The channel – levee sedimentary facies and their synsedimentary deformation: a case study from Huty Fm. of the Podtatranská skupina Group (Western Carpathians)

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Abstract. The paper is aimed at detailed sedimentological study of the channel – levee sedimentary facies of submarine deep-sea fan, which are documented on the Huty profile. The rhythmic, thin-bedded sandstones and claystones predominantly characterize the sedimentary record. The massive, pinching-out sandstones of the channel margin have been found in the upper part of profile. Typical evolution of the channel – levee sedimentary facies, with numerous and quickly pinching-out sandstone beds of the variable thickness, is documented. Lenticular bedding and well-developed starving ripples are very frequent. The internal fabric of beds is predominantly formed by cross-bedding and horizontal lamination. Convolute lamination is relatively common, too. Synsedimentary deformations are another evidence of the channel - levee sedimentary facies that originated during gravitational sliding of the semiconsolidated sediments from the levee slope. These synsedimentary deformations are proved by the asymmetric slump folds, clastic dykes, and by evolution of the boudinage in the sandstone beds. The direction of sedimentary sliding on the levee elevations has been reconstructed by means of original orientation of synsedimentary deformational structures. The direction of sliding is perpendicular to both local and general paleotransport direction in the western part of Central Carpathian Paleogene Basin.

Key words: Western Carpathians, Podtatranská skupina Group, Paleogene, channel – levee sedimentary facies, synsedimentary deformation

Introduction

The studied locality is situated on the northern border of the Chočské vrchy Mts. in the bedrock of the Kvačianka stream near Huty village. The outcrop is localized approximately 350 m NE of local church and 2,500 m WNW of Biela Skala elevation point (1,613 m above the sea level) (Fig. 1). The sedimentary profile is characterized by the rhythmic alternation of sandstones and claystones with ratio 1:3. In the sedimentary record, synsedimentary slump folds, clastic dykes, and boudinage of the sandstone beds were also identified. These sedimentary deformations (mainly clastic dykes) are rather seldom and from the Huty Formation have not been described. Similar clastic dikes were described by Marschalko (1965) from Šarišská vrchovina Mts.

Geological setting

From the geological point of view, the area of studied locality belongs to the Podtatranská skupina Group, which is formed by the Paleogene sediments (Gross et al., 1993). The sediments of the Podtatranská skupina Group are situated in the northern part of the Central Western Carpathians and formed the Orava, Liptov, Poprad, Podhale Basins, Levočské vrchy Mts. and Spišská Magura Mts. To the south it is bounded by the Paleozoic and Mesozoic Paleoalpine nappe systems and in the north it is separated from the Outer Western Carpathians (Flysch zone) by the Pieniny Klippen Belt (Fig. 1). The basin is developed as a forearc basin on the proximal part of the accretionary wedge.

Deposits in the Podtatranská skupina Group consist of four sedimentary formations according Gross et al. (1984, 1993; Fig. 1). The lowermost Borové Formation consists of basal terrestrial and shallow-marine transgressive deposits. The Borové Formation is covered by the Huty Formation formed by deep marine sediments of mud-rich fan. The overlying Zuberec Formation consists of rhythmical flysch deposition. The uppermost part of the Podtatranská skupina Group is formed by the Biely potok Formation, which is characterised by the thick massive sandstones of sand-rich fan.

Sedimentary record occurring on the profile corresponds to the Huty Formation of the Podtatranská skupina Group. The Huty Formation ranges from the Lower to Middle Priabonian (Gross et al., 1993), locally even to the Rupelian (Soták, 1998a, b; Olszewska a Wieczorek, 1998; Starek, 2001).

Sedimentological and facies analysis

The sediments are predominantly characterized by lithofacial sets that create geometrically limited bodies of the deep marine fan (Soták et al., 2001; Starek, 2001).

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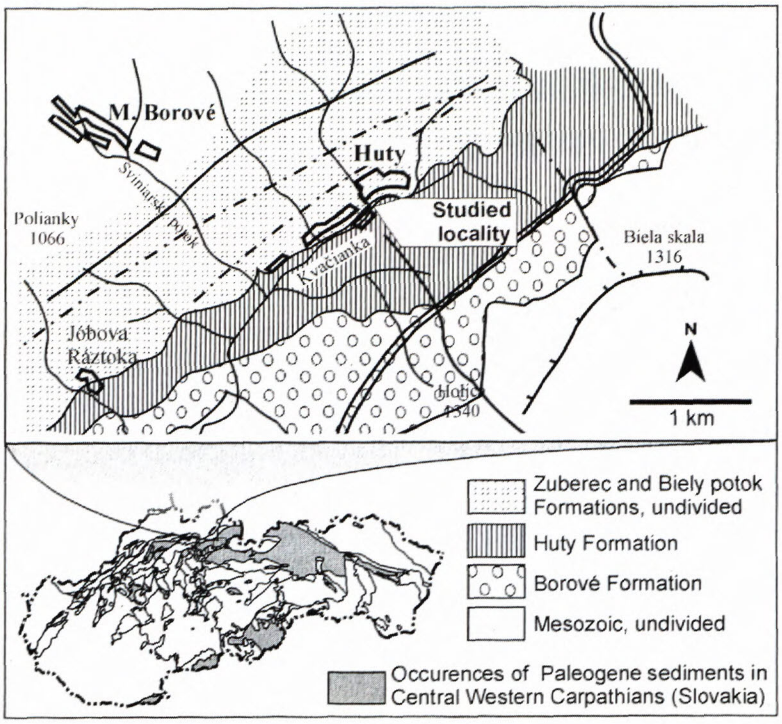

Fig. 1. Location and geological relations in neighbourhood of the Huty sedimentological profile. The profile is situated near the border between the Huty and Zuberec Formations.

The Huty profile documents facies characterizing specific part of the complex geometry of the deep marine fan (Fig. 2).

In the lower part of the profile (Fig. 2c, e) are recorded rhythmic sandstones, alternating with thin siltstones and claystones. Thick beds in this part of the profile are rare. The maximum thickness of sandstone beds is 15-20 cm. The sandstones are fine-grained, and structureless. The most common thickness of sandstones is 1-10 cm. They are fine-grained to silty and their inner structure commonly displays well-developed Tc cross-bedding, accompanied with Td, siltstone interval (Fig. 2e) (sensu Ta-e intervals of Bouma, 1962).

Convolute lamination is relatively common. In most cases, it originates by hydroplastic deformation of cross-bedding. Another common case is sandstones pinching out, as well as variable bed thickness. The beds are even locally formed by lenses and contain well-developed starving ripples (Fig. 3b). On the lower bedding planes, rare faint grooves have been observed (Fig. 2c). These NE-SW oriented structures originated by grooving of coarser material, floating in diluted flows.

This type of sediment represents facies of channel margin, levees (aggradation bars) and related inter-channel areas (Fig. 2a, b). The mentioned sediments were generated by diluted turbiditic suspensions that have overflown the channel levees. Because the levee bars are usually overflown by upper parts of turbiditic currents with lower density of material in suspension, the area of aggradation bars and mainly the overbank areas are characterized by domination of pelites. This environment is generally starving in respect to the sandy material. It is evidenced by smaller thickness and common pinching out beds, as well as presence of lensoid bedding and starving ripples.

Typical feature of levees is common occurrence of slump bodies, being formed on the edges of levee elevations towards both channel and interchannel areas. These bodies have commonly shape of slump folds, thickenings, and plastically deformed horizons, bounded by undeformed beds from the top (Nelson & Nilsen, 1984, Walker, 1985, Mutti, 1977). A slump body can be also observed at the discussed section (Fig. 2c, Fig. 3c). It consists of several dissected beds that are even folded (with fold axes 2/30° a 330/50°) which indicate a deformation in unconsolidated or only partly lithified sediment. The slump is interpreted as a result of sedimentation and motions of beds on the primary levee slope.

The highly energetic gravitation currents transported through the channels have diluted suspensions of fine sand and silt in their upper parts. These use to overflow the levees and are deposited in the inter-channel (overbank) area. A relatively common case is crewassing of the levee bar and penetration of bigger amount of channel-transported material to the inter-channel area. This is the origin of so called crevasse-splays deposits (Nelson & Nilsen, 1984, Mutti, 1977). The thick channel axis sandstone bed pinch-out over short distances into thinner bedded, finer grained deposits that onlap on the inner levee slope during infilling of the deeper parts of the channel. These sediments are termed as channel margin facies (Mutti, 1977) and can be documented in the higher part of the studied section (Fig. 2c, d). The deposits are represented by about 3 m thick layer of medium to fine-grained sandstones (Fig. 3a). Two trends of bed evolution can be seen in this part (Fig. 2c):

– The thickening-upward trend, in which upward-coarsening sandstones start to occur in otherwise typical levee facies, dominated by pelites and fine-grained sandstones. The trend documents a shift of coarse grained channel margin facies onto fine grained .levee facies. The sedimentary record displays irregular, actively prograding, and 30-60 cm thick bodies of sandstones. The beds are rarely amalgamated, mostly with homogenous bedding and platy disintegration. The lower bedding planes are predominantly flat, with rare load casts. Flute casts are not developed.

– The thinning-upward trend documents a gradually decreasing energy of a dense turbiditic current due to channel branching or avulsion. In sedimentary record, this process is documented by gradual fining and thinning of the sandstones at the expense of increasing amount of pelites.

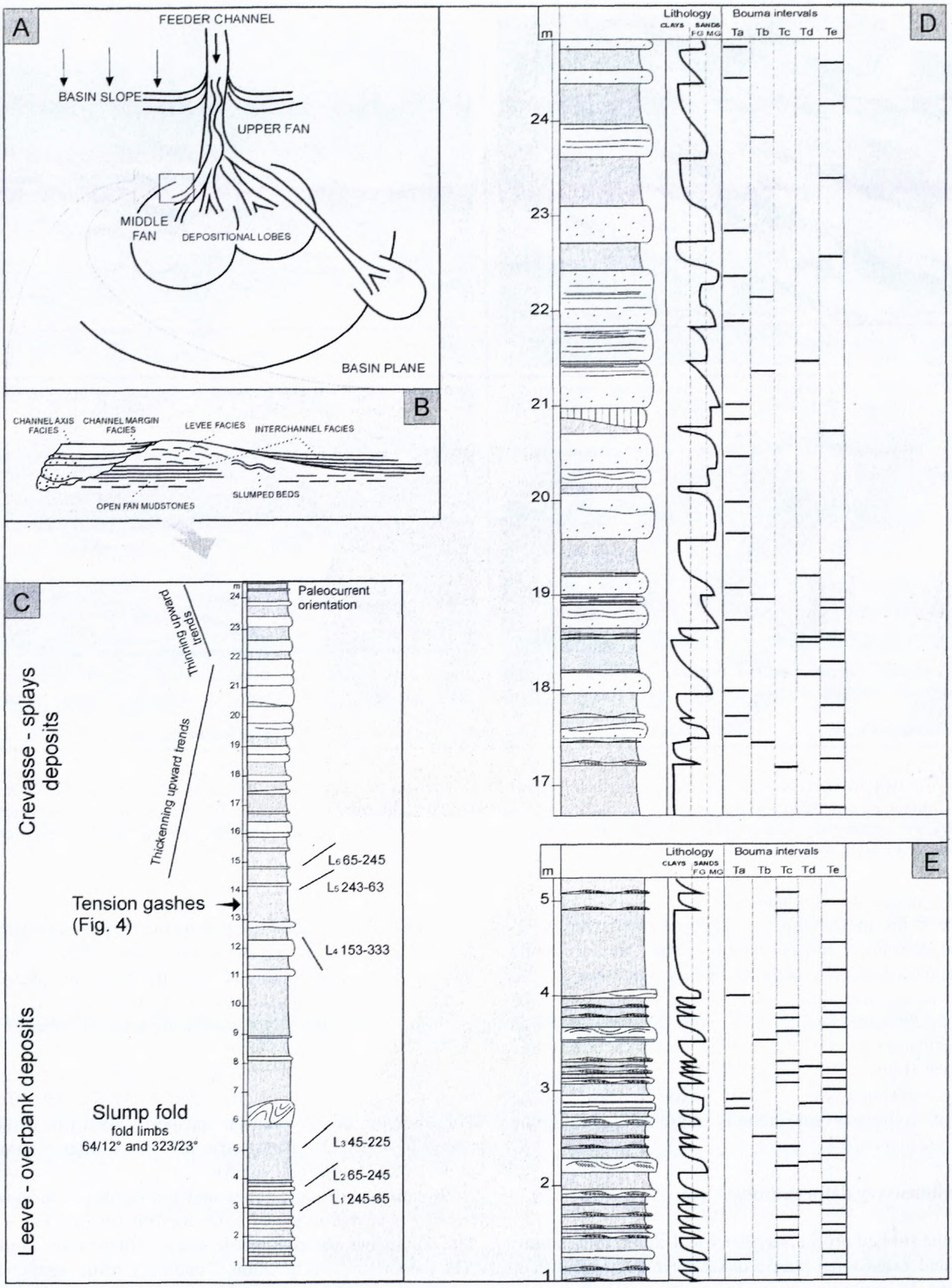

Fig. 2. The sedimentological feature of the Huty profile.

A) Position of sedimentary profile under deep marine fan (Walker, 1978); B) Schematic cross-section of the upper fan channel – levee – overbank area (Mutti, 1977); C) Schematic sedimentological log of studied outcrop and its interpretation (L – azimuth of groove casts); D, E) Detailed view of selected part of the Huty profile.

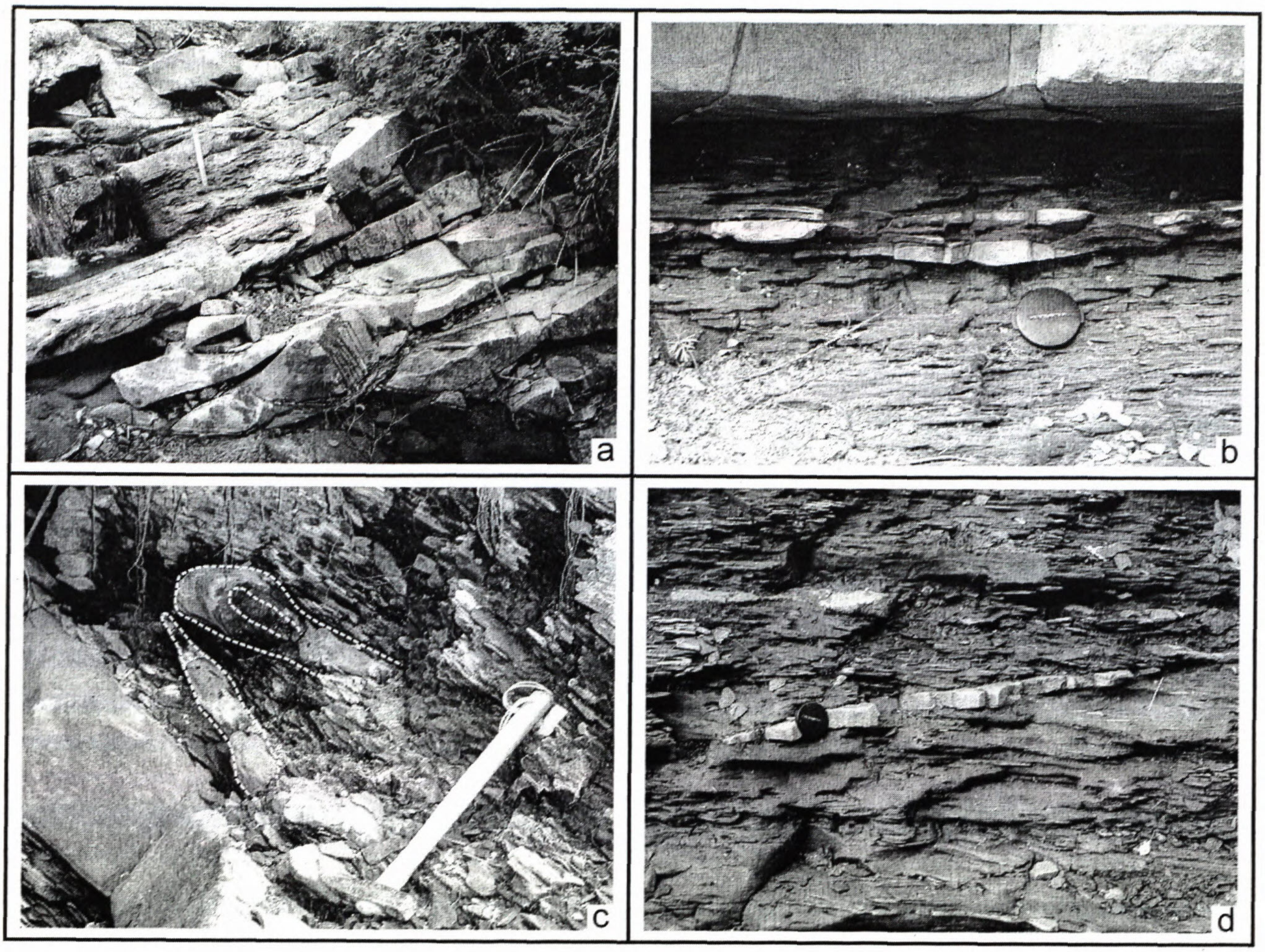

Fig. 3. The significant sedimentological and structural features in the Huty profile: a) massive, fine to medium-grained sandstones, laterally pinching out. Sedimentary facies of channel margin. b) rippled and laterally pinching out fine-grained sandstones of levee deposits. c) asymmetric slump fold and boudinage of sandstones. d) detailed view of the diagonal arranged clastic dykes and boudinage of sandstones

The migration of channel – levee sedimentary sequence is the most frequent related to autocyclic evolution of deposition fan. Formation of this sequence could be influenced also by external factors like there are sea level changes, tectonics and climatic changes. The formation of subrecent channel – levees in the Amazon fan is predominantly related to autocyclic processes during low sea level (Lopez, 2001). The sea level changes influence mainly avulsion frequency. During low sea level is the avulsion frequency substantially rapid like during the rising sea level.

Synsedimentary deformations

In the studied profile, asymmetrical slump fold, boudinage, and extensional clastic dykes have been identified, referring to synsedimentary deformation. These deformational structures, together with sedimentary textures and structures also refer to the depositional environment (Fig. 4). The observed sediments were affected by the younger deformational events, as evidenced by bedding tilted towards NW. From the point of view of this fact, the measured geological structures had to be rotated to the original position. Orientation of the rotation axis and value of the rotation are defined by the measured bedding (S_0 337/27°). The strike of bedding plane (67°) defines the orientation of rotational axis in space and dip of bedding (27°) specifies the value of rotation (Fig. 5).

In the lower part of the sedimentary profile (metres 5 to 7), a synsedimentary asymmetric slump is visible (Fig. 3c). The b-axis (36/25°) of the fold was reconstructed from the measured limbs R_1 (2/30°) and R_2 (330/50°). The direction of sedimentary transport (299°) was determined by means of asymmetric fold shape after rotation to the original position (Fig. 5).

Boudinage of sandstones and clastic dykes in claystones are visible in the 12 – 13 m of the section (Fig. 4). The boudinage has asymmetric shape, which points to the NW paleotransport direction. Boudinage of the semiconsolidate sandstones is typical feature of the synsedimentary deformation. Aditionally, two lenticular clastic dykes are developed in this part of profile. They are 70 cm long, with wedge-shaped ends (Fig. 3d, Fig. 4). The clastic dykes are en-echelon arranged with orientation T_1 324/36°, T_2 319/40° (dip direction/dip of plane). Course of the dykes is diagonal both, to the bedding of the profile

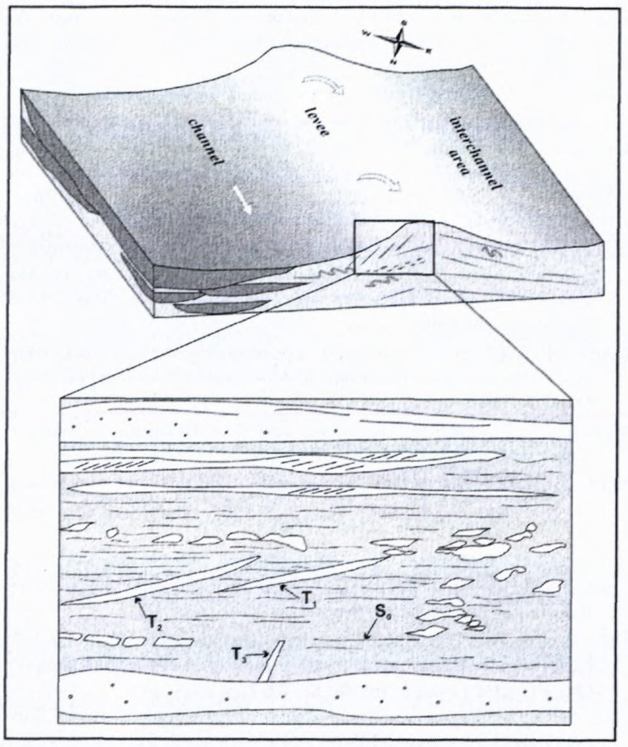

Fig. 4. Reconstruction of depositional environment from the sedimentological and structural record in the Huty profile. Detailed view in the lower part of picture represents studied clastic dykes and boudinage (redrawn from photo; the scale is 100:150 cm).

(S_0 337/27°), and to the claystones in which are they developed (Figs. 3 and 5). Except of these dykes, a subvertical clastic dyke (T_3 302/85°) has been found in the lower part of the claystone sequence, which is directly related to the underlying sandstone bed (Fig. 4). All the clastic dykes in the section are filled with fine-grained sandstone. Paleotransport direction with azimuth 295° was determined on the basis of orientation of clastic dykes, which were first rotated to the original position (Fig. 5).

Observed clastic dykes were formed under tensional stress on the low-pitched surface (Hancock, 1985; Park, 1993; Dadlez & Jaroszewski, 1994), therefore they do not represent true neptunian dykes that use to be filled either from top (Potter & Pettijohn, 1963). En-echelon arranged tension gashes in claystones originate in favourable conditions during the tensional stress and the neighbouring sands subsequently fill the joints. The tensional deformation is concentrated into highly cohesive claystones shortly after deposition. Sandstones are less cohesive as claystones and tensional stress results in the sand liquefaction and remobilisation into the open tension fractures.

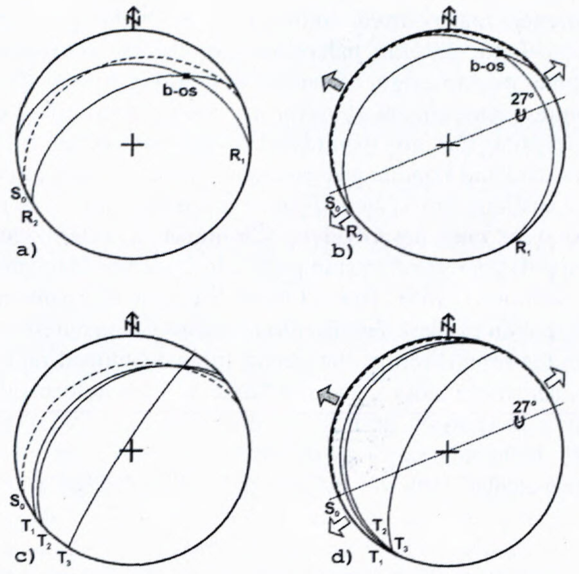

Fig. 5. Reconstruction of the original paleotransport direction from asymmetric folds and tension gashes. The planar structures have been shown by the great circle and linear structures by squares. For the diagrams have been used Lambert projection and the lower hemisphere. a) orientation of the measured structures (R_1 2/30° and R_2 330/50° fold limbs, b-axis 36/25° reconstructed from R_1 and R_2 fold limbs, S_0 337/27° bedding). b) original orientation of structures after 27° clockwise rotation around 67/0° rotational axis (original orientation of measured data R_1 64/12°, R_2 323/23° and b-axis 29/9°). Grey arrow represents sliding direction of the semiconsolidated material with 299° azimuth and white arrows are oriented parallel with local paleotransport. The azimuth of the sliding is perpendicular to the b-axis of fold. c) orientation of the measured structures (en-echelon tension gashes T_1 324/36°, T_2 319/40° and subvertical T_3 302/85° (S_0 337/27° bedding). d) original orientation of structures after 27° clockwise rotation around 67/0° rotational axis (original orientation of measured data T_1 294/11°, T_2 292/16° and T_3 297/63°). Grey arrow represents sliding direction of the semiconsolidated material with 295° azimuth and white arrows are oriented parallel with local paleotransport. The azimuth of the sliding is perpendicular to the tension gashes.

Discussion and conclusions

Study of the channel - levee–overbank sedimentary facies of submarine deep-sea fan are limited in the Podtatranská skupina Group. Poorly uncovered relief, together with relative scarcity of these facies in overall volume of turbidite fan often disable observation of their distribution and spatial relationship. However, channel – levee deposits were identified from Levočské vrchy Mts. and Spišská Magura Mts. by Janočko et al. (1998) and Janočko & Jacko (1998). The Huty profile enabled interpretation of this environment on the basis of characteristic and well developed structural and textural features of the sediments. Typical feature of levee environment is dominance of pelites, thin-bedded sequences and rapid pinching out of beds. Starving ripples, lenticular bedding, slump folds and common occurrence of upper Bouma's intervals in sandstones are typical, too. This facies are associated with thick layer of medium to fine-grained sandstones in the upper part of the studied section, which we interpret as channel margin facies. Other possible interpretation point out origin of crevasse splays deposits that have similar sedimentary features to previous one.

However, paleocurrent indicators on bedding planes (parallel to general paleotransport direction) support channel margin origin of sandstones. Along with of these features, synsedimentary deformations were identified on the profile, that are manifested by tension gashes filled with sand and boudinaged sandstone beds. These types of deformations are scarce. From the ancient levee facies they were only described by Cronin et al. (2000), and clastic dykes related to slumped beds described Dzułyński & Walton (1965) from Outer Western Carpathians. Orientation of these deformation structures coincides well with the orientation of the slump folds developed on the inclined levee slopes. On the basis of such deformation structures (tension gashes, asymmetric slump folds), the NW slump direction was reconstructed. This direction is perpendicular both to the general NE trend of paleotransport in the western part of the Podtatranská skupina Group (Soták et al., 2001; Starek, 2001) and local paleotransport on studied section (Fig. 5b, d). The clastic dikes described by Marschalko (1965) are similar in origin, but there are related to basin slope failure not to levee elevations, thus their orientation is parallel to paleoslope strike.

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