GEOL. CROAT.	46/2	243 - 261	18 Figs.	1 Tab.		ZAGREB 1993

Sedimentology and Depositional Setting of Alluvial Promina Beds in Northern Dalmatia, Croatia

Ervin **MRINJEK**

Key words: Braided river, Braid-delta, Facies association, Foreland basin, Promina beds, Jelar breccia, Northern Dalmatia

Ključne riječi: prepletena rijeka, prepletena delta, asocijacija facijesa, Promina slojevi, Jelar breča, sjeverna Dalmacija

Abstract

Facies associations comparable with Scott- or Donjek-type facies associations have been recognised in the alluvium of the Promina beds in northern Dalmatia (Late Eocene to possible Early Oligocene). Scott-type facies associations prevail in the upper part of the studied succession whereas Donjek-type facies associations characterise its lower part. Vertical variations in sediment supply, stream gradient or base level are primarily related to south-westward thrustings followed by tectonic quiescence and erosion of the source area.

Sažetak

Asocijacije facijesa usporedive sa Scott ili Donjek tipom asocijacija utvrđene su u aluvijalnom dijelu Promina slojeva (starost gornji eocen do vjerojatno donji oligocen) u sjevernoj Dalmaciji. Asocijacije facijesa usporedive sa Scott tipom asocijacija prevladavaju u gornjem dijelu, dok asocijacije facijesa slične Donjek tipu karakteriziraju donji dio istraživanog slijeda. Takve vertikalne varijacije u donosu materijala, strujnom gradijentu ili razini baze najvećim dijelom su vezane za višestruka reversna rasjedanja zaleđa praćena njihovom erozijom za vrijeme tektonskog mirovanja.

1. INTRODUCTION

The Promina beds (Upper Lutetian to possibly Early Oligocene age) outcrop over a vast area of northern Dalmatia. The sediments represent an aproximately 2000 m thick carbonate-clastic succession, with a clear shallowing-upward trend - from deep-marine turbidites to shallow-marine and alluvial deposits. The Promina beds either conformably overlie the Upper Lutetian Flysch Formation or unconformably cover Cretaceous and Palaeogene carbonates (in the internal part of northern Dalmatia IVANOVIĆ et al., 1969; BABIĆ & ZUPANIČ, 1983) as shown in Fig. 1. These sediments together with the Jelar breccia (which overlies deformed Triassic, Jurassic and Cretaceous deposits in the marginal part of the northern Dalmatia and is considered as the source of carbonate detritus for the Promina beds and Flysch formation BAHUN, 1974; HERAK & BAHUN, 1980), are indicators of strong Eocene and younger tectonic deformation.

In order to gain a better understanding of the depositional and tectonic setting of the Promina beds and their relation to the Jelar breccia, the main object of this study is the poorly known alluvial part of Promina beds (Fig. 1). The investigation includes facies analysis combined with petrography and paleocurrent analysis as well as the description of facies associations.

2. DESCRIPTION OF THE STUDY AREA

The study area is located along the NW-SE extension of Jurišinka Hill, within the Benkovac-Obrovac sector, and as the highest and most geologically exposed part of northern Dalmatia, enables very extensive observation of the alluvial strata (Fig. 1). The layers are tectonically relatively undisturbed, only gently tilted towards the northeast. The alluvial succession has a thickness in excess of 600 m since the youngest portion is eroded by an unknown thickness.

In the foot-hill of Jurišinka, between the villages of Karin and Gornje Drače (Fig. 1), the alluvial succession displays a continous transition downwards into shallow-marine and shoreline sandstones and conglomerates whereas several kilometres northeast of the study area, between Obrovac and Žegar, it unconformably overlies Cretaceous and Palaeogene carbonates (Fig. 1).

In the vicinity of Karin, BABIĆ & ZUPANIČ (1990) established and in detail described continous but cyclically repeated prograding transition from shelf muds and sands through shoreface sands and Gilbert-type foreset conglomerates into the alluvial (braided-type) conglomerate succession. The shallow-water cycles are separated by erosional surfaces covered by thin transgressive and bioturbated lags of conglomerates and pebbly sandstones with benthic foraminifers. According to BABIĆ & ZUPANIČ (1990) the stacking of sequences has been coused by alternating progradatinal and transgressive tendencies during the basin filling.

A few papers published on the alluvial Promina-beds in northern Dalmatia illustrated a predominance of

---

Department of Geology and Paleontology, Faculty of Sciences, University of Zagreb, Kralja Zvonimira 8, 41000 Zagreb, Croatia

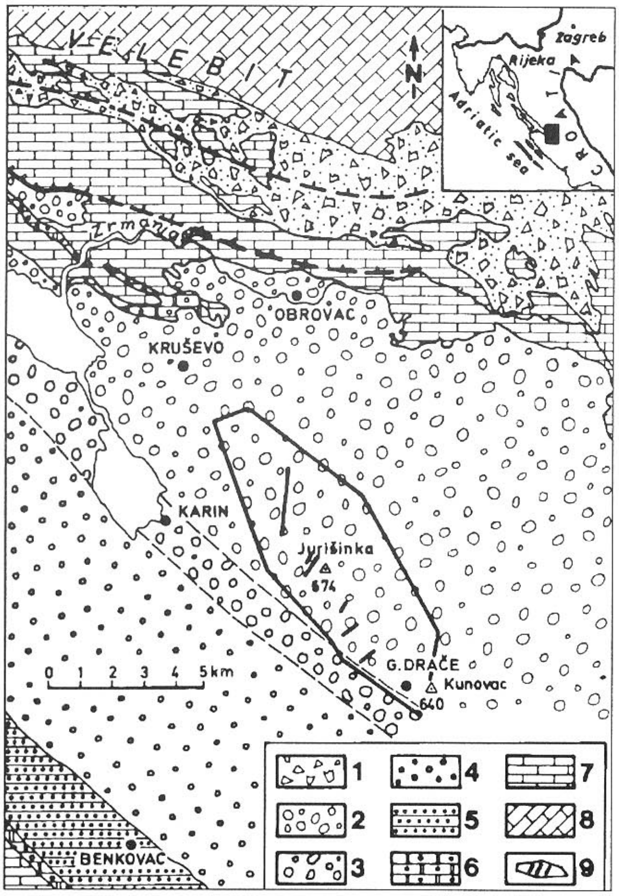


Fig. 1. Geologic map of northern Dalmatia (from IVANOVIĆ et al., 1976, partly modified according to HERAK & BAHUN, 1980, BABIĆ & ZUPANIČ, 1983 and MRINJEK, 1993). 1 - Eocene to possible Early Oligocene Jelar breccia, 2 -Alluvial Promina beds, 3 - Shallow marine Promina beds, 4 - Deep marine Promina beds, 5 - Lower Eocene Flysch, 6 - Lower Eocene Foraminiferal limestones, 7 - Cretaceous carbonates, 8 - Jurassic and Triassic carbonates, 9 - Studied area and sections.

sheet-like and channel-fill conglomerates, in common association with cross-bedded conglomerates and sandstones, and very rare sheet-like breccias arranged in fining-upwards and coarsening-upwards sequences (BABIĆ & ZUPANIČ, 1988; MRINJEK, 1989, 1993). Statistical analysis of clast-imbrication measurements from the sheet-like conglomerates shows a consistent palaeoflow direction towards the SW (MRINJEK, 1993) which together with lithofacies characteristics and sedimentary geometry implies braided-river and braided-plain depositional environments. According to MRINJEK (1993), most of the alluvial succession represents subaerial deposition, whereas the earlier-mentioned shallow-marine and shoreline deposits represent subaqueous sedimentation of an extensive and cyclically prograding, coarse-grained braid-delta system.

3. FACIES

Facies within the alluvial Promina beds are distinguished by the type of framework support, sedimentary structures and general lithology. Additional characteristics in conglomerate facies designation include fabric, sorting and also unit geometries. The terminology used in facies classification is similar to that of MIALL (1977, 1978) and RUST (1978). Facies description are summarised in Table 1 and described below.

3.1. CONGLOMERATE AND BRECCIA

Conglomerate is the dominant lithofacies in the alluvial Promina beds (59%), whereas breccia is very rare (3.5% of total sediment thickness). Both contain various carbonate clasts, mostly of Cretaceous age, and considerably fewer clasts of Palaeogene, Jurassic and Triassic ages. Clasts of sandstone, marl, chert, dolomite and rudist fragments are also present but very rare. Conglomerates are clast- supported and breccias are matrix-supported. Both organised and disorganised clast-supported conglomerates are present in the alluvial Promina beds.

3.1.1. Organised clast-supported conglomerates (Facies Gm, Gp, Gt)

Organised conglomerates are the most abundant type of conglomerate lithology (93 % of conglomerate thickness and 55 % of total sediment thickness). They have a generally bimodal grain-size distribution, with pebble to cobble-size framework clasts and a fine-grained to granule-size matrix. Clast ranges from subrounded to rounded. Normal grading occurs locally in the matrix.

Organised, clast-supported conglomerates can be subdivided into three main lithofacies based upon sedimentary structures and fabric (Table 1).

Massive to crudely flat-bedded conglomerate (facies Gm) accounts for 40 % of the conglomerate thickness (25.4 % of total sediment thickness). These conglomerates occur in sheet-like forms as single units or as amalgamated, vertically stacked units (Fig. 2). In the case of amalgamated conglomerates, individual units can be distinguished by scour or slightly erosive surfaces or by the presence of very thin sandstone sheets and lenses (less then 25 cm thick) between them (Figs. 2 and 3). The conglomerate sheets are 0.3 - 1.5 m thick (mainly 0.5 - 1 m) with tens of metres lateral extension and with a weakly flat-bedded interior. The internal beds have a short extension in flow direction (from several cm to about 10 m) and a thickness proportional to the clast sizes (from several cm to 0.5 m). This flat, internal stratification is due to the vertical alternation of different clast sizes, clast sorting or matrix content.

Lithofacies Gm generally exhibits closed-framework packing, but some parts of units with open-framework packing are present locally. Clast sorting varies from moderate to good. The beds composed of granules and small clasts are well to very well sorted. Clasts are mainly subrounded or rounded. Sandy and fine-grained clasts are mostly disc- or blade-shaped. Clast imbrication (long axis transverse to palaeoflow and intermedi-

Lithofacies Code	Description	Sedimentary Structures	Interpretation
Gm	clast-supported, moderately sorted, pebble-boulder conglomerate	massive to crude flat-bedding imbrication	longitudinal gravel bars
Gt	clast-supported, well sorted, pebble-cobble conglomerate	large-scale trough cross-bedding	three-dimensional mega ripples, channel fills
Gp	clast-supported, well sorted, pebble-cobble conglomerate	large-scale planar cross-bedding	two-dimensional mega ripples, late stage transverse bars, late stage modification of longitudinal bars
GmsI	clast-supported, very poorly sorted, pebble-boulder conglomerate	none	debris flow or high-density turbulent flow
GmsII	matrix-supported, very poorly sorted, pebble-boulder breccia	mostly massive, local inverse and/or normal grading	debris flows
St	well sorted, medium to coarse-grained sandstone	large-scale trough cross-stratification	three-dimensional mega ripples
Sp	well sorted, medium to coarse-grained sandstone	large-scale planar cross-stratification	two-dimensional mega ripples, late-stage bar modification
Sh	well sorted, medium to coarse-grained sandstone	horizontal lamination	upper flow regime plane beds, very shallow water
Sr	well sorted, fine to medium-grained sandstone	ripple cross-lamination	two-dimensional small ripples
Fl	matrix-supported, silty mudstone	horizontal lamination	overbank deposits
Fm	matrix-supported, mottled, silty mudstone	burrows and plant fragments	reworked overbank deposits

Table 1. Summary of alluviall Promina beds facies (terminology and facies code after MIALL, 1977, 1978; RUST, 1978).

ate axis dipping at about 25°) is locally common indicating a strictly south-westward palaeocurrent direction (MRINJEK, 1993 and Fig. 10). The mean maximal clast size (BLUCK, 1967) within uniform units varies from 2.1 cm - 32.4 cm, but mostly from 10 - 15 cm, although some individual clasts may reach 45 cm in length. Grain-size trends are generally lacking. This facies is interbedded with all other conglomerate facies as well as sandstone facies and forms multistorey sequences several tens of metres thick (Figs. 11, 12 and 13).

Trough cross-bedded conglomerate (facies Gt) is a very common conglomeratic lithofacies (29 % of conglomeratic thickness and 16.2 % of total sediment

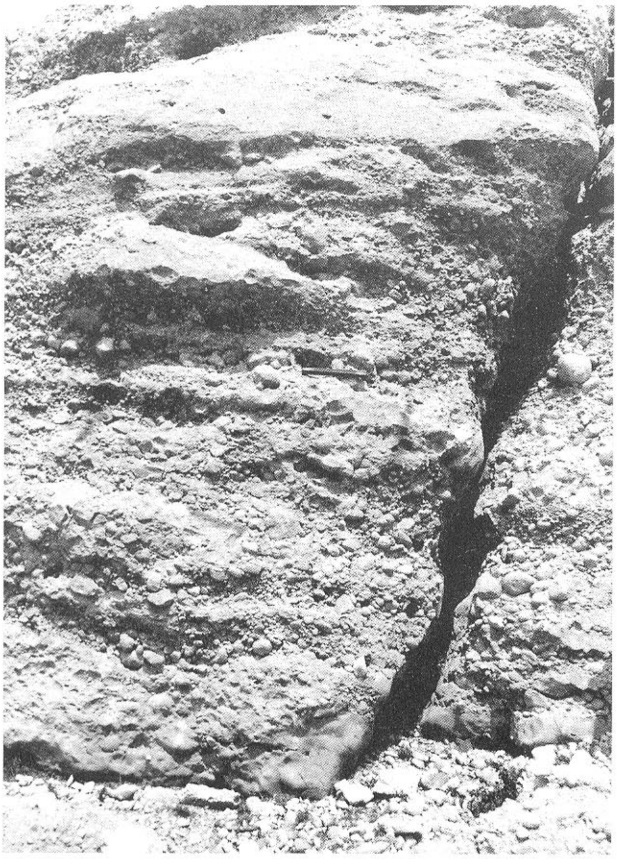


Fig. 2. Crudely flat-bedded conglomerates of the facies Gm with vertically stacked, sheet-like units and a weakly developed fining-upward trend. In the lower part individual units can be distinguished by the scour surfaces and conglomerates with open-framework packing. The scale is 22 cm long.

Fig. 3. Horizontally laminated sandstone (facies Sh) in the facies Gm. The scale is 20 cm long.

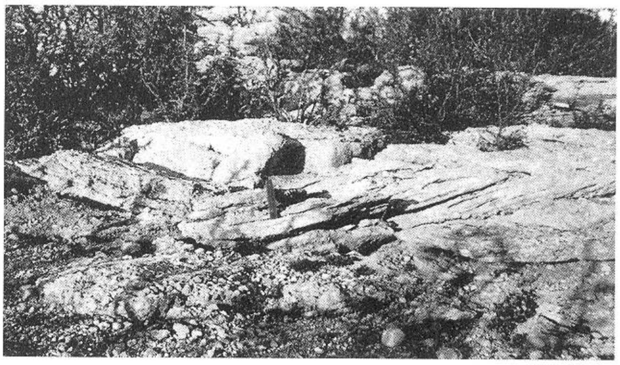


Fig. 4. Low-angle trough cross-bedded conglomerates (facies Gt) underlain by clast-supported conglomerate (facies Gm). Foresets consist of alternating fine and coarse pebbles. The scale is 22 cm long.

thickness). This lithofacies occurs as single sets (Fig. 4) or cosets. Trough sets are 0.2 -1 m thick and consist of alternating foresets mostly with a mean maximal clast size from 4 - 10 cm, although foresets composed either of granules or clasts greater in size than 10 cm have been observed. The clasts are moderately sorted. The average foreset thickness within sets varies from 5 - 10 cm. The inclination of foresets are between 10° and 20° and trough widths from 1 - 7 m. The trough-axes have mostly a SW direction (Fig. 10). The trough sets are distinctly interbedded with thin discontinous sandy lenses. The clast imbrication is not visible. At the bases of troughs the conglomerates are coarser, clast-supported with the internal stratification less recognizable while the trough flanks contain finer, matrix-supported clasts and slightly better visible internal stratification (Fig. 15). The trough bases are gently concave-up or irregular, with a relief of up to 0.5 m (Figs. 4, 13 and 15).

The trough sets commonly pass up vertically into various sandstone and mudstone facies (Figs. 11 and 13) while laterally they pass into sheets of massive to flat-bedded conglomerates. The trough sets also represent multi-storey channel-fill commonly up to 2 m thick, incised into interbedded sandstone and mudstone lithofacies and are vertically and laterally associated with cross-bedded pebbly sandstone facies (Figs. 14 and 15).

Tabular cross-bedded conglomerates (facies Gp) is a little less common conglomeratic lithofacies than those described above (24 % of conglomerate thickness and 13.4 % of total studied sediment thickness). The cross-bed sets show average thickness of between 0.5-2 m and inclination of foresets between 15° and 25°. The average foreset thickness within sets is from 5 - 15 cm (Figs. 5 and 12). The mean maximal clast size in sets varies from 4 -15 cm, although there can be cross beds composed of either granules or clasts greater than 15 cm in diameter. Compared with facies Gt, the clasts are coarser and better sorted. Improvement of sorting and smaller clast size is usually accompanied by decrease of set thickness (Fig. 12). The sets mostly consist of planar and in places tangential foresets. The planar foresets usually have a greater inclination and show coarser grain size and increase in thickness down-dip while tangential foresets show a wider range of grain sizes, from sandstone to pebble conglomerates and down-dip decreasing thickness (Fig. 12). The clasts are rarely imbricated, with AB planes of clasts dipping up the foreset slope. The spread of planar cross-bed directions is greater than the spread of trough-axis directions in facies Gt and clast orientations in facies Gm. The more

Fig. 5. Set of tabular cross-bedded pebble conglomerates (facies Gp) overlain and underlain by crudely flat-bedded conglomerates of facies Gm. The section is parallel to the flow direction. The hammer is 33 cm long.

divergent orientation is mostly displayed in the smaller and fine-grained sets. In places, groups of foresets are separated by inclined erosion surfaces and thin sandstone drapes. The set bases are weakly inclined, flat or slightly erosive and usually underlain by massive to flat-bedded conglomerates (Figs. 5 and 12). The tops are roughly scoured by facies Gt or sharply truncated by facies Gm, or horizontally overlain by sandstone facies (Figs. 5, 11 and 12). These conglomerates pass laterally into sheet- or channel-fill conglomerates.

3.1.2. Disorganised clast-supported conglomerate (Facies GmsI)

This conglomeratic lithofacies is very rare (6.8 % of conglomerate thickness and 4 % of total sediment thickness). There are three occurences of that lithofacies in the middle part of the succession in the form of solitary sheets. The sheets are 2, 2.5 and more than 3 m thick and can be traced hundreds of metres laterally. The sheets are interbedded with facies Gm and GmII (Figs. 11 and 12). Their basal surfaces are sharp and irregular with a maximum observed relief of 0.5 m, while their tops are flat or weakly convex. They are clast-supported, poorly to moderately sorted, having a polymodal grain-size distribution, with pebble to cobble-size clast framework (mean max. clast size is between 7.8 and 25 cm), and a sand-size to granular sand-size matrix. The degree of roundness ranges from subrounded to rounded.

The sheets are ungraded, without internal stratification. A weakly developed, planar fabric is formed only in places by the alignment of the AB planes of the clasts. Also, a very rare A-axis imbrication sometimes occurs, mostly in the basal or uppermost parts of the sheets where the imbrication dip is similar to that of accompanying flat-bedded conglomerates. Because of the absence of sedimentary structures it is difficult to recognise distinct bedding planes but a positive correlation between maximum particle size (MSP) and sheet thickness (BTh), and rare imbrication indicate that sheets would be individual units rather than stacked units.

3.1.3. Disorganised matrix-supported breccia (Facies GmsII)

Generally disorganised, matrix-supported breccias also occur in sheet-like forms, 0.7 - 3.8 m thick extending for hundreds of metres and are interbedded with conglomerate and sandstone facies (Figs. 6 and 12). Since there are only a few occurrences of these sheets in the middle part of succession, this lithofacies constitutes a relatively minor proportion of the alluvial Promina beds (3.5 % of total sediment thickness). This lithofacies occurs as single units or, sometimes, as amalgamated, stacked units.

The upper and lower contacts are typically sharp, except in some cases where the tops grade with protruding clasts into pebbly sandstone. The basal surfaces are mostly flat. In places, the sheets are almost totally eroded by conglomerate facies over a distance of several hundreds of metres.

This lithofacies generally consists of poorly sorted, matrix-supported, pebble to boulder breccia (mean max. clast size varies between 5.1 - 19.7 cm) with silt to coarse sand and granule-size matrix. The matrix is also poorly sorted. Clast ranges from angular to subangular (Figs. 6 and 12). A massive structure is common, although the upper portion of some sheets is normally or inversely graded. The lower portions of some GmsII units are inversely-graded and clast-supported, with clasts aligned parallel to the basal contact. One of these sheets is characterised by a weakly inversely graded basal portion and normally graded uppermost portion. Both portions are clast-supported and finer-grained, whereas the middle portion (two thirds of the sheet) is massive, coarser-grained and matrix-supported.

3.2. SANDSTONES AND MUDSTONES

Sandstones and mudstones account for a relatively small proportion of the overall alluvial Promina sediment thickness (38 %), but they are locally predominant lithologies, especially in the lower part of the studied succession.

Sandstones are litharenites. They mostly contain various types of micritic and sparitic grains. Quartz grains are present (less than 5%) and labile components, chiefly feldspars, micas, chlorites, low-grade metamorphic fragments account for the less than 1% of the grains. The sandstone vary from fine- to coarse-grained, medium-grained types being predominant. Grains are subangular to rounded with generally good

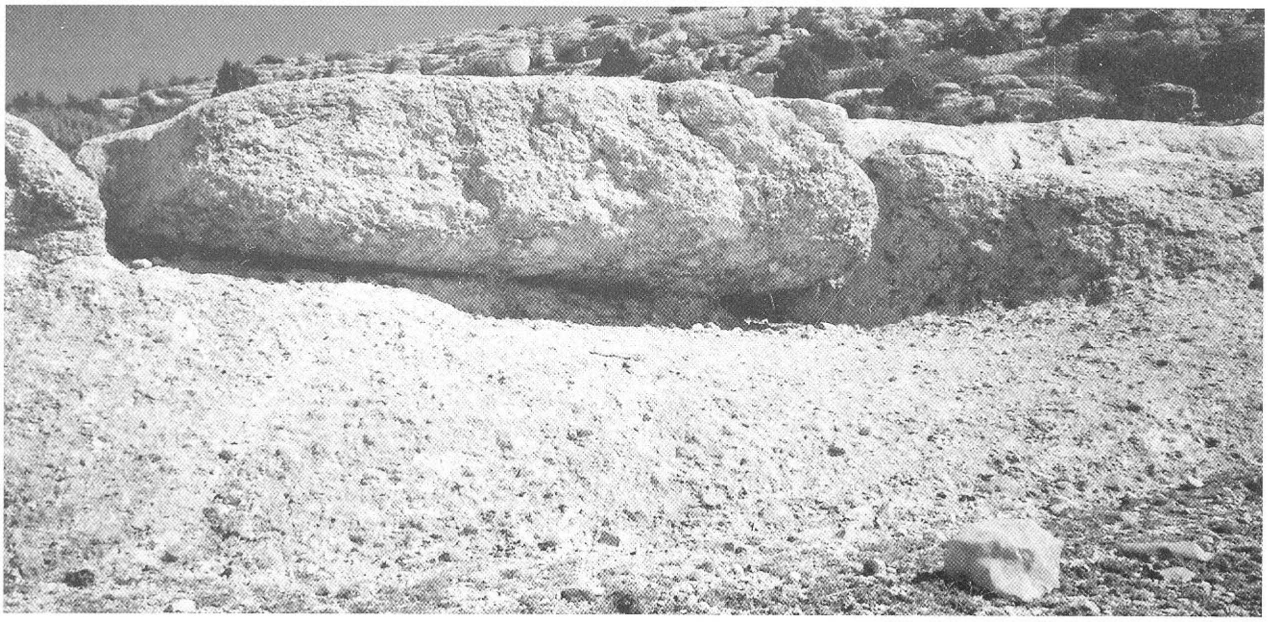


Fig. 6. Portion of sheet-like matrix-supported breccia with weakly developed fining-upward trend (facies GmsII). The scale is 22 cm long.

sorting. Dispersed carbonate pebbles (up to 5 cm, most less than 1 cm in diameter) are common, especially near the base of some sandstone beds. The sandstones are usually grain-supported, mostly with point and planar grain to grain contacts. Pore space is occupied by sparite cement or filled with fine-grained sediments.

These sandstones can be subdivided into four lithofacies: trough cross-stratified sandstones (facies St), planar cross-stratified sandstones (facies Sp), horizontally stratified sandstones (facies Sh) and ripple-laminated sandstones (facies Sr).

Trough cross-stratified sandstones (facies St) are the dominant lithofacies. They occur as single sets or cosets (Fig. 7). The set thickness ranges from 5 - 30 cm, and coset thickness is from 0.5 - 1 m. Trough widths are between 1 and 3 m. The dip angle of foresets is between 10° and 15°, while the trough-axis direction is commonly south-westward. The lower contacts of this facies are gently concave-up or slightly erosive with respect to underlying sediments (Figs. 7, 11, 13 and 14). Dispersed granules are usually present at the bases of trough sets. Trough cross-bedded sets overlie flat-bedded and cross-bedded conglomerates passing upwards into horizontally laminated or ripple cross-laminated sandstones and/or massive or laminated mudstone being laterally impersistent (Figs. 11 and 13). In

Fig. 7. Sets of low-angle trough cross-stratified sandstones and pebbly sandstones (facies St) underlain by massive mudstone (facies Fm). The scale is a cap.

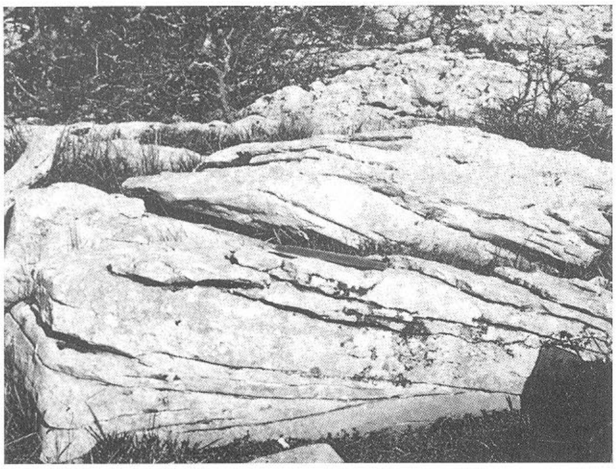


Fig. 8. Two sets of planar cross-stratified sandstones and pebbly sandstones of facies Sp overlain by clast-supported conglomerates. The scale is 22 cm long.

other cases they overlie erosional scours with shallow relief (up to 0.2 m), incised into relatively thick and laterally mappable sandstone and mudstone facies assemblages. These pass upwards into planar cross-bedded and horizontally laminated or ripple cross-laminated sandstones capped by mudstones facies (Fig. 7 and 14).

Planar cross-stratified sandstones (facies Sp) consist of planar cross-bedded sets with dip angles of foresets between 15° and 20°. The sets mostly occur as solitary units, but in some places cosets of up to 3 sets can be seen. The set thickness ranges from 10 - 60 cm (Fig. 8). The dip directions are mostly considerably different to trough axis directions in facies St. The set bases are flat or moulded over underlying beds. At places the unit is marked by reactivation surfaces.They mostly contain medium sand grains.

These sandstones occur in lateral and vertical association with trough cross-bedded and horizontally laminated sandstone within mappable sandstone and mudstone bands or, more rarely, occur within lithofacies Gp (Figs. 11, 12, 13, 14 and 15).

Horizontally laminated sandstones (facies Sh) form horizontal and laminated units which vary in thickness from 4 - 65 cm, but are normally less than 20 cm. They extend laterally from a couple of meters to several tens of metres, within very laterally extensive fine-grained members (Figs. 7, 12, 13 and 14). They are also present in the form of thin lenses or sheets within conglomerate deposits (Fig. 3). In places, laminated sandstones are not horizontal, but gently inclined (<10°). Sandstone units within fine-grained members have flat or slightly erosive bases, but those within conglomerates have bases moulded over underlying bedforms. In both cases their tops are flat or scoured (Fig. 3). In some places the laminations may show slight irregular undulations, due to soft sediment deformation.

Ripple cross-laminated sandstones (facies Sr) are mostly present on the top of planar and trough cross-bedded sandstones or are interbedded with mudstone. These units consist of very thin (from 3 - 55 cm) sets or cosets which are laterally very impersistent (Figs. 13 and 14). The cross-laminated sets are often plastically disturbed but in places their trough-like form is preserved. They are composed of fine to medium-grained sand.

Massive and horizontally laminated mudstones (facies Fm, Fl) are composed of calcisiltites and micrites and may be slightly clayey. The calcisiltites are matrix-supported, composed of silt-sized carbonate (mostly sparitic) grains, less than 5% quartz grains and have a micritic matrix. The micrites are often characterised by bioturbation that is sporadically very vigorously expressed. The mudstones also sporadically contain various plant fragments. They occur mostly as laterally persistent beds from 5 cm to 1.4 m thick,

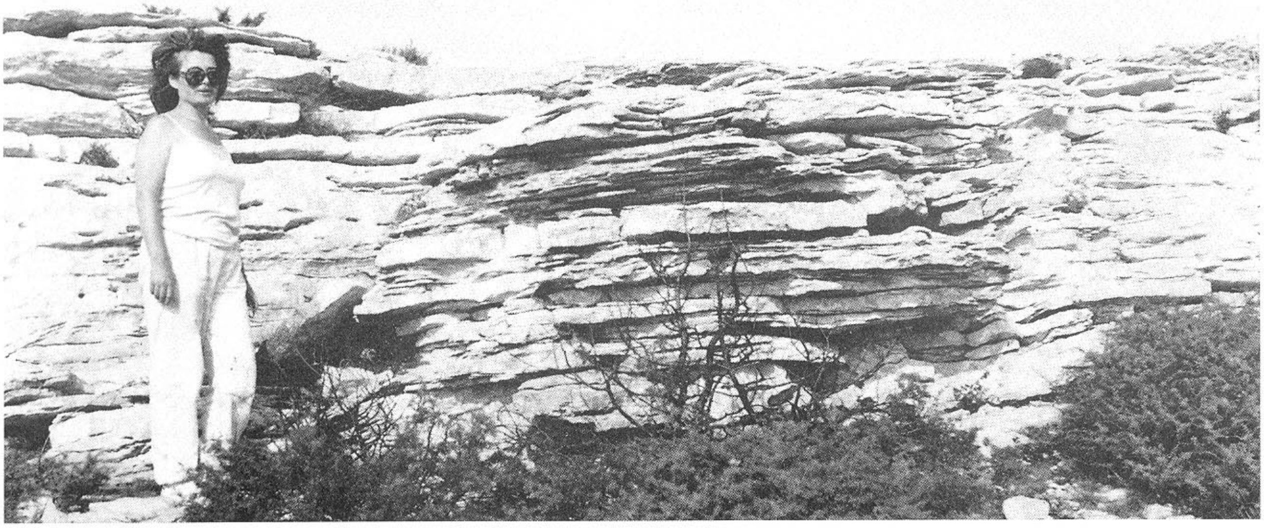


Fig. 9. Massive and horizontally laminated mudstones (facies Fm and Fl). A thin horizon of trough cross-stratified sandstone (facies St) is weakly visible in the upper part.

interbedded with sandstones and underlain and overlain by multi-storey channel-fill sandstone to pebbly sandstone. Less commonly they occur as thin lenses which cap cross-bedded conglomerates and sandstones (Figs. 7, 9, 13, 14 and 15).

4. PALAEOTRANSPORT AND PROVENANCE

Palaeocurrent patterns, indicated by imbrication of cobbles in massive to crudely flat-bedded conglomerates (facies Gm), and trough-axis orientations in the trough cross-bedded conglomerates, are illustrated in Fig. 10. Large scale planar cross-bedding in conglomerates and sandstones is not a reliable indicator of the main palaeocurrent directions.

The grand vector mean calculated from clast imbrication is 226°, while vector means of individual samples range from 203° to 254° (MRINJEK, 1993). The grand vector mean calculated from trough axes orientation is 213°. Both grand vector means are closely similar, demonstrating that the braided streams in the studied succession flowed south-westwards from a northeastern source (Fig. 10).

The alluvial deposits of Promina beds are almost exclusively composed of carbonate clasts, grains and matrix. Conglomerates and breccias contain more than 95 % carbonate clasts and very rare clasts of sandstone, marl, various cherts and fragments of rudists. Throughout the studied succession carbonate clasts are predominantly of the Cretaceous age, with some of Palaeogene, Jurassic and Triassic ages. So the association of clast compositions probably indicates a thrusted source terrain where layered rocks of different lithologies and different ages have been simultaneously exposed. This conclusion is in accordance with BAHUN (1974) and HERAK & BAHUN (1980), who state that an extensive thrusted hinterland (Mt. Velebit) towards the northeast is the source of the Jelar breccia and Promina beds. In more distal environments, clast composition can also be result of fluvial processes (STEIDTMANN & SCHMITT, 1988).

5. FACIES ASSOCIATIONS AND INTERPRETATIONS

Lateral and vertical arrangement of facies associations coupled with palaeocurrent analysis indicate that the alluvial Promina beds mostly occured within a braided fluvial system (BABIĆ & ZUPANIČ, 1988; MRINJEK, 1989, 1993). The absence of any features or association of features suggestive of marine transport and sedimentation indicates a continental setting. Many textural and sedimentary structural features within the alluvial Promina beds are reported from both modern (BOOTHROYD & ASHLEY, 1975; ORE, 1964; RUST, 1972; SMITH, 1974; WILLIAMS & RUST, 1969) and ancient (BLUCK, 1967, 1980; BULL, 1972; LARSEN & STEEL, 1978) alluvial fan/braided stream settings.

Although vertical variation of facies occurs throughout the studied succession, it was possible to distinguish three laterally extensive and recurring facies associations or assemblages in the alluvial Promina beds.

5.1. FACIES ASSOCIATION A

This facies association (Figs. 11 and 12) mostly occurs in the middle part of the succession (Figs. 16a, b and c) and shows a cyclical arrangement in sequences 6-15 m thick. The fundamental characteristic of the facies association A is an interbedding of the most coarse and sheet-like Facies Gm, GmsI and GmsII, including subordinate planar and trough cross-bedded conglomerate (Facies Gp, Gt,) and very minor cross-bedded and horizontally-bedded sandstone (Facies Sp, St, Sh) enclosed by conglomerate facies. Contacts between these facies are usually scoured or less commonly planar (Figs. 11 and 12).

Disorganised, matrix-supported breccia (GmsII) can be interpreted as debris-flow deposit. SHULTZ (1984) attributed this type of deposit to plastic debris flow with matrix strength, laminar flow and viscous clast interactions. An inversely graded basal zone with parallel aligned clasts may form in the region of the maximum shear gradient. Vertical inhomogeneity may also result from the stacking of successive debris-flow deposits. Inverse to normal graded breccia sheets and disorganised clast-supported conglomerate (facies GmsI) can be attributed to a pseudoplastic debris flow (SHULTZ, 1984) or clay-poor, noncohesive debris flow (LOWE, 1982) with relatively low yield strength, in which laminar flow is replaced by more turbulent flow and viscous clast interaction by more collisional clast interaction. Alternatively, the disorganised, clast-supported conglomerates may have been deposited by high density, turbulent flows during major floods ("hyperconcentrated flood-flows", SMITH, 1986).

The lithofacies Gm strongly supports the interpretation of gravel-dominated braided streams in shallow, low sinuosity channels (ORE, 1964; WILLIAMS & RUST, 1969; SMITH, 1974; RUST, 1975, 1978; MIALL, 1978) which were capable of moulding the sediment into broad sheet-like bodies. Alternation of different clast sizes, together with a clast-supported framework with closed or open packing indicates high- and low-discharge events, i.e. indicate currents which were capable of winnowing finer grained sediments and, therefore, the matrix of these conglomerates likely represents a late-stage infiltrate (SMITH, 1974).

A traction process origin is also supported by the presence of imbricated clasts with B-axis imbrication. Large, discoidal clasts are a particularly reliable indicator of the main flow direction, because they were oriented during a high flow regime and resisted movement at lower discharges when deviations occur from the general trend (MRINJEK, 1993).

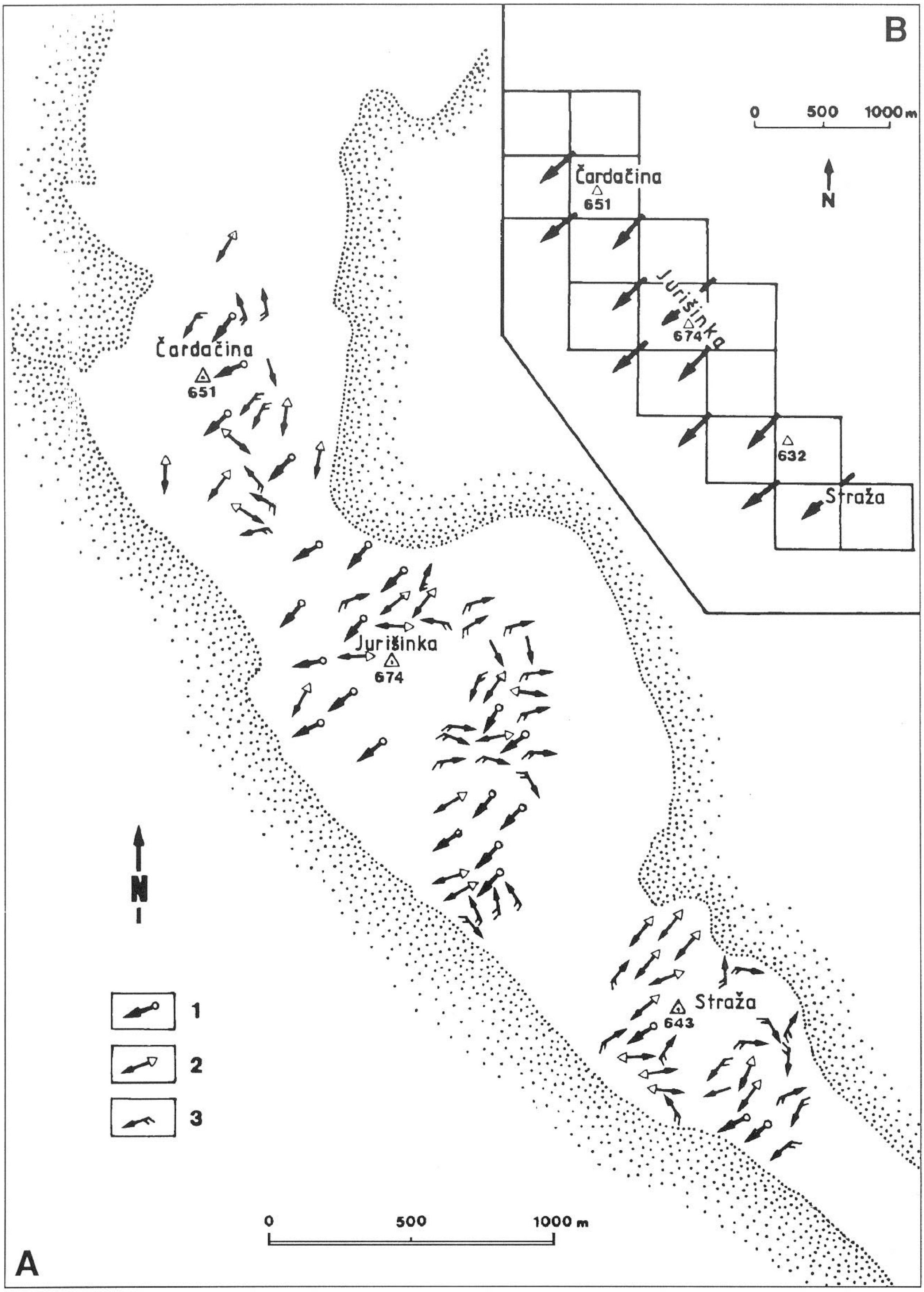


Fig. 10. A - Palaeocurrents in studied area. Key: 1-vector mean of clast imbrications; 2-trough-axis directions; 3-planar cross-bed directions. B - Moving average paleocurrent map based on the clast imbrication (from MRINJEK, 1993).

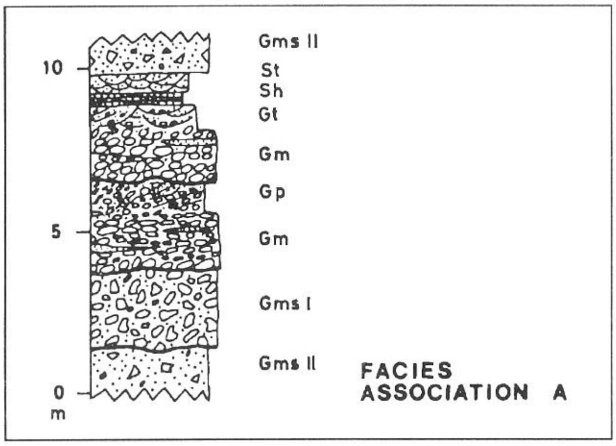
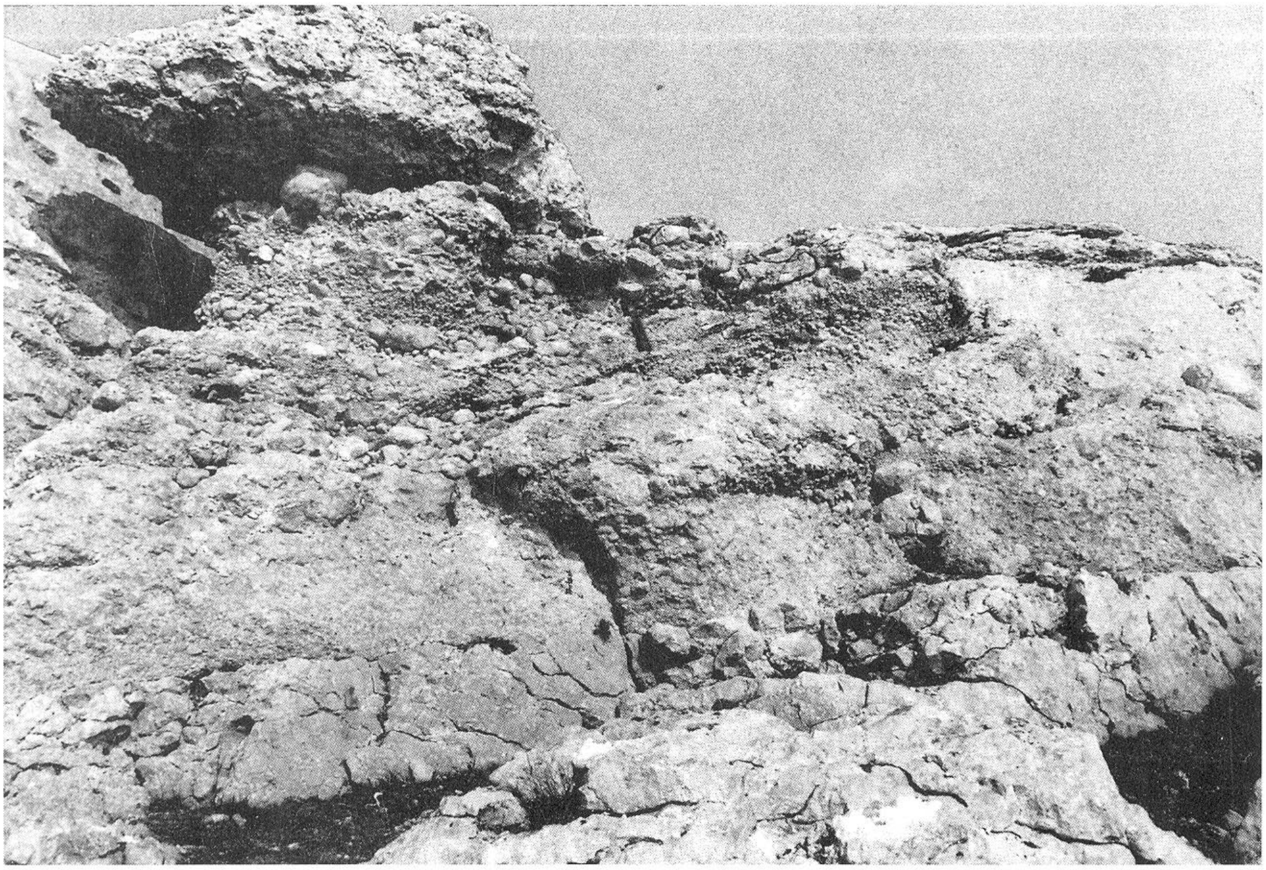


Fig. 11. Typical section of the Facies association A.

Crudely flat-bedded conglomerates were emplaced following deposition of different gravel sheets during high-water stages (HEIN & WALKER, 1977), when the streams were strong enough to move all clast sizes including the coarsest ones. Slightly reduced flows promoted downstream growth of horizontally stratified gravel sheets. With continued vertical and lateral growth the sheets developed into longitudinal and/or diagonal bars. During waning-flow conditions finer grained material was deposited on top of the bars and also infiltrated into the open framework of the gravels, as pointed out by RUST (1978). The lateral migration of braided channels with abundant longitudinal bars could result in generation of sheet-like gravels. Alternatively, these could result from emplacement of gravel sheets during major floods. In the cases of the absence of channelised bases in these units, the latter interpretation is more likely.

Lithofacies Gp could be formed by migration of independent transverse or linguoid bars, but in this facies association, it is considered less likely. The tabular cross-bed sets in the conglomerate succession are



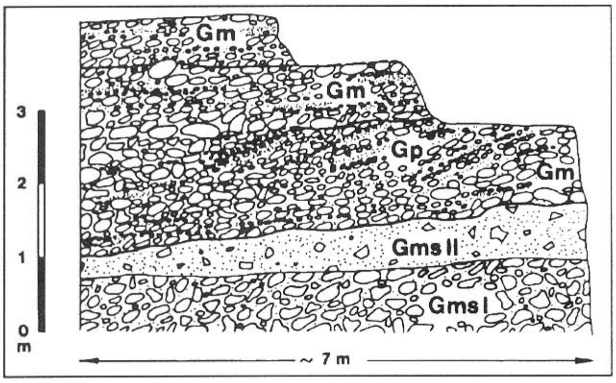


Fig. 12. A - Facies association A: Crudely flat-bedded conglomerates (facies Gm), tabular cross-bedded conglomerates (facies Gp), interbedded matrix-supported breccias (facies GmsII) and disorganized clast-supported conglomerates (facies GmsI). The scale is 22 cm long. B - Outcrop sketch of 11 A, illustrating the facies. Heavy lines denote erosion surfaces.

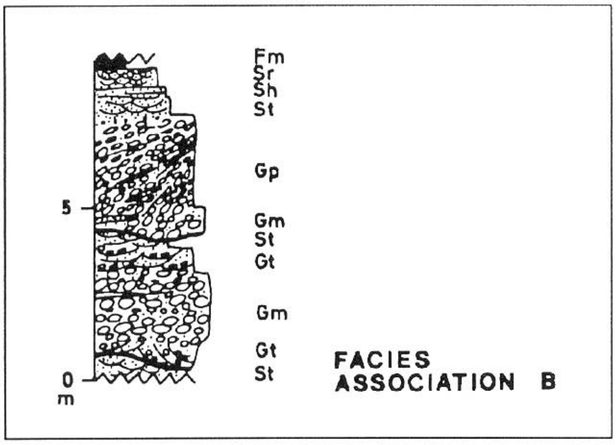


Fig. 13. Typical section of the facies association B.

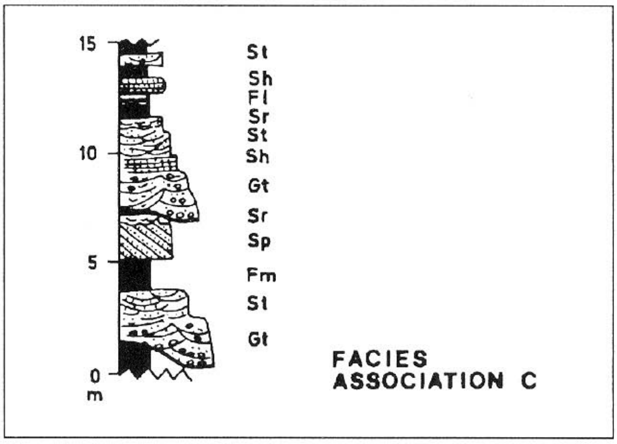


Fig. 14. Typical section of the facies association C.

relatively small, commonly enclosed by flat-bedded conglomerates. With the possible exception of the largest cross-bed sets, they can be considered as lateral modifications of longitudinal bars during falling stages, when flow diverges away from bar axes. Decreasing sediment and water discharges and availability of greater channel depth can favour vertical accretion on the tops of bars and simultaneous development of foreset slopes and slip-face accretion of bars (HEIN & WALKER, 1977; RUST, 1978). Vertical accretion was minor in comparison with lateral accretion and was controlled by the depth of water, and thus foresets are mostly thinner on top of bars and thicker laterally and downwards with a maximum towards the base. Sandstone drapes between foresets and alternation of different grain size foresets can represent changes in flow state. Continued accretion formed downstream and lateral foresets, dipping towards the lateral channels at angles up to 90°.

The Lithofacies Gt, interbedded within flat-bedded conglomerates, can be interpreted as a result of deposition by migrating three-dimensional large gravel dunes during floodstages in braided channels and as the filling of shallow scours and channels on bar top and/or bar front during falling stages (RUST, 1972; EYNON & WALKER, 1974; MIALL, 1978).

Trough and horizontally stratified sandstone occurs on the top of a longitudinal bars. The Facies St can be interpreted to represent dune migration across the tops of longitudinal bars or infill of shallow bar-top scours and channels. The Facies Sh was probably formed during plane bed transport of sand over the bars while facies Sp, placed within facies Gp, represents changes in flow state during lateral modification of longitudinal bars. In both facies the absence of coarser sediment implies decreasing flow discharges.

This type of association can be equated with the Scott facies assemblege of MIALL (1978), or the GII facies assemblage of RUST (1978), implying deposition in a distal alluvial-fan to proximal braided-river setting, probably along the fan fringe.

5.2. FACIES ASSOCIATION B

This facies association is the most abundant and occurs throughout the studied succession. It arranged in cycles 4.5-15 m thick. The majority of this facies association is composed of organised clast-supported conglomerates of the facies Gm interbedded with planar or trough cross-bedded conglomerates (facies Gp and Gt), and subordinate sandstone lithofacies (St, Sp and Sh) in the top of facies association (Fig. 13).

Although depositional processes are for the most part discussed in the previous section, some Gp facies display characteristics which must be discussed further. Some cosets of the planar cross-bedded conglomerates are unusually thick (up to 5 m) and extend laterally for approximately 20 m, comprising more than 50% of the association. Their relatively great lateral extent in directions parallel to and perpendicular to palaeoflow, in addition to their thickness, suggests that this facies could result from downstream migration of transverse or medial bars during flood stages (BLUCK, 1971, 1976) rather than from falling stage-modification of longitudinal bars (EYNON & WALKER, 1974; RUST, 1978). Additional evidence for this interpretation includes: (1) the absence of any observable lateral transition between the Gm and Gp facies; (2) sequences in which the Gp facies is overlain by the Gm facies; (3) the relative volumetric abundance of the Gp facies.

Flood-stage depths as suggested by the cross-set thickness, must have been in the order of some metres. Such depths imply more prolonged and also more frequent flows which can be indication of humid conditions (RUST, 1978).

Association B can also be compared with the Scott facies assemblage of MIALL (1978), or the GII assemblage of RUST (1978), but without debris flow deposits and with more clearly expressed upward fining and thinning trends. These characteristics and palaeocurrent trends (MRINJEK, 1993) suggest a proximal braided rivers system, but rather deeper with more stable flow conditions relative to the previous facies association.

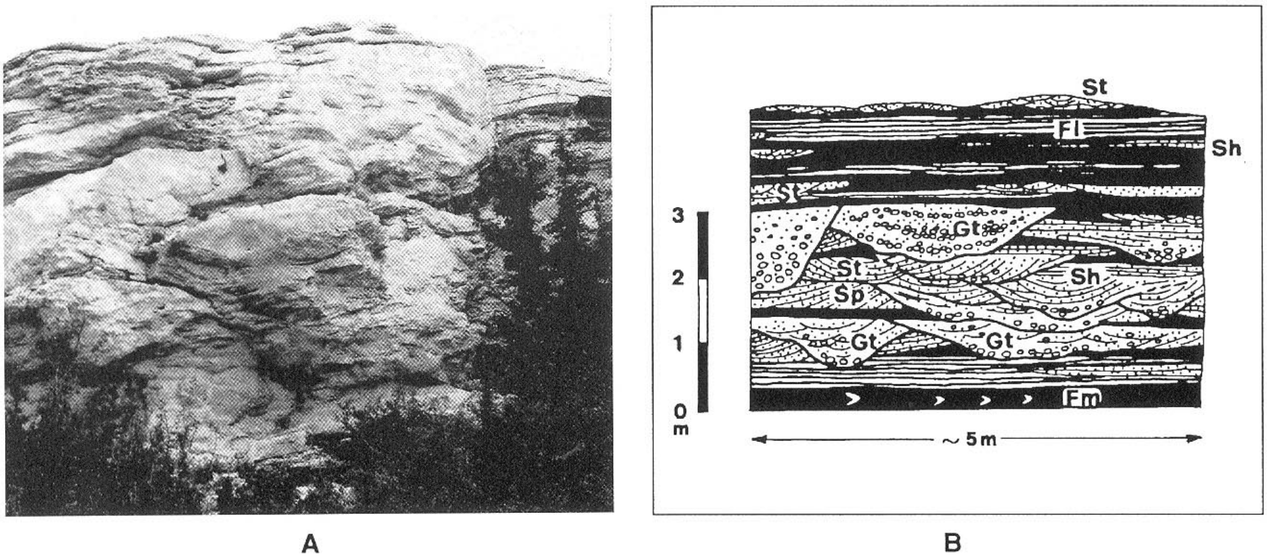


Fig. 15. A - Facies associations C: Multi-storey channel-fill with trough cross-bedded pebble conglomerates and sandstones (facies Gt and St) overlain and underlain by horizontally laminated and massive mudstones (facies Fl and Fm) interbedded with horizontally laminated sandstones (facies Sh) and thin sets of trough cross-stratified sandstones (facies St). B - outcrop sketch of 15 A, illustrating the facies. Heavy lines denote erosion surfaces.

5.3. FACIES ASSOCIATION C

This facies associatin occurs in all parts of the studied succession, but more frequently in the lower part. Cycles within this facies association have wider range in thickness (1-10 m) than those of facies association A and facies association B.This facies association is characterised by predominance of facies Gt (in the base), and facies St, Sp with subordinate facies Sh, Sr, Fl and Fm (Figs. 14 and 15).

Trough cross-bedded conglomerates (facies Gt) commonly occur in cosets, with an erosional base, incised into mudstones and sandstones, and fine upwards to smaller sets of trough-bedded pebbly sandstone and sandstone (facies St). Both facies represent gradual filling of shallow multi-storey channels by migration of three-dimensional dunes during waning flow. Mudstones (facies Fl, Fm) are interbedded with thin horizontally-stratified sandstone (facies Sh), minor sets of ripple cross-laminated sandstone (facies Sr) or small channels filled by sandstone which were generated by crevesse channels and splays spread over the flood plain during floodstage (Fig. 15).

Facies association C is charaterised by a substantial sandstone and mudstone content and clear cyclical thining-upward and fining-upward trends (flood cycles). In the succession studied several associations composed of a number of flood cycles express a coarsening-upward trend which can be explained by channel switching and filling (Fig. 16a).

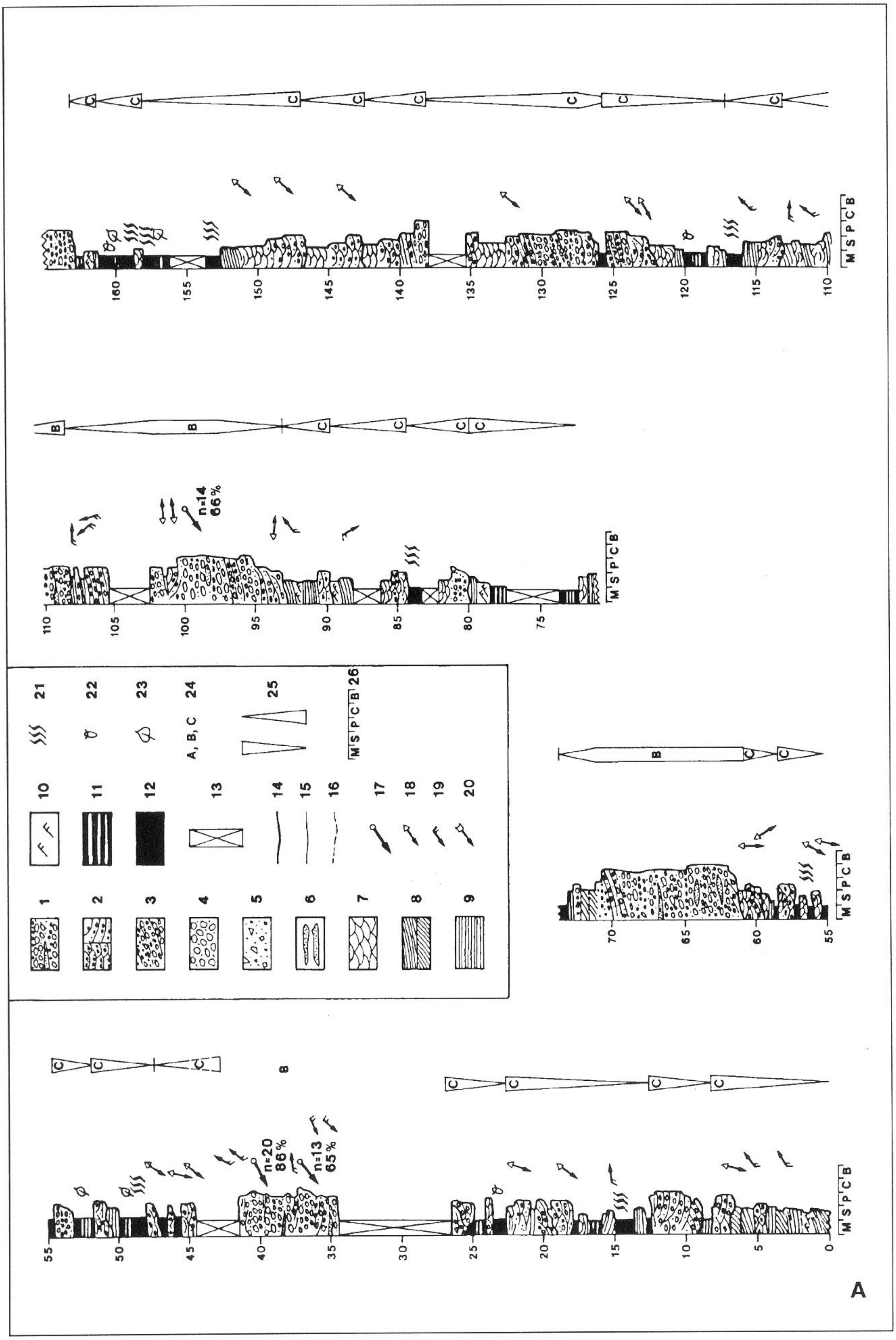
The described association has characteristics of distal gravel braided rivers and suggest a comparison with the Donjek facies assemblage (MIALL, 1978) or with the GIII facies assemblage of RUST (1978).

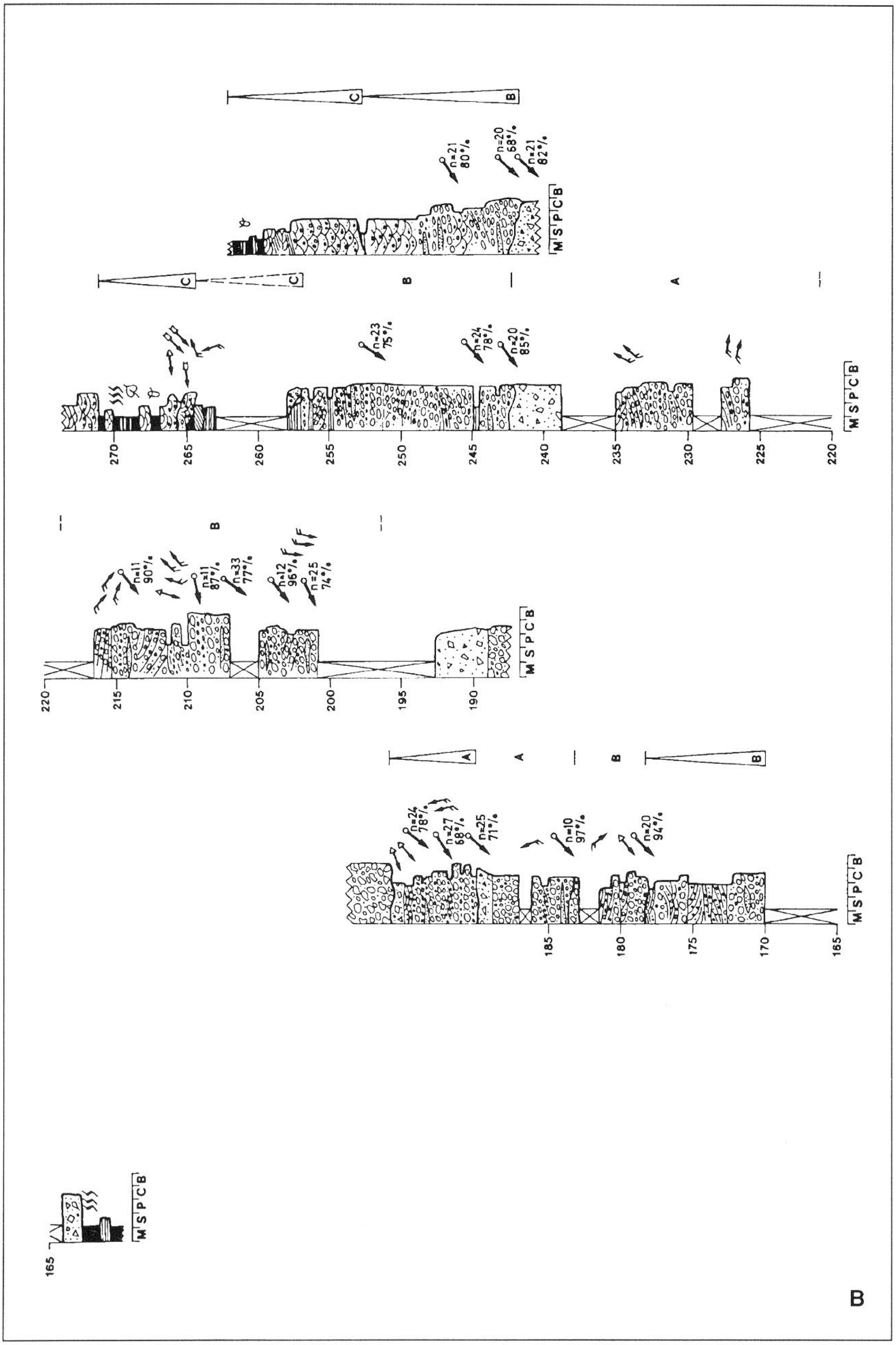
6. ALLOCYCLIC CONTROL ON EVOLUTION

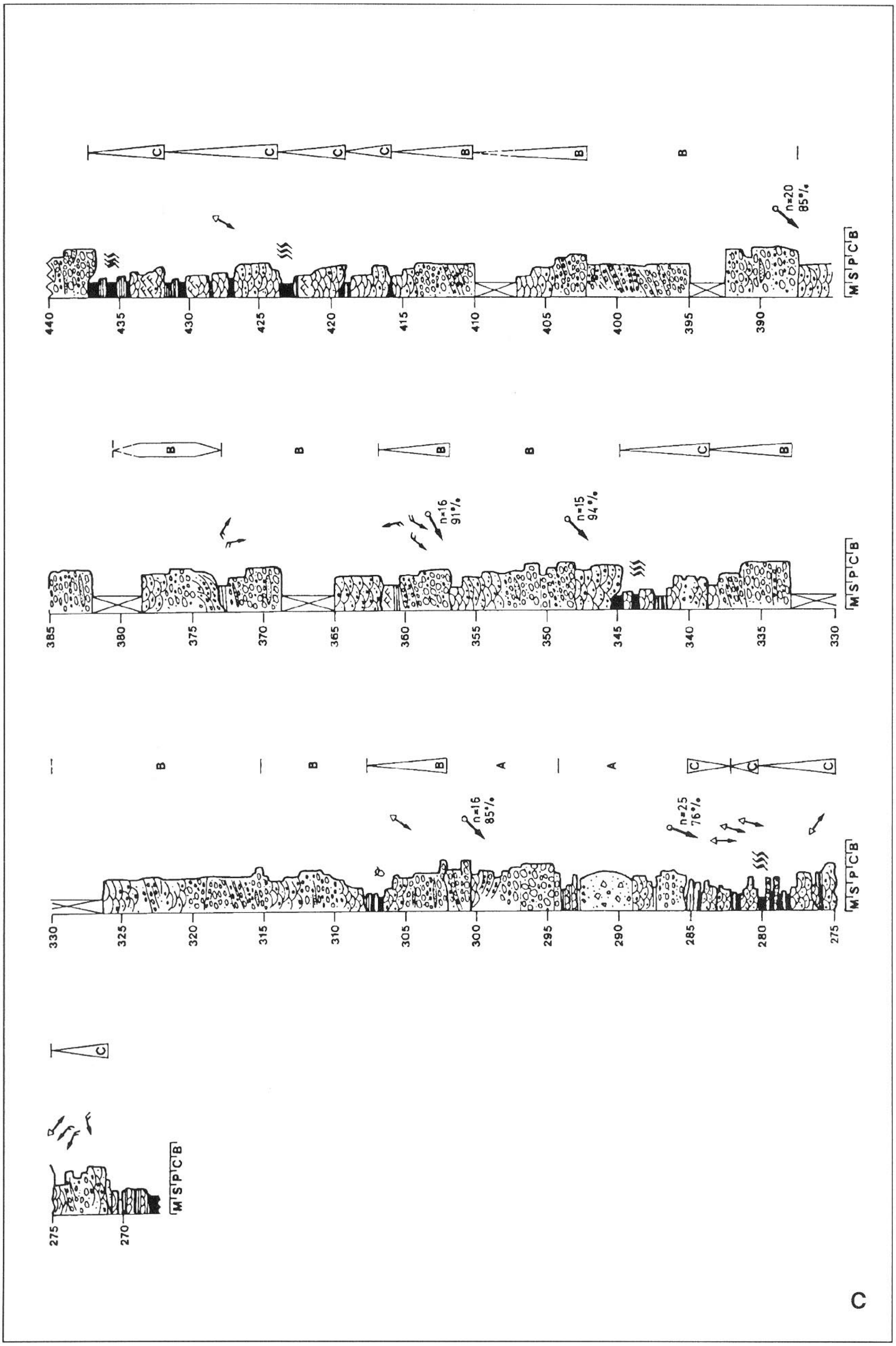
Although the studied succession is characterised by an overall upward prograding trend, it can be subdivided into five discrete parts (Figs. 16a, b, c and 17). The first, lowest and thickest part (0-163 m), consists of irregularly arranged facies associations C and subordinate facies associations B (Figs. 16a and 17). The second and fourth parts (163-253 m and 285-415 m) are characterized by markedly higher proportion of conglomerates, almost exclusively arranged in facies associations B and subordinate facies associations A (Figs. 16b and c and 17). The third and fifth, relatively thin parts (253-285 m and 415-437 m), only contain facies associations C (Figs. 16b, c and 17).

Facies associations A and B, in the second and fourth parts, can be attributed to the tectonic uplift of

Fig. 16. A, B, C - Section of studied alluvial Promina beds. 1 - massive to crudely flat bedded conglomerates (facies Gm); 2 - trough cross-bedded conglomerates (facies Gt); 3 - planar cross-bedded conglomerates (facies Gp); 4 - disorganized clast-supported conglomerates (facies GmsI); 5 - disorganized matrix-supported breccias (facies GmsII); 6 - sandstone lenses within facies Gm and Gp; 7 - trough cross-stratified sandstones (facies St); 8 - planar cross-stratified sandstones (facies Sp); 9 - horizontally laminated sandstones (facies Sh); 10 - ripple cross-laminated sandstones (facies Sr); 11 - horizontally laminated mudstones (facies Fl); 12 - massive mudstones (facies Fm); 13 - covered interval; 14 - erosion surfaces; 15 - sharp contacts; 16 - gradational contacts; 17 - vector mean of clast orientations, number of measurements, vector magnitudes; 18 - trough-axis directions; 19 - planar cross-bed directions; 20 - channel directions; 21 - bioturbation; 22 - burrows; 23 - plant fragments; 24 - facies associations A, B and C; 25 - grain size and bed thickness trends in facies associations; 26 - grain size scale: M=mud, S=sand, P=pebble, C=cobble, B=boulder.


A
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
125
130
135
140
145
150
155
160
M S P C B
n=20
86%
n=13
65%
n=14
66%
A, B, C
B
C
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26


C
B
n=21 80%
n=20 68%
n=21 82%
M S P C B
C
C
B
A
270
265
260
255
250
245
240
235
230
225
220
n=23 75%
n=24 78%
n=20 85%
M S P C B
B
220
215
210
205
200
195
190
n=11 90%
n=11 87%
n=33 77%
n=12 96%
n=25 74%
M S P C B
A
A
B
B
185
180
175
170
165
n=24 78%
n=27 68%
n=25 71%
n=10 97%
n=20 94%
M S P C B
165
M S P C B
B


440
435
430
425
420
415
410
405
400
395
390
385
380
375
370
365
360
355
350
345
340
335
330
325
320
315
310
305
300
295
290
285
280
275
270
M S P C B
n=20 85%
n=16 91%
n=15 94%
n=16 85%
n=25 76%
A
B
C
C

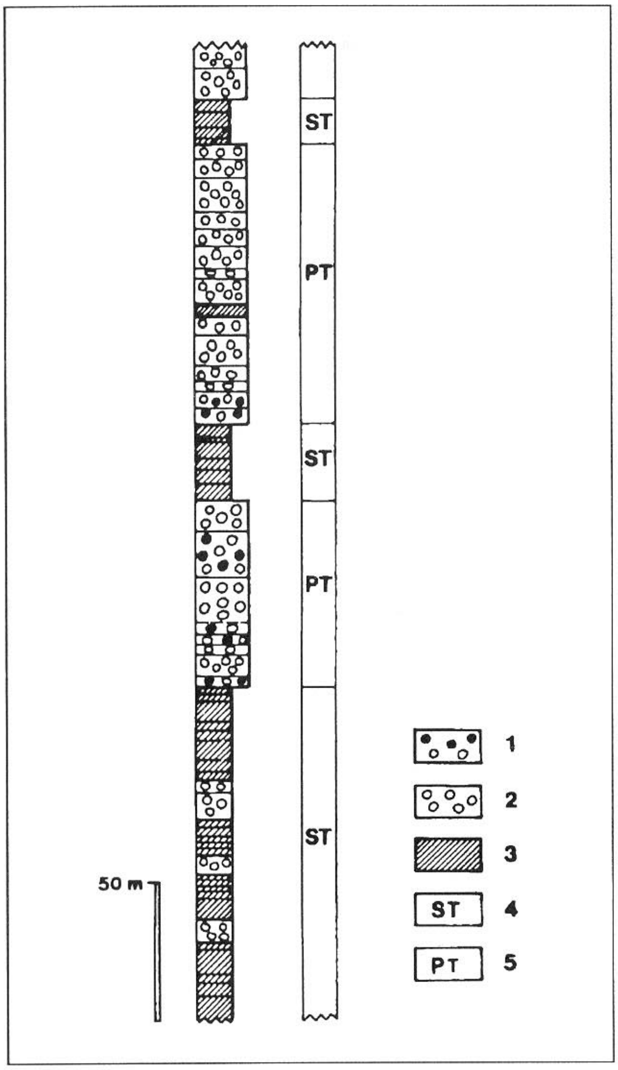


Fig. 17. Simplified section of studied alluvial Promina beds displaying possible syntectonic and post-tectonic phases. 1. Facies association A; 2. Facies association B; 3. Facies association C; 4. Syntectonic phase; 5. Post-tectonic phase.

the source area and accompanying increase of sediment supply. Pronounced erosion and large mean clast size in facies Gm is a direct response to a high stream gradient and lowering of the base level. On the contrary, facies association C in the first, third and fifth parts suggests relatively a low stream gradient or high base level. Several cycles of facies association B inserted within facies association C in the first part can be explained by higher stream discharges caused by an intermittent increase of the rainfall rates. In addition, facies association C (especially in the thin third and fifth parts) could be caused not only by tectonic inactivity but raising of the sea level or climatic changes as well.

Distribution of facies associations suggests five allocyclic phases (Fig. 17) in the entire studied succession probably with tectonics as a primary allocyclic control and climatic and sea-level changes as alloyclic controls with important but secondary role. Autocyclic controls could be also important, but probably in the case of small-scale cycles and events.

7. DEPOSITIONAL SYSTEM

It is obvious from the characteristics of facies associations and their vertical and lateral transition, that the facies geometries and palaeocurrent directions in the alluvial Promina beds are the result of deposition in an extensive and complex alluvial setting. This is characterised by alluvial fans and braided rivers with a clearly developed southwestward trend of dispersal.

The repeated phases with Scott- or Donjek-type facies associations imply variations in sediment supply, stream gradient or base level during the alluvial deposition.

Since the Promina beds display an overall upward prograding trend (IVANOVIČ et al., 1969; BABIĆ & ZUPANIČ, 1983) and have a thrusted and folded hinterland (BAHUN, 1974; HERAK & BAHUN, 1980), the Promina beds evolution can be explained by repeated and progressive thrusting to the southwest during Late Eocene and Oligocene. This relativelly long-term compression also gave rise to periodic rejuvenation and southwestward tectonic transport of the source area. Other, allocyclic processes such as climatic and sea-level changes could have been important, but played a secondary role in the alluvial sedimentation.

The Jelar breccia, which outcrops in the foothills of Mt. Velebit (Fig. 1), consists of various talus deposits (BABIĆ & ZUPANIČ, 1988) and represents a direct response to thrust uplifts and erosion of the source area. Because of strong Eocene and especially younger and recent tectonics and accompanying erosion, the Jelar breccia is detached from the Promina beds depositional area (Fig. 1) although the both belong to the same depositional and tectonic setting.

The vertical transition from shallow-marine to braid-river and braid-plain sediments described in the studied area by BABIĆ & ZUPANIČ (1990) together with palaeocurrent pattern (Fig. 10) suggest that the braided river settings are the subaerial component of an extensive, complex and overall prograding braid-delta (MRINJEK, 1993).

8. DISCUSSION: SUBSIDENCE-DRIVEN VS. FLUX-DRIVEN SEDIMENTATION

Recent studies of the allocyclic facies variations in alluvial successions of foreland basins use a new model of subsidence-driven sedimentation with syntectonic and post-tectonic phases for explanation of gravel progradation (BLAIR & BILODEAU, 1988; HELLER et al., 1988; ANGEVINE et al., 1990; HELLER & PAOLA, 1992; PAOLA et al., 1992). Involving asymmetrical subsidence and subsequent isostatic rebound of the basins these studies polemize with the traditional model of flux-driven sedimentation where the gravel progradation is generally a syntectonic phenomenon generated by tectonic uplift of the source area and related increase in flux of coarse sediment (STEEL et al., 1977; RUST & KOSTER, 1984).

Viewed in the light of subsidence-driven sedimentation, the studied succession would display the alternation of syntectonic and post-tectonic phases (Fig. 17). The first, third and fifth parts of Donjek-type facies associations could be interpreted as syntectonic phases, i.e. as the result of maximum subsidence during the active thrusting when coarse alluvial sediments were accumulated only in the most proximal part of the basin and graded rapidly into fine-grained deposits toward the distal part of the basin. On the other hand, Scott-type of facies associations in the second and fourth parts (Fig. 17) could be interpreted as mainly post-tectonic phases, i.e. as the result of waning of thrustings followed by tectonic quiescence when erosion of the uplifted areas dominated. These would lead to isostatic rebound of the source areas and also, at the same time, to the uplift and erosion of the sediments previously deposited in the proximal part of the basin. These sediments would have been transported across the basin and redeposited in its distal part over relatively fine-grained, syntectonic facies associations. Moreover, the large-scale prograding sequences in the shallow-marine Promina beds, vaguely interpreted by BABIĆ & ZUPANIČ (1990) as the result of alternating progradational and transgressive tendencies, could be simply explained on the basis of subsidence-driven sedimentation (the influence of eustatic sea-level and climatic changes are not considered). The lower part of a complete prograding sequence, which mainly consists of shelf mudstone and hummocky cross-stratified or low angle laminated shelf and shoreface sandstone and is underlain by erosive surface and thin transgressive lags of conglomerates and pebbly sandstones, should be related to the reduction in sediment supply and maximum subsidence during syntectonic phase (subsidence-driven transgression). The upper part, which consists of the large-scale (metres thick) foreset conglomerates comparable to Gilbert-type bodies, should be ascribed to an isostatic rebound and erosion of the source area and proximal part od the basin followed by coarse sediment progradation into distal part of the basin during post-tectonic phase.

Since the correlation of post-tectonic coarse sediments with erosional surfaces in the most proximal part of the basin is impossible because of Oligocene and younger thrusting (several phases of uplift, tectonic transport and cannibalism of the proximal part of the basin), and since the mathematical test, proposed by PAOLA et al. (1992) and HELLER & PAOLA (1992)

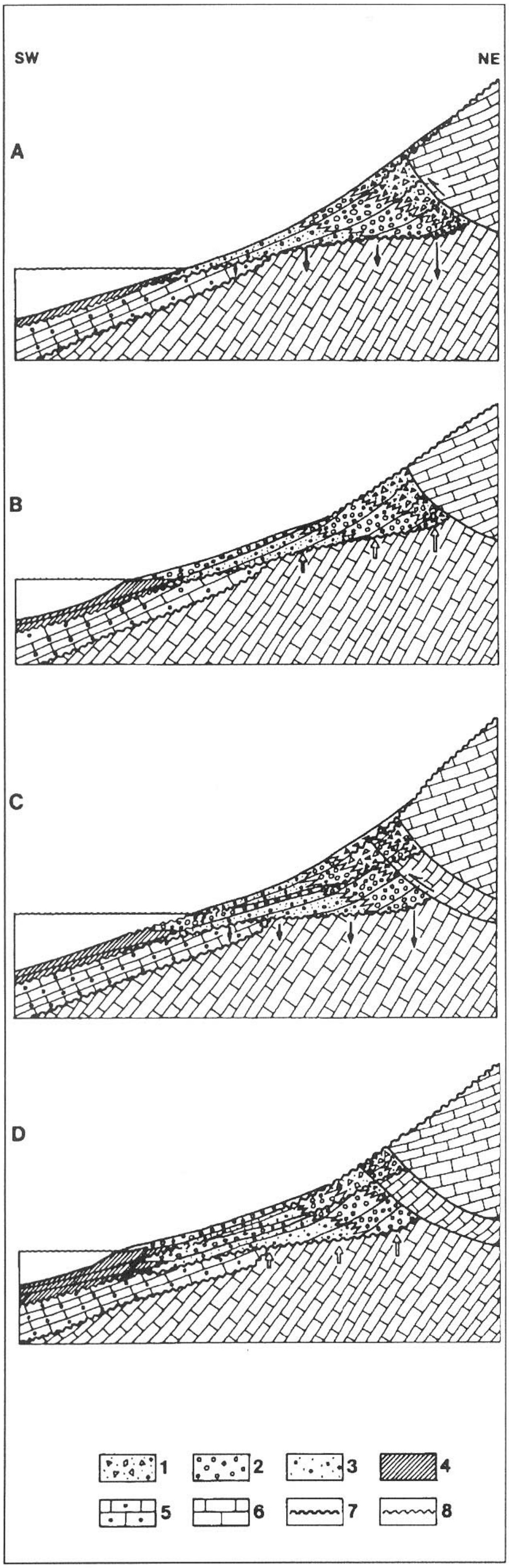


Fig. 18. Hypothetic depositional model of Promina beds in northern Dalmatia based on two-phase sedimentation. A and C - Syntectonic phases. B and D - Post-tectonic phases. 1. Jelar breccias and alluvial-fan deposits; 2. Scott-type braided-river deposits; 3. Donjek-type braided-river deposits; 4. Shallow-marine deposits; 5. Foraminiferal limestone; 6. Cretaceous and Jurassic carbonates; 7. Subaerial unconformities; 8. Submarine unconformities.

as an exact proof of syntectonic or post-tectonic conglomerate progradation, is inapplicable for the Promina basin at the moment, the sediment-driven Promina beds sedimentation should be only considered as a hypothetical model based on some indications (Fig. 18).

9. SUMMARY AND CONCLUSIONS

From the results and discussions described above it is possible to derive several conclusions:

1. In the studied alluvial succession, using the modified lithofacies code and description of MIALL (1977, 1978) and RUST (1978), it is possible to distinguish 11 facies. The organised conglomerate facies (Gm, Gt and Gp) are the dominant facies, the sandstone and mudstone facies (St, Sp, Sh, Sr, Fl and Fm) are substantially less abundant, whereas disorganised conglomerate and breccia facies (GmsI and GmsII) are very rare.
2. The described and interpreted facies are vertically arranged in three types of the facies associations which can be compared with those of MIALL (1978) or RUST (1978). Facies association A rarely occurs in the second and fourth parts of the succession. It suggests deposition in a distal alluvial-fan to proximal braided-river setting and could be compared with Scott or GII facies assemblage. Facies association B dominates in the second and fourth parts and facies association C in the first, third and fifth parts of the succession. Facies association B is ascribed to a proximal braided-river setting and can be also compared with Scott or GII facies assemblage. Facies association C has characteristics of a distal braided-river setting and suggests a comparison with Donjek or GIII facies assemblage.
3. The description and distribution of facies associations suggests five allocyclic phases (Fig. 17) in the entire studied succession with tectonics as primary allocyclic control on the sedimentation and climatic, and sea-level changes as allocyclic controls with a secondary role.
4. The Promina beds evolution is primarily related to repeated and progressive thrusting to the southwest during Late Eocene and Oligocene. This also gave rise to the periodic rejuvenation and southwestward tectonic transport of the source area.
5. Displaying colluvial characteristics, the Jelar breccia represents a direct response to the thrust uplift and erosion of the source area and together with the Promina beds belongs to the same depositional and tectonic setting.

Acknowledgements

I would like to thank Prof. F. Massari and T. Marjanac for their helpful comments and precious criticism. Thanks also go to J. Robson for her language-editing and useful comments.

Special thanks to A. Truhan for her nice graphical work.

I would like to excuse to Prof. F. Massari for not mentioning his very valuable help in my former paper ("Conglomerate Fabric...", Geol. Croat. 46/1).

10. REFERENCES

ANGEVINE, C.L., HELLER, P.L. & PAOLA, C. (1990): Quantitative Sedimentary Basin Modeling.- Amer. Assoc. Petrol. Geol., Contin. Educ. Course Note Series No 32, 133p.

BABIĆ, Lj. & ZUPANIČ, J. (1983): Palaeogene clastic formations in Northern Dalmatia. In: Contributions to sedimentology of Some Carbonate and clastic Units of the coastal Dinarides.- In: BABIĆ, Lj. & JELASKA,V. (eds.): Excursion Guide-book. 4. I.A.S. Regional Meeting (Split 1983), 37-61.

BABIĆ, LJ. & ZUPANIČ, J. (1988): Coarse-grained alluvium in the Palaeogene of Northern Dalmatia (Croatia, Yugoslavia).- Rad Jugosl. akad. znan. umjetn., 441, (Prir. istraž., br. 23), 139-164.

BABIĆ, LJ. & ZUPANIČ, J (1990): Progradational sequences in the Palaeogene clastic basin of the Outer Dinarids, from Northern Dalmatia to Western Hercegovina.- Rad Jugosl. akad. znan. umjetn., 449, (Prir. istraž., br. 24), 319-343.

BAHUN, S. (1974): Tektogeneza Velebita i postanak Jelar-naslaga.- Geol. vjesnik 27, 35-51.

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.

BLUCK, B.J. (1967): Deposition of some Upper Old Red Sandstone conglomerates in the Clyde area: A study in the significance of bedding.- Scott. J. Geol., 3/2, 139-167.

BLUCK, B.J. (1971): Sedimentation in the meandering river Endrick.- Scott. J. Geol. 7/2, 93-138.

BLUCK, B.J. (1976): Sedimentation in some Scottish rivers of low sinuosity.- Trans. Roy. Soc. Edinb., 69/18, 425-456.

BLUCK, B.J. (1980): Structure, generation and preservation of upward fining braided stream cycles in the Old Red Sandstone of Scotland.- Trans. Roy. Soc. Edinb., 71, 29-46.

BOOTHROYD, J.C. & ASHLEY, G.M. (1975): Processes, bar morphology, and sedimentary structures on braided outwash fans, northeastern Gulf of Alaska.- In: JOPLING, A.V. & MCDONALD, B.C. (eds.): Glaciofluvial and Glaciolacustrine Sedimentation. Soc. Econ. Pal. Mineral., Spec. Publ., 23, 193-222.

BULL, W.B. (1972): Recognition of alluvial fan deposits in the stratigraphic record.- In: RIGBY, J.K. & HAMBLIN, W.K. (eds.), Soc. Econ. Pal. Mineral., Spec. Publ., 16, 63-83.

EYNON, G. & WALKER, R.G. (1974): Facies relationships in Pleistocene outwash gravels, Southern Ontario: a new component of the braided river model.- J. Sediment. Petrol., 42, 389-400.

HEIN, F.J. & WALKER, R.G. (1977): Bar evolution and development of stratification in the gravelly, braided, Kicking Horse River, British Columbia.- Can. J. Earth Sci., 14, 562-570.

HELLER, P.L., ANGEVINE. C.L., WINSLOW, N.S. & PAOLA, C. (1988): Two phase stratigraphic model of foreland-basin sequences.- Geology, 16, 501-504.

HELLER, P.L. & PAOLA, C. (1992): The large scale dynamics of grain-size variation in alluvial basins. 2. Aplications to syntectonic conglomerate.- Basin Res., 4, 91-102.

HERAK, M. & BAHUN, S. (1980): The role of the calcareous breccias (Jelar Formation) in the tectonic interpretation of the High Karst Zone of the Dinarides.- Geol. vjesnik 31, 49-59.

IVANOVIĆ, A., MULDINI-MAMUŽIĆ, S., SAKAČ, K., VRSALOVIĆ-CAREVIĆ, I. & ZUPANIČ, J. (1969): Razvoj paleogenskih naslaga na širem području Benkovca i Drniša u sjeverozapadnoj Dalmaciji.- 3. simp. Dinarske asoc., 1 (1968), 51-71, Zagreb.

IVANOVIĆ, A., SAKAČ, K., MARKOVIĆ, S., SOKAČ, B., ŠUŠNJAR, M., NIKLER, L. & ŠUŠNJARA, A. (1976): Osnovna geološka karta SFRJ, list OBROVAC, 1:100 000.- Institut za geološka istraživanja, Zagreb, Savezni geol. zavod, Beograd.

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 deposits of high density turbidity currents.- J. Sediment. Petrol., 52, 279-297.

MIALL, A.D. (1977): A review of the braided-river depositional environment.- Earth Science Reviews, 13, 1-62.

MIALL, A.D. (1978): Lithofacies types and vertical profile models in braided river deposits.- In: MIALL, A.D. (ed.): Fluvial Sedimentology. Mem. Can. Soc. Petrol. Geol., Calgary, 5, 587-604.

MRINJEK, E. (1989): Alluvial conglomerates in Promina Formation.- 4. Int. Confer. on Fluv. Sediment., (Barcelona, Sitges, 1989), 189-189.

MRINJEK, E. (1993): Conglomerate Fabric and Paleocurrent Measurment in the Braided Fluvial System of the Promina Beds in Northern Dalmatia (Croatia).- Geol. Croat., 46/1, 125-136.

ORE, H.J. (1964): Some criteria for recognition of braided stream deposits.- Univ. Wyoming Contr. Geol., 3, 1-14.

RUST, B.R. (1972a): Structure and process in a braided river.- Sedimentology, 18, 221-245.

RUST, B.R. (1975): Fabric and structure in glaciofluvial gravels.- In: JOPLING, A.V. & McDONALD, B.C. (eds.): Glaciofluvial and Glaciolacustrine Sedimentation. - Soc. Econ. Pal. Mineral. Spec. Publ., 23, 238-248.

RUST, B.R. (1978): Depositional models for braided alluvium.- In: MIALL, A.D. (ed.): Fluvial Sedimentology. Mem. Can. Soc. Petrol. Geol., Calgary, 5, 605-625.

RUST, B.R. & KOSTER, E.H. (1984): Coarse alluvial deposits.- In: WALKER, R.G. (ed.): Facies Models. Geoscience Canada Reprint series 1, 53-69.

SHULTZ, A. (1984): Subaerial debris flow deposition in the Upper Palaeozoic Cutler Formation, western Colorado.- J. Sediment. Petrol., 54, 749-772.

SMITH. G.A. (1986): Coarse grained volcaniclastic sediment: Terminology and depositional process.- Bull. Geol. Soc. Am., 97, 1-10.

SMITH, N.D. (1974): Sedimentology and bar formation in the Upper Kicking Horse River, a braided outwash stream.- J. Geol., 82, 205-223.

STEEL, R.J., MAEHLE, S., NILSEN, H., ROE, S.L. & SPINNANGR, A. (1977): Coarsening-upward cycles in the alluvium of Hornelen Basin (Devonian), Norway: Sedimentary response to tectonic events.- Bull. Geol. Soc. Amer., 88, 1124-1134.

STEIDTMANN, R.J. & SCHITT, J.G. (1988): Provenance and Dispersal of Tectogenic Sediments in Thin-Skinned, Thrusted Terrains.- In: KLEINSPEHN, K.L. & PAOLA, C. (ed.): New Perspectives in Basin Analysis. Springer-Verlag, 353-366.

WILLIAMS, P.F. & RUST, B.R. (1969): The sedimentology of a braided river.- J. Sediment. Petrol., 39/2, 649-679.

Manuscript received May 03, 1993.
Revised manuscript accepted July 02, 1993.