phy clearly shows that several dikes are right-laterally offset. These offsets appear on TM imagery only as subtle bends, rather than breaks in the dikes. However, because TM imagery reveals subtle spectral differences that aerial photography cannot, the imagery will display more information. This is demonstrated by nearly twice the number of dikes being mapped using TM imagery than with aerial photos.

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Computer Modeling and Graphic Representation of Development of Secondary Porosity and Cements in Reservoirs Rocks

We have developed a set of programs for analysis of surface and subsurface data that (1) organize the data to reduce its bulk without violating its integrity, (2) present 3-dimensional graphic representations of the data, and (3) use transport/reaction models to predict the evolution and spatial distribution of secondary porosity and cements. This evolution path and distribution arise through the interaction of flow, diffusion, dispersion, mineral dissolution, and cement precipitation.

These programs are applied to 2 types of reservoir rock: (1) a feldspathic arenite in which feldspar dissolves and calcite cement precipitates, and (2) a limestone undergoing dolomitization.

Knowledge of spatial distribution of porosity and cements derived from these models is valuable in choosing drill-hole sites.

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Use of Conodont Genus *Gondolella* in High-Resolution Biostratigraphic Zonation of Middle-Upper Pennsylvanian Rocks, Central North America

Several conodont taxa have been suggested for use as biostratigraphic tools in the Pennsylvanian, but each has its limitations. Some are severely restricted paleobiogeographically or paleoecologically. Others existed through a relatively short interval of time, leaving the bulk of the Pennsylvanian column unzoned. Frustratingly, the single most promising group, the *Idiognathodus-Streptognathodus* plexus, has eluded taxonomic treatment that is both phylogenetically sound and biostratigraphically useful.

Gondolella Stauffer and Plummer, 1932 (type-species *G. elegantula,* O.D.), is subject to many of these restrictions, especially geographically and paleoecologically, but offers a highly precise zonation in the rocks where it does occur that can serve as an interim standard for some (mostly Missourian) and a supplement for others (mostly Desmoinesian). Enough occurrences have been amassed to facilitate interregional, and in some cases, intercontinental correlations.

Desmoinesian gondolellids are known from 9 stratigraphic units in the Illinois basin and 5 from the Mid-Continent, and 5 zones are recognized. Distribution is relatively uniform, and zonation of this part of the column is almost total. This zonation is less detailed than the contemporary *Neognathodus* zonation, but it is a valuable supplement to it. The most dense concentration of *Gondolella*-bearing units is in the Mid-Continent Missourian where 15 units have produced gondolellids. These and the 6 Illinois basin units can be assigned to at least 6 zones, totally contiguous in the lower Missourian, less so upward. The Virgilian cannot be completely zoned, but the 2 productive Mid-Continent units are assigned to different zones.

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Environmental Significance of Pisoliths, Mississippian Madison Formation of the Williston Basin, Bottineau, Renville, and McHenry Counties, North Dakota

Pisoliths from the Mississippian Madison Formation of North Dakota originated in an agitated, shallow-water marine environment. Evidence for this interpretation includes: (1) association of pisoliths with ooliths and marine fossils; (2) well-rounded clastic pisolith morphology; (3) vertical facies succession in core from open-marine facies through the pisolith-oolith facies band into lagoonal and intertidal facies featuring fenestral fabrics and possible tepee structures; (4) upward-shallowing cycles with reverse grading, submarine hardgrounds, and desiccation features.

Madison pisolites (pisolith-rich carbonate) differ markedly from those set forth by Dunham as indicators of vadose, caliche soil conditions: (1) they lack fitted polygonal structure; (2) they have large amounts of primary pore space or cemented pore space; (3) they contain no peds (soil components); (4) no evidence of rooting is visible; (5) no classic "caliche" horizons are present; (6) only minor occurrence of vadose cements postdate pisolith initiation, development, and deposition; (7) no evidence for replacement of parent rock was observed.

Similar evidence was used by Esteban, and Esteban and Pray, to show that the "type" Capitan Formation pisoliths were not formed by caliche soil-forming processes. Pisoliths and pisolites should be viewed in relation to other carbonate allochems, sedimentary structures, and diagenetic fabrics to determine their origin and environmental significance.

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Regional Facies Distribution and Tectonic Evolution of Appalachian and Ouachita Thrust Belts

A series of 12 tectonic and lithofacies maps representing critical periods of the evolution of the Appalachian-Ouachita orogen were compiled from published sources and interpretation of seismic and subsurface data. The distribution of sediments supports the concept of multiple deformation that resulted from the collision and accretion of small plates or irregular margins of larger plates with North America.

During the Eocambrian and Early Cambrian, a series of rifts developed within the craton subparallel to the continental margin of the Iapetus Ocean. Ouachita sediments were deposited in this rift zone along the southern margin of the craton. However, the rift zone did not persist in the Appalachians, and the sediments in that belt were deposited along the continental margin.

In the Middle Ordovician, the extensional regime continued in the Ouachita belt while compression associated with plate collision began in the Appalachians. The northwest-southeast-trending boundary between these areas persisted throughout the evolution of the orogens. The sedimentary records indicate that the initial compressional deformation in the Ouachita belt began during the Late Mississippian, and the final phase of deformation in the Appalachians was initiated slightly later, during the Early Pennsylvanian.

Structural features associated with thrusting basin sediments over foreland areas were controlled to a great extent by the presence or absence of buttresses. The Ouachita Mountains area provides the best illustration of contrasting structural styles along the thrust belt. Elsewhere along the thrust belts the evidence is either covered by younger sediments or altered by a complex tectonic history.

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Resources of Small Oil and Gas Fields

In presently known small oil fields, a remaining recoverable reserve of about 3,100 million bbl appears evident. As much as 2,000 million bbl remain in place in abandoned small fields, of which at least 500 million eventually may be recovered through redevelopment or, in a few cases, mining. Reserves of oil in stripper wells amount to about 5,200 million bbl. Research on only 2 basins, Gulf Coast and Permian, indicates that, should a high rate of drilling activity persist into the future, at least 10,000 million bbl more in small fields could be anticipated in the United States. This suggests that a total of at least 19,000 million bbl of oil in small fields remains to be recovered in the future in the United States.

Gas from presently-known small oil fields should account for more than 17 tcf, nearly all nonassociated. In addition, at least 67 tcf of gas and nearly 2,000 million bbl of condensate will come from small, nonassociated gas fields. It is not known how much gas, as compared with oil, will be found in small fields as a result of future exploration. The amount will be substantial.

An enormous exploration effort will be required to yield this petroleum. The aggregate return is substantial, but because it is from a collection of small fields, it will not be possible to optimize exploitation in the same way as for a similar amount of petroleum from a few large fields.