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PETROCHEMICAL CORRELATION AND I/S CLASSIFICATION OF VARISCAN GRANITOIDS FROM THE CZECH MASSIF, WEST CARPATHIANS (CZECHOSLOVAKIA), AND THE CAUCASUS MTS. (USSR)

(Figs. 1—7)

Abstract: Variscan granitoids from the Czech Massif, West Carpathians and Caucasus Mts. were correlated on the basis of 2000 chemical analyses of the dominant rock types. Granitoids from the Caucasus Mts. and the Czech Massif are similar, but differ from those for granitoids of the West Carpathians.

According to I/S classification (Chappell and White, 1974) most Variscan granites of the Czech Massif belong to the S-type. The I-types are less common and are represented by granitoids of the tonalite formation (Central Bohemian Pluton). The same pattern holds for Variscan granitoids from the Caucasus Mts. West Carpathian granitoids have a varying proportion of both types in individual crystalline blocks.

Резюме: Варискне гранитоиды из Чешского массива, Западных Карпат и Кавказа были сопоставлены на основании 2000 химических анализов главных типов пород. Гранитоиды из Кавказа и Чешского массива породные, а отличаются от гранитоидов Западных Карпат.

По I/S классификации (Чепл и Вайт, 1974) большинство вариских гранитов Чешского массива принадлежит S типу. I типы являются меньше общее и представляют их гранитоиды тоналитической формации (центральный чешский плутон). Одинаковый узор действительным для вариских гранитоидов из Кавказа. Западнокарпатские гранитоиды имеют разняющиеся пропорции сбоих типов в отдельных кристаллических блоках.

Introduction

Granitoids have long been in the center of attention because they contain fingerprints of their source rocks and because the mineralization accompanying them can be predicted. Chappell and White (1974) defined granitoids of the S-type formed from metasedimentary rocks and I-granitoids, which underwent no weathering (i.e., granitoids formed by regeneration of magmatic material).

The above genetic division of granites was recently applied to calc-alkaline granitoids representing a significant part of the Circum Pacific orogenic belt (Takahashi et al., 1980; White et al., 1974).

In a similar manner we applied the I/S classification to granitoids from crystalline basements of the West Carpathians Mts. and the Caucasus Mts. The correlation was standardized with typically autochtonous Variscan gra-

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nitoids from the Czech Massif, which lies in the neighbourhood of the West Carpathians Mts. For the purpose of a petrochemical correlation in all three areas, the granitoids were assigned to the following petrographic types (C a m b e l et al., in print):
1. Leucogranites, 2. two-mica and biotite granites or granodiorites, 3. biotite hornblende granodiorites, 4. tonalites and amphibole-biotite granodiorites,

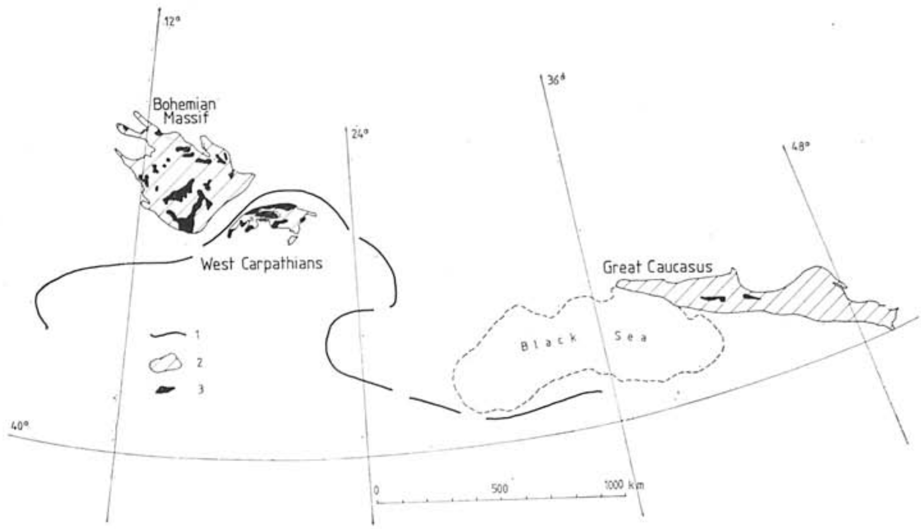

Fig. 1. Geography of the Czech Massif, West Carpathians and Caucasus Mts. and the extent of their Variscan granitoids. 1 — Alpine-Carpathian orogene zone. 2 — Extent of the Czech Massif and Crystalline cores of the West Carpathians and Caucasus Mts. 3 — Variscan granitoids.

5. durbachites/melagranites or quartz syenites, a specific groups for granitoids in the Czech Massif.

The total area of outcrops of Variscan granitoids is largest in the Czech Massif. Their age has been determined by the K/Ar and Rb/Sr methods; in some cases this has been verified biostratigraphically. The most frequent types in all areas studied are two-mica granites and biotite granodiorites. Petrographically and petrochemically most variable are the Variscan granitoids of the Czech Massif. They are represented by lithium-bearing granites (alaskites), two-mica granites, biotite granodiorites, tonalites, and durbachites. West Carpathian granitoids contain all above rock types except durbachites. In the Caucasus Mts. no durbachites or tonalites have been described.

Geographic distribution of outcrops in the areas studied is illustrated in fig. 1 Detailed accounts of their geology and petrology can be found in J. K l o m í n s k y and A. D u d e k (1978), M. P a l i v c o v á et al. (1978), B. C a m b e l et al. (1980) and B. C a m b e l et al. (in print).

Petrochemical Correlation

The comparison of the composition of granitoids is based on chemical analyses plotted in the Q-Ab-Or and A-F-M diagrams (Fig. 2, 3) according to individual petrographic types mentioned above. The contoured areas are constructed for 260 analyses from the Caucasus Mts. and 600 analyses from

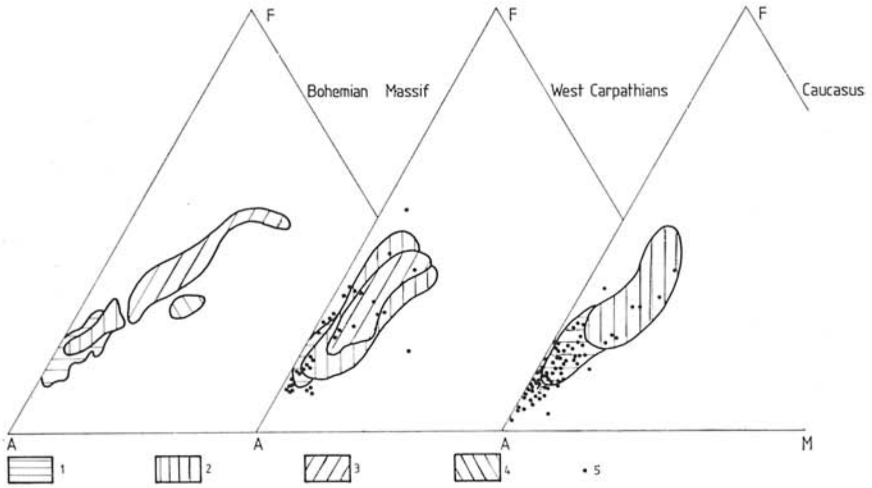

Fig. 2. AFM diagrams (atomic ratios) of Variscan granitoids of the Czech Massif, West Carpathians and Caucasus Mts.

1 — leucogranites, two-mica granites and biotite granites; 2 — biotite ± amphibole granodiorites; 3 —biotite and biotite-amphibole tonalites; 4 — durbachites; 5 — Permian biotite-muscovite granites.

the West Carpathians (Hovorka, 1972; Cambel et al., 1980). For the Czech Massif the areas are based on average compositions for 100 bodies representing a total of 1200 chemical analyses (Klomínský and Dudek, 1978). Within the contours plot 80 % of all data for the rocks from the Caucasus Mts. and West Carpathians. Inasmuch as the data for the Czech Massif are averages, they are all enclosed in the contours.

In the AFM diagram Variscan granitoids of the Czech Massif span over the whole range of the calc-alkaline series, while West Carpathian granitoids concentrate along the AF line, where the three rock types define overlapping fields. The position of the fields for granitoids from the Caucasus Mts. is similar to those for granites and granodiorites of the Czech Massif. The same can be seen in the Q-Ab-Or diagrams (Fig. 3). In contrast to granites from the Czech Massif and the Caucasus Mts., the field of granites from the West Carpathians is displaced towards the Ab-Q line, the same being even more pronounced for granodiorites and tonalites. Tonalites from the West Carpathians differ from those from the Czech Massif by a higher quartz content and lower content of femic minerals. The similarity of granitoids from the Czech Massif and the Caucasus Mts. is visible also in the Na_2O vs. K_2O plot (Fig. 4); tonalites and durbachites are not shown.

I/S Classification

Among the most recent attempts at interpreting genetic relationships between the sources of granitoid magmas and their hydrothermal products belongs the division to S- and I-types (Chappell and White, 1974; White and Chappell, 1977). A similar division was suggested by Ishihara

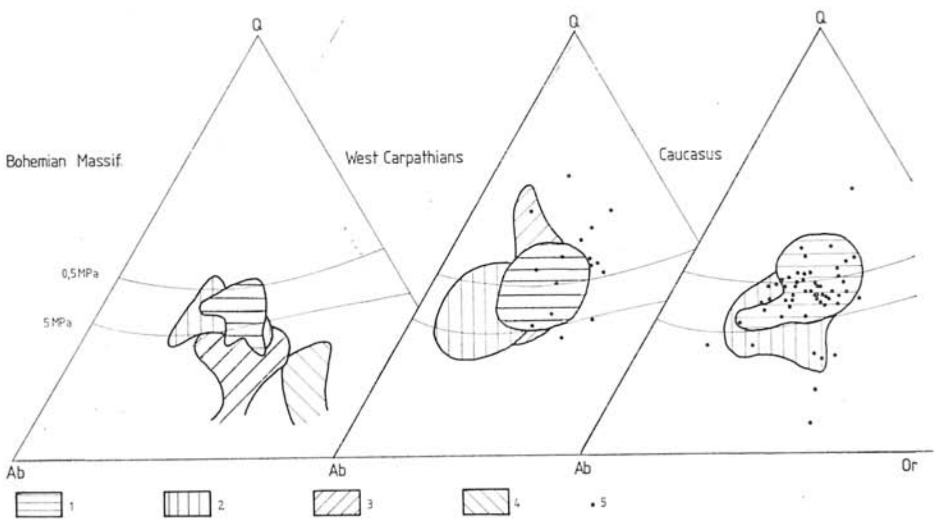

Fig. 3. Ab-Q-Or diagrams (normative ratios) of Variscan granitoids of the Czech Massif, West Carpathians and Caucasus Mts.
1 — leucogranites, two-mica granites and biotite granites, 2 — biotite ± amphibole granodiorites; 3 — tonalites; 4 — durbachites; 5 — Permian biotite-muscovite granites.

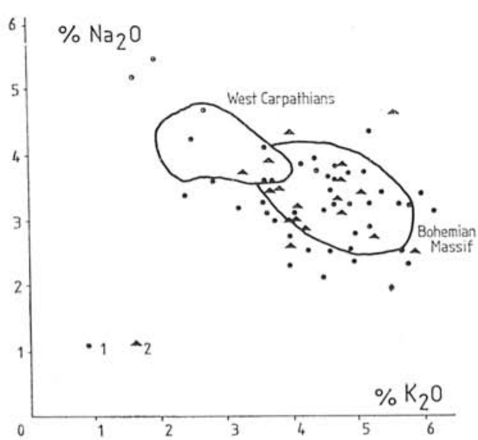

Fig. 4. Na_2O/K_2O ratio of Variscan granitoids of the Czech Massif, West Carpathians and Caucasus Mts. (O—Carboniferous granitoids, △ — Permian granitoids).

(1977), whose magnetite series corresponds to the I-type and whose ilmenite series includes the S-types and some I-types.

The differences between I- and S-types are explained by Chappell and White (1974) as due to losses of sodium and calcium and an enrichment in alumina suffered by the source rocks of the S-type. A low oxygen fugacity indicated by a low Fe^{3+}/Fe^{2+} ratio in the S-types is ascribed to reducing effect of carbon and hydrocarbons originally present in sediments that underwent progressive metamorphism and partial fusion.

The above divisions of granitoids correlate with their metallogenic capacity. According to White et al. (1977) and Ishihara and Terashima (1977) molybdenum and base-metal sulfide deposits and porphyry copper deposits are associated in space with the I-type granitoids (magnetite series), while greisen-type tin deposits accompany the ilmenite series (S-type granitoids). Burnham and Ohmoto (1980) assign the metallogenetic specialization to S- or I-types to partial pressure of oxygen. Both classification are applicable not only to abyssal rocks, but also to their effusive equivalents (Ishihara, 1979).

The salient geochemical and petrologic characters of I- and S-types defined by Chappell and White (1974) are as follows:

I-types	S-types
1. Comagmatic sequences that include a wide range of composition	1. Restricted to composition high in SiO_2
2. Mafic members contain hornblende and hornblende-bearing mafic inclusions. Usually these members contain sphene $\pm$ allanite, and magnetite	2. May contain aluminum silicates, cordierite, garnet and muscovite, but not hornblende unless xenocrystic and derived locally. Rare earths are comonly in monazite and not in sphene and allanite. Ilmenite is a common opaque mineral. Inclusions of sedimentary gneisses may be present and abundant, but hornblende-bearing mafic inclusions are present only if derived from a local source.
3. Generally are diopside normative, but some felsic rocks may contain as much as 1 % normative corundum	3. Always corundum normative in amounts > 1 %
4. Felsic rocks generally contain > 3.2 % Na_2O and mafic rocks > 2.2 %	4. Generally contain < 3.2 % Na_2O at 5 % K_2O and < 2.2 % at 2 % K_2O
5. Inter-element variation diagrams are regular	5. Variation diagrams are somewhat irregular
6. $Al/(Na+K+(Ca/2))$ is generally < 1.1	6. $Al/(Na+K+(Ca/2))$ is generally > 1.1
7. Initial $^{87}Sr/^{86}/Sr$ generally < 0.707	7. Initial $^{87}/Sr^{86}/Sr$ generally > 0.707

8. High 100 x $Fe^{3+}/(Fe^{2+}+Fe^{3+})$ ratio	8. Low 100x$Fe^{3+}/(Fe^{2+}+Fe^{3+})$ ratio
9. Low Rb/Sr ratio	9. High Rb/Sr ratio
10. Granites with lower content of normative quartz	10. Granites with higher content of normative quartz

Of these, histograms of Na_2O/K_2O appear as Fig. 4, ratios $Al/(Na + K + (Ca/2))$ and $Fe^{3+}/(Fe^{2+} + Fe^{3+})$ are presented in Figs 5 and 6, respectively.

In addition to the above parameters, White and Chappell (1980) found a separation of S and I granitoids in the ACF diagrams. Therefore,

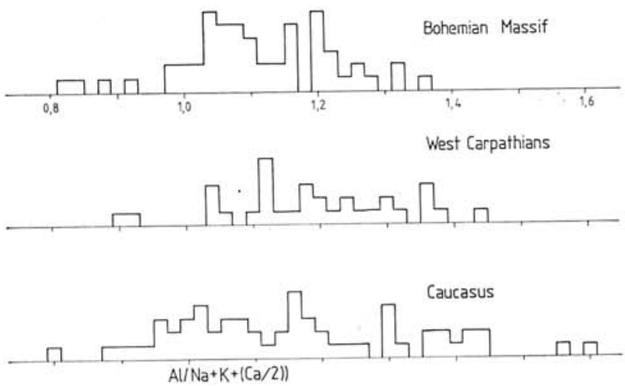

Fig. 5. Histograms of $Al/(Na+K+(Ca/2))$ ratio (atomic ratios) for Variscan granitoids of the Czech Massif West Carpathians and Caucasus Mts.

we chose the ratio of ACF components as one of the main discriminating characters of I and S granitoids from the Czech Massif, the West Carpathians Mts. and the Caucasus Mts. (Fig. 7).

The boundary separating Variscan S- and I-granitoids in the Czech Massif is based on average data for individual bodies. Most of them belong to the S-type, the typical examples being granites of the marginal zone, the Krušné hory Mts. pluton and the Moldanubian pluton (Klomínsky and Dudek, 1978). Typical I-granitoids are members of the tonalite series of the Central Bohemian pluton (types „marginal", Požáry, Sázava, Blatná, Červená) occuring in the central part of

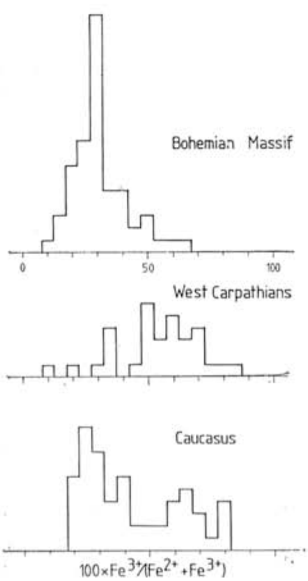

Fig. 6. Histograms of the oxidation degree — 100 × × $Fe^{3+}/(Fe^{2+}+Fe^{3+})$ (atomic ratios) for Variscan granitoids of the Czech Massif, West Carpathians and Caucasus Mts.

the Czech Massif. Among the granitoids of the West Carpathians prevail I-types over S-types, but their proportion in individual parts of the crystalline cores varies. In the Gemerid unit S-types dominate. In Tatrid and Veporid units prevail I-types, and in the Little Carpathians both types occur in equal proportion (Bratislava Massif). The geochemicall data indicate that most granites in the Caucasus Mts., like in the Czech Massif, belong to the S-type. The oxidation ratio (Fig. 5), the Al/(Na+K+(Ca/2)) ratio (Fig. 6), and the spread of data in the ACF diagram show that both types are present in all three regions studied. The relative frequency of I- or S-types can thus indi-

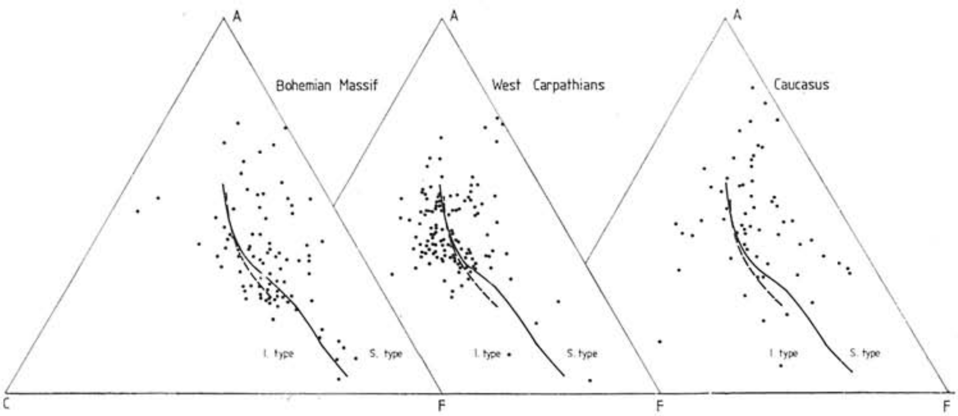

Fig. 7. ACF diagrams [A = Al_2O_3 + Fe_2O_3 — (Na_2O + K_2O), C = CaO, F = FeO+MgO+MnO for Variscan granitoids of the Czech Massif West Carpathians, and Caucasus Mts. Solid line — the boundary separating Variscan Sand I granitoids in the Czech Massif (based on average data for cca 100 individual bodies). Dashed line — I/S boudary for Australian paleozoic granites according to H i n e et al. (1978).

cate differences in the composition of source rocks that in turn may aid in reconstruction of the composition of the deeper parts of the Earth's crust.

Conclusions

Petrography and petrochemistry of the dominant rock types of Variscan granitoids from the Caucasus Mts. and the Czech Massif are similar, but differ from those for granitoids of the West Carpathians. According to C a m b e l et al. (1980) the latter are comparable to pre-Variscan plutonic rocks of the Czech Massif.

In the AFM and Ab-Q-Or diagrams the fields for granites from all three areas overlap. The center of gravity for West Carpathian granites is, however, shifted towards the Ab-Q line. The same holds even more markedly for granodiorites and tonalites. Tonalites from the West Carpathians differ from those of the Czech Massif by a higher quartz content and lower contents of femic minerals.

Variscan granitoids of the Czech Massif and the Caucasus Mts. display the same ratio of alkalies Na_2O/K_2O. The criteria for separation of granitoids in all three regions into I- and S-types do not yield identical results (Fig. 3, 5, 6). It follows that the separation criteria should be applied with caution. Also, it indicated a high complexity of the origin of granitoids. Nevertheless, most Variscan granites of the Czech Massif belong to the S-type. The I-types are less common and are represented by granitoids of the tonalite formation. The same pattern holds for Variscan granitoids from the Caucasus Mts. West Carpathian granitoids have a varying proportion of both types in individual crystalline blocks.

The correlation of Variscan granitoids from the Caucasus Mts., the West Carpathians, and the Czech Massif demonstrates that, despite the distances involved, the Czech Massif and the Caucasus Mts. contain granitoids of the same age and a similar composition. Applying the arguments of Chappell and White (1974), we can conclude that the predominance of S-granites in both regions points to a similar history of parts of the Earth's crust where diapirs of S-type granitoids formed by partial fusion of progressively metamorphosed sediments.

Our study has shown that typical S- granites prevail in activized block of old fundaments and assume the form of intrablock plutons (Palivcová and Šťovíčková, 1968). I-granitoids tend to occur in zones between blocks and fill linear structures of deep-seated faults.

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