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Lithostratigraphic and facies division of the Flysch units, Outer Western Carpathians (northern Orava, Slovakia)

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Abstract. The lithostratigraphic units were defined via six facies types which repeated in various formations and members. The facies types reflect not only type of deposition (turbiditic, hemipelagic), type of sediment (thickness, granularity, structures) expressed by descriptive facies, but also the differences of the source of turbidite currents (e.g. composition and sorting of sediments, paleocurrent measurements).

Key words: Flysch Belt, lithostratigraphy, facies types, Cretaceous - Paleogene

Introduction

The area studied is situated in the Magura Unit of the Flysch Belt around Pilsko mountain on the Slovakian-Polish frontier. The area is built of several tectonic slices of the Rača and the Bystrica subunits (Fig. 1).

Many lithological types of sandstones and claystones repeated in a few lithostratigraphic units and tectonic slices. The lithostratigraphic members and formations are composed of turbidites of various origin. Therefore, it is useful to define the *facies types* and then to state their portion in every *lithostratigraphic unit*. It helps in better characterization of the formations and members to determine their depositional environment. The facies types are well characterized by common *descriptive facies* of turbidite sediment (Pickering et al. 1986).

The facies types include the features of descriptive facies, but their description is more actual. The facies types also reflect the differences of the source of turbidite currents. Therefore the important marks are added, which describe character of the source area: composition of sandstones, conglomerates and claystones, paleocurrent measurements, sorting of sandstones, roundness of clasts and distribution of granularity.

The usage of facies types was outlined in earlier works only. For example, it is written of sandstones of the Magura type, of the mudstones of both the Lacko or the Bystrica types. The use of the same names of the facies types as the names of the lithostratigraphic units is rather intransparent and confusable because of their mistaking (e.g. Pivko et al. 1991).

The facies types were used by Potfaj et al. (1991). The names were combined either after formations either after type of sediment what is not suitable resolution. In the studied area we chose the names, which reflect the most simple their rocky composition, characteristic feature easily distintive in the field. The abbreviations were added to the facies types.

The schematic lithostratigraphic sections (Fig. 2) for every tectonic slice were arranged. From them the summary stratigraphic table (Fig. 3) and the table with proportional content of the facies types in the lithostratigraphic units (Fig. 4) were created.

Facies types

Massive sandstones (*MaSa*)

The facies type is composed of mostly very thick - to thick-bedded massive sandstones (up to 4 m) with thin layers of claystones. The sandstone beds are often amalgamated. The most common is interval S3 (Lowe 1982) or Ta Bouma interval. Locally the comglomeratic layer are present with well rounded granule clasts (max. 15 mm) consisted of quartz, less feldspars, granitoids, metamorphids, carbonates. The granule clasts are often distributed to gradation of „coarse-tail„ type (Middleton 1966), the amount of the clasts in sandstone are decreased to the top of bed. The Tb-Td Bouma intervals are commonly imperfectly evolved. Thin Te interval is presented by dark grey non-calcareous mudstones to claystones.

The *MaSa* facies type is classified by B1.1, little A2.7 and C2.1, rarely A2 descriptive facies (Pickering et al. 1986). The massive gravely sandstones and the sandstones were deposited from high-density turbidity currents mostly in distributaries and inner parts of the lobes of deep-sea fans (Walker - Mutti 1973, Pickering et al. 1986, Mutti 1992). The material was transported from NE and E.

Thick-bedded glauconitic flysch (*TkGl*)

The *TkGl* facies type is created of very thick beds composed of calcareous sandstones with glauconite and calcareous grey mudstones with shelly disintegration. The proportion of sandstones and mudstones are changeable. The beds mostly begin with Lowe interval S3 or Bouma

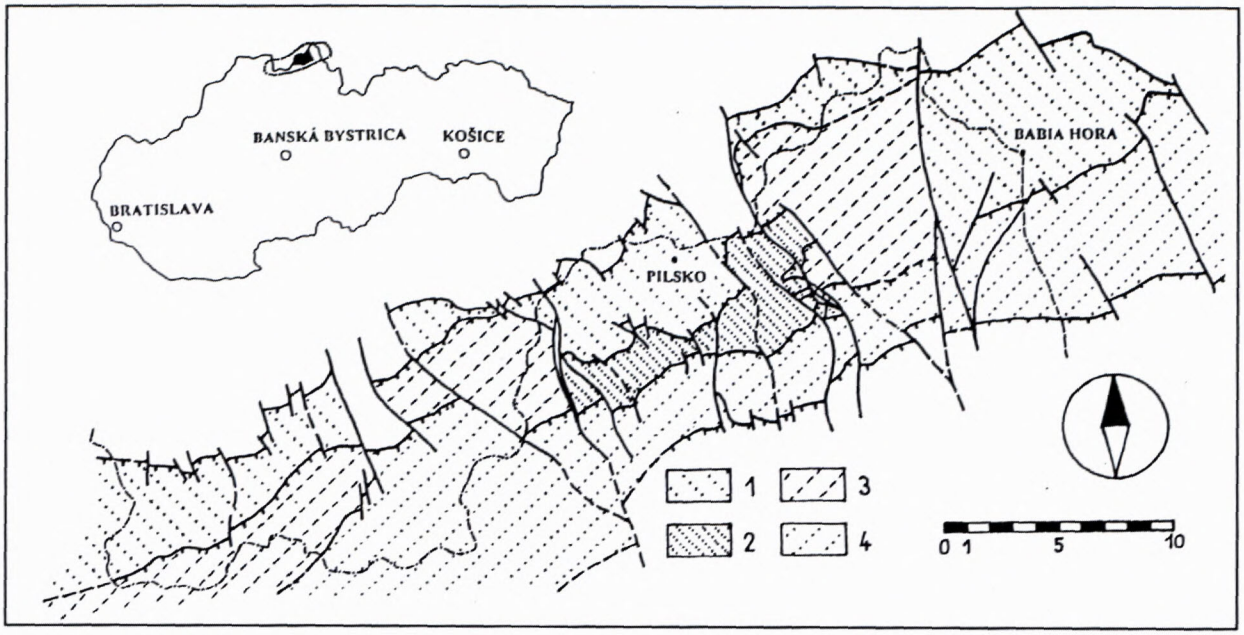


Fig. 1: The position of the studied area and the tectonic scheme of surrounding region. Explanation: 1 - 1st to 4th slice of the Rača Subunit, 2 - 5th slice of the Rača Subunit, 3 - 1st slice of the Bystrica Subunit and 4 - 2nd to 5th slice of the Bystrica Subunit.

Ta, less Tb, rarely Tc or Td. The sandstones are often of vitreous appearance, very hard, grey (greenish). Ta interval are most often homogenous. Locally the conglomeratic layers sharply separated from sandstones are presented with granule imperfectly rounded clasts. The clasts are composed of quartz, less epimetamorphids, granitoids, feldspars and carbonates. There are also large foraminifers there. Tb - Td intervals are distinct.

The facies type is classified by C2.1 and C2.4, less C2.2 descriptive facies, the conglomeratic and the coarse-grained sandstone layers by A2.3, A2.8 and B2.1 (Pickering et al. 1986). The *TkGl* facies type was deposited from high- to low-density turbidite currents on deep-sea fans, especially on the inner parts of their lobes, less on distributaries (Walker - Mutti 1973, Pickering et al. 1986, Mutti 1992). Some very thich beds were probably created by several times reflection from sides of a basin (Pickering et al. 1986). The material was transported from N, NW and NE.

Medium-bedded limestone flysch (*MeLi*)

The facies type is built of mostly medium-bedded clayey limestone (Te), less siltstone - limestone (Tde) and rarely sandstone - siltstone - limestone beds (Tcde, Tbcde, Tabcde). The sandstones are the most often grey with well evolved Bouma intervals. Te and partially Td interval is represented by grey-green, red, less grey and green calcilutite - calcipelite with various portion of clay.

The *MeLi* facies type is classified by descriptive facies E2.1, less D2.1 and little C2.2 and C2.3 (Pickering et al. 1986). The material was transported along with axis of the basin from NE.

Thin-bedded green flysch (*TnGr*)

The facies type is typical of very thin- to thin- (less medium-) bedded alternation of green, greenish sandstones, siltstones and green-grey mudstones. The portion of sandstone to mudstone is 1:3 to 2:1. The beds mostly begin of Tc, little Tb or Td, still less Ta Bouma intervals.

Ta interval is finegrained, less medium- and coarse-grained, rarely conglomeratic (up to 5 mm). The clasts are predominantly consisted of quartz and feldspar, less quartzites and metamorphites. The areas of lamination (interval Tb, Tc) are covered by lamellas of mica and chlorite. Sharp transitions are often evolved between sandstone and mudstone part of beds.

The *TnGr* is classified by C2.3, less D2.1 and D2.2, rarely C2.1 a B2 descriptive facies. The facies type was deposited mainly from low-density turbidite currents. Some beds were probably reworked by bottom currents. The material was probably transported along with axis of the basin from NE and partially from N.

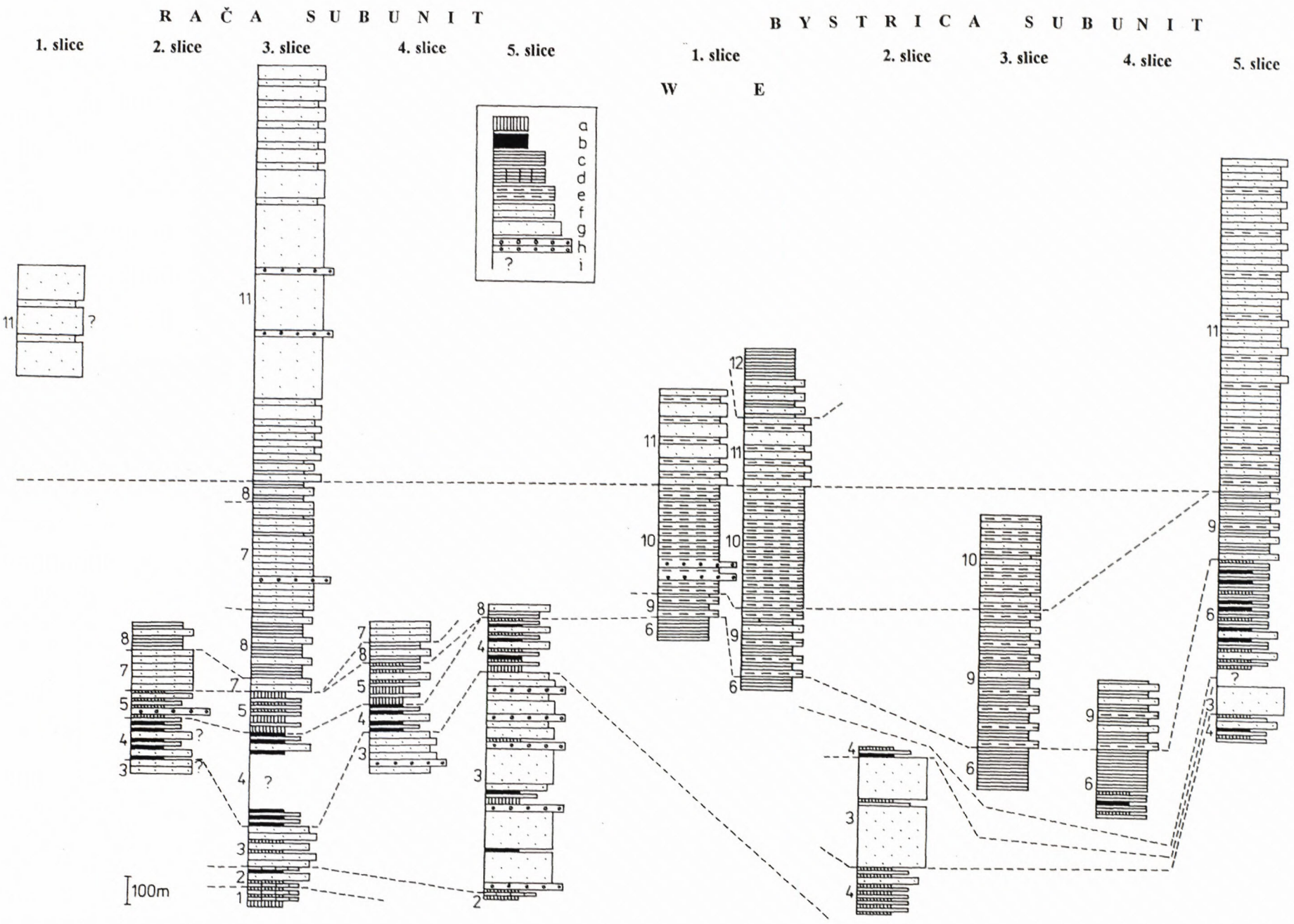
Thin-bedded trace fossil flysch (*TnTF*)

The facies type is created of thin- (medium-) bedded alternation of grey calcareous sandstones, siltstones and mudstones. The portion of sandstone to mudstone is 2:1 to 1:2. The sandstones (Tc, less Tbc) are with distinct dark laminae with muscovite and plant debris and with trace fossils on the bottom of beds. The transition from the sandstones to the siltstones and to mudstones is fluent.

The facies type belongs mainly to C2.3 descriptive facies. It was deposited from low-density turbidity currents on the distal parts of deep-sea fans. The material was transported along with axis of the basin from NE.

Non-calcareous mudstones (*NcMu*)

The facies type consists of non-calcareous claystones and mudstones. Grey-greenish colour prevails over dark red one. The portion of red and green claystones is changeable. Their thickness changes from few mm to 100 cm.


RAČA SUBUNIT
BYSTRICA SUBUNIT
1. slice
2. slice
3. slice
4. slice
5. slice
W
E
a
b
c
d
e
f
g
h
i
100m

The *NcMu* facies type is mostly classified by descriptive facies E1 (Pickering et al. 1986). It was deposited as hemipelagic claystone under CCD with posible influence of low-density turbidity and bottom currents (Pickering et al. 1986, Leszczyński - Uchman 1991).

Lithostratigraphic units

The lithostratigraphic units are composed of above defined facies types. Biostratigraphy of the units is not discussed in this article. It has been analysed in detail in previous works (Pivko et al. 1991, Pivko 1998, 2000).

Malinowa Formation (Lower Campanian)

The *NcMu* facies type prevails (distinctly in the lower part of the formation) over the beds of the *MeLi* facies types. Red colour predominates.

Haluszowa Formation (Upper Campanian - Maastrichtian)

The formation is composed of the *NcMu* facies type, which is interrupted by the beds of the *MeLi* facies types. The first one prevails in the lower part and the second one in the upper part of the formation. In the lower part the greygreenish claystones and limestones predominate over red ones, which are sporadic in upper part. In the upper part of the formation the *MaSa* facies type is presented.

Szczawina Sandstone (Maastrichtian - Rača Subunit, Paleocene - Bystrica Subunit)

In the Szczawina Sandstone the *MaSa* facies type predominates with large amount of muscovite. Inside the member the packages of the variegated *NcMu* facies type together with the *TnGr* facies type with the thickness of a few dm to m (max. some tens m) are presented. The Szczawina Sandstone in the 3rd slice is more distal than in the 5th slice.

Ropianka Formation (Maastrichtian - Lower Eocene)

The Ropianka Formation is very changeable in different tectonic slices. The predominance of the *TnGr* and *NcMu* facies types is common feature with prevailing of grey-green colour, less the *TnTF*, *TkGl* and *MaSa* facies types. In the 2nd and the 3rd slice there are coarse and medium-grained sandstones (*TnGr*) with quartz and feldspars. In the 5th slice, the Ropianka Formation has individual features (Fig. 2) with the lower part similar to Labowa Formation.

Labowa Formation (Upper Paleocene - Lower Eocene)

In the Labowa Formation the *NcMu* facies type (with predomination of red colour) prevails over the *TnGr* and *TnTF* facies types. The beds of *TkGl* and *MaSa* facies type are also present. The formation is changeable in the various slices.

Beloveža Formation (Lower Eocene)

In the Beloveža Formation the *TnTF* facies type predominates over *NcMu* (mainly of greygreenish colour). Generally calcareous mudstones prevail over non-calcareous ones. The red non-calcareous mudstones (*NcMu*) are found especially in the lower part of the formation, where are sporadic beds of the *MaSa*, *TkGl* and *TnGr* facies types.

Osielec Sandstone (Middle Eocene)

The Osielec Sandstone is almost exclusively created by the *TkGl* facies type, in which the sandstones with rare conglomeratic layers prevail over mudstones. The *TnTF*, *MaSa* and *NcMu* facies types are sporadic.

Hieroglyphic Member (Middle Eocene)

In the Hieroglyphic Member the *TnTF* facies type generally prevails over the *TkGl* facies type, that created single beds or sets of beds in the first type. Between the beds very thin layers of *NcMu* facies type are present. The sandstone parts of beds totally predominate over mudstone parts, where non-calcareous (*NcMu*) mudstones prevail over calcareous ones (*TnTF* and *TkGl*). Beds of the *MaSa* facies type are very sporadic.

Vychylovka Formation (Middle Eocene)

The Vychylovka formation can be characterized as a transitional development between both the Beloveža and the Zlín formations, because the facies types typical for both them are mixed here. The Vychylovka formation. formation is composed of three basic facies types:

1. *TnTF*. To the top of the formation the proportion of the type is decreasing and the thickness of beds of the type increases.
2. *TkGl* with predomination of mudstones. To the top of the formation, the thickness of the beds of the type increases. The facies type is present in single beds of the whole formation.
3. *MaSa*. The beds of the type are present especially in 4th and 5th slice.

Between the beds of the previous facies types (espec. of *TnTF*) thin layers of facies type *NcMu* are present.

Fig. 2: The lithostratigraphic sections through the slices of the Rača and the Bystrica subunits. Explanation: a) hemipelagic variegated mudstones (NcMu), b) hemipelagic greengrey mudstones (NcMu), c) thin- (medium-) bedded turbidites (TnTF and TnGr), d) medium-/thin-bedded turbidites (limestones>sandstones, MeLi), e) thick- (medium-) bedded turbidites (mudstones>sandstones, TkGl), f) thick- (medium-) bedded turbidites (sandstones >mudstones, TkGl,MaSa), g) massive sandstones (sandstones>>mudstones, MaSa), h) conglomeratic layers, i) unknown and supposed bed succesion. 1 - Malinowa Formation, 2 - Haluszowa Formation, 3 - Szczawina Sandstone, 4 - Ropianka Formation, 5 - Labowa Formation, 6 - Beloveža Formation, 7 - Osielec Sandstone, 8 - Hieroglyphic Member, 9 - Vychylovka Formations, 10 - Bystrica Member, 11 - Kýčera Member and 12 - Malcov Formation.

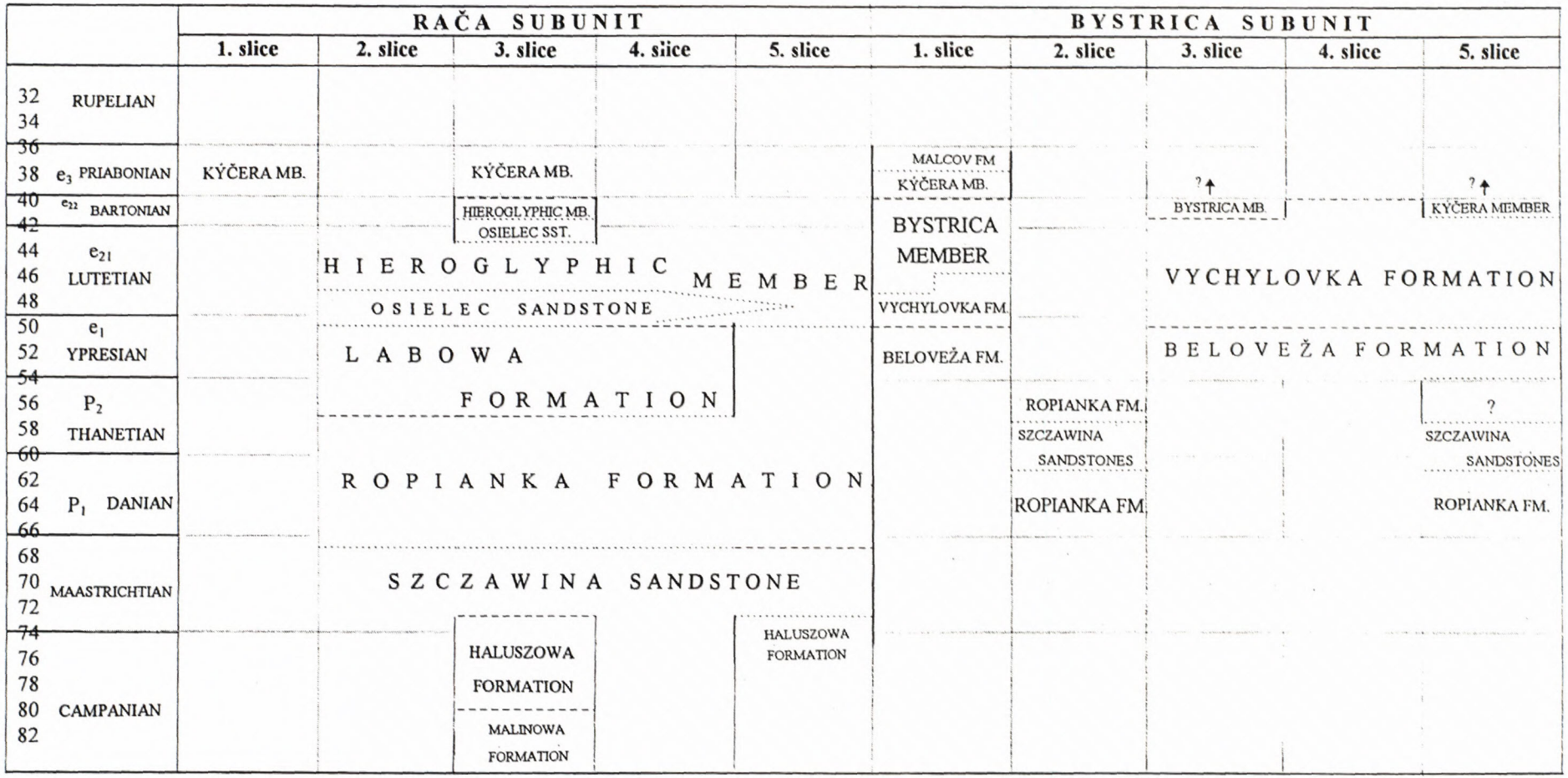


Fig. 3 The stratigraphic table with the lithostratigraphic units and their occurence in the tectonic slices of the Rača and the Bystrica Subunits.

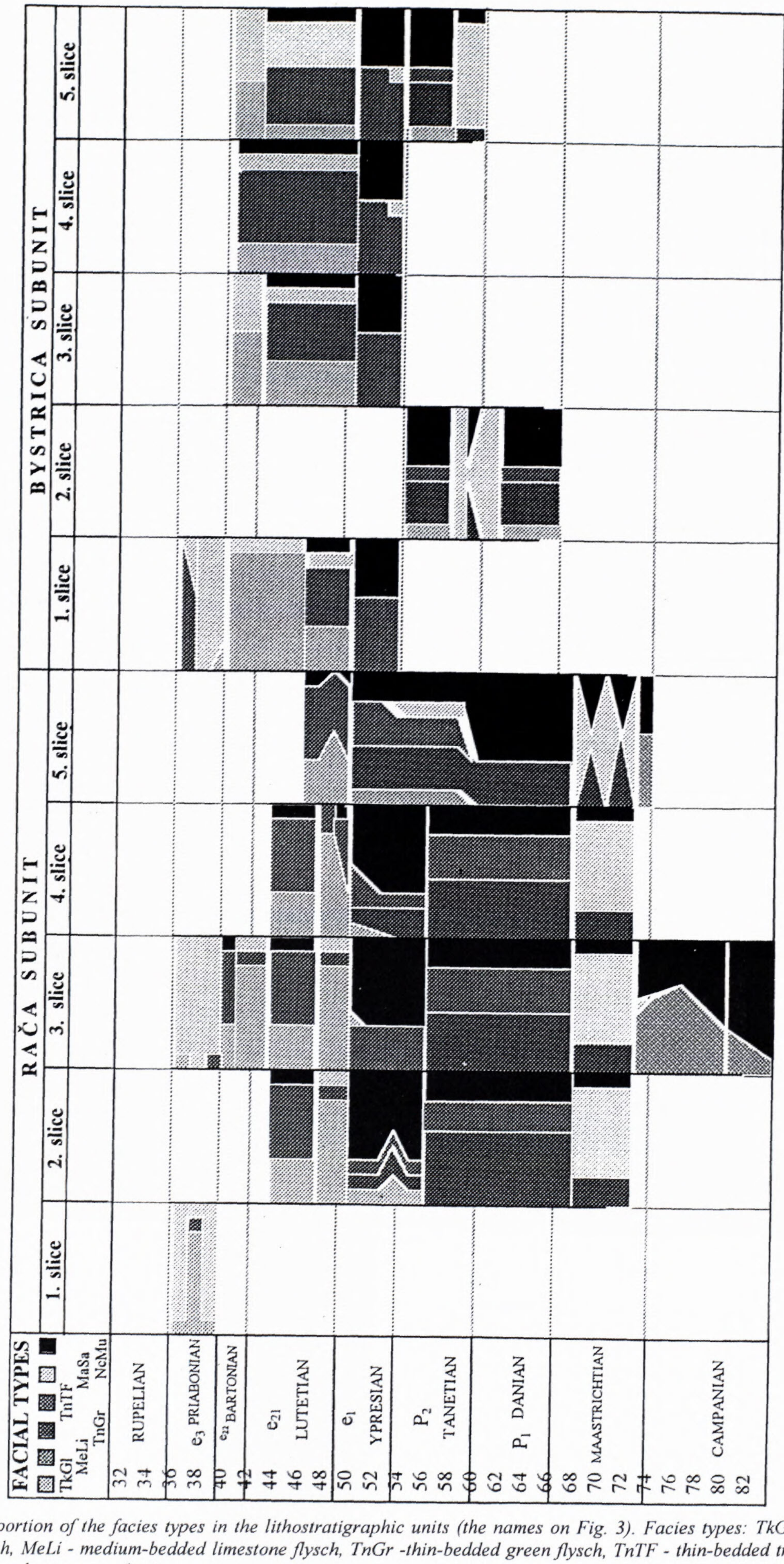


Fig. 4: The proportion of the facies types in the lithostratigraphic units (the names on Fig. 3). Facies types: TkGl - thick-bedded glauconitic flysch, MeLi - medium-bedded limestone flysch, TnGr -thin-bedded green flysch, TnTF - thin-bedded trace fossil flysch and NcMu - non-calcareous mudstones.

Zlín Formation - Bystrica Member (Middle Eocene)

The Bystrica Member is predominatly built of the *TkGl* facies type with a prevalence of calcareous mudstones, various portion of the *MaSa* facies type, little presence of the *TnTF* in lower part of the member and subordinate portion of the *NcMu*.

Zlín Formation - Kýčera Member (Upper Eocene)

The Kýčera Member is composed of the *MaSa* facies type and less of the *TkGl* facies type. In the lower part of the member the beds of the *TnTF* facies type are present. The proportion of the *NcMu* facies type is very low.

The portion the *MaSa* to the *TkGl* is changeable in various slices and also in bed succesion in terms of one slice. In the 1st slice of the Rača Subunit the packages of a few tens meters of the *TkGl* facies type are present. In the 3rd slice of the Rača subunit the *MaSa* facies type is substantial. In the 1st slice of the Bystrica subunit the beds of the *TkGl* facies type are sporadic present, especially in the lower part by calcareous mudstones. In the 5th slice of the Bystrica subunit the *MaSa* facies type generally predominates, but in some part of the section the *TkGl* facies type (mainly mudstones) outweighes.

Malcov Formation (Upper Eocene)

The formation is built of the *TnTF* facies type alternating with the *NcMu* facies type of greenishgrey colour and less proportion of the *MaSa* facies type diminishing to the top of the formation. Mudstones (*TnTF* and *NcMu*) prevail over sandstones (*TnTF*).

Conclusion

The geological structure of the area studied near Pilsko mountain in the northern Orava is very complicated. It is built of five tectonic slices of the Rača Subunit and five slices of the Bystrica Subunit. Each slice is created of different lithostratigraphical section (Fig. 2) with characteristic lithostratigraphic units (Fig. 3). The lithostratigraphic units were defined by six facies types which were repeated in various formations and members.

The facies types reflect not the type of deposition (turbiditic, hemipelagic) only, the type of sediment (thickness, granularity, structures) expressed by descriptive facies, but also the differences of the source of turbidite currents (e.g. composition and sorting of sediments, paleocurrent measurements).

Defined facies types were recognized in the major part of the sequence studied. However, transitional features between individual facies have been recorded. This transitions may have originated by repetitive erosion and transport of older sediments or by gradual passage between individual genetic zones.

The definition of the lithostratigraphic units via facies types is contribution to more evolved understanding of paleogeographic and paleotectonic regime of flysh basins.

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