gross discrepancies between seismic lines, faults, or suspected bad well data.

In addition to the basic surface manipulation tools, an interactive environment allows the system user to manipulate individual data items (add, delete, or alter well data, shift seismic data, etc), attempt different approaches, and play "what-if" games, until the most satisfactory set of results is obtained.

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Stratigraphy of Blair Formation, an Upper Cretaceous Slope and Basin Deposit, Eastern Flank of the Rock Springs Uplift, Wyoming

The Blair Formation (Upper Cretaceous) is the lowermost unit of the Mesaverde Group in southwestern Wyoming. Outcrop study of the Blair exposures on the east flank of the Rock Springs uplift reveals 1,100 ft (330 m) of sandstone, siltstone, and shale. The formation has a sharp conformable to locally erosional basal contact and contains intraformational channeling, syndepositional slumping, and high-energy sedimentary structures. Facies relationships indicate the Blair represents a slope and basinal deposit laterally equivalent to the shelf and delta complex of the lower Rock Springs Formation to the north. Overall stratification types, textures, and southeast paleotransport directions recorded within the Blair, which are normal to the southwest-trending Rock Springs shoreline, support this interpretation.

High sedimentation rates in excess of subsidence rates during the early Campanian, possibly related to early movement on the Absaroka thrust and a eustatic lowering of sea level approximately 81 Ma, caused rapid shoreline progradation and favored the development of a narrow shelf. These conditions enabled sand-sized material to bypass the shelf and be deposited in slope and basin environments. A present-day example of these relationships is the modern Mississippi delta located near the shelf-slope break of the Gulf of Mexico.

Recognition of a narrow shelf in southwestern Wyoming during the early Campanian requires a modification of Late Cretaceous paleogeography to incorporate the concept of depositional topography. The occurrence of slope and basin sandstones in the Blair suggests that new interpretations may be needed to explain sandstone distribution for other stratigraphic intervals within the Cretaceous of the Western Interior.

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Three Ancient Montana Fluvial Systems: Pennsylvanian Tyler, Lower Cretaceous Muddy, and Upper Cretaceous Eagle—Their Reservoir and Source Rock Distribution

The importance of using Holocene geology as a model in mapping reservoir and source rock distribution is demonstrated in three Montana river-related systems: alluvial valley, barrier bar, and distributary channel-prodelta.

The Pennsylvanian Tyler Formation was deposited by a westward-flowing meandering-stream system controlled by an east-west-trending rift valley, and surrounded by backswamp deposits. It is underlain by its probable hydrocarbon source, the marine Mississippian Heath shale and limestone, and overlain locally by the lagoonal Pennsylvanian Bear Gulch Limestone. To date, about 90 million bbl of recoverable oil have been found in Tyler sands.

The oil-producing Lower Cretaceous Muddy sandstones in the northern Powder River basin are considered to be barrier bars, encased in organic-rich shales, which are most probably the source rock. The Upper Cretaceous Eagle Sandstone in north-central Montana is a distributary channel system, similar to that of the modern Mississippi, which dumped highly carbonaceous materials into an organic-rich delta system. The Eagle now contains possibly enormous amounts of biogenic methane.

By using Galveston Island and the modern Mississippi delta as models, in conjunction with employing electric log shapes and porosity logs, it is possible to map ancient fluvial patterns in the study areas. One can then predict the location of possible hydrocarbon accumulations in porous and permeable sand bodies, along with their encasing hydrocarbon source rocks.

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Tectonic History of Sweetgrass Arch, Montana and Alberta—Key to Finding New Hydrocarbons

The Sweetgrass arch of northwestern Montana and southern Alberta is a major ancient structural feature. Initial anticlinal emplacement occurred during the early Paleozoic and was parallel with the cratonic margin. Strong uplift followed by peneplanation occurred during the Late Jurassic and basal Cretaceous during the westward drifting of the North American plate following the breakup of Pangea. During Cretaceous and early Tertiary times, the Sweetgrass arch was quiescent, but was rejuvenated in mid to late Tertiary, upwarped by a basement flexure to its present structural configuration: a 200 mi (322 km) long, north-plunging anticline showing 10,000 ft (305 m) of structural relief. Midway down its plunge, the anticline is offset 30 mi (48 km) by a right-lateral transcurrent fault.

During Late Cretaceous and early Tertiary, plutonic uplifts were emplaced on the east flank, forming traps for oil then migrating updip from the Williston and Alberta basins. Oil and gas accumulated in Mississippian, Jurassic, and basal Cretaceous reservoirs in structural and stratigraphic traps around these plutonic uplifts. Subsequent late Tertiary doming of the Sweetgrass arch tilted the earlier structural traps and drained them, resulting in remigration of much of the oil and gas to the crest of the arch. The tilting failed to destroy many of the stratigraphic traps. As a result, down the flanks of the Sweetgrass arch are many "frozen" stratigraphic traps including Cut Bank field, the largest single-pay stratigraphic trap in the northern Rockies (164,000 bbl of oil, 0.5 tcf gas). On the crest are large structural accumulations of remigrated oil at Kevin Sunburst (81,000 bbl of oil) and Pondera (26,000 bbl of oil). Evidence of remigration is recorded by live oil show "tracks" in the reservoirs and remnant gas caps throughout the area of earlier accumulations. A potential exists for finding new "frozen" traps on the flanks and remigrated oil accumulations on or near the crest of the Sweetgrass arch.

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Prospect Generation Using Digital Well Log Data—Minnelusa Formation

Trapping in the Permian Minnelusa Formation is almost entirely stratigraphic. Much of the oil is trapped in "buried hilltops" controlled by the unconformity at the top of the Minnelusa. Highly localized stratigraphic changes within the upper Minnelusa are also important.

The database used for computer mapping of the Minnelusa play includes cartographic data, formation and zone tops, and digital well log traces. Digital log data consist of sonic and gamma-ray curves from all but 300 of the 4,100 wells penetrating the Minnelusa Formation. Using this data base, exploration geologists have been able to make any needed type of regional stratigraphic map in a few days.

Many recent discoveries have been made on leads previously generated by computer maps.

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Paleotectonic Controls on Deposition of Niobrara Formation, Eagle Sandstone, and Equivalent Rocks (Upper Cretaceous), Montana and South Dakota

The deposition of the Niobrara Formation, Eagle Sandstone, and equivalent Upper Cretaceous rocks was controlled by paleotectonic activity on lineament-bound basement blocks in Montana and South Dakota. Linear features observed on Landsat images provide an interpretation of lineament geometry that is independent of stratigraphic data. Paleotectonism on lineament-bound blocks is documented in three areas that were located in distinctly different depositional environments.

In central Montana, coastal and inner-shelf sandstones and nonmarine coastal-plain and wave-dominated delta deposits reflect paleotectonic control by lineaments trending north-south, east-west, northwest, and northeast. In the northern Black Hills, chalks and outer-shelf sandstones reflect control by lineaments trending north-south, northwest, and northeast. In central South Dakota, erosion and deposition of chalk and calcareous shale on a west-sloping carbonate ramp were controlled by lineaments that generally trend northeast and northwest.

Paleotectonism on lineament-bound blocks characterized four tectonic zones located in the Late Cretaceous seaway: the western foredeep, the west-median trough, the east-median hinge, and the eastern platform. The regional geometry of all four tectonic zones appears to be related to the geometry of the convergent plate margin on the west. Paleotectonic activity on lineament-bound blocks may have been the result of horizontal forces related to the convergent margin and to vertical forces related to the movement of the North American plate.

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Geologic Setting and Natural Gas Potential of Niobrara Formation, Williston Basin

Chalk units in the Niobrara Formation (Upper Cretaceous) have potential for generation and accumulation of shallow, biogenic gas in the central and eastern Williston basin. Similar to areas of Niobrara gas production in the eastern Denver basin, Niobrara chalks in South and North Dakota were deposited on carbonate ramps sloping westward off the stable eastern platform of the Western Interior seaway. Within the Williston basin, the Niobrara of the western Dakotas, eastern North Dakota, and central South Dakota has different stratigraphic relationships. These three areas can be further subdivided and ranked into six areas that have different exploration potential. The south margin of the Williston basin in central South Dakota is the most attractive exploration area.

Niobrara chalk reservoirs, source rocks, and structural traps in the southern Williston basin are similar to those in the eastern Denver basin. Chalk porosities are probably adequate for gas production, although porosity is controlled by burial depth. Organic carbon content of the chalk is high and shows of biogenic gas are reported. Large, low-relief structural features, which could serve as traps, are present.

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Stratigraphy and Petroleum Potential of Trout Creek and Twentymile Sandstones (Upper Cretaceous), Sand Wash Basin, Colorado

The Trout Creek and Twentymile Sandstones (Mesaverde Group) in Moffat and Routt Counties, Colorado, are thick, upward-coarsening sequences that were deposited along the western margin of the Western Interior basin during Campanian time. These units trend northeast-southwest and undergo a facies change to coal-bearing strata on the northwest. Surface data collected along the southeastern rim of the Sand Wash basin were combined with well-log data from approximately 100 drill holes that have penetrated the Trout Creek or Twentymile in the subsurface. The sandstones exhibit distinctive vertical profiles with regard to grain size, sedimentary structures, and biogenic structures. A depositional model that incorporates the key elements of the modern Nile River (northeast Africa) and Nayarit (west-central Mexico) coastal systems is proposed for the Trout Creek and Twentymile Sandstones and associated strata. The model depicts a wave-dominated deltaic, strand-plain, and barrier-island system. Depositional cycles are asymmetrical in cross section as they are largely progradational and lack significant transgressive deposits. Source rock–reservoir rock relationships are ideal as marine shales underlie, and coal-bearing strata overlie sheetlike reservoir sandstones. Humic coal, the dominant source of Mesaverde gas, generates major quantities of methane upon reaching thermal maturity. Existing Mesaverde gas fields are largely structural traps, but stratigraphic and combination traps may prove to be equally important. The sparsely drilled deeper part of the basin warrants testing as large, overpressured-gas accumulations in tight-sandstone reservoirs are likely to be found.

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Williston in the Family of Cratonic Basins

The Williston basin is one of a clan of subcircular to elliptical elements in the interiors of all cratons; such basins are distinguished by characteristics common to all. In each, the basement consists of continental crust and each basin is surrounded by areas of continental crust. Subsidence rates are typically low, so that conditions near depositional base level prevailed during much of the history of sediment accumulation. Episodic subsidence occurred over time spans of 10^7-10^8 years; major episodes of subsidence are broadly concurrent on all cratons. Tectonic tempo and mode of subsidence evolved synchronously on all cratons; therefore, similar isopach and facies patterns (and similar oil or gas maturation, migration, and trap potentials) occur on all cratons.

All members of the clan exhibit a range of individual variations imposed by latitude and climate. Intraplate tectonism and volcanism, approach to or distance from source areas, and distribution paths of detrital sediment. Nevertheless, facts and concepts developed by intensive study of basins with high-density documentation (outcrop and subsurface) are commonly applicable to basins such as the Williston, which is in a less mature stage of exploration.

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Hummingbird Structure in Southeastern Saskatchewan

Saskatchewan's first Devonian oil pool was discovered September 1966, at Hummingbird, 45 mi (72 km) southwest of Weyburn, Saskatchewan. The Hummingbird structure, located on the northwest flank of the Williston basin, is domal in nature and covers approximately 1 mi^2 (2.6 km^2). Oil production is from two zones. The Ratcliffe Member of the Mississippian Charles Formation produces from an algal and bioclastic limestone averaging 49 ft (15 m) thick. The Devonian Birdbear Formation produces from a finely crystalline vuggy dolomite averaging 56 ft (17 m) thick.

The Hummingbird structure is a sedimentary structure resulting from multiple-stage salt solution and collapse. Recurring local solution of Middle Devonian Prairie Evaporite during Late Devonian and Early Mississippian time resulted in collapse of overlying strata and deposition of compensating thicknesses of Souris River, Duperow, and Bakken sediments. Between Mississippian and Cretaceous time, solution of Prairie Evaporite in the surrounding area caused collapse of all super-Prairie Evaporite beds. The extra Souris River, Duperow, and Bakken strata at Hummingbird created the structure. Vertical migration of formation waters along a high-angle fault is suggested as the cause of the local salt solution at Hummingbird.

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

Pennsylvanian Morrow sandstones are oil and gas productive through a large area in southeastern Colorado. The Sorrento field is a recent Morrow discovery with reserves estimated at over 10 million bbl of oil over an area of 3,200 ac at depths of 5,400-5,600 ft (1,646-1,707 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.

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Paradox—Pull-Apart Basin of Pennsylvanian Age

The Paradox basin (Colorado Plateau province) is an intracratonic depression developed on continental crust. The elongate northwest-trending rhombic-shaped basin of Middle Pennsylvanian age is bounded on the northeast by the Uncompahgre-San Luis segments of the Ancestral Rocky Mountains and on the southwest by the less prominent Four Corners lineament. The basin sagged along intersecting basement fractures by strong east-west extension during Middle Pennsylvanian time. The master fracture system was the northwest-trending Olympic-Wichita structural lane.

Oblique divergent strike-slip faulting along the Uncompahgre–San Luis segment created a tension-releasing bend where the Paradox pull-