Noble gases in ultramafic mantle xenoliths of the Persani Mountains, Transylvanian Basin, Romania

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The alkali basalts of the Persani Mountains are products of a late Pliocene to early Pleistocene (2.5–0.7 Ma) intra-plate volcanism, subsequent to an extended period (Mio-Pliocene) of calc-alkaline activity in the Eastern Carpathians. The basaltic to basanitic lavas and pyroclastics carry peridotitic mantle xenoliths and megacrysts of pargasitic amphibole. We have studied abundances and isotopic compositions of all noble gases in samples from the Bogata and La Gruiu Fintina quarries. Sample types investigated are whole rock xenoliths, mineral separates thereof, single crystals and host basalts. These studies are aimed at better characterising the isotopic composition of noble gases in the European subcontinental mantle and revealing the existence and origin of an assumed mantle plume below the Transylvanian Basin. We have found clear evidence for a mantle origin in He, Ne and Ar isotopic compositions (Table 1), whereas Kr and Xe did not show any deviation from the atmospheric ratios.

^3He / ^4He ratios of 6.5–7.3 times the atmospheric value (R/R_A = 6.5–7.3) in mineral separates from Bogata xenoliths are similar to R/R_A values of 6.1 ± 0.7 observed by Dunai and Baur (1995) in samples from the western Pannonian Basin (Kapfenstein). The pargasitic amphibole megacrysts have even higher R/R_A values of up to 9.5, which is above the $^3He/^4He$ ratio in the average MORB mantle (R/R_A = 8.2) and may point to the possibility of a deep-seated mantle plume below the Transylvanian Basin. In an olivine separate from La Gruiu Fintina a $^3He/^4He$ ratio intermediate between the maximum values of the Bogata xenoliths and amphiboles has been found (Table 1).

The dominant He component (6.5–7.3 R_A) is released during the first heating step (1200°C) and is probably stored in fluid inclusions. Two crushing experiments also yielded consistent results of 5.6–6.0 R_A for the fluid inclusion component. The relatively low $^3He/^4He$ ratio points to the shallow lithospheric mantle as its origin. Such an interpretation is supported by studies of Istrate *et al.* (1997), who provide closure depths of 37–40 km in the rising magma column for most of the fluid inclusions. Furthermore geophysical data give a Moho depth of about 40 km below the Persani Mountains (cf. Istrate *et al.*, 1997).

In some olivines and orthopyroxenes we have observed extremely high $^3He/^4He$ ratios of more than 20 R_A in the final (1800°C) heating step. As the He abundances involved are very low ($< 5 \times 10^{-10}$ cm^3

TABLE 1. Noble gas isotope data for selected samples from the Persani Mountains

	$^3He/^4He$ (R/R_A)	$^{20}Ne/^{22}Ne$	$^{21}Ne/^{22}Ne$	$^{40}Ar/^{36}Ar$
Bogata				
Xenolith WR	2.3	9.7	0.028	303
Range	−5.8	−10.1	−0.033	−508
Mineral separates				
B1-X1	1.63	9.73	0.0394	446
cpx	± 0.22	± 0.51	± 0.0068	±60
B1-X1	6.46	10.35	0.0338	421
opx	± 0.24	± 0.40	± 0.0050	± 30
B1-T5	6.9	9.74	0.0310	352
opx	± 1.2	± 0.16	± 0.0025	± 13
B1-27 *	7.3	10.00	0.0313	430
Ol	± 1.5	± 0.24	± 0.0031	± 4
Amphibole megacrysts				
B1-T10	7.05	10.31	0.0420	763
	± 0.45	± 0.29	± 0.0061	± 51
B1-T12	9.50	10.21	0.0366	422
	± 0.79	± 0.16	± 0.0023	± 15
La Gruiu Fintina				
R 87 *	7.97	9.82	0.0433	1263
Ol	± 0.45	± 0.36	± 0.0050	± 66
R 87 *	6.31	11.02	0.0576	5389
Cpx	± 0.21	± 0.21	± 0.0056	± 98
For reference:				
Atmosphere	1	9.80	0.029	296
MORB	8.2	>12.5	> 0.059	> 28000

*preliminary results

STP/g), these high ratios do not affect substantially the values given in Table 1 for the total He released. A spallogenic origin due to cosmic irradiation during surface exposure of the rocks seems to be excluded, because these samples were taken from the bulk of the Bogata lava flows, exposed recently by ongoing quarry activity. Therefore it is possible that the small amount of high R/R_A helium represents a distinct mantle component entrained in the xenolith minerals at much greater depths. We shall test this hypothesis with additional investigations.

The $^{40}Ar/^{36}Ar$ ratios of the xenoliths from the Bogata quarry are moderately elevated above the atmospheric value (Table 1). A higher ratio of 763 ± 51 was observed in one of the pargasitic amphibole megacrysts. The most extreme Ar ratios were measured in the mineral separates from La Gruiu Fintina ($^{40}Ar/^{36}Ar$ = 5390 in clinopyroxene). These samples also have the highest He and Ar concentrations of all Persani Mountains rocks. In contrast the xenolith-bearing alkali-basanitic lavas of the Bogata quarry have strongly radiogenic He ratios (R/R_A = 0.055 ± 0.005). They carry 20–50 times more He than the xenoliths. Obviously there was no He exchange between them.

K-Ar ages of the alkali-basanite flows at Bogata quarry are around 0.79 Ma. These values are in good agreement with Downes *et al.* (1995), who report ages between 0.71 and 1.02 Ma for the Bogata flows. As the potassium concentrations observed in the xenoliths and their separates are very low (<0.03 wt.%), it is not possible to explain the ^{40}Ar excesses in these samples with *in situ* production during 0.79 Ma. Therefore, these excesses must be of mantle origin. Based on the K-Ar ages we have calculated the amounts of ^{4}He produced by *in situ* decay of U and Th in order to obtain the original He isotope ratios at eruption time. For the pargasitic amphiboles the correction is negligible.

Assuming that all the radiogenic ^{4}He has been retained, the $^{3}He/^{4}He$ ratio of one whole rock xenolith increases markedly from 4.2 R_A to 6.4 R_A. This value is in better agreement with those observed in the mineral separates, but still clearly below the 9.5 R_A found in one amphibole.

The $^{20}Ne/^{22}Ne$ ratios of the Bogata whole rock xenoliths and of the alkali-basanites show no deviation from the atmospheric value of 9.80. Some of the xenolith mineral separates have elevated $^{20}Ne/^{22}Ne$ and $^{21}Ne/^{22}Ne$ ratios as compared to the air value (Table 1, Fig. 1). The largest deviations from the atmospheric $^{20}Ne/^{22}Ne$ ratio are found in the pargasitic amphiboles from Bogata and the clinopyroxene separate from La Gruiu Fintina ($^{20}Ne/^{22}Ne$ = 11.02 ± 0.21). Increased $^{20}Ne/^{22}Ne$ ratios cannot be explained by nuclear processes in the rocks, but are clear evidence of a mantle Ne component. However, Fig. 1 shows that the $^{21}Ne/^{22}Ne$ ratios are higher than expected based on the MORB correlation line of Sarda *et al.* (1988). The excess of ^{21}Ne relative to MORB Ne has not been produced in an *in situ* nuclear process such as ^{18}O (α,n) ^{21}Ne, as the concentrations of U and Th in these samples are three orders of magnitude lower than required. It is possible that the mantle-plume below the Transylvanian Basin is characterised by an increased (U+Th)/Ne ratio as compared to the average MORB-mantle. This would be similar, but even more pronounced, to the situation observed at North Chile Ridge (Niedermann and Bach, 1997). However in this kind of mantle source $^{3}He/^{4}He$ ratios should be lower than in the MORB mantle, in contrast to the observations in the amphiboles. Further studies are aimed at resolving this apparent contradiction.

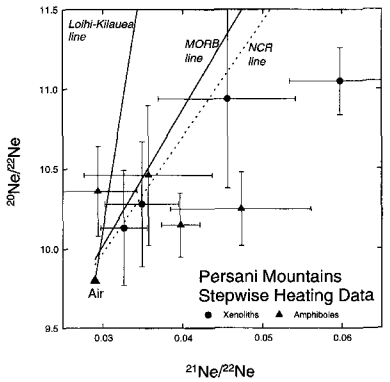

FIG. 1. Ne three-isotope plot for stepwise heating data from Persani mountains xenoliths and amphibole megacrysts. At least three data points are offset considerably from the MORB line. The correlation line for North Chile Ridge basalts (NCR line; Niedermann and Bach, 1997) is also given for reference.

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