Marine Sediments

Images: Ocean Drilling Program
Figure 6.1 Pelagic sedimentation in the ocean (Hay, 1974).
Ocean Sediments

- Terrigenous sediments
  - Weathering and erosion of land
  - Transport by rivers, glaciers and wind
  - Gravels, sand, silts and clays

- Volcanogenic component
  - Ash and dust
  - Spatially defined typically by volcanic source
  - Major eruptions
    - Krakatoa AD 1886

- Extra-terrestrial component
  - Remains of meteorites
    - accumulation 0.1- 1mm /million years
Figure 1.4 Distribution of dominant sediment types on the floor of the present-day oceans. Note that red clays are also terrigenous sediments.
Biogenic Material

• Assemblages of Living organisms
  – Biocoenoses

• Processes
  – Selective dissolution
  – Differential removal by scouring
  – Introduced exotic species

• Assemblages of Dead organisms
  – Thanatocoenoses
Biogenic Ooze

- Coccoliths
  - *Gephyrocapsa ornata*
- White Cliffs of Dover, UK
  - Mainly coccoliths
- Diatoms
- Radiolaria
Figure 1.3 Some deep-sea sediment cores,
(a) Top: Chocolate-coloured terrigenous ‘red clay’, typically structureless and with few organic remains other than occasional fish teeth.
Bottom: Diatom ooze from the Antarctic Ocean. The high concentration of diatoms gives the sediment a ‘fluffy’ aspect—when dry, it looks like glass wool.
(b) Top: Mixed radiolarian and calcareous ooze, typical of tropical oceans, especially the tropical Pacific. The mottling is due to the burrowing activities of benthic organisms (bioturbation).
Bottom: Calcareous ooze, formed of coccoliths and foraminiferal remains, between them making up about 90% of the whole.
Foraminifera

- Commonly used in Paleoclimate Studies
- Calcite
- Exoskeleton or tests
  - 30um to 1mm
- Zooplanktonic forams
  - top 1000m
- Benthic
  - More commonly preserved

*Holmanella valmonteensis*
(UCMP Berkeley)
FIGURE 6.6  Sea-surface temperature ranges of some contemporary planktonic foraminifera, illustrating their temperature dependence. Width of lines indicates relative abundance (Boersma, 1978).
• Species dependence
• Carbonate dissolution
  – Selective removal, usually planktonic species
  – Carbonate compensation depth (CCD)
    • 3-5km CaCO$_3$ solution = CaCO$_3$ supply

Bradley, 1999
Figure 1.4  Distribution of dominant sediment types on the floor of the present-day oceans. Note that red clays are also terrigenous sediments.
Oxygen Isotope Stratigraphy

• Proportion of $^{18}$O in carbonate shell
  – Temperature
  – Isotopic composition of seawater during secretion
  • Function of Volume of land ice
    – e.g. benthic foram $^{18}$O

• Record of Paleoglacioclination
  – Eustatic sea-level changes
Limitations in $^{18}$O Analysis

- **Resolution**
  - How many years per sample
- **Sediment mixing**
  - Turbation and bioturbation
  - Clarity of the record blurred
- **Isotopic equilibrium between test and water**
- **Synchronicity of $^{18}$O changes**
Oxygen Isotope Stratigraphy

**FIGURE 6.11** A composite oxygen isotope record for the Brunhes chron, derived by correlating the common features in 11 planktonic and 2 benthic foraminifera records from different oceanic regions. Each record was normalized before they were combined, so the composite record is scaled in terms of standard deviation units. Isotope stage boundaries are shown (Prell et al., 1986).
Relative Abundance Studies

- Core top calibration studies
  - Species composition
  - Modern environmental parameters
    - Summer/winter SST
  - Transfer functions
    - Relates the surface data to data at depth

**FIGURE 6.18** Schematic quantitative paleoclimatic model. In step 1, the transfer function \( X \) is calculated by calibration of the modern (core-top) foraminiferal data set \( (F_m) \) with modern sea-surface temperatures \( (T_m) \). In step 2 the transfer function is applied to a down-core (fossil) data set \( (F_p) \) to yield estimates of past temperatures \( (T_p) \) (Hutson, 1977).
Core Tops provide Modern Data

- Polar
- Subpolar
- Transitional
- Subtropical
- Gyre margin

Bradley, 1999
91% of variance explained

**FIGURE 6.21**  Winter sea-surface temperature based on modern instrumental observations (including interpolated values) vs those estimated from faunal assemblages in 61 core-top samples using factor analysis and transfer function methods (Imbrie and Kipp, 1971).
Marine core Record

Ice core Record

Figure 5.22 The GRIP $\delta^{18}$O record from Summit, Greenland, plotted linearly with respect to depth. Section A (left) is the Holocene section, showing only minor changes; section B (right) shows the preceding 250 kyr record at the same $\delta^{18}$O scale. Note the very large and rapid oscillations throughout the pre-Holocene record. Proposed interstadial isotope stages (IS) 1-24 are indicated, together with comparable European pollen stages. Dating was by annual layer counting to 14.5 kyr B.P. and beyond that by an ice-flow model (Dansgaard et al., 1993).

Figure 6.22 Winter sea-surface paleotemperature estimates (right) and $\delta^{18}$O values (left) based on Caribbean core V12-122. The sea-surface temperature estimates are derived from transfer functions, in the manner shown schematically in Fig. 6.18 (Imbrie et al., 1973).