rewetting. These observations imply: (1) the criteria for recognizing subaqueous shrinkage cracks need reevaluation and (2) a careful study of mud-crack characteristics and their vertical and lateral variations in stratigraphic sections may provide detailed data on basin morphology, hydrology, and sedimentation rates.

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Early Diagenetic Controls on Allochthonous Carbonate Debris Flows—Examples from Egyptian Lower Eocene Platform-Slope

Many of the models that have been proposed for the origin of carbonate debris flows are based upon examples from ancient carbonate slope settings. Few ancient slope environments have been described, however, where submarine cementation processes were prevalent. This early diagenetic phenomenon, common on many modern carbonate slopes and platforms, can control the mechanisms by which debris flows are generated, as well as the ultimate form of the beds they produce.

Within the Duwi Trough of central Egypt, a basin to slope facies transition is preserved within the lower Eocene chalks and limestones of the Thebes Formation. Basinal facies are characterized by sequences of laminated chalks and limestones with thin, intercalated horizons of nodular limestone and limestone hardgrounds. Carbonate platforms developed on structural highs adjacent to the basin and periodically shed bioclastic detritus downslope in the form of fine-grained, skeletal turbidites. Nodular limestones and hardgrounds, that formed upslope, were in places dislocated and reworked into the basin as submarine debris flows. Individual debris flow beds preserved within the lower slope and basinal facies can be traced over 50 km down the trough axis and several kilometers laterally.

Nodular conglomeratic debris found within the flows range from 30 to 300 cm in thickness and are mud supported. Unlike most ancient debris flow breccias, larger clasts are unusually uniform in size and well rounded. This is not a reflection of textural maturity but a result of the primary nodular morphology of these clasts. Channels and basal scour features are poorly developed in these beds owing to the cemented (hardground) nature of the basin-floor during debris flow deposition.

Sites of nodular limestone bed dislocation are not recognized within the slope facies. Neither large-scale rotational slides, nor slump structures associated with translational slides are developed. The proposed mechanism for the detachment of these nodular horizons is one of relatively shallow decoupling of the early-cemented surface layer from the underlying, unconsolidated sediment. This process would have been accelerated by the presence of high pore fluid pressures owing to an impermeable surface layer (hardground) and loading, resulting from both sedimentation and cementation. Where submarine cementation was a continuous process, as on the upper slope, and uninterrupted sequences of nodular limestone were developed, sediments were stable and debris flows were not generated.

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Paleophosphate Determinations: Potentially Useful Paleo-Oceanographic Tool

Using recent hydrographic data from the Indian Ocean, we have derived an empirical relation that predicts PO_4^{3-} concentrations (μg - atoms/l) from the concentration of dissolved O_2 and temperature (°C), where $PO_4^{3-} = 4.82 - 2.26 \log T - 0.30$ dissolved O_2. The $\delta^{13}C$ and $\delta^{18}O$ of certain species of planktonic foraminifera have been demonstrated to be functions of apparent oxygen utilization ($AOU = 205.0 - 100\delta^{13}C$) and temperature (calculated from the $\delta^{18}O$ paleotemperature equation). Utilizing the down-core $\delta^{18}O$ and $\delta^{13}C$ of planktonic foraminifera, substituted into the equation above, permits determinations of paleophosphate concentrations for fossil oceans. In rewritten form: $PO_4^{3-} = (43.5(16.0) - 7.43 \log T) - (43.5\ O_2$ saturated seawater (ml/l) $- 205.0 - 100\ \delta^{13}C)/145.0$. A comparison of the PO_4^{3-} values calculated from recent forams collected from 14 sites in the Indian Ocean with recent hydrographic values showed no significant differences ($M = 0.91$, $B = 0.28$, $R = 0.89$).

Having measured the isotopic concentrations of $\delta^{13}C$ and $\delta^{18}O$ obtained from 5 species of planktonic foraminifera from two cores in the Arabian Sea, we attempted down-core paleophosphate determinations. Foraminifera were collected from three time horizons in each core, the 0, 9, and 18 thousand years before present (KYBP) isochrons as determined from $\delta^{18}O$ ice-volume curves, using a linear age model. Our results indicate that the average surface and deep water (approximate O_2 minimum depth) paleophosphate concentrations for the three isochrons are, respectively: 0.575 and 2.07 at 18 KYBP, 0.205 and 2.30 at 9 KYBP, and 0.33 and 1.92 for the Holocene. These determinations may indicate greater productivity or upwelling at 9 KYBP relative to the Holocene at 18 KYBP.

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Isotopic Composition of Heavy ($C_{15}+$) Saturate and Aromatic Fractions of Crude Oils

One hundred and sixty oils from producing wells and drill-stem tests in the United States and around the world have been analyzed for the stable carbon isotope composition of the heavy ($C_{15}+$) saturated and aromatic fractions. Extreme reproducibility in the separation techniques and in the isotope preparation and measurement has allowed the plotting of the aromatic isotope composition versus that of the saturated composition with a very high degree of confidence. It appears that there is a linear relation between the isotopic composition of the aromatic and saturated fractions of oils of marine origin. A parallel relation, but with a more positive "y" intercept, seems to hold for oils of terrigenous origin. Oils which have undergone bacterial degradation show a different linear relation which can be extrapolated to the composition of the original non-degraded oil.

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Modern Depositional Analogs to Monterey Formation

The eastern Pacific Ocean encompasses three regions of modern sediment deposition that could be considered imperfect analogs to the depositional environment of the Monterey Formation. These are: (1) the shelf and slope areas off California; (2) shelf and slope areas off Peru-Chile; and (3) the basin margins of the Gulf of California.

All three regions lie within or near the influence of biologically productive eastern boundary current regimes. The differences between these regions, in terms of topography, climate, surface and subsurface water mass influence, and ecosystem productivity, are expressed in the modern sediment records.

Paleogeographic and paleo-oceanographic evidence indicates that at least some of the factors that influence modern deposition must have found similar expression in the Monterey. Perhaps workers familiar with the laminated sediment facies of the Monterey will recognize a range of stratigraphic features that are contained in the core samples collected from the modern deposits.

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Geology and Reservoir Distribution, Pinda Formation, Offshore Zaire and Southern Offshore Cabinda

The Albian-Cenomanian Pinda Formation of offshore Zaire and Cabinda is composed of mixed carbonates and siliciclastics deposited in a transgressive sequence of supratidal, intertidal, and subtidal facies. The Pinda overlies Aptian salts of the Loeme Formation and is unconformably overlain by calcareous shales of the Iabe Formation.

The supratidal sediments were probably deposited on sabkhas, in coastal playas, and by intermittent streams. Intertidal environments included offshore bars, tidal flats, tidal channels, and restricted lagoons. Shallow-water subtidal sediments accumulated on a broad, gently sloping ramp on which a few isolated shoals developed.

A series of north-northwest-trending growth faults, active during and after Pinda deposition, have affected the thickness and attitude of Pinda rocks, influenced the distribution of secondary dolomite, and created both productive and prospective structures.

Pinda reservoirs are primarily dolomites with intercrystalline, moldic and vug porosity, and sandstones with intergranular porosity. Less important are lime packstones and grainstones with interparticle porosity. Facies, dolomitization, distance from source area, and growth faulting control the occurrence and quality of Pinda reservoirs. Thicker, more prospective reservoirs exist on the eastern part of the shelf, where coarser siliciclastics accumulated closer to their source and secondary dolomitization occurred. Production rates in Pinda fields of offshore Zaire reflect the differences between reservoir characteristics in the eastern and western shelf areas.

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Integrated Stratigraphic and Seismic Approaches to Reservoir Mapping, Mibale Field, Offshore Zaire

Located on a north-northwest-trending growth fault block on the continental shelf of offshore Zaire, the Mibale field produces medium grade oil from the Cretaceous Pinda Formation and is sealed by calcareous shales of the overlying Iabe Formation. An integrated geologic-geophysical study of the field resulted in detailed characterization and mapping of the Pinda reservoir, from which locations for future development and water injection wells have been selected.

The Albian-Cenomanian carbonates and terrigenous clastics of offshore Zaire form a transgressive sequence comprised of landward thickening supratidal and intertidal deposits, and seaward thickening subtidal deposits. In the Mibale field major lithofacies are: (1) supratidal—thick-bedded sandstones and dolomites, with minor shales and anhydrites; (2) intertidal—thin-bedded shales, dolomites, and sandstones with minor anhydrites; and (3) subtidal—(a) thick-bedded dolomites and sandstones; (b) dolomites; and (c) lime wackestones to packstones containing various skeletal and non-skeletal grains.

Cores show that the sandstones and dolomites have better permeabilities than the limestones. The areal distribution of permeable reservoirs is controlled by facies configuration, growth-fault movements, and secondary dolomitization. Within a single facies, thickness variations greater than 300 ft (91 m) occur.

Because of the unpredictable thickness variations, seismic inversions (pseudo-sonic logs) were used to define the subsurface configuration of depositional and diagenetic facies across the field. Inversions were carefully calibrated to sonic logs and used for direct interpretation of lithology in areas lacking well control. Structure and gross pay maps, as well as lithologic and petrophysical characteristics of reservoir facies, enabled engineers to develop a three-dimensional simulation model of the field.

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Mineralogy and Pore Fluid Geochemistry of Great Salt Lake, Utah

Piston cores from the South Arm of Great Salt Lake, Utah, have been analyzed chemically and mineralogically. The major detrital minerals are quartz and clay minerals (illite, smectite, mixed layers, and minor kaolinite) with lesser amounts of feldspars and volcanic ash (both felsic and basaltic). Carbonate minerals include aragonite, calcite (0 to 15% $MgCO_3$), high-Mg calcite (50% $MgCO_3$), and dolomite. The carbonate minerals reflect detrital input as well as authigenic growth in the lake. Saline minerals are halite, mirabilite, and gypsum.

Pore fluids were extracted from 7 piston cores and subjected to wet chemical analyses. The major ion profiles are similar and cut time-stratigraphic units of the cores indicating little influence from primary formation waters. Instead, compositions are controlled primarily by fluctuations in lake water compositions and mineral reactions. Major ion concentrations are determined by mass transport from the lake waters and from the most soluble minerals present in the sediment. Presence or absence of halite influences Cl^- profiles, while SO_4^{2-} is largely controlled by mirabilite dissolution. Because mirabilite and halite solubilities are nearly equal in Great Salt Lake brines, Na^+ is affected by both phases. Gypsum is present; however, because of the much higher solubility of mirabilite, the effect of gypsum on SO_4^{2-} is obscured, while Ca^{2+} responds to gypsum. The effects of carbonate mineral reactions are not apparent in the Ca^{2+} profiles. Because of the relatively small carbonate alkalinity with respect to other weak bases, reactions involving carbonate minerals are difficult to identify.

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Late Pleistocene and Holocene Sedimentary History of Great Salt Lake, Utah