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THE WEST CARPATHIANS MESOZOIC AND CENOZOIC BESALTS

(Fig. 1—9)

Abstract: The West Carpathians Mesozoic and Cenozoic basalts belong to 3 from stratigraphical and petrological point of view different units: a) Triassic paleobasalt of the „diabase"-spilite-keratophyre association are members of the "incomplete ophiolite formation" of the Gemerides; b) Upper Jurassic-Low Createaceous volcanites of the Inner West Carpathian zones are represented by weakly unsaturated alkali basalts to basanites (alkali olivine basalts, basanites, limburgites, augitites); c) Cenozoic basalts of the Inner West Carpathians show the character of basalts of calc-alkaline rock series, and that of alkali olivine basalts of striking unsaturated character.

Резюме: Западнекарпатские мезозойские и кайнозойские базальты приурочены к трем различным с точки зрения стратиграфии и петрологии единицам: а) триасовые палеобазальты «диабаз»-спилит-кератофировой ассоциации относятся к «неполной офиолитовой формации» гемерид; б) верхнеюрские-нижнемеловые вулканиты зон Внутренних Западних Карпат представлены слабо ненасыщенными щелочными базальтами до базанитов (щелочные оливиновые базальты, базаниты, лимбургиты, авгититы); в) кайнозойские базальты Внутренних Западных Карпат имеют характер базальтов известково-щелочных серий и также характер чрезмерно ненасыщенных щелочных оливиновых базальтов.

Introduction

The last decades shifted definitely the region of basic magma generation into the Upper Mantle of the Earth. At the same time a number of geophysical, petrologic and geochemical criteria have been elaborated and tested to solve the basic magma generation depth. Simultaneously their division into groups (calc-alkaline, tholeiitic, the group of "primitive" basalts etc.) is a clear progress in knowledge of volcanic complex petrogenesis. Whereby the opinion was accepted by most authors, that differences in Upper Mantle composition (continental, oceanic, intermediate type of the crust, the type of oceanic and continental rift zones, type of the island arc crust etc.) might be one of the reasons for the genesis of different effusive associations.

Fundamental changes of views concerning the volcanic activity in space and time were brought about by ideas designated in its entirety "new global tectonics". For island arc regions, as well as for regions of interaction of oceanic and continental plate types a scheme was elaborated at present illustrating the dependence of volcanism on depth of the Benioff zone, i. e. on the distance from oceanic trenches etc. It should be noted here, that the problem of volcanic complex petrogenesis in regions of potential plate colision of the continent: continent type (Alpine-Carpathian or Tethys type) is not so definite as in the case of the island arcs of the Pacific region.

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For contamporaneous petrogenetic models is characteristic, that they suggest partial melting of basaltic magmas from the Upper Mantle pyrolite, or peridotite. The well known characteristic chemical variability of the basaltic magmas may be explained as the consequence of different pressure during partial melting, i. e. by various depth of basic magmatic mass genesis; the differences in chemical composition of various basalt types may be due also to various degree of partial melting (D. H. Green – A. E. Ringwood 1968, D. W. Gast 1968), eventually to local different composition of the Upper Mantle compared with its "average" composition. The idea generally accepted is that alkali olivine basalts do originate by partial melting of Upper Mantle material at high pressures (indicating at the same time the great depth of this magma type formation); a small amount only of the total Upper Mantle mass (up to 5 %) being melted. Tholeitic basalts generate by melting of a larger volume of Upper Mantle material at lower pressures (melting of up to 30 % of the Upper Mantle).

Water content in the Upper Mantle (R. W. Kay et al. 1970), the amount of imported heat, tectonic (seismic) processes conditioning different pressure relations (D. W. Gast 1968) or other factors are designated as facts influencing the amount of melted Upper Mantle material.

Triassic paleobasalts of the "diabase"-spilite-keratophyre association

Basic effusives and the relevant pyroclastic members are situated in the Triassic of the southernmost tectonic unit of the Inner West Carpathians – the Gemericum. They build one of the members of the "incomplete ophiolite group" of this tectono-geological unit. Analoguously as the basic effusives of other ophiolite groups s. l. paleobasalts of the Gemeride Triassic have the character of diabases, diabase porphyrites, spilites sporadically even granular doleritic types. Problems of their geological occurence, the petrographic nature of the basic types and their chemical compositions are given in J. Kantor's (1955) and J. Kamenický's (1957) papers. Local transitions of diabase rock types into spilites and keratophyres are characteristic (rarely even to quartz keratophyres), so that the whole volcanic sequence shows the character of diabase-spilite-keratophyre formations (D. Hovorka 1977), being frequently members of ophiolite groups.

On the triangle diagram $CaO : Na_2O : K_2O$ (Fig. 1 A) Na – Ca nature of the basic members of the Triassic Gemeride diabase-spilite-keratophyre formation is striking. The keratophyres are of conspicuous natrium character. On the $MgO : FeO_{total} : Na_2O + K_2O$ diagram (Fig. 1 B) the trend of the "diabase"-spilite-keratophyre formation stands near to that of Mesozoic volcanics of the Alps (A), the Ural (U) and New Zealand (NZ).

The spilitic trend the basic effusive rocks from the Gemeride Triassic is documented in their chemical composition by the ratio $CaO/Na_2O - < 1{,}5$, in the mineral composition of volcanites it is displayed by the presence of acid plagioclases and by spilitic rock structures.

In the projection field with CaO and Na_2O axes as critical oxids of the rock sequence basalts-spilite-keratophyre the projection points of the analyzed volcanics in the Triassic of Spišsko-gemerské rudohorie Mts. are presented (Fig. 2). The high CaO values dispersion at paleobasalts (diabases) is generally due to the considerable portion of secondary carbonates, appearing prevalently as vein filling. In case of the pertinent CaO linkage to CO_2 for calcite formation, the CaO : Na_2O ratio decreases from diabases (paleobasalts) over spilites up to keratophyres.

At low MgO contents and iron oxid sums the courses of the differentation curve of basic volcanic in Triassic of Spišsko-gemerské rudohorie Mts. (Gemericum) approaches maximally the course of the curve for the calc-alkaline effusive rock series. Compared with the shape of the calc-alkaline, the alkaline

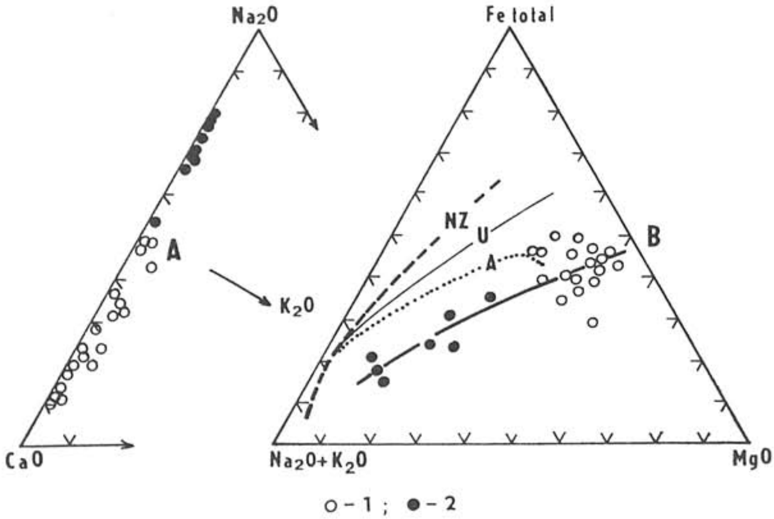

Fig. 1. 1 – "Diabases" from the Gemeride Triassic; 2 – Keratophyres from the Gemeride Triassic.

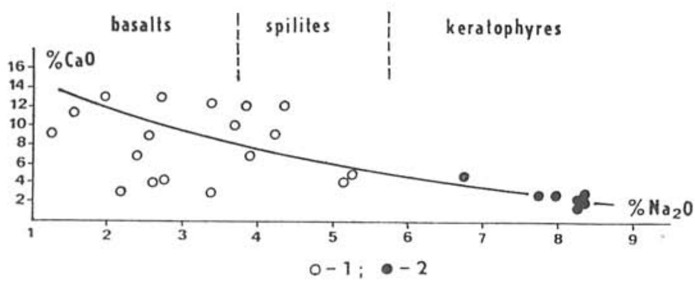

Fig. 2. 1 – "Diabases" from the Gemeride Triassic; 2 – Keratophyres from the Gemeride Triassic.

and tholeiitic curve, the effusive series is differently shaped (Fig. 3). The contact-thermic effect of basic volcanics on the Low Triassic of schists and sandstones development (Werfenian) and the Middle Triassic carbonate complexes determinates their low stratigraphical boundary. Local contact-hydrothermal action on ultrabasic massifs (Bretka, Jaklovce) determinates their relation to ultrabasic massifs protrusion (D. H o v o r k a – J. Z l o c h a 1974).

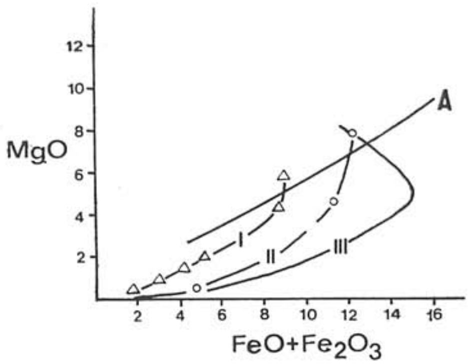

Fig. 3. I — Calc-alkaline rocks series (S. R. Nockolds 1954), II — Hawaii alkaline rocks series (average composition of hawaiite, mugearite and trachyte — G. A. MacDonald — T. Katsura 1964); III — Tholeiitic Thingmuli series of Island: A — "Diabases" from the Gemeride Triassic.

Upper Jurassic — Low Cretaceous volcanic of the Inner West Carpathians

Basic effusive and explosive rocks of the Upper Jurassic and Low Cretaceous of the Inner West Carpathians appear on a largespaced area; in the form of sporadic occurences they are known from the Mesozoic envelope series (Ďumbier and High-Tatra series), from overthrusted series (Križná and Manín series) and from the mantle of the Klippen belt of the river Váh valley. In addition to lava flows (noticeable on some localities only) with local fluidal to ropy structures (Z. Kotański — A. Radvanski 1960), lava brecciae, hyaloclastites and fine volcanoclastic material predominates. Among the effusive rocks amygdaloidal types dominate; the effusions took place under shallow-water conditions — over the zone of vesiculation depth. Basic volcanic sporadically (Višňové, Ďumbier) form hypoabysal bodies in Middle Triassic carbonate complexes. On the basis of petrographical features, mineral and chemical composition they may be assigned also to the Upper Jurassic-Low Cretaceous volcanic formation.

Basic volcanics of the Upper Jurassic-Low Cretaceous show the character of originaly often glassy, mostly feldsparlacking, intensively autometamorphosed basaltic rocks. According to present classification schemes the whole association may be designated as "alkali olivine basalts up to basanites". These are alkali effusives partly unsaturated character (normative nepheline), among which augitite, limburgites, augitite and limburgite porphyrites and amygdaloidal types of above mentoined rock-types (S. Kreutz 1909, V. Zorkovský 1949) had been described in the past. One part of these effusive types may be designated as "basanites" or "basanitoides" (following Mac Donald — T. Katsura 1964 terminology).

The mineral composition of rocks belonging to this association is comparatively simple. Representatives of the I. generation are olivines (completely serpentinized and chloritized). Ti-augites, barkevitic brown amphiboles, sporadic biotite and plagioclases. In the matrix the II. generational of these minerals appears, as well as ore minerals, rarely also nepheline. Originally also volcanic glass was present. In amygdaloidal types the amygdale filling is made up of carbonates, chlorite and in places even of zeolites, following high alkali contents in amygdale rock-types.

In case of effusive and extrusive rocks in the Krížna unit the volcanic activity took place prior to its shifting i. e. in its sedimentation area. This follows from the deformation of the adjacent carbonates by basic effusive hyaloclasts still in the stage of their unconsolidated character (M. S ý k o r a 1975).

Contact-thermic effects of the volcanites belonging to this association are unconspicuous. They displayed particularly in the case of hypabysal bodies by recrystallization of the adjacent carbonates, while intensive hydrothermal alteration followed after thermic recrystallization. Owing to this alteration in exocontact zones with increased oxid and Fe hydrate sporadically sulfide content generated. The width of these transformed zones is usually few centimetres only.

While it was so far not possible to interprete definitelly the effecs of assimilation acting in deeper levels of the Earth crust, the nature of the assimilation processes acting closely prior to the extrusion (effusion) was interesting. On one side intensive chemical reactions are noticeable between xenoliths of carbo-

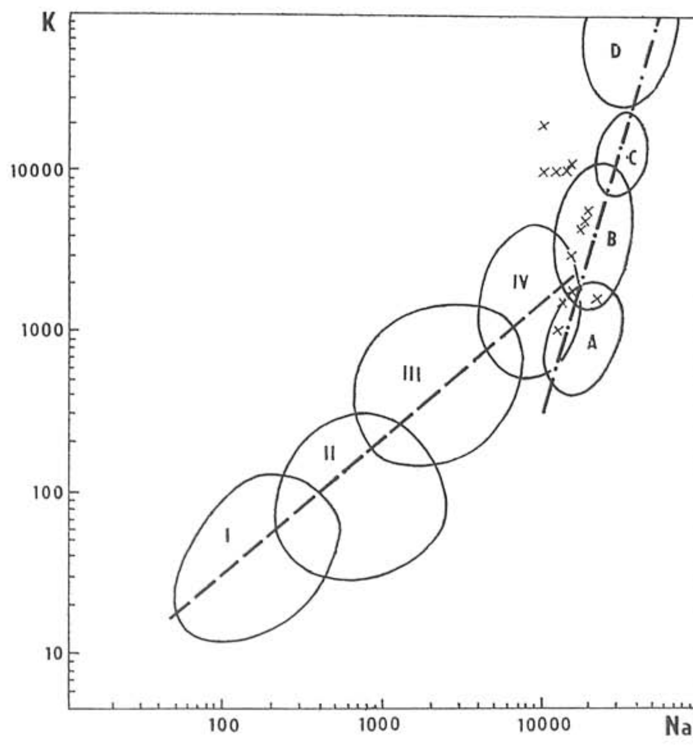

Fig. 4. I — Field of the alpine-type peridotites; II — Field of the spinel peridotites; III — Field of the garnet peridotites; IV — Field of the Upper Mantle eclogites; A — Field of the oceanic tholeiites; B — Field of the continental tholeiites; C — Field of the alkali olivine basalts; D — Field of the K-basalts (all fields according to B. G. Lutc 1975). 1 — Upper Jurassic-Low Cretaceous volcanites of the Inner West Carpathians.

nate rocks and the magma under the formation of III. amphibole and pyroxene generation, which "grow over" into the xenolith space of the rock matrix; on the other side in some lava flows carbonate rock xenoliths were found with still preserved needle pattern (Ďumbier).

Upper Jurassic-Low Createaceous volcanics are marked by extremely SiO_2 contents (38 – 42 % SiO_2 - the rocks were analyzed after amygdale separation).

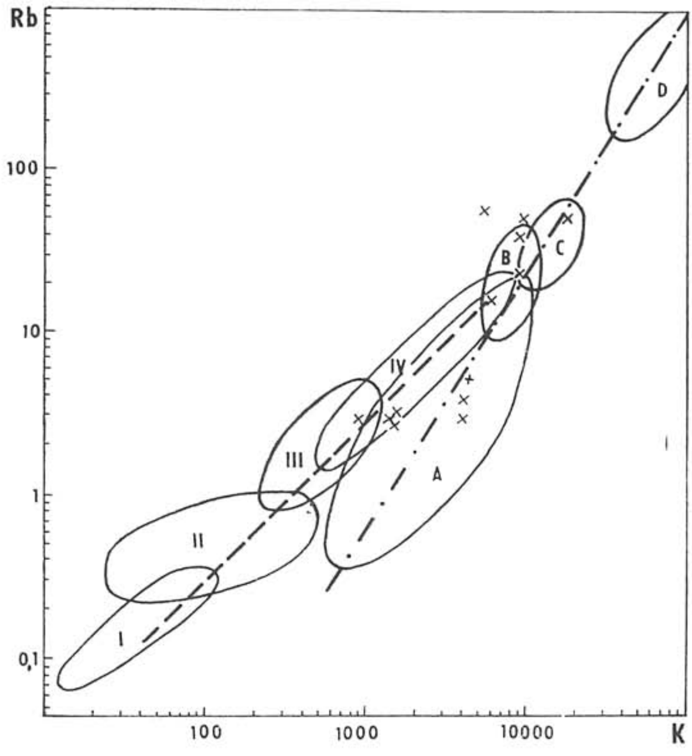

Fig. 5. Explanation see fig. 4.

This genetic attribution to the group of basalts and not to that of "primitive" ultrabasic effusives of the komatiite, meimechite or picrite type is evident. It follows from the low contents of magnesium (8 – 11 % MgO), nickel, chromium, cobalt and from the high alkali and aluminium contents. The correlation ratios of couples show also trends typical for basaltis rocks and not undifferentiated of weakly differentiated rock associations of the Upper Mantle. Thus Na and K ratios expressed in the logarithmic scale (Fig. 4) follow at lower K contents the line of basaltic effusive rocks and the projection points of the Upper Jurassic–Low Createaceous volcanics lie in the fields of oceanic and continental tholeiites while at higher K contents they deviate from the "basalt line" (B. G. Lutc, 1975). In turn the projection points of Jurassic-Createaceous volcanic in the diagram with Rb: K axes (Fig. 5) show considerable dispersion. On the whole at lower values the Rb projection points are near to the line of various undifferentiated, or less differentiated Upper Mantle rock types, at higher values the Rb projection points follow the line of different basalts types and lie in the fields of oceanic and tholiitic basalts and that of alkali basalts.

Cenozoic basalts of the Inner West Carpathians

At the inner side of the Carpathian arc in the Cenozoic volcanic province also effusive rocks with basaltic chemical composition appear besides the predominating intermediate or even acid types. The rock types designated as basaltic andesites, andesitic basalts, basalts and basanites are present on various sites of Kremnicko-štiavnické pohorie Mts. and in the region Podrečany—Lučenec—Fiľakovo. The main problem of their geological position, structure, petrography and chemical composition may be found particularly in the papares of F. Fiala (1938a, 1938b, 1952, 1962), M. Šímová (1965), A. Mihaliková (1966), K. Karolus (1970, 1973), M. Kuthan (1968 — in T. Buday et al., 1968), J. Forgáč (1970), J. Forgáč — G. Kupčo (1973) and others.

Recently the Cenozoic basalts were devided into two basic groups: basaltic andesites, andesitic basalts and olivine andesites resp. (F. Fiala, 1962) build according to M. Kuthan (1963) products of the "preparative" phase of final volcanism (in the H. Stille's 1953 sense), whose product are various basalt types. The basaltic andesite and andesitic basalts are Miocene — Pliocene in age, those of the "final" basalt types is Pliocene-Pleistocene (V. Čechovič, 1959; O. Fejfar, 1957).

Actually there is disagreement in the attribution of basalt affusives to any petrographical suite, or province. J. Fiala (1962) for example assigns the basalts definitely to alkali rocks. M. Šímová (1965) and A. Mihaliková (1966) characterized basalts as alkali effusives, which gained their alkali nature by gradual differentiation of calc-alkaline magma type. Based on the modal and normative composition A. Mihaliková — M. Šímová (1956) differentiated 2 basalts types: 1. tholeiitic, 2. alkali basalts. According to this authors (1. c.) the process of basaltic magma development was conditioned by gravitational and crystalizational differentiation of the calc-alkaline type of the parent magma. J. Forgáč et al. (1968) stated the calc-alkaline trend of andesitic basalts, while the products of final volcanism (II. type of this paper) are marked by subalkali chemical composition. K. Karolus (1970) characterized the products of final basalts (i. e. Miocene — Pleistocene) volcanism as "subalkali basalts". From the recent period the papers of J. Forgáč (1970), J. Forgáč — G. Kupčo (1973) are valuable, where analytical data for both basalt types are given. According to these authors (1. c.) basaltic andesites (type I of this paper) represent the differentiation product of the calc-alkaline parental magma, while for the "final" basalts (type II) they considered both alternatives of their origin, leaving the problem open.

Recently the Cenozoic West Carpathian and in adjacent part of Pannonian massif situated volcanics were the subject of interest particularly in relation to the solution of the dependance of volcanic complexes to the global tectonic phenomena (J. Lexa — V. Konečný, 1974: L. Stegena et al., 1975; E. Szádecky-Kardoss, 1975). These authors disagree in views concerning the problem of basalts linkage to the subduction zones. While E. Szádeczky-

Kardoss (1. c.,) brings the young volcanic effusives (basalts included) into unequivocal dependent relation to tectonic elements of global extent (subduction zones), other authors (J. Lexa – V. Konečný, 1974; L. Stegena et al., 1975 and others) regard volcanic activity during the Cenozoic era as the result of diapyre penetration of the Upper Mantle in the adjacent Pannonian block.

From this brief survey follows the variability of views on the assignment of the West Carpathian Cenozoic basalts to petrogenetic volcanite suites.

Present knowledge on the geological occurence and nature of the West Carpathian Cenozoic basalts may be summarized as follows.

I. Basaltic andesites, andesitic basalts, olivine andesites are in the next designated as basalts s. 1. of the calc-alkaline suite (type I. of this paper). They are known from several volcanic mountain chains of central and eastern Slovakia. Based on their close relations to volcanic rocks of the calc-alkaline suite and on their chemical composition I consider them as final members of the differential suite of the calc-alkaline sequence (rhyolite?)—dacite—andesite – calk-alkali basalt.

II. Alkali olivine basalts, basanites, limburgite basanites build a separate, definite alkaline unsaturated association (type II of this work). Compared with basalts of the calc-alkaline type, the alkali olivine basalts s. 1. are generally younger in age. They represent the product of changed tectonic regime in the contact area of the Tatric and Pannonian block during the Pliocene-Pleistocene era.

The following observations result from the evaluation of accessible data concerning Cenozoic West Carpathian basalts.

Differentiation of the calc-alkali magma in the West Carpathian Cenozoic volcanic province was accomplished substantially in the suite rhyolite (?) —dacite —andesite calc-alkali basalt. The relations among the members within calc-alkali association are not yet solved definitely. The diversity of the other basalt group (type II) compared with the volcanics of the above mentioned suite follows from their different chemical composition, particularly the diverse content of some trace elements (J. Forgáč, 1970, J. Forgáč – G. Kupčo, 1973). White the content level especially of the iron group metals in the suite dacite – andesite – calc-alkali basalt is balanced (decreases gently, or increases), these element contents in alkali olivine basalts-basanites differ by range as a rule. A similar external position of alkali olivine basalts related to volcanics of the calc-alkali suite may be found also in the projection according to A. N. Zavaritski (K. Karolus, 1970).

It is typical for alkali olivine basalts s. 1. (type II) that in spite of the large-space extension of volcanics of the calc-alkali suite on the inner side of the Carpathian arc in its northern part, basalts of this type are known from Kremnicko-štiavnické rudohorie Mts. and from the region of Podrečany—Lučenec—Fiľakovo only.

The origin of genetically different volcanic formations in the Cenozoic of the West Carpathian arc (calc-alkali : alkali formation) reflects the geodynamical conditions in the period of their formation. While the calc-alkali volcanic formation has generated under compression conditions the area of magma generation in geotectonic sense the product of orogenic volcanism ("sinorogenic calc-alkali formation"), for the creation of the alkali olivine basalt (+ basanites) formation ("postorogenic alkali basalt formation") these are processes of lateral dilatation–pressure relax (L. Stegena et al. 1975) which are the determinative conditions.

Following results of experimental works (D. H. Green – A. E. Ringwod, 1967; O'Hara, 1968) alkali basalt do generate in the Upper Mantle in depths of 40–100 km. Applying this notion for the region of Kremnicko-štiavnické rudohorie Mts. the established presence of deep-seated magmatic masses

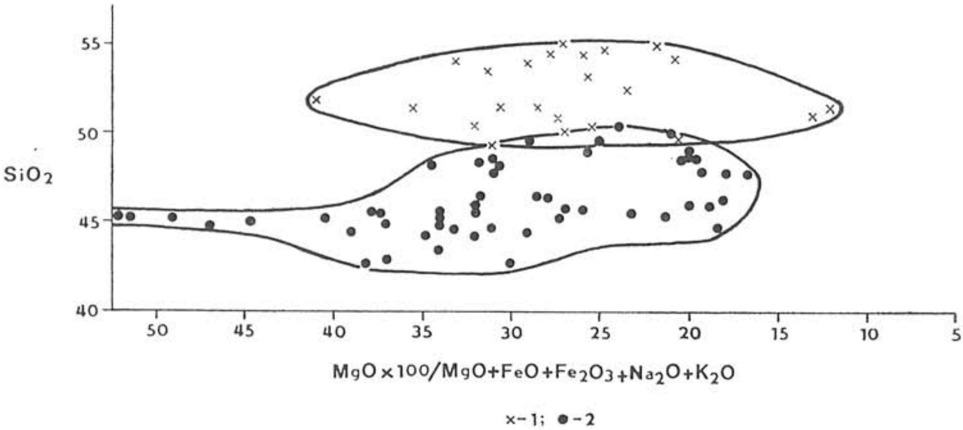

Fig. 6. 1 – The West Carpathian Cenozoic basalts of the calcalkaline rock series; 2 – The West Carpathian Cenozoic basalts of the alkali olivine basalts clan.

(J. Forgáč et al. 1968) must be taken into consideration, which masses might be the reservoir of calc-alkali magmas of the Cenozoic volcanics. Thus the genesis of the successing alkali olivine basalts s. l. is due to change of the tectonic regim in the total region – a consequence of stress release on the boundary between the Tatric and Pannonian block, on which boundary the Upper Mantle low differentiated masses had penetrated (prostorogenic alkali olivine basalt formation).

On the diagram SiO_2: solidification index (Fig. 6) the vertical range of the basaltic andesite (calc-alkali basalt) and alkali olivine basalt fields is different. Owing to high SI one part of the alkali olivine basalts brings about a striking elogation of the field towards the high SI values. At the same time the fields of the basalt groups I and II are overlapping only in the small extent of the SiO_2 values.

On the $SiO_2 : Na_2O + K_2O$ diagram (A. E. K. Middelmost, 1973) the majority of the analyzed basic effusive rocks falls into the basalt field (Field II), the smaller part into the field "anepic" (field I) and one part of the analyses also in the andesite field (field III). Analyses of the rock group I (type I) fall in the projection field of subalkaline basalts, while a part of the projection points of this rock group lies also in the alkali basalt field. In turn the majority of the projection poins of the II type basalts lies in the field of alkaline to hyperalkaline basalts, eventually even in the hyperalkaline rock group "anepic" (Fig. 7). The development of basalt differentation of both groups-type I and type II (of the West Carpathian Cenozoic volcanic province is similar to the development of

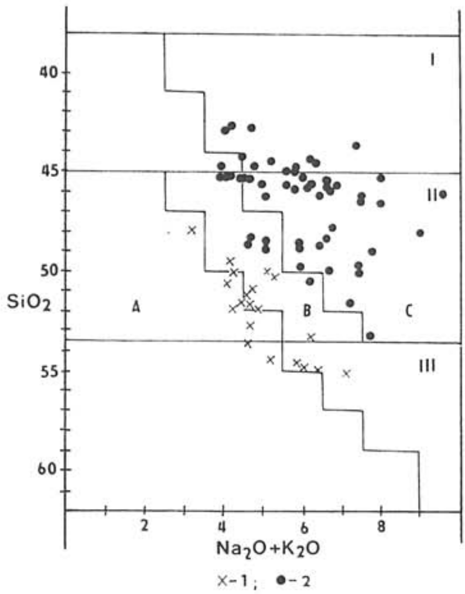

Fig. 7. A part of E. A. K. Middlemost's (1973) diagram, I — Anepic field; II — Basalt field; III — Andesite field; A — Subalkaline rocks types; B — Alkaline rock types; C — Hyperalkaline rock types; 1 — The West Carpathian Cenozoic basalts of the calcalkaline rock series; 2 — The West Carpathian Cenozoic basalts of the alkali olivine basalt clan.

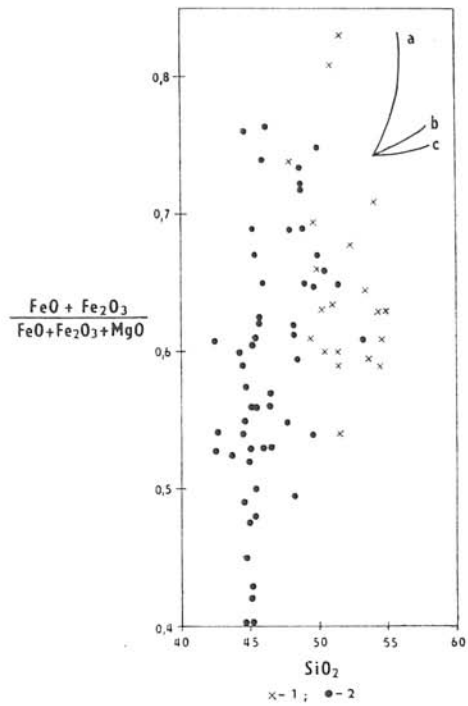

Fig. 8. 1 — The West Carpathian Cenozoic basalts of the calcalkaline rock series; 2 — The West Carpathian Cenozoic basalts of the alkali olivine clan.

differentiation under constant pressure — E. F. Osborn, 1959), and corresponds of genesis of these volcanics.

From the graphical representation (Fig. 8) it results that the group of alkali olivine basalts is marked by a higher range of $FeO + Fe_2O_3/FeO + Fe_2O_3 + MgO$ values. In the AFM diagram (Fig. 9) the projection fields of Triassic, Jurassic-Gretaceous and Cenozoic basalts of the Inner West Carpathians are partly overlaping. The alkali nature of the Cenozoic basalts reveals by partial shift of their projection field towards the peak A.

Differentiation processes in the alkali olivine basalt association itself were of unconsiderable extent. Basic and also predominating rock types are alkali olivine basalts s. s. and basanites. Owing to the presense of modal nepheline these types are of conspicuos unsaturated nature. In agreement with the worldover trend of rock name simplification, the whole alkali basalt assemblage of the West Carpathian Cenozoic should be designated as association of "alkali olivine basalt s. 1.". This denomination follows from the present chemical classifications (H. Kuno, 1960, Mac Donald – T. Katsura, 1964; A. E. K. Middlemost, 1973; 1975; B. N. Church, 1975) and is in agreement with classification scheme of H. S. Yoder – C. E. Tilley, 1962 and P. Jakeš – A. J. R. White, 1972) etc.

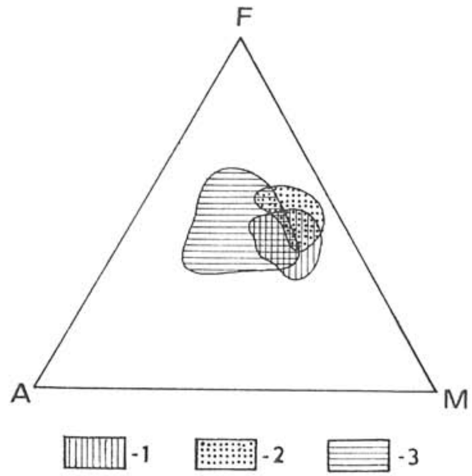

Fig. 9. 1 – Basic volcanics in the Gemeride Triassic; 2 – Volcanics of the Upper Jurassic – Low Cretaceous age of the Inner West Carpathian; 3 – The West Carpathian Cenozoic basalts of the calc-alkaline rock series.

Conclusion

In spite of the large surface extent of the sedimentary area in the Triassic, volcanic activity was known only at the southernmost geological – tectonic unit of the West Carpathians – the Gemericum. The basic effusive rocks in this formation are the member of the "diabase"-spilite-keratophyre association genetically allied with the members of the "incomplete ophiolite formation" of this unit.

Upper Jurassic-Low Cretaceous volcanics are present on a large surface areal, while individual occurences appear in various distances from the tectonic lineaments ("peripienian lineament"). Their penetration to the bottom of the sedimentation areas of the different units was not controled by lawful bond to this global tectonic fenomenon.

The West Carpathian Cenozoic basalts belong to two associations: a) calc-alkaline, b) alkali. The differentiated associations are marked by different age, mineral and chemical composition. The genesis of two basalt associations is due to different tectonic conditions: to compression (calc-alkaline association) and to space dilatation (alkaline association).

Translation L. Mináriková

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Review by B. CAMBEL Manuscript received October 25, 1976