Geophysical Research Abstracts
Vol. 16, EGU2014-8632-1, 2014
EGU General Assembly 2014

Deccan Volcanism: a main trigger of environmental changes leading to the KTB mass extinction?

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The nature and causes of mass extinctions in the geological past have remained topics of intense scientific debate for the past three decades. Central to this debate is the question of whether the eruption of large igneous provinces (LIP) was the primary mechanism driving the environmental changes that are commonly regarded as the proximate causes for four of the five major Phanerozoic extinction events.

Model results predict that Deccan Traps emplacement was responsible for a strong increase in atmospheric pCO_2 accompanied by rapid warming of 4°C that was followed by global cooling. During the warming phase, increased continental weathering of silicates associated with consumption of atmospheric CO_2 likely resulted in the drawdown of greenhouse gases that reversed the warming trend leading to global cooling at the end of the Maastrichtian. Massive CO_2 input together with massive release of SO_2 may thus have triggered the mass extinctions in the marine realm as a result of ocean acidification leading to a carbon crisis and in the terrestrial realms due to acid rains. Global stress conditions related to these climatic changes are well known and documented in planktic foraminifera by a diversity decrease, species dwarfing, dominance of opportunistic species and near disappearance of specialized species.

Deccan Traps erupted in three main phases with 6% total Deccan volume in phase-1 (base C30n), 80% in phase-2 (C29r) and 14% in phase-3 (C29n). Recent studies indicate that the bulk (80%) of Deccan trap eruptions (Phase-2) occurred over a relatively short time interval in magnetic polarity C29r, whereas multiproxy studies from central and southeastern India place the Cretaceous-Tertiary (KT) mass extinction near the end of this main phase of Deccan volcanism suggesting a cause-and-effect relationship.

In India a strong floral response is observed as a direct response to Deccan volcanic phase-2. In Lameta (infratrappean) sediments preceding the volcanic eruptions, palynoflora are dominated by gymnosperms and angiosperms with a rich canopy of gymnosperms (Conifers and Podocarpaceae) and an understory of palms and herbs. Immediately after the onset of Deccan phase-2, this floral association was decimated leading to dominance by angiosperms and pteridophytes at the expense of gymnosperms. In subsequent intertrappean sediments a sharp decrease in pollen and spores coupled with the appearance of fungi mark increasing stress conditions apparently as a direct result of volcanic activity. The inter-trappean sediments corresponding to Phase-2 (80% of Deccan basalt emissions, latest Maastrichtian) are characterized by the highest alteration CIA index values. This is probably better explained by increased acid rains due to SO_2 emissions than a global climatic shift; since clay minerals from the corresponding sediments do not reflect a significant climatic change. This increased alteration is coeval with the sharp decline in pollen and an increase in fungal spores observed by Samant and Mohabey, (2009) and corresponds to the main phase of Deccan activity.

Beyond India, multiproxy studies also place the main Deccan phase in the uppermost Maastrichtian C29r below the KTB (planktic foraminiferal zones CF2-CF1), as indicated by a rapid shift in 187Os/188Os ratios in deep-sea sections from the Atlantic, Pacific and Indian Oceans, coincident with rapid climate warming, coeval increase in weathering, a significant decrease in bulk carbonate indicative of acidification due to volcanic SO_2, and major biotic stress conditions expressed in species dwarfing and decreased abundance in calcareous microfossils (planktic foraminifera and nannofossils). These observations indicate that Deccan volcanism played a key role in increasing atmospheric CO_2 and SO_2 levels that resulted in global warming and acidified oceans, respectively, increasing biotic stress that predisposed faunas to eventual extinction at the KTB.