Geological Quarterly, 2025, 69, 29
DOI: https://doi.org/10.7306/gq.1802

Junction area between the Western and Eastern Outer Carpathians (Ukraine) as the contact of two accretionary prisms: geological structure, sedimentary features and stratigraphy based on foraminifera

Oleh HNYLKO[1, *], Svitlana HNYLKO[1], Larysa HENERALOVA[2], Anna MUROVSKAYA[3, 4], Milena BOHDANOVA[1, 2], Oleksiy DVORZHAK[2] and Kseniia NAVARIVSKA[1, 2]

[1] National Academy of Sciences of Ukraine, Institute of Geology and Geochemistry of Combustible Minerals, Naukova 3a, 79060 Lviv, Ukraine, ORCID: 0000-0001-5983-952X [O.H.], 0000-0002-4167-3514 [S.H.], 0000-0002-7850-4482 [M.B.]

[2] Ivan Franko Lviv National University, Faculty of Geology, Mykhailo Hrushevskyi 4, 79005, Lviv, Ukraine, ORCID: 0000-0002-6033-6556 [L.G.], 0009-0005-8122-1108 [K.N.]

[3] National Academy of Sciences of Ukraine, Institute of Geophysics, Kyiv, Ukraine, ORCID: 0000-0001-8034-7335 [A.M.]

[4] University of Parma, Department of Chemistry, Life and Environmental Sustainability, Parma, Italy

Hnylko, O., Hnylko, S., Heneralova, L., Murovskaya, A., Bohdanova, M., Dvorzhak, O., Navarivska, K., 2025. Junction area between the Western and Eastern Outer Carpathians (Ukraine) as the contact of two accretionary prisms: geological structure, sedimentary features and stratigraphy based on foraminifera. Geological Quarterly, 69, 29; https://doi.org/10.7306/gq.1802

At the junction area where the Outer Western Carpathian and Outer Eastern Carpathian accretionary prisms converged, the first was developed ahead of the moving Alcapa Terrane, and the second one ahead of the Tisza-Dacia Terrane. We have compiled a new geological map of the junction area, located in the Latorytsa and Pynya river basins, comprising the Burkut and Svydovets nappes of the Fore-Marmarosh (Fore-Tisza-Dacia) prism and the Dukla Nappe of the Fore-Alcapa prism. The sedimentary formations of these nappes, composed mainly of turbidites and similar deposits, contain foraminifera, which allow us to determine the age of the most of these formations that range from the mid-Cretaceous to the Eocene. Our mapping shows that the Burkut and Svydovets nappes of the Eastern Carpathians plunge to the west under the Dukla Nappe of the Western Carpathian. The thrust boundary between the nappes is deformed and forms gentle antiforms and synforms. In addition, strike-slip faults of sub-Carpathian (NW–SE) direction cut these structures. We mapped broken formations and tectonic mélanges along these faults. The thrusting of the Dukla Nappe of the Fore-Alcapa prism over both Burkut and Svydovets nappes of the Fore-Marmarosh prism was probably caused by the collision of the Alcapa Terrane (upper plate) and Tisza-Dacia Terrane (lower plate) in late Eocene to early Oligocene time. Subsequent movement along NW–SE strike-slip faults may have been caused by the lateral extrusion of the East Carpathian formations towards the Western Carpathians.

Key words: Western and Eastern Outer Carpathians, Dukla, Burkut and Svydovets nappes, accretionary prism, stratigraphy, foraminifera, geological structure, sedimentary features.

INTRODUCTION

The Outer Carpathians belong to the flysch nappe belt located between the Alcapa Terrane, the Tisza-Dacia Terrane and the European platform. One nappe system bounding the Alcapa Terrane is developed in the western part of this belt, and another nappe system bounding the Tisza-Dacia Terrane is located in its eastern part. (Fig. 1; Mahel, 1973; Shakin, 1978; Vialov et al., 1981; Csontos and Vörös, 2004; Jankowski et al., 2004, 2007; Horvath and Galacz, 2006; Hnylko, 2011b; Kováč et al., 2016, 2017).

* Corresponding author, e-mail: ohnilko@yahoo.com

Received: October 11, 2024; accepted: July 9, 2025; first published online: September 19, 2025

The Ukrainian Carpathians occupy the junction where the Outer Western and Outer Eastern Carpathian nappe systems converged (Fig. 1; Horvath and Galacz, 2006; Hnylko, 2012), though the structure of this junction is disputable (see Hnylko et al., 2015a and references therein). There are two main concepts about this structure. The first assumes that the main internal nappes of the Outer Carpathians, such as the Burkut (Porkulets after Kruglov, 1986) and Dukla nappes, belong to both the Eastern and Western Carpathians (Kruglov, 1986; Matskiv et al., 2003; Kruhlov and Hyrsky, 2007; Matskiv, 2009). In accordance to this idea, these internal nappes stretch out from the Uzh River near the Ukrainian-Polish border up to the Cheremosh River basin near the Ukrainian – Romanian border in the Ukrainian part of the orogen. In line with this concept, balanced cross-sections and reconstructions of the Ukrainian Carpathian accretionary wedge were made (Nakapelukh et al., 2017, 2018; Roger et al., 2023). According to the second con-

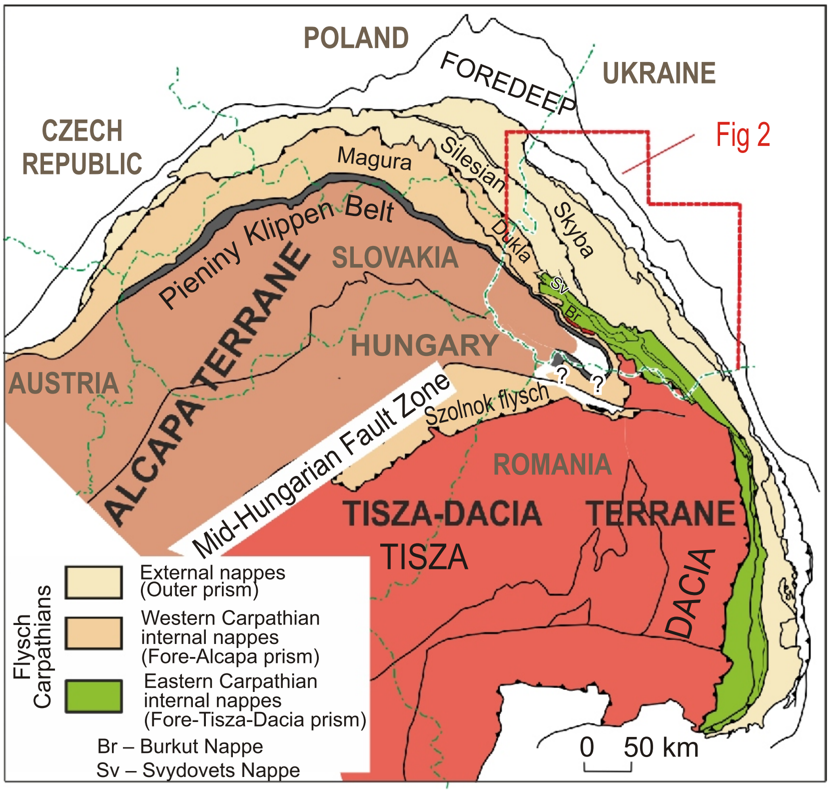


Fig. 1. The main tectonic units of the Carpathian-Pannonian region after Sandulescu (1988, 2009), Kováč et al. (1998, 2016), Csontos and Voros (2004), Horvath and Galacz (2006), Oszczypko (2006), Schmid et al. (2008, 2020), Hnylko (2012) and Murovskaya et al. (2025), simplified and partly modified

cept, the Outer Carpathians internal flysch nappes do not extend from the western to the eastern part of the Ukrainian Carpathians (Mahel, 1973; Shakin, 1976; Vialov et al., 1981; Csontos and Vörös, 2004; Jankowski et al., 2004, 2007; Horvath and Galacz, 2006). It was also inferred that the boundary between the Eastern and Western Carpathians is expressed by the complicated Latorytsa-Stryi strike-slip zone (Hnylko, 2011a, 2012), which was probably related to the lateral extrusion of the East Carpathian formations to the north-west (Hnylko, 2017).

Thus, the location and structure of the junction, where the internal nappes of the Outer Western Carpathians and Outer Eastern Carpathians converge, remain controversial, and variously depicted (Matskiv et al., 2003; Csontos and Vörös, 2004; Jankowski et al., 2004, 2007; Horvath and Galacz, 2006; Kruhlov and Hyrsky, 2007; Matskiv, 2009; Hnylko, 2011a, 2012). This uncertainty is due, first of all, to incomplete biostratigraphic study of the strata of this area, especially the thick sandstone and sandy flysch deposits with poor microfauna. These sandy deposits are of similar origin (sandy turbidites and/or grain-flow deposits) and different ages (from the Lower Cretaceous to the Eocene), and belong to different tectonic units (nappes) from both Eastern and Western Carpathians, although they are practically indistinguishable in field geological mapping without palaeontological dating. For example, the age of the sandy Burkut Formation, which belongs to and indicates the Burkut Nappe in this junction area, has not been constrained palaeontologically, with the exception of one locality (Byzova and Maslakova, 1974, see below). This stratigraphic uncertainty causes significant difficulties in identifying tectonic units and determining whether the deposits belong to the Eastern Carpathian or Western Carpathian units.

The state geological map of the junction region at 1:200,000 scale (Matskiv et al., 2003; Matskiv, 2009) and the international geologic map (Jankowski et al., 2004, 2007) at the same scale were compiled on the basis of geological mapping carried out in the 1960s–1980s. Stratigraphical, sedimentological and structural studies have not been conducted in this area since that time.

In this study, we have compiled a new geological map, and also complement knowledge regarding the lithostratigraphy, foraminiferal biostratigraphy, sedimentology and tectonic structure of the junction area between the internal Outer Western and internal Outer Eastern Carpathian nappes, identifying tectonic units (nappes) located in this area and determining their stratigraphic content, boundaries and structure as well as some features of their origin and evolution. We consider that understanding the origin of the lateral coupling of these two Carpathian nappe systems (= accretionary palaeoprisms, see Oszczypko, 2006; Hnylko, 2012; Kováč et al., 2016, 2017; Golonka et al., 2019; Roger et al., 2023 and references therein) can help to understand the nature of such coupling of accretionary (palaeo)prisms in general.

GEOLOGICAL OUTLINE

The Outer Carpathians are made of several thin-skinned nappes thrust over each other towards the north-east and over the Miocene Carpathian Foredeep. These nappes consist of Upper Jurassic–Neogene, mainly flysch deposits uprooted from their original substratum. The main Outer Carpathian nappes have their own lithostratigraphy and tectonic structure and are therefore considered as structural-facies/tectonic units

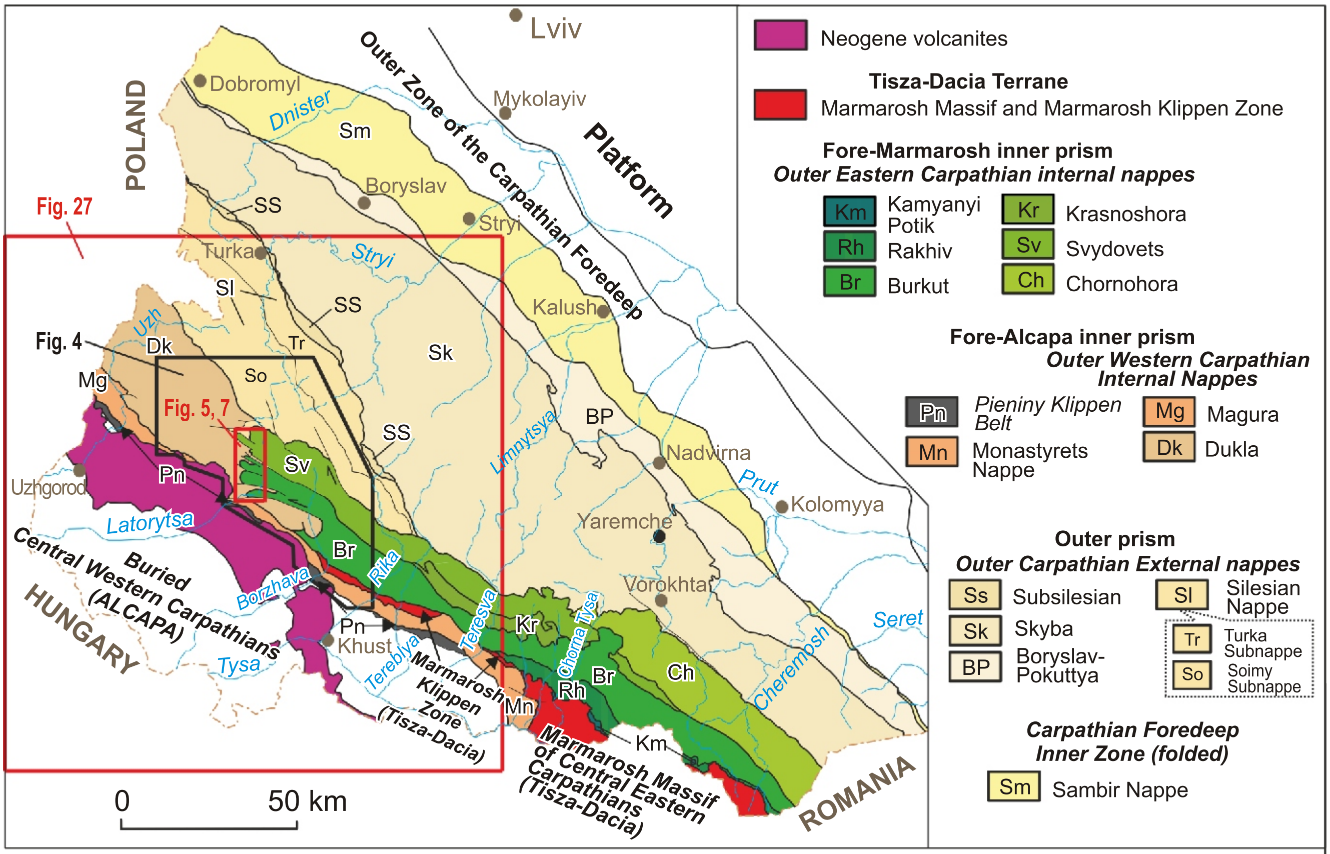


Fig. 2. The main tectonic units of the Ukrainian Carpathians (Hnylko, 2012; Murovskaya et al., 2025, modified)

(e.g., Vialov at al., 1981; Golonka et al., 2006, 2019; Horvath and Galacz, 2006; Oszczypko, 2006; Gawęda et al., 2019, 2021; Kowal-Kasprzyk et al., 2021). The Outer Carpathians form an arc, which envelops the Central Western and Central Eastern Carpathians belonging to the Alcapa and Tisza-Dacia terranes respectively (Kováč et al., 1998, 2016, 2017; Csontos and Vörös, 2004; Oszczypko, 2006; Golonka et al., 2006, 2019; Horvath and Galacz, 2006; Schmid et al., 2008, 2020; Hnylko, 2012).

On the basis of previous research (Danysh, 1973, 2004; Byzova and Beer, 1974; Vialov et al., 1981; Kruglov, 1986; Csontos and Vörös, 2004; Jankowski et al., 2004, 2007; Săndulescu et al., 1981; Săndulescu 1984, 1988, 2009; Hnylko, 2011b, 2012; Hnylko et al., 2015a-c; Schmid et al., 2020 and references therein) and our own data, the following main tectonic elements related to the formation of the junction between the Western and Eastern Carpathians (listed from internal to external ones) can be identified in the Ukrainian part of the Carpathian orogen (Figs. 1 and 2):

Central Western Carpathians: part of the Alcapa Terrane buried beneath Neogene deposits of the Transcarpathian Basin (Hnylko, 2011b; Murovskaya et al., 2023, 2025) and cropping out in the Western Carpathians outside of Ukraine. As a whole, Central Western Carpathians represent a pile of crystalline basement and cover, thick- and thin-skinned nappes thrust over the Outer Carpathians (see Plašienka, 2018; Schmid et al., 2020 and references therein).

Central Eastern Carpathians: part of the Tisza-Dacia Terrane including both the Marmarosh Crystalline Massif, and the Marmarosh Klippen Zone (see Figs. 1 and 2). In Ukraine, the *Marmarosh Massif* is composed of Precambrian and Paleozoic metamorphic rocks, and Upper Paleozoic and Meso-Cenozoic strata. It is dismembered into thick-skinned basement Marmarosh nappes thrust over the Outer Carpathians (Matskiv et al., 2009a, b). These basement nappes were formed in the Early Cretaceous and sealed by a Late Cretaceous-Paleogene post-nappe cover (Matskiv et al. 2009a, b). In Romania, the basement nappes are overlapped by Transylvanian ophiolitic nappes (Săndulescu et al., 1981; Horvath and Galacz, 2006).

The *Marmarosh Klippen Zone* (=*Vezhany Nappe*) is located in the north-west prolongation of the Marmarosh Crystalline Massif between the Monastyrets Nappe and the Outer Carpathians. It consists only of a Cretaceous-Paleogene sedimentary succession with thick (>1000 m) Aptian-Albian olistostrome/conglomerate deposits at its base. These deposits belonging to the Soymul Formation contain clasts of both crystalline metamorphic rock of the Marmarosh Massif and ophiolites (including ultrabasites and basalts; Hnylko et al., 2015b). Olistostrome/conglomerate deposits of the Soymul Formation can be correlated (Hnylko et al., 2015b and references therein) with the Barremian-Albian wildflysch succession in Romania, which either forms an independent tectonic unit after Höck et al. (2009) or lies on top of the Bucovinian sequence (part of the Central Eastern Carpathians) and underlies the Transylvanian ophiolite nappes according to Săndulescu (1984). The Cretaceous-Paleogene succession of the Marmarosh Klippen Zone can be assigned to the post-nappe cover, which originally was lying on the Central Eastern Carpathian nappes (Horvath and Galacz, 2006). Subsequently, the Marmarosh Klippen Zone sedimentary succession was detached from the Marmarosh Massif substrate and thrust over the Outer Carpathians (Hnylko et al., 2015b; Hnylko and Hnylko, 2016). Similarly, the wildflysch succession of the Romanian Central Eastern Carpathians was thrust as an independent tectonic unit over the

Flysch Carpathians (Höck et al., 2009). Therefore, the Marmarosh Klippen Zone, as part of the Marmarosh Massif cover, can be assigned to the Dacia unit.

The **Pieniny Klippen Belt** forms the boundary between the Central Western Carpathians and the Outer Western Carpathians, and wedges to the SE into the Central Carpathian area between the Alcapa and Tisza-Dacia terranes. In Ukraine, it is represented by a Jurassic-Paleogene sedimentary succession. The strata are intensely deformed, up to mélange structure formed by isolated blocks or "klippens" composed of competent Jurassic to Lower Cretaceous limestones surrounded by a soft matrix consisting of mainly Upper Cretaceous Puchov red marls (Kruglov, 1986; Plašienka and Soták, 2015). These intensely deformed strata are unconformably overlain by Eocene conglomerates (Kruglov, 1986; Hnylko et al., 2015b and references therein).

Flysch Carpathians (= Outer Carpathians+Monastyrets Nappe). The *Monastyrets Nappe* is made of a Paleogene succession containing typical flysch deposits of the Paleocene–Eocene Sushmanets Formation and sandstones of the Eocene Drahovo Formation (Hnylko and Hnylko, 2016 and references therein). Most likely, the Monastyrets Nappe is a prolongation of the inner part of the Western Carpathian Magura Nappe (Byzova and Beer, 1974; Oszczypko, 2004; Oszczypko et al., 2005) wedged (as well as the Pieniny Klippen Belt, see above) between the Tisza-Dacia and Alcapa terranes (see Hnylko and Hnylko, 2016; Kováč et al., 2016 and references therein), and further in the article is called the "between-terrane" flysch.

The *Outer Western Carpathian Fore-Alcapa internal flysch nappes (units)* are located ahead of Central Western Carpathian nappes. They contain the Magura and Dukla thin-skinned nappes, comprising Paleogene and Cretaceous-Paleogene flysch respectively (Figs. 1–3).

The *Outer Eastern Carpathian Fore-Marmarosh (Fore-Tisza-Dacia) internal flysch nappes (units)* are situated ahead of Marmarosh basement nappes and built of the Kamyanyi Potik, Rakhiv, Burkut and Krasnoshora nappes formed of Cretaceous flysch, as well as the Svydovets and Chornohora nappes comprising Cretaceous-Paleogene deposits (Figs. 1–3).

The *Outer Carpathian external flysch-molasse nappes (units)* comprise the Silesian, Subsilesian, Skyba, and Boryslav-Pokuttya nappes. These thin-skinned nappes filled with Cretaceous-Miocene flysch and molasse deposits are thrust over each other and over the Carpathian Foredeep, towards the north-east (Figs. 1–3).

Therefore from the geological point of view, the boundary between the Eastern and Western Outer Carpathians is located between the Fore-Alcapa and Fore-Marmarosh internal nappes (see Horvath and Galacz, 2006; Hnylko, 2012; Figs. 1 and 2). The external Silesian, Sub-Silesian, Skole-Skyba nappes are located both in the Western and Eastern Outer Carpathians (Figs. 1 and 2).

According to Mahel (1973), Shakin (1976), Vialov et al. (1981), Csontos and Vörös (2004), Jankowski et al. (2004, 2007) and our own mapping (see below), the two Outer Carpathian internal nappe systems located in the Western Carpathians and Eastern Carpathians adjoin each other "laterally" in the junction area at the Borzhava and Latorytsya river basins (see Figs. 1 and 4). The Dukla Nappe (Western Carpathian) extends to this area from the NW as well as the Burkut and Svydovets nappes (Eastern Carpathians) having expanded here from the SE. The large Magura Nappe of the Western Carpathians is overlain by the Neogene volcanics in the Uzh River Basin (Fig. 2) and, as already mentioned, probably prolongs to the SE as the Monastyrets Nappe located between the Alcapa and Tisza-Dacia terrains (Byzova and Beer, 1974; Oszczypko, 2004; Oszczypko et al., 2005; Hnylko and Hnylko, 2016). The Kamyanyi Potik, Rakhiv, Krasnoshora, and Chornohora nappes of the Eastern Carpathians prolong from the SE to the NW and disappear from the earth's surface at the Chorna Tysa, Teresva and Tereblya river basins and so do not reach the junction between the Western and Eastern Carpathians (see Fig. 2).

Therefore, in the basins of the Borzhava and Latorytsa rivers, the boundary between the Outer Eastern Carpathian internal nappes represented by the **Burkut and Svydovets nappes** and the Outer Western Carpathian internal nappes are expressed by the **Dukla Nappe** is located. This junction area is bordered by the Outer Carpathian external **Silesian Nappe** in the northwest. Next, we will briefly describe these tectonic units.

GENERAL DESCRIPTION OF THE BURKUT, SVYDOVETS, DUKLA AND SILESIAN NAPPES

The **Burkut Nappe** (Porkulets Nappe after Kruglov, 1986 as well as Sukhiv+Burkut units after Mahel, 1973; Shakin, 1976; Vialov et al., 1981; Jankowski et al., 2007) is the largest tectonic nappe among the Ukrainian Outer Eastern Carpathian internal nappes. We accept the name of this tectonic unit after Świdziński (1947). It is a prolongation of the Bodoc digitation of the Ceahleu Nappe of the Romanian Carpathians (Kruglov, 1986; Matskiv et al., 2009a, b). The Burkut Nappe is composed of a continuous Jurassic-Cretaceous succession (no unconformities are recorded) represented by the Trostyanets, Bila Tysa, Burkut, Sukhiv and Tereshova formations (see Fig. 3).

The Trostyanets Formation is developed in the front of the Burkut Nappe at the base of the Burkut succession as lenses of the Jurassic-Lower Cretaceous limestone and mafic volcanic rocks of both oceanic and continental origin (according to Liashkevych et al., 1995; Hnylko and Vaschenko, 2010; Generalova et al., 2013).

The Bila Tysa Formation (Slavin, 1956), up to 1000 m thick, is composed of thin- and medium-bedded grey and green-grey flysch with sandstone and conglomerate packages in its upper part. The age of the Bila Tysa Formation is Uppermost Barremian?-Albian (Pasternak et al., 1966; Gorbachyk and Byzova, 1974; Leshchukh, 1979, 1980; Vialov et al., 1989; Romaniv, 1991, 1999).

The Burkut Formation (Sujkowski, 1930), up to 1000 m thick, partly replacing the Bila Tysa Formation, is represented by sandstones and sandy flysch (Byzova, 1979), and completes the stratigraphic succession of the Burkut Unit over most of its outcrop. Its age is Albian-Cenomanian (Byzova et al., 1966a; Byzova and Maslakova, 1974; Vialov et al., 1988).

The Sukhiv Formation (Kulchytskyi et al., 1965), 200 m thick, locally overlies the Burkut and Bila Tysa formations. It is represented by green-grey and variegated (red and green) marls and shales (Vialov et al., 1981, 1989). Its age is Cenomanian-Coniacian (Vialov et al., 1989; Romaniv, 1991, 1999).

The Tereshova Formation (Dabagyan et al.,1967), up to 500 m thick, is composed of medium- and thick-bedded sandy flysch deposits with conglomerates in upper part. It is assigned to the Senonian (Gabinet at al., 1976; Vialov et al., 1988).

Some authors (Byzova and Maslakova, 1974; Byzova and Beer, 1974; Kruglov and Smirnov, 1979; Kruglov, 1986; Ślączka et al., 2006; Shlapinskyi, 2012; Nakapelukh et al., 2017; Roger et al., 2023) considered that the Cretaceous deposits of the Burkut (Porkulets) Nappe are stratigraphically normally overlain by the Paleogene flysch. However, such transi-

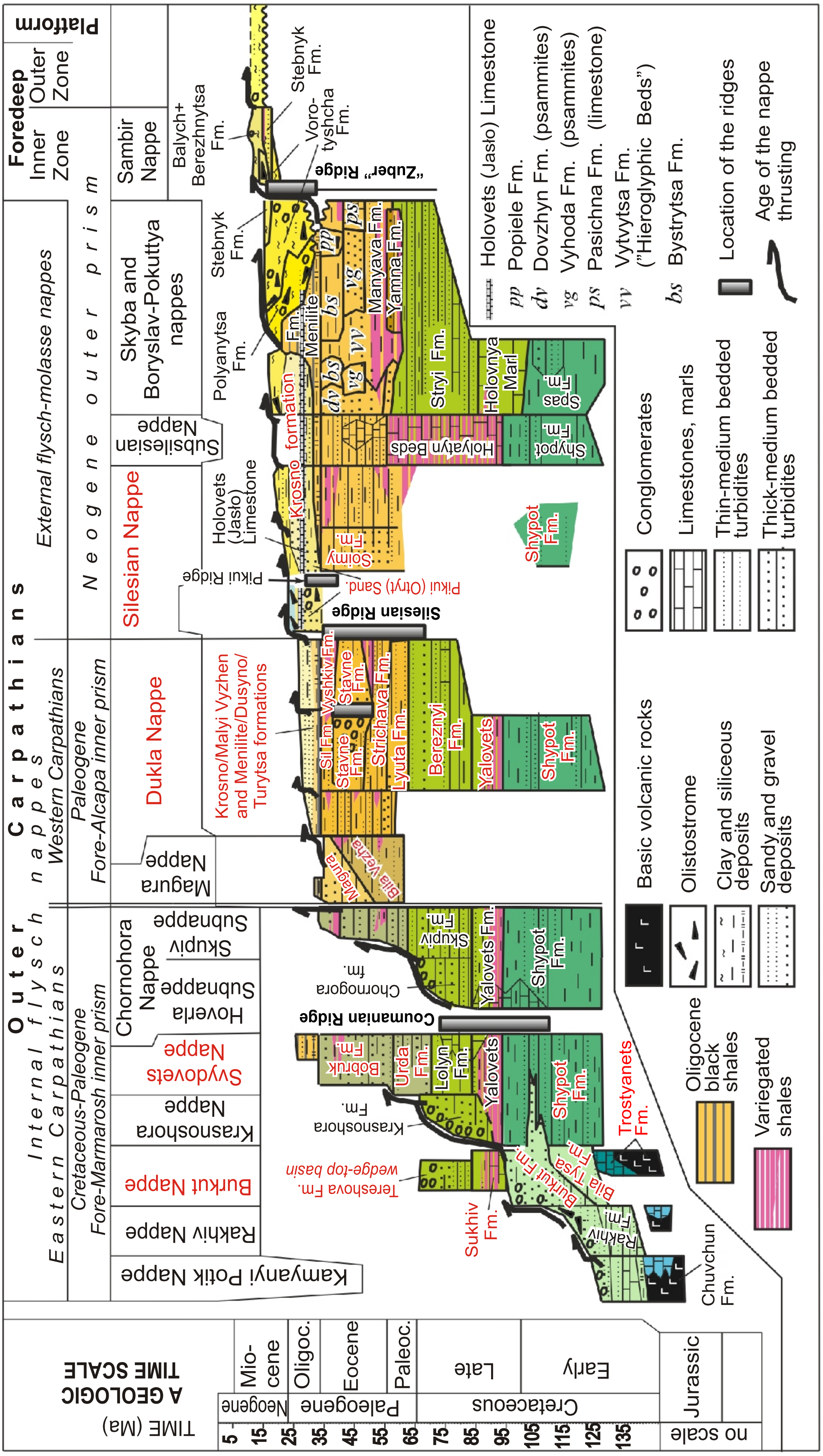


Fig. 3. Lithostratigraphic table of the Outer Carpathians in Ukraine (Hnylko, 2011b; Hnylko et al., 2015a, 2023; Hnylko and Hnylko, 2024) simplified and modified

The units marked in red are shown in Figures 4–7

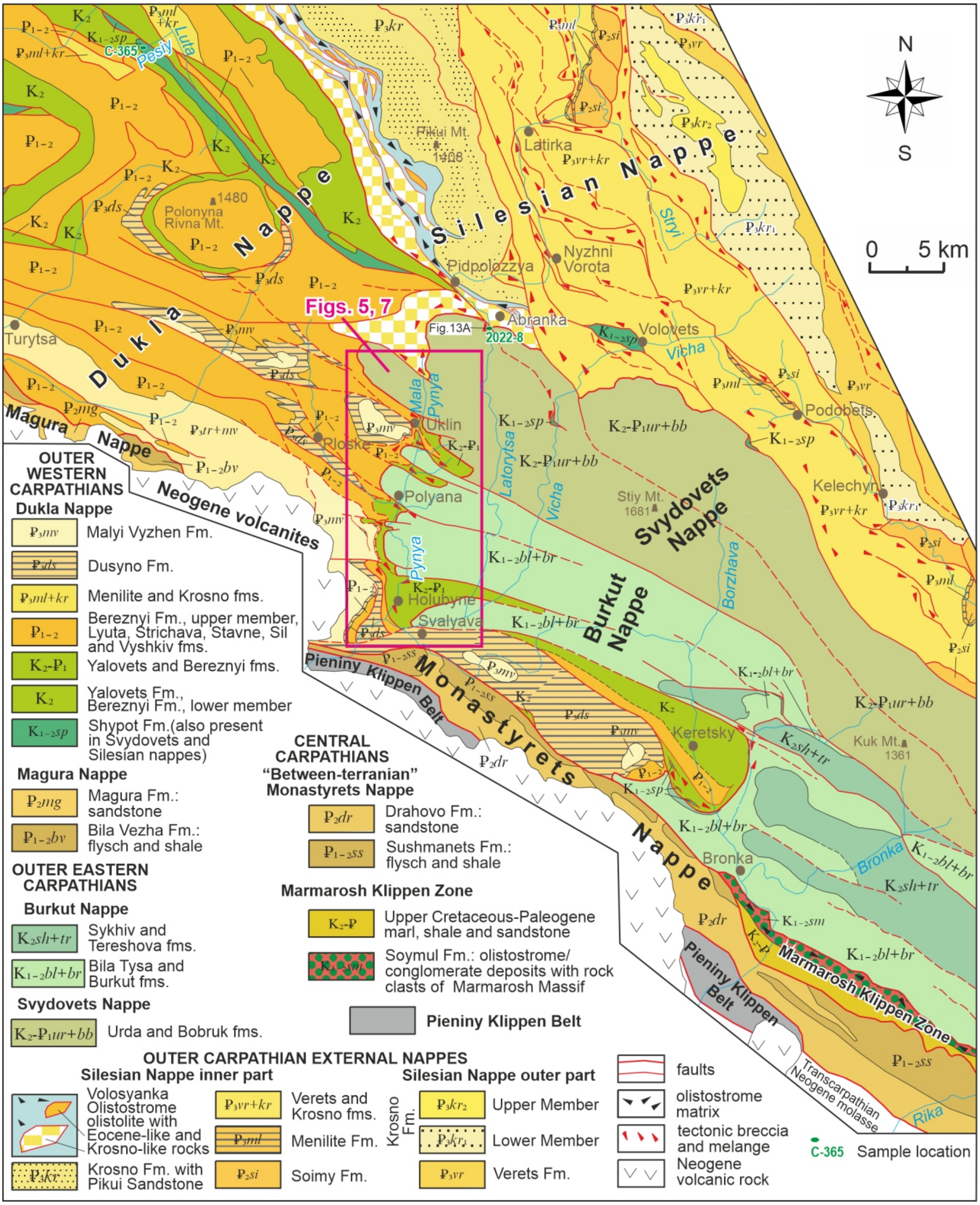


Fig. 4. Geological map of the junction area between the Internal nappes of the Outer Eastern Carpathians and Outer Western Carpathians as well as adjacent territories and position of the area mapped

Compiled on the basis of previous maps (Shakin, 1976; Matskiv et al., 2003, 2009a, b; Jankowski et al., 2004, 2007; Matskiv, 2009) and our observations along the large rivers as well as detailed geological mapping (scale 1:25,000) carried out in the basin of the Borzhava River (near the villages of Keretsky and Bronka) and in the basins of the Latorytsa and Pynya rivers (near the city of Svalyava and the villages of Holubyne, Polyana and Uklin) of the Transcarpathian region. The map also shows some results of the geological mapping of the the Silesian Nappe carried out as preparation for the Ukrainian State Geological Map at 1:200,000 scale (Stryi sheet) published partly (Hnylko, 2011a; Hnylko et al., 2021) tions from the Cretaceous to the Paleogene have not been observed and palaeontologically are not proven, and we assume, following Danysh (1973), Shakin (1976), Vialov et al. (1981, 1989), Andreyeva-Grigorovich et al. (1985), and Jankowski et al. (2007), that the Tereshova Formation is not overlain by any younger deposits (see Fig. 3), and that the Paleogene flysch exposed near the Tereshova Formation belongs to the Dukla Nappe located nearby.

The **Svydovets Nappe** (Blyznytsa Subnappe of the Dukla Nappe after Kruglov, 1986) is a tectonic unit of the Ukrainian Outer Eastern Carpathian internal nappes (see Figs. 1, 3 and 4). It extends from the Cheremosh and Prut River basins in the SE, towards the Latorutsa and Pynya River basins in the NW (Hnylko, 2012; Hnylko and Hnylko, 2012 and references therein).

Some researchers attribute the Svydovets tectonic element to either the Dukla Nappe (Kruglov, 1986) or the Silesian Nappe (Beer et al., 1971; Danysh, 2004). However, the Svydovets Nappe is characterized by its own tectonic style and characteristic stratigraphic succession (including a notable development of thick Paleocene-Eocene sandy deposits and the almost complete absence of Oligocene strata: see Hnylko and Hnylko, 2012). Thus, we attribute this nappe to a separate tectonic element following Vyalov et al. (1981).

The Svydovets Nappe is composed of Cretaceous-Paleogene flysch deposits, as a continuous sedimentary succession of the Shypot, Yalovets, Lolyn, Urda and Bobruk formations and minor Oligocene deposits (see Fig. 3). The Cretaceous Shypot, Yalovets and Lolyn formations and Oligocene strata are developed mainly in the eastern part of the Svydovets Unit and do not reach the surface near the junction of the Western and Eastern Carpathians, where the Senonian-Eocene Urda and Bobruk formations dominate (see Fig. 4).

The Urda Formation (Vialov and Tsarnenko, 1970), up to 900 m thick, is represented by medium-bedded sandstones alternated with green and grey, rarely black, mudstones and siltstones. Its age is Senonian-Paleocene (Beer at al., 1971; Tsarnenko,1988 and references therein; Vialov et al., 1989).

The Bobruk Formation (Beer et al., 1971), up to 1600 m thick, consists of thick-bedded sandstones with minor green, grey and rarely red clay shales. It overlies the Urda Formation and completes the stratigraphic succession of the Svydovets Nappe over the greater part of its territory (Hnylko and Hnylko, 2012). The age of the Bobruk Formation is assigned to the Paleocene-Eocene (Hnylko and Hnylko, 2012).

The **Dukla Nappe** is the largest tectonic unit among the Ukrainian Outer Western Carpathian internal nappes. It extends from Slovakia and Poland (see Jankowski et al., 2004) to the Borzhava and Latorytsa river basins in Ukraine (see Fig. 4). The Dukla sedimentary succession is continuous and consists of the Cretaceous Shypot and Yalovets formations, the Upper Cretaceous-Paleocene Bereznyi Formation, the Paleocene-Eocene hieroglyphic-type deposits and the Oligocene Menilite, Dusyno, Turytsa, Krosno and Malyi Vuzhen formations (see Fig. 3).

The Shypot Formation (Paul,1869) is represented by black and green-grey shales (lower part up to 500 m thick), and medium-bedded black siliciclastic “glassy” sandstones and shales (upper part 150–180 m thick; Leshchukh, 1988a). The uppermost part of the Shypot Formation contains green clay shales with cherts (Vialov et al., 1981; Hnylko et al., 2023). Ammonites of Aptian age were found in the lower part of the Shypot Formation (Tsarnenko and Leshchukh, 1974; Vialov et. al., 1989). Foraminifera of late Albian and Albian-Senomanian age were found in the upper part of the Shypot Formation according to Byzova et al. (1966b). The age of the Shypot Formation is Barremian?-Albian after Vialov et. al (1989) and also ranges into the Cenomanian after Byzova et al. (1966b) and Hnylko et al. (2023).

The Yalovets Formation (Kulchytskyi, 1959) consists of variegated (red and green) shales (lower part 20–30 m thick), and green shales and thin-bedded turbidites (upper part 100–200 m thick). Its age is assigned to the Turonian-Santonian (Maslakova, 1965; Romaniv, 1991, 1999; Hnylko, S.R. et al, 2023). The Bereznyi Formation (Vialov, 1960), up to 1000 m thick, is composed of thin- to medium- and thick-bedded typical turbidite flysch: alternations of polymictic sandstones, siltstones, black and grey mudstones and marls (Vialov and Danysh, 1988). The age of the Bereznyi Formation is assigned to the Campanian-Danian (Romaniv, 1991, 1999).

Paleocene-Eocene deposits of the Dukla Unit are represented, according to Danysh (1973), Andreyeva-Grigorovich et al. (1985) and Vialov et al. (1988), by a number of formations (Figs. 3 and 4) comprising hieroglyphic-type bedded flysch deposits, sandstones and rarely conglomerates.

Oligocene deposits comprise the Menilite Formation, characterizated by non-calcareous black shales and cherts. The Menilite Formation is laterally replaced by both the Dusyno Formation with a predominance of black marls and the Turytsa Formation with siliciclastic “glassy” sandstones. The Dukla sedimentary succession is terminated by both the grey flysch of the Krosno Formation, located in the north of the Dukla Unit, and polimictic sandstones of the Malyi Vyzhen Formation situated in the south of the Dukla Unit (Danysh,1973; Vialov et al., 1981, 1988).

The **Silesian Nappe** belongs to the Outer Carpathian external nappes and extends from Poland (see Jankowski et al., 2004). In Ukraine it bounds to the NE the junction area of the Western and Eastern Outer Carpathian internal nappe systems. The stratigraphic succession of the Silesian Nappe in Ukraine includes Lower Cretaceous and Paleocene-Lower Miocene flysch deposits. Oligocene-Miocene deposits are widespread and pre-Oligocene strata are exposed locally (Vialov et al., 1981; Hnylko and Hnylko, 2019; see Fig. 3).

The Barremian?-Cenomanian Shypot Formation is locally exposed in the Vicha River basin near the Volovets (see Fig. 4; Hnylko et al., 2024). Turonian-Senonian deposits of the Silesian Nappe in Ukraine are not well-constrained. Typical pre-Oligocene deposits are composed mainly of Eocene black shale and flysch (Hnylko and Hnylko, 2019). The Oligocene–Miocene stratigraphic succession is represented by the Menilite Formation (black shales is typical), Verets Formation (transitional from the Menilite to Krosno formations) and Krosno Formation (grey flysch; Vialov et al., 1981; Hnylko and Hnylko, 2019).

MATERIALS AND METHODS

Geological mapping at 1:50,000 and in places 1:25,000 scale, and stratigraphic, tectonic and sedimentological documentation of the formations in the Latorytsa and Pynya River basins near the city of Svalyava and villages of Holubyne, Solochyn, Polyana and Uklin (Transcarpathian region, Mukachiv district, the vicinity of Svalyava,) was carried out during fieldwork in 2016 and 2019–2023 (Fig. 5). Detailed field mapping identified localities of the contact fault zones between the Eastern Carpathian and Western Carpathian tectonic units. Particular attention was paid to study of the exposed melanges and shear-zones (some of these were partly described by Hnylko, O. et al., 2023).

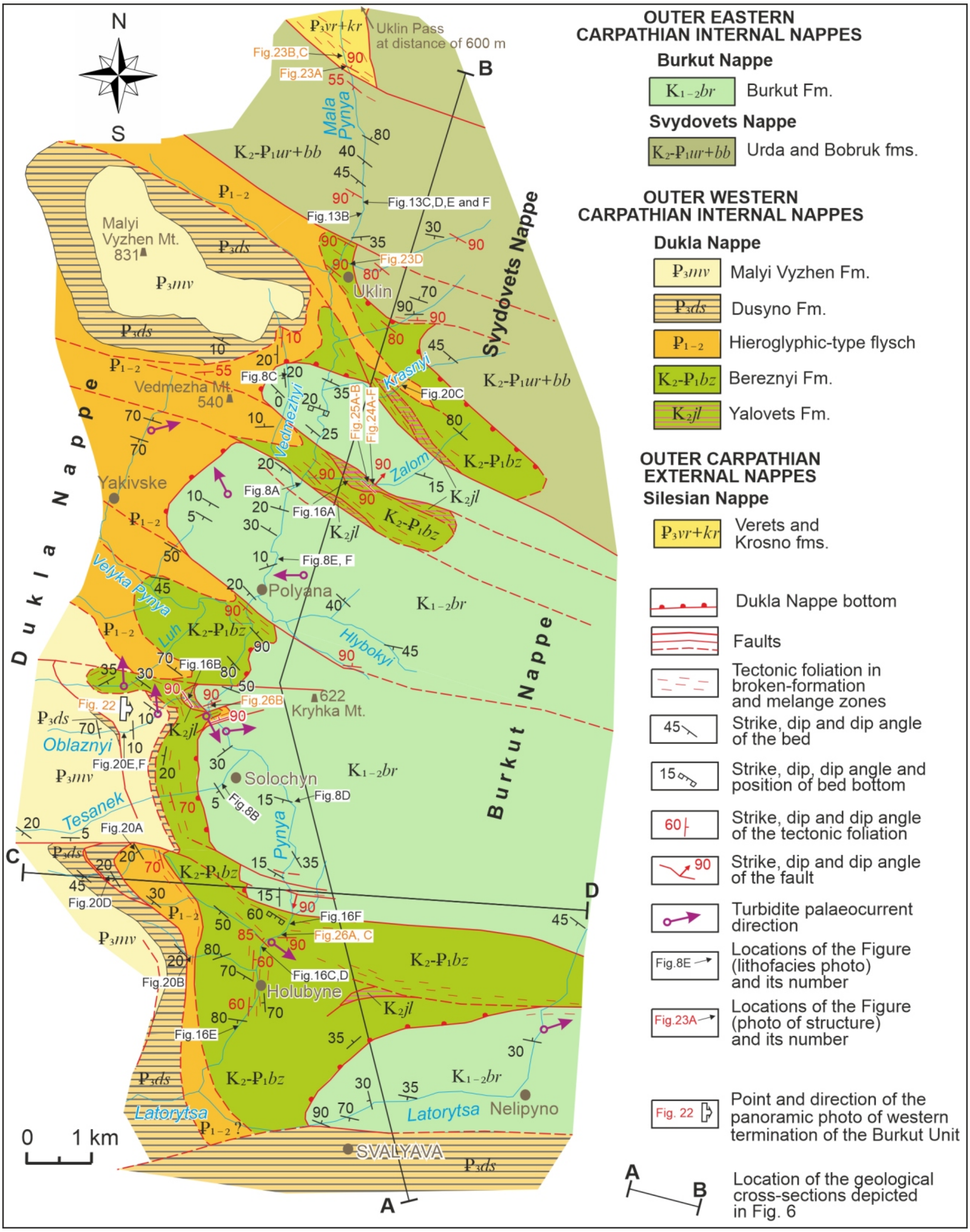


Fig. 5. Geological map of the study area (Transcarpathian region, Latorytsa and Pynya River basins, the vicinity of Svalyava); compiled by O. Hnylko

The area located at the junction of the Outer Eastern Carpathian internal nappes is represented by the Burkut and Svydovets nappes and the Outer Western Carpathian internal nappes are represented by the Dukla Nappe

Samples for micropalaeontological analysis were collected from both exposures along the 6 sections studied and the separate exposures located in the Burkut, Svydovets and Dukla units. As a rule, individual samples from the separate exposures were grouped in the compiled sections. Unfortunately, the poor exposure and intense deformation of the rocks did not allow study of complete successions of the sedimentary formations, and only parts of this succession were investigated. More than 100 samples were analysed in the micropalaeontological laboratory of the Institute of Geology and Geochemistry of Combustible Minerals of the National Academy of Science of Ukraine, Lviv. Among these, small foraminifera were found in 97 samples. A total of 74 species of agglutinated foraminifera and 3 species of planktonic foraminifera were identified.

RESULTS

As a result of our geological mapping, a geological map at 1:25,000 scale of the junction area of the Outer Eastern Carpathian Internal nappes (represented by the Burkut and Svydovets nappes) and the Outer Western Carpathian Internal nappes (represented by the Dukla Nappe) was compiled (Fig. 5) and geological cross-sections of this mapped area were drawn (Fig. 6). Lithostratigraphic, sedimentological and microfaunal (Fig. 7) studies made it possible to date and correlate the formations mapped, and on this basis to determine the stratigraphic content and boundaries of the the Burkut, Svydovets and Dukla tectonic units in this area.

LITHOSTRATIGRAPHY, SEDIMENTARY FEATURES AND CHARACTERISTIC FORAMINIFERA OF THE DEPOSITS STUDIED

As a rule, the lithostratigraphy and sedimentological features of the formation are described only on the basis of studying individual exposures and incomplete sections, since well-preserved sedimentary successions of the formations were not found due to intense deformation and poor rock exposure in the area mapped. It is difficult to establish the true thickness of the formations here for these reasons.

BURKUT NAPPE SEDIMENTARY SUCCESSION

The **Burkut Formation** (Albian-Cenomanian) constitutes the entire sedimentary succession of the Burkut Nappe in the area mapped (see Figs. 5 and 6). It is exposed on the banks of the Pynya, Mala Pynya and Latorytsa rivers and their tributaries. The contacts observed, of the Burkut Formation with the surrounding rocks, are tectonic. The formation is represented by massive, thick- and medium-bedded sandstones (Fig. 8A), some with grey siltstone and mudstone intercalations (Fig. 8B) as well as with thick packets of thin- and medium-bedded flysch. Occasionally, sedimentary lenses of matrix-supported microconglomerate are present and pebbles are scattered in the sandstones (Fig. 8C). These clastic rocks consist of quartz (up to 60–80%), feldspar, muscovite, redeposited flysch clasts and inclusions of carbonized organic matter. Metamorphic schist detritus was also noted.

The massive and thick-bedded Burkut Sandstone is the most widespread unit in the Burkut Formation. The sandstone beds are usually amalgamated, building bedsets up to several tens of metres thick. The bases of the beds are sharp and occasionally show flute and load casts (Fig. 8D). Clasts of flysch and other rocks (up to a decimetre across) are usually located in the lower part of the sandstone strata. In places, the sandy deposits are characterized by Bouma divisions T_a, T_{ab} and T_{abc} (Fig. 8E) as well as by thin- and the medium-bedded flysch packets of divisions T_{abc} T_{abcd} and T_{bcd} (Fig. 8F), which suggest deposition from turbidity currents. Matrix-supported sandy microconglomerates are interpreted as the products of high-density turbidity currents and/or grain/debris flows. Mudstone intercalations, locally present in the sandy deposits, can be interpreted as (hemi)pelagites and/or turbidites of Bouma division T_e. Several measured turbidite palaeocurrent directions are from the SW and E–SE (see Fig. 5).

Micropalaeontological studies were carried out on 5 exposed sections (1–5) with a length of 25–75 m and in individual samples from small exposures grouped into compiled sections (7–10), where 47 samples were analysed (Figs. 9–11), A total of 21 species of agglutinated foraminifera have been identified, but a large proportion of the foraminifera remain undetermined due to inconsistency with known species or poor preservation (see Figs. 9 and 10).

Among the foraminifera determined, some characteristic mid-Cretaceous species are distinguished.

Spiroplectinella gandolfii (Carbonnier) (Fig. 12O) is present: in the lower part of Section 2 (samples 2021-9-1; 2021-9-2); in middle part of the Compiled Section 9 (sample 2016-122); in individual sample 2016-110 near Section 5; and in Compiled section 10 (sample 2016-151). *S. gandolfii* is a characteristic species of the Albian-Cenomanian Burkut Formation (Byzova et al., 1966a; Byzova and Maslakova, 1974). This species is located in the upper part of the stratigraphic section of the deposits studied (Fig. 11).

Gerochammina stanislawi Neagy (Fig. 12S) is present: in Section 1 (samples 2021-5 and 2021-5-2); in Section 5 (sample 2021-23-2); in Compiled Section 10 (sample 2016-137). *G. stanislawi* is recorded in the Albian-Turonian of the Carpathians (Neagu, 1990).

Tritaxia gaultina (Morozova) (Fig. 12R) is present in Section 5 (sample 2021-23-2) together with *G. stanislawi*.

Recurvoides imperfectus (Hanzlikova) (Fig. 12P) is present: in Section 1 (samples 2021-5-1); in Section 5 (sample 2021-23-2) together with *G. stanislawi*; in Compiled Section 10 (individual sample 2016-151) together with *S. gandolfii*.

Kadriayina cf. *gradata* (Berthelin) (Fig. 12T) is present in the lowermost part of Compiled Section 10 (sample 2016-145).

The tubular species *Bathysiphon brosgei* Tappan (Fig. 12A, B), *Bathysiphon vitta* Nauss (Fig. 12C, D) and *Rhizammina algaeformis* Brady (Fig. 12I), which are cosmopolitan Cretaceous species in flysch facies according to Weidich (1990 with references therein), are common in the deposits studied. The species *Rhizammina indivisa* Brady (Fig. 12E), *Pseudonodosinella* cf. *troyeri* (Tappan) (Fig. 12K, L), *Haplophragmoides* cf. *walteri* (Grzybowski) (Fig. 12N), *Haplophragmoides* sp. (Fig. 12M), *Trochamminoides* sp. (Fig. 12J) often occur in the Burkut Formation.

SVYDOVETS NAPPE SEDIMENTARY SUCCESSION

The sedimentary succession of the Svydovets Nappe is represented by the Urda and Bobruk formations in the area mapped (see Figs. 4 and 5).

The **Urda Formation** (Maastrichtian-Paleocene) is present in a small sheared tectonic slice up to 100 m wide located in the contact zone between the Svydovets and Silesian units and is also locally developed in the inner part of the Svydovets Unit (see Fig. 4). It is exposed along the Latorytsa River banks and consists of thin- and medium-bedded flysch expressed by alternations of sandstones and grey up to black-grey mud- and siltstones (Fig. 13A, see Fig. 4). Some sandstone beds demonstrate indistinct Bouma divisions T_{abc}. In general, the rocks are highly deformed and the sedimentary structures are poorly visible.

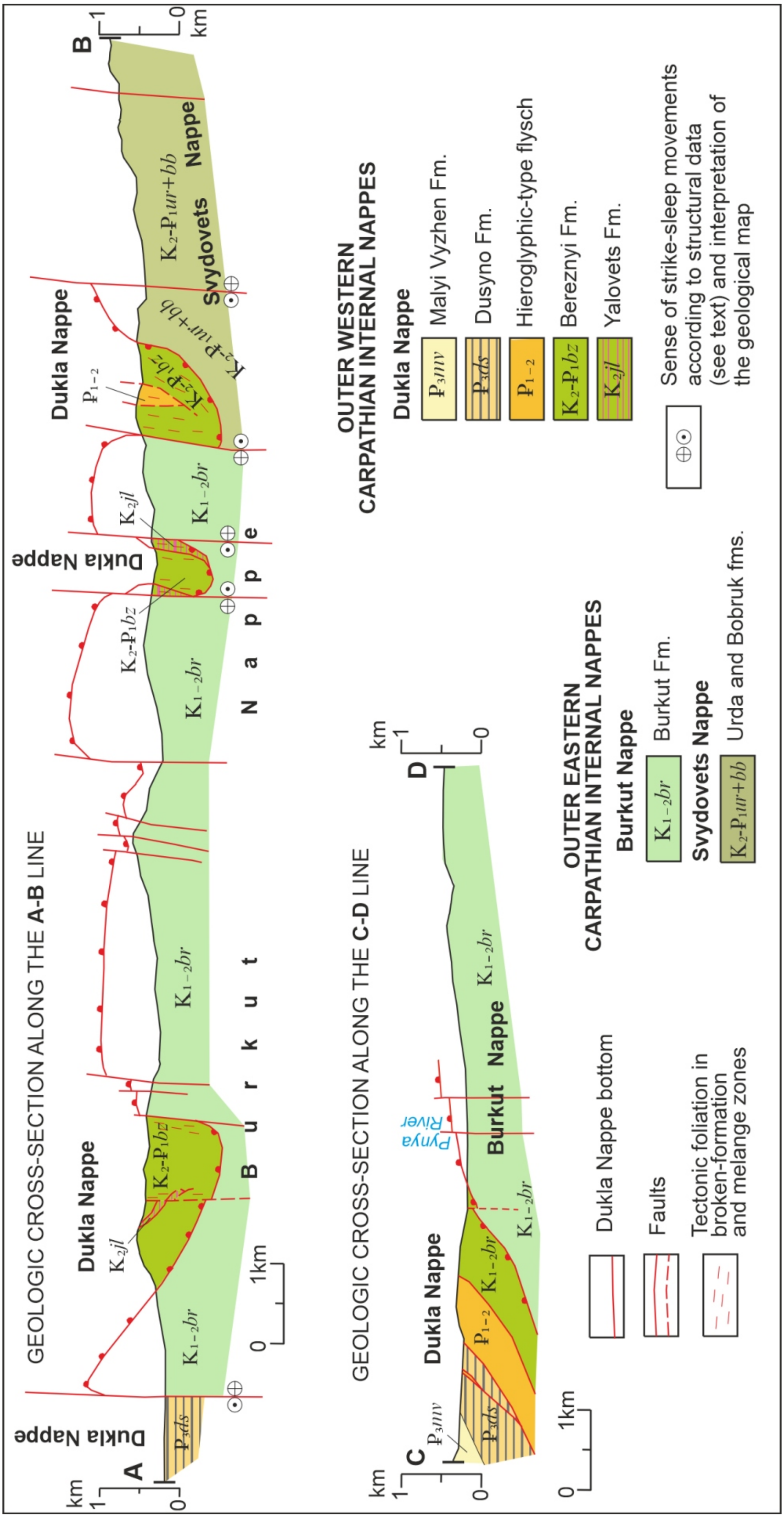


Fig. 6. Geological cross-sections of the area mapped along lines A–B and C–D (for location see Fig. 5)

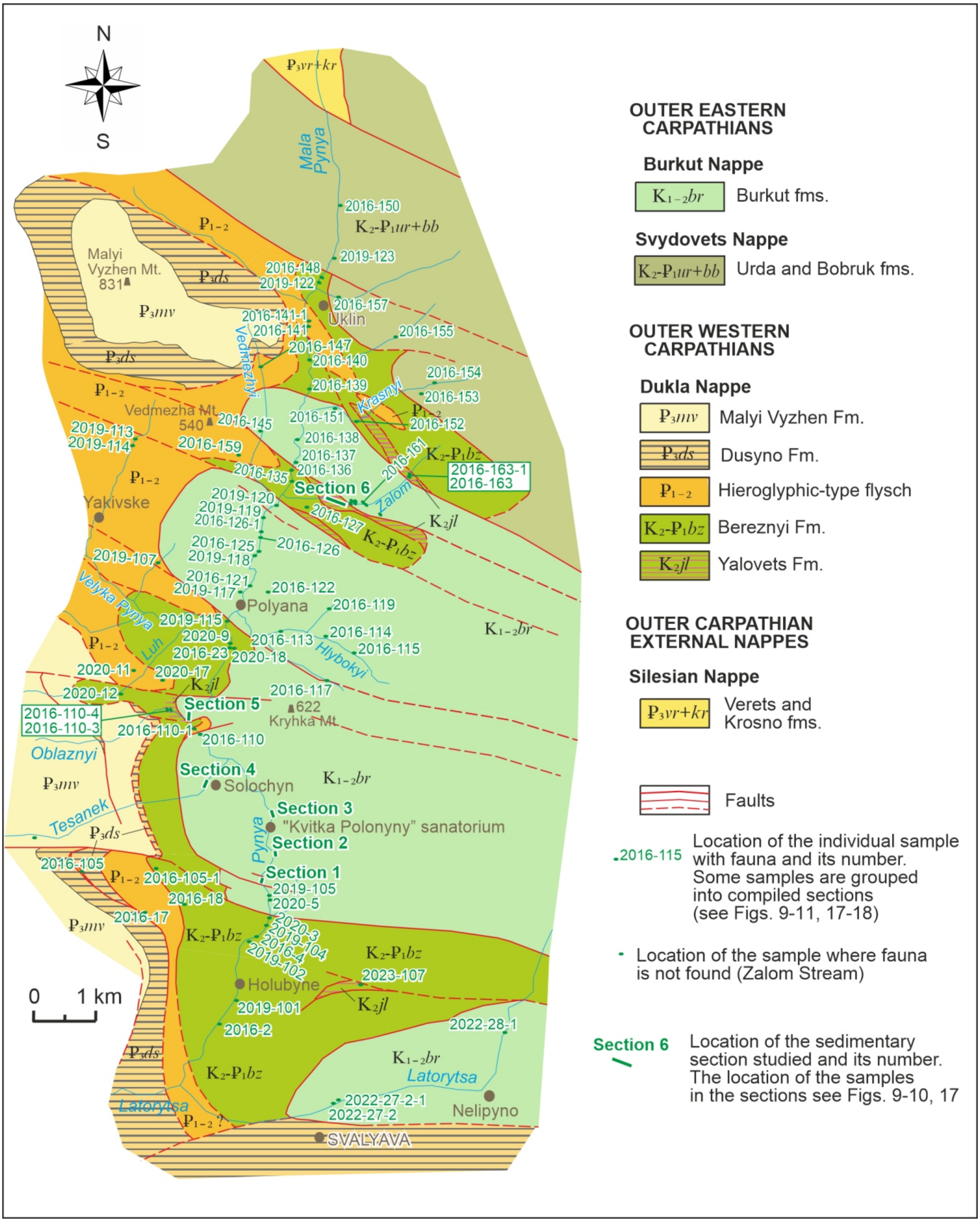


Fig. 7. Sample locations on the geological map of the study area (see Fig. 5)

Fig. 8. Lithology and sedimentary features of the Albian-Cenomanian Burkut Formation (Burkut Nappe) in the area mapped

A – massive Burkut Sandstone (Mala Pynya River near the mouth of the Zalom Stream); **B** – grey siltstone and mudstone intercalations in sandstones of the Burkut Formation (Tesanek Stream, Solochyn village); **C** – quartz clasts scattered in the Burkut Sandstone (Vedmezhyi Stream); **D** – flute and load casts in the base of a sandstone bed (Pynya River near Solochyn); **E** and **F** – Bouma divisions in the Burkut Formation (Mala Pynya River, village of Polyana)

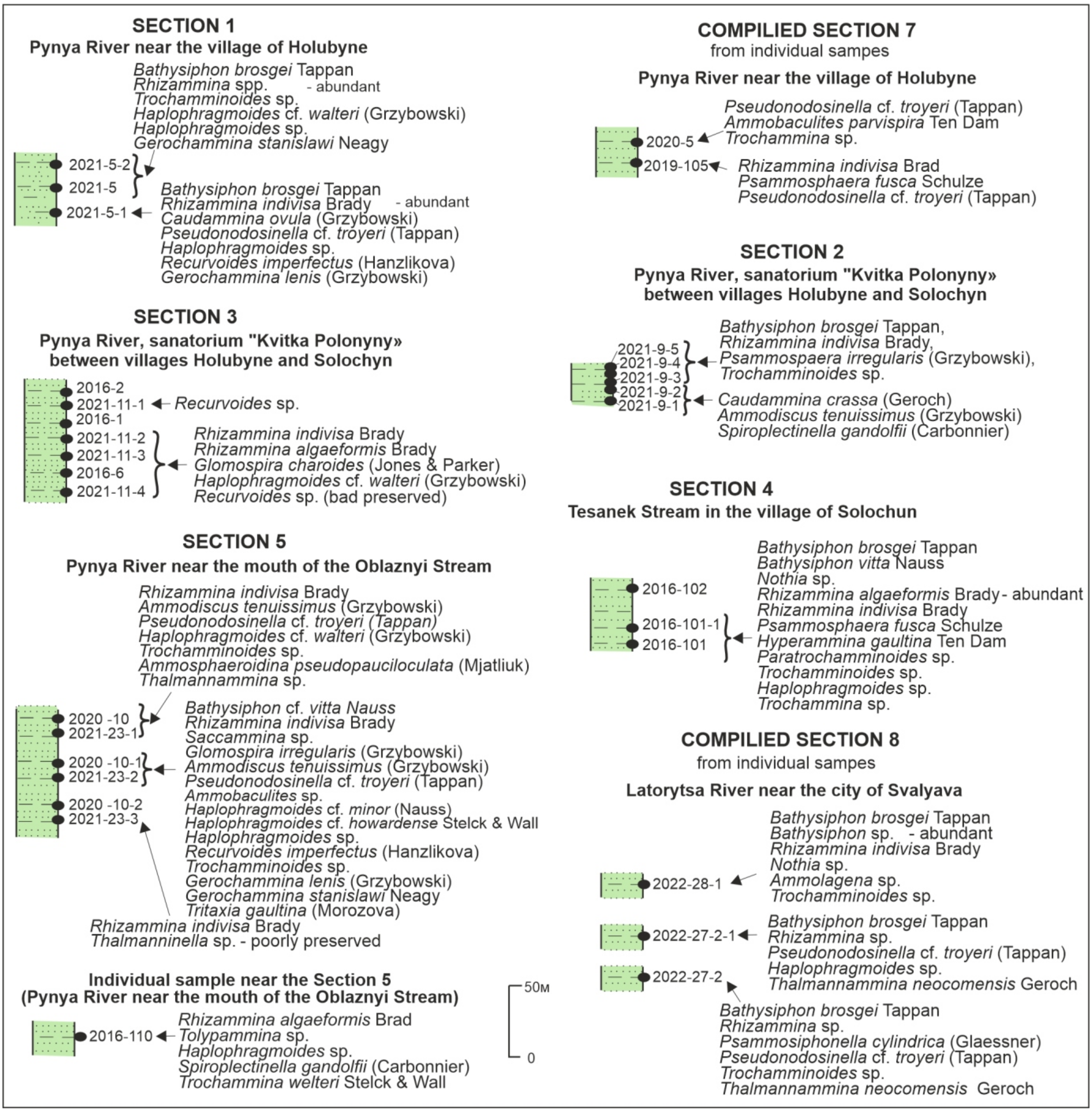


Fig. 9. Distribution of foraminifera in the Burkut Formation (sections 1–5 and compiled sections 7, 8), mid-Cretaceous, Burkut Unit, Latorytsa River basin

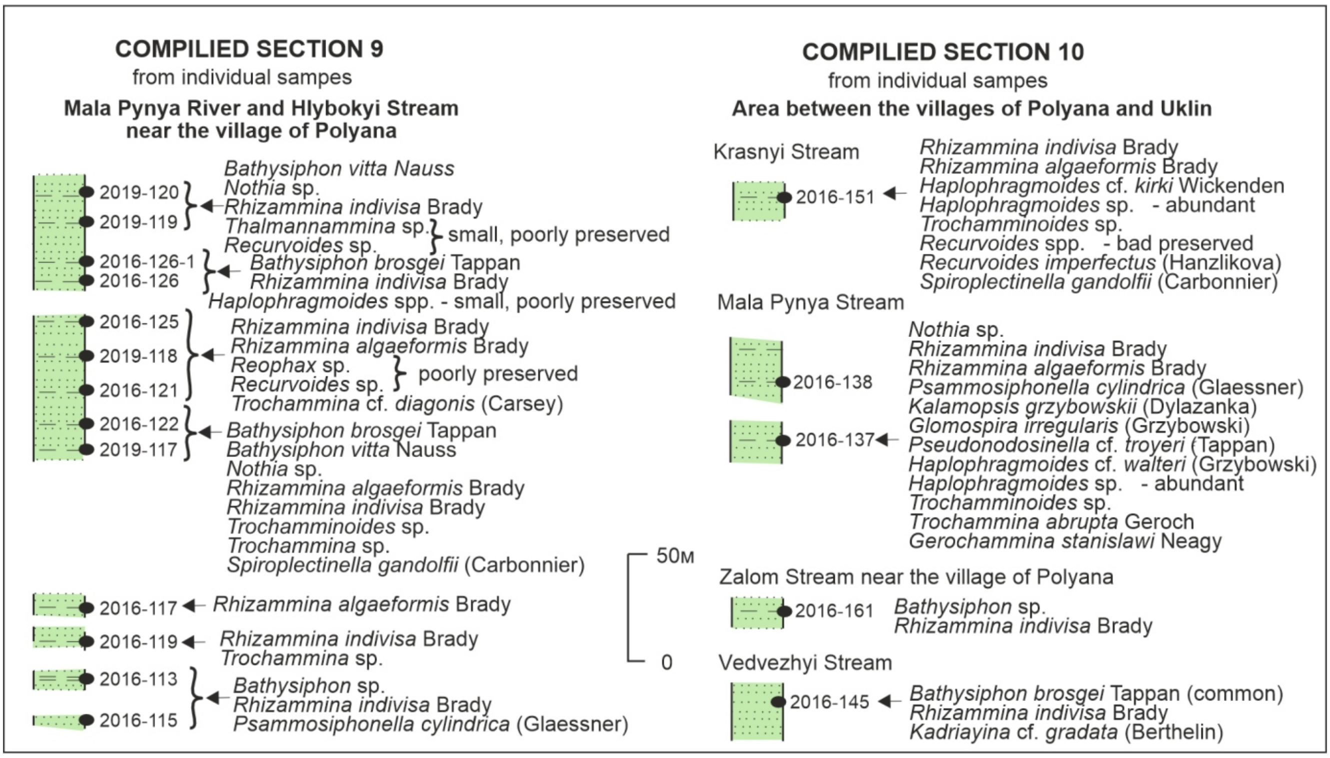


Fig. 10. Distribution of foraminifera of the Burkut Formation (compiled sections 9, 10), mid-Cretaceous, Burkut Unit, Latorytsa River Basin

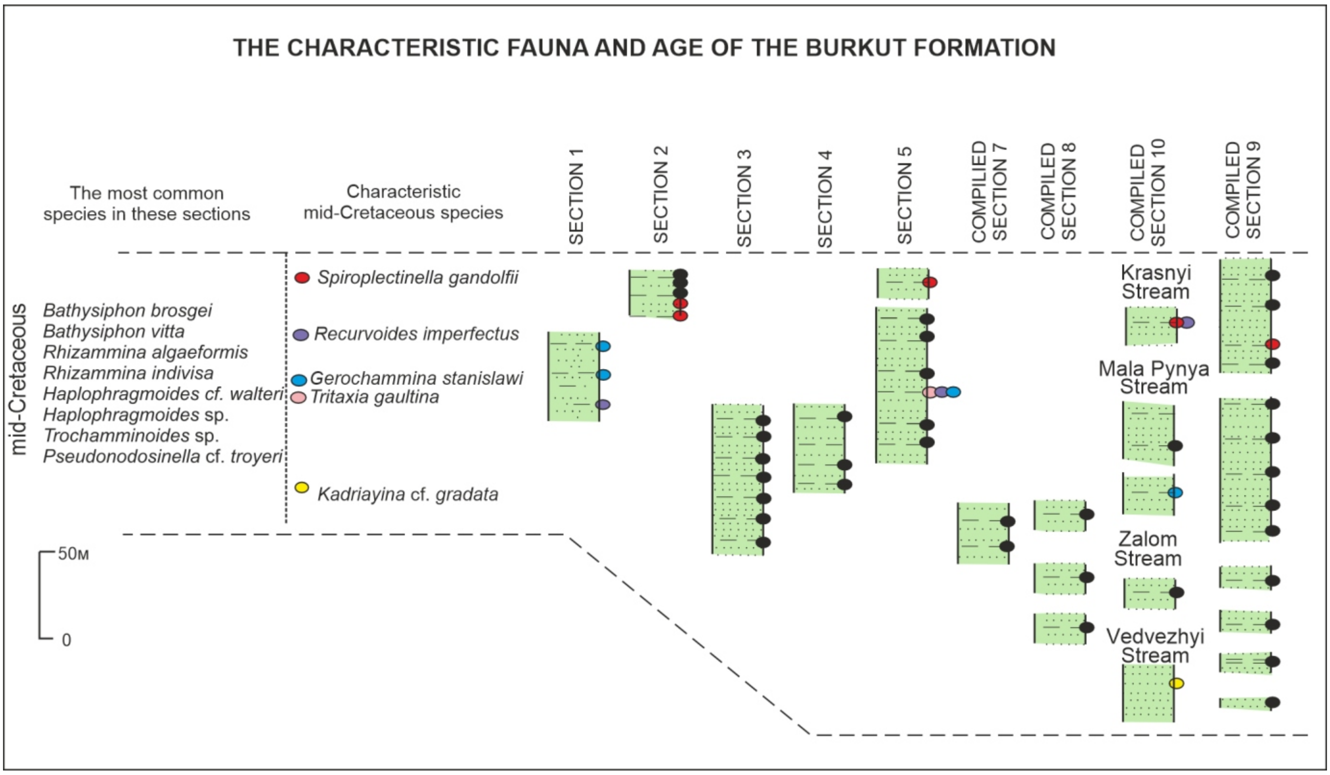


Fig. 11. Correlation of the Burkut Formation deposits studied, based on the characteristic foraminifera and the exposed lithostratigraphic successions; Burkut Unit, Latorytsa River Basin

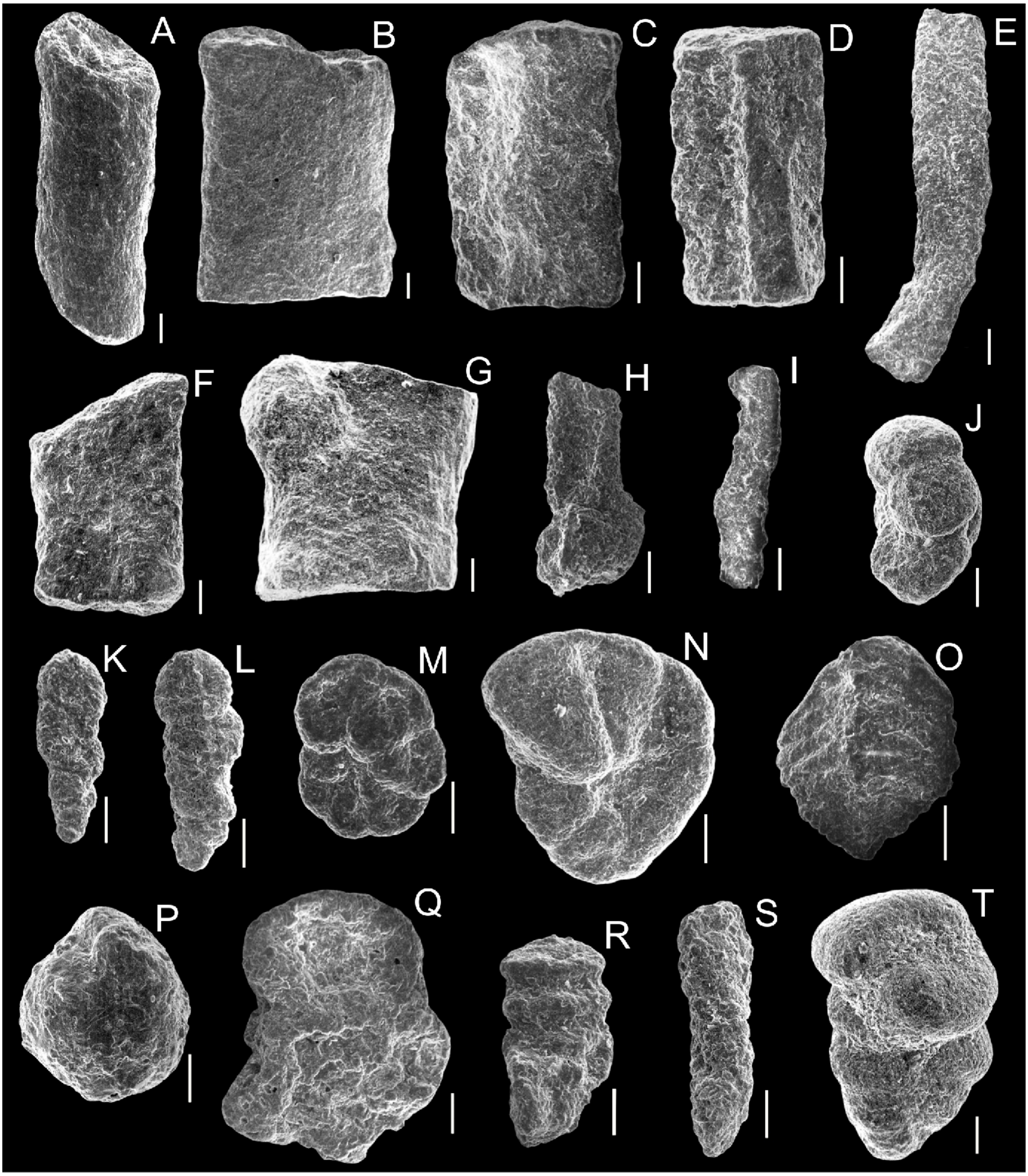


Fig. 12. Foraminifera from the Burkut Formation, mid-Cretaceous, Burkut Unit, Latorytsa River Basin

A – *Bathysiphon brosgei* Tappan (sample 2019-118); **B** – *Bathysiphon brosgei* Tappan (sample 2021-5); **C** – *Bathysiphon vitta* Nauss (sample 2016-101-1); **D** – *Bathysiphon vitta* Nauss, aggregate of few thin specimens (sample 2021-23-2); **E** – *Rhizammina indivisa* Brady (sample 2019-15); **F** – *Nothia* sp.; **G** – *Ammolagena* sp. attached on *Nothia* sp. (sample 22-28-1); **H** – *Rhizammina* sp. (sample 2021-5-1); **I** – *Rhizammina algaeformis* Brady (sample 2016-101-1); **J** – *Trochamminoides* sp. (sample 2020-5); **K** – *Pseudonodosinella* cf. *troyeri* (Tappan) (sample 2022-27-2-1); **L** – *Pseudonodosinella* cf. *troyeri* (Tappan) (sample 2020-10-1); **M** – *Haplophragmoides* sp. (sample 2016-101-1); **N** – *Haplophragmoides* cf. *walteri* (Grzybowski) (sample 2021-23-1); **O** – *Spiroplectinella gandolfii* (Carbonnier) (sample 2021-9-1); **P** – *Recurvoides imperfectus* (Hanzlikova) (sample 2016-151); **Q** – *Trochammina* cf. *diagonis* (Carsey) (sample 2016-121); **R** – *Tritaxia gaultina* (Morozova) (sample 2021-23-2); **S** – *Gerochammina stanislawi* Neagy (2021-5-2); **T** – *Kadriayina* cf. *gradata* (Berthelin) (sample 2016-145); length of bars: 0.1 mm

Fig. 13. Lithology and sedimentary features of the Maastrichtian-Paleogene deposits of the Svydovets Nappe in the area studied

A – thin- and medium-bedded alternation of sandstones and grey up to black-grey mud- and siltstones of the Maastrichtian-Paleocene Urda Formation (Latorytsa River, near the village of Abranka); **B** – massive and thick-bedded sandstone of the Paleocene-Eocene Bobruk Formation (Mala Pynya River, near Uklin village); **C** – indistinct T_{abc} Bouma divisions in the sandstone of the Bobruk Formation (Mala Pynya River, near village of Uklin); **D** and **E** – clasts of flysch rocks and casts of such clasts in a sandstone of the Bobruk Formation (Mala Pynya River, near village of Uklin); **F** – sand volcano structure in the Bobruk Formation (Mala Pynya River, near Uklin village)

Foraminifera were studied only in one sample (2022-8) taken from this tectonic slice (see Fig. 4 for location), where 12 agglutinated and 2 planktonic foraminifera were identified (Figs. 14 and 15). Planktonic *Subbotina triangularis* (White) of Danian age (Fig. 14B) and the typical forms of agglutinated *Haplophragmoides walteri* (Grzybowski) (Fig. 14A), the first occurrence of which was noted in the Paleocene, were present here. Agglutinated species of Early Cretaceous–Paleogene (Miocene) age, including *Aschemocella grandis* (Grzybowski), *Caudammina ovula* (Grzybowski), *Caudammina ovuloides* (Grzybowski) and numerous *Nothia excelsa* (Grzybowski) are also present (sample 2022-8, see Fig. 15). The age of foraminifera was determined according to (Olsson et al., 1999; Kaminski and Gradstein, 2005).

The **Bobruk Formation** (Paleocene-Eocene) represents most of the Svydovets Unit and is exposed in the upper of the Mala Pynya River in the area mapped (see Figs. 4 and 5). The recorded contacts of the Bobruk Formation are all tectonic. The formation is represented mainly by massive and thick-bedded sandstones (Fig. 13B), some with thin- and medium-bedded flysch and grey siltstone and mudstone intercalations. Bouma divisions T_a, T_{ab} and T_{abc} were observed (Fig. 13C). Clasts of flysch and casts of such clasts (up to a few decimetres in size) are scattered in the sandstones in many places, suggesting deposition from high-density turbidite currents and/or debris-grain flows (Fig. 13D, E). Mudstone intercalations locally present between the sandy deposits can be interpreted as (hemi)pelagites. Probable sand volcano structures were observed in the Bobruk Formation (Fig. 13F).

Foraminifera were studied in 6 individual samples from the Bobruk Formation (Fig. 15). A total of 13 species of agglutinated foraminifera including *Hormosina trinitatensis* Cushman and Renz, *Recurvoides anormis* Mjatliuk (Fig. 14G) and *Placentammina placenta* (Grzybowski) (Fig. 14E) of Campanian-Eocene age as well as *Nothia robusta* (Grzybowski) (Fig. 14C), *N. excelsa*, *Glomospira glomerata* (Grzybowski) (Fig. 14D) and *Aschemocella grandis* (Fig. 14F) of Cretaceous-Paleogene age are present here (see Fig. 15). The age of the foraminifera was determined according to Kaminski and Gradstein (2005).

DUKLA NAPPE SEDIMENTARY SUCCESSION

The Cretaceous Shypot and Yalovets formations, the Campanian-Paleocene Bereznyi Formation, the Paleocene-Eocene hieroglyphic-type undivided deposits, and the Oligocene Dusyno and Malyi Vuzhen formations comprise the Dukla sedimentary succession in the area mapped and adjacent territory.

The **Shypot Formation** (Barremian?-Cenomanian) is not exposed in the area mapped and was studied nearby. It comprises small tectonic lenses (up to 100–150 m wide) in melange and sheared zones in the Borzhava River basin near the village of Keretsky in the easternmost part of the Dukla Unit (see Fig. 4) as well as underlying the Dukla sedimentary succession in the more western parts of the Dukla Unit, where the Shypot Formation is well exposed along the Pesiy Stream (the left tributary of the Luta River of the Uzh River basin, see Fig. 4).

A mélange zone composed of strongly deformed sheared flysch rocks was observed in the lower part of the Pesiy Stream in the Luta River basin. Black and dark-grey medium-bedded flysch rocks of the Shypot Formation are exposed along the stream bed 1.2 km above the mouth of this stream. This formation overlies the mélange zone. This flysch of the Shypot Formation is composed of alternations of “glassy” essentially quartzose fine-grained sandstones (0.1–0.5 m thick) and black shales (siltstone and mudstone intercalations up to 0.2 m thick). All rocks are non-calcareous. The Bouma divisions T_{abc} T_{bcde} and T_{bcde} are characteristic. In the top part of these deposits, green mudstones (up to 4 m thick) are developed, characterized by thin parallel-layered and homogeneous textures of either the upper Bouma division (T_e) or as hemipelagites. They complete the Shypot Formation and are conformably overlapped by variegated (green and red) shales of the Yalovets Formation. The thickness of the Shypot Formation reaches up to 100 m here.

Only one sample (C-365, see Fig. 4) selected by S.P. Gavura (collection of the Department of Carpathian Geology, Institute of Geology and Geochemistry of Combustible Minerals of NAS, Ukraine, Lviv) from the top of the Shypot Formation has been studied. The agglutinated foraminifera *Plectorecurvoides alternans* Noth, *Caudammina crassa* (Geroch) and *Thalmannammina neocomensis* Geroch, characteristic of the mid-Cretaceous in the Carpathians (according to Geroch and Novak, 1984; Dabagian, 1969) were found here.

The **Yalovets Formation** (Turonian-Santonian) is exposed in the Pynya River basin along the Zalom, Oblaznyi and Krasnyi streams (see Fig. 5). It consists of variegated (red and green) shale and thinly layered mudstones (Fig. 16A) suggesting their hemipelagic/pelagic origin. Thin (up to 1–5 cm thick) fine-grained quartz sandstone intercalations with Bouma divisions T_{cde} are developed in the upper part of the formation and represent fine-grained turbidites. Some strata are characterized by well-sorted grains, cross-laminated textures (Fig. 16B), and stronger bioturbation. Most likely these strata represent the deposits of submarine bottom currents (so called “contourites”). The variegated shale deposits are intensely deformed up to mélange, and therefore, the contacts of the Yalovets Formation with surrounding deposits, and its thickness, are unclear in the area mapped.

Foraminifera were studied from Section 6 and some individual samples (Figs. 17 and 18). A total of 13 species of agglutinated foraminifera were recognised here (see Fig. 17). Among the foraminifera identified, two characteristic species are distinguished.

Uvegirinammina jankoi Majzon (Fig. 19F) is present: in Section 6 (samples 2019-302, 2016-128 and 2016-128-2); in individual sample 2016-163 from the Zalom Stream; and in sample 2016-110-3 of Compiled Section 12 along the Oblaznyi Stream (see Figs. 5 and 17).

Gerochammina stanislawi (Fig. 19G) is present: in Section 6 (samples 2019-302, 2016-128 and 2016-128-1); in individual samples 2016-163 from the Zalom Stream; and 2016-110-3 of Compiled Section 12. These species are recorded from the Albian-Turonian of the Carpathians (Neagu, 1990).

Small species belonging to the genera *Ammodiscus, Paratrochamminoides, Haplophragmoides, Recurvoides* and *Trochammina* are common in the red shales studied.

The **Bereznyi Formation** (Campanian-Danian) is exposed in the Pynya River basin along the contact zone between the Burkut and Dukla tectonic units. It is composed of polymictic or siliciclastic mainly thin- and medium-bedded flysch (Figs. 16C, D) characterized by Bouma divisions T_{bcde}, T_{cde}, T_{abc}, T_{abcde} (Fig. 16E) and represented by fine- and medium-grained turbidites. The flysch contains intercalations of black “Menilite-like” shales and “Dusyno-lyke” marls and some siderites. These shales and marls are homogeneous and thinly layered, and they are evidently hemipelagic/pelagic in origin. Near the village of Holubyne along the Pynya River and its tributaries, the thin-bedded grey clay and silt deposits (mainly hemipelagites and thin-bedded turbidites) are dominant in exposures of the Bereznyi Formation (Fig. 16F). Several measured turbidite palaeocurrent directions are from the NW and S (see Fig. 5).

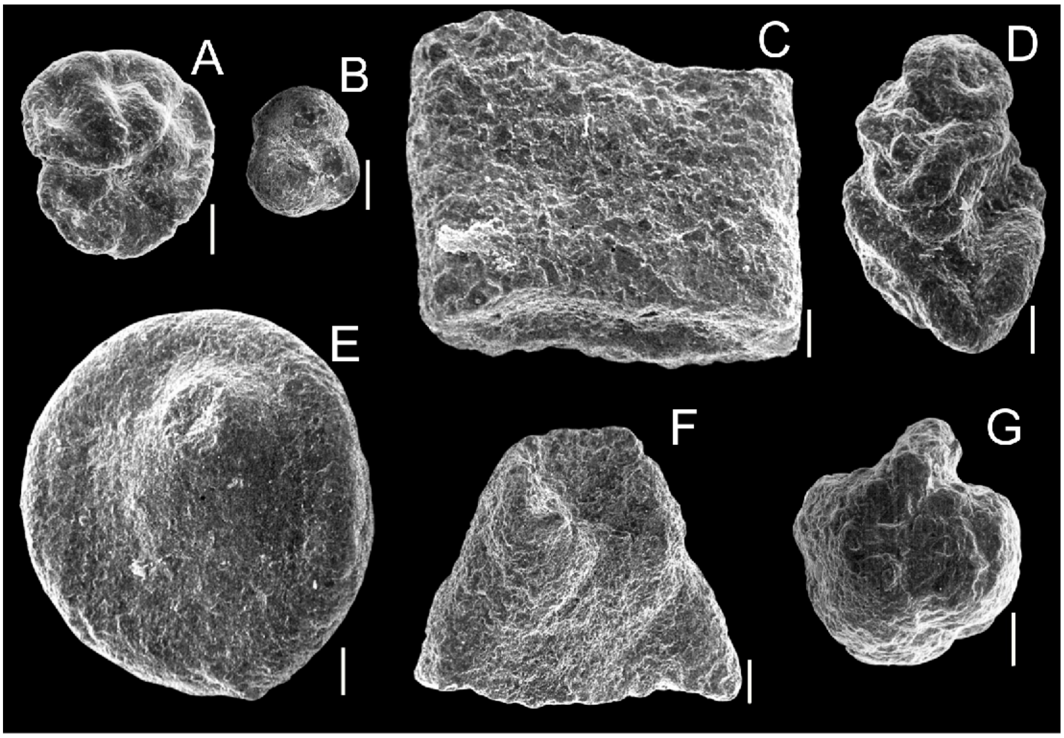


Fig. 14. Foraminifera from the Urda and Bobruk formations, Paleocene–Eocene, Svydovets Unit

A – *Haplophragmoides walteri* (Grzybowski) (sample 2022-8); **B** – *Subbotina triangularis* (White) (sample 2022-8); **C** – *Nothia robusta* (Grzybowski) (sample 2016-154); **D** – *Glomospira glomerata* (Grzybowski) (sample 2016-154); **E** – *Placentammina placenta* (Grzybowski) (sample 2016-154); **F** – *Aschemocella grandis* (Grzybowski) (sample 2016-157); **G** – *Recurvoides anormis* Mjatliuk (sample 2016-155); length of bars: 0.1 mm

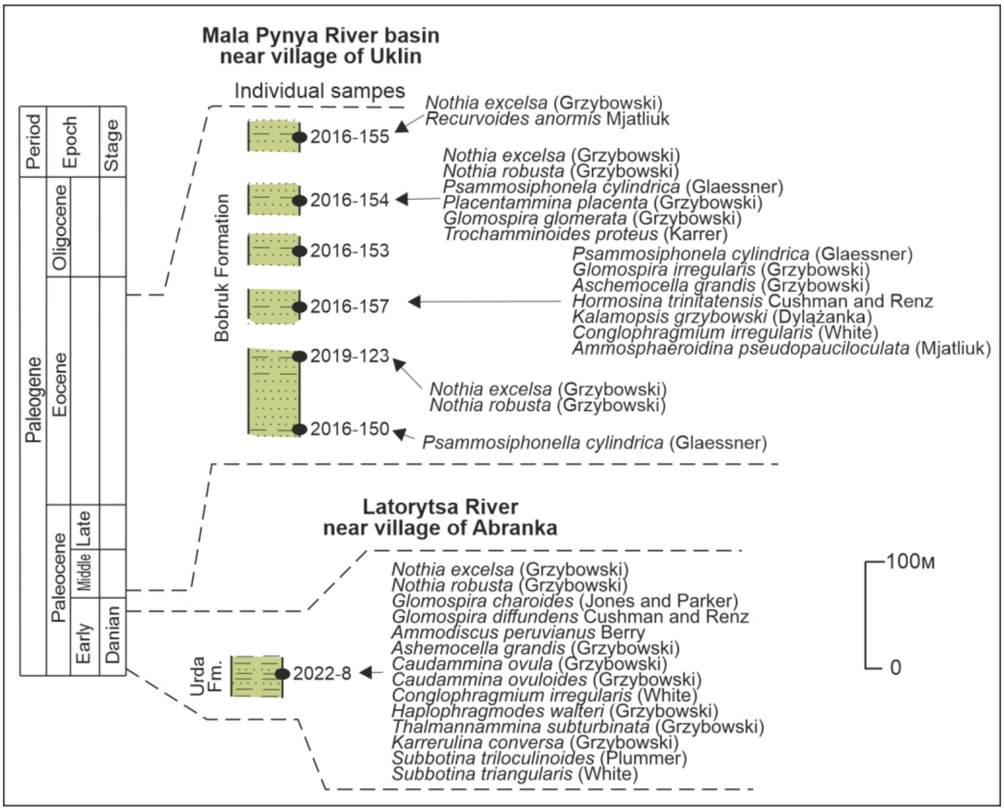


Fig. 15. Distribution of foraminifera in the parts of the Urda and Bobruk formations studied, Paleocene-Eocene, Svydovets Unit, Latorytsa River Basin

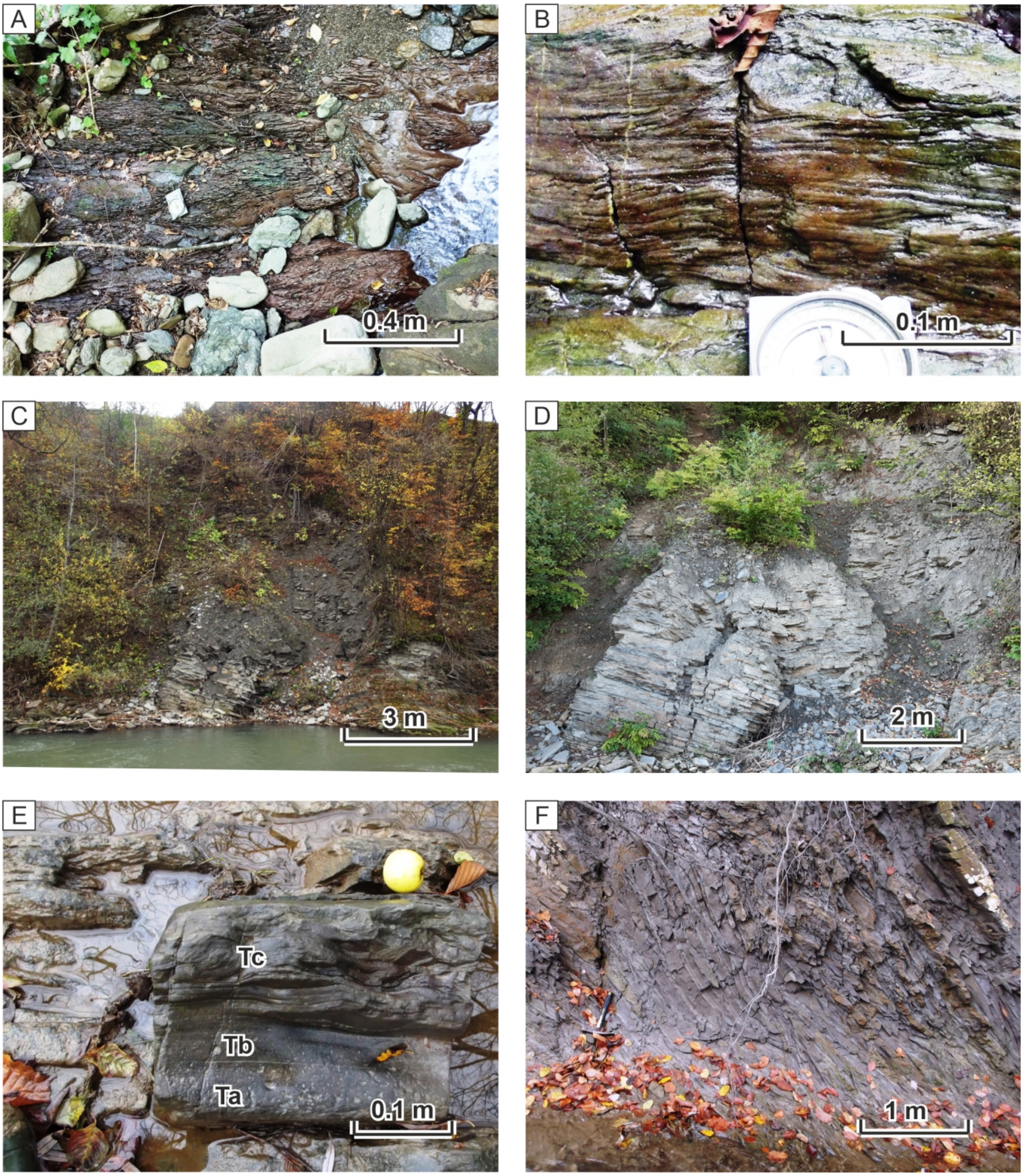


Fig. 16. Lithology and sedimentary features of the Upper Cretaceous-Paleocene deposits of the Dukla Nappe in the area mapped

A – Cenomanian-Santonian Yalovets Formation, variegated (red and green) shale of hemipelagic origin (Zalom Stream); **B** – Cenomanian-Santonian Yalovets Formation, fine-grained sandstone with well-sorted grains and cross-laminated texture suggests its deposition from submarine bottom currents (Oblaznyi Stream); **C** and **D** – Santonian-Danian Bereznyi Formation, thin- and medium-bedded flysch: fine- and medium-grained turbidites (Pynya River near the village of Holubyne); **E** – Santonian-Danian Bereznyi Formation, medium-grained turbidites with Tabc Bouma divisions (Pynya River near the village of Holubyne); **F** – Santonian-Danian Bereznyi Formation, thin-bedded grey clay and silt deposits: mainly hemipelagites and thin-bedded turbidites (Pynya River near Holubyne village)

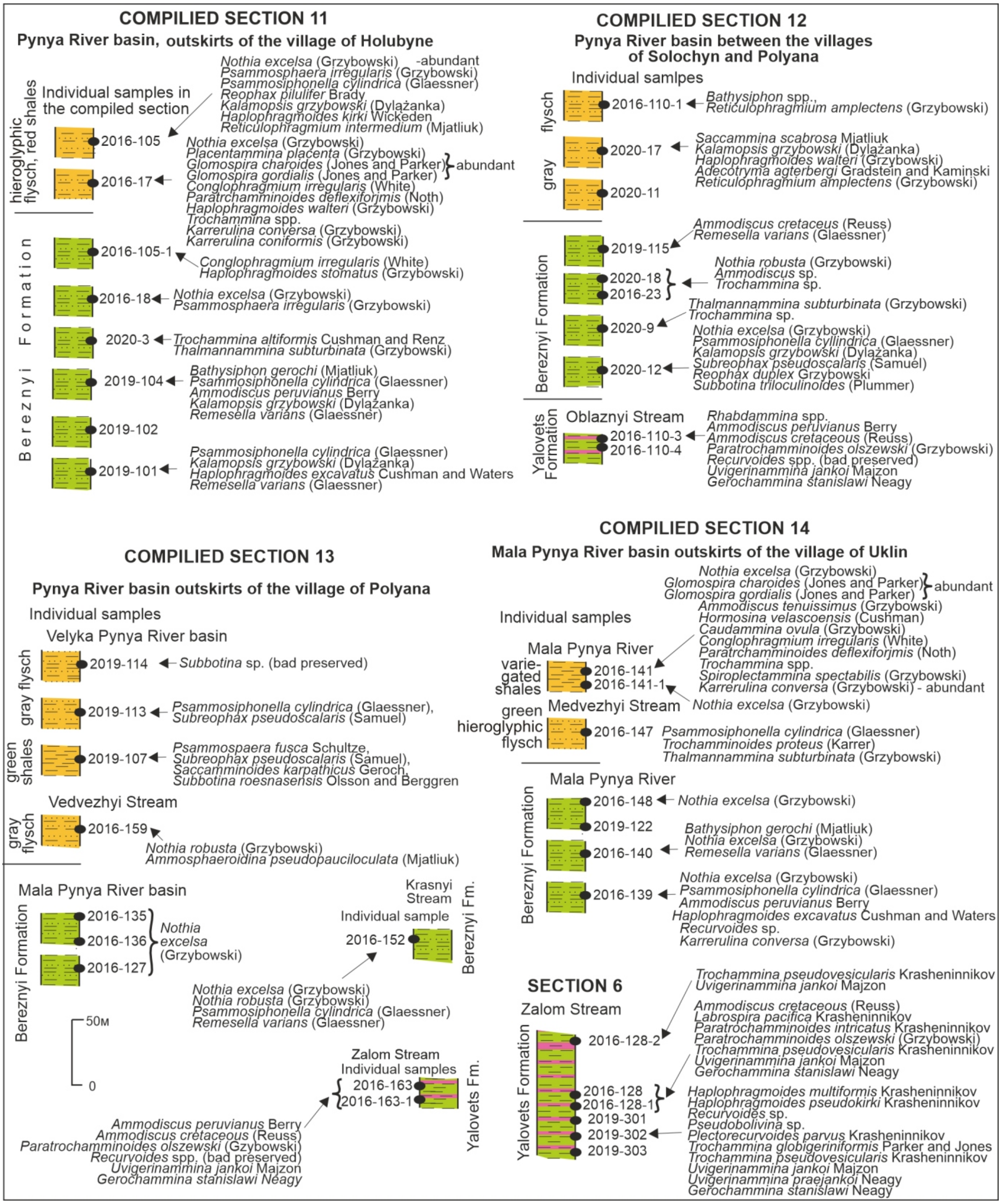


Fig. 17. Distribution of foraminifera in the part of the Yalovets Formation studied (Turonian), Bereznyi Formation (Senonian-Paleocene), hieroglyphic-type deposits (Paleocene-Eocene), Dukla Unit

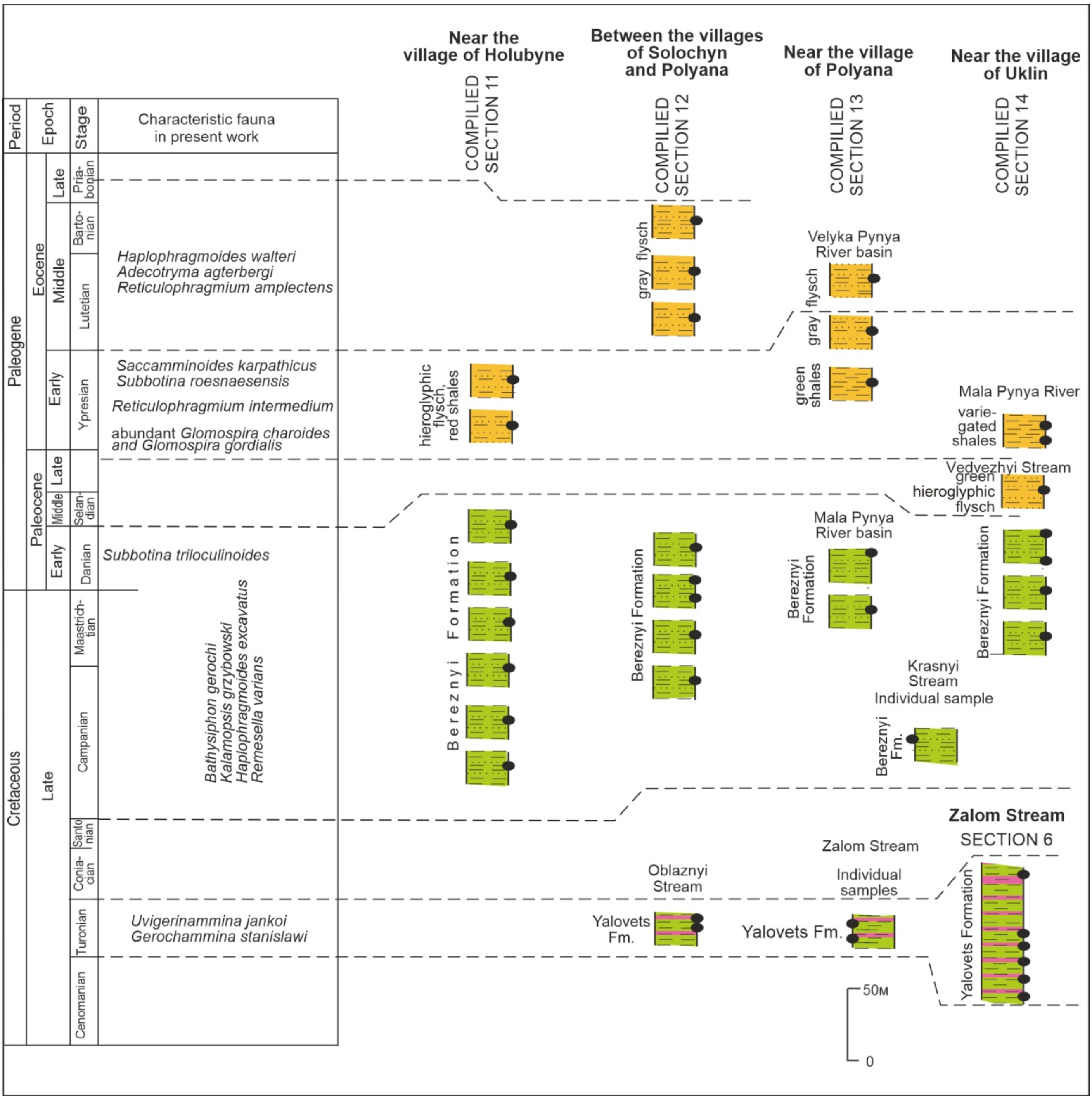


Fig. 18. The age, correlation and characteristic foraminifera of the Yalovets Formation (Turonian), Bereznyi Formation (Senonian-Paleocene) and hieroglyphic-type deposits (Paleocene-Eocene), Dukla Unit, Latorytsa River Basin, time scale after Gradstein et al. (2020)

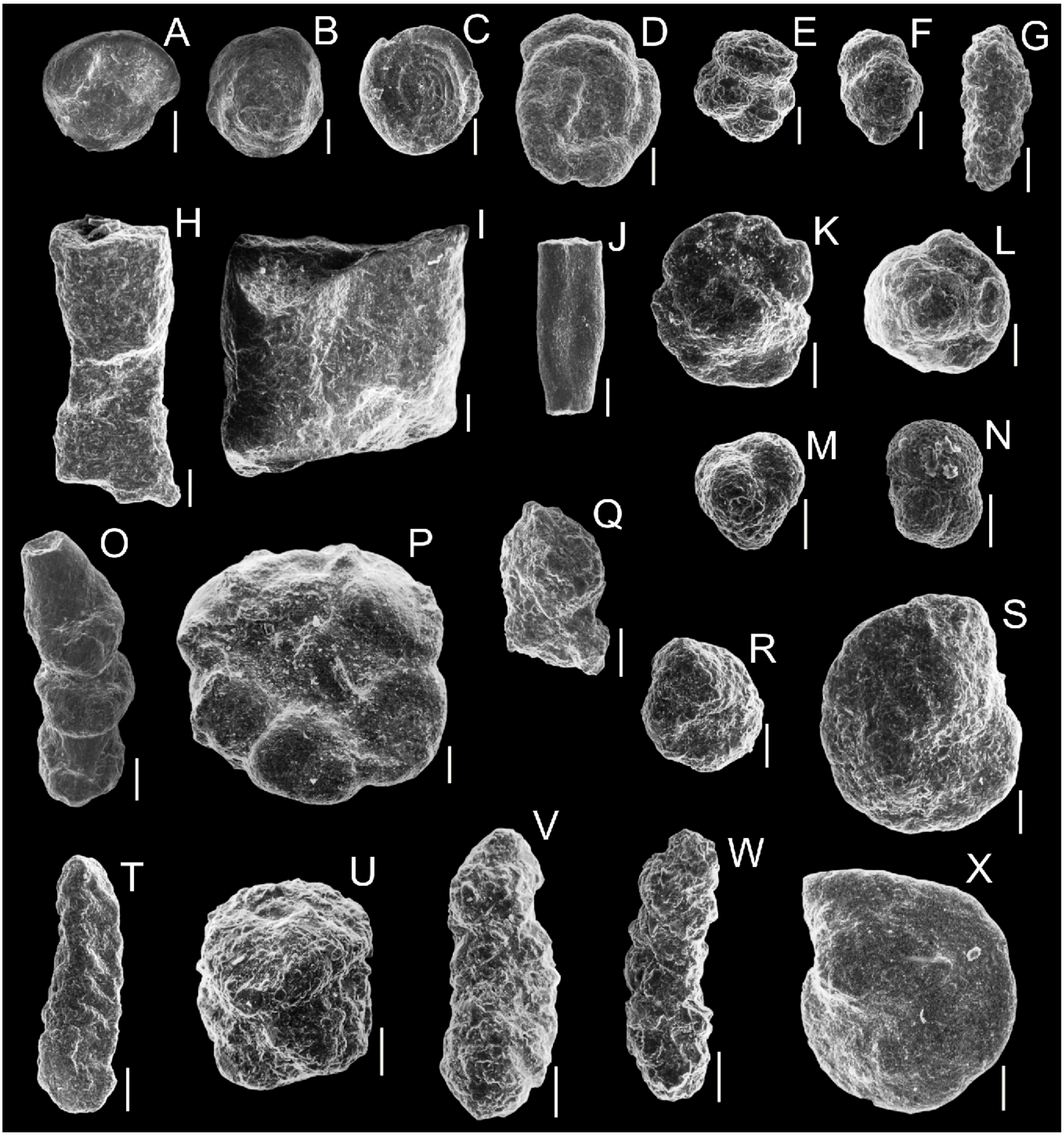


Fig. 19. Foraminifera from deposits of the Dukla Unit

Shypot Formation (mid-Cretaceous): **A** – *Plectorecurvoides alternans* Noth (sample C-365); **B** – *Ammoanita* sp. (sample C-365). Yalovets Formation (Turonian): **C** – *Ammodiscus cretaceous* (Reuss) (sample 2016-110-3); **D** – *Paratrochamminoides olszewski* (Grzybowski) (sample 2016-128); **E** – *Trochammina globigeriniformis* Parker and Jones (sample 2019-128); **F** – *Uvegirinammina jankoi* Majzon (sample 2019-302); **G** – *Gerochammina stanislawi* Neagy (sample 2016-163). Bereznyi Formation (Senonian-Paleocene): **H** – *Bathysiphon gerochi* (Mjatliuk) (sample 2019-104); **I** – *Nothia robusta* (Grzybowski) (sample 2016-152); **J** – *Kalamopsis grzybowski* (Dylążanka) (sample 2020-12); **K** – *Haplophragmoides excavatus* Cushman and Waters (sample 2019-101); **L** – *Thalmannammina subturbinata* (Grzybowski) (sample 2020-9); **M** – *Karrerulina conversa* (Grzybowski) (sample 2016-139); **N** – *Subbotina triloculinoides* (Plummer) (sample 2020-12). Hieroglyphic-type deposits (Paleocene-Eocene): **O** – *Hormosina velascoensis* (Cushman) (sample 2016-141); **P** – *Conglophragmium irregularis* (White) (sample 2016-17); **Q** – *Saccamminoides karpathicus* Geroch (sample 2019-107); **R** – *Haplophragmoides kirki* Wickeden (sample 2016-105); **S** – *Reticulophragmium intermedium* (Mjatliuk) (sample 2016-105); **T** – *Spiroplectammina spectabilis* (Grzybowski) (sample 2016-141); **U** – *Adecotryma agterbergi* Gradstein and Kaminski (sample 2020-17); **W** – *Karrerulina horrida* (Mjatliuk) (sanmple 2016-17); **X** – *Reticulophragmium amplectens* (Grzybowski) (sample 2016-110-1); length of bars: 0.1 mm

The deposits of the Bereznyi Formation are strongly dislocated, and stratigraphic contacts with both the Yalovets Formation and with Paleocene-Eocene deposits were not observed, and their thickness is unclear in the area mapped.

Foraminifera were studied from 18 samples from four compiled sections 11–14 and one further sample (2016-152, Krasnyi Stream; Fig. 17). 16 species of agglutinated foraminifera and one planktonic species were identified in the deposits studied which are generally microfauna-poor. Most of the species identified are common in the Upper Cretaceous-Paleogene of the Carpathians. Several characteristic species have been identified.

Small specimens (probably juvenile forms) of *Remesella varians* (Glaessner) (Fig. 19M) of Maastrichtian-Paleocene age (according to Kaminski and Gradstein, 2005) are present in Compiled Section 11 (samples 2019-101, 2019-104), Section 12 (sample 2019-115), Section 14 (sample 2016-140,) and sample 2016-152 from outside these sections.

Bathysiphon gerochi (Mjatliuk) (Fig. 19H) is present in Compiled Section 11 (sample 2019-104) and Section 14 (sample 2016-140). This species was also recorded from the Stryi Formation (Senonian–Danian) of the Skyba Unit, Ukrainian Carpathians (Mjatliuk, 1970).

Subbotina triloculinoides (Plummer) (Fig. 19N) of Paleocene age (according to Olsson et al., 1999) is present in Compiled Section 12, sample 2020-12.

Thalmannammina subturbinata (Grzybowski) (Fig. 19L) and *Karrerulina conversa* (Grzybowski) (Fig. 16W) of Senonian-Paleogene age (according to Kaminski and Gradstein, 2005) were found in the Bereznyi Formation.

The tubular species *Nothia robusta* (Fig. 19I), *N. excelsa* and *Psammosiphonella cylindrica* (Glaessner), as well as the species *Kalamopsis grzybowski* (Dylążanka) (Fig. 19J), occur quite frequently in the deposits studied.

Paleocene-Eocene hieroglyphic-type undivided deposits are sparsely exposed in the western part of the area mapped (see Fig. 5). They are represented by polymictic and siliciclastic thin- and medium-bedded flysch composed of alternating beds of sandstone, siltstone, grey and variegated (red and green) mudstone shale (Fig. 20A). The beds often show T_{abcde}, T_{bcde}, T_{cde} Bouma divisions (Fig. 20B) and consequently were deposited by turbiditity currents. Some strata of green fine-grained sandstone are characterized by well sorted grains, cross-bedded textures and stronger bioturbation (“hieroglyphic beds”) and may be the products of bottom water current sedimentation. Along the Medvezhyi and Krasnyi streams (see Fig. 5), several exposures of matrix-supported unsorted microconglomerates and/or sedimentary breccias (debris-flow deposits) with detritus of metamorphic rocks including green schists are present (Fig. 20C). The exotics-bearing deposits may be analogues of the Eocene Stavne Formation belonging to the Dukla sedimentary succession (see Fig. 3), where similar exotic metamorphic rock clasts were found (see Danysh, 1973; Hnylko and Hnylko, 2024).

The Paleocene-Eocene stratigraphic succession is strongly deformed and partially destroyed, and its contacts with both Bereznyi Formation and Oligocene deposits are tectonically disturbed. Therefore, the identification of formations in this succession is difficult.

Foraminifera were studied in 12 samples from compiled sections 11–14 (Fig. 17). A total of 29 species of agglutinated foraminifera and one planktonic species were identified in the deposits studied. Most of the species identified are common in the Upper Cretaceous-Paleogene of the Carpathians. Among these, characteristic microfauna are noted below.

Abundant *Glomospira charoides* (Jones and Parker) and *Glomospira gordialis* (Jones and Parker), comprising 30 percent of the foraminiferal assemblages, were found in red shales both in the Pynya River basin (sample 2016-17, section 11) and Mala Pynya River basin (sample 2016-141, Section 14). *Karrerulina* spp., *Trochammina* spp., *Conglophragmium irregularis* (White) (Fig. 19P), *Paratrochamminoides deflexiformis* (Noth) and *N. excelsa* are common co-occuring species here. These assemblages correspond to the *Glomospira charoides* (Jones and Parker) – *Glomospira gordialis* (Jones and Parker) Acme of latest Thanetian-early Ypresian age (*sensu* Waśkowska, 2021) which has been defined in the Silesian and Magura units of the Polish Carpathians (Waśkowska, 2021). Stratigraphically higher, in Compiled Section 11 of the Pynya River basin (sample 2016-105), the species *Reticulophragmium intermedium* (Mjatliuk) (Fig. 19S) of Early Eocene age (according to Mjatliuk, 1970; Kaminski and Gradstein, 2005) was found (see Fig. 17).

Saccamminoides karpathicus Geroch (Fig. 19Q) of later Ypresian age (sample 2019-107, Section 13), *Reticulophragmium amplectens* (Grzybowski) (Fig. 19X) of latest Ypresian–earliest Oligocene age (sample 2016-105, section 11; samples 2020-17 and 2016-110-1, Section 12) and *Adecotryma agterbergi* Gradstein and Kaminski (Fig. 19U) of Middle Eocene-Early Oligocene age (sample 2020-17, section 12) are present in the sections studied. The age of the foraminifera was determined according to Olszewska (1997), Kaminski and Gradstein (2005) and Waśkowska (2011).

The **Dusyno Formaion** (Oligocene) is exposed in the basins of the Medvezhyi and Oblaznyi streams and near the village of Holubyne. The formation has a tectonically detached contact with the underlying Eocene strata and is represented by bituminous black and dark-grey marls and calcareous mudstone (Fig. 20D). At the bottom of the formation, several horizons (up to 0.2 m thick) of black chert are developed. The deposits are characterized by homogeneous massive or thinly layered textures suggesting their hemipelagic/pelagic origin. In the upper part of the Dusyno Formation, intercalations of pale grey calcareous mudstone and polymictic sandstone appear, which indicates a gradual transition to the terrigenous Malyi Vuzhen Formation.

The **Malyi Vuzhen Formation** (Oligocene) is distributed in the basins of the Medvezhyi, Oblaznyi and Tesanek streams. It conformably overlies the Dusyno Formation and consists of thick- and medium-bedded polymictic sandstones (Fig. 20E) with intercalations of grey siltstone and mudstone. The sandstones contain scattered organic detritus. Bouma divisions are indistinct in these deposits. Debris-flow deposits up to several tens of metres in thickness are observed in the upper part of the Malyi Vuzhen Formation. They consist of a clay-silt matrix with scattered clasts of sand and marl up to a few decimetres across (Fig. 20F). The Malyi Vuzhen Formation completes the stratigraphic succession of the Dukla Nappe.

SILESIAN NAPPE SEDIMENTARY SUCCESSION

In the area mapped, the Silesian succession is represented only by the Verets Formation, which is transitional from the organic-rich black-shale Menilite Formation to the grey flysch of the Krosno Formation. The Verets Formation consists of thin-up to medium-bedded alternations of grey polymictic sandstone, siltstone, mudstone and Menilite-like black shale. These deposits are strongly deformed, up to broken formation and/or mélange. Their thickness is unclear and relations with other sedimentary formations are unexposed.

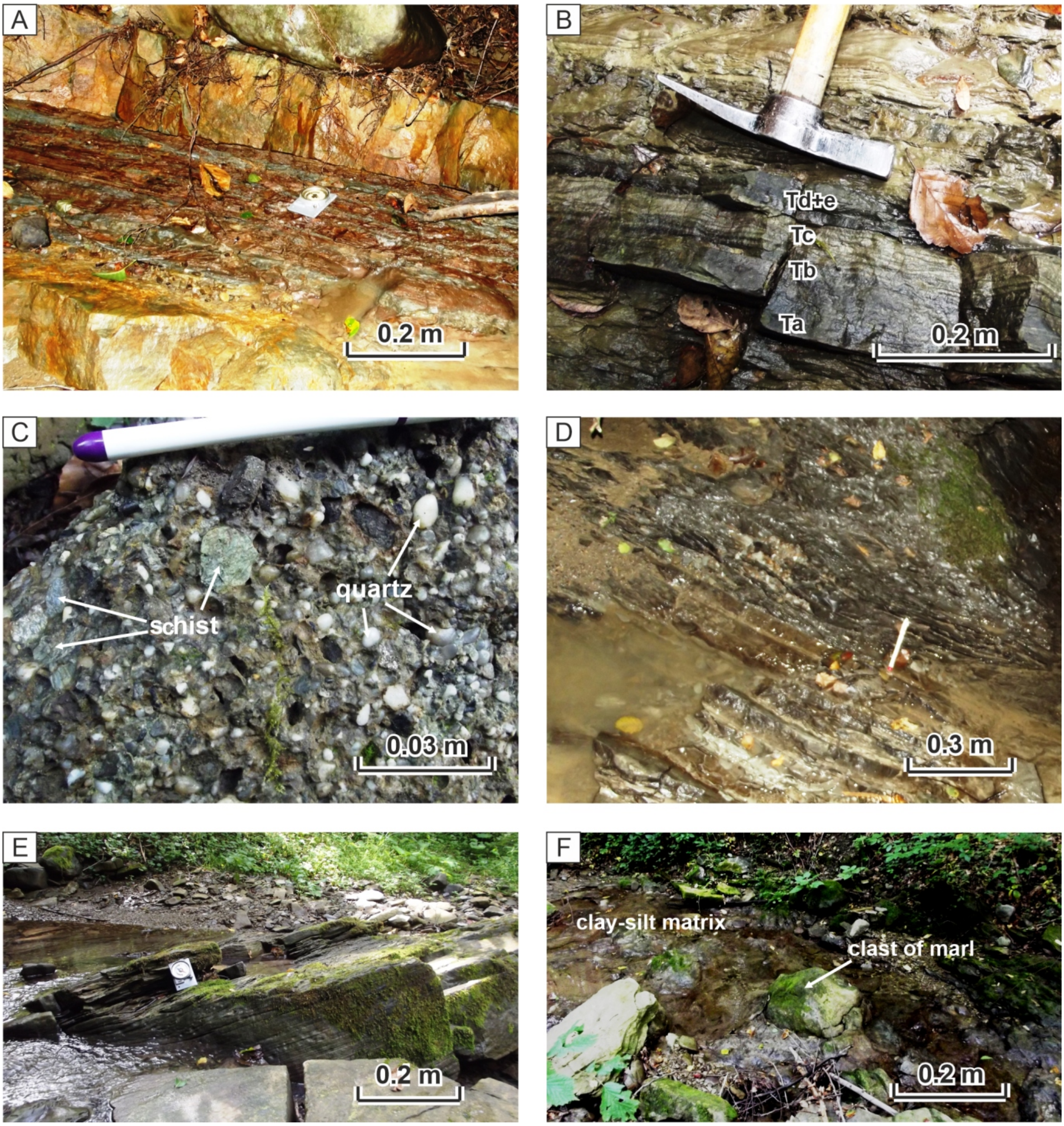


Fig. 20. Lithology and sedimentary features of the Paleogene deposits of the Dukla Nappe in the area mapped

A – hieroglyphic-type deposits, alternation of sandstone beds and variegated (red and green) shales (right tributary of the Pynya River near Holubyne village); **B** – T_{abcde} Bouma divisions in hieroglyphic-type deposits (right tributary of the Pynya River near the Holubyne); **C** – exotics-bearing deposits with clasts of schist can be analogues of the Eocene Stavne Formation (Krasnyi Stream near Uklin village); **D** – bituminous black and dark-grey marl and calcareous mudstone of the Oligocene Dusyno Formation (right tributary of the Pynya River near Holubyne); **E** – sandstone of the Oligocene Malyi Vyzhen Formation (Oblaznyi Stream); **F** – debris-flow deposits with clay-silt matrix and clasts of sands and marls (Oblaznyi Stream)

Thus, according to lithostratigraphic and sedimentological features, within the study area, it is possible to outline successions of formations that allow us to identify the Burkut Nappe (Burkut Formation), the Svydovets Nappe (Urda and Bobruk formations) and the Dukla Nappe (Shypot, Yalovets and Bereznyi formations, Paleocene-Eocene hieroglyphic flysch deposits and characteristic Oligocene formations).

NOTES ON BIOSTRATIGRAPHY

Foraminifera of the Cretaceous and Paleocene-Eocene age have been identified in the deposits studied. However, comparison of these assemblages with regional foraminiferal zonations remains debatable both due to the lack of a relatively complete stratigraphic sequence and the prevalence of mainly long-ranging species. However, we consider it advisable to correlate the strata studied with the foraminiferal zonation (Olszewska, 1997) as accurately as possible (Fig. 21).

Mid-Cretaceous. Foraminifera of this age are common in the deposits studied, of the Burkut Formation (Burkut Nappe) as well in the Shypot and Yalovets formations (Dukla Nappe).

The age of the deposits studied of the Burkut Formation is indicated by the species *G. stanislawi* (Albian-Turonian), *S. gandolfii, T. gaultina, R. imperfectus and K.* cf. *gradata*. *T. gaultina* is recorded in the Cenomanian-lower Turonian of the Carpathians (Geroch and Novak, 1984) and in the upper Albian of the Indian Ocean (Holbourn and Kaminski, 1997). In the Carpathians, *R. imperfectus* is recorded in the upper Albian-Cenomanian (Geroch and Novak, 1984; Olszewska, 1997), this species being noted from the Aptian-Albian of Morocco and the Cretaceous and Paleogene of Europe (Weidich, 1990 with references therein). The species *K.* cf. *gradata* has been described from Aptian-Albian of the Indian Ocean (Holbourn and Kaminski, 1997). *S. gandolfii* is recorded in the mid-Albian-Cenomanian of the northern Alps (Weidich, 1990), in the upper Albian of the Indian Ocean (Holbourn and Kaminski, 1997) and in the uppermost Albian-Cenomanian (*Bulbobaculites problematicus* Zone) of the Polish Carpathians (Olszewska, 1997). Considering that *S. gandolfii* occurs in the upper part of the deposits studied, their age is not younger than the Cenomanian. According to N.I. Maslakova, the characteristic species of foraminifera in the Burkut Formation of the Ukrainian Carpathians are *S. gandolfii, Haplophragmoides minor* Nauss, *Haplophragmoides platus* Loeblich, *Trochammina subbotinae* (Tairov) and *Ammodiscus rotalaris* Loeblich and Tappan, which indicate a Albian-Cenomanian age (Byzova and Maslakova, 1974).

The deposits studied of the Shypot Formation contain *Plectorecurvoides alternans* (Noth), typical of the middle Albian-Cenomanian (*Plectorecurvoides alternans* and *Bulbobaculites problematicus* zones; see Fig. 21).

The red shales studied, belonging to the Yalovets Formation, contain *U. jankoi*. In the Carpathians, this species is recorded in the Turonian to lower Campanian (Geroch and Novak, 1984). The co-occurrence of *U. jankoi* and *G. stanislawi* (Albian-Turonian) indicates a Turonian age for most of the deposits studied of the Yalovets Formation and allows it to be correlated with the *Uvigerinammina jankoi* Zone). An assemblage of agglutinated foraminifera with *U. jankoi* characterizes the variegated shales of the Yalovets Formation in the Ukrainian Carpathians (Dabagian, 1978; Leshchukh, 1988b; Vialov et al., 1989).

Maastrichtian-Paleocene. Foraminifera of this age are common in the deposits studied of the Bereznyi Formation (Dukla Nappe). They include *R. varians* (Maastrichtian-Paleocene) which, according to Olszewska (1997), is typical of the upper part of the *Rzehakina inclusa* Zone and occurs in the lower part of the *Rzehakina fissistomata* Zone.

Danian. The presence of *S. triangularis* is indicated Danian age in deposits of the Urda Formation (Svydovets Nappe). According to previous research, the Campanian-Maastrichtian *Rzehakina inclusa* Grzybowski characterizes the lower part of the Urda Formation (Beer at al., 1971) and the *Rzehakina fissistomata* Zone (Paleocene) occupies the upper part of the Urda Formation (Hnylko and Hnylko, 2012).

Campanian-Eocene. In the studied outcrops, only foraminifera of a long age range (Campanian-Eocene) were found in the Bobruk Formation (Svydovets Nappe). According to previous research, the *Recurvoides smugarensis–Glomospira charoides* Zone (Lower Eocene), the *Reticulophragmium amplectens* Zone and *Ammodiscus latus* Zone (Middle Eocene) and the *Reticulophragmium rotundidorsatum* Zone (Upper Eocene) were identified in the Bobruk Formation (Hnylko and Hnylko, 2012).

Uppermost Thanetian-lower Upresian. Abundant *Glomospira* corresponding to the *G. charoides–G. gordialis* Acme of latest Thanetian-early Ypresian age (*sensu* Waśkowska, 2021) were found in variegated shales in the Dukla Nappe.

Eocene. *Saccamminoides karpathicus* characterizing the *Saccamminoides karpathicus* Zone of late Ypresian age was found in the green shales of the Dukla Nappe (see Fig. 21). The co-occurrence of *R. amplectens* and A. *agterbergi* of Middle-Late Eocene age was identified in the grey flysch of the Dukla Nappe (see Fig. 21).

Thus, the deposits studied, based on foraminifera, correspond to the following age intervals: Mid-Cretaceous, Maastrichtian-Paleocene, Danian, Campanian-Eocene, uppermost Thanetian-lower Ypresian and Eocene (Fig. 21). The foraminiferal fauna constrains the age of the mid-Cretaceous Burkut Formation (Burkut Nappe), the Campanian-Paleogene Urda and Bobruk formations (Svydovets Nappe), the mid-Cretaceous Shypot and Yalovets formations, the Senonian-Danian Bereznyi Formation, as well as the Eocene hieroglyphic-type beds (Dukla Nappe).

STUCTURAL RESULTS

According to our geological mapping, the northwestern ends of the Burkut and Svydovets units of the Eastern Carpathians are represented by elongated tectonic blocks (up to a few kilometres across) extending in the sub-Carpathian (NW–SE) direction and bordering the Dukla and Silesian units (Figs. 4 and 5). The blocks are bounded by straight subvertical faults at the SW and NE sides and by arch-like faults on the NW side (Figs. 4 and 5).

The arc-like faults most likely represent thrust boundaries. Unfortunately, exposures of these thrust boundaries were not found by us on the area mapped. However, we can observe that the thick-bedded Burkut sandstone of the Burkut Unit dips at angles of 5–35° in the western direction beneath Cretaceous and Paleogene flysch deposits of the Dukla Nappe (see Fig. 5). The thick-bedded sandstones of the Bobruk Formation of the Svydovets Unit also dip beneath the flysch deposits of the Dukla Nappe (see Figs. 5 and 6). Based on these observations and the results of our own geological mapping, we assume that the Dukla Nappe is thrust over the Burkut and Svydovets units. It looks as if the Eastern Carpathian nappes plunge to the west beneath the Western Carpathian Dukla Nappe (see Figs. 4 and 5).

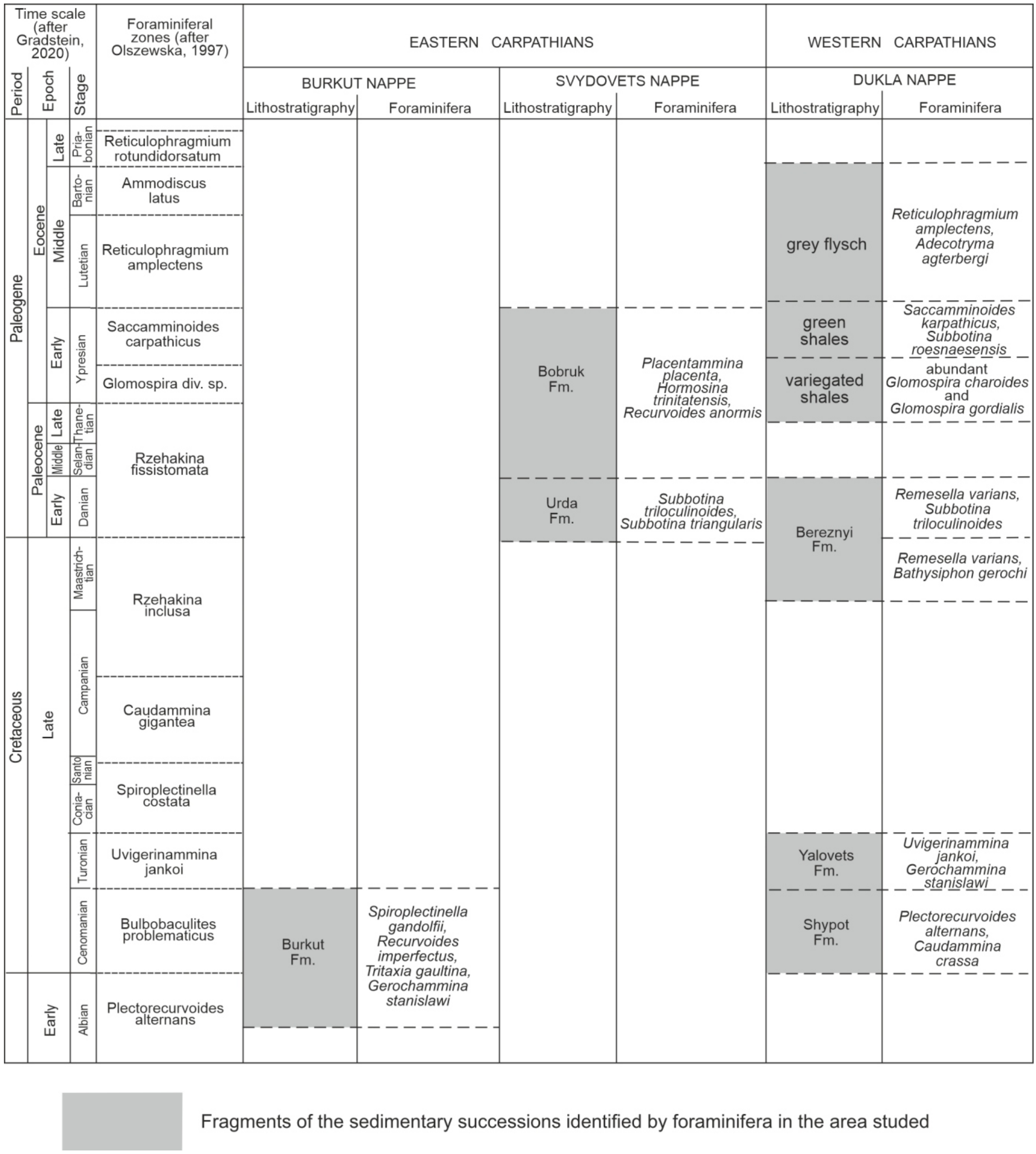


Fig. 21. Correlation of the deposits studied with the biostratigraphical scheme of Olszewska (1997) for the late Albian-Eocene interval

In addition, the thrust boundary between the upper Dukla Nappe and the lower Burkut and Svydovets nappes is tectonically deformed and forms gentle antiforms and synforms. In the cores of the antiforms, the rocks of the lower Burkut and Svydovets nappes are exposed, and in the cores of the synforms, the deposits of the upper Dukla Nappe are developed (see Figs. 5 and 6). The arc-like forms of the thrusts demonstrate these antiforms and synforms on the geological map (see Figs. 4 and 5). Furthermore, subvertical faults limit these antiforms and synforms, dividing them into the elongated tectonic blocks of sub-Carpathian (NW–SE) direction noted above (Figs. 4, 5 and 22).

In general, the East Carpathian Burkut and Svydovets units are mainly comprise massive and thick-bedded sandstones of the Burkut and Bobruk formations, which built relatively rigid tectonic bodies. These sandstones are weakly deformed, characterized by a monotonous bedding arrangement and form some gentle folds. On the other hand, the Western Carpathian Dukla Unit is composed mostly of thin- and medium-bedded flysch deposits of the Cretaceous-Paleogene succession, which are soft and strongly deformed formations. Soft Oligocene deposits are also developed in the Silesian Unit adjacent to the Western/Eastern Carpathian junction area. All these soft formations are intensely deformed up to tectonic mélange, especially along the boundaries of the tectonic units (see Fig. 5).

Fig. 22. Panoramic photo of the western termination of an E–W elongated tectonic block of the Eastern Carpathian Burkut Unit plunging to the west beneath the Western Carpathian Dukla Nappe (the point of the photo is located between the Oblaznyi and Luh streams)

In the Dukla Unit, only the Oligocene deposits located far from the contact with the East Carpathian tectonic units are deformed weakly and form gentle synclines, including the Malyi Vyzhen brachysyncline which is developed around the Maly Vyzhen mountain as well as a syncline in the area of the village of Holubyne in the west of the area mapped (see Figs. 4 and 5).

The subvertical and straight shape of the faults bounding the tectonic blocks of both the Burkut and Svydovets units at the SW and NE sides of the Dukla unit most likely suggests the strike-slip nature of these faults. Along these faults, we observed zones of intense tectonic deformation, such as shear zones with numerous tectonic slickensides, broken formations and tectonic mélanges, the width of which reaches tens and hundreds of metres, some of these being described below.

In the far north of the studied area, the Eastern Carpathian Svydovets Unit is bordered to the NE by strongly deformed rocks of the Silesian Unit (see Fig. 4). The border zone itself, between the Svydovets and the Silesian units, is not visible in the area mapped, but a few tens of metres to the north of this border zone, broken formations and melanges are exposed along the Mala Pinya riverbed near the Uklin Pass. These are made up by the Oligocene Verets (transitional) Formation of the Silesian Unit. Broken formations (disrupted deposits in which the primary stratal sequence can still be recognized, see Hsü, 1968; Starzec et al., 2015; Festa et al., 2019 and references therein) are represented here by bedded rocks with folded and destroyed layers (Fig. 23A). Sandstone beds up to a few centimetres and decimetres thick alternate with mud- and clay shales. Some beds are boudinaged and disrupted into angular clasts randomly included in black-grey shaly matrix (see Fig. 23A right side). The clayey matrix is deformed by cleavage planes, which split the matrix into millimetre- to centimetre-scale lenses. As a rule, the tectonic foliation (i.e. cleavage), and bedding and bedding remnants, are subvertical, while small faults and conjugate drag folds are characterized by subvertical fault planes and fold hinges (see Fig. 23A left side), which suggest strike-slip movement with subhorizontal principal axes of compression and extension. The drag folds suggest right-lateral movement (see Fig. 23A left side). Tectonic foliation is characterized by a Subcarpathian (SE–NW) strike, as with the direction of the border zone between the Svydovets and Silesian units. On the other hand, the rocks of the Svydovets Unit exposed to the south of the border zone are weakly deformed. They are mainly composed of rigid thick-bedded and massive sandstones (Bobruk Formation), which are characterized by monotonous bedding and form gentle folds with subhorizontal hinges.

A few tens of metres to the north of the broken formation noted above, the tectonic mélange (completely destroyed units: see Hsü, 1968; Starzec et al., 2015; Festa et al., 2019 and references therein) is exposed along the Mala Pynya riverbed near the Uklin Pass (Fig. 23B, C). The mélange comprises more intensely disrupted units compared to the broken formation. It is characterized by a block-in-matrix fabric, in which the primary stratal sequence is not preserved and blocks of different sizes are scattered in a black-grey shaly matrix. The blocks are either the remnants of individual sandstone layers (Fig. 23C) or clasts (visible sizes up to a few metres) of thin- to medium-bedded flysch of the Verets Formation (Fig. 23B). Lenticular and sigmoidal blocks up to a few decimetres and metres in size are characteristic (Fig. 23C). The rocks in the blocks are folded, strongly fractured and/or transformed into tectonic breccias. The matrix of the mélange is characterized by a scaly fabric formed by subvertical cleavage surfaces with mm spacing.

Near the SW margin of the Svydovet Unit at the border zone between the Svydovets and Dukla units, the tectonic mélange formed by the Bereznyi Formation is sporadically exposed around the village of Uklin along the Mala Pinya River and its

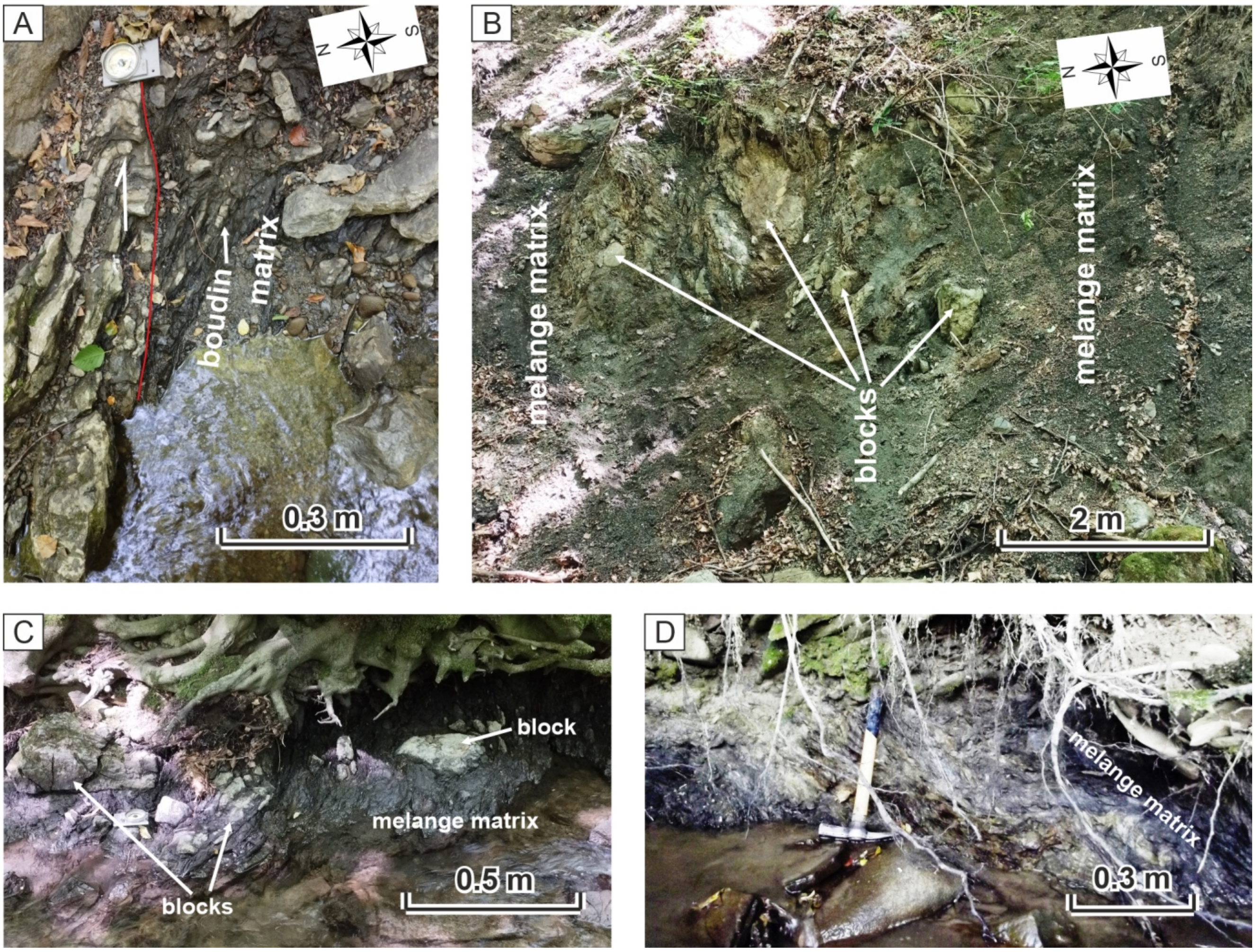


Fig. 23. Broken formations and mélanges near the contact zone of the Eastern Carpathian Svydovets Unit with both the Silesian Unit (A–C) and the Western Carpathian Dukla Unit (D)

A – broken formation (the top view) resulting from deformation of the Oligocene deposits near the northern contact of the Svydovets Unit: folded and destroyed sediments, some beds are boudinaged and disrupted into angular clasts included in black-grey shaly matrix (right side); tectonic foliation, bedding, small fault and hinge of the fold are subvertical and small fault with conjugated drag fold (left side) suggest right-lateral movement (Mala Pynya River near Uklin Pass); **B** – tectonic mélange (the side view) characterized by the block-in-matrix fabric with subvertical foliation, formed as a result of the deformation of Oligocene deposits near the northern contact of the Svydovets Unit (Mala Pynya River near Uklin Pass); **C** –tectonic mélange with little blocks represented by remnants of individual sandstone beds of Oligocene deposits embedded in a clay matrix (Mala Pynya River near Uklin Pass); **D** – tectonic mélange formed by rocks of the Upper Cretaceous - Paleocene Bereznyi Formation near the southern contact of the Svydovets Unit (Mala Pynya River near the village of Uklin)

tributaries (see Fig. 5). The mélange is represented by black and grey tectonic breccia-like formation, in which small elongated lenticular sandstone clasts up to a few centimetres and decimetres in size are embedded in the black-shale matrix (Fig. 23D). The matrix is penetrated by cleavage, and the sandstone clasts are elongated and flattened in the cleavage plane.

A characteristic contact of the Burkut and Dukla units is exposed along the Zalom Stream, the left tributary of the Mala Pinya River (see Fig. 5). In this area, the Burkut Unit comprises thick-bedded sandstone (Burkut Formation), and the Dukla Unit contains variegated shales (Yalovets Formation) and thin-bedded grey flysch (Bereznyi Formation). In the channel of the Zalom stream 1 km upstream of its confluence with the Mala Pynya River, a vertical fault surface with fault grooves is exposed as a sandstone wall. The slickenlines on the fault surface are oriented subhorizontally in a NW–SW direction indicating strike-slip type kinematics (Fig. 24A, B). To the NE of this fault surface, sandstones of the Burkut Formation are located. Their thick beds lie subhorizontally, forming gentle folds. To the SW of the fault surface, a mélange formed by rocks of the Yalovets and Bereznyi formations of the Dukla Unit is exposed. The mélange can be traced down along the Zalom Stream for several hundreds of metres. Below, we call it the Zalom mélange.

The Zalom melange is characterized by a block-in-matrix fabric. Blocks ranging in size from centimetres to several tens of metres are made of grey bedded flysch of the Bereznyi Formation (Fig. 24A, C on the left), and fine-grained sandstones and variegated shales of the Yalovets Formation. The blocks have either an elongated lenticular shape if composed of relatively ductile thin-bedded flysch and clay shales, or an angular shape (Fig. 24D) if composed of rigid sandstones. The rigid sandstone blocks are as a rule highly fractured, up to tectonic breccia (Figs. 24E).

The matrix of the Zalom mélange is represented by red and green shales of the Yalovets Formation (Figs. 24A in its central part; 24C and D on the right side; 24F on the left side) and grey

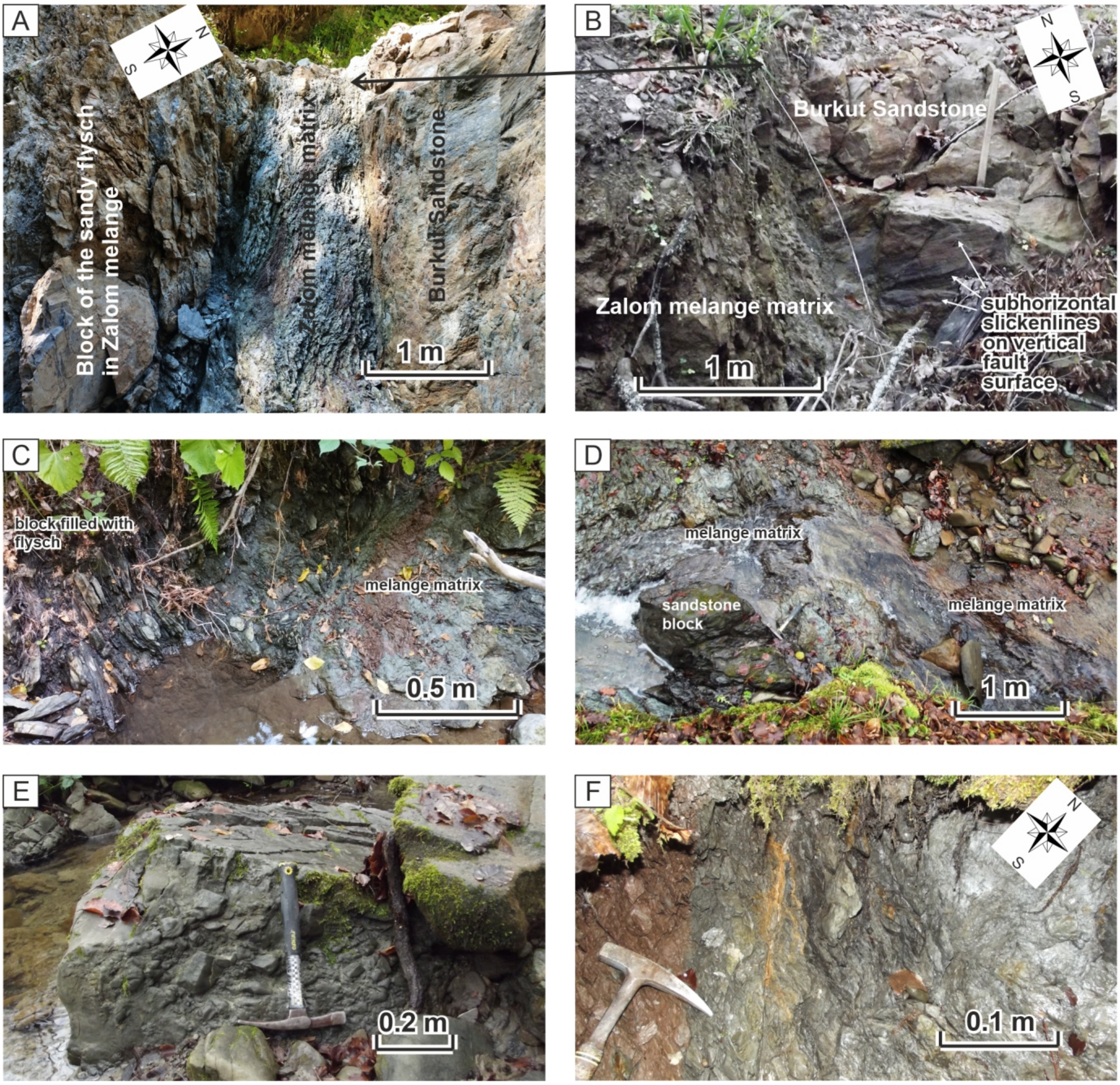


Fig. 24. Zalom mélange near the contact zone between the Eastern Carpathian Burkut Unit and the Western Carpathian Dukla Unit (Zalom Stream between the villages of Polyana and Uklin)

A, **B** – vertical fault surface (side view of the same exposure from the east – A and from the south – B) with subhorizontal fault grooves on a sandstone wall located between the rigid Burkut Sandstone (on the right) and the Zalom mélange (on the left); the mélange is formed of intensely deformed ductile shales of the Yalovets Formation and flysch of the Bereznyi Formation with vertical tectonic foliation; **C** – Zalom mélange with block filled with grey flysch of the Bereznyi Formation and matrix represetted by red and green clay deposits of the Yalovets Formation; **D** – rigid sandstone block in the Zalom mélange; **E** – rigid sandstone block fractured up to tectonic breccia; **F** – sigmoidal and lenticular clasts embedded within scaly matrix generally show their long-axis aligned to the vertical tectonic foliation (the side view)

and black shales of the Bereznyi Formation (Figs. 24B on the left side; 24F on the right side). It is characterized by a vertical scaly fabric locally arranged as S-C structures (Fig 25A) as described by Festa et al. (2019) in the mélanges. The S-C structures suggest left-lateral strike-slip movement near a vertical contact zone (see Fig. 24A and B) between the Burkut Sandstone of the Burkut Nappe and the Zalom mélange of the Dukla Nappe. Sigmoidal and lenticular clasts and blocks embedded within this scaly matrix show their long-axis aligned to the tectonic foliation (Fig. 24F). The transitions from the blocks to the matrix are either sharp, if the blocks are composed of sandstones, or gradual, if the blocks are composed of clayey shales similar to the matrix.

In addition, fragments of folds with subvertical hinges are observed in the Zalom mélange (Fig. 25B). This evidence, as well as the vertical tectonic foliation in the mélange matrix (see Figs. 24A, B and F), and subhorizontally oriented slickenlines on the straight vertical fault surface between the Burkut and Dukla tectonic units (see Fig 24A, B), testify to strike-slip movement between the Burkut and Dukla units. The S-C structures

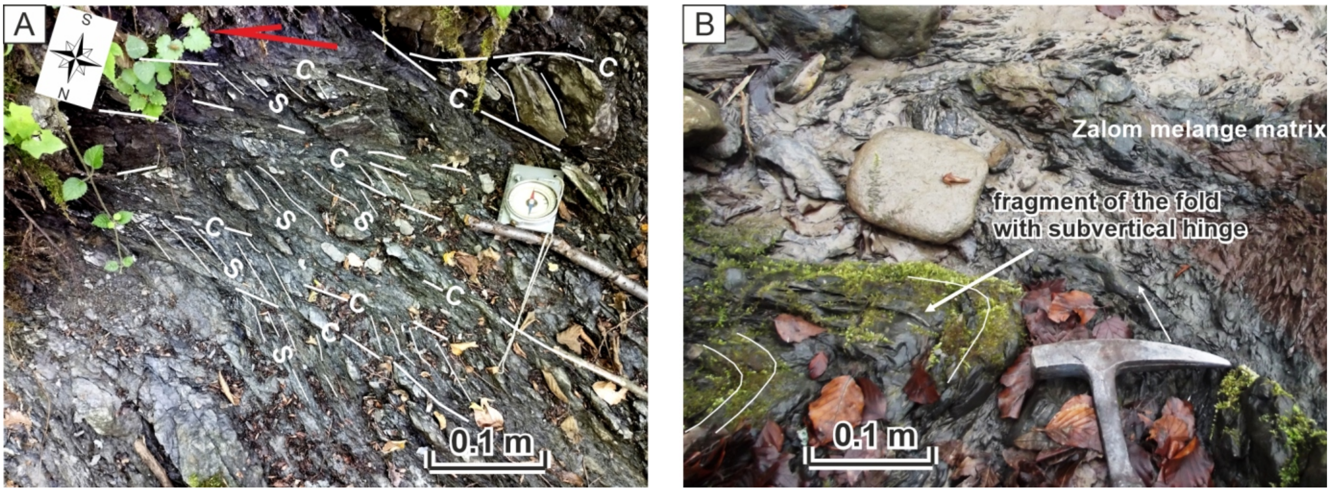


Fig. 25. Zalom mélange near the contact zone between Burkut and Dukla units (Zalom Stream between the villages of Polyana and Uklin)

A – vertical scaly fabric locally arranged in shear-zones with S-C structures (top view); **B** – fold fragment with subvertical hinge in the Zalom mélange (top view)

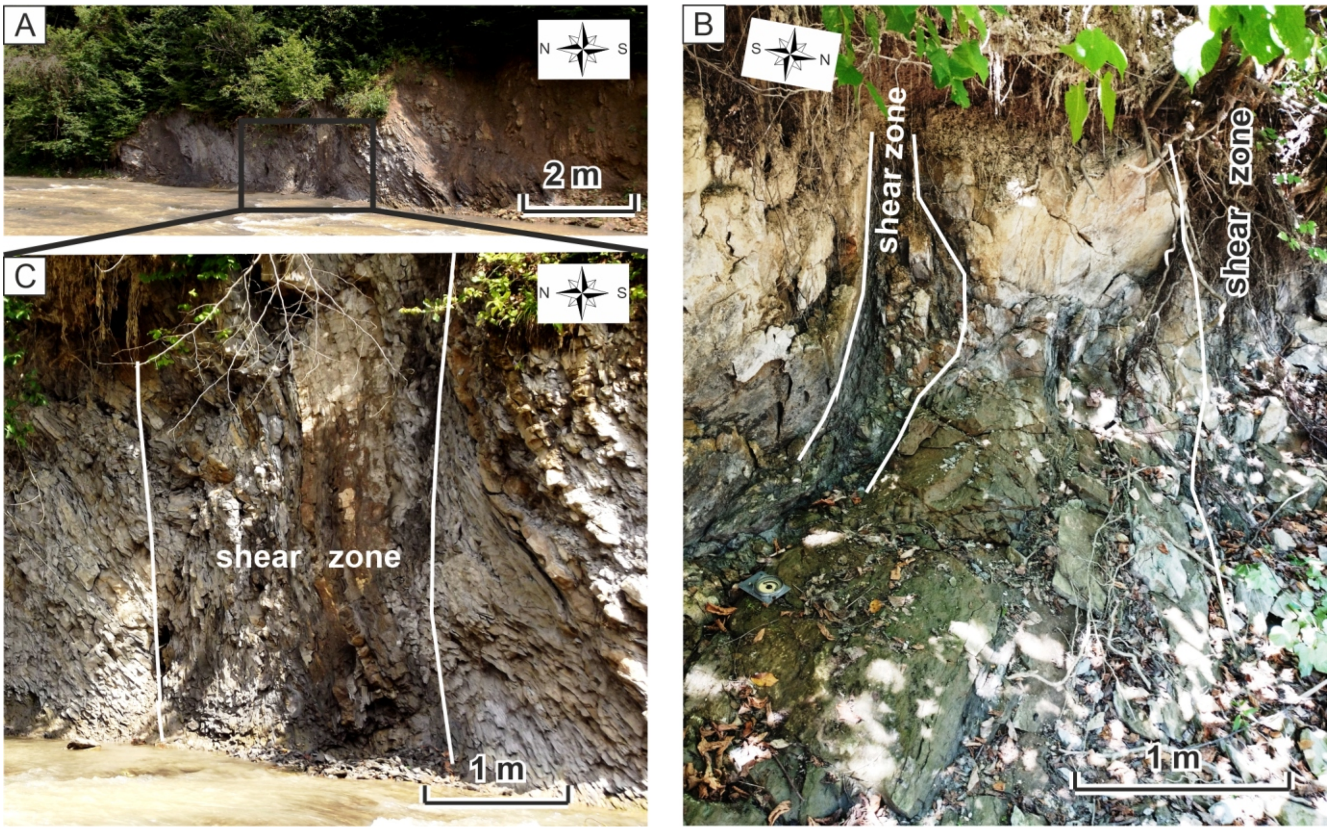


Fig. 26. Shear zones near the contact of the Burkut and Dukla units

A – subvertical shear-zones in deformed flysch deposits of the Bereznyi Formation belonging to the Dukla Unit (side view; Pynya River near Holubyne village); **B** – shear-zones in the Burkut Sandstone filled with tectonic breccia mainly formed by disrupted sandstones and characterised by a subvertical tectonic foliation (side view; Pynya River near mouth of the Oblaznyi Stream); **C** –part of Figure 25A with subvertical shear-zone in flysch deposits of the Bereznyi Formation

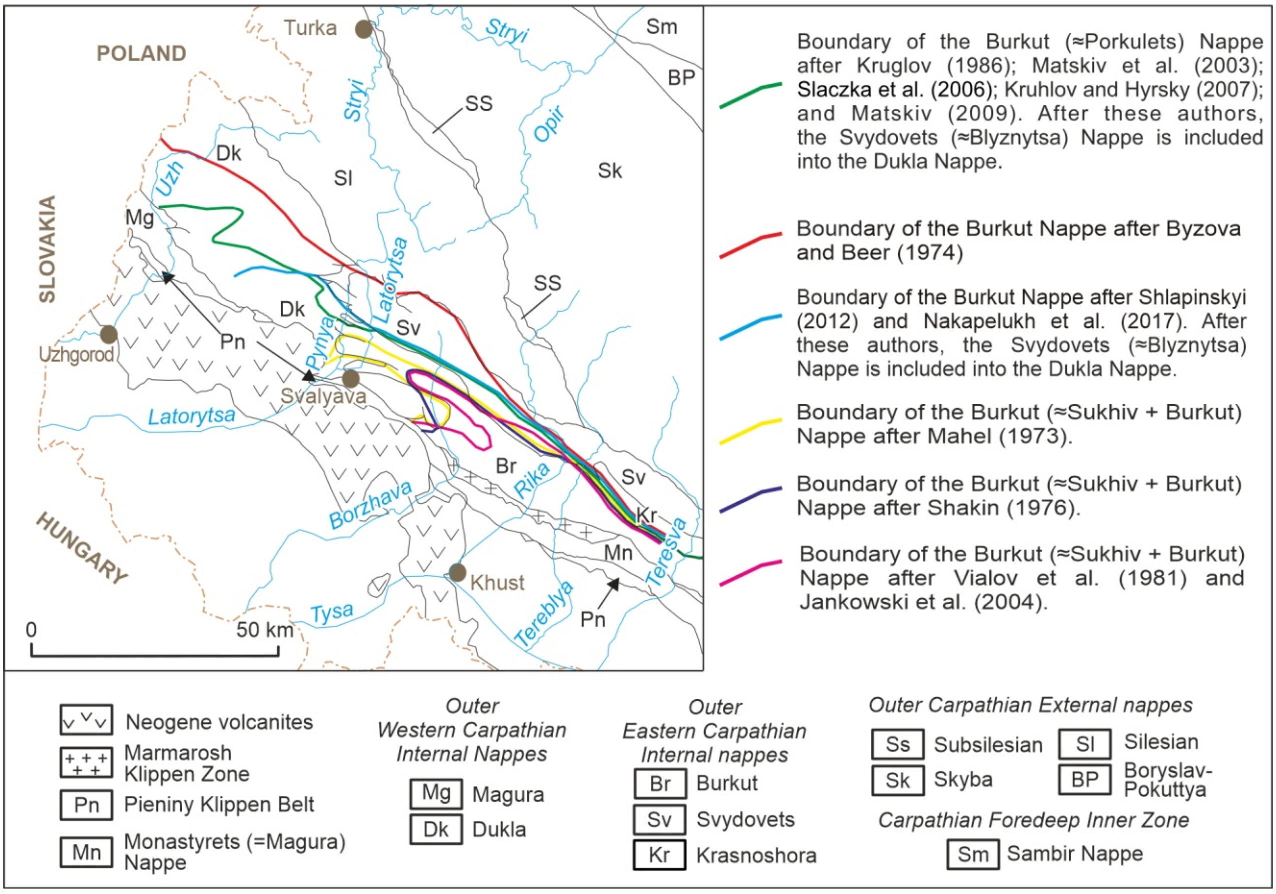


Fig. 27. The boundaries (coloured lines) of the most disputed Outer Eastern Carpathian Burkut Nappe in the Western/Eastern Carpathian junction area according to previous researchers (see Fig. 2 for location)

The boundaries depicted as black lines are adopted in this article (see Figs. 1 and 2)

suggest a left-lateral sense for these movements (see Fig. 25A). The strike-slip movements probably took place in a fairly wide shear zone (tens and up to hundreds of metres, as shown by the width of the Zalom mélange).

Along the Mala Pynya riverbed near the village of Holubyne, a few tens of metres to the south of the contact between the Burkut and Dukla units, broken formations and mélanges are exposed. They are made up of thin- and medium-bedded grey flysch of the Upper Cretaceous-Paleocene Bereznyi Formation of the Dukla Unit. This flysch generally dips to the south-west and is dissected by subvertical shear-zones from a few metres to tens of metres thick (Fig. 26A, C). In the shear-zones, the flysch is boudinaged, disrupted and shows a mélange block-in-matrix structure. Some sandstone bed remnants up to a few centimetres and decimetres thick are intensively folded and here included in the shaly matrix. The mélange matrix is characterized by a scaly fabric formed by cleavage surfaces. These cleavage surfaces and elongated blocks in the mélange, as well as the hinges of small folds, are oriented usually subvertically, suggesting strike-slip type kinematics.

Along other contact zones of the East Carpathian and West Carpathian tectonic units, mélanges and broken formations up to hundreds of metres wide are also observed, although these contacts are usually unsatisfactorily exposed and the mélange comes to the surface in fragments. Shear-zones were also observed within the Burkut and Svydovets units. They are usually oriented subvertically and extend in the sub-Carpathian direction (NW–SE), and have a thickness of up to a few metres. These shear-zones are filled with tectonic breccias mainly formed by disrupted sandstones and characterised by a subvertical tectonic foliation. Sandstone clasts are elongated and flattened in the plane of the foliation here (Fig. 26B).

Thus, in the area mapped, the Dukla Nappe of the Western Carpathians is thrust over the Burkut and Svydovets units of the Eastern Carpathians. The thrust boundary between them was subsequently deformed into gentle antiforms and synforms and cut by subvertical strike-slip faults elongated in a NW–SE parallel-Carpathian direction. Along these faults, zones of intense tectonic deformation, such as shear zones with numerous tectonic slickensides, broken formations and tectonic mélanges, the width of which reaches tens and hundreds of metres, are developed. The matrix of the tectonic mélange is characterized by a vertical scaly fabric locally arranged as S-C structures indicating the sense of the strike-slip movements. Subhorizontally oriented slickenlines on the straight fault surfaces as well as fragments of folds with subvertical hinges are also observed here.

DISCUSSION: CONNECTION BETWEEN THE EASTERN AND WESTERN OUTER CARPATHIAN INTERNAL NAPPES AS A CONTACT OF TWO ACCRETIONARY PRISMS

The boundary between the internal nappes of the Outer Western Carpathians and Outer Eastern Carpathians is depicted in different ways. This is most clearly expressed in the different interpretation of the Burkut (Porkulets) Nappe border, which marks the most disputable link of the boundary between the Eastern and Western Carpathians (Fig. 27, see also Kruglov and Smirnov, 1981).

According to some published tectonic schemes and geological maps of the Ukrainian Carpathians (Byzova and Beer, 1974; Kruglov, 1986; Ślączka et al., 2006; Matskiv et al., 2003; Matskiv, 2009a) and Ukraine (Kruhlov and Hyrsky, 2007), the

Burkut (Porkulets) Nappe extends from the Eastern Carpathians towards the NW up to the Uzh river basin near the Ukrainian/Slovakian state boundary (see Fig. 27). In our opinion, the Burkut Nappe is absent from the Uzh River basin, and the Duklya Nappe of the Western Carpathians is developed instead. The key difference between the stratigraphic successions of the Dukla and Burkut tectonic units is the completely dissimilar early-mid Cretaceous formations. The lower and lowermost Upper Cretaceous are represented by either black shale deposits (Shypot Formation) in the Dukla succession or by grey sandy flysch (Burkut and Bila Tysa formations) in the Burkut succession. Additionally, the Burkut sedimentary succession contains Cretaceous deposits only, while the Dukla sedimentary succession consists of Cretaceous-Paleogene (including Oligocene) deposits (see above and Fig. 3) The presence in the Uzh River basin of the mid-Cretaceous Shypot Formation as well as the Paleogene (including Oligocene) deposits characteristic of the Dukla Nappe indicates that the Dukla Nappe is developed here (Danysh, 1973; Shakin, 1976; Vialov et al., 1981; Jankowski et al., 2004). However, in the opinion of Byzova and Maslakova (1974), such an interpretation is contradicted by the findings of Albian and Cenomanian foraminifera in clay deposits near sandstone exposures, that look like the Burkut Formation in the basin of the Uzh River (Byzova and Maslakova, 1974). In our opinion, these faunal records require additional verification, because the fauna can be located in the mélange zones widely developed in the area. According to Vialov et al. (1981), these sandstones are not fragments of the Burkut Formation and belong to the Upper Cretaceous and/or Paleogene sandstones of the Dukla Nappe. Thus, the prolongation of the Burkut Nappe within the Uzh River basin has not been proven, just as Danysh (1973, 2004), Mahel (1973), Shakin (1976), Vialov et al. (1981) and Jankowski et al. (2004, 2007) assumed.

The westernmost outcrops of the faunally constrained Burkut Formation are located to the east of the Uzh River basin in the Pynya River basin (Latorytsa River basin), where along the Zalom Stream (left tributary of the Mala Pynya River, for location see Fig. 5), *S. gandolfii, H. minor, H. platus, T. subbotinae* and *A. rotalaris* had been previously identified in the Burkut Formation (Byzova and Maslakova, 1974).

According to our own litho- and biostratigraphic and structural and mapping, the boundary between the Burkut and Svydovets nappes of the Eastern Carpathians and the Dukla Nappe of the Western Carpathians is identified in the basins of the Borzhava and Latorytsa rivers (see Figs. 2, 4 and 5). The location of the boundary according to our mapping differs from previous opinions and is only moderately close to some previous points of view (e.g., Mahel, 1973; Shakin, 1978; Vialov et al., 1981; Csontos and Vörös, 2004; Jankowski et al., 2004, 2007). In addition, we have mapped that the Dukla nappe as thrust over the Burkut nappe, and not vice versa, which differs from previous points of view.

The genesis of the connection zone between the eastern and western Outer Carpathian nappe systems is related to the nature of these systems. In general, the Outer Carpathian nappes are considered as an accretionary prism growing in front of the Central Carpathian terranes (Oszczypko, 2006; Kováč et al., 2016, 2017; Golonka et al., 2019; Roger et al., 2023 and references therein).

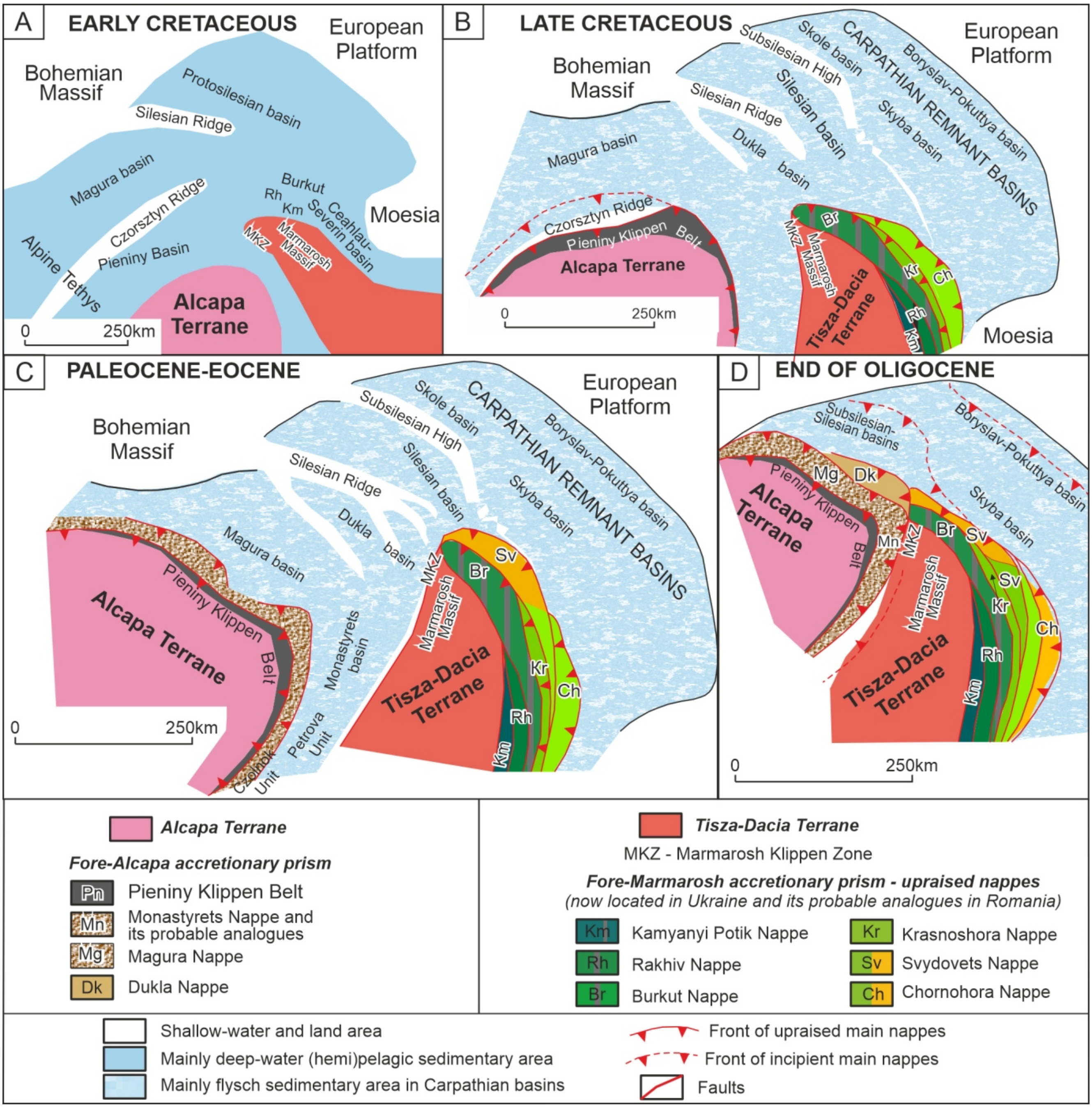
In Ukraine, the principal difference is observed in the stratigraphic successions of the internal flysch nappes of the Outer Eastern Carpathians, and the internal flysch nappes of the Outer Western Carpathians (Fig. 3). The Outer Eastern Carpathian internal nappes consist of mainly Cretaceous flysch deposits with a small Paleogene, especially Oligocene, component. The age of these deposits gradually changes from the Early Cretaceous to the Paleogene towards the more external units. This phenomenon is related to the development of the Outer Eastern Carpathian internal nappes as the Fore-Marmarosh accretionary prism during this time (Gnylko, 1999; Hnylko and Generalova, 2014; Figs. 1–3). The Outer Western Carpathian internal nappes contain flysch deposits which become gradually younger during the Paleogene towards the more external nappes. This suggests that they also belong to the accretionary prism, which, however, grew during Paleogene time. The Outer Western Carpathian internal nappes are assigned to the Fore-Alcapa accretionary prism (Hnylko, 2015c, Hnylko and Hnylko, 2024; Figs. 1–3). The external nappes of the Outer Carpathians, comprising Cretaceous-Miocene flysch and molasse deposits, developed as an outer prism ahead of both the Alcapa and Tisza-Dacia terrains (Hnylko, 2012). These three prisms make up the Flysch Carpathian Cretaceous-Neogene composite accretionary prism.

The Outer Carpathian composite prism formed as a result of the closure of the eastern branches of the Alpine Tethys, such as the Magura, Protosilesian (see Golonka et al., 2019 and references therein) and Ceahlau-Severin basins (Fig. 28; see Schmid et al., 2008, 2020 and references therein). These branches opened in Jurassic-early Cretaceous time, and were transformed into a remnant-type Outer Carpathian flysch basin located between the Eurasian passive margin and the active edges of the Alcapa and Tisza-Dacia terranes in the mid Cretacous (Fig. 28; see Csontos and Vörös, 2004; Oszczypko, 2006; Schmid et al., 2008, 2020; Hinsbergen et al., 2020). The outer Carpathian composite prism was formed as a result of subduction of the Outer Carpathian sedimentary flysch basin substrate beneath the Alcapa and Tisza-Dacia terranes: ancient microcontinents/continental fragments in the Tethys Ocean (Fig. 28; Kováč et al., 1998, 2016, 2017; Csontos and Vörös, 2004; Oszczypko, 2006; Golonka et al., 2006, 2019; Horvath and Galacz, 2006; Schmid et al., 2008, 2020; Merten et al., 2010; Bonova et al., 2016; Hnylko, 2011b, 2012 ;Roban et al., 2017; Hinsbergen et al., 2020; Plašienka et al., 2020).

The history of forming the the junction area between the Fore-Alcapa and Fore-Marmarosh prisms is closely related to the development of these prisms and to their subsequent interaction. These prisms developed autonomously ahead of the active margins of two different microcontinental terranes, such as the Alcapa and Tisza-Dacia.

The Fore-Alcapa accretionary prism consists of the Pieniny Klippen Belt, as well as Outer Western Carpathian internal flysch nappes such as the Magura/Monastyrets and Dukla thin-skinned nappes (see Figs. 1, 2 and 28; Murovskaya et al., 2025). The Pieniny Klippen Belt accretionary wedge began to rise in the Late Cretaceous (Plašienka, 2018 and references therein). The Magura and Dukla nappes were attached to the Fore-Alcapa prism during the Eocene-Oligocene concordantly with forelandwards shift and uplift of the trench-like Magura and Krosno lithofacies during this time (see Fig. 3; Hnylko et al., 2015c; Kováč et al., 2016; Golonka et al., 2019; Hnylko and Hnylko, 2024).

The Fore-Marmarosh (Fore-Tisza-Dacia across the Carpathians, see Fig. 1) accretionary prism comprises Outer Eastern Carpathian internal flysch nappes such as the Kamyanyi Potik, Rakhiv, Burkut, Krasnoshora, Svydovets and Chornohora nappes. The coarsening-upwards and regular younging pattern of the stratigraphic successions from upper to lower nappes suggest their attribution to an accretionary wedge which grew in the Early Cretaceous-Paleogene time due to the subduction of the Outer Carpathian flysch basin basement beneath the Marmarosh Massif. The innermost Kamyanyi Potik,



Fig, 28. Conceptual reconstruction of the main tectono-sedimentary units in the Carpathian realm

A – Early Cretaceous, modified after Golonka et al. (2006, 2021), Hinsbergen et al. (2020); **B** – Late Cretaceous, modified after Csontos and Vörös (2004), Oszczypko (2006), Schmid et al. (2008, 2020), Hinsbergen et al. (2020), Plašienka et al. (2020) and using the work of Danysh (1973), Vialov (1981), Sandulescu (1988), Merten at al. (2010) and Roban et al. (2017); **C** – Paleocene-Eocene, modified after Hnylko and Hnylko (2016, 2019); Kováč et al. (2016); Golonka et al. (2019) and using the work of Danysh (1973), Vialov (1981), Gawęda et al. (2019, 2021); Kowal-Kasprzyk et al. (2021); **D** – Oligocene, modified after Hnylko and Hnylko (2016); Kováč et al. (2016); Golonka et al. (2019)

Rakhiv, Burkut and Krasnoshora nappes comprise exclusively Late Jurassic-Cretaceous deposits and were formed during the Cretaceous (see Fig. 3; Hnylko and Generalova, 2014).

It seems that these two prisms developed separately until the Oligocene (see Fig. 28; Hnylko and Hnylko, 2016; Kováč et al., 2016). Closing of the Monastyrets “between-terrainian” flysch basin in the latest Eocene suggests the collision of the Alcapa and Tisza-Dacia terranes as the Eocene gave way to the Oligocene (Hnylko et al., 2015b; Hnylko and Hnylko, 2016). As a result, the Fore-Alcapa prism, including the Monastyrets Nappe, was thrust over the Oligocene deposits of the Marmarosh Massif sedimentary cover (see Hnylko and Hnylko, 2016). Rocks parallel with the Pieniny Klippen Belt or with the Magura Nappe in present-day Romanian territory were also thrust over clastic deposits of the Paleogene-Early Miocene sedimentary cover of the Tisza-Dacia Terrane (Sandulescu et a., 1981; Csontos and Nagymarosy, 1998; Oszczypko, 2004). Several south-vergence thrusts could be observed or inferred in the Mid-Hungarian zone (Csontos and Nagymarosy, 1998) dividing the Alcapa and Tisza-Dacia terranes. Thrusting occurred first during the Late Oligocene-Early Miocene (Csontos and Nagymarosy, 1998; Tischler et al., 2008). The Alcapa Terrane overrided the Tisza-Dacia Terrane during the collisional events (Tischler et al., 2008).

Overriding of the Alcapa Terrane onto the Tisza-Dacia Terrane may have caused thrusting of the Fore-Alcapa prism over the Fore-Tisza-Dacia prism, including thrusting of the Dukla Nappe over the western part of the Fore-Marmarosh prism (Burkut and Svydovets nappes). The Oligocene psammite and debris-flow deposits in the upper part of Dukla Nappe sedimentary succession (see Fig. 20E and F) may be synorogenic and related to the thrust uplifting of the Dukla Nappe. This way, the thrust structure of the area studied may have formed, in which the Dukla Nappe tectonically overlaps both the Burkut and Svydovets nappes of the Fore-Marmaros prism (see Fig. 28).

Note that the upper Dukla Nappe is composed of younger Cretaceous-Paleogene deposits than the lower Burkut Nappe, which is made only of Cretaceous deposits (see Figs. 5 and 6). This is explained by the fact that the Burkut Nappe was accreted to the accretionary prism in the Cretaceous, and the Dukla Nappe was attached to another prism only in the Paleogene. Subsequently, during Alcapa and Tisza-Dacia collision, the Dukla Nappe as part of the Fore-Alcapa prism was thrust onto the Cretaceous Burkut Nappe as part of the Fore-Tisza-Dacia prism (see Fig. 28).

At the end of the Oligocene, the combined Dukla, Burkut and Svydovets nappes, which already formed a single internal prism, were together thrust onto the Silesian and Skyba basins (see Fig. 28).

Subsequently in the study area, the nappes were deformed into folds, in which the cores of the antiform contained deposits of the Burkut and Svydovets nappes, and the cores of the synform consisted of deposits of the Dukla Nappe (see Figs. 5 and 6). In addition, this nappe building was cut by subvertical strike-slip faults. These faults limit the tectonic blocks elongated in a NW–SE Carpathian-parallel direction.

In general, the elongated tectonic blocks composed of rigid sandstone deposits of the Svydovets and Burkut units are grouped in a large multiplex wedge in plane view. This wedge is represented by units which extend from the Eastern Carpathians towards the Western/Eastern Carpathian junction. The wider part of the wedge is situated in the study area of Western and Eastern Carpathian junction in the Pynya and Latorytsa river basins, and its narrower part is located to the east in the basins of the Borzhava and Bronka rivers (see Figs. 2 and 4). This wedge is bounded on the northern side by a right-sense strike-slip faults, and on the southern side by a left-sense strike-slip faults (see Fig. 2), which may indicate lateral extrusion of the wedge deposits in a northwest direction. Thus, Eastern Carpathian rigid Burkut and Svydovets units could been pushed into soft deposits of the Western Carpathian Dukla Unit during lateral extrusion. Domination of the subvertical tectonic foliation in the mélange zones and subhorizontally oriented slickenlines on the straight fault surfaces as well as the presence of the folds with subvertical hinges in the Western/Eastern Carpathian junction area studied corroborate the possibility of this lateral extrusion.

The compressional thrust deformations of the Outer Carpathian sediments occurred diachronously. In the late Miocene, these compressional events ended in the Outer Western Carpathians, but continued in the Outer Eastern Carpathians (see Fodor et al., 1999; Sperner at al., 2002), which may have led to the lateral extrusion of the Eastern Carpathian units towards the Western Carpathian area at this time (Hnylko, 2017). Further detailed structural studies are needed to test the concept of this lateral extrusion.

CONCLUSIONS

1. The Outer Western Carpathian Internal flysch nappes of the Fore-Alcapa inner accretionary prism and Outer Eastern Carpathian Internal flysch nappes of the Fore-Marmarosh prism converge in the junction area located in the Latorytsa and Pynya river basins. In this study area, the Burkut and Svydovets nappes of the Fore-Marmarosh prism and the Dukla Nappe of the Fore-Alcapa prism are developed (see Figs. 1, 2, 4 and 5).

The deposits of the **Burkut Nappe** are here represented only by the Burkut Formation (Albian-Cenomanian). They consist of mainly thick-bedded sandstones and sandy flysch, in which were found characteristic the mid-Cretaceous species *S. gandolfii*, *G. stanislawi*, *T. gaultina* and *R. imperfectus* as well as the cosmopolitan Cretaceous species *B. brosgei*, *B. vitta* and *R. algaeformis*.

The sedimentary succession of the **Svydovets Nappe** is represented by the Urda and Bobruk formations in the study area. The Urda Formation (Maastrichtian-Paleocene) consists of thin- and medium-bedded flysch. *S. triangularis* of Danian age and the typical form *H. walteri* of Paleocene-Eocene age occur here.

The Bobruk Formation (Paleocene-Eocene) is represented mainly by massive and thick-bedded sandstones. *R. anormis* and *P. placenta* of Campanian-Eocene age were found here.

The sedimentary succession of the **Dukla Nappe** is represented by the Cretaceous Shypot and Yalovets formations, the Senonian-Paleocene Bereznyi Formation, Paleocene-Eocene hieroglyphic-type undivided deposits, and the Oligocene Dusyno and Malyi Vuzhen formations in the area mapped and adjacent territory.

The Shypot Formation (Barremian?-Cenomanian) is developed near the area mapped. It is a black and dark-grey medium-bedded flysch with “glassy”, essentially quartzose fine-grained sandstones and black shales. In the Luta River basin, *P. alternans*, characteristic of the mid-Cretaceous in the Carpathians, was found at the top of the Shypot Formation.

The Yalovets Formation (Turonian-Santonian) consists of variegated (red and green) shale of hemipelagic/pelagic origin with thin fine-grained turbidite intercalations. The co-occurrence of *U. jankoi* and *G. stanislawi* indicates a Turonian age for the most of the deposits studied.

The Bereznyi Formation (Campanian-Danian) is composed of polymictic or siliciclastic mainly thin- and medium-bedded flysch with shale/marl intercalations. Most of the foraminifera species identified are common in the Upper Cretaceous-Paleogene of the Carpathians. The Paleocene *S. triloculinoides* and Maastrichtian-Paleocene *R. varians* have been identified in the deposits studied.

Paleocene-Eocene hieroglyphic-type undivided deposits are represented by thin- and medium-bedded flysch, red and green shales and locally debris-flows deposits with metamorphic rock detritus. Abundant *Glomospira* which suggest the Paleocene and Eocene boundary, the species *R. intermedium* and *S. karpathicus* of Early Eocene age, and *R. amplectens* and *A. agterbergi* Gradstein and Kaminski characteristic of the Middle-Upper Eocene, were found in the deposits studied.

The Oligocene Dusyno Formation is represented by bituminous black and dark-grey marls and calcareous mudstones and the Malyi Vuzhen Formation consists of thick- and medium-bedded polymictic sandstones with scattered organic detritus.

2. Our geological mapping indicates that the northwestern ends of the Burkut and Svydovets units of the Eastern Carpathians plunge to the west beneath the Western Carpathian Dukla Nappe. The thrust boundary between the upper Dukla Nappe and the lower Burkut and Svydovets nappes is tectonically deformed and forms gentle antiforms and synforms. In addition, subvertical faults cut these antiforms and synforms, dividing them into elongated tectonic blocks of sub-Carpathian (NW–SE) direction. Zones of intense tectonic deformations such as shear zones, broken formations and tectonic mélanges, the width of which reaches tens and hundreds of metres, are developed along these faults. The matrix of the well-exposed mélange zones is characterized by a vertical scaly fabric locally arranged as S-C structures. The vertical tectonic foliation and fold fragments with subvertical hinges in the mélange matrix, as well as subhorizontally oriented slickenlines on the straight vertical fault surfaces between the rigid sandstones and mélange matrix, suggest strike-slip movements along the faults.

3. The genesis and history of development of the junction area between the Fore-Alcapa and Fore-Marmarosh prisms is closely related to the development of these prisms and to their subsequent interaction. It seems that these two prisms developed separately until the Oligocene (see Fig. 28). Closing of the Monastyrets “between-terrane” flysch basin in the latest Eocene suggest the collision of the Alcapa and Tisza-Dacia terranes at the end of the Eocene and beginning of the Oligocene. As a result of the collisional event, the Monastyrets Nappe of the Fore-Alcapa prism was thrust over the Marmarosh Massif, and the most outer Fore-Alcapa Dukla Nappe was thrust over the western part of the Fore-Marmarosh prism (Burkut and Svydovets nappes). Subsequently, the nappes were deformed into folds and cut by subvertical faults of strike-slip sense.

4. In general, the elongated tectonic blocks composed of rigid sandstone deposits of the Svydovets and Burkut units are grouped in a large multiplex wedge in plan view. This wedge is represented by units which extend from the Eastern Carpathians towards the Western/Eastern Carpathian junction. The wedge is bounded on the northern side by a right-sense strike-slip faults, and on the southern side by a left-sense strike-slip faults, which may indicate lateral extrusion of the wedge deposits in a northwest direction. Thus, the Eastern Carpathian rigid Burkut and Svydovets units may been pushed into the soft deposits of the Western Carpathian Dukla Unit during lateral extrusion.

Acknowledgements. The geological studies described were carried out at the Institute of Geology and Geochemistry of Combustible Minerals of the National Academy of Sciences of Ukraine. The authors thank Jan Golonka, Robert Kopciowski and Anna Wysocka for a detailed analysis of the manuscript and valuable recommendations for revision and improvement of the paper. Part of fieldwork in the Ukrainian Transcarpathian and micropalaeontological studies were supported by the research grants “Tectonic architecture of northern Carpathians from geophysical and geological data” of the Department of Chemistry, Life and Environmental Sustainability of University of Parma, Italy. The authors thank Fabrizio Storti for valuable recommendations on structural data interpretation.

REFERENCES

Andreyeva-Grigorovich, A.S., Vialov, O.S., Gavura, S.P., Gruzman, A.D., Dabagyan, N.V., Danysh, V.V., Ivanik, M.M., Kulchitskiy, Ya.O., Lozynyak, P.Yu., Maslun, N.V., Petrashkevich, M.Y., Ponomaryova, L.D., Portnyagina, L.A., Smirnov, S.E., Sovchyk, Ya.V., 1985. Regional stratigraphic scheme of the Paleogene deposits of the Ukrainian Carpathians (in Russian with English summary). Paleontologicheskiy Sbornik, **22**: 88–89.

Beer, M.A., Byzova, S.L., Maslakova, N.I., 1971. Geological structure of the Bliznitsa subzone of the Flysch Carpathians (in Russian). Vestnik Moskovskogo universiteta, (4): 41–51.

Bónová, K., Bóna, J., Kováčik, M., Laurinc, D., 2016. Heavy minerals from sedimentary rocks of the Malcov Formation and their palaeogeographic implications for evolution of the Magura Basin (Western Carpathians, Slovakia) during the Late Eocene–Late Oligocene. Geological Quarterly, **60**: 675–694; https://doi.org/10.7306/gq.1285

Byzova, S.L., 1979. Burkut Suite (in Russian). In: Stratigraphic Dictionary of the USSR. Triassic. Jurassic. Cretaceous (ed. V.N. Vereshchagin): 77. Nedra Press, Leningrad.

Byzova, S.L., Beer, M.A., 1974. Main features of the tectonics of the Soviet part of the Flysch Carpathians (in Russian). Geotektonika, **6**: 82–94.

Byzova, S.L., Maslakova, N.I., 1974. Features of the structure and distribution of the Burkut Formation in the Soviet Carpathians (in Russian). Vestnik Moskovskogo Universiteta, (1): 96–104.

Byzova, S.L., Gorbachyk T.N., **Maslakova, N.I., 1966a.** About the age of the Cretaceous deposits of the Rakhov Zone (in Russian). In: Essays on the Geology of the Soviet Carpathians (ed. V.I. Slavin): 62–67. Moscow University Publishing House, Moscow.

Byzova, S.L., Maslakova, N.I., Gorbachyk, T.N., 1966b. New data on the structure and age of the Shipot Formation in the southeastern part of the Soviet Carpathians (in Russian). In: Essays on the Geology of the Soviet Carpathians (ed. V.I. Slavin): 48–62. Moscow University Publishing House, Moscow.

Csontos, L, Nagymarosy, A., 1998. The Mid-Hungarian line: a zone of repeated tectonic inversions. Tectonophysics, **297**: 51–71; https://doi.org/10.1016/S0040-1951(98)00163-2

Csontos, L., Vörös, A., 2004. Mesozoic plate tectonic reconstruction of the Carpathian region. Palaeogeography, Palaeoclimatology, Palaeoecology, **210**: 1–56; https://doi.org/10.1016/j.palaeo.2004.02.033

Dabagian, N.V., 1969. Foraminifera from the transition beds between Lower and Upper Cretaceous in the Ukrainian Carpathians. Rocznik Polskiego Towarzystwa Geologicznego, **39**: 213-223.

Dabagyan, N.V., 1978. On the horizon with *Uvigerinammina jankoi* Majzon in the Ukrainian Carpathians (in Russian with English summary). Paleontological Sbornik, **15**: 9–13.

Dabagyan, N.V., Kulchytskyi, Ya.O., Lozynyak, P.Yu., 1967. Geologic structure and Cretaceous stratigraphy of the Rakhiv zone (in Russian). In: Reports of VIII Congress of Carpathian-Balcan Geological Association (CBGA): 283–288. Belgrade.

Danysh, V.V., 1973. Geology of the western part of the southern slope of the Ukrainian Carpathians (in Ukrainian). Naukova Dumka, Kyiv.

Danysh, V.V., 2004. Folded Carpathians. Tectonics. In: Carpathian oil and Gas-bearing Province (in Ukrainian): 57–77. Ukrainian Publishing Center, Lviv-Kyiv.

Festa, A., Pini, G.A., Ogata, K., Dilek, Y., 2019. Diagnostic features and field-criteria in recognition of tectonic, sedimentary and diapiric mélanges in orogenic belts and exhumed subduction-accretion complexes. Gondwana Research, **74**: 11–34; https://doi.org/10.1016/j.gr.2019.01.003

Fodor, L., Csontos L., Bada, G., Gyorfi, I., Benkovics, L., 1999. Tertiary tectonic evolution of the Pannonian basin system and neighbouring orogens: a new synthesis of palaeostress data. Geological Society Special Publications, **156:** 295–334; https://doi.org/10.1144/gsl.sp.1999.156.01.15

Gabinet, M. P., Kulchytskyi, Ya.O., Matkovskyi, O.I., 1976. Geology and mineral resources of the Ukrainian Carpathians, part 1. Vyshcha Shkola, Kyiv.

Gawęda, A., Golonka, J., Waśkowska, A., Szopa, K., Chew, D., Starzec, K., Wieczorek, A., 2019. Neoproterozoic crystalline exotic clasts in the Polish Outer Carpathian flysch: remnants of the Proto-Carpathian continent? International Journal of Earth Sciences, **108**: 1409–1427; https://doi.org/10.1007/s00531-019-01713-x

Gawęda, A., Golonka, J., Chew, D., Waśkowska, A., Szopa, K., 2021. Central European Variscan Basement in the Outer Carpathians: a case study from the Magura Nappe, Outer Western Carpathians, Poland. Minerals, **11**, 256; https://doi.org/10.3390/min11030256

Generalova, L., Pashchenko, V., Stepanov, V., 2013. Some features of vulcanites chemism of Trostyanetsky Mesozoic complex (Ukrainian Carpathians) (in Ukrainian with English summary). Visnyk of the Lviv University. Series Geology, **27**: 104–115.

Geroch, S., Nowak, W., 1984. Proposal of zonation for the Late Tithonian-Late Eocene, based upon arenaceous Foraminifera from the Outer Carpathians, Poland. Bulletin des Centres de Recherches Exploration – Production Elf-Aquitaine, **6**: 225–239.

Gnylko, O., 1999. Cretaceous evolution of the Fore-Marmarosh flysch basins (Ukrainian Carpathians). Geologica Carpathica, **50**: 26–27.

Golonka, J., Gahagan, L., Krobicki, M., Marko, F., Oszczypko, N., Ślączka, A., 2006. Plate tectonic evolution and paleogeography of the circum-Carpathian region. AAPG Memoir, **84**: 11–46; https://doi.org/10.1306/985606M843066

Golonka, J., Waśkowska, A., Ślączka, A., 2019. The Western Outer Carpathians: origin and evolution. Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, **170**: 229–254; https://doi.org/10.1127/zdgg/2019/0193

Golonka, J., Gawęda, A., Waśkowska, A., 2021. Carpathians. Encyclopedia of Geology, 2nd Edition (eds. D. Alderon and S.A. Elias). Elsevier, Amsterdam: 372–381.

Gorbachyk, T.N., **Byzova, S.L., 1974.** On occurrences of foraminifera from the Lower Cretaceous deposits of the Soviet Carpathians (in Russian with English summary). Paleontological sbornik, **11**: 3–10.

Gradstein, F.M., Ogg, J.G., Schmitz, M.D., Ogg, G.M. (eds.), 2020. Geologic Time Scale. Elsevier.

Hinsbergen, D.J.J. van, Torsvik, T.H., Schmid, S.M., Matenco, L.C., Maffione, M., Vissers, R.L.M., Gürer, D., Spakman, W., 2020. Orogenic architecture of the Mediterranean region and kinematic reconstruction of its tectonic evolution since the Triassic. Gondwana Research, **81**: 79–229; https://doi.org/10.1016/j.gr.2019.07.009

Hnylko, O.M., 2011a. On the shear zone at the western part of the Ukrainian Carpathians, Geology and Geochemistry of Combustible Minerals, **156–157**: 68–80.

Hnylko, O.M., 2011b. Tectonic zoning of the Carpathians in terms of the terrane tectonics. Section 1. Main units of the Carpathian Building (in Ukrainian with English summary). Geodynamics, **10**: 47–57; https://doi.org/10.23939/jgd2011.01.047

Hnylko, O.M., 2012. Tectonic zoning of the Carpathians in terms of the terrane tectonics Article 2. The Flysch Carpathian – ancient accretionary prism (in Ukrainian with English summary). Geodynamics, **12**: 67–78; https://doi.org/10.23939/jgd2012.01.067

Hnylko, O.M., 2017. Structure of the lateral extrusion in the Carpathians (in Ukrainian with English summary). Geodynamics, **22**: 16–25; https://doi.org/10.23939/jgd2017.01.018

Hnylko, O.M., Generalova, L.V., 2014. Tectonic-sedimentary evolution of the Fore-Marmarosh accretionary prism of the Ukrainian Carpathians (in Russian with English summary). Vestnik of Saint Petersburg University, Series 7, Geology, Geography, **2**: 5–23.

Hnylko, O.M., Hnylko, S.R., 2012. Stratigraphy of the Paleocene-Eocene flysch from the Svydovets Nappe of the Ukrainian Carpathians (in Ukrainian with English summary). Geologichniy zhurnal, **3**: 59–67; https://doi.org/10.30836/igs.1025-6814.2012.3.139294

Hnylko, O.M., Hnylko, S., 2019. Geological environments forming the Eocene black-shale formation of the Silesian Nappe (Ukrainian Carpathians). Geodynamics, **26**: 60–75; https://doi.org/10.23939/jgd2019.01.060

Hnylko, O.M., Hnylko, S.R., 2024. Tectonic-sedimentary evolution of the Dukla Nappe, Ukrainian Carpathians. Geologichniy zhurnal, **389**: 15–33; https://doi.org/10.30836/igs.1025-6814.2024.4.299015

Hnylko, O.M., Vashchenko, V.O., 2004. Trostyanets basaltoids in the structure of the Eastern Flysch Carpathians (in Ukrainian). Geology and Geochemistry of Combustible Minerals, **1**: 71–84.

Hnylko, O., Krobicki, M., Feldman-Olszewska, A., Iwańczuk, J., 2015a. Geology of the volcano-sedimentary complex of the Kamyanyi Potik Unit on Chyvchyn Mountain (Ukrainian Carpathians): preliminary results. Geological Quarterly, **59**: 145–156; https://doi.org/10.7306/gq.1220

Hnylko, O.M., Hnylko, S.R., Generalova, L.V., 2015b. Formationof the structure of the Klippen zones and the interklippen flysch of Inner Ukrainian Carpathians – result of convergence and collision of microcontinental terranes (in Russian with English summary). Vestnik of Saint Petersburg University, Series 7, Geology, Geography, **2**: 5–23.

Hnylko, O.M., Hnylko, S.R., Generalova, L.V., 2015c. Tectonic-sedimentary evolution of the south-western part of the Ukrainian Flysch Carpathians (in Ukrainian with English summary). Scientific Bulletin of National Mining University, **146**: **5–13.**

Hnylko, O., Hnylko, S., Heneralova, L., Tsar, M., 2021. An Oligocene olistostrome with exotic clasts in the Silesian Nappe (Outer Ukrainian Carpathians, Uzh River Basin). Geological Quarterly, **65**, 47; https://doi.org/10.7306/gq.1616

Hnylko, O., Murovskaya, A., Bohdanova, M., 2023. Characteristics structures of the melange zones in the Ukrainian Carpathians. Geofizicheskiy Zhurnal, **45**: 67–86; https://doi.org/10.24028/gj.v45i6.293308

Hnylko, O.M., Murovska, A.V., Bohdanova, M.I., 2024. Structural position and distribution of the Lower Cretaeous black-shale deposits within the Silesian Nappe of the Ukrainian Carpathians (in Ukrainian with English summary). Geologichniy zhurnal, **386**: 47–61; https://doi.org/10.30836/igs.1025-6814.2024.1.287312

Hnylko, S., Hnylko, O., 2016. Foraminiferal stratigraphy and palaeobathymetry of Paleocene-lowermost Oligocene deposits (Vezhany and Monastyrets nappes, Ukrainian Carpathians). Geological Quarterly, **60**: 77–105; https://doi.org/10.7306/gq.1247

Hnylko, S.R., Hnylko, O.M., Suprun, I.S., Navarivska, K.O., Heneralova, L.V., 2023. Stratigraphy of the Upper Cretaceous sediments with oceanic red beds (CORBs), Ukrainian Carpathians (in Ukrainian with English summary). Geologichniy zhurnal, **384**: 79–107; https://doi.org/10.30836/igs.1025-6814.2023.3.281067

Höck, V., Ionescu, C., Balintoni, I., Koller, F., 2009. The Eastern Carpathians “ophiolites” (Romania): Remnants of a Triassic ocean. Lithos, **108**: 151–171.

Holbourn, A.E.L., Kaminski, M.A., 1997. Lower Cretaceous deep-water benthic foraminifera of the Indian Ocean. Grzybowski Foundation Special Publication, **4**.

Horvath, F., Galacz A., (eds.), 2006. The Carpathian-Pannonian Region: A Reviev of Mesozoic-Cenozoic Stratigraphy and Tectonics, **1**. Stratigraphy, **2**. Geophysics, Tectonics, Facies, Paleogeography. Publ. Hantken Press, Budapest.

Hsü, K.J., 1968. Principles of mélanges and their bearing on the Franciscan-Knoxville Paradox. GSA Bullettin, **79**: 1063–1074; https://doi.org/10.1130/0016-7606(1968)79[1063:POMATB]2.0.CO;2

Jankowski, L., Kopciowski, R., Ryłko, W., (eds.), 2004. .Geological map of the Outer Carpathians: borderland of Ukraine, Poland and Slovakia, 1:200 000. Państwowy Instytut Geologiczny, Warszawa.

Jankowski, L., Kopciowski, R., Ryłko, W., (eds.), 2007. Geological map of the Outer Carpathians: borderland of Ukraine and Romania, 1:200 000. Państwowy Instytut Geologiczny, Warszawa.

Kaminski, M.A., Gradstein, F.M., 2005. Atlas of Paleogene Cosmopolitan Deep-Water Foraminifera. Grzybowski Foundation Special Publication, **10**.

Kovač, M., Nagymarosy, A., Oszczypko, N., Ślączka, A., Csontos, L., Marunteanu, M., Matenco, L., Márton, M., 1998. Palinspastic reconstruction of the Carpathian-Pannonian region during the Miocene. In: Geodynamic Development of the Western Carpathians (ed. M. Rakus): 189–217. Geological Survey of Slovak Republic, Bratislava.

Kováč, M., Plašienka, D., Soták, J., Vojtko, R., Oszczypko, N., Less, G., Ćosović, V., Fügenschuh, B., Králiková, S., 2016. Paleogene palaeogeography and basin evolution of the Western Carpathians, Northern Pannonian domain and adjoining areas. Global and Planetary Change, **140**: 9–27; https://doi.org/10.1016/j.gloplacha.2016.03.007

Kováč, M., Márton, E., Oszczypko, N., Vojtko, R., Hók, J., Králiková, S., Plašienka, D., Klučiar, T., Hudáčková, N., Oszczypko-Clowes, M., 2017. Neogene palaeogeography and basin evolution of the Western Carpathians, Northern Pannonian domain and adjoining areas. Global and Planetary Change, **155**: 133–154; https://doi.org/10.1016/j.gloplacha.2017.07.004

Kowal-Kasprzyk, J., Waśkowska, A., Golonka, J., Krobicki, M., Skupien, P., Słomka, T., 2021. The Late Jurassic–Palaeogene carbonate platforms in the Outer Western Carpathian Tethys – a regional overview. Minerals, **11**, 747; https://doi.org/10.3390/min11070747

Kruglov, S.S., (ed.), 1986. Tectonics of the Ukrainian Carpathians (explanatory report to the Tectonic map of the Ukrainian Carpathians, scale 1:200 000) (in Russian). Naukova Dumka, Kiev.

Kruglov, S.S., Smirnov, S.E., 1979. Stratigraphy of the Porkulets Nappe of the Ukrainian Carpathians (in Russian). Geologicheskiy Zhurnal, **39**: 93–103.

Kruglov, S.S., Smirnov, S.E., 1981. Some controversial issues of geology of the Ukrainian Flysch Carpathians (in Russian). Geologicheskiy Zhurnal, **41**: 38–48.

Kruhlov, S.S., Hyrsky, D.S., (eds.), 2007. Tectonic map of Ukraine, scale 1:1 000 000 (in Ukrainian). State Geological Survey, Kyiv.

Kulchytskyi, Ya.O., 1959. Stratigraphy of Cretaceous and Paleogene deposits of the southeastern part of the Eastern Carpathians. In: Geological structure and oil and gas potential of the western and southern regions of Ukraine (ed.-in-chief V.H. Bodnarchuk): 207–218 (in Ukrainian). Publishing House of the Academy of Sciences of Ukraine, Kiev.

Kulchytskyi, Ya.O., Lozynyak, P.Yu., Dabagyan, N.V., Marhel, M.D., 1965. Geological structure and oil and gas prospects of the Dukla, Magura and Pieniny Klippen zones (in Russian). Trudy Ukrainskogo nauchno-issledovatelskogo geologo-razvedyvatelnogo instituta, **14**: 69–77.

Leshchukh, R.I., 1979. About new finds Ammonites from the Lower Cretaceous flysch of the South-East Ukrainian Carpathians (in Russian with English summary). Paleontologicheskiy sbornik, **16**: 59–64.

Leshchukh, R.I., 1980. The finds of the ammonites in the Lower Cretaceus deposits in the basin of the Belaya Tisa (in Russian with English summary). Paleontologicheskiy sbornik, **17**: 54–60.

Leshchukh, R.I., 1988a. The Shypot Formation. In: The stratotypes of the Cretaceous and Paleogene deposits of the Ukrainian Carpathians (ed. S.I. Pasternak) (in Russian): 176–178. Naukova Dumka, Kiev.

Leshchukh, R.I., 1988b. The Yalovets Formation. In: The stratotypes of the Cretaceous and Paleogene deposits of the Ukrainian Carpathians (ed. S.I. Pasternak) (in Russian): 182–184. Naukova Dumka, Kiev.

Liashkevitsch, Z.M., Medvedev, A.P., Krupskiy, Y.Z., Varichev, A.S., Tymoshchuk, V.P., Stupka, O.O., 1995. Tectonomagmatic evolution of Carpathians (in Russian with English summary). Naukova Dumka, Kiev.

Mahel, M., (ed.), 1973. Tectonic map of the Carpathian-Balkan mountain system and adjacent areas – Scale 1:1,000,000. UNESCO, Paris; Dionýz Stúr's Geological Institute, Bratislava.

Maslakova, N.I., 1965. New data on the stratigraphy of the Upper Cretaceous deposits of the Chornohora Zone of the Eastern Carpathians (in Russian). Bulletin of Moscow University, Geological series, **2**: 3–20.

Matskiv, B.V., 2009. State Geological Map of the Ukraine, scale 1:200,000. Carpathian series. Sheets M-34-XXXVI (Hust), L-35-I (Vişeu de Sus). Geological Map of the Pre-Quartery deposits. Published Ukrainian State Geological Explore Institute, Kyiv.

Matskiv, B.V., Kovalov, Y.V., Pukach, B.D., 2003. State Geological Map of the Ukraine, scale 1:200,000. Carpathian series. Sheets: M-34-XXIX (Snina); M-34-XXV (Uzhhorod), L-34-V (Satu-Mare). Geological Map of the Pre-Quartery deposits. Published "Zakhidukrheolohiya", Kyiv.

Matskiv, B.V., Pukach, B.D., Hnylko, O.M., 2009a. State Geological Map of the Ukraine, scale 1:200,000. Carpathian series. Sheets M-35-XXXI (Nadvirna), L-34-VI (Baia Mare). Geological Map of the pre-Quartery formations. Published Ukrainian State Geological Explore Institute, Kyiv.

Matskiv, B.V., Pukach, B.D., Vorobkanych, V.M., Pastukhanova, S.V., Hnylko, O.M., 2009b. The State Geological Map of Ukraine in the scale 1:200 000, map sheets M-34-XXXVI (Khust), L-34-VI (Baia-Mare), M-35-XXXI (Nadvirna), L-35-I (Vişeu-de-Sus). Carpathian Series. Explanatory Notes. Published Ukrainian State Geological Explore Institute, Kyiv.

Merten, S., Matenco, L., Foeken, J.P.T., Stuart, F.M., Andriessen, P.A.M., 2010. From nappe stacking to out-of-sequence postcollisional deformations: Cretaceous to Quaternary exhumation history of the SE Carpathians assessed by low-temperature thermochronology. Tectonics, **29**: 1–28; https://doi.org/10.1029/2009tc002550

Murovskaya, A., Verpakhovska, O., Hnylko, O., Chorna, O., Yegorova, T., 2023. Transcarpathian depression: Study of low-velocity zones in the earth's crust based on the seismic regional profiles data. Geofizicheskiy Zhurnal, **45**: 30–43; https://doi.org/10.24028/gj.v45i2.278310

Murovskaya, A., Hnylko, O., Makarenko, I., Savchenko, O., Kitchka, A., Verpakhovska, O., Legostaeva, O., 2025. Review and updates of the lithosphere structure and geodynamics evolution of the Neogene Transcarpathian Basin and its substratum (Ukraine). Geological Society Special Publications, **554**; https://doi.org/10.1144/SP554-2024-19

Mjatliuk, E.V., 1970. Foraminifers of the Flysch Deposits of the Eastern Carpathians (Cretaceous-Paleogene) (in Russian). Nedra, Leningrad.

Nakapelukh, M., Bubniak, I., Yegorova, T., Murovskaya, A., Gintov, O., Shlapinskyi, V., Vikhot, Yu., 2017. Balanced geological cross-section of the Outer Ukrainian Carpathians along the PANCAKE profile. Journal of Geodynamics, **108**: 13–25; https://doi.org/10.1016/j.jog.2017.05.005

Nakapelyukh, M., Bubniak, I., Bubniak, A., Jonckheere, R., Ratschbacher, L., 2018. Cenozoic structural evolution, thermal history, and erosion of the Ukrainian Carpathians fold-thrust belt, Tectonophysics, **722**: 197–209; https://doi.org/10.1016/j.tecto.2017.11.009, 2018

Neagu, T., 1990. *Gerochammina* n.g. and related genera from the Upper Cretaceous flysch-type benthic foraminiferal fauna, Eastern Carpathians-Romania. NATO ASI Series, **327**: 245–265.

Olsson, R.K., Hemleben, Ch., Berggren, W.A., Huber, B.T., (eds.), 1999. Atlas of Paleocene Planktonic Foraminifera. Smithsonian Institution Press, Washington. Smithsonian Contributions to Paleobiology, **85**; https://doi.org/10.5479/si.00810266.85.1

Olszewska, B., 1997. Foraminiferal biostratigraphy of the Polish Outer Carpathians: a record of basin geohistory. Annales Societatis Geologorum Poloniae, **67:** 325–337.

Oszczypko, N., 2004. The structural position and tectonosedimentary evolution of the Polish Outer Carpathians. Przegląd Geologiczny, **52**: 780–791.

Oszczypko, N., 2006. Late Jurassic-Miocene evolution of the Outer Carpathian fold-and-thrust belt and its foredeep basin (Western Carpathians, Poland). Geological Quarterly, **50** (1): 169–194.

Oszczypko, N., Oszczypko-Cloves, M., Golonka, J., Krobicki, M., 2005. Position of the Marmarosh Flysch (Eastern Carpathians) and relation to the Magura Nappe (Western Carpathians). Acta Geologica Hungarica, **48**: 259–282.

Pasternak, S.I., Vialov, O.S., Kulchitzky, J.O., 1966. New data on the age of the Rahov Suite (in Russian with English summary). Paleontologicheskiy sbornik, **3**: 114–119.

Paul, K.M., 1869. Die geologischen Verrhaltnisse des norlichen Sarover und Zempliner Cimitates. Das Karpathen-Sandsteingebiet des nördlichen Ungher und Zempliner Comitates. Jahrbuch der Geologischen Bundesanstalt, **19**: 256–280.

Plašienka, D., 2018. Continuity and episodicity in the early Alpine tectonic evolution of the Western Carpathians: how large-scale processes are expressed by the orogenic architecture and rock record data. Tectonics, **37**: 2029–2079; https://doi.org/10.1029/2017TC004779

Plašienka, D., Soták, J., 2015. Evolution of Late Cretaceous-Palaeogene synorogenic basins in the Pieniny Klippen Belt and adjacent zones (Western Carpathians, Slovakia): tectonic controls over a growing orogenic wedge. Annales. Societatis Geologorum Poloniae, **85**: 43–76; https://doi.org/10.14241/asgp.2015.005

Plašienka, D., Bučová, J., Šimonová, V., 2020. Variable structural styles and tectonic evolution of an ancient backstop boundary: the Pieniny Klippen Belt of the Western Carpathians. International Journal of Earth Sciences, **109**: 1355–1376; https://doi.org/10.1007/s00531-019-01789-5

Roban, R.D., Krézsek, C., Melinte-Dobrinescu, M.C. 2017. Cretaceous sedimentation in the outer Eastern Carpathians: implications for the facies model reconstruction of the Moldavide Basin. Sedimentary Geology, **354:** 24–42; https://doi.org/10.1016/j.sedgeo.2017.04.001

Roger, M., de Leeuw, A., van der Beek, P., Husson, L., Sobel, E.R., Glodny, J., Bernet, M., 2023. Construction of the Ukrainian Carpathian wedge from low-temperature thermochronology and tectono-stratigraphic analysis. Solid Earth, **14**: 153–179; https://doi.org/10.5194/se-14-153-2023

Romaniv, A.M., 1991. Calcareous nanoplankton of the Cretaceous and Paleogene deposits of the Ukrainian Carpathians (In Ukrainian). Naukova Dumka, Kiev.

Romaniv, A.M., 1999. Results of the study of calcareous nannofossils from the Ukrainian Carpathians (In Ukrainian). Geology and Geochemistry of Combustible Minerals, **106**: 67–77.

Săndulescu, M., 1984. Geotectonics of Romania (in Romanian). Editura Tehnică, Bucharest.

Săndulescu, M., 1988. Cenozoic tectonic history of the Carpathians. AAPG Memoir, **45**: 17–26.

Săndulescu, M., 2009. The Black Flysch Nappe of the Maramureş East Carpathians – a “Valaisanne-Type” Tectonic Unit? Proceedings of the Romanian Academy, Series B, **1**: 45–51.

Săndulescu, M., Kräutner, H.G., Balintoni, I., Russo-Săndulescu, D., Micu, M., 1981. The Structure of the East Carpathians. (Guide Book B1). Carpathian-Balkanian Geological Association 12th Congress. Published by the Institute of Geology and Geophysics, Bucharest.

Schmid, S., Bernoull, D., Fugenschuh, B., Matenco, L., Schefer, S., Schuster, R., Tischler, M., Ustaszewski, K., 2008. The Alpine-Carpathian-Dinaric orogenic system: correlation and evolution of tectonic units. Swiss Journal of Geosciences, **101**: 139–183; https://doi.org/10.1007/s00015-008-1247-3

Schmid, S.M., Fügenschuh, B., Kounov, A., Matenco, L., Nievergelt, P., Oberhansli, R., Pleuger, J., Schefer, S., Schuster, R., Tomljenovic, B., Ustaszewski, K., van Hinsbergen, D.J.J., 2020. Tectonic units of the Alpine collision zone between Eastern Alps and western Turkey. Gondwana Research, **78**: 308–374; https://doi.org/10.1016/j.gr.2019.07.005

Shakin, V.A., (ed.), 1976. Geological map of the Ukrainian Carpathians and adjacent deeps of scale 1:200 000 (in Russian). MinGeo USSR, Kyiv.

Shlapinskyi, V.E., 2012. Some aspects of the Ukrainian Carpathian tectonics (in Ukrainian). Proceedings of the Shevchenko Scientific Society, Geological Collection, **30**: 48**–**67.

Slavin, V.I., 1956. Belaya Tissa Suite (in Russian). In: Stratigraphic dictionary of the USSR (ed. B.K. Likharev): 129. Gosgeoltehizdat, Moscow.

Ślączka, A., Kruglov, S., Golonka, J., Oszczypko, N., Popadyuk, I., 2006. Geology and hydrocarbon resources of the Outer Carpathians, Poland, Slovakia, and Ukraine: general geology. AAPG Memoir, **84**: 221–258; https://doi.org/10.1306/985610M843070

Sperner, B., Ratschbacher, L., Nemcok, M., 2002. Interplay between subduction retreat and lateral extrusion: tectonics of the Western Carpathians. Tectonics, **21**: 1–24; https://doi.org/10.1029/2001TC901028

Starzec, K., Malata, E., Wronka, A., Malina, L., 2015. Mélanges and broken formations at the boundary zone of the Magura and Silesian nappes (Gorlice area, Polish Outer Carpathians) – a result of sedimentary and tectonic processes. Geological Quarterly, **59** (1): 169–178; https://doi.org/10.7306/gq.1273

Sujkowski, Z., 1930. Serie Szypockie na Huculszyznie (in Polish). Prace Państwowego Instytutu Geologicznego, **3**: 1–105.

Świdziński, H., 1947. Słownik stratygraficzny Północnych Karpat fliszowych (in Polish). Biuletun Państwowego Instytutu Geologicznego, **37**.

Tischler, M., Matenco, L., Filipescu, S., Groger, H.R., Wetzel, A. Fugenschuh, B., 2008. Tectonics and sedimentation during convergence of the ALCAPA and Tisza–Dacia continental blocks: the Pienide nappe emplacement and its foredeep (N. Romania). Geological Society Special Publications, **298**: 317–334; https://doi.org/10.1144/SP298.15

Tsarnenko, P.N., 1988. The Urda Formation (in Russian). In: The stratotypes of the Cretaceous and Paleogene deposits of the Ukrainian Carpathians (ed. S.I. Pasternak): 168–170. Naukova Dumka, Kiev.

Tsarnenko, P.N., Leshchukh, R.I., 1974. About age of the Shypot Formation in the Svydovets subzone, Ukrainian Carpathians (in Ukrainian). Dopovidi Akademii Nauk URSR, **2**: 131–134.

Vialov, O.S., 1960. Crossing the Carpathians (in Russian). In: Materials of VI Congress of Carpathian-Balkan Geological Association, **3**: 148–156.

Vialov, O.S., Andreyeva-Grigorovich, A.S., Gavura, S.P., Dabagyan, N.V., Danysh, V.V., Kulchitskiy, Ya.O., Leshchukh, R.I., Lozynyak, P.Yu., Petrashkevich, M.Y., Ponomaryova, L.D., Romaniv, A.M., Tsarnenko, P.N., 1989. Explanatory report to the regional stratigraphic scheme of the Cretaceous deposits of the Ukrainian Carpathians (in Russian). Preprint of Institute of Geology and Geochemistry of Combustible Minerals, Lviv.

Vialov, O.S., Danysh, V.V., 1988. The Bereznyi Formation (in Russian). In: The stratotypes of the Cretaceous and Paleogene deposits of the Ukrainian Carpathians (ed. S.I. Pasternak): 19–24. Naukova Dumka, Kiev.

Vialov, O.S., Gavura, S.P., Danysh, V.V., Leshchuch, R.J., Ponomaryova, L.D., Romaniv, H.M., Tsarnenko, P.N., Tsizh, I.T., 1981. The history of the geologic development of the Ukrainian Carpathians (in Russian). Naukova Dumka, Kiev.

Vialov, O.S., Tsarnenko, P.N., 1970. Cretaceous deposits of the Svydovets and Krasnoshora subzones in the Ukrainian Carpathians. Dopovidi Akademiyi Nauk URSR. Seriya B, **11**: 969–972.

Vialov, O.S., Havura, S.P., Danysh, V.V., Lemishko, O.D., Leshchukh, R.Y., Ponomarova, L.D., Romaniv, A.M., Smirnov, S.Ye., Smolinskaia, N.I., Tsarnenko, P.N., 1988. Stratotypes of Cretaceous and Paleogene deposits of the Ukrainian Carpathians (in Russian). Naukova Dumka, Kiev.

Waśkowska, A., 2011. The Early Eocene *Saccamminoides carpathicus* assemblage in the Outer Flysch Carpathians**.** Grzybowski Foundation Special Publication, **16**: 331–341.

Waśkowska, A., 2021. Agglutinated Foraminiferal Acmes and Their Role in the Biostratigraphy of the Campanian–Eocene Outer Carpathians. Geosciences, **11**, 367; https://doi.org/10.3390/geosciences11090367

Weidich, K.F., 1990. Die kalkalpine Unterkreide und ihre Foraminiferenfauna. Zitteliana, **17**.