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Atmospheric re-organization during Marine Isotope Stage 3 over the North American continent: sedimentological and mineralogical evidence from the Gulf of Mexico

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A B S T R A C T

Mineralogical and sedimentological records from the Gulf of Mexico (GOM) reveal major changes in the terrigenous particles provenance during the Marine Isotopic Stage 3 (MIS3) that likely resulted from modifications of the environmental conditions – including glacial activity and precipitation distribution – over the North American continent. The southeastern margin of the Laurentide Ice Sheet (LIS) was active throughout the entire MIS3, whereas the southwestern margin contributed to short-term meltwater events only during late MIS3. Some of the major mineralogical changes cannot be attributed to glacial activity but rather result from the changes in precipitation distribution. Combining sedimentological records from the GOM with previously published climate-related archives from the North American continent allows the reconstruction of two main schematic patterns of moisture inflow and precipitation distribution that may have prevailed during MIS3. Meltwater discharges contribute to modifying the LIS configuration and the GOM hydrological properties, ultimately affecting large-scale oceanic circulation and may have influenced atmospheric re-organizations although the insolation variation rate appears to be the main driver of the system.

1. Introduction

Throughout the last decades, oxygen isotopic studies of Greenland ice cores (Dansgaard et al., 1982, 1993; Stuiver and Grootes, 2000) revealed important and rapid climatic fluctuations over the North Atlantic during the Marine Isotope Stage 3 (MIS3: 21–55 ka BP). Temperatures of Greenland air masses rose abruptly at the beginning of an interstadial ($\delta^{18}O$ maxima) and then decreased slowly to a minimum: a stadial ($\delta^{18}O$ minima). These millennial-scale climatic oscillations were called Dansgaard–Oeschger cycles. They could be applied to longer-duration cooling cycles called Bond cycles (Bond et al., 1993) with termination often characterized by the collapse of northern hemispheric ice sheets, generating large discharges of icebergs in the North Atlantic known as Heinrich events (Heinrich, 1988; Broecker et al., 1992), followed by a sudden shift from cold to warm temperatures.

Impacts of these climatic fluctuations have been identified in both marine and continental sites all over the world (Voelker et al., 2002). Although some regions may experience warmer and wetter conditions during interstadials compared with stadials (Clement and Peterson, 2008), temperatures as well as moisture availability and distribution displayed a pronounced regional heterogeneity. In the Gulf of Mexico (GOM), climatic conditions depend on the respective positions of the Inter-Tropical Convergence Zone, Jet-Stream, Bermuda High and subtropical gyre (Forman et al., 1995; Liu and Fearn, 2000; Harrison et al., 2003; Knox, 2003). Grimm et al. (2006) suggested that climatic conditions over Florida were warm and wet during the coldest periods of Bond cycles, while cold and dry conditions were predominant in interior North America (Wang et al., 2003; Jacobs et al., 2007; Jiménez-Moreno et al., 2010). The conclusions of Grimm et al. (2006) are consistent with the hypothesis that decreased North Atlantic Deep Water formation, caused by the calving of icebergs into the North Atlantic during Heinrich events (Ganopolski and Rahmstorf, 2001), reduced the transport of heat from the GOM to northern high latitudes, leading to the warming of Florida.

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Hill et al. (2006) reconstructed the oxygen isotopic composition of the northern GOM seawater during the MIS3 and demonstrated that meltwater pulses from the Laurentide Ice Sheet (LIS) occurred when temperatures over Greenland were cold, in contradiction with the previous theory which stipulated that "Dansgaard–Oeschger" warming corresponds to freshwater routing to the GOM (Clark et al., 2001). Understanding climatic and environmental conditions in the North America/GOM system during the MIS3 appears to be all the more difficult since continental evidence for the position of the LIS are very scarce due to glacial re-advance and erosion during the Last Glacial Maximum (Dyke et al., 2002).

Since the clay mineralogy of the potential main source areas in and around the Mississippi River watershed have been determined (Sionneau et al., 2008; Fig. 1a), clay mineral records of the northern continental slope of the GOM have provided valuable information on the provenance of freshwater inputs in the GOM during the last deglaciation (Montero-Serrano et al., 2009; Sionneau et al., 2010) and allowed reconstructions of atmospheric circulation shape and humidity transfer patterns over North America during the Holocene and Last Interglacial (Montero-Serrano et al., 2010, 2011).

In this article, we present sedimentological and mineralogical records of terrigenous sediments deposited during the MIS3 in the Orca Basin (26°56.77′N, 91°20.74′W; northern GOM), which is considered to be an ideal site for high-resolution paleoclimatic studies (Flower et al., 2004; Hill et al., 2006; Sionneau et al., 2010), in order to determine a regional paleoatmospheric circulation model that could explain results of previous studies (Grimm et al., 2006; Hill et al., 2006).

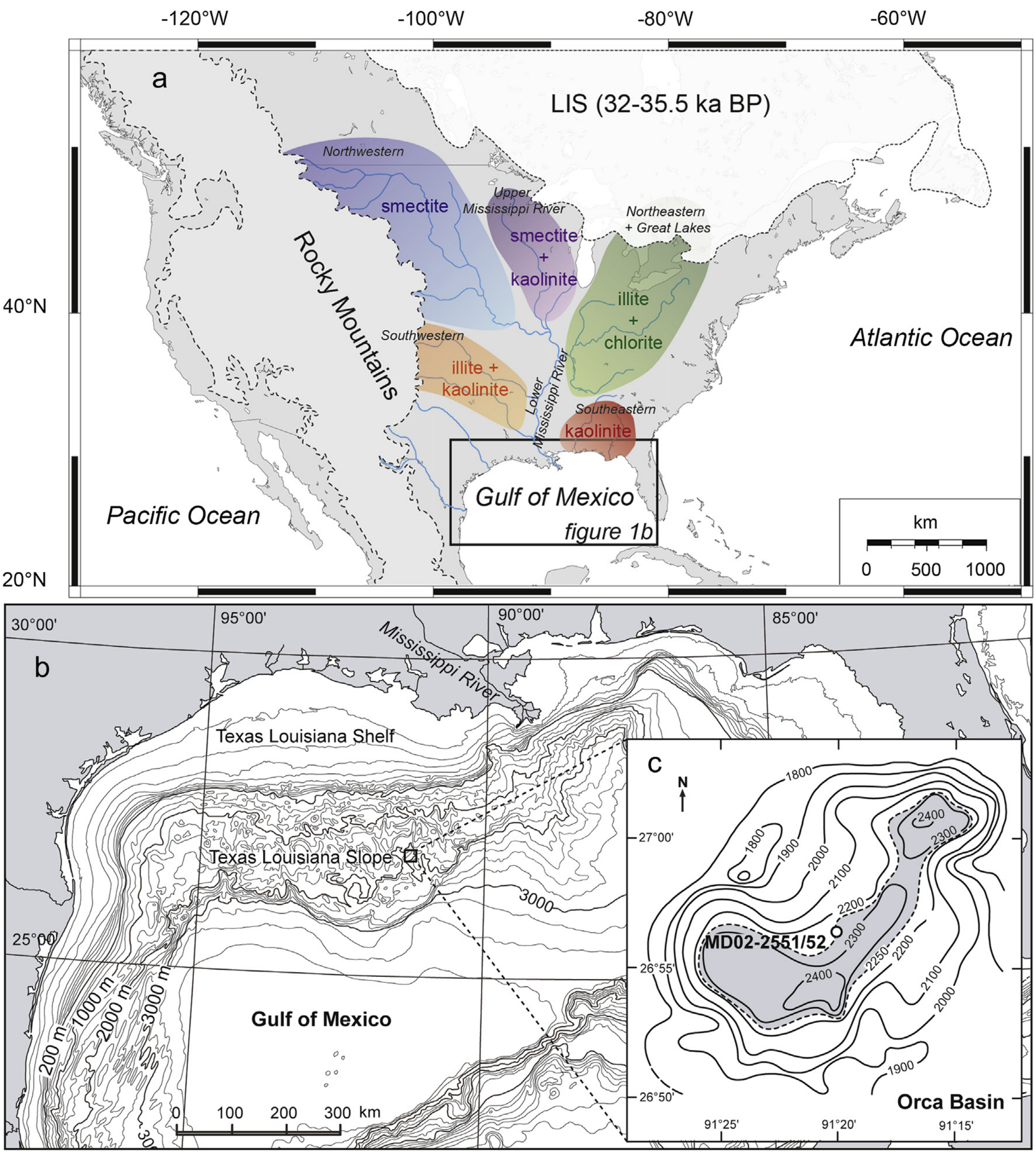

Fig. 1. Location of (a) the main mineralogical province in and around the Mississippi River watershed and limit of the Laurentide Ice Sheet (LIS) during MIS3 (Dyke et al., 2002); (b) the Orca Basin on the Louisiana continental slope; (c) the two cores reported in this study.