Geophysical Research Abstracts
Vol. 12, EGU2010-8419, 2010
EGU General Assembly 2010

From the Cretaceous-Tertiary Boundary to the Paleocene-Eocene Thermal Maximum (PETM): New Insights from the Wadi Nukhul Section (Sinai, Egypt)

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The Wadi Nukhul section (SE Sinai, Egypt) includes two of the most dramatic environmental changes in the earth's history: the Cretaceous-Tertiary boundary mass extinction (K/T) and the Paleocene-Eocene Thermal Maximum (PETM). It consists of a 38 m thick continuous succession of late Maastrichtian to early Eocene pelagic sediments. Lithologically, the base of the section is formed of chalk alternating with marly limestone of late Maastrichtian age (uppermost part of the Sudr Formation), conformably overlain by approximately 18.5 m of marls, marly shale and shales of the Paleocene Dakhla Formation. Its topmost part gradually changes to a bioturbated chalk with flint layers coinciding with the base of the Paleocene Tarawan Formation followed upward by the late Paleocene - early Eocene Esna Formation, characterized by alternating shaly marls, shales and silty shales.

The K/T boundary clay layer is identified at 1.75 m above the top of the Sudr Fm within the Dakhla shales. Upwards, the Paleocene-Eocene boundary (PE) was observed about 5 m over the top of the Chalk Tarawan within the Esna Shale and consists of a 90 cm thick black clayey interval enriched in organic matter and small phosphatic pebbles and corresponds biostratigraphically to the NP9a/Np9b nannofossil subzonal boundary.

31 and 25 samples covering the K/T and P/E intervals respectively have been subjected to an extensive geochemical study, including bulk and clay mineralogy, major, trace elements, total P, TOC, and TON contents, and stable isotopes ($\delta^{13}C_{car}$, $\delta^{18}O_{car}$, $\delta^{13}C_{org,}$ $\delta^{15}N_{org}$).

The K/T boundary interval exhibits: (1) a gradual negative shift in $\delta^{13}C_{car}$ and$\delta^{13}C_{org}$ starting 1m below the boundary clay layer, (2) a significant increase in P content within the K/T clay layer which persists upwards (3) a decreased carbonate content beginning 1m below the boundary clay layer which coincides with important kaolinite inputs, (4) an abrupt enrichment in major elements such as Ti, Fe, Mn, Mg within the boundary clay which coincides with a peak in Ni, Ba, Cu, Zn, As, Sc, La, Nd, Ce, V, Cr, Co and Pb trace elements.

The P/E boundary exhibits: (1) an abrupt negative shift of both $\delta^{13}C_{car}$ and$\delta^{13}C_{org}$ values (–6‰¸and –2‰ from the background value before the boundary, respectively) (2) a severe and persistent decrease in $\delta^{15}N_{org}$ to ∼0‰ (3) a significant increase in TOC, TON and P contents just above the negative isotopes excursion (4) a decrease in carbonate content and the appearance of significant amount of kaolinite (5) a short-lived depletion of all major elements within the boundary, followed upwards by a general increase, Ti excepted, (6) an increase in V, Cr, Ni, Cu and Zn trace elements 5 cm above the $\delta^{13}C_{car}$ shift.

The observed decrease in both carbonate and $\delta^{13}C_{car}$values coinciding with large kaolinite input before and through the KT boundary reflects enhanced greenhouse conditions maybe linked to the main Deccan eruptive phase which started in the uppermost Maastrichtian C29r (CF2-CF1 transition).

At the P/E transition, the lag observed between the $\delta^{13}C_{car}$ and$\delta^{13}C_{org}$excursions and the decrease in carbonate contents could be explained by oxidation of the released methane already in the water column, providing isotopically light dissolved inorganic carbon. Increased kaolinite contents reflect a change towards more humid conditions through the PETM and may explain the coeval increase in nutrients (e.g. P, N) leading to high productivity and anoxic conditions as indicated by high TOC and TON content and trace elements. The $\delta^{15}N$ ∼0‰ values above the boundary and persisting along the interval suggests a bloom and high production of atmospheric N_2-fixers, as cyanobacteria.