First Toba supereruption revival: Comment and Reply

COMMENT

Phil Shane*
Department of Geology, University of Auckland, Private Bag 92019, Auckland, New Zealand
Stephen Self*
Stephen Blake*
Volcano Dynamics Group, Department of Earth Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK
Michael R. Rampino*
Earth & Environmental Science Program, New York University, New York, New York 10003, USA

The article by Lee et al. (2004) suggests that at least one "supereruption" from the Toba caldera, Sumatra, was associated with a climatic warming, rather than a cooling trend. The background to this is that Rampino and Self (1992, 1993) originally suggested that the supereruption that produced the younger Toba tuff ca. 74 ka could have helped to usher in the last glacial period (isotope stage 4). This long-term climatic feedback effect would be in addition to the severe short-term climatic effects or "volcanic winter" predicted for that eruption. Lee et al. (2004) have studied deep-sea ashes in the South China Sea that they contend were produced by the smaller older Toba tuff eruption at a revised age of 788 ka, which they then propose was not involved in a long-term cooling episode. We here raise three points that challenge the results of their study.

1. The identification of the tephra in the South China Sea core by Lee et al. is based on correlation with layer D in Ocean Drilling Program (ODP) Site 758 in the Indian Ocean. The correlation rests on stratigraphic position and major element glass chemistry, and appears sound. However, the major premise of the paper depends on the assumption that layer D (ca. 800 ka) in the ODP Site 758 core is older Toba tuff. They provide no mineralogical or major and trace element geochemical data on glass shards, nor are there data in other literature, to support this correlation. Previous workers who have studied the Toba ashes in deep-sea cores think that layer E (not D) in ODP Site 758 represents the older Toba tuff eruption (840 ka), but this is based only upon the apparent age of the ashes (Dehn et al., 1991; Westgate et al., 1998; Pattan et al., 1999).

2. In Lee et al.'s (2004) study, ash shards in South China Sea cores are correlated with other presumed Toba ashes in deep-sea cores. They do not provide the obvious correlation to prove their case—there is no geochemical data linking the deep-sea ashes to older Toba tuff on land in Sumatra. Thus, their proposed 788 ka age for older Toba tuff, which is more than 50 k.y. younger than dates on older Toba tuff on land (840 ka), is also not substantiated. The age of older Toba tuff (840 ka) fits better with layer E (also 840 ka) in ODP Site 758 (found just below layer D).

3. Comments about the dispersal of layer D/South China Sea tephra being as wide as that of the ca. 74 ka younger Toba tuff are unfounded. Ash in the Central Indian Ocean basin reported by Pattan et al. (1999) is contained within sediment younger than 200 ka based on microfossils and Th isotopes. Thus, they cannot match older eruptions such as layer D (800 ka). Similarly, ash on land in India has been dated using isothermal plateau fission-track methods at younger than 100 ka (Westgate et al., 1998). Again, correlation to younger Toba tuff is indicated (not older Toba tuff or layers E or D). The dispersal of the layer D/South China Sea tephra is limited to areas between the sites of ODP 758 and MD972142 at the most, and is therefore not comparable to the much wider dispersal of the younger Toba tuff ash. The volume of the eruption that generated the layer D/South China Sea ash may also be considerably smaller than younger Toba tuff, because, to date, there is no demonstration of correlation to on-land pyroclastic flow deposits.

In summary, the proposed younger age for the older Toba tuff is not substantiated, and thus the correlation of the older Toba tuff eruption with any effects on Pleistocene climate remains unknown.

Another point is that the much larger volume younger Toba tuff is now possibly recognized as a large acidity peak in Greenland ice cores (Zielinski et al., 1996), which occurs within a brief cold period prior to the major cooling from isotope stage 5 to 4. Oppenheimer (2002) presents a review of why direct correlations of the younger Toba tuff eruption with climatic and demographic phenomena must be viewed with caution until more precise age dating of the various events and better understanding of the volcanic eruption are available. These reservations also apply to interpretations of the long-term environmental impact of the considerably more ancient older Toba tuff event.

REFERENCES CITED

Dehn, J., Farrel, J.W., and Schmincke, H.-U., 1991, Neogene tephrochronology from Site 758 on northern Ninetyeast Ridge: Indonesian arc volcanism of the past 5 Ma: Proceedings of the Ocean Drilling Program, Scientific results, v. 121, p. 273–295.

Lee, M.Y., Chen, C.-H., Wei, K.-Y., Iizuka, Y., and Carey, S., 2004, First Toba supereruption revival: Geology, v. 32, p. 61–64. doi:10.1130/G19903.1

Oppenheimer, C., 2002, Limited global change due to the largest known Quaternary eruption, Toba ~74 kyr BP?: Quaternary Science Reviews, v. 21, p. 1593–1609. doi:10.1016/S0277-3791(01)00154-8

Pattan, J.N., Shane, P., and Banakar, V.K., 1999, New occurrence of youngest Toba tuff in abyssal sediments of the Central Indian Basin: Marine Geology, v. 155, p. 243–248. doi:10.1016/S0025-3227(98)00160-1

Rampino, M.R., and Self, S., 1992, Volcanic winter and accelerated glaciation following the Toba super-eruption: Nature, v. 359, p. 50–52. doi:10.1038/359050A0

Rampino, M.R., and Self, S., 1993, Climate-volcanism feedback and the Toba eruption of ~74,000 years ago: Quaternary Research, v. 40, p. 269–280. doi:10.1006/QRES.1993.1081

Westgate, J.A., Shane, P.A.R., Pearce, N.J.G., Perkins, W.T., Koristtar, R., Chesner, C.A., Williams, M.A.J., and Acharyya, S.K., 1998, All Toba tephra occurrences across Peninsular India belong to the 75 ka eruption: Quaternary Research, v. 50, p. 107–112. doi:10.1006/QRES.1998.1974

Zielinski, G.A., Mayewski, P.A., Meeker, L.D., Whitlow, S., Twickler, M., and Taylor, K., 1996, Potential atmospheric impact of the Toba mega-eruption: Geophysical Research Letters, v. 23, p. 837–840. doi:10.1029/96GL00706

REPLY

Chang-Hwa Chen*
Meng-Yang Lee
Yoshiyuki Iizuka
Institute of Earth Sciences, Academia Sinica, P.O. Box 1-55, Nankang, Taipei, Taiwan, Republic of China
Jonathan Dehn
Alaska Volcano Observatory, University of Alaska, Fairbanks, Alaska 99775-7320, USA
Kuo-Yen Wei
Department of Geosciences, National Taiwan University, Taipei, Taiwan, Republic of China
Steven Carey
Graduate School of Oceanography, University of Rhode Island, Rhode Island 02882, USA

*E-mails: Shane—pa.shane@auckland.ac.nz; Self—Stephen.self@open.ac.uk; Blake—S.Blake@open.ac.uk; Rampino—mrr1@nyu.edu.

*E-mail: china@earth.sinica.edu.tw.

We appreciate the comments by Shane et al. on our paper (Lee et al., 2004). Shane et al. raise several interesting points about the main conclusion of our paper, which is the possibility of a link between the oldest Toba tuff eruption and the Pleistocene climate, although their main criticisms were focused on whether tephra layer D or E from Ocean Drilling Program (ODP) core 758 is the better representative of the oldest Toba tuff. The following is our rebuttal to each of the points raised by Shane et al.

In addition to the data presented in our paper, some handpicked pure glass shards from both layer D and layer E of ODP Site 758, collected by Dr. Dehn, were analyzed recently for their chemical and isotopic compositions. In general, the glass shards from layers D and E are distinct in their Na_2O/K_2O ratio and K_2O content, with lower Na_2O/K_2O (<0.8) and higher K_2O (>4.5%) for layer D, as opposed to higher Na_2O/K_2O (>0.9) and lower K_2O (<4.5%) in layer E. Consequently, the characteristics of lower Na_2O/K_2O and higher K_2O are entirely consistent with those of the oldest Toba tuff (Chesner, 1988, 1998). Moreover, Sr isotopic composition is very different between the glass shards from layer D and layer E. The $^{87}Sr/^{86}Sr$ value of the glass shard in layer D is 0.71306 ± 0.00003, which is quite comparable to those of the oldest Toba tuff from Sumatra (Chesner, 1988). In contrast, the $^{87}Sr/^{86}Sr$ ratio of the glass shard in layer E is 0.70559 ± 0.00002, significantly lower than that of the oldest Toba tuff in Sumatra (Chesner, 1988). This is further illustrated in Figure 1, where K_2O content is plotted against $^{87}Sr/^{86}Sr$ for each sample, and it is readily apparent that glass shards from layer D of ODP Site 758 are well correlated, while layer E bears no resemblance to the oldest Toba tuff in Sumatra.

We have also analyzed the tephra glass shards extracted from South China Sea core MD972142 at the depth of 39.04 m for their chemical and Sr isotopic compositions, and they are also plotted in Figure 1. This tephra glass from the South China Sea core MD972142 is characterized by Na_2O/K_2O ~0.59 and $^{87}Sr/^{86}Sr$ = 0.71573 ± 0.00002 (Fig. 1), which is again entirely comparable to that observed in oldest Toba tuff from Sumatra and layer D in ODP Site 758.

As stated previously, layer D of ODP Site 758 is the better representative of the oldest Toba tuff. Nevertheless, the tephra layer D of ODP Site 758 along with the similar tephra layers from cores 17957 and MD972142 all are sandwiched between the Brunhes-Matuyama geomagnetic boundary and the Australasian microtektite layer, (Fig. 2 of Lee et al., 2004) which have been dated at 778.0 ± 1.7 ka (Tauxe et al., 1996) and 803 ± 3 ka (Hou et al., 2000), respectively. Based on this, our previous conclusion that the age of the oldest Toba tuff should be no older than 800 ka (Lee et al., 2004) remains valid. However, this age is in conflict with that reported by Diehl et al. (1987), which was based on a biotite cooling age dated at 840 ± 30 ka. Since all the ages are from literature data, we have no explanation for the discrepancy at this stage. Apparently, additional dating for the oldest Toba tuff in Sumatra and also the tephras from these drill cores is necessary in order to resolve the discrepancy of these studies and to provide better constraints for the timing of oldest Toba tuff eruption.

The sedimentation rate in the Central Indian Ocean basin is generally very slow, ~2–4 m/m.y. (Banakar et al., 1991). Three out of the eight cores inferred in the Banakar et al. study show evidence of severe bioturbation and current erosion (Banakar et al., 1991). In addition, microtektites have been found in the surface sediments (Prasad, 1994), and thus one should not be surprised if glass shards associated with the oldest Toba tuff are found in these drill cores. Similarly, in the case of Peninsula India, only two out of the seven sample sites have good glass fission-track ages (Westgate et al., 1998). As a result, the rest of the ash sites remain problematic due to the lack of good and systematic geochemical, isotopic, and age data. Although more detailed dating, chemical, and isotopic work for these ash deposits is needed to fully understand the nature and influences of Toba eruptions on the global climate, all the points raised by Shane et al. are speculative, and the conclusions of our previous paper remain valid.

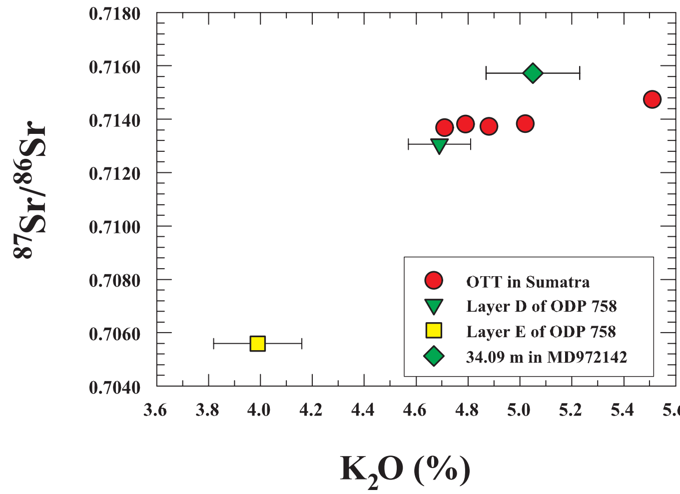

Figure 1. K_2O contents versus $^{87}Sr/^{86}Sr$ values of glass shards in tephra layers D and E in Ocean Drilling Program (OPD) Site 758 and 34.09 m tephra layer in MD974142. Data of oldest Toba tuff (OTT) in Sumatra are from Chesner (1988). Error tick represents 1σ error in K_2O content; 2σ error of Sr isotopic ratio is much smaller than size of symbol.

REFERENCES CITED

Banakar, V.K., Gupta, S.M., and Padmavathi, V.K., 1991, Abyssal sediment erosion in the Central India Basin: Evidence from radiochemical and radiolarian studies: Marine Geology, v. 96, p. 167–173. doi:10.1016/0025-3227(91)90214-O

Chesner, C.A., 1988, The Toba tuffs and caldera complex, Sumatra, Indonesia: Insights into magma bodies and eruptions [Ph.D. dissertation]: Houghton, Michigan Technological University, 428 p.

Chesner, C.A., 1998, Petrogenesis of the Toba tuffs, Sumatra, Indonesia: Journal of Petrology, v. 39, p. 397–438. doi:10.1093/PETROLOGY/39.3.397

Diehl, J.F., Onstott, T.C., Chesner, C.A., and Knight, M.D., 1987, No short reversals of Brunhes age recorded in the Toba tuffs, north Sumatra, Indonesia: Geophysical Research Letters, v. 14, p. 753–756.

Hou, Y., Potts, R., Yuan, B., Guo, Z., Deino, A., Wang, W., Clark, J., Xie, G., and Huang, W., 2000, Mid-Pleistocene Acheulean-like stone technology of the Bose Basin, south China: Science, v. 287, p. 1622–1626. doi:10.1126/SCIENCE.287.5458.1622

Lee, M.Y., Chen, C.-H., Wei, K.-Y., Iizuka, Y., and Carey, S., 2004, First Toba supereruption revival: Geology, v. 32, p. 61–64. doi:10.1130/G19903.1

Prasad, M.S., 1994, New occurrences of Australasian microtektites in the Central India Basin: Meteoritics, v. 29, p. 66–69.

Tauxe, L., Herbert, T., Shackleton, N.J., and Kok, Y.S., 1996, Astronomical calibration of the Matuyama-Brunhes boundary: Consequences for magnetic remanence acquisition in marine carbonates and the Asian loess sequences: Earth and Planetary Science Letters, v. 140, p. 133–146. doi:10.1016/0012-821X(96)00030-1

Westgate, J., Shane, P., Pearce, N., Perkins, W., Korisettar, R., Chesner, C., Williams, M., and Acharyya, S., 1998, All Toba tephra occurrences across peninsular India belong to the 75,000 yr B.P. eruption: Quaternary Research, v. 50, p. 107–112. doi:10.1006/QRES.1998.1974