gas producing wells on similar features that are on trend with and to the south of the Langley Deep field. Thus, the effort of improving the quality of seismic reflections not only led to the discovery of the Langley Deep field but also generated the impetus that discovered additional reserves on other features along the same general trend.

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Coal-Bed Methane Development in Warrier Coalfield of Alabama

The University of Alabama School of Mines and Energy Development is conducting research on coal-bed methane development and utilization in the Warrior coalfield. Four test core holes, funded by the U.S. Department of Energy, have been drilled to depths of 2,800 to 3,400 ft (853 to 1,036 m). Gas quantities from coal samples were obtained by non-isothermal desorption and gas quality was determine by chromatographic analyses. Data from these tests were used to estimated total gas resources on targets of varying acreage around each core hole. Seams of the Pratt, Mary Lee, and Black Creek coal groups were found to have the greatest potential with gas contents ranging from 200 to 400 ft^3 per ton, typically consisting of about 95% methane. An evaluation of well completion options and stimulation techniques indicate that multiple stimulation open-hole completion provides the best return on investment. Utilization options considered include: (1) direct on-site use as a fuel for heating, (2) vehicular fuel, (3) sale to a gas transmission company, and (4) sale to other users (local only). The feasibility of various well completion and gas utilization options was assessed using Internal Rate of Return (IRR) techniques over a 10-year life with 50% to 75% recoverability. These analyses indicate an acceptable rate-of-return, but are tentative as the percentage of in-place gas that can be recovered and the optimum well spacing are still under investigation. A demonstration well completed on the University of Alabama campus is being observed to confirm estimates of production rate, capital cost, and operating expenses.

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An Integrative Gas Geochemical Technique for Surficial Petroleum Exploration

A new, innovative method of integrated gas geochemical exploration for petroleum has recently been developed and is being evaluated. The technique involves the shallow burial of Curie-point wire coated with a small amount of activated carbon in a cylindrical container in the topsoil where the carbon interacts with emanating soil gases. A collection period of several days to weeks is employed, depending on soil conditions. After removing the wires from the support apparatus, analysis is conducted using a Curie-point pyrolyzer directly coupled to a quadrapole mass spectrometer. The resulting mass spectra are analyzed by multivariate statistics using the program, ARTHUR. The results of the data analysis have been correlated to the presence of oil and gas along with the effects of gas emission on areal pattern variation.

The initial gas geochemical experiments have been conducted over known accumulations of petroleum in the Weld County section of the Denver-Julesburg basin, the southern overthrust belt in central Utah, and the Patrick Draw oil field in the eastern Green River basin of Wyoming. Initial testing of the technique has been over a period extending from June through September 1982. Effects on gas emission rates and pattern variations will be discussed with respect to geologic structure, hydrodynamic factors, soil conditions, and seasonal variations. The advantages and disadvantages of the integrative sampling techniques when compared to conventional gas geochemical methods used in petroleum exploration will also be discussed. Although the technique has been applied to a limited number of areas, the early results show great promise in reducing many of the problems associated with other gas geochemical methods.

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Bioturbation Patterns in a Channel-Levee-Overbank Sequence of Paleocene Submarine-Canyon Fill, Point Lobos, California

Bioturbation patterns in the Paleocene submarine canyon fill (Carmelo Formation) at Point Lobos, California, differ for channel, levee, and overbank deposits. Variation in (1) such ichnoassemblage characteristics as taxonomic composition, diversity, abundance, and behavioral/preservational types, and (2) the overall degree of biogenic reworking of the sediment are particularly significant. The ichnoassemblage of the channel-levee-overbank sequence includes *Arenicolites*, *?Aulichnites*, *Chondrites*, *?Helminthoida*, *?Neonereites*, *Ophiomorpha*, *Scolicia*, *Thalassinoides*, escape structures, and two unidentified traces. All the trace fossils were produced by infaunal organisms burrowing at various depths below the sediment-water interface.

The channel deposits are characterized by relatively low diversity and density (in comparison with the overbank deposits), and mainly consist of traces of deep-burrowing animals (e.g., *Ophiomorpha*). The overbank deposits have a relatively diverse and dense ichnoassemblage produced by both deep- and shallow-burrowing animals. The levee deposits are similar to the overbank deposits in trace diversity, but are intermediate between the channel and overbank deposits with respect to their overall degree of bioturbation.

Bioturbation patterns in these three subenvironments differ as a consequence of the chance of preservation of biogenic sedimentary structures. Each bed type (e.g., mudstone) contains similar ichnoassemblages regardless of the depositional subenvironment in which the bed type occurs. This pattern indicates that the distribution of the infaunal organisms producing the traces was influenced more by factors associated with a particular lithology (e.g., texture or organic content) than by environmental factors peculiar to a specific subenvironment. Therefore, the relative abundance of the various bed types ultimately preserved within each subenvironment corresponds to the bioturbation patterns characteristic of the channel-levee-overbank sequence.

For example, physical sedimentary structures (e.g., Bouma a-b intervals in thick sandstone beds) and biogenic sedimentary structures (e.g., escape structures and truncation of traces) in the channel environment indicate frequent episodic events of extensive erosion, followed by rapid deposition of sand bed several tens of centimeters thick. Thus, traces produced by deep-burrowing organisms in thick sandstone beds are most frequently preserved. In the overbank deposits, an abundance of traces left by shallow-burrowing organisms (e.g., *Arenicolites*) in mudstone beds, the type of behavior (e.g., feeding burrows) represented by such traces, and the higher degree of bioturbation of all bed types indicate relatively slow, continuous deposition. Therefore, the change in conditions of sedimentation (e.g., frequency of significant erosional/depositional events, amount and/or type of sediment eroded/deposited, ratio of erosion to deposition) results in the preservation of a different bioturbation pattern within the more "tranquil" overbank subenvironment. The bioturbation pattern characteristic of the levee deposits represents a transition between the bioturbation patterns of the channel and overbank deposits—that is, it results from a transition in the factors that dictate the preservation of biogenic sedimentary structures.

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Cay Sal Bank, Bahamas—A Partially Drowned Carbonate Platform

Recent high resolution seismic profiling, sediment sampling, scuba observations, and Landsat imagery show that Cay Sal Bank (CSB) has very limited reef development, no active sand shoals (ooid or otherwise), few islands, a thin to nonexistent sedimentary cover, and a relatively deep margin (20 to 30 m [66 to 100 ft]) and shelf lagoon system (10 to 20 m [33 to 66 ft]). Windward and leeward margins can be discerned, but their health and general development are poor when compared to the shallower, more active margins of Little Bahama Bank (LBB) and Great Bahama Bank (GBB).

Windward margins (facing north and east) along CSB are generally deep, rocky, sediment barren terraces supporting limited, low relief, relict(?) reefs. Leeward margins do have small sand bodies (maximum thickness 10 m [33 ft]) covering reef structures at the bank edge, indicating the offbank transport of sands has occurred. However, these marginal sand bodies are limited in extent, suggesting that this transport system was not ubiquitous along these south and west facing margins.

Seismic and grab sample data from the deep (200 to 500 m [660 to 1,650 ft]) slopes seaward of the leeward margins show a thin, discontinuous unit of periplatform, shallow-water derived *Halimeda*, molluscan, nonskeletal sands. The limited extent (no deeper than 330 m [1,080 ft]) of this unit, which is easily recognized by its reflection-free seismic facies, also indicates that sand production and transport off the bank were never prolific. This is in stark contrast to new seismic data from the leeward margins of GBB which clearly show thick (20 m [66 ft]) sand bodies covering 12 to 15 m (40 to 50 ft) high reefs along the outer margin and multiple reflection-free units extending to great depths (600 m [2,000 ft]) all along the adjacent slope.

The apparent immature development of normal bank-top processes and facies and the absence of key modern depositional environments on CSB may be related to the rate at which this platform was submerged. Due to its comparatively low elevation, the initial Holocene flooding occurred at approximately 8 to 10 ka when sea-level rise was rapid (6 m/ka [20 ft/ka]). By comparison, the higher LBB/GBB were flooded later at a much slower rate (1.5 m/ka [5 ft/ka]). The relatively rapid flooding of CSB provided little time for the shallow depositional environments to start up. The continued rapid rate of rise after drowning, plus offbank sediment transport and the export of chilled waters (formed during winter), prevented the resulting facies from catching up. Consequently, CSB appears to be partially drowned, particularly when compared to the other, healthier, rimmed Bahamian platforms.

Other investigators have pointed out that drowned carbonate banks are very common in the ancient and that these features potentially provide excellent stratigraphic traps for hydrocarbons. CSB provides us with a modern example of a bank that may be in the very early stages of termination.

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Two Depositional Models for Pliocene Coastal Plain Fluvial Systems, Goliad Formation, South Texas Gulf Coastal Plain

The Goliad Formation consists of four depositional systems—the Realitos and Mathis bed-load fluvial systems in the southwest and the Cuero and Eagle Lake mixed-load fluvial systems in the northeast. Detailed facies analysis indicates that Goliad bed-load and mixed-load fluvial systems represent two contrasting depositional environments.

Five facies are recognized in the Realitos and Mathis bed-load fluvial systems: (1) primary channel-fill facies, (2) chaotic flood channel-fill facies, (3) complex splay facies, (4) flood plain facies, and (5) playa facies. Both channel-fill and splay deposits consist primarily of gravel, sandy gravel, and coarse to medium gravelly sand. Primary channel-fill deposits are characterized by large-scale accretionary foresets and trough cross-beds, localized scour-and-fill structures, and massive beds. Fining upward trends are crudely developed to absent, and no diagnostic vertical sequence of sedimentary textures and structures has been recognized. Chaotic flood channel-fill deposits are characterized by erratic interbedding of coarse and fine units, and of erosional and accretionary features. Individual beds have chaotic or poorly ordered textural profiles, and an absence of well-developed internal structures. Extensive flocks of stacked scour-and-fill structures are common. Complex splay deposits share characteristics of both crevasse and sheet splays.

A model for Realitos-Mathis depositional environments shows arid-climate braided stream complexes with extremely coarse sediment load, highly variable discharge, and marked channel instability. Broad, shallow, straight to slightly sinuous primary channels were flanked by wide flood channels. These acted as part of the flood plain under most conditions, but as channels during high intensity flood flow. Flood channels passed laterally into broad, low-relief flood plains. Small playas occupied topographic lows near large channel axes.

Three facies are recognized in the Cuero and Eagle Lake mixed-load fluvial systems: (1) channel-fill facies, (2) crevasse splay facies, and (3) flood plain facies. Channel-fill deposits consist of coarse to medium sand and gravelly sand, with a variety of large- and intermediate-scale sedimentary structures. Small-scale structures are common in finer grained beds. Fining-upward sequences are moderately well developed and commonly stacked. Crevasse splay deposits consist of medium to fine sand and silt, with abundant small-scale sedimentary structures.

A model for Cuero-Eagle Lake depositional environments shows coarse-grained meander belts in a semi-arid climate. Slightly to moderately sinuous meandering streams were flanked by low, poorly developed natural levees. Crevasse splays were common, but tended to be broad and ill-defined. Extensive, low-relief flood plains occupied interaxial areas.

While a number of models for coarse-grained meander belts exist in the literature, there are few models for arid-climate, gravel-rich braided stream complexes. These systems are likely to be characterized by extreme hydrodynamic complexity, which will be reflected in the resultant sedimentary package. The model proposed for the Realitos and Mathis fluvial systems may aid in recognition of analogous ancient depositional systems. In addition, since facies characteristics exercise broad controls on Goliad uranium mineralization, the proposed depositional models aid in defining target zones for Goliad uranium exploration.

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Carbonate and Siliciclastic Deposits on Slope and Abyssal Floor