NDGS NEWSLETTER

Industrial Commission of North Dakota
North Dakota Geological Survey

Volume 24, No. 3
Fall, 1997

Geologists of the North Dakota Geological Survey in 1964. Pictured from left are Wilson Laird, John Bluemle, Sid Anderson, Rusty the Dog, Dan Hansen, Kelly Carlson, Ted Freers, and Ned Noble.

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.

Your comments - and contributed articles, photographs, meeting announcements, and news items - are welcome. Correspondance, subscription requests, and address changes should be addressed to: Editor, *NDGS Newsletter*, North Dakota Geological Survey, 600 East Boulevard Avenue, Bismarck, ND 58505-0840 (701) 328-8000.

When requesting a change of address, please include the number on the upper right hand corner of the mailing label.

From the State Geologist

By John P. Bluemle

Governor Schafer has proclaimed October 12-18, 1997, as *Earth Science Week* in North Dakota. The proclamation, and an article by NDGS geologist and *NDGS Newsletter* editor Ann Fritz (page 3), notes some of the ways that geology and the earth sciences are important to the well-being of society. Setting aside a week to recognize the role the earth sciences play in our lives gives us a chance to reflect on some of the ways geology impacts us every day.

Earth science and geology are not exactly synonymous. Geology is just one of several earth sciences. Other earth sciences include geography, meteorology, soil science, and seismology. The study of the rocks and weather on Mars by Sojourner, an engineering feat that captured our imagination in July, is planetary geology, probably not really "earth" science, but earth scientists still claim it as part of their discipline.

It is unfortunate that we often are not aware of the role earth science plays in our lives until we experience some kind of natural disaster - an earthquake, a hurricane, a flood. We were recently made painfully aware of one of the geologic hazards we face in North Dakota. The recent floods in the Red River Valley and the ongoing flood at Devils Lake are examples of the worst that geology has to offer North Dakota.

NDGS geologists are studying the geology of the Devils Lake area and appraising the geologic effects of the floods there and on the Red River (see *NDGS Newsletter*, v. 24, no. 2; Summer, 1997). If we can better understand the geologic factors that cause floods, and make people aware of those factors, our public officials can deal with them effectively.

The main role of the NDGS is an economic one - most of the studies we do are intended to find and develop the state's mineral and energy resources. Probably one-third to one-half of our work deals with the geology of the rocks in the Williston Basin that produce hydrocarbons. We also try to identify and find ways to utilize other mineral resources. We conduct a variety of studies of environmental problems - potential groundwater contamination resulting from oil and gas drilling fluids, herbicides, and municipal wastewater impoundments and landfills. Our geologists investigate natural hazards in the environment such as mercury, arsenic, radon, and radioactive materials.

The North Dakota Geological Survey is the state agency that studies the geology of North Dakota and makes that information available in a variety of ways. Other state and federal agencies also generate geologic information. Hydrologists and engineers with the North Dakota State Water Commission deal with groundwater and surface water. Geologists and hydrologists with the United States Geological Survey deal primarily with issues relating to groundwater hydrology. Together, our staffs cooperate to understand the geology and hydrology of the state. Over a 30-year period from the 1960's into the 1990's, our three agencies worked together to map the geology of every county in North Dakota and to appraise the groundwater resources in every county. Students and professors at the universities in North Dakota also study the state's geology. Members of our staff work with geologists at colleges and universities, sometimes hiring or otherwise supporting students to map parts of the state, sometimes contracting for studies we don't have the staff or equipment to do ourselves.

I think that most of our geologists would say that the part of their jobs they like best is learning new things about the geology of our state. I know that I will never tire of trying to figure out how the North Dakota landscape came to be the way it is. John Hoganson, our paleontologist, can get so involved in, and concerned about, collecting a fossil specimen in the field that he will work for days on the task with little or no sleep. His purpose, as mine, is to better understand the earth's history, in his case, ancient life. Randy Burke, our carbonate geologist, can get just as enthusiastic while studying how a 400-million-year-old limestone formed and applying that knowledge to the search for oil in that particular formation. Each of our geologists is dedicated to his or her discipline.

North Dakota's landscape is determined by geology. The badlands along the Little Missouri River are a product of erosion by the river. Our flat, fertile farmland in the Red River Valley is the floor of an old glacial lake. Our rolling prairies were formed by glaciers during the Ice Age. Our ducks feed and nest in the hundreds of thousands of prairie pothole sloughs on the Missouri Coteau. All of these things are part of our natural heritage. They are "why" we are what we are and, if we are the least bit curious, knowing more about them is satisfying and enriching to our lives. As geologists, we are anxious to share what we know. It's interesting to us; we hope it might be interesting to you.

NEWS IN BRIEF

Compiled by Ann M.K. Fritz

Survey Has Two New Employees

The NDGS has two new employees: Steve Kranich and Don Thom. Steve and Don come to the NDGS from the ND State Soil Conservation Committee (SSCC) by way of legislation passed by the 55th legislative session.

For the past 13 years, Steve has been working as a cartographer for the SSCC. He also teaches art, on a volunteer basis, to fifth graders at Will-Moore Elementary School in Bismarck. Steve is married and has two "great kids": Amber, 17, and Stephanie, 11. Golfing, playing football and an interest in early American art are what Steve enjoys doing best when he is not working at the Survey.

Don was born in Center, ND, and enjoys fishing in his spare time. Don is no stranger to most folks at the NDGS. Prior to his six years working at the SSCC, Don worked at the NDGS-GIS Center on a temporary basis.

Steve and Don will eventually be joined by three additional personnel who will be working on compiling and digitizing the state soil survey information. The soil compilers are working closely with personnel from the Natural Resource Conservation Service (NRCS) and the NDGS GIS Center.

Foster, Dahl & Bluemle Tour Lignite Energy Facilities

Reprinted from the Mouse River Journal

Three members of the Air Pollution Control Advisory Board - Steve Foster, Towner, ND, and Phillip Dahl and John Bluemle, both of Bismarck, ND - participated with a group of legislators and state officials in getting a firsthand look at the lignite industry during the Lignite Energy Council's annual Legislative Tour on July 10, 1997.

Stops included the byproduct facilities at the Great Plains Synfuels Plant; surface mining and reclamation areas at Coteau's Freedom Mine; and the energy conversion and pollution control areas at Basin Electric Power Cooperative's Antelope Valley Station. During the tour, legislators and state officials received an update on the future of the Great Plains Synfuels Plant and byproduct development, as well as the competitive position of the lignite industry.

The legislators and state officials learned that the lignite industry has a major impact on North Dakota's economy through the direct and indirect employment of over 20,000 people; the annual generation of $1.5 billion in business volume; and the annual generation of over $65 million in tax revenue (from coal severance, energy conversion, sales and use, and personal and corporate income tax).

(Left to Right): John Dwyer, President of the Lignite Energy Council, Steve Foster, Phillip Dahl, and John Bluemle stand in front of the Great Plains Synfuels Plant near Beulah, ND.

Hug a Rock . . .
or the people that study them!
by Ann Fritz

In August, Governor Edward T. Schafer signed a proclamation to proclaim October 12-18 as *Earth Science Week* in North Dakota. The earth sciences include any of the essentially geologic sciences concerned with the origin, structure and physical phenomena of the earth.

You may think that any science that deals with the origin, structure or physical phenomena of the earth doesn't *really* relate to you. During the week of October 12-18, take some time to go outside, look at the landscape around you, look up at the sky and the clouds, and look at the land under your feet. Now ask yourself, "How did all this get to be like this?" This seemingly simple question is what earth scientists ask every day. Paleontologists unearth triceratops bones and try to piece together information about the creature's life. Their knowledge is shared with us in a display at the North Dakota Heritage Center. Glacial geologists study the sediments left behind and the landforms shaped by long-gone ice sheets to try to unravel our most recent geologic past. Glacial geologists also find deposits of sand and gravel for paving roads and building materials. Petroleum geologists find oil that is refined to gasoline that fuels Mom's Buick and Grandma and Grandpa's motorhome. Hydrogeologists "discover" groundwater for us to drink and soil scientists describe the chemistry of soils so farmers know how much fertilizer their corn crop will need. Meteorologists study and predict weather patterns and climatic cycles to prepare us for potentially damaging storms or blizzards.

All of the scientists mentioned above are Earth Scientists. Earth science impacts us in some way, every day, whether we realize it our not. The articles and departments in the *NDGS Newsletter*, as well as the geologists at the NDGS, hope to answer any earth science questions you may have, not just during *Earth Science Week*, but every week. Give us a call or better yet, write us a letter with your "earth observations". If I get enough responses, I will print your observations in a future issue of the *NDGS Newsletter*.

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EDWARD T. SCHAFER
GOVERNOR

PROCLAMATION

Geology and the other earth sciences are fundamental to the well-being of our society.

The earth sciences are integral to finding, developing, and conserving mineral, energy and water resources needed for society.

The earth sciences provide the basis for preparing for and mitigating natural hazards such as floods, landslides, drought, storms and earthquakes.

The earth sciences are crucial to environmental and ecological issues ranging from water and air quality to waste disposal.

Geological factors are vital to resources and land management decisions to local, state, regional, national and global levels.

The earth sciences enrich our appreciation and understanding of the natural features in North Dakota including the Badlands, Red River Valley, Prairie Pothole Region and other unique areas.

The earth sciences contribute to our understanding of the weather, climate and soils of North Dakota.

The earth sciences contribute to our understanding of North Dakota's rich and diverse fossil resource heritage.

For these reasons, I proclaim the second full week of October as

"EARTH SCIENCE WEEK"

in North Dakota.

EDWARD T. SCHAFER
Governor

ATTEST:
Secretary of State

By ____________________
Deputy

NDGS Office Has A New Location

As of July 1 of this year, the NDGS has moved to a new office location. Visitors to our old office may have noticed that NDGS offices were spread out over three floors and there was limited space to add new offices as our staff grows. Our new office, however, is in a single story building with plenty of room to expand. Stop by and visit us sometime! Our new location is:

1600 East Interstate Avenue, Bismarck
(across the street from Basin Electric)
Phone (701) 328-8000
Fax (701) 328-8010

Our mailing address and hours have remained the same:

600 East Boulevard Avenue
Bismarck, ND 58505-0840
Monday through Friday
8:00 a.m.-12:00 p.m. and 1:00 - 5:00 p.m.

NDGS goes Electronic!

We are in an age of increasing computer use and computer literacy. The NDGS is trying to keep up with the times by offering a new service: customers can now order publications via e-mail. To order publications via e-mail, simply send us your name, mailing address, phone number, and the name and quantity of the publication you wish to order to: **ndgspubs@rival.ndgs.state.nd.us**.

Your order will be processed in 1-2 business days. Customers will be invoiced for materials plus shipping costs, if applicable.

Do you have a geologic question you would like to ask our staff directly? Below is a list of e-mail addresses for our staff members. Their areas of specialization are listed below and on the back cover of each issue of the NDGS Newsletter. Please save this chart for future reference!

Graham Leaves Survey

Recent NDGS hire, John Graham, traded in his pencil and field notebook for chalk and a blackboard. John resigned his position and accepted a teaching position at Colby College, a small, private school in Maine. John accomplished many things at the NDGS even after being on the job only four months. John was coordinator of the *Earth Science Information Center* office and assisted in geologic mapping projects. He assisted fellow NDGS geologist, Ann Fritz, with air photo compilation and field work for the Grafton 1:100,000-scale surficial geologic mapping project. John's expertise in clastic sedimentology was an asset to the project. Best of luck to John and his family as he begins his career as "Professor Graham"!

Geologist	Field	E-mail Address
John Bluemle	State Geologist; Glacial geology	bluemle@rival.ndgs.state.nd.us
Randy Burke	Petroleum geology; Carbonate geology	rburke@rival.ndgs.state.nd.us
Paul Diehl	Petroleum geology; Sedimentary geology	pdiehl@rival.ndgs.state.nd.us
Ann Fritz	*NDGS Newsletter* editor; Earth Science Information Center (ESIC); Environmental geology; Geologic mapping program; Glacial geology; Geothermal energy	afritz@rival.ndgs.state.nd.us
Tom Heck	Global Positioning System (GPS); Geographic Information System (GIS) Center; Petroleum geology	tom@rival.ndgs.state.nd.us
John Hoganson	Paleontology; Earth science education; Western ND geology	jhoganso@pioneer.state.nd.us
Julie LeFever	Director of Wilson M. Laird Core and Sample Library in Grand Forks; Petroleum geology; General geology	(701) 777-2231 (701) 777-2857 fax
Ed Murphy	Environmental geology; Geologic mapping program, Western ND geology, Coal exploration; Subsurface minerals; Waste disposal	ecmurphy@rival.ndgs.state.nd.us
Ryan Waldkirch	Geographic Information System (GIS) Center; Earth Science Information Center (ESIC)	ryan@rival.ndgs.state.nd.us

"New" Geothermal Heat Transfer Fluids Approved
by Ann Fritz

In addition to being *NDGS Newsletter* editor, I am also administrator of the geothermal regulatory program. The geothermal regulations are administered by the NDGS and a permit from the State Geologist is required prior to installation of a geothermal system. Although a permit is not required for private residential heating or cooling systems, a completion report must be filed with the NDGS. All construction of geothermal energy systems must comply with the rules contained in North Dakota Century Code Chapter 43-02-07. The geothermal energy extraction rules were made to protect geothermal system installers, to better track geothermal energy usage, and to protect the natural resources of our state.

All heat transfer fluids used in geothermal systems must be approved by the State Geologist for use in North Dakota. In mid-May of this year, I received two separate requests for approval of heat transfer fluids, ethanol and Environol™. Environol™ is ethanol with corrosion inhibitors and is manufactured by WaterFurnace International for use in their geothermal systems. I forwarded the requests to Scott Radig, N.D. Department of Health Division of Water Quality, for his recommendation regarding the toxicity of the proposed fluids.

Based on the recommendations of Scott Radig and myself, and our review of the literature, John Bluemle, State Geologist, recommended approval of methanol and ethanol-based heat transfer fluids. It is important to note that while approval is an attempt to identify heat transfer fluids that will not harm the environment, it is the responsibility of the installer and owner of the system to become familiar with the safe and proper use of the fluids, as well as to protect surface and ground water. It is also the responsibility of the installer to be familiar with the compatibility of heat transfer fluids and piping materials. High quality, compatible installation materials can greatly increase the life and performance of a geothermal system, as well as protect against leaks from joints or piping. In a report from the University of New Mexico titled *Assessment of Anti-Freeze Solutions for Ground-Source Heat Pump Systems*, the authors state that "while the choice of anti-freeze fluids can minimize potential leakage, high-quality parts and good installation practices may ensure that a range of fluids can be used in many applications" (p.89, E. Heinonen, R. Tapscott, M. Wildin, and A. Beall, *ASHRAE Report 908RP*, August 1996).

At present, the NDGS does not approve some heat transfer fluids that may currently be used in other parts of the country, such as urea, calcium magnesium acetate, glycerine, dipotassium phosphate solutions and sodium chloride. At this time, there is not enough information available about the leakage potential, health and safety hazards to determine if these solutions would pose a significant threat to human health and the environment. As more research is completed on these fluids, we could revisit this decision. If you have questions about the geothermal regulatory program or permitting process, please call me at (701) 328-8000.

Prairie Quiz

Test your prairie and National Grassland knowledge with the following questions . . .

1. There are 20 National Grasslands, totaling nearly four million acres in 12 western states. Which of the following states has a National Grassland? a. Arizona b. California c. Nevada d. Montana
2. What National Grassland has the nation's largest surface coal mine?
3. *True or False*. National Grasslands were once National Forests before the trees were cut. T F
4. What is the nation's largest ecosystem, comprising nearly 600 million acres?
5. Where is the world's largest hand-planted forest?
6. Grass is the lifeblood of the prairie, with over 1,000 species of grass. What percentage of a prairie grass volume is actually underground?
7. What wildlife species lives with prairie dogs and is one of the rarest mammals in North America?
8. Where is the only visitor center dedicated to National Grassland and prairie ecosystem education and information?
9. The largest National Grassland is over one million acres. What is it and where is it located?
10. Native grasslands are being lost to encroachment of exotic plants, cultivation, urbanization, and other factors. What percentage of native tall grass prairie remains intact?
11. About 11 million people live on the Great Plains, less than metropolitan Los Angeles. What percentage of the 11 million people live in rural areas?

Reprinted from the Northern Great Plains Management Plans Revisions *Revision Reporter* newsletter, January 1996.

Answers on page 6.

MEETINGS & CONFERENCES

CSPG-SEPM Joint Convention
by
Randy Burke

I had the good fortune to be invited by the Canadian Society of Petroleum Geologists-Society of Economic Paleontologists and Mineralogists Joint Convention organizing committee to present a Core Workshop on Lodgepole Formation cores from the Dickinson oil play. It was an outstanding meeting organized by weaving together applied and academic research presentations around the theme *Sedimentary Events and Hydrocarbon Systems* using the concept of cratonic sequences as the binding thread. The convention commemorated the 35th anniversary of the publication of Larry Sloss' concept of cratonic sequences, the foundation for modern sequence stratigraphy. Sadly, Dr. Sloss passed away several months before the meeting. I am confident he would have been thrilled with the recounting by many of his students (e.g. Peter Vail, J.M. Andrichuk and others) about how they were sent by him all over North America to field test his concept. Likewise, he would have been delighted to hear the pro and con arguments over the details of his concept. Personally, I was glad to hear many arguments supporting the importance of tectonics as causing many third and fourth order sequence boundaries. Not only eustatic forces, as is emphasized by Peter Vail and the Exxon group, but also glacio-tectonic processes, on both a local and global scale, combine to create many sequences.

My presentation, *Carbonate Buildup Reservoirs, Lower Mississippian Lodgepole Formation, Dickinson Field, North Dakota, USA,* emphasized the rock characteristics utilizing portions of five cores. We owe CSPG and SynerTech many thanks for picking up the tab for shipping the pallet of cores to Calgary. The Core Conference was open to all 3,000 plus attendees of the meeting, and all received the volume of papers written by Core Conference presenters. Based on the numerous large groups (40 to 60 persons) that attended my several formal presentations, interest in the Lodgepole play is still high. The damper is that no one has figured out how to discover more buildups. Obviously more work needs to be done. Exciting news about the play that I learned at the meeting, and was allowed to incorporate in my presentation, regarded *new buildup discoveries* in Saskatchewan. One, maybe two, economically productive buildups have been discovered around the North Antler Field area previously reported by Rick Sereda and Don Kent. The exciting aspect of this discovery is that the oil has been typed by Kirk Osadetz to be from Lodgepole source rocks. Therefore, those people limiting their area of exploration to the distribution of mature Bakken are reducing their probability of a Lodgepole discovery.

North Dakota State Fair
by
John P. Bluemle

The North Dakota Geological Survey had a booth at the North Dakota State Fair in Minot, July 18-26, 1997. Our staff took turns at the booth, greeting people who stopped to ask questions about geology - rocks and minerals, fossils, floods - a great variety of topics. It's good to get the chance to visit with people to find out what they want to know about North Dakota geology. Hundreds of people stopped by our booth and many requested publications on specific topics or asked to be put on our newsletter mailing list.

This was the second consecutive year that the NDGS has been at the fair. I was there during the last couple of days, and it seemed that I spent most of my time answering questions about the floods at Grand Forks and Devils Lake.

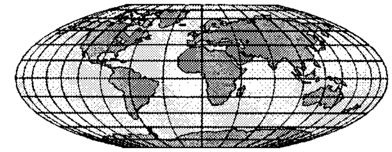
Probably the most "exciting" event while I was there was the tornado warning on Friday, July 25, which forced virtually everyone to congregate in the All Season's Arena, presumably the safest place on the fairgrounds during a tornado. The tornado funnel was visible for quite some time in the distance south of Minot. Fortunately, neither Minot nor the fairgrounds was actually hit by the tornado and there was no serious damage.

Answers

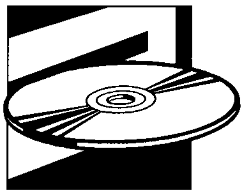
Answers to *Prairie Quiz* on page 5.

1. California (b)
2. Thunder Basin National Grassland, eastern Wyoming
3. False
4. Great Plains
5. Bessey District in Nebraska sandhills
6. Over 50 percent
7. Black-footed Ferret
8. Wall, South Dakota
9. Little Missouri National Grassland in North Dakota
10. Less than ½ percent
11. About 30 percent

ESIC NEWS



The NDGS is an affiliate of the Earth Science Information Center (ESIC) network. Coordinated by the U.S. Geological Survey, the nationwide ESIC network provides information about geologic, hydrologic, topographic and land use 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 earth science materials dealing with North Dakota, as well as other states. For more information, contact Ann Fritz or Ryan Waldkirch at (701) 328-8000.



DIGITAL SPATIAL DATA

Great Basin Geoscience Data CD-ROM

The following CD-ROM is now available: DDS-41, "Great Basin Geoscience Data Base". This 2-CD set contains digital data for the Great Basin collected to assist in the modeling and map generation for mineral resource assessments. The data are also applicable to other geologic, land management, and assessment problems. The geoscience coverages are stored in three different formats: ARC export, Federal Data Exchange format (SDTS), and PC visualization (ARCVIEW1). It was produced in accordance with the ISO 9660 standard. The PC ARCVIEW1 software is intended only for use with Windows for viewing the data. Cost for the 2-CD set is $42.00 + $3.50 handling charge for each order. DDS-41 is available from: *USGS-Information Services, Box 25286, Denver, CO 80225.* MasterCard and VISA orders can be faxed to (303)202-4693. For credit card orders, please include expiration date. *(Reprinted from ESIC Info Bulletin 361)*

Golden Valley Digital OrthoQuad Available

The Golden Valley, North Dakota digital orthoquad (DOQ) is now available on CD-ROM. The price per CD is $32.00 + $3.50 handling charge for each order. The DOQ can be ordered from: *USGS-Information Services, Box 25286, Denver, CO 80225.* MasterCard and VISA orders can be faxed to (303)202-4693. For credit card orders, please include expiration date. *(Reprinted from ESIC Info Bulletin 364)*

USGS Digital Orthophoto Quadrangle (DOQ) Header Format Changes

The U.S. Geological Survey (USGS) DOQ header records changed to a keyword format beginning in May, 1997. The new format and content of the DOQ header makes information about the image easier to read and interpret while the DOQ image specifications remain unchanged.

The new keyword header contains data for identification, display, and registration of the image to geospatial data such as digital line graph data or raster maps. Other header entries address data lineage, quality and information, such as file and header sizes to aid file processing. Along with the change to keywords, the number of data fields has been reduced to 45. The flexibility of adding keywords to meet changing metadata requirements was an important factor in developing the header modifications.

Each keyword entry consists of three fields: keyword, parameters, and comments. A keyword is a unique string of non-blank ASCII characters that defines an object or attribute. Parameters are strings of ASCII characters, numeric or text that represent the members of the domain of values that describe the keyword. Text parameters containing embedded blank characters are enclosed in double quotation marks. For example, "Half Moon Bay" is a text parameter with embedded blanks for the QUADRANGLE_NAME keyword. Comments may describe the parameter or specify a valid parameter format. Blank characters separate the keyword from the parameters, multiple parameters from each other, and the last parameter from the comment. Each 80 character entry is terminated by a new line (return) included in the character count of the line. This header format change will affect all uncompressed DOQ data distributed by the USGS, including the approximately 50,000 completed DOQ's covering 25% of the conterminous US. County-based, JPEG-compressed DOQ CD products will continue to have the original, fixed-record header.

The USGS National Mapping Program's "Standard for Digital Orthophotos" has been completely revised to document both format and content of the new DOQ header and to include color-infrared and true color DOQs as standard products. An Adobe Portable Document Format (PDF) copy of the revised standard is available at **ftp://mapping.usgs.gov/pub/ti/DOQ/doqstnds**. The revised "Standards for Digital Orthophotos" with the new keyword header in Appendix 2b, can be viewed online at **http://mapping.usgs.gov/www/ti/DOQ/standards_doq.html**. For technical information about the new DOQ keyword header, contact: *USGS Western Mapping Center, 345 Middlefield Road, MS 531, Menlo Park, CA 94025.* Fax questions to (415) 329-5528 or e-mail to *doq_info@usgs.gov*. *(Reprinted from ESIC Info Bulletin 363)*

Geospatial Data Website Under Development

The USGS and Microsoft Corporation have signed a Cooperative Research and Development Agreement to participate in cooperative commercial geospatial data website development. This agreement will run for at least 18 months and will present vast amounts of USGS geospatial data over the Internet. The initial effort will be focused on the storage and presentation of aerial imagery and will make available to the public the entire USGS digital orthophoto quadrangle (DOQ) dataset currently in the USGS archive. Microsoft will edit and package the DOQ information in such a way that it can be searched on the Internet and downloaded on the average home computer over low-speed connections. These "Internet-sized" images will be very small portions of the DOQ.

With this agreement, the USGS hopes to increase public awareness of and access to USGS information and involve private sector expertise in the marketing, public access and distribution of USGS data and information. It will present USGS data in an easy to use interface available to the general public over low-speed connections and streamline the process of finding, ordering, and purchasing USGS data. A parallel partnership agreement has been signed between Microsoft and Russian Interbranch Association Sovinformsputnik (Spin2). Global satellite images provided by Spin2 will be highlighted along side USGS DOQs as part of the same Microsoft website development. Stay tuned to *ESIC News* for more details. *(Reprinted from ESIC Info Bulletin 365)*

Digital Products No Longer Distributed on 9-Track Computer Tapes

Based on the recommendation of the Product Proposal Review Board, the Business Council approved the EROS Data Center's proposal to discontinue offering digital products from the National Mapping Center Sales Data Base on 9-track tape. A 90-day alert to customers began in June, and as of August 31, 1997, the EROS Data Center will no longer offer digital products on 9-track tape media.

The approval was based on a long period of steady decline in customer requests for products on 9-track tapes and a cost savings to be realized from discontinuing the maintenance of 9-track tape processing equipment. Once an industry standard for distributing digital data, 9-track tapes have been superseded by the compact disk (CD), 8 mm cartridge, 3480 tape cassette, and custom Internet file transfer options. For more information, please contact EROS Data Center Customer Services at (605) 594-6151, fax (605) 594-6589, e-mail *custserv@edcmail.cr.usgs.gov* or *Customer Services, EROS Data Center, Sioux Falls, SD 57198.* *(Reprinted from ESIC Info Bulletin 367)*

FREE Digital Line Graph Viewing Software

For a limited time only, experimental Windows 95 software, dlgv32, for viewing USGS Digital Line Graph Optional (DLG-O) and Digital Raster Graphic (DRG) data has been offered to the public via Anonymous/FTP. It was developed at the Mid-Continent Mapping Center in support of DLG-O production activities. dlgv32 provides a viewing capability previously unavailable to non-GIS users of DLG-O and DRG data. Two versions will be available until at least August 31, 1997, while additional testing and research are conducted. If favorable responses are received, the USGS may make the viewer available as a standard supplement to DLG-O data.

The dlgv32, Version 1 for viewing DLG-O data includes some basic viewing tools such as the ability to load multiple files and overlays; zoom and pan functions; the ability to determine line, area, and node attribute codes via a pick tool; and the ability to make point to point measurements. A second version of dlgv32 for viewing DLG-O and DRG data is being offered as a means to solicit user input to software development. Please note that dlgv32 runs only on Windows95 or Windows NT platforms. dlgv32 operates on DLG-O ASCII data and DRG GeoTIFF data. It will not operate on DLG-S, an older DLG format which is no longer sold or supported, or DLG data distributed as zip-compressed files. Zip-compressed files must be unzipped first. In addition, dlgv32 will not operate on DLG files in Spatial Data Transfer Standard (SDTS) format at this time. An SDTS version is being developed and will be released this fall.

Both versions of the software are available over the Internet as self-extracting zip files. Once downloaded to local storage, a double-click on either file in Windows Explorer will start the Windows 95 installation process. Installation of the software takes less than a minute. Instructions for downloading the software, a user manual and sample data files can be found on the dlgv32 WEB page at **http://mcmcweb.er.usgs.gov/viewers/dlg_view.html**. According to Ryan Waldkirch, NDGS GIS manager, dlgv32 is easy to use and "a really cool program".

dlgv32 on the Internet is an important step toward being more responsive to the needs and requirements of our customers. A user input form is included on the dlgv32 WEB page and users are encouraged to forward their comments to Mid-Continent Mapping Center. User feedback will be considered in decisions about the continued availability of and support for this viewer. Questions and comments about dlgv32 may be directed to Larry Moore at (573) 308-3661 or *lmoore@usgs.gov*. *(Reprinted from ESIC Info Bulletin 373)*

GENERAL INFORMATION/EDUCATIONAL MATERIALS

Search for National Aerial Photography Program Photos Online

You can now search for aerial photography from your own computer. Aerial photographs from the National Aerial Photography Program (NAPP) can now be searched and ordered through the Global Land Information System (GLIS). Customers can do online queries, identify photographs covering specific areas of interest, look at maps outlining the area covered by each photograph and create orders for the photographs selected. NAPP photography, flown at 20,000 feet, is available for the 48 conterminous states, with photographs starting in 1987. Each image covers an area of about 33 square miles. Most of the photographs are in black and white, although some areas are available in color infrared.

GLIS searches for NAPP photography can be made by identifying a geographic area on a map, by typing in latitude and longitude coordinates, or by entering a U.S. Place Names feature name. Acquisition date and film type may also be specified. The inventory search results will list all photographs meeting the entered criteria. If a date is not specified, the results will include all of the photography flown over that area with the most recent listed first. Detailed information, which can be viewed for each photograph listed, includes an outline of the area covered shown on a map background, film type, acquisition date, roll and frame number. EROS Data Center (EDC) plans for enhanced map background graphics in the near future include the 1:100,000-scale transportation, hydrography, and boundary layers.

Customers placing orders for NAPP photographs through GLIS will be contacted for credit card information. Customer assistance in ordering is available from EDC Customer Services at (605) 594-6151. The fax number is (605) 594-6589. E-mail can be sent to *custserv@edcmail.cr.usgs.gov*. The Internet address for NAPP online database is **http://edcwww.cr.usgs.gov/webglis/glisbin/search.pl?NAPP**. Or customers can browse through the full functionality of GLIS at **http://edcwww.cr.usgs.gov/glis/glis.html**. *(Reprinted from ESIC Info Bulletin 368)*

Aerial Photography Price Changes

Effective August 1, 1997, the price of certain standard photographic products from the USGS has increased. The price of a 9x9-inch black and white paper print and the price of a 9x9-inch film product is now $10.00. The price of a 40-inch color or color infrared print is now $75.00. The price increases were made to cover the costs of reproduction, which have risen substantially over the last ten years. Questions or comments about the price increase should be addressed to Harry Zohn at (703) 648-5903. *(Reprinted from ESIC Info Bulletin 374)*

Wilson Morrow Laird
1915-1997

Note: *The initial comments that follow are some I wrote for delivery at the annual meeting of the Association of American State Geologists in Breckenridge, Colorado, on June 24, 1997. The additional comments were compiled by Dr. F.D. Holland, Jr., Geology Professor Emeritus at the University of North Dakota. They are remembrances that were delivered at a memorial service for Dr. Laird on July 3, 1997, at the University of North Dakota. ~John P. Bluemle*

Wilson Morrow Laird, State Geologist of North Dakota from 1941 until 1969, died on May 14, 1997 in Kerrville, Texas at the age of 82. He is survived by three sons, Douglas, David, and Donald, and one daughter, Dorothy. He was preceded in death by Reba (Latimer) Laird, his wife of 50 years who died in 1989, and by Margaret (Ray) Laird, who died in 1996.

Born in Erie, Pennsylvania on March 4, 1915, Wilson Laird received his B.A. from Muskingum College in 1936, his M.A. from the University of North Carolina in 1938, and his Ph.D from the University of Cincinnati in 1942. He was also awarded honorary D.Sc. [doctorate of science] degrees by Muskingum College in 1964 and by the University of North Dakota in 1984. Wilson Laird came to North Dakota in September, 1940, from the University of Cincinnati and he was named state geologist in 1941 at the age of 26.

Wilson was nationally known and respected for his work in geology. His research included work in Ohio, Pennsylvania, North Dakota, Minnesota, Alaska, Manitoba, Germany, and Turkey. He worked as a petroleum geologist for Carter Oil in Montana and for Hudson Bay Oil & Gas in Calgary. He also consulted for the USGS and for Beers and Heroy.

Wilson published extensively on subjects as diverse as biostratigraphy, regional geology, limnology, mineral deposits, glacial geology, groundwater geology, and petroleum geology. His work included a great number of diverse geologic projects in the Williston Basin of North Dakota involving rocks ranging in age from Paleozoic through Cenozoic.

Wilson received many honors during his long and distinguished career. In 1948 he shared (with his friend and colleague, Larry Sloss) the President's Award of the American Association of Petroleum Geologists for work on the Devonian stratigraphy of Montana and he received the AAPG Public Service Award in 1981. In 1992 he received the first Arthur Gray Leonard Medal, the highest honor awarded by the University of North Dakota Department of Geology, which he chaired for many years.

Wilson served as Vice Chairman of the Interstate Oil Compact Commission and as Chairman of the Research Committee of the IOCC. In 1948 he was elected Vice President of the Association of American State Geologists and in 1950 he was elected President. He also served as President of the North Dakota Academy of Science for the 1952 term.

Wilson Laird is credited with the foresight that oil would one day be discovered in the Williston Basin in North Dakota. To insure that North Dakota avoided the problems that had beset some oil-producing states, he had legislation introduced in 1941 that resulted in a model oil-and-gas conservation law being in place ten years prior to the discovery of oil in North Dakota. He also recognized the necessity of establishing a facility for the storage and study of oil and gas core and samples.

In 1980, the State of North Dakota recognized Wilson Laird's diligent efforts in collecting the information obtained from oil and gas wells by naming a new core repository after him. This North Dakota Geological Survey building is located on the campus of the University of North Dakota in Grand Forks (it is among the few buildings in Grand Forks that was not flooded this spring).

During his tenure, the North Dakota Geological Survey grew from a staff of one (himself) to over 40 employees. The larger staff was needed to enforce the oil and gas regulations and rules and to provide information and answers to the increasing number of questions concerning the geology of the state following the discovery of oil in 1951. Wilson initiated several new programs during the 1950's, including the innovative County Geology and Groundwater Resource mapping program, a cooperative program with the U.S. Geological Survey and the State Water Commission. This was the first program of its kind in the United States and it was adopted as a model by many states. Wilson also began many subsurface studies of the oil-productive Paleozoic and Mesozoic rocks and economic studies of the mineral resources of North Dakota.

In 1969, Wilson left the North Dakota Geological Survey and moved to Washington, DC to become Director of the Office of Oil and Gas in the Department of Interior. He subsequently served as Director of the Committee on Exploration of the American Petroleum Institute. Wilson retired from that position in 1979, but remained active for many years as a consulting geologist from his home in Kerrville, Texas and his summer home near Bemidji, Minnesota.

More than any other person, Wilson Laird shaped the North Dakota Geological Survey into the kind of agency it is today. A Memorial Service was held at the Alumni Center at the University of North Dakota in Grand Forks on July 3, 1997.

Remarks by F.D. (Bud) Holland, Jr.

It was here in the President's Residence, in the ballroom on the third floor, that President and Mrs. West held a reception for new faculty and welcomed the Lairds to the UND Campus in the fall of 1940. Subsequently, for nearly 30 years, Wilson Laird guided the expansion of the Geology Department and North Dakota Geological Survey as educator, research scientist, and administrator.

He was an active man: decisive, dynamic and anxious for progress. So some thought him abrupt. But those people didn't know that he was very thoughtful - he usually thought things out well in advance of the discussion at hand; he was ahead of them. He was always mindful and thoughtful of students and of the citizens/taxpayers of the state. He was a conservationist before it was popular. He was a scholar, a visionary, and a leader; but he would listen and then consider carefully a well-thought-out position. He was a fun camping companion and always kept things livened up, out-of-doors, or even in a meeting. He was fun to work for and with. I miss him.

Remarks by Sidney B. Anderson

(Sid Anderson was a geologist with the NDGS from 1952-1990. He served as Acting State Geologist from 1985-1988 and again from 1989-1990)

I had the good fortune to know Wilson Laird as a teacher and later to have been hired by him to work for the North Dakota Geological Survey. As a teacher, he was excellent, being able to get and maintain the interest of his students in geology. In addition to classroom teaching, he probably did as much teaching outside of the class as he did in class.

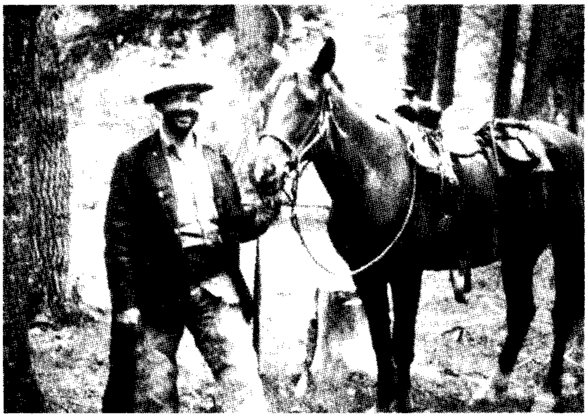
When I first knew him as a student, the Geology Department, including the Geological Survey, consisted of Wilson Laird and Irving Grossman and was housed in the basement of Merrifield Hall. I was still a student when the University obtained several wooden buildings from a former airbase in Sioux Falls, South Dakota. Wilson was able to get one of these buildings for the Department and the Survey. The acquisition of this building gave the Department much more room and, in addition to housing the Department and Survey, it also housed the Ground Water Division of the USGS. During this period, most of his students were in the building (the library) most evenings and Saturdays. During these times, Wilson often dropped in to engage in informal discussions with the students.

On April 4, 1951, oil was discovered in North Dakota and, fortunately for North Dakota, Wilson Laird had had the foresight to persuade the Legislature to pass the *Rules and Regulations* covering the exploration for and production of oil and gas. These rules still form the basis for oil and gas production and exploration in North Dakota today.

Shortly after the discovery, the American Association of Petroleum Geologists held their annual meeting in St. Louis. Wilson took four students, including me, along to the meeting. In as much as North Dakota was a new oil province, Wilson Laird was paged continually. I believe it is safe to say no one who attended this meeting left without knowing who Wilson Laird was. At this point, Wilson's duties with the Survey greatly increased - duties which he handled very well.

Because of his foresight, the North Dakota Geological Survey's Wilson M. Laird Core and Sample Library contains the most complete collection of cores and samples of any basin in the world. Also during his tenure as State Geologist, the Survey joined with the N.D. State Water Commission and the Water Resources Branch of the USGS to conduct the *County Studies Program*. This program has produced the basis for ground water evaluation and studies of surficial geology.

Wilson was instrumental in obtaining funds for a new building from the North Dakota Legislature. In 1965, the Geology Department and the NDGS moved into the new building, Leonard Hall, named for one of the outstanding early Department heads and State Geologists. A medal bearing Dr. A.G. Leonard's



Top left: Wilson Laird in the field in Montana (?).

Top right: Adjusting the load. Laird watches as a colleague secures field equipment.

Center: John Bluemle, Wilson Laird, and Ted Freers in 1964.

Bottom left: George Starcher, President of UND, and Wilson at groundbreaking ceremonies for Leonard Hall, UND campus, September 16, 1963.

Bottom right: Wilson (far right) and Nick Kohanowski watch as members of the UND Geology faculty break ground for Leonard Hall.

Top left: Ned Noble listens as Dr. Laird accepts the Leonard Award. Ned was state geologist from 1969-1978.

Top right: Bud Holland admires the Leonard Award.

At right: Dr. Wilson Laird, North Dakota State Geologist, 1941-1969.

name is presented annually by the Department to outstanding former students and faculty - Wilson Laird was the first recipient of the award.

Wilson left the Geology Department and Survey in 1969 when he was appointed to head the Office of Oil and Gas in the Department of Interior. After serving in that office, he went to the American Petroleum Institute where he headed the Office of Petroleum Exploration. Following his retirement, Wilson moved to Kerrville, Texas, where for a long time, he kept up his interest in geology by leading senior citizens on field trips and by teaching in elderhostels. Wilson is missed by his many former students and friends including those in both industry and academia.

Remarks by Frank Karner

(Frank Karner is Professor of Geology at University of North Dakota)

Even though Wilson Laird was the complete professional geologist, my recurring recollection of him is as a leader with an unusual style. When I was a beginning faculty geology at UND, he was Department Chairman and not only welcomed my visits with his familiar warmth, but also with another easily felt attitude. The attitude always said "Yes, let's try it." He encouraged me greatly by clearly expressing his natural positive response to people, their ideas, and change.

Remarks by Earl Strinden

(Earl Strinden is Executive Vice President of the UND Alumni Association. He served in the North Dakota Legislature for many years as a Grand Forks representative and House Majority Leader.)

I'm not at all sorry this special memorial tribute to Wilson Laird is here at the Alumni Center rather than the flood-ravaged Lecture Bowl in Leonard Hall. This old mansion, a campus landmark, stands as a tribute to the builders of this fine University. Wilson Laird was one of the builders. To the members of the family, welcome home! We know you are very proud of this unique individual who was a father, father-in-law, and granddad. I proudly claimed Wilson Laird as a friend. My comments will be as the Alumni Director of this University, former majority leader of the North Dakota House of Representatives, and a member of the Grand Forks community. Wilson Laird was dedicated to his profession, to this University, to his students, and to his colleagues. He touched so many lives in such a beneficial way. This becomes an ever increasing circle of goodness. The students he shared knowledge, experience, and wisdom with, and those he inspired, are serving and achieving and in turn making their lives count for the benefit of others.

The very early statutes of North Dakota stated, "The professor of geology at the University of North Dakota shall serve as the State Geologist." If there ever was a man for his time, it was Wilson Laird. He served as the North Dakota State Geologist during the time of our great and historic oil boom. Wilson was the respected expert and authority. He was the individual who was listened to and who, more than anyone else, shaped oil development policies for our state which made us a model for our nation. I can tell you from my own personal experience, Wilson Laird achieved something very unique in being highly respected and totally trusted by those in the oil industry and by both the executive and legislative branches of government and those who were on both sides of the political aisle. His service to our state as the State Geologist was distinguished and exemplary.

I wish we could turn the clock back to those exciting times. We were younger then. Wilson Laird made a host of friends. They would be counted in the thousands - elected officials, average North Dakota citizens, members of the industry, and so it goes. He was an unpretentious individual, exuding a genuine friendliness. He had a flair for life and had a great sense of humor. A very wise person once said something like this, "Fame is a vapor; popularity is often a mistake. It is only one's strength of character which has true and lasting meaning." Wilson Laird had a great strength of character. We are a better University, a better community, a better state, and it is not stretching it at all to say a better nation because Wilson Laird was here. I join with so many others in being grateful that we had an opportunity to walk a part of life's journey with him.

Remarks by John R. Reid

(John Reid is Professor of Geology at the University of North Dakota)

I was hired right out of the University of Michigan in 1961 to work with Wilson Laird on an NSF-sponsored research project on the Martin River Glacier in southeast Alaska. Working together in that rugged, insect- and bear-infested region taught me much about my boss. He enjoyed the outdoor activity; he always carried his share of the workload, and he always had appropriate remarks to liven up the discussions. As Chairman, Wilson realized that we faculty worked best with the least restrictions imposed, as long as we fulfilled our obligations. I owe much to Wilson Laird for all the opportunities he arranged for me and the support that was always available.

Remarks by Marcella Hanson Melsted

(Marcella Melsted was the North Dakota Geological Survey's Administrative Assistant from 1953 until 1965)

In 1953, I had returned from working at the American Embassy in Europe and I started working for Dr. Laird. It was an exciting time to be working for the North Dakota Geological Survey with the oil business booming. I remember the Laird children coming to the office often and Dorothy was telling me today that she was five years old when she came to visit her dad's office. I remained in that office for 12 years. Dr. Laird was a good boss and I enjoyed working for him. I kept in touch with him these last years as I would send him clippings from the *Grand Forks Herald*. He would reply with a postcard and tell me how things were going for him. I will miss those cards.

Viscosity of the Asthenosphere Beneath the Lake Agassiz Basin, Eastern North Dakota

by

Eric C. Brevik

If you could travel down through the earth, you would find that it is divided into several distinct layers. The top layer, called the lithosphere, is rigid. The lithosphere is made up of the crust and the part of the upper mantle that will not flow. Beneath the lithosphere is the asthenoshere, which is partially melted and has some fluid properties (Figure 1). The asthenosphere is the part of the upper mantle that will flow when stressed. Below the asthenosphere is the mantle, then the outer core, and finally at the center of the earth is the inner core. In this paper, I address the ease with which the asthenosphere will flow when stressed.

Recent geophysical studies have provided evidence that indicate the viscosity of the asthenosphere beneath the Canadian Shield may not be 4×10^{19} Pascal seconds (Pa s), which is considered average (Turcotte and Schubert, 1982). Viscosity is a measure of a fluid's resistance to flow, with higher viscosity values indicating more resistance. An example of viscosity values is motor oil ratings. Oil rated as a 10W30 is "thinner", or has less resistance to flow, than 10W40, for example.

As they travel through a material, the velocity of seismic waves change with differences in the viscosity of the material. Silver and Chan (1988) conducted seismic studies on the western shield region of Canada and recorded velocity values that indicate a higher viscosity value than expected. Heat flow rates through a material can also indicate viscosity. Pinet et al (1991) studied the rate of geothermal heat flow on the eastern side of the Canadian Shield, a study that also suggested the viscosity of the asthenosphere beneath the shield was higher than expected. And Hager (1990) suggested that an asthenosphere with a viscosity of 2×10^{20} Pa s explains observed plate velocities, heat flow in the mantle, and sea-level variations better than the currently accepted value.

I used strandlines in the Lake Agassiz basin, which is on the southwestern margin of the Canadian Shield (Figure 2), to calculate asthenosphere viscosity beneath eastern North Dakota. I then compared viscosity calculated with the strandlines to asthenosphere viscosity calculated using geophysical methods. Strandlines are beaches or wavecut terraces that formed at the edge of a lake and have been preserved. Strandlines tend to be slightly higher than the surrounding landscape. The surface of the Lake Agassiz strandlines is irregular due to sand dunes and differential erosion (Figure 3).

The Lake Agassiz basin (commonly refered to as the Red River Valley) formed when this region was submerged beneath Glacial Lake Agassiz. Along the former shores of Lake Agassiz, a series of strandlines formed. Today, these strandlines are tilted, decreasing in elevation from north to south. Because strandlines form at the water line they should be at a constant elevation. However, these strandlines were tilted by the isostatic rebound which followed the retreat of the Laurentide Ice Sheet from this area (Johnston, 1946). The weight of large ice sheets such as those that covered North Dakota cause depression of the crust. Isostatic rebound occurs both during ice melting and after the ice has melted and the surface slowly recovers to its pre-glaciated position. Because the rate of isostatic rebound is controlled by asthenosphere viscosity, these now-tilted strandlines can be used to calculate the viscosity of the asthenosphere beneath them.

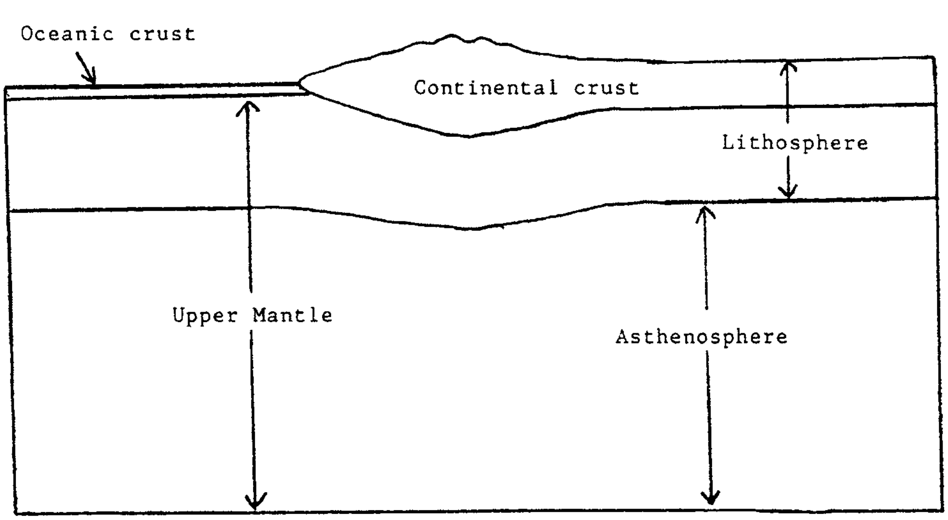


Figure 1. Generalized cross-section of the upper 700 km of the earth. Total distance to the center of the earth is 6371 km (Lutgens and Tarbuck, 1986).

Determining Rebound

I measured the rebound of each strandline by finding the difference between the highest and lowest elevations on them. Strandlines formed in the early stages of Lake Agassiz show the most rebound because less time passed between the retreat of the ice and formation of the strandline, thus there was less isostatic rebound prior to the strandline's formation. The difference in rebound between two strandlines of known ages gives the amount of rebound that occurred over a given time.

I located each strandline on U. S. Geological Survey 7.5 minute topographic maps and determined its elevation. The amount of rebound recorded by each strandline is shown in Table 1.

Table 1: Elevations of selected Lake Agassiz strandlines at their lowest (south end) and highest (measured at the North Dakota-Canada border) points. The difference in the rebound amount for any two strandlines represents the amount of uplift that occurred between formation of those strandlines.

Name	Lowest Point	Highest Point	Rebound	Date+
Herman	325.3 m	379.8 m	54.5 m	10,900
Campbell	301.8 m	322.1 m	20.3 m	9,800
Emerado	271.3 m	281.9 m	10.6 m	8,800
Burnside*	249.9 m	256.0 m	6.1 m	8,500

+ - C^{14} years Before Present (BP) (Fenton et al., 1983; Thorleifson, 1990; and Teller 1997)

* - Modified from Bluemle (1991)

Viscosity

With the amount of rebound between any two strandlines and their ages known, the only information still needed to calculate asthenosphere viscosity is the time between formation of each of the strandlines and a starting time. The Herman strandline, presumably the oldest Lake Agassiz strandline, has been dated at about 10,900 years before present (B.P.) using the carbon-14 dating method (Teller, 1997; Thorleifson, 1996; Fenton et al., 1983). By assuming this to be time zero (or the starting time), asthenosphere viscosity can be calculated as 2.85×10^{20} Pa s. A more complete discussion of the calculations used to get these results is given in the inset, "Calculation of Asthenosphere Viscosity".

The actual viscosity of the asthenosphere could be either higher or lower than what is calculated here. There are two major factors that indicate this. First, the elevation data has a margin of error of +/- 1 m. For example, if the low point of the Herman strandline is 324.3 m (instead of 325.3 m) and the high point 380.8 m (instead of 379.8 m), the rebound indicated by the Herman is actually 56.5 m instead 54.5 m. However, it is assumed that any errors in elevation measurements will average out. Second, there are very few carbon-14 dates for the Lake Agassiz strandlines, consequently there are few dates to compare to and verify or refute the ages that have been assigned to the strandlines. In addition, carbon-14 dates on the order of 10,900 years have a margin of error of about +/- 100 to 300 years. Because of the amount of uncertainty in the data used to calculate the asthenosphere viscosity, it cannot be said with certainty that the calculated value is the true value. However, because of the large difference between the calculated value and what is considered average asthenosphere viscosity, it can be said that the viscosity of the asthenosphere beneath the Lake Agassiz basin is higher than average.

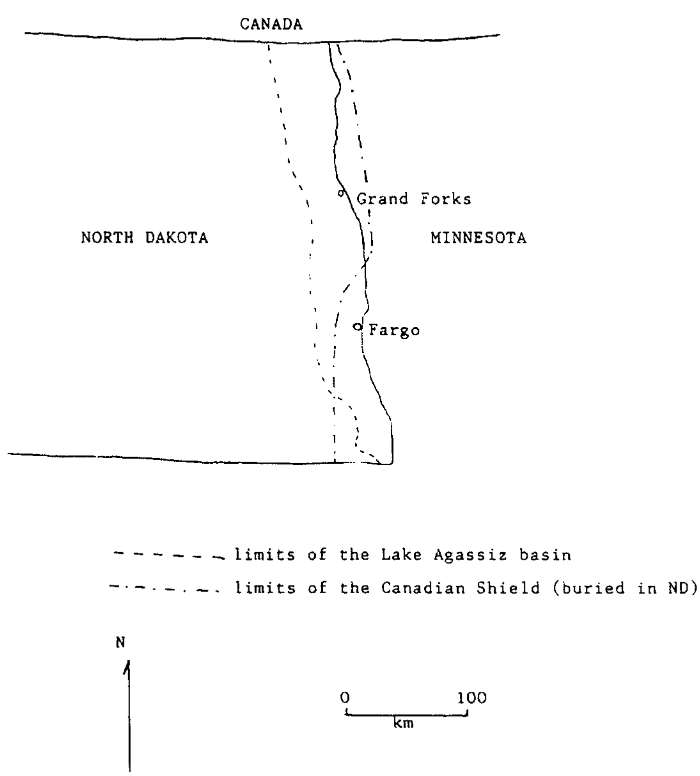


Figure 2. Location of the Lake Agassiz basin and the edge of the Canadian Shield (buried) in eastern North Dakota (information compiled from Espenshade, 1990).

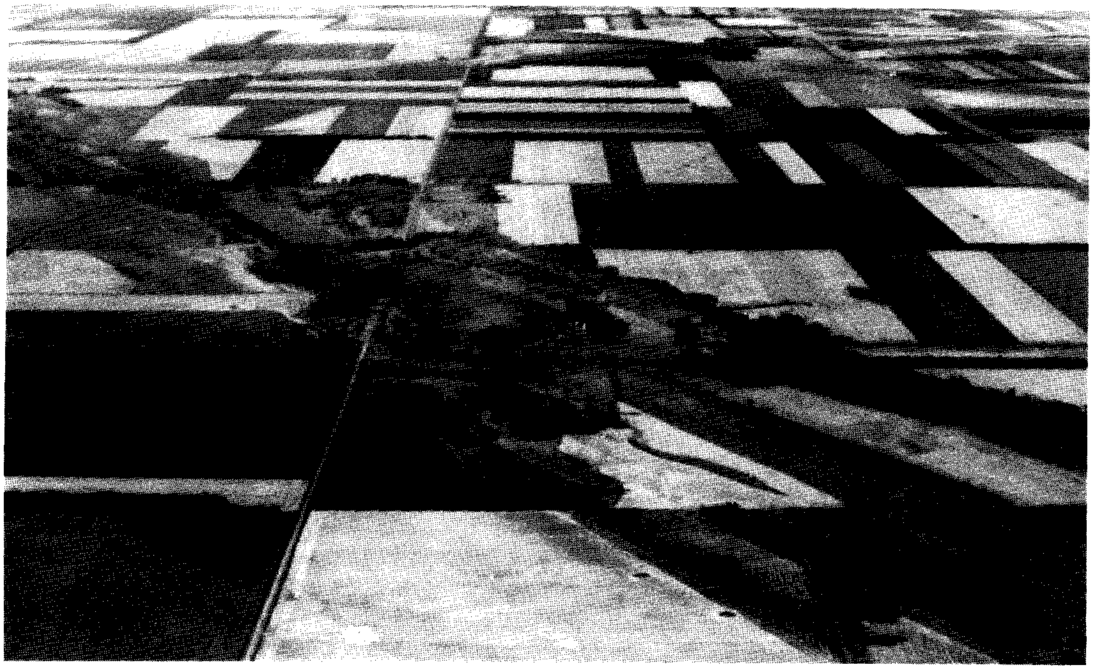


Figure 3. Air view of the Campbell Beach in Grand Forks County near Turtle River State Park. The Campbell Beach is the most continuous of the several Lake Agassiz shore lines and, in most places, it is the best developed of the beaches. Unlike most of the other shore features, which can be traced for only short distances, the Campbell Beach can be traced for much of the distance around the old lake shore that marks the extent of the lake about 11,000 years ago. Much of the gravel that was deposited in the beach has been removed for commercial purposes (Bluemle, 1991).

Effects

Why is knowing asthenosphere viscosity important? Isostatic rebound rates are controlled by asthenosphere viscosity, and rebound has had several effects on the Lake Agassiz basin. These effects include decreased river gradients, changing river courses, highly meandering channels, and more frequent flooding. Each of these effects can impact land use in the region, both urban and agricultural. More complete discussions of these effects can be found in Bluemle (1991) and Brevik (1994). Whether or not rebound is complete (and thus, the changes in the items listed above are finished) can be calculated if the viscosity of the asthenosphere, the amount of depression, and the elapsed time is known.

Conclusions

Experiments in other parts of the Canadian Shield suggest the viscosity of the asthenosphere beneath the shield is higher than the average value of 4×10^{19} Pa s. The calculated viscosity of 2.85×10^{20} Pa s for the asthenosphere beneath the Lake Agassiz basin shows viscosity values that are considerably higher than average.

The data gathered in this study are not precise enough to determine an exact value for asthenosphere viscosity. The elevation data have a margin of error of +/- 1 m, and the usual margin of error also applies to the C^{14} dating of the strandlines. However, findings in the Lake Agassiz basin clearly support the earlier studies and indicate a higher than average asthenosphere viscosity beneath eastern North Dakota, along the edge of the Canadian Shield.

Calculation of Asthenosphere Viscosity

The amount of isostatic rebound that has occurred as a function of time is given by:

$$w = w_m e^{-(t/Tr)}, \qquad (1)$$

where w is the present amount of depression, w_m is the initial amount of depression, e is a constant with a value of 2.71828, t is the amount of time elapsed since rebound began, and Tr is the asthenosphere relaxation time (Turcotte and Schubert, 1982). Total elapsed time since formation of the Herman strandline is 10,900 years (Teller, 1997; Thorliefson, 1996; Fenton et al., 1983). The asthenosphere relaxation time is given by:

$$Tr = (4p_i v)/(p_m g l), \qquad (2)$$

where p_i is 3.14, v is the asthenosphere viscosity, p_m is asthenosphere density, g is gravitational acceleration, and l is the wavelength of the ice sheet (Turcotte and Schubert, 1982). Asthenosphere density beneath the mid-continent of North America is 3300 kg/m^3 (Braile, 1989), and the wavelength of the Laurentide Ice Sheet (distance from center to edge) was about 3,000 km (Andrews, 1991).

Equation 1 was used to estimate the amount of depression over time, given an initial depression of 54.5 m and assuming various experimental asthenosphere viscosities. From this, an experimental amount of uplift over time between the formation of the four strandlines listed in Table 1 was found. The observed uplift and the rebound curves generated from the experimental asthenosphere viscosities were graphed against time. The experimental viscosity value that produced an experimental uplift curve that fit closest to the observed uplift over time was accepted as the viscosity of the asthenosphere beneath the Lake Agassiz basin. Asthenosphere viscosity is calculated at 2.85×10^{20} Pa s for the Lake Agassiz basin because the curve generated using this viscosity came closest to matching the observed uplift values (Figure 4).

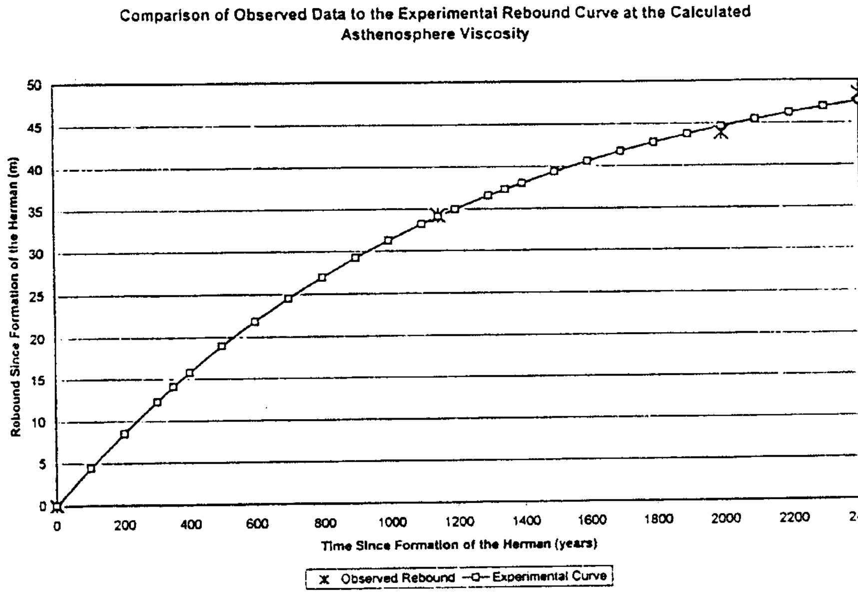


Figure 4. Fit of the experimental rebound curve to the observed data. Note that the observed data points at 0 and 34.2 m of rebound are nearly covered by the experimental curve.

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About the Author . . . *Eric Brevik worked on Lake Agassiz beaches as part of his master's degree at the University of North Dakota. Currently he is pursuing a Ph.D. in soil morphology and genesis at Iowa State University.*

Impact Craters - Part 1

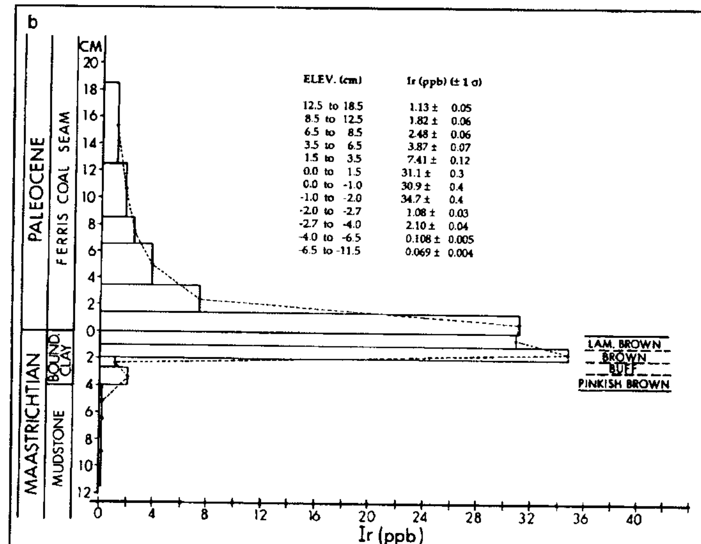
by

Thomas Heck

A recent news story reported that new cores recovered from a well off the Florida coast in the Gulf of Mexico contained additional evidence that an asteroid had impacted the earth at the end of the Cretaceous Period 65 million years ago (Ma) and that the impact site was close to the well's location. Finding the crater is important because it has been suggested that this impact caused the mass extinction of animals that occurred at the end of the Cretaceous Period-start of the Tertiary Period (K-T boundary). The fact that the crater was thought to be near Florida was news to me but, as I have since learned, the Chicxulub crater (pronounced *Chix-a-loo*) in the Yucatan Peninsula of Mexico has been studied for some time and it probably is the location where the asteroid hit. This is the first of two articles I will write on impact features and in it I will discuss the Chicxulub crater and the K-T boundary. My second article (in the next issue of the *NDGS Newsletter*) will focus on the Manson Crater in Iowa and three suspected impact craters in North Dakota: Red Wing Creek, Newporte, and Crater. These latter three anomalies that have been interpreted to be craters are of interest to North Dakotans because all three are oil fields. Whether or not more craters are waiting to be found is certainly an intriguing idea.

THE THEORY

Alvarez and others (1980) were the first to propose that a large meteorite, comet, or asteroid hit the earth at the end of the Cretaceous Period and caused the extinction of most large land animals including the dinosaurs. They based their theory upon the discovery of a clay-layer in strata that recorded the end of Cretaceous Period deposition in Italy. The clay-layer contained unusually high concentrations of iridium, 30 or more times over background, and they suggested that the iridium-enriched clay-layer could be distributed worldwide because additional samples from time-equivalent strata in Denmark and New Zealand also contained unusually high concentrations of iridium. A more recent analysis of a section in southern Saskatchewan shows a similar pattern *(Figure 1)*. The concentration of iridium reported by Alvarez and others is much higher than that found in normal earth crustal rocks but similar to chondritic, or "stony", meteorites and they concluded that the source of the iridium was extraterrestrial in origin. They calculated that the impact of a large asteroid would have ejected enough material into the atmosphere to block off sunlight from the earth's surface for several years. Without sunlight for photosynthesis, the lower end of the food-chain would die and many of the species higher on the food-chain would in turn die off. No large land vertebrates survived the end of the Cretaceous Period and most of the larger marine animals also became extinct. Russell (1979) listed the fossil genera known before and after the K-T boundary event. The decrease of 1366 genera, from 2,868 to 1,502 genera, is compelling evidence that the extinction at the end of the Cretaceous was a major event, whatever the cause. Alvarez and others presented a theory that tied together seemingly unrelated data - the mass extinction at the end of the Cretaceous Period and a layer of iridium-rich rocks at the Cretaceous-Tertiary boundary into a single theory. One thing Alvarez and others were unable to do was to identify the impact site.



Iridium profile of the K/T boundary interval of the Rock (Morgan) Creek West "E" section.

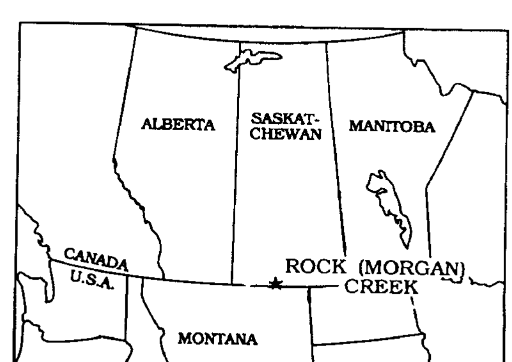


Figure 1. Iridium profile in parts per billion (ppb) across the K-T boundary at the Morgan Creek site in southern Saskatchewan (modified from Lerbekmo, 1996).

The size of the asteroid must also be considered. How large an asteroid or meteorite is required to distribute enough Platinum Group Elements (PGE) enriched sediment around the entire world? By estimating the volume of extraterrestrial material required to enrich the clay-layer to the "known" average PGE concentration, Alvarez and others estimated the size of the impacting body to be 10 ± 4 km in diameter. They further calculated that an asteroid of this size would form a crater around 200 km in diameter.

An extraterrestrial object of this size is an asteroid and not a meteorite with the difference being the size of the body. Subsequent research on Alvarez and others' theory has provided a large volume of data which proves that a large meteorite impacted the earth and the impact crater itself, the Chicxulub Crater, has apparently been located in the Yucatan Peninsula (*Figure 2*). Whether this impact alone caused the mass extinction at the end of the Cretaceous is less well accepted.

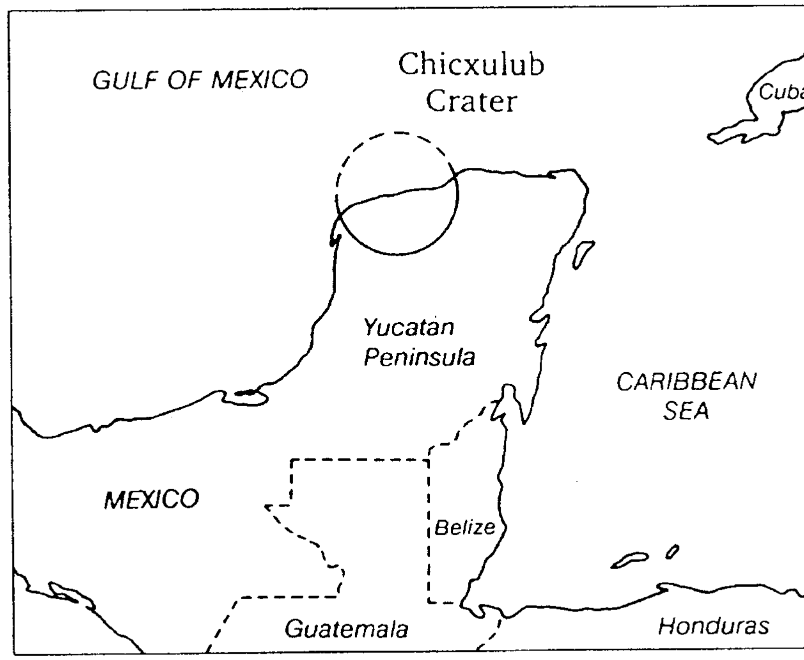


Figure 2. Location of the Chicxulub impact crater on the Yucatan Peninsula (modified from Koeberl, 1996).

GLOBAL EVIDENCE OF AN IMPACT

There are a number of lines of evidence that indicate that some massive body hit the earth at the end of the Cretaceous Period. I will review some of the evidence for an impact relying heavily upon Koeberl (1996) who provides an introduction to impact crater studies including crater morphology, formation, and recognition. Koeberl also discusses the evidence for Chicxulub being a large impact crater.

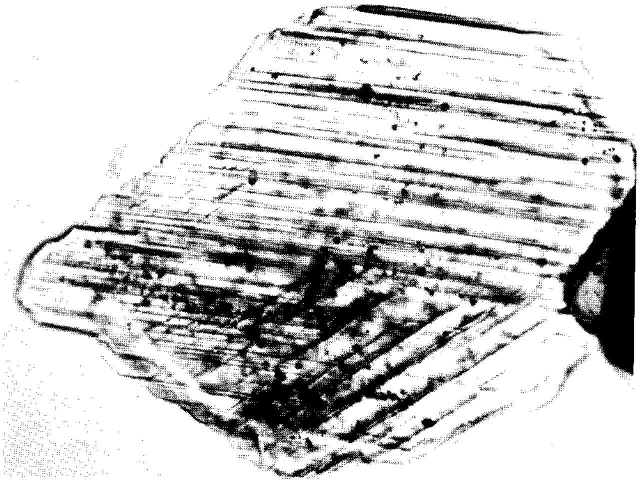
Besides being enriched in iridium, the clay-layer is also enriched in other PGEs, up to four orders of magnitude above normal crustal concentrations. The amount of enrichment and the distribution of the enriched strata cannot be satisfactorily explained by any known earth processes. In addition to being enriched with PGEs, the ratios between the various elements are similar to those found in chondritic meteorites. An extraterrestrial source, a large meteorite or asteroid, is a simple and logical explanation of the PGE enrichment and distribution.

Micron-size fragments of both unaltered and altered rocks and minerals have been found in samples of the K-T boundary layer around the world. Upon impact, most of the impacting body, and some of the host rock, are vaporized. Various size rock fragments are ejected into the atmosphere by the impact and eventually fall back to earth. Many of these rocks and minerals are deformed both micro- and macroscopically by the impact forces. Some forms of mineral alteration are considered to be diagnostic of an impact because the pressures and temperatures generated by an impact exceed those generated by normal earth processes (*Figure 3*).

One type of microscopic deformation is Planar Deformation Features (PDFs). These are thin, generally less than three microns wide, closely-spaced parallel zones of deformation in a mineral crystal and are considered to be diagnostic of shock forces (*Figure 4*). The greater the forces involved are, the more closely spaced and homogeneously distributed the PDFs become in a crystal. PDFs have been found in nearly every sample of K-T boundary strata taken. To be this widely distributed a large volume of material must have been ejected into the earth's atmosphere by the impact.

Other rocks and minerals that are indicative of pressures and temperatures beyond those generated by normal earth processes are impact glasses, mineral melts, and rock melts in order of increasing temperature and pressure (*Figure 3*). Impact glasses formed from rock melted by the impact have been found in the general present-day Gulf of Mexico region and nanometer size diamonds have been found in Alberta, Canada and elsewhere. Rock and mineral melts have been identified in cores from the Chicxulub Crater.

Additional, but less direct, evidence of the global effects of an impact are the layers of charcoal and soot found coincident with the iridium-rich layer at some K-T boundary sites (Wolbach and others, 1988). The soot contains a hydrocarbon, retene, that is a diagnostic residue of burned



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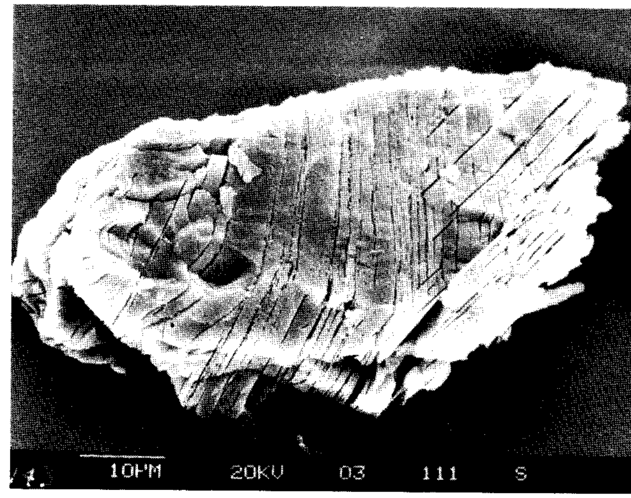

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Figure 3a. Photomicrogrph of a shocked quartz grain taken from the K-T boundary layer at Brownie Butte, Montana. The grain is approximately 350 micons long and shows two directions of PDFs.

Figure 3b. SEM image of a schocked quartz grain from the K-T boundary layer at Deep Sea Drilling Project Site 596 in the Southwest Pacific Ocean. The grain has been briefly etched with Hydrofluoric Acid (HF) and at least three different sets of PDFs are visible. *Photomicrograph and SEM imarge are courtesy of Bruce Bohor, U.S. Geological Survey, Denver, Colorado.*

resinous plants like coniferous trees, and is unique to the K-T boundary layer. Much of the C^{13} in K-T carbon closely matches natural charcoal from forest fires. The rest of the Late Cretaceous stratigraphic section has been searched for similar occurrences of soot or charcoal but none have been located. The soot layer has been interpreted to be evidence of global wildfires ignited by the meteorite impact. The release of soot into the atmosphere by global wildfires would have been enormous because soot adsorbs more sunlight and settles slower than rock dust so sunlight would have been significantly reduced. Soot from the forest fires in Yellowstone National Park during 1988 was visible in North Dakota. What would have been the effect of hundreds or thousands of similar fires around the world?

The energy needed to start global wildfires would have been enormous. Theoretical calculations of the thermal energy released by a 10^{15}-10^{16} kg asteroid impacting the earth were compared to the thermal energy levels known to ignite dry forest material during a nuclear explosion (Melosh and others, 1990). They concluded that there probably was sufficient thermal energy radiated to ignite global wildfires. If the wildfires were not global in extent Melosh and others concluded that it is almost a certainty that local hot spots of thermal energy would have been created and some fires would have started. At the very least, they postulate that there would have been a massive kill-off of animal life and a dessication of plant life from the pulse of thermal energy from the impact leaving a lot of downed and dead plant matter that later lightening strikes would ignite.

The preceding data are not direct evidence of an impact, the so-called "smoking gun". The most direct evidence of an impact would be found in the crater itself.

CHICXULUB CRATER

While the exact location was not known for some years after Alvarez and others first proposed an impact, the impact site was thought to lie on or near the North American continent from the abundance and size distribution of shocked quartz (Koeberl, 1996). The thickest known deposits of boundary layer material were reported in Haiti and northeast Mexico (Hildebrand and others, 1991), narrowing the location to the Gulf of Mexico region. A geophysical anomaly was known to exist, and had been tested for oil, near the towns of Chicxulub Puerto and Merida on the northern end of the Yucatan Peninsula in Mexico *(Figure 2)* and was named Chicxulub. Chicxulub lies roughly equidistant from the thick boundary layer deposits in Haiti and northeastern Mexico.

Penfield and Carmargo (1981) were the first to suggest that the Chicxulub feature might be an impact crater. Subsequent Bouger gravity and magnetic studies have confirmed a geophysical anomaly that has been variously estimated to be between 170 and 300 kilometers (km) in diameter. Hildebrand and others (1991) concluded that this was an impact crater and that it also was the K-T boundary impact site after studying the geophysical, petrological, and stratigraphic data at Chicxulub. The most definitive evidence that Chicxulub is an impact crater is contained in the cores cut in several wells. These cores were recognized to contain impact melts and breccias with abundant shock deformation features like PDFs. The Chicxulub feature has been confirmed as an impact crater and is one of the largest impact craters found on earth to date *(Appendix 1)*.

The age of the crater is extremely important in determining whether or not this crater was the K-T boundary impact. Impact melts from cores in the Chicxulub feature were age dated and the resulting dates were tightly grouped around 65 (Ma), the end of the Cretaceous Period. Age dates from the impact glasses in Haiti are indistinguishable from the Chicxulub dates. From size, location, the presence of shock features, and the age of the Chicxulub Crater it seems clear that it is the K-T boundary impact site.

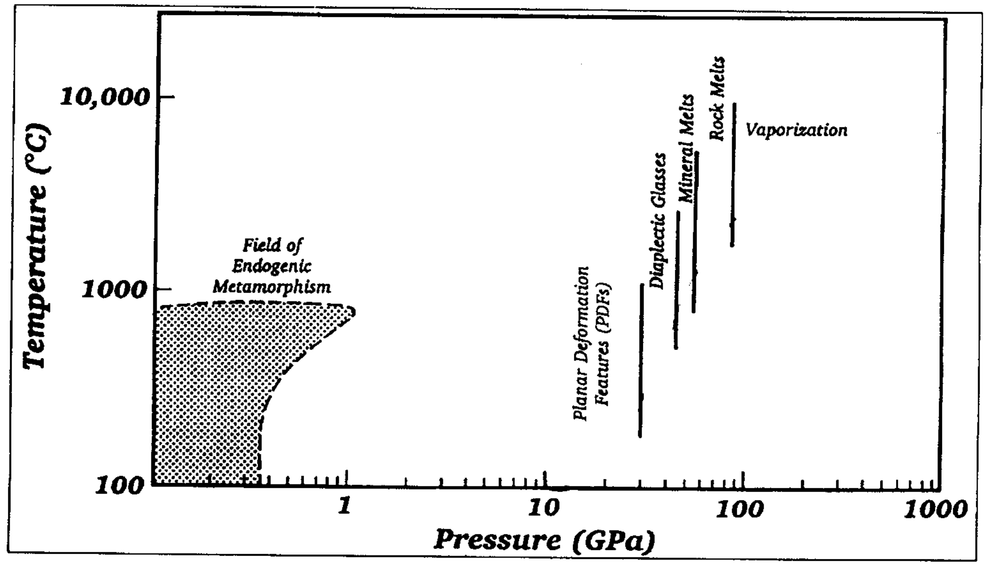

Figure 4. Field of endogenic, or normal internal earth, metamorphism compared to the onset pressures of various irreversable changes due to shock metamorphism (modified from Koeberl, 1996).

K-T EVENT EFFECTS IN NORTH DAKOTA

For the most part, there are very few known effects in North Dakota. Murphy and others (1995) studied the K-T boundary at 32 sites in south-central North Dakota and found that either the boundary clay-layer is not present or cannot be readily distinguished from other clays in this area. Because of this, no iridium layer was found nor was any shocked quartz, common identifiers of the boundary layer. One site, Pyramid Butte in western North Dakota, has an iridium-enriched boundary layer (Johnson and others, 1989). At this location the clay-layer is coincident with a palynological, or fossil pollen and seeds, change evidence of a plant fauna change across the boundary. At a second site near Huff, an iridium-enriched zone was found 2½ feet above the K-T boundary determined from palynology.

Presumably the mass extinction of large land animals also occurred in North Dakota. Most of the stratigraphic sections Murphy and others measured were non-fossiliferous as only some of the sections contained any dinosaur or mammal bones. The principal faunal change was noted in the fossil pollen. The known effects of the Chicxulub impact are few in North Dakota, but, given the effect of the impact elsewhere around the world and our relative proximity to the impact site, there may be unpreserved or as yet undiscovered evidence in the state.

[Next issue . . . *Impact Features in North Dakota*]

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APPENDIX I - Location, Diameter, and Age of the 50 Largest Impact Features on the North American Continent

NAME	STATE/ PROVINCE	COUNTRY	DIAMETER (km)	Latitude DEG-MIN-DIR	Longitude DEG-MIN-DIR	AGE (MA)
Sudbury	Ontario	Canada	250	46-36-N	81-11-W	1850 ± 3
Chicxulub	Yucatan	Mexico	170	21-20-N	89-30-W	64.98
Manicouagan	Quebec	Canada	100	51-23-N	68-42-W	214 ± 1
Chesapeake Bay	Virginia	USA	85	37-15-N	76-5-W	35.5 ± .5
Beaverhead	Montana	USA	60	44-36-N	113-0-W	600
Charlevoix	Quebec	Canada	54	47-32-N	70-18-W	357 ± 15
Montagnais	Nova Scotia	Canada	45	42-53-N	64-13-W	50.5 ± .76
Saint Martin	Manitoba	Canada	40	51-47-N	98-32-W	220 ± 32
Carswell	Saskatchewan	Canada	39	58-27-N	109-30-W	115 ± 10
Clearwater West	Quebec	Canada	36	56-13-N	74-30-W	290 ± 20
Manson	Iowa	USA	35	42-35-N	94-31-W	73.8 ± .3
Slate Islands	Ontario	Canada	30	48-40-N	87-0-W	450
Mistastin	Labrador	Canada	28	55-53-N	63-18-W	38 ± 4
Clearwater East	Quebec	Canada	26	56-5-N	74-7-W	290 ± 20
Steen River	Alberta	Canada	25	59-31-N	117-37-W	95 ± 7
Haughton	Northwest Territories	Canada	24	75-22-N	89-41-W	23 ± 1
Presqu'ile	Quebec	Canada	24	49-43-N	78-48-W	< 500
Eagle Butte	Alberta	Canada	19	49-42-N	110-35-W	< 65
Ames	Oklahoma	USA	16	36-15-N	98-10-W	470 ± 30
Deep Bay	Saskatchewan	Canada	13	56-24-N	102-59-W	100 ± 50
Marquez	Texas	USA	13	31-17-N	96-18-W	58 ± 2
Sierra Madera	Texas	USA	13	30-36-N	102-55-W	< 100
Kentland	Indiana	USA	13	40-45-N	87-24-W	< 97
Nicholson	Northwest Territories	Canada	12.5	62-40-N	102-41-W	< 400
Avak	Alaska	USA	12	71-15-N	156-38-W	> 95
Wells Creek	Tennessee	USA	12	36-23-N	87-40-W	200 ± 100
Upheaval Dome	Utah	USA	10	38-26-N	109-54-W	< 65
Red Wing	North Dakota	USA	9	47-36-N	103-33-W	200 ± 25
Couture	Quebec	Canada	8	60-8-N	75-20-W	430 ± 25
Des Plaines	Illinois	USA	8	42-3-N	87-52-W	< 280
Glover Bluff	Wisconsin	USA	8	43-58-N	89-32-W	< 500
La Moinerie	Quebec	Canada	8	57-26-N	66-37-W	400 ± 50
Serpent Mound	Ohio	USA	8	39-2-N	83-24-W	< 320
Wanapitei	Ontario	Canada	7.5	46-45-N	80-45-W	37 ± 2
Crooked Creek	Missouri	USA	7	37-50-N	91-23-W	320 ± 80
Decaturville	Missouri	USA	6	37-54-N	92-43-W	< 300
Middlesboro	Kentucky	USA	6	36-37-N	83-44-W	< 300
Pilot	Northwest Territories	Canada	6	60-17-N	111-1-W	445 ± 2
Gow	Saskatchewan	Canada	5	56-27-N	104-29-W	< 250
Glasford	Illinois	USA	4	40-36-N	89-47-W	< 430
Ile Rouleau	Quebec	Canada	4	50-41-N	73-53-W	< 300
Brent	Ontario	Canada	3.8	46-5-N	78-29-W	450 ± 30
Flynn Creek	Tennessee	USA	3.55	36-17-N	85-40-W	360 ± 20
New Quebec	Quebec	Canada	3.44	61-17-N	73-40-W	1.4 ± 0.1
Newporte	North Dakota	USA	3.2	48-58-N	101-58-W	< 500
West Hawk	Manitoba	Canada	2.44	49-46-N	95-11-W	100 ± 50
Bee Bluff	Texas	USA	2.4	29-2-N	99-51-W	40
Barringer	Arizona	USA	1.186	35-2-N	111-1-W	0.049 ± 0.003
Odessa	Texas	USA	0.168	31-45-N	102-29-W	< 0.05
Haviland	Kansas	USA	0.015	37-35-N	99-10-W	< 0.001

Modified from Geological Survey of Canada, 1997

TEACHING TOOLS

Educator's Guide to Impact Craters

Courtesy of the Jet Propulsion Laboratory

Cratering in your Classroom

Impact cratering is a process found everywhere in the solar system except on the giant gaseous planets. Earth has been heavily impacted but erosion has removed most of the craters.

Perhaps the finest surviving impact crater on earth is the *Barringer Meteor Crater* near Winslow, Arizona. It is 1.2 kilometers (0.75 miles) across and 200 meters (650 feet) deep. It was formed about 49,000 years ago when a 50 meter (150 foot) nickel/iron meteorite struck the desert at a speed of 11 kilometers per second (25,000 miles per hour).

An examination of actual craters, almost any image of the moon will do, will prepare the students for this activity. Just about all craters have deep central depressions, raised rims, and a blanket of ejected material surrounding them.

Let's Get Started

You and your students can observe the moon directly during daylight. Check your newspaper for the phases of the moon and observe it in the afternoon during "first quarter" and in the morning during "third quarter." The moon will be separated from the sun by 90 degrees to the east (left) at first quarter and 90 degrees to the west (right) during third quarter. The large dark regions are the remains of very great impacts and many retain their circular boundaries. Binoculars on a tripod provide a spectacular view.

You can create craters in the classroom with a box, lined with a trash bag, with sides at least 4 inches high (the lid to photocopier paper boxes is perfect); flour (3 to 4 inches deep with at least an inch of clearance to the box rim), some dry (powdered) tempra paint (red or blue), and some marbles or other round objects of various size and weight (pool ball, bearings, styrofoam ball, etc.). You should also have a ruler to measure crater depth and width, and the height from which you drop the objects.

Place the flour in the box and smooth and firmly pack it (experiment with different firmnesses). Place a dusting of the paint powder over the flour (colored water in a spray bottle works, but not as well). Use the marbles to bombard the surface (one at a time). Look for classical cratering features: basin, raised rim, ejecta blanket (material excavated from the crater and dumped around it, visible as white flour on the colored powder), and rays (material shot out at high velocity forming lines pointing directly away from the impact site).

Students should keep careful records and can do top and profile drawings of the craters and compare craters formed by different size and weight projectiles, different velocities, and different angles of impact. Different size projectiles can be dropped from measured heights so that they will have common velocities. They should also remember that the quality of their tests is more important than quantity.

After several craters, the flour and tempra can be mixed and re-smoothed without changing the white of the flour too much. Then a new layer of tempra can be applied and additional experiments conducted. In real impacts, the impacting object is destroyed, vaporized, or broken up into small chunks. Of course, the marble will not do this and will remain whole in the crater.

Vocabulary

Central Peak: A mountain found in the center of large craters. It is formed by a "rebound" of the rock at the impact site (the marble will be sitting there in this activity).

Crater: A (usually) circular depression in a surface caused by an impact.

Ejecta: Material tossed out of the crater.

Ejecta Blanket: Ejecta tossed out at low speed. The material looks like a blanket around the crater.

Floor: The interior of the crater. It is flat in large craters (the marble will be there in this activity).

Rays: Ejecta tossed out of the crater at high speed. The material forms long lines pointing directly away from the crater.

Rim: The raised edge of the crater. It is formed by the outwards and upwards compression of the crater walls, not ejecta.