There are two extraordinary and detailed long term records of the Earth’s climate:

[**Deep Sea Cores**](file:///J:\NEOTOMA\NeotomaGLOSSARY.docx)**:** Sediment accumulates on the ocean’s floors through time. Cores of ocean sediments throughout the world have yielded considerable information about the earth’s past climate over the last 2.7 million years. Chemical analysis of **foraminifera** (unicellular animals with carbonate shells) provides a record of sea surface temperature and ice volume, and sediment analysis records changes in the amount material eroded from the earth’s surface and frequency of icebergs through time. Also, variation in species of forams in a core reflects changes in the oceans salinity and currents.

**Figure 1**

**Deep sea cores recovered via ocean going drill rigs, like the *Poides Resolutin*, record changes in oceanic conditions over time.**

**One such change is in the number of *foraminifera*.**

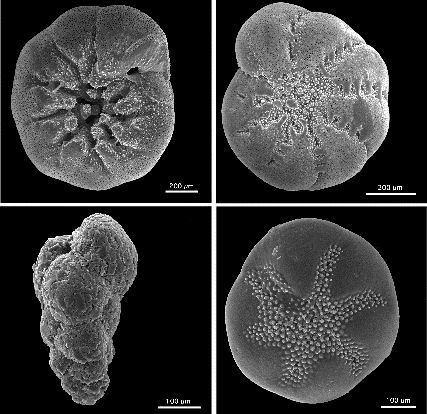
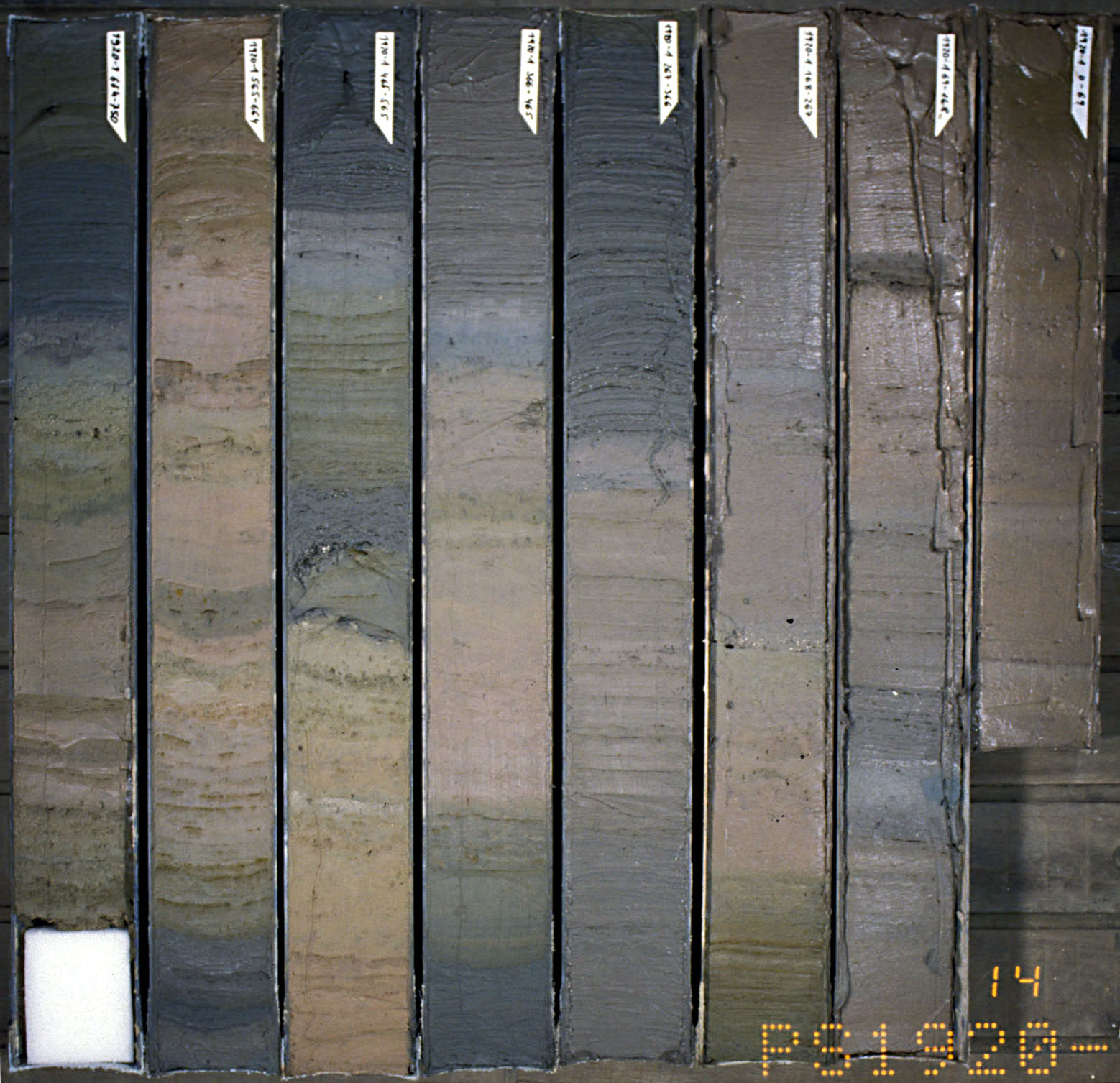
**The lighter colored bands represent times of deposition when forams were very abundant, while darker bands are times when fewer forams lived off the coast of Greenland.**

**Like all animals, different foraminifera have specific environmental requirements, some requiring colder, less saline water, while others prefer saltier, warm water.**

**Figure 2**

**The global benthic δO18 record from 57 deep sea cores. The greater the δO18 values the more water was locked in glaciers, and thus, the colder the earth’s climate.**

**Note the “saw-tooth” pattern in which climate became gradually colder and then rapidly warmed several times over the last 2.7 million years.**

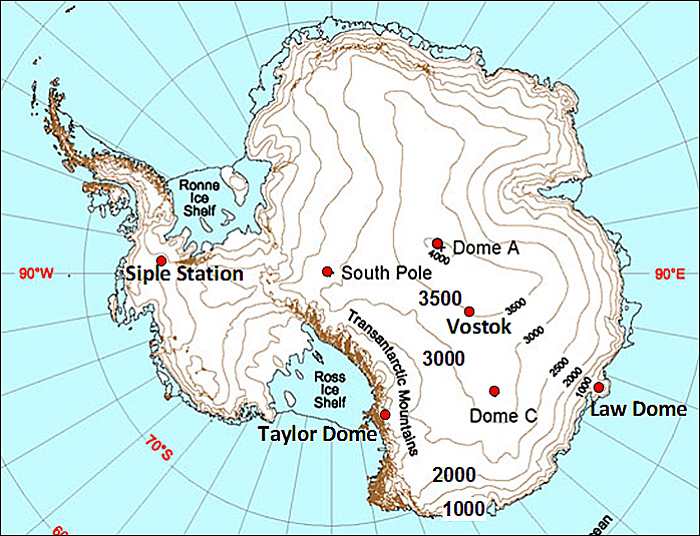
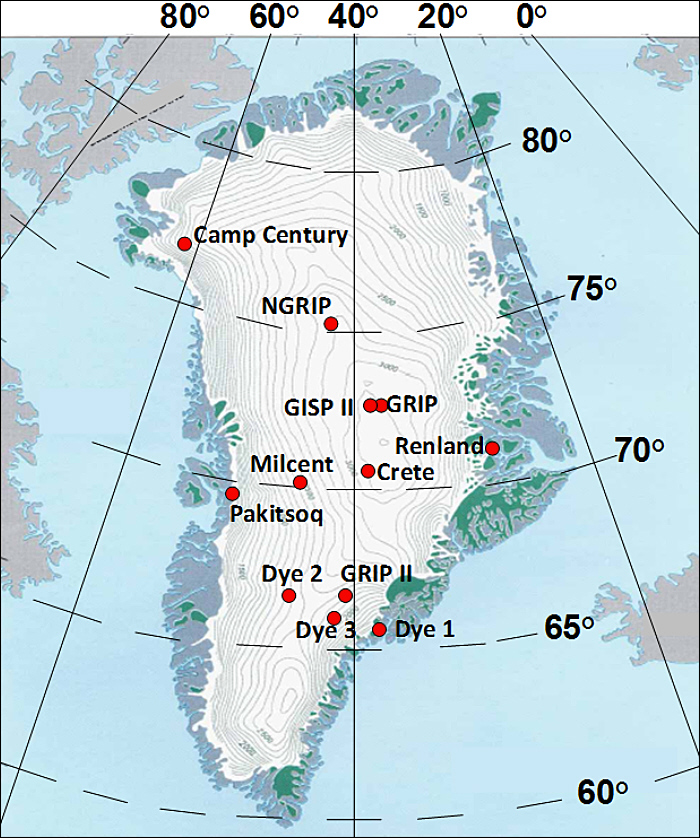
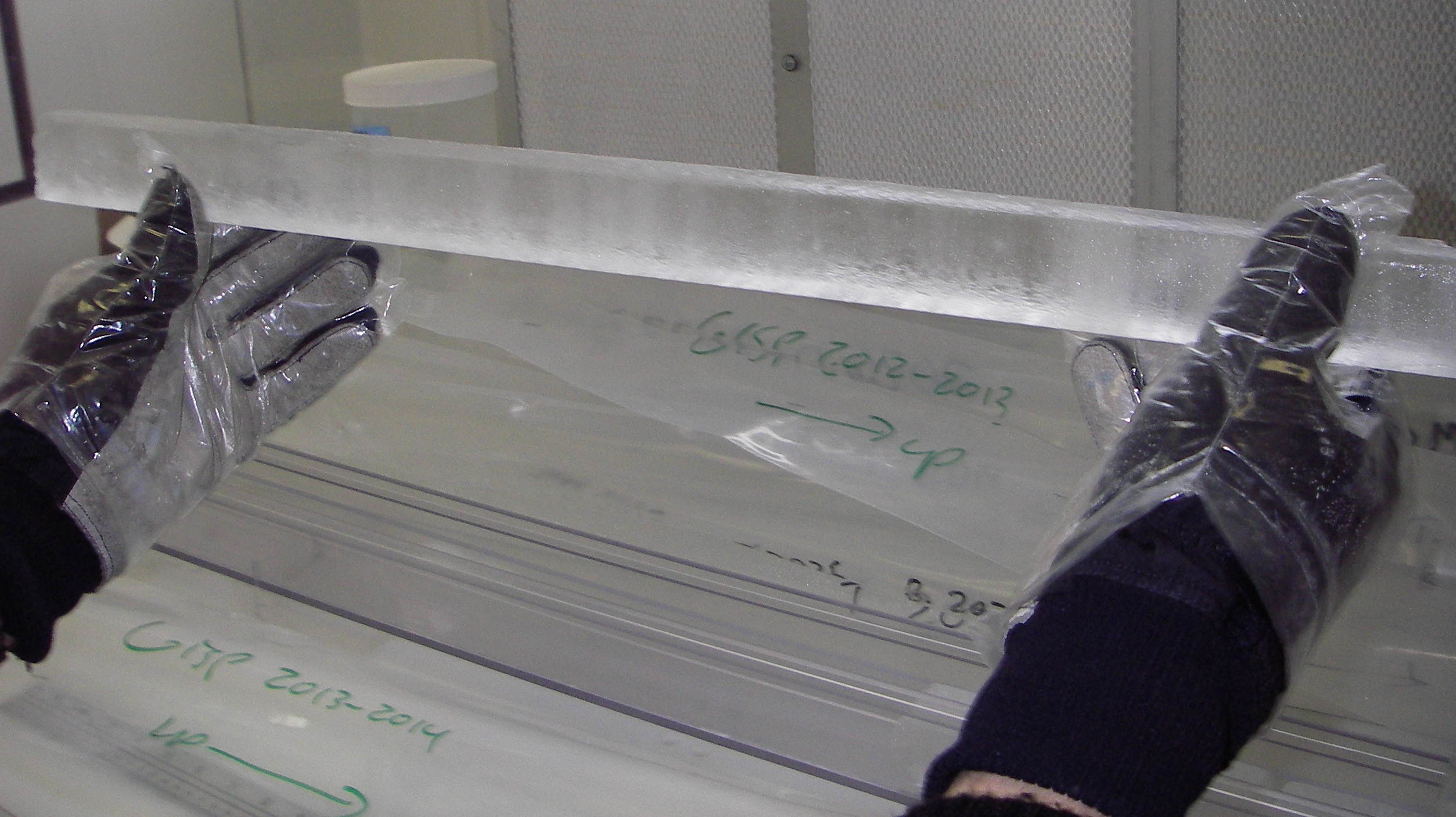


[**Ice Cores**](file:///J:\NEOTOMA\NeotomaGLOSSARY.docx): Chemical analysis of ice cores from Greenland and Antarctica provide long records of ice sheet growth, precipitation, air temperature, and insolation. Sediment analysis (dust) provides long records of major episodes of volcanic activity, provides material for dating ice-core layers, and document changes in wind patterns.

Oxygen isotopes within the carbonate shells of forams in deep sea cores and air bubbles trapped in glacial ice provide the most important record of warm and cold periods on Earth.

**Figure 3**

**A section of a Greenland ice core and locations of some important ice cores from Greenland and Antarctica**.



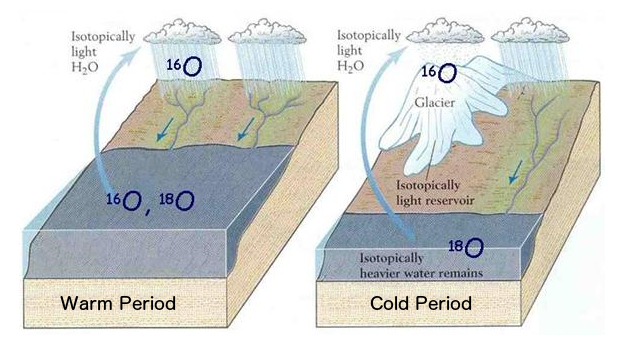
**Oxygen Isotopes**

There are two forms of oxygen, a heavier 18O isotope and a lighter 16O isotope. The ratio of these isotopes (the 18O/16O ratio) in a core tells us about cold and warm periods in the earth’s climate because the lighter 16O molecules evaporate slightly easier. Thus, precipitation has more 16O than in the ocean. When this precipitation falls in the form of rain it eventually mixes with ocean water keeping the ratio in balance.

* When precipitation accumulates in ice sheets, however, the bubbles of air contain more 16O causing the amount of 16O in oceans to be depleted.
* Likewise uptake of oxygen by forams for their calcium carbonate (CaCO3) shells records the 18O/16O

ratio in the ocean. During warm periods the ratio is balanced, but when 16O becomes trapped in ice, the foram shells have a higher concentration of the heavier 18O while ice bubbles contain greater concentrations of 16O.

Fluctuations in number of heavy and light isotopes of other chemicals also reflect ice-sheet size. Among these is hydrogen. The normal hydrogen molecule 1H is lighter than the heavier molecule 2H, called deuterium.



**Figure 4**

**Because 16O is lighter than 18O, it *evaporates more readily,* and precipitation is enriched in 16O. During warm periods (interglacial periods) when precipitation falls mainly as rain and ice sheets are melting, 16O quickly mixes with ocean water and the 18O levels remain only slightly higher than those of 16O.**

**If 16O becomes trapped on land, however, as occurs when ice sheets form and grow (glacial periods), the amount of 18O in the ocean increases relative to the amount of 18O. Air trapped in the ice during these cold periods is enriched in lighter 16O. important ice cores from Greenland and Antarctica.**

**QUESTIONS:**

**Helpful Hint: Very carefully measure the ages asked for in the questions below. It may help to use a straight edge to identify dates.**

**Express all answers as years before present (or ybp).**

1. What important organism do marine paleontologists use to analyze deep-sea cores and document past climate change? Give *two* examples of how this organism reveals information about the past.

**Foraminifera (Forams)**

1. **Variations of species** of these organisms allow scientists to reconstruct past ocean currents, temperature, pH, etc.
2. **The shells of forams** are made of CaCO3 – which can be used for ***oxygen isotopes*** to tell planetary temperatures (ice age or interglacial period).
3. Observe the chemical signature (18O record in Fig. 2 on the first page) of deep-sea cores. Has global climate remained the same for the last 2.7 million years? Describe how it has changed.

No, climate has shifted from periods much colder than now (ice ages) to temperatures around our current temperature. It has done so many times over the last 2.7 million years.

1. Are the changes ***more*** or ***less*** extreme before 1.0 million years? **Less Extreme before 1.0 mya**
2. At what times in the past were temperatures as warm as or warmer than the present? (Hint: The 18O record ends at the present at the top of the Fig. 2.)

**Example:** **125,000 years ago, 320,000 years ago, 400,000 years ago,**

1. Is there a pattern in the curve showing the build-up and decline of ice sheets? Which took longer ice-sheet growth or decline? Can you think of some reasons why this might be the case?

**Yes, ice sheets were slow to build up but disappeared very quickly. This is due to positive feedback loops associated with the ice. As the ice sheets grew, so does the albedo feedback. More ice = more of the planet is reflecting light back into space.**

1. **Identify three times** (in years before present) when oceans were the most highly *enriched* in 18O. What was the global climate at these times?

**This is when the isotope line is going all the way to the left (or the 18O values are close to 5).**

**Approximately 140,000 years ago, 430,000 years ago, 625,000 years ago.**

1. **Identify three times** (in years before present) isotope 18O levels in the oceans were the most *depleted*.

**This is when the isotope line is going all the way to the right (or the 18O values are close to 3.2).**

**Approximately 125,000 years ago, 320,000 years ago, 400,000 years ago**

1. What 18O values indicate ice sheets were at their largest?

**A value of close to 5**

1. What 18O values indicate ice sheets were at their smallest extent?

**A value close to 3.2**

1. How many times does this graph indicate the Earth’s climate was coldest with its largest ice sheets (otherwise stated: how many times does the isotope record reach 5 per mille)?

**4 times**

1. How many times does this graph indicate the Earth’s climate was warm like the present?

**4-5 times**

1. Has the Earth’s climate over the last 600,000 years been dominated by warm periods like the present, or cold periods when ice-sheets covered much of the earth?

**Way more often the planet has been colder than now. Maybe not as cold as the maximum of an ice age, but the planet is almost always somewhere between as warm as now and as cold as the last ice age maximum.**