Mineralia Slovaca, 42 (2010), 179 – 188
ISSN 0369-2086

Sedimentary analysis of the Cretaceous flysch sequences at the Zemianska Dedina locality (Nižná Unit, Pieniny Klippen Belt, northern Slovakia)

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Abstract

The studied Cretaceous flysch succession of the Pieniny Klippen Belt in the Orava territory is similar to the Kysuca Unit where the lower, sandstone flysch (Snežnica Beds) and the upper, conglomerate flysch (Sromowce Formation) were distinguished (Andrusov and Samuel, 1985). Although the studied flysch successions at the Zemianska Dedina locality show sequences similar to the other localities in the Orava territory, there are some differences, mainly in the bed thickness, sandstones/claystones ratio, as well as in the presence of thick slump and slide matrix-supported conglomerate bodies.

The sedimentological and stratigraphical evaluations of the section revealed mostly thin- to medium-rhythmic turbiditic development. The cyclicity of the thickening-upward sequences, relatively high lateral stability of the beds, their smaller thickness, presence of the Bouma´s intervals and the assemblage of ichnofossils point to a deposition at the slope toe, within the central to outer part of deep-sea fans, rarely dissected by migrating feeding channels filled with upward-fining graded conglomerates and sandstones. The thick matrix-supported conglomerate bodies represent a result of slump and slides on steep submarine slopes transformed to debris-flows and mud-flows that transported sedimentary loads as far as the distal part of the turbiditic fans.

Key words: Cretaceous, Pieniny Klippen Belt, Nižná Unit, sedimentology, flysch, exotic conglomerates

Introduction

History of the Nižná Unit started in 1967 when Scheibner (1967) distinguished it as a particular subunit of the Kysuca Unit. The Kysuca and Pieniny units originated in the deepest part of a trough which is believed to be a transition to one of the branches of the Jurassic Piemont--Ligurian-Penninic oceanic domain, situated between the Central Western Carpathians and a crustal block called Oravicum (Maheľ, 1983) (synonym = Pieninicum, see e.g. Andrusov, 1968, Fig. 5). Klippes of the Kysuca Unit, together with the shallow-water Czorsztyn Unit and some transitional units, represent recently the substantial part of the narrow tectonic mélange zone which is known as the Pieniny Klippen Belt (separating internides and externides of the Western Carpathian orogene). In the northern Slovakia (Kysuce and Orava regions), the Kysuca Unit even dominates the Pieniny Klippen Belt (Haško and Polák, 1980; Gross et al., 1994). The lithostratigraphic record of the Kysuca Unit is dominated exclusively by the deep-water, pelagic to hemipelagic sediments all through its history since Middle Jurassic until Late Cretaceous. However, the Nižná Unit contains an exceptional, Urgonian-type development (Nižná Limestone) of the Barremian-Aptian which is an unusual shallow-water element (black shales of the Koňhora Formations are typical for the Kysuca Unit s.s.). The occurrences of these shallow-water limestones can be traced from Dlhá nad Oravou, as far as Tvrdošín in the Orava territory. The Nižná Unit, because of this particularity, was earlier considered as being related to the Manín or Haligovce units which are also typical by their Urgonian-type limestones, i.e. it was placed paleogeographically to the other side of the trough, close to the Central Western Carpathians (see Józsa and Aubrecht, 2008 for overview). One of the supporting theories was also a presumed Albian onset of the exotic flysch sedimentation in this unit (Scheibner, 1967) which is only typical for more internal units (Upohlav Conglomerates of the Klape Unit, Poruba Formation of the Tatric and Fatric units), whereas in the Kysuca Unit itself, exotics-free turbiditic sedimentation started in Turonian (Snežnica Formation), followed by the exotic conglomerate flysch in Coniacian and Santonian (Sromowce Formation). However, Józsa and Aubrecht (2008) on the basis of their

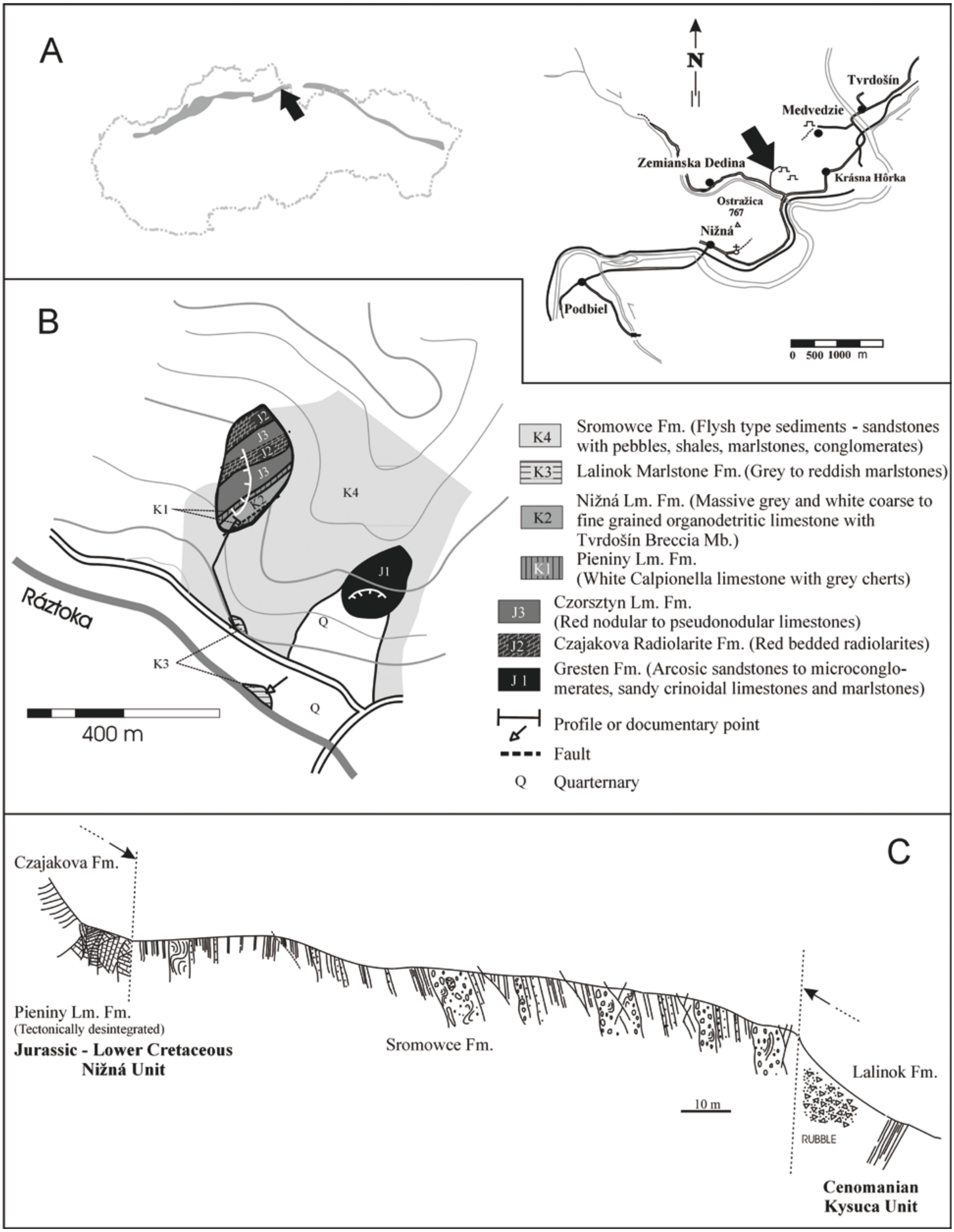

Fig. 1. A – Localization of the studied section. B – Geological map of the studied area with marked line of the section. C – Schematic section running through the studied sequences.

Obr. 1. A – Lokalizácia študovaného sedimentárneho profilu. B – Geologická mapa študovanej oblasti s vyznačenou líniou prebiehajúceho odkryvu. C – Schematický profil študovaných sekvencií.

study of 8 key sections of the Nižná Unit showed that Albian-Cenomanian is still in the pelagic development in the Nižná Unit and the exotic flysch must have started later, just like in the Kysuca Unit. Recently, one of the previously studied sections (Zemianska Dedina of Józsa and Aubrecht, 2008 – known among the local people under the name Červená baňa – GPS coordinates: N 49°19'50.6", E 19°32'24.0") has been perfectly outcropped by a restoration of mining in a local limestone quarry (Fig. 1A). The mining itself and building of an access road to the quarry revealed considerable part of the Nižná Unit in this site which could be studied in detail. The klippe is formed by a continuous succession from the Middle Jurassic radiolarites to the Aptian organodetritic Nižná Limestone (the age was proved by foraminifers *Globigerinelloides ferreolensis* Moullade and *Globigerinelloides algerianus* Cushman & Ten Dam; Fig. 1B). Newly excavated parts of the quarry and the parts above the quarry just confirmed the occurrence of the Tvrdošín Breccia Member (Fig. 3A, B) at the base of the Nižná limestone Formation (Józsa and Aubrecht, 2008). Along the access road, exotics-bearing flysch (Sromowce Formation) is perfectly outcropped (Fig. 1C). Unfortunately, the contact between the Nižná Limestone and the flysch is tectonized here and the Albian-Cenomanian pelagites were not preserved. These pelagites are exposed on the opposite, southern part of the section, below the Sromowce Fm. (this contact is undoubtedly tectonic). The pelagites are represented by the black clays with rich microfauna. Besides abundant ostracods and echinoderm plates (mainly ophiuroids), scarce Cenomanian planktonic foraminifers were identified: *Rotalipora* sp. *Praeglobotruncana delrioensis* Plummer and *Hedbergella delrioensis* (Carsey). A small outcrop of the reddish, green and grey marls of the Lalinok Fm. can be found below, in the creek channel. It consists of the Late Cenomanian poorly preserved planktonic foraminiferal assemblage: *Rotalipora cushmani* (Morrow), *Rotalipora* sp., and *Praeglobotruncana gibba* Klaus.

This paper is dedicated to a detailed sedimentological and stratigraphical analysis of the turbiditic sequence of the Sromowce Formation. It was an unique occasion to study such sequence as most of the flysch outcrops use to weather very rapidly.

Methods

The research involved evaluation of the section, lithological and sedimentological study of the sequences, local bed-by-bed sampling, investigation and description of the fossil contents. The material for micropaleontological study was treated by the standard laboratory methods, including thin sections and the study of washed material from slightly lithified marls. Eight samples were randomly taken from various parts of the section and evaluated by planimetric analysis. We used shape classification of particles *sensu* Powers (1953) and the grain-size scale *sensu* Folk (1980). Paleocurrent analysis included measurement of erosive current marks and the directions were restored by the simple rotation along horizontal axis.

Results

Sedimentary succession of the Sromowce Formation exposed in the studied section represents thin- to medium--rhythmic flysch, similarly as at other localities in the Orava territory (Marschalko, 1986). The succession is formed by the sandy, silty to clayey turbidites (Fig. 2A, C). A typical feature is the presence of the coarse-clastic matrix--supported conglomerates (Fig. 2D; Marschalko, 1986).

Lithology and bed thickness

The studied section, which is 164 m long, is disturbed by several faults (Fig. 2A). The dominant lithological components are sandstones and siltstones which form 48 % of the section. Petrography of all sandstone samples showed that they represent lithic greywackes. Despite of the smaller number of samples it was possible to see some petrographic and morphometric differences between the fine-grained, coarse-grained and very coarse-grained sandstones (the analysed coarse fraction usually formed bases of the graded-bedded sandstone layers). The fine--grained sandstones have higher portion of matrix and the higher percentage of quartz and stable rock fragments (48 % in average) in comparison with the coarse-grained sandstones (16 % in average). The difference is also in the proportion of carbonate rock fragments. Whereas the average content of the carbonates in the fine-grained sandstones is 35 % from the all clastic compounds, their average contents increase to 75 % in the coarse-grained sandstones. Other differences are in sorting and roundness of the clasts. The fine-grained sandstones are formed by the angular, relatively well-sorted grains; very coarse-grained sandstones are poorly sorted, with prevailing suboval to oval clasts.

The claystones are mostly thin, rarely exceeding 10 cm. They are calcareous and often silty. Their colour is greyish--brown, with light patina at the surface. Their ratio in the studied succession is 29.2 %. The conglomerates and mudflows form 22.8 % of the overall lithology of the studied section (Fig. 2E). The pebble analysis showed that the conglomerates involve pebbles of the rocks like granitoids, volcanics, rhyolites, basalts, shallow-water Upper Jurassic limestones which have no affinity to the known rocks of the Pieniny Klippen Belt and the adjacent units of the Central Western Carpathians and can be named as exotic, sensu Mišík and Marschalko (1988) or Mišík and Sýkora (1981).

Thickness of the individual beds varies from 1 cm to about 1 m. The average thickness of the sandstone and siltstone beds is 9.2 cm. The average thickness of all beds (including matrix-supported conglomerate layers) is 13.2 cm (Fig. 2E). Thicker beds show relatively high lateral stability. Percentage distribution of the bed thickness measurements show that the most numerous (67.9 %) are thin beds (0 – 5 cm in thickness). From this group, the beds 0 – 2 cm thick represent 40.5 % and the beds 2 – 5 cm represent 27.4 %. The percentage of thicker beds is considerably lower (5 – 10 cm – 11.7 %, 10 – 25 cm – 11.2 %, 25 – 50 cm – 6.2 %, 50 – 100 cm – 1.9 %; Fig. 2E).

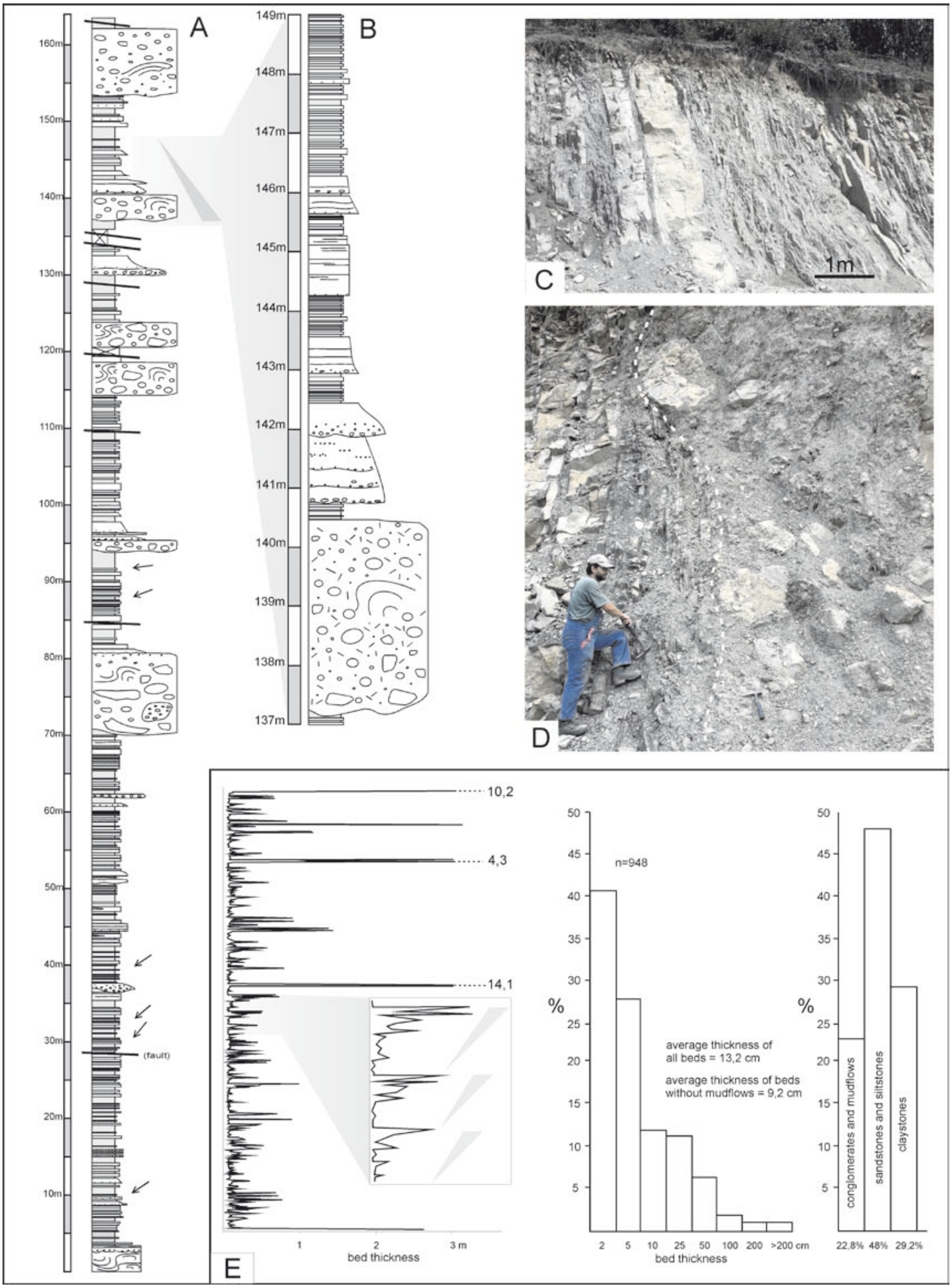

Fig. 2. A – Sedimentary log of the Cretaceous flysch succession at the Zemianska Dedina locality. B – Upward-thinning trends in the bed thickness and upward-fining granulometric trends were recorded in association with conglomerates and coarse-grained sandstones. The flysch succession is formed by the rhythmic sandy, silty to clayey turbidites. D – Boulder matrix-supported conglomerates. E – Charts showing (from left to right) bed thickness distribution; percentage of bed thickness; percentage of sedimentary rocks at the studied section.

Obr. 2. A – Sedimentárny profil kriedových flyšových sekvencií na lokalite Zemianska dedina. B – Trend stenčovania hrúbky vrstiev smerom nahor a postupné zjemňovanie zrnitosti zaznamenané v asociácii so zlepencami a hrubozrnnými pieskovcami. C – Flyšové sekvencie tvorené rytmickými turbiditmi pieskovcov, prachovcov a ílovcov. D – Balvanovité zlepence s podpornou stavbou základnej hmoty. E – Grafy zobrazujúce (zľava doprava) distribúciu hrúbky vrstiev; percentuálne zastúpenie hrúbky vrstiev; percentuálne litologické zastúpenie sedimentárnych hornín na študovanom profile.

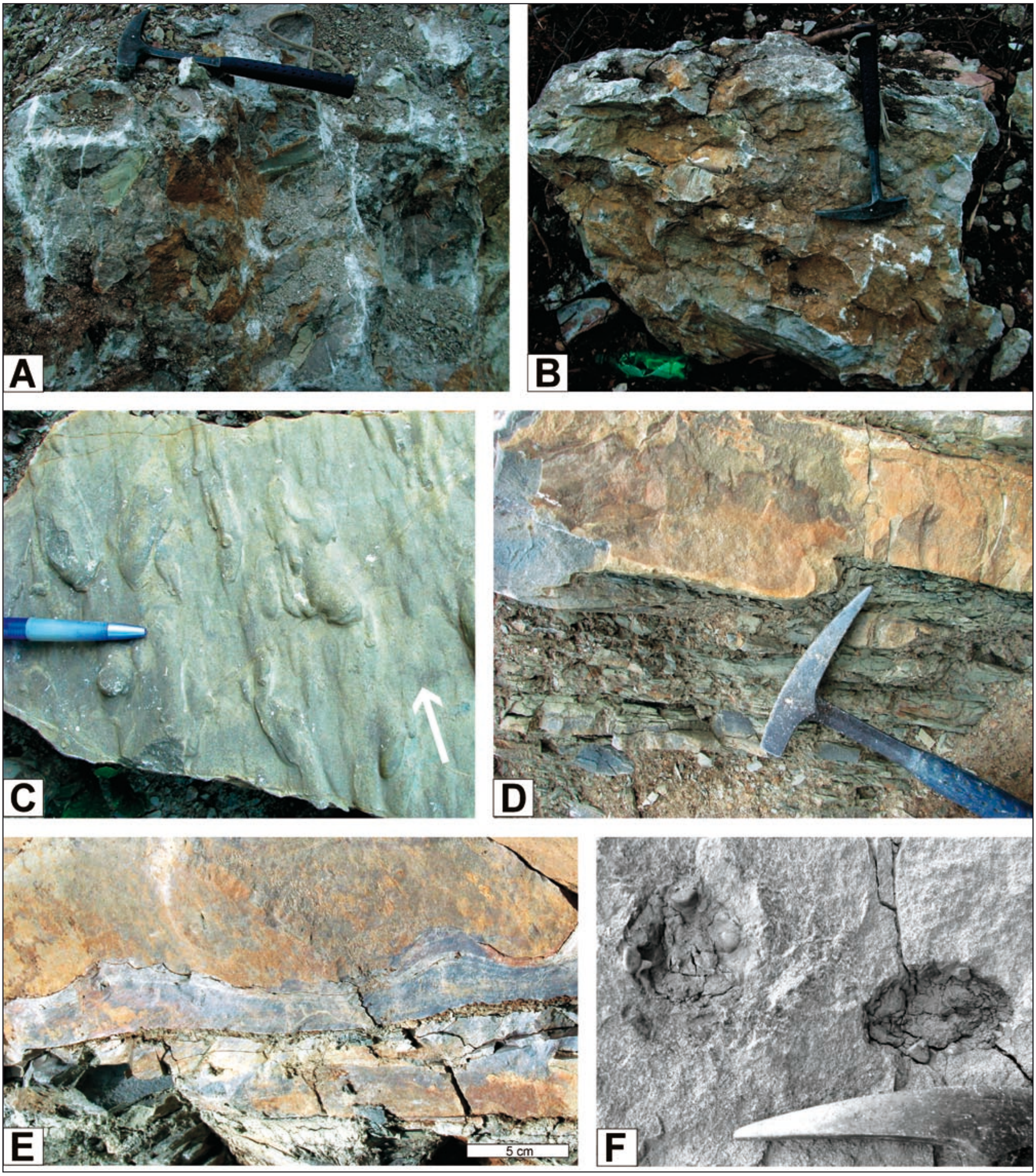

Fig. 3. A, B – Tvrdošín Breccia exposed at the base of the Nižná Limestone Formation. C – Lower bedding plane of a turbidite sandstone with well-developed, small-size erosional flute-casts. The transport direction is marked by the arrow. D – Erosional base of the turbidite sandstone. E – Pressure-modified uneven relief at the boundary between massive sandstone and the underlying thin-rhythmic sequence. F – Armoured mud-balls formed by the rounded claystone clasts, covered with tiny pebbles. They occur in various levels of thick sandstone beds and point to the erosive activity of the flows, as well as to "freezing" of the flow in various stages.

Obr. 3. A, B – Tvrdošínska brekcia odkrytá na báze nižnianskych vápencov. C – Spodná plocha turbiditného pieskovca s dobre vyvinutými erozívnymi prúdovými stopami menšej mierky (flutecasts). Smer transportu je vyznačený šípkou. D – Erozívna báza turbiditného pieskovca. E – Tlakom modifikovaný, zvlnený reliéf na rozhraní masívneho pieskovca a podložnej tenkorytmickej sekvencie. F – Obrnené závalky tvorené zaoblenými ílovcovými útržkami obalenými drobnými obliakmi vystupujú v rôznych úrovniach hrubých pieskovcových vrstiev a poukazujú na erozívnu činnosť tokov, ako aj „zamrznutie“ toku v rôznych štádiách.

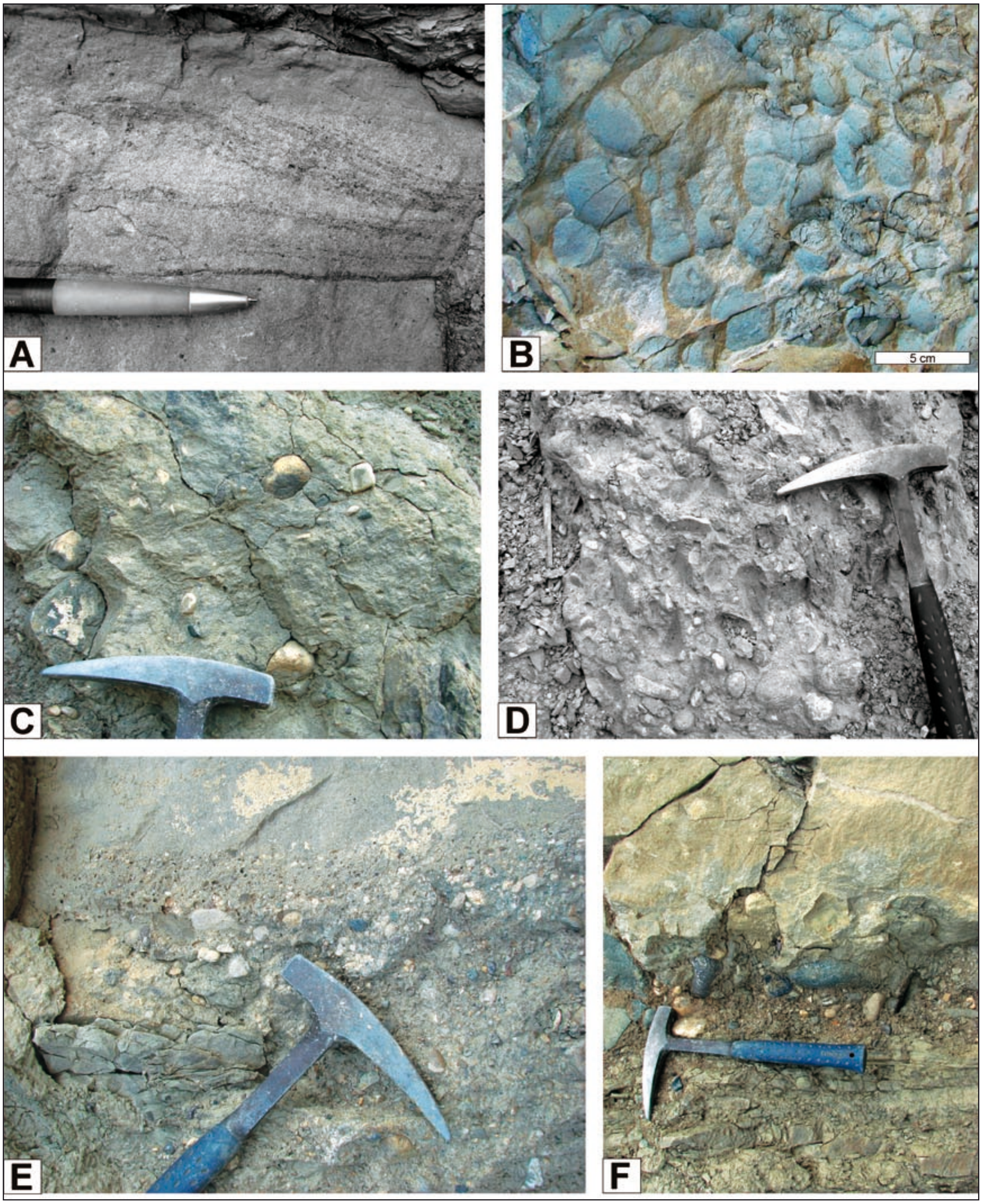

Fig. 4. A – Upper part of the sandstone with parallel lamination and cross-bedding emphasized by coalified plant detritus. B – Lower bedding plane of the sandstone with regular circular to polygonal pressure marks of relatively equal diameter. These marks originated by the uniform pressure onto thin, unlithified clay layer between thick sandstone layers. In some polygonal forms, remnants of claystones are visible. C – Mudflow formed mainly by well-rounded pebbles to boulders supported by clayey-sandy matrix. D – Blocks of lithified conglomerates forming parts of mud-flows. E – Development of the uppermost part of a mud-flow with transition to normally-graded conglomerate to massive sandstone. F – Coarse-grained conglomerate forming base of a massive sandstone. It is underlain by thin--rhythmic sequence developped directly above a slump body.

Obr. 4. A – Vrchná časť pieskovca s paralelnou lamináciou a šikmým zvrstvením zvýrazneným preuhoľnateným organodetritickým materiálom. B – Spodná plocha pieskovca s vývojom pravidelných kruhovitých až polygonálnych tlakových stôp približne rovnakého priemeru. Tieto stopy vznikali rovnomerným roztláčaním tenkej nelitifikovanej polohy ílovca medzi hrubými vrstvami pieskovcov. V niektorých polygonálnych útvaroch je možné ešte pozorovať zvyšky ílovcov. C – Bahnotok tvorený zväčša dobre opracovanými obliakmi až balvanmi s podpornou stavbou ílovito-piesčitej základnej hmoty. D – Bloky spevnených zlepencov tvoriace súčasť bahnotokov. E – Vývoj najvyššej časti bahnotoku s prechodom do normálne gradovaného zlepenca až masívneho pieskovca. F – Hrubozrnný zlepenec tvoriaci bázu masívneho pieskovca. V podloží vystupuje tenkorytmická sekvencia vyvinutá v tesnom nadloží zosuvného telesa.

The beds thicker than 1 m are represented by less than 1 % and are mostly formed by slides and slump, matrix--supported conglomerate bodies. Thicker sandstone bodies also occur, but these are mostly amalgamated from several beds. It is well documented by the grain-size grading in several levels of these massive sandstones.

Granulometry, internal arrangement of beds and structures

Most of the sandstones are fine- to very fine-grained. Medium- to coarse-grained fraction is mostly present only at the base of layers where it forms thin grade--bedded intervals. Granulometric studies show that the grain size is generally independent from the bed thickness. Only in thin beds (less than 3 cm), some dependence is visible (the grain size increases with the bed thickness), where the granulometry shifts from fine-grained siltstone through coarse-grained siltstone up to very fine-grained sandstone. The thicker beds do not show such dependence and the fine-grained fraction forms entire beds which are tens of cm thick. The lower sides of the beds are mostly plain, with common small-size erosional current marks (Fig. 3C, D). Sandstone structures are relatively faint. In thicker sandstone beds (>10 cm), massive bedding is the most common (S3 interval *sensu* Lowe, 1982). These beds (or their parts) are formed by the interval with uniform size fraction, locally fining upwards, with relatively sharp transition to siltstone and claystone intervals. At the base of homogeneous sandy interval, thin gradation interval is developed locally (Ta – *sensu* Bouma, 1962). It is usually formed by the poorly sorted fine-grained conglomerate to coarse-grained sandstone fraction, or by some dispersed coarser clasts. The lower bedding planes of such beds are slightly modified by the pressure and are uneven (Fig. 3E). Parallel lamination and cross--beddings are represented subordinately in thicker beds but are poorly developed. They form only thin intervals at the top of the beds, near the transitions to siltstones. Thicker beds are characterized mostly by the presence of claystone intraclasts, locally even armoured mud--balls (Fig. 3F) and coalified plant detritus. This type of sediment corresponds to the B1.1 facies (coarse- to medium-grained, poorly ordered sandstones) which was deposited from the dense turbidity currents (Pickering et al., 1986), or C facies sensu Mutti & Ricci Lucchi (1975).

The typical Bouma intervals (Ta-e) (*sensu* Bouma, 1962), typical for medium-grained turbidites, or T1-8 (*sensu* Stow and Shanmugam, 1980) as well as E1-3 intervals (*sensu* Piper, 1978), typical for fine-grained turbidites, form mostly thin beds (<10 cm thick). The thinnest fine-grained to very fine-grained sandstone beds usually do not exceed 2 – 3 cm. They are mostly formed by the upper Bouma intervals and are often corrugated to lensy. The individual intervals are well discernible where they are emphasized by the organogenic admixture (Fig. 4A).

A typical feature of the thin-rhythmic sequences of the silty to sandy fraction is a relatively variable assemblage of ichnofossils, mainly with the traces after bioturbation (Fig. 5). They form a relief on the lower bedding planes. Some softground traces were identified, such as *Thalasinoides* isp., *Ophiomorpha* isp., *Scolicia* isp., *Paleodictyon* isp., *Lorenzinia* isp., *Cosmorhaphe* isp., *Urohelminthoida* isp., *Nereites* isp. and *Megagrapton* isp.. The studied ichno--fossils occur in relatively well-oxygenated environments and belong to several ecological categories: domichnia, repichnia, pascichnia and agrichnia, or chemichnia. The mentioned ichnofossil assemblage can be ranked to Zoophycos and Nereites ichnofacies which characterize deep-water environments and are often associated with the turbidite successions.

Thin claystone intervals between the massive sandstone beds are often squeezed to irregular, circular to polygonal patterns of relatively equal size (Fig. 4B). This process is a result of lithostatic pressure.

The matrix-supported conglomerate bodies occur mainly in the upper part of the studied section (Fig. 2A). The matrix is characterized by the clayey-siltstone to clayey-sandstone composition, with rounded clasts of the conglomerate rocks (Fig. 4D), armoured mud balls, or pebbles of various rocks (e.g. granitoids, volcanics, basalts and carbonates; Fig. 4C). This coarse material was transported by the high-energy debris flows (or mud flows) which is documented by the presence of large boulders (several tens of centimetres in diameter, Fig. 2D), irregularly dispersed in the matrix. Lower bedding plains of the slump bodies are mostly erosional (Fig. 2B, D), but the erosion rarely reaches cuts deeply into the underlying beds; deeper erosional channels are missing. The upper limits of the matrix-supported conglomerates are mostly plain. They represent graded to massive conglomerates and sandstones (Fig. 4E, F), often composed of several amalgamated beds. Normal and reversed gradation, multiple repetitions of the gradation, horizontal bedding and rounded claystone intraclasts are their typical features. These features point to deposition from the concentrated debris-flows (traction carpets) as well as rapid settling of the suspension.

Paleocurrent analysis was focused mainly on the measurements of the oriented lineations – erosive current marks on lower bedding planes. These are relatively common mainly in the thin- to medium-rhythmic sequences all along the studied section, as visible mostly from the debris. However, the bedding orientation in the section enabled to study the lower bedding planes only in some places. Results of the measurements show that the sedimentary transport was from E/NE to W/SW. These paleocurrent directions are plotted to the schematic section in the Fig. 2A, where the individual arrows mean prevalent values in the certain intervals of the section. However, the small statistical assemblage, uneven distribution of the measurements restricted to short section intervals, as well as no possibility to calculate block rotation correction (which is unavoidable in the strongly tectonized mélange of the Pieniny Klippen Belt) disabled the use of these results for paleogeographic interpretations.

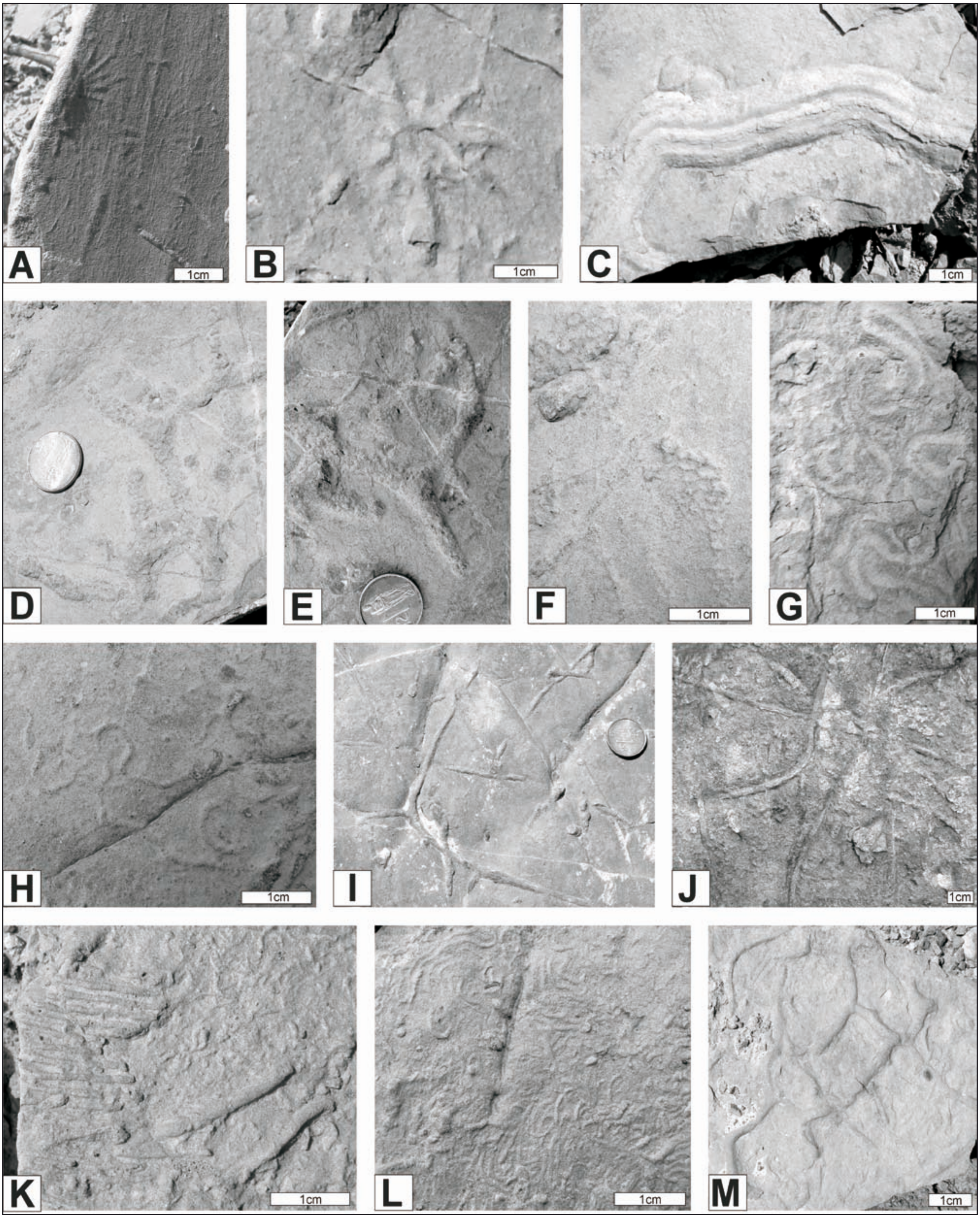

Fig. 5. Ichnofossil assemblage documented at the studied section. For description see Slovak explanation.

Obr. 5. Spoločenstvo ichnofosílií dokumentovaných na študovanom sedimentárnom profile. A, B – *Lorenzinia* isp., C – *Scolicia* isp., D, E – *Ophiomorpha* isp., F – *Paleodictyon* isp., G – *Nereites irregularis*, H – *Helminthopsis* isp., I – *Thalasinoides* isp., J – *Planolites* isp., K – *Urohelminthoida* isp., L – *Helminthoraphe* isp., M – *Megagrapton irregulare*.

Sequence trends

Within the studied flysch sequences the both, upward-thickening and upward-thinning trends of bedding were identified. More distinct thickening-upward trends repeated in approximately 3 to 8 m thick cycles, consisting of approximately 40 to 100 layers. These are mostly characteristic for thin- to medium-rhythmic fine-grained sequences. The cyclicity of the upward-thickening sequences cannot be correlated with the grain-size changes of the sediment. On the other hand, the upward-fining granulometric trends and upward-thinning trends in the bed thickness were recorded mostly in conglomerates and the coarse-grained sandstones, which gradually pass higher to the thin- and fine-grained forms (Fig. 2B).

Discussion

According to Marschalko (1986), the Cretaceous flysch succession of the Pieniny Klippen Belt in the Orava territory belongs to the Orava section of the Pieniny Unit. Its facies evolution is similar to the Kysuca Unit; forming its more inner, SE part of the sedimentary area. The Cretaceous flysch of the Kysuca Succession is divided to the lower, sandstone flysch (Snežnica Beds) and the upper, conglomerate flysch (Sromowce Formation). The described sedimentary succession at the Zemianska Dedina is dominated by the sandstones which should be an equivalent of the sandstone dominated flysch (10 : 1 to 5 : 1) documented by Marschalko (1986), but the presence of the exotic conglomerate beds shows that these represent Sromowce Formation. Similar development is mentioned by Marschalko (1986) from the central Orava territory (e.g. localities Sedliacka Dubová, Horná Lehota, Pribiš). However, there are some differences between the Zemianska Dedina locality and the above mentioned localities, mainly in the bed thickness, sandstones/claystones ratio, as well as in the presence of thick slump and slide matrix-supported conglomerate bodies.

The studied flysch successions at the Zemianska Dedina locality are mostly thin- to medium-rhythmic, with the presence of regularly arranged thicker (up to 1 m) sandstone lithosomes (only 1.9 % of all beds). The average sandstone thickness is 9.2 cm, with the most numerous thinner beds up to 5 cm (67.9 % of all beds); the sandstone/claystone ratio is about 2 : 1. The beds are characteristic by the diverse structures either of biogenic (ichnofossil) or mechanical origin on their lower plains. This is more characteristic for the Snežnica Beds (Scheibner and Scheibnerová, 1958) but the rare presence of small-scale erosional channels with conglomerates is atypical for them. Similarly atypical is volumetrically important presence (up to 22.8 % of the entire volume of the studied succession) of thick slump and slide bodies (mud-flows). The presence of several m thick matrix-supported conglomerate beds attributes the succession to the higher, conglomerate flysch (Sromowce Formation). This formation is, however, different at the typical localities of Krivá and Široká, where the massive, boulder conglomerates filled deep erosional channels and valleys (after Marschalko, 1986). These localities are also characteristic by slump, conglomerate and sandstone bodies forming tens of metres thick sequences whereas the thin-rhythmical sequences are represented subordinately.

The cyclicity of the thickening-upward sequences, relatively high lateral stability of the beds, their smaller thickness and the presence of the Bouma´s intervals may point to a turbiditic deposition at the slope toe, within the central to outer part of deep-sea fans, rarely dissected by migrating feeding channels filled with upward-fining graded conglomerates and sandstones. The thick matrix-supported conglomerate bodies formed by disorganized mixture of boulders, pebbles, mud-balls and mud probably represent a result of the slump and slides. These originated on the steep submarine slopes and were transformed to debris-flows and mud-flows. Bases of such layers of coarse-clastic sediments are mostly erosional, but do not show any signs of deposition in the deep channels or canyons which indicates that the large-energy debris-flows with the high transportation abilities could preferentially transport sedimentary loads (mostly also by channels) through the toe of the slope as far as the distal part of the turbiditic fans.

Conclusions

1. A new outcrop of the Sromowce Formation (Upper Cretaceous flysch with exotic conglomerates, Pieniny Klippen Belt) was studied near Zemianska Dedina in the Orava region (northern Slovakia). The formation is dominated by the sandstones (mostly lithic greywackes) and siltstones (48 %), with lesser proportion of claystones (29.2 %), conglomerates and mudflows (22.8 %).

2. Within the studied flysch sequences both, upward-thickening and upward-thinning trends of bedding were identified. The upward-fining granulometric trends correspond well with the upward-thinning trends in the bed thickness, but the cyclicity of the upward-thickening sequences cannot be correlated with the grain-size changes of the sediment.

3. The cyclicity of the sequences, relatively high lateral stability of the beds, their smaller thickness, diverse structures either of biogenic (ichnofossil) or mechanical origin on their lower plains and the presence of the intervals characteristic by the fine- to medium grained turbidites point to a deposition at the slope toe, within the central to outer part of the deep-sea fans, rarely dissected by migrating feeding channels filled with conglomerates and coarse grained sandstones.

4. The thick matrix-supported conglomerate bodies represent a result of slump and slides. These originated on the steep submarine slopes and were transformed to debris-flows and mud-flows that reached more distal parts of the turbiditic fans.

Acknowledgements. The paper is a contribution of the projects APVV-51-011305, VEGA 0140, APVV 0465-06 and APVV 0571-06. The authors are thankful to Dr. V. Šimo (SAS) for his assistance at determination of the ichnofossils and also Dr. M. Potfaj (ŠGÚDŠ) for his constructive comments.

References

ANDRUSOV, D., 1968: Grundriss der Tektonik der Nördlichen Karpaten. *Bratislava, Vyd. Slov. Akad. Vied, 1 – 188.*

ANDRUSOV, D. & SAMUEL, O. (eds.), 1985: Stratigraphic dictionary of the Western Carpathians 2, L – Z. *Bratislava, GÚDŠ, 1 – 359 (In Slovak).*

BOUMA, A. M., 1962: Sedimentology of some flysch deposits. *Amsterdam, Elsevier, 1 – 168.*

FOLK, R. L., 1980: Petrology of sedimentary rocks. *Austin, Hemphill Publ. Co., 1 – 182.*

GROSS, P. (ed.), 1994: Geological map of southern and eastern part of Orava, 1 : 50 000. *Bratislava, GÚDŠ.*

HAŠKO, J. & POLÁK, M. (eds.), 1980: Geological map of the Kysucké vrchy Mts. and Kriváńska Malá Fatra Mts., 1 : 50 000. *Bratislava, GÚDŠ.*

JÓZSA, Š. & AUBRECHT, R., 2008: Barremian-Aptian erosion of the Kysuca – Pieniny trough margin: New view on the Nižná Unit of the Pieniny Klippen Belt (Western Carpathians). *Geol. Carpath. (Bratislava), 59, 2, 103 – 116.*

LOWE, D. R., 1982: Sediment gravity flows: II. Depositional models with special reference to the deposits of high-density turbidity currents. *J. sed. Petrology (Tulsa), 52, 279 – 297.*

MAHEĽ, M., 1983: Proposal for tectonic nomenclature of the principal tectonic elements of the Western Carpathians. *Mineralia Slov., (Bratislava), 6, 559 – 565 (In Slovak with English summary).*

MARSCHALKO, R., 1986: Evolution and geotectonic consequence of the Cretaceous flysch of the Pieniny Klippen Belt. *Bratislava, Veda, 1 – 137 (In Slovak with Russian and English summaries).*

MIŠÍK, M. & MARSCHALKO, R., 1988: Exotic conglomerates in flysch sequences: Examples from the West Carpathians. *In: Rakús, M., Dercourt, J. & Nairn, A. E. M. (eds.): Evolution of the Northern Margin of Tethys, I. Mém. Soc. géol. France, Nouvelle Sér. (Paris), 154, 95 – 113.*

MIŠÍK, M. & SÝKORA, M., 1981: Pieniny exotic ridge reconstructed from pebbles of carbonate rocks of Cretaceous conglomerates of the Pieniny Klippen Belt and Manín Unit. *Západ. Karpaty, Sér. geol. (Bratislava), 7, 7 – 111 (In German).*

MUTTI, E. & RICCHI LUCCHI, F., 1975: Turbidite facies and facies associations, *In: Nelson, C. H. & Nilsen, T. H. (eds.): Modern and ancient deep-sea fan sedimentation. SEPM short course no. 14, 1984.*

PICKERING, K., STOW, D., WATSON, M. & HISCOTT, R., 1986: Deep--water facies, processes and models: A review and classification scheme for modern and ancient sediments. *Earth-Sci. Rev. (Amsterdam), 23, 75 – 174.*

PIPER, D. J. W., 1978: Turbidite muds and silts on deep-sea fans and abyssal plains. *In: Stanley, D. J. & Kelling, G. (eds.): Sedimentation in submarine canyons, fans and trenches. Stroudsburg, Dowden, Hutchinson and Ross, 163 – 176.*

POWERS, M. C., 1953: A new roundness scale for sedimentary particles. *J. sed. Petrology (Tulsa), 23, 117 – 119.*

SCHEIBNER, E., 1967: Nižná subunit- new stratigraphical sequence of the Klippen Belt (West Carpathians). *Geol. Sbor. (Bratislava), 18, 1, 133 – 140.*

SCHEIBNER, E. & SCHEIBNEROVÁ, V., 1958: Kysuca and Snežnica Beds: New Cretaceous members of the Pieniny series in the Kysuca development. *Geol. Sbor. (Bratislava), 9, 2, 178 – 181 (In Slovak).*

STOW, D. A. V. & SHANMUGAM, G., 1980: Sequence of structures in fine-grained turbidites: Comparison of recent deep-sea and ancient flysch. *Sedimentary Geol. (Amsterdam), 25, 23 – 42.*

Rukopis doručený 5. 10. 2009
Revidovaná verzia doručená 10. 11. 2009
Rukopis akceptovaný red. radou 7. 9. 2010

Sedimentárna analýza kriedového flyšu na lokalite Zemianska Dedina (nižnianska jednotka, bradlové pásmo, severné Slovensko)

Obnovenie ťažby v kameňolome pri Zemianskej Dedine na Orave odkrylo bradlo nižnianskej jednotky v stratigrafickom rozsahu od strednej jury po vrchnú kriedu. Zvlášť pozoruhodná je flyšová sekvencia vrchnej kriedy. Jej opisu sa venuje tento článok. Skúmaná kriedová flyšová sukcesia bradlového pásma na Orave sa podobá vývoju v kysuckej jednotke, kde bol vyčlenený spodný, pieskovcový flyš (snežnické vrstvy) a vrchný, zlepencový flyš (sromowské vrstvy) (Andrusov a Samuel, 1985). Hoci sú flyšové sukcesie na študovanej lokalite podobné iným lokalitám na Orave, existujú niektoré odlišnosti, ako napr. hrúbka vrstiev, pomer pieskovcov a ílovcov či prítomnosť sklzových a zosuvných telies parakonglomerátov.

Sedimentologické štúdie na tejto lokalite preukázali prítomnosť prevažne drobnozrnných, tenko- až stredno-rytmických flyšových sekvencií tvorených v dominantnej miere pieskovcami (litické droby) a prachovcami. Cyklické, smerom nahor hrubnúce sekvencie, pomerne dobrá laterálna stálosť vrstiev, ich menšia hrúbka, prítomnosť Boumových intervalov, sedimentárne textúry a spoločenstvo ichnofosílií poukazujú na sedimentáciu na úpätí svahu v prostredí strednej až vonkajšej časti turbiditového depozičného vejára. Toto prostredie brázdia migrujúce distribučné kanály s gradačne zvrstvenými zlepencami a pieskovcami, ktoré sa smerom nahor stenčujú a zrnitostne zjemňujú. Hrubé polohy parakonglomerátov sú výsledkom sklzov a zosuvov na strmých podmorských svahoch. Tie sa transformovali do úlomkotokov a bahnotokov, ktoré boli ojedinele schopné transportovať hruboklastický materiál až do distálnejších častí turbiditného vejára.