

# Volcanic Ash and its Enigma: A Case Study from the Central Indian Ocean Basin

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**Abstract:** An ash layer occurs between 10-35 cm depth in sediment cores from the Central Indian Ocean basin. Morphology, major, trace and rare earth element composition of glass shards from the ash layer suggest that the Youngest Toba Tuff of ~74 ka from Northern Sumatra may be its source. To understand the implication of ash on the elemental distribution, a sediment core (NR-54) where abundant Youngest Toba glass shards occur at 30-35 cm depth interval was studied. The presence of ash layer resulted in the enrichment of coarse fraction (260%),  $Al_{\text{excess}}$  (104%), K (43%) and  $Al/Al + Fe + Mn$  (28%) and depletion of Mg (58%), Fe (55%), Mn (50%), Ti (44%) and biogenic opal (37%) compared to their average concentrations in the core. Therefore, precaution should be taken while studying the parameters indicative of productivity (biogenic opal, coarse fraction and  $Al_{\text{excess}}$ ), detrital terrigenous influx ( $Al/Al + Fe + Mn$ , Ti, K and Mg) and redox sensitive metal (Mn), whose concentration is affected by the presence of glass shards from the ash layer in the sediment cores from Bay of Bengal, Central Indian Ocean basin, South China Sea basin and Western continental margin of India where the widespread Youngest Toba ash is reported.

**Keywords:** Ash layer, Glass shards, Youngest Toba Tuff, Terrigenous influx, Indian Ocean.

## INTRODUCTION

Marine ash layers provide information about cyclicality of volcanism, volcanic production rate and volume, eruption duration, geochemical character of the source and temporal relation between paleoclimate and volcanic history (Kennet 1981; Fisher and Schmincke, 1984). Volcanic ash in marine sediments is derived either from continent through wind or river runoff and *in situ* submarine volcanism. Ash layers of a few centimetre thickness of Youngest Toba Tuff (YTT) of ~74 ka origin are reported from Bay of Bengal (Ninkovich et al. 1978; Rose and Chesner 1987; Dehn et al. 1991; Westgate et al. 1998), Central Indian Ocean basin (Pattan et al. 1999), South China Sea basin (Song et al. 2000), Arabian Sea (Schulz et al. 1998) and Western continental margin of India (Pattan et al. 2001). Recently, Pattan and Shane (1999) showed that glass shard from the ash layer is mainly responsible for the elevated Al/Ti ratio in the bulk sediment. In the present study, the behaviour of element concentration in a sediment core where ash layer was present is relooked into and its possible implications are discussed. For this study, a sediment core (NR-54) from latitude 7°S and longitude 78° 15' E at a water depth of 5200 m from Central Indian Ocean basin (CIOB) where ash layer occurs at 30-35 cm depth interval is used.

## RESULTS

Analysis of glass shards from tephra deposits by electron microprobe for their major element composition is widely accepted and has been used to identify and distinguish the ash beds in sedimentary formations (Westgate and Gorton, 1981). The composition of glass shards from CIOB has high  $SiO_2$  (77%) and total alkali (8.5%) with low CaO (0.78%), FeO (0.95%),  $TiO_2$  (0.06%), MgO (0.04%) and MnO (0.08%) contents suggesting rhyolitic composition (Table 1). Bubble wall morphology of these glass shards indicates magmatic origin (Pattan et al. 1999). The chemical composition and morphology of glass shards are indistinguishable from that of YTT from the Northern Sumatra (Ninkovich et al. 1978; Rose and Chesner, 1987; Dehn et al. 1991; Shane et al. 1995; Westgate et al. 1998).

The presence of ash layer at 30-35 cm depth in a sediment core (NR-54) from CIOB resulted in the enrichment of coarse fraction,  $Al_{\text{excess}}$ , K,  $Al/Al + Fe + Mn$  and detrital silica and decrease of biogenic silica, Ti, Fe, Mn, Cu and Ni contents.

## DISCUSSION

Coarse fraction (>63  $\mu\text{m}$ ) in the marine sediments is

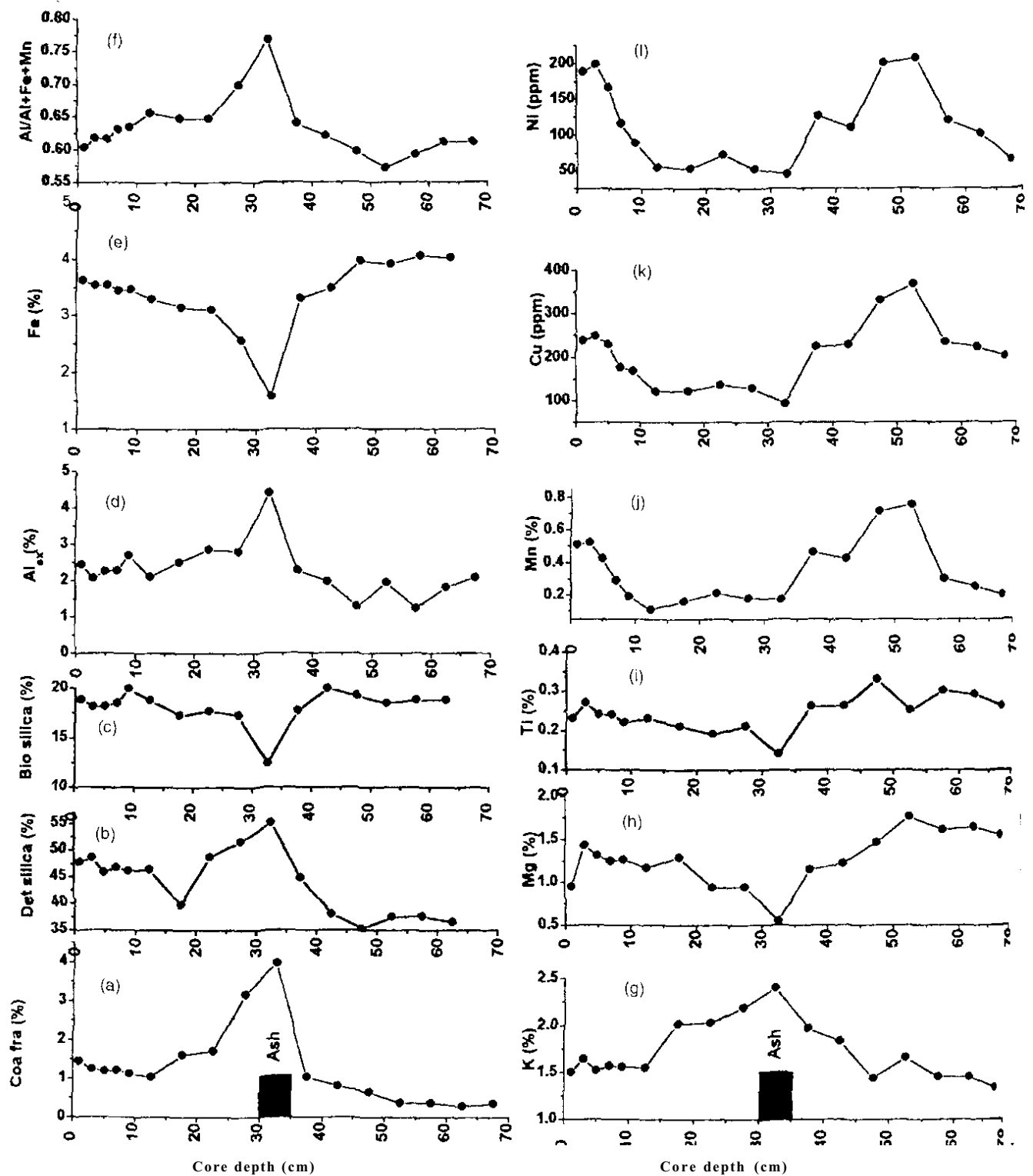


Fig.1. Distribution of (a) coarse traction (wt%), (b) detrital silica (wt%), (c) Biogenic silica (wt%), (d)  $Al_{excess}$  (wt%). (e) Fe (wt%), (f)  $Al/(Al+Fe+Mn)$ . (g) K (wt%). (h) Mg (wt%), (i) Ti (wt%). (j) Mn (wt%), (k) Cu (ppm) and (l) Ni (ppm) in a sediment core (NR-54) from Centra Indian Ocean basin. Ash layer is present at 30-35 cm depth.

Table 1. Average chemical composition of glass shards (n=10) analysed by electron microprobe

Oxides	NR-54 (30-35cm)*		YTT**	
SiO <sub>2</sub>	76.94	(0.28)	77.58	(0.23)
Al <sub>2</sub> O <sub>3</sub>	12.74	(0.15)	12.60	(0.13)
TiO <sub>2</sub>	0.06	(0.05)	0.06	(0.04)
FeO	0.95	(0.05)	0.90	(0.05)
MnO	0.08	(0.04)	0.06	(0.03)
MgO	0.04	(0.02)	0.05	(0.02)
CaO	0.78	(0.08)	0.77	(0.07)
Na <sub>2</sub> O	3.46	(0.10)	3.24	(0.13)
K <sub>2</sub> O	4.98	(0.12)	4.96	(0.14)
Cl	0.14	(0.01)	0.14	(0.03)
N <sub>2</sub> O	5.52	(0.85)	1.99	(0.83)
N	10		275	

\*Pattan et al. (1999). \* Westgate et al (1998) Number in the bracket is the standard deviation. N is number of individual shards analysed

used to study productivity variation. Coarse fraction is mostly composed of radiolarians, small quantity of glass shards and manganese micronodules. Coarse fraction varies in general from 0.1 to 1.5% except at 30-35 cm depth, where it reaches to 4% and shows 260% increase compared to its average content in the core (Fig.1). This could be due to the presence of abundant glass shards with high specific gravity (2.45 gm/cm<sup>3</sup>). Further increase in coarse fraction due to the presence of glass shards depends upon the distance from the volcanic source. It is well known that as the distance from the volcanic source increases the size and decreases the abundance of glass shards. Al<sub>excess</sub> (structurally unsupported) or Al/Ti ratio in the marine sediments has been used as a possible indicator of productivity ( Murray et al . 1993; Dymond et al. 1997. Banakar et al. 1998; Pattan and Shane 1999). Average Al<sub>excess</sub> is 2.16% of the bulk Al concentration in a sediment core except at 30-35 cm depth interval, where it reaches to maximum of 4.4% (fig.1) which is more than 104% compared to its average. This could be due to high Al and low Ti content of the glass shards. Therefore the elevated coarse fraction and Al<sub>excess</sub> or Al/Ti ratio in the sediment core is due to presence of glass shards and not related to productivity variation.

Terrigenous index factor (Al/(Al+Fe+Mn)) was used in the past to trace the detrital terrigenous influence. and this ratio decreases as the distance increases from the continent (Bostrom et al. 1973). Nath et al. (1989) and Mudholkar et al.( 1993) used this ratio and suggested terrigenous influence upto 8° and 14°S based on surface and subsurface sediments of the CIOB. respectively. This ratio is around 0.6 throughout the core depth except at 30-35 cm depth where it reaches to a maximum of 0.77 (Fig. 1). suggesting 28% increase. This is due to high Al and low He and Mn content

in the glass shards (Table 1). The detrital silica content was obtained by subtracting the biogenic silica from the bulk silica (Pattan et al. 1992; Mudholkar et al. 1993). Potassium and detrital silica contents are enriched by 43% and 35% at 30-35 cm depth in the core, respectively (Fig. 1). This is again due to high content of K and Si in the glass shards (Table 1).

Biogenic silica in the sediment suggests siliceous productivity. Biogenic silica in the sediment core is almost uniform (~19%) except at 30-35 cm depth, where it reaches to a minimum (12%) and is depleted by 37% (Fig. 1). The glass shards with very high detrital silica may dilute the biogenic silica. Therefore, lowest biogenic silica in the sediment core cannot be interpreted as low siliceous productivity. Titanium, He and Mg are mostly associated with detrital component in the marine sediments. These elements are depleted by 44%, 55% and 58% respectively compared to their average content. This is mainly due to their very low concentration in the glass shards (Table1). Manganese is a redox- sensitive metal whose concentration depends upon oxidizing/reducing environment. Earlier, reducing environment was traced at intermediate depth in a number of sediment cores of CIOB (Banakar et al. 1991; Mudholkar et al. 1993). In the present core, the ash layer as well as reducing zone overlap each other. Glass shards with very low Mn content may result in depletion of Mn content of the bulk sediment (Fig.1: Table1) and this should not be interpreted as indicative of reducing environment. Similar to Mn, Cu and Ni contents are also reduced, where ash layer is present (Fig. 1).

Recently, YTT is traced in South China Sea basin (Song et al. 2000) and along the Western continental margin of India (Pattan et al. 2001), in addition to the earlier occurrence from Bay of Bengal (Ninkovich et al. 1978 Rose and Chesner 1987; Dehn et al. 1991; Westgate et al. 1998) and CIOB (Pattan et al. 1999). YTT occurs at ~300 cm depth in a sediment core from the Western continental margin of India (latitude 9°21'N: longitude 71°59' E at water depth of 2300 m; Pattan et al. 2001) and similarly here also. most of the metal concentration are effected by the presence of glass shards. Therefore, it appears that volcanic glass acts as a dilutant to a number of geochemical proxies used to interpret palaeoclimate and palaeoproductivity. Hence, before studying bulk geochemistry of sediments, it is necessary to look into sedimentological aspects, as otherwise it may lead to misinterpretations.

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## References

- BANAK R, V.K., GUPTA. S.M. and PADMAVAN. V. K. (1991) Abyssal sediment erosion in the Central Indian basin: evidence from radiochemical and radiolarian studies. *Mar. Geol.*, v.96, pp.167-173.
- BANAKAR. V.K., PARTHIBAN, G., PATTAN. J.N. and JAUHARI. P. (1998) Chemistry of surface sediment along a north-south transect across the equator in the Central Indian basin: An assessment of biogenic and detrital influences on elemental burial on the seafloor *Chem. Geol.*, v. 147, pp.217-232.
- BOSTROM. K., KRAEMER, T. and GARTNER, S. (1973) Province and accumulation rates of opaline silica. Al, Ti, He, Mn, Cu, Ni and Co in Pacific pelagic sediments. *Chem. Geol.*, v. I]. pp. 123-146
- 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. *Proc. Ocean Drilling Programme. Scientific Results*, v.121, pp. 273-295.
- DYMOND. J., COLLIER. R., McM NOS. J., HONIO. S. and MANGANINI. S. (1997) Can the aluminum and titanium contents of ocean sediments be used to determine the paleoproductivity of the ocean " *Paleoceanography.*, v. 12, pp.586-593.
- FISHER. R.V. and SCHMINCKE, H.U. (1984) *Pyroelastic Rocks*. Springer Verlag. New York, 472p.
- KENNEY. J.P. (1981) Marine tephrochronology. *In: C. Emiliani (Ed.). The Oceanic Lithosphere. The Seas*, v.7. pp. 1373-1436.
- MUDHOLKAR. A.V., PATTAN, J.N. and PARTHIBAN G. (1993) Geochemistry of deep-sea sediment cores from the Central Indian Ocean basin. *Indian Jour. Mar. Sci.*, v.22. pp.24 1-246.
- MURRY, R W., LINEN. M. and ISERN. A.R. (1993) Biogenic flux of Al to sediment in the Central Equatorial Pacific Ocean evidence for increased productivity during glacial episodes. *Paleoceanography.* v.8. pp.65 1-670.
- NATH, B.N., RAO, V.P.C. and BECKER. K.P. (1989) Geochemical evidence of terrigenous influence in deep-sea sediments upto 8°S in the Central Indian basin. *Mar. Geol.*, v.87. pp.301-313.
- NINKOVICH, D., SHACKLETON. N.J., AHDEL-MOSEM. A.A , OBRADOVICH, J.D. and IZETT. G. (1978) K-Ar age of the Pleistocene eruption of Tuba, north Sumatra. *Nature* , v 276, pp.574-577.
- PATTAN, J.N. and SHANE. P. (1999) Excess aluminum in deep-sea sediments of the Central Indian basin. *Mar. Geol.*, v.161, pp.247-255.
- PATTAN. J.N., SHANE. P. and BANAK R, V.K. (1999) New occurrence of Youngest Toba Tuff in abyssal sediments of the Central Indian basin. *Mar. Geol.*, v. 155. pp.243-248.
- PATTAN. J.N., SHANE, P., PEARCE , N.J.G., BANAK R, V.K. and PARTHIBAN. G. (2001) An occurrence of the ~74 ka Youngest Toba tephra from the Western continental margin of India. *Curr. Sci.*, v.80. pp. 1322-1326.
- ROSE W.I. and CHESNER.C.A. ( 1987) Dispersal of ash in the great Toba eruption 75 ka. *Geology.*, v.15, pp.913-917.
- SCHULZ. H., VOX RAD, U. and ERLLENKEUSER, H. ( 1998) Correlation between the Arabian sea and Greenland climate oscillations of the past 11 0.000 years. *Nature.* v.393 pp.54-57.
- SHANE, P.A.R., WESTGATE. J.A. WILLAMS. M.A J. and KORISHENAR, R. (1995) New geochemical evidence for the Youngest Toba Tuff in India. *Quat. Res.*, v.44. pp.300-304.
- SONG. S.R., CHEN. C.H., LEE, M.Y. YANG, T.E. HIZNKA, Y. and WEI. K.Y. (2000) Newly discovered eastern dispersal of the Youngest Toba Tuff. *Mar. Geol.*, v. 167, pp.303-312.
- WESTGATE. J.A. and GORION M.P. (1981) Correlation techniques in tephra studies *In S. Self, and R.S.J. Sparks (Eds.), Tephra Studies*. Reidel Dordrecht, pp. 73-94.
- WESTGATE. J.A., SHAM . P.A.R., PEARCE N.G.J., PERKINS, Y.T. KORISHENAR., CHESNER, C.A., WILLAMS. M.A.A.J. and ACHARYYA. S.K. (1998) All Toba tephra occurrences across Peninsular India belong to the 75,000 yr B.P. eruption. *Quat. Res.* v.50, pp. 107-122.

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