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Compiled by

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

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

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MacDonald, Chloe, McGregor, Joseph K., Edwards, Carol A., & Hopkins, Isabella

This poster session presents the effects of standard geoscience imagery hazards: temperature and relative humidity, light, base medium, pollution, security, and organisms. It describes preservation techniques that are easy to apply and recommends procedures to adopt that mitigate imagery hazards to photographic and paper mediums. Hazards survey, housekeeping, environmental control, damage prevention, security, disaster protection, and disaster recovery are illustrated.

1992, Geological Society of America, Abstracts with Programs, V. 24, No. 7

THE NEW GEOLOGIC MAP OF NORTH AMERICA

John C. Reed, Jr, U.S. Geological Survey, MS 913 Box 25046, Federal Center, Denver, CO 80225

The new geologic map of North America is being compiled as a contribution to the Decade of North American Geology (DNAG) project of the Geological Society of America. The map will be published at a scale of 1:5M in four sheets, each approximately 1 m x 1 m, with a fifth sheet for the consolidated explanation. A hand-colored version of the nearly completed compilation of the southeastern quarter will be on display. John O. Wheeler (Geological Survey of Canada, Vancouver) has principal responsibility for compilation of the on-land geology of the northern two quarters; John C. Reed, Jr. (U.S. Geological Survey, Denver), has principal responsibility for the on-land geology of the southern two. Brian E. Tucholke (Woods Hole Oceanographic Institution) is compiling the offshore geology for the entire map. Coordination is provided by A.R. Palmer (Geological Society of America).

Compilation of the on-land geology of the conterminous U.S. in the southeastern quarter is based on the best available state maps, supplemented where necessary with data from 1:250,000-scale quadrangle maps, DNAG continent-ocean transect maps, and miscellaneous regional compilations. Compilation in Canada is based on material furnished by the Geological Survey of Canada. Compilation in Mexico is based on 1:1M sheets sheets published by PEMEX. The geology of the Antilles, Central America, and northern South America is based on U.S. Geological Survey Miscellaneous Geologic Investigations Map I-1100 (Case and Holcombe,1980) except in Cuba, Costa Rica, and Columbia where more recent national maps are available.

The compilation of the southeastern quarter distinguishes 91 map units of sedimentary rocks, 68 units of volcanic rocks, 57 units of intrusive rocks, and 16 units of high-grade metamorphic and undivided crystalline rocks, a total of 213 units. Units offshore will carry the same labels as equivalent onshore units, and insofar as possible will be shown in lighter tones of the same colors. Overprint patterns will distinguish selected continental deposits and areas of low- to medium-grade Phanerozoic metamorphism. Low- to medium-grade Precambrian rocks are shown with the volcanic or sedimentary units, but high-grade metamorphic rocks are shown separately. Special features in onshore regions (not shown in the exhibit) include limits of Pleistocene glaciation, mafic dike swarms, impact structures, salt domes, volcanos, calderas, and ultramafic bodies. Special offshore features, shown on a clear film overlay in the exhibit, include submarine contours, axes of submarine canyons, spreading centers, sea floor isochrons, occurences of manganiferous materials, and locations of selected dredge hauls.

The southeastern quarter of the map awaits final scribing, selection of colors, and agreement on the layout of the consolidated explanation. Cartographic preparation should be completed in early 1993. Whether this quarter will be published separately or will wait completion of the other quarters will be decided when cartography is complete.

Displayed at GSA Annual Meeting in Cincinnati

USGS CORE RESEARCH CENTER--A MILLION FEET OF GEOLOGIC HISTORY

Richards, Diana L. and Michalski, Thomas C.

The Core Research Center (CRC) of the USGS, situated in Denver, Colorado, currently houses in excess of 1,000,000 (1-million) feet of core from 25 States, the majority of which are from the Rocky Mountain and Great Plains regions; cores from Wyoming, Montana, Colorado, North Dakota, Utah, New Mexico, and Kansas comprise 95 percent of the collection. Increasing geologic and geographic diversity of samples at the (CRC) has resulted in its becoming one of the largest, best organized, and most heavily utilized public core repositories in the United States.

Preservation of valuable core material for use by government, industry, and academia has been a concern of the USGS for many years, and resulted in the establishment of a permanent core storage and research facility in 1974. The goals of the repository are to gather cores from a wide variety of sources, process and store them efficiently, and make them available on a daily basis for examination and sampling by all interested scientists. Although gathered from a variety of sources, most cores in the collection were generated as a result of oil and gas exploration and have been donated to the repository by a large number of companies in the petroleum industry. A majority of the cores have been slabbed and photographed, and all are available for immediate viewing. In excess of 15,000 thin sections and a large number of analyses made from core in the CRC collection are available to users. The CRC also houses a unique collection of 240,000 feet of oil shale core.

The recently renovated facility offers a pleasant environment for core examination and sampling: a large, well-lit, climate-controlled core examination room provides an ideal setting where 1,500 feet of slabbed core can be examined at one time, a conference room and a small reference library are also available. To facilitate the extensive daily use of the collection, the CRC has established a core information database and provides custom computer searches of its holdings by operator, location, formation, or geologic age. A series of State core catalogs are also available for purchase. The CRC encourages use of its facility by all interested geologists and welcomes inquiries about the collection, donation of core samples, computer printouts, and the location of other public repositories. More information can be obtained by contacting the CRC at:

U.S. Geological Survey
Core Research Center
Box 25046, MS 975
Denver, Colorado 80225
(303)236-1930

D.L Richards and T.C. Michalski, 1992, One Million Feet of Geologic History in L.M.H. Carter, eds., USGS research on energy resources 1992, program abstract: U.S. Geological Survey circular 1074, 2p.

LEACHING OF MESOZOIC MARINE SHALES OF EASTERN COLORADO--ENVIRONMENTAL HAZARD AND (OR) SOURCE FOR URANIUM IN YOUNG DEPOSITS?

Sigrid Asher-Bolinder and Robert A. Zielinski (U.S. Geological Survey, Denver CO)

East of Canon City, Colorado, Cretaceous marine shales, and soils derived therefrom, are the prevalent units in the drainage basin of the middle Arkansas River (AR) valley. Irrigation along the AR below Canon City artificially enhances recharge to and drainage from those shaly units, with resultant effects on water chemistry. Total dissolved solids and uranium (U) content are positively correlated, and they increase significantly east of La Junta, Colorado, where irrigation-return waters are a major component of river flow throughout much of the year. AR waters in eastern Colorado commonly exceed proposed EPA drinking-water standards for U (20 ppb); tributary streams may contain more than 100 ppb U.

Chemical evolution of surface and ground waters in contact with weathered and fractured Pierre Shale and shale-derived soils is being monitored north of Canon City. Soluble salts, U, and other elements associated with marine shales (As, Se, Mo, B, and V) will be analyzed in waters and leachates of soil profiles from irrigated, unirrigated, and waterlogged soils. Waterlogged soils are sites of evapotranspiration, producing brines and salts that contain elevated concentrations of readily mobilized U.

The abundance of irrigated Mesozoic marine shales in the arid and semiarid Western Interior suggests the possibility of environmental contamination from U as well as from other shale-derived elements such as Se. Accumulation of the latter element has produced well-documented environmental contamination at Kesterson National Wildlife Refuge, California.

During the alternately wet and dry Quaternary Period, marine shales and shale-derived soils of the southern High Plains may have provided U and V to Ogallala aquifers. These aquifers may have been the source of U in carnotite of the Ogallala calcrete horizons of the Texas Panhandle.

Presented at the SEPM 1992 Theme meeting, Mesozoic of the Western Interior, Ft. Collins, Colorado, August 17-19, 1992, Abstracts, p. 10-11.

QUATERNARY CARBONATE PALEODUNE DEPOSITS IN CENTRAL AND WESTERN ABU DHABI EMIRATE, UNITED ARAB EMIRATES

BROUWERS, E.M., U.S. Geological Survey, MS 919, Denver, CO 80225, U.S.A.;
HADLEY, D.G., NDC/USGS, P.O. Box 15287, Al Ain, U.A.E.; and
BOWN, T.M., U.S. Geological Survey, MS 919, Denver, CO 80225, U.S.A.

Remnants of Quaternary paleodunes are exposed near the coast of the Arabian Gulf and in large inland sabkhahs and interdunal areas in central and western Abu Dhabi Emirate over a distance normal to the coast of 45 km. Paleodunes were observed south to Madinat Zayed (lat 23°35' N.), which marks the beginning of a dune field that grades into the mega-dune sand sea of the ar Rub al Khalui in Saudi Arabia.

Coastal paleodunes are composed of weakly cemented miliolid foraminifers and oolites, whereas inland and southward the paleodunes progressively show an increasing proportion of eolian quartz sand. Paleodunes exhibit impressive large-scale trough foresets in remnant exposures 0.5 to 10 m thick. Paleowind directions range from 65° to 184°, and indicate dominantly southeast transport.

Scattered paleosabkhah remnants provide paleodune scale. Northern paleosabkhahs form buttes 30-50 m high. If coeval with the paleodunes, large-scale paleodune fields are implied (100+ m high), comparable to star dunes and sand mountains at the northwestern edge of the ar Rub al Khali.

Based on stratigraphic position and the miliolid foram assemblage, the carbonate paleodune sands are most likely Pleistocene. The carbonate source was a shallow, nearly dry Arabian Gulf at a time when large areas were exposed during a low sea-level stand. Paleowind direction determined from crossbedding indicates that Pleistocene prevailing winds were from the northwest, which is today the dominant (winter shamal) wind. The geographic extent and implied magnitude of the paleodunes suggest large-scale eolian transport of carbonate sand during the Pleistocene desiccation, and the admixed quartz sand identifies a youthful stage of contemporaneous evolution of the ar Rub al Khali. Wave-eroded paleodunes probably floor much of the present-day Gulf.

Geological Society of America Abstracts with Programs, v. 24, no. 7, p. A314

Holocene Deformation in the Ganges-Brahmaputra Delta: a Factor in Flood Distribution in Bangladesh

D.A. Coates, J.W. Whitney, D.L. Sawatzky
(U.S. Geological Survey) and A.K.M.K. Alam
(Geological Survey of Bangladesh)

The alluvial plains of the Brahmaputra-Ganges delta are being actively deformed under complex stress caused by collision of the northeast corner of the Indian teconic plate with Asia. Warping and faulting elevate some areas and depress others. Elevation differences, although small, are critical in controlling the pattern of inundation during seasonal flooding.

The Sylhet trough south of the uplifted Shillong massif is rapidly subsiding, as indicated by lakes with bottoms below sea level and unusually small alluvial fans along the southern margin of the massif.

West of the Sylhet trough the Mymensingh terrace stands above flood level, yet contains unmodified floodplain features. Between the mid-1700s and 1830 the Brahmaputra diverted from an incised course flanked by this terrace to its present course (the Jamuna) west of the uplifted Madhupur tract. The Old Brahmaputra shares flood flow with the Jamuna so that the surface of the two rivers is at the same elevation; yet while the Jamuna floodplain is beneath 1-1/2-3 m of floodwater, the Mymensingh terrace stands 2 m above the flood, suggesting a differential vertical movement of 3-5 m. Some of the deepest flooding on the Jamuna floodplain, and the greatest concentration of permanent ponds, are near the base of the faulted west scarp of the Madhupur tract. The Madhupur tract is an uplifted area east of the Jamuna floodplain that is mantled with a deeply weathered soil and dissected by incised drainage. In parts of the tract, tilting has diverted drainage from a generally southern course to the east, northeast, and northwest.

The distribution, flow direction, depth, and persistence of floodwater on the alluvial plain, as shown on satellite imagery, are indicators of Holocene subsidence and uplift. The problems, including human suffering, that are caused by flooding in Bangladesh are increasing, and in order to understand flooding in this region, we must also understand Holocene tectonics.

Coates, D.A., Whitney, J.W., Sawatzky, D.L., and Alam, A.K.M.K., 1991, Holocene deformation in the Ganges-Brahmaputra delta: a factor in flood distribution in Bangladesh, EOS, Transactions, American Geophysical Union, AGU Fall meeting, v. 72, no. 44, p. 501.

Coates, D.A., Sawatzky, D.L., and Alam, A.K.M.K., 1992, Geomorphic evidence of Holocene deformation along the eastern margin of the Indian plate: one key to understanding flooding in Bangladesh. First South Asia Geological Congress Abstracts, p. 10.

Alam, A.K.M.K., and Coates, D.A., (in press), Geology of the Tangail and Mymensingh areas, northern Dhaka Division; submitted to Geological Survey of Bangladesh for publication as a Geological Survey of Bangladesh Report, 72 p., 16 figs.

RADON MEASUREMENT UNCERTAINTY: WHY A BLACK AND WHITE NUMBER SHOULDN'T BE PULLED FROM A SEA OF GRAY

G. M. Reimer, S.L. Szarzi, and J.M. Been
U.S. Geological Survey, MS 939, Denver Federal Center, Denver, CO 80225-0046

The measurement of radon (Rn) is not so straightforward as commonly perceived. Although standard, calibrated systems for radioactive counting and presumptive Poisson distributions will describe a concentration and standard deviation, often overlooked are the natural temporal and spatial concentration variations and the uncertainties introduced by different sample collection techniques. Gas concentrations in the natural environment are strongly influenced by meteorological effects, and show both short-term (response time in minutes) and longer-term variations (seasonal changes). Even for the higher Rn concentrations typically found in soil gas or ground water, the sample collection techniques, though individually standardized, are subject to variability. Research has shown that the diameter of the collection hole made in the soil influences detection sensitivity, and calculated Rn concentrations appear to depend on the rate at which the gas is extracted or at which it is collected onto a concentrating device, such as charcoal. Because background concentrations are not constant, lower concentrations are especially subject to uncertainty. Because Rn progeny are often measured rather than Rn directly, various assumptions and extrapolations are required in order to calculate a Rn concentration. As a general principle, it is better to select a value range for guidance when suggesting recommendations for action rather than to select a fixed number that is derived without a comprehensive understanding of the measurement uncertainties. Earth scientists are commonly aware of the natural variabilities, and thus have a vital role to educate and inform policy makers so that guidelines or regulations adequately reflect the uncertainties.

Originally presented at the American Institute of Professional Geologists Meeting, "Geologic Reason, A Basis For Decisions Affecting Society," Spetember 27-30, 1992.

GEOCHEMICAL VARIATION OF ARCTIC MARGIN LOW-SULFUR CRETACEOUS AND TERTIARY COALS, NORTH SLOPE, ALASKA

by
Ronald H. Affolter, Gary D. Stricker, Stephen B. Roberts
and Michael E. Brownfield

U.S. Geological Survey, Denver, Colorado

More than 6 trillion hypothetical short tons of low-sulfur coal occur in Alaska north of the Arctic Circle. Statistical comparison (t-test, 95% confidence level) of the element contents (whole coal basis) from samples of 125 Cretaceous and 154 Tertiary North Slope coals indicate that the Cretaceous coals are characterized by higher contents of Na, B, Ce, Ge, Hg, La, Li, Th, and U while the Tertiary coals have higher contents of Ca, Mg, Fe, Br, Cu, F, Mn, Mo, Ni, Pb, Se, Sn, Y, and Zn. Sulfur contents for Cretaceous coals range from 0.1% to 2.0% and for Tertiary coals from 0.06% to 1.7%. The mean for both is 0.31% which is 50% lower than U.S. coals of similar age and rank. Ba contents for North Slope coals range from 18 to 24,000 ppm (mean 1200 ppm); P contents range from 20 to 8,900 ppm (mean 700 ppm); and Sr contents range from 16 to 4,380 ppm (mean 190 ppm). These maximum values are some of the highest reported in any U.S. coal.

The low temperature ash (LTA) mineralogy was determined by X-ray diffraction and is primarily quartz, kaolinite, and mica- type clays. Mineralogy of coals with high Ba, P, and Sr contents confirms the presence of authigenic phosphate minerals of the crandallite group. These minerals are due in part to the alteration of apatite-bearing air-fall tuffs. Major differences between the element contents of Cretaceous and Tertiary coals are the result of changes in the source areas for the coal bearing sediments. During Cretaceous time, the source area consisted of pre-Jurassic clastic rocks to the west, whereas during the Tertiary, the source area was to the south in the central Brooks Range plutonic belt.

International Conference on Arctic Margins (Abstracts and Program, Anchorage, Alaska, September 2-4, 1992, p. 1)

An Estimate of the Minimum Number of Measurements Needed to Constrain the Mean Random Vitrinite Reflectance of Disseminated Organic Matter

Charles E. Barker[1,2] and Mark J. Pawlewicz[1]

U.S. Geological Survey, Denver[1]
The University of Adelaide, South Australia[2]

The number of reflectance measurements required for adequate characterization of the mean random vitrinite reflectance (R_{vr}) is a major concern in the petrographic analysis of dispersed organic matter (DOM). Existing recommendations on the number of reflectance measurements required are based on statistical methods that suggest hundreds of reflectance measurements are required for accurate and precise measurements of R_{vr}. Such large sample size recommendations are usually demanded by industry predicting, to a high degree of accuracy and precision, the response of coal to coking. In studies of thermal maturation using DOM, this can be an unrealistic, and possibly unnecessary, requirement given the small amount of vitrinite often found in such samples and a reduced need for assuring extreme accuracy in most thermal maturity studies. A survey of published thermal maturation studies indicates that DOM studies commonly have a target of 50 to 100 reflectance measurements. These published studies surveyed cite no particular reason for selecting this target range and its acceptance is apparently originally one of convenience, and later, conformity to historical habit. The problem is that this target range is often not met in lean DOM samples.

This study addresses the question of what is the minimum number of reflectance measurements necessary to constrain R_{vr} to accuracy levels acceptable in DOM and thermal maturation studies. Our approach to answer this question is to compute the reflectance distribution parameters, mean, variance, kurtosis, and skewness, as the number of reflectance measurements increases. Reflectance distribution parameters were computed in increments of 10 measurements starting at 10 and finishing at a maximum of 250, given sufficient vitrinite grains are present.

This study uses samples of drill cuttings that contain dominantly humic DOM from the Cerro Prieto geothermal field, Mexico (Barker, 1979; Barker and Elders, 1981). Cerro Prieto has a high geothermal gradient that has produced a high thermal maturation gradient allowing measurements over a wide rank range. Polished mounts of DOM concentrate were analyzed using generally accepted microscope conditions and methods (Robert, 1988). Generally, low to moderate volumes of DOM were recovered from the samples. R_{vr} was determined using an operator edit style of measurement where the operator uses subjective characteristics of the vitrinite grains to select them for analysis. The operator edit style is widely used in DOM studies because of the need to select between vitrinite of diverse origins and thermal histories in a sample. The operator edit style has the disadvantage of only reporting a portion of the information available in the DOM sample and makes the reported numerical results dependent on the experience and competence of the operator. A perhaps more objective method for measuring R_{vr} involves a complete scan and measurement of all vitrinite or all macerals in the slide and subsequent subjective selection by the operator of the distribution mode representing the appropriate vitrinite (Robert, 1988). Operator selection is involved in either style, so the distinction between them is blurred. The operator edit style was used here because many of Cerro Prieto samples are sparse in DOM content and often produce a flat (relatively uniform class frequency over a wide range) reflectance histogram without significant modes when done by the complete scan style.

Measurement of R_{vr} on immature to overmature samples from Cerro Prieto

samples shows that 20 to 30 measurements are needed to constrain the mean to within a few percent of its final value reached at n = 50 or higher. The influence of operator becoming increasingly selective to a particular vitrinite population is shown by an increase in kurtosis (distribution peakedness) with an increasing number of reflectance measurements. The skewness of the reflectance distribution also becomes increasingly negative, with an increasing number of measurements, as the operator attempts to select for the least mature vitrinite.

These results suggest that smaller sample sizes than typically measured in the operator edit style of analysis are adequate to determine R_{vr} to within a few percent of its final value at 50 grains. Consequently, in sparse samples, perhaps a better strategy would be for the operator to concentrate on selecting a few high-quality vitrinite grains for analysis rather than seeking a quantity of inconsistent vitrinite grains in order to make the results more statistically important. Further, R_{vr} values calculated on fewer than 20 readings of vitrinite are potentially unreliable.

REFERENCES

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Barker, C.E., and Elders, W.E., 1981, Vitrinite reflectance geothermometry and apparent heating duration in the Cerro Prieto geothermal field: Geothermics, v. 10, no. 3/4, p. 207-223.

Robert, P., 1988, Organic Metamorphism and Geothermal History: Reidel, Dordrecht, Netherlands. 311 p.

Published in Stout, S.A., editor, 1992, Abstracts and Programs, ninth annual meeting of The Society for Organic Petrology, p. 10-11.

Petrography and Reflectance of Vitrinite-Like Particles in Precambrian Rocks, U.S.A and Russia.

Mark Pawlewicz and James Palacas, 1991, American Association of Petroleum Geologists 1991 Annual Meeting, Calgary, Alberta, Canada, Abstracts with Program, p. 102.

Vitrinite-like particles were isolated from three widely scattered Precambrian terraces: the Proterozoic Chuar Group, Grand Canyon, Arizona, U.S.A.; the middle Proterozoic, Keweenawan Group (Nonesuch Shale equivalent), Midcontinent Rift System (MRS), western Iowa, U.S. A.; and the Vendian-Riphean rocks in the Lena-Tunguska Province, eastern Siberia, (former) U.S.S.R.. Samples that were processed to concentrate the organic matter (OM) were extracted with chloroform to remove any soluble bituminous substances. Some of the remaining material, examined in reflected light, is indistinguishable from post-Silurian vitrinite-group macerals. The particles of organic matter are angular pieces and have a weakly expressed cellular structure. In addition, in the analysis of whole rock samples, the distribution of the OM was as isolated particles, disassociated from any bedding features or mineral fabric, suggesting a nonbitumen macromolecular entity.

With few exceptions, reflectance (Rm) values of the vitrinite-like particles agree with Rock-Eval pyrolysis Tmax values, providing some validity to the reflectance measurements. These two measurements showed a range of maturity values (with respect to liquid hydrocarbon generation) in the studied samples. Those from eastern Siberia are immature or marginally mature (average Rm= 0.42%, Tmax= 432 °C), those from the Chuar Group (Kwagunt Formation) are mature (average Rm= 0.73%, Tmax~ 437 °C), and the MRS (Keweenawan) rocks are overmature (average Rm= 2.2%, Tmax= 503°C).

These results demonstrate that the reflectance technique can be extended to Precambrian rocks for determination of thermal maturation levels.

Mark Pawlewicz and James Palacas, 1991, American Association of Petroleum Geologists 1991 Annual Meeting, Calgary, Alberta, Canada, Abstracts with Program, p. 102.

EFFECTS OF SUBSIDENCE RATES ON CRETACEOUS COAL ACCUMULATION, WESTERN INTERIOR U.S.

Roberts, Laura N. R. and Kirschbaum, Mark A. (U.S. Geological Survey, MS 972, Denver, CO)

To better understand the relative importance of tectonism to climate and eustasy in determining the location and size of coal deposits, a paleogeographic atlas of Cretaceous coals of North America is being compiled. Data on stratigraphic thickness, depositional environments, and location and thickness of coal were collected for biostratigraphically constrained intervals. We constructed isopach maps and calculated sediment accumulation rates to determine relative rates of subsidence.

In the Cenomanian, the thickest coal (beds >1 m thick) formed in a narrow asymmetric foreland basin in the Frontier and Dakota Formations of Wyoming and Utah where subsidence rates were 70-215 m/m.y. In the Late Campanian, a broad foreland basin dominated the western U.S. Coal beds are thickest in the Williams Fork, Neslen, and Fruitland Formations of central Utah and western Colorado, where subsidence rates were 90-150 m/m.y. During the Maastrichtian, an intermontane basin complex was present in southern Wyoming. Coal beds are thickest in the Almond, Laramie, and Lance Formations where subsidence rates were 50-500 m/m.y.

Upper Cretaceous coal beds are thickest where subsidence rates were >50 m/m.y., primarily in coastal-plain environments; however, not all areas with these subsidence rates have thick coal deposits. Factors such as high sediment influx (Two Medicine Formation, Montana, during the Upper Campanian), seasonal rainfall, or fluctuating water tables can inhibit peat formation. Only thin coal beds formed on coastal plains where subsidence rates were <50 m/m.y. (Dakota Formation, Oklahoma, during the Cenomanian). Thin coal beds indicate that although the environment was suitable for peat formation, slow subsidence rates allowed fluvial and marine processes to terminate the mire prior to thick peat accumulation.

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*Modified from:
Roberts, L. N. R., and Kirschbaum, M. A., 1992, Effects of subsidence rates on Cretaceous coal accumulation, Western Interior U.S., Theme Meeting Abstracts, Mesozoic of the Western Interior, Ft. Collins, CO, Society of Economic Paleontologists and Mineralogists, p. 57.

CRETACEOUS COALS IN ALASKA'S ARCTIC MARGIN (NORTH SLOPE) --GEOLOGY AND RESOURCES

by
Gary D. Stricker
U.S. Geological Survey, Denver, Colorado

Two major Cretaceous deltas systems were responsible for most of the coal accumulation on the western and central North Slope of Alaska. The Corwin delta, in the western part of the coal field, prograded northeastward and eastward during the Albian to Cenomanian time; its sediments were derived from the western end of the ancestral Brook Range and the offshore Herald arch. The Umiat delta, a slightly younger system (mid- Albian to Cenomanian), prograded north and northeast in the central part of the North Slope; its sediments were derived from the central ancestral Brooks Range. The Corwin delta, approximately 75,000 km^2 in size, was a high-constructional "birdfoot" system with sediments as thick as 3,450 m. Numerous thick peat-accumulating mires developed on platforms provided by abandoned distributary lobes. The resulting coals are as thick as 10 m. The Umiat delta is lobate in shape; it began as a high-constructional system but later was wave-dominated. Umiat sediments rapidly prograded into marine units to the north. Due to the small size (approximate 10,000 km^2) of the Umiat delta and higher subsidence rates, coal beds are thin and discontinuous.

Apparent coal rank ranges from lignite A to high-volatile A bituminous. Higher rank coal is located in the southern half of the coal field probably the result increased thermal effects associated with uplift of the Brooks Range. Onshore, there are an estimated 1.3 trillion short tons of subbituminous and 1.9 trillion short tons of bituminous hypothetical coal resources. Offshore, there are an estimated 2.22 trillion short tons of hypothetical coal resources.

International Conference on Arctic Margins (Abstracts and Program, Anchorage, Alaska, September 2-4, 1992, p. 59)

COAL IN NORTHWESTERN PUERTO RICO

By

Jean N. Weaver

Lignite coals have long been known to be present in Puerto Rico but definitive information about the quality and quantity of the resources has been lacking. During the present study, information gathered in field investigations and derived from laboratory analyses was integrated with existing data such as published and unpublished reports and subsurface (well) information.

In northwestern Puerto Rico, the area underlain by the coal-bearing San Sebastian Formation and its partial lateral-equivalent, the overlying Lares Limestone, is all within the North Coast Tertiary Basin. Both the San Juan and Lares are of Oligocene age, are overlain by younger sedimentary units of Tertiary and Quaternary age, and rest unconformably on an irregular surface of folded and faulted rocks of Cretaceous, Paleocene, and Eocene age. Sedimentary rocks of equivalent age to the San Sebastian and Lares were deposited south of the central mountainous spine but have not been reported to contain coaly material.

Field studies were conducted during February 1991. A total of 19 samples were collected, mainly from four localities near Lares. Proximate, ultimate, along with major, minor, and trace element analyses were performed on the samples. Results indicate that the coal is lignite B.

Coal resources were calculated for the Lares coal field. Resource estimates for coal beds more than 0.3 m thick (mostly overlain by 150 m of overburden) total about 1.5 million tons. All of the resources fall in the sub-economic class because most of the resources are too thin to mine under present economic conditions. The coal has both high ash and sulfur contents.

Many areas along the northwest coast of the island may contain peat deposits. Samples of surficial material (1 foot or less in depth) were collected at several locations. None of the samples qualified as peat due to the large percentage of inorganic material. However, both the observed depositional settings of the samples and available literature indicate that peat could be present under some, or many, of the present-day swampy areas in Puerto Rico. Peat should still be considered as a potential energy resource and for other purposes. Further investigations and sampling programs would be needed to properly assess the peat potential of the island. The deposits accumulating now, in and around mangrove swamps along the north coast of the island, are in many ways present-day analogues to the coaly sequences of the San Sebastian Formation.

Presented at the USGS National Mineral Resource Assessment Program (NAMRAP) meeting held June 25, 1992 in San Juan, Puerto Rico.

Proterozoic Oil in Fluid Inclusions in the Midcontinent Rift: Implications for the Origin of Oil at White Pine, Michigan.

R. C. Burruss, USGS
and
J. L. Mauk, Univ. of Michigan

Oil-filled fluid inclusions, some of which are primary, were trapped in calcite veins in the Nonesuch Formation during second-stage copper mineralization related to a 1.05-Ga compressional event in the Midcontinent rift at White Pine. Yellow to orange fluorescent inclusions in 14 samples of calcite were analyzed by a crushing-cell, capillary gas chromatographic method capable of resolving C_1 to > C_{30} hydrocarbons. The inclusions contain an *n*-alkane-rich liquid petroleum that includes a homologous series of monomethylalkanes and is generally similar to previously reported oils from seeps in the White Pine mine. The C_1 to C_{17} fraction of the oils shows extensive but variable loss of normal, branched, cyclic, and aromatic hydrocarbons. Patterns of depletion are consistent with published laboratory simulations of water-washing and are different from patterns due to devolatilization or biodegradation. Water/oil ratios necessary to produce the alteration range from ~10^3 to greater than 10^6, suggesting that only very small amounts of liquid hydrocarbons migrated with ~100°C hydrothermal fluids during second-stage copper mineralization at White Pine. C_4-C_7 compound ratios in the least altered samples suggest generation of crude oils from kerogen with aliphatic characteristics similar to that found in the Nonesuch Fm. outside the mine locality. The estimates of thermal maturity from C_4-C_7 compound ratios imply oil generation at an equivalent vitrinite reflectance > 1.0, which is higher than that estimated for the hydrothermally altered sediments at White Pine. We conclude that the oil in inclusions was generated from the Nonesuch Formation outside the mine locality in more thermally mature parts of the Midcontinent rift, was extensively water-washed during migration and interaction with Cu-bearing hydrothermal fluids, and was not biodegraded.

Reference:

Burruss, R. C., and Mauk, J. L., 1992, Proterozoic Oil in Fluid Inclusions in the Midcontinent Rift: Implications for the Origin of Oil at White Pine, Michigan[abs.]: Geological Society of America, Abstracts with Programs, v. 24, p. A213.

A Microcomputer Program to Generate Lognormal Probability Distribution Graphs for Petroleum Resource Assessment

Robert A. Crovelli
U.S. Geological Survey
P.O. Box 25046, MS-971
Denver, CO 80225, U.S.A.

and

Richard H. Balay
Department of Mathematical Sciences
Metropolitan State College of Denver
Denver, CO 80204, U.S.A.

ABSTRACT

Lognormal Graph for Resource Assessment Forecast (LOGRAF) is a computer program that plots graphs of the conditional and unconditional resource potential of an assessment study area. It produces complementary (more-than) cumulative distribution function curves for one or two three-parameter lognormal distributions on the same graph. Examples of two probability curves on the same graph are (1) conditional and unconditional oil potential, and (2) recoverable and economically recoverable (unconditional) gas potential. The system is completely generic in that the user determines the resource type; it is not restricted to petroleum.

Program LOGRAF plots the graph described above on an IBM-PC compatible computer from input supplied by the user. It accepts user input, computes the parameters of the graph, displays the graph on the computer screen, and transfers the image to a PostScript laser printer. LOGRAF requires a minimum 400 Kbytes free memory, MS-DOS 3.3 or later, a VGA graphics adapter, and a PostScript laser printer. A numeric coprocessor is not required.

Crovelli, R.A. and Balay, R.H., 1992, A microcomputer program to generate lognormal probability distribution graphs for petroleum resource assessment, in--Roberts, C.A., ed., GeoTech '92 Proceedings: Denver GeoTech, Inc., p. 58-72.

Thermal History of Selected Areas in the Paradox Basin, Utah and Colorado

B.L. Crysdale, V.F. Nuccio, and C.E. Barker

U.S. Geological Survey, Box 25046, MS 939, Denver, CO 80225

ABSTRACT: The Paradox Basin is a southeast-trending structural depression in southeast Utah and southwest Colorado that is dominated by a thick sequence of Pennsylvanian-age cyclic deposits of evaporites, carbonates and black shales. Preliminary evidence from fluid inclusion, Rock-Eval pyrolysis, and burial history reconstruction data indicates that in different areas of the basin many of these Pennsylvanian strata are within the temperature range for generation of oil and/or gas. Fluid inclusions in calcite, halite, gypsum, and anhydrite in veins, layers and nodules found in limestones and black shale samples indicate that temperatures have reached at least 195°C in the basin. These inclusions suggest that cementation and vein formation occurred near maximum burial and/or temperature; oil inclusions in the veins imply that oil migrated through the rocks sometime after vein formation occurred. Burial history reconstruction shows Lower Paleozoic rocks in the Paradox Basin may have reached depths as great as 18,000 ft, with subsequent uplift and erosion of as much as 7,000 ft of overburden.

Present-day geothermal gradients calculated from drill-stem tests range from 18°F/1000 ft. (33°C/km) in the southeast portion of the basin to 8°F/1000 ft (14.5°C/km) in the western portion of the basin. Paleogeothermal gradients calculated from fluid-inclusion homogenization temperatures and burial-history reconstruction are similar to or lower than the present-day gradients, suggesting that the basin is presently at or near maximum temperature.

Published in: American Association of Petroleum Geologists Bulletin, 1992, vol. 76/8, p. 1257.

Tar Sands and Heavy Oils: Resources, Recovery and Realism

B.L. Crysdale, C.J. Schenk, and R.F. Meyer

Resources--Bitumen (tar-sand) and heavy-oil deposits represent a significant energy resource in the United States. The total bitumen resource for the United States is estimated to be 57 billion bbl. Utah has the largest resource, an estimated 29 billion bbl, followed by California with 9 billion bbl, Alabama with 6 billion, Texas with 5 billion and Kentucky with 3 billion.

California leads the United States in the amount of heavy-oil resources in place, with 42 billion bbl, followed by Alaska with 25 billion bbl (although some estimates put Alaska's heavy oil resources as high as 50 billion bbl). Wyoming has 5 billion bbl, and Texas, Arkansas and Louisiana each have 2 billion, for a total U.S. heavy-oil resource estimate of 80-100 billion bbl.

Recovery--Bitumens (<10° API gravity) and heavy oil (10°-20° API gravity) have high viscosities (100-10,000 cP (centipoises) for heavy oil; >10,000 cP for bitumens) and cannot be recovered using conventional methods. The current technology for recovering these hydrocarbons involves thermal stimulation of reservoirs (generally steaming) to provide heat to the oil, which reduces the viscosity and allows the oil to be mobilized and thus recovered. Few tar sands, if any, are currently being exploited in the United States, except for road-surfacing material.

Of the estimated 80-100 billion bbl of heavy oil resources in place in the United States, approximately one-half is not economically recoverable using current technologies. The difficulty in recovering heavy oil is exemplified by the Santa Rosa Sandstone in northeast New Mexico, estimated to contain 95 million barrels of 15° API gravity oil. Two steamflood projects were initiated, but only 365 barrels were ever produced.

Realism--Nearly all of today's economically recoverable heavy oil is in California, and is being utilized now. Seventy percent of California's present daily oil production is heavy oil. Production of light oil peaked in California in 1954, and more heavy oil than light oil has been produced there since 1972. Recovering Alaska's heavy oil is problematic due to transportation and environmental problems.

Unless the economic market changes dramatically, the future of tar sands as a viable resource is marginal at best. However, new techniques or refinement of present ones that make the recovery of high-viscosity oils possible, such as fireflood or emulsion technology, may unlock some of the presently unavailable oil.

Published in: U.S Geological Survery Circular 1074, 1992, USGS Research on Energy Resources, Program and Abstracts, p. 15-16.

RESULTS FROM 1991 WILDCAT WELLS NEAR YUCCA MOUNTAIN, NEVADA

By A. G. Harris, J. E. Repetski, J. L. Clayton,
J. A. Grow, M. D. Carr, & T. A. Daws

The likelihood of hydrocarbon resources in the vicinity of the potential nuclear waste storage site at Yucca Mountain (YM) has become controversial. Thus, the results from three wildcats drilled in 1991 within 20 miles of the YM site have more than usual interest. The Coffer no. 1 well, 20 miles northwest of YM, was drilled to 3,877 ft, terminated in Neogene volcanics, and had no shows of oil or gas. Two wells about 15 miles south of YM were drilled to 5000 ft (Felderhoff Federal (FF) #25-1) and 1466 ft (FF #5-1) and had no shows of oil or gas. The FF #25-1 well penetrated 2200 ft of Neogene(?) deposits, followed by carbonate rocks. Twelve samples from 2460 to 5000 ft were processed for conodonts. Ten samples from 3460 to 5000 ft produced Early Ordovician conodonts indicative of the C. lindstromi Zone (highest sample), the R. manitouensis Zone (to 4510 ft), and low Fauna D (>4510 ft). The conodont succession indicates that bedding is overturned; age and lithology indicate correlation with the Goodwin Limestone in the nearby Striped Hills. The upper 1000 ft of Paleozoic carbonate rock that did not yield conodonts may represent the Nopah Formation. All conodonts have a CAI (color alteration index) of 5 indicating the host rock reached at least 300°C. Cuttings from 3000 to 4300 ft have TOC (total organic carbon) values of <0.12%. CAI and TOC values indicate no source rock potential.

The FF #5-1 well penetrated 850 ft of low-density Neogene(?) deposits followed by chiefly carbonate deposits of greater density (2.5-2.7 g/cc). Caverns between 1410 and 1450 ft resulted in lost circulation and abandonment of the well. The dense carbonates were barren of conodonts but produced thermally unaltered ichthyoliths of uncertain age. The cuttings have TOC values of <0.4% except for 1.3% value at 700 ft. ROCK-EVAL analyses indicate organic materials are immature. The thermal maturity and lithologic succession suggest Neogene lacustrine(?) deposits below 850 ft. Similar Neogene deposits have been mapped 3 miles NE, near the Skeleton Hills.

CAI and TOC values in wells near YM indicate a poor potential for oil and only a fair potential for gas. The same may be said for Paleozoic rocks that crop out in a wide area surrounding YM. In general, these rocks have CAI values of 4 or greater. One exception is a relatively narrow area having low to high CAI values, 1.5 to 25 miles NE of YM. The hydrocarbon potential of the YM area has been likened to that of the Railroad and Pine Valley areas, >100 miles NE of YM. CAI values in Devonian-Triassic rocks in the Railroad and Pine Valley areas are predominantly low, whereas CAI values in the YM area are predominantly high. Thus, the thermal potential for hydorcarbons, particularly oil, in the YM area is substantially lower than in the productive Railroad and Pine Valley areas.

GSA Abstracts with Programs, Vol. 24, No. 6, p. 17, May 1992

Multifaceted Studies of a Lacustrine Source Rock--The Paleogene Green River Formation, Colorado, Utah, and Wyoming

By Michele L. Tuttle, Walter Dean, Mark Stanton, James Collister, Wendy Harrison, Thomas Fouch, Janet Pitman, Trond Hanesand, and Nils Telnaes

Geologic and geochemical studies of petroleum source rocks formed in lakes are fewer in number and, historically, less detailed than are studies of source rocks formed in marine environments. Lacustrine sediments are less studied partly because of the large variability in physical, chemical, and biological processes within and among lakes. This variability limits the ability to construct depositional or diagenetic models that can be used to interpret study results from lacustrine units other than those originally modeled. However, we have found certain lithofacies of the lacustrine Paleogene Green River Formation to be well suited for source-rock studies because lithologic variability was minimal during hundreds-of-thousands to millions of years of deposition in the large Green River lakes. Our goal is to investigate processes active during deposition and diagenesis of the open-water facies of the Green River and to evaluate variability in processes among depositional basins and lake phases.

The Green River formed in lakes that existed for 10-23 m.y. in three Laramide fault-bounded basins that collectively covered more than 62,000 km^2. Ancient Lake Uinta occupied the Uinta basin of Utah and the Piceance basin of Colorado, and ancient Lake Gosiute occupied the greater Green River basin of Wyoming. Part of the Green River is an excellent source rock, but in most areas, the formation is not buried deep enough to thermochemically mature the kerogen. An exception is in the western portion of the Uinta basin, Utah, where the lower part of the Green River is within the oil-generation window and has produced significant amounts of oil.

Geochemical and biogeochemical studies used material cored from a 6-m.y. interval (latest early Eocene to middle Eocene) of the Green River that was deposited within the three lacustrine depocenters. The rocks within this interval are still immature with respect to petroleum generation. In order to better integrate results from each study and to increase the applicability of these results to lacustrine source rocks in general, many of the analyses were performed on the same samples. Our studies span a wide range of disciplines--inorganic and organic chemistry; stable isotopy ($^{34}S/^{32}S$), petrography, and trace-element content of sulfide minerals; stable isotopy of organic matter ($^{13}C/^{12}C$, $^{15}N/^{14}N$, $^{34}S/^{32}S$); evaluation of a modern lake as a geochemical analog for the ancient Green River Lakes Uinta and Gosiute; and an experimental study on iron diagenesis in saline, high-pH environments similar to those within the Green River lakes. Results and preliminary interpretations of these studies are appearing in U.S. Geological Survey Bulletin 1973. Work in progress addresses major- and trace-element chemistry and stable isotopy of carbonate minerals ($^{13}C/^{12}C$, $^{18}O/^{16}O$), sedimentology of core material, and composition of the bitumen and kerogen of the Green River Formation.

Results of these studies have identified chemical and biological processes active within each lake depocenter and variably influenced by climatic and tectonic cycles having observed durations from ~0.1 to 5 m.y. Primary productivity (that of algae) is linked to these cycles because the cycles, in part, affected the availability of nutrients. Inflow was the source of sulfate and probably phosphate, but nitrogen was replenished by recycling through a complex set of inorganically and biologically mediated reactions . During fresh and brackish-water phases, nutrients were abundant and productivity was high in both lakes. The abundant organic matter produced anoxic conditions within the sediment where anaerobic bacterial processes formed sulfide and carbonate minerals. During lake lowstands, Lake Uinta was sufficiently deep to remain stratified. Euxinic (H_2S-bearing) bottom water conditions were established as bacteriogenic H_2S diffused out of the sediment where extremely high porewater pH kinetically inhibited formation of iron sulfides. The extensive bacterial activity in Lake Uinta during this time, together with the very long stability of lake stratification, caused an evolution of the isotopic composition of both the sulfur and carbon reservoirs -- in the case of sulfur, to unprecedented ^{34}S enrichment. During compaction, saline waters were expelled, carrying solutes into overlying beds where additional sulfide and saline carbonate minerals formed. In contrast to Lake Uinta, Lake Gosiute was only intermittently stratified during lowstands due to frequent mixing of the shallow water column. Organic-matter production and preservation decreased under these conditions but was sufficient to support some anaerobic bacterial activity during early diagenesis. Again, high porewater pH inhibited iron sulfidization, but because the water column frequently mixed, euxinic conditions were ephemeral and isotopic evolution much less dramatic than in Lake Uinta.

The interpretive results of these studies have increased our understanding of, and appreciation for, the complex geochemical processes affecting the Green River lakes. Similarities between Lakes Uinta and Gosiute have been proposed in previous studies and have often been used to justify extrapolations of study results from one lake to the other. We have shown that, although geochemical and biological processes within the two lakes were similar, depositional and diagenetic conditions were significantly different , and that the differences affected the hydrocarbon-producing capability of these lacustrine source rocks.

Carter, L.M.H., ed., USGS Research on Energy Resources--1992, Program and Abstracts, Eighth V.E. McKelvey Forum on Mineral and Energy Resources: U.S. Geological Survey Circular 1074, pp. 76-77.

CONSTRAINTS ON EXTENSIONAL FAULT GEOMETRIES IN EASTERN RAILROAD VALLEY, NEVADA BASED ON SEISMIC REFLECTION AND GRAVITY DATA

By J. A. Grow, H. R. Blank Jr., C. J. Potter, & J. J. Miller

Previously published seismic reflection and gravity data along the eastern flank of central Railroad Valley (RRV), near the Eagle Springs oil field, have been interpreted to require high-angle (>60°), west-dipping normal faults. In contrast, recent seismic reflection data near the prolific Grant Canyon oil field and recent geologic mapping by Karen Lund and others in the Grant Range to the east indicate that in southern RRV low-angle (20°-30°) normal faulting is the dominant style of extension. Horizontal gravity gradients along the east flank of central RRV reach 6-8 mGal/km, and these gradients require an abrupt lateral change in densities near Eagle Springs. In southern RRV, the gravity gradients are as much as 3-4 mGal/km. The USGS recently obtained 12 seismic reflection lines in which the absence of fault plane reflections near Eagle Springs suggests higher angle (>40°) faulting, whereas fault plane reflections near Grant Canyon clearly define a low-angle fault. Late Cretaceous(?) igneous rocks have been encountered at four wells within 2 km of the Grant Canyon field. The top of the igneous body in these wells coincides with the low-angle normal fault. The reservoir rocks at Grant Canyon are Devonian carbonates that overlie the low-angle fault in hanging wall (or slide?) blocks. Well logs show 30-50 percent lateral increases in velocity and density values within the Neogene valley fill deposits which account for part of the gravity gradient. Several exploration wells that have been drilled or permitted recently on or east of the gravity gradient should help further constrain the rock densities and the fault geometries when drilling results become available.

GSA Abstracts with Programs, Vol. 24, No. 6, May 1992, Rocky Mountain Section

AN AEROMAGNETIC AND AERORADIOACTIVITY OVERVIEW OF THE COLORADO FRONT RANGE.

REED, J.C., Jr., U.S. Geological Survey, MS 913, Box 25046, Federal Center, Denver, CO 80225; ZIETZ, Isidore, Institute for Geographical and Geological Sciences, George Mason University, Fairfax, VA 22102; DUVAL, J.S., U.S. Geological Survey, 927 National Center, Reston, VA 22091.

Aeromagnetic and aeroradioactivity data acquired along 1-mile spaced flight lines at 400 ft above terrain during the DOE-NURE program have been compiled to provide a synoptic overview of the Colorado Front Range between 38° and 41° N. These data constitute one of the largest blocks of systematically collected data of this type in the U.S. Features related to surface geology clearly shown on the aeromagnetic map include major northeast-trending Precambrian shear zones, trends of steeply dipping foliation (but not foliation with shallow dip), and a variety of Proterozoic, Mesozoic and Tertiary plutons, some of which show hitherto unrecognized internal subdivisions. A conspicuous north-south trending discontinuity in the western part of the Precambrian core of the range does not correlate closely with surface geology and may be related to downward steepening of east-dipping Laramide thrust faults that bound the Precambrian rocks along the west side of the range. Seismic and/or gravity data may help test this interpretation.

The aeroradioactivity maps show many details of the outcropping plutons, including major differences in U, Th, and K contents of plutons of the same general age, subtle compositional gradients within individual plutons, and the location of individual intrusive centers in the Pikes Peak batholith. Distribution of alluvium derived from high U-Th plutons and trends of Tertiary paleovalleys containing high-U ash-flow tuffs are also locally evident.

Compilations of geophysical data of this type and scale provide an invaluable overview for studies of regional tectonics, structure, and plutonism in crystalline terranes, even where surface geology is reasonably well known.

Geological Society of America Abstracts with Programs, v. 24, no. 7, p. A205

WORK SHEETS FOR SEISMOTECTONIC MAP OF THE NEW MADRID 2° X 2° AREA

Susan RHEA, Russell L. WHEELER, and Arthur C. TARR, U.S. Geological Survey, Box 25046, M.S. 966, Denver Federal Center, Denver, CO 80225

A planned seismotectonic map of part of the upper Mississippi embayment will encompass the area from 35° to 37°N. lat. and from 89° to 91°W. long. The map area includes the main epicentral alignments of earthquakes in the Reelfoot rift. The 1:250,000-scale map will show geological, seismological, and other geophysical information bearing on crustal structures and recent tectonic history, and on hazards from shaking, liquefaction, amplification, and ground failure. We show half-sized work sheets of many of the data sets.

We expect that the map will reveal hitherto-unrecognized spatial relations between seismicity and other data, and that these spatial relations might suggest testable hypotheses about causal processes. For example, the most abundant earthquake epicenters form a band trending northwest from Dyersburg, Tennessee, to New Madrid, Missouri. This trend forms a left-stepping jog between two northeast-trending, mostly right-lateral alignments of epicenters. Focal mechanisms in the band are predominantly reverse. Our work sheets show that the northwest-trending epicentral band coincides with a crustal region characterized by low P-wave velocities, low Q in the upper 5 km, high heat flow, high concentrations of soil radon, and mafic intrusions recently inferred from high-resolution aeromagnetic data. Previous workers attributed the velocity and Q anomalies to abundant fluid-filled cracks, the heat-flow anomaly to water convecting along permeable and active faults, and the radon anomaly to uranium enrichment in the faulted peripheries of intrusions or to gas emanating along faults related to intrusions. We suggest that tough mafic intrusions could have localized the left-stepping jog. Intrusion, cooling, and continuing compression of rocks in this jog could have formed or reactivated reverse faults and propagated the fluid-filled cracks. These cracks and faults could provide circulation paths for uranium leached from the intrusions (radioactive mafic plutons are uncommon but not unheard of). However, uranium is only weakly soluble in water; low solubility implies that the circulation must have been prolonged. Another implication is that reverse-faulting earthquakes might have occurred in the jog for many recurrence intervals, and might continue to occur there until the northeast-striking, dextral-slip faults break through the jog. This hypothesis of prolonged reverse faulting can be tested: The Lake County uplift coincides roughly with the northwest-trending epicentral band, and this area was uplifted both during the 1811-1812 New Madrid earthquakes and several times before them. Perhaps a geomorphic record by which to detect and date prolonged uplift exists within the Lake County uplift.

For another example of spatial relations leading to testable hypotheses, our work sheets show that along the borders of the Mississippi Valley graben (shallow part of the Reelfoot rift), shapes of plutons inferred from gravity data differ from shapes inferred from aeromagnetic data. The differences are expected because plutons can be heterogeneous in composition, and therefore in density and in content of trace magnetic minerals. The shapes inferred from the two potential fields might improve models of the plutons' internal structure, compositions, and possible alteration halos. In turn, these results might sharpen finite-element models testing hypotheses that associate seismicity with the plutons' anisotropies.

Susan Rhea, Russel L. Wheeler, and Arthur C. Tarr, in press, Work Sheets for Seismotectonic Map of the New Madrid 2° X 2° Area; Seismological Research Letters.

PALYNOSTRATIGRAPHY OF THE MID-CRETACEOUS MANCOS SHALE, WESTERN COLORADO

Robert A. Cushman Jr. (Dept. of Geology and Geological Engineering, Colorado School of Mines, Golden, CO 80401)

The purpose of this study is to develop a palynostratigraphic zonation for the lower portion of the Mancos Shale in western Colorado. The study includes a composite section of the upper Naturita Formation and lower Mancos Shale at Delta, Colorado. In the study area, the Naturita Formation consists of thin, interbedded marine sandstone and shale, and nonmarine sandstone, siltstone, and coal. The Mancos Shale consists of marine sandstone, siltstone, shale, and limestone. Twenty palynomorph species are recognized as being stratigraphically significant for this section. The significant palynomorphs include *Appendicisporites* spp., *Cicatricosisporites crassiterminatus, Florentinia cooksoniae, Florentinia mantellii, Isabelidinium magnum, Surculosphaeridium longifurcatum, Chatangiella spectabilis, Heterosphaeridium difficile, Palaeoperidinium cretaceum, Xenascus ceratioides,* and *Dinogymnium* sp. A. The palynomorph biozones correlate with previously published Western Interior fossil zonations that include both ammonites and inoceramids.

Five palynological assemblage zones are recognized ranging from middle Cenomanian into lower Coniacian. In the upper Naturita Formation, one nearshore marine assemblage zone (Zone 1, middle Cenomanian) is established. In the lower Mancos Shale, four marine biozones are recognized. Zones 2 through 5 correlate with upper Cenomanian, middle Turonian, upper Turonian, and lower Coniacian ammonite zones, respectively. Zones 2 and 3 are separated by a hiatus in the lower Turonian, which was previously recognized on the basis of the ammonite biostratigraphy. The Cenomanian-Turonian stage boundary occurs at the base of Zone 3 and the Turonian-Coniacian stage boundary occurs at the base of Zone 5. Based on the ammonite zonations and the palynomorph assemblages, the age of the boundary between the Naturita Formation and the Mancos Shale at Delta, Colorado is middle Cenomanian.

published in: **SEPM 1992 Theme Meeting: Mesozoic of the Western Interior; Fort Collins, Colorado, Program and Abstracts, p. 21.**

TRIPROJECTATE POLLEN FROM THE CAMPANIAN OF THE MANCOS SHALE, WESTERN COLORADO

CUSHMAN, Robert A., Jr.,[1] and NICHOLS, Douglas J.[2]
[1]Colorado School of Mines, Golden, Colorado 80401, U.S.A.
[2]U.S. Geological Survey, Denver, Colorado 80225, U.S.A.

This study documents a diverse and abundant congregation of species of triprojectate pollen from the western United States. The species are present in the upper part of the Mancos Shale exposed near the town of Delta in western Colorado. The Mancos is a marine unit of Cenomanian to Campanian age consisting predominantly of shale and including sandstone, siltstone, calcareous shale, and thin beds of limestone. In the study area, marine sandstone units of the Cozzette and Rollins Members of the Mesaverde Formation respectively interfinger with and cap the uppermost part of the Mancos Shale. Mollusks that date this section are *Scaphites hippocrepis III* and *Baculites aquilaensis* in the lower Campanian, *Inoceramus subcompressus* in the middle Campanian, and *Didymoceras stevensoni* in the upper Campanian.

Fifteen species and varieties of the triprojectate genera *Aquilapollenites, Integricorpus, Mancicorpus*, and *Pseudointegricorpus* are present in the lower to upper Campanian part of the Mancos Shale in the study area. Eight taxa that are useful for palynostratigraphy are *Aquilapollenites attenuatus, A. quadrilobus, A. senonicus, A. trialatus* var. *uniformis, A. trialatus* var. *variabilis, A. turbidus, Integricorpus rigidus,* and *Mancicorpus calvus.*

The stratigraphically lowest occurrence of triprojectate pollen is in the lower Campanian. The first species to appear is *Mancicorpus calvus*. The other species have their first appearances at successively higher stratigraphic levels. The stepwise pattern of appearances parallels that previously reported for triprojectate pollen in the Rocky Mountain region. However, the influx of triprojectate pollen in the study area probably results from a facies change within the Mancos Shale and therefore may not represent the first appearances of these species in time. The palynoflora below the influx of triprojectates is dominated by marine dinoflagellate cysts, and the first few occurrences of triprojectate pollen are sporadic. The marine palynomorphs characterize the lower, calcareous part of the Mancos Shale, whereas samples from successively higher levels within the upper, noncalcareous part of the Mancos tend to show progressively greater terrestrial influence. Following their first appearance, the triprojectates rapidly diversify and increase in relative abundance.

The Mancos triprojectate species occur together with pollen of the genera *Proteacidites* and *Siberiapollis* and spores of the genera *Aequitriradites, Cicatricosisporites, Foraminisporis,* and *Ghoshispora*; the marine component of the palynoflora includes species of the dinocyst genera *Dinogymnium* and *Chatangiella*. The Mancos species represent the stratigraphically oldest reported occurrences of triprojectate pollen in the southern part of the *Aquilapollenites* province.

published in: 8th International Palynological Congress, Aix-en-Provence (France), Program and Abstracts, p. 29.

MEASURED SECTIONS AND PALEOTECTONIC INTERPRETATION OF UPPER FRONTIER FORMATION AND LOWER BEAVERHEAD GROUP, LIMA PEAKS AREA, SOUTHWEST MONTANA

J.C. Haley, T.S. Dyman, and W.J. Perry, Jr. (U.S. Geological Survey, Denver, Colorado 80225)

The Upper Cretaceous Frontier Formation and overlying Beaverhead Group south of Lima and Monida, Montana form a thick sequence of nonmarine, predominantly clastic sedimentary rocks deposited in a rapidly subsiding foredeep in front of the Idaho-Montana thrust belt. Five measured sections, each averaging approximately 1 km thick, and detailed mapping of the upper Frontier and lower Beaverhead illustrate that (1) clastic facies coarsen upwards and vary laterally from conglomerates dominated by Mesozoic limestone detritus in the northwestern part of the outcrop belt to conglomerates dominated by Proterozoic quartzite clasts in the southeast, (2) limestone conglomerates fine and diminish in a southeastward direction, (3) porcellanite beds form important continuous time and lithostratigraphic markers throughout the area, and (4) the Frontier-Beaverhead contact is a syntectonic unconformity.

Our interpretation of these relationships is as follows: (1) Cenomanian to Turonian uplift of Precambrian quartzite highlands in the western thrust belt in Idaho produced a foredeep that was filled with quartzite-clast conglomerate, sandstone, and volcaniclastic material that make up much of the Frontier Formation. (2) Turonian or Coniacian initiation of the Laramide Blacktail-Snowcrest uplift, north of the outcrops studied, shed Mesozoic limestone and sandstone detritus into the foredeep (upper Frontier Formation at the northwestern end of the outcrop belt) and pushed the axis of thrust belt-derived quartzite-clast conglomerate deposition to the southeast. (3) Continued uplift and unroofing of the Blacktail-Snowcrest terrane deformed the early formed limestone-clast conglomerate and produced a local syntectonic unconformity (the Frontier-Beaverhead contact) in the vicinity of the uplift. Meanwhile, deposition to the southeast, away from the Blacktail-Snowcrest uplift, continued to be dominated by thrust belt-derived quartzite-clast conglomerate.

Haley, J.C., Dyman, T.S., and Perry, W.J., Jr., 1992, Measured sections and paleotectonic interpretation of upper Frontier Formation and lower Beaverhead Group, Lima Peaks area, southwestern Montana [abs]: SEPM 1992 Theme Meeting, Ft. Collins, CO, Mesozoic of the Western Interior: Abstracts, p. 28

SHOCKED ZIRCONS IN THE ONAPING FORMATION: FURTHER PROOF OF IMPACT ORIGIN; B.F. Bohor and W.J. Betterton, U.S. Geological Survey, Box 25046, MS 972, Denver, CO 80225

The Onaping Formation fills the structural basin at Sudbury, Ontario, Canada. This formation is composed of three members: a basal, coarse, mainly quartzitic breccia (Basal Member), a light-colored, heavily-included, polymict middle unit (Gray Member), and a similar, but dark-colored upper unit (Black Member). Two different origins have been proposed for the Onaping: 1) volcanic ash-flow sheet, and 2) impact fall-back ejecta. These origins are critically discussed in a review paper coauthored by proponents of each view [1].

French [2] identified multiple sets of shock lamellae in quartz and feldspar grains from the Onaping Formation at Sudbury. We have also identified sets of shock lamellae (called planar deformation features, or PDF) in a single quartz grain from a thin section of the Black Member. These PDF usually consist of "decorated" lamellae that are much less distinct than those in younger impacted rocks and ejecta, such as the K/T, because of annealing by subsequent metamorphic events.

Because it is more refractory than quartz and feldspar, zircon should resist annealing by thermal metamorphism. We have already shown that some zircons from K/T distal ejecta display PDF when subjected to an alkaline etch [3]. We dissolved samples of both the Gray and Black Members of the Onaping with acids to free the contained zircons, which were then etched in alkaline solutions to reveal any PDF. These samples were collected from outcrops of the Onaping along Highway 144 south of Levack and west of the High Falls on the Onaping River. In the process of separating the zircons, we also recovered other resistant trace minerals indicative of target rock lithologies. These include tourmaline, garnet, kyanite, rutile, staurolite, chromite, pyrite, and pyrrhotite.

Many of the etched zircons from both the Gray and Black Members display PDF when viewed in an SEM. Figure 1 shows an area of a shocked zircon from the Black Member that displays at least 4 sets of PDF. These shock lamellae in zircon are much narrower than those in quartz and do not etch as deeply, probably because they contain less glass within them. Precession X-ray photos of zircons from K/T ejecta with PDF show extreme broadening and streaking (asterism) of diffraction maxima, confirming that they have been highly shocked [3].

Krogh et al. [4] reported zircons from the Onaping Formation at Sudbury that show linear, crystallographically-oriented fracturing. They ascribed these features to shock caused by impact, and this conclusion is supported by U-Pb data. The discordance of these zircons is crudely proportional to the amount of fracturing they display, caused by the Sudbury Event dated from a lower intercept age of ~1836 Ma. We have also observed both linear and irregular fractures in our Onaping zircons, but the finer-scale PDF probably indicate a significantly higher level of shock than do these coarse, open features.

In addition to fractures and PDF, Onaping zircons also show another type of textural feature that indicates exposure to a high level of shock. This texture, first noted in zircons from K/T ejecta [3], we have called "granular" or polycrystalline (Fig. 2). Often, zircons displaying this texture are idiomorphic, with some of the original

crystal surfaces still visible. This indicates that the zircons have not melted, but instead have been recrystallized due to shock. Thus, these granular zircon grains can be considered to be diaplectic--that is, shock-converted by solid state transformation into polycrystalline zircon below their fusion temperature. On the other hand, zircons also can be melted by impacts, as shown by fused grains partially or completely converted to baddeleyite in high-temperature impact glasses [5]. The granular zircons in K/T ejecta and from the Onaping show no phase or compositional changes by X-ray analyses, in either diffraction or energy dispersive modes. This is another indication that their texture is due to solid-state transformation induced by shock, and not thermal melting.

It is instructive that these granular-textured zircons have been found only in ejected material, and not in shocked, in-situ target rocks around craters. However, zircons bearing impact-generated PDF have been identified from three types of sites and materials: K/T distal ejecta, Sudbury fall-back ejecta (Onaping), and Manicouagan target rocks. More importantly, PDF and granular textures have never been seen in volcanic zircons. Therefore, zircons can provide corroborating evidence of impact-generated shock; this discovery could prove very useful in evaluating the metamorphic histories of quartz-poor lunar rocks and meteorites.

ACKNOWLEDGMENTS. We thank B. Dressler for guiding one of us (BFB) to the "type" locality of the Onaping. T. Krogh provided the Manicouagan zircons, and E. Foord performed the X-ray analyses.

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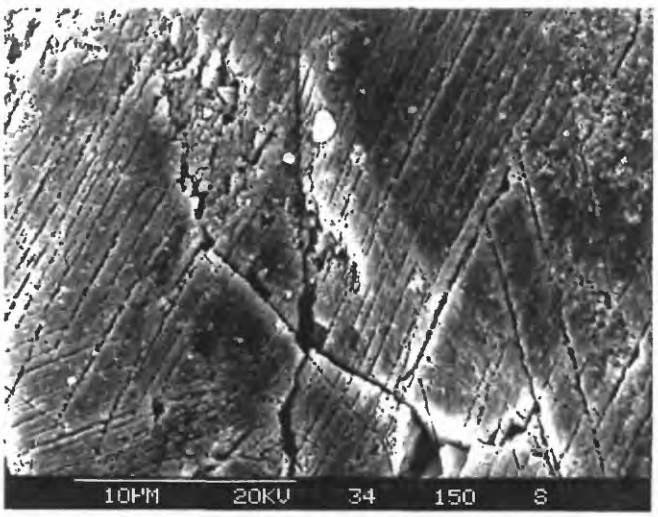

Fig. 1. PDF (4 sets).

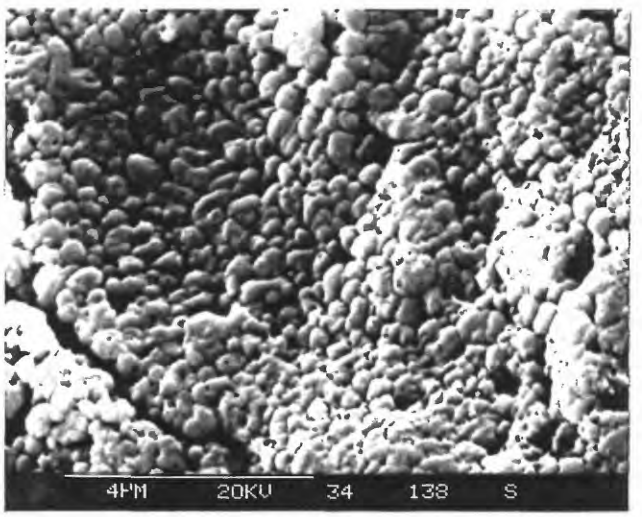

Fig. 2. Granular texture.

Abstracts Volume, International Conference on Large Meteorite Impacts and Planetary Evolution, Aug. 31 - Sept. 2, 1992, Sudbury, Ontario, Canada; LPI Contrib. #790, p.9.

Evidence for Petroleum-Assisted Speleogenesis, Lechuguilla Cave, Carlsbad Caverns National Park, New Mexico

By K.I. Cunningham and K.I. Takahashi

Limited sulfur isotope, mineralogic, and cave morphogenetic data suggest that speleogenesis (cavern development) in the Guadalupe Mountains of New Mexico and Texas was the result of solution via sulfuric acid derived from H_2S gas. The cave-bearing reef complex is adjacent to many oil and gas fields and numerous gas migration routes into the reef complex are plausible. Cave gypsum and elemental sulfur isotopic values as light as -25.8 parts per mil (referenced to the Canyon Diablo Troilite) link these cave deposits to H_2S-bearing gas deposits. Uncommon cave deposits of pH-dependent minerals like 10Å halloysite (endellite) indicate strongly acidic (pH = 1-2) conditions consistent with the sulfuric acid hypothesis. Blind passages, passages dying with depth, and long (300-1000 meters) horizontal passage extents have also been cited as evidence that the majority of solution occurred at a lowering water table where H_2S and atmospheric oxygen mixed to produce sulfuric acid. Whether or not the main acid-producing reaction occurred at the water table, in the mixing zone between fresh water and brines, or deeper in the system is debatable and important to carbonate dissolution mechanisms. With the 1986 discovery and subsequent aggressive exploration of Lechuguilla Cave, we have recently been provided with additional data from a uniquely preserved 100+ kilometer long cave and the only Guadalupian cave to penetrate to the apparent water table.

Most caves in the Guadalupe Mountains, including Carlsbad Cavern, have been extensively invaded by seep water resulting in the appreciable loss of massive and speleothemic gypsum. Sulfuric-acid-stage elemental sulfur is very rare: one small deposit is documented at Cottonwood Cave where oxidation has apparently slowed due to limited air exchange or other unknown factors. In contrast, Lechuguilla may contain more preserved gypsum and sulfuric-acid-stage sulfur than all other known caves in the Guadalupes combined: a laterally extensive siltstone caprock has apparently diverted most recent water away from the cave, such that occurrences of flowstone and other calcitic speleothems are highly contained and localized. Massive, chemically precipitated gypsum deposits and fragile, secondary speleothems begin near the entrance and extend to within 175 meters of the water table, an overall vertical distance of nearly 290 meters. The gypsum deposits are up to 10 meters thick in large rooms, occasionally fill passages, and sometimes occur on steep slopes and balconies on the sides of vertical shafts. Replacement textures have been noted in some blocks, but most accumulations appear to be the result of chemical precipitation or oxidation of early-formed sulfur masses. Elemental sulfur occurs as multi-ton, massive, vuggy, or encrusting deposits at diverse vertical levels in the cave. The remarkable preservation of the deposits (in contrast with other Guadalupe caves) suggests that oxygen availability in Lechuguilla has been very limited after drainage. The sulfur is slowly oxidizing to gypsum and liberating COS and SO_2 into the humid cave atmosphere. This mixture ascends convectively to the higher sections of the cave where modern solution of the carbonate bedrock occurs. Sulfur and gypsum isotopic compositions are light: average $\delta^{34}S$ values for the main Lechuguilla sulfur deposits are -23.29, and -25.55 for selenite from the Chandelier Ballroom. That inclusions in the sulfur contain a gas phase and both saline and fresh water strongly suggests that the deposits formed in the fresh water-saline water mixing zone at temperatures <50°C. The morphology of Lechuguilla passageways further supports a model where upwardly circulating H_2S-rich saline water in joints and fractures encounters fresh, oxygen-rich water, resulting in greater-than-normal vertical solution above these leak points (vertical mazes). Zones of intensely dissolved and occasionally mineralized reef limestone ("todo corrodo" zones) are often associated with the bottom of these vertical mazes and are linked to underlying fissures that penetrate downward to the current water table. The structural attitude of these deep fissures is commonly dipping toward the back-reef beds (not into the basin) and may reflect a preferred ascending flow component in the system.

This information is presented at the 1992 McKelvey Forum in an expanded visual form as a sequence of text, charts, and photographic images running on an Apple Macintosh IIfx computer.

Evidence for Petroleum-Assisted Speleogenesis, Lechuguilla Cave, Carlsbad Caverns National Park, New Mexico, Cunningham, K.I. and Takahashi, K.I., 1992: USGS Research on Energy Resources, Programs and Abstracts of the Eighth V.E. McKelvey Forum on Mineral and Energy Resources, U.S. Geological Survey Circular 1074, p. IX.

8th Annual USGS McKelvey Forum
Houston, TX, February 18-20, 1992

PETROLOGY AND DIAGENESIS OF PENNSYLVANIAN TRADEWATER GROUP SANDSTONES IN THE ILLINOIS BASIN, SOUTHWESTERN INDIANA

By

Paula L. Hansley

The Pennsylvanian Tradewater Group on the southeastern margin of the Illinois Basin was deposited on a tidally influenced coastal plain and estuary and contains a variety of lithologies ranging from quartzose sandstones to low-sulfur (< 1 percent) coals. Sandstone core samples (6 to 285 m in depth) are very fine to fine grained and include subarkoses, sublitharenites, and rare quartzarenites. Lithic fragments are predominantly chert and metamorphic types, such as chlorite, stretched metaquartzite, and schist. In addition, many grain-size areas of detrital and authigenic mixed-layer illite-smectite may actually be altered metamorphic rock fragments.

Clayey sandstones associated with coals tend to be poorly sorted and contain microcrystalline siderite concretions, pyrite, muscovite, and abundant terrestrial organic material as lenses and scattered fragments. Tiny (30-50 microns) siderite rhombohedra that occur on the margins of grains in the organic-rich sandstones formed early in a reducing, alkaline (methanogenic?) environment. Early diagenetic precipitation of ankerite and calcite cement postdated the siderite. In these sandstones, the margins of quartz grains and overgrowths are commonly badly corroded, and porosity is high.

Quartz-rich sandstones are moderately well sorted and contain primarily authigenic rather than detrital clay. Under transmitted light, petrographic thin sections of quartzose sandstones showed numerous, apparent, long and concavo-convex contacts between detrital quartz grains. Cathodoluminescence, scanning electron microscopy, and polished-thin-section study revealed, however, that the contacts are actually between quartz overgrowths. In many areas, quartz grains are welded together by up to 12 volume percent authigenic quartz. Recognition of overgrowths is difficult because dust rims between grains and overgrowths are faint to absent. Most contacts between detrital grains, therefore, are point contacts suggesting that early carbonate(?) cement held grains apart and/or that burial of the Tradewater has not been deep.

Most plagioclase and potassium feldspars show only minor dissolution; however, some plagioclase is albitized or has small overgrowths. Large areas of nonferroan carbonate cement remnants in optical continuity indicate that there was widespread dissolution during later (meteoric?) diagenesis. Coarse-grained booklets of kaolinite occur in many intergranular pores and dissolution cavities in feldspars. Locally, submicroscopic authigenic illite overgrowths are present on kaolinite and detrital illite-smectite.

In the future, petrologic analyses will be combined with sedimentologic studies so that diagenesis can be correlated with depositional environment, and this research will be continued on deeper cores in the central part of the Illinois Basin.

GSA Abstracts with Programs, 1992 Annual Meeting, p. A58.

ANADARKO BASIN RESERVOIR AND NON-RESERVOIR SANDSTONES--
A COMPARISON OF POROSITY TRENDS

By Timothy C. Hester and James W. Schmoker

Sandstone porosity normally decreases during burial and is commonly treated as a function of burial depth. Treating sandstone porosity as a function of vitrinite reflectance (R_o), however, minimizes the effects on porosity data of regional differences in burial history. Thus, porosity data from areas with regional differences in burial, uplift, and thermal gradient may be combined and (or) compared within a normalized context.

Two porosity-R_o data sets representing sandstones of the Anadarko basin, Oklahoma, have been compiled: (1) non-reservoir sandstones of the central and southern Anadarko basin, and (2) hydrocarbon-reservoir sandstones of the Anadarko basin as a whole. Each of these data sets is compared to a composite set of sandstone porosity-R_o data from numerous basins that represents a preliminary porosity framework of sandstones in general, and the two are also compared to each other.

Porosity data of non-reservoir sandstones in central and southern Anadarko basin consist of two populations; in both, porosity generally declines as a power function of increasing thermal maturity. For R_o <1.1 percent, Anadarko basin non-reservoir sandstone porosity decreases more rapidly than does porosity of sandstones in general. For R_o >1.1 percent, Anadarko basin non-reservoir sandstone porosity decreases less rapidly than does porosity of sandstones in general.

Reservoir sandstones of the Anadarko basin, however, follow a different pattern. Reservoir sandstones lose porosity much more slowly than do non-reservoir sandstones (for R_o <1.1 percent) and sandstones in general. This slower rate of porosity decline with increasing R_o could be due to geologic factors such as overpressuring or the inhibiting effects of early hydrocarbon emplacement on diagenesis, and (or) to economic factors inherent in the selection of hydrocarbon reservoirs.

In any case, as R_o increases from about 0.65 percent to about 1.1 percent, the porosity trends of Anadarko basin reservoir and non-reservoir sandstones rapidly diverge. Above about R_o =1.1 percent, however, the porosity trends of Anadarko basin reservoir and non-reservoir sandstones have similar slopes, suggesting that sandstones of the central and southern Anadarko basin may retain sufficient porosity for economic accumulations of hydrocarbons, even at high thermal maturities.

Hester, T.C., and Schmoker, J.W., 1992, Anadarko basin reservoir and non-reservoir sandstones--A comparison of porosity trends [Abs.]: U.S. Geological Survey Circular 1074, USGS Research on Energy Resources, 1992, Program and Abstracts, p. 33-35.

Effects of sedimentologic and petrologic heterogeneity on reservoir properties of the Upper Cretaceous Sussex Sandstone in the House Creek Field, Powder River basin, Wyoming

By Debra K. Higley

Reservoir-grade porosity and permeability in the Upper Cretaceous Sussex Sandstone, House Creek field, Wyoming, are a combination of preserved primary porosity and secondary porosity (average porosity and permeability values in the field are 13% and 15 millidarcies, respectively). Overall, the Sussex Sandstone exhibits an upward increase in grain size and a corresponding increase in porosity and permeability, this is characteristic of marine-bar sandstones. Reduction in porosity and permeability in the Sussex Sandstone is caused mainly by early calcite and quartz cementation, and by sedimentological heterogeneity. Sedimentologic heterogeneity results primarily from interbedding of the porous trough cross-bedded ridge-facies sandstone with the low porosity and permeability inter-ridge and shelf sandstone and mudstone. Intercalation of these units causes isolation and compartmentalization of the trough cross-bedded reservoir sandstones.

Cementation by calcite and quartz results in significant loss of depositional porosity. Average volume percentages of calcite and quartz are 10.4 and 11, respectively, in reservoir facies, whereas compactional porosity loss is relatively minor, accounting for 5%-10% loss of depositional porosity. A period of grain dissolution and replacement by (possibly syndepositional) carbonate cements occurred during very early diagenesis. Because of both later cementation by quartz and calcite and precipitation of authigenic clays, this period of porosity development is poorly preserved. Authigenic ferroan chlorite, illite-smectite, illite, and kaolinite line and fill pore spaces; these minerals comprise an average 5.5% by volume of reservoir sandstones. Microporosity was not measured in the thin-section analysis; however, a considerable amount of Sussex Sandstone porosity is microporosity in clays and chert.

Porosity was enhanced by locally extensive, late-diagenetic dissolution of lithic grains, quartz and feldspar overgrowths, and calcite cements, which filled pore spaces and replaced grains and overgrowths. This dissolution may have resulted from pore-fluid changes associated with oil generation and migration. Calcite cements are absent to volumetically minor in oil-stained and productive intervals.

Higley, D.K., 1991, Effects of sedimentologic and petrologic heterogeneity on reservoir properties of the Upper Cretaceous Sussex Sandstone in the House Creek Field, Powder River basin, Wyoming: American Associaton of Petroleum Geologists Bulletin, v. 75, p. 595.

ISOTOPIC DATING OF LAVA CREEK B TEPHRA IN TERRACE DEPOSITS ALONG THE WIND RIVER, WYOMING--IMPLICATION FOR POST 0.6 MA UPLIFT OF THE YELLOWSTONE HOTSPOT

IZETT, G.A., PIERCE, K.L., NAESER, N.D., U.S. Geological Survey, Denver, CO and JAWOROWSKI, C., Department of Geology and Geophysics, University of Wyoming, Laramie

In terrace deposits along the Wind River near Kinnear in the Pavillon quadrangle, a meter-thick tephra layer occurs within main-stem gravel deposits ~100 m above the river (Jaworowski, GSA abs. 1992), and at a similar altitude above Muddy Creek in the Mexican Pass SW quadrangle, but here at the base of the terrace deposit. At the C1453 site in the Blue Holes quadrangle 67 km upstream from Kinnear, a similar-appearing tephra layer occurs within main-stem gravels of a terrace deposit 140 m above the Wind River. This upstream increase in terrace height of 40 m raises the concern that the tephra layers might not be of the same age. However, the observation that all three tephras contain the same assemblage of glass-mantled phenocrysts (quartz, sanidine, oligoclase, clinopyroxene, hornblende, fayalite, colorless zircon, chevkinite, allanite, magnetite, and ilmenite) as that in the Lava Creek Tuff, Member B in Yellowstone National Park and the Lava Creek B volcani ash bed of the Western United States (Izett and Wilcox, USGS MI 1325, 1982) indicates that they are correlatives. We confirm this petrographic correlation by isotopic dating of sanidine crystals recovered from cm-size pumice lapilli in the Kinnear tephra and from coarse-grained tephra at the Muddy Creek site. Laser-fusion ^{40}Ar-^{39}Ar ages of sanidine from the two sites are coeval, 0.66 ± 0.01 Ma (weighted mean of two determinations) and 0.67 ± 0.01 Ma, respectively. Conventional K-Ar dating of sanidine from the tephra at the C1453 site resulted in an age of 0.60 ± 0.02 Ma. Glass-mantled zircon crystals from the C1453 site yielded a fission-track age of 0.67 ± 0.16 Ma. These isotopic ages are compatible with conventional K-Ar, ^{40}Ar-^{39}Ar, and fission-track ages of the Lava Creek Tuff, Member B in Yellowstone National Park and other occurrences of Lava Creek B as beds (J.D. Obradovich and G.A. Izett, unpublished data). We suggest that the terrace deposit that contains the Lava Creek B tephra rises from the Kinnear site northwest up the Wind River as a result of Quaternary uplift in the area of the Yellowstone hotspot (Pierce and Morgan, GSA Memoir 179, 1992).

1992, Geological Society of America, Abstracts with Programs, V. 24, No. 7 (Cincinnatti Meeting), p. A102,

Measuring Stone Decay with Close-Range Photogrammetry, Merchants Exchange, Philadelphia, Pennsylvania, USA

James A. Messerich[1], Jeffrey A. Coe[1], Charles L. Pillmore[1], Susan I. Sherwood[2], Anett Andersen[2], Victor G. Mossotti[3]

[1]US Geological Survey, MS 913, Box 25046, Denver Federal Center, Denver, Colorado 80225, USA

[2]National Park Service, 1100 L St., NW, Washington, DC 20013, USA

[3]US Geological Survey, 345 Middlefield Road, MS 938, Menlo Park, California, 94025, USA

ABSTRACT

Degradation of the Pennsylvania and Carrara marble exterior of the 160-year-old Merchants Exchange building (MEEX) in Philadelphia is being studied in relation to micro-environmental conditions that exist around the building. Rates of loss of material are being determined from detailed photogrammetric measurements at several locations on the east- and west-facing sides of the building. At each location, close-range stereoscopic photographs were taken in 1987 and 1991; these locations will be rephotographed in five-year or longer increments. An analytical stereo plotter equipped with Multi-Model Stereo Restitution software was used to orient the photographs to hand-measured distances and surveyed sapphire rods. Three-dimensional profiles were collected, plotted, and analyzed, and then archived for future reference. Maximum long-term degradation rates were 0.1 mm/yr for Pennsylvania marble on the east side of the MEEX as determined by comparing the amount of erosion at an interior location to the amount at exposed locations more extensively degraded. The maximum short-term degradation rate determined from measurements made from 1987 and 1991 photographs was approximately 0.1 mm/yr for Pennsylvania marble on the east side of the MEEX.

Coe, J.A., Sherwood, S.I., Messerich, J.A., Pillmore, C.L., Andersen, A., Mossotti, V.G., 1992, Measuring stone decay with close-range photogrammetry, Proceedings - 7th International Congress on Deterioration and Conservation of Stone, Lisbon, Portugal, pp. 917-926.

ORIGIN OF BRECCIA OF THE ISOM FORMATION NEAR CEDAR BREAKS NATIONAL MONUMENT, MARKAGUNT PLATEAU, SOUTHWESTERN UTAH

MOORE, David W., U.S. Geological Survey, P.O. Box 25046, Denver Federal Center, M.S. 913, Denver, CO 80225

Breccia forms an unconsolidated residual deposit on parts of the Markagunt Plateau near Cedar Breaks. Grain size ranges from silt to clasts 4 m across. The breccia is chiefly highly resistant tuff of the Isom Formation but includes mixed volcaniclastic rocks of the underlying white Claron Formation. It is generally 2-10 m thick but locally is 40 m. Terrain formed on the breccia is hummocky, bouldery, and marked by closed depressions; it resembles glacial ground moraine.

Breccia south of Cedar Breaks was emplaced by successive small-scale landsliding in clay beds in the uppermost white Claron Formation. At the same time, streams were cutting deeply into the Claron Formation. Brecciation of the sheet of tuff (Isom Formation) probably began about early Miocene time with the onset of basin-range faulting. This tectonism produced NE-trending fractures and normal faults in the tuff. Lateral support was removed from the northwest flank of the plateau and the tuff as the Colorado Plateau was uplifted and separated from the Basin and Range Province along the Hurricane and Paragonah Faults. At the northwest and south edges of the sheet, blocks slid and rotated on local shear surfaces in the wet, plastic clay beds high in the underlying white Claron Formation. Rotational sliding was multiple (on many failure surfaces tangential to a common slip sole) and successive. Gravitational spreading brecciated and attenuated the brittle tuff. These processes continue presently at Brian Head, a small remnant of the autochthonous tuff on the western Markagunt Plateau. While frost-shattering, solifluction, and transport of breccia by ice may have occurred in Pleistocene time, no unequivocal evidence for such processes was seen in the field.

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