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Cârlibaba-Broşteni strike-slip fault - a possible old segment of Bogdan Vodă-Dragoş 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 Dragoş Vodă fault to the south-east, on the line Cârlibaba-Zugreni-Crucea-Holdiţa, reaching the eastern limit of the Crystalline-Mesozoic Zone of the Eastern Carpathians north of Broşteni. This segment is a strike-slip fault, which can be named the Cârlibaba-Broşteni fault. The proposed structural arrangement indicates the presence of a distinct tectonic compartment of the Crystalline-Mesozoic Zone, comprising Rodna Mountains and Bistriţei Mountains, delimited, to the north and north-east, by the Dragoş Vodă fault and the Cârlibaba-Broşteni fault, and, to the south and south-west, by the Dârmoxa-Grinţieş 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 Infrabucovinian Nappes (Anieş, Ştiol, Valea Vinului, Rusaia, Iacobeni, Borcut-Ulm and Arsiţa Barnarului) are cropping out. Because of its southeastward movement, the structural features of the tectonic compartment Rodna Mountains-Bistriţei Mountains differ from those of the adjacent compartments to the north and to the south. It is inferred that the Leşul Ursului and Baia Borşa ore fields were initially parts of the same metallogenetic zone, the former being displaced to the south-east along the Cârlibaba-Broşteni fault.

Key words: strike-slip fault, Eastern Carpathians, Rodna Mountains, Bistriţei 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 Ghilcoş-Hăghimaş-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 Hăghimaş 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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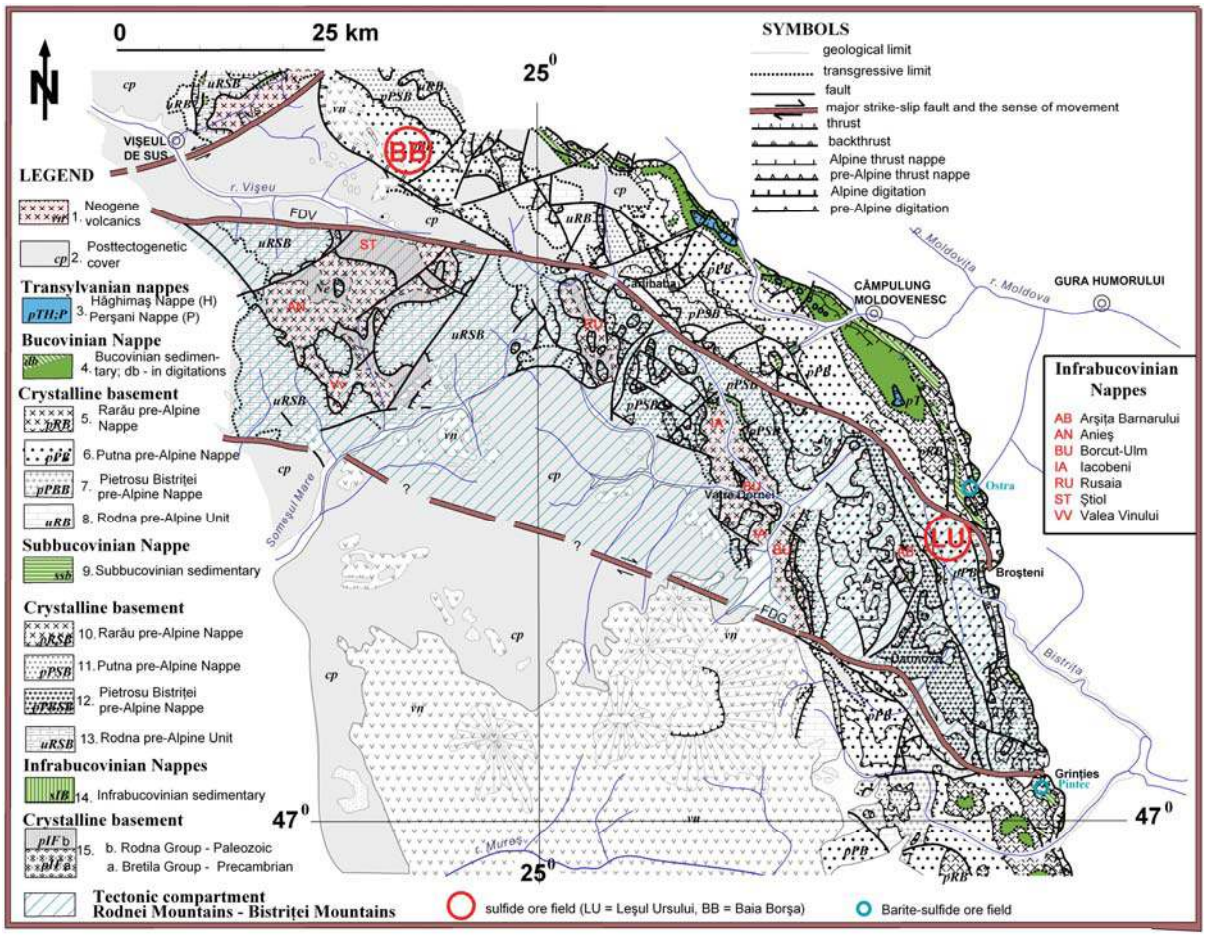

Fig. 1. Simplified geological map of the central and northern parts of the Crystalline-Mesozoic Zone of the Eastern Carpathians, including the tectonic compartment delimited by the strike-slip faults Cârlibaba-Broşteni and Dârmoxa-Grinţieş.

strike-slip fault, which probably is an old segment of the Bogdan Vodă-Dragoş Vodă fault system. South of this fault, the Rodna Mountains and most parts of the Bistriţei Mountains constitute a tectonic compartment that extends to the Dârmoxa-Grinţieş 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 Hăghimaş Mountains

2. Geological evidence

2.1 The geological situation at Cârlibaba

The analysis of the stratigraphic and structural context from the eastern sector of the Dragoş Vodă fault, made by L. Szasz during the elaboration of the Geological Map of Romania, scale 1:50.000, Dragoş Vodă Sheet (Kräutner et al., 1993; Vodă et al., 1997) argued for the extension of this fault to the left slope of the Ţibău valley, at ca. 1 km upstream from the confluence with Bistriţa 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 Dragoş Vodă fault.

At Gura Ţibăului, south of the eastern extension of the Dragoş Vodă fault, within the geological reserve from Stânca Ţibăului, 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 Dragoş Vodă fault and do not extend in the eastern side of Bistriţa valley,

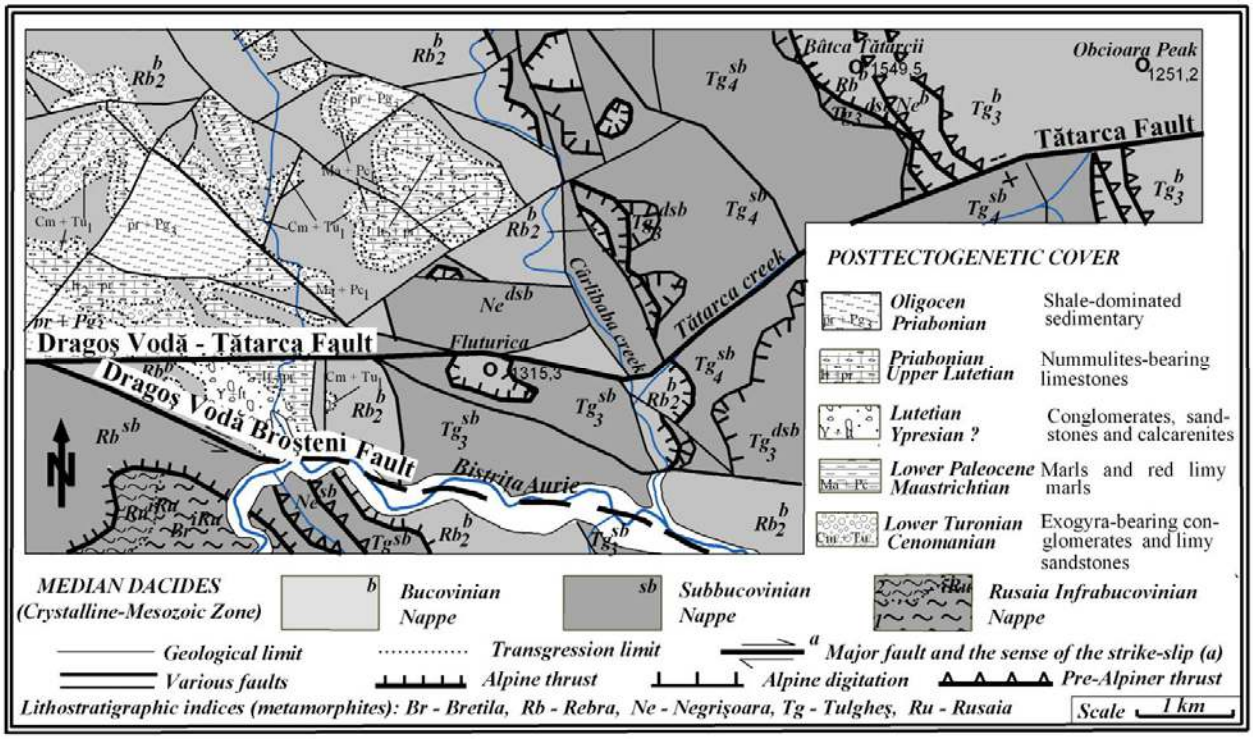

Fig. 2. Simplified geological map of the Cârlibaba-Ţibău zone

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 Bistriţa and Bretila. East of Ţibău valley, the direct continuation of the Dragoş Vodă fault passes north of Fluturica Peak (1345.3 m), follows the course of the Tătarca Cârlibabei valley, the crest between the hydrographic basins of Bistriţa and Moldova rivers, south of Obcioara Peak (1251.2 m) and reaches Moldova valley downstream from the confluence with Tătarca 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 Bistriţa river, at Cârlibaba, and the ridge toward the Moldova river, close to its confluence with Tătarca tributary, shown in Fig. 2, indicates an uplift of the tectonic compartment south of the eastern extension of the Dragoş Vodă fault (named Tătarca fault), which is coherent with the structural situation to the west, at the northern limit of Rodna Mountains.

South of Tătarca fault, the geological structure continues to the Bistriţa valley, but cannot be correlated with the structure in the western slope of Bistriţa 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 Bistriţa River. The domain with different features from the western side of Bistriţa 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 Broşteni, led to the tracing of the strike-slip fault Cârlibaba-Broşteni, named in Fig. 2 Dragoş Vodă-Broşteni fault, to highlight the possible relation with the strike-slip fault system Bogdan Vodă-Dragoş Vodă.

2.2 The geological situation at Broşteni

Fig. 3 contains a geological map with the interpretation of the Cârlibaba - Broşteni fault between Crucea and Holdiţa. 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 Leşul Ursului mining field (Kräutner et al, 1975; 1978; 1986). The strike-slip character of the fault was

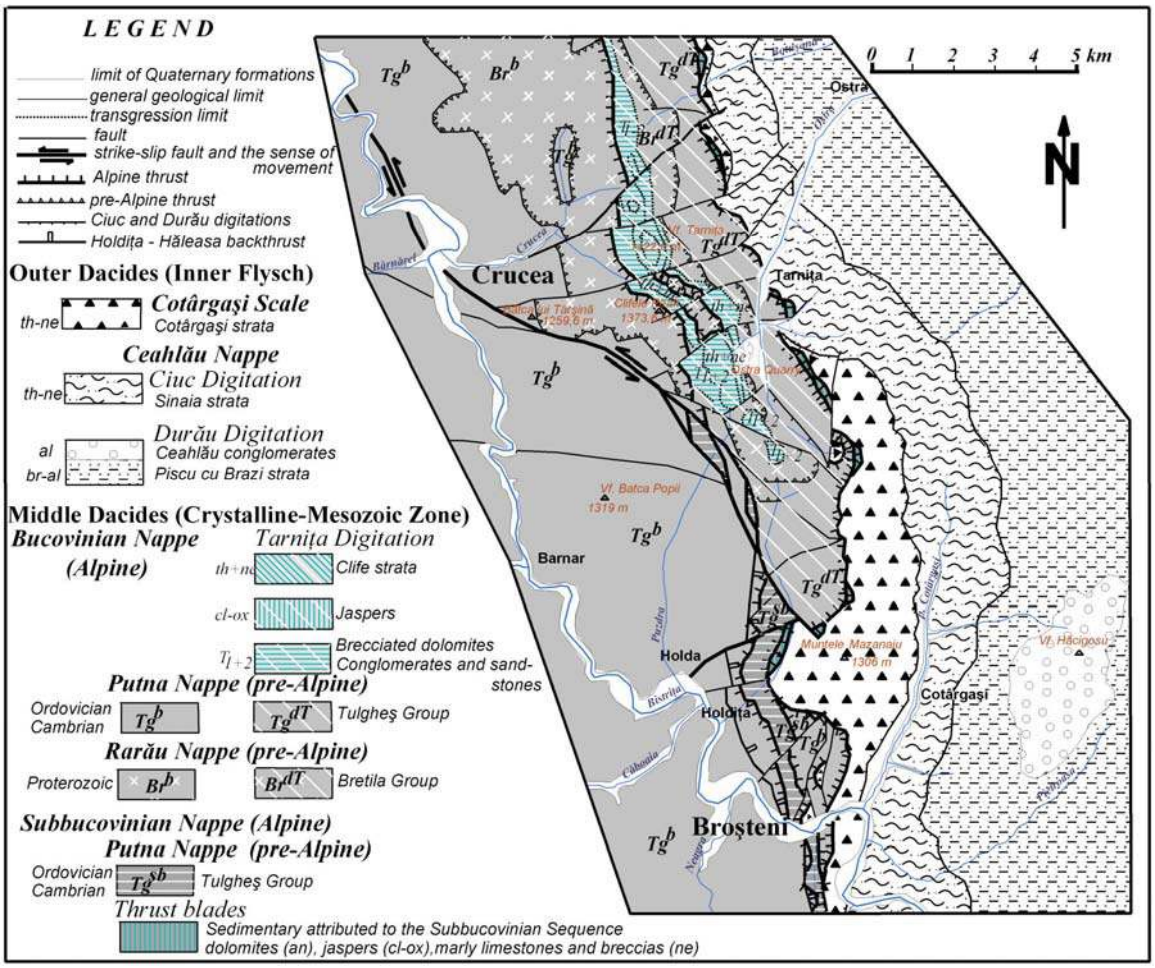

Fig. 3. Simplified geological map of the Broşteni-Ostra zone. The eastern part, the Cotârgaşi Scale and the digitations of the Ceahlău Nappe after Săndulescu (2008).

neglected. The continuation of the fault to the left hand slope of the Holdiţa 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 Holdiţa-Broşteni 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 Holdiţa creek, at the confluence with the Haştei 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 Cotârgaşi scale, under the thrust of the Crystalline-Mesozoic Zone over the Inner Flysch, with the greatest extent in the right hand side of the Cotârgaşi creek and on the Haştei creek, tributary of the Holdiţa creek from the left side, in the area where the strike-slip fault Cârlibaba-Broşteni 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-Broşteni strike-slip fault is characterized by the presence of the Bucovinian Nappe and its frontal digitation, Tarniţa 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 Holdiţa-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 Cotârgaşi strata, whose age is Tithonian-Neocomian (Săndulescu, 2008).

3 Discussions

3.1 The trace of the Cârlibaba-Broşteni 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 Bistriţa River. The Cârlibaba-Broşteni strike-slip fault follows Bistriţa valley from Gura Ţibăului downstream, to Ciocăneşti, where it passes in the eastern slope, downstream of the confluences with the tributaries Pârâul Rece and Colacu, then crossing the Brezuţa creek at ca. 1 km from the confluence with Bistriţa and Puciosu creek, at the margin of Mestecăniş village. It continues by the source of Pârâul Roşu 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 Bistriţa valley again, in Bistriţa Gorges from Zugreni. From Zugreni to Crucea, the fault follows Bistriţa valley, cutting locally through the left hand slope (most obviously at « Dâmbul Colacului »), then remains in the left hand (eastern) slope of Bistriţa, 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 Holdiţa creek, at the confluence with Haş creek.

3.2 The tectonic compartment Rodna Mountains-Bistriţei Mountains

In Fig. 1, it cam be seen how the Dragoş Vodă fault and its extension, the Cârlibaba-Broşteni fault, delimit, to the south, a tectonic compartment that extends southward to the Dârmoxa-Grinţieş fault. Between the two strike-slip faults, the entire Rodna Massif and most of the Bistriţei Mountains are comprised. To the east, this tectonic compartment is limited by the border of the Crystalline-Mesozoic Zone between Broşteni and Grinţieş. To the west-north-west, the Dârmoxa-Grinţieş fault is overlain by the formations of the posttectogenetic cover and by the Neogene volcanic rocks of the Călimani Massif from Păltiniş. 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-Bistriţei 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): Anieş, Ştiol, Valea Vinului, Rusaia, Iacobeni, Borcut-Ulm and Arşiţa 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 Maramureş, 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-Bistriţei Mountains:

- North of the Cârlibaba-Broşteni fault, from the left hand slope of the Holdiţa 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 Tarniţa digitation of the Bucovinian Nappe.
- In the compartment Rodna Mountains-Bistriţei Mountains, from Holdiţa-Broşteni, in the north, to the Grinţieşul Mare creek, in the south, the border of the Crystalline-Mesozoic Zone is constituted of the Subbucovinian Nappe. Between Broşteni 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-Grinţieş 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 Hăghimaş type in the segment between Broşteni and Grinţieş, 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-Bistriţei Mountains compartment, between the strike-slip faults Cârlibaba-Broşteni and Dârmo-

xa-Grinţieş. 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 Dragoş Vodă-Cârlibaba-Broşteni fault (which could be named Maramureş-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-Broşteni fault, coupled with the Bogdan Vodă-Dragoş 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 Leşul Ursului and Baia Borşa pyrite and polymetallic sulfide deposits (pyrite + copper and pyrite + lead, zinc, copper, hosted in the formation of acid metavolcanics (Tg3) of Tulgheş 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 Leşul Ursului mining field, and by Zincenco (1971, 2000), for the ore field from Baia Borşa.
Leşul Ursului is situated near Broşteni, in the Bucovinian Nappe, in the tectonic compartment Rodna Mountains-Bistriţei Mountains, south of the Cârlibaba-Broşteni fault. The lithostratigraphic sequence from Leşul 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 Bistriţa 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 Leşului and Ursului creeks, reaching, north of Bâtca Popii, at the confluence of Grebin and Puzdra creeks (Kräutner, in Săndulescu et al., 1989). That fault is part of the Cârlibaba-Broşteni fault.

At Baia Borşa, there is the same geologic-metallogenetic context as that from Leşul 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-Ţiganu 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 Leşul Ursului ore field in the southern extension of the Baia Borşa ore field. It is of note the similar geological context of the two areas: from Broşteni to the south, at Borca, and from Baia Borşa to the north-west, in the Bardi-Bardău zone, beneath the sequences of Tulgheş Group with sulfide deposits, from the Bucovinian Nappe, there are sequences of the Tulgheş 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-Broşteni 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 Tarniţa digitation, north of the Cârlibaba-Broşteni 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-Grinţieş 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 Tarmiţa 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 Podaşcă (1988) occur in a similar geological context, in a frontal digitation of the Bucovinian Nappe (Chicera Digitation), which correlates with Tarniţa Digitation.

It can be remarked that, similar to the areas with barite and sulfides from the frontal digitations of the Bucovinian Nappe (Tarniţa and Chicera), the uranium accumulations of Crucea type also occur only north of the Cârlibaba-Broşteni strike-slip fault (in Crucea zone) and south of the Dârmoxa-Grinţieş strike-slip fault (at Tulgheş). 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-Broşteni sector ceased before the deposition of the posttectogenetic cover of the Crystalline-Mesozoic Zone, while the segment represented by the Tătarca fault remained active.

4 Conclusions

• The strike-slip fault Cârlibaba-Broşteni was traced; this can be considered as a continuation of the fault system Bogdan Vodă-Dragoş 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-Broşteni 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-Broşteni strike-slip fault is limited, to the south, by a dextral strike-slip fault, the Dârmoxa-Grinţieş fault. This tectonic compartment was pushed eastward, most likely by the blocking of the movement in the compartment north of the Cârlibaba-Broşteni fault.
• The structural interpretation derived from the identification of the Cârlibaba-Broşteni fault, imposes structural correlations and metallogenetic at regional scale, the most interesting outcome being the correlation between the Leşul Ursului and Baia Borşa 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 Tarniţa Digitation and Chicera Digitation, both frontal digitations of the Bucovinian Nappe, which are missing from the compartment Rodna Mountains-Bistriţei Mountains, displaced ca. 75 km eastward, between the strike-slip faults Cârlibaba-Broşteni and Dârmoxa-Grinţieş.

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