Namibia Upwelling: Ocean Meadows off the Desert

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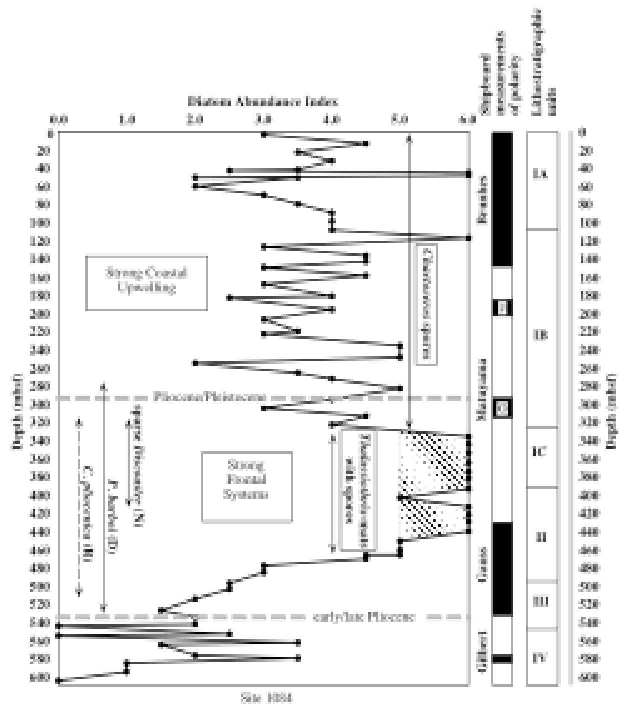
A central finding of the ocean drilling expedition off Namibia and South Africa (Leg 175, 1997) is that the history of the intense coastal upwelling in that region is intimately tied into global climate change and the geochemistry of the deep ocean. The high productivity associated with this flow of cool, nutrient-dense deep water upwards along the coast cannot simply be described as a progressive increase of productivity that began ten million years ago. Instead, physical upwelling of cold water follows global cooling rather closely, while silicate content of the water (crucial for diatom production) runs out of phase with upwelling but is highly correlated with changes in thermohaline circulation.

Productivity indicators all along southwestern Africa suggest the presence of increased upwelling and organic matter supply to the sea floor during glacial periods. At the same time, there is a decrease in the supply of diatoms and other siliceous plankton remains – an opposite reaction than one would expect. This disparity is the Walvis Opal Paradox (Berger and Wefer, 1996), and its resolution is fundamental to the understanding of glacial-interglacial productivity fluctuations on a global scale.

On a longer time scale, the central feature of the history of late Neogene upwelling off Namibia is the Matuyama Opal Maximum (Wefer et al., 1998; see Fig. 1). It is due to the fact that diatom supply first increases when the planet cools and then decreases again during additional cooling. The Late Pliocene diatom maximum is centered around 2.6 to 2.0 Ma. This maximum was observed at all sites off southwestern Africa between 20°S and 30°S. The maximum has a diatom flora rich in Southern Ocean representatives as well as coastal upwelling components.

Before the time of the maximum, diatoms are rare until ca. 3.6 Ma. A rather sharp increase in both organic matter deposition and opal deposition occurs near 3 Ma, in association with a series of major cooling steps (Fig. 2a). As concerns organic matter, high production persists at least to 1 Ma, when there are large changes in variability, heralding subsequent pulsed production periods. From 3 Ma to 2 Ma, trends in the deposition of organic matter and opal run more or less parallel but after 2 Ma opal goes entirely out of phase with organic matter. Apparently, this is the point when silicate becomes limiting to opal production. Thus, the MOM conundrum is solved by linking planetary cooling to increased mixing and upwelling (ramping up to the MOM) and a general removal of silicate from the upper ocean through excess precipitation over global supply (ramping down from the MOM). In addition, a link to NADW production (which governs deepwater chemistry) is apparent (Fig. 2b). After the maximum, in the Pleistocene, the composition of the diatom flora points to increased importance of coastal upwelling toward the present, but is

Fig. 1. Upwelling record in Site 1084, as seen in diatom deposition. Note the maximum in the early Matuyama (Matuyama Opal Maximum, MOM).



accompanied by a general decrease in opal and diatom deposition. The increase in upwelling (not necessarily reflected in diatom productivity) is linked to increasing development of drought on adjacent land areas, and the evolution of the Namibian desert.

It appears that opal deposition off Namibia is not directly tied to glacial-interglacial fluctuations (as seen in the global δ^{18}O record), but that, instead, a strong deepwater link exists with increased NADW production (as seen in the deepwater δ^{13}C record) accounting for higher supply of silicate to the thermocline waters that feed the upwelling process. The hypothesis concerning the origin of the Namibia opal acme or MOM is fundamentally the same as the Walvis Hypothesis, stating that glacial conditions result in removal of silicate from the thermocline (and quite likely from the ocean as a whole, given enough time). The Namibia opal acme, and other opal maxima in the latest Neogene in other regions of the ocean, mark the interval when a cooling ocean selectively removes the abundant silicate inherited from a warm ocean. When the excess silicate is removed, the process ceases. According to the data gathered by Leg 175, major upwelling started in the late part of the late Miocene. Presumably this process contributed to the drawing down of carbon dioxide from the atmosphere, helping to prepare the way for northern hemisphere glaciation.

References

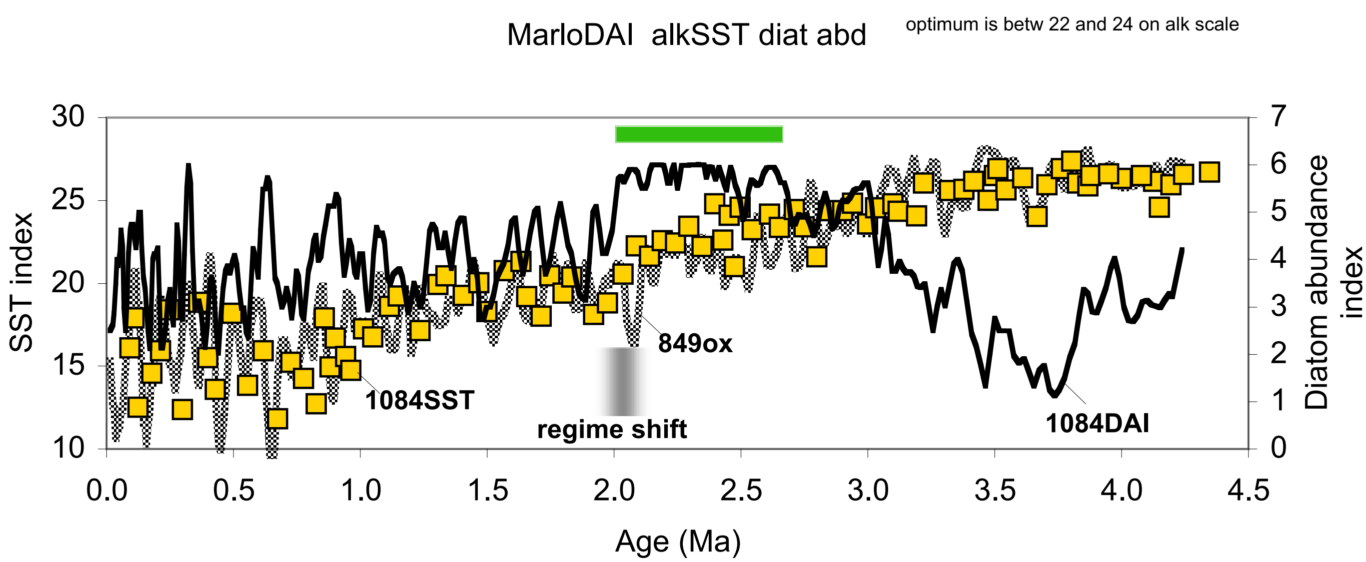
Berger, W.H., Wefer, G., 1996. Expeditions into the past: Paleoceanographic studies in the South Atlantic. In: Wefer, G., Berger, W.H., Siedler, G., Webb, D.J. (Eds.), The South Atlantic: Present and Past Circulation. Springer-Verlag, Berlin, Heidelberg, pp. 363-410.

Berger, W.H., Wefer, G., Richter, C., Lange, C.B., Giraudeau, J., Hermlin, O., and Shipboard Scientific Party, 1998. The Angola-Benguela upwelling system: paleoceanographic synthesis of shipboard results from Leg 175. In: Wefer, G., Berger, W.H., Richter, C. (Eds.) Proc ODP, Init. Repts., 175, 505-532.

Lange, C.B., Berger, W.H., Lin, H.-L., Wefer, G., and Shipboard Scientific Party Leg 175, 1999. The early Matuyama Diatom Maximum off SW Africa, Benguela Current System (ODP Leg 175). Mar. Geol. 161, 93-114.

Marlow, J.R., Lange, C.B., Wefer, G., and Rosell-Melé, A., 2000. Upwelling intensification as part of the Pliocene-Pleistocene climate transition. Science, 290, 2288-2291.

Wefer, G., Berger, W.H., Richter, C., and Shipboard Scientific Party, 1998. Initial Reports, Leg 175, Benguela Current. Proceedings of the Ocean Drilling Program, vol. 175 (2 pts.), Texas A & M, College Station.



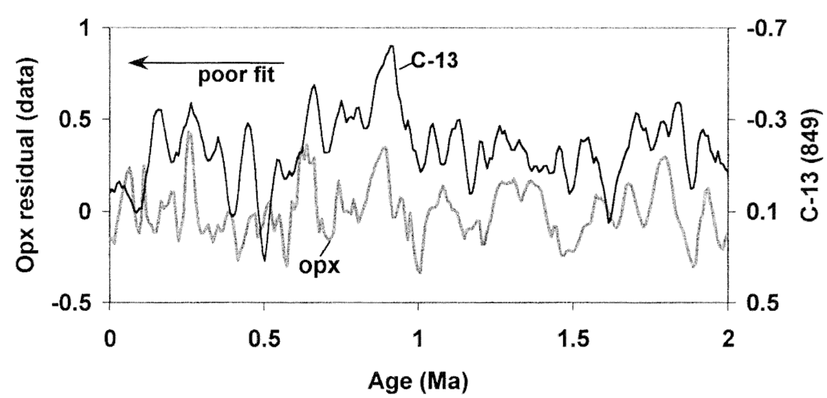


Fig. 2a (top): Surface temperature (UK37) and deep ocean Δ^{18}O are closely parallel; **Fig 2b (side)**: diatom deposition, to some degree, runs parallel to the age of Pacific deep water (as seen in the Δ^{13}C record), which n turn indicates a link to NADW production.