Oceanography - Marine Provinces and Sediment Sources

I. Shape of Seafloor
  A. Bathymetry- measurement of depths from sea surface to seafloor
    1. negative elevation measurements
      a. units: meters, feet, miles, fathoms
      b. 1 fathom = 6 ft
    2. Ocean Floor Depths
      a. abyssal plains: 4 - 6 km depth
      b. average depths
        (1) Atlantic 3900 km
        (2) Pacific 4300 km
        (3) Indian 3900 km

  B. Sea Level and Sea Level Change
    1. Tidal Fluctuation diurnal, vertical fluctuation of sealevel under the influence of planetary gravity. Results in bulging of sealevel sytematically throughout the day, around the world.

      a. tides set in motion by gravitational attraction of the moon and sun (heavenly bodies close and large enough respectively to influence force of gravity on earth).

        (1) gravitational pull of sun and moon result in pulling at the ocean surface, causing it to bulge. Since the earth's crust in rigid and relatively unaffected by this gravitational pull, tidal fluctuations of sea level occur relative to land. (tidal pull is relatively negligible in surface bodies of water, i.e. lakes)

        (2) Moon has most significan daily impact on tidal levels. Gravitational effectiveness of sun relative to the moon in 44%.

      b. Normal tidal bulges: influenced by moon primarily, moon in line with equator, pulling bulge equatorially, low tides at top and bottom, hide tides at equator

        (1) tidal bulge follows the moon as it orbits around earth, water facing the moon is drawn/bulged towards the moon, side opposite moon is also bulged outward because the solid portion of the earth (facing the moon) is pulled away from the ocean on the side opposite the moon.

          (a) at same time as tidal bulge, there are compensating low tides at 90 degrees to the bulge

        (2) Entire effect is complicated by the earth's revolution from east to west, also coupled with moons revolution around earth: result in 2 complete tidal cycles every 24 hours and 50 minutes. (i.e. 2 high

and 2 low tides in a little over each day)

2. Global Sea Level Change

a. Sea Level Relative to Global Ice Budget
(1) > Ice Storage, < Sea Level
(2) < Ice Storage, > Sea Level
(a) presently melt all glacial ice: > SL by 60 m globally
(b) Last Glacial Maximum: SL < by 100 m

C. Slope of Seafloor

1. Slope = rise / run = change in elevation / change horizontal distance
a. units
(1) dimensionless, ft/mi, m/km, percent
b. Percent Slope

%slope = 100% * invtan (rise/run)
e.g. 100% = 100% * invtan (45^{o})

c. steep slopes at oceanic trench ~5 degrees
d. gentl slopes at continental shelf ~0.2 degrees
e. continental slope ~ 2 degrees

f. Slope morphology as function of age of seafloor
(1) old seafloor = colder, > density
(a) steeper slopes at trench
(2) younger seafloor = warmer, < density
(a) gentler slopes at mid-oceanic ridge

D. Depth / Bathymetry Measurment Techniques
1. Sonar
a. side scanning sonar
2. Seismic Surveys

II. Marine Provinces and Seafloor Features

A. Deep Ocean Basin - offshore marine depths (depths > 4000 m)
1. Tectonic Features
a. trench - at subduction zone
b. spreading center
(1) mid-ocean ridge
(2) mid-ocean "rise"
(3) hydrothermal vents (100 to 300 deg. C)
(a) white smokers
(b) black smokers
i) sulfides
(4) Hot spot tracks
(a) trail of submarine volcanoes

c. abyssal plain- flat expanse, low relief, deepest depths
d. Guoyotes and submarine volcanoes
(1) fringing reefs
e. Volcanic arc at subduction zone
f. fracture zones at transform boundaries

B. Continental Margin - nearshore
1. Tectonic classification
a. passive margins - cont. margins removed from plate boundaries
(1) e.g. Atlantic passive margin
b. active margins - cont. margins near plate boundaries
(1) e.g. Pacific type margines
2. Seafloor topography (in offshore direction)
a. continental shelf
(1) shelf break
(2) submarine canyons
(a) turbidity currents
b. continental slope
c. continental rise
(1) submarine fans
d. abyssal plain

III. Marine Sediments and Sediment Sources

A. Sediment- derived from latin sedimentum = "a settling", sediment may be defined as regolith, or weathered bedrock that has been transported. May include both physical particles (sand, gravel, silt, clay), or dissolved ions that are carried in solution and re-precipitated as chemical and/or biochemical deposits.

Sedimentary Rocks = lithified sediment, or hardened sediment through cementation, alteration or compaction (includes both clastic sedimentary rocks (fragmental) or nonclastic (chemical deposits)

B. Sediment Types
1. Clastic Sediments: those that are weathered, eroded and physically transported in a solid state before being deposited (i.e. particles, e.g. sand).
a. Lithogenic
b. chemical
c. biogenic

2. Nonclastic Sediments: those that are weathered and transported in solution (dissolved ions) and subsequently chemically precipitated in situ from solution, i.e. as mineral crystals. These sediments were not transported physically as solid objects.
a. chemical
b. biogenic

C. Clastic Sedimentary Particles

1. Weathering Products of Pre-existing Rocks

a. Siliciclastic Sediment (Inorganic Composition): Physical particles that are derived from the weathering and erosion of terrigenous, pre-existing, rock material. Silciclastic sediment is largely comprised of silicate-based mineral and lithic fragements.

(1) Sediments are derived by
(a) chemically and physically weathering bedrock,
(b) erosion/transportation via mass wasting processes, and/or
(c) the crushing and grinding action of glacial activity.

(2) Composition of Siliciclastic Sediment Particles

(a) Rock Fragments-particles may be comprised of mineral assemblages that bear recognizable resemblance to the lithic composition of the parent rock material from which they were weathered.

Survival of Rock Fragment = f(lithology, spacing of partings (microstructure/cleavage), kinds of weathering (climate), transportation process (energy), and/or post-depositional diagenetic alteration (e.g. pressure dissolution, clay alteration)

(b) Quartz - ubiquitous component of nearly all igneous and metamorphic parent rocks (Tr-40% commonly) and comprises an average of 60-80% of sediment found.

(c) Feldspars (Kspar and Plagioclase)- comprise the dominant silicate mineral found in igneous and metamorphic parent rocks, however, high susceptibility to weathering and clay alteration render this mineral species unstable and not as commonly preserved in the sedimentary environment.

(d) Clay Minerals: layer lattice silicates comprised of an aluminous-hydroxide component

(e) Carbonaceous Organic Debris: solid particles of organic matter

(f) Pyroclastic Particles: sedimentary particles derived explosively from volcanoes including rock fragments (lithic components), single mineral crystals (crystal components) or bits of volcanic glass (vitric components).

i) volcanogenic sediment

D. Chemically-Derived Sedimentary Particles: includes 1) animal-secreted skeletal debris, 2) nonskeletal calcium carbonate materials, and 3) glauconite minerals

1. Animal-secreted Skeletal Debris: comprised of either calcium carbonate or silica

   a. Calcium Carbonate Skeletal Debris: includes whole-body tests of animals as well as broken and fragmented pieces. Largely marine-based organisms and fossil material. Fragments for "bioclastic" sediments available for transport and deposition.

      (1) Mineralogy: modern carbonate skeletal tests comprised of minerals calcite and/or aragonite. Aragonite is a pure form of CaCO3 while calcite contains more impurities such as Mg (Low-Mg calcite <8.0% $MgCO_3$ vs. High Mg calcite >8.0% $MgCO_3$). Aragonite and High Mg calcite are most common as skeletal tests.

   b. Siliceous Skeletal Particles: skeletal tests composed of SiO_2, primarily diatoms and radiolaria, microscopic sea critters.

Siliceous deposits are not abundant on seafloor, but do occur.

2. Nonskeletal Carbonate Solids: includes pellets, pelloids, ooids, intraclasts and pisolites.

   a. Carbonate Pellets: sand-sized (1/16 mm to 2.0 mm) spherical or ellipsoidal particles of calcium carbonate. Generally internally massive and homogenous in structure. Thought to represent fecal secretions.

   b. Peloids: particles that resembe carbonate pellets but for which no particular origin has been ascribed. Possibly associated with dissolution and recrystallization of carbonate minerals.

   c. Ooids: greek word = egg like, generally consist of aragonite, sand-sized spherical to elliptical in shape with concentric-ring internal structure. Thought to be formed in shallow-water turbulent zones where pre-existing particles form nucleii for concentric carbonate precipitation.

3. Glauconite Minerals- sand sized (1/16 mm to 2.0 mm), translucent green pellets of marine origin. Generally oval or spheroidal in shape with massive internal structure. Chemical composition: complex

4. Evaporite minerals
   a. precipitates from sea water as evaporation occurs
   b. gypsum, rock salt, anhydrite

E. PROPERTIES OF SEDIMENTARY PARTICLES

1. Shape: geometric form of sediment = f(origin, history and internal lattice structure of particle. Shapes may range from spherical quartz grains to very complex in cases of skeletal tests and pyroclastic debris.

(1) General relationship: as distance of transport increases, sediment becomes more worn and rounded with time.

2. Geometry of sediment shape: sphericity and roundness

a. Sphericity-degree to which a particle approximates the shape of a sphere. In a perfect sphere, 3 mutually perpendicular axes are equidimensional

$$\text{Sphericity} = \frac{\text{Surface Area particle}}{\text{Surface Area of Sphere (of same volume)}}$$

b. Roundness - geometric form of particle related to the sharpness or curvature of edges and corners of the grain. Roundness is independent of sphericity. E.g. an elongated grain of low sphericity may be well rounded with respect to its edges.

$$\text{Roundness} = \frac{\text{average radius of corners and edges}}{\text{radius of maximum inscribed circle}}$$

(1) Roundness commonly qualitatively defined relative to visual comparison: very angular, angular, subrounded, rounded and well rounded (see related diagram)

F. Sizes of Sedimentary Particles

1. Sediment Size Classification (i.e. Average Diameters of Particles)

a. Clay = < 1/512 mm = < 0.002 mm = > +9 phi
b. Silt = 1/512 - 1/16 mm = 0.002 - 0.0625 mm = +9 phi to +4 phi
(1) very fine=1/512 - 1/256 mm = 0.002-0.0039 mm = +9 - +8 phi
(2) fine = 1/256 - 1/128 mm = 0.0039-0.0078 mm = +8 - +7 phi
(3) medium = 1/128 - 1/64 mm = 0.0078-0.0156 mm = +7 - +6 phi
(4) coarse = 1/64 mm - 1/32 mm = 0.0156-0.031 mm = +6 - +5 phi
(5) very coarse = 1/32-1/16 mm = 0.031-0.0625 mm = +5 - +4 phi

c. Sand = 1/16 - 2 mm = 0.0625 -2.0 mm = +4 - -1 phi
(1) very fine = 1/16 - 1/8 mm = 0.0625-0.125 mm = +4 - +3 phi
(2) fine = 1/8 mm - 1/4 mm = 0.125-0.25 mm = +3 - +2 phi
(3) medium = 1/4 - 1/2 mm = 0.25-0.5 mm = +2 - +1 phi
(4) coarse = 1/2 - 1 mm = 0.5 -1.0 mm = +1 - 0 phi
(5) very coarse = 1.0-2.0 mm = 0 - -1 phi

d. Gravel = >2.0 mm = > -1 phi
(1) Pebbles= 2.0 - 64 mm = -1 to -6 phi
(a) V. Fine = 2.0 -4.0 mm = -1 to -2 phi
(b) Fine = 4.0 -8.0 mm = -2 to -3 phi
(c) Medium = 8.0-16.0 mm = -3 to -4 phi

(d) Coarse = 16.0-32.0 mm = -4 to -5 phi
(e) V. Coarse = 32 - 64 mm = -5 to -6 phi

(2) Cobbles = 64 - 256 mm = -6 to -8 phi
(a) Small = 64 - 128 mm = -6 to -7 phi
(b) Large = 128 - 256 mm = -7 to -8 phi

(3) Boulders = >256 mm = > -8 phi
(a) Small = 256 - 512 mm = -8 to -9 phi
(b) Medium = 512- 1024 mm = -9 to -10 phi
(c) Large = 1024 - 2048 mm = -10 to -11 phi
(d) V. Large = > 2048 mm = > -11 phi

NOTE: Size Classes in above list differ by multiples of 2.

PHI = $-\log_2$ (Diameter) where D = particle diameter in mm

IV. Classification of Marine Sediments

A. Neritic Sediments - shallow water, continental margins

1. lithogenous sediments from offshore river deposition
   a. sand, silt, clay primarily

2. Turbidites
   a. graded bedding
   b. turbidity deposition of sediment-laden water

B. Deep Ocean Sediments
1. chemical oozes
   a. biogenous origin
2. pelagic or abyssal clays
3. fecal pellets
4. skeletal / bioclastic sediment