AAPG Studies in Geology #38 "Hydrocarbons from Coal"

edited by **B. E. Law and D. d. Rice,** published in 1993 by the American Association of Petroleum Geologists, ISBN 0-89181-046-3, 400 pages.

Review by **Christopher G. Kendall**

This book is aimed at increasing our awareness of the use of coalbed methane and the development of oil and gas from coal. It focuses on the research and development going on in this field. The editors have managed to gather into a single reference a most complete range of different topics related to coal and methane. It is another excellent AAPG text and consists of seven papers on coalbed geology and hydrocarbons derived from coal. It summarizes quite completely the occurrences of coalbeds and their relationship to the production of hydrocarbons. The papers are extremely tightly written and address the point of their topic. The papers are well illustrated but though some illustrations are not quite as clearly printed as they might have been. I guess bad economic times are upon us and paper quality and the quality of some of the reproduction reflects this. This does not affect the high scientific quality of the book or I think reflect on the authors.

The book begins with a paper by Landis and Weaver on the global occurrence of coal. This includes a historical review of the first production of coal and then discusses various world resource estimates for coal, compiled by different authors. The paper provides a listing of coal resources by a country, with a map showing where coal producing basins may be found. This paper is followed by one by Flores on coal-bed and related depositional environments in methane gas-producing sequences. The paper is illustrated with some beautiful block diagrams, maps and cross-sections. It describes the various depositional settings that coals formed in and accumulated. It is also referred to the modern peatland systems including bogs, fens, swamps and marshes relating these to alluvial fans, alluvial plains, deltaic coastal plains, and non-deltaic coastal plains. It discusses raised bogs and emphasizes how low lying fans, swamps and marshes are the sites of thin peat accumulation. The paper discusses the occurrence of organic matter as woody and degraded tissue and then discusses the geometry of coalbed in the various settings and the processes that control their distribution. It recognizes that the heterogeneity of coals and their continuity, thickness, geometry distribution and composition are also related to the depositional environment.

Next is a paper by Levine on coalification and the evolution for coal as source rock and reservoir rock for oil and gas. It provides an overview of coalification, namely the five stages of coalification, the ranks of coals, the mechanism of peatification, the peat-to-lignite transition, bituminous coals, and anthracites. It discusses the chemical processes of coalification dealing with molecular structure, the composition of the molecular fraction, moisture content, the hydrocarbons in the molecular fraction, and the formation and expulsion of molecular constituents. It considers the effects of coalification on coal properties, namely the appearance of macerals viewed through optical microscopy, reflectance changes with rank, suppression of vitrinite reflectance, pyrolysis yields, rock-eval, sorbate accessibility, density, impact of coalification on methane sorption and expulsion, the influence of coalification on gas transport, mechanical properties, the causes of coalification, biogenic processes, pressure and coalification, and the effect of shear strain, the coalification in the geological contents, etc. This is complete and well written paper.

It is followed by a paper by Mukhopadhyay and Hatcher on the composition of coal. This paper summarizes and provides a review of the present state of knowledge of coal composition and its relationship to depositional environment, early diagenesis and various characteristics associated with the physical and chemical processes related to coalification. It discusses the

various lithotypes and macerals, characterizing macerals using both in color and black and white photographs. It considers various coal networks, microlithotypes, mineral bituminous groundmass, etc. It discusses organically associated elements, coal components, chemical composition of coals, their proximate analysis, calorific value, geochemical analyses, hydrocarbon composition and rank, and the structure, genesis and source rock potential of coal macerals, and their relationship between maceral association and hydrocarbon potential. This again is an extremely complete and well written paper.

It is followed by a paper by Close on natural fractures in coal. Using outcrop photographs and X-ray radio graph illustrations, this paper illustrates how natural fractures are formed in coals and how various fracture systems can be detected; how they are measured and categorized into various types of coal rank and lithotypes; and the heights of various individual seams, porosity and surface morphology. This paper includes scanning electron photomicrographs.

Then is a paper by Boreham and Powell dealing with petroleum source rock potential of coal and associated sediments including their qualitative and quantitative aspects. It deals with different topics including indicators for oil and gas generation from terrestrial sequences. Methods described include petrographic characterization, pyrolysis, the maturation of organic matter, mass balance approach, kinetic modeling, modeling vitrinite reflectance, biomarkers and their use in petroleum-source correlations, expulsion of petroleum from coal and terrigenous sediments and empirical hydrocarbon thresholds for petroleum expulsion.

Next is a paper by Rice on the composition and origins of coalbed gas, dealing with generation of coalbed hydrocarbons, storage and migration of coalbed gas, composition of coalbed gas, various characteristics of coalbed gases from selected areas including Western Germany, the Bowen and Sydney basins in Australia, Eastern China, the Lower Silesian basin in Poland, the San Juan Basin in New Mexico and Colorado, Piceance Basin of Colorado, the Powder River Basin in Montana and Wyoming, and the Black Warrior Basin of Alabama and Mississippi. In this paper the author recognizes that large amounts of gas are generated in the coalbeds throughout their burial history. The gas is generated by biogenic and thermogenic processes. Large quantities of this natural gas is stored in coal beds through adsorption and absorption. The paper recognizes that these gases are quite variable in their molecular and isotopic composition and the coalbed gas composition and depth appear to be related to the rank of the coal but that the zone of alteration of coalbed gases can occur at variable depths. In the end, the author recognizes that the various factors controlling coalbed gases are extremely complex and that it is quite difficult to predict the occurrence of different types of gases associated with coalbeds. Various hypotheses are suggested to explain the genesis of fractures which may contain gases. The thesis is presented that if one understands the development of these natural fractures, then one can predict the occurrence of gases in the coals.

Clayton describes the composition of crude oils generated from coals and coaly organic matter in shales. He considers how oils are derived from shales and coals containing coaly organic matter. These oils have been recognized from a variety of basins throughout the world. Production comes from Paleozoic to Tertiary Age sediments with the most coming from Mesozoic and Tertiary reservoirs. Geochemical studies of the oils reveal common compositional features that have aided the recognition of the oil's source from coaly materials. High wax content often accompanies the oils and depends on both maturation level and specific composition of coaly organic matter source. Sulfur content of oils from coaly organic matter tend to be low. Poly-cyclic biologic marker compounds can be used as indicators.

Yee, Seidle, and Hanson consider gas sorption on coal and measurement of gas content. It appears that the big difference between coal and conventional gas reservoirs is that in conventional reservoirs, the gas exists in a free state in the pores of the reservoir rocks, while in coal, gas exists in a condensed, near liquid-like state because of physical sorption. In this paper, the behavior of sorbed gas is described in terms of the physical sorption process and

sorption isotherms. It investigates the effects of the pressure, temperature, mineral matter, moisture, rank, petrology, different pure gases, and multi component sorption. Techniques of measuring isotherms are presented. The paper also deals with direct and indirect methods of measuring the amount of gas present.

Littke and Leythaeuser describe the migration of oil and gas from coals. The authors list six groups of observations which support the assumption that large amounts of petroleum are generated from coals. They point out that liptinites constitute much of coals. Upon artificial maturation, most coals generate significant quantities of petroleum compounds. They recognize that bituminous coals contain great quantities of bitumen that can be released by solvent extraction and may be a source of hydrocarbons. Indeed coals contain great volumes of hydrocarbon gases, though this is mainly methane. In fact, coal-bearing strata are often associated with commercial gas fields. The authors point out that when coals undergo coalification from peats to anthracites, there is significant loss of volatile products. These volatiles support the suggestion that the petroleum is generated from the coals. The paper goes on to describe various techniques for examining and measuring the potential hydrocarbon content of coal and for investigating this in terms of the composition of coals and the volatile matter and so on. It suggests that coals are, in fact, sources of hydrocarbons, namely oil and gas.

Diamond has a paper on methane control for underground coal mines. This paper explains why methane drainage is needed and then describes how the geological framework of a mine can help establish this drainage. The paper details examples of various kinds of mines, coupled with discontinuous and continuous geological frameworks for coals. It provides plans for horizontal methane drainage, along with a description of methane drainage technology. It details a variety of schematic plans for horizontal holes associate with long wall mining, various types of fans and pipes that can be inserted into the mine to improve the drainage, and various schemes that can be used to protect the mine from gas moving to other areas once the gas has been drained from the mine. This is an extremely practical paper, which should be useful to those involving mining coal where there is an occurrence of free methane.

Logan has a paper entitled "Drilling Techniques for Coalbed Methane". This describes how the shallow eastern and deeper western basin coal reservoirs have been drilled and produced. The paper shows how about 6,000 coalbed methane wells have been drilled in the United States with the majority of the drilling having occurred in the San Juan basin of Colorado and New Mexico, and in the Black Warrior basin in Alabama. To determine the size of reservoirs, the author proposes schemes involving coring, drill-stem testing, and open-hole logging. A pilot exploration program is provided includes designated wells to collect as much reservoir and geologic data as possible. Two basic completion techniques used in the western basins are cased hole with hydraulic fracture stimulation, and an open hole with cavity. In eastern basins, completion is done in one of three ways: open hole in a single seam, cased-hole multiple seams using jet slot-ting, and cased-hole multiple seams using conventional perforating techniques. Casing and multiple coal seam perforations appear to be the preferred techniques for the eastern basin.

Scholes and Johnston have a paper entitled "Coalbed Methane Applications of Wireline Logs". This involves a description of the use of resistivity, gamma ray, acoustic, neutron, density, natural gamma ray spectrometry and induced gamma ray spectrometry logging. The paper describes the various qualities of these different logging techniques with color output and the relationship of the log output to lithology and mineral content.

Palmer, Lambert, and Spitler describe coalbed methane well completions and stimulations. This paper deals with production from San Juan Basin and from the Black Warrior Basin, describing the various engineering techniques and measurements that can be made to improve the potential productivity of methane from the different wells. The paper discusses hydraulic fracture stimulations and the two fracture classes that have been produced. Vertical

fractures that have substantial height growth and falling pressures. Here fracture width is controlled by the properties of surrounding strata. The other fractures are confined to local seams and are accompanied by constant or rising pressure, have ISIP values greater than 1.0 psi/ft. These are probably T fractures.
A paper by Schraufnagel is next and entitled "Coalbed Methane Production" begins with a discussion of reserves and production rates of coalbed methane, listing schemes for handling production from coalbed methane including the sucker-rod pumping and various pumping techniques and various methods for storing the produced gas, and managing its production.
McElhiney et al. have a paper next entitled "Reservoir Engineering Aspects of Coalbed Methane". This paper deals with a reservoir engineering of coalbed methane and the importance of considering the permeability of coalbeds. Finally there is a paper by Kuuskraa and Boyer on the economic and parametric analysis of coalbed methane.
The theme of this book is followed most completely and as such it probably hits most aspects of hydrocarbon production from coal, beginning with the geological model and ending with an overview description of the engineering. Undoubtedly each paper by itself is incomplete but for an overview of the relationship for hydrocarbons to coals this book hits the spot. It can be used as a source when more information is required about specific details of the topics that you read and may be interested in. It should definitely be available to anybody dealing with hydrocarbon production from coal and should be in the library of the most hydrocarbon companies and universities as a reference and source book for this topic. This is a great book and AAPG should be congratulated for its professional feel.