The latest Miocene-early Pliocene biogenic bloom: duration, causes and paleoceanographic implications

(Proposers: Prof. Claudia Agnini; Prof. Laia Alegret)

The late Miocene-early Pliocene (ca. 8.5-3.5 Ma) is an interval of the geological history characterized by important paleoclimatic and paleoceanographic changes such as the expansion of ice caps at both poles, the gradual uplifting of the Isthmus of Panama (Farrell et al., 1995), the evolution and domination of the global deep circulation by the North Atlantic deep water (NADW), the "Messinian salinity crisis" caused by the isolation of the Mediterranean from the Atlantic Ocean (Hodell et al., 1994; Krijgsman et al., 1999) and the so-called biogenic bloom (Farrell et al., 1995; Dickens and Owen, 1999; Fig.1).

During the biogenic bloom sediments beneath upwelling zones display remarkable changes that include a significant increase in the mass accumulation rate (MAR) of the biogenic components, major changes in planktic and benthic fauna assemblages, and a marked decrease in sedimentary redox conditions (e.g. Van Andel et al., 1975; Leinen, 1979; Theyer et al., 1985; Woodruff, 1985; Kennett and Von der Borch, 1986; Berger et al., 1993; Delaney and Filippelli, 1994; Farrell et al., 1995a; Rea et al., 1995; Dickens and Owen, 1996). These conditions have been recognized at different sites in the Indian Ocean, including holes drilled during ODP Leg 115 (equatorial Indian Ocean; Peterson and Backman, 1990), ODP Site 756 (southern Ninetyeast Ridge; Brumer and Van Eijden, 1992), or ODP Sites 752, 754, and 757 (Broken and Ninetyeast ridges, central Indian Ocean; Dickens and Owen, 1994).

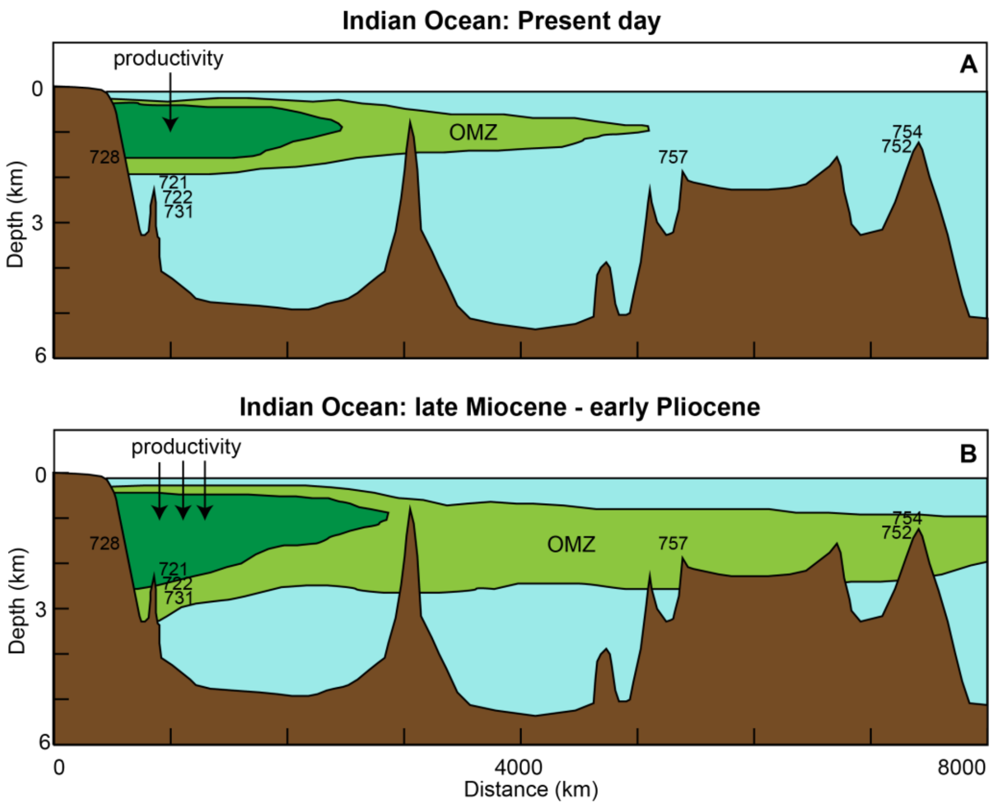

Figure1. (modified from Dickens and Owen, 1999) (A) Bathymetric profile. The present locations of ODP sites 721, 722, 728, 731, 752, 754, and 757 are shown on this profile as well as the present dimensions of the Indian Ocean Oxygen Minimum Zone (OMZ) Note that the lateral dimensions of the Indian Ocean OMZ are much greater than the zone of high primary productivity in the northwest Indian Ocean. (B) The biogenic bloom hypothesis in the Indian Ocean. During the latest Miocene–early Pliocene, productivity in the north and west Indian Ocean was significantly elevated, and the underlying OMZ was greatly expanded. Note that the OMZ dimensions in the lower figure are highly schematic.

The duration, possible global extent and mechanisms of this event are still poorly known. The biogenic bloom lasted for ca. 5 Ma (Dickens and Owen, 1999), but high productivity conditions cannot be maintained for long periods in the modern oceans because primary productivity is limited by the availability of nutrients, and their residence time is usually short (< 10^5 years, Delaney and Filippelli, 1994; Treguer et al., 1995). In order to understand the duration and mechanisms of the biogenic bloom, a different system or, at least radically different global nutrient cycling of the oceans during the late Miocene-early Pliocene need to be hypothesized.

Two main hypotheses have been proposed to explain this phenomenon. The first one suggests that the biogenic bloom was caused by an increased delivery of nutrients through rivers, as a result of intensified continental weathering (Berger et al., 1993; Berger and Stax, 1994; Delaney and Filippelli, 1994; Farrell et al., 1995). The second one is based on the “redistribution of nutrients”: the intensified formation of deep waters (Wright and Miller, 1996) and high-latitude warming (Hays and Opdyke, 1967; Koizumi, 1986) could have accelerated the deep-water conveyor belt (Rind and Chandler, 1991) and in turn, enhanced transport of nutrients from the Atlantic to the Pacific and Indian Oceans (Dickens and Owen, 1996).

This is the rationale of the event, but most studies were carried out during the 90´s and further work is needed to better understand the causes and mechanisms behind the event, and to understand its consequences and geographical extent. A number of locations globally distributed need to be studied at very high resolution, with firm age models because in the previous datasets there is a number of apparent inconsistencies, for instance the possible diachronity and the different durations inferred for the event at various sites.
This project thus aims at providing datasets from different areas of the planet which include an integrated stratigraphy (calcareous nannofossils, magneto and isotope stratigraphy, etc.) that will serve to construct highly-resolved and precise age models. More importantly, we will analyze the evolution of the paleoenvironmental conditions at the seafloor especially in terms of nutrient availability, trophic conditions and oxygen concentrations, through quantitative studies on benthic foraminiferal assemblages and statistical analyses. Paleoceanographic proxies such as stable carbon and oxygen isotopes will be compared with paleontological data in order to depict a reliable scenario of the conditions that occurred during the biogenic bloom.

This project will additionally benefit from the relatively good knowledge of the oceanography/ paleoceanography during the Neogene, which will contribute to understand the causes, mechanisms and effects of the variations recorded in the geological record. This is of particular importance because the geological record represents a unique opportunity to test processes that lasted millions of years in the past and, more interestingly, which can reoccur in the future.

The project will benefit from the collaboration with a number of colleagues from different Institutions: Prof. Laia Alegret (Universidad de Zaragoza, Spain), Dr. Thomas Westerhold (MARUM, Bremen, Germany) and Dr. Edoardo Dallanave (Universität Bremen, Germany).

Available funds: DOR and residual funds to Prof. Agnini.

References

Berger, W.H., Stax, R., 1994. Terra Nova 6, 520-534
Berger, W.H., Leckie, R.M., Janecek, T.R., Stax, R., Takayama, T., 1993. Proc. ODP, Sci. Res. 130, 711-744.
Brummer, G.J.A., Van Eijden, A.J.M., 1992. Marine Micropaleontology 19, 99-117.
Delaney, M.L., Filippelli, G.M., 1994. Paleoceanography 9, 513-527.
Dickens, G.R., Owen, R.M., 1994. Paleoceanography 9, 169-181.

Dickens, G.R., Owen, R.M., 1996. Marine Micropaleontology 27, 107-120.
Dickens, G. R., Owen, R. M., 1999. Marine Geology 161 (1999) 75- 91.
Farrell, J.W., Ra, I., Janecek, T.R., Murray, D.W., Levitan, M., Delaney, M., Dadey, K.A., Emeis, K.-C., Lyle, M., Flores, J.-A., Hovan, S., 1995. Proc. ODP Sci. Res. 138, 717-756.
Hays, J.D., Opdyke, N.D., 1967.
Science 158, 1001-1011.
Hodell, D.A., Benson, R.H., Kent, D.V., Boersma, A., Racic-El Bied, K., 1994. Paleoceanography 9, 835-855.
Kennett, J.P., Von der Borch, C.C., 1986. Initial Rep., DSDP 90, 1493- 1517.
Koizumi, I., 1986. Marine Micropaleontology 10, 309-325.
Krijgsman, W., Hilgen, F.J., Raffi, I., Sierro, F.J., Wilson, D.S., 1999. Nature 400, 652- 655.
Leinen, M., 1979. Geological Society of America Bulletin 90, 1310-1376.
Peterson, L.S., Backman, J., 1990. Proc. ODP, Sci. Res. 115, 467-507.
Rea, D.K., Basov, I.A., Krissek, L.A. et al., 1995. Proc. ODP, Sci. Res. 145, 577-596
Rind, D., Chandler, M., 1991. Journal of Geophysical Research 96, 7437-7461.
Theyer, F., Mayer, L.A., Barron, J.A., Thomas, E., 1985. Initial Rep., DSDP 85, 971-985.
Treguer, P., Nelson, D.M., Van Bennekom, A.J., DeMaster, D.J., Leynaert, A., Queguiner, B., 1995. Science 268, 375-379.
Van Andel, T.H., Heath, G.R., Moore Jr., T.C., 1975. Memoirs - Geological Society of America 143, 143 pp.
Woodruff, F., Douglas, R.G., 1981. Marine Micropaleontology 6, 617- 632.
Wright, J.D., Miller, K.G., 1996. Paleoceanography 11, 157-170.