UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Abstracts of the U.S. Geological Survey, Central Region, 1990 Poster Review

Collected Abstracts of Selected Poster Papers Presented at Scientific Meetings

Compiled by

Charles E. Barker[1] and Anny B. Coury[1]

Open-File Report 90-656

[1] U.S. Geological Survey, Box 25046, Denver Federal Center, Denver, Colorado 80225 U.S.A.

CONTENTS

Coates, D.A., G.D. Stricker, and E.R. Landis

PERMIAN COAL IN TRANSANTARCTIC MOUNTAINS--QUALITY AND QUANTITY

Fluvial coal-bearing rocks of the Victoria Group of the Beacon Supergroup crop out in a 2,000-km long belt from north Victoria Land to the Ohio Range. Although coal beds as thick as 10.7 m have been reported, they are generally thinner and lenticular and commonly not more than 3 km in lateral extent. In north Victoria Land, the small Victoria basin contains coal in the Takrouna Formation; in south Victoria Land, the larger Victoria basin contains the Weller Coal Measures; and the southernmost and largest Nimrod-Ohio basin, which extends from the Nimrod Glacier to the Ohio Range, contains the coal-bearing Buckley Formation and its equivalents.

The 144 published analyses of Permian coal from this region indicate that as-received ash contents range from 3.2 to almost 50% with an arithmetic mean of 15.3%. As-received sulfur contents range from 0.0 to 4.8% with an arithmetic mean of 0.57%. Calculated apparent rank ranges from high volatile C bituminous coal to meta-anthracite.

Paucity of data on coal thickness and distribution dictates that coal resource estimates be classified as hypothetical. Hypothetical coal resources, calculated on the basis of information from published geologic maps, geologic descriptions, and measured sections, total 3 billion MT in the North Victoria basin, 50 billion MT in the South Victoria basin, and 100 billion MT in the Nimrod-Ohio basin.

Coates, D.A., G.D. Stricker, and E.R. Landis, 1989, Permian coal in Transantarctic Mountains--Quality and Quantity: American Association of Petroleum Geologists Bulletin, vol. 73, no. 3, p. 345.

Hatch, J. R., Leventhal, J. S., and Desborough, G. A.

Early Diagenetic Aerobic Degradation of Organic Matter and Sulfides in Some Middle and Upper Pennsylvanian Marine Shales, Midcontinent Region, U.S.A.

Organic and elemental analyses of 127 core samples of Middle and Upper Pennsylvanian, organic-matter-rich, marine shales (offshore shale lithofacies) from the Midcontinent region of the United States show that organic matter and sulfides in some shales have been extensively altered. Altered and unaltered shales are similar in that they are laminated, phosphatic, organic-matter rich, and metalliferous with V contents 500-2500 ppm; Cr, 200-800 ppm; Ni and Mo, 100-500 ppm; and U, 30-100 ppm. Other compositional parameters, however, are significantly different. For example, the Desmoinesian Excello Shale Member of the Mouse Creek Formation in southern Iowa and northern Missouri is altered and has: (a) relatively low organic carbon contents (3.8 to 9.2 percent compared to 8.2 to 30 percent for unaltered shales from the same area); (b) very low hydrogen indices (3 to 58 mg/g compared to 230 to 410 mg/g); (c) isotopically heavy organic matter ($\delta^{13}C$ = -22.0 to -24.3 per mil compared to -25.2 to -27.2 per mil); and (d) low contents of sulfur (<0.1 to 1.0 percent compared to 1.2 to 2.6 percent). These differences suggest that hydrogen-rich, isotopically light organic matter and most sulfides have been lost from the Excello Shale.

Alteration apparently took place during subaerial exposure following marine regression. Oxygenated rainwater circulated down to the level of the Excello mud and allowed metabolism of organic matter and sulfides by aerobic microorganisms. This hypothesis is supported by previous researchers, who have identified fresh-water carbonate cements within, and soil horizons at the top of the limestone overlying the Excello Shale (Blackjack Creek Limestone Member of the Fort Scott Limestone). The period of alteration is constrained in that organic matter and sulfides in the Little Osage Shale Member of the Fort Scott Limestone (immediately overlying the Blackjack Creek Limestone, 20-25 ft [6.1-7.6 m] above the Excello Shale) appear unaltered. Alteration similar to that in the Excello Shale has also occurred in the Missourian Hushpuckney Shale Member of the Swope Limestone in north-central Kansas.

Hatch, J. R., J. S. Leventhal, and G. A. Desborough, 1990, Early diagenetic, aerobic degradation of organic matter and sulfides in some Middle and Upper Pennsylvanian marine shales, Midcontinent region, U.S.A.: American Association of Petroleum Geologists Bulletin, v. 74, p. 671-672.

LANDIS, E.R.[1], KHAN, R.A.[2], WARWICK, P.D.[1], OMAN, C.L.[1], KHAN, S.A.[2], and BRAGG, L.J.[1]

Quality of Coal from the Paleocene Bara Formation, South Sind, Pakistan

The Geological Survey of Pakistan and the U.S. Geological Survey, under the auspices of the Government of Pakistan and the U.S. Agency for International Development, assessed coal quality in parts of the Lakhra and Sonda coal fields in southern Sind Province, Pakistan. The assessment is based on 292 samples collected from the Bara Formation of Paleocene age.

Weighted arithmetic means of proximate analyses for the 292 samples (as-received basis) show that the coals contain about 30 percent moisture, 28 percent volatile matter, 25 percent fixed carbon, and 18 percent ash. The samples have an average heat-of-combustion of about 6,700 Btu/lb. By ASTM standards, the coal has an average apparent rank of lignite A to subbituminous C and a moist, mineral-matter-free Btu/lb of about 8,200. Ultimate analyses for the 292 samples (as-received basis) average about 6 percent hydrogen, 37 percent carbon, 0.7 percent nitrogen, 34 percent oxygen, and 4.0 percent sulfur. About 70 percent of the sulfur in the Sind coals is in the form of pyrite, and part of it can be removed through coal cleaning procedures. Similarly, part of the ash may also be removed by coal cleaning methods. The high ash and sulfur contents of much of the southern Sind coal are, of course, undesirable grade factors, but available coal cleaning methods, and combustion technologies such as fluidized bed applications, should allow effective, economical utilization of these coals.

---

[1]U.S. Geological Survey

[2]Geological Survey of Pakistan

Landis, E.R., Khan, R.A., Warwick, P.D., Oman, C.L., Khan, S.A., and Bragg, L.J., 1990, Quality of coal from the Paleocene Bara Formation, South Sind, Pakistan: American Association of Petroleum Geologists Bulletin, v. 74, no 6, p. 985.

Roberts, S.B., Stricker, G.D., and Affolter, R.H.

200+ Billion Tons of Low Sulfur Coal in the Sagavanirktok Formation, North Slope, Alaska.

Coal deposits within the Upper Cretaceous-Tertiary Sagavanirktok Formation underlie a region of more than 8,400 sq km in the east-central North Slope of Alaska. The coals are distributed within Maastrichtian and Paleocene fluvio-deltaic deposits of an east to northeast-prograding delta system.

Recent investigations have focused on areal distribution and quality of the coals. Coal-bearing outcrops occur in an 80 km belt between the White Hills and Kavik River, and comprise clast-supported conglomerate, sandstone, siltstone, shale (mudstone), carbonaceous shale and coals beds as thick as 7m. Borehole data indicate that the coals extend northward to the Arctic coast and offshore, and eastward from the Kuparuk River to the Canning River where they pinch out in the Staines Tongue of the Sagavanirktok Formation. The major coal-bearing interval ranges from 220m to 850m in thickness, and more than half of the coal beds are greater than 1.5m thick. Analyses of 55 coal outcrop samples indicate that the apparent rank ranges from lignite A to subbituminous B, with the majority being subbituminous C. Mean content of ash for the samples is 10.9% ;mean content of sulfur is 0.39%.

Interpretation of data from drill holes penetrating the Sagavanirktok Formation in the Prudhoe Bay/Kuparuk region has resulted in a reevaluation of hypothetical coal resources to at least 200 billion metric tons. This value far exceeds previous estimates of 55 to 65 billion metric tons for this region of the North Slope.

Roberts, S.B., Stricker, G.D., and Affolter, R.H., 1990, 200+ Billion Tons of Low Sulfur Coal in the Sagavanirktok Formation, North Slope, Alaska: American Association of Petroleum Geologists, Bulletin 74, No. 8, p. 1343.

Gary D. Stricker

Alaska has 4.0 trillion tons of low sulfur coal; is there a future for this resource?

The demand for and utilization of low-sulfur coal may increase because of concern with acid rain. Alaska's low-sulfur coal resources can only be described as enormous: 4.0 trillion tons of hypothetical onshore coal. Mean total sulfur content is 0.34% (range 0.06 - 6.6%, n=262) with a mean apparent rank of subbituminous B. There are 50 coal fields in Alaska; the bulk of the resources are in six major fields or regions:

Coal field or region	Age	Coal resources		Mean sulfur content	Mean apparent coal rank
		Identified	Hypothetical		
Nenana	Tertiary	8.9 billion	15 billion	0.24%	Subbituminous C
Cook Inlet	Tertiary	10 billion	65 billion	0.25%	Subbituminous C
Matanuska	Tertiary	150 million	500 million	0.45%	High-volatile A bituminous
Chignik-Herendeen Bay	Cretaceous	360 million	3 billion	0.82%	High-volatile B bituminous
North Slope	Cretaceous	49 billion	3.2 trillion	0.32%	Subbituminous B
Bering River	Tertiary	110 million	3.5 billion	1.2%	Semianthracite

For comparison, Carboniferous coals in the Appalachian Region and Interior Province have a mean total sulfur content of 2.3% (range 0.1 - 19.0%, n=5,497) with a mean apparent rank of high-volatile A bituminous coal and Rocky Mountain and Northern Great Plains Cretaceous and Tertiary coals have a mean total sulfur content of 0.86% (range 0.02 - 19.0%, n=2,754) with a mean apparent rank of subbituminous B. Alaskan coal has two-fifths the total sulfur of western U.S. coals and one-sixth that of Carboniferous U.S. coals.

Even though Alaska has large resources of low-sulfur coal, these resources have not been developed because of: 1) remote locations and little infrastructure; 2) inhospitable climate; and 3) long distances to potential markets. These resources will not be utilized in the near future, unless there are some major, and probably violent, changes in the world energy picture.

Stricker, G.D., 1990, Alaska has 4.0 trillion tons of low sulfur coal; is there a future for this resource? : American Association of Petroleum Geologists Bulletin, v. 74, p. 772.

EVIDENCE OF SUDDEN LATE HOLOCENE UPLIFT IN THE CENTRAL PUGET LOWLAND, WASHINGTON

R C Bucknam and T P Barnhard (U.S. Geological Survey, MS 966, Federal Center, Denver, CO 80225; 303-236-1604)

At least two areas in the central Puget lowland show evidence of abrupt late Holocene uplift that greatly exceeds any observed historical deformation in the region. At Restoration Point on Bainbridge Island, about 5 km west of Seattle, a well defined wave-cut marine platform (Gower and others, U.S. Geol. Surv. Misc. Invest. Series Map I-1613, 1985) 50-150 m wide has been uplifted about 7 m. A bog behind a raised beach ridge at the landward edge of the raised platform is underlain by more than 5 m of interlayered peat and sediment. The sediment beneath the bog is interpreted to be marsh deposits that formed near sea level during a slow late Holocene transgression prior to uplift. A ^{14}C age for charcoal from a layer of sandy mud that occurs near the top of the section and which contains brackish water diatoms suggests a maximum age of about 1.5 ka for the uplift.

About 30 km southwest of Restoration Point, stratigraphic relations at a marine salt marsh at Lynch Cove near Belfair, Washington, suggest several decimeters of uplift occurred there about 1.1 ka. The salt marsh is underlain by about 60 cm of peat and muddy peat containing remains of salt-marsh plants. This sequence is underlain by about 40 cm of freshwater peat, which locally contains abundant wood and freshwater plant fragments, sparse leaves, and tree roots interpreted to be in growth position. The freshwater peat has a sharp basal contact with underlying tidal-flat sediment. A ^{14}C age on the basal peat closely dates the onset of the growth of freshwater vegetation on the uplifted tidal flat. A subsequent slow rise of relative sea level led to development of a salt marsh over the freshwater peat.

The geomorphic and stratigraphic evidence for abrupt uplift at these two geographically separate sites suggests that the uplift resulted from an earthquake or earthquakes. No comparable coseismic deformation has been observed historically in the region despite the occurrence of earthquakes as large as magnitude 7.2 (1949), suggesting the sudden uplift was produced by an earthquake source and mechanism greatly different from any observed to date.

Bucknam, R.C., and Barnhard, T.P., 1989, Evidence of sudden late Holocene uplift in the Central Puget Lowland, Washington (abs): Eos, Transactions, American Geophysical Union, v. 70, p. 1332.

Abstract published in *Eos*, Transactions, American Geophysical Union (1989) v. 70, p. 1332.

Fracture Studies in the Welded Grouse Canyon Tuff: Laser Drift of the G-Tunnel Underground Facility, Rainier Mesa, Nevada Test Site, Nevada

By S.F. Diehl, M.P. Chornack, H.S. Swolfs, and J.K. Odum

We studied fractures in the welded Grouse Canyon tuff in the Laser Drift of the G-Tunnel Underground Facility (GTUF) located in Rainier Mesa, about 64 km northwest of Mercury, Nevada. The Grouse Canyon Tuff has lithologic properties, stress conditions, and an overburden depth comparable to those of the proposed repository horizon at Yucca Mountain.

Several horizontal boreholes were cored in the Laser Drift as part of the Yucca Mountain prototype testing program. The USGS conducted surveys in these boreholes using a borehole video camera and video tape recorder. Video tapes of the boreholes were used to detect the presence and orientation of fractures intersecting the boreholes. The numbers of fractures observed in the video surveys compare well with fracture counts during the examination and logging of the recovered core samples from the boreholes. The video tape recording did offer the advantage of a more accurate count of fractures in rubble zones, which were impossible to reconstruct from the core once it had been removed from the borehole.

The boreholes were oriented to intersect the prominent fracture trends (N. 25° E. and N. 40° E.) exposed in the Laser Drift. Most of the fractures are relatively planar with near-vertical dips. Mineralization along the fractures generally consists of iron and manganese staining, but one predominant fracture, trending N. 5° E. with a dip of 86° SE, is filled with clay.

Four microfracture trends that average N. 75° W; N. 29° W; N. 3° E; and N. 70° E. were determined from two oriented samples. Microfracture orientations commonly are perpendicular and parallel to welding and are abundant around stress-concentration points of phenocrysts. Authigenic mineral phases commonly seal microfractures, which indicates precipitation of these minerals from fluids moving through the microfractures. Adularia and iron, titanium, manganese, and rare earth mineral phases fill the microfractures. A few adularia-filled microfractures are parallel to and at 45° to the plane of welding.

The microfractures appear to be extensional in origin. A profile of shut-in pressures from hydraulic fracture testing in two vertical holes near the GTUF site (Warpinski and others, 1981) indicates that the least horizontal stress magnitude in the welded Grouse Canyon is half as much as in the adjacent nonwelded units. Thus, the welded unit is in a state of extension, probably due to lateral spreading in the more ductile nonwelded tuff.

Although the Grouse Canyon tuff is currently in the unsaturated zone, the hydrous mineral phases that coat fracture surfaces and seal microfractures indicate that fluid movement has occurred along these structures. This shows that the microfractures were once well-connected flow paths for fluid movement.

Warpinski, N.R., Northrop, D.A., Schmidt, R.A., Vollendorf, W.C., and Finley, S.J., 1981, The formation interface fracturing experiment--an in situ investigation of hydraulic fracture behavior near a material property interface: Sandia National Laboratories Report SAND81-0938, 82 p.

Presented Sept. 13 and 14, 1990, Colloquium on Fractures and Hydrology: Committe for the Advancement of Science at Yucca Mountain, U.S. Geological Survey.

There is Nothing Better Than Good S

J.S. Gomberg and K.M. Shedlock (both at USGS, MS 966, Box 25046, Denver Federal Center, Denver, CO, 80225)

S.W. Roecker (Department of Geology, Rensselaer Polytechnic Institute, Troy, NY, 12180)

The problem of hypocenter determination has been studied by many researchers and 'rules of thumb' pertaining to the number and configuration of recording stations, the starting solution, and the distribution and number of P and S phases have been developed. We present a summary of what these studies have shown about the sensitivity of hypocenter determination to the inclusion of S phases, and discuss the theoretical basis behind these 'rules'. An understanding of the importance of S phases is especially relevant to regional seismic network design. The requirement for accurate focal depth is that at least one S phase be recorded within approximately 1.4 focal depth's distance from the source; this implies that the optimal station spacing is such that seismographs be separated by no more than 1.4 times the minimum focal depth's distance of likely earthquakes. Mis-identification of an S phase can lead to both biased velocity models and depth estimates; this is most easily avoided if S phases are measured from a transverse component and from a seismogram that remains on scale. Thus, each station should include one vertical and two orthogonal horizontal components, and should have sufficient dynamic range to not saturate in the relevant magnitude and distance ranges. We illustrate these requirements by showing a series of experiments using hypothetical data.

Gomberg, J.S., Shedlock, K.M. and Roecker, S.W., in press, The effect of S wave arrival times on the accuracy of hypocenter estimation: Seismological Society of America Bulletin.

HOW CALDERAS RESURGE

HON, Ken, USGS, Hawaiian Volcano Observatory, Hawaii National Park, HI, 96718, and
FRIDRICH, Chris, Department of Energy, Box 98518, MS 523, Las Vegas, NV, 89193

The resurgence of large ash-flow calderas was first recognized by Smith and Bailey (1968), who proposed that renewed pressure arched the roof of the main magma chamber. The deeply eroded Lake City and Grizzly Peak calderas in Colorado provide strong evidence that the resurgent intrusions rise above basement rocks and are emplaced within ash-flow tuffs of the caldera fill. Probable resurgent intrusions identified in remnants of other deeply eroded calderas (Questa, Turkey Creek, Mt. Aetna, Salma) also intrude intracaldera tuff. Excellent exposures and preservation of complete stratigraphic sections within the Lake City and Grizzly Peak calderas allow reconstruction of the top of the resurgent intrusions and the resurgent domes; areas of maximum uplift of the domes are centered directly over the main part of the resurgent plutons. The interface between fractured caldera floor and the coherent block of intracaldera tuff serves to localize the upwardly migrating magma.

Multiple pulses of intrusion can be documented at both calderas. At Lake City, early radially oriented intrusions, which are reversely zoned, were later truncated by the main resurgent intrusive body; geophysical data indicate that the final form of the intrusion was stock-like and extends at least 4-5 km below the present surface. Two main intrusive pulses were a principle cause of resurgence within the Grizzly Peaks caldera, and the shapes of these reversely zoned plutons define a resurgent intrusion of laccolithic form. Initially, most resurgent intrusions probably spread as sill-like bodies near the base of the intracaldera fill. Increased loading by the growing intrusion, which may downwarp the underlying caldera floor rocks, and stoping of the conduit during emplacement of succesive intrusive phases eventually produce intrusions with stock-like shapes (e.g., the central intrusions of ring complexes).

Laccolithic models for resurgent domes differ in two respects from those developed in sedimentary rocks. First, slip parallel to bedding planes that accompanies flexure of sedimentary strata does not appear to occur in the relatively massive intracaldera tuff units. The absence of weak bedding-plane layers causes an increase in the effective thickness of caldera fill in comparison to a similar thickness of sediments and requires development of brittle fractures to account for extension of units during doming. Radial, and possibly concentric, fractures appear to form early and allow lava to extrude in the center of resurgent domes, whereas greater extension during later stages of resurgence is accommodated by the formation of a keystone graben structure, which inhibits the rise of magma. The number and size of all fractures diminishes with depth in the domed caldera fill. Second, the ring fault--and other subsidence-related faults--act as detachment surfaces surrounding the growing dome. During advanced stages of doming, the intracaldera block may pull away from wall rocks outside of the ring fault; this dislocation can result in large upward displacements along the ring fault (>1 km) and provide pathways for magma to reach the surface as ring domes.

Regional detumescence and renewed magmatic pressure due to vesiculation were suggested by Marsh (1984) as the most likely causes of resurgence. Evidence for regional detumescence is difficult to establish from field observations and, furthermore, the effectiveness of this model is dependent on viscous rather than elastic behavior of the upper crust. Increased pressure due to volatile exsolution seems improbable because of the relatively nonvesiculated condition of most resurgent intrusions. Instead, we favor a simpler alternative of continued magmatic input. Most resurgent domes have volumes ranging from 50-150 km^3; published eruptive rates for large silicic calderas range from 10^{-2} to 10^{-3} km^3/yr. Thus, reasonable times for resurgence due to continued magmatic input within the system generally fall between 10^4-10^5 years, in agreement with radiometric dates bracketing the formation of resurgent domes in young calderas.

Hon, Ken, and Fridrich, Chris, 1989, How calderas resurge: New Mexico Bureau of Mines and Mineral Resources Bulletin 131, p. 135.

Damage and Intensity Survey of the October 17, 1989 Loma Prieta Earthquake

Hopper, Margaret, Leyendecker, E. V., Thenhaus, Paul C., Stover, Carl W., Algermissen, S. T., Reagor, B. Glenn, Perkins, David M., Hanson, Stanley L., Brewer, Lindie, Baldwin, Francis W.

Teams from the Branch of Geologic Risk Assessment and the National Earthquake Information Center surveyed damage and Modified Mercalli intensities (MMI) in the San Francisco Bay area. A preliminary map of intensities assigned for the high-damage area has been prepared. The preliminary maximum MMI assigned to the earthquake is VIII based on substantial damage to wood-frame houses and unreinforced masonry buildings such as those in Santa Cruz, Los Gatos, and Watsonville. Within the MMI-VIII area were also many cripple-wall failures.

Isolated instances of MMI IX are assigned to the collapse of the elevated section of the Nimitz freeway in Oakland, to the damaged Embarcadero freeway in San Francisco, and to the Marina district of San Francisco. The freeways are assigned MMI IX because they were reinforced concrete structures designed to meet seismic requirements in force when they were built; the Marina IX is based on wide-spread structural damage to substantial buildings within the district.

The amplification of ground motion associated with surficial geologic materials or local topography undoubtedly contributed to the observed damage pattern. For example, areas of San Francisco underlain by thick sediments and bay mud show intensity levels one to three MMI units higher than the central part of the city.

Intensities were not assigned to landsliding, liquefaction and other observed ground effects due to their uncertain placement in the MMI scale. Although ground failures and shaking damage are inextricably mixed in some areas, overall assessment of damage included nearby structures not influenced by the ground failure.

Hopper, Margaret, Leyendecker, E. V., Thenhaus, Paul C., Stover, Carl W., Algermissen, S. T., Reagor, B. Glenn, Perkins, David M., Hanson, Stanley L., Brewer, Lindie, Baldwin, Francis W., 1990, Damage and intensity survey of the October 17, 1989 Loma Prieta earthquake: Eos, v. 71, no. 8, p. 288.

Seismic Deformation in the Pacific Northwest

Kaye M. Shedlock
Craig S. Weaver
David Oppenheimer
G. C. P. King

Knowledge of the earthquake source regions and the forces responsible for generating earthquakes within them are fundamental to estimating the earthquake hazards of the Pacific Northwest. In an effort to increase our understanding of the intraplate source regions in the Cascadia subduction zone, we are examining the deformation associated with over 6500 earthquakes that have occurred in northern California, Oregon, and Washington. In northern California, we are concentrating on over 4400 earthquakes that have been located near or onshore in the Cape Mendocino area (between 40° and 42°) since 1974. Our northern Oregon and Washington data set consists of over 2100 earthquakes that have been located north of 44° since 1960. No earthquakes have been instrumentally located in southern Oregon (between $\approx$ 42° and 44°). Fault plane solutions have been determined for over 600 of the earthquakes located in northern California and for 21 of the earthquakes located in Oregon and Washington. We are using these data to calculate a generalized moment distribution map for the region that will clearly illustrate where the onshore deformation is occurring in the Pacific Northwest. We can then use those earthquakes for which fault plane solutions exist to determine the how much of the deformation represents crustal/lithospheric shortening or stretching and the spatial and temporal variation of each.

Abstract published in *EOS, Transactions of the American Geophysical Union, 70,* 1330, 1989.

GEOCHEMICAL EXPRESSION OF POORLY EXPOSED METALLIZATION IN THE SOUTHEASTERN CHALLIS VOLCANIC FIELD, IDAHO--EMPHASIS ON BIOGEOCHEMICAL METHODS

Erdman, J.A., U.S. Geological Survey, Denver, Colorado 80225; Moye, Falma, Idaho State University, Pocatello, Idaho 83209; and Theobald, P.K., U.S. Geological Survey, Denver, Colorado 80225

Biogeochemical and geochemical exploration techniques were used in the Lava Creek mining district, north of Craters of the Moon National Monument, and in the Baker Creek area near Ketchum to assess the potential for new metallic mineral occurrences. Stream sediments, soils, heavy-mineral concentrates, and several species of plants, principally big sagebrush *(Artemisia tridentata)*, were collected in reconnaissance-scale, drainage-basin surveys. Biogeochemical methods can be especially effective where surface expression of mineralization is poor.

The Lava Creek area was selected because of its historical importance as a silver producer with byproduct gold. Most of this area is underlain by Eocene Challis Volcanics that have been so hydrothermally altered that good outcrop is extremely limited. Hydrothermal alteration east of Baker Creek chiefly affects dacitic lava; a central zone of intense argillic alteration is surrounded by a broader zone of propylitic alteration. The Baker Creek area showed no permanent evidence of mineral prospecting when the survey was made, but it has geological characteristics that favor the existence of an epithermal precious-metal system.

At Lava Creek, initial results showed geochemical anomalies in sagebrush which suggested that a possible host for epithermal, precious metals was the Mississippian McGowan Creek Formation (chiefly turbidites), peripheral to the formerly active mines. Follow-up sampling of sagebrush, stream sediments, and soil defined a source of a Hg-Ag-Au-As-Sb anomaly in a fault breccia near a poorly exposed dacite porphyry intrusion.

In the Baker Creek area, heavy-mineral concentrates all contain abundant barite, even beyond the zone of propylitic alteration. Botryoidal pyrite was also found, but it is restricted to the alteration zones. Visible gold and pyromorphite, a lead phosphate, were found in heavy-mineral concentrates from a small drainage near a stockwork-veined outcrop in the central zone of argillic alteration. A grab sample of the outcrop contained 50 ppm Au, 1.5 ppm Ag, and 50 ppm Mo. The maximum concentration of Au in nearby stream sediments and upland soils was only 2 ppb, but aquatic mosses from within the argillically altered zone contained as much as 64 ppb Au in the ash. This intensely altered zone is characterized by anomalous levels of Ag, Mo, Pb, Cd, and Zn, and, to a lesser extent, Au, Bi, Mn, As, Sb, and Tl in the various media samples. The geochemical signature suggests a Ag- and Mo-rich, low-temperature, epithermal type of mineralization.

Erdman, J.A., Moye, Falma, and Theobald, P.K., 1989, Geochemical expression of poorly exposed metallization in the southeastern Challis volcanic field, Idaho--Emphasis on biogeochemical methods, *in* Geology and mineral deposits of the Hailey and western Idaho Falls 1° x 2° quadrangles, Idaho: U.S. Geological Survey Open-File Report 89-639, p. 91.

ALTERATION MINERAL ASSEMBLAGE AND TRACE-ELEMENT ZONING IN THE BODIE MINING DISTRICT, MONO COUNTY, CALIFORNIA--A COMPARISON TO THE "HOT SPRING" MODEL

Peter A. Herrera, Colorado School of Mines, Miles L. Silberman, U.S. Geological Survey, and L. Graham Closs, Colorado School of Mines

Mineralized quartz veins that cut lava flows and pyroclastic rocks and coeval intrusions of dacite at the Bodie mining district produced 1.45 million ounces of Au and 7.3 million ounces of Ag. The occurrences of sinter clasts and of clasts of mineralized quartz veins in hydrothermal fallback breccias near the top of Bodie Bluff, the highest point in the district, suggest to us that a surface-venting geothermal system formed part of the volcanic-hydrothermal evolution that produced the mineral deposits.

At Bodie Bluff, in the northern part of the district, the geometry of silicic, potassium-silicate, argillic, and propylitic alteration assemblages conforms to that of generally recognized models for geothermal system-based hot-spring, epithermal, precious-metal, stockwork-disseminated Au deposits; however, the vertical and lateral zoning of volatile and precious metals departs significantly from that predicted by these models. Several hundred trace-element analyses of both surface and underground quartz veins and breccias were sampled over a 200-m range starting above, passing through, and extending below the bonanza mineralization zone at Bodie Bluff. Analyses of these samples show that Tl is enriched in the near-surface, and Au is most abundant in the bonanza zone, as the models predict, but the distribution patterns of other trace elements (Ag, Hg, As, Sb, Cu, Pb, Zn, Mn, Ba, and Sr) are much more complex. For example, Ag concentrations are highest in chalcedonic stockwork quartz veins at the top of Bodie Bluff, and As and Sb are more enriched in the deeper part of the system. The concentrations for Cu, Pb, Zn, Mn, and Ba are highest in the deep part of the system as well and show a lateral zoning pattern with the base metals most enriched towards the center of the bluff, whereas Mn and Ba are most enriched towards its periphery. At the 200-m depth, Au is also higher in concentration towards the periphery relative to the interior.

Detailed sampling and analyses of altered wall rocks surrounding mineralized quartz veins in the bonanza and 200-m-deep levels in the Bodie Bluff area show that Hg and Mn form halos around the veins. Vein proximity is indicated by increasing K and Rb content and decreasing Sr content and oxygen isotope ratios. The trace-element zoning patterns at Bodie Bluff are complex and do not conform to predictive models, but they do have empirical relationships to zones of mineralization on both district and ore-shoot scales.

Reference:

Herrera, Peter A., Colorado School of Mines, Silberman, Miles L., U.S. Geological Survey, and Closs, L. Graham, Colorado School of Mines: Alteration mineral assemblage and trace-element zoning in the Bodie mining district, Mono County, California--A comparison to the "hot spring" model [abs.]: Geology and Ore Deposits of the Great Basin, Great Basin Symposium, Program with Abstracts, p. 127-128.

OWEN, D.E.[1], J.K. OTTON[2], R.R. SCHUMANN[1], R.A. ZIELINSKI[1], J.P. MCKEE[3], E.I. ROBBINS[2], and F.A. HILLS[1] ([1]U.S. Geological Survey, Denver, CO; [2]U.S. Geological Survey, Reston, VA; [3]Colorado State University, Fort Collins, CO)

The Boston Peak fen: a multidisciplinary case study of a uraniferous mountain wetland.

Uranium (U) enrichments as high as several thousand ppm occur in surficial, organic-rich sediments of mountain wetlands, which provide natural laboratories for studying the transport and fixation of U. Boston Peak fen covers about 8 acres in the glaciated upper Laramie River valley of north-central Colorado. The valley follows a north-trending fault zone that was active as late as the Oligocene. The fen is bounded primarily by Precambrian rocks along the sides and upper end and by a postglacial landslide deposit on the lower end. Ground-water hydrology is characterized by a basal, confined, gravelly, locally artesian aquifer overlain by lacustrine clay and an unconfined peat aquifer. Faults and fractures in the bedrock are conduits for uraniferous waters that enter the fen through seeps and springs. Present-day vegetation communities are controlled by peat thickness and seasonal ground-water fluctuations.

Uranium mineralization in the fen is closely related to its depositional history. Immediately after the landslide dammed the valley floor, a pond formed and began filling with silt and clay. About 10,000 years ago, pond weeds became established and organic productivity increased. During this time, U was sorbed from the pond water by organic matter in the sediment, forming layers containing 10 to 150 ppm U (dry weight). About 3,000 years ago, downcutting of the spillway and sediment infilling resulted in depths shallow enough for the establishment of peat-forming sedges. Since then, up to 3.5 m of peat has accumulated. During this time, ground-water recharge zones in the fen became point sources of metal input, and as much as 3,300 ppm U (dry weight) accumulated locally in the peat.

Owen, D.E., Otton, J.K., Schumann, R.R., Zielinski, R.A., McKee, J.P., Robbins, E.I., and Hills, F.A., 1990, The Boston Peak Fen: A Multidisciplinary Case Study Of A Uraniferous Mountain Wetland: AAPG Bulletin, v. 74, p. 1340-1341.

Structurally controlled gold trends imply large gold resources in Nevada

Daniel R. Shawe, U.S. Geological Survey, MS 905,
Box 25046, Federal Center, Denver, Colorado 80225

ABSTRACT

Numerous gold deposits aligned along the regional Battle Mountain-Eureka, Carlin, and other trends in Nevada coincide with zones of faults, intrusive igneous rocks, and (or) geophysical discontinuities, indicating that mineralization was localized along major crustal structures. These structures penetrated deep into or through the crust, controlled emplacement of magmas into the upper crust, and guided dispersal of hydrothermal solutions derived from the intrusions or formed from heated ground waters. Deformation along the regional structures shattered upper crustal rocks, providing local permeable zones favorable for solution flow and precipitation of gold ores.

The 200 km-long Battle Mountain-Eureka structural trend is marked by gold deposits associated with hypabyssal stocks, although other types also are present. These deposits were formed at depths perhaps as great as 5 km. K-Ar studies at some stock-associated deposits indicate that they formed at about 40-38 Ma. Deep erosion has removed much of the Tertiary volcanic cover that blanketed the Battle Mountain-Eureka trend at the time of intrusion and mineralization.

In contrast, the Carlin structural trend, about 80 km long, is characterized mostly by sedimentary rock-hosted disseminated-type gold deposits. These formed at depths probably no greater than about 3 km, and above the level of hypabyssal stock emplacement. K-Ar studies at the Gold Quarry deposit in the Carlin trend indicate that mineralization occurred substantially later (at about 29 Ma) than the dated deposits in the Battle Mountain-Eureka trend. The Carlin trend has been less deeply eroded than has the Battle Mountain-Eureka trend, and volcanic rocks are still abundant. The recent discovery of a deep-level gold deposit beneath the Post disseminated deposit in the Carlin trend suggests that deeper gold deposits similar to those exposed in the Battle Mountain-Eureka trend may be present beneath other disseminated ores.

The great linear extent of the Battle Mountain-Eureka and Carlin gold trends, the large number of deposits in each trend, and the evidence for a large vertical range of gold deposition indicate that extremely large hydrothermal systems were concentrated along these trends. Numerous other gold deposits of many types occur throughout Nevada, commonly in geologic settings similar to those just described, and regional structures likely controlled major gold deposition in those areas as well. Probably many deposits remain to be discovered, and the potential for additional resources of gold in the State appears to be large.

Shawe, Daniel R., 1990, Structurally controlled gold trends imply large gold resources in Nevada, in Raines, G.L., and others, eds., Geology and ore deposits of the Great Basin, Symposium Proceedings: Geological Society of Nevada, Reno (in press).

Acid Mine Drainage and Wetlands

Contacts: Kathleen S. Smith and Katherine Walton-Day
U.S. Geological Survey, Geologic Division, Branch of Geochemistry, MS 973, DFC, Box 25046, Denver, CO 80225

Acid mine drainage is acidic, metal-rich water formed from reactions with rocks containing sulfide minerals. Acid mine drainage often flows from areas where mining activity has exposed sulfide-rich rocks (e.g. tailings piles and mine adits). In Colorado alone, 1300 miles of streams are contaminated by acid mine drainage. Potential problems associated with acid mine drainage include contaminated drinking water and disrupted growth and reproduction of aquatic organisms, especially fish. The bottom of streams contaminated by acid mine drainage is commonly coated with red, orange, or yellow sediment composed of iron-oxyhydroxide compounds. Researchers at the U.S. Geological Survey are studying a variety of processes in systems affected by acid mine drainage.

Wetlands are capable of improving the water quality of acid mine drainage which flows through them through a variety of physical, biological, and geochemical processes. Research conducted by the Branch of Geochemistry in a wetland near Leadville, Colorado, has shown that the wetland removes both iron and copper from the influent mine drainage. Because of these cleansing properties, wetlands are being considered by regulators as a possible passive treatment technique for streams affected by acid mine drainage.

A Fluid Inclusion Technique for Determining Peak Temperature and its Application to Establish a Refined Calibration for the Vitrinite Reflectance Geothermometer

CHARLES E. BARKER, U.S. Geological Survey, Denver, Colorado 80225 U.S.A.

ROBERT H. GOLDSTEIN, University of Kansas, Lawrence, Kansas 66045 U.S.A.

Theory, laboratory experiments, and empirical observation suggest that many low-temperature, aqueous fluid inclusions in calcite should reequilibrate and approach the peak temperature (Tpk) during natural overheating. Plots of homogenization temperature (Th) and Tpk for systems now at peak temperature demonstrate a direct relationship between the variables. Although caution should be applied, the relationship suggests Th of fluid inclusions in calcite may be a useful measure of peak temperature.

Relationships between Tpk, heating duration, and thermal maturation of sedimentary organic matter have been obscured by imprecise geologic data. This study uses the Th approximation of Tpk and compares it to mean random vitrinite reflectance (Rm) to develop a refined calibration for the vitrinite reflectance geothermometer. Fluid inclusion and Rm data were measured or compiled from diverse geologic systems that have been at peak temperature from 10^4 to millions of years. Present Tpk ranged from 72-345°C, Th from 55-347°C and Rm from 0.4-4.6%, spanning the temperature and thermal maturity range associated with burial diagenesis, hydrothermal alteration and low-grade metamorphism. The refined calibration is: $\ln(Rm) = 0.00776(Tpk) - 1.24$.

The strong correlation ($r=0.90$) between Tpk and Rm in these systems suggests that peak temperature is the major control on thermal maturation.

Carter, L.M.H., ed., 1990, U.S. Geological Survey Circular 1060, p. 6.

Play Analysis Methodologies for Petroleum Resource Assessment

Robert A. Crovelli and Richard H. Balay

The petroleum resource assessment studies of the U.S. Geological Survey (USGS) have resulted in a wide variety of analyses, geologic models, quantitative methods, and computer programs. The type of analysis refers to the basic geologic assessment unit; for example, province, basin, or play. The geologic model consists of the geologic assumptions and mathematical description of the assessment approach; for example, reservoir engineering, volumetric yield, field size, or direct assessment. The quantitative method is the type of probabilistic methodology that is mathematically derived from the geologic model; for example, Monte Carlo simulation or analytic probability theory. Computer programs are written on the basis of the probabilistic methodology.

During recent years, the USGS has made major strides in designing and developing play analysis and analytic probabilistic methodology with a variety of geologic models. Play analysis is a general approach using various geologic models and probabilistic methods for analyzing a geologic play. In applying play analysis, a petroleum assessment area is first partitioned into geologic plays, and then the individual plays are analyzed. The individual play estimates of oil and gas are aggregated, respectively, in order to estimate the petroleum potential of the entire assessment area.

A probabilistic system of petroleum resource assessment for play analysis has been designed to meet the following requirements: (1) includes a variety of geologic models, (2) uses an analytic methodology instead of Monte Carlo simulation, (3) can aggregate estimates from many areas that have been assessed by different geologic models, and (4) runs quickly on a microcomputer. The geologic models consist of four basic types: reservoir engineering, volumetric yield, field size, and direct assessment--listed in order of decreasing amount of geologic information required. The reservoir-engineering model, the most data-intensive, was used in the three recent studies by the USGS described herein. These three assessments are followed by a National assessment using a field-size model.

Arctic National Wildlife Refuge Assessment

The Arctic National Wildlife Refuge (ANWR) study completed in 1987 assessed in-place oil and gas resources of geologic plays in the North Slope of Alaska using a reservoir-engineering model. An analytic methodology using probability theory was developed, and a package consisting of six computer programs was created and called Fast Appraisal System for Petroleum, Reservoir Engineering (FASPRE).

Hungary Assessment

The Hungary assessment of the Békés basin generalized the reservoir-engineering model and the aggregation model that were used in the 1987 ANWR study, which was site-specific to the North Slope of Alaska. The modifications required that the system produce output in metric units and run on an IBM-PC-XT compatible computer.

The analytic probabilistic methodology was adapted from the 1987 ANWR study by replacing the site-specific reservoir-engineering equations with general equations and parameters. The Universal Metric version of the play analysis software was called FASPUM.

Tight Gas Sands Assessment

The Tight Gas Sands study assessed low-permeability gas resources of the Upper Cretaceous Mesaverde Group in the Piceance basin of western Colorado. The system used in this study (FASPUE) was adapted from FASPUM by conversion to English (inch-pound) units. An entire play area is treated as a single gas accumulation.

National Assessment

The USGS recently completed its first petroleum resource appraisal of the entire United States using the field-size model of play analysis. An analytic probabilistic methodology was developed based upon the field-size model and a new risk structure. A computer package called Fast Appraisal System for Petroleum, Field Size (FASPF) was written for play analysis, subplay analysis, economic analysis, and aggregation analysis. Subplay analysis includes estimation of resources on State offshore areas. Economic analysis truncates field-size distributions using a minimum economic cut-off value. Aggregations of individual play and subplay estimates of oil and gas are made at the provincial, regional, and national levels.

Crovelli, R.A., and Balay, R.H., 1990, Play analysis methodologies for petroleum resource assessment, in Carter, L.M.H., ed., USGS research on energy resources--1990; Program and abstracts Sixth V.E. McKelvey Forum on Mineral and Energy Resources: U.S. Geological Survey Circular 1060, p. 18-19.

NEW INFORMATION ON THE NUWOK MEMBER OF SAGAVANIRKTOK FORMATION; IMPLICATIONS FOR PETROLEUM GEOLOGY OF THE NORTH SLOPE AND BEAUFORT SEA--EVIDENCE FROM CARTER CREEK, ARCTIC NATIONAL WILDLIFE REFUGE (ANWR), ALASKA

T.D. Fouch, E.M. Brouwers, D.H. McNeil[1], Louie Marincovich, Jr., K. J. Bird, and H. Rieck,
[1]Geological Survey of Canada, Calgary, Albt., Canada

Examination of the Nuwok Member of the Sagavanirktok Formation has identified at least 220 m of Nuwok-like strata, a significant addition to the previously described 80 m assigned to the member. The beds are exposed on the north limb of the Marsh Creek anticline along Carter Creek, which is located about 160 km east of Prudhoe Bay and 0.8 km south of the Beaufort Sea (latitude 70° N.). Beds are deeply weathered and eroded, but where trenched, yield exposures sufficient for stratigraphic reconstruction, and for sedimentologic, paleomagnetic, and biostratigraphic sampling and analysis.

The Nuwok at Carter Creek represents marine shelf and prodeltaic sedimentation and consists primarily of lithified and unconsolidated pebbly fine sands and silts. Upper parts of the Nuwok contain concretions, and medium- and coarse-grained sandy units. Lower strata of the Nuwok contain laminated to thin flat beds of siltstone, argillaceous claystone and fine grained sandstone, associated with ostracode and benthic foraminifers that suggest middle-shelf water depths. Abundant suspended siliceous pebbles (dropstones?) and a high proportion of rafted plant material (fine organic debris, twigs, limbs, and mineralized and woody logs) express considerable terrestrial input. Some units contain pebbles, their long axes randomly aligned, suspended in a poorly sorted, very fine grained structureless matrix; these probably represent submarine debris flows.

The section displays an overall-upward shoaling trend indicated by progressive upward coarsening of the overall sequence and of individual units, increasing thickness of bed sets and scale of crossbeds, concentration of large log fragments upsection, and the appearance of inner-shelf mollusk and ostracode assemblages. Coarsest strata are best developed between 95-105 m and between 155-176 m above the base of the measured exposures. The sequence includes units several meters thick composed of prograding unconsolidated medium- and coarse-grained sand units in multiple cycles of offlap-downlap crossbeds sets (some greater than 10 cm thick) each mantled by clayey drapes (traction and suspension cycles). This association suggests periodic episodes of near shore progradational sediment transport across a shallow (inner-shelf?) sea floor.

The precise age of the Nuwok Member at Carter Creek is uncertain. Benthic fossil groups yield widely disparate ages. A prolific calcareous benthic foraminifer assemblage ranges through the entire Nuwok sequence. The ubiquitous occurrence of *Turrilina alsatica*, known from the western North Atlantic, the North Sea, and northwestern Europe, indicates a late Oligocene age; this age is supported by Sr 87/86 ages of 23.8-27.0 Ma from Nuwok foraminifers and mollusks. The foraminifer

assemblage is diverse and abundant for a high-latitude site: absolute diversity is greater than 70 species, and specimen abundance is as high as 100 per gram. The fauna is dominated by *Cibicidoides, Cribroelphidium, Elphidiella, Melonis, Nuttallides, Trifarina, Turrilina,* as well as miliodids, nodosarids, polymorphinids, and unilocular genera. A normal marine-shelf environment is indicated.

The Nuwok contains two distinct mollusk assemblages with mutually exclusive species: a lower *Chesapecten nuwokensis* zone, ranging from the base of the sequence to a concretionary unit at 95 to 105 m, and an upper *Arctica carteriana* zone, extending from 105 to 300 m from the base. The mollusks are all Atlantic-derived, indicating a pre-Bering Strait age (> 3 Ma). Generic level correlations and the evolutionary lineage of *Chesapecten* imply a maximum age of middle Miocene.

Age arguments based on ostracodes are weaker being based on the presence of extant species, correlation with global climatic trends, and genus-level comparison with lower latitude faunas. Two ostracode assemblages are recognized: the lower assemblage ranges from 60 to 90 m above the base and includes warm-water genera (*Cytheretta, Echinocythereis, Cytherelloidea*); the upper assemblage, ranging from 90 to 245 m above the base, consists of temperate to warmer subfrigid genera (*Rabilimis, Robertsonites, Cytheropteron, Paracyprideis*). Several taxa range throughout the section, but most species show stepwise disappearance believed related to changes in climate and water depth. Warm-water genera do not occur above 110 m, most dropping out just below a concretionary zone at 95 to 105 m.

Paleomagnetic analysis indicates that the Nuwok strata have normal polarity from the base of the measured section to about 40 m, reversed polarity from the 40 to 180 m level with several ~10-m-thick sequences of normal polarity, one of which corresponds to the concretionary zone extending from 95 to 100 m; and normal polarity from 180 to 190 m. Lack of adequate exposures precludes collection of samples from 190 to 300 m. Laboratory analysis indicates some magnetization is carried by secondary minerals. However, the presence of clearly defined polarity zones suggests that the mineralogic changes occurred shortly after deposition.

Strata that are presumably partial age equivalents to the Nuwok (Oligocene and younger--based upon palynomorph interpretations) have been penetrated in drill holes west of Carter Creek near the Canning River, and in the Beaufort Sea north of Camden Bay. Excellent reservoir sandstone units for petroleum were penetrated in these tests that may be represented by the thick inner-shelf progradational sand sequences exposed along Carter Creek.

Fouch, T.D., E.M. Brouwers, D. H. McNeil, Louie Marincovich, K. J. Bird, and Hugh Rieck, 1990, New information on the Nuwok Member of Sagavanirktok Formation; implication for petroleum geology of the North Slope and Beaufort Sea--evidence from Carter Creek, Arctic National Wildlife Refuge (ANWR), Alaska, abs., in U.S. Geological Survey Circular 1060: 1990 McKelvey Forum, Houston, Texas, p. 30-31,

Debra K. Higley and Kenneth I. Takahashi

Interactive computer display of exploration through time for petroleum producing regions in the conterminous United States

Petroleum exploration through time in the conterminous United States is animated and displayed on a Macintosh IIcx[1] computer. Trends in national and basin exploration are shown with drill-hole data for cumulative 5-year increments from 1900 through 1986. The temporal evolution of exploration proceeds from drilling of large structures and mostly shallow fields, to deeper drilling and the discovery and development of subtle traps.

The source of drill-hole data is the Petroleum Information Corporation's Well History Control System database. Drill-hole location, completion date, and production data were analyzed using a series of U.S. Geological Survey computer programs which divided the U.S. into approximately 1 mi^2 grid cells and calculated the type and highest level of petroleum production within each cell. Mapped data show the earliest time interval of exploration and the oil and gas, oil, gas, or non-producing category of each grid cell. A grid cell with an oil and gas symbol, for example, might contain an oil and gas, a gas, and a non-producing drill hole; whereas, a dry-hole cell has only one or more non-producing drill holes within it.

The exploration maps were generated with Macintosh Macspin[1] software on a Macintosh II computer. U.S. political boundaries were created with Select Micro Systems' Mapmaker software. SuperCard software is used to select and animate national and basin map images.

Debra K. Higley and Kenneth I. Takahashi, 1990, Interactive computer display of exploration through time for petroleum producing regions in the conterminous United States: AAPG Bulletin, v. 74, p. 674.

[1] Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Sequential-partial extraction of Pinal Creek aquifer material near Globe, Arizona for SO and PO

Alonza H. Love and Walter H. Ficklin

ABSTRACT

Sequential-partial extractions (SPE) are useful for the determination of mode of occurrence of cations in solid materials. However, the matrix of the resulting solutions prevents easy determination of anions. Ion chromatography (IC) is useful in the determination of anions, but interfering ions from the sequential solutions must be removed before sulfate and phosphate can be determined. Large quantities of chlorides in some of the solutions can be removed with commercial precolumns.

SPE procedures have been used on samples collected from the Pinal Creek aquifer, an area that receives acid mine waters from mines in the Globe, Arizona area. We anticipated that the coating on the aquifer material would occur as a carbonate phase, a manganese oxide phase, and an amorphous iron oxide phase. Consequently, we extracted the carbonates with 1.0 M sodium/acetic acid buffer, the manganese oxides with 0.01N HNO_3 + 0.1N NH_2OH HCl, and the amorphous iron oxides with 0.25N HCl + 0.25N NH_2OH HCl. Results indicate that sulfate is associated with the carbonate phase and phosphate is associated with the amorphous iron oxide phase.

RESULTS

Copper mines and dumps near Globe, Az. have been contributing acid mine waters to an aquifer in that area. The Pinal Creek aquifer is changing as the acid mine waters advance through it, at a rate of 0.2 to 0.3 km/yr (Eychaner,1988). Concentrations of several chemical contaminants deposited from the acid mine waters, including aluminum, copper, iron, and manganese are greatly increased.

The median values for sulfate obtained with the sequential-partial extraction indicate change when compared to the non-contaminated background sample site (010), located above and away from the flow of the acid mine water. The site nearest the mines and tailings dumps has a 22:1 increase of sulfate (sample:background). Sample site 451 has an increase of sulfate of about 10:1. The site farthest from the mines (505), but in the path of the advancing acid mine waters has a 4:1 increase of sulfate.

CONCLUSIONS

Dionex* Ag cleanup sample pretreatment columns removed excess chloride from the manganese oxide and amorphous iron oxide extraction solutions, which resulted in improved IC baseline and sensitivity. Sulfate is localized chiefly in carbonate minerals and is extracted by sodium acetate and acetic acid. Phosphate is localized by iron oxides and is extracted by the hydroxylamine, hydrochloric acid solution.

REFERENCES

Eychaner, J.H., 1988, Movement of inorganic contaminants in acidic water near Globe, Arizona, *in* Mallard, G.E., and Ragone, S.E., eds., U.S. Geological Survey Toxic Substances Hydrology Program--Proceedings of the technical meeting, Phoenix, Arizona, September 26-30, 1988: U.S. Geological Survey Water-Resources Investigations Report 88-4220, p. 567-575.

*Use of brand names in this paper is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Love, Alonza H., Ficklin, Walter H., 1990, Sequential-partial extractions of Pinal Creek aquifer material near Globe, Arizona, for sulfate and phosphate [abs.]: 32nd Rocky Mountain Conference, Denver, Colo., July 29-Aug. 3, 1990.

NUCCIO, VITO F., U.S. Geological Survey, Denver Colorado, 80225

Determining Source Rock Maturity Using Direct Measurements vs. Predictive Modeling--Comparison and Application of Five Methods to Hydrocarbon Generation

Five methods of determining thermal maturation, using the same samples of Upper Cretaceous Steele Member of the Cody Shale from the Powder River basin, Wyoming, indicate different maturation levels and timing of hydrocarbon generation. Three methods were direct-measurement techniques (vitrinite reflectance, and Tmax and production index from Rock-Eval pyrolysis), and two were predictive modeling techniques (Time-Temperature Index and Kinetic modeling).

Mean random vitrinite reflectance ($\%R_m$) measurements indicate that the Steele samples are either immature or marginally mature (0.50-0.70%) with respect to hydrocarbon generation. If vitrinite reflectance records maximum burial and temperature, then hydrocarbon generation began shortly before or at maximum burial, which occurred at 10 Ma. Rock-Eval pyrolysis data indicate that the samples are marginally mature to mature (Tmax values of 431-444°C and production indices of 0.10-0.40). Similarly, if the Rock-Eval data record maximum maturity of the kerogen, which occurred at both maximum burial depth and temperature, then the timing of petroleum generation is constrained to about 10 Ma.

Both of the modeling techniques predict higher levels of maturity than the measured techniques and thus an earlier timing for petroleum generation. Time-Temperature Index modeling (Waples, 1980; Issler, 1984; and LOM of Hood et al., 1975) indicates that petroleum generation from the Steele began at about 55; 52; and 53 Ma respectively in the southwestern part of the Powder River basin. Two Kinetic models were run because Rock-Eval analyses indicated that the Steele is a mixture of types II and III kerogen. Organic petrography indicated a significant amount of types III and IV kerogen as well. Type II kerogen Kinetic modeling of Lawrence Livermore National Laboratory (LLNL) indicates that the Steele began to generate some petroleum as early as 60 Ma and reached a transformation ratio of 10 percent (significant generation for migration and accumulation) around 40 Ma. Type III kerogen Kinetic modeling of LLNL indicates minor amounts of petroleum generation as early as around 60 Ma, but never significant amounts needed for migration and accumulation. A LLNL model using kinetics for vitrinite maturation was also run to see how it matched the measured vitrinite reflectance values; it slightly overpredicts the measured values.

All of the techniques have innate problems; hence, the "true" maturity and timing of petroleum generation is probably somewhere between the results of the measured and predictive techniques. If only one technique were used, it could lead to an erroneous determination of the level of thermal maturation and timing of petroleum generation. The results of the three direct-measurement techniques are comparable, and likewise, the two modeling methods give similar results. The two predictive models are based on the same reconstructed burial history and assumed paleogeothermal gradients; therefore, the results are likely to be similar. These predictive models may also overestimate the effect of time on maturation of the Steele in the Powder River basin.

American Association of Petroleum Geologists Bulletin, v. 74/5, p. 731.

POLLASTRO, RICHARD M., U.S. Geological Survey, Denver Federal Center, P.O. Box 25046, MS 960, Denver, CO 80225

Geothermometry from smectite and silica diagenesis in the diatomaceous Monterey and Sisquoc Formations, Santa Maria basin, California

Indigenous, immature, low-gravity oils are produced from organic-rich diatomaceous rocks of the Monterey and Sisquoc Formations of Miocene-Pliocene age in tectonically active basins along the coast of California. Original depositional components of these rocks are primarily biogenic silica (opal-A) and clay. Diagenetic changes in silica and interstratified illite/smectite (I/S), studied in the Union Newlove 51 well, Orcutt field, Santa Maria basin using X-ray powder diffraction (XRD), constrain the thermal and burial histories of the diatomaceous source rocks.

The dominant clay mineral in these rocks is I/S, which composes about 60 weight percent of the clay minerals in the <2-μm fraction. There is a progressive decrease in expandability of I/S with increased burial depth from about 85 percent at 150 m to about 35 percent at 1,100 m in the Union Newlove 51 well. The change from random I/S (R=0) to ordered I/S (R=1) occurs at about 800 m in the well. Because of considerable uplift and erosion in the Orcutt area, no opal-A zone is present in the Union Newlove 51 well and the opal-CT zone occurs near the surface. The progressive diagenesis of opal-CT to quartz in the well is documented on XRD profiles. The transformation reaction of opal-CT to quartz begins at about 600 m and is complete at about 650 m; quartz is the only silica phase present below 650 m.

The utility of I/S- and silica-phase geothermometry can be tested in the Union Newlove 51 well from the established profiles. After burial-history reconstructions, calculated temperatures from geothermal gradient profiles for changes in I/S (R=0 to R=1) and silica phase (opal-CT to quartz) in the well are 100-105 °C and 85-90 °C, respectively. These calculated temperatures are in good agreement with established diagenesis models, and therefore, I/S- and silica-phase geothermometry is a useful tool for understanding the thermal and burial histories of these economically important rocks thoughout the basin.

Pollastro, R. M., 1990, Geothermometry from smectite and silica diagenesis in the diatomaceous Monterey and Sisquoc Formations, Santa Maria basin, California: American Association of Petroleum Geologists Bulletin, v. 74, p. 742.

PRICE, LEIGH C., U.S. Geological Survey, Denver, CO, and LLOYD M. WENGER, Exxon Production Research Co. Houston, TX

The influence of pressure on petroleum generation and maturation as suggested by hydrous pyrolysis

Because of the transient state of fluid pressures in sedimentary basins over geologic time, the effect of increasing fluid pressure on hydrocarbon (HC) generation and maturation is difficult to determine, and conflicting opinions and statements exist concerning its influence. Assuming that hydrous pyrolysis reactions simulate HC generation and maturation in nature, then such laboratory experiments offer an excellent way to study any possible influence of pressure. Such experiments carried out on Permian Phosphoria shale (Type II-S organic matter) at different constant temperatures demonstrate that increasing pressure significantly retards both HC generation and maturation reactions. This conclusion is derived from quantitative analysis of the generated C_1-C_4 HC gases, C_4-C_7 gasoline-range HC's, C_8+ bitumen and pyrolysis-gas chromatography of asphaltenes; ROCK EVAL and pyrolysis-gas chromatography of the Soxhlet-extracted, reacted rock; and numerous, detailed, qualitative gas-chromatographic and mass spectrometric analyses of the various generated products. If hydrous pyrolysis does mimic natural HC generation and maturation, these data have relevance to HC generation, accumulation, and destruction in nature, specifically regarding the influence of abnormal fluid pressures and the factors which create and disrupt such pressure systems.

Price, L.C. and Wenger, L.M., 1990, The influence of pressure on petroleum generation and maturation as suggested by hydrous pyrolysis. American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 743.

CRYSDALE, BONNIE L., U.S. Geological Survey, Denver, CO

Stratigraphic Framework of the Powder River Basin, Wyoming and Montana, Utilizing Computer-Generated Isopach and Structure Contour Maps and Cross Sections

A series of U.S. Geological Survey (USGS) Miscellaneous Field Investigations maps show regional structure, thickness, and areal extent of selected Precambrian through Tertiary stratigraphic units in the Powder River basin, Wyoming and Montana. These maps were prepared for the Evolution of Sedimentary Basins (ESB) Program from a computerized data base that contains depths to the tops of stratigraphic units (including major bentonite and coal beds) from more than 8500 boreholes in the Powder River basin. These tops were determined from electric logs by USGS scientists. Mapping and statistical and graphic applications have been accomplished using commercially available software on a VAX 11/780 computer.

The maps were generated to aid in the description and interpretation of basin evolution and tectonic history, and the characterization of hydrocarbon reservoirs within producing fields. All of the units mapped in the Powder River basin exhibit structural characteristics typical of Laramide-style basins: deep, asymmetric structural depressions adjacent to major basin-bounding thrust faults and thick sequences of Upper Cretaceous and Tertiary strata. The maximum thickness of sedimentary rocks in the basin is more than 16,500 ft, including 14,000 ft within the Cretaceous and Tertiary. Uplift of the Belle Fourche arch in the northeast part of the basin during the Laramide orogeny (which affected the pattern of hydrocarbon migrations and accumulations) is indicated on north-south cross sections that show the deformation and erosion of Cretaceous and older beds across the arch.

American Association of Petroleum Geologists Bulletin, 1990, v. 74/8, p. 1320.

FRANCZYK, K.J., FOUCH, T.D., JOHNSON,R.C , AND MOLENAAR, C.M., U.S. Geological Survey, P.O. Box 25046, MS 939, Denver, CO

Late Cretaceous and Tertiary Paleogeographic Reconstructions--Uinta and Piceance Basins, Northeastern Utah and Northwestern Colorado

Paleogeographic reconstructions for Late Cretaceous through early Oligocene time in the Uinta and Piceance basins area illustrate several major geologic events: incursion of a Cretaceous sea, tectonism in the Sevier thrust belt, changes in eustacy, breakup of a Late Cretaceous foreland, formation of intermontane basins, and establishment and disappearance of large lacustrine complexes. Throughout most of the Late Cretaceous, the reconstruction area was part of a foreland in which depositional patterns were controlled both by tectonism in the Sevier thrust belt to the west and by eustatic changes. In late Campanian through early Maastrichtian time, the sea withdrew from much of this area, rates and centers of subsidence changed, and basement-involved uplifts became active. Small intermontane basins began to form in the western part of this area at this time.

By late Maastrichtian time, the sea completely withdrew from this area, the basement-involved uplifts continued to form, and sediment accumulated only in these small, western intermontane basins. The more regionally extensive intermontane basins that characterized much of this area during the Paleogene formed by middle Paleocene time. Initially, deposition occurred primarily in alluvial fans and plains, wetlands, and shallow lakes. These lakes expanded until the early Eocene when they occupied large parts of both the Uinta and Piceance basins. The lakes expanded further, crossed the Douglas Creek arch, and joined to form a single major lake, Lake Uinta, in the middle Eocene. During the latter half of the middle Eocene, clastic sediments from the north began to fill the lake in the Piceance basin. From then through the late Eocene, Lake Uinta retreated westward, and it's remnant finally disappeared from the western end of the Uinta basin in latest Eocene or earliest Oligocene time.

Franczyk, K.J., Fouch, T.D., Johnson, R.C., and Molenaar, C.M., 1990, Late Cretaceous and Tertiary paleogeographic recontructions--Uinta and Piceance basins and surrounding areas, northeastern Utah and northwestern Colorado [abs]: American Association of Petroleum Geologists, v. 74, no. 8. p. 1324

MOLENAAR, C.M., U.S. Geological Survey, Denver, CO; MACK, G.H., New Mexico State University, Las Cruces, NM; BLACK, B.A., Black Oil, Inc., Farmington, NM; and COBBAN, W.A., U.S. Geological Survey, Denver, CO

Stratigraphy and Provenance of Upper Cretaceous Rocks in South-Central New Mexico

Three reference sections of Upper Cretaceous strata in south-central New Mexico were selected for study as part of the Western Interior Cretaceous Project of the Global Sedimentary Geology Program. From northeast to southwest, these sections are near Carthage, Truth or Consequences (T or C), and Santa Rita. The basal unit of these sections, the dominantly nonmarine 25-85-m-thick middle to upper? Cenomanian Dakota Sandstone or equivalents, unconformably overlies Triassic and older rocks. Strata that overlie the Dakota at Carthage and T or C consist of, in ascending order, 130 m of the upper Cenomanian to middle Turonian part of the marine Mancos Shale, 57-84 m of middle to upper Turonian Tres Hermanos Formation, 80 m of upper Turonian D-Cross Tongue of Mancos Shale, 18-58 m of upper Turonian to lower Coniacian? regressive Gallup Sandstone, and 570 m of lower Coniacian to lower Campanian? nonmarine Crevasse Canyon Formation. The strata below the Crevasse Canyon record two transgressive-regressive cycles. At T or C the Crevasse Canyon contains numerous paleosols indicative of diastems; it is unconformably overlain here by the upper Maastrichtian to Paleocene nonmarine McRae Formation. Biostratigraphic data indicate a hiatus or condensed section at the base of the D-Cross Tongue at Carthage. Cretaceous rocks at Santa Rita include 85 m of Beartooth quartzite, 100 m of Mancos Shale, 41 m of regressive Atarque Sandstone, and 37 m of nonmarine Moreno Hill Formation. The Beartooth is probably coeval to or slightly older than the Dakota, and the Atarque and Moreno Hill correlate with the lower part of the Tres Hermanos. The Moreno Hill is unconformably overlain by Tertiary volcanic rocks.

Quartzarenites of the Beartooth and Dakota were derived from a sedimentary provenance. In contrast, feldspathic litharenites of the Mancos through Crevasse Canyon were derived from volcanic and sedimentary provenances, with minor contributions from low-grade metamorphic and granitic/gneissic rocks. Fine grain size and east and northeast paleocurrents suggest that the source terrane was far to the west-southwest, although the Beartooth and Dakota may have been, in part, locally derived.

Molenaar, C.M., Mack, G.H., Black, B.A., and Cobban, W.A., 1990, Stratigraphy and Provenance of Upper Cretaceous Rocks in South-Central New Mexico: American Association of Petroleum Geologists Bulletin, v. 74, no. 8, p. 1338.

MOLENAAR, C.M. and COBBAN, W.A., U.S. Geological Survey, Denver, CO, and WOLFE, D.G., University of Nebraska, Lincoln, NE

Stratigraphy of Upper Cretaceous Rocks in the Zuni Basin, West-Central New Mexico

As much as 600 m of Upper Cretaceous rocks is preserved in the Zuni basin, a small Laramide basin south of Gallup, New Mexico. Two reference stratigraphic sections were selected for study as part of the Western Interior Cretaceous Project of the Global Sedimentary Geology Program. In the section at the north end of the basin, these rocks unconformably overlie Jurassic rocks and consist of, in ascending order, 30-40 m of dominantly nonmarine middle to upper? Cenomanian Dakota Sandstone, 200 m of the upper Cenomanian to upper Turonian part of the marine Mancos Shale, 100 m (including tongues of Mancos) of upper Turonian, regressive Gallup Sandstone, and 250 m (top eroded) of upper Turonian to Santonian, nonmarine Crevasse Canyon Formation. In the section at the south end of the basin, Triassic rocks are unconformably overlain by about 30 m of Dakota Sandstone, 120 m of the upper Cenomanian to lower Turonian part of the Mancos Shale, 25 m of middle Turonian regressive Atarque Sandstone, and 200 m of middle Turonian to Coniacian or Santonian, nonmarine Moreno Hill Formation. The Moreno Hill, which is unconformably overlain by middle Tertiary coarse clastic rocks, is equivalent to much of the marine section at the north end of the Zuni basin.

A cross section between the two reference sections, using intervening measured sections, shows facies changes and intertonguing of marine and nonmarine strata, which record two transgressive-regressive cycles. These cycles include the landward and seaward limits of a complete transgressive-regressive cycle as represented by the 85-m-thick, middle to upper Turonian Tres Hermanos Formation and lower part of the overlying 18-m-thick upper Turonian Pescado Tongue of the Mancos Shale.

Molenaar, C.M., Cobban, W.A. and Wolfe, D.G., 1990, Stratigraphy of Upper Cretaceous Rocks in the Zuni Basin, West-Central New Mexico: American Association of Petroleum Geologists Bulletin, v. 74, no. 8, p. 1337.

PALYNOMORPHS FROM CENOMANIAN, TURONIAN, AND CONIACIAN MARINE STRATA IN THE POWDER RIVER BASIN, WYOMING

Terrence A. Okumura and Douglas J. Nichols
U. S. Geological Survey, M. S. 919, Box 25046, Denver, CO 80225

Palynomorphs were extracted from the cores of two stratigraphic test wells drilled by the U.S. Geological Survey on the east and west flanks of the Powder River basin in Wyoming. The eastern well, at Beaver Creek, near the town of Osage, penetrated rocks deposited in a deep shelf environment during the early Late Cretaceous. These strata are assigned to, in ascending order, the Belle Fourche Shale, the Greenhorn Formation, and the Pool Creek, Turner Sandy, and Sage Breaks Members of the Carlile Shale. The western well, at Bailey Flats, near the town of Kaycee, includes strata deposited in a shallow shelf environment during the same time interval. These rocks are assigned to the Frontier Formation and the overlying Cody Shale. Ages of the rock units are based on fossil mollusks from nearby outcrops and from the cores.

Approximately 275 m of core was recovered from the eastern well and over a 305 m from the western well. Samples were taken only from dark silty shales, which resulted in a variable sample interval of 3-9 m. Preliminary examination of the material has revealed diverse and abundant palynomorph assemblages throughout the study interval that are strongly dominated by dinoflagellate cysts; pollen, spores, and acritarchs are less common. Topics to be investigated in this study include morphology and taxonomy of the dinocysts and development of a palynological biostratigraphy by comparison with the standard zonation based on mollusks. Changes in dinocyst assemblages can then be compared with parasequence events as well as the Cenomanian-Turonian and Turonian-Coniacian stage boundaries.

American Association of Stratigraphic Palynologists, 23rd Annual Meeting (Banff, Alberta, Canada), Program and Abstracts.