IDENTIFICATION
of
SHALLOW BIOGENIC GAS SYSTEMS
IN
EASTERN NORTH DAKOTA

Grant Requested from the
North Dakota Oil and Gas Research Council

Submitted by:	GeoShurr Resources, LLC
Principal Investigators:	George W. Shurr GeoShurr Resources, LLC
	David W. Fischer Fischer Oil & Gas, Inc

Amount Requested:	$90,000
Grant Deadline:	June 1, 2009

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ABSTRACT

The margin of the Williston Basin in eastern North Dakota has potential for shallow biogenic gas resources. Immature, organic-rich Cretaceous shales subcrop beneath glacial sediments in a geologic setting that is basically the same as the northern margin of the Michigan Basin. Commercial shallow biogenic gas is produced from the Antrim Shale in northern Michigan and the systems have been studied extensively. Based on this published work, an exploration methodology is available for application on the eastern margin of the Williston Basin.

Identification of shallow biogenic gas systems in eastern North Dakota starts with an interpretation of regional lineament zones. Linear features mapped on satellite images will be integrated with available summaries of stratigraphic and structural data to extract lineament zones. The second phase of the investigation will focus on specific sweetspots within these corridors of fractured shale reservoirs.

Specific county-sized sweetspots will be identified using water quality and gas show data sets available from state agencies. Follow-up field screening of observation wells within the sweetspots will employ portable gas detectors. Wells with high levels of methane will be sampled for lab analyses. Based

on the field screening and laboratory results, the sweetspots will be ranked on their potential for shallow biogenic gas.

The primary objective of the proposed investigation is to generate information that will enhance exploration and development of shallow biogenic gas in North Dakota. This will be accomplished by identifying sweetspots with high potential in counties in eastern North Dakota that are currently not producing oil or gas.

PROJECT DESCRIPTION

This proposal focuses on shallow biogenic gas resources in eastern North Dakota. By way of introduction, the regional context for the study is described and then a review of precursor investigations in North Dakota is given as background information. The remainder of the project description includes the objectives, methodology, and various other project aspects. It is anticipated that the project results in eastern North Dakota will enhance exploration and development of shallow gas. That is the fundamental objective of the proposed investigation.

Introduction

The eastern margin of the Williston Basin has essentially the same geologic setting as the northern margin of the Michigan Basin. Over 2 TCF of shallow biogenic gas has been produced from the fractured, immature Antrim Shale (Devonian) in Michigan. Specific exploration components have been extracted from published descriptions of the Antrim gas shale and the resulting methodology has been used in eastern South Dakota (Shurr, 2008).

Immature, organic-rich Cretacous shales outcrop and subcrop beneath glacial deposits over a large area in the Great Plains (Figure 1). The distribution of this belt is shown by the Niobrara Formation which is a representative fine-grained Cretaceous rock that hosts biogenic gas. This fairway is anchored on the south by an area of substantial biogenic gas production on the northeastern margin of the Denver Basin. At the northern end of the fairway, an extensive drilling program of more than 30 wells has targeted biogenic gas in Cretaceous shales on the eastern margin of the Alberta Basin. At various places along the fairway (Figure 1), more than half a dozen companies have drilled approximately a dozen tests exploring for shallow gas in North Dakota, South Dakota, and Nebraska. Most of these tests had significant shows, but no economic production has yet been established.

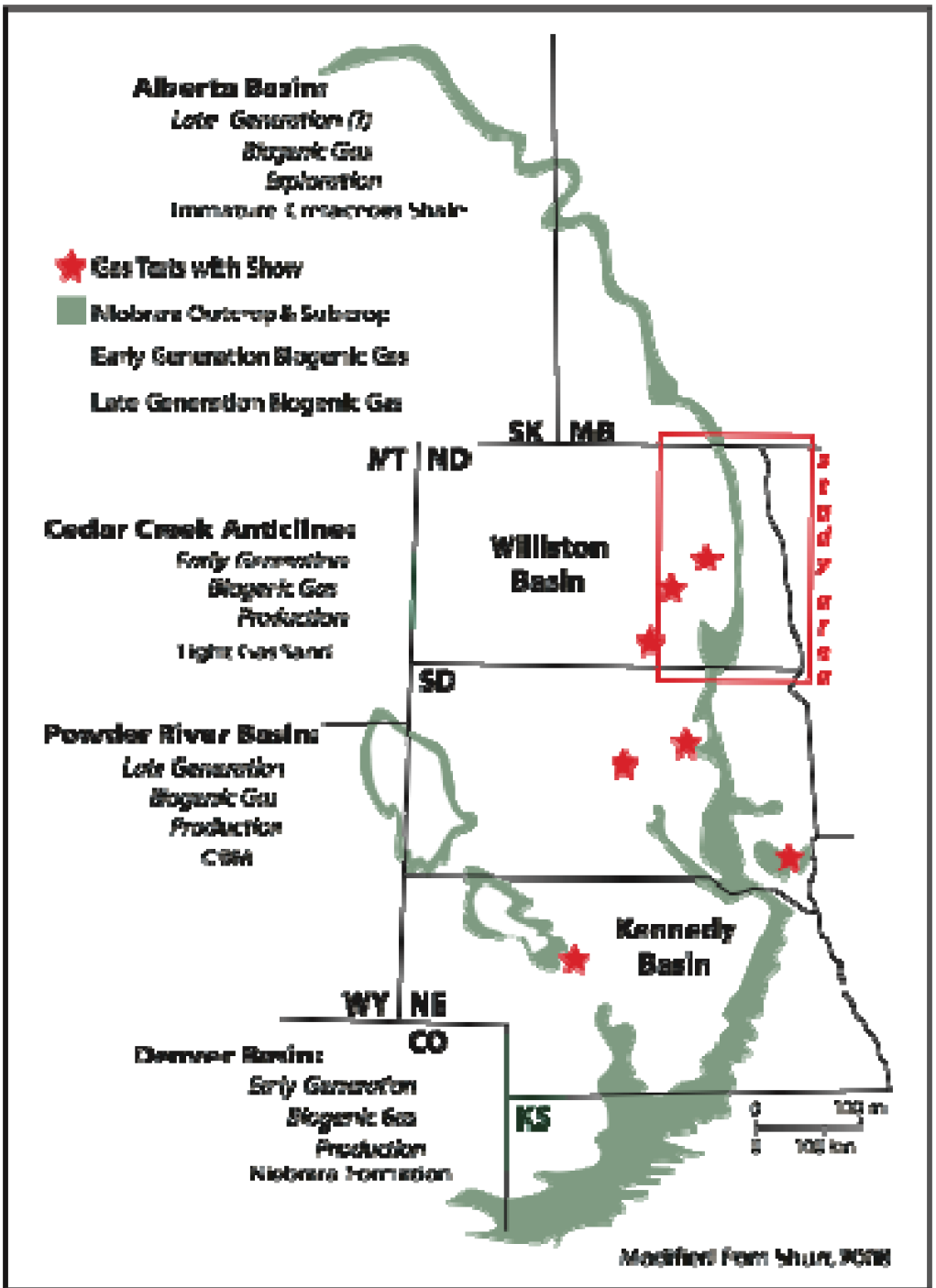

Figure 1. Location of the proposed study area relative to distribution of Niobrara outcrop and subcrop. Gas shows in Cretaceous shales and areas of biogenic gas production are also shown.

There are two types of biogenic gas (Shurr and Ridgley, 2002) found in commercial accumulations in the Great Plains (Figure 1). ***Early-generation*** biogenic gas is produced in the Denver Basin and on Cedar Creek Anticline. This is "old" or "primary" gas that forms at the time of deposition and diagenesis of the host rock. ***Late-generation*** biogenic gas is produced as CBM in the Powder River Basin and is the likely target of exploration in the northeastern Alberta Basin. This is "new" or "secondary" gas generated in the relatively recent geologic past, viz. during Pleistocene glaciation; methanogenesis may even continue into the present day. Late-generation biogenic gas is the type produced from Michigan's Antrim Shale. Several test wells in eastern South Dakota have yielded isotopic evidence that both early-generation and late-generation biogenic gas are present within the fairway of Cretaceous outcrops and subcrops.

Background

Over the past several years, the state of North Dakota has had an initiative to encourage exploration for and development of shallow gas resources. As a part of that initiative, the North Dakota Geological Survey (NDGS) has carried out an ambitious program of field screening. The program utilized a flame ionization detector (FID) to measure methane concentrations in observation wells maintained by the state. Initial feasibility studies conducted by the NDGS in 2006 (Anderson, 2006) provided the basis for a proposal to screen observation wells for methane throughout the state with follow-up sampling of favorable wells for biotech laboratory experiments. That original proposal was substantially modified when the industry partner ended its shallow gas efforts in the state.

Subsequently, the NDGS took up the task of field screening. During 2006, 2007, and 2008, FID measurements were made in more than 17,000 observations wells in 18 counties. The

results of that screening program are described in more than two dozen NDGS publications and summarized in Anderson (2009). Through that same time period, sampling aspects of the original plan were carried out in a preliminary way in southeastern Steele County under a grant from the ND Oil and Gas Research Council. Unfortunately, extended FID measurements suggested that efforts to collect a sample be discontinued because observed methane concentrations were low and variable. However, the work did demonstrate that the shallow hydrologic and biogenic systems in which methane is generated, migrates, and trapped are very dynamic.

Fractured reservoirs are extremely important in shallow biogenic gas exploration. Linear features mapped on satellite images and integrated into interpretations of regional lineament zones are a basic aspect of the exploration strategy to be employed (Shurr, 1998 and 2008). Again, work by the NDGS over the past several years, (Anderson, 2008a and 2008b) is useful by demonstrating the utility and significance of lineament mapping in North Dakota.

Objectives

The fundamental objective of this proposed work is to *generate information that will enhance exploration and development of shallow gas in North Dakota.* This will be done by *identifying non-producing counties in eastern North Dakota that have shallow gas potential.* The study will focus on the area that lies generally to the east of longitude 100° West (see Figure 1). This will exclude Bottineau, Renville, and Ward Counties which have clear shallow gas potential (Anderson, 2009), but also have extensive oil and gas production.

Sweetspots that are approximately the size of individual counties will be extracted from initial regional investigations. Areas of potential fractured reservoirs in immature Cretaceous

shale will be mapped from satellite lineament zones. Gas shows and water quality data within these fracture corridors will further delineate the sweetspots.

Methodology

The methodology employed in this investigation starts with a regional overview and then focuses down to the scale of individual sweetspots and finally ends with field screening specific water wells. It has received industry recognition when a descriptive presentation was named the best poster at the 2006 national meeting of AAPG (Shurr, Haggar, and Chadima, 2006). Several recent projects in eastern South Dakota have successfully employed the methodology. The procedures have been used to identify specific areas that yielded methanogenic microbes (Vo, Gilcrease, Haggar, and Shurr, 2009.)

The regional overview begins with mapping linear features on satellite images as well as compilation of published gravity and magnetics, syntheses of Precambrian basement geology, and structural and stratigraphic summaries. These diverse data sets are integrated and regional lineament zones are interpreted.

On a more local scale within the regional lineament zones, public domain data describing shallow gas shows and water composition will be used to identify sweetspots. In particular, the data available from the NDGS field screening program (Anderson, 2009) will be used. Water quality data available from state agencies will be employed to identify areas with (>500 mg/L) bicarbonate and low (<500 mg/L) sulfate waters. These are characteristic of areas with biogenic gas potential.

Within the identified sweetspots, specific water wells will be "sniffed" using a portable gas detector. Concentration levels of methane are measured in the well bore above the water level. Based on the results of this field screening, water samples will be collected and analyzed for bicarbonate and sulfate, headspace gases, and possible preliminary indications of methanogenic microbes. If it is feasible to collect actual gas samples, isotopic analyses will be done to evaluate the relative importance of early-generation and late-generation biogenic gas.

Other Project Aspects

Anticipated results include a map of regional lineament zones, locations of ranked sweetspots, and a set of supporting field and laboratory measurements. These are concrete results that will be in the form of deliverable products included in interim and final reports.

Facilities for generation of satellite images and compositional analyses will be commercial vendors and labs. Gas detectors will be rented. Publications of the NDGS and data from other state agencies will be employed. The *techniques* have been demonstrated successfully in South Dakota by GeoShurr Resources, LLC.

Minimal *environmental impacts* are anticipated because field screening with gas detectors and sampling procedures are relatively non-invasive. *Economic impacts* during the project will include fees for lab work, equipment rental, and field expenses.

The *ultimate economic impacts* of the work will be identification of sweetspots with shallow biogenic gas potential. These sweetspots can be targets for exploration and development or they can be used to search for methanogenic microbes. A search for methanogens would be an *ultimate technical impact* of the study and could be construed as a possible reason for *why* the

project is needed. The previous effort to sample water in North Dakota for biotech lab studies was not based on such detailed background work and consequently had only limited success.

STANDARDS OF SUCCESS

The *standards of success* for this proposed project will be submission of specific deliverable products. These include, but are not limited to: compilation of linear features observed on satellite images, interpretation of regional lineament zones, locations of county-scale sweetspots, ranking of relative sweetspot potential, and a variety of field and laboratory measurements and analyses.

The new information will specifically identify shallow gas potential in non-producing counties. This will be of value to the private sector as a guide to efficient prospect generation and increase the likelihood of successful exploration programs. This fundamental background information can also be used by public and private entities to design sampling regimes most likely to collect indigenous methanogens.

The project will illustrate the use of technologies not widely used in shallow gas exploration. Satellite mapping and water compositions have been used in a limited way, but the use of portable gas detectors is innovative.

BACKGROUND/QUALIFICATIONS

GeoShurr Resources, LLC, has been engaged in research of and prospect generation for shallow biogenic gas systems over the past ten years. Prior to that, the principal investigator, Dr.

George W. Shurr, had three decades of experience with Cretaceous stratigraphy and paleogeography and will basement-block tectonics in the Williston Basin of Montana, South Dakota, and North Dakota. Specific work experience included part-time appointments with the SD Geological Survey, the US Geological Survey, consulting, and full-time teaching at St Cloud State University in Minnesota. The university years involved management activities as department chairperson, supervision of student research, and participation in institutional governance in addition to teaching. A formal resume is included in the Appendix and a fairly complete publication history is available at www.geoshurr.com.

As a founding partner in GeoShurr Resources, LLC, Dr. Shurr has focused on shallow biogenic gas in Cretaceous rocks of the Northern Great Plains. More than half a dozen prospects have been generated; leasing, permitting, and test drilling have proceeded on at least four prospects. All prospects had good shows, although commercial production has not yet been achieved. In addition, ten papers have been published and numerous oral and poster presentations have been completed. Formal references for both papers and abstracts are included with the resume in the Appendix. A more complete bibliography can be found at www.geoshurr.com.

David W. Fischer of Fischer Oil and Gas, Inc. will be another participant in the project. He will be mainly working in the field screening of the sweetspots, but he will also be advising and facilitating other aspects of the investigations. Mr. Fischer is a well-respected petroleum geologist with many years of experience in North Dakota's Williston Basin. His insights and local expertise will be an important part of the project. It is also anticipated that Mr. Fred J. Anderson of the NDGS will provide some useful input.

MANAGEMENT

Management responsibilities will be carried out by the principal investigator, George W. Shurr. Internal management will probably be relatively simple because only a limited number of people will be directly involved in the work. External management aspects include acquisition of satellite images, coordination with commercial labs and state agencies, and direct interaction with the Oil and Gas Research Council. Evaluation points and milestones are set forth in the following timetable.

TIMETABLE

Oct, Nov, Dec, 2009	Regional Studies	Map linear features on satellite images. Compile published summaries.
Jan, Feb, Mar, 2010	Regional Studies	Integrate data sets. Interpret regional lineament zones. Evaluation point--prepare status report.
Apr, May, Jun, 2010	Sweetspots	Compile public domain data. Integrate with lineament zones. Interpret sweetspots.
Jul, Aug, Sep, 2010	Sweetspots	Field screening with gas detectors. Sample and analyze water and gas. Rank sweetspots. Evaluation point--prepare final report.

BUDGET

Professional Fees

GeoShurr...

Half time for 50 weeks = 1000 hrs x $125 = $125,000

Fischer...

Full time for 4 weeks* = 160 hrs x $150 = $ 24,000

$149,000

**(Note: shorter time commitment commands higher hourly rate.)*

Travel Expenses

Lodging & per diem	30 days x $200	= $ 6000	
Mileage	10,000 mi x $.60	= $ 6000	
			$ 12,000

Direct Expenses

Satellite Images	$ 5000	
Gas Detector Rental	$ 4000	
Lab Analyses	$10,000	
		$ 19,000

Total Budget... $180,000

Matching Funds Summary

In-kind Labor Contributions:

GeoShurr	= $ 84,000
Fischer	= $ 6,000

Total Match... $ 90,000

Total Request from NDOGRC.....$ 90,000

TAX LIABILITY

I, George W. Shurr, certify that GeoShurr Resources, LLC does not have any outstanding tax liability owed to the State of North Dakota or any of its political subdivisions.

_____ _____

George W. Shurr Date
GeoShurr Resources LLC

CONFIDENTIAL INFORMATION

The applicants do not request any confidentiality period for this project.

PATENT RIGHTS TO TECHNICAL DATA

The applicants do not request to reserve any patent rights to technical data.

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APPENDIX

Resume

GEORGE W. SHURR

DIGEST OF PROFESSIONAL EXPERIENCE

1998--Present GEOSHURR RESOURCES, LLC--Set up company that generates shallow gas prospects in the Great Plains with special emphasis on biogenic gas.

1985--1998 CONSULTANT TO INDUSTRY AND GOVERNMENT AGENCIES *(part-time)*—Assess gas and oil resources, characterize Cretaceous reservoir rocks, and conduct regional tectonic studies.

1967--1998 DEPARTMENT OF EARTH SCIENCES, ST. CLOUD STATE UNIVERSITY--Full professor doing research, classroom instruction, and student research supervision. Four years as Department Chair.

1975--1985 UNITED STATES GEOLOGICAL SURVEY *(part-time)*--Evaluate hydrocarbon resources in the Northern Great Plains and conduct regional stratigraphic and tectonic investigations.

1965--1975 SOUTH DAKOTA GEOLOGICAL SURVEY *(part-time)*--Field geologist doing Cretaceous stratigraphy and ground water studies.

EDUCATION

PhD, 1975, University of Montana, Missoula, MT
MS, 1967, Northwestern University, Evanston, IL
BA, 1965, University of South Dakota, Vermillion, SD

PROFESSIONAL AFFILIATIONS

SOCIETIES: American Association of Petroleum Geologists (AAPG), Rocky Mountain Association of Geologists (RMAG), Geological Society of America (GSA).

CERTIFICATION: Certified as a professional geologist in the states of Wyoming and Minnesota.

PROFESSIONAL AND RESEARCH ACTIVITIES

COMMUNICATION: Annual presentations at national and sectional meetings of AAPG and GSA and at regional professional societies. Organized and chaired technical sessions at AAPG and GSA meetings 2004 through 2009.
RESEARCH: Topics include late generation biogenic gas systems, basin margin shallow gas plays, fractured reservoirs, Cretaceous stratigraphy, and tectonism on lithosphere blocks.
CO-EDITOR: GSA Special Paper 287 entitled "Perspectives on the Eastern Margin of the Cretaceous Western Interior Basin".
AUTHOR: More than 60 published technical papers and more than 75 presentations at professional meetings.
HONORS: Best poster award at AAPG national meeting, April 2006 for presentation entitled "Exploration strategies for Ultra-shallow Microbial Methane on the Eastern Margin of the Williston Basin".

A DECADE AS INDEPENDENT GEOLOGIST

ORGANIZED an email network of people interested in shallow gas that includes an occasional informal newsletter.
COMPLETED 10 publications and 23 presentations at national and regional meetings; most focus on shallow biogenic gas.
CONTINUED collaboration with professional staff of the US Geological Survey, North Dakota Geological Survey, and South Dakota Geological Survey and a variety of private companies.
INVITED to give talks in SD, ND, MT, CO, TX, and MI.
CONSULTING activities include projects in Canada and Africa, as well as the US Northern Great Plains. *PROSPECT* generation has resulted in leasing over a quarter millions acres and drilling a dozen test wells.

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AMENDED BUDGET

for proposal entitled

"Identification of Shallow Biogenic Gas Systems in Eastern North Dakota"

Professional Fees

GeoShurr...

Half time for 50 weeks = 1000 hrs x $125 = $125,000

Fischer...

Full time for 4 weeks* = 160 hrs x $150 = $ 24,000

$149,000

**(Note: shorter time commitment commands higher hourly rate.)*

Travel Expenses

Lodging & per diem	30 days x $200	= $ 6000	
Mileage	10,000 mi x $.60	= $ 6000	
			$ 12,000

Direct Expenses

Satellite Images	$ 5000	
Gas Detector Rental	$ 4000	
Lab Analyses	$10,000	
		$ 19,000

Total Budget... $180,000

Matching Funds Summary

In-kind Labor Contributions:

GeoShurr Resources, LLC	= $ 64,000
Fischer Oil & Gas, Inc	= $ 6,000

Cash Contribution:

White Eagle Exploration, Inc = $ 20,000

Total Match... $ 90,000

Total Request from NDOGRC.....$ 90,000

Amended...June 15, 2009