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TECTONIC DEFORMATIONS AND PALEOSTRESSES WITHIN THE SOLOTVINE BASIN (TRANSCARPATHIAN UKRAINE)

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Regional geology. The Solotvyne and Mukacheve basins represent Ukrainian part of the Neogene Transcarpathian Basin (TB) (Fig. 1) [1, 2]. Vygorlat Huta Pliocene volcanic range divides the Mukacheve and Solotvyne segments of TB, with is a north-eastern marginal part of the large Pannonian basin covering Central Europe. The Neogene TB located along of the Carpathian orogen in hinterland area and represent an internal basin originated during orogenic stage [3]. The crustal structure of the Pannonian segment within TB is interpreted to be a pile of thick- and thin-skinned basement nappes of the Tisza and ALCAPA terrains with superimposed younger extensional structures [4]. The TB borders the Outer Ukranian Carpathians by subvertical Transcarpathian fault controlling the strike of the Pieniny Klippen Belt. The TD evolution connected with suture between the Internal and External Carpathians represented by the Pieniny Klippen Belt.

In Late Miocene, the TB was developing as a peripheral segment of the Pannonian Basin. According to tectonophysical studies and earthquake mechanisms in the TB, recent NE-SW-oriented compression was recorded [5,6].

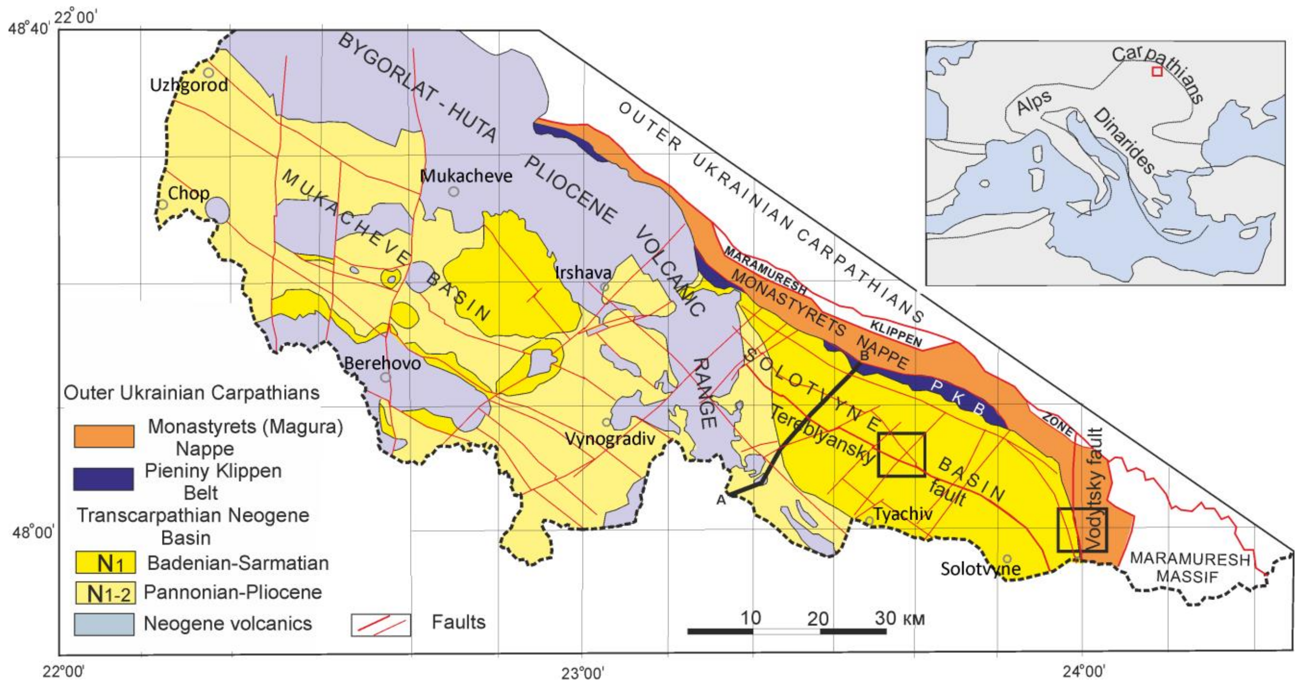

Figure 1. Tectonic scheme of the Transcarpathian Basin [7,8] Black rectangles show areas of the presented geological and structural study.

The Solotvyne Basin (SB) is one of the promising areas for hydrocarbon exploration in the western Ukraine. The first Solotvyne gas field in TD was discovered in 1982. Its gas is trapped in the anticline, created by salt diaper. The geological structure of the SB is presented on a geological cross-section [7] (Fig. 2**)**. The Pre-Neogene basement of the SB composed of Mesozoic and Paleogene structural levels with a thrust structure. The Cretaceous deposits are represented by a carbonate-terrigenous complex. Paleogene sediments consist of terrigenous turbiditic formation. Neogene deposits of the depression are distinguished by facial diversity: clastic rocks, chemogenic sediments and volcaniclastic rocks.

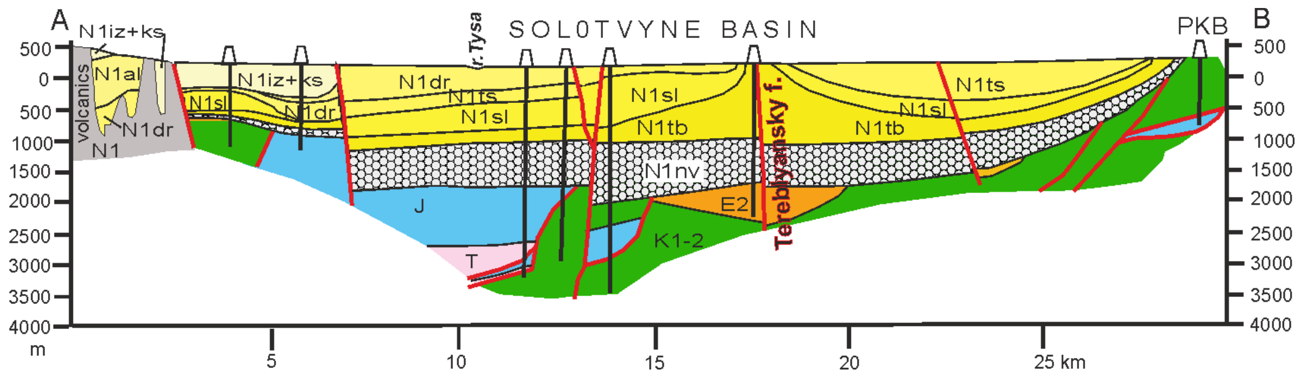

Figure 2. Geological cross-section through the Solotvyne Basin along line A – B, after [7, 8]. The cross-section line position is shown in Fig. 1.

The oldest Miocene rocks on the geological cross-section - the Lower Badenian sediments of the Novoselytsya formation (N_1nv) of 300-900 m of thickness composed mainly of dacite and dacite-liparite tuffs, with interbedded tuffs, tuff-sandstones, and mudstones. The Novoselytsya Fm it overlain by the Tereblya one (N_1tb) (up to 300 m), composed of the lower and upper parts. The lower one are of sandy clays with interbedded sandstones, siltstones, tuffs and tuffites, the upper part contains of salt, interbedded with clay. The Middle Badenian is represented by the terrigenous Solotvyne formation (N_1sl) and the Teresva Fm (N_1ts), which is composed of clays, sandstones, siltstones with a horizon of tuffs at the bottom. Sarmatian deposits of Dorobratovo Fm (N_1dr) are composed of clays, sandstones and conglomerates as well as sandstones and tuffs of the Lukovo and Almash ones. The Pannonian sediments of Iza and Kosheliovo Formations (N_1iz-ks) are represented mainly by clays, sandstones, siltstones, tuffs and tuffites. The Vygorlat Huta volcanic range is composed of basalt, andesite, and their tuffs.

Results of the field study of fault zones within the SB. In Neogene deposits of SB, systems of along-strike and transcurrent faults are established, which, as a rule, inherited main tectonic structures in the pre-Neogene basement. Manifestations of salt tectonics are confined to longitudinal faults. The study of faults, the conditions for their formation and subsequent activation is an important task of geological research. Fields of hydrocarbons, deposits of salts, mineral waters are confined to the faults and anticlines of the SB. Based on the results of field studies, deformation regimes and paleostress fields of adjacent territories were established [5, 9]. There are results of reconstruction of stress fields based on earthquake data [6]. In [10] the first results of field tectonophysical studies of deformational mesostructures of the SB (the village of Lazy) were obtained.

Tereblyansky fault. In 2022-2023, we conducted detailed geological and structural field studies in two areas of the Solotvine Basin (Fig. 1). The first site is located in the central axial part of the CB in the area of the Tereblyansky fault, in the basin of the Tyachevets river on the northern outskirts of the village of Lazy. The rocks of the site are represented by pelitic-psamite tuffs of the Teresva Formation of rhyolite and dacite composition. The tuffs at all observation points are intensely tectonized. Tectonic slicken-sides, shearing zones and tectonic breccias are observed (Fig. 3, 4). We have studied and measured fold elements and more than 100 small faults in 6 outcrops.

The Tereblyansky fault has a northwest 310° strike and a steep northeastern dipping (dip angle 70-80°). Within the fault zone, we have measured 35 slicken-sides and reconstructed two paleostresses using the Win-Tensor program [11]. In the first stress field with the extension axis oriented across the Solotvine trough, the Tereblyansky fault developed under transtension conditions as a left-lateral strike-slip one (Fig. 4, top stereogram). In the second stress field with the northeastern direction of the compression axis, the Tereblyansky fault has a kinematic type of right-hand strike-slip fault with a reverse component (Fig. 4, lower stereogram). The stress fields of the first type was revealed by our research at most other observation points, and the second one is characteristic only for the Tereblyansky fault. The stress field with compression axis across SB may be resent one, since the mechanisms of earthquakes in the TB have reverse and strike-slip types and close orientations of the compression axes [6].

Figure 3. Fracture system with tectonic breccia in tuffs of the Middle Badenian Teresva Formation. Solotvine Basin, northwestern outskirt of village Lazy.

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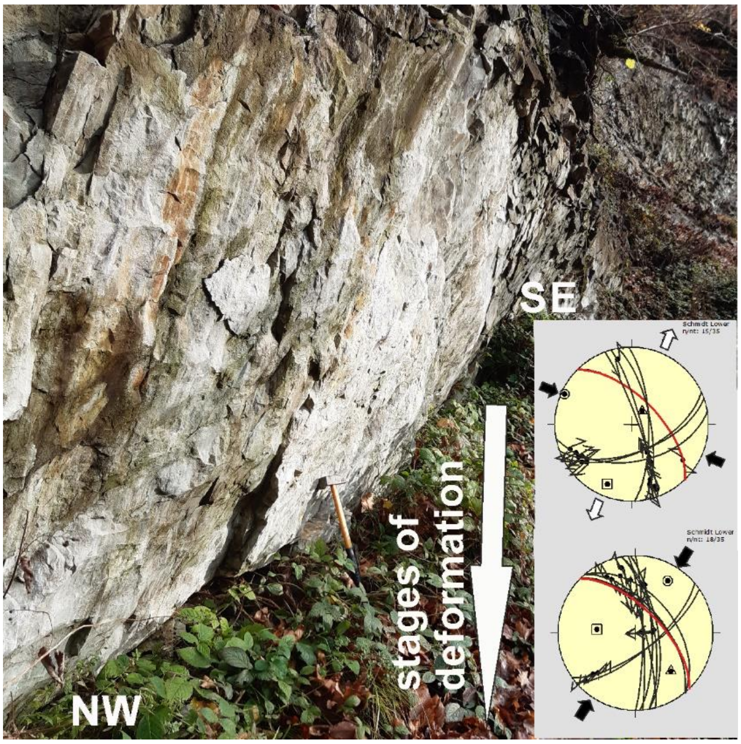

Figure 4. The large slicken-side of the Tereblyansky fault zone and paleostress reconstruction. The red arc corresponds to the fault. Teresva Formation, Solotvine Basin, northwestern outskirt of village Lazy

In the study area of Lazy, stress fields of strike-slip and normal types with a W-E direction of the extension axis are widely represented, which we associate with salt diapirism and landslide processes. Zones of rupture deformation under shear conditions with additional extension are favorable for the migration of mineral waters to the surface and the development of salt diapirism.

Vodytsky fault. The second study area is located in the N-S trending Vodytsky fault zone, separating the Solotvine Basin and Monastyrets nappe of the Outer Ukrainian Carpathians (Fig. 1). The western wing of the fault, represented by the Neogene SB, is thrown down more than 1000 m in relation to the eastern wing, represented by the Monastyrets nappe of the Flysch Carpathians. We observed deformations in the Neogene clays of the Teresva Formation of the SB and in the conglomerates and sandstones of the Shopurka Formation of the Monastyrets nappe, as well as a melange zone at their contact. We measured tectonic slicken-sides in the eastern flank of the fault, where brittle deformations are well manifested in microconglomerates of Shopurka Formation. When approaching the fault, the strike of the Shopurka flysch changes from the typically Carpathian direction (320° northwest) to 350°-0° north, and their dip angle changes from 25-30° to steep and vertical. Based on the paleostress reconstruction, two strike-slip type stress fields were restored (Fig. 5).

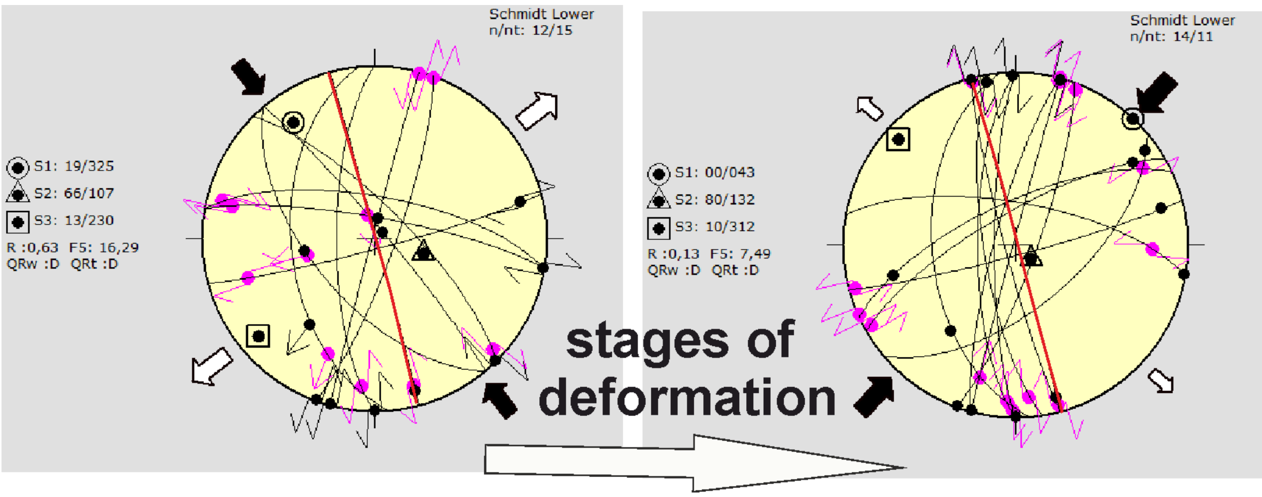

Figure 5. Stereograms of paleostress fields in the eastern wing of the Vodytsky fault. The red arc corresponds to the fault orientation.

The first stress field is characterized by the southwestern extension axis across the SB (Fig. 5, left stereogram). The second stress field is characterized by the northeastern compression axis (Fig. 5, right stereogram). Under the northeastern compression, the Vodytsky fault developed as a right-lateral strike-slip fault, which is clearly indicated by the kinematic sense of N-S striking tectonic mirrors. Interpretation of the reconstructed stress fields in the context of the Neogene evolution of the SB allows us to relate them to the stages of the basin opening and its recent contraction.

The studies performed show the complex tectonic structure of the Solotvine Basin, repeated activation of regional and local faults, and the predominance of strike-slip displacements along large faults. Deposits of hydrocarbons, salts, mineral waters, etc. are confined to the faults and folds of the Solotvine Basin. The presented materials, methods and research results are used in education to train specialists in the field of geology and ecology.

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