basin while Ordovician carbonates and shales form potential fields throughout parts of the southern Canning basin. Thick sequences of interbedded clastics and marine rocks of Silurian to Permian age form additional targets in several depocenters in the Canning. Oil reservoirs of Ordovician age occur in the western Amadeus basin but new plays exist in the basal Cambrian sands of the eastern Amadeus and potentially in the northern thrust sheet belt. Oil has now been found in rocks of Permian, Triassic, Jurassic, and Cretaceous age in the Cooper-Eromanga basin. New plays exist with the extensions of the central Eromanga basin where higher heat flow and deeper burial has matured younger Jurassic sources. The more established Surat basin has further potential in Permian and Triassic rocks as does the Mesozoic in the coastal Clarence-Moreton and Sydney basins. With less than 200 wildcats being drilled every year, the potential for this corridor certainly lies in the future.

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A Uraniferous Granite in Central Texas

The Precambrian Oatman Creek granite exposed in Gillespie County, central Texas, contains 5 to 10 times more uranium than that of an average granite. Samples of this granite, collected from outcrops and quarry openings, were studied by petrographic, delayed neutron counting, fission track, and gamma-ray spectrometry methods. Experiments of leaching uranium from disaggregated samples were also made.

The granite is medium grained with an average composition of 36% quartz, 25% K-feldspar, 38% plagioclase, and 1% biotite and others. In an 80-acre (32 ha.) outcrop area 32 samples, most of which have some uranium removed from weathering, show an average uranium content of 25 ppm; relatively unweathered samples have 50 to 100 ppm uranium. Most uranium occurs between grain boundaries which is called intergranular uranium; some occurs in microfractures developed during late, hydrothermal stages. A portion of the uranium also occurs in discrete minerals, particularly oxides of iron or iron-titanium, and accessory minerals such as zircon, sphene, garnet, and others. This distribution indicates that much of the uranium mineralization was a result of deuteric or hydrothermal activities.

Selected acids of various concentrations were used in experimental leaching of uranium from Oatman Creek granite. Other variables in the experiments were degree of disaggregation and duration of leaching. The results indicate that more than two thirds of the uranium can be leached in a few hours time from the granite without excessive grinding, when a 5N acid is used.

This study shows that the Oatman Creek granite may be a long-term source of uranium in the future.

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Thermal Maturation Model of Late Proterozoic-Paleozoic Amadeus Basin, Central Australia

The thermal maturation of the Amadeus basin, central Australia, was modeled using a modified version of Lopatin's time-temperature index. The late Proterozoic-Paleozoic basin presented numerous difficulties: (1) the absence of vitrinite in pre-Silurian strata (about 75% of the total section), (2) two major orogenic events that markedly deformed the basin, (3) moderate to extreme (25,000 ft, 7,620 m) amounts of surface erosion since the Carboniferous, and (4) a paucity of data (27 wells in an area equal in size to Oklahoma). The presence of possible giant oil and gas fields (from Ordovician shales as source) and significant gas discoveries in Proterozoic rocks made the study of special interest.

Assuming a constant geothermal gradient of 1.65°F/100 ft to be representative of the basin, the amount of surface erosion was found to be the most significant factor controlling distribution of thermal facies. Interval-transit times in shales and palinspastic reconstructions of sedimentary thicknesses were used to estimate amounts of surface erosion and missing section associated with unconformities. An estimated 25,000 ft (7,620 m) of section has been removed along the northern margin of the basin, with approximately 8,000 to 9,000 ft (2,438 to 2.743 m) absent in the vicinity of the major oil and gas fields. Surficial erosion in both areas is the result of uplift associated with the Alice Springs orogeny.

The Amadeus basin is an excellent example of a generation/migration/accumulation system favorable for commercial reserves of petroleum. The formation and accentuation of large anticlinal traps in Cambro-Ordovician sandstones slightly predated deep burial and strong oil generation in the Lower Ordovician Horn Valley Siltstone (Early to Late Carboniferous). The late Proterozoic Bitter Springs Formation, another possible source, was generative in the late Proterozoic to Early Ordovician. Suitable traps were also extant at this time.

The thermal history of the Amadeus also demonstrates that maturation essentially halts if burial temperatures are substantially decreased by erosional unloading. In this manner sediments may remain deeply buried for long periods without undergoing substantial thermal alteration.

The Amadeus is a very "mature" basin, with 47% of the strata being overmature (prospective for gas only). Hydrocarbon liquids are most likely preserved in the north-central part of the basin, as shown on a depth to liquid-limits map.

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Aspects of Silurian Clinton Sandstone Development in Ohio More Conducive to Oil and Gas Production

The drilling of 2,000 to 3,000 development wells a year for several years into the Clinton Sandstone reservoir in eastern Ohio has provided a data base for distinguishing a number of deltaic sedimentary patterns that are more productive of oil and gas than others. Clinton Sandstone development drilling in Ohio, Pennsylvania, and New York is price-driven and tax shelter related. With the designation of almost all of the Clinton reservoir sands as "tight sands" for gas pricing, payout can be expected in many, but not all Clinton wells despite the nearly 90% or higher drilling success ratio.

New regional studies show the upward, deltaic progradation to the west as previously documented, but they also demonstrate new stratigraphic relationships between the upper Cabot Head shales, the sandstone reservoirs of the Clinton, and the overlying Packer Shell Limestone. The upper Cabot Head lies only landward of the progradational edge and the transition westward is from reservoir sands into calcareous sands and carbonate rocks. Within this deltaic system, one which covered much of eastern Ohio, Clinton wells have produced oil and gas from these fluvial, fluvial delta-margin and delta-margin bars, and beach sands for over 50 years.

Both regional and local patterns indicate better areas of Clinton development drilling at various depths. In the fluvial sequences, total sand maps, clean sand maps, porosity maps, and water, oil, and gas saturation maps point to locations of higher oil and gas deliverability. In the delta margin system, sand mapping, cross sections, and porosity maps show multiple bar systems at the edges of deltaic plains and tidal flats where there is higher gas and oil production from the Clinton reservoirs.

Local structural highs and faults affect production in this mainly stratigraphic trap. Locally, structure segregates oil and gas in the same reservoir body, but separate, though laterally equivalent, reservoir sands act differently on the same structure in adjacent wells.

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Precision Measurements of Interval Velocity Differences from Seismic Data

A new seismic technique, the DIVA (Differential Interformational Velocity Analysis) (trademark, Copyright Zenith Exploration Co., patents pending), which makes use of ultra refined seismic velocity analysis has been developed to identify and localize low velocity anomalies in the subsurface. Reservoir quality porous rock formations will always be distinguished by reduced seismic velocities whether or not hydrocarbons are present. In favorable settings, however, low velocities correlate well with hydrocarbon reservoirs. Where gas is present, the velocity reductions can be spectacular making the DIVA display an indicator with as much visual impact as the "bright spot" offshore. Color acoustic impedance sections further corroborate the reality of DIVA detection anomalies and assist in localizing them in reflection time. In addition, the color display, which in fact represents the essential information content of the seismic amplitudes, though very imprecise, is a vital monitor of the detailed changes in lithology. Fourteen wells to date have tested the concept ranging in depths from 7,00 to 15,000 ft (2,133 to 4,572 m) and targeting both carbonate and sandstone reservoirs. Several of these results are reviewed to illustrate the power of the approach. The technology has not only been proven by the drill but has also initiated new and exciting exploration plays which can not even be detected with usual seismic approaches. An east Texas reef bank sequence illustrates such a circumstance.

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Sedimentology of Some Allochthonous Deep-Water Carbonate Reservoirs, Lower Permian, West Texas: Carbonate Debris Sheets, Aprons, or Submarine Fans?

During the Wolfcampian, sediment gravity flows were common events at some shelf margins in the Permian basin. These mass flows transported large volumes of shoal-water bank and reef carbonates downslope into the Midland and Delaware basins, forming a wide variety of redeposited lithofacies. For example, along a segment of the Eastern shelf margin at least 40 km (25 mi) long, redeposited carbonates extend into the Midland basin 25 km (16 mi) or more. Within this basin margin setting, several petroleum pay zones occur in mass-transported debris.

In designing exploration strategies for these types of frontier deep-water reservoirs, whether within the Permian basin or elsewhere, one must develop appropriate depositional models. Some questions come to mind. Do these deposits represent episodic, widespread, single-pulse debris sheets, debris aprons dominated by numerous but rather random pulses of areally extensive sheet-flow calcarenites, or more systematically developed submarine fan facies having both channelized deposits in inner and mid-fan settings as well as sheet-flow calcarenites deposited as outer-fan lobes?

Redeposited Wolfcampian carbonates are subdivided into three major lithofacies. (1) Limestone and dolomite conglomerate debris flows and turbidites with dark interstitial micrite. Individual beds are as much as 8 m (26 ft) thick, normal to massively graded, and some beds are arranged by thinning-upward sequences. These carbonates form on of the reservoir facies with intercrystalline, solution interparticle, fracture, and vuggy porosity. (2) Wackestone to packstone calcarenite turbidites consisting largely of biotic grains. This lithofacies forms the most abundant type of redeposited sediment. The calcarenites occur in beds a few cm to 2.5 m (8 ft) thick that exhibit a variety of Bouma turbidite divisions and in some localities are arranged in thickening-upward units. Calcarenite turbidite locally form petroleum reservoirs with solution interparticle, intrabiotic, biomoldic, and fracture porosity. (3) Wackestone to packstone calcisiltite and calcarenite turbidites that occur in less than 2 cm (1 in.) thick beds. This facies does not exhibit vertical cycles of bed thickness nor good reservoir qualities.

Analyses of cores from 12 wells both within and outside the petroleum fields suggest that these redeposited carbonates may represent a combination of debris sheet and submarine fan depositional processes. The conglomerates could be genetically unrelated to the calcarenites and represent episodic debris sheet pulses; or alternatively, these conglomerates may be channelized deposits in inner fan to mid-fan positions near the basin margin. Some of the thick-bedded calcarenites possibly represent mid-fan channelized deposits whereas the more basinward thickening-upward calcarenites resemble unchannelized outer-fan calcarenite lobes. Thin-bedded calcisiltite turbidites appear to occupy basin plain, outer-fan fringe, and interchannel settings. If these reservoirs are developed within one or more fan facies, the size and spatial arrangement of the individual fans still remain to be determined. A better knowledge of appropriate depositional models should enhance future exploration efficiency.

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Upper Jurassic Carbonate Deposition, Smackover and Buckner Formations, East Texas

Examination of cores from the upper Smackover Formation from 30 wells in east Texas confirms the presence of a belt of blanket high-energy ooid sandstone throughout much of the area. Pockets of lower energy deposits within this ooid grainstone belt are characterized by pellet-*Favreina* packstones and