water volume in the borderland bounded above by the air-sea interface and below by the sediment-sea interface clarifies the situation.

Carbonate deposition (output) totals approximately 125×10^{10} g/yr. The major carbonate mineral is Mg-calcite$_{(<4)}$, with some Mg-calcite$_{(<4)}$, aragonite, and dolomite. Noncarbonate dilution totals about 800×10^{10} g/yr.

Other mechanical transfer is primarily river input (15×10^{10} g/yr) of Mg-calcite$_{(<4)}$ and some dolomite. Neither aerial nor ocean current transfer affects the budget significantly.

Biologic transfer involves primarily input of $CaCO_3$. Foraminifera produce about 250×10^{10} g/yr of Mg-calcite$_{(>4)}$ and aragonite. Production of 400 (g/m^2)/yr by macrobenthos in shallow, hard-bottom areas is comparable to tropical, nonreef production rates.

Chemical transfer involves solution (output) of about 200×10^{10} g/yr $CaCO_3$ on basin floors. Apparently all carbonate minerals except dolomite undergo solution.

These input and output estimates balance to within about 10%.

Rivers entering the borderland supply only enough dissolved calcium for 30% of the $CaCO_3$ deposited.

Of the $CaCO_3$ input to the borderland, over half dissolves, the remainder is deposited. The $CaCO_3$ deposition rate is sufficient to extract some dissolved calcium from seawater flowing through the borderland.

STADUM, CAROL J., and HSIN-YI LING, Dept. Oceanog., Univ. Washington, Seattle, WA 98105

Silicoflagellate Biostratigraphic Zonation of Deep-Sea Sediments

Silicoflagellates have been recognized in land outcrops and deep-sea sediments, but they have not been accepted widely as biostratigraphic indicators. In order to evaluate their occurrences and to establish a workable biostratigraphic framework, approximately 100 deep-sea sediments were studied. These were from a broad geographic area and were of Cretaceous (Cenomanian) and the middle Eocene to Holocene ages. The samples chosen were dated by other planktonic microfossils, thus making cross correlation possible.

The complete absence of silicoflagellates in the few JOIDES samples examined from the Upper Cretaceous and the lack of samples from the Paleocene through the early Eocene interval prevent a complete zonation. Three zones are recognized from the middle Eocene to the top of the Oligocene. There was a sharp decrease in the silicoflagellate population in the Oligocene. In the Miocene evolutionary diversification of taxa permits greater biostratigraphic resolution; 7 zones have been recognized. A massive extinction of silicoflagellates occurred toward the end of the Miocene, with only a few species continuing into the Holocene. The brief recurrence of *Mesocena* cf. *elliptica* at the Jaramillo event within the Matuyama Reversed Epoch both in low and middle latitudes of the Pacific marks a biostratigraphic datum within the Pleistocene. Determining the first appearance of many Holocene taxa will add further resolution within the Quaternary interval.

STANLEY, DANIEL J., and TER-CHIEN HUANG, Div. Sedimentology, Smithsonian Inst., Washington, DC 20560

Multiple Origin of Hemipelagic Mud Fill in Mediterranean Basin

Mud, predominantly silty clay, accounts for at least 95% of the Holocene fill of the western Alboran basin in the western Mediterranean Sea, 110 km east-southeast of the Strait of Gibraltar. This mud has a multiple origin; it is not deposited from a simple rain of pelagic material onto the basin floor. The mud distribution is closely related with topography, as determined from cores and high-resolution seismic records. Total thickness of the Holocene section is approximately 2 m on basin slopes, but increases to over 4 m (sedimentation rates up to 30 cm/1,000 years) in the near-horizontal basin plain at a depth of 1,500 m. Thickest mud deposits are localized in lows where thin sand layers most abound, and major mud transport paths appear to be similar to sand dispersal patterns. Mud is hemipelagic in composition: lutite with planktonic and benthonic Foraminifera, deep- and shallow-water ostracods, and plant fibers. Components are, at least in part, nearshore in origin.

X-radiographs show that 10–20% of the mud in the cores is parallel- and cross-laminated, indicating the importance of bottom traction transport. Bottom currents also have truncated the top of sand layers and concentrated microfossils in thin laminae. A few graded mud units are probably *mud turbidites*. The predominant "trigger mechanism" of the fine-grained turbid flows is floods that seasonally inject material at fluvial point sources along the mountainous Moroccan and Spanish margins. Homogeneous mud layers with scattered microfossils, comprising more than half of the Holocene fill, reflect a more regular deposition from less dense suspension layers. The suspensate is also in part extrabasinal, derived from low-density Atlantic surface water entering at the Strait of Gibraltar and denser Mediterranean water circulating at depth.

STEINECK, P. LEWIS, and MACOMB T. JERVEY, Dept. Geol., Louisiana State Univ., Baton Rouge, LA 70803, and JAMES GIBSON, Dept. Geoscience, Univ. Southern California, Los Angeles, CA 90007

Paleoecologic and Biostratigraphic Implications of Eocene Planktonic Foraminiferal Assemblages, California

Correlations and age assignments based on the system of benthic-foraminiferal faunizones and provincial stages developed for the California region are contravened by those based on planktonic species, notably within the Eocene. For example, the Ulatisian and Narizian provincial stages are presently assigned to the middle and upper Eocene, respectively. Our data indicate that strata containing Ulatisian benthic-foraminiferal assemblages range in age from late early Eocene to early middle Eocene whereas Narizian sequences are of early to late middle Eocene age and further, that the "Ulatisian" Rose Canyon and the "Narizian" Cozy Dell formations are correlative. Significantly, none of the Narizian sequences for which planktonic foraminiferal data are available are of late Eocene age. Inasmuch as the presently available stages and faunizones are time-transgressive, it is urged that this system no longer be used for West Coast Paleogene correlations.

The development of a faunizonal succession based on planktonic foraminiferal species provides an adequate chronostratigraphic framework for paleogeographic interpretation, but the absence or rarity of thermophilic species important in standard faunizonations necessitates use of regionally dominant forms.

Delineation of dominance and diversity trends reveals modification by shifting watermass boundaries of planktonic-foraminiferal assemblages occurring over the Paleogene California continental margin. Diverse subtropical upper Paleocene-lower Eocene faunas containing *Morozovella* pass upward into temperate middle Eocene ones characterized by diminished diversity, lack of *Morozovella,* and by high dominance values for truncorotaloidid and subbotinid species, thus lending support for the concept of a bipolar middle Eocene cooling interval.

STOEN, JONATHAN D., and JOHN E. KENNEDY, Amoco International Oil Co., Chicago, IL 60611

BIOGENIC AND SEDIMENTARY FEATURES ASSOCIATED WITH JURASSIC CARBONATE TIDAL CHANNEL, WEST PAKISTAN

Exposures of steeply dipping Jurassic limestones in the Surghar Range, West Pakistan, allow detailed observations of various biogenic and sedimentary features. Thin-bedded dolomites, desiccation cracks, scour-and-fill structures, and shallow-water benthonic Foraminifera, within a dominant lithology of pellet carbonate grainstones and mudstones, indicate very shallow carbonate shelf conditions at the time of deposition. Periods of subaerial exposure, and subsequent lithification are indicated by the presence of oriented bivalve borings, both on surfaces which have been desiccated and on one surface which has been corraded by tidal currents. The latter exposure surface contains pebbles of identical lithology within the reticular gullies. Encrusting oysters are common. Submarine cementation of the surfaces is discounted because of the absence of inverted borings, superimposed bored surfaces, and extensively bioturbated sediment.

SUPKO, PETER R., Deep Sea Drilling Project, Scripps Inst. Oceanog., La Jolla, CA 92037

ASPECTS OF SUBSURFACE BAHAMIAN DOLOMITES AND INSIGHTS INTO THEIR ORIGIN

A continuous 168-m core was collected on San Salvador in the eastern Bahamas. Dolomite is present in the interval between 35 and 147 m. The dolomite is of 2 basic lithologic types. Those dolomites which are probably supratidal mudstones and show laminations, a poorly developed fauna, a few intraformational clasts, and in places a capping red crust, are termed "stratal" dolomites. These stratal sequences are less than 10 cm thick. Those dolomites which are replacements of grain-supported carbonate sediments or rocks, probably of backreef or lagoonal facies, are termed "massive" dolomites.

Stable isotope analyses show both types of dolomite to have δC^{13} values within the range of Holocene sediments, but to be higher in δO^{18} than either Holocene sediments or Pleistocene limestones. These data indicate the dolomites formed by reaction of host carbonate sediments or rock with Mg-rich hypersaline brines. The stratal sequences were probably dolomitized by upward capillary movement of the fluids, whereas the massive sequences were dolomitized by seepage refluxion. Stratal dolomites seem to be relatively lower in δO^{18} and mol % $MgCO_3$ and more poorly ordered than massive dolomites. This may reflect different efficiencies of the 2 dolomitization processes.

TAPPAN, HELEN, Dept. Geol., UCLA, Los Angeles, CA 90024, and ALFRED R. LOEBLICH, JR., Chevron Oil Field Research Co., La Habra, CA 90631

GEOLOGIC HISTORY OF OCEANIC PLANKTON

In its evolution throughout geologic time, the oceanic microplankton became increasingly diverse in major taxonomic representation and biochemical variety, but fluctuated markedly in species diversity, abundance, size range, morphology, and dominant skeletal composition.

Organic-walled phytoplankton of the Precambrian was locally abundant, specimens relatively large, but diversity low. By Ordovician and Silurian times, phytoplankton varied widely in size and morphology; zooplankton included radiolarians and rare tintinnids. Decreasing suddenly in the Late Devonian, both phyto- and zooplankton were rare in the late Paleozoic.

Slow development of plankton in the Triassic left a meager record of acritarchs, coccolithophorids and radiolarians. Rapid diversification characterized the later Mesozoic; abundant dinoflagellates, tintinnids (calpionellids), and planktonic Foraminifera were added during the Jurassic; siliceous phytoplankton arose in the Cretaceous (diatoms, silicoflagellates, chrysomonads), and radiolarians and coccolithophorids expanded.

Another severe reduction in plankton diversity and abundance closed the Mesozoic, hence most groups are poorly represented in the Danian. Paleocene and Eocene diversification and proliferation of phytoplankton (dinoflagellates, coccolithoporids, diatoms, silicoflagellates, ebridians) and zooplankton (radiolarians, foraminifers and some tintinnids) were accompanied by increased morphologic complexity and greater size range. Although plankton abundance, diversity, and complexity fluctuated in the later Cenozoic, no new higher taxa arose.

At present, abundant plankton indicates high productivity, but diversity may be low. Geologically, this abundance was reflected in rapid accumulation of biogenic sediments (chalks, cherts, diatomites); extensive photosynthetic utilization of CO_2 also may have contributed to the accumulation and preservation of calcareous sediments.

THOMSON, ALAN F., Shell Development Co., Houston, TX 77001

CONTINUITY OF PLIOCENE TURBIDITE SANDSTONES, VENTURA AREA, CALIFORNIA, WITH APPLICATIONS TO SUPPLEMENTAL RECOVERY

Outcrops of turbidite sandstones of the Pico Formation (upper Pliocene) at Ventura field and vicinity were examined to gain an insight into their continuity.

Two types of reservoir quality sandstones were recognized based on physical and petrophysical properties. Type A sandstones (graded, poorly sorted) have low permeabilities (several hundred millidarcys). Type B sandstones (nongraded, moderately to well sorted) have high permeabilities (several thousand millidarcys).

Three classes of turbidite packages were distinguished based on internal arrangement of sandstone types. All 3 packages contain thin-bedded Type A and B sandstones. A Class I package has, in addition, massive, composite Type A sandstones at the base; a Class II package has the massive, composite Type A sandstones in the middle; and a Class III package has no massive, composite Type A sandstones.

Thick, composite Type A sandstones have good lateral continuity because they are amalgamated. Type B sandstones have poorer lateral continuity because of lack of communication with other sandstones.

Observations on a single turbidite package over a