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The record of Tethyan planktonic foraminifera at the early Paleogene hyperthermal events and Middle Eocene Climatic Optimum in northeastern Italy: are they comparable?

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The early Paleogene is one of the more climatically and evolutionary dynamic periods in the Earth history that records a pronounced warming trend peaking in the Early Eocene, and a successive composite transition towards the modern icehouse world. Ever increasingly scientific attention is dedicated to definitely comprehend timing, nature and characters of the complex, non-linear evolution of the Paleogene climate.

Several complete and expanded Paleogene successions (Forada, Possagno, Alano, Farra), with a sound magneto-biochronostratigraphic and stable isotope record crop out in the Venetian Southern Alps (Northeast Italy). Recent studies (Giusberti et. al., 2007; Luciani et al., 2007; Agnini et al., 2008) and unpublished data document the presence in these section of the main short-lived warming events (hyperthermals) of the Eocene (Paleocene-Eocene Thermal Maximum, PETM, ca 55 Ma, Eocene Layer of Mysterious Origin (ELMO, ca 53,6 Ma), X-event (ca 52.5 Ma), of the Early Eocene Climatic Optimum (EECO, ca 50-52 Ma) and of the Middle Eocene Climatic Optimum (MECO, ca 40 Ma; Zachos et al., 2001. 2008). All these events are typified by marked negative shifts in $\delta^{13}C$ curves that correspond to carbonate decrease related to rise of the carbonate compensation depth in turn induced by large introduction in the ocean-atmosphere system of CO_2.

Common features to the warming events are pronounced and complex changes in planktonic foraminiferal assemblages, indicating strong environmental perturbations that perfectly parallel the variations of the stable isotope curves in all the examined events. These strict correspondences indicate close cause-effect relationships between changes in environmental conditions and modifications of the assemblages. Our analysis shows that the most striking variations are recorded by the PETM and MECO assemblages that reflect highly perturbed environments. The ELMO, X-event and EECO exhibit planktic foraminiferal responses that are similar to, though less intense than, those observed across the PETM and the MECO. In addition, sedimentological and quantitative micropaleontological data from the hyperthermal events from the Venetian Southern Alps essentially suggest as the main response to the pronounced warmth, increased weathering and runoff as well as sea surface eutrophication. A pronounced shift from relatively oligotrophic to eutrophic, opportunist planktonic foraminiferal assemblages was observed at the MECO as well, thus showing analogies with the hyperthermal events recorded in the same area. The taxa indicating eutrophic environmental conditions are however different at the MECO from the Alano section; on the other hand we can expect that the planktonic foraminiferal taxa indicating analogous scenarios might be different in different Eocene time-intervals. Remarkably, the PETM and MECO events record a significant occurrence of giant and malformed foraminifera, evidence of transient alteration in the ocean chemistry, including possible pH oscillations and increase in trace metal content. Our data suggests therefore that a major threshold in the photic zone ocean chemistry has been passed only for those prominent events.

In conclusion, from the biotic response to the hyperthermal events, to the EECO and MECO we deduce that the most important effect of pronounced warming, that is the aspect common to all these events, has been the eutrophication of surface waters, as a consequence of modification in the hydrological cycle. The location adjacent to land masses of the studied Tethyan setting evidently facilitated the terrigenous input that was apparently the main responsible for the increase in nutrient availability during the cited Paleogene warming events.

Finally, several lines of evidence indicate that PETM, EECO and MECO were linked to permanent changes in

planktonic foraminiferal evolution beside the transient, ecologically controlled variations. Even though the true mechanisms forcing evolution of life on Earth are still unexplained, our record of the major climatic Paleogene events suggests a close interaction between global climate and biological evolution.

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