Anthropogenic CO_2 signals recorded in stable isotopes of planktonic foraminifera from the northern Gulf of Aqaba, Jordan#

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Published in the International Journal of Earth Sciences (2004) 93: 1066-1076.
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Introduction

Over the last 1000 years, but before the industrial revolution, CO_2 concentration was relatively stable, fluctuating by about ±10 ppm at around 280 ppm (Friedli et al. 1986; IPCC 1996). During the industrial period, the increased use of fossil fuel and deforestation led to a rise of this concentration, exceeding 369 ppm in 2000 (Keeling and Whorf 2001).
Since anthropogenic CO_2 has a highly negative carbon-isotope composition, the $\delta^{13}C$ of the atmosphere has decreased in the last two centuries by about 1.43‰ as deduced from the air bubbles trapped in ice cores (Francey et al. 1999). This decrease is imprinted on the $\delta^{13}C$ signal of the dissolved inorganic carbon ($\delta^{13}C_{DIC}$) in the ocean. Long-term variations in seawater $\delta^{13}C_{DIC}$ have been estimated from shallow-dwelling corals, sponges and planktonic foraminifera (e.g., Nozaki et al. 1978; Böhm et al. 1996; Beveridge and Shackleton 1994).

Present study

We have investigated the variations in the stable carbon isotope composition of seawater ($\delta^{13}C_{DIC}$) as recorded by the planktonic foraminifera *G. sacculifer* and *G. ruber* and the sedimentary organic matter from the northern Gulf of Aqaba during the last 1000 years (Fig.1). Sedimentation rates in the area are high (40-65 cm/kyr) providing a high temporal sampling resolution of about 10 years (Fig.2)

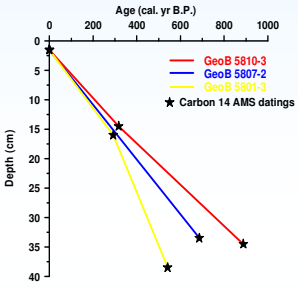

Figure 2. Age-depth relation of the investigated multicores from the northern Gulf of Aqaba, Stars indicate the calibrated ^{14}C AMS dating positions

Results

Figure 3 shows the $\delta^{13}C$ record of the planktonic foraminifera *G. sacculifer* and *G. ruber* from the three multicores. These records display similar trends. The values before the 1750's have a fairly uniform $\delta^{13}C$ pattern, ranging between 1.28 and 1.35‰ with an average of 1.31‰. An initially slow decline begins in the middle 1700's, from ca. 1.31‰ in the sediments older than A.D. 1750 to about 0.68‰ near the top of the cores.

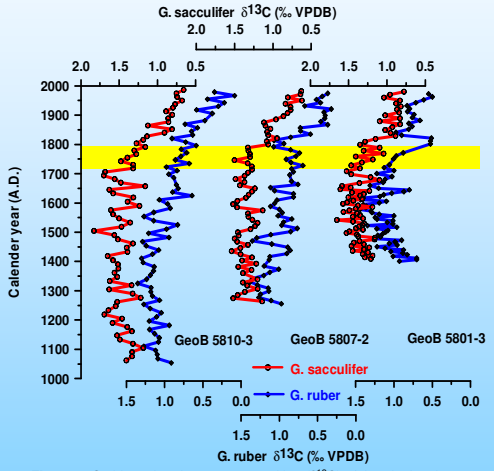

Figure 3. Stable carbon isotope composition ($\delta^{13}C$) of the planktonic foraminifera *G. sacculifer* and *G. ruber*, over the last 1000 years from three multicores collected in the northern Gulf of Aqaba, Red Sea. The yellow bar indicates the transition zone between the pre-industrial and industrial periods

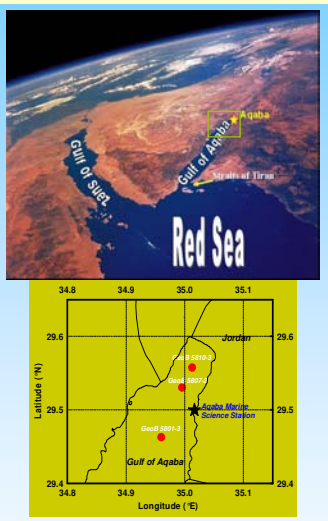

Figure 1. Map of the northern Gulf of Aqaba, Red Sea, showing the location of the multicores (GeoB 5810-3, GeoB 5807-2 and GeoB 5801-3) investigated in this study

Discussion

Results from this study show a decline in the $\delta^{13}C$ of planktonic foraminifera (*G. sacculifer*) of roughly 0.63‰ from approximately the beginning of the industrial revolution (A.D. 1750). The $\delta^{13}C$ record of the same species in a gravity core from the same area (GeoB 5810-2) shows a consistent $\delta^{13}C$ pattern over the last 3000 years BP (mid-late Holocene). The values are similar to their counterparts from the lower parts of the multicores older than A.D. 1750.
If we assume that the intraspecific range of foraminiferal $\delta^{13}C$ values attributed to vital effect remained rather constant since the late Holocene, then changes in the $\delta^{13}C$ composition of the foraminiferal shells should be still proportional to changes in the carbon-isotope composition of DIC in seawater (Beveridge and Shackleton 1994). Therefore, the 0.63‰ decrease during the last two centuries can be partly attributed to the invasion of fossil fuel CO_2 into the surface waters, which caused a decrease in the $\delta^{13}C_{DIC}$.

Seawater $\delta^{13}C_{DIC}$

Direct measurements of seawater in the northern Gulf of Aqaba show that $\delta^{13}C$ of the dissolved inorganic carbon (DIC) has decreased by about 0.44‰ during the period 1979-2000 (Fig. 4). The average annual decrease is 0.021‰, which is similar to values measured in the Pacific and Indian Oceans (Quay *et al.* 1992; Sonnerup *et al.* 2000).

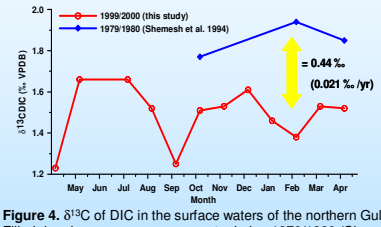

Figure 4. $\delta^{13}C$ of DIC in the surface waters of the northern Gulf of Aqaba. Filled rhombuses are measurements during 1979/1980 (Shemesh et al. 1994); open circles are values during 1999/2000 (This study). The offset between the two records seems to represent the decrease in $\delta^{13}C_{DIC}$ of seawater during the past 20 years due to uptake of anthropogenic CO_2 in surface waters

Sedimentary organic carbon

The organic carbon in our samples is contributed predominantly from primary producers, and the content increase near the tops of the cores is not related to an increase in local productivity but can be attributed to preservation effects (Fig. 5).
The quite uniform C/N values (~9) throughout the cores and the lack of a relationship between $\delta^{13}C_{org}$ and the C/N ratio, as well as the consistent carbonate content (Fig. 5), all suggest comparatively low terrigenous organic matter contribution to the sediments.

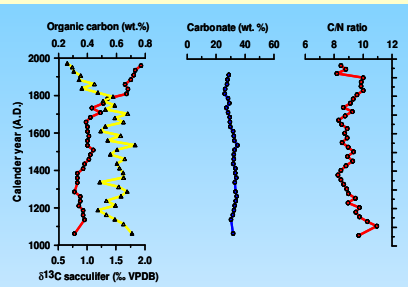

Figure 5. Variations of organic carbon, $\delta^{13}C$ of the planktonic foraminifera (*G. sacculifer),* carbonate content and C/N ratio in the multicore GeoB 5810-3 from the northern Gulf of Aqaba. The organic carbon increase in the upper part of the core is most likely due to preservation effect

$\delta^{13}C$ of organic matter ($\delta^{13}C_{org}$)

Results of $\delta^{13}C_{org}$ from the same multicores show a trend toward lighter values during the last 200 years (–19.45 to –21.2‰), and the variation of about 1.82‰ closely follows that of the $\delta^{13}C$ of the planktonic foraminifera (Fig. 6). The difference in stable carbon-isotope composition ($\delta^{13}C_{org}$) between modern phytoplankton and underlying surface sediments older than 200 years was explained by the penetration of ocean surface waters by isotopically light carbon (e.g., Bentaleb and Fontugne 1996; Fischer et al. 1998; Wolf-Gladrow 1999; Rosenthal et al. 2000). This supports our interpretation obtained from the planktonic foraminiferal $\delta^{13}C$, and indicate that the CO_2 variations are probably the reason for isotopic variations in the $\delta^{13}C_{org}$.

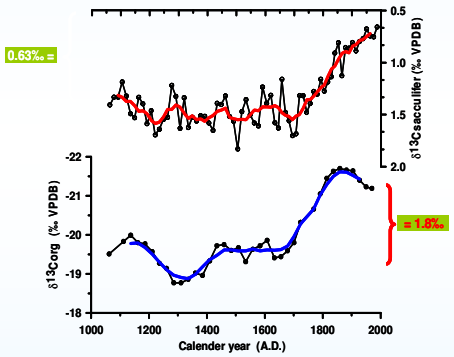

Figure 6. Stable carbon isotopic record of the planktonic foraminifera *G. sacculifer* and the sedimentary organic matter ($\delta^{13}C_{org}$), during the last 1000 years from the multicore GeoB 5810-3 from the northern Gulf of Aqaba. The thick lines represent a five-point running average

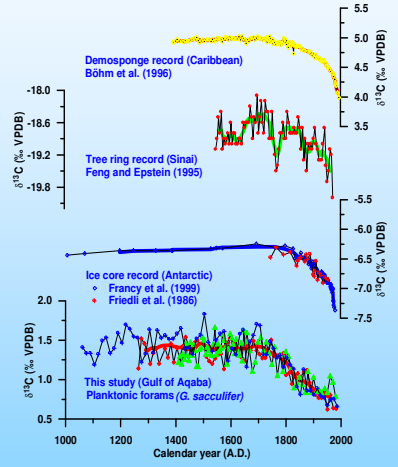

Figure 7. Comparison between $\delta^{13}C$ stack record (planktonic foraminifera *G. sacculifer*) from the three multicores with other published records from different proxies, showing the decrease in $\delta^{13}C$ of the atmosphere (tree ring and ice core records) and surface water $\delta^{13}C_{DIC}$ (sclerosponge and foraminifera records) over the last two centuries due to the increase of the anthropogenic CO_2 input into the atmosphere

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This work was partly supported by the "Red Sea Program" (RSP II), of the "Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie" (BMBF), and a grant from the University of Bremen.