PETROGRAPHY AND GEOCHEMISTRY OF MIDDLE MIOCENE (SARMATIAN) VOLCANIC ARC OF THE PIENINY MTS, WEST CARPATHIANS.

T. TRUA[1], K. BIRKENMAJER[2], G. SERRI[1] and Z. PÉCSKAY[3]

[1] *Dipartimento di Scienze della Terra, Università degli Studi di Parma, Parco Area delle Scienze, 157A, 43100 Parma, Italy; gserri@ipruniv.cce.unipr.it*

[2] *Institute of Geological Sciences, Polish Academy of Sciences, Senacka 1/3, 31-002 Kraków, Poland; ndbirken@cyf-kr.edu.pl*

[3] *Institute of Nuclear Research, Hungarian Academy of Sciences, Bem tér. 18/c, 4026 Debrecen, Hungary; pecskay@moon.atomki.hu*

Abstract.: A petrographical and geochemical study was carried out on samples collected from Miocene hypabyssal volcanic intrusions of the Pieniny Mts. The studied rocks belong to the calc-alkaline series and consist of medium-K basaltic andesites, high-K basaltic andesites and andesites. They show multi-element patterns characteristic of subduction-related magmas comparable to few volcanic rocks from the Carphatian Arc.

Key words: Carphatians; Pieniny Mts; calc-alkaline magmatism.

Introduction

The Miocene volcanics of the Pieniny Mts area (12.5 to 10.8 Ma, Birkenmajer and Pécskay, 2000) are represented by numerous small- to moderate-size andesitic hypabyssal dykes and sills (Fig. 1a: *P*). They form a belt about 20 km long parallel/subparallel with the Pieniny Klippen Belt (Fig. 1b), and represent the northernmost segment of the West Carpathian magmatic arc. Two phases of intrusive activity have been recognized (Birkenmajer & Pécskay, 1999): the 1st phase dyke swarm runs parallel/subparallel with the Pieniny Klippen Belt, cutting the Grajcarek Unit and the Magura Nappe; the 2nd phase andesite intrusions propagate along transversal faults, which displace the 1st phase dykes and sills, related to the late Styrian deformation phase (Sarmatian age). Previous petrographic studies reveal that Pieniny volcanics range from basic (amphibole-augite andesites) to acidic (amphibole andesites) varieties (see Youssef, 1978, and references therein).

Here we report the petrography and geochemistry of samples collected from both 1st phase and the 2nd phase Miocene hypabyssal volcanic intrusions of the Pieniny Mts.

Petrography

Most of the rocks under investigation show clear petrographic evidence of variable degrees of secondary transformation due to deuteric alteration (Tab. 1). Thus, their classification has been done using combined chemical and mineralogical criteria. The studied rocks consist of basaltic andesites and andesites (Total Alkalis vs. Silica diagram, Fig. 2a). They belong to the calc-alkaline series and, according to the K_2O vs. Silica diagram (Fig. 2b), they should best be termed high-K or medium-K basaltic andesites (HKBA or MKA) and medium-K andesites (MKA).

All the investigated rocks show porphyritic texture with a micro- to cryptocrystalline groundmass (Tab. 1). Plagioclase (*pl*) and amphibole (*amph*) as the most abundant, ubiquitous phenocryst phase. Clinopyroxene (*cpx*) occurs only in the Mt Wzar and Kroscienko volcanic rocks. *Pl*, *amph* and *cpx* are variably zoned. Sporadic microphenocrysts of biotite (*bt*) are encountered in a few MKA rocks, and in one HKBA sample. Opaques (*opq*) and apatite (*ap*) are the main accessory minerals in almost all the investigated rocks. Sporadic sphene (*sph*), K-feldspar, *bt* and *qz* occur in the groundmass of MKA. Cumulates of *amph*, *pl*, *bt+op+sph+ap* are present in the Mt Jarmuta MKA rocks (Tab. 1).

Geochemistry

In the variation diagrams of major and minor elements relative to SiO_2 (Fig. 3), the Pieniny volcanic rocks reveal a small gap in silica content (from 57 wt% to 61 wt% SiO_2). MgO, Fe_2O_3tot, CaO and TiO_2 show negative trends against SiO_2. Na_2O increases from the basaltic andesites to MKA rocks, but is very variable among the former. Basaltic andesites and MKA, but one, rocks display the same restrict range in Al_2O_3 content. It is worthy of note that the *pl-amph-bt* cumulate rocks from Mt Jarmuta (Tab. 1) represent the end of curved trends, which pass through the basaltic andesites and end at the MKA rocks, once plotted on Harker diagrams of Fig. 3.

In the primitive-mantle normalized diagrams (Fig. 4a), the Miocene Pieniny basaltic andesites display negative Nb and Ti anomalies and high LILE (Large Ion Lithophile Elements)/HFSE (High Field Strength Elements) ratios (e.g., Ba/Nb=46-

82) typical of subduction- or collision-related magmatic rocks. All these volcanics display a strong positive Pb anomaly and REE pattern with positive Eu anomaly (Eu/Eu*= 1.05-1.20).

Discussion and conclusions

Both petrographical and geochemical data suggest that fractionation, mainly of *pl* and *amph+bt*, was involved in the genesis of the Pieniny Mts volcanic rocks. We computed fractionation calculations on major elements, from one of the least evolved basaltic andesite to the most differentiated MKA. A good fit was obtained between calculated and observed major element compositions, with a strong fractionation of *pl* and *amph* and, to a lesser extent, of *bt*, indicating that the MKA rocks of the Pieniny Mts could be generated by fractionation starting from a magma having major elements composition similar to the basaltic andesites.

It is difficult to characterize the geochemical mantle source of the Miocene Pieniny magmas due to the lack of relatively primitive composition among the most primitive basaltic andesites. The primitive-mantle normalized diagrams of the least evolved Pieniny Mts volcanic rocks (Fig. 3a) reveal an "excess" in LILE elements (e.g., K, Rb, Ba) with respect to the HFSE characteristics of all subduction-related magmas. The LILE enrichment could reflect either a virtually contemporaneous contribution from the subducted slab or it could be a feature of the mantle wedge produced by older enrichment events. Moreover, a strong Pb positive anomaly characterizes the basaltic andesites from the Pieniny Mts similarly to the East and Inner West Carpathian lavas (Fig. 3a). In terms of alkalis (Fig. 2), the Pieniny volcanic rocks resemble the Miocene-Quaternary calc-alkaline volcanics from East- and Inner West Carpathians. They all show similar trace element patterns, although the Pieniny basaltic andesites show a distinct Ba positive anomaly only encountered in few volcanic rocks from both Inner West Carpathians and East Carpathian (Fig. 4a).

The Sr-Nd-Pb isotopic study in progress on the Pieniny volcanic rocks will help to put constraints on the nature and composition of the "subduction components" and on the possible crustal assimilation processes occurred during the ascent of the Pieniny Mts magmas.

References

Birkenmajer, K., Pécskay, Z., 1999. K-Ar dating of the Miocene andesite intrusions, Pieniny Mts, West Carpathians. Bull. Pol. Acad. Sci., Earth Sci. 47: 155-169.

Birkenmajer, K., Pécskay, Z., 2000. K-Ar dating of the Miocene andesite intrusions, Pieniny Mts, West Carpathians, Poland: a supplement. Stud. Geol. Polon 117: 7-25.

Downes, H., Pantó, G., Póka, T., Mattey, D.P., Greenwood, P.B., 1995. Calc-alkaline volcanics of the Inner Carpathian arc, Northern Hungary: new geochemical and oxygen isotope results. Acta Vulcanol. 7 (2): 29-41.

Kovác, M., Nagymarosy, A., Oszczypko, N., Csontos, L., Slaczka, A., Marunteanu, M., Matenco, L. & Márton, E., 1998. Palinspastic reconstruction of the Pannonian -Carpathian region during the Miocene. In: M. Rakús, M. (ed.), Geodynamic development of the Western Carpathians. Geol. Surv. Slovak Rep. (Bratislava): 189-217.

Le Maitre, R.W., 1989. A classification of Igneous Rocks and Glossary of Terms. Recommendations of the International Union of Geological Sciences, Subcommission on Systematics of Igneous Rocks. Le Maitre, R.W. (ed.), Blackwell Sci. Publ.: 193 pp.

Mason, P.R.D., Downes, H., Thirlwall, M.F., Seghedi, I., Szakács, A., Lowry, D., Mattey, D., 1996. Crystal assimilation as a major petrogenetic process in the East Carpathian Neogene and Quaternary Continental Margin Arc, Romania. J. Petrol. 37: 927-959.

Youssef, M.M.M., 1978. Large-scale geological survey of the Mt Wzar andesites, Pieniny Mts, Poland. Stud. Geol. Polon. 66: 1-30.

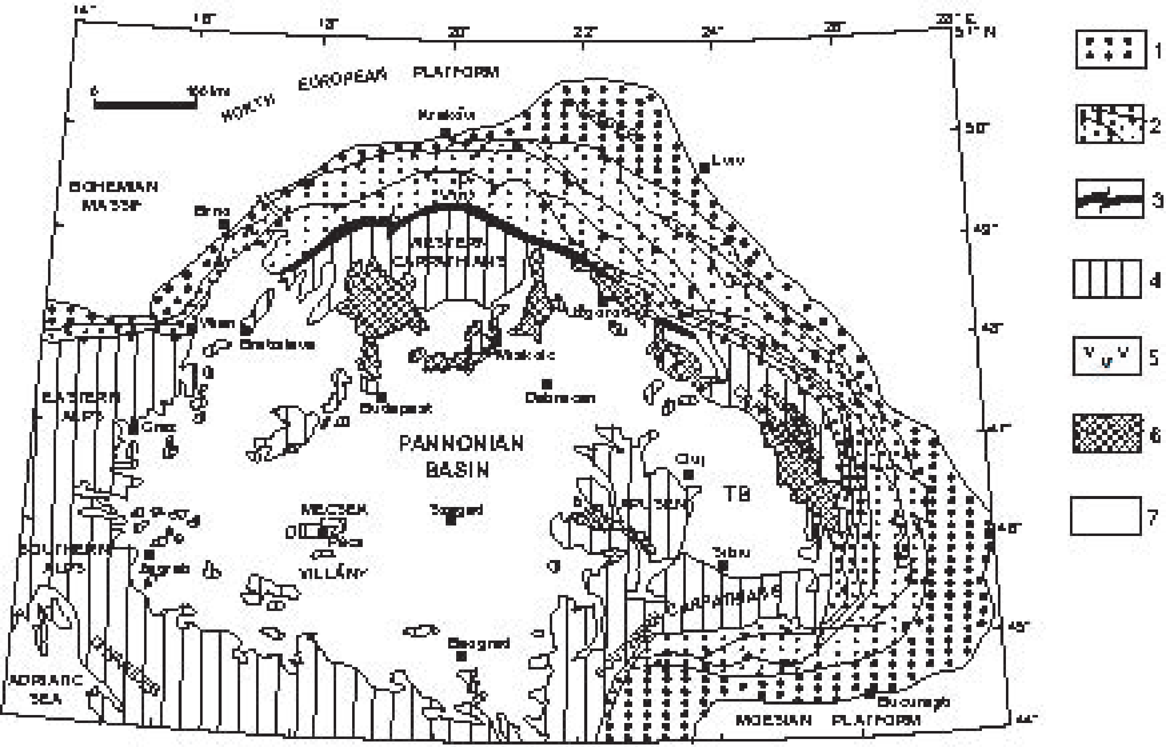
Table 1. Synthetic petrographic description of the analyzed Miocene dykes of the Pieniny Mts (Poland).

Fig 1. a) Location of the Miocene volcanics of the Pieniny Mts (*P*) (Kovác *et al.*, 1998, modified). 1 - Carpathian and Alpine Foredeep; 2 - Outer tectonic units; 3 - Pieniny Klippen Belt; 4 - Inner tectonic units; 5 - Outer Carpathian Pieniny volcanic arc (Sarmatian); 6 - Inner Carpathian volcanics (Miocene-Quaternary); 7 - Neogene of the Pannonian Basin and the Transylvanian Basin (*TB*). **b)** Occurrence of the K-Ar-dated Pieniny Mt volcanic rocks (Birkenmajer & Pécskay, 2000). 1 - major fault systems; 2 - andesitic rocks; 3 - fresh-water Neogene; 4 - Palaeogene of the Magura Nappe (Outer Carpathians); 5 - Palaeogene of Inner Carpathians; 6-13 - Pieniny Klippen Belt, tectonic units; More important sites: J - Mt Jarmuta; K - Mt Krupianka; KL - Kluszkowce; KR - Kroscienko; S - Szczawnica; W - Mt Wzar.

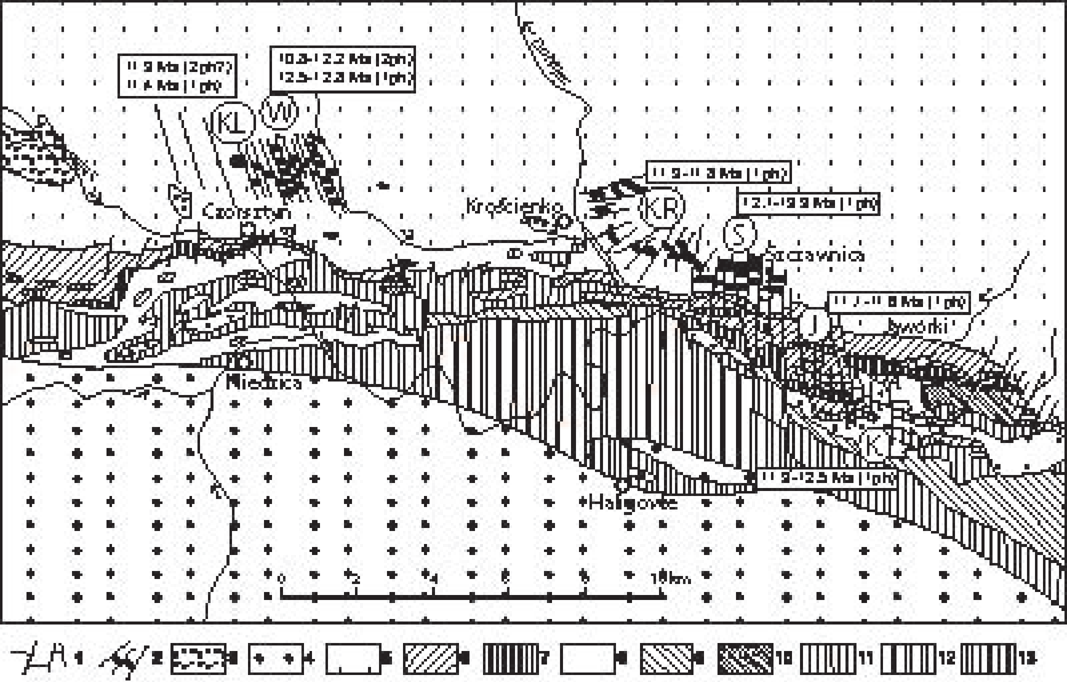
Fig. 2. a) Total alkalis-silica and **b)** K_2O vs SiO_2 diagrams (Le Maitre, 1989), for the Middle Miocene (Sarmatian) volcanic rocks of the Pieniny Mts. Reference data: East and Inner West Carpathian volcanic rocks from Mason *et al.* (1996) and Downes *et al.* (1995), respectively.

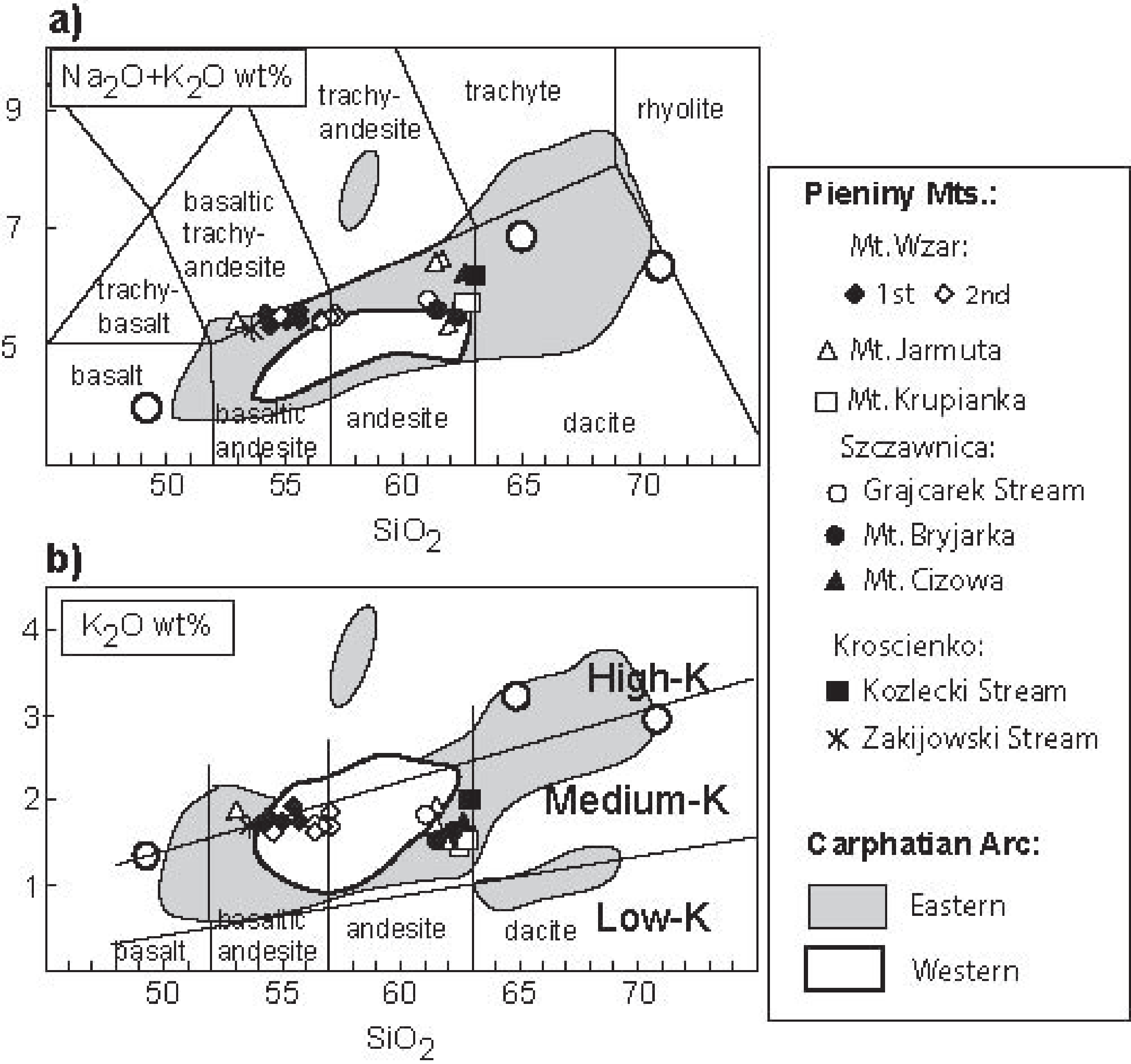
Fig. 3. Variation diagrams of major elements vs. SiO_2 (wt%) for the Middle Miocene (Sarmatian) volcanic rocks of the Pieniny Mts. Symbols as in Fig. 2.

Fig. 4. a) Primitive mantle normalized multi-element fields for the Middle Miocene (Sarmatian) basaltic andesites of the Pieniny Mts. Normalizing values and E-MORB data from Sun and McDonough (1989). **b)** Comparison between sample 7S (Mt. Wzar) and the East- (Mason *et al.*, 1996) and Inner West Carpathians (Downes *et al.*, 1995) calc-alkaline rocks. Abbreviations: *SH* - south Harghita, *C* - Calimani, *B* - Börzsöny, *T* - Tokaj.

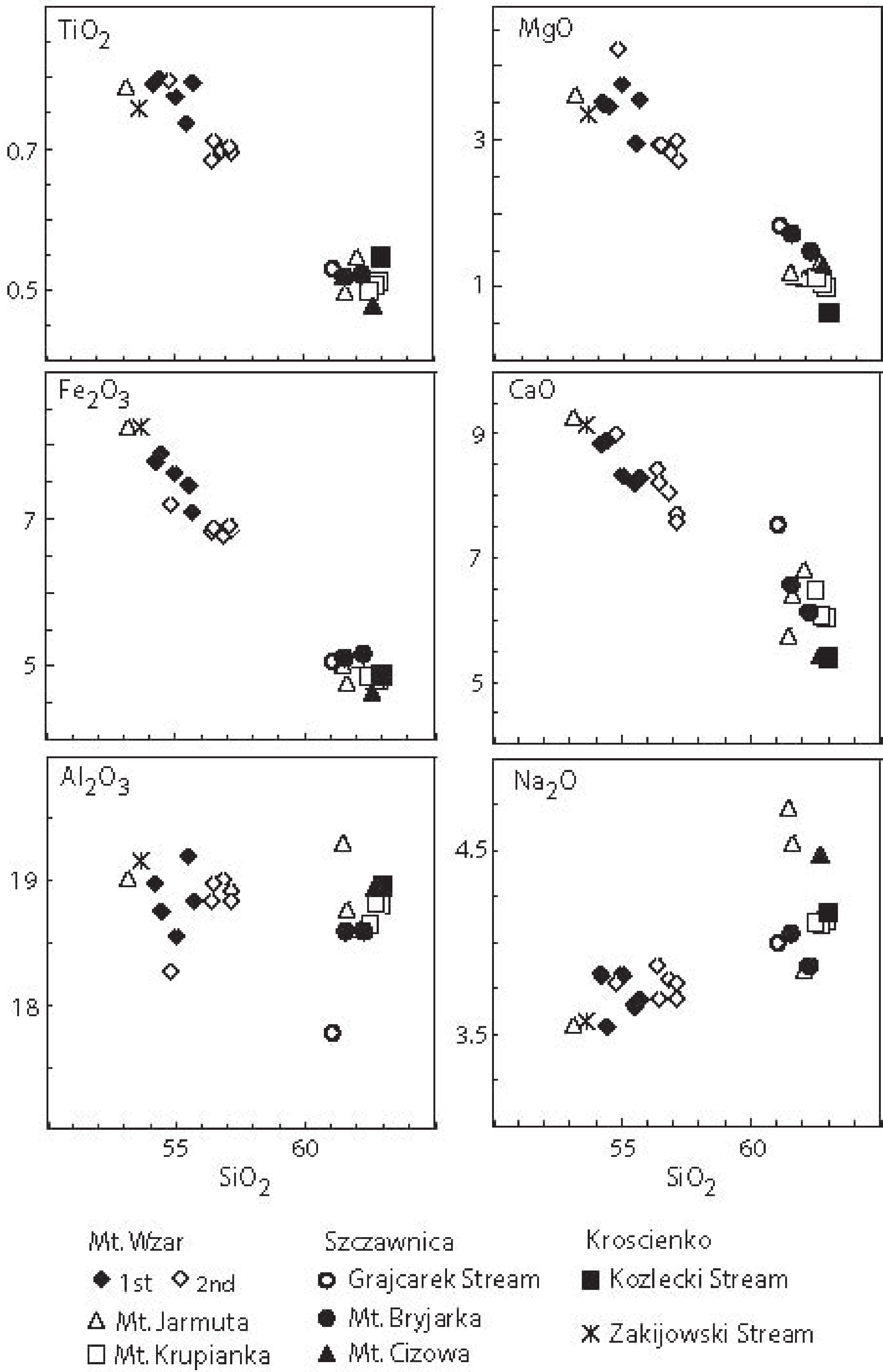


NORTH EUROPEAN PLATFORM
BOHEMIAN MASSIF
WESTERN CARPATHIANS
PANNONIAN BASIN
EASTERN ALPS
SOUTHERN ALPS
ADRIATIC SEA
MOESIAN PLATFORM
MECSEK
VILLÁNY
TB
Kraków
Lviv
Brno
Wien
Bratislava
Miskolc
Debrecen
Budapest
Graz
Cluj
Szeged
Pécs
Zagreb
Sibiu
Beograd
1
2
3
4
5
6
7

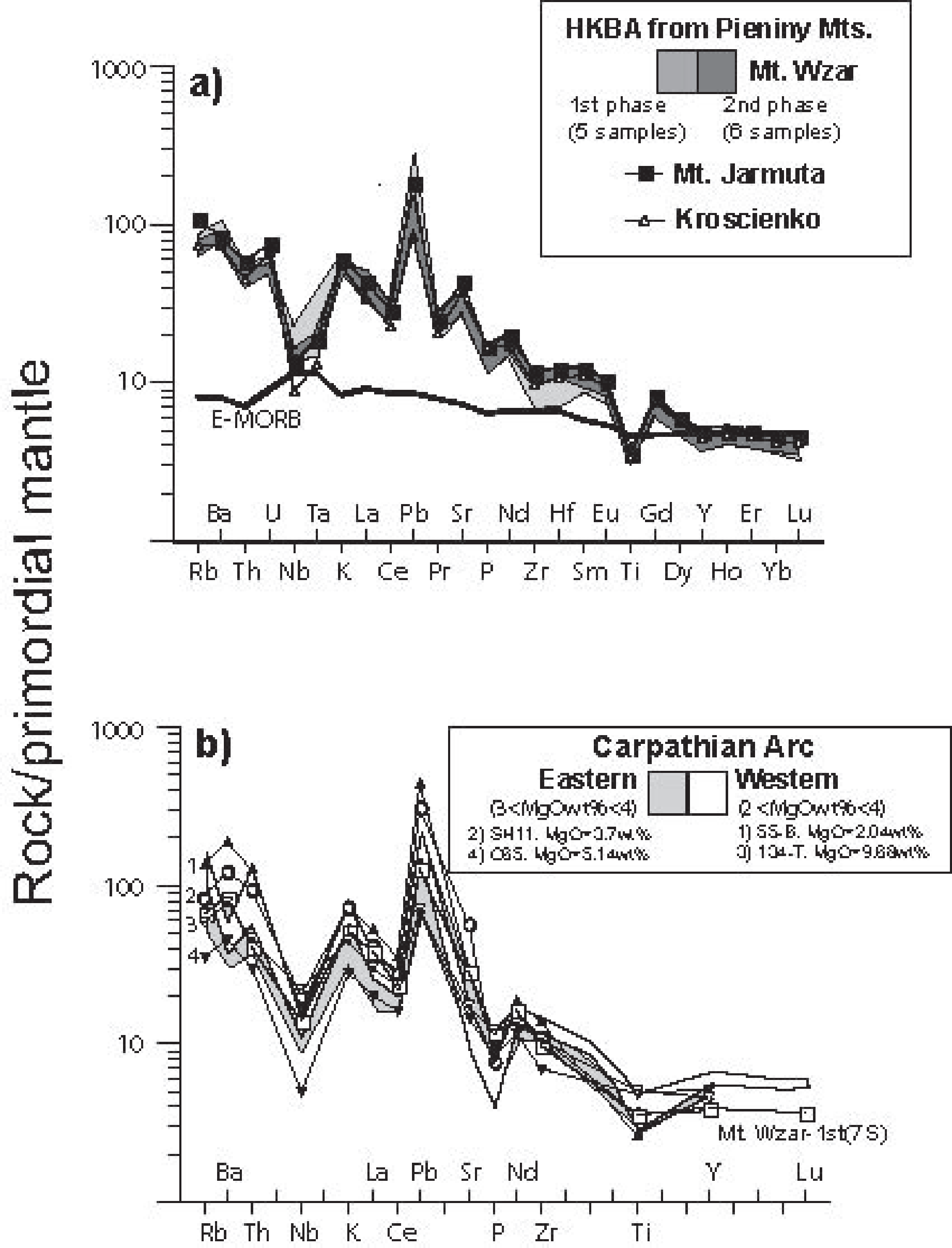

11.9 Ma (2ph?)
11.4 Ma (1ph)
10.2-12.2 Ma (2ph)
12.5-12.3 Ma (1ph)
KL
W
Czorsztyn
Krościenko
11.9-11.3 Ma (1ph)
KR
12.1-12.3 Ma (1ph)
S
Szczawnica
11.7-11.8 Ma (1ph)
J
Jaworki
K
Niedzica
11.9-12.5 Ma (1ph)
Haligovce
0
2
4
6
8
10km
1
2
3
4
5
6
7
8
9
10
11
12
13



a)
Na2O+K2O wt%
trachy-
andesite
trachyte
rhyolite
basaltic
trachy-
andesite
trachy-
basalt
basalt
basaltic
andesite
andesite
dacite
SiO2
b)
K2O wt%
High-K
Medium-K
Low-K
basalt
basaltic
andesite
andesite
dacite
SiO2
Pieniny Mts.:
Mt. Wzar:
1st
2nd
Mt. Jarmuta
Mt. Krupianka
Szczawnica:
Grajcarek Stream
Mt. Bryjarka
Mt. Cizowa
Kroscienko:
Kozlecki Stream
Zakijowski Stream
Carphatian Arc:
Eastern
Western



TiO2
MgO
Fe2O3
CaO
Al2O3
Na2O
0.7
0.5
3
1
7
5
9
19
18
4.5
3.5
55
60
SiO2
Mt. Wzar
1st
2nd
Mt. Jarmuta
Mt. Krupianka
Szczawnica
Grajcarek Stream
Mt. Bryjarka
Mt. Cizowa
Kroscienko
Kozlecki Stream
Zakijowski Stream



Rock/primordial mantle
a)
HKBA from Pieniny Mts.
Mt. Wzar
1st phase (5 samples)
2nd phase (6 samples)
Mt. Jarmuta
Kroscienko
E-MORB
1000
100
10
Ba U Ta La Pb Sr Nd Hf Eu Gd Y Er Lu
Rb Th Nb K Ce Pr P Zr Sm Ti Dy Ho Yb
b)
Carpathian Arc
Eastern
Western
2) SH11. MgO=3.7wt.%
4) OBS. MgO=5.14wt.%
1) SS-B. MgO=2.04wt.%
3) 104-T. MgO=9.88wt.%
1
2
3
4
Mt. Wzar-1st(7 S)
1000
100
10
Ba La Pb Sr Nd Y Lu
Rb Th Nb K Ce P Zr Ti