The Subduction-related Magmatism in Southeastern Europe and Southwestern Asia

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With 4 Figures

Zusammenfassung

Ein im Mittel granodioritischer Magmatismus kretazisch-tertiären Alters, teils intrusiv, teils extrusiv, begleitet den Südrand der Euroasiatischen Platte in wechselndem Abstand vom Ophiolithgürtel. Der stark wechselnde Chemismus der Magmatite zwischen den Süd-Karpaten, der Srednegorje, den Pontiden, dem Kaukasus, den Iraniden und den Chagai Hills wird verglichen; es ist ein typischer Magmatismus der Subduktionszonen, vergleichbar dem der pazifischen Küsten Amerikas, wobei eine Kontaminierung durch kontinentale Kruste im K-Gehalt und Pb-Gehalt erkennbar ist. Für das Alter dieses gegen Vorderasien immer jünger werdenden Magmatismus sowie seine Dauer ist das Ausmaß der Subduktionen, besonders der Breite des vorgelagerten ozeanischen Beckens, bestimmend gewesen. Der Magmatismus ist der Träger des Tethys-Eurasischen Kupfergürtels im Sinne von Janković.

Introduction

The subduction-related magmatism of the southern margin of the Euroasian plate, occuring in marginal parts of the plate or along its margin, is interesting from many aspects. It is continuous from SW Carpathians (SW Romania), passing through the Timok magmatic area (Eastern Serbia, Yugoslavia), Srednegorie (Bulgaria), Northeastern Pontides (Turkey), Central Iranian belt, to the Chagai-Hills (Baluchistan, Pakistan). All along the belt it exhibits the same geochemical features and metallogeny, despite of variations in geological setting and age.

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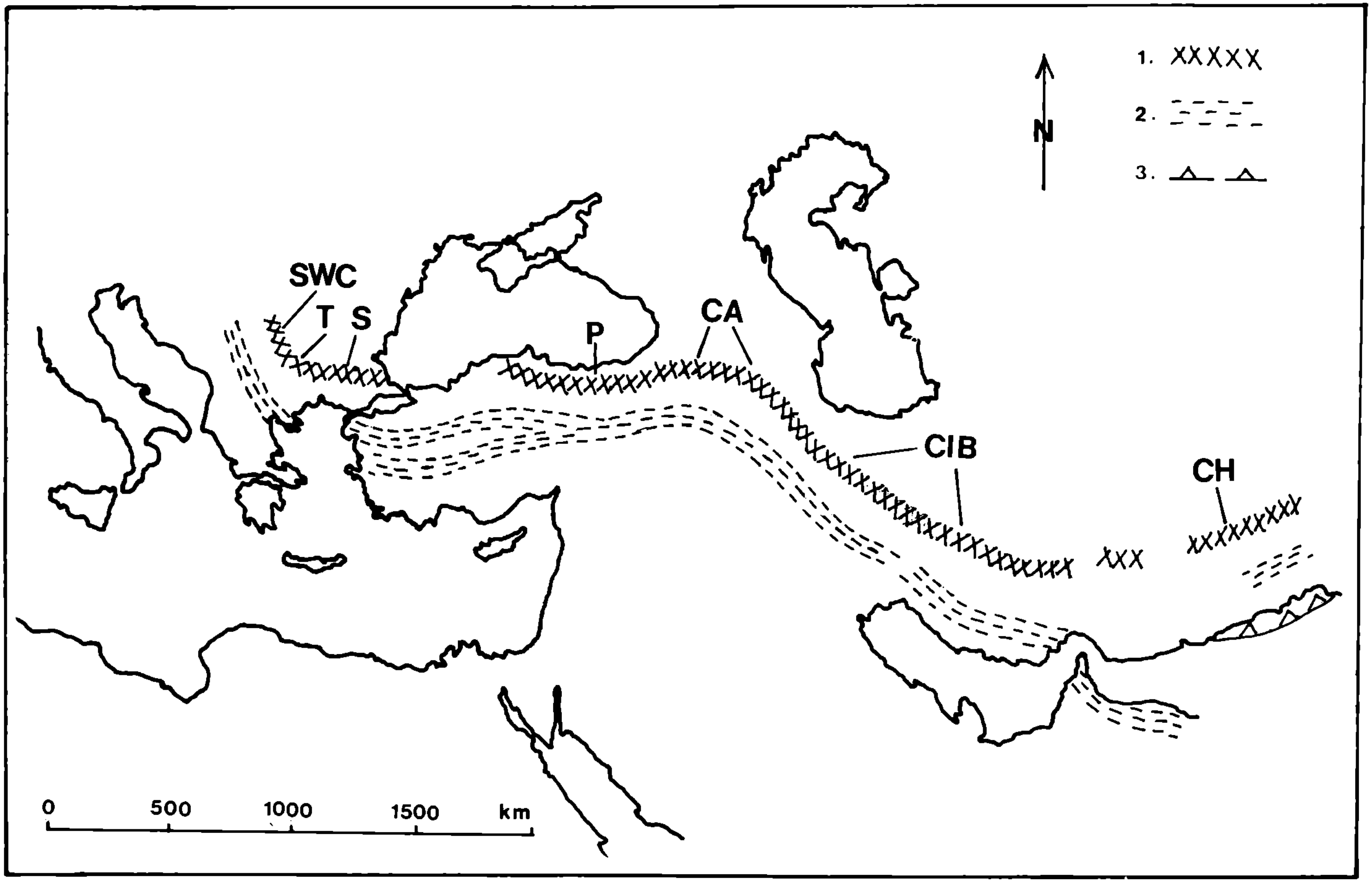

Fig. 1. The extension of subduction-related magmatism in southeastern Europe and southwestern Asia. 1 = the subduction-related magmatism; 2 = the ophiolite belts; 3 = active subduction zone. SWC = Southwestern Carpathians, Romania; T = Timok magmatic complex; Eastern Yugoslavia; S = Srednegorie, Bulgaria; P = Pontides, Northeastern Turkey; CA = Caucasus, USSR; CIB = Central Iranian belt; CH = Chagai-Hills, Baluchistan, Pakistan.

It is parallel to the ophiolite belts, and in the western parts to the young granodioritic-granitic/dacitic-rhyodacitic magmatism belt of crustal origin.

The distribution of the subduction-related magmatic rocks and of the ophiolite belts is presented in figure 1.

Petrology of igneous rocks

All along the belt volcanic and intrusive rocks of this association are occuring. In deep eroded parts the intrusive rocks are more exposed, in very young volcanic areas intrusives are absent. The uplift after the formation of these rocks associated with erosion exposes deeper seated intrusive rocks.

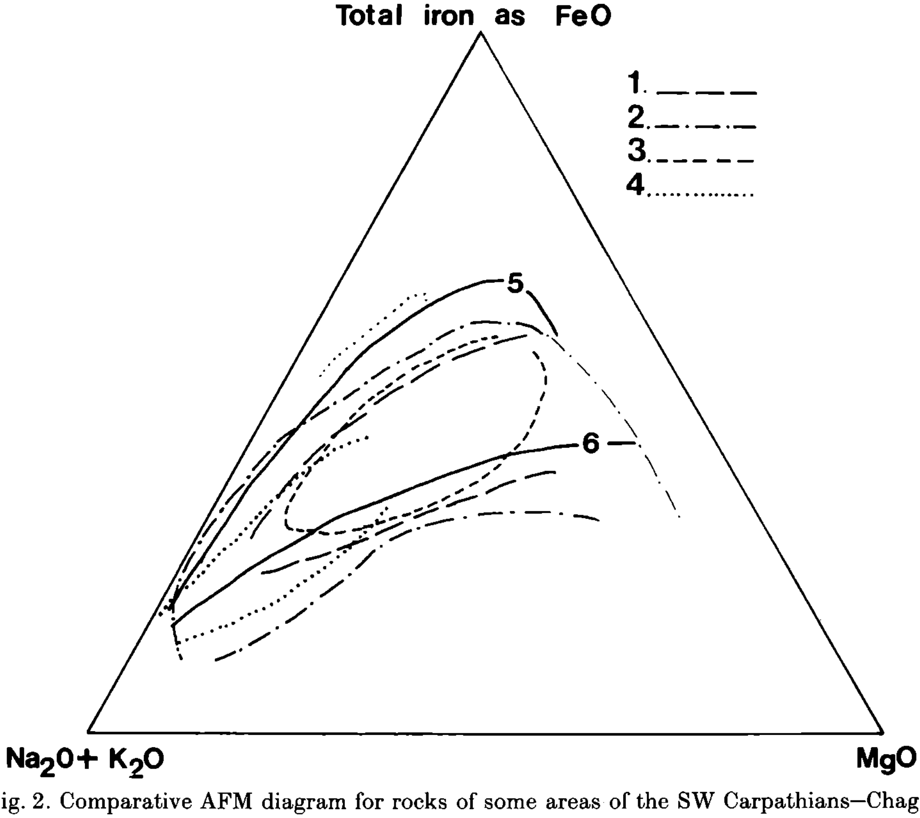

Fig. 2. Comparative AFM diagram for rocks of some areas of the SW Carpathians–Chagai-Hills zone. 1 = Timok magmatic complex (Karamata et al., 1967, supplemented by new data); 2 = Pontides (Akinci 1980, supplement from Akin, 1978, and Moore et al., 1980); 3 = Central Iranian belt (Förster et al., 1972); 4 = Chagai-Hills; 5 = differentiation trend for igneous rocks of the Tonga-Marianas-S. Sandwich island arcs and 6 = for the Cascades-N. Chile-New Guinea areas (after Brown, 1982). For 1–4 the signs embrace the main concentration of the data, the same signs but thinner indicate the field of scattered data.

The volcanic rocks range in composition from basalt, through basaltic andesite, andesite and dacite to rhyolite, but the intermediate and acidic rocks may be sodic or enriched in potassium (K-poor andesite or trachyandesite and even latite, K-poor dacite or rhyodacite, and Na-rhyolite or K-Na rhyolite, which is very rare). The main group of this series are andesites. The intrusive rocks corresponding to these volcanics, are ranging from gabbro through diorite, quartz diorite to granodiorite and even to granite (sodic), and because of enrichment in potassium to monzodiorite, monzonite, and locally to syenite and granite (K-Na). The quartz diorites are the most abundant rocks among the intrusives.

Both groups of igneous rocks, the volcanic and the intrusive ones, are corresponding, and the rocks of the series differ only in the fabric, i. e. in the depth and time of consolidation.

The intrusive rock association corresponds to the I-type granitoids (CHAPELL and WHITE, 1974), but if the intrusive rocks are treated as members of an I-type granitoid association then the associated analogous volcanics have to be considered as members of the same association. It means that the I-type granitoid association has to be treated as an intrusive-volcanic association.

The chemical characteristics of rocks from this association are ploted at the AFM diagram (Fig. 2). For comparison at the same diagram are indicated the differentiation trends of magmatic rocks from primitive island arcs (i. e. Tonga, Mariana, S. Sandwich) and of mature island arcs or marginal parts of continents (i. e. New Guinea, Cascades, N. Chile) given by BROWN (1982).

The igneous rocks of different parts of the SW-Carpathians – the Chagai-Hills belt are situated in the AFM diagram between these two extreme differentiation trends. All these rocks have calc-alkaline differentiation trends characteristic for igneous activity related to subduction zones.

A similar feature is noticeable when the data are plotted at the alkalies versus silica diagram (Fig. 3). Some differences among the rocks from separate parts of the belt may be explained by the thickness and heating of the crust or by the island arcs maturity at the time when magmas passed and consolidated. The data are concentrated in the field of high-alumina basalts and their differentiates or at both sides of it. Only the igneous rocks of the Central Iranian belt are generally poorer in alkalies and therefore situated in the field of tholeiitic basalts and their differentiates.

The silica contents of these magmatic rocks range from about 45 to 75% (in Pontides and Srednegorie between 40 and 78%), but the rocks with about 60% of silica (± 2 to 4%) are most frequent. This most common silica content is analogous to the mean silica content of andesites from Pacific Ocean island arcs (TAYLOR, 1969).

Althoug the most frequent silica contents of subduction-related igneous rocks from the SW-Carpathians – Chagai-Hills zone and the andesites from Pacific Ocean island arcs are identical, the rocks of these two regions differ clearly in K_2O contents. The mean K_2O content of island arcs andesites of Pacific Ocean is 1.60% (TAYLOR, 1969) and much lower than the most common K_2O contents of subduction-related igneous rocks of the SW-Carpathian – Chagai-Hillszone. The K_2O contents of subduction-related magmatics ranges from 0.2 to about 8%, with concentration

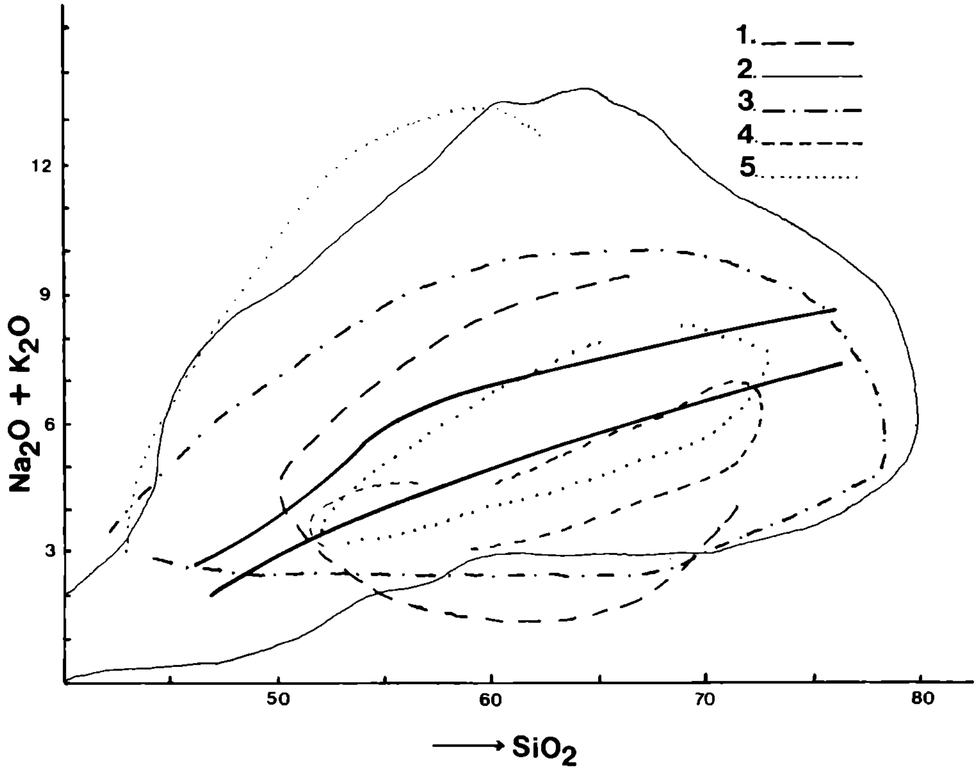

Fig. 3. $K_2O + Na_2O$ vs Sio_2 diagram for igneous rocks of some areas of the SW-Carpathians – Chagai-Hills zone. 1 = Timok magmatic complex; 2 = Srednegorie; 3 = Pontides; 4 = Central Iranian belt; 5 = Chagai-Hills. References as for Fig. 2, for Srednegorie after STANISHEVA-VASSILEVA, 1980.

arround 3.5% in rocks of the Timok magmatic complex, 2.5% in the rocks of Pontides, 2.1% in these of the Central Iranian belt, and about 1.3% in the rocks of Chagai-Hills. The K_2O contents of these rocks are very variable, except for the Chagai-Hills area, wherefrom analytical data are scarce, and the K_2O content may be very different even for the same silica content (Fig. 4), i. e. sodic, sodic-potassic and potassic rocks occur among rocks of all acidities. Only a weak increase of K_2O with SiO_2 is noticeable. Here should be noted that K_2O content is not dependent on the distance from the suture zone, it shows only a tendency of increase with evolution of igneous activity in some areas.

Geochemistry and metallogeny

The data on trace element contents of the subduction-related igneous rocks of the SW-Carpathians – Chagai-Hills zone are very scarce. Therefore only selected elements occuring or almost missing in the ore deposits are considered here.

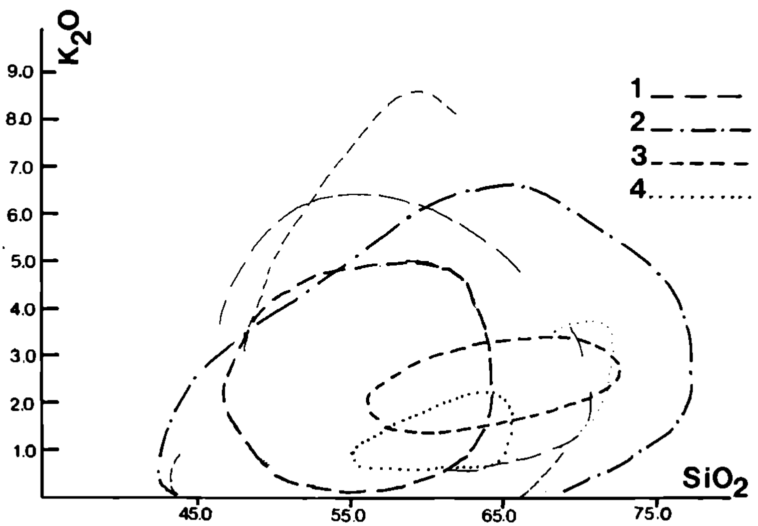

Fig. 4. K_2O vs SiO_2 diagram for igneous rocks of some areas of the SW Carpathians–Chagai-Hills zone. Legend as for Fig. 2.

With this igneous activity are connected copper deposits of different type (Janković, 1977, 1980). Molybdenum, gold, silver, arsenic, selenium, germanium, and locally platinum group elements are associated with copper in these deposits although often in minimal contents. Zinc and lead occur but are very subordinated to copper. From all these elements some analytical data exist only for copper and lead. These data are summarised in Table 1.

It is clear from these data that the igneous rocks of the SW-Carpathians – Chagai-Hills zone (if neglected some anomalous values belonging to weakly mineralised rocks) have copper contents arround 40 to 60 ppm. There is no essential difference between intrusive and volcanic rocks, as well as among rocks from different areas. These mean copper contents are similar to the mean copper content of Pacific Ocean island arc andesites (54 and 55 ppm Cu according to Taylor, 1968). However between these two groups of rocks exists a clear difference in lead contents. The Western Pacific island arc andesites are poor in lead (4 to 6.7 ppm mean content according to Taylor, 1968) compared to the igneous rocks of the western part of the SW-Carpathians – Chagai-Hills zone (lead contents: 10 to 55 ppm). Only in the easternmost part of the zone, in the Chagai-Hills, the mean lead content is already 12 ppm, approaching the low lead contents of the Western Pacific island arcs andesites.

The relatively high copper contents and low lead contents of the igneous rocks of the studied zone may be in relation with the metallogenic character of this magmatism. The enrichment of lead in comparison to Western Pacific island arcs andesites is probably connected with a contamination of magmas by continental crust material. This is an explanation for the enrichment of potassium in these rocks too.

Table 1. Cu and Pb concentrations in some magmatic complexes related to Mesozoic-Tertiary subduction in Eastern Mediterranean and Southwestern Asia (Romania-Pakistan)

Area (in brackets the number of analysis)	Cu range	x̄	σ	Pb range	x̄	σ	Metallogeny	Remark	Reference
Banatites, SW Romania									
Monzonitic-dioritic-granodioritic association	57– 163			11– 22			Cu		Ianovici et al., 1977
Granodioritic-granitic association	12– 40			13– 32			Cu, Zn, Pb	hybridised	Ianovici et al., 1977
Timok magmatic area, Eastern Serbia									
Volcanics (40)	3– 97	39	28	2– 92	22	18	Cu		Karamata, 1974 a
Intrusives (3)	38	38	–	43– 67	55	10	Cu (Pb-Zn)	hybridised	Karamata, 1974 a
Pontides, NE Turkey									
Volcanics (27/26)	15–1000	243	240	5–100	30	21	Cu	Mostly mineralised samples	Karamata et al., 1979
Volcanics (15)	15– 150	63	36					Unmineralised samples	Karamata et al., 1979
Intrusives (16)	4– 650	288	228	7–105	40	26	Cu (Pb-Zn)	Mostly Cu-mineralised samples	Karamata et al., 1979
Intrusives (7)	4– 125	57	44					Unmineralised samples	Karamata et al., 1979
Volcanics (15)	8– 52			10– 60	10		Cu		Akin, 1978
Intrusives (6)	10– 57			10– 66	10		Cu (Pb-Zn)		Akin, 1978
Intrusives (12)	3– 330	51	87	4– 31	15	9	Cu (Pb-Zn)	1 sample high in Cu	Moore et al., 1980
Intrusives (11)	3– 65	25	25						Moore et al., 1980
Chagai Hills, Baluchistan, Pakistan									
Volcanics (6)	24– 77	50	21	5– 17	12	4		Quarternary volcanics	
Calc-alkaline andesites (18)	25– 150	54		2– 11	6, 7			Ngauruhoe (New Zealand), Asama (Japan), Bouganville (Solomon Islands), Fiji	Taylor, 1968
Saipan andesites, average		54			4				Taylor, 1968

x̄ = mean content; σ = standard deviation.

Geological setting and age of the igneous rocks

All these igneous rocks are situated in the southern marginal parts of the Euroasian plate, or they represent island arcs added later to the Euroasian plate. The belt of these igneous rocks occur at a distance of 100 to 250 km from the ophiolite belt. The igneous rocks originated during differend time intervals depending on the time and other conditions of the subduction which caused this magmatism.

In southwestern Banat these magmatic rocks originated during Senonian until Paleocene (Cioflica and Vlad, 1984), in Eastern Serbia the igneous activity began at Albian and lasted until the beginning of Tertiary (Karamata et al., 1967, Janković et al., 1980), in the Srednegorie area the magmatic activity lasted from Turonian to Paleogene (Bogdanov et al., 1983). In all these areas the magmatism occured on or in the continental crust. In the Pontides (Akin, 1978, Akinci, 1980) and along the Caucasus (Azisbekov and Dzodzenidze, 1970, Adamia et al., 1977) the igneous activity was partly in island arcs, partly in a continental crust environment, beginning at Jurassic and continuing to Oligocene or Miocene respectively. The igneous activity in the Central Iranian belt (Förster et al., 1972, Förster, 1974) began during Paleocene and is still continuing. It is situated in the marginal part of the Euroasian plate. The igneous rocks of Chagai-Hills originated during two intervals, the first was Upper Cretaceous to Lower Miocene, the second from Pliocene to recent time. This is related to a displacement of the subduction zone.

This magmatism occurs, as was mentioned before, along the southern margin of the Euroasian plate, inside the plate or along its margin at added islands arcs. This depends mainly on the type and width of the oceanic area which was closed, i. e. subducted. If the oceanic area was narrow, this type of magmatism does not occur; if it was wider, a short lasting magmatism at the marginal part of the Euroasian plate (of Andean type) developed, but if the oceanic area was very wide, a long lasting magmatism of Andean type or island arcs later added to the continental margin, originated. From SW-Carpathians to Chagai-Hills all these cases exist.

Summary

The Upper Cretaceous to Tertiary, and in the East to Quaternary magmatism on the southern margin of the Euroasian plate or next to this margin is, according to all its features, typical for a subduction related environment. Its differences from one region to the next depend on the type of the former oceanic basin, on the time of the subduction and its continuance and the development or absence of island arcs. However, such differences are logical for an Tethys-type area with microblocks, their displacements and rotations during the approach of the African plate towards the Euroasian.

This magmatism is of calc-alkaline character, embracing very different igneous rocks. The differentiation processes associated with hybridisation by compounds of the continental crust especially in later phases gave a I-type granitoid

association together with its volcanic equivalents. All these processes influenced the geochemistry of these igneous rocks too, particularly in late phases.

However the fundamental geochemical and metallogenetic features of this magmatism are preserved and clearly expressed. The rocks are enriched in copper and are initially poor in lead. Finally, the copper wealth of the Euroasian metallogenic belt (JANKOVIĆ, 1977) is genetically related to this igneous activity.

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