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Objekttyp: **Article**

Zeitschrift: **Schweizerische mineralogische und petrographische Mitteilungen = Bulletin suisse de minéralogie et pétrographie**

Band (Jahr): **68 (1988)**

Heft 3: **Geodynamik des eurpäoschen Variszikums : Kaledonisch-Variszische Strukturen in den Alpen**

PDF erstellt am: **27.04.2024**

Persistenter Link: https://doi.org/10.5169/seals-52080

SCHWEIZ. MINERAL. PETROGR. MITT. 68, 433-439, 1988

The "Cetic Massif" below the Eastern Alps - characterized by its granitoids

by *G. Frasl*[1] and *F. Finger*[1]

Abstract

The Cetic Massif is a hypothetical crystalline basement block, a part of the European Plate, which adjoins the Moldanubicum to the south below the Eastern Alps. It can only be studied by means of its exotic boulders and pebbles, which can be found between Vienna and Salzburg in Mesozoic to Eocene sediments of the Ultrahelvetic and the Rheno-Danubian flysch nappes, the lowest and most peripheral nappes of the Alpine-Carpathian Chain. These exotics indicate that large parts of the Cetic Massif consist of a weakly metamorphosed quartzdiorite-tonalite-granodiorite I-type association, with characteristically high Na_2O, Sr and Ba concentrations. The petrographic and geochemical features suggest a correlation with the Cadomian granitoid suite of the Bruno-Vistulicum in the southeastern Bohemian Massif (CSSR). An original geological connection between the Bruno-Vistulicum and the Cetic Massif is assumed.

Keywords: Eastern Alps, basement, exotic granitoids, flysch nappes, geochemistry.

1. Introduction

The reconstruction of the pre-alpine paleogeography of the southeastern continuation of the Central European Variscides - a continuation which was incorporated into the Alpine-Carpathian Chain when the European Plate was subducted far under the Adriatic Plate - is challenging. In Moravia (CSSR), for example, the Bruno-Vistulicum, the easternmost part of the Bohemian Massif, could be followed in boreholes and also by geophysical methods some dozens of kilometers below the Carpathian Flysch Zone. Further to the west, in the Austrian section, the Moldanubicum can be traced in a similar same way under the Eastern Alps.

However, within the lowest and most peripheral nappes of the Alpine chain exotic granitoid boulders, which differ very clearly from Moldanubian rocks, led FRASL (1980) to propose the existence of another distinct buried massif below the Eastern Alps adjoining the Moldanubian units to the south. Using petrographic and geochemical studies on these granitoid boulders we now attempt to shed some more light on this hypothetical buried massif - which we call the "Cetic Massif" - on its composition and geological history.

2. Geological notes

The exotic Cetic granitoid boulders crop out over a length of 300 km between Vienna and Salzburg in two tectonic units along the northern front of the Alps, the *Ultrahelveticum* and the *Rheno-Danubian Flysch Belt* (several main localities are shown in Fig. 1). In these nappes the boulders are embedded in sediments of Eocene to Liassic age (in conglomerates, sandstones or in wildflysch-facies) and are thought to be derived from a hypothetical long east-west trending crystalline ridge ("Cetischer Rücken", see BRINKMANN et al., 1937; HAGN, 1960; FREIMOSER, 1972; TOLLMANN, 1987), which functioned since Upper Jurassic times as a "marginal high" (HOMEWOOD, 1977) of the Central European Plate against the stepwise-opening Northern Pennine Ocean.

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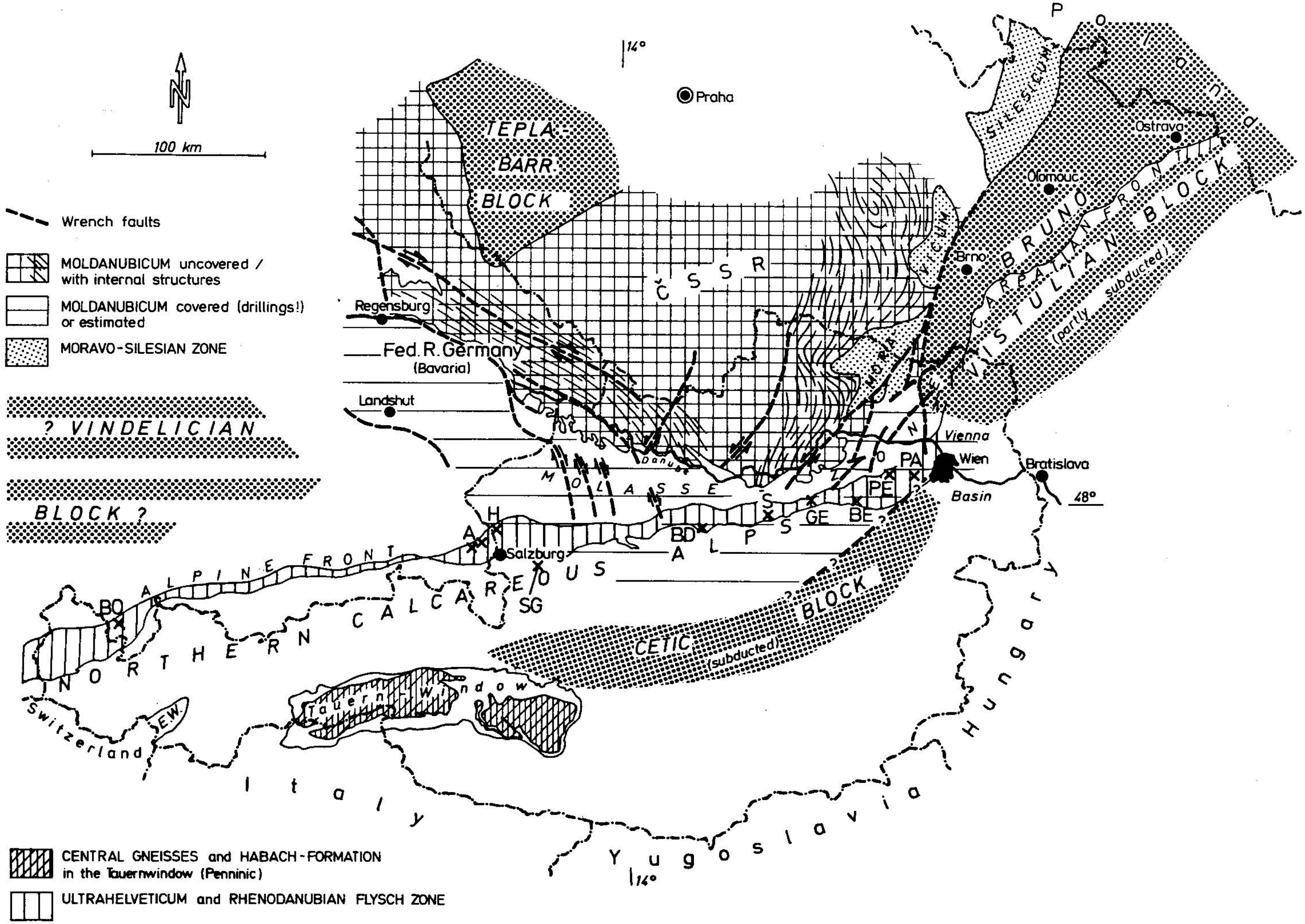

Fig. 1 Sketch of the Variscides in the southern part of the Bohemian Massif and their subducted continuation under the Alpine-Carpathian Front, with the assumed site of the subducted Cetic Massif below the Alps. Dark-stippled: well established or assumed pre-Variscan blocks.
Main localities of granitoid boulders: A=Achthal, BD=Buch-Denkmal, BE=Bernreith, BO=Bolgen, GE=Glosbach, H=Haunsberg, L=Laa bei Neulengbach, PA=Paunzen, PE=Penzing, S=Schaitten, SG=St. Gilgen.

3. Petrography

There are two main types of Cetic granitoids, both distributed from Salzburg up to Vienna (Fig. 1):

1) the quartz-dioritic to (quartz-poor) tonalitic *"Schaitten type"* (FRASL, 1980, 1984; type locality see Fig. 1).

2) the lighter, essentially granodioritic *"Buch-Denkmal type"* (type loc.: The "L. v. BUCH Memorial" see Fig. 1).

Apart from these two main types there are also some other variants of Cetic granitoids known (e.g. dark quartz-diorites, leuco-tonalites, two-mica granites - see Fig. 2), which are, however, comparatively rare.

Schaitten type granitoids, which have the best-preserved plutonic habit (FAUPL, 1975; FRASL, 1980), are massive, medium-grained and in fresh samples dark grey, because of the often astonishingly clear plagioclases (54-64 vol.%), which are markedly euhedral (grainsize usually 3-5 mm, sometimes up to 10 mm) and weakly zoned to unzoned (An 25-40). Green amphibole occurs in stubby crystals with 5 to 10 mm length (6-17 vol.%). Both these components are oriented roughly parallel to one another. Olive-brown biotite (2 mm) occurs as additional mafic phase (6-17%), and quartz is interstitial (10-24%). Typical accessories are euhedral sphene and well-zoned allanites.

Many of the Schaitten type granitoids suffered very-low- to low-grade alteration, indicated e.g. by chloritization of biotite and amphibole. The latter can also be replaced by carbonate. The primary plagioclases are mostly altered to albite (or peristherite) with micaceous or epidote and clinozoisite microliths, and K-feldspar to chessboard-albite with carbonate. Chloritized biotite can contain either zeolithic lenses, or prehnite, pumpellyite and exsolved Ti-minerals. Fe-rich epidote is sometimes rimmed by clinozoisite due to increasing metamorphic grade (e.g. WINKLER, 1979). Sphenes are frequently replaced by calcite, leucoxene and (?) anatase. Allanites often show isotropic cores and secondary rims of epidote/clinozoisite.

A remarkable small-scale variability in the degree of alteration is ubiquitous: for example, hand specimen with clear and colourless pla-

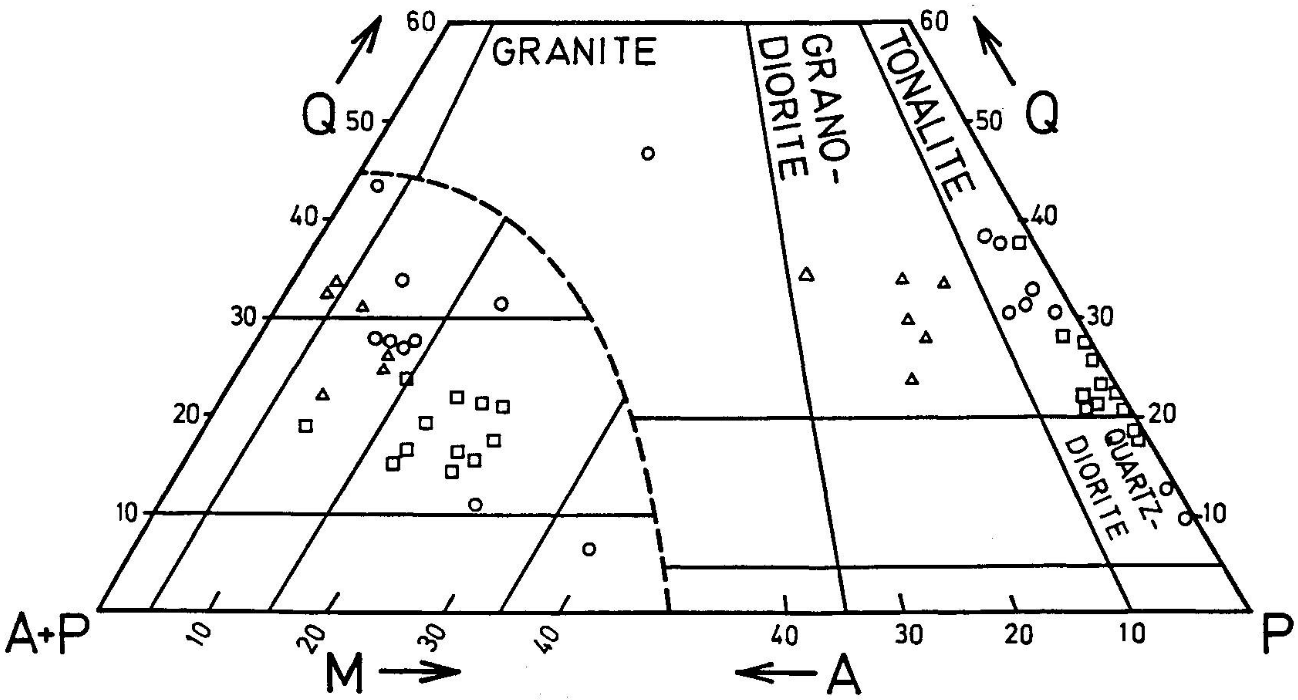

Fig. 2 Combined Alkalifeldspar-Plagioclase-Quartz and Alkalifeldspar+Plagioclase-Mafites-Quartz diagram according to STRECKEISEN (1967) with plots of Cetic granitoids (squares: Schaitten type; triangles: Buch-Denkmal type; circles: other Cetic granitoids, undifferentiated). Data from FAUPL and SCHNABL (1987, three modal analyses) and FRASL (1980, 1984 and unpubl.).

gioclases at the one end are often completely altered on the other end and show a weak reddish of greenish colouration of the dull feldspars. This alteration is not necessarily coupled with a gneissic deformation. A striking epidotization may extend for several cm on both sides of fissures and Kies deposition also occurs along cracks.

The Buch-Denkmal-type granitoids (see GÖTZINGER and EXNER, 1953; FAUPL, 1975, 1978; FRASL, 1980, 1984) suffered an alteration similar to the Schaitten type. They rarely show a well-preserved plutonic habit. The light pink, medium grained "Buch-Denkmal-Granit" of the type locality is actually a rather massive granodioritic gneiss with lenses (approx. 1 cm thick), which consist of clusters of feldspar and quartz grains. Usually the plagioclases (40–50%) are much more square-idiomorphic than the predominantly xenomorphic and pink K-feldspars (2–20%). Besides they are altered to a greater or lesser extent to albite and very fine micaceous microliths. Relictic sectors have An-contents around 20 and may show a weak oscillatory magmatic zoning and a narrow lamellation. K-feldspar is often slightly cross-hatched and weakly perthitic and some relictic parts of orthoclases are preserved. The main mafic phase is biotite (4–9%), some variants, however, also contain stubby green amphibole crystals (1–2%). Small biotite flakes, sometimes with beards of greenish-white mica, are usually streaked out between the feldspar/quartz lenses. Zeoliths, prehnite, pumpellyite or epidote occur both in and adjoining chloritized biotites. Sphene, in rhombic sections, is partly altered to carbonate and opaque minerals. Other accessories are well-zoned allanites, roundish apatites, a few small zircons and some opaque grains of ore.

4. Geochemistry

The analysed granitoid boulders (Tab. 1) yielded similar geochemical signatures throughout the Ultrahelvetic and the Rheno-Danubian Flysch Zone (see Fig. 1), indicating derivation from a single granitoid terrain. This Cetic granitoid terrain was obviously an I-type terrain (CHAPPELL and WHITE, 1974; PITCHER, 1983) with expanded compositional variation, high Na_2O features and a relatively low Al_2O_3/K_2O+Na_2O+CaO characteristics (0,92–1,08). Trace element contents imply that the Cetic granitoids originated in a "volcanic arc setting" (PEARCE et al., 1984).

With their high Na_2O/K_2O (Fig. 3) and Na_2O/CaO ratios and their high Sr and Ba concentrations, the Cetic granitoid rocks are very similar to the high Na_2O I-types of the Cadomian Bruno-Vistulicum in Moravia (CSSR) (DUDEK, 1980 and pers. comm.). On the other hand, the Na_2O/K_2O ratios of the Cetic granitoid suite are clearly higher than those of the Variscan K_2O-dominant Moldanubian granitoid province (Fig. 3) and also higher than those of the main types of the Central gneisses in the Tauern Window (see Fig. 3 and Fig. 1).

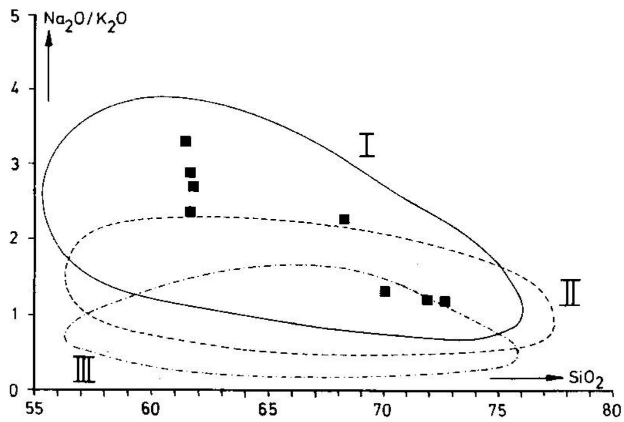

Fig. 3 Na_2O/K_2O vs. SiO_2 diagram with plots of Cetic granitoids (filled squares) and fields of:

I: 36 analyses of Cadomian Bruno-Vistulian granitoids (DUDEK, 1980 and pers. comm.) including granitoids of the Slavkov type, the Ždánice type, the Stupava type and biotite-granites of the Southern Moravian Block.

II: 65 analyses of Variscan Penninic granitoids ("Zentralgneise") from the Hohe Tauern (data from ANGEL, 1954 [18 analyses], KARL and MORTEANI, 1966 [17], DROOP, 1982 [2], FINGER and STEYRER, 1988 and unpubl. [28]).

III: 128 analyses of Variscan granitoids from the Southern Bohemian Massif (data from FUCHS and THIELE, 1968 [35 analyses], REISS, 1952 [11], KOLLER and NIEDERMAYR, 1981 [4], and FINGER, unpubl. [78]).

Tab. 1 Major and selected trace element analyses (XRF) of eight large, massive low-strain samples of Cetic granitoids (sample localities: Fi-20, Fi-21, Achthal; Fi-23, Fi-30, Buch-Denkmal; Fi-24, Schaitten; Fi-25, St. Gilgen; Fi-26, Laa; Fi-27, Penzing; see Fig. 1).

	SCHAITTEN GROUP				BUCH-DENKMAL GROUP			
Sample	Fi-20	Fi-24	Fi-25	Fi-26	Fi-21	Fi-27	Fi-30	Fi-23
SiO_2	60.30	60.32	60.48	60.56	67.57	68.80	70.95	72.38
TiO_2	0.78	0.64	0.68	0.71	0.34	0.36	0.29	0.19
Al_2O_3	17.30	17.12	17.97	17.27	16.86	15.36	14.74	14.97
FeO_{tot}	5.16	4.81	4.77	4.93	2.83	2.94	2.26	1.87
MnO	0.07	0.09	0.10	0.11	0.11	0.05	0.07	0.03
MgO	2.91	3.05	2.85	3.09	0.96	1.10	0.66	0.42
CaO	5.12	5.13	5.16	5.18	3.26	2.69	2.06	2.05
Na_2O	4.06	4.61	4.64	4.17	4.74	3.78	4.10	4.07
K_2O	1.73	1.61	1.41	1.55	2.10	2.89	3.43	3.45
P_2O_5	0.29	0.35	0.25	0.37	0.14	0.21	0.01	0.04
LOI	2.33	2.56	1.61	2.11	1.07	1.86	0.63	0.86
Total	100.05	100.29	99.92	100.05	99.98	100.04	99.20	100.33
Rb	35	29	28	27	42	65	63	61
Sr	911	930	1124	1002	734	468	468	545
Ba	884	868	964	898	628	1574	1279	1743
Nb	8	8	6	7	10	8	8	8
Y	14	15	12	13	33	20	25	17
Zr	145	128	119	126	199	196	153	137

5. Conclusions

Mainly because of the widespread distribution of similar exotic granitoid boulders over at least 300 km in the Ultrahelveticum and the Rheno-Danubian Flysch Belt (Fig. 1), we are convinced that large parts of the Mesozoic to Tertiary Cetic Ridge, which delivered the exotics, consisted of one granitoid complex and that this granitoid terrain was in turn part of a larger block, the "Cetic Massif". Searching for equivalents of the Cetic granitoids in the Central European Variscides, which might be able to reveal ancient continuations of the Cetic Massif, FRASL (1984) detected a striking similarity between the Cetic Schaitten type granitoids and the Cadomian Slavkow-type and Ždánice-type granitoids of the *Bruno-Vistulicum* in the Eastern Bohemian Massif (DUDEK, 1980), with regard to both macroscopic and microscopic rock features. When the similar geochemical signatures of the Cetic and the Bruno-Vistulian granitoid suite are also taken into consideration, we suggest that the Cetic Massif was originally coupled somehow with the Bruno-Vistulicum and that it is also very old, of at least Cadomian age. Like the Bruno-Vistulian Block it was possibly partly subducted below the Moldanubicum in Variscan times, as might be indicated by the ubiquitous signs of weak metamorphism in the Cetic granitoids.

However, today there is no direct contact between the Cetic and the Bruno-Vistulian Massif, and both are separated by a Moldanubian protrusion beneath Vienna (FRASL and FINGER, 1988), presumably due to late- or post-Variscan strike slip movements. Thus we cannot yet reconstruct the arrangement of the Cetic Massif in the Variscan Fold Belt exactly. Neither a correlation of the Cetic granitoids with the Middle Penninic Variscan granitoid terrain exposed in the Tauern Window (see Fig. 1) nor with the southern Moldanubian granitoid province is convincing, because of the strikingly different geochemical and petrographic parameters. E. JÄGER (Bern), A. GANSSER (Zürich) and L. KAMENITZKÝ (Bratislava) informed us that rocks corresponding to certain Cetic granitoids (e.g. to the very significant Schaitten-type), are also uncommon in the External Massifs of Switzerland and in the Western Carpathians.

On the other hand, the question of how far the hypothetical Cetic Massif extends to the west below the Alps today and whether the granitoids of the Bolgen conglomerate of the Feuerstatt Nappe (Fig. 1), which are in a comparable tectonic and stratigraphic position to our Cetic boulders, come from the Cetic Massif, is important. At first sight there is no visible similarity to the Cetic granitoid family and it appears more likely that the Bolgen conglomerate derived from a different source area, maybe from the hypothetic Vindelician Massif (Fig. 1) of WEBER (1986). The relationship between the Vindelician and the Cetic Massif is, nevertheless, an open problem.

The knowledge that the granitoids of the Cetic Massif and the Bruno-Vistulicum are well characterized by several striking geochemical and petrographic features, facilitates the search in the Alpine-Carpathian Chain for equivalents and possible former continuations of these old blocks.

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Manuscript received July 4, 1988; accepted as extended abstract September 27, 1988.