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Petrology and geochemistry of the layered dike of Almaş-Sălişte (Mureş zone, Romania)

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Петрология и геохимия магматически складчатой дайки месторождения Алмас-Салисте (мурешская зона, Румыния)

Габроидная дайка месторождения Алмас-Салисте установлена в центральной части мурешской зоны (южной Апусени). Была объявлена Саву (1953-непубликованные данные) и позже описано её магматически складчатое строение и соответствующие петрографические фации Циофликом и Саву (1963). Изучение структурных петрохимических и геохимических аспектов этой дайки привело к составлению этой работы.

Petrologie et géochemic de le dykes stratitifié d'Almaş-Sălişte (Zone de-Mureş, Roumanie)

Le dyke stratifié d'Almaş Sălişte se trouve dans le complexe des basaltes de fond océanique (O_1) de la zone de Mureş. A sa partie supérieure, les trois zones suivantes se sont formées par différentiation gravitationelle (in situ): (1) la zone supérieure constituée d'anorthosites à niveaux de gabbros; (2) la zone médiane gabbroïde, à alternances de leucogabbros et de roches mélanocrates et ferrogabbros; (3) la zone inférieure surtout gabbroïde. Dans la zone supérieure se sont concentrés Al, Ca, Na, Sr et Ba et dans la zone médiane Fe, V et Co. La zone inférieure est moins différenciée. Les derniers différenciés du magma tholéiitique sont les plagiaplites filoniennes.

The gabbroic dike of Almaş-Sălişte is situated in the central part of the Mureş zone (Southern Apuseni Mts.). It was discovered by H. Savu in 1953 (unpublished data) and later described with respect to the layered structure and the petrographic facies by G. Cioflica and H. Savu (1963). Subsequently it was mentioned in various correlation papers.

In 1979, when the investigations in the

Almaş-Sălişte region were resumed (Savu et al., 1983), the gabbroic body was studied from the structural, petrochemical and geochemical points of view. The data obtained allowed the drawing out of the present paper.

Structure of the Gabbroic Body

The gabbroic body is hosted in the ocean floor basalt complex (0_1) of the Alpine ophiolitic series (J_1—J_2) in the Mureş zone (Savu, 1983). This complex consists of basalts, hyalobasalts, anamesites and variolites in pillow lava facies, in which dolerite sills are intercaled (Fig. 1) as well as small gabbro bodies and a body of ultrabasic rocks (Savu et al., 1983). The layered gabbroic dike trends NE—SW, being of 2.6 km in length and reaching the maximal width of 1 km. In the upper part, where the dike gets wider, the boreholes showed that it has a rhythmic layered structure (Wager — Brown, 1968) within which three zones can be distinguished (Fig. 1); upper, median and lower (Cioflica — Savu, 1963). Only the first two zones crop out, the third one being reached by boreholes at the depth of 200 m under the level of the Almaş Valley.

The rock structure in the three zones is highly irregular both vertically and horizontally due to the extremely varied dimensions and frequency of crystals, the rocks consequently showing a structure in bands, schlieren and successive lenses with thicknesses ranging from a few centimeters to a few decimeters or meters.

1. The Upper Zone consists of anorthosites with gabbro intercalations. Anorthosites are leucocrate rocks formed of plagioclase (> 90 %), sometimes partially albitized, and low amounts of clinopyroxene, titanite, rutile and magnetite or ilmenite. Plagioclase (An 55) shows on the margins an andesine zone (An 34); diopside (c > Ng = 38.5°) is xenomorphic and is associated with magnetite. The late magmatic solutions from the deuteric stage, which led to the formation of the plagioclase marginal zone, determined also the recrystallization of some clinopyroxene crystals. The gabbro rhythms occurring in anorthosites in the eastern part of the dike consist of plagioclase (An 55—48) and diopside replaced by a brown hornblende (Ng = brown; Nm = dark brown; Np = yellowish-brownish; c Ng = 20°) < at the expense of which there form a green-bluish hornblende and then actinolite.

2. The Median Zone, within which G. Cioflica and H. Savu described the rhythmic layering in 1963, consists mainly of diopside gabbros, four horizons being distinguished: (a) an upper horizon formed of gabbros with thin levels (rhythms) of leucogabbros with diopside and quartz, and hypersthene gabbros; (b) three horizons situated in the lower part of the zone. All the horizons form a structure with rhythmic layering, the concavity of which being upward (Fig. 1.)

a. The leucogabbros and gabbros from the upper horizon are rocks rich in slightly zoned plagioclase (64—54 %), within which clinopyroxene is accompanied by hypersthene and quartz.

b. The three lower horizons consist of microrhythms of rocks varying in structure and composition (dolerites, hypersthene gabbros, hyperites, gabbros with vanadium titanomagnetite etc.). These horizons are thicker on the south-eastern margin of the body, where higher vanadium magnetite concentrations (5—15 %) are found. The gabbros in this zone consist of 50 % plagioclase (An 52), but in some schlieren the rocks tend to enrich in clinopyroxene and brown-greenish deuteritic hornblende which occurs also on the fissures (Photo 1); other schlieren consist of pegmatoid gabbros.

The rocks of the three lower horizons with rhythmic layering differ from the other gabbros by the more elongated aspect of the plagioclase crystals and the divergent structure. One should mention the hyperites that consist of 54 % plagioclase (An 58), 14 % diopside, 15 % hypersthene, 6.5 % olivine, 7 % deuteritic hornblende and 3 % biotite. The xenomorphic diopside presents pigeonite exsolution in the form of little plates. Hypersthene shows the following characteristics: Ng = slightly greenish, Np = slightly reddish; it is replaced by bastite on the fissures. Olivine, which forms small and idiomorphic crystals included in pyroxenes,

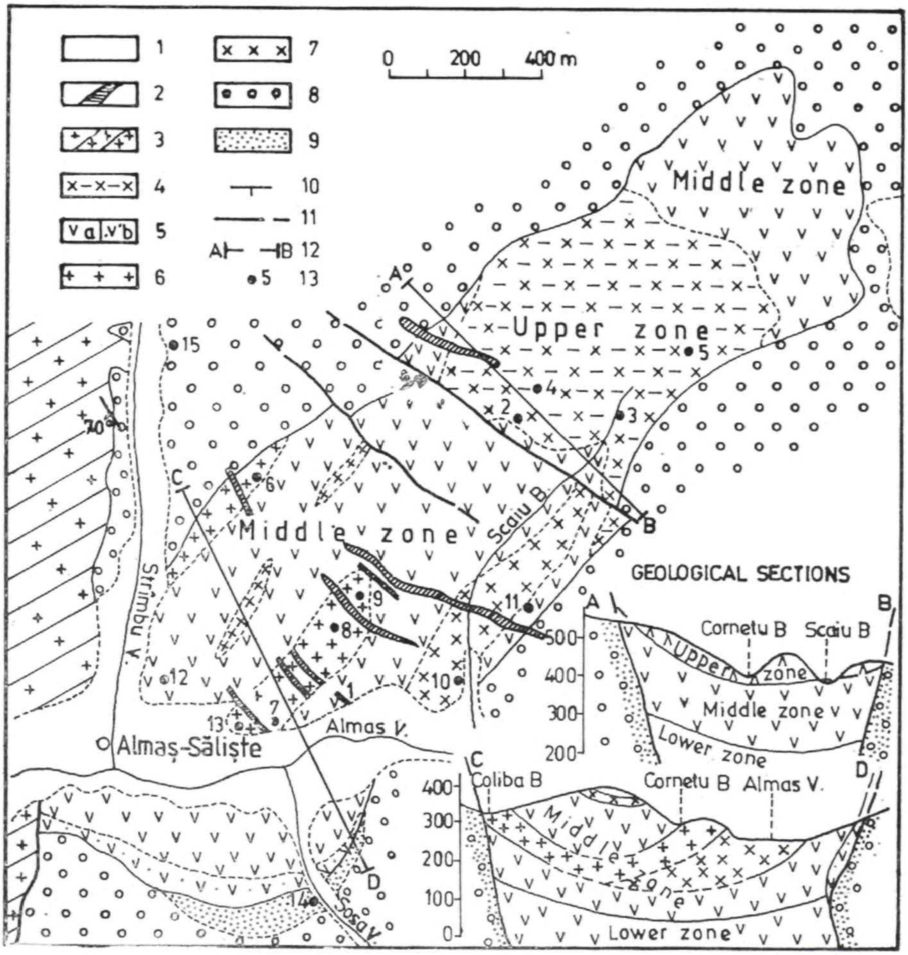

Fig. 1. Geologic map of the layered gabbroic dike of Almaş-Sălişte. 1 — alluvia, 2 — vein rocks, 3 — granites and granodiorites (Cerbia massif), 4 — anorthosites, 5a — gabrros with diopside ± quartz, 5b — microgabbros, 6 — ferrogabbros, 7 — gabbros with hypersthene, hyperites, ferrogabbros, 8 — basalts and anamesites, 9 — basic hornfelses, 10 — granite/basalt contact, 11 — fault, 12 — geological section, 13 chemical and spectral analysis

is frequently replaced by bowlingite. The most characteristic rocks in this zone are ferrogabbros or gabbros with vanadium titanomagnetite; the latter mineral is usually xenomorphic and contains ilmenite exsolutions.

Microgabbros are found on the southern margin of the body (Fig. 1).

3. The Lower Zone seems to be more homogeneous as it consists of diopside gabbros, within which rare thin levels of hypersthene gabbros can be separated.

The ocean floor basalts were thermally metamorphosed at the contact with the gabbro body and transformed into hornfelses with the plagioclase-clinopyroxene-amphibole-magnetite paragenesis. This paragenesis formed under the conditions of the hornblende hornfelses facies at about 700 °C, the temperature at which, as established by H. Savu and C. Udrescu in 1967, the gabbro body was also formed. Like the whole ophiolitic series in the Mureş Zone, the effusive and intrusive rocks at Almaş-Sălişte ere also subjected to ocean floor metaborphism processes in the albite-epidote-amphibolitic, greenschist and zeolitic facies (Savu, 1967; Coleman, 1977).

The gabbro body is crossed by dolerite and albitic plagiaplite dikes (Photo 2) of the concanguineous ophiolitic series, island arc basalt, rhyolite and orthophyre veins (J_3—Cr_1) and by porphyries connected with the Cerbia acid body.

Petrology and Geochemistry

The chemical composition of gabbros is rather similar to that of the tholeiitic basalt (Table 1, № 15) except for the ferrogabbro, which is richer in iron (Table 1). Leucogabbros are marked by higher Al_2O_3 and CaO amounts, while anorthosites are richer in SiO_2, Al_2O_3, CaO and Na_2O, but they are poor in iron and MgO. The albitic plagiaplites, which are the last differentiates of the tholeiitic magma, are the richest in SiO_2, Na_2O, Y and Yb.

The minor elements show a similar behaviour to the major ones, with which they are closely connected. Vanadium, which is of about 250 ppm in most rocks (Kraft — Schindler, 1961), reaches 730—1,000 ppm in the ferrogabbros and leucogabbros rich in magnetite from the Median Zone. The Cr-Ni correlation is positive, while the Cr/Ni ratio decreases from gabbros (3.5—2 ppm) to anorthosites

Photo 1. Gabbro with diopside and deuteritic hornblende. Almaş Valley

Photo 2. Plagiaplite veins in gabbro. Almaş Valley

Major and trace elements analyses

Table 1

Sample / Element	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SiO_2	52.57	51.98	51.53	50.20	51.71	48.13	47.96	47.37	46.85	46.20	45.94	45.58	46.20	48.79	48.45
Al_2O_3	19.80	23.20	20.90	21.50	15.81	19.14	16.64	21.80	22.85	16.65	18.31	20.42	16.65	14.74	14.84
Fe_2O_3	1.08	0.57	0.88	0.87	2.39	2.13	2.72	3.36	2.45	3.77	2.39	3.05	3.77	5.99	3.61
FeO	1.86	0.59	0.76	1.58	3.79	3.52	3.98	4.07	3.11	4.80	3.45	4.21	4.80	4.78	5.30
MnO	0.08	0.05	0.06	0.10	0.13	0.13	0.15	0.13	0.11	0.15	0.13	0.15	0.15	0.09	0.20
MgO	3.68	2.58	3.44	4.90	8.91	4.09	8.66	3.71	4.15	8.30	6.67	8.79	8.30	5.85	7.43
CaO	11.10	14.17	15.27	15.03	11.79	15.04	14.34	13.38	15.15	15.61	15.72	13.62	15.61	12.87	13.01
Na_2O	4.62	3.22	3.50	2.95	2.35	2.95	1.70	2.25	1.80	1.40	2.25	1.80	1.40	2.79	2.30
K_2O	0.40	0.30	0.10	0.01	0.25	0.45	0.53	0.50	0.45	0.15	0.20	0.65	0.15	0.20	0.55
TiO_2	1.39	1.18	1.36	0.98	0.70	1.44	0.48	0.71	0.52	0.57	1.68	0.62	0.57	1.65	1.22
P_2O_5	0.67	0.21	0.51	0.27	0.31	0.77	0.05	0.42	0.20	0.06	0.33	0.11	0.06	0.27	0.26
CO_2	0.30	0.30	—	—	—	1.07	0.62	—	0.59	0.40	0.69	0.30	0.40	—	—
H_2O+	1.78	0.97	1.19	1.01	1.89	1.70	1.58	1.64	1.19	1.36	1.62	0.99	1.36	1.38	2.31
S	0.07	0.07	0.06	0.06	0.07	0.07	0.07	0.09	0.08	0.08	0.06	0.06	0.08	0.18	0.07
Fe(S)	0.06	0.06	0.05	0.05	0.06	0.06	0.06	0.08	0.07	0.07	0.05	0.05	0.07	0.15	0.06
Total %	99.46	99.46	99.61	99.42	100.16	100.69	99.54	99.41	99.57	99.56	99.51	100,40	99.56	99.73	99.60
Ni	55	14	32	48	210	44	100	44	28	180	130	67	75	77	70
Co	17	6	9.5	14.5	43	28	33	40	22	55	31	40	50	30	46
Cr	42	4.5	14	75	550	17	145	17	38	420	34	160	12	225	260
V	250	230	440	420	310	520	215	320	250	400	1000	350	730	430	290
Sc	29	14	30	30	36	44	38	30	19	45	65	39	44	44	35
Zr	67	66	66	57	115	55	38	50	20	35	80	53	72	120	110
Y	38	13	20	17	17	30	11	16	< 10	10	16	12	12.5	39	27
Yb	4.7	2.5	2.3	3.4	2.7	5	1.8	2.3	1.1	1.5	4.7	2.1	2.3	6	4.6
Nb	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	10	< 10
Ba	190	140	90	65	190	85	120	160	190	75	160	100	92	26	44
Sr	70	480	400	420	520	480	360	550	480	340	550	440	370	160	290
Ga	22	23	22	17	14.5	18.5	15	20	16	14.5	19	17	21	23	12
Cu	11	7	5	6.5	8.5	13	14	70	17	22	28	38	115	29	30
Pb	5.5	5	5.5	2	3.5	3.5	3	5	2.5	3.5	10	9	4.5	< 2	3.5
Sn	3.5	< 2	< 2	< 2	2	2.5	3	< 2	< 2	2	< 2	2	3.5	< 2	< 2

Anorthosites: 2, 3, 4; gabbro in anorthosites: 5; leucogabbros: 6, 7, 8, 9; magnetite leucogabbro: 11; hyperite: 10; gabbro: 12; magnetite gabbro: 13; basalt: 15; basic hornfelse: 14; plagiaplite: 1.

(1—0.3 ppm). Ferrogabbros and some leucogabbros contain a low amount of Cr, a reason why the Cr/Ni ratio is round 0.3. The Co values greatly decrease from gabbros to anorthosites (Table 1).

Zr, Y and Yb have a positive correlation with Ti (Fig. 2), which shows that the parental magma underwent a differentiation process. The Ba contents range between 26 and 120 ppm in gabbros and basalts, but in most rocks rich in plagioclase they are above 120 ppm. Sr shows much higher values than in the ocean floor rocks, its concentration being favoured by the plagioclasic character of the Ca-rich rocks that resulted from the accumulation of the plagioclase crystals in the upper part of the dike.

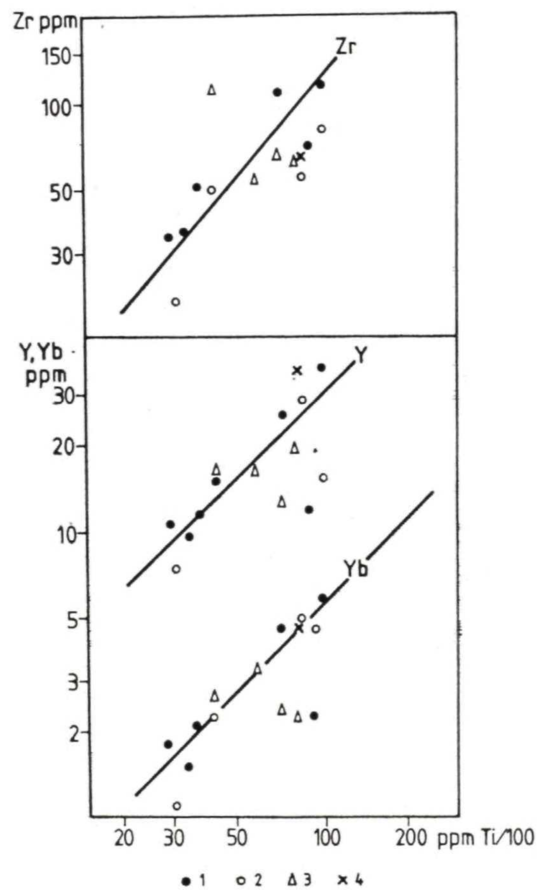

Fig. 2. Zr, Y, Yb-Ti diagram. 1 — basalts and gabbros, 2 — leucogabbros, 3 — anorthosites, 4 — albitic plagiaplites

The gabbroic dike started at the level of the sheeted-dike complex (O_2) of the Mureş Zone or even at a lower level. At the moment of the intrusion the parental magma, the composition of which was similar to that of the tholeiitic basalt (Fig. 3), had already undergone a certain differentiation in the magmatic chamber situated in the mantle, under the spreading zone or in an intermediary one, so that it had become somewhat richer in aluminium and calcium.

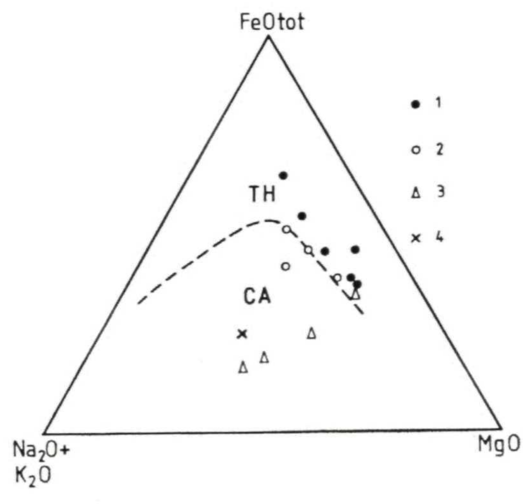

Fig. 3. FeO (tot) — MgO — $Na_2O + K_2O$ diagram (after Irvine and Baragar, 1971). Legend from Figure 2

The more aluminous magma character allowed first the crystallization of the plagioclase, which floated towards the upper part of the intrusion, forming the anorthosite zone and the leucogabbro rhythms beneath it. Under these conditions iron (Kennedy, 1948) and magnesium

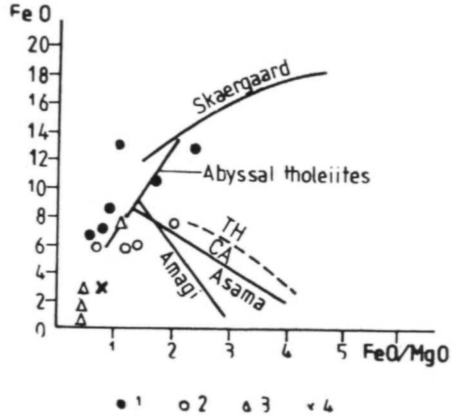

Fig. 4. FeO (tot) — FeO (tot)/MgO diagram (after Miyashiro, 1975). Legend from Figure 2

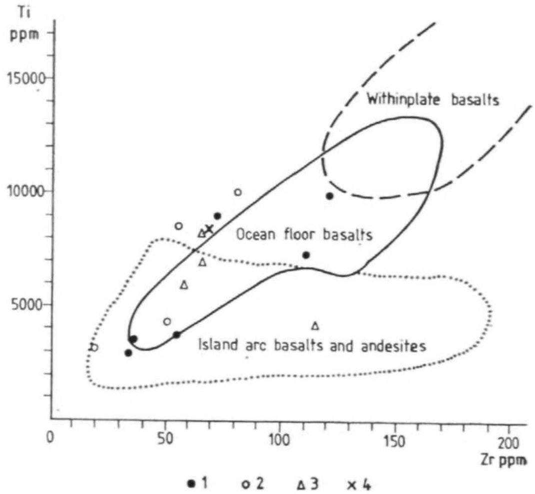

Fig. 5. Ti-Zr diagram (after Pearce and Gale, 1977). Legend from Figure 2

accumulate in the lower horizons with rhythmic layering from the Median Zone, there resulting more melanocrate rocks and ferrogabbros. This phenomenon seems to be slightly manifested in the Lower Zone, in which only rare rhythms of hypersthene gabbros form.

Thus the intrusion undergoes a gravitational differentiation (in situ) through fractional crystallization, under the control of the variable tension of the volatiles, especially of the PH_2O and the mean oxidation degree of the magma (W — 0,42). Nevertheless most rocks preserve the charaster of ocean floor tholeiites of the ophiolitic series in the Mureş (Figs. 4 and 5), excepting, as in Figure 3, the cumulates rich in plagioclase and the plagiaplites.

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