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CONTRIBUTION TO PETROLOGY AND K/Ar AMPHIBOLE DATA FOR PLUTONIC ROCKS OF THE HAGGIER MTS., SOCOTRA ISLAND, YEMEN

Ferry FEDIUK [1)]* **and Kadosa BALOGH** [2)]

[1)] *Geohelp, Na Petřinách 1897, Praha 6, Czech Republic*
[2)] *Institute of Nuclear Research of the Hungarian Academy of Sciences*
**Corresponding author's e-mail:* ferry.fediuk@seznam.cz

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ABSTRACT

A morphologically distinct intrusive massif emerges from sedimentary Mesozoic/Tertiary cover in Eastern Socotra forming the high Haggier Mts. It is mostly composed of peralkaline and hypersolvus granite partly accompanied by gabbroic rocks. Amphibole, the sole mafic mineral of the granite, shows predominately the arfvedsonite composition, while riebeckite, for which Socotra is reported in most manuals of mineralogy as the "locus typicus", occurs subordinately only. Either Paleozoic or Tertiary age has been assumed for this massif for a long time. In the last decade, however, K/Ar datings have been published clearly showing Precambrian (Neoproterozoic) age. The present authors confirm with somewhat modified results this statement by five new radiometric measurements of monomineral amphibole fractions yielding values of 687 to 741 Ma for granites and 762 Ma for gabbroic rocks. The massif represents an isolated segment of numerous late postorogenic Pan-African A-granite bodies piercing the Nubian-Arabian Shield and is explained as the result of partial melting of Pan-African calc-alkaline shield rocks in the closing stage of the orogeny.

KEYWORDS: Yemen, Socotra, Arabian–Nubian Shield, K/Ar data, amphiboles, peralkaline granite, coronitic gabbronorite, Neoproterozoic

1. INTRODUCTION

As shown by Beydoun and Bichan (1969) (see also Terragni et al., 2002), the geological structure of the Socotra Island splits into two units: the platform and the basement (Fig. 1). The platform forms nearly 75 % of the island surface and consists mostly of limestones and marls with subordinate sandstones of Triassic to Tertiary age (Samuel et al., 1997; Fleitmann et al., 2004). The coastal plains, valleys and inland depressions are covered by Quaternary incoherent sands, salty soil, debris and conglomerates; the island is lined by coral reefs. The basement is exposed mainly in the Haggier Mts., in the eastern part of the island and, to a limited extent, also in three separate areas near the western as well as eastern coast. The composition of the basement is rather complex, consisting of four independent groups: a) high-grade metamorphic rocks (paragneisses, orthogneisses, migmatites and amphibolites), b) folded and low-grade metamorphosed acidic tuffs, tuffites and mudstones in the Hadibo area, c) volcanics of the rhyolite-andesite association (lavas and volcaniclastics) in the southern part of the Haggier Mts., d) plutonic rocks formed mostly by peralkaline granites, a member of rather special, usually minor bodies forming worldwide occurring post–collisional A–type granitic plutonites (Whalen et al., 1987; Sylvester, 1989), accompanied to lesser amount by varied dyke rocks and gabbroids.

2. PRESENT KNOWLEDGE ON THE BASEMENT GEOCHRONOLOGY

Metamorphic rocks of the group a) are the oldest rocks of the island, as unspecified and radiometrically not dated Precambrian (Proterozoic) basement, the easternmost segment of the Nubian/Arabian Shield. The age of group b), the complex of the so called Hadibo series (Beydoun and Bichan, 1969), is controversial. Samuel et al. (1997) placed it to Devonian based on a single and dubious K-Ar determination (400 Ma); some of these rocks, however, near the Hadibo harbour show features of contact metamorphism probably connected with the intrusion of the Haggier Mts. granites, and should therefore be older than this intrusion. Geochronological position of the volcanics of group c) remains, in the absence of radiometric data, also problematic. Fleitmann et al. (2004), based on the statement of Beydoun and Bichan (1969) that peralkaline Haggier Mts. granites cut them, assume these volcanics as pre-granitic and consequently of Precambrian age. On the other hand, in our opinion,

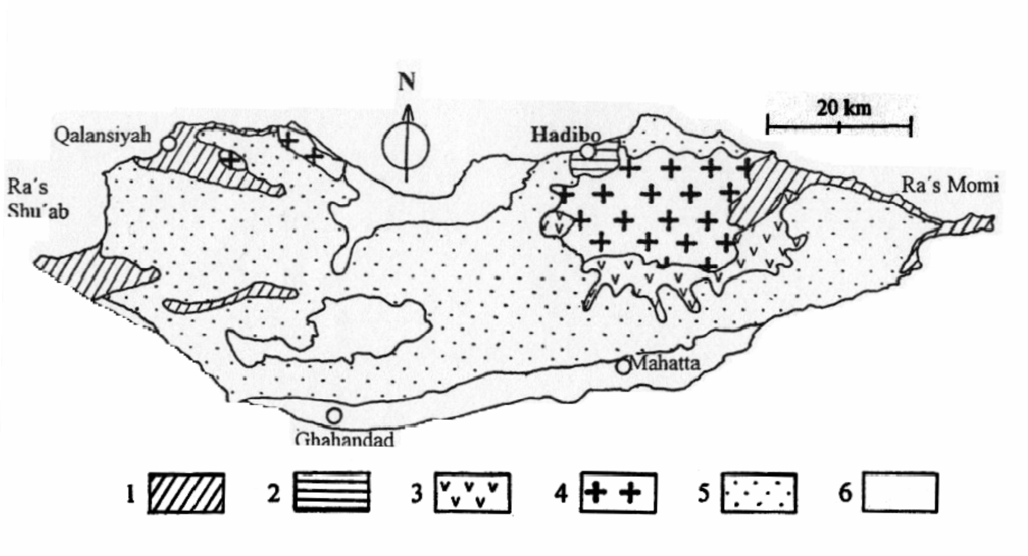

Fig. 1 Geological map of Socotra Island according to Beydoun and Bichan (1969) and Terragni et al. (2002), simplified. 1 – high grade metamorphites, 2 - low-grade metamorphosed schists (Hadibo series), 3 – volcanics of rhyolite – andesite association, 4 – the Haggier Mts. massif (granite >>gabbro), 5 – Mesozoic and Tertiary platform sediments (mainly limestones), 6 – Quaternary.

this volcanic sequence covers the Haggier Mts. granites and should be probably Paleozoic. Missing radiometric datings of them are urgently needed.

The most crucial problem of geochronology concerns plutonic rocks of group d): granites, their dyke swarm and gabbroic rocks. Beydoun and Bichan (1969) claimed Paleozoic age for them, while Greenwood - in the discussion appendix of this paper – proposed rather a Tertiary age in analogy with the Aden area. New radiometric data (Samuel et al., 1997 and the unpublished report of Siegen cited by Samuel et al.) shifted the problem to an entirely different level: the authors reported the determined minimum K-Are ages of 573 ± 17 Ma to 674 ± 20 Ma for dykes and sills, and 768 ± 31 Ma to 826 ± 41 Ma for granites (see also Fleishmann et al., 2004). This means that neither Beydon and Bichan (1969) nor their opponents were right with their Palaeozoic and Tertiary concepts, respectively, and that the plutonic activity on Socotra must be placed into Neoproterozoic. In our contribution, we support this revolutionary point of view by somewhat different additional K-Ar datings and extend them also for hitherto not dated gabbroic rocks. Consequently, these plutonites must be formed in the final stage of the Pan-African orogeny. These postorogenic magmatites, mostly A-type granites of Neoproterozoic/early Cambrian age, have been thoroughly studied in continental sectors of the Nubian/Arabian Shield by Harris and Mariner (1980), Radain et al. (1981), Jackson et al. (1984), Harris (1985), Abdel-Rahman (1995, 2006), Kessel et al. (1998), Jarrar et al. (2003), etc. They occur in numerous dispersed set of minor bodies from Egypt, Sudan, Ethiopia, Djibouti and Somalia to Jordan, Saudi Arabia and Yemen inclusive Socotra as their isolated insular easternmost member.

3. SAMPLES AND THEIR PETROGRAPHY

The following five rock samples were collected from the northern part of the Haggier Mts. intrusive massif for the radiometric dating:

1. Red peralkaline granite, outcrop at the road on the western slope of the Daneghen valley 5.5 km SE of Hadibo, 54°03′05′′ E, 12°36′57′′ N.
2. Whitish gray peralkaline granite, outcrop in the bed of the Daneghen Valley 5 km SE of Hadibo, 54°03′11′′ E, 12°37′06′′ N.
3. Layered rosy/whitish peralkaline granite, a steep hill over the road SW of Lahas village 9.5 km ESE of Hadibo, 54°06′48′′ E, 12°39′03′′ N.
4. Pinkish peralkaline granite, a rocky wall S of Kam village 12 km ESE of Hadibo, 54°08′07′′ E, 12°38′58′′ N.
5. Coronite olivine gabbro, an outcrop at the road S of Rokob village, 18 km SE of Hadibo, 54°09′54′′ E, 12°35′34′′ N.

The thin section study and modal analysis using the point counter brought out quantitative results on mineral composition of five above listed rocks, presented in Table 1. All four granitic samples 1 to 4 correspond to alkali feldspar granite according to the IUGS classification (LeMaitre, ed., 2002), and the presence of alkali amphiboles places them among peralkaline granites. Quartz (~ 30%) and perthitic

Table 1 Modal composition of studied plutonites.

	1)	2)	3)	4)	5)
Quartz	30	35	34	28	-
alkali feldspar (perthite)	60	57	63	58	-
calcic plagioclase	-	-	-	-	49
Biotite	<1	<1	-	1	1
alkali amphibole	9	8	6	11	-
calcic hornblende	-	-	-	-	26
Clinopyroxene	-	-	-	-	9
Orthopyroxene	-	-	-	-	7
Olivine	-	-	-	-	3
Ore	-	<1	-	1	4
Accessory minerals	1	<1	<1	1	1
IUGS rock classification	a-fG	a-fG	a-fGl	a-fG	G-N

Abbreviations: a-fG = alkali-feldspar granite. a-fGl = layered alkali-feldspar granite, G.N = gabbronorite, olivine bearing. For sample locations see text.

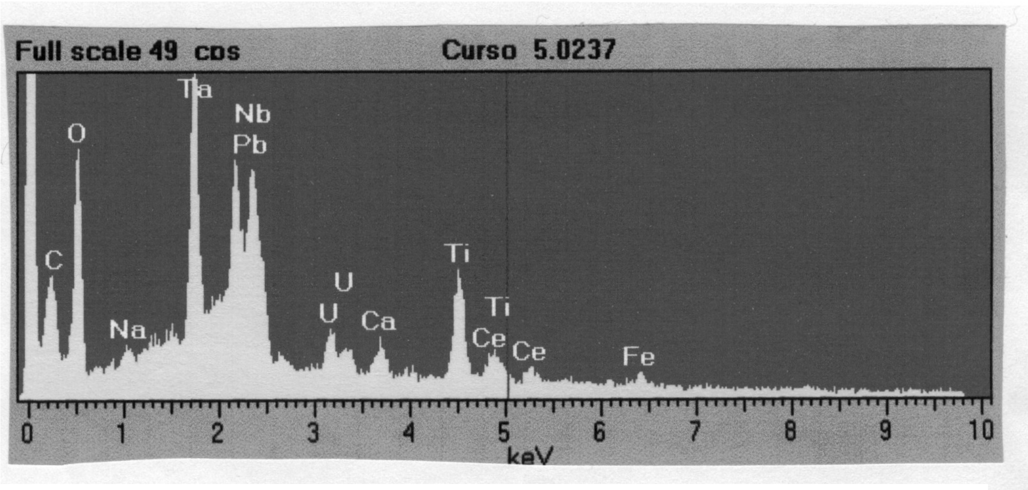

Fig. 2 Edax record of plumbomicrolite, a rare accessory mineral of Haggier Mts. peralkaline granite.

K-feldspar (~ 60%) with subordinate albite grains is the main constituent indicating the hypersolvus character, alkali amphiboles (Table 3) in the amount of around 10 % are the only mafites, mica minerals are practically absent. Zircon, monazite, magnetite (not ilmenite as in some analogous A-granites from the Nubian part of the shield, comp. Abdel-Rahman 2006), ± apatite and sphene occur as accessory minerals. Astrophyllite $(K,Na)_3(Fe^{2+}Mn)Ti_2Si_8O_{24}(O,OH)_7$, optically determined by Beydoun and Bichan (1969) and plumbomicrolite $Pb(TaNb)_2O_6(OH)$ of our new analysis by EMPA (see Edax record Fig. 2.) were found scarcely, but symptomatically underline the alkaline character of the Haggier Mts. granites.

Sample 5 is a medium - to coarse - grained gabbronorite in the sense of LeMaitre, ed. (2002) with calcic plagioclase > hornblende > ortho- and clinopyroxene >> olivine and ore. Coronite structure of this sample, however, is rather exceptional among prevailing rock types of the gabbroic complex. The main mafic minerál of this rock, amphibole, is a magnesian hornblende, alkali amphiboles being entirely absent here.

4. GEOCHEMISTRY

Results of chemical analyses of samples 1 and 2 are given in Table 2, the REE abundances are shown in Table 3. These silicate rock analyses, together with a new chemical analysis of gabbronorite – see Sample 5), are up to now, since the single, more than one hundred years old analysis by Pelikan (1902, Table 2, AP), the sole analyses for the whole Socotra Island.

Chemical analyse in Table 2 were treated using the software GCDkit of Janoušek et al. (2003) in Figures 3 to 10. In the TAS diagram modification Figure 3 by Middlemost (1994) the analyses 1, 2

Table 2 Chemical compositions (wt. %) of granites, sample 1, 2 and AP, and of gabbronorite, sample 3.

	1)	2)	AP	3)
SiO_2	71.96	77.38	74.02	45.85
TiO_2	0.38	0.14	n.d.	0.28
Al_2O_3	12.91	11.23	13.56	21.07
Fe_2O_3	1.99	1.28	1.93	1.62
FeO	0.90	0.79	1.09	5.13
MnO	0.06	0.04	tr.	0.18
MgO	0.33	0.05	0.23	6.82
CaO	1.34	0.57	0.56	15.02
Na_2O	4.61	3.90	5.80	2.14
K_2O	4.33	4.16	2.06	0.09
P_2O_5	0.06	0.03	n.d.	0.21
H_2O+	0.47	0.34	1.05	1.09
H_2O-	0.02	0.08	n.d.	0.11
CO_2	0.07	0.06	n.d.	0.20
Total	99.43	100.05	100.30	99.81

Samples 1, 2 and 3 analysed in Chemical laboratory of Fac. Sci., Charles Univ. Prague. For locations and rock types see text. Sample AP is the hitherto sole published silicate rock analysis from an uncertain locality (according the village Dahamis which, however, exists neither on contemporaneous maps nor in the field) of Socotra (Pelikan, 1902) of alkali-granite aplite called dahamite, a rock name recently discredited by LeMaitre, ed. (2002).

Table 3 REE abundances (ppm) in granites 1 and 2 and gabbronorite 3 of the Table 1.

	1)	2)	3)
Y	82.20	148.80	30.60
La	59.30	49.90	18.80
Ce	137.30	122.50	40.20
Pr	20.20	20.50	5.40
Nd	77.00	68.10	24.30
Pm	n.d.	n.d.	n.d.
Sm	18.60	19.16	7.40
Eu	3.64	5.97	3.36
Gd	16.90	20.60	10.19
Tb	n.d.	n.d.	n.d.
Dy	16.57	26.22	12.27
Ho	3.27	5.36	2.70
Er	10.43	17.09	8.15
Tm	1.38	2.41	1.12
Yb	9.66	18.19	7.91
Lu	1.48	2.63	1.03

Analysed in Chemical laboratory of Czech geol. Survey Prague, ICP method.

and AP plot in the centre of the not subdivided granite field and the gabbronorite 3 in the gabbro field. The same holds for the TAS diagram modification Figure 4 by Cox et al. (1979 supplemented by Wilson (1989) but here the granite field is divided into granite and alkali granite sub-fields. The plot of analysis 2 with its high SiO_2 value 77.38 wt. % falls already outside the diagram limite. Two remaining granite analyses 1 and AP occur not in the alkali granite field as could according to their mineral composition be expected but in the (normal) granite sub-field. This discrepancy will be commented in the chapter Discussion. Figure 5 shows the tholeiite vs. calc-alkaline series discrimination of Irvine-Baragar (1971): three granite analyses plot, due their high alkalis content, in a diagram sector which is insensitive for the discrimination, anyway they should more likely be classified as calc-alkaline. The plot of the gabbronorite, on the other hand, occurs clearly in the tholeiite series field. The SiO_2 vs. K_2O diagram

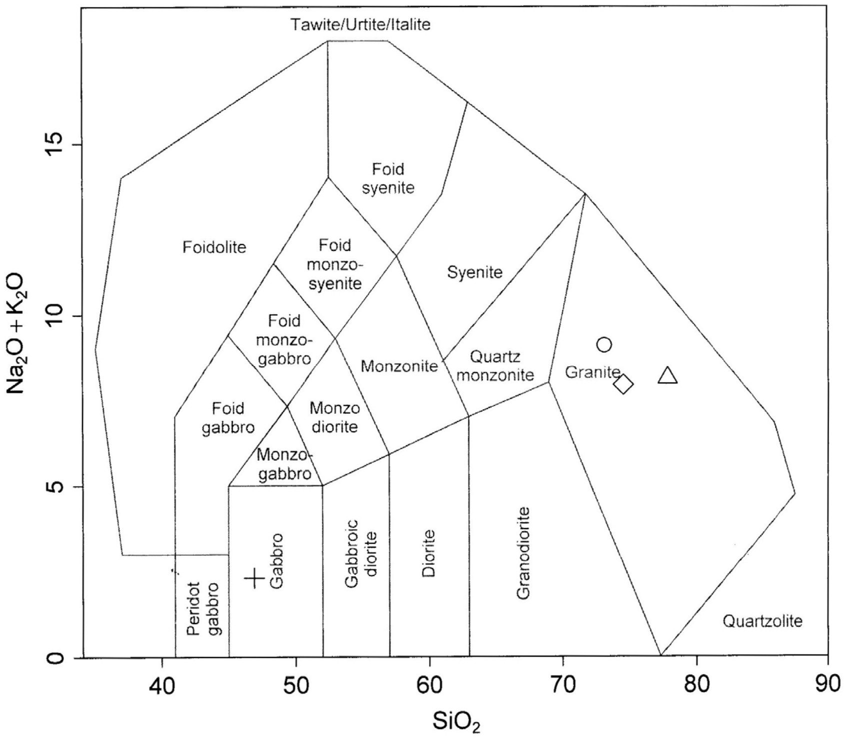

Fig. 3 TAS diagram of four Haggier Mts. plutonites (after Middlemost, 1994). Symbols: circle = granite no1, triangle = granite no 2, diamond = granite porphyry („dahamite“) AP, cross = gabbronorite no 3.

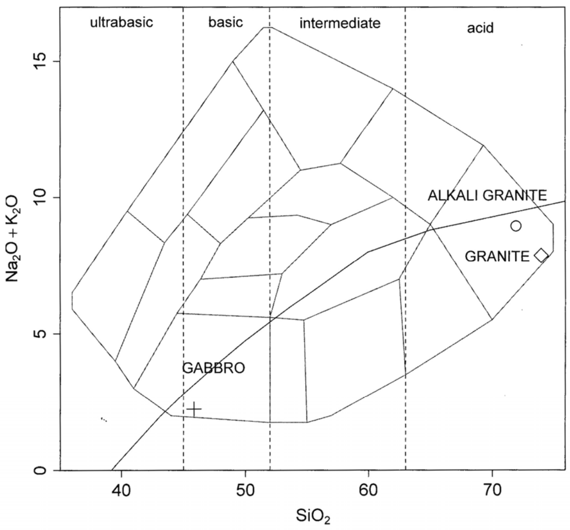

Fig. 4 TAS diagram of three plutonites of the Haggier Mts. (the plot of granite analysis 2 , Table 2 falls outside the limit of the diagram), modification of Cox et al. (1979) and Wilson (1989) with the dividing line SA/A according to Irvine and Baragar (1971). Symbols as in Figure 3. Only relevenat classifiaction fields annotated.

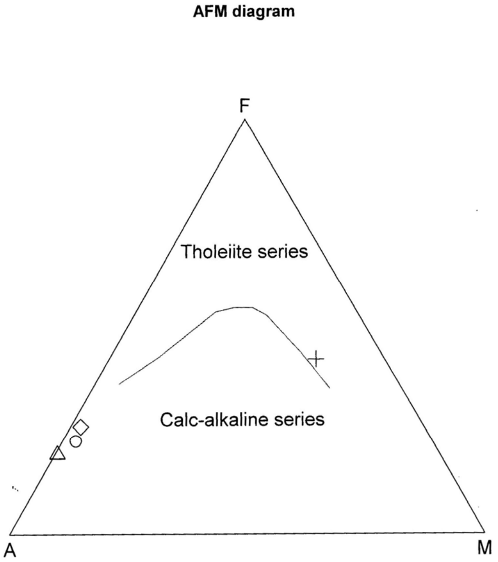

Fig. 5 AFM diagram of four Haggier Mts. plutonites (Irvine and Baragar, 1971). Symbols as in Figure 3.

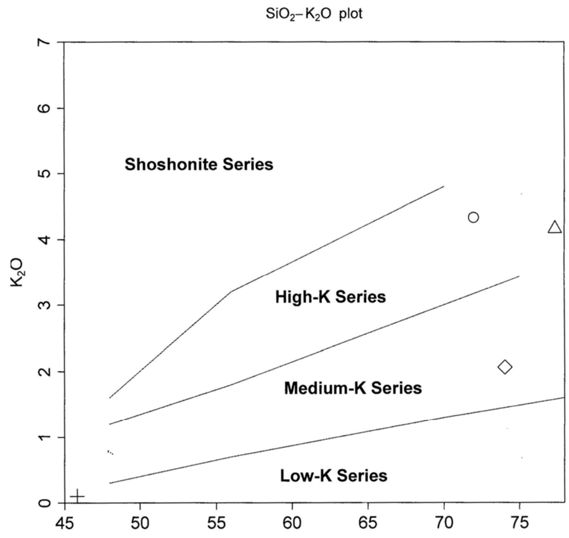

Fig. 6 SiO_2 vs K_2O plot of four Haggier Mts. plutonites (Peccerilo and Tailor (1976)). Symbols as in Figure 3.

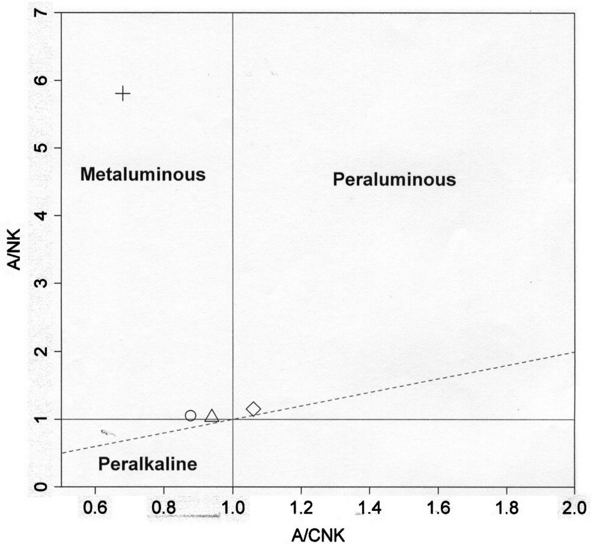

Fig. 7 Shand´s diagram (modified by Maniar and Piccoli (1989)) for four Haggier Mts. plutonites. Symbols as in Figure 3.

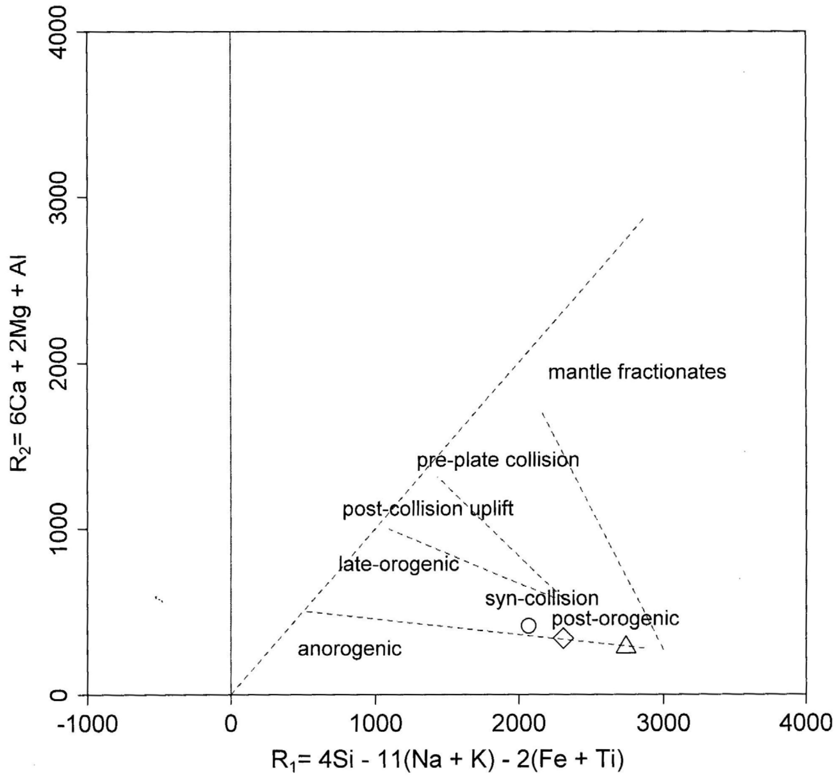

Fig. 8 Tectonomagmatic discrimination diagram of three Haggier Mts. granites after Batchelor and Bowden (1985). Symbols as in Figure 3.

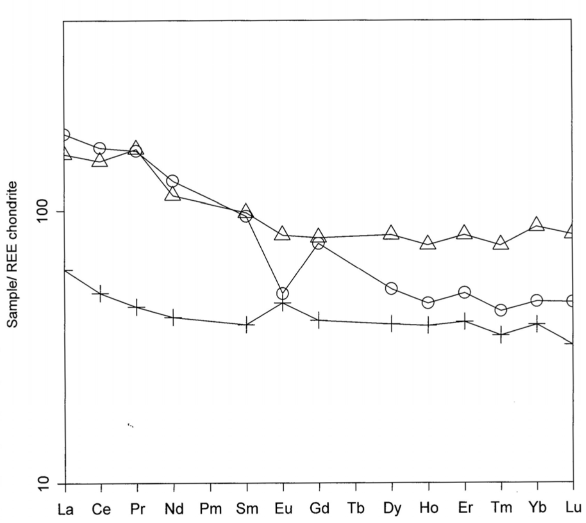

Fig. 9 Chondrite normalised REE patterns (Boynton, 1984) of two Haggier Mts. granites and the gabbronorite. Symbols as in Figure 3.

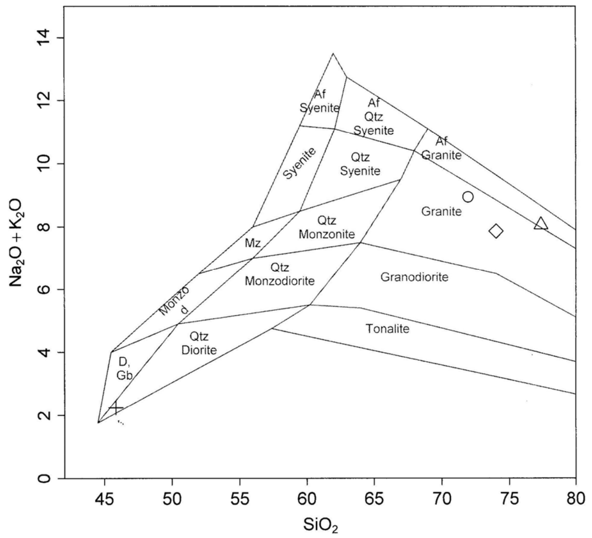

Fig. 10 TAS diagram of four Haggier Mts. plutonites (modification of Middlemost (1985)). Symbols as in Figure 3.

Figure 6 of Peccerillo, Taylor (1976) shows the appurtenance of studied granites to high - K to medium - K series while the gabbronorite belongs to the low-K series. In the Shand´s diagram (Figure 7) modified by Maniar and Piccoli (1989), granite analyses plot near the peralkaline field boundary but already outside of it. The gabbronorite plot, however, is situated far in the metaluminous field. In the multicationic diagram of Batchelor and Bowden (1985) (Figure 8), the tectonomagmatic setting of Haggier Mts. granites is demonstrated: the analytical plots occur in the post-orogenic corner with some affinity to syn-collision sector. Chondrite normalised REE patterns (Figure 9) of granites show a negative Eu-anomaly, pronounced for granite 1, weak for granite 2 (Eu/Eu^* 0.58 and 0.92 respectively). The REE sum is almost equal in both of them: 375.7 for 1 and 378.6 for 2 , but the LaN/YbN ratio for 1 is distinctly higher for 1 than for 2: 4.14 and 1.85 respectively. These REE characteristics do not differ from REE patterns of most other alkaline granites of Nubian/Arabian Shield (comp. Abdel–Rahman 2006). Substantially different picture, however, shows the normalised REE curve of the gabbroic rock (the same Figure); it shows a very flat course (LaN/YbN 1.60), and a low REE sum (142.83). A slight positive Eu anomaly (Eu/Eu^* 1.18) bear upon the high calcic plagioclase content of this rock.

5. RADIOMETRY

All radiometric analyses (Table 5) were performed on monomineral amphibole and feldspar fractions separated in the Laboratories of the Institute of Geology of the Academy of Sciences in Prague, no whole-rock analyses were used. The grain size of samples varies between 2 and 4 mm, the purity was tested in binocular microscope and improved by hand-selection. The K/Ar determinations were made on 0.05 g powdered and in acids treated samples in the Institute of Nuclear Research in Debrecen, using the mass spectrometry and isotope dilution method. Potassium content was determined by flame photometry with Na buffer and Li internal standard and checked by inter-laboratory standards Asia 1/65, LP-6, HD-B1, Gl-O. Argon was extracted by RF fusion in Mo crucibles in previously backed stainless steel vacuum system. ^{38}Ar spike was added from gas pipette system. Evolved gases were cleaned using Ti and SAES getters and liquid nitrogen traps. The purified Ar was transported directly into a 15 cm radius magnetic sector type mass spectrometer and Ar isotope ratio was measured in the static mode. For details see Balogh (1985). Atomic constants suggested by Steiger and Jäger (1997) were used for the ages calculation. For stratigraphic classification we use the timescale of Gradstein et al. (2004).

The EMPA data of amphiboles used for the radiometry proved a scattered composition and zoned structure of these minerals in the granites studied as shown in Table 4. Arfvedsonite prevails while riebeckite (Fediuk, 2005), for which most manuals on systematic mineralogy claim Socotra for the locus typicus, is substantially less frequent and mostly restricted to narrow rims of zoned amphibole columns only. Riebeckite in granites of the same province (Nubian/Arabian shield) reported Radain et al. (1981) from Saudi Arabia, however without any analytical data. Abdel-Rahman (2006) analysed amphiboles from analogous but a little younger (Cambrian) peralkaline granite in Egypt and found here also

Table 4 Representative compositions of amphiboles (wt. %) from granites (1, 2) and from gabbro (3) of Socotra Island and their crystal-chemical formulae normalised to 23 (O).

	1) a	1) b	2) a	2) b	2) c	3)
SiO_2	50.92	44.32	46.17	50.10	51.08	48.59
TiO_2	1.08	1.50	1.31	1.27	1.29	0.49
Al_2O_3	2.64	4.89	2.16	0.91	1.49	8.15
FeO	32.51	27.86	33.92	33.30	34.09	16.63
MnO	0.32	0.94	0.95	0.93	0.33	0.22
MgO	0.43	4.66	1.63	0.98	0.55	11.12
CaO	0.42	9.54	6.67	0.29	0.12	11.68
Na_2O	8.48	2.81	4.43	9.17	7.58	1.12
K_2O	0.68	0.80	0.72	1.18	0.70	0.09
Total	97.48	97.32	97.86	98.13	97.23	98.09
TSi	7.981	7.005	7.383	7.921	7.961	7.124
TAl	0.019	0.910	0.407	0.079	0.039	0.876
TFe^{3+}	0.000	0.085	0.211	0.000	0.000	0.000
Cal	0.468	0.000	0.000	0.090	0.234	0.530
CFe^{3+}	0.442	0.385	0.528	0.539	1.033	0.177
CTi	0.127	0.178	0.158	0.151	0.151	0.054
CFe^{2+}	3.820	3.213	3.798	3.864	3.411	1.797
CMn	0.042	0.126	0.129	0.125	0.044	0.014
CMg	0.100	1.098	0.389	0.231	0.128	2.429
BFe^{2+}	0.000	0.000	0.000	0.000	0.000	0.064
BCa	0.071	1.616	1.143	0.049	0.020	1.833
BNa	1.929	0.384	0.858	1.951	1.980	0.089
ANa	0.648	0.477	0.485	0.860	0.311	0.229
AK	0.136	0.161	0.147	0.238	0.139	0.017
Species	Fe-EC	Fe-ED	KAT	ARF	RIEB	Mg-HB

Analysed in Laboratory of the Czech Geol. Survey Prague using the scanning microscope Cam Scan 4 with the energy-dispersing analyser Link Isis, operator Z. Kotrba. Ferric and ferrous iron for total cation charge 46 were balanced according to the recalculation of Richard (1998) using the 13-CNK mode, the classification of species followed Leake et al. (1997). Abbreviations: Fe-EC = ferro-eckermannite Fe-ED = ferro-edenite KAT = katophorite, ARF = arfvedsonite, RIEB = riebeckite, Mg-HB = magnesian hornblende. For sample location and the rock type see text.

mainly arfvedsonite (as we in Socotra) together with richterite which we did not found in our samples. Amphiboles in gabbronorite (sample 5) are rather uniform, almost not zoned, belonging to the calcic group as its magnesian hornblende member. Alkali-amphiboles, present in granites, are absent here. Low K and Ar contents in these amphiboles are responsible for the comparatively large error in age determination. (note: EMPA data of further minerals – feldspars, sphene, ore, chlorite, epidote, as well as more amphibole analyses – not included in this contribution, are available on request, see the corresponding author´s address).

Feldspar fractions were also separated from samples 3, 4 and tested for K/Ar contents. The obtained data show, however, a substantial loss of radiogenic Ar, so that the calculated ages, approximately 30 % lower than for amphiboles, cannot be taken into account.

Jackson et al. (1994) divided granitoid rocks of Arabian Shield into older (820 to 715 Ma) and younger (686 to 517 Ma) series. The first „high Ca“ group consists mainly of granodiorites and tonalites, the second „low Ca“ group has mostly alkali granite composition. In this conception, the gabbronorite of the Haggier Mts.could be ranged into the „high Ca“ series as its „dismebered“ part, while granites of the massif belongs in this division to the „low Ca“ association, even when their age here is somewhat higher than indicated by Jackson et al. for Saudi Arabia. It should be also mentioned that many of alkali granite bodies in western part of the Nubian/Arabian Shield are younger than the Haggier Mts. massif, oscillating mostly around the Proterozoic/Cambrian boundary (El-Ramly and Hussein (1985) – 578 Ma, Abdel-Rahman (2006) – 522 Ma). Comment on differences between our radiometric data and the values of Samuel et al. (1997) and Fleitmann et al. (2004) is treated in chapter Discussion.

6. DISCUSSION

Facts presented in this contribution evidence that the Haggier Mts. granites of the Socotra Island represent a remote member of the widespread post-collisional A-type granite clan which intruded in

Table 5 Radiometric analyses of amphibole fractions from five plutonic rocks, the Haggier Mts. massif, NE Socotra.

Sample	Rock	K %	40Ar(rad) 10^{-5}ccSTP/g	40Ar(rad) %	Age Ma
1)	Granite	0.818	2.835	65.9	724 ± 24
2)	Granite	0.627	2.038	90.4	687 ± 21
3)	Granite	0.639	2.214	33.9	724 ± 30
4)	Granite	0.320	1.140	49.1	741 ± 26
5)	Gabbronorite	0.0594	0.2189	0.091	762 ± 99

Analyst K. Balogh, Institute of Nuclear Research, Debrecen. For sample locations 1 to 5 see text.

Fig. 11 Layered peralkaline granite, Haggier Mts. location no. 3 (see text). Length of the sample: 14 cm.

many places from Egypt and Sudan to Yemen the Nubian/Arabian Shield rocks. The mineralogy, petrography, geochemistry as well as the radiometric data presented in the previous chapters fit well with this setting. Nevertheless, some controversial features should be mentioned. The mineral composition of granites is evidently peralkaline from mineralogical point of view, manifested not only by the alkaline composition of their amphiboles and the perthitic one-feldspar character, but by the occurrence of symptomatic alkali granite rare accessory minerals as astrophyllite and plumbomicrolite and by special zircone habit with very short prismatic form as well. Nevertheless, the rock geochemistry is not so unambiguous. Namely, the TAS diagram Figure 4 shows that the analysed samples plot not in the normal granite sub-field, the AFM diagram Figure 5 indicates rather the calc-alkaline character of the plots and in the Shand´s diagram Figure 7 the granite plots come up near to the peralkaline sector only. Also the tectonomagmatic discrimination diagram Figure 8 shows rather a compromise feature between pure post-orogenic and syn-collisional setting. As Figure 10, a further and earlier modification of the TAS diagram (besides of analogous Figures 3 and 4) by Middlemost (1985) is presented. Only one plot of three lies in the alkali feldspar granite field while two other show a normal granite character. If we combine both criteria, mineralogical as well as chemical, a rather transitional character of Haggier Mts. granites can be stated.

Another problem concerns the radiometric data. Our datings remain in the range of Neoproterozoic like those of Samuel et al. (1997) and Fleitmann et al. (2004) but they are approximately 100 Ma lower in the average. For this difference we do not offer any other explanation than impurities and zoned structure of analysed minerals, rather than the applied analytical process. Anyway it should be pointed out in this connection that Samuel´s data for dyke rocks, probably connected with granites, show values even substantially lower than our data for granites.

The radiometric analysis no 5 is the first age determination for gabbroic rocks of Socotra. Its result (higher age as for granites) fits well with field observations (gabbro xenoliths in granite). Nevertheless, the age difference is only slightly higher. This could lead to the conclusion that both rock types are co–magmatic and that the gabbroic magma is the source material for evolving granitic rest melt. The comparison of mineral as well as chemical compositions of both rock types excludes this interpretation showing that these rocks are mutually quite incompatible. Anyway, we have to admit that one age determination for gabbroic rocks is definitely insufficient for any conclusions and can be considered as a stimulation for further research only. Another dept of our contribution is the absence of trace element and isotope chemistry, due to lack of any financial support. In this respect we can for the meantime refer to the comprehensive set of analytical data from an analogous alkaline granitic body of the western sector of the Nubian/Arabian Shield by Abdel-Rahman (2006).

7. CONCLUSIONS

The plutonic complex of the Haggier Mts. in NE Socotra Island consists of two independent units: strongly predominant granite and subordinate gabbroic rocks. While granites are of peralkaline to transitional character with calc-alkaline affinities, gabbroids are distinctly subalkaline and of tholeiitic type.

Radiometric data, presented in this contribution, confirm the statement coined in the recent decade (Samuel et al., 1997; Fleitmann et al., 2004.) that the intrusion of granitoids of the Haggier Mts. massif occurred neither in the Paleozoic nor in the Tertiary. Instead, it is dated to Precambrian (Neoproterozoic) in the final stage of the Pan-African tectonomagmatic event. According to our analyses, this age applies not only for granites, but also to gabbroic rocks. The origin of these mafic plutonites obviously slightly predates the granitic magmatism and we do not suppose the co–magmatic origin of them. As stated by Jackson et al. (1984) and many other authors, we also suppose that the Ca-poor granitic melt originated most probably by partial melting (+ fractionation) of crystalline complexes of the Nubian/Arabian Shield while the generation of gabbroic magma was independently situated much deeper. Only the same plate motion as the trigger of the magmatic activity was perhaps common for both of them.

The mineralogy as well as the geochemistry of the Haggier Mts. granites point to the presumption that the massif crystallised from a comparatively highly evolved fractionated melt. A strange feature of this massif is the extremely rare occurrence of aplite and pegmatite dykes (in contrast with abundant „aschistic“ dykes) and the scarcity of xenoliths. The fact that hitherto no granite–dependent ore deposits or manifestation have been found does not mean that more detailed investigation will not discover any. The same holds for rare mineral species which are usually connected with alkali granitic magmatism. From morphological point of view, frequent splendid eolian cavities „tafoni“ in Haggier Mts. granites should be mentioned.

Many of A-granites of the Nubian/Arabian Shield show the ring structure (El-Ramly and Hussein, 1985; O´Halloran, 1985; Triech andAbdel-Rahman, 1999, etc.). Such structure is in typical form not developed in the Haggier Mts. Nevertheless, some faint indication of it should not be overlooked. Sample no. 3 of our set exhibits a distinct layering (Figure 11) and a large scale (regional) sequences of thick sub–horizontal granite layers of different colours can be observed at the high levels of the mountains. The northern rim of the granite massif consisting of biotite granite to granodiorite could be perhaps interpreted as a manifestation of some marks of zoned structure; this arrangement is reverse in comparison with ring complexes in Saudi Arabia where Harris (1985) reported a biotite granodiorite core and arfvedsonite granite rim. The peculiar Socotran massif calls for much more continued research not only in the structural respect.

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