ANNALES GÉOLOGIQUES DES PAYS HELLÉNIQUES
PUBLIÉES SOUS LA DIRECTION DE DÉPARTEMENT DES SCIENCES DE LA TERRE DE L'UNIVERSITÉ D'ATHÈNES

H. DRINIA & M.D. DERMITZAKIS

SEDIMENTARY HISTORY OF PRINA COMPLEX, IERAPETRA BASIN, CRETE. AN OVERVIEW

Χ. ΝΤΡΙΝΙΑ & Μ.Δ. ΔΕΡΜΙΤΖΑΚΗΣ

ΙΖΗΜΑΤΟΓΕΝΗΣ ΙΣΤΟΡΙΑ ΤΟΥ ΣΥΜΠΛΕΓΜΑΤΟΣ ΠΡΙΝΑ, ΛΕΚΑΝΗ ΤΗΣ ΙΕΡΑΠΕΤΡΑΣ, ΑΝ. ΚΡΗΤΗ. ΜΙΑ ΚΡΙΤΙΚΗ ΘΕΩΡΗΣΗ

ATHÈNES
DÉPARTEMENT DES SCIENCES DE LA TERRE DE L'UNIVERSITÉ
Panepistimiopolis, Athènes (157 84)
1996-1997

Ανάτυπον εκ των «Γεωλογικών Χρονικών των Ελληνικών Χωρών» **37,** 1996-97, σ. 999-1014
Extrait des «Annales Géologiques des Pays Helléniques» **37,** 1996-97, p. 999-1014

SEDIMENTARY HISTORY OF PRINA COMPLEX, IERAPETRA BASIN, CRETE. AN OVERVIEW*

by

H. DRINIA ** & **M.D. DERMITZAKIS** **

INTRODUCTION

The occurrence of Neogene deposits in the Ierapetra region was first mentioned by BONARELLI (1901), CHALIKIOPOULOS (1904), CHRISTODOULOU (1963) and SYMEONIDIS (1965) and was first studied by DERMITZAKIS (1969) and later on by FORTUIN (1977), DERMITZAKIS & THEODORIDIS (1978) & DERMITZAKIS (1980). More recently DRINIA, MONOGIOU & POSTMA (1989), DRINIA (1989), MONOGIOU (1989), POSTMA & SOTER (1991), POSTMA & DRINIA (1993) present some new data.

Below, we present updated interpretations on facies analysis and sedimentary processes, on basis of existing and reinvestigated paleontological data and additional sedimentological and structural data. We focus our study on «Prina Complex» (one of the nine formational units which constitute the Ierapetra basin, FORTUIN, 1977) because of its complexity and ambiguous origin.

Definition of the Prina Complex: The Prina Complex was named after the village Prina (FORTUIN, 1977; 1978) which is situated along the Males-Kalo Chorio road in the southwest part of the Merabellou district (Fig. 1).

Fortuin used the name «Complex» instead of that of «Formation» to describe this unit, mainly for «...the uncertain stratigraphic position of several of the outcrops in culmination of Tripolitza limestone (Alpine basement); in addition the complicated stratigraphy of the layered units, their poor traceability in the field due to rapid lithological changes and the strong faulting...», were the reasons for FORTUIN (1977; p. 37) suggesting this term. Apart from the fact that this statement itself is somewhat ambiguous and reasons such as those described above have not been documented in the study area, the term «Complex» is retained in this study.

---

* Ιζηματογενής Ιστορία του Συμπλέγματος Πρίνα, Λεκάνη της Ιεράπετρας, Αν. Κρήτη. Μία κριτική θεώρηση.

** Dep. of Hist. Geology-Paleontology, Subfaculty of Earth Sciences, University of Athens, Panepistimiopolis, 157-84.

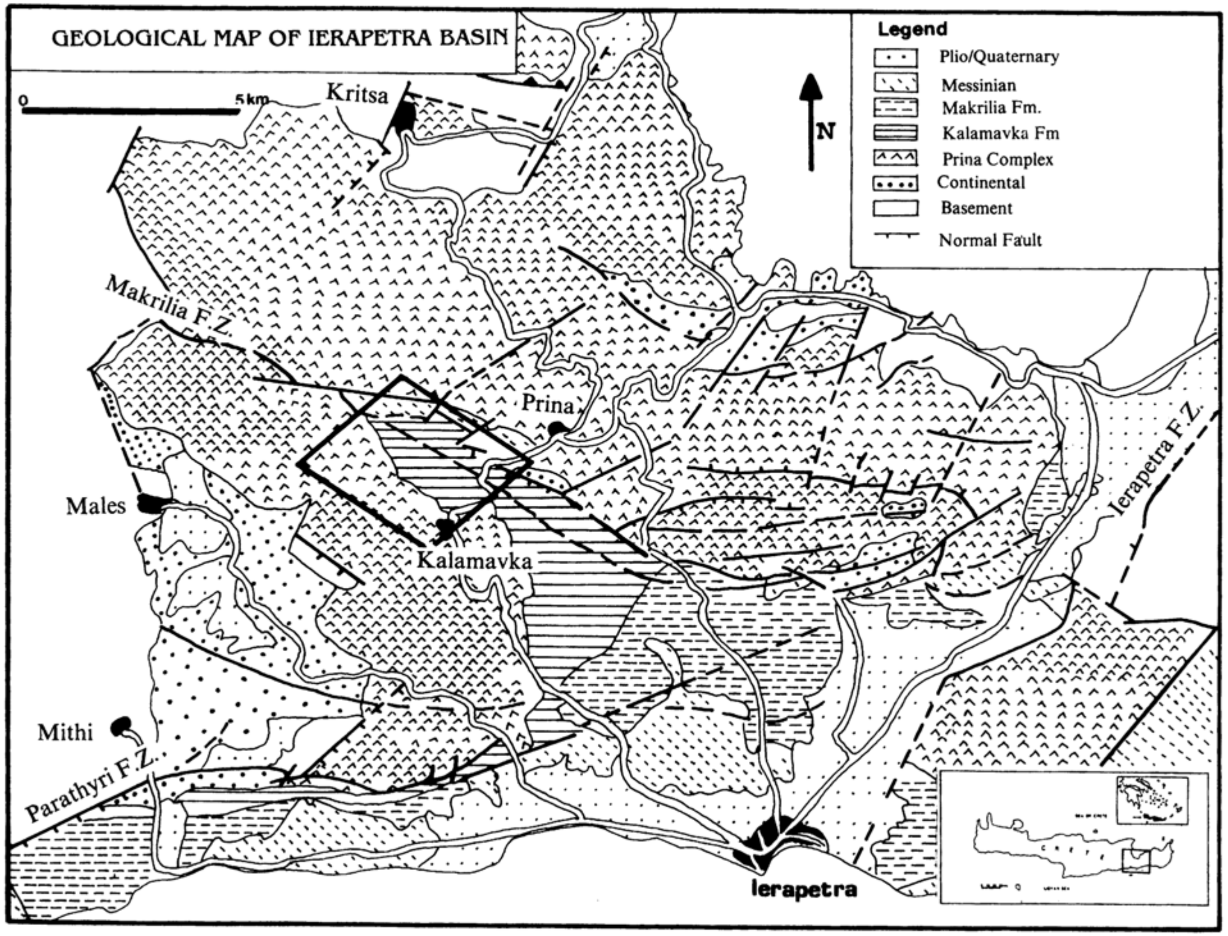

Fig. 1. Geological map of the Neogene deposits in the Ierapetra region according to POSTMA *et al.*, 1993, modified.

According to FORTUIN (1977; 1978) the sediments assigned to the Prina Complex could be roughly subdivided into two groups.

1. stratified breccias, breccio-conglomerates, and conglomerates with a variable number of fine-grained interbeds; most of the components originated from the Tripolitza Series (Alpine basement);

2. slabs and large masses of brecciated Tripolitza limestone; these slabs probably originated from uplifted areas in the northern part of the Ierapetra region, where rocks of the pre-Neogene Tripolitza Series had been exposed (N. of a line from Omalos Plain to the Gulf of Merabellou).

The Prina Complex has been subdivided by FORTUIN & PETERS (1984) into three structural levels: the lower structural level comprises slides and debris flow deposits containing material from the underlying formation (Mithi and Males Formation, FORTUIN, 1977). This sequence is covered by a series of slides with exotic large Tripolitza blocks (Alpine basement) which are buried by progradational series of south-facing breccia cones and alluvial fans up to 100m thickness in the north (the middle structural level). The latter series are covered by a level of corals and Oyster beds and stromatolites, which separate the lower and middle structural levels of FORTUIN & PETERS (1984) from the upper structural level of the Prina Complex further described below.

The sedimentary succession comprising the upper structural level of the Prina Complex is regularly bedded (stratified Prina Complex) and has a total stratigraphical thickness in the order of 350 m WNW of the village of Kalamavka (Fig 2). The whole succession is deposited on top of the coral and stromatolite beds. The age of the series present in the type section near Kalamavka village is Early Tortonian (POSTMA *et al.*, 1993) (N15 zone), yet the presice age is still a matter of discussion. Recent investigations by ZACHARIASSE (pers. comm.) put doubt on this age and place the same deposits at the base of N16 biozone. Furthermore, according to POSTMA & DRINIA (1993), the stratified upper structural level of Prina Complex constitutes the base of the half-graben fill which is part of the Neogene fill of Ierapetra basin (DERMITZAKIS, 1969; FORTUIN, 1977). The tectonic history for this basin has been reconstructed in a recent paper (POSTMA *et al.*, 1993).

GEOLOGICAL SETTING

The Ierapetra basin developed as a large, N-S oriented transverse graben structure in upper Middle Miocene in eastern Crete. Its present day morphology is a central NE-SW oriented depression (Fig. 3). The pattern of basin fill is strongly controlled by tectonics which changed the basin relief and sediment flux. In the Ierapetra basin two important compressional phases are recognized on basis of sedimentary and tectonic features: in Late Serravallian/Early Tortonian, and in Late Messinian/Early Pliocene times (POSTMA *et al.*, 1993). In Late Serravallian times sedimentation was controlled by roughly E-W running

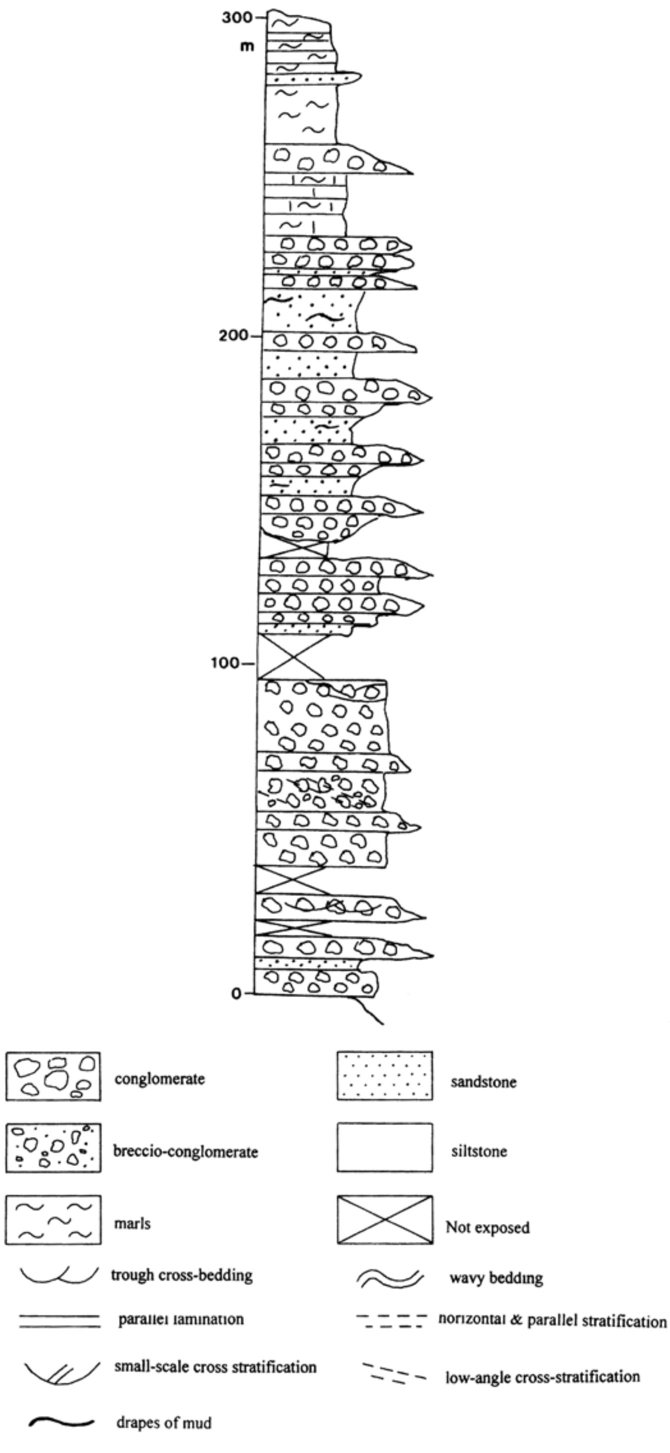

Fig. 2. The overall fining-upward grain size sequence.

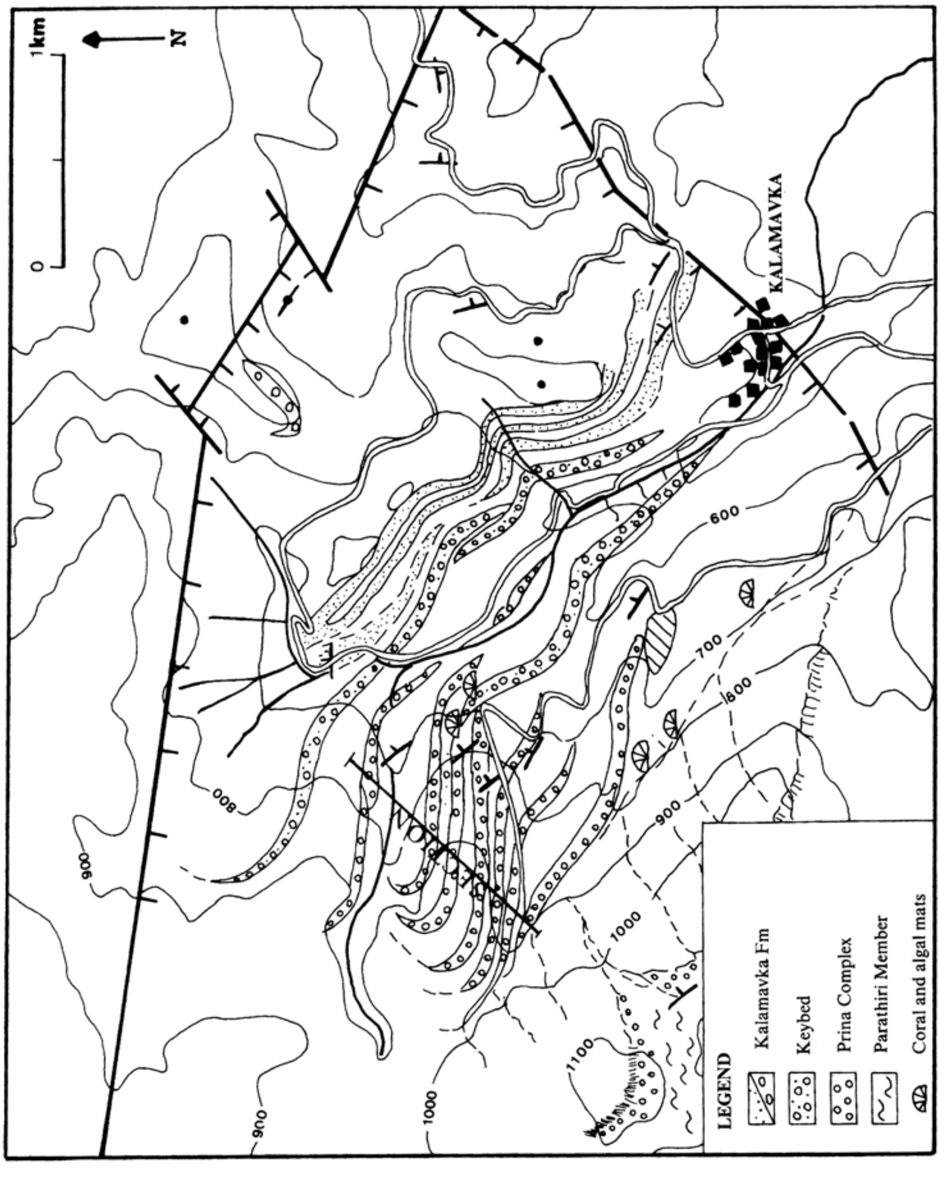

Fig. 3. Detailed map of the study area.

faults, one of which runs just north of the Ierapetra basin (FORTUIN & PETERS, 1984). Transpression along these faults resulted in folding and thrusting of both the basement and the basin fill determining the basin relief.

After the compressional phase, the Ierapetra Basin became dominated by NNE-SSW extension in Early Tortonian times. The extension was accomodated by northward rotation of a fault block along Ayios Nikolaos Fault Zone and at a later stage, along the Parathiri Fault Zone and Makrilia Fault Zone (Fig.1).

In the area study (Ierapetra Basin) a sediment wedge has been studied which contains the Upper structural level of Prina Complex and the Kalamavka Formation and forms the basal part of the Upper Miocene basin fill (FORTUIN, 1977; 1978; FORTUIN & PETERS, 1984). As shown by the geological map and cross-sections, deformation of the wedge is complex, with syn- and post-depositional faults. The Prina succession passes to the south into a stratigraphically complex area where sediments of the underlying formation of Males are intermixed with those of the Prina Complex and huge slabs of Tripolitza basement rock. Towards the east the stratified Prina breccias and conglomerates pass gradually into the finer deposits of the Kalamavka Formation. The boundary between the Prina Complex and the Kalamavka Formation in the study area, is thought to be stratigraphic as indications for a tectonic contact were not observed.

The stratigraphy of the Prina Complex is affected by thrusting, strike-slip faulting and normal faulting (Fig. 1). Pleistocene landsliding further complicates accurate mapping and logging. However, an approximately 350 m sequence from the base of the Strarified Prina Complex up to the base of the Kalamavka Formation has been studied. Furthermore, three main rock units, which are also indicated on the map of the study area, were used as key beds: a) a coral and algal horizon in the basal part of the sequence and b) two poorly-sorted boulder conglomeratic megabeds which probably represent river flood-generated debris flow deposits (POSTMA & SOTER, 1991).

SEDIMENTARY FACIES ANALYSIS

The stratified Prina deposits comprise, from the base to the top: (i) mono-to oligomict breccias, (ii) polymict breccias and breccio-conglomerates, (iii) oligo- to polymict cobble and boulder conglomerates and (iv) calcareous marls (FORTUIN, 1977).

Furthermore, detailed sedimentary facies analysis allowed us the distinguish of two main depositional units:

Depositional Unit I: Alluvial Systems

The base of this unit is dominated by mass-flow deposits. Beds are structureless to crudely stratified and contain clast-supported fine- to very coarse pebble conglomerates with mud-rich matrix. Clasts are generally subangular to sub-rounded. The mud matrix suggest that the conglomerate beds originate from cohesive debris flow, sensu LOWE (1982) and POSTMA (1986). The intercalated sandy beds with pebble streaks and shallow scour and fill structures are due to stream-flow and/or fluidal mass-flow (cf. NEMEC & STEEL, 1984).

Going upwards in the continental Stratified Prina Complex, stream-flow deposits dominate. Conglomerates become polymict and subrounded to rounded. The up to 2.5 m thick conglomerate beds often have a tripartite composition consisting of (i) a basal part of coarse pebbles in a sandy matrix, (ii) a central part of fine to coarse-pebbly, crudely horizontally and cross-stratified, clast-supported conglomerates and (iii) an upper part horizontal- and cross-stratified sandy layers. The tripartite composition suggest sediment transport by shallow, bed-load dominated rivers (MIALL, 1977; STEEL & THOMPSON, 1983), such as those occurring on gravelly alluvial fans (LARSEN & STEEL, 1978; RUST, 1977). Current directions of these alluvial systems vary over 130^{o} and are predominantly south/southwest.

Depositional Unit II: Shallow water delta systems

Four main Facies Associations have been defined:

Facies Association 1: This facies association can be described as a small-scale, fining-upward sequence (2-3 m), consisting of a composite unit of conglomerate overlain by sandstone (Fig. 4a). The composite unit has a lens-shaped geometry, and overlies a high relief basal erosive surface; its width does not exceed 100-200 m.

The fine to coarse pebble conlomerates are crudely stratified, clast-supported, with sub-rounded to rounded clasts, and commonly well-sorted and graded. Paleocurrent direction is to southwest. Bed thickness varies from 1.5 to 2.5 m. The pebbly sandstones which occur at the top of the conglomerates display an erosive base, are horizontally to cross-stratified and normally graded and vary in thickness from 30 to 50 cm (Fig. 4b). These fining-upward sequences could be explained as deposits of a heavily sediment-laden stream-flow. The conglomerates at the base probably represent high transport competence for such flow, and the stratified sandy capping probably represents deposition during waning energy conditions.

Although this facies association is not very common in the sequence studied, it could by interpreted as distributary channels in the distal subaerial segment of a delta system.

Facies Association 2: This facies association consists of vertically stacked conglomerates, locally separated by thin sandstone interbeds. The conglomerates have a lens-shaped geometry and are bounded by slightly erosive to non-erosive surfaces (Fig. 5). They are made up of pebbles, cobbles and boulders. They are unstratified to crudely stratified, ungraded to inversely graded and clast to

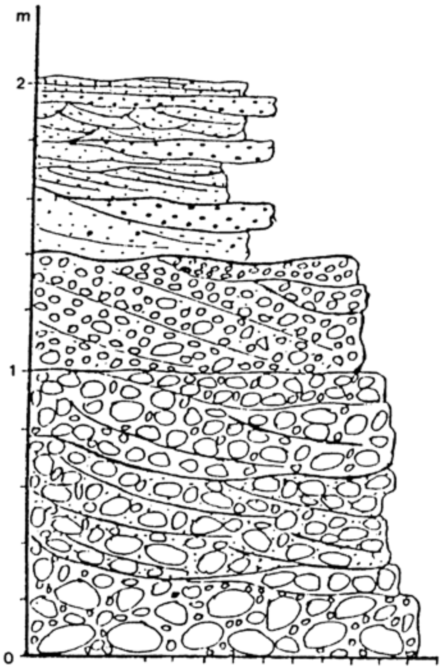

Fig. 4a. Facies Association 1.

Fig. 4b. Horizontally stratified, graded sandstone bed overlying the fine pebble conglomeratic bed.

matrix supported with subangular to subrounded clasts; the matrix is sandy or pebbly with minor amounts of silt. Bed thickness varies from 0.5 to 3 m.

The fine to very coarse sandstone beds are partly parallel-laminated and/or wave-ripple cross-laminated, locally homogenized by bioturbation; burrows such as *Skolithos* and *Ophiomorpha* have been occasionally found. Bed thickness varies from 10 to 50 cm.

The above mentioned characteristics lead to a mass flow origin for the conglomeratic facies (similar facies have been described by LARSEN & STEEL, 1981; GLOPPEN & STEEL, 1981; KLEINSPEHN *et al.*, 1984; NEMEC & STEEL, 1984; MARZO & ANADON, 1988). In addition, clear evidence for the subaquatic origin of these debris flow deposits is provided by the presence of wave-induced and biogenic structures in the associated sandstone interbeds; (wave ripples, *Skolithos* and *Ophiomorpha* burrows indicate a very shallow environment).

The mass flow origin of the debris flows could be attributed to river floods rather than to slope instability, as there are no indications for a slope in the delta system studied. Therefore, the vertically stacked conglomerate beds could be interpreted as proximal mouth bars, although their poor preservation due to marine reworking leaves the above interpretation open to further debate. The sandstone interbeds possibly represent channel effluent-derived sands which were subject to marine reworking after deposition (MARZO & ANADON, 1988).

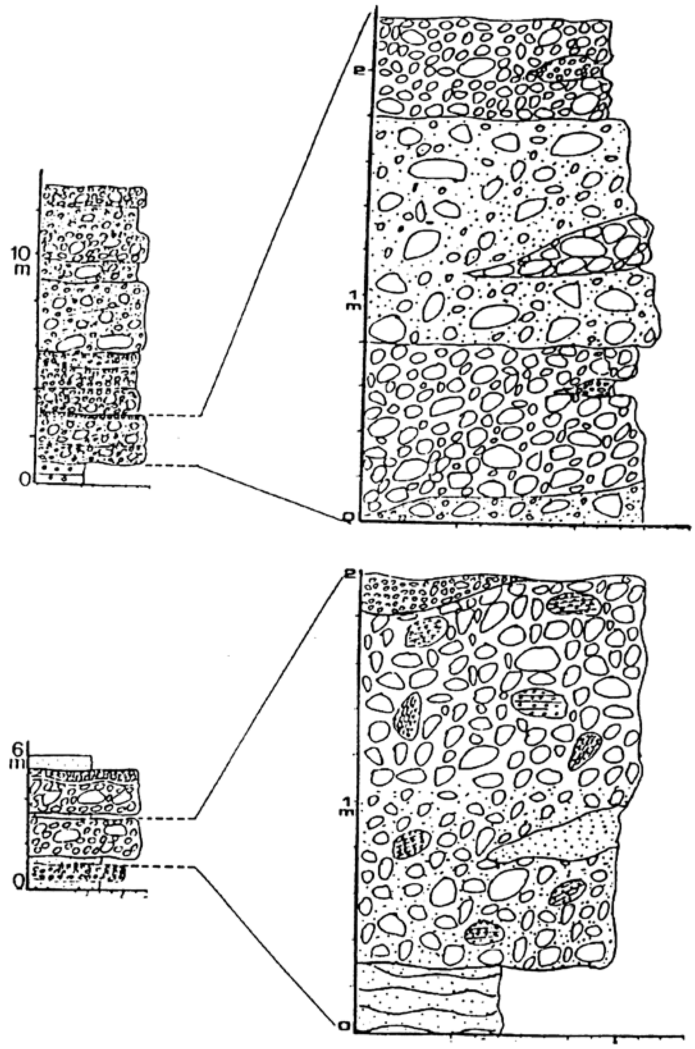

Fig. 5. Facies Association 2.

Facies Association 3: This facies association predominantly consists of sandstones and siltstones with the conglomerates occurring only in thin beds on top of the finer-grained deposits (Fig. 6a). Thus, well-defined coarsening-upward sequences (3-6 m) are characteristic of this Facies association. The sandstone and siltstone occur in alternating sheet-like beds which commonly show irregular, slightly erosive bases. Some marly beds with very thin sandstone interlayers occur in the stratigraphically higher part of the sequence. This Facies association has been further subdivided into three subfacies based on their lithology:

a) Very fine to medium pebble conglomerates occur in thin beds at the top of the finer-grained sediments. Their thickness ranges from 0.5-1 m.

b) Fine to medium-grained sandstone beds which are ungraded to slightly graded and show crude to well-developed traction structures (horizontal or low-angle lamination, wave ripple cross-lamination, low-angle cross-stratification). Hummocky cross-stratification and silty/clay laminations are commonly recognized. Beds are heavily affected by bioturbation and occasionally body fossils are present. Gravel pockets with subangular to subrounded clasts are locally present at the top of the sandstone beds as load structures. The thickness of the sandstone beds range from 0.2 to 2 m.

c) Muddy sandstone (or siltstone) beds are horizontally and parallel laminated, and locally show trough cross-stratification, wave induced structures and slumping. They are intensely bioturbated and contain broken shells which suggest compression movements. The thickness of the beds ranges from 0.1 to 0.8 m.

d) Fossiliferous marly beds, with thin sandstone intercalations, are horizontally laminated and strongly bioturbated with *Skolithos* and possibly *Thalassinoides* burrows (Fig. 6b).

Marine reworking can be inferred from the wave-rippled, cross-laminated sandstones, and/or from the hummocky cross-stratification, which reflects storm wave deposition above storm wave base (Fig. 6c) (similar deposits have been described by HARMS *et al.*, 1975; DOTT & BOURGEOIS, 1982; HUNTER & CLIFTON, 1982; SWIFT *et al.*, 1983). The storm-induced deposits could have originated from the transformation of subaqueous gravelly debris flows of the proximal mouth-bar fronts by storm currents. Thus it is speculated that this facies association could be interpreted as wave-reworked distal mouth-bar deposits which interfinger with, and extend downslope from, the gravelly debris flow lobes of facies association 2, the proximal mouth-bar deposits.

Boulder conglomerates are associated with facies association 3. The conglomerates are structureless lobe-shaped beds up to 2 m thick. Cobble and boulder-sized clasts occur dispersed in a «matrix» of clast-supported fine to coarse pebbles mixed with sandy to marly sediments. Due to local amalgamation of these conglomerate beds, up to 10 m thick pseudomegabeds occur. Some of these megabeds can be traced over a distance of nearly 2 km perpendicular to the current direction and are thus excellent markerbeds (first and second key beds in Fig. 3). The top of boulder beds is commonly winnowed and covered by turbiditic sandstones and marls.

DISCUSSION-CONCLUSIONS

The facies analysis, description and interpretation, allow the reconstruction of the depositional environment of the sedimentary sequence study. The model depicted is proposed on the basis of: a) lack of any indication for a primary slope (i.e. sliding and slumping), b) the presence of mass flows probably triggered by river floods, c) the presence of wave-induced structures (i.e. wave ripples) and storm-induced structures (i.e. hummocky-cross-stratification), and

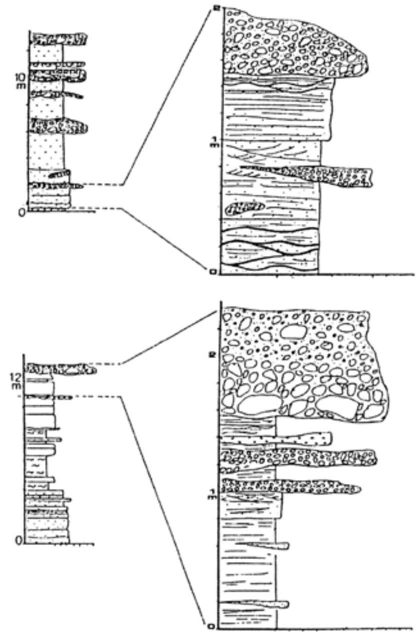

Fig. 6a. Facies Association 3.

Fig. 6b. Vertical burrows in intensely bioturbated siltstone beds.

Fig. 6c. Wave-induced structures in sandy/silty strata are locally recognized.

d) the presence of shallow marine biogenic features (i.e. burrows and fossils). The proposed model represents a shallow marine, wave-dominated, mouth bar type of delta with flood-generated debris-flow lobes, mainly deposited in a more offshore direction.

Based mainly on field study and facies analysis, it is inferred that three main factors played an important role during the sedimentation of the succession studied: a) features of the basin, b) sea-level fluctuations and c) climate.

Basin tectonics may have operated as an extrabasinal control on the stratigraphic evolution of the succession. The overall fining-upward trend of the grain size in the sequence could be explained as the result of transgression due to eustatic sea level change. But as no evidence for a major sea-level rise in Late Serravallian-Early Tortonian is recorded (VAIL *et al.*, 1977; VAIL & MITCHUM, 1979), it is speculated that the fining-upward trend of the sequence was the result of a transgression due to the gradual subsidence of basin controlled by tectonics.

Both subsidence rate and the amplitude of sea-level fluctuations, which are probably controlled by minor eustatic changes, significantly influence the distribution of the facies in the delta system; this combination of gradual subsidence and a low-amplitude eustatic signal, gives a relative sea-level curve which consists of only slight falls (or stillstands) separated by periods of rise. During periods of slightly lowered sea-level, the coarser sediment is transported basinwards by rivers while during periods of higher sea-level, only fine grained sediments are deposited; these deposits are subsequently reworked by waves. The resulting small-scale (10-35 m) coarsening-upward cycles (Fig. 7), interpreted here as mouth-bar deposits, could therefore represent the product of a combination of basin subsidence and low-amplitude sea level fluctuations causing progradation of these sequences; the stacking of the coarsening-upward sequences may represent delta lobe shifting.

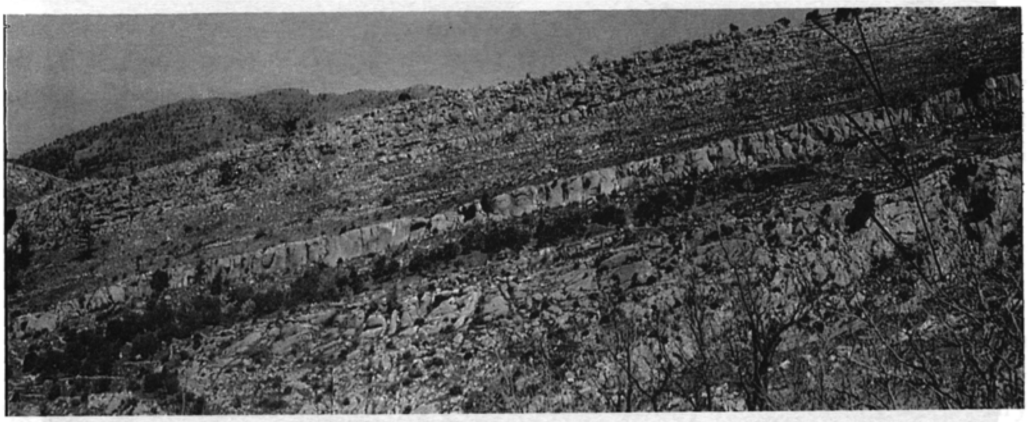

Fig. 7. Coarsening-upward cycles (10m); these cycles display alternations of conglomerates and finer clastics (sandstones, sandy mudstones).

In addition, the progressive northward tilting of the fault block may have controlled the depositional style of the alluvial and shallow-marine delta system. Periods of strong progradation may be related to periods of tectonic quienscence (BLAIR & BILODEAU, 1988). On the other hand, progradation may be induced by climatic changes and related to periods of high discharges (BULL, 1991) or both. Alternatively fine and coarse intervals in tectonic active areas have been ascribed to climatic fluctuations earlier (e.g. FROSTICK & REID, 1989; DE BOER, PRAGT & DOST, 1991; MANSPELZER, 1985). The Miocene basins of Crete were located at a palaeo-latitude of about 35° (ANGELIER *et al,* 1982), which appears to be sensitive to astronomically induced climatic changes (FISCHER, DE BOER & PREMOLI SILVA, 1990).

Our facies analysis suggest that ephemeral (seasonal) streams rather than perennial ones were dominant during the Prina Complex deposition, because much of the coarse material was transported during stream floods and because the coarse-grained delta fronts are «wave-dominated» (Fig. 8). On a large scale, we note that the topmost depositional units of the Prina Complex show repetitions of the subfacies of facies association 3. This trend suggests either spasmodic

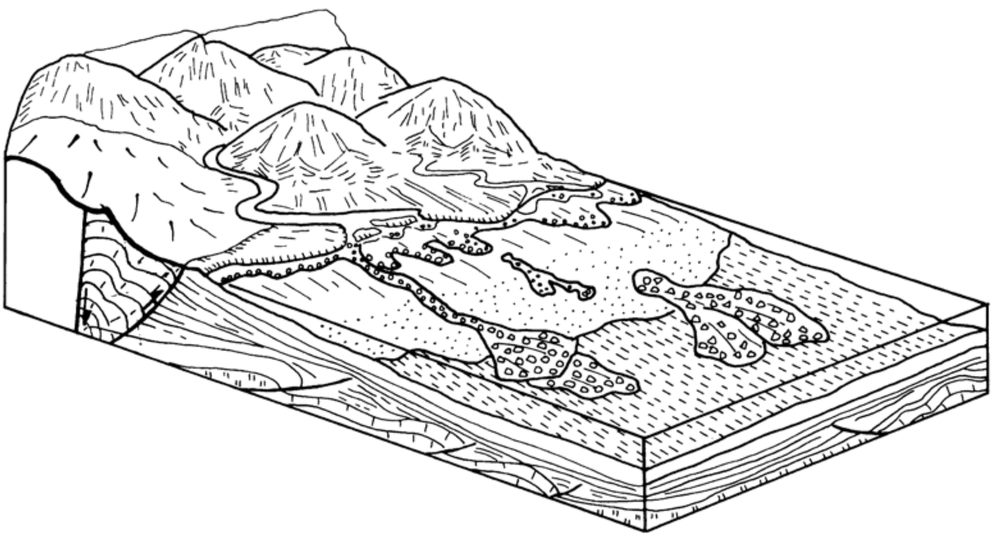

Fig. 8. The proposed model for a shallow-marine, wave-dominated, mouth-bar type of delta with flood-generated debris flow lobes.

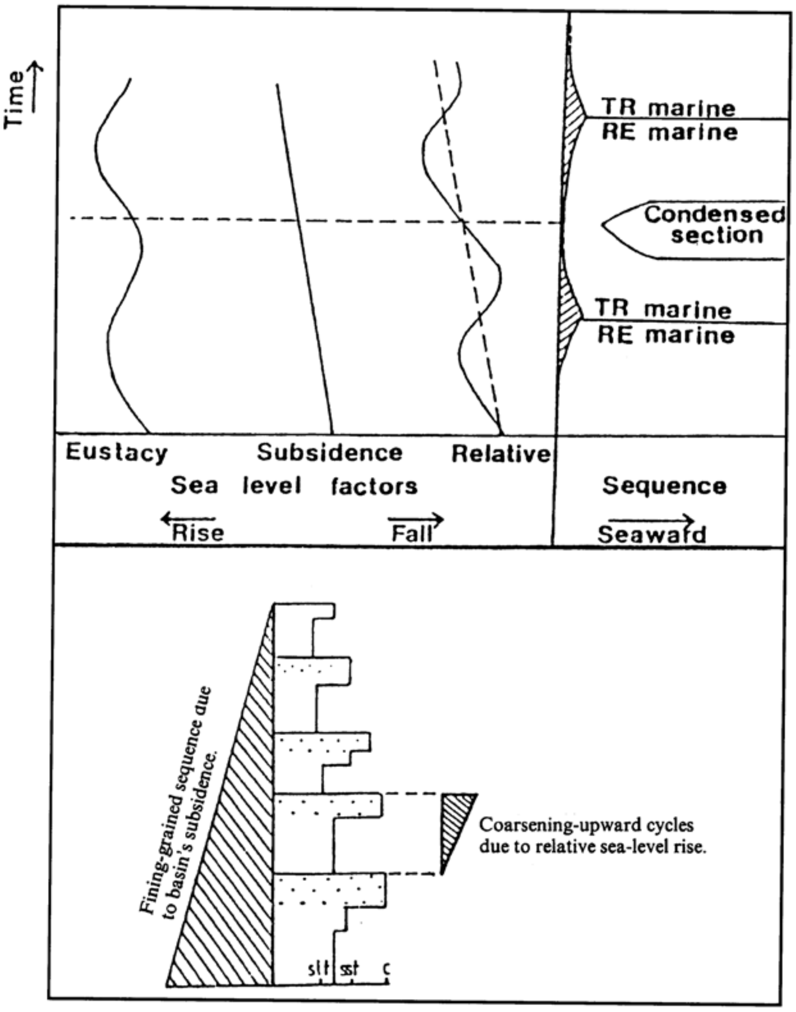

Fig. 9. Schematic diagram showing the relative sea-level curve as a function of the overall tectonic subsidence due to low amplitude of absolute (eustatic) sea-level fluctuations. The relative sea-level consists of only slight falls (or stillstands) separated by periods of rise.

subsidence and continuous sediment supply (STEEL & GLOPPEN, 1980; GJELBERG & STEEL, 1983), gradual subsidence and spasmodic sediment supply, or both spasmodic subsidence and spasmodic sediment supply (Fig. 9). The successive pulses of delta progradation in the upper part of the Prina Complex may be punctuated by a variety of causes, among which astronomical controlled increases in discharge (a precession punctuated variation in discharge maybe controls the denudation of the relatively small drainage basins of the Prina Complex), autocyclic changes or higher order fluctuations in discharge. The high preservation potential of fine-grained sediment strongly suggests increase in accomodation space due to continued, either gradual or spasmodic subsidence.

REFERENCES

ANGELIER, J., LYBERIS, N., LE PICHON, X., BARRIER, E. & HUCHON, P. 1982. The tectonic development of the Hellenic Arc and the sea of Crete: a synthesis. In: *Geodynamics of the Hellenic Arc and Trench* (Ed. by X. Le Pichon, S.S. Augustithis and J. Mascle), *Tectonophysics*, 86, 159-196.

BLAIR, T.C. & BILODEAU, W.L., 1988. Development of tectonic cyclothems in rift, pull apart, and foreland basins: Sedimentary response to episodic tectonism. *Geology*, 16, 517-520.

BONARELLI, G., 1901. Appunti sulla costituzione geologica del□ isola di Creta. *Atti della Reale Academia dei Lincei,* Serie quinta, Memorie, Vol. III, p. 518-548 Roma.

BULL, W.B., 1991. Geomorphic responses to climatic change. 326pp. Oxford University Press, New York.

CHALIKIOPOULOS, L., 1904. Sitia, die Osthalbinsel Kretas. *Veroff. Inst. Meereskd. Berlin*, 4,1-138.

DE BOER, P.L., PRAGT, J.S.J., & OOST, A.P., 1991. Vertically persistent sedimentary facies boundaries along with growth anticlines and climate-controlled sedimentation in the thrust-sheet-top South Pyrenean Tremp-Graus Foreland Basin. *Basin Research*, 3,63-78.

DERMITZAKIS, M.D., 1969. Geological Researches of the Neogene Deposits of the Hierapetra Province in Crete. *Ann. Geol. Pays Hellen.*, 21, 342-484.

DERMITZAKIS, M.D., 1980. Biostratigraphic Survey in the Pliocene Sediments of Ammudhares and Aghios Charalambos Sections (Hierapetra Province, E. Crete). *Ann. Geol. d. Pays Hellen.*, 30,1,130-142.

DERMITZAKIS, M.D. & S.A. THEODORIDIS, 1978. Planktonic Foraminifera and Calcareous Nannoplankton from the Pliocene of Koufonisi Island (E. Crete, Greece). *Ann. Geol. d. Pays Hellen.*, 29, 2, 630-643.

DOTT, R.H. Jr & BOURGEOIS, J., 1982. Hummocky stratification: significance of its variable bedding sequences. *Bull. Geol. Soc. Am.*, 93, 663-680.

DRINIA, H., 1989. Shallow marine, sandy carbonate clastic sedimentation in a forearc basin (Kalamavka Formation, Late Serravallian-Early Tortonian, E. Crete), *MPhil. thesis.* University of East Anglia, Norwich, 123 pp.

DRINIA, H., MONOGIOU, E. & POSTMA, G., 1989. Carbonate clastic alluvial fan and fan-delta sedimentation during compressional tectonics. In: *Sea level changes at active plate margins-processes and products*, Geological Society of London, May 1989, Abstracts.

FISCHER, A.G., DE BOER, P.L. & PREMOLI SILVA, I., 1990. Cyclostratigraphy. In: *Cretaceous Resources, Events and Rhythms* (Ed. by R.N. Ginsburg and B. Beaudoin), 139-172, Kluwer, Dordtrecht.

FORTUIN, A.R., 1977. Stratigraphy and sedimentary history of the Neogene deposits in the Ierapetra region, eastern Crete. *GUA Paper of Geology*, Series 1, 8: 164pp.

FORTUIN, A.R., 1978. Late Cenozoic history of Eastern Crete and implications for the geology and geodynamics of the southern Aegean sea. *Geol. & Mijnb. 57*, 451-464.

FORTUIN, A.R. & PETERS, J.M., 1984. The Prina Complex in eastern Crete and its relationship to possible Miocene strike-slip tectonics. *J. Struct. Geol.*, 6, 5, 459-476.

FROSTICK, L.E. & REID, I., 1989. Climatic versus tectonic controls of fan sequences: lessons from the Dead Sea, Israel. *J. Geol. Soc.*, London, 146, 527-538.

GLOPPEN, T.G. & STEEL, R.J., 1981. The deposits, internal structure and geometry in six alluvial fan-fan delta bodies (Devonian, Norway)-a study in the significance of bedding sequences in conglomerates. In: *Recent and ancient nonmarine depositional environments: Models for exploration* (Ed. by F.G. Ethridge & R.M. Flores) *Spec. Publ. Soc Econ. Paleont. Mineral*, 31, 49-69.

GJELBERG, J. & STEEL, R.J., 1983. Middle Carboniferous marine transgression, Bjornoya, Svalbard: Facies sequences from an interplay of sea-level changes and tectonics. *Geol. Journ.*, 18, 1-19.

HARMS, J.C., SOUTHARD, J.B., SPEARING, G.R. & WALKER, R.G., 1975. Depositional environments as interpreted from primary sedimentary structures and stratification sequences. *Short Coarse Lect. Notes 2, Soc. Econ. Paleont. Miner.*, Tulsa, 161p.

HUNTER, P. & CLIFTON, H.E., 1982. Cyclic deposits and hummocky cross-stratification of probable storm origin in Upper Cretaceous rocks of the Cape Sebastian area, southwestern Oregon. *J. Sediment. Petrol.*, 52, 127-143.

KLEINSPEHN, K.L., STEEL, R.J., JOHANSSEN, E. & NETLAND, A., 1984. Conglomeratic fan-delta sequences, Late Carboniferous-Early Permian, Western Spitsbergen, In: *Sedimentology of Gravels and Conglomerates* (ed. by E.H. Koster and R.J. Steel) *Can. Soc. Petrol. Geol. Memoir*, 10, 279-294.

LARSEN, V. & STEEL, R.J., 1978. The sedimentary history of a debris flow dominated, Devonian alluvial fan - a study of textural inversion. *Sedimentology*, 25, 37-59.

LOWE, D.R., 1982. Sediment gravity flows II: Depositional models with special reference to the deposits of high-density turbidity currents. *J. Sedim. Petr.*, 52, 279-298.

MANSPEIZER, W., 1985. The Dead-Sea rift: Impact of climate and tectonisms on Pleistocene and Holocene sedimentation. In: *Strike-slip deformation, basin formation and sedimentation* (Ed. by K.T Biddle and N. Christie-Blick) *Spec. Publ. Soc. econ. Paleont. Mineral.* 37, 143-158.

MARZO, M. & ANADON, P., 1988. Anatomy of a conglomeratic fan-delta complex: the Eocene Montserrat Conglomerate, Ebro Basin, northeast Spain. In: *Fan Deltas: Sedimentology and Tectonic Settings* (Ed. by W. Nemec and R.J. Steel), 319-340. Blackie, Glasgow.

MIALL, A.D., 1977. Lithofacies types and vertical profile models in braided river deposits. In: *Fluvial Sedimentology* (Ed. A.D. Miall) *Can. Soc. Petrol. Geol. Memoir.* 5, 597-604.

MONOGIOU, E., 1989. Shollow marine, gravelly carbonate clastic sedimentation during the compressional tectonics (Prima Complex, Serravallian, E. Crete). *Mphil. thesis,* University of East Anglia, Norwich, 122pp.

NEMEC, W., & STEEL, R.J., 1984. Alluvial and coastal conglomerates: Their significant features and some comments on gravelly mass-flow deposits. In: *Sedimentology of Gravels and Conglomerates* (Ed. by E.H. Kosters & R.J. Steel) *Can. Soc. Petrol. Geol. Memoir* 10, 1-32.

POSTMA, G., 1986. Classification for sediment gravity-flow deposits based on flow conditions during sedimentation. *Geology,* 14, 291-294.

POSTMA, G. & DRINIA H., 1993. Architectural and sedimentary facies evolution of a marine, expanding outer-arc half-graben (Crete, late Miocene). *Basin Research,* 5, 103-124.

POSTMA, G. & SOTER, S.T., 1991. Features and stratigraphic significance of bouldery mass-flow deposits from the modern and ancient Mediterranean nearshore zone.

POSTMA, G., FORTUIN, A.R. & VAN WAMEL, W.A., 1993. Basin-fill patterns controlled by tectonics and climate: the Neogene «forearc» basins of eastern Crete as a case history. In: Tectonic control and Signatures, In Sedimentary successions, (Ed. by L.E. Frostick & L.J. Steel), *Spec. Publ. Int. Ass. Sed.,* 19, 335-362.

RUST, B.R., 1977. Deposition models for a braided alluvium. In: *Fluvial Sedimentology* (Ed. by A.D. Miall) *Can. Soc. Petrol. Geol. Memoir,* 5, 605-625.

STEEL, R.J. GLOPPEN, T.G., 1980. Late Caledonian (Devonian) basin formation, western Norway: signs of strike-slip tectonics during infilling. In: *Sedimentation in Oblique-Slip Mobile Zones* (Ed. by P.F. Ballance and H.G. Reading), *Spec. Publ. int. Ass. Sediment.,* 10, 91-112.

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

SWIFT, D.J.P., FIGUEIREDO, A.G. Jr., FREELAND, G.L. & OERTEL, G.F., 1983. Hummocky cross-stratification and megaripples: a geological double standard. *J. Sediment. Petrol.,* 53, 1295-1317.

SYMEONIDIS, N.K., 1965. Das Neogen von Ostkreta, *Ann. Geol. Pays Hellen,* 16, 249-314, Athens.

VAIL, P.R. & MITCHUM, R.M. 1979. Global cycles of relative changes of sea-level from seismic stratigraphy. *A.A.P.G.* Memoir, 29, 469-472.

VAIL, P.R., MITCHUM, R.M. & THOMSON, S. 1977. Seismic stratigraphy and global changes of sea level, Part 4: Global cycles of relative changes of sea level. *A.A.P.G.* Memoir 26, 83-97.