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Interaction of Living Radiolarians and Their Environment

Studies of living radiolarians in the field and in the laboratory reveal the extent of their trophic diversity. Solitary and colonial radiolarians feed opportunistically on a wide variety of prey organisms in nature, but respiration studies have shown that they can rely heavily on their symbiotic algae to provide the energy required for basal metabolism. Some radioisotopic evidence has implicated an intricate relationship between the host, its predatory success and the photosynthesis by its symbionts.

Field data on the abundance of subtropical radiolarians suggest that their populations respond to seasonal changes such as temperature. The existence of separate cohorts in a population suggests that several life cycles may occur in a single season lasting only a few months.

Such studies will amplify our understanding of the interactions of the radiolarians with the biological component of their environment based on their nutritional requirements and physiological limitations. This is an important first step towards elucidation of which factors affect the distribution of radiolarians.

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Application of Integrated Reservoir Analysis to Design of a Waterflood Project in Miocene LL3 Field, Lake Maracaibo, Venezuela

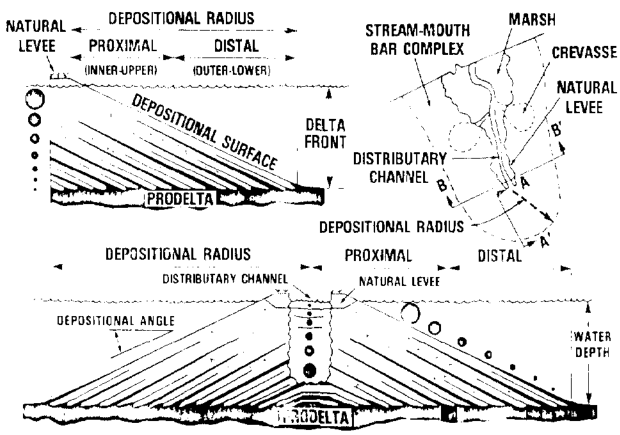
Integrated Reservoir Analysis is a procedure where interpreted stratigraphic and facies frameworks are combined with structural analysis to produce more accurate and appropriate reservoir maps. The result is a three dimensional interpretation of the thickness, shape, lateral extent, and internal distribution of porosity and permeability in individual reservoir units. The principal steps of the procedure are: (1) planning, (2) data gathering, (3) determination of the stratigraphic framework, (4) determination of the facies framework, (5) structural analysis, (6) data manipulation, and (7) mapping.

The stratigraphic framework is developed by combining pattern correlation techniques with knowledge about the influence of specific facies on stratigraphic patterns. A network of cross sections are designed utilizing correlation "grain" and/or depositional strike. Correlations on these sections develop a framework of horizons which ideally will isolate, in a stratigraphic envelope, individual reservoir units resulting from a unique depositional episode.

The facies framework results from environmental facies analysis and the use of electric log facies. The proper identification of reservoir facies is required for the mapping of reservoir geometry and the determination of the internal distribution of porosity and permeability. Facies-biased contouring techniques and the lateral extension of facies relationships along cross sections were used in the planning and design of a waterflood project by Lagoven, S.A., in fluvial-deltaic clastics of the Miocene La Rosa Formation in the LL3 field, Lake Maracaibo, Venezuela. Important clastic reservoir facies recognized in cores were (1) stream-mouth-bar, (2) distributary-channel-fill, and (3) fluvial point-bar deposits. These environmental facies often occurred in various combinations in deltaic lobes and displayed the electric log shape of the deltaic couplet. Characteristic electric log shapes of specific reservoir facies were an essential part of the study.

The pilot waterflood was designed to inject into stream-mouth-bar facies and withdraw from centrally located distributary-channel-fill deposits with their better porosity and permeability. Critical to the design and subsequent performance of the waterflood project were (1) the distribution of porosity within the various reservoir facies, and (2) the occurrence, attitude, and lateral distribution of clay laminations within the lower stream-mouth-bar and upper fluvial deposits. The influence of clay laminations in lower stream-mouth-bar facies was particularly critical to waterflood performance. They were deposited on the distal slope of the stream-mouth-bar at a slight angle to the rock unit boundaries and therefore could mask parts of the reservoir from waterflood treatment. The amount of masking was determined by calculations from facies geometry. After one year's operations, radioactive tracers indicate that the flood is operating as designed only at a reduced rate—probably as a result of the clay laminations.

MODEL OF STREAM-MOUTH BAR COMPLEX
(SHALLOW WATER)



Integrated Reservoir Analysis can be useful not only to production operations such as waterflood projects, infill drilling, recompletions, and reserve estimates, but a similar procedure could also be applied to exploration activity in mature areas with plentiful log data.

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Modeling Basin Subsidence and Stratigraphy: Blake Plateau Basin

Blake Plateau basin on the continental margin off Georgia and Florida contains 12 to13 km (39,000 to 43,00 ft) of Jurassic and younger sedimentary rock. Although such thicknesses of strata are common to sedimentary basins off the eastern United States, the Blake Plateau basin is underlain by unusually thick basement rocks (20 to 24 km; 66,000 to 79,000 ft) and is much wider (350 km; 220 mi) in comparison with other basins. Simple extensional models for the basin's origin would suggest thinner basement to correspond with the observed sedimentary thicknesses, i.e., basement 4 to 16 km (13,000 to 52,000 ft) thick. In contrast, a two-dimensional gravity model across the continental margin details the anomalous crustal structure. The basement is about 30 km (98,000 ft) thick under the shelf; 18 km (59,000 ft) under the basin, thickening seaward to 24 km (79,000 ft) under the basin's eastern edge; and 6 km (20,000 ft) thick seaward of the Blake Escarpment.

The basin's subsidence history places limits on possible models of the crustal development of this part of the margin. Because of the paucity of well data, a detailed "backstripping" analysis of the stretched continental-crust area is not possible, but an estimation can be made of the post rift, thermal-subsidence history using multichannel seismic data. Stratigraphic control for Cretaceous and younger reflectors observed in these seismic profiles is available from the Continental Offshore Stratigraphic Test GE-1 well on the landwardside and from an eroded exposed escarpment on the seaward edge of the basin. The Jurassic age assignments were based on correlations with Jurassic sea level history.

When a different and simplified technique is used, the subsidence due to stretching and cooling, but not to sedimentation, during the pre-, syn-, and post-rift periods combined, can be obtained by calculating the depth of basement that would exist without a sedimentary load. Unlike the other east coast basins, in the Blake Plateau basin this unloaded basement depth indicates local maximum values in both the subsidence due to stretching and cooling and in sedimentary thickness. These maxima occur where the gravity model shows a transition to increasing crustal thickness seaward and near the southwest continuation of the trend of the East Coast Magnetic Anomaly, which marks where, on the rest of the margin, the stretched continental crust finally separated and new oceanic crust began to form. Rifted crust of the Blake Plateau basin never failed, and generation of new oceanic crust seems finally to have begun far to the east, east of the present Blake Plateau and almost against the West African craton.

The presence of rift-stage crust on either side of this aborted break, and lack of an extensional basin on the opposing African margin south of Senegal basin, and the paleoreconstruction of the area imply that the Blake Plateau basin continued to be rifted after the rift-to-drift transition had taken place in the basins to the north. This extended period of rifting may be responsible for the anomalous width of the Blake Plateau basin and for continued volcanism (dike injection?) which produced the unusual thickness of its rift stage crust.

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Sand Bodies on Muddy Shelves: A Model for Sedimentation in Western Interior Cretaceous Seaway, North America

The continental shelf on the western margin of the Cretaceous Interior seaway was a muddy surface which bore abundant northwest-southeast trending sand bodies, up to 20 m (65 ft) thick and many km long (Medicine Hat, Mosby, Shannon, Sussex, Duffy Mountain, and Gallup Sandstones). These features resemble the storm-built or tide-built sand ridges reported from the modern Atlantic continental shelf, or from the Southern Bight of the North Sea. However, whereas modern sand ridges may rise from the Holocene transgressive sand sheet through overlying Holocene mud deposits to be exposed at the present sea floor, no modern examples are known where sand ridges are completely encased in mud, as the Cretaceous examples seem to have been.

Hydrodynamical theory suggests that special circumstances may make it possible to build sand bodies from a storm flow regime whose transported load consists of sandy mud. Under normal circumstances, such a transport regime would deposit little clean sand. The sea floor is eroded as storm currents accelerate, but erosion ceases when the boundary layer becomes loaded with as much sediment as the fluid power expenditure will permit (flow reaches capacity). Deposition of the graded bed occurs as the storm wanes; the resulting deposit is liable to consist of a sequence of thin shale beds with basal sand laminae. However, slight topographic inequalities in the shelf floor may result in horizontal velocity gradients so that the flow undergoes acceleration and deceleration in space as well as in time. Fluid dynamical theory predicts deceleration of flow across topographic highs as well as down their down-current sides. The coarsest fraction of the transported load (sand) will be deposited in the zone of deceleration, and deposition will occur throughout the flow event. Relatively thick sand deposits, 20 to 50 cm (8 to 20 in.) can accumulate in this manner. Enhancement of initial topographic relief results in position feedback; as the bed form becomes higher, it extracts more sand from the transported load during each successive storm. Individual storm beds may tend to fine upward (waning current grading), but the sequence as a whole is likely to coarsen upward, reflecting increasing perturbation of flow by the bed form as its amplitude increases.

Stability theory suggests that the end product of these processes should be a sequence of regularly spaced sand ridges on the shelf surface. However, sand bodies are localized in stratigraphic position and lateral distribution within Cretaceous shelf deposits. Upward-coarsening sequences are a widespread phenomenon in the Western Interior Cretaceous System, and the sand bodies appear to constitute localized sand concentrations within more extensive sandy or silty horizons. Especially widespread upward-coarsening sequences appear to be due to the close coupling between activity in the overthrust belt to the west and sedimentation in the foreland basin. In the proposed sequence of events, a thrusting episode increases relief in the source terrane as well as the load on the crust. Sedimentation at first dominates over subsidence, and initially the shelf on the western margin of the basin becomes shallower. As it does so, intensified wave scour on the shelf floor increases the amount of bypassing, which results in the deposition of increasingly coarser sediment, culminating in a sandy horizon. As relief in the hinterland wanes, subsidence overtakes sedimentation and the shelf subsides. Renewed thrusting begins the cycle anew.

In a second mechanism for the formation of upward-coarsening sequences, tectonic uplift affects parts of the shelf as well as the hinterland. The initiation of Sevier or Laramide structural elements beneath the shelf, and the remobilization of other, older structures, creates submarine topographic highs. These highs cause slight sand enrichment over broad sectors by means of the process described above. The development of sand-enriched areas on the shelf floor by both mechanisms leads to the flow-substrate feedback behavior that builds large scale, elongate bodies of clean sand.

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Radiolarian Biocoenosis-Thanatocoenosis Relationship in Pelagic Oceans

Detailed fluxes of radiolarian biocoenosis including 420 species have been measured by PARFLUX sediment trap experiments in the Sargasso Sea (Station S), western tropical Atlantic (E), central tropical Pacific (P_1), and Panama basin (PB). The samples were collected at 3 to 5 trap depths in the mesopelagic and bathypelagic zones during 2 to 4 month deployments. The measured fluxes of total Radiolaria in the unit of $\times 10^5$ shells/$cm^2/10^3$ yr at each station were: (E) 5.83 to 8.66; (P_1) 0.21 to 6.22; and (PB) 10.72 to 19.40. In all cases, the suborder Nassellaria represented the most contributions in number of shells (60 to 73%), followed by Spumellaria (18 to 36%). Paeodaria, a soluble end member, represented 1 to 8% in the flux of the shell number, although it contributed up to 23% in SiO_2 mass fluxes owing to the large shell size. Comparisons of these fluxes with the Holocene accumulation rates yielded the percentage of preservation of total Radiolaria: (S) 0%, (E) 0.8%, (P_1) 0.004%, and (PB) 9.3%. The extent of preservation appears to be proportional to the