GEOLOGICA CARPATHICA, 47, 2, BRATISLAVA, APRIL 1996
63–72

MESOZOIC NON-OPHIOLITIC VOLCANICS OF THE CARPATHIAN ARC AND PANNONIAN BASIN

DUŠAN HOVORKA

Department of Mineralogy and Petrology, Faculty of Sciences, Comenius University, Mlynská dolina, 842 15 Bratislava, Slovak Republic

Project 369

(Manuscript received March 16, 1995; accepted in revised form October 5, 1995)

Abstract: In the geological units under consideration besides Mesozoic ophiolites alkaline as well as calc-alkaline volcanics are known. They have various stratigraphic (mainly Upper Triassic and Cretaceous as well) and tectonic settings. Alkaline volcanic provinces are products of extension-related volcanic activity, volcanics of calc-alkaline trend originated in the zone of active continental margins.

Key words: Carpathians, Pannonian Basin, Mesozoic, alkaline volcanics, calc-alkaline volcanics.

Introduction

The Carpathian arc and Pannonian Basin Mesozoic alkaline and calc-alkaline volcanics are an integral part of Mesozoic sequences of various age. They are known from several tectonic units of the Carpathians and the Pannonian Basin as well. The volcanics have different stratigraphic positions and their petrological character varies in a wide range, as well. Research in recent years has produced a wealth of data on individual volcanic provinces.

Since the Carpathian arc is a mountain range with a total length of approximately 1400 kilometres (Fig. 1), the basic characteristics are presented for individual segments of the mountain range separately. This is also applied to the Pannonian Basin Mesozoic volcanics, too.

In the following text volcanics of the calc-alkaline and alkaline clans will be discussed. Those of the tholeiitic parentage together with other members of the ophiolite complex (e.g. bodies of ultramafics, sheeted dykes, gabbros) have been summed up in the paper by Hovorka (in print).

Several synthetizing papers concentrating on problems of paleotectonic/paleodynamic reconstruction of the Mesozoic complexes/terranes of the given mountain chain have been published. Unfortunately volcanics and volcanic activity from the point of view of the whole mountain range in the majority of cases are more-or-less outside the general attention. Papers by Szádeczky-Kardoss et al. (1967), Balla et al. (1980), Hovorka & Spišiak (1988), Kubovics et al. (1990), Narębski (1990) and others are concentrated on problems of individual volcanic provinces of a lower order.

For all correlation studies, the existence of sets of analytical data from individual units, e.g. volcanic provinces, is fundamental. From this point of view the situation is as follows: in some units top quality sets of data are available, from the others there are only some data on the main oxides.

I. The Western Carpathians

Mesozoic volcanics of uneven character occur in varied facial zones/tectonic units of the Western Carpathians. In the following text individual volcanic provinces will be described within defined geological units in a perpendicular direction (from the outside to the innerside) to the prolongation of the mountain belt. Their characteristics can be summed up as follows.

I.1. The outer (flysch) zone: teschenite-picrite association

Volcanic rocks, represented by various types of extrusive as well as subvolcanic bodies in the Silesian Unit of the flysch zone on the Czech and Polish territories, form the teschenite-picrite (+ monchiquite, alkali basalts, ankaratrites, ouachitites, fourchites, pyroxenites) association/province.

The rock names "teschenite" type locality Těšín/Teschen; (Hohenegger 1861) and "picrite" (Tschermak 1866), were used for the first time merely for the rocks of the above mentioned province. The best description of those rocks was published by Pacák (1926) and Smulikowski (1929).

Present understanding of the teschenite-picrite association has made great progress in the past decades due to the studies of numerous authors (Mahmood 1973; Guczwa & Wieser 1985; Kudělásková 1987; Hovorka & Spišiak 1988; Narębski 1990).

Volcanic activity in the Silesian Cretaceous Basin operated within a longer time-period (Hauterivian–Aptian). It was simultaneous with the deposition of the flysch type sedimentary pile of the unit under consideration.

The leading geological process, e.g. abrupt acceleration of extensional processes within the basin under discussion with slightly thinned (but still fairly thick) continental crust, provided a tectonic background for this volcanic activity (Guczwa &

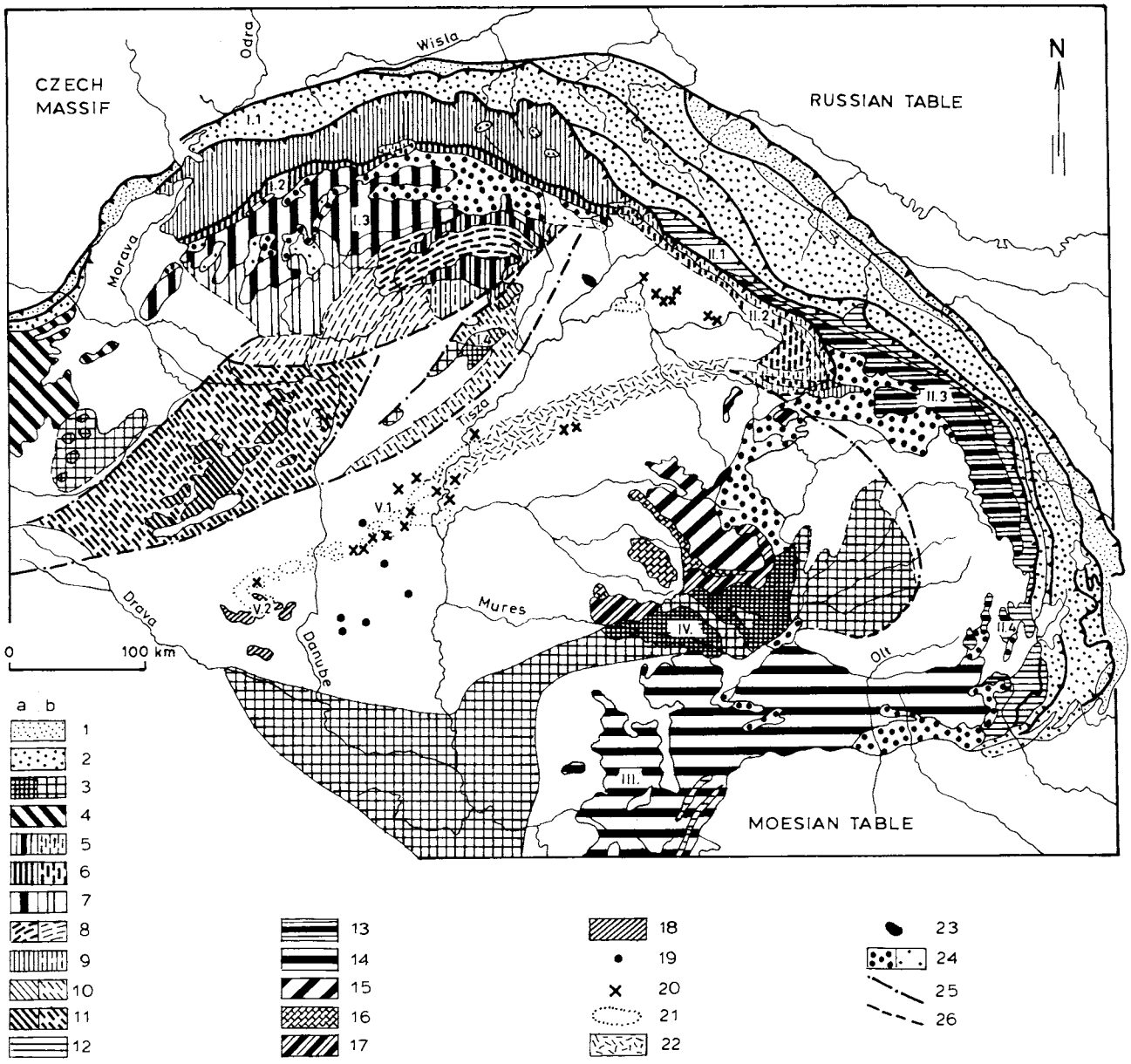

Fig. 1. Tectonic scheme of the Carpathians and the Pannonian Basin (Balla 1984, adapted) with location of some Mesozoic volcanic subprovinces. **a** — surface occurrences, **b** — hidden occurrences; **1** — folded molasse, **2** — flysch belt, **3** — basic and ultrabasic magmatites + deep-water sediments, **4** — Austroalpine complexes, **5** — Magura Unit, **6** — Pieniny Klippen Belt, **7** — Tatric Unit, **8** — Paleozoic complexes, **9** — Mesozoic complexes (mostly Gemeric Unit), **10** — Bukkides, **11** — Bakonides, **12** — Ceahlau Unit, **13** — Bukovina units, **14** — Getic and Danubian units, **15** — Bihor autochton, **16** — Codru nappe system, **17** — Bihor nappes, **18** — south Transdanubian Mesozoic units, **19** — Middle and Upper Cretaceous, **20** — Cretaceous basalts, **21** — Z magnetic anomalies, **22** — Cretaceous-Paleogene flysch, **23** — Zemplin Unit, **24** — posttectonic cover, **25** — boundary between the Western and Eastern Carpathians, **26** — faults.

Wieser 1985; Hovorka & Spišiak 1988; Narebski 1990). Such an assertion should, then, allow us to classify this volcanic activity as the "continental rift volcanism conditioned by speeded up extensional processes within a flysch basin". On the contrary thick continental crust in the basement of the Silesian Unit is projected on last paleogeographic map of the Barremian (Dercourt & Ricou 1990).

In the **Vienna Basin** Tollmann (1972, 1985) mentioned some of 30 occurrences of Albian and Cenomanian-Turonian picrites (both of dyke and hyaloclastic character) which according to Prey (1975) geologically belong to the innermost Flysch unit. Equivalent rocks have very seldom been penetrated by boreholes in the Czech part of the basin under consideration.

I.2. The Western Carpathians segment of the Pieniny Klippen Belt (Pienides)

A comprehensive survey of volcanics occurrences has been presented by Mišík (1992). As a result of the limited space in this paper only the geologically most significant occurrences are discussed. For further information, the paper by Mišík (1992) is recommended. The problem of acid as well as basic

volcanic pebbles of the "Upohlav" and "Proč" Sennonian conglomerates belongs to the most topical. Rather a large amount of description of pebbles exists (Šímová 1985; Birkenmajer & Skupinski 1989; Birkenmajer & Wieser 1990). The existing radiometric data (Černov 1973; Rybár & Kantor 1978; Mišík & Sýkora 1981; Birkenmajer & Wieser 1990) yielded 121-179 Ma.

I.3. The central zone

The zone between the Peri-Pieniny and the Margecany-Lubeník lineaments (the zone of the crystalline-Mesozoic complexes of the Eastern Carpathians is its equivalent) is very complicated. Volcanics can be characterized within two provinces as follows.

I.3.1. Alkali basalt/basanite Early Cretaceous province

Conspicuous volcanic activity is manifested in the sedimentation basin of the Krížna Nappe, representing a typical allochthonous tectonic unit. Subautochthonous Mesozoic (cover) units also bear minor occurrences of alkali basalt/basanite volcanics mostly of a hyaloclastite character. Both, the cover unit and the Krížna Nappe sedimentation areas experienced volcanic activity during Barremian-Albian, mostly in the form of lavas and hyaloclastites. From some places (the western part of the Nízke Tatry Mts. and the Veľká Fatra Mts.) numerous xenoliths of carbonates, have been reported (Hovorka & Sýkora 1979; Hovorka & Spišiak 1988).

Dykes of alkaline basalts are known to appear sporadically in the Middle Triassic limestones of the above mentioned units. They represent the communication paths of the effusives under consideration. The geochemical features of both characterized alkali basalt/basanite subprovinces are identical.

The sedimentation areas of "subautochthonous" and allochthonous units have spatially been clearly distinguished. Identical products of volcanic activity which took part in the very same stratigraphic horizons allow us to assume that identical speeded-up extensional processes were responsible for it.

I.3.2. Picrites of the Krížna and Choč Nappes

In the Triassic carbonates of the Krížna and Choč Nappes in the surroundings of the city of Banská Bystrica phlogopite picrites occur (Hovorka & Slavkay 1966; Slavkay 1979). They are represented by olivine-phyric effusives of fresh appearance. On the basis of geologically accepted opinion on sedimentation in two separated (the Krížna and Choč Nappes) basins exactly identical volcanics are very improbable. In accordance with Hovorka & Spišiak's (1988) view, the present author considers the discussed volcanics to be the product of volcanic activity which occurred after the emplacement of the two nappes into their present position. So Late Tertiary age of volcanics (and their membership of the Late Tertiary central Slovak volcanic province) is probable.

I.4. The inner zone

This zone being tectonically very complex, is located southeast of the Margecany-Lubeník lineament. Geological units with known products of volcanic activity are situated on both, the Slovak and Hungarian territories.

I.4.1. Acid calc-alkaline volcanics of the Drienok Nappe

The Drienok Nappe represents one of the "upmost" nappes, located within the central zone. Products of the Lower Triassic volcanic activity show the character of lava flows, ignimbrites and hyaloclastites, even ash-like deposits are known (Slavkay 1965). Among volcanic rocks, those of rhyolite and dacite composition are the most widespread. The distinguished products of volcanic activity enable us to suggest that subaerial and simultaneously subaquatic volcanic activity may be considered.

I.4.2. NE Bükk Mts. Anisian andesite volcanics (Szentistvánhegy "porphyrite" Fm.)

A slightly metamorphosed (Árkai 1983) stratovolcanic sequence about 250 m thick, mostly of andesite chemistry (formerly called "porphyrites"), crops out in the northeastern part of the Bükk Mts. A subordinate amount of acid volcanics could be the product of fractional crystallization. The original mineral asemblages and their magmatic features are almost completely recrystallized.

I.4.3. NE Bükk Mts. Upper Ladinian–Lower Carnian basaltic volcanics (Óhuta "diabase" Fm.)

Volcanic activity of submarine origin yielded basaltic lava (often amygdaloidal) flows as well as their volcaniclastics. Quartz porphyry bodies appear to be relatively younger intrusions into basic volcaniclastics (Szádeczky-Kardoss 1959 in Árkai 1973). A volcanic complex is known to occur within carbonate platform sediments.

Analytical data with discrimination value are missing. The only exception to this are clinopyroxene analyses (Dobosi 1986). They display a composition characteristic for alkali basalts Cpx. In contrast to that elevated alkali and Al content in intermediate volcanics (trachyandesite-trachyte trend of volcanics under consideration, Kubovics et al. 1990) is considered to be the consequence of metamorphic alterations.

II. The Eastern Carpathians

Within the Eastern Carpathians (on both the Ukrainian and Rumanian territories) non-ophiolitic volcanics occur in several tectonic zones attaining the length of approximately 600 km.

II.1. The Black Flysch Nappe (Outer Dacides)

This nappe (Bleahu 1962) belongs to the most internal units of the Flysch zone. It corresponds to the Kamenný potok brook and Chivchin units on the territory of Ukraine. The presence of a "mafic complex" is characteristic (Bleahu 1962). Its equivalent on the Ukraine territory is described as the Chivchin-Trostenec Complex (Lomize 1968). The volcanic activity under consideration is of Late Jurassic-Early Cretaceous in age (Tkachuk et al. 1977). Volcanics (of the total thickness up to 200 m) are located on the base of the tectonic unit discussed. Its rock association is as follows: basaltic lava flows and lava breccias prevail over various types of volcaniclastics. The volcanics are mostly of spilitized basalts and an-

desite chemistry, locally even more acid types are also present. Complex under consideration is penetrated by dykes and sills of dolerites. An alkaline character and within plate setting is documented (Săndulescu et al. 1981). The Black Flysch Nappe underwent hP-lT metamorphism with nucleation of glaucophane and pumpellyite in places (Săndulescu et al. 1981).

II.2. Pienides

Products of volcanic activity occur at the SE termination of the discussed tectonic unit (Terebla and Teresva river basins). They are present in the Czorsztyn Unit shallow water sediments of Tithonian-Berriasian in age. Occurrences of several tens of meters thick mostly volcanic breccias are spread within the 20 km long zone (Bolshoy Kamenec, Vulkhovchik, Drahovo: Andrusov 1945; Lazarenko et al. 1963; Lomize 1968; Tkachuk et al. 1977). In the disagreement with Lomize (1968) who classified the rocks sequence as "subalkaline", Tkachuk et al. (1977 — in accordance to Lazarenko et al. 1963) identified the rocks under consideration as potassic diabases with transitions to amygdaloids and their agglomerates. Such ranking is based on determined 3.75-6.00 per cent K_2O in effusives.

II.3. Central Eastern Carpathians nappes

This extremely complicated nappe system can be divided into the Bucovinian, sub-Bucovinian and infra-Bucovinian nappes of the Alpine age (Săndulescu 1975). The presence of pre-Alpine metamorphic sequences as well as Permian-Mesozoic sedimentary pile is characteristic for all nappes of this group. Dismembered Mesozoic ophiolites have been recently discussed in a paper by Hovorka (in print).

The characteristic member of the Bucovinian nappe system is the **Ditrău Complex**, Jurassic in age (Streckeisen & Hunziker 1974). On the other side Pb radiometric data on monazite and zircon (326-297 Ma) indicate Hercynian emplacement of the massif.

The Ditrău intrusion is the greatest, the most peculiar and at the same time the most controversial alkaline body within the whole Carpathian arc. It is composed of kaersutite peridotite, alkali gabbros, syenites to quartz syenites. It penetrates metamorphic formations of the Eastern Carpathians allochthons. Some authors (Russo-Săndulescu et al. 1983) connect its generation with the processes of initial rifting that preceded oceanic spreading of the Dacides. Other authors suppose Ditrău massif to be the product of Na-metasomatosis combined with recrystallization and redistribution of material. Existing analytical data suggest derivation of plutonic rocks of the massif from a volatile-rich alkali basalt parental magma. The most primitive magmas reaching a high level were already strongly fractionated (Morogen et al. 1995).

The Getic nappes, that is those of Holbav and Braşov, which tectonically correspond to the infra-Bucovinian nappes, are also units with known non-ophiolitic volcanics. They have the character of subvolcanic bodies or effusives of Liassic age. Their prononced alkaline character is documented by the presence of arfvedsonite in acidites. The majority of rock bodies in the Braşov Unit have the character of dykes.

II.4. Transylvanian nappes

Apart from the relatively widespread occurrences of the members of an ophiolite complex, that is those of the Persani, Hăghimas and Olt Nappes, non-ophiolitic volcanics also occur in some nappes.

Within the Olt Nappe in the Persani Mts. alkaline rocks of trachyte, syenite, bostonite and rhyolite character (being of rift setting: Russo-Săndulescu et al. 1981) cut the tholeiitic basalts of the OFB affinity. The different age of eruptives (e.g. Middle Triassic-Neocomian) is documented by the incorporation of various parts of the spreading zone (the Transylvanides) into individually forming Transylvanian nappes.

II.5. Banatite province

A discontinuous belt of Cretaceous-Eocene (Laramian) magmatites (= banatites) runs from the Apuseni Mts. to the western part of the Southern Carpathians and southward to eastern Serbia.

Within the Banatite province the intrusive rocks prevail, and volcanics are of limited areal extent. Magmatic activity mostly of calc-alkaline type exhibits a marked polystadial character.

The emplacement of Laramian eruptives is intimately connected with the development of a trench-arch system (Cioflica et al. 1980). The Upper Cretaceous closing of the trough of a small ocean type, which separated the western Southern Carpathians from the Moesian platform, was accompanied by a consumption of the oceanic crust in a westward oriented subduction. A setting, which exhibits zonal distribution of eruptives, allows us to correlate it with the Andean type subduction (Nastăseanu et al. 1981).

III. The Southern Carpathians

Within the Southern Carpathians realm Mesozoic sequences have been deposited both on the ocean floor and continental type basements (Rădulescu & Săndulescu 1973). They belong to several major tectonic units.

Within the Danubian autochthon sediments have been deposited with simultaneous volcanic activity of the Bajocian-Early Tithonian age. They are known from the Presacina zone. Character of the volcanics corresponds to those of basalts and keratophyres.

IV. The Apuseni Mountains

The southern Apuseni Mts. are known for occurrences of product of huge volcanic activity of the Early Jurassic-Cretaceous in age. Tholeiitic volcanics (together with metaperidotite and metagabbro bodies) have OFB trend of differentiation. The 2nd (calc-alkaline) and 3rd (alkaline) phase volcanics are mostly classified as a volcanic arc "initialites" (Savu et al. 1978; Savu 1980), or as products of the developed stage of a volcanic arc (Hovorka in print). Together with tholeiitic magmatites they are known as "Mures zone ophiolites" (Rădulescu & Săndulescu 1973; Cioflica et al. 1981; Savu 1983; Nicolae 1985).

On the southwestern limb of the Apuseni Mts. on the eastern margin of the Lipova Basin in the vicinity of Costei small basalt occurrences ("the Costei basalts") are known (Dusa 1965 in Savu et al. 1992). Basalts together with keratophyres overlay the metamorphic rocks of the Tisa Unit. Very recently they have been interpreted as Triassic volcanics of intraconti-

nental setting (Savu et al. 1992). The volcanics of varying appearance are of tholeiitic character and in places they were differentiated to keratophyres. The available analytical data allow us to classify the rock under discussion as tholeiites.

V. The Pannonian Basin

Apart from the Mesozoic complexes comprising basic volcanics and/or ultrabasites, occurring on the surface, large Mesozoic areas of the Pannonian Basin are covered by Neogene sediments. Prospection activities for oil and gas (geophysical survey, boreholes) have delimited areas with buried volcanic complexes. Their characteristics are given below.

V.1. Intra-Pannonian volcanic belt

The summary of the discovered buried volcanics in the basement of the Pannonian Basin filling enabled the delimitation the "Alföld ophiolite belt" (Szepesházy 1977) and/or the "intra-Pannonian ophiolite belt" (Horváth et al. 1977). According to the latter authors (l.c.), the zone with abundant occurrences of volcanics with a SW-NE direction represents, at the same time, a tectonic boundary of the lst order and its turning in the western part in N-S trend enables its prolongation to the Vardar zone of the Dinarides.

Volcanics and volcaniclastics in the zone between the Danube and Tisza rivers (Nagykőrös-Szandaszőllős) in Neogene basement are Early Cretaceous in age (Szádeczky-Kardoss et al. 1967). In the view of Szepesházy (1977), the volcanic activity had already begun in the Liassic and it reached its maximal activity towards the end of the Jurassic and at the beginning of the Cretaceous. In this zone, a predominance of basalts (tholeiites ?) is documented. Extrusives and subvolcanic bodies of dolerite and gabbro character and/or veins and sills of various size are also known. Ultramafic bodies are not present. The volcanic complex reaches a thickness of 200 m. The volcanics in the SW part of the zone are younger in age than those in the NE part (Juhász & Vass 1977).

The considerable variation in the volcanics within the Danube-Tisza area, the presence of only one member of the assumed ophiolite complex, abundant veins of "ophiolites" in the Jurassic sediments, but also the presence of extrusives (?) confirm that the discussed volcanics cannot be assigned to the ophiolite complex.

V.2. The Meczek Mts.

The volcanic complex of the Lower Cretaceous is of considerably alkaline character. It is represented by alkali basalts, basanites, phonotephrites, trachyandesites and phonolites. K-rich volcanic rocks of variable character are also known (Harangi 1994).

As for the composition, their alkaline character is testified by the presence of aegirine, aegirine-augite, K-feldspars, barkevitic hornblendes and also by the presence of natrolith and sanidine in the groundmass of intermediate and acid rock-types (Szádeczky-Kardoss et al. 1967; Bilik 1974, 1983). Among alkaline rocks of the discussed province two mafic magma groups have been distinguished (Harangi 1994): ankaramite-alkali basalts, and basanite-phonotephrites.

Clinopyroxenes studied (Dobosi 1986) show a salite composition and have a pronounced affinity to the within-plate alkaline (WPA) rock-clan.

The higher content of Ca in structural formula of clinopyroxenes (which is characteristic for Cpx in alkaline rocks) in the case of Cpx in volcanic rocks from the Meczek Mts. assigns them to the diopside and salite fields (Dobosi 1986). In Cpx phenocrysts "cores" of different composition (comparing the outer parts of phenocrysts) are reported (Dobosi 1986). They are probably the result of an early high pressure pyroxene crystallization stage (l.c.).

Whilst the above mentioned authors (l.c.) assigned the initial volcanic activity to a shallow-water setting, the younger phases continue in terrestrial conditions and are mostly of subvolcanic character. On the contrary Bilik (1974) put the emphasis on considerably submarine character of the volcanic activity. In the view of Viczián (1970), the volcanic complex of the Meczek Mts. penetrated the eugeosynclinal sedimentary sequence, and he suggested the term "alkaline miogeosynclinal initial volcanism".

The significantly alkaline character of the volcanics, high explosivity of the volcanic activity, together with their geotectonic position and lithology of synchronous sediments provide the evidence for their origin in a riftogeneous structure within continental-type crust (Bilik 1980).

V.3. The Velence Mts.–Buda Hills Late Cretaceous mafic-ultramafic dyke-swarm

In NE Transdanubia between the Velence Mts. and the Buda Hills, several dozen dykes of alkaline basic to ultrabasic rocks have been described very recently (Horváth et al. 1983; Kubovics 1985; Horváth & Ódor 1983; Dobosi & Horváth 1988; Kubovics et al. 1989; Embey-Isztin et al. 1989; Kubovics et al. 1990; Szabó et al. 1993). Dykes (of 5 cm to several meters in thickness) are of N-S or NW-SE direction. They are known only from rare surface occurrences, dykes and dyke-swarms penetrated by boreholes are described in detail (l.c.). The whole rock association according to the composition of its clinopyroxenes belongs to the WPB (Horváth et al. 1983). Horváth & Ódor (1983), Szabó et al. (1993) attributed the rocks under consideration to the group of lamprophyres of the Late Cretaceous in age. The authors (l.c.) consider monchiquite to be the main rock type. Appart from monchiquites, the above authors also introduced the presence of polsenites, silicocarbonatites or alkali picritic porphyries, but also microgabbro. All the rock types are characterized by a high content of volatiles.

For the majority of rock types phenocrysts of olivine and rarely clinopyroxene and development of so called felsic globular structure are characteristic. Taking into account the presence of carbonates, the rocks under consideration should be divided into two groups (Kubovics et al. 1990):

a — carbonate-poor varieties contain mostly Cpx, micas, Ol, a small amount of carbonates, feldspars, feldspathoids and glass as well;

b — the carbonate-rich rock types with a high amount of carbonates, and a lack of feldspars, feldspathoids and glass. K/Ar ages from fresh phlogopite offered data 69 and 77 Ma (= Late Cretaceous).

Discussion

Mesozoic volcanic activity of various geodynamic settings took part in all segments of the Carpathians and the main units of the Pannonian Basin as well. Middle-Upper Cretaceous and younger tectonic processes fundamentally reconstructed the

original architecture of Mesozoic units, those with products of volcanic activity included. As a consequence geological units with a different tectonic setting came together, through being vertically and/or laterally transported from their original setting.

For all correlation studies, the existence of sets of analytical data from individual units, e.g. volcanic provinces, is fundamental. From this point of view, the situation in individual units/provinces is uneven: in some of them top quality sets of data are available, from the others there are only some data on the main oxides. Main characteristics based on stratigraphy of volcanic activity could be expressed as follows.

Triassic volcanic activity (especially within the Drienok Nappe, the volcanics of the NE part of the Bűkk Mts., most probably also some volcanic suites of the Eastern Carpathians) have the features of active continental margin volcanism. They bear a calc-alkaline trend of fractionation and are characterized by a changeable proportion of volcanics and volcaniclastics. Some volcanic provinces, together with contemporaneous sedimentary pile underwent dynamic metamorphic recrystallization under low-grade conditions (Árkai 1973). The volcanic formations under consideration are associated with platform-type sediments.

Where rock types are concerned, rock-types acid volcanics/volcaniclastics are dominant. Lower Triassic acid volcanics together with sediments lithology comparable to the lithologies of the inner Western Carpathians zone in the Drienok Nappe, which is located at present within the central Western Carpathians zone, serve as arguments in favour of the Inner Carpathians provenience of this nappe. On the basis of more-or-less equivalent stratigraphy as well as rock suite this volcanic province could be correlated with those of the northeastern part of the Bűkk Mts. Supposed Triassic volcanics present in the form of clastic material in the Pieniny Klippen Belt are not suitable for correlation studies.

Data on **Jurassic volcanic activity** are even more scarce than for the Triassic period. Some volcanic complexes are most probably of the Late Jurassic age (the Black Flysch Nappe, Pienides, Central Eastern Carpathians nappes — see Tab. I).

The **Cretaceous** is characterized by alkaline as well as by calc-alkaline volcanic activity. Its products are spread over all the main zones (in a perpendicular direction to the prolongation of the mountain belt) and in the Pannonian Basin as well. The clearly expressed alkaline character of its products and the time ranking of its activity distinguish it from other Mesozoic Carpathian and Pannonian Basin volcanic provinces. Cretaceous volcanic activity is attributed both to Lower and Upper Cretaceous as well. In individual volcanic provinces the amount of volcanic material varies significantly. Each volcanic province is characterized by specific features.

For alkaline volcanics, and in subordinate amount subvolcanic rocks of the teschenite-picrite association of the outer flysch zone of the Western Carpathians, assimilation (mostly of carbonates) is known (Hovorka & Spišiak 1988). In such a way processes of fractional crystallization, assimilation processes and postvolcanic hydrothermal processes as well are responsible for the wide spectrum of rock types present (l.c.). On the other hand volcanics of the Krížna Nappe and cover units of the Western Carpathians are characterized by a narrow span (alkaline basalt-basanite) of fractionation. This is mostly due to small amounts of lava speedily penetrating the basin floor. Thin lava flows and subvolcanic bodies penetrating into not yet consolidated sediments underwent intensive desintegration. Hyaloclastites are the most common type of alkaline basalts/basanites in the Krížna Nappe and mantle units, with occurrences spread over a large area. It ought to be stressed that the volcanic material is identical in both above mentioned tectonic units. The uniformity of the products of volcanic activity in these two units are the result of identical: —crust in the basement of the discussed sedimentation basins; —tectonic background (extension-related volcanism); —the internal regime in the lava chambers; —conditions during efussions on the sea floor; —P-T condition in the magma generation areas etc.

The now much described rock-association in the Velence Mts. and the Buda Hills present in the form of a dyke-swarm has no equivalents among the Mesozoic volcanic provinces of the area under consideration. On the basis of the rock-types present, the province has the specific features ascribed to lamprophyres.

— The presence of silicocarbonatite dykes is a specific feature of the dyke-swarm of NE Transdanubia. High contents of volatiles, strong hydrothermal alteration as well as a wide spectrum of rock types present (among which ultrabasic rocks of uneven character are typical) together with various xenoliths present, allow us to classify them as alkali lamprophyres. They have no equivalents among the alkali volcanics of the discussed area. N-S or NW-SE strike of the dyke-swarm respectively indicate more-or-less perpendicular position to the boundary of the Laurasia continent. It is probable that in the area under consideration, there was an Upper Cretaceous asthenospheric upwelling (mantle plume). As a consequence small to minimal (several centrimetres only) thickness of dykes indicate not real extension-related magmatic activity, but activity caused by tensionally thinned continental crust and intrusion of primitive fluid-rich melts originated by partial melting processes within a metasomatized upper mantle source.

Another very characteristic volcanic province is that of the Meczek Mts. Beside prevailing volcanics a subordinate amount of alkaline plutonites is also known. The connection of the intra-Pannonian volcanic belt with the volcanics of the Meczek Mts. is not yet proved definitelly.

For all the above mentioned alkaline volcanic provinces of the Carpathians and Pannonian Basin Mesozoic a sudden rapid extension of the basement represented by the continental-type crust can be assumed.

— According to Szepesházy (1977), the whole Meczek Mts. Lower Cretaceous rock suite represents fragment of the "Alföld ophiolite zone". Its members can be followed (as covered occurrences known from numerous boreholes in the Great Hungarian Plain) from the Meczek Mts. up to the northeastern Carpathians (Szepesházy 1977). On the basis of very intensive secondary alterations only relics of rarely present clinopyroxenes allow us to identify the slightly alkaline character of the volcanics under consideration (Dobosi 1987). Such ranking (e.g. tholeiitic to slightly alkaline) is also based on the REE distribution pattern (Kubovics et al. 1990).

Geotectonic assignment of the volcanics known from this belt/zone to the ophiolite complex or to products of continetal rift-related volcanics is not yet definitely solved. Balla (1985) correlated the volcanics of the Meczek Mts. to those of the Moravian-Silesian Beskydes (teschenite-picrite province) with the rock association originated in the same (Magura-Pieniny-Szolnok) marginal basin.

— During the Cretaceous, rapid extension related volcanic activity took place near the southern margin of the European

Table 1: Survey of Carpathian arc and Pannonian Basin Mesozoic non-ophiolitic volcanism.

	Geol. unit	Stratigraphy	Types	Magm. suite	Main rock types	Tectonic backround	Type locality	References (selected)
I.	WESTERN CARPATHIANS							
I.1.	Outer (flysch) zone	Hauteriv-Aptian	dykes, lava flows, hyaloclastites	Alk	teschenite, picrite, alk. basalts	extension-related volcanism	Těšín	Pacák 1926, Smulikowski 1929, Mahmood 1973, Hovorka-Spišiak 1988, Narebski 1990
I.2.	Pieniny Klippen belt	pre-Mesozoic, pre-Middle Cretaceous	pebbles, cobles, mineral detrit	CA, Th	rhyolites, basalts, granites	IAV (?) BABB (?)	river Váh valley	Mišík 1992
I.3.	Central zone							
I.3.1.	Krížna nappe + mantle units	Barremian-Aptian	lava flows, hyaloclastites	Alk	alk. basalt/ basanite	extension-related volcanism	Veľká Fatra Mts.	Hovorka-Sýkora 1979 Hovorka-Spišiak 1988
I.3.2.	Krížna and Choč nappes	Late Tertiary (?)	volc. breccia	CA	phlogopite picrite	subduction related volcanism	Banská Bystrica	Hovorka-Slavkay 1966, Slavkay 1979, Hovorka-Spišiak 1988
I.4.	Inner zone							
I.4.1.	Drienok nappe	Lower Triassic	volcaniclastics, lava flows, ignimbrites	CA	rhyolites	active continental margin	Poniky	Slavkay 1965
I.4.2.	Szentistván hegy Fm. (Bükk Mts.)	Upper Anisian - Lower Ladinian	volcaniclastics	CA	andesites	active continental margin (?)	NE Bükk Mts.	Árkai 1973, Kubovics et al. 1990
I.4.3.	Óhuta Fm. (Bükk Mts.)	Upper Ladinian - Lower Carnian	lava flows, volcaniclastics	Alk (?)	basalts-rhyolites	embryonal rifting ?	NE Bükk Mts.	Árkai 1973, Kubovics et al. 1990
II.	EASTERN CARPATHIANS							
II.1	The Black Flysh nappe (Outer Dacides)	Upper Jurassic - Lower Cretaceous	lava flows, volcaniclastics	Alk	alk. basalts, andesites > acidites	IAV ~ extension related volcanism	Chivchin - Trostenec	Tkachuk et al. 1977, Săndulescu et al. 1981
II.2.	Pienides	Upper Jurassic - Lower Cretaceous	volcanic agglomerates	Alk	alk. basalts, andesites	?	Terebla-Teresra rivers	Lazarenko et al. 1960, Lomize 1968, Tkachuk et al. 1973
II.3.	Central Eastern Carpathian nappes	Jurassic	intrusives/dykes /effusives	Alk	alk. gabbro, syenite, Q-syenite, alk. basalts	?	Ditrău Holbau Brasov	Russo-Săndulescu et al. 1983, Morogan et al. 1995
II.4.	Transylvanian nappes	Midle Triassic - Neocomian	intrusives/ effusives	Alk	trachytes, syenites	rift-related volcanism	Olt nappe - Persani Mts.	Russo-Săndulescu et al. 1981
II.5.	The Banatite province	Cretaceous - Eocene	intrusives	CA	granodiorites, Q-diorites, tonalites	subduction-related volcanism	Banat county	Cioflica et al. 1980, Nastaseanu et al. 1981
III.	SOUTHERN CARPATHIANS							
	Danubian authochton	Bajocian - Lower Tithonian	lava flows, volcaniclastics	?	basalts, keratophyres	?	Presacina zone	Rădulescu-Săndulescu 1973 .
IV.	APUSENI MOUNTAINS							
	Mures zone (IInd phase)	Upper Jurassic	volcanics/volca-niclastics	Th	basalt-andesites	IAV		Rădulescu-Săandulescu 1973, Savu et al. 1978, Cioflica et al. 1981
	Mures zone (IIIrd phase)	Cretaceous	volcanics/volca-niclastics	Alk	alk. basalts	IAV ?		Rădulescu-Săndulescu 1973, Savu et al. 1978, Cioflica et al. 1981
V.	PANNONIAN BASIN							
V.1.	Intrapannonian volcanic belt	Jurassic - Lower Cretaceous	lava flows, volcaniclastics	CA-Th ?	basalts	IAV ?	Nagykörös - Szandaszölös boreholes	Szádeczky-Kardoss et al. 1967, Szepesházy 1977, Horváth et al. 1977
V.2.	Meczek Mts.	Early Cretaceous	lava flows, intrusives	Alk	alk. basalts/basanites, phonolites, trachytes	extension-related volcanism	Meczek Mts.	Szádeczky-Kardoss et al. 1967, Bilik 1974, 1983, Harangi 1994
V.3.	Velence Mts.- Buda hills	Lower Cretaceous	dykes	Alk	alk. basalts, monchiquite, silicocarbonatite	extension-related volcanism	Velence-Buda Mts.	Horváth et al. 1983, Kubovics 1984, Dobosi-Horváth 1988, Embey-Isztin 1989

platform covered by epicontinental sea mostly with carbonate platform sedimentation. The following volcanic provinces of this type can be distinguished:

a) teschenite-picrite province in the outermost Western Carpathians (Silesian) unit (Czech Republik and Poland as well);

b) alkaline volcanics of the SE frontier of the Pieniny Klippen Belt on the territory of Ukraine (Tithonian-Berriasian in age);

c) alkali basalt/basanite province of the Western Carpathian central (crystalline-Mesozoic) zone (Krížna Nappe and "cover" units (Slovak Republic);

d) alkali volcanics of NE slopes of the Bűkk Mts. (Hungary);

e) lamprophyre dyke swarm in the Buda Hills and Velence Mts. (Hungary);

f) ankaramite-alkali basalt-basanite-phonolite suite of the Meczek Mts. (Hungary).

While the provinces listed under *a-*, *c-*, *e-* and *f-* are generaly considered to be of Early Cretaceous age, those of *b-* are most probably Late Jurassic-Early Cretaceous in age. At least those of *e-* could be of Late Cretaceous (69-76 Ma) stratigraphy. The age of volcanics under *d-* is not yet proved well.

A low degree of partial melting (Hovorka & Spišiak 1988; Harangi 1994) of the upper mantle garnet peridotite protolith is considered to occur in the framework of the province listed under *a-* and *e-*.

— The data at present available on the volcanics present on the north-eastern slopes of the Bűkk Mts. do not allow us to solve several fundamental aspects. One of them is the problem of the existence of one (Pantó 1961; Balla 1984; Kubovics et al. 1990) or two magmatic suites (Szentpétery 1953; Balogh 1964; Balogh et al. 1984). The general lack of modern analytical data is reflected in the uneven assignment of the rock-suites under consideration. The older metaandesite-metarhyolite association could be attributed to the convergent plate margin (Pantó 1961; Balla 1984), while clinopyroxene studies (Dobosi 1986) are in favour of a slightly alkaline nature of the basaltic rocks, which with high probability could be correlated to continental alkali basalts. According to the at present available data a different tectonic setting for the volcanic activity of the discussed mountain range should be taken into consideration.

Conclusion

The very complex paleodynamic history of the Carpathians and Pannonian Basin Mesozoic units is documented by volcanic activity of various types, as well as by other types of evidence. Its main features can be summed up as follows.

— Within the whole area under consideration three pronounced stratigraphic levels of magmatic activity are documented: *a)* Lower to Middle Triassic calc-alkaline, *b)* Lower to Middle Cretaceous alkaline volcanism, and *c)* calc-alkaline (banatitic) Upper Cretaceous magmatites. Besides these maxima of volcanic activity products of the Upper Triassic and the Jurassic volcanism, are also known.

— Calc-alkaline volcanism of the Triassic age has all the main features of volcanic activity of stratovolcanic as well as of areal types. Acid to intermediate volcanics predominate. Subaquatic as well as subaeric activity is documented. Fine-grained extrusives (volcanic ash) were spread over large areas — intercalations of mostly argilized tuffs occur in several tectonic units of the inner Western Carpathians. Carbonate platform sediments represent adjacent rock-strata.

— Beside volcanics plutonites are also products of magmatic activity in a broader sense. The Ditrău Complex as well as plutonites and volcanics of the "banatite province" ought to be considered in this context. To this category some of granite bodies, e.g. in the West-Carpathian Gemeric Unit (which has not been discussed in the paper) should be added.

— Some of the Triassic volcanic provinces were subjected to later metamorphic processes. Metamorphic recrystallization did not go beyond low-grade metamorphic conditions (anchimetamorphism, greenschist and locally even blueschist facies conditions).

— Carbonate platform sediments which accompany Triassic calc-alkaline volcanics locate volcanic activity of this type on the active continental margin (Laurasia supercontinent). Cretaceous subduction processes are most probably responsible for calc-alkaline magma generation. Alkaline volcanics are products of volcanic activity conditioned by short-term rapid extensional processes which occurred during the Cretaceous. In this case asthenospheric upwelling (the initial activity of the Late Mesozoic-Cenozoic mantle plume in Central Europe) would be responsible for alkaline magma penetration on the surface in several individual terranes of the megaprovince. The high content of volatiles in mantle generated magmas in some of the discussed provinces is in favour of the supposed metasomatized mantle being the source area of partial melting. After the Cretaceous period of alkaline volcanism (no Upper Mantle xenoliths have been reported yet) repeated alkaline volcanic activity appeared in the Pliocene-Pleistocene (= alkali basalts/basanites with the Upper Mantle xenoliths in the Pannonian region and adjacent parts of the Carpatians). From the point of view of rock types, the Cretaceous volcanic activity was more complex than the Late Cenozoic volcanism.

— The magmatic events in the Banat region of Rumania during the Late Cretaceous are characteristic for the Mesozoic history of the Carpathian arc. Their products — banatites — mostly have the features of subvolcanic bodies, but volcanics of the calc-alkaline clan are also present in smaller amount. The banatite magmatic activity reflects changed geodynamic conditions in comparison to those of the Lower to Middle Cretaceous.

— Determined affiliation of individual volcanic provinces to magma series (calc-alkaline versus alkaline), together with other criteria allow us to reconstruct the original setting of the sedimentary-volcanic complexes. The Drienok Nappe can be used as example of such reconstruction. Although it is situated in the central Western Carpathians zone, its original setting is connected with units which are part of the inner Western Carpathians zone (units of the Bűkk Mts.).

— Tectonic/dynamic synthesis of the Carpathian and Pannonian realm has devoted little or no attention to volcanic activity and its products. The worldwide opinion that modern geochemical and petrological studies bring valuable results for the solution of major geological/geodynamical problems also applies to the Carpathian and Pannonian realm.

Acknowledgement: In presented paper some results of project sponsored by the Slovak Grant Agency (Grant No. 1/1805/94) are presented. Author express his thankfullnes to both reviewers for their suggestions which improved the presented paper.

References

Andrusov D., 1945: Geological investigation of the Inner Klippen Belt in the West Carpathians. Part IV-V. *Práce Št. geol. úst.*, 13, 1-176.

Árkai P., 1973: Pumpellyite-prehnite facies Alpine metamorphism in the Middle Triassic volcanogenic-sedimentary sequences of the Bűkk Mountains, Northeast Hungary. *Acta Geol. Hung.*, 17, 67-83.

Árkai P., 1983: Very low- and low-grade Alpine regional metamorphism of the Paleozoic, and Mesozoic formations of the Bukkium, NE-Hungary. *Acta Geol. Hung.*, 27, 341-357.

Balla Z., 1984: The North Hungarian Mesozoic mafics and ultramafics. *Acta Geol. Hung.*, 27, 341-357.

Balla Z., 1985: Pre-Senonian mafic and ultramafic complexes of Hungary. *Proc. Repts. 13th Congr. CBGA, Craców, Poland. Part 1, Sect. 3, Magmatism and Metamorphism*, 363-366.

Balla Z., Baksa Cs., Földessy J., Havas L. & Szabó I., 1980: The tectonic setting of the ophiolotes in the Bűkk Mountains (North Hungary). *Geol. Zbor. Geol. Carpath.*, 31, 465-493.

Balogh K., 1964: Die geologischen Bildungen des Bűkk-Gebirges. *Ann. Hung. Geol. Inst.*, 48, 555-708.

Balogh K., Kozur H. & Pelikan P., 1984: Der Deckenstruktur der Bűkk Gebirge. *Geol. Paleont. Mitt.*, 13, 89-96.

Bilik I., 1974: Unterkretazische Vulkanite des Meczek-Gebirges. *Acta Geol. Hung.*, 18, 315-325.

Bilik I., 1983: Lower Cretaceous submarine (rift) volcanism in South Transdanubia (South Hungary). *Proc. 17th Asembly of the ESC*, Budapest, 569-576.

Birkenmajer K. & Skupinski A., 1989: On some volcanic and plutonic rock fragments from the Upper Cretaceous of the Pieniny Klippen Belt, Carpathians, Poland. *Stud. Geol. Pol.*, 92, 9, 69-78.

Birkenmajer K. & Wieser T., 1990: Tuffites from variegated beds of the Pieniny Klippen Belt mantle, Central Carpathians, Poland. *Acta Geol. Pol.*, 97, 9, 7-67.

Bleahu M., 1962: Recherches géologique dans le basin supérieur de Valea Ruscova (Monts de Maramures). *D. S. Com. géol.*, XLV, 290-308.

Cioflica G., Savu H., Nicolae L., Lupu M. & Vlad S., 1981: Alpine Ophiolitic Complexes in South Carpathian and South Apuseni Mountains. *12th Congr. CBGA, Guide to Exc. A3*, Bucuresti, 80.

Černov V.G., 1973: Paleogene conglomerates in the Pieniny Klipen zone of the Soviet Carpathians and their paleogeographical importance. *Sov. Geol.*, 5, 144-152.

Dercourt J. & Ricou E.L., 1990: Northern margin of Tethys. Paleogeographic maps 1:10,000,000 — Pl. 6: Barremian. S.G.F., E.S.R.I. *GÚDŠ*, Bratislava.

Dobosi G., 1986: Clinopyroxene composition of some Mesozoic igneous rocks of Hungary: the possibility of identification of their magma type and tectonic setting. *Ofioliti*, 11, 1, 19-34.

Dobosi G., 1987: Chemistry of clinopyroxenes from the Lower Cretaceous alkaline volcanic rocks of the Meczek Mountains, South Hungary. *Neu. Jb. Mineral., Abh.*, 156, 281-301.

Dobosi G. & Horváth I., 1988: High- and low-pressure cognate clinopyroxenes from the alkali lamprophyres of the Velence and Buda Mountains, Hungary. *Neu. Jb. Mineral., Abh.*, 158, 241-256.

Embey-Isztin A., 1981: Statistical analysis of major element patterns in basaltic rocks of Hungary. *Acta Geol. Hung.*, 24, 351-368.

Embey-Isztin A., Dobosi G., Noske-Fazekas G. & Árva-Sós E., 1989: Petrology of a new basalt occurrences in Hungary. *Miner. Petrol.*, 40, 183-196.

Guczwa I. & Wieser J., 1985: The limburgites of the Polish Carpathians. *Kwart. geol.*, 29, 3-30.

Harangi S., 1994: Geochemistry and petrogenesis of the Early Cretaceous continental rift-type volcanic rocks of the Meczek Mountains, South Hungary. *Lithos*, 33, 303-321.

Hohenegger L., 1861: Die geognostischen Verhaltnisse der Nordkarpaten in Schlesien und den angrenzenden Teilen von Mähren und Galizien etc. Gotha.

Horváth F., Vörös A. & Onouha K.M., 1977: Plate tectonics of the western Carpatho-Pannonian region: A working hypothesis. *Acta Geol. Sci. Hung.*, 21, 207-229.

Horváth I., Darida-Tichy M. & Ódor L., 1983: Magnesitiferous dolomitic carbonatite (beforsite) dyke rock from Velence Mountains. *Magy. Áll. Földt. Intéz. Évi Jelent., 1981-ról*, 369-389 (in Hungarian).

Horváth I. & Ódor L., 1983: Alkaline ultrabasic rocks and associated silicocarbonatites in the NE part of the Transdanubian Mts. (Hungary). *Miner. slovaca*, 16, 115-119.

Hovorka D., (in print): Carpathian Arc and Pannonian Basin Mesozoic ophiolites.

Hovorka D. & Slavkay M., 1966: Picrite of Poníky. *Geol. Práce, Spr.*, 39, 41-51 (in Slovak).

Hovorka D. & Spišiak J., 1988: Mesozoic volcanism of the Western Carpathians. *Veda*, Bratislava, 1-220 (in Slovak).

Hovorka D. & Sýkora M., 1979: Neocomian alkaline volcanics of the Krížna Nappe in the Veľká Fatra Mts. *Čas. Mineral. Geol.*, 24, 4, 371-383 (in Slovak).

Juhász A. & Vass G., 1977: Mesozoische Ophiolithe im Beckenuntergrund des Grosser Ungarischen Tiefebene. *Acta Geol. Hung.*, 18, 349-358.

Kubovics I., 1985: Mesozoic magmatism of the Transdanubian Mid-Mountains. *Acta Geol. Hung.*, 28, 3-4, 141-158.

Kubovics I., Szabó Cs. & Gál-Sólymos K., 1989: A new occurrences of lamprophyre: Buda Mountains, Hungary. *Acta Geol. Hung.*, 32, 149-168.

Kubovics I., Szabó Cs., Harangi S. & Józsa S., 1990: Petrology and petrochemistry of Mesozoic magmatic suites in Hungary and adjacent areas—an overwiew. *Acta Geod. Geophys. Mont. Hung.*, 25, 3-4, 345-371.

Kudělásková J., 1987: Petrology and geochemistry of selected rock types of teschenite association, Outer Western Carpathians. *Geol. Zbor. Geol. Carpath.*, 38, 545-573.

Lazarenko E.K., Lazarenko E.A., Baryšnikov E.K. & Malygina O. A., 1963: Mineralogy of Transcarpathian Region. *Izd. Lvov. Univ.*, Lvov, 1-614.

Lomize M.G., 1968: Post-Jurassic vulcanism of the Eastern Carpathians. *Vest. Mosk. Univ., Ser. Geol.*, 6, 42-58 (in Russian).

Mahmood A., 1973: Petrology of the teschenitic rocks series from the type area Cieszyn (Teschen) in the Polish Carpathians. *Rocz. Pol. Tow. Geol.*, 43, 153-212.

Mišík M., 1992: Pieniny Klippen Belt in relationship with Mesozoic and Tertiary volcanism. *Západ. Karpaty, Sér. Geol.*, 16, 47-64.

Mišík M. & Sýkora M., 1981: Pieniny exotic ridge reconstructed from the pebbles of carbonate in the Cretaceous conglomerates, Klippen Belt and Manín unit. *Západ. Karpaty, Sér. Geol.*, 7, 7-111.

Morogen V., Upton B.G.Z. & Bindea G., 1995: Petrogenesis of the Ditrau complex, East Transilvania, Romania. *Terra Abstr.* Suppl. 1, 7, 302.

Narębski W., 1990: Early rift stage in the evolution of western part of the Carpathians: geochemical evidence from limburgite and teschenite rock series. *Geol. Zbor. Geol. Carpath.*, 41, 5, 521-528.

Nastăseanu S., Bercia I., Iancu V., Vlad S., & Hartopanu I., 1981: The Structure of the South Carpathians (Mehedinti-Banat Area). *12th Congr. CBGA, Quide to Exc. B2*, Bucuresti, 1-100.

Nicolae I., 1985: Ophiolites of the Trascau mountains (south Apuseni Mts.). *D. S. Inst. geol. geofiz.*, LXV, 143-205.

Pacák O., 1926: Volcanic rocks of the northern base of Moravské Beskydy Mts. *Rozpr. Čs. Akad. Věd a um., Ř. mat-přír. Věd*, 27, Praha, 1-98 (in Czech).

Pantó G., 1961: The mesozoic magmatism in Hungary. *Ann. Hung. Geol. Inst.*, 49, 979-995.

Prey S., 1975: Neue Forschungsergebnisse uber Bau und Stellung der Klippenzone des Lainzer Tiergarten im Wien (Osterreich). In: M. Maheľ (Ed.): *Tectonic problems of the Alpine system. Veda*, Bratislava, 57-68.

Rădulescu D.P. & Sandulescu M., 1973: The plate-tectonic concept and the geological structure of the Carpathians. *Tectonophysics*, 16, 2, 155-161.

Russo-Săndulescu D., Udrescu C. & Modesan A., 1981: Petrochemical characteristics of the Mesozoic ophiolites of the Rarau-Hagimas Marginal Syncline. *D. S. Inst. géol. géofiz.*, LXL1, 1.

Russo-Săndulescu D., Săndulescu M., Udrescu C., Bretosin I. &

Modesan A., 1983: Le magmatisme d'age mésozoique dans les Carpathes orientales. *Ann. Inst. géol. géophys.*, LXI, 245-252.

Rybár M. & Kantor J., 1978: Radiometric data from the West Carpathians: ages from eruptive rocks from Upohlav conglomerates, Klippen Belt (I). *Manuscript, Archív GÚDŠ,* Bratislava (in Slovak).

Săndulescu M., 1975: Essai de synthése structurale des Carpathes. *Bull. Soc. Géol. France,* 17, 3, 299-358.

Savu H., 1980: Ophiolitic rocks and other initial magmatites in the Carpathians. *Ophioliti, Tethyan ophiolites. Spec. Issue,* 97-104.

Savu H., 1983: Geotectonic and magmatic evolution of the Mures zone (Apuseni Mts.)—Roumania. *An. Inst. géol. géoph.*, LXI, 253-261.

Savu H., Nastaseanu S., Lupu M. & Nicolae I., 1978: Ophiolites and sedimentary formations in South Apuseni and Southern Carpathians. *Guidebook for the Field Works of the 2.1 and 2.2 Groups,* Bucuresti, 43.

Savu H., Udrescu C. & Neacsu V., 1981: Geochemistry and geotectonic setting of ophiolites and island arc volcanics of the Mures zone (Roumania). *Ofiolity,* 6, 269-286.

Savu H., Udrescu C., Neacsu V. & Stoian M., 1992: The Costei basalts: products of a pre-Mures ocean continental intra-plate volcanism. *Rev. Roum. Géol.*, 36, 35-44,

Slavkay, M. 1965: Vulcanogene rocks of Mesozoic near Poníky. *Čas. Mineral. Geol.*, 10, 3, 249-259 (in Slovak).

Slavkay M., 1979: Further occurrences of ultrabasic effusive rocks in Choč and Krížná Nappes in the vicinity of Banská Bystrica. *Miner. slovaca,* 11, 3, 239-245 (in Slovak).

Smulikowski K., 1929: Les roches éruptives de la zone subbeskidique en Silesie et Moravie. *Kosmos,* A, Lwów, 54.

Streckeisen A. & Hunziker C.J., 1974: On the origin and age of the nepheline syenite massif of Ditro (Transylvania, Rumania). *Schweiz. Mineral. Petrogr. Mitt.*, 54, 1, 59-77.

Szabó Cs., Kubovics I. & Molnár Zs., 1993: Alkaline Lamprophyre and Related Dyke Rocks in NE Transdanubia, Hungary: The Alcsutdoboz-2 (AD-2) Borehole. *Min. Petrol.* 47, 127-148.

Szádeczky-Kardoss E., Juhász A., Pantó G., Szepesházy K. & Széky-Fux V., 1967: Der ophiolitische Magmatismus in Ungarn. *Acta Geol. Hung.*, 11, 71-76.

Szentpétery Zs., 1953: Le massif de diabase et de gabbro de la partie méridionale de la Montagne Bukk. *Magy. Áll. Földt. Intéz. Évk.*, 41, 1, 1-91.

Szepesházy, K. 1977: Mesozoic igneous rocks of the Great Hungarian Plain. *Bull. Hung. Geol. Soc.*, 107, 384-397 (in Hungarian, English abstract).

Šímová M., 1985: Magmatogene Gesteine kretazischer Konglomerate des westlichen Teiles der Klippen- und Manín Zone der Westkarpaten. *Západ. Karpaty, Sér. Min., Petr., Geoch., Metal.*, 10, 91-110 (in Slovak, German abstract).

Tkachuk L.G., Lozynjak P.Ju., Reifman L.M., Spitkovskaja S.M. & Danilovič Ju.P., 1977: Pyroclastic rocks of the Carpathian region. In: Tkačuk L.G. (Ed.): *Ukrainian pyroclastic rocks. Naukovaja dumka,* Kijev, 4-69 (in Ukrainian).

Tollmann A., 1972: Der karpatische Einfluss am Ostrand der Alpen.. *Mitt. Geol. Gessell. (Wien),* 64, 173-208.

Tollmann A., 1985: Geologie von Österreich. Bd. 2. *F. Deuticke,* Wien, 1-710.

Tschermak G., 1866: Felsarten von ungewohnlicher Zusammensetzung in der Umgebung von Teschen und Neutischein. *Sitzungber. Akad. Wiss.*, Wien.

Viczián I., 1970: Geotektonische Beziehungen des unterkretazischen Alkalimagmatismus miogeosynklinale characters im Meczek-Gebirge. *Földt. Közl.*, 100, 372-378 (in Hungarian, German abstract).