Shale Member of the Purgatoire Formation. Deposits include shoreface, beach (foreshore) and dune, estuarine and tidal channel, marine marginal bay and swamp/marsh in a generally progradational sequence associated with marine regression in the Western Interior.

The shoreface sand, characterized by ripple lamination, bioturbation and the trace fossils *Teichichnus* and *Thalassinoides*, is fine-grained, 5-10 m (15-30 ft) thick and grades into the underlying Kiowa Shale. Beach and associated dune deposits are 2-5 m (6-16 ft) thick, medium to fine-grained, medium to thick-bedded, tabular-planar cross-bedded, and lenticular; cross-bed paleocurrent headings are northeasterly and northwesterly. Estuarine channel deposits are 3-5 m (10-16 ft) thick, trough to tabular-planar cross-bedded, and medium to coarse-grained with local conglomerate overlying the scoured base which commonly cuts into the Kiowa Shale or overlying shoreface sandstone; rip-up clasts and wood pieces are common but trace fossils are rare; southeasterly and southwesterly paleocurrents predominate.

Tidal channel deposits are thinner (up to 2 m or 6 ft) and finer grained (medium to fine-grained) than the estuarine channel deposits; they occur within fine-grained sandstone and mudrock sequences, are trough cross-bedded, and commonly contain trace fossils (e.g., *Skolithos*) and wood fragments. Marine marginal (tidal flat or bay?) deposits comprise fine-grained sandstone, siltstone and interbedded shale, that are 1-3 m (3-10 ft) thick with abundant burrows, small ripple marks, and parallel lamination. These grade into the fine to very fine-grained sandstones, siltstones, shales, and coals of the swamp/marsh deposits that are 1-5 m (3-16 ft) thick and contain ripple marks, burrows, other trace fossils, and parallel lamination.

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Role of Stepovers in Strike-Slip Tectonics

We show that the key to understanding the tectonic complexity of large strike-slip fault systems is fault stepovers. Secondary structures such as folds, thrust or reverse faults, cracks, dikes, normal faults, or smaller strike-slip faults, known to occur in strike-slip environments, localize in stepovers between en echelon faults. Two types of en echelon geometry are recognized: (1) strike-slip faults that are en echelon in map view with discontinuities along the strike of faults; (2) strike-slip faults that are en echelon in cross-sectional view with discontinuities along the dip direction of faults.

Depending on the sense of stepover, discontinuities along the strike of faults result in pull-apart basins and push-up ranges, several examples of which are presented to illustrate the associated structures and their complexities. Discontinuities along the dip direction of strike-slip faults are poorly known because of the lack of field observations. Data from seismicity, however, can be used to fill this gap. One example of such en echelon fault geometry is found along the Calaveras fault, California. It is inferred that stepovers along the dip direction of strike-slip faults may produce secondary strike-slip faulting on inclined planes connecting the en echelon segments of the major fault. As the amount of overlap increases, features similar to pull-apart basins or push-up ranges are expected to occur.

Causes for the formation of discontinuities and control of the sense of stepover are not well known. Some possible factors are: spatial variability of the coefficient of friction, spatially variable elastic moduli, high pore pressure, and interaction between neighboring faults in an array of faults. The first two would give rise to both senses of stepover, whereas the last two lead only to one sense of stepover, which induces pull-apart basins.

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Lithofacies Control of Lignite Distribution and Ground-Water Quality, Wilcox Group (Eocene), East-Central Texas

Deep lignite resources (200-2,000 ft; 61-610 m) were evaluated regionally using 1,470 geophysical well logs to interpret lithofacies, lignite occurrence, and resistivity (water quality). The regional distribution of lithofacies indicates that in the region, the Wilcox Group is a fluvial-deltaic system. The primary fluvial system entered the Wilcox coastal plain west of Waco, Texas, trended southeast, and supplied a 75-mi (120-km) wide fluvial-deltaic system comparable in size to the Mississippi system.

Lignites are most abundant in the Calvert Bluff Formation (upper Wilcox). Lower Calvert Bluff lignites are thickest and most extensive southwest of the Navasota River, whereas those of the upper Calvert Bluff are thickest northeast of the Brazos River. In the shallow subsurface, Calvert Bluff lignites are found in dip-elongate low-sand areas (flood plains) between channel-sand belts. Basinward, laterally continuous lignites coincide with high net sand areas comprised of distributary channel sands indicative of a delta-plain setting.

The Wilcox Group is a major aquifer. Maps of resistivity values show that Wilcox channel sands are conduits for ground-water flow. High values of formation resistivity (low total dissolved solids) exist in recharge areas at outcrop and around salt domes. Elongate trends of high resistivity values extend tens of miles basinward and coincide with axes of major sands. Resistivity values decrease basinward and the 20 ohm-m contour delineates the downdip limit of fresh water.

Lithofacies and lignite occurrence maps are guides to exploration for deep lignite. Resistivity maps can be used to explore for ground-water resources.

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High-Potential Geothermal Energy Resource Areas of Nigeria and Their Geologic and Geophysical Assessment

The widespread occurrence of geothermal manifestations in Nigeria is significant because the wide applicability and relative ease of exploitation of geothermal energy is of vital importance to an industrializing nation like Nigeria. There are two known geothermal resource areas (KGRAs) in Nigeria: the Ikogosi Warm Springs of Ondo State and the Wikki Warm Springs of Bauchi State. These surficial effusions result from the circulation of water to great depths through faults in the basement complex rocks of the area. Within sedimentary areas, high geothermal gradient trends are identified in the Lagos subbasin, the Okitipupa ridge, the Auchi-Agbede area of the Benin flank/hinge line, and the Abakaliki anticlinorium. The deeper Cretaceous and Tertiary sequences of the Niger delta are geopressured geothermal horizons. In the Benue foldbelt, extending from the Abakaliki anticlinorium to the Keana anticline and the Zambuk ridge, several magmatic intrusions emplaced during the Late Cretaceous line the axis of the Benue trough. Positive Bouguer gravity anomalies also parallel this trough and are interpreted to indicate shallow mantle. Parts of this belt and the Ikom, the Jos plateau, Bauchi plateau, and the Adamawa areas, experienced Cenozoic volcanism and magmatism.

Geothermal gradients indicate that steam would be encountered at a depth of about 6,000 ft (1,800 m) in the Lagos and Auchi-Agbede areas, and at about 4,250 ft (1,300 m) in the Abakaliki area. A combination of heat-flow measurements and analysis of existing aeromagnetic data would provide a basis for the determination of geothermal gradients in the undrilled resource areas and the determination of depths to Curie isogeotherm (about 570°C, 1,058°F) in the basement complex and the intrusive areas from thermal attenuation of the remanent magnetic field. The separate but preferably combined application of gravity analysis, and electrical, refraction-seismic, electromagnetic, and telluric methods would help in the accurate delineation and evaluation of Nigeria's known and suspected geothermal resource areas for future detailed investigations and possible exploitation.

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Printer-Posted Maps from a Well-Data File

A series of microcomputer programs have been written to aid the geologist in building a well-data file, selectively retrieving data from the file, and generating posted maps on a printer. The system uses an IBM PC with 64K of memory, one disk drive, and an Epson MX 100 printer. The programs are written in BASICA to run under DOS 1.1. The system has been used to conduct regional geologic studies in the Michigan basin and to make field studies.

The data files contain well-identification information such as well names, location, API number, completion date, elevation, and total depth. Up to 34 depth-related markers can be defined for each project-oriented file. In addition, an x-y location is assigned for each well by reading the coordinates from a graph-paper overlay to the user's base map.

One program is used to build and maintain the file with a screen menu of available operations. A screen data form is used to enter and correct the items. Tables of contents of the wells in the file sorted in several different sequences can be listed on the monitor or the printer.

A program to selectively retrieve up to 8 data items per run through the file generates a tabular listing of the wanted items together with the well-identification information. The data items retrieved can be the stored value, the stored value less minus elevation, and the difference between 2 stored values. The retrieved data can be sorted in the same ways as the tables of contents.

The last program creates a printer-posted map of the stored values, or subsea depths, or isopach interval values. Values are normally posted to the right of an asterisk well symbol unless 2 values print in the same position, and then the second value is posted to the left. In places where 3 or more values overprint, the first 2 are posted and the well symbol is changed to a plus sign.

The programs are flexible and easy to run via screen menus. Additions and corrections to the data base are accomplished very quickly.

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Geologic Field Number and Size Assessments of Oil and Gas Plays

Assessments of undiscovered oil and gas potentials for a group of untested but geologically related prospects can be made from an estimate of the possible ranges in number and size of potential fields, assuming the play exists, coupled with an evaluation of geologic risks that it might not exist. Field size distributions can be constructed from known field reserves in geologically similar plays, from assessments of representative prospects in the play, or from simulations of distributions of the play's prospect areas, reservoir parameters and potential hydrocarbon fill. The field size distributions are truncated at both ends, at a practical minimum and at the largest size reasonable expected in the play. The possible range of number of potential fields is estimated from counted and postulated numbers of untested prospects in conjunction with a success ratio, or from look-alike field densities. The chance that the play exists is the chance that there is at least 1 field of at least the minimum size assessed. The final assessment curves, developed by Monte Carlo simulation, portray exceedance probability vs. the range of possible recoverable hydrocarbon potential.

BANKS, RICHARD B., Scientific Computer Applications, Inc., Tulsa, OK

Production Graphics and Forecast and Evaluation Systems

The production graphics system (PGS) stores historical oil, water, and gas production data, plots these on a screen, automatically fits exponential and/or hyperbolic decline curves to the data, allows the user to alter these curves interactively, and allows transfer of the resulting decline curve information to the property record data base of the forecasting and evaluation system (FES).

The FES maintains a lease or well data base, and uses information on producing rates and prices to calculate before-tax and after-tax economics for oil and gas properties. Both PGS and FES are managed by a color-enhanced, screen-oriented facility, for entering and reviewing pertinent data.

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Geophysical Exploration in Brazilian Continental Margin: History and State of the Art

Geophysical exploration by PETROBRAS started in 1954 in the onshore basins and in 1968 in the offshore basins of the Brazilian continental margin. The major problems that these basins share are: (1) short-range lateral velocity variations; (2) poor seismic data quality in many areas, especially on land, and (3) small traps with some degree of stratigraphic control.

In the search for the solution to these problems, the best techniques available have been tried. CDP was introduced in the early 1960s; digital recording and processing in 1968; bright-spot methodology in 1973; trace inversion in 1976; 3-D migration in 1978; and image-ray depth migration in 1981.

Facilities for computer-generated display for geophysical interpretation were made available in the early 1970s. Presently, an interactive interpretation mapping system with graphic stations is in use.

Examples of techniques applied to exploration and field development activities include time-to-depth conversion, generation of seismic synthetic logs, and porosity prediction.

Geophysics plays an important role in the exploration of the Brazilian continental margin, where recoverable volumes of oil have increased in onshore basins from 86.342 million BOE in 1954 to 2,132.81 million BOE in June 1983, and in offshore basins from 0.069 million BOE in 1968 to 1,626.73 million BOE in June, 1983. These volumes correspond to 246 bbl onshore and 520 bbl offshore per drilled meter for the same periods.

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Thermal Stabilization of Kerogen Maturation Over a Finite Reaction Duration

If a first order reaction can be assumed for kerogen maturation during burial diagenesis, then its reaction rate constant is $k = -\ln(f)/t$, where f is the fraction of kerogen transformable to hydrocarbon remaining after some functional reaction duration, t. The fraction of reactive kerogen is estimated from Tissot and Espitalie's model of vitrinite reflectance (R_o) evolution. A method for calculating the functional reaction duration is suggested by kerogen maturation experiments that show hydrocarbon generation proceeds by concurrent reactions with successively higher activation energies (E_a), which at a given temperature: (1) are already complete and not generating products; (2) are generating significant products; or (3) are slow and will not generate significant products in geologic time. The general correlation of R_o with maximum temperature suggests that at a given temperature, only a limited suite of reactions control hydrocarbon generation, and increased time at that temperature will not make the slower (high E_a) reactions geologically significant. Thus, the functional reaction duration cannot exceed the time necessary for the controlling reactions to essentially complete hydrocarbon generation (to the 99% level). Geologic field data, and kerogen maturation experiments extrapolated to geologic time and temperature ranges, suggest this occurs in 10^6-10^7 years.

When plotted on an Arrhenius diagram (ln k versus l/T), reaction rate constants calculated for 80 cases of kerogen maturation at maximum temperature show a strong linear relationship ($r = 0.77$). The pseudo E_a of the overall kerogen maturation reaction is about 9 kcal/mole, and its frequency factor is 10^{-11} sec^{-1}. This curve provides a method of assessing maximum paleotemperature from R_o if the kerogen has had sufficient time to stabilize.

BARKER, COLIN, and SPYRO TSOUTSOURAS, Univ. Tulsa, Tulsa, OK

Distribution of Oil and Gas on Active Continental Margins

Accumulation of oil and gas in an area depends on amount and type of organic matter, adequate temperatures for generation, suitable trapping configuration, and correct timing of events. All these factors can vary considerably across active margins of both island arc and continental (Andean) type.

Forearc areas are characterized by low geothermal gradient owing to subduction, poor reservoirs derived from volcaniclastics, and relatively low organic carbon content. Although tectonic complexity may offer a wide variety of trapping configurations, overall petroleum potential is low. Gas is present in some commercial (and many noncommercial) accumulations and is in part biogenic. What little oil is present is usually paraffinic with a low sulfur content ($\approx 0.1\%$) and an API gravity in the range 30°-35°. These facts suggest a major role for land-derived organic matter, an idea supported by the available geochemical data.

Back arc areas are characterized by higher geothermal gradients and