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RADIOMETRIC AGES OF IGNEOUS ROCKS FROM NORTHWESTERN ECUADOR

by

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RESUME

L'ensemble des données radiométriques publiées pour la Cordillère occidentale colombienne et équatorienne est discuté sommairement et, dans ce cadre, de nouveaux âges obtenus sur cinq roches éruptives sont présentés et interprétés. Ces roches appartiennent à des complexes ophiolitiques et volcaniques, ainsi qu'à des intrusions, du Nord-Ouest de l'Equateur. Dans chaque cas, la signification des nouveaux résultats est discutée dans son contexte géologique régional.

SUMMARY

After summarizing previous radiometric data from the Colombian and Ecuadorian Western Cordillera, new dating results obtained on five igneous rock samples are presented. They belong to ophiolitic and volcanic complexes and also to intrusives in the Northwest of Ecuador. In each case, the significance of these new results is discussed within its regional geological context.

MOTS CLE

Geochronologie, K-Ar, Equateur, intrusions, laves, ophiolites.

KEY WORDS

Geochronology, K-Ar, Ecuador, intrusives, volcanics, ophiolites.

1. INTRODUCTION

Between 1980 and 1986, the Ecuadorian Mining Institute (INEMIN) developed a geological and mining investigation project, called "NOROCCIDENTE". The area investigated was mainly in the Western Cordillera between the Colombian border and a river called "Guyallabamba" (fig. 1). From 1982 on, this project was executed together with Belgian Technical Assistance.

Since geological knowledge of the study area is extremely limited, a fundamental geological investigation program has been carried out simultaneously with regional prospection. This investigation includes a few radiometric datings. A total of five samples (sample location see fig. 1) has been taken, two in ophiolitic and volcanic complexes, and three in important intrusive bodies. The K-Ar method has been applied on those samples by the Geochronoloy unit of the "Vrije Universiteit Brussel". The present article describes and discusses the results of this first radiometric dating reconnaissance within this part of the Ecuadorian Republic. Results of the age determinations are shown in the table provided in the appendix.

2. RADIOMETRIC AGE DETERMINATIONS

2.1. In ophiolitic and volcanic complexes

Previous work

Only a limited number of radiometric age data is avalaible on Mesozoic-Tertiary ophiolitic and volcanic complexes from Western Ecuador. This is mainly due to the fact that these rocks, generally from oceanic origin, are poor in potassium, and have been subjected to secondary processses (spilitization).

Goossens and Rose (1973) published ages from 54 to 110 Ma. (Eocene to Upper Cretaceous) for their "Basic Igneous Complex". Cotecchia & Zezza (1969) obtained an Eocene age for the base of the Interandine Graben near Ambato. Toussaint and Restrepo (1982) assigned a Cretaceous age to the volcanic complex of the Colombian Western Cordillera, while Alvarez (1983) obtained the same

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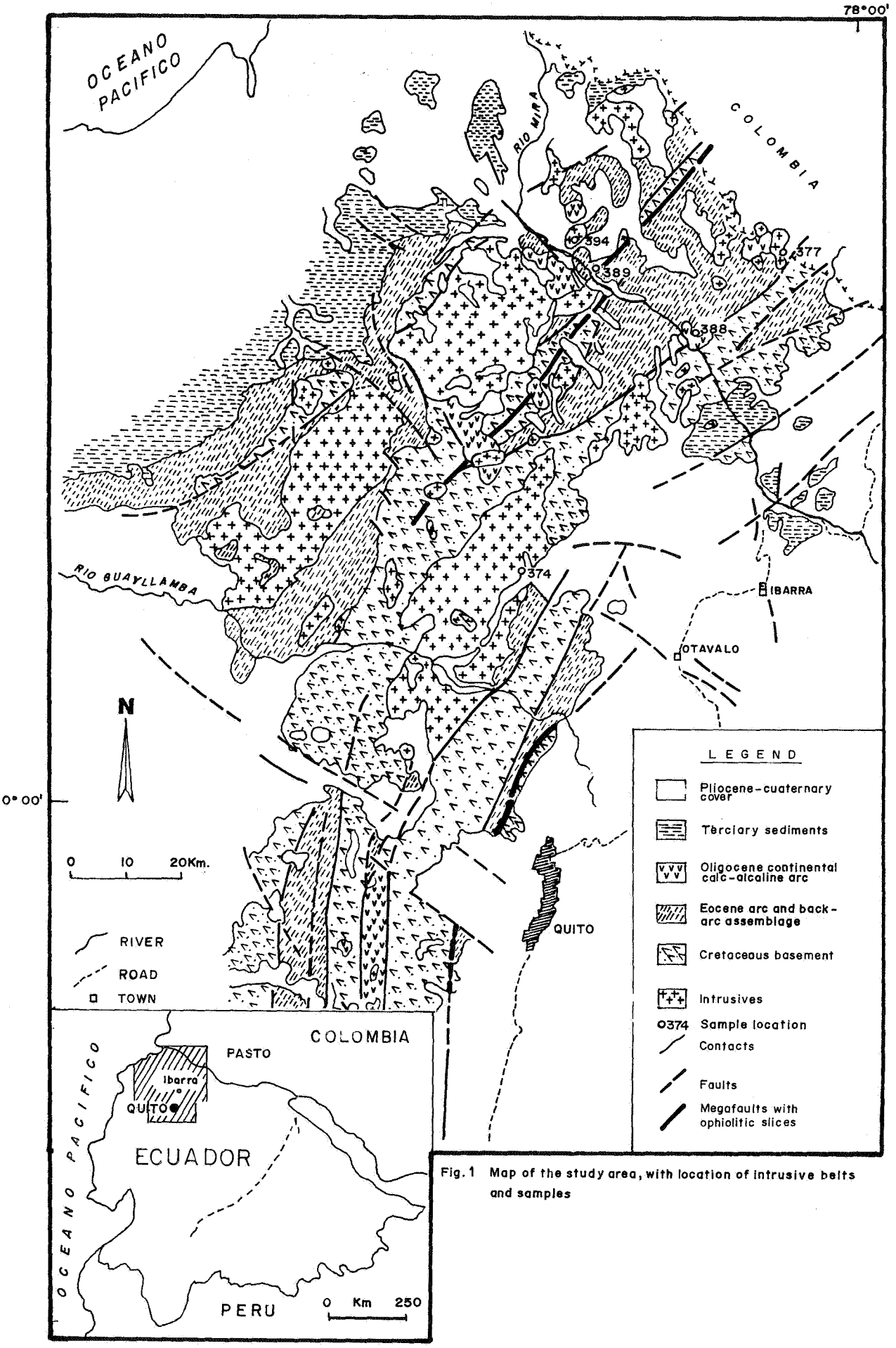

Fig. 1 Map of the study area, with location of intrusive belts and samples

Figure 1. : Map of the study area, with location of intrusive belts and samples.

age for ultramafic rocks of the same Cordillera. However, along the Buga-Buenaventura highway, the same rock assemblage yielded an Upper Jurassic age (Restrepo, 1983).

Age determinations based on paleontological methods are, generally speaking, more reliable in this type of environment, such as those obtained in associated calcareous flysch-type sediments, more to the south, by Eguez (1986) and also during recent, so far unpublished work (Van Thournout, in preparation). However in the area considered, the associated sediments are fossil-poor.

The two investigated samples belong respectively to a hornblende-rich gabbro, with cumulate textures, near Lita, and to hypabyssal rocks from the adjacent lithologic unit called "San Juan de Lachas".

Gabbro near Lita

Localization and description

The sample was taken in the southern roadcut of the Guallupe-Lita highway, approximately 2 km to the SE of Cachaco, in a point with coordinates (UTM) 91.500/791.000.

The outcrop consists of banded grabbos, with subautomorphic calcic plagioclase, which constitutes 50 to 55 % of the rock. The second important mineral is clinopyroxene, with poikilitic texture. Those pyroxenes are surrounded by a very thin reaction rim of very pale amphibole, of a green and brown variety. Opaque minerals are abundant. Secondary minerals are : a very pale biotite (phlogopite), olivine and orthopyroxene.

Generally the rock is fresh, with little alteration, but secondary silicification, affecting the plagioclase, is locally important and may be due to the influence of a later granodioritic intrusive nearby. Granodiorite outcropping in the vicinity contains xenoliths of the same gabbro.

The considerable analytical error in the pyroxene measurement is due to the very low K-content (0.028 %). The disagreement between results on two different minerals may be related to the existence of excess argon, a phenomenon which is commonly observed in pyroxenes from plutonic rocks. The influence of a relatively small quantity of excess-argon, on the apparent age of pyroxene can be considerable, because of its very low K-content. This is a difficulty proper to the dating of potassium-poor rocks. Excess argon often occurs in igneous rocks, under conditions where the magmatic gases cannot establish their equilibrium with atmospheric gases. This can happen with magmas, crystallized in deep magma chambers. Therefore, from a methodological point of view, the assumption that the rock solidified 12 Ma ago does not seem improbable.

On the other hand, more to the south, in the same Cordillera the existence of an Eocene island arc has been proven, and its deposits were called : "Macuchi Formation sensu strictu" (Eguez, 1986). Regional mapping in the northwestern part defined its extension to the north up to the area where the dated samples were taken (Van Thournout, Quevedo, in preparation). The dated gabbros seem to be part of a basement, or of a deep magma-chamber, belonging to this complex. In this case, the Eocene age, obtained from the pyroxenes and hornblendes seems much more probable within the regional geological framework. An alternate hypothesis to explain the discrepant ages is that the Miocene age, obtained on plagioclase, would be the expression of a "re-setting" caused by the late nearby granodioritic intrusive event, which has also brought some secondary quartz and which could possibly be the cause of the hornblende reaction rim around the pyroxene. The expression of the first Eocene magma crystallisation would then have been preserved in the pyroxene cores.

"San Juan de Lachas" Igneous Complex

Localization and description

This lithologic unit has been identified for the first time in 1981 (Salazar). It is mainly composed of lavas and volcanic breccias and agglomerates, with a very small proportion of stratified tuffaceous material.

The whole is intruded by dykes and small intrusive bodies, whose composition is identical of those of the volcanic rocks. There is a very strong similarity with the Tandapi-unit, identified by Eguez (1986) along the Aloag-Santo Domingo highway. The unit is gently folded, almost subhorizontal, and rests unconformably on top of more tightly folded, locally vertical strata. The age of the latter is inferred to be Cretaceous to Eocene, based on mainly lithologic analogies with the units defined by Eguez (1986) more to the south. This tentative correlation is sustained by unpublished paleontological evidence (Van Thournout, in preparation).

Petrographically, the predominant rocks are hornblendic andesites and diorites with calc-alkaline affinity, and basalts. Textures are generally porphyritic.

The sample was taken from a hornblende porphyritic dyke, intruding a series of lavas and agglomerate of the same composition, in the eastern roadcut of the Guallupe (San Juan de Lachas) - Rio Blanco (Jijon y Caamaño) highway. The coordinates of this point, considered as type locality for the new unit, are 83.600/806.400 (UTM). The rock was identified as a microdiorite, with porphyritic texture, with 50 to 60 % phenocrysts of mainly automorphic plagioclase (50 % of the phenocrysts) displaying strong zonation, and up to 7 mm long. Also important are : hornblende (pseudomorphic with augite), strongly pleiochroic with deep green to green brown colors, opaque minerals and hypersthene. Olivine is present in small quantities. The matrix is very fine-grained, and consists mainly of very thin microliths of plagioclase with ophitic texture. The whole of the plagioclase has been subjected to a strong secondary alteration, possibly hydrothermal. The inner part of most crystals is replaced by cryptocrystalline

mass (clay ?). The use of plagioclase for dating is ruled out in this case, but the hornblende is relatively fresh.

This age is in good agreement with data obtained in the south by Eguez (1986) on hornblendic intrusives, which produced ages from Oligocene to Lower Miocene. Obviously, it is the expression of a first magmatic event, after a very important phase of tectonic deformation in the Lower to Middle Oligocene. Consequently, this unit, and the Tandapi unit, its probable equivalent in the south, have to be separated from the former Macuchi Complex. This is consistent with the minor grade of tectonic deformation and metamorphism to which it has been subjected, and also with the unconformities which have been observed.

2.2. Intrusive bodies

Previous work

All radiometric data from igneous rocks in Ecuador were compiled and interpreted by Hall and Calle in 1982. However, since that year, new data have been published on the Ecuadorian Western Cordillera and on the Northern Andes in general (Colombia and Ecuador).

In Colombia, Toussaint and Restrepo (1982) distinguished three main phases of magmatic activity. After a gradual migration from west to east within each phase the transition to the next phase happens through a sudden jump to the west, with partial overlap. Those phases evolved through following ages : Middle Jurassic to Middle Cretaceous, Lower Cretaceous to Upper Eocene and finally, from Lower Eocene to present-day, including recent volcanism.

In his important thesis about granitoid intrusives in Colombia Alvarez, (1983) differentiated Paleocene intrusives (including the Piedbrancha batholith near the Ecuadorian border, with an age of 63 Ma), a Pliocene phase, and mainly subvolcanic units from Miocene to Pliocene. He also puts emphasis on a gradual migration from west to east, within each of those phases.

Finally, Aspen and McCourt (1987) proved the existence in the Western Cordillera of Colombia, of low-potassium leucotonalites, which could be cogenetic and contemporaneous with the tholeiitic Cretaceous series. Those same authors, together with Brook (Aspen, McCourt & Brook, 1987) proposed five intrusive phases for Western Colombia, from Triassic to Upper Miocene, with a sudden jump to the west between each of the phases and a gradual migration to the east during the phases. The events are Triassic, Jurassic, Cretaceous, Paleogene and Neogene.

On the basis of personal work, and datings by Aly (1980), Eguez (1986) proposes a new synthesis for Ecuador, including 4 phases of igneous activity :

- Upper Cretaceous tonalites (Aly, 1980), which could be cogenetic with their surrounding tholeiitic series (see also leucotonalites of Aspen and McCourt, 1987).
- Diorites and granodiorites from the Eocene to the Oligocene.
- Subvolcanic hornblendic intrusives and diorites from the Upper Oligocene to the Lower Miocene.
- Upper Miocene intrusives.

These two last events could correspond to the two last events in Colombia. However, the gradual migration to the east within each phase could not be demonstrated in Ecuador. This could be due to a stronger lateral compression of the Ecuadorian Andes, which would have resulted in a more pronounced superposition of the different belts, hiding the postulated zonation.

In the Ecuadorian Northwestern Cordillera, an intrusive belt, consisting of important batholiths such as : Maldonado, Buenos Aires and Apuela, is known since a long time (Bristow and Hoffstetter, 1977).

Regional mapping during recent work, revealed the existence of another belt more to the west, which includes the Rio Babosa intrusive near Lita, and another very large batholith which extends in the middle courses of the Santiago and Cayapas rivers (fig. 1).

The three samples from intrusives have been taken respectively in the Maldonado, Apuela and Rio Babosa batholiths.

Rio Baboso intrusive

Localization and description

This is the only intrusive from the newly identified western belt, mentioned on previous geologic maps (Baldock, 1982). The sample was taken along the course of the Baboso river, approximately 2.5 km to the N of Lita, in a point with coordinates (UTM) 98.500/784.100.

It has the composition of a tonalite, or a hornblende quartzdiorite with phaneritic texture. Zoned plagioclase (50 %) is subautomorphic. Hornblende crystals (15 %) show a blue-green to green-brown pleiochroism, with a clear secondary alteration. Quartz (10 %) is interstitial or occurs as large crystals. Poikilitic strongly chloritized biotite, clinopyroxenes, orthopyroxenes, orthoclase, remnants of olivine, opaque minerals, and apatite, have also been observed. Secondary minerals consist of sericite in the cores of plagioclase crystals, of a reaction rim around the amphibole crystals, consisting of another, pale amphibole with opaque inclusions, of epidote, and of chloritization of about 30 % of the biotite.

Beside chlorite, the biotite contains 5 % impurities (hornblende and epidote). The reproducibility of K and Ar analyses is however very good. The low K-content is due to the strong chloritization.

Ages from both minerals are in good agreement, despite the fact that both both have been subjected to secondary alteration. It can be assumed that the

measured age is little affected by alteration, perhaps because the latter took place shortly after crystallization of the rock.

Discussion

No additional data are available for the newly recognized western intrusive belt. This first indication on its age is in keeping with that of a similar belt, identified in Northwestern Colombia (Aspen *et al.*, 1970). It also fits with the second series of ages (Eocene to Oligocene) identified by Eguez (1986).

This age is slightly younger than that measured on pyroxene from the Lita gabbro, though error limits overlap.

It corresponds well with the ages, inferred for the Macuchi unit (sensu strictu) and proved for other associated formations (Apagua Formation, Eguez 1986).

As a first working hypothesis, it is proposed that the Baboso and the Rio Santiago batholiths could be possible intrusive roots of the Eocene Macuchi island arc. The Pascuales tonalite would belong to the same belt, on the base of the similar ages obtained for it (Baldock, 1982).

Apuela Intrusive

Localization and description

This intrusive is a large, elongated batholith extending over 50 km in the NE-SW direction, with a NW-SE width of 10 to 15 km.

Its composition is quartz diorite. Up to 60 % of the rock is composed of subautomorphic, zoned plagioclase. Subautomorphic poikilitic hornblende is slightly pleiochroic. Biotites are partly chloritized (about 10 % chlorite). Quartz is secondary and interstitial. Augite and sphene crystals have been observed. Besides chloritization of biotite, plagioclase crystals are locally altered to secondary products. Some of the hornblende seems to be locally altered to low temperature hornblende with opaque inclusions.

The sample was taken in an outcrop overlain by very thick lahar deposits along the Apuela-Aguagrun road, on the northern margin of the Rio Intag, approximately 500 m to the SW of the Apuela village ; coordinates (UTM) of the point are : 30.100/776.600.

The small difference between the ages can be explained either by slow cooling, or by excess argon in hornblende, or possibly through loss of argon due to alteration (chloritization) of biotite crystals.

Discussion

The results are in agreement with previous datings, and inferred ages for the major part of the Western Cordillera batholiths in Ecuador (Hall and Calle, 1982) and in Colombia (Aspen *et al.*, 1987).

These intrusions seem to correspond to the third intrusive phase, identified by Eguez (1986).

Maldonado intrusive

Localization and description

This complex intrusion belongs to the belt which also contains the Apuela batholith. It consists of a series of stocks emplaced in various successive phases, which include a phaneritic phase, and a later hypabyssal porphyritic one, in which the sample was taken.

The diameter of the large phenocrysts is about 2 mm. About 50 % of the rock is composed of microphenocrysts. Main minerals are : automorphic, corroded and zoned plagioclase, sometimes broken, biotite, amphibole and quartz. Biotite and amphiboles have been strongly altered to chlorite, carbonates and opaque minerals. The matrix consists of plagioclase, with little quartz, and a large amount of secondary products. Alteration is stronger along some fissures. A large part of the alteration seems to be late magmatic-hydrothermal.

The sample location is situated in the western road cut, at the entrance of the Maldonado village, with coordinates (UTM) : 101.500/822.200.

The low K content of the biotite indicates alteration. The analysed material contains some chlorite. Both results are in very good agreement. The 8.9 My. age could indicate the age of crystallization of the rocks, or a later (hydrothermal ?) event.

Discussion

The Upper Miocene age is in good agreement with data obtained on other, similar porphyries from the western Cordillera, especially Chaucha. It also fits with ages of some intrusives obtained by Eguez (1986).

3. GENERAL CONCLUSIONS

Above datings have permitted to put some age constraints on a few lithologic units and intrusive belts of Northwestern Ecuador. The existence of an Upper Oligocene to Miocene continental-type calc-alkaline volcanic arc, as proposed by Eguez (1986) more to the south, is confirmed. Furthermore, two belts of batholitic intrusives were identified ; an Eocene one, near the coast, representing the possible root of an Eocene island arc systems, and a Miocene one, being the possible deep expression of the Oligocene to Miocene calc-alkaline volcanic arc.

Rock sample roche	mineral	40Ar rad x 10-7 ml STP	40Ar rad/Ar tot X100	K %	tMa
NWA-R-374	biotite	42.7	72.4	6.90	15.8+/-0.6
NWA-R-374	hornblende	3.90 3.84 3.78	53.3 53.1	0.529	18.5+/-0.9
NWA-R-377	biotite	19.7 19.65 19.6	58.0 59.2	5.67	8.9/- 0.4
NWA-R-377	plagioclase	0.89	24.7	0.261	8.8+/-0.4
NWA-R-377	hornblende	7.57 7.55 7.52	80.3 72.7	0.59	32.6+/-1.3
NWA-R-389	plagioclase	1.71	57.6	0.354	12.4+/-0.4
NWA-R-389	pyroxene + hornblende	0.489 0.494 0.498	20.3 21.9	0.028	45+/-9
NWA-R-394	biotite	76.8 76.5 76.1	79.9 73.3	4.60	42.3+/-1.7
NWA-R-394	hornblende	6.38 6.20 6.02	69.6 72.1	0.394	40.0+/-3.0

Table 1. : Table of analytical data.

Decay contents and isotopic abundances are those recommended by the IUGS Subcommission on Geochronology (Steiger and Jäger, 1977).

Analytical techniques described in Pasteels and Boven (1989).

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