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Structural Styles and Plate-Tectonic Settings of Divergent (Transtensional) Wrench Faults

A divergent (transtensional) wrench fault is one along which strike-slip deformation is accompanied by a component of extension. Faulting dominates the style and can initiate significant basin subsidence and sedimentation. The divergent wrench fault is distinguished from other wrench faults by predominantly normal separation on successive profiles, negative flower structures, and a different suite of associated structures. En echelon faults, most with normal separation, commonly flank the zone and exhibit evidence of external rotation. Associated folds are predominantly vertical drag and forced flexures parallel and adjacent to the wrench. Hydrocarbon traps can occur in fault slices within the principal strike-slip zone, at culminations of forced folds, in adjacent tilted fault blocks, and within less common en echelon folds.

The divergent wrench style may develop within transform systems where major strands splay or bend toward the orientation of associated normal faults (e.g., San Andreas fault zone in Mecca Hills). The style also occurs where wrench faults overstep in a divergent sense, or where regional plate motion is obliquely divergent to a linear fault (e.g., southern Dead Sea fault). Within extensional settings, divergent wrench faults may develop at graben doglegs or oversteps (e.g., between the Rhine and Bresse grabens) and may separate regions that experienced different magnitudes of extension (e.g., Andaman Sea area; Furnace Creek fault zone, California). The style has also been recognized in magmatic arcs and backarc settings (e.g., Lake Basin fault) near convergent plate boundaries and in intraplate basins (e.g., Cottage Grove fault system).

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A Microcomputer Geologic Well Data Management System

A well data management system, geoGRAM, is used to store historical well data and current data from geologic studies of the Rocky Mountain area. The program is a state-of-the-art data-base management system with the ease of use required by the geologist with limited computer experience. It allows the geologist to design map data files to suit the geology of the local or regional study area. Well record formats can handle information on 48 zones and, depending on disk capacity, store from 1 to more than 30,000 wells in each file. User-defined defaults for formation names and other data allow data to be entered mostly from the numeric keypad. Data stored is that normally gleaned from scout tickets, test reports, and well log analysis. The program automatically calculates elevations and potentiometric surfaces and any user-selected thicknesses and ratios. It allows data input in both metric and traditional units, and output in units the user selects.

Access to stored data and report writing are as simple as data entry. The file access method allows rapid on-screen viewing of records either by random access to individual well records or by "thumbing through" the file using a single keystroke. Well records may be shown on the screen singly or displayed side by side for data comparison on a 132-column screen. Printouts are provided with single-well cards holding up to 48 lines of data with graphics showing well location, API well symbol, and user-selected symbols to indicate producing zones. Multiwell listing on either printer or CRT screen is also provided. Report design including data selection, column layout and headings is accomplished entirely by menu selection.

In addition to the file data output to the CRT screen and the 2 hard-copy printout methods, file data may also be transferred to mainframe computers for graphics or other special processing by modem, disk, or tape using IMB 3740 protocol.

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Location of Gilmer Shelf Margin, Upper Jurassic, East Texas Basin

Regional stratigraphic correlations, based on wireline logs, have defined a distinctive sequence of shales within the Bossier Formation. This lower Bossier shale member, of near constant thickness, extends across the East Texas basin into Louisiana. The overlying upper Bossier shale member thickens markedly to the south and east but northward and westward intertongues with Schuler Formation siliciclastics. Below the lower Bossier shale member a shale-dominated sequence with carbonates exists in some parts of the East Texas basin. This Gilmer shale member thickens to over 500 ft (150 m) in Panola and Harrison Counties and Louisiana, but is thin or absent over the Gilmer shelf margin, where lower Bossier shales rest on Gilmer limestone buildups. Across the center of the East Texas basin the Gilmer shales average 100-150 ft (30-45 m). The continuation of the conformable, uniform lower Bossier shale member across the basin implies some time equivalence of, at the least, the thicker Gilmer shales with the massive undifferentiated Gilmer/Smackover carbonates within the East Texas basin.

The Gilmer shelf margin is situated where this carbonate succession passes laterally into eastward-derived shales; the margin is east-facing and east of the basin depocenter, trending through Upshur, Smith, and Rusk Counties. A subsidiary trend in the Gilmer limestone on the northwestern and western flanks of the basin is controlled by the presence of an underlying Buckner carbonate barrier. Only in the northeast of the basin is the Gilmer shelf margin coincident with earlier shelf edges. This reevaluation of the Gilmer shelf margin presents a major target for future hydrocarbon exploration.

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Rudists as Historians—Smoky Hill Chalk Member (Upper Cretaceous), Kansas

Remains of Smoky Hill rudists yield a wide spectrum of data relating to growth attitude, nature of substrate, death, and postmortem events. Well-preserved skeletal remains of these organisms occur mainly in the lower half of the Smoky Hill Chalk Member, and are most common in a highly fossiliferous interval that lies approximately 23 m (75 ft) above the base of a recently established reference section. Early records of Great Plains explorations suggest that extensive collecting accounts in part for low apparent specimen density. Among the many *Durania* specimens examined during this study, including numerous nearly intact lower valves, few have closely similar morphology. Specimens are solitary or compound, thin walled to thick walled, tall-conical to short-discoidal, symmetrical to highly asymmetrical in lateral aspect, and have little to extreme lateral expansion of last-formed parts of the valve wall. Wide morphological variability manifests adaptation to unstable substrate conditions, and compensation for gradual tilting or abrupt toppling as specimens approached adult size. Distribution of epizoans, particularly oysters, permits assessment of specimen orientation during life and after death, especially by defining sediment-water interfaces. Epizoan distribution also furnishes evidence of pre-burial fragmentation of Smoky Hill rudists. Texture and structure of enclosing chalky sediments are consistent with a low-energy depositional environment, so wave or current damage is unlikely. Pre-burial fragmentation of some specimens, fragments oriented contrary to normal gravitational settling, overturned specimens, and possible tooth marks combine to suggest that large vertebrates left in their wake the wreckage of extensive predation.

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Interpretation of Hydrocarbon Shows Using Light (C_1-C_5) Hydrocarbons

Mathematical treatment of light hydrocarbons (C_1-C_5) in the interpretation of hydrocarbon shows has been attempted by many authors. The methods so far developed have been used on specialized grids and can only be used for a few readings per grid.

A study of a large number of mud logs from many different geologic environments was conducted to compare hydrocarbon shows to various ratios of C_1-C_5 hydrocarbons. The aim of the study was to produce a method of interpretation of reservoir hydrocarbon character using C_1-C_5 gas shows that would be relatively simple to calculate, plot, and interpret. The method also had to be easily integrated with other reservoir character plots and logs such as mud logs and wireline data; hence it had to be plotted on a depth log while not losing any interpretational value.

From this study, a new method of mathematical treatment was evolved which can be performed at the wellsite during drilling, and by study of the relationship of the ratios, initial evaluation of the reservoir characteristics is possible.

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Fluid-Bearing Capacity of Strandline Sand Deposits—Implication for Hydrocarbon Exploration

The fluid-bearing capacity of the Holocene coastal sand deposits of central South Carolina was determined in order to estimate their potential oil-in-place reservoir capacity. These sand bodies, which vary considerably in size, thickness, shape, and continuity, were deposited in a variety of depositional settings including barrier islands, tidal deltas, exposed sand flats, tidal sand ridges, and tidal point bars. Minimum potential sand thickness and conservative mud cutoff values of 10-15% were used to define each sand body type. Average thickness values ranged from 20 ft (6 m) for barrier islands to 15 ft (4.5 m) for exposed sand flats. Within the study area, barrier islands have average sand volumes of 1.3×10^5 acre-ft (1.6×10^8 m^3), and tidal delta sands average 1.0×10^5 acre-ft (1.2×10^8 cm^3).

Potential oil reserve values averaged 7 million bbl for individual barrier islands and 5 million bbl for individual ebb-tidal deltas. If the Holocene sand deposits of the central 50 mi (80 km) of the South Carolina coast were preserved in place, 150-200 million bbl of oil could be contained within the reservoir-quality sands. Of course, these values represent only one small segment of geologic time, approximately 5,000 years.

These calculations were based on typical reservoir characteristics and recovery factors found in Cretaceous sandstones buried at 5,000 ft (1,500 m) in the Rocky Mountain area. Average reservoir values used included porosity of 25%, oil saturation of 65%, formation volume factor of 1.3, and 10% of the sand body occupied by hydrocarbons.

A better understanding of these strandline sand deposits could improve exploration and future development of these significant, potentially oil-bearing sands.

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Morphostratigraphy of Foraminifera Via Automated Image Analysis

Morphologic variability of foraminifera is a virtually unexploited resource for definition of biozones, morphozones, and phylozones. The morphologic information contained within foraminiferal tests can result in a zonation based on subspecific characters and therefore can more finely divide stratigraphic sequences in comparison with more conventional biostratigraphic techniques. This morphozonation is extremely valuable for time intervals characterized by long ranging species and thick sedimentary sequences with few evolutionary marker events. Biozones can be used to identify sequences within a basin which have common ecomorphologic imprints. Through this precise measurement and determination of a common original shape, morphozones afford the possibility of evaluating diagenetic gradients.

The advantage of using foraminiferal morphometrics lies in great abundance of forams in relatively small samples, thus permitting measurement and evaluation of large numbers of forams in a narrow chronostratigraphic range. Measurement of such samples requires the use of automated image analysis procedures, by which large numbers of specimens can be measured in a short period of time. The development of automated image analyzers now allows for rapid and precise analysis of foraminiferal morphological changes. Our image analyzer is a TV signal fast analog-to-digital converter installed in a Z80-based microprocessor. It is capable of locating and digitizing foraminifera at the rate of more than 150 specimens per hour. The subsequent analysis of shape changes is via closed-form Fourier series and multivariate statistical techniques. Through the use of both image analysis and statistical methods, a precise quantification of morphological change is possible.

We have analyzed more than 12,000 specimens of 15 species of planktonic and benthic foraminifera from Holocene and Pleistocene sedimentary environments. The results clearly indicate that the quantification of morphological change is capable of precisely delineating common shapes within a zone which are related to changing environmental or evolutionary influences.

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Isotopic Provenance of Sandstones from the Displaced Tyee Formation, Oregon Coast Range

A significant component of the Eocene Tyee Formation of Eocene age in the Oregon Coast Range was not derived from local source areas but appears to have come from terranes that presently lie far to the east. Traditional basin analyses, including studies of paleocurrents, lithofacies, and sandstone compositions, have generally been interpreted as indicating local derivation from the Klamath Mountains which lie to the south. However, isotopic analyses of whole-rock sandstone samples and mineral separates preclude derivation solely from the Klamath region.

Sandstone samples collected throughout the Tyee basin were analyzed for Sm-Nd, Rb-Sr, K-Ar, and ^{18}O. Whole-rock negative ϵ_{Nd} values (-7.1 to -7.3) coupled with positive ϵ_{Sr} values imply a source area underlain by Precambrian continental crust. Whole-rock Rb-Sr data fall along a trend dissimilar to data from Klamath-derived sandstones. Detrital K-feldspar has $^{87}Sr/^{86}Sr$ ratios that are too high to have been derived from plutonic rocks in the Klamaths. Consistent Rb-Sr ages for white mica from samples throughout the basin indicate a Late Jurassic age, and K-Ar ages have been uniformly reset to about 68 Ma, an overprint not recognized in the Klamath terranes. $\delta^{18}O$ values of white micas cluster around 9.5 per mil, and are similar to values for S-type granites like those in the Idaho batholith but higher than those of normal I-type granites. Also, these values are much lower than those of white micas from metamorphic rocks in the Klamath Mountains.

These data preclude the Klamath Mountains as the principal source for detritus feeding the Tyee basin. The most likely source region is the Idaho batholith. Derivation of abundant sediment from this eastern source area suggests that during deposition the Oregon Coast Range basin lay much farther east and has subsequently moved westward to its present position. Such a major displacement is consistent with the inferred tectonic rotational history that has been suggested for the Oregon Coast Range since the time of deposition of the Tyee Formation.

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Geothermal Energy Resources in Trans-Pecos Texas—Characteristics and Potential for Development

Convective geothermal systems in Trans-Pecos Texas, and Chihuahua and Coahuila, Mexico, are potential energy resources. The geothermal systems, which lie along a narrow belt near the Rio Grande River, are characterized by hot springs and shallow hot wells located along normal faults. The hot water is meteoric water that has circulated to depths of 2-3 km (1-2 mi), been heated, and risen to the surface through fractures along fault zones. The heat source is the Earth's normal thermal gradient, which is as high as 40°C/km (202°F/100 ft); no young magma bodies are involved. Maximum measured temperatures are 90°C (194°F) at a hot spring in Chihuahua, about 80°C (176°F) in 2 wells in the Sierra Vieja, and about 75°C (167°F) in several wells east of El Paso. Many springs have temperatures in the range 35-50°C (95-122°F). Maximum subsurface temperatures estimated from chemical geothermometers are 100-160°C (212-320°F); most are considerably lower. Chemical constraints on use should be negligible except for the El Paso-area waters, which have moderately high dissolved solids (10,000 mg/L). Hydrologic data to evaluate possible production rates are generally sparse. None of the waters are hot enough to generate electricity by currently available technology. The highest temperature waters could be used for industrial or space heating, but, except for the area near El Paso, they are too far from population centers.