Marine Minerals as Tracers of Detrital Provenance and Transport Agent

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INTRODUCTION

In marine sediments mineral assemblages may be used to determine the provenance of detrital inputs. In particular clay minerals have been used as a tracer of provenance and transport mechanisms (e.g., Biscaye, 1965; see Fagel, 2007 for a review – Fig. 1). Detrital clay minerals are formed in soils by physical or chemical weathering. Eroded by river, wind or ice they are carried into shallow and deep water masses of the adjacent seas. Their modern distribution pattern on the sea floor provides information on their dispersion by atmospheric or oceanic currents (Gingele et al. 2001a, b).

A prerequisite for the reconstruction of transport pathways is the identification of specific source areas on the adjacent continent (Hillenbrand and Ehrmann 2005). Once the relationship between a specific clay mineral assemblage, a given source and a transport agent is established, variations of this assemblage in down-core profiles may be used to detect paleocurrent changes (Diekmann et al. 1996, Gingele et al. 1999, Gingele et al. 2004). However the interpretation of down-core changes in mineral assemblages depends on available information on the modern distribution and sources.

The use of clay proxies to reconstruct transport pathways is most efficient in areas characterised by distinct mineralogical provinces (e.g., Gingele et al. 2001a; Moriarty 1977; Fagel et al., 1992; Liu et al. 2003; Venkatarathnan and Ryan 1971). For instance the alternation of two distinct clay mineral assemblages as expressed by their clay mineral ratios has been used to trace seasonal monsoon circulation in the South China Sea (Liu et al. 2003) and the Arabian Sea (Fagel et al. 1992).

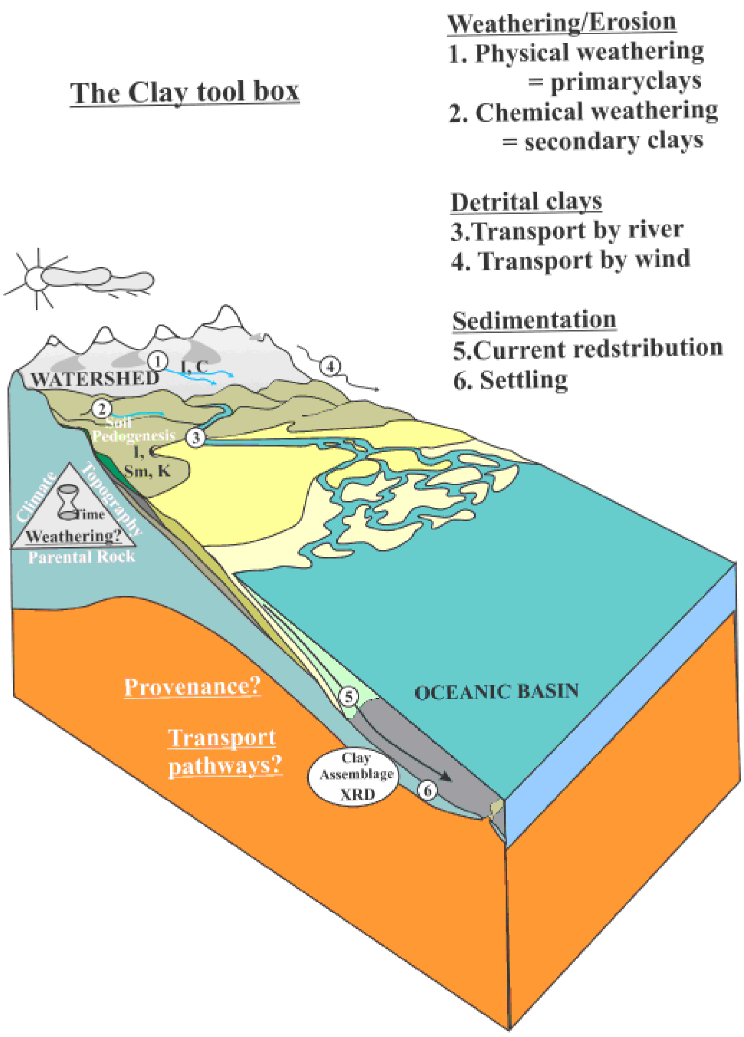

fig. 1. The clay tool box (modified from Fagel 2007)

Likely Petschick et al. (1996) has used the clay mineral assemblages in surface ocean sediments to outline the extent and propagation of North Atlantic Deep water into the South Atlantic.

However it may be difficult to assign one main source area to a specific clay mineral assemblage since several sources and transport processes may be involved. In that case the distribution pattern of clay minerals is not sufficient to define their provenance (Carson and Arcaro 1983). The radiogenic isotopic signature of the detrital sedimentary fraction may provide additional

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constraints to identify the sources and trace sediment provenance (e.g., Grousset et al. 1988, Fagel et al. 1999, Walter et al. 2000, Rutberg et al. 2005, Fagel and Mattielli, 2011).

In this study we will combine mineral and geochemical proxies to trace detrital source and to identify the main transport agent in two oceanic settings, the North Atlantic and the Central Arctic. The variation in down-core assemblage and composition will be further used to estimate the temporal changes in detrital particle supplies. We will emphasize how this multiproxy approach is powerful to provide paleoceanographical implications, especially in complex environments.

CASE STUDIES

Labrador Sea and North Atlantic Basins

We have analysed the mineralogy and Nd and Pb isotope signatures of the clay-size fraction of several deep sediment cores collected in Labrador Sea and adjacent basins (fig. 2).

The cores are located along gyres of the North Atlantic Deep Water (NADW) components.

Modern distribution of minerals in bottom sediment evidences a relationship between the clay assemblage and the current pathway.

An enrichment in smectite was systematicaly observed along the path of the Western Boundary Undercurrent (WBUC), i.e. the main current that carries the NADW masses in the North Atlantic basins.

Based on this calibration down-core changes in clay composition and their isotope signature have been therefore use to monitor deep current variability through the Holocene. Evolution of smectite/illite ratios and clay fluxes evidence enhanced supplies by WBUC into the Labrador Sea. Changes in the Nd and Pb signatures of clay-size fraction of Holocene sediments provide constraints on the different sources areas that supplied the fine clayey particles into the Labrador Sea.

Based on sedimentary mixings, our isotopic dataset emphasizes significant shifts in the radiogenic composition of the sedimentary fractions are evidenced during the last 6 kyr, suggesting a main change in the relative contribution of the two major components of NADW, i.e. the North East Atlantic Deep water (NEADW) and the Danmark Strait Overflow Water (DSOW) during the Holocene.

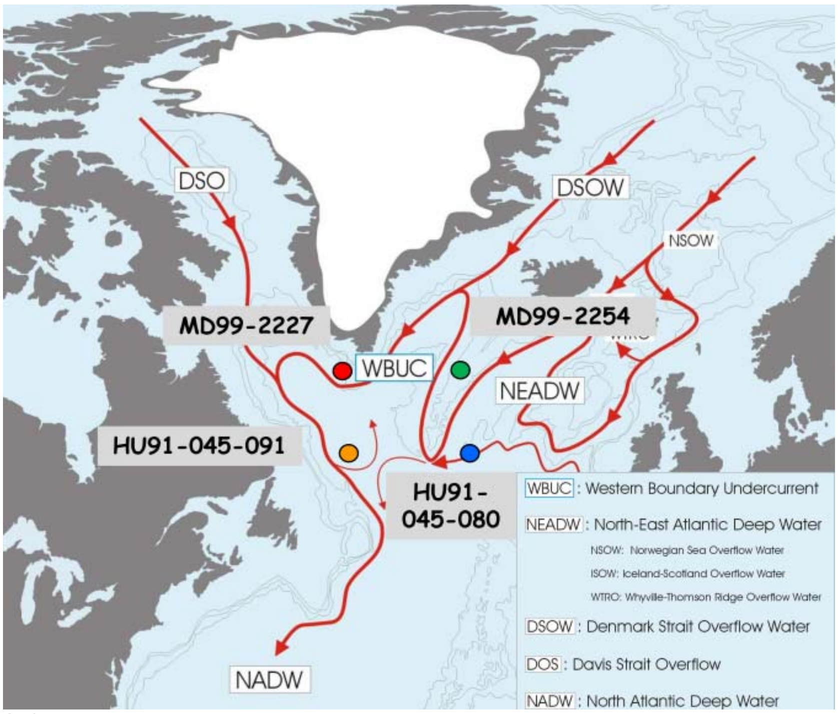

fig 2. Location of sedimentary cores in North Atlantic basins and modern pathway of deep water masses. Map modified from Fagel et al., 2004.

Central Arctic Ocean

For Central Arctic Ocean, we focus our provenance discussion on the relative contribution of surface currents since in deep Arctic sea-ice is probably the most important sediment carrier, especially for clays and silts (e.g., Eicken et al., 2005). For this study we identify the mineralogical and geochemical (trace and Nd and Pb isotope) signature of a sediment core collected on the Mendeleev Ridge, in Central Arctic Ocean (Fig. 3).

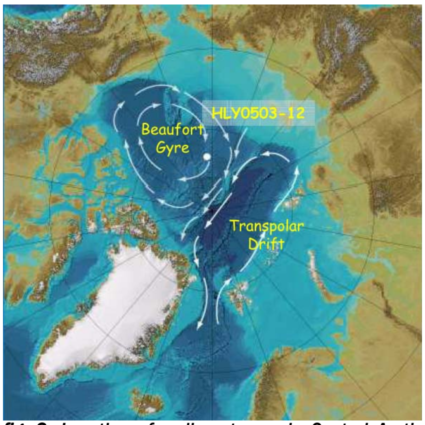

fig. 3. Location of sediment core in Central Arctic and distribution of main surface currents (Darby et al., 2005).

According to ^{230}Th and ^{210}Pb stratigraphy, the study interval covers the last 300 kyr. The mineralogy of the silt and sand fractions display pronounced changes in the relative contribution of carbonates (calcite and dolomite) in regard with silicates (mainly quartz and feldspars). Carbonate-rich layers match with interglacial stages.

The clay mineralogy of the fine fraction (< 20 µm) is dominated by illite (60-70%) with no major down-core variation, except some enrichment in kaolinite.

The clay mineral distribution alone does not bring any pertinent information on provenance. However our Nd and Pb isotope data measured on the fine detrital fraction display significant changes over glacial/interglacial periods. Based on literature review the various geological terranes outcropping along the Arctic margins were characterised by their radiogenic fingerprints.

Since the main sources were identified we interpret the glacial/interglacial variability by changes in their relative contribution to particle supplies on the

Mendeleeiv Ridge. During interglacials the site receives material from erosion from the Canadian and American margins whereas during glacials the particles are mainly derived from the Eurasian margin. We attribute the contrasted sedimentary supplies to changes in the position between the Beaufort Gyre and the Transpolar Drift, i.e. the two main Arctic surface currents. Our bulk mineralogical and geochemical data confirm that the sediment provenances in Central Arctic remain close to the Present conditions during the earlier interglacials. In contrast the limit between the Beaufort Gyre and the Transpolar Drift may be different during glacial.

CONCLUSION

In marine sediments clay minerals are mainly detrital. They usually derive from several source areas and may be supplied by different transport agents. We propose to combine mineralogical and geochemical proxies to trace detrital provenance and provide valuable information on paleocurrents.

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