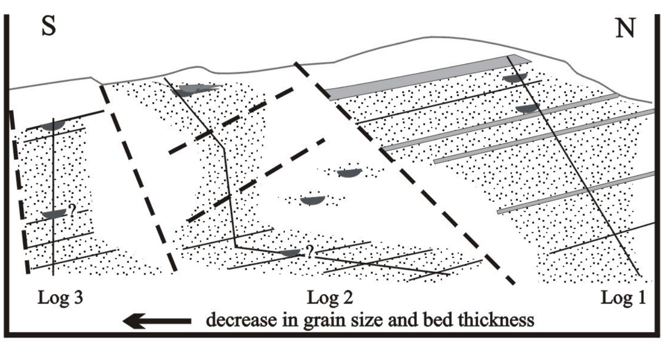

Figure 2.25: Diagram showing component arrangement in the proximal lobe zone. Pod-like structures identified from photomosaics revealed coarser, strongly erosive, and partly wedging sandstone bodies which are interpreted to represent distributary channels. Components: Lobe B deposits (*sandstone signature*), interlobe deposits (*grey*), distributary channels (*dark grey*). Blank areas denote dominantly very poor or no exposure, only major faults are shown. Distances from base Log 1 to base Log 3 approximately 1.8 km. 5 x vertical exaggeration.

The Lobe B deposits are composed of coarse-grained sandstones and pebbly sandstones (fig. 2.24, plate 5.1) which typically exhibit massive bases and some crude stratification, poor to moderate sorting and normal grading (59 % of beds). Occasional parallel lamination and trough-cross bedding are present as well as zones of synsedimentary water escape structures (plate 5.2). Bioturbation (burrowing) is rare (plate 5.3). Beds are highly amalgamated, and they appear to be between 0.4 to 1.2 m thick. Composite beds with indistinguishable amalgamation surfaces may reach thicknesses of up to 3-4 m, (plate 5.4), in some cases forming up to 35 m thick amalgamated complexes. These composite beds are often structureless, non-graded and may contain abundant shale clasts resembling deep-water massive sands (DWMS) of Stow

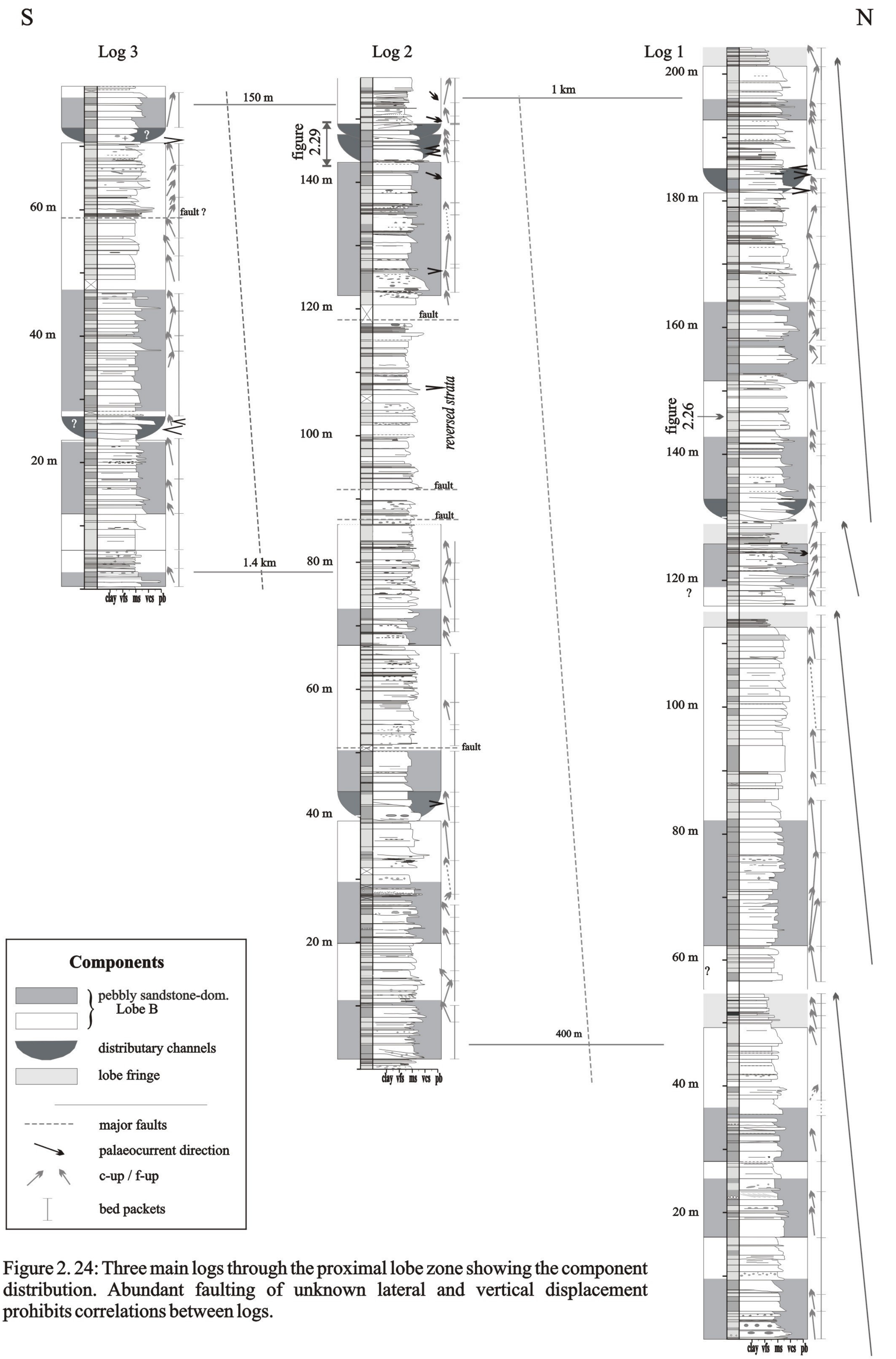

Figure 2. 24: Three main logs through the proximal lobe zone showing the component distribution. Abundant faulting of unknown lateral and vertical displacement prohibits correlations between logs.

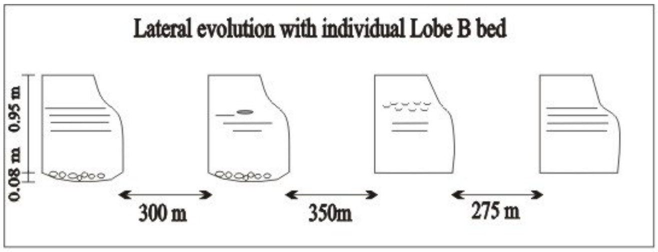

Figure 2.26: Over 925 m lateral extent no significant changes in grain size and thickness are present. Thickness variations are a function of the depth of scours.

& Johansson (2000). Sandstone beds and DWMS are laterally extensive and can be traced for up to 1.2 km maximum without displaying any significant thickness changes apart from irregular, but abundant basal scouring (11 % of beds) resulting in subtle thickness variations. No significant lateral facies changes were observed (fig. 2.26). Pebbly sandstones and matrix-supported pebbly conglomerates are mostly confined to scour-infills. Occasionally, distinct wedging of beds can be observed (plate 5.5). The deposits can be classified as R3,S1-3 deposits of Lowe (1982) and DWMS (Stow & Johansson 2000), resulting from deposition of gravelly to sandy high density turbidity currents and sandy debris flows (*sensu* Shanmugam 1996). Little shale and fine-grained facies are preserved, however, shale-rip up clasts are common suggesting initial shale deposition and subsequent erosion and short transport distances by succeeding flows (Johansson & Stow 1995).

Internally, the lobes are composed of poor to moderately defined bed sub-packets (fig. 2.24). These are typically 2-6 m thick (max. 11 m), involving an average 6-8 beds and are characterised by either asymmetric or random organisation or distinctive grain sizes and often display erosional bases. Asymmetric bed thickness trends (52 %) slightly dominate over random arrangements (44 %), with 3 - 4 bed thinning-upward sequences the most common (fig. 2.27). Symmetric sandstone compensation cycles or microsequences suggested to be characteristic in proximal lobe environments (Stow & Johansson 2000) are rare (4 %). Similar to Lobe A deposits, the small asymmetric and random bedding organisation are believed to reflect different process such as irregular variations in flow volume and concentration and topographic compensation (e.g. Mutti *et al.* 1978; Chen & Hiscott 1999a). The differentiated fining-/coarsening-upward trends at bed sub-packet scale (fig. 2.24) do not always correlate well to the observed bed thickness trends. Individual lobes show crude fining upward, however, some basal coarsening upward (centre log 1, fig. 2.24) and overall coarsening upward (top log 1) has been observed. Generally, though, the observed overall lack of well-defined vertical order at bed package and lobe scale is striking and typifies an aggradational mode in lobe accumulation (Ricci Lucchi 1985; Chen & Hiscott 1999a).

In absence of the complete lateral and 3-D exposure, the general Lobe B geometry can only be inferred. Lensing was not observed at outcrop scale, at 1.2 km lateral extent, the beds, bed packages and lobe bodies appear to possess a more tabular geometry which is believed to reflect the whole-body geometry (fig. 2.28; Stow & Johansson 2000). Deposits in the south of the study area (log 3; fig. 2.25) are slightly thinner-bedded and finer-grained, essentially suggesting that these inhabit a more lateral (cross current) position within the proximal lobe depositional environment (*see Lobe B accumulation*).

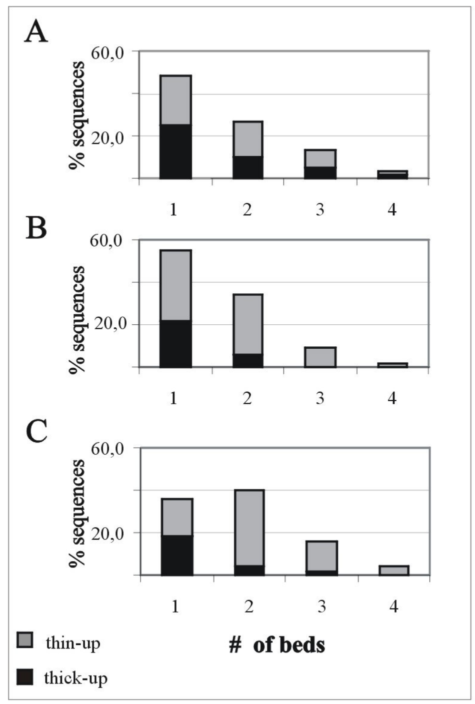

Figure 2.27: Asymmetric bedding sequences within A) Lobe B, B) distributary channels and C) lobe fringe deposits of the proximal lobe zone (2-bed moving-average smoothing technique after Heller & Dickinson 1985). Note that 44% of beds in Lobe B deposits show random vertical organisation.

Distributary channels

The lobe deposits are occasionally cut into by prominent, shallow channels (8 % of total section; fig. 2.24; table 2.7). These channels display width/depth ratios of 20:1 to 4:1 (1 - 5 m deep / up to 20 m across).

Their infill is characterised by moderately defined bed sub-packets of 3- 5 beds of very coarse-grained sandstones, pebbly sandstones and pebbly conglomerates (R1 and R3, S1-2 of Lowe 1982), arranged in thinning- and fining- upward sequences (67 % of sequences; fig. 2.27). Irregular interbedding with thinly-bedded fine sand and shales (Tc,d of Bouma 1962) is present. The conglomerate/sand/shale ratio is 1:10:1.

Multiple-stage infill is occasionally present (fig. 2.29). The infills display a series of erosional features such as scours, cut-downs and the deposition of residual facies representing the erosional-depositional channel type *sensu* Normark (1970) and Mutti & Normark (1987). 0th to 2nd order bounding surfaces, based on Pickering *et al.* (1995), are present (table 2.28).

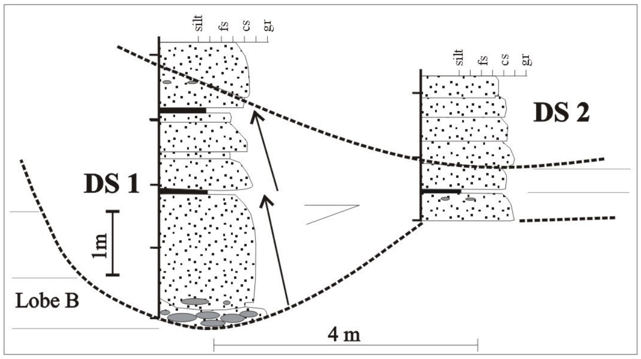

Figure 2.29: Channel amalgamation and multistage infill of distributary channel component. Note erosion into Lobe B to left and "wing"-development to right of DS1.

The channels represent isolated features within the proximal lobe deposits (fig. 2.25). However, plate 5.1 shows an example of a multilateral offset-stacked channel growth pattern (*sensu* Pickering *et al.* 1995). The distinct wedging of beds towards the channel margin (65 % thickness decrease) and bed continuation beyond the actual channel geometry (plate 5.6; fig. 2.29) suggest that the shallow depth of the channel could probably not retain the head of the density current (Weimer 1989). It thus resulted in deposition outside the channel geometry, leading to a wing-like geometry (fig. 2.28).

Wüllner & James (1989) imply that the observed pod-like geometries and thinning-upward sequences are characteristic of meandering channel systems. Einsele *et al.* (1994) found fining-upward sequences to result from lateral channel migration. The flow conditions that could lead to the development of meandering or branching submarine turbidite channels are poorly known at present (Mutti & Normark 1987; Shanmugam 2000). The erosional-depositional style and the occasional channel amalgamation further suggest prolonged channel activity in places. The observed channel abandonment and/or shift may be caused by up-stream channel avulsion, the progressive plugging of a channel fairway or lobe build-up (Normark *et al.* 1979; Normark & Piper 1985; Surlyk 1995).

Bounding surfaces in distributary channels	Hierarchy after Pickering *et al.* (1995)	Architectural elements after Pickering *et al.* (1995)
Bed planes of laminae	0th order	Pebble and sandstone laminae (> 0.01 m thick)
Individual bedding planes	1st order	Individual bed (0.01 - 0.6 m thick)
Bed sub-packet planes	2nd order	Bed package (1.6 – 5 m thick)

Table 2.8: Bounding surfaces distinguished in distributary channels of proximal lobe zone.

Small distributary channels have been noted in the normally unchannelized lobe environment (Normark *et al.* 1979; Ericella *et al.* 1998) where they are commonly associated with the coarsest facies present (Cazzola *et al.* 1985), showing little to no associated levee development (Ricci Lucchi 1975a; Damuth & Flood 1985; Wilde *et al.* 1985). The lack of levee deposits in conjunction with the channel geometries may result from the rapid migration and deposition within this distributary system (Normark 1978; Normark & Piper 1985; Garrison *et al.* 1982).

The distributary channels associated with Lobe B deposits are probably located along their edges and/or in marginal depressions as suggested by the asymmetric erosional pattern where confinement by lobe deposits is present on one side and a partial wing development on the other. Fairways in that position may result from slightly accelerated turbidity current flow as the current moves off the lobe onto the adjacent lower surface of the fan (Normark *et al.* 1979; Normark & Piper 1985). Ricci Lucchi (1975a) found channeling in proximal lobe environment to result from fan progradation and their association with the pebbly sandstone-rich intervals is striking (fig. 2.24).

In other areas, well-defined channel geometries are absent but prominently wedging sediments, individual beds and groups of beds, are present. These are present throughout the whole section (fig. 2.24). Strongly wedging beds were observed in connection with channel geometries (this study), however, proximal lobes were found to have prominent topography (Normark *et al.* 1979) and wedging resulting from topographic compensation cannot be discounted (Kneller 1995).

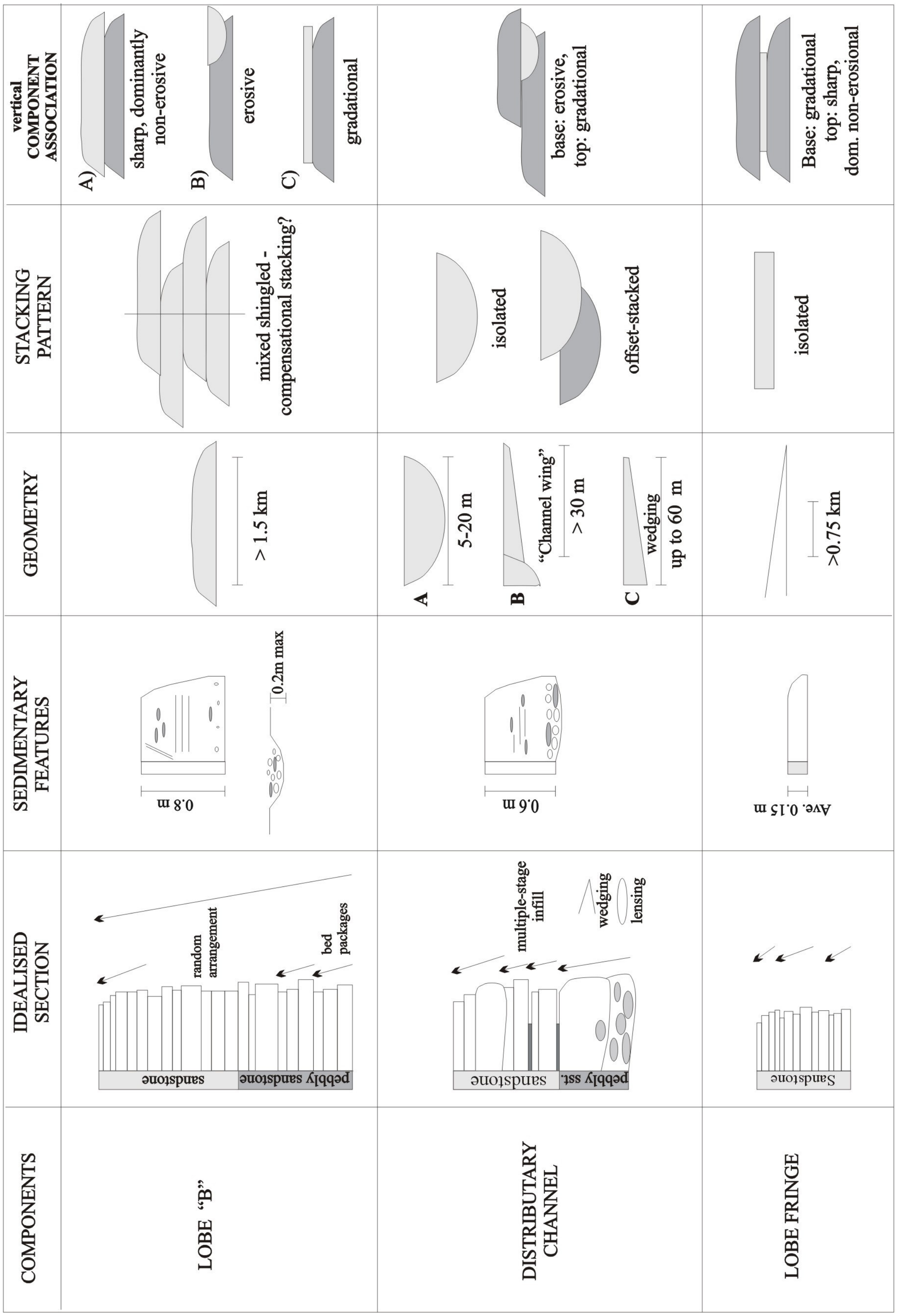

Figure 2.28: Characteristics of differentiated components in proximal lobe zone, their sedimentology, geometries and stacking pattern.

Lobe fringe deposits

The lobe deposits may transitionally grade into distinctly finer-grained and thinner-bedded units which are characterised by a considerably lower net sand content (sand/shale ratio = 3:1). These deposits are interpreted to represent the fringe environment (*sensu* Mutti & Ricci Lucchi 1975; Ricci Lucchi 1981) of the proximal Lobe B deposits. The lobe fringes are always sharply overlain by lobe deposits (fig. 2.24).
The fringe facies is characterised by thin-bedded (2 - 20 cm), fine to very fine sand-sized sandstones, often displaying well developed lamination (Tc-e; Bouma 1962), which are typically interbedded with thinly-bedded shales (plate 5.7). The sediments indicate relatively more tranquil depositional conditions (Mutti & Normark 1987). Bioturbation was not observed. Beds are arranged in crude, up to 60 cm thick, thinning-upward sequences typically involving 2 - 4 beds (fig. 2.27). These sequences are likely to result from waning flow volume or concentration (Chen & Hiscott 1999a).
The overall thickness of the fringe deposits varies. In mid section (fig. 2.25), they are up to 2 m thick, becoming increasingly more common and thicker (> 6 m) towards the top. They are a laterally continuous feature which can be traced for approx. 1200m (midsection; top: 750 m; Log 1: fig. 2.24), before being obscured by vegetation and faulting. Throughout this lateral distance, no significant lateral changes in facies and thickness were observed. The absence of their lateral development into lobe deposits is striking.
Overall, the lobe fringe deposits appear as isolated features, representing approximately 2 % of the section (table 2.7). Their geometry is inferred to be smooth wedge-like representing the cross-current as well as downcurrent pinch-out of lobe deposits.

2.4.2.2 Lobe B accumulation

The depositional pattern of the Lobe B deposits does not fit the classical lobe definition *sensu strictu* Mutti & Normark (1987) where well-defined, coarsening-upward lobe deposits are encountered in the non-channelized outer-fan environment (*sensu* Mutti & Ricci Lucchi 1972), separated by variable amounts of fine-grained material. The Lobe B deposits are characterised by a very high net sand content, poor vertical organisation at bed sub-packet scale and often crude fining upward at lobe scale separated by minor intervals of thin-bedded turbidites in an overall fining-upward complex.
Irregular lobe topography and erosive flow power appear to characterise the proximal lobe depositional environment. For example, sandy to fine gravelly macrodunes with mean wavelength of several 100 m and > 5 m relief have been recognised in the proximal sandy lobes of the Laurentian Fan (Hughes Clarke *et al.* 1990; Normark & Piper 1991), while at the same time small-scale compensation cycles, expressed as asymmetric sequences, suggest progressive smoothing of topographic relief (Hecho Group: Mutti & Sonnino 1981; Mutti & Normark 1987). Similar small asymmetric compensation cycles are common throughout the Lobe B deposits, however, strongly wedging beds probably due to relief compensation (Kneller 1995) are most conspicuous. Subtle wedging beds (1 m over 100 m) of the proximal lobe environment of the Kongsfjord Formation (Pickering 1981) result from laterally subtle but extensive erosion. Similar lobe down-cutting was observed in the Laga Formation, Italy (Mutti *et al.* 1978). However, this cannot be confirmed for the E-Fan proximal lobes. Erosional flow power is confined to sediment reworking and relatively frequent basal scouring of individual beds, which Savoye & Piper (1990) relate to the initial erosive power of sandy flows before deposition takes place. Frequent scouring is a common feature in ancient proximal lobe depositional systems (e.g. Hecho Group/Fiscal Lobes: Mutti & Normark 1987; Laga Formation/Italy: Mutti *et al.* 1978).
The component arrangement reveals stacked Lobe B deposits forming a large, approximately 300 m thick sand-rich complex. The lobes are occasionally interbedded with shallow, isolated and/or offset-stacked distributary channels and isolated lobe fringe deposits (fig. 2.25). While the distributary channels form small entities within the large complex, both the Lobe B and lobe fringe deposits are laterally persistent features in excess of 1200 m. No lateral gradation to and from lobe to lobe fringe deposits was observed at outcrop scale.
The thinning- and fining upward of most of the lobes and the lobe complex contradicts the typical view of thickening-upward lobe successions, interpreted to result from lobe progradation (e.g. Mutti & Ricci Lucchi 1972). The internal organisation of the lobes reveals a slight dominance of asymmetric, mostly thinning-upward sequences, however, random arrangements are frequent. It has been recognised that lobes can forme by aggradation resulting in the lack of thickening-upward successions (e.g. Ricci Lucchi & Valmori 1980; Hiscott 1981; Shanmugam & Moiola 1988; 1991; Chen & Hiscott 1999a). Rarely, the lobes display some

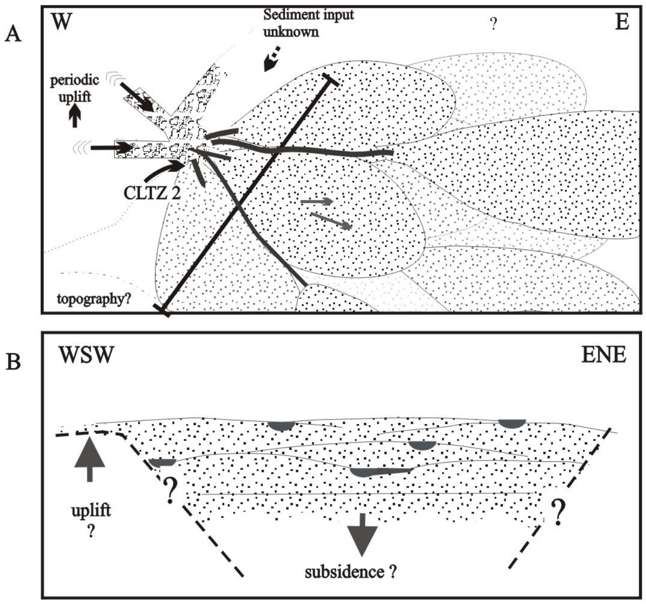

Figure 2.30: A) Conceptual drawing of Lobe B development in proximal lobe zone.The area is fed from the W and NW, the input from the N is believed to be diminished at this stage. The channel-lobe transition zones 3 / 4 are located between the feeder channels and the proximal lobe zone.
B) The pre-Cingöz basin topography was controlled by pre-existing structures (Williams *et al.* 1995) leading to locally enhanced sediment accumulation. A probably fault-controlled intrabasinal depression underlying the NW E-Fan area created a semi-restricted accommodation space which acted as sediment trap and fairway to more distal fan areas. Tectonic and/or bulk sediment weight controlled subsidence. Sporadic overspilling at topographic margins led to reduced sediment deposition in especially the WNW fan area.

basal or overall coarsening upward suggesting lobe progradation or migration into this particular depositional area. The presence of distributary channels throughout the lobe complex, however, suggests that some progradation is taking place (Ricci Lucchi 1981; Shanmugam & Moiola 1991).

Observations from the modern Navy Fan (Normark 1979; Normark *et al.* 1979) suggest that "true" distributary channels other than the depressions along the edges of lobes are not present in the proximal lobe environment. The lobe topography diverts distributary channels, following a path between the lobe depocentres leading to a sinuous channel pattern. While this appears to explain the isolated nature of the observed distributary channels underlining their status as short-term conduits and their abrupt channel relocation probably along the marginal lobe edge depressions (e.g. top log 2, fig. 2.24), it, however, does not explain channel positions not located at lobe edges (e.g. top log 1, fig. 2.24). They rather indicate channel formation on top of older lobes. Thus some channel locations appear to be controlled by allocyclic rather than autocyclic mechanisms. Lobe formation at the respective distributary channel mouth will either be located between or overlap with distal parts of previously deposited sandstone bodies. The development of channel wings, where poorly-contained flows laterally develop into sheet-sandstones blurrs the difference between "true" channel and "true" lobe deposits (top log 2), leading to interlobe depressions filled with relatively coarse-grained sheet sandstones.

Chen & Hiscott (1999a) favour autocyclic mechanisms to drive lobe accumulation at 10s of metre scale discounting progressive basinward-landward advance or retreat of one sub-environment over another. Simple lateral lobe switching resulting from lobe build-up, upstream channel switching and avulsion (e.g. Walker 1978; Chen & Hiscott 1999a) is likely to result in the observed vertical organisation and stacking pattern, producing a latero-vertical growth pattern akin to “compensation cycles” (Normark *et al.* 1979; Ricci Lucchi 1981; Surlyk 1995). As some progradation exists, a mixed shingled-compensational pattern *sensu* Bouma (2000) may be present, amalgamating lateral and progradational offset-stacking (fig. 2.30a).

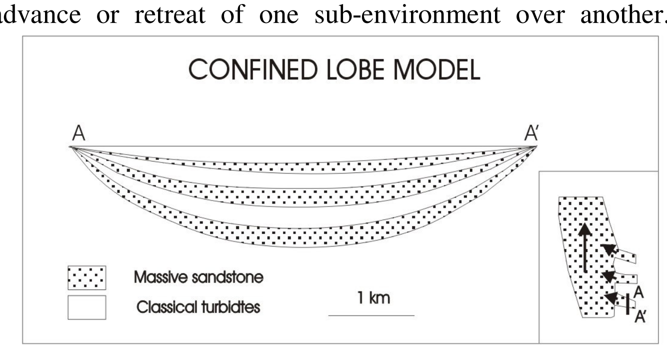

Figure 2. 31: Diagrammatic representation of the confined lobe model, showing the vertical alternate stacking of broadly lenticular units composed of massive sandstone and classical turbidites. Deposition occurred in pre-existing topographic depressions that very likely acted as sediment fairways to the open basin. Inset shows the alleged position of the fairways with respect to the open Pindus Basin (from Schuppers 1995).

However, a mechanism to explain the top lobe location of some of the channels suggests that other mechanisms such as tectonics, sediment supply and eustasy may play a role in the development of the proximal lobe zone (Normark & Piper 1991; Pickering *et al.* 1995).

For one, tectonic activity causing localised uplift, exposing the hinterland and proximal (channelized) fan areas to erosion, proved to be frequent throughout the fan development (*chapter 2.2*). This may account for the observed increased supply of coarse material to the basin, periodically bringing on coarser sedimentation, resulting in the sharp, coarse onset of the Lobe B deposits. A gradual recession of an individual lobe following retrogressive slumping and headward migration of the source area may also account for the observed smaller-scale fining-upward cycles (Surlyk 1995) as well as higher frequency changes in relative sea level and/or changes in sediment supply, flow volume, shelfal accommodation space and denudation of the hinterland (Einsele & Ricken 1991; Normark *et al.* 1993; Mutti *et al.* 1994; Pickering *et al.* 1995; Chen & Hiscott 1999a). The observed sharp onset of lobe fringe deposits following a coarsening-upward Lobe B body (top log 1) suggests abrupt lobe abandonment in places. However, the overall facies organisation reflects the effect of a generally rising sea level and/or grain size reduction following denudation of the hinterland resulting in a landward shift of the depositional locus producing the observed overall fining-upward sequence.

The observed aggradational lobe-fill and mixed vertical, off-set stacking pattern reflect a semi-restricted spacial development where deposition is not free to migrate. Sedimentary input from the N (feeder channel 1) is unknown and no evidence of flow mixing is present. However, the rapid thickness reduction and eventually pinch-out towards the S-SW is striking (*chapter 2.2*, lateral-marginal fan facies). The complex seafloor topography prior to fan deposition (Williams *et al.* 1995) may lead to enhanced sediment deposition in some areas (Kneller 1995), while differential subsidence recognised within the basin allowed for vast thickness accumulations in the central basin sector during later stage fan development (*chapter 2.2*). Lobes B are believed to have developed in a similarly restricted environment, where tectonically driven and/or load induced differential subsidence of a basin segment created laterally restricted accommodation space akin to the confined lobe model of Schuppers (1995). But while the lobes of the Arakinthos Sandstone (Schuppers 1995; fig. 2.31) formed "depression-wide" features, the component distribution of the proximal lobe zone suggests at least some lateral migration of lobe deposition (fig. 2.30b), although intraformational onlapping was not observed. Ricci Lucchi & Valmori (1980) demonstrate that syndepositonal subsidence maintained a topographic depression into which the Post-Contessa subinteral of the Marnosa Arenacea Formation was deposited resulting in the highest rate of deposition within the system, something similar which is suggested for the Lobe B accumulation. This probably fault-controlled topographic depression acted as a sediment trap but also as a fairway for sediment to more distal areas, damming lateral sediment dispersal (Ricci Lucchi 1975a, 1981; Normark & Piper 1991; Stow & Johansson 2000).

The lateral and vertical association of Lobe B with distributary channels and their proposed deposition in intervening lows suggests a more elongate, sheet-like geometry. Their areal extent, i.e. downcurrent extent, is suggested to range in excess of between 2400 to 4800 m based on length:width ratios of 2:1 to 4:1 for ancient lobes (Stow & Johansson 2000). The actual downcurrent extent is believed to be much greater, since only partial width measurements are available.

2.4.3 Distal lobe deposits

In the east sediments of the relatively distal fan environment are well exposed along the Seyhan River road cut (plate 6.1). 860 m of laterally extensive, sand-rich packages and associated finer-grained deposits span from the slope/fan contact in the north to the basinal shales in the south (fig. 2.32; *chapter 2.2*). The outcrop quality is generally good, only limited by occasional poor exposure and deep erosion by Quaternary fluvial gravels. The section essentially forms a linear exposure with maximal 200 m lateral control. The best exposed sections of primarily sand-dominated deposits were selected for detailed studies. Vertical and lateral logging was carried out to analyse the sedimentology and dynamics of the system, the elemental components, their geometry and small- to large-scale vertical and lateral variability. The detailed analysis of the lateral logging is discussed in chapter 4 (reservoir characterisation). The palaeocurrent pattern points to an ENE-NE transport direction which is near parallel to the confining northern basin margin. The sections are mostly dip-parallel and either perpendicular or slightly oblique (max. 15°) to the general palaeocurrent direction.

The deposits are of Langhian age and thus younger than the channel-lobe transition zones and proximal lobe zone. They are sourced from the same feeders (geochemical pilot study: Satur 1999).

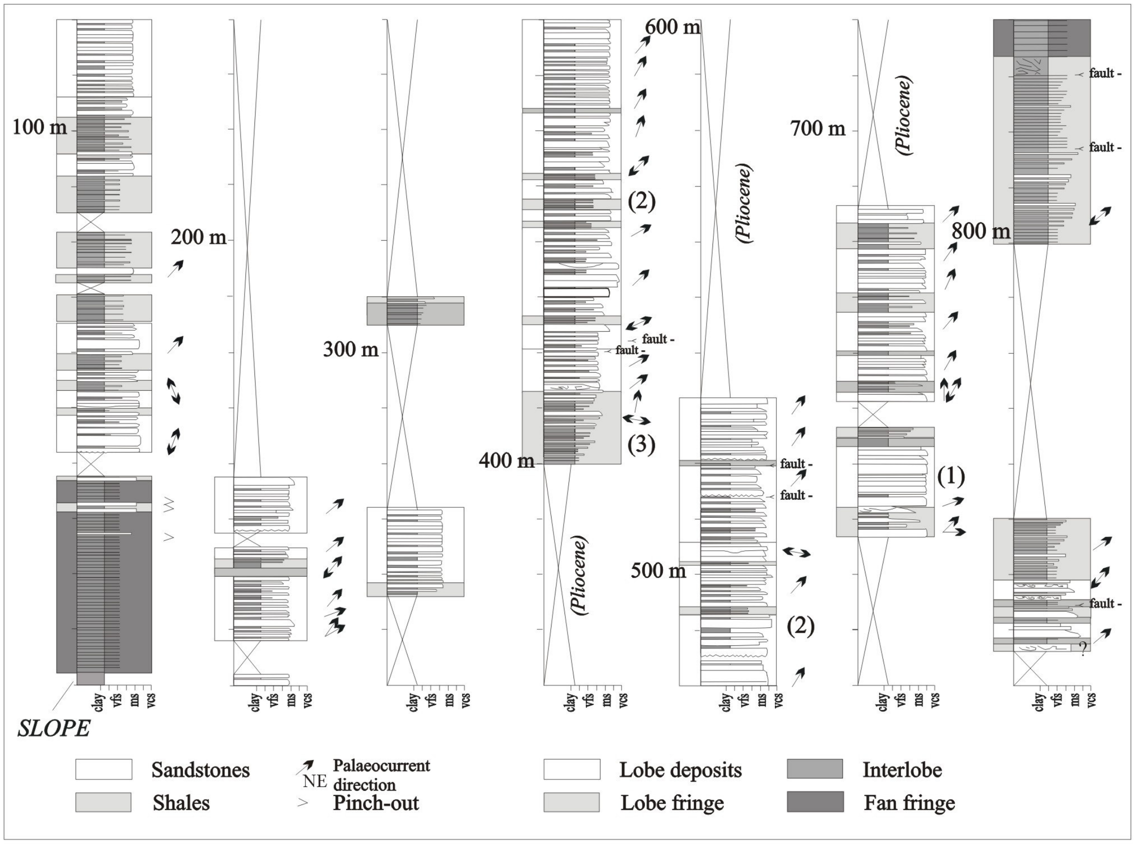

Figure 2.32: Summary log of the distal lobe zone exposed along the Seyhan River showing fan sediment from fan-slope contact in north (bottom left) to fan fringe deposits in south (top right). The palaeocurrent indicators point to a general NE transport direction. Detailed logs presented in chapter: (1) lobe fringe-lobe deposits, (2) bed thickness plot lobe deposits, (3) stacked lobe fringe. The component interpretation is based on detailed logs of the section.

2.4.3.1 Component analysis: internal organisation and geometry

Lobe C deposits

Discrete packages of high sand: shale ratio (6:1) dominate the eastern section. They form 65 % of the total section. Individual packages are between 4 - 35 m thick, dominated by non-erosive, laterally extensive sandstones. They are interbedded with distinctly finer-grained and thinner-bedded deposits exhibiting largely transitional contacts. They can be defined as "depositional lobes" *sensu* Mutti & Normark (1987).

Components	Total %	Magnitude components (v:lat in m)	Magnitude sediment beds (v:lat in m)	Constituents ave. ratio (S/SH)	Sedimentology	Vertical arrangement
Lobe C	65 %	4 – 35 : >200	S: 0.15-2.5 : >200; ave v: 0.45 SH: 0.01-0.1: >200	6/1	S2-3, Ta-d(e), rare pebbly S & SH, sandy debrites	random, some asymmetric c-up & f-ups
Lobe fringe	22 %	3 – 15 : > 150	S(ave): 0.2 : >150 SH: 0.01–0.12 : >150	2/1	S3, mostly Tc,d (e)	asymmetric, c-up & f-ups
Interlobe	4 %	5 – 15 : > 150	S(ave): 0.1 : >150 SH: 0.01–0.1 : >150	1/1	Tc-e	random; some symmetric
Fan fringe	9 %	> 10 : > 100	S: 0.05-0.1 : >100 SH: 0.5–0.2 : >100	1/1.5	Tc-e, hemipelagites	random

(Abbreviations: v=vertical, lat=lateral, S=sandstone, SH=shale, ave=average, f-up=fining up, c-up=coarsening up)

Table 2.9: Hierarchies of scales of components in the distal lobe zone.

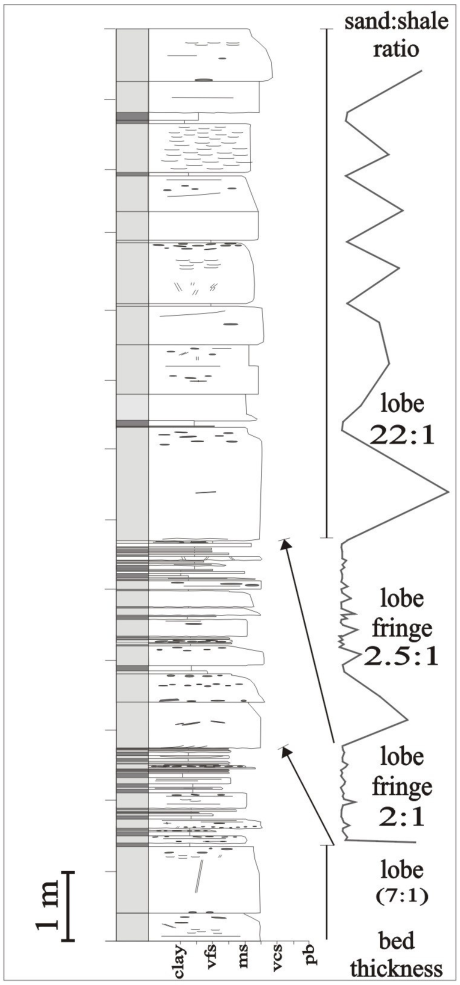

Figure 2.33: Stacked, fining-upward lobe fringe deposits, overlain by sand-rich Lobe C deposit (mid-section Seyhan River Section: (1) of figure 2.32)

The sand content varies widely reflecting the more central or marginal position of the lobe deposits respectively. The lobe deposits have sand/shale ratios ranging from 22:1 (central section; plate 6.1) to 4:1 (marginal areas). They are composed of medium- to coarse-grained sandstone beds averaging 0.45 m in thickness (fig. 2.33; table 2.9). Amalgamation of beds can lead to composite thicknesses of up to 2.50 m in places. The bed thickness can vary considerably at metre scale, which is largely a function of the size and depth of present scours. However, over 200 m lateral exposure, no significant overall thickness variations are present. Towards the marginal areas beds become thinner-bedded and finer-grained and eventually pinch out against the slope (*chapter 2.3.1*) and into fan-margin/basin plain facies respectively (fig. 2.32).

The moderately to well sorted sandstone beds show normal grading (75 % beds), often with rapid fining towards the top of beds (plate 6.2). Massive bases and stratified tops (S1-3 (Lowe 1982) and Ta-c(d,e) (Bouma 1962)) are most common, suggesting deposition from sandy, high-density turbidity currents and diluted flows (Lowe 1982) or occasionally from sandy debris flows (*sensu* Shanmugam 1996; *discussion chapter 5.1*). Deposits of high density currents are typically non-graded, however, the observed normal grading may result from syndepositional fluidisation (Nichols *et al.* 1994). In the marginal positions, beds show more often Tc-e (Bouma 1962) divisions.

The sandstone beds are often separated by thin shale to fine sands (T(c)d,e), equally, amalgamation of up to 2-3 beds, especially in the central section, is common. Here, clay-draped amalgamation surfaces prevail. Shallow scours, typically infilled with very coarse to granule sands, are rare. Their shallow tabular shape results primarily form impact of dense flows on soft substratum (Mutti & Normark 1987). Other common features include shale rip-up clasts, which suggest reworking of underlying beds (Stow & Johansson 2000). The net:gross ratio is high (*see chapter 4*), individual sandstone beds contain 90 – 100% and bed packages and lobes 75 - 90% net sand (fig.2.33). Syndepositional water-escape structures, i.e dish structures, are locally present. Bioturbation is abundant as burrows and top-bed features indicating relatively tranquil phases between sandstone deposition. The trace fossil assemblage is characterised by a mixed and Nereites fauna (Demircan & Toker 1998; plate 6.3). Slumping and shaley debris flows are a relatively common feature close to the slope margin area, less common in the main depositional area (plate 6.4), suggesting topographic relief and collapse of slope/fan fringe and lobe fringe deposits respectively.

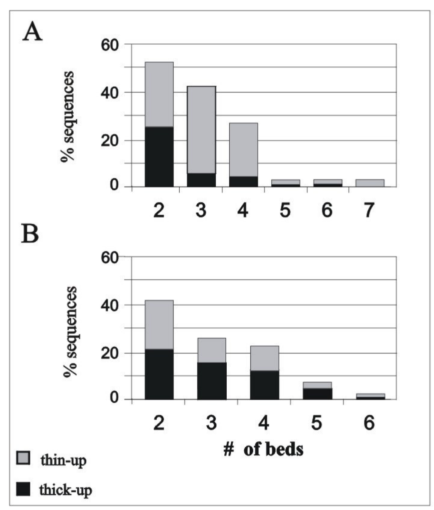

Fig. 2.34: Bedding sequences within A) Lobe C and B) lobe fringe deposits of the more distal lobe section determined by 2-bed moving-average technique (Heller & Dickinson 1985). 70% of the Lobe C and 72% of the fringe deposits show an ordered vertical arrangement.

Internally, the lobes are composed of moderately well defined bed sub-packets (fig. 2.33). These are 3 - 8 m thick and characterised by distinct bed thickness or grain size trends. The bed thickness analysis reveals that approximately 70 % of the beds are arranged in asymmetric bed thickness sequences, the remainder showing random organisation. Thinning-upward trends dominate, 3 and 4-bed sequences are the most common ones (fig. 2.34). Like in Lobe A and B deposits, the high number of 2-bed sequences (52 %) is striking.

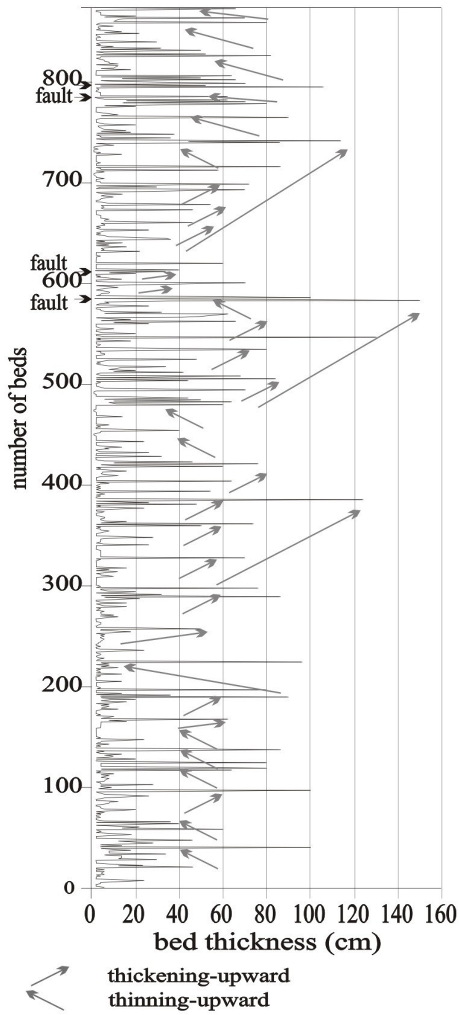

Figure 2.35: Bed thickness versus bed number plot for lobe and lobe fringe deposits of the Seyhan River Section, Cingöz Formation ((2) of fig. 2.32). Thickening- and thinning-upward trends at bed packet, stacked bed-packet and lobe scale are present throughout. Random arrangements are subordinately present.

Minor asymmetric sequences are interpreted to result from topographic compensation or variation in flow volume and concentration (e.g. Mutti & Sonnino 1981; Chen & Hiscott 1999a).

The above method, however, does not pick up the large-scale trends observed when plotting bed thickness against bed number. Figure 2.35 shows that some thickening-upward trends involving up to 130 beds are present, composed of a variable number of smaller-scale thickening- and/or thinning-upward trends involving approximately 20 - 35 beds. The thickening- in conjunction with coarsening-upward sequences suggest abrupt lobe abandonment (Pickering 1981). Thinning-upward and symmetrical sequences are subordinately present as well as some distinctly random vertical arrangements (bottom fig. 2.35).

Solemarks such as erosive groove and flute casts are common (plate 6.5), indicating a general ENE-NE transport direction (216 data points). On single bedding surfaces, flute casts are recording up to 60° divergence (mean 15°) in palaeoflow direction (fig. 2.36), the divergence probably resulting from a transversely divided current head (“lobes and clefts”) moving at slightly different rates in slightly different directions (Allen 1971). However, the general transport direction in i) individual beds, ii) individual Lobe C packates and iii) the individual lobes section is strikingly persistent throughout (fig. 2.32), suggesting that only the northern to north-eastern flank of much larger lobe deposits are exposed.

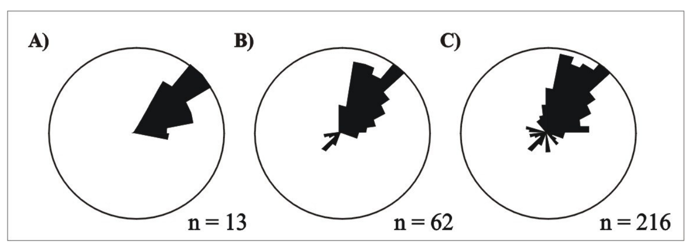

Figure 2. 36: Palaeoflow directions in a) individual bed, b) Lobe C and c) total eastern distal lobe zone.

The limited exposure of the Lobe C bodies prohibits direct observation of the complete lobe geometry. Individual beds and packages of beds appear to be sheet-like and laterally extensive, however, the observed gradual pinch-out of lobe bodies towards the margin with low angles of inclination (*chapter 2.3.2*) together with some degree of “fanning-out” transport directions presents limited evidence of a general (convex upward?) lobate geometry (fig. 2.37).

Lobe fringe deposits

Associated with the lobes are lobe fringe deposits (*sensu* Mutti & Ricci Lucchi 1975; Ricci Lucchi 1981), characterised by a lower average sand: shale ratio (2:1) and distinctly asymmetric bed thickness sequences (plate 6.6). Vertically, they transitionally grade to and from lobe and interlobe deposits respectively. Since lobe and lobe fringe deposits transitionally pass into each other, this study uses the arbitrarily chosen maximum sand/shale ratio of 3:1 to distinguish between them. Individual lobe fringe packages are between 3 - 15 m thick (fig. 2.38), forming approximately 22 % of the total section (table 2.9).

The sandstones are composed of 5 - 30 cm thick, fine- to medium-grained sandstones (S3 of Lowe 1982 and Tb-d(e) divisions of Bouma 1962) separated by 1 - 15 cm thick, thin-bedded silt-/mudstone alternations (Td,e) (fig. 2.38). Amalgamation is uncommon. Beds are laterally extensive and display very little facies and thickness changes at outcrop scale (~ 150 m).

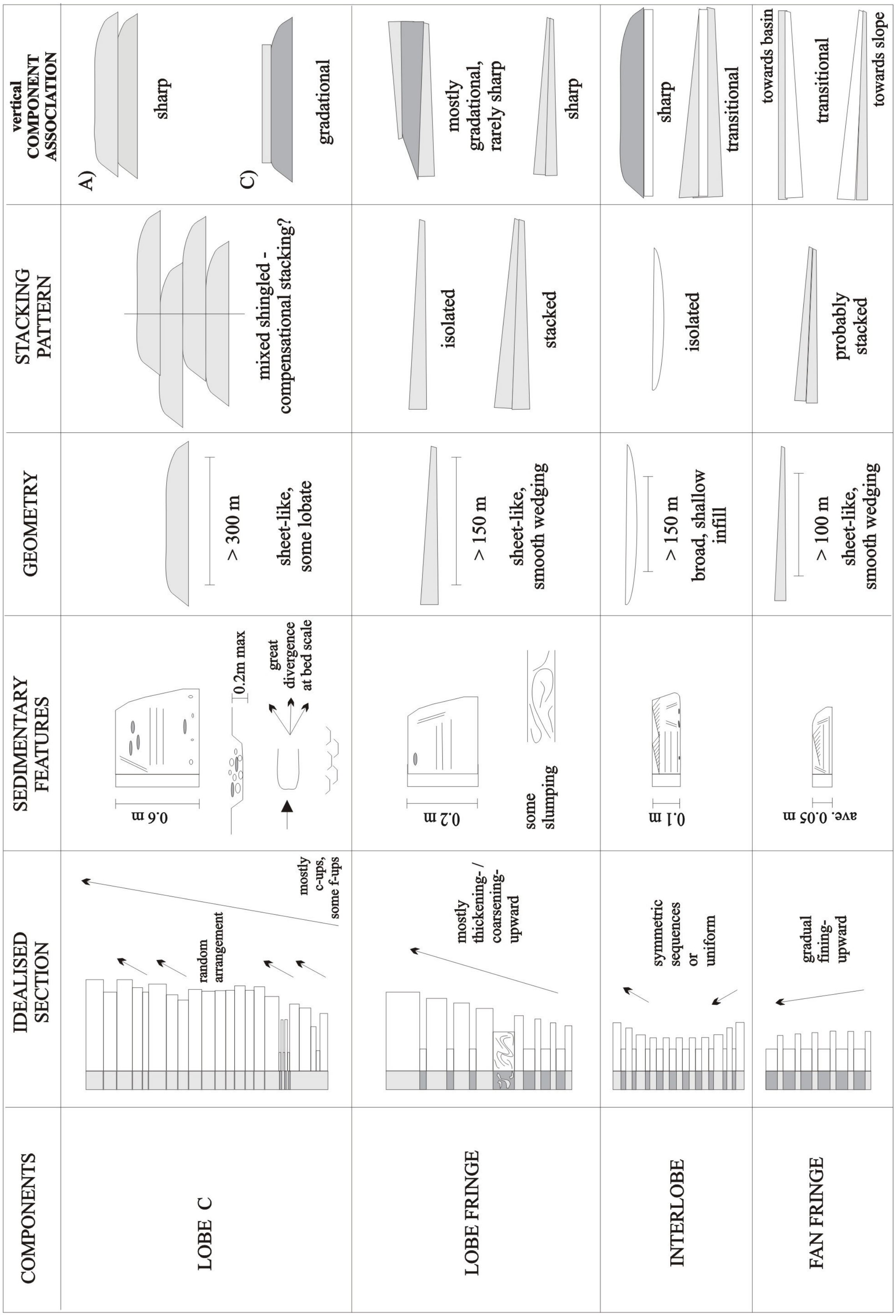

Fig. 2.37: Component characteristics and relationships within the distal lobe environment.

Bioturbation is abundant, showing the same trace fossil assemblage as the lobe deposits. Slumping is occasionally present (fig. 2.38), suggesting fringe collapse into adjacent interlobe depressions. Palaeocurrent indicators point to the ENE - NE direction (mean 032° / 24 data points), thus being consistent with the transport directions measured in the lobe deposits.

The deposits are arranged in up to 8 m thick well-defined asymmetric bed thickness cycles. These findings appear to be consistent with lobe fringe deposits as defined by Mutti & Ricci Lucchi (1975) belonging to the group of TBTs (thin-bedded turbidites) of Mutti (1977). Pickering (1981) and Surlyk (1995) recognised fining- and thinning-upward cycles also to be common in the lobe fringe. Both types of asymmetric bed thickness patterns were recorded in the lobe fringe deposits of the Seyhan River section with thickening-coarsening-upward sequences slightly more common (fig. 2.34). Figure 2.38 shows a distinct coarsening and thickening upward of the sandstones into lobe deposits associated with a marked upward increase in the sand/shale ratio from 1:1 (base) to 3:1 (top). The observed bed thickness cycles are both interpreted to result from lobe switching. While coarsening-/thickening-upward sequences are produced by lobe migration (progradation or lateral switching) into a particular area, the "shifting away" or retrogradation of a lobe leaves progressively thinning and fining deposits behind.

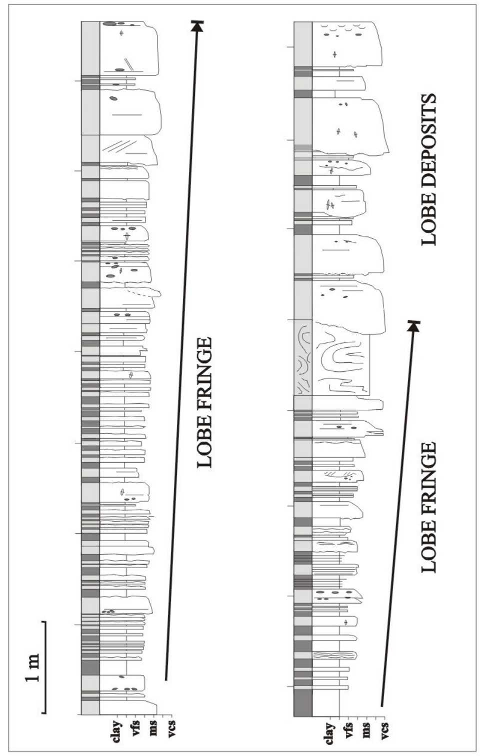

Figure 2.38: Stacked lobe fringe deposits showing distinct thickening- and coarsening-upward sequences ((3) of fig. 2.32). A distinct increase in the sand:shale ratio from 1:1 (base) to 3:1 (top) is present. Slumped features suggest occasional fringe collapse.

The lateral evolution of lobe fringe into lobe and interlobe deposits respectively could not be observed at outcrop scale. Studies by Mutti & Ricci Lucchi (1975), Mutti (1977), Ricci Lucchi & Valmori (1980) and Pickering (1981) show that lobe fringe deposits laterally grade into the coarse, thick-bedded sediments of depositional lobes. Lobe fringes can thus be classified as the peripheral fringes of lobe deposits, being their distal equivalents in a downcurrent and crosscurrent direction (fig. 2.39; Mutti 1977). At the stratigraphic top of the section, the lobe fringe deposits laterally grade into less sand-rich fan fringe sediments.

The lobe fringes are believed to have a very smooth wedging geometry since they represent the eventual lateral and distal pinch-out of the depositional lobes (fig. 2.37). The observed lobe/lobe fringe pinch-out against the slope underlines the presence of low angles of inclination at the lobe margins (*chapter 2.3.2*).

<u>Interlobe deposits</u>

Occasionally, the lobe and lobe fringe deposits are interbedded with distinctly finer-grained and thinner-bedded deposits which display an overall low sand/shale ratio of 1:1 (< 50 % sand). They classify as interlobe deposits (e.g. Kongsfjord Formation: Pickering 1981; Matilija Sandstone: Link & Welton 1982). Their deposition occurred in the intervening lows between individual depositional lobes (fig. 2.39), an area reached only by dilute currents. They therefore represent a fairly passive depositional environment within the fan lobe.

The interlobe deposits may reach between 5 - 15 m in thickness, forming approximately 4 % of the total section (table 2.9). Their basal and top contacts are mostly transitional, however, sharp contacts with overlying lobes may occur (plate 2.8).

Internally, the interlobe deposits are composed of well-sorted 1 - 15 cm thick sandstones of fine sand-size, commonly showing T(c)de subdivisions (Bouma 1962). They are separated by 1 - 10 cm thick shale beds (Td,e), forming relatively thick monotonous successions (plate 6.7). These sediments are the product of dilute turbidity currents depositing their fine-grained suspension load (Bouma 1962). Occasionally, isolated thicker-bedded and coarser-grained sandstone beds are present indicating sporadic spill-over of larger turbidity currents into the depression of the interlobe area, probably triggered by tectonic activity (Ricci Lucchi 1981). Symmetric bed thickness patterns are most common, marking the transition to and from lobe fringe deposits (fig. 3.37).

Plate 2.8 shows that the interlobe deposits have great lateral extent in excess of 150 m. The interlobes are inferred to possess a shallow, lenticular infill-geometry (fig. 2.37), reflecting the gradual infill of depressions between lobe mounds.
In their appearance the interlobe deposits (plate 2.8/6.7) are similar to fan fringe deposits (*see below*). The interlobe deposits are identified by their association with lobe and lobe fringe deposits, while fan fringe deposits are associated with lobe fringe and basin plain deposits (plate 6.8). Furthermore, the interlobe deposits of this study are characterised by a slightly higher sand content than the fan fringe deposits.

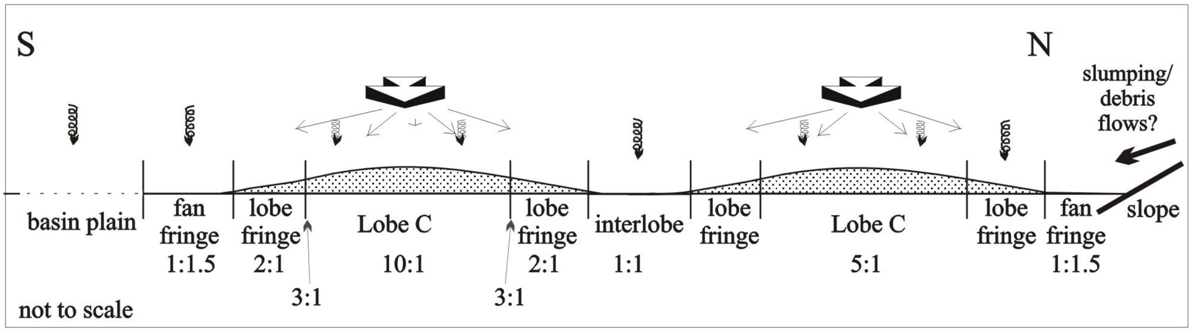

Figure 2.39: Schematic component association in the distally located eastern area of the E-Fan. Their differentiation is largely based on sand:shale ratios, their geometries inferred by vertical facies associations, diverging palaeocurrent patterns and field observations.

Fan fringe deposits

The top 15 m of the Seyhan River section are dominated by a monotonous sequence of alternating thin beds of sandstone, shales and hemipelagic marls, characterised by a low sand content (sand/shale ratio = 1:1.5; table 6.8). The contact with the underlying lobe fringe deposits is transitional. The contact with the overlying basin plain deposits (Güvenç Formation) is not exposed, however, it is believed to be transitional as recorded in the central and western section of the E-Fan (*chapter 2.2*). The fan fringe deposits form about 9 % of the eastern section.
The deposits are made up of 5 - 10 cm thick, fine- to very fine-grained sandstones (Tc-e; Bouma 1962), which are interbedded with 20 - 50 cm thick siltstone-shale intercalations (Td,e) and hemipelagic mud. The sediments are intensily bioturbated. Few thicker sandstone beds are randomly interbedded (plate 6.8). The sediments are the product of diluted turbidity currents (Ghibaudo 1980), while the interbedded thicker sandstones result from coarser flows occasionally reaching this area. The bedding arrangement appears impressively regular, however, a very subtle thinning and fining upward is present (fig. 2.32).
Their association with and position between basin plain and lobe fringe deposits (fig. 2.32; fig. 2.39) suggests them to be TBT fan fringe deposits *sensu* Mutti (1977). Fan fringe deposits are defined as representing the most distal submarine fan deposits both in a distal and lateral direction (Mutti 1977; Mutti & Johns 1978; Ghibaudo 1980; Pickering 1981). Thus, their geometry is believed to be smooth, sheet-like, eventually pinching out towards the basin plain (fig. 2.37; fig. 2.39, e.g. Macigno Formation: Ghibaudo 1980).

2.4.3.2 Lobe C accumulation

The distal lobe deposits, Lobe C, present the more classical lobe deposits often described in literature (e.g. Mutti & Ricci Lucchi 1972; 1975; Mutti *et al.* 1978; Walker 1978; Ghibaudo 1980; Pickering 1981; Mutti & Normark 1987, 1991; Surlyk 1995). They are non-channelized, sand-dominated deposits associated with lobe fringe, interlobe and towards the top of the section with fan fringe sedimentation. The Lobe C deposits are characterised by a high sand/shale ratio.
The internal organisation of the Lobe C shows smaller-scale asymmetric and random bedding organisation at bed sub-packet and stacked bed sub-packet-scale within overall coarsening-upward sequences, suggesting that aggradation is the dominant process at bed sub-packet-scale, while the entire lobe results from progradation and/or lateral migration, especially in mid-section (fig. 2.32; e.g. Mutti & Ricci Lucchi 1972; Mutti 1985b; Mutti & Normark 1987, 1991; Shanmugam & Moiola 1991). The observed thinning-upward

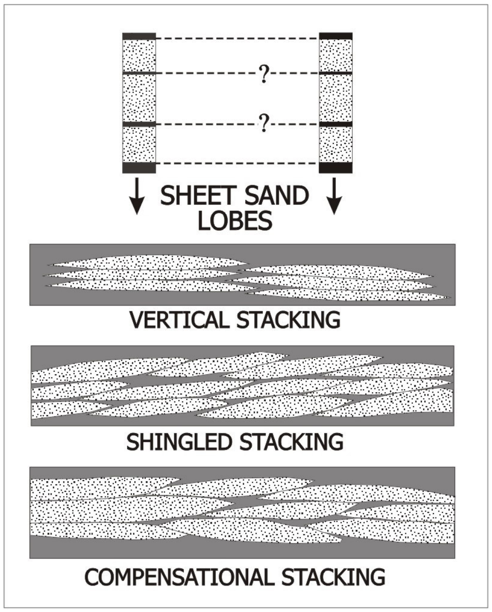

Figure 2.40: Schematic drawing of three possible stacking patterns resulting from lateral switching within sheet sand lobes. Presently it is not known which ones are the most common. It is likely that those patterns mix according to downdip gradients and the most favourable accommodation space (from Bouma 2000).

sequences suggest gradual lobe abandonment (Mutti & Ricci Lucchi 1975; Pickering 1981) and/or in combination with the observed random vertical organisation reflect aggradation (e.g. Ricci Lucchi & Valmori 1980; Ricci Lucchi 1981, 1985; Hiscott 1981; Ghibaudo 1981; Shanmugam & Moiola 1991; Chen & Hiscott 1999a). Thus, Lobe C accumulation in the more distal fan area reflects some degree of fan progradation combined with latero-vertical growth (fig. 2.40).

The well developed, small-scale or high frequency cycles of bed sub-packets (roughly comparable to the elementary facies tract (EFT) of Mutti 1992) may result from a variety of autocyclic and allocyclic controls such as, for example, topographic compensation, flow path, flow volume and concentration, changing sediment supply, high frequency climatic changes in the source area, tectonic activity and high frequency sea-level fluctuations (*see* Normark *et al.* 1993; Mutti *et al.* 1994; Chen & Hiscott 1999a) for discussion). It is however acknowledged, that the reasons for high frequency cyclicity are largely unknown (Mutti *et al.* 1994).

The symmetrical coarsening/thickening upward to thinning/fining upward of the section (fig. 2.32) reflects the transition from fan margin to main depositional area to fan fringe and eventually basin plain deposits in the relatively distal outer fan environment (*sensu* Mutti & Ricci Lucchi 1972). The marginal and relatively distal fan areas received little sand deposition. This is reflected by the progressive increase in net sand content from 1:1 - 5:1 at the margin (slope) to 22:1 (mid-section), decreasing to 1:1.5 at the fan fringe.

The component arrangement reveals an irregular spacing of the lobes. The clustered appearance in mid-section points to the main depositional area. Here, the lobes occur either stacked or as isolated components separated by isolated and/or stacked lobe fringe and isolated interlobe deposits of varying thickness. Towards the fan margin (slope and basinal direction) the individual lobes are associated with increasingly thicker fine-grade material of lobe fringe and lobe- and fan fringe origin respectively. The observed vertical organisation may result from lobe switching due to lobe build-up, upstream channel switching and avulsion in mid-section (Mutti & Ricci Lucchi 1975; Walker 1978; Ghibaudo 1981; Ricci Lucchi 1985; Shanmugam & Moiola 1988; Surlyk 1995; Chen & Hiscott 1999a), producing an offset-stacked pattern within a relatively distal outer fan environment, leading to a mixed shingled-compensational stacking pattern (Bouma 2000), amalgamating progradation and lateral migration (fig. 2.40).

Towards the top of the section, increasing abandonment of the outer fan lobe is reflected by the (offset?-) stacked lobe fringe deposits. This resulted in lobe fringe and eventually fan fringe sedimentation in an area in which otherwise sandlobes would have been deposited, probably driven by the overall rising sea level (Yetiş *et al.* 1995; Kostrewa *et al.* 1997). Seismic and borehole data indicate that E-Fan deposition extends much farther to the south during its earlier development (*chapter 2.2.2*).

True lobe geometries are rarely observed in outcrop where down- and cross-current wedging of convex-upward bodies into lobe fringe deposits (Ricci Lucchi & Valmori 1980) with the resulting low angle inclinations at the margin of the lobe can be observed (Surlyk 1995). Cazzola *et al.* (1985) suggest that if slope-onlap can be observed, the lobes are likely to form basin-wide features. This, however, is not supported by the component distribution pattern (fig. 2.41) where mid-section interlobe deposits are believed to be flanked by lobe bodies on either side, although no lateral gradation to and from interlobe to lobe fringe/lobe has been observed. Lateral facies changes were only observed along the margins (lobe/lobe fringe pinchout and lobe fringe to fan fringe transition). It is not believed that the interlobe deposits are in fact fan fringe deposits, representing basin-wide features, thus indicating temporary, high frequency regression of the active fan lobe. That this landward-basinward shift resulting in cycles of progradation is driving lobe accumulation at 10s of metres of scale is unlikely (Chen & Hiscott 1999a) and rather the lateral shifting of depositional locus is favoured for the observed facies distribution.

The palaeocurrent pattern persistently points to a NE-ENE transport direction all throughout the section. Kneller & McCaffrey (1999) suggest that flow deflection may also have contributed to the phenomena of persistent slope-parallel palaeocurrent directions. This could be envisaged for the more marginal parts of the succession, however, it appears more likely that the exposed lobe deposits represent the north-eastern margin of much larger lobes while the top section lobe fringe / fan fringe palaeocurrent patterns indicate a general west-ward shift in the depocentre (fig. 2.41c).

Tectonic activity resulting in thick debris-flow deposits or the periodic onset of very coarse sedimentation as recorded in the proximal and central fan areas is not evident in the distal lobes of the Seyhan River section. Occasional slumping and thin-bedded debris-flow deposit associated with fringe collapse and proximity to the slope are believed to have been brought on by seismic activity and/or sediment instability due to overloading (Reading 1996). However, the thick slumped packages of fan sediments observed along the north-eastern margin (*chapter 2.3.2*) indicate that tectonic activity and/or oversteepening played a role during sediment accumulation. Underlying slope sediments are of late (?) Langhian age (Cronin *et al.* 2000), thus these thick slumps correlate time-wise with the Seyhan River section deposits and record fan aggradation against the slope at some stage during its development.

Lobe C accumulation within the distal lobe zone is controlled by a complex interplay of auto- and allocyclic mechanisms. Most apparent are lobe switching driven by topographic build-up and/or upstream channel avulsion, some degree of flow deflection along the confining margin as well as the overall rising sea level resulting in the observed retrogradation of the whole fan system. Basin topography apart from the confining margin, sporadic tectonic activity resulting in thick debris-flow deposits or significant changes in sediment availability and size as recorded elsewhere in the system appear to have less direct impact in the Lobe C accumulation.

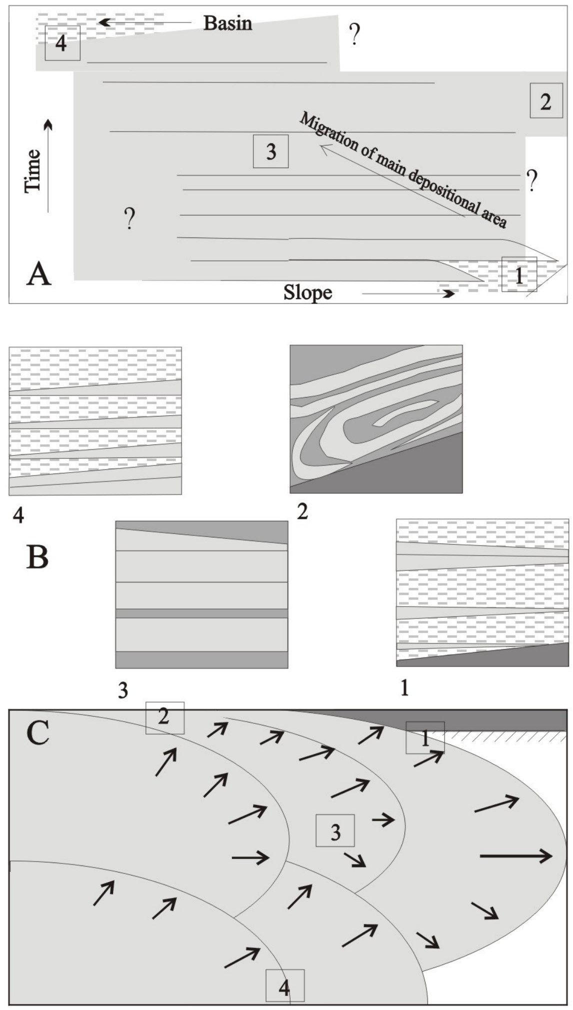

Figure 2.41: A) Diagramme showing the spatial and temporal component distribution in the more distal E-Fan area (Seyhan River road cut).
B) Schematic drawings of relationships between components located in marginal, main depositional centre and basinal position: 1) isolated lobes/lobe fringe onlap low-angle slope in area with mostly fan fringe sedimentation (lower Langhian); 2) massive slumping of aggraded, sandy fan sediments against steep slope (upper Langhian ?); 3) thick stacked lobes and associated lobe fringe and interlobe deposits in main depositional area; 4) lobe and fan fringe sedimentation towards the basin (upper Langhian?).
C) Conceptual drawing showing how lateral lobe switching generated observed component distribution.
Note that no absolute time and distances are implied.