Sands do not correlate well between the wells, but individual coals and groups of coals make excellent correlations. Seismic processing experiments show that resolution of the data improves when high frequencies are retained; in fact, the lower Wilcox "wipe-out" zone disappears.

On the reprocessed seismic data, fairly uniform cycles appear whose boundaries correlate with slightly thicker coals or groups of coals on the well logs. The log interval of each seismic cycle is about 300 ft (90 mi) and includes three or four stacked point-bar sands. An individual point-bar sand, and hence the producing reservoir sand, cannot be resolved on seismic data. It is thought the seismic cycles represent meander-belt cycles, each containing several point-bar sands.

A reprocessed dip line shows that the seismic cycle which includes the producing sand pinches out between the discovery well and the two dry holes. More seismic is necessary to define the lateral limits.

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Upper Cretaceous Tempestites in Mancos and Mesaverde Formations—A Model for Shallow-Shelf Sandstone Reservoirs

The sedimentologic features that characterize the pinchout of Mesaverde Group sandstones into the Mancos Shale are spectacularly exposed along the Book Cliffs in east-central Utah. We traced the upper portion of the Blackhawk Formation of the Mesaverde Group as it graded into Mancos Shale, and observed textural trends and sedimentary structures which match those that are observed in modern tempestites formed on siliciclastic shelves. The upper-most portion of the Mancos consists of upward coarsening sequences of mudrocks that exhibit large-scale scour and fill structures and slump features. Above the Mancos, sandstone units of the Blackhawk Formation commonly display sole marks within partial Bouma sequences, and sandstone units higher in the section consist of hummocky cross-strata sets grading up to asymmetrical ripple sets. These units represent tempestites that were deposited by wave-modulated, wind-driven currents generated by storms as they crossed the mud-dominated western shelf of the Cretaceous seaway. Tempestite sequences can be traced up depositional dip into tongues of prograding shoreface sandstones.

The moving of large quantities of sand and silt-sized siliciclastics out onto mud-dominated shelf environments appears to be a major process along margins of epicontinental seaways. We believe that these movements are storm-generated, and that sands, which later became petroleum reservoirs, were placed in shelf settings in the form of tempestites. In particular, many petroleum-bearing Cretaceous sandstones in Wyoming, Colorado, and Utah that have previously been interpreted as either deltaic-coastal bars or "shallow-water turbidites," are actually tempestites.

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Seasonal Growth Rates and Carbonate Production in *Halimeda opuntia* at Marquesas Keys, Florida

Rates of growth and carbonate production of the calcifying green alga, *Halimeda opuntia,* were measured from July 1982 to September 1983 at the Marquesas Keys, 29 km (18 mi) west of Key West, Florida. Seasonal fluctuations in growth rate were determined by collecting and analyzing whole colonies of algae that had been previously stained in situ with Alizarin Red-S. Weight increase of individual plants was calculated by recording weights of various *H. opuntia* colonies harvested at different times during the year. Growth was strongly seasonal with 80–90% of new plates being produced in summer months (May through October). From November through April, colonies appear to be in a semidormant state generating little new growth. Surprisingly, more than 90% of the new plates produced by parent plants were the offspring of only a few (usually less than 50) "dominant" plates.

Measured growth rates appear sufficient to explain the 12 m (6.6 ft) thick, 6 km (4 mi) wide, 16 km (10 mi) long, crossbedded *Halimeda* accumulation located west of the study area.

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Late Atokan Brachiopod Biostratigraphy, Bird Spring Group, Arrow Canyon, Clark County, Nevada

Pennsylvanian rocks at Arrow Canyon have been proposed as a stratotype for the base and top of the Pennsylvanian System and for the "Atokan" Series. Fusulinaceans and conodonts document an essentially continuous biostratigraphic succession, and detailed petrographic descriptions have been published. Systematic descriptions and local ranges for the extensive and biostratigraphically significant brachiopod fauna are, as yet, unpublished. This report on brachiopods from the Zone of *Fusulinella* is part of an ongoing investigation of the Arrow Canyon invertebrate fauna being conducted at the University of Illinois. Materials under study include about 1,000 weathered-free specimens, and silicified material etched from about 500 pounds of matrix. Twenty-eight taxa have been identified, most notably a new species of *Brasilioproductus* Mendes, a genus previously known only from the Amazon basin. Ranges of *Spiriferellina ceres, Antiquatonia hermosana, Neochonetes dominus, Cleiothyridina milleri,* and *Rhipidomella elyensis* are here extended into the late "Atokan." *Composita trinuclea,* characteristically Mississippian, also occurs. Biostratigraphic correlation with both the southern Rocky Mountain region and Ohio is strong. Midcontinental correlations are less firm, probably because Atokan rocks in that area are poorly fossiliferous.

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Diagenesis of Burbank Sandstone, North Burbank Field, Osage County, Oklahoma

The Pennsylvanian (Desmoinesian) Burbank sandstone in Tract 97 of Osage County, Oklahoma, is 2,845–2,945 ft (867–897 m) deep. Samples of the Burbank from cored intervals of five wells were analyzed to determine depositional environment, diagenetic alterations, and the effects of diagenesis on reservoir rock properties.

The Burbank sandstone consists of very fine to fine-grained lithic arenites deposited under fluvial-deltaic conditions. Though quartz dominates in the detrital fraction, rock fragments, primarily metamorphic, and feldspars constitute as much as one-third of the grains. Compaction, authigenesis, replacement, and dissolution have significantly altered the texture and composition of the Burbank sandstone. Compaction is relatively minor due to early cementation. However, multiple stages of authigenesis have given rise to abundant silica and carbonate cements and clay minerals, which together constitute approximately one-fourth of the bulk volume of the sandstone. Clay minerals, dominantly iron-rich chlorite with minor illite, occur as pore lining, pore filling, and replacement of silicate grains. Replacement of detrital particles by carbonate cement is ubiquitous; such replacement seems to be susceptible to dissolution. Dissolution of grains and particularly cement has yielded the present average porosity of 15%.

Hydrocarbon recovery from the Burbank sandstone is complicated by depositional changes and diagenesis. For a tertiary recovery program to be successful, the effects of cementation, dissolution, and authigenesis must be considered in the design.

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Review of Electrical Methods in a Multidisciplinary Exploration Program

As petroleum exploration enters a period of searching for increasingly subtle traps, a number of exploration companies have begun to reconsider electrical techniques as a supplement to ongoing seismic programs. Many domestic companies have either established in-house electrical research groups or have utilized the services of various electrical contractors. This renewed interest in electrical techniques warrants review of the major approaches used today in exploration.

Modern electrical techniques can be divided according to survey objective into three categories. The first and most controversial approach

attempts the direct detection of oil by virtue of its intrinsically high resistivity. Although success has been reported for several very shallow fields, strong theoretical arguments indicate that direct detection is untenable as a standard exploration technique. A second approach utilizes magnetotelluric or similar techniques to map deep, very large-scale structures, but high cost and poor resolution confine this work primarily to areas where seismic is unobtainable. A third approach is mapping electrochemical alteration patterns in the top 1,000 m (3,000 ft) of sedimentary overburden. These patterns are attributed to clay-mineral alteration or sulfide precipitation resulting from upward seepage of light hydrocarbons and brines from the traps below. Recent advances in instrumentation and data processing have made alteration mapping a promising supplement to ongoing seismic and geologic exploration programs, especially in the search for subtle stratigraphic traps, and in distinguishing productive from nonproductive structures.

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Depositional Environments of Devonian Cairn Formation, Rocky Mountain Foothills, Alberta, Canada

The Cairn Formation is a carbonate sequence of Frasnian (Late Devonian) age that is the stratigraphic equivalent of the major oil-producing Leduc Formation of southern Alberta. During the summers of 1982 and 1983, detailed stratigraphic sections were measured near Canmore where the Cairn Formation is a platform sequence of carbonates approximately 50 km (31 mi) from the nearest reef edge.

The entire sequence consists of sediments deposited in a subtidal environment. No evidence of intertidal or supratidal deposition was found. The formation consists of very fine to medium crystalline, buff to dark gray dolomite, in which original textures (usually mudstones, grainstones, and stromatoporoid floatstones) often can be identified. The sequence contains fair to good intercrystalline, biomoldic, and vuggy porosity. Some of the vuggy porosity has been infilled by very late, coarse crystalline dolomite and calcite.

Individual beds typically are composed of a consistent lithologic character throughout. These beds are usually 10 cm to 2 m (1 in. to 6 ft) thick, and are virtually always bounded by disconformities. Some individual beds can be seen to swell and pinch out.

The stromatoporoid floatstones are composed of 10–40% fossils consisting of *Amphipora, Euryamphipora,* bulbous stromatoporoids (5–20 cm, 2–8 in.), tabular stromatoporoids, horn corals, and colonial corals. All organisms are not in place but have only moved a short distance.

Some thin beds consist of a black bituminous dolomite and probably represent a restricted lagoon environment of deposition.

Although most beds are horizontal, some constructional bioherms up to 5 m (16 ft) in relief have been recognized in the sequence.

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Geology of Oscar Range (Devonian) Reef Complex, Canning Basin, Western Australia

The Oscar Range is a Late Devonian reef complex that formed at the margin between the Precambrian Kimberley craton and the Canning basin. The range covers an area of 80 × 10 km (50 × 6 mi), and resembles a large atoll in that Frasnian and Famennian reef, marginal-slope, and back-reef subfacies grew around an exposed Precambrian core.

Frasnian reefs are dominated by stromatoporoids and *Renalcis,* and the reefs show periods of upbuilding, drowning, backstepping, and basinward progradation. Fault-controlled reef growth is developed locally. Marginal-slope deposits contain stromatoporoid debris, sponge boundstone, and crinoids. Back-reef deposits are generally *Amphipora*-rich biostromes, although fenestral oolite-intraclast-peloid beds are widespread in the southern Oscar Range. Dolomite is best developed in Frasnian back reef and, to a lesser extent, in reef-margin and reef-flat subfacies. In the area of the Precambrian core, conglomerates of Precambrian debris are interbedded with Frasnian limestones that are in depositional contact with basement. Hills of Precambrian rocks rise tens of meters above these peritidal back-reef deposits, indicating perhaps several hundred meters relief during the Frasnian.

The exposed Frasnian-Famennian contact is a disconformity. Famennian reefs are dominated by *Renalcis* and associated algal stromatolites; the equivalent marginal-slope is characterized by allochthonous reef blocks, sponge bioherms, and crinoidal debris. Steeply dipping (40°) basinward-prograding reef and marginal-slope tongues make up the shelf margin. The Famennian back reef is composed of fenestral oolite-peloid lithologic units with common teepee structures, flat-pebble conglomerates, and cryptalgal fabrics.

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Early to Middle Pennsylvanian Changes in Paleoslope and Sediment Source Terranes in Northwest Illinois

The Abbott Formation (Atokan) conformably overlies the Caseyville Formation (Morrowan) which unconformably overlies Silurian and Mississippian units in the Rock Island area, Illinois. The two formations have a similar composition of $Qm_{95\text{-}100}$, $Ls_{0\text{-}5}$. More than 70% of quartz and heavy mineral grains (tourmaline and zircon; minor rutile and garnet) are rounded to well rounded. Their source is interpretated as a mature sediment on the craton, whereas equivalent sandstones in southern Illinois have an inferred metamorphic terrane component in the source.

Sediments of the Spoon Formation (Desmoinesian) conformably overlie the Abbott Formation, but their sandstones differ in composition. Spoon sandstones comprise $Qm_{45\text{-}60}$, $Qp_{7\text{-}20}$, $F_{5\text{-}10}$, $Lm_{5\text{-}18}$, $Ls_{1\text{-}8}$, and heavy minerals (tourmaline and zircon; minor sphere, garnet, hornblende). More than 55% of grains are angular to subrounded. The compositional change reflects a new sediment supply to the Rock Island area during the Desmoinesian. Grains from a metamorphic terrane are inferred to be mixed with those from a mature sediment.

Paleocurrent data indicate that a change in paleoslope near Rock Island coincided with the compositional change. The early Pennsylvanian fluvial system was probably locally controlled by the Mississippi River arch and flowed to the north. The arch could then have been submerged during the Desmoinesian, and flow was toward the southwest down cratonic paleoslope (which had influenced regional flow since the Morrowan.

Paleocurrent and petrologic data indicate that lower Pennsylvanian basin fill in western Illinois was derived from the northeast rather than the northwest (Transcontinental arch) as previously suggested.

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A Sedimentologic Model for a Microtidal Flood-Tidal Delta—San Luis Pass, Texas

San Luis Pass is a microtidal inlet located at the southwest end of Galveston Island, Texas. Continuous cores taken with a portable vibracoring rig, and surface grab samples provide data for developing a 3-dimensional sedimentologic model of the flood-tidal delta complex located landward of the tidal inlet. This model is based on the type, and vertical and lateral distribution of lithologic units, sedimentary structures, textures, and trace fossils.

A complete bayward vertical sequence in the flood-tidal delta complex consists (from base to top) of highly bioturbated bay clays and associated oyster reefs, highly bioturbated clayey sands/sandy clays of the delta margin, variably burrowed sand to shelly sand of the delta, and rooted or burrowed muds of the marsh or mud flat. Washover shell-hash deposits may occur at random intervals throughout this sequence. A more seaward sequence in the vicinity of San Luis Pass consists of a basal tidal inlet deposit of graded layers of sand and shell overlain by burrowed to shelly sand of the barrier spit.

This model for microtidal flood-tidal deltas differs significantly from models presented for mesotidal flood-tidal delta systems in the general lack of large-scale, high-angle sedimentary structures; the presence of intense bioturbation; the presence of washover deposits; and the general upward-coarsening nature of the vertical sequence. Mesotidal flood-tidal deltas with clean, coarse to medium-grained sands may make good petro-