PRELIMINARY K/Ar GEOCHRONOLOGY OF THE CRATER BASALT VOLCANIC FIELD (CBVF), NORTHERN PATAGONIA

Zoltán PÉCSKAY[1], Miguel[1] J. HALLER[2] and Károly NÉMETH[3, 4]

[1] Institute of Nuclear Research of the Hungarian Academy of Sciences, Debrecen, Hungary
[2] Universidad Nacional de la Patagonia San Juan Bosco y CONICET, Puerto Madryn, Argentina
E-mail: haller@cenpat.edu.ar
[3] Institute of Natural Resources, Dept. Soil and Earth Sciences, Massey University, Palmerston North, New Zealand
[4] Geological Institute of Hungary, Budapest, Hungary

RESUMEN: *Geocronología preliminar K/Ar del Campo Volcánico del Basalto Cráter, Patagonia Septentrional.*
El campo volcánico del Basalto Cráter (CVBC) constituye uno de los campos basálticos cuaternarios de intraplaca de la Patagonia septentrional. El estudio sistemático de la geología, volcanología y geocronología del CVBC muestra una historia eruptiva "multiepisódica" de volcanes basálticos. Las dataciones K-Ar realizadas sobre roca total son coherentes con el control estratigráfico. Las edades obtenidas para el Basalto Cráter permiten distinguir tres episodios diferentes, pero individualmente coherentes, de actividad volcánica, ocurridos hace ~1,0 Ma; 0,6 Ma y 0,3 Ma. Las diferencias de edad parecen ser significativas, aún cuando el contenido de argón radiogénico determinado en los análisis de roca total resultó menor al 10 %.

Palabras clave: *Basaltos, Cuaternario, Patagonia, geocronología*

ABSTRACT
The Crater Basalt volcanic field is one of the Quaternary intraplate basaltic fields in northern Patagonia. A systematic geological, volcanological and geochronological study of CBVF indicates a "multistage history" of eruptions of basaltic volcanoes. K/Ar dating, using whole rock samples shows that the measured analytical ages are fully consistent with the available stratigraphic control. The radiometric ages fall into three distinct, internally consistent age groups, which give evidence that there were at least three major episodes of volcanic activity, at about 1.0 Ma, 0.6 Ma and 0.3 Ma ago. The age differences appear to be just significant, even although less than 10 % radiogenic argon was found in the isotope analysis of whole rock samples.

Keywords: *Basalts, Quaternary, Patagonia, geochronology*

INTRODUCTION

The Crater Basalt volcanic field (CBVF) is one of the intraplate basaltic fields in northern Patagonia. It consists of at least nine monogenetic volcanic centres covering an area of *ca.* 700 km^2 and an erupted lava volume of 6 km^3 based on mapping and satellite image analyses (Fig. 1). The volcanic centres constructed scoria cones and lava flows. The lava flows are mainly pahoehoe type with pressure ridges, tumuli and microflow structures on their surface.
Previously, Volkheimer (1964) and Ravazzoli and Sesana (1977) described the regional geology of the area. Recently Massaferro *et al.* (2002) and Massaferro *et al.* (2006) characterized the CBVF volcanic rocks as alkaline basalts and hawaiites. Haller (2004 a) pointed out the lineation of eruptive centres following tensional and synthetic shear fault directions of the transtensional trench formed by the Gastre fault zone, the main structural feature of the area. Haller (2004b) described eruption mechanisms in this volcanic field and concluded that scoria cone formation was accompanied with late stage lava spatter cone formation. Such small spatter cones form a volcanic complex in the centre of the volcanic field. Many of the scoria cones are point sources of extensive lava flows up to five km-long. Small scale lava spatter-fed lava flows are common in the near vent zones of the scoria cones and forming erosion resistant capping units over most of the cones.

PREVIOUS AGE CONSTRAINS

The Crater Basalt volcanic field lava flows cover glacio-fluvial terraces and poured into valleys. Basaltic lava flows also cover sub-recent clay-evaporite deposits as in Salinas Grande and Salina del Pito (Fig.1). On the other hand, the alluvial sediments transported by Mamil Choique creek cover the Loma Guacha's volcanics. These stratigraphic relationships among different terrace deposits and volcanic rocks suggested that the eruption of the volcanic center occurred during Quaternary times.

GEOLOGY OF THE SAMPLED SITES

As part of a volcanological mapping project, three sites were sampled for K/Ar age determination studies: 1) Cerro Fermín; 2) an unnamed eroded scoria cone in the central part of the basalt field; and 3) a second scoria cone located in the western margin of the field next to Rio Chico (Fig. 1).
1) Cerro Fermín is the most outstanding volcanic feature in the area. It is located in the centre of CBVF (Fig. 2). It forms an almost equidimensional star shaped crown-

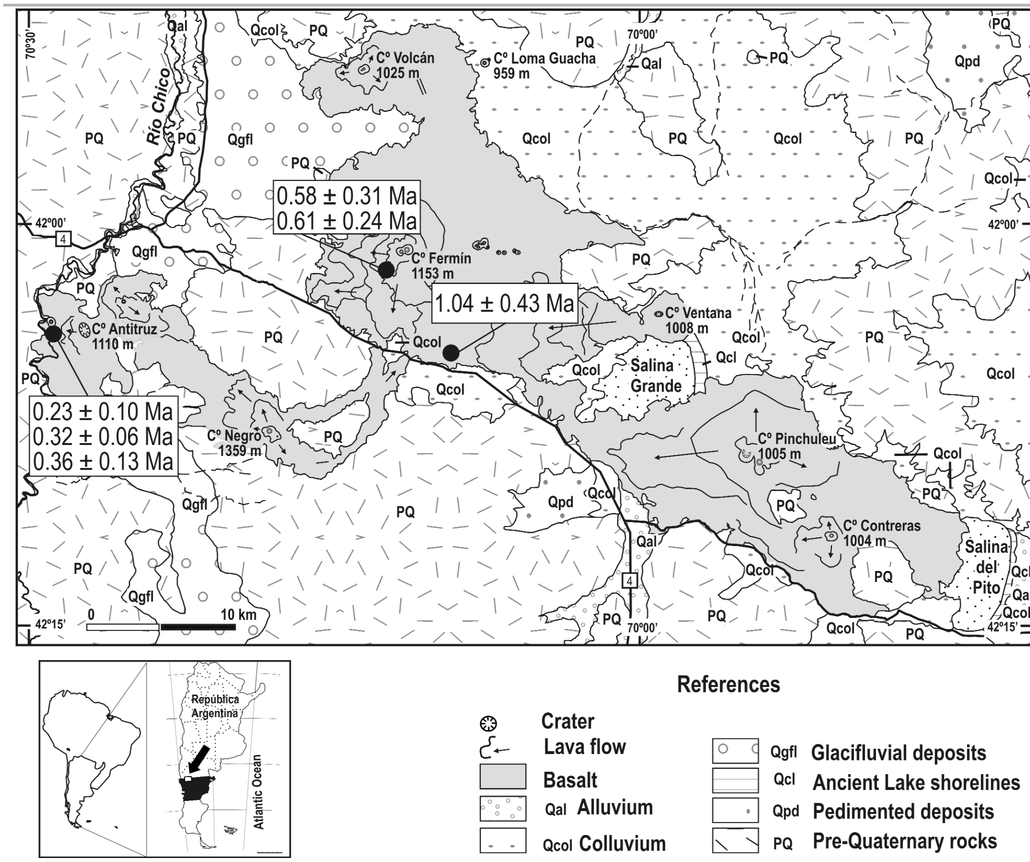

Figure 1: Map of the Crater Basalt volcanic field showing the distribution of effusive volcanic centres and K-Ar ages.

Figure 2: Site 1, Cerro Fermín from the south. Two scoria cones surrounded by an almost equidimensional star shaped crown-like over-steepened lava complex with some concentric lava surface morphologies.

like over-steepened lava complex with some concentric lava surface morphologies suggesting circular lava flow movements around two gently sloping nested spatter cone. The lava flows of Cerro Fermín are covered by younger lava flows poured out from a fissure-fed eruption in the eastern side of CBVF. Other lava flows coming from Cerro Negro in the south-west collide with Cerro Fermín's lavas, indicating their later age.

2) An almost eroded scoria cone situated in the lava field is surrounded by lava flows originated in the fissure fed eruption above mentioned (Fig. 3).

3) A scoria cone close to the Rio Chico has erupted on an ancient fluvial terrace (Fig.4).

SAMPLING AND EXPERIMENTAL METHODS

Mostly fresh lava flows were sampled, however sometimes pyroclastic fragments of the scoria cones have been also taken for analytical measurements. However the interpretation of the analytical result from pyroclastic rocks was taken with caution similar to other works on age constrains on pyroclastic rocks (e.g. Balogh and Németh 2005). The most suitable samples, free of alteration and of xenoliths, were selected on the basis of the examinations of thin sections.

Samples for K-Ar dating were crushed and sieved to 250-100 m. Sieved fraction was washed with distilled water and dried at 110º C for 24 h for Ar-analysis. A portion of the whole rock sample prepared for age determination was ground using mortar and the resulting powder was analysed for potassium, and the other part of the sample was used for argon analysis.

The analytical work has been made in the Institute of Nuclear Research of the Hungarian Academy of Sciences (ATOMKI), Debrecen, Hungary.

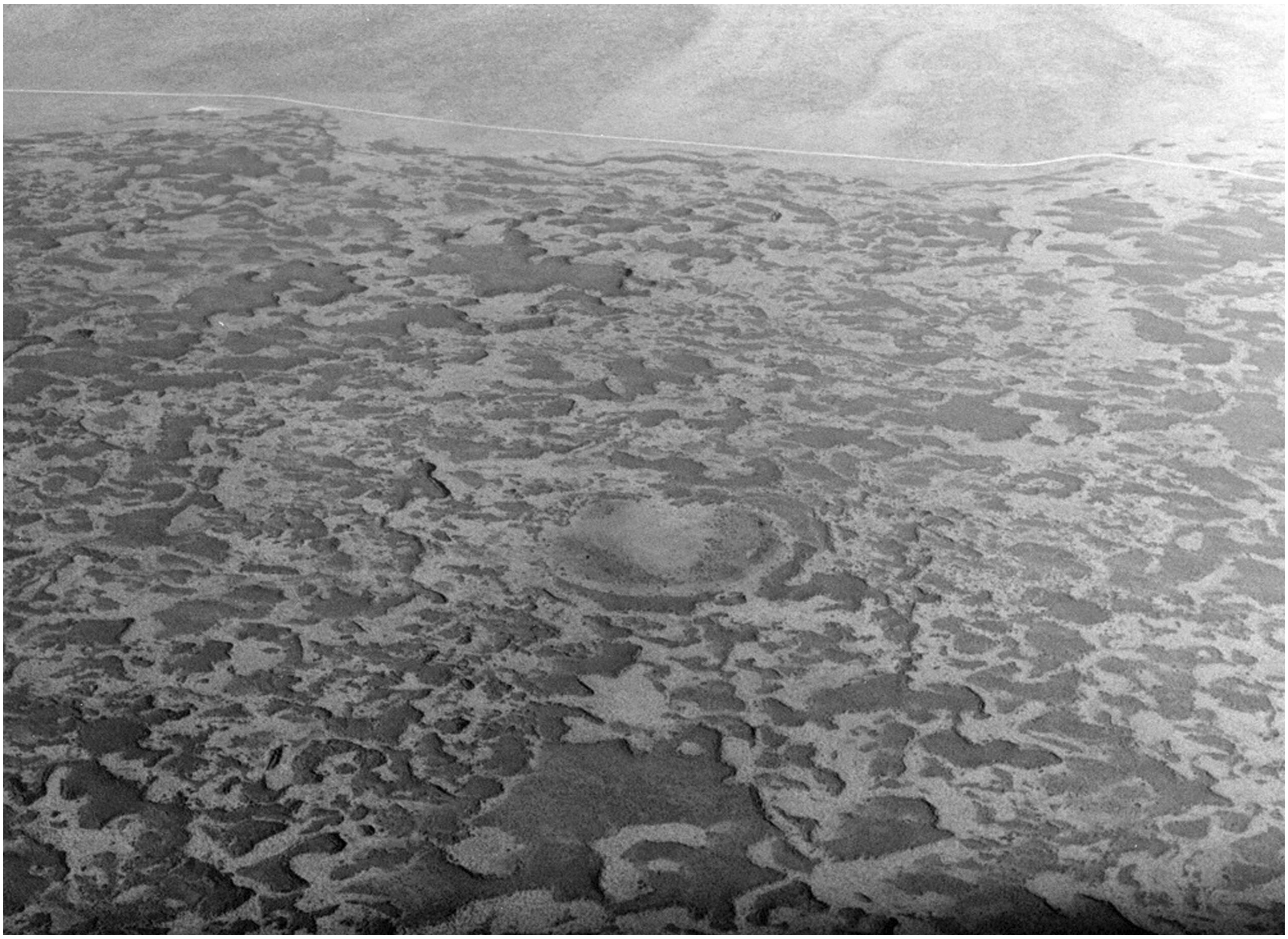

Figure 3: Site 2, an almost eroded scoria cone surrounded by younger lava flows. View from the south.

POTASSIUM DETERMINATION

Approximately 0.1g of finely ground sample was digested in acids and finally dissolved in 0.2M HCl. For the sake of improving the precision of the potassium determination, in all the cases duplicate analyses have been made. Potassium was determined by flame photometry with a Na buffer and Li internal standard. The inter-laboratory standards Asia 1/65, LP-6, HD-B1, GL-O were used for checking the measurements. The analytical uncertainty is better than 2%.

Figure 4: Site 3, a scoria cone erupted on an ancient fluvial terrace of Rio Chico. View from the south.

ARGON MEASUREMENTS

Argon was extracted from the samples by RF fusion in Mo crucibles, in previously backed stainless steel vacuum system. ^{38}Ar spike was added from gas pipette system and the evolved gases were cleaned using Ti and SAES getters and liquid nitrogen traps, respectively. The purified Ar was transported directly into the mass spectrometer and Ar isotope ratio was measured in the static mode, using a 15 cm radius magnetic sector type mass spectrometer built in Debrecen, Hungary. Details of the procedures are described in Pécskay and Molnár (2002).

Details of the instruments, the applied methods and results of calibration have been described elsewhere (Balogh 1985).

TABLE 1: Analytical data for basaltic products in Crater Basalt Volcanic Field (CBVF), Northern Patagonia*.

Sample no. of K/Ar lab	Sample	Location	Latitude	Longitude	K (%)	$^{40}Ar_{rad}$ (ccSTP/g) x 10^{-8}	$^{40}Ar_{rad}$ (%)	K/Ar age (Ma)	Mean age (Ma)
6661	GS-10	Crater on Rio Chico	42º 03.308'	70º 28.037'	1.99	2.499	6.6	0.32 ± 0.06	0.34 ± 0.09
6664	GS-7	Crater on Rio Chico	42º 03.308'	70º 27.824'	2.04	2.853	3.7	0.36 ± 0.13	
6665	GS-8	Crater on Rio Chico	42º 03.390'	70º 27.878'	1.94	1.757	3.1	0.23 ± 0.10	
6689	GS-4	Eroded scoria cone	42º 04.244'	70º 10.002'	1.28	5.190	3.3	1.04 ± 0.43	
6690	GS-5	Cº Fermín	42º 01.144'	70º 11.692'	1.39	3.141	2.6	0.58 ± 0.31	0.60 ± 0.28
6663	GS-6	Cº Fermín	42º 01.084'	70º 11.211'	1.48	3.494	3.4	0.61 ± 0.24	

*) K/Ar dating in whole rock in the Institute of Nuclear Research of Hungarian Academy of Sciences (ATOMKI), Debrecen, Hungary.

AGE CALCULATION

Atomic constants suggested by Steiger and Jäger (1977) were used for calculating the ages. All analytical errors represent one standard deviation (i.e. 68 % analytical confidence level). Since we base our analytical errors on the long time stability of instruments and on the deviation of our results obtained on standard samples from the inter-laboratory mean the analytical errors are likely to be overestimated.

K-AR DATA FOR CRATER BASALT (CBVF)

Analytical data of K/Ar dating are presented in table 1. K/Ar ages of the CBVF show, that it has developed within a time span 0.3 Ma-1.0 Ma (i.e. age span of volcanic activity at the volcanic centre).

One single age determination was carried out on the sample GS-4. The obtained age suggests that the oldest volcanic structure of the study area is an eroded scoria cone, which was active from at least 1 Ma ago.

Two samples were dated (GS-5. and GS-6., respectively) from the Cerro Fermin's lava flows. The concordancy of the dates (0.58 Ma and 0.61 Ma, respectively) is convincing evidence of the reality volcanic activity of this age.

The latest episode dated volcanic occurrence of CBVF corresponds to the scoria cone on the Rio Chico-fluvial terrace. Three radiometric ages range from 0.23 Ma to 0.36 Ma, were measured on pyroclastic rock samples from different sites of the scoria cone. Two dates (0.32 Ma and 0.36 Ma, respectively) on the samples taken from the same stratigraphic position yield ages that are reproducible and indistinguishable from one another. Probably the best approach of the time of eruption can be given by mean age: 0.34 Ma.

Younger K/Ar age (0.23 Ma) has been determined on the sample GS-8. This radiometric age can reflect the termination of the volcanic activity of CBVF. This younger age is also supported by the available geological data.

DISCUSSION AND CONCLUSIONS

All the K/Ar ages available for the CBVF confirm the Quaternary age postulated on field observations, on volcanological and on stratigraphic interpretations. On the other hand all data are in full accordance with the model given by Massaferro *et al.* (2006) for the evolution of CBVF.

The concordancy of the radiometric data in each groups strongly suggest that voluminous eruptions occurred at discrete times, separated by periods of quiescence. The most precise time of eruptions can be given by the mean ages (0.34 ± 0.09 Ma and 0.60 ± 0.28 Ma, respectively) of the groups, except the oldest age (GS-4; 1.04 ± 0.43 Ma), which comes from only one dated sample.

The significant age difference between the age groups indicates that there were periods of profound erosion, which occurred sometime during the intervals of quiescence. Landscape evolution in northern Patagonia could have eroded the fluvial valleys to almost their present level in pro-glacial areas during Pleistocene times, and the erosion could slowed later as the arid conditions prevailed and water availability was lesser during the Holocene.

The considerable time difference among the three studied sites indicates also a long-lived volcanic evolution for the CBVF. This implies that the volcanic field has a relatively steady magma source with low-magmatic output rate over time. Perhaps the time difference among the identified individual age groups is approximately the same as the time passed since the last eruption occurred in the CBVF. This indicates that a future eruption, and therefore the activity of the volcanic field cannot be ruled out, and certainly should not be neglected. To draw a probabilistic volcanic hazard map for the volcanic field similar to those created for Taveuni in Fiji (Cronin and Neall 2001), or Crater Flat, Nevada (Connor *et al.* 2000), need statistical number of data in the future. However, this study showed that further work in the region is necessary to answer the following questions:

. Is there any apparent relationship between size of the remnant scoria cone and the age of the centre?

. Is there any correlation of age with degree of erosion of volcanic cones?

. Is there any relationship between age of the volcanic centre and the style and type of volcanism (explosive or effusive)?

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