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MAJOR EVENTS AND STAGES IN THE SEDIMENTARY EVOLUTION OF THE PALEOGENE PROMINA BASIN (DINARIDES, CROATIA)

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A study of sedimentary successions in different parts of the Eocene-Oligocene Promina basin has revealed major changes in the evolution of upper Promina Beds (PB). The first one refers to the origin of the erosional surface cutting different units ranging from Cretaceous limestones to different parts of older PB. It was formed during the fall of relative sea-level, and corresponds to a sequence boundary. This surface is overlain by onlapping alluvial sediments during the lowest relative sea level, and its early rise. The next main event is marked by a transgressive surface above the alluvium, that led to the deposition of shallow-marine limestones with diverse biota in the photic zone, as well as their lagoonal equivalents. This change resulted from an increase in accommodation space outpacing the rate of sediment supply. A further change refers to the deposition of mud with planktonic foraminifera on an outer shelf resulting from a further rise in the relative sea-level, which halted deposition of shallow-water limestones. The subsequent progradation of shelf and delta was related to the slowing down of the creation of accommodation space compared to the increase of sediment supply.

Key words: alluvium, shelf, Gilbert delta, sequence stratigraphy, Promina Beds, Paleogene, Croatia

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Istraživanje taložnih sukcesija u raznim dijelovima eocensko-oligocenskog bazena Promine pokazalo je glavne promjene u razvitku mlađih naslaga Promine. Prva se odnosi na postanak erozijske plohe, koja siječe razne jedinice, od krednih vapenaca do raznih dijelova starijih naslaga Promine.

Ona je nastala u vrijeme pada relativne morske razine i odgovara sekvencijskoj granici. Na toj plohi naklopno se slažu aluvijalni sedimenti u vrijeme najniže relativne morske razine i njena ranog rasta. Naredni glavni događaj označuje transgresivna ploha na aluviju. On je doveo do taloženja vapnenaca sa diverzificiranom biotom u fotičkoj zoni, kao i njihovih lagunarnih ekvivalenata. Uzrok te promjene je u porastu akomodacijskog prostora, koji je nadišao brzinu prinosa sedimenta. Sljedeća promjena odnosi se na taloženje mulja s planktonskim foraminiferama na vanjskomu šelfu, što je posljedica rasta relativne morske razine, koji je prekinuo taloženje plitkovodnih vapnenaca. Tomu je slijedila progradacija šelfa i delte, što je bilo vezano za usporenje stvaranja akomodacijskog prostora u odnosu na brzinu prinosa sedimenta.

Ključne riječi: aluvij, šelf, Gilbertova delta, sekvencijska stratigrafija, Bazen Promine, Paleogen, Hrvatska

INTRODUCTION

The correlation of stratigraphic successions from different parts of a sedimentary basin is an indispensable component when studying sedimentary basin evolution. Such work should combine features and processes related to sedimentary facies, the character of individual sedimentary units, the succession of these units, as well as the character of their boundaries and relevant changes through time, all of which are to be compared across the basin area (review in MIALL, 2000). The purpose of this work is to propose a correlation of sedimentary successions from different parts of a Dinaric foreland basin as to identify the main events and stages in its sedimentary evolution. The studied basin is the Eocene-Oligocene Promina basin situated in the coastal belt of the Outer Dinarides (Fig. 1). The sedimentation in this basin succeeds Eocene flysch sediments of the coastal Dinarides, and the deposits are regarded as the molasse of the Dinaric foreland (e.g. HERAK & BAHUN, 1979; MARINČIĆ, 1981; reviews in BABIĆ & ZUPANIČ, 1983; MARJANAC & ĆOSOVIĆ, 2000).

This work deals with an upper part of the overall succession of the Promina basin. We use the sections located in different parts of the basin for describing their common features including facies, sedimentary units and their succession, as well as the boundaries between the units. The emphasis is on the lateral extent of common features, which reflect the character of the main steps in the sedimentary evolution of the Promina basin.

GEOLOGICAL SETTING AND OUTLINE STRATIGRAPHY

The Promina Beds (PB) occupy an area located in the Adriatic coastal zone (Fig. 1), which is a part of the Outer Dinarides. A major part of this zone consists of late Mesozoic and Paleogene platform carbonates. They are overlain by Paleogene clastics including the flysch and PB, minor Neogene fresh-water deposits, and Quaternary sediments. In northern Dalmatia, like in other parts of the coastal zone, carbonate deposition ended in the Middle Eocene, and were replaced by Middle Eocene flysch (e.g. MAMUŽIĆ, 1975; IVANOVIĆ *et al.*, 1976; 1978), which reflects the denudation of the Dinaric orogen, and deposition in a deep foreland basin. The flysch is overlain by the PB, which is late Middle Eocene to Early Oligocene in age (e.g. IVANOVIĆ *et*

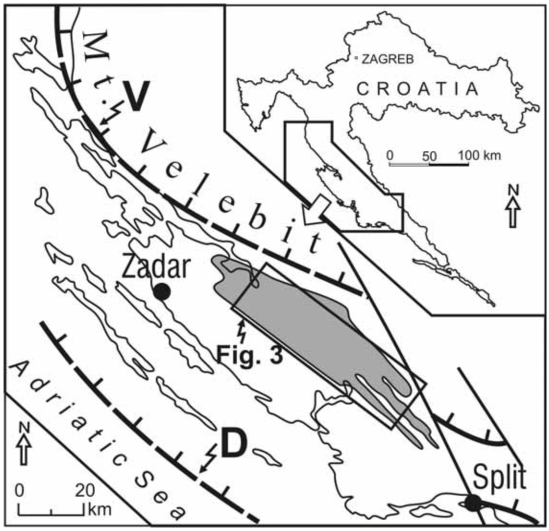

Fig. 1. The Promina basin (in grey) is located in an imbricate-folded belt bounded by the Dugi Otok Fault Zone (D) and Velebit Thrust (V). Tectonic structure after ALJINOVIĆ *et al.* (1987). Framed area is shown in Fig. 3.

al., 1978). Towards the inland, the flysch unit is lacking, and the PB onlap deformed Paleogene and Cretaceous carbonates with local bauxite deposits at their base (IVANOVIĆ *et al*., 1976; 1978).

The PB represent a more than 2 km thick sedimentary succession, which occupies an area more than 80 km long, and up to 20 km wide, in northern Dalmatia (Fig. 1). Several parts of the succession of the PB exposed in the NW part of the basin have been described in detail. They include basin, and base-of-slope sediments from the lower part of the PB (BABIĆ & ZUPANIČ, 1983), subsequent shelf deposits (MRINJEK, 2005), cyclic shelf to delta/coast deposits (POSTMA *et al*., 1988; ZUPANIC *et al*., 1988; BABIĆ & ZUPANIČ, 1990), and overlaying alluvial sediments (BABIĆ & ZUPANIČ, 1988; MRINJEK, 1993; BABIĆ *et al*., 1995). Additionally, an intermediate alluvial unit, which is underlain by a sequence boundary, has been reported to occur below the shelf to delta/coast cycles in the same area (Fig. 2), however, relevant descriptions are lacking, and are included in this work.

Other areas of the Promina Basin also show heterogeneous deposits, however, details on depositional environments, and vertical evolution are much less understood than those in the NW part mentioned above. Reports on these areas cite marine, brackish, and fresh-water environments (ETTINGSHAUSEN, 1855; STACHE, 1889; KERNER, 1894, 1901; ZUPANIČ, 1969), and cyclicity (KERNER, 1894; ZUPANIČ, 1969), which includes shelf-delta cycles comparable to those in the NW (BABIĆ & ZUPANIČ, 1990). This work presents more data from these areas, and compares them to those in NW part of the basin.

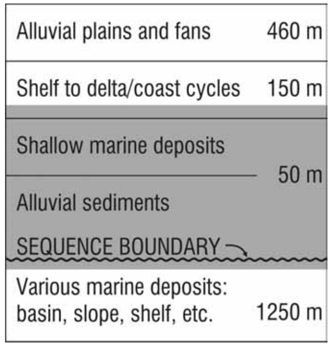

Fig. 2. The succession of Promina Beds formerly proposed for the Benkovac-Obrovac area in the NW Promina basin (simplified after BABIĆ & ZUPANIČ, 1995, with references). The present work provides refinements of the segment in grey, which is much thicker than previously thought (see also Fig. 4, log 1, Fig. 5-C, and Fig. 11), and includes its correlatives across the basin. After IVANOVIĆ *et al.* (1976), the sediments below the sequence boundary are late Middle Eocene to Late Eocene in age, while those above are Late Eocene to Early Oligocene in age.

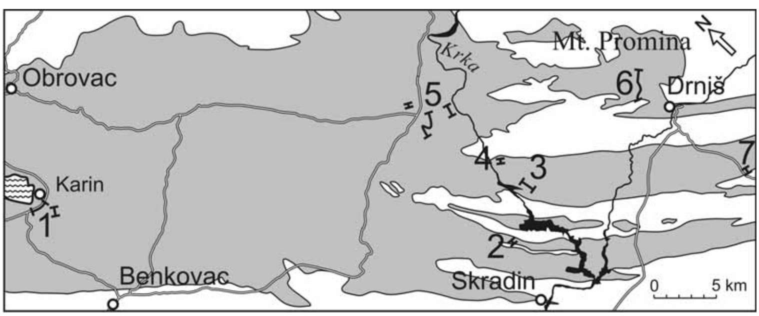

Fig. 3. Location of studied sections. 1 Karin area (St. Ciril-Karišnica, and Dubraja-Karišnica), 2 Uzdaj (upper part of the road Rupe-Dubravice, 3 Roški slap (uppermost part of the road – canyon wall), 4 Donji Bogetići, 5 Kistanje area (Monastery-Krnete, Bjelanovići-Carigradska draga-Krnete, and Railway station), 6 Kalun–Varoš-Čuline, 7 Gradina by Planjane. PB area is in grey.

DESCRIPTION AND INTERPRETATION OF SEDIMENTARY UNITS

The following descriptions and interpretations refer to (1) the main data on the sediments underlying the sequence boundary, (2) the alluvial unit, (3) the fossiliferous limestones, and lateral equivalents, and (4) the shelf to delta succession. The overall sedimentary evolution is discussed in the subsequent paragraph.

The terms sand and sandstone are here used for arenites consisting of exclusive to highly predominant limestone lithoclast particles, rarely containing 2 to 10% non-carbonate particles. This usage simply denotes their terrigenous character.

(1) Main features of sediments underlying the sequence boundary

Three types of sediments belonging to different sedimentary units and facies occur below the inferred sequence boundary, and are briefly described.

(A) This type includes Cretaceous shallow-marine carbonates, and Eocene shallow-marine Foraminiferal Limestones (Fig. 4, logs 6 and 7), as well as local bauxite

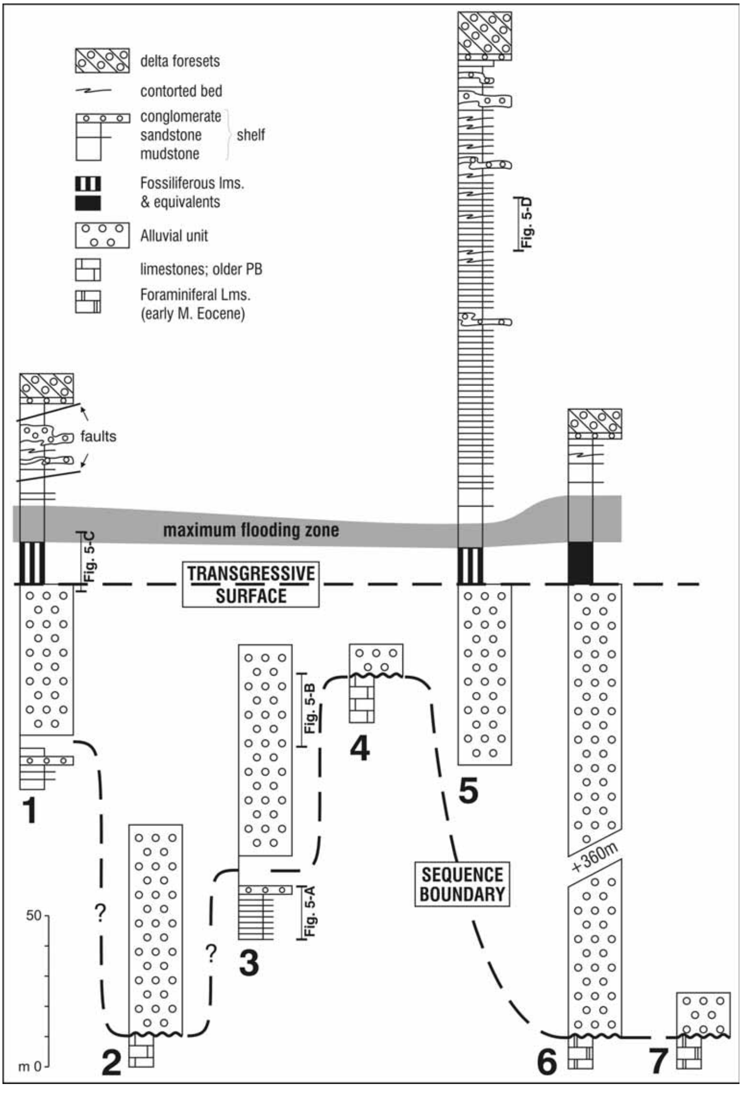

Fig. 4. Simplified logs of the studied sections 1–7, with proposed correlation. Details of selected segments are shown in Fig. 5. For explanation see text. For location see Fig. 3.

on their top. This relationship is best known from the NE part of the basin (e.g. KERNER, 1894, 1901; IVANOVIĆ *et al.*, 1976; 1978).

(B) These sediments are poorly bedded, bioturbated lime wackestones, packstones, and mudstones (Fig. 4, logs 2, and 4) containing *Discocyclina*, *Nummulites*, *Actinocyclina*, miliolids, bryozoans, echinoid remains, and locally, bivalves, gastropods, corallinaceans, and corals. The combination of the diverse biota, intense bioturbation, and larger foraminifera indicates a shallow marine setting, i.e. a shallow shelf.

(C) The succession at locality 3 (Fig. 3; Fig. 4, log 3, and Fig. 5-A) consists of interbedded sandstones and mudstones, except for its conglomeratic top portion. Strongly bioturbated mudstones may contain rare planktonic and benthic foraminifera including *Operculina*, and miliolids. Up to 50 cm thick sandstone beds are either structureless, intensely bioturbated, or locally show horizontal laminae. They contain plant fragments, benthic foraminifera including *Nummulites*, *Operculina*, and miliolids, and rare planktonic foraminifera. Some sandstones contain scattered pebbles. The top of the section shows a matrix-rich conglomerate with inverse grading in its basal part, and a poorly exposed interval upsection contains conglomerates with mud matrix. Strong bioturbation, larger and smaller benthic foraminifera along with planktonic faraminifera in the mudstones, together with reworked various foraminifera in the sandstones suggest a shelf setting with mud deposition during fair-weather conditions, and deposition of sands by storm-related processes. Alternatively, a part of the sandstones may have been deposited by river-derived, hyperpycnal inputs. The influence of a neighbouring delta is inferred from the occurrence of pebbly sandstones deposited by debris flows, as well as from the inversely graded, debris-flow conglomerates. The coarse-grained sediments occurring above sandstones and mudstones may indicate a delta progradation.

Locality 1 (Fig. 3) shows alternating mudstones and sandstones in the lower part (Fig. 4, log 1). The sandstones show flute casts, gutter casts, current-ripple lamination, and wave ripples indicating a storm-influenced shelf setting. Isolated outcrops of poorly sorted conglomerates appearing upwards within the covered interval probably represent debrites.

(2) Alluvial unit

Description

The unit shows a large-scale onlap at its base, and related variable thickness attaining 500 m. At the outcrop scale, the basal erosion shows a relief of up to 1 metre. The unit consists of conglomerates, sandstones and mudstones (Figs. 4, and 5-B). The pebble, less cobble and granule conglomerates are horizontally bedded to slightly inclined, locally showing b-axis imbrication. The conglomerates contain lenses and intercalations of coarse to medium grained, horizontally and cross-laminated sandstones. Cross-bedded conglomerates are locally present. The conglomerate and conglomerate-dominated packages (Fig. 6) are laterally extensive bodies, which may pinch out laterally. They may also form laterally restricted, sevaral metres thick channel-fill bodies (Fig. 7) incised into interbedded sandstones and mudstones. The top surfaces of conglomerates may display rhyzocretions. The sandsto-

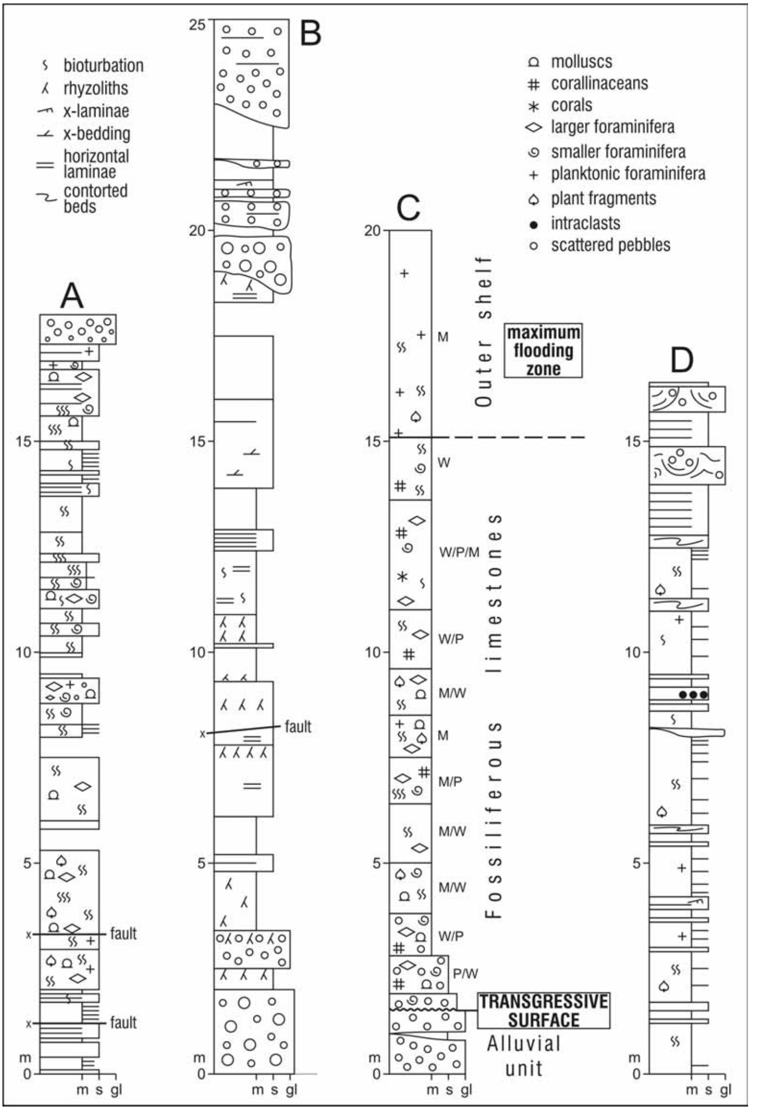

Fig. 5. Selected segments of the studied sections showing details of typical features from the sedimentary units. A, Shelf sediments of older PB from the lower part of log 3 in Fig. 3; location: uppermost part of the road climbing the E side of the Krka canyon at Roški slap. B. Detail of the Alluvial unit from the upper part of log 3 in Fig. 3; location: upper part of the Krka canyon wall, by the road bend in Donji Bogetići. C, Fossiliferous limestones, and bounding units from the middle part of log 1 in Fig. 3; location: middle part of the road descending from Dubraja plain to Karišnica creek. D, Shelf sediments from the middle part of log 5 in Fig. 3; location: middle part of the road climbing from the monastery in the Krka canyon to Kistanje plateau. m, s, cgl are mudstones, sandstones, and conglomerates, respectively. M, W, P are lime mudstones, wackestones, and packstones.

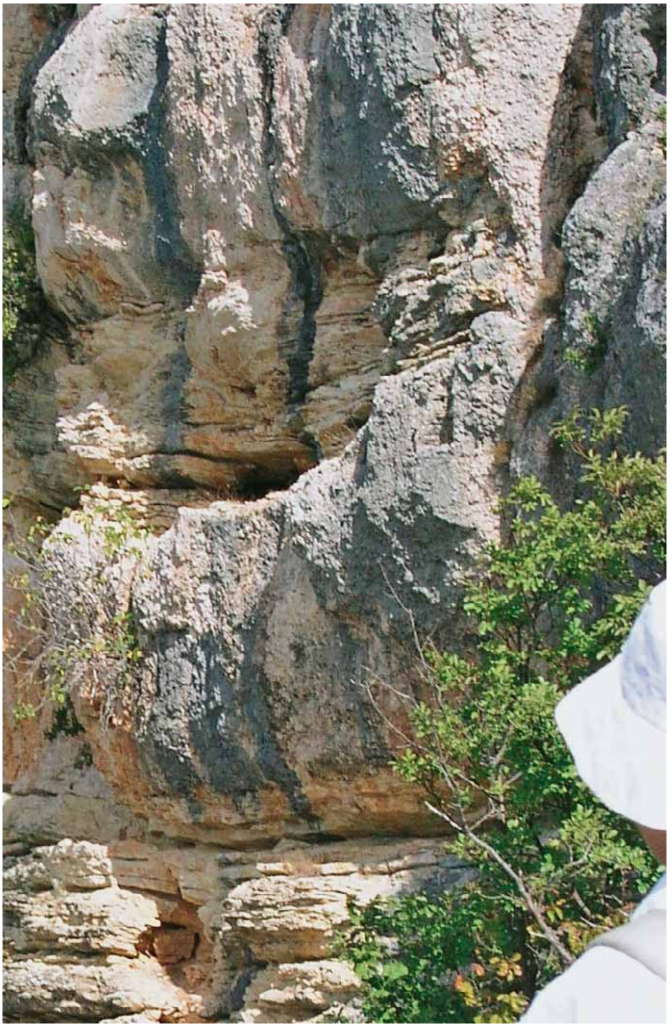

Fig. 6. Alluvial unit. Two packages of interbedded sandstones and mudstones showing thin beds alterenate with two thick, dominantly conglomeratic units (about 1.8 m thick), which are massive in appearance. E Krka canyon wall, above Roški slap.

nes may be horizontally laminated, cross-bedded, and current-ripple laminated, bioturbated, and locally show rhyzocretions, pedotubules as well as plant fragments including leaves. Mudstones show analogous pedogenic alteration (Fig. 5-B). Rare examples of polymodal conglomerates containing subangular clasts have been observed in one of the studied sections (6, Fig. 3). An upstanding tree trunk represented by a conglomeratic pillar, 30 cm in diameter, has been observed surrounded by interbedded mudstones and sandstones. The middle part of the unit in Section 6

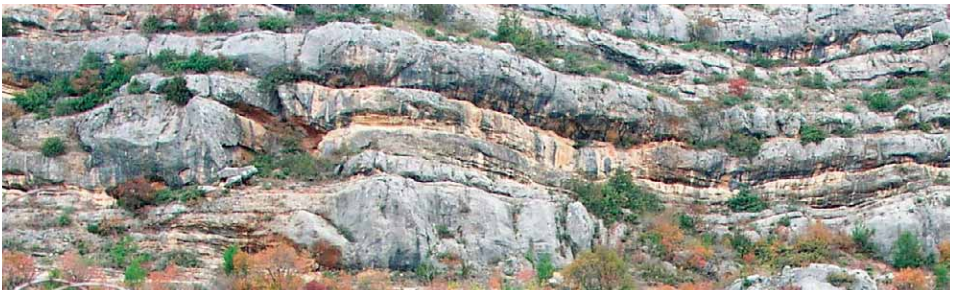

Fig. 7. Alluvial unit. Prominent units are predominantly conglomerates. Three, lensoid, channelised bodies are seen. The body in the middle left is about 5 m thick. Other two channel bodies are at the bottom of the picture, in the middle and right. Above the road climbing W side of the Roški slap.

(Fig. 3; not shown in Fig. 4) contains a poorly exposed, thin coal bed, and thin marls with gastropods.

Interpretation

Horizontally bedded to very gently inclined conglomerates showing b-axis imbrication and erosional bases, and cross-bedded conglomerates, reflect the activity of braided streams, i.e. the deposition, erosion, and migration of longitudinal bars, and intervening channels (review in COLLINSON, 1996). The sandstone lenses in the conglomerates are erosional relics and fills of smaller depressions filled during the falling stage of floods. The cross-bedded conglomerates were deposited at the bar front and flanks. Horizontally laminated sandstones record the upper plane bed flow regime, while cross-bedded and cross-laminated sandstones originated by the migration of dunes and ripples, respectively. The complex, laterally extensive sheet-like bodies consisting of conglomerates and sandstones should have originated in wide channel belts. The sandstone beds of the interbedded sandstone – mudstone facies have been deposited by sheetfloods on the floodplains. The pedogenic alterations, and a tree trunk indicate vegetated alluvial plains between channel belts, and above abandoned channel belts. Individual channel-fill bodies incised in interbedded sandstone – mudstone facies testify to the presence of local, isolated channels in the floodplain areas. Most of the alluvial unit therefore originated in alluvial plains characterised by braided channel belts, alternating with, and juxtaposed to vegetated floodplains. Rare debrites in Section 6 (Fig. 3) may be explained by very short, rare time intervals, when the relevant depositional sites were situated at the transition to the alluvial fans. The coal and marls in the middle part of the Section 6 (Fig. 3) might have originated in marsh environments of a lake.

(3a) Fossiliferous limestones

Description

Sharply overlying the alluvial sediments are 8 to 14 m thick, poorly bedded, bioturbated lime wackestones, packstones, and rare mudstones (Fig. 4, logs 1, and

5, and Fig. 5-C), which contain *Discocyclina, Nummulites, Operculina*, miliolids, as well as corallinaceans, molluscs, and corals. The basal portion of the limestones includes scattered limestone pebbles.

Interpretation

The combination of diverse biota including larger foraminifera, and intense bioturbation indicates a very shallow marine setting, within the photic zone, i.e. a shallow shelf. The limestone pebbles in the basal limestones must have been eroded from the underlying alluvium and reworked during transgression.

(3b) Equivalents of the fossiliferous limestones

Description

These sediments overly the Alluvial unit, and underlay marine mudstones at locality 6 (Fig. 4, log 6), i.e. occupy the same place in the vertical successions as do the fossiliferous limestones, and are regarded as their lateral equivalents. They consist either of stromatolites and mollusc-bearing marls, or additionally, coal is intercalated between the alluvium and stromatolites. This coal is the main coal seam of the PB in the area of Mt. Promina (review in MARKOVIĆ, 2002)

Interpretation

The coal originated in a marsh environment, which presumably occurred in a restricted lagoon, as suggested by the high sulphur content (MARKOVIĆ, 2002). Associated stromatolites and marls may also have originated in lagoons.

(4) Shelf to delta unit

Description

The lowermost part of the unit is represented by mudstones, which are followed either by interbedded lime mudstones and sandstones (Fig. 4, logs 1, and 5), or mudstones continue to dominate higher in the section (Fig. 4, log 6). Both sediment types commonly show intense bioturbation. The mudstones contain planktonic foraminifera, while molluscs, and benthic foraminifera including *Operculina* may rarely appear in the higher mudstones. The sandstones are 1 mm to 30 cm thick, show sharp bases, and sharp to gradual contacts with overlying mudstones. Their lower bedding planes may show flute casts and longitudinal ridges (Fig. 8), as well as groove and brush casts (terms after DZULYNSKI & WALTON, 1965). The sandstones may be either massive, locally showing an overall grading, only exceptionally show horizontal laminae, while individual trains of ripples and isolated ripples are common (Figs. 9 and 10). Ripples are asymmetric, unidirectional, or locally symmetric. They are commonly draped by thin, sand to mud laminae. The sandstones are rich in plant fragments, and also contain leaves. Some sandstones contain mudstone intraclasts, and foraminifera. The upper part of the interbedded mudstones and sandstones may be intercalated by mud-matrix conglomerates, pebbly sandstones, and contorted beds comprising mudstones, sandstones, and conglomerates.

Fig. 8. Shelf deposites. Slabs of sandstones showing longitudinal ridges and flute casts. Lens cap is 4.4 cm in diameter. Upper part of the road climbing from the monastery in the Krka canyon to the Kistanje plateau.

The upper part of the unit consits of conglomerates, sandstones, and minor mudstones and contorted beds. The thickness of the beds offten changes laterally. The conglomerates are predominantly massive, and may show either clast-supported or matrix-supported fabrics. These sediments are overlain by up to 20 m thick clinoforms showing an inclination between 14° and 24°, and angular to tangential basal contacts. They consist of conglomerates, and even laminated sandstones. The top of the clinoforms is a truncation surface overlain by less than 1 m thick sandstones and/or conglomerates containing marine fossils.

Interpretation

The basal mudstones containing planktonic foraminifera have been deposited in a deeper, quiet, marine environment. Interbedded sandstones and mudstones with planktonic and larger foraminifera, and other organisms suggest shelf settings, where sandstones represent event beds. The flow marks at sandstone bases were produced by flows which may have originated either from storm-induced processes, or from hyperpycnal inputs from river mouths. Horizontal lamination may have been produced either by the oscillatory, unidirectional, or combined flows (e.g. MYROW & SOUTHARD, 1991). However, symmetric ripples indicate oscillatory flows related to the storm-related processes on this shelf. This also suggests that the origin of many other sandstones are probably related to storm-related processes. In general, the interbedded sandstones and mudstones are inferred to have been deposited between the storm and fair-weather wave bases. It follows, that the quiet environment for the underlying basal mudstones mentioned above, may correspond to an outer shelf setting, below the storm wave base.

Massive, matrix-supported and clast-supported conglomerates associated with shelf sediments, which occur below delta foresets (see below) must be of a debris-flow origin, and were derived from Gilbert delta slopes, or possibly, by direct input from rivers. The features and processes related to the overlying, steeply inclined clinoforms representing Gilbert delta foresets largely correspond to previously described Gilbert deltas, which are components of the repeating shelf-delta cycles overlaying the first Gilbert delta in Fig. 4 (POSTMA *et al.*, 1988; ZUPANIČ *et al.*, 1988; BABIĆ & ZUPANIČ, 1990). These authors also described the truncation surface above the clinoforms, and the overlying marine sediments, which resulted from transgressive erosion, and subsequent deposition of a transgressive unit preceeding the next shelf-delta cycle (*op. cit.*).

In general, the upward increasing proportion of sandstones, and subsequent conglomerates, as well as the overlying delta, reflect a prograding trend from muddy shelf, to dominantly sandy shelf, to base of the delta slope, and finally, to the delta slope itself.

DISCUSSION: MAJOR EVENTS AND STAGES IN THE SEDIMENTARY EVOLUTION

The units described above are considerably thinner compared to the stratigraphic units described and mapped by IVANOVIĆ *et al*. (1973, 1976, 1977, 1978), and MAMUŽIĆ (1971, 1975). Besides, the relevant dating by these authors refer to long time intervals, which, in addition, may differ between neighbouring sheets of their geological maps. Hence, they could not be adequately used for the correlation discussed here. The correlation in Fig. 4 is based partly on the comparative vertical distribution of facies, units, and boundaries in the studied sections, and partly, on the mapping and tracing in several restricted areas. The proposed correlation, therefore should be checked by further work. In particular, Section 2 could possibly be positioned lower, resulting from a previous but identical sequence of events including the origin of the sequence boundary (Fig. 4).

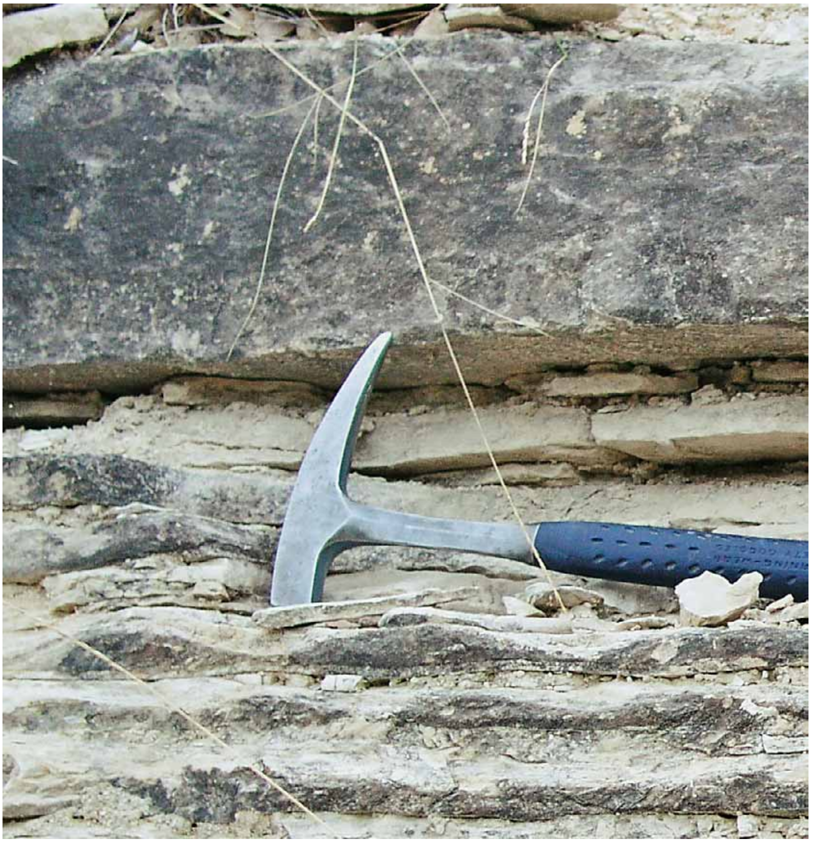

Fig. 9. Shelf deposites. Interbedded thin sandstones and mudstones are overlain by a thicker sandstone bed. Ripples are well seen below the hammer. Hammer head is 18cm long. Middle part of the road climbing from the monastery in the Krka canyon to the Kistanje plateau.

The lower part of the correlated successions (Fig. 4) shows a prominent stratigraphic boundary characterised by the erosional truncation dissecting sediments of considerably different ages: Cretaceous limestones (not shown in Fig. 4), early Middle Eocene limestones, and different levels of the older PB. The relevant surface showing a relief of more than 30 m is covered by onlapping alluvial sediments. The origin of these features must have been related to an important fall in relative sea level. Hence, it is proposed that the relevant unconformity well known from the inner, NE basin margins, where the underlying sediments are Cretaceous and early Middle Eocene Foraminiferal Limestones (e.g. IVANOVIĆ *et al.*, 1976; 1978), extends to the south, and cuts the succession of PB (Fig. 3, logs. 1–4). The features and processes related to this significant break correspond to those of a sequence boundary (e.g. POSAMANTIER & ALLEN, 1999). In comparison to the large gaps occurring to the NE, the gaps between the underlying, older PB and the alluvium are smaller. The gap is probably the smallest where the discontinuity is underlain by thick shelf sediments of the lower PB, as observed below sections 1 and 3 (Figs. 3 and 4.

The origin of the pronounced relief of the boundary surface may be partly related to tectonic deformation including uplift, which involved the inner part of the basin (e.g. IVANOVIĆ *et al.*, 1978). However, the evaluation of the relative importance of tectonics and sea-level fall is not attempted at this stage of research. In any case, the features of this boundary are related to the main event in the sedimentary evolution of the Promina basin (Fig. 11).

The alluvial sediments filling the relief may be compared to the fill of incised valley(s) of the sequence stratigraphic nomenclature (VAN WAGONER *et al.*, 1988). During this stage, the lowest and initially rising relative sea level provokes the filling of the river valley(s) incised during the falling relative sea level. However, the upper part of the alluvial successions must have been deposited in a laterally extensive belt of alluvial plains generated above the infilled depressions, as suggested by the extent of the alluvial unit over the area of the PB (Fig. 4). Probable palustrine intercalation in one of the studied sections possibly reflects a short-term rise in the base level or a decrease in sediment supply.

The sharp, erosional boundary at the top of the alluvial unit marks another drastic change in the evolution of the PB. This boundary is overlain either by shal-

Fig. 10. Shelf deposites. Interbedded thin, rippled sandstones and mudstones. Lens cap is 4.4 cm in diameter. Upper part of the road climbing from the monastery in the Krka canyon to the Kistanje plateau.

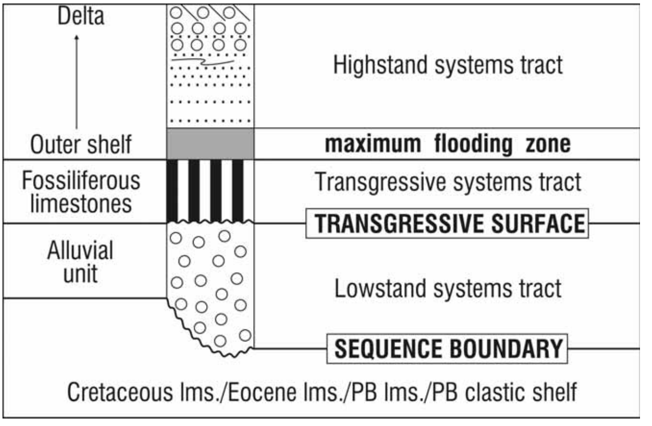

Fig. 11. Summary of the major events and stages in the sedimentary evolution of the upper Promina Beds. To the left are units described in this work. To the right is a sequence stratigraphic interpretation. Not to scale. For explanation see text.

low-marine limestones (»Fossiliferous limestones«) with pebbles winnowed from the underlying alluvial sediments during transgression, or by inferred lagoonal sediments. The lateral difference in facies may be explained by a more open position seewards, in the first case, and a restricted setting landwards, in the other. The installation of a very shallow carbonate shelf, as well as marginal, lagoonal settings, together characterising a new stage in the evolution of the PB, was made possible by the increase of accommodation space outpacing sediment supply. The shoreline was shifted landwards. The transgressive basal surface, and the overlying limestones correspond to the transgressive surface, and transgressive systems tract of the sequence stratigraphic approach (VAN WAGONER *et al.*, 1988; POSAMANTIER & ALLEN, 1999) (Fig. 4 and 11).

The next important event in the history of the PB was the change from very shallow marine carbonate settings with a diverse biota, and their restricted, lagoonal equivalents, to a distal muddy shelf representing the deepest sediments of the entire studied succession. This was related to the continuation of the trend by which the accommodation space was being created faster than the rate of sediment supply. At this point, the shoreline was shifted to its maximum landward position. Consequently, the distal shelf mudstones may be interpreted as the maximum flooding zone (Fig. 4). Alternatively, the boundary between shallow water limestones and overlying, distal shelf mudstones might be denoted as the maximum flooding surface.

Going upwards, the input of sand increases. It was deposited between storm-weather and fair-weather wave bases, as shown by the features of the interbedded sands and muds. Later on, more and more debris-flow conglomerates and slumps are intercalated in the sandstone-mudstone succession, and finally become dominant. Their derivation from Gilbert deltas is suggested by the overlying Gilbert delta foresets (Fig. 4), as mentioned above (see also POSTMA *et al.*, 1988; ZUPANIČ *et al.*, 1988; BABIĆ & ZUPANIČ, 1990). The relevant, progradational trend starting above the zone of maximum flooding reflects a change in the relationship between the creation of accommodation space, and rate of sediment supply, by which the later became more significant. Such conditions correspond to the highstand systems tract of the sequence stratigraphic nomenclature (VAN WAGONER *et al.*, 1988) (Fig. 11). The progradational succession ended at the truncation surface on top of Gilbert delta foresets, which reflects a transgression as suggested by the overlying, thin marine unit. The relevant evolution, which includes a series of shelf-delta cycles has been described elsewhere (POSTMA *et al.*, 1988; ZUPANIČ *et al.*, 1988; BABIĆ & ZUPANIČ, 1990).

CONCLUSION

The correlated sedimentary successions from different parts of the Eocene-Oligocene Promina basin reveal three major events in the evolution of the upper Promina Beds (Fig. 11).

1. The first major event refers to the origin of the high-relief erosional surface generated during the fall of relative sea-level. This process was responsible for dissecting units of different ages and facies including Cretaceous limestones, Eocene Foraminiferal Limestones, and different parts of lower PB.

The following stage in the evolution of the PB is represented by the filling depressions by onlapping alluvial sediments, and by subsequent generation of a basin-wide belt of alluvial plains. This may have occurred during the lowest relative sea level and its early rise.

2. The next main event was a transgression caused by a much higher increase in accommodation compared to the rate of sediment supply, resultanting in a pronounced rise in relative sea level. This produced a sharp, transgressive, erosional surface above the alluvium, and led to a stage during which a very shallow carbonate sea and its lagoonal correlatives covered the area.

3. A further rise in the relative sea-level halted shallow limestone deposition, and led to the deposition of mud in the deepest shelf sea as compared to the depths for other studied sediments. The shoreline shifted to its farthest position landwards. The change resulted from a further increase of accommodation space outpacing the rate of sediment supply.

The subsequent progradation of shelf to Gilbert delta settings was related to the slowing down of the creation of the accommodation compared to the rate of sediment supply.

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