Two AMS Radiocarbon dates for the TBJ tephra from Ilopango Caldera, El Salvador, Central America.

Shigeru Kitamura

1. Introduction

TBJ tephra is one of the most important time markers in the northern area of Central America. It is important especially for mesoamerican archaeologists, because it had been considered as a stratigraphic boundary between the Preclassic and the Classic horizons. In spite of its importance, two different radiocarbon dates for the eruption were suggested; A. D. 260 ± 114 yr. B. P. (Sheets, 1983) and A. D. 430 with 2σ error range of A. D. 408 to 536 (Dull, et al., 2001). The latter was determined more precisely than the former using modern AMS radiocarbon dating, so that it is gradually gaining acceptance in mesoamerican archaeology. On the other hand, the latter date was determined with ambiguous procedure such as the 'combination' of calibrated 'traditional' radiocarbon dates with AMS radiocarbon dates, probably because it is necessary to supply the deficiency of AMS radiocarbon dating. It means that AMS radiocarbon dating is still insufficient to determine the reliable eruptive age of the TBJ tephra.

This study aims at reporting two AMS radiocarbon dates for the TBJ tephra to determine its eruptive age reliable enough for archaeological study.

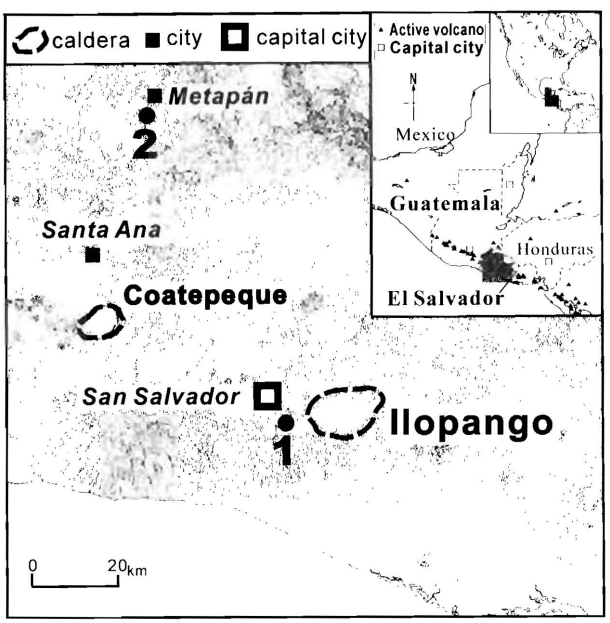

Fig.1 General map of study area

Contour lines with an interval of 100 m was gegnerated by Kashimir3D from SRTM (Shuttle Radar Topography Mission) elevation data. Solid circle with number indicates sampling site and sample number.

2. Ilopango Caldera and its latest eruption

Ilopango Caldera is a large caldera (8 x 11 km) located to the eastern neighbor of San Salvador City, the capital of the Republic of El Salvador (Fig. 1). At least four gigantic eruptions with rhyolite to dacite tephra have occurred since the late Quaternary.

In the latest eruption, voluminous pumice flow was erupted and emplaced to the extent of ca. 40 km from the volcano (Kitamura, 2009). Accompanied with the pumice flow, white fine volcanic ash with small accretionary lapilli was dispersed broadly in the northern area of Central America and the east Pacific (Kutterolf, et al., 2008). These pumice-flow and air-fall deposits are called the TBJ pumice-flow deposit and the TBJ tephra, respectively, after spanish words meaning young white earth, 'Tierra Blanca Joven'. The TBJ tephra is one of the most famous marker tephras in Central America, which has been important especially for mesoamerican archaeologist because it had been considered as the boundary horizon between the Preclassic and the Classic periods in mesoamerican archaeology until recently, although it is being changed by recent investigation.

3. Previous study on the radiocarbon age for the TBJ tephra

For the tephrochronological and archaeological importance mentioned above, the radiocarbon date of the TBJ tephra has been investigated.

The first radiocarbon dating for the TBJ tephra carried out by Sheets(1983), and suggested a calendar age of A. D. 260 ± 114 yr. B. P. It had been the only reliable eruptive age of the TBJ tephra for mesoamerican archaeology during 1980s and 1990s. This result, however, was obtained as a 'composite' age of nine 'traditional' radiocarbon dates which were not calibrated with measuring $\delta^{13}C$. And Dull, et al. (2001) rechecked the nine radiocarbon dates and indicated that some of them include large error, some were determined with organic soil presumably influenced by reservoir effect, and some are too far from other data.

On the other hand, another calendar age of ca. A. D. 430 (2 sigma = A. D. 408 - 536) for the TBJ tephra was suggested by Dull, et al. (2001) with AMS (Accelerated Mass Spectrometry) radiocarbon dating. They eliminated less reliable dates from the nine radiocarbon dates presented by Sheets (1983) and remained four radiocarbon dates are calibrated by assuming $\delta^{13}C$. And they determined three AMS radiocarbon dates of a carbonized wood from the TBJ pumice-flow deposit, .5-cm-thick peat immediately below the TBJ tephra from the lacustrine piston core, and its alkali-soluble component obtained in the preparation procedure. Although this age is nearly two hundred years younger than that, it is gaining acceptance in mesoamerican archaeology, probably because it shows smaller error and was determined by recent precise measurement.

This calendar age, however, did not result only from the recent AMS radiocarbon dating without duplicate measurement, but resulted from the 'combination' of calibrated dates under some assumption from selected four 'traditional' radiocarbon dates and three AMS radiocarbon dates for two samples. Probably, Dull, et al. (2001) must have chosen such a procedure to supply the insufficiency of the recent AMS radiocarbon dating. It means that further AMS radiocarbon dating is still necessary to determine reliable eruptive age for the TBJ tephra.

4. AMS radiocarbon dating

In this study, two radiocarbon samples were collected from outcrops in the field (Table 1).

Table 1 Radiocarbon samples and their sampling sites

No.	Sample ID.	Sampling Site (Lat. / Long.*)	Sample
1	07031001-1	13° 39' 3.0" N / 89° 8' 55.6" W	charred wood contained in the TBJ pumice-flow deposit
2	06082701-1	14° 18' 11.0" N / 89° 27' 23.5" W	organic sediment immediately beneath the TBJ ash-fall deposit

*: Positioned by a handheld GPS using WGS84 (World Geodetic System 1984) coordinate system

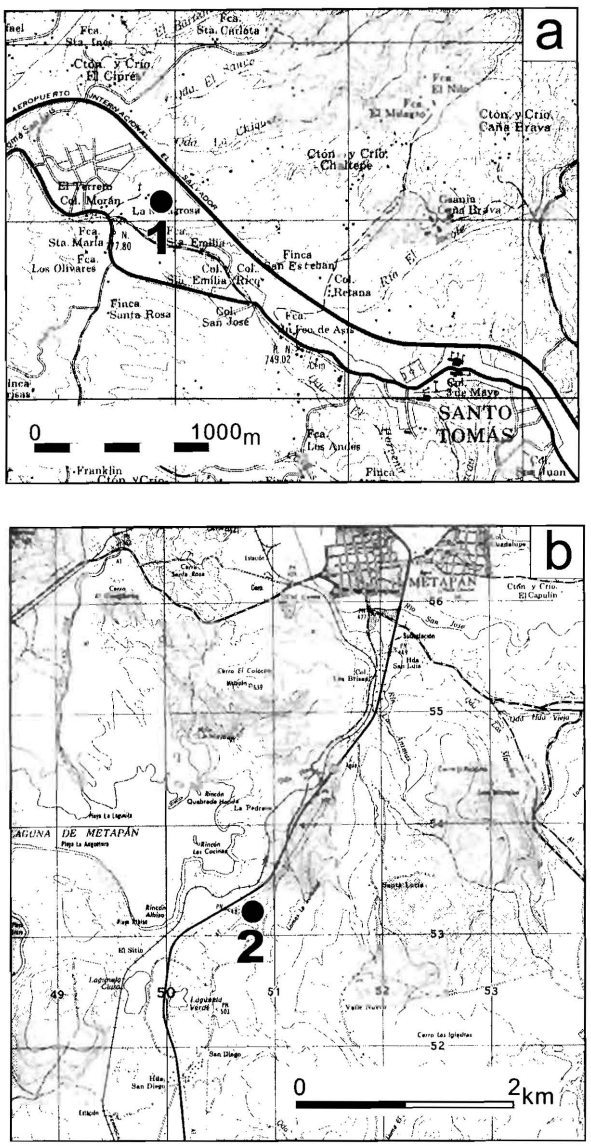

Fig. 2 Location of sampling sites

Solid circle on each map shows the location of sampling site obtained by translating GPS coordinates (WGS84) to map coordinates (NAD27). Number associated with the solid circle corresponds to location number in fig. 1 and it also agrees with sample number. The base map is derived from topographic map on scale of 1:25,000 published by the Instituto Geográfico Nacional de El Salvador; a: Panchimalco (2356-I NW), b: Metapán (2358-IV NW).

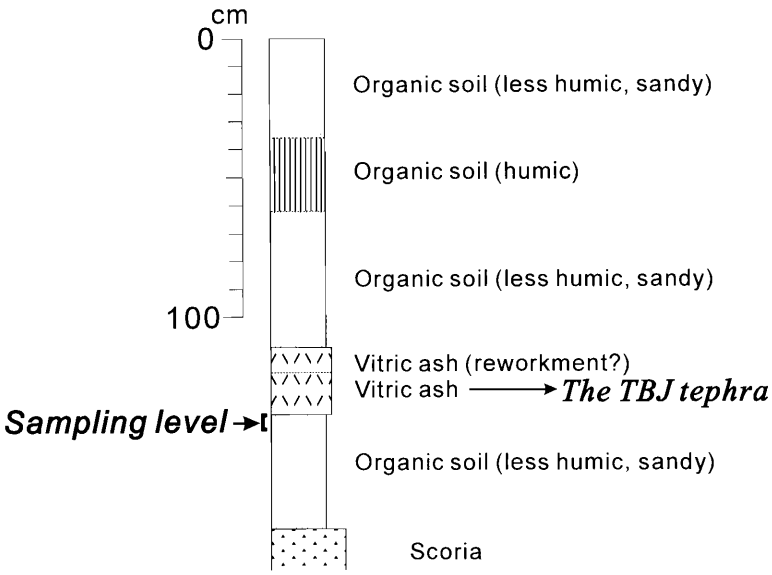

Fig. 3　Stratigraphy and sampling levels at the sampling site no.2.

Table 2　Results of AMS radiocarbon dating

No.	Sample ID.	Lab. No.	Preparation method*	Measured radiocarbon age (yr. B. P.)	$\delta^{13}C$ (‰)	Conventional radiocarbon age (yr. B. P.)
1	07031001-1	Beta-234542	3A	1570 ± 40	-23.7	1590 ± 40
2	06082701-1	Beta-257441	A	1450 ± 40	-14.3	1630 ± 40

*; 3A: acid / alkali / acid wash, A: acid wash

Table 3　Calendar dates calibrated by fitted calibration curve*

No.	Sample ID.	Lab. No.	Intercept age	One Sigma Ranges	Two Sigma Ranges
1	07031001-1	Beta-234542	430 AD	420 AD to 540 AD	390 AD to 560 AD
2	06082701-1	Beta-257441	420 AD	390 AD to 430 AD	340 AD to 540 AD

*: Talma & Vogel (1993)

The first radiocarbon sample was found out at a quarry located ca. 8 km to the southeast of San Salvador City (Location 1 in fig. 2), where the TBJ pumice-flow deposit containing many carbonized wood is accumulated more than 10 m thick. A charred wood that keeps original form of a tree branch was picked up from the lowermost level at the outcrop. A 1.3-cm surface of the charred branch with a thickness of ca. 4.5 cm was taken for radiocarbon dating.

The second radiocarbon sample is organic sediment immediately below the TBJ ash-fall deposit found near Metapan City (Location 2 in fig. 2). This organic sediment is considered as accumulated organic soil developed above the deposit of scoria and volcanic sand, and intercalates the TBJ tephra (Fig. 3). A 5-cm thick organic sediment immediately below the TBJ tephra was collected for

radiocarbon dating.

The AMS radiocarbon dating of both samples was carried out at Beta Analytic Radiocarbon Dating Laboratory. From obtained conventional radiocarbon dates (Table 2), calendar dates were calculated using splines through INTCAL04 data set as calibration curves (Talma & Vogel, 1993). The resultant calender dates are shown in table 3.

5. Conclusion and discussion

The resultant AMS radiocarbon dates in this study are very close to the radiocarbon age suggested by Dull, et al. (2001), consequently, it strongly supports that the eruptive date of Ilopango Caldera occurred in the period from the mid-4th to the mid-6th century.

For only four samples, however, the AMS radiocarbon dating has been carried out in Dull, et al. (2001) and this study. It is still insufficient for statistical discussion, so that further AMS radiocarbon dating is necessary to illustrate reliable eruptive age of the TBJ tephra.

Moreover, even the AMS radiocarbon dates determined in this study include the uncertainty of about two centuries because the calibration curve has a plateau in the period approximately from the mid-5th to the early 6th century, that is, a calibrated calendar date always includes more than a hundred years uncertainty in the case that the intercept age lies around the early 5th century. Other dating technic, such as dendrochronology, is necessary to be combined to AMS radiocarbon dating for determining the more precise eruptive age of the TBJ tephra aplicable enough for archaeological study.

Acknowledgments

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