GEOLOGIC NOTE

# Climatic significance of Holocene beachrock sites along shorelines of the Red Sea

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## ABSTRACT

Seaward-dipping prograding successions of beachrock of the shoreline of the rift valley of the Gulf of Aqaba, a steep-sided tectonic valley that forms the northern segment of the Red Sea, reflect progressive stages of cementation, which unravel a geologic history of the shoreline. The oxygen isotopic composition of Gulf of Aqaba beachrock, recorded by carbonate cement, reflects a temperature decrease of ambient seawater for approximately half of the Holocene.

The computed temperature excursion of the Red Sea beachrock cement implies a temperature decrease between the ages 7.07 ± 0.380 and 2.62 ± 0.23 ka, an interval of approximately 4500 yr, during which the average Red Sea seawater temperature fell from 33 to 17°C. This discovery is at variance with the climate-change debate that involves increasing temperatures.

## INTRODUCTION

The world literature, including the daily paper delivered to our front door, is full of controversy over climate change. The debate has focused on human involvement, such as "nations seek to curb the world's top polluter" (Hanley, 2004, p. A-18). In these arguments, the debate whether humanity is changing the Earth's climate is an example of an argument "in which science plays a secondary role to social policy and international economics" (Gerhard, 2004, p. 1212). The purpose of this article, however, is to provide an example of past climate changes, and the influence of natural processes in climate changes. Many nongeologists believe that "humans



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Friedman began his career as a geochemist in the Appalachians and Canadian Shield. He switched to soft-rock geology and became director of sedimentology for Amoco Research, Tulsa, Oklahoma. Since returning to academia, he has worked with his graduate students on carbonate deposits, regional stratigraphy, and environmental geology. He has studied modern facies in the Bahamas, the Red Sea, the Dead Sea, and the Mediterranean.

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**Table 1.** Radiocarbon Age Determinations and Stable Isotopes $\delta^{13}C_{PDB}$ $\delta^{18}O_{PDB}$ of Beachrock Samples from Four Levels of a Prograding Sequence, Northernmost West Shore of Gulf of Aqaba, Red Sea

| | Radiocarbon Ages $^{14}$C ka ($^{13}$C Corrected) | | | |
|---|---|---|---|---|
| | Elat 1-99<br>2.62 ± 0.23 $^{14}$C ka | Elat 2-99<br>3.57 ± 0.17 $^{14}$C ka | Elat 3-99<br>6.22 ± 0.28 $^{14}$C ka | Elat 4-99<br>7.07 ± 0.38 $^{14}$C ka |
| $\delta^{13}C_{PDB}$ | +3.4,* +3.2‰* | +2.8‰ | +2.3‰ | +1.1‰ |
| $\delta^{18}O_{PDB}$ | −0.1,* −0.2‰* | −0.7‰ | −1.9‰ | −3.5‰ |

*Duplicate analyses on separate aliquots of the original sample.

are causing climate change, based on the theory that increasing greenhouse gases in the atmosphere . . . contribute to climate change . . . '' (Gerhard, 2004, p. 1212). Yet there is overwhelming geologic evidence that natural variability in the Earth's climate greatly exceeds human-induced effects (Lamb, 1995; Bluemle et al., 2001; Gerhard et al., 2001).

This article takes us back to a geologic time interval between about 2.5 and about 7 ka to the Gulf of Aqaba, Red Sea, to a time and place before humans affected their environment. As Gerhard (2004, p. 1211) states, ''natural phenomena . . . have driven global climate change for eons.''

During the past 7000 yr, the general tendency (in the Red Sea area) has been toward global cooling. As W. M. Kazmann (2004, personal communication) notes, ''these data contradict the short term (100 yr) climate models in both magnitude of temperature change and direction.'' Furthermore, the deduced temperature change occurred during a time of relatively stable $CO_2$ concentration, implying that $CO_2$ was not driving the global temperature change (Jenkins, 2001, p. 1211).

This article presents data about past climate change. It does not address the current climate-change debate. It discusses the ignored science in the current debate.

## INFORMATION FROM OXYGEN ISOTOPES

Table 1 shows the oxygen- and radiocarbon-isotopic record for the Red Sea prograding beachrock ledges studied along the shore of the Gulf of Aqaba.

The isotope ratios of beachrock cements were precipitated in equilibrium with the surrounding seawater. For this reason, the oxygen isotopic composition of beachrock may be used in climate reconstructions. Depending on the climatic setting, beachrock cement $\delta^{18}$O primarily reflects sea-surface temperature, but salinity may also affect it. Where absolute temperature reconstruction may be uncertain, relative temperature variations can be determined. Sea-surface salinity affects the temperature signal, but relative climatic changes may be resolved. One of the purposes of this study has been to compute the paleotemperature at the time of precipitation of the interstitial carbonate cement. The $\delta^{18}$O value of $CaCO_3$ is related to the $\delta^{18}$O of seawater ($\delta_\omega$) and the temperature ($t$) in degrees Celsius by the equation

$$t(^\circ C) = 16.9 - 4.2(\delta_c - \delta_\omega) + 0.13(\delta_c - \delta_\omega)^2$$

where $\delta_c$ is the $\delta^{18}$O value of $CaCO_3$ and $\delta_\omega$ is related to the $\delta^{18}$O of seawater (Epstein et al., 1953; Arthur et al., 1983). The oxygen isotope composition of seawater is variable, depending on the rate of evaporation from the surface, and because of possible mixing with freshwater rivers or ground-water discharge. In the Gulf of Aqaba, increased salinity introduces a slight complication. In this study, I have computed the temperatures from the above equation, but not knowing the $\delta_\omega$ of the original water, I have set it at 0°C and used modern water samples from the shallow-water setting to calibrate for the unknown $\delta_\omega$. The mean annual sea-surface temperature is 24°C (Friedman, 1968, p. 900, figure 5, quoting data from Ashbell, 1963).

Following the equation and the isotopic temperature scale of Epstein et al. (1953) (Arthur et al., 1983), Figure 1 presents the computed mean sea-surface paleotemperatures and the adjusted temperatures obtained by relating modern average sea-surface temperature (24°C) to computed temperature ($t$°C) for prograding beachrock samples from four levels of a beachrock sequence of the Red Sea. For the middle Holocene centuries between 7.07 ± 0.38 and 2.62 ± 0.23 $^{14}$C ka, an interval of approximately 4500 yr, a decrease of wide-ranging sea-surface temperature is indicated (Figure 1). The interval 6–5 ka corresponds to the Flandrian or Atlantic period, when climate in many places was warmer and more humid, and sea

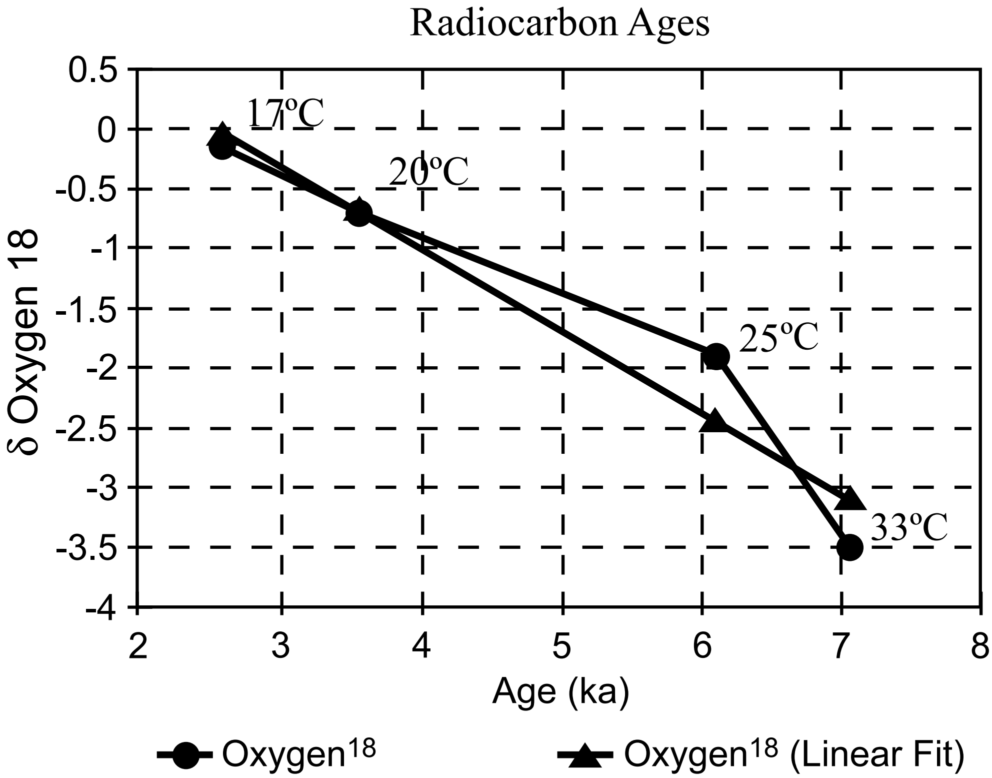


**Figure 1.** Plot of oxygen-isotopic ratios against radiocarbon ages of interparticle carbonate cement for Gulf of Aqaba, Red Sea, prograding beachrock sequence. Plot with elliptical (rounded) pattern provides data points, and triangular pattern represents linear fit ($r^2 = 0.930$). Temperatures are computed according to the equation of Epstein et al. (1953).

levels in most oceans was +2 m (+6.6 ft). Ritchie et al., (1985) suggested a humid tropical climate with annual monsoonal rainfall of at least 400 mm (15 in.) during the middle Holocene based on sediment and pollen evidence from the eastern Sahara. Stable isotopic composition of middle Holocene fossil *Porites* spp. corals from the northern Gulf of Aqaba revealed heavier values compared with modern corals, meaning enrichment in $\delta^{18}O$ and cooler temperature (Moustafa et al., 2000). Mesopelagic pteropoda suggest an arid continental climate in the Red Sea region for the past 4000–5000 yr and a humid climate for the preceding 5000 yr (Almogi-Labin et al., 1991). Figure 1 indicates the beachrock data of the Red Sea, showing progressive cooling in the Holocene and suggesting a major cooling event. Oxygen isotopes confirm that the climate in Britain 5000 yr ago was about 2°C warmer than the area today (Evans et al., 2001). This conclusion contradicts the general impression gained from reading news reports, which project a warming trend for the recent past (last 100 yr).

**Table 2.** Computed Mean Sea-Surface Temperatures for Prograding Beachrock Samples from Four Levels of a Sequence, Northernmost West Shore of Gulf of Aqaba, Red Sea

| Sample | Radiocarbon Date ($^{14}C$ ka) | Computed Temperature (*t* in °C)* |
|---|---|---|
| Elat 1 | 2.62 ± 0.23 | 17 |
| Elat 2 | 3.573 ± 0.170 | 20 |
| Elat 3 | 6.22 ± 0.28 | 25 |
| Elat 4 | 7.07 ± 0.38 | 33 |

*Paleotemperature computed according to the equation of Epstein et al. (1953).

The implied temperature variation (16°C warmer at 7.7 ka) may indicate dramatic change in climate. Bard (2002) cites this temperature swing at 8.2 ka. He claims that unstable models of climate swings are "in fact, very hard to answer" (Bard, 2002, p. 32). "The climate system is complex because it is made up of several components (such as the atmosphere, oceans, and ice sheets), each of which has its own response times and thermodynamic properties" (Bard, 2002, p. 32).

The computed sea-surface temperatures cited in this note (Table 2; Figure 1) were determined to indicate a trend of temperature changes, not specific paleotemperatures. The assumption that the present temperature of 17°C was identical at 2.62 ka is not necessarily valid; the purpose of the computations is to imply a direction of change during an approximately 4500-yr Holocene interval.

In conclusion, the oxygen isotopic composition of beachrock cement reflects temperature decrease of ambient seawater for approximately half of the Holocene. This discovery of cooling is at variance with the climate-change debate.

## REFERENCES CITED


Almogi-Labin, A., C. Hemleben, D. Meischner, and H. Erlenkeuser, 1991, Paleoenvironmental events during the last 13,000 years in the central Red Sea as recorded by pteropoda: Paleoceanography, v. 6, p. 83–98.

Arthur, M., T. F. Anderson, I. Kaplan, J. Beizer, and L. S. Land, 1983, SEPM Short Course 10, 385 p.

Ashbell, D., 1963, Climate conditions of Elath, *in* ''Elath'': Israel Exploration Society, 18th Archeological Convention, Jerusalem, Israel, p. 242–256.

Bard, E., 2002, Climate shock: Abrupt changes over millennial time scales: Physics Today, v. 55, p. 32–38.

Bluemle, J. P., J. M. Sable, and W. Karlén, 2001, Rate and magnitude of past global climate changes, *in* L. C. Gerhard, W. E. Harrison, and B. M. Hanson, eds., Geological perspectives of global climate change: AAPG Studies in Geology 47, p. 193–211.

Epstein, S., R. Buchsbaum, H. A. Lowenstam, and H. C. Urey, 1953, Revised carbonate-water isotopic temperature scale: Bulletin of the Geological Society of America, v. 64, p. 1315–1326.

Evans, M. J., L. A. Derry, S. P. Anderson, and C. France-Landord, 2001, Hydrothermal source of radiogenic Sr to Himalayan rivers: Geology, v. 29, p. 803–806.

Friedman, G. M., 1968, Geology and geochemistry of reefs, carbonate sediments, and waters, Gulf of Aqaba (Elat), Red Sea: Journal of Sedimentary Petrology, v. 38, p. 895–919.

Gerhard, L. C., 2004, Climate change: Conflict of observational science, theory, and politics: AAPG Bulletin, v. 88, p. 1211–1220.

Gerhard, L. C., W. E. Harrison, and B. M. Hanson, eds., 2001, Geological perspectives of global climate change: AAPG Studies in Geology 47, 372 p.

Hanley, C. J., 2004, Approaches debated at climate conference: Times Union, Albany, New York, December 14, 2004, p. A-18.

Jenkins, D. A. L., 2001, Potential impact and effects of climate change, *in* L. C. Gerhard, W. E. Harrison, and B. M. Hanson, eds., Geological perspectives of global climate change: AAPG Studies in Geology 47, p. 337–359.

Lamb, H. H., 1995, Climate, history and the modern world, 2d ed.: New York, Routledge, 433 p.

Moustafa, Y. A., J. Pätzold, Y. Loya, and G. Wefer, 2000, Mid-Holocene stable record of corals from the northern Red Sea: International Journal of Earth Sciences, v. 88, p. 742–751.

Ritchie, J. C., C. H. Eyles, and C. V. Haynes, 1985, Sediment and pollen evidence for an early to mid-Holocene humid period in the eastern Sahara: Nature, v. 314, p. 352–355.