and can only obtain that oil at the expense of other countries.

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Lacustrine Humate Model—Sedimentologic and Geochemical Model for Tabular Uranium Deposits

Facies control of some tabular uranium deposits in sandstone implies that certain inherent features in the depositional environment set the stage for uranium mineralization. The lacustrine-humate model was developed to explain the facies control of uranium in fluvial-lacustrine units of the Salt Wash Member of the Morrison Formation in south-central Utah and in the Stockton Formation of the Newark Group in the eastern United States. In both of these areas, a close spatial relation exists between offshore-lacustrine primary gray mudstones and uranium-bearing fluvial and marginal-lacustrine sandstones. The primary gray mudstones lie directly above, below, or a short lateral distance from the tabular uranium deposits within the sandstones. This proximity suggests a model in which alkaline pore waters containing dissolved humic substances (humic and fulvic acids) were expelled by compaction or seepage from the gray mudstones into the adjacent sandstone beds where they were fixed as tabular humate deposits. Uranium carried by groundwater that flowed toward the lakes was then concentrated by the humate to form tabular uranium deposits. Thus, the sedimentologic setting of the host rocks was an important factor in the mineralization process.

Because the dissolved humic substances are thought to be expelled from certain types of mudstones, the nature of these beds becomes important in using the model as an exploration guide. Mudstones deposited in reducing alkaline conditions are considered favorable, because reducing conditions would favor preservation of humic matter in the pore waters of the lake sediments, and alkaline conditions would favor solubilization of the humic substances so that they could be expelled with the pore fluids.

A second important aspect of the model is the means by which humic substances are fixed in the sandstone beds following their expulsion from the mudstones. Formation of organo-clay complexes, with the organic materials interacting with clay coats on sand grains, has been suggested as a possible mechanism. The nature of these complexes has been unclear because of the negative charge associated with both the clays and the humic and fulvic acid molecules. Iron and aluminum hydroxides coating clay surfaces may have formed "bridge linkages" between the clay films and the organic acids because the hydroxides carry a positive charge below pH 8. The hydroxides, abundant in near-surface sediments during early diagenesis, are most effective in fixing humic substances at pH 7, which is within the range of normal groundwaters.

The lacustrine-humate model differs from others in that the humic substances are believed to have migrated only short distances from mudstone beds that lay near the ore-bearing sandstone beds. The model is also an attempt to work within the constraints developed during facies analysis; pore-water and groundwater chemistry and flow patterns are based on reconstruction of sedimentary facies and are consistent with what would be expected in a natural system.

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Sedimentology of Volcaniclastic Deposits from 1971-1974 Eruption Cluster of Volcano Fuego, Guatemala

Volcaniclastic sedimentation during and subsequent to the 1971-74 eruption cluster of the Volcano Fuego in Guatemala has occurred in four distinct phases which are part of a 15 to 25 year cycle of sedimentation. In phase 1, the eruption cluster generated 6×10^8 cu m of tephra, one-third in the form of glowing avalanches, the remainder as an elongate airfall ash blanket west-southwest of the cone. Glowing avalanches with a volume of 5×10^7 cu m formed two fans, each 1 to 3 m thick, east and west of the crater. Further avalanches flowed down seven narrow canyons radiating to the south of the crater forming 40-m-thick deposits totaling 1.3×10^8 cu m. During phase 2, debris flows and flash floods removed about one-third of the phase 1 canyon deposits in the first 2 years following eruption. Fan deposits remained intact. Three digitate, 1 to 2.5-m-thick, debris-flow deposits (2.2×10^7 cu m) and two 1-m-thick flood fans (1.8×10^7 cu m) formed south of the crater. In phase 3, terraced, meandering, suspended-load streams were metamorphosed to braided, aggrading, bed-load systems annually eroding 6 million tons of phase 1 and 2 debris, primarily from the canyon deposits. Transport of about two-thirds of this debris to the sea has produced rapid coastal progradation. During phase 4, 15 to 25 years of phase 1 and 2 activity will remove canyon avalanche deposits, redistributing the material in stable fans on the lower volcanic slopes. Phase 1 and 2 processes become inactive while stream incision produces discontinuous terracing. Fluvial systems return to meandering, suspended-load streams.

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Solution Mining of Uranium and Its Effect on Exploration

In-situ uranium leaching substantially increases the volume of the subsurface from which uranium can be mined and therefore the scope of a uranium exploration program. There are however many limiting factors that restrain the application of in-situ leaching. These factors include formation permeability and porosity, the chemistry and hydrology of the interstitial fluids, host-rock and ore mineralogy, and the depth to the deposit. A knowledge of these factors is essential in any exploration program where the target is an in-situ leachable orebody.

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Geology and Current Development Activity at Little Knife Field, North Dakota

Recent Gulf exploration efforts in the Williston basin have resulted in the discovery of a major new field, Little Knife, with multiple reservoir potential in a relatively untested area of the basin. The 70 producing wells drilled have been completed in the Mission Canyon Formation, but potential Devonian Duperow production has also been established in restricted areas of the field.

The dominant factor in entrapment appears to be a north-plunging structural nose, though stratigraphic contribution to entrapment has not been fully evaluated.

The Mission Canyon can be divided into five zones (A to E) based on lithologic and sonic log data. Zone B is the principal producing zone and was deposited in a wide variety of shore and nearshore environments. The depositional environments and diagenetic settings associated with zone B are responsible for an intricate pattern of carbonate deposition and porosity development.

Little Knife, now 2 years old, has already produced 3,675,000 bbl of oil (January 1, 1979) even though during much of that time many wells capable of much higher production were restricted to 100 BOPD. Little Knife now vies for position as North Dakota's largest oil producer, as a gas treatment plant became operational in late 1978 and allowed daily field capacity to increase to approximately 15,000 BOPD.

AAPG EASTERN SECTION MEETING
October 15-17, 1978
Cleveland, Ohio

Abstracts of Papers

BIRCH, MICHAEL J., and WILLIAM C. MACQUOWN, Univ. Kentucky, Lexington, Ky.

Petroleum Production from Basal Greenbrier Formation in Hyden West Pool, Eastern Kentucky

The Hyden West pool of northeastern Leslie County in eastern Kentucky produces from the Mississippian "Big Lime" (Greenbrier or Newman Limestone). The pool includes approximately 7,000 acres (2,800 ha.), with more than 60 wells which range in depth from 1,900 to 2,400 ft (570 to 720 m). Production in the pool is primarily gas, with small amounts of oil, from the basal Greenbrier.

Drill cuttings from 10 wells within the pool and on its margins were studied using a binocular microscope. The thickness of the Greenbrier was determined throughout the pool from gamma-ray logs and samples. Drillers' logs have been used cautiously, and only if other sources of data were unavailable. These thicknesses, as well as intervals within the Greenbrier and structural data from the logs, were used to construct maps and cross sections of the pool.

The Greenbrier has a thickness of between 160 and 250 ft (48 and 75 m) in this pool, and consists of limestone and dolomite, with minor amounts of shale. Evidence suggests that the sequence was deposited in a shallow epicontinental sea that was transgressing across low-lying, exposed surfaces of the Maccrady siltstone.

The dolomite present in the basal part of the Greenbrier is mainly a secondary replacement of limestone. Porosity and permeability in the dolomite provide the pay zone of the Hyden West pool.

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Structure of San Cayetano and Oak Ridge Thrust Faults, East-Central Ventura Basin, California

The central Ventura basin, containing at least 20,000 ft (6,000 m) of Pliocene and Pleistocene sedimentary rocks, has been long recognized as bounded by thrust faults—the north-dipping San Cayetano fault (SCF) on the north and the south-dipping Oak Ridge fault (ORF) on the south. Field investigations and synthesis of available surface and subsurface data show that the three strands of the SCF, here named the Main, Goodenough, and Piru, join at depth to form a single fault plane. The SCF shows a 30,000-ft (9,000 m) maximum separation in the Fillmore area where a possible structural downstep is stepped to the left along the Goodenough strand. The SCF loses the separation progressively eastward and within about 14 mi (22 km) the fault apparently disappears in the north flank of the Santa Clara Valley syncline. The ORF, exposed within the southeastern part of the study area, also loses its separation eastward and disappears along the axis of the syncline. The Main strand of the SCF was initiated during the deposition of the "Pico." West of Hopper Canyon, the fault involves movement during and after the deposition of the Pleistocene Saugus Formation. The SCF cuts late Quaternary deposits and should be considered as potentially active. Most of the folds in the upper (north) block, and all the folds in the lower (south) block of the SCF, were contemporaneous with fault movement.

CORRE, PIERRE, and GILDAS OMNÈS, CGG, Houston, Tex., and Denver, Colo.

Shallow Seismic Reflection in Appalachian Basin with Mini-Sosie

The Mini-Sosie is a digital seismic system developed by Barbier and Viallix. The source is a 130- or 220-pound (59 or 99 Kg) tamper identical with those used for earth compaction. By acting on the throttle, the operator obtains a series of random impulses at an average rate of 10 per second. The digital recorder is connected to a normal 12- or 24-trace seismic reflection array and to a sensor set up on the tamper base plate. Each pulse from the sensor activates a register for each trace; thus, each repeatable seismic event corresponding to the impact which created the pulse is stored in the registers at a constant time interval after the activation of the register. Therefore, seismic events occurring at a constant time interval after the surface impulse will add up when the contents of a group of registers are stacked. Other events due to preceding or subsequent impulses behave as random noise and their sum decreases as more register contents are stacked. The operation amounts to a real-time correlation between the series of random pulses and the input from the geophones. The Mini-Sosie method is in fact a product of the microprocessor revolution. For two-way times of 1 second, decoding in