Palaeoecology

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2-Transitional environment.

3- Marine environment

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Palaeoecology

The branch of ecology that studies ancient ecology. The dedicated study of past environments by studying the fossil records of organisms that lived in that environment at the time.

Introduction:

The relations linking organisms with environments are the subject matter of ecology. Like ecology, its sister field in the biologic Science, paleoecology, seeks to understand the relationships of organisms to their environment. Unlike ecology, however it must first resurrect the life and environments of the past form long dead and much altered organisms and sediments before it can attempt to interpret relationships. Therefore, paleoecologic analysis derives from two sources, fossils and associated rooks. The fossils, biological aspects of paleoecalogy, are especially important because the organisms are responsible for the production and madification of much sediment, and organisms are more delicate index to variation in environment than the rocks, physical aspects, characterizing the environment. The physical and biological aspects of paleoecology are very closely related and each supplements and serves as check upon the other.

Environments

An environment is a combination of mutually interacting physical and biologic conditions. It is not something that can be seen although some of its factors are visible or measurable. As a whole, a paleoenvironment can only be inferred from it's results as these are exhibited in the form of sedimentary accumulations and fossil associations. Because the adjustments of organisms to their environments are so intimate and specific, the distribution and associations of fossil plants and animals reveal many differences in environments that are not clearly indicated by any other evidence.

Geologist generally subscribe to the view that, even allowing for a variation in organic influences through geological time, there are a relatively limited number of basic types of sedimentary environments, which, in turn, give rise to a relatively limited number of associations of lithologies, Faunas; and flora. There is clearly a close connection between the environment of deposition and the nature of the sediments deposited. For the geologist working with ancient sedimentary rocks, however, the primary data are the rocks and the environment must be interpreted From them.

CLASSIFICATION OF ENVIRONMENTS

1- Non marine environment (Continental)

i-Desert and semiarid environment.

ii- Fluvial environment.

iii- Lake environment.

iv- Glacial environment.

2-Transitional environment.

i-Supratidal zone.

ii-Intertidal zone.

iii- Subtidal zone.

3- Marine environment

i- Neritic zone.

ii- Bathyal zone.

iii— Abysmal zone.

1- NON-MARINE ENVIRONMENTS (CONTINENTAL ENVIRONMENTS)

Although continental environments are the ones best known to man and the most easily studied, the sedimentary product of these non marine (continental) environments, are least represents in geologic record because (1) most continental environment situated above the base level of erosion and their deposits are easily eroded. (2) Large parts of the present continents were submerged beneath shallow sea and thus accumulated only marine deposits.

CONTINENTAL ENVIRONMENTS INCLUDES:

i- Desert and semiarid environment.

ii— Fluvial environment.

iii— Lake environment (lacustrine).

iv— Glacial environment.

i- Desert and semiarid environment :

Low precipitation and a high proportion of evaporation to precipitation characterize a desert. Desert area receives no more than 25 cm of precipitation per year. Most deserts are semiarid regions in which annulal precipitation ranges between 25 and 50 cm, characterized by grassy vegetation that gradually merge into humid areas.

Desert environment include

A-Bare rook surfaces:

It is the smoothed pavement of the rocks of the desert by the wind action. Residual gravel as a deflation lag may form a veneer on bare rook surfaces.

B- pediments:

The surfaces of pediments slop gently toward the basin and away from the highlands • Pediments are covered by thin veneer of loose sediment. It may preserve in the rock record as unconformities.

C- Fans:

Fans are deposits having surfaces that are segments of cones and that radiate downslope from the point where streams emerge from rocky highlands. The surface of the fans is concave upward. At the edges of highlands, adjacent fans grow and coalesce to form pediment. Silt, sand, gravels with little visible clays are the fan sediments • Many fans originate at the abrupt change of slop caused by block faulting. Deposits of fans in rock record should have the following diagnotic features; (1) lenticular or wedge shaped (2) sediments are coarse grained sandstone and conglomerates (3) deposits may be cross stratified or plane bedded (4) absence of organic materials (5) yellow brawn or red color of the sediments.

D- Wind deposits (dunes):

The speeds needed for wind transport of sediment particles of a given size are higher than those needed for water transportation and because of this lesser density, air is moved at the same speeds by much smaller pressure gradients than is water. These wind deposits are of sand, silt, and clay size forming dunes. Modern dunes show various morphologies such as dome-shaped dunes, transverse dunes, star dunes, parabolic dunes and longitudinal dunes.

E- Sabkhas

Sabkhas are equilibrium deflation-sedimentation surfaces related to the groundwater table. The sediments of the sabkha consist of sand, silt and clay. Gypsum and ha1ite precipitate within the framework of sedimentary particles forming sabkhas,

F- Playas

Are broad, shallow depressions in desert regions which may be covered with a thin sheet of water the sediments of playas are deposited by the waters brough in by floods. The floods deliver to the playa chiefly fine grain sediments. Plays deposits consist of interbedded thin layers of sand, silt, clay and evaporate minerals. Plays has an access of Oxygen that oxidized the surface of the sediments giving it brown or red color while the down parts below the surface are grey where reducing conditions are prevailed.

ii- Fluvial environmentt

Fluvial environment include the sites of sediment deposition associated with rivers. The alluvial deposits are formed in stream channels and associated flood plains of individual streams or as broad alluvial fans or plains. The energy of the alluvial environment lies mainly in the kinetic energy of the stream. The boundary conditions include the stream gradient. Linear shape of the channel, and limiting valley walls. The materials range from boulder to clay, with coarse sediments commonly associated with headword portion of the stream.

Fluvial deposits include:

1- Channel and bar deposits

Consists of gravels, sand and silt. In semiarid climates, pools may develop during dry season in the main channel, with the accumulation of fine grain sediments.. The fossils which may occur in the finer sediments include diatoms, seeds, spores, pelecypods, gastropads, ostracods, insects, fishes and vertebrate remains.

2- Flood plain sediments

Consists of sand, silt and clays which are usually thin bedded and may contain introduced seeds, spores, pollen, pelecypods, gastropods, ostracods, fish remains and mammals.

<u>iii- Lacustrine (Lake) environment</u> :

Lacustrine environment includes the varying environments of lake in all climates. Because the water of most lakes is derived from rainfall the salinity of most lake water is low, the water is fresh. However, some lake water has always been saline because the lakes are former parts of the sea that became hand locked as a result of crustal movements.

Because of the small size and shallowness of most lakes, waves and currents are not strong and less effective in Sorting and transporting sediments. The lacustrine sediments include 1ight dark color deposits of silty claye to fine clay and sands. Few but rare examples of aragonite and halite (evaporites) deposits are precipitated in some lakes which are highly sa1ine. Calcareous bodies are rare. Pollen, seeds, algae, diatoms, pelecypods, gastropods, ostracods, foraminifera are common fossils of lacustrine deposits.

iv- Glacial environments

Glaciers have been recognized as powerful agents for erosion and for transport of sediment of all sizes, including huge boulders.

2- Transitional environment

In transitional environments, marine and non marine process interacts. Marine processes are controlled by the salinity and circulation of seawater and by waves, currents and tides. The chief non-marine processes are controlled by the characteristics of the fresh water flows of rivers.

Transitional environments are subdivided into:

<u>i- Littoral Environment:</u>

Littoral environment identified as the area characteristic of positions close above, but more generally close below, sea level. Littoral deposits are transitional. The sediments laid down in them share some of the features of marine and non marine deposits. The littoral zone requires tolerant organisms, since it is alternately wet and dry as tides move up and down. However, the cyclic nature of this alternating condition is regular, and many organisms are specially adapted to survive in **it. Mobil** organisms can **move with the tides** and some clams **do** so, always found burried in the substrata. Some animals bury themselves in **the** moist substrata during low tide to_prevent desiccation, and there they wait for **the tide** to come in, bringing food and relief from during conditions. Certain algae which live on the substrata can retain enough moisture in their tissues to survive the period of exposure during the tidal cycle.

Sediments deposited on such flats vary from sand to mud. Sand or gravel beaches are present along a large proportion of the sea shores. They are products of wave action and make most open casts. Most beach deposits consists of_conspicuously cross bedded layers—cross—bedding may dip either outward or inward from the coast, generally depending upon whether these structures were built respectively on the foreshore, between high—and low-tide levels, or on the backshore that is swept by the strong waves of storms. This zone may contain plant remains, transported seeds and spores, worms, miscellaneous vertebrates and brackish foraminifera.

The Littoral environment can be subdivided into:

A- Supralittoral zone (Supratidal); which is relatively narrow zone above normal high tide having specific characteristics and is occupied by a distinct assemblage of organisms. This zone is subjected to spray of waves or indurations during storms. Most of the time, it is exposed to the atmosphere. A few algae and other plants have adapted to the unique condition of this environment. It is also represent site of dolomite formation.

B- Intertidal zone; is the zone which is lies between high and low tide level. Green algae and molluscs may adapt in this zone.

C- Subtidal zone, which is occasionally emerged area. This zone may contain red or brawn algae, corals and sea anemones,

3-Marine Environment:

The marine realm much more important than the continental as a region of most of the sedimentary deposition and most of the important Fossil groups are marine. Marine environment have been classified on the basis of depth of water, nearest to shore, penetration of light, type of benthonic life, relation to topographic bottom zone and kinds of sediments. The sea floor consists of the intertidal region, the continental shelf, the continental slop and the deep sea or the abyssa1 region, corresponding to the regions of sea floor on depth zones of the overlying water, these are littoral zone (previously disscussed) sublittoral zone, bathyal zone, and the abyssal zone. Therefore the marine environment can be divided into two great realms:

1. Benthonic realm, which is a collective designation for all the bottom of the sea.
2. Pelagic realm that is all the ocean water lying seaward of low— tide level. The pelagic realm consists of two major provinces.
   a) Neritic province, the coastal—ocean water overlying the continental shelves.
   b) Oceanic province, the blue—water regions overlying the deep sea basins.

The marine environment is an important region of sedimentary deposits. The effectiveness of waves and currents in the transportation of sediments decreases from the shoreline outward into deeper water.

Sediments that are moved slowly and with difficulty are left behind. In areas of active but relatively slow deposition, therefore, a natural gradient is likely to develop from gravel along a beach, to sand in very sha1low water, mud in deeper water and possibly calcareous material in situation beyond the reach of detrital sediments.

The action of waves in the marine environment tends to move coarser material toward the beach, and pebble and sand are carried along the shore rather than into deeper water. Sands is not ordinarily transported in water more than thirty to fourty feet deep and it characteristically marks a narrow near-shore zone. A really extensive sand deposit may indicate a corresponding zone of very shallow water or an unstable coastline. A near-shore sandy zone commonly grades outward into a zone of silty mud. Generally, the silt content decreases as water deepens and the shore becomes more distant, some silt is likely to be carried **as** for **as** wave action or currents stir bottom sediments, that ordinarily does not greatly exceed 300 feet.

The distribution of calcareous sediments is limited by factors controlling the organisms that produce it. Because most of the calcareous material originates on the sea bottom however, it may escape the turbulence of a near-shore zone through which most terrigeneous material must pass. The production and deposition of dominantly calcareous sediment occurs at favorable places almost anywhere within the neritic zone. Calcareous deposits may extend to the shore line and grade laterally into deterital sand.

Evaporite deposits such as salt and gypsum are products at a highly specialized environment that does not constitute a zone but prevails in restricted areas. It results from excess evaporation, which concentrates the mineral matter dissolved in sea water and eventually causes its precipitation. This can occur only in shallow, more or less landlocked extensions of sea, confined by barriers that present free water circulation **and** in regions of arid and warm climate.

Marine fauna are especially abundant in the upper 200 meters of the ocean. Accordingly, most marine animals also in habit the sublittoral depth zone (neritic zone). Moreover, the creatures that lived in the ancient seas which flooded the continents generally seem to resemble those creatures which inhabit the present neritic environment; hence, the neritic environment is being carefully studied for evidence which will help to interpret sediments and animals of the geologic part.

In some cases it is convenient to classify marine animals according to their relationship to their environment as follow:

1. Plankton: The floating organisms. These lack locomotary organs, or have they so little developed that they are essentially ineffective, their distribution is controlled primarily by waves and currents in the sea, and consequently they have wide geographical distribution. They may upon death sink to the sea floor in any depth of water, or they may be washed. Common planktonic organisms include foraminifera, Diatoms and some Ostracode.

2. Nekton: These are the organisms that have the power swimming through the water with comparative case. Their remains may be found in neritic, in bathyal and rarely in Abyssal sediments. Fish, molluscs, and marine mammals are nektonic organisms.

3. Pelagic: The term pelagic is commonly applied to drifting, floating and swimming organisms near the surface of the open sea far from the shore influence. Mainly they can be grouped in two categories; these swimming organisms that are living motional in the water, and those that are sometimes living on the surface and other time inside the water.

4. Benthos: Benthonic organisms are bottom dwellers and can be distinguished into two types;

a) Vagrant benthos, which hare limited power of crawling and creeping. Most of the genera of foraminifera, gastropods, Gastropods, pelecypods are classed as vagrant benthos.

b) Sessile benthos, which in the adult stage becomes permanently attached to the ocean floor, corals, sponges and stalked crinoides are example of sessile benthos.

Ecologic factors in marine environment

I- Physical factors

A)Temperature factors

Temperature is one of the most important factors of environment. It sets rather narrow limits beyond which life, as it occurs on earth, cannot exist. The ease and accuracy, with which temperature can be measured however, may have resulted in overemphasis of its importance in specific instances because some of its side effects, such as viscosity and density of water and solubility of both gases and solids, may actually be the contr-olling factor. Thus, viscosity of the sea water which is important to all planktonic organisms is twice as great at 32 as at 75 degrees. Because $CaCO_3$, which is utilized by many marine animals for shells or other hard parts, is much more soluble in cold than in warm water, the development of such structure may be either inhibited or favored.

On the other hand, metabolic activity is related directly to temperature and a rise of 20^0c may result in doubling its rate.

All organisms thrive best at certain optimum temperatures which vary greatly for different species. Likewise, there is difference in the maximum and minimum temperatures that limits their existence.

Here, the time value (factor) also is important because the limits vary depending upon the length of time extreme conditions can be endured. Generally, the optimum temperature is much closer to the maximum and too great a rise in temperature results in swift and certain death. on the other hand, lowering of temperature slows metabolic activity and organisms may pass into a resting stage. Same animals can with stand temperatures lower then that at which the body fluids freeze.

Temperature also in the sea declines with depth, but not regularly and stratification is well marked especially in warmer portions. There, the surface water is bourded below by a thermocline, where temperature falls relatively rapidly and at some places attains a rate of 10c in 7 meters. If a well marked thermocline exists it generally is encountered at depth ranging from 50 to 160 meters varying somewhat with the seasons. Below about 200 meters further decline is slow and at any level at any temperature zone Is essentially constant at all times. Temperature at the bottom of the deep sea everywhere is low. In some areas freezing temperature of sea water is nearly reached. The relative uniformity and stability of temperature in different parts of the marine environments are reflected by the generally narrow adaptation of marine organisms in this respect.

Warm water provides an optimum environment for marine life. Metabolism is rapid and generation follows each other in quick succession. Under these conditions evaluation might be expected to attain a maximum rate. Although no actual relation between rapidity of reproduction and evaluation has been established, a greater variety and larger number of associated species occur in tropical communities than in less element habitats. This is one example of the general rule that, with increasingly favorable physical conditions, the number of species in a community increases without a corresponding increase in the total population density, and therefore, the community is less likely to be dominated by one or a few species.

Temperature affected the solubility of many minerals and gases and has an important effect on chemical precipitation. Certain salt minerals may be precipitated in the winter time but dissolved in the summer, at low temperatures the solubility of CO_2 is greatly enhanced; hence the solution of calcium carbonate is promoted in cold waters, and conversely the precipitation of the same material is brought about by a rise in temperature. The temperature also affected the composition of mixed crystals or solid solutions. Shell carbonate is richer in MgO at the lower temperature.

TEMPERATURE and morphological variations of benthic foraminifera

Carpenter (1856) was the first to suggest that temperature can play an important role in the morphological variations of the foraminifcral test. Many studies have suggested that specimens of the same species get larger with colder temperatures. Rhumbier (1911) pointed out that the same species (e.g., *Triluculina rricarinata* and some Astrorhizidae) may be represented by larger specimens in cold water than in warm. He emphasized that this is particularly true for species that do not require large amounts of calcium carbonate to construct their test. Similar observations were made by Bandy (1963) on *Cyclammina cancellata, Robulus thalrnanni. Martinoticlla* sp., and *Pyrgo* sp., by Lewis and Jenkins (1969) on *Nonionella flemingi,* and by Arnold (1967) on laboratory cultures of *Calcitub polyrnorpha.* It should be mentioned, however, that a few studies (e.g., Phleger and Hamilton, 1946) seem to indicate that the size of benthic species increases with increasing temperature, which seems to contradict the above results. Theyer (1971) also observed that *Cyclammina cancellata* is smaller at a depth of 500 m than in deeper water, suggesting that decreasing water temperature was the main factor explaining this phenomenon.

Temperature also appears to play a role in variability of test shapes.

Schnitker (1974), in one of the few studies in which foraminifers were actually cultured with the idea of observing morphological variability, reared cultures of *Ammonia beccarii* and was able to reproduce at least five different “species” from various clones simply by varying the temperature. In this study no specific morphological trend is discernible; except that it appears that the number of varieties increases with increasing temperature. Walton and Sloan (1990) came to the same conclusion as Sehnitker for *A. beccarii* based on geographic distributions. A very similar trend was observed in wild populations by Miller ct al. (1982) for the various formae of *Elphidiurn excavat urn.*

Although changing of coiling directions is well known for planktonic foraminifers in relation to temperature, it is less well documented for benthic species. Hallock and Larsen (1979) cited an observation by Muller that the percentage of dextral specimens of *Arnphistegina lessonii* and sinistral specimens of *A. lobifera* increase in +4^{0}C thermal effluent. Collins (1989) claimed the first unambiguous observation of a correlation between coiling directions in benthic foraminifera *Bulimina* spp., and temperature. In samples taken from the Gulf of Maine to the Gulf of Mexico, Collins (1989) observed that dextrally coiled specimens are strongly associated with warm temperatures but cold temperatures do not necessarily produce dominantly sinistral specimens.

In summary, notwithstanding some contradictory evidence, decreases in temperature apparently result mostly in size increases. It is quite probable, although the evidence is still tenuous and more study is required, that changes in temperature can affect the sinistral/dextral ratio in some species. Although this is difficult to quantify, it also appears that intra-specific morphological variability increases with increasing temperature.

Oxygen isotopes: the thermometer of the Earth

Harold Uri first outlined the idea to use the oxygen isotopic composition of carbonates to deduce the temperature at which the carbonate was deposited. These measurements are now one of the cornerstones of paleoceanographic research, but not always dominantly for derivation of paleotemperatures: the data are commonly used for evaluation of polar ice volume. Carbon isotopic data are obtained at the same time as oxygen isotopic data. The element oxygen occurs in nature as 3 stable isotopes the **common isotope ^{16}O** (99.765%), the rare **isotope ^{18}O** (0.1995%), and the very rare isotope ^{17}**O** (0.0355%). We just pay no attention to ^{17}**O** because it is so very rare.

$$\delta^{18}O = \{(^{18}O/^{16}O)sample / (^{18}O/^{16}O)standard - 1\} \times 100$$

The oxygen isotopic composition of sea water.

It is one of the major problems in isotope paleoceanography that an estimate of the average isotopic composition of sea water. For instance, the strongly negative isotopic ratios measured in well-preserved Paleozoic carbonates suggest that ocean temperatures at that time were over *500C*, which may be unrealistic biologically, or that the overall isotopic composition of sea water was lighter. A change in isotopic composition of sea water over geologic time might have resulted from addition of juvenile water (from the Earth's mantle) with an isotopic signature of +7 to +9%o at mid-oceanic ridges. Hydrothermal alteration of basalts at high temperatures increases the **$d^{18}O$** of seawater even more. Thus the effect of basaltic weathering at low temperatures on the sea floor counteracts the effect of juvenile water input and hydrothermal alteration, with the most recent reports suggesting that the two processes are about in equilibrium. Low-temperature weathering of fresh, crystalline rocks on land also tends to make the isotopic composition of run-off, thus ultimately of sea water, lighter. Therefore it is a possibility that changes in the relative rates of spreading at oceanic ridges and weathering on land might cause changes in the long-term isotopic composition of the oceans. Such changes occur slowly (range: 10^6 years), and thus the isotopic changes as a result of such processes must be slow.

The largest known, and fastest, effect on isotopic composition of the oceans in the Cenozoic (the last 65 million years) has been by the volume of the polar ice sheets. These ice sheets are strongly enriched in the LIGHT isotope of oxygen. This enrichment in light isotopes is a result of the evaporation of water dominantly at low latitudes, and long travel from tropics to poles of water vapor from which more and more relatively heavy water rains out.

Most water on Earth (97.25%) is stored in the oceans, 2.05% in ice (90% of which resides in the Antarctic ice sheet), with the remainder stored as ground water (0.68%), while the water occurring as freshwater (lakes and rivers), as soil moisture, in the biosphere and atmosphere is an insignificant amount. Oxygen isotopic fractionation occurs during evaporation and condensation of water, with enrichment of the heavier isotope in the liquid phase (a = 1.010 at 200C). Water vapor is thus isotopically light compared with the ocean water from which it evaporated, and condensed rain is isotopically heavy compared with the water vapor from which it condensed. Rain that falls inland is therefore more depleted in ^{18}O than rain in coastal areas, because much rain condenses in coastal areas (especially when humid air has to move up to cross mountains), and the remaining water vapor traveling inland has been isotopically depleted.

Cenozoic climates

The oxygen isotopic records from low-latitude and high-latitude planktonic and benthoc fomifera can be studied to derive the The combined temperature and ice volume history of the Earth during the Cenozoic.We can also derive temperature gradients from surface to deep water at low latitude, and from surface waters at high to those at low latitudes. The Cenozoic record clearly shows the following features, which have been recognized at many different sites in the world's oceans and thus can be seen as the record of global changes. During the Cenozoic the $\mathbf{d^{18}O}$ values of benthic and planktonic foraminifera at high latitudes, and benthic foraminifera at low latitudes, increased, but the values in surface.water planktonic foraminifera at low latitudes showed little to no change. The increases did not occur gradually, but in "steps", intervals of sudden change, alternated with stable intervals. Major steps each lasted about 10^5 years (one hundred thousand years) or less, and occurred in the earliest Oligocene (about 35.5 Ma; establishment of the east Antarctic ice sheet), the middle Miocene (13.6 Ma; increase in volume of the Antarctic ice sheet, possibly establishment of the west Antarctic ice sheet and small northern hemispheric ice sheets), and in the Pliocene (about 2.7 Ma, initiation of large scale northern hemispheric ice sheets).

B) Light factor:

Light is of primary importance to plants because they depend upon its energy for photosynthesis. Therefore, in the sea, plants are restricted to the well lighted shallow water zone. In low latitudes bright sunlight penetrates clear water to a depth of about 100 meters in a sufficient quantity be used by plants. The depth of light penetration in water depends upon 4 factors:

1. Intensity of light following on the water.
2. Time of day.
3. Latitude.
4. Clarity of water.

Maximum penetration occurs when light falls from directly over head. When it enters at an angle more light is reflected upward and the light does not reach a great depth. Water absorbs light of different wave lengths differentially. In clear water, the shorter wave length penetrate more and more deeply. The longer waves are used by plants most effectively for photosynthesis. In more opaque turbid water, the penetration of all waves is reduced but the short waves also are filtered out. The clarity of water adjacent to most coasts is highly variable from place to place and from time to time, depending on the depth, nearness to rivers, the type of bottom, and the kind of weather, but all is turbid to some extent. Therefore, plant life is restricted to a much shallower zone in most coastal areas and at high latitudes than in the open tropical oceans.

Animals are not directly dependent upon light but because ultimately plants constitute the food of all animals, light is necessary for their existence. Most marine animals are sensitive to light, whether or not they are equipped with eyes.

Some hide during the day and come forth to fell at night, this does not necessarily mean that light is detrimental to them. The reaction may be one that makes them less conspicuous to their enemies or prey. Sedentary or sessile animals have no need for eyes. They simply wait for food to be brought to them by water currents and live as successfully in darkness as in light. Eyes are as great advantage to mobile creatures, however, and many different kinds of animals possess eyes in various stages of perfection and in various positions.

The efficiency of the eyes of most animals is not known; but there is a little reason to conclude that they are much less perspective of light than the human eye, which can distinguish illumination less than one-millions as bright as sunlight. Faint light (shadows) are discernible in very clear water at a depth of 500 meters, and some light can still be little seen at 666 meters. Photographic plates indicate that a little light reaches 1000 meters but it is too faint to be seen by human eyes. Absolute darkness prevails deeper in the sea. Some of the benthonic animals inhabiting the deep twilight zone have much enlarged eyes but the eyes of others have degenerated and in a few they have completely attrophied.

C) Current and Tides

Is of relatively minor ecologic importance in marine environment, except in the littoral zone where the mechanical energy reaches its maximum. On the whole, currents in the sea are more advantageous to, marine life than they are harmful. They perform a particularly valuable service in facilitating the distribution of many organisms. Spares and the resting stages of plants and the eggs and larvae of animals are moved primarily by currents. Currents and waves are very important factors in the indirect dispersal of the attached and sessile organisms. Wave action is very destructive in shallow water and long exposed coasts. They stir the bottom actively to a depth of 15 m. or more and move the pebbles and even cobb1es along beaches. In the tropics this environment supports a specialized community of organisms that builds extensive reefs.

D) Salinity:

Salinity= the number of grams of solved salts in 1.000 grams of water.

Water can also classify into:

Fresh water salinity< 0.5 g/Kg

Oligohaline salinity 0.5-5 g/Kg

Mesohaline salinity 5-15 g/Kg

Polyhaline salinity 15-30 g/Kg

Euhaline salinity >30 g/Kg

One of the most characteristic features of the sea is its salinity. Sea water consists of dissolved materials of chlorides and sulphates of Na, Mg, Ca, K. Sodium chloride NaC1 is the most common compound, it forms about 80% of the dissolved materials, The origin of these compounds in water of the sea is the result of the dissolving of the minerals loaded by streams to the seas, many of these are deposited as calcite and dolomite, gypsum and anhydrite.

The salinity of the sea is remarkably constant. Salinity of the open sea is about 35 per mille. Surface water varies between 33 and 37 per mille, the concentration being increased by evaporation in some areas and reduced in others by the admixture of fresh water falling as rain, entering from rivers or produced by melting ice. Great variations occur in some partly isolated water bodies such as Baltic Sea, where salinity decreases almost to zero of its head, and the Red sea where the salt content may exceed 40 per mille.

Aqueous organisms are sensitive to salinity because osmotic pressure varies with salt content. If their body fluids are not in equilibrium with the surrounding medium, water passes either into or out of their bodies. Most of organisms can adjust themselves only within a narrow salinity range because of limitations to tolerable concentration of their fluids. Consequently, salinity is an ecologic factor of great importance that determines their possible distribution. More adaptable organisms can control the amount of outflow with respect to inflow through their bodies.

Nitrogen and phosphorus compounds are nutrients necessary for plant growth. They occur in solution in sea water in small amounts but are rapidly depleted. In many parts of the sea the small planktonic plants, like diatoms, lead a cyclic existence that varies with the seasons. Favorable conditions in the spring result in the rapid and enormous multiplication of individuals. This continues until the nutrients are depleted, generally by early summer. Further growth is limited by the rate at which nitrogen and phosphorus compounds defuse upward from the deeps. More or less permanent upwelling currents maintain the fertility of the sea in some regions; particularly near continents where offshore winds cause the depleted surface water to drift away such places are rich in all types of marine life.

The food requirements of aqueous animals are simpler than those of land animals. Being surrounded by water, they can obtain mineral substances by absorption.

Salinity and morphological variations of benthic foraminifera

For survival, growth, and reproduction, each benthic foraminiferal species has specific limits of tolerance to salinity (as well as other factors). Salinity and $CaCO_3$ solubility are closely associated; $CaCO_3$ solubility will be discussed in the following section. If, for a given species, salinity is within the species' normal growth limits, it obviously has no special effect on the morphology of the test. If, however, it is lower, many foraminiferal species become smaller, thin walled, and their ornamentation can decrease or even disappear altogether. The obser-vations in regard to this are numerous and have been made in various environments (Pratje, 1931; I.e Calvez and I.e Calvez, 1951; Morishima, 1955; Furssenko, 1959; Kurc, 1961; Forti and Roettger, 1967; Wright, 1968; many others).

Interesting observations on the importance of salinity for the morphology of foraminifers were made on materials from wells of Kara-Kum and Ust-Urt deserts (Middle Asia). In these wells, several authors found living foraminifers (i.e., with protoplasm) that were very small in size, possessed thin walls and fragile tests, and belonged to genera (and some of them to species) that now inhabit coastal brackish and normal salinity waters of tropical, subtropical, and temperate areas *(Haplophragmoides, Jadammina, Elphidiella, Elphidium, Discorbis, Bolivina,* some Miliolidae; Mikhalevich, 1976, and references therein). The salinity of the ground waters in which these foraminifers were found approaches the salinity of the Aral, Caspian, and Black Seas, which is considerably lower than normal seawater. Apparently these forms, adapted to the interstitial coastal environment after the sea regressed, represent good examples of the effects of lowered salinity on the foraminiferal test. Tappan (1951) recorded that, in cultures of benthic foraminifers, when distilled water was added, tests became thinner and transparent. It should be mentioned, however, that according to Bradshaw (1961), *Ammonia* increases its size in low-salinity water.

Other types of morphological change have also been recorded. Murray (1968, 1973) reported that *Elphidium* in normal-marine conditions was represented by keeled species, while *Elphidium* from mud or brackish marshes was characterized by species with a rounded periphery. There are several observations indicating that foraminifers dwelling in low salinity tend to become deformed. Hofker (1971) recorded abnormal specimens of *Triloculina carinata* in hypohaline waters in Curacao. Brasier (1975) found aberrant forms of *Quinqueloculina subpoevana,* *Triloculina rotunda, T. oblonga,* and *Archaias annulatus* in marginal Caribbean lagoons characterized by fluctuations of salinity. Bugrova (1975) observed several abnormalities in the Eocene benthic foraminifers of Middle Asia (small size, fragile transparent tests, lacking ornamentation, abnormal formation of the last chamber, etc.) and explained them as a consequence of the decrease and fluctuation of salinity in the shallow-water environment. Wang et al. (1985) observed abnormal test morphology in several calcareous species found in the Paleogene and Pleistocene sediments deposited in hypohaline seawater in East China. They illustrated their observations by figures of aberrant individuals of *Protelphidium glabrum, Discorbis vunchengcnsis, Ammonia liuqiacensis,* and *Ammonia* sp. Poag (1978) studied *Ammonia parkinsoniana, ELphidium gunlen. F. galvestonense, Palmerinella palmerae*, and *Ammotiutn salsum* in the U.S. Gulf Coast estuaries and concluded that smaller, thinly calcified ecophenotypes with fewer chambers are typical of environments that are near optimum salinity and temperature conditions for a given calcareous species. Larger individuals with more chambers are characteristic of environments approaching the minimum limit of tolerance for each species. He explained this phenomenon in terms of delayed reproduction, which results in the production of larger tests. Bik (1964) observed that in Miocene brackish-water deposits in Germany, *Nonion demens* had a tendency to produce irregular tests. A closely related species was found alive by Boltovskoy (1958) initially in completely fresh water of the river Parana (salinity 0.1—0.15‰, western part of the fluvial zone of the Rio de la Plata); later this species was found in the same area and adjacent parts of the Rio de la Plata by Boltovskoy and Lena (1971) and later described as the new species *Nonion? pseudotisburyense* by Boltovskoy and Giussani de Kahn (1980). This is the first calcareous multilocular foraminifer found in great quantities alive (with protoplasm) in completely fresh water, and its very thin-walled tests show the same tendency to irregularity as those of *N. demens.*

Very little information is available on the effects of abnormally high salinity on test morphology. Scott and Medioli (1980a) suggested that development of the two ecophenotypes of *Trochammina macrescens* (i.e., forma *macrescens* and forma *polystoma)* depends largely on salinity, with the forma *macnescens* developing in lower salinities (<20%o) while forma *polystoma* develops in higher salinities. Morphologically the two formae are easily distinguishable as forma *polystoma* is characterized by the presence of supplemental areal apertures. According to Shokhina (fide Furssenko, 1959), the test of *Rotalia beccarii* becomes larger in high-salinity environments. Seiglie (1964) and Ayala-Castaflares and Segura (1968) found that in a hyperhaline Mexican lagoon the population *of Ammonia beccarii* had a high proportion of teratological tests. Brasier (1975) also recorded many aberrant forms in a shallow hyperhaline creek of the marginal zone in the Caribbean. Malmgren (1984) found *Ammonia beccanii* living in an environment where salinity reached 92%o (This is the highest salinity in which living foraminifers have been found so far), but he did not find any clear relationship between test morphology and salinity. Scott et al. (1976) found rich populations of A. *beccarii* in lagoons of southern California where salinities ranged from 15 to 68%o; they found no apparent morphological trend either.

In summary, most observations suggest that the effects of abnormal salinity consist of size changes, loss of ornamentation, and increase in percentage of aberrant forms.

E) Calcium Carbonate Equilibria

$CaCO_3$ in the form of calcite or aragonite is responsible for the great majority of all forms found as fossils. Therefore, the availability of calcium carbonate for the precipitation of tests and shells is important in determining the distribution and character of fossil organic assemblages. The stability of $CaCO_3$ shells in sea water is a function of depth (pressure) and temperature. In deep, cold waters $CaCo_3$ is highly soluble, while in shallow, worm waters, the saturation point is reached. Then the thin delicate shells of arctic and deep-water animals as compared with the heavy shells of tropical and shallow water forms. Shell composition, however, sometimes change the proportion of the Sr and Mg to Ca, and too the ratio of O^{16} to O^{18} varies with temperature at least in some groups. Provided the changing in salinity and the diagenetic process, have no interference, it would then be possible to estimate the ancient change in temperature from the evaluation of those proportions in shells and consequently the change in proportion of different salts.

Solubility of Calcium Carbonates

A number of factors control the solubility of $CaCO_3$ in seawater. Revelle (1934) suggested three elements control solubility: concentration of Ca and bicarbonate ions and the value of the temperature-dependent constant $KCaCO_3$. Revelle (1934) went on to say that these elements in turn are dependent on salinity, temperature, and depth (hydrostatic pressure), among other factors. In short, although carbonate solubility is closely linked with salinity, there are many other factors that can counteract higher or lower salinities. Greiner (1974) suggested the following relationships based on $CaCO_3$ solubility: colder, less saline areas are characterized mostly by agglutinated faunae, whereas temperate areas contain regular calcareous hyaline forms and low- to high-salinity tropical areas contain abundant miliolids. There are many more specific observations. The wall of several *Elphidium* species *(E. gunlen. E. incertum, E. excavalurn)* living in the Dos Patos Lagoon (southern Brazil) become thinner in the winter months due to the lower temperature of the water and thus the higher solubility of $CaCO_3$ (Forti and Rttger, 1967). Herb and Hekel (1973) related surface reticulation on specimens of the *Numrn u/it esfabiani group* to $CaCO_3$ solubility. Miklukho-Maklaj and Kashik (1975) observed that the increase in the calcite content of a rock was accompanied by increasing diameters of the tests of *Pseudonodosania nodosaniaform is.* Scott et al. (1977) observed, in low pH (high $CaCO_3$ solubility) estuarine sediments, that the calcareous species *Protelphidium orbiculare* developed an arenaceous sheath with an ultra-thin $CaCO_3$ layer underneath. Furssenko (1978) observed that tests of *Ammonia beccarii* from the Mediterranean Sea are larger and with considerably thicker walls as compared with those from the Black Sea (and particularly the Caspian Sea), explaining this phenomenon by the lower solubility in the former due to its higher temperature. Corliss (I 979a), while explaining the size variations of *Globocassidulina subglobosa*, suggested that the high solubility of $CaCO_3$ at great depths is probably one of the factors responsible for the presence of only uniformly small-sized specimens at those sites. Scott and Medioli (1980b), during a study of seasonal distribution of salt-marsh foraminifers, noticed that in areas of constant high salinity the numbers of calcareous living forms were high in summer (when temperature was > 20^0C) and low in the winter (when temperature was <0^0C). This seems to be in line with Greiner's (1974) reasoning lower temperatures bring about lower availability of $CaCCO_3$.

In summary, $CaCO_3$ solubility is undoubtedly a factor of s importance in controlling the morphology of the foraminiferal test, but it is linked with many other factors. If the solubility low, calcareous species are able to build larger and more robust tests; as solubility increases, tests get thinner and some calcareous species develop alternate morphologies (e.g., Scott et 1977).

F) Oxygen in marine environments:

After nitrogen, oxygen is the second most abundant dissolved gas in seawater. Overall, the ratio of oxygen to nitrogen is about 1:2 in seawater, in contrast to the 1:4 ratio in the atmosphere (Kalle, 1972). The solubility of oxygen varies positively with salinity and negatively with temperature. The amount of dissolved oxygen in seawater (including values of supersaturation) varies between 0 and 8.5ml/l, the usual range being 1-6 ml/l (Tait, 1981), and, unlike in the air, the distribution of oxygen in the oceans may vary widely on the same horizontal plane. Marine ecologists and geologists commonly recognize a pre-anoxic range of oxygen levels within which seawater is significantly depleted in oxygen. The classification of aquatic environments and corresponding biofacies in terms of dissolved oxygen (Tyson and Pearson, 1991) is as follows:

Environment	Biofacies	Oxygen content
oxic environment	aerobic biofacies	8.0—2.0 ml/l O_2
dysoxic	dysaerobic	2.0—0.2 ml/l O_2
suboxic	quasi anaerobic	0.2—0.0 ml/l O_2
anoxic	anaerobic.	0.0 ml/l O_2

The more general physiological or ecological term "hypoxia" indicates a degree of oxygen depletion that would induce a severe stress on marine organisms, without necessarily implying a specific threshold value (Tyson and Pearson, 1991). This threshold, of course, can be observationally defined for a particular area or habitat.

Seawater dissolves oxygen at or close to the ocean surface. The supply comes mainly from the atmosphere, with a small addition from primary producers, i.e., photosynthetic organisms. Ocean-surface waters are often supersaturated with oxygen, because of entrapment of air bubbles and the abundance of oxygen released by producers (Broecker and Peng, 1982). In the upper part of the photic zone, the producers generate more oxygen than they use up by respiration, but a balance is attained farther down the water column. Below this level, the oxygen content of seawater drops conspicuously because of respiration by organisms and the decay (i.e., oxidation) of organic matter. In deep oceanic waters, generally below 1000 m, the oxygen level rises again, in response to the sinking and spreading of oxygen-rich, relatively dense, surface waters from polar or subpolar latitudes (e.g., North Atlantic Deep Water and Antarctic Bottom Water). Thus, in a standard ocean water profile, the least amount of dissolved oxygen is generally recorded at depths of several hundred meters where the utilization of oxygen by organisms and organic debris (resulting in the production of $C0_2$) is high and not replenished by water mixing. This is the oxygen minimum zone (OMZ), present in all major and marginal ocean basins. The least value of dissolved oxygen within this OMZ ranges from <1 to >3 ml/l.

The OMZ is thicker and much more oxygen-depleted in the tropical Pacific Ocean than in the tropical Atlantic, a greater amount of organic matter being oxidized in the former. This, in turn, is related to the higher concentration of nutrients and the higher productivity in the Pacific Ocean photic zone. The development of severe hypoxia in the Atlantic OMZ is also hindered by the fact that the deeper parts of this ocean are more thoroughly flushed than those of the Pacific and the Indian Oceans (Richards, 1965a). Without a source of oxygen resupply in stratified bottom waters, much of the deeper waters of a shallow-silled marine basin or a fjord are likely to become oxygen-poor or even anoxic. In other words, the OMZ would extend all the way down to the deepest ocean floor. The most striking example of this comes from the Black Sea, where a true anoxia has been established below a depth of about 180 m in the past 9000 years (Deuser, 1974). The seawater in this anoxic zone contains hydrogen sulfide produced by bacterial sulfate reduction (Jannasch et ai., 1974), and bacteria are the only long-term survivors in this zone.

Benthic foraminifera utilize the oxygen present at the sediment-water interface and in the pore water. The level of this “habitat oxygen” may be depressed significantly where the sediment is rich in organic matter, because oxygen is consumed in the natural chemical transformation of carbonaceous compounds. In areas of coastal upwelling and other areas of high productivity (e.g., mudflats, salt marshes, and mangrove swamps) large amounts of organic matter accumulate in bottom sediments, leading to an oxygen depletion in bottom waters and pore waters (Valiela, 1984). Where the consumption of oxygen exceeds renewal by water exchange, anoxia results. For endobenthic species burrowing several centimeters into substrates rich in organic matter, the ambient oxygen level (in pore water) may be substantially lower than at the sediment-water interface.

Tolerance limits of most benthic foraminiferal species for physical and chemical factors of the environment, including oxygen, are unknown. Thus, in many instances, although oxygen stress may be the obvious immediate reason for an unusual foraminiferal distribution, the primary reason may lie elsewhere.

Oxygen requirements of foraminifera:

Foraminifera, like most other free-living protozoans, are aerobes, i.e., metabolic consumers of oxygen. The oxygen is taken by the organism from seawater, transported by diffusion through the cell, and used in the mitochondria to produce energy by the oxidation of organic molecules of food matter. Apparently, pores in the test surface, if present, facilitate the intake of oxygen and the release of $C0_2$, a metabolic product (Hottinger and Dreher, 1974; Berthold, 1976; Leutenegger and Hansen, 1979). Clusters of mitochondria have been observed near inner terminations of pores in a few benthic foraminiferal species that are tolerant of hypoxia (Fig. 1), suggesting an evolutionary linkage between these pores and mitochondria (Leutenegger and Hansen, 1979).

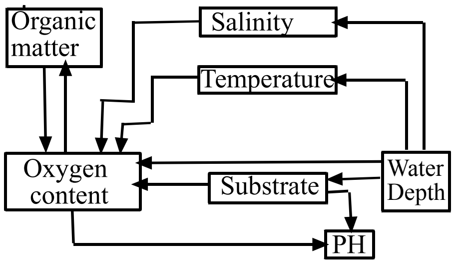
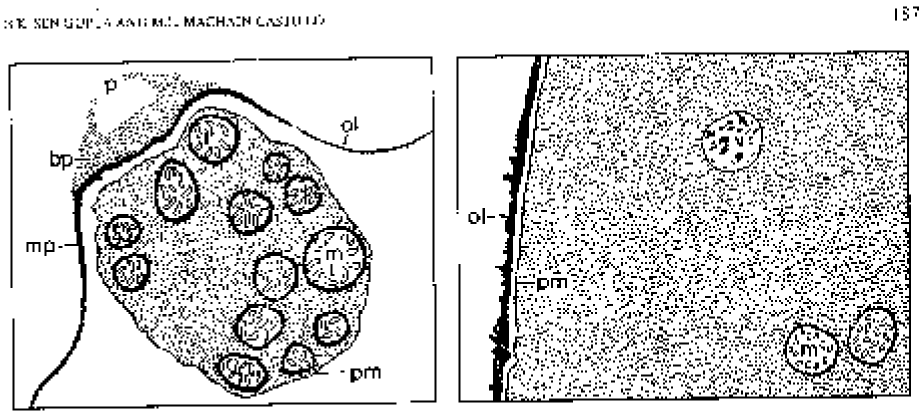


Fig (1): Common variables in the physical environment affecting benthic foraminiferal distributions. Arrows indicate interrelationships of variables

On the basis of rather scant data, it seems that in calcareous perforate species typically adapted to well-oxygenated waters, the mitochondria are generally more uniformly distributed through the cytoplasm, although clustering of mitochondria near pore terminations is also known (Berthold, 1976; Leutenegger and Hansen, 1979). Because of a distinct infaunal habit, some agglutinated species (e.g., *Haplophragmoides bradyi* and *Glomospira charoides)* seem adapted to hypoxia, but the gas exchange processes of agglutinated foraminifera are unknown (Mackensen and Douglas, 1989). The function of parapores, present in some agglutinated species of well-oxygenated waters, is unclear; the uptake of dissolved organic matter, rather than gas exchange, has been suggested as a possibility (Hottinger et al., 1990). Relevant to the survival of hypoxic foraminiferal species is the fact that sarcodines, in general, have lower respiration rates than flagellates and ciliates of comparable sizes (Fenchel, 1987).



Fig(2): Mitocohondria in benthic foraminifera.

As a rule, marine species can tolerate significant variations in the oxygen content of the ambient water. Furthermore, many species of diverse taxonomic affinities can exist in relatively oxygen-poor habitats for a considerable length of time (Theede et al., 1969). If all oxygen is removed from marine waters, the process of sulfate reduction begins and sulfide (undissociated H_2S and HS^-) is produced in the sapropelic substrate. Sulfides are toxic to organisms other than anaerobic bacteria; their occurrence in the environment is a “near-catastrophic event” (Richards, 1965b). However, some protozoans are definitely known to live under anoxia (e.g., Noland and Gojdics, 1967). One of the better field documentations is for ciliates from an anaerobic lacustrine environment (Webb, 1961). The majority of these species are facultative anaerobes, surviving also in well-oxygenated habitats. Webb suggests that some ciliate populations increase in the sapropel simply because bacterial food is more available in this environment, and that 3ome related chemical and biotic factors may be more important than the oxygen gradient in controlling these ciliate distributions. The trophic connection of these facultative anaerobes is highlighted by the fact that the species often begin to proliferate before the attainment of total anoxia. Experiments performed on other anaerobic ciliates have shown that their time of survival under anoxia depends on the rate of degradation of stored carbohydrates (Beadle and Nilsson, 1959). Among other protozoans, the respiration of one soil amoeba is actually stimulated by low concentrations of H_2S, which undergoes oxidation. At somewhat higher concentrations of H_2S, the species survives partial inhibition of respiration by using alternative electron-transport pathways instead of the main respiratory chain. Beyond a critical H_2S level, however, mortality is caused by the irreversible destruction of the respiratory system (Lloyd et al., 1981). Although living foraminifera have been reported from sed-iments with H_2S (Alve, 1990), no information is available on the tolerance of any species to varying levels of this toxic gas.

G) Nutrition

Hallock (1987) proposed that diversity of habitats in surface waters of the oceans is partly controlled by nutrient availability, which explains why taxonomic diversity often appears to be inversely related to nutrient supplies (Longhurst. 1967). Habitat diversity should be inversely related to nutrients because: (a) food-chain length and complexity tend to be an inverse function of food supply, (b) eutrophic (nutrient-rich) environments are inherently unstable, and (c) the great depths of low-nutrient (oligotrophic) euphotic zones provide much greater potential for specialization to narrow ranges of light intensity than do the shallower and more variable euphotic zones in areas influenced by upwelling, runoff, or seasonal blooms (Hallock, 1987).

The relationship between taxonomic diversity and nutrient supply is even more complex. Hallock (1987) emphasized that some taxonomic groups cannot take advantage of the potential plethora of niches in low nutrient environments because they metabolically require more energy than is available under such conditions. For example, diatoms and marine vertebrates diversify when nutrients are abundantly available. General patterns of competitive response to nutrient supplies are well known for phytoplankton (Rhyther, 1969). Diatoms bloom and flourish where upwelling or other sources of turbulence supply abundant nutrients. Dinoflagellates succeed the diatoms as nutrient supplies decline and/or physical stability is established. When nutrient supplies are scarce, nano- and picoplankton, including coccolithophorids, dominate the phyto-plankton. A dominance gradient also occurs in shallow-water benthic communities (Birkeland, 1988). Where nutrient supplies are abundant, dense plankton communities limit light penetration to the benthos, which is dominated by suspension feeding animals. At intermediate nutrient supplies, water is sufficiently clear to support benthic communities dominated by macroalgae or seagrasses.

In modern oceans, high latitude sea-ice formation provides an active source of deep-water formation. Hallock (1987) proposed that changes in rates of oceanic circulation should influence the global nutrient gradient in surface waters of the oceans (Fig.1a). Reduced rates of oceanic circulation would result in expanded global gradients, because subtropical gyres would become more nutrient deficient, while the upwelling zones might be locally richer because older subsurface water had more time to accumulate fluvially-supplicd nutrients. Increased rates of oceanic circulation would result in better mixing of nutrient resources and therefore in reduced gradients. A comparison of the modern gradients in the Atlantic versus the Pacific provide something of an analogy. The older subsurface Pacific waters promote richer meridional upwelling zones than those of the Atlantic. Yet the subtropical gyres of the Pacific are more remote from advected nutrient sources and are therefore consistently more nutrient poor than those of the Atlantic (Fredericks, 1970: Birkeland, 1987).

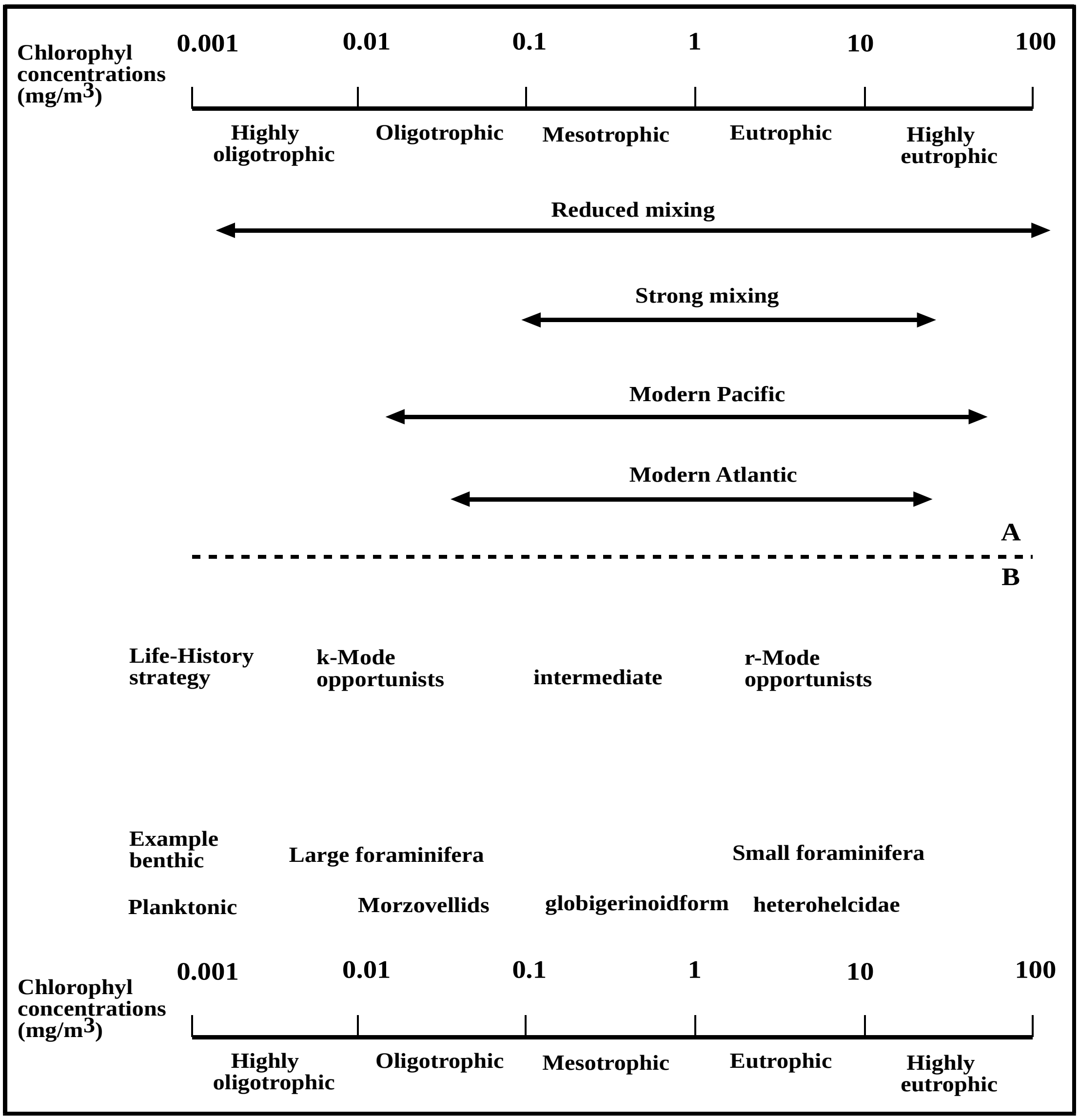


Fig.1a. A representation of the oceanic surface-water trophic-resource continuum (TRC). b. Paleogene life-history strategies and trophic resources

Nutrient flux provides a key link between global-tectonic and climatic cycles and biotic cycles.

Global cycles in nutrient flux should influence both planktonic communities living in oceanic waters and carbonate shelf communities bathed by those oceanic waters and with limited local terrigenous influence (Hallock, 1 987). The Paleogene is characterized by transition from globally equable climates to the strong thermal gradients of the glacial world. These changes undoubtedly involved changes in oceanic circulation rates and therefore changes in rates and patterns of nutrient flux to surface waters. Two groups of organisms that are sensitive to nutrient supplies are the larger benthic foraminifera and the planktonic foraminifera

Trophic resources and foraminiferal assemblages

Within the water column in mesotrophic to oligotrophic oceans, there is a gradient in trophic resources that can support a diversity of taxa. Benthic communities are also strongly influenced by nutrient resources (Birkeland. 1988). Hallock et al. (1988) characterized response of carbonate platforms to nutrient resources. Under the most nutrient-deficient) conditions, carbonate buildups are dominated by coral /coralline framework and larger foraminiferal sands. As nutrient supplies increase relative to coralgalframework production and calcareous-algal production increases, so that muds and bioeroded debris become increasingly prevalent. High energy, meso- to mildy eutrophic environments are characterized by coralline algal crusts and rhodoliths. As nutrient supplies increase in warm, shallow Waters. Miliolid and soritid foraminifera predominate over larger hyaline taxa. However. modern *Heterostegina* and *Operculina* flourish (Tudhope and Scoffin. 1988) under mesotrophic conditions that promote *Halimeda* bioherms on relatively deep (30-50 m) banks (Drew and Abel. 1988). More eutrophic conditions eliminate photosynthetic carbonate producers in favor of heterotrophic suspension feeders such as bryozoans, barnacles, and bivalves (Birkeland. 1988: Hallock et. al., 1988). As nutrient supplies further increase, oxygen becomes limiting at the sediment water interface, and so carbonate production is limited to taxa able to tolerate low oxygen concentrations.

Thus, both pelagic and benthic carbonate productmon is active in oligotrophic to mildly eutrophic waters. Under truly eutrophic conditions, short diatom-based Food chains eliminate most planktonic foraminifera and coccolithophoroides, while high CO_2 Concentrations in subsurface waters severely limit carbonate preservation. In benthic communities beneath mildy eutrophic waters, bioerosion and dissolution eliminate most carbonate production, unless burial is rapid.

Ecologists and paleoecologists often categorize organisms by their life-history' strategies, specifically their reprodtictive potential (Valentine, 1973). At One extreme are r-mode opportunists, able to rapidly increase their population densities, usually by early maturation and reproduction. Opportunists proliferate in resource-rich, low-stability regimes where their numbers fluctuate widely. At the other extreme are k-mode specialists, characterized by' long individual life and low reproductive potential. This life-history strategy is most advantageous in highly stable, typically oligotrophic environments where organisms compete by specialzation and habitat partitioning. In between are the whole range of organisms adapted to mesotrophic environments. Where tendencies towards r-or k-mode strategies vary, rendering this terminology primarily useful for relative comparisons.

In foraminifera, size is often directly related to reproductive potential: the faster a foraminifer matures and reproduces, the higher its reproductive potential (Hallock, 1985). Thus, as a general rule, smaller foraminifera tend more towards the r-mode end of the reproductive spectrum, while larger foraminifera tend towards the k-mode end (Fig.1b). The characteristics of larger foraminifera, i.e., relatively long life, growth to large sizes, morphologic complexity, and dependence on symbiotic algae, are all integrated into their k-mode life-history strategy (Hottinger, 1982, 1983), which is adaptive in stable environments low in trophic resources (Hallock, 1985). Larger foraminifera that Hottinger

(1982, 1987) considered k-strategists characteristic of oligotrophic euphotic environments include the alveolinids, nummulitids, disco-cyclinids, and miogypsinids.

Similarly, planktonic forarninifera exhibit the full range of life history strategies. Opportunistic species are typically small, morphologically variable, widely distributed, and rapidly increase in abundance when nutrients become available. K-mode planktonics may be larger, morphologically more complex and specialized, host algal symbionts, and should be most diverse in oligotrophic waters where they compete by specialization and habitat partitioning.

Typical Paleogene opportunistic foraminifera (Fig.1b) include the biserial heterohelicids, triserial heterohelicids. *"Planorotalites'' eugubinus,* low-spired subbotinids, tenuitellids, and *Globigerina praebul/oides.* These forms were cosmopolitan, morphologically generalized and highly variable, and proliferated in large numbers in equatorial upwellings. They also become highly dominant at various levels in the stratigraphic succession.

Difinitions:

Eutrophic: waters that are rich in nutrients and plant life. Lower parts of eutrophic lakes may suffer from lack of light and oxygen. Eutrophic areas are characterized by a well-mixed upper water column, a shallow thermocline, and low-diversity communities composed largely of opportunistic species, r-mode specialists.

Oligotrophic: water that are relatively low in nutrients and cannot support much plant life, such as the open oceans and some lakes. Oligotrophic areas such as the central gyres are characterized by stable water column structure, a deep thermocline, and diverse phytoplankton communites dominated by specialized species, known as K mode specialists.

Eutrophication: rapid increase in the nutrient status of a water body, natural or occurring as a by-product of human activity.

II. Chemical Factors

a) Alkalinity-acidity (pH)

The hydrogen ion concentration (pH) of an environment is an important factor in determining weather or not certain minerals will precipitate. In strong acid environment, the carbonates will not be deposited (acidic environment, pH less than 7.0, neutral environment, pH 7.0-7.8, alkaline environment pH over 7.8). Silica dissolves in the alkaline medium and devosited in acidic one. Marcasite (iron sulphide) indicative of acidification subsequent to deposition. Kaoline requires an acidic medium_for its formation.

Marine plants can tolerate or exist in environments with pH ranging between 5.0 and 10.0 and many animals can tolerate the same wide range.

b) Oxidation-Raducition Potentiol (Eh)

Sediments are deposited under either oxidizing (aerobic) or reducing (anaerobic) conditions. The irons minerals are most useful in determine the Eh of the environment. Deposition of hematite indicates aereated (oxidizing) environment. Iron sulphides (pyrite or marcasite) signifying a reducing or oxygen-deficient medium. Siderite is indicative of intermediete oxidation potential.

Based on the Eh, the cheimical environment is subdivided into:

-Sulphide zone (strong reducing).

- Reducing zone (iron carbonate and iron sulphide)
- Weakly reducing zone (siderite and vivianite)
- Neutral zone (iron rich chlorites)
- Weakly oxidized zone (gluconite)
- Oxidized zone (ferric oxide and hydroxide)

Other criteria of low oxidation potential are the absence of normal benthonic fauna and the presence of only such forms as can tolerate the toxic conditions produced by oxygen deficiency or those forms which are wholly free swimming or are attached to floating objects. In the former category are certain phosphatic brachiopods, especially Lingula and Discina. Conodonts, occasional fish remains and spores and pollen complete the fauna or flora of these shale formed in a highly reducing environment. Burrowing organisms, such as clams or some worms, may occupy aerobic sediments while utilizing oxygenated water from above the substrate.

III. Biological Factors

A) Dispersal and migration

The ability of a certain species to disperse is kind to all possible habitat, that are available is a significant factor is determining its ability to survive in the sea. Attached bottom-dwelling forms, both plant and animal, have to depend entirely on the success of planktonic larvae, eggs, or spores to be carried by currents to areas favorable to their growth and development. Because of this rather inefficient method of distribution, tremendous numbers of the embryonic forms are necessary in order for some of them to settle in satisfactory environments. Swimming or vagrant bottom-dwelling animals may also have planktonic larvae or eggs, for example, the mollusks, echinoderms, and most fish. Bottom-dwelling fish generally lay their eggs on the shallow shelf area where they hatch, and the fry become floaters until they can swim with enough power to over come prevailing currents.

By for the greatest amount of dispersal within a population takes place in the mobile larva and other immature forms, but adult individuals also contribute to dispersal of the specie. With the exception of attached form they wander about in search of food and/or shelter. In doing so, they can and frequently do extend their area of distribution when favorab1e conditions are encountered. There are numerous physical and chemical barriers to this type of migration and dispersal.

b) Food

Sea water contains a large amount of particulate organic detritus in suspension in addition to many forms of tiny plankton. Many different kinds of marine animals feed on these food sources by filtering out the solid materials, Filter feeders include many small floating animals, shel fish, worms, sea lilies and others.

Many bottom dwellers and some swimming animals are scavengers that feed selectivdy on available plant and animal debris. In addition, there are predacious carnivores that feed on specific type of animals.

c) Space

There is little problem among the floaters and swimmers as for as crowding in the sea in concerned. The only significant limitation on these organisms in this respect is overderm and on the food supply; there is no problem of lock of space to physically support the population. Such is not always the case with bottom-dwelling organisms; however it is not always possible to distinguish between crowding for space and crowding for the food supply. Actually there may be competition for other things as well oxygen, sunlight or a desirable substrate type.

Competition for these necessary elements may take place between individual of the same or different species. crowding that might be detrimental in one environment would not be so in another due to differences in availability of light, food, and other necessary elements of environment.

Biologic aspects in palaeoecology

Every species of organism is adapted to some preferred environment that is more or less definitely limited. The environment is not known accurately for most fossil species, but generalizations can be made with respect to many groups and types of fossil based on observations of their occurrence in the rocks and by analogy with living organisms. These generalizations are variously useful in the identification of poleoenvironment.

Land plants

Most land plants possess well-differentiated roots, sterns and leaves. They are the only plants that are preserved as abundant and conspicuous fossils. With few exceptions, they identify terrestrial or fresh water deposits. Details of cellular structures, if these can be observed, provide information with respect to some features of climate and may indicate whether it was wet or dry, equable or marked by seasonal extremes. Fruits and reproductive organs also suggest environments because spores require much moisture but seeds are capable of germinating in relatively dry situations. Most plants preserved as fossils grew in lowland areas. Very little is known of upland floras in periods older than tertiary because sediments rarely accumulated and were preserved in such places. Environmental interpretations based on lowland florae of course do not apply to other terrestrial regions.

Planktonic plants

All pelagic plants are planktonic most are microscopic, and except for diatoms, few are likely to be fossilized, they are widely distributed in both fresh and solt water. Fossils are not commonly observed, however, except at places where detrital sedimentation was very slow and their remains accumulated in enormous numbers. These fossils give little information about sedimentary conditions except to indicate that deposition probably was slow.

Calcareous algae:

These benthonic plants require shallow, well lighted and relatively sediment-free water. They have been important as calcium carbonate produces and also as agents that bind loses calcareous materials as on organic reefs. Calcareous algae are rarely well preserved as fossil but their remains are believed to have been identified in limestone dating for back into the Precambrian. Several types of encrusting or nodular bodies in limestone are suggestive of these plants especially if microscopic study reveals obscure cellular structure.

Foraminifera:

The protozoan most commonly observed as fossils are foraminifera. Most species are marine benthonic forms and they are confining to more or less definite zones determined by temperature salinity and nature of the bottom.

The largest foraminifera occur in shallow, typically marine water of the tropics. Some forms adhere to seaweeds or other objects rose above the sea bottom. Generally these can be identified because then shells show guidance of attachment. A few genera, such as *Globigerina*, are planktonic and are widely distributed without regards to conditions in deep water or on the bottom.

Sponges:

Sponges are sessile benthonic organisms that inhabit many different environments in both shallow and deep water Most of them occur in shallow, clear water situations, but fossils are abundant at some places in very silty strata that appear to have accumulated rapidly. Sponge fossils, however, are not common except for disarticulated spicules. On the whole they provide little environmental information's.

Corals:

Corals are exclusively marine they are adapted to a variety of environments but most of them required shallow and relatively clear worm water. Corals begin their growth attached to some hard object later they may break loose or grow outward over soft bottom sediment some solitary corals are common in argillaceous sediments, but deposition must have been slow, or they would have smothered. Colonial corals generally are more restricted. Their fossils ordinarily indicate well aerated shallow water uncontaminated with much suspended sediments. Reef building corals mostly are restricted to depths of less than 250 feet reefs of greater thickness indicate either that sea level has risen or that the reefs grew upward as the bottom sank.

Graptolites

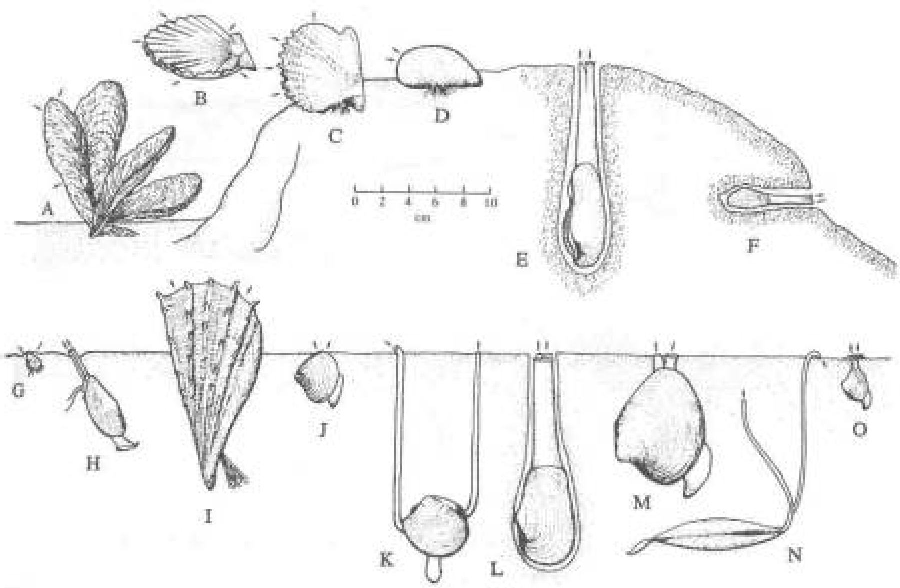
Graptolites are extinct, early Paleozoic, colonial fossils of doubtful zoologic affinity. Most commonly they have been considered hydrozoans although some similarity to hemichordates has been rated. Some members of one group of graptolites were attached to hard objects and grew upward from the sea bottom. They occur in various kinds of sediments. Little is known about their environmental implications accept that sedimentary deposition probably was slow. Others were suspended from floating objects or developed. flating organs, and these planktonic condies had wide geographic ranges. They are preserved mainly in dark shale that appears to record the existence of oxygen deficient bottom conditions inhospital to most benthonic organisms.

Brachiopods:

These bivalve animals are the most important fossils occurring in Paleozoic rocks but they were largely supplanted by mollusks in later time. Brachiopod has always been exclusively marine organisms. Most of them were sessile creatures living on the surface of the sea bottom and attached by fleshy pedicle to some hard object and also possibly to seaweed. In some, the pedicle degenerated and these existed free upon the bottom but were incapable of movement. In a few, like lingula, the pedicle became specialized as an organ of locomotion and these burrowed in muddy bottom or perhaps moved clumsily upon the surface. Different brachiopods were adapted to so great a variety of environments that few Paleozoic fossil assemblages occur without representatives of this group. Most brachiopods, however, inhabited relatively clear water where the bottom was firm and stable. These fossils are most abundant in limestone and calcareous shale.

Pelecypods:

Pelecypods live abundantly in both marine and fresh water. Most of them are free mobile animals that obtain their food by filtering suspended matter from the surrounding water. Many bury themselves in loose bottom sediment or plow through it by action of their so-called foot. After becoming established in favorable situations, some of them move very little but others are more or less continuously active. A few can swim swiftly for short distances. Some leads a sedentary existence, however, cemented to rocks or other resistant objects or attached by an adhesive byssus. Clams of this type occur closely crowded together in enormous numbers at some places. Pelecypoda are adapted to a wide variety of environments and are abundantly represented in very shallow turbid water where many other kinds of organisms cannot live.



Ecology of pelecypods

Gastropoda

The gastropods are a group of highly successful animals that include water breathers in both marine and fresh water and air breathers, many of which are terrestrial. Most of them are active although they move slowly on their foot. Most marine gastropod live upon the bottom or among sea weeds but some are burrowers in loose sediments. The principal food of gastropods is vegetation, which they shred with tongue-like organ equipped with rasps. Some, however, eat carrion and a few are carnivorous and attack living pelecypods. Gastropods occupy many marine environments but most prefer warm shallow water with abundant plants. Non-marine species inhabit streams, ponds, and lakes, and terrestrial forms occur in many damp shady situations in tropical and temperature regions.

Cephalopods

Cephalopods are the most active and highly organized mollusks. They are exclusively marine organisms. Mainly predatory carnivorous animals, they all can swim effectively in pursuit of prey and to escape their enemies. Many shelled cephalopods that occur as fossils probably lived mostly on the bottom, and different species were adapted to different bottom conditions. Some of them, however, evidently were nektonic because their shells locally are common in dark sediments recording an environment inhospitable to most benthonic organisms. Some empty cephalopod shells float long distances and they may finally sink and be buried far from places where the creatures lived. For this reason, and because of their swimming habits, fossil cephalopods generally are less indicative of environmental conditions than many other animals.

Trilobites

Trilobites were exclusively marine animals that became extinct at the end of Paleozoic era. Most of them were benthonic creatures that crawled upon or burrowed shallowly in the bottom. They could also swim but probably few of them did more than skim along the bottom or rise occasionally short distances in the water. Trilobites were not equipped with pinching claws and therefore could not have been effective predators. Probably most of them were scavengers and surface mud eaters although they may have captured small slowly moving creatures. Trilobites occur in various types of fine-grained sediments most of which appear to have accumulated in quite water. Some species, however, were adapted to turbulent conditions on and adjacent to organic reefs.