Proceedings of the Twentieth Annual Meeting of The Society for Organic Petrology

Edited by

Linda J. Bragg
Erika E. Lentz
Peter D. Warwick
Robert B. Finkelman
Michael H. Trippi

Digital Compilation by

Alex W. Karlsen

UNITED STATES DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Open File Report 2004-1283

2004

Table of Contents

(Please click on any of the headers below to link to the referenced section)

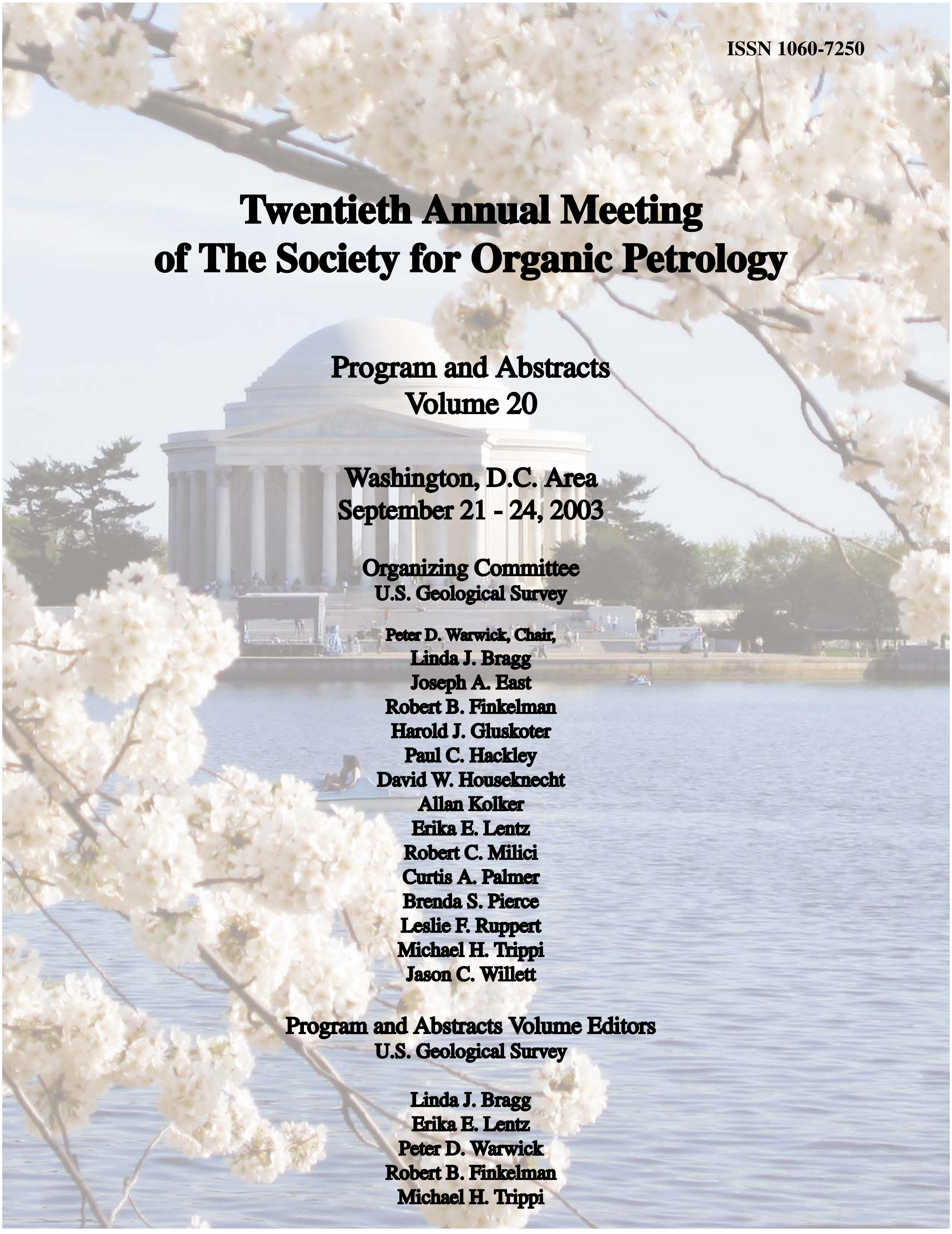
Instructions on using the PDF file

2003 Annual Meeting TSOP Abstract and Programs

Supplemental Materials

Instructions on using this PDF document:

Please use the "Bookmarks" tab (located in the lefthand portion of the Adobe Acrobat Reader viewer) to navigate through this document. Bookmarked items located in the Supplemental Materials section of the navigation tree will link you to PDF files outside of this document.



ISSN 1060-7250

Twentieth Annual Meeting of The Society for Organic Petrology

Program and Abstracts
Volume 20

Washington, D.C. Area
September 21 - 24, 2003

Organizing Committee
U.S. Geological Survey

Peter D. Warwick, Chair,
Linda J. Bragg
Joseph A. East
Robert B. Finkelman
Harold J. Gluskoter
Paul C. Hackley
David W. Houseknecht
Allan Kolker
Erika E. Lentz
Robert C. Milici
Curtis A. Palmer
Brenda S. Pierce
Leslie F. Ruppert
Michael H. Trippi
Jason C. Willett

Program and Abstracts Volume Editors
U.S. Geological Survey

Linda J. Bragg
Erika E. Lentz
Peter D. Warwick
Robert B. Finkelman
Michael H. Trippi

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Table of Contents

TECHNICAL SESSION A

Petroleum Systems, Source Rocks, and CBM

Peter Warwick, Chair

Cretaceous Crud from Canada — Organic Facies Analysis of the Colorado Group, Western Canada Sedimentary Basin

Lisa Buckley and Richard V. Tyson

NRG, School of Civil Engineering and Geosciences, University of Newcastle upon Tyne, England, NE1 7RU

The Cretaceous Colorado Group (Albian-Turonian) is a sequence of homogeneous organic-rich shales deposited within the Western Interior Seaway of North America. Bulk geochemical analysis (Rock-Eval, TOC, Total Carbon, Total Sulphur), and palynofacies observations have been conducted along transects across the Western Canada Sedimentary Basin (WCSB), in order to reconstruct lateral and sequence stratigraphic variations of the organic facies.

The Viking and Westgate formations are typified by low percentages of poorly preserved (weakly fluorescent) marine amorphous organic matter (AOM) and abundant terrestrial phytoclasts, associated with low TOC and average measured hydrogen indices of only 106 mg HC/g TOC (Type III kerogen). The Fish Scales and Belle Fourche formations have a transitional organic facies reflecting mixing with better preserved marine AOM, and thus exhibit higher mean TOC and measured HI values (158 and 170 mg HC/g TOC respectively). The Second White Specks Formation and the upper Colorado Group are both dominated by moderate to strongly fluorescent AOM, resulting in a mean measured HI of 320 mg HC/g TOC (Type II kerogen). The mean average HI values of the Type III and Type II kerogen components, computed from the slope of S2 *versus* TOC trends, are approximately 170 and 500 respectively. The transgressive Albian-Turonian interval is associated with a progressive upward decrease in terrestrial phytoclast supply, and progressive improvement in the preservation of the AOM, related to changing basin redox conditions.

Stable carbon isotope analysis has identified a significant (~4 percent) positive shift in $^{13}C_{org}$ values in the vicinity of the Belle Fourche-Second White Specks Formation boundary in three WCSB cores. This is interpreted as the regional expression of the isochronous Cenomanian/Turonian (C/T) global isotopic event. The formation boundary apparently becomes older towards the east, where the lower siliciclastic input allows the development of a calcareous facies to occur earlier than in the west.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Mechanism of Hydrogen Gas Generation in Coalbed Methane Desorption Canisters — Causes and Remedies

Basim Faraj[1, 2, 3], Anna Hatch[1, 4], Derek Krivak[1, 5] and Paul Smolarchuk[1, 6]

[1]*GTI E & P Services Canada, Suite 720, 101-6th Avenue S.W., Calgary, Alberta T2P 3P4 Canada*
[2]*Faraj Consultants Pty. Ltd., 96 Moreton Avenue, Wynnum, Brisbane 4178, Australia*
[3]*MGV Energy Inc., One Palliser Square 2000, 125-9th Avenue S.E., Calgary, Alberta T2G0P8 Canada*
[4]*Nerji Consultants, 1777 Larimer Street, Suite 2003, Denver, Colorado 80202*
[5]*Alberta Research Council, 3608-33 St. N.W., Calgary, Alberta T2L 2A6 Canada*
[6]*Colt Ventures Ltd., 77 GlenEagles Close, Cochrane, Alberta T4C1N7 Canada*

Hydrogen gas (H_2) was detected in desorption canisters in various proportions (between ~0.1 percent and 82 percent of total desorbed gas). It was found to form in the canisters during the desorption experiments. Complementary analytical techniques were used to characterize the desorbed gases, water and coal samples within the desorption canisters. Stable isotopes analysis of four H_2 gas samples show an extraordinary depletion of the stable isotope Deuterium, with D range between -706.5 percent and -749.3 percent with a mean value of -733 percent. This strongly depleted H_2 indicates biogenic origin of H_2. Stable isotopes of carbon and hydrogen of the associated CH_4 show a very different composition (^{13}C between -44.75 percent and -52.61 percent and D between -260.3 percent and -276.1 percent). These values indicate a mixed origin of the desorbed methane of geological biogenic/thermogenic mixtures. The hydrogen in CH_4 is much heavier (more enriched in Deuterium) than that of H_2 and this points to a very different origin for it. Accordingly, our data show that only H_2 gas and not CH_4 was generated in the canisters.

High Resolution Scanning Electron Microscopy (HRSEM) confirmed the presence of the bacteria (1-2 μm in size) most probably responsible for hydrogen generation. Hydrogen is formed as a result of fermentation reactions of anaerobic bacteria within the canisters during desorption of coal samples. The hydrogen is generated within the canisters in the presence of coal, water and reducing headspace gases (mostly methane). Although the canisters used in this study were either made of aluminum or anodized aluminum, it is unlikely that the make up of canisters have any bearing on the hydrogen generation capacity of the bacteria.

The most likely sources of introduction of the bacteria communities into the canisters are: (1) water used as headspace filler in the canisters, (2) water used to make the drilling mud, (drilling mud would invade and permeate coal sample fractures/cleats and other porosity types during drilling and coring), and (3) cross contamination between canisters, as these are not usually sterilized between desorption experiments.

Successful measures to overcome the problem of hydrogen (and other biogenic gases) being produced in canisters are discussed.

Application of Organic Petrology in Astrobiology — Ancient Terrestrial Life, and Biological Entities in Meteorites and Planetary Samples

Lavern D. Stasiuk

Natural Resources Canada, Geological Survey of Canada, 3303-33rd St. N.W., Calgary, Alberta, Canada

One of the most established methods for recognizing and evaluating in situ, micron-scale organic matter within rocks is organic petrology. Despite the method's successful application to geological and environmental problems in the coal, oil and gas industries, the potential for applications in astrobiology has not yet been realized. Reflected light microscopy, fluorescence microscopy and confocal laser scanning fluorescence microscopy are the main systems currently used to evaluate macerals and their micro-morphology, as well as to quantify their visible light region optical properties. Optical properties such as percent reflectance, degree of anisotropy and visible light region fluorescence provide a constraint on the maximum temperature to which the organic matter has been exposed. In geological applications, organic petrology is used to identify, characterize, and classify biologically-derived organic matter preserved within recent sediments which have seen limited geothermal alteration (i.e. < 1Ma; < 30 °C) and within ancient rocks which have undergone significant geothermal alteration at elevated temperatures (up to 1.6-2.2 Ga and older; 40 to ~ 250 °C). Optical and laser microscopy of recent and ancient floral-, algal/bacterial-, and fungal-derived in situ organic matter and associated bio-mineralization within rocks potentially provide a valuable tool for astrobiology studies. This paper will illustrate anomalous microscopic biological components, such as intracellular biological entities (e.g. zoospores; cellular division), organics, and microfossils from the geological record, which specifically address the issue of morphology versus metabolism in astrobiology.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Coal Characteristics and Coalbed Methane Potential in the Jurassic Coal Measures of Tuha Basin, Northwestern China

Liu Honglin[1], Zhang Jianbo[2], Wang Hongyan[3] and Li Jingming[1]

[1]*Langfang-Branch Research Institute Petroleum Exploration and Development, PetroChina Ltd.*
[2]*China University Of Mining Technology*
[3]*China University of Geology*

Exploration for coalbed methane (CBM) in China has been fairly active since late 1994 but commercial production did not start until recently. Between 1990 and 2001 the total number of CBM wells in China had grown to more than 240, including wildcat wells and pilot wells. Exploration to date is being conducted in basins of north China and south China, which possess most of the CBM resources. As well as containing vast CBM resources in Paleozoic basins, China also contains very substantial volumes of Jurassic coal within Mesozoic basins such as the Tuha, Zhungaer, Ordos, and so on. However, there has been little research or exploration in the coalbed methane potential of these basins. The Jurassic coal measures could contain recoverable CBM considerably in excess of 4 trillion cubic meters.

The Tuha Basin, which formed as an intermountain basin in the Mesozoic, underlies approximately 53,500 km^2 in northwestern China, and can be divided into four structural units: Turfan depression; Liaodun ridge; Hami depression; and Shaerhu-danianhu depression (fig.1). Sedimentation has been generally continuous across the depressions since the Jurassic. Sediment fill thickness exceeds 9,000 km in the Turfan depression.

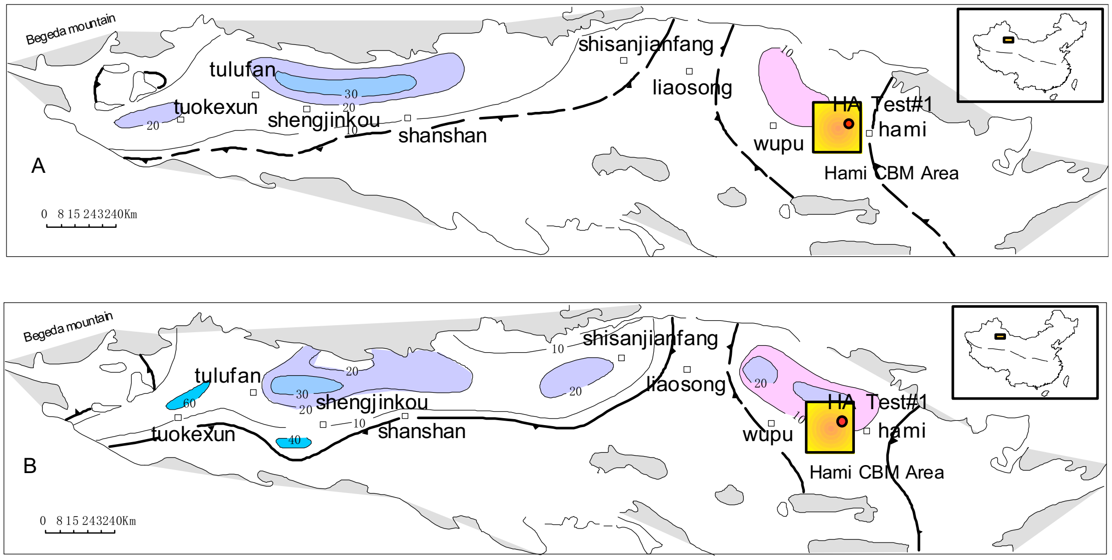


Figure 1. — A) The Tuha Basin: Net thickness (m) of coal in the Xishanyao Formation, and (B) Net thickness (m) of coal in Badaowan Formation.

Both the Xishanyao and Baodaowan Formations contain coal seams that are prospective for coalbed methane. The Xishanyao Formation ranges in thickness from 370 m in the west central region of the basin to 780 m in the eastern region. These units contain numerous and exceptionally thick coal seams and net coal thicknesses reaching 50-60 m. Coal thickness varied from the eastern to the western margin of the basin, with the coal interval ranging from 2 to 5 m (fig. 1). There is a single seam with an average thickness of greater than 16 meters in the southeast part of the basin. Vitrinite is the dominant coal maceral in the basin. Thermal maturity, as indicated by vitrinite reflectance, is generally marginal for coalbed methane; however maturity often increases in the vicinity of intrusions that are common throughout the basin. Coal at 300 m depth has a mean max reflectance of 0.6 percent. Cleat systems are well developed in most seams and many of these cleat systems have not been affected by infilling of mineral matter. Gas content ranges from 2 to 7 m^3/t (as-received basis), which does not include 0.5 to 1.5 m^3/t residual gas. Many methane adsorption isotherm analyses were carried out at strata temperature. Some samples are nearly saturated based on the isotherm results. Gas compositions are attractive; the average methane content ranges between 90 and 95 percent and in some areas, the gas contains up to 5 percent ethane.

In March 2002, exploration drilling commenced in the Hami depression of the Tuha Basin by PetroChina. To date, a wildcat CBM well (HA TEST #1), where gas flows and blowouts have occurred and are close to the oil well Ha Para #1, has been completed and water-fractured. PetroChina began testing production in HA TEST #1. Conventional gas drilling indicates that many seams contain small quantities of water and that gas production would initiate shortly after water production commenced. These relatively low volumes of groundwater would assist in maintaining low production costs and the relatively good quality of the water would minimize the cost of its disposal.

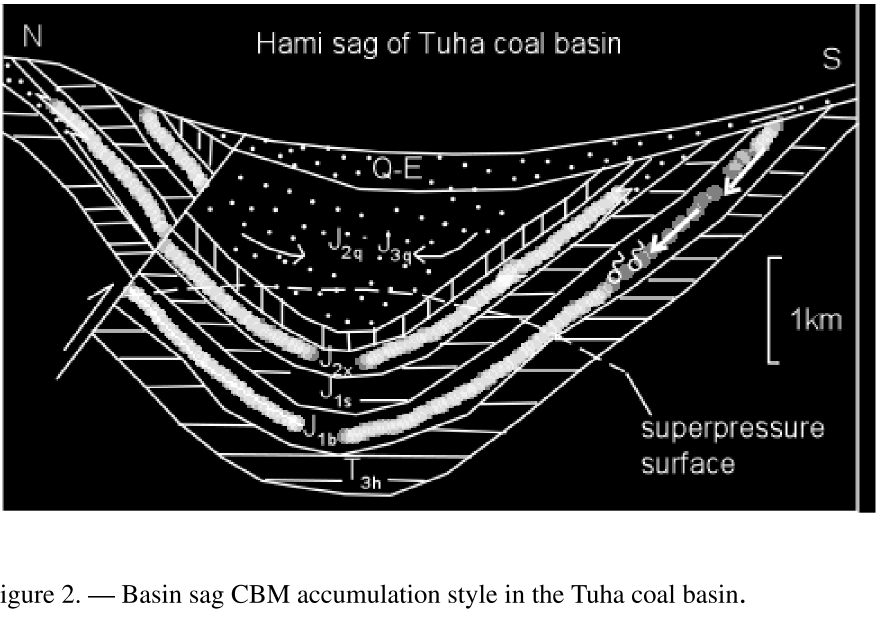


Figure 2. — Basin sag CBM accumulation style in the Tuha coal basin.

In the Tuha Basin, CBM plays have a character of medium- to high-gas content, low- to high-gas saturation and medium- to high-permeability variance by area. The Tuha Basin CBM can be generalized by a sag accumulation style, as shown in figure 2. The Tuha Basin is similar to the Powder River Basin of the U.S. in many aspects. The relatively shallow depth to thick seams, the stress regime, and the relatively short distance to pipelines, all make the Jurassic coal measures of the Tuha Basin a potential target for CBM development.

Petroleum System Risk Assessment of the Scotian Slope , Eastern Canada and its Significance to East Coast Energy Prospects Beyond 2010

Prasanta K. Mukhopadhyay (Muki)

Global Geoenergy Research Ltd., 1657 Barrington Street, Suite 427, Halifax, Nova Scotia, Canada B3J 2A1

The Petroleum System Risk Assessment (PSRA) has predicted the presence of viable petroleum systems within deepwater fans and other salt-related reservoirs of the Scotian Slope, Eastern Canada. Four factors (heat flow and basement fractures, reservoir development and source rock kitchens, timing of fluid flow movement within the defined trap, and survival of hydrocarbons) have controlled the variations within the major components (play types, hydrocarbon charge and drainage systems, and hydrocarbon sustainability) of the individual Petroleum System.

Fluid Flow Modeling (1D and 2D) using all components (geological/geophysical, geochemical, and survival) of the PSRA suggests the presence of four to six petroleum systems with major prospects for natural gas, gas-condensate, and gas hydrates within the Scotian Slope. The expected hydrocarbon families in the Scotian Slope would be somewhat different compared to the shelf and shelf-break petroleum already discovered. Although the preliminary probabilistic resource assessment of selected play types within the Scotian Slope by Canada-Nova Scotia Offshore Petroleum Board (CNSOPB) has indicated a maximum of 5-53 Tcf (including both risked and unrisked) of gas and 1.7-4.7 BB of crude oil (mostly of light oil and condensate), preliminary PSRA by Global Geoenergy Research Limited predicts possible presence of greater than 50 Tcf (approximate estimate) of gas in the Scotian Slope. Based on the geochemical assessment of various Deep Sea Drilling Project (DSDP) wells on both sides of the Atlantic Ocean and the earlier wells drilled in the areas surrounding the Scotian Margin and the northeastern part of the United States, major prospects for gas (natural gas and gas hydrates) and condensates could be predicted in these areas.

Currently, the reserve of gas hydrates is unknown although some probabilistic assessments on entire Canadian and eastern United States margins have been made. Possible development of fuel cell technology beyond 2010 may increase demand for methane as the major source for hydrogen to steer cleaner fossil fuel energy in North America. The abundant prospects of natural gas, condensate and gas hydrates within the Scotian Margin (including surrounding areas) and deepwater areas of other eastern Canadian and northeastern United States will mitigate the future energy demands beyond 2010. This may allow the opening up of the moratorium on the U.S. East Coast and Georges Bank in Canada, so that exploration may begin in to find gas and condensates in this region in the near future.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

M & M — A Sweet Petroleum System

Louis L. Tsai[1], Li-Chung Sun[2], Jane Hsieh[1], Hsien Tsung Lee[3]

[1]*Institute of Applied Geology, National Central University, Jungli, Taiwan, R.O.C.*
[2]*Department of Electric Engineering, Nankai College, Nantou, Taiwan, R.O.C.*
[3]*General Education Center, Nankai College, Nantou, Taiwan, R.O.C.*

Introduction

Evaluation of hydrocarbon potential in petroleum systems is one of the most important aspects of oil exploration (Dow, 1974). Its precision is related to the prediction of location and reserve of the prospect area and the outcome of exploration projects (Magoon and Dow, 1994). A hydrocarbon reserve can be generated by a proper combination of good source rock, depositional and tectonic structures, and thermal maturation (Otis and Schneidermann, 1997). Therefore, "Material" and "Maturity" (M & M) of the hydrocarbon are two important topics in the study of petroleum systems. Additionally, in order to achieve a reliable overall evaluation of the hydrocarbon potential, various methods in geology, geochemistry, stratigraphy, structure, biology and statistics need to be combined.

The purpose of this study is to promote a synthetic evaluation technique for the hydrocarbon potential of local petroleum system. The samples studied include Miocene high volatile bituminous coal and kerogen and organic matter in cores recovered from exploration wells, in addition to maceral mixtures prepared by density centrifuge separation. Various optical, physical and biochemical methods were then performed to evaluate their characteristics on both material and maturity issues.

Local Petroleum System Studies

Taiwan is located in an active arc-continent collision zone between the Eurasian Plate and the Philippine Sea Plate. The so-called Penglai Orogeny starting from Plio-Pleistocene led to the lifting of the Central Mountain Range and the exposure of small-sized hydrocarbon fields, especially on the northwestern part of the Western Foothill Belt of Taiwan. Various methods had been developed for oil and gas exploration in the past, such as thermal study (Bar and Dahlen, 1989; Lin, 2000), basin analysis (McKenzie, 1978; Chi and others, 1987), paleontology (Hashimoto and Kurihara, 1974), and tectonic structures (Hwang and Wang, 1993; Wang, 2001). Chiu (1972; 1975) finished a detailed Miocene stratigraphic study in western-central Taiwan. Afterwards, the Cenozoic basin study of offshore Taiwan was done by Sun (1982; 1985). In addition, Liou and Hsu (1988) followed by Hsiao and others (1991) completed thorough studies on the evaluation of hydrocarbon potential. Furthemore, Huang (1984; 1986) and Huang and others (1991; 2001) combined paleontology, stratigraphy and geodynamics to improve the understanding of local geologic settings.

Methods Of Study

This study included two parts:

1) Material study — Initially, using the collection of coal samples with maturities closest to the early oil window, various maceral groups were prepared by using density centrifuge separation. Rock-Eval pyrolysis and elemental analysis were then performed to evaluate the relationship between hydrocarbon potential and maceral composition. The pyrolysis and elemental analysis of kerogen or organic matter having the same maturities but with different hydrocarbon potentials, were compared with their maceral compositions so as to study the mechanism of hydrocarbon generation.

2) Maturity study — Using the collection of coal or kerogen samples of a maturity within the oil window, the relationships among their vitrinite reflectance, liptinite fluorescence and Rock-Eval pyrolysis were studied. Combined with statistical analysis and other relevant techniques, a reliable synthetic evaluation model for the evaluation of hydrocarbon potential can be established after a better understanding about thermal maturation processes in the study area. The outcome of oil exploration can thus be expected to improve.

Conclusion and Discussion

1) As a result of this study, we expect to promote the evaluation techniques of petroleum systems, (to develop or improve some evaluation methods about the source rock, the reservoir, the structural evolution, and the thermal maturity). The measurements in the evaluation are expected to be more detailed in local conditions, better quantified, and more accurate.

2) These evaluation techniques will be applied elsewhere in the future, so as to discover more economic hydrocarbons. After all, material and maturity are always two important issues that need to be considered, especially in a sweet business like oil exploration.

References

Bar, T.D., and Dahlen, F.A., 1989, Brittle frictional mountain building — thermal structure and heat budget: Journal of Geophysical Research, v. 94, no. 4, p. 3923-3947.

Chi, W.R., Wang, W.H., Lu, D.L., Lin, L.H., and Wu, R.C., 1987, The application of back stripping method in basin analysis and oil exploration of the Peiking area: Bulletin of the Exploration and Production Research, Chinese Petroleum Corporation, v. 10, p. 63-88.

Chiu, H.T., 1972, Miocene stratigraphy of the Nantou area, central Taiwan: Petroleum Geology of Taiwan, v. 10, p. 159-177.

______1975, Miocene stratigraphy and its relation to the Paleogene rocks in western-central Taiwan: Petroleum Geology of Taiwan, v. 12, p. 51-80.

Dow, W.G., 1974, Application of oil correlation source rock data to exploration in Williston basin: American Association of Petroleum Geologists Bulletin, v. 58, no. 7, p. 1253-1262.

Hashimoto, Wataru, and Kurihara, Kenji, 1974, Discocyclina from the Tsukeng Formation, Tsukeng, Nantou, central Taiwan, and its geological significance: Taipei, Taiwan, Geological Survey of Taiwan Bulletin 24, p. 35-49.

Hsiao, P.T., Hu, C.C., Lin, K.A., Hsu, S.H., Fuh, S.C., Chang, T.Y., Hsiuan, T.H., Sheen, H.C., Kuo, C.L., and Lee, C.J., 1991, Hydrocarbon potential evaluation of the Penghu Basin: Petroleum Geology of Taiwan, v. 26, p. 215-229.

Huang, C.Y., 1984, Late Oligocene benthic foraminiferal assemblages in northern Taiwan: Pau, France, Benthos'83, 2nd International Symposium on Benthic Foraminifera, v. 6, p. 317-323.

______1986, Oligocene and Miocene stratigraphy of the Kuohsing area, central Taiwan: Acta Geologica Taiwanica, v. 24, p. 281-318.

Huang, C.Y., Xia, K.Y., Yuan, P.B., Chen, P.G., 2001, Structural evolution from Paleogene extension to Latest Miocene-Recent arc-continent collision offshore Taiwan — comparison with on land geology: Journal of Asian Earth Sciences, v. 19, no. 5, p. 619-639.

Huang, C.Y., Yang, W.T., Huang, C.H., 1991, Stratigraphic study of the Tsukeng Formation, central Taiwan [abs.]: Program with Abstract, Annual Meeting of the Geological Society of China, p. 8-9.

Hwang, W.T., and Wang, C.Y., 1993, Sequential thrusting model for mountain building — constrains from geology and heat flow of Taiwan: Journal of Geophysical Research, v. 98, p. 9963-9973.

Lin, C.H., 2000, Thermal modeling of continental subduction and exhumation constrained by heat flow and seismicity in Taiwan: Tectonophysics, v. 324, no. 3, p. 189-201.

Liou, C.H., and Hsu, C.Y., 1988, Petroleum exploration on the southwestern plain of Taiwan: Petroleum Geology of Taiwan, v. 24, p. 18-36.

Magoon, L.B., and Dow, W.G., eds., 1994, The petroleum system—from source to trap: American Association of Petroleum Geologists Memoir, v. 60, 655 p.

McKenzie, D.P., 1978, Some remarks on the development of sedimentary basins: Earth and Planetary Science Letters, v. 40, no.1, p. 25-32.

Otis, R.M., and Schneidermann, Nahum, 1997, A process for evaluating exploration prospects: American Association of Petroleum Geologists Bulletin, v. 81, no. 7, p. 1087-1109.

Sun, S.C., 1982, The Tertiary basin of offshore Taiwan: Proceedings, 2nd ASCOPE conference and Exhibition, p. 125-135.

______1985, The Cenozoic tectonic evolution of offshore Taiwan: Energy, v. 10, nos. 3-4, p. 421-432.

Wang, W.H., 2001, Lithospheric Flexure under a Critically Tapered Mountain Belt — A new technique to study the evolution of the Tertiary Taiwan orogeny: Earth and Planetary Science Letters, v. 192, no. 4, p. 571-581.

TECHNICAL SESSION B

Ron Stanton Coal Characterization Session

Leslie (Jingle) Ruppert, Chair

In Memoriam
Ronald W. Stanton

On Thursday, September 27, 2001, Ronald W. Stanton of Vienna, Virginia, 50, a long time member of The Society for Organic Petrology (TSOP) and International Committee for Coal and Organic Petrology (ICCP), and research geologist with the U.S. Geological Survey (USGS), died at his home from cancer. Ron was born in Wilkes-Barre, Pennsylvania and lived in Fairfax County, Virginia.

Ron started his career at the USGS as a field assistant in 1973. Following his completion of undergraduate and masters degrees in geology at West Virginia University, he returned to the USGS Branch of Coal Resources in 1975 as a coal geologist specializing in organic petrology. He was responsible for developing new techniques and approaches to the description, characterization, and prediction of coal bed thickness and quality of world coal resources. Ron continued to analyze coal components throughout his career and his observations led to significant modifications of coal petrographic classifications that are currently used by the American Society for Testing and Materials and by other coal geologists throughout the world.

In 1993, Ron was appointed Assistant Branch Chief of the Branch of Coal Geology at the USGS and had responsibility for budgets and staffing. From 1995 to 1999, he served as the Team Chief Scientist of the Eastern Energy Resource Team where he was responsible for science directions, plans, and supervision of the professional and administrative staff.

Ron was recognized worldwide as a coal geologist. He held numerous leadership positions at the American Society for Testing and Materials Committee D5 on Coal and Coke, and was a founding member of TSOP. He was the primary organizer of the first TSOP meeting that was held in the Washington, D.C. area in 1984. In addition, he was a member of the ICCP, Geological Society of America, Sigma Xi, Scientific Research Society, American Association of Petroleum Geologists, and the Society of Mining Engineers.

He was a Boy Scout leader, a soccer and basketball coach for youth leagues in Fairfax County, and an organizer of the Hunter Mill Defense League, which fought development in Fairfax County. His interests included fly-fishing and bluegrass music. He played the violin, banjo, piano and trumpet. He will be remembered fondly.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

The World Coal Quality Inventory

Susan J. Tewalt and Robert B. Finkelman

U.S. Geological Survey, MS 956, National Center, Reston, VA 20192

Abstract

National and international policymakers require information on global coal quality to make informed decisions regarding international import needs and export opportunities, foreign policy, technology transfer policies, foreign investment prospects, environmental and health assessments, and byproduct use and disposal issues. The U.S. Geological Survey (USGS), in conjunction with collaborators in about 50 countries, has initiated the World Coal Quality Inventory (WoCQI), a digital compilation that will contain coal quality information that emphasizes the major coal beds currently being mined and combusted from around the world. WoCQI will include, but is not limited to, proximate and ultimate analyses, sulfur-form data, major-, minor-, and trace-element analyses, semi-quantitative analyses of minerals, elemental modes of occurrence, coal petrography, and other factors that affect technological behavior, economic byproduct recovery, and environmental impact. The coal quality data will be linked with spatially georeferenced data on coal geology, political boundaries and infrastructure, as well as environmental/human health information. WoCQI data will be accessible through the internet, as well as on hard copy maps and in a series of CD-ROM publications.

Discussion

Global economic or environmental issues, such as energy availability and global warming, regularly impact our daily lives. Coal-fired power plants produce more than half of the electricity in the United States with 55 percent of the coal consumed worldwide being used for electrical generation. Worldwide coal production and consumption, even in a low economic growth scenario, are projected to increase during the next several decades (International Energy Outlook, 2003). Therefore, national and international policymakers will require accurate information on coal, including coal quality data. Thus the availability of information on world coal quality may have a significant impact on global coal use.

The USGS has been compiling coal quality data on the nation's coal resources since the 1970s, but the database includes information for coal resources that have probably been mined. In the rest of the world, coal quality data reside in obscure publications in the native languages of the authors and are rarely accessible. Energy policymakers in the United States and abroad require information on the chemical characteristics of coals that are being mined and used today. The coal quality parameters to be incorporated into the WoCQI database include, but are not limited to, proximate and ultimate analyses, sulfur-form data, and about 45 major-, minor-, and trace-elements. These coal quality parameters will be determined on every sample. Major, minor, and trace element analyses will be conducted in the USGS laboratories using uniform sample preparation and analytical procedures. Thus, the data in WoCQI will have the highest possible degree of internal consistency. The USGS may also determine semi-quantitative analyses of minerals, elemental modes of occurrence, petrography, and other factors that affect technological behavior.

Coal samples are being obtained from worldwide collaborators in academia, coal mining and combustion industries, and government for important coal beds in all of the major coal producing countries as well as from many of the smaller coal producers. The host country collaborator is responsible for the collection of the samples, using USGS sample collection protocols, while the USGS is responsible for sample characterization, database development, and information dissemination. Descriptive information, such as location, mine source, geologic/stratigraphic nomenclature, and collection methods are requested to accompany each sample. These data are used to link the chemical data in a Geographic Information System (GIS) with other data, such as coal basins, geologic units, land use, transportation, and environmental/human health information.

Status

The USGS has analyzed samples from about 40 countries (fig. 1) of the approximately 50 coal-producing countries that, to date, have agreed to collaborate; samples continue to be collected and processed for analysis. The density of sample collecting varies among countries – for a few

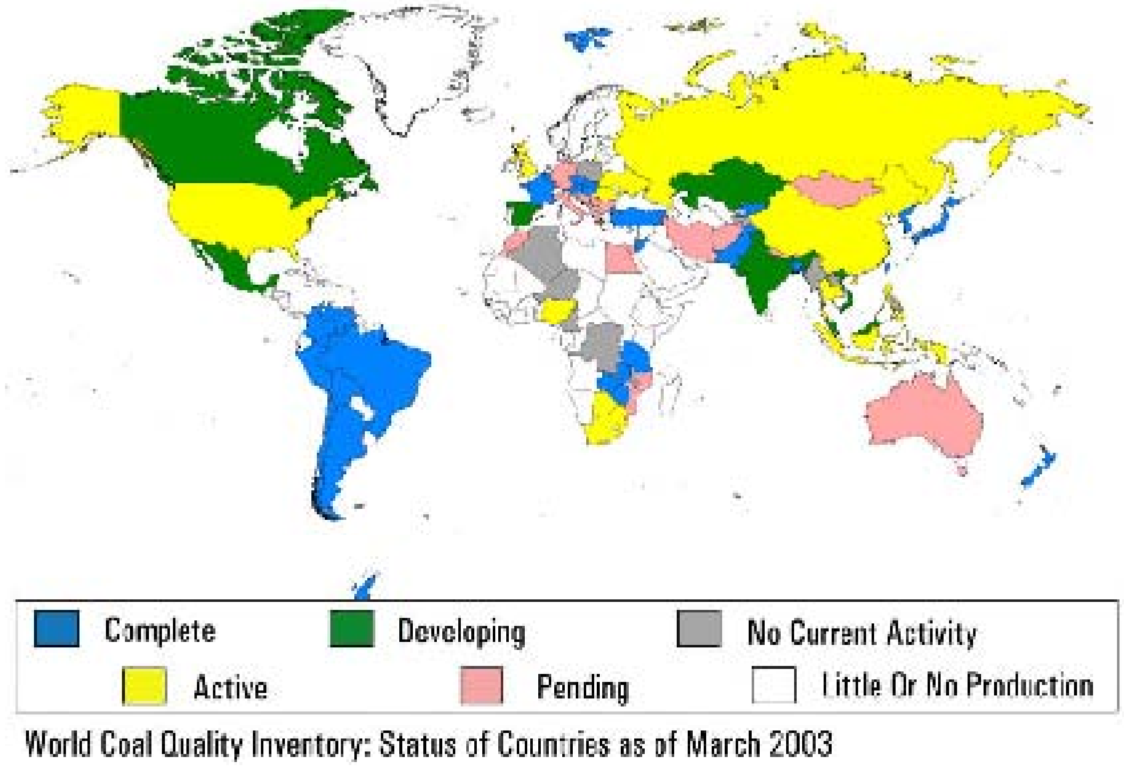


Figure 1. — World map showing the status of sample acquisition for WoCQI as of March, 2003. Status definitions: complete – collection and analysis complete; active – samples being collected; developing – foreign collaborators have agreed to collect samples; pending – foreign collaborators contacted, agreement to collect is pending; no current activity – no contacts made; little or no production – country will not be included in WoCQI.

countries samples from every operating mine have been submitted. When sample collection, data generation and data interpretation are completed, USGS and foreign collaborators jointly publish the results. Eventually, the USGS will make all the WoCQI data available on the internet through Geo-Data Explorer (GEODE), a USGS interactive map and information web page. GEODE will be updated on a regular basis and can be accessed through: http://dss1.er.usgs.gov/. At present, the data for the coal samples of Turkey are viewable through GEODE (fig. 2).

Figure 2. — Example of output from USGS Geo-Data Explorer (GEODE) depicting the locations of WoCQI coal samples (red dots) and political boundaries (black lines) in Turkey.

The USGS is also producing hard copy maps, such as the map entitled Coal-bearing Regions and Structural Sedimentary Basins of China and Adjacent Seas [USGS Open-file Report 00-047], which is also available on the internet at: http://pubs.gov/openfile/of.00-047. At present, a detailed digital map of the geology of Venezuela is in review by South American collaborators, which will also be released as hard copy.

A series of CD-ROMs will be produced that contain written chapters describing the coal distribution and usage by country and include the GIS data layers and coal quality data. Most of the CD-ROMs will be compiled for publication at a continental scale; the CD-ROM for South America is currently in preparation. Two CD-ROMs have been already produced as USGS open-file reports for China and the Former Soviet Union (Karlsen and others, 2001[http://pubs.usgs.gov/of/of01-318/]; Brownfield and others, 2001[http://greenwood.cr.usgs.gov/energy/OF01-104/]).

Future Plans

We anticipate that the WoCQI sample collection will be as complete as possible in one to two years. Thus the data will represent a "snapshot in time" of global coal chemistry of actively mined and combusted coals. The project is a good example of multinational cooperation to develop a reliable, comprehensive, global coal quality database that can be used to help ensure the efficient and environmentally compatible use of our global coal resources for the rest of the 21st century.

Collaborators are still being sought to collect additional coal samples and assist in interpreting and publishing the coal quality data. New coal information or digital map layers relating to coal or environmental/health issues related to coal usage are especially useful. Recommendations for improving the WoCQI and the dissemination of results are also desired.

References

Brownfield, M.E., Steinshouser, D.W., Povarennykh, M.Yu., Eriomin, Ivan, Shpirt, Mikhail, Meitov, Yevgeny, Sharova, Irena, Goriunova, Nina and Zyrianova, M.V., 2001, Coal Quality and Resources of the Former Soviet Union — An ArcView Project: U.S. Geological Survey Open File Report 01-104, CD-ROM.

International Energy Outlook, 2003, Energy Information Administration: DOE/EIA-0484 (2002), 262 p. [ftp://ftp.eia.doe.gov/pub/pdf/international/0484(2003).pdf].

Karlsen, A.W., Schultz, A.C., Warwick, P.D., Podwysocki, S.M., and Lovern, V.S., (Compilers), 2001, Coal Geology, Land Use, and Human Health in the Peoples Republic of China: U.S. Geological Survey Open File Report 01-318, CD-ROM.

Podwysocki, S.M., and Lovern, V.S., (Compilers), 2000, Coal-bearing Regions and Structural Sedimentary Basins of China and Adjacent Seas: U.S. Geological Survey Open File Report 00-047, CD-ROM.

Variations in Coal Maceral Chemistry and Mineral Matter Characteristics with Rank Advance in the German Creek Coal Measures of the Bowen Basin, Australia, using Electron Microprobe and Other Techniques

Colin R. Ward[1], Zhongsheng Li[1] and Lila W. Gurba[2]

[1]*School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney 2052, Australia*
[2]*CRC for Coal in Sustainable Development, Kenmore 4069, Australia*

Variations in the elemental composition of individual macerals in seams from the Permian German Creek Coal Measures in the Bowen Basin of Queensland have been studied over a wide range of rank conditions, using light-element electron microprobe techniques, to establish the coalification tracks of key macerals in a single coal-bearing sequence over the range from sub-bituminous and bituminous coal to anthracite. Vitrinite reflectance (Rvmax) in the seams studied increases from less than 0.4 percent in the western part of the basin to over 3.5 percent in the east, apparently due to increases in burial depth (Beeston, 1995).

The proportions of carbon, oxygen, nitrogen and sulphur, along with several other elements (Si, Al, Ca, and Fe), were determined in the macerals directly from polished sections, using methods originally developed by Bustin and others (1993) and refined by Mastalerz and Gurba (2001). The results show that the carbon content of the telocollinite in the coals increases dramatically from 66 percent to 90 percent as the vitrinite (telocollinite) reflectance (Rvmax) increases from 0.39 to 1.75 percent (fig.1a). In contrast, carbon in telocollinite increases only slightly, from 90 percent to 91 percent, as Rvmax increases over the rest of the rank range. Oxygen in the telocollinite decreases from around 26 percent to approximately 5 percent as Rvmax increases from 0.39 to 1.75 percent (fig. 1b), and then decreases only slightly as rank increases into the anthracite range.

Desmocollinite shows a similar variation in carbon and oxygen content to telocollinite, but has a slightly higher proportion of carbon and slightly lower proportion of oxygen relative to the telocollinite in the same coal samples. The difference is slight, but seems to persist to at least some extent throughout the entire rank range.

Fusinite and inertodetrinite have significantly higher but more constant carbon contents than the vitrinite macerals, varying respectively from about 81 and 86 percent to around 93 percent C over the same rank interval. Oxygen in these macerals decreases respectively from 12 and 9 percent to a little over 2 percent with the same degree of rank advance. Inertodetrinite appears to have higher proportions of carbon and lower proportions of oxygen than the fusinite in the same coals over the lower part of the rank range, although the difference becomes insignificant at higher rank levels. Semifusinite has carbon and oxygen contents that are intermediate between those of the fusinite/inertodetrinite and those of the vitrinite in the same coal samples. The carbon and oxygen contents of all the maceral groups converge to the point where they show only slight differences between each other above a vitrinite reflectance of around 1.8 percent.

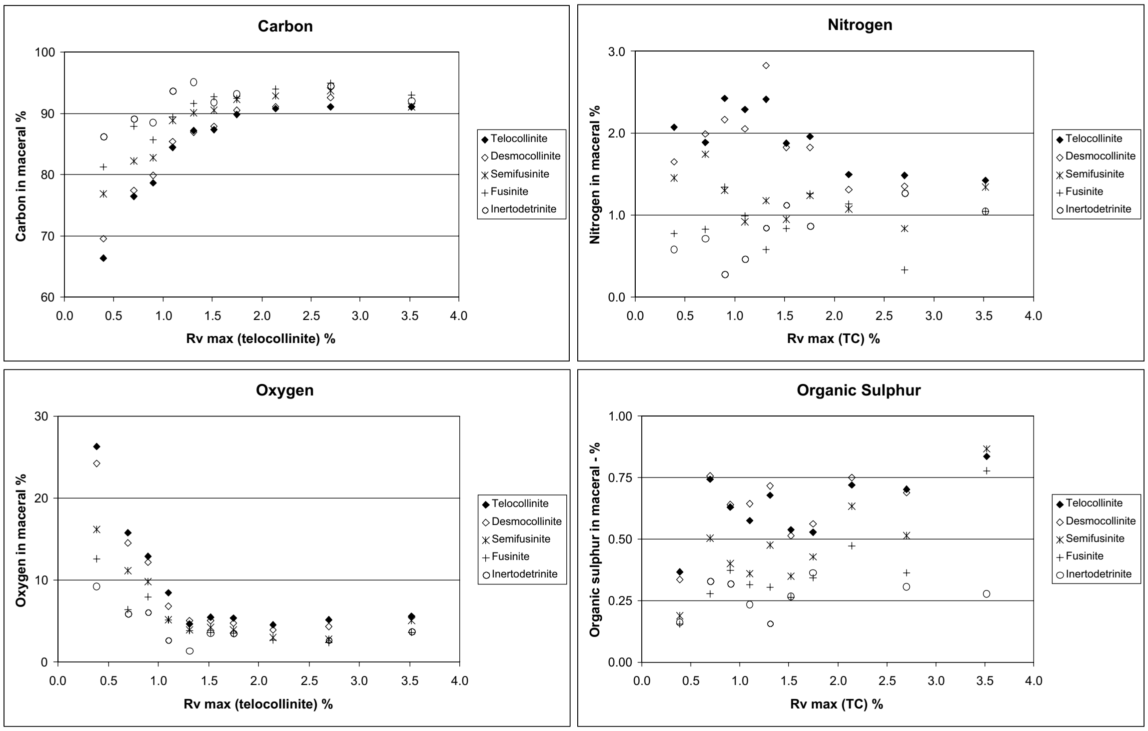


Figure 1. — Variations in C, O, N and S contents (weight percent by microprobe) in the different macerals of the German Creek Coal Measures with rank advance. Each data point represents the average concentration of the respective element for a number of such macerals in each coal sample.

Nitrogen and organic sulphur both appear to be significantly lower in the fusinite and inertodetrinite than in the vitrinites of the same coal samples, confirming the findings from other coals by Gurba (2001). Semifusinite generally has intermediate nitrogen and sulphur contents. The nitrogen content of both vitrinite macerals decreases slightly with rank (fig. 1c), and in particular appears to display a relatively abrupt drop at around 2 percent Rvmax. This may be associated with the development of ammonium illite in the mineral matter, which has been identified in other Bowen Basin coals at a similar rank level (Ward and Christie, 1994). Nitrogen in the inertinite macerals, however, appears to remain relatively constant with rank advance, and may even show a slight increase with rank in the inertodetrinite component. Differences in nitrogen content between vitrinite and inertinite macerals are therefore most marked in the sub-bituminous and bituminous coals (up to Rvmax = 2 percent), and appear to be less significant above that rank level.

Although the macerals, especially the vitrinite macerals, in the lowest rank coal studied have the lowest (organic) sulphur contents, and those of the highest rank coal (with the exception of inertodetrinite) have the highest levels of organic sulphur (fig. 1d), the proportion of organic sulphur in the individual maceral groups of the bulk of the samples does not appear to vary significantly with rank. As with findings reported from other coals by Ward and Gurba (1998), the organic sulphur content of the inertinite macerals, with some exceptions, is typically around half that of the vitrinites in the same coal samples, especially below the 2 percent vitrinite reflectance level.

The dramatic chemical changes in the elemental composition of the vitrinite from Rvmax 0.39 to 1.75 percent probably reflect the breakdown of large-molecule organic compounds to smaller compounds, and the associated volatile loss associated with the rank advance. The vitrinite and semifusinite macerals of the lowest-rank coal (Rvmax = 0.39 percent) also show small proportions of calcium in the organic matter, but this is lost, apparently due to similar molecular changes, at higher rank levels.

Studies of the mineral matter in the coals, using low-temperature oxygen plasma ashing and quantitative X-ray diffraction techniques, show an abundance of well-ordered kaolinite in the coals at lower rank levels, but the appearance of illite and chlorite instead of kaolinite at the upper end of the rank range. The X-ray diffraction pattern exhibited by the coal's organic matter, as well as the FTIR characteristics of particular macerals, have also been studied as part of the program, to test the applicability of other technologies in evaluating changes in the organic and mineral components of coals from the same stratigraphic interval with the rank advance process.

References

Beeston, J.W., 1995, Coal rank and vitrinite reflectivity *in* Ward, C.R., Harrington, H.J., Mallett, C.W., and Beeston, J.W., eds., Geology of Australian Coal Basins: Geological Society of Australia Coal Geology Group Special Publication 1, p. 83-92.

Bustin, R.M., Mastalerz, Maria, and Wilks, K.R., 1993, Direct determination of carbon, oxygen and nitrogen content in coal using the electron microprobe: Fuel, v. 72, p. 181-185.

Gurba, L.W., 2001, Distribution of organic nitrogen in Australian coals: Pittsburgh, Pennsylvania, Proceedings of 18th Annual Pittsburgh International Coal Conference (CD-ROM), 13 p.

Mastalerz, Maria, and Gurba, L.W., 2001, Determination of nitrogen in coal macerals using electron microprobe technique — experimental procedure: International Journal of Coal Geology, v. 47, no. 1, p. 23-30.

Ward, C.R., and Christie, P.J., 1994, Clays and other minerals in coal seams of the Moura-Baralaba area, Bowen Basin, Australia: International Journal of Coal Geology, v. 25, no. 3-4, p. 287-309.

Ward, C.R., and Gurba, L.W., 1998, Occurrence and distribution of organic sulphur in macerals of Australian coals using electron microprobe techniques: Organic Geochemistry, v. 28, no. 11, p. 635-647.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Geological Processes that Control Lateral and Vertical Variability in Coal Seam Moisture Contents — Latrobe Valley (Gippsland Basin) Australia

Guy R. Holdgate

School of Earth sciences, Melbourne University, Victoria 3010, Australia.

Coal seam moisture in the Latrobe Valley of Victoria (Australia) plays a significant role in the use made of these coals; the volume of coal required for a given power output in thermal power stations, the calorific value of the coal, and the emission of greenhouse gases. Previous work on the moisture content of Latrobe Valley brown coals has largely omitted geological influences, concentrating more on localized variability within the scale of the individual mines (e.g. Higgins and others,1980; Brockway and others,1983).

Historically Latrobe Valley open cut developments for thermal power generation have concentrated on the shallow higher moisture coals due to their low stripping ratios. Discovery of large shallow lower moisture coal fields near the Latrobe Valley such as Gormandale and Longford post-date the delineation and development of the current mined deposits at Yallourn, Morwell and Loy Yang. These new fields have coals with moisture contents over 10-20 percent lower than the currently mined coal. This can translate to significant volume reductions of >25 percent for equivalent energy outputs (Holdgate, 1996) and as a consequence would provide for large CO_2 emission reductions. This paper aims to determine the major factors that contribute to coal seam moisture and rank variability both vertically and laterally across the Latrobe Valley and to study the principle determinants to moisture decrease.

Volumetrically water is one of the most important constituents in low rank coals typical to the Latrobe Valley, Gippsland Basin. From the precursor peat stage (where water content may reach up to 90 percent; George and Mackay, 1991) moisture content has decreased to about 60-65 percent for Lignite B – Latrobe Valley coals, but in some areas is below 50 percent. Moisture content in the Latrobe Valley is often interpreted to be solely a function of depth of burial. Studies supporting this were localized to open cuts of the time, e.g. Yallourn (Edwards, 1945; 1947). Effects of folding on moisture were also investigated in the Yallourn area (Edwards, 1945; 1948). Petrographic (lithotype) effects on moisture have been broadly quantified by Edwards (1945); Allardice and others (1978); Higgins and others (1980); Hibbert and others (1981); King and others (1983); Gaulton (1985); and Gaulton and others (1992), but a regional appraisal of lithotype and maceral distributions was not incorporated in these studies. Research on other effects on moisture content, such as age of seam, overburden composition, relative abundance of wood, and geothermal gradients have not previously been undertaken.

There exists a large database on the coal quality, moisture, calorific value and maceral composition for Latrobe Valley brown coals. An extensive data set of over 140,000 sample analyses is available as vertical profiles in bores and open cuts for moisture content, volatile matter and ash content. This database has been used in the current brown coal open cut mines to predict boiler performance (which is affected by changes in moisture, calorific value and ash). Bore data usually consists of composited 3 m core intervals for moisture, 6 m composites for ash (and constituents) and 12 m core intervals for volatiles. Some detailed 0.5-1 m sampling is also available in the main coal fields.

Previous analysis of this data for regional trends has been carried out on individual economic coal fields with figures often quoted as weighted averages for individual or composited coal seams. A regional synthesis has been lacking due to the sheer volume of data and the difficulties of presenting gradational changes both vertically and laterally. Recently, a large interactive 3D mining model (instigated by Geological Survey of Victoria) has been generated that incorporates all the stratigraphic and coal quality data across the Latrobe Valley. From this model lateral and vertical changes of moisture content can be depicted from grided coal quality data sets onto geological cross-sections. Vertical down-hole moisture changes can also be useful to depict stepwise jumps in the moisture content.

Results indicate the following features:

1) Average moisture down seams decreases by 1-2 percent per seam and at a rate of approximately 1 percent every 20 meters.
2) Average moistures for each seam show an overall decrease in an easterly direction towards the marine interface which does not completely correlate to depth of burial, e.g. the values for the Yallourn Seam between Loy Yang and Rosedale decrease from 65 percent to 57 percent and the Morwell 2 seam for the same interval decrease from 55 percent to 45 percent. This is supported by the averaged moisture isolines (as calculated from the downhole moisture gradients) that show an overall rise to the east against dip and depth.
3) Seam moisture content decreases with the age of the seam, reflecting the influence of time on the coalification process. On average there is a decrease in moisture content between the major seams of between 1 percent and 7 percent. There is an average decrease between the Middle Miocene Yallourn seam and late Early Miocene M1A seams of 4.8 percent. Between the M1A and the Early Miocene M1B it is 2.7 percent, between the M1B and the Late Oligocene M2 it is 1.8 percent and between the M2 and Late Eocene Traralgon Seams it is 2.7 percent.
4) If the weight average moisture content for each seam is plotted against seam age, then an envelope can be drawn around the data from the coal field areas of Narracan, Morwell, Loy Yang and Flynn. Within this envelope, moisture decreases on average at a rate of 0.5 percent every 1 million years, although faster than normal coalification appears to have occured between Yallourn and M1A which are separated by a comparatively short 2 Ma. period. The Yallourn and Maryvale coal fields occur outside this data envelope, with a faster rate of moisture decrease at around 2 percent per Ma. This is due to an increase in the thickness of interseam clays and sands between Yallourn and Morwell seams at Yallourn-Maryvale, compared to the Narracan/Morwell/Loy Yang/Flynn fields.
5) Abrupt step-like profiles in moisture content occurs across seam boundaries. Regular moisture decrease with depth is not always present but can markedly decrease across the major seam boundaries. The weight averaged whole seam moisture contents decreases

between 1-2 percent below major seam boundaries irrespective of burial depth, but within split seams, moisture content tends to remain constant. This pattern is best explained if all the coal seam splits from one major seam accumulated over a comparatively short time period whereas between major seams there are comparatively long time breaks enabling coalification to proceed uniformly. Moistures tend to be higher and show a more regular downwards decreasing moisture gradient, where successive thick seams overlie each other such as at Loy Yang. In contrast where thick sediment (clay-sand) interseams overlie or interbed with coals, moisture is substantially decreased for the same depth of burial, such as the M1B coal seam in the Traralgon Syncline. This reflects a greater weight per volume of sediment (approximately twice) to that of the coal. The sandy marine sediment ingressions at the eastern end of the Latrobe Valley also have this effect on seam moisture content.

6) Differential compaction, which by definition must involve moisture (volume) loss, has been considered an important factor influencing the geometry and architecture of the coal depocenters in the Latrobe Valley (Holdgate, 1985). In the Latrobe Valley where coals are still in the lignite stage, this equalization does not appear to have finished, and consequently areas of the same seam where loaded by more sediment tend to contain lower moistures for the same depth of burial. The volume decrease can be calculated using the measured specific-gravity of dry coal at Loy Yang (sg=1.44). Between 70 percent and 60 percent moisture, volume decreases 27 percent, whereas between 60 percent and 50 percent moisture the volume decreases 23 percent. For coals below 40 percent moisture content this moisture-volume decrease is further reduced. Because most Latrobe Valley coals have moisture contents in the 50-65 percent range they lie within the zone of rapidly changing volumes and these small changes can be significant. This volume decrease is supported petrographically in bore R-324 near the marine margin where the coal macerals appear more gellified and compacted than their equivalents at Loy Yang, and where the liptinite macerals appear flattened (Bolger, 1984).

7) Compression by monoclinal folding can decrease moisture contents by up to 7 percent (Edwards (1945, 1948). However on most anticlines in the Latrobe Valley, moisture content for a given depth is higher because the intensity of compression is less than in the adjacent synclines and/or the anticlines are more fractured and contain higher groundwater contents.

8) Moisture trend reversals can occur where moisture values increase downwards with depth. This occurs particularly in the Yallourn Seam and relates to the abundance of the wetter darker lithotypes towards the base of the seam.

9) Down the Latrobe Valley most coal seams show an increase in the relative abundance of the wetter medium dark and darker lithotypes due to an increasing marine influence from the east (Holdgate, 1996). This results in a small reversal in the eastward trend towards moisture decrease.

References

Allardice, D.J., and Evans, D.G., 1971, The brown coal/water system 1 — the effect of temperature on the evolution of water from brown coal: Fuel, v. 50, p. 201-210.

Allardice, D.J., George, A.M., King, T.N.W., and Kiss, L.T., 1978, The properties of brown coals from the Latrobe Valley — results of analyses and tests: State Electric Commission of Victoria Research and Development Department Report 357, 145 p.

Bolger, P.F., 1984, Petrology of some deeply buried coals from bore Rosedale-324, Latrobe Syncline: Electric Commission of Victoria Exploration and Geology Laboratory Report GL/84/7, 5 p.

Brockway, D.J., Hibbert, W.D., George, A.M., Attwood, D.H., and Kiss, L.T., 1983, Coal quality zones in Yallourn open cut, part 1 — first cross-section: Electric Commission of Victoria Research and Development Department Report SO/83/70, 27 p.

Edwards, A.B., 1945, The composition of Victorian brown coals: Proceedings, Australian Institute of Mining and Metallurgy, v. 140, p. 205-287.

______1947, Coal types in the Yallourn and Latrobe brown coal seams: Proceedings, Australian Institute of Mining and Metallurgy, v. 146-147, p. 23-69.

______ 1948, Some effects of folding on moisture content of brown coal: Proceedings, Australian Institute of Mining and Metallurgy, v. 150-151, p. 101-112.

Gaulton, R.J., 1985, The variation of moisture with lithotype and of nitrogen and certain inorganics with petrography in Yallourn Seam brown coal: Wollongong, NSW, Australia, University of Wollongong, M.S. Thesis, 215 p.

Gaulton, R.J., Wood, W., and Bell, A., 1992, Property trends in Latrobe Valley brown coals and implications for future utilisation, *in* Energy, Economics and Environment, Gippsland Basin Symposium: Melbourne, Victoria, Australia, Australian Institute of Mining and Metallurgy, p. 73-83.

George, A.M., and Mackay, G.H., 1991, Petrology (Chapter 2), *in* Durie, R.A., ed., The Science of Victorian Brown Coal — Structure, Properties and Consequences for Utilisation: Butterworth-Heinemann Ltd., Linacre House, Jordan Hill, Oxford, UK, p. 45-102.

Hibbert, W.D., Smith, G.C., and Kiss, L.T., 1981, Variation of coal properties with lithotype, Part 1 — Morwell open cut: State Electric Commission of Victoria Research and Development Department Report SO/81/32, 8 p.

Higgins, R.S., Kiss, L.T., Allardice, D.J., George, A.M., and King, T.N.W., 1980, Properties of brown coal from the Latrobe Valley — a basis for the evaluation of quality: State Electric Commission of Victoria Research and Development Department Report SC/80/17, 22 p.

Holdgate, G.R., 1985, Latrobe Valley brown coals — their geometry and facies equivalents as a guide to depositional environment: Australian Coal Geology, v. 5, p. 53-68.

______1996, The influence of sea-level changes on coal seam deposition and equivalent facies onshore Gippsland Basin: Melbourne, Australia, Monash University, Ph.D. Thesis, 419 p.

King, T.N.W., George, A.M., Hibbert, W.D., and Kiss, L.T., 1983, Variation of coal properties with lithotype; Part 2 — Latrobe Valley coals: State Electric Commission of Victoria Research and Development Department Report SO/83/55, 19 p.

Murray, J.B., and Evans, D.G., 1972, The brown coal/water system 3 — Thermal dewatering of brown coal: Fuel, v. 51, p. 290-296.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Mercury Variation in Powder River Basin Coal Samples

Allan Kolker[1], Joseph R. Hatch[2], Curtis A. Palmer[1], and Linda J. Bragg[1]

[1]*U.S. Geological Survey, MS 956, National Center, Reston, VA 20192*
[2]*U.S. Geological Survey, Denver, CO 80225*

The Powder River Basin (PRB) of Wyoming and Montana is one of the most important coal-producing areas of the country, with more than 350 million short tons of coal produced in 1999. Powder River Basin coal beds are low in sulfur, and they are generally viewed as desirable with respect to most coal quality parameters. Although the overall coal quality and accessibility of Powder River Basin coals has led to enormous growth in production, these coals are by no means uniform or without potential sources of concern. In this paper we use available information to examine mercury contents of PRB coals, a first step toward defining the nature and extent of mercury variation in these coals and the factors that control it.

Stricker and Ellis (1999) report concentration averages in the Wyodak-Anderson coal zone for elements of interest from the standpoint of atmospheric emissions (Be, Cr, Mn, Co, Ni, As, Se, Cd, Sb, Hg, Pb, and U). All of these concentration averages are less than half of the respective in-ground COALQUAL U.S. averages (Bragg and others, 1998), with the exception of manganese (60 percent), uranium (62 percent) and mercury (76 percent of U.S. average). The mean mercury value reported for Wyodak-Anderson coal (0.13 ppm; Stricker and Ellis, 1999) exceeds the average mercury content for coals delivered to U.S. power plants in 1999 (0.10 ppm; Quick and others, 2003). The mean mercury content for PRB coals as a whole is lower (0.08 ppm; Tewalt and others, 2001), but on an equal energy basis, they likely exceed the average mercury loading to U.S. coal-burning power plants. These findings suggest that a better understanding of the geographic and stratigraphic variation of mercury, its mode of occurrence, and geologic control in PRB coals is warranted.

On a plot of mercury vs. pyritic sulfur (fig.1), results for Power River Basin coal samples from Wyoming (Bragg and others, 1998) define an extended array that intersects the mercury (pyritic sulfur = 0) axis at a positive mercury value of about 0.1 ppm, indicating that a significant proportion of mercury resides in the organic fraction, or, less likely, in mineral matter other than pyrite. This is consistent with results of Palmer and others (2000), who found no change in mercury content comparing an as-mined PRB coal sample having 0.08 ppm mercury with an equivalent sample subjected to a simulated cleaning procedure. Selective leaching results for several PRB samples indicate significant organic associations for both mercury and selenium (Palmer and others, 1998, 2000; Kolker and others, 2002). A plot of mercury vs. selenium for the Gillette Coal Field (fig. 2) shows co-variation of these elements as a more steeply sloping array than in figure 1, intersecting the mercury axis closer to the origin, at about 0.05 ppm mercury. Figure 2 also shows pyritic sulfur = 0 intercept values for selenium (1.08 ppm) and mercury (0.113 ppm) in Gillette samples, based on plots similar to figure 1. These values are estimates of typical selenium and mercury contents for Gillette samples that lack measured pyritic sulfur, based on the COALQUAL data.

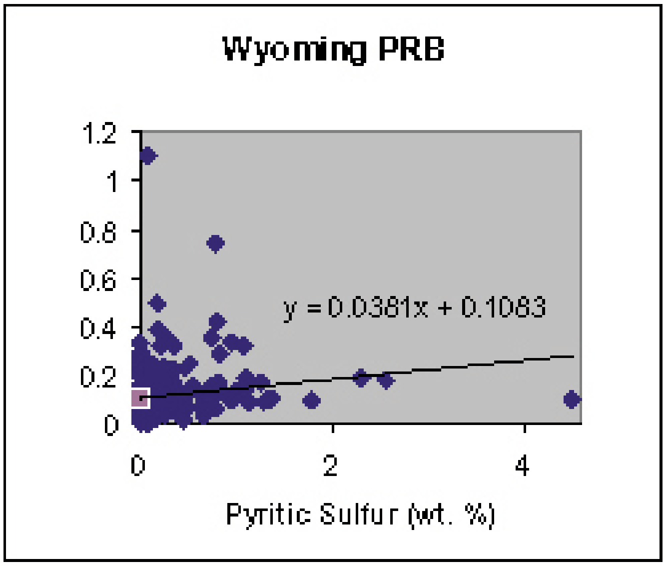


Figure 1. — Plot showing mercury variation as a function of pyritic sulfur in Wyoming PRB coal samples (Bragg and others, 1998). Intersection of array with mercury axis indicates an average mercury value of about 0.1 ppm (square) for samples lacking pyritic sulfur. These samples likely contain a very large fraction of their total mercury in an organic association. Trend-line is a linear best fit to the data (n = 283).

Stratigraphic differences in sulfur contents are evident in the Wyodak-Anderson coal zone, and in general, the proportion of pyritic sulfur increases with sulfur content (Ellis, 2002; Flores and others, 1999). Despite this variation in pyrite content, on a basin scale the overall correlation between mercury and sulfur content is indistinct at best (fig. 1). The lack of a strong link between mercury in PRB coals and pyrite indicates that attempts to reduce mercury by removing pyrite will be unsuccessful.

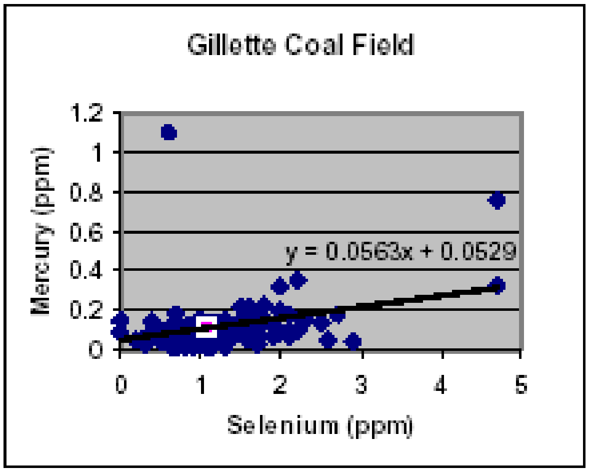


Figure 2. — Plot showing co-variation of mercury and selenium, elements having similar modes of occurrence in PRB coals. Square represents approximate composition of samples lacking pyritic sulfur, inferred from intersection of element vs. pyritic sulfur trend lines with selenium or mercury axes, as shown in figure 1. Trend line is a linear best fit to the data (n = 110).

References

Bragg, L.J., Oman, J.K., Tewalt, S.J., Oman, C.L., Rega, N.H., Washington, P.M., and Finkelman, R.B., 1998, U.S. Geological Survey Coal Quality (COALQUAL) Datbase: Version 2.0, U.S. Geological Survey Open-File Report 97-134, CD-ROM.

Ellis, M.S., 2002, Quality of economically extractable coal beds in the Gillette coal field as compared with other Tertiary coal beds in the Powder River Basin, Wyoming and Montana: U.S. Geological Survey Open-File Report 02-174, 20 p.

Flores, R.M., Ochs, A.M., Stricker, G.D., Roberts, S.B., Ellis, M.S., Keighin, C.W., Murphy, E.C., Cavaroc, V.V., Jr., Johnson, R.C., and Wilde, E.M., 1999, National coal resource assessment non-proprietary data — Location, stratigraphy, and coal quality of selected Tertiary coals in the Northern Rocky Mountains and Great Plains Regions: U.S. Geological Survey Open-File Report 99-376, CD-ROM.

Kolker, Allan, Mroczkowski, S.J., Palmer, C.A., Dennen, K.O., Finkelman, R.B., and Bullock, J.H., Jr., 2002, Toxic substances from coal combustion — a comprehensive assessment; Phase II — Element modes of occurrence for the Ohio 5/6/7. Wyodak, and North Dakota coal samples: U.S. Geological Survey Open-File Report 02-224, 79 p.

Palmer, C.A., Mroczkowski, S.J., Finkelman, R.B., and Crowley, S.S., 1998, The use of sequential leaching to quantify the modes of occurrence of elements in coals: Proceedings of the Fifteenth Annual International Pittsburgh Coal Conference, 28 p., CD-ROM.

Palmer, C.A., Mroczkowski, S.J., Kolker, Allan, Finkelman, R.B., and Bullock, J.H., Jr., 2000, Chemical analysis and modes of occurrence of selected elements in a Powder River Basin coal and its corresponding simulated cleaned coal: U.S. Geological Survey Open-File Report 00-322, 53 p.

Quick, J.C., Brill, T.C., and Tabet, D.E., 2003, Mercury in U.S. coal: Observations using the COALQUAL and ICR data: Environmental Geology, v. 43, p. 247-259.

Stricker, G.D., and Ellis, M.S., 1999, Coal quality and geochemistry, Powder River Basin, Wyoming and Montana, chap. PQ in U.S. Geological Survey Professional Paper 1625-A, CD-ROM

Tewalt, S.J., Bragg, L.J., and Finkelman, R.B., 2001, Mercury in U.S. coal – Abundance, distribution, and modes of occurrence: U.S. Geological Survey Fact Sheet FS-095-01, 4 p.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Distribution of Mercury in Indiana Coals

Agnieszka Drobniak[1], Maria Mastalerz[1], and Gabriel M. Filippelli[2]

[1] *Indiana Geological Survey, Indiana University, Bloomington, IN 47405*

[2] *Department of Geology, IUPUI, Indianapolis, IN 46202*

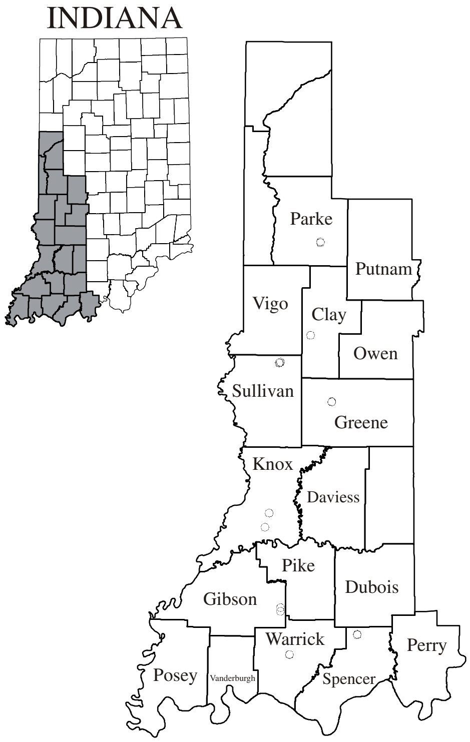


Figure 1. — Location of coal samples.

Coal samples (several benches from each location) were collected from nine mines in Indiana to study the distribution of Hg between different coal seams and within individual seams. Coal mine samples were located in Parke, Clay, Sullivan, Green, Knox, Gibson, Warrick, and Spencer Counties (fig. 1). The analyzed coals include Danville, Hymera, Springfield, Minshall, Upper Block, and Lower Block Coal Members, an unnamed coal in the Mansfield Formation, and the Mariah Hill. Both raw coals (R) and float fractions (F) were analyzed. Average Hg concentrations for the whole seam samples, their float fractions, and ranges of Hg in coal benches are presented in Table 1.

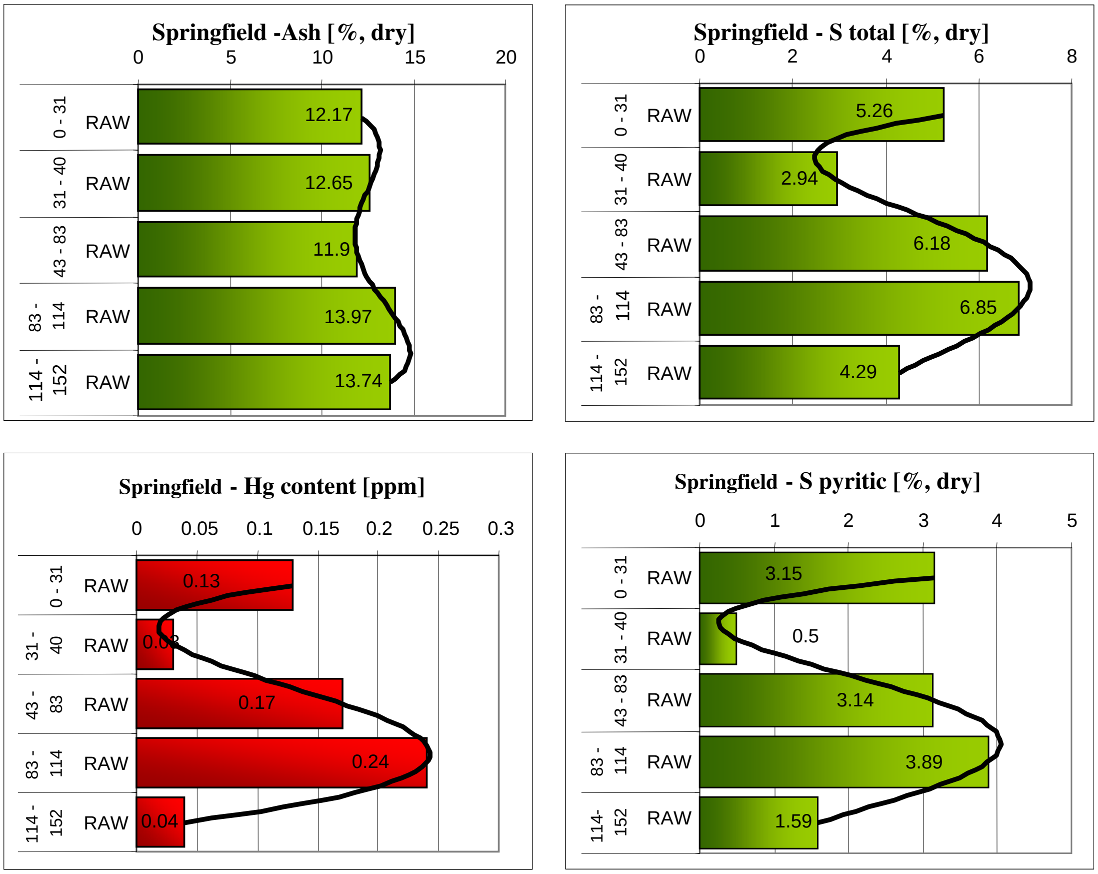
Hg contents in seam samples range from 0.03 to 0.31 ppm; a similar range also occurs between individual benches of one seam section, for example, in the Lower Brazil coal in Spencer County, and the Hymera coal in Sullivan County. In the seams studied, three types of Hg distribution have been observed. In the most common relationship, the Hg content is strongly related to total sulfur and pyritic sulfur contents (fig. 2A); such a relationship suggests the association of Hg with pyrite; the high-sulfur Springfield coal is a typical example. In the second relationship, the Hg content does not correlate with total sulfur or pyrite and is negatively correlated with ash content (fig. 2B). This relationship suggests that Hg is associated with organic matter, as exemplified by the Danville coal. A third relationship, where Hg content correlates negatively with total sulfur and pyritic sulfur and positively with ash yield (fig. 2C); suggests that Hg is associated with mineral matter other than pyrite, for example, in the Mariah Hill and unnamed Mansfield coals. Our interpretation of the Hg associations is supported by ratios of the Hg content in raw coal to that in its float fraction. Coals in which Hg correlates with S, pyrite, and ash generally have higher R/F ratios (table 1) than coals in which Hg does not correlate with mineral matter and occurs dominantly in the organic fraction of the coal. Higher R/F ratios indicate that Hg was removed during washing and must be associated with the mineral matter.

Relationships between Hg content and maceral composition also were investigated with special emphasis on those samples in which the previously observed relationships suggested an association with organic matter. No clear tendency has been noted. In most cases, Hg was higher in coals with higher liptinite content and often the Hg content decreased with an increase in vitrinite content. In many samples, however no relationships between maceral compositions and Hg contents were detected. Current analyses of pairs of bright (vitrinite-rich) and dull liptinite- and inertinite-rich) coal are likely to help reveal differences in Hg content between coal lithotypes.

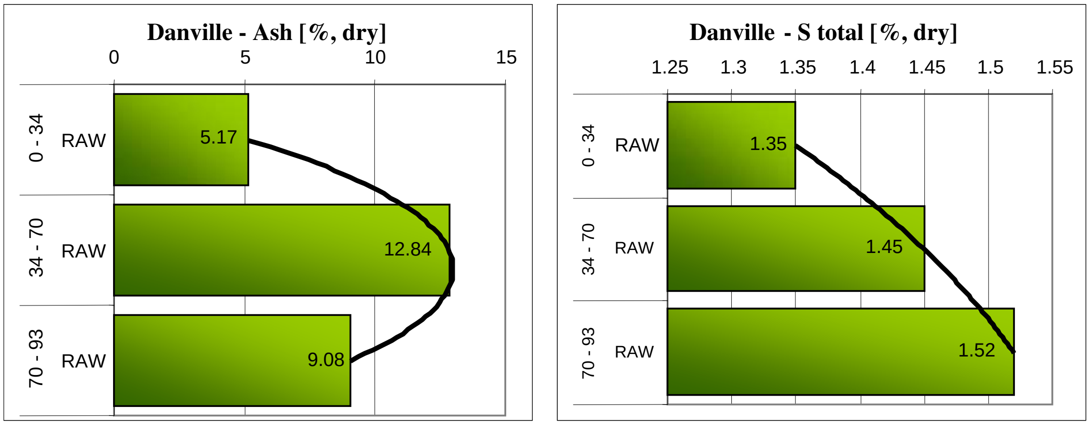
Table 1. — Hg contents in raw coal samples and float fractions in the coal mines studied. R/F is a ratio of Hg content in raw coal to Hg content in the float. Coals arranged in stratigraphic order.

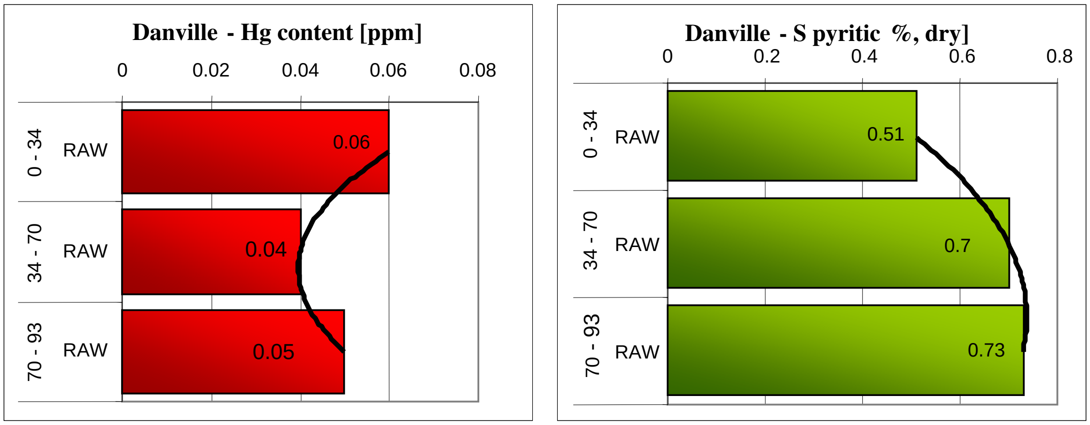
Coal Seam	County	HG IN FULL SEAM SAMPLE (PPM) [R]	HG IN FLOAT FRACTION (PPM) [F]	R/F	HG RANGE IN BENCHES (PPM)
Danville	Sullivan	0.07	0.04	1.75	0.01 – 0.13
Danville	Sullivan	0.05	0.04	1.25	0.04 – 0.06
Danville	Knox	0.03	0.02	1.50	0.02 – 0.04
Hymera	Sullivan	0.25	0.18	1.39	0.08 – 0.49
Hymera	Gibson	0.06	0.05	1.20	0.05 – 0.06
Springfield	Warrick	0.13	0.06	2.17	0.03 – 0.24
Springfield	Gibson	0.06	0.05	1.20	0.04 – 0.11
Minshall	Parke	0.13	0.10	1.30	0.09 – 0.18
Upper Block	Parke	0.31	0.15	2.07	0.27 – 0.33
Lower Brazil	Spencer	0.11	0.06	1.83	0.05 – 0.21
Lower Block	Greene	0.04	0.04	1.00	0.01 – 0.13
Lower Block	Clay	0.21	0.02	10.50	0.05 – 0.39
Un. Mansfield	Greene	0.11	0.09	1.22	0.02 – 0.23
Un. Mansfield	Clay	0.16	0.09	1.78	0.12 – 0.24
Mariah Hill	Spencer	0.05	0.04	1.25	0.04 – 0.06

A)


Springfield -Ash [%, dry]
0
5
10
15
20
0 - 31 RAW 12.17
31 - 40 RAW 12.65
43 - 83 RAW 11.9
83 - 114 RAW 13.97
114 - 152 RAW 13.74
Springfield - S total [%, dry]
0
2
4
6
8
0 - 31 RAW 5.26
31 - 40 RAW 2.94
43 - 83 RAW 6.18
83 - 114 RAW 6.85
114 - 152 RAW 4.29
Springfield - Hg content [ppm]
0
0.05
0.1
0.15
0.2
0.25
0.3
0 - 31 RAW 0.13
31 - 40 RAW 0.03
43 - 83 RAW 0.17
83 - 114 RAW 0.24
114 - 152 RAW 0.04
Springfield - S pyritic [%, dry]
0
1
2
3
4
5
0 - 31 RAW 3.15
31 - 40 RAW 0.5
43 - 83 RAW 3.14
83 - 114 RAW 3.89
114- 152 RAW 1.59

B)


Danville - Ash [%, dry]
0
5
10
15
0 - 34 RAW 5.17
34 - 70 RAW 12.84
70 - 93 RAW 9.08
Danville - S total [%, dry]
1.25
1.3
1.35
1.4
1.45
1.5
1.55
0 - 34 RAW 1.35
34 - 70 RAW 1.45
70 - 93 RAW 1.52



C)

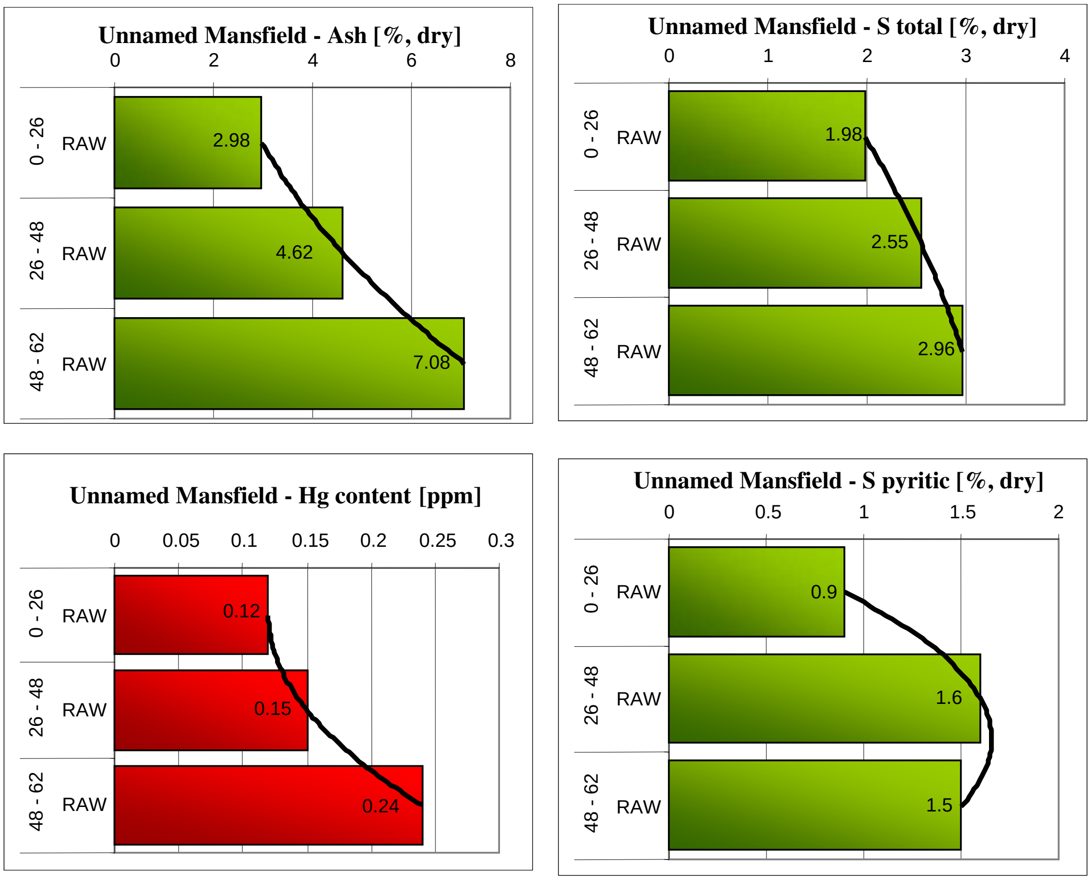


Figure 1. — Ash, total sulfur, Hg, and pyritic sulfur content in the Springfield coal (A), Danville coal (B), and unnamed Mansfield coal (C). Lines indicate trend in vertical seam section.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Response of Major Geochemical Thermal Maturity Parameters to Suppression of Vitrinite Reflectance, Gunnedah-Surat Basins, New South Wales, Australia

Rushdy Othman and Colin R. Ward

School of Biological, Earth and Environmental Sciences, University of New South Wales,
Sydney NSW 2052, Australia

The level of organic matter maturity is expected to increase steadily with depth in a vertical sequence of strata. Hence, individual maturity parameters should correspondingly show a steady change with depth. Although thermal maturity is the main control on these organic matter maturity parameters, it has also been documented that some parameters may be affected by the depositional environment, the type or source of the organic matter, or other factors. Depositional environment and the type of organic matter involved in a coal or dispersed organic matter, for example, are two major factors that may result in anomalously low vitrinite reflectance values in a buried sedimentary succession; more specifically, the influence of marine conditions or an increased abundance of associated liptinite macerals may result in anomalously low values for this particular parameter.

Previous studies have shown that two different stratigraphic intervals in the Gunnedah and Surat Basins of New South Wales have been subjected to vitrinite reflectance suppression. In the northern part of the basin, one is a marine-influenced sequence and one is a liptinite-rich succession. Rock-Eval T_{max} values in these intervals respond in a similar way to vitrinite reflectance, being lower in the intervals with suppressed reflectance values. Despite the development of anomalously low vitrinite reflectance and T_{max} levels at these horizons in the study area, a number of other geochemical maturity parameters, such as those based on hopane and sterane ratios, maintain a steady pattern of variation with depth, even in intervals where suppression of vitrinite reflectance or T_{max} values occur.

Maturity parameters based on the generated hydrocarbons, such as the bitumen/TOC ratio, respond in a similar way to the hopanes and steranes, and show no anomalous values within the suppressed intervals. Instead, these generation maturity parameters increase regularly with increasing burial depth. The actual amount of hydrocarbons generated therefore increases regularly with increasing burial depth, even though the thermal stress maturity parameters, vitrinite reflectance and T_{max}, are suppressed in certain intervals.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Coal Sample Storage — Preservation using Foil Multilaminate Bags

David C. Glick, Gareth D. Mitchell and Alan Davis

Coal and Organic Petrology Laboratories, The Energy Institute,
The Pennsylvania State University, University Park, PA 16802

Introduction

Deterioration of coal samples during storage can eliminate the possibility of reproducing analyses or continuing research over time. Typically, decreases are observed in moisture, calorific value, and thermoplasticity (Gieseler maximum fluidity and fluid temperature range), whereas increases in sulfate sulfur result from oxidation of sulfide minerals. Following an initial short-term study, the Penn State Coal Sample Bank adopted the use of foil multilaminate bags (layers of polyethylene - aluminum - fibrous polyethylene) for inert atmosphere coal storage in 1989, and in 1993 began refrigerating all DECS-series samples at 3 ^{o}C. To evaluate the technique, monitoring of preservation was conducted annually through 1999 and again in 2003. Selected samples stored in foil bags and in the presence or absence of refrigeration have been analyzed for moisture, sulfur forms, calorific value, Gieseler fluidity (on samples of appropriate rank), gaseous oxygen within the bags and, less frequently, ultimate analysis. Interim results (Glick and others, 1997) showed that foil multilaminate bags preserved the initial properties of pulverized coals for at least eight years. This presentation will include additional monitoring information on samples stored in foil bags for 12 to 14 years and will compare room temperature storage to refrigerated storage.

Initial study on medium-volatile bituminous coal

A one-month study by Sharp (1986) on the preservation of a subbituminous sample prompted a similar study of bituminous coal in this laboratory (Glick and others, 1991). In that study, a run-of-mine sample of medium-volatile (mean-max R_o = 1.27 percent) Lower Kittanning seam coal was collected and promptly crushed, subsampled and analyzed. Splits of the sample were packaged in a variety of container types; analyses have been reported for storage times of 4, 16 and 52 weeks (Glick and others, 1991) and 116 weeks (Davis and Glick, 1993). These and subsequent analyses have shown two sensitive indicators of deterioration (Gieseler fluid temperature range and sulfate sulfur) to be essentially unchanged after 8 years of storage in foil bags (fig. 1). Even the steel cans purged with argon, which appeared to be a good container type early on, allowed the loss of all thermoplasticity and an increase in sulfate sulfur from 0.06 percent to 1.18 percent during the same period. Volatile matter, calorific value, carbon and oxygen exhibited only minor changes over 8 years in foil bags, whereas both volatile matter and oxygen increased and carbon and calorific value decreased significantly for the can and exposed samples. Coal deteriorated at a faster rate in buckets stored in an uncontrolled environment (-5 to 35 ^{o}C) than even the exposed sample stored at 18 to 23 ^{o}C . It was found that the screw-on, gasketed bucket lids had loosened, breaking the seal.

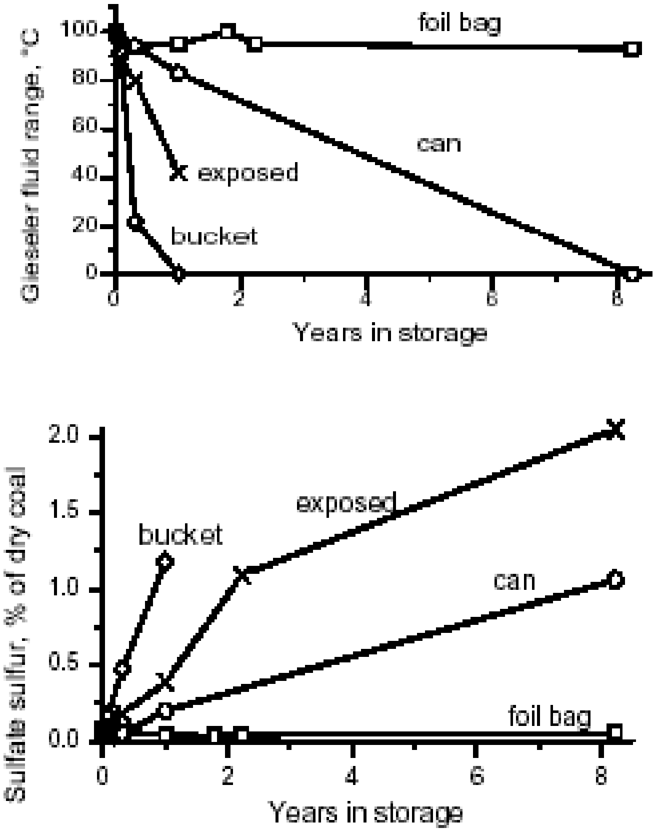


Figure 1. — Changes in medium-volatile bituminous coal sample stored in various container types.

Comparison to glass ampoules from the Argonne Premium Coal Sample Program

A separate study was performed to compare several Argonne premium samples (Vorres, 1990) sealed in their original ampoules to identical splits resealed in foil bags. Gieseler fluidity after one and two years showed that inert atmosphere storage of coal in the foil bags was comparable to that in glass ampoules (Davis and Glick, 1993).

Annual monitoring of bituminous and subbituminous DECS samples

Sealing of a standard 250 g subsample of -0.85 mm (-20 mesh) coal is accomplished by placing the subsample in a 15 x 20 cm bag of 0.15 mm polyethylene which is then folded over and placed inside a 20 x 25 cm foil multilaminate bag. The inner bag prevents coal particles from contaminating the area of the outer bag which will be heat sealed. The foil bag is placed in a vacuum/inert gas bagger which evacuates the chamber including the open bag to a specific pressure, introduces argon gas to nearly 1 atmosphere, and heat seals the bag. The manual method described below may also be used. Regardless of sealing method or size, currently all DECS samples in the Penn State Coal Sample Bank are stored under refrigeration except for a small non-refrigerated research subset used for comparison.

Large bags (28 x 40 cm, holding 2.5 kg, or 40 x 62 cm, holding 5 kg) for -6 mm (-1/4 inch) coal are sealed by placing the coal directly in the multilaminate bag, purging with argon flowing from a tube, then heat-sealing in a manually actuated sealer at 180 °C for 4 seconds. Use of foil bags holding more than 5 kg of pulverized coal is not recommended.

Coals of a variety of ranks, sulfur contents and thermoplastic behavior were monitored annually; a fresh 250 g bag of each sample was used each year. A polarographic oxygen analyzer punctured the bag wall and measured the gaseous oxygen inside. The bag was opened and subsampled for proximate, sulfur forms, ultimate and calorific value (in some cases), Gieseler fluidity and free-swelling index analyses.

Results from six stored coals are shown in the two graphs in fig. 2; this presentation will extend the results to 12 years. Gieseler fluid temperature range for the five bituminous coals was maintained with no significant decrease for three samples and with slight decrease for the Lower Sunnyside and Blind Canyon. Only one sample, the high-sulfur Illinois #6, showed a slight increase in sulfate sulfur (fig. 2, shown as linear regression lines). Coal samples stored in the bags also showed no significantly decreasing trend in moisture, calorific value or free-swelling index.

Refrigeration theoretically reduces the rate of reactions causing coal sample deterioration; a study was undertaken to compare unrefrigerated versus refrigerated samples of Blind Canyon seam hvAb

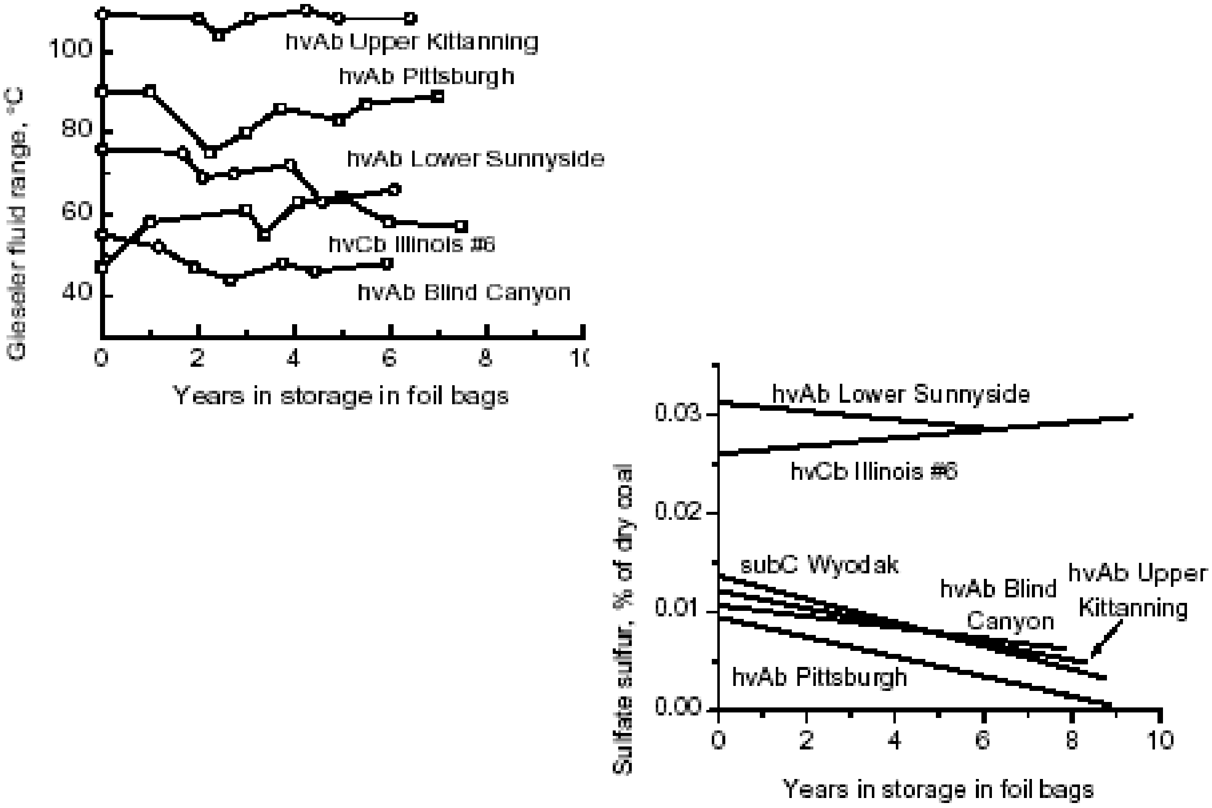


Figure 2. — Changes in six samples stored in foil bags over six to nine years.

coal from Utah. The sample not refrigerated showed slightly lower and more variable Gieseler fluid temperature range and a more uniform and slightly increasing amount of sulfate sulfur (fig. 3), but the differences may not be statistically significant. This presentation will show additional data for this comparison as well as six other refrigerated/unrefrigerated sample pairs stored for eight years.

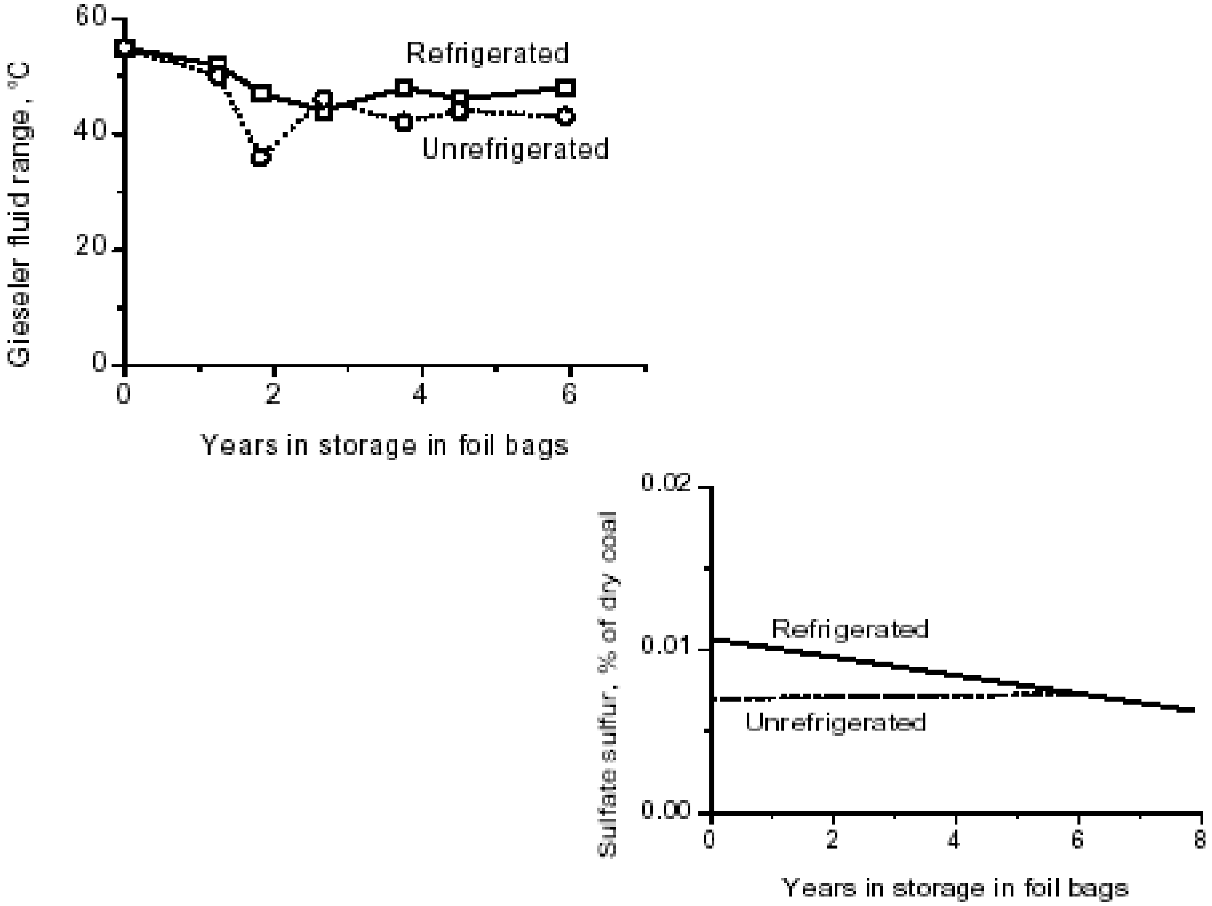


Figure 3. — Changes in hvAb Blind Canyon coal in foil bags, refrigerated vs. unrefrigerated storage.

Discussion and Conclusions

Regardless of refrigeration, it would seem beneficial to store samples at a constant temperature, in order to avoid pressure changes inside sealed containers which tend to stress the seal. Freeze-thaw cycles could be expected to partially or completely fragment particles of moist coal, leading to change in thermoplastic behavior and exposure of fresh sulfide mineral surfaces to possible oxidation. Because the foil bag method preserves samples so well, it may take decades for differences arising from room temperature versus refrigerated storage to be revealed.

All indicators of deterioration which were employed showed that foil multilaminate bags preserved the initial properties of pulverized coal samples extremely well. The bags are available in a variety of sizes, allowing for all splits of a sample of pulverized coal to be stored in the same container type. Larger bags have been used to seal core boxes approximately 1 meter long. Smaller bags have been used for a few grams of coals, individual coal/epoxy pellets, and asphalt samples. They provide a cost-effective method for short- or long-term preservation of moderate quantities of coal samples for research.

References

Davis, Alan, and Glick, D.C., 1993, Establishment and maintenance of a coal sample bank and data base: Final Report DOE/PC/79997-1 to U.S. Dept. Energy, Contract No. DE-RP22-87PC79997, 266 p.

Glick, D.C., Mitchell, G.D., and Davis, Alan, 1991, Monitoring the oxidation of coals in storage: American Chemical Society Divison Fuel Chemistry Preprints, v. 36, no. 3, p. 861-868.

______1997, Coal sample preservation in foil multilaminate bags [abs.]: Lexington, Kentucky, 14th Annual Meeting of The Society for Organic Petrology, Sept. 27-30, 1997, p. 45-47.

Sharp, P.A., 1986, Storage of 8 mesh subbituminous coal: Journal of Coal Quality, v. 5, p. 131-132.

Vorres, K.S., 1990, The Argonne Premium Coal Sample Program: Energy & Fuels, v. 4, p. 420-426.

TECHNICAL SESSION C

Energy and Government Session

Brenda Pierce, Chair
Suzanne Weedman, Co-Chair

Federal Energy Policy — The Earth Science Dimension

David Applegate

American Geological Institute, 4220 King Street, Alexandria, VA 22302-1502

After an unsuccessful attempt last year to pass comprehensive energy legislation, Congress is again working to pass the framework of a new national energy policy. This legislation would impact the earth sciences directly by authorizing inventories of energy resources on federal lands, energy-related research programs and a geoscience data preservation initiative. It also would have indirect impacts through tax credits for geological and geophysical expenses associated with petroleum exploration and incentives for geothermal energy development. Whether the current legislative efforts succeed will largely depend on the ability of the Bush Administration to reach common ground with a wide array of interests in both houses of Congress.

Although the comprehensive energy bill lays out a strong surge in support for geoscience-related research topics in both fossil and renewable energy sources, that support has not been forthcoming in actual federal spending. Oil and gas research programs, in particular, have been targeted for significant reductions by the administration. The geoscience community faces a significant challenge in convincing policymakers of the value of such research and the contributions that geoscientists make to the nation's energy security. Having a clear sense of the political landscape is crucial to meeting this challenge.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

The National Academy of Sciences

Tamara Dickinson

NAS, National Research Council, 500 5th Street NW, Washington, DC 20001

The National Academy of Sciences was established by Abraham Lincoln to provide scientific and technological advice to the nation. Advice is provided in several different forms: written consensus reports; symposia engaging large audiences in discussion of national issues; proceedings from workshops; or “white papers” on policy issues. Activities may be requested by a federal entity or generated by the National Research Council (NRC) and funding can come from federal agencies or the private sector. Within the NRC, the Committee on Earth Resources has responsibility for energy and mineral resources and inextricable environmental issues. Publications are available on the NRC website at http://www.nap.edu.

Federal Science Policy And Science Funding

Gene Whitney

Policy Analyst for the Office of Science and Technology, Executive Office of the President, Washington, DC 20502

Federal science policy and science funding priorities arise out of agency planning and budgeting processes, from Congressional priorities and actions, and from Administration leadership and guidance. The body primarily responsible for establishing and implementing the Administration's science agenda is the Office of Science and Technology Policy (OSTP), an office within the Executive Office of the President. OSTP's continuing mission is set out in the National Science and Technology Policy, Organization, and Priorities Act of 1976. It calls for OSTP to: serve as a source of scientific and technological analysis and judgment for the President with respect to major policies, plans, and programs of the Federal Government.

The Act authorizes OSTP to: (1) advise the President and others within the Executive Office of the President on the impacts of science and technology on domestic and international affairs; (2) lead an interagency effort to develop and implement sound science and technology policies and budgets; (3) work with the private sector to ensure Federal investments in science and technology contribute to economic prosperity, environmental quality, and national security;
(4) build strong partnerships among Federal, State, and local governments, other countries, and the scientific community; (5) evaluate the scale, quality, and effectiveness of the Federal effort in science and technology.

The President's Science Adviser, who is also Director of OSTP, enunciates the President's science priorities each year and works with the Office of Management and Budget to implement those priorities through agency budgets and interagency initiatives.

Department of Interior — Land and Minerals Management

Patricia Morrison

Deputy Assistant Secretary, Department of Interior, MS 6618-MIB, Washington, DC 20240

The functions of the Department of Interior are organized into four major sections: (1) Fish and Wildlife and Parks (National Park Service and U.S. Fish and Wildlife Service); (2) Indian Affairs (Bureau of Indian Affairs); (3) Land and Minerals Management (Bureau of Land Management, Office of Surface Mining, Reclamation, and Enforcement, and Minerals Management Service); and (4) Water and Science (U.S. Geological Survey and Bureau of Reclamation). The Assistant Secretary for Land and Minerals Management at the Department of the Interior has administrative and managerial responsibility for the Bureau of Land Management, the Minerals Management Service and the Office of Surface Mining Reclamation and Enforcement – three federal agencies with unique, controversial and complex mandates. Recreational opportunities on public lands, wild horses and burros, grazing rights, the exploration and development of on and offshore minerals and coal development and reclamation are just a small sample of the broad ranging multiple-use resources under the purview of the Assistant Secretary for Land and Minerals Management.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20,
ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

The U.S. House of Representatives Resources Committee — Subcommittee on Energy and Mineral Resources

Jack Belcher

Staff Director, 1626 Longworth House Office Building, Washington, DC 20515-6208

The House Resources Committee's Subcommittee on Energy and Mineral Resources has vast jurisdictional authority, including over most USGS programs, geothermal resources, uranium, oil and gas interests of the Outer Continental Shelf, and petroleum conservation on public lands. The Subcommittee maintains oversight of mining interests generally, including: all matters involving mining regulation and enforcement, the reclamation of mined lands, the environmental effects of mining, and the management of mineral receipts, mineral land laws and claims, long-range mineral programs, and deep seabed mining.

The USGS Energy Resources Program

Brenda S. Pierce
(Frances W. Pierce, speaker)

U.S. Geological Survey, Energy Resources Program Coordinator, MS 915-A, National Center, Reston, VA 20192

The U.S. Geological Survey, a bureau of the Department of the Interior, provides reliable, unbiased scientific information to describe and understand the Earth, minimize loss of life and property from natural disasters, and manage water, biological, energy, and mineral resources. Created by an act of Congress in 1879, the USGS has evolved over the ensuing 120 years, matching its talent and knowledge to the progress of science and technology. Today, the USGS stands as the sole science agency for the Department of the Interior.

The Energy Resources Program of the USGS is responsible for assessing the energy resource potential of the Nation and the world (exclusive of Federal offshore waters) and the environmental and health impacts of energy production and use. In order to accomplish this mission, the Energy Resources Program has four main objectives: (1) to assess national and global resources (oil, gas, coal, coalbed methane, and methane hydrates); (2) to understand the geologic framework and processes of energy resources; (3) to evalute the environmental and economic impact of developing and using those resources, and (4) to deliver energy resource information to land and resource managers, energy policy makers, other scientists, academia, private industry, environmental groups, and other non-governmental organizations.

The USGS Energy Resources Program is unique in comparison to other energy-related federal agencies. The Department of Agriculture Forest Service is responsible for land management; the Department of Energy is responsible for technology development as well as nuclear and renewable energy; the Energy Information Administration delivers energy reserve statistics. Within the Department of Interior, the Bureau of Land Management is responsible for leasing federal solid and liquid minerals and for land management activities; the Minerals Management Service is responsible for royalty management of federal resources and for federal offshore leasing; and the USGS Energy Resources Program assesses the remaining undiscovered energy resources, conducts research on the framework and occurrence of energy resources, and studies the effects of development and use of energy resources.

Some Perspectives on Longer-term Domestic Oil and Gas Supply Technologies and Needs in a Carbon-constrained Future

David Beecy

Director, Office of Planning and Environmental Analysis, Department of Energy, Office of Fossil, Energy's Oil and Natural Gas Programs, Bldg. GTN, Washington, DC

This presentation will include a broad set of future carbon-constrained oil and gas supply and demand scenarios, and the critical roles for advanced exploration and production technologies, including carbon management technologies. The latter set will include technologies for managing both carbon dioxide and methane emissions from oil and gas production and processing.

TECHNICAL SESSION D

TSOP General Session

Robert (Bob) Finkelman, Chair

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

The Source of the Coal in the Titanic and Effects of Exposure to Seawater

Curtis A. Palmer[1], Robert B. Finkelman[1], Gerald H. Luttrell[2],
Chaosheng Zhang[3], and Cortland Eble[4]

[1] *U.S. Geological Survey, MS 956, National Center, Reston, VA 20192*
[2] *Virginia Polytechnic Institute and State University, Blacksburg, VA 24061*
[3] *Department of Geography, National University of Ireland, Galway, Ireland*
[4] *Kentucky Geological Survey, Lexington, KY 40506-0107*

The White Star luxury liner Titanic was thought to be unsinkable when it left Southampton, England on its maiden voyage to New York on April 10, 1912. Yet just 4 days later, on the night of April 14, the Titanic struck an iceberg and sank, killing 1,522 people and carrying the remains of more than 4,000 metric tons of coal in her bunkers to the ocean bottom. It was not until 1985 that the wreck was located. Artifacts, including coal, were retrieved during several expeditions in the 1990s.

There are several mysteries surrounding the coal on the Titanic. For example, there are reports suggesting that the coal was on fire when the Titanic left port and the fire may have contributed to the disaster. Even the source of the coal in the Titanic is largely unknown. At the time of the sailing, coal was scarce in Southampton because of a six-week nationwide strike by coal miners. Coal fueling the Titanic was scavenged from several other ships, including some American ocean liners that cancelled their voyages due to the coal strike. Because the coal was scavenged from other ships, there are no clear records of where the coal originated, and some of the coal may have come from the United States. The uncertainty surrounding the source of the coal in the Titanic presented us with a challenge: to see if we could determine Titanic's coals provenance from available samples.

Twenty pieces of the coal retrieved from the wreck of the Titanic were obtained through the curator of RMS Titanic, Inc. The pieces were selected by the curator because each piece appeared to be different. The objectives of this study were to use the limited quantity of coal to determine its source and to assess what alteration may have occurred during its 80+ year residency 3780 meters (12,400 feet) below the surface of the Atlantic Ocean.

The Titanic coal samples were analyzed by instrumental neutron activation analysis, and compared to data for 24 United Kingdom (U.K.) samples (Spears and others, 1999) and 1450 United States samples (Bragg and others, 1998). Only U.S. coal beds that were mined during the 1912 era were selected for comparison. Values for fixed carbon and volatile matter indicate that the Titanic samples are all bituminous in rank, and equally distributed among low volatile, medium volatile, and high volatile samples. These data are consistent with the data for both U.K. and eastern U.S. coal and indicate that the coal onboard the Titanic came from at least three different sources. Rare earth element data suggest the Titanic coal samples have five distinct patterns and could come from as many as five different sources, perhaps reflecting the different ships from which the coal was scavenged (Palmer and others, 2002). The ash yield (fig. 1) results for the Titanic samples are more consistent with the samples from the United Kingdom, but are

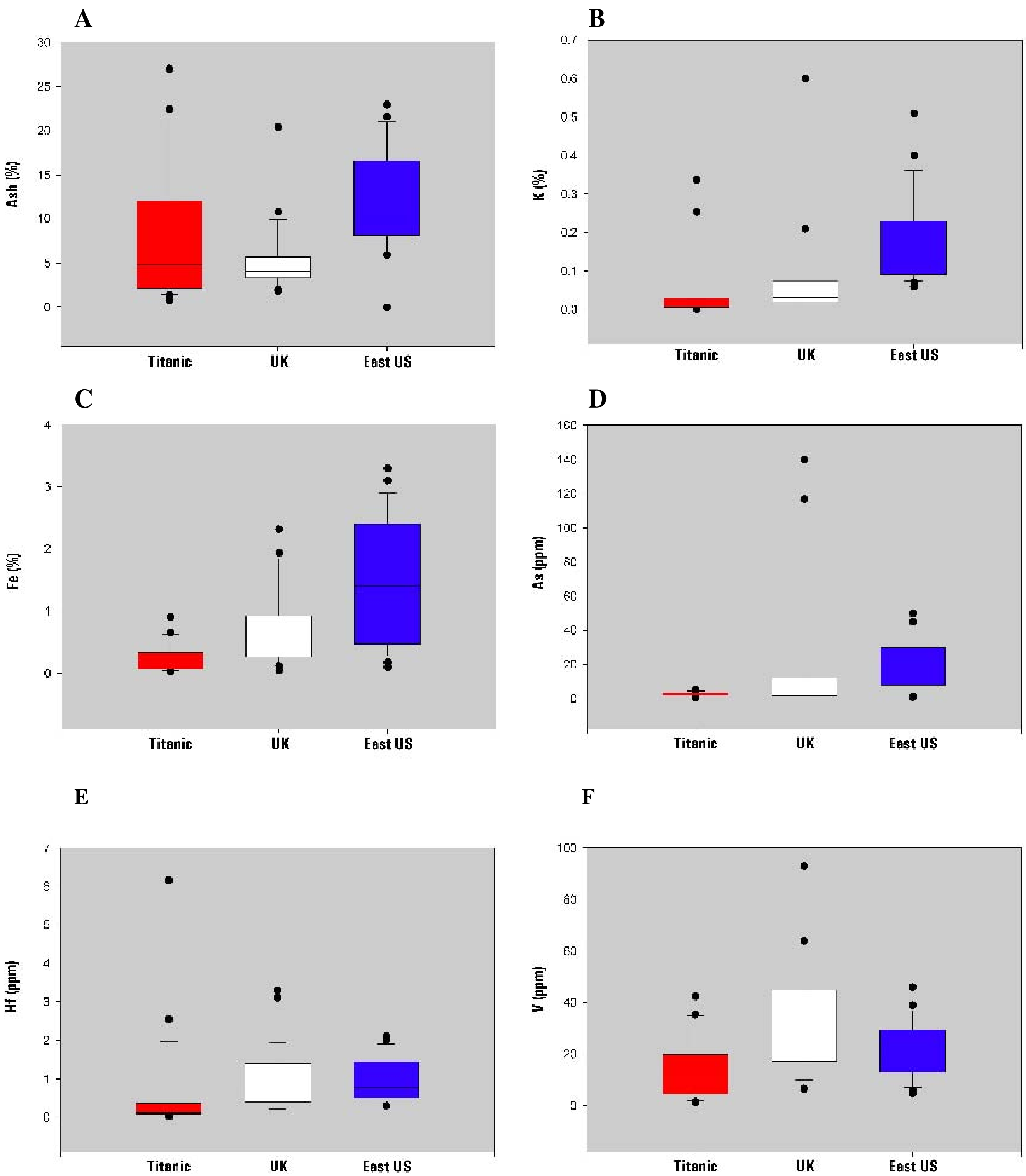


Figure 2. — Boxes which represent values from the 25th percentile to the 75th percentile for ash (A), K (B), Fe (C), and As (D) and the median (the line within the box) for both the Titanic and U.K. (UK) coals than for the U.S. (US) coals showing that the Titanic samples are similar to the U.K. samples and are generally lower in concentration than the U.S. samples and are typical of most elements in this study. A few elements like Hf (E) in the Titanic appear to be lower than both the U.S. and U.K. samples which are similar, but if the error bars (10th percentile to 90th percentile) are included there is no difference. There are also a few elements like V (F) where the range of values for the U.S. and Titanic samples are similar.

not diagnostic. The range and median values for iron (Fe), potassium (K), and arsenic (As) are closer to the range and medians for the coals from the United Kingdom than to the U.S. coal samples and these plots were typical of those for many other elements. For some elements, for example Hf and V, the element ranges and medians for the coal samples from the United Kingdom and the United States were indistinguishable.

For most elements the median value for the Titanic coal samples was less than either the coal from England or from the United States. This may be due to: 1) differences between the composition of the coal mined in the 1900s and those mined today, 2)“high-grading” of the coal loaded onto the Titanic, or 3) leaching of the Titanic coal by seawater. Because of the wide range of chemical properties of the many elements and the fact that the ash yield of coal samples from the Titanic is virtually identical to that of the U.K. coal samples, we are inclined to believe that the differences in element concentration are due to differences in the original composition of the coal and not to leaching or high-grading.

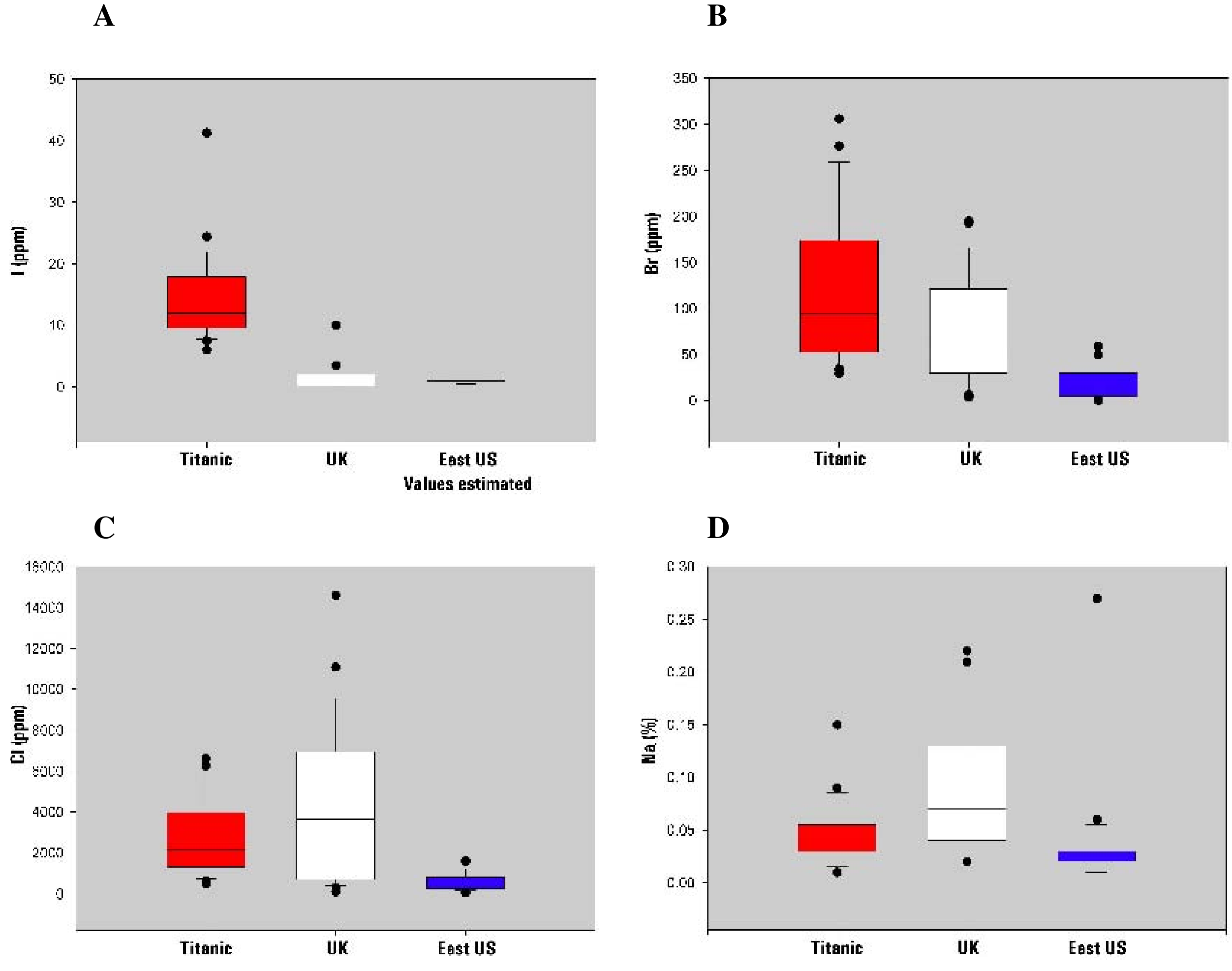


Figure 3. — Box plots of elements associated with seawater. Titanic samples have higher concentrations of I (A) and Br (B) but concentrations of Cl (C) and Na (D) are not elevated over U.K. coals samples which were apparently already saturated in these elements.

Multivariate analysis was used to determine whether individual samples may have come from the United States or the United Kingdom. Two methods were used: discriminate analysis and neutral network analysis. For neutral network analysis, 24 U.K. samples and a random 20 sample subset of the U.S. samples were used to train the neutral network. Twelve of the Titanic samples were found to be most probably from the United Kingdom and three samples were found to be most probably from the United States based on agreement of both statistical procedures. The remaining samples gave mixed results. Four samples were determined to be of U.S. origin by discriminate analysis and U.K. origin by neutral network analysis. One sample was found to be of U.K. origin by discriminate analysis and U.S. origin by neutral network analysis.

The Titanic samples were examined microscopically for spores to determine their age. Spore recovery was only achieved from two samples. Both samples contained spore assemblages assignable to the Radiizonates aligerans spore assemblage zone (VI) of Smith and Butterworth (1967), which is indicative of a Langsettian (=Westphalian A) age. Index spores include: *Schulzospora rara, Radiizonates aligerans, Radiizonates striatus, Florinites mediapudens, Laevigatosporites spp., Lycospora spp*. Among British coal fields, nearly all contain Langsettian age coal beds, many of which were actively mined in the early 1900's. Coals of this age being mined in the United States at that time were rare. Therefore, we conclude that both samples containing identifiable spores originated from the United Kingdom, which agrees with the two statistical studies.

The average concentrations of I and Br in the Titanic samples (fig. 2) are significantly higher than those in either the U.K. or the U.S. samples. The box plot for Br shows that 75 percent of the Titanic samples are greater in concentration than the average U.K. samples and in turn 75 percent of the U.K. samples are higher than the U.S. samples. This suggests significant enrichment of Br in the Titanic samples due to absorption from sea water. The same can be said of I although there is little U.S. data on I. The average I concentration in the Titanic coal was about 10 times that of the average U.K. coals which is higher than the U.S. average of <1 ppm (Finkelman, 1993).

Na and Cl concentrations for Titanic coals averaged slightly less than U.K. coals and slightly more than U.S. coals. The range of the 1450 samples for U.S. coals overlapped with the ranges of both Titanic and U.K. coals (fig. 2). The box plots show no overlap of Na data within the boxes (50 percent of the data) for United States and United Kingdom, but that the Titanic box overlaps both the U.S. and U.K. boxes and the mean of Na for the Titanic samples is between the U.S. and U.K. means. Cl shows similar results but there is overlap in all groups and the means are of the same order. If these samples assumed to be mostly from the United Kingdom, then the data suggest that there is only modest modification to the coal chemistry, reflected in leaching rather than absorption of Na and Cl by seawater.

We conclude that most of the Titanic samples originated in England. With the exception of Cl, Br and I, the coals are generally unaltered by their submersion with the Titanic. This indicates that coal spilled from barges and ocean liners will have minimal environmental impact due to leaching of trace elements for at least 75 years.

References

Bragg, L.J., Oman, J.K., Tewalt, S.J., Oman, C.L., Rega, N.H., Washington, P.M. and Finkelman, R.B., 1998, U.S. Geological Survey Coal Quality (COALQUAL) Database: Ver. 2.0, U.S. Geological Survey Open-File Report 97-134, CD-ROM.

Finkelman, R.B., 1993, Trace and minor elements in coal, chap. 28 *of* Engel, M.H., and Macko, S.A., eds., Organic Geochemistry: Plenum Press, New York, NY, p. 593-607.

Palmer, C.A., Finkelman. R.B., and Luttrell, G.H., 2002, Coal from a Mid-Atlantic Ocean shipwreck — the source of the coal in the Titanic and effects of exposure to seawater: Proceeding of the International 19th Annual Pittsburgh Coal Conference, CD-ROM, 6 p.

Smith, A.H.V., and Butterworth, M.A., 1967, Miospores in the Coal Seams of the Carboniferous of Great Britain: Special Papers in Palaeontology No. 1, The Palaeontological Society, London, England, 324 p., 27 plates.

Spears, D.A. and Zheng, Y., 1999, Geochemistry and origin of elements in some UK coals: International Journal of Coal Geology, v. 38, nos. 3-4, p. 161-179.

Influence of a Basic Intrusion on the Vitrinite Reflectance and Chemistry of the Springfield (No. 5) Coal, Harrisburg, IL

Alexander K. Stewart,[1,2] Matt Massey,[1] Penny L. Padgett,[3] Susan M. Rimmer,[1] James C. Hower[4]

[1] *University of Kentucky, Department of Geological Sciences, Lexington, KY 40506*
[2] *now at: University of Cincinnati, Department of Geology, Cincinnati, OH*
[3] *Black Beauty Coal, Evansville, IN*
[4] *University of Kentucky, Center for Applied Energy Research, Lexington, KY 40511 (speaker)*

The Springfield (No.5) coal, a Pennsylvanian-age high volatile B bituminous coal from the Carbondale Formation, was mined in the southeastern section of the Illinois basin by the Arclar Coal Company. Intruded into this coal is a 10.1-meter-wide basic dike that is near-vertical through the extent of the mined coal seam, and striking ~158 degrees. We studied both the intrusion and the effects it had on the coal. Through microscopic analysis it was determined that the intrusion was a kimberlite with a lamprophyric texture that subsequently underwent at least two stages of serpentinization. Using a heat flow model by Carslaw and Jaegar (1959) in conjunction with microscope analysis, a contact temperature of ~600°C was determined. We also measured the vitrinite reflectance of the coal from a suite of samples collected distal to the intrusion. Vitrinite reflectance values rose uniformly from the ambient reflectance values of ~0.69 percent, at just greater than one-dike thickness away, up to >6 percent at the dike/coal contact. This increase in reflectance values, proximal to the dike ~1.2 times dike thickness, is concordant with data put forth by Bostick and Pawlewicz (1984) the effects of mafic intrusions into Cretaceous-age shales in Walsenburg, Colorado. Our data and theirs indicate that, despite differences in intrusion temperature, timing, or coal rank at time of the intrusion, ambient reflectance values remain unchanged at just greater than one-dike width from an intrusion.

Organic Pollutants from the Recent Sediments of the Halifax Harbour, Lake Ontario, and New York Bight — A Comparative Analysis

Prasanta K. Mukhopadhyay (Muki)[1], Michael A. Kruge[2], Gerald M. Friedman[3],
and C.F.M. Lewis[4]

[1]*Global Geoenergy Research Ltd., 1657 Barrington Street, Suite 427, Halifax, Nova Scotia, Canada B3J 2A1*
[2]*Montclair State University, Upper Montclair, NJ 07043*
[3]*City University, Brooklyn, NY*
[4]*GSC, Atlantic, Dartmouth, Nova Scotia, Canada*

The organic components of recent sediments (0-20 cm) from three selected areas (two marine sediments: Halifax Harbour and New York Bight and one lacustrine sediment: Lake Ontario) have been fingerprinted using organic petrological and organic geochemical analytical techniques. These data document both the natural and anthropogenic organic sediments that have been deposited during the last 100 to 150 years.

The natural components include algal and exinitic/humic components whereas four distinct types of anthropogenic components could be detected. The pollutants include: (a) amorphous organic matter formed due to sewage discharge; (b) coal and coal-combustion products originated as airborne and discharge materials from the ships and power plants; (c) petroleum related components originated from the discharge of ships, refineries, and chemical factories; and (d) various forms of plastics originated from various sources.

The comprehensive fingerprinting of both natural and organic pollutants from these three areas suggest that both Halifax Harbour and New York Bight contain abundant organic pollutants (including normal alkanes, polyaromatic hydrocarbons, hopanes, tricyclic terpane compounds) possibly derived from the petroleum spills and sewage discharge; the coal combustion products are minor components. On the other hand, coal combustion products and the sewage-derived amorphous organic matter are major pollutants in Lake Ontario. These data clearly demonstrate the origin of various organic carbons (natural and anthropogenic components) in recent sediments.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Integrated Approaches to Understanding the Relationship of Coal to Human and Ecosystem Health

Joseph E. Bunnell and Robert B. Finkelman

U.S. Geological Survey, 956 National Center, Reston, Virginia 20192

The emerging scientific discipline of medical geology applies integrative research approaches and techniques to develop solutions to health threats of complex nature and obscure etiology (Finkelman and others, 2001). Medical geology addresses the health impacts of earth materials and dynamic processes. Examples that demonstrate the broad range of medical geology research include:

— ***Valley fever:*** Linkages between earthquakes, dust mobilization and infectious agents result in valley fever, a severe respiratory disease in humans.

— ***Vector-borne diseases:*** Climate and landscape features may be used to predict vector-borne disease outbreaks such as Lyme disease, West Nile virus fever, and malaria. Geographic information systems (GIS), spatial statistics, and remote sensing are tools used in such efforts.

— ***Dust:*** Remote sensing devices on satellites and airplanes now monitor huge transoceanic dust clouds. Such clouds carry heavy metals, particulate matter, and pathogenic microbes that are killing Caribbean coral and may induce asthma and allergies in exposed human populations.

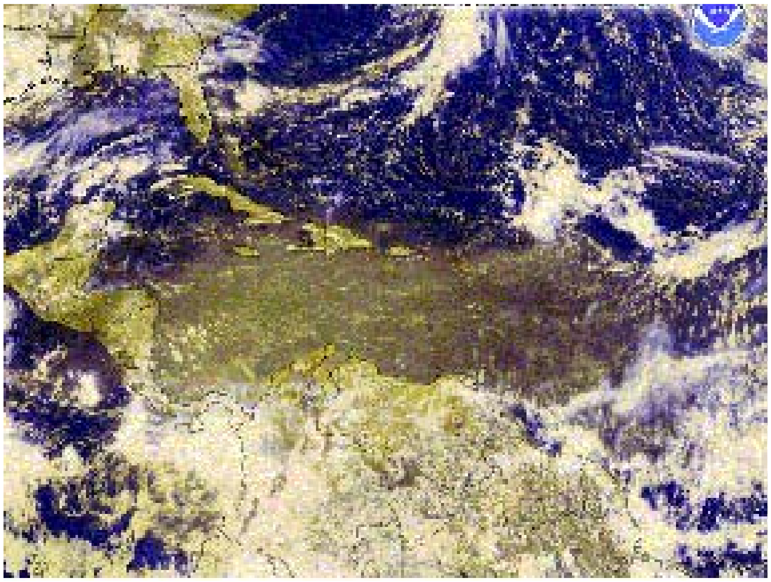


Figure 1. — Visible in this satellite image, a dust cloud that originated in the African Sahara and Sahel reaches the Americas, possibly bringing pathogens and trace metals along with particulate matter.

— ***Arsenic in Bangladesh and India:*** With up to 80 million people affected, the world's largest inadvertent mass poisoning has occurred in Bangladesh and India. In an attempt to reduce cholera cases from microbially contaminated groundwater sources of drinking water, the World Bank, non-governmental organizations, and other international aid agencies drilled tubewells to provide potable water. However, currently almost half of the country's four million tubewells contain arsenic at levels exceeding World Health Organization safety standards (Kinniburgh and others, 2003).

— ***Asbestos:*** For a quarter century, workers at a vermiculite mining operation in Libby, Montana were exposed to inhalable tremolite asbestos fibers, and family members in their households inhaled the microscopic particles brought in on the workers' clothes. Children running on a footrace track were also exposed to asbestos by kicking up dust containing fibers from the mine. Almost ten percent of the town's populace have already died from asbestosis, and new cases will likely continue to arise, as the disease takes decades to develop.

Examples of health issues related specifically to coal include:
— ***Home coal use in China:*** Residential cooking and heating with mineralized coal in Guizhou Province, P.R. China, has resulted in millions of cases of fluorosis and thousands of cases of arseniasis (Finkelman and others, 2002). The primary route of exposure is by consumption of foodstuffs dried over unvented stoves, rather than by smoke inhalation. Environmental (deforestation, climate), cultural (diet preferences), and economic factors (coal is cheap and the people poor) all contributed to this public health burden. A field test kit, developed by a government/private industry partnership, has been distributed at no cost to villagers in the affected region so they can determine relative concentrations of arsenic in coal.


Figure 2. — Consequence of eating food (and inhaling fumes) laden with arsenic. The body moves the As to the hands, feet, and skin (as far away from the internal organs as possible). Shown here is an example of extensive keratosis. Dark lesion above left breast was diagnosed as Bowens Disease, a precursor to squamous cell carcinoma.

— ***International work relates to the United States:*** We are now investigating the links between coal combustion and respiratory disease in the Navajo Nation, where coal is burned residentially as well as industrially.
— ***Other biomass fuel combustion:*** Worldwide, hundreds of millions of people are adversely affected by indoor combustion of biomass fuels (coal, peat, wood, dung, coke, and briquettes made from these materials). The World Health Organization ranks such fuel use as the fourth most significant contributor to disease in the developing world.
— ***Black lung:*** Coal workers' pneumoconiosis, also known as black lung disease, is perhaps the best known example of a health effect related to coal (Finkelman and others, 2002). The respiratory problems caused by the particulate matter itself are compounded by the high concentrations of potentially toxic elements such as As, F, Se, and Hg in some coals.
— ***Renal failure:*** Low-rank coal beds are the principal aquifers supplying water to rural villagers in some areas of the world. Ground water leaches toxins from the coal such as aromatic amines, possibly contributing to Balkan endemic nephropathy, a severe, ultimately fatal kidney disease (Tatu and others, 1998). Investigation is now underway to determine if a similar situation contributes to high rates of kidney disease incidence in parts of the United States overlaying low-rank coals and lignite deposits (Bunnell


Figure 3. — Over 100,000 coal miners have died of coal workers' pneumoconiosis ("black lung") in the United States.

and others, 2002; Bunnell and others, 2003).

Not all health effects of coal use are negative:
— ***Coal tar is used to manage skin conditions such as psoriasis:*** coal products have also been used in the manufacture of antibacterial drugs and aspirin, and as an antiseptic (Schobert, 1987).
— ***Some concerns about coal combustion are unfounded:*** U.S. Geological Survey (USGS) research has found that the concentration of radionuclides in combusted coal fly ash is no greater than in ambient soils (Zielinski and Finkelman, 1997).

Health issues relating to coal that are presently being considered for further study by the USGS and other interested researchers include:
— In developing the use of coal bed methane as an energy source, scientists are considering the impacts to the environment of produced water, which possibly mobilizes toxic organic compounds or metals.
— USGS and the Office of Surface Mining's Reclamation Office are working to determine the relative safety of abandoned mines and tailings, and to better manage acid mine drainage.
— Gastrointestinal and neurologic impairments are well known outcomes of mercury poisoning. An international group of geomedical scientists are proposing a study to examine the extent of mercury-induced disease in the Donbass region of Ukraine where coal mining supports much of the economy. USGS scientists and collaborators will look specifically at the potential cardiovascular manifestations of mercury exposure.

References

Bunnell, J.E., Orem, W.H., Tatu, C.A., and Finkelman, R.B., 2002, Is Balkan endemic nephropathy restricted to the Balkans?: Epidemiology, v. 13, p. 612.

Bunnell, J.E., Bushon, R.N., Stoeckel, D.M., Gifford, A.M., Beck, M.C., Lerch, H.E., Shi, R.H., McGee, B.D., Hanson, B.C., Kolak, J.O., and Warwick, P.D., 2003, Preliminary geochemical, microbiological, and epidemiological investigations into possible linkages between lignite aquifers, pathogenic microbes, and kidney disease in northwestern Louisiana: U.S. Geological Survey Open–File Report 03-374.

Finkelman, R.B., Skinner, C.W., Plumlee, G.S., and Bunnell, J.E., 2001, Medical Geology — A 10,000 year-old opportunity: Geotimes, v. 46, no. 11, p. 20-23; http://www.agiweb.org/geotimes/nov01/feature_medgeo.html.

Finkelman, R.B., Orem, W.H., Castranova, V.N., Tatu, C.A., Belkin, H.E., Zheng, B.S., Lerch, H.E., Maharaj, S.V., and Bates, A.L., 2002, Health impacts of coal and coal use — possible solutions: International Journal of Coal Geology, v. 50, p. 425-443.

Kinniburgh, D.G., Smedley, P.L., Davies, J.J., Milne, C.J., Gaus, I.P., Trafford, J.M., Burden, S., Huq, S.M.I., Ahmad, N.A., and Ahmed, K.M., 2003, The scale and causes of the groundwater arsenic problem in Bangladesh, *in* Welch, A.H. and Stollenwerk, K.G., eds., Arsenic in Ground Water — Geochemistry and Occurrence: Boston, Mass., Kluwer Academic Publishers, p. 211-257.

Schobert, H.H., 1987, Coal — the Energy Source of the Past and Future, American Chemical Society, Washington, D.C., 298 p.

Tatu, C.A., Orem, W.H., Finkelman, R.B., and Feder, G.L., 1998, The etiology of Balkan endemic nephropathy — still more questions than answers: Environmental Health Perspectives, v. 106, no. 11, p. 689-700.

Zielinski, R.A., and Finkelman, R.B., 1997, Radioactive Elements in Coal and Fly Ash — Abundance, Forms, and Environmental Significance: Denver, Colo., USGS Fact Sheet FS-163-97, 2 p.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Where do the Maidens Fly? Trace Elements and What Controls Their Fate: Examples from the Greymouth Coalfield, New Zealand

Zhongsheng Li[1], A.H. Clemens[2], Tim A. Moore[1, 3], D. Gong[2], S.D. Weaver[1], Nelson Eby[4]

[1]*University of Canterbury, Department of Geological Science, Christchurch 8004, New Zealand*
[2]*CRL Energy Ltd., PO Box 31 244, Lower Hutt, New Zealand*
[3]*Solid Energy New Zealand, P.O. Box 1303, Christchurch, New Zealand*
[4]*Department of Environmental, Earth & Atmospheric Sciences, University of Massachusetts, Lowell, MA 01854*

Introduction

Because of the increasing awareness of the environmental impact of coal combustion and the stringent regulations on emission of some potentially hazardous air pollutants (HAPs) in developed countries, the behavior of trace elements during mining and subsequent utilization has attracted a great deal of interest. The U.S. Clean Air Act Amendments of 1990 specifically identified As, Be, Cd, Co, Cr, Hg, Mn, Ni, Pb, Sb, Se and U as potential HAPs (U.S. Statutes at Large, 1990). Some coals with a high abundance of HAPs may become less useable or unusable in the near future if stringent regulations on HAPs emissions have to be met. This could lead to mine closures or require the introduction of coal cleaning or blending technology to produce beneficiated coal products. As part of a broader project, the Cretaceous coal seams in the Greymouth coalfield, West Coast of New Zealand, have been subjected to a detailed case study on the partitioning behavior and fate of trace elements upon combustion.

The partitioning behavior of trace elements can vary significantly between different coal beds simply because they have different modes of occurrence or because they are used under different combustion conditions. There are few geochemical rules that apply universally to all coals because of the complexity of trace element occurrence and behavior upon combustion. Therefore, this study was designed specifically to investigate the Greymouth Cretaceous coals and the behavior of selected trace elements during stoker-fired combustion. The study also aimed to identify the other factors (such as temperature, coal particle residence time in combustor, the mineralogical transformations occurring within the combustion chamber) that control the partitioning behavior of the trace elements. This understanding of trace element partitioning allows us to assess their environmental impact, identify any undesirable impacts, and to avoid or mitigate these potential problems.

Results and Discussion

In order to understand trace element behavior during combustion, stoker-fired combustion on tests were performed on three E seam composite samples. The major and trace elements from sub-samples of feed coal, bottom ash, fly ash and flue gas were analyzed by inductively coupled plasma mass spectrometry (ICP-MS), X-ray fluorescence (XRF), and scanning electron microscopy with energy-dispersive X-ray (SEM-EDX) analyzer techniques. Instrumental Neutron Activation Analysis (INAA) was also employed to determine trace element content in float and sink fractions of fly ash as well as three major phases in the bottom ash. Mass balance and partitioning of major and trace elements have been studied to determine the fate of trace elements after combustion. Finally, the environmental significance of some trace elements in combustion ash, especially HAPs are discussed.

The mineralogy in the feed coal was investigated in order to better understand the mineralogical transformation mechanism taking placed during combustion. The major minerals found in the feed coal were clays (mainly kaolinite, illite, and minor smectite), quartz, and carbonates (mainly siderite, ankerite and calcite, etc.). The minor minerals include sulphides (pyrite, marcasite) and phosphates (apatite, crandallite, monazite, etc), with trace amounts of sulphates (gypsum), oxides (anatase TiO_2, hematite, magnetite, etc.), chlorides (NaCl, KCl), zircon and other silicates (biotite). Crocoite ($PbCrO_4$) was also found in both the Main and E coal seams (Li and others, 2001).

The partitioning of trace elements, especially HAPs, in different combustion ashes can be summarized as follows:

1) Although the low ash Greymouth coals have the advantage of generating solid combustion ash, one of the accompanying consequences is that trace element content of the ash can be enriched to a surprisingly great magnitude upon combustion. For example, B, S, and Cl have been enriched to undesirable levels of 1100 ppm, 4.4 percent and 2000 ppm, respectively.

2) The trace elements can be categorized into five different groups in terms of their differential partitioning patterns in flue gas, fly ash, and bottom ash.

Group I (As, B, Pb, Zn), and to a lesser extent Group II (Hg, Se, Cd, Cu), elements, are significantly enriched in the fly ash fraction. Most of these elements are on the list of HAPs and should be treated with caution when disposal and/or utilization are considered. However, the concentrations of most trace elements in this case are in the low concentration range compared with combustion ash from other countries. B and, occasionally, As are exceptions. These two elements are often regarded as highly volatile but in this case they were found mainly retained in the bottom ash because of a silicate association in the feed coal. B and As are unlikely to be leached in large proportions particularly if the pH does not become too acidic (pH <4) in the combustion ash disposal sites.

Group III (>90 percent of the S and up to 64 percent of the Cl) and some toxic elements from Group I and II [>90 percent Hg, and to a lesser extent B (up to 44 percent), Cd (up to 50 percent), etc.] tend to be dominantly partitioned into the flue gas fraction, whereas most other trace elements mainly partition into the bottom ash. More than 90 percent of the Hg appears to be partitioned into the flue gas, but the rest of the Hg (<10 percent) is probably absorbed onto the surface of the fly ash particles with the concentrations ranging from 0.4 to 0.9 ppm. This fraction of the Hg is likely to be mobile under acidic conditions.

In contrast, elements assigned to Group IV (Co, Cr, Ni) and Group V (Ba, V, Zr, Rb, Sr, F, REE) are chiefly retained in the bottom ash and are probably encapsulated or cemented in the aluminosilicate or glass matrix. They are not easily leachable except under extreme conditions.

Fluorine was also partitioned into the bottom ash probably because of its phosphate association in feed coal.

3. The Pb abundance is relatively low in feed coal, but two other factors must be taken into account in assessing its environmental impacts. These two factors are the general low ash content of the Greymouth coal and the rare mode of occurrence for Pb (crocoite, containing the highly toxic Pb^{6+}) in the feed coal.

The general low ash content of the feed coal means that trace elements may be greatly enriched in the combustion ash. For example, Pb, As, and Se concentrations reach 1013 ppm, 26 ppm, and 13 ppm, respectively, in 400 °C HTA ash samples. Likewise some other trace elements are also greatly enriched including Ba (up to 2400 ppm), As (up to 38 ppm), Se (up to 30 ppm), Ni (up to 1413 ppm) and S (up to 20 percent).

From the result of this study we concluded that the trace elements behavior is not only mainly controlled by their modes of occurrence in the feed coal, but also largely determined by combustion conditions [e.g. combustion temperature and fuel residence time during coal combustion (i.e. the differential partitioning between the short residence time in the stoke-fired combustion and long residence time int the electric furnace at 400 °C)].

References

Li, Zhongsheng, 2002, Mineralogy and Trace elements of the Cretaceous Greymouth coals and their combustion products: University of Canterbury, New Zealand, unpublished Ph.D thesis.

Li, Zhongsheng, Moore, T.A., Weaver, S.D., and Finkelman, R.B., 2001, Crocoite — an unusual mode of occurrence of lead in coal: International Journal of Coal Geology, v. 45, no, 22, p. 289-293.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Petrographic Comparison of Several Coal Seams in Ningxia Hui Autonomous Region

Zhiwen Han

Ground Technology, Inc., 14227 Fern Drive, Houston, Texas 77079

The Ningxia Hui Autonomous Region of China is coal-prolific. The Permo-Carboniferous sequence and Jurassic sequence are the two major coal measures in the region. Each sequence contains about sixteen coal seams. Four of them are laterally stable and widely mined. They are the Carboniferous Coal No. 8, Permian Coals No. 3 and No. 4, and Jurassic Coal No. 2. In this research, column samples representing the four major minable coal beds were collected at five locations and petrographically studied.

The coal columns were further divided into individual lithotype layers as bright, semi-bright, semi-dull, and dull coals based on differences in luster and appearance. Samples representing each of the lithotype layers were prepared for petrographic study in accordance with standard analytical procedures. The samples were microscopically analyzed for maceral composition, vitrinite reflectance, and photographically documented. In addition, a small number of samples were selected for proximate analyses.

The Carboniferous Coal No. 8 is about 1.5 meters thick and very uniform laterally, a characteristic of the Carboniferous paralic coals deposited on the coastal and lower deltaic plains. Unlike the other Carboniferous coals occurring in the region, which are usually enriched in sulfur and minerals, the No. 8 coal is characterized by low sulfur content (less than 1 percent by weight) and low ash yield (less than 10 percent by weight). The coal is dominated by bright and semi-bright lithotypes and has a maceral composition of about 70 percent vitrinite and 30 percent inertinite. Having mean vitrinite reflectances ranging from 1.27 percent to 1.66 percent, the coal is ideal for coke-making. Due to its higher rank, liptinitic macerals are hardly recognizable under microscope. With semi-dull and dull lithotypes occurring at the top, the coal seam shows a darkening-up feature. The semi-dull and dull lithotypes contain higher amounts of minerals and inertinite macerals, suggesting that the coal-forming swamps ended as a result of drowning.

The Permian sequence in the region is a continuation of the Carboniferous coal-bearing deposition. However, the sea had moved out of the region in the Permian Period. The coal-forming swamps mainly developed on upper deltaic plains and fluvial plains. Compared to the Carboniferous coals, the Permian coals (No. 3 and No. 4) contain less sulfur (less than 0.5 percent by weight) but higher amounts of minerals (about 15 percent by volume). Therefore, the Permian coals are mainly used for industrial and residential combustion. The coal beds usually have a complicated structure, characterized by occurrence of multiple parting layers and frequent alteration of coal lithotypes, suggestive of periods of flooding and higher inorganic input to the swamps. The coal seams contain more semi-dull and dull lithotypes that are rich in both inertinite and minerals (fig. 1).

During the Jurassic Period, the Ningxia Hui Autonomous Region was located at the western

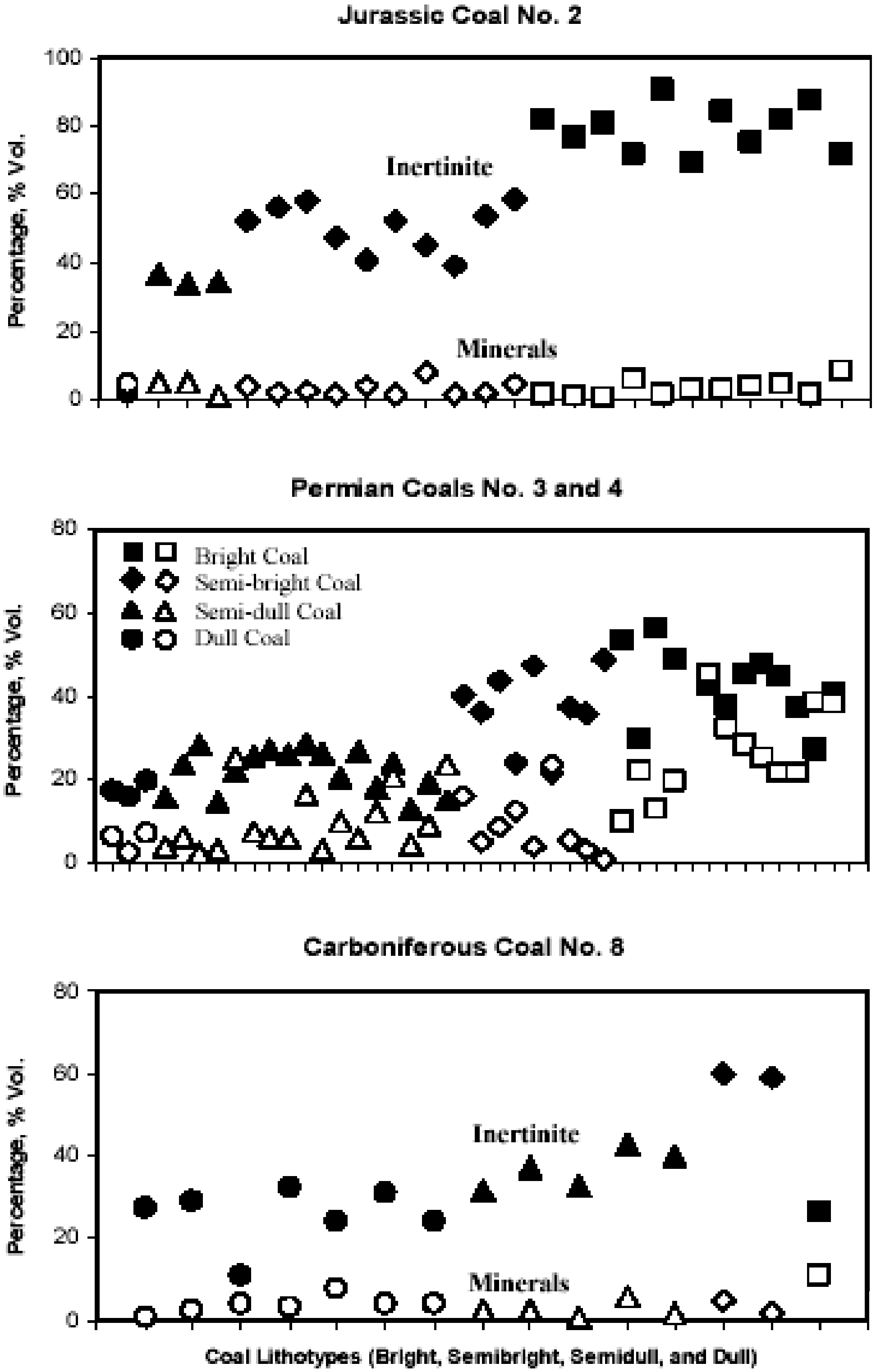


Figure 1. — Variation of inertinite and mineral contents on coal lithotypes (filled symbols represent inertinite; unfilled represent minerals).

periphery of the Erdos Basin, a vast intracratonic lacustrine basin. Most of the Jurassic coal seams of the Erdos Basin are characterized by thickness, richness in minerals, and complicated structure. However, the Jurassic Coal No. 2 in this region is thick (7 to 9 meters) but contains only small amounts of minerals (2 to 3 percent by volume). The average ash yield ranges from 8 percent to 9 percent by weight. The coal bed has a simple structure and hardly contains any partings. It is also interesting to note that nearly 90 percent of the coal seam is composed of dull and semi-dull lithotypes. The inertinites, mainly consisting of fusinite, semifusinite, and macrinite, are the major maceral components (average, 60 to 66 percent by volume). In some dull lithotypes, inertinite content is as high as 80 to 90 percent (fig. 1). Bright and semi-bright lithotypes occur at the bottom of the coal bed, suggesting that the swamp began with the deposition of a strongly decomposed peat layer. The low moor soon evolved into a raised bog where the peat was deposited in relatively dry conditions and inorganic input was restricted due to its higher topography. Long duration of the raised bog resulted in the formation of the thick and inertinite-rich Jurassic No. 2 coal in the region. The measured mean vitrinite reflectances of the Jurassic coal range from 0.50 to 0.59 percent, falling in the rank of subituminous C coal. The Jurassic coal has mainly been used for combustion, but also used as raw materials for activated carbon-making.

POSTER SESSION

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20,
ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Coalbed Methane Potential (CBM-P) in Main Bituminous Field (SW. PA) and the Anthracite Fields (E. PA), and CBM-P in MD, VA, MA, RI (U.S.A.)

Paul C. Lyons[1], R. Marc Bustin[2], Antonette K. Markowski[3]

[1]206 Amber Road, Middleboro, MA 02346
[2]Department of Earth and Ocean Sciences, University of British Columbia, 6339 Stores Road,
Vancouver, B.C. V6T 2B4, Canada
[3]Commonwealth of Pennsylvania, Department of Conservation and Natural Resources,
Bureau of Topographic and Geologic Survey, 3240 Schoolhouse Road, Middletown PA 17057

Thirteen Appalachian coal samples ranging in rank from medium-volatile bituminous coal to meta-anthracite were tested for high-pressure methane adsorption (fig. 1). These include three coal samples from the Narragansett basin of Massachusetts and Rhode Island (Skinner and Hardon Mines MA coals and Portsmouth RI main coal bed); six coal samples from the Anthracite coal fields of eastern Pennsylvania: Buck Mountain (two samples), Seven Foot (one sample), and Mammoth (three samples) coal beds; two samples from the bituminous coal region of western Maryland (Upper Freeport and Upper Kittanning coal beds); and two coal samples from the Valley coal fields of Virginia (Longhorne and Merrimac coal beds). In general, the

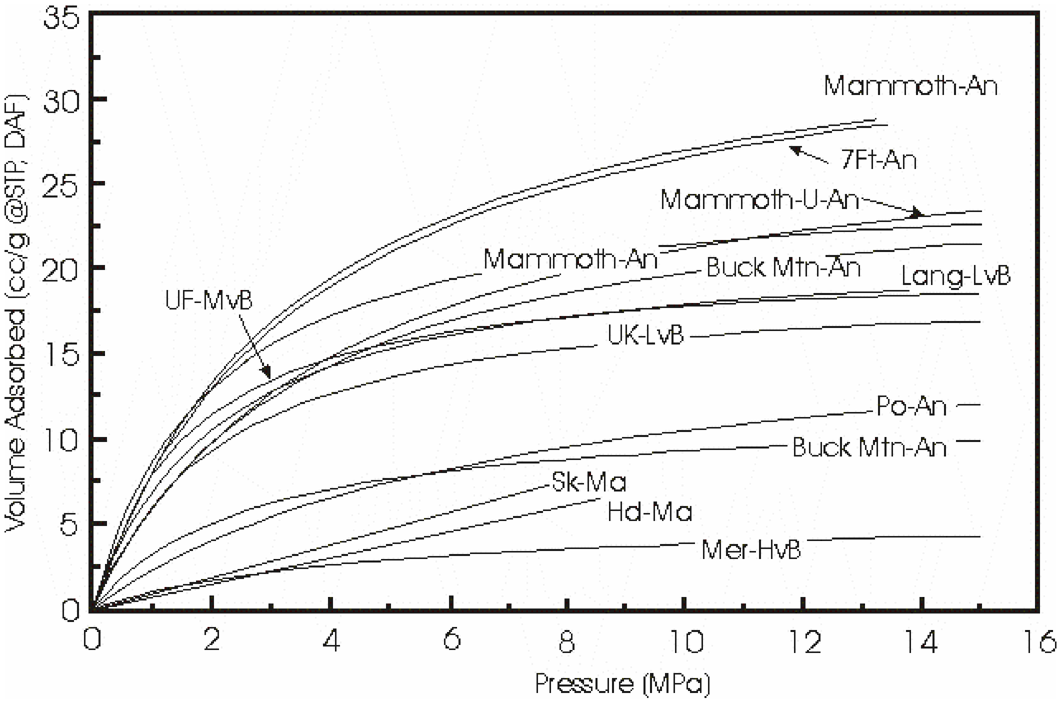


Figure 1. — Langmuir isotherms (dry, ash free basis) of samples analyzed in this study. Abbreviations used are: 7-Ft = Seven Foot coal bed; U=upper sample; Mtn = Mountain; Lang= Langhorne coal bed; UF = Upper Freeport coal bed; UK = Upper Kittanning coal bed; Po = Portsmouth main coal bed; Sk = Skinner mine coal; Hd = Hardon mine coal; hvB = high volatile bituminous coal; mvB =medium volatile bituminous coal; LvB = low volatile bituminous coal; An =anthracite; Ma =meta-anthracite.

of methane capacity for the coals of the Anthracite fields, where previously reported very low desorption values are attributed to methane drainage due to coal mining.

The New England coal samples have low methane adsorption values and indicate no potential for coalbed methane (CBM) development in that region probably because of the high degree of metamorphism of the coal beds. The Portsmouth coal shows low-moderate CBM-P, but the Portsmouth coals are not gassy. The very high adsorption capacities for coal samples from the Mammoth and Seven Foot coal beds of the Western Middle Anthracite field indicate very high potential for CBM development where geologic, hydrologic, structural, and other factors are favorable. The Upper Freeport and Upper Kittanning coal samples from the Bituminous Region have high adsorption values indicating high potential for CBM potential where the structure and overburden are favorable. One of the two coal samples from the Valley coal fields indicates limited potential for CBM development where continuity, bed thickness, and depth below the surface are favorable; the other sample (Merrimac, fig. 1) indicates apparent low rank and low adsorption due to weathering.

It is estimated that about 3.6 Tcf (0.102 Tm^3) of in-place CBM resources exists in the Anthracite fields, where an estimated 74 percent of the original coal resources still remains. About two-thirds of the CBM resources are in Schuylkill County, where the coal beds are more deeply buried. Development of CBM in the Anthracite fields will be dependent upon geologic structure, hydrology, technological advances, as well as other factors.

As of April 2003, in southwestern Pennsylvania in the Main Bituminous field, there are 132 commingled-gas CBM wells and 93 gob-gas CBM wells. About 375 permits since 1938 reflect wells exhibiting serendipitous discoveries of gas from coal, unsuccessful attempts at CBM, and various degrees of CBM production. Target depths documented to date in southwestern Pennsylvania range from less than 61 m (200 ft) in Fayette County to 659 m (2,162 ft) in Greene County. The commingled-gas CBM wells are producing mainly from coal beds of the Allegheny Formation (e.g., Clarion, Kittannings, and Upper Freeport) at depths as much as 445 m (1,459 ft). The gob-gas wells are producing mainly from the Upper Freeport, Pittsburgh, and Sewickley coal beds at depths from 148 m (485 ft) to about 244 m (800 ft).

There has been a general increase in CBM production in southwestern Pennsylvania since 1988 and dramatic growth since 1999 (fig. 2). Total reported CBM commercial production in southwestern Pennsylvania from 1988 to 2001 is 4.1 Bcf (0.12 Bm^3). The most recent CBM production is 1.2 Bcf for 2001 at a spot market contract price of $6 million per MMBtu. Indiana County has the largest CBM production at 865 MMcf (fig. 3). Other counties producing CBM are Cambria, Fayette, Greene, and Washington.

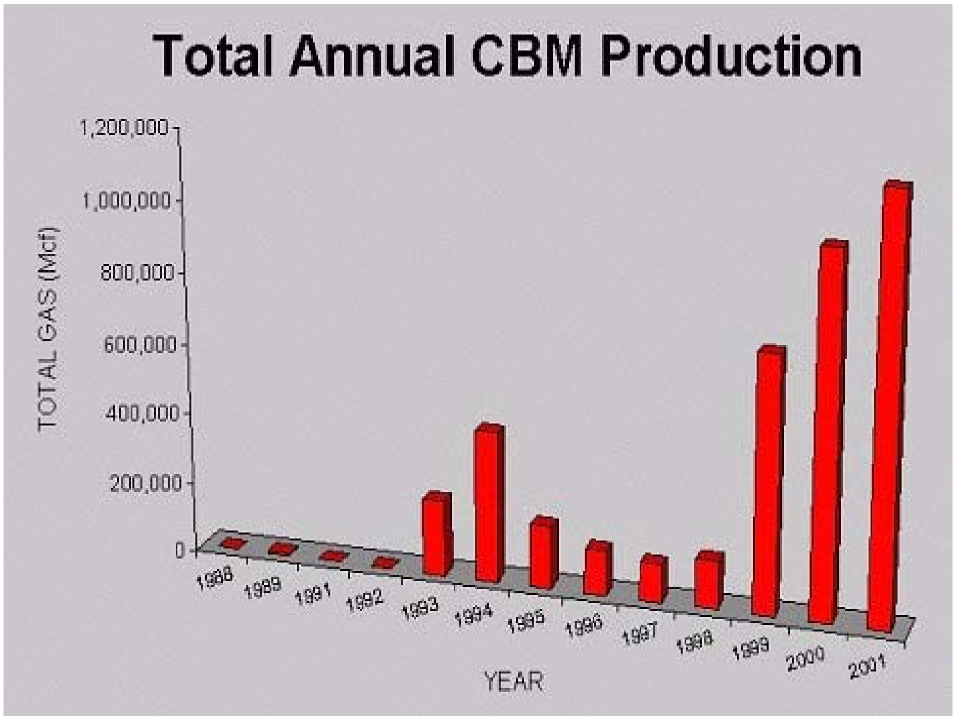


Figure 2. — Reported annual CBM production (Mcf) in southwestern Pennsylvania from 1988 to 2001.

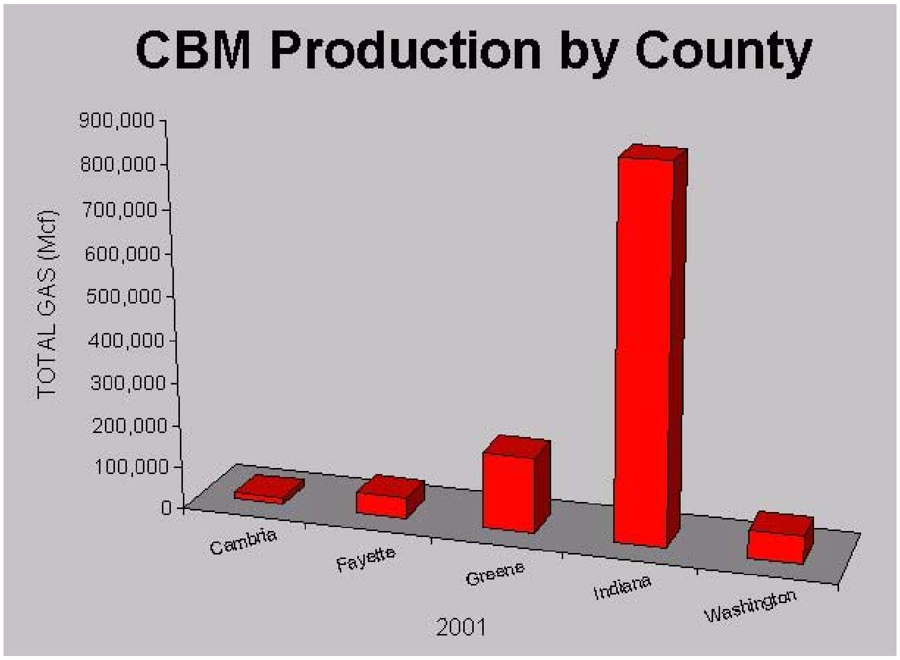


Figure 3. —Reported annual CBM production (Mcf) in Cambria, Fayette, Greene, Indiana, and Washington Counties for 2001.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20,
ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Effect of Geological Factors on the Permeability of Coal Seam Gas Reservoir

Xingjin Wang

School of Biological, Earth and Environmental Sciences, University of New South Wales,
Sydney, NSW, 2502 Australia

Cleat in coal provides the dominant permeability channels for fluid flow in coal seams. The permeability of a coal seam as a gas reservoir is governed by cleat properties, particularly the orientation, spacing, and compressibility. A study on the eastern edge of the Ordos Basin, China, has made contributions to two aspects of permeability studies: 1: How are cleat development and coal permability affected by the degree of coalification, the tectonic regime and aquifer occurrence? 2: How does permeability vary in the course of gas and water production due to compaction of the cleat fractures?

The research results indicate that permeability increases with increasing proportions of bright coal that occur from east to west in the study area, and that the cleat permeability is higher in zones close to faults where stress was more intense. A numerical modeling study of the sensitivity of fluid production to shrinkage of coal porosity showed that permeability decreases significantly with depletion of formation pressure, due to the compaction of cleat when fluid is released.

This research has established a model of coal seam permeability dependent on both geological variables and the course of gas and water production, which in turn provides an efficient tool for fairway selection in coal-bed methane exploration. It also identified a need to formulate a system for CBM production that avoids any abrupt drop in permeability of the coal seam reservoir in the course of gas and water production.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

The Inorganic Chemistry of 15 Coal Samples from the Prince Charles Mountains, East Antarctica

Lora A. Chiehowsky[1], Robert B. Finkelman[1], Tim A. Moore[2], Guy R. Holdgate[3],
Jason C. Willett[1], Stephen McLouglin[4], and Andrew N. Drinnan[4]

[1]*U.S. Geological Survey, MS 956, National Center, Reston, VA 20192*
[2]*Department of Geological Science, University of Cantebury, Private Bag 4800, Christchurch, New Zealand*
[3]*School of Earth Sciences, University of Melbourne, Victoria 3010, Australia*
[4]*School of Botany, University of Melbourne, Victoria 3010, Australia*

Although there have been papers describing the coal beds found in Antarctica, there is a lack of information concerning their inorganic constituents. Coates and others (1990) provided a summary of coal geology, quality, and resources of the coals in the Transantarctic Mountains, Anatarctica. They present proximate and ultimate analyses data but no information on major, minor, or trace element contents of coal samples. Rose and McElroy (1987) looked at a broader range of Antarctic coal beds but nothing beyond proximate and ultimate analyses were reported. Bradshaw (1974) and Faure and Botoman (1983) characterized zeolite and calcite constituents of coal beds but offered no insights into the bulk chemistry. In this paper we present the inorganic chemistry of 15 samples collected from the Prince Charles Mountains in East Antarctica (fig. 1).

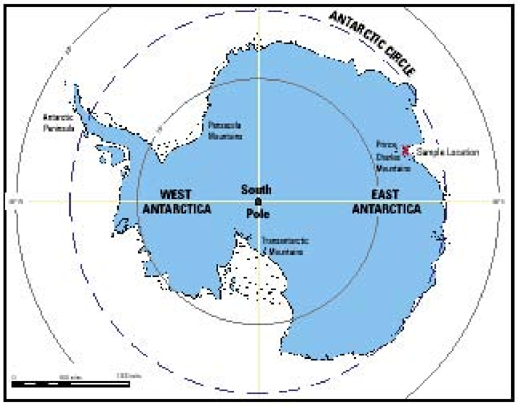


Figure 1. — Map location of sampled coalbeds from the Bainmedart Coal Measures, Prince Charles Mountains, East Antarctica

Grab samples were collected from coal outcrops of the Glossopteris Gully (6 samples), Dragons Teeth (1 sample), Toploje (2 samples), and McKinnon Members (6 samples) of the Permian Bainmedart Coal Measures (table 1). The samples were taken from approximately the middle of each coal bed (McLouglin and Drinnan, 1997a and b). No attempt was made to systematically sample each coal bed.

Proximate and ultimate analyses and forms of sulfur data for these samples appear in table 2. The samples then were analyzed for major-, minor-, and trace-elements using the U.S. Geological Survey's (USGS's) standard procedures for coal analysis (Bullock and others, 2002). Results of the chemical analysis are in tables 3 and 4. In addition, the mineral composition of the low temperature ash (LTA) of the coal samples was determined semi-quantitatively by X-ray diffraction.

The proximate ash yield (750 °C) ranged from 11.41 to 47.76 weight percent with an average of 24.65 weight percent (table 2). Total sulfur (table 2) was low, ranging from 0.32 to 0.79 weight percent. Pyritic sulfur (table 2) did not exceed 0.11 weight percent and was less than the organic sulfur content in each sample. The coal ash consisted predominately of alumina and silica (table 3). The high sum of $Al_2O_3 + SiO_2$ (76.4 to 93.6 weight percent) is reflected in the mineralogy. Kaolinite, quartz, and illite were the only minerals present in measurable quantities in the LTA and generally account for at least 90 percent of each sample. Traces of feldspars, rutile, and siderite were detected in most LTA samples. Trace amounts of pyrite were detected in five samples.

Table 1. — Descriptions of sampled coal beds from the Bainmedart Coal Measures, Prince Charles Mountains, East Antarctica.

Laboratory Id	Sample Number	Member (Radok Conglomerate, Bainmedart Coal Measures)	Approx. height above sea-level of sample collection (m)
E199409	95/15	McKinnon Member	2045
E199410	95/21	McKinnon Member	1710
E199411	95/24	McKinnon Member	?1750
E199412	95/27	McKinnon Member	1965
E199413	95/35	McKinnon Member	1990
E199414	95/42	McKinnon Member	2000
E199415	95/46	Glossopteris Gully Member	950
E199416	95/52	Glossopteris Gully Member	945
E199417	95/54		
E199418	95/66	Glossopteris Gully Member	930
E199419	95/67	Glossopteris Gully Member	825
E199420	95/123	Toploje Member	390
E199421	95/124	Toploje Member	385

The concentrations of most trace elements in the 15 Antarctica coal samples on a whole coal basis were low compared to averages for U.S. coal samples (Finkelman, 1993). The Antarctic coal samples had an average arsenic content of 1.4 ppm compared to 24 ppm for U.S. coal samples and an average Hg content of 0.05 compared to 0.2 for U.S. coal. Exceptions include Cr, V, Cu, and Sn which exceeded the U.S. averages in most Antarctic coal samples. One sample (95/123) had the highest S content as well as the highest concentration of 18 other elements including As, Hg, Mo, Sb, Te, Tl, Cr, Cu, Ni, and Zn.

Although the data set studied in this report is small, it provides additional published literature on major and trace element contents of Permian coal from Antarctic coal beds.

Table 2. — Summary of standard coal characteristics on an as-received basis from 15 samples of Bainmedart Coal Measures, Prince Charles Mountains, East Antarctica.

[All values are in percent except for Calorific value which is in British Thermal Units per pount (Btu/lb). Abbreviations are as follows: H=hydrogen; C=Carbon; N=nitrogen; O=oxygen].

Laboratory Id	Sample Number	Residual Moisture	Air Dry Loss	Proximate Analysis				Ultimate Analysis					Calorific Value	Forms of Sulfur		
				Moisture	Ash	Volatile Matter	Fixed Carbon	H	C	N	S	O		Sulfate	Pyritic	Organic
E199409	95/15	3.21	0.82	4.00	24.26	33.45	38.29	4.49	55.31	1.21	0.57	14.16	9840	0.10	0.01	0.46
E199410	95/21	2.13	1.23	3.33	47.76	24.17	24.74	3.12	36.11	0.80	0.45	11.76	6160	0.03	0.04	0.38
E199411	95/24	2.89	1.14	4.00	28.24	32.85	34.91	4.34	51.28	1.28	0.59	14.27	9090	0.07	0.05	0.47
E199412	95/27	2.98	1.13	4.08	34.21	29.05	32.66	3.85	46.80	1.13	0.59	13.42	8220	0.01	0.01	0.57
E199413	95/35	2.84	1.16	3.97	26.95	34.44	34.64	4.53	53.42	1.24	0.53	13.33	9540	0.04	0.01	0.48
E199414	95/42	3.67	0.78	4.42	30.88	31.27	33.43	4.02	48.26	1.18	0.52	15.14	8350	0.01	0.11	0.40
E199415	95/46	3.78	0.28	4.05	24.07	34.09	37.79	4.14	52.92	1.28	0.63	16.96	9060	0.19	0.04	0.40
E199416	95/52	4.21	0.86	5.03	29.76	31.14	34.07	3.66	47.17	1.24	0.44	17.73	7920	0.06	0.01	0.37
E199417	95/54	4.32	0.90	5.18	24.35	31.80	38.67	4.09	52.08	1.42	0.55	17.51	8870	0.13	0.04	0.38
E199418	95/66	3.30	0.56	3.84	11.41	39.30	45.45	5.03	65.74	1.77	0.70	15.35	11560	0.07	0.03	0.60
E199419	95/67	4.40	0.98	5.34	16.48	34.52	43.66	4.32	58.12	1.37	0.44	19.27	9860	0.03	0.04	0.37
E199420	95/123	2.10	0.49	2.58	20.00	33.64	43.78	4.74	63.05	1.61	0.79	9.81	11180	0.05	0.10	0.64
E199421	95/124	2.09	0.38	2.46	16.44	33.32	47.78	4.82	66.82	1.61	0.69	9.62	11800	0.04	0.05	0.60
E199422	95/133	5.49	1.09	6.52	16.90	34.58	42.00	4.24	55.82	1.56	0.63	20.85	9320	0.07	0.03	0.53
E199423	95/160	1.98	0.15	2.13	18.05	12.98	66.84	2.37	70.33	1.73	0.32	7.2	11270	0.01	0.03	0.28
Mean		3.29	0.80	4.06	24.65	31.37	39.91	4.12	54.88	1.25	0.56	14.43	9470	0.05	0.04	0.43

Table 3. — Major element oxides, USGS ash (samples ashed at 550 °C), and USGS moisture values in percent determined on an ash basis for 15 samples of the Bainmedart Coal Measures, Prince Charles Mountains, East Antarctica.

Laboratory ID	Sample Number	SiO_2	Al_2O_3	Fe_2O_3	K_2O	TiO_2	MgO	CaO	SO_3	Na_2O	P_2O_5	USGS ASH	USGS Moisture
E199409	95/015	65.00	21.10	1.30	2.30	1.20	0.72	0.51	0.84	0.35	0.03	25.10	3.90
E199410	95/021	67.80	25.80	1.60	2.20	1.60	0.54	0.20	0.14	0.10	0.02	48.50	1.82
E199411	95/024	61.30	25.10	3.30	2.30	1.30	0.62	0.37	0.43	0.12	0.02	28.90	2.21
E199412	95/027	67.10	25.60	1.50	3.10	1.60	0.85	0.34	0.55	0.55	0.04	35.00	2.12
E199413	95/035	66.50	24.20	1.70	3.00	1.40	0.80	0.39	0.41	0.20	0.03	27.50	2.22
E199414	95/042	65.40	23.90	5.80	2.30	1.40	0.96	0.44	1.00	0.20	0.02	31.80	2.90
E199415	95/046	59.90	23.00	2.60	2.40	1.60	0.73	0.36	0.95	0.50	<0.02	24.90	2.39
E199416	95/052	64.20	23.90	1.10	2.20	1.30	0.78	0.12	0.50	0.57	0.03	30.20	3.21
E199417	95/054	63.50	22.90	3.10	2.60	1.10	0.92	0.29	0.70	0.28	0.07	25.00	3.44
E199418	95/066	61.40	28.90	5.00	1.30	1.50	0.85	0.97	2.00	0.17	0.05	11.80	2.55
E199419	95/067	67.50	25.00	3.10	1.80	1.60	0.60	0.18	0.49	0.24	0.05	17.00	3.59
E199420	95/123	49.00	28.20	11.10	3.10	0.85	2.60	0.36	1.10	0.39	0.03	20.80	1.77
E199421	95/124	47.50	28.90	4.80	3.00	0.90	1.80	4.30	1.70	0.36	<0.02	17.40	1.55
E199422	95/133	63.30	22.10	2.80	1.90	1.00	0.78	0.40	1.30	1.00	0.12	17.60	4.49
E199423	95/160	62.30	26.80	4.20	1.50	1.50	0.63	1.30	1.20	0.47	1.40	18.60	1.25
	Mean	62.11	25.03	3.53	2.33	1.32	0.95	0.70	0.89	0.37	0.13	25.34	2.63

Table 4. — Trace element values in parts per million on a whole coal basis (converted from the ash on a dry basis except for arsenic, mercury, selenium and sulfur, which were analyzed on a whole coal basis) for 15 samples of Bainmedart Coal Measures, Prince Charles Mountains, East Antarctica.

USGS Lab No.	Sample Id	Ag	As	Au	B	Ba	Be	Bi	Cd	Cl	Co	Cr	Cs	Cu	Ga	Ge	Hg	Li	Mn	Mo	Nb
E-199409	95/015	<0.50	0.73	<2.5	<5.0	84	1.1	0.40	0.093	650	10	31	1.4	23	7.8	1.4	0.03	8.1	19	0.55	5.2
E-199410	95/021	<0.97	1.8	<4.9	<9.7	150	1.7	0.73	0.11	450	9.3	37	3.0	35	18	3.0	0.14	28	49	0.68	4.4
E-199411	95/024	<0.58	0.78	<2.9	<5.8	88	2.2	0.98	0.098	670	8.3	26	4.9	35	20	4.9	<0.02	19	51	0.90	4.7
E-199412	95/027	<0.70	0.49	<3.5	<7.0	130	7.4	0.53	<0.035	1200	16	46	6.6	27	19	6.6	0.07	10	28	0.49	2.5
E-199413	95/035	<0.55	0.94	<2.8	<5.5	120	3.4	0.52	0.088	370	10	32	3.7	23	16	3.7	0.02	11	17	0.52	7.7
E-199414	95/042	<0.64	1.4	<3.2	<6.4	110	2.4	1.3	0.19	300	9.1	35	5.3	32	25	5.3	0.03	18	74	2.0	9.2
E-199415	95/046	<0.50	0.70	<2.5	<5.0	76	18	0.95	0.16	990	13	29	9.2	28	23	9.2	0.03	22	28	1.0	3.6
E-199416	95/052	<0.60	1.5	<3.0	<6.0	150	5.6	0.97	0.11	1300	14	29	6.3	21	23	6.3	0.04	16	9.4	0.97	8.5
E-199417	95/054	<0.50	0.93	<2.5	<5.0	120	2.1	0.70	0.070	160	14	26	4.5	27	15	4.5	<0.020	8.7	48	1.3	5.6
E-199418	95/066	<0.24	0.73	<1.2	<2.4	25	0.41	0.24	0.065	180	25	17	0.77	11	5.0	0.77	<0.020	8.2	44	0.55	3.1
E-199419	95/067	<0.34	0.48	<1.7	<3.4	52	1.0	0.49	0.041	<150	5.5	18	0.87	22	8.9	0.87	<0.020	8.2	23	0.34	5.0
E-199420	95/123	<0.42	6.1	<2.1	<4.2	150	30	0.77	0.14	330	19	120	80	60	24	80	0.10	24	52	5.3	6.3
E-199421	95/124	<0.35	2.1	<1.7	<3.5	160	22	0.68	0.14	<150	19	57	35	35	16	35	0.03	23	76	1.5	2.6
E-199422	95/133	<0.35	0.32	<1.8	<3.5	83	1.2	0.21	0.058	1000	11	17	4.5	15	5.8	4.5	0.04	10	29	1.3	2.4
E-199423	95/160	<0.37	1.4	<1.9	<3.7	700	3.2	0.32	0.32	1400	8.3	58	1.1	41	9.7	1.1	0.06	8.5	64	1.2	0.24
Mean		<0.51	1.4	<2.5	<5.1	150	6.8	0.65	0.11	610	13	38	11	29	16	11	0.045	15	41	1.2	4.7

Table 4. — Trace element values in parts per million on a whole coal basis (converted from the ash on a dry basis except for arsenic, mercury, selenium and sulfur, which were analyzed on a whole coal basis) for 15 samples of Bainmedart Coal Measures, Prince Charles Mountains, East Antarctica — continued.

USGS Lab No.	Sample Id	Ni	Pb	Rb	S	Sb	Sc	Se	Sn	Sr	Te	Th	Tl	U	V	Y	Zn	Zr	Zn	Zr
E-199409	95/015	14	11	45	6000	0.35	6.9	<0.10	2.2	22	0.10	7.8	0.43	2.1	42	11	20	64	20	64
E-199410	95/021	14	27	90	4700	0.22	11	0.28	2.6	12	0.16	14	0.78	3.4	55	19	30	150	30	150
E-199411	95/024	13	23	74	6200	0.46	8.7	0.44	3.4	29	0.20	8.7	0.78	4.0	40	14	12	75	12	75
E-199412	95/027	14	20	90	6100	0.46	10	0.33	2.5	19	0.12	14	0.77	2.7	51	26	17	130	17	130
E-199413	95/035	14	21	82	5600	0.33	7.6	0.29	3.1	32	0.12	9.4	0.58	4.5	35	14	15	83	15	83
E-199414	95/042	15	38	89	5400	0.73	8.9	0.45	7.1	22	0.23	8.2	0.92	5.4	41	13	6.8	87	6.8	87
E-199415	95/046	28	29	68	6500	0.35	9.0	0.40	3.6	62	0.16	10	0.70	4.1	34	19	6.5	77	6.5	77
E-199416	95/052	23	31	79	4700	0.79	8.5	<0.10	6.3	20	0.22	11	0.82	5.0	43	18	5.3	65	5.3	65
E-199417	95/054	18	23	61	5800	0.75	6.5	<0.10	2.5	59	0.16	8.0	0.68	5.1	36	9.9	5.9	47	5.9	47
E-199418	95/066	22	6.5	8.0	7600	0.24	3.8	<0.10	1.2	69	0.073	3.6	0.25	1.3	19	6.8	4.0	34	4.0	34
E-199419	95/067	11	25	28	4500	0.41	6.1	0.14	2.2	50	0.14	6.1	0.46	2.8	27	8.8	8.6	44	8.6	44
E-199420	95/123	61	15	44	8200	2.7	17	0.16	1.9	30	0.29	7.1	0.96	4.8	220	30	54	64	54	64
E-199421	95/124	30	8.0	27	6900	1.4	14	<0.10	0.94	51	0.11	7.6	0.28	3.0	85	37	73	30	73	30
E-199422	95/133	7.4	6.9	23	6800	0.33	4.3	<0.10	1.0	70	0.048	5.0	0.39	1.1	24	7.4	13	39	13	39
E-199423	95/160	23	13	19	6000	0.028	14	0.37	<0.56	490	0.089	8.9	0.35	2.7	49	23	36	48	36	48
Mean		20	20	55	6100	0.63	9.1	0.19	2.7	69	0.15	8.7	0.61	3.5	54	17	21	69	21	69

References

Bradshaw, M.A., 1979, Occurrence and origin of an analcimolite from the Permian measures of Antarctica: New Zealand Journal of Geology and Geophysics, v. 22, no. 6, p. 729-35.

Bullock, J.H., Jr., Cathcart, J.D., and Betterton, W.J., 2002, Analytical methods utilized by the United States Geological Survey for the analysis of coal and coal combustion by-products: U.S. Geological Survey Open-File Report 02-389, 15 p.

Coates, D.A., Stricker, G.D., and Landis, E.R., 1990, Coal geology, coal quality, and coal resources on the Permian rocks of the Beacon Supergroup, Transantarctic Mountains, Antarctica, in Mineral Resources Potential of Antarctica: Antarctica Research Series, v. 51, p. 133-162.

Faure, Gunter, and Botoman, George, 1984, Origin of epigenetic calcite in coal from Antarctica and Ohio based on isotope compositions of oxygen, carbon, and strontium: Chemical Geology, v. 45, no. 4, p. 313-324.

Finkelman, R.B., 1993, Trace and minor elements in coal, *in* Engel, M. H., and Macko, S.A., eds., Organic Geochemistry: New York, NY, Plenum Press, p. 593-607.

McLoughlin, Stephen, and Drinnan, A.N., 1997a, Revised stratigraphy of the Permian Bainmedart Coal Measures, northern Prince Charles Mountains, East Antarctica: Geology Magazine, v. 134, no. 3, p. 335-353.

______1997b, Fluvial sedimentology and revised stratigraphy of the Triassic Flagstone Bench Formation, northern Prince Charles Mountains, East Antarctica: Geology Magazine, v. 134, no. 6, p. 781-806.

Rose, G., and McElroy, C.T., 1987, Coal potential of Antarctica: Australia Bureau of Mineral Resources Resource Report, Geology, and Geophysics, v. 2, 19 p.

Splettstoesser, J.F., 1985, Antarctic geology and mineral resources: Geology Today, v. 1, no. 2, p. 41.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

The Influence of Extractable Organic Matter on Vitrinite Reflectance — Implications to Liquid Hydrocarbon or Bitumen Impregnation as a Suppression Mechanism

Charles E. Barker, Michael D. Lewan, Mark J. Pawlewicz and Corinne L. Carlson

U.S. Geological Survey, Box 25046, MS 977, Denver, CO 80225

Vitrinite reflectance is a physical measurement widely used in assessing the maximum paleotemperature and thermal history of organic matter; it is particularly useful in defining the oil and gas windows in petroleum exploration. However, numerous studies suggest that false indications of thermal maturation, collectively termed "suppression", are possibly spuriously reducing vitrinite reflectance (Price and Barker, 1985). The major causes of suppression are operator bias in maceral selection, natural variations in liptinite content (Hutton and Cook, 1980) and differences in depositional and diagenetic environments (Newman and Newman, 1982; Taylor and Liu, 1987; Suarez-Ruiz and others, 1994) and pressure (McTavish, 1978).

This study investigates the basis for a widely cited cause of suppressed vitrinite reflectance: bitumen (exsudatinite) or liquid hydrocarbon impregnation of vitrinite (for example, Raymond and Murchison, 1991). Liquid hydrocarbons and bitumen, by definition, are soluble in organic solvents. Kerogen maturation results in the generation of bitumen, an intermediate product, that in turn breaks down to form liquid hydrocarbon, gas and a less soluble higher-rank bitumen or insoluble pyrobitumen. The liquid hydrocarbon and bitumen impregnation hypothesis suggests that during diagenesis, bitumen or oil is internally generated by vitrinite, or externally by liquid hydrocarbon-prone organic matter. The resulting liquid hydrocarbons impregnate the vitrinite by migrating into its solid structure.

A search of the literature, however, indicates that hydrocarbon or bitumen impregnation is not well documented as a cause of vitrinite reflectance suppression. A well-documented example of impregnation appears to be due to liquid hydrocarbon or bitumen physically sorbed by wood limbs that have reached the ulminite gelification stage of the huminite to vitrinite transition (Suárez-Ruiz and others, 1994). Ulminite is a relatively open, partially gelified huminite in peat and subbituminous coal, whereas vitrinite in bituminous coal is completely gelified. Thus, this Spanish case is distinct from liquid hydrocarbon or bitumen sorbing or diffusing into a completely gelified, homogeneous vitrinite maceral approaching main stage oil generation. Textbook photographs of microscope observations (Alpern, 1980; p. 381; Stach and others, 1982, p. 77; Bustin and others, 1983, p. 214-215; Potter and others, 1998, p. 86-87) show that rather than impregnation, liquid hydrocarbon and bitumen in coal or kerogen are seen as typically forming surface coatings on gelified vitrinite and other macerals and mineral grains or filling fractures and voids in these materials. This petrographic evidence strongly indicates that the liquid hydrocarbon or bitumen migrated onto the surfaces of vitrinite after gelification. These photographs show that infiltration of liquid hydrocarbon or bitumen, is typically limited to surface contact as a thin, relatively low reflectance, detectably fluorescent rinds that would not directly affect reflectance readings taken well away from the edge of the gelified vitrinite maceral. When we do see naturally-caused reflectance gradients in vitrinite, it is commonly due to impregnation of cell walls by resinite (Tyson, 1995, Petersen and Vosgerau, 1999). Resinite impregnation is a primary process related to plant life cycles, rather than a depositional or burial process like liquid hydrocarbon or bitumen impregnation. Resinite impregnation would not directly affect reflectance readings taken away from the immediate zone of infusion of resinite.

We investigated liquid hydrocarbon and bitumen impregnation as a cause of suppression by a simple experiment using coal and carbonaceous mudrock samples that were coarsely crushed and split into two parts. One sample split was Soxhlet-extracted using chloroform and the other split was left as received. The extraction continued until the refluxing solvent was clear. Both splits were then mounted as whole rock samples and polished for reflectance analysis. The hydrous pyrolysis utilized a sample of a Wilcox Group coal from Texas (Behar and others, 2003) that expelled a waxy oil into the reactor. The remaining sample suite includes typical humic coals as well as liptinite or resinite-rich humic coal, and mudrocks containing type II and type I kerogen.

Mean random vitrinite reflectance (Rv-r) was measured using vertical illumination on a Zeiss Universal microscope fitted with a MPM 01 microphotometric system. The photometer was restricted with a pinhole diaphragm to read a 3 µm spot on the sample at 500x total magnification under oil immersion (Cargille PCB free Type A immersion oil, ne = 1.5180). The system was calibrated by synthetic crystal standards in filtered 546 nm light.

The Soxhlet extracted samples averaged a reflectance 0.016 percent Rv-r less than the unextracted samples where the largest difference was 0.09 percent Rv-r less than the unextracted split in one sample (fig. 1). Because the intrinsic uncertainty of vitrinite reflectance is about 0.1 percent (Barker and Pawlewicz, 1993), for this sample suite, there is no detectable difference in the measured vitrinite reflectance in extracted or unextracted samples.

Given that liquid hydrocarbon or bitumen impregnation implies a mobile phase, its removal by extraction, at least in low thermal maturity samples, should result in an increased reflectance, but does not. However, the hydrous pyrolysis samples have demonstrably generated oil that passed through the kerogen structure and out of the sample. Thus, having oil pass through vitrinite-rich coal does not result in detectable differences in reflectance. Further, Robert (1988) noted that, in general, vitrinite existing in oil-saturated reservoirs for millions of years at elevated temperature and pressure does not show reduced reflectance, supporting our contention that impregnation of gelified vitrinite is not significant.

Coalbed methane studies show that whereas matrix porosity of vitrinite is high, its permeability, mostly related to microcleat, is low at 1-2 percent, and it is solid state diffusion that controls the movement of molecules into and out of the vitrinite structure (Masszi, 1991). For example, the diffusion rate of normal alkaline hydrocarbons through source rocks is exponentially reduced with increasing chain length (Verweij, 1993). From this relationship, we infer that bitumen, a high molecular weight molecule, would require a long time to diffuse into a vitrinite particle and, in practical terms, may be largely precluded from entering the crypto-porous structure. These considerations, and the photographic documentation, indicate that both primary migration from within the vitrinite particle and secondary migration near the vitrinite particle preferentially occurs along fractures, micro-cleat or perhaps submicroscopic paths rather than by diffusion.

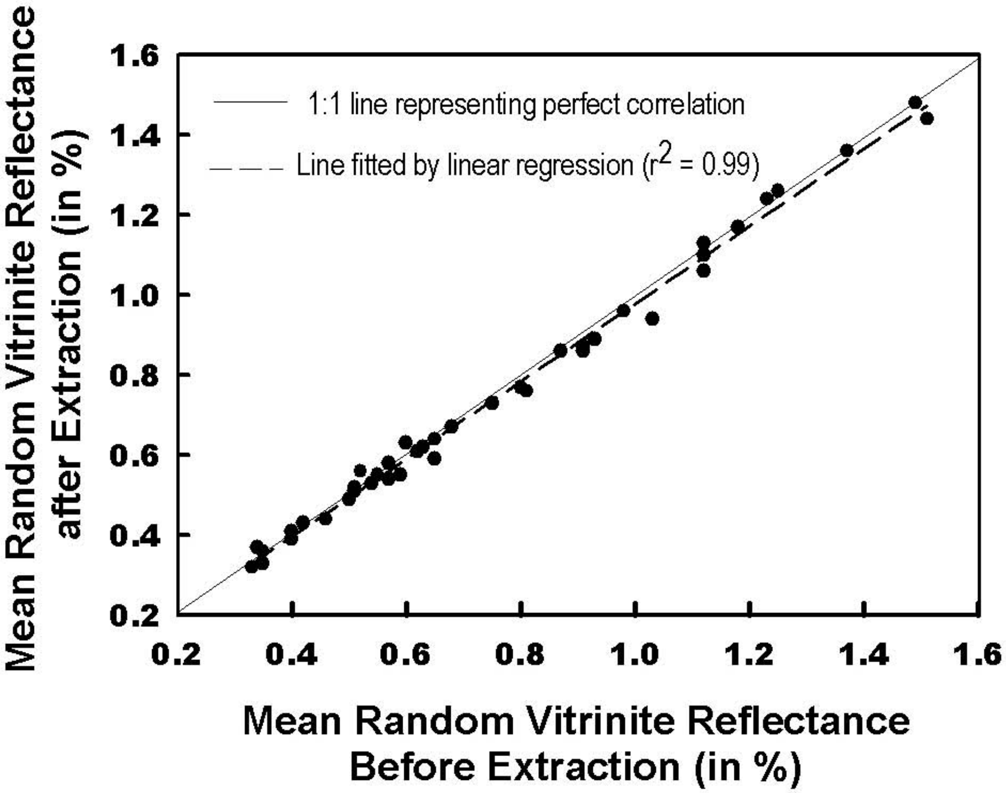


Figure 1. — Vitrinite reflectance from unextracted and extracted coal and mudrock samples.

We conclude from our observations, as well as those reported in the literature, that reflectance suppression by liquid hydrocarbon or bitumen impregnation in huminite-vitrinite maceral group, above the huminite stage of gelification, is not supported by microscopic evidence or the experimental evidence presented here. If the microscope operator selects resin-free vitrinite surfaces for measurement well away from grain edges or resinite-infused vitrinite, vitrinite reflectance suppression by liquid hydrocarbon or bitumen impregnation seems to be a negligible process in gelified vitrinite. We note that our study is limited in that it only addresses the issue of the physical presence of liquid hydrocarbon or bitumen that is changing vitrinite reflectance, but not the question of whether the presence of liquid hydrocarbon or bitumen changes the rate of vitrinite maturation.

References

Alpern, B., 1980, Petrographie du kerogene, *in* B. Durand, ed., Kerogen - insoluble organic matter from sedimentary rocks: Paris, France, Editions Technip, p. 339-383.

Barker, C.E., and Pawlewicz, M.J., 1993, An empirical determination of the minimum number of measurements needed to estimate the mean random vitrinite reflectance of disseminated organic matter: Organic Geochemistry, v. 20, no. 6, p. 643-651.

Behar, F., Lewan, M.D., Loranta, F., and Vandenbroucke, M., 2003, Comparison of artificial maturation of lignite in hydrous and nonhydrous conditions: Organic Geochemistry, v. 34, p. 575-600.

Bustin, R.M., Cameron, A.R., Grieve, D.A., and Kalkreuth, W.D., 1983, Coal Petrology, its Principles, Methods and Applications: Victoria, Canada, Geological Association of Canada, Short Course Notes, v. 3, 230 p.

Hunt, J.M., 1996, Petroleum Geochemistry and Geology (2nd ed.): New York, NY, W.H. Freeman and Co., 743 p.

Hutton, A.C., and Cook, A.C., 1980, Influence of alginite on the reflectance of vitrinite from coals, North-East Greenland — evidence for liptinite-induced suppression of huminite reflectance: International Journal of Coal Geology, v. 41, p. 257-274.

Potter, J., Stasiuk, L.D., and Cameron, A.R., 1998, A Petrographic Atlas of Canadian Coal Macerals and Dispersed Organic Matter: Canadian Society for Coal Science and Organic Petrology, 105 p.

Price, L.C., and Barker, C.E., 1985, Suppression of vitrinite reflectance in amorphous rich kerogen — a major unrecognized problem: Journal of Petroleum Geology, v. 8, p. 59-84.

Raymond, A.C., and Murchison, D.G., 1991, Influence of exinitic macerals on the reflectance of vitrinite in Carboniferous sediments of the Midland Valley of Scotland: Fuel, v. 70, p. 155-161.

Robert, Paul, 1988, Organic metamorphism and geothermal history; microscopic study of organic matter and thermal evolution of sedimentary basins: Norwell, MA, Kluwer Academic Publishers, 311 p.

Stach, E., Mackowsky, M. T., Teichmueller, M., Taylor, G.H., Chandra, D., and Teichmueller, R., 1982, Stach's textbook of coal petrology, third revised and enlarged edition: Berlin-Stuttgart, Gebrüder Borntraeger, 569 p.

Suárez-Ruiz, I., Iglesias, M.J., Jiménez, A., Laggoun-Défarge, F., and Prado, J.G., 1994, Petrographic and geochemical anomalies detected in Spanish Jurassic jet, *in* Mukhopadhyay, P.K., and Dow, W.G., eds., Vitrinite reflectance as a maturity parameter: applications and limitations: Washington, D.C., America Chemical Society, Symposium Series 570, p. 76-92.

Taylor, G.H., and Liu, S.Y., 1987, Biodegradation in coals and other organic-rich rocks: Fuel, v. 66, p. 1269-1273.

Tyson, R.V., 1995, Sedimentary Organic Matter: Chapman and Hall, London, 615 p.

Verweij, J.M., 1993, Hydrocarbon Migration Systems Analysis: Developments in Petroleum Science Series, v. 35: Amsterdam, Elsevier, Netherlands, 276 p.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Characterization of the Petrology, Mineralogy, and Geochemistry of Mined Coals, Western Venezuela

Paul C. Hackley[1], Peter D. Warwick[1], and Eligio Gonzáles[2]

[1]*U.S. Geological Survey, 956 National Center, Reston, VA 20192*
[2]*INGEOMIN, Torre Oeste Parque, Central Piso 8, Caracas, Venezuela 1010*

Tertiary (Upper Paleocene-Middle Miocene) coal samples from active mines in the States of Táchira, Merida, and Zulia, western Venezuela (fig. 1), have been characterized through an integrated geochemical, mineralogical, and petrographic investigation. Proximate, ultimate, and forms of sulfur values, major and trace element concentrations, vitrinite reflectance, maceral concentrations, and mineral matter content have been determined for sixteen channel samples from fourteen mines. The mines produce high quality (low-ash, moderate-sulfur), high-volatile bituminous coal primarily for thermal use in the export market.

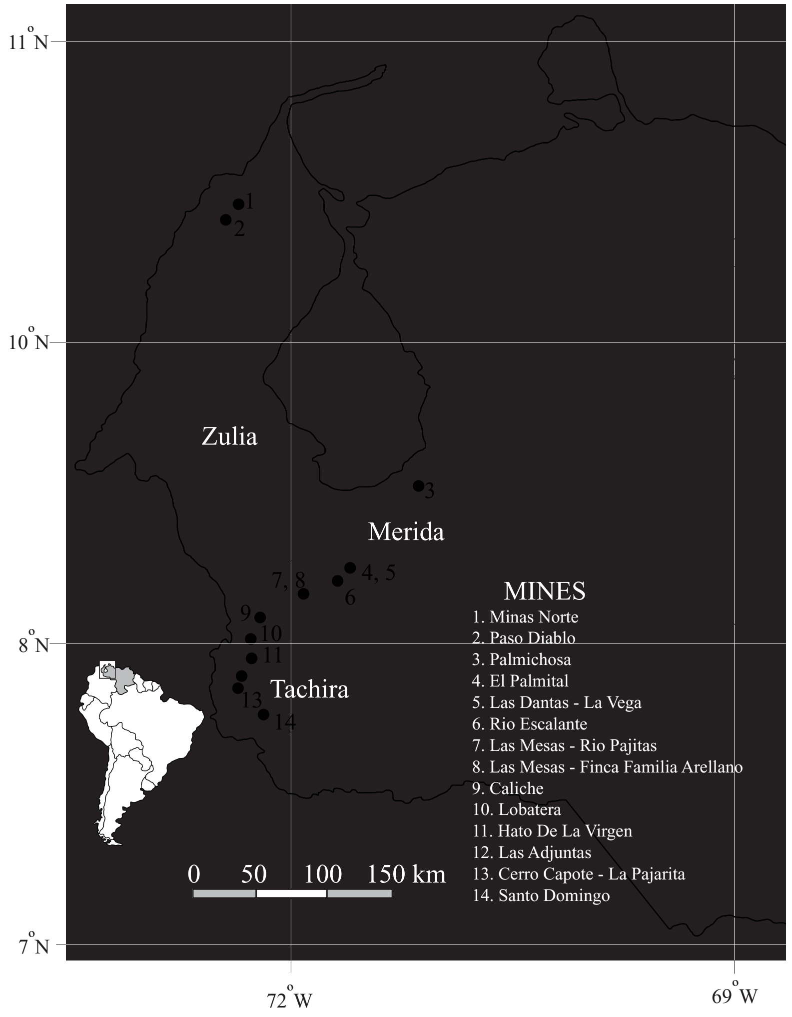


Figure 1. — Shaded relief image of western Venezuela showing locations of coal mines and internal political boundaries. Area of figure shown by box in index map of South American continent.

Detailed characterization of these coal samples was undertaken to address a relative lack of such information as presented in the English language literature at a time when Venezuelan coal production is undergoing a dramatic increase. Mine production (8 million metric tons per year) has increased almost four-fold over the last decade, primarily due to the development of deposits in the Guasare basin of northern Zulia (Minas Norte and Paso Diablo), and current production is expected to double over the next five years (Energy Information Administration, 2003). Therefore, a comprehensive investigation of commercially produced Venezuelan coal utilizing multiple analytical techniques was designed and executed to provide a reconnaissance-level characterization of in-ground coal. The following observations and conclusions summarize the more important points of our results.

Proximate, ultimate, and forms of sulfur values were obtained through standard ASTM methods and procedures (ASTM, 1998). Ash yield generally is low, ranging from less than one percent to a maximum of 17 percent (average = 5 percent) on an as-received basis. Total sulfur content is moderate, ranging from less than one percent to a maximum of 6 percent (average = 1.6 percent). Calorific value ranges from 10,750 to 15,500 Btu/lb (5,970 to 8,520 kcal/kg) (average = 13,430 Btu/lb; 7,450 kcal/kg), placing most of the coal samples in the apparent rank classification of high volatile bituminous (following ASTM, 1998).

Major and trace-element concentrations were determined through inductively coupled plasma emission spectrometry (ICP-AES) and mass spectrometry (ICP-MS). Mercury (Hg) and selenium (Se) were determined on whole coal by cold vapor atomic absorption analysis and hydride generation atomic absorption respectively. Of particular interest are the concentrations of the possible environmentally sensitive elements (As, Be, Cd, Cr, Co, Hg, Mn, Ni, Pb, Sb, Se, and U) that are identified in the past and present United States Clean Air Acts. The concentrations of these environmentally sensitive elements in the Venezuelan coal samples, with one exception, generally are similar to the concentrations of these elements in most coals of the world (Swaine, 1990), which indicates that there may be little exceptional environmental or health impact as a consequence of Venezuelan coal utilization. Although concentrations of some environmentally sensitive elements are relatively high in one sample from Las Mesas (Rio Pajitas) compared to the other Venezuelan coal samples, they are within the higher end of the range of these elements found in most coals. We assert that further characterization of the coal from this mine would be necessary to define the potential impacts of its utilization.

The relative concentrations of coal macerals were identified in each sample through petrographic analyses in blue-light fluorescence and reflected white light. Results illustrate the diverse character of coal currently produced in Venezuela. Concentrations of the liptinite maceral group range from less than 1 volume percent in coal from Las Adjuntas to almost 70 percent in coal from La Pajarita. Five of the sixteen samples contained greater than 20 percent liptinite, typically dominated by the macerals bituminite and sporinite. Vitrinite constitutes the dominant maceral group in all but the most liptinite-rich coal samples. The maceral collotelinite dominates the vitrinite group, which indicates that conditions in the peat environment were conducive to the formation of matrix gels or that the original plant materials were depleted in woody substance. Telinite was observed in quantities of one percent or less, despite efforts to better quantify this maceral by etching the sample pellets in a potassium permanganate solution, and also by exposure in an oxygen plasma chamber. Macerals of the inertinite group typically represented less than 10 percent of the coal samples and were found to be highest in samples from the Las Adjuntas and Santo Domingo mines as well as from the two mines in the Guasare basin. The Minas Norte coal sample contained 22 percent inertinite, comprised almost equally of fusinite, semifusinite, macrinite, and inertodetrinite.

Maximum reflectance of vitrinite in oil ($R_{o\ max}$) was determined for fourteen of the sixteen samples. Reflectance values for samples from the Las Mesas mine (Finca Familia Arellano) and the La Pajarita mine in Táchira were not determined due to the general lack of vitrinite and possible suppression by high liptinite content (48 and 69 percent liptinite, respectively). Values of $R_{o\ max}$ for the other samples ranged between 0.42 and 0.85 and generally were consistent with the high-volatile bituminous rank classification obtained through the methods described in ASTM (1998).

Mineral matter content of the coal samples was determined by X-ray diffraction (XRD) analysis of low-temperature ash (LTA) residues. Kaolinite, quartz, illite, and pyrite were found to dominate the inorganic fraction of most samples; plagioclase, potassium feldspar, calcite, siderite, ankerite, and marcasite were found in minor concentrations. Rutile, anatase, and apatite were found in trace quantities in several samples. Bassanite was generated as an artifact of the ashing procedure.

Although this data set represents only a limited number of coal samples from the active mines in western Venezuela, it provides a comprehensive analysis of the petrology, mineralogy, and geochemistry of commercially produced Venezuelan coals. We anticipate that these data can have application in the course of coal resource allocation, investment, utilization impact, and byproduct use and disposal, among others.

References

American Society for Testing and Materials (ASTM), 1998, Annual book of ASTM standards — Petroleum products, lubricants, and fossil fuels, v. 5.05 Gaseous fuels; coal and coke, 536 p.

Energy Information Administration, 2003, Venezuela: Energy Information Administration web site at http://www.eia.doe.gov/emeu/cabs/venez.html (Accessed June 3, 2003).

Swaine, D.J., 1990, Trace elements in coal: Butterworths, London, 278 p.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Prediction of Co_2 Sorption in Coal Seams using Uncrushed Coal Cores under Realistic P, T, and Moisture Conditions

Rachel Walker[1], Maria Mastalerz[2], Arndt Schimmelmann[1], Laurence Hawkes[1],
Jon Fong[1], Wilfrido Solano-Acosta[2]

[1]*Department of Geological Sciences, Indiana University, 1001 East 10th Street, Bloomington, IN 47405*
[2]*Indiana Geological Survey, 611 North Walnut Grove, Bloomington, IN 47405*

With growing concern about possible adverse long-term effects of global greenhouse warming, there is a need to develop methods for sequestering byproducts of fossil fuel combustion such as carbon dioxide (CO_2). One idea currently under investigation involves injecting CO_2 into coal seams. This technique can also force naturally occurring coalbed methane (CH_4) out of the coal seam; the methane then can be recovered and subsequently used as an energy resource having less CO_2 emission per energy unit than burning coal. The main purpose of this project is to study CH_4/CO_2 adsorption/desorption characteristics associated with uncrushed coal core sections under pressure, temperature, and moisture conditions that are representative for in-situ coal seams. The overall objective is to develop a reliable and practical method of placing an undisturbed section of a coalbed (core) in a temperature-controlled pressure reactor.

Figure 1. — View of the instrumentation. A is the reactor in which coal core samples will be placed; B is the injection pump for metering gas to the reactor; C are several pressure transducers; D is part of the data acquisition board to which instrumentation is connected, and E is the fume hood in which the apparatus is located, allowing safe venting of gases.

The instrumentation developed by our team for this project consists of a pressure reactor vessel designed to house a section of uncrushed coal core (fig. 1). The reactor is fed a compositionally controlled gas at one end using a piston-driven injection pump that meters gas from cylinders, while the effluent gas from the other end of the reactor is monitored compositionally over time. The temperature of the reactor is controlled using heating elements and thermocouples. Pressure transducers monitor pressures on both the input and output sides of the reactor. Feed and effluent gas samples can also be characterized isotopically.

On the output side of the system, a back-pressure regulator throttles the flow of effluent gas in order to maintain system pressure. Gas will subsequently pass through a digital flow meter and a binary gas analyzer that determines the percentage of CO_2 in CH_4. Data from the pressure transducers, flow meter, thermocouples and the binary gas analyzer are fed automatically and continuously through a data acquisition board installed in an adjacent computer. LabView software will manage data logging and real-time data display. Results can be exported for further evaluation.

Rigorous leak checking of the instrumentation with helium gas has demonstrated system integrity (fig. 2). Remaining tasks prior to experimenting with coal samples include calibration of the binary gas analyzer and use of a dud coal to test run the system and allow for final adjustments. After a reliable system has been developed, our objective is to determine CO_2 and CO_2/CH_4 sorption/desorption characteristics in coals of specific rank, type, and lithotype structure. We will evaluate how fast and efficient the initially present coalbed methane CH_4 can be desorbed from coals during CO_2 adsorption, and determine the influence of various coal lithotype structures on the kinetics of adsorption/desorption processes.

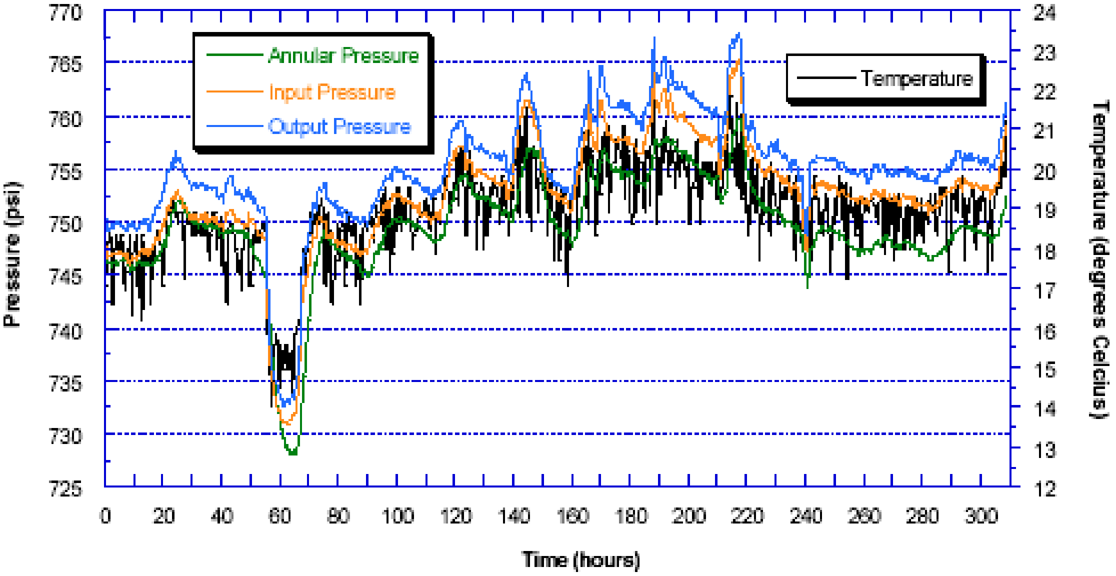


Figure 2. — Graph of system pressure and temperature over time, illustrating the effect of temperature on system pressure. The absence of an overall, long-term pressure decrease indicates the absence of significant gas leaks. Input and output pressures refer to conditions at the input and output sides of the pressure reactor, respectively.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Rare-earth Element Systematics in Upper Permian Mineralized Coal, Southwestern Guizhou Province, P.R. China

Harvey E. Belkin[1], Baoshan Zheng[2], and Robert B. Finkelman[1]

[1]U.S. Geological Survey, 956 National Center, Reston, VA 20192
[2] State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry,
Chinese Academy of Sciences, Guiyang 550002, P.R. China

Rare-earth element concentrations (REE) are commonly used as geochemical tracers to study many geologic processes because of their unique, chemically distinct behavior. This behavior can be employed to understand the origin of rocks and to trace the movement and interaction of crustal fluids. Southwestern Guizhou Province, P.R. China, is the site of small- to moderate-sized gold deposits that are also enriched in As, Sb, Ba, ±Hg, and ±Tl (Peters, 2002). Upper Permian, bituminous coal beds have interacted with ore-forming fluids and became mineralized by the same suite of elements that occur in the adjacent gold deposits (Belkin and others, 1998). Arsenic is especially enriched and ranges typically from greater than 100 ppm to 3 weight percent (on a whole-coal basis). Domestic combustion of these coals for use in heating, cooking, and drying food stuffs has lead to 3,000 cases of arsenic poisoning, whereas the affected population is about 10,000 (Belkin and others, 1997, Liu and others, 2002). We have investigated the REE content of selected coals to help understand the origin and various processes of enrichment of arsenic and related heavy metals in the coal and to assess the potential human health effects of domestic coal ash disposal.

The gold occurrences in Guizhou Province and adjacent Yunnan Province and Guangxi Districts are characterized as the Carlin-type of gold deposit. These deposits contain micron-sized disseminated gold which appears to be mostly contained in arsenic-rich pyrite. The deposits are usually located along structural trends and related to structural windows that expose Paleozoic strata in an area of mostly Mesozoic carbonates. Fluid inclusion data suggest that the main metallogenic phase occurred between 180-230 °C by fluids with salinities of 3-4.5 weight percent NaCl equivalent. The geochemical signature is variable with each particular deposit and these deposits also show enrichment in REE.

The Upper Permian coal fields in western Guizhou Province are classified into three types: continental facies, mixed marine-continental facies, and marine facies (Wang and others, 1993). The total sulfur content of the coals reflects these depositional environments and increases toward the marine facies. All coal-bearing rocks occur stratigraphically between the Permian Emeishan Basalt (or Maokou Limestone) and Lower Triassic rocks. The coal studied in southwestern Guizhou Province occurs in the Longtan Formation (or correlative) and is anthracite ($R_{\text{o, max}}$ 2.4-4.5).

REE in the studied coals were determined by Instrumental Neutron Activation Analysis (INAA) at the U.S. Geological Survey laboratories in Denver, Colorado. Data are reported on a whole-coal basis with the moisture content of the coal as analyzed. Figure 1 shows the suite of coals collected in 1997 normalized to chondritic abundances (Anders and Ebihara, 1982). These data are from three studied areas, Dadi, Haizi, and Jiaole. In general, all the patterns are moderately

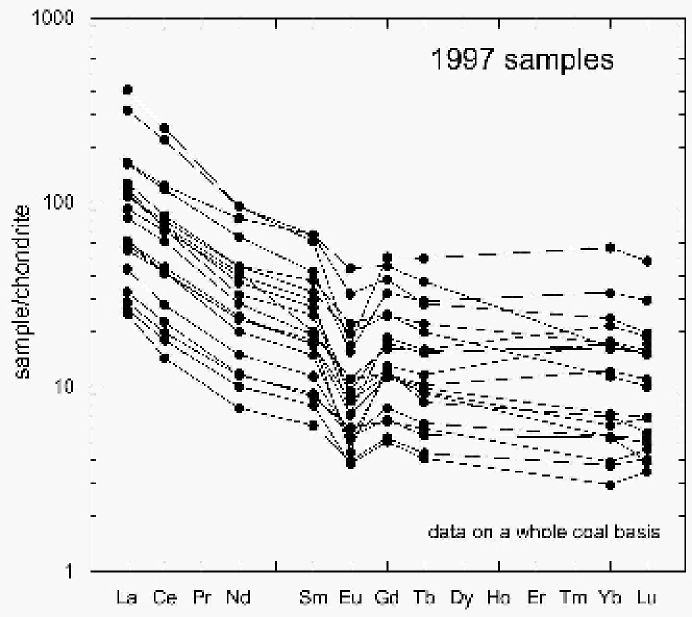


Figure 1. — INAA analyses of 1997 coal samples normalized to chondritic abundances.

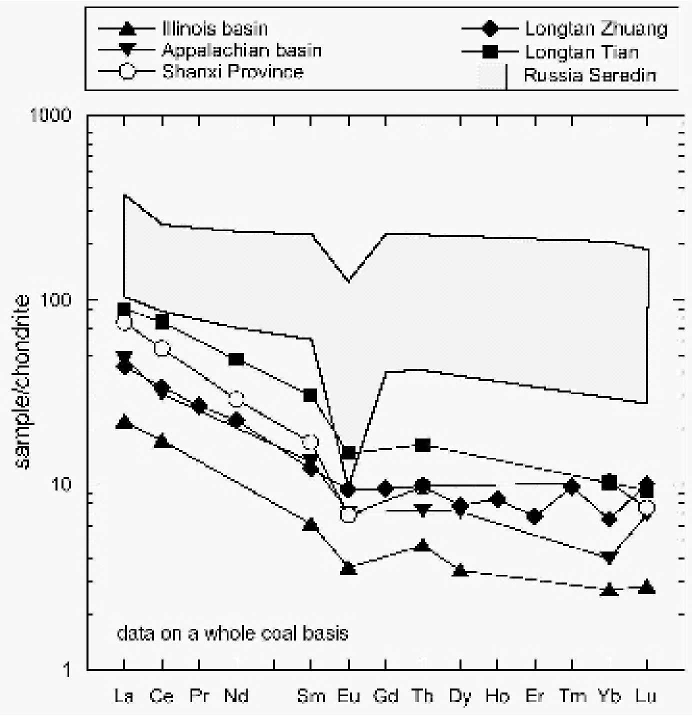


Figure 2. — Diagram showing REE-chondrite plots for Illinois basin (Gluskoter and others, 1977), Appalachian basin (Gluskoter and others, 1977), Shanxi Province (Zhao unpublished data), Longtan Formation coals (Zhuang and others, 2001), Longtan Formation coals (Tian, Belkin unpublished data) and from Russia Far-East (Seredin, 1996).

to strongly enriched in light REE, have a moderate Eu anomaly, and a flat heavy REE portion. The mean ash content of these coals is 23 weight percent. Figure 2 shows REE data from a variety of coals from different basins and provenances and also shows a comparison with non-mineralized Longtan Formation coals. These coals contain, on average, less REE for a given ash content than the studied mineralized coals. We have also shown the mean for a suite of Carboniferous-Permian coals from Shanxi Province, northeast of Guizhou Province. Also shown are representative means for the Illinois basin and Appalachian basin, and a suite of highly REE-enriched coals from Russia. In general, the REE content of the Upper Paleozoic coals of the United States appears to be quantitatively less than similar rank, age, and ash content of the Chinese coals. The Russian coals have a similar degree of light REE enrichment compared to the studied Chinese coals, but have a more pronounced Eu anomaly and more heavy REE enrichment.

Detailed petrographic, mineralogical, and geochemical studies have shown that the three studied areas experienced different mineralizing histories. Figure 3 shows the relation between La and Al_2O_3 in coals from the three areas. The general positive correlation is compatible with the observation of REE-bearing Al-phosphates and clays in the coals. The relation with arsenic enrichment and REE abundance is more complex. Figure 4 shows that As enrichment for these samples is generally not correlated directly with REE abundances. We believe that sulfur content, the mode of occurrence of arsenic, and different fluid properties in the three areas is reflected in the REE, As and heavy metal systematics.

Prior to the domestic use of coal in the studied areas, wood or wood charcoal was the common fuel source. As is typical in wood or biomass fuel technologies, disposal of the ash was usually accomplished by spreading or mixing it with local garden soils. Wood contains about 1 to 5

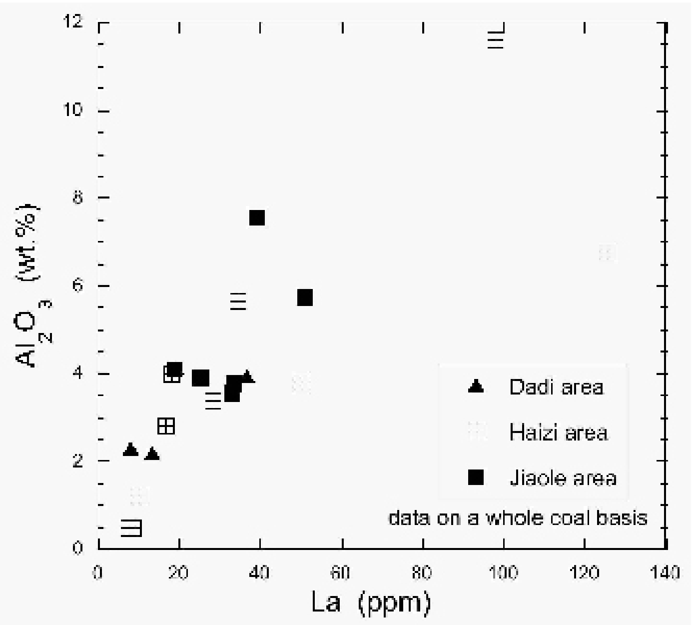


Figure 3. — Diagram showing Al_2O_3 versus La in 1997 coal samples shown in fig. 1.

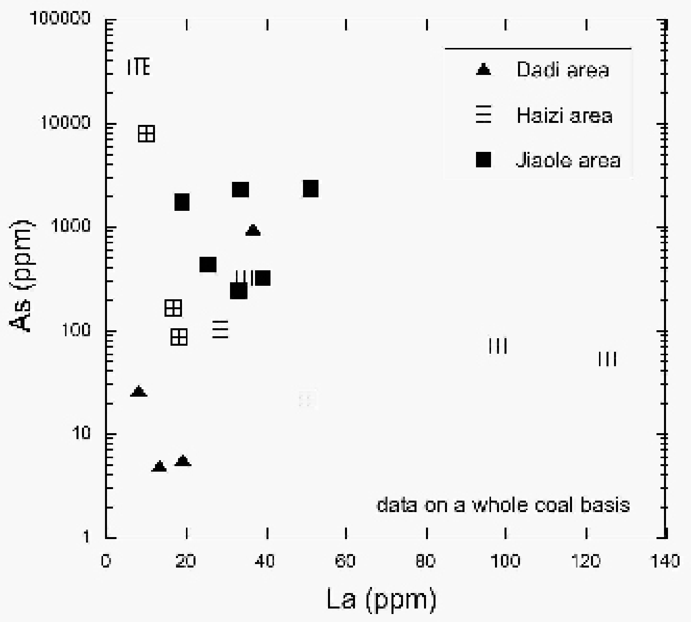


Figure 4. — Diagram showing As versus La in 1997 coal samples shown in fig. 1.

weight percent ash, and of this will typically be 1-2 percent phosphate, 4 -10 weight percent potash, and 20 to 50 percent lime which is quickly converted to calcium carbonate during exposure to humid air. Such wood ashes have a minor effect on the soil chemistry except by increasing the alkalinity. However, the disposal of coal ash on local garden soils may have a deleterious effect on human health. Herein we just discuss the REE content which would be concentrated in the residual coal ash. The Chinese have used REE in fertilizers in their agriculture for about 20 years. Although, such REE additions have improved the yield and quality of several kinds of crops (Pang and others, 2002), little is known about their long-term environmental or human-health effects. The toxicological effects of REE compounds are mainly due to intratracheal and inhalational exposure (Haley, 1965; Hirano and Suzuki, 1996). Although, minor amounts are absorbed by food plants (Su and others, 1993) care should be taken with the disposal of REE-rich coal ash in the domestic environment.

References

Anders, Edward, and Ebihara, Mitsuru, 1982, Solar-system abundances of the elements: Geochimica et Cosmochimica Acta, v. 46, no. 11, p. 2362-2380.

Belkin, H.E., Zheng Baoshan, Zhou, Daixing, and Finkelman R.B., 1997, Preliminary results on the geochemistry and mineralogy of arsenic in mineralized coals from endemic arsenosis areas in Guizhou Province, P.R. China{abs.], *in* Chiang, S.-H., ed., Coal—Energy and the Environment: 14th Annual Pittsburgh Coal Conference in Taiyuan, China, Pittsburgh, Pa., September 23-27, 1997, 1 CD-ROM (ISBN 1-890977-14-4).

Belkin, H.E., Warwick, P.D., Zheng, Baoshan, Zhou, Daixing, and Finkelman, R.B., 1998, High arsenic coals related to sedimentary rock-hosted gold deposition in southwestern Guizhou Province, People's Republic of China [abs.], *in* Chiang, S.-H., ed., Proceedings, Coal—Energy and Environment, 15th Annual Pittsburgh Coal Conference, Pittsburgh, Pa., September 15-17, 1998: Pittsburgh Coal Conference, Pittsburgh, Pa., 1 CD-ROM (ISBN 1-80977-15-2).

Gluskoter, H.J., Ruch, R.R., Miller, W.G., Cahill, R.A., Dreher, G.B., and Kuhn, J.K., 1977, Trace elements in coal — occurrence and distribution: Illinois State Geological Survey, Circular 499, 154 p.

Haley, T.J., 1965, Pharmacology and toxicology of the rare earth elements: Journal of Pharmacology Science, v. 54, no. 5, p. 663-670.

Hirano, Seishiro, and Suzuki K.T., 1996. Exposure, metabolism, and toxicity of rare earths and related compounds: Environmental Health Perspectives, v. 104, no. 1, p. 85-95.

Liu, Jie, Zheng, Baoshan, Aposhian, H.V., Zhou, Yunshu, Chen, M-L, Zhang, Aihua, and Waalkes, M.P., 2002, Chronic arsenic poisoning from burning high-arsenic-containing coal in Guizhou, China: Environmental Health Perspectives, v. 110, no. 2, p. 119-122.

Pang, X., Li, D., and Peng, A., 2002, Application of rare-earth elements in the agriculture of China and its environmental behavior in soil: Environmental Science Pollution Resources International, v. 9, no. 2, p. 143-148.

Peters, S.G., 2002, Geology, Geochemistry, and Geophysics of Sedimentary-rock hosted gold deposits in P.R. China: U.S. Geological Survey Open-File Report 02-131, Version 1.0, CD-ROM.

Seredin, V.V., 1996, Rare earth element-bearing coals from the Russian Far East deposits: International Journal of Coal Geology, v. 30, no. 1-2, p. 101-129.

Su, D.Z., Xiang, L.D., and Zhai, Y.X., 1993, Studies on the rare earth element content in food and its daily intake in man: Zhonghua Yu Fang Yi Xue Za Zhi, v. 27, no. 1, p. 6-9. (in Chinese with English abstract)

Wang, Liting, Lo, Jinhui, Wang, Changwei, and Wang, Min, 1993, Geology and coal-accumulating regularity of the paralic coal fields of Late Permian in western Guizhou: Geology of Guizhou, v.10, no. 4, p. 291-299. (in Chinese with English abstract)

Zhuang, Xinguo, Gong, Jiaqiang, Wang, Zhanqi, Zeng, Rongshu, Xu,Wendong, 2001, Trace elements of the late Permian coal in the Shuicheng and Liuzhi coal fields, Guizhou, China: Geological Science and Technology Information, v. 20, no. 3, p.53-58. (in Chinese with English abstract)

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Organic Geochemistry of Retained and Expelled Oil Based on Hydrous Pyrolysis Experiments — An Example from the Irati Oil Shale, Brazil

Noelia Franco[1], Wolfgang Kalkreuth[1] and Henrique Penteado[2]

[1]*Departamento de Geologia, UFRGS, Porto Alegre, Brazil*
[2]*CENPES, Petrobrás, Rio de Janeiro, Brazil*

Abstract

Hydrous pyrolysis experiments were performed on immature samples from the Irati oil shale, Paraná Basin to study compositional, molecular and isotopic changes in the oil generated during a stepwise increase in maturity. The analyses included both the expelled oil and the oil left behind in the rock matrix (retained oil). Geochemistry parameters such as Rock Eval, Tmax and hydrogen index, and biomarker ratios of Ts/(Ts+Tm), C29 20S/(20R+20S) and abb/(abb+aaa) steranes show a significant increase in maturity related to the time the organic matter was exposed to the maximum temperature applied (350° C). On the other hand, biomarker parameters used in the evaluation of the origin of the organic matter such as the hopane/sterane ratio, and the concentration of C_{27} and C_{29} steranes show significant variations related to the stage of maturity. It could be demonstrated that with increasing duration time at maximum temperature (350 °C) expulsion efficiencies (EE) and transformation ratios (TR) based on evaluation of Rock Eval parameters increase. Important differences were observed in the composition of the expelled and retained oil. The retained oils were found to be enriched in polar components of high molecular weight (NSO), whereas the expelled oil had higher quantities of saturated and aromatic components. At relatively low maturity levels, the gas chromatograms (GC) of expelled oils indicate a somewhat higher maturity when compared to the GC of the retained oil in the rock. At higher maturity levels, the gas chromatograms indicate the same level of maturity for the expelled and retained oil.

Introduction

Several geochemical studies performed in different source rocks and their related oils have reported significant compositional and molecular differences between expelled oils and source-rock extracts with comparable maturity level. Oils recovered from reservoirs are usually richer in saturates, whereas resins and asphaltenes are preferentially retained in source rocks, thus making rock extracts richer in these classes of compounds. At the same time, the use of biological markers as a tool for oil-source rock correlations is based on a premise that no major molecular changes occur during petroleum expulsion and secondary migration. This assumption allows geochemists to directly correlate the biomarkers of oils with those of source-rock extracts. Also based on an idea of bulk petroleum expulsion, geochemists have used the biomarker pattern of reservoired oils to infer the depositional environment of their source rocks and the level of thermal maturity of their organic matter when petroleum expulsion took place.

Results and Discussion

Aiming to obtain a better appraisal of the compositional and molecular differences between the expelled petroleum and that remaining in source rocks, hydrous pyrolysis (Lewan, 1985) experiments were performed in an immature organic-rich sample of the Irati shale (Permian, Paraná Basin, Brazil). The sample collected in a quarry in São Mateus do Sul, Paraná, Southern Brazil, comes from the basal portion of the formation.

After sample sieving and homogenization, aliquots of the sample were separated for TOC, Rock-Eval and organic petrography analyses. To perform the hydrous pyrolysis experiments, 50 g of sample were introduced in a stainless steel reactor filled with 50 ml of deionized water. Temperature and pressure were progressively increased up to a maximum of 350ºC and 2500 psi. Duration of the experiments ranged from 1.5 to 98 hours, with variable heating rates (0.9 and 3.7ºC/min) adopted before isothermal conditions around 350ºC. At the end of the experiments, the expelled oil and the remaining rock sample were recovered for further analyses. Aliquots of the residual rock were submitted to Rock-Eval pyrolysis and organic petrography analyses. The residual source rock was then extracted, and the extracts were analyzed by liquid (MPLC) and gas chromatography (whole extract and saturated fraction), GC-MS (saturated fraction), and stable carbon isotope determination (whole extract and all fractions). The expelled oils underwent an analytical procedure similar to that used for extracts.

The results of the TOC and Rock-Eval analyses are shown in figure 1. Kerogen transformation ratios (TR) and petroleum expulsion efficiencies (EE) were calculated from TOC and Rock-Eval data with the following equations:

$$TR = \left[\frac{(HI_o - HI_r + S1_o/TOC_o) \times 100}{(HI_o + S1_o/TOC_o) \times 100} \right] \times 100$$

$$EE = \left[\frac{(HI_o - HI_r + S1_o/TOC_o) \times 100 - (S1_r/TOC_r) \times 100}{(HI_o + HIr + S1_o/TOC_o) \times 100} \right] \times 100$$

in which the subscript “$_o$” denotes the value (HI: hydrogen index in mg/g TOC; S1: free hydrocarbons in mg/g rock; TOC: total organic carbon in percent) in the original immature sample and “r” the residual value after the hydrous pyrolysis experiment.

From the results in figure 1, a clear trend of decreasing TOC, S2 and HI is observed with the increase in maturation (Tmax). The estimated values of transformation ratios (3-84 percent) and expulsion efficiencies (0-95 percent) indicate that the maturity range investigated covers the whole petroleum generation window. Due to the high content of organic matter in the original sample, expulsion efficiencies were shown to be very high in the Irati shale.

Source-rock extracts and expelled petroleum share a similar behaviour in some biomarker ratios with increasing maturity, such as an increase in pristane/phytane, and C_{29} steranes maturity ratios, and a decrease in pristane/n-C_{17}, phytane/n-C_{18} and Ts/(Ts+Tm) (fig. 2). However, some biomarker ratios that are reputed to be mostly source-dependent, such as the proportions of the

C_{27}, C_{28} and C_{29} steranes, vary considerably with increasing maturation. In our case, C_{29} steranes predominated over their C_{27} and C_{28} homologues in the immature sample, whereas C_{27} was

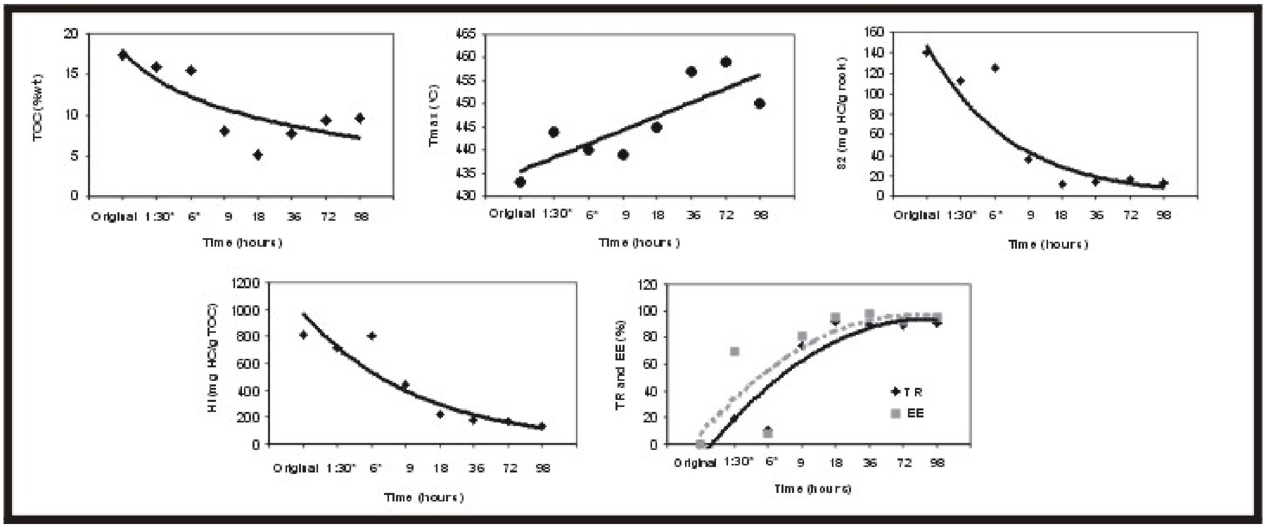


Figure 1. — Results obtained of total organic carbon (TOC), Rock Eval maximum temperature (Tmax), source rock potential (S2), hydrogen index (HI), transformation ratio (TR) and expulsion efficiency (EE) of samples before (original) and after hydrous pyrolysis.

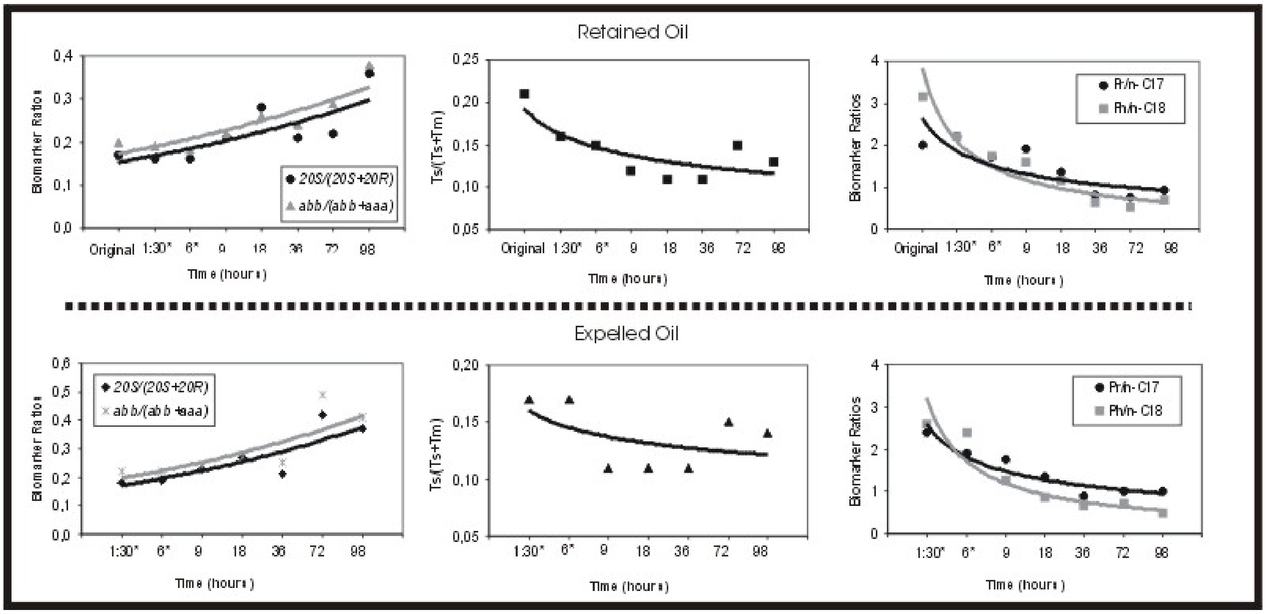


Figure 2. —Variations of the biomarkers ratios Pr/n-C17, Ph/n-C18, Ts/(Ts+Tm) and C29 steranes maturity ratios in, retained and expelled oils obtained in the experiments.

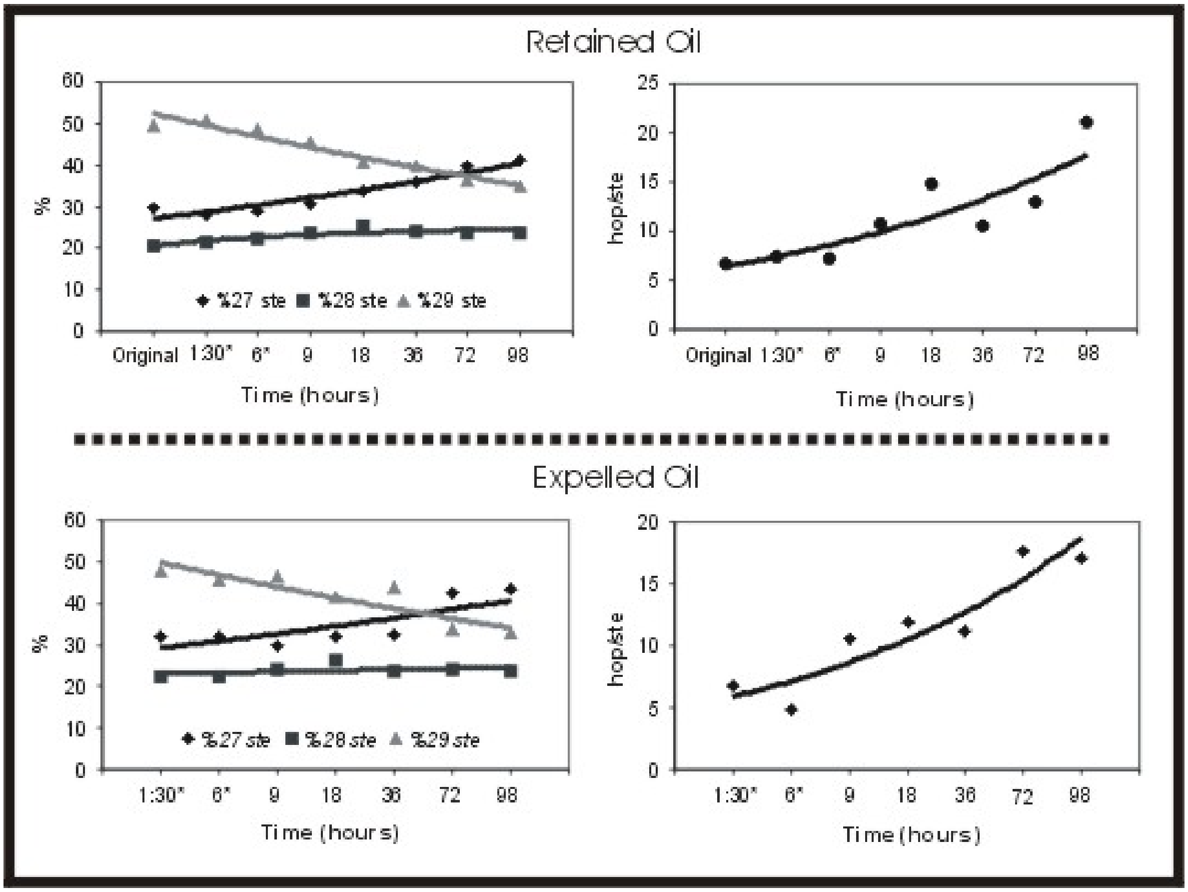


Figure 3. —Variations of the biomarkers ratios hopanes/steranes (hop/ste) and C27, C28 and C29 steranes in, retained and expelled oils obtained in the experiments.

predominant in the more mature oils and extracts (fig. 3).

Compared to source-rock extracts, the expelled petroleum is always richer in normal paraffins. An interesting feature is that biomarker ratios indicative of maturity like Ts/(Ts+Tm), proportions of isomers of C_{29} steranes and tricyclics/pentacyclics were generally higher in oils than in related extracts. Furthermore, differences were observed in biomarker source indicators like hopanes/steranes (fig. 3) and gammacerane/C_{30} hopane ratios. Unless the expulsion process in hydrous pyrolysis experiments does not adequately reproduce the same process under geological conditions, these results suggest that molecular differences between retained and expelled oils generated at a given thermal history can be significant, and that inferences on properties of source rocks based on biomarkers from oils should be made with caution.

References

Lewan, M.D., 1985, Evaluation of Petroleum Generation by Hydrous Pyrolysis Experiments: Philosophical Transactions of the Royal Society, v. 315A, p. 123-134.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Comparative Analysis of Moscow Lignite and Kama Coal Basins

Albina Gazizova

Saint-Petersburg Mining University, Saint-Petersburg, Russia

The Moscow lignite basin (MLB) and the Kama coal basin (KCB) are significant as solid fuel suppliers for the European regions of Russia. Both of the basins are situated within the Eastern-European platform. The MLB has been geologically well-studied and intensively exploited for about 300 years. The KCB was discovered during exploration oil drilling. Abundant data on the coal-bearing formation of the KCB has been obtained from oil well records. The highest coal-bearing potential in the basins is located in the Bobrikovsky horizon and is of an Early Carboniferous to Visean age.

In the MLB (fig. 1), the Bobrikovsky horizon ranges from 10 to 60 m in thickness. It contains up to 11 lignite beds with thicknesses ranging from 0.1 to 3.0 m, though only three of these beds are more than 1.3 m thick and economically significant. The average depth of the lower stratigraphic boundary of the horizon ranges from 100 to 130 m below the surface. The Bobrikovsky horizon is dominated by sandstone and shale. The lignite has a moderate to high sulfur content (S_t^d = 0.5-12 percent with an average of 4 percent) and high ash yield (A^d = 14-45 percent with an average of 31 percent). The lignite is also characterized by considerable fluctuations of analytical moisture content (W^a = 4-45 percent with an average of 32 percent) and volatile matter content (V^{daf} = 25-65 percent with an average of 46 percent). There is a narrow coalification range of R_0 = 0.43 to 0.47 with an average of R_0 = 0.46.

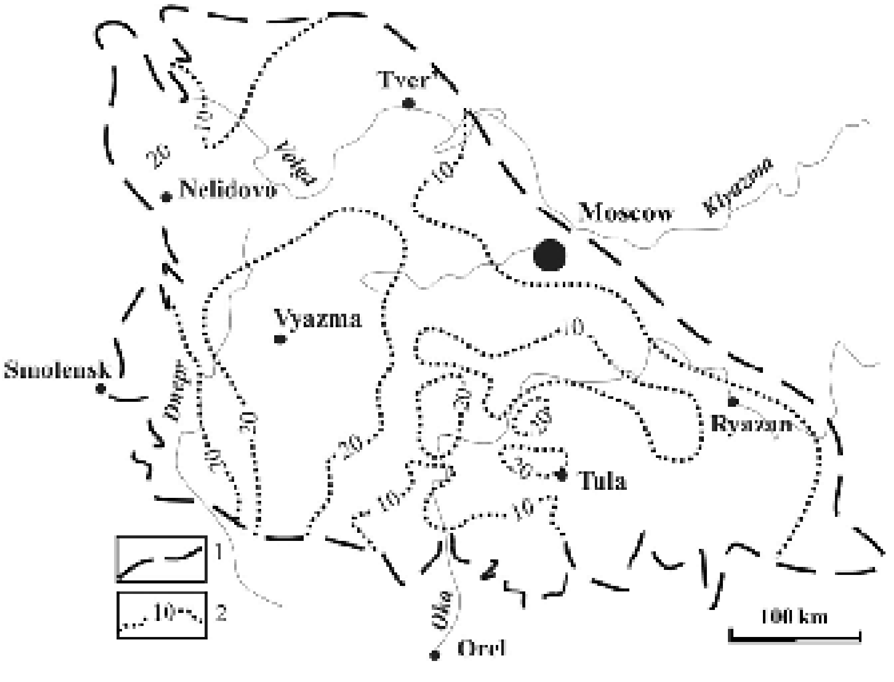


Figure 1. — Bobrikovsky horizon thickness in the Moscow lignite basin (adopted from M.K. Makhlina, and others, 1993). 1) the Moscow lignite basin regional boundaries; 2) Bobrikovsky horizon isopach, m.

In the KCB (fig. 2), the thickness of the Bobrikovsky horizon varies from 20 to 140 m. It contains 3-15 coal beds with thicknesses from 0.4 to 13.0 m of which two possess economic potential. The average depth of the Bobrikovsky horizon (the lower stratigraphic boundary) varies from 980 to 1650 m below the surface. The horizon is dominated by sandstone and shale with minor layers of limestone. The coal is subbituminous with moderate to high amounts of sulfur (S_t^d = 1.9-3.0 percent with an average of 2.4 percent) and ash (A^d = 16-24 percent with an average of 19 percent). These coals contain moderate to high moisture (W^a = 2.2-9.6 percent with an average of 4.8 percent). Volatile matter content (dry ash free basis) ranges from 34.0-58.6 percent with an average of 42.0 percent. The coalification range varies from 0.46 to 0.50 with an average of $R_0 = 0.49$.

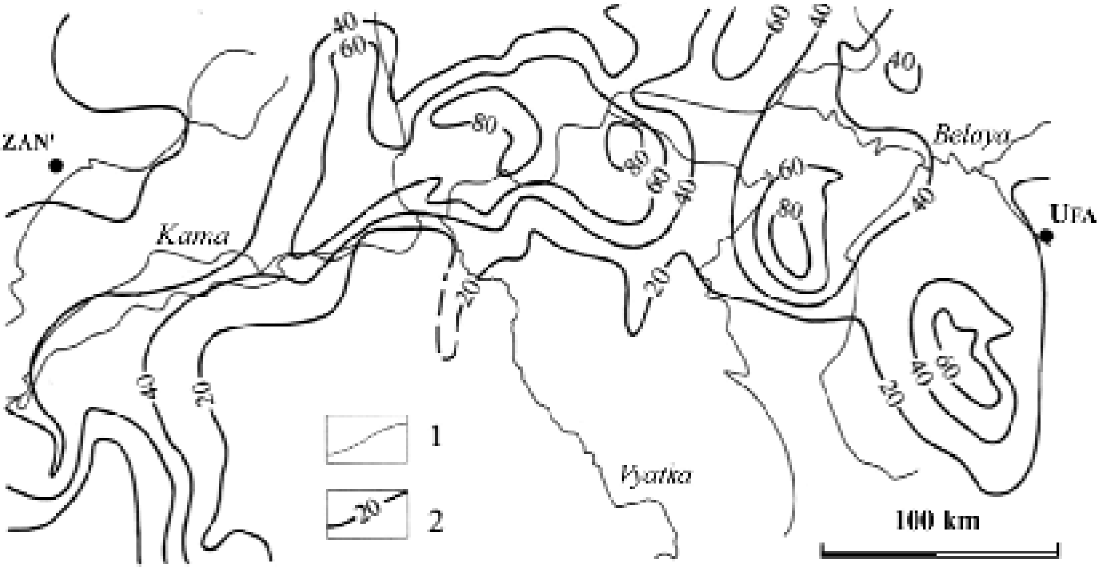


Figure 2. — Bobrikovsky horizon thickness in the Kama coal basin (adopted after A.P Bludorov, 1968). 1 – rivers; 2 – Bobrikovsky horizon isopach, m.

Petrographic compositions of both lignites and coals from the MLB and KCB are shown in figure 3. The maceral compositions of both lignites and coals have greater changes in vitrinite and inertinite contents while maintaining constant exinite contents. Generally, lignites show vitrinite content variations from 45 percent to 65 percent, inertinite content variations from 25 to 45 percent, while exinite remains constant at 10 percent. Sub-bituminous coals from the KCB demonstrate lower vitrinite and higher exinite contents, with vitrinite contents of 25 to 55 percent, with inertinite contents of 15 to 45 percent, and an exinite content of 30 percent. Some coals from the lower seams of the Bobrikovsky horizon demonstrate a relatively low content of exinite at 10 percent.

The chemical analyses of the lignite and coal are shown in table 1. They show relatively high concentrations for Ti, Au, Y and Ga in the MLB coals. However, the lignites also demonstrate a high content of toxic elements such as Cd, Hg and Zn. Whereas chemical composition of coals from the KCB have not been studied systematically, the preliminary data show potential economic concentrations of Ag and Ti, and high concentrations of such toxic elements as Zn and Cd.

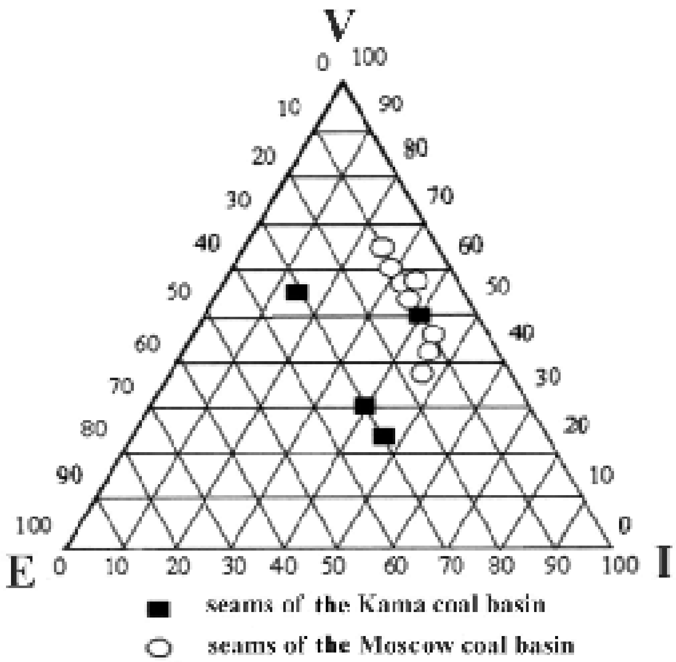


Figure 3. — Maceral composition (mineral matter free) of the Lower Carboniferous lignites and coals from the Moscow lignite and the Kama coal basins (V – vitrinite, E – exinite, I – inertinite) (T.M. Akchurin and S.A. Gorbunov, 2001).

Table 1. — Chemical analyses of Carboniferous lignite and coal samples from the Moscow lignite and the Kama coal basins (compiled after: Y.E. Judovich, and others, 1985; J.N. Zharov, and others, 1996) Prince Charles Mountains, East Antarctica.

[Abbreviations: nd = no data available; nr = not representative data; A^d = ash on a dry-basis]

		A^d,%	Chemical elements in lignites and coals, ppm (dry basis)											
			Ge	Ga	Y	Au	Ag	Li	Sr	Zn	Ti	Cd	Hg	As
Moscow coal basin (lignite)	max	48	6.3	39	85	0.3	0.015	45	1250	213	6120	2.0	4.5	37
	min	12	1.8	9	15	0.05	0.002	29	300	20	833	0.5	0.09	20
	avrg.	31	4.5	26	32	nr	0.003	36	nrr	59	1980	0.8	0.16	28
	clark	-	1.5	7	7	$2*10^{-3}$	0.3	20	130	18	500	0.3	nd	14
Kama coal basin (subbit. coal)	max	24	25.0	nd	nd	nd	8.0	nd	nd	nd	nd	nd	nd	nd
	min	16	1.0	nd	nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd
	avrg.	19	1.8	7	18	nd	1.5	7.1	55	47	1329	0.6	nd	nd
	clark	-	2.9	7	6	$2*10^{-3}$	0.4	25	76	22	500	0.6	nd	20

References

Akchurin, T.M., and Gorbunov, S.A., 2001, Petrographic types of Visean coals from Kama coal basin: State University of Kazan Press, Kazan, 316 p.

Bludorov, A.P., 1968. The ways of the Kama coal basin industrial exploitation: State University of Kazan Press, Kazan, 17 p.

Judovich, Y.E., Ketris, M.P., and Merts, A.V., 1985, Trace elements in the coals: Nauka Publishing, Leningrad, 172 p.

Makhlina, M.K., Vdovenko, M.V., and Alekseev, A.S., 1993, The Early Carboniferous formations of the Moscow and Voronezh Synclines: Nauka Publishing, Moscow, 340 p.

Zharov, J.N., Meitov, E.S., and Sharova, I.G., 1996, Valuable and toxic elements of the commodity coals of Russia *in* The reference book, Nedra Publishing, Moskow, 238 p.

Program and Abstracts for the Twentieth Annual Meeting of The Society for Organic Petrology: 2003, Volume 20, ISSN 1060-7250, Washington, D.C. Area, September 21 - 24, 2003

Thermodynamic Modeling of Trace Elements in South African Coals

Fernando Martinez-Colon, Sharon Miller and Harold Schobert

Coal Utilization Laboratory, The Pennsylvania State University, University Park, PA 16802

A thermodynamic model, FactSage, has been used to model the species of selected trace elements in coal that have potential health hazards, specifically mercury (Hg), lead (Pb), copper (Cu) and arsenic (As). The forms of these elements that might volatize during coal combustion were of particular concern. A series of Zambian coals was studied to determine the concentrations of trace elements that would be used as input for the program. These coals are being studied because they are used as a household energy source by low-income people who are burning the coals in poorly designed, inefficient stoves and heaters. In these units there is no control of the emissions that can cause, over an extended period of time, detrimental health effects. After completing the study and analyzing the data it can be said that FactSage does predict environmentally hazardous components that can be emitted as gases or particulate matter during the process of coal combustion.

Author Index and Contacts

Dickinson, Tamara, NAS, National Research Council, 500 5th Street NW, Washington, DC 20001, Email: tdickins@nas.edu, See page 47

Drinnan, Andrew N., School of Botany, University of Melbourne, Victoria 3010, Australia, Alberta, T2G0P8 Canada, Email: and@unimelb.edu.au, See page 76

Drobniak, Agnieszka, Indiana Geological Survey, Indiana University, Bloomington, IN 47405, Email: agdrobni@indiana.edu, See page 35

Eble, Cortland, Kentucky Geological Survey, Lexington, KY 40506-0107, eble@kgs.mm.uky.edu:, See page 54

Eby, Nelson, Department of Environmental, Earth & Atmospheric Sciences, University of Massachusetts, Lowell, MA 01854, Email: Nelson_Eby@uml.edu, See page 65

Faraj, Basim, GTI E & P Services Canada, Suite 720, 101-6th Avenue S.W., Calgary, Alberta T2P 3P4 Canada; Faraj Consultants Pty. Ltd., 96 Moreton Avenue, Wynnum, Brisbane 4178, Australia; MGV Energy Inc., One Palliser Square 2000, 125-9th Avenue S.E., Calgary, Email: bfaraj@MGVENERGY.COM, See page 9

Filippelli, Gabriel M., Department of Geology, IUPUI, Indianapolis, IN 46202, Email: gfilippe@iupui.edu, See page 35

Finkelman, Robert B., U.S. Geological Survey, MS 956, National Center, Reston, VA 20192, Email: rbf@usgs.gov, See page 21, 54, 61, 76, 92

Fong, Jon, Department of Geological Sciences, Indiana University, 1001 East 10th Street, Bloomington, IN, 47405, Email: jfong@indiana.edu, See page 90

Franco, Noelia, Departamento de Geologia, UFRGS, Porto Alegre, Brasil, Email: noefranco@hotmail.com, See page 97

Friedman, Gerald M., Brooklyn College of the City, University of New York, P.O. Box 746, Troy, NY 12181, Email: gmfriedman@juno.com, See page 60

Gazizova, Albina, Saint-Petersburg Mining University, Saint-Petersburg, Russia, Email: albina-g@hotmail.ru, See page 101

Glick, David C., Coal and Organic Petrology Laboratories, The Energy Institute, The Pennsylvania State University, University Park, PA 16802, Email: xid@psu.edu, See page 40

Gong, D., CRL Energy Ltd., PO Box 31 244, Lower Hutt, New Zealand, Email: d.gong@crl.co.nz, See page 65

Gonzáles, Eligio, INGEOMIN, Torre Oeste Parque, Central Piso 8, Caracas, Venezuela 1010, Email: ingeoccidental@cantv.net, See page 87

Gurba, Lila W., School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, 2052, Australia, Email: l.gurba@unsw.edu.au, See page 25

Hackley, Paul C., U.S. Geological Survey, MS 956, National Center, Reston, VA 20192, Email: phackley@usgs.gov, See page 87

Han, Zhiwen, Ground Technology, Inc., 14227 Fern Drive, Houston, Texas 77079, Email: zhiwenhan@yahoo.com, See page 68

Hatch, Anna, GTI E & P Services Canada, Suite 720, 101-6th Avenue S.W., Calgary, Alberta T2P 3P4 Canada: Nerji Consultants, 1777 Larimer Street, Suite 2003, Denver, CO 80202, See page 9

Hatch, Joseph R., U.S. Geological Survey, Box 25046, MS 977, Denver, CO 80225, Email: jrhatch@usgs.gov, See page 32

Hawkes, Laurence, Department of Geological Sciences, Indiana University, 1001 East 10th Street, Bloomington, IN 47405, Email: lhawkes@aol.com, See page 90

Holdgate, Guy R., School of Earth Sciences, University of Melbourne, Victoria 3010, Australia, Email: grh@unimelb.edu.au, See page 28, 76

Hower, James C., University of Kentucky Center for Applied Energy Research, Lexington, KY 40511, Email hower@caer.uky.edu, See page 59

Hsieh, Jane, Institute of Applied Geology, National Central University, Jungli, Taiwan, R.O.C., See page 15

Kalkreuth, Wolfgang, Departamento de Geologia, UFRGS, Porto Alegre, Brasil, Email: wolfgang.kalkreuth@ufrgs.br, See page 97

Kolker, Allan, U.S. Geological Survey, MS 956, National Center, Reston, VA 20192, Email: akolker@usgs.gov, See page 32

Krivak, Derek, GTI E & P Services Canada, Suite 720, 101-6th Avenue S.W., Calgary, Alberta T2P 3P4 Canada: Alberta Research Council, 3608-33 St. N.W., Calgary, Alberta T2L 2A6 Canada, See page 9

Kruge, Michael A., Montclair State University, Upper Montclair, NJ 07043, Email: krugem@mail.montclair.edu, See page 60

Lee, Hsien Tsung, General Education Center, Nankai College, Nantou, Taiwan, R.O.C., See page 15

Lewan, Michael D., U.S. Geological Survey, Box 25046, MS 977, Denver, CO 80225, Email: mlewan@usgs.gov, See page 83

Lewis, C.F.M., GSC, Atlantic, Dartmouth, NS, Canada, See page 60

Li, Jingming, Langfang-Branch Research Institute Petroleum Exploration and Development, PetroChina Ltd., See page 11

Li, Zhongsheng, School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney 2052, Australia, Email: zs.li@unsw.edu.au, See page 25, 65

Liu, Honglin, Langfang-Branch Research Institute Petroleum Exploration and Development, PetroChina Ltd., Email: liuhonglin69@petrochina.com.cn, See page 11

Luttrell, Gerald H., Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, Email: glutt@vt.edu, See page 54

Lyons, Paul C., 206 Amber Road, Middleboro, MA 02346, Email: Paulusgs@aol.com, See page 72

Markowski, Antonette K., Commonwealth of Pennsylvania, Department of Conservation and Natural Resources, Bureau of Topographic and Geologic Survey, 3240 Schoolhouse Road, Middletown, PA 17057, amarkowski@state.pa.us, See page 72

Martinez-Colon, Fernando, The Energy Institute, C211 Coal Utilization Laboratory, The Pennsylvania State University, University Park, PA 16802, Email: fermarcolon@hotmail.com, See page 105

Massey, Matt, University of Kentucky, Department of Geological Sciences, Lexington, KY 40506, Email: mamass1@uky.edu, See page 59

Mastalerz, Maria, Indiana Geological Survey, Indiana University, Bloomington, IN 47405, Email: mmastale@indiana.edu, See page 35, .90

Miller, Sharon F., The Energy Institute, C207 Coal Utilization Laboratory, The Pennnsylvania State University, University Park, PA 16802, Email: sfm1@psu.edu, See page 105

Mitchell, Gareth D., Coal and Organic Petrology Laboratories, The Energy Institute, The Pennsylvania State University, University Park, PA 16802, Email: n8h@psu.edu, See page 40

McLouglin, Stephen, School of Botany, University of Melbourne, Victoria 3010, Australia, See page 76

Moore, Tim A., University of Canterbury, Department of Geological Science, Christchurch 8004, New Zealand; Solid Energy New Zealand, P.O. Box 1303, Christchurch, New Zealand, Email: Tim.Moore@solidenergy.co.nz, See page 65, 76

Morrison, Patricia, Deputy Assistant Secretary, Department of Interior, MS 6618-MIB, Washington, DC 20240, Email: Patty_Morrison@ios.doi.gov, See page 49

Mukhopadhyay (Muki), Prasanta K., Global Geoenergy Research Ltd., 1657 Barrington Street, Suite 427, Halifax, Nova Scotia, Canada B3J 2A1, Email: muki@global-geoenergy.com, See page 14, 60

Othman, Rushdy, School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney NSW 2052, Australia, Email: r.othman@student.unsw.edu.au, See page 39

Padgett, Penny L., Black Beauty Coal, Evansville, IN, 47714, Email: ppadgett@bbcoal.com, See page 59

Palmer, Curtis A., U.S. Geological Survey, MS 956, National Center, Reston, VA 20192, Email: cpalmer@usgs.gov, See page 32, 54

Pawlewicz, Mark J., U.S. Geological Survey, Box 25046, MS 977, Denver, CO 80225, Email: pawlewicz@usgs.gov, See page 83

Penteado, Henrique, CENPES, Petrobrás, Rio de Janeiro, Brasil, Email: hpenteado@cenpes.petrobras.com.br, See page 97

Pierce, Brenda S., U.S. Geological Survey, MS 915-A, National Center, Reston, VA 20192, Email: bpierce@usgs.gov, See page 51

Rimmer, Susan M., University of Kentucky, Department of Geological Sciences, Lexington, KY 40506, Email: srunner@uky.edu, See page 59

Schimmelmann, Arndt, Department of Geological Sciences, Indiana University, 1001 East 10th Street, Bloomington, IN 47405, Email: aschimme@indiana.edu, See page 90

Schobert, Harold, Director, The Energy Institute, C211 Coal Utilization Laboratory, The Pennsylvania State University, University Park, PA 16802, Email: Schobert@ems.psu.edu, See page 105

Smolarchuk, Paul, GTI E & P Services Canada, Suite 720, 101-6th Avenue S.W., Calgary, Alberta T2P 3P4 Canada: Colt Ventures Ltd., 77 GlenEagles Close, Cochrane, Alberta T4C1N7 Canada, Email: paul.smolarchuk@gastechnology.org, See page 9

Solano-Acosta, Wilfrido, Indiana Geological Survey, 611 North Walnut Grove, Bloomington, IN 47405, Email: wsolano@indiana.edu, See page 90

Stasiuk, Lavern D., Natural Resources Canada,Geological Survey of Canada, 3303-33rd St. N.W., Calgary, Alberta, Canada, Email: LStasiuk@NRCan.gc.ca, See page 10

Stewart, Alexander K., University of Kentucky, Department of Geological Sciences, Lexington, KY 40506, now at: University of Cincinnati, Department of Geology, Cincinnati, OH, Email: seismite@hotmail.com, See page 59

Sun, Li-Chung, Department of Electric Engineering, Nankai College, Nantou, Taiwan, R.O.C., See page 15

Tewalt, Susan J., U.S. Geological Survey, MS 956 National Center, Reston, VA 20192, Email: stewalt@usgs.gov, See page 21

Tsai, Louis L., Institute of Applied Geology, National Central University, Jungli, Taiwan, R.O.C., Email: ltsai@geo.ncu.edu.tw, See page 15

Tyson, Richard V., NRG, School of Civil Engineering and Geosciences, University of Newcastle upon Tyne, England, NE1 7RU, Email: R.V.Tyson@ncl.ac.uk, See page 8

Walker, Rachel, Department of Geological Sciences, Indiana University, 1001 East 10th Street, Bloomington, IN 47405, raiwalke@indiana.edu, See page 90

Wang, Hongyan, China University of Geology, See page 11

Wang, Xingjin , School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, NSW 2502 Australia, See page 75

Ward, Colin R., School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney NSW 2052, Australia, Email: C.Ward@unsw.edu.au, See page 25, 39

Warwick, Peter D., U.S. Geological Survey, MS 956, National Center, Reston, VA 20192, Email: pwarwick@usgs.gov, See page 87

Weaver, S.D., University of Canterbury, Department of Geological Science, Christchurch 8004, New Zealand, Email: s.weaver@geol.canterbury.ac.nz, See page 65

Whitney, Gene, Policy Analyst for the Office of Science and Technology, Executive Office of the President, Washington, DC 20502, Email: gwhitney@ostp.eop.gov, See page 48

Willett, Jason C., U.S. Geological Survey, MS 956, National Center, Reston, VA 20192, Email: jwillett@usgs.gov, See page 76

Zhang, Chaosheng, Department of Geography, National University of Ireland, Galway, Ireland, Email: chaosheng.zhang@nuigalway.ie, See page 54

Zhang, Jianbo, China University Of Mining Technology, See page 11

Zheng, Baoshan, State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang 550002, P.R. China, Email: zhengbs@public.gz.cn, See page 92

Title Index

Program and Abstracts for the 2003 TSOP Annual Meeting

Sunday, September 21, 2003

0715-0830 Registration (Douglas Room, Hyatt Arlington)

0830-1200 Short Course A (Health Impacts of Coal: Douglas Room, Hyatt Arlington)

0830-1200 Short Course B (Petroleum Source Rocks and Coal, a Core Workshop: Meet in hotel lobby at 0730 for transportation to the USGS)

1200-1300 Lunch

1300-1630 Short Course B (Petroleum Source Rocks and Coal, a Core Workshop: transportation from the USGS to the hotel lobby at 1630)

1300-1630 Short Course C (Modes of Occurrence of Trace Elements in Coal: Douglas Room, Hyatt Arlington)

1630-1800 Registration (Ballroom Foyer, Hyatt Arlington)

1800-2000 Ice Breaker Reception (Salon C, Hyatt Arlington — James Madison High School Orchestra)

1800-2000 Dinner - OPEN

2000-2400 Outgoing Council meeting (Executive Board Room, 4th floor, Hyatt Arlington)

Monday, September 22, 2003, (All oral presentations in Salon A, Hyatt Arlington)

0730-0830 Registration (Ballroom Foyer, Hyatt Arlington)

0800 - 1200 Technical Session A: Petroleum Systems, Source Rocks, and Coalbed Gas, *Peter Warwick, Chair*

0800-0805 Introduction

0805-0840 Cretaceous Crud from Canada — Organic Facies Analysis of the Colorado Group, Western Canada Sedimentary Basin *by Lisa Buckley and Richard V. Tyson*

0840-0915 Mechanism of Hydrogen Gas Generation in Coalbed Methane Desorption Canisters — Causes and Remedies *by Basim Faraj, Anna Hatch, Derek Krivak, and Paul Smolarchuk*

0915-0950 Application of Organic Petrology in Astrobiology — Ancient Terrestrial Life, and Biological Entities in Meteorites and Planetary Samples *by Lavern D. Stasiuk*

0950-1005 ***BREAK***

1005-1040 Coal Characteristics and Coalbed Methane Potential in the Jurassic Coal Measures of Tuha Basin, Northwestern China *by Honglin Liu, Jianbo Zhang, Hongyan Wang, and Jingming Li*

1040-1115 Petroleum System Risk Assessment of the Scotian Slope, Eastern Canada and Its Significance to East Coast Energy Prospects Beyond 2010 *by Prasanta K. Mukhopadhyay (Muki)*

1115-1150 M & M — A Sweet Petroleum System *by Louis L. Tsai, Li-Chung Sun, Jane Hsieh, and Hsien Tsung Lee*

1200 - 1330 Lunch — TSOP Business Lunch (Judiciary Hall, Hyatt Arlington)

1330 - 1730 Technical Session B: Ron Stanton Coal Characterization Session, *Leslie Ruppert, Chair*

1330-1400 The World Coal Quality Inventory *by Susan J. Tewalt and Robert B. Finkelman*

1400-1430 Variations in Coal Maceral Chemistry and Mineral Matter Characteristics with Rank Advance in the German Creek Coal Measures of the Bowen Basin, Australia, using Electron Microprobe and other Techniques *by Colin R. Ward, Zhongsheng Li, and Lila W. Gurba*

1430-1500 Geological Processes that Control Lateral and Vertical Variability in Coal Seam Moisture Contents — Latrobe Valley (Gippsland Basin) Australia *by Guy R. Holdgate*

1500-1530 Mercury Variation in Powder River Basin Coal Samples *by Allan Kolker, Joseph R. Hatch, Curtis A. Palmer, and Linda J. Bragg*

1530-1545 ***BREAK***

1545-1615 Distribution of Mercury in Indiana Coals *by Agnieszka Drobniak, Maria Mastalerz, and Gabriel M. Filippelli*

1615-1645 Response of Major Geochemical Thermal Maturity Parameters to Suppression of Vitrinite Reflectance, Gunnedah-Surat Basins, New South Wales, Australia *by Rushdy Othman and Colin R. Ward*

1645-1715 Coal Sample Storage — Preservation using Foil Multilaminate Bags *by David C. Glick, Gareth D. Mitchell, and Alan Davis*

1730 - 1900 Happy Hour, Poster Session (Gallery Room, Hyatt Arlington)

1900 - 2030 Conference Dinner (TSOP Banquet, Judiciary Hall, Hyatt Arlington — Marcus E. Milling, Executive Director, American Geological Institute, Speaker)

2000 - 2400 Incoming Council meeting (Executive Boardroom, 4th floor, Hyatt Arlington)

Tuesday, September 23, 2003, (All oral presentations in Salon A, Hyatt Arlington)

0730-0830 Registration (Ballroom Foyer, Hyatt Arlington)

0800 - 1200 Technical Session C: Energy and Government Session, *Brenda Pierce, Chair; Suzanne Weedman, Co-Chair*

0800-0830 Federal Energy Policy — The Earth Science Dimension *by David Applegate*

0830-0900 The National Academy of Sciences *by Tamara Dickinson*

0900-0930 Federal Science Policy and Science Funding *by Gene Whitney*

0930-1000 Department of Interior — Land and Minerals Management *by Patty Morrison*

1000-1015 ***BREAK***

1015-1045 The U.S. House of Representatives Resources Committee — Subcommittee on Energy and Mineral Resources *by Jack Belcher*

1045-1115 The USGS Energy Resources Program *by Brenda S. Pierce (Frances W. Pierce, speaker)*

1115-1145 Some Perspectives on Longer-term Domestic Oil and Gas Supply Technologies and Needs in a Carbon-constrained Future *by David Beecy*

1200 - 1310 Lunch (OPEN), Poster Session (Gallery Room, Hyatt Arlington)

1315 - 1330 Group Photo (TBA)

1330 - 1730 Technical Session D: TSOP General Session, *Robert Finkelman, Chair*

1330-1405 The Source of the Coal in the Titanic and Effects of Exposure to Seawater *by Curtis A. Palmer, Robert B. Finkelman, Gerald H. Luttrell, Chaosheng Zhang, and Cortland Eble*

1405-1440 Influence of a Basic Intrusion on the Vitrinite Reflectance and Chemistry of the Springfield (No. 5) Coal, Harrisburg, IL *by Alexander K. Stewart, Matt Massey, Penny L. Padgett, Susan M. Rimmer, and James C. Hower (speaker)*

1440-1515 Organic Pollutants from the Recent Sediments of the Halifax Harbour, Lake Ontario, and New York Bight — A Comparative Analysis *by Prasanta K. Mukhopadhyay (Muki), Michael A. Kruge, Gerald M. Friedman, and C. F. M Lewis.*

1515-1530 ***BREAK***

1530-1605 Integrated Approaches to Understanding the Relationship of Coal to Human and Ecosystem Health *by Joseph E. Bunnell and Robert B. Finkelman*

1605-1640 Where do the Maidens fly? Trace Elements and What Controls their Fate — Examples from the Greymouth Coalfield, New Zealand *by Zhongsheng Li, A.H. Clemens, Tim A. Moore, D. Gong, S.D. Weaver, and Nelson Eby*

1640-1715 Petrographic Comparison of Several Coal Seams in Ningxia Hui Autonomous Region *by Zhiwen Han*

POSTERS (Gallery Room, Hyatt Arlington)

Coalbed Methane Potential (CBM-P) in Main Bituminous Field (SW. PA) and the Anthracite Fields (E. PA), and CBM-P in MD, VA, MA, RI (U.S.A.) *by Paul C. Lyons, R. Marc Bustin, and Antonette K. Markowski*

Effect of Geological Factors on the Permeability of Coal Seam Gas Reservoir *by Xingjin Wang*

The Inorganic Chemistry of 15 Coal Samples from the Prince Charles Mountains, East Antarctica *by Lora A. Chiehowsky, Robert B. Finkelman, Tim A. Moore, Guy R. Holdgate, Jason C. Willett, Stephen McLouglin, and Andrew N. Drinnan*

The Influence of Extractable Organic Matter on Vitrinite Reflectance — Implications to Liquid Hydrocarbon or Bitumen Impregnation as a Suppression Mechanism *by Charles E. Barker, Michael D. Lewan, Mark J. Pawlewicz, and Corinne L. Carlson*

Characterization of the Petrology, Mineralogy, and Geochemistry of Mined Coals, Western Venezuela *by Paul C. Hackley, Peter D. Warwick, and Eligio Gonzáles*

Prediction of CO_2 Sorption in Coal Seams using Uncrushed Coal Cores under Realistic P, T and Moisture Conditions *by Rachel Walker, Maria Mastalerz, Arndt Schimmelmann, Laurence Hawkes, Jon Fong, and Wilfrido Solano-Acosta*

Rare-earth Element Systematics in Upper Permian Mineralized Coal, Southwestern Guizhou Province, P.R. China *by Harvey E. Belkin, Baoshan Zheng, and Robert B. Finkelman*

Organic Geochemistry of Retained and Expelled Oil based on Hydrous Pyrolysis Experiments — An Example from the Irati Oil Shale, Brazil *by Noelia Franco, Wolfgang Kalkreuth, and Henrique Penteado*

Comparative Analysis of Moscow Lignite and Kama Coal Basins *by Albina Gazizova*

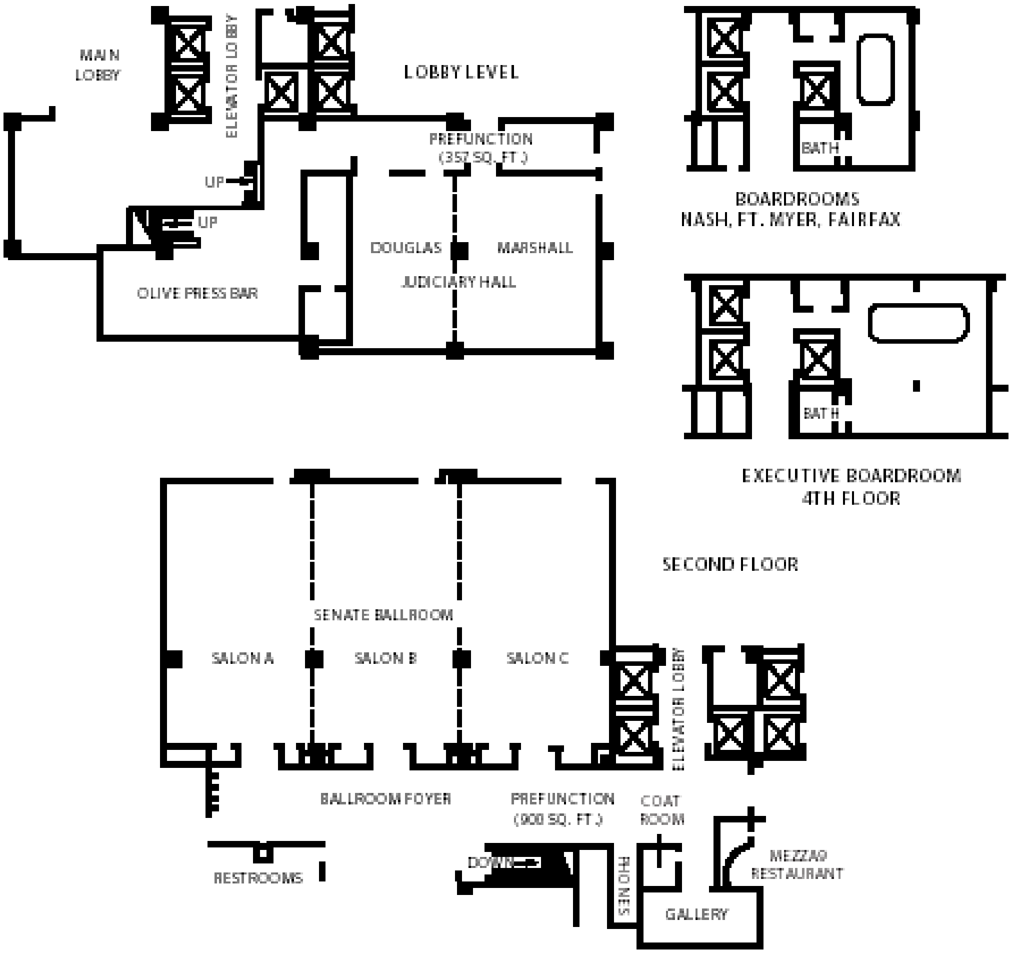
Thermodynamic Modeling of Trace Elements in South African Coals *by Fernando Martinez-Colon, Sharon Miller and Harold Schobert*

Wednesday, September 24, 2003

0730-1800 Field Trip A (All day trip — Geology and Energy Resources of the Triassic Basins of Northern Virginia: Meet in the lobby of the Hyatt at 0730)

0900-1200 Field Trip B (half day trip — Tour of the Smithsonian Natural History Museum: Meet in the lobby of the Hyatt at 0900)

Hyatt Arlington Floor Plan



♿ ALL MEETING SPACE, RESTROOMS AND PHONES ARE WHEELCHAIR ACCESSIBLE

THE SOCIETY FOR ORGANIC PETROLOGY

Phillips

USGS
science for a changing world

CONOCO

The U.S. Geological Survey

ChevronTexaco

CHEVRONTEXACO

The Pennsylvania State University

Shell

UNOCAL

THE SOCIETY FOR ORGANIC PETROLOGY

TWENTY-FIRST ANNUAL MEETING

Organic Matter Down Under

Sydney, Australia

26 September – 1 October, 2004

The 21st Annual Meeting of TSOP will be held in Sydney, Australia, home of the 2000 Olympics and centre for a variety of organic petrology research activities.

Meeting Program:

• Sunday, September 26	— Pre-meeting field trip: Joadja torbanite deposit
• Monday, September 27	— Short course, registration, icebreaker reception
• Tuesday, September 28	— Technical sessions, TSOP business lunch
• Wednesday, September 29	— Technical sessions, conference dinner
• Thursday, September 30	— Technical sessions, field trip departure
• Friday, October 1	— Post-meeting field trip: Hunter Valley coal geology

Key Conference Themes:

- Non-marine source rocks
- New techniques in organic petrology and geochemistry
- The role of coal in sustainable development

  Papers on other aspects of organic petrology and geochemistry are also welcome

Short Course:

- Analysis and significance of mineral matter in coal

Meeting Venue:

- Crowne Plaza Hotel, Coogee Beach. A 4½ star accommodation and conference facility overlooking the Pacific Ocean and only 15 minutes from both the airport and the city centre.
  http://www.coogeebeach.sydney.crowneplaza.com

Field Trips:

- Oil shale (torbanite) geology at the historic Joadja mine site, south-west of Sydney
- Geology of the Sydney Basin coal measures in coastal outcrops south of Newcastle

Abstract Deadline: April 30, 2004. See TSOP web site (http://www.tsop.org) for details

Sydney has many attractions for those who can stay a little longer, and a special partners' program will be available to complement the technical activities.
For more information on the meeting contact:

• Neil Sherwood, CSIRO Petroleum:	Neil.Sherwood@csiro.au
• Colin Ward, University of New South Wales:	C.Ward@unsw.edu.au