Exam Paleoceanography and Climate variability, Thursday November 6th, 13:30-16:30

The oxygen isotope record

The benthic foraminiferal oxygen isotope record over the last 5 million years gives us a good indication of how global climate evolved over this time period.

1. Describe how the foraminiferal oxygen isotope proxy works and why it tells us something about global sea-level and deep-sea temperature evolution. **(15 Points)**

   You need to address the following aspects in you answer:
   How are oxygen isotopes measured?
   How does the delta notation work?
   What is fractionation?
   Which environmental factors lead to fractionation in oxygen isotopes?
   What is Rayleigh distillation?

2. The oxygen isotope composition of foraminiferal calcite is not identical to the oxygen isotope composition of the seawater in which the foraminifera lived. Why not? **(3 Points)**

3. Name two (other) geochemical methods (proxies) that can be used to derive seawater temperatures from foraminiferal calcite. **(2 Points)**

4. Describe the benthic oxygen isotope record over the last 5 million years. **(10 Points)**

   What is the general trend?
   What kind of periodicity is observed?
   Does this periodicity change through time?
   How does the amplitude of the cycles change?
   Which orbital parameters drive the observed cycles?

   (Do you have an explanation why periodicity changed over the last 5 million years?) **(4 Extra Points)**

Dating sediments

5. How can you use the oxygen isotope record of a deep-sea sediment core to date the sediments? Why would you use the benthic and not the planktic foraminiferal oxygen isotopes in your core for this purpose? **(4 Points)**

6. Name two radiogenic isotope systems that can be also used to date your sediment core. **(4 Points)**

7. What is the Suess effect? **(2 Points)**

Primary Productivity

8. Define: 1. Gross-Primary Production, 2. Net primary production 3. Export production. **(6 Points)**

9. What is the Redfield ratio? Where is it based on and why is it important? **(10 Points)**

Deep sea circulation

10. From the North Atlantic, via Antarctica, to the Pacific deep water becomes increasingly older. Please describe how the following parameters change along this path, and the mechanisms involved:
    a. Oxygen
    b. Phosphate
    c. Salinity
    d. Total dissolved CO_2
    e. Cadmium
    (15 points)
11. A more rapid formation of deep water in the North Atlantic affects the apparent 14C age, which is also often expressed as $\Delta^{14}C$.
    a. Explain the relation between the apparent age and $\Delta^{14}C$
    b. How is the formation rate of deep water affecting $\Delta^{14}C$ and is this a temporary or permanent effect?
    c. What other process could affect $\Delta^{14}C$?
    (15 points)

High frequency climate variability

12. Laminated sediments provide important archives for high-resolution paleoclimate reconstructions. To verify the role of anoxia in the formation of laminated sediments often redox sensitive sediments are analyzed.
    a. Name 2 elements enriched under oxygen-depleted conditions and 2 elements depleted under these conditions.
    b. Describe the impact of later re-oxygenation on these elements.
    (7 points)

13. El Nino/La Nina type climate variability involves changes in the coupled ocean-atmospheric circulation in the tropical Pacific.
    a. Explain how ocean and atmosphere circulation reinforce each other during La Nina and El Nino times respectively.
    b. Why is not only the circum Pacific affected by El Nino/La Nina, but also other, more remote, tropical (and sub-tropical) areas, such as Florida and Central Africa by El Nino/La Nina type climate variability.
    (7 points)

14. BONUS: Why/How is El Nino/La Nina Type climate variability probably affecting also global climate?
    (4 points)

Total points: 108 (100 regular, 8 bonus)