K-Ar AGE DETERMINATION OF THE LATE TERTIARY AND QUATERNARY ANDEAN VOLCANIC ROCKS, SOUTHERN PERU

Ichiro KANEOKA

Geophysical Institute, University of Tokyo
Bunkyo-ku, Tokyo 113, Japan

Introduction

In order to clarify the geochemical and petrographical characteristics of the Andean volcanic rocks, it is essential to examine the rocks of the same period. In this context, it is indispensable to know the age of volcanic activity.

Concerning the period of volcanic activity in the Andean volcanic zone, some investigators have studied it by radiometric dating (e.g., Bellon and Lefèvre, 1976; Weibel et al., 1978). Drake (1976) have revealed that there are systematic differences in the period of volcanic activity along the latitudes as shown in Fig. 1. Furthermore, Baker and Francis (1978) summarized the data on the dating results of volcanic rocks from the central Andes by comparing them to those of samples from the central Oregon and assigned the main volcanic activities to around 20-25 Ma, 10 Ma and 5 Ma ago. Noble et al. (1974) demonstrated a possibility of the correlationship between the Andean volcanic and tectonic activities since Tertiary. Although they determined only seven samples by themselves, they also identified the relatively intense volcanic activity in the southern Peru area about 12 Ma ago together with that of about 40-50 Ma ago based on the compilation of the radiometric age data. Although Stewart et al. (1974) reported more than 60 K-Ar ages on the Andean igneous rocks from Peru, which ranged from 27 to 679 Ma, those rocks were mostly plutonic and metamorphic rocks. Hence, we cannot use the data to infer the Andean volcanic activity directly.

On the other hand, Baker (1977) pointed out a possible migration of volcanic activity in the central Andes from west to east and Farrar et al. (1970) also identified a similar migration for the age of igneous rocks. However, such tendency has been revealed to be a reverse trend for recent volcanic activity (Thorpe and Francis, 1979). In effect, the youngest volcanic activity occurs along the western edge of the Cordillera Occidental. Furthermore, Schwab and Lippolt (1976) reported that the andesitic volcanic activity became remarkable about 10 Ma ago. In the southern Peru area, the activity of ignimbrite were identified to have occurred about 25 Ma ago (Tosdal et al., 1979).

As shown above, most dated rocks were of Tertiary in age. However, some radiometric age data have revealed that even the volcanic rocks which were assumed to be of Quaternary show the age of Tertiary (e.g., Bellon and Lefèvre, 1976). This demonstrates an example for the importance of radiometric dating. In the present study, K-Ar age determinations were made for 30 volcanic rocks, which were collected during the summer of 1980 by the scientific team on "Geochemical Investigation of the Central Andes Volcanic Zone" (Leader : Naoki ONUMA) sponsored by the Ministry of Education under contract No. 504112. These rocks have been regarded to belong to the Barroso Group of Quaternary in southern Peru. The main objectives in this study are to examine the lateral variations of young volcanic activity in southern Peru and to check the stratigraphically assigned ages based on the K-Ar dating.

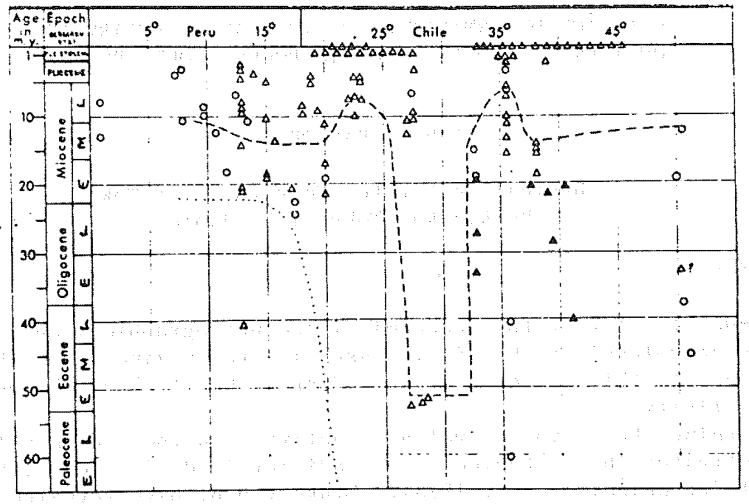

Fig. 1. Cenozoic igneous and tectonic events plotted against latitude in the central and southern Andes. o , intrusive event; Δ , volcanic event. Solid triangles indicate locations west of the present Cordillera. Dotted line shows approximate limit of last marine transgression. Dashed line separates deformed and undeformed volcanic strata. (After Drake, 1976)

STAGE			FORMATION
CENOZOIC	QUATERNARY	RECENT	Alluvial deposits Pyroclastic deposits
		PLEISTOCENE	Morrains and fluvial glaciers Mud flows
			BARROSO GROUP
			Conglomerates
	TERTIARY	UPPER	SENCCA GROUP
			Millo Formation
		MIDDLE	JACAZA GROUP
		LOWER	Sotillo Formation Huanca Formation

VOLCANIC

Fig. 2. Schematic stratigraphic sequence in southern Peru, central Andes. The underlined groups indicate those composed of volcanic materials.

Stratigraphy and samples

In southern Peru, geological periods are classified as shown in Fig. 2, where Barroso Group, Sencca Group and Tacaza Group are belonging to the volcanic series since Tertiary. Among them, only Barroso Group is regarded to be of Quaternary. Although pyroclastic deposits are found in recent years, there are not so many examples to show the extruded volcanic rocks.

As recent volcanic activities in this area, there are several examples. For example, Ubinus volcano, located to the east of Arequipa, is showing fumes or smokes since 1974 and recorded a great eruption in 1622. Huainaputina volcano also has a record of great eruption around 1600 (Weibel et al., 1978).

In the present study, most samples used for K-Ar dating are regarded to belong to the Barroso Group except for one sample (A-166) which is regarded to belong to the Sencca Group. Hence they were expected to show the ages of less than 2 Ma in most cases. However, their appearances of the exposure state were so different for each sample and we had no guarantee that they were surely extruded less than 2 Ma ago. Hence in the present study, we have selected samples in order to cover the wide area in southern Peru as much as possible. Samples were selected by the following criteria.

(1) The sample should be fresh as much as possible, showing no effects of secondary alteration or oxidation.
(2) Such a sample as contains large phenocrsyts of more than a few mm in size should be discarded to prevent from the possible effect of excess ^{40}Ar.
(3) The sample should be sufficiently large so that the fresh part in the interior of the sample might be used for K-Ar dating.

The criterion (3) is required to remove the dirty surfaces in order to exclude the secondary effects. The criterion (1) is the most important requisite in the K-Ar dating and the examination of a sample should be done carefully under macro- and microscopic observations.

In Andean samples, most of which are andesites and dacites, large phenocrysts of plagioclase or biotite with the size of more than a few mm are often observed. Since large phenocrysts are considered to have been formed in a magma reservoir, they are expected to contain the ambient gases in them, resulting in keeping some amount of excess ^{40}Ar. For example, such noble gas components have been identified in large olivine and clinopyroxene phenocrysts (e.g., Kaneoka and Takaoka, 1980). Even plagioclase phenocrysts show the occurrence of excess ^{40}Ar in some cases (e.g., Damon et al., 1967). Hence, it is very important to exclude such phases from samples for K-Ar dating. However it is not easy to separate them completely to exclude the fine fragments. In this study, only those which do not contain large phenocrysts of more than a few mm in size are used for K-Ar dating.

Experimental

From the interior of each block sample, we cut the fresh part in the form of rectangular with about 10 mm in size. Among such rectangular samples, we selected a few pieces of about 2-3 g for Ar analysis and the remains were powdered for K-analysis.

K was analysed with a flame photometer by using Li as an internal standard. Ar was analysed on a Reynolds type mass spectrometer with a radius of 15 cm. ^{38}Ar was used as a tracer for isotope dilution method. K contents for some samples were analysed by the X-ray fluorescence method.

K-Ar ages were calculated by using the constants recommended by Steiger and Jäger (1977). K-analysis includes the uncertainty of 1 - 1.5%

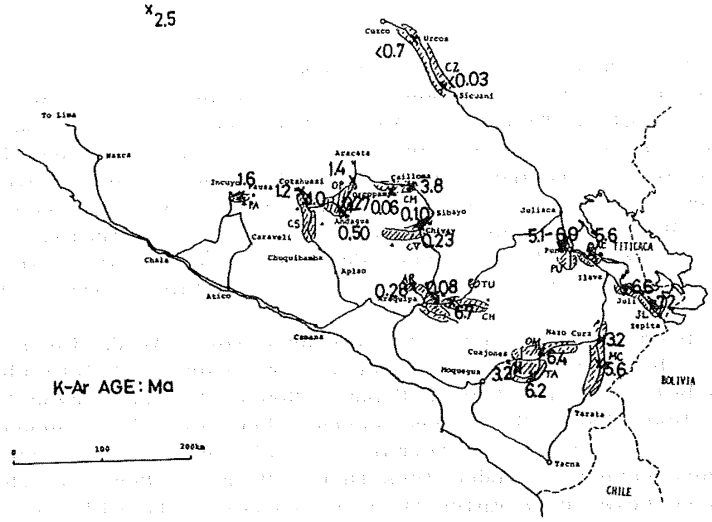

Fig. 3. The results of K-Ar ages determined in the present study. Note that relatively young ages of less than 1 Ma are found for rocks collected from the northwestern part including the vicinity of Arequipa, whereas the samples collected from the southeastern part show the ages of late Tertiary in most cases. Except for one sample from Ayachucho area, these rocks were thought to belong to the Barroso Group.

and Ar-analysis includes those of about 0.5% and 0.2 - 0.3% for $^{40}Ar/^{36}Ar$ and $^{40}Ar/^{38}Ar$ ratios, respectively. The uncertainty in ages is calculated based on these uncertainties together with the degree of atmospheric contamination.

Results and discussion

The results of K-Ar ages of samples and sampling localities are shown in Fig. 3.

For each sampling area, only samples which fullfill the criteria were selected. Hence, it does not always mean that we have selected typical samples from the area. Even in this case, however, we can at least say that the results shown in Fig. 3 probably reflect some tendency concerning their eruption ages, because they were selected on the basis of common criteria for each area.

In the present study, one of the most conspicuous results is that more than half of samples show the ages of more than 2 Ma, though they were collected as samples of the Barroso Group of Quaternary. Some samples show the ages of more than 5 Ma, which are regarded to be of late Miocene. This results suggest that the ages of the volcanic rocks which are reported to belong to the Barroso Group are not always less than 2 Ma. In effect, Bellon and Lefèvre (1976) also reported two examples in which samples of the Barroso Group show the K-Ar ages of more than 4 Ma. Weibel et al. (1978) reported a K-Ar age of 5.3 Ma for a volcanic rock of probably Barroso Group which was collected at the foot of Coropuna volcano. This case is also raised as an example that the rocks of the Barroso Group do not always show

the ages of Quaternary. Hence, we must be very careful to use the stratigraphically ssigned age to infer the eruption age of a sample.

So long as present dated samples are concerned, we have observed some regional difference in the apparent volcanic activity. As shown in Fig. 3, the samples collected from the northwestern part of Arequipa, located in the area around 15 - 17.5°S, 71.5 - 73°W, show the K-Ar ages of less than 1 - 2 Ma, whereas those collected from the eastern part of Arequipa such as the Puno, Juli and Mazo Cruz area show the K-Ar ages of late Tertiary. We have selected samples from each area based on the criteria as mentioned before and have not adopted any other preference. Hence there is a possibility that the main volcanic activity in the southeastern part of southern Peru was older compared with that in the northwestern part such as the Andagua and Arequipa areas. As an example for relatively young age in the southeastern part, a biotite sample in andesite collected from the northwestern foot of Tutupaca volcano is reported to show a K-Ar age of about 0.7 Ma (Tosdal et al., 1979). The sample is located in the Tarata area (TA) in Fig. 3. In the present study, we discarded such samples as included large phenocrysts. One may argue that young samples in the southeastern part in this region might have been systematically dismissed during the procedure. However, we have no reason to believe that relatively young volcanic rocks contain large phenocrysts systematically.

In the present surveyed area, the youngest volcanic activity occurs along the northwestern edge of the Cordillera Occidental. Present results suggest that even in the CZ area which is located at rather inner continental area there occurred very young volcanic activity as shown by the data CZ-02-02 and CZ-04. Although the apparent volcanic activity occurred at similar ages for the northwestern edge of the Cordillera Occidental and the CZ area, the depth of the subducted lithosphere is different between them, which may reflect to the mode of volcanism.

In the northwestern outsuburbs of the Puno area, there are some hills which are composed of shoshonitic rocks. Although they are also believed to belong to the Barroso Group, K-Ar dating results show the ages of about 6 Ma. All samples were collected from different hills and the sample PU-03 shows a little younger ages. However, there is no reason to assume that the hill alone erupted about 0.8 Ma later than the other hills. Since all the other five samples show similar ages of 5.9 ± 0.1 Ma, it is more likely that the shoshonitic rocks were erupted rather in short period. Bellon and Lefèvre (1976) also reported a K-Ar age of 5.7 ± 0.3 Ma for one sample in the Puno area.

Furthermore, an andesite collected at the northwestern part of the lake Titicaca (AC-03) shows an age of about 5.6 Ma and those collected at the southern part of the lake Titicaca indicate the ages of about 7 Ma. Hence, it may be unreasonable to classify them in the Barroso Group.

These results strongly suggest that the stratigraphically assigned ages are not sufficient enough to infer the period of volcanic activity in the central Andes, southern Peru, and their ages should be carefully controlled by radiometric ages.

References

Baker, M.C.W. (1977) Geol. Rundsch., 66, 455.
Baker, M.C.W. and P. Francis (1978) Earth Planet. Sci. Lett., 41, 175.
Bellon, H. and C. Lefèvre (1976) C.R. Acad. Sci., 283, ser D, 1.
Damon, P.E., A.W. Laughlin and J.K. Percious (1967) Int. Atomic Energy Agency, Vienna, 463.
Drake, R.E. (1976) J. Volcanol. Geotherm. Res., 1, 265.

Farrar, E.H., S.J. Clark, G.S. Haynes, H. Quirt, H. Conn, and M. Zentilli (1970) Earth Planet. Sci. Lett., 10, 60.
Kaneoka, I. and N. Takaoka (1980) Science, 208, 1366.
Noble, D.C., E.H. McKee, E. Farrar and V. Peterson (1974) Earth Planet. Sci. Lett., 21, 213.
Schwab, K. and H. Lippolt (1976) Proc. Symp. on Andean and Antarctic Volcanology Problems, Santiago, Chile, 698.
Steiger, R.H. and E. Jäger (1977) Earth Planet. Sci. Lett., 36, 359-362.
Stewart, J.W., J.F. Evernden and N.J. Snelling (1974) Geol. Soc. Amer. Bull., 85, 1107.
Thorpe, R.S. and P.W. Francis (1979) Tectonophys., 57, 53.
Tosdal, R.M., E. Farrar, and A.H. Clark (1979) J. Volcanol. Geother. Res., 10, 157.
Weibel, Von M., M. Frangipane-Gysel and J. Hunziker (1978) Geol. Rundsch., 67, 243.