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.

HATCH, JOSEPH R., and RONALD H. AFFOLTER, U.S. Geol. Survey, Denver, CO

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.

HATCH, JOSEPH R., and JOEL S. LEVENTHAL, U.S. Geol. Survey, Denver, CO

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.

HAY, PETER W., Canadian Stratigraphic Service, Ltd., Calgary, Alberta, Canada

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