EFEK ERUPSI SUPER TOBA ~ 73 RIBU TAHUN YANG LALU TERHADAP LINGKUNGAN BERDASARKAN BUKTI TEPRA; SUMBER DARI TERBITAN JURNAL INTERNASIONAL[1]

Super Toba EruptionEffect~ 73 Kya to Enviroment Based on Tephra Evidences; References from the International Publication[1]

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Abstrak

Erupsi super Toba di Sumatera Utara terjadi ~ 73 ribu tahun yang lalu. Letusan ini tercatat merupakan salah satu letusan terbesar pada periode Pleistosen. Letusan yang terjadi telah mempengaruhi perubahan iklim dan lingkungan di dunia pada saat itu. Tulisan ini memaparkan erupsi super Toba berdasarkan bukti-bukti keberadaan tepra yang menjadi penanda kronologi.

Kata kunci: Tepra, Erupsi Super Toba, Lingkungan Purba

Abstract. *Super eruption of Toba in North Sumatra occurred ~ 73 thousand years ago. This eruption was recorded is one of the largest eruptions in the Pleistocene period. An eruption has affected the climate and environmental changes in the world at that time. This paper describes the Toba super eruption based on the evidence the existence of which is a marker tephra chronology .*

Keywords*: Tephra, Super Toba Eruption, Palaeoenvironment.*

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1. Introduction

Tephra is a term used for all pyroclastic material ejected during an explosive volcanic eruption (Rapp 2009). The term tephra is derived from the Greek word and introduced as a modern scientific term by Sigurdur Thorarinsson in 1944. Tephra fragments are classified by size; ash- smaller than 2 mm, lapilli-between 2 and 64 mm and volcanic bombs - larger than 64 mm. Tephra does not include volcanic gases, not a consolidated rock, not a liquid.

It's very important when it comes to the use of tephrochonology because it removes any need to consider the exact mode of formation (Vivien Gornitz 2009). For many Quaternary researcher, tephrochronology is some sort of specialist "black box" for linking dating, and synchronizing geological, paleoenviromental, or archaeological sequences or events. As well as utilizing the law of superposition, tephrochronology in practice requires tephra deposits to be characterized (or "finger-printed") using physical properties evident in the field in the field together with those

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obtained from laboratory analyses (David J. Lowe 2011).

Cryptotephra layers have been widely used as chronological markers, often alongside radiocarbon dating, within palaeoenviron-mental studies of peatlands and lake. In such records the rapidly accumulating sediments are ideal for preserving multiple cryptotephra layers, often with only minimal disturbance of the horizon. The chemical composition of the glass shards is the most unique characteristic of the tephra and therefore determining the glass composition is crucial for correlating the tephra and using the layer as a chrono-stratigraphic marker.

Archaeological cryptotephra investi-gations require the generation of compositi-onal data from small concentrations of tephra that are typically composed of very small shards (<80 µm) with irregular morphologies. Further-more, the typical high biogenic silica content of archaeological sediment samples makes it critical to consider extra steps toward the isolation of small tephra concentrations for compositional analysis.

Indonesia as the largest country of islands, have lots of volcanoes from Sumatera island until Papua island, line of volcanoes is called “ring of fire”. One of the biggest volcano explosive eruption during Quaternary is Toba volcano in northern Sumatera, the caldera is the product of at least three major Pleistocene eruptions, the youngest which dated to 73 ± 2 kya before present. Produced over 2500-3000 km³ of dense rock equivalent of pyroclastic ejecta, at least 800-1000 km³ of which consisted of volcanic ash, termed the Youngest Toba Tephra or YTT (Sander van der Kaarst et al. 2012), beside YTT there are others

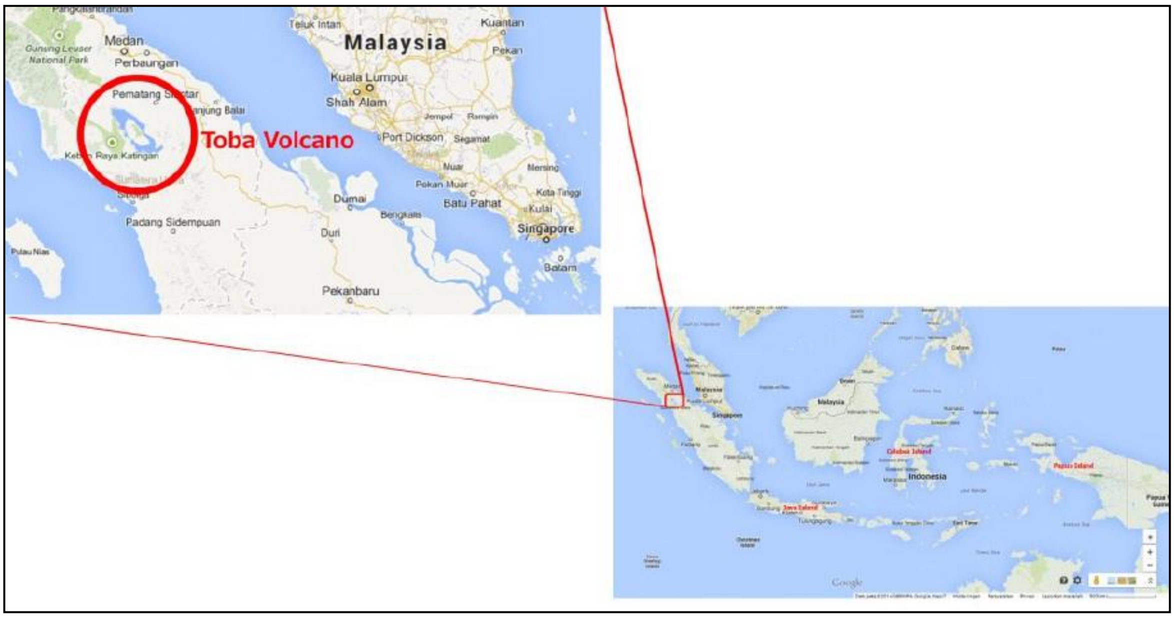

Figure 1. Location Toba volcano in Indonesia (source: modified from googlemaps)

explosive eruption in Yellowstone (USA), Jones said both of them ansupervolcanoes because their impact on climate and human evolution (Sacha Jones 2012). The YTT is found across peninsular India and in the Indian Ocean (Martin William AJ et al. 2009) covered approximately 40,000,000 km² of Asia and South-East Asia (Darren F Mark et al. 2014).

That the eruption gave rise to a “volcanic winter” of such as a catastrophic scale that it caused a human population bottleneck. It has been proposed that the direct effect of the eruption caused widespread human mortality in South Asia (F.J. Gathorne Hardy and W.E.H. Harcourt Smith 2003). This note will discuss tephras examples from YTT as key chronostratigraphic markers from the international literature for:

1. Dating method for known age YTT and their correlation.
2. Environment and climate condition during YTT.
3. Mineralogical and geochemical criteria identification and their potential for their correlation with the YTT.

2. Discussion

2.1. Dating method for known age YTT and their correlation.

For dating method, tephra can be used, among others (Darren F Mark et al. 2014):

1. Dating tephras directly and indirectly

Tephras may be dated direcly using primary minerals (such as zircon, hornblende, K-feldspar, biotite, quartz) or flass from within the tephra layer, or indirectly on enclosing or encapsulated material, using a range methods : radiometric (^{14}C or ^{40}Ar/ ^{39}Ar), incremental, age-equivalence and age-modelling.

2. Depositional age modelling

Using sediment depositional age modelling and wiggle matching techiques using Bayesian statistical frameworks and the internationally-agreed ^{14}C calibration curves (IntCal04 and IntCal09) and other time-series that span earlier time periods.

3. Isothermal-plateau fission-track (ITPFT) dating of glass

For older tephras can be dating using ITPFT with accurate.

4. Magnetostratigraphy

Using geomagnetic polarity transition by checking munerical ages obtained on tephras by radiometric methods or by orbital tuning.

For dating YTT, last paper from Darren F. Mark et al, 2014 try to find high-precision ^{40}Ar/ ^{39}Ar from archaeological sites in the Middle Son Valley and Jurreru valley, India, which have distance from source of eruption more than 2500 km. The dating of proximal YTT utilised a standard analytical approach owing to the presence of large crystals of

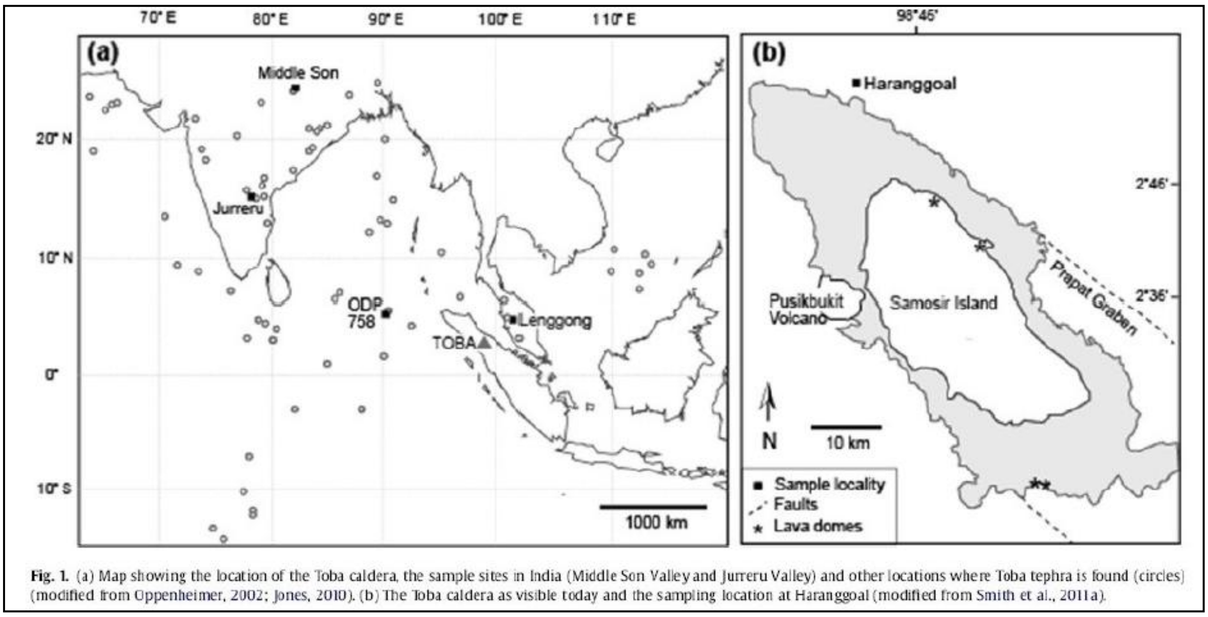

Figure 2. Location Toba caldera and sample sites (source: Darren F Mark et al. 2014)

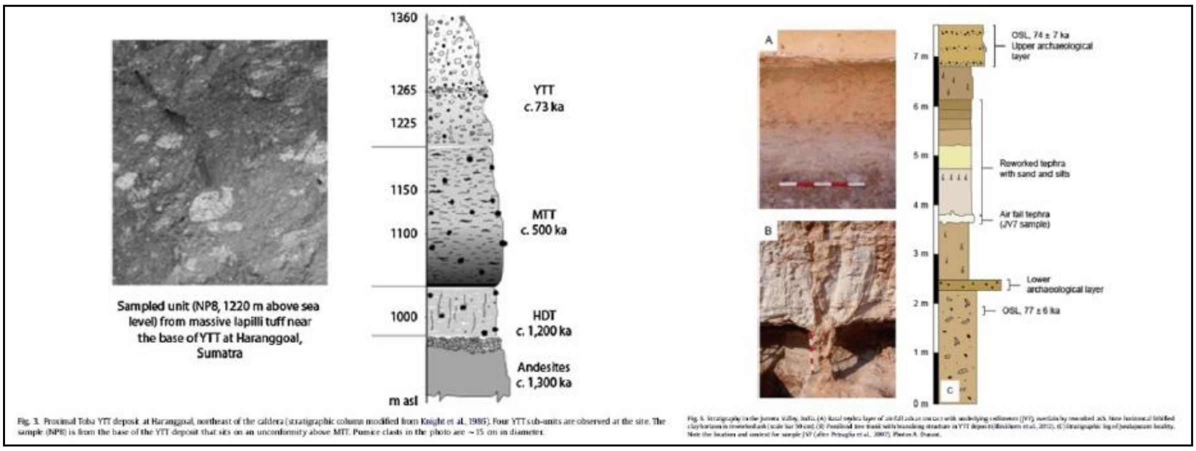

Figure 3. Stratigraphy from Haranggoal and Jureru Valley (source: Darren F Mark et al. 2014)

sanidine and biotite.

The analytical challenge for this project was the preparation and dating of the distal YTT deposits. Although the distal samples contain abundant K-bearing glass shards, volcanic glass shards have been shown to provide unreliable $^{40}Ar/^{39}Ar$ ages likely due to a combination of post eruption K-loss (potentially due to glass hydration) and ^{37}Ar and ^{39}Ar recoil effects. These effects are amplified by a high surface area to volume ratio of glass shards and thus short effective diffusion dimensions (radii of glass shards) (Darren F Mark et al. 2014).

From the research, they found coveal $^{40}Ar/^{39}Ar$ ages for sanidine and biotite do not always match due to the presence of extraneous ^{40}Ar in biotite, and its absence in sanidine. With the continued development of highly-sensitive multi-collector noble gas mass spectrometers that allow for dating of ever decreasing sample sizes, and the refinement of sample irradiation protocols, achievable precision and hence stratigraphic resolution will improve. The $^{40}Ar/^{39}Ar$ age data presented the corelations between tephras from the Middle Son Valley and Jurreru valley, India with the YTT which presented age : 75.0 ± 0.9 ka (Darren F Mark et al. 2014).

From others papers by Biswas et al, 2013 were their research with methodological studies on luminescence (TL) dating of vulcanic ashes, samples from river valley across peninsular India, and have been correlated geochemically to the YTT. Thermoluminescence applications to the fine -grained (4- 11 μm) glass component of Mazama ash yielded a TL age concordant with the ^{14}C control ages. However, glass shards physically separated from other ashes, using the same treatment did exhibit significant anomalous fading, used purification of the 4e11 mm glass shards fraction using heavy liquids and centrifuge along with an extended preheat of 50 - 60 ^{0}C for 8 days, and suggested that these steps ensured a TL signal that was free of athermal fading and, the TL additive-dose technique yielded accurate ages for tephra from a few hundred years to 400 ka. For sediment samples, the quartz fractions (90-150 μm) were extracted after sequentially treating the sample with 1N HCl, 30% H_2O_2, magnetic separation, 40% HF etching for 80 min and 12N HCl treatment for 30 min. Purity of these grains (absence of feldspar) was confirmed by the absence of IRSL in them. The conclusion from dating with TL, the evidence of a physical movement of radioactivity in thick ash beds was seen and their mechanism needs elucidation. There is a need to develop additional field criterion to identify such horizons that suffer migration of radioactivity.

Furthermore, there is also a need to understand the cause of change in radioactivity with distance from the source. The ash horizon at Rehi, Kuntheli and at Tejpur yielded ages of 81 ± 15, 82 ± 13 and 71 ± 6 ka respectively, with a weighted mean value of 74 ± 5 ka, confirming that these belong to the w74 ka YTT event. The ash units at Bori and Morgaon are not in primary context and were reworked some <24 and <37 ka ago respectively (R.H Biswas et al. 2013).

2.2. Environment and climate condition during YTT

Volcanic sulfate from the Greenland ice core at ~73 ka supports the hypothesis proposed by M.R Rampino dan S. Self (1992) that the Toba eruption caused a six-year volcanic winter . The impact of Toba is estimated to have been about a 5^0 C temperature drop, and possibly 15^0 C summer cooling in the temperate to high latitudes within a year or so and lasting for

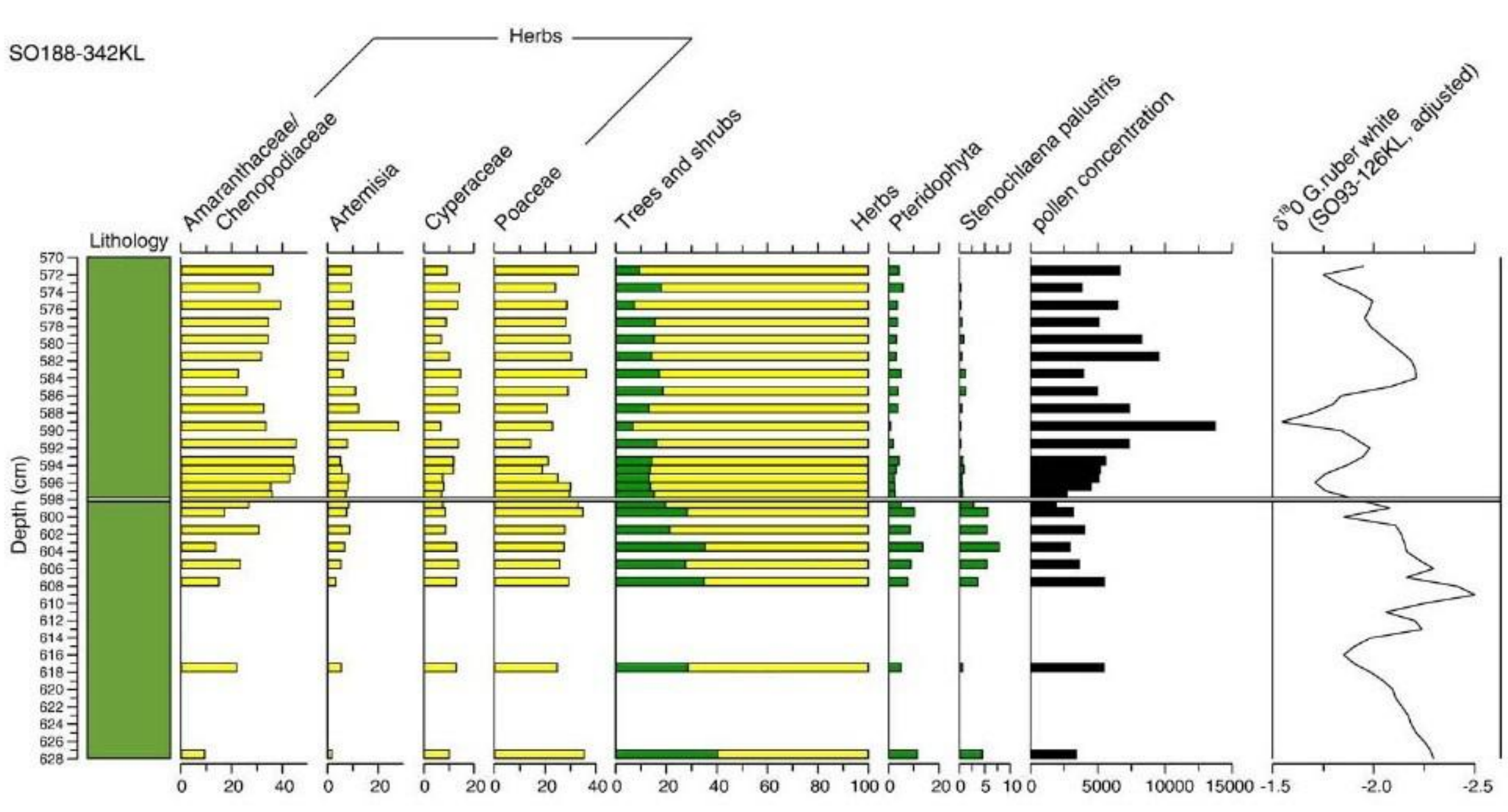

Fig. 8. Simplified pollen diagram of part of marine core S0188-342KL from the Bay of Bengal (19°58.41´N; 90°02.03´E) showing changes in pollen spectra after the Toba eruption. Changes in $\delta^{18}O$ values for the planktonic foraminifera *Globigerinoides ruber* (white) are shown alongside the pollen curves to facilitate comparison with Fig. 6.

Figure 4. Pollen diagram of part of marine core S0188-342KL from the Bay of Bengal (source: Martin William AJ et al. 2009)

several more years (William Burroughs, 2005). This sulfate spike also marks the abrupt onset of an 1800 year period of the coldest temperatures of the last 125,000 years. The effects on the growth of plants, and on life in the oceans, of such a dramatic temperature drop would be catastrophic. In many places the dust veil from the volcano would have effectively blotted out the Sun. The cooling would have led to unseasonable frosts in many parts of the world and the disruption of growing seasons. Pollen grains extracted from samples collected immediately beneath and above the Toba ash from a marine core, in the Bay of Bengal, show a reduction in tree cover and cooling followed by prolonged drought the results provide the first directterrestrial evidence of a significant regional environmental impact of the Toba eruption.We can see there is a reduction in tree and shrub numbers and Pteridophyta after the Toba eruption suggests drier conditions. However, the marked reduction in *Stenochlaena palustris*, a fern mostly restricted to wet environments in the lowland tropics from sea level to 300 m elevation may also point to cooler condition

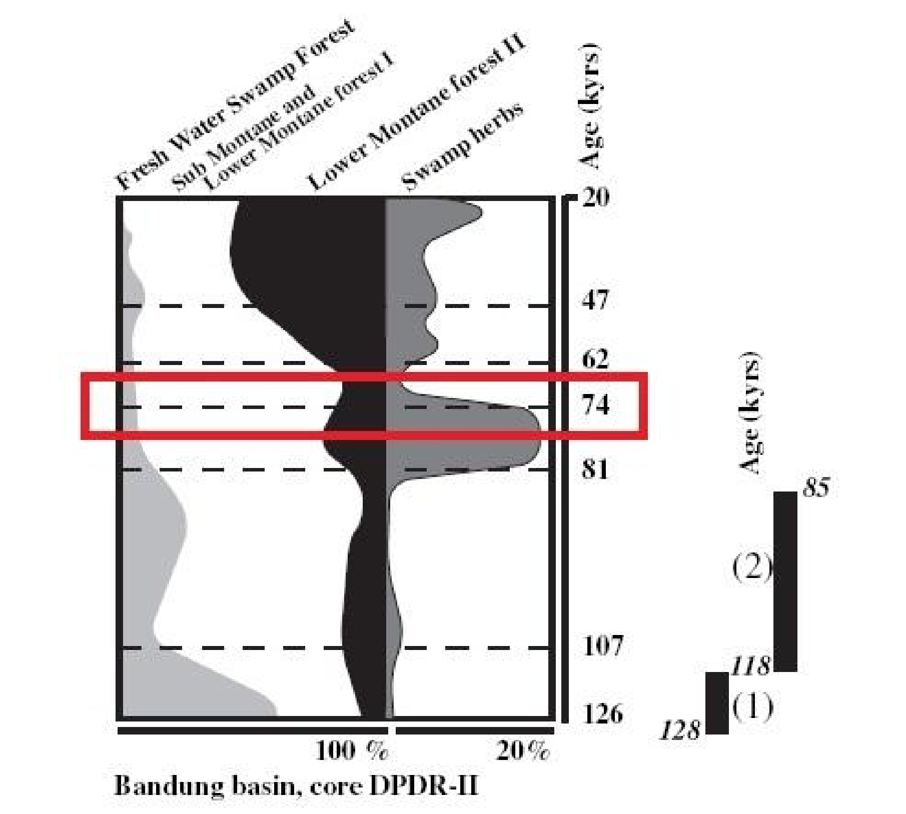

Fig. 3. The Upper Pleistocene landscapes recorded in Java (Synthetic pollen analysis data compiled from Van der Kaars and Dam (1997)). (1) Chronological position of the so-called Punung fauna in the fissures (after Westaway et al., 2007). (2) Chronological position of MIS 5 related occupation floors in the Song Terus cave (after Sémah et al., 2007 and Fauzi, 2008).

Figure 5. Pollen analyses from Bandung basin, core DPDR-II (source : Anne-Marie Sémah and François Sémah 2012, with modification)

and its would suggest significantly drier conditions in this region for at least one thousand years after the Toba eruption (Martin William AJ et al. 2009).

Others reseacrh in pollen doing by Anne-Marie Semah and Francois Semah (2012), where doing research at Bandung basin core DPDR-II for MIS 4 (Marine Isotope Stages), which repesented of drier conditions in plain subject to seasonal flood only with open swamp vegetation rich in grasses and sedges.Recent excavations in the rich Punung area yielded archaeological remains dating back to 300 ka in the Song Terus cave. Subsequent filling from c. 75 ka reflects a drastic change in the mode of cave occupation, which might record a change in human groups occupying the area following a somewhat catastrophic volcanic eruption, marked by the deposition in the cave of a thick riverlain volcanic ash. A drier and cooler climate prevailed after 81 ka.

Changes in vegetation are most important consequence of the YTT eruption. The change in vegetation composition may have created the biggest pressure on humans, who had to adapt to more open space with vewer trees and more grasses for some decades. Changes vegetation make changes animals too, based on the current paleontological records, the total number of species recorded for the period of the super-eruption of Toba is small. From research on mamals show that the effect of the YTT reveals reratively few species became extinct following the eruption. It is suggestted that species survived in regufia immediately following the eruption, and that they repopulated vast areas following a propable short period of enviromental devastation. Based on the current palaeontological record, however, no mammals appear to have become extinct on Sumatra immediately following the eruption, either as a result of the initial blast, or the proceeding climatic changes. While Java, Sumatra and Borneo could have been repopulated following their connection to the mainland during periods of lower sealevel following the eruption, this is not the case for the Mentawai Islands, which preserve nine rainforest endemics (J Louys 2007). The different extinct between plants and animals probabably because mamals can move to others place more safe and confortable, while the plants can not move.

From Oppenheimer papers in 2012 about migration Anatomically Modern Human (AMH) from Africa to Asia during the YTT shown India was not the first place toolsassociated with YTT have been invoked as evidence for AMH outside Afric pre-YTE. The Kota Tampan Palaeolithic culture foundin Lenggong Valley, in Perak on the Malay Peninsula, is two-thirdsof the way from Africa to Australia. This culture first identified bythe find of quartzite pebble tools fashioned on one side only and

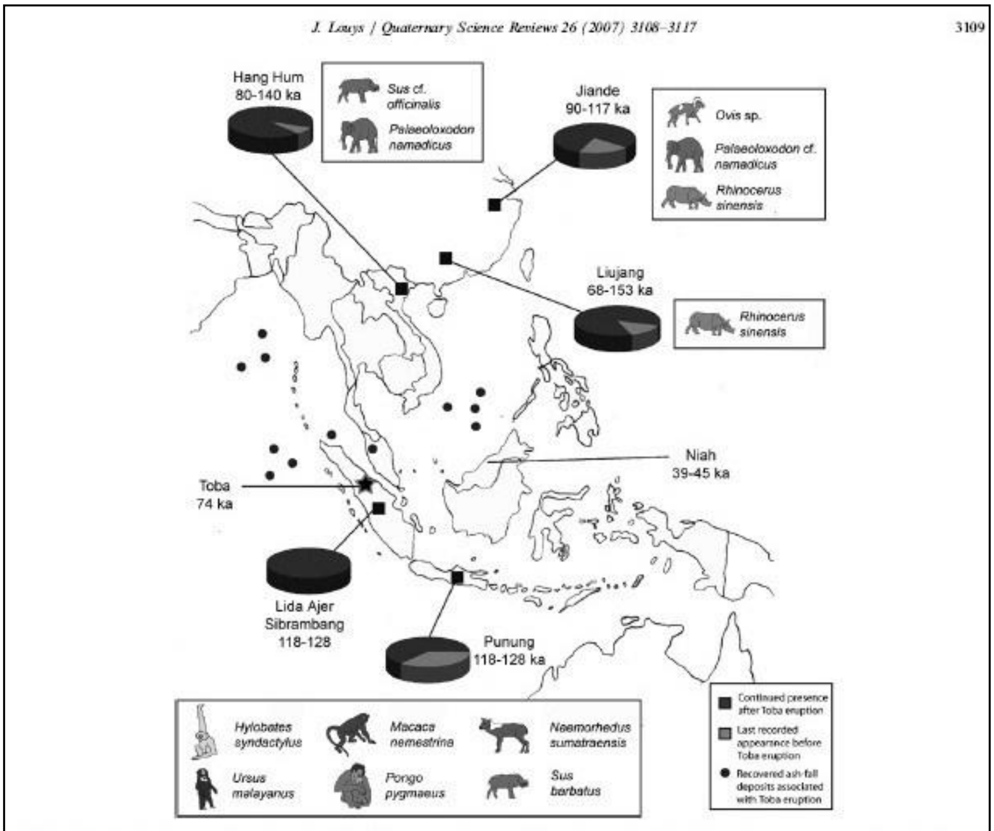

Fig. 1. Map showing the approximate locations of fossil sites preserving an extinction signature for Toba. Pie graphs represent proportion of species not represented after the eruption for each respective site. Extinct species for each country are illustrated in the boxes next to the pie graphs. Circles show recovered ash-fall deposits in the region (after Oppenheimer, 2002). Not to scale.

Figure 6. Showing location fossils, extinct speciest and ash-fall deposits (source : J Louys 2007)

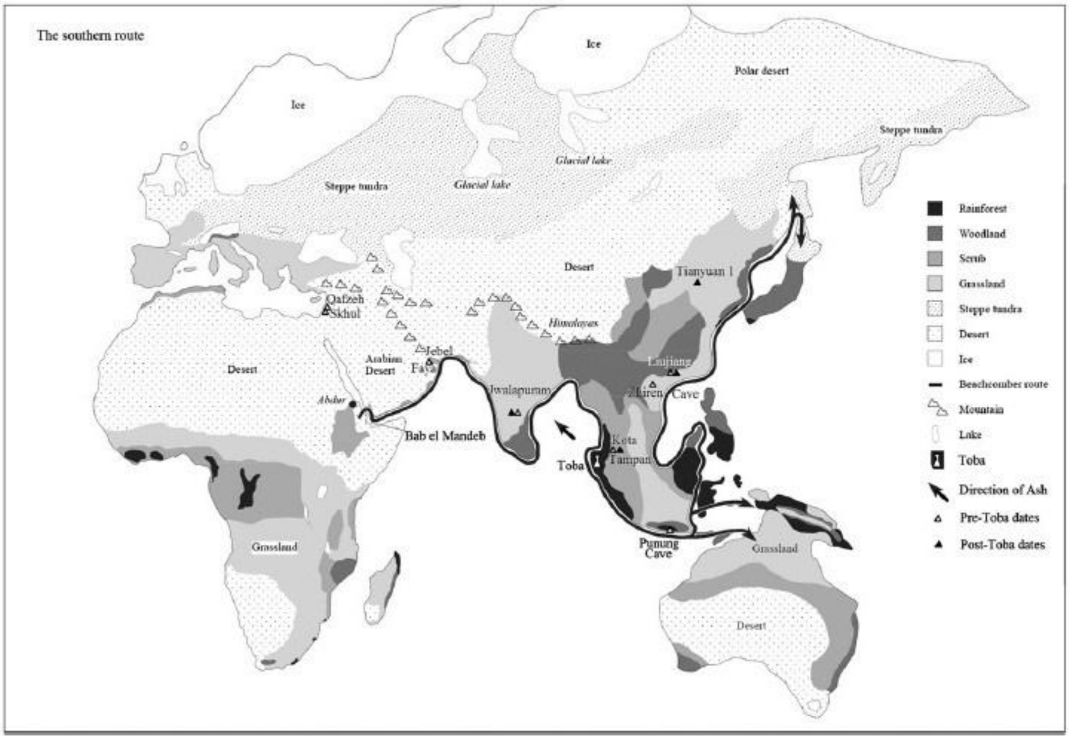

Fig. 3. Map showing single southern route out of Africa and beachcomber arc route from the Red Sea along the Indo-Pacific coast to Australia, including likely extensions to China, Japan and New Guinea, from MIS-4. Vegetation and sea level shown as at LGM. Overlay: claimed fossil and cultural evidence for AMH in Eurasia during MIS-5–MIS-4 (dates in text). Modified from Fig. 1.6, Oppenheimer (2003, 2009).

Figure 7. Single southern route Anatomically Modern Human (AMH) (source : Stephen Oppenheimer 2012)

embedded in volcanic ash. A separate and latercultural site on the same Pleistocene lake shore, contained numeroussimilar artefacts made of quartz in this instance, but no fossils,producing OSL dates of 70 ka. Extensive workat a number of sites in the Lenggong Valley suggests that this localpebble-tool culture may have existed from the days of the YTE until7 ka or even only 4 ka, one of the most recent finds of this culturebeing associated with a near complete AMH skeleton.The genetic confidence intervals straddle the Toba event thus cannot resolve the pre-Toba issue, but do appear to exclude significant (i.e. >5%) AMH survival from any earlier, Eemian exit, as claimed from the Jebel Faya, Zhiren Cave and a controversial older dating of the Liujiang skull (Stephen Oppenheimer 2012).

2.3 Mineralogical and Geochemical Criteria Identification and Their Potential for Their Correlation With the YTT.

Chemical fingerprinting the deposits of large volcanic eruptions is invaluable for identifying these chronostratigraphic markers over wide areas, and correlating them to particular eruptions. Typically the chemistry of the glass shards, which comprise most of the deposits at distal locations (>95%), is unique and allows different eruptions to be distinguished. Eruptions from the same volcano are, however, generally compositionally similar and glass chemistry of successive eruptions is commonly not distinctive.

Notable examples are the large-volume eruptions from Toba caldera in Sumatra, the Younger Toba Tuff (YTT), Middle Toba Tuff (MTT), and Older Toba Tuff (OTT), which share a similar glass chemistry. Glass chemistry of the tephra that outcrops in India and Malaysia matches that of eruptions from the Toba volcano but, as glass chemistry of all eruptions is similar, it is not clear which event deposited these ash units. Consequently correlations to particular Toba eruptions have been based on stratigraphic or independent chronological information (Victoria C. Smith et al. 2011).

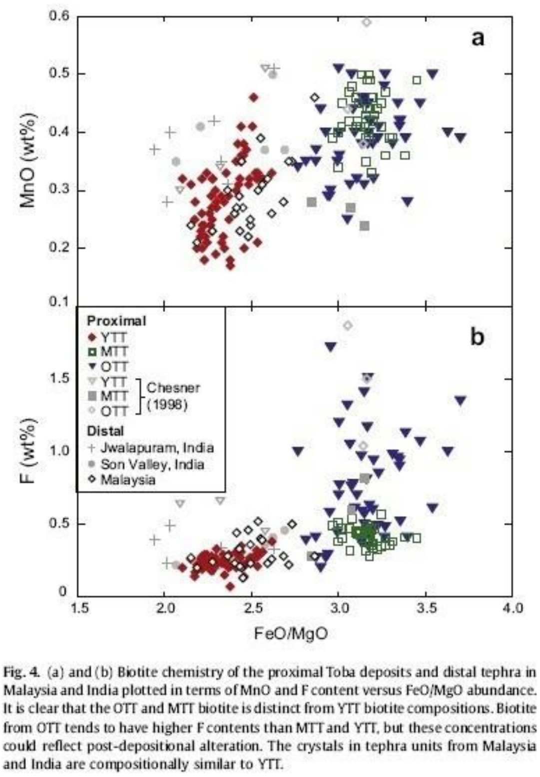

Figure 8. Biotite from ETT,MTT and YTT (source : Victoria C. Smith et al. 2011).

From geochemical tephra samples using biotite composition from Smith et al, were collected from a 20 cm thick primary airfall deposit within a soil profile in Lenggong, Malaysia (360 km from Toba), samples were also collected from archaeological sites situated in two localities: the Jurreru valley near Jwalaparum in the Kurnool area in central India, 2600 km from Toba and Son Valley, Ghogara in NE India, 3000 km from Toba. Biotite occurs as large (few mm in diameter) euhedral crystals in the proximal Toba deposits, whereas only small (5-10 μm) thin sheets of the mica are found in the distal deposits in Malaysia and India. In proximal deposits, YTT biotite has 16.0-24.0 wt% FeO and 6.7-10.2 wt% MgO (n = 63); MTT with 22.1-26.5 wt% FeO and 6.7-8.5 wt% MgO (n = 39); and OTT with 22.9-27.0 wt% FeO and 7.1-8.6 wt% MgO (n = 49). YTT biotite is distinct from that erupted during OTT and MTT, with clearly lower FeO/MgO (2.1=2.6) compared with the older eruptions. Biotite from MTT and OTT is compositionally similar, except OTT biotite typically has higher F contents (up to 1.7 wt%). The higher F in the bioitite from the OTT sample that has devitrified glass could be associated with post-depositional alteration. OH within the hydroxyl site could have exchanged with F in fluids moving through the ignimbrite after emplacement. The biotite in distal units in Malaysia (n = 22) and India (Son Valley: n = 6; Jurreru: n = 8) have similar compositions, with 15.8-24.5 wt% FeO, 6.8-11.0 wt% MgO, and <0.5 wt% F (Victoria C. Smith et al. 2011).

Toba glass compositions are almost eutectic and even though crystallisation extent and modal mineralogy varies the compositions of glasses remain similar from YTT,MTT and ETT, the similar glass compositions of all the large eruptions mean that these compositions cannot be used to correlate the distal ash deposits to particular eruptions. YTT biotite crystals are relatively depleted in FeO and MnO, and have slightly higher MgO, than those erupted during the older events. Biotite in the older units is compositionally similar but biotite in the widespread OTT commonly has much higher F contents (avg. 0.75 wt%) than biotite from the MTT (avg. 0.42 wt%). However, the high F contents observed in OTT biotites from the proximal ignimbrite could reflect post-emplacement alteration and the distally dispersed OTT biotite may not be enriched in F. FeO and MgO contents of biotite in two of the ODP 758 tephra units, have the same ranges as the eruption deposits they have previously been correlated to, YTT (unit A-B; n = 9; FeO/MgO 2.1-2.7) and OTT (unit D; n = 5; ~3.1 FeO/MgO). The compositions of the biotite in the distal ash units sampled in India and Malaysia are the same as YTT biotite crystals from proximal samples. Biotite and glass compositions indicate that these distal units are undoubtedly from the YTT eruption. Further evidence for this YTT correlation are the fission track, K-Ar and $^{40}Ar/^{39}Ar$ ages of ~68-84 ka obtained from crystals in ash samples at similar distal locations (Victoria C. Smith et al. 2011).

3. Conclusion

Tephra deposits preserved within sedimentary sequences create time synchronous marker horizons (isochrons) that allow precise dating (tephrochronology) and correlation of palaeoenvironmental or archaeological sites (tephrostratigraphy) across wide geographical areas. In recent years palaeoenvironmental studies have demonstrated the potential of 'extending' the use of visible tephra isochrons by looking for non-visible tephra layers, known as cryptotephra, which can in some cases be found more than 1000 km from their source eruption from the Toba volcano likes from archaeological sites in the Middle Son Valley, Jurreru Valley, India and Lenggong, Malaysia.

About the YTT event based on the tephrochronology, scientist know effect from YTT to environment and climate changes. The scientist also can make a simulation of the climate change based on tephra evidence were found in India, where more than 1000 km from source volcanoes explosive eruption. Scientist can date even when an eruption happened from a track from tephra using a radiometric (^{14}C or $^{40}Ar/\ ^{39}Ar$), Isothermal-plateau fission-track (ITPFT) and TL. Based on that YTT event included to Marine Isotope Stages 4, marked by decreased climates and dried environment and there is a rapid migration from AMH during MIS 4, probably caused by the Toba volcanic eruption.

From mineralogical and geochemical analysis, scientist known glass chemistry of the tephra from the Toba volcano that found in India and Malaysia matches that of eruptions from Toba volcano source, but as glass chemistry of all eruptions is similar from ETT, MTT, YTT it is not clear which event deposited these ash units. Consequently correlations to particular Toba eruptions have been based on stratigraphic or independent chronological information. The biotite compositions are distinct for the YTT eruption, and these compositions provide a chemical fingerprint that can be used to correlate distal units.

For reconstruction paleoenviroment results from tephras dating using ^{14}C or $^{40}Ar/\ ^{39}Ar$ and TL can be compared with pollen and paleoanthropology sequence for looking corelations in paleoclimates. This existing approaches to finding and analyzing cryptotephra are easily adapted to archaeological sequences, so long as the often complex nature of archaeological stratigraphies and sediment taphonomy are borne in mind.

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