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Geology of the Ţibleş Mountains. A review

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Abstract: The paper reviews the main geological features and data from Ţibleş Mountains, based on the detailed geological map at 1:25,000 scale, currently digitized and published for the first time. The Ţibleş Mountains belong to the „Subvolcanic Zone" of the Eastern Carpathians volcanic chain from the northwestern part of the Romanian territory. They represent a multiphase intrusive complex consisting of a few large (km-sized) and numerous small (up to several hundred meters across) intrusive bodies which crosscut the Paleogene and Lower Miocene sedimentary deposits. The magmatic intrusive rocks belong to two main complexes: 1) the Complex of the acidic rocks including the Hudin (microgranodiorites) and Tomnatec (dacites) large bodies and the small bodies from the Buza Dealului, Baicului Valley and Grohot zones, and 2) the Complex of the intermediate rocks comprising the main large Ţibleş-Bran-Măgura Neagră monzodioritic body and the marginal rocks (Arcer basaltic andesites and Arsuri quartz microdiorites), and the smaller intrusive bodies from Izvorul Netedului, Izvorul Negru-Izvorul Roşu and Hudieş-Stegioara zones. The magmatism took place during a large time interval (11.5-8.7 Ma), with the main monzodioritic intrusion being younger than the acidic rocks. Overall, for all intrusive bodies, the gravimetric and magnetic data suggest a larger extent at depth. The main Ţibleş-Bran-Măgura Neagră monzodioritic body is supposed to be two times larger at depth than at the surface and includes all the small surrounding intrusions. The thermal metamorphic aureoles associated with the monzodiorites-monzogabbros and quartz diorites/microdiorites intrusions are the most extensive and have the most complex composition. The widest aureole is associated with the main Ţibleş-Bran-Măgura Neagră monzodioritic body. An important pneumatolytic metamorphic phase (rich in boron) with a wide extent is recognized in the tourmaline breccias. A three stages polyascending metallogenesis assigned to the formation of the main monzodioritic-monzogabbroic intrusion took place in Ţibleş Mountains. The first stage led to the formation of the hidden prophyry copper system from the southeastern area of the main Ţibleş-Bran-Măgura Neagră magmatic body.

***Keywords*:** Subvolcanic, monzodiorite, microgranodiorite, thermal metamorphism, boron pneumatolysis, polyascending metallogenesis**,** Eastern Carpathians.

1. Introduction

The current paper reviews and summarizes the main geological data from Ţibleş Mountains based on the detailed 1:25,000 scale map (a compilation of multiple 1:5000 scale maps).

The Ţibleş Mountains lie on the northwestern part of the Ţibleş-Rodna-Bârgău subvolcanic area of the northern group of Eastern Carpathians. They have captured the attention of researchers for a long time, despite being isolated and difficult to access.

The first significant attempts to map the sedimentary formations belongs to by Partsch, and the crystalline schists and eruptive rocks to Richthofen, as noted by Hauer and Stache (1863). Their geological observations were used to produce the Geological Map of Transylvania. The sedimentary rocks were named „Eocene Carpathian sandstones" and the eruptive rocks were classified as trachytes. Volkner, Koch, Primics, Rosenbusch, Ferenczi, Laţiu, Pánto, Stoicovici (cited by Edelstein et al, 1980a, unpubl.) investigated the igneous rocks and classified them according to their contemporaneous terminology.

A second stage of investigation includes Pavelescu (1953) who carried out the first systematic and complete study of the igneous rocks from Ţibleş massif, Maier (1962) who published the geological and petrographic data of the Hudin massif, Atanasiu (1956) and Mutihac (1955) who published their findings on the stratigraphy and tectonics of the sedimentary formations. Scarlat and Scarlat (1966, unpubl.) mapped and presented their results about the Bran-Arsuri and Ţibleş south-east sectors.

Starting with 1970, geological mapping by Kalmar (1970, unpubl.), Cojocea et al. (1974, unpubl.), Istvan et al. (1977, unpubl.), Edelstein et al. (1980a, unpubl.) resumed in Ţibleş Mountains.

The first references regarding the mineralizations intercepted in Ţibleş Mountains are mentioned by Hauer and Stache, citing a report of the mining engineer Joseph Antos who estimated the ore grades in 1855. Documents regarding the mining companies that explored the mineralizations from Ţibleş Mountains are preserved at the Maramureş County Archives. Extensive mining works aiming to investigate the Tomnatec vein were carried out by ISEM (IGEX) Bucharest, between 1954 -1959 (Boţoman, 1958, unpubl). The mineralizations from Măgura Neagră were investigated with trenches and galleries by TPEDMN Bucharest and IE Maramureş (Bordea, 1960, unpubl.). Since 1970, IPEG Maramureş continued the exploration of all the mineralizations. The results of these exploratory works were summarized by Huba (1972, unpubl.), Paşca et al. (1977, unpubl.) and Valdman et al. (1995, unpubl.). IPEG Cluj explored the mineralizations from Izvorul Zimbrului and Măgura Neagră (Lucian, 2015). In 2017, these mineralizations were investigated by Vast Resources plc (a private company).

Based on the 1955-1980 extensive exploration, several new petrologic, mineralogical, metallogenetic, and geochemical studies were produced: Stiopol (1962), Steclaci et al. (1959), Andronescu (1959), Petrulian et al. (1953), Superceanu et al. (1961), Peltz et al. (1972), Petrulian et al. (1974, unpubl.), Kalmar and Pop (1974), Steclaci et al. (1975, unpubl.), Udubaşa et al. (1978, unpubl.), Pop N. et al. (1979, unpubl.), Edelstein et al. (1980a), Pop V. et al. (1982a, b, unpubl.)

Data on the sedimentary formations were acquired by Dicea et al. (1980), Săndulescu & Russo-Săndulescu (1981), Săndulescu et al. (1990 unpubl.).

A series of papers regarding the new minerals described in Ţibleş Mountains were published by Edelstein et al. (1980b), Cioroianu and Pop (1980), Udubaşa et al. (1980), Udubaşa et al. (1982), Kovacs et al. (1985, 1994), Pomârleanu et al. (1985). The petrography and geochemistry of the igneous rocks from the whole Ţibleş massif were published by Pop et al. (1984a). Data on mineralizations and the evolution of the metallogenetic processes were published by Udubaşa et al. (1983, 1984, 1995), Pop et al. (1984b), Pintea (1998), Pintea et al. (1999). The absolute ages of the igneous rocks and the post-magmatic mineral phases (radiometric dating with the K-Ar) were published by Pécskay et al. (1995, 2009) and Kovacs et al. (1995, 1997).

A very large database has been consulted for this review, mostly old unpublished reports and some publications that are cited and listed as references. It should be noted that the 1:25,000 scale map, the data about the sedimentary formations, on the outlines of the magmatic bodies at depth and the post-magmatic products are published herein for the first time.

2. Geological setting

The Ţibleş Mountains belong to the Eastern Carpathians volcanic chain that extends in the northwestern part of the Romanian territory. Same as the entire Neogene-Quaternary volcanic arc from the inner Carpathians, Ţibleş Mountains were built up during the Miocene geotectonic evolution of the Carpathian-Pannonian Region involving the two ALCAPA and Tisza-Dacia mega-blocks at the margin of the East European Platform (Csontos, 1995). An intermediate calc-alkaline magmatism took place from Middle Miocene to Quaternary (13.4 - 0.03 Ma, Pécskay et al., 2006) in the Eastern Carpathians, from Oaş-Gutâi Mountains in northwest to South Harghita in southeast. Ţibleş Mountains belong to the central part of the „Subvolcanic Zone" of the Eastern Carpathians (e.g., Săndulescu, 1984), that comprises the Ţibleş, Toroiaga, Rodna, and Bârgău segments intruded in the pre-volcanic sedimentary and metamorphic rocks. The intrusive magmatism from the „Subvolcanic Zone" developed for ca. 3.5 Myr during Pannonian times (11.5 - 8.0 Ma, Pécskay et al., 2009). An important tectonic feature in the area is the >75 km long E-W striking left-lateral Bogdan Vodă - Dragoş Vodă fault system (Săndulescu et al., 1984), that acted as a complex transpres-

Vodă - Dragoş Vodă fault system (Săndulescu et al., 1984). that acted as a complex transpressional-transtensional tectonic regime during the Pannonian time (Tischler et al., 2006) and controlled the generation and emplacement of the intrusive bodies during ca. 12-8 Ma in the Subvolcanic Zone (Pécskay et al., 2009).

Ţibleş Mountains are located southwards from the Bogdan-Dragoş-Vodă fault system and eastward from the bending zone of the Pienniny Klippen. They form a complex multiphase intrusion consisting of a few large (km-sized) and numerous small (up to several hundreds meters across) intrusive bodies that crosscut the Paleogene and Lower Miocene sedimentary deposits. The basement is represented by the Median Dacides (Săndulescu, 1984). The Oligo-Miocene sedimentary formations of the *Autochthon* (the Lăpuş Unit, according to Săndulescu and Russo and Săndulescu, 1981) underlie the *Central Unit* (defined by Istvan in Edelstein et al., 1980a unpubl.) and *Wildflysch Nappe*, both of Eocene and Oligocene age. The intrusive magmatic bodies are preferentially located in the area of the Central Unit, or southwards from the front of this nappe.

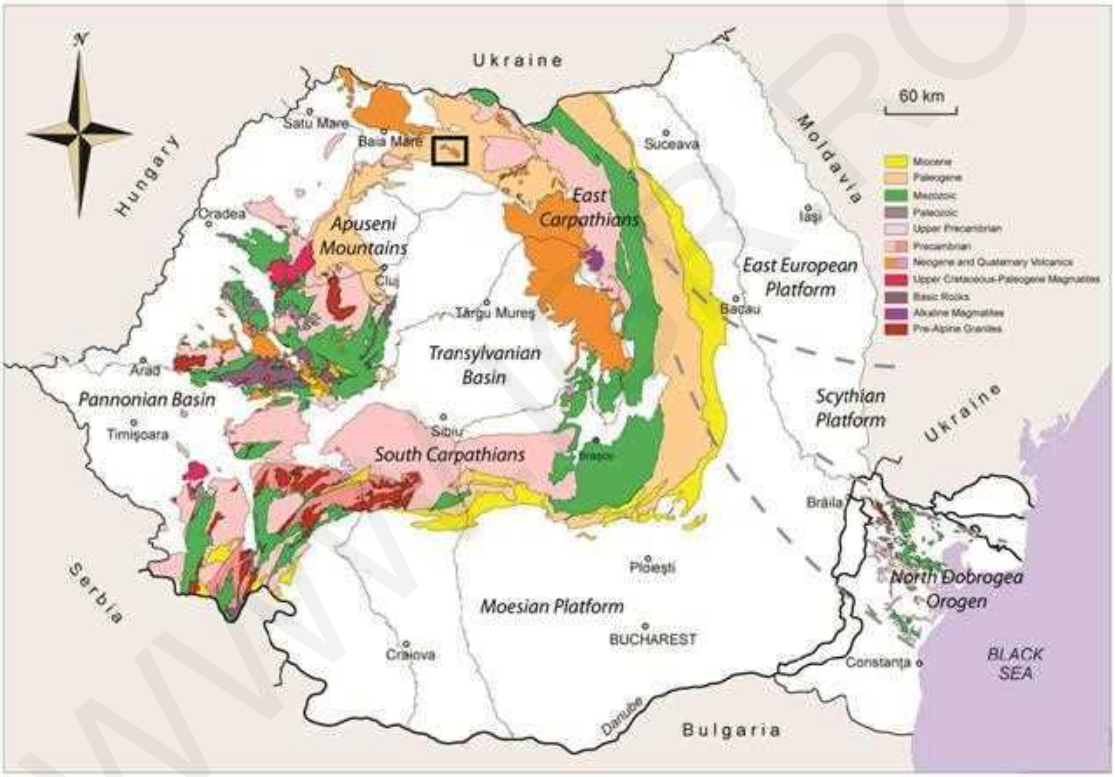

Fig.1. Location of the Ţibleş Mountains on the simplified geological map of Romania.

3. Structural units of the Ţibleş Mountains

In the area of the Ţibleş Mountains, the following structural units are separated (Fig. 2):

- in the sedimentary domain:

The *Autochthon*, the *Central Unit* and the *Wildflysch Nappe*. The Autochthon is developed in the south-western area of Ţibleş Mountains and includes the Hudin magmatic massif and most of the intrusive bodies from the Izvorul Netedului-Izvorul Ţibleşului area. The Central Unit has the largest extent and occupies the central area of Ţibleş Mountains, while the Wildflysch Nappe lies on a small area in the northern part of Ţibleş Mountains (Fig. 2).

- in the magmatic domain:

The main magmatic body Ţibleş-Bran-Măgura Neagră (TBMN in Fig. 2), with a N40^{0}W orientation, and 6 km long and 2 km wide. It forms the compact ridge of the Arcer-Ţibleş-Bran-Arsuri-Măgura Neagră massif. Based on the thermometamorfic aureole and the magnetic data (Andrei et al., 1980, 1981), a large extent at depth can be assumed towards the N, NW and S.

The Hudin magmatic massif (H in Fig. 2) with *the intrusive bodies from the Buza Dealului* and *Valea Baicului area* (BD and VB in Fig. 2) are located in the northwestern part of Ţibleş Mountains. The Hudin massif has an irregular, elliptical-like shape, elongated towards the WSW-ENE and a supposed large extent at depth towards the NW.

The *Tomnatec magmatic massif* (T in Fig. 2) is represented by a large intrusive body located in the central-northern area of Ţibleş Mountains, to the northwest from the main eruptive body Ţibleş-Bran-Măgura Neagră, with direct contact both at the surface and underground (as visible in the mining works).

The *Grohot magmatic body* (G in Fig. 2) is located westwards from the main Ţibleş-Bran-Măgura Neagră body that crosscuts through the sedimentary formations of the Central Unit and the Autochthon.

The *intrusions from the Izvorul Netedului area* (IN in Fig. 2) are represented by magmatic bodies of different sizes, and occupy the SW area of the main Ţibleş-Bran-Măgura Neagră body.

The *intrusions from the Izvorul Negru-Izvorul Roşu area* (IN-IR in Fig. 2) are represented by smaller bodies developed in the NW of the central-southern part of the Ţibleş-Bran-Măgura Neagră main body.

The *intrusions from the Hudieş-Stegioara area* (HS in Fig. 2) developed in a larger area located between the Hudin massif and the main body Ţibleş-Bran-Măgura Neagră.

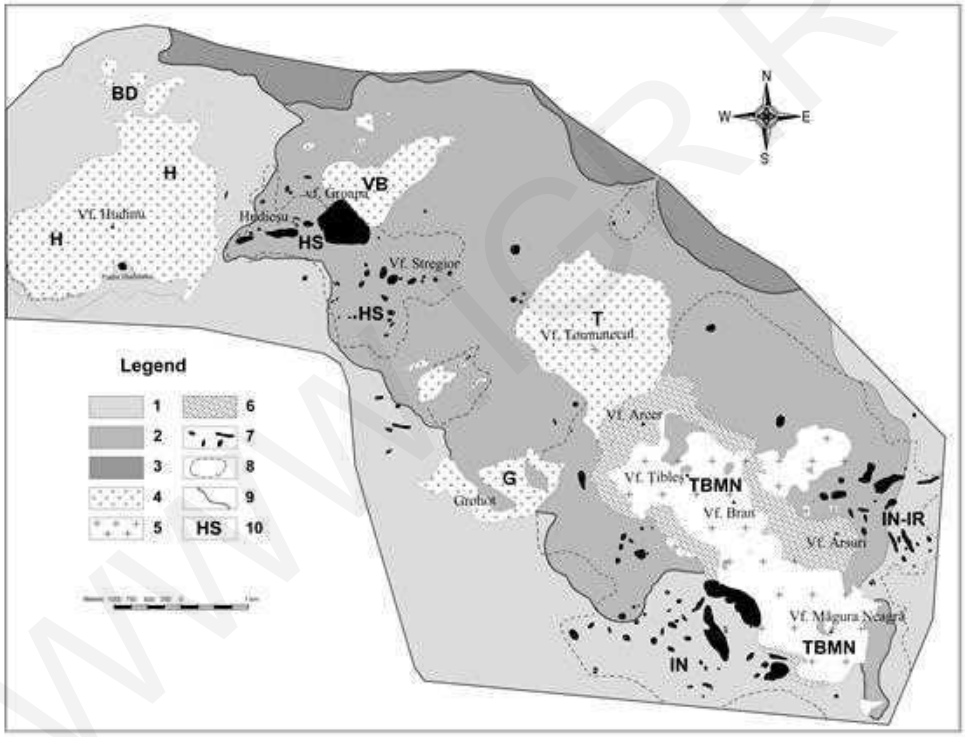

Fig. 2. Simplified geological map of the Ţibleş Mountains with the structural units. (digital version achieved by the geologist Ştefan Gönczi). Sedimentary formations: 1. The Autochthon; 2. The Central Unit; 3. The Wildflysch Nappe; Magmatic formations: 4. The intrusive bodies from the Complex of the acidic magmatic rocks; 5. The Ţibleş-Bran-Măgura Neagră main magmatic body; 6. The magmatic rocks from the border of the Ţibleş-Bran-Măgura Neagră magmatic body; 7. Small intrusive bodies from the Complex of intermediate magmatic rocks; 8. Thermometamorphic aureoles; 9. Overthrust; 10. The magmatic structural units: **H** - Hudin magmatic massif; **BD** - Intrusive bodies from Buza Dealului area; **VB** - Intrusive bodies from Valea Baicului; **T** - Tomnatec magmatic massif; **G** - Grohot magmatic body; **TBMN** - Ţibleş-Bran-Măgura Neagră main magmatic body; **IN** - Intrusive bodies from Izvorul Netedului area; **IN-IR** - Intrusive bodies from Izvorul Negru-Izvorul Roşu area; **HS** - Intrusive bodies from Hudieş-Stegioara area.

WWW.MIGR.RO

4. Sedimentary formations

The three major structural units, the Wildflysch Nappe, the Central Unit and the Autochthon consist of sedimentary formations with various lithologies and microfaunistic associations. Their description is achieved based on the detailed 1:5000 scale mapping corroborated with previously published geological studies.

4.1. The Wildflysch Nappe

In the area of the Ţibleş Mountains, this unit occurs in a small area in the South, where three lithological horizons with stratigraphic significance were separated:

- *The lower horizon* – consisting of conglomerate is 200-300 m thick. The conglomerates are sorted, crudely stratified, with 3-20 cm size rounded crystalline shale and minor sandstone and limestone clasts. The carbonate cement forms approximately 80% of the rock. Dicea et al. (1980) considered this horizon contemporaneous with the lower Eocene clay formation, and potentially getting to the base of the middle Eocene at the upper part.
- *The marl-clay-sandstone horizon* with marl-limestone intercalations consists of marl and blackish clays with metamorphic quartz and carbonate cement and 5-20 cm thick micaceous sandstones interlayered. This horizon has 1-20 cm thick marl-limestone layers. The overall poor microfauna indicates an Upper Paleocene–Middle Eocene age: Psammosiphonela discreta (Brady, 1881), Ammodiscus cf. glabratus (Cush and Jarvis, 1928), Karreculina conversa (Grzybowski, 1901), Paratrochamminoides deflexifor-mis (Noth, 1912), Spiroplectammina navarroana, Neoconorbina terquemi (Rzehak, 1888), Tro-chammina sp. (Parker & Jones, 1859), Subbotina triloculinoides (Plummer, 1927).
- *The upper-sandstone horizon* is represented by yellowish medium and fine-grained sandstones. Since they lack a microfaunistic content, their age can only be inferred based on the contact relationships with the other formations, and seems to be younger than the marly-clay-sandstone horizon, Upper Eocene or Oligocene. A similar point of view belongs to Săndulescu (1981), who attributed the Priabonian+Oligocene (?) age to the formations of the Wildflysch Nappe.

4.2. The Central Unit

The sedimentary formations of the Central Unit display a different lithology than the Wildflysch Nappe and the Autochthon and abnormal contact relationships. Since most of the igneous rocks are located in this area, the stratigraphy is difficult to establish. The lithology is relatively monotonous, represented by alternations of marls and sandstones. The silty marl-sandstone sequences predominate at the bottom, and the sandstone at the top. Two main horizons were separated:

- *The clay-sandstone horizon* which is predominantly pelitic at the bottom (Mesteacănului and Căliman valleys), locally with sandstones beds containing nummulites and marl-limestone interlayered (Piatra valley, Faţa Tăului Summit, below Măguriţa Peak, Faţa Talgerilor, Zgleamănului Valley, the left slope of the Căliman valley). It becomes marly-sandy in the middle part, with more sandstones at the top (Stegioara valley, Preluci, Izvorul Rău, Izvorul Ţibleşului, Izvorul Negru, Izvorul Roşu, Obârşia Fiezel, Bichigiului valley).
- *The upper sandstone horizon* occurs on small surfaces, generally at the top (Faţa Tăului summit, Piatra summit, Şaua Stegioara-Şătriţa saddle).

The age of the Central Unit formations was previously considered Oligocene or Miocene, difficult to establish due to the scarcity of the fossil fauna and the unrecognizable sedimentary deposits modified by thermometamorphic processes. The Eocene age, assigned with uncertainty to some of the sedimentary deposits is established in a few outcrops with scarce microfauna, with agglutinate and rarely calcareous foraminifera. As an example, Glomospira charoides (Jones and Parker), Bathysiphon eocenicus (Cush and Hann), Tritaxilina hantkeni (Cushman 1936), Haplophragmoides tenuis Cushman, Globigerinides were identified at 550 m in the Preluci crosscutting gallery. At the headwaters of the Stegioara valley, Psammosiphonella discreta (Brady, 1881) and Haplophragmoides sp. were described from the top of the marly-clay-sandstone horizon. Other samples with microfauna attesting the Eocene age were collected from the Zgleamăn and Calul din Dreapta valleys, from a left tributary of the Călimani valley and from the headwaters of the Arieşul valley. In the upper part of the Baicu valley, in the Călimani valley area and more frequent in the Faţa Talgerilor, SE of Măguriţa

Peak and Zgleamănu valley occur fine, compact marl-limestone interlayered. On the left slope of the Călimani valley, interlayers of calcareous, coarse sandstones occur with unidentifiable nummulites. There is an occurrence of red-brownish marl and marl-limestone, with greenish spots, similar to the Senonian red marls of the Puchow facies.

4.3. The Autochthon

The sedimentary formations belonging to the Autochthon of the Țibleș Mountains correspond to the Lăpuş Unit defined by Săndulescu and Russo Săndulescu (1981). It covers the entire area southwards from the igneous complex and consists of two horizons:

- *The lower horizon* consists of alternations of marls and sandstones, with marly sequences locally. The microfauna of the middle course of the Stegioara valley includes: Globigerina bulloides (d'Orb), Paragloborotalia mayeri (Cush and Ellisor), Globigerinoides trilobus (Reuss), Lenticulina cultrate (Montf), Robulus alatolimbatur (Gumb), Globigerina falconensis (Blow), Globoturborotalita apertura (Cush), Cibicidoides pseudoungerianis (Cush), Cibicidoides wuellerstorfi (Schwager).
- *The sandstone horizon* consists of massive banks of coarse, polymictic sandstones (subgraywacke, arkose and feldspathic graywacke) with micaceous marls intercalations. Towards the upper part, the coarse sandstones pass into microconglomerates. The macrofauna collected from similar lithologies in adjacent areas was assigned to Oligocene (Mutihac, 1955; Maier, 1962; Dicea et al., 1976). Isolated fragments of highly fossiliferous limestone with poorly preserved fauna were found on the Uşorul Mare valley and Calyptraea chinensis (Linné) and Balanus sp. in the lower course of the Stegioara valley. Only a small number of samples from the clay intercalations had micropaleontological content: Ciperoella cf. ciperoensis (Bolli), Globigerina cf. concinna (Reuss), Globigerina cf. globularis, Globigeria cf. Opima nana (Bolli), Bulimmina sp. (from Izvorul Şurii valley), an association that characterizes the upper part of the Oligocene. In the Cârligătura valley, Biddulphia sp. and pyritized diatomites have been identified. Similar to Săndulescu (1977), who studied a wider area, we attribute the marly horizon to the Oligo-Miocene and the sandstone horizon to the lower Miocene, suggesting that more data is required to confirm these ages.

5. Magmatic rocks

The igneous rocks of the Țibleș Mountains belong to two main complexes: the Complex of the acidic igneous rocks and the Complex of the intermediate igneous rocks. The petrographic classification involves difficulties due to transitions from one petrotype to another, within the same intrusive body. The mapped rock types are represented on the map. The nomenclature based on the modal composition recommended by the IUGS was used to classify the rocks and, in some cases (e.g. the basaltic andesite of Arcer), the nomenclature based on the TAS diagram.

5.A. The Complex of the acidic magmatic rocks

This complex comprises: Hudin porphyry microgranodiorites, Tomnatec dacites and Grohot dacites/porphyritic microgranodiorites.

5.A.1. Hudin porphyry microgranodiorites

The Hudin massif (Fig. 3), which represents one of the major magmatic units of the Țibleș Mountains, consists exclusively of porphyry microdiorites. Plagioclase, quartz, orthoclase, biotite and other altered mafic minerals are found in these rocks, with cordierite in significant high proportion. According to the modal composition (the classification recommended by IUGS), the rocks correspond to granodiorites. The SiO_2 content is between 67.87 – 71.11 wt % and the K_2O content is between 1.28 and 4.33 wt %. An average of seven analyses indicates 69.7 wt % SiO_2 and 2.82 wt % K_2O (geochemistry data from Edelstein et al., 1980a).

The presence of two other textural varieties was noticed, a porphyritic granodiorite at about 1000 m NE from the Hudin Peak and an argillized and sericized dacite in the south-eastern margin of the massif (Fig. 3).

The Hudin microgranodioritic massif is connected with a series of dacitic bodies developed in the NE area, in the Baicu valley

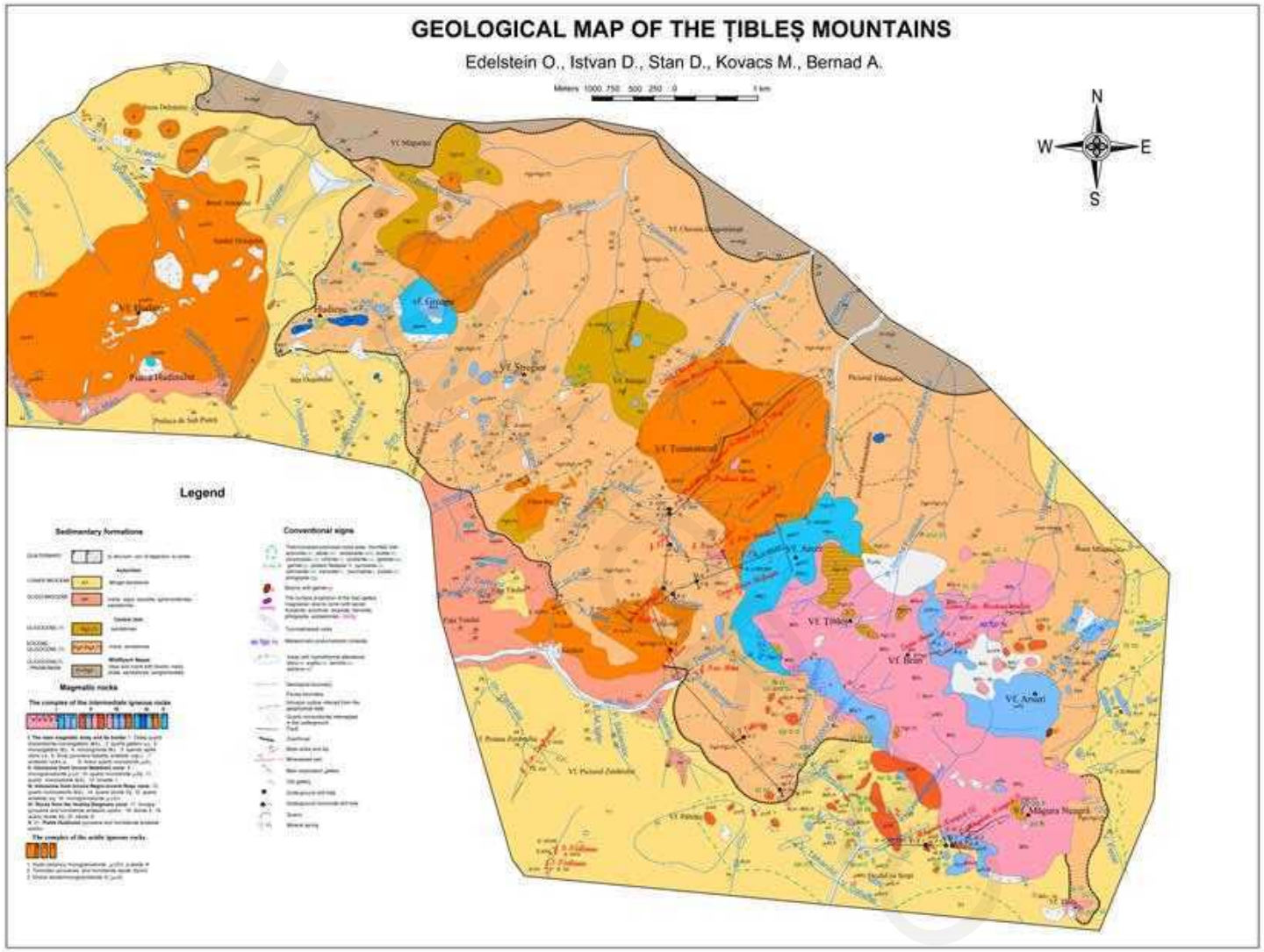

Fig. 3. Geological map of the Țibleș Mountains (digital version achieved by the geologist Ștefan Gönczi) at 1:25,000 scale, sed on the detailed geological maps at 1:5,000 scale.

basin, and with the small bodies from Buza Dealului in the NW area (Fig. 3).

5.A.2. Tomnatec pyroxenes and hornblende dacites

The Tomnatec pyroxenes and hornblende dacites are leucocratic rocks. The presence of a small number of large amphibole phenocrysts is a typical feature of these rocks. Because of the strong alteration, it is difficult to identify with accuracy the primary composition, but a series of minerals are recognized: plagioclase, pyroxenes, amphiboles, quartz, biotite, apatite, titanite, zircon, in a groundmass that represents 62-70% of the rock. Cordierite was observed in some marginal areas. Note the similarity of the Tomnatec dacite with the dacitic facies of the Hudin microgranodiorite. The content of SiO_2 varies between 65.79 and 69.72 wt % and the content of K_2O between 2.12 and 2.82 wt %.

On the south-western slope of the Tomnatec massif, a discontinuous strip of breccia rocks developed on the contact between the Tomnatec dacite and the sedimentary deposits (intrusive contact breccias; Fig. 3). The breccias consist of fragments of black marls, sandstones and dacite trapped in a marly cement with fragments of feldspars.

5.A.3. Grohot dacites/microgranodiorites

The Grohot dacites/microgranodiorites form an E-W elongated body with more than 2000 m in length and about 500 m in width (Fig. 3). The body extends about 500 m towards the N with 200 m width, as mapped in the Izvorul Rău 1 gallery. The leucocratic rocks resemble with the Tomnatec dacite suggesting a similar position in the sequence of magmatogenetic processes. However, some differences exist, owing to a larger amount of plagioclases and mafic minerals and a smaller amount of magmatic quartz in the Grohot dacites/microdiorites.

5.B. The Complex of the intermediate magmatic rocks

This magmatic complex comprises five groups of rocks with different extent: the igneous rocks of the main Ţibleş-Bran-Măgura Neagră body and its margins, the intrusions from the Izvorul Netedului area, the intrusions from the Izvorul Negru-Izvorul Roşu area, the igneous rocks from the Hudieş-Stegioara area, and the andesites from Piatra Hudin.

5.B.1. The igneous rocks from the Ţibleş-Bran-Măgura Neagră main magmatic body and its margins

The main eruptive body consists of quartz monzodiorite-monzogabbro with pyroxenes and amphiboles as predominant rocks, with subordinate quartz gabbros, monzogabbros, porphyritic monzogranites and micromonzogranites, quartz syenites with lateral or local extent.

5.B.1.1. The *Ţibleş quartz monzodiorites-monzogabbros* represent the central area of the main igneous Ţibleş-Bran-Măgura Neagră body. The same rock types occur on the upper course of the Izvorul Mesteacănului valley, crosscutting the main body (Fig. 3), and are intersected along 1500 m by 4 Arcer galleries and to a smaller extent in the Preluci adit where it pierces the Tomnatec dacite.

Monzodioritic-monzogabbroic rocks and/or transitional rocks between the two petrotypes also occur in the Izvorul Negru - Izvorul Roşu, Izvorul Netedului - Izvorul Ţibleşului - Vf. Păltiniş areas.

The quartz monzodiorites-monzogabbros are holocrystalline, coarse-grained, and with equigranular to porphyritic textures. Grain size is frequently greater than 2 mm; the large plagioclase crystals of 7-8 mm in length were observed in the porphyritic rocks. The ratios between the phenocrysts and the groundmass, as well as the crystal size vary from the monzodiorite to the porphyritic monzodiorite that can be occasionally mapped. The coarse-grained textures occur more frequently in the south-eastern part of the massif and at the lower levels (in the Izvorul Rău 1 gallery). The plagioclase, orthoclase, clinopyroxene, orthopyroxene, amphibole and quartz can be identified as phenocrysts, while biotite occurs in the groundmass. The primary alkaline feldspars and quartz appear in the groundmass and form graphic textures. Albite and adularia crystallized from hydrothermal solutions corrode the plagioclase or the alkaline feldspars.

The types of plagioclase feldspars are: cumulus, intercumulus and postcumulus types, often with an albite-oligoclase rim separated from the core by a corrosion and reaction zone. Some large crystals are microbrecciated, with percolation and corrosions from the residual liquid enriched in alkaline components. Metasomatic alkalinization of plagioclase leads to antiperthitic textures.

Based on the anorthite content of the plagioclase, the igneous rocks have a transitional character between the monzodiorite to the monzogabbros. The accessory mineral phases are represented by apatite, sphene, orthite and magnetite. Albite, epidote, uralite, chlorite, hydrobiotite, rutile, carbonates, clay minerals, and illite appear as secondary minerals.

The SiO_2 content varies between 52.27 – 58.81 wt %, with an average of 55.79 wt % and the K_2O content is between 1.33 – 2.94 wt % with an average of 1.88 wt %, calculated based on 14 samples. For the same elements, the contents are higher in five samples from gallery 1 Izvorul Rău: 56.60 – 62.70 wt % (with an average of 59.35 wt %) for SiO_2 and 0.84 – 3.74 wt % (with an average of 2.58 wt %) for K_2O.

The quartz monzodiorites identified in gallery 1 Izvorul Rău show a hollocrystaline quasiequigranular texture and contain more pyroxenes and less amphiboles. There are transitional varities such as the quartz diorites with less potassium feldspar and quartz, or granodiorites with more quartz. Often, these transitional varieties outcrop but they cannot be mapped.

5.B.1.2. The *Quartz gabbros* are rocks with less extent, developed at the margins of the monzodioritic body. The quartz gabbros outcrop in the middle course of Izvorul Branilor and east from the saddle between Vf. Arsuri and Măgura Neagră (Fig. 3). Mapping of quartz gabbros was enabled by the well-defined alignment of massive rocks, parallel to the main body of quartz monzodiorite-monzogabbros from Țibleş. The quartz gabbro from Izvorul Branilor has contents of SiO_2 - 52.03 wt % and K_2O – 0.89 wt %.

5.B.1.3. The *Monzogabbros* developed on a small area on Izvorul Branilor (Fig. 3).

Both the quartz gabbros and monzogabbros are considered lateral facies of the Țibleş monzodiorites-monzogabbros, with a series of compositional inhomogeneities within the alignment of quartz gabbros from Izvorul Branilor.

5.B.1.4. The *porphyry monzogranites and micromonzogranites* are compositional varieties of the main intrusion of Țibleş monzodiorites-monzogabbros, without excluding potentially single intrusions crosscutting the main monzodioritic body. The rocks were mapped on the Cascades valley, on the left slope of the Țibleşului spring and in the upper course of the Băilor spring (Fig. 3). The monzogranitic rocks were intercepted in the Arcer IV gallery, on an interval between 976 m and 1168 m. The have a holocrystalline, porphyritic texture, with graphic or granophyric and microcryptopertitic microtextures. The alkaline feldspars, an important component of the rocks, are represented by anorthoclase coexisting with orthoclase. Quartz forms micrographic intergrowths with orthoclase and myrmekitic intergrowths with oligoclase.

5.B.1.5. The *quartz syenites* are leucocratic rocks consisting of plagioclase and orthoclase, with quartz in the groundmass. The rocks were found only in the catchment area of the Țibleşului spring, as centimeter wide veins filled with aplite, developed in the quartz monzodiorite- monzogabbro (Fig. 3). In thin sections, 0.5-1.5 cm thick veins of pegmatitic and aplitic rocks of granitic composition, with quartz, alkaline feldspar, epidote, amphibole, mica, and tourmaline were identified.

5.B.1.6. The *Arcer pyroxene basaltic andesites* form at the margins of the quartz monzodiorite-monzogabbro main body in the NW part (Fig. 3). At the catchment area of the Izvorul Rău, the relationships with the monzodioritic rocks are complex and the discrimination can only be achieved under the microscope.

The Arcer basaltic andesites are porphyritic rocks comprised of a small number of large feldspar phenocrysts in an aphanitic groundmass. The feldspars are fragmented and pierced along the cleavage lines by the groundmass components. The variation of SiO_2 contents is between 52.58 – 57.60 wt % (with an average of 55.24 wt %), while the K_2O content varies between 1.34 – 2.11 wt % (average 1.77 wt %), averages based on eight samples.

5.B.1.7. The a*ndesitic rocks* show a fine grained texture and occur in the catchment area of the Izvorul Țibleşului valley and in the right slope of the Izvorul Branilor valley (Fig. 3). They are part of the margins of the main Țibleş-Bran-Măgura Neagră magmatic body, continuous from the Arcer basaltic andesites.

5.B.1.8. The *Arsuri quartz microdiorites* lie in the area of the Arsuri Peak and in the NE area of the Bran Peak (Fig. 3), and represent the petrographic equivalent of the quartz microdiorites from the SW area of the quartz monzodiorites-monzogabbros Țibleş-Bran-Măgura Neagră main magmatic body (left slope of Izvorul Branilor, Fig. 3). The mineralogy consists of plagioclase, clino- and orthopyroxene, and amphibole. The plagioclases from Izvorul Branilor area are less basic than those from the Arsuri Peak. SiO_2 content varies between 52.35 - 58.10 wt %, with an average of 55.04 wt % and K_2O content ranges between 0.84 - 2.41 wt %, with an average of 1.52 wt %, averages calculated based on eight samples.

5.B.2. The intrusions from Izvorul Netedului zone

5.B.2.1. The *Izvorul Netedului* m*icrogranodiorites and porphyry microgranodiorites* occur mainly in the area of Izvorul Netedului - Pălținiș Peak (Fig. 3). They are holocrystalline, porphyritic, usually microgranular leucocratic rocks. The phenocrysts are represented by plagioclase, orthoclase, clinopyroxenes, amphiboles, biotite and quartz. Magnetite, apatite, sphene, rutile, and zircon are accessory minerals. Uralite, hydrobiotite, chlorite, carbonates, albite, epidote, and clay minerals are common secondary minerals. The micrograno-diorites from Izvorul Netedului have the SiO_2 content between 59.21 – 60.33 wt % (59.71 wt % on average) and K_2O content between 1.88 – 2.77 wt % (2.44 wt % on average), averages calculated based on five samples.

5.B.2.2. The *quartz microdiorites, porphyry quartz microdiorites and quartz diorites* form several small magmatic bodies in an area between Pălținiș Peak in the West, Dealul cu Șerpi in the South, and the interfluve of the Țibleșului Valley and Izvorul Netedului. The rocks are similar with the Arsuri quartz microdiorites (Fig. 3).

5.B.2.3. The q*uartz monzodiorites* form a few small magmatic bodies in the area of the quartz microdiorites. The rocks have porphyritic (porphyritic quartz monzodiorites), to equigranular textures. Transitional compositions of quartz diorite-quartz monzodiorite type are also found.

5.B.2.4. The *tonalites* are represented by a few occurrences on the right side of the Țibleşului Valley and in the Izvorul Netedului area. The rocks are leucocratic, similar with the granodiorites, but with a lower amount of alkali feldspar.

5.B.3. The intrusions from Izvorul Negru-Izvorul Roșu zone

The rocks form small bodies that crosscut the sedimentary formations east from the main Țibleş-Bran-Măgura Neagră magmatic body, in the basins of the Izvorul Negru and Izvorul Roșu valleys, and the interfluve between the Izvorul Negru valley and the Mesteacănului valley. All these bodies are comprised of quartz monzodiorites, quartz diorites, quartz andesites, microgranodiorites and transitional rocks to dacites.

5.B.3.1. The q*uartz monzodiorites* form several intrusive bodies in the northwestern area of Arsuri Peak and one body located outside the main Țibleş-Bran-Măgura Neagră magmatic body, in the area between the Mesteacănului Valley and Izvorul Fundăului Valley (Fig. 3). Transitions to quartz diorites can be observed.

5.B.3.2. The *quartz diorites* are coarse-grained (equigranular or porphyritic) rocks, with transitions to microdiorites. The plagioclases, clinopyroxenes, orthopyroxenes, amphiboles and quartz occur both as phenocrysts and components of the groundmass. Orthoclase and biotite are sometimes present in the groundmass. Graphic structures between quartz and alkali feldspar and sideronitic structures between feldspar and magnetite can be observed in some of the rocks. The morphology and the relationships with the other minerals indicate the presence of three plagioclase generations. Accessory minerals are represented by titanomagnetite, ilmenite, apatite, sphene, orthite, rutile and zircon.

Transitional compositional aspects towards quartz monzodiorites are also found.

The SiO_2 content is 54.51 – 55.31 wt % (54.94 wt %, average of six samples) and the K_2O content varies between 1.33 – 1.73 wt % (with an average of 1.36 wt %).

5.B.3.3. The *quartz andesites* appear mostly marginal to the quartz diorite bodies. Most of them are in the Izvorul Roşu basin, but a small intrusion of quartz andesites outcrops in the Buza Mlaştinilor area (Fig. 3).

5.B.3.4. The *porphyry microgranodiorites* are represented by four intrusive bodies located outside of the main Ţibleş-Bran-Măgura Neagră magmatic body, in the area between the Izvorul Negru valley and the Mesteacănului valley (Fig. 3).

Transitional rocks to dacites. There are only a few small bodies in the easternmost area, initially classified as plagidacites (Edelstein et al., 1980a, c).

5.B.4. The igneous rocks from Hudieş-Stegioara zone

The intrusive complex comprises small bodies with a varied composition and texture: porphyritic diorites, porphyritic quartz diorites and porphyritic quartz microdiorites, quartz andesites and andesites with pyroxenes and hornblende. There are also transitional rocks, sometimes even within the same body. By increasing the potassium feldspar and quartz amount, the rocks shows transitions to monzodiorites and granodiorites.

5.B.4.1. The p*orphyry diorites* emplaced in the Hudieş area, east of the Stegioara (Stregior) Peak, and on the left slope of the Şurii Valley (Fig. 3). The plagioclases, amphiboles and pyroxenes represent the phenocrysts and the main components of the groundmass. In the Hudieş Peak, the rocks have no porphyritic texture. The content in SiO_2 varies between 52.30 – 59.06 wt % and that of K_2O between 1.2 -1.71 5 wt %.

5.B.4.2. The p*orphyry quartz diorites and* p*orphyry quartz microdiorites* outcrop in the catchment area of the Calului din Stânga valley, in the Groapa Peak, the Stegioara Peak, Sitniţa Peak, Plaiul Bătrân, and in the catchement area of the Hudieşului Valley (Fig. 3). These rocks are more common than the porphyritic diorites. Three mineralogical varieties can be distinguished but were not mapped distinctly as they occur within the same body: varieties with orthopyroxenes, biotite and pyroxenes and amphiboles.

Two geochemical analyses of the quartz diorites indicate 58.04 and 58.50 wt % SiO_2 and 1.71 and 1.73 wt % K_2O.

5.B.4.3. The *Groapa pyroxene and hornblende andesites* (Fig. 3) contain plagioclase feldspars, hornblende, and pyroxene as phenocrysts, in a hyalopilitic groundmass with fluidal texture. The geochemical composition is quite close to that of the Piatra Hudinului andesite: SiO_2 content of 60.68 wt % and K_2O content of 2.10 wt %. The rocks are in contact with the dacitic body from the catchment of the Baicului valley and with a porphyry quartz diorite body located right in the Groapa Peak.

In the Stregiorului Valley-Piatra Rea area, there are several small bodies comprised of andesites with pyroxene and amphibole (Fig. 3). In this area, the magnetic data suggest the existence of magmatic sources at depth. In the Obcina Pietrii area, there are two petrographic varieties (leucocratic and melanocratic) without significant mineralogical differences. Both varieties have plagioclase feldspars, pyroxene and hornblende phenocrysts in a groundmass that represents 50 - 60 % of the rock. From a petrographic point of view, these rocks are similar with the andesites with pyroxenes and amphiboles from Groapa Peak.

5.B.4.4 The d*acites from Piatra Rea zone* form an intrusive body on top of Piatra Rea Peak and several small intrusive bodies in the same area (Fig. 3), with petrographic similarities with the Tomnatec dacites and the Grohot microgranodiorites/dacites.

5.B.5. Piatra Hudinului pyroxene and hornblende andesites

This type of rock is part of the intrusive body from the Piatra Hudinului Peak located at about 600 m south of Hudin Peak (Fig. 3). The outcropping body has a diameter of about 150 m

and a height of 10-40 m. The rock consists of plagioclase, ortho- and clinopyroxene and hornblende phenocrysts in a hyalopilitic-textured groundmass. The SiO_2 content is 59.65 wt % and the K_2O content is 2.10 wt %. There are textural transitions from microcrystalline to medium-crystalline. Enclaves are frequent and consist of Hudin microgranodiorites and subordinately muscovite quartzite schists.

6. Temporal relationships between the igneous rocks in the Ţibleş Mountains

The igneous bodies developed in large areas, but the surface contact limits are absent and consequently, their spatial connections are difficult to establish. The only two visible contact relationships are: 1) the large Hudin microgranodiorite body is crosscut by the small Piatra Hudinului andesite body, the latter containing numerous enclaves of micrograno-diorite; 2) the large Tomnatec dacite intrusion is crosscut by a small quartz monzodiorite body near the top of Tomnatec Peak. This relationship is also confirmed in the underground mining works where the monzodioritic rocks piearce the dacitic rocks, suggesting overall, that the monzodioritic rocks of the main Ţibleş-Bran-Măgura Neagră magmatic body are younger than the dacitic rocks of the Tomnatec massif, and the Piatra Hudinului intrusive body is younger than the Hudin massif.

In the case of other large bodies, although in the first instance the rocks appear to be very different, their discrimination can only be achieved under the microscope. These are the cases of the Arcer basaltic andesites that connect with the Ţibleş quartz monzodiorites-monzogabbros, at surface in some locations. Underground, the Arcer gallery IV and two of its branches crosscut the monzodioritic rocks (on the surface this portion is occupied by the Arcer basaltic andesites). This relationship suggests that the monzodioritic rocks are younger than the Arcer basaltic andesites.

The absolute ages of the two rock types were determined with the K-Ar method. The similar values of 10.2±0.8 Ma, 9.4±0.6 Ma and 8.7±0.4 Ma for the Arcer basaltic andesites and 9.8±0.5 Ma, 9.6±0.4 Ma and 8.3±0.4 Ma for the Ţibleş quartz monzodiorites-monzogabbros (Pécskay et al., 1995, Kovacs et al., 1997) do not clarify the temporal relations between the magmatic rocks of the main Ţibleş-Bran-Măgura Neagră magmatic body and its northwestern margin (the Arcer basaltic andesites). Regarding the relationships between the rocks belonging to the two main magmatic complexes - Complex of acidic magmatic rocks and Complex of intermediate magmatic rocks, in addition to the previously mentioned (the Piatra Hudinului andesites are younger than the Hudin microgranodiorites and Ţibleş quartz monzodiorites-monzogabbros are younger than the Tomnatec dacites), more data are required.

The absolute ages of the two Hudin microgranodiorite samples from different occurrences are identical – 10.0±0.4 Ma (Pécskay et al., 1995) and confirm that the acidic magmatic rocks are older than the rocks of the main Ţibleş-Bran-Măgura Neagră magmatic body (previously proven based on the direct contact between the Tomnatec dacites – contemporaneous with the Hudin microgranodiorites - and the Ţibleş quartz monzodiorites-monzogabbros). The time of emplacement of the Grohot dacites/microgra-nodiorites, which are not in direct relationship with any other type of rock, remains a problem to be clarified in the future. They were included in the Complex of acid rocks, but the absolute age of 9.4±0.9 Ma (Pécskay et al., 1995) is similar with the age of the rocks from the main Ţibleş-Bran-Măgura Neagră magmatic body.

A complicated situation from the perspective of the time of emplacement of some intrusive rocks that do not have direct contact with other intrusive rocks is that of the intrusions from the Hudieş-Stegioara area. Initially, the intrusive rocks from this area (diorites, quartz diorites and andesites) have been considered to belong to a second stage of emplacement corresponding to an intermediate-basic magmatism, that followed the first acidic stage (the Hudin microgranodiorite and the Tomnatec dacites, Edelstein et al, 1980a, c, 1981).

Currently, there are two K-Ar radiometric ages from the dioritic rocks of the Hudieş Peak area – 10.6±0.7 Ma and 10.2±0.4 Ma, and other two from the quartz diorites from the Stregior Peak area – 11.5±0.5 Ma and 10.9±0.5 Ma (Pécskay et al., 1995). Based on these new data, this group of rocks was considered to be older than the acidic rocks (Kovacs et al., 1997, Pécskay et al., 2009). The time when the intrusive rocks from the Hudieş-

(Kovacs et al., 1997 c). These ages confirm the ages acquired on fresh magmatic rocks.

7. Observations on the outlines of the magmatic bodies at depth

The extent of the intrusive bodies from the Ţibleş Mountains at depth have been investigated based on the data acquired underground coupled with geophysical data. The underground data from the mining works indicated that the main Ţibleş-Bran-Măgura Neagră magmatic body extends well below the surface area of the Tomnatec massif (Fig. 4). In the absence of underground data for other intrusive bodies, the gravimetric and magnetic data of Andrei et al. (1980, 1981, unpubl.) indicated a large extent of all the intrusive bodies at depth (Fig. 4). The acidic intrusive bodies from the western area seem to slightly exceed the projection of the surface outline at depth, while the intermediate intrusive bodies seem to exceed far more the projection of the surface outline at depth.

It is worth noting that in the Hudieş-Stegioara area, all the small outcropping intrusive bodies are merging at depth. The main Ţibleş-Bran-Măgura Neagră body also extends at depth to aproximately double the known surface area, including all the small surrounding intrusions and overlapping the large thermal metamorphic aureole.

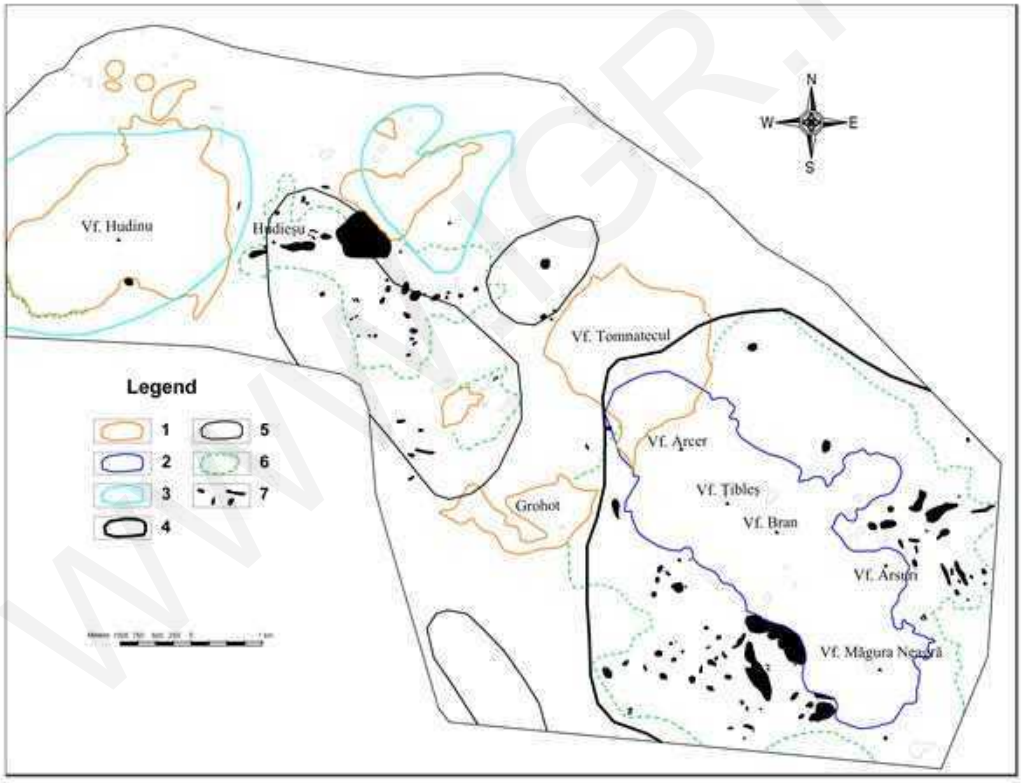

Fig. 4. The outlines of the main magmatic bodies from the Ţibleş Mountains, inferred at depth based on the gravimetric and magnetic data (digital version acquired by the geologist Ştefan Gönczi). 1. The outline of the intrusive bodies of the Complex of the acidic rocks at surface; 2. The outline of the main Ţibleş-Bran-Măgura Neagră monzodioritic body at surface; 3. The outline of the main acidic intrusive bodies at depth; 4. The outline of the main monzodioritic body at depth; 5. The outline of the intrusive bodies from the Hudieş-Stegioara and Păltiniş zones at depth; 6. Thermal metamorphic aureoles; 7. Small intrusive bodies of the Complex of the intermediate magmatic rocks.

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8. The products of the post-magmatic processes

The magmatic complexes in the Ţibleş Mountains are associated with a suite of products of post-magmatic processes: contact metamorphism - thermal or metasomatic, pneumatolytic and hydrothermal.

8*.1. The products of the contact metamorphism*

The products of the contact metamorphism are the result of the thermal metamorphic and metasomatic processes. They occur around the intrusive bodies, in the thermal metamorphic aureoles/haloes, or right at the contact between intrusions and sedimentary rocks.

8.1.1. The products of the thermal metamorphism

The acidic magmatic bodies interacted with the surrounding sedimentary rocks on a short distance (1-5 m), rather than across a longer one. The thermal metamorphic aureoles associated with the monzodiorites-monzogabbros and quartz diorites/microdiorites intrusions are more extensive and have a more complex composition. The widest aureole is associated with the main Ţibleş-Bran-Măgura Neagră monzodioritic body (Fig. 3). It is an aureole of thermal metamorphism at the level of the chlorite zone, with a width of 200-2000 m (ca. 1000 m the average), reflecting the overall influence of the large magmatic body, or the interference of the combined thermal effects of the main magmatic body and adjacent bodies.

The products of the thermal metamorphism are represented by *spotted schists* and *hornfelses*. The degree of metamorphism and the mineralogical composition of the thermal metamorphosed rocks depend on the lithology of the sedimentary rock and the composition of the magmatic rock. The slightly thermally metmorphosed rocks are in the zeolitic facies; the hornfelses in the albite-epidote, hornblende and pyroxenes facies are formed on the pelitic and siltic rocks. The mineralogical composition varies depending on the respective metamorphic facies and in correlation with the petrography of the magmatic bodies. The geological map displays the most characteristic minerals of rocks affected by thermal metamorphism (Fig. 3)

The opaque minerals from the spotted schists and hornfelses comprise 1-20 wt% of the rocks. Pyrite reaches up to 15-20% of the rock in some hornfelses, and pyrrhotite occurs frequently. Ilmenite, magnetite, chalcopyrite and goethite are also present. Chalcopyrite is found locally in small amounts (50 microns in size) associated with chlorite or scattered, associated with pyrrhotite in the cordierite-+sillimanite hornfelses from the Izvorul Mesteacănului-Izvorul Negru interfluve (Fig. 3).

On the arenitic rocks (sandstones and graywacke) are formed *quartzites* in the albite-epidote and hornblende hornfelses. The quartzites occur in the contact zones of the main Ţibleş-Bran-Măgura Neagră monzodioritic body. In the mineralogical composition of the quartzites, besides the quartz which represents the main constituent (up to 95% of the rock), were also identified the tourmaline, sericite, clay minerals and sporadically opaque minerals, chlorite, epidote, plagioclase, zoisite, and cordierite.

Thermal metamorphism processes are also reported within magmatic rocks. At the contact zone between the Arcer basaltic andesite and the Tomnatec dacite, in the low crystallinity gray-black rock, was identified a mineralogical association composed of albite and tremolite+zoisite, with plagioclase and augite relict (characteristics of the Arcer andesite). South of the Bran Peak, a high amount of amphiboles (40% of the rock), typical for the hornblende facies was observed in a porphyritic microdiorite. In the Preluci I and Preluci II galleries, where the Tomnatec dacite is crosscut by two monzodiorite bodies, garnet crystals were identified in the dacite.

At the contact between the magmatic bodies and the sedimentary rocks, various *contact breccias* are often formed, depending on the petrographic nature of the intrusive bodies. In the case of the Tomnatec dacites, the contact breccias suggest exclusively mechanical processes responsible for their formation. They consist of marls, sandstones, clay fragments (25-60% of the breccias) incorporated in a dacitic matrix. The fragments of sedimentary rocks do not show any thermal metamorphic transformation. The breccias occur marginally, extending off the margins of the magmatic body (Fig. 3).

Thermal metamorphic effects are also found in the breccias associated with the Ţibleş-Bran-Măgura Neagră monzodioritic rocks, or with the Izvorul Netedului granodiorites. The breccias contain fragments of sedimentary rocks

incorporated in a magmatic matrix. The thermal metamorphic effects of the embedded sedimentary rocks reflect the temperature of the intruded magma from a low to a very high temperature, almost reaching fusion state.

Often, a mixture of sedimentary and magmatic rocks (mélange) is formed, and the initial lithology of the components is no longer recognized. The contact breccia zone is a few meters wide. In the breccias from the Măgura Neagră area, in a melange with graphic structure (between quartz and feldspar), fine-grained clinopyroxenes and phlogopite are recognized.

8.1.2. The products of contact metasomatism

The products of the contact metsomatism are represented by *skarns* formed on the sedimentary rocks in contact with magmatic bodies and by *"skarnoid"* rocks, defined by the crystallization of specific contact metasomatism mineral assemblages within the magmatic rocks.

Skarns were described underground, in the Izvorul Sacilor gallery, in the contact zone of the extensive monzodioritic body at the level of the Arcer IV gallery (Edelstein et al, 1980a, 1981, Fig. 3). Three lenticular bodies of magnesian skarns have been mentioned by Udubaşa et al. (1982). A magmatic stage - spinel, forsterite, diopside and basic plagioclase and a postmagmatic stage - phlogopite, tremolite, pargasite, wollastonite associations were described in these skarns. Some ore minerals - magnetite, hexagonal pyrrhotite, chalcopyrite, sphalerite and valerite occur also in the post-magmatic association. In geodes, fluorine, epidote, leuchtembergite, prehnite, calcite, dolomite, quartz, laumontite, opal and kaolinite were formed as products of residual solutions. Other occurrences of skarns were reported on the right tributaries of Izvorul Mesteacănului. "Skarnoid" rocks were identified in the catchment zone of the left tributary of Izvorul Netedului and in the Arsuri-Măgura Neagră saddle (Fig. 3), where garnets (up to 80-85% of rock), quartz and feldspars occur in the rocks.

8.2. The products of the pneumatolytic metamorphism

Almost all types of rocks in the Ţibleş Mountains were more or less affected by the boron pneumatolysis: the quartzites, the sedimentary rocks affected by thermal metamorphism, and some of the magmatic rocks: the Arcer basaltic andesites, the quartz monzodiorites-monzogabbros of the main Ţibles- Bran-Măgura Neagră magmatic body and the andesitic rocks from their margins, the Tomnatec dacites, the Grohot dacites/microgranodiorites, and the Arsuri quartz microdiorites. The most widespread products affected by the pneumatolytic metamorphism are the quartzites and the breccias with tourmaline.

In the *quartzites with tourmaline*, where the effects of pneumatolytic metasomatosis overlapped those of thermal metamorfism, tourmaline, as a pneumatolytic product, is replaced by minerals of thermal contact. Tourmaline is found in significant quantities (up to 30% of the rock) as small aggregates in between the quartz grains, sometimes forming rosettes. More rarely, tourmaline appears as fine prismatic crystals (0.03-0.05 mm), evenly disseminated in the rock. Quartzites with tourmaline occur on large areas in Ţibleş Peak and Arcer Peak (Fig. 3).

The *breccias with tourmaline* occur on a large area located on a left tributary of the Izvorul Rău, upstream of the Izvorul Rău 1 gallery, inside the area of Arcer basaltic andesites (Fig. 3). One of the largest occurence zone has a surface of 90x30 m. Two types of tourmaline were identified: 1) crusts of black prismatic crystals; 2) matrix of the andesitic breccias. Tourmaline is represented by a term of the schörlit-elbait series with boron contents between 5,000 and 10,000 ppm.

The texture of the breccias suggest their formation as a result of explosions caused by the volatiles in the pneumatolytic phase, controlled by the emplacement of the quartz monzodiorite-monzogabbro body. The occurence of topaz and apatite in the area of the Ţibleş Peak is also attributed to the pneumatolytic metasomatosis.

Products of pneumatolytic metasomatosis were also described in the Izvorul Mesteacănului area, where a very rich assemblage of post-magmatic minerals occurs in the contact zone of the quartz monzodiorite-monzogabbro magmatic body with the sedimentary rocks affected by thermal metamorphism. Kovacs et al. (1985, 1994 and 1995) described more than 30 mineral species in this contact zone, including the uncommon fluorapatite columnar crystals (up to 3 cm)

associated with large pseudohexagonal crystals of fluorphlogopite (maximum 1 cm).

8.3. The products of the hydrothermal metamorphism

The products of the hydrothermal metamorphism are associated with the main mineralizations. They form the hydrometasomatic aureoles developed in the vicinity of the Tomnatec-Preluci vein groups and Măgura Neagră mineralized structure (Fig. 3).

In the hydrometasomatic aureole of the Tomnatec vein, Bogancsik et al. (1980) have identified an internal zone of 2-3 m in the footwall of the vein and 1-2 m in the hanging wall, with quartz + clay minerals, hydromicas, pyrophyllite, talc, sulfates and an external zone extended over several tens of meters. The external zone is also divided into an inner subzone with illite+quartz+pyrite and an outer subzone with quartz+hydromicas, albite+potassium feldspar. From this outer zone, there is a gradual transition to the propylitic facies of hydrothermal alteration. In the hydrometasomatic aureole of the Preluci vein, besides the mineralogical associations highlighted in the Tomnatec vein aureole (without the sulfates), adularia was also described (Bogancsik et al., 1980). In both aureoles, the hydrothermal alterations are much stronger at lower levels.

In the Măgura Neagră mineralized structure, the hydrometasomatic aureoles are strictly limited to the zone near the veins (1-5 m width); in the inner part towards the veins argillization is predominant, sericitization (subordinated argillization) is developed in the middle zone, passing outwards to the propylitic facies.

9. Mineralizations from the Țibleș Mountains

The mineralizations from the Țibleș Mountains are represented by veins and subordinately impregnations of stockwork-type. The veins are located in sedimentary rocks, in the Tomnatec dacites, Țibleș quartz monzodiorites-monzogabbros, and the Arcer basaltic andesites. They measure 120-300 m in length, rarely up to 1400 m (the Tomnatec vein) or even 1900 m (Vein 15, Fig. 3), and are commonly thin (below 0.5 m). The main veins are up to 3 m thick. The NE-SW orientation is predominant in the Tomnatec and Preluci veins, Izvorul Băilor I vein, Măgura Neagră I, II, III and IV veins, Izvorul Zimbrului and Izvorul Sacilor I veins. The E-W orientation is also common, such as in Izvorul Sacilor III, vein 15, Ramură I, Preluci Ramură Coperiș, Târlișua I, II and III veins. Some small veins have WNW-ESE (vein 16), or NNW-SSE (vein 18, Fiezel vein) or NW-SE (Izvorul Băilor 2 vein) orientation. The main ore minerals are pyrite, pyrrhotite, sphalerite, galena and arsenopyrite.

At the level of the entire Țibleș Mountains, the mineralizations can be assigned to three different groups based on their setting and the placement in the metallogenetic evolution (Udubașa et al., 1983, 1984, 1995): 1) Central-Northwestern group with high-temperature mineralizations of zinc and lead predominantly and copper and arsenic subordinately, including the following veins: Tomnatec, Preluci, Izvorul Băilor, Vein 15, Saci, Arcer 5, some of the veins from Stegioara area, veins from Târlișua area and Izvorul Rău 2 gallery (Fig. 3); 2) The external belt with low-temperature mineralization characterized by the presence of antimony: Izvorul Zimbrului where berthierite was identified (Udubașa et al., 1980), Șătrița, where stibnite and kermesite occur, and the Fiezel valley zone, where low contents of antimony have been noticed; 3) The Măgura Neagră Group, which differs from the others due to the frequent chalcopyrite and rare sphalerite and galena.

In the Izvorul Mesteacănului zone, a brecciation/stockwork-type mineralization was discovered, consisting of veinlets, aggregates and impregnations with sphalerite + chalcopyrite, molybdenite, pyrite and rutile (Edelstein et al, 1980a, Kovacs et al, 1985, 1995). In the Izvorul Netedului-Izvorul Băilor-Izvorul Țibleșului area, impregnations and rare veinlets of magnetite were identified in microgranodiorites and monzodiorites.

The magnetite is non-titaniferous, sometimes associated with chalcopyrite. This association was considered as a marker for the presence of a porphyry copper type of ore (Udubașa in Edelstein et al. 1980a). Udubașa et al. (1983, 1984, 1995), Pintea (1998) and Pintea et al. (1999) showed the evidence of a prophyry copper system in the southeastern area of the main Țibleș-Bran-Măgura Neagră magmatic body, including the Izvorul Netedului-Izvorul Băilor-Izvorul Țibleșului and the Măgura Neagră zones.

The metallogenetic processes were assigned to the main stage of monzodioritic-monzogabbroic intrusion (Udubaşa et al., 1983, 1984). During the polyascending metallogenesis, three stages were highlighted: a first porphyry system stage, followed by a second stage of high-temperature vein-type mineralization, and a third stage of low-temperature mineralizations from the external zone. Within this succession, the stockwork-type of mineralizations from the Izvorul Mesteacănului zone are closer to the dissemination-type than to the vein-type.

10. Conclusions

The current paper reviews the main geological data from the detailed geological map of the Ţibleş Mountains at 1:25,000 scale, published herein for the first time. The data regarding the sedimentary formations and the products of the thermal and metasomatic contact and of the pneumatolytic and hydrothermal metamorfism are described in detail and also published for the first time. Three units from the sedimentary domain and twelve units from the magmatic domain were separated as the main structural units in the Ţibleş Mountains.

The magmatic intrusive rocks belong to two main complexes: 1) the Complex of the acidic rocks including the Hudin (microgranodiorites) and Tomnatec (dacites) bodies and the small bodies from the Buza Dealului, Baicului Valley and Grohot zones, and 2) the Complex of the intermediate rocks comprising the main Ţibleş-Bran-Măgura Neagră monzodioritic body and the adjacent rocks (Arcer basaltic andesites and Arsuri quartz microdiorites) and the small intrusive bodies from Izvorul Netedului, Izvorul Negru-Izvorul Roşu and Hudieş-Stegioara zones. The magmatic activity has taken place during a large time interval (11.5-8.7 Ma, K-Ar ages determinations). The temporal relationships between the main intrusions are difficult to establish because of the absence of good exposures. Nevertheless, the main monzodioritic intrusion is younger that the acidic rocks, based both on the direct contact relationships (at surface and underground) and their K-Ar ages. The time of emplacement of some of the intrusive rocks requires further clarifications (e.g. intrusions from the Hudieş-Stegioara area).

Overall, for all the intrusive bodies, the gravimetric and magnetic data suggest a larger extent at depth. The main Ţibleş-Bran-Măgura Neagră monzodioritic body extends at depth two times the projection of the outline at surface, including all the merging intrusions from the surrounding area.

The thermal metamorphic aureoles associated with the monzodiorites-monzogabbros and quartz diorites/microdiorites intrusions are the most extensive and have the most complex composition. The widest aureole is associated with the main Ţibleş-Bran-Măgura Neagră monzodioritic body. Rich and complex metasomatic and pneumatolytic mineral associations were noticed in the contact zones of the monzodioritic body with the sedimentary rocks. A typical feature of Ţibleş Mountains is the well developed pneumatolytic metamorphic phase (rich in boron) that has formed the tourmaline breccia areas.

A three stage polyascending metallogenesis assigned to the main monzodioritic-monzogabbroic intrusion had taken place in the Ţibleş Mountains. The first stage led to the formation of the hidden prophyry copper system from the southeastern area of the main Ţibleş-Bran-Măgura Neagră magmatic body.

The geological complexity of the Ţibleş Mountains remains a challenge for future geological investigations.

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