← Contents
← Previous Section

Introduction

By T.S. Dyman, D.D. Rice, *and* P.A. Westcott

GEOLOGIC CONTROLS OF DEEP NATURAL GAS RESOURCES IN THE UNITED STATES

U.S. GEOLOGICAL SURVEY BULLETIN 2146–A

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1997

CONTENTS

FIGURE

Introduction

By T.S. Dyman, D.D. Rice, *and* P.A. Westcott

Drilling activity in the United States has declined and exploration companies are looking overseas for oil and gas exploration prospects because of lower worldwide oil prices and a highly mature state of drilling and production in many U.S. oil provinces. Concurrently, total oil production is declining, and U.S. reliance on imported oil is increasing. Even if prices were to increase drastically, it would take several years for domestic exploration to reach previous levels of intensity. If the issue of economics is set aside, many drilling frontiers deserve review. One such frontier is natural gas in deep sedimentary basins (fig. 1).

In some respects, natural gas is more preferable than oil. First, the United States is rapidly exhausting its oil reserves, whereas resource estimates of natural gas remain high. According to the National Petroleum Council (1992), the United States has almost 1,300 trillion cubic feet (TCF) of recoverable natural gas resources. Second, natural gas is a clean-burning fuel and thus is more environmentally acceptable than oil. And third, increased use of domestic natural gas resources would lessen our reliance on foreign oil imports.

According to Petroleum Information Corporation's (1991) Well History Control System (WHCS), more than 16,000 wells have been drilled deeper than 15,000 ft (4,572 m) in the United States. These deep wells are widely distributed geographically and are drilled into rocks of various ages and lithologies, but they represent a very small percentage of the more than 2.2 million U.S. wells contained in the data file.

Commercial gas production has been established for many years in deep reservoirs at or below 15,000 ft (4,572 m). According to NRG Associates 1991 Significant Field File, 256 significant reservoirs (reservoirs containing at least 6 billion cubic feet of gas (BCFG), or equivalent, ultimate recoverable production) produce hydrocarbons from depths of more than 15,000 ft (4,572 m) (NRG Associates, 1991). These 256 reservoirs make up approximately 2 percent of the approximately 15,000 reservoirs in the data file. About half (21.4 TCFG) of the cumulative deep natural gas so far produced in the United States has been extracted from these significant reservoirs. Almost one-third of the total undiscovered natural gas resources of the onshore and offshore United States are estimated to occur below 15,000 ft (Potential Gas Committee, 1990). For example, one of the most significant new exploration plays in the United States is the deep Norphlet Formation (Upper Jurassic) play of the eastern Gulf Coast Basin region, and substantial growth in production is predicted for this play through 2005 (Woods, 1991). Geologic and geochemical studies (Rice and others, 1992) indicate significant potential for Norphlet and perhaps Upper Jurassic Smackover Formation reservoirs in the eastern Gulf region. In some deep basins, however, only a few deep wells have been drilled, and the natural gas potential of deep horizons is unknown.

Of the total natural gas resource of the United States (almost 1,300 TCFG), about 40 percent (519 TCFG) is considered unconventional and includes such sources as coalbed methane, gas in low-permeability shale and sandstone reservoirs, and deep basin gas accumulations. The need for new geologic research dealing with all aspects of natural gas exploration and production is obvious.

The U.S. Geological Survey has undertaken a research program to investigate the geological parameters controlling the distribution of deep natural gas in basins in the United States. Areas of study include the distribution of known deep natural gas resources, structural evolution of deep sedimentary basins, source-rock analysis and reservoir geochemistry, and petroleum assessment. These study areas were defined in collaboration with the Gas Research Institute in order to determine the most important research areas of mutual interest.

Papers in this bulletin address the major areas of geologic research funded by the U.S. Geological Survey Onshore Oil and Gas Program and the Gas Research Institute (Rice, 1989; Dyman, 1992). During the first phase of this work (Rice, 1989), deep well data were tabulated and summarized, preliminary reservoir properties and structural settings for deep natural gas accumulations were identified, porosity and source-rock geochemistry studies were conducted for selected deep sedimentary basins, and U.S. basins were evaluated for favorability of natural gas accumulations. During the second phase of this work (Dyman, 1992),

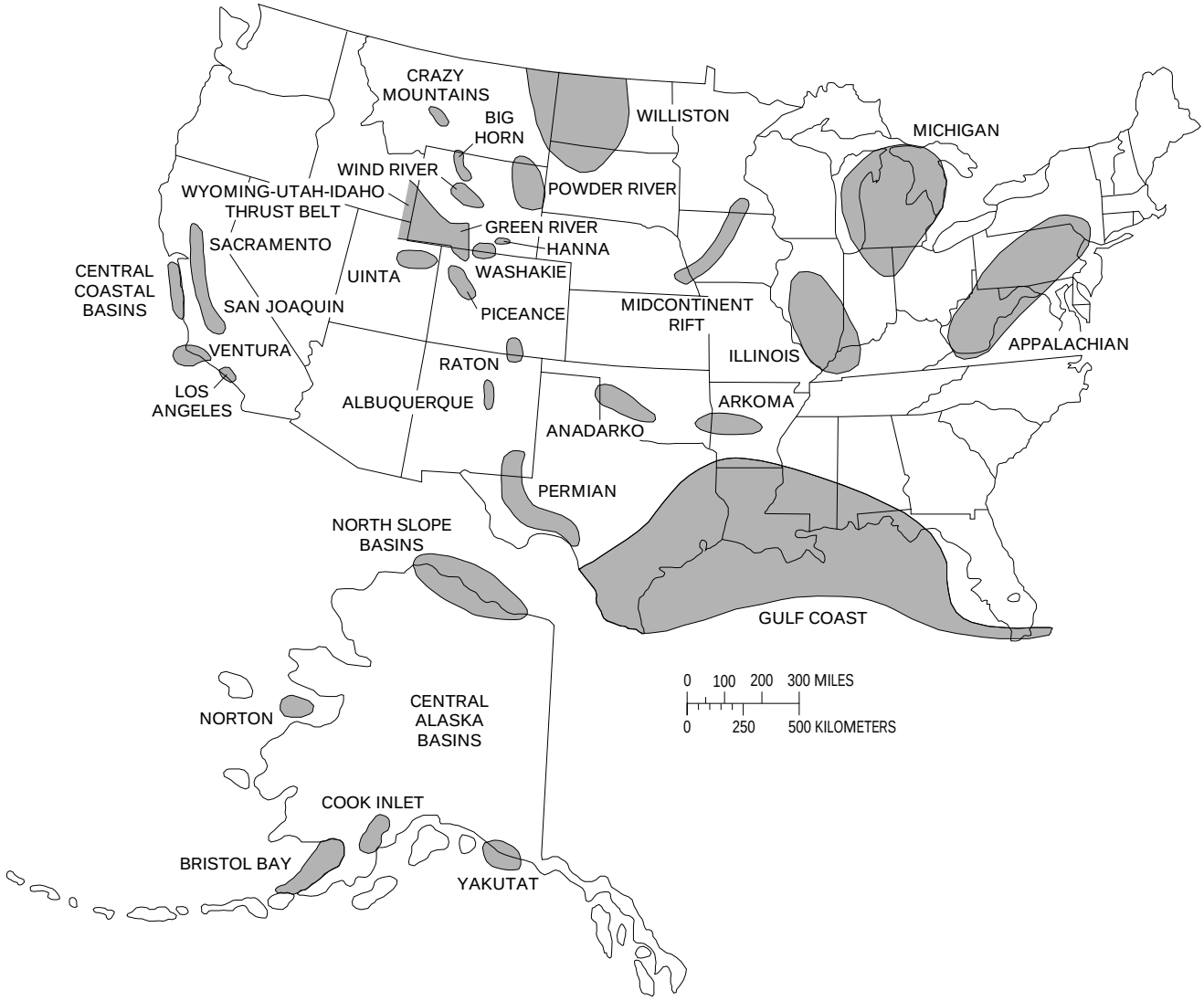

Figure 1. Map of the United States showing basins containing sedimentary rocks more than 15,000 ft (4,572 m) deep. Shading indicates entire basin area, in which some of the sedimentary rocks are at shallow depths.

general geologic controls governing the distribution of natural gas in deep sedimentary basins were determined, geologic and production data for large, significant reservoirs were tabulated and summarized, diagenetic controls for selected reservoirs were established, production-test and pressure data from deep wells were interpreted on both a regional and a national basis, geochemical controls and geologic settings of nonhydrocarbon gases were identified, the setting and controls of unusually high porosity in deeply buried rocks were defined, the source-rock potential of Precambrian sedimentary rocks was investigated, and the range of generating potential of kerogen at high levels of maturation was studied. The problem of assessing volumes of natural gas in deep sedimentary basins also was addressed during the second phase of work after geologic studies were well underway.

Papers in this bulletin summarize major conclusions reached during both phases of our work on deep natural gas resources. Chapters B and C define the areal extent of deep drilling and known resources in the United States. In chapter C, geologic controls of deep natural gas resources are summarized by basin and region. Although not complete, this summary is meant to introduce and establish a framework for subsequent chapters. Chapters D and E present a plate-tectonic framework for deep natural-gas resources (chapter D) and a sequence of Laramide deformation for the Rocky Mountain region with respect to the emplacement of deep natural gas accumulations (chapter E). Chapters F through I discuss reservoir rocks including a summary of reservoir pressures in deep sedimentary basins (chapter F), microporosity trends in reservoirs using mercury-injection porosimetry (chapter G), and porosity in clastic reservoirs in

relation to thermal maturity for Rocky Mountain basins and the Anadarko Basin (chapters H and I). Chapters J through M describe geochemical and source-rock studies on Precambrian source-rock potential (chapter J), source and controls of deep-basin natural gas (chapters K and L), and migration of hydrocarbon and nonhydrocarbon gases (chapter M). Chapter N discusses the potential of deep natural gas resources in the Gulf Coast Basin in terms of both source- and reservoir-rocks. In chapter O, assessment methodologies are evaluated, an assessment is presented for a hypothetical deep natural gas play, and play input parameters are modelled in order to show the range of results under different play conditions. Assessment methods were based on natural gas plays, which are defined by unique geologic characteristics and commonly are basinwide.

The papers presented herein are intended to introduce the petroleum community to a set of geologic tools that may be used to predict deep undiscovered natural gas accumulations. This set of tools is not meant to be complete but is a starting point from which to conduct future exploration and production studies. We hope that future studies will include new and expanded applications of the techniques presented here. For example, studies of porosity prediction using thermal maturity measurements must be tested in many deep sedimentary basins and compared with reservoir controls governing the distribution of natural gas. Our assessment models must be evaluated under a broader range of geologic environments and tested in areas of known deep natural gas accumulations. With continued scientific commitment, we hope that deep natural gas resources will become an even more significant and valued part of our Nation's petroleum endowment.

Acknowledgments.—We acknowledge the careful and critical reviews of manuscripts by Katharine L. Varnes, Mahlon M. Ball, Jerry L. Clayton, Mitchell E. Henry, and Michael D. Lewan. Ronald R. Charpentier, Timothy Klett, and Raymond C. Obuch retrieved reservoir data from the NRG Associates file and well data from the Well History Control System for quantitative analysis. James K. Baird, Diane T. Nielsen, and David K. Vaughan of the U.S. Geological Survey tabulated production data summaries and prepared graphical output for analysis. Many thanks also to Tommy Kostick of the U.S. Geological Survey for his patience in preparing some text figures and to Leslie Oliver and Shirley Oscarson for their work in computer manuscript processing. Judy Stoeser and Lorna Carter of the U.S. Geological Survey patiently and carefully reviewed the manuscripts for editorial standards. Work was conducted in part under contract to GRI, Chicago, Illinois (Contract Nos. 5087–260–1607 and 5090–260–2040).

REFERENCES CITED

Dyman, T.S., ed., 1992, Geologic controls and resource potential of natural gas in deep sedimentary basins in the United States: U.S. Geological Survey Open-File Report 92–524, 287 p.

National Petroleum Council, 1992, The potential for natural gas in the United States—Executive summary: National Petroleum Council, 24 p., with appendices.

NRG Associates Inc., 1991, The significant oil and gas fields of the United States (through December 31, 1991): Available from Nehring Associates, Inc., P.O. Box 1655, Colorado Springs, Colorado 80901.

Petroleum Information Corporation, 1991, Well History Control System (through December 1991): Available from Petroleum Information Corporation, 4100 East Dry Creek Road, Littleton, Colorado 80122.

Potential Gas Committee, 1990, Potential supply of natural gas in the United States: Golden, Colorado, Colorado School of Mines, 169 p.

Rice, D.D., ed., 1989, Distribution of natural gas and reservoir properties in the continental crust of the U.S.: Gas Research Institute Final Report GRI–89/0188, 132 p.

Rice, D.D., Schenk, C.J., Schmoker, J.W., Fox, J.E., Clayton, J.L., Dyman, T.S., Higley, D.K., Keighin, C.W., Law, B.E., and Pollastro, R.M., 1992, Potential for deep natural gas resources in eastern Gulf of Mexico, *in* Malone, R.D., Shoemaker, H.D., and Byrer, C.W., eds., Proceedings of the natural gas research and development contractors review meeting: U.S. Department of Energy, Morgantown Energy Technology Center Report 92/6125, p. 151–166.

Woods, T.J., 1991, The long-term trends in U.S. gas supply and prices—1991 edition of the GRI baseline projection of U.S. energy supply and demand to 2010: Gas Research Institute, 54 p.