The Krebs Formation (Middle Pennsylvanian-Desmoinesian) forms the lower portion of the Cherokee Group in the Cherokee basin of southeastern Kansas. The Krebs Formation near its outcrop in Cherokee and Crawford Counties consists of 78% shale and mudstone, 18% sandstone and siltstone, 3% coal, and 1% limestone, comprising a total thickness of 120 to 220 ft (37 to 67 m). Integration of data from continuous cores, outcrops, and geophysical logs provides a detailed stratigraphic framework and facilitates interpretation of depositional environments. Coal beds and associated seat-rock units, some having an areal extent of several thousand square miles, provide excellent stratigraphic marker beds for correlation of discontinuous reservoir sandstones. Radioactive dark-gray shale units and argillaceous limestone units often overlie coal beds and may be equally widespread.

Net-sandstone isolith maps reveal the presence of a lobate deltaic complex in southwestern Missouri, characterized by both stacking and offset of major sandstone bodies. Coal beds commonly cap upward-coarsening, mud-dominated sequences consisting of dark-gray shale with occasional argillaceous limestones overlain by lenticular-bedded shale or wavy-bedded siltstones. This vertical transition of lithofacies is interpreted to result from the progradational infilling of large interdistributary bays. Coarsening-upward sandstone sequences—consisting of lenticular-bedded shale grading upward into wavy-bedded siltstone, flaser-bedded sandstone, and rippled or cross-bedded sandstone—represent distributary mouth-bar or crevasse-splay deposits. Fining-upward sequences—composed of a basal scour surface overlain by mud-clast conglomerates, large-scale cross-bedded sandstone, and rippled or flaser-bedded sandstone—are interpreted to be channel-fill or point-bar deposits.

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Seismic Exploration for Pennsylvanian Granite Wash Reservoirs, Palo Duro Basin

A seismic reflection common-depth-point technique was designed specifically for the Palo Duro basin. The goal was to locate hydrocarbon traps in the Pennsylvanian granite wash. Success ratios using the designed techniques were approximately as follows: (1) to locate hydrocarbon-bearing features, approximately 25%; (2) to locate structures, approximately 50%; (3) to pinpoint development locations, approximately 75%.

The specific technique design is presented as it relates to: (a) density and layout of seismic lines; (b) spread lengths and configuration; (c) field parameters, e.g., geophone array and shot-hole depths; (d) data correction techniques, including weathering correction, choice of datum plane, and choice of datum velocity; (e) data processing requirements and quality control; and (f) interpretation of data, including depth conversion and well ties.

This paper covers the aforementioned topics with a minimum of advanced mathematics, and it poses questions for the advanced mathematician.

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Atokan (Pennsylvanian) Berlin Field: Anatomy of a Recycled Detrital Dolomite Reservoir, Deep Anadarko Basin, Oklahoma

Berlin gas field in Beckham County, Oklahoma, was discovered in 1977, and is the largest Atoka (Pennsylvanian) hydrocarbon accumulation in the Anadarko basin. It is an overpressured reservoir at a depth of 15,000 ft (4,572 m) and occupies a surface area of 41 mi^2 (106 km^2). The reservoir rock consists of recycled, detrital Arbuckle dolomite (Cambrian-Ordovician), and contains ultimate recoverable reserves of 242 to 362 bcf.

Arbuckle dolomite and limited exposures of Precambrian granite rocks were eroded from the Amarillo-Wichita Mountains in the Atokan and were deposited as a terrigenous, sandy dolomite clastic wedge adjacent to the uplift. In the late Atokan, the Elk City structure was uplifted and subaerially exposed in the vicinity of the northern limit of the dolomite clastic wedge. The detrital dolomite on the structure was concurrently eroded and recycled northward as a shallow marine fan delta. Subsequent recrystallization destroyed the detrital depositional texture and created the present intercrystalline porosity.

The deep Elk City structure consists of an upthrust block bound by the late Atokan unconformity that is genetically associated with the Berlin fan delta. Present relief on the upthrust block and overlying anticlinal folds formed during post-Atokan growth of the structure.

Berlin field provides a model of a large, localized clastic deposit derived from uplift and erosion of a prominent structure, and it is an example of the potential for large detrital stratigraphic traps around the perimeters of prominent structures that contain crestal unconformities.

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Upper Pennsylvanian Marine Algal Banks of Kansas: Comparison and Implications

Marine algal banks (mounds or buildups) present in the Shawnee Group (Upper Pennsylvanian) crop out in eastern Kansas. The youngest of about 20 banks known to occur in the section differ in shape and size but, in general, cause a local increase in thickness that is compensated by a decrease in thickness of the overlying shale. The phylloid algae, *Eugonophyllum* and *Epimastopora,* trapped and bound the carbonate mud in a role similar to the modern sea grass, *Thalassia,* in Florida Bay. The soft mudbanks created barriers to water circulation and fauna distribution. The Shawnee banks decrease in size, contain less algae and more micrite, and are more difficult to define with decreasing age. The Plattsmouth bank formed instantaneously by building on the "normal" lithology over a large area; the Ervine Creek bank started locally and spread laterally so it is funnel shaped; the Hartford bank is diffuse with the algae occurring in small curls instead of larger, flat blades. All three banks are capped with a layer of osagite/pellets/fusulinids. The Plattsmouth bank is topped with a crust of algal(?) material, and the Ervine Creek bank shows evidence of solution features, indicating possible subaerial exposure. Interpretation of the sequence is that the elongated banks were formed in shallow, warm water parallel to shore in a regressive environment until smothered by an influx of fine clastic material. Differences in size, shape, algae type and quantity, and postdepositional alterations result from subtle differences in setting and timing of development.

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Reservoir Characterization Study of Mississippian "Chat" Reservoirs, South-Central Kansas

Mississippian "Chat" intervals in south-central Kansas have produced more than 20 million bbl of oil as of December 1983, but only 8-12% of estimated oil in place was produced. Generally, poor "Chat" production has been attributed to low API gravity and low-viscosity oils, producing from high-porosity, low-permeability in-situ chert intervals. Production is from Mississippian "Chat" residual, tripolitic, in-situ chert intervals and overlying Pennsylvanian Cherokee sands.

One reservoir initially classified as having low API gravity and low-viscosity oil is the Hardtner field in southern Barber County, Kansas, near the axis of Pratt anticline. Previous studies using structure, isopach, net-pay, and combinations of porosity and water saturation maps have had limited success in defining hydrocarbon migration paths or increasing reserves through drilling. Recent studies indicate that, by mapping the reservoir parameters of relative oil-water permeability, water- and oil-wet rock conditions, and phase-drive mechanism, producibility may be better estimated.

Reservoir core analysis and geophysical well logs indicate both water-wet and oil-wet rock conditions are present within 80-ac spacings. Further core analysis indicates pore-throat geometries are related to the dissolution of sponge spicules present in the cherts.

The present study uses variables of relative permeability, paleotopography, pore-throat tortuosity, and coordination numbers as input for multivariant vector-analytical algorithms (CABFAC-QMODE family of algorithms). Results of this and other "Chat" reservoir studies suggest a practical evaluation criteria for more effective exploitation drilling and increased efficiency in enhanced recovery programs.

PHILLIPS, ERIC H., Gulf Oil Exploration & Production Co.-U.S., Casper, WY

Gravity-Slide Thrusting and Folded Faults in Western Arbuckle Mountains, Oklahoma

One or more major gravity-slide thrusts have been documented in the Eola, Southeast Hoover, and Southwest Davis oil fields, and in the western Arbuckle Mountains, Garvin and Murray Counties, Oklahoma. The gravity-slide area initially covered portions of at least nine townships; it was more than 30 mi (50 km) long and 5-6 mi (8-10 km) wide. It involved a stratigraphic sequence greater than 5,000 ft (1,500 m), extending from the lower Springer Formation into the upper portion of the Arbuckle Limestone. The major slides moved to the northeast and northwest, probably in the Middle Pennsylvanian. Slides and faults were subsequently isoclinally folded in the Late Pennsylvanian. The tensional updip segment of the major folded slide fault now coincides with the trace of the Washita Valley fault. The compressional end of the slide coincides with the Reagan fault in the east and the frontal Eola fault in the west. In the Lake Classen area the latest folding has turned all formations involved in the slide—and the associated faults—to a near-vertical position. Thus, the slide is exposed in a "profile view" on the south limb of the overturned Washita Valley syncline. On the north normal limb of the Washita Valley syncline, the slide is exposed in "plan view," with the Dougherty anticline and related folds representing compressional folding at the toe of the slide. Several tectonic breccias near the top of the Kindblade Formation of the Arbuckle Group probably mark the orogenic event.

PULLING, DAVID M., Independent, Oklahoma City, OK

Clinton Gas Field: A Significant Stratigraphic Discovery

Clinton gas field has developed into one of the most significant stratigraphic discoveries in Oklahoma. This field is important not only for the magnitude of its hydrocarbon reserves, but also for the model it provides for finding similar fields.

The Clinton field is part of the Clinton-Geary trend, which is productive from upper Red Fork sandstones of Desmoinesian age. This trend is a 65-mi long, 0.5-2-mi wide incised fluvial channel that runs through Blaine, Caddo, Canadian, and Custer Counties. The Geary field at the northeastern end of the channel was discovered and subsequently developed in the 1970s. In 1979, the Clinton field was discovered, and since that time no less than 50 productive wells have been drilled. Development of the field is still continuing at a rapid pace.

The Clinton-Geary channel developed on a pre-Pink limestone erosional surface and eroded a 200-ft deep valley, which was subsequently filled by stream deposits, predominantly sands, silts, and clays. Sandstones in the channel range from a few feet in thickness to almost 200 ft.

Individual wells in the Clinton field have had flow rates exceeding 10 MMCFGD, with calculated open flow in excess of 40 MMCFGD. Estimated reserves are 30-40 bcf of gas and 0.6-0.8 million bbl of oil for the best wells in the field. Ultimate recoveries for the field are estimated to be 0.75 tcf of gas and 15 million bbl of oil.

The Clinton field is the most prolific Red Fork gas field in Oklahoma. A thorough understanding of its depositional history may help us discover similar significant fields.

RASMUSSEN, NOEL F., BOREXCO, Tulsa, OK

Use of Airborne Magnetics in Overthrust Areas

Detailed airborne magnetic surveys have been useful in exploring overthrusts containing magnetic, igneous rocks. The structural configuration of these rocks can be closely approximated. The most important information is the thickness of igneous material overlying sediments and the dip of the overthrust base. Thicknesses and dips of magnetic rocks in overthrusts can be highly variable. Thickness variations of 20,000 ft have been found to occur over the course of 5 mi parallel with the toe of the thrust. The igneous to sedimentary rock contact can range from vertical to horizontal in the same distance.

Interpretations can be used to guide the exploration program in overthrust areas. Seismic surveys can be located in areas of thin granite cover so prospective structures in the underlying sediments might be located at shallower depths.

The Arbuckle Mountain Range is an example of an overthrust that can be explored in this fashion. This overthrust covers a large surface area; in places it is very thin and in others, very thick, being in contact with the basement. The thrust covers a large surface area in an intensely drilled basin. The sediments below the thrust cover an area large enough to "hide" several major oil fields.

Undrilled areas large enough to contain major oil reserves are becoming increasingly scarce. The use of magnetics to detect and map igneous overthrusts can find undrilled sedimentary areas large enough to contain major reserve prospects.

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Dry Creek Field, Nebraska: Subsurface Methods Case History

Dry Creek field produces oil from thin Lansing (Pennsylvanian) limestone beds at a depth of about 4,000 ft (1,200 m) in central Hitchcock County, Nebraska. This subtle oil accumulation was discovered in 1963 by good fortune and weakly quantified subsurface geology; it remains geologically ill-defined. Conventional subsurface studies have been of little value in explaining the oil accumulation at Dry Creek field.

We have developed a method for evaluating thin Lansing reservoir beds that incorporates careful analysis of cuttings and logs of early vintage. This method facilitates mapping Lansing reservoir distribution, thereby permitting a better understanding of the subtle trap at Dry Creek. We believe this method can be used as an additional subsurface exploration tool in the northern Mid-Continent.

Subsequent to original publication of the methods described in this study, additional wells have been drilled at Dry Creek field. Some of these wells supported our original interpretation of reservoir distribution at Dry Creek, while others did not. Recently, the geologic techniques developed at Dry Creek field have been used successfully in exploration drilling in Decatur County, Kansas.

SONNENBERG, STEPHEN A., Bass Enterprises, Denver, CO

Tectonic and Sedimentation Model for Morrow Sandstone Deposition, Sorrento Field Area, Denver Basin, Colorado

Pennsylvanian Morrow sandstones are oil and gas productive throughout a large area in southeast Colorado. The Sorrento field is a recent major Morrow discovery with recoverable reserves estimated at over 10 million bbl of oil from an area of 3,200 ac (1,295 ha.) at depths of 5,400 to 5,600 ft (1,646 to 1,707 m). Minor production also occurs from the Mississippian Spergen and Saint Louis, and the Pennsylvanian Marmaton.

Productive Morrow sandstones are interpreted on the basis of subsurface mapping to be fluvial valley-fill deposits, consisting mainly of channel sandstone. These deposits are encased in marine shale and range in thickness from 5 to 55 ft (1.5 to 16.7 m); net pay ranges from 5 to 30 ft (1.5 to 9.1 m). Porosities average 19%, and permeabilities range from 1 to 4,000 md.

Isopach maps of the Morrow and associated stratigraphic intervals indicate that paleostructure influenced Morrow depositional patterns. Morrow channel sandstones accumulated in paleostructural low areas created by movements on basement fault blocks. Structural nosing is present in the same location and trend as the Morrow channels, indicating structural inversion. Analyses of stratigraphic intervals above the Morrow indicate that the structural inversion occurred during the Early and Middle Pennsylvanian. The field is regarded as a combination structural-stratigraphic trap.

Knowledge of paleostructural control on reservoir facies provides a new idea for exploration for Morrow reservoirs in southeast Colorado.

STOUTAMIRE, P. STEVE, Essex Exploration Co., Tulsa, OK

Furgerson Field: A Lesson in Serendipity

Serendipity is the aptitude for making desirable discoveries by accident. The development of the Arkoma basin's Furgerson field in Pope County, Arkansas, is an excellent example of this.

Although it was discovered in 1965, little development occurred in this field until 1981 when Texas Oil & Gas drilled the 1 Beard (Sec. 32, T9N, R20W). This well encountered two pay sands within the Pennsylvanian Atoka and one within the Pennsylvanian Morrow for total reserves of 4-5 bcf of gas. The TXO 1 Forehand (Sec. 33, T9N, R20W) was then drilled as an offset, supposedly aimed at encountering the same sands. Unfortunately, the Atoka pays present in the 1 Beard were faulted out, and the