

## THE TECTONIC SETTING AND ORIGIN OF THE SMILNO TECTONIC WINDOW (EASTERN SLOVAKIA)

### ZAŁOŻENIA TEKTONICZNE I GENEZA OKNA TEKTONICZNEGO SMILNA (WSCHODNIA SŁOWACJA)

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**Abstract.** The Smilno tectonic window is located in eastern Slovakia between Smilno in the west and Nižný Mirošov in the east. Geologically, the Smilno tectonic window occurs in the Magura Unit, within the Racza Subunit. In this area, deposits of the Grybów and Dukla units crop out from under the Magura Unit rocks and occur at the surface. The Dukla Unit section is represented by the Submenilite Formation occurring in the northern part of the window. The upper Grybów Unit is represented by the Menilite Formation and the Krosno Beds. The Smilno window developed as a result of a multi-stage formation of flysch masses in this region. In the earliest stage, flysch masses were displaced over the Makovice Ridge from the south into the graben. The graben was filled mostly with deposits of the Silesian and Dukla units, overlain by the Grybów and Magura units. In the next stage, there was a restructuring of the Makovice Ridge, which extended into the overlying deposits of the Silesian and Dukla units. During the later stage, tectonic deformation spread out into the Grybów and Magura units. Not only discontinuous tectonic deformation, but also the beginnings of folding processes, developed as a result of SW-oriented stress, is observed within them. In the next stage, the SW-oriented stress plays a significant role. It resulted in a shift of the Grybów and Magura units and the top part of the Dukla Unit in relation to the Dukla and Silesian units. The last stage included primarily a shortening and thrusting of the Grybów and Magura units and the top portion of the Dukla Unit. Due to this process, the Magura Unit broke up, and the Grybów and Dukla units, today present in the Smilno window, pierced up to the surface along discontinuity planes. In each case described, the occurrence of a tectonic window within flysch deposits was associated with the presence of a resisting element in the consolidated basement of the Carpathians to the south of the window zone; in the case of the Smilno window, it was the Makovice Ridge.

**Key words:** Smilno tectonic window, Magura, Grybów and Dukla units, Western Carpathians.

**Abstrakt.** Tektoniczne okno Smilna położone jest na obszarze wschodniej Słowacji, w obrębie jednostki magurskiej. W obrębie okna Smilna mamy do czynienia z profilami dwóch jednostek, jednostki dukielskiej i jednostki grybowskiej. Okno Smilna uformowało się w rowie podłoża pomiędzy grzbietem makowickim na południu a regionalnym skłonem podłoża na północy. Powstało ono w wyniku wieloetapowego formowania się mas fliszowych. W każdym opisanym przypadku pojawienie się okna tektonicznego w obrębie mas fliszowych związane było z wystąpieniem elementu oporowego w skonsolidowanym podłożu Karpat na południe od strefy okiennej. Element ten był przeszkodą dla ruchu mas fliszowych ku północy, wyhamowywał go i w wyniku tego powstawała składowa pionowa siła powodująca wypiętrzenie mas fliszowych z głębi na powierzchnię. W przypadku okna Smilna był to grzbiet makowicki.

**Słowa kluczowe:** okno tektoniczne Smilna, jednostka magurska, grybowska, dukielska, Karpaty Zachodnie.

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## INTRODUCTION

The Smilno tectonic window is located in eastern Slovakia between the localities of Smilno in the west and Nižný Mirošov in the east. To the north it is bounded approximately by the line trending from Smilno through elevation point 410 m a.s.l., Mikulašova, Četa Mt. 403.9 m a.s.l. and Nižný Mirošov. In the south, the boundary of the window runs from Smilno through elevation point 429.2 m a.s.l., Zvernik Mt. 513.4 m a.s.l., elevation point 454.0 m a.s.l., elevation point 429.1 m a.s.l., Krasna Mt. 585 m a.s.l. and Nižný Mirošov.

The Smilno tectonic window is located within the Magura Unit (Fig. 1), precisely within the Racza Subunit. In this area, deposits of the Grybów and Dukla units crop out from under the Magura Unit rocks to occur at the surface. Morphologically, the area between Nižný Mirošov and Smilno is included in the so-called Zborov Ridge. Earlier maps, detailed maps of the authors performed at the scale of 1:25 000, and seismic reflection sections were used to analyse the tectonic setting of the Smilno window.

The area is located between Nižný Mirošov and Smilno. It has been the subject of numerous studies since the nineteenth century. Full description of the history of research in this area is found in Stránik and Hanzliková (1963). The main objective of the present study was to determine the age of deposits in this region and their stratigraphy to iden-

tify the tectonic and facies unit they represent. In particular, much attention was paid to black, hard, leafy shales, the so-called Smilno Shales. Initially, they were considered Lower Cretaceous deposits of the Magura Unit. Only since 1934 (Świdziński, 1934; Kozikowski, 1953), many authors pointed to their menilite character. In 1956, Książkiewicz (1956) noted the similarity of the Smilno beds to the Grybów Beds. Since 1958, when Świdziński published "Geological map of the Polish Carpathians", the eastern part at the scale of 1:200 000 (Świdziński, 1958), the deposits described from the Smilno and Nižný Mirošov region have been included in the Grybów Unit. These deposits are similarly interpreted in the "Atlas of the Outer Carpathians" (Poprawa, Nemčok, eds., 1988–1989).

In establishing the stratigraphy of this region, the authors based their interpretation mainly on the papers by Stránik, Hanzliková and Nemčok (Stránik, Hanzliková, 1963; Nemčok, 1990). The authors are of the opinion that there are two units cropping out in the Smilno window: the Grybów and Dukla units. The Dukla Unit section is represented by the Submenilite Formation found in the northern part of the window. These deposits are distinguished in the area extending from the northern slopes of Uboč Mt. to Dubova upon the Ondava River. The upper, Grybów Unit is represented by the Menilite Formation and Krosno Beds.

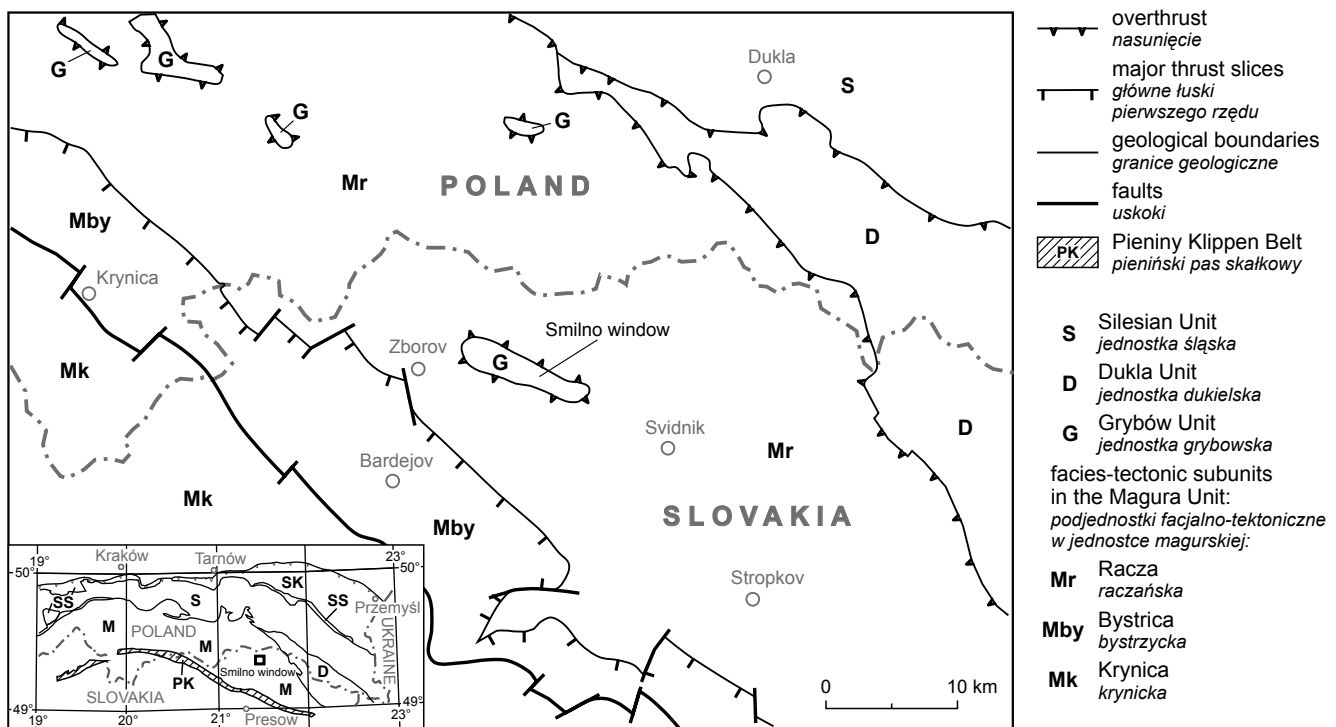


Fig. 1. Structural scheme of the Smilno window (after Poprawa, Nemčok, 1988)

Szkiec strukturalny okna tektonicznego Smilna (według Poprawy, Nemčoka, 1988)

## GEOLOGICAL SETTING

The area extending between Smilno, Nižný Mirošov and Šarišské Čierne is situated within the most elevated part of the Racza Subunit, included in the Magura Unit of the Zborov Ridge. The oldest strata in this area are the Ropianka and Bela Ves beds, within which deposits of the Grybów and Dukla units crop out at the surface in the Smilno window (Fig. 2).

The oldest deposits of the Racza Subunit, the Ropianka Beds, outcrop between Smilno, Šarišské Čierne and Nižný Mirošov. In this area, they are the southern aureole of the

Smilno window. Between Smilno and Krasna Mt., the Ropianka Beds dip at moderate angles towards the southwest (Fig. 3A–D) under the overlying Bela Ves Beds. A change in the dip angle of the Ropianka Beds is observed at the southeast end of the window (Fig. 3D). In this section, just south of Nižný Mirošov and east of Krasna Mt., there is a distinct stacking, imbrication and thickness reduction of the Ropianka Beds and the variegated shales (Fig. 3d). These strata dip here at clearly higher angles; first towards the south and then

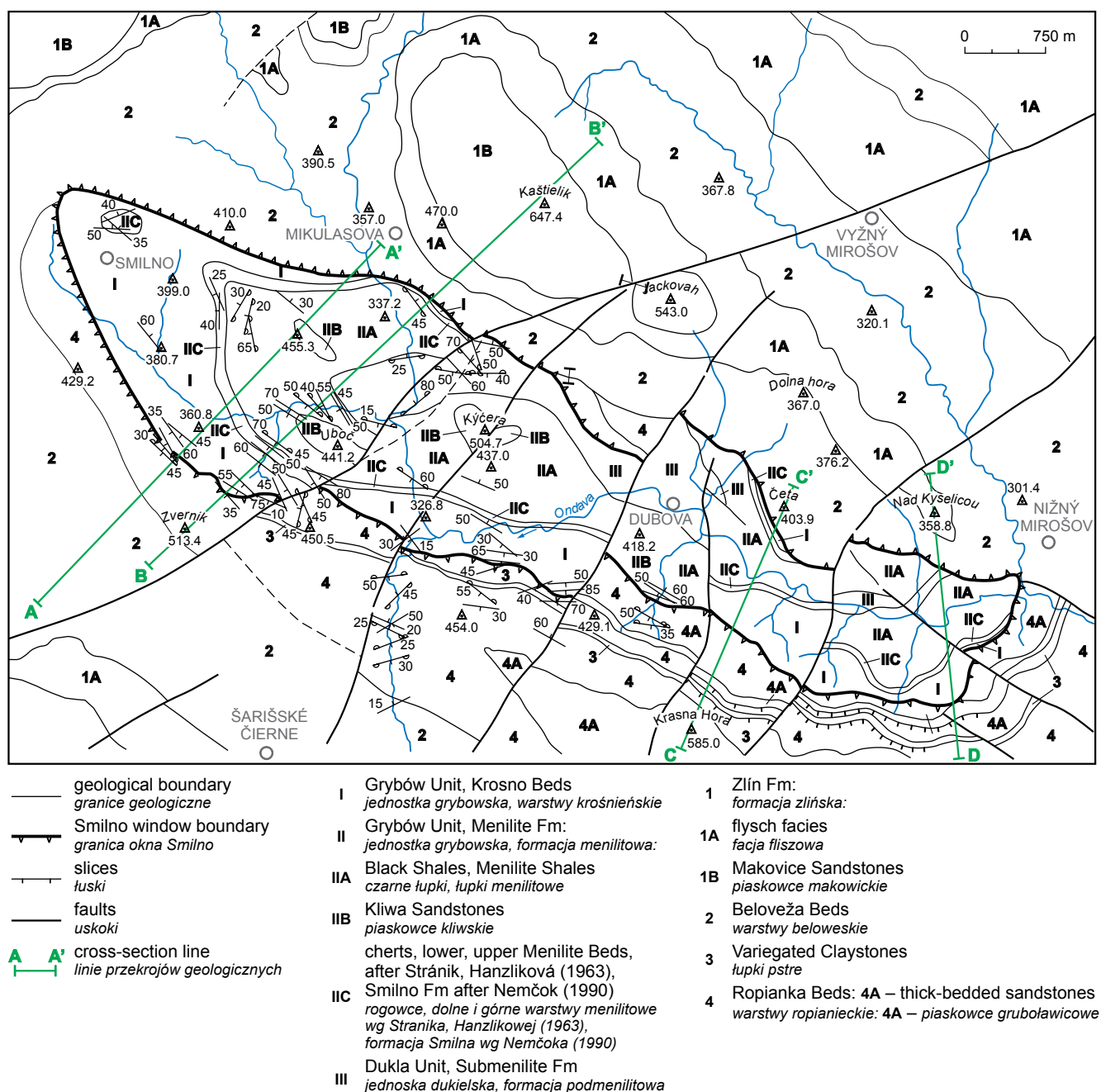


Fig. 2. Geological map of the Smilno window (according to Stránik, Hanzliková, 1963, supplemented)

Mapa geologiczna okna tektonicznego Smilna (według Stránika, Hanzlikowej, 1963, uzupełnione)

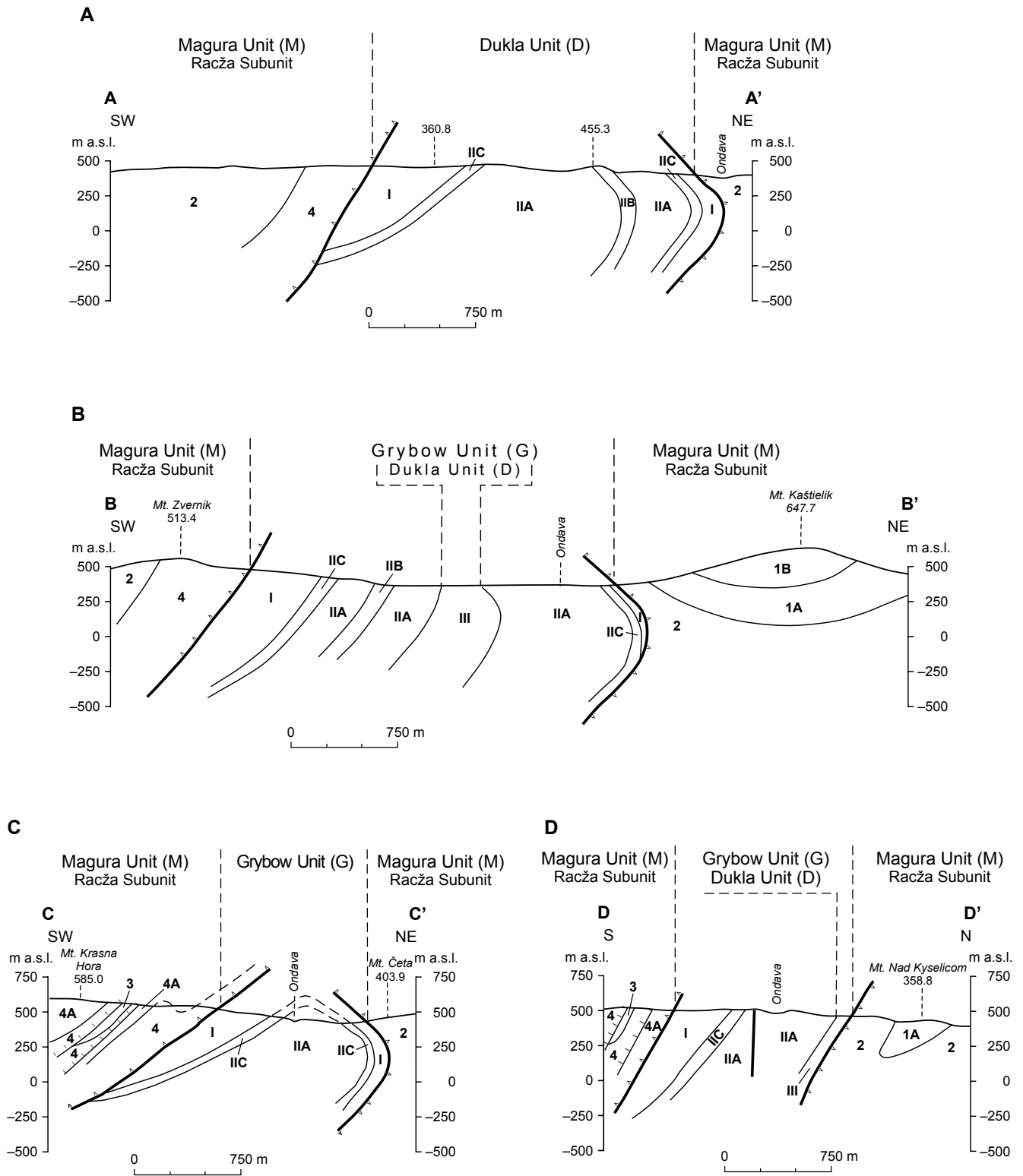


Fig. 3. Geological cross-sections

For explanation see Fig. 2

Przekroje geologiczne

Objaśnienia jak na figurze 2

towards the southeast. On the northern side of the window, the Ropianka Beds are found only in local, poorly preserved outcrops located northeast of Dubova.

A change in the geological structure of the Racza Subunit is observed to the northeast of the tectonic window (Fig. 3A, B). In this region there is a vast brachysyncline, whose NW–SE axis runs between Kostielik Mt. and Nad Kyselickou Mt. In the core of the brachysyncline there are outcrops of sandy facies (Makovice Sandstones) of the Zlín Formation (Fig. 3A). In the limbs, flysch facies of the Zlín Formation is first observed, followed by the Bela Ves Beds more outside (Fig. 3B). The strata found in the limbs dip at relatively small angles. The south-western limb of the brachysyncline shows significant tectonic thickness reductions of the Bela Ves Beds near the tectonic window.

The deposits included in the Smilno tectonic window expose between Smilno in the west and Nižný Mirošov in the east (Fig. 2). The length of the window is about 10 km, whereas the maximum width does not exceed 2 km.

Flysch deposits found in this area represent, according to the authors, two tectonic units: the Dukla Unit and

the upper, Grybów Unit. The rocks included in these two units form a large brachyantycline. For the tectonic style of tectonic window, this term was proposed by Stránik who thoroughly described the window structure (Stránik, Hanzliková, 1963).

The present authors have maintained the traditional term, however considering that the core part of the brachyantycline is composed of the Submenilite Beds that can be included in the Dukla Units, whereas its limbs consist of deposits of the Menilite Formation and Krosno Beds, but representing the upper, Grybów Unit.

The axis of the brachyantycline shows the general direction NWW–SEE, which is more longitudinal than those of the structures within the Magura Unit, surrounding the window. Along all its length, the brachyantycline is overturned towards the northeast and shows strongly tectonically reduced limbs, in particular the northern limb. Several segments with a characteristic structure can be identified within this form. The geological structure is illustrated in detail by the geological cross-sections produced by the authors (Fig. 3A–D).

## STAGES OF SMILNO WINDOW FORMATION

The Smilno window formed in a graben of the basement between the Makovice Ridge in the south (Leško, ed., 1987) and the regional slope of the basement (Ryľko, Tomáš, 2001) in the north. It developed as a result of multi-stage formation of flysch masses in this region. The origin of this window

can be analysed on seismic profile 80/87 (Santavy, Vozár, eds., 1999) (Fig. 4).

In the earliest stage (Fig. 5A), the flysch masses were emplaced over the Makovice Ridge from the south into the graben. The graben was filled mostly with deposits of the Si-

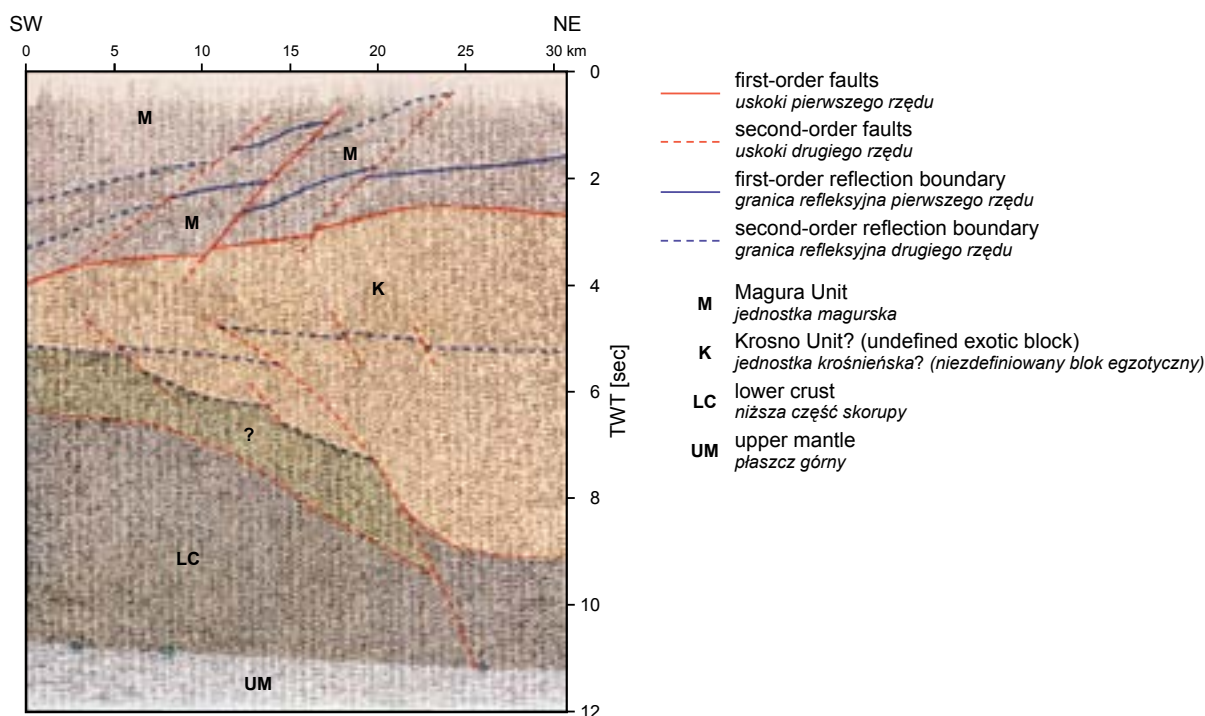


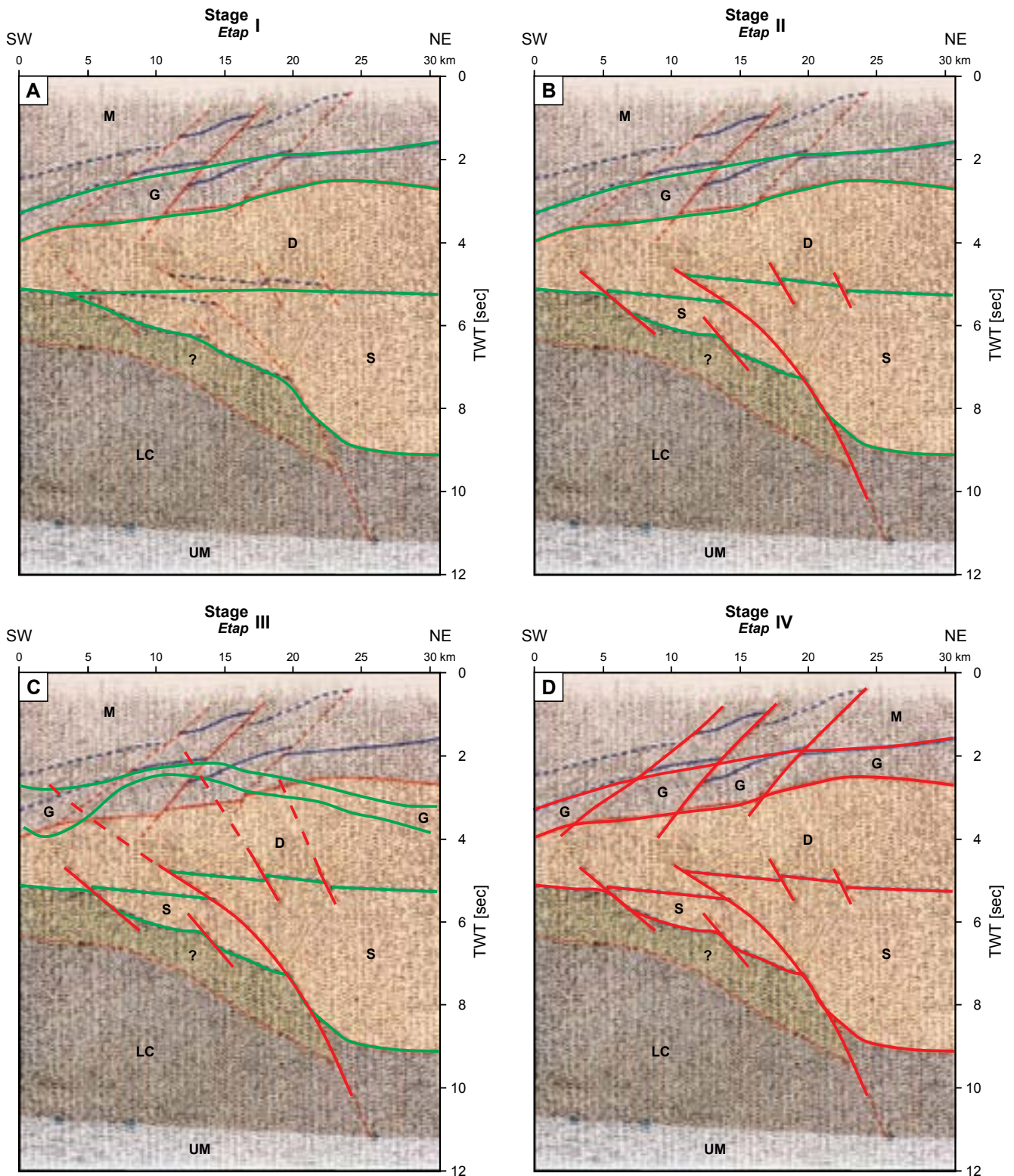
Fig. 4. Tectonic interpretation of the seismic profile 80/87 (after Santavy, Vozár, eds., 1999)

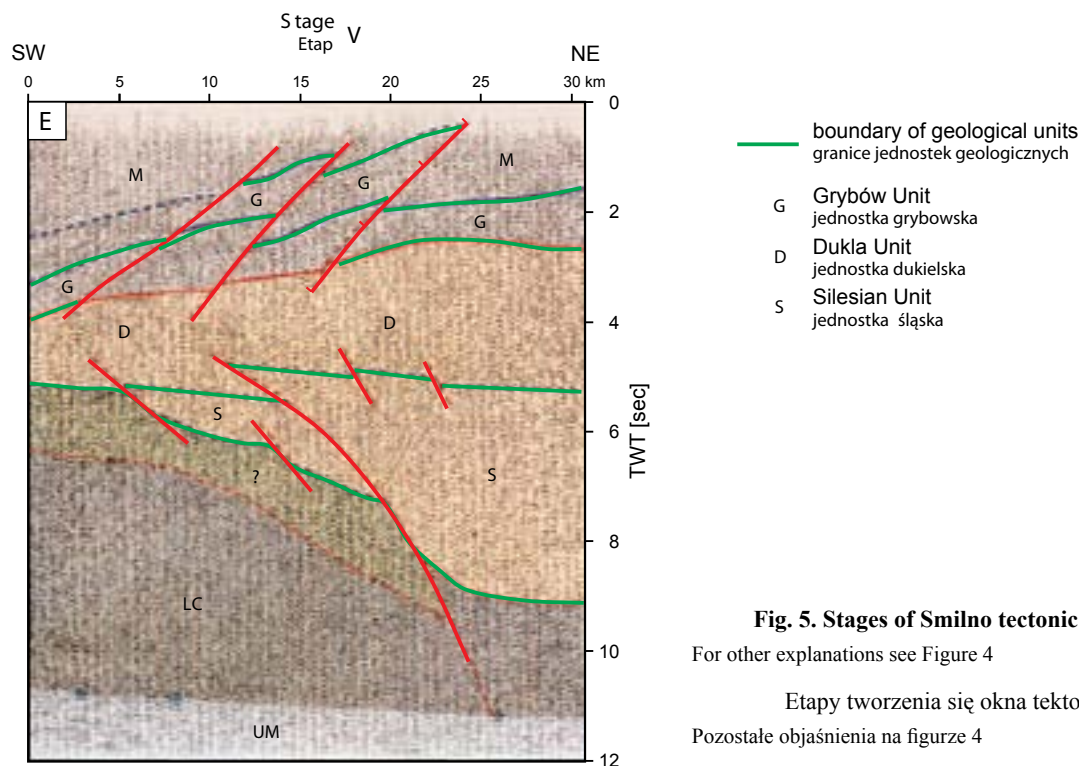
Interpretacja tektoniczna profilu sejsmicznego 80/87 (według Santawy, Vozara, red., 1999)

lesian and Dukla units, overlain by the Grybów and Magura units.

In the next stage (Fig. 5B), there was a restructuring of the Makovice Ridge, transmitting into the Silesian and Dukla unit rocks. Discontinuous tectonic deformation is observed. A series of fault zones developed, cutting both the ridge and

the overlying rocks of the Silesian Unit and the bottom parts of the Dukla Unit. The fault planes are angled towards the NE and strike towards the NW–SE. The contact surface between the Silesian and Dukla units became disturbed. The Magura and Grybów units are the overburden that is still undisturbed. In the following stage (Fig. 5C), tectonic deforma-





**Fig. 5. Stages of Smilno tectonic window formation**

For other explanations see Figure 4

Etapy tworzenia się okna tektonicznego Smilna

Pozostałe objaśnienia na figurze 4

tion was transferred into the Grybów and Magura units. This is not only discontinuous deformation, but also folding that started as a result of stress directed from the SW.

In the next stage (Fig. 5D) stress from the SW played a significant role. As a result, the Grybów and Magura units and the top part of the Dukla Unit were shifted towards the NE in relation to the Dukla and Silesian units. Within the Grybów and Magura units, SW-dipping faults developed, which continued into the top part of the Dukla unit. They can take the character of imbrications. A resisting element (regional slope of the basement), located in the north, began to play an important role.

In the last stage (Fig. 5E), the main processes are the shortening and stacking of the Grybów and Magura units and

the top part of the Dukla unit. As a result, the Magura Unit broke up and the Dukla and Grybów units, today present in the Smilno window, were uplifted to the surface along discontinuity planes. Here, we observe the essential role of “the regional slope of the basement”, as a resisting element.

In each case described, the occurrence of a tectonic window within flysch masses was associated with the occurrence of a resisting element in the consolidated basement of the Carpathians, to the south of the window zone. This element was an obstacle to the northward movement of flysch masses. It hampered the movement, resulting in the creation of a vertical component of forces, causing an uplift of the flysch masses from the depth to the surface. In the case of the Smilno window, it was the Makovice Ridge.

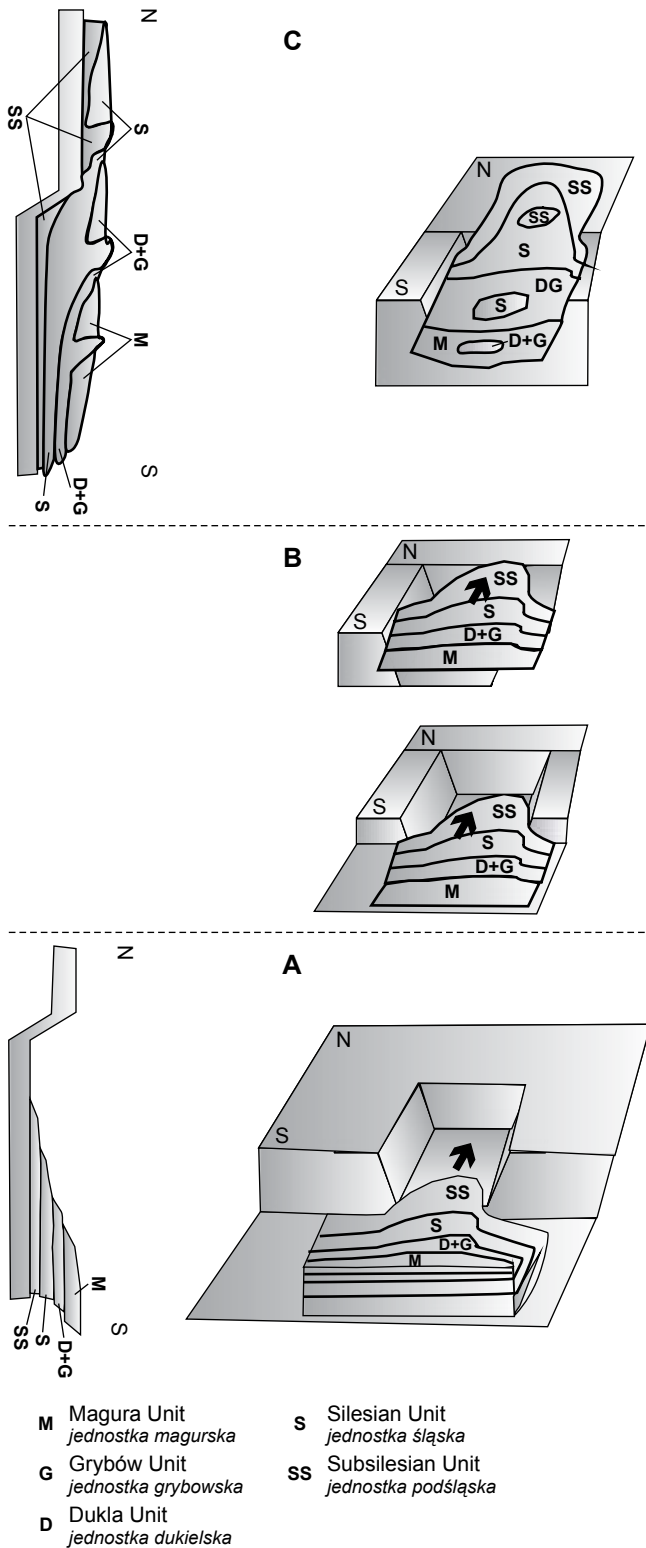
## CONCLUSIONS

According to Ryłko and Tomáš (Ryłko, Tomáš, 2001), three general stages (Fig. 4) can be distinguished in the formation of tectonic windows within flysch masses.

In the first stage (Fig. 6A), the nappes, partly thrust over each other, and the partially folded flysch masses were located south of the resisting element in the basement. This element was not homogeneous: there were elevations – “horsts”, and depressions – “grabens”. The depressions were the predisposed areas facilitating partial “pouring” of flysch masses into them. In the case of the Smilno window, the Makovice Ridge was the resisting element in the initial stage; in

the next stages, the role was played by the “regional slope of the basement”.

In the second stage (Fig. 6B), the nappes continuously moved towards the north. They piled up in front of the resisting element, and were partly emplaced over it. The Makovice Ridge was the resisting element over which the flysch rocks were emplaced. The role of the main resisting element, inducing a compressional field, was the “regional slope of the basement” located in the north. This is a compressional stage of horizontal shear. The nappes were stacked: the deeper their position, the stronger their



**Fig. 6. Final stage of tectonic window formation**  
(after Rylko, Tomáš, 2001)

Ostatni etap formowania okna tektonicznego Smilna  
(według Rylki, Tomasia, 2001)



stacking. In front of the nappes, folds of strongly reduced northern flanks, or frequently even slices were formed. Reverse faults that had formed before, became transformed into overthrusts. Such tectonic features are now observed in the southern margin of the tectonic windows of Żywiec, Mszana Dolna and Klęczany–Pisarzowa.

The third stage (Fig. 6C) was the final step in the formation of the windows. The flysch masses migrated further northwards and were completely emplaced over the resisting element of the basement. The shallower-seated nappes became broken up by the stacked (or stacking) deeper-seated nappes. This break-up may have been compounded by gravity flow of the nappes after they had emplaced over the resisting element. This step refers only to the tectonic windows located north of the “regional slope of the basement”.

Ultimately, a gradational system of tectonic windows was formed, in which the Smilno window is included in the southernmost part of the system.

In the southernmost area, the windows developed within the Magura Unit from below which the elements of the Grybów and Dukla units, locally even of the Silesian Unit, are exposed. These are the Sopotnia, Mszana Dolna, Szczawa, Grybów, Ujście Gorlickie, Świątkowa, Ropa and Smilno windows. A more external (northern) generation is represented by the windows within the Dukla–Grybów Unit from below which the Silesian Unit rocks are exposed. An example might be the Klęczany–Pisarzowa window. The northernmost family of windows is represented by those within the Silesian Unit from below which the Sub-Silesian Unit rocks are exposed. These are the Dziegiełłów, Ustroń and Żywiec windows.

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