Mineralog. Rev. Мінералогічний збірник
2009. N 59. Is. 1. P. 31–44 2009. № 59. Вип. 1. С. 31–44

UDC 550.4:551.24(234)

PARTICULAR TECTONIC ZONES (THE MÉLANGE ZONES) AS POTENTIAL AND SIGNIFICANT PATHS FOR FLUID MIGRATION AND MINERAL FORMATION

L. Jankowski[1], K. Jarmolowicz-Szulc[2]

[1]*Polish Geological Institute, Carpathian Branch*
Skrzatów St. 1, PL – 31-560 Cracow, Poland
E-mail: leszek.jankowski@pgi.gov.pl
[2]*Polish Geological Institute*
Rakowiecka St. 4, PL – 00-975 Warsaw, Poland
E-mail:katarzyna.jarmolowicz-szulc@pgi.gov.pl

On the background of description of the chaotic complexes, the mélange in the Bieszczady area was studied in detail. It has an evidently tectonic character with features pointing to tectonic deformation – in some occurrences westwards it seems to be rather a chaotic complex of a more complicated, perhaps partly flow, genesis. Generally, the mélange zones represent open or close geochemical systems. Due to their strata defragmentation degree, they may be concerned as a path for a fluid flow, a site for mineral crystallization and/or migration zones of hydrocarbons and mineralized waters. In that context the tectonic mélange in the Jabłonki and Rabe vicinity was studied from the petrological, mineralogical and geochemical points of view.

Key words: tectonic mélanges, fluid migration, Carpathians.

Recognition of the character of mineralization of tectonic mélanges, which are one of many types of the chaotic complexes recognized recently in the Outer Carpathians, is the objective of the present paper. In this area the mélange zones are frequently outcropped in bands of a variable width.

The primary research was concentrated in the Bieszczady Mts (Polish Outer Carpathians, fig. 1). The mélange in the Bieszczady area has an evidently tectonic character, with features unveiling the tectonic deformation. In fact, there are broad shear zones separating some blocks of Outer Carpathians. In some outcrops in western part of area of investigation chaotic complexes seem to be of sedimentary origin as well.

The mélanges in this region of the Carpathians are most probably a result of the secondary deformation of the Carpathian thrust belt and they are connected with a stage of some kind of *out-of-sequence deformation*. Possible that they are related with extensional collapse of Carpathian orogeny and in some cases there are parts of geometry of relay ramps.

The mélange zones represent an open or closed geochemical system. Due to their strata defragmentation they may be a path for a fluid flow, a site for mineral crystallisation and/or migration zones of hydrocarbons and mineralized waters. More and more frequently, the problem of hydrocarbon migration has been connected with the fluid inclusion studies.

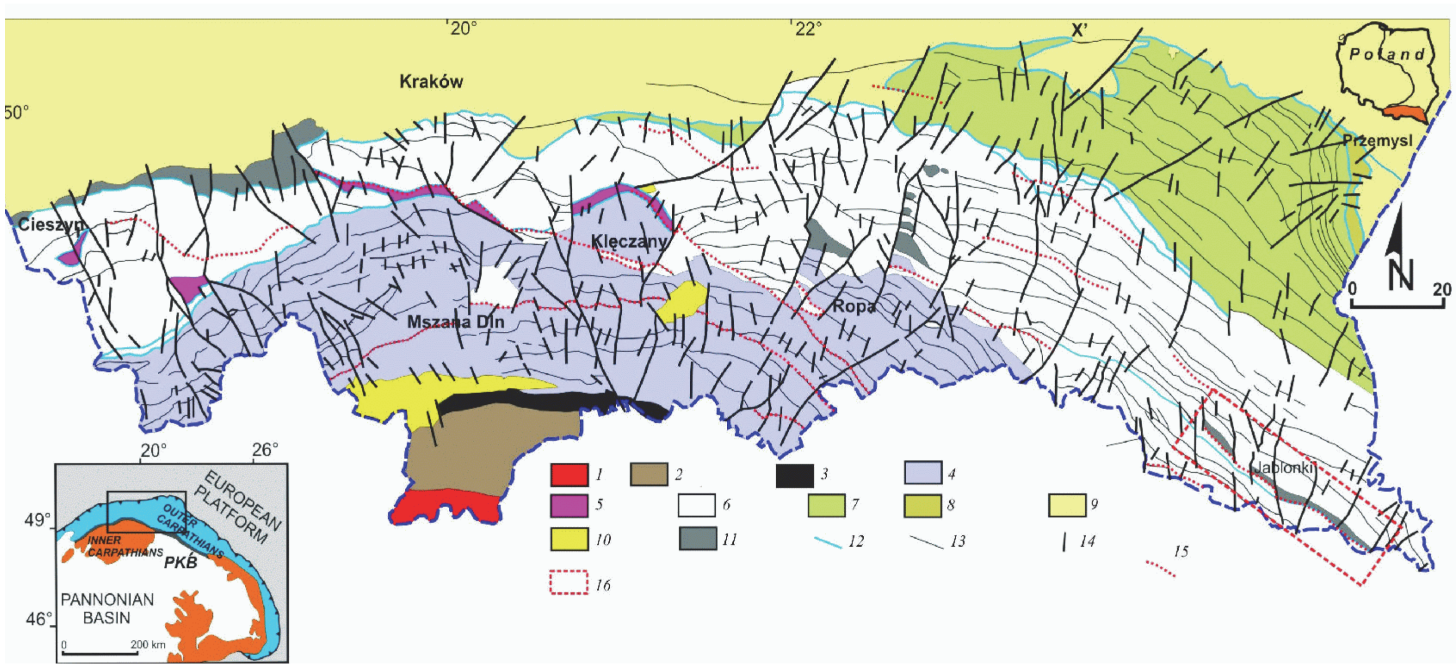

Fig. 1. Polish Outer Carpathians [20]:

1 – Tatra Mts; *2* – Central Carpathian Paleogene; *3* – Pienine Klippen Belt; *4* – Magura unit; *5* – Subsilesian unit; *6* – Silesian, Węglówka and Dukla units; *7* – Skole unit; *8* – Borislav-Pokuttia unit; *9* – foredeep; *10* – Intracarpathian Neogene basins; *11* – chaotic complexes; *12* – main thrusts; *13* – thrusts faults; *14* – high-angle transverse faults; *15* – normal faults; *16* – area of investigations.

Recent studies on the material filling the calcite- quartz veins as well of bitumens and fluid inclusions were conducted in the eastern part of the Polish Carpathians and in the western part of Ukraine [23–25]. In the Slovak territory in the Western Carpathians, V. Hurai et al. (1989, 2001) studied the origin of the methane in the quartz.

Some mineralogical research has been till present conducted in the distinguished mélange zones in the Bieszczady region. First relations come from last years [21, 26].

The aim of the paper is to present the mélange zone in the eastern part of the Carpathians, especially in the region between Jabłonki and Ustrzyki Górne (see fig. 1) as well as to introduce the idea of connection between mineralization and the tectonic mélange. It should be underlined here that observations were conducted also more to the west, in the western Bieszczady and in Beskid Niski, the mélange zones discovered there do not display such a rich mineralization as in the area under a present description.

The results shown in the paper have a primary character, while figures and photographs represent an illustration of the occurrence of the tectonic mélange and are an example of a combination of field and cartographic works with mineralogical studies.

The **chaotic complexes** which usually display a character of olistostromes or wide zones of the tectonic mélange are poorly described in the Carpathians. The last years have brought some discoveries of the different type of the chaotic units [18–20]. In many cases chaotic complexes were false described as some members of litostratigrafic profile (i.eg. variegated shales) or some tectonic "disturbances".

According to the traditional point of view sedimentary deposits formed at the slope or the shelf of Carpathian basin could have been totally subducted due to the processes of subduction or collision.

Recent researches of Carpathians profiles indicate that a wide spectrum of the Carpathian deposits contains in majority the chaotic sediments. Part of them is the "products" of the high density turbidity currents as well as those deposited by different mass movements.

A basin configuration, a geological structure of the alimentation area and e.g. tectonic activity shortening the basin hale an influence on the grain composition and variety of the material. A big role plays a permanent "cannibalism" of the earlier deposited material and redeposition of the accreted parts of the accretionary wedge.

The chaotic complexes are often formed as syntectonic deposits which allow dating of thrusting [3]. The reconstruction of the youngest history of the basin closure (in that – frequent "slope collapses") is difficult due to the erosion of the majority of the folding zones already during thrusting and after that process as well as a low preservation potential of the deposits [9].

In case of the Carpathians, the erosion of the accretionary wedge and removement of the deposits of the youngest parts of the remnant basins is the cause of the preservation of the syntectonic deposits only in case of their "capture" under the thrusts.

In some cases a stages of the shortening process can be dated by chaotic complexes [3]. In fact, described chaotic complexes are the rocks displaying a texture "*block in matrix"* (a term introduced by D. Cowan, 1985; *bimrocks*), with a destroyed primary continuity of the layers.

The formation of the chaotic complex may result from pure tectonic processes (secondary chaotic complexes), or sedimentary (primary complexes) processes. In many cases, however, the specific geological context (e.g. of the migrating accretionary prism) results in superposition of these two processes which erases a primary character of the deposit and causes different types of interpretation.

In many papers, the term **mélange**, occasionally ascribed only to the deposits formed due to the tectonic processes, comprises deposits of sedimentary, tectonic or mixed origins. Since the mélange zones are not distinguished at the existing maps of the Carpathians, it is necessary to evidence them at least at the size limited by the scale of the map under elaboration [15, 29]. Where it is possible, it should be imperative to place a chaotic complex in the geological position and to recognize its origin.

In case of many recognized formed in the Miocene mélange zones in e.g. the Bieszczady area total body of mélange is creating by so called the Transition beds (Oligocene) or the Krosno (Oligocene–Miocene) beds or Inoceramus beds (Cretaceous–Palaeogene age). Although these beds sometimes represent different ages (and creating sometimes total body of mélange complex) such a mélange must be shown as the Miocene chaotic complex not as e.g. the Cretaceous–Palaeogene units.

It should be underlined that a tendency of using a term mélange for very thick complexes and a very complicated history, usually connected either with the process of subduction and collision or with areas of terrain accretion and their boundaries, has recently appeared in bibliography [2, 4, 5, 7, 30, 35, 36].

The term "mélange" was first introduced to bibliography by E. Greenly to determine rocks in Angesley [12]. In this case it corresponded to the rocks formed due to the typical tectonic deformation. Criteria of description and classification of so called fault rocks are theoretically uniform. The different geological context (as shear depth, types of rocks tectonically engaged, movement velocity and frequent "synsedimentation", especially in the collision orogen), however, create a whole set characterized by numerous intermediate products. Different classifications of the fault rocks comprise different factors [31]. The character of the deformation influencing both the character of the zone and the character of "products", i.e. the rocks formed, is most significant. The deformation type, ranking from the brittle to ductile type, leads to the formation of zones displaying miscellaneous character [1], i.e. from the fault and thrust zones (rather brittle deformations) and their products (i.e. different breccias, tectonic flour and cataclasites) to so called *shear zones,* which are characterized by a high, rather well geometrically defined concentration of deformations, and are highly flexible. The rock discontinuity is visible in the brittle fault and thrust zones, while it cannot be observed macroscopically in the shear zones [1].

Shallower fault zones display a rather brittle character. Low and high angle Riedel shears with tension gashes are developed, which results in a formation of a wide, even anostomosing zone of the breccia character [28].

It should be stressed that both types of zones already mentioned, do not occur in their "pure" form, being fragments of the deformation set. Structures characteristic both for the brittle and ductile deformations co-occur. A later reactivation of the flexible shear zone (occasionally in other "shallow" conditions) causes e.g. an interaction of the brittle structures and the ductile ones, for example the occurrence of the Riedel type faults in the mylonites characteristic for the shear zones. Both types of zones display metamorphic conditions in which specific rocks (cataclasites, mylonites, pseudotachylites) and characteristic textures are formed. In the shear zones, numerous kinematic indicators may be observed, being applicable to reconstruction of directions of the tectonic transport [6] as well as numerous characteristic textures as e.g. a specific pattern of the foliation (structures s-c underlined by schliers of the mylonitic substance) and a distinct rotation of different porphyroclasts. Generally, it can be accepted that the occurrence of the shear zones (with the rocks of the mylonite type) is connected with relatively high depths of their formation under a thick overburden. The thick zones may act as the closed or opened geochemical system, characterized by a fast fluid migration (despite the dimension of the zone). Fluids may cause a change in the colour of the rocks under deformation or of the shear elements separated by foliation surfaces (oxidizing fluids cause red colour of the mélange – that is why the deposits are often recognized as “variegated shales”. As it has been already mentioned, some features of the wide shear zones (as schistosity or foliation underlined by colours) were treated as false bedding.

The shear or fault zones may be usually an output for the process of the mélange forming. They represent “core” zones around which the mélange is formed. The process itself follows the hitherto described mechanisms. That is why the Anglo-Saxon geologists have booked the term “mélange” generally for the deposits of the tectonic origin. Still the timescale and numerous processes lead to the “rock product”, more differentiated in its textures, structures and petrographic composition. The mélange is a result of several processes which in the active thrusting zones (basement of the accretionary prism), boundaries of dislodged slices or limits of terrains). The tectonic zone develops primary as a narrow zone, being gradually enlarged and enriched by products of the “tectonic erosion” of two contacting plates. Finally, it represents a complex of a varied petrographic composition, rich in inherited textures or those gained due to the deformation process, i.e. the mélange.

So the mélange is formed as a result of the destruction of the inner, originally compact rock succession despite the primary rock texture (either “normal” or “block-in-matrix”). The successive deformation of the rock units has been a base for the mélange classification [8, 29], which is in fact a descriptional classification.

In the present paper, the term “mélange” is applied to wide zones of the deposits of the ”blocks-in-matrix” texture which underwent the tectonic deformation, despite the primary origin of the mélange forming material. These zones generally accompany different shears and thrusts, and comprise fragments and blocks “strange” for the rocks close to the faults.

Tectonic mélange zones in the Carpathians. Field observations – mainly mapping of the mélange zones – were held in a distinct area of the south-eastern part of the Polish Carpathians and in the adjacent zone of the Ukrainian Carpathians. Sets of profiles perpendicular to the run of main tectonic units were studied, resulting in distinguishing the mélange zones, previously not shown on the maps [13, 14, 33].

The main zone under observation, followed at the distinct Bieszczady Mts. and Beskid Niski area, stretches from the territory of Ukraine through the Bieszczady region, being seen in numerous outcrops (fig. 2). The mélange outcrops are seen at the Polish side of the Bieszczady Mts. west of Ustrzyki Górne (in the Bystry stream), further westwards, the mélange zone may be seen in the left tribute of the Prowcza stream. Still westwards, the mélange outcrops occur in the upper run of the Wetlinka stream (under the Wyżnia pass) as well as in Smerek (fig. 3).

Further westwards the mélange zone is outcropped in Kalnica, at left side of the Wetlinka stream, slightly below the mouth of the Kalnica stream.

Next good outcrop of the mélange occurs in the Dołżyca settlement, at right side of the Solinka-river (close to the mouth of the Dołżyca stream tributary).The most beautiful mélange outcrops in the Bieszczady area are present in the Jabłonki region (the Jabłonki stream). This zone runs through Kołonice, is well seen in the Rabski stream (near the "Gołoborze" natural reserve), turning westwards through Huczwice. It is also outcropped in Kalnica. A potential prolongation of this mélange zone towards the west demands further observations.

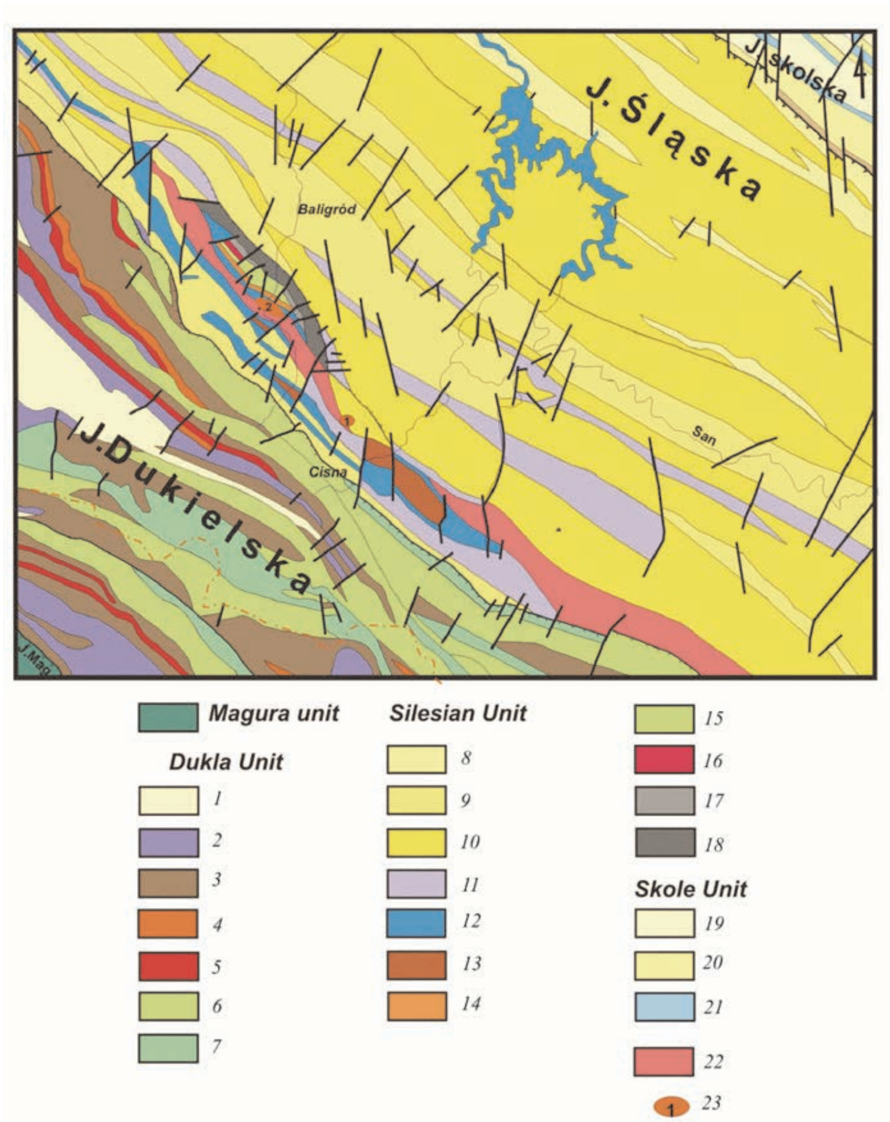

Fig. 2. Geological map of the Bieszczady region, based on [22].

Dukla unit, beds: *1* – Krosno; 2 – menilite; 3 – hieroglyph; 4 – Przybyszów; 5 – variegated schists; 6 – Cisna; 7 – Łupków; Silesian unit, beds: 8–10 – Krosno: 8 – upper, 9 – lower, 10 – lower – sandstones; 11 – transition; 12 – menilite; 13 – hieroglyph; 14 – Ciężkowice sandstones; 15 – Istebna; 16 – variegated schists; 17 – Lgota; 18 – Cieszyn; Skole unit, beds: 19, 20 – Krosno upper: 19 – schists, 20 – sandstones; 21 – menilite; 22 – chaotic complexes; 23 – sampling locality.

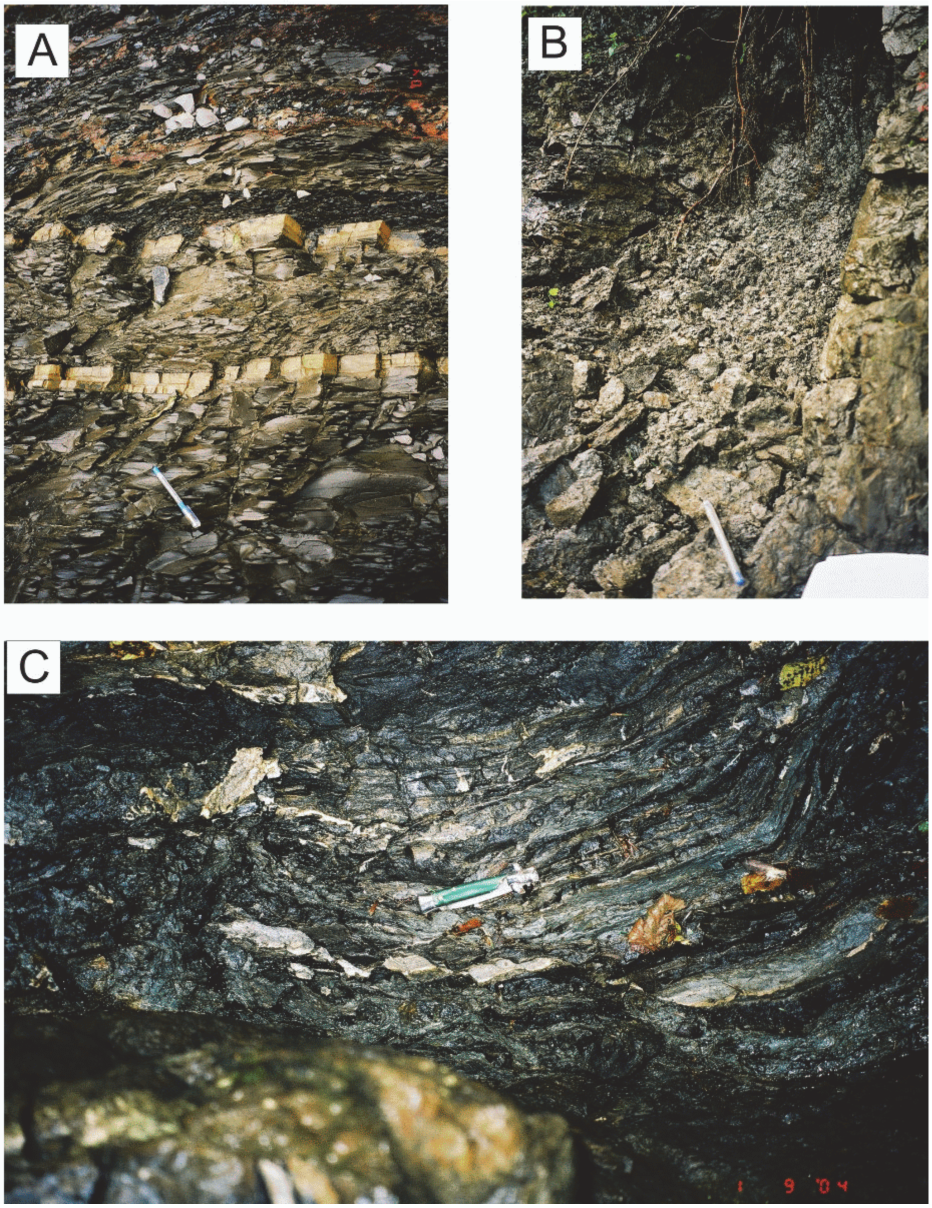

Fig. 3. Field photographs in the Jabłonki and Rabe region:

A – black bituminous intercalations in the rocks in the mélange (turn of the stream); *B* – outcrop at right side of the stream; *C* – tectonic mélange. Phot. K. Jarmołowicz-Szulc.

As it has been already mentioned, best mélange outcrops occur in the Jabłonki and Kołonice regions. The mélange zone is built here by deposits which represent a lithotype of the menilite and Krosno beds – this zone was earlier treated as a so called transition zone [32]. Apart from the fragments typical for the Menilite and Krosno beds, other rock types may be observed in the deformed complexes, e.g. limestones or siderites not seen in typical profiles. The mélange seen in the outcrop displays features of the tectonic mélange described above. Structures of *c* and *s* types are well developed. Rotated clasts with well seen "shadows" are well seen in the outcrops. The preliminary studies point to diverse directions of the tectonic transport in his zone – apart from the direction towards N, also directions pointing to back thrusting (southwards) occur. The observations of the outcrops in other region than the Bieszczady area, suggest reactivation of the mélange zones – a possible change in the directions of the tectonic transport at the successive deformation stage. A strong mineralization of this zone is, however, restricted only to the Bieszczady area and is manifested in the accumulation of the minerals in a genetic sequence. Extremely distinct are accumulations in the caverns and fissures gradually filled.

Results of cartographic works correspond to the detailed map where the following chaotic complexes are distinguished (see fig. 2): 1) undeformed olistostroms, rare and stated only in some; 2) mélange (the olistostroms of which could represent an input material for later deformations); 3) wide mélange zones of distinctly tectonic genesis.

The cartographic work presents several chaotic complexes which separate different tectonic units of different rank. Wide complexes of thickness of some dozens meters displaying chaotic lithology and features of tectonic deformation, which form a tectonic mélange between overthrusts are well seen. These mélange parts separate tectonic elements formed "in the sequence".

However, (that is characteristic for this region) exceptionally wide tectonic origin chaotic complexes are connected with some out-of-sequence thrust, possibly normal fault connected with tectonic extension. But the presence "extrabasinal blocks" within the matrix, not connected with surrounding areas (e.g., presence of limestones, shallow water sandstones) can indicate primary sedimentary origin of mélange material.

Sampling took place in the mélange zone in the vicinity of Jabłonki–Rabe and Cisna in the Bieszczady Mts. In black, sheared matrix of the mélange occur larger and smaller blocks ("block-in-matrix"), clasts and lenses (Fig. 4). Fragments of clasts vary in size, from some tens of centimetres to some meters. The rocks are fractured. The fractures are filled with mineralization which is the object of the petrological, mineralogical and geochemical studies.

Clay-carbonate rocks with veinlets and nests of quartz-carbonate-bitumen filling and iron-clayish interlayers are also observed. The structure of these rocks is generally random, sometimes directional, being shown by undulated mica flakes. The dispersed organic matter has been microscopically characterised as primary bituminous material (weakly matured liptinite material), solid organic matter and bituminous infiltrations around the quartz and calcite. The vitrinite reflectance index (R_o) oscillates from 0,80 to 1,54 % R_o (average 1,0 % R_o) depending on the sample.

The field works conducted by L. Jankowski resulted in distinguishing and mapping the tectonic mélange zones which till present have not been presented in the maps (see fig. 1, 2) [22].

The zones of the rocks of the "blocks-in-matrix" type, which underwent a tectonic deformation, are concerned as the mélange despite the primary genesis of the material. The rocks "strange" to those rock types close to the fault zones were found there. In the Jabłonki region, these rocks are fractured limestones and sandstones rich in carbonate-quartz mineralization and the organic matter.

The tectonic mélange recently distinguished and described by L. Jankowski occur in different localities of the eastern part of the Polish Western Carpathians and in the adjacent territory of Ukraine and Slovakia. Only some of them, however, are mineralized in the rocks of the character "block-in-matrix". Among numerous mélange occurrences within the Polish boundaries, the mineralization occurs in the Cisna–Kalnica and Jablonki–Rabe regions. This is the carbonate-quartz mineralization and distinct accumulations of bitumens.

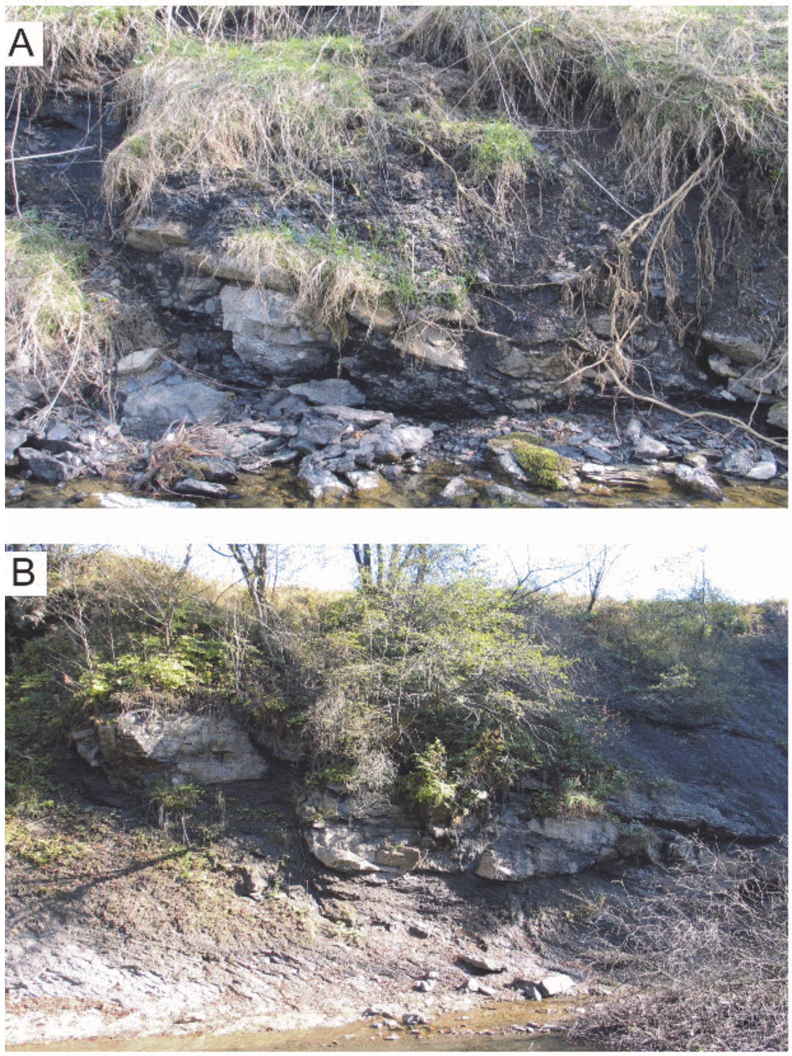

Fig. 4. Field photographs of the melange west of Ustrzyki Górne:
A – Wetlina, the tectonic mélange of the Wetlinka stream; *B* – the tectonic mélange in Prowcza.
Phot. L. Jankowski.

These last ones, but one lens in the Jablonki region of a very high TOC, display a similar character to the accumulations in the Silesian and Dukla units (compare [11, 25]). The results of the Rock-Eval analysis for bitumens from the mélange zone in the Jabłonki region are presented in the table.

Results of rock-eval pyrolitic analysis of samples from the melange zone in the Bieszczady mountains

Samples	T_{max}, °C	S_1, mgCH/g rock	S_2, mgCH/g rock	S_3, $mgCO_2$/g rock	PI, $S_1/(S_1+S_2)$	S_2/S_3	TOC, %	HI, mgHC/g TOC	OI, $mgCO_2$/g TOC
Ja2	475	0,88	4,02	0,45	0,18	8,93	3,48	116	13
A3	463	0,23	1,74	0,78	0,12	2,23	4,44	37	17
B7	476	7,36	39,11	1,07	0,16	36,55	35,83	109	3
Me 3	468	0,15	0,73	0,68	0,17	1,07	1,08	68	63
Me 5B	465	0,07	0,98	0,53	0,06	1,85	2,43	40	22
Me 6	465	0,07	0,98	0,53	0,06	1,85	2,43	40	22
Me 7	469	0,50	3,50	0,15	0,13	23,33	4,43	79	3
Me 9B	465	0,09	1,19	0,40	0,07	2,98	2,56	46	16
Me 11	447	0,09	0,94	0,14	0,09	6,71	2,50	38	6
Me 12	438	0,15	0,53	0,09	0,23	5,89	1,78	30	5
Me 13	474	0,04	0,44	0,48	0,08	0,92	0,77	57	62
Me 17	469	0,21	0,85	0,53	0,20	1,60	1,34	63	40

The characteristic feature of the mélange is an occurrence of the carbonate-quartz mineralization with bitumens filling fissures and cavers and nests and in form of veinlets, brushes and nests. The mutual relations of these components are seen both in the macroscopic and microscopic scale together with a differentiated chemical composition. Detailed petrological, mineralogical and geochemical characteristics are shown by K. Jarmołowicz-Szulc (2009, in press).

Several generations of carbonates were observed in the mélange region under discussion. They are either white or honey in colour and display granoblastic texture. Small veinlets of yellow calcite occur together with pure carbonate veins, quartz accumulations being present in the centre of them. That points to later formation of the quartz in respect to the calcite.

Calcite is the primary mineral. It either fills whole veins or forms dispersed accumulations. Its colour corresponds to white, milk-white or yellow. The large calcite crystals display a form of rhombohedrons (calcite I), while in the central part of veinlets, scalenohedrons occur (calcite II). Crystal size varies from one to over 20 mm. Sometimes a thin film of bitumens covers crystal surface. As for its chemism, diversity occurs as for the manganese percentage.

Quartz occurs mostly in sandstone and claystone blocks, less frequently in schists (Karwowski, Dorda, 1986; Dudok, 1993). It is accompanied by carbonates and black bitumens. The Marmarosh "diamonds" have been found either in central parts of veinlets, mostly open, filled with brownish or white calcite and inhomogeneously arranged bitume concentrations or in asphaltitic accumulations in lower parts of the sandstones. The Marmarosh "diamonds" are in general colourless and transparent. Their size varies from below one mm to even more than one centimetre, generally being 2–3 mm. The crystals display a combination of several crystallographic forms, mostly of hexagonal prism and a rhombohedron, occasionally also trigonal prism. There occurs some connection between morphology and occurrence. Mostly prismatic crystals with weak developed rhombohedrons prevail in the calcite-filled fissures, while the dominance of the rhombohedron over the prism is more characteristic for the crystals from asphaltite. As it results from the earlier research [25], the isotopic composition of the quartz ($\delta^{18}O_{SMOW}$), in average equal to 22,3 ‰, points to the composition of the aqueous palaeofluid co-occurring with this quartz in the interval between 5 and 10 ‰, assuming homogenization temperature of brine inclusions as close to the trapment.

Bitumens fill in the space between calcite grains, forms inclusions and – in the central part of veins – forms coating of loose quartz grains. Geochemical analyses of the organic master in some samples show high hydrogen factor values in respect to $(H/C)_{at}$. Values of R_o fall into the field between 0,5 and 1,35 % [27], that corresponds to calculation results of I. Matyasik (oral information), equal to 1,24 %.

Other minerals are also present in quartz-calcite veins. They are as follows: dolomite, anhydrite and pyrite. The ore mineralization in the paragenesis with the Marmarosh "diamonds" and calcite has been fund in some localities as e.g. in the Rabe region (Wieser, oral information; [32]). This mineralization comprises realgar, orpiment antimonite, zinnabar, metazinnabarite and mercury.

Consequently, it is possible to draw such conclusions on the basis of the expounded materials:

– tectonic mélange zones are common in the Polish Carpathians and in other regions of this mountain chain being not distinguished and understood till present;

– some regions display strong mineralization, the example of which has been studied in the Bieszczady Mts. region;

– organic matter occurs in association with minerals either filling in veins and caverns or being dispersed in the rocks;

– tectonic mélange zones distinguished represent evident paths for fluid migration;

– seismic studies as well as advanced geochemical-mineralogical studies are necessary to determine exact connection of the tectonic mélange zones with zones of hydrocarbon migration and to evaluate depths of the "rooting" of the mélange zones referred to the out-of-sequence-zones.

Thanks are due to Dr Irena Matyasik and Dr Grzegorz Leśniak for their help in analytical studies and favour.

---

1. *Aleksandrowski P.* Uskoki i strefy ścinania // Badania elementów tektoniki na potrzeby kartografii wiertniczej i powierzchniowej. Instrukcje i metody badań geologicznych. 1992. Z. 51. S. 105–115.
2. *Barber A.J., Tjokrosapoetro S., Charlton T.R.* Mud Volcanoes, Shale Diapirs, Wrench Faults, and Melanges in Accretionary Complexes, Eastern Indonesia // AAPG Bull. 1986. Vol.70. N 11. P. 1729–1741.
3. *Burbank D.W., Reynolds G.H.* Stratigraphic Keys to the Timing of Thrusting in Terrestial Foreland Basins // Applications to the Northwestern Himalaya. 1988. P. 331–351.
4. *Busby C.J., Ingersoll R.V.* Tectonics of Sedimentary Basins. Blackwell Science, 1995.
5. *Byrne T.* Early deformation in melange terranes of the Ghost Rocks Formation, Kodiak Islands, Alaska // Melanges: Their nature, origin and significance. Geol. Soc. of America. 1984. Special Paper 198.
6. *Carreras J., Cobbold P.R., Ramsay J.G., White S.H.* Shear zones in rock. // J. Struct. Geol. (Special issue). 1980. Vol. 2. P. 1–287.

7. *Cloos M.* Flow melanges and the structural evolution of accretionary wedges // Melanges: Their nature, origin and significance. Geol. Soc. of America. 1984. Special Paper 198.
8. *Cowan D.S.* Structural styles in Mesosoic and Cenosoic melanges in the western Cordillera of North America // Geol. Soc. of America Bulletin. 1985. Vol. 96. P. 451–462.
9. *Dewey J.F., Bird J.M.* Plate tectonics and geosynclines // Tectonophysics. 1970. Vol. 10.
10. *Doglioni C.* Some remarks on the origin of foredeeps // Tectonophysisc. 1993. Vol. 228. P. 1–20.
11. *Dudok I.V., Kotarba M., Jarmołowicz-Szulc K.* Employment of pyrolitic methods in geochemical studies of organic matter of the vein formations in the flysch of the Carpathians Mts. // Геологія і геохімія горючих копалин. 2002. Вип. 1. С. 76–87.
12. *Greenly E.* The Geology of Angesley: Memoir of the Geological Survey of Great Britain. In 2 vol. 1919. 980 p.
13. *Gucik S., Paul Z., Ślączka A., Żytko K.*, Mapa geologiczna Polski w skali 1:200 000, arkusz Przemyśl–Kalników (Mapa bez utworów czwartorzędowych). W-wa: Wydanie B. IG., 1980.
14. *Haczewski G., Bak K., Mastella L.* et al. Szczegółowa mapa geologiczna Polski w skali 1 : 50 000. Ark. Ustrzyki Górne. Arch. PIG OK (w druku).
15. *Hsu K.J.* Principles of Melanges and Their Bearing on the Franciscan–Knoxville Paradox // Geol. Soc. of America Bulletin. 1968. Vol. 79. P. 1063–1074.
16. *Hurai V., Francu J., Bajova L., Gavacova H.* Hydrocarbon inclusions in "Marmarosh diamonds" from flysch sediments of Eastern Slovakia // Fluids in geological processes. Czechoslovakian Contributions to the Session devoted to Fluid Inclusions: Abstracts. Bratislava, 1989. P. 5–6.
17. *Jankowski L., Ślączka A.* Detailed Geological Map of Poland 1:50 000. Sheet Jabłonki. PGI Archive (in press).
18. *Jankowski L.* Budowa geologiczna przedpola jednostki magurskiej pomiędzy Wisłoka a Dunajcem ze szczególnym uzględnieniem utworów chaotycznych: Praca doktorska, 2003. Arch. PIG.
19. *Jankowski L.* Rozwój karpackiej pryzmy akrecyjnej-ujęcie koncepcyjne // Materiały konferencyjne LXXV Zjazdu PTG. Iwonicz Zdrój, 2004.
20. *Jankowski L.* Field guide book: Materials of conference "Chaotic complexes in Polish Carpathians". Krakow–Polańczyk, 2008. P. 27–52 (in Polish).
21. *Jankowski L., Jarmołowicz-Szulc K.* Wstępna charakterystyka melanży tektonicznych w Bieszczadach // Materiały konferencyjne LXXV Zjazdu PTG. Iwonicz Zdrój, 2004.
22. *Jankowski L., Kopciowski R., Ryłko W.* et al. Geological map of the Outer Carpathians: bordelansd of Poland, Ukraine and Slovakia. Warszawa, 2004.
23. *Jarmołowicz-Szulc K.* Characteristic features of vein fillings in the southeastern part of the Polish Carpathians (calcite, quartz, bitumens) // Przegl. Geol. 2001. Vol. 49. P. 785–792 (in Polish with English summary).
24. *Jarmołowicz-Szulc K., Dudok I.V.* Fluid inclusion studies in vein minerals of the Capathians, Poland–Ukraine // Abstracts of the XI Congress of Regional Committee in Mediterranean Neogene Stratigraphy. Fes, Morocco, 2000. P. 132.
25. *Jarmołowicz-Szulc K., Dudok I.V.* Migration of palaeofluids in the contact zone between the Dukla and Silesian units, Western Carpathians – evidence from fluid in-

clusions and stable isotopes in quartz and calcite // Geol. Quart. 2005. Vol. 49. P. 291–304.
26. *Jarmołowicz-Szulc K., Matyasik I., Jankowski L.* Comparative studiem of mineral assemblages in the Bieszczady region // Pr. Specjalne PTM. 2005. Vol. 25. P. 307–312 (in Polish).
27. *Kotarba A., Kowalski A., Kowalski T.* et al. Geochemical analyses of the organic matter in the Flysch Carpathians // Unpublished materials. Centr. Arch. Geol. Państw. Inst. Geol. Warszawa, 2000 (in Polish).
28. *Needham D.T.* Mechanism of melange formation: examples from SW Japan and southern Scotland // Journal of Structural Geology. 1995. Vol. 17. N 7. P. 971–985.
29. *Raymond L.A.* Classification of melanges // Melanges: Their nature, origin and significance. Geological Society of America. 1984. Special Paper 198.
30. *Sarwar G., Dejong K.A.* Composition and origin of the Kanar Melange, southern Pakistan // Melanges: Their nature, origin and significance. Geological Society of America. 1984. Special Paper 198.
31. *Sibson R.H.* Fault rock and fault mechanism // Journal of the Geological Society of London. 1977. Vol. 133. P. 191–213.
32. *Ślączka A.* Stratygrafia serii śląskiej łuski bystrego na południe od Baligrodu // Biul. IG. 1959. Vol. 131. P. 203–251.
33. *Ślączka A., Żytko K.* Mapa geologiczna Polski 1:200 000, arkusz Łupków. Warszawa: Wyd. Geol., 1978.
34. *Świerczewska A., Tokarski A. K. , Hurai V.* Architecture and history of joints and mineral veins in Paleocene sandstones of the Magura nappe; *p-t* conditions // Przewodnik LXXII Zjazdu PTG, 2001. P. 182–187.
35. *Vollmer F.W., Bosworth W.* Formation of melange in a foreland basin overthrust setting: Example from the Taconic Orogen // Melanges: Their nature, origin and significance. Geological Society of America. 1984. Special Paper 198.
36. *Yilmaz P.O., Maxwell J.C.* An example of an obduction melange: The Alakir Cay unit, Antalya Complex, southwest Turkey // Melanges: Their nature, origin and significance. Geological Society of America. 1984. Special Paper 198.

СПЕЦИФІЧНІ ТЕКТОНІЧНІ ЗОНИ (ЗОНИ МЕЛАНЖУ) ЯК ПОТЕНЦІЙНІ І ВАЖЛИВІ ШЛЯХИ ДЛЯ МІГРАЦІЇ ФЛЮЇДІВ ТА МІНЕРАЛОУТВОРЕННЯ

Л. Янковскі[1], К. Ярмоловіч-Шульц[2]

[1]*Польський геологічний інститут, Карпатське відділення*
31–560 м. Краків, вул. Скжатув, 1
E-mail: leszek.jankowski@pgi.gov.pl
[2]*Польський геологічний інститут*
00-975 м. Варшава, вул. Раковецька, 4
E-mail:katarzyna.jarmolowicz-szulc@pgi.gov.pl

Детально досліджено зони меланжу в гірському масиві Бескиди. Цим зонам притаманні особливості, які є доказом прояву тектонічних деформацій. Загалом зони меланжу – це відкриті або закриті геохімічні системи. Ступінь тектонічної переробки верств свідчить про те, що їх можна трактувати як шляхи для міграції флюїдів, місце кристалізації мінералів та/або зони міграції вуглеводнів і мінералізованих вод. З цього погляду петрологічно, мінералогічно та геохімічно досліджено тектонічний меланж у районі Яблонки–Рабе.

Ключові слова: тектонічний меланж, міграція флюїдів, Карпати.

СПЕЦИФИЧЕСКИЕ ТЕКТОНИЧЕСКИЕ ЗОНЫ (ЗОНЫ МЕЛАНЖА) КАК ПОТЕНЦИАЛЬНЫЕ И ВАЖНЫЕ ПУТИ ДЛЯ МИГРАЦИИ ФЛЮИДОВ И МИНЕРАЛООБРАЗОВАНИЯ

Л. Янковски[1], К. Ярмолович-Шульц[2]

[1]*Польский геологический институт, Карпатское отделение*
31–560 г. Краков, вул. Скжатув, 1
E-mail: leszek.jankowski@pgi.gov.pl
[2]*Польский геологический институт*
00-975 г. Варшава, ул. Раковецкая, 4
E-mail:katarzyna.jarmolowicz-szulc@pgi.gov.pl

Детально исследованы зоны меланжа в горном массиве Бескиды. Этим зонам присущи особенности, которые являются доказательством проявления тектонических деформаций. В общем, зоны меланжа – это открытые или закрытые геохимические системы. Степень тектонической переработки слоев свидетельствует о том, что такие зоны могут быть путями миграции флюидов, местом кристаллизации минералов и/или зонами миграции углеводородов и минерализованных вод. В таком аспекте петрологически, минералогически и геохимически исследован тектонический меланж в районе Яблонки–Рабе.

Ключевые слова: тектонический меланж, миграция флюидов, Карпаты.

Стаття надійшла до редколегії 01.07.2009
Прийнята до друку 15.09.2009