UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Abstracts of the U.S. Geological Survey, Central Region, 1988 Poster Review

Collected Abstracts of Selected Poster Papers Presented at Scientific Meetings

Compiled by

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

Open-File Report 88-643

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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

CONTENTS

MINERALOGY/PETROLOGY

ORE DEPOSITS

SEDIMENTOLOGY/STRATIGRAPHY

PETROLEUM GEOLOGY

STRUCTURE/TECTONICS

ENVIRONMENT OF CRYSTALLIZATION OF TOPAZ AS DETERMINED FROM CRYSTAL CHEMISTRY AND INFRARED SPECTRA

FOORD, Eugene E., JACKSON, Larry L., TAGGART, Joseph E., CROCK, James G., and KING, Trude V. V., M.S. 905, U.S. Geological Survey, Box 25046, Denver Federal Center, Denver, CO 80225

Topaz, $Al_2SiO_4(F,OH)_2$, is usually found as a vapor-phase or hydrothermal crystallization product in three geologic associations: in rhyolites(R), pegmatites and greisens(P), and hydrothermal veins(H). The mineral also occurs as a liquidus phase in ongonites and some rhyolites. Compositions of 46 topaz samples (4R, 27P, 15H) are distinctly grouped in terms of H_2O^+, F, and trace element content. The average H_2O^- content for all samples was 0.04($\pm$0.01) wt. %. H_2O^+ contents (in wt. %) for R topaz ranged from 0.06 to 0.11, for P topaz from 0.20 to 0.91, and for H topaz from 1.98 to 2.67; fluorine content is inversely related to water content. A maximum of about 30% of the F site is occupied by OH in H topazes. The F-OH ratio correlates with, and possibly is controlled by the temperature of crystallization. Results obtained confirm the correlation of Ge content with OH/(OH+F) ratios discovered by Duck (1986) and Duck & Cohen (1988).

Trace and minor elements that vary by association include Li, Fe, Cr and Ge. The average Li content of R topaz (50 ppm) is $\geq$ five times that of P and H topaz. All samples contain trace amounts of Fe (as much as 0.3 wt. %). Chromium, present in some samples of H topaz, and derived from host schist or ultramafic host rocks, is the chromophore in the pink-red and orange-red crystals from Ouro Preto, Brazil and Katlang, Pakistan; pink to burgundy colored crystals from both of these localities contain 400 - 500 ppm Cr. Germanium contents are elevated in four samples of P topaz (200 ppm Mt. Antero, CO; 500 ppm Little Three mine, Ramona, CA; 550 ppm Maple Lode mine, Aguanga Mtn., CA; and 400 ppm Satao (Viseu), Portugal).

Other physical properties, e.g. density, unit-cell data, and optical data vary linearly with the substitution of OH for F. Any of these properties may be used to predict topaz type.

Reflection IR spectra of F-rich (R type topaz) and OH-rich (H type) are distinctly different. Three narrow, well-defined, OH bands are characteristic of R topaz (3400 to 3800 cm^{-1}). P topaz shows OH bands from 3400 to 4200 cm^{-1}. OH-rich topaz (H type) displays a further intensified spectrum of OH bands between 3400 and 4200 cm^{-1}. OH-rich topaz also contains CO_2 as indicated by a sharp peak at 2300 cm^{-1}. Disorder is indicated for the OH-rich material which is consistent with its known triclinic symmetry.

GSA Abstracts with Programs, 1988, v. 20, no. 7.

CARBONATE SPELEOTHEMS IN A FAULT-CONTROLLED CAVE IN PRECAMBRIAN GNEISS, COLORADO FRONT RANGE

MODRESKI, Peter J.; VERBEEK, Earl R.; WENRICH, Karen J.; VAN GOSEN, Bradley S., U.S. Geological Survey, Mail Stop 905, Box 25046, Federal Center, Denver, CO 80225; and MAST, Virginia, Geology Museum, Colorado School of Mines, Golden, CO 80401

Unusual and exceptionally well-developed examples of aragonite and calcite speleothems in a cave within Proterozoic gneiss were discovered May 12, 1988, during blasting in a quarry on the north side of Clear Creek Canyon, Jefferson County, CO. The cave is about 50 m long, as much as 20 m high, and as much as 10 m wide (narrowing upwards). It trends N. 50° W. and is developed in altered, crushed, and collapsed rock along the Junction Ranch fault zone, a major, recurrently active fault zone of Precambrian ancestry. In surface exposures immediately above the cave, the intensely sheared zone is 1.5-4 m wide, trends N. 50° W., and dips 75° NE; subhorizontal slickenside striations document the last tectonic movement along the shear surfaces as strike-slip. Lenticular voids that formed along mismatched fault surfaces during movement (probably Pliocene or older) on the fault itself may have been the original openings that, through later collapse and/or solution of gouge by groundwater, developed into the fissure cave. The open space along the shear surfaces could also have formed or been enlarged by downslope sliding and rotation of footwall blocks along SW-dipping foliation surfaces on the steep canyon slope. Other fissure caves, lacking speleothems and not located on a fault, are developed along joints in bedrock a few km from this locality.

Parts of the hanging wall and ceiling are thickly covered with actively growing aragonite stalactites, helictites (including beaded helictites), and crystal clusters. "Frostwork" aragonite crystals and hydromagnesite "moonmilk" on the tips of some speleothems are a result of buildup of Mg^{2+} in slowly-dripping water. A thin (1-3 mm) drusy crust of aragonite covers much of the footwall and cements breccia fragments. Larger masses of calcite "flowstone" (travertine) formed locally in the cave. The source of Ca for the speleothems could have been marble and calcareous horizons within the surrounding gneissic terrane, probably augmented by dissolution of ankeritic carbonate previously deposited within the fault zone.

GSA Abstracts with Programs, 1988, v. 20, no. 7.

CLAY MINERALOGY AND DIAGENETIC EVOLUTION OF DEEPLY BURIED ROCKS OF THE SIMPSON GROUP (MIDDLE ORDOVICIAN), ANADARKO BASIN, OKLAHOMA

Richard M. Pollastro

U.S. Geological Survey, Box 25046, MS 960, Denver, Colorado 80225

The mineral composition and petrography of sandstones, shales, and carbonates were determined from 120 core samples of the Middle Ordovician Simpson Group recovered from present depths of 15,900 to 17,200 ft. Although the bulk-rock mineral composition of these rocks is quite diverse, clay minerals are restricted to illite and chlorite due to deep burial conditions.

The main clay mineral in the Simpson Group at these depths is illite, though iron-rich chlorite is sometimes concentrated locally in sandstones. Illite, defined as both a discrete 10-angstrom phase and an apparent "mixed-layer" illite/smectite (R3) from X-ray powder diffraction (XRD) profiles, is of both detrital and diagenetic origin; it typically makes up >90 relative weight percent (wt%) of the clay minerals in sandstones and >95 wt% of those in shale and carbonate. SEM shows that much of the diagenetic illite occurs as tabular fibers in pores or as pseudomorphic intergrowths after smectite. Thin section microscopy also shows that much of the illite appears as sericite. Textural relationships also suggest that the conversion of smectite to illite at depth contributed, in part, to the formation of dolomite and ankerite cements. Much of the dolomite is found replacing detrital clay.

Iron-rich chlorite typically makes up <10 wt% of the clay minerals; however, chlorite sometimes composes >80 wt% of the clay minerals in sandstones. Most chlorite is authigenic and occurs as a pore-lining cement and as a pseudomorphic replacement after kaolinite. Such an assemblage is consistent with burial conditions wherein temperatures exceeded 150 °C.

Shales are clay rich and quartz poor, averaging about 85 wt% clay minerals, 7 wt% quartz, and 3 wt% feldspar, as determined by XRD; carbonate minerals and pyrite are present in variable amounts. Such high clay/quartz ratios are not characteristic of shales and suggest that significant quantities of silica have been expelled by diagenetic processes during deep burial.

Pollastro, R. M., 1988, Clay mineralogy and diagenetic evolution of deeply buried rocks of the Simpson Group (Middle Ordovician), Anadarko basin, Oklahoma [abs.]: Program and Abstracts, 25th Annual Meeting, Clay Minerals Society, Grand Rapids, Michigan, p. 54.

MONODISPERSE COLLOIDS FROM A STREAM CONTAMINATED BY ACID MINE DRAINAGE

Kathleen S. Smith, U.S. Geological Survey, DFC, Box 25046, MS 973, Denver, CO 80225, James F. Ranville, Donald L. Macalady, and Terry F. Rees

A suite of samples of flocculated streambed material was collected along a metal-rich, acid-mine-drainage impacted stream (pH 3.5). Physical, chemical, and surface properties of this iron-rich flocculated material were investigated. Examination by scanning-electron microscopy and laser-light scattering (photon correlation spectrometry) reveals that the samples are composed of aggregates (1-10 microns) of monodisperse, 0.04-micron spheroids. Measurements of the electrophoretic mobility of these aggregates, using an electrophoretic light-scattering technique, indicate a uniform, near-neutral charge in the shear plane. This near-neutral surface charge may affect adsorptive and photoreductive processes involved in metal transport along the stream.

Smith, K. S., Ranville, J. F., Macalady, D. L., and Rees, T. F., 1988, Monodisperse colloids from an acid-mine-drainage impacted stream [abs.]: International Meeting of the American Chemical Society, Toronto, Canada, June 5-10, 1988.

IMAGE PROCESSING OF TIMS DATA OF CARLIN, NEVADA - NOISE REMOVAL AND REGISTRATION TO 1:24,000 SCALE MAPS

Susanne Hummer-Miller

U.S. Geological Survey
Denver, Colorado

The Thermal Infrared Multispectral Scanner (TIMS) is an experimental aircraft instrument that provides six channels of radiance data in the 8-12 micron region of the electromagnetic spectrum. TIMS data were acquired July 1983 at approximately 10:30 local solar time of the Tuscarora Mountains, including the Carlin gold deposit, in north-central Nevada. Data covering most of the Rodeo Creek NE 7 1/2 minute quadrangle were noise filtered and registered to a 1:24,000 scale map.

TIMS data, in general, contain noise from a number of sources: random detector noise, low- and high-frequency striping, microphonic interference, and signal-dependent bit error noise. The random and the bit error noise were removed by applying a median threshold filter in the spatial domain. The remaining noise was diminished by creating special filters in the Fourier domain using a trial-and-error process on decorrelated imaes that enhance the detection of the noise.

Registration of the TIMS aricraft data to the 7 1/2 minute topography base was accomplished in two steps. Thematic Mapper (TM) satellite data, acquired July 1984 at approximately 10:00 local solar time, were first registered using an affine transformation to the topographic map of the Rodeo Creek NE quadrangle. Subsequently, the TIMS data, which were acquired with similar illumination geometry, were registered to the TM data using an algorithm that is the weighted sum of the nearest control points.

Both noise removal and accurate registration are important factors for detailed geologic interpretation of TIMS data. Although the six thermal channels contain emittance information of rock-forming minerals, the emissivity contrast of geologic materials in the 8-12 micron region is low and decorrelation techniques are required to extract the subtle differences. Because random noise is also enhanced by decorrelation, such noise can cause spurious spectral artifacts and thus must be removed before detailed interpretation can be performed.

Accurate registration of the data to a map base is important for studying the spatial association of anomalies, some of which are quite small on decorrelated images. Accurate location is also required for comparison of TIMS data with other data sets (geology, topography, TM, etc.) and for accurate field checking of results.

Hummer-Miller, Susanne, 1988, Image processing of TIMS data of Carlin, Nevada - noise removal and registration to 1:24,000 scale maps: Summaries from 6th Thematic Conference on Remote Sensing for Exploration Geology, Houston, Texas, p. 115.

GEOLOGICAL RELATIONSHIPS, K-AR AGES, AND ISOTOPIC DATA FROM THE WILLOW CREEK GOLD MINING DISTRICT, SOUTHERN ALASKA

MADDEN-McGUIRE, DAWN J., SILBERMAN, MILES L., and CHURCH, STANLEY E., U.S. Geological Survey, Box 25046, MS 973, Federal Center, Denver, CO 80225-0046

The Willow Creek mining district is located in the Peninsular terrane, on the southwestern margin of the Talkeetna Mountains batholith. The district contains exposures of tonalite (74-73 Ma, *61-65 Ma to north of Willow Creek district) and adamellite (67-65 Ma) of the batholith and an older unit of schist which has no nearby correlative units. The tonalite and schist both host gold-bearing quartz veins in fractures and shears, whereas the adamellite appears to be barren of gold mineralization. Our data suggest that there is a previously unmapped fault along the contact between the mineralized tonalite and schist. The fault may have provided a conduit for mineralizing fluids, and may represent a potential target for gold exploration.

Geologic relations and K-Ar ages indicate that at least two periods of hydrothermal activity occurred at 66 Ma and at 57-55 Ma. At 66 Ma, gold-bearing quartz veins were emplaced while the intruding adamellite and dikes of pegmatite and aplite provided heat to the host rocks. At 57-55 Ma, the hydrothermal activity coincided with minor volcanism recorded in the overlying sedimentary rocks and with the first movement along a regional strike-slip fault south of the mining district. This second period of hydrothermal activity could have led to a new phase of mineralization or to remobilization of the constituents of the older mineralized veins. Both periods of hydrothermal activity occurred during right-oblique subduction of the Kula plate beneath the Peninsular terrane and mineralizing fluids may have originated in zones of metamorphism and partial melting in the descending Kula plate.

Calculations from our data suggest that the oxygen-isotopic compositions of the mineralizing fluids in the tonalite and schist were similar to the tonalite and unlike the schist. This could have resulted if the fluids equilibrated with the tonalite at temperatures high enough that fractionation approached zero. The measured values of $\delta^{18}O$ from quartz in gold-bearing veins are +13.2 to +15.8, with one low value of +9.2, and the calculated fluid values are +6 to +8. These values occur in the veins with ages of 66 Ma, as well as in undated veins. The Pb-isotopic compositions of sulfides from two veins in the tonalite are nearly identical, but differ from those in the schist. These compositions suggest that the Pb in veins in the tonalite had a common source. In the schist, the gold-bearing fluids may have exchanged Pb with the metasedimentary rocks.

We suggest that at 66 Ma, a fluid equilibrated with the tonalite at high temperature, then mineralized both the tonalite and the schist. However, the fluid exchanged Pb with the schist and developed a more radiogenic Pb-isotopic signature than it had in the tonalite.

Madden-McGuire, D.J., Silberman, M.L., and Church, S.E., 1988, Geological relationships, K-Ar ages, and isotopic data from the Willow Creek gold mining district, southern Alaska: Geological Society of Australia Abstracts Series Number 23, Extended Abstracts, Poster Programme, Bicentennial Gold Conference, May 16-20, 1988, Melbourne, Australia, v. 1, p. 368-370.

RECONNAISSANCE OF COLORADO FRONT RANGE BOGS FOR URANIUM AND OTHER ELEMENTS

OWEN, Douglass E., SCHUMANN, R. Randall, and OTTON, James K., U.S. Geological Survey, Box 25046, MS 939, DFC, Denver, CO 80225

Alpine bogs or mountain wetlands in the Colorado Front Range commonly form along spring lines in valley floors and in areas where drainage is restricted by moraines, slides, and beaver dams. The bogs generally lie between 7,000 and 10,000 feet elevation and are geologically young (late Pleistocene or early Holocene to late Holocene). The alpine bogs are classified botanically as fens (sedge, grass, or reed-dominated minerotrophic peatlands), as carrs (wetlands that occur on organic soil composed of minerotrophic peat with greater than 25% shrub cover), as bogs (where sphagnum moss is dominant),or as a combination of these. These bogs or wetlands contain peat and organic-rich muck from a few decimeters to several meters thick. Peat has a great affinity for highly charged cations such as uranyl (UO_2^{2+}) that can be complexed and carried in local ground water. The geochemical enrichment factor between peat and uranium-bearing ground water can approach or exceed 10,000 to 1. As the bog sediments are geologically young, the uranium is in gross disequilibrium with its daughters, and the resultant low gamma radioactivity makes these occurrences undetectable by ground and aerial gamma ray surveys.

Reconnaissance auger sampling of bogs was conducted in the Colorado Front Range from the South Park area to the Colorado- Wyoming State line. Samples were dried and analyzed for elemental uranium and thorium using a delayed neutron activation technique. In addition, some samples were analyzed for 44 elements using ICP-OES (inductively coupled plasma-optical emission spectrometry). Most of the bogs have uranium concentrations in the 10-100 ppm range; however, samples from several of the bogs have uranium concentrations as high as 1,000-3,000 ppm on a dry weight basis. Some of the bog samples show concentrations of between 100 and 1,000 ppm for barium, manganese, strontium, and zinc. Bismuth, chromium, cobalt, copper, gallium, lead, nickel, tin, and vanadium were found in concentrations between 10 ppm and 100 ppm on a dry weight basis in some of the samples. These elements are not necessarily associated with high uranium concentrations.

Some of the bogs, in addition to being mined for peat, may contain enough uranium to be of commercial interest. Furthermore, uraniferous bogs are of environmental concern because of the previously unrecognized risk to local water quality. Uranium (and other metals) could be remobilized from the peat during interaction with acid mine drainage or during oxidation following a lowering of the water table or draining of the bogs. Because of the results of this reconnaissance study and the importance of these wetlands as natural filters, in a region where a high percentage of the water for domestic use comes directly or indirectly from the wetlands, a multidisciplinary approach has been initiated to investigate the processes involved in the migration and trapping of uranium and other elements.

Owen, Douglass E., Schumann, R. Randall, and Otton, James K., 1988, Reconnaissance of Colorado Front Range bogs for uranium and other elements _in_ USGS Research on Energy Resources-1988; Program and abstracts: USGS Circular 1025 pp. 42-44

A POST-TECTONIC RARE-METAL-RICH GRANITE IN THE SOUTHERN COMPLEX, UPPER PENINSULA, MICHIGAN

SCHULZ, K.J., U.S. Geological Survey, Reston, VA 22092; Sims, P.K. and Peterman, Z.E., U.S. Geological Survey, Denver, CO 80225

A small undeformed alkali feldspar granite of Early Proterozoic age in the southern complex, 2 miles south of Humboldt in the Upper Peninsula of Michigan, is compositionally similar to rare-metal-rich granites and has a possible potential for Sn-W (Ta-Nb) mineralization. The granite was discovered and briefly described by Mark Hoffman (1987). It is roughly circular in outline, about 1 1/2 miles in diameter, and intrudes Archean Compeau Creek Gneiss. The granite is massive, fine- to medium-grained, equigranular to hypidiomorphic granular, nonfoliated, and light red to brick red. A prominent biotite foliation and (or) lineation is present near the margins. Fractures and joints are ubiquitous and typically are coated with micas. The mineralogy consists of K-feldspar, albite, quartz, biotite, muscovite, and accessory fluorite and zircon. Accessory uranothorite, columbite, euxenite, cassiterite, molybdenite, and topaz were reported by Hoffman (1987).

The granite is characterized by high SiO_2 (>74%), low $FeO_{(T)}$ (<2%), MgO (<0.2%), CaO (<0.5%), and TiO_2 (<0.02%), and near equal Na_2O and K_2O (4-5%) contents. The trace elements Rb (350-1000 ppm), Pb (20-70 ppm), Y (28-115 ppm), Nb (35-209 ppm), and Ta (21-36 ppm) are strongly enriched, and Sr (<17 ppm), Ba (<20 ppm), and Eu (<0.07 ppm) are strongly depleted compared to average granites. The REE have U-shaped chondrite normalized patterns with very large negative Eu anomalies (Eu/Eu* <0.025). A Rb-Sr age on three whole rock samples is 1,733 ± 25 Ma; the Sr initial ratio is 0.817 ± 0.078 (Model I, MSWD = 1.55).

Compositional features of the granite stock are similar to those of Sn-W mineralized alkali-feldspar granites of the Arabian Shield and the Nigerian Younger Granite province, and to the topaz rhyolite suite of the Western United States. Highly evolved, rare-metal-rich granite stocks, or cupolas, typically occur in clusters or linear arrays that commonly are related to larger granite bodies as, for example, in the Arabian Shield. Although highly greisenized rocks have not been found in the granite near Humboldt, its enrichment in trace elements and the possibility of other similar intrusions in the area suggests this region of the Upper Peninsula of Michigan could have a significant potential for Sn-W (Ta-Nb) resources.

Schulz, K.J., Sims, P.K., and Peterman, Z.E., 1988, A post-tectonic rare-metal-rich granite in the southern complex, Upper Peninsula, Michigan: Thirty-fourth annual meeting Institute on Lake Superior Geology, Marquette, Michigan, p. 95-96.

WEATHER FACTORS AFFECTING SOIL-GAS RADON CONCENTRATIONS AT A SINGLE SITE IN THE SEMIARID WESTERN U.S.

SCHUMANN, R. Randall, OWEN, Douglass E., and ASHER-BOLINDER, Sigrid, U.S. Geological Survey, MS 939, DFC, Denver, CO 80225

Measured concentrations of radon-222 in soil gas may vary by an order of magnitude or more in response to short- and long-term changes in weather and seasonal weather regimes. To gain insight into the effects of weather on soil-gas radon concentrations, a stationary soil-gas radon monitoring station was installed on the grounds of the Denver Federal Center (DFC) in Denver, Colorado, and has been in operation since March 1987. On a day-to-day basis, precipitation and changes in barometric pressure, temperature, and wind that accompany storms affect radon concentrations in soil gas. Day-to-day changes are generally relatively small in comparison to the larger-scale seasonal variations in soil-gas radon concentrations. Increased soil moisture resulting from precipitation reduces the gas permeability of soils and can produce capping effects that concentrate radon in the near-surface soil layers. Barometric pumping and thermal convection can increase or decrease radon concentrations in the shallow soil layers by drawing soil gas upward from greater depths or by forcing atmospheric air downward into the soil, diluting gases in the near-surface soil layers. Larger-scale variations in soil-gas radon concentrations are related to seasonal changes in weather regimes. At the DFC study site, radon concentrations in soils were highest during winter and spring, seasons which, in the Denver area, are characterized by generally unstable weather, with frequent storms and higher average soil moisture content. Summer and fall, seasons with less precipitation, drier soils, and generally stable weather conditions, were associated with lower soil-gas radon concentrations.

Schumann, R. Randall, Owen, Douglass E., and Asher-Bolinder, Sigrid, 1988, Weather factors affecting soil-gas radon concentrations at a single site in the semiarid Western U.S. (abs): EPA 1988 Symposium on Radon and Radon Reduction Technology, Denver, Colorado, Oct. 17-21, 1988.

CO-REGISTERED TIMS, GEOLOGY, AND TOPOGRAPHY DATA SETS FOR EVALUATING LITHOLOGIC DISCRIMINATION, CARLIN DISTRICT, NEVADA

Ken Watson[1], Fred A. Kruse[2], and Susanne Hummer-Miller[1]

[1]U.S. Geological Survey, Denver, Colorado

[2]Center for the Study of Earth from Space, University of Colorado, Boulder, Colorado

The Carlin Trend in northern Nevada is one of the most visible and active areas of mineral exploration in the United States. Thermal Infrared Multispectral Scanner (TIMS) data of the Rodeo Creek NE 7 1/2 minute quadrangle, Eureka County, covering the Carlin gold mine have been processed to remove substantial noise artifacts and then co-registered first to Landsat Thematic Mapper (TM) satellite data and then to the 1:24,000-scale geologic and topographic maps. Accurate registration of these data is necessary to examine a variety of geologic issues including additional discrimination, residual topographic artifacts in the data, and use of these data for exploration. Both decorrelation and thermal modeling techniques were applied to evaluate the use of these data in lithologic discrimination.

The Carlin gold mine lies within the Lynn subdistrict of the Carlin Trend of epithermal, sediment-hosted, disseminated gold deposits. Fine-grained siliceous clastics and cherty units were thrust over continental shelf carbonates in Late Devonian to Early Mississippean time and eroded. Plutons were then emplaced in the late Mesozoic. Doming and erosion of the upper plate rocks has exposed lower plate rocks in windows along a north-northwest trend. The prevailing basin-and-range topography resulted from Cenezoic extensional faulting; also Tertiary intermediate composition stocks, dikes, and flows are common in the area. The gold deposits of the Carlin Trend, introduced sometime between 4 and 145 m.y., are believed to be controlled by high angle faults in facies of favorable permeability. These deposits exhibit a close association with secondary silica and are generally localized within lower plate carbonate rocks.

The 8-14 micron region of the electromagnetic spectrum contains diagnostic spectral features of rock-forming minerals and thus has important potential for lithologic identification. Images of both day and night TIMS data were calibrated, noise corrected, color-composited, and then co-registered to the geologic and topographic maps. A detailed examination of these data indicate that, in addition to the disturbed ground related to mining activity, jasperoids, outcrops of quartzite, and extensive quartz latite flows are clearly discriminated from the surrounding carbonate assemblage of the Roberts Mountains Thrust. In addition, a significant number of spectral anomalies were also detected that indicate compositional differences within mapped units.

Watson, Ken, Kruse, F.A., and Hummer-Miller, Susanne, 1988, Co-registered TIMS, geology, and topography data sets for evaluating lithologic discrimination, Carlin district, Nevada: Summaries from 6th Thematic Conference on Remote Sensing for Exploration Geology, Houston, Texan, p.34.

THE FERN-SPORE ABUNDANCE ANOMALY: A REGIONAL BIOEVENT AT THE CRETACEOUS-TERTIARY BOUNDARY

Fleming, R.F., University of Colorado, Boulder, CO, and
Nichols, D.J., U.S. Geological Survey, Denver, CO

At most localities where the palynological Cretaceous-Tertiary (K-T) boundary has been located in continuous deposition sequences in nonmarine rocks, the boundary interval is characterized by anomalous concentrations of iridium, shocked mineral grains, and fern spores. The occurrences of iridium and shocked minerals are essentially coincident with the palynological extinction horizon that marks the boundary and are taken as evidence of an extraterrestrial impact event. The fern-spore abundance anomaly is characterized by: (1) unusually high relative abundance of spores, ranging from 70% to almost 100% (in contrast with 10% to 40% for typical Upper Cretaceous and Paleocene palynomorph assemblages in the same sections); (2) dominance of the fern-spore assemblage by only one of a few species at each locality; (3) restriction of the anomaly to a layer 0-15 cm above the K-T boundary; (4) isochroneity (based on palynological and geochemical evidence) and widespread distribution (from New Mexico to Saskatchewan); and (5) independence of lithology (the anomaly occurs in coals, carbonaceous shales, and mudstones). The fern-spore anomaly indicates the occurrence of a regional bioevent in earliest Tertiary time: the overwhelming dominance of the continental flora by pioneer species following massive destruction of existing plant communities. Initial colonization of a devastated land surface by ferns, followed by reestablishment of complex, angiosperm-dominated communities, has been observed on a small scale following volcanic eruptions in historic times. The bioevent associated with the K-T boundary was similar, but continental in scale.

Fleming, R.F., and Nichols, D.J., 1988, The fern-spore abundance anomaly: a regional bioevent at the Cretaceous-Tertiary boundary: The Third International Conference on Global Bioevents: Abrupt Changes in the Global Biota, Boulder, Colorado, Abstracts, p. 16.

PALEOCENE DRAINAGE SYSTEMS, ROCK SPRINGS UPLIFT, WYOMING

KIRSCHBAUM, M.A., U.S. Geological Survey, Box 25046, MS 972, Denver, CO; ANDERSEN, D.W, BALDWIN, R.J., and HELM, R.L., Dept. of Geology, San Jose State Univ., San Jose, CA 95192

The Green River basin of southwestern Wyoming is a large intermontane basin bounded by Laramide-age uplifts. Within the basin, the Rock Springs uplift was an active Laramide structure during early Paleocene time. In the Rock Springs uplift, an angular unconformity between Cretaceous and middle Paleocene rocks constrains the time of uplift.

The Paleocene Fort Union Formation consists mostly of feldspathic litharenite rich in metamorphic rock fragments that was derived from the Wind River Mountains, 100 km north of the Rock Springs uplift. A narrow belt of sublitharenite, rich in sedimentary rock fragments, is adjacent to the Uinta Mountains 15 km south. A zone of mixed facies is present near the southern edge of the uplift. On the west edge, sedimentary structures in fine- to medium-grained lenticular sandstone bodies indicate southerly paleocurrents. On the south edge, sandstones are coarser and structures indicate easterly paleocurrents. Pebbly sandstones are present adjacent to the Uinta Mountains. Sandstone bodies have erosional bases and fine upward, and are interpreted as fluvial channel deposits. Coal beds are associated with the channel sandstones north of the mixed zone.

Streams flowed parallel to the trend of the Rock Springs uplift on the west edge and were tributary to east-flowing streams on the south edge during the Paleocene. Easterly paleocurrents and mixed lithologies define the axis of a main trunk drainage parallel to the Uinta Mountains. South-flowing drainages were initially controlled by the topography of the north-south trending Rock Springs uplift. However, the presence of coal indicates the area began to subside in the middle Paleocene. Sediment derived from the Wind River Mountains indicates a southerly gradient in much of the Green River basin in Paleocene time. We interpret the orientation of the main drainage to be the result of basin subsidence during Paleocene uplift of the Uinta Mountains.

Kirschbaum, M.A., Andersen, D.W., Baldwin, R.J., and Helm, R.L., 1988, Paleocene drainage systems, Rock Springs Uplift, Wyoming [abs.]: Geological Society of America Abstracts with Programs, v. 20, no. 6, p.424.

NEW STRATIGRAPHIC AND PALEONTOLOGIC DATA FROM THE LOWER CAMBRIAN TO LOWER ORDOVICIAN(?) PREBLE FORMATION, HUMBOLDT COUNTY, NEVADA

MADDEN-McGUIRE, Dawn J., U.S. Geological Survey, DFC, Box 25046, MS 973, Denver, CO 80225; CARTER, Claire, U.S. Geological Survey, MS 915, 345 Middlefield Road, Menlo Park, CA 94025

Outcrops of the gold-bearing Preble Formation extend about 30 mi (50 km) from the northern Osgood Mountains south-southwestward into the Sonoma Range. The formation is the host for gold deposits in the Preble and Getchell mines in the Osgood Mountains, Humboldt County. The type locality of the Preble is in the southern Osgood Mountains at the site of the old Preble railroad station. In the mapped type area, weakly metamorphosed, intensely deformed shelf/slope(?) deposits consist of phyllite, redeposited limestone, quartzite, and bedded barite. These deposits are tightly folded, plunge southward, and are structurally overturned to the west; strata dip steeply to the east, 40°-75°. Early Ordovician graptolites were collected 1 mi (1.6 km) southeast of the type locality, from phyllite that previously was mapped as Preble Formation. The recent identification of these graptolites suggests that the age of the Preble Formation may extend into the Ordovician near its type locality.

Mapping of several distinctive limestone beds near the type locality of the Preble Formation has served to illustrate the westward-overturned structure in the Preble and has permitted us to see for the first time a stratigraphic succession consisting of quartzite, bedded barite, phyllite, and at least five interbedded limestone strata. The most extensive limestone is a blue-gray ooid packstone (oolite), which contains distinctive, orange-brown-weathered dolomitic lenses. The oolite can be traced around folds, and it pinches and swells along strike for more than 4 mi (6 km). A stratigraphically higher, pale-orange bioclastic limestone with a grain-supported texture extends 2 mi (3.5 km) along strike, parallel to the trace of the oolite. A limestone that is stratigraphically below the oolite contains local limestone breccia interpreted as debris flow and associated turbidite. Stratigraphically beneath this interval is a siliciclastic section that contains bedded barite, and quartzitic channel deposits as much as 400 ft (120 m) in thickness.

Madden-McGuire, Dawn J., and Carter, Claire, 1988, New stratigraphic and paleontologic data from the lower Cambrian to lower Ordovician(?) Preble Formation, Humboldt County, Nevada: Geological Society of America Abstracts with Programs, Annual Meeting, Denver, Colorado, October 31-November 3, v. 20.

STRATIGRAPHIC DISTRIBUTION SUGGESTING ENVIRONMENTAL SIGNIFICANCE OF POLLEN IN LATE CRETACEOUS UPPER ILES AND LOWER WILLIAMS FORK FORMATIONS, RIFLE GAP, GARFIELD COUNTY, COLORADO

MADDEN-McGUIRE, Dawn J., U.S. Geological Survey, Box 25046, MS 973, Federal Center, Denver, Co 80225; and NEWMAN, Karl R., Dept. of Geology and Geological Engineering, Colorado School of Mines, Golden, CO 80401

Intertonguing marine and coal-bearing nonmarine strata (364 m) constitute the upper Iles and lower Williams Fork Formations of the Mesaverde Group in Rifle Gap. The Trout Creek Sandstone Member (33 m) at the top of the Iles Formation formed in shoreface environments. Below the Trout Creek is a unit of marine siltstone and shale (94 m). Above the Trout Creek, in the Williams Fork Formation, are a coal-bearing unit (95 m) formed in fresh- and brackish-water environments on a lower delta plain, a shoreface sandstone (21 m) recording a local shoreline transgression, and a second coal-bearing unit (121 m) of fresh- and brackish-water lower delta plain deposits of the last local shoreline regression in late Campanian time.

We have found a distinctive assemblage of Normapolles pollen in these 364 m of strata, but not in overlying freshwater deposits of upper delta and meandering stream plains. Short-ranging Myrtaceoipollenites is found only in the 364 m interval, and the local range-zone tops of Trudopollis, Pseudoplicapollis, Vacuopollis, and possibly, Plicapollis all occur in this interval. We conclude that the plants producing the pollen lived in lower delta plain environments and that the local range-zone tops were environmentally, as well as age, controlled. Four of the genera may have become locally extinct before the end of Campanian time as shorelines prograded eastward; only (?) Trudopollis continued into similar deposits of early Maestrichtian age in eastern Colorado.

Madden-McGuire, Dawn J., and Newman, Karl R., 1988, Stratigraphic distribution suggesting environmental signficance of pollen in Late Cretaceous upper Iles and lower Williams Fork Formations, Rifle Gap, Garfield County, Colorado: Geological Society of America Abstracts with Programs, Rocky Mountain Section, Sun Valley, Idaho, May 16-18, v. 20, no. 6, p. 430.

The Frontier Formation and Associated Rocks of
Northeastern Utah and Northwestern Colorado

by C. M. Molenaar[1] and B. W. Wilson[2]

The Frontier Formation of the Mancos Group in northeastern Utah and northwesternmost Colorado (proposed new rank designations; formerly known as the Frontier Sandstone Member of the Mancos Shale) consists of several facies of marine and nonmarine rocks of Late Cretaceous (Turonian) age that grade eastward into totally marine rocks in easternmost Utah and northwestern Colorado. The Mancos Group in the report area is divided into the Mowry Shale, an unnamed shale unit, the Frontier Formation, and the main body. Six major facies, some of which are only in parts of the report area, are recognized in the Frontier. In ascending order, these are: (1) a basal, transgressive marine sandstone; (2) a marine shale tongue that correlates with the Tununk Member of the Mancos Shale in central Utah and is here recognized as a member of the Frontier; (3) a prograding coastal sandstone; (4) a sequence of nonmarine sandstone, shale, and coal; (5) an upper, transgressive coastal sandstone; and (6) an offshore-bar sandstone. Along the south flank and along the north flank of the eastern part of the Uinta Mountains, these rocks range in thickness from 760 ft (232 m) on the west to 140 ft (43 m) on the east. A lower Turonian transgressive sandstone at the base of the Frontier unconformably overlies an unnamed Cenomanian(?) shale unit in the southwestern part of the Uinta Mountains area. Elsewhere around the Uinta Mountains, an upper middle Turonian shale member of the Frontier unconformably overlies the Lower Cretaceous (Albian) Mowry Shale (proposed new rank designation; formerly known as Mowry Member of Mancos Shale in all but the Utah part of the north flank of the Uinta Mountains). Apparently the intervening Turonian rocks onlap from west to east. After deposition of the basal shale member of the Frontier, a deltaic wedge prograded eastward and southeastward to the vicinity of Split Mountain east of Vernal, Utah, and Vermillion Creek in northwesternmost Colorado. The shoreline trend of the deltaic wedge was about N. 60° E. across the eastern Uinta Mountains but probably swung abruptly to the northwest in Wyoming north of the mountains. To the southwest, the shoreline trend was about N. 55° E. across the Uinta basin. A 100- to 200-ft (30-60 m) relative sea-level rise resulted in deposition of a transgressive shale and overlying offshore-bar sandstone at the top of the Frontier in the eastern part of the area. The offshore-bar and underlying shoreface-equivalent sandstones extend far to the east in Colorado as offshore-shelf units of thinly bedded sandstone and shale.

Correlation of the Frontier Formation near the Uinta Mountains with the 7800-ft-thick (2377 m) Frontier Formation near Coalville, Utah, in the overthrust belt to the northwest, indicates great depositional thickening at Coalville, where both older and younger rocks are included in the Frontier. At Farnham dome southeast of Price, Utah, on the south side of the Uinta basin, the Frontier is represented by the much thinner, totally marine, upper middle Turonian Ferron Sandstone Member of the Mancos Shale.

REFERENCE

Molenaar, C.M., and Wilson, B.W., The Frontier Formation and associated rocks of northeastern Utah and northwestern Colorado: U.S. Geological Survey Bulletin 1787 (in preparation).

[1]U.S. Geological Survey, Box 25046, MS 940, Federal Center, Denver, CO 80225
[2]Deceased

PRELIMINARY FACIES ANALYSIS OF THE SEQUENCE OF ROCKS BELOW THE UPPER WYODAK COAL BED, PALEOCENE FORT UNION FORMATION, SOUTHEASTERN POWDER RIVER BASIN, WYOMING

PIERCE, Frances Wahl, and JOHNSON, Edward A., U.S. Geological Survey, Box 25046, MS 937, Federal Center, Denver, CO 80225

We conducted a preliminary facies analysis of as much as 646 ft of the rock sequence below the upper Wyodak coal bed, Paleocene Fort Union Formation, at three locations along the southeastern margin of the Powder River Basin, Wyoming. Channel, overbank sandstone, floodplain, and swamp facies are recognized. We believe these facies were deposited on an alluvial plain.

In the main study area, the channel facies is characterized by channel-form, fine to very fine grained sandstone bodies 10-50 ft thick that fine upward and have erosional bases. Lower parts of these bodies are trough cross stratified or convolute bedded. Upper parts generally consist of thin-bedded sandstone with rare, poorly developed ripple laminations and mudrock partings. Paleocurrent measurements indicate sediment transport to the north and west.

Interchannel areas are represented by the three remaining facies noted. The overbank sandstone facies is represented by fine to very fine grained tabular beds about 1-7 ft thick. Basal contacts are generally sharp and upper contacts are sharp to gradational. Lower parts of these beds are usually featureless; upper parts are parallel laminated or display poorly developed ripple laminations. Burrows, fluid escape structures, and weakly developed paleosols are also present. We interpret the overbank sandstone facies to represent crevasse splay or sheet flood deposits. The floodplain facies consists primarily of rooted gray mudrock 1-30 ft thick with zones of ironstone concretions. The mudrock is commonly laminated and contains abundant fossil plant debris. This facies accumulated on a floodplain that was probably permanently saturated by a high water table. The swamp facies consists of brown to black carbonaceous shale 1-17 ft thick and coal beds 1-7 ft thick.

In outcrop, these facies occur in laterally continuous zones that we call sandstone-dominated and mudrock-dominated complexes. These complexes are arranged vertically in an alternating sequence, possibly reflecting the migration of meandering fluvial channels across the alluvial plain.

Eleven miles to the north and 13 mi to the south, additional outcrop studies identified similar facies in the interval below the upper Wyodak coal. To the north, the facies occur in almost the same proportion as in the main study area, but to the south, facies of the interchannel areas are much more common than the channel facies. In neither outlying area can we recognize sandstone-dominated complexes as we can in the main study area. We believe that the changes in facies proportion and arrangement can be explained by different depositional processes operating in each of the three areas.

By analyzing facies and interpreting the environment of deposition, we are beginning to reconstruct the paleogeography of part of the south-eastern Powder River Basin just prior to the accumulation of peat that resulted in the economically important Wyodak coal deposit. By understanding the conditions preceding the accumulation of this peat, we are gathering information that will enable us to design a model depicting the origin of the deposit. Such a model could be used by the mining industry to help develop exploration and mining plans.

Pierce, Frances Wahl, and Johnson, Edward A., 1988, Preliminary facies analysis of the sequence of rocks below the upper Wyodak coal bed, Paleocene Fort Union Formation, southeastern Powder River Basin, Wyoming, in Carter, L.M.H., ed., USGS research on energy resources--1988--Program and abstracts: U.S. Geological Survey Circular 1025, p. 47.

CORRELATION OF LOWER CRETACEOUS ROCKS, MADISON RANGE TO LIMA PEAKS AREA, SOUTHWESTERN MONTANA

by

R.G. Tysdal, T.S. Dyman, and D.J. Nichols

ABSTRACT

Lower Cretaceous strata in southwestern Montana were deposited in a nonmarine facies of the Cordilleran foreland in the west and a marine shelf facies of the foreland in the east. Some of the strata represent time-equivalent sediments deposited in different environments, and different names have been applied previously to the same strata even within the same area. The four measured sections presented here are in sequences of strata that have been telescoped by thrust faults of Late Cretaceous to early Tertiary age, and facies represented in the measured sections originally were deposited farther apart than they are now. Strata described herein are underlain by the Aptian to Albian(?) Kootenai Formation and are overlain by the Cenomanian to Turonian lower part of the Frontier Formation.

In the Snowcrest Range and Lima Peaks area, strata represented by the western two measured sections are assigned to the Albian Blackleaf Formation, which contains the Flood Member and the overlying volcaniclastic-rich Vaughn Member. The Taft Hill and Bootlegger Members of the Blackleaf Formation, in their type area near Great Falls, are not recognized by us in southwestern Montana. The eastern two measured sections represent strata in the Madison, Gravelly, and Greenhorn Ranges, where Albian rocks are assigned to the Thermopolis Shale, Muddy Sandstone, and Mowry Shale. In southwestern Montana the Thermopolis Shale and overlying Muddy Sandstone are lithically equivalent to the Flood Member of the Blackleaf Formation, whereas the Mowry Shale is equivalent to the Vaughn Member. Strata in the Snowcrest Range have characteristics in common with both the eastern and western facies. The geographic location for the change in nomenclature is arbitrary, but is placed along the axis of the Ruby River Valley, which separates the Snowcrest Range from the Greenhorn and Gravelly Ranges.

Dyman, T.S., Tysdal, R.C., and Nichols, D.G., 1988, Correlation of Lower Cretaceous rocks, Madison Range to Lima Peaks area, Montana (abs.): Geological Society of America, Abstracts with Programs, v. 20, no. 6, p. 413.

TERTIARY IGNEOUS INTRUSIONS AND RENEWED PETROLEUM GENERATION IN THE WESTERN DELAWARE BASIN, TEXAS

BARKER, Charles E., and PAWLEWICZ, Mark J., U.S. Geological Survey, MS 971, DFC, Denver, CO 80225

Above-average paleogeothermal gradients in the western Delaware Basin, which are associated with numerous igneous intrusions and increased heat flow, have thermally matured rocks as young as Late Permian. Mean random vitrinite reflectance (R_m)-depth profiles of samples collected from boreholes throughout the Delaware Basin form two distinct groups. One group, with a 0.5 %R_m/km gradient, is from the eastern portion of the basin, and the other, with a 0.7 %R_m/km gradient, is from the western portion. The difference between the two groups is attributed to Tertiary thermal events that increased heat flow and reheated the rocks of the western Delaware Basin after uplift and erosion. Reheating of the Magnolia Cowden-1 borehole has caused R_m to vary from 0.6% at 60 m (200 ft) near the top of the Guadalupian (Late Permian) to 2.8% in Devonian rocks at 2,900 m (9,500 ft).

Post-Mississippian tilting has produced a thicker, mostly uneroded sedimentary section in the eastern portion of the Delaware Basin. In the western part of the basin, this tilting caused uplift and erosion that exposed the Upper Permian section, prior to Cretaceous time. Ages of igneous intrusions in the western half of the Delaware Basin show that they were emplaced 40-30 Ma, followed by Miocene to Holocene (20-10 Ma) basin-and-range type block faulting and associated high heat flow. Iso-reflectance contours cut across formation contacts in the western Delaware Basin, indicating that this heating is post-tectonic--that is, it occurred after eastward tilting and erosion had reduced burial depth. The R_m data and burial history reconstruction indicate that oil was generated during near-maximum burial in Permian time, and that the area was reheated by increased heat flow in Tertiary time. Maximum temperatures computed from R_m-depth relationships suggest that paleogeothermal gradients exceeded 40 °C/km (2.2 °F/100 ft) in Tertiary time. This reheating thermally matured rocks as young as Guadalupian in the western Delaware Basin and caused a second episode of petroleum generation. By this time, however, the Permian reservoir rocks and Ochoan evaporite seals had been partially to completely eroded. Consequently, it appears that this further maturation of the Permian source rocks occurred when conditions for trapping the generated petroleum were poor.

These data suggest that there is little potential for major petroleum discoveries in the western Delaware Basin. Further, this study reiterates that the petroleum potential of large areas can be assessed by simple geologic methods--thermal history reconstruction and measurement of maturity of the sedimentary organic matter.

Barker, Charles E., and Pawlewicz, Mark J., 1988, Tertiary igneous intrusions and renewed petroleum generation in the western Delaware Basin, Texas (abs): U.S. Geological Survey Circular 1025, p. 1-2.

FLUID INCLUSION AND OTHER EVIDENCE FOR THE TIMING OF FLUID MIGRATION IN THE NIOBRARA FORMATION, BERTHOUD STATE 4 WELL, BERTHOUD OIL FIELD, DENVER BASIN, COLORADO

CRYSDALE, B.L., and BARKER, C.E., U.S. Geological Survey,
Box 25046, M. S. 921, Denver Federal Center, Denver, CO 80225

Petroleum production from the Upper Cretaceous Niobrara Limestone in the Denver Basin is largely restricted to the more permeable, fractured portions of the formation. Berthoud State 4 well cores from about 880-975 m (2900-3200 ft) depth contain zoned calcite in veins filling nearly vertical fractures. Primary, two-phase oil inclusions in these veins homogenize at a mean temperature (Th) of about 85 °C. These Th data are uncorrected for pressure and represent minimum rock temperature. Mean random vitrinite-reflectance (Rm) over this same depth interval is 0.65 percent. Interpretation of this Rm, using an empirical calibration with peak burial-temperature (Tpeak), indicates that these rocks reached a Tpeak of approximately 100 °C. Published clay-mineral assemblage data suggest Tpeak was at least 100 °C.

Burial history reconstruction for Berthoud State 4 suggests Tpeak was reached about 70 Ma, quickly followed by temperature decrease due to uplift and extensive erosion. This unique burial history fixes the time of oil migration at near-maximum burial.

Is this petroleum indigenous to this type II, kerogen-rich, thermally mature Niobrara source rock? Vertical fluid flow in the Denver Basin has been restricted by impermeable Cretaceous shales, perhaps resulting in the isolation of oils generated from the Niobrara Formation. The pale-yellow fluorescence of oil inclusions in the veins, indicative of a 30 to 45° API oil, is consistent with the 40° API oil produced from the Niobrara Limestone in the Berthoud field. However, attempts to prove the Niobrara is the source of the oil are ambiguous to date.

Abstracts with Programs Geological Society of America 1988, Annual Meeting, v. 20, no. 7, [in press.]

CORRELATION AND CHARACTERIZATION OF OILS USING BIOLOGICAL MARKERS, CUYAMA BASIN, CALIFORNIA

Paul G. Lillis

U.S. Geological Survey
Denver, Colorado 80225

ABSTRACT

Biological marker data obtained from gas chromatography and gas chromatography/mass spectrometry were used to characterize and correlate the oils in the Cuyama basin and to determine the likely source facies. Biological markers provide a wealth of information about petroleum and source rocks including information on paleoecology, depositional environment and thermal maturity. Pristane/phytane (pr/ph) ratios, and steroid and hopanoid distributions indicate that the Cuyama basin oils share a common source and thermal history, that the source facies was deposited in a slightly restricted marine environment, and that the organic matter was derived primarily from marine phytoplankton with a significant contribution from land plants and bacteria.

Previous studies have documented that the Miocene Monterey Formation is a major source rock for oils in several California basins. However, clear differences exist between the composition of Cuyama basin oils and typical Monterey oils. Cuyama basin oils have lower sulfur contents (< 0.5 wt. %), higher pr/ph ratios (1.7-1.9) and no 28,30-bisnorhopane, in contrast to Monterey oils which have higher sulfur contents (1-6 wt. %), lower pr/ph ratios (<1), and significant amounts of 28,30-bisnorhopane. The low sulfur content of the Cuyama basin oils is probably due to precipitation of microbially reduced sulfur with iron associated with terrigenous clay input, thus preventing sulfur incorporation into the kerogen. The higher clay content in the source facies is also indicated by higher diasterane content.

The Soda Lake Shale is the most likely source rock for the oil in the Cuyama basin although the lower member of the Monterey, the Saltos Shale, cannot be discounted as a possible source. If the Monterey Formation were the only source, the dissimilarity observed in Cuyama oil geochemistry could be attributed to variations in the depositional environment and organic source input.

in Bazeley, W.J.M. ed., 1988, Tertiary tectonics and sedimentation in the Cuyama basin, San Luis Obispo, Santa Barbara, and Ventura Counties, California: Pacific Section Society of Economic Paleontologists and Mineralogists, v. 59, p. 39-48.

SURFACE THERMAL MATURITY MAP OF THE UINTA, PICEANCE, AND EAGLE BASINS AREA, UTAH AND COLORADO

NUCCIO, Vito F., and JOHNSON, Ronald C., U.S. Geological Survey, Denver Federal Center, Box 25046, MS 939, Denver CO, 80225

Knowledge of thermal maturity is essential for basin analysis studies because heat and heat flow play major roles in mineral formation, hydrocarbon generation and destruction, ground-water flow, and petroleum reservoir quality.

We studied the thermal maturity of several hundred outcrop samples of coal and carbonaceous shale from Pennsylvanian through Quaternary rocks in the area encompassing the Uinta, Piceance, and Eagle basins of Utah and Colorado. All samples were analyzed for mean random vitrinite reflectance (Rm); thus, thermal maturity is defined by Rm for this study.

Our data show that Rm generally increases with age of the rock, reflecting increasing burial depth and residence time at maximum temperature. Some coals show local anomalously high maturities because of proximity to Tertiary intrusives. Rocks of the same age show a general decrease in maturity from south to north in all three basins, which probably results from a decrease in geothermal gradients from south to north. In the Uinta basin, Rm values range from about 0.40 to 0.70% around the margins of the basin to 0.45% in the Altamont-Bluebell oil field near the center. In the Piceance basin, Rm values range from about 0.50 to 0.70% around the margins to about 0.25 to 0.35% in the center. The Eagle basin shows the widest range of Rm values, from 0.30 to 0.50% around the margins to values in the 4.0% range near the center.

Some vitrinite anomalies in the study area are best explained by sampling and analytical problems, such as choosing recycled vitrinite grains from organically lean shales or collecting weathered, oxidized samples.

Nuccio, Vito F., and Johnson, Ronald C., 1988, Surface thermal maturity map of the Uinta, Piceance, and Eagle basins area, Utah and Colorado, [abs.]: American Association of Petroleum Geologists Bulletin, vol. 72/2, p. 229.

THERMAL MATURATION OF THE EASTERN ANADARKO BASIN, OKLAHOMA

Mark J. Pawlewicz

U. S. Geological Survey
Denver, CO

Thirteen wells were sampled in a profile across the eastern Anadarko basin, Oklahoma, from the northern shelf area near the Kansas state line, 125 miles (200 km) south to the deep portion of the basin in Caddo County, Oklahoma. Vitrinite reflectance measurements on these samples show that the level of thermal maturity of the sedimentary organic matter was set after maximum burial, by synorogenic heating.

Burial history reconstruction curves show the tectonic evolution of this area. Vitrinite reflectance measurements indicate temperatures higher than those generally accepted for the onset of hydrocarbon generation, and also higher than those found by other workers in the basin. Regression analysis yields a reflectance gradient of 0.109 percent R_m/1,000 ft (300 m). The 0.6 and 1.3 percent R_m isoreflectance lines define the interval of the oil window along the well profile. These lines can be used to estimate the level of thermal maturity of source rocks, and their volume. This information, in turn, can be used to estimate the volume of hydrocarbons generated by those rocks whose thermal maturity is within or above the oil window. Also, the generation potential of the thermally immature source rocks can be estimated by considering their volume above the 0.6 percent isoreflectance line.

Pawlewicz, M. J., in press, Thermal maturation of the eastern Anadarko basin, Oklahoma: U.S. Geological Survey bulletin 1866.

PERSISTENT COAL-FORMING SWAMP ADJACENT TO A TECTONICALLY ACTIVE BASIN MARGIN, SOUTHWEST POWDER RIVER BASIN, WYOMING

JOHN HARDIE AND DAVID SEELAND, U.S. GEOLOGICAL SURVEY

The Powder River Basin of Wyoming and Montana contains some of the largest coal deposits in the world. The late Paleocene Tongue River Member of the upper Fort Union Formation contains a major portion of these resources within the Wyodak coal deposit including its lateral equivalents--the Anderson-Canyon, Sussex, and Big George coal beds/deposits. In the southwest part of the Powder River Basin, the thick (178 ft) upper split of the Wyodak accumulated adjacent to a tectonically active basin margin, in contrast to the remainder of the Wyodak which lies primarily in the central part of the basin near the depositional axis.

In the southwestern basin adjacent to the Casper arch, the upper Wyodak either splits westward into as many as eight beds or thins rapidly (from 154 to 25 ft in 1.2 miles), suggesting that the west margin of the Wyodak swamp was the tectonically active east margin of the arch during the late Paleocene. Isolith trends within the coal-bearing interval and crossbedding measurements indicate a swamp elongated parallel to northeast-flowing streams with extrabasinal sources.

Sediment input into the Wyodak swamp was minimized by the following factors: (1) streams crossing the Casper Arch were geographically fixed, restricting stream migration near the swamp; (2) the swamp may have been topographically elevated (ombrotrophic); and (3) Waltman Lake, in the eastern Wind River Basin on the west side of the Casper Arch, acted as a sediment trap minimizing sediment input from west of the arch.

These results are based on outcrop study, and interpretation of oil and gas well-log data and recently acquired uranium well-log data.

Hardie, J.K. and Seeland, D., 1988, Persistent coal-forming swamp adjacent to a tectonically active basin margin, southwest Powder River Basin, Wyoming: Geological Society of America Abstract With Programs, v. 20, no. 7.

AEROMAGNETIC AND GRAVITY SIGNATURE OF THE WICHITA FRONTAL FAULT SYSTEM

JONES-CECIL, Meridee, ROBBINS, S.L., AND CRONE, A.J., U.S. Geological Survey, MS 966, Box 25046, Denver Federal Center, Denver, CO 80225

The Wichita frontal fault system, extending NW-SE more than 300 km across SW Oklahoma, is the transitional boundary between the Wichita Mountains to the south and the Anadarko basin to the north. The Wichita Mountains contain a bimodal suite of igneous rocks emplaced during late Precambrian-Cambrian rifting; subsequent late Paleozoic compression and left-lateral wrenching occurred along the Wichita frontal fault system. Gravity and aeromagnetic expressions of the fault system are dominated by steep gradients due to large differences in density and magnetic susceptibility between the rocks of the uplift and the basin. Near the Slick Hills northwest of Lawton, Okla., the fault system widens and changes trend; the regional gravity data show a more gentle gradient and a change in trend from NW-SE in the east to almost N-S in the west.

The Meers fault is the southernmost fault in the widened part of the frontal fault system. Holocene movements on at least 26 km of the Meers fault shows that this and possibly other faults in the system may be seismogenic. Detailed gravity and magnetic data in the widened part of the fault system clarify the subsurface relationship of the Meers to other faults in the system. Preliminary magnetic models of data from a 2954 aeromagnetic survey (E-W flight lines at 500-ft elev. with 1/4-mi spacing) indicate that the Meers fault is nearly vertical. The models also show that the Mountain View fault, the northernmost fault in the fault system, has a moderate southward dip consistent with the interpretation of COCORP reflection data in a 1982 study by J.A. Brewer. A wedge(s) of buried high-susceptibility material, possibly gabbro, lies between these two faults. The wedge both widens and tilts down to the NW. Detailed gravity data along the N-S COCORP line 6, 20 km W of the NW end of the Holocene scarp on the Meers fault, indicate that the buried wedge is very dense. Aeromagnetic data suggest that the NW end of this scarp may be controlled by subsurface splaying of the fault a few kilometers to the NW. Analysis of gravity data from over 300 new stations will provide insight into the relation of the Meers fault to other faults in the Wichita frontal fault system.

Jones-Cecil, Meridee, Robbins, S.L., and Crone, A.J., 1988, Aeromagnetic and gravity signature of the Wichita frontal fault system: Geological Society of America Abstracts with Programs, v. 20, no. 7.

GEOMETRY OF NORMAL FAULTS IN THE UPPER PLATE OF A DETACHMENT FAULT ZONE, BULLFROG HILLS, SOUTHERN NEVADA

MALDONADO, Florian, U.S. Geological Survey, MS 913, Box 25046, Federal Center, Denver, CO 80225

A complex distended terrane in the Bullfrog Hills area of southern Nevada contains a detachment zone overlain by a system of normal faults. The zone comprises two detachment faults that define three structurally discordant plates. The lower detachment fault separates a lower plate of metamorphosed Late Proterozoic rocks from an overlying middle plate composed of slivers of lower and middle Paleozoic clastic and carbonate rocks. These middle-plate rocks are brecciated and unmetamorphosed, and their stratigraphic succession is incomplete and highly attenuated. The upper detachment fault separates the middle-plate rocks from an upper-plate assemblage of block-faulted Miocene volcanic, volcaniclastic, and sedimentary rocks.

Rocks of the upper plate dip at moderate to steep angles into the upper detachment fault or, where the middle plate has been removed, into the lower detachment fault. The upper plate is broken, tilted, and repeated in blocks bounded by normal faults that terminate against, or flatten and merge with the detachment faults. The normal faults in the upper plate are (1) planar rotational faults and (2) listric faults that are characterized by oval, horseshoe, and imbricate map patterns. These patterns result from different degrees of flattening of the faults, different degrees of rotation of the upper-plate blocks, or different stages of fault development, all dependent on degree of extension. These patterns are locally interpreted to reflect a single listric fault or the complex intersection of two or more faults that have been eroded to different structural levels.

The normal faults generally have shallow west-northwest dips and predominantly strike north-northeast. This geometry suggests that the upper plate predominantly extended west-northwest, and that strata were downdropped and repeated generally in that direction. Palinspastic reconstruction of geologic sections in the upper plate generally indicate more than 100 percent extension and locally approximately 200 percent. The extension is probably younger than 6.3 Ma--the age (Noble and others, 1984) of the youngest dated rock involved in the deformation.

Map patterns like those of the normal faults in the Bullfrog Hills, if recognized in other terranes in the Basin and Range province, may indicate detachment faults in the subsurface.

Maldonado, Florian, 1988, Geometry of normal faults in the upper plate of a detachment fault zone, Bullfrog Hills, southern Nevada [abs.]: Geological Society of America Abstracts with Programs, v. 20, no. 3, p. 178.

DETACHMENT OF TERTIARY STRATA FROM THEIR PALEOZOIC FLOOR NEAR MERCURY, NEVADA

MYERS, W.B., U.S. Geological Survey, MS 913, Federal Center, Denver CO 80225

Structural relationships interpreted from detailed USGS geologic maps of the Nevada Test Site area suggest that Tertiary strata are tectonically detached from their Paleozoic substrate. Mapping of about 5 km^2 of the hill country along the southwest margin of Frenchman Flat revealed exposures of a low-angle tectonic contact between a massive, undulating pavement of Ordovician limestone and overlying strongly fractured Tertiary strata. The Tertiary rocks are conformable to moderately inclined to the smooth, unstriated floor. The resistant Ordovician section dips gently eastward, is not folded, but is broken by easterly and northeasterly trending steep faults. The overlying Tertiary section, originally mapped as the Horse Spring formation of Oligocene age, is composed of incompetent siltstone and claystone, minor lacustrine limestone beds, and a distinctive conglomerate bed. These marker beds demonstrate that the Tertiary strata are strongly folded and locally overturned. The fold geometry largely reflects the shape of the Paleozoic floor, which is partly paleotopographic and partly due to high-angle faulting, and implies that the Tertiary blanket was folded as it was detached and transported over the irregular surface. These events post-date regional volcanic activity as young as 11.5 Ma. The high-angle faults were probably active at the same time that the Tertiary strata were moving across the Paleozoic floor because the Tertiary blanket generally is not cut by these faults. The extent of the detachment, its movement direction, and the magnitude of lateral transport have yet to be defined. Preliminary mapping at the north end of Yucca Flat, 60 km to the north, suggests similar relationships between a floor of Paleozoic sedimentary rocks intruded by Cretaceous granite and the overlying 16 Ma tuffs. Detachment of the Tertiary strata apparently is not a local phenomenon related to oroclinal bending at the northwest end of the Las Vegas shear zone.

Myers, W.B., 1987, Detachment of Tertiary strata from their Paleozoic floor near Mercury, Nevada: Geological Society of America Abstracts with Programs, v. 19, no. 7, p. 783.

THE GEOTECTOBOLT--HELICAL STRUCTURE IN AN EOCENE VOLCANIC PIPE, NORTHWESTERN FERRY COUNTY, WASHINGTON, OR, SCREWED UP AGAIN

PEARSON, Robert C., U.S. Geological Survey, Box 25046, M.S. 930, Federal Center, Denver, Colorado

The Geotectobolt, as named facetiously by H.W. Little, G.S.C., and known locally as Corkscrew Mountain, is a volcanic feature with a peculiar twisted structure that is speculated to be the result of magma congealing in a pipe beneath a "bathtub vortex," similar to the one that formed during the drainback of Kilauea Iki's lava lake in 1959. The bolt has a left-handed thread!

The pipe is oblong in plan (120x300 m), and its south side is exposed for a vertical distance of about 100 m on the slope north of the valley of Toroda Creek, 4 km above its confluence with Kettle River. It cuts bedded tuffaceous deposits of the Eocene Klondike Mountain Formation. From a distance, the pipe appears to consist of a series of curving parallel dikes about 0.6-3 m thick and about 5-8 m apart. The thin "dikes" stand out in relief and indeed resemble threads of a giant screw. But rather than being dikes, the thin sheets are actually older than the thicker sheets between, as determined by devitrification dikelets that emanate from the one and penetrate the other. The thin sheets are vitric, whereas the thicker sheets are lithoidal. Both types are dacitic in composition and contain small sparse phenocrysts of plagioclase and of two pyroxenes. Petrographically the vitric rocks match Klondike Mountain vitric lava flows 150-300 m higher in elevation and 1.6-4 km to the south, and the lithoidal rocks match sills and dikes that intrude the lower Klondike Mountain. Both sets of sheets have a crude columnar jointing normal to their walls; the jointing is finer in the thinner sheets.

The helical layered structure is explained as the result of cooling of uniform magma. As the moving magma gradually slowed and cooled, it became more and more viscous until it sheared or fractured along equally spaced shear surfaces or joints. These surfaces were curved in three dimensions because of torsional stress. The resulting loss of pressure along the shear surfaces caused the adjacent magma to freeze, producing the vitric sheets. The remaining magma then cooled more slowly to form the lithoidal rock. Longitudinal joints are present in the center of some of the vitric sheets, but not in all, suggesting perhaps that viscous shear rather than fracturing produced the low-pressure surfaces.

Pearson, R.C., 1988, The Geotectobolt--helical structure in an Eocene volcanic pipe, northwestern Ferry County, Washington, or, screwed up again: Geological Society of America Abstracts with Programs, 1988, v. 20, no. 6, p. 462.

Modern Fissures in the Pahranagat Shear System, SE Nevada

W C Swadley and R B Scott (both at: U.S. Geological Survey, MS 913, Federal Center, Denver, CO 80225

Recent mapping in the Delamar Valley at the NE end of the Pahranagat shear system (PSS) has delineated two sets of about 30 open and partly filled fissures in late Holocene alluvium. Both open and partly filled fissures occur in the two sets: a dominant N55^{o}E set and a N40^{o}W set. Open fissures that have a freshly broken appearance are vertical, 0.3-0.6 m wide, and at least 2 m deep in weakly consolidated alluvium. Partly filled fissures are sparsely vegetated, very slight depressions 1-2 m wide. Although the age of partly filled fissures can be restricted only to the late Holocene, open fissures may be no older than tens of years (one open fissure postdates 1976 aerial photographs). Open and partly filled fissures presumably represent a continuum of fissure development. Both types of fissures occur in fine sandy valley-fill alluvium, and partly filled fissures also extend into laterally equivalent fan deposits of slightly gravelly sand. The only apparent offset on fissures is perpendicular to their walls; however, small dip- or strike-slip offset cannot be ruled out. Both types of fissures have disrupted drainage patterns by locally capturing small drainages. The N55^{o}E set can be continuously traced on the ground and on aerial photographs for as much as 9 km. Similar fissures elsewhere have been related to ground water withdrawal, compaction of sediment, or movement along fault zones. However, no ground water has been removed in the valley, the fissures do not parallel basin margins in Delamar Valley, and compaction seems unlikely in gravelly sand of fan deposits. Because the dominant set of fissures appears to be a linear extension of major faults in the PSS, the fissures may be related to the PSS. The PSS exhibits left-lateral shear over 50 km and separates extended terrane to the NW from relatively unextended terrane to the SE. The NE end of the PSS appears to terminate at the west-dipping normal fault west of the Delamar Mountains, and the SW end of the PSS appears to terminate at a similar normal fault west of the Sheep Range. Oblique slip-direction indicators on the major northwest-dipping faults of the PSS require westward movement of the extended terrane, the upper plate of a detachment system. If these fissures are related to the PSS, and thus to the extensional framework, then the fissures are evidence of modern extension in the Great Basin.

Swadley, W C, and Scott, R.B., 1988, Modern fissures in the Pahranagat Shear System, SE Nevada: American Geophysical Union fall meeting, San Francisco, 1988.

Overthrusting in the Northwestern San Juan Basin, New Mexico
A New Interpretation of the Hogback Monocline

By
David J. Taylor and A. Curtis Huffman Jr.

Abstract

The Hogback monocline is a prominent northeast trending structure which bounds the northwestern edge of the San Juan Basin. Multichannel seismic reflection lines, shot at various angles to the monocline in the vicinity of Waterflow, New Mexico, reveal a series of complex faults at depth. The seismic data together with selected adjacent well data has allowed us to locate the major faults, identify the type of faulting involved, and determine the movement along the faults over time. Domal structures genetically related to the observed faulting are major hydrocarbon producers in this part of the San Juan Basin.

Twelve fold CDP seismic reflection lines and geophysical well logs were the primary input to this investigation. Six stratigraphic boundries were identified from the well logs and were correlated with the seismic data through the use of synthetic seismograms. Interval velocity data used in converting the picked time horizons to depth were established from acoustic and resistivity logs from sides of the major faults.

These data yield a pattern of intersecting northeast and northwest trending faults of probable Precambrian ancestry. These faults display a complex history of movement, including:

1. Northwest trending faults with vertical components of movement from early Paleozoic through at least Triassic time.
2. High angle reverse faulting and significant thrusting on both northwest and northeast faults during the Laramide including northeast, southeast, and southwest directed thrusting.

The observed fault pattern was most likely inherited from Precambrian orogenic movements. Thickness variations between northwest trending blocks indicate vertical movement along a northwest trending fault zone during the Paleozoic and early Mesozoic. During the Laramide, general east-west shortening resulted in right-reverse movement along the northeast trending fault zone, left-reverse movement along the northwest trending zone, and transpression in the area of intersection that produced concurrent overthrusting in several directions, forming the Hogback monocline and related hydrocarbon rich domal structures.

Taylor, D.J., and Huffman, A.C., Jr., 1988, Overthrusting in the northwestern San Juan Basin, New Mexico. A new interpretation of the Hogback monocline, in Carter, L.M.H., ed., USGS research on energy resources-1988, program and abstracts: U.S. Geological Survey Circ. 1075, p. 60-61.