heat capping shales are prepared by the geologist. Then, working with the engineer, correlations of reservoir heat patterns are made by matching actual temperature response and production trends within their geologic constraints. These geologic-engineering evaluations of existing projects have often pointed out the need for significant changes in steam-injection profiles, steam rates, and other operating conditions. The geologist has an important role to play not only in forward planning for steam-drive projects, but also in formulating operational plans and decisions throughout the life of the project.

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Weathering-Induced Chemical Changes in Surface Coals from Paleocene Fort Union Formation, Red Rim Area, Sweetwater and Carbon Counties, Wyoming

Statistically significant differences in chemical composition between 20 outcrop and 22 stratigraphically equivalent core coal samples were demonstrated by proximate and ultimate analyses, heat-of-combustion and forms-of-sulfur determinations, and chemical analyses for 37 elements. The outcrop samples were collected from depths of 30 to 72 in. (75 to 180 cm) on very steep (> 45°) slopes. Core samples were from depths of 31 to 190 ft (9 to 58 m) at distances between 300 and 1,500 ft (91 and 457 m) from the outcrop. Mean annual precipitation in the Red Rim area is ~11 in. (28 cm); mean monthly temperatures range from 22°F (−5.5°C) in January to 68°F (20°C) in July. Apparent rank of unweathered coal is subbituminous C coal. Compared with the core samples (moisture and Btu/lb, as-received basis, all others moisture-free basis) the outcrop samples have significantly higher mean moisture (37.4 vs 23.8%), volatile matter (43.8 vs 35.1%), oxygen (24.9 vs 15.6%), and nitrogen (1.0 vs 0.8%); lower ash (13.3 vs 18.2%), hydrogen (3.0 vs 4.7%), sulfur (0.6 vs 1.1%) and heat of combustion (5,330 vs 7,690 Btu/lb); similar fixed carbon (42.5 vs 46.6%) and carbon contents (56.7 vs 60.3%). The sulfate part of the total sulfur increased from 5% in core to 18% in outcrop samples; pyritic sulfur decreased from 14 to 10%, and organic sulfur decreased from 84 to 71%. As indicated by differences in element/Al ratios between core and outcrop samples, the relative rates of removal of Si, K, B, Cr, Ga, La, Li, and V from coal during weathering are significantly greater than Al; Cd, Co, F, Ni, Se, and Zn are significantly greater than Al; Cd, Co, F, Ni, Se, and Zn are significantly less than Al; and Ca, Mg, Na, Fe, Ti, As, Ba, Be, Cu, Mg, Mn, Mo, Nb, Pb, Sb, Se, Sr, Th, U, Y, Yb, and Zr are similar to Al. Additional significant chemical changes in outcrop samples should be expected in areas of warmer, more humid climates, where coal is of lower rank, or in samples collected on less-steep slopes or at shallower depths.

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Geochemistry of Organic-Rich Shales and Coals from Middle Pennsylvanian Cherokee Group and Lower Part of Marmaton Group, Oklahoma, Kansas, Missouri, and Iowa

Middle Pennsylvanian rocks have produced substantial quantities of oil in eastern Oklahoma and southeastern Kansas. Initial results (Table 1) of a study of possible petroleum source rocks in these units show that organic-rich shales (> 1% organic C) can be divided into four groups. Group I shales are nonfossiliferous to fossiliferous marine, and commonly pyritic. Groups II, III, and IV shales are laminated, phosphatic, and nonfossiliferous to slightly fossiliferous. Groups III and IV shales are most common in the northern part of the area, which would be closer to the paleo-shoreline. Bulk organic geochemical properties of groups II and III shales are similar to coals, suggesting that most of the organic matter was derived from peat swamps. Reworking of organic matter, particularly in shale groups I and IV, was considerable, as indicated by low inferred hydrogen contents (H index) and relatively high inferred oxygen contents (O index). For types II and III shales and coals, average H and O indices decrease, and T_{max} (S_2 peak − Rock-Eval) increases from north to south, indicating an increasing maturity of organic matter to the south. This increasing maturity is consistent with changes in coal rank, which increases from high-volatile C bituminous coal in Iowa to high-volatile A and medium-volatile bituminous coal in Oklahoma. Total sulfur-organic carbon plots for the four shale groups do not intercept the sulfur axis, which suggests a lack of H_2S-containing bottom waters; different slopes of these plots suggest variability of sulfate availability, possibly due to salinity differences or rates of sedimentation.

Table 1.--*Summary data for rock samples from the Cherokee and Marmaton Groups*

	Shale class				
	I	II	III	IV	Coal
Number of samples-------------	37	35	15	11	70
Organic Carbon % [1]	3.3	10.5	21.3	8.4	55.8
Hydrogen index [1,2]	45	180	325	26	227
Oxygen index [1,2]	26	9	9	13	7
C vs S slope----------	.7	.24	.19	.14	--[3]
C vs S intercept % C----------	.8	1.5	14.4	3.9	--
C vs S correlation (r)	.9	.9	.8	.9	--

[1] mean values; [2] determined by Rock-Eval; [3]--, no data.

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Regional Upper Devonian Wabamun Lithofacies Computer Maps, Alberta

Regional distribution of lithology, fossils, and porosity within the Upper Devonian Wabamun Formation is summarized on ten maps covering Alberta and northeast British Columbia. The 2,600 data points on each map were derived from the Constrat digital lithology file and were contoured using Union Oil's Calgary 370/138 computer. The maps were made to outline regional lithofacies and biofacies environments and to pinpoint porosity pinch-out plays.

Maps displayed include: Wabamun isopach, net-feet dolomite, ratio of net dolomite to limestone, net anhydrite, porosity isopach, good oil shows, bioclast isopach, pellet isopach, crinoid isopach, and average particle size.

Interpretation of these maps defines four distinct depositional environments within the Wabamun: (1) a shallow shelf in southern Alberta that has interbedded dolomite and anhydrite with negligible porosity development; (2) a north-trending porous dolomite funnel or channel running up the 5th meridian; (3) a shallow-water basinal environment in central Alberta, characterized by abundant porous dolomite pods (pinnacle reefs?) in a pelletal and bioclastic limestone; and (4) a deep-water basin in northern Alberta and British Columbia, with tight crinoidal limestone.

These maps are a first step in basin analysis, and also outline possible traps for further evaluation. Preparation of such regional percentage maps is virtually impossible without computer assistance.

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Seismic Inversion by Modeling

Direct estimates of subsurface material properties are obtained by rigorous inversion of conventional seismic data. The inversion procedure employs an iterative model perturbation technique to fine the earth model whose response best fits the input data in a least mean-squared sense. The method is applicable to 1-D, 2-D, or 3-D fluid or solid earth models, and to shot record or CDP stacked data. The synthetic response computed in the inversion process is a rigorous solution of the wave equation appropriate for the chosen earth model and data type.

For 1-D earth models and synthetic CDP stacked data representing various reflection sequences, the modeling method accurately recovers the true acoustic impedance profile. When a nonrigorous recursive technique is applied to the same models, accurate results are obtained only for weak reflection sequences. Also, the modeling technique exhibits greater stability in the presence of noise. For poststack inversion of field data, the processing sequence leading to the CDP stacked trace is of key importance.

For 1-D earth models and shot record input data, the modeling method accurately recovers both density and velocity profiles. A key issue in prestack inversion of field data is the generation of synthetic shot records consistent with data collection geometry.

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Geothermal Gradients, Organic Metamorphism, and Mineral Diagenesis in Tertiary Rocks, Santa Ynez Mountains, California

Organic metamorphism, as expressed by vitrinite reflectance, may be used to correlate mineral diagenesis with the thermal history of a sedimentary basin. Levels of organic metamorphism were compared with diagenetic minerals in three Paleogene sandstone and shale sections of the Santa Ynez Mountains and were used to determine paleotemperatures by means of the established time-temperature-reflectance relation. Calculated paleogeothermal gradients range from 31.0 to 40.3°C/km in the eastern end of the basin to 47.2 to 51.0°C/km in the west.

Changes in the geothermal gradient in the Santa Ynez Mountains through the Tertiary were modeled using present surface temperatures and heat generation at the earth's center as boundary conditions. For instantaneous and continuous deposition, the governing equation is a linear parabolic partial differential equation. To model continuous deposition, a small dispersion coefficient term is used. The equations were solved by finite difference numerical techniques involving matrix solution by the Thomas algorithm. In instantaneous deposition, thermal equilibration is rapid in terms of geologic time, with temperatures restored to their presedimentation levels after 500,000 years. For continuous deposition, sedimentation rates of the Paleogene strata are slow enough to allow for nearly complete thermal equilibration during deposition.

The first appearance of laumontite in the eastern and central parts of the basin occurs at vitrinite reflectivities of 1.1 and 1.3% R_O (200°C) respectively, while laumontite first occurs at vitrinite reflectance of 0.5% R_O (110°C) in the western end of the basin. Variation in the ratio of fluid pressure to total pressure may be responsible for the observed distribution of laumontite. The transition from a mixed-layer illite/smectite illite-chlorite asemblage to an illite-chlorite assemblage in the interbedded shales occurs at vitrinite reflectance of 2.4% R_O (235°C) in the eastern part of the basin.

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Geology of Hibernia Discovery

Chevron discovered the Hibernia oil field in 1979 by drilling the Chevron et al Hibernia P-15 well, on the Grand Banks, 195 mi (314 km) east of St. John's, Newfoundland. Delineation drilling, completed during 1980 and the early part of 1981, has confirmed the presence of a giant oil field which, in all probability, will contain recoverable reserves in excess of one billion bbl.

The oil field is located near the western edge of the Jeanne d'Arc subbasin, a southwestern extension of the much larger East Newfoundland basin. These depocenters developed as a consequence of Mesozoic extensional rift tectonics and contain up to 40,000 ft (12,192 m) of Mesozoic and Cenozoic sediments.

The Hibernia structure is a large north-northeast trending rollover anticline, bounded on the west by a major listric growth fault, and dissected into a number of separate blocks by transverse faults. The crest of the structure is truncated by a major middle Cretaceous unconformity.

The most potentially productive reservoirs are sandstones of Lower Cretaceous age which appear to be deltaic in origin. Porosities vary from 17% to more than 30%; permeabilities range from 200 md to 1,300 md.

The discovery and early delineation wells each have an indicated productivity in excess of 20,000 bbl per day.

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Interstitial Water Chemistry of DSDP Holes on Guatemala Transect (Leg 67) Related to Occurrence of Methane Clathrates (Gas Hydrates)

High gas-concentrations, and methane/ethane ratios approaching the DSDP-safety limit, caused premature termination of drilling on Sites 496 to 498 (2,064 to 5,497-m water depth) on the Pacific continental slope off Guatemala. Methane concentrations in organic-matter-rich Quaternary to Miocene middle and lower trench slope sediments cause the formation of clathrates that were recovered for the first time in volcanic ash from two drill holes. The potential clathrate-bearing zone (below 80 to 100 m subbottom depth) is associated with a spectacular decrease in interstitial water chlorinity, which drops below half the chlorinity of seawater at the bottom of the holes (near 400 m subbottom). It is proposed that the crystallization of gas hydrates, which like ice exclude