Terr. Atmos. Ocean. Sci., Vol. 21, No. 3, 611-614, June 2010 doi: 10.3319/TAO.2009.12.11.02(TH)

NOTES AND CORRESPONDENCE

Time of a Near Holocene Volcanic Eruption in the Tatun Volcano Group, Northern Taiwan: Evidence from AMS Radiocarbon Dating of Charcoal Ash from Sediments of the Sungshan Formation in Taipei Basin

Cheng-Hong Chen[1, *], George S. Burr[1, 2], and Szu-Bin Lin[1]

[1] *Department of Geosciences, National Taiwan University, Taipei, Taiwan, ROC*
[2] *National Science Foundation - Arizona Accelerator Mass Spectrometer Facility, Physics Department, University of Arizona, Tucson, USA*

Received 29 May 2009, accepted 11 December 2009

ABSTRACT

Using the charcoal ash in the Kuandu well of the Taipei Basin sediments as dating material, we obtain an AMS radiocarbon result with a ^{14}C age of 16950 ± 150 yrBP (calendar age of 19814 - 20431 yrBP). Regarding the charcoal ash as a likely remnant of a forest fire caused by volcanic eruptions, this result confirms our earlier report that there was a volcanic event around 20 Ka in the Tatun Volcano Group.

Key words: Volcanic eruption, Tatun Volcano Group, AMS dating

Citation: Chen, C. H., G. S. Burr, and S. B. Lin, 2010: Time of a near Holocene volcanic eruption in the Tatun Volcano Group, northern Taiwan: Evidence from AMS radiocarbon dating of charcoal ash from sediments of the Sungshan Formation in Taipei Basin. Terr. Atmos. Ocean. Sci., 21, 611-614, doi: 10.3319/TAO.2009.12.11.02(TH)

1. INTRODUCTION

Tatun Volcano Group consists of more than twenty volcanoes distributed in an area where hydrothermal activity is still prevalent. A series of micro-seismic activities, such as volcano-tectonic earthquakes, tremors, short duration monochromatic events and long-period spasmodic bursts, have been detected in and around Chihsingshan since the installation of the local seismological network in 2003 (Lin et al. 2005a, b; Konstantinou et al. 2007). Fissures revealed by Lidar DEM detection (Liu et al. 2007) are also in this volcano and confirm the earlier suggestion that regional extension of the Taipei Basin including Tatun volcanic area is ongoing (Lu et al. 1995; Chan et al. 2008). Moreover, deformation with a total subsidence of 10 mm over a 14 month period is observed using precise leveling (Murase et al. 2007). Geochemical data of fumaroles in the Tatun volcanic area, mainly He isotope ratios and relative abundances of rare gases of N_2, He, and Ar, indicate a magmatic source (Yang et al. 2003, 2005; Lee et al. 2005, 2008). Soil CO_2 flux values and total sulfur contents in the area are similar to other active high CO_2, high flux hydrothermal systems in the world, implying active magmatic degassing (Lan et al. 2007). All these geophysical and geochemical phenomena reveal that the prevailing hydrothermal activities in the vicinity of metropolitan Taipei may indicate the presence of an existing magma chamber beneath the Tatun Volcano Group. Since volcanic activity from the Tatun Volcano Group is a major public concern, it is important to assess the degree of peril caused by potential volcanic activity using volcanic eruption histories.

Dating young volcanic eruptions is difficult for two reasons: lack of suitable dating materials and methodological difficulties. Sediments of some wells drilled in the northern part of the Taipei Basin, especially the northernmost Kuandu well (KT-1), are rich in fine volcanogenic materials accompanied by granules and pebbles of andesite near the bottom of the Sungshan Formation (Chen and Lin 2002). These authors concluded that fine volcanogenic materials in KT-1 probably represent debris of volcanic eruptions from

* *Corresponding author*
E-mail: chench@ntu.edu.tw

the neighboring Tatun Volcano Group under a lacustrine depositional environment based on the following evidence: (1) the clay fraction exhibits a significantly higher percentage of the montmorillonite component (48 - 54% vs. < 10% in other sections); (2) the silt fraction has lower quartz/feldspar ratios (< 0.69 vs. 1.9 - 2.4 in other sections); and (3) the sand fraction contains abundant acute broken fragments of minerals common in andesites, such as hypersthene, hornblende and plagioclase, an indicator of in-situ deposits after eruption; and (4) the presence of very few sandy grains of charcoal ashes that presumably represent wood remnants following forest fires caused by volcanic eruptions. Yet no direct geochronological information is known for these activities so far. The purpose of this paper is to report an AMS radiocarbon date of the charcoal ash that can document the time of this volcanic eruption.

2. DATING MATERIAL AND METHODS

Charcoal ash samples are mostly dust-like, only one recovered at a depth of 88.4 - 91.4 m in KT-1 (KT-88.4-89.9-91.4) was big enough for Accelerator Mass Spectrometry (AMS) dating. The size is about 2.0 mm long and 0.8 mm wide (Fig. 3b in Chen and Lin 2002). A radiocarbon date was obtained for this sample at the US National Science Foundation (NSF)-Arizona AMS Facility. The sample was cleaned in three steps according to a well-established protocol for AMS wood analysis (Hajdas et al. 2004). These steps include: (1) a 30 minute treatment in 0.1 N HCl, to remove potential carbonate contamination; (2) a 24 hour treatment in 0.1 N NaOH solution to dissolve humic and fulvic acids; and (3) a second 30 minute treatment in 0.1 N HCl. The sample was rinsed to neutrality after each step, and then dried at the end of the cleaning procedure. After the sample was cleaned, it was combusted to CO_2, at which point the $\delta^{13}C$ value was measured using a conventional mass spectrometer. After this analysis the CO_2 was reduced to graphite using an iron catalysis reaction. The graphite target was measured by AMS as described by Donahue (1995). The radiocarbon result given here (Table 1) has been ^{13}C-corrected using the measured $\delta^{13}C$ value. The date was calibrated using the CALIB 5.0.1 program (Reimer et al. 2004).

3. DISCUSSION

In the work of Chen and Lin (2002), three more wells in the northwestern part of this basin in addition to the KT-1, including Luchou (LC-1), Wuku (WK-1), and Shihlin (SL-1), were found to contain some layers of volcanic materials in the lower part of the Sungshan Formation as well. Sites of these wells can be seen in the preface pages of the Special Publication of the Central Geological Survey No. 11 (issued in the year 1999 for the subsurface geology and engineering environment of Taipei Basin). The KT-1 well is situated in the northwest corner of the Taipei Basin and the closest to the Tatun Volcano Group among these wells. Volcanic materials are present in several segments of KT-1 (88.4 - 91.4, 93.15 - 93.8, 94.4 - 96.2, and 104 - 107.3 m), but seem to be in two segments of LC-1 (88 - 89.8 and 93 - 95 m), and only one segment of WK-1 (107 - 110.8 m) and SL-1 (101.9 - 106 m).

The age information previously reported for the Sungshan Formation, the uppermost stratigraphic layer in the Taipei Basin, was based on the conventional ^{14}C dating on large driftwood samples and AMS ^{14}C dating (hereafter referred as AMS dating relative to ^{14}C dating for the former) on driftwood, mollusk fossils, and peats in the sediments. The earlier ^{14}C dating results in relation to the lower part of this Formation may include 8750 ± 270 yrBP at the depth 30.0 m of the Taipei Railway Station in the center of the basin and 9430 ± 70 yrBP at the depth 39.5 m of the Sungmei Bridge (Nanking East Road) in the eastern part of the basin (Liu et al. 1988), where the top of the underlying Chingmei Formation is 50.2 and 41.5 m, respectively. In the WK-1 well of the western part of the Taipei Basin, a large number of age data have been accumulated. Here we only choose those which indicate the deposition time of the lower part of this Formation for comparison. They include two ^{14}C dating results, 18950 ± 540 yrBP at 89.3 - 89.5 m and 21300 ± 160 yrBP at 94.0 - 94.1 m (Lin et al. 1999), and two AMS dating results, 17380 ± 70 yrBP at 80.5 m and 21820 ± 80 yrBP at 90.8 m (Tseng and Liew 1999), and the boundary between the Sungshan and underlying Chingmei Formation is 110.8 m deep (Chen and Lin 2002). In the LC-1 well where the lower limit of the Sungshan Formation is down to 95 m, two ^{14}C dating results, 12700 ± 90 yrBP at 85.1 m and 23450 ± 90 yrBP at 109.1 m were obtained (Lin et al. 1999). Therefore, the earliest deposition of the Sungshan Formation here is sometime between these two age values.

Three uncorrected AMS dating results (analyzed by Beta Analytic Inc., USA) have been reported for different materials from the Sungshan Formation of the KT-1 well, namely, 21150 ± 150 yrBP (peat at 94.0 m), 26040 ± 160 yrBP (peat at 101.8 m), and 33320 ± 290 yrBP (driftwood at 114.5 m)(Shieh 2001). Using these data, Chen and Lin (2006) proposed that the volcanic ashes made of pumice tuff (90.0 - 90.6 m) were deposited at the time of 18.6 kyrBP by extrapolation. Our new AMS dating result of 16950 ± 150 yrBP (or 19814 - 20431 yrBP calendar age) on sandy charcoal at 88.4 - 91.4 m is in good accord with age records of the lower part of the Sungshan Formation of both the WK-1 and LC-1 wells, and confirms that the volcanic eruption of the Tatun Volcano Group really occurred at ~20 Ka. We are also aware of the most recent reports of radiocarbon dating of paleolake sediment near Shamao lava dome giving ^{14}C ages of 13610 ± 70 to 11600 ± 60 yrBP that may contain intercalating ash layers (Belousov et al. 2009), and

Table 1. The AMS radiocarbon dating result of charcoal ash in Kuandu well (KT-1) of the Taipei Basin.

Sample ID	Arizona ID	$\delta^{13}C$ (‰)	^{14}C age BP (1σ)	Calendar age BP (2σ)
KT-88.4-89.9-91.4	AA82490	-25.3*	16950 ± 150 yr	19814 - 20431 yr

* *The value of $\delta^{13}C$ is exactly as one would expect for a tree (Reimer et al. 2004).*

a large-scale collapse occurred at Chisingshan giving its ^{14}C age of 5400 ± 50 yrBP (Belousova et al. 2009). Whether these events were related to volcanic eruptions need to be further clarified. Moreover, the sign that indicates the possible existence of a magma chamber beneath the Tatun Volcano Group as mentioned can not be overlooked, and hence monitoring of the volcanic activities there needs to be continued.

Acknowledgements Core samples of the Kuandu well were provided by the Central Geological Survey, Ministry of Economic Affairs, Republic of China. Constructive comments and corrections made by two anonymous reviewers are thanked.

REFERENCES

Belousov, A., M. Belousova, and C. H. Chen, 2009: Eruptions in recent history of Tatun Volcano Group, northern Taiwan. The 6th Biennial Workshop on Subduction Processes Emphasizing the Kurile-Kamchatka-Aleutian Arcs. Univ. Alaska, June 22 - 26, 2009, Fairbanks, USA, 97-98.

Belousova, M., A. Belousov, and C. H. Chen, 2009: Large-scale edifice failures in the history of Tatun Volcano Group, northern Taiwan. The 6th Biennial Workshop on Subduction Processes Emphasizing the Kurile-Kamchatka-Aleutian Arcs. Univ. Alaska, June 22 - 26, 2009, Fairbanks, USA, 113-114.

Chan, Y., K. Chang, R. Chen, J. Lee, and Y. Hsieh, 2008: Characteristics of active normal faulting in the northern Taiwan mountain belt: Evidence from LiDAR-derived DTM and geologic observations. AGU Fall Meeting 2008, abstract #T53D-1983.

Chen, C. H. and S. B. Lin, 2002: Eruptions younger than 20 Ka of the Tatun Volcano Group as viewed from the sediments of the Sungshan Formation in Taipei Basin. *West. Pac. Earth Sci.*, **2**, 191-204.

Chen, C. H. and C. C. Lin, 2006: The recent eruption of the Tatun volcanic group: Inferred from juvenile volcanic ash in the Taipei basin (Abs.). Abstract Volume 2006 Annual Meeting of Geological Society of Taiwan, Taipei, p. 65.

Donahue, D. J., 1995: Radiocarbon analysis by accelerator mass spectrometry. *Int. J. Mass Spectrom. Ion Process.*, **143**, 235-245, doi: 10.1016/0168-1176(94)04132-Q. [Link]

Hajdas, I., G. Bonani, J. Thut, G. Leone, R. Pfenninger, and C. Maden, 2004: A report on sample preparation at the ETH/PSI AMS facility in Zurich. *Nucle. Instru. Method Phys. Res. B*, **223-224**, 267-271, doi: 10.1016/j.nimb.2004.04.054. [Link]

Konstantinou, K. I., C. H. Lin, and W. T. Liang, 2007: Seismicity characteristics of a potentially active Quaternary volcano: The Tatun Volcano Group, northern Taiwan. *J. Volcanol. Geotherm. Res.*, **160**, 300-318, doi: 10.1016/j.jvolgeores.2006.09.009. [Link]

Lan, T. F., T. F. Yang, H. F. Lee, Y. G. Chen, C. H. Chen, S. R. Song, and S. Tsao, 2007: Compositions and flux of soil gas in Liu-Huang-Ku hydrothermal area, northern Taiwan. *J. Volcanol. Geotherm. Res.*, **165**, 32-45, doi: 10.1016/j.jvolgeores.2007.04.015. [Link]

Lee, H. F., T. F. Yang, T. F. Lan, S. R. Song, and S. Tsao, 2005: Fumarolic gas composition of the Tatun Volcano Group, northern Taiwan. *Terr. Atmos. Ocean. Sci*, **16**, 843-864.

Lee, H. F., T. F. Yang, T. F. Lan, C. H. Chen, S. R. Song, and S. Tsao, 2008: Temporal variations of gas compositions of fumaroles in the Tatun Volcano Group, northern Taiwan. *J. Volcanol. Geotherm. Res.*, **178**, 624-635, doi: 10.1016/j.jvolgeores.2008.06.005. [Link]

Lin, C. C., T. C. Lai, L. Y. Fei, H. G. Liu, T. G. Gi, and T. W. Hsu, 1999: Sampling results of the geological drilling wells in Taipei Basin during 1992-1996. *Spec. Publ. Cent. Geol. Surv.*, **11**, 7-39. (in Chinese)

Lin, C. H., K. I. Konstantinou, W. T. Liang, H. C. Pu, Y. M. Lin, S. H. You, and Y. P. Huang, 2005a: Preliminary analysis of volcanoseismic signals recorded at the Tatun Volcano Group, northern Taiwan. *Geophys. Res. Lett.*, **32**, L10313, doi: 10.1029/2005GL022861. [Link]

Lin, C. H., K. I. Konstantinou, H. C. Pu, C. C. Hsu, Y. M. Lin, S. H. You, and Y. P. Huang, 2005b: Preliminary results from seismic monitoring at Tatun volcanic area of northern Taiwan. *Terr. Atmos. Ocean. Sci.*, **16**, 563-577.

Liu, J. K., Y. C. Chan, T. Y. Shih, and Y. C. Hsieh, 2007: Lidar DEM for characterizing the volcanic landforms of Tatun volcanoes in metropolitan Taipei. Geoscience and Remote Sensing Symposium 2007 (IGARSS 2007), IEEE International Volume, Issue 23-28, July 2007, 3752-3755.

Liu, T. K., Y. Wang, and Y. G. Chen, 1988: C-14 dating of Sungshan Formation, Taipei Basin. Abstract Volume, 1988 Annual Meeting of Geological Society of Taiwan Located in Taipei, p. 2.

Lu, C. Y., J. Angelier, H. T. Chu, and J. C. Lee, 1995: Contractional, transcurrent, rotational and extensional tectonics: Examples from Northern Taiwan. *Tectonophysics*, **246**, 129-146, doi: 10.1016/0040-1951(94)00252-5. [Link]

Murase, M., K. Ishikawa, C. Lin, J. Lin, H. Pu, F. Kimata, R. Miyajima, H. Nakamichi, and A. Suzuki, 2007: Estimated pressure source and vertical deformation in Tatun volcano group, Taiwan, detected by precise leveling in June 2006-August 2007. AGU Fall Meeting 2007, abstract V11C-0740.

Reimer, P. J., M. G. L. Baillie, E. Bard, A. Bayliss, J. W. Beck, C. J. H. Bertrand, P. G. Blackwell, C. E. Buck, G. S. Burr, K. B. Cutler, P. E. Damon, R. L. Edwards, R. G. Fairbanks, M. Friedrich, T. P. Guilderson, A. G. Hogg, K. A. Hughen, B. Kromer, G. McCormac, S. Manning, C. B. Ramsey, R. W. Reimer, S. Remmele, J. R. Southon, M. Stuiver, S. Talamo, F. W. Taylor, J. van der Plicht, and C. E. Weyhenmeyer, 2004: IntCal04 terrestrial radiocarbon age calibration, 0-26 cal kyr BP. *Radiocarbon*, **46**, 1029-1058.

Shieh, Y. T., 2001: A preliminary study of the foraminifer assemblages in the KT-1 observation well in the Taipei basin and their paleoenvironmental implications. *Bull. Cent. Geol. Surv.*, **14**, 83-102. (in Chinese)

Tseng, M. H. and P. M. Liew, 1999: A preliminary probe on spore-pollen assemblages and paleoenvironments of the recent 20 Ka in Taipei Basin. *Spec. Publ. Cent. Geol. Surv.*, **11**, 159-179. (in Chinese)

Yang, T. F., H. H. Ho, P. S. Hsieh, N. J. Liu, Y. G. Chen, and C. H. Chen, 2003: Sources of fumarolic gases from Tatun Volcano Group, north Taiwan. *J. Natl. Park*, **13**, 127-156. (in Chinese)

Yang, T. F., T. F. Lan, H. F. Lee, C. C. Fu, P. C. Chuang, C. H. Lo, C. H. Chen, C. T. A. Chen, and C. S. Lee, 2005: Gas compositions and helium isotopic ratios of fluid samples around Kueishantao, NE offshore Taiwan and its tectonic implications. *Geochem. J.*, **39**, 469-480.