NEWSLETTER
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Industrial Commission of North Dakota, North Dakota Geological Survey

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Massive Waulsortian-type buildup from the Mississippian Lodgepole Formation, Big Snowy Mountains (Swimming Woman Canyon), Montana. Similar reef-like deposits occur in the Lodgepole Formation of the Williston Basin in Saskatchewan and have been postulated in North Dakota. Around the "oil patch" there is much talk about the new Conoco Inc., Dickinson State #74 well producing from such a deposit. Core data showing internal lithologic character, fossil content and distribution, and the attitude of strata will probably be required to adequately address the question of Waulsortian carbonate mud mounds. See article on page 6. *Photo courtesy of Jim Ehrets, Reserve Characterization Consortium, Boulder, Colorado.*

FEATURES

DEPARTMENTS

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NEWSLETTER
NDGS

NDGS NEWSLETTER
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FROM THE STATE GEOLOGIST

by John P. Bluemle

State Geological Surveys and Economic Development

I recently received a copy of a report compiled by the Colorado Geological Survey Committee, a group of geologist members of the American Institute of Professional Geologists. The report was done to provide background material on the Colorado Geological Survey that would be useful to state policy makers concerned about the organization, funding, staffing, and role of the Survey.

To compile their report, the Colorado group decided to look at what other states are doing. They begin: *"We have collected, evaluated and compared relevant information on the geological surveys of all seven states contiguous to Colorado, as well as seven additional state surveys--Alabama, California, Illinois, Nevada, North Dakota, Texas, and West Virginia--all of which are considered to be among the best and most successful in the United States."*

Some of the committee's findings have application beyond Colorado and I think it would be interesting to review them. The report's introduction is succinct and I'll quote directly from it:

"State geological surveys appear to be useful things for a state to have. Large or small, rich or poor, resource-endowed or not, all 50 states have one. A few states have shut down their geological surveys from time-to-time, but as they are useful and inexpensive, they always seem to be revived. Usually, the principal roles of state geological surveys are:

- *identification and mitigation of geologic hazards;*
- *assistance to government in geologic matters and in land-use management and planning;*
- *geologic mapping and evaluation of the earth's surface, including soils;*
- *water resource and/or environmental monitoring, control and remediation are additional survey responsibilities in many states;*
- *and in states with commercially exploitable natural resources:*
    - *identification, mapping and description of mineral and/or energy resources;*
    - *publication of detailed studies describing these resources;*
    - *basic applied research designed to aid industry in exploration for new sources of mineral and/or energy resources, which sometimes includes geologic mapping, and geophysical and/or geochemical surveys;*
    - *active promotion of exploration activities and responsible development as a means of increasing natural resource wealth of the state, as a source of employment, revenues and taxes;*
    - *maintain inventories of geologic materials and data useful in mineral and/or energy resource studies; and*
    - *education of the public and governmental officials concerning resource occurrence, availability, and development and the economic and environmental consequences of resource development."*

The report was intended to make people more aware of the Colorado Geological Survey and to build constituencies supportive of the survey. The compilers hoped to reach the general public, industry, local communities, educational and environmental groups, and state government officials. They quickly confirmed the same thing we already knew--that outside of the geologic community, the geological survey is little known, and less understood. Even legislators and officials who, although they are aware of the existence of, and may be sympathetic to the role of the geological survey, are nonetheless unaware of its potential, especially in the economic development area.

Of the 14 state geological surveys reviewed, the NDGS is average in terms of its budget. Last biennium, North Dakota, with a population of about 700,000 people, spent $1.44 per capita annually to support the geological survey — Kansas and Nebraska, with over $2.00 per capita, were highest; Colorado, with $0.31, was lowest. The size of the NDGS ("full-time professional staff per capita") is also average among the states reviewed. The report provides considerable additional information, including that related to economic development.

A geological Survey is one of the few state agencies that can indirectly return more funds to the state than have been invested in it — far more. Like most states, the NDGS allocates about 40 percent of its budget for economic development studies. The NDGS has always had an important role in developing the state's petroleum resources. The recent Horizontal Drilling Workshop (*see article below*) is just one example of our ongoing work in this area.

HORIZONTAL DRILLING WORKSHOP

by
William A. McClellan

The NDGS and Saskatchewan Energy and Mines sponsored a one day horizontal drilling workshop in Minot, North Dakota on May 13, 1993. The purpose of the workshop was to better facilitate communication and cooperative efforts by companies and individuals interested in horizontal drilling and production in the Williston Basin. There is a definite need to bring together and foster an interchange of people and experience across the U.S.-Canada border. The enthusiastic response of the participants confirmed that feeling during the meeting. By sponsoring this event the two surveys were acting as a catalyst bringing together people from Texas to Montana, and from Alberta to Manitoba, at one time and place.

Several Canadian operators presented papers on their fields and production experience in Canada and received keen interest and questions from the Americans. In turn, they had many questions about operating procedures in North Dakota, who was active, and where to get information. All of this centered around drilling of potential Mississippian targets, which are prime candidates for future Williston Basin horizontal drilling, particularly in development work in the many small, old fields.

The workshop was arranged with a series of papers in the morning and four discussion sessions in the afternoon, each with short presentations for starters and tables available for people to put out displays of their work or products. The sessions included Geology/Logging, Drilling/Completion, Production Practices, and Regulatory/Business. An introduction to many areas was thus provided in hopes of fostering future in-depth discussions among workshop participants.

When the plan for the workshop was initially discussed, we had anticipated about 70 invitees; the final registration count was 170 participants, a nearly overwhelming response. We ran out of registration handouts and the hotel almost ran out of space, a happy problem for everyone. The message was clear: the people are out there and they want to drill wells in the Williston Basin if they can just get together with each other. In fact, the single most requested material we provided was an address list of participants. And, everyone agreed that the horizontal drilling workshop was very definitely a success, asking when would we have the next one.

We would like to thank all those who so generously agreed to make presentations, who worked to make it run smoothly, and to Halliburton Services for the previous evening's reception where many new acquaintances and contacts were made.

Quaternary Mapping Workshop
September 26-28, 1993
Bismarck, North Dakota

The North Dakota Geological Survey will convene a workshop on September 26, 27, and 28, 1993 for those interested in mapping Quaternary deposits. The focus of the workshop will be a day-long meeting where participants discuss: 1) the dual role of GIS (automated map production, and standardization and data transfer of digital geologic map information), and 2) glacial stratigraphy. Other topics, such as map design and use of the maps may also be considered. The meeting will be preceded on the 26th by an informal fieldtrip to the Stumpf dinosaur site, and followed on the 28th by an all-day field trip through north-central North Dakota where we will look at a variety of glaciotectonic and glacial stagnation deposits. For those who are interested and have not already done so, please contact Bob Biek at (701) 224-4109.

Landfill Investigations

by Phil Greer

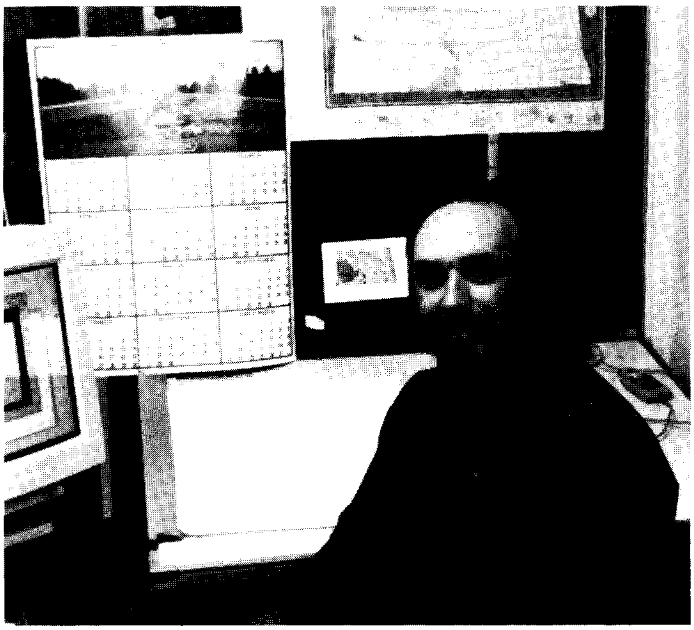
The landfill investigation project is now in its second year. The North Dakota Geological Survey and the State Water Commission are evaluating the active landfills in the State as mandated by the 1991 State Legislative Assembly in House Bill 1060. During the summer of 1992 the two agencies completed field work on nineteen landfills. Reports have been completed on twelve of the nineteen landfills.

The landfills scheduled for study in 1993 include Beach, Hettinger, Dakota Sanitation, St. John, Rolla, Dunseith, Bottineau, Rugby, Alsen, Osnabrock, New Rockford, Minot, McDaniel, and Parshall. Reports on each landfill are provided to the State Department of Health and Consolidated Laboratories and to the landfill operators.

Two students - John Hardy from the University of Kansas and Jeff Herman from Minot State University - have returned this summer to assist with field investigations.

New Employee

Harlan Jirges started working for the North Dakota Geological Survey as a part-time draftsman on May 17th. He replaces Darin Scherr who has taken a position with the Falkirk Mining Company. Harlan worked in the oil industry for 14 years; the last ten years were with Well Tech Inc. of Dickinson. In July of 1992, Harlan, his wife Carla and their four children, Melanie, Heather, Tyler and Tanner, moved to Bismarck from Dickinson. Presently, Harlan has finished his first year of the pre-engineering curriculum at BSC. He plans to attend BSC again in the fall to work toward his A.A.S. Degree and then to attend UND at Grand Forks to obtain his B.A. Degree in Civil Engineering.



Kelly Carlson Retires

Clarence G. "Kelly" Carlson, with multitudes of friends and colleagues, recently celebrated 39 years of service to the State of North Dakota. Kelly worked for 27 years with the North Dakota Geological Survey (from 1954 to 1981) and 12 years with the Oil and Gas Division (from 1981 to 1993).

As State Geologist John Bluemle notes, Kelly has been an extremely - unusually - versatile geologist and published reports on virtually every aspect of the state's geology. He has worked with rocks representing virtually the entire stratigraphic column in North Dakota, and has mapped large areas of the state, including most of the counties southwest of the Missouri River. He has studied most of the state's mineral resources, including materials as diverse as potash, cement rock, gravel, coal, uranium, and - of course - oil and gas. Kelly's knowledge of Williston Basin stratigraphy is unmatched. For many years, since he joined the Oil and Gas Division, Kelly picked formation tops on all the logs received by the Division. The name C. G. Carlson is indelibly etched into the geologic literature and history of the state.

Kelly intends to continue working on North Dakota geology after his retirement, working part time on some favorite projects. But, as Wilson Laird pointed out in a letter to Kelly on the occasion of his retirement, there are still a lot of fish to catch in Minnesota and North Dakota.

From Rocks and Fossils to Art
Summer Road Trips

This program series is sponsored by the North Dakota Geological Survey, State Historical Society of North Dakota, and the North Dakota Humanities Council. All programs are free and open to the public. Lecture presentations will be held in the Russell Reid Auditorium at the North Dakota Heritage Center from 1:00 to 1:45 p.m. Field tours will be conducted from 1:45 to 5:30 p.m. **Pre-registration is required only for the field tours following the Heritage Center Presentations.** For more information contact the Education and Interpretation Division of the State Historical Society at (701) 224-2799.

June 27: "Landforms and Geologic Materials in the Bismarck-Mandan Area," Dr. John Bluemle, State Geologist.

July 11: "Fossil Evidence of Prehistoric Life in North Dakota," Dr. John Hoganson, paleontologist.

July 25: "Rock Art Sites in the West," Dr. Larry Loendorf, archaeologist.

The Face of North Dakota

The **Face of North Dakota: Revised Edition**, written by State Geologist John Bluemle and published by the NDGS, was recently selected for inclusion in the 1992 Notable Government Documents list. As reported in the May 15, 1993 *Library Journal*, the American Library Association annually selects the best international, federal, and state and local government publications. The publications are chosen for their quality and usefulness. **The Face of North Dakota**, one of 21 state and local publications to make this annual list, is a non-technical summary of North Dakota's geology and geologic history. This profusely illustrated book is available from the NDGS for $5.00.

U.S. Bureau of Mines *1991 Annual Report* Available

The *1991 Annual Report*, published by the U.S. Bureau of Mines, summarizes nonfuel mineral activity in North Dakota for the 1991 calendar year. Included are discussions on trends and developments, employment, legislation and government programs, and a review by mineral commodity. The report is available free of charge from the North Dakota Geological Survey (while supplies last) or from Robert H. Wood III, U.S. Bureau of Mines, Intermountain Field Operations Center, Denver Federal Center, P.O. Box 25086, Denver, CO 80225 (Tel. 303-236-0451).

State Rock, Mineral, and Gemstone Collection Established

by
John Hoganson

Since moving to Bismarck, the Survey has gained a greater awareness of public needs in matters pertaining to geology. This is particularly true because of our involvement with the Heritage Center where we have direct contact with people interested in geological objects (rocks, minerals, and fossils mostly). They are interested in learning more about these objects and, at times, are interested in donating them to the State to be taken care of for posterity. For example, in the last year and a half, since the Survey has had a paleontology laboratory in the Heritage Center, many specimens have been donated to the State Fossil Collection and the collection there is growing rapidly.

We have perceived a need for establishment of a State Rock, Mineral, and Gemstone Collection primarily because of our involvement with the Central Dakota Gem and Mineral Society and its members, and because of recent offers of donations to such a collection. Melvin "Mel" Anderson of Bismarck, long-time member of the Central Dakota Gem and Mineral Society and volunteer in the Survey's paleontology laboratory, recently donated his mineral and fossil collection to the Survey. Mel is known for his beautiful lapidary work and has donated some of these art pieces to our newly established rock, mineral, and gemstone collection as well. I will have an article about Mel's collection in the next *NDGS Newsletter*.

The object of establishing a rock, mineral, and gemstone collection is not only to take care of these specimens for future generations, but to exhibit them so that the public can enjoy and learn from them now. We plan to have rock, mineral, and gemstone exhibits in the Survey office building and perhaps in the Heritage Center some time in the future after that museum is expanded. Once the collection is established, we hope to be able to provide specimens for temporary exhibits around the state as we do now with fossil specimens in the State Fossil Collection. At least initially, we may house the State Rock, Mineral, and Gemstone Collection in the Survey's paleontology laboratory at the Heritage Center. Space is limited there, however, and other arrangements will have to be made in the future.

WAULSORTIAN MOUNDS AND CONOCO'S NEW LODGEPOLE WELL

by
Randy Burke and Paul Diehl

The record-breaking hydrocarbon production - greater than 2,000 barrels of oil per day - from Conoco's recent discovery was exciting in itself, but the fact that the oil was coming from the Lodgepole Formation (Fig. 1) was particularly interesting. To a petroleum geologist, this quality of production from the Lodgepole was previously unknown in North Dakota. To a sedimentologist or stratigrapher working the Williston Basin, the interesting thing about the Lodgepole is the Waulsortian mound facies. My (RB) predilection for all types of reef structures provoked the idea that this could be the first production from a Waulsortian-type mound in North Dakota.

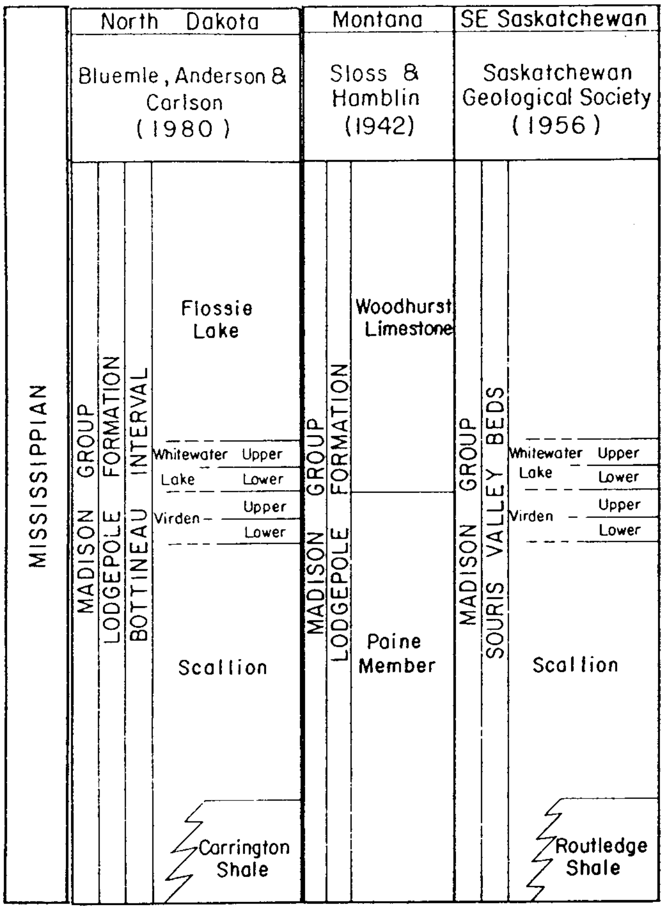


Figure 1. *Regional nomenclature for the Lodgepole Formation.* Modified from LeFever and Anderson (1984).

The presence of a Waulsortian facies - "massive lime mudstone containing scattered crinoid and bryozoan fragments and forming lens-like buildups and mounds" (Wilson, 1975) - in Lodgepole Fm. rocks in the Williston Basin region is well documented. Mounds are reported from outcrops in central Montana (Cotter, 1965; Stone, 1972; Smith, 1972a, 1972b, and 1982), from cores in Saskatchewan (Sereda and Kent, 1987), and postulated from analysis of cores and stratigraphy in North Dakota (Bjorlie, 1979) and Manitoba (Young and Rosenthal, 1991) (Fig. 2). Similar age mounds and flanking beds have produced oil in Alberta (Morgan and Jackson, 1970; Davies, et al., 1989), in the Hardeman basin of Texas (Ahr and Ross, 1982), and in the Appalachian fold belt of Tennessee (MacQuown and Perkins, 1982).

What Are Waulsortian Mounds?

Waulsortian mounds are found in the Lower Carboniferous throughout the northern hemisphere (Wilson, 1975). The term comes from mud mounds described from the Waulsort region of Belgium (Lees and Miller, 1985). Similar massive mud-cored bioherms occur throughout the geologic record from the Paleozoic and, to a lesser extent, the Mesozoic (Tucker and Wright, 1990). The term has been applied to a variety of mud-cored buildups and their facies, but usage should be confined to lens-like or mound buildups composed of massive calcareous mudstones with subordinate amounts of skeletal components (Fig. 3) (Lees, 1961; Wilson, 1975).

Crinoids and bryozoans are the most abundant skeletal components within the mounds, whereas molluscs, ostracods, trilobites and calcispheres are less common. Sedimentary structures common to mounds include some degree of layering and stromatactis structures. Stromatactis are centimeter-scale calcite structures of isopachous cements filling voids in mudstones and wackestones; they have reasonably flat bases and irregular tops. The origin of stromatactis is controversial, but these structures and steeply dipping beds (30°-50°) on the flanks

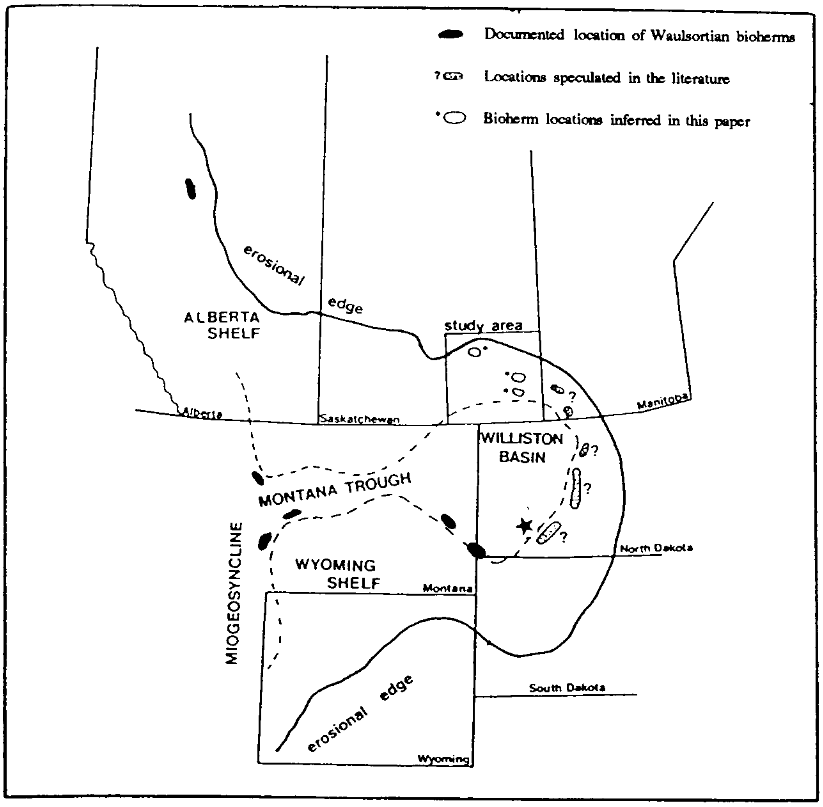


Figure 2. *Map showing known and inferred locations of Waulsortian-type mounds in the Early Mississippian of the Williston Basin. The black star indicates the approximate position of the Conoco, Inc. Dickinson State #74 well.* Modified from Sereda and Kent, 1987).

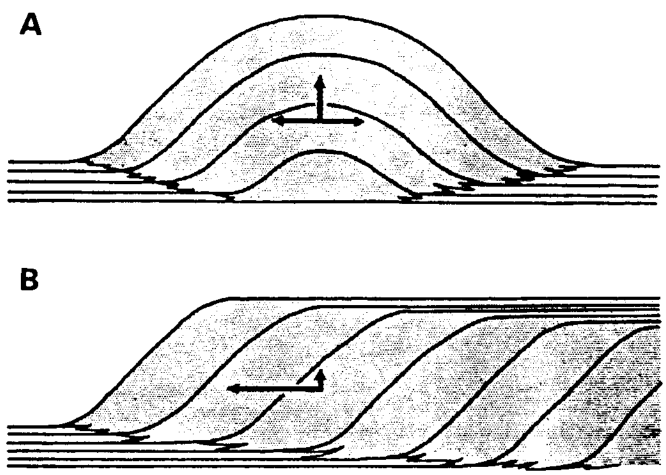


Figure 3. Diagrammatic cross sections of growth forms of Waulsortian mudbanks: **A**, *mound form;* **B**, *lens form. The arrows indicate relative rates and directions of growth.* Modified from Lees (1961).

of mounds have been cited as evidence for synsedimentary cementation of the mounds.

Recent work has shown that many of the mud mounds are microbial in origin (Pratt, 1982). Based on this work, Pratt presented a theoretical reconstruction of the internal structure of the mud mounds and the life on the surface of the mounds (Fig. 4). Bryozoans and crinoids are believed to be more abundant in North American mounds and cyanobacteria more prevalent in European buildups. Large buildups are hundreds of meters thick, typically 1 km in diameter, and can occur in mound complexes covering thousands of square kilometers. Paleogeographic reconstructions in areas with mounds suggest that lens-like mounds develop on shelf margins, whereas mound buildups occur in more basinal positions.

Porosity and Permeability of Mounds

Porosity development in Waulsortian mounds is generally limited to secondary processes of vug and moldic solution porosity enhanced by dolomitization and fracturing (Eby and Kirkby, 1991). The grainy interbeds and flank beds are good candidates for dissolution if they have not been cemented early. Replacement of mud by dolomite is one way of forming intercrystalline porosity and has produced up to 15% porosity in flank and intermound facies (Winfrey, 1982). In general, the mound cores do not have a great deal of primary porosity because of early cementation and homogeneous fine grained textures. The coincidence of mounds with tectonic zones of weakness increases the probability of fracture porosity and permeability.

Modern Analogues

The general absence of mud mounds in the Cenozoic has yet to be satisfactorily explained, but some workers report similar mound buildups in modern oceans (Fig. 5) (Neumann, et al., 1977; Mullins, et al., 1981; Boscence, et al., 1985). Wilson (1975) pointed out some of the problems with strictly applying these modern analogues to their ancient counterparts. He, however, used knowledge about the processes that formed the modern analogues to develop a theoretical model for Waulsortian mound development (Fig. 6).

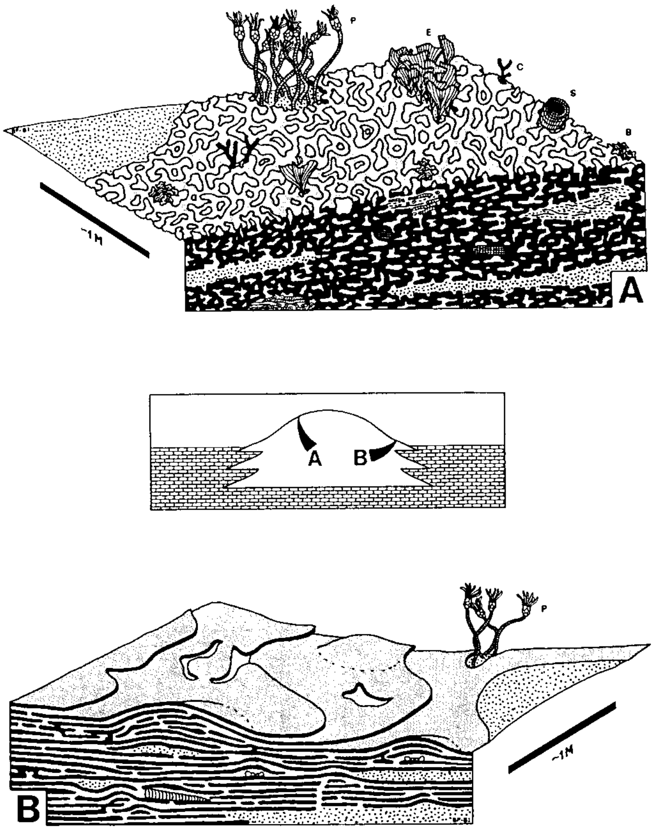


Figure 4. *Hypothetical reconstructions of mud-mound living surfaces and internal framneworks. Shaded pattern indicates living algal mats; black indicates algal-bound sediment; dots indicate bioclastic grainstone; blank indicates unbound sediment and cavities; "P" = pelmatozoans; "E" = bryozoans; "B" = brachiopods; "C" = corals; "S" = sponges.* ***A)*** *Reticulate framework from mud-mound core, with unbound sediment, cavities, fossil "nests," and discontinuous grainstone layers; note patchy distribution of living algal mat.* ***B)*** *Laminar framework forming on mud-mound flank, with flat and undulating, sheet-like bound and unbound sediment, cavities and grainstone layers; note nearly continuous algal mat cover.* Modified from Pratt (1982).

Waulsortian Mounds in Montana Outcrops

Waulsortian mounds have been reported in Montana from the Little Belt and Big Snowy Mountains, the Bridger Range, and the Cedar Creek anticline (Smith, 1982). The buildups occur in the Paine member of the lower Lodgepole Fm. (Figs. 1 and 7). In the Big Snowys, the mounds have a maximum stratigraphic thickness of 60 meters and length of 570 meters, whereas the smaller mounds in the Bridgers have maximum dimensions of 18 meters thick and 160 meters long (Fig. 8). Tracing individual layers indicates relief of the mounds above the sea floor was as much as 50 meters. Compositional layering in the Big Snowy mounds show maximum depositional dips of 35° whereas layering in the Bridger mounds is between 29° and 40°. Stromatactis structures are present in both the Big Snowy and Bridger mounds, but less common at Bridger.

Measured sections of the Big Snowy buildups through both the mound core and the off-mound strata indicate the core is composed of alternating, steeply dipping layers of crinoid and bryozoan wackestone and mudstones. The mound core is surrounded by thin bedded, argillaceous lime mudstones and crystalline dolomites with sparse crinoid fragments, and chert beds and nodules (Fig. 7). Detailed sedimentologic studies (Cotter, 1965) found the core to consist of 60% mud and 25% bioclastic debris, with the remaining 15% calcite cement in stromatactis and other voids, and as neomorphic microspar. Neptunian dikes or dilational fractures, filled with crinoidal grainstones and packstones, occur in the Big Snowy mounds, whereas local brecciation is present in the Bridger mound core. These sedimentary structures suggest paradepositional tectonics from either regional crustal movements or differential compaction between the mounds and surrounding beds. Cotter (1968) and Stone (1972) disagreed slightly on the processes of diagenesis. Cotter suggested subaerial exposure to explain the presence of dolomite and the orange coloration of sediments, whereas Stone (1972) found no evidence of subaerial exposure.

Depositional Environment

The depositional environment of the central Montana mounds is controversial. Both shallow water and deep water depositional settings have been envisioned (Glenister, et al., 1985; Winfrey, 1982; Smith, 1982). The conflict primarily centers around the juxtaposition of grainstone and massive mudstone textures enveloped in thin-bedded mud textures. Most workers agree that the abundant mud textures reflect deposition below wave base, however, one must consider the range of wave bases in restricted embayments. Another consideration is the capability of organisms to baffle sediment within a low wave energy regime.

The controversy of mound origin between shallow or deep environments for the Bridger and Big Snowy mounds may arise because they represent two different mound forms built in different paleogeographic settings. The lens shape of the Big Snowy mounds may indicate they formed on the shelf margin, whereas the mound buildup form of the smaller Bridger mounds may indicate they formed along the paleo-slope or in the basin.

Structural Influence?

The location of the central Montana buildups is coincident with fault-generated breaks in slope (Smith, 1977). Increased thickness in the deposits underlying these bioherms can be interpreted to indicate the bioherms were initiated on preexisting topographic highs. Fault blocks have been proposed as localizing mechanisms for mounds in Saskatchewan (Sereda and Kent, 1987), in association with the north-trending Trans-Hudson Orogenic belt. This structural boundary is interpreted to extend through North Dakota and is considered to be a cratonic suture zone separating the Wyoming and Superior cratons. Extensive faulting in deeper strata was presented in Conoco testimony (Anonymous, 1992) for permitting the location of the Lodgepole discovery well in North Dakota.

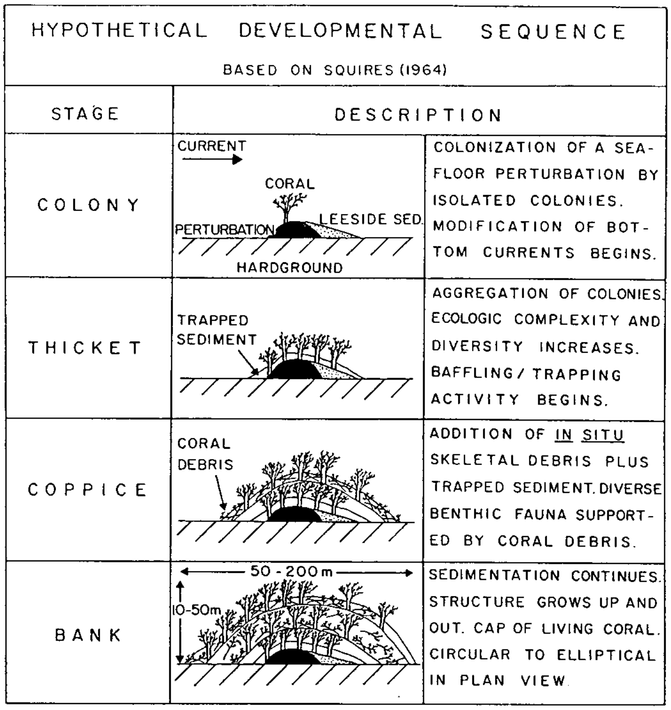


Figure 5. *Hypothetical development sequence for deep-water coral mounds.* From Mullins, et al., 1981).

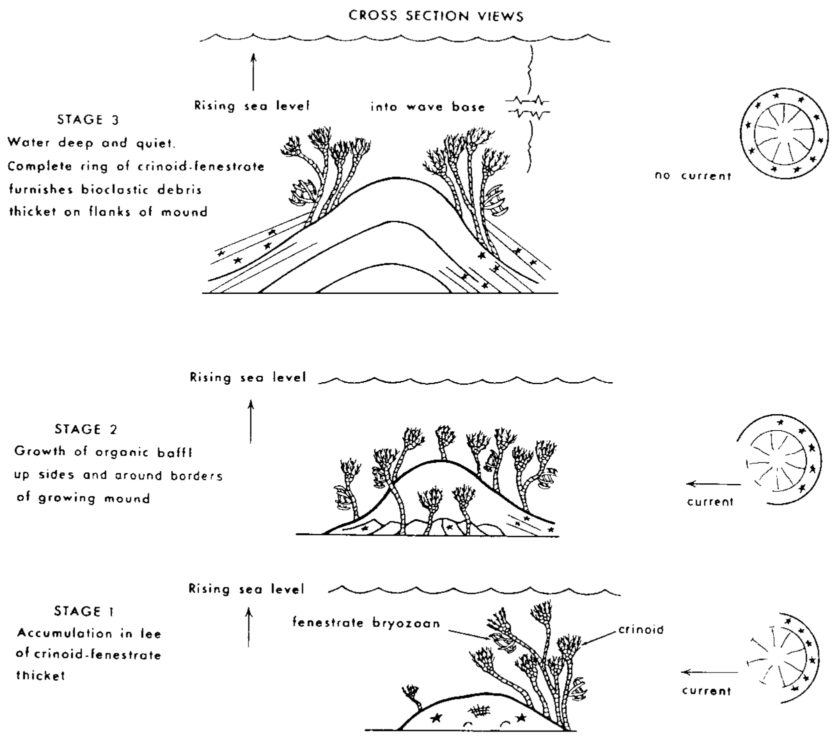


Figure 6. *Hypothetical development of Waulsortian mounds through progressive colonization of current-induced pile of fine sediment in lee of crinoid-fenestrate bryozoan thicket. Rising sea level accounts for mud accumulation in center of thicket. Flanking beds develop coarse debris derived from outer edges of thicket where finest lime-mud sediment is winnowed.* From Wilson (1975).

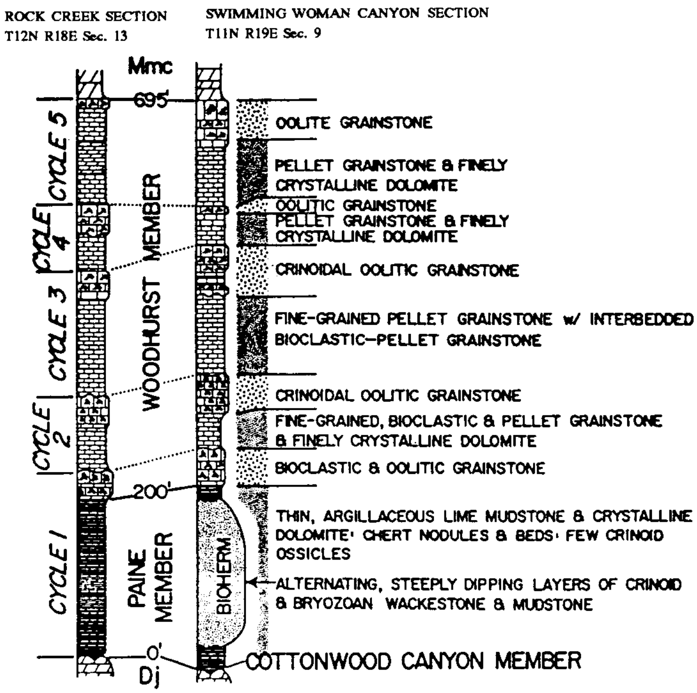


Figure 7. *Stratigraphic sections, Lodgepole Formation, Big Snowy Mountains, Montana. Lodgepole strata are underlain by the Devonian Jefferson Dolomite (Dj) and overlain by the Mission Canyon Formation (Mmc). Thin bedding is depicted by the thin block pattern; relatively thick bedding by the thicker block pattern. Cross-stratification is depicted by the cross-hatched pattern. Lodgepole cycles are numbered consecutively from top to bottom and upper and lower units of each cycle are depicted on the right-hand column by coarse and fine patterns, corresponding to the coarse- and fine-grained lithologies that characterize these units.* From Smith (1972a).

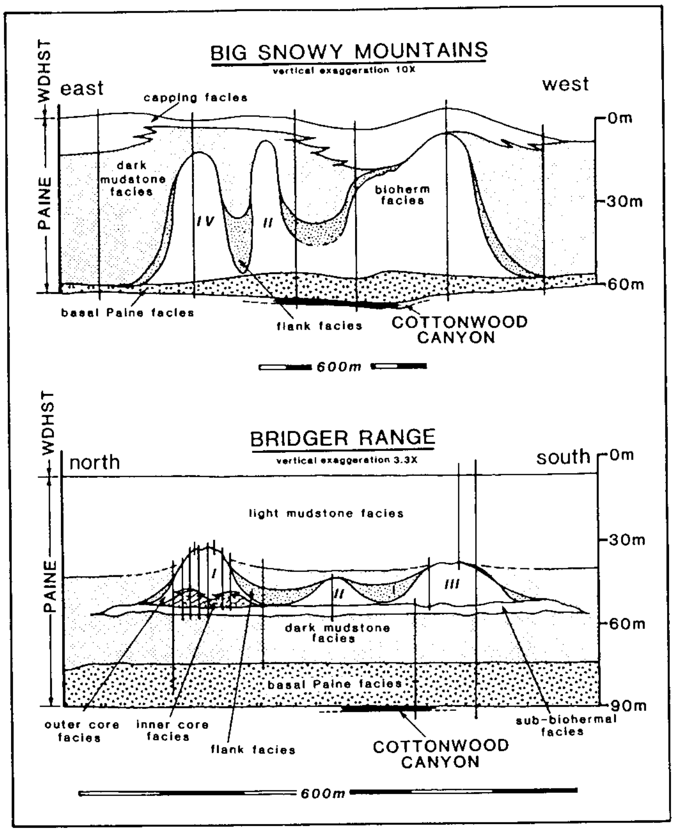


Figure 8. *Cross sections of Waulsortian bioherm in the Big Snowy Mountains (Swimming Woman Canyon) and the Bridger Range (Sacajawea Peak). Vertical lines indicate locations of measured sections. Note change of horizontal scales. Mound in photograph above is included in the Bridger Range cross section (note two figures at bottom center for scale), whereas mound in cover photograph is included in cross section of Big Snowy Mountains.* Cross sections from Smith (1982).

Lodgepole Formation in the Subsurface of North Dakota and Canada

The lower Lodgepole Fm. (Scallion subinterval) in North Dakota has been divided into six facies (Fig 9) (Heck, 1979). Both he and Bjorlie (1978) recognized a "Waulsortian" bioherm facies within the open shelf facies near the shelf break. Young and Rosenthal (1991), reporting on Lodgepole oil and gas fields in southwestern Manitoba, found bryozoan and crinoid wackestone and packstone channel deposits surrounded by bioclastic shales on the shelf slope just east of the "Waulsortian" mounds discussed by Sereda and Kent (1987). Young and Rosenthal (1991) recognized the shelf break is coincident with north-trending basement lineaments. Processes assumed to be associated with the lineaments are believed to have contributed to localizing dissolution of middle Devonian salts, which could have created structure during Lodgepole time. LeFever and Anderson (1984) reported on a clean carbonate unit in northwestern North Dakota that was similar to one observed on logs in Billings County, but the stratigraphic relationship of the two remains unclear.

A look at Heck's (1979) map shows the Conoco, Inc. Dickinson State #74 well located in his central basinal facies at the base of the shelf slope, whereas the mounds postulated by Bjorlie (1978) occur within the shelf facies. This apparent paleogeographic disparity may be because they are of the two different forms: lens shaped mounds associated with a break in the shelf slope, and the possible mound buildup form for the Conoco well in the basin.

Conoco's Lodgepole Discovery

Historically, in the North Dakota portion of the Williston Basin, the Lodgepole Formation has not been an interval highly regarded for its oil-producing potential. Except for early efforts of the 1950s, it has rarely been the primary target of exploration. Many have considered the Lodgepole to be economically unattractive, characterized by strata of poor reservoir quality. But even in a maturing petroleum basin there are surprises. The Conoco, Inc. Dickinson State #74 Lodgepole discovery this past February just northwest of Dickinson, and more than 70 miles from the closest known Lodgepole producer, was such a surprise. Prolific test flow rates of over 2,000 barrels of oil per day along with 1.2 million cubic feet of natural gas, two month's cumulative

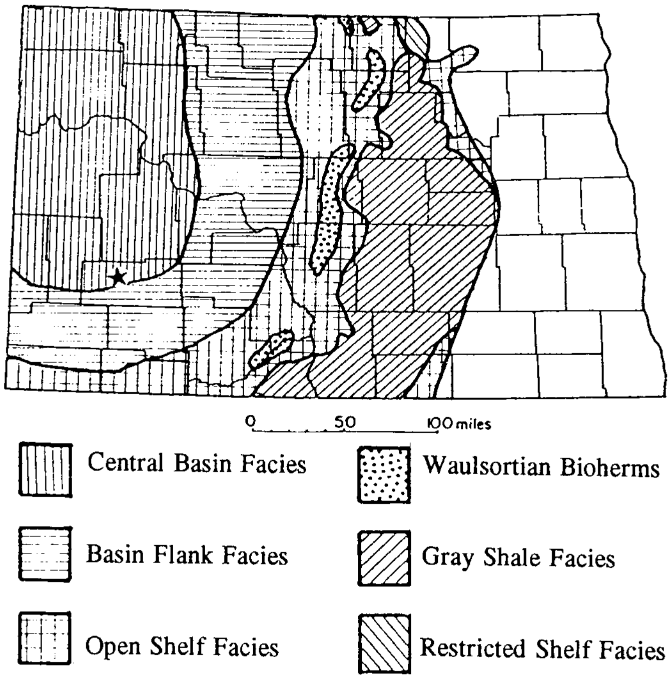


Figure 9. *Facies distribution during lower Scallion subinterval time. Black star indicates approximate position of Conoco, Inc. Dickinson State #74 well.* Modified from Heck (1979).

production of 53,949 barrels of oil (more than four times the total production of the best previously known Lodgepole well), and the thus far sustained flow rates in excess of 600 barrels of oil per day have grabbed the attention of many people. This discovery has provoked many questions about the Lodgepole encountered in the Conoco well and elsewhere in the basin. Is this a unique, one-time occurrence of such an apparently prolific reservoir in the Lodgepole or could this provide a key that will lead to finding other good quality Lodgepole reservoirs in North Dakota? What is it that makes the Lodgepole so different in the Dickinson State #74? Can these conditions be expected to occur elsewhere?

The Conoco, Inc. Dickinson State #74 is located in the west half of section 32 T140N R96W just west-northwest of Dickinson. Figure 10 shows the well location and all other wells and dry holes drilled within the surrounding 12-township area. The Lodgepole penetration closest to the Conoco well is 4.75 miles southeast. There is no other Lodgepole production within the area represented by Figure 10; the closest Lodgepole production is over 70 miles north in Antelope Field. See Table 1 and sidebar for known Lodgepole producers in North Dakota.

Cross section A-A' (Fig. 11) includes the Conoco well log and logs from dry holes to the northwest and to the southeast; the cross section is an approximately dip-oriented section perpendicular to the former basin margin. The most immediately noticed difference in these logs is the 302 feet of unusually low gamma ray in the Conoco well, indicating the presence of an uncharacteristically thick, "clean" carbonate. Although "clean" limestone intervals of 50 feet or more do occur in the lower Lodgepole in this area, this thickness of uniformly "clean" carbonate has not previously been encountered. Logs from the Zelinsky 1-32 and the Gress 11-23 illustrate the normal character of the Lodgepole.

The 25 feet of strata between the typical looking upper Bakken and the base of the Lodgepole limestone (10029' to 10054') is unusual and is not seen in other logs of the area. These strata have densities, resistivities, and sonic travel times close to those of the upper Bakken but are not as highly radioactive as "normal" Bakken. Tentatively, these strata are considered an additional depositional sequence above the normal upper Bakken and not the argillaceous zone (commonly called "false Bakken") seen in this area at the base of the Lodgepole just above a thin basal limestone. Whatever these rocks are called, this Bakken-like and Bakken strata comprise an interval between Three Forks and Lodgepole that is anomalously thick in the Dickinson State #74. The significance of this unit is not yet known.

Correlative intervals from the top of the Duperow to the base of the Bakken are all of nearly equal thickness on all three logs (Fig. 11). Likewise, zones defined by gamma ray markers from the top of the Lodgepole up

TABLE 1--Known Lodgepole Producers in North Dakota

KNOWN LODGEPOLE PRODUCERS **							
FILE #	6789	7820	8645	2172	10047	8039	3899
OPERATOR WELL	Argonaut Energy Barkie #1	Texakota, Inc. Borstad 34-1	Donald C. Slawson Moe 2-1	Amerada Petroleum Nelson Tr.1 #1	American Exploration Total - State #1-36	Hunt Energy Corp. Sevre #1	Shakespeare Oil Cater #1
LOCATION	sw/sw 23-156-103	c/sw 34-158-95	nw/se 2-156-96	sw/sw 5-152-94	ne/sw 36-159-96	sw/nw 10-159-97	nw/nw 28-158-95
COUNTY	Williams	Williams	Williams	McKenzie	Williams	Williams	Williams
FIELD-POOL	Bull Butte - Lodgepole	W.Tioga - Lodgepole	West Bank - Lodgepole/Bakken	Antelope - Madison	Temple - Madison	Corinth - Madison	McGregor - Madison
CMPLT. DATE	10/26/79	11/13/81	4/6/82	12/23/66	5/24/92	4/30/81	7/15/66
IP	6 bo+ 5 bw	F/27 bo + 4 bw + 73 mcf	28 bo + 28 bw	F/94 bo + 0 bw + 134 mcfd	12 bo + 0 bw + 36 mcfd	30 bo + 0 bw + ?	94 bo + 0 bw
API Gravity	34.1	44.0	35.0	44.3	44.0	36.0	40
GOR	0	2700		1420	3000	?	?
PERFS (Log Ft)	10065-115	9274-90	9250-880 OA	10070-138	9152 - 68	9294 - 9312 OA	9221 -26 also pf Ratcliff
Porosity - Ft		56			89	60	116
Max Porosity	3 % sonic D:NG	10% N, D & S not run	8% N (2 ft.)	Radioactivity log only	7% xp; 7% s	7% xp; 6% s	12 -13% s ? borehole ?
Porosity Type	Fractured	Primary & Fracture	Predom. Fracture, some prim.	Fractures reported in core; No visible por.	Primary; subord. fract probable	Mostly primary; sdy N-D profile?	Primary; MLL "ratty": low to mod. K. Fract. likely.
Lithology	Ls; ?anhy strngrs	? Ls.	Ls.; sli dolo	Ls: core descrip.	Ls (spl log)	Ls; poss. cherty (log)	Ls; cri, bry, brach, spics. (spl log)
CUM O/W/mcf sld	1372/2277/	2425/59/1910	5883/10366/	12825/105/	701/1836/1463	273/0/0	230666 bo/ 33933 bw
P&A	7/17/80	5/1/82	11/30/83	7/10/71	pumping well	5/18/82	pumping well
***There may be other Lodgepole producers not specifically identified as such within "Madison" pools*							

This table lists known Lodgepole producers in North Dakota along with some production and geologic information about each well. These wells, located in Williams and McKenzie Counties, produced from a "clean" (very low gamma ray response on radioactive geophysical logs) carbonate zone in the lower Lodgepole. Carlson and Anderson (1966) called this zone the L_2 subinterval and reported that it developed as a facies change within the lower Lodgepole, attaining a thickness of 80 to 100 feet. They noted that up to 20 feet of fair to good porosity can be found in some of the "clean" limestone. Later, LeFever and Anderson (1984) published an isopach map of the L_2 interval showing that its development was confined to northwest North Dakota, pinching out east of R90W to R92W and south of T151N. They did, however, indicate the occurrence of a similar clean carbonate interval in Billings county.

section to at least the top of the Ratcliffe are essentially the same thickness on each of the logs. Thus, no marked interval thickness changes are apparent above the Lodgepole nor below the Bakken. This suggests that there was no marked paleotopography on the Three Forks unconformity at the location of these tests during initiation of Bakken deposition in this area. Nor is there evidence for the existence of a persistent high-relief feature on the depositional substrate during late Lodgepole and younger deposition.

Production in the Dickinson State #74 is from within the 129-foot perforated interval at the top of the lower Lodgepole "clean" limestone. There, 10% to 14% neutron-density crossplot porosity has developed in several three- to four-foot intervals. There is also a more continuous 15-foot interval of 6% to 9% crossplot porosity within the perforated interval. Fracturing of the rocks is especially evident from the logs over the lower part of the "clean" zone. As indicated by the irregular borehole throughout the entire "clean" limestone, fractures are probably present as well in the upper part of the zone, thus enhancing the deliverability of the well. An apparent oil-water contact may occur at about 9875 feet with water saturation increasing toward the base of the formation.

What is the origin of this anomalous 302 feet of unusually "clean" limestone? Around the "oil patch" there is much talk of this limestone being a Waulsortian-type carbonate mud mound. Characteristics and occurrences of these features are discussed above. Within the Williston Basin, the mounds of the lower Souris Valley Formation of southeast Saskatchewan are perhaps the best examples of Waulsortian-type buildups. These mounds are documented by log, seismic (Fig. 12), and core data (Sereda & Kent, 1987; Sereda, 1990). Figure 13 shows

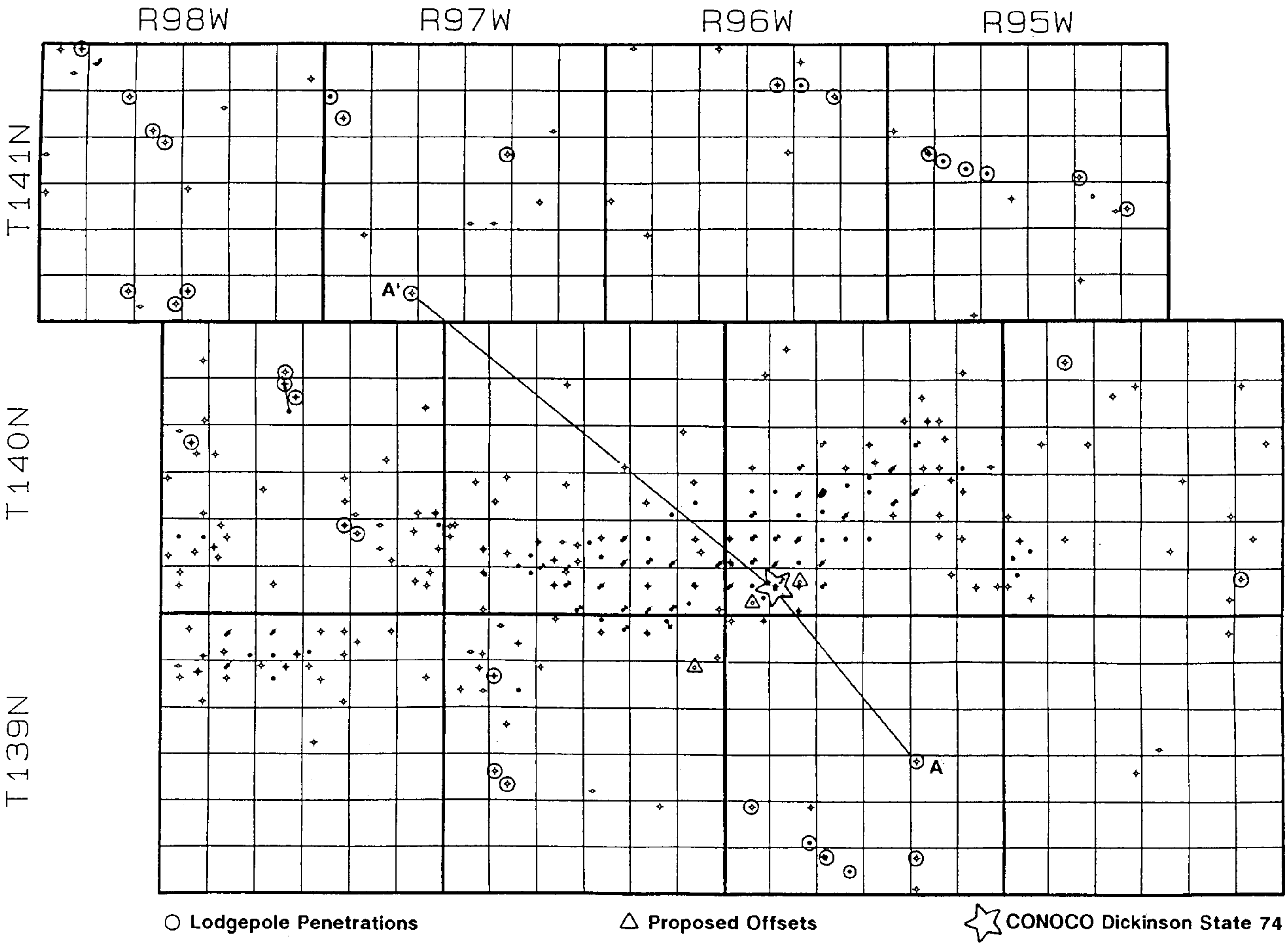


Figure 10. *Location of wells and dry holes surrounding the Conoco, Inc. Dickinson State #74 well.*
dry hole • oil well cancelled permit

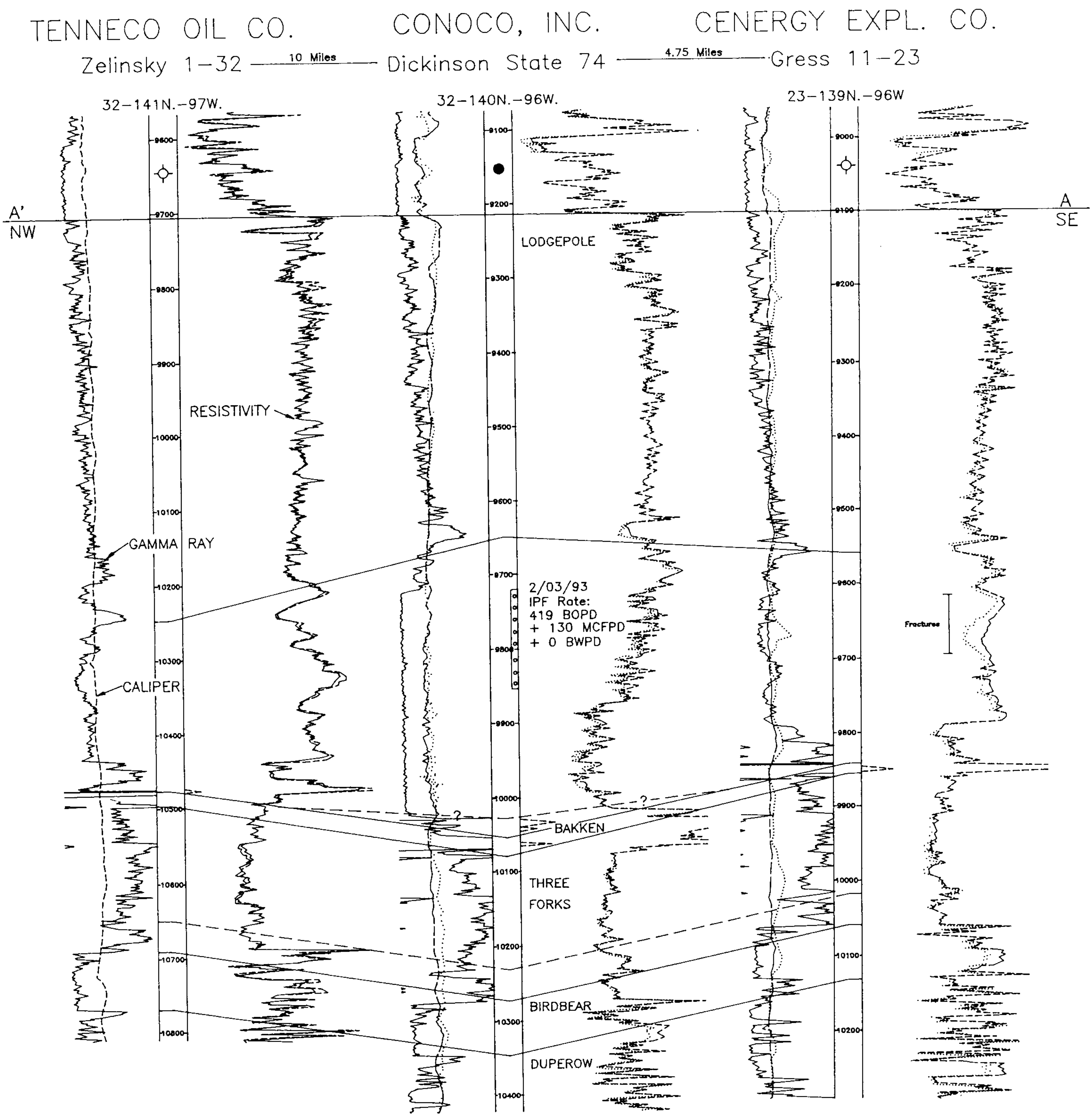


Figure 11. *Laterolog cross section through the Conoco, Inc. Dickinson State #74 well. Note the 302 feet of lower Lodgepole "clean" carbonate seen in the Conoco log. Production from the Conoco well comes from the 129 foot perforated interval at the top of this "clean" carbonate.*

an interpreted log cross section through mound, intermound, and flank facies (Kent: pers. comm., 1993). Photographs of core taken from the tests illustrated by logs on the cross section are also shown. From this illustration as well as from other examples of Waulsortian mounds reported in the literature, it seems improbable that log data alone will be sufficient to distinguish Waulsortian-type carbonate mound buildups from "clean" carbonate thickenings caused by some other non-mound related origin - both look like thick "clean" carbonates. Core data showing internal lithologic character, fossil content and distribution, and the attitude of strata will probably be required to adequately address the question of Waulsortian carbonate mud mounds.

It is obvious that Conoco has found something in the Lodgepole significantly different from that in previous Lodgepole penetrations in North Dakota. Just how this discovery fits into the Lodgepole depositional history and the evolution of the Williston Basin will no doubt be discussed and debated for some time.

ACKNOWLEDGEMENTS

We want to thank Dr. Don Kent (University of Regina) for providing cross sections and seismic information, and Dr. Dean Potter (Upton Resources, Calgary, Alberta) for providing log cross sections and depositional models.

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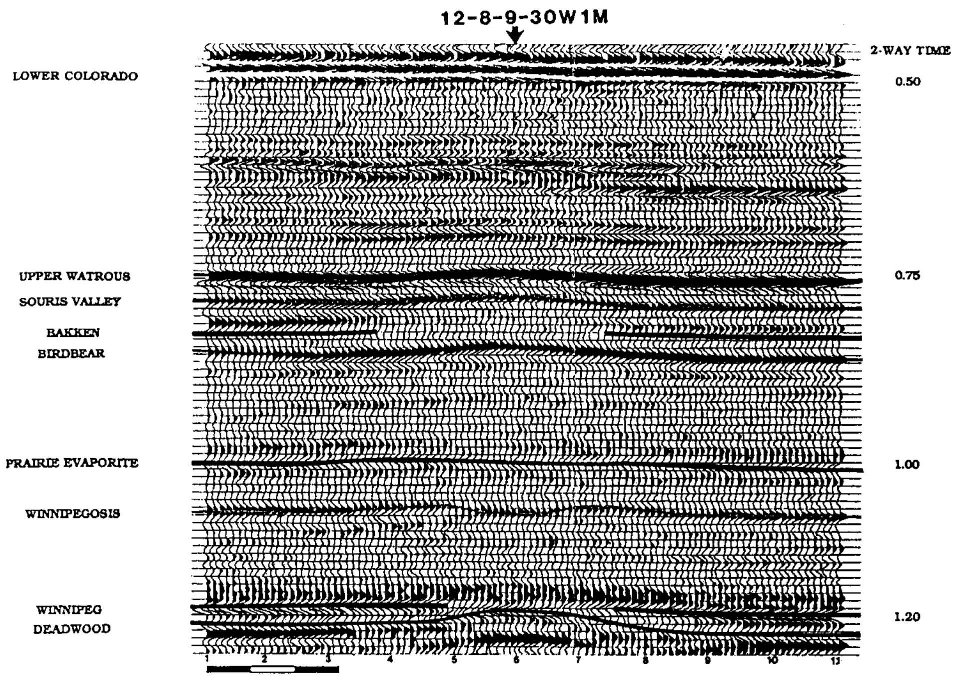
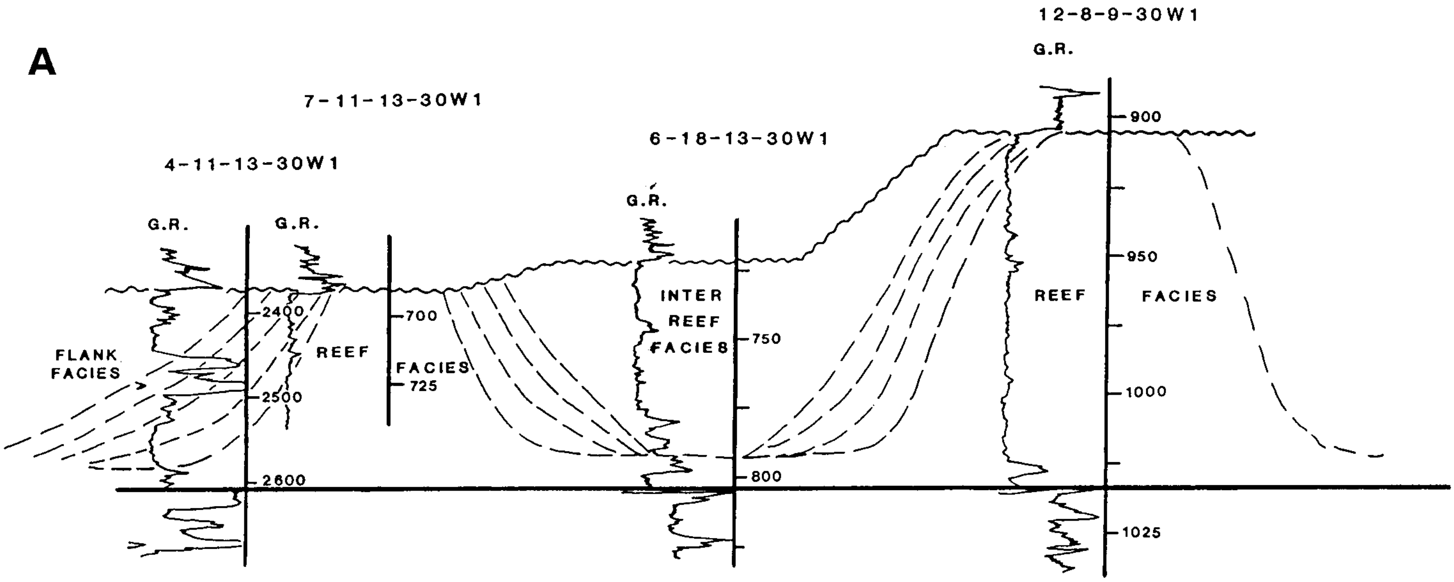


Figure 12. *Reflection seismic record through "reef" structure seen on log from test 12-8-9-30W1M illustrated in Figure 12. Arrow at top center of seismogram shows where test was drilled.* (From Sereda, 1990).

A



B

C

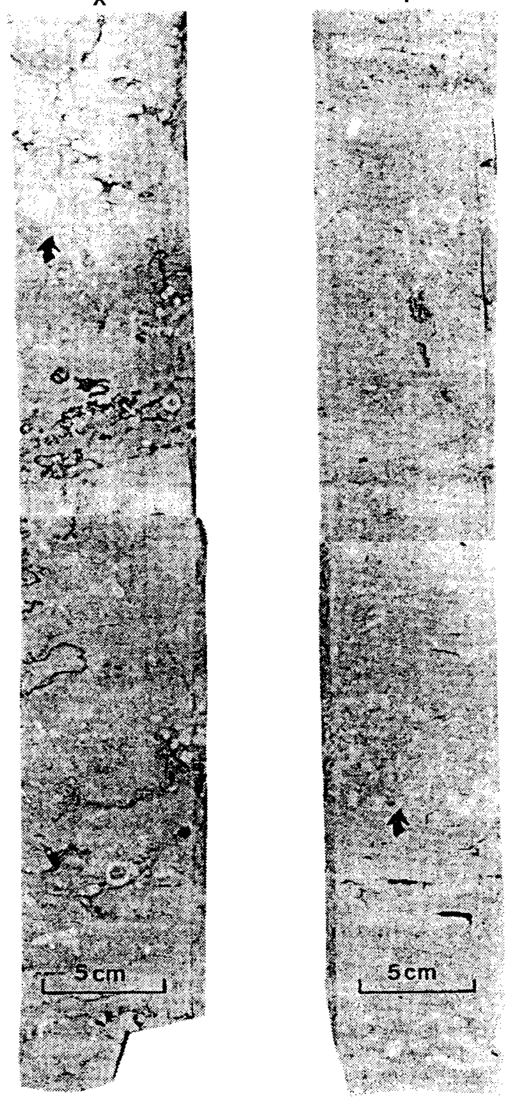


Figure 13. **A.** *Log cross section of Waulsortian mound facies in southeastern Saskatchewan* (from Kent, 1993, pers. comm.).

B. *Tenneco et al. Flemming 4-11-13-30W1M, 724.00 to 724.40 m. Depositional fabric indicative of a Waulsortian-type mound, flanking facies. Note the steeply dipping interbeds of lime mud and crinoidal grainstones.* (Modified from Sereda and Kent, 1987).

C. *Suncor et al. North Antler 12-8-9-30W1M. X (912.75 to 913.25 m)and Y (916.00 to 916.50 m). The depositional fabric is indicative of a Waulsortian-type mound, core facies. Note the large crinoid ossicles floating in a lime mud matrix (arrows). The depositional fabric is present in the entire core interval and, on the gamma ray log, correlates to a structure approximately 45m high.* (From Sereda and Kent, 1987).

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A DAY TO REMEMBER

by

Wilson M. Laird, State Geologist Emeritus

[Editor's Note: Wilson Laird originally wrote this article about 10 years ago. He recently sent it to John Bluemle, who made minor revisions before submitting it for publication.]

"Light the flare." With those words Blackie Davidson tossed up a lighted, oil-soaked rag and the gas started to burn in a flare 30 feet long. This was the real beginning--the opening of the Williston Basin to oil production on April 4, 1951. The discovery of oil will always be remembered by those who were in North Dakota at the time. Its effect on the State and the Nation can probably never be entirely assessed.

As far as I was concerned, this day had really started ten years almost to the month prior to the actual coming in of the Clarence Iverson No. 1 in Williams County. In 1941, the North Dakota legislature, primarily through the foresight of one man, had passed an adequate oil and gas conservation measure. That man, George Saumer, was a representative from Grand Forks County, about as far from the oil area in North Dakota as one could be and still stay in the same state.

Because of that law, the State was in a position to encourage, through proper regulation, the development of a resource that has come to mean so much. That story--the passage of North Dakota's oil and gas conservation law--deserves greater attention than has been paid to it. Perhaps the story can be written at another time. In any event, because of that law, I, as State Geologist, was present at the testing of the Silurian Interlake Formation in the Clarence Iverson No. 1, an event that opened the Williston Basin.

The "why" of my actually being there goes back to my friendship with Clyde Noe, a resident of Williston at the time. Clyde called me about two days before the well came in and told me he thought it was going to come in. He said he thought I should be there. How Clyde knew about the well I don't know, but I suspect he learned of it from Blackie Davidson, who was tool pusher on the rig.

Blackie Davidson was someone who was believed by everyone in the area. If Blackie said it was so, it was so. He had far more credibility than any of the technical officials connected with Amerada Petroleum Company or, for that matter, anyone else concerned with the industry. Blackie was well known in the area and it was a real loss to the oil industry when he passed away some years later.

In any event, I went to the President of the University, Dr. John C. West, and told him that I had heard that the oil well near Tioga was going to come in. He asked me if I was going to be there. I said that I had four classes to teach that particular day and that I thought I had better stay in Grand Forks. Dr. West said, "Laird, you don't get to see an oil well in North Dakota every day; to hell with the classes." With that kind of encouragement, I left for Williston.

I got to Williston on the evening of April 3, contacted the Amerada geologists, and said that I would like to go to the well the next day. They said that was fine. I left Williston about 9 the next morning and arrived at the well site about 10 a.m. There I met Roy Fuller, who was Amerada's district superintendent working out of Casper at the time. He later moved to Williston where he became an institution in himself. Roy explained to me what was being done with the well and the preparations that were being made for the test.

It was a beautiful clear, cool day in North Dakota. The ground was still frozen as the preceding winter had been a cold one. This was not my first visit to the well site as I had been there in January after the famous "pint of oil" had been obtained in a drill stem test of the stratigraphically higher Devonian Duperow Formation. In January, the drifts of snow had been bulldozed as high as the telephone lines along the road coming from Highway 2 to the well site six miles south of the highway. Some of these drifts were still quite apparent on that April day.

Roy Fuller, Blackie Davidson, the drilling crew and I were about the only people who witnessed this historic event, which began almost exactly at noon on April 4. A few local visitors were there also, but Roy asked me to caution them to stay behind the wire stretched across the access road to the site because of the danger always present when such operations are underway.

On the side of the tank receiving the oil from the well was a trip valve which kept going up and down rather rapidly. Never having seen an oil well come in before, I wanted to know if this was a good sign and if this was really going to make a well. Roy kept telling me he didn't know, but I noted that he smiled a lot when he was telling me that. I knew that he had seen many wells come in during his long career with the industry. In the meantime, the flare was burning, the ground beneath it was beginning to thaw, and the steam was rising in the cool air.

About 4 p.m., I decided it was time to go back to town to get something to eat and to talk to others about this exciting and historic event I had witnessed. Among the first people I met on returning to town were Herman Zahl and his wife, who invited me to have a steak at their home. Herman was the publisher of the newspaper. So we proceeded to go to his home, where we had a "few" drinks and one of the biggest steaks I had seen for some time. Later we adjourned to the Elks Club for more drinks.

Along about 11 o'clock, someone decided that it might be a good idea to go and see how the well was doing. That seemed at the time like a capital idea, so Herman, his wife, and I piled into the car and drove to the well site. The flare could be seen for a distance of about 10 miles or more from the location. I forget now where we were when we first saw it, but it was some miles west of the well. We finally got to the well where, by this time quite a crowd had gathered. It was this night that the famous night picture of the well was taken by Bill Shemorry. I also took a color picture of the sight, which was later reproduced and incorporated in a beautiful wooden frame and presented to me by Dr. Rodger Denison, the exploration Vice-President of Amerada.

After that night scene, we drove rather slowly back to Williston, reflecting on what we had seen and what it would mean to Williams County, Williston, and the State of North Dakota.

On the side of the tank receiving the oil from the well was a trip valve which kept going up and down rather rapidly. Never having seen an oil well come in before, I wanted to know if this was a good sign and if this was really going to make a well. Roy kept telling me he didn't know, but I noted that he smiled a lot when he was telling me that.

Like many things human, the discovery of oil in the Clarence Iverson was regarded by many as good luck. Actually it was a combination of good interpretation of the geology of the area, the knowledge and guts of the company, which took a considerable risk in drilling the well, and the vision of many geologists dating back many years who had faith in the area. Notably, in this latter group was Tom Leach, who took the leases on this land, which were later turned to Amerada. However, it is worthy of note that he and others, such as Clyde Noe, and many others associated with the early development, didn't live long enough to see how big it really was. In this respect, I feel unduly fortunate. While I am sure they thought it would be big, I doubt if they could visualize the impact the discovery of oil would have on North Dakota.

NEW PUBLICATIONS

The Chadron, Brule, and Arikaree Formations in North Dakota: The Buttes of Southwestern North Dakota, by Edward C. Murphy, John W. Hoganson, and Nels F. Forsman, NDGS Report of Investigation No. 96, (1993), 144 pages, 7 color plates, $25.00.

This report is the culmination of a five-year study designed to determine the age and relationships of the Chadron, Brule, and Arikaree Formations in southwestern North Dakota and to map the contacts between them. Thirty-one geologic sections were measured and twelve holes were cored on buttes in southwestern North Dakota to characterize and correlate the formations. Prospecting for fossils took place at all known exposures to establish biochronologic control. Petrographic studies, XRD analyses of claystones, and fission track dating and trace element fingerprinting of tuffs were also undertaken. Determination of the lithologic characteristics, ages, and relationships of these formations has enabled reconstruction of the depositional environments that existed throughout southwestern North Dakota during this time. This project was funded in part through the U.S. Geological Survey's Cooperative Geologic Mapping Program (COGEOMAP).

The report is profusly illustrated with photographs and has eight color maps in the text and seven color plates. One very important aspect of this report is its organization. The geology of each butte or butte complex is presented in a separate chapter; other chapters discuss regional stratigraphy, paleontology, correlation, economic geology, etc. Thus while the report is technical in scope, information on the geology of individual buttes is readily accessible to those curious about the geology of a favorite butte.

Permian to Jurassic Redbeds of the Williston Basin, by C. G. Carlson, NDGS Miscellaneous Series 78, (1993), 21 p., $5.00.

Since the earliest days of exploration in the Williston Basin the age and correlation of redbeds has been controversial. Redbeds of Permian to Jurassic age are present in outcrops in the Black Hills of South Dakota. Redbeds, which have been referred to as Jurassic in age, are present in outcrops in southern Manitoba. In the subsurface, equivalent strata are referred to as the Spearfish Formation of Triassic or Permo-Triassic age in North Dakota and the lower Watrous or Amaranth Formations of Jura-Triassic or Jurassic age in Saskatchewan and Manitoba.

While paleontological data are lacking for age resolution, careful examination of physical evidence from the subsurface indicates that previously unrecognized regional unconformities occur within the clastic redbeds. The report suggests several redefinitions of these units.

Outside Publications

Vertebrates of the Cannonball Formation (Paleocene) in North and South Dakota, by Alan M. Cvancara and John W. Hoganson: Journal of Vertebrate Paleontology, v. 13, no. 1, p. 1-23, March, 1993.

At least 22 taxa of vertebrates are recognized and described from the Cannonball Fm., which records the last marine transgression into North Dakota. All but three of the taxa are described and illustrated for the first time for the formation. The marine fishes confirm a Paleocene, more specifically Thanetian, age for the formation, and suggest a temperate Cannonball Sea of primarily shallow subtidal depths. Fish occurrences also imply a connection to the Atlantic Ocean, and support proposed K-T boundary marine fish extinctions and Paleocene fish renewals.

Exceptionally long, narrow drumlins formed in subglacial cavities, North Dakota, by John P. Bluemle, Mark L. Lord, and Nathan T. Hunke: Boreas, v. 22, p. 15-24, 1993.

An array of about 200 exceptionally long and narrow drumlins occurs in north-central North Dakota, directly upglacier from an area of extensive ice thrust topography. Excavations through the longest (27km) of these linear ridges revealed complex internal structures. Materials contained within the drumlins were transported from higher pressure areas beneath the glacier, inward toward lower pressure areas (cavities) by flowing, thrusting, squeezing, and other processes.

EARTH SCIENCE EDUCATION

by Bob Biek

Within the past year, two good books on rocks and minerals have passed across my desk. Both proclaimed rock and mineral collecting to be one of the fastest growing hobbies in the United States. As well it should be in my opinion, for there is little to compare with spending a day outdoors caught up in the adventure of looking for pretty, useful, and sometimes valuable rocks, minerals, and fossils. Collecting them is fun. Working with them is fun. But more than that, rocks, minerals, and fossils tell us something about the earth. They are to geology what the alphabet is to language - the script from which we can read the history of the earth.

By any measure, rock and mineral collecting was *extremely* popular from the 1950s through the 1970s, when cutting and polishing equipment became readily available. But if this hobby is growing nationally, we in North Dakota seem to be bucking the trend. Several rock and mineral clubs across the state have closed in recent years.

Three clubs are still active in the state, however. The clubs have regular meetings, fieldtrips, publish monthly newsletters, and are excellent sources of information. Like any hobby or sport, rock, mineral, and fossil collecting has its own code of conduct, and, indeed, rules and regulations that concern collecting; club members can help you understand the common courtesies and legal rules involved. Whether you belong to a club or not, rock, mineral, and fossil collecting is an open door to the fascinating science of geology. I and other rock club members encourage responsible collecting and the knowledge and fun it brings.

Central Dakota Gem and Mineral Society
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Bismarck, ND 58502
Contact: John Atwood, President (701)-221-0389

Lake Agassiz Rock Club
P.O. Box 10314
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Contact: Wil DeGraff (701) 293-3582

North Dakota Paleontological Society
P.O. Box 1921
Bismarck, ND 58502-1921
Contact: Mike Marquart, President (701) 223-0652

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