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AMS Radiocarbon Dating of a Charcoal Fragment from the Irosin Ignimbrite, Sorsogon Province, Southern Luzon, Philippines

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The eruption of dacitic to rhyolitic pyroclastic flows, Irosin ignimbrite, resulted in the formation of the Irosin caldera in Bicol Peninsula, southern Luzon, Philippines. This paper presents the AMS (Accelerator Mass Spectrometry) ^{14}C date of charcoal fragment from the Irosin ignimbrite that is distributed in the province of Sorsogon. The obtained ^{14}C age is 35,930±250 BP (NUTA2–10795), and tentatively calibrated to the calendar year of 41,329±169 cal BP. This new age result contributes to the study of the Irosin caldera and to the database of widespread tephra deposits in the Philippines.

Key words: Irosin caldera, Irosin ignimbrite, AMS ^{14}C dates, Philippines

1. Introduction

The Philippine Institute of Volcanology and Seismology (PHIVOLCS, 2002) identifies 22 active and 27 potentially active volcanoes in the Philippine archipelago. Among the active volcanoes, Bulusan volcano (12°46.2′N, 124°03.0′E), which is located in the province of Sorsogon in the southern end of the Bicol Arc, southern Luzon (Fig. 1) has erupted in recent historic times. Bulusan volcano is generally known for sudden occurrence of phreatic type of eruption. The most recent volcanic activity involved a series of phreatic eruptions which started from March 2006 until 24 January 2007 (http://www.phivolcs.dost.gov.ph).

This stratovolcano is one of the post-caldera cones of Irosin caldera. The caldera was formed by the eruption of the Irosin ignimbrite, which is mostly massive, poorly to moderately sorted, dacitic to rhyolitic pyroclastic flows, and distributed widely around the caldera (Delfin *et al.,* 1993; McDermott *et al.,* 2005). Previous radiocarbon (^{14}C) ages of 33,500±150 BP, >34,000 BP and >36,000 BP (Newhall, unpublished data) for the ignimbrite plotted within the 33–36 kyr BP range but near the limit of ^{14}C detection.

In order to refine the chronology of the caldera formation, we performed ^{14}C dating with accelerator mass spectrometry (AMS) of charred wood fragments collected from the Irosin ignimbrite. This paper presents the result of the ^{14}C dating and discusses the eruption age of the ignimbrite. This new age is important not only in understanding the eruptive history of the Irosin caldera and associated volcanoes such as the active Bulusan volcano, but also in providing a chronological framework of the volcanism of the Bicol Arc.

2. Outline of the Irosin caldera

The Irosin caldera, together with the active Bulusan volcano and associated older volcanic centers in various stages of erosion, comprise the Bulusan Volcanic Complex (BVC). The rim of the caldera forms a semicircle showing a strong topographic expression and steep gra-

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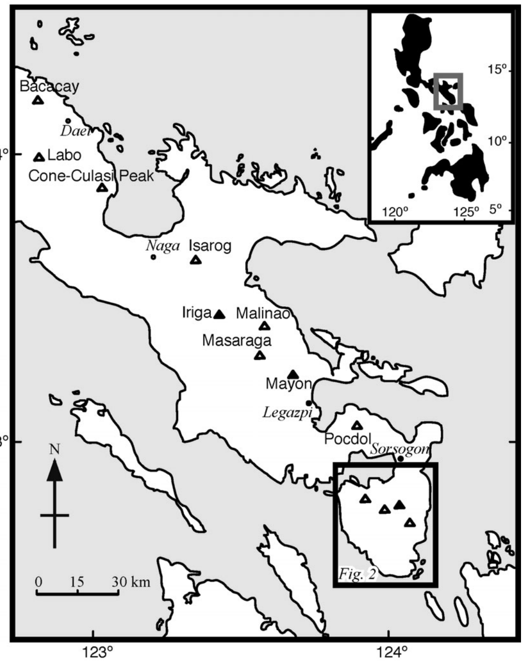

Fig. 1. Map showing the volcanoes of the Bicol Arc (after PHIVOLCS, 2002). Box approximates the location of Bulusan Volcanic Complex (Fig. 2). Inset shows a map of the Philippines; box in the inset map shows location of the Bicol Peninsula.

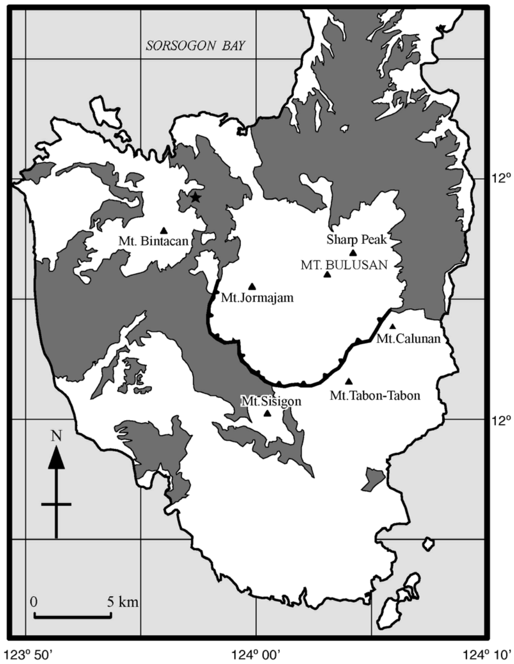

Fig. 2. Map of the Bulusan Volcanic Complex. Shadowed areas show distribution of the Irosin Ignimbrite. The active volcano, Bulusan and other volcanoes are represented by triangles. Star represents the sampling location of charred wood fragment (Fig.3). Solid line traces the outline of Irosin caldera rim (after Delfin *et al.,* 1993, McDermott *et al.,* 2005).

dient in the south but the northern trace is absent. The northern rim was presumed to be covered by younger post-caldera deposits (Fig. 2: Delfin *et al.,* 1993) however, a gravity survey conducted at the BVC confirmed the absence of the northern trace (Komazawa *et al.,* 2000).

The largest single extrusion of dacite to rhyolite magmas in the Bicol Arc led to a collapse and formation of the 11 km-wide Irosin caldera (Delfin *et al.,* 1993). The formation of the caldera represents the second stage of the 3-stage eruptive history of the BVC. Cone-building episode constituted the first stage which commenced at 1.10 Ma, and formed the pre-caldera andesitic volcanoes (Delfin *et al.,* 1993). Post-caldera volcanism followed forming the stratovolcanoes, Sharp Peak and the currently active volcano, Bulusan (Fig. 2).

3. Experimental procedure

At least two types of ignimbrite are recognized in the field: lower fine and upper coarse ignimbrites. Both units consist of beige, massive and pumice-rich pyroclastic flow deposits. The phenocrysts consist of plagioclase, biotite, magnetite and trace amounts of amphibole and quartz. The bulk chemistry of the pumice sample shows 75.8 wt.% SiO_2, which is consistent with a rhyolite composition (Delfin *et al.,* 1993; McDermott *et al.,* 2005).

The charcoal fragment was embedded in the lower portion of the fine pyroclastic flow deposit exposed in Juban, Sorsogon north-northwest of the caldera (Fig. 2). In this outcrop, the ignimbrite is approximately 15 meter-thick and consists of many thin flow units especially at the upper horizon (Fig. 3).

The charcoal sample was purified by acid-alkali-acid (AAA) treatments. The pretreated material was oxidized by heating at 900℃ for 2 hours in a sealed Vycor® tube together with CuO. The produced CO_2 was reduced catalytically to graphite on Fe-powder with hydrogen gas in a sealed Vycor® tube (Kitagawa *et al.,* 1993). We used a HVEE Tandetron AMS system at Nagoya University to make ^{14}C measurements of graphite targets with NIST oxalic acid (HoxII) as standards (Nakamura *et al.,* 2000). We corrected for carbon isotopic fractionation using the $^{13}C/^{12}C$ ratio ($\delta^{13}C_{PDB}$). To estimate the ^{14}C background level, the ^{14}C age of commercial graphite powder (dead carbon) was also measured in the same sequence of sample measurements. The

Fig. 3. Photo of the Irosin ignimbrite in Juban, Sorsogon (12°49.35″N, 123°57.35″E). Charcoal sample was taken from the lower part of the 15 meter-thick outcrop of the ignimbrite.

^{14}C age was calculated by subtracting the ^{14}C concentration of the background sample.

4. Result and discussion

Table 1 shows the result of AMS dating and its calibration. The obtained ^{14}C age of 35,930±250 BP (NUTA2–10795) is significantly younger than 44,670±310 BP (NUTA2–10789), which is used as the ^{14}C background level. The obtained age is consistent with the ages reported by Newhall (unpublished data), thus, further constrains the eruption age for the ignimbrite to be 36 kyr BP. Currently, the ^{14}C age calibration curve IntCal04 (Reimer *et al.,* 2004) extends back to 26 cal kyr BP but no precise calibration curve is available for the time range, 26–50 cal kyr BP (van der Plicht *et al.,* 2004). Thus, we tentatively used the Fairbanks calibration program (Fairbanks *et al.,* 2005), and obtained calibrated year of 41,329±169 cal BP.

Catane *et al.* (2005) suggested that the post-caldera

Table 1. Result of AMS ^{14}C dating for the Irosin ignimbrite.

Material	δ^{13}C (‰)	^{14}C age (BP)	Lab Code
Charcoal fragment	-29.3	35,930±250	NUTA2-10795
Rod graphite	-17.9	44,670±310	NUTA2-10789

volcanism at BVC occurred around 25–30 ka based on the assumption that the typical timing of post-caldera volcanism in intermediate-sized calderas occurs within 5–10 kyr after caldera collapse (Mahood, 1980). However, it has been shown at Kikai and Aira calderas in Japan that post-volcanism has started 1–3 kyr after the ignimbrite eruption (Okuno, 2002; Okuno and Nakamura, 2003; Okuno *et al.,* 1997). These studies at Kikai and Aira calderas underscore the importance in determining the age of the first activity in a post-caldera stage. The new ^{14}C date provides additional data in constraining the age of post-caldera volcanoes in the BVC. Further, the study on widespread ash-fall deposits associated with Irosin ignimbrite will be useful for establishing the chronological framework of the volcanism in Luzon, and probably throughout the Philippines.

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References

Catane, S.G., Taniguchi, H., Goto, A., Givero, A.P. and Mandanas A.A. (2005) *Explosive volcanism in the Philippines.* Center for Northeast Asian Studies, Tohoku Univ., Sendai, CNEAS monograph series No. 18, 146p.

Delfin, F.G., Panem, C.C. and Defant, M.J. (1993) Eruptive history and petrochemistry of the Bulusan volcanic complex: implications for the hydrothermal system and volcanic hazards of Mt. Bulusan, Philippines. *Geothermics,* **22**, 417–434.

Fairbanks, R.G., Mortlock, R.A., Chiu, T.-C., Cao, L., Kaplan, A., Guilderson, T.P., Fairbanks, T.W. and Bloom, A.L. (2005) Radiocarbon calibration curve spanning 0 to 50,000 years BP based on paired ^{230}Th/^{234}U/^{238}U and ^{14}C dates on pristine corals. *Quaternary Science Reviews,* **24**, 1781–1796.

Kitagawa, H., Masuzawa, T., Nakamura, T. and Matsumoto, E. (1993) A batch preparation method for graphite targets with low background for AMS ^{14}C measurements. *Radiocarbon,* **35**, 295–300.

Komazawa, M., Pantig, J., Andico, B. and Listanco, E. (2000) Gravity anomalies of Bulusan volcano, South Luzon.Report of international research and development cooperation ITIT Projects. *Research on Volcanic Hazard Assessment in Asia,* 35–38.

Mahood, G. (1980) Geological evolution of a Pleistocene rhyolitic center — Sierra La Primavera, Jalisco, Mexico. *Jour. Volcanol. Geotherm. Res.,* **8**, 199–230.

McDermott, F., Delfin, F.G., Defant, M.J., Turner, S. and Maury, R. (2005) The petrogenesis of volcanics from Mt. Bulusan and Mt. Mayon in the Bicol arc, the Philippines. *Contribution to Mineralogy Petrology,* **150**, 652–670.

Nakamura, T., Niu, E., Oda, H., Ikeda, A., Minami, M., Takahashi, H., Adachi, M., Pals, L., Gottdang, A. and Suya, N. (2000) The HVEE Tandetron AMS system at Nagoya University. *Nuclear Instruments and Methods in Physics Research,* **B172**, 52–57.

Okuno, M. (2002) Chronology of tephra layers in southern Kyushu, SW Japan, for the last 30,000 years. *The Quaternary Research (Japan),* **41**, 225–236 (in Japanese with English abstract).

Okuno, M. and Nakamura, T. (2003) Radiocarbon dating of tephra layers: recent progress in Japan. *Quaternary International,* **105**, 49–56.

Okuno, M., Nakamura, T., Moriwaki, H. and Kobayashi, T. (1997) AMS radiocarbon dating of the Sakurajima tephra group, southern Kyushu, Japan. *Nuclear Instruments and Methods in Physics Research, B123*, 470–474.

Philippine Institute of Volcanology and Seismology (2002) **Volcanoes of the Philippines.** Department of Science and Technology (DOST), 41p.

Reimer, P.J., Baillie, M.G.L., Bard, E., Bayliss, A., Beck, J.W., Bertrand, C., Blackwell, P.G., Buck, C.E., Burr, G., Cutler, K.B., Damon, P.E., Edwards, R.L., Fairbanks, R.G., Friedrich, M., Guilderson, T.P., Hogg, A.G., Hughen, K.A., Kromer, B., McCormac, F.G., Manning, S., Ramsey, C. Bronk, Reimer, R.W., Remmele, S., Southon, J.R., Stuiver, M., Talamo, S., Taylor, F.W., van der Plicht, J. and Weyhenmeyer, C.E. (2004) IntCal 04 terrestrial radiocarbon age calibration, 0–26 cal kyr BP. *Radiocarbon,* **46**, 1029–1058.

van der Plicht, J., Beck, J.W., Bard, E., Baillie, M.G.L., Blackwell, P.G., Buck, C.E., Friedrich, M., Guilderson, T.P., Hughen, K.A., Kromer, B., McCormac, F.G., Ramsey, C Bronk, Reimer, P.J., Reimer, R.W., Remmele, S., Richards, D.A., Southon, J.R., Stuiver, M. and Weyhenmeyer, C.E. (2004) NotCal04 — comparison/calibration ^{14}C records 26–50 cal kyr BP. *Radiocarbon,* **46**, 1225–1238.

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フィリピン共和国，ルソン島南部のイロシン火砕流堆積物から採取した炭化木片の加速器 ^{14}C 年代

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フィリピン共和国，ルソン島南東部に位置するイロシンカルデラは，イロシン火砕流の噴出によって形成された．この研究では，この火砕流堆積物中の炭化木片を採取し，加速器質量分析（AMS）法によって ^{14}C 年代を測定した．得られた ^{14}C 年代は 35,930±250 BP（NUTA2-10795）であり，41,329±169 cal BP の暦年に予察的に較正される．この結果は，イロシンカルデラの噴火史研究だけでなく，フィリピンにおける広域テフラのデータベース構築にも貢献することが期待される．