Meetings

Report on Symposium "Marine Plankton and Sediments" and Third Planktonic Conference, Kiel, September 9-13, 1974 by G. VILKS, Atlantic Geoscience Centre Bedford Institute of Oceanography, Dartmouth, Nova Scotia.

The theme of the conference was to try to reconstruct paleoenvironments of the oceans on the basis of the knowledge of existing processes in the water column and at, or below the sediment-water interface.

The papers dealt with foraminifera, radiolaria, diatoms, coccolithopores, dinoflagellates and others. Cretaceous to Recent was the most widely discussed time interval. Of the 19 morning papers 7 dealt with processes occurring in the Recent environment and below the sediment-water interface, 4 dealt with methods, 6 with stratigtaphy and 2 with paleoenvironments. It has been recognized for some time that dissolution of both calcareous and siliceous material in the water column and deep sea sediments make detailed stratigraphy difficult. Large effort has therefore been placed in trying to understand the biological-chemical-physical cycles of the fossil-bearing microplankton in the oceanic environment.

A major impact on the ocean geoscience has been the Deep Sea Drilling Project (DSDP). In addition to the large number of deep-sea piston cores collected largely by the United States oceanographic institutions, the DSDP provided a wealth of material deposited from the time when the present ocean basins began to develop. This material has been utilized both by geochemists and micropaleontologists to provide a basis for the following: the construction of models depicting the changes in the ocean environment as the continents separated, the occurrences and causes for hiatuses in the sediment column for the last 60 MY, the major localities of chert deposits including probable explanations for the formation of chert, bottom and surface ocean paleotemperatures, and the synoptic plots which can be used to infer ocean paleodynamics within a given time interval. The sedimentary record is best for the Neogene, in which the paleontological and paleomagnetic information is used together to define stratigraphy of the ocean sediments.

Although the majority of papers dealt with baseline studies, it was still felt that more work along these lines should be carried out in the future. This was evident from the recommendations for future work proposed by the various working groups.

Planktonic foraminifera:
1) Culturing of species for a better understanding of life cycles,
2) The process of shell formation with expanded SEM work,
3) Paleoecology
4) Standardization of taxonomy - a symposium is needed
5) Calibration of planktonic foraminiferal stratigraphy versus other plankton
6) Development of statistical methods - modelling of paleoenvironment, etc.

Diatoms:
1) Culturing of offshore and nearshore species,
2) Set up a standardized ecological data bank,
3) Problems of preservation,
4) Techniques for a better understanding of the conversion of assemblages from biocoenoses to thanatocoenoses,
5) Standardize stratigraphy based on diatoms,
6) Improve systematics by publishing a catalogue and extending research in biomatics.

Silicoflagellates:
1) Culture living species to understand life cycles,
2) Problems dealing with ecotypes,
3) Utilize DSDP core samples,
4) Study ultrastructures with SEM
5) Arrange a symposium.

Dinoflagellates:
1) Culture living species to understand life cycles,
2) Investigate problems of preservation,
3) Improve relationships of neontologists versus paleontologists,
4) Standardize stratigraphy.

Coccolithophores:
1) Standardize nomenclature,
2) Investigate dissolution,
3) Prepare distribution charts using DSDP data,
4) Restudy DSDP early samples.

Organization

The conference was organized by the Scientific Committee on Oceanic Research (SCOR) Working Group 37. It was held in the various lecture rooms of Kiel University's Auditorium Maximum. The entrance hall of the auditorium contained displays and demonstrations, and was sufficiently large to contain all the participants during the breaks in sessions. The number of attendants was nearly 300.

The program was divided into two parts: The morning sessions from 0830 to 1300 hrs. contained invited papers, each given one hour and for the afternoon sessions, four of which ran concurrently from 1530 until 1930, each paper was given 15 minutes. The morning sessions and afternoon sessions on planktonic foraminifera were held in a large auditorium with good acoustics and projectors.

The morning papers provided the general theme for the day (of interest to all specialists) and were attended by everyone. The afternoon papers were more specialized and were presented in the various concurrent sessions.

September 9

Morning session: The four papers dealt with oceanographic factors influencing the distribution

of plankton, factors determining the biogeographic patterns of planktonic foraminifera, mechanical processes influencing the distribution of pelagic sediments and deep-sea carbonate sedimentation in view of the dissolution patterns of carbonate in the water column.

The paper given by Zeitzschel from Kiel reviewed the status of present knowledge of plankton production, dispersion and sinking. Briefly, the production of planton depends on the vertical movement of water and productive areas in the oceans are found where the vertical mixing is prevalent. Dispersion is facilitated by tidal currents, surface waves and internal waves. Sinking of plankton follows Archimedes Law; however, mechanisms of keeping plankton in water are not entirely dependent on morphological features of the skeletons, but also on metabolic activity of the animal, viscosity of water and motion of water within the euphotic zone. The latter refers to small cells of downwelling and upwelling.

Allen Be from Lamont presented his paper in two parts: the biological aspects of planktonic foraminifera, including sample-collecting technique by diving, and biogeographic patterns. In the first part the ability of planktonic foraminifera to devour large animals was demonstrated by photographs showing an amphipod being eaten by *Globigerinella aequilateralis*. The digestion was taking place extra-cellularly with pseudopodia enwrapping the animal. He demonstrated also that some planktonic forams are entirely herbivores (e.g. *P. obliguiloculata* feeds on algae). Of the species studied, 6 were carnivores and 4 were herbivores or omnivores demonstrating that planktonic forams occupy more than one trophic level in the food chain. Symbiosis of certain surface-dwelling species such as *G. sacculifera* was also demonstrated. Good photographs showed that pores are closed with membranes containing perforations for the excretion of waste only. The second part of the paper discussing biogeography did not contain new material and the speaker was not permitted to finish his paper, due to running over his time limit.

Seibold from Kiel discussed mechanical processes in the deep sea environment responsible for the sedimentation and re-distribution of the sediment. In certain parts of the ocean the aolian sediments are important. The distribution of these sediments is influenced by surface currents. Conversely, deep-water current influence very little the settling of fine sediments. Fine sediments including diatoms and coccoliths sink as aggregates. At the sediment-water interface - bioturbation is an important factor in the redistribution of sediments both horizontally and vertically. With this mechanism, fine sediments are resuspended and in areas of bottom currents, redistributed. Along slopes, slumping causes redistribution requiring very low inclination of the bottom. Associated with the distribution studies of sediments, current studies are essential including those on the theoretical geostrophic currents and tidal currents. The detection of bottom currents can be facilitated by bottom photographs which show scour, and inclination of sessile bottom organisms. Various bottom features shown on side-scan images can also demonstrate the presence of bottom currents. Size analysis of sediments and some species assemblages may be used to identify areas of continuous deposition. In core profiles shear strength of sediments increases gradually with depth, however discontinuities can be detected by anomalous shear strength-core depth relationship.

Berger from Scripps discussed the complex patterns of carbonate dissolution in the water column. The $CaCO_3$ content in the water column decreases with depth and a sharp decrease usually is present at the calcium carbonate compensation depth, although the relationship of the amounts of $CaCO_3$ in the water column with the lysocline is poorly understood. The questions was raised whether the mapping of carbonate facies of the seabottom really indicates the dissolution patterns of carbonate particles. Among the complicating factors are the productivity of the surface waters and physiography of the seafloor. In the Atlantic the carbonate compensation depth is at 5.5 km, rapidly shallowing towards the continents. At the continental margins both negative and positive correlation of CCD with plankton productivity can be found. It is suggested that mapping the dissolution rates of $CaCO_3$ is more helpful in determining the sedimentation of carbonate.

Highlights of Morning Session

The morning session provided a baseline background for the various topics to follow. Mechanisms responsible for plankton production are reasonably well understood, but those involving the sinking of skeletons and redistribution on the bottom are complex. Dissolution of carbonate is poorly understood and because of the importance of paleostudies, this aspect of plankton research should be expanded. The first steps in the understanding of the natural history of planktonic foraminifera were shown and the entirely new aspect of planktonic forams being carnivores was convincingly demonstrated.

Session 1: Planktonic Foraminifera (General)

In this session, living and preserved specimens at the sediment-water interface were compared in waters off New Zealand, the continental margin off west Africa and in the Canadian Arctic. In each case the thanatocoenoses were modified by dissolution of the more fragile foram tests. The study area off New Zealand contained various watermass boundaries with specific faunas. These faunas did not correspond to forms found on the bottom primarily due to dissolution as a result of depth or relatively recent migration of watermass boundaries. The continental shelf off west Africa is an area of upwelling and here the faunal contents in the surface waters contained species normally living in deeper levels in mid-ocean water, e.g. *Globorotalia menardii*. The effect of dissolution and redistribution of skeletal material was demonstrated, and indicated that in areas of upwelling the dead assemblages may not have a simple relationship with the living population in surface waters. A similar situation exists in the Canadian Arctic archipelago where, in Lancaster Sound, the product-

ive surface waters produce a fragile phenotype of the planktonic foraminifera *G. pachyderma*, which is dissolved in the water column. Less productive waters to the west of Lancaster Sound contain more resistant phenotypes which are preserved in sediment.

A unique assemblage of planktonic foraminifera for tropical waters of the continental shelf of Persian Gulf was discussed. Here a small foram resembling the subarctic species of *Globigerina quinqueloba* was found in large numbers and associated with a form called *Guembelitria vivans*. The latter species is a triserial form and the author proposed that it is planktonic. This paper created a discussion of the questions, what are typical features of planktonic foraminifera versus benthonic and, how does one go about separating the two in fossil populations.

This section also contained a paper devoted entirely to the study of scanning electron photomicrographs. It was demonstrated that juveniles of all species lack spines. Spinal growth starts from the primary organic layer of the test and is not structurally connected to the test wall and therefore can be readily removed. The spines of *Hastigerina pelagica* are different in that they originate on the surface of the test. The pustules of *Globorotalia menardii* also originate on the test wall as a direct outgrowth. The keel of this species is divided in "spaghetti"-like striae which are directed towards the aperture in a rope-like form.

Comments on Session 1

The complex patterns of preservation and production of planktonic foraminifera in marginal oceanic waters was demonstrated. Although the problem of dissolution of skeletal material also exists in other types of environment, the areas of upwelling and mixing provide an environment for a large turnover of biomass. Here normally the more soluble tests are produced, which are less readily preserved in the sediment. The existence of anomalous faunas for a particular environment was also demonstrated, with corresponding implications in taxonomy and paleooceanography.

September 10

Morning session: The four invited papers dealt with processes controlling siliceous biogenous deposits, Quaternary paleoecological problems of plankton, Cenozoic and Mesozoic pelagic sediments and the occurrences and causes of major hiatuses in pelagic sediments.

G.R. Heath from the School of Oceanography, Oregon State Univ. gave an excellent talk on silica in the ocean as a source for microplankton, its deposition and diagenesis. Silica is supplied to the oceans via rivers, as glacial flour, halmyrolysis and metamorphic processes of bedrock. The fixation of dissolved silica is associated with upwelling and thus productive zones of the ocean. The dissolution of silica is complex and mostly takes place in the upper layers of the waters as organic oxidative dissolution, although here the skeletons may be protected to some extent by organic coating. The inorganic dissolution takes place on the sea-floor and the rates are more dependent on chemical equilibria. Silica reaches the sea-floor in the form of pellets that are broken and redistributed as a result of bioturbation. As a result of these processes only about 5% of the fixed silica is preserved. The rates of preservation are higher in sedimentary basins.

The record of preserved siliceous material is reasonably good in Quaternary sediments, below which the data have only qualitative meaning in terms of micropaleontology. Deep-sea cherts are absent in areas close to the source of terrestrial sediments and in areas of sediments younger than 40 million years. Relatively young cherts occur in areas of rapid sedimentation with early exposure to high temperatures. In the diagenesis of siliceous material, several steps can be recognized such as infilling of voids, and the forming of micrite-christobalite. Christobalite is common in all cherts although it is relatively unstable.

J.D. Hays from Lamont discussed paleoecological problems of radiolaria for the interpretation of past climates. The talk was based on the material from his Antarctic cores and the data were analyzed using Imbrie-Kipps method for the determination of apleotemperatures with radiolarian assemblages. The method works in the South Atlantic but not in the South Indian Ocean. Some of the species may respond to factors other than temperature and therefore the tolerance of living radiolarian species to the various ecological parameters must be sudied. Among the unknown factors are the depth habitats of the various species. At the present time *Cyclodiphora divisiana*, a cosmopolitan deep-living radiolarian species, can be used in the determination of the Holocene-Pleistocene boundary, the South Atlantic cores. This species appeared in large numbers during that time.

B.H. Funnell from the University of East Anglia discussed the influence of the developing ocean basins on pelagic sediments during the Mesozoic and Cenozoic eras. Initially the Pacific is larger and there is no Indian Ocean while the Tethyan Sea is developing. In the western Pacific the sediments during that time consisted basically of cherts and calcareous cherts. During Early Cretaceous time Central Pacific chert and limestone sequences are found for the most part adjacent to the mid-ocean ridges. Sediments recovered along the present eastern seaboard of United States (leg 11, DSDP) suggest a Mediterranean-type North Atlantic that existed during the initial stages of opening. There sediments consist basically of micritic calcite and plant remains, that were deposited on uneven terrain. By mid-Cretaceous the North Atlantic had increased in size but the South Atlantic was still closed. During that time, Central Pacific calcareous sediments occur in lesser amounts, suggesting the presence of a sea floor below compensation depths. However in the Indian Ocean shallow-water sediments are common. During early Tertiary a narrow North

Atlantic Ocean developed with equatorial deposition of calcareous and siliceous oozes taking place. In the late Tertiary the Ocean Basins are those of today with high-latitude siliceous oozes, and glacial sediments associated with colder faunas during late Miocene. In Antarctica, glaciation began during early Miocene, however, most ice was created during late Miocene. The cold conditions in the north Atlantic and Pacific also commenced during late Miocene.

T.C. Moore from Oregon State University discussed causes and distribution of hiatuses during the last 60 million years from the information of the DSDP cores. In the oceanic environment, there is a dynamic balance between depositon and removal, and a hiatus is defined where the sedimentation rates are less than one metre/MY. In general the rate of supply depends on oceanographic factors, and the rate of removal on mechanical and chemical. Chronologically, the hiatuses occur in greater abundances in older sediments; approximately 80% at the Mesozoic-Cenozoic boundary to 20% in the Quaternary. Sporadic maxima occur also at the Eocene-Oligocene boundary, and minima in Middle Eocene and Lower Miocene. Mapped hiatuses in the Pacific generally follow the pattern of current flow.

Comments on morning session

Three of the four papers dealt with data accumulated from the DSDP. There is enough information available to understand the formation of cherts in the ocean basins, and the general trends in sedimentation during the changes of ocean-basin configurations from the Jurassic to the end of the Tertiary. Hiatuses can be mapped, thus allowing for the reconstruction of reasonably detailed paleocurrent systems. We are a step closer to understanding the formation of cherts in ocean sediments, and it seems that elevated temperatures compensate for the geologic time necessary to take silica through the various crystallographic stages.

Session 5 (Dissolution)

The papers dealt with dissolution of skeletal material in the water column and at the sediment-water interface. Diagenesis of siliceous material was also discussed. Three papers described the dissolution of foraminiferal tests at and below the calcium carbonate compensation depth (CCD). Box-core samples below the CCD in the tropical Pacific contained partly dissolved resistant fragments of planktonic foraminifers (reels of *G. menardii*), together with whole specimen of spinose forams abundant in the water column above. The study indicated that most of the dissolution may take place at the sediment-water interface, and that the residence time of planktonic foraminiferal tests on top of the sediments in the study area was approximately one month.

Along a transect at the eastern seaboard of United States, between the depths of 1000 and 5000 the calcareous benthic and planktonic content was investigated. The benthic forams progressively decrease in numbers towards the deeper waters, and all forams disappear at 5000. A maximum of planktonic forams was found at the depth between 2000 and 3000 m, but there is a peak in the ratio of benthic over planktonic forams on the continental rise between 4000 and 5000 m. The dissolution of both benthic and planktonic species is selective, although benthic species are in general more resistant.

A sediment core in the Vema channel containing Pleistocene and Holocene deposits indicated a fluctuation of CCD during the various interglacials of the Pleistocene. The relative depth of CCD was determined by the per cent of broken foraminiferal tests; higher per cents indicating shallower CCD. At present the CCD is approximately 500 m shallower than at the time of occurrence of the Holocene-Pleistocene boundary. At this locality the Pteropod CCD is at 3500 m.

In three papers SEM photomicrographs were used to demonstrate diagenesis and dissolution of microplankton. Coccoliths are dissolved selectively. The initial effect is etching in the form of serrate margins and then removal of the more fragile species until only fragments remain. On larger specimens secondary growth can be found at the expense of smaller fragments.

A silica dissolution index was determined by exposing deep-sea microfossils of Quaternary age to natural seawater, for various periods of time. The index was used to determine the state of dissolution of sediments in the tropical Pacific. It was found that in deeper areas of the Pacific Ocean the state of preservation of siliceous material improved, but the index is higher in less productive areas.

Comments on Session 5

In view of the importance of dissolution in the marine environment the papers were rather weak. Most of the presentations described the various effects of dissolution on skeletal material both from a structural point of view and the destruction of species. A useful dissolution index of calcareous material has been the per cent of fragments of foram tests, in use since 1952. The dissolution index of siliceous material described in one of the papers can provide an objective means to assess various changes in paleooceanography and from that point of view can be considered the best presentation.

September 11

Morning session: In the morning, three papers were given and one hour was spent in considering resolutions of the conference. The papers dealt with recent advances in Cenozoic planktonic foraminiferal biostratigraphy, problems in Neogene and Paleogene correlations based on planktonic microfossils and evolutionary biogeography of Cretaceous planktonic foraminifera.

W.A. Berggren of Woods Hole described Cenozoic planktonic foraminiferal biostratigraphy. Depending largely on the material collected from the DSDP

cores, the paleomagnetic time scale has been correlated with the paleontological one. The successive planktonic foraminiferal zones have been calibrated with the radiometric chronology. Low-latitude zonation is by far more detailed than that for high latitudes, to the latter of which assemblage zonation must be reverted.

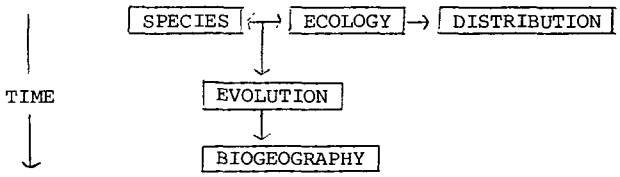
The relative time scale established by paleontological methods is ordonal; it predicts hiatuses, and the resolution does not deteriorate with age. Magnetic time scale is not ordonal and must be calibrated with the paleontological time scale. By correlating the magnetic, radiometric and paleontological time scales, sea-floor spreading rates are established.

Planktonic biogeography depends on boundaries of water masses, the spatial relationships of which have not been constant throughout time. The diversities of planktonic forams in the world oceans throughout the Cenozoic reflect the changes in water-mass properties.

Throughout the Tertiary slow separation of land masses took place in the Atlantic. From Middle Cretaceous to Pliocene gulf-stream waters entered the Labrador Sea according to the evidence of subtropical faunas found there. During the Tertiary bottom currents were developing in the North Atlantic as evidenced by seismic reflectors. Prior to that time sedimentation was continuous and non-eventful.

During the Pliocene several events took place: 1) 5 MY ago the North Atlantic was connected to the Mediterranean, 2) the Isthmus of Panama was closed, 3) increased intensity of North Atlantic Gyre brought warm water and moisture to the north, leading to glaciation. The first appearance of ice-rafted sediments is sudden, taking place only 3 MY after the disappearance of subtropical faunas. In the North Atlantic the disappearance of *Neogloboquadrina atlantica* marks the Pliocene-Pleistocene boundary. In the Lower Middle Pleistocene, dextral *G. pachyderma* disappears, and is replaced entirely by the sinistral *G. pachyderma*.

R.G. Douglas from Western Reserve University, Cleveland, discussed the development of planktonic foraminifera through the various stages in Cretaceous. A two-dimensional scheme was presented:



The paleoecology of the various morphotypes from Maestrichtian to Recent was shown. Basically four morphotypes were considered: Globigerine, Globorotalid, clavate and biserial. Through this time a consistency of morphologic adaption to depth was shown as follows.

Globigerine	shallow	eurytopic (oportunistic)
Globorotalid	shallow (deep)	"
Clavate	deep	stenotopic
Globorotalid	deep	stenotopic
Biserial	shallow	eurytopic

The evolution of these forms was generalized as shown in Table 1.

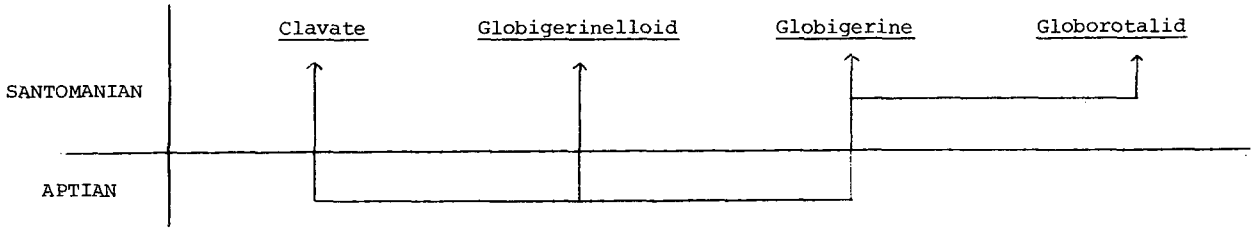
The distribution of these morphotypes provided a better understanding of Cretaceous paleotemperatures and paleobathymetry. For example, between the Upper and Lower Cretaceous there is a warming of temperatures in the euphotic zone from 20° to 25°C, and a return to 20°C. At the time between the Middle and Late Cretaceous the total area of transgressing seas increased, and decreased at the close of the Cretaceous.

The preservation of the various forms has been best in the equatorial neritic seas. The preservation potential of the equatorial lower bathyal and abyssal waters is equivalent to that of polar surface waters. In general, the shallow-water forms are most readily dissolved.

Comments on morning session

The impact of the DSDP on transcontinental Cenozoic stratigraphy was re-emphasized by Berggren's paper. Especially in the Neogene a well-defined planktonic foraminiferal zonation has been established with excellent correlation between magnetic and paleontological chronology. The morpho-

Table 1. Evolution of Four Foraminiferal Morphotypes in the Cretaceous



logic development of planktonic foraminifera during Cretaceous was outlined, and the various morphotypes associated with the oceanic environment. The established principles has expanded our knowledge of Cretaceous paleoenvironments.

September 12

Morning Session: This session dealt with stratigraphy and evolution of tropical Cenozoic radiolarians, dinoflagellate evolution, Cenozoic diatom stratigraphy, and biostratigraphy of marine sediments from the study of calcareous nannoplankton.

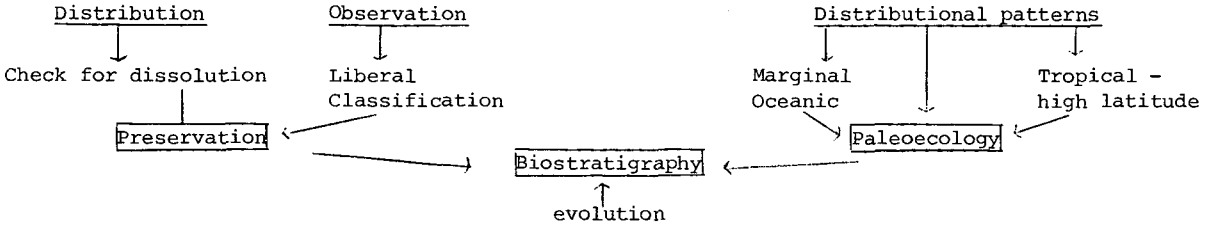
H.J. Schrader from the University of Kiel and A.P. Jouse from Moscow discussed aspects of Cenozoic diatom stratigraphy. Diatoms are useful for the zonation of pelagic sediments especially in areas of high productivity and high latitudes, where calcareous matter is not found. The abundance of diatoms is low in the Early Miocene, but the diversity of species increased in the Late Miocene. The duration of species also becomes progressively shorter in the younger sediments of Neogene age, with very high rates of evolution in the high latitudes during the Pleistocene. There are at least four diatom species indicating the Pliocene-Pleistocene boundary in equatorial waters, and five diatom levels within the Pleistocene. The zonation established by diatoms is as good or better than that established by other means.

D. Burky and H. Thierstein of Scripps and Lamont-Doherty, respectively discussed coccoliths. In the sediments coccoliths are most abundant between latitudes 40°N and 40°S. Of all the DSDP sites only eight (basically in lower latitudes) contain complete Neogene sections of coccoliths. Coccolith zonation is poor at high latitudes, although Leg 12 contained reasonably good assemblages. Assemblages of Oligocene age seem to be the poorest with respect to coccoliths.

The initiation of new nannoplankton genera is largest during the times of higher-water temperatures. In the Pacific, the most famous Cretaceous sites of coccoliths are in the mid-Ocean. In general, discoasters dominate in warm latitudes and platholiths in cold. In the Pacific discoaster/coccolith ratios in sediment cores were used as indicators for paleocurrents (cold vs warm).

Stratigraphy is affected by preservation and productivity of coccoliths. The state of preservation is indicated by surface features such as overgrowths, obliteration of perforation and etching.

A working scheme for coccoliths to determine biostratigraphy is shown in the following flow chart:



Session (14) Paleoecology I

(Atlantic) Temperature fluctuations in the North Atlantic during the last 130,000 years were determined by various workers, mainly the members of the CLIMAP group. The paleotemperatures were determined by the Imbrie-Kipp method, which statistically compares planktonic foraminiferal assemblages from core tops with those down the core. From the changes in formas, corresponding differences in temperature can be established. The dating of the various levels in the cores is usually achieved radiometrically, but one paper used the two dated erruptions in Iceland (9,300 and 63,000 years B.P.).

Paleotemperature fluctuations can be used to synthesize paleodynamics of the oceans. The polar fronts migrated between latitudes 45° and 55°N extending to the more southerly latitudes during the glacial maxima. During a glacial maximum (the latest being 18,000 BP) the intermediate waters are reduced to a narrow zone and as a result, temperature gradients of 10°C may exist over the distance of 4° latitude. Evidently, during a glacial maximum the North Atlantic Gyre intensified. The circulation of surface waters also intensified during the various glacial maxima in the eastern equatorial Atlantic. The northeast and southeast Trade Winds intensified during a glacial maximum, and sediment cores showed evidence of increased upwelling off northwest Africa and cooler surface temperatures of the South Equatorial Current.

The migration of polar fronts evidently took place in a northwesterly and southeasterly direction. This finding was based on a study in which the 9,000 BP level of volcanic ash was plotted in the North Atlantic. Faunas characteristic of polar fronts were found below this layer in the northeast Atlantic, within the layer in the central Atlantic, and above it in the northwestern Atlantic.

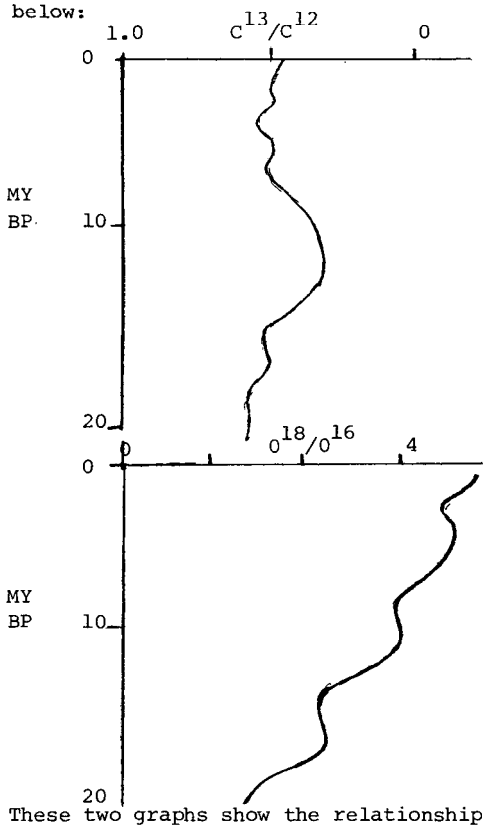
Comments on Paleoecology Session

The large numbers of sediment cores collected over the years, principally by Lamont-Doherty workers, provide excellent material for the CLIMAP group dealing with paleotemperatures in the Atlantic. In conjunction with the various methods of dating, it is possible now to plot the migration of temperature maxima and minima over the Atlantic, and possibly construct models of ocean paleodynamics.

September 13

Morning Session: The emphasis in this session was on critical reviews of various working methods.

great increase of C^{13} in surface waters due to a selective incorporation of C^{12} in organic matter; therefore, planktonic forams should have relatively higher C^{13} content in the tests than in those of the benthonic forams. This suggested that relative C^{12}/C^{13} ratios in Cretaceous forams should be a useful criterion for distinguishing planktonic from benthonic forams during that time, however, the possible effect of changes in photosynthetic activity should always be considered; as shown below:



These two graphs show the relationship of the two isotopes in tests in planktonic foraminifera during the last 20 MY.

Benthonic foraminifers show that the cooling of bottom waters since the Cretaceous took place in several discrete steps from 15°C to the present 1°-2°C. The cooling periods occurred near the end of the Cretaceous period, near the end of Middle Miocene, and during the Pliocene. There seems to be a casual relationship between the great extinctions of planktonic foraminifers and the drop of bottom paleotemperatures; however, the greatest cooling during the Pliocene caused very samll changes in the planktonic foraminiferal populations.

Comments on Morning Session:

The morning session was typical of the conference and dealt primarily with the question: how to utilize the mass of new data provided by the DSDP. The transfer functions described by Imbrie is a method widely used by the CLIMAP working group and is known as the Imbrie-Kipp method for synthesis of paleotemperatures of the sea surface by considering the faunal assemblages of marine sediments. It works very well in North Atlantic but the results are not as good for the Mediterranean Sea and Indian Ocean. Nevertheless, the synoptic paleotemperature maps covering whole oceans could prove to be useful for the construction of models depicting future climatic trends. The excellent paper of Saito covered a large range of problems dealing with isotopic studies of carbon and oxygen in foraminiferal tests.

Session 17 (Paleoecology II)

The interesting papers dealt with paleotemperatures in the Pacific, basically during Pleistocene. In the North Pacific radiolarians were analyzed with the Imbrie-Kipp transfer function to estimate paleotemperatures and paleophosphate levels. During the Pleistocene the North Pacific paleotemperature changes are in phase with those of the North Atlantic. The deterioration of paleotemperatures showed several readvances, and during these times the North Pacific gyre intensified. However, the surface water was never sufficiently cold to be converted to bottom waters.

In the Equatorial Pacific, Late Pleistocene planktonic foraminifera were analyzed in the high productivity belt at the junction of the California and Peru currents. The Pliocene-Pleistocene boundary was established by the extinction of *Globorotalia tosaensis* and *Globoquadrina pseudofoliata*. During the last glacial maximum the area was invaded by the temperate species *Globorotalia inflata, G. crassaformis* and dextral *G. pachyderma*.

For the South Pacific, paleotemperatures were determined by the O^{18} method. The discussion also dealt with a problem of selective uptake of O^{18} by the various species of foraminifera, causing an error of about 1 °/00. It was found that the relationship of O^{18} uptake and temperature of the genus *Uvigerina* follows the standard closely. At DSDP site 277 the surface temperatures deteriorated, from Early Eocene to Oligocene, from about 19°C to 7°C. This cooling probably produced continental ice in Antarctica, which was rather limited in extent. A temperature dip during the Middle Miocene provided the beginnings of continental ice sheets of the present size. The relatively constant values of O^{18} indicate that since Middle Miocene to the beginning of the Pleistocene, the Antarctica ice sheets were relatively stable.

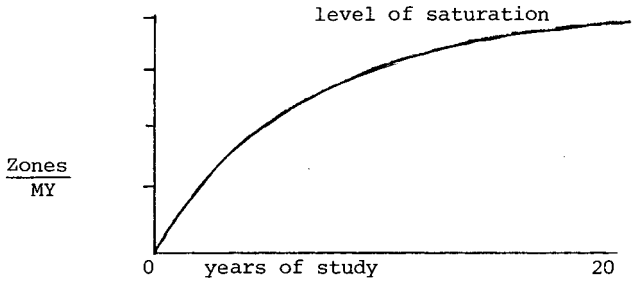
The papers dealt with Late Mosozoic and Cenozoic-isotope paleotemperatures, probability in stratigraphy, integration of biostratigraphical information from numerous sequences and a critical review of transfer functions and their role in developing a theory of past climates.

John Imbrie from Brown University explained the basic principles of transfer - functions and gave a critical review of the method. In a very saimple form, T = K (A) is a transfer function where T is the estimated temperature of the water during the time when species A lived there, say, 18,000 years ago. A transfer function therefore is a tool that can be used to make a quantitative estimate of various paleoenvironmental factors on the bais of species that lived in that environment. The modern species normally depend on a range of environmental factors and a sample normally contains more than one species; therefore, in order to obtain an exact paleotemperature as possible a transform function is used with more than one species : T = K (A.B.C.). In general, a quantitative estimate of *m* environmental factors can be made with *m+1* species in the transform function. To deal with various errors these estimates are made with the help of multivariate statistics.

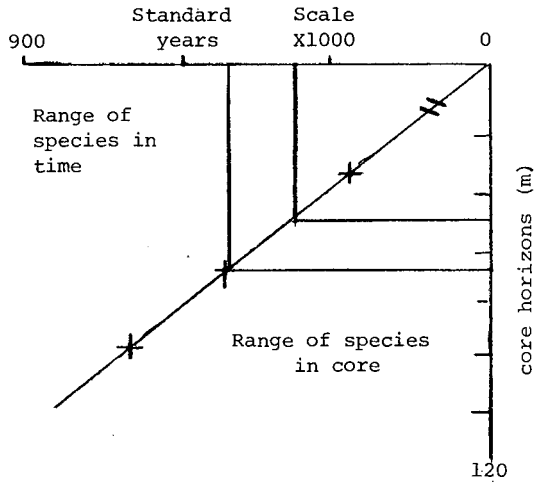
There are many benefits to this approach. In addition to making the science of paleooceanography more explicit, it is possible now to normalize information obtained from various sources. For example, synoptic maps of paleotemperatures in the North Atlantic of 18,000 years ago can be drawn on the basis of foraminifera, radiolaria, diatoms, etc., for which one source of information can be checked against another. The method also establishes contact with other sciences that work with mathematical models describing some aspects of the earth's history; for example, numerical models of ancient ice-sea-atmospheric systems depend largely on quantitative paleontological data.

William Hay from the University of Miami gave a steroscopic view of stratigraphic problems. The audience were issued steroscopic glasses to view projections demonstrating possible three-dimensional relationships between stratigraphic planes. Having demonstrated how the concept of stratigraphy is often oversimplified, the reader described in principle a method how "statistical zones" could be obtained. In short, the statistical analyses are used to obtain probabilities of species occurring first or last in a sequence including confidence intervals and reliability. Thus links between stratigraphic events are established on the basis of these probabilities, which also provide estimates of the strength of these links. It is therefore possible to construct a chain or chains of events at any level of probability.

On the basis of the initial reports of the DSDP, planktonic foraminifera provide the least useful extractable information for establishing Tertiary stratigraphy. The graph below is a generalization of how much information can be extracted from the raw material.

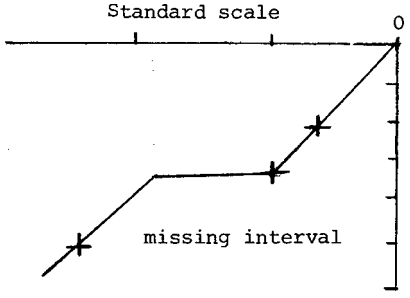


A.B. Shaw's paper on integration of biostratigraphical information was ready by W.R. Riedel from Scripps. This paper was interesting from the point of view of graphical projection of core levels to the actual time-sequence of strata. DSDP site 66 was selected to obtain a standard scale of time based on initial and final occurrence of species and radiometric dating.



\+ first occurence of species
= last occurrence of species.

The standard scale can be applied to other cores to obtain a graphical presentation of their depositional history.



+, 0 first and last occurence of species

T. Saito from Lamont-Doherty gave a paper on problems of O^{18} and C^{13} analysis of foraminifers for paleoenvironmental determinations. For paleotemperature estimations, the background values of O^{18} in seawater must be known. Considering Cretaceous paletemperatures, relative rather than absolute temperatures must be used because of the probable lack of Cretaceous ice caps. There is a