

Cârlibaba-Broșteni strike-slip fault - a possible old segment of Bogdan Vodă-Dragoș Vodă fault system: implications for the structural and metallogenetic correlations in the Crystalline-Mesozoic Zone of the Eastern Carpathians (Romania)

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Abstract: This study proposes the ramification of the Dragoș Vodă fault to the south-east, on the line Cârlibaba-Zugreni-Crucea-Holdița, reaching the eastern limit of the Crystalline-Mesozoic Zone of the Eastern Carpathians north of Broșteni. This segment is a strike-slip fault, which can be named the Cârlibaba-Broșteni fault. The proposed structural arrangement indicates the presence of a distinct tectonic compartment of the Crystalline-Mesozoic Zone, comprising Rodna Mountains and Bistriței Mountains, delimited, to the north and north-east, by the Dragoș Vodă fault and the Cârlibaba-Broșteni fault, and, to the south and south-west, by the Dârmoxa-Grințieș fault. The tectonic compartment between these two strike-slip faults has a southeasterly offset of ca. 75 km and comprises all tectonic windows where the Infracarpathian Nappes (Anieș, Știol, Valea Vinului, Rusaia, Iacobeni, Borcut-Ulm and Arșița Barnarului) are cropping out. Because of its southeasterly movement, the structural features of the tectonic compartment Rodna Mountains-Bistriței Mountains differ from those of the adjacent compartments to the north and to the south. It is inferred that the Leșul Ursului and Baia Borșa ore fields were initially parts of the same metallogenetic zone, the former being displaced to the south-east along the Cârlibaba-Broșteni fault.

Key words: strike-slip fault, Eastern Carpathians, Rodna Mountains, Bistriței Mountains

1 Introduction

Many of the arguments for the delimitation of the structural units and tectonic compartments of the Crystalline-Mesozoic Zone used in this work are based on the detailed study of the pre-Alpine basement of the Alpine tectonic units. The traditional structural delimitations and modeling in a coherent system for the entire Carpathian area were based on the Alpine evolution deduced from the knowledge on the sedimentary formations. In 1907, Uhlig evidenced the Marginal Syncline of the Eastern Carpathians – the Rarău Syncline, in the north, and the Ghilcoș-Hăghimaș-Ciuc syncline, in the south, both constituted of Mesozoic formations. The

lack of continuity between the two synclines was explained by an axial raise of the geological structure between the Rarău Mountains and Hăghimaș Mountains. The model largely accepted since the late 1900s is the outcome of numerous studies resulted in synthetic works on facies, sedimentation zones and geological evolution accomplished by Patrulius et al., (1969) and Săndulescu et al. (1989). A remarkable presentation, for the Carpathians and the neighboring areas, is comprised in the book *Geotectonics of Romania* (Săndulescu, 1984). The geological data presented here support an interpretation according to which, the continuity of the Alpine structures of the Crystalline-Mesozoic Zone is interrupted by a sinistral

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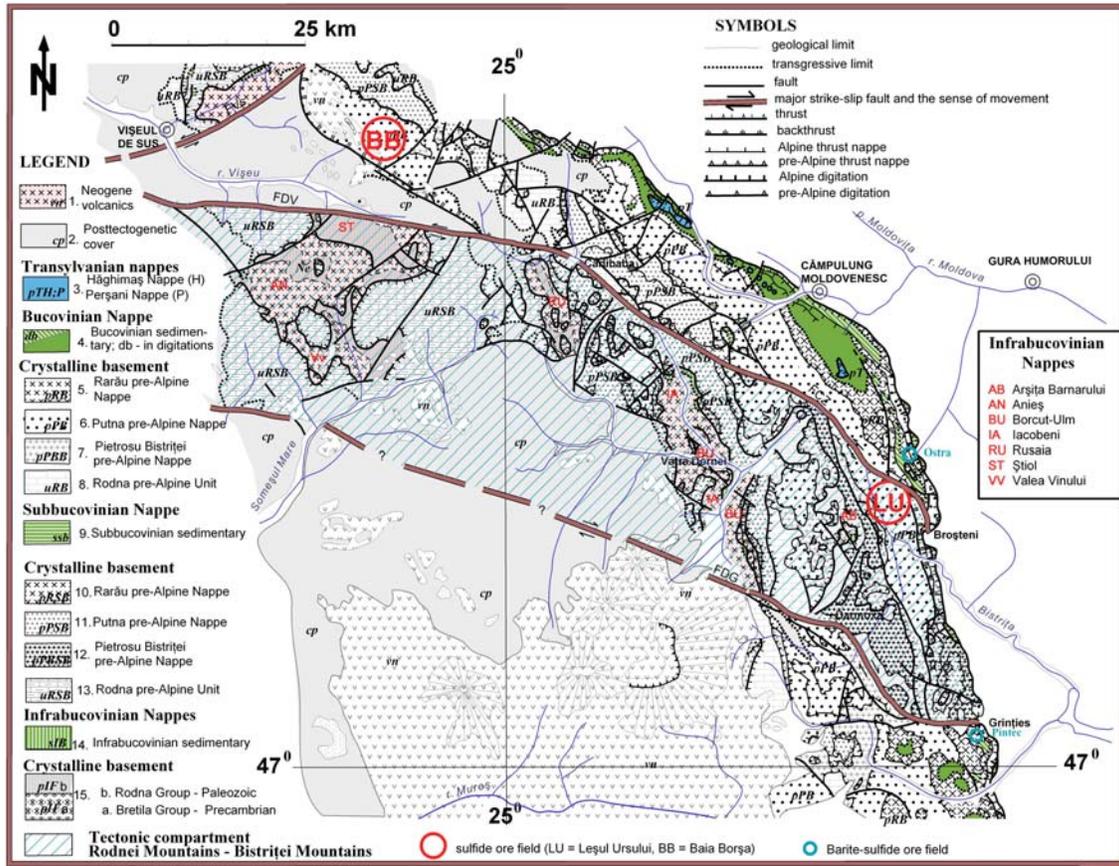


Fig. 1. Simplified geological map of the central and northern parts of the Crystalline-Mesozoic Zone of the Eastern Carpathians, including the tectonic compartment delimited by the strike-slip faults Cărlibaba-Broșteni and Dârmoxa-Grințieș.

strike-slip fault, which probably is an old segment of the Bogdan Vodă-Drăgoș Vodă fault system. South of this fault, the Rodna Mountains and most parts of the Bistriței Mountains constitute a tectonic compartment that extends to the Dârmoxa-Grințieș dextral strike-slip fault (Vodă, 1999). The compartment between the two strike-slip faults, was interpreted as having a great south-eastward displacement, which could explain the absence of the structural features known at the eastern border of the Crystalline-Mesozoic Zone to the north, in the Rarău Mountains, and to the south, in the Hăghimaș Mountains

2. Geological evidence

2.1 The geological situation at Cărlibaba

The analysis of the stratigraphic and structural context from the eastern sector of the

Drăgoș Vodă fault, made by L. Szasz during the elaboration of the Geological Map of Romania, scale 1:50.000, Drăgoș Vodă Sheet (Kräutner et al., 1993; Vodă et al., 1997) argued for the extension of this fault to the left slope of the Țibău valley, at ca. 1 km upstream from the confluence with Bistrița river, based on the sedimentary formations of the posttectogenetic cover, Cenomanian-Oligocene in age. The sequence of the sedimentary deposits contains numerous gaps of sedimentation and erosion, which mark the movement of the tectonic compartments along the Drăgoș Vodă fault.

At Gura Țibăului, south of the eastern extension of the Drăgoș Vodă fault, within the geological reserve from Stâncă Țibăului, polymictic conglomerates, sandstones and fossiliferous calcarenites occur across a small area, lying directly on the metamorphic formations. These sedimentary formations are missing north of the Drăgoș Vodă fault and do not extend in the eastern side of Bistrița valley,

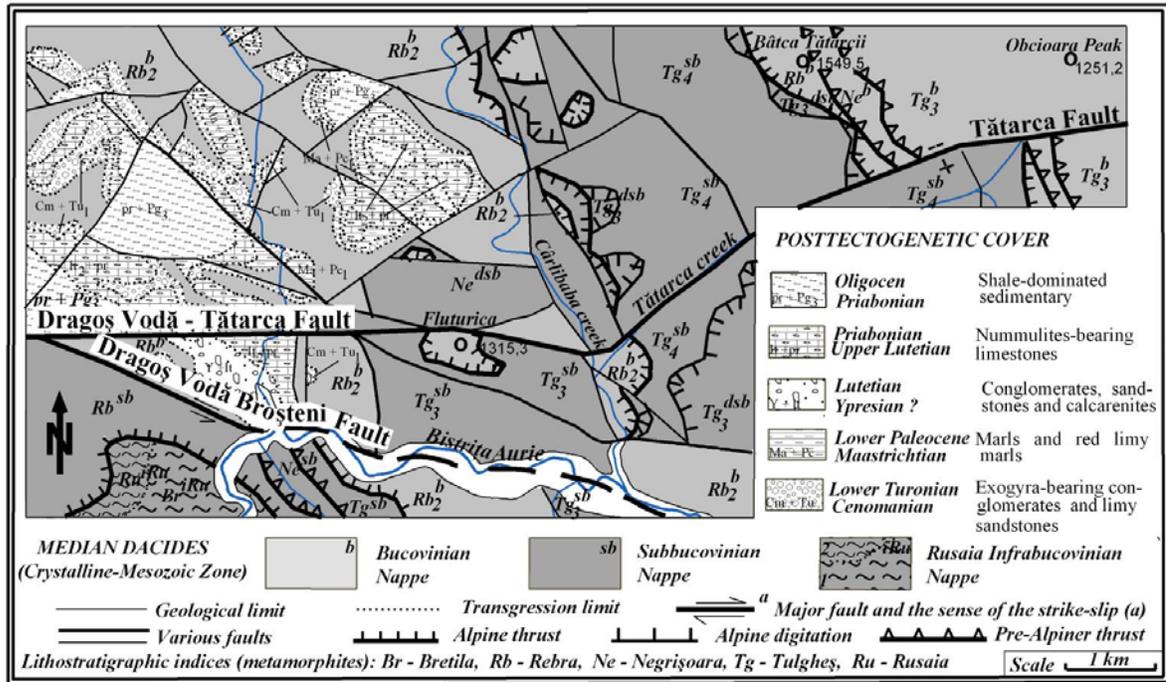


Fig. 2. Simplified geological map of the Cârlibaba-Țibău zone

obviously from tectonic reasons, i.e. uplifting that induced the retreat of the outcropping zone of the posttectogenetic sedimentary cover far to the west, in an area upstream from the confluence between the valleys Bistrița and Bretila. East of Țibău valley, the direct continuation of the Dragoș Vodă fault passes north of Fluturica Peak (1345.3 m), follows the course of the Tâtarca Cârlibabei valley, the crest between the hydrographic basins of Bistrița and Moldova rivers, south of Obcioara Peak (1251.2 m) and reaches Moldova valley downstream from the confluence with Tâtarca creek, tributary of Moldova river from the right hand side (Kräutner et al., 1993; Vodă et al., 1997).

The cartographic shape of the area between the Bistrița river, at Cârlibaba, and the ridge toward the Moldova river, close to its confluence with Tâtarca tributary, shown in Fig. 2, indicates an uplift of the tectonic compartment south of the eastern extension of the Dragoș Vodă fault (named Tâtarca fault), which is coherent with the structural situation to the west, at the northern limit of Rodna Mountains.

South of Tâtarca fault, the geological structure continues to the Bistrița valley, but cannot be correlated with the structure in the western

slope of Bistrița valley, characterized by the presence of lithostratigraphic sequences and tectonic features of the Bucovinian and Subbucovinian nappes different from those in the eastern slope of Bistrița River. The domain with different features from the western side of Bistrița valley also includes the Rusaia Infrabucovinian Nappe occurring in a tectonic window. An analysis of the geological structure and of the lithostratigraphic content of the structural units from this area as far to the south as south of Broșteni, led to the tracing of the strike-slip fault Cârlibaba-Broșteni, named in Fig. 2 Dragoș Vodă-Broșteni fault, to highlight the possible relation with the strike-slip fault system Bogdan Vodă-Dragoș Vodă.

2.2 The geological situation at Broșteni

Fig. 3 contains a geological map with the interpretation of the Cârlibaba - Broșteni fault between Crucea and Holdița. In the area between the Holda (Puzdra) creek and Crucea, the fault was revealed by the surface mapping correlated with the underground works from the Leșul Ursului mining field (Kräutner et al, 1975; 1978; 1986). The strike-slip character of the fault was

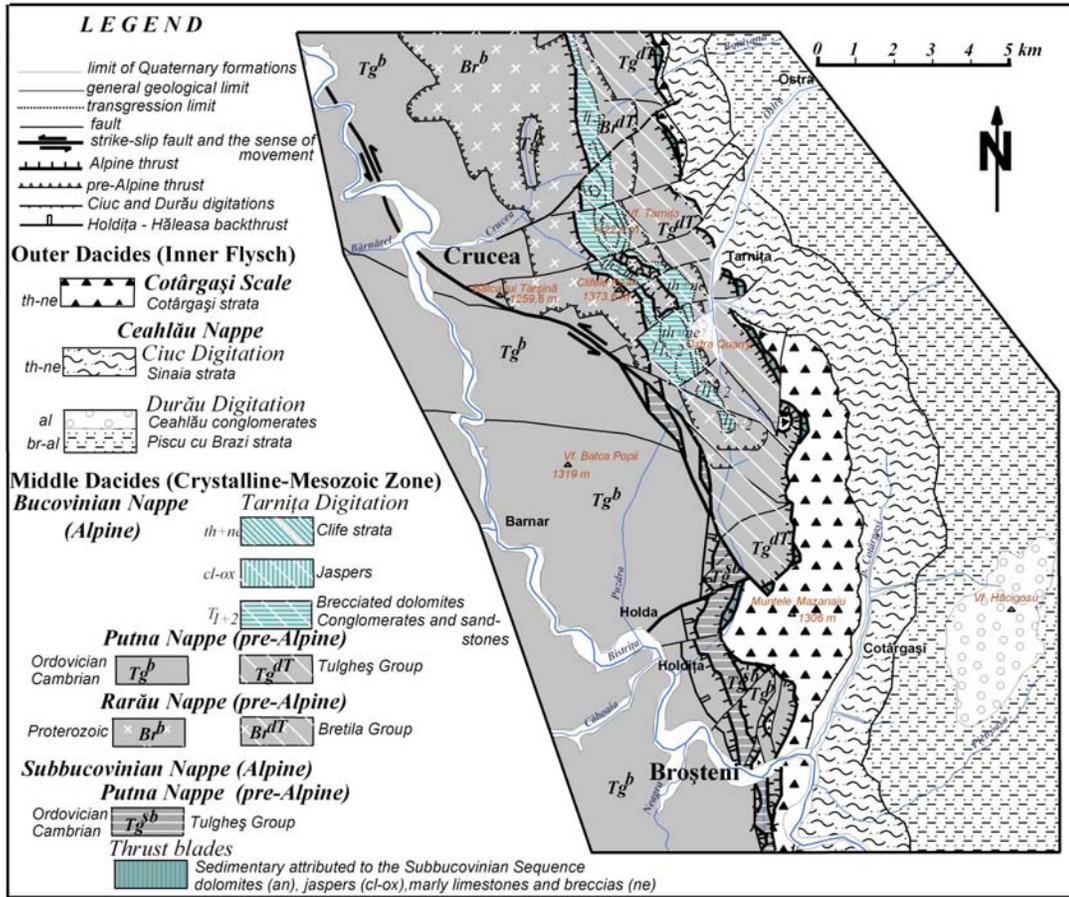


Fig. 3. Simplified geological map of the Broșteni-Ostra zone. The eastern part, the Cotârgești Scale and the digitations of the Ceahlău Nappe after Săndulescu (2008).

neglected. The continuation of the fault to the left hand slope of the Holdița creek, at the contact between the Crystalline-Mesozoic Zone with the Inner Flysch Zone, was easy to draw due to the occurrence, on the fault, of several outliers of black graphitic quartzites similar to those from Holdița-Broșteni and Borca, from the Subbucovinian Nappe (Vodă et al., 1999). Previous mapping results (Vodă, 1980) outlined a small half-window in the right hand slope of the Holdița creek, at the confluence with the Haștei creek, the border of the Crystalline-Mesozoic Zone being indented westward with more than 1 km. On the contact with the Inner Flysch Zone, there is a thrust blade made up of Anisian dolomites, in the base, and a Neocomian sequence composed of red jasperoid argillites with thin intercalations of coarse sandstones. Recently, Săndulescu (2008) identified the Ciuc digitation, on the Ceahlău Nappe, and the Cotârgești scale, under the thrust of the Crystalline-Mesozoic Zone over the Inner Flysch, with the greatest extent in the right hand

side of the Cotârgești creek and on the Haștei creek, tributary of the Holdița creek from the left side, in the area where the strike-slip fault Cârlibaba-Broșteni reaches the border of the Crystalline-Mesozoic Zone. Fig. 3 contains this structural interpretation of the Inner Flysch Zone (after Săndulescu, 2008). The structure of the Alpine nappes of the Crystalline-Mesozoic Zone obviously exhibits peculiar features in this sector:

- the tectonic compartment north-east of the Cârlibaba-Broșteni strike-slip fault is characterized by the presence of the Bucovinian Nappe and its frontal digitation, Tarnița digitation (Săndulescu, 1981);
- the tectonic compartment south-west from the strike-slip fault contains the Bucovinian Nappe and, beneath it, the Subbucovinian Nappe, on a zone uplifted by a reverse fault, named Holdița-Hăleasa fault (Vodă, 1982).

The strike-slip fault ends to the contact with the Inner Flysch Zone, which indicates the freeze of the tectonic movement

after the deposition of the Cotârğași strata, whose age is Tithonian-Neocomian (Săndulescu, 2008).

3 Discussions

3.1 The track of the Cârlibaba-Broșteni strike-slip fault

The lack of sedimentary formations of the posttectogenetic cover made possible the observation of the great differences between the lithostratigraphic sequences and structure of the metamorphic formations in both slopes of the Bistrița River. The Cârlibaba-Broșteni strike-slip fault follows Bistrița valley from Gura Țibăului downstream, to Ciocănești, where it passes in the eastern slope, downstream of the confluences with the tributaries Pârâul Rece and Colacu, then crossing the Brezuța creek at ca. 1 km from the confluence with Bistrița and Puciosu creek, at the margin of Mestecăniș village. It continues by the source of Pârâul Roșu creek (tributary of the valley Putna of Pojorâta), passes the Giumalău Mountain (1856.5 m) near the sheepfold from Poiana Ciungi (1513.1 m) and reaches Bistrița valley again, in Bistrița Gorges from Zugreni. From Zugreni to Crucea, the fault follows Bistrița valley, cutting locally through the left hand slope (most obviously at «Dâmbul Colacului»), then remains in the left hand (eastern) slope of Bistrița, passing by the source of Holda (Puzdra) creek and stops at the tectonic contact between the Crystalline-Mesozoic Zone and Inner Flysch Zone, on the Holdița creek, at the confluence with Haș creek.

3.2 The tectonic compartment Rodna Mountains-Bistriței Mountains

In Fig. 1, it can be seen how the Dragoș Vodă fault and its extension, the Cârlibaba-Broșteni fault, delimit, to the south, a tectonic compartment that extends southward to the Dârmoxa-Grințieș fault. Between the two strike-slip faults, the entire Rodna Massif and most of the Bistriței Mountains are comprised. To the east, this tectonic compartment is limited by the border of the Crystalline-Mesozoic Zone between Broșteni and Grințieș. To the west-north-west, the Dârmoxa-Grințieș fault is overlain by the formations of the posttectogenetic cover and by the Neogene volcanic rocks of the Călimani Massif from Păltiniș. Because of this, its extent and location

at the southwestern margin of the Rodna Massif are just inferred.

The main feature of the compartment Rodna Mountains-Bistriței Mountains consists of the occurrence, over extended areas, of the lowermost Alpine tectonic units of the Crystalline-Mesozoic Zone. In this compartment, the Subbucovinian Nappe has the greatest extent of all parts of the Crystalline-Mesozoic Zone. From beneath the Subbucovinian Nappe, the following Infrabucovinian structural units occur (from north-west to southeast): Anieș, Știol, Valea Vinului, Rusaia, Iacobeni, Borcut-Ulm and Arșița Barnarului.

The eastern border of the Crystalline-Mesozoic Zone of the Eastern Carpathians, at the contact with the Ceahlău Nappe (Inner Flysch Zone), represented by the Ciuc Digitation, is a continuous tectonic line from Maramureș, in the north, to Ciuc Depression, in the south. Along this major tectonic contact, there are different structural situations, induced by the specific features of the compartment Rodna Mountains-Bistriței Mountains:

- North of the Cârlibaba-Broșteni fault, from the left hand slope of the Holdița creek, in the south, to Slătioara (south of Câmpulung Moldovenesc), in the north, along the contact with the Ceahlău Nappe (Inner Flysch Zone), the Crystalline-Mesozoic Zone is represented by the Tarnița digitation of the Bucovinian Nappe.

- In the compartment Rodna Mountains-Bistriței Mountains, from Holdița-Broșteni, in the north, to the Grințieșul Mare creek, in the south, the border of the Crystalline-Mesozoic Zone is constituted of the Subbucovinian Nappe. Between Broșteni and Borca, outliers and scales that could be attributed to the Bucovinian Nappe occur along the border of the Crystalline Mesozoic Zone.

- South of the Dârmoxa-Grințieș fault, the Bucovinian Nappe reappears, with a frontal digitation (Chicera Digitation), best visible between the Bistricioara and Bicaz valleys.

The lack of continuity of the Mesozoic sedimentary formations of Rarău and Hăghimaș type in the segment between Broșteni and Grințieș, and, also, the lack of the frontal digitations of the Bucovinian Nappe in the same segment, can be considered as resulting from the southeastward movement of Rodna Mountains-Bistriței Mountains compartment, between the strike-slip faults Cârlibaba-Broșteni and Dârmoxa-

xa-Grințieș. Regarding the evolution of this compartment, it can be conceived that the onset of the strike-slip movements was triggered by the blocking of the movement in the northeastern compartment of the Dragoș Vodă-Cârlibaba-Broșteni fault (which could be named Maramureș-Rarău compartment) and the escape in the east-south-east direction of the land from the southwestern side of the fault. Several studies concerning the Tertiary displacement of the major structural units of the Alps and Carpathians (Tischler, 2005; Tischler et al., 2007; Groger et al., 2008) allow the consideration of the strike-slip and rotation along the Cârlibaba-Broșteni fault, coupled with the Bogdan Vodă-Drăgoș Vodă fault system and with the possible connection to the west and south-west (to tectonic system of the Mid Hungarian Line).

3.3 Structural and metallogenetic correlations

Out of all the possible structural and metallogenetic correlations in the presented framework, maybe the most interesting is the possible correlation between the Leșul Ursului and Baia Borșa pyrite and polymetallic sulfide deposits (pyrite + copper and pyrite + lead, zinc, copper, hosted in the formation of acid metavolcanics (Tg3) of Tulgheș Group from the Bucovinian Nappe. The geologic and metallogenetic models, based on numerous geochemical and depositional studies, were elaborated by Kräutner (1965) and Kräutner et al. (1975, 1976, 1986), for the deposits in the Leșul Ursului mining field, and by Zincenco (1971, 2000), for the ore field from Baia Borșa. Leșul Ursului is situated near Broșteni, in the Bucovinian Nappe, in the tectonic compartment Rodna Mountains-Bistriței Mountains, south of the Cârlibaba-Broșteni fault. The lithostratigraphic sequence from Leșul Ursului, with numerous ore layers and lenses exposed in outcrops and known in detail from numerous adits and drill holes in the left hand slope of Bistrița river downstream of Crucea village, could not be found north from a fault that cut the structure, from the left hand slope of Crucea creek, the middle courses of Leșului and Ursului creeks, reaching, north of Bâtea Popii, at the confluence of Grebin and Puzdra creeks (Kräutner, in Săndulescu et al., 1989). That fault is part of the Cârlibaba-Broșteni fault.

At Baia Borșa, there is the same geologic-metallogenetic context as that from Leșul Ursului, but the two ore fields could not be

correlated because of the great distance between them (ca. 75 km), because of some complications generated by the Neogene intrusions from Toroiaga-Țiganu complex, of the posttectogenetic sedimentary cover from some areas and of the structure, characterized by shallow dips, which poses difficulties in detecting the effects of the faults. In the structural conditions presented here, the two regions can be easier correlated, with an initial (pre-fault) position of the Leșul Ursului ore field in the southern extension of the Baia Borșa ore field. It is of note the similar geological context of the two areas: from Broșteni to the south, at Borca, and from Baia Borșa to the north-west, in the Bardi-Bardău zone, beneath the sequences of Tulgheș Group with sulfide deposits, from the Bucovinian Nappe, there are sequences of the Tulgheș Group with manganese ores, from the Subbucovinian Nappe. This correlation would lead to the estimation of an offset of ca. 75 km along the Cârlibaba-Broșteni fault.

The structural arrangement proposed here also favors the correlation between the epigenetic mineralization (barite and sulfides) of Ostra-Gemenea-Slătioara type, which occurs in Tarnița digitation, north of the Cârlibaba-Broșteni fault, and the barite mineralization from the right hand slope of the Bistricioara valley, upstream of the confluence with Pintec creek, in the tectonic compartment south of the Dârmoxa-Grințieș fault. The barite + sulfides mineralization of Ostra-Gemenea-Slătioara type consists of unconformable vein-type bodies. These cut the metamorphic basement and the Mesozoic sedimentary sequence from Tarnița Digitation (at Ostra), are in contact with the Triassic sedimentary and the Callovian-Oxfordian jasper but do not reach the flysch-type sequence of the Clifele strata, Neocomian in age. At Pintec, the barite mineralization identified by Moga and Podașcă (1988) occur in a similar geological context, in a frontal digitation of the Bucovinian Nappe (Chicera Digitation), which correlates with Tarnița Digitation.

It can be remarked that, similar to the areas with barite and sulfides from the frontal digitations of the Bucovinian Nappe (Tarnița and Chicera), the uranium accumulations of Crucea type also occur only north of the Cârlibaba-Broșteni strike-slip fault (in Crucea zone) and south of the Dârmoxa-Grințieș strike-slip fault (at Tulgheș). In the tectonic compartment between the two faults there is no indication of either Ostra-type or Crucea-type mineralization.

The movement along the Cârlibaba-Broșteni sector ceased before the deposition of the posttectogenic cover of the Crystalline-Mesozoic Zone, while the segment represented by the Tătarca fault remained active.

4 Conclusions

- The strike-slip fault Cârlibaba-Broșteni was traced; this can be considered as a continuation of the fault system Bogdan Vodă-Dragoș Vodă. The fault does not cross the eastern border of the Crystalline-Mesozoic Zone and has no effect on the nappes of the Inner Flysch.
- The sinistral displacement of the Cârlibaba-Broșteni fault is subsequent to the emplacement of the Alpine nappes in the Crystalline-Mesozoic Zone and precedes their thrust over the nappes of the Inner Flysch.
- The tectonic compartment south of the Cârlibaba-Broșteni strike-slip fault is limited, to the south, by a dextral strike-slip fault, the Dârmoxa-Grințieș fault. This tectonic compartment was pushed eastward, most likely by the blocking of the movement in the compartment north of the Cârlibaba-Broșteni fault.
- The structural interpretation derived from the identification of the Cârlibaba-Broșteni fault, imposes structural correlations and metallogenetic at regional scale, the most interesting outcome being the correlation between the Leșul Ursului and Baia Borșa polymetallic sulfide deposits, which are located at more than 75 km from each other. Also of interest are the correlations between the barite and sulfide mineralization of Ostra type and of the uranium mineralization (Crucea-type), occurring in Târnița Digitation and Chicera Digitation, both frontal digitations of the Bucovinian Nappe, which are missing from the compartment Rodna Mountains-Bistriței Mountains, displaced ca. 75 km eastward, between the strike-slip faults Cârlibaba-Broșteni and Dârmoxa-Grințieș.

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