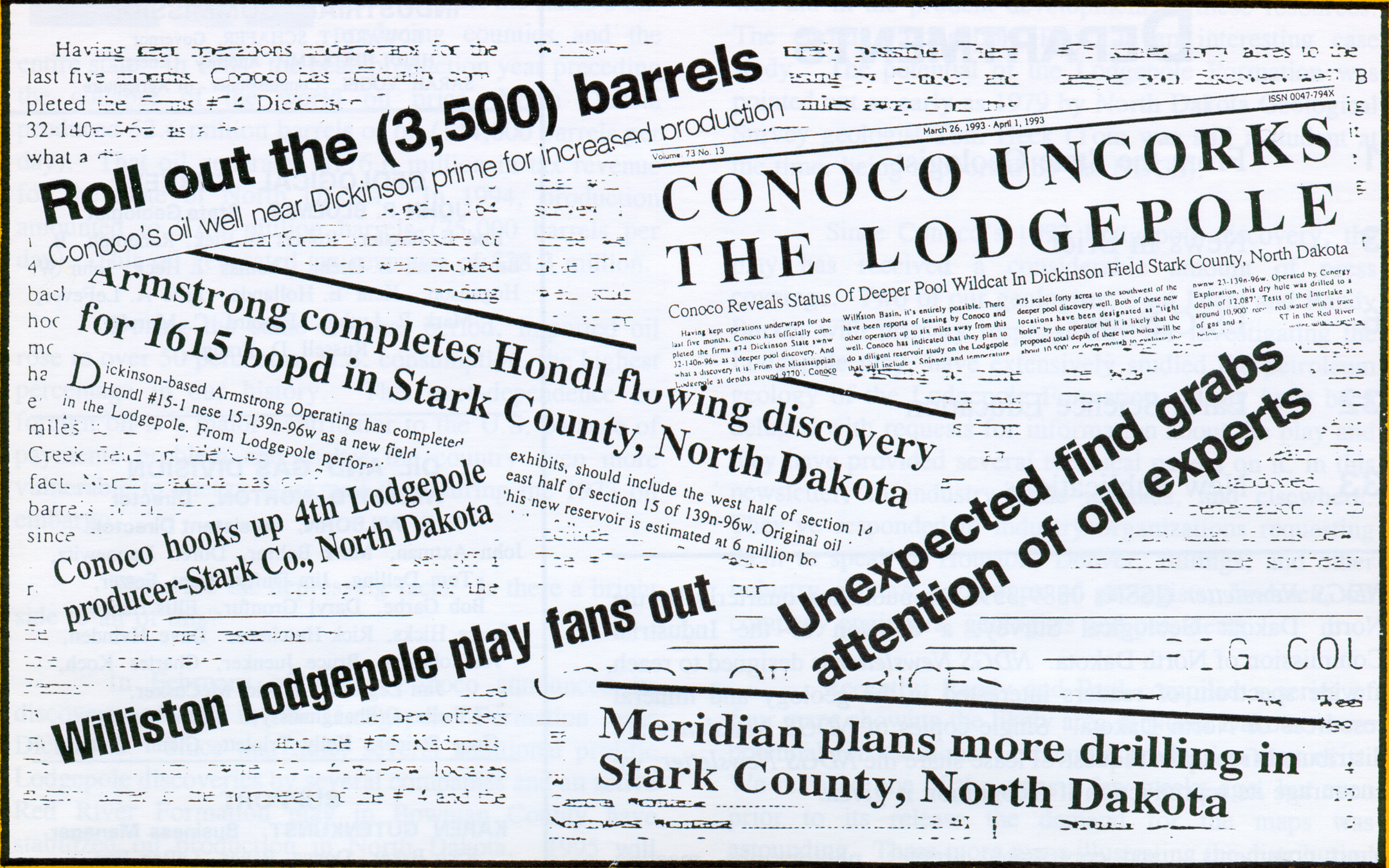
NEWSLETTER

NDGS

Industrial Commission of North Dakota, North Dakota Geological Survey Vol. 22, No. 4, Winter 1995



One of the major statutory roles of the North Dakota Geological Survey is to conduct research on the energy-bearing geologic formations in the state, with the purpose of providing unbiased, scientific information that will aid in the prudent development of our mineral resources. Nowhere has this been more clear as of late than with the Lodgepole Formation, an interval that until recently was largely unrecognized for its petroleum potential. Since its discovery in February, 1993, by Conoco, Inc., the Lodgepole play has received an astounding amount of press coverage. See pages 1 and 8 for a summary of this important play.

FEATURES

DEPARTMENTS

NDGS Newsletter (ISSN: 0889-3594) is published quarterly by the North Dakota Geological Survey, a division of the Industrial Commission of North Dakota. *NDGS Newsletter* is designed to reach a wide spectrum of readers interested in the geology and mineral resources of North Dakota. Single copies of *NDGS Newsletter* are distributed free upon request. Please share the *NDGS Newsletter*; we encourage its reproduction if recognition is given.

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NEWSLETTER
NDGS

FROM THE STATE GEOLOGIST

By John P. Bluemle

Encouraging Petroleum Exploration

The North Dakota Geological Survey is continuing its efforts to halt the decline in oil production in North Dakota.

Between 1984 and 1994, North Dakota's annual production of oil dropped about 48 percent. The resulting loss of jobs and taxes has hurt the states's oil-producing counties and the entire state. In 1984, the peak production year preceding the collapse of the world oil price, North Dakota produced 52.6 million barrels of oil (144,000 barrels per day). That oil generated $176.6 million in tax revenue for the State of North Dakota. In 1994, production amounted to 27.5 million barrels (75,000 barrels per day). This oil generated tax revenues of $38.3 million.

During the same ten-year period, imported oil rose to over 50 percent of U.S. consumption, the highest percentage in our history. This over-dependence on foreign oil is a major contributor to the U.S. balance of payments problem and makes the country even more vulnerable to energy blackmail than during the 1973 oil embargo.

These are the depressing facts. Is there a bright side to all of this?

In February of 1993, Conoco announced its discovery of oil in the Lodgepole Formation near Dickinson. Since that time, several additional prolific Lodgepole discoveries by several companies and an active Red River Formation play in Bowman County have stabilized oil production in North Dakota. 1995 will actually see an increase in the state's total production over 1994.

Do discoveries like Conoco's just happen and do we just wait around and hope someone finds something? Are there things the NDGS can do to make things happen? And finally, what does it take to turn production around?

The quick answer to the first question — should we do nothing? — is "definitely not!" The answer to the second question is that the NDGS is already doing the basic studies on the formations that have potential to produce oil and gas and other mineral resources as well. NDGS geologists have always done the basic groundwork that mineral-producing companies use in their exploration. In fact, one of the major statutory roles of the North Dakota Geological Survey is to conduct research on the energy-bearing geologic formations in the State, with the purpose of providing unbiased, scientific information that will aid in the prudent development of these resources. The current "Lodgepole Play" is an interesting case study. The potential of the Lodgepole Formation was pointed out as early as 1979 by North Dakota Geological Survey geologist Tom Heck (Tom was still a student at the time, being supported by the NDGS).

Since Conoco's 1993 Lodgepole discovery, the play has received a considerable amount of press coverage. Two of our geologists, Paul Diehl and Randy Burke, with primary responsibility for investigating the Lodgepole play, have extensively studied the petroleum geology of the Lodgepole Formation. They have been deluged with requests for information about the play and they have provided several technical papers on it, in this newsletter, in industry trade journals, and elsewhere. They've responded to industry organizations requesting them to speak in Houston, Denver, Billings, and other industry centers, to groups of geologists, landmen, oil company engineers, geologists and presidents.

Recently, Randy and Paul compiled a series of four maps showing the likely area in North Dakota where potential for additional Lodgepole production may exist. We released one of the maps a few weeks ago, but even prior to its release the demand for the maps was astounding. Three more maps illustrating the distribution of geologic units and factors which may relate to the location of Lodgepole buildups are due for release by the NDGS soon.

An obvious example of the immediate monetary benefit to the State resulting from our efforts to provide accurate information about the current Lodgepole play is the over $12 million North Dakota has received in the last three State lease sales. By far, most of that revenue was for leases within the Lodgepole play. The coincidence of nominated leases with the area Paul and Randy designated as having Lodgepole potential shows the possible influence their work had (see figures 5, 6, and 7 in Randy's and Paul's article). This $12 million is revenue only from lease of state-owned minerals. Many more dollars have been spent in North Dakota for privately owned minerals.

As a result of our geologist's publications, people and companies never before interested in North Dakota or the Williston Basin have become interested. These people call the Survey almost daily to discuss the Lodgepole play, and to ask for whatever information we can provide on the play, as well as for any other sources of geologic and reservoir data. A Shell exploration geologist recently told us that our work and publications on the Lodgepole were a major influence in Shell's decision to return to North Dakota.

We take every opportunity to point out that many other exploration opportunities exist in North Dakota. The pre-Madison strata had been penetrated by the bit only 2,835 times in the entire North Dakota portion of the Williston Basin prior to Conoco's Lodgepole discovery; in other words the potential for production from deeper formations is essentially untested. Potential for oil production also exists in shallower strata such as the Tyler and Spearfish, whereas Cretaceous strata have potential for gas production.

What else is the North Dakota Geological Survey doing to encourage investment and exploration? Three years ago, in April 1993, we co-sponsored, with the Saskatchewan Energy and Mines (our counterparts in Saskatchewan), the first of three workshops on horizontal drilling. The first two workshops were held in Minot, the third in Regina. Our fourth workshop will be held in Bismarck next May. These workshops have been extremely successful, with more people attending each year (over 450 people attended the one we held last April in Regina). The workshops have been one of the most important reasons for the resurgence in interest in North Dakota for oil exploration.

Our workshops have accomplished several things. More than anything else, they have made people aware of the latest in horizontal drilling technology and they have served to point out opportunities to apply that technology in North Dakota. The workshops have driven home the point that North Dakota has the same potential for successful horizontal drilling applications as does Saskatchewan, where the success has been phenomenal; production there doubled as a result of horizontal drilling. Beyond horizontal drilling considerations, the workshops have made Canadian oil companies aware of opportunities for investment and exploration in North Dakota (between a half and two-thirds of the people attending each workshop have been Canadians). The workshops have brought the active players together and served as an effective catalyst for much of the current leasing and drilling activity in North Dakota.

At our 1994 horizontal drilling workshop, Survey geologist Bill McClellan presented a paper and maps on the Red River Formation in Bowman County. He pointed out that Red River production should extend westward from the then-known productive area. The result is a very successful Bowman County Red River play that is bringing millions of dollars per month into Bowman County and the State. Continental Resources alone is spending over $2 million a month drilling in Bowman County. In an almost bizarre turn of events, I had to let Bill go last May as a result of a reduction-in-force mandated during last winter's legislative session. The money "saved" by the State in eliminating that position is a tiny fraction of the revenue Bill generated for the State through his work on the Red River. Bill was not long without a job; Continental Resources hired him soon after he left the Survey.

I've also tried to do my part. Last January I addressed a conference in Calgary, pointing out opportunities for investment and exploration in North Dakota, explaining North Dakota's oil and gas conservation law, and responding to a variety of questions. After my talk, officials from about a dozen Canadian oil companies contacted me. Since then, most of those companies have either become active in North Dakota or have indicated to me that they soon will. Our efforts to attract Canadian investment have been very successful and have been another reason for the current turnaround in the state's oil industry.

So, have our efforts had an effect? The answer is an emphatic "Yes!" The impact of our three horizontal drilling workshops has been considerable. Our recent Lodgepole maps had a major impact on the last three North Dakota lease sales. Will oil-productive Lodgepole structures be found in the areas Paul and Randy delineated on their maps? Only drilling will answer that question. Even if productive Lodgepole structures are not immediately found in the projected "favorable" areas, it is nearly a sure thing that new oil will be found in places that have not been previously productive.

As the search for Lodgepole oil progresses, in the Dickinson area and beyond, new production will be found in other formations by "accident," — the so-called "serendipity factor" — just as the Dickinson Lodgepole structures were found by "accident." Paul's and Randy's maps point out the shortage of tests deeper than Madison outside the basin center. The east flank of the basin in North Dakota is virtually unexplored! The western flank in Montana also needs exploration and has great potential for new production.

Finally, the answer to my third question: how is the production decline reversed? Ultimately, the only way oil is found is by drilling for it and, all of our efforts at encouragement aside, it won't be found until someone puts a hole in the ground. We know from experience that oil is always found in the Williston Basin whenever people look. We need to continue doing everything we can to encourage them to drill.

NEWS IN BRIEF

compiled by Bob Biek

Internet Addresses for Earth Science Information

by Mark Luther

As more and more people obtain access to the Internet, the ESIC Network (including the NDGS) is striving to put more earth science information "online." One example of how the NDGS is using the Internet was highlighted in the Winter 1994 *NDGS Newsletter* ("NDClear Online"). The NDGS's "Home Page," or site on the Internet, has averaged 20 "hits" or requests for information per day. For those with Internet access, this is a rapid and very inexpensive vehicle for the NDGS to disseminate some types of information. The following are Internet addresses of selected earth science organizations from which information can be obtained.

NDGS Home Page
http://www.state.nd.us/ndgs/NDGS.HomePage.html

NDIC Oil & Gas
http://www.state.nd.us/ndic/NDIC.HomePage.html

ND Water Comm.
http://water.swc.state.nd.us

ESIC Home Page
http://www-nmd.usgs.gov/esic/esic.html

USGS Home Page
http://www.usgs.gov/

USGS Geologic Mapping Education Program Funded

1996 marks the first year that the Geologic Mapping Education Program (EDMAP), a component of the National Geologic Mapping Program, is scheduled for funding by the U.S. Geological Survey. Through cooperative agreements with the USGS and State Geological Surveys, the EDMAP program will support Masters and Doctoral students undertaking geologic field mapping. The emphasis of the program is on the prompt release of geologic map information, which is generally accomplished by releasing the map and attendant information as an Open-File Report at the end of the contract period. Those seeking more information about the program in North Dakota should contact Bob Biek at the NDGS.

NDGS Has New Telephone and Fax Numbers

Last September, the telephone number for the NDGS was changed to (701) 328-9700; our fax number is (701) 328-9898.

Attention *NDGS Newsletter* Subscribers

In order to continue receiving the *NDGS Newsletter*, you must return the enclosed postage-paid card. This is the first time that we have asked our readers to renew their subscription since the newsletter's inception in 1975 (although we continue to update the mailing list as we learn of address changes). We need to be certain that those of you who receive the newsletter still wish to do so. (Organizations on our library exchange list need not return the enclosed renewal card.)

We also want to ensure that individuals and organizations that do not currently receive the newsletter have the opportunity to do so. We will do that in part through targeted mailings, but ask for your assistance as well. Please send us the name and address of one other person that you feel will enjoy reading the *NDGS Newsletter*. Consider asking your doctor, dentist, auto mechanic, local librarian, your best friend — anyone that might benefit from reading this free, quarterly publication. Please add their name and address on the enclosed renewal card.

The *NDGS Newsletter* will remain a free, quarterly publication, but subsequent issues will only be sent to those who send in their renewal card — don't delay, send in your response today!

Please also take a moment to answer the following questions (the answer form is on the enclosed postcard). Please use one answer form per respondent; additional answer forms are available on request. Your response will help us tailor the *NDGS Newsletter* to better suit your needs.

1. What is your gender?
   a. male
   b. female

2. What is your age?
   a. under 18
   b. 18-34
   c. 35-45
   d. 46-64
   e. 65 or older

3. What is the highest level of education you have achieved? Check one category.
   a. attended high school
   b. high school graduate
   c. attended college
   d. college graduate
   e. advanced degree

4. What is your occupation? Check **all** categories that apply.
   a. biologist
   b. educator
   c. engineer
   d. farmer
   e. geologist
   f. government employee
   g. healthcare worker
   h. homemaker
   i. hydrologist/hydrogeologist
   j. legislator
   k. own a business
   l. planner
   m. politician
   n. rancher
   o. retired
   p. soil scientist
   q. work in industrial minerals industry
   r. work in lignite industry
   s. work in petroleum industry
   t. work in sales
   u. other occupation

5. Check **all** the topics that you read in the *NDGS Newsletter*.
   a. From the State Geologist
   b. News in Brief
   c. Feature articles
   d. Annual oil and gas updates
   e. Announcements of new publications
   f. Earth Science Education
   g. Annual list of NDGS projects
   h. Annual list of geologic projects in North Dakota

6. Suggestions or comments:
   ____
   ____
   ____
   ____
   ____
   ____

GIS Technical Committee and State Mapping Advisory Committee Established by Governor Schafer

by Mark Luther

On May 2, 1995 Governor Schafer signed Executive Order 1995-05 (shown at right), formally establishing both a Geographic Information System Technical Committee (GISTC) and a State Mapping Advisory Committee (SMAC). This action, which is in line with the Governor's stated goal of increasing efficiency in government, will result in increased productivity through coordination and prioritization of effort.

The GISTC is chaired by Al Veit of the Information Services Division (ISD) of the Office of Management and Budget, and the SMAC is chaired by Mark Luther. We are encouraged that the Governor recognizes the vital roles that mapping and map-related data play in the management and economic development of the state. His support of these activities, and insistence that they be done in the most efficient manner ensures that the residents of North Dakota will receive the highest level of needed service for the lowest cost possible.

Map of Glacial Sediment Thickness

The U.S. Geological Survey recently published a 1:1,000,000-scale map that portrays the thickness and character of Quaternary sediments in the glaciated western part of the northern plains states. The map covers northern Montana west of the Rockies, and the western one third of North Dakota. Three main sediment types (till, sand and gravel, and silt and clay) are shown with different color intensities that correspond to the total thickness of Quaternary sediments, creating a 3-D effect.

The map (USGS Miscellaneous Investigations Series Map I-1970-D, *Map Showing the Thickness and Character of Quaternary Sediments in the Glaciated United States East of the Rocky Mountains: Northern Plains States West of 102⁰ West Longitude*) is one of four compiled by USGS geologist David R. Soller; each presents a regional synthesis of available geologic data and is useful to provide a regional, multi-state perspective. USGS Bulletin 1921 (Soller, 1992) offers additional explanatory notes to accompany the maps. Both the map and bulletin are available through the USGS Information Center, Box 25286 Federal Center, Denver, CO 80225.

State of North Dakota
OFFICE OF THE GOVERNOR
600 E. BOULEVARD – GROUND FLOOR
BISMARCK, NORTH DAKOTA 58505-0001
(701) 328-2200

EDWARD T. SCHAFER
GOVERNOR

EXECUTIVE ORDER 1995-05

Whereas, Geographical Information Systems (GIS) is currently being used and developed across North Dakota by local, state and federal agencies, as well as the business community, and

Whereas, GIS medium serves a valuable medium for scientific investigation, resource management, and development planning, and

Whereas, GIS provides a computer system for storing, assembling, manipulating, and displaying geographically referenced material, and

Whereas, there exists a need to coordinate these efforts to provide a cost effective, efficient means of assembling and distributing this information among interested agencies and parties,

NOW THEREFORE, I, Edward T. Schafer, Governor of the State of North Dakota, by the authority vested in me, do hereby establish the Geographic Information System Technical Committee (GISTC) to be composed of representatives from each state agency as set forth below:

ND Health Department	ND Department of Transportation
ND Water Commission	ND Geological Survey
ND Parks & Recreation	ND Information Services Division
ND Game & Fish Department	

The GIS Technical Committee shall be chaired by ISD, and shall issue to other state, local and federal agencies and members of the business community interested in geographical information systems, an invitation to participate in the committee as associate members.

The GIS Technical Committee shall serve as advisory council to the full committee including associate members, shall coordinate and provide overview of GIS activities within the state, will be available to review proposed GIS projects, and shall serve as the executive committee. The Committee shall also act as a clearinghouse of GIS activities, including the orderly accumulation and dissemination of digital-spatial data (DSD). State agencies and committee members are requested to report DSD holdings to the Committee at the end of each fiscal year, which will be maintained by North Dakota Geological Survey. The committee shall issue a report to the Governor's office at the end of each fiscal year, detailing progress, and problems encountered with GIS development in the state.

Executive Order 1995-05
Page 2

The Committee shall appoint a State Mapping Advisory Committee (SMAC), subject to my approval, which shall be chaired by the NDGS, and which will coordinate and prioritize mapping activities within the state.

This order is issued upon the following bases and for the following reasons:

1. The Governor is vested with the executive authority pursuant to Article V, Section 1 of the North Dakota Constitution.
2. A SMAC is needed to coordinate and prioritize mapping requirements in the state, and its recommendations greatly enhance the likelihood of federal support for mapping requirements in the state.
3. A GISTC is needed to keep the agencies and public of North Dakota informed, with respect to advances in GIS technologies, upcoming GIS projects, standards, and DSD availability.

Executed at Bismarck, North Dakota this 2 day of May, 1995.

EDWARD T. SCHAFER
Governor

Attest:
Secretary of State

Deputy

By Mark Luther

For several years the NDGS has been an affiliate office of the Earth Science Information Center (ESIC) network. Coordinated by the U.S. Geological Survey (USGS), this nationwide ESIC network provides information about geologic, hydrologic, topographic, and landuse maps, books, and reports; aerial, satellite, and radar images and related products; earth science and map data in digital form and related applications software; and geodetic data. As an ESIC office, the NDGS can assist the public in locating those earth science materials dealing with North Dakota, as well as other states.

USGS Topographic Map Prices Increase

On August 14, 1995 the NDGS learned that effective August 12, 1995, the price of 1:24,000 scale (7.5' quadrangle) topographic maps was increased from $2.50 to $4.00 per map. The cost of other USGS map series remains the same.

Revised/New Map Products

In addition to providing information about the availability of various earth science materials, the NDGS's ESIC office operates a distribution center for federally produced cartographic products. The following 1:24,000 scale (7.5-minute quad), USGS topographic maps have recently been revised and are available for purchase from the NDGS at a cost of $4.00 each (plus shipping).

* Buchanan
* Fried
* Camp Grafton
* Grand Forks
* Courtenay NW
* Grand Harbor
* Crary
* Homer
* Devils Lake
* Jamestown
* Eldridge
* Jim Lake
* Eldridge NW
* Minnewaukan East
* Eldridge SE
* Penn
* Eldridge SW
* Pingree
* Fort Totten
* Pingree SW
* Free Peoples Lake
* Tokio

The following 1:100,000 scale (30 X 60-minute quad), USGS **metric topographic** map has recently been produced and will replace the earlier planimetric (non-topographic) map version. This map is also available from the NDGS at a cost of $4.00 (plus shipping). Until our current stock of planimetric (PL) maps is depleted, they will be sent unless the topographic (TM) version is requested.

* Eureka

To place map orders or receive additional information, contact our publications clerk or the ESIC Coordinator. Shipping costs on federally produced paper maps purchased from the NDGS are:

1 to 5 maps	$2.75
6 to 30 maps	$4.00
31 or more maps	$6.00

Digital Raster Graphic (DRG) Availability

The USGS's newest digital map product, and one which the NDGS had a hand in initiating, is the Digital Raster Graphic (DRG). A detailed description of DRGs was included in the Spring 1995 issue of the *NDGS Newsletter*. Briefly, a DRG is a digital (computer readable) file containing an image of a standard USGS paper topographic map. The DRG is produced by scanning the paper topographic map with a high-resolution scanner, then using computer software to correct distortion and georeference the map image to ground coordinates. The USGS plans to produce DRGs from maps of several scales, including: 1:24,000 scale (7.5-minute quad); 1:100,000 scale (30' X 60' quad); and 1:250,000 scale (1° X 2° quad). The plan is to distribute the DRGs on CD-ROM, with all the maps within an area of 1° of latitude by 1° of longitude available on a single CD. Thus, each CD would contain sixty-four 7.5' quads, two 30' X 60' quads, and one 1° X 2° quad in a digital format.

As reported in the Spring 1995 *NDGS Newsletter*, the NDGS had a Joint Funding Agreement (JFA) with the USGS to produce DRGs for several North Dakota cities (listed in the spring issue). At that time we anticipated that several years would pass before complete coverage of the state by DRGs would be attained.

Now, however, it appears that North Dakota will have complete DRG coverage within months instead of years as earlier thought. Through the combined efforts of the NDIC - Oil and Gas Division, the ND Department of Health, and the USDA - Natural Resources Conservation Service (formerly SCS), which entered into JFAs with the USGS, the remainder of the DRGs needed to complete coverage in the state will be achieved by early 1996.

Statewide completion of DRGs will be of great benefit to both the public and private sector in North Dakota, allowing agencies to perform their missions more efficiently and providing private firms with the opportunity to become proficient in the use of advanced technologies. The participating agencies are to be commended for coordinating their efforts and maximizing benefits to the state.

The NDGS's ESIC Coordinator is Mark R. Luther
mark@eagle.ndgs.state.nd.us

USBM Releases 1994 Industrial Mineral Production Estimates

According to the U.S.Bureau of Mines, in 1994 North Dakota ranked 49th in the nation in total nonfuel (industrial) mineral value, down from 48th, a position the State had held for 15 of the previous 16 years. The estimated value for 1994 was $26 million. Sand and gravel used for construction purposes accounted for nearly 84% of this total; lime, used in sugar beet refining, was the second most valuable nonfuel mineral commodity. North Dakota accounted for about 0.1% of the nation's total industrial mineral output in 1994. Elemental sulfur, krypton, xenon, anhydrous ammonia, cresylic acids, and liquid nitrogen were recovered during natural gas processing and coal gasification, but are not included in USBM statistics.

NONFUEL RAW MINERAL PRODUCTION IN NORTH DAKOTA[1]

Mineral		1992		1993		1994[p]	
		Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
Gemstones		NA	$643	NA	W	NA	W
Lime	thousand metric tons	101	4,288	W	$4,512	W	W
Peat	do.	W	W	(2)	W	W	W
Sand and gravel (construction)	do.	7,929	20,609	[e]7,700	[e]20,400	8,000	$22,000
Stone (crushed)	do.	10	W	W	W	W	W
Combined value of clays (common), sand and gravel (industrial), stone (crushed volcanic cinder), and values indicated by symbol W		XX	210	XX	131	XX	4,290
Total		XX	25,750	XX	25,043	XX	[4]26,300

[e]Estimated. [p]Preliminary. NA Not available. W Withheld to avoid disclosing company proprietary data; value included with "Combined value" data. XX Not applicable.
[1]Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
[2]Less than 1/2 unit.
[3]Value excluded to avoid disclosing company proprietary data.
[4]Data do not add to total shown because of independent rounding.

The Lodgepole Formation Carbonate Buildup Play and Waulsortian Mounds in North Dakota

by Randolph B. Burke and Paul E. Diehl

Editor's Note: The following article first appeared in the Nov. 2-3, 1995 Workshop Notes of the 22nd Annual Fall Land Institute, sponsored by The Denver Association of Petroleum Landman.

Since the Conoco, Inc. discovery of productive carbonate buildups in the lower Lodgepole Formation, a total of 58 Lodgepole tests have been permitted in North Dakota (Fig. 1). These permits have resulted in 21 oil producers, 18 dry holes, one re-entry dry hole, and 18 locations either drilling/completing or waiting to be drilled. In addition to the Lodgepole pools found by the Conoco, Inc. Dickinson State 74 (Dickinson Lodgepole Unit) and the Duncan Oil Knopik 1-11 (Eland field), three additional separate buildup reservoirs have been discovered thus far this year. The Conoco, Inc. Kuntz #1-2 (sec. 2-139N-97W), the Armstrong Operating Inc. Haller 29-1 (sec. 29-139N-96W), and the Armstrong Operating, Inc. Hondl 15-1 (sec. 15-139N-96W) each have penetrated separate productive lower Lodgepole buildups. These are the discovery wells for the two-well Duck Creek field, the thus far one-well Versippi unit, and an unnamed field. Drilling continues at a rapid pace, both to define the physical extent of these reservoirs and to explore for other Lodgepole buildups. Figure 1 illustrates the well status and activity in a twelve-township area centered around Dickinson, North Dakota.

Lodgepole Play History

Conoco, Inc. started the play in the Dickinson field in February, 1993 with the discovery of a 294 foot-thick lower Lodgepole Waulsortian-like carbonate buildup while drilling for a deeper Silurian Interlake and Ordovician objective on a small structural closure defined by 2-D seismic data. They estimated 18 million to 19 million barrels of original oil in place in the Dickinson Lodgepole pool. The development of the Dickinson Lodgepole pool has been completed and the pool was unitized in June, 1994. At the time of unitization, Conoco, Inc. estimated an ultimate recovery of 7.86 million barrels of oil and 3.7 billion cubic feet of gas employing a waterflood to maintain reservoir pressure. Pressure maintenance by water injection was initiated in October, 1994. The unit consists of two injector wells and two producing wells. Cumulative production from the Dickinson Lodgepole pool through July, 1995 was over 1.5 million barrels of oil, 835 million cubic feet of gas (MMcfg), and 15,990 barrels of water (BW). July's unit production was 117,584 BO, 61.8 MMcfg, and 5148 BW in 29 days for a per well average of 2027 BOPD.

After the Conoco discovery, nine unsuccessful wildcat tests were drilled in search of Lodgepole buildups before Raymond T. Duncan drilled the Knopik 1-11 (sec. 11-139N-97W) which penetrated the second productive buildup in the lower Lodgepole. This well, located about 3.4 miles southwest of the Conoco, Inc. discovery, was completed in December, 1994 with an initial flowing potential of 2707 BOPD and 1.55 million cubic feet of gas per day (MMcfgpd). It is the discovery well for Eland field (Fig. 1). The buildup in this well is approximately 231 feet thick with about 130 feet above the oil/water contact. Through July, 1995, the Knopik 1-11 had produced 254,111 BO, 55 MMcfg, and 4069 BW. Currently, production from the Knopik 1-11, as well as the other producers in the Eland field, is being restricted to conserve reservoir pressure until the field can be unitized and a pressure maintenance program initiated.

Since the drilling of the Knopik 1-11, three other tests have discovered lower Lodgepole buildups that appear to be reservoirs separated from the Dickinson and Eland pools. Conoco, Inc. drilled the Kuntz #1-2 (sec. 2-139N-97W), which penetrated about 318 feet of buildup and is the discovery well for the Duck Creek field. From the date of first production in March, 1995 through July, 1995, the Kuntz #1-2 has produced approximately 80,500 BO and 6800 BW. Armstrong Operating, Inc. has found two additional productive Lodgepole buildups with their Haller 29-1 (sec. 29-139N-96W) and Hondl 15-1 (sec. 15-139N-96W) wells. The Versippi Lodgepole voluntary unit was formed to include the Haller 29-1 and a currently drilling Armstrong Operating, Inc. Gruman 20-1

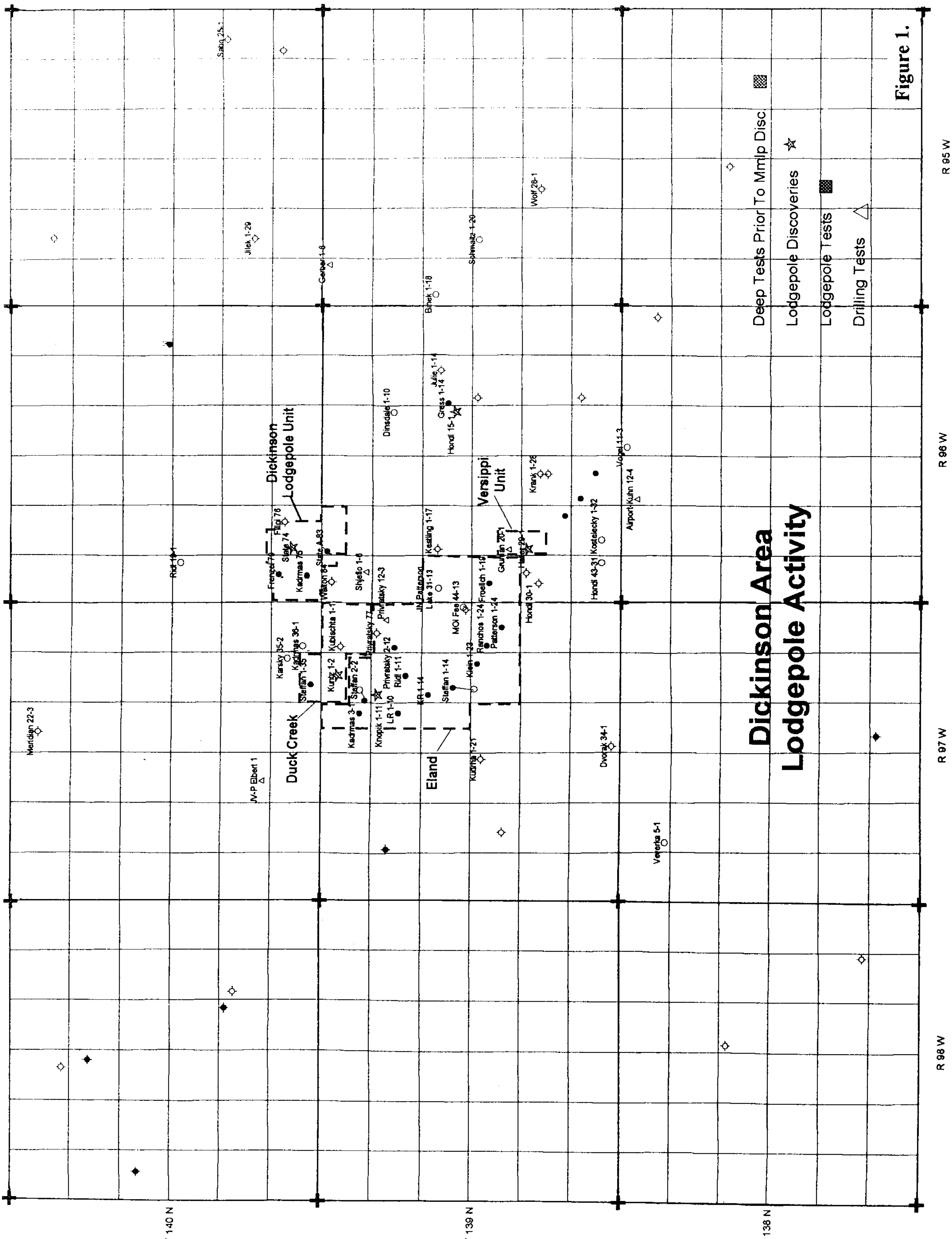

Dickinson Area
Lodgepole Activity
Deep Tests Prior To Mmlp Disc.
Lodgepole Discoveries
Lodgepole Tests
Drilling Tests
Dickinson Lodgepole Unit
Versippi Unit
Duck Creek
Eland
T 140 N
T 139 N
T 138 N
R 95 W
R 96 W
R 97 W
R 98 W

Figure 1.

(sec. 20-139N-96W). As reported in the *Rocky Mountain Oil Journal* (Sept. 1 - Sept. 7, 1995), exhibits filed with the North Dakota Industrial Commission Oil and Gas Division reported an initial flowing potential of 157 BOPD, 78 thousand cubic feet of gas per day (Mcfgpd), and 55 barrels of water per day (BWPD) from the Haller 29-1. Although the well data and logs remain confidential until November 16, 1995, many reservoir properties, log data, and maps were reported in the above referenced *Rocky Mountain Oil Journal* article. These exhibits are on file at the North Dakota Oil and Gas Division office in Bismarck. Well information regarding the Hondl 15-1 will remain confidential until December 12, 1995. However, "lease use and sales" show 17,762 BO were reported for the month of July, 1995 (Table 1).

Exploration

Several factors appear to be considered, at least by some individuals, while exploring for Lodgepole carbonate buildups. Paleogeography (the shape of the Williston Basin and the position of the central deep basin, the basin flank, and the shallow open shelf during early Mississippian time) when the lower Lodgepole buildups were growing is thought to have influenced the position of these buildups. Although there is some disagreement among geologists involved with this play as to the depositional environment of these buildups, we think the buildups found in the lower Lodgepole initiated growth in relatively deep water at the foot of the basin flank where the deep basin begins (Fig. 2). This interpretation is based in part on the character of adjacent shaly limestone strata, on occurrence in the buildup strata of only those organisms that do not require light to live, on lack of definitive shallow water indicator features, and on study of literature describing similar lower Mississippian carbonate buildups.

Some explorationists feel that the Lodgepole buildups in the Williston Basin must not only overlie the Bakken shale, but must overlie the shale where it has been buried deeply enough to have become thermally mature and has generated oil. Source rock evaluation and oil analysis indicate that the source rock for the oil produced from the Lodgepole at Dickinson is primarily

					Cum. Production (9/'95)			
Operator	Name	First Prod.	Perfs	IP (24 hr. Rates)	Bbls. Oil	Gas (MMcf)	Bbls Wtr	Field
Conoco, Inc.	Unit	Feb-93	D: 9721' - 9850' K: 9722' - 9824'	F/ > 2000 Bo + 0 Bw + 1.5 MMcfpd	1,766,862	965,835	26,987	Dickinson Un.
Conoco, Inc.	Steffan 1-35	May-95	9790' - 9818' 9830' - 44'	F/116 Bo + 36 Bw + 58 Mcfpd	9,327	1,890	3,109	Duck Creek
Conoco, Inc.	Kuntz 2-1	Mar-95	9756' - 66' 9772' - 82'	F/2110 Bo + 147 Bw + 1.1 MMcfpd	108,982	55,022	11,915	Duck Creek
Conoco, Inc.	Steffan 2-2	Jul-95	9971' - 85'	F/1134 Bo + 0 Bw + 628 Mcfpd	20,153	2,220		Eland
Conoco, Inc.	Privratsky 12-2	May-95	9667' - 83'	F/ 2908 Bo + 0 Bw + 1454 Mcfpd	45,977	6,398	0	Eland
Conoco, Inc.	Kadrmas 3-1	Apr-95	9856' - 66	P/122 Bo + 160 Bw + 60Mcfpd	4,595	578	9,433	Eland
Conoco, Inc.	Ridl 11-1	Mar-95	9650' - 60' 9666' - 78' 9684' - 9700'	F/1752 Bo + 0 Bw + 808Mcfpd	115,232	10,421	0	Eland
Duncan Oil, Inc	Froehlich 1-19	Jul-95		Not yet released	21,884			Eland
Duncan Oil, Inc	LR 1-10	Jul-95		Not yet released	2,108			Eland
Duncan Oil, Inc	Patterson 1-24	Jun-95	9800' - 12'	F/498 Bo + 0 Bw + 249 Mcfpd	6,120			Eland
Duncan Oil, Inc	Ranchos 1-24	May-95	9626' - 38' 9643' - 56'	F/2016 Bo + 0 Bw + 1 MMcfpd	52,089	7,655	0	Eland
Duncan Oil, Inc	Steffan 1-14	Jun-95	10106' - 122'	F/396 Bo + 0 Bw + 192 Mcfpd	32,705	3,176	0	Eland
Duncan Oil, Inc	Klein 1-23	Mar-95	9608' - 18' 9624' - 34'	F/2571 Bo + 0 Bw + 1.2 MMcfpd	148,523	17,687	0	Eland
Duncan Oil, Inc	Knopik 1-11	Dec-94	9714' - 24' 9730' - 40' 9746' - 60'	F/2707 Bo + 0 Bw + 1.55 MMcfpd	269,293	60,635	4,069	Eland
Armstrong Op., Inc.	Haller 29-1	Jun-95	9622' - 34'	F/157 Bo + 55 Bw + 78 Mcfpd	5,617	1,399	2,982	Versippi
Armstrong Op., Inc.	Hondl 15-1	Jul-95	9544' - 66'	F/1615 Bo + 0 Bw + 807 Mcfpd *	91,029			Hiline
Duncan Oil, Inc.	Gress 1-14	Aug-95		Not yet released	5,525			Hiline
* Rocky Mountain Oil Journal				Total =	2,706,021	1,132,916	58,495	

Table 1. *Date of first production, initial potential, and cumulative production for wells with production data in the North Dakota Oil and Gas Division monthly production reports.*

the Bakken shale. Figure 3 shows the area encompassed by the onset of Bakken shale hydrocarbon generation as well as the area where mature Bakken hydrocarbon generation occurs. These Bakken shale maturity areas are shown in relation to the area that we interpret as being favorable for the occurrence of basal Lodgepole buildups (Fig 2). Although we present this map (Fig. 3) to provide information on the distribution of the Bakken shale and the area known to have generated hydrocarbons, we believe potential for production from the lower Lodgepole buildups exists where they do not overlie mature Bakken shales. Production of Bakken-sourced oil from reservoirs in the Canadian part of the Williston Basin which are miles from the area of mature Bakken supports this potential. In addition, organic-rich argillaceous beds within the Lodgepole itself have generated oil and are mature over a large area of North Dakota (Fig. 3a).

Others have suggested that Prairie Formation salt dissolution is responsible for not only the position of the Lodgepole buildups in the Dickinson area and elsewhere, but also led to the vuggy and fractured character of the reservoir rock. Figure 4 illustrates the present distribution of the Prairie salt as well as the interpreted original depositional limit of the salts. The limits of both the present and the depositional edges of the salt are about 40 miles north of the Dickinson area. Before this concept should be accepted, several factors must be considered, not the least of which is evidence for the Prairie salt ever having been present in the Dickinson area.

Several operators are using 3-D seismic methods in their efforts to locate Lodgepole buildups in the Dickinson area and elsewhere with varied success. While little is publicly known about the specifics of the methods

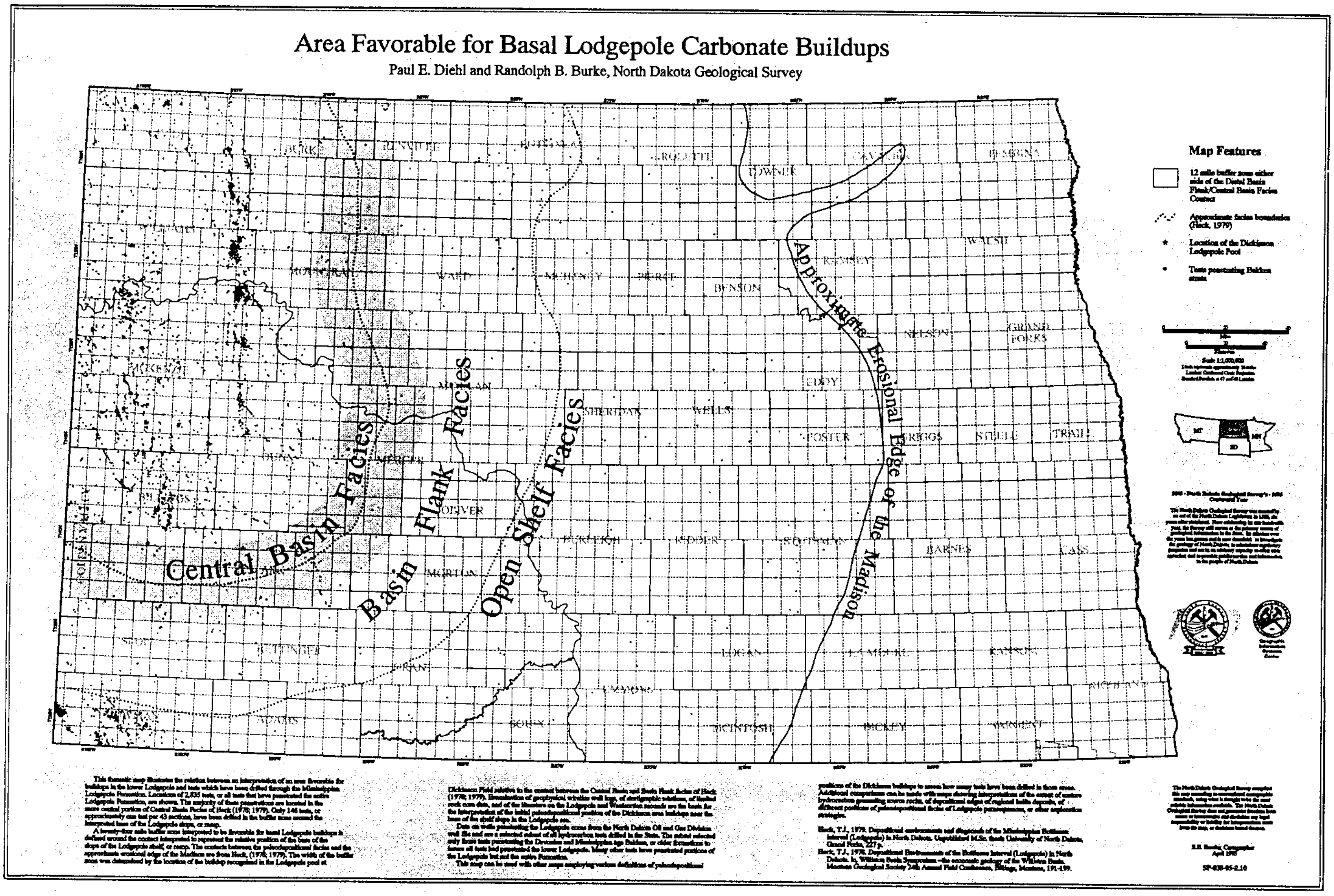


Figure 2. *Depositional facies and erosional edge of the Madison Group. The locations of 2,835 tests that have penetrated the Lodgepole Formation and a 24-mile-wide buffer zone believed to be favorable for lower Lodgepole carbonate buildups are also shown.*

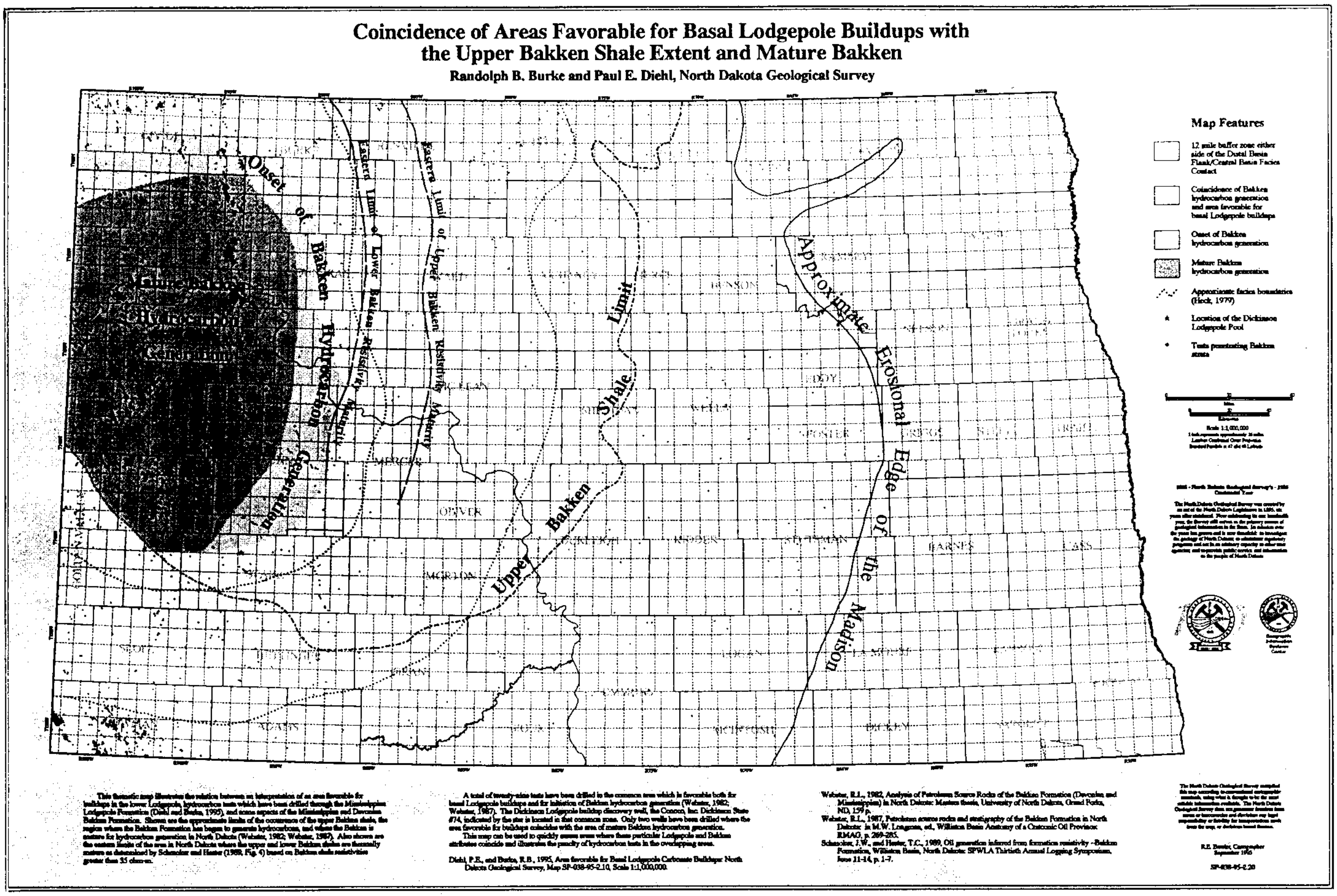


Figure 3. *The same base map as Figure 2, but showing the eastern limit of the upper Bakken Shale, the region where the Bakken has begun to generate hydrocarbons, and the area of mature Bakken hydrocarbon generation. Also shown are the eastern limits where the upper and lower Bakken shales are thermally mature.*

employed, the reported and rumored misses of buildups by tests intended to define the extent of the already drilled buildups might suggest that whereas this method may be capable of locating the tops or thicker parts of buildups, it may not be as good at defining the actual subsurface positions of the steeply dipping and irregular edges of these features.

Leasing

Most if not all of the leasable minerals in the Dickinson area are essentially all leased. Leasing activity has spread westward to the North Dakota - Montana border and beyond. Figures 5 and 6 show state tracts that were leased in the May and August state lease sales. Figure 7 shows the tracts nominated for the coming November 7th state lease sale. In addition to leasing in North Dakota, Lodgepole prospects are being generated and leasing is occurring in eastern and central Montana. A Lodgepole discovery outside the immediate Dickinson area would add impetus to an already "hot" play.

What are Waulsortian Mounds?

Waulsortian mounds are 330 to 360 million year old lens-like, or mound shaped, limestone buildups composed predominantly of massive calcareous mudstone containing the scattered, small skeletal remains of marine organisms. This type of mound was named after the village of Waulsort in Belgium near which they were first described in 1863.

Viewed from above, mounds are subcircular where they occur as solitary features, but are more elongate and irregular where they coalesce into large complexes. Mound complexes in Europe cover thousands of square miles but the width, or diameter, of a solitary mound is highly variable although its width is always many times greater than its height. A view from the side in a trench cut through a mound shows a conical to lens-like structure indicative of how the mound accumulated (Fig. 8). Mounds attain heights of hundreds of feet and their sides slope steeply at angles of 30° to 50°.

Close examination of the rocks comprising the mound finds that the majority (>60%) of the sediments are mud size (less than 0.00015 inches or 0.004 mm). This is interpreted to indicate that the mounds formed in calm waters, otherwise the mud would have been swept away by waves and currents. The remainder of the rock consists of calcareous cement (minerals precipitated out of solution into open voids) and sand-size skeletal fragments, consisting predominantly of bryozoans, sponges, crinoids, and brachiopods.

The community of organisms associated with mounds (Fig. 9) is not as diverse compared to that of a coral reef, and other than for their similarities in geometry, mounds should not be thought of as coral reefs. The skeletons of mound organisms are very delicate and indicate they could not flourish in the turbulent waters characteristic of coral reefs. However, persistent currents are important to mound organisms for delivery of food. Because the major mound dwelling organisms are attached to the bottom, or imbedded in the mud, they must filter food from the water that passes by them. None of the organisms are phototrophic, that is, capable of utilizing light to photosynthesize nutrients to build organic tissue. This makes them particularly well suited for deep and/or dirty water, and well adapted to live in the mud in which they are found. To help them trap food most of them stand erect on the ocean floor and are specially adapted to expose as much food-capturing surface area to the passing water as possible; crinoids have many feather-like "arms" at the top of a stalked body, bryozoans are like vertical sheets of window screen facing across the current, and sponges pump water throughout their entire body (Fig. 9). It is the presence of all these organisms obstructing the moving water that allows the mud to settle out around their bases and raise their community above the surrounding sea floor into a mound.

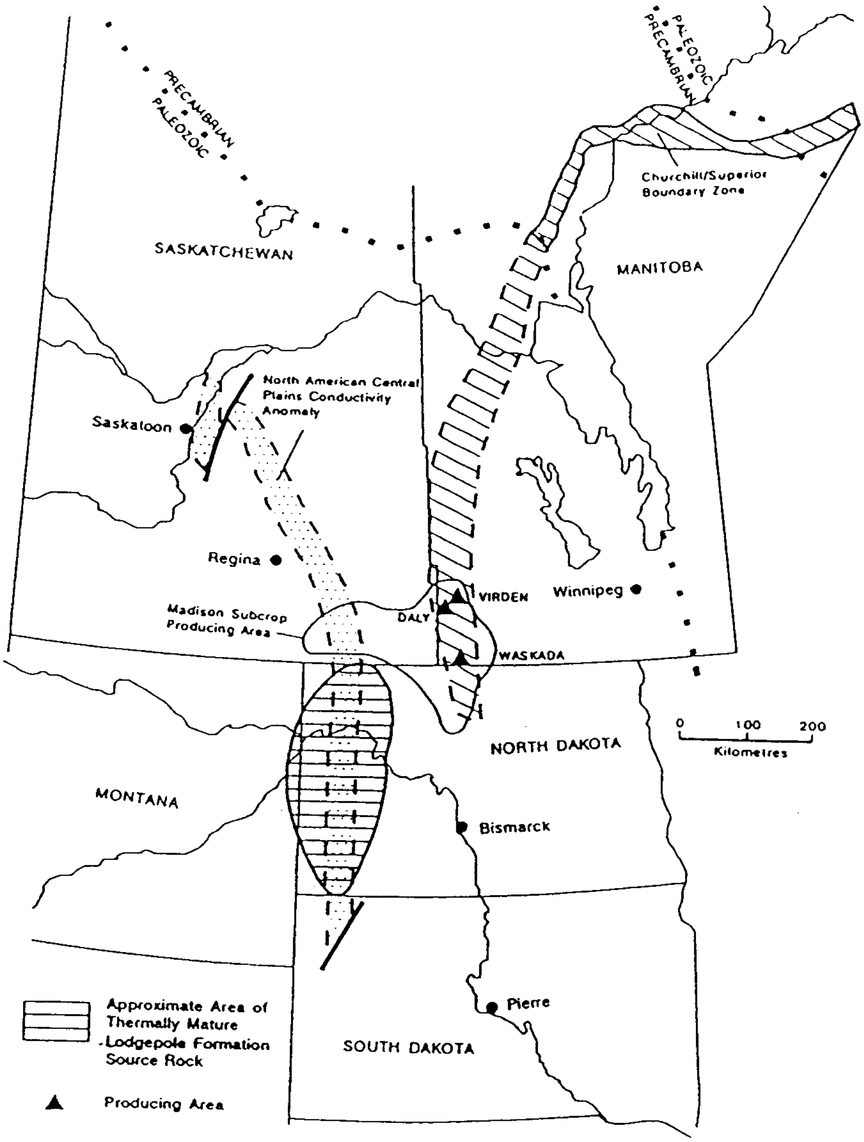


Figure 3a. *Family C oil-source systems (after Osadetz, pers. comm.). From C.D. Martiniuk and D. Barchyn, 1994.*

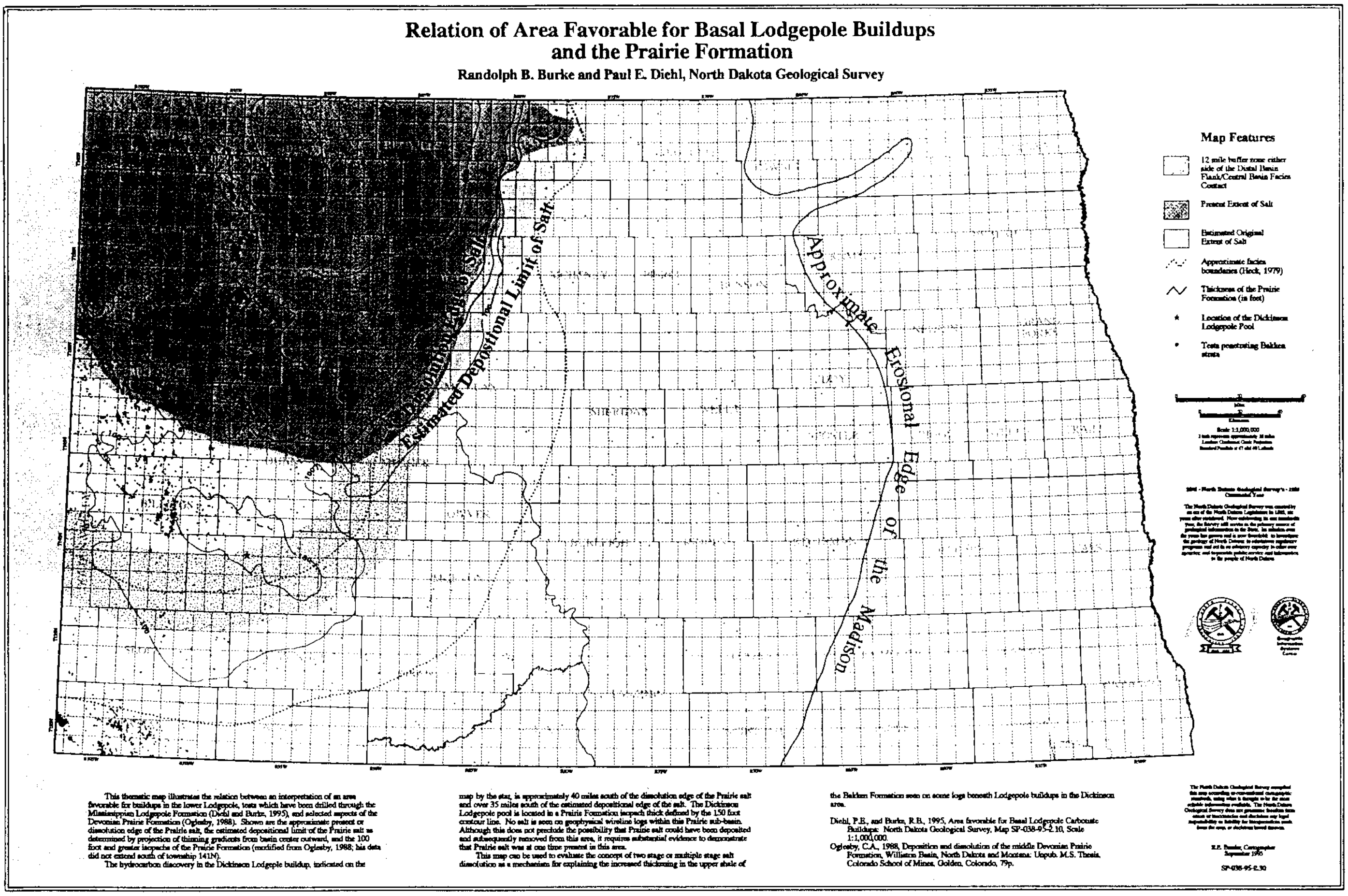


Figure 4. *Same base map as Figure 1 but showing the edge of the Prairie salt, the estimated depositional limit of the salt, and the 100 foot and greater isopachs of the Prairie Formation.*

How Do The Mounds At Dickinson, North Dakota, Compare?

There are many similarities between the buildups producing oil in the Dickinson area and Waulsortian mounds, but the differences are fundamental enough that the Dickinson mounds should not be referred to as true Waulsortian mounds; terms like buildups, mounds, or Waulsortian-like are more appropriate. The most important difference is the general lack of mud within the Dickinson buildups. Instead these mounds are dominated by sand-size sediment and cements. Similarities include their age, the dominance of bryozoan and crinoid skeletal components, and their geometry. The Dickinson mound complex has a subcircular geometry in map view (Fig. 10), and a flattened lens-like shape from a side view as seen on a cross section constructed from geophysical well logs (Fig. 11). The sides of the Dickinson mound are calculated to be a steep 40°. Recognizing that these mounds are different is important because, as you will read below, there is a spectrum of compositional and architectural types of buildups in this Williston Basin region. Recognition of mound variability opens up new plays within the Lodgepole Formation and is important to finding not only more of the Dickinson mound type, but also other types that are known to have produced significant economic quantities of oil in Canada.

Waulsortian-like Mounds in the Williston Basin and Central Montana

The presence of Waulsortian-like mounds in the Lodgepole Formation is well documented (Fig. 12) and their distribution is shown on a map illustrating the extent and thickness of the Lodgepole in the Williston Basin

May 1995 State Lease Sale

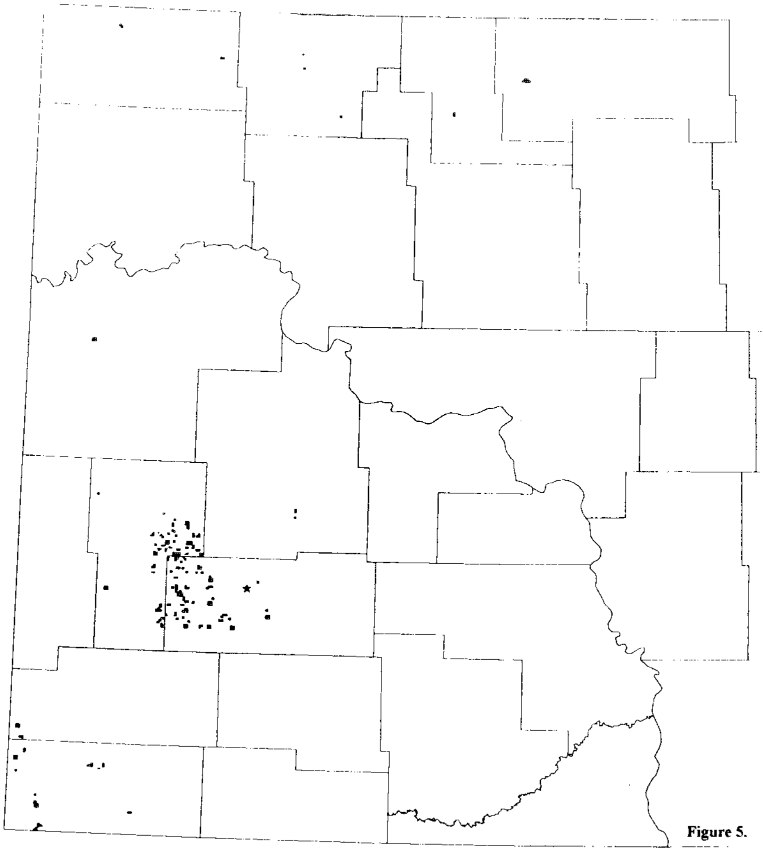


Figure 5.

August 1995 State Lease Sale

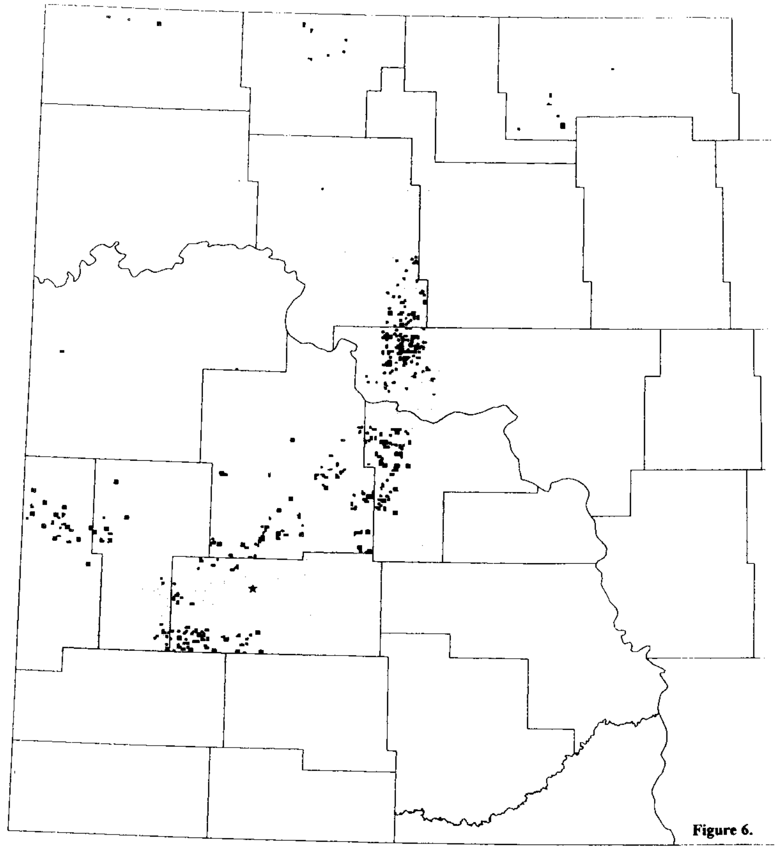


Figure 6.

November 1995 State Lease Sale

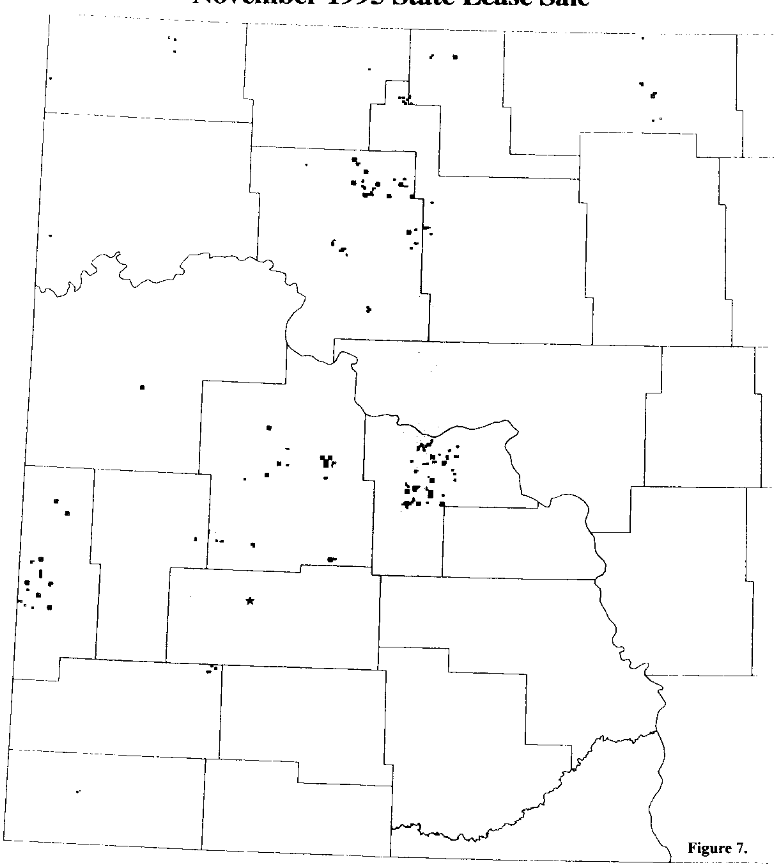
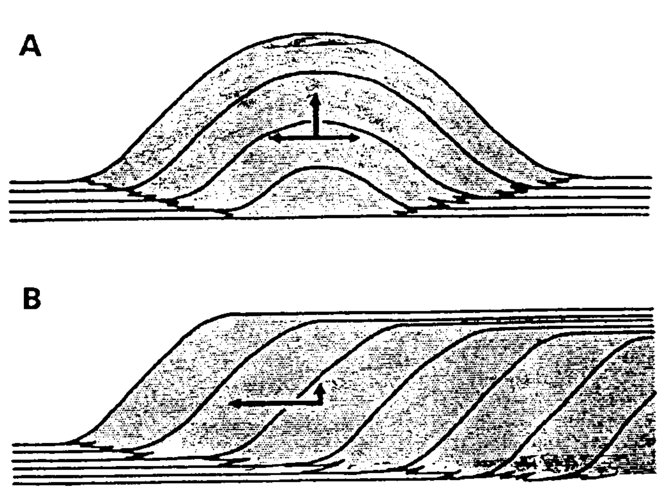
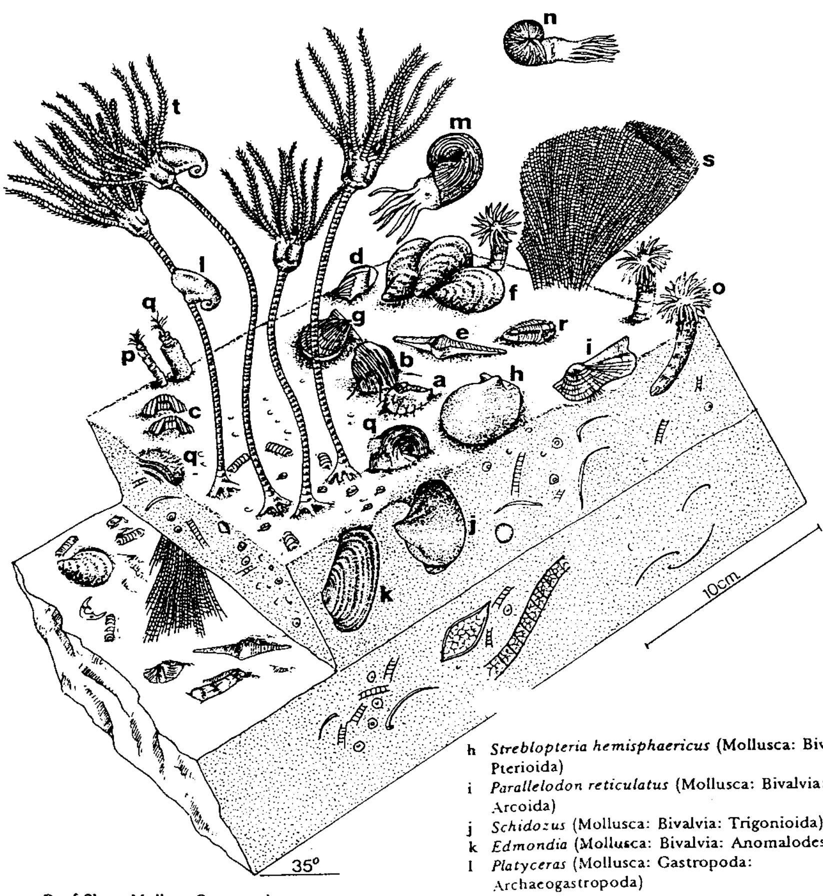


Figure 7.

Figures 5, 6, and 7. *Comparison of May, August, and November 1995 state lease sales in western North Dakota. The Lodgepole play is expanding throughout the Central Basin Facies (shaded area), the area interpreted to be favorable for lower Lodgepole carbonate buildups. Star shows location of discovery well.*

Figure 8. *Diagrammatic cross sections of growth forms of Waulsortian mudbanks. A. Mound form. B. Lens form. The arrows indicate relative rates and directions of growth. Modified from Lees (1961). From, Burke and Diehl, 1993.*





Lower Reef Slope Mollusc Community

- a *Plicatifera plicatilia* (Brachiopoda: Articulata: Strophomenida)
- b *Alitaria* (Brachiopoda: Articulata: Strophomenida)
- c *Pugnax pugnus* (Brachiopoda: Articulata: Rhynchonellida)
- d *Tylothyris subconica* (Brachiopoda: Articulata: Spiriferida)
- e *Fusella triangularis* (Brachiopoda: Articulata: Spiriferida)
- f *Posidoniella vetusta* (Mollusca: Bivalvia: Pterioida)
- g *Aviculopecten* (Mollusca: Bivalvia: Pterioida)
- h *Streblopteria hemisphaericus* (Mollusca: Bivalvia: Pterioida)
- i *Parallelodon reticulatus* (Mollusca: Bivalvia: Arcoida)
- j *Schidozus* (Mollusca: Bivalvia: Trigonioida)
- k *Edmondia* (Mollusca: Bivalvia: Anomalodesmata)
- l *Platyceras* (Mollusca: Gastropoda: Archaeogastropoda)
- m *Goniatites maximus* (Mollusca: Cephalopoda: Ammonoidea)
- n *Bollandoceras* (Mollusca: Cephalopoda: Ammonoidea)
- o *Amplexus coralloides* (Coelenterata: Anthozoa: Rugosa)
- p *Serpula* (Annelida)
- q *Fistulipora* (Bryozoa: Ectoprocta)
- r *Brachymetopus* (Arthropoda: Trilobita)
- s *Polypora* and *Fenestella* (Bryozoa: Ectoprocta)
- t crinoids (Echinodermata: Crinozoa)

Figure 9. *Marine organisms associated with Waulsortian mounds. The skeletons of many mound organisms, such as the palm-like crinoids and fan-like bryozoans, are delicate and indicate they could not flourish in the turbulent, relatively shallow waters characteristic of coral reefs. From, Mundy, D., 1978, in W.S. McKerrow.*

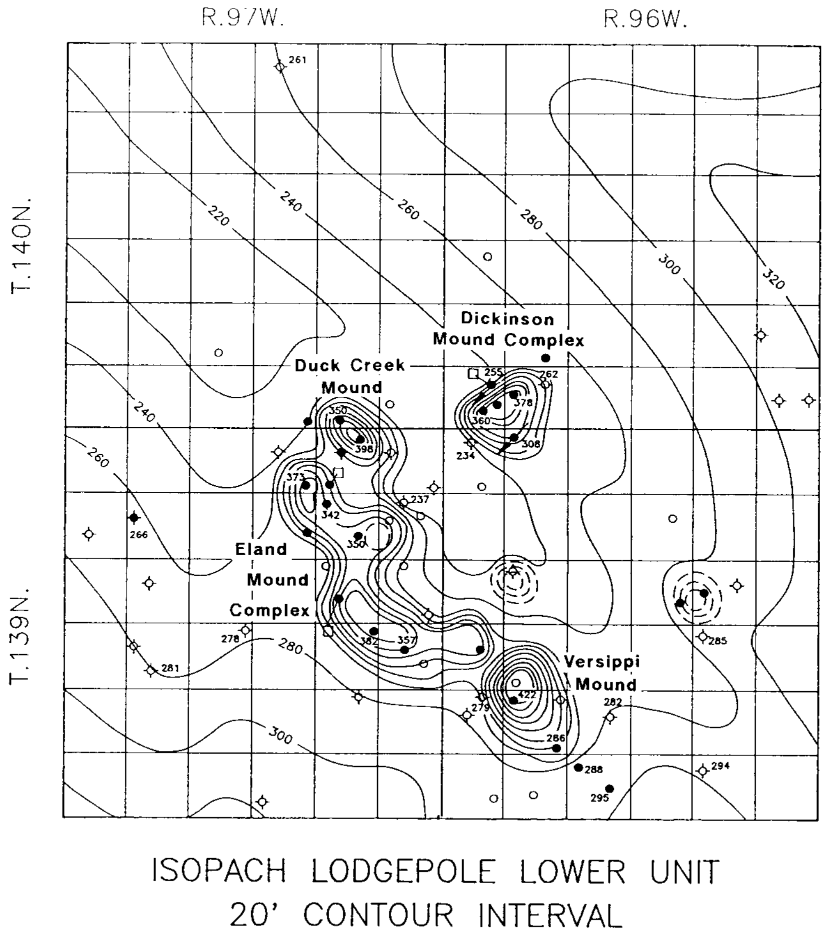


Figure 10. *A map showing the thickness of the lower Lodgepole Formation. Note the subcircular areas and irregular, elongate area enclosing others. These represent the mounds and mound complex respectively.*

region (Fig. 13, *see page 19*). For decades Lodgepole mounds have been known from exposures in the mountains of central Montana, but it was only recently with examination of oil-well cores that mounds were known to occur in Saskatchewan and North Dakota. Oil has been produced from the flanking beds of mounds of similar age in Alberta, in the Hardeman Basin of Texas, in the Appalachia fold belt of Tennessee, and in Illinois from associated deposits.

The fact that Waulsortian-like mounds in the Williston Basin occur in clusters has recently been recognized from outcrops in Montana. Numerous clusters occur in three widely separated mountain ranges in central Montana and some coalesce to form mound complexes. In the Big Snowy Mountains, four clusters of mounds were observed with a spacing between clusters of 2.5, 0.85, and 3.6 miles. These observations are consistent with the development and distribution of mounds found in the Dickinson area (Fig. 10) and imply that more mounds are likely outside of the Dickinson area.

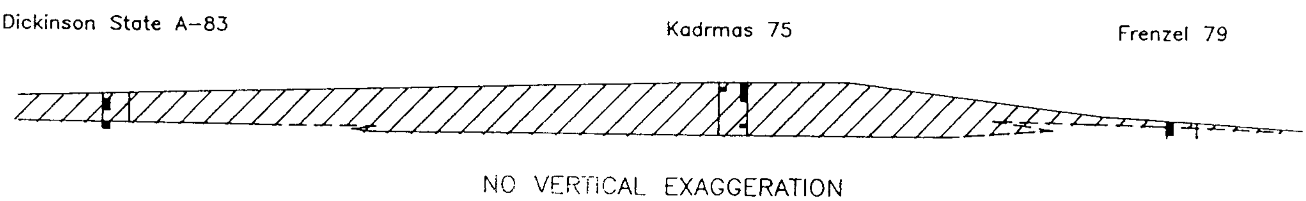


Figure 11. *Cross-section illustrating the broad, relatively low relief of the Dickinson mound complex. From Burke and Diehl, 1995a.*

Examination of the Montana outcrops further indicated that there is a significant diversity in the compositional and architectural style of Lodgepole buildups, and that they occur throughout the Lodgepole Formation and not just at the bottom (Fig. 12). Based on these observations, a depositional model showing potential environments suitable for development of a spectrum of Lodgepole buildups was constructed (Fig. 14). Recognition of this spectrum of Lodgepole buildups has broad implications to Lodgepole exploration. It expands the potential area for Lodgepole exploration across the entire basin flank facies (Fig. 15). The viability of this concept is supported not only by production of 39 million barrels of oil from the Lodgepole in Manitoba from distinctively different buildups from those at Dickinson, but also by analogy with oil production from sediments associated with similar mounds in the Illinois basin. Buildups can occur from the top of the shelf slope to the basin floor and on, and around, raised intrabasinal blocks. The association of the Dickinson Lodgepole buildups with faults has been documented (Figs. 16 and 14), and will contribute to the success of future Lodgepole mound exploration.

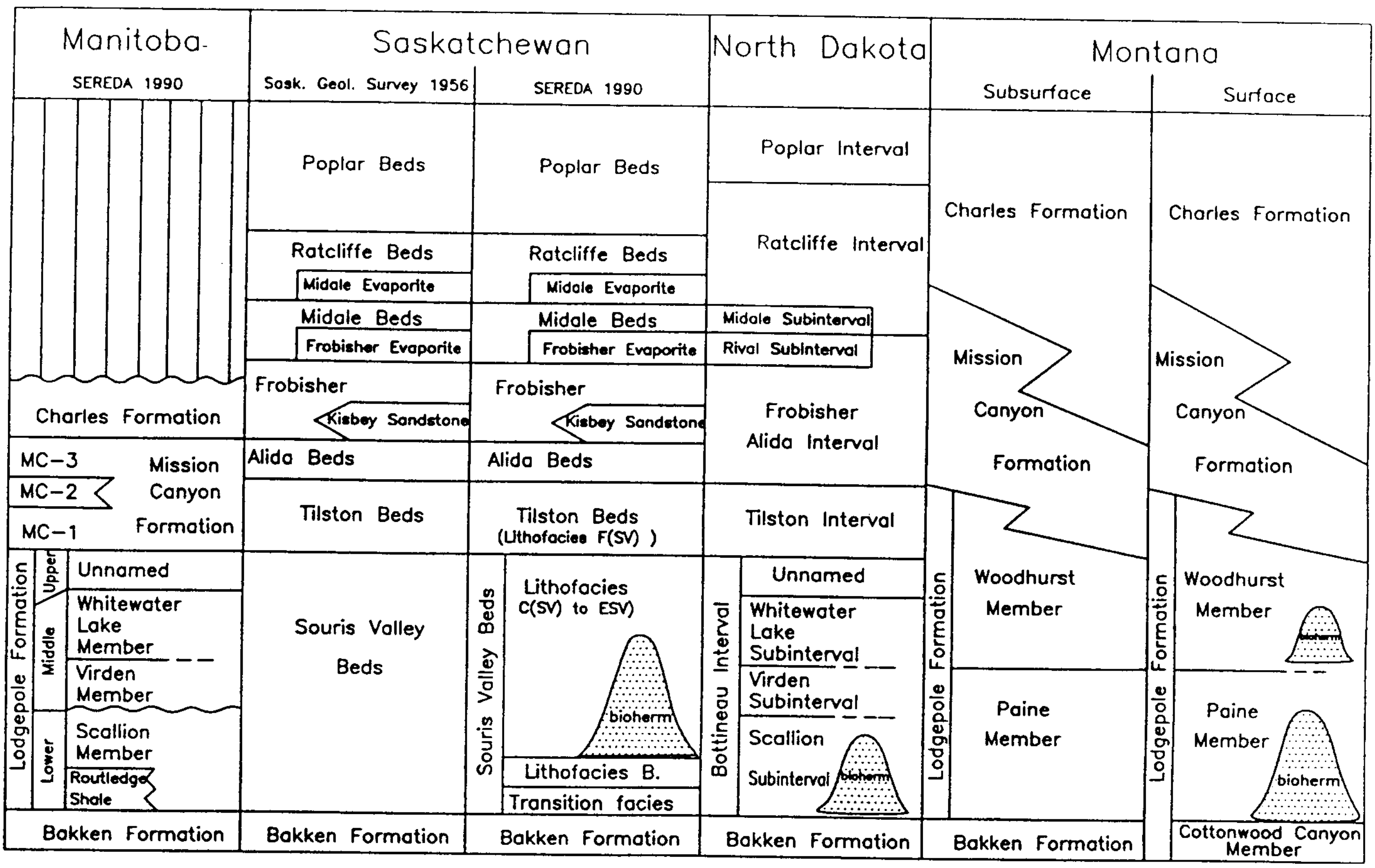


Figure 12. *Stratigraphic nomenclature in the Williston Basin and central Montana modified from Sereda (1990). Illustrated are the stratigraphic positions of known carbonate buildups. This shows that carbonate buildups occur throughout the Lodgepole Formation and are not restricted to the bottom of the Formation. From Burke, Diehl and Heck, 1995.*

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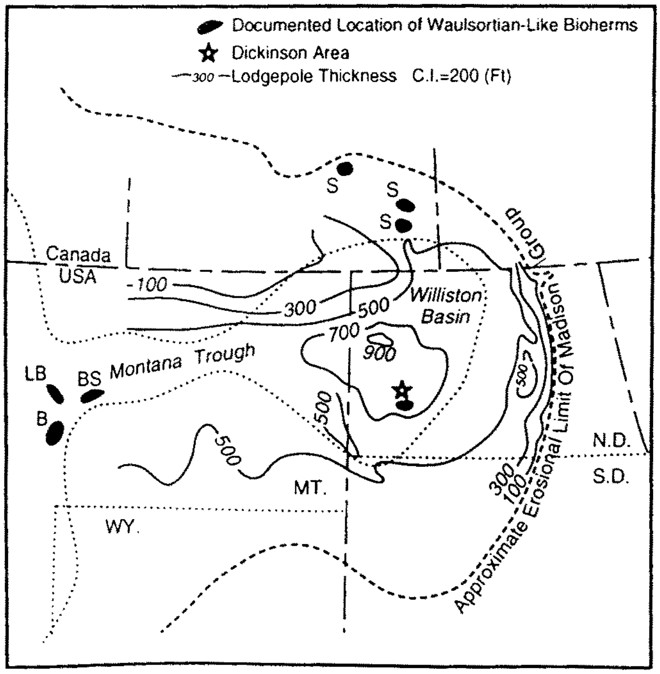


Figure 13. *Regional isopachous map of the Lodgepole Formation and the locations of known or inferred Waulsortian mounds. LB - Little Belt Mountains; B - Bridger Range; BS - Big Snowy Mountains. Modified from Sereda and Kent, 1987. From Burke and Diehl, 1995b.*

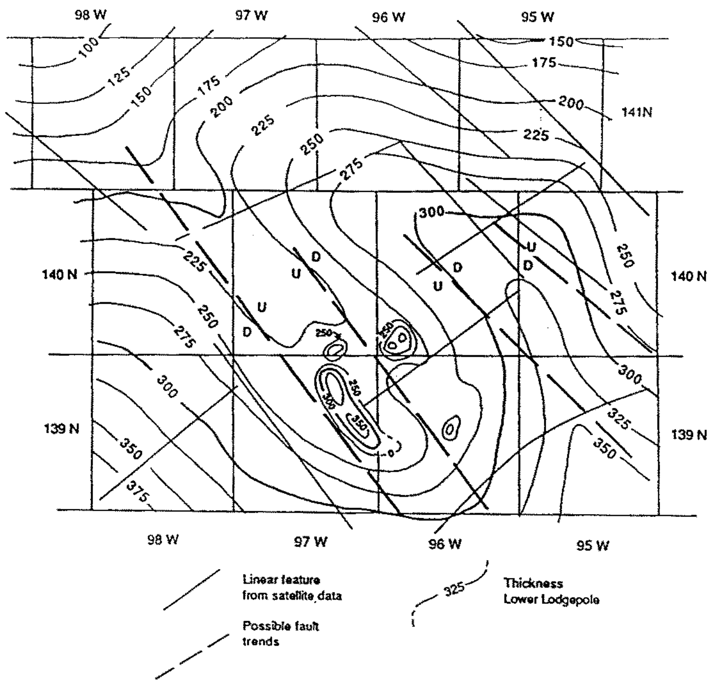


Figure 16. *Isopach map of lower Lodgepole (base to middle Lodgepole shale), showing strong NW-SE trends. Waulsortian-type buildups occur within or along the margins of an apparent high (isopach thin) that may be fault bounded. Contour interval 25 ft; 50 ft within mounds. Modified from Shurr, Ashworth, Burke, and Diehl, 1995. From Montgomery, 1995.*

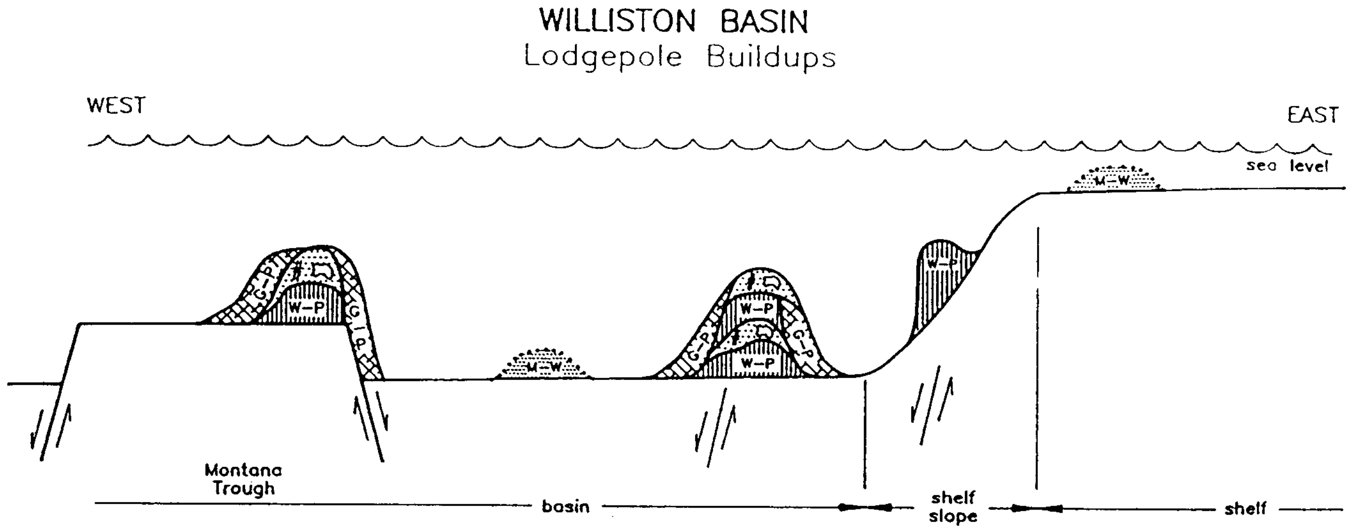


Figure 14. *Schematic interpretation of the potential paleogeographic positions for Lodgepole Formation carbonate buildups. The cross section extends from central Montana in the west through the Williston Basin to central North Dakota in the east. Buildups may occur on, or around, intrabasinal high blocks, on the basin floor, at the base of, or across, the slope/ramp, or at the top of the slope/ramp. Skeletal composition and architectural style varies according to paleodepositional location in response to hydrodynamic and photic variations. Mound geometries, muddier textures, and aphotic, delicate organisms will characterize deeper water settings, whereas lens geometries, grainy textures, and photic, massive, durable-organisms will characterize shallow water settings. The buildups in the Bridger Range and probably Dickinson areas are interpreted to have developed in deep water; those in Swimming Woman Canyon in shallower water associated with an intrabasinal block; and those in the Little Belt Mountains and Saskatchewan in the shallowest setting, possibly high on a block or the slope/ramp respectively. The abundance of grainy textures associated with the Dickinson area buildups and the moderate diversity of organisms suggests the possibility that there may have been a period of shallower water in the buildup's growth history.*

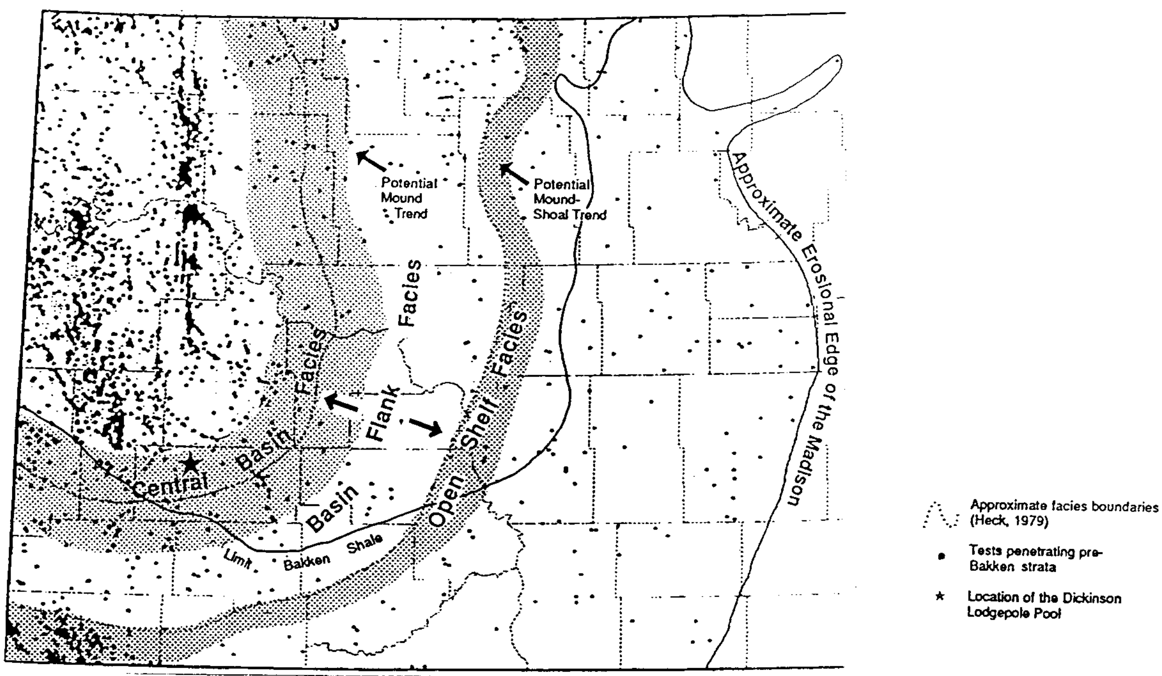


Figure 15. *Map showing wells penetrating the Bakken Shale, with overlay of Lodgepole facies trends and interpreted area favorable for growth of Waulsortian-type mounds. Note small number of deep penetrations within this area (roughly 1 well average for every 37 sections). Modified from Diehl and Burke, written communication, 1995. From Montgomery, 1995.*

Micro-Jaws I! (aka, Scolecodonts)

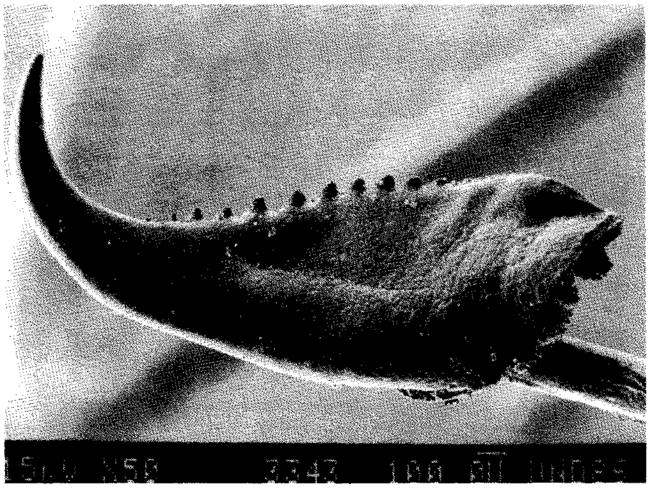
by Mark Luther

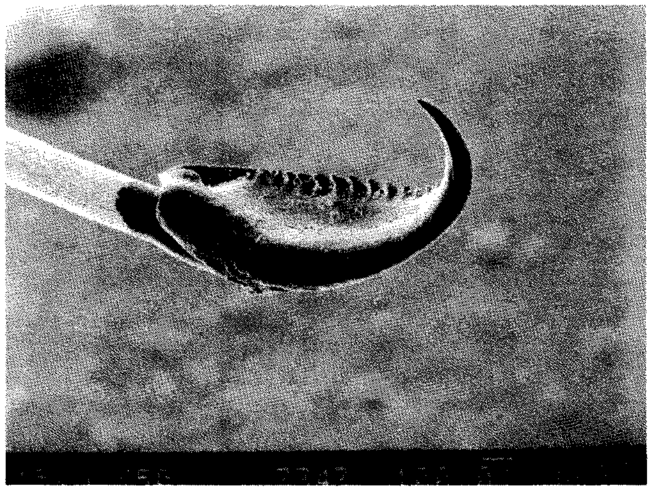
For the last 600 million years or so, there has been a fearsome carnivore living in shallow water and along beaches of the world's seas and oceans. This creature prowls through its marine environment, devouring its prey with a frightening set of toothed jaws. Much like a shark, only the teeth or jaws of this creature are commonly preserved as fossils.

The fossil remains of this animal are found in North Dakota in geologic formations that were deposited when the state was covered by a shallow sea. I recovered numerous fossilized remains of this creature while studying Mississippian-age (about 350 million year old) rocks from the Mission Canyon Formation. These rocks formed from sediments deposited in a shallow sea in what is now Bottineau County, North Dakota. Photographic images of the terrible, toothed jaws of this animal are shown on the next few pages (Figs. 1-12). What was this fearsome beast, and what are its fossil remains called?

The beast was a worm! A marine worm of the class Polychaetia, order Errantida to be a bit more precise. Individuals belonging to that order commonly have toothed jaw elements called scolecodonts, examples of which are illustrated here (Figs.1-12). Scolecodonts and traces of burrowing (Fig. 13) are typically the only fossil evidence we have of this variety of fauna that is preserved in rocks. Evidence such as this indicates that marine worms (probably similar in appearance to that illustrated in Figure 14) were present and active during deposition of the sediments that later became stone.

The exceptionally well preserved fossils pictured here are photographs of images created by a scanning electron microscope. The largest of the scolecodonts pictured is only about 2 millimeters (1/16th of an inch) long; the smallest about 0.4 millimeters. I discovered the scolecodonts while performing a microscopic examination of a rock core taken from a depth of 4,180 feet below surface by the California Oil Company. The core



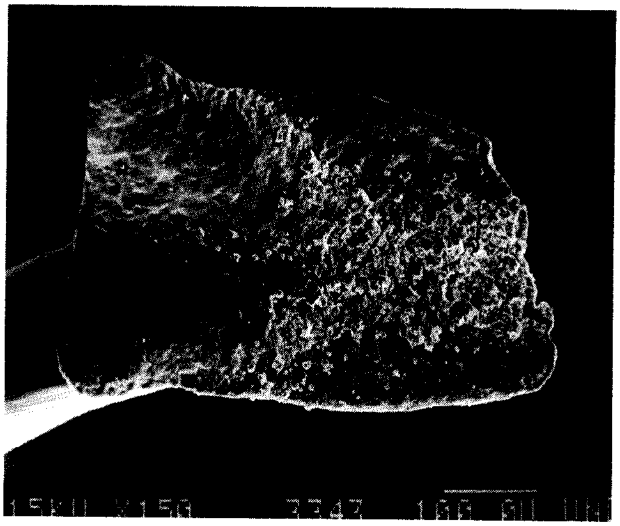


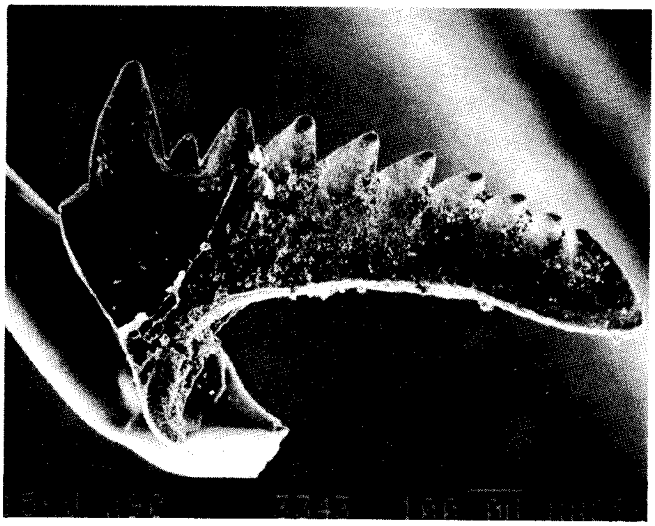
Figures 1-3 (top to bottom). *Scolecodonts (forcep element) shown at equal magnification to illustrate size range. Scale bar equals 100 microns (0.1 millimeters). Specimens mounted on thin rods (Figs. 1 and 3), or on a flat plate.*

containing the scolecodonts consisted of light-gray, argillaceous, burrowed, dolomudstone. Numerous plant fragments, and megaspores were associated with the scolecodonts in this core.

Initially, the scolecodonts seen in the core were thought to be conodonts, a similar looking but unrelated microfossil. This caused some excitement, as conodonts are very useful for determining ages of rocks, and none were known to have been found in the Mission Canyon Formation in this area. Unfortunately for geologists though (fortunately for the worms!), scolecodonts changed very little through time (millions of years) when compared to conodonts. This limits the usefulness of using scolecodonts for determining the age of rocks they are found in, but probably means that they were better suited to their environment than the conodonts, which changed rapidly through time.

Though scolecodonts and conodonts are somewhat similar in appearance and function, there are noteworthy differences. Scolecodonts are hollow and composed of an organic material called chitin, while conodonts are solid and composed of calcium phosphate. Scolecodonts are the jaw elements of a type of segmented worm, but conodonts are the jaw elements or teeth of a very early vertebrate similar in appearance to a small eel. Scolecodonts are found in rocks and sediments ranging in age from Cambrian (570 million years old) through recent, while conodonts are limited to rocks deposited during Ordovician through Triassic periods (500-200 million years old). Scolecodonts and conodonts are similar in that both can be used as indicators of thermal maturation of rocks. That is, they change reflectance or color based on the temperature that they have been subjected to. This is important for oil exploration due to the fact that rocks capable of oil generation (source rocks) must reach a certain temperature (65°-150° C) before oil is generated. Knowing the locations of mature versus immature source rocks aids oil explorationists in selecting areas for drilling.





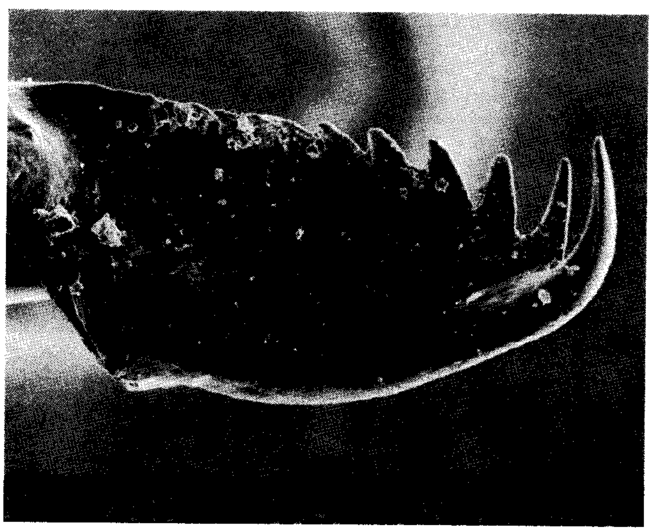


Figure 4 (top). *A scolecodont (carrier element) showing indentations from dolomite crystals (some of which are still present). Scale bar equals 100 microns.*

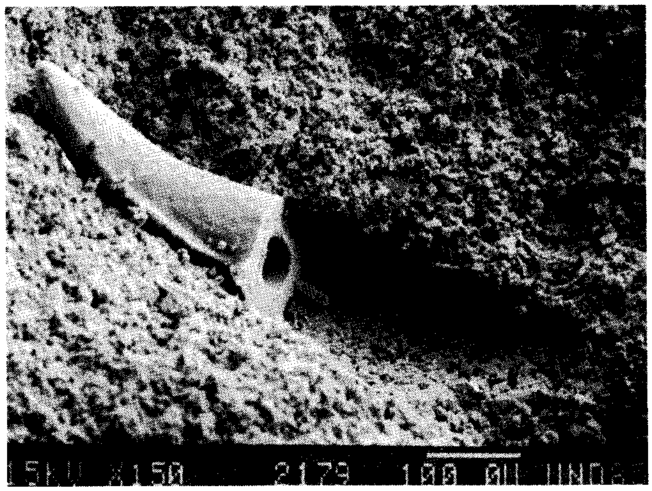
Figure 5 (middle). *A dental plate element. Scale bar equals 100 microns.*

Figure 6 (bottom). *A forcep? showing dolomite crystal indentations. Scale bar equals 100 microns.*

Since the dolomudstone containing the scolecodonts was a carbonate rock, it could be dissolved with acid, leaving non-carbonate materials such as organic matter and other insoluble materials as a residue. Although less reactive, dilute acetic acid was used instead of hydrochloric acid for removing the scolecodonts from the fine dolomite matrix they were contained in (Fig. 7). This was done as a precaution, due to the fact that conodonts are more prone to damage by hydrochloric acid than by acetic; however no conodonts were found. With the exception of the jaw assemblage (Figs. 9-12) and the broken jaw forcep (Fig. 7), all of the scolecodonts illustrated were extracted from the rock with dilute (10%) acetic acid.

Dolomite crystal impressions seen on the surface of several jaw elements (Figs. 4 and 6) suggest that the dolomite matrix they were contained in had formed prior to deep burial and compaction of both the jaws and original sediments. This kind of information about the timing of dolomite formation (early, near-surface versus late, deep-burial), is extremely important in reconstructing the original depositional environment and locating potential oil reservoirs or migration paths.

Although I've been able to label the scolecodonts as to order and class, further definition of them has been difficult. There just are not many examples of Mississippian-age scolecodonts shown in the literature. Hopefully, some micropaleontologist reading this will have the answers and be willing to share them with me! The jaw elements that I found appear most similar to those found in the family Paulinitidae, although that family is thought to have ended prior to the Mississippian period. Likely, the exact name (genus and species) of the scolecodonts recovered from Bottineau County will remain a mystery for some time. For those interested,



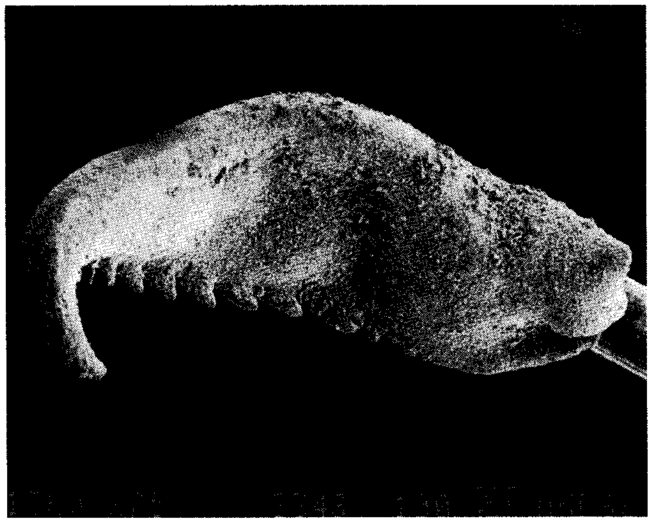


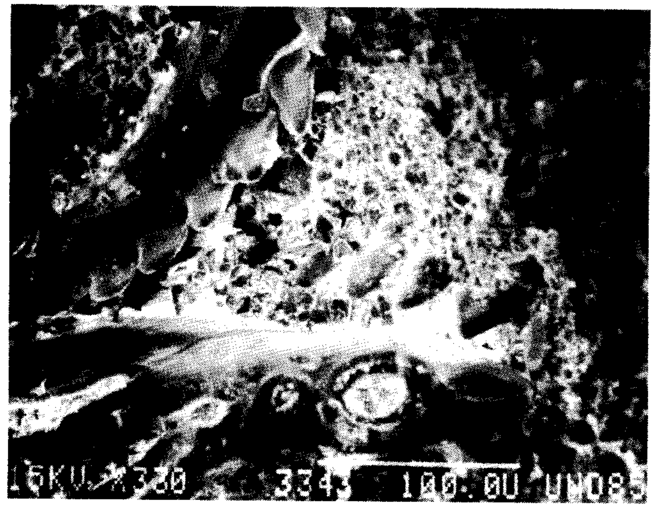
Figure 7 (top). *A forcep tip imbedded in a dolomite matrix. Note the hollow nature of the scolecodont. Scale bar equals 100 microns.*

Figure 8 (middle). *A scolecodont (forcep element) that has been replaced by the mineral pyrite. Scale bar equals 100 microns.*

Figure 9 (bottom). *A scolecodont assemblage imbedded in a dolomite matrix. Note the symmetrical impression left where jaw fragments are missing. Scale bar equals 100 microns.*

the scolecodont specimens are stored in the paleontological collection of the University of North Dakota Department of Geology and Geological Engineering (Accession number A2660).

Even though tiny, scolecodonts are interesting and potentially useful fossils that reveal additional information about North Dakota's varied geologic past.



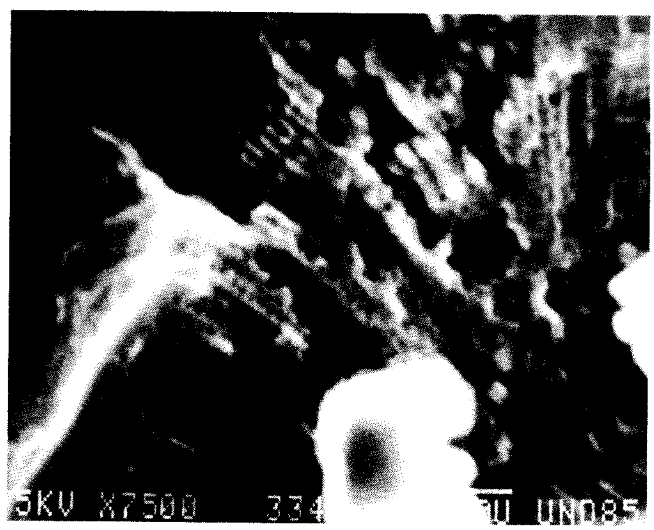


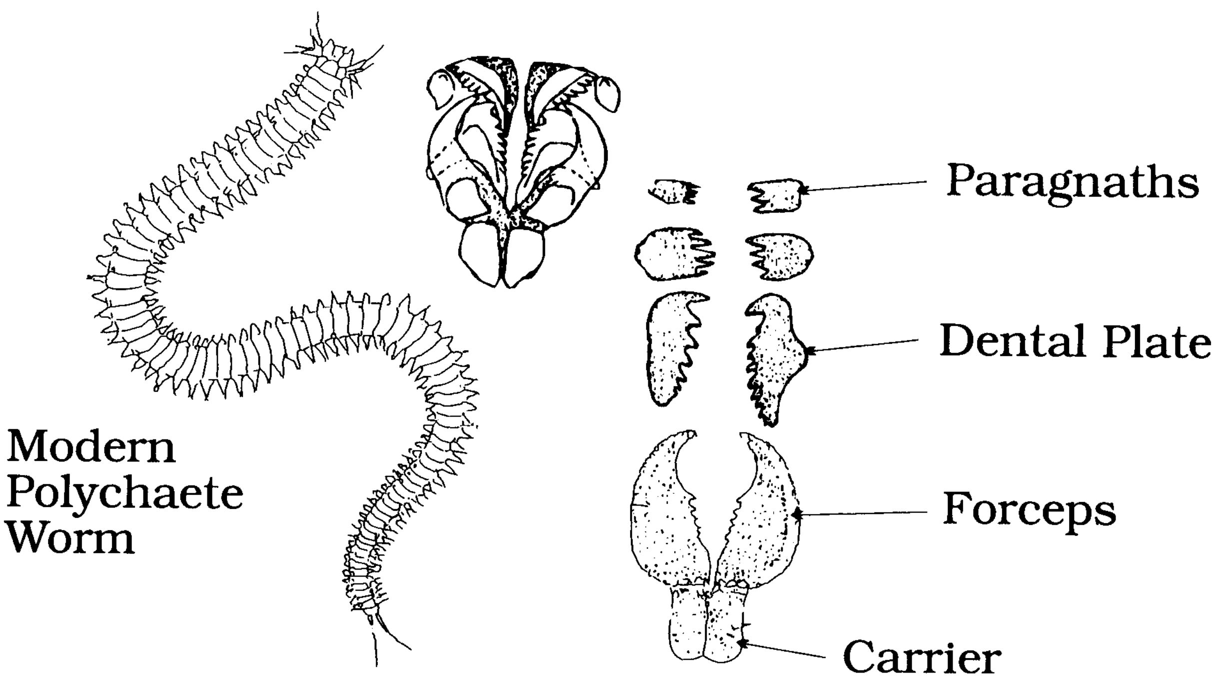
Figure 10 (top). *A closer view of Figure 9, showing some dental plates in a dolomite matrix. Scale bar 100 microns.*

Figure 11 (middle). *A closer view of Figure 10 showing where teeth have been broken off a hollow dental plate. Scale bar 10 microns.*

Figure 12 (bottom). *A closeup of one of the broken teeth in Figure 11, showing the incredibly well preserved "honey comb" structure of the scolecodont. Scale bar equals 1 micron.*

Figure 13. *A photograph of the light-gray, argillaceous, burrowed, dolomudstone core from which some of the scolecodonts were recovered. Core taken from a depth of 4180.5 feet below the ground surface, in the Mississippian-age (about 350 million-year-old) Mission Canyon Formation. Note that there are both vertical and horizontal burrows shown. Width of core shown approximately 5.5 centimeters (2.25 inches).*

Figure 14. *Illustration of modern polychaete worm (left) and scolecodont jaw elements (right).*

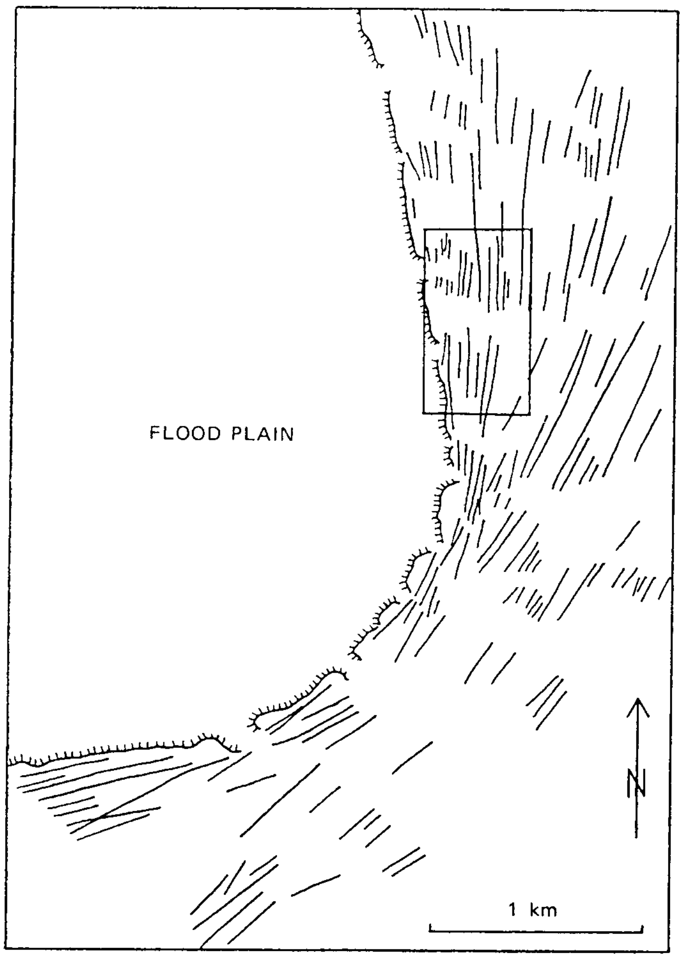


BISON TRAILS AND BUFFALO BOULDERS

by Bob Biek

Two of the more unusual landforms found in North Dakota are those created by once vast herds of bison. The bison, apparently, trampled shallow grooves across the prairie, forming bison trails, and created depressions around many of the larger glacial erratics, now known as buffalo boulders.

The bison trails were first recognized in North Dakota in the mid-1970s by former University of North Dakota geologist, Lee Clayton. The trails are shallow trenches generally a few feet deep, several feet wide, and several hundred feet long. Where they cross narrow depressions, the trails often form low ridges. The ridges probably formed as sediment was tracked downslope by thousands of hooves. Bison trails are common throughout the grasslands of the northern plains, and, in fact, many have previously been misinterpreted as bedrock joints or glacial features.

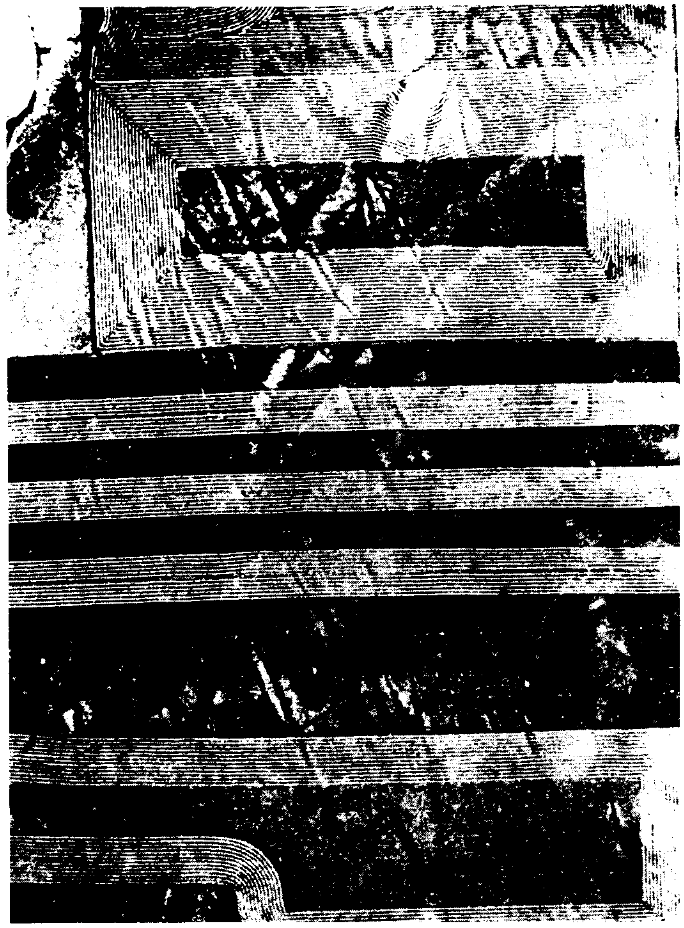


Bison trails are straight or gently curved, and show up on aerial photographs as dark lines. The trails tend to parallel high-relief features such as bluffs and steep slopes, and otherwise often trend northwest to southeast, parallel to the prevailing wind direction. The trails formed, then, when sufficient numbers of bison converged on water holes or were funneled along a particular path by the constraints of topography. The trails are best preserved where they cross areas of sandy soil, such as outwash plains, perhaps because such soils are more permeable, allowing precipitation to infiltrate the soil rather than run off, eroding the slope and trails. Even so, I have seen similar trails that cross areas of glacial till.

Throughout the glaciated portion of North Dakota, large glacial erratics often seem to lie in a bowl-shaped depression. The depression formed when bison rubbed against the rock, trampling and loosening the soil which was subsequently blown away. Often the rock itself has been polished by their dirty, gritty hides. Buffalo boulders, as they are called, have been recognized on the northern plains for a long time, though today they are perhaps better known as cattle rubbing stones.

Bison trails around a southeast bend of the Souris River flood plain in sections 25 and 36, T155N, R77W, McHenry County. Hachured line marks the bluff at the edge of the floodplain. From Clayton, 1975, Bison trails and their geologic significance: Geology, v. 3, no. 9, p. 498-499.

Bison trails crossing a braided esker in secs. 28 and 33, T. 159 N., R. 66 W., Towner County, North Dakota. Area is 1.2 km wide. South is toward top so that shadows fall away from observer, preventing apparent negative relief. From Clayton (1975).



Bison trails trending north-northwest in western half of sec. 33, T. 142 N., R. 70 W., Kidder County, North Dakota. Area is 1 km wide. South is toward top. Material is collapsed superglacial fluvial sand and gravel. From Clayton (1975).

Limestone erratic near Spiritwood Lake, North Dakota. This 12-foot diameter boulder (note trowel at right) is surrounded by a depression formed as bison, and later cattle, rubbed against the rock, trampling and loosening the soil which was subsequently blown away.

CURRENT GEOLOGIC INVESTIGATIONS

compiled by Bob Biek

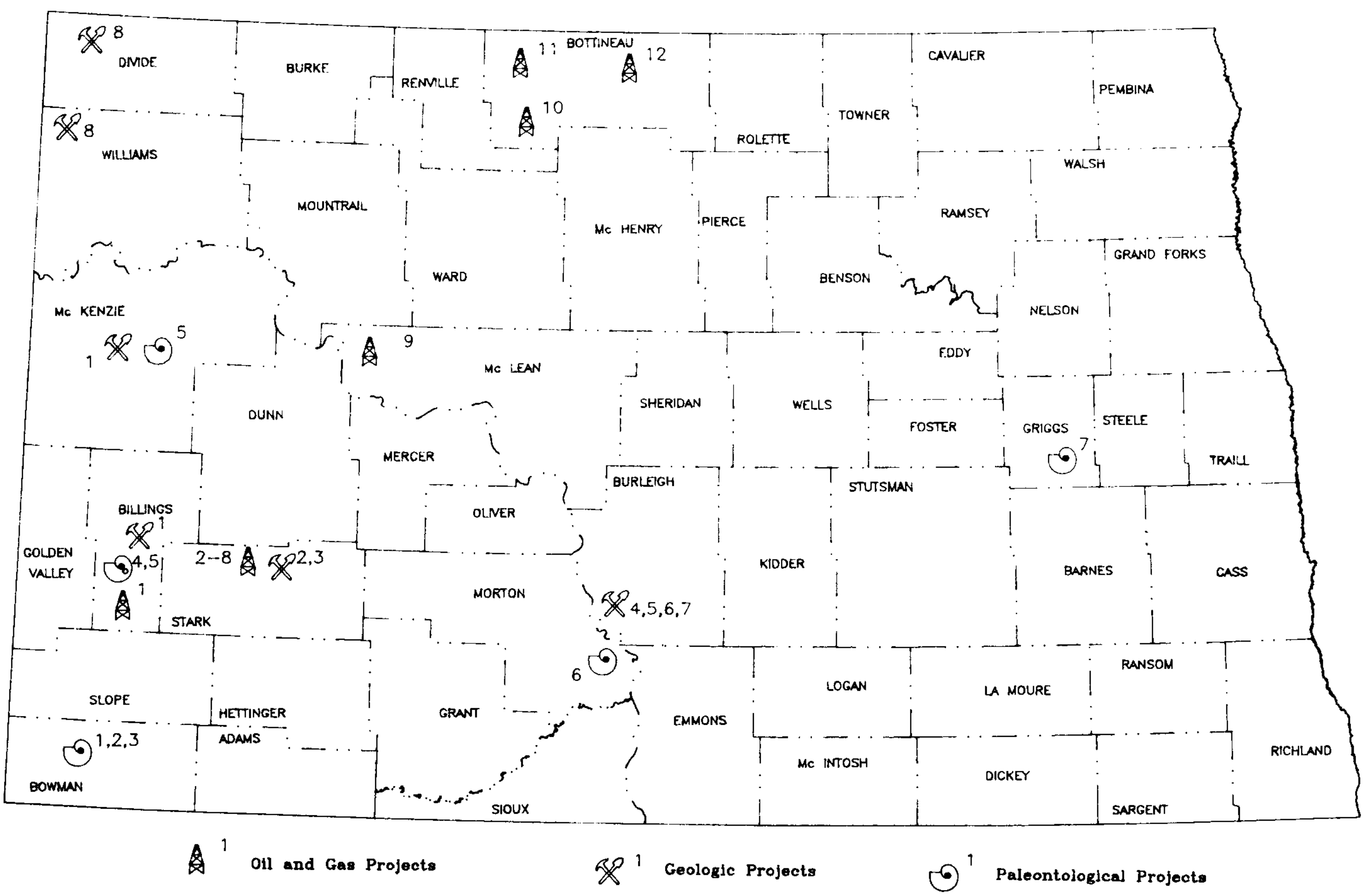
In addition to our numerous regulatory and service functions, NDGS staff are involved in the geologic investigations outlined below. The investigations are grouped under three headings: oil and gas projects, geologic projects, and paleontologic projects. In each case, the titles of projects completed in 1995 are italicized; all other (non-italicized) investigations are in progress.

The map below shows the location of site-specific projects; the symbol and number directs one to the appropriate project catagory and title. Investigations of a regional or statewide nature are not shown on the map, but are listed under each project heading.

Regional oil and gas projects include those numbered 13 through 30;

Regional geologic projects include those numbered 9 through 31; and

Regional paleontologic projects include those numbered 8 through 11.



Oil and Gas Projects

1. Rocky Ridge Field Study - Paul Diehl.

2. *Buildup (Waulsortian-like Mound) Facies*, 1995, by R.B. Burke: *in* R.W. Fisher, ed., 7th International Williston Basin Symposium Core Workshop Volume.

3. *The Lodgepole Formation Carbonate Buildup Play and Waulsortian Mounds in North Dakota*, 1995, by R.B. Burke and P.E. Diehl: *in* 22nd Annual Fall Land Institute Workshop Notes, The Denver Association of Petroleum Landmen, p. 1-19.

   A Non-Technical Discussion of the Geology of the Dickinson-Lodgepole Oil Play, 1995, by R.B. Burke and P.E. Diehl: The Rocky Mountain Landman, vol. 14, issue 1, p. 10-11.

   Discoveries of Oil in Waulsortian Mounds in the Lodgepole Formation, Williston Basin, 1995, by R.B. Burke and P.E. Diehl: Houston Geological Society Bulletin, v. 37, no. 10, p. 41-44.

   Log Analysis, Buildup and Proximal Buildup Facies, 1995, by P.E. Diehl: *in* R.W. Fisher, ed., 7th International Williston Basin Symposium Core Workshop Volume.

   North Dakota's Dickinson Lodgepole Discovery: A Preliminary Exploration Model, 1995, by Julie LeFever, S.P. Halabura (Northrim Exploration Ltd.), D.W. Fischer (independent), and Carol Martiniuk (MEM): Oil and Gas Journal, August 14, 1995, p. 50-59.

8. *Tectonic Controls on the Lodgepole Play in Northern Stark County, North Dakota — Perspectives from Surface and Subsurface Studies*, 1995, by G.W. Shurr (SCSU), A.C. Ashworth (NDSU), R.B. Burke, and P.E. Diehl: *in* L.D.V. Hunter and R.A. Schalla, eds., 7th International Williston Basin Symposium, 1995 Guidebook, p. 203-208.

9. Lucky Mound Field Study - Randy Burke.

10. *The Wiley Field: A Mission Canyon Depositional Model with No Topographic Barrier*, 1995, by M.R. Luther: *in* L.D.V. Hunter and R.A. Schalla, eds., 7th International Williston Basin Symposium, 1995 Guidebook, p. 450-451.

11. South Antler Creek Field Study - Tom Heck.

12. Landa Field Study - Julie LeFever.

13. Lodgepole Fm. play - Paul Diehl and Randy Burke.

14. Bakken source systems - Julie LeFever and Leigh Price (USGS).

15. Central-basin gas - Tom Heck and Julie LeFever.

16. *A Preliminary Comparison of Waulsortian Mound Facies in the Williston and Illinois Basins*, 1995, by R.B. Burke and Z. Lasemi(ISGS): *in* L.D.V. Hunter and R.A. Schalla, eds., 7th International Williston Basin Symposium, 1995 Guidebook, p. 115-128.

17. *Diversity and Distribution of Lodgepole Buildups in the Williston Basin and Central Montana*, 1995, by R.B. Burke and P.E. Diehl: North Dakota Academy of Science, v. 49, p. 58.

18. *Introduction — Lodgepole Buildups (Waulsortian-like Mounds) in the Williston Basin and Central Montana*, 1995, by R.B. Burke and P.E. Diehl: *in* R.W. Fisher, ed., 7th International Williston Basin Symposium Core Workshop Volume.

19. *Area Favorable for Basal Lodgepole Carbonate Buildups*, 1995, by P.E. Diehl and R.B. Burke: NDGS map no. SP-038-95-2.10, 1:1,000,000.

20. Relation of Area Favorable for Basal Lodgepole Buildups and the Prairie Formation, in press, by R.B. Burke and P.E. Diehl: NDGS map no. SP-038-95-2.30, 1:1,000,000.

21. *Coincidence of Areas Favorable for Basal Lodgepole Buildups with the Upper Bakken Shale Extent and Mature Bakken*, in press, by R.B. Burke and P.E. Diehl: NDGS map no. SP-038-95-2.20, 1:1,000,000.

22. 1995 State Lease Parcels, in press: NDGS map in SP-038-95-2.40, 1:1,000,000.

23. *Assessment of Undiscovered Resources in Petroleum Plays: U.S. Portion of Williston Basin and North-Central Montana*, by T.S. Dyman (USGS), J.A. Peterson (USGS), J.W. Schmoker (USGS), C.W. Spencer (USGS), D.D. Rice (USGS), K.W. Porter (MBMG), D.A. Lopez (MBMG), T.J. Heck, and W.R. Beeman (USGS): *in* L.D.V. Hunter and R.A. Schalla, eds., 7th International Williston Basin Symposium, 1995 Guidebook, p. 323-340.

24. *Lodgepole Formation — A Brief Regional Perspective*, 1995, by T.J. Heck: *in* R.W. Fisher, ed., 7th International Williston Basin

Symposium Core Workshop Volume.

25. *Fault Control on Late Stage Diagenetic Creation and Enhancement of Reservoirs*, 1995, by R.A. Inden (LSSI-Denver) and R.B. Burke: *in* L.D.V. Hunter and R.A. Schalla, eds., 7th International Williston Basin Symposium, 1995 Guidebook, p. 351-366.

26. *North Dakota Horizontal Drilling Activity Update*, 1995, by Julie LeFever, *in* Ken Stalwick, compiler, Third International Williston Basin Horizontal-Well Workshop.

27. *Relationship of Salt Patterns to Hydrocarbon Accumulations, North Dakota Williston Basin*, 1995, by J.A. LeFever and R.D. LeFever (UND): *in* L.D.V. Hunter and R.A. Schalla, eds., 7th International Williston Basin Symposium, 1995 Guidebook, p. 69-88.

28. *Hydrocarbon Resources of the North Dakota Williston Basin*, 1995, by R.D. LeFever (UND) and T.J. Heck: *in* L.D.V. Hunter and R.A. Schalla, eds., 7th International Williston Basin Symposium, 1995 Guidebook, p. 279-290.

29. *Lithofacies and Petroleum Potential of the Birdbear Formation (Upper Devonian), Southwestern Manitoba and North-Central North Dakota*, 1995, by C.D. Martiniuk (MEM), H.R. Young (Brandon Univ.), and J.A. LeFever: *in* L.D.V. Hunter and R.A. Schalla, eds., 7th International Williston Basin Symposium, 1995 Guidebook, p. 89-102.

30. *Petroleum Frontiers*, 1995, by S. Montgomery (with special acknowledgements to R. Burke, P. Diehl, G. Shurr (SCSU), E. Marker (Petroleum Information, Denver), D. Liller (Cattas Resources, Denver), B. Lenz (Duncan Oil, Denver), and P. Duncan (Gresham Resources, Vancouver)): Petroleum, v. 12, no. 2, 108 p.

Geologic Projects

1. Geologic mapping of Theodore Roosevelt National Park - Bob Biek.

2. Geology of the Dickinson area - Bob Biek and Ed Murphy.

3. *Geology of the Davis Buttes, Dickinson North, Dickinson South, and Lehigh Quadrangles, Stark and Dunn Counties, North Dakota*, 1995, by R.F. Biek and E.C. Murphy: NDGS Open-File Report 95-1, 64 p, 5 plates, 1:24,000.

4. *Urban Outcrops — Building Stones of the North Dakota Capitol Grounds*, 1995, by R.F. Biek: North Dakota Academy of Science, v. 49, p.66.

5. *Urban Outcrops — Building Stone as an Educational Resource*, 1995, by R.F. Biek: Geological Society of America Abstracts with Programs, v. 27, no. 3, p. 40.

6. *Slope Stability in the Bismarck-Mandan Area*, 1995, by Edward C. Murphy: North Dakota Academy of Science, v. 49, p. 69.

7. Geologic mapping of the Bismarck-Mandan urban corridor - Ed Murphy and Bob Biek.

8. Sodium sulfate deposits in North Dakota - Ed Murphy.

9. *Glaciotectonic Map of North America*, 1995, by J.S. Aber, J.P. Bluemle, J. Brigham-Grette, D.J. Sauchyn, and D.L. Ackerman: Geological Society of America Map and Chart Series MCH079, 1:6,500,000.

10. *Little Faults and Folds on the Prairie — Evidence for Neogene Tectonism in North Dakota*, 1995, by A.C. Ashworth (NDSU), R.F. Biek, E.C. Murphy, and G.W. Shurr (SCSU): Geological Society of America Abstracts with Programs, v. 27, no. 3, p. 35.

11. Field Guide to Tertiary Tectonism in the Northern Great Plains - A.C. Ashworth (NDSU), R.C. Benton (Badlands N.P.), R.F. Biek, E.C. Murphy, G.W. Shurr (SCSU), K.K. Stevens (SDSMT), and D.O. Terry, Jr. (UN-Lincoln).

12. Digital shaded-relief of North Dakota (with thematic varients) - Rod Bassler and Mark Luther.

13. Profiles of North Dakota's geology - Bob Biek and John Bluemle.

14. *The Mineral Industry of North Dakota*, 1995, by R.H. Wood II (USBM) and R.F. Biek: U.S. Bureau of Mines 1993-1994 Annual Report, p. 179-181.

15. History of the North Dakota Geological Survey - John Bluemle.

16. *1895-1995 — North Dakota Geological Survey's First Century*, 1995, by J.P. Bluemle: North Dakota Academy of Science, v. 49, p. 52.

17. Bibliography and Index of North Dakota Geology - Larry Greenwood (MSU), Tom Heck, and Bob

Biek.

18. Red River Valley surficial geologic map - Ken Harris (MGS) and Mark Luther.

19. Red River Valley Quaternary stratigraphy - Ken Harris (MGS) and Mark Luther.

20. *Stratigraphy, Vertebrate Fossil Record, and Age of the Arikaree Formation in North Dakota*, 1995, by J.W. Hoganson, E.C. Murphy, and N.F. Forsman (UND): Geological Society of America Abstracts with Programs, v. 27, no. 3, p. 59.

21. *Lithostratigraphy and Biochronology of the Chadron and Brule Formations in Southwestern North Dakota*, 1995, by J.W. Hoganson, E.C. Murphy, and N.F. Forsman (UND): Geological Society of America Abstracts with Programs, v. 27, no. 3, p. 59.

22. Roadside Geology of North Dakota - John Hoganson, Ed Murphy, and Don Schwert (NDSU).

23. Flakable lithic resources in North Dakota - Mark Luther and Robert Christensen (NDDOT).

24. *Flakable Lithic resources in North Dakota*, 1995, by M.R. Luther and R.C. Christensen (NDDOT): North Dakota Academy of Science, v. 49, p. 71.

25. Trace elements in Cretaceous shales - Mark Luther and David Brekke (EERC).

26. The occurence of uranium in Fort Union, White River, and Arikaree strata in southwestern North Dakota - Ed Murphy.

27. *Coal and Subsurface Mineral Exploration Drill Hole Maps*, 1995, by E.C. Murphy and H. Jirges: NDGS OFRs 94-2, 94-3, 94-4, 94-5, 94-6, 1:125,000.

28. *The Cretaceous/Tertiary Boundary in South-Central North Dakota*, 1995, by E.C. Murphy, D.J. Nichols (USGS), J.W. Hoganson, and N.F. Forsman (UND): NDGS Report of Invesigation No. 98, 74 p., 2 pl.

29. Coal stratigraphy in western North Dakota - Ed Murphy, Romeo Flores (USGS), Bill Keighin (USGS), Peter Warwick (USGS), Doug Nichols (USGS), and Gary Stricher (USGS).

30. *History of Glacial research in North Dakota*, 1995, by J.R. Reid (UND) and J.P. Bluemle: North Dakota Academy of Science, v. 49, p. 55.

31. Regional Context for Tertiary Tectonism in the Northern Great Plains — G.W. Shurr (SCSU), A.C. Ashworth (NDSU), R.C. Benton (Badlands N.P.), E.C. Murphy, and R.F. Biek.

Paleontology

1. Paleontology of the Chadron Formation at the Medicine Pole Hills site - John Hoganson.

2. *The Medicine Pole Hills Local Fauna — A Chadron Formation (Eocene) Vertebrate Assemblage from Bowman County, southwestern North Dakota*, 1995, by D.A. Pearson (Pioneer Trails Regional Museum) and J.W. Hoganson: Geological Society of America Abstracts with Programs, v. 27, no. 3, p. 79.

3. *The Medicine Pole Hills Local Fauna — Chadron Formation (Eocene:Chadronian), Bowman County, North Dakota*, 1995, by D.A. Pearson (Pioneer Trails Regional Museum) and J.W. Hoganson: North Dakota Academy of Science, v. 49, p. 65.

4. *Champsosaurus gigas Erickson — A Restored and Mounted Skeleton (ND94-225.1) in the North Dakota State Fossil Collection*, 1995, by J.M. Campbell and J.W. Hoganson: North Dakota Academy of Science, v. 49, p. 64.

5. Paleontology of Theodore Roosevelt National Park - John Hoganson.

6. Stratigraphy and Paleontology of the Cretaceous Hell Creek Formation, Stumpf Site, Morton County, North Dakota - John Hoganson.

7. Paleontology of the Cooperstown Pierre Shale site - John Hoganson.

8. *Cartilaginous Fishes from the Fox Hills Formation (Cretaceous:Maastrichtian), North Dakota*, 1995, by J.W. Hoganson, J.M. Erickson (St. Lawrence Univ), and F.D. Holland, Jr. (UND emeritus): North Dakota Academy of Science, v. 49, p. 60.

9. Paleontology of the Breien Member of the Hell Creek Fm. - John Hoganson.

10. Vertebrate paleontology of the Fox Hills Formation in North Dakota - John Hoganson.

11. *A Symposium on North Dakota Geology*, 1995, by J.W. Hoganson (editor), North Dakota Academy of Science, v. 49, p. 49-71.

Earth Science Education

by Bob Biek

The American Association of State Geologists recently completed the *Earth Science Education Source Book*. This 115-page source book is a compendium of earth-science-education materials available from the nation's 50 state geological surveys. The book's compiler, Robert Fakundiny, State Geologist of New York, notes that the book "is primarily intended to be a comprehensive quick reference for teachers seeking resources for their classrooms, but also to be useful to post-secondary instructors and hobbyists, mineral and fossil collectors, and anyone interested in earth-science-information products from State Geological Surveys."

The *Earth Science Education Source Book* will soon be made available as photocopies through individual state geological surveys. Single copies are available free upon request. To order, please contact Sheila Senger, our publications clerk.

Another useful resource, the *Earth Science Education Resource Directory*, is available from AGI, the American Geological Institute. This directory has descriptions of educational resources from more than 170 earth-science organizations. Subject categories include atmosphere, biosphere, environment, hydrosphere, solid earth, and space and planetary sciences. To order, send $19.95 ($14.95 for teachers and members of AGI Member Societies) to: AGI Publications Center, P.O. Box 205, Annapolis Junction, MD 20701 (telephone 301-953-1744).

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NEW PUBLICATIONS

Area Favorable for Basal Lodgepole Carbonate Buildups, 1995, by Paul E. Diehl and Randolph B. Burke: NDGS map no. SP-038-95-2.10, scale 1:1,000,000. $10.00.

This map, shown reduced from its original full-color version on page 11, shows the paleodepositional facies of the Lodgepole Formation and the erosional edge of the Madison Group as defined by NDGS geologist Tom Heck. Superimposed on this map are the locations of 2,835 tests that have penetrated the Lodgepole Formation and a 24-mile-wide buffer zone that straddles the contact between the Central Basin and Basin Flank Facies. This buffer zone is the area believed to be favorable for carbonate buildups in the lower Lodgepole Formation.

Coincidence of Areas Favorable for Basal Lodgepole Buildups with the Upper Bakken Shale Extent and Mature Bakken, in press, by Randolph B. Burke and Paul E. Diehl: NDGS map no. SP-038-95-2.20, scale 1:1,000,000. $10.00 when available.

This map, also shown reduced from its original full-color version on page 12, is expected to be available late in 1995. In addition to the information shown on the map above, it shows the eastern limit of the upper Bakken Shale, the region where the Bakken has begun to generate hydrocarbons, and the area of mature Bakken hydrocarbon generation. Also shown are the eastern limits in North Dakota where the upper and lower Bakken shales are thermally mature.

Outside Publications

Burke, Randolph B. and Diehl, Paul E., 1995, *The Lodgepole Formation Carbonate Buildup Play and Waulsortian Mounds in North Dakota: in* 22nd Annual Fall Land Institute Workshop Notes, The Denver Association of Petroleum Landmen, p. 1-19.

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