Geometry of trapezoidal fan deltas and their relationship to extensional faulting along the south-western active margins of the Corinth rift, Greece

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ABSTRACT

A new subtype of Gilbert-type fan deltas, 'the trapezoidal fan delta', characterized by the absence of bottomset deposits, is recognized in the south-western active margins of the Corinth rift in central Greece. They are formed adjacent to master extensional listric faults and developed by progradation either onto a subaqueous basin escarpment or across a subaerial platform where alluvial fans have accumulated. Simultaneously with master fault activity, displacements on counter faults along intrabasinal basement highs produced fan delta foreset deposits. Furthermore, footwall imbrication and uplift along the listric faults, as well as transfer fault displacement, have strongly influenced the pattern of fan delta sedimentation.

INTRODUCTION

Continental rifts consist of a series of asymmetric grabens, which are separated by transfer faults and basement highs developed on both listric and planar extensional faults (Gibbs, 1984). In the case of normal rifting, extensional faults strike parallel to the rift trend, whereas transfer faults indicate the opening direction of the rift (Steward, 1980; Withjack & Jamison, 1986). Transfer faults linking extensional fault segments accommodate not only displacement but also elevation differences between adjacent fault blocks (Poulimenos et al., 1989; Morley et al., 1990). Owing to these tectonic effects, different sedimentary facies accumulate adjacent to the basin margins (Leeder & Gawthrope, 1987).

Fan delta sedimentation along basin margins is represented by Gilbert- and conical-type deltas. Gilbert-type deltas are classical deltas with tripartite depositional geometry (Gilbert, 1980); the distributary plain (topset) overlies a relatively steep prograding delta face (foreset), which further out passes into a low-gradient delta-toe zone (bottomset). These deltas are frequently preserved in the stratigraphic record, especially where they have filled basin-margin depressions, either formed tectonically or related to slope failure (Massari & Colella, 1988). The progradation of these deltas reflects some kind of positive imbalance between the sediment supply and the effects of basinal water depth (Nemec, 1990).

Conical underwater deltas frequently develop where bedload-dominated rivers debouch directly into excessively deep coastal water. Subaerial components are often very minor or absent (Nemec, 1990). Such deltas belong to the slope-type delta category of Ethridge & Wescott (1984). Moreover, the development of conical deltas reflects a negative imbalance between the sediment supply and the effects of basinal water depth. They often precede the development of Gilbert-type systems along cliffed, deep-water coasts (Nemec, 1990).

Neogene rifted domains in the Aegean area are frequently associated with Gilbert-type fan deltas (Philippson, 1930; Doutsos et al., 1988; Ori, 1989; Zelilidis & Doutsos, 1992). Those developed in the south-western part of the Corinth graben are characterized by a lack of bottomsets and a positive imbalance between the sediment supply and the basinal water depth. These elements lead us to propose a new fan delta depositional type, referred to as a 'trapezoidal fan delta'. The aim of this paper is to isolate the tectonic subsidence control on such fan deltas, paying particular attention to their form and internal geometry. The trapezoidal geometry is due to tectonic control and differs from previously described fan delta types. The resulting models are helpful in the study of ancient basin-fill successions; a study of obvious relevance to hydrocarbon exploration.

TECTONIC AND STRATIGRAPHIC BACKGROUND

Back-arc extension behind the Hellenic trench since the late Pliocene has controlled the formation of several WNW-trending continental rift zones (Jackson et al.,
Among these the Corinth graben is thought to be the most important. The Corinth graben, undergoing extensional listric faulting in response to NNE–SSW crustal extension, is separated into two WNW-trending rifted segments (Zelilidis et al., 1988). The northern submerged segment reaches a maximum depth of 850 m in the Gulf of Corinth and is bounded to the south by a major listric fault (Brooks & Ferentinos, 1981). The southern segment, which occupies the coastal areas of the northern Peloponnese, has been elevated about 1000 m above the present-day sea level (Dufaure et al., 1975; Doutsos & Piper, 1990). It consists of a series of asymmetric grabens, which are separated by NNE transfer faults and basement highs developed on WNW-trending listric extensional faults (Poulimenos, 1993). Graben-fill sediments exposed in the uplifted southern segment of the graben comprise late Pliocene to early Pleistocene, fluvial and lacustrine-lagoonal deposits up to 600 m thick. These are unconformably overlain by alluvial-fan and fan-delta deposits with a maximum exposed thickness of 500 m and marine terraces up to 30 m thick (Poulimenos et al., 1989). Cumulative vertical displacements and biostratigraphical elements along the major extensional faults reveal that the main subsidence of the graben has migrated northwards throughout Quaternary time (Doutsos & Poulimenos, 1992).

REGIONAL SETTING

Fault geometry
Four major WNW extensional faults, each more than 12 km long and involving up to 800 m vertical displacements (Doutsos & Poulimenos, 1992), divide the
Fig. 2. (A) Simplified geological map of the south-western end of the Corinth graben showing cross-section locations. Arrows depict palaeocurrent trends derived from clast imbrications and foreset dips. (B) Cross-sections illustrating the influence of the WNW extensional and NNE transfer faults on the fan-delta sequence development. Sequence C topsets are not shown.
south-western end of the Corinth graben into a series of tilted blocks 0.7-4 km wide (L₁ to L₄ in Fig. 1B). Mesoscopic observations on the WNW faults, many of which are demonstrably listric (Fig. 3A), have led to the general acceptance of their listric geometry. The major extensional faults dip towards the north at 50-85° and show an antithetic rotation sense in the downthrown beds (cross-sections of Fig. 2B), although homoclinally rotated sags have also been observed (e.g., the northern faulted basin in Fig. 2B: HH'). Each of these faults is accompanied by 1-4 closely spaced minor faults with the same kinematic sense and by one counter fault (e.g., the southern faulted basins in Fig. 2B: GG'). In addition, the major extensional faults vary along strike, with changes in vertical throw and the rotation sense in the downthrown beds (fault L₁ in Fig. 2B). Such changes are accomplished by NNE-trending transfer faults (faults T₁ to T₄ in Fig. 1B).

High-angle transfer faults (Fig. 3B) with a maximum length of 11 km and vertical displacements of up to 450 m (Doutos & Poulimenos, 1992) subdivide the graben into discrete blocks with differing subsidence (faults T₁ to T₄ in Fig. 1B and Fig. 2B: NN', OO'). They dip either to the east or to the west and show both a synthetic and an antithetic rotation sense in the downthrown beds.

No precise chronology is available for the transfer faults. However, field criteria suggestive of the transfer faults being active throughout Quaternary time include: (a) northwards the fault zones T₁ and T₄ form WNW-dipping scarps, up to 200 m and 100 m in height, respectively, separating the lacustrine-lagoonal deposits from the pre-Neogene basement (Fig. 1B), and (b) the transfer faults rotate the fan delta deposits up to 25° (Fig. 2B: NN'; Fig. 3B) and cross-cut the present topography.

Sedimentation dependent on tectonics

In the southern margin of the south-western Corinth graben, initial rifting, accomplished by large-scale WNW extensional faults and NNE transfer faults (Fig. 1B), resulted in the accumulation of lacustrine-lagoonal sands and silty sands with early Pleistocene fauna and with a maximum exposed thickness of 200 m (Frydas, 1989). Renewed faulting after the early Pleistocene along these faults led to the formation of alluvial fans up to 100 m thick and fan deltas with a vertical maximum thickness of 500 m. Fan deltas have been unconformably deposited over the lacustrine-lagoonal sediments and in places they are unconformably overlain by thin marine terraces. The fan deltas comprise three distinct systems, referred to as the western, middle and eastern deltaic systems. They extend from the southern basin margin towards the north (Fig. 1B). They are characterized by a variable architecture and consist of three superposed deltaic sequences A, B and C (Figs 2B: HH', II'; 4 and 6), with characteristic absence of foresets. Sequences A and C prograded northwards from the southern margins of the graben, whereas sequence B prograded southwards, derived from an intrabasinal basement high.

The intrabasinal basement high, with southern margins confined by the antithetic faults I₁ and I₂ and the northern margins confined by the major fault L₄ (Fig. 1B), has a maximum width of 4.5 km and a length of 20 km. Foresets of sequence B, which developed perpendicular to the counter faults I₁ and I₂ (Fig. 2A), suggest that sequence B was derived from the intrabasinal basement high rather than being derived from elsewhere and transported across the intrabasinal high. In addition, the
Trapezoidal fan deltas, Greece

Fig. 4. Cross-section of the middle deltaic system (location shown in Fig. 1B). A, sequence A; B, sequence B; C, sequence C; al, al1, al2, alluvial fan; fr, fr1, fr2, foresets; tp, topsets. Stratigraphic columns 2–4 show sequences A–C, respectively, in the progradation direction.

Fig. 5. Deltaic sequence successions. Localities shown in Fig. 2(B). (A) Alluvial fans of sequence C (C_{al}, C_{fr}) developed on the footwall of fault L1. Alluvial fans (C_{al}, C_{fr}) and foreset (C_{fr}, C_{tp}) deposits of sequence C influenced by fault L2 activity. Foreset deposits of sequence C, developed in the hangingwall of fault L2, rest unconformably over topset deposits of sequence A (A_{tp}). Arrows point out the erosional contact between sequences A and C. LL, lacustrine-lagoonal deposits. For locations see Fig. 2(A).

(B) Panoramic view of the middle deltaic system showing the oppositely prograding deltaic sequences B and C. Localities shown in Fig. 2(B).
Sequence A, derived from the southern margin of the graben, has been developed unconformably over alpine basement in the most proximal parts (Fig. 2B: GG', HH'; A_d in Fig. 4) and over lacustrine-lagoonal sediments (LL in Fig. 5A) in distal areas (Fig. 2B: GG', HH'; A_p in Figs 4 and 5A). Sequence B, derived from an intrabasinal high, consists only of fan delta foresets, and rests unconformably over the lacustrine-lagoonal deposits (Fig. 2B: GG', HH'; A_b in Figs 4 and 5A). These sequences are unconformably overlain by sequence C (Figs 2B: HH', HH'; B_c in Figs 4 and 5B). The vertical and horizontal variation has been studied independently in each deltaic system. Distinctive sedimentological sequences and consistent palaeogeographical trends have been used to correlate between delta systems.

**Deltaic sequence A**

**Alluvial fans**

*Description.* Alluvial fan deposits occur between faults L_1 and L_2 (A_a in Figs 4 and 5A). They consist of three sedimentary cycles (30, 30 and 40 m thick). Each cycle becomes coarser upwards and consists, from bottom to top, of flat-based, poorly sorted, clast- or matrix-supported, pebbly-cobbly conglomerates. No grading or stratification is present in these deposits. Imbrication is poor and rarely observed. The uppermost part of each cycle consists of massive or laminated muddy, coarsening-upward sandy and massive gravelly lenticular lenses, up to 5 m thick.

**Interpretation.** The coarseness and the poor sorting of these sediments, the lack of sedimentary structures, the rare pebble imbrication and the presence of pebbles suggest debris flows (Miall, 1978) in a progradational alluvial fan environment (Nichols, 1987). The uppermost part represents the change from high-viscosity transportation to low-viscosity transportation as the sediment-to-water ratio decreases during the waning stages of debris flow (Steel & Wilson, 1975).

**Fan deltas. (a) Foresets**

*Description.* Foreset beds have been deposited in the hangingwall of the fault L_2 and rest upon the lacustrine-lagoonal deposits exposed in the floor of the Kerinitis valley north of St Andreas (Fig. 1B; A_b in Figs 4 and 5A). They attain a thickness of 420 m in the dip direction and consist of eight fining-upward conglomeratic cycles (40, 60, 30, 70, 50, 70, 50 and 50 m thick), dipping 30° basinwards. Each cycle consists upwards of: (a) clast- or matrix-supported, unstratified cobbly conglomerates. ‘Open-work’ gravel lenses, up to 50 cm thick and 3 m long, with rare grading, are also present. This facies passes upslope into thin to medium interbedded, normally graded, well-sorted, gravelly sand and gravel beds, characterized by massive and rare cross-stratification (A_p in Figs 4 and 5A). The pebble a-axis orientation (NNW) is parallel to the slope, with flat pebbles dipping either upslope or parallel to the slope direction. (b) Massive sandy or gravelly sand beds, up to 5 m thick, constitute the uppermost part of the conglomeratic cycles.

*Interpretation.*** Various features of the conglomerates suggest debris fall accumulations on slopes of conical underwater deltas during the early stage of slope development (Prior & Bornhold, 1988; Nemec, 1990).
Alternatively, they may have been deposited in chute and pool bedforms with sedimentation related to upstream-migrating hydraulic jumps (Massari & Parea, 1990). The upslope change of the conglomerates suggests 'backset' deposits reflecting the upstream migration of chutes and pools (Postma, 1984; Postma & Roep, 1985). The uppermost part of each cycle may have resulted from seasonal periods of low sediment discharge (Colella et al., 1987).

(b) Topsets

These were deposited in the hangingwall of fault L2 (Aun in Figs 4 and 5A). They consist of massive or laminated sand beds, up to 20 m thick, developed over the four lower foreset cycles (Aun in Figs 4 and 5A). Topsets rest unconformably on the underlying foreset deposits of the fourth cycle. This pattern suggests that destructional phases (during which the progradation stopped and a shoreface platform developed) pass into active progradation phases of the system where the beachface ramp merged into the foreset slope (Massari & Parea, 1990).

Deltaic sequence B

Foresets

Description. These sediments dip south, with a maximum thickness of 120 m, and were deposited in the antithetic fault L2 hangingwall (Fig. 2B: GG', HH'; II'; Bn in Figs 4 and 5B). This fault, involving vertical displacement of up to 300 m, defines the southern margin of an intrabasinal basement high partly covered by lacustrine-lagoonal deposits. Foresets are capped by the distal foreset parts of sequence C (Bn, Cn; in Fig. 4), and comprise three fining-upward conglomeratic cycles of equal thickness with individual massive sand beds in the upper part of each cycle, up to 15 m thick. Clasts are oriented parallel to the slope direction (SSE) and dip 20–35°.

Interpretation. The conglomerates, derived from the basement high as suggested by palaeocurrent trends, are similar to the foresets of sequence A. The sand beds issuing from the lacustrine-lagoonal deposits are interpreted to have been deposited under the same conditions.

Deltaic sequence C

As in sequence A, alluvial fans, fan delta foresets and topsets were recognized (Fig. 2: GG', HH'; Figs 4 and 5A).

Alluvial fans

Description. Alluvial deposits of this sequence rest unconformably on the alluvial fan deposits of sequence A. They can be subdivided into a lower part with a maximum thickness of 200 m (Cun in Fig. 4) and an upper part, up to 200 m thick (Cunw, Cunz in Figs 4 and 5A). The lower part resembles sequence A alluvial deposits and the upper part comprises thick interbedded massive sand beds with rare reddish lenticular mud lenses. Unstratified, clast- or matrix-supported, normally or inversely graded, pebbly conglomerate beds also occur. Conglomerate beds consist of 'open-work' gravels in lens-shaped layers up to 30 cm thick with rare grading, and lenticular sand lenses, with low-relief erosional upper bedding surfaces.

Interpretation. The lower part, which is similar to sequence A, represents debris flows in a progradational alluvial fan environment. The upper part can be interpreted as an alternation of high-viscosity transport and low-viscosity transport on an alluvial fan. The sand units may represent braided stream facies (Mack & Rasmussen, 1984). The reddish lenticular mud lenses are interpreted as local overbank sediment that accumulated along migrating braided channels (Anderson & Picard, 1974).

Fan deltas. (a) Foresets

Description. Foreset deposits of sequence C developed in the hangingwall of fault L2, although in places they have overstepped the fault scarp (Cun, Cunw in Figs 4 and 5A). Immediately north of the scarp of fault L2, foresets rest with a high-relief erosional contact (up to 15 m in height) on the topsets of sequence A (Fig. 5A) and consist of three vertically stacked micro-fan-delta subsequences (Figs 4, 5A and 6) with oblique and sigmoidal clinoform geometries. Each micro-fan is composed of coarse-grained foreset and fine-grained topset deposits. Topsets rest unconformably over the proximal foresets and pass laterally into the distal foresets. Northwards and westwards, in the direction of progradation, the foresets pass gradationally onto the underlying foreset deposits of sequence A and rest unconformably over the lacustrine-lagoonal sediments (Fig. 2B: GG'; Figs 4 and 6). The foreset deposits of sequence C, with a maximum horizontal thickness of 600 m, comprise repeated fining-upward cycles 10–60 m thick.

Interpretation. These sediments have an origin similar to the foreset deposits of sequence A. Moreover, the three vertically stacked micro-fan-delta subsequences can be interpreted to reflect episodes of tectonic slip and no slip (Gawthorpe & Colella, 1990) during sequence C development. The most important indicators of tectonic control are: (1) evidence for syndepositional tilting and (2) identification of synsedimentary faulting.

(b) Topsets

Topset deposits of sequence C, with a maximum thickness of 5 m, consist of fine-grained cross-stratified
and clast-supported conglomerates which pass upwards into red-coloured sandy mudstones. The conglomerates probably resulted from deposition in braided-stream channels on an alluvial fan and pass laterally into fine-grained floodplain sediments. The topsets unconformably overlie the foreset deposits (Fig. 7A). This succession reflects slow retreat of a fan-delta system, in conditions of general uplift. In some sections, at the base of the topsets, sandy marine terraces, up to 2 m thick, are present. This upward change from marine to terrestrial environment supports the concept of a general regression of relative sea level resulting from the fan progradation.

**DETAILED ANALYSIS IN A WNW TRANSECT CROSS-CUTTING THE DELTAIC SYSTEMS**

The NNE transfer faults form several sub-basins which are characterized by different subsidence (Figs 2B: OO'; 6). This morphology controlled the direction of the feeding channels and, in this way, the lateral distribution of the deltaic sequences in the studied deltaic systems. These features allowed variation from the typical succession described at the middle deltaic system. The major differences are discussed below.

**Western deltaic system**

The western deltaic system has been deposited in a sub-basin bordered by the transfer faults T₂ and T₃ and by L₁ and L₄ master faults (Figs 1B, 2B: AA', BB', CC', DD'; 6 and 7B). The foreset deposits of sequence A, occurring in the hangingwall of the fault L₂, are overlain by the foresets of sequence C with a high-relief erosional contact (Figs 2B: BB', CC'; 6). The erosional contact, as well as the lack of the topsets of the sequence A, indicate an increasing basinal water depth during the development of sequence A from the middle towards the western deltaic system. The foresets of sequence C across the scarp of fault L₁ are composed of alternating gravel and sand lens-shaped layers. Gravel lenses increase in thickness from 6 to 30 m towards the fault scarp, whereas the sand beds wedge out in the same direction from a maximum thickness of 10 m (Fig. 6). The occurrence of these lenses, corresponding to the stacked micro-fan delta in the middle deltaic system,
indicates slip and no slip episodes on fault L₂. Northwards, in the progradation direction, foresets become finer and consist of interbedded normally or inversely graded pebbly conglomerate and sand beds. The latter probably represent more massive influxes of sediments and an initially rather high concentration of the flows. Northwards, the sequence C foresets rest upon the sequence B foresets which attain a maximum thickness of 40 m.

Middle deltaic system

The middle deltaic system is cross-cut by transfer fault Tₙ (Figs 1B and 2A). This fault interacted with faults L₁ and L₂ to form a rectilinear pattern, with differential subsidence taking place during deltaic sedimentation. Maximum subsidence occurred in the fault block bounded by faults Tₙ and L₂. This arrangement of faults produced a westward shifting of sequence C foreset propagation (Fig. 11), reaching a maximum thickness of 400 m.

Eastern deltaic system

The eastern deltaic system developed between transfer faults Tₙ and Tₘ (Figs 1B and 2A), and comprises alluvial fan (subaerial sector) and fan-delta foreset deposits of sequence A (Figs 2B: LL' MM'; 6) which prograded directly onto submarine slopes along the fault L₂ scarp. However, the alluvial fan deposits are up to 200 m thick and rest with angular unconformity on the foresets (Fig. 7B). This indicates that the deposition of sequence A was completed above sea level. Depositional conditions of sequence A in the eastern deltaic system (e.g. the foresets are capped by thick alluvial fans) and the middle deltaic system (e.g. the foresets are capped by thin marine topsets) indicate a westwards increase in water depth.

MODELLING FAN-Delta DEVELOPMENT

Characteristics of trapezoidal fan-delta development

Figure 8 demonstrates an eastward increasing subsidence of the Corinth graben floor, which is likely to have been achieved by ESE-dipping transfer fault activity. Due to this graben floor asymmetry, intrabasinal highs in the eastern Corinth graben have been overstepped by the lacustrine sedimentation, whereas in
the south-western Corinth graben they are exposed (Fig. 8). It may be reasonably argued that this basin configuration strongly affected fan-delta architecture. Thus, in the eastern Corinth graben typical Gilbert-type fan deltas prograded uninterrupted from the southern graben margins towards the sea (Fig. 8). In contrast, in the south-western Corinth graben the fan deltas abruptly abut against intrabasinal highs and display an overall trapezoidal geometry resulting from the absence of low-gradient delta bottomsets (Fig. 8).

The studied fan deltas that prograded into a marine basin (Figs 6 and 9) have the following characteristics. (1) Absence of bottomset deposits. (2) Deposition in protected basins confined by topographical highs with a horst morphology. (3) Coarse grain size, with the fan delta sediment flux dominated by grainflows, rather than by underflows or outflows with appreciable sediment in suspension. The source area was the alpine limestone-chert basement. (4) Powerful underflows that probably developed between the major L₂ fault and counter faults I₁ and I₂, which completely bypassed the area, led to the transportation of the fine-grained sediments outside of the protected basin. (5) Steep, fault-controlled nearshore slopes, which promote the development of large-scale foresets (middle system in Figs 4 and 6). (6) Periods of sea-level stillstand result in topsets and sandy marine terraces. (7) Vertically stacked fan-delta subsequences occur within foreset deposits adjacent to the border fault.

Characteristics 5 to 7 occur also in Gilbert-type deltas (Dunne & Hempton, 1984; Postma & Roep, 1985; Colella et al., 1987; Postma et al., 1988; Gawthorpe & Colella, 1990). Classical Gilbert-type deltas with bottomsets developed toward the eastern Corinth graben where the conditions were more marine or brackish (Piper et al., 1990b).

Interplay of WNW listric faults and sedimentation

The foregoing tectonostratigraphic successions analysis leads us to propose the following palaeogeographical scenario. Lacustrine to open-marine conditions have been established since the early Pleistocene in the western Corinth graben (Piper et al., 1990b). During this time a thick succession of lacustrine-lagoonal deposits has accumulated adjacent to the fault L₂ (Fig. 6; Fig. 10a: C-D). Vertical displacements on this fault are estimated up to 700 m. The presented field criteria support the concept that fault L₂ defined the main submarine escarpment at the south-western edge of the palaeo-Gulf of Corinth. In some places the lacustrine-lagoonal deposits occur at the footwall of fault L₂, indicating that the early Pleistocene shorelines had overstepped the fault L₁ scarp (Fig. 10a: CD). These palaeogeographical features resulted from a low structural relief along the scarp of fault L₂, due either to transfer fault activity, or...
Middle Pleistocene

In the middle (?) Pleistocene the increasing subsidence along fault L2 led to the formation of successive failures cutting backwards into the undeformed footwall (Fig. 10a: CD). These failures, called 'floor' faults in the terminology of Gibbs (1984), are a common feature of extensional terrains (Tchalenko, 1970; Jaeger & Cook, 1979; Grainer, 1985; Lyon-Caen et al., 1988). Subsequently, the fault L2 footwall block has been gradually uplifted, in response to the high subsidence rates of the hangingwall, giving rise to the footwall-sourced alluvial fans (Fig. 10a: CD).

The resulting structural relief has been capped by the deltaic sequence A, formed by the progradation of the alluvial fans from the adjacent highlands into a standing body of water in the hangingwall block of fault L2. As subaerial components have been deposited over the structural relief produced by the floor faults, the coarse-grained foreset deposits have been developed across the steep submarine escarpments of fault L2 (Fig. 10a: CD).

Simultaneously, with activity of fault L2 and deposition of sequence A, displacements on antithetic faults (fault L3 in Fig. 10a: CD) produced the foreset deposits of sequence B.

Later in the Pleistocene, fault L2 activity diminished, whereas the southernmost floor fault (fault L1) became the most active fault across the graben margins (fault scarp in Fig. 10b: C'D'). This sequence of faulting has also been proposed by Gibbs (1984). Intensive subsidence along the fault L1, followed by progressive footwall uplift, gave rise to the subaerial component (coarse-grained alluvial fans) of deltaic sequence C,
which prograded into the sea to form the subaqueous component (coarse-grained foreset deposits) of fan deltas (Fig. 10b: C'D'). Lower activity of fault \( L_2 \) had a marked influence on the complexity of the foreset unit (stacking subsequences and internal foreset beds).

However, two stratigraphic elements indicate uplift of the whole area between faults \( L_1 \) and \( L_4 \), which coincides with the footwall of fault \( L_1 \). (a) Marine influences did not reach the fault \( L_1 \) scarp. Along this scarp only alluvial fans were deposited. (b) In the hangingwall of fault \( L_2 \) fine-grained marine topset sedimentation took place unconformably over coarse-grained foreset deposits.

Fan deltas have been elevated up to 1000 m above sea level and they feed the modern fan-delta deposits developed in the basin of the Gulf of Corinth (Ferentinos et al., 1988; Piper et al., 1990). However, the topographical height of the sequence C topsets decreases southward to 800 m, involving post-fan delta sedimentation, and antithetic rotation on fault \( L_1 \) by at least 6°.

Interplay of NNE transfer faults and sedimentation

The hangingwall block of fault \( L_2 \) is subdivided by NNE transfer faults into three segments with different subsidence (Fig. 10a: AB). The subsidence of these segments relative to the sea level increases westwards.

The western and the middle segments, bounded by the transfer faults \( T_2-T_3 \) and \( T_1-T_4 \), respectively, have intensively subsided (Fig. 11), resulting in the formation of the floor faults (Fig. 10a: CD).

The eastern segment, bounded by the transfer faults \( T_3-T_4 \), is characterized by low subsidence rates, which have not been adequate for the development of floor faults (Fig. 10a). Hence, because of the lack of the floor faults the deltaic sequence A comprises successive subaqueous cones (foreset deposits), developed directly upon the fault-controlled submarine escarpment. In places where the accumulated underwater cones built above sea level, thin alluvial fans were formed (Fig. 10a: AB). However, as extension proceeded during the late Pleistocene, the subsidence of this segment increased, producing a second set of minor floor faults in the basement (Fig. 10b). Corresponding to these movements, thick alluvial fans have accumulated over the foreset deposits (Fig. 10b: A'B').

CONCLUSIONS

1 Fan deltas that prograded into protected sub-basins confined by topographical highs, characterized by an absence of bottomsets, produced the 'trapezoidal' fan delta type.

2 Two types of trapezoidal deltas were recognized: (a) those that prograded directly onto faulted submarine margins, and (b) those that prograded onto the subaqueous basin escarpment across a subaerial platform.

3 Fan delta sedimentation at the south-western Corinth graben is the result of a complex interplay between subsidence and uplift, attributed to a series of WNW-directed listric faults. Intensive subsidence along the southern marginal faults of the south-western Corinth graben, followed by footwall uplift, gave rise to successive deltaic sequences. However, the fan-delta deposits have suffered an isostatic footwall uplift of the master fault which at the present time separates the onshore and offshore areas of the graben.

4 The ratio of subsidence in the hangingwall of fault \( L_2 \) to uplift of the whole area is recorded in the relative sea-level variation in the fan deltas.

5 Although the deposition of deltaic sequences A and C is mainly controlled by WNW normal faults, transfer faults influenced the basinal water depth and consequently stratigraphic relations of the sequences A and C.

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Trapezoidal fan deltas, Greece


191
G. Poulimenos et al.


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