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Water Injection Scheme in E2.0 Sand of Nigerian Kolo Creek Field—Optimization through Geological Modeling

The Kolo Creek field is a 5 × 10 km (3 × 6 mi) size, faulted, rollover structure with the E2.0 reservoir as the main oil-bearing sand. The reservoir is a 200 ft (66 m) thick, complex, deltaic sandstone package with a 1.9 tcf size gas cap underlain by a 200 ft (66 m) thick oil rim containing some 440 × 10^6 bbls STOIIP. The sand is penetrated by 34 wells, 25 of which are completed as producers. Nine of the producers have been closed-in for excess gas production.

During the first two years of production (1973 to 1975), a 7% (350 psi, 2,400 kPa) decline from the initial reservoir pressure was associated with a cumulative oil production of 4.5% (20 × 10^6 bbls) of STOIIP. To date, 16% (72 × 10^6 bbls) of STOIIP has been produced with an attendant 16% (800 psi, 5,500 kPa) drop in pressure. A reservoir engineering study, based on the early pressure decline, led to the implementation of a water injection scheme for which, so far, 5 injection wells have been drilled. Immediately prior to the initial phase of the scheme, cores were taken in two wells. These cores, side wall samples from other wells, and the detailed correlation made possible by the denser well pattern have resulted in a realistic geological model. It will be demonstrated how this model will influence the optimal location of future injection and production wells based on the structural and sedimentological characteristics of the reservoir.

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Regional Geomorphic Expressions of Subsurface Structure on Poorly Consolidated Surface Sediments, Coastal Mississippi

Formational contact and stream channel directional data totaling 5,356 measurements were taken from topographic and geologic maps of coastal Mississippi to determine the relationship of drainage and outcrop patterns to the Wiggins uplift. Data were compared to structural models developed by Moody and Hill in 1956 and by Miller in 1982, and to orientations of faulting and axes of structure. The Rayleigh test for uniformity reveals that neither orientations of drainage channels nor orientations of the trace of the unconformable contact between the Pascagoula and Citronelle formations exhibit a random distribution.

The effects of structure on the outcrop pattern can be seen by (1) the mean orientation of formational contact, which is nearly coincident with part of a wrench fault structural model, and (2) the greater areal extent of Tertiary outcrops in this region than in comparable regions of Louisiana Alabama. The predominant orientations of drainage channels exhibit: (1) a greater degree of coincidence with the predominant orientations of formational contacts than with any other single factor; (2) a significant coincidence with the axis of the Wiggins uplift; (3) a directional relationship to the structural axes that conforms to the relationship of wrench structures predicted in the structural models; and (4) poor alignment with the faulting described by Fisk in 1944 which are thought to also be wrench structures. It is suggested that anomalies in the courses of Red Creek, Black Creek, and the Pascagoula River are related to the Wiggins uplift and other associated wrench structures, and further, that structures described by Fisk in 1944 are locally deformed by the Wiggins uplift.

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Sedimentology of Cretaceous Kuskokwim Group, Southwestern Alaska: A Borderland Complex

The southern portion of the Albian to Coniacian Kuskokwim Group was deposited in a continental borderland setting formed during accretion of exotic terranes to continental Alaska. This borderland was characterized by a broad, deep shelf with local highlands and confined basins. The Kuskokwim Group includes braided stream, marginal-marine, shelf turbidite, and borderland basin depositional facies. These facies are analogous to those of rocks deposited on the Neogene continental borderland of southern California.

The detritus which makes up the Kuskokwim Group was at least partly derived from highlands within the continental borderland, perhaps including islands. Sediment was transported by braided streams and deposited along shorelines. The detritus was then redeposited on the borderland shelf in submarine fans. Middle fan, outer fan, and basin plain facies have been recognized. Some fan turbidites may have been reworked by wave action during major storms, as suggested by the presence locally of sandstone beds with hummocky cross-stratification. Much of the Kuskokwim Group is characterized by thin-bedded T_{CDE} siltstone-shale turbidites. These may represent deposition in areas of the borderland which were far from a sediment source. Detritus was also deposited in borderland basins, defined by submarine channel complexes composed of sandstone, conglomerate, and classic turbidites.

The Kuskokwim Group depositionally overlies diverse tectono-stratigraphic terranes of continental, magmatic arc, and oceanic affinity, indicating that those terranes were juxtaposed by the time of deposition. The continental borderland character of the Kuskokwim Group indicates that deposition occurred in a tectonically active environment. This may have been a fore-arc environment analogous to the present Kodiak-Shumagin shelf, or a transform environment analogous to the Neogene southern California borderland.

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Biostratigraphic and Paleoenvironmental Results from Neogene Radiolarians, U.S. Mid-Atlantic Coastal Plain and Continental Margin

Biostratigraphic and paleoenvironmental studies were carried out on radiolarians from over 50 core and outcrop localities from the U.S. mid-Atlantic coastal plain and continental margin. These deposits consist of sandy diatomaceous silts and clays, and represent depositional environments ranging from inner shelf (onshore localities) to upper continental slope (offshore localities).

The limited radiolarian assemblage (approximately 50 species) lacks many stratigraphically important low latitude forms but nevertheless allows the recognition of zones (i.e., those of Riedel and Sanfilippo in 1978). Radiolarians occur at onshore localities in New Jersey, Delaware, Maryland, and Virginia representing ages from early Miocene (*Stichocorys wolfii* zone) to middle Miocene (*Diartus petterssoni* zone). Late Miocene deposits are devoid of radiolarians at all the coastal plain localities studied. However, certain deposits of presumed Pliocene age in Virginia contain a sparse radiolarian assemblage. Offshore wells (such as COST B-3 and ASP 15) appear to have a longer Neogene radiolarian record, ranging from earliest Miocene (probable *Cyrtocapsella tetrapera* zone) to Pliocene age.

Analyses of variations in the entire assemblage with time were conducted on samples from several onshore localities. These were conducted by counting more than 40 important family and generic groups. The results reflect the fluctuating role of oceanic processes in the Neogene shelf environments. Abundance and diversity increase (particularly in the rarer nassellarians and in apparently deeper dwelling forms) in the intervals interpreted to have been strongly influenced by oceanic processes (i.e., upwelling of subsurface waters). Abundance and diversity decrease, and dominance by certain spumellarians increases in the intervals believed to represent shallower, lower salinity and/or more terrestrially influenced environments, as interpreted from independent paleontological and sedimentological evidence.

These results are consistent with the idea that both coastal upwelling and deltaic progradation were significant processes in the Neogene development of the U.S. mid-Atlantic continental margin. Their relative importance at any given time or locality appears to have been determined by paleobathymetry and amount of terrigenous influx, resulting from effects of changes in sea level and local tectonic conditions.

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Concepts and Creativity (AAPG Presidential Address)

No abstract.

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Reference-Rotated Eigenshape Analysis of Sands and Sandstones

Sedimentary particles with minor differences in overall shape are selectively sorted according to shape during transport. Krumbein in 1942 demonstrated a difference in fall velocity for "disks" and "rollers," and Nagle in 1967 showed that right and left pelecypod valves transported by the same longshore current ended up at different locations along a beach. Selective shape sorting of sand-size particles occurs at various rates and in distinct patterns during different modes of transport, but the subtle shape differences are hard to recognize by conventional techniques. Visual comparison methods for "roundness" and "sphericity" have such low accuracy and reproducibility as to be virtually meaningless. Also, two particles can have equal sphericity and roundness and yet be of different overall shape. The Corey shape factor (widely used by civil engineers) with its various modifications is inadequate for subtle shape variations. In two-dimensional maximum projection, simple symmetrical shapes (i.e., ellipse) are fully defined by two measurements: length of major and minor axes. Less symmetrical shapes (i.e., oval or kidney bean) need more than two measurements. Griffiths in 1967 stated that n measurements are needed for an irregular shape (where n is not known in advance).

Eigenshape analysis is a method of reducing a large number of measurements (i.e., 36 radial lengths at equal angular increments) to the minimum number of linear combinations needed to portray a significant proportion (80 to 90%) of observed shape variation. Reference-rotation is needed for sand grains in order to compare the wide variety of shapes that occur; when comparing only similar objects, reference-rotation may not be necessary. Unlike Fourier shape analysis, which as currently used involves only small-scale irregularities, Eigenshape analysis is a new approach to quantifying larger scale shape characteristics.

Laboratory experiments designed to simulate shape-sorting effects of sediment transport (slow versus fast fall velocity in a sedimentation tube; inner versus outer ring in a gold prospecting pan) separated quartz sand samples composed of grains of the same sieve size into two subsamples. These showed recognizably different assemblages of shape types by Reference-Rotated Eigenshape Analysis. Similar Eigenshape distinctions were observed when the same size fraction of two sands with different Eigenshape "signatures" were mixed in 2:1 ratio and then separated by selective shape sorting as above.

Eigenshape analysis achieved similar results with thin-section input data. Artificial rocks were made with the above sands by "lithifying" with epoxy resin. Thin sections were made perpendicular and parallel to "bedding" and at other orientations. Eigenshape analysis was performed on the grains as seen in section (not "maximum projection"). Results from bedding-parallel sections most closely resemble results from loose-grain mounts.

Inferences about provenance, transport mode, transport distance, mixing from different sources and/or different transport histories, and depositional environments are made from Eigenshape analysis results. The intrinsic R-mode factor analysis approach helps untangle these intermixed effects.

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Upwelling Deposits: Nature of Association of Organic-Rich Rock, Chert, Chalk, Phosphorite, and Glauconite

An association of organic-rich sediment with phosphorite and glauconite is commonly found in modern coastal upwelling zones. The three lithologies do not always occur together, but where they do, they lie in a characteristic facies pattern, with organic-rich sediment in the center, surrounded by a phosphorite facies which is, in turn, rimmed by a glauconite facies. A fourth lithologic element of upwelling deposits is biosiliceous ooze. Biosiliceous ooze is most commonly composed of diatoms, which evolved in the Cretaceous Period. Radiolarian oozes tend to occur in the deep sea, under divergence zones in the open ocean. Despite the predominance in modern upwelling zones of diatoms, the association of chert, organic-rich rock, phosphorite, and glauconite is common in older rocks as well; the chert in these rocks is radiolarite or spiculite. A possible fifth element of upwelling deposits is calcareous ooze; phosphatized and/or glauconitized and cherty chalks are common in the fossil record, as are organic-rich chalks. The relationship of chalk to upwelling is obscure because in modern upwelling zones, siliceous organisms are far more abundant; calcareous and siliceous phytoplankton appear to occur almost mutually exclusive of one another. By analogy with the sediments under modern upwelling zones, the presence or absence in rocks of each of the five lithologies—organic-rich rock, phosphorite, glauconite, chert, and chalk—provides clues to the nature of individual upwelling deposits. The presence or absence of each lithology, particularly chert versus chalk or the presence or absence of phosphorite, can also provide clues to such parameters as temperature and water mass characteristics.

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Sandstone Diagenesis and its Variation with Deltaic Depositional Environments, Upper Cretaceous, Southern Rio Escondido Basin, Coahuila, Mexico

Prodelta, delta-front, and delta-plain sandstones and shales were deposited in a wave-dominated lobate delta in the Rio Escondido basin during Campanian and Maestrichtian time. The