# Proceedings of the NORTH DAKOTA Academy of Science


April 1982 Volume 36

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NORTH DAKOTA ACADEMY OF SCIENCE
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1981-82

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## Editor's Notice

The Proceedings of the North Dakota Academy of Science was first published in 1948, with Volume I reporting the business and scientific papers presented to the fortieth annual meeting, May 2 and 3, 1947. Through Volume XXI, the single yearly issue of the Proceedings included both Abstracts and Full Papers. Commencing with Volume XXII the Proceedings were published in two Parts. Part I, published before the annual meeting, contained an Abstract of each paper to be presented at the annual meeting. Part II, published later, contained full papers by some of the authors.

Commencing with Volume XXXIII of the Proceedings of the North Dakota Academy of Science, a new format appeared. The Proceedings changed to an 8½ x 11 format, it is produced from camera-ready copy, and it is issued in a single part prior to the annual meeting (*i.e.* in mid-April).

Each presentation at the annual meeting is represented by a full page "Communication" which is more than an abstract, but less than a full paper. The communications contain results and conclusions, and permit data presentation. The communication conveys much more to the reader than did an abstract, but still provides the advantage of timeliness and ease of production.

The first section of this volume of the Proceedings contains papers presented in the seven symposia at the 1982 annual meeting of the Academy. The papers are presented in the same sequence as presented at the meeting, and are numbered as they appeared in the meeting program. The annual Invited Paper follows.

The second section of this volume of the Proceedings contains communications presented in the Professional section of the 1982 annual meeting of the Academy. All professional communications were reviewed by the Editorial Committee prior to their acceptance for presentation and publication herein. The professional communications have been grouped together in this volume, and are numbered in the sequence in which they appear in the meeting program.

The third section of this volume contains collegiate communications representing those papers presented in the A. Rodger Denison Student Research Paper Competition. Undergraduate and graduate students reported on the results of their own research activities, usually carried on under the guidance of a faculty advisor. While the student competitors were required to prepare a communication similar to those prepared by their professional counterparts, these communications were not subject to editorial review prior to publication herein. The students also were required to prepare a full manuscript for submission to the Denison Awards Committee which judged the oral presentation, the communication, and the manuscript in arriving at their decision for the first and second place awards in both the graduate and undergraduate competition. The collegiate communications are numbered in the sequence in which they appear in the meeting program.

Readers may locate papers by presentation number within the major sections of these Proceedings or by referring to the author index in this volume.

A. William Johnson
Editor

# Table of Contents

# NORTH DAKOTA ACADEMY OF SCIENCE

*I. Rules for Preparation of Proceedings Communication*

1. Each paper presented at the annual meeting of the Academy must be represented by a communication in the Proceedings, including A. Rodger Denison student research competition papers.
2. Only communications intended for presentation at the annual meeting will be considered for publication. They must present original research in as concise a form as possible. Quantitative data should be presented with statistical analysis (i.e., means with standard errors). Papers which merely summarize conclusions or ideas without supporting data are discouraged and will not normally be accepted. The communication should include the purpose of the research, the methodology, results, and conclusions.
3. Authors are encouraged to utilize the full space available in order to provide sufficient information to fully describe the research reported.
4. Communications must be prepared on the special blue-line form and sent, with three legible xerox copies, by first class mail to the Secretary, North Dakota Academy of Science, University Station, Grand Forks, ND 58202. The form must not be folded; a cardboard backing should be used to avoid damage. The Proceedings will be published by direct photo-offset of the submitted communication. No proofs will be prepared.
5. All typing, drawing and secured art or photographic materials must be within the boundaries of the blue-line form. Consult the example on the reverse side of the special form for proper style (i.e., titles, authors, address, tables, figures, references, indentations, headings, and punctuation). *Indicate the author to present the communication by an asterisk (*) after that person's name.*
6. Tables, diagrams, and photographs are acceptable provided they are secured to the special form and do not occupy a total area of more than 100 square centimeters.
7. Only essential references should be cited, and should be indicated in the text by numerals and quoted at the end of the communication. Up to three authors' names may be cited in full; with four or more authors only the first should be cited. The following form of citation should be used:

   Journals: Neary, D., Thurston, H. and Pohl, J.E.F. (1973) *Brit. Med. J.* 3., 474-475. (Abbreviate titles.)

   Books: Batsone, G.F., Blair, A.W. and Slater, J.M. (1971) *A Handbook of Pre-natal Paediatrics*, pp. 83-90. Medical and Technical Publishing, Lancaster.

   Individual chapters in books: Farah, A.E. and Moe, G.K. (1970) in *The Pharmacological Basis of Therapeutics*, 4th edition (Goodman, L.S. and Gilman, A., eds.), pp. 677-708. Macmillan, New York.

   Conferences and symposia: Rajewsky, M.F. (1973) Abstr. 2nd Meeting European Association for Cancer Research, Heidelberg, Oct. 2-5, pp. 164-5.

8. Use a typewriter with elite type and with a carbon or good quality black silk ribbon. Single space and begin paragraphs with a 3 space indentation. Special symbols, not on the typewriter, must be hand lettered in black ink.
9. Abbreviations: Only standard abbreviations should be used, and should be written out the first time used with the abbreviation following in parentheses.
10. Titles: It is suggested that authors select a sufficient number of keywords to describe the full content of their paper, and then construct a title using as many as these as practicable. Titles normally should not exceed 140 characters in length. In particular, they should be free from unnecessary phrases such as "a preliminary investigation of" or "some notes on" which add little or nothing to their meaning.
11. Session Assignment: In order to assist the program committee in organizing the presentations, please indicate on the reverse side of the blue-line form your 1st, 2nd, and 3rd preferences for the topical classification of your paper.
12. The authors' permission for the North Dakota Academy of Science to publish is implied by a submission. The Academy does not restrict the right of authors to include data presented in a communication in full papers submitted at a later date to other publishers.

*II. Rules for Oral Presentation of Paper*

1. All papers are limited to 15 minutes total time, for presentation and discussion. It is suggested that the presentation be limited to 10 minutes with an allowance of 5 minutes for discussion. It is also suggested that major emphasis be placed on the significance of the results and the general principles involved rather than on the details of methods and procedures.
2. Academy members represent a variety of scientific disciplines; therefore, speakers should avoid "jargon" and briefly explain or define such specialized terminology as may be judged to be indispensable to the presentation.
3. Projectors for 2" x 2" slides only will be available in all session rooms. Opaque projectors will NOT be provided. Only slides which can be read easily on projection should be used. Authors who desire suggestions for preparation of slides are referred to Smith, Henry W. 1957. "Presenting information with 2 x 2 slides." Agron. J. *49*. pp. 109-113.
4. Timed rehearsals with slides are highly recommended. There is usually time for a *maximum* of 6 or 7 slides for a presentation of this kind.

SYMPOSIUM
on

# GASIFICATION OF NORTH DAKOTA LIGNITES

Presiding: Steven Benson
Grand Forks Energy Technology Center (DOE)
Grand Forks, North Dakota

1. Great Plains Update
   Michael J. Mujadin*, ANG Coal Gasification Company
   Detroit, Michigan

2. Thirty-five Years of Lignite Gasification Research at Grand Forks
   Gordon H. Gronhovd*, Former Director, and Everett A. Sondreal, Director
   Grand Forks Energy Technology Center (DOE)
   Grand Forks, North Dakota

3. Prediction of Distribution Coefficients for Aromatic Solutes in a Coal Conversion Wasterwater
   James R. Campbell, Richard G. Luthy* and Manuel J.T. Corrundo
   Department of Civil Engineering, Carnegie-Mellon University
   Pittsburgh, Pennsylvania

4. Contribution of Alkali Reactions to Refractory Degradation in a Slagging Coal Gasification Reactor
   G.J. McCarthy*
   Department of Chemistry, North Dakota State University
   Fargo, North Dakota
   M. Mitchell, F. Karner, D. Rindt and M. Jones
   Grand Forks Energy Technology Center (DOE)
   Grand Forks, North Dakota

5. Viscosity of Coal Ash Slags from North Dakota Lignites
   Robert C. Streeter* and Erle K. Diehl
   Bituminous Coal Research, Inc.
   Monroeville, Pennsylvania
   Harold H. Schobert
   Grand Forks Energy Technology Center (DOE)
   Grand Forks, North Dakota

1.

# GREAT PLAINS UPDATE

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The previous papers written on the Great Plains Gasification Associates Coal Gasification Project have described in detail the ten year history of the project and how the various components will work together to produce 125 million cubic feet per day (MMCFD) of synthetic natural gas (SNG) from North Dakota Lignite. This paper provides an update of the project describing the accomplishments since the August 8, 1981 loan guarantee commitment was signed by the U.S. Department of Energy (DOE). This includes a report on the status of engineering, procurement, construction and operations planning.

The basic engineering documents such as process flow diagrams, material and energy balances, piping and instrumentation diagrams, process vessel sketchs and plot plans were completed long ago. However, these comprise only a small fraction of the total engineering documents. Modern process plants such as this are detail designed by modeling followed by computerized isometric drawings. An update of this procedure as it applies to Great Plains is included.

The procurement of major equipment and large subcontracts on a major project like Great Plains is extremely important. The procurement effort not only must insure that the most economic technically acceptable equipment is purchased, it must also support both engineering and construction from a timing standpoint. Certain vendor drawings are necessary before detailed engineering can proceed.

The actual construction of the Great Plains Plant is proceeding per schedule in spite of severe weather in January, 1982. A description of what has been accomplished in the field is included.

Finally, a discussion is provided of the many activities which are currently taking place to be sure that we can successfully start-up, operate and maintain the Great Plains Plant. These include such mundane items as recruiting and staffing; start-up scheduling, developing computer systems for preventative maintenance, warehousing, inventory control, accounting and document control; identifying and ordering spare parts, catalysts and chemicals; development of safety and technical training programs and numerous other tasks. Once a sound technical base has been formed, as is the case in Great Plains, then equal emphasis must be placed on operations planning to insure the success of the project.

2. # THIRTY FIVE YEARS OF LIGNITE GASIFICATION RESEARCH AT GRAND FORKS

Gordon H. Gronhovd*, Former Director, U.S. DOE Grand Forks Energy Technology Center
Everett A. Sondreal, Director, U.S. DOE Grand Forks Energy Technology Center
Grand Forks, North Dakota 58202

The federal government has sponsored lignite gasification research at Grand Forks almost continuously for the past thirty five years. The first gasification program was started in 1945 when a fairly large pilot plant was constructed on the campus of the University of North Dakota. The objective of the program was to produce synthesis gas ($CO+H_2$) for use as a reducing agent for beneficiation of the low-grade iron ores in Minnesota. The externally-heated gasifier was successfully operated for about 9,000 hours from 1945 to 1951. Because of the relatively low capacity of the unit and its being limited to atmospheric pressure operation, the process was never commercialized.

In the early 1950's the Bureau of Mines constructed a new Lignite Research Laboratory adjacent to the UND campus and work started there on a new gasification process called slagging fixed-bed gasification. This pilot plant, which is the only one of its kind in the United States, operates at pressures up to 400 psig, uses pure oxygen and steam to react with the lignite and operates at temperatures in excess of 3000°F, resulting in slagging of the lignite ash. The process was developed and successfully demonstrated during the period from 1958 to 1965 at which time the project was stopped and the pilot plant moth-balled. The testing had demonstrated the advantages of extremely high capacity (3 to 6 times greater), low steam consumption (one fourth as great) and low liquid effluent production as compared to the conventional Lurgi process.

In 1975 the slagging gasification program at Grand Forks was restarted because of renewed interest in coal conversion following the 1973-74 Arab oil embargo. The primary goal of the restarted gasification program was to develop environmental data on liquid and solid effluent characteristics for fixed-bed gasification. Significant information on effluent characteristics and treatment are being obtained and should be useful for the fixed bed gasification plants now being designed and built, such as the Great Plains Gasification Associates (GPGA) plant now under construction in North Dakota. Effluent treatment studies conducted by others under contract have established the data base for how to best biologically treat gas liquor. It is expected that operation of the Grand Forks slagging gasifier will be terminated in the summer of 1982 although research on the accumulated and stored effluents will continue beyond this date. The primary focus of the future liquid effluent studies will be to determine the environmental responses of a cooling tower operated on gasifier wastewater that has been pretreated to the degree proposed at the GPGA plant.

1. Oppelt, W.H., W.R. Kube, M.H. Chetrich, T.W. Kamps and E.F. Golob. Gasification of Lignite in a Commercial-Scale Pilot Plant: Progress Report for July 1, 1950 to December 31, 1951 and Summary of Work Previous to July 1, 1950, BuMines RI 5164 1955, 80 pp.

2. Gronhovd, G.H., A.E. Harak, M.M. Fegley, and D.E. Severson. Slagging Fixed-Bed Gasification of North Dakota Lignite at Pressures to 400 psig. BuMines RI 7408, 1970, 40 pp.

3. Willson, W.G., L.E. Paulson, R.S. Majkrzak, Slagging Fixed-Bed Gasification of Lignite. Paper presented at the 1981 Lignite Symposium, June 15-17, 1981. San Antonio, Texas, 41 pp.

3. PREDICTION OF DISTRIBUTION COEFFICIENTS FOR AROMATIC SOLUTES IN A COAL CONVERSION WASTEWATER

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Experiments were performed to measure distribution coefficients ($K_D$) for aniline and pyridine in single solute buffered clean water systems with five organic solvents: methylisobutyl ketone (MIBK), n-butyl acetate (NBA), diisopropyl ether (DIPE), toluene (TOL), and tetradecane (TET). The solvents MIBK, NBA, DIPE, and TOL were employed in tests to observe the distribution of aniline, pyridine and phenol in a coal gasification wastewater obtained from run RA-92 of the slagging fixed-bed gasifier at the Grand Forks Energy Technology Center. This data was used to assess the accuracy of various methods to estimate the value of the distribution coefficient. In these tests, phenol was selected as a representative acid-fraction solute while pyridine and aniline were taken as representative base-fraction solutes. The solvents MIBK, NBA, DIPE, and TOL were selected in order to provide representative solvent classes that may be used in a commercial process; TET was selected in order to obtain comparison data with a representative alkane.

Table I shows mean values and standard deviations for the distribution coefficients of aniline and pyridine in clean water and wastewater systems. This data indicate that, except for the pyridine-toluene system, the equilibrium partitioning of aniline and pyridine is not affected by the presence of the wide range of organic and inorganic compounds present in the raw coal gasification wastewater. Comparison of measured distribution coefficient data for phenol in the raw gasification wastewater with literature data for clean water systems showed that $K_D$ for phenol was also the same in wastewater and clean water. This observation is important in that wastewater distribution coefficients may be determined accurately by clean water, single solute laboratory experiments.

When the data shown in Table I were compared with distribution coefficients estimated by modelling techniques, it was observed that model accuracy depended upon solvent type. For solvents which do not hydrogen bond and which show a greater affinity for the solute than water (i.e., toluene), a regular solution theory model (1) provided reasonable estimates of the range of $K_D$ values. It was found that for solvents which act as proton acceptors (i.e., MIBK, NBA, DIPE) that the distribution coefficient could be correlated with a reference hydrogen bonding solvent system. Octanol-water was chosen as the reference solvent system because distribution coefficients with octanol are readily available for a large number of solutes, and because the octanol-water system has been employed to provide correlations with various extrathermodynamic parameters (2). A least squares analysis was used to correlate solvent distribution coefficients ($K_{OW}$) for aniline, pyridine, phenol, and other phenolic solutes for which data was available in the literature. This analysis provided excellent correlations, r-squared values being 0.97, 0.94 and 0.93 for DIPE, NBA, and MIBK, respectively. This approach appears to offer an accurate estimate of distribution coefficients.

1. Helpinstill, J.G., and Van Winkle, M. (1968) I. and E.C. Pro. Des. Dev., 7(2), 213-220.

2. Leo, A., Hansch, C., and Elkins, D. (1971) Chem. Rev., 71(6), 525-616.

TABLE I
DISTRIBUTION COEFFICIENTS FOR ANILINE AND PYRIDINE

| Solute | Solvent | $K_D$ (mg/l/mg/l) | | | |
|---|---|---|---|---|---|
| | | Clean Water | | Wastewater | |
| | | mean | S.D. | mean | S.D. |
| Aniline | DIPE | 7.6 | 0.4 | 7.3 | 0.3 |
| | MIBK | 31.4 | 1.4 | 31.4 | 1.8 |
| | NBA | 23.1 | 1.5 | 23.4 | 1.4 |
| | TOL | 8.4 | 0.4 | 8.4 | 0.4 |
| | TET | 0.74 | 0.07 | -- | -- |
| Pyridine | DIPE | 1.3 | 0.1 | 1.3 | 0.1 |
| | MIBK | 2.9 | 0.1 | 2.9 | 0.2 |
| | NBA | 2.8 | 0.2 | 2.7 | 0.1 |
| | TOL | 2.5 | 0.2 | 4.8 | 0.6 |
| | TET | 0.46 | 0.05 | -- | -- |

4.

# Contribution of Alkali Reactions to Refractory Degradation in a Slagging Coal Gasification Reactor

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The gasifier used in the work reported here is operated at the Grand Forks Energy Technology Center and is the only fixed-bed slagging coal gasifier in the United States. A slagging fixed-bed coal gasifier is operated at a sufficiently high temperature, as high as 3000°F in the tuyere region, so that the inorganic constituents of the coal are melted and drained from the bottom of the reactor as a liquid. Temperatures decrease up the wall above the slag zone. The interior of the steel reactor is lined with refractory bricks. Above the slag, these refractories can be subjected to alkali attack and degradation by reactive vapor species released from high sodium lignite coals such as the North Dakota coals used in these studies. We report here a study of alkali reactions with two candidate refractories, a mullite ($Al_6Si_2O_{13}$) and an alumina ($Al_2O_3$).

At several times during pauses in gasifier operation, selected refractory bricks were removed for study. Reacted and unreacted portions of the brick were characterized by X-ray fluorescence (XRF) for elemental chemistry, by X-ray diffraction (XRD) for crystalline phases and by scanning electron microscopy (SEM) for microstructure and microchemistry.

XRD study of sections of the bricks indicated that the mullite refractory reacted with Na according to a two-step reaction such as the following:

$$Al_6Si_2O_{13} + Na_2O \rightarrow 2\ Al_2O_3 + 2\ NaAlSiO_4$$

$$11\ Al_2O_3 + Na_2O \rightarrow 2\ NaAl_{11}O_{17}\ .$$

The $NaAlSiO_4$ crystallized in its high temperature carnegieite polymorph in the hotter regions of the gasifier and in the low temperature nepheline polymorph in the cooler regions.

The $Al_2O_3$ refractory also reacted with Na according to a reaction such as:

$$17\ Al_2O_3 + 2\ Na_2O \rightarrow 2\ NaAl_{11}O_{17} + Na_2Al_{12}O_{19}$$

The $NaAl_{11}O_{17}$ and $Na_2Al_{12}O_{19}$ phases are structurally very similar and are called β and β" alumina respectively. At higher temperatures, lower in the gasifier, only β alumina is formed. This appears to be consistent with the phase diagrams proposed by De Vries and Roth.[1]

The actual chemistry of all reaction products is more complex than the nominal formulas would imply. Various phases are stabilized by small quantities of impurities in the crystal structure as well as by temperature. SEM characterization of individual crystal grains indicated this solid solution substitution of K for Na and Fe, Mg and Ti substitution for Al. Also, a glassy intergranular phase rich in $SiO_2$ and $P_2O_5$ was observed.

These chemical reactions contribute to the degradation of the brick above the slag zone. The reaction products have an increased volume which leads to a structural weakening of the refractory.

(1) De Vries, R.C. and Roth, W.L. (1969) J. Am. Ceram. Soc. 52., 364-369

This research was supported by the Department of Energy.

5. VISCOSITY OF COAL ASH SLAGS FROM NORTH DAKOTA LIGNITES

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For the past two years, Bituminous Coal Research, Inc. (BCR) has obtained data on the viscosity of western U.S. low-rank coal ash slags under a contract with the Grand Forks Energy Technology Center (GFETC), U.S. Department of Energy. From a practical standpoint, these data were relevant to the operation of a slagging coal gasifier at GFETC. More fundamentally, the viscosity data form a base upon which predictive ash composition/viscosity correlations can be developed.

The viscosity behavior of slags from 16 different lignite and subbituminous coal samples has been characterized using a Haake RV-2 Rotovisco rotary viscometer. Data were obtained for both cooling and heating cycles over the temperature range of 1150 to 1500°C (2102 to 2732°F), and in a reducing atmosphere (20% $H_2$, 80% $N_2$). During the cooling cycle, most slags exhibited Newtonian behavior down to some temperature of critical viscosity ($T_{cv}$), below which the viscosity increased more rapidly (sometimes very abruptly) with further decreases in temperature. Although methods for predicting coal ash slag visocity and $T_{cv}$ based on ash composition have appeared in the literature, they were based on data for higher-rank eastern U.S. and British bituminous coals. Results of the BCR slag viscosity studies have shown that these predictive correlations generally are not satisfactory for western U.S. coals, largely because the amounts of certain ash constituents (notably the alkali and alkaline earth metals) are greater than in bituminous coal ashes.

The viscosity curves of slags produced from the ash of three North Dakota lignites are shown in the accompanying Figure. The lignites used were Indian Head (North American Coal Company, Mercer County), Gascoyne (Knife River Coal Mining Company, Bowman County), and Baukol-Noonan (Baukol-Noonan, Inc., Oliver County). The coals were ashed at 1100-1200°C. For the viscosity determination the ash was melted at approximately 1550°C in the test furnace. The data shown here were taken during the cooling cycle with a spindle rotation of 64 rpm. After the tests, samples of the solidified slags were analyzed by energy-dispersive X-ray fluorescence and examined by X-ray diffraction. The elemental analyses, expressed as weight percent oxides, are given in Table 1.

Figure 1. Viscosity curves for North Dakota lignite ash slags.

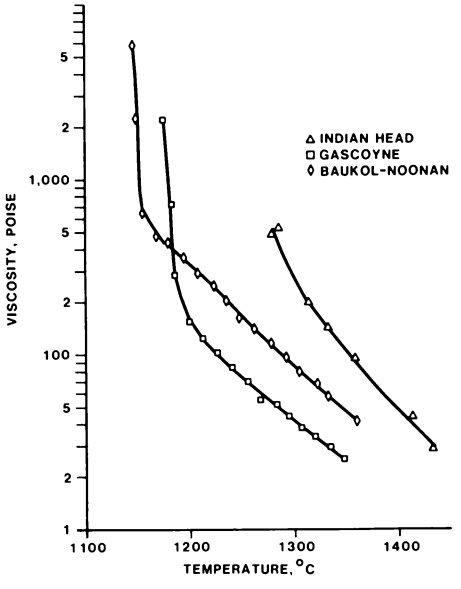


Table 1. Composition of North Dakota lignite ash slags.

| Sample | Baukol-Noonan | Gascoyne | Indian Head |
|---|---|---|---|
| $SiO_2$ | 41.4 | 42.4 | 18.7 |
| $Al_2O_3$ | 19.2 | 14.8 | 24.5 |
| $Fe_2O_3$ | 1.0 | 3.1 | 13.1 |
| $TiO_2$ | 2.3 | 1.4 | 1.0 |
| $P_2O_5$ | 0.0 | 0.0 | 0.0 |
| CaO | 21.8 | 25.7 | 22.7 |
| MgO | 4.3 | 8.2 | 2.7 |
| $Na_2O$ | 7.7 | 3.7 | 14.6 |
| $K_2O$ | 0.6 | 0.1 | 0.3 |
| $SO_3$ | 1.2 | 0.2 | 2.4 |
| Total | 99.5 | 99.6 | 100.0 |

Current research focuses on attempts to relate slag viscosity behavior to ash composition and to mineralogical species identified in both the ash and slag. It is likely that the nature of aluminosilicate polymers in the melt will be a major factor in determining the viscosity behavior. A comparison of the X-ray diffraction patterns of solidified Baukol-Noonan and Gascoyne slags shows as principal phases gehlenite and nepheline in Baukol-Noonan but gehlenite and fassaite (an aluminian diopside) in Gascoyne. Nepheline has a network structure, similar to tridymite, whereas the diopside is a simpler, single chain silicate. A previous publication on the viscosity behavior of slags from Rosebud (Montana) subbituminous coal (1) has shown that melts in which the diopside-like structure may predominate have lower viscosities than those with network-type structures. The comparatively lower viscosity of the Gascoyne slag in the Newtonian range can be explained in the same way. The extreme silica deficiency of Indian Head slag will require development of a separate paradigm.

(1) Schobert, H.H. and Witthoeft, C. (1981) Fuel Processing Tech. 5., 157-164

# SYMPOSIUM
on
# GEOGRAPHY AS AN APPLIED FIELD

Presiding: Douglas C. Munski
University of North Dakota
Grand Forks, North Dakota

6. Development of Internships in Applied Geography as a Vehicle to Prepare Students for Nonacademic Geography Careers in North Dakota
Douglas C. Munski*
Department of Geography, University of North Dakota
Grand Forks, North Dakota

7. Community Attitude Survey of Williston, North Dakota
Ted Alsop*
Department of Geography, University of North Dakota
Grand Forks, North Dakota

8. The Development of Coal Mining in Colombia's Guajira Peninsula El Cerrejon Strip Mine Project
Roland D. Mower and Myriam Ardila*
Department of Geography, University of North Dakota
Grand Forks, North Dakota

Panel Discussion of Geography as an Applied Field
Jo Ann Burghard, Basin Electric Cooperative
Leo Reinbold, Public Service Commission
David Torkelson, Economic Development Commission

6. DEVELOPMENT OF INTERNSHIPS IN APPLIED GEOGRAPHY AS A VEHICLE TO PREPARE STUDENTS FOR NONACADEMIC GEOGRAPHY CAREERS IN NORTH DAKOTA

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Recognition of the importance of nonacademic career opportunities within the field of geography has become increasingly widespread and is influencing geography curriculum worldwide (1,2). Such a shift in both undergraduate and graduate training in geography is often identified as being directed toward "applied geography." Ambiguity has characterized the use of the term, "applied geography," since the late nineteenth century (3). However, a majority of geographers surveyed in the mid-1970's employ the term to emphasize teaching students to use disciplinary concepts, methodologies, and techniques to solve physical and social environmental problems and, in particular, to prepare geographers for nonacademic positions (4).

Because of the general neglect by academic geographers of nonacademic opportunities other than consulting, connections between nonacademic geographers and academic geographers have not been successfully developed in many instances to prepare students for posts outside academe. Indeed, input by nonacademic geographers to college geography curriculum has been limited beyond those few institutions engaged in cooperative programs (1,2). However, development of new intern programs in private industry and governmental agencies are one means by which to increase productive interchange among nonacademic geographers and academic geographers and their students (5).

In order for internships to be an effective means of training students to be able to specialize in applied geography and to better prepare for nonacademic career options, four criteria must be met (6). First, nonacademic geographers must be contacted to assess the changing demands and techniques required in the market. Second, courses must be revised appropriately, i.e., must be academically sound as well as in keeping with market demands. Third, interns must be supervised by a sponsoring nonacademic geographer and be in contact with the accrediting academic geographer. Finally, arrangements must be made to make the program cost-effective for all parties involved.

Internship activities in applied geography have been offered since 1979 at the University of North Dakota, but only on a temporary basis (6). Programs in medical geography with the North Dakota State Health Department operated in the summers of 1979 and 1980 in Bismarck but were discontinued because of insufficient funding in 1981. Students were placed in remote sensing work at EROS in Sioux Falls, South Dakota and in community and rural planning work at North Central Planning Council in Devils Lake, North Dakota in the summer of 1981. Efforts are underway to secure internships in cartography in the private sector for the summer of 1982. However, all of these efforts have been hampered by insufficient funding of students, difficulty of identifying opportunities for students due to low visibility of nonacademic geographers, less than satisfactory curriculum in applied geography topics, and relatively little support for coordinating off-campus projects. Compounding the situation is a low level of inter-college cooperation in developing a network of applied geography programming to create stronger state-wide connections among academic and nonacademic geographers. Still, a start has been made in developing a more formal connection between the public and private sectors and the academic community using geography internships.

Opportunities for a state-wide program of internships in North Dakota must be maximized, however. Land use management, planning for social welfare, and responding to changing political-economic demands for North Dakota's major exports of energy and food are major issues being addressed by nonacademic geographers in both the private and public sector. Internships are one means by which geography training in problem-solving of such intertwinned local, state, and global issues can be more responsive to physical and social crises (7). Never as before in this interdependent world has there been such a critical need for increased training of North Dakota students in applied geography.

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7.

# COMMUNITY ATTITUDE SURVEY OF WILLISTON, NORTH DAKOTA DECEMBER 1981

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The community of Williston, North Dakota is located in the Williston Oil Basin wherein some of the world's largest known reserves of lignite, salt, and leonardite are located. Associated with these natural resources are an abundance of oil and natural gas. With increasing emphasis on the development of energy resources, Williston City has emerged as an energy-impacted area serving as the wholesale and retail distributive center for northwestern North Dakota, northeastern Montana, and southern Saskatchewan, Canada. During the time period 1970-80, Williston City increased 18.2% in population and 37.9% in housing units while the State of North Dakota realized an increase of 5.7% in population and 26.7% in housing units for the same time period (1). Such dramatic local growth imposes a stress on the quality of life in the community and magnifies the need for communal growth management including a precise investment strategy. An important element in urban growth management which leads to an effective investment strategy is a thorough knowledge of the desires of the citizens in the community.

In an effort to assess the attitude of the Williston City populace towards growth, a community attitude survey was executed during December 1981. With the cooperation of the Williston Basin Regional Council for Development, the Department of Geography at the University of North Dakota designed a survey instrument tailored to the Williston Basin Region and capable of being analyzed by computer software packages. The survey was conducted using the systematic random sampling technique which produced 283 samples satisfying the number of households necessary to achieve a confidence level of 0.05 at a tolerated error of plus or minus 6.0 (2).

Employing the Statistical Analysis System (3) with the computer, an analysis of the survey reveals the community profile of Williston City. Of the households sampled, 67% had at least one child of preschool age, 68% had at least one child of elementary school age, 85% had at least one child of junior high school age, and 79% had at least one child of high school age. The substantial nature of the community is documented by the fact that 47% of the respondents indicated that they had lived in Williston for longer than 10 years while 58% responded that they intended to remain longer than 10 years. The dominant dwelling unit is a single-family home in which 60% of the respondents indicated that they reside. Nineteen percent of the families indicated that they are living in apartments and another 16% responded that they dwell in mobile homes. Forty-six percent of the families are buying their dwelling units while 26% are renting and 26% outright own their homes. The average family in Williston owns 1.92 automobiles and has 1.22 wage earners earning $12-20,000 per year.

A generally positive attitude towards growth in Williston City is documented by the fact that 70% of those surveyed either agreed or strongly agreed that growth is beneficial to the community and a healthy attitude towards local government is evident as 53.7% agreed or strongly agreed that the local government is making every effort to manage growth and 49.4% agreed or strongly agreed that the local government is effective in managing growth in the community. The greatest deviation in responses is recorded in the controversial issue of permitting mobile homes to be located in restricted residential areas. Respondents most frequently cited the high cost of living, inadequate housing, and an increase in crime and drugs as the biggest problems resulting from growth in the community. When asked to rate the services and quality of life factors in the community, the only service perceived as being excellent is the availability of banks. Fire protection and the quality of childhood education are perceived as being very good. The only condition rated by respondents as being very poor is the availability of housing.

When asked to prioritize for the improvement of the services and quality of life factors in their community, Williston City respondents set as highest priorities childhood education, law enforcement, and fire protection. These three services also received the least deviation in priority responses. Other very high priority items in order of importance include recreation facilities, parking facilities, housing, a quality environment, and community planning. Lowest priority services are identified as banking facilities, radio stations, dental facilities, and sidewalks/curbs/gutters.

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8. THE DEVELOPMENT OF COAL MINING IN COLOMBIA'S GUAJIRA PENINSULA
EL CERREJON STRIP MINE PROJECT

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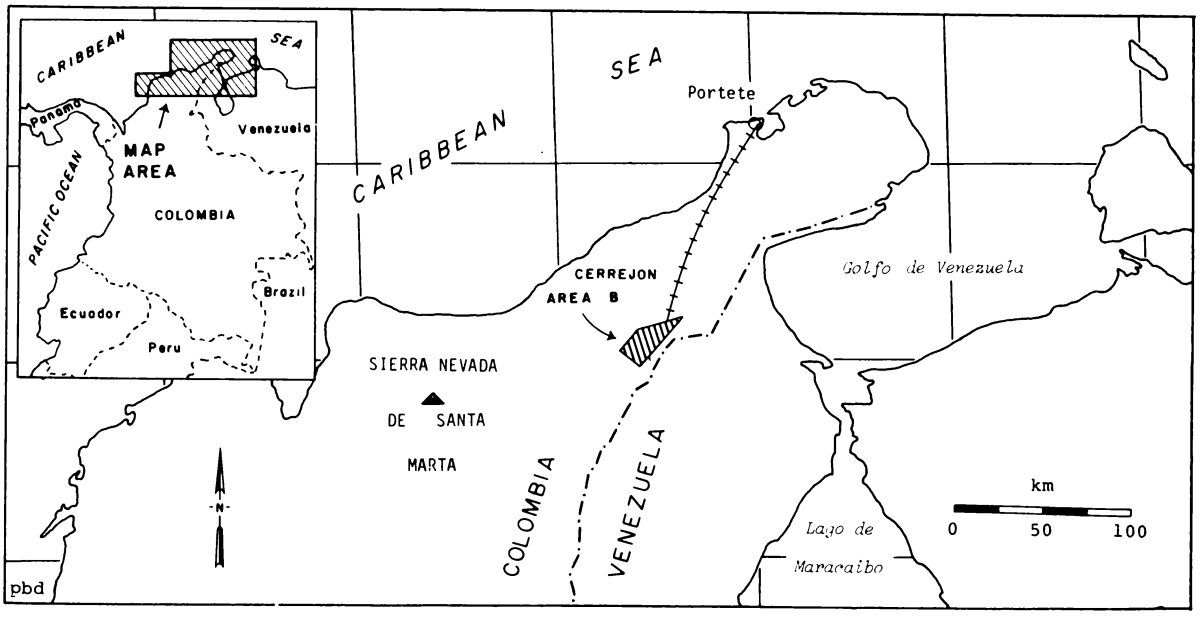
One of the world's largest coal mines is presently undergoing development near the Caribbean Coast of Colombia's Guajira Peninsula (1). The huge "El Cerrejon" mining project was initiated in 1976 when a contract of association was signed by Carbones de Colombia, S.A. (CARBOCOL) and the International Colombia Resources Corporation (INTERCOR) (2). CARBOCOL is the Colombian agency responsible for development of national coal resources, and INTERCOR is a wholly owned subsidiary of the EXXON Corporation (3). According to their contract, INTERCOR was to determine the feasibility of developing the coal resources found in a portion of the Guajira designated "Area B" (4). Although this region was known to have substantial coal reserves of high quality, the extent of proven reserves was not sufficient to justify large scale development without additional exploration (5). Likewise, additional studies were needed because Area B was located in a hot, semiarid to arid region nearly devoid of social and economic infrastructures (6).

Several factors make El Cerrejon an important, if not unique, mining project (7). For example, this project will require an investment of more than three billion dollars over a six year period prior to the time of first scheduled production. The mine itself will consist of two open pits that will permit the recovery of coal deposits down to six hundred feet below the present surface. An entirely new port facility will be constructed at Portete which will be capable of loading ships of 250,000 tons. A new railroad with a capacity for hauling over 15 million tons per year will be constructed between the mine and port. In addition, new towns must be constructed to accommodate approximately 5,500 employees of the mining project. As the mine becomes operative, an additional 30,000 people are expected to move into the Guajira. The El Cerrejon mining project has been designed in such a way that annual production can be increased from 15 to 25 million tons per year without major difficulty. Although El Cerrejon has been developed as a joint project between INTERCOR and CARBOCOL, the entire project reverts to the Colombian government after 23 years of operation.

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SYMPOSIUM
on

# GEOLOGIC HISTORY OF NORTH DAKOTA

Presiding: Robert L. Houghton
United States Geological Survey
Bismarck, North Dakota

9. Geology and Mineralization of the Precambrian Basement, North Dakota
B. Q. Davidson* and J. R. Chandler
Western Minerals, Limited
Ottawa, Ontario

10. A Plate-Tectonic Origin for the Williston Basin, North Dakota
Robert L. Houghton*
U.S. Geological Survey
Bismarck, North Dakota

11. The Geology and Environment of Deposition of the Kinneman Creek Interval, Sentinel Butte Formation (Paleocene), North Dakota
Katherine J. Logan*
North Dakota State Health Department
Bismarck, North Dakota

12. Stratigraphy and Paleoenvironment of the Paleocene Fort Union Group of the Williston Basin near Gascoyne, Southwestern North Dakota
Robert L. Houghton*
U.S. Geological Survey
Bismarck, North Dakota
Douglas Davison
Knife River Coal Mining Company
Bismarck, North Dakota

13. Evidence for Glaciation in Southwestern North Dakota and Northwestern South Dakota
Eric N. Clausen*
Division of Science and Mathematics, Minot State College
Minot, North Dakota

9. GEOLOGY AND MINERALIZATION OF THE PRECAMBRIAN BASEMENT, NORTH DAKOTA

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Western Minerals, Limited
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Our knowledge of the Precambrian basement of North Dakota is very sketchy, based principally on information gathered during drilling for subsurface mineral resources. No Precambrian rocks are exposed at the surface. Mapping of observed and residual gravity and magnetic anomalies permits geographic extension of point information gathered during drilling. Rb-Sr, U-Pb, and K-Ar dates for the basement rocks sampled during drilling suggest a sequence for the events that produced them.

Rocks of two Precambrian provinces form the basement of North Dakota. The location of the boundary between the Churchill and Superior province crustal blocks is only poorly known but is believed to coincide approximately with 101°W longitude (1). Superior province rocks underlying eastern North Dakota are a remnant of an early Precambrian craton. The Towner and McIntosh granites which form the North Dakota portion of this craton were emplaced as deep crustal plutons marginal to a western sea about 3.2 billion years ago. Migmatized zones in these granites display an enrichment in disseminated tin and molybdenum, suggesting the granite plutons may have been emplaced over an eastward-dipping subduction zone. About 2.6 billion years ago, the western part of the Superior crustal block was uplifted and fractured. Deep crustal ultramafic rocks were exposed along northeast-trending fracture zones. Basic volcanism also occurred along these faults. Volcanism was accompanied by low-grade metamorphism of the surrounding craton. Fracture zones are highly mineralized with metal sulfides. Volcaniclastic sediments surrounding volcanic centers contain banded iron formations, the silica apparently derived from altered volcanic ash. Shallow inland seas also formed around the volcanoes due to isostatic adjustment of the crustal block and provided restricted basins for dolomite formation and periodic evaporite accumulation. Between 2.4 and 2.2 billion years ago, the entire crustal block was metamorphosed, with volcanic lineaments altered to amphibole schist and granite terrains altered to granite gneiss.

Churchill province rocks underlying western North Dakota consist mostly of metamorphosed miogeosynclinal and eugeosynclinal sediments and associated volcanics. Prior to the Hudsonian orogeny, arkose was deposited on the continental shelf bordering the western coast of the Superior craton. Further offshore, shales were deposited, grading into graywackes adjacent to an island arc located beneath the present Nesson anticline. Approximately 2.4 to 2.2 billion years ago, the arc was welded to the craton and the subduction zone destroyed. In the process, the volcanic pile was metamorphosed into meta-andesite and the sediments into granulite facies rocks. Magnetic highs adjacent to andesitic volcanic piles suggest exhalative metal deposits may be present. Miogeosynclinal metasediments are cut by diabase dikes intruded during a resurgence of tectonic activity 1.9 to 1.6 billion years ago. Carbonate mineralization is associated with the diabase intrusions.

Subsidence of the Williston Basin in the late Precambrian involved differential subsidence of these two crustal blocks. Subsidence was accompanied by extensive loading of the Churchill block by sediments derived from the north. Loading was initiated between 600 and 580 million years ago. Sediments appear to have been derived from elsewhere in the Chruchill province.

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10. A PLATE-TECTONIC ORIGIN FOR THE WILLISTON BASIN, NORTH DAKOTA

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The usefulness of plate tectonics in explaining diverse tectonic features adjacent to plate margins is well established. Similarly, application of hot-spot theory to intraplate ocean basins successfully provides a probable explanation of lithospheric swells and volcanic lineaments. However, only recently has hot-spot theory been actively employed to explain geologic features in intraplate continental locales (1, 2).

Hot-spot theory may provide an explanation for the belt of sedimentary basins which extends across north-central North America. About 2.2 billion years ago, a hot spot appeared in the Bear structural province of northern Canada. The lithosphere overlying the thermal anomaly expanded to create a thermal bulge about 740 miles in radius and probably more than 2,500 feet high. As the rigid lithosphere expanded, it fractured in the typical trilinear manner. Two aulacogens developed extending from the center of the bulge, indicated today by a kimberlite plug, to the late Aphebian continental margin and forming what are today Bathurst Bay of Coronation Gulf and the East Arm of Great Slave Lake. The third aulacogen failed to form completely and is represented by a discontinuous fault trace. Bowing of the lithosphere over the thermal bulge also created tension at its extremities to produce normal faulting and marginal basin subsidence, as advocated by McKenzie (2). Passage of the North American plate over the hot spot elongated the lithospheric bulge into an arch, with basins becoming elongated along the arch or giving way to new basin formation depending on Precambrian basement control. The thermal arch is evidenced today by a broad band of Aphebian and Archaean rocks exposed across central and southern Canada. These ancient rocks were exposed when younger strata were eroded from the arch, uncovering the core of the lithospheric thermal bulge.

Dated volcanism from the center of the arch help attest to the time-transgressive nature of the formation of the arch. Similarly, the initiation of basin subsidence becomes younger eastward as the plate passes over the hot spot. Basin subsidence rates, as indicated by basin fill, are approximately proportional to the basin's proximity to the hot spot.

About 580 million years ago when the hot spot was situated just north of Lake Winnipeg, it began to influence the Churchillian basement block in Saskatchewan, western Manitoba, and western North Dakota. Subsidence of the Williston basin began, reaching its initial maximum about 460 million years ago. Subsequent pulses of subsidence in the basin reflect increased sediment loading due to tectonism farther west.

Projection of the hot-spot trace eastward suggests it corresponds to the Canary Islands hot spot of Morgan (3).

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11.

# THE GEOLOGY AND ENVIRONMENT OF DEPOSITION OF THE KINNEMAN CREEK INTERVAL, SENTINEL BUTTE FORMATION (PALEOCENE), NORTH DAKOTA

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To date, most environmental reconstructions of lignite bearing formations in western North Dakota have been done on a formational scale. The objective of this study was to investigate one of the non-lignite intervals, the Kinneman Creek Interval, directly above the stratigraphically lowest lignite in the Paleocene Sentinel Butte Formation. The Kinneman Creek Interval has been recognized in the Sentinel Butte Formation throughout most of western North Dakota.

The field area is located in west-central North Dakota in Mercer, Oliver, and McLean Counties and is bisected by the Missouri River. Excellent exposures are provided in the highwalls of Baukol-Noonan, North American, and Consolidation Coal Companies surface lignite mines and numerous logs are available from test holes drilled by coal companies and the North Dakota Geological Survey.

The Kinneman Creek Interval is a laterally continuous, poorly indurated light bluish gray to yellowish brown gray, silt and fine sand unit with associated clay beds. The interval dips gently to the west and varies in thickness from six to thirty-eight metres. The dominant bedforms in the study area are: climbing ripples and rhythmites, most commonly found in highwall exposures at Glenharold and Center; homogeneous sands, found most frequently at Falkirk; and trough shaped ripples and draped bedforms found commonly at all three mines. Measurements of paleocurrent direction taken from primary sedimentary structures suggest the sediment source for the interval was west and northwest of the study area.

Laboratory analyses were conducted on eleven samples from two vertical sections of the Kinneman Creek Interval (one from the Glenharold Mine and one from the Falkirk Mine). The analyses included determination of sand-silt-clay ratios, approximate bulk chemistry using scanning electron microprobe techniques, and bulk mineralogy using x-ray diffraction techniques. The samples suggest grain size is coarsest at the Falkirk Mine. Bulk chemical analyses did not reveal any major differences in samples. Relative amounts of clay minerals, kaolinite, chlorite, and micas were greatest in Glenharold Mine samples. The proportion of feldspars was greatest in Falkirk Mine samples.

The interval in the study area has many features attributable to a range of environments including fluvial, lacustrine and fluvial deltaic. The character of sediments and structures at the Falkirk Mine as indicated by test holes and highwall exposures, is somewhat different than that of Center and Glenharold Mines. The Kinneman Creek Interval in the Falkirk area may have been deposited in a fluvial system while the interval in the Center and Glenharold area suggest a quiet water or lacustrine depositional environment.

12.

# STRATIGRAPHY AND PALEOENVIRONMENT OF THE PALEOCENE FORT UNION GROUP OF THE WILLISTON BASIN NEAR GASCOYNE, SOUTHWESTERN NORTH DAKOTA

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Coal-bearing strata of the Northern Great Plains are principally of Cretaceous and early Tertiary ages. Regionally, the sediments comprising these strata were eroded from Mesozoic and Paleozoic sedimentary and metamorphic rocks in tectonically active areas and transported across broad alluvial fans by large, low-gradient, meandering streams that terminated at the shorelines of fluctuating, shallow inland seas and lakes. However, subenvironments on the alluvial fans controlled the deposition and geochemistry of local stratigraphic sequences. The Paleocene Fort Union Group[1/] is typical of the Cretaceous-early Tertiary sedimentary sequence. Mapping of Fort Union exposures in mines supplemented by 546 U.S. Geological Survey and industry geophysically logged test holes and 15 U.S. Geological Survey core sites in the 50 square miles surrounding the Gascoyne mine in southwestern North Dakota permits a detailed evaluation of some of the Paleocene alluvial subenvironments.

The major stream incising the Paleocene alluvial fan near Gascoyne was only slightly sinuous and remained relatively stationary. The ancestral channel is still being occupied today by the principal stream in the area--Buffalo Creek. Sedimentation in the channel was dominated by homogeneous sand deposited in largely oxidizing environments on channel beds, accounting for an abundance of iron oxides in the channel fill.

Numerous tributary channels flowed from adjacent topographic highs into the main channel. Near the hills, tributary channels were typically sinuous with infill composed of upward-fining mixed sand, silt, and mud, indicating that both bed and bank accretion were active. Basal-scour surfaces have high relief characteristic of modern mixed-load channels. Upon reaching the flood plain of the main channel, tributaries became more sinuous, frequently reaching anastomosing conditions. Infill into the tributary channel traces was extremely variable but was dominated by sand, silt, and mud accumulated on point bars under highly oxidizing conditions. Multiple thalwegs are typically superimposed on a pronounced trend toward profile asymmetry. Tributary channel migration was extensive, as indicated by the complexity of alternating sequences of sand, silt, and mud delineating tributary traces. Periodic stabilization of tributary channel positions is indicated in rare instances by thick deposits of coarse to fine silt deposited under generally oxidizing conditions on natural levees bounding the channels.

Lignite beds resulted from deposition of organic materials in reducing environments in broad flood-plain swamps dammed by the natural levees flanking stream channels. Plant impressions in the lignite are dominated by fernlike leaves and small-diameter (<0.25 inch) vertical stems. Woody stems and logs are common only adjacent to topographic highs and typically are preserved in a horizontal orientation. The clastic matrix mixed with and separating organic-rich lignite seams is dominantly clay and very fine silt. The lateral continuity of flood-plain deposits is interrupted by major-channel fills but uncommonly by tributary traces, indicating rapid lateral migration of tributaries across the alluvial plain.

Paleotopographic highs are indicated by radiating tributary patterns and eroded subsurface nobs mantled by loamy paleosols. Typically, these paleosols contain abundant evaporative salts such as gypsum, indicating periods of Paleocene climate were characterized by evaporation in excess of precipitation, similar to the present.

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1/ The stratigraphic nomenclature used in this report is that developed by the North Dakota Geological Survey and differs in some places from that currently accepted by the U.S. Geological Survey.

## 13. EVIDENCE FOR GLACIATION IN SOUTHWESTERN NORTH DAKOTA AND NORTHWESTERN SOUTH DAKOTA

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The presence of glacial deposits covering all except the southwestern corner of North Dakota is well recognized (1). Several workers have assumed North Dakota's landscape was not significantly altered by glacial erosion (2). This assumption has led to the conclusion that southwestern North Dakota may not have been glaciated. An alternative is suggested by White (3), who proposed that continental glaciers were major agents of erosion throughout northern North America. White's hypothesis has been challenged by Sugden (4) and others. Evidence from southwestern North Dakota and northwestern South Dakota seems critical to the resolution of this controversy.

The Chalky Buttes region in southwest North Dakota is a north-south trending upland about eight kilometers in length and one kilometer in width. At the southern and highest end, the upland makes a sharp bend to the east. Rocks making up the Chalky Buttes upland are usually mapped as Oligocene White River Group, although similar deposits are missing from an upland immediately to the west. The deposits mapped as White River contain a thick basal conglomerate with well-rounded cobbles. Many of the cobbles represent distinctive igneous lithologies which can be matched with alluvium found elsewhere. Seven of these distinctive lithologies appear to be present in the gravel capping the highest points along the divide between the Yellowstone and Redwater Rivers in eastern Montana. Nine of the distinctive lithologies appear to have source areas in the Absaroka, Beartooth and Crazy Mountain areas of Wyoming and Montana.

Slim Buttes, a north-south trending upland in northwestern South Dakota, has a similar eastward bend at its southern end. Some deposits making up Slim Buttes have likewise been mapped as Oligocene in age (5). Cross bedding in a basal unit, mapped as the Slim Buttes Formation, has been described as indicating that stream flow, at the time of deposition, was from the northwest (6). The well-rounded pebbles and cobbles found at Chalky Buttes are not present at Slim Buttes. However, angular boulders of quartzite, up to 5.6 kilograms in weight, have been found. At least one of these is an angular fragment of what was a much larger, well-rounded boulder.

Several distinct trails of alluvium containing the distinctive lithologies found at Chalky Buttes extend in a northwest-southeast direction across eastern Montana, southwestern North Dakota, and northwestern South Dakota. These trails of alluvium appear to head in the extensive gravel deposits capping the divide between the Yellowstone and Redwater Rivers in eastern Montana. The gravels capping the divide are as much as 390 meters above the modern Yellowstone River. The trail between the source areas and eastern Montana appears to correspond with the present-day Yellowstone River Valley.

The trails of alluvium strongly suggest a glacial origin for all deposits described here. What must have been floods of meltwater from glaciers in the mountains of Wyoming and Montana apparently carried the alluvium from the source areas into eastern Montana. The northeast-flowing river, which must have been on a surface at least 390 meters higher than the present-day Yellowstone River, appears to have been blocked by a continental ice sheet. What must have been a relatively shallow valley was filled completely with alluvium as the floodwaters spilled across divides to the southeast along the ice margin. This process was apparently repeated several times, each time with the ice margin in a different position. Local north-trending valleys were also blocked by the ice and became filled with alluvium as the floodwaters cut across the previous drainage system. The floodwaters would enter these local north-trending valleys from the northwest and continue to the southeast using the valley of the first major tributary south of the blockage. The absence of morainal material typical of glacial deposits in central and eastern North Dakota can be explained by glaciers which were not cutting into the Precambrian rocks of the Canadian Shield.

Abundant paleontologic evidence at both Chalky Buttes and Slim Buttes has been used to support the Tertiary age of the deposits described (5). While the evidence presented here does not rule out the possibility of Tertiary glacial events, a Quaternary age for these deposits appears more consistent with other evidence. Additional work is necessary to resolve this apparent conflict concerning the age of these deposits.

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SYMPOSIUM
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# IMPLICATIONS OF GARRISON DIVERSION UNIT
## Review and Analysis of International Joint Commission Study

Presiding: Allen L. Fisk
Bismarck, North Dakota

32. Historic Background and Organization
Allen L. Fisk*
Bismarck, North Dakota

33. International Joint Commission - Uses Study Committee Summary
Neal A. McClure*
North Dakota Rural Water Systems Association
Minot, North Dakota

34. International Garrison Diversion Study Board - Engineering Committee Summary
Howard M. Olson*
Carrington Irrigation Station-NDSU
Carrington, North Dakota

35. International Joint Commission - Biology Study Committee Summary
Dale L. Henegar*, Commissioner
North Dakota Game and Fish Department
Bismarck, North Dakota

36. Impact of Garrison Diversion Return Flows on Quantity of Water in Receiving Streams in Canada
E. J. Doering*
Agricultural Research Service-USDA
Mandan, North Dakota

37. International Joint Commission Garrison Diversion Unit - Water Quality Report
Norman L. Peterson*
Environmental Health Section, State Department of Health
Bismarck, North Dakota

38. Status Report on the Garrison Diversion Unit
Darrell Krull*, Project Manager
Bureau of Reclamation
Bismarck, North Dakota

32. GARRISON DIVERSION STUDY

Historic Background and Organization

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The drouth of the 1930's motivated a comprehensive approach to the development and management of the natural resources of the Missouri Basin. By that time, the concept of integrated resource development was being applied in the Tennessee Valley and some other basins in the United States.

Two pieces of legislation were passed by Congress in 1933 that were to have a long-range effect on planning in the Missouri Basin. The first was authorization of the Corps of Engineers' Fort Peck project in Montana, and the second was passage of the Case-Wheeler Project Act.

The Corps' authorization was not limited to approval of Fort Peck alone but granted that agency broad planning authority for flood control and navigation throughout the Missouri Basin. The Case-Wheeler Act authorized the Bureau of Reclamation to plan, construct, and operate irrigation and power generation projects in the West.

With the stage then set, both the Bureau of Reclamation and the Corps of Engineers began independently planning for full-scale development of the Basin. It was inevitable that conflicts would develop. The two plans were eventually consolidated under the "Pick-Sloan" plan and this consolidated plan was approved by Congress on December 22, 1944. The "Pick-Sloan" plan provided for construction of 316 separate projects including Garrison Diversion, and 112 dams having a storage capacity of 107 million acre-feet of water with generation capacity of 2.6 million kw of electrical energy. Navigation water supply was given the lowest priority but the plan did include a 9-foot navigation channel from Sioux City, Iowa, to St. Louis, Missouri. The six main-stem dams on the Missouri River have a combined storage capacity of 75 million acre-feet or 70 percent of the total basin storage and Garrison Reservoir stores over 18 percent of the Basin total here in North Dakota.

Therein lies the beginning of the Garrison Diversion Irrigation Project or Garrison Diversion Unit (GDU). Planning for the project started this same year, 1944. As planning proceeded on this project and other projects in the Basin, the International Joint Commission (IJC) was appraised of progress and there were exchanges of technical information between Canada and the United States. Construction was authorized for the GDU in 1965.

The first serious concerns of the Canadian Government were expressed in a note to the Government of the United States early in 1969. Increasing concerns led to a note forwarded to the United States in October 1973 requesting a moratorium on further construction of the GDU until an acceptable solution of possible damage to Canadian waters could be found. In January 1975, the two countries agreed to a joint study of those aspects of the GDU that could adversely affect the waters of Canada. Subsequently, the International Garrison Diversion Study Board was formed and given the following "Terms of Reference" for conduct of the study: (1) the present state of water quality in the Souris and Red Rivers, their tributaries and other downstream waters, with particular reference to the Canadian portions which might be affected by the GDU; (2) the present uses and reasonably anticipated uses of these waters; (3) the effects of present water quality on these uses; (4) the impacts on the quality and quantity of these waters resulting from completion and operation of the GDU; (5) the impacts of the completion and operation of the GDU on present uses and on reasonably anticipated uses of these waters; and (6) the impact on commercial and recreation fisheries in Manitoba of the possible introduction by the GDU of foreign species of fish, fish diseases, and fish parasites.

In addition, the Reference stated that if the Commission should make any recommendations to relieve or avoid any adverse effects on uses in Canada, the Commission should indicate the approximate cost of these measures.

The study was organized with a Board made up of six members and a secretary from each nation and the following five technical committees that eventually involved 53 members from 15 agencies or organizations.

The five technical committees were as follows: (A) Water Quality; (B) Water Quantity; (C) Biology; (D) Uses; (E) Engineering. With us today are representatives of each of these committees who will review with you the findings of each committee and the Project Manager of the Missouri-Souris Projects Office who will review features of the GDU and revisions in the plan made subsequent to the IJC report.

# 33. INTERNATIONAL JOINT COMMISSION - USES STUDY COMMITTEE SUMMARY

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The Uses Study Committee analyzed the impacts of Garrison Diversion Unit (GDU) on major water uses in the Red, Assiniboine, and Souris River basins and on Lakes Winnipeg and Manitoba. Water Uses included in the analysis are: municipal, industrial, agricultural, rural domestic, recreational, fish and wildlife, and other. The analysis of GDU impacts is confined to uses in Canada.

## Physical Features.

The study area is defined as the Souris, Assiniboine and Red River Basins and Lakes Manitoba and Winnipeg. Within this area the streams which will carry return flows from the GDU include the Souris River downstream of Minot, the Assiniboine River downstream from the mouth of the Souris River, the Wild Rice River and Sheyenne Rivers, and the Red River from the mouth of the Wild Rice River into Lake Winnipeg. Approximately 57% of the study area is in Canada. This excludes the surface areas of Lake Manitoba and Lake Winnipeg.

## Present and Anticipated Water Use

Water in the study area has often been in short supply and of poor quality. These water supply problems have compelled municipalities to seek alternative sources, or to install costly storage and treatment facilities.

A moderate increase in population is expected by the year 2000. The trend for people to move into urban areas is expected to continue. In Manitoba, about 27,000 people live in six communities served by the surface waters which would receive return flows from the GDU. That number is expected to increase to about 36,000 by the year 2000.

Almost 3.5 million gallons daily were withdrawn in 1975 for municipal purposes in Manitoba of which 1.6 mgd were withdrawn from the Red River, 1.7 mgd from the Assiniboine, and 14,000 gallons per day from the Souris. These withdrawals are expected to increase by the year 2000 to 2.0 mgd from the Red, 2.5 mgd from the Assiniboine, and 130,000 gallons per day from the Souris.

Rural domestic water requirements in Manitoba include household uses on farms, Indian reservations, and rural settlements that are supplied from surface waters that could be affected by return flows from GDU. Though small, these withdrawals are vital to the individual users because groundwater supplies are often brackish. In 1975, about 650 gallons per day were withdrawn from the Red, 36,000 gallons per day from the Assiniboine, 7700 gallons per day from Lake Winnipeg, and 34,000 gallons per day from Lake Manitoba for a total of 78,350 gallons per day. This is expected to increase to about 238,850 gallons per day by the year 2000. Although water quantity is not normally a limiting factor for rural domestic use along the Red and Assiniboine Rivers, periods of zero flow in the Souris River limit its use for rural domestic purposes. In many instances some form of treatment is necessary.

Most of the Manitoba industries in the study area rely on municipal water supplies. The major exceptions are two thermal-generating plants and sugar beet processors. They presently withdraw 66.6 mgd from the Red River. Some treatment is usually provided for these withdrawals, to control scaling and corrosion for boiler water used by the generating plants, and to reduce hardness, total solids, color, and chlorine for food processing. By the year 2000, industrial water use in the study area in Manitoba is expected to increase to about 158 mgd because of new vegetable and potato processing plants, a nuclear-generating station, a glass plant, a winery, a distillery, a sugar beet processor, and a fertilizer plant.

Agricultural uses of water consist of irrigation and livestock watering. Withdrawals in the study area of Manitoba for irrigation totalled 1800 acre-feet in 1975. In the Portage la Prairie area, the center of vegetable poduction in Manitoba, vegetables, sunflowers and rapeseed were grown on 1000 acres of irrigated land. About 400 acres are irrigated by water withdrawn from the Red River and 100 acres from the Souris. By the year 2000, it is expected that 30,000 acres will be irrigated by waters from the Assiniboine, 25,000 acres from the Red, and 6000 acres by waters from the Souris.

The 34,000 head of livestock in the study area in Manitoba consumed 680 acre-feet of water in 1975.

The provision of services and supplies to cottages, guiding and outfitting hunters and fishermen, trapping and other such activities produce income for Canadians along the waterways, and many of these activities are expected to expand. Earnings from guiding and outfitting in 1975 totalled about $1.5 million. This is expected to increase to $8 million by the year 2000. Subsistence hunting, fishing, and trapping are also important.

The strip of land within a half-mile on either side of the Red, Assiniboine and Souris Rivers, and within a half-mile of Lakes Winnipeg and Manitoba encompasses most of the region's water-based recreational opportunities. These opportunities, although limited in number, are experiencing intensive use.

34. INTERNATIONAL GARRISON DIVERSION STUDY BOARD

ENGINEERING COMMITTEE SUMMARY

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The Garrison Diversion Unit (GDU) is a multi-purpose water resource project designed to divert Missouri River water into central and eastern North Dakota. The Snake Creek Pumping Plant will lift Missouri water from the reservoir behind Garrison Dam into Lake Audubon from which water will flow by gravity through the 73.6-mile McClusky Canal into Lonetree Reservoir. The reservoir will be created by construction of dams on the headwaters of the Wintering and Sheyenne Rivers and dykes on the James River. The 424,000 acre reservoir is located on a topographic high allowing diversion north through the Velva Canal to the Karlsruhe and Souris areas, eastward through the New Rockford canal for eventual delivery to the Devils Lake basin, James and Sheyenne River watersheds. Most of the lands to be irrigated are sandy loams and loamy sands formed from lake sediments which characterize the shallow glacial lakes, Souris and Dakota. Lands in the New Rockford, Warwick and McVille areas were formed from glacial outwash sediments. Water holding capacity of these soils is moderate to low causing them to be very drought susceptable. The soils are predominately non-saline.

Construction of the GDU Project allows transfer of water from the Missouri River to the Hudson Bay drainage system with the possibility of adverse impacts on the later to the extent of probable violation of the 1909 Boundary Waters Treaty between the United States and Canada.

The engineering committee had two main responsibilities. The first was to provide engineering services to the Board and its other committees. Its second task was to identify and examine possible modifications, alterations or adjustments to the authorized GDU plan that would eliminate or reduce undesirable international effects of the project. Cost estimates of proposed modifications were to be included. Of primary concern was the possibility of transfer of fish and related biota from the Missouri River drainage to Hudson Bay drainage.

Committee findings and/or recommendations are summarized as follows:

a) Modify fish screen to increase effectiveness. Cost: $2,000,000.
b) Eliminate direct surface water connections between Missouri and Hudson drainage by: 1. Eliminate wasteway return flows from irrigation distribution system by designing a "closed system" of water delivery. Cost: $22,000,000. 2. Employ sand filtration for all M & I deliveries from Lonetree Reservoir into Hudson drainage. Cost: $11,000,000. 3. Relocate evacuation outlet in Lonetree Dam from Sheyenne River to James River. Cost: $26,000,000. 4. Ensure no flow between Rock Lake and Devils Lake. Cost: $20,000.
c) Suspended sediment concentration in the Souris, Assiniboine and Red Rivers will not be changed but the annual suspended loads will increase 55% on the Souris, 4% in the Assiniboine and 1% in the Red. Increase in annual sediment in Lake Manitoba would be 2% and Lake Winnipeg, 1%.
d) Stream bed and bank erosion changes resulting from GDU would be minimal.
e) Water treatment costs for Manitoba cities using Souris, Assiniboine and Red River as sources could increase from $59,000 to $1,900,000 annually as a result of increased chemical constituents due to GDU return flows.
f) Incremental flooding from GDU along the Souris in southern Manitoba could be eliminated by enlarging the river channel from Westhope to Hartney. Cost: 2,000 acres of land and $5,300,000.
g) Selection of lands in the Souris area for irrigation that avoid the more saline soils would reduce the TDS levels 12% in the receiving stream. Cost: Negligible.
h) Membrane lining of Velva Canal where excavated in glacial till would reduce TDS in the Souris River up to 18%. Cost: $14,000,000.

The IJC in its report to the Governments of Canada and the United States concerning the transboundary implications of the Garrison Diversion Unit concluded: "Modifications to GDU envisaged such as the elimination of direct connections between the Missouri River and the Hudson Bay Drainage Basin, replacement of highly-saline soils with a similar acreage of soils less saline, lining the Velva Canal, wetland habitat restoration, would reduce but not eliminate, all the adverse impacts in Canada." "Most of the remaining impacts, other than those from possible biota transfers, can be mitigated to a significant extent."

## 35. INTERNATIONAL JOINT COMMISSION - BIOLOGY STUDY COMMITTEE SUMMARY

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The occurrence of waterfowl and fish in the study area encompassed by the Biology Committee is discussed. Waterfowl present in North Dakota one year may occupy similar habitat in Manitoba another year and this is substantiated by numerous band returns. There is also another behavior phenomena known as the "shuffle". This is the intra-area movement of waterfowl between Manitoba and North Dakota. It is imperative to consider waterfowl populations in North Dakota as well as Manitoba because they exhibit interdependency for breeding areas.

Habitat is the key to waterfowl abundance. The Garrison Diversion Unit affects a number of marshes, potholes and waterways extensively used by waterfowl. Production of figures from these areas approach 115,000 ducks on an annual basis. There are 28,000 ducks produced annually in three North Dakota wildlife refuges on the Souris River and tributaries. In addition to this the Souris, Red, Sheyenne and Wild Rice rivers in North Dakota produce approximately 14,000 annually.

The Manitoba portion of the Souris River, the Assiniboine River downstream from the confluence with the Souris, and Red River, produce approximately 9,000 ducks. Lake Manitoba, with 271,500 acres of major marshes annually produces 115,000 ducks. The Delta Marsh, considered the world's largest duck hatchery, is adjacent to Lake Manitoba. The lake also supports and stages large populations of waterfowl. Lake Winnipeg, which has 100,000 acres of major marshes, produces 58,000 ducks annually.

The Souris and Assiniboine rivers, while not fished commercially, do support a good sport fishery for northern pike, walleye, and sauger. The lower 30 kilometers of the Red River is the most heavily fished waterway in all of Manitoba. Annual commercial fish catches ranged from two to seven million pounds during the past 15 years from Lake Manitoba. The most valuable commercial species (walleye, sauger and northern pike) make up about 50% of the total catch. Most fish are taken in the northern portion of Lake Manitoba. Gross income of commercial fishermen on the lake in 1975 was $412,000.00. In addition, approximately 75,000 pounds of fish are taken annually for subsistence use by Indians and Metis.

Manitoba's largest commercial fishery is found in Lake Winnipeg. The area is extensively fished during both the summer and winter seasons. Lake whitefish, walleye and sauger comprise about two-thirds of the total catch. The gross income of commercial fishermen on the lake in 1975 was $2,614,000.00. This lake also furnishes an important sport fishery for walleye and northern pike, particularly along the west shore of the lake where roads provide ready access. In 1975, Indians and Metis living in communities adjacent to Lake Winnipeg harvested approximately 175,000 pounds of fish for subsistence use.

There are at least 20 species of fish in the Missouri River drainage basin not found in the Hudson Bay drainage basin. These include such fish as the pallid and shovel-nosed sturgeon, paddlefish, short-nosed gar, gizzard shad, rainbow smelt, river carp, suckers, small-mouthed buffalo, and Utah chub. The absence of these undesirable species in Manitoba waters is important because they have a high reproductive potential and could successfully compete for food and space required by existing species. They could also reduce and replace indigenous forage fish such as lake herring, and alter the balance between existing predators and prey. The transfer of Missouri basin fish to the Hudson Bay area could also be the transfer method for introducing parasites which in the worst possible case could destroy some of the present species such as lake sturgeon.

The rainbow smelt has been in the headwaters of the Rainy River system in Ontario and Minnesota since 1970. These fish have apparently not moved downstream. These smelt may or may not reach Lake Winnipeg through the Rainy River system.

The black bullhead has recently been found in the Delta Marsh area of Lake Manitoba as a result of the operation of the Portage Diversion, which conveys floodwaters from the Assiniboine River to Lake Manitoba. This serves as an example for the potential movement of foreign species of fish.

The Souris River in Manitoba is an important wintering area for white-tailed deer and could be impacted by the Garrison Diversion Project. The Delta Marsh area at the south end of Lake Manitoba, produces highly significant numbers of muskrats and other furbearers. Black fly outbreaks, which are a nuisance to humans and animals, occur along some reaches of the Souris River during periods of high flow and this high flow would more often be duplicated under operation of the Garrison Diversion Project.

## 36. IMPACT OF GARRISON DIVERSION RETURN FLOWS ON QUANTITY OF WATER IN RECEIVING STREAMS IN CANADA

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The Water Quantity Committee of the International Garrison Diversion Study Board (1) inventoried the existing water quantities within the Souris, Assiniboine, and Red Rivers and in Lakes Winnipeg and Manitoba to identify general flow and lake stage characteristics, and (2) estimated the impact that development of the 250,000 acre Garrison Diversion Unit (GDU) would have on those stage and flow characteristics. The committee's "Water Quantity Report" was included as Appendix B of the International Garrison Diversion Study Board Report to the International Joint Commission in 1976, and is the primary reference for this communication.

The inventory of existing conditions for the Souris and Red Rivers and for Lakes Winnipeg and Manitoba was based on data for the period 1936 through 1974 that were available from the United States Geological Survey and from the Canada Department of Environment. The period of record for the Assiniboine River above Portage Diversion was 1952 through 1974.

Flows in the Souris, Assiniboine, and Red Rivers are characterized by large seasonal and annual variations, by annual peaks because of snowmelt runoff, and by lesser peaks because of rainfall. Lower reaches of the Souris River often have 2 peak flows; the first respresenting local runoff from tributary areas in the lower reaches and the second resulting from runoff originating in the upper reaches in Saskatchewan. Average flows for the study period were 234 cfs, 2,000 cfs, and 3,810 cfs for the Souris River at Westhope, the Assiniboine River above Portage Diversion, and the Red River at Emerson, respectively. Recorded daily flow rates at the same stations ranged from zero to 6,300 cfs, 25 to 31,200 cfs, and 0.9 to 94,400 cfs for the Souris, Assiniboine, and Red Rivers, respectively. Water surface elevation for Lake Manitoba ranged from 809.9 to 816.2 feet above mean sea level (AMSL) and is currently regulated between 810.9 and 812.9 feet AMSL. Water surface elevation for Lake Winnipeg ranged from 708.6 to 719.7 feet AMSL and is currently regulated between 711 and 715 feet AMSL.

Estimates of GDU impacts were developed in terms of irrigation return flow, canal seepage, operational waste, municipal and industrial use, and fish and wildlife management areas. The Water Quantity Committee reviewed the U. S. Bureau of Reclamation's (USBR) "Detailed Return Flow Salinity and Nutrient Simulation Model" and concluded it was the best tool that was available for integrating the complex flow processes involved in the soil-water system. Using the 1976 model run as a base, adjustments were made with regard to (1) climatic variability, (2) variation in crop pattern, (3) estimation of evapotranspiration, (4) estimation of deep percolation, and (5) estimation of snowmelt infiltration---to provide the committee's judgement of high, low, and best estimate of irrigation return flows.

Return flows resulting from canal seepage, operational waste, municipal and industrial use, and fish and wildlife areas were not estimated by the above model, so USBR estimates for these flows were evaluated. The committee's judgement was that the USBR estimate for return flow resulting (1) from canal seepage be accepted, (2) from operational waste be increased, (3) from municipal and industrial use be reduced, and (4) from fish and wildlife areas be accepted with reference to the Souris and Sheyenne Rivers but be reduced with reference to the Wild Rice River.

High, low, and best estimates of annual return flows from GDU were distributed to the Souris, Sheyenne, Wild Rice, and Red Rivers. However, occurrence of either the high or the low estimates is considered unlikely because the combination of factors required to produce either of them will probably not occur simultaneously. The annual best estimates of return flow were distributed on a monthly basis and routed from the various entry points to downstream locations of concern. Estimated average monthly GDU additions ranged from 46 cfs in March to 178 cfs in September for the Souris River near Westhope, from 30 cfs in April to 62 cfs in September for the Red River at Emerson, and from 66 cfs in April to 239 cfs in September for the Red River at Lockport.

Maximum peak flows would not be significantly increased by GDU return flows. For example, adding the committee's best estimate for GDU return flows to the historic flows for the 39-year study period increased the maximum daily peak flows from 6,300 to 6,350 cfs for the Souris River near Westhope, from 31,200 to 31,248 cfs for the Assiniboine River above Portage Diversion, and from 94,400 to 94,440 cfs for the Red River of Emerson.

GDU return flows will increase the duration and extent of flooding along the Souris River from Westhope to Souris. The average duration of flooding would be extended from 85 to 126 days when 50 acres are flooded, and from 38 to 45 days when 500 acres are flooded. Once in every 2 years, the 30-day extent of flooding would be increased from about 96 to 190 acres, i.e. about 94 additional acres would be flooded in 50% of the years.

GDU return flows would supplement critically low flows. Based on the 1936 to 1974 period, GDU return flows would have increased the minimum mean monthly flow from zero to 34 cfs for the Souris River at Westhope and from 1 to 33 cfs for the Red River at Emerson. Based on the 1952 to 1974 period of record for the Assiniboine River above Portage Diversion, the minimum mean monthly flow would have been increased from 32 to 78 cfs.

37.

# INTERNATIONAL JOINT COMMISSION GARRISON DIVERSION UNIT – WATER QUALITY REPORT

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The task of the Water Quality Committee (WQC), established by the International Garrison Diversion Study Board (IGDSB), was to describe present water quality conditions and to predict future water quality with and without the Garrison Diversion Unit (GDU). The WQC was directed to focus its studies on six locations: the Souris and Red Rivers at the International Boundary (Westhope, North Dakota and Emerson, Manitoba); the Assiniboine River at Portage la Prairie, Manitoba; the Red River at Selkirk, Manitoba; Lake Manitoba; and Lake Winnipeg.

Present water quality was determined from an inventory of existing records available from federal, state, and provincial agencies. All records were subjected to examination of sampling and analytical procedures and data comparisons before being entered into the master file of the computer. Summary tables were then prepared from the computer master file that indicated variability in water quality annually, seasonally, and monthly.

The scope of GDU was based on the design for 250,000 acres under irrigation. The WQC was instructed to determine the impacts on water quality at this level of irrigation, fully implemented, for the "Peak Impact Period" when concentrations of salts were expected to be at a maximum and at "Equilibrium Period" when the concentrations were expected to be stabilized. The projected impact of GDU on water quality at the above two periods was developed from the U. S. Bureau of Reclamation model "The Detailed Return Flow Salinity and Nutrient Simulation Model". The WQC, after reviewing literature, consulting with researchers, irrigation experts and others, concluded that the model was acceptable and it was used, with some modifications, for predicting the quality of irrigation drainage from GDU. The modifications were made after performing sensitivity analysis to determine significant variables. The modifications included changes in drainage volume, certain model assumptions, data manipulations on total dissolved solids (TDS) and major ion concentrations in return flows, and incorporation of new fertilizer management schedules for the nitrogen determinations in the return flows.

The final study results of the WQC were generally accepted by the IGDSB and used in the final report of the International Joint Commission (IJC). The IGDSB report concluded that significant changes could be expected in concentrations of TDS, sulphates, sodium, total phosphates, nitrate-nitrogen, and hardness in the Souris, Assiniboine, and Red Rivers as a result of GDU. The most marked change was expected in the Souris River and to a lesser degree in the Assiniboine. The effect on the Red River was expected to be of considerably less significance and little or no effects on water quality were expected to occur in either Lake Manitoba or Lake Winnipeg. The peak impact period was expected to be reached about 25 to 30 years after full development of GDU and the equilibrium period some 30 to 35 years after the peak impact periods. The expected seasonal range of change for certain primary parameters for the Souris at Westhope and the Red River at Emerson are respectively as follows: TDS: -10% to +170% and +1% to +15%; Hardness: +1% to +160% and +5% to +20%; Sulphates: +60% to +300% and +2% to +30%; Sodium: -40% to +15% and +10%. The magnitude of the impact on the Assiniboine averages about 80% less than the peak impacts on the Souris as noted above.

The IGDSB and IJC did not accept the WQC findings on nitrates. The existing seasonal nitrate range for the Souris River at Westhope is 0.03 to 0.59 mg/l. The IJC report concluded that expected nitrate concentrations with GDU at Westhope would range from 6.0 to 9.0 milligrams per liter (mg/l) in the fall and winter and 1 to 3 mg/l in the summer as compared to the WQC expected seasonal range of increase to 0.61 mg/l to 3.79 mg/l. The reason the higher levels were used is not well documented in the IJC report.

A number of assumptions were necessarily made by the WQC and IGDSB; however, some should be viewed with extreme caution: (1) Present water quality and flows in the rivers were used for comparing water quality, with and without GDU, at peak impact and equilibrium periods. These periods are about 30 to 65 years in the future. (2) Certain ionic concentrations that were developed were based upon the assumption of an inverse relationship between dissolved ionic concentrations and flows in the rivers. This may be valid to a point but is questionable for some parameters, especially as it relates to the Red River. (3) Predicted high sulphate levels were assumed to increase the laxative effects on those consuming the water; however, magnesium sulphate is considerably more agressive than sodium sulphate and the report does not indicate any great magnitude of increase in magnesium due to GDU. (4) A 1.9 million dollar cost was assumed necessary to restore municipal water supplies to present water quality levels. This was based primarily on a demineralization process to reduce sulphates and nitrates. This process, however, also reduces other ionic constituents and the resulting water quality would be better than currently available. Such costs should not be all attributed to GDU.

The IJC directive to the IGDSU was to determine the effects of GDU, but it did not cover the benefits that could be expected in addition to the economic benefits. For water quality and use, the major benefit is flow augmentation. Historically, the Souris River experiences seasonal low or no flow conditions. Low flows are not uncommon for the Red River. GDU would provide additional flows to these rivers as well as to the Sheyenne, James, and Wild Rice Rivers. Some 30 or more municipalities have expressed an interest in or a desire to use these waters for municipal supplies if the source was reliable. GDU would be a reliable source and in most instances would provide a better quality source than the existing groundwaters presently used. Other water users, such as industries, agriculture, recreation, and wildlife, would also benefit. This would also be true for water users in Canada.

1. International Garrison Diversion Study Board (1976) Appendix A, Water Quality Report.

2. International Joint Commission (1977) Transboundary Implications of the Garrison Diversion Unit.

38. STATUS REPORT ON THE GARRISON DIVERSION UNIT

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The Garrison Diversion Unit is a part of the Missouri River Basin Project which was authorized by the Flood Control Act of 1944. The Act of August 5, 1965 (79 Stat. 433) provided for construction of the intiial stage of the Unit for irrigation of 250,000 acres and other purposes.

Due to concerns expressed by Canada that the project could cause damages to persons and property in Canada, in contravention of Article IV of the Boundary Water Treaty of 1909, the International Joint Commission (IJC) was charged with examining the impacts of the project on waters flowing into Canada. Subsequently, the IJC established the International Garrison Diversion Study Board to investigate into transboundary implications of the project. The Study Board was given specific instructions to determine the water quantity and quality impacts on the river systems draining to Canada, the effects of undesirable fish and other biota on Canadian fisheries, and the cost of the impacts. The Study Board recommended modifications to the project to reduce impacts in Canada. The major recommendations were directed toward improvements to a fish screen structure in the McClusky Canal and other modifications to eliminate undesirable fish species from being conveyed through project canals and waterways. Also recommended was construction of a test area to verify the accuracy of projections of project-caused water quality and quantity impacts to water flowing into Canada.

The IJC's recommendations differed from the Study Board principally in two areas. IJC Recommendation No. 1 states:

> "1. That because the "closed system" and the McClusky Canal Fish Screen cannot with any certainty prevent biota and disease transfers which would cause severe and irreversible damage to the ecosystem and, in particular, to the commercial and sport fisheries in Canada, those portions of the Garrison Diversion Unit which could affect waters flowing into Canada not be built at this time. This is not intended to preclude construction of Lonetree Reservoir, subject to the conditions set forth in Chapter VIII."

The added recommendation in Chapter VIII different from the Study Board's recommendations is that fishing should be forbidden in Lonetree Reservoir.

As a result of the Study Board recommendations, the Department of the Interior, through the Bureau of Reclamation, has implemented specific programs to address Canada's concerns. A research and testing program was undertaken to determine required modifications to the fish screen in the McClusky Canal. Based on laboratory and field testing, an effective barrier to passage of undesirable fish can be constructed and operated. A test area is proposed in the West Oakes Irrigation Area to verify water quantity and quality impacts of return flows on receiving streams and test other recommended modifications to irrigation system design.

The recommendation by the IJC that those portions of the project affecting Canadian waters not be constructed at this time and Canada's continued opposition to the project have resulted in a proposal by North Dakota officials to construct the authorized project in phases. It is proposed that about 85,000 acres of irrigation be developed in the James River Basin and the Devils Lake Basin in Phase I. No irrigation return flows from these areas would go to Canada. All direct connections of water transfer to Canada would be eliminated from Phase I. Municipal and industrial water for the Sheyenne River, which flows to the Red River and eventually to Canada, would be discharged through a sand filter.

Phase II would include the remainder of the authorized project, about 165,000 acres, and would be constructed if obligations of the Boundary Waters Treaty could be met. By the time Phase II decisions had to be made, results of additonal testing and research would be available and the effects of the modifications demonstrated.

Two consultation sessions were held in 1981 among representatives of the governments of the United States, Canada, North Dakota, and Manitoba. North Dakota officials presented the details of Phase I and the proposal is under review by the United States and Canadian governments. Additional consultations are anticipated in 1982.

SYMPOSIUM
on

TOPICS IN EXPERIMENTAL DESIGN
(But Why Can't I Just Use the T-Text)

Presiding: Doris Hertsgaard
North Dakota State University
Fargo, North Dakota

39. Advances in Design of Experiments
Ariyaratna M. Wijetunga*
Mathematics Department, Moorhead State University
Moorhead, Minnesota

40. Multiple Comparison Procedures for the Analysis of Variance
LuAnn K. Johnson*
USDA, Grand Forks Human Nutrition Research Center
Grand Forks, North Dakota

41. Estimation of Variance Components
David Smith*
Mathematical Sciences Department, North Dakota State University
Fargo, North Dakota

42. The Analysis of Variance with Messy Data
Leigh W. Murray*
Mathematical Sciences Department, North Dakota State University
Fargo, North Dakota

43. Analysis of Variance Using Computer Statistical Systems
James A. Clark*
Department of Psychology, University of North Dakota
Grand Forks, North Dakota

39. ADVANCES IN DESIGN OF EXPERIMENTS

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The foundation of design of experiments was laid by R. A. Fisher towards the end of the present century. Thereafter, the development of the subject was done by many others who were interested in increasing the precision of field experiments. The principles of design of experiments as introduced by Fisher are randomization, replication and local control. The simplest design in the series is called the Completely Randomized Design (CRD), where we assume that the experimental units being used in the experiment are homogeneous. As it is given in the theory of Linear Models, the analysis of such designs and interpretation of results are quite simple. The next step of the advancement was the introduction of the Randomized Block Designs (RBD), which can be used to eliminate the main disadvantage of the CR designs, the lack of homogeneity between a large set of experimental units. In RBD, every treatment is applied to one and only one plot within a block, and the plots within a block are again assumed to be homogeneous. When there are a large number of treatments, this assumption does not seem to hold true. These designs were then improved by Yates (1936), who introduced Balanced Incomplete Block designs (BIB). He investigated BIB designs and lattice designs. The construction of BIB designs are somewhat complicated. The subject of combinatorics plays an important role in construction of BIB and other designs which came thereafter. Next, Bose & Nair (1939) generalized lattice designs and introduced Partially Balanced Incomplete Block designs (PBIBD). The analysis of these designs is not very complicated compared to the analysis of the well-known RBD's. After Euler (1782), another class of designs, namely, Latin Square designs, was brought into the subject which is used to eliminate heterogeneity in two directions. Construction of these designs amounts to solving problems in combinatorics.

Another important class of designs which is used extensively in areas such as Psychology, Agriculture and Agronomy is Factorial designs. In factorial experiments, we study several factors each at different levels simultaneously. The analysis of such designs and the interpretation of results are relatively complicated compared to incomplete block designs. Construction of these designs in higher cases involve very complicated problems in combinatorics, some of which are not yet solved. The recent advances of these designs are due to J. N. Srivastava, S. Yamamoto and their associates.

40. MULTIPLE COMPARISON PROCEDURES FOR THE ANALYSIS OF VARIANCE

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Several multiple comparison methods have been developed for the analysis of variance (ANOVA). The Scheffé test, the Bonferroni method, Tukey's tests and their several variations, Newman-Keuls test, and Dunnett's test will be discussed and compared. The power and robustness of each procedure under varying degrees of variance heterogeneity, nonnormality, and sample size imbalance must be considered when selecting the most appropriate multiple comparison procedure to use on a set of experimental data. Other considerations include the conservativeness of the method and the convenience of calculating the test statistic.

41. ESTIMATION OF VARIANCE COMPONENTS

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Many applications make use of random effects in experimental designs. The purpose of the present paper is to review the model, to consider solutions used in the balanced case, and to look at new results in multivariate variance components. Attention will be given to practical matters such as computing and interpretation.

For illustrative purposes, we shall make use of the following example. Reading scores for students in the eighth month of first grade are of interest to a group studying statewide educational attainment in North Dakota. Ten students are random selected in each of 25 randomly selected first grade classes. The group doing the study is aware of the impact of teachers and wishes to account for teacher in the model. Note that it is assumed that 25 teachers are randomly selected from a large population of teachers in the state.

For the example above, assume the scores are normally distributed. Note that the scores are not independent. Students scores in the same class (same teacher) are expected to be correlated. Thus, we have the following model:

$$Y_{ij} \sim N(\mu, \sigma_e^2 + \sigma_t^2) \quad , \quad i=1, \ldots, 25;\ j=1, \ldots, 10$$

$$\mathrm{Cov}(Y_{ij}, Y_{i'j'}) = \begin{cases} \sigma_e^2 + \sigma_t^2, & i=i',\ j=j' \\ \sigma_t^2, & i=i',\ j \neq j' \\ 0, & i \neq i' \end{cases}$$

The model implies that student scores show a certain variability ($\sigma_t^2$) due to teachers and a certain variability ($\sigma_e^2$) due to differences among students.

There are several things needed. First, we wish to estimate the level of student ability as measured by the student scores in the state ($\mu$). Next, we wish to estimate the variability due to teachers ($\sigma_t^2$). Finally, variability in students ($\sigma_e^2$) needs to be estimated. Concomitantly, we may wish to test certain hypotheses. Typically, the hypothesis of no teacher variability ($\sigma_t^2=0$) is of interest.

In terms of remedial action, teachers may be encouraged to participate in in-service training or other types of training to decrease the amount of teacher variability.

The difference between this model and the more or less standard fixed effects model is, first of all, a conceptual one. We are not really interested in these 25 teachers, but in the population of teachers. As a result of this the distributions of the statistics used to test hypotheses are somewhat altered.

Several methods of estimation will be considered. For the balanced case, the AOV estimators and the maximum likelihood estimators are of interest.

A complication will also arise if scores are collected on Social Studies as well as Reading. There is every indication that the two are correlated and should be analyzed simultaneously. This is accomplished using multivariate variance components.

Computations for the above using the Statistical Analysis System (SAS) will be discussed.

42. THE ANALYSIS OF VARIANCE WITH MESSY DATA

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In designed experiments, researchers ideally obtain equal numbers of observations for each treatment combination ("balanced data"). Frequently, however, the numbers of observations per treatment combination may not be equal ("unbalanced data") or, in fact, there may be treatment combinations for which there are no observations ("missing data"). These are situations of "messy data".

In situations of balanced data, most analysis of variance procedures (e.g., SAS ANOVA, SAS GLM, SPSS MANOVA, programs of BMDP and BMD, etc.) will give the same numerical results, and hence all perform the same statistical analyses (i.e., test the same hypotheses about the parameters of interest). These hypotheses are readily understood and interpreted by the researcher since they are simple unweighted linear combinations of the means of the treatment combinations.

In situations of messy data, analysis of variance procedures do not all give the same numerical results nor is it clear what hypotheses are tested by a particular procedure. Different algorithms produce different numerical results and the researcher is left to guess which results he should choose.

The choice of a particular analysis of variance algorithm and concomitant results should depend on some some criterion of goodness. The criterion that is used here is as follows: that the analysis performed (i.e. hypotheses tested) be the same as, or as close as possible to, the analysis that would have been performed had the data been balanced.

Fortunately, in the case of unbalanced data, this criterion is easy to satisfy in choosing a statistical procedure. Several procedures are available in SAS, SPSS, BMDP, and BMD which test the same hypotheses for unbalanced data as for balanced data.

Unfortunately, in the case of missing data, there is no consensus of opinion among statisticians as to what should be done. Alternatives range from deleting the treatment combinations with no observations from the analysis to imposing conditions on the relations among the means of the treatment combinations. One new technique is that of "effective hypotheses". This analysis tests the original hypotheses (the hypotheses that would have been tested had the data been balanced) to the extent that they can be tested. This technique is probably the most reasonable way to analyze such data.

The different analysis of variance procedures employ various strategems in the analyses of missing data. One procedure, in particular, does test "effective hypotheses". With all the procedures, however, the researcher has little control over the analysis performed.

43. ANALYSIS OF VARIANCE USING COMPUTER STATISTICAL SYSTEMS

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There are several standard statistical packages generally available on the larger computer systems. They are The Statistical Analysis System (SAS), (Helwig and Council, 1979); The Statistical Package for the Social Sciences (SPSS), (Nie et al 1975; Hull and Nie 1979); the Biomedical Programs (BMDP), (Dixon and Brown 1979); and a few others like DataText. These systems each perform a number of different statistical computations including analysis of variance. Analysis of variance (AOV), is the general name for a complexity of statistical procedures for examining the outcomes of experiments. The purpose of this presentation is to examine and illustrate how these various statistical packages approach analysis of variance problems.

Each statistical package will be looked at separately to see how they require the raw data to be arranged, how one instructs the package to perform the appropriate analysis and how the results are presented. To facilitate this examination two different AOV models will be utilized. Each package will be required to show how it approaches these two problems. In addition, the strengths, weaknesses, and important features of each system will be outlined.

The first model to serve as an example is a 2 x 3 factorial design (fixed effects) with 3 observations in each of the 6 cells. Table 1 shows the data which is from Winter (1962, p. 233). Classically, this model is written $y_{ijk}=\mu+\alpha_i+\beta_j+\gamma_{ij}+e_{ijk}$ where $\mu$ is the grand mean, $\alpha_i$ is the raw effect, $\beta_j$ the column effects, $\gamma_{ij}$ the interaction and $e_{ijk}$ the random error term. The second model is a repeated measures design with two groups of 3 subjects each with 4 repeated measures. Table 2 shows the data also from Winer (1962, p. 306). This design involves a nesting (of subjects within groups) along with random and fixed effects. This model is written $y_{ijk}= \mu+\alpha_i+b_{ij}+\gamma_k+\delta_{ik}+e_{ijk}$ where $\alpha_i$ is the group effect (fixed), $b_{ij}$ is the subject effects nested with group (random), $\gamma_k$ is the repeat effect (fixed) $\delta_{ik}$ is the group of repeat interaction (fixed), and $e_{ijk}$ is the subject by repeat interaction (random).

Each of the statistical packages will be explained by a different presenter. This will be followed by a discussion comparing the statistical systems regarding their performance in analysis of variance problems.

Table 1
DATA FOR A TWO-WAY FACTORIAL DESIGN

| | $b_1$ | | | $b_2$ | | | $b_3$ | | |
|---|---|---|---|---|---|---|---|---|---|
| $a_1$ | 8 | 4 | 0 | 10 | 8 | 6 | 8 | 6 | 4 |
| $a_2$ | 14 | 10 | 6 | 4 | 2 | 0 | 15 | 12 | 9 |

Table 2
DATA FROM A REPEATED MEASURES DESIGN

| | Subject | $b_1$ | $b_2$ | $b_3$ | $b_4$ |
|---|---|---|---|---|---|
| $a_1$ | 1 | 0 | 0 | 5 | 3 |
| | 2 | 3 | 1 | 5 | 4 |
| | 3 | 4 | 3 | 6 | 2 |
| $a_2$ | 4 | 4 | 2 | 7 | 8 |
| | 5 | 5 | 4 | 6 | 6 |
| | 6 | 7 | 5 | 8 | 9 |

SYMPOSIUM
on

# DESCRIPTION AND CLASSIFICATION OF THE POTENTIAL NATURAL VEGETATION OF NORTH DAKOTA

Presiding: Warren Whitman
North Dakota State University
Fargo, North Dakota

60. Landforms of North Dakota
John P. Bluemle*
North Dakota Geological Survey
Grand Forks, North Dakota

61. Relationships Between Landscapes, Soils and Vegetation
D. D. Patterson and J. L. Richardson*
Department of Soil Science, North Dakota State University
Fargo, North Dakota

62. Major Woodland and Shrub Community Types in North Dakota: A Synthesis
Mohan K. Wali* and Richard H. Bares
Department of Biology, and Project Reclamation
University of North Dakota
Grand Forks, North Dakota
Robert L. Burgess
Department of Environmental and Forest Biology
State University of New York
Syracuse, New York

63. Ordination and Classification of North Dakota Grasslands
H. A. Kantrud*
Northern Prairie Wildlife Research Center
Jamestown, North Dakota
R. L. Kologiski
Endangered Species Office, U.S. Fish and Wildlife Service
Albuquerque, New Mexico

64. Classification of Wetland Vegetation in North Dakota
William T. Barker* and Gary W. Fulton
Botany Department, North Dakota State University
Fargo, North Dakota

65. Description and Classification of Grassland Types in North Dakota
Harold Goetz*
Botany Department, North Dakota State University
Fargo, North Dakota

60. LANDFORMS OF NORTH DAKOTA

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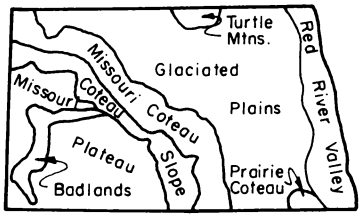
North Dakota's landforms can be broadly grouped into two categories: erosional and depositional. Most of the topography in the southwestern part of the state is the result of erosional processes that operated apart from the action of glaciers or processes directly related to glaciation. Conversely, most of the topographic features throughout northern and eastern North Dakota result directly from glaciation.




The map of North Dakota (at left) identifies several distinct physiographic or geomorphic regions. Although great individual variations characterize the landforms in each region, overall internal similarities make it possible to generalize about the geomorphic processes that operated to shape each region.

The area southwest of the Missouri River in North Dakota is referred to as the Missouri Plateau. Although some parts of the Missouri Plateau near the Missouri River were glaciated, in most instances an occasional erratic boulder or patch of glacial sediment is the only evidence of that glaciation. The Missouri Plateau is an extension of the Great Plains, which slope eastward away from the Rocky Mountains in Montana and Wyoming. The landscape throughout this vast region is the result of erosion, during Late Tertiary time, of flat-lying beds of sandstone, shale, and lignite (primarily the Fort Union Group deposits). These sediments have been modified by the formation of natural brick, baked by burning underground coal seams, and by mineral-rich groundwater, which formed layers of silcrete, petrified wood, concretions, and nodules of varying sizes and shapes. Secondary processes such as these resulted in great differences in lithification and durability of the sediments to erosion and weathering. The shapes of individual landforms of the Missouri Plateau are most notably the result of the differences in resistance of the near-surface materials to erosion by wind and running water.

The carving of the Little Missouri River badlands began in Pleistocene time when the river was diverted by glaciers from its northerly route into Saskatchewan. As a result of its diversion, the Little Missouri River was forced to flow eastward over a shorter, steeper route, resulting in a cycle of vigorous erosion that continues today.

In eastern and northern parts of North Dakota, depositional glacial landforms predominate. The overall aspect there is one of closely spaced hills and valleys, which have lower relief than landforms in the unglaciated "wide-open spaces," where large buttes and gently sloping areas are found. The unglaciated areas are also well drained. This contrasts with the glaciated parts of the state, where drainage ranges from completely unintegrated to areas with only poorly developed stream systems. Landforms in the glaciated parts of North Dakota are the result of depositional processes that operated over a drastically shorter period of time than did the erosional processes in unglaciated areas. Although some important erosional features, such as certain melt water trenches, are found in the glaciated areas, most of the topography is the result of relatively small-scale reshuffling by the ice of the materials it was flowing over. A layer of reworked sediment, some of it transported great distances by the glaciers, but most of it locally derived, completely changed the overall aspect of the landscape during Quaternary time. This layer of glacial sediment, which reaches thicknesses as great as 220 metres in central North Dakota, contains a broad mix of minerals, making possible extremely rich soils, in contrast to the poorer soils developed on some of the Cretaceous and Tertiary marine formations found farther west in unglaciated areas.

The glaciated part of North Dakota can be logically subdivided into four major physiographic units. These are 1) the Coteau Slope, an area adjacent to the Missouri River where glacial deposits are thin and the preglacial topography was only slightly modified by glacial processes; 2) the Missouri Coteau (along with the Turtle Mountains and Prairie Coteau), where glacial stagnation processes predominated; 3) the Glaciated Plains, an area where large-scale glacial thrusting, coupled with deposition due to ablation by the glacier, resulted in an intricate glacial landscape; and 4) the Red River Valley, an exceptionally flat area that is largely the surface expression of glacial Lake Agassiz.

To some degree, geologic factors such as slope angles, composition and texture of the subsoil materials, and groundwater conditions, all helped determine the type of soils that developed on North Dakota's landforms. However, changes in the climate since the end of the glacial epoch were undoubtedly the single most important factor governing the character of vegetation (and resulting soils) that developed on the landforms. This can be most readily illustrated by considering a modern analog: the Turtle Mountains and the Missouri Coteau have landforms that are essentially identical in all respects. Yet, the slight differences in climate that exist between the two areas results in strikingly differing types of natural vegetation in the two areas. Similarly, areas in central Minnesota, which have landforms identical, both in shape and composition, to those found on the Missouri Coteau in North Dakota, also have entirely different vegetation and soils.

61. RELATIONSHIPS BETWEEN LANDSCAPES, SOILS AND VEGETATION

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Present North Dakota landscapes evolved through a sequence of geologic events such as tectonic activity, natural erosion and glaciation. Two distinct end members and various intermediate phases of a landscape or drainage continuum occur in North Dakota. Closed drainage systems occur in glaciated areas such as the Drift Prairie and Missouri Coteau. Drainage patterns have not developed in these areas and runoff water collects in depressions or potholes in the lower portions of the landscape. Open drainage systems prevail in the older, dissected landscapes of southwestern North Dakota. Runoff water is removed from the landscape by a network of streams, tributaries and branching drainageways.

North Dakota soils developed on these contrasting landscapes from a variety of parent materials under the influence of a subhumid regional climate and grassland vegetation. The effects of climate and vegetation were modified by topography over time.

The distribution and productivity of native plant species are strongly influenced by soil-landscape parameters. Native species do not respond equally to all environments or sites. Plants which are intolerant of drought generally occur on a variety of sites but tend to be concentrated on sites where moisture is least likely to be limiting. Site factor influence is due to variations in landscape characteristics, microclimate and soil properties.

In North Dakota, soil water is the most limiting factor to plant growth. Assuming a relative similarity in soil properties, the amount of plant available water at a given site is affected by landscape characteristics such as slope gradient, shape and aspect and by the presence or absence of a water table. Higher slope gradients and convex slopes encourage runoff while concave slopes receive runon water from adjacent areas. North and east facing slopes tend to have lower rates of evapotranspiration than do south and west slope exposures. Subirrigated sites or depressional sites where runoff water collects are least likely to be deficient in moisture for plant growth.

Soil texture is the most enduring of all soil properties. Texture affects available water capacity, rates at which air and water enter and move through the soil, and erodibility. Fine textured soils hold more total water but less plant available water than do medium textured soils. Most soils with high clay contents are restrictive of air and water movement and are resistant to erosion by wind and water. In general, coarse textured soils have low available water capacities, allow rapid passage of air and water and are more subject to erosion. Subirrigated or depressional sites provide a more desirable environment for some species, regardless of soil texture.

Soluble salts (including sodium) occur in all North Dakota landscapes and soils but in most areas concentrations are not sufficiently high to limit native plant growth. Excessive amounts of soluble salts, however, affect plant growth by reducing the capacity of plant roots to remove water from the soil (osmotic effect), by upsetting plant metabolic processes (specific-ion effect), or by a combination of the two. Soluble salts are inherited from parent materials and accumulate from saline groundwaters. Sodium salts cause the clay fraction of the soil to disperse, thereby creating an undesirable physical condition for plant growth.

Thickness of rooting zone determines soil water storage capacity. The productivity of native species on soils with shallow rooting zones may be further affected by landscape characteristics, soil texture or soluble salts.

The response of a species to a given site is the net result of interaction between landscape, microclimate and soil. The distribution and productivity of native plants in North Dakota are a reflection of regional climate modified by numerous soil-landscape parameters.

# 62. MAJOR WOODLAND AND SHRUB COMMUNITY TYPES IN NORTH DAKOTA: A SYNTHESIS

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Classification schemes are useful constructs that reflect the extent to which an area can support particular species assemblages, as well as the changes in biota through time. However, all such schemes are limited by constraints of the state of knowledge in a given time period. Vegetation classifications all over the world have had a rich and varied history (1), and have been based on several attributes: physiognomy, floristics, structural features, and environmental relations. Regardless of the criteria used, the diverse classifications of natural or potential vegetation generally share three basic characteristics (2): (a) when similar environmental conditions prevail, similar species combinations will be found regardless of the geographic separation among the areas; (b) as a result of variations at the micro-scale, no two stand surveys are exactly alike; and (c) given the dynamic nature of vegetation, changes in species combinations are more or less continuous over time. Recognition of these factors notwithstanding, vegetation classifications contribute greatly to understanding the ecology of an area; these classifications have proven of great value in land use management as well. They shall become even more important in view of the ever-increasing disturbance of ecosystems, and the subsequent need to rehabilitate them.

Less than one percent of the total land area in North Dakota is covered by woodlands. Although the extent of land covered by shrubs is not known, their total area in the state probably does not exceed 2-3 percent. Despite their limited extent, wood- and shrubland areas have significant importance in a predominantly grassland region; these features of importance include their role: (a) as wildlife habitats, (b) in minimizing erosion, (c) in recreational use, and (d) in landscape aesthetics. A number of studies have been conducted in these areas, however, only a few share common methodology and purpose on which direct comparisons can be made. In spite of these difficulties, we have attempted a first-order synthesis for classification; three studies in particular have served as a base (3,4,5). The major types that emerge from this synthesis are given below.

## WOODLAND

**Riparian Type**
Cottonwood
Cottonwood-Green ash
Cottonwood-River Birch
Cottonwood-Juniper
Basswood-American elm
Basswood-Paper birch
Basswood-Bur oak
Aspen-American elm
Aspen-Paper birch
Aspen-Bur oak
Box elder
Box elder-Basswood
Box elder-American elm
Box elder-Green ash
Box elder-Paper birch
American elm-Box elder
American elm-Bur oak
Green ash
Green ash-Bur oak
Bur oak
Bur oak-Basswood
Bur oak-Green ash
Bur oak-Box elder

**Wooded Draw Type**
American elm-Green ash
Green ash
Green ash-American elm
Green ash-Box elder
Green ash-Juniper

**Upland Hardwood Type**
Aspen
Aspen-Missouri willow
Aspen-Paper birch
Aspen-Bur oak
Aspen-Green ash
Paper birch-Aspen
Green ash-Paper birch
Green ash-Juniper
Bur oak
Bur oak-Aspen
Bur oak-Paper birch
Bur oak-Green ash
Bur oak-American elm

**Upland Coniferous Type**
Ponderosa Pine
Limber Pine
Juniper

## SHRUBLAND

**Salt-desert Type**
Big sagebrush
Silver sagebrush

**Low Shrub Type**
Wolfberry
Silverberry
Rose
Creeping Juniper

**Tall Shrub Type**
Choke cherry
Wild plum
Buffalo berry
Juneberry
Juniper
Willows

These woody vegetation types, which are primarily controlled by available moisture, reflect different floristic origins; major ones include the eastern deciduous forest (most species in riparian, wooded draw, and upland hardwood types), the boreal forest (some species in upland hardwood), Rocky Mountain forest and shrub (upland coniferous and salt desert types), and mid-american prairie (low and tall shrub types).

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63. ORDINATION AND CLASSIFICATION OF NORTH DAKOTA GRASSLANDS

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Vegetative composition was determined in 1974 on 180 plots (16-259 ha) of uncultivated upland grassland located throughout North Dakota. Samples were stratified among 21 combinations of 13 physiographic landforms and four biotic regions. Land-use categories were heavily (n = 53), moderately (n = 63), and lightly (n = 57) grazed. Seven plots were hayed in 1973 but not at time of survey in 1974.

Bray-Curtis and reciprocal averaging ordination produced remarkably similar (Spearman rank correlation 0.99, p .0001) arrangements of the 21 composite stands. Three major breaks in vector continuity of the ordinations reflected three distinct vegetation types. These types included tallgrass prairie on lake plain and lake shore deposits in the Agassiz Lake Plain, mixed grass prairie in the Drift Plain, Missouri Coteau, and Southwestern Slope regions, and an ecotone between these two types on remaining landforms in the Agassiz Lake Plain region. This ecotone may be related to a grassland community recognized by Watts (4) on well drained soils on the western edge of the Agassiz Lake Plain in southern Manitoba. The western Agassiz Lake Plain has also been recognized as a zone of vegetative transition in the classifications of Shantz (3), Whitman (5), Kuchler (2), and Bailey (1). The ordinations also showed the relationship between the vegetation and the biotic regions: the arrangement clearly reflected the four biotic regions, attesting to the similarity of vegetation on landforms within regions.

Of 314 plant species recorded, the 20 species with the highest cover value in each of the 21 strata (a total of 117 species) were used in the ordinations. Characteristic species of the tallgrass prairie such as Panicum virgatum and Andropogon scoparius were important components of the stands in the mesic end of the ordination and species typical of the mixedgrass prairie (Agropyron smithii, Bouteloua gracilis, Koeleria pyrimidata, and Stipa comata) were dominant in the stands on the xeric end. The stands situated between the extremes were dominated by mixtures of mesic tallgrass and xeric mixedgrass species, plus other species that likely reached peak development in central North Dakota, thus reflecting a gradual change from tallgrass to mixedgrass prairie along a continuum likely related to a soil moisture gradient.

Native grasslands in the Agassiz Lake Plain, Drift Plain, and Missouri Coteau have become degraded due to fire suppression, overgrazing, and the introduction of non-native plants. On nearly all glacial landforms east of the Southwestern Slope region, Poa pratensis, an introduced perennial, had the highest cover value. In the Drift Plain and Missouri Coteau, and on ground moraine areas of the Agassiz Lake Plain, the shrub Symphoricarpos occidentalis was an important member of the grassland community. Both of these species decreased in importance from east to west.

In addition to the two aforementioned species, Andropogon gerardi, A. scoparius, Panicum virgatum, and Sorghastrum avenaceum were important in the Agassiz Lake Plain. On the Drift Plain and Missouri Coteau these grasses became less important except for Andropogon scoparius and Panicum virgatum which were occasionally locally abundant. Agropyron smithii, Bouteloua gracilis, Carex eleocharis, C. pensylvanica, Koeleria pyramidata, Stipa comata, and S. viridula were important components on the Drift Plain and Missouri Coteau. Some of these became increasingly dominant on the Southwestern Slope. Grasslands on all physiographic landforms on the more arid Southwestern Slope region were dominated by various combinations of Agropyron smithii, Bouteloua gracilis, Koeleria pyrimidata, Poa sandbergii, Stipa comata, and two short carices (Carex eleocharis and C. filifolia). Poa pratensis was recorded as one of the five dominant species on eolian sand and outwash deposits in this area.

Forbs and other shrubs common on grasslands throughout the state included at least Achillea millefolium, Antennaria rosea, Artemisia dracunculus, A. frigida, A. ludoviciana, Aster ericoides, Astragalus agrestis, Cirsium flodmani, Comandra umbellata, Galium boreale, Geum triflorum, Potentilla pensylvanica, Psoralea argophylla, Ratibida columnifera, Rosa arkansana, Senecio plattensis, Tragopogon dubius, and Vicia americana.

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64. CLASSIFICATION OF WETLAND VEGETATION IN NORTH DAKOTA

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In 1967, the total wetland acreage in North Dakota was estimated to be about 3.2 million acres. (1) The wetlands are most prevalent in glaciated regions of North Dakota. Natural basin wetlands and "other wetlands" comprise 2.5 and 0.7 million acres, respectively. Table 1 gives the wetland types and their percentage of wetland acreage for each biotic region in North Dakota.

Table 1. Composition of Wetland Types in Major Biotic Regions of N.D., 1967. (Taken from Stewart and Kantrud, 1973).

| | Percent of Wetland Acreage Biotic Region | | | | |
|---|---|---|---|---|---|
| Wetland type | Agassiz Lake Plain | Prairie Pothole | Coteau Slope | South western Slope | State-wide |
| Natural basin wetlands | 92 | 93 | 16 | 4 | 76 |
| Streams and oxbows | 3 | 5 | 6 | 41 | 5 |
| Stockponds and dugouts | T | T | 3 | 54 | 2 |
| Reservoirs and large impoundments | T | 2 | 74 | T | 15 |
| Road ditches and drainage channels | 6 | T | T | 1 | 1 |
| Other (sewage lagoons, etc.) | T | T | T | T | T |

T = trace

Stewart and Kantrud presented a classification system of natural ponds and lakes in the glaciated prairie region of North Dakota. (2) The major basis of their system was zonal vegetation patterns and water permanence. The wetland vegetation can be assigned to seven zonal types as follows: (1) wetland-low prairie zone, (2) wet-meadow zone, (3) shallow-marsh zone, (4) deep-marsh zone, (5) permanent-open-water zone, (6) intermittent-alkali zone and (7) fen (alkaline bog) zone. Seven classes of wetlands are recognized on the basis of water permanence and vegetation zonation. These are: Class I - ephemeral ponds, Class II - temporary ponds, Class III - seasonal ponds and lakes, Class IV - semi-permanent ponds and lakes, Class V - permanent ponds and lakes, Class VI - alkali ponds and lakes and Class VII - fen (Alkaline bog) ponds. Due to the reliability of precipitation the water permanence of wetland flucuates greatly. Therefore, there is a definite cyclic nature of the vegetation and other biota in the semipermanent wetland. (3)

Each wetland vegetation zone can be characterized by one or more distinct plant communities which form concentric bands or mosaic patterns around or in a wetland. Studies by Fulton, Barker and Fulton and Olson have delimited the following plant communities associated with North Dakota wetlands: (4, 5, 6 and 7)

Table 2. North Dakota Wetland Plant Communities Arranged by Zone.

Wet Meadow zone
*Hordeum jubatum*
*Distichlis spicata - Hordeum jubatum*
*Carex lanuginosa*
*Spartina pectinata*

Deep marsh zone (emergents)
*Phragmites australis*
*Scirpus fluviatilis*
*Typha latfolia*
*Typha augustifolia*
*Typha glauca*
*Typha augustifolia - Typha glauca*
*Typha latifolia - Typha glauca*
*Scirpus acutus - Typha latifolia*
*Scirpus validus*
*Scirpus acutus*

Shallow marsh zone
*Eleocharis palustris*
*Scirpus americanus*
*Scirpus maritimus*
*Polygonum coccineum*
*Carex atherodes*
*Scolochloa festucacea*
*Sparganium eurycarpum*

Deep marsh zone (submerged)
*Potamogeton pectinatus*
*Potamogeton pectinatus - Myriophyllum spicatum*
*Myriophyllum spicatum*
*Potamogeton pectinatus - Potamogeton spp.*

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65. DESCRIPTION AND CLASSIFICATION OF GRASSLAND TYPES IN NORTH DAKOTA

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Recognition of a need for the delineation of naturally occurring vegetation types on the landscape for management purposes has resulted in a variety of approaches and schemes to achieving this end. The general overall objectives are to identify natural associations of plants and soil units which occupy a given place in the landscape and are recognizable on the basis of species composition and their reoccurence elsewhere under similar conditions. A substantial number of different schools of thought, which advocate different classification systems for a variety of purposes, can easily be identified and are reviewed in some detail in publications by Whittaker (1962) and Shimwell (1971). The scope of this paper is to present only the grassland classification activities in North Dakota specifically, and the Northern Great Plains in general.

The grassland classification systems generally applied to the grasslands in the already mentioned areas are based on the determination of presently occurring species composition and its relative comparison to what is deemed the potential ecological climax for that particular soil-plant landscape unit. A second approach involves only the consideration of a species composition measurement of what is presently found on a specific grassland type with no major concern for the potential climax condition. Serious problems may be encountered in the utilization of the latter approach since the presently existing vegetation type may not be in or near harmony with what the inherent potential of the site may be. The potential climax vegetation approach was first applied in North Dakota by Hanson and Whitman (1938), in which numerous grassland sites were investigated and classified according to natural occurring soil-grassland units. This central concept was greatly elaborated upon and instituted as an ecologically based approach to rangeland (grassland) site evaluation and classification by the Soil Conservation Service under the direction of Dyksterhuis (1948). This approach today remains the guiding principle in evaluating the ecological condition and trend of grasslands in the Great Plains States under various grazing and other management schemes.

More refined information regarding the ecological status and classification of major range sites in western North Dakota was recently published by Dr.Warren C. Whitman (1979). Ten major grassland types were identified and described as to species composition, topography, and soil conditions. Another rather recent study by Brand and Goetz (1978) evaluated the successioned status of selected grazed and ungrazed range sites which had been established to obtain baseline information by Dr. Warren C. Whitman some 45 years ago. Changes observed on these sites showed the rate of change in plant composition and soil characteristics over time when comparing utilized and similar non-utilized sites. The U.S. Forest Service (1974) developed an ecosystems classification scheme in this same area which is more broadly based but does identify naturally occurring units in terms of topography, vegetation, landscape aspect, geologic materials and soil texture. The system has some utility since it is easy to apply with readily identifiable ecological units in the field.

Present on-going efforts in grassland classification studies are being supported by the U.S. Forest Service (1981) in both southeastern and western North Dakota and elsewhere in the Northern Great Plains. The approach is to classify the different recognizable natural plant communities into habitat types. Various habitat types would be grouped on the basis of essentially similar biotic potentials. The concept was originally developed by Daubenmire (1952) as a forest vegetation habitat classification system and was later applied to grassland and shrub types in eastern Washington and northern Idaho (Daubenmire, 1970). The most recent application of this system to Montana grasslands and shrublands was carried out by Mueggler and Stewart (1980).

While certain variations exist in the approach to grassland classification efforts, the concept of determining the species composition, structure and ecological status remains central to all of them. It is an essential ingredient in the development of appropriate management plans which are in harmony with the ecologic condition of the existing grasslands. Likewise, it also provides the scientific knowledge necessary to interpret potential directional trends with different levels and intensities of utilization by livestock and wildlife species, non-use or under-use, and massive disturbances.

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## SYMPOSIUM
on

## HYDROLOGIC IMPACTS OF COAL MINING AND UTILIZATION IN NORTH DAKOTA

Presiding: Q. F. Paulson and R. L. Houghton
United States Geological Survey
Bismarck, North Dakota

66. Hydrogeology and Geochemistry of the Wibaux-Beach Lignite Deposit Area, Eastern Montana and Western North Dakota
W. F. Horak*
U.S. Geological Survey
Bismarck, North Dakota

67. Hydrochemistry of Shallow Ground Water From the Fort Union Group Near the Peerless Lignite Strip Mine, Gascoyne, Southwestern North Dakota
Robert L. Houghton*
U.S. Geological Survey
Bismarck, North Dakota

68. Strip Mine Disposal of Fly Ash and Flue Gas Desulfurization Wastes in Western North Dakota
Gerald H. Groenewold* and Oscar E. Manz
Engineering Experiment Station, University of North Dakota
Grand Forks, North Dakota
Harvey M. Ness
Grand Forks Energy Technology Center
Grand Forks, North Dakota

69. Hydrologic Analysis of High Flow From Snowmelt on Small Basins in the Fort Union Coal Region
Douglas G. Emerson*
U.S. Geological Survey
Bismarck, North Dakota

70. Water Use and Movement in the Rootzone of Soil-Minespoil Profiles
S. D. Merrill*, J. F. Power, and S. J. Smith
USDA-Agricultural Research Service
Mandan, North Dakota

66. HYDROGEOLOGY AND GEOCHEMISTRY OF THE WIBAUX-BEACH LIGNITE DEPOSIT AREA, EASTERN MONTANA AND WESTERN NORTH DAKOTA

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The Harmon lignite (lower Tongue River Member, Fort Union Formation), the principal commercial bed of the Wibaux-Beach deposit, underlies at least 200 square miles along the Montana-North Dakota border. Strippable reserves are estimated to be slightly more than 1 billion tons and underlie about 50 square miles. The great available tonnage and low overall stripping ratio have targeted the deposit for development. The Harmon lignite bed, however, also is the most consistently occurring shallow aquifer in the area.

A study has been conducted by the U.S. Geological Survey to determine possible impacts of surface mining on the area's ground-water resources. The study objectives were to define the stratigraphic sequence associated with the lignite deposit and to determine the premining hydrologic and geochemical regime of the deposit area.

Two other aquifers were identified within a depth of about 300 feet below the Harmon lignite aquifer, but no areally extensive aquifers were identified within the overlying 300 feet of section.

The Harmon lignite, lower Tongue River, and upper Ludlow aquifers (in descending order) are separated vertically by varying thicknesses of interbedded clay and silt. The Harmon lignite aquifer extends without interruption for several miles eastward (downdip) from the outcrop. Its thickness ranges from 3 to 34 feet and the depth to the aquifer ranges from virtually zero to 350 feet. The lower Tongue River aquifer lies some 20 to 180 feet below the Harmon lignite and ranges in thickness from 15 to 100 feet. The upper Ludlow aquifer lies from 140 to 300 feet below the Harmon lignite and ranges in thickness from 10 to 85 feet.

Both the lower Tongue River and upper Ludlow aquifers consist of discontinuous, vertically stacked, sinuous sand bodies that were deposited as channel and bar sediments in meandering and braided streams. The probability of encountering a sand bed within the aquifers at any one location in the study area is about 60 percent for the lower Tongue River aquifer and 80 percent for the upper Ludlow aquifer.

Water in each aquifer occurs under confined conditions, except very near the outcrop, and flow is toward the northeast with gradients of 10 to 20 feet per mile. The aquifers are recharged directly by precipitation at the outcrop and by downward leakage everywhere else. Only the Harmon lignite aquifer discharges water to surface drainages within the study area, and that discharge is minor. The major discharge from each aquifer is downward leakage.

Differences in chemical quality of water among the three aquifers are subtle, but significant. The mean dissolved-solids concentrations are: Harmon lignite aquifer, 1,930 mg/L (milligrams per liter); lower Tongue River aquifer, 1,810 mg/L; and upper Ludlow aquifer, 1,560 mg/L. Sodium and sulfate concentrations are almost constant, while alkaliity, calcium, and magnesium concentrations decrease with aquifer depth. Although the ionic makeup of water in the Harmon aquifer can vary greatly, the majority of samples were a sodium sulfate-bicarbonate type. Water in the upper Ludlow aquifer generally is a sodium sulfate type, with sodium always greater than 80 percent. Water in the lower Tongue River aquifer is intermediate in ionic composition relative to the other two aquifers. The median pH values, from the uppermost to the lowermost aquifer, were 8.1, 8.3, and 8.5.

The chemical quality of water in the westernmost shallowest parts of the Harmon lignite aquifer is affected by reactions in the aerated soil zone and unsaturated parts of the aquifer nearest the outcrop. Where the outcrop is heavily clinkered, recharge waters reach the aquifer rapidly and have little opportunity for solute uptake in the unsaturated zone. In the nonclinkered areas, recharge waters slowly percolate through chemically active soil profiles and unsaturated aerated parts of the aquifer. Water from the aquifer near the outcrop in these nonclinkered areas commonly contains 2,500 to 5,000 mg/L of dissolved solids, is a calcium-magnesium sulfate type, and has a pH ranging from 6.0 to 6.2.

67. HYDROCHEMISTRY OF SHALLOW GROUND WATER FROM THE FORT UNION GROUP NEAR THE PEERLESS LIGNITE STRIP MINE, GASCOYNE, SOUTHWESTERN NORTH DAKOTA

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The Fort Union Group[1/] of western North Dakota is the principal coal-bearing strata of the Northern Great Plains. As the lignite seams commonly serve as important shallow aquifers, concern has been expressed that expanded mining of these aquifers will significantly degrade the quantity and quality of shallow ground water available in this semiarid part of the nation.

To respond to this concern, the U.S. Geological Survey is conducting hydrochemical investigations in the vicinity of the Peerless lignite strip mine near Gascoyne in southwestern North Dakota. Production from the 30-foot Harmon lignite bed of the Bullion Creek Formation, which is characterized by an average coal-to-overburden stripping ratio of 0.8, has increased from 0.2 to 3.2 million tons annually since initiation of U.S. Geological Survey investigations in 1974.

In the Gascoyne area, the Harmon lignite aquifer supplies water for livestock and for limited domestic use. In most of the area, the Harmon lignite aquifer is underlain by a claystone as much as 40 feet thick. The underlying Slope-basal Bullion Creek aquifer is confined throughout much of the area by the claystone. The Slope-basal Bullion Creek aquifer supplies water for agricultural purposes throughout the southwestern part of the State.

Currently, 2- to 20-foot cones of depression in the potentiometric surfaces of both aquifers extend about 1.5 miles beyond the mine boundaries. Mine operations during the past 8 years have destroyed 10 observation wells. Although active pits approached within a quarter of a mile in several instances, no change in the surface configuration of these cones of depression was observed in any of these wells prior to their destruction. A year after mining, the altitudes of water levels in wells installed at the base of mine spoils on top of the claystone were similar to those previously measured in wells completed in the lignite aquifer.

Water quality in both aquifers is principally controlled by the following processes: acidification of precipitation, oxidation of organic compounds in the soil, oxidation of iron sulfide minerals in the unsaturated zone, dissolution of carbonate minerals, concentration and precipitation of gypsum and calcite by evapotranspiration, gypsum dissolution, cation exchange of calcium and magnesium ions for sodium on clays, adsorption and cation exchange on organic compounds in lignite, and sulfate reduction. The quality of water in aquifers undisturbed by mining did not change significantly during the investigation. However, the quality of water in aquifers reestablished in the spoils is significantly degraded, characterized by elevated sulfate and sodium concentrations.

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1/ The stratigraphic nomenclature used in this report is that developed by the North Dakota Geological Survey and differs in some places from that currently accepted by the U.S. Geological Survey.

68. STRIP MINE DISPOSAL OF FLY ASH AND FLUE GAS DESULFURIZATION WASTES IN WESTERN NORTH DAKOTA

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Fly ash and flue gas desulfurization (FGD) waste constitute the two major solid byproducts generated by lignite-burning power plants in North Dakota. Presently, on an annual basis, approximately 1,750,000 tons of these wastes are generated in North Dakota. These quantities will increase significantly as additional thermo-electric and lignite gasification facilities are constructed. The potential impacts of fly ash and fly ash-generated FGD waste on groundwater quality by disposal in various surface mine settings is being evaluated by an ongoing study at the Center Mine near Center, North Dakota. The research, presently funded by DOE-Grand Forks Energy Technology Center, involves detailed field studies, laboratory studies involving column and batch leaching experiments, and computational geochemical studies. The field study is evaluating two hydrogeologically distinctive types of disposal sites at the Center Mine: the pit bottom and the v-notch between spoil ridges. In the restored landscape, pit bottom disposal sites are typically below the water table (a saturated setting) and are characterized by relatively high permeabilities. The v-notch sites are typically above the reestablished water table (an unsaturated setting) and are commonly enclosed by materials of relatively low permeabilities. Approximately 150 piezometers and 40 soil water samplers have been installed within the waste-disposal areas and in undisturbed adjacent areas. This instrumentation has allowed for an evaluation of baseline subsurface water conditions as well as an evaluation of the effects of FGD waste and fly ash on subsurface water quality.

Preliminary data indicate that groundwater adjacent to or below FGD waste is characterized by concentrations of sodium and sulfate that are considerably greater than the average for those ions in unaffected spoils water. Total-dissolved-solids concentrations in the FGD waste-affected groundwater range from 6564 to 9521 mg/L. The average total-dissolved-solids concentration in unaffected spoil water at the Center Mine is 3375 mg/L. Other soluble species, such as iron and magnesium, are present in FGD waste-affected groundwaters at levels that do not exceed levels in unaffected groundwater. The concentrations of arsenic and selenium in FGD waste-affected groundwater are within the same ranges as spoil water in unaffected areas. Molybdenum concentrations show considerable variability, ranging from 70 to 51,180 μg/L in FGD waste-affected groundwater. The pH of groundwater in FGD waste-affected areas ranges from 6.15 to 7.50. The most significant impacts of FGD waste on groundwater quality have occurred around saturated disposal sites with no indications of decreasing impact after three years of monitoring.

Fly ash disposal has been restricted to v-notch positions in spoils. Subsurface water impacted by fly ash leachate shows highly variable concentrations of sodium and sulfate. Total-dissolved-solids concentrations in fly ash-affected groundwater range from 5425 to 52,650 mg/L. Iron and manganese concentrations in fly ash-affected water vary considerably, ranging from 4 to 2590 μg/L and 10 to 6500 μg/L respectively. Arsenic concentrations range from 1 to 613 μg/L in fly ash-affected groundwater. Selenium ranges from 1 to 800 μg/L. In all cases, however, the concentrations of arsenic and selenium are significantly below levels designated as hazardous by Federal regulations. The pH of fly-ash affected water ranges from 6.95 to 12.1. Noteworthy is the fact that both arsenic and selenium show highest concentrations in groundwater having high pH values. Molybdenum concentrations in fly-ash affected water range from 218 to 38,460 μg/L. The high values for all parameters are for samples obtained immediately below fly ash emplaced in unsaturated settings that had been in place less than one year. Data from some sites suggest significant decreases in concentrations of all parameters within one to two years after burial of the fly ash.

The field data are in close agreement with laboratory leaching data and suggest that disposal of these highly soluble waste products in saturated settings, as are typical of pit bottoms, significantly increases the potential for dissolution, leaching, and migration of various constituents. This is particularly problematic with respect to fly ash. Disposal of the wastes in unsaturated settings, such as the v-notch, significantly decreases the potential for leaching and groundwater contamination. In addition, with respect to fly ash, disposal in an unsaturated setting may allow for the inherent pozzolanic characteristics of the waste to generate a relatively nonreactive solid. The desireability of disposal of these wastes in unsaturated settings is enhanced by the semi-arid climate of western North Dakota. Under these climatic conditions, most potential groundwater recharge is lost to the processes of evapotranspiration, thus further decreasing the potential for contact with subsurface water. The apparent relationship between high pH and mobility of arsenic and selenium from fly ash may be offset by the natural alkaline buffering capacity of the Tertiary sediments.

## 69. HYDROLOGIC ANALYSIS OF HIGH FLOW FROM SNOWMELT ON SMALL BASINS IN THE FORT UNION COAL REGION

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The complexity of watershed hydrology limits the capability for analyzing all seasonal changes; therefore, recognizing critical hydrologic periods is important (2). In many watersheds, there exists a particular seasonal period, controlled by cyclical hydrologic processes, for which data analysis and model application can be aimed, therefore decreasing the components needed in a watershed model. The exceedance probability of hydrologic events during critical hydrologic periods can often be statistically evaluated because the periods are often governed by similar hydrologic conditions and commonly recur on a cyclical basis. Data needs for analysis or calibration and verification of a watershed model can thus be decreased.

The understanding of high flow is an integral part of any watershed analysis. To adequately evaluate high flow, the controlling processes and the numerous and complex factors that affect the processes need to be understood. The major processes that affect high flow are water availability, water excess, and water routing.

A ratio between the number of annual peaks due to snowmelt to the total number of annual peaks was compiled from all the U.S. Geological Survey stations that are located in the Fort Union Coal Region of North Dakota except those stations located in the badlands area, which appears to have different hydrologic characteristics; are nonregulated; and have 10 or more years of record. The mean of these ratios is 0.61 and the standard deviation is 0.17. Discharge records have been collected at two stations in the Hay Creek study area since March 1978 and at two stations in the West Branch Antelope Creek study area since October 1976. Of the 17 annual peak discharges that have been recorded at the stations only 2 have been due to rainfall runoff. Although this is a small sample on which to base any substantial conclusions, if high flow is a critical event, the snowmelt period is the critical period to be considered for the Fort Union Coal Region in North Dakota. Based on the exceedance probabilities established by regression equations (1), all of the rainfall runoff peaks recorded in the study areas were greater than the 50-percent exceedance probability.

Although snowmelt is considered to be the principal source of high flow, snowmelt is the least studied and understood process. Most snowmelt research has been in mountainous or forested areas; relatively little on the prairie. Factors affecting snowmelt in mountainous or forested regions can be significantly different from those affecting snowmelt on an open prairie. Extensive analysis of each factor affecting the processes that cause runoff from snowmelt is needed for the prairie, but is beyond the scope of this study. Therefore, only those factors that are believed to have the greatest affect on runoff from snowmelt are examined.

Snow that is available for melt cannot be adequately determined from precipitation gages or point-depth measurements. Areal variability of the snowpack due to land use and terrain can only be adequately determined by some type of snow survey. In the energy transfer that determines the rate of snowmelt, radiation is the major melt-producing flux. The ability of the other fluxes to assist or counteract is a major factor in determining whether runoff will occur. Most models use a simple temperature index to calculate snowmelt, which may be adequate if the factors affecting the processes do not vary greatly. A temperature-index model is simple and requires only temperature data; whereas, an energy-budget model can handle varying conditions, but is more complex and requires more data.

Of the water excess processes, infiltration is probably the most critical in determining runoff. Whether the ground is frozen or not during the melt period can greatly effect the amount of runoff. The snow cover for a prairie environment can vary greatly, resulting in substantial variations in frost depths. A simple frozen or nonfrozen solution may not be applicable.

Water routing during snowmelt runoff is more complex than rainfall runoff because of the additional factor of snow in the fields and in the channels which the melt water must flow through, melt, or erode. These conditions for the overland flow and the channel flow are constantly changing during the runoff period. The main stem of Hay Creek and West Branch Antelope Creek flow through numerous stock-dam type reservoirs and section-line roads that have varying number and conditions of culverts, bridges, and embankments. This type of complex water routing is common in North Dakota and is a critical process in determining high flow.

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# 70. WATER USE AND MOVEMENT IN THE ROOTZONE OF SOIL-MINESPOIL PROFILES

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The hydrologic problem of predicting deep percolation involves understanding of the relations among precipitation pattern, plant growth and evapotranspiration (ET), and soil hydraulic properties. In the case of soil-covered minespoils of very low permeability, deep percolation is believed to involve saturation of the profile at the soil-minespoil interface and subsequent piping erosion. Study of the effects of the depth of overspread soil material is important for understanding the hydrology of such reclaimed lands.

The objective of our study was to observe the effect of soil depth over minespoil upon water movement and use and upon crop growth. Observations were made over 2-1/2 years on a crested wheatgrass (Agropyron desertorum) stand at an experimental reclamation site (1) in Mercer Co., ND. Minespoil was sodic and in a dispersed condition. Small plots, laterally isolated to a depth of 75 cm, were located at positions where total depths of Boroll topsoil (20 cm overall) plus subsoil were 25, 50, 75, and 100 cm. Plant growth was measured and water use and movement was monitored by measurements of water content, water potential, temperature, and flow tracers.

Where water limits plant growth, a linear relationship usually exists between biomass yield and ET (2). This is the basis for the ability of plants to modify and reduce variations of deep percolation generated by field variation in soil physical properties and topography. Where soil-water use by plants interacts significantly and negatively with other factors, the slope of a plant yield versus ET relationship will be increased; but the potential to modify variations in deep percolation may decrease. A survey of literature indicates many plant-soil-water systems possess relative biomass to relative ET functions with slopes ranging from 1.2 to 2.6.

Forage yields were 2.6- to 1.7-fold higher in the 100 cm soil-thickness plots than for the 25-cm soil-depth treatment, which had the lowest yields each year. Spring and early summer ET was 11 to 24% lower for the 25-cm soil depth treatment than for 75- or 100-cm soil-depth treatments. Lower ET is an indication of lower total soil water extraction. The relation between relative yield and relative ET was $Y = -1.09 + 1.97$ ET ($r = .72$, $n = 12$). This indicates a moderate level of interaction between water use and soil factors in comparison with other experiments.

The most apparent interactions between water use and profile factors were low or nonexistent water extraction in portions of the root zone occupied by minespoil and (b) very low capacity of minespoil to accept water during infiltration and redistribution. During active growth in May and June, extraction from the 30- to 60-cm depth interval of the 50 cm or greater soil-depth treatments was 2 to 4 cm compared to only 0.5 cm or less from this same depth interval occupied by minespoil in the 25-cm soil-depth treatment. On the average, 82% of total soil water extraction in the 25-cm depth treatment occurred in the upper 30 cm of the profile. Comparable figures for the 50-cm depth treatment and for the 75- and 100-cm depth treatments together were 58 and 50%, respectively.

Studies of root water extraction and flow through plants indicate that plant resistances and meteorological conditions control transpiration until the soil dries to a point at which hydraulic conductivity (HC) becomes limiting, at critical values of $10^{-4}$ to $10^{-7}$ cm/day (3). For soil zones depleted of water to this extent, root extraction rate can be described as $q = K (h_s - h_p)$ bL, where K is HC, $h_s$ and $h_p$ are soil and plant water potentials, b is a constant and L is the relative root density of the zone. Calculation of unsaturated HC values from laboratory measurements on minespoil and soil materials in our study revealed that the minespoil was at critical HC values of less than $10^{-4}$ cm/day except for a 10-cm zone immediately below soil-spoil interfaces. Thus, soil water extraction from minespoil would not occur until water in covering soil (which usually had HC values at least $10^2$ times greater) was relatively exhausted.

Roots readily penetrated minespoil, but proliferated to a somewhat lesser extent than in subsoil. Root weight profiles were well represented by exponential functions of depth. In the 25-cm soil-depth treatment, 7.2% of the root system occupied minespoil at the 30- to 60-cm depth interval; comparable values for 50-cm or greater soil-depth treatments averaged 14.2%. As shown by the equation, root density is a multiplicative factor; it was evidently much less important than the effect of the orders-of-magnitude difference between minespoil and subsoil HC values.

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# DUTCH ELM DISEASE IN NORTH DAKOTA AFTER THE FIRST DECADE

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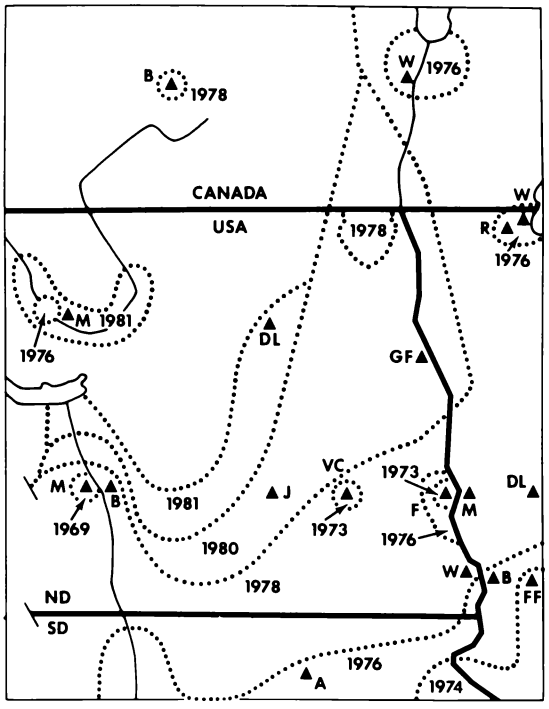
Dutch elm disease is a lethal disorder of the native American elm, Ulmus americana L., and related North American species. Dutch elm disease is caused by the parasitic fungus Ceratocystis ulmi Buism. This pathogen grows within the xylem vessels of the tree and its presence results in vascular dysfunction from which arise the characteristic wilting symptoms of the disease (2,3).

The pathogen is believed native to Asia and was introduced into Europe about the time of World War I. It was introduced into North America on diseased elm logs in the late 1920's in the vicinity of Cincinnati, Ohio (1). Because the native elm species are highly susceptible, the disease spread rapidly from this initial center. Dutch elm disease first was reported in Minnesota in 1961, South Dakota in 1967, and North Dakota (at Mandan) in 1969; the first report in eastern North Dakota was in 1973 at Fargo and Valley City (2,3).

In North Dakota, American elm is found principally in two types of forests: 1) as a major component of the native gallery forest along waterways and river valleys; and 2) as a major part of the planted urban forest in cities and towns. All of the first reports of Dutch elm disease in North Dakota were from cities: Mandan 1969, 70,71,72,73,74,75,76,77; Fargo, 1973, 75,76; Valley City 1973; Minot 1976. The first confirmation of Dutch elm disease in native woodland came in 1977 when we discovered two infection centers, one on the Rush River west of Amenia in Cass County, the other along the Sheyenne River in Ransom County in what is now Sheyenne State Forest. In both of these cases, well-developed infection centers involving many trees were already present in 1977. Examination of the pattern of spread and dissection of dead trees enabled us to determine that the disease had been present since about 1973. We propose that the difference in discovery dates is therefore due to the difference in human population density and their concern with tree mortality as well as ease of observation and sampling rather than due to any difference in behavior of the disease in the native versus the urban forest.

FIGURE 1. SPREAD OF DUTCH ELM DISEASE IN NORTH DAKOTA 1969-1981.




Between 1978 and 1981, an extensive aerial visual survey was made over most of the native elm stands in eastern and central North Dakota. The 1978 flights revealed the presence of numerous well established centers throughout southeastern North Dakota along the Red, Sheyenne, Wild Rice and Maple Rivers. Obviously, the disease had been present in this part of the state for several years. The map in Figure 1 shows results from a combination of the 1978-1981 aerial survey of native woodlands, ground sampling and diagnosis, and records of confirmed cases of Dutch elm disease submitted to the NDSU plant diagnostic laboratory.

On the map the dotted contour lines show dates when the disease became generally widespread in the area. This was usually preceded by the development of a few infection centers 20 to 50 miles beyond, or two to five years ahead of this widespread establishment.

The main spread of the disease through North Dakota has been from the southeast to the northwest at about 30 miles per year. Two originally isolated disease centers at Mandan and Minot have now spread along their respective river valley forests.

The pattern of Dutch elm disease spread now appears established and is similar to that observed in other areas with similar climates (1). It appears that the American elm will remain a component of the native forest but at populations only one percent or less of the present ones and that level will be reached in 10 to 20 years (1,2). A similar prognosis can be made for cities without control programs (2).

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The authors acknowledge cooperative efforts by the N.D. Forest Service, U.S. Forest Service, N.D. Game and Fish Dept., N.D. National Guard and City Foresters at Bismarck, Mandan and Fargo.

## 14. PALEOCOLOGY OF A LATE QUATERNARY BIOTA AT THE MCCLUSKY CANAL SITE, CENTRAL NORTH DAKOTA

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Late Quaternary lake and slough deposits were examined and sampled at the McClusky Canal Site, 3.2 miles north of McClusky, North Dakota. The site was selected because of the well-preserved fossil material present and because a complete lacustrine section was exposed at the site. The objectives of the study were to (1) identify the fossils in the sediments and present the data in an accurate stratigraphic framework, (2) interpret the environmental conditions under which the sediments were deposited, and (3) relate changes at the site to regional vegetational and climatic history.

One complete section, 6.1 m thick was measured and described. Samples were collected at 10 cm intervals. Wood samples for radiocarbon dating were excavated carefully to prevent contamination, wrapped in aluminum foil, and stored in plastic bags. Additional fossil material was collected from spoil piles. This was often well-preserved and included fish, leaves, amphipods, and beaver scat.

Sand, silt, and clay percentages were determined by pipette analysis. An estimate of organic content was obtained by igniting samples and calculating weight loss. Wood samples for dating were cleaned, dried, wrapped in double layers of aluminum foil, and again stored in plastic bags. Dating was done by Geochron Laboratories Division, Kreuger Enterprises, Cambridge, Massachusetts. Samples for fossil identification were soaked in a 4% Calgon solution, washed through sieves, dried, and examined with a binocular microscope.

Seven units were distinguished on the basis of lithology and fossil content. Unit 1, the basal unit, was a gray, pebbly, clayey sand with no fossils. It was interpreted to be till. It was overlain by Unit 2, a thin unlaminated, organic claystone, with abundant fossils. Valvata tricarinata and Gyraulus parvus dominated the molluscan assemblage. Physa, Pisidium, Armiger crista, and Helisoma anceps were also present. Seed diversity was greatest in this unit, which contained Picea, Potomogeton, Najas flexilis, Myriophyllum, Scirpus, Typha, Carex, Sparganium, Rubus, Chenopodium, Rumex, and Potentilla. The molluscan and seed assemblages of this unit resemble modern communities in northern Minnesota lakes. Unit 3 consisted of fossiliferous, laminated claystone. The molluscan assemblage was made up of the same species as Unit 2, but in increased numbers. Some samples contained more than 2000 molluscs in 50 cc of sediments. The seed assemblage of Unit 3 also resembled Unit 2, with an increase in seed abundance in the upper part. Picea, Najas, and Carex predominated. Wood from the boundary of Units 2 and 3 was dated at 12,595 $\pm$ 375 radiocarbon years B.P.

Unit 4 was essentially the same as Unit 1. It was probably deposited by slumping from adjacent slopes into the lake. Unit 5 was a laminated, organic claystone, resembling Unit 3, but with a distinctly different fossil assemblage. Unit 5 contained fewer than 10 molluscs per 50 cc of sediment. Gyraulus parvus and Valvata tricarinata predominated, with occasional Armiger crista, Pisidium, and immature lymnaeids. The seed assemblage was dominated by Typha and Chenopodium. Cyperacea, Scirpus, Ranunculus, Potentilla, Epilobium, Lycopus, and Zanichellia also occurred. The fossil assemblage suggests shallowing of the water and development of marshy areas along the lake margins. Wood from the base of Unit 5 was dated at 10,995 $\pm$ 310 radiocarbon years B.P. An average sedimentation rate of 32 cm per 1000 years was calculated using the radiocarbon dates. At this rate, Units 2, 3, and 5 would have been deposited approximately 13,000-9600 years ago.

Unit 6 was a silty claystone with few fossils and a very high gypsum content. The gypsum may be secondary. Unit 7, the uppermost unit, consisted of silty claystone, with increased sand at a depth of about 3 m. Mollusc fossils increased irregularly upward in Unit 7. Promenetus exacuous, Gyraulus parvus, Armiger crista, Fossaria, and Pisidium casertanum were present. Valvata tricarinata was present in the lower part of the unit but occurred only once in the upper half. The seed assemblage was dominated by Chenopodium. Lemna and various Cyperacea also occurred. The fossils indicate that spruce forest had disappeared from the region and that conditions similar to the modern slough gradually prevailed.

Sediments and fossils at the McClusky Canal Site reflect a regional warming and drying trend. The disappearance of spruce forest from the site approximately 10,500 years ago is consistent with findings from similar deposits in South Dakota and Canada. The decline of spruce forest can be used to approximately mark the Pleistocene-Holocene boundary. Increased sand in Unit 7 at the McClusky Canal Site may correspond to the relatively arid Hypsithermal climatic episode of approximately 8000-4000 years B.P.

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15. PERIPHYTON PRODUCTION IN A SALINE PRAIRIE POTHOLE

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It has been well documented that prairie potholes comprise one of the best wetland habitats for waterfowl breeding on the continent. Since prairie potholes are closed ecosystems, they are important natural retention storage basins for spring and summer runoff from native grasslands and cultivated land. Thus, potholes act as "energy sinks," which reduce sediment and nutrient loading to streams and lakes. The purpose of this study was to determine periphyton productivity in Fox Lake, a prairie pothole, located in Ramsey County, 56 km west of Grand Forks.

Fox Lake was chosen for this investigation because (1) it is small (0.4 x 1.2 km) and shallow (60-75 cm); (2) it supports a large macrophyte community; (3) it is easily accessible; (4) the system is closed except for groundwater import and export and watershed runoff; (5) it does not stratify during the summer months; and (6) baseline data on water quality are available (1).

Fox Lake was sampled every two weeks during the 1981 growing season (June-September). A single transect with three sampling points was established in the NE corner of Fox Lake. The shoreline was dominated by the common cattail, Typha latifolia, the open water by sago pondweed, Potamogeton pectinatus, and the opposite shoreline (island area) by bulrush, Scirpus paludosus. At the beginning of the growing season, 50 artificial substrates (extruded acrylic rods) were placed at each of the three plant community sites to stimulate growth on plant surfaces (stems and leaves). At every sampling date, water samples were collected for chemical and phytoplankton chlorophyll a analysis, acrylic rods for periphyton chlorophyll a analysis and C-14 productivity estimates, and vascular plants for surface area and biomass estimates. In addition, phytoplankton and periphyton samples were fixed for species identification.

The chemical-physical characteristics of Fox Lake demonstrated that it was alkaline (pH 8.4-9.2), saline (7-8 °/oo; 9.0 Mmhos/cm) and moderately eutrophic (0.07-0.23 ppm Total P; 8.9-23.0 ppm $NO_3$-N) during 1981. There was a trend for most nutrients to increase during the growing season, which coincided with a steady decrease in the lake level. All three plant communities had similar water quality characteristics, although they did vary in their maximum depth. It was interesting to observe that measurements for $NH_3$-N were not detectable throughout the growing season. It is well known that $NH_3$-N is a preferable form of available nitrogen for plant growth. It can be concluded that the extensive rooted aquatic plant communities were depleting the available pool.

Submerged surface area for all three plant communities increased with time. Scirpus paludosus had the greatest submerged surface area (6979 $cm^2m^{-2}$). The surface area increased with time and correlated well with the seasonal pattern of aquatic plant production. Scirpus paludosus and T. latifolia had nearly identical maximum biomass values (0.28 and 0.34 kg $m^{-2}$), and P. pectinatus was 50% less (0.15 kg $m^{-2}$). Thus, T. latifolia had the greatest production but not the highest submerged surface area. This is not surprising, since T. latifolia is in shallower water than S. paludosus, whereas P. pectinatus was always completely submerged.

Analysis of chlorophyll a in the phytoplankton and epiphytes (periphyton) on the artificial substrates demonstrated an opposite seasonal trend in all three plant community sites. Generally, phytoplankton showed an increase early and/or late in the season (diatom blooms), whereas the epiphytes on the rods were most abundant in the main part of the growing season (July to mid August). Grazing by zooplankton was particularly intense late in the season and was a major factor for a decrease in epiphyte biomass. Epiphytes on the bottom of the rods (near the sediment surface) demonstrated higher biomass values (54.8 mg chl a $cm^{-2}$), whereas epiphytes on the top of the rods (just below the water surface) were maximum at 43.5 mg chl a $cm^{-2}$. The T. latifolia community had the lowest bottom epiphyte values and S. paludosus had the highest top epiphyte values. Maximum phytoplankton chlorophyll a values were essentially equivalent for all three plant communities (19-24.6 mg chl a $cm^{-2}$). It is suggested from these data that S. paludosus would have greater periphyton production than either T. latifolia or P. pectinatus.

Fox Lake is an excellent model for testing limiting factors, therefore further experiments need to be conducted to determine what environmental variables are having the greatest effect on periphyton production.

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This work was supported by a grant from the North Dakota Water Resources Research Institute.

16. COMPARISON OF TREE HEIGHTS IN THE GREENHOUSE WITH EARLY HEIGHT GROWTH IN THE FIELD FOR PROGENY OF CONTROL-POLLINATED SCOTCH PINE

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If 1-year-old seedling heights would permit consistent indications of relative height ranking at later ages, much valuable time could be saved in tree improvement work. Very young ages, usually 1 to 3 years, have proved to be poor indicators of later performance for several species of pines or for Douglas-fir (1). However, heights of progeny from control-pollinated Scotch pine (Pinus sylvestris, L.) parents have not been compared with corresponding heights soon after field planting.

North Dakota tests of 49 Scotch pine seed origins have shown several provenances to be well-suited for northern Great Plains plantings (2). From a test plantation on the Denbigh Experimental Forest, 32 phenotypically superior parents, representing 14 provenances, were included in a tree improvement breeding program. The 32 selected trees were crossed in 30 different combinations. Parents' heights ranged from 9.6 m to 11.9 m at plantation age 18. Progeny from these parents were used to compare seedling heights in the greenhouse with heights reached after 2 and 3 years in field plantations.

Progeny were grown in an experimental greenhouse at Bottineau, N. Dak. Seeds were sown in styroblock containers, 8 blocks per cross. The containers were filled with a 1:1 mixture of peat moss and vermiculite, which had been inoculated with mycorrhizal fungi in duff collected from within the Denbigh plantation. Seedling heights were measured in one styroblock per cross, at the end of one greenhouse growing season, while seedlings were dormant.

After overwintering in the greenhouse, the seedlings were machine planted in progeny test plantations in Nebraska, South Dakota, and North Dakota. Plant competion was controlled by machine cultivation, supplemented by occasional hand weeding as needed. Total heights were measured after 2 growing seasons in South Dakota and after 3 growing seasons in North Dakota.

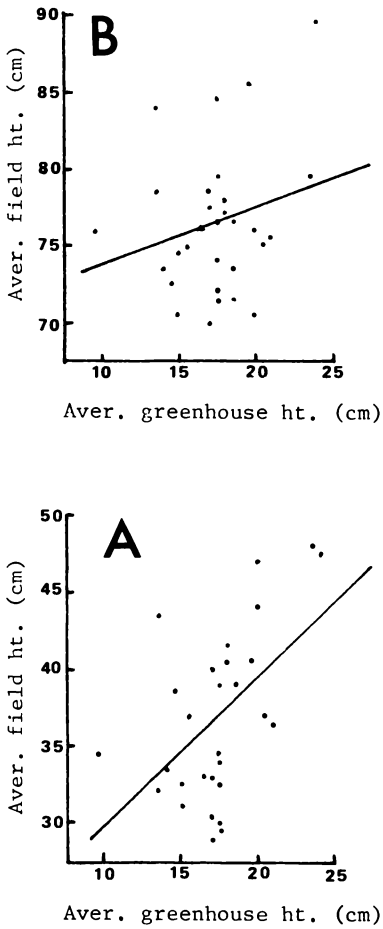


Figure 1. Relationship of average heights in the field to average heights in the greenhouse. A: Two growing seasons in S.D.; B: Three growing seasons in N.D.

Average tree heights in each greenhouse sample of the 30 crosses were compared by analysis of variance. Average height of each cross at age 1 (greenhouse) was regressed against average height attained after 2 years in the field (South Dakota) or 3 years in the field (North Dakota). There was significant height variation ($p<.05$) among the 30 crosses after 1 greenhouse growing season. Average heights ranged from 9.3 cm to 24.0 cm. In the field, average heights in South Dakota ranged from 29.2 cm to 48.0 cm and in North Dakota, from 70.0 cm to 89.4 cm.

The regression of greenhouse heights on field heights is expressed by (A): Y(aver. SD ht.) = 20.30 + 0.95 X (aver. grnhse. ht.); $r = 0.52$; and $S_y = 4.71$; and (B): Y(aver. ND ht.) = 70.0 + 0.37 X (aver. grnhse. ht.); $r = 0.23$; and $S_y = 4.64$ (fig. 1). The correlation between average greenhouse height and average field height was significant for the South Dakota data, but nonsignificant for the North Dakota data.

As progeny from the 30 crosses grew for 2 or 3 years in the field, greenhouse ranking of average heights may have been upset by the trees' adjustment and response to the field environment. There may have been a reduction in height growth by trees of some crosses as they put more of their growth into roots or stem diameter instead of height. If there is a tendency toward faster height growth by trees of some crosses, that superiority may be detected at later ages.

The conclusion is that average greenhouse height of seedlings produced from controlled pollinations of Scotch pine is not a good indicator of average heights attained by those seedlings after 2 field seasons in South Dakota or 3 field seasons in North Dakota.

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17. BIG GAME BROWSE STUDY EVALUATION

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James V. McKenzie, N. Dak. Game & Fish Dept.
Harold Goetz, Botany Department, N.D.S.U.

In the early 1960's, the North Dakota Game and Fish Department initiated a research program to monitor and survey condition and trend of shrub vegetation on big game ranges throughout the state. Such research is essential in big game management because it provides information relating to the carrying capacity, species composition, and successional trends of big game habitat. This communication is a progress report on a study designed to evaluate the data collected and methods used by the Game and Fish Department. Data used in this report are from 33 transect clusters that are established in the Little Missouri Badlands area of Billings and Golden Valley counties. The mule deer (*Odocoileus hemionus*) is the dominant big game species in the area.

The sampling methods incorporated into the study include: line intercept transects, age and form classifications, and pellet group belt transects. The sites for the transect clusters are spaced approximately one per township. Each cluster consists of three 100 foot permanent line transects positioned at three different topographical locations. The locations represented are coulee bottoms, hillsides (primary mule deer range), and hilltops. Intercept measurements are determined by guiding a plumb bob along the transect tape and recording distance intercepted below the five foot level (accessible mule deer height). Browse species, as defined in the study, are all woody shrubs, or herbaceous plants with secondary growth. Age and form classifications are also assigned to each browse species. The age classifications used are: seedling, young, mature, or decadent. Form classifications range from 1 through 8 and are based upon the shrub's availability and degree of hedging. The pellet group transect is 145 feet long and 6 feet wide (1/50 acre). It is established perpendicularly to one end of each line intercept transect. Deer-days usage per acre is calculated from the pellet group data (2). The intercept transects are sampled at three year intervals and the pellet group transects annually.

A total of 33 different species occurred within the transects of the two counties. Twelve species with the largest intercept percentages are listed in Table 1. Skunkbush (*Rhus trilobata*), a preferred browse species, has increased in total lineal feet intercepted since the initial sampling (1). Other species showing significant increases include: chokecherry (*Prunus virginiana*), buffaloberry (*Shepherdia argentea*), and rose (*Rosa spp.*). Two species that remained relatively stable are Juneberry (*Amelanchier alnifolia*) and shrubby cinquefoil (*Potentilla fruticosa*). Big sage (*Artemisia tridentata*) has decreased. Age and form classifications probably best elucidate trend predictions. It appears there may be a shift occurring from the mature to decadent state (Table 2). Nineteen year averages of deer-days usage per acre derived from the pellet group segment of the browse study indicate occupancy by deer of hillsides is 2.9 times greater than that of hilltops and 6.7 times greater than that of coulee bottoms. Hilltops show 2.3 times as much deer-days usage when compared to coulee bottoms.

The sampling methods utilized in the study are relatively reliable. There is some variability of data between sampling years that may be attributed to sampling error. Age and form classifications are especially subject to personal observer bias.

Table 1. Percent of total lineal feet intercept on all topographical locations from 1979 sampling.

| Species | % Intercept | Species | % Intercept |
|---|---|---|---|
| *Juniperus horizontalis* | 16.2 | *Prunus virginiana* | 7.2 |
| *Symphoricarpos occidentalis* | 15.2 | *Juniperus communis* | 4.8 |
| *Rhus trilobata* | 11.2 | *Juniperus scopulorum* | 4.5 |
| *Shepherdia argentea* | 10.2 | *Potentilla fruticosa* | 3.5 |
| *Rosa spp.* | 9.2 | *Rhus radicans* | 2.3 |
| *Artemisia cana* | 7.6 | *Fraxinus pennsylvanica* | 1.8 |

Table 2. Percent of each age classification by sampling year.

| | 1964 | 1967 | 1970 | 1973 | 1976 | 1979 |
|---|---|---|---|---|---|---|
| Seedling | 1.7 | - | - | - | - | 0.2 |
| Young | 28.7 | 4.2 | 9.0 | 9.1 | 3.1 | 7.1 |
| Mature | 58.3 | 76.5 | 60.5 | 72.1 | 71.2 | 57.6 |
| Decadent | 11.3 | 19.3 | 30.5 | 18.7 | 25.7 | 35.1 |

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## 18. FUSARIUM SPECIES ASSOCIATED WITH SURFACE MINED AND UNMINED GRASSLAND SOILS

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Fusarium is one of the most common grassland soil fungi. Fusarium species were found to be the predominant colonizers of organic and mineral particles of a Canadian prairie soil (5), and accounted for 17% of all isolates from a Colorado grassland soil (2). Fusarium species are also an integral part of the complex of organisms that cause root rot of cereals and grasses, with Fusarium graminearum and F. culmorum being the two distinctly pathogenic species causing root rot of Gramineae. However, these two species comprised only 0.18% of 1715 isolations from root rots of Gramineae in the Northern Great Plains (3).

The goal of reclamation of mined sites is establishment of vegetation and pre-mining productivity and soil microorganisms play a large role in achieving this goal. However, very little research has been published on the effects of strip mining on soil microorganisms (4) and none on Fusarium populations associated with strip mined and unmined grassland soils. Our study was done to determine the Fusarium density and diversity associated with various-aged mine spoils and to compare these to unmined soils.

Six sampling sites were chosen in 1980 near Beulah, ND. Their history, soil type and dominant vegetation are as follows: 1) mined 1973; leveled and seeded 1974, no top soil, Bromus inermis and Agropyron spp. dominant, 2) mined 1975; leveled and seeded 1976, no top soil, Medicago sativa and Melilotus officinalis dominant, 3) mined 1977; leveled 1978, small amount of top soil disked in and then seeded, Medicago sativa and Melilotus officinalis dominant, 4) mined 1979; leveled and lift 1 (top 5') returned 1980, seeded to oats, rye and legumes but Kochia scoparia dominant, 5) unmined, undisturbed; fine-loamy mixed Typic to Entic Haploboroll (Williams-Zahl series), Andropogon scoparius and Bouteloua curtipendula dominant, 6) unmined, cropped; fine-loamy, mixed Pachic Haploboroll (Arnegard series), fallow in 1980. Five soil cores of the top 12cm were taken 1 meter apart along a line transect at each site on July 17, 1980. Samples were stored at 3°C until processing, within 3 weeks. Samples were processed using 3 methods and plated on 3 selective agar media. Fusaria were identified according to the system of Booth (1).

From 1694 isolates recovered, 15 species plus two varieties were identified. Overall, Fusarium oxysporum was most abundant (32.4%), followed by F. equiseti (32.3%), F. avenaceum (11.0%), F. solani (8.4%), and F. acuminatum (7.9%). The root rot organisms, F. culmorum and F. graminearum, were only 0.30% of the isolates. Chi-square analysis (testing for uniform distribution) showed that species density was non-uniform across sites (Table 1). The unmined, undisturbed site had the lowest density, the 1974 mined site the second lowest density, and the unmined, cropped site the highest density, while the other mined sites were intermediate. This data indicates that disturbance initially increases Fusarium numbers, while increased time from disturbance returns numbers toward unmined, undisturbed levels. Diversity index values (Table 1) indicate that unmined, undisturbed soils are less diverse than other soils tested, with mined sites showing the highest diversity. All sites were resampled in 1981 and analysis of these data will give additional information as to mine reclamation effects on Fusarium populations.

TABLE 1. Fusarium species number, relative density and diversity index per sample site

| Sites | Number of species plus varieties | Relative[a] density ** | Diversity index (1-Simpson's Index) |
|---|---|---|---|
| 1. Mined, seeded 1974 | 11 | 11.51 | 0.70 |
| 2. Mined, seeded 1976 | 9 | 19.48 | 0.75 |
| 3. Mined, seeded 1978 | 12 | 14.94 | 0.82 |
| 4. Mined, seeded 1980 | 14 | 13.64 | 0.76 |
| 5. Unmined, undisturbed | 11 | 7.50 | 0.57 |
| 6. Unmined, cropped | 14 | 32.94 | 0.67 |

[a] Relative density (%) = $\frac{\text{isolates at the given site}}{\text{total isolates}} \times 100$

** Significant at 1% level using Chi-square analysis

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The authors acknowledge Mohan Wali, Dan Jordan, Julie Stauber, and Louis Iverson of Project Reclamation, UND, Grand Forks, for aid in selection of sites and vegetation information.

19. EVALUATION OF THE SEED BANK ON TWO WESTERN NORTH DAKOTA PRAIRIES IN RELATION TO REVEGETATION AFTER MINING

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The vegetation emerging after currently mandated reclamation practices (i.e., contouring, replacing topsoil, fertilization and seeding) is determined not only by the planted seed mix, but also by the seed stock (seed bank) present in the topsoil and the immigration of seeds and disseminules from neighboring ecosystems. Because seeds accumulate in the soil over time, the diversity of these buried, viable seeds reflects the past, present, and potential future vegetation on a site. This study was conducted in order to assess the contribution of the seed bank in the pre-mined topsoil towards the floristic makeup of the post-mining communities, and to evaluate the seed bank with respect to grazing and depth of sampling.

In a mixed grass prairie adjacent to active mining sites near Beulah, North Dakota, grazed and ungrazed sites were sampled in April 1979 for the estimation of buried seed populations. From each site, 50 randomly placed 5-cm cores were taken to represent the following depths: 0-2.5 cm, 0-7.5 cm, 7.5-15.0 cm. In addition, a nearby fresh topsoil stockpile and a 1 year old stockpile were sampled. Samples were then placed in containers and allowed to germinate under growth chamber conditions. After emergence, seedlings were identified, removed and evaluated over a period of 16 months.

Calculated total germinable seeds $m^{-2}$ were significantly higher on the grazed site than on the ungrazed site, and both stockpiles had very low seed densities (Table 1). On the ungrazed site samples, 140 seedlings emerged representing 23 species with *Artemisia dracunculus* and *Melilotus officinalis* accounting for 44% of the total. In contrast, the grazed site samples had 319 seedlings emerge representing 26 species with *Conyza canadensis, Festuca octoflora* and *Hedeoma hispida* accounting for 46% of the total. The grazed site not only had the highest seed numbers, but also a higher proportion of weed seeds (44% as against 7% for the ungrazed site). The presence of larger numbers of weed seeds after grazing may be attributed to the reduction in range species with concommitant increase in space for weeds, which resulted in a greater seed output by weeds (ruderal-selected species) (1).

With respect to seed distribution by depth, seed quantity and diversity diminished with depth (Table 1). About 94% of the seeds at the grazed site were in the top 7.5 cm compared with 74% on the ungrazed site. The paucity of seeds in the bottom layer (7.5-15.0 cm) on the grazed site may be the result of increased compaction of soils from trampling and a consequent decrease in the number of fissures for seed transport.

Comparison of the species composition of the seed bank with that of the aboveground vegetation of newly reclaimed surface mined areas reveals that species dispersal in time (through dormancy) as well as dispersal in space (through immigration) are important in revegetation. Although some pioneering species were represented in the seed bank on pre-mined areas, no seeds of the dominant pioneers, *Kochia scoparia, Salsola collina,* and *Setaria viridis* (2), were found in the seed bank. This indicates that the seeds of these species must arrive after the respreading of topsoil; wind and water dispersal seem to be the most important, especially for the "tumbleweed" chenopods. Further evidence for this dispersal in space comes from the paucity of such seeds in the stockpiled topsoil (Table 1), indicating that the seeds are not present in the soil prior to respreading. However, respreading topsoil does apparently reintroduce some species such as *Hedeoma hispida, Artemisia ludoviciana,* A. *frigida,* A. *absinthium,* and *Plantago patagonica*, which otherwise do not colonize readily. These species evidently became established via a persistent seed bank (dispersal in time).

Table 1: Seed density and diversity by depth in the seed banks from ungrazed and grazed prairie, and two topsoil stockpiles in western North Dakota.

| SITE/DEPTH | 0-2.5 cm | 0-7.5 cm | 2.5-7.5 cm* | 7.5-15.0 cm | 0-15 cm (total) |
|---|---|---|---|---|---|
| | | seeds $m^{-2}$ [percentage in brackets] | | | |
| Ungrazed | 2235 [58] | 2860 | 625 [16] | 1005 [26] | 3865 |
| Grazed | 4560 [59] | 7240 | 2680 [35] | 500 [ 6 ] | 7740 |
| Fresh stockpile | | 255 | | | |
| 1 yr. stockpile | | 520 | | | |
| | | seed diversity index | | | |
| Ungrazed | 2.99 | 3.02 | | 1.79 | |
| Grazed | 3.63 | 3.06 | | 1.25 | |
| Fresh stockpile | | 2.32 | | | |
| 1 yr. stockpile | | 2.24 | | | |

*Calculated by difference of 0-2.5 and 0-7.5 cm level.

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20. A TECHNIQUE FOR ESTIMATING PLANT AVAILABLE MOISTURE CAPACITY FROM SOIL TEXTURE

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Crop yields in North Dakota are frequently limited by the capacity of soil to absorb, store and release water for plant growth. The study reported herein describes the initial efforts to relate plant available soil moisture to the texture of North Dakota soils.

The capacity of the soil to hold plant available water (PAW) is called plant available water capacity (PAWC). Not all water held in the soil is plant available. PAW is that amount of water held between field capacity (FC) and the permanent wilting percentage (PWP). FC is the water content in the soil after drainage to deeper levels becomes negligibly small. This value is often estimated by subjecting a disturbed sample to 1/3 bar pressure on a pressure plate device. Although a convenient procedure, it is subject to considerable error when results are compared to in situ field measurements. PWP is the percent of water in the soil when plants permanently wilt. The PWP is often estimated by subjecting a disturbed soil sample to a pressure of 15 bar in a pressure plate device. Several authors have shown a close relationship between this measure and that obtained when sunflowers extract water until they permanently wilt. Further details on FC and PWP are given by Cassell and Sweeney (2).

The PAWC of a soil is related to texture, structure, porosity, soluble salt content and organic matter. In this study, soil moisture data from two North Dakota reports (2,3) were combined to give a broad range of textures for soils of North Dakota. Samples with a high salt or sodium content were excluded. To minimize the influence of organic matter, results were used only from samples obtained from 38 cm or deeper. A total of 335 observations were used for the statistical analyses.

Table 1. Equations relating soil water to soil texture.

| No. | Data | n | Equations | $R^2$ |
|---|---|---|---|---|
| 1 | N. Dak. | 342 | $y=3.81 +0.42*clay +0.003*clay^2$ | .85 |
| 2 | Texas | 26 | $y=0.31 +0.62*clay$ | .95 |
| 3 | N. Dak. | 335 | $y=2.49 +0.65*clay +0.003*sand*silt -0.0057*sand*clay$ | .87 |
| 4 | Iowa | 1/ | $z=22.58 -0.147*sand -0.003*clay^2 +0.0005*sand*clay -0.000007*sand^3$ | .99 |

y = percent 15 bar volumetric soil water
z = plant available water capacity (percent)
1/ selected data points from a graphical representation (1)

Unger (4) and other authors have reported good correlations between 15 bar soil water and clay content. The North Dakota data show a similar trend (Eq. 1, Table 1). The relationship between clay content and 15 bar soil water for some Texas soils (4) is given in Eq. 2, Table 1. Soil moisture values estimated using Eqs. 1 and 2 differ by only 2% over a range of clay contents from 5 to 55% indicating that soil moisture-texture relationships apply over a large geographic region.

The results of the more detailed analyses given in Eq. 3, Table 1 (Fig. 1) can be used with soil texture data from soil survey information, particle size analyses or field textural estimation to estimate 15 bar volumetric soil water (PWP). (PAW) may then be calculated by subtracting the 15 bar water from total soil water (volumetric basis). FC may be determined by adding 15 bar soil water to PAWC from Eq. 4, Table 1 (Fig. 1), assuming regional applicability.

This paper presents equations for calculating FC, PWP, and PAWC from soil texture. If total soil water is expressed on a volumetric basis, PAW may also be determined. Studies are currently underway to correlate 1/3 bar soil water with soil texture and in situ field capacity. The effect of organic carbon, soluble salts and sodium on PAWC will also be investigated for North Dakota Soils.

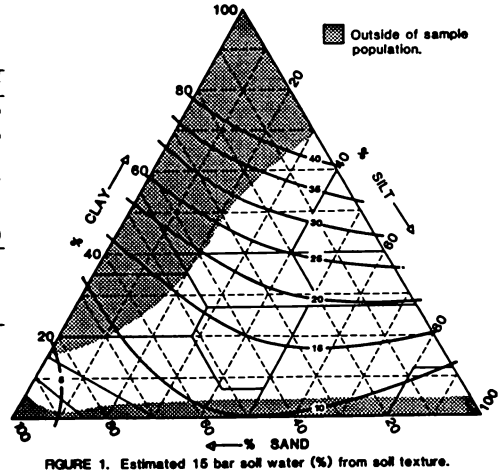


FIGURE 1. Estimated 15 bar soil water (%) from soil texture.

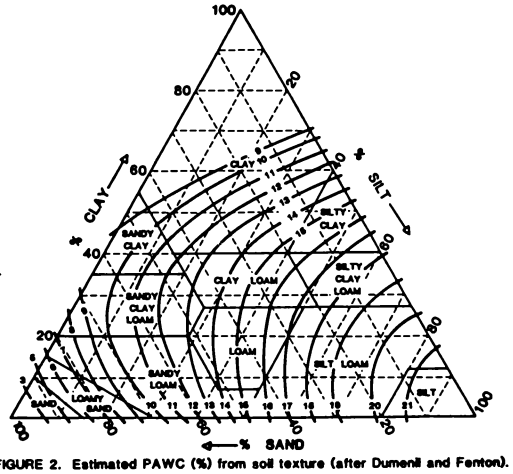


FIGURE 2. Estimated PAWC (%) from soil texture (after Dumenil and Fenton).

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21. A TECHNIQUE FOR SCREENING BARLEY LINES FOR RESISTANCE TO *PYRENOPHORA TERES* USING ROLLED SEED GERMINATION PAPER

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Conventional methods used to screen barley genotypes for resistance to *Pyrenophora teres* (Died.) Drechsl. (causal organism of net blotch) include dipping or spraying inoculum on detached leaves or on plants grown in pots (1,2,3). When screening large numbers of lines these methods are labor intensive and require large areas of greenhouse space. In order to improve the efficiency of screening procedures, a rolled germination paper technique was used. This paper describes the technique and presents results of studies conducted to determine optimum conditions for obtaining maximum differences in disease reaction on seedling leaves among 3 barley genotypes.

Two sheets of 26 x 54 cm seed germination paper (Anchor Paper Co., St. Paul, Minn.) were folded in half lengthwise and laid upon a similar width sheet of waxed paper. The germination paper was moistened, unfolded and seeds were placed 1.5 cm apart, embryo end towards the fold, with the tip of the seed even with the edge of the paper. The seeds were secured in place by replacing the unfolded paper over the seed and the germination paper and waxed paper were rolled together, secured with a rubber band and placed upright in water 2 cm deep in a plastic tray and placed in the greenhouse at 20 $\pm$ 2 C for seed germination.

When seedlings were in the early two leaf stage they were dip inoculated by immersing them several times in a 300 ml conidial suspension containing 10-20,000 conidia per ml and 2 drops of Tween-20 until the leaves were uniformly wetted. Each roll was dropped upright into a 4 cm ID x 32 cm long black plastic (PVC) pipe standing in water in the tray. A plastic bag was secured over the top of the pipe to maintain leaf wetness during the infection period. After the period the pipes were removed and the rolls of seedlings were kept in the greenhouse at 22 $\pm$ 2 C for 7-10 days. Disease severity was assessed by visual estimation of lesion development on a 1-9 scale with 1 representing no necrosis and 9 representing severe leaf necrosis. Resistant, intermediate and susceptible genotypes (ND5388, Dickson and Shabet) were used in the study.

A study of the effect of temperature during a 20 hr leaf wetness period following inoculations was carried out in growth chambers at 15, 20, 25 and 30 $\pm$ 1 C. A split plot design was used with three replications of 8 seedlings of each genotype at each temperature. Temperatures of 20-25 C were optimum for disease development. Differences between genotypes were highly significant at all temperatures (Table 2).

The effect of leaf wetness duration was carried out in a growth chamber at 20 $\pm$ 1 C. A split plot design was used with three replications of 8 seedlings of each genotype at each of 9 leaf wetness durations ranging from 0-48 hrs. Severity of disease increased as the duration of leaf wetness was extended. Except for the 0 hr duration treatment, differences between genotypes were significant at all durations tested. Maximum differences were obtained with 18 hr leaf wetness (Table 1).

Based on the results of these tests, routine inoculations of barley lines are being conducted at 20 $\pm$ 2 C with 15 to 18 hr leaf wetness periods using concentrations of 15-20,000 spores per ml. Infection is uniform and repeatable and the method is very economical of greenhouse bench space. An area of 1 $m^2$ will readily accommodate over 1000 lines.

TABLE 1. NET BLOTCH SYMPTOM RATINGS ON THREE BARLEY GENOTYPES EXPOSED TO DIFFERENT PERIODS OF LEAF WETNESS FOLLOWING INOCULATION WITH *PYRENOPHORA TERES*.

| Leaf Wetness | Lesion Severity | | |
|---|---|---|---|
| Hours | ND5388 | Dickson | Shabet |
| 0 | 1.0 | 1.0 | 1.0 |
| 6 | 1.0 | 2.0 | 4.0 |
| 12 | 1.0 | 4.3 | 7.7 |
| 18 | 1.7 | 5.0 | 8.0 |
| 24 | 3.0 | 4.7 | 8.0 |
| 30 | 3.7 | 6.0 | 8.0 |
| 36 | 4.3 | 6.0 | 8.7 |
| 42 | 4.7 | 6.3 | 9.0 |
| 48 | 6.0 | 6.3 | 9.0 |

LSD .05 = 0.96

TABLE 2. NET BLOTCH SYMPTOMS ON THREE BARLEY GENOTYPES EXPOSED TO DIFFERENT TEMPERATURES DURING A 20 HR WET PERIOD FOLLOWING INOCULATION.

| Temp. | Lesion Severity | | |
|---|---|---|---|
| C | ND5388 | Dickson | Shabet |
| 15 | 1.7 | 4.7 | 6.7 |
| 20 | 2.0 | 6.0 | 8.7 |
| 25 | 2.3 | 6.0 | 8.7 |
| 30 | 1.0 | 3.0 | 4.3 |

LSD .05 = 0.82

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44. Morphology and Anatomy of Leafy Spurge, A Major Weed in Pastures

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Leafy spurge(Euphorbia esula or E. podperae, depending on the preference of names (1) is a perennial weed in pastures and other non-cultivated areas. Its control is a serious problem because it is spreading extensively and the cost of control is expensive partly due to the high cost of the chemicals used, and partly because those same chemicals do not translocate to the subterranean buds that are a major source of new plants. Morphological and anatomical studies of leafy spurge now in progress will serve as a basis for physiological studies aimed at chemical and biological control. This report is a preliminary survey of morphological features of seeds, leaves, and other structures of plants at various stages of growth. A scanning electron microscope was used for detailed morphological observations. Freshly harvested leaves were coated with gold and palladium directly without further processing. The leaves became dehydrated and distorted somewhat, but the wax structures and many stomata remained in good condition. Wax platelets on leaves of greenhouse grown plants are about 0.5 to 1 μm (young leaves) and 1 to 3 μm (mature leaves) and appear to be similar on adaxial (upper) or abaxial (lower) leaf surfaces. The structures are also very similar between several biotypes grown in various parts of the United States and one from Austria. One biotype (selected for physiological studies) was examined in greater detail than the others.

Leaf replicas were made using red finger nail polish:acetone (1:1). The replicas were observed under a light microscope for stomatal patterns and to determine the numbers of stomata per unit area. The stomatal pattern of leaves from greenhouse-grown plants of this biotype varies according to the position of the leaf on the plant. Upper surfaces have stomata over the entire surface, but the numbers vary from about ten per $mm^2$ on the older leaves to about 200 per $mm^2$ on the youngest leaves. The lower surfaces are more consistent than the upper surfaces, with about 150 to 200 stomata per $mm^2$ for all leaves. However, the stomata are found only over the laminae on the lower surfaces and not over the midribs as in the upper surfaces. In general the stomata appear to follow the pattern of the minor veins, being positioned directly over the veins.

Anatomical studies have been limited, but several prominent features were observed by means of light and transmission electron microscopy. Developing buds were fixed with buffered 2% glutaraldehyde followed by 1% osmium tetroxide, dehydrated and embedded in Spurr resin. Thick sections were stained with methylene blue-azur II for light microscopy. Thin sections were stained with lead and uranium and then were observed in a transmission electron microscope. Some light microscopy was done at low magnifications using hand sections of mature organs stained with coomassie brilliant blue, safranin, and several other stains. Laticifers were observed within the phloem tissues of developing buds and of mature stems. Anatomical features in general appear to be those described by Myers et al. (2) except that the underground horizontal structures that contain the numerous buds do not appear to have a typical root anatomy (as claimed by Myers et al.) nor a typical stem anatomy. The vascular system appears to be intermediate between the two types.

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45.

## A POWDERY MILDEW OF LEAFY SPURGE

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The biology of leafy spurge, Euphorbia podperae Croiz., a perennial weed species of the northern tier of the United States and Canada, has become the object of intensive investigation because of its continuous expansion and increasing economic impact. To support these researches, several collections and nurseries of leafy spurge have been established. It has been reported that the field specimens in these collections, all of which have been identified as the same species, have marked morphological differences which persist through numerous vegetative reproductions. It has been suggested that these different type plants or plant forms constitute biotypes of the same species. This laboratory has been involved in the procurement of various morphological and biochemical evidences which support the hypothesis these plant forms represent biotypes of leafy spurge.

Under greenhouse conditions, some of the twenty biotypes in our collection in Fargo, ND, have developed symptoms of a fungal growth, a powdery mildew. Three biotypes show only slight infection while one biotype is so susceptible to the fungus that plant growth is severely impaired and some specimens die. The objectives of this study were: (1) to identify the mildew as completely as possible, (2) determine its life habit, (3) verify the differing degrees of susceptibility or resistance between leafy spurge biotypes and, (4) explore the possibility of the use of this parasite as a biological control agent for leafy spurge.

CLASSIFICATION: Several mildews have been reported in other species of Euphorbia in the United States. Because of the general appearance of the mycelial mass of this organism, it was obviously a mildew and was classified as a powdery mildew, family Erysiphaceae, on the basis of the following criteria: (1) white weft-like mycelial mass, (2) branched and septate hyphae, (3) attachment to the host and penetration limited to epidermal cells, (4) conidiophores upright at right angles from the mycelium producing one-celled conidia in chains and (5) the conidia hyaline and barrel shaped. Since the sexual phase of the life cycle (perithecia) of this mildew has not been observed, we are forced to use the form-genus Oidium. This is based on conidiophore characteristics of a short stipe of one or two cells with a chain of maturing conidia.

SYMPTOMOLOGY AND LIFE HABIT: Conidiospore germination, hyphal growth and characteristics, invasion of epidermal cells and the formation of haustoria in the epidermal cells have been observed by light and electron microscopy. Conidiophores develop about five days after germination of the mother spore cells and shortly release mature conidia by abstriction. Infection is readily recognized by the highly visible white mycelial mass which is initially more dense along the midrib and secondary leaf veins. Little morphological change in the spurge leaves is noticeable with mild infestations but severe infestation of the susceptible biotype results stunting of leaf growth, leaf edge curling and finally necrosis of the entire leaf when it is completely infected.

SUSCEPTIBILITY OF SPURGE BIOTYPES: Shortly after establishing the Fargo collection specimens of each biotype were grown and vegetatively propagated in a greenhouse. It was noticed that plants of one biotype origin were becoming severely infected by the mildew described above. Three other biotypes subsequently have shown signs of mild infection and the remaining biotypes no infection. All biotypes were grown on the same greenhouse bench. Attempts to innoculate young propagules of mildew free biotypes were unsuccessful although spore germination could be induced and observed on agar plates. Spore germination on agar plates containing leaf extracts of infected and uninfected plants gave no indication of whether infection is due to susceptibility of a few biotypes or whether lack of infection in the majority of biotypes is due to a resistance factor. The use of this mildew as an agent for biological control of leafy spurge is doubtful at this point .

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46. A SENSITIVE BIOASSAY FOR TOXIC METABOLITES OF HELMINTHOSPORIUM SATIVUM

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Common root rot, caused by Helminthosporium sativum P. K. & B., is an important disease of spring wheat and barley in North Dakota and Canada. While the disease has been studied extensively, little is known of the mechanism of pathogenesis. Production of toxic metabolites by fungi of the genus Helminthosporium has been the focus of several investigations (3). In some systems, disease symptoms can be reproduced by using culture filtrates containing toxic metabolites of the causal organism (2). Several bioassays for toxicity of culture filtrates have been developed using the amount of reduction in root growth in test plants (2,3).

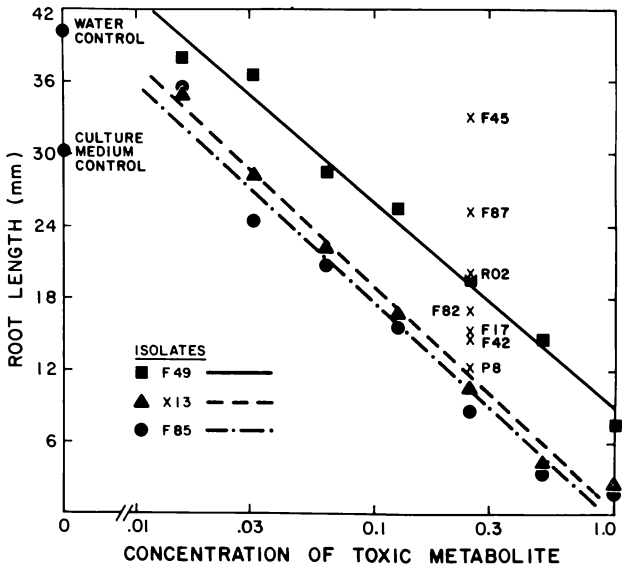
Toxic metabolites of H. sativum have been implicated in disease etiology but their role has not been clearly defined (3). The present study was initiated to further develop and refine a simple and reliable bioassay of the toxic metabolites found in culture filtrates of H. sativum.

Ten isolates of H. sativum were obtained from diseased plants collected in North Dakota. The fungi were maintained on Emerson's yeast-starch agar medium at 24°C with 14 hour daylength. Conidia, harvested from plates after 8 days, were used to inoculate liquid shake cultures in 250 ml erlenmeyer flasks. The inoculated flasks of glucose-asparagine-mineral salts medium were placed on a rotary shaker at 24°C in the dark for 8 days (1). The culture liquid was filter sterilized and stored at -15°C until used.

The effect of the culture filtrates from three of the isolates on the elongation of lettuce roots was studied using the following methods. Lettuce seeds (Lactuca sativa L. cv. 'Light Sensitive') were surface sterilized for 2 minutes in 30% hydrogen peroxide, rinsed in sterile distilled water, and germinated on 2% water agar in Petri dishes. The seeds were germinated for 24 hours at 24°C with 14 hour photoperiod. Serial water dilutions up to 1/64 of the culture filtrate and controls of uninoculated culture medium and sterile distilled water were made. Ten germinated lettuce seedlings with uniform root lengths between 3.0-4.0 mm were placed in a water agar plate and 2.0 ml of each treatment was added. There were 10 replicate plates per treatment. The plates were incubated at 24°C with a 14 hour photoperiod. The linear root length of each seedling was measured after 72 hours.

Root length showed a log linear response to the different concentrations of toxic metabolites (Figure 1). The undiluted culture filtrate produced extreme inhibition of root growth for all isolates while at intermediate dilutions there appeared to be more readily observable differences between isolates. The culture medium control was slightly inhibitory. The slopes of the dilution curves are parallel which suggests that the isolates tested differ in amount of toxic metabolite produced rather than in the nature of the substance.

FIGURE 1. ROOT GROWTH INHIBITION BY H. SATIVUM TOXIC CULTURE FILTRATE.




Because the pure culture filtrates produced almost total inhibition of root growth, the culture filtrates of the seven other isolates were used in the lettuce bioassay at 1/4 strength in order to separate activity between isolates. Inhibition of root growth by culture filtrates of the isolates varied considerably (Figure 1).

We conclude that the toxicity of the culture filtrates was highly variable. Variability in pathogenicity between isolates occurs but its relationship with toxin production is undefined. The lettuce seedling root growth bioassay as described above was found to be very simple and gave consistent response for toxic metabolites found in culture filtrates of Helminthosporium sativum. Using this bioassay, it should be possible to compare toxigenicity and pathogenicity of populations of H. sativum.

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47. MANNITOL INDUCED STRESS OF SOYBEAN CELL SUSPENSION CULTURES

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Water stress induces changes in plant cells. The activity of assimilatory enzymes is reduced, while that of hydrolytic enzymes is increased under water stress. Previous experiments by other workers are based on data obtained from whole plants or detached leaves. Water stress in these earlier experiments was either artificially induced by the use of PEG (MW 6,000-20,000) or mannitol or by simply dehydrating the tissue. In the following studies cell suspension cultures were used to characterize the effects of mannitol induced water stress on plant cell growth.

Cell suspension cultures of soybean (Glycine max (L.) Merr. 'Wilkin') were maintained in the dark on Gamborg's B5+1 growth medium with continuous gyratory shaking. Stress treatments consisted of 25ml of B5+1 and 5ml of cell suspension containing various concentrations of mannitol to produce different water potentials (Table 1). These procedures were carried out under sterile conditions. Actual water potentials of the test solutions at 25°C were determined with a thermocouple psychrometer (Wescor Chamber C-52, Wescor Microvoltmeter MJ55), which was previously calibrated with NaCl. Cells were harvested on preweighed miracloth at 1, 3, 5, and 7 days age by vacuum filtration and continuous washing. Samples were oven-dried at 70°C for 24 hrs. and weighed for dry matter accumulation (Table 2). Protein was estimated by the Lowry method.

Growth, as measured by dry matter accumulation, was reduced with increased water potentials. Under mild stress (-10b) dry matter accumulation was only slightly less than that of the control. This indicates that the cells may have the capacity to adapt to certain levels of water stress. In some experiments an enhancement of dry matter production was observed under low levels of stress during the early stages of the study. At higher water potentials (-15b & -20b) growth was noticably reduced. Differences between treatments became greater with time. It is possible that a stress threshold exists below which cultures may adapt (overcompensate) and above which physiological processes become impaired. The pattern of protein accumulation in the cells followed that of dry matter production with the exception of increased protein accumulation under mild stresses (-5b & -10b) at 1 day. This indicates the possibility of an adaptive mechanism which enhances protein synthesis or decreases protein degradation. Since protein increases during the early stages of stress, investigations of the short-term effects of stress are in progress. When protein accumulation and dry matter production are compared, both appear to be a good measure of the response of the culture to the degree of stress.

Mannitol has been an effective osmoticum in these experiments; however, it is difficult to determine the actual level of stress incurred by the cells. Traditionally, water potential has been an indication of the level of stress. However, differences exist between the calculated and tested water potential of the growth media (Table 1). These descrepancies are probably the result of interactions among the solutes in the growth media (Table 1). The possibilities that mannitol is metabolized by the cells or that it binds to the cell wall are under consideration.

Table 1

Mannitol Water Potentials

| Treatment | C | -5b | -10b | -15b | -20b |
|---|---|---|---|---|---|
| Molarity-Mannitol | 0 | 0.16 | 0.32 | 0.48 | 0.64 |
| Water Potential/S.D. | -5.3b±1.79 | -7.4b±1.72 | -10.8b±0.60 | -13.6b±1.76 | -15.4b±0.88 |

Table 2

Dry Matter (mg)

| Treatment | C | -10b | -15b | -20b |
|---|---|---|---|---|
| Initial | 43.7 | | | |
| Days | | | | |
| 1 | 73.2 | 68.0 | 58.7 | 51.3 |
| 3 | 112.9 | 98.9 | 76.2 | 54.9 |
| 5 | 197.0 | 178.8 | 124.0 | 86.7 |
| 7 | 272.3 | 270.1 | 159.0 | 90.2 |

# 48. DITHIOTHREITOL AS A MEANS FOR DIFFERENTIATION OF HERPESVIRUS: FIELD AND VACCINE STRAINS

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## Introduction

The ability of reduced dithiothreitol (DTT), a disulfide bond reducing agent, to inactivate viruses has been described (1,2). The ability of DTT to inactivate herpes virus, pseudorabies (PRV), was reported by Gainer (1). In 1972, Klingeborn and Dinter (2) found equine herpes virus (EHV) could be divided into three groups dependent upon their susceptibility to DTT. The strain used in vaccine production was found most resistant to inactivation by DTT. On the basis of this result they suggested that susceptibility to DTT could be used as a marker of attenuation. This study was undertaken to determine if any correlation could be made using DTT susceptibility on three herpes viruses; EHV, infectious bovine rhinotracheitis (IBR), and PRV.

## Materials and Methods

Virus. Herpes virus isolates from samples submitted to the North Dakota State University (NDSU) Diagnostic Laboratory were collected. Equine herpes isolates and vaccine histories were furnished by Dr. J.T. Bryans from specimens submitted to the University of Kentucky. Additional equine herpes virus (EHV) and pseudorabies (PRV) field strain virus were furnished by Dr. C.L. Kelling at the University of Nebraska. Attenuated live vaccine were purchased and viruses were grown by (2-5) serial passage on tissue culture.

Dithiothreitol. Dithiothreitol (Cleland's Reagent, DTT) was purchased from Sigma Chemical Company, St. Louis, Missouri.

Cell Cultures. Two cell lines were used in this study; BT cells, a line of bovine turbinate cells which are susoeptible to bovine rhinotracheitis and pseudorabies, were used at a passage level of 11 to 40. EHV was propagated in rabbit cells. Primary rabbit kidney cells through passage 6 were maintained, as were the BT cells, in Eagles minimal essential medium (MEM), 0.5% lactalbuminium hydrolysate and 10% calf serum. One percent herpes buffer was added to growth and maintenance media used to propagate RK cells.

DTT Inactivation Studies. Herpes isolates were propagated on the appropriate cell line and identified by serum neutralization and fluorescent antibody techniques. Using 100 $TCID_{50}$ of virus, DTT inactivation studies were determined according to a modification of the method of Klingeborn and Dinter (2).

A fresh solution of 0.01 M DTT, pH 7.8, in MEM was prepared on the day of the experiment. Test virus was diluted to a concentration of 100-300 $TCID_{50}$ in the DTT solution (test) and in MEM (control). Test and control samples were incubated at 32 and 37°C. Aliquots were withdrawn at 15, 30, 45 and 60 minute intervals and placed in an ice bath to stop inactivation.

Standard flat bottomed microtiter plates were used to measure infectivity. Test and control samples were transferred in 25 ul aliquots to microtiter plates such that three wells contained 25 ul each of the sample incubated for 15, 30, 45 and 60 minutes or a total of 24 wells per sample. A volume of 0.01 ml, containing 15,000 cells of BT or RK cells, as appropriate, were added. Plates were sealed and incubated at 37°C for 48 hours, when they were examined microscopically for viral inactivation. CPE was graded as 0, +, ++, +++ and ++++.

## Discussion

A total of 38 isolates have been tested; 90% of these were inactivated by DTT. Vaccine isolates accounted for all those which remained virulent (10%). DTT susceptibility is a property of the majority of virus isolates; the process of attenuation for use in vaccines appears to alter the virus by increasing its resistance to the chelating agent DTT.

1. Gainer, J.H., Jang, J., Hill, P., Capps, W.I. (1971) Virol. 45, 91-100.

2. Klingeborn, B., Dinter, Z. (1972) Appl. Microbiol. 1121-1124.

3. Klingeborn, B. (1973) Appl. Microbiol. 566-569.

## 49. EVALUATION OF SEROLOGICAL TESTING PROCEDURES FOR DETECTION OF PSEUDORABIES VIRUS

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### Introduction

Pseudorabies (Herpesvirus suis) is a naturally occurring disease in swine. It causes an acute, infectious disease characterized by signs of central nervous system disorders. Pseudorabies appears to be of serious importance in young pigs, though a minor clinical ailment in older swine. Older animals are highly susceptible to the virus, but undergo an inapparent infection and are usually not observed to be ill. Rapid serologic testing procedures are needed to detect infected animals that appear healthy, but could be capable of transmitting the disease to noninfected herds. To improve diagnosis of pseudorabies in swine, a study was initiated comparing the approved test method (Serum Neutralization) with an Agar Gel Immunodiffusion Test (AGID). The main emphasis was placed on time involved and accuracy achieved.

In 1962 pseudorabies occurred in virulent forms on several farms in Indiana. Since that time it has spread across the nation from coast to coast (1). It appears that: 1) bringing swine together from many sources for redistribution, 2) operation of a continuous open-end operation, and 3) feeding garbage to swine, operate to the advantage of virus in keeping the disease active. In the past, commercial hog cholera virus vaccines were found to be contaminated with pseudorabies virus. The disease in swine is of veterinary importance because the virus also affects cattle, horses, goats, sheep, dogs, cats, as well as other domestic and wild animals.

### Materials and Methods

Cell Cultures. Monolayer cultures of Bovine Turbinate (BT) and Vero Monkey[a] cells were maintained at 37°C in MEM (Minimal Essential Medium) with 1% lactalbumin hydrolysate and 10% heat inactivated fetal bovine serum.

Virus. The Shope strain of pseudorabies virus (from NADL) was used in serum neutralization and in antigen preparation.

Antigen. Monolayers of BT and Vero Monkey cells were grown in Falcons infected with pseudorabies virus. The cultures were incubated for 1 hour at 37°C to allow for virus adsorption. At that time MEM (without calf serum) was added and the Falcons were allowed to incubate until extensive CPE was evident. Antigen was harvested and concentrated using polyethylene glycol and amicon filteration.

Test Samples. Serum samples were obtained from a known positive herd[a] and samples submitted to the North Dakota State University (NDSU) Diagnostic Lab.

### Results

Serum neutralization (SN), the test of choice, was set up first to determine titers of serum samples. This test was compared with an AGID test. The data (Table 1) indicates that AGID should be considered as a rapid screening technique for the diagnosis of pseudorabies in swine. A 97.1% correlation of SN and AGID results was achieved. The SN test proved to require: 1) more specialized equipment, 2) the maintenance of tissue culture cells, 3) better aseptic techniques, 4) more set up time, 5) a longer incubation period, and 6) more technical training to read results. Condition of the serum samples was also a factor. Samples that were toxic, contaminated, or highly hemolyzed were more easily read by the AGID method. The only drawback to the AGID test was antigen preparation. Antigen must be concentrated 100 times, therefore large amounts of cells and time were required for production. The results indicate that the AGID test could become an important diagnostic tool.

Table 1. Correlation of SN and AGID Results

| | + | - | Total |
|---|---|---|---|
| SN | 127 | 172 | 299 |
| AGID | 122 | 186 | 308 |
| | | | 607 |

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[a]Furnished by Dr. C.L. Kelling at the University of Nebraska.

50. PROTEIN AND ZINC INTERRELATIONSHIPS IN THE DIET OF GROWING RATS

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The interdependence of protein and Zn homeostasis has been well documented (1-3). We decided to examine the effect of covarying these constituents at marginal levels in the diet of growing rats. Nine groups of 30-day-old rats were fed nine different biotin-enriched diets, which contained 8, 15 or 20% egg white solid (equivalent to 6, 11.3 or 15% protein), and at each protein level three concentrations of Zn (6, 12 or 18 ppm) were added. The rats were given distilled deionized drinking water. The body weight and food intake for each rat was recorded daily. After 30 days of this regimen the rats were killed by decapitation. Trunk blood was collected in heparinized beakers on ice and hematocrits were measured. Plasma was separated from the blood cells by centrifugation and stored at 4° for 24 hr. Livers were perfused with physiological saline, lyophilized and digested with concentrated $HNO_3$ and $H_2O_2$ (30%) as described (4). Femurs were removed and cleaned of excess tissue and then length and width recorded. They were ashed in a muffle furnace as described (4). Plasma was analyzed for Zn and the ashed femur samples were analyzed for Zn, Cu, Fe and Ca by flame atomic absorption spectroscopy. Zn, Cu, Fe, Mg and Ca were measured in the digested liver samples by plasma emission spectrometry. Data were evaluated by standard analysis of variance (5).

A number of dietary protein and Zn interactions were found in this study. Rats fed the 6% protein diet gained significantly ($P < 0.0001$) less weight than rats fed the 11.3% or 15% protein regardless of Zn content. Animals in the 11.3 or 15% protein dietary groups gained significantly ($P < 0.0001$) less weight when fed 6 ppm rather than 12 or 18 ppm Zn in the diet. Dietary levels of 11.3% protein and 12 ppm Zn appeared adequate to achieve optimum growth in these rats. In these studies 81.6%, 4.7% and 4.6% of the total variation in rate of weight gain could be explained by protein, Zn and protein x Zn respectively.

Hematocrits increased significantly ($P < 0.0001$) with increasing dietary protein content ($6 < 11.3 < 15\%$), but were unaffected by the Zn level in the diet.

At all levels of dietary protein, rats fed 6 ppm Zn had significantly ($P < 0.0001$) lower plasma Zn levels than animals fed 12 or 18 ppm Zn. Also at all levels of dietary protein, rats fed 12 or 18 ppm Zn had plasma Zn concentrations which were similar.

Rats fed 6% protein had significantly ($P < 0.0001$) lower liver Zn concentrations than rats fed 11.3 or 15% protein. Likewise, rats fed 6% protein had significantly ($P = 0.0263$) lower liver Cu levels than the rats fed 11.3 or 15% protein. Liver Fe concentrations were influenced by both a dietary protein effect ($P = 0.0448$) and a dietary protein x Zn interaction ($P = 0.0076$). Liver Ca concentrations were unaffected by either dietary protein or Zn in this study. On the other hand, liver Mg levels increased with increasing dietary protein concentrations ($P = 0.0035$). Of the liver trace metals examined only Fe appeared to be influenced by a protein/Zn interaction. Increasing dietary protein led to increased concentrations of liver Zn, Cu and Mg.

Dietary protein content was also an important factor in the growth of long bones. The weight, length and width of femurs were significantly ($P = 0.0001$) decreased by low dietary protein. The femur width was also significantly ($P = 0.0193$) decreased by low dietary Zn levels. Dietary protein and Zn appeared to be interrelated in their affect on femur Zn levels. Thus rats fed 6% protein and 6 ppm Zn had significantly ($P < 0.0001$) higher femur Zn than rats fed 11.3 or 15% protein and 6 ppm Zn. However, at every level of dietary protein, femur Zn content increased significantly ($P < 0.0001$) with increasing dietary Zn ($6 > 12 > 18$ ppm). Femur Cu, Fe and Ca were significantly ($P < 0.0004$) higher in rats fed 6% than 11.3 or 15% protein, but were not influenced by dietary Zn.

The data demonstrates diverse interactions between dietary Zn and protein on body growth, bone growth, liver and femur trace metal content in the growing rat.

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4. Wallwork, J.C., Fosmire, G.J. and Sandstead, H.H. (1981) Br. J. Nutr. 45, 127-136.
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51.

# DIETARY TIN AFFECTS RIBOFLAVIN NUTRITURE OF THE RAT

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In 1970, Schwarz et al. (1) reported that a dietary supplement of 1-2 μg of tin/g slightly improved the growth of suboptimally growing rats fed a low-tin amino acid diet. Apparently, the suboptimal growth of the rats was caused mainly by riboflavin deficiency (2). This would be of particular concern with tin because the oxidation-reduction potential of $Sn^{2+} \rightleftarrows Sn^{4+}$ is 0.13 V, which is near the oxidation-reduction potential of flavin enzymes. Thus, we decided to ascertain whether tin stimulated growth in riboflavin-deficient rats because it substituted to a slight degree for riboflavin in some biological function.

Male weanling Fisher-344 rats (Charles River Labs, Wilmington, MA) were assigned to groups of six in a fully-crossed, two-way, three by three design. Tin was supplemented to the amino acid based diet (1,3) at levels of 0, 1 and 3 μg/g as stannic sulfate. Riboflavin was supplemented to the diet at levels of 0.5, 1.5 and 15 mg/g. Environmental conditions were those described for other studies in our laboratory (4). The rats were fed their respective diets for six weeks, then decapitated subsequent to ether anesthesia and cardiac exsanguination with a heparin-coated syringe. Several tissues were removed and weighed. Plasma urea was determined by using a described procedure (5). Some of the results are summarized below.

| Treatment | | Weight, | $\frac{\text{Kidney wt}}{\text{Body wt}} \times 100$ | $\frac{\text{Heart wt}}{\text{Body wt}} \times 100$ | Plasma Urea |
|---|---|---|---|---|---|
| Tin | Riboflavin | 6 weeks | | | |
| μg/g | μg/g | g | | | mg/100 ml |
| 0 | 0.5 | 58 | 0.555 | 0.432 | 11.97 |
| 1 | 0.5 | 44 | 0.656 | 0.541 | 16.65 |
| 3 | 0.5 | 46 | 0.605 | 0.488 | 16.49 |
| 0 | 1.5 | 146 | 0.384 | 0.340 | 9.13 |
| 1 | 1.5 | 82 | 0.469 | 0.393 | 12.76 |
| 3 | 1.5 | 70 | 0.523 | 0.421 | 13.74 |
| 0 | 15.0 | 166 | 0.403 | 0.343 | 9.17 |
| 1 | 15.0 | 165 | 0.391 | 0.344 | 10.26 |
| 3 | 15.0 | 171 | 0.412 | 0.339 | 10.34 |
| | | Analysis of Variance - P Values | | | |
| Tin effect | | 0.0001 | 0.0001 | 0.0001 | 0.004 |
| Riboflavin effect | | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| Tin x riboflavin | | 0.0001 | 0.0008 | 0.0002 | NS |

The findings were not those expected. Tin supplementation of the diet exacerbated, not alleviated, the signs of riboflavin deficiency in rats. This finding was most marked in the groups fed the borderline deficient level of riboflavin (1.5 μg/g of diet). Gross signs of riboflavin-deficiency such as ragged greasy fur and alopecia were more severe in the tin-supplemented rats. Also in riboflavin-deficient rats, growth was more severely depressed, and heart wt/body wt ratio, kidney wt/body wt ratio and plasma urea were more markedly elevated in tin-supplemented than tin-deprived rats. We were unable to discern from the parameters determined whether tin was destroying riboflavin in the diet or acting as a metabolic antagonist of riboflavin. In the riboflavin-adequate rats, tin-deprived rats did not show depressed growth. Thus, we did not confirm the growth findings of Schwarz et al. (1). In contrast, our findings indicate that relatively low levels of dietary tin may be detrimental, not beneficial to rats, especially if dietary riboflavin is not adequate.

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52.

# ORIGINS OF PARTICULATES PRODUCED IN A COAL-FIRED COMBUSTOR

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Particulate control research at the Grand Forks Energy Technology Center (GFETC) involves the characterization of the inorganics in the coal and the particulates formed during combustion. The particles originate from the inorganic species associated with the coal. These species are combined with the coal in several forms: cations bound to the humic acid groups, chelated species, mineral species which have been formed in the coal during coalification, and those minerals which were accumulated during deposition. During conventional pulverized coal combustion, these inorganics melt, forming spherical particles which escape from the combustion zone with the stack gases. In the stack, reactions occur between the non-volatile species and volatiles in the region of lower temperature where the volatile phases can condense.

The GFETC Particulate Test Combustor was used to burn a subbituminous coal from the Energy Mine in Routt County, Colorado. Multi-analytical techniques were used to characterize coal and fly ash. The methods used to ascertain the occurrence and distribution of inorganics in the coal were chemical fractionation (1) and X-ray diffraction. Chemical fractionation included selective removal of ion-exchangeable cations with 1 molar ammonium acetate, and removal of carbonates and acid soluble oxides with 1 molar hydrochloric acid. The insoluble species which remain include quartz, clay minerals, feldspars, and pyrite minerals. Another method used to concentrate the inorganics in the coal for X-ray diffraction analysis is low-temperature oxygen plasma ashing. The fly ash was characterized using scanning electron microscopy and microprobe analysis and X-ray diffraction analysis.

The results of the chemical fractionation work revealed that in terms of the major inorganics in the coal, 85.5% Mg, 7.8% K, and 48.5% Ca were ion-exchanged with ammonium acetate. The hydrochloric acid removed 14.5% Mg, 25% Al, 29.7% K, and 40% Ca. The major element which remained almost unchanged was Si. X-ray diffraction of the low-temperature ash determined quartz as the major phase, and kaolinite and calcite as minor phases. The identification of the inorganic species in the coal suggests a relationship to those phases present in the fly ash.

The fly ash was collected by isokinetic extraction from the stack on a dust loading filter. Part of this sample was mounted for SEM/microprobe characterization, in which approximately 250 particles were sized and analyzed for 12 major elements. Statistical analysis indicate some direct relationships between the mineral phases identified in the coal and those phases which are present in the fly ash. For example, the relationship between $Al_2O_3$ and $SiO_2$ suggests the presence of clay minerals, feldspars, and quartz in the coal. The major minerals identified in the fly ash by X-ray diffraction are quartz and mullite ($Al_6Si_2O_{13}$). Mullite is the product of high temperature decomposition of kaolinite. In addition, other correlations drawn from the SEM data provide insight into the origin and fate of the alkali species after combustion as shown in Figure 1. Note that both $K_2O$ and $Al_2O_3$ increase as a function of $SiO_2$ and from these observations it can be deduced that most of the potassium is tied up with the clay minerals and feldspars. This is supported by chemical fractionation. On the other hand, the calcium and magnesium have a strong negative correlation with aluminum and silica (shown in Figure 1), apparently because they are either organically associated or associated as carbonates in the coal.

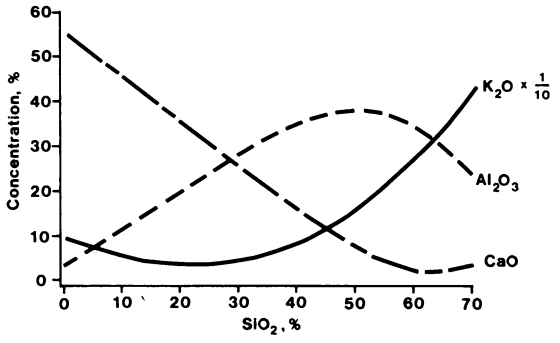


Figure 1. Oxide Concentrations Versus $SiO_2$

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53. ACTIVATED SLUDGE BATCH KINETICS STUDY OF COAL GASIFICATION WASTEWATERS

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The ultimate goal of coal gasification processes are to produce a cleaner burning, higher BTU energy source, and reduce dependence on diminishing sources of other economically competitive fuels. Major environmental concerns center around disposal of toxic wastewaters which are produced. Each individual coal gasification wastewater treatment facility will have to be designed to meet current effluent quality requirements, based on its intended disposal method. The wastewater samples used in this study were obtained from the U.S. Department of Energy, Grand Forks Energy Technology Center, Grand Forks, N.D., slagging fixed bed gasifier. The objectives of this investigation were to assess coal gasification wastewater treatability, and determine the process kinetic coefficients of activated sludge batch systems.

Preliminary characterization of the raw gas liquors showed that pretreatment would be required to prevent inhibition in subsequent activated sludge treatment. Lime precipitation, ammonia-stripping, and dilution were employed to reduce excessive levels of alkalinity, ammonia, and organics prior to batch kinetic studies. Dechlorinated tap water was used for all dilutions. Batch reactors 1 through 5 contained 50, 20, 10, 5, and 2% strength pretreated gasifier wastewater, respectively, while reactor 6 served as a control without wastewater additions. Each reactor had a total volume of 2 liters which also contained acclimated microorganisms and nitrogen and phosphorous nutrients. The mixed contents were aerated and substrate (COD) removal rates were determined periodically by determining various pollutant levels in the reactor contents (1).

Typical performance data of the activated sludge batch reactors are shown in Tables 1 and 2. Removal rates for COD and phenol increased with longer aeration time. The influent mixed liquor COD concentration for 50% strength gas liquor was 1262 mg/l. Effluent COD levels for 50% strength wastewater after aeration times of 12 and 24 hours were 724 and 356 mg/l. The minimum COD obtained was 34 mg/l for reactor 5 at 24 hour aeration. For all strengths of wastewater examined, influent phenol levels were reduced to 5 mg/l or less after 24 hours aeration.

The substrate removal rate equation (2) was used to predict organic removal rates in an activated sludge system. It is expressed as: (Influent Substrate) (Infl. Substrate - Effluent Substrate) / (Mixed Liquor Volatile Suspended Solids) (aeration time) = (Organic removal rate coefficient) (Effl. Substrate - non-biodegradable organics). The organic removal rate coefficient was estimated to be 1.25 ($day^{-1}$), while the non-biodegradable material was 40 (mg/l) for coal gasification wastewater. Oxygen utilization was correlated to the COD removal rate in the following equation: Oxygen uptake rate = (oxygen utilization coefficient for synthesis) (COD removal rate) + (oxygen utilization coefficient for endogenous activities). The oxygen utilization coefficient for synthesis was predicted to be 0.76 (mg $O_2$/mg COD removed), and the oxygen utilization coefficient for endogenous activities was 0.11 (mg $O_2$/mg MLVSS-hr) for coal gasification wastewater.

Table 1

COD Data Summary

| Aeration Time (hr) | Reactor 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 0 | 1262 | 477 | 188 | 116 | 87 | 85 |
| 12 | 724 | 167 | 82 | 63 | 58 | 69 |
| 24 | 356 | 141 | 76 | 61 | 34 | 16 |

Table 2

Phenol Data Summary

| Aeration Time (hr) | Reactor 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 0 | 297 | 100 | 15 | 5 | 4 | 0 |
| 12 | 121 | 3 | 1 | 1 | 1 | 0 |
| 24 | 5 | 1 | 1 | 1 | 1 | 0 |

All values in mg/l

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54. AUGER SPECTROSCOPIC EXAMINATION OF A NOVEL THREE-LAYER PARTICLE PRODUCED DURING LAMINAR FLAME COMBUSTION OF A SUBBITUMINOUS COAL

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The application of highly sophisticated laboratory instrumentation to the analysis and characterization of fine particulate matter is a continuing research effort in support of the GFETC program in Particulate Control for Low-Rank Coals. This preliminary report describes the discovery of a new, three-layered particle produced during the laminar flame combustion of Decker subbituminous coal. The discovery was made possible by using a newly-installed, state-of-the-art scanning Auger spectrometer. The combustion experiments and sampling were performed by Midwest Research Institute (Kansas City, MO) under contract to GFETC. The particles examined in this study were 10-13 microns in diameter.

The results reported here were obtained using the high precision Physical Electronics* model 595 scanning Auger spectrometer. The 595 multiprobe permits a comprehensive surface analysis of a wide range of materials. This is accomplished using scanning Auger microscopy, a refinement of Auger electron spectroscopy. This technique uses a finely focused electron beam to excite a specimen and an electron spectrometer to analyze the Auger electrons emitted from the surface. The electron gun used with the 595 provides an electron beam diameter down to 50 nm. This gun is positioned coaxilly inside the cylindrical mirror analyzer to minimize shadowing effects and help insure uniform transmission over the scanned area. This system offers the highest elemental sensitivity and signal-to-noise performance.

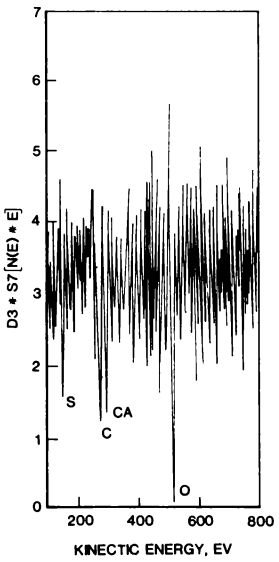


Figure 1. $CaSO_4$ Outer Layer

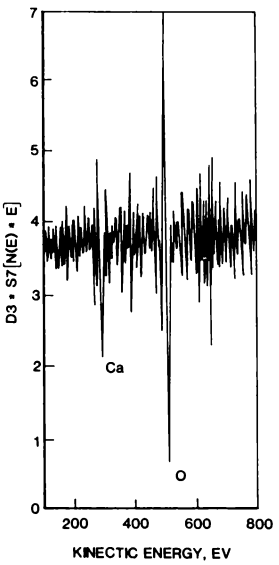


Figure 2. CaO Inner Layer

The outer layer is an extremely thin layer of calcium sulfate. The Auger spectrum is given in Figure 1. This layer was observed prior to sputtering the particle. However, as the electron beam was directed onto the surface for analysis, some of this first layer began to be lost. This observation suggests that the total thickness of the calcium sulfate layer may be on the order of 10-20 nm. If the surface material is the anhydrite form of $CaSO_4$, this result indicates that the outer layer is no more than 15-30 unit cells in thickness.

The second layer of the particle is composed of calcium oxide. The Auger spectrum shown as Figure 2 was recorded after two sputterings, each of which removed approximately 400 nm of the surface.

The innermost material is a nucleus or core of aluminosilicates. This nucleus has not as yet been observed with the Auger spectrometer, but its existence has been confirmed by experiments with a scanning electron microscope equipped with a microprobe analyzer.

Thus, the particle consists of a very thin outer layer of calcium sulfate surrounding a thick layer of calcium oxide, which in turn surrounds a core of aluminosilicates. Although the data presented here was obtained from analysis of a single particle, this new three-layered structure has now been observed in numerous other samples. The calcium sulfate-calcium oxide-aluminosiliate three-layer structure has not been reported prior to this study.

Studies such as this one add to the data base of particle structure, morphology, and composition and will eventually contribute to a fundamental understanding of the mechanisms of particulate formation in low-rank coal combustion. In addition, these studies also contribute to an understanding of particulate behavior--for example, the possible reduction in $SO_2$ absorption ability by the blinding of the surface by formation of a sulfate or sulfite.

* Reference to specific brand names or models is done to facilitate understanding and does not constitute or imply endorsement by the U.S. Department of Energy.

55. COMPARISON OF LIQUEFACTION PRODUCTS FROM A LIGNITE AND A SUBBITUMINOUS COAL

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A Texas lignite from the Big Brown mine (BB1) and a Wyoming subbituminous coal from the Wyodak mine (WY01) were liquefied in the Grand Forks Energy Technology Center's 4.5 kg slurry/hr continuous processing unit operated in the bottoms recycle mode (1). The liquefaction was carried out under $H_2$ at a pressure of 17.9 MPa and an average temperature of 460°C. The start-up solvent was a surrogate solvent consisting of a mixture of 60% Crowley[a] anthracene oil and 40% SRCII middle distillate from the Ft. Lewis pilot plant.

ASTM D-1160 distillates of the recycle slurry were fractionated by silica gel column chromatography. A 1 g sample was eluted with solvents of increasing polarity: pentane, 5 x 50ml, 5% benzene/pentane, 2 x 50ml, 15% benzene/pentane, 2 x 50ml, 20% benzene/20% ether/60% methanol, 2 x 50ml and methanol, 150ml. Twelve fractions were collected; the first fraction contained the dead volume of the column and fractions 2-12 contained the sample. Fractions 2-10, containing mostly hydrocarbons, were analyzed by capillary gas chromatography using a 50m methyl silicone-fused silica column, temperature programmed from 100 to 280°C at 4°C/min. All of the fractions were examined using 200 MHz $^1H$ NMR spectrometry. Identification of the individual components of the mixture was carried out by comparing chemical shift values, peak intensity and pattern matching with 450 standards whose spectra had been obtained using the same NMR procedure and by comparing the GC retention times. Several of the fractions were also analyzed by capillary gas chromatography/mass spectrometry.

The slurry ASTM D1160 distillates were also extracted with 2N NaOH to determine the percent phenols. The extracted phenols were 17.1%, 21.5%, and 12.0% for the BB1, WY01, and surrogate solvent, respectively. A comparison of the two coal recycle slurry distillates with the start-up surrogate solvent is given in Table 1. Fraction 2 contains alkanes; fraction 3 contains alkanes, alkyl benzenes, tetralins, and indans; fractions 4 and 5 contain naphthalenes, acenaphthenes, biphenyls, and heavier hydrogen donors; fractions 6-10 contain aromatic hydrocarbons; and fractions 11 and 12 contain polar compounds, mainly phenols and bases.

Table 1

Composition of Coal-Derived Recycle Slurry Distillates and the Surrogate Solvent (Wt %)

| Fraction | 64 PB-25 BB1 | 67PB-25 WYO 1 | Surrogate Solvent |
|---|---|---|---|
| 2 | 8.6 | 6.3 | 4.1 |
| 3 | 8.6 | 2.9 | 2.1 |
| 4 | 17.0 | 16.6 | 14.2 |
| 5 | 6.1 | 7.5 | 10.5 |
| 6 | 5.4 | 6.4 | 15.3 |
| 7 | 4.5 | 5.9 | 11.2 |
| 8 | 4.4 | 5.2 | 9.6 |
| 9 | 3.0 | 2.9 | 3.6 |
| 10 | 2.3 | 2.5 | 2.9 |
| 11 | 0.9 | 0.6 | 0.5 |
| 12 | 36.0 | 39.9 | 24.4 |

Comparison of the capillary gas chromatograms and of the $^1H$ NMR spectra of the recycle-slurry distillates with the start-up solvent showed increases in the methyl and other alkyl substituents resulting in larger numbers of components in every fraction.

Hydrocarbons decreasing in concentration in the slurry distillate during recycle include acenaphthene, fluorene, phenanthrene, benz(a) anthracene, chrysene, and most notably fluoranthene, which decreased from approximately 25% of fraction 9 in the start-up solvent to 1-4% of the fraction 9 recycle distillates.

The following conclusions may be drawn. The recycle solvent composition after 12-13 passes through the reactor is much more complex than the start-up solvent. Some of these changes in the solvent composition appear to be coal-independent and some appear to be coal-dependent. The coal-independent changes involved changing the balance of the solvent from a mixture of mostly unsubstituted aromatic hydrocarbons to a complex mixture of alkylated aromatic hydrocarbons. This change was accompanied by an increase in the percentage of alkanes and of phenols in the solvent. The two recycle oils examined resemble each other more than they resemble the start-up solvent; however, there are some coal-dependent changes. Some coal-dependent changes involve the amount of the alkane fraction and the phenolic fraction. The lignite produced more alkanes and less phenols than the subbituminous coal when processed in this way. In addition, the lignite, BB1, gave over twice as many tetralins and indans as WY01, while the WY01 coal-derived liquid contained larger quantities of the identifiable polynuclear aromatic hydrocarbons.

1. Willson, W.G., Knudson, C.L., Baker, G.G., Farnum, S., Severson, D.E., Owens, T.C., and Souby, M. Comparison of Liquefaction Yields. 1981 Lignite Symposium, June 15-17, San Antonio, Texas.

[a]Reference to specific brand names and models is done to facilitate understanding and neither constitutes nor implies endorsement by the Department of Energy.

56.

# CAPILLARY GAS CHROMATOGRAPHIC COMPARISON OF PHENOLS IN COAL LIQUEFACTION PRODUCTS

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Liquefaction of four coals of varying rank was carried out in the Grand Forks Energy Technology Center's continuous processing unit (1) under a nominal 17.9 MPa pressure and at a temperature of 460°C. The reducing gas was a 50/50 mixture of CO and $H_2$ (syngas). The unit was operated in the bottoms recycle mode. The four coals processed included two lignites, North Dakota Beulah-3, B3, (69.1% maf C), Texas Big Brown, BB1, (72.4% maf C); a subbituminous coal, Wyodak, WY01, (73.7% maf C) and a bituminous coal, Powhatan, POW1, (79.0% maf C).

The distillable oil products from the liquefaction, consisting of a light oil and a recycle slurry distillate oil were analyzed for phenolic components.

The phenols of both oils were separated by extraction with aqueous sodium hydroxide, the aqueous solution was next neutralized and re-extracted with pentane and then with methylene chloride. Two fractions were obtained from each oil after evaporation of the solvent under vacuum. The bulk of the most water soluble phenols such as o-, m-, p-cresol and phenol were extracted by methylene chloride. Capillary gas chromatography of each fraction was carried out on a Hewlett-Packard** 5880A chromatograph equipped with an autosampler. The autosampler accessory was used to provide the reproducibility required. The column was a J and W 60m DB5 wide bore column, the carrier gas was $H_2$, and flame ionization detection was used. Temperature programing in steps from 30 to 350°C sufficiently expanded the chromatogram providing excellent resolution of all the phenolic components (Figure 1). Identification of the components was confirmed by comparison with the retention indices of standards. The major components found in the recycle oils were phenol, o-cresol, m- and p-cresols, 2,4-dimethylphenol, 2,5-dimethylphenol, 4-ethylphenol, 3,5-dimethylphenol/3-ethylphenol, 3-ethyl-5-methylphenol and 4- and 5-indanols. A larger number of phenols were present in small amounts. A total of 34 phenols was identified.

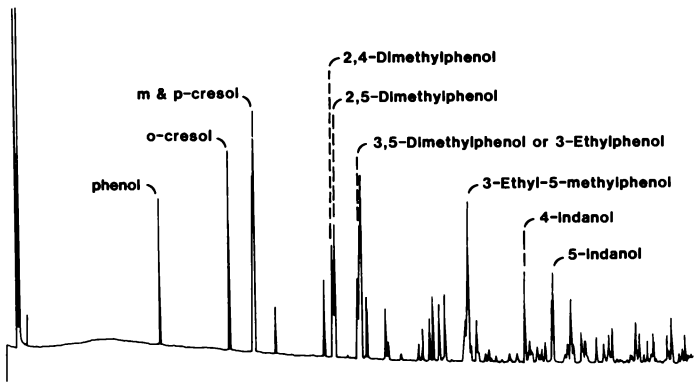


Figure 1

There was no strong correlation found between the total percent phenols in the distillable products calculated on an maf coal basis and the rank of the coal, although the low-rank coals tend to contain more phenols. The WY01 run produced the most phenols calculated on an maf coal basis, 7.7%. B3 and BB1 liquefaction produced 7.3% and 6.1% phenols, respectively, while POW1 produced the least, 5.1%. The yield of distillate generally increases as the percent phenols in the product increases when lignites are processed. In the set of data presented here the WY01 run did not follow this trend.

Phenols are known to facilitate the solubility of reactants during liquefaction processes and have been reported to act as catalysts in ether cleavages. They may also act as efficient hydrogen donors (2). The analyses reported here will be used to compare the phenols produced in syngas processing with the results of bottoms recycle liquefaction under other conditions.

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** Reference to specific brand names and models is done to facilitate understanding and neither constitutes nor implies endorsement by the Department of Energy.

57. CHARACTERIZATION OF THE HYDROGEN DONOR PORTION OF A HYDROGENATED LIQUEFACTION SOLVENT BY CAPILLARY GAS CHROMATOGRAPHY AND GC/MS

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Researchers at the Grand Forks Energy Technology Center and at the Chemical Engineering Department of the University of North Dakota have been investigating the effects of hydrogenation of liquefaction solvents on conversion of low-rank coals using a hot-charged, time-sampled batch autoclave. A one-gallon hot-charged autoclave is equipped so that reactant material may be charged rapidly into the preheated autoclave from two pressured reservoirs, one for the coal-solvent slurry, and one for the gas mixture. This study compares the solvents used in the coal-solvent slurry. The solvents used were anthracene oil (A04) and hydrogenated anthracene oil (HA04). The latter was produced by catalytic hydrogenation at GFETC. This will be referred to as HA04.

Solvent samples were fractionated using silica gel column chromatography. The solvent schedule and elution volumes used were: pentane, 5 x 50ml, 5% benzene/pentane, 2 x 50ml, 15% benzene/pentane, 2 x 50ml, 20% benzene/20% ether/60% methanol, 2 x 50ml, and methanol, 150ml. Each fraction was analyzed by capillary gas chromatography on a Varian* 3700 using a 50 meter methyl silicone fused silica column. Column temperature was programmed from 100-280°C at 4°C/min. GC/MS analysis was performed on a Hewlett-Packard* 5985B mass spectrometer operating in the electron impact ionization mode. One microliter of sample, split 75:1, was injected on a 60 meter DB-5 fused silica capillary column and the column effluent was introduced directly into the ion source. Typical source pressure with the GC/MS valve open and 1ml of helium flowing through the column is $5 \times 10^{-6}$ torr. The column temperature was ramped using the following program: initial temperature was 100°C and initial rate was 2°C/min; after 25 minutes the rate was changed to 3°C/min and finally after 50 minutes the rate was increased to 4°C/min. A typical run took about 75 minutes with more than 2500 scans being recorded.

The hydrogen donor fractions (fractions 3-5) of both A04 and HA04 were analyzed by GC/MS to identify as many compounds as possible. Approximately 15% of the total material recovered from the A04 fractionation was found in fractions 3-5. This compares to 42% for the corresponding fractions of the hydrogenated solvent, HA04. A04 fractions 3 thru 5 consisted mainly of naphthalenes and C1 to C3 naphthalenes, acenaphthenes and C1 to C2 acenaphthenes/biphenyls and phenanthrene. While these compounds were also found in HA04, the difference causing the increase in material in fractions 3 through 5 in HA04 was that they contained large amounts of hydrogen donor material. These hydrogen donors can be grouped into three major compound classifications. They are tetralins and C1 to C6 substituted tetralins, tetrahydroacenaphthene and C1 to C2 substituted tetrahydroacenaphthenes, and hydrogenated phenanthrenes (dihydro and octahydro). Identification of compounds was based on mass spectral data, 200 MHz $^1$H NMR, and on gas chromatographic retention time data with respect to standard compounds.

A comparison of data obtained for liquefaction of the same coal and at similar operating conditions (Table 1) but with A04 and HA04 as solvents indicate that the increased amount of hydrogen donor in HA04 can be correlated with an increase in conversion from 82% to 90%. This is in spite of the fact that the average reaction temperature of the hydrogenated solvent was 10°C less than that for the unhydrogenated A04. (Lower reaction temperatures would be expected to result in lower conversion which clearly is not the case with HA04 as the solvent.) The amount of hydrogen consumed during the run decreased from 2.1 equivalents to 1.5, which indicates that the increase in conversion is due to hydrogen transfer by the hydrogen donors present in much greater quantities with HA04. This also indicates that hydrogen transfer occurs much more readily in the liquid than between the gas and liquid phase with its resultant energy requirement for breaking a H-H bond.

Table 1

Run Conditions

| Run # | N16 | N51 |
|---|---|---|
| Coal | Zap | Zap |
| Solvent | A04 | HA04 |
| Run Time, min | 20 | 20 |
| Av Temp., °C | 463 | 453 |
| Max Pressure, psig | 3870 | 3800 |
| % $H_2$ Feed Gas | 51 | 50 |
| Moisture | 99 | 99 |

* Reference to specific brand names or models is done to facilitate understanding, and neither constitutes nor implies endorsement by the Department of Energy.

58. X-RAY FLUORESCENCE METHODS FOR DETERMINATION OF MINOR ELEMENTS IN PARTICULATE EMISSIONS FROM LOW-RANK COAL COMBUSTION

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The Grand Forks Energy Technology Center is engaged in a project to characterize particulate emissions from power plant stack gases. Special interest has been placed on the distribution of certain elemental species as a function of particle size. Particulate samples were collected from the stack by the use of 5-stage multicyclone which is capable of collecting size fractions of samples of 0.1 to 10 micrometers. Large quantity samples are collected so many types of analyses can be performed, which include scanning electron microscopy, surface analysis, Coulter Counter particle-size counting, X-ray diffraction and X-ray fluorescence analysis. Energy dispersion X-ray analysis is used to determine the concentrations of the major and minor elements in these particulate emissions. The major elements are elements most commonly analyzed and include Na, Mg, Al, Si, S, P, K, Ca, Ti, and Fe. All other elements are considered minor elements.

The sample preparation methods are the same as those used previously (1). Precautions must be made to avoid sample contaminations. Grinding equipment cannot be used that contains elements that are either analyzed for or that cause interference so that other elements cannot be analyzed. For example, using a tungsten carbide shatterbox produces contamination from tungsten that makes it impossible to analyze for several elements.

A multiple target energy dispersion (E.D.S) X-ray fluorescence spectrometer was used for the analysis of the major and minor elements. Several modes of excitation have to be used to most efficiently analyze certain suites of elements. Direct excitation and secondary excitation were used in analyzing for the different elements. In direct excitation the sample is bombarded with X-rays from the X-ray tube itself, creating a very high flux and a spectrum of radiation. In secondary excitation, the X-rays hit a specific element target to produce essentially monochromatic radiation characteristic of this particular target element. The secondary targets, excitation conditions in kilovolts (KV) and milliamps (MA) and the elements they particularly excite are shown in Table 1. There is difficulty in analyzing for small concentrations of elements since the data acquisition time for the heavier atomic weight elements has to be at least 1000 seconds for good counting statistics. Copper results, for example, would be much less precise with a reduction in analyzing time. The results for some elements along with their standard deviations are shown in Table 2, in parts per million. The results are from an analysis of the National Bureau of Standards Fly Ash Standard NBS1633. The sensitivity of certain elements is such that very low concentrations of these elements are below the detection limits of the X-ray spectrometer. For example, in the standard NBS1633 the concentration of nickel was below 20 parts per million so the spectrum of nickel was indistinguishable from the surrounding background.

Table 1

| Elements | Target | Excitation KV | Excitation MA |
|---|---|---|---|
| Na - S | Direct | 4 | 0.35 |
| Al - Cr | Iron | 16 | 2.0 |
| K - Zn | Germanium | 20 | 1.5 |
| Fe - Zr | Silver | 33 | 1.5 |
| Cd - Ba | Gadolinium | 55 | 1.5 |

Table 2

| Elements | NBS 1633 Std | E.D.S. |
|---|---|---|
| Lead | 75[a] | 99.6 ± 2[a] |
| Yttrium | 63 | 62.6 ± 1 |
| Chromium | 130 | 167 ± 10 |
| Manganese | 496 | 600 ± 35 |
| Copper | 128 | 100 ± 4 |
| Zinc | 210 | 190 ± 5 |

[a] Results are in parts per million.

The investigation of the enrichment of minor elements will be a part of the ongoing program of research at the Grand Forks Energy Technology Center. The X-ray fluorescence analysis of minor elements is an important part of this program. Eventually it is intended that the results from atomic spectroscopy will insure proper precision in our analytical results. The data will also be used to determine trends in concentrations of different sizes of particles in the emissions from power plants.

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59. AUTOMATED QUANTITATIVE DIFFRACTION METHODS FOR BINARY AND TERNARY SYSTEMS OF CALCIUM COMPOUNDS

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Powder x-ray diffraction is most commonly used as a qualitative technique to determine the presence or absence of a crystalline phase in a sample. The next task often faced by the analyst is to attempt to quantify the analysis. In some cases it is worth the time to develop a quantitative x-ray diffraction procedure for a system of multicomponents. This may be particularly important in a system where one element is found in more than one phase and chemical analysis is unable to clarify the system. The system discussed here is $CaSO_4$, $CaCO_3$, and $SiO_2$. These phases are commonly seen in low-rank coal combustion processes dealing with sulfur capture.

Quantitative diffraction is based on determining the relationship between concentration, usually as weight pct, and intensity of some peak or peaks in the diffractogram. The intensities may be taken from the peak height or the integrated area under the peak. The latter allows for slight peak shifts and provides better counting statistics because a larger number of x-ray counts are accumulated. The diffracted line intensity depends on geometric parameters developed from the angular position of the line in the diffractogram, the Bravais lattice, its volume and the atomic number of the atoms associated with each lattice point, the number of planes of a given spacing, and the linear absorption coefficient. The mass absorption coefficient is readily available but must be multiplied by the density of the material. This is one place error can enter a theoretical calculation. In practice, several techniques are available for data interpretation. All require a large enough number of standard samples to characterize the system. Eighteen have been used in the ternary system discussed here. Instrument operation is a variable, so one sample containing equal amounts of the three phases is used as an external reference. All intensity values are ratioed to this reference, referred to as $I_{relative}$. An automated system was used to run the calibrations and is very advantageous due to the large number of samples required. It has been found that the use of binary system calibrations is very helpful in establishing a basis of understanding for the parameters involved, previous to the interpretation of ternary systems. For instance, the region analyzed for on a given peak is a crucial factor in obtaining optimum calibrations, and variations of this parameter are more difficult to follow in a ternary system. The same is true of variations of increment counting rates across the peak. Base line conditions are therefore best determined in binary systems before moving into ternary calibrations.

A number of methods have been used to check the data for interphase or matrix effects. These include linear, cubic and quadratic line fits based on plots of concentration versus relative intensity of a single phase. In these plots, relative intensities that are higher than would be expected from equating 33% concentration with an $I_{relative}$ of 1 indicate that the phase has a low absorption coefficient in a matrix of higher absorbing material. The curve is a function of the matrix effects. An example of this is given in Figure 1 for quartz in a matrix of various amounts of $CaSO_4$ and $CaCO_3$. A problem associated with the linear model is that very low values are poorly estimated. The line intercept on the concentration axis is an indication of the detectability limit for the phase in the matrix used. It is necessary to obtain usable ternary curve fit calibrations for a phase in a matrix of two components of different absorption characteristics such as $CaCO_3$ in a $SiO_2$-$CaSO_4$ matrix. An empirical corrections model based on a plot C(Concentration)/$I_{relative}$ of one phase against the $I_{relative}$ of one of the other phases in the system is available in the automation package. Care must be taken in the use of a C/$I_{relative}$ term since it becomes indeterminant as the concentration and intensity approach zero.

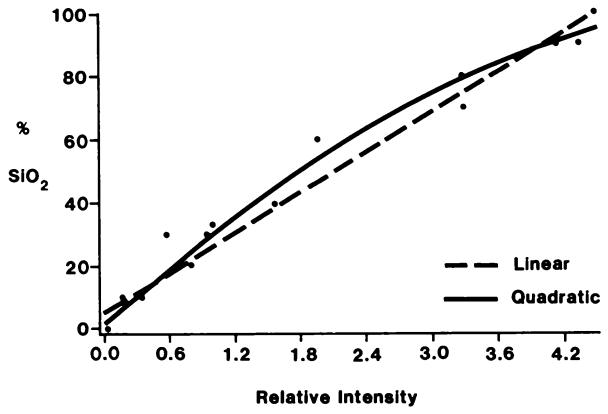


**Figure 1. Linear and quadratic fits for the calibration of $SiO_2$ in a matrix of $CaSO_4$ and $CaCO_3$.**

A constant problem is one of sample preparation uniformity. Results in which a few percent (± 8%) of the amount present have been obtained using curved fit calibration and emperical models. The sum of the concentrations of the three phases analyzed is usually between 90 and 110%.

71. HIGH TEMPERATURE REDUCTIVE CLEAVAGE OF C-N BONDS IN N,N-DIMETHYLANILINE

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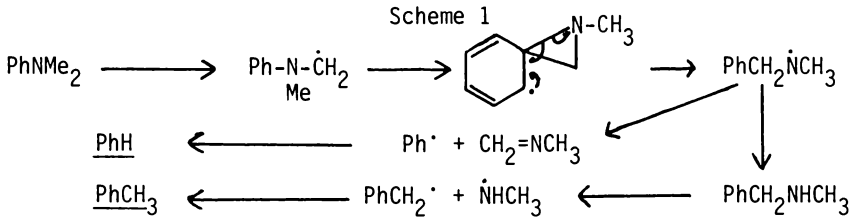
The need for hydrotreatment processes for heteroatom removal from fossil fuel liquids to prevent catalyst poisoning and meet environmental constraints is imminent. Most hydrodenitrogenation (HDN) studies use N-heterocycles as model compounds and employ a supported $MoO_3$ or $WO_3$ with or without CoO or NiO promotors (1,2). Based on these studies, it is postulated that the HDN process needs complete saturation of the α and β carbons which are bound to nitrogen prior to nitrogen removal (3).

When N,N-dimethylaniline (DMA) is reacted with $H_2$ at 425°C in metal autoclaves, benzene (PhH), toluene ($PhCH_3$), N-methylbenzylamine (NMBA), N-methylaniline and aniline are formed (Table 1). Not all of the products are formed simultaneously. Under these reaction conditions, NMBA is formed from DMA via a 1,2-phenyl shift from N to C (Scheme 1). NMBA further decomposes readily to form benzene and toluene. Analogous rearrangements have been observed in alkyl phenyl ethers (4), alkyl phenyl sulfides (5), and bibenzyl (6). In order to determine whether toluene is formed by an intra- or intermolecular rearrangement, N,N-dimethyl-o-toluidine, N,N-dimethyl-m-toluidine and N,N-dimethyl-p-toluidine were reacted under similar conditions, and o-xylene, m-xylene and p-xylene

Scheme 1




were the respective products. This proves that the rearrangement is intramolecular and occurs at the "ipso" position of the ring in the starting material. Thus, these results demonstrate that cleavage of the aromatic C-N bond can be achieved without reduction of the aromatic ring. This has significant implications on future studies for the removal of nitrogen from coal.

TABLE 1

Reductive Denitrogenation at 425°C

| Compound | Product (mole %) PhH | $PhCH_3$ | NMBA | Xylene |
|---|---|---|---|---|
| N,N-Dimethylaniline | 2.5 | 2.8 | 5.9 | -- |
| N,N-Dimethyl-o-toluidine | - | 9.3 | -- | 19.4 (ortho) |
| N,N-Dimethyl-p-toluidine | - | 3.1 | -- | 5.3 (para) |
| N,N-Dimethyl-m-toluidine | - | 1.0 | -- | 1.2 (meta) |
| N-Methylbenzylamine | 15.8 | 35.9 | -- | -- |

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72.

# PHENOLS AND QUINONES AS SCAVENGERS OF SUPEROXIDE

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In the normal immune system, superoxide radical anion is produced by neutrophils and is converted to hypochlorite, a bacteriostat. In rheumatoid arthritis, the neutrophils invade the synovium and release superoxide. The enzyme superoxide dismutase (SOD), discovered by McCord and Fridovich[1], is a natural defense that the body has against superoxide, but it is only found within the cytoplasm. As a result, superoxide, when released in the synovium can depolymerize hyaluronic acid[2,3] and cause joint damage.

SOD, when injected into the joints of rheumatoid arthritics, exhibits anti-inflammatory activity. It is the purpose of this research to test a variety of simple molecule radical inhibitors for superoxide scavenging ability. Later, the functional groups of the most potent inhibitors are to be incorporated into a larger molecular framework which is designed to carry the inhibitor moiety to the synovium. Two assays for the superoxide quenching studies were employed in order to assure accuracy of the results.

As shown in Table I, quinone completely scavenges superoxide in Fried's assay and gives the greatest inhibition (78.3%) in the $KO_2$ assay. 1,4-Naphthoquinone also shows some scavenging ability in the $KO_2$ assay (45.7%), but not as much in Fried's assay (20.0%).

The 1,2,3-trihydroxy-substituted benzenes also exhibit good scavenging ability. Pyrogallol gives 100% inhibition in Fried's assay and 60.3% in the $KO_2$ assay. Gallic acid and propyl gallate give similar results, although the parent compound, pyrogallol, is a better scavenger.

The dihydroxybenzenes: catechol (1,2-dihydroxybenzene), resorcinol (1,3-dihydroxybenzene), and hydroquinone (1,4-dihydroxybenzene) were also tested. Catechol is the best scavenger of the three, but hydroquinone also shows activity. Several monohydroxybenzenes, including phenol, BHA, and BHT were examined, but these showed no activity.

Several non-steroidal anti-inflammatory drugs: indomethacin, sulindac and aspirin, were tested to determine if their primary mode of action includes scavenging superoxide. These drugs appear not to quench the superoxide radical ion as their primary mechanism.

Table I
Relative Quenching Ability of Selected Compound for Superoxide Radical Anion

| | Fried[4] | $KO_2$[5] |
|---|---|---|
| Quinone[6] | 100 ± 0 | 78.3 ± 6.3 |
| Pyrogallol | 100 ± 0 | 60.3 ± 19.7 |
| Gallic acid | 89.1 ± 3.8 | 71.0 ± 5.2 |
| Propyl gallate | 81.0 ± 9.7 | 64.6 ± 14.3 |
| Catechol[7] | 34.8 ± 2.5 | 36.2 ± 15.6 |
| SOD | 26.8 ± 1.7 | 12.9 ± 12.9 |
| 1,4-Naphthoquinone | 20.0 ± 19.2 | 45.7 ± 3.6 |
| Indomethacin | 3.0 ± 1.3 | 12.5 ± 7.1 |
| Sulindac | 3.0 ± 3.3 | 11.6 ± 6.9 |
| Aspirin | 0.4 ± 3.8 | 13.0 ± 12.6 |
| Butylated hydroxytoluene (BHT) | 0 | 0 |

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6. $1 \times 10^{-4}$ M in DMSO.
7. From human blood; 3 units.

73. METAL-BINDING LIGANDS IN A PANCREATIC EXTRACT

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A commercial pancreatic enzyme preparation, Viokase®, has been reported to be effective in the treatment of acrodermatitis enteropathica (AE). The therapeutic effect has been attributed to the zinc binding ligand, picolinic acid (1), and to another zinc binding ligand, citric acid (2). The object of this study was to detect low molecular weight zinc binding ligands in Viokase by the technique of modified gel chromatography (3,4) using copper(II) as the metal contained in the solvent. Copper was selected as the experimental metal because of its similarities in binding properties to zinc along with its greater affinity for ligands, including citrate and picolinate.

## Materials and Methods

Aqueous Viokase extracts were prepared from tablets or from the powder form, and centrifuged. The supernatant fraction was ultrafiltered, yielding the soluble portion of Viokase of 500 ± daltons.

A sephadex G-15-120 gel chromatography column previously treated with $NaBH_4$ to prevent metal-gel interactions (5) was used in these studies. The solvent system consisted of 25 mM acetate/acetic acid buffer pH 5.7, 0.5M $NaNO_3$, 5 ppm $Cu^{++}$ as $Cu(NO_3)_2$. Samples were dissolved in 1.0 ml buffer before application to the column. Eluted fractions were diluted with 1% $HNO_3$, and the copper content determined by atomic absorption spectrophotometry. Samples were also measured to quantitate amino acids detected in the preparation. The Furth and Herrmann reaction for citric acid or structurally similar compounds (6) was carried out on the lyophilized ultrafiltrate.

## Results

Typical modified gel chomatographs of Viokase ultrafiltrate resulted in three peaks with elution volumes corresponding to Ve/Vo's of 1.43, 1.71, and 2.57. Amino acid analyses indicated that the peak at Ve/Vo = 1.43 consisted of glutamic acid and the peak at Ve/Vo = 1.71 consisted of several amino acids, serine, alanine, leucine, glycine, and lysine. The third peak Ve/Vo = 2.57 is believed to be due to interferences of metal ions which displace solvent copper ions from the column.

Neither citrate or picolinate were detectable in samples up to 5.0 mg of lyophilized UM05 ultrafiltrate (< 500 daltons). Citrate or picolinate were detectable to a lower limit of 0.3 umoles with this system.

The Furth and Herrmann reaction resulted in a faint color change which indicated the presence of small amounts of citrate or similar compounds such as aconitate. Viokase was extracted with pure water, 0.1N HCl and 0.1N NaOH solutions; all extracts yielded similar results.

## Discussion

Though citrate and picolinate are claimed to be zinc binding ligands present in Viokase, neither was detectable by modified gel chromatography using copper as the complex-forming metal. Both citrate and picolinate are detectable at levels of 0.3 μmole as pure samples, yet with a maximum of 5.0 mg Viokase ultrafiltrates (MW<500) applied to the column, neither was apparent. Levels of citrate (2) and picolinte (1) reported in Viokase may be below the modified gel detection limits. However, several amino acid ligands are readily detectable in Viokase extracts and must be considered as major copper binding ligands. Citrate or picolinate may be effective in zinc absorption at very low concentrations but the likelihood to act effectively at such concentrations is seriously decreased particularly in the face of high levels of amino acids as competitive ligands. The relief offered to the AE patient by Viokase may be the result of increased zinc uptake by a mechanism other than those previously proposed.

We wish to thank Nat Suwarnasarn and J.A. Stewart for amino acid analysis. This research was supported in part by a grant from the U.S. Dept. of Agriculture/SEA CRGO 59-2382-0-1-508-0. Any opinion, findings and conclusions or recommendations expressed in this publication are that of the authors and do not necessarily reflect the view of the U.S. Dept. of Agriculture.

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74. ECONOMIC CONSIDERATIONS FOR SCHOOL BUS ROUTES BY COMPUTER OPTIMIZATION

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The increasing cost of transportation and the desire for energy conservation for rural school districts has resulted in the development of a program at North Dakota State University to reduce operational busing costs. It was reasoned that since most districts perform a manual analysis resulting in non optimum solutions that a computer model could rapidly analyze a large number of conditions and produce several alternatives for reducing operational mileages.

The process of developing the program was based on the idea that the computer programs should have sufficient flexibility to incorporate the many individual requirements of the district and still minimize data requirements. This program differs from others by optimizing the route configuration independently of the highway network and then manually matching the results to the useable highway network. A variety of parameters were incorporated into the models to allow different configurations to be generated. The major parameters used in designing the route configurations were bus speed, maximum student ride time and bus capacity. Other parameters control the shape of the routes with possibilities such as complete loops, line routes and internal and external routes included. The programs also provide for the analysis of districts with multiple school centers and for transfers of students either at mid route or at school locations. Two computer models were developed (1). The CHOOSE program analyzes the bus stops and determines a minimum mileage configuration. The second program called EVALUATE, utilizes the manually matched data to produce the exact mileages and ride times. Computer graphics programs have also been developed to aid in the process.

The results of the analysis are based on the application of the computer approach to thirty eight school districts, thirty two in North Dakota and six in Minnesota. The total potential miles saved, as produced by the computer based approach was 506,063 miles per year or an average of 13,317 miles per year per district. This is a 12.3% reduction. In addition as a result of the elimination of bus routes, a reduction of 25 buses could also be achieved. These route reductions generally are achieved because of the overcapacity of the bus fleet and in all cases attempts are made to maintain the ride times at the existing levels.

The value of the program must also be measured by the degree of implementation by the school districts. For a variety of reasons such as contractual obligations to the bus operator, and parent and operator objections, the potential results were not always implemented. A survey of twenty seven of the districts analyzed was performed and indicated that sixteen districts have implemented part of the analysis; 38% the first year of the program and 78% the second year. Although not determined from the survey, the increase in utilization is believed to be the result both of increased concern for transportation costs and of improved methods of coordination between the analyst and the school district. The results also indicated that 44.9% of the potential mileage savings were actually implemented with a reduction of 9 buses. This is a saving of 153,857 miles per year for the twenty seven districts or a 5.5% actual reduction per district. In terms of potential fuel savings approximately 30,771 gallons of fuel were actually saved per year.

The benefit cost ratio, which reflects only the cost of performing the analysis and the actual savings, indicates a value of 3.0 and is based only on the first years operation. The benefits and costs are $133,245 and $43,993 respectively. Benefits should continue to accrue for several years, however, further increasing the benefit cost ratio. This increase is currently being evaluated in the current program by a repeat analysis of districts which have implemented the recommended route configuration. The results from one district are available to date. This district was analyzed in 1978 and implemented the recommended changes for a savings of 8,640 miles per year. The analysis completed in 1982 showed potential savings of 3,710 miles per year indicating that normal yearly changes in route system can result in inefficiencies in the system. The analysis of additional districts, however, is recommended to confirm these results.

The conclusions are:

1. Savings can be achieved by utilizing computer analytical methods
2. Close coordination between the analyst and the school district improves the implementation rate.

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75. CONODONT COLOR ALTERATIONS AND THE GEOTHERMAL HISTORY OF SOME SURFACE AND SUBSURFACE ROCKS IN THE WILLISTON BASIN REGION

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Field and laboratory experiments have shown that color alterations in conodonts are directly related to depth and duration of burial and the geothermal gradient. Five progressive and irreversible color changes ranging from pale yellow to black have been discriminated and a color alteration index developed (1). The relationship between the geothermal history of petroleum source rocks and their oil-producing ability is also well established.

The purpose of this study was to determine the color alteration index of conodonts extracted from surface and subsurface samples from the Williston Basin Region. Five surface carbonate samples were collected and analyzed from the Ordovician Red River Formation exposed in quarries near Winnipeg, Manitoba. Six subsurface Red River Formation samples of well cuttings and core fragments were examined from a well located at Section 15, T155N, R87W near Berthold, North Dakota. A total of seven samples of the Ordovician Big Horn dolomite were collected from Brown's Gulch in the Little Rocky Mountains, Montana and from Shell Creek Canyon, Wyoming. Five samples of the Devonian Clark's Fork Formation were collected from near Crystal Lake in the Big Snowy Mountains, Montana. Conodonts from productive samples were compared with standards in order to establish geothermal histories.

Conodonts were extracted from samples using standard procedures involving acetic acid treatment and concentration with a magnetic separator and heavy liquids. The conodont color alteration index was determined by comparing the color of extracted specimens with standards containing the same faunal elements prepared at the United States National Museum.

The selected surface samples examined were found to have a conodont alteration index (CAI) of one to two, suggesting a temperature history of 50-140°C. Well cuttings from 10,792-11,898 feet from a well near Berthold, North Dakota had a CAI of four, suggesting a temperature range of 190-300°C.

1. Epstein, Anita, Epstein, J. B. and Harris, L., 1977, Conodont Color Alterations: An Index to Organic Metamorphism. U.S. Geological Survey Prof. Paper 995, 27 p.

22.

# GROUNDWATER QUALITY IN THE GLENBURN OIL FIELD

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The community of Glenburn, North Dakota is situated in an area of active oil exploration and exploitation. Some of the by-products of oil drilling and extraction, such as drilling mud solutions, are recognized as potential sources of surface and groundwater contamination. Some rural residents of the Glenburn area suspect that aquifer contamination has taken place, complaining that their well water tastes salty.

Little scientific data exists on the relationship between groundwater quality and oil-related activity in North Dakota. This study was undertaken with a two-fold purpose: 1) to determine the current water quality of the area aquifers, and 2) to relate those findings with possible sources of contamination.

Well water sampling was done in a 13 square mile area which includes the town of Glenburn. Test wells were chosen to give a representative areal coverage and were picked without regard to any specific structure, activity, or topography. Strict sampling procedures were followed to ensure that the water sample came from the aquifer and not from the water pipe system or well residual.

EPA procedures have been followed in sample analysis. Five samples were sent to the North Dakota State Health Department Environmental Laboratory for the analysis of major ions and the trace metal chromium. The State Lab is additionally involved in the quality control of chemical analysis performed at Minot State College.

Water sample data is analyzed to determine the relationship between constituent concentrations, the geology of the region, and the proximity to specific oil field activities. With an estimated disposal of 360 million cubic feet of oil and gas drilling fluid waste in North Dakota over the past 30 years, the relationship between this waste and groundwater quality may be of critical importance to future water resource development.

23. Fuel Conservation During Warm-up of Automobile Engines In Cold Weather

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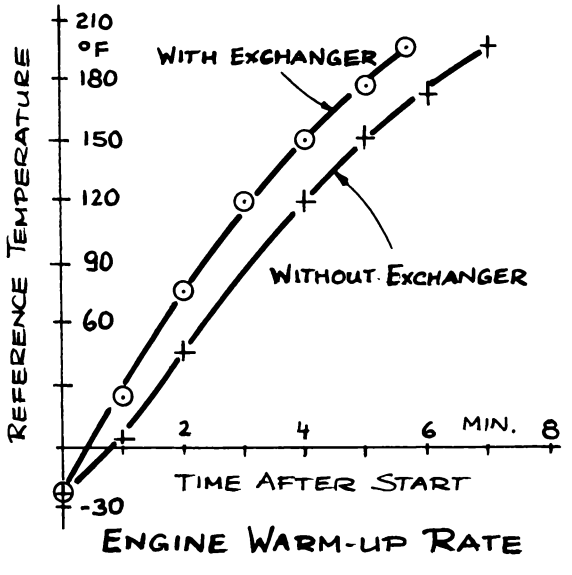
PURPOSE: The purpose of this study is to evaluate an engine warm-up system proposed by one of the authors (DSM). The basic idea of the system is to preheat engine coolant with heat from the engine exhaust gas by means of a heat exchanger. After warm-up the exhaust gases are routed to a conventional exhaust system to avoid overheating. By decreasing warm-up time the system will theoretically increase engine efficiency, decrease exhaust emissions, and increase driver comfort.
METHOD: Two testing systems have been developed to date, one using a 1976 Buick V-6 laboratory engine, and one using a 1981 Ford Granada with an inline 6 cylinder engine, automatic transmission, and accessories typical of an American automobile.

A mobile test stand was devised for the laboratory engine so that it can be rolled into the open to "cold soak" between tests. The temperatures of various points in the exhaust and cooling systems, the fuel flow rate, total fuel consumption, and the coolant flow were monitored and recorded by a data logger. A small water brake simulated light engine loads. Tests with and without heat exchangers installed, without load and with a constant 12 hp load have been run at various temperatures under constant speed conditions. Heat exchangers evaluated include a finned tube counterflow design, a shell and tube design, and a design developed to use automotive heater cores.

The 1981 Ford Granada was fitted with a driving computer to monitor fuel consumption. Thermocouples were located in the exhaust and coolant systems in a manner similar to the test engine. For tests under actual driving conditions a digital thermometer monitored each thermocouple location. The data logger recorded the temperatures under no load idle conditions and chassis dynamometer load conditions. Tests to date using the automobile have included a preliminary chassis dynamometer test, no-load warm-up tests, and transient and steady state driving tests using the shell and tube design heat exchanger. The exhaust system has been modified to allow switching of the exhaust flow either through the heat exchanger or through a conventional exhaust system.
RESULTS: Testing is being done presently using both the laboratory engine under no-load and light load conditions, and the automobile under actual driving conditions. The critical component in the system is the heat exchanger. The finned tube heat exchanger gives extremely low heat transfer under no-load conditions. The shell and tube heat exchanger has been evaluated and produced significant heat gains in the coolant. The exchanger is being evaluated on the Ford Granada because of its compact size and ready availability. The heater core design is being evaluated on the laboratory engine.

The figure illustrates a decrease in warm-up time observed with and without the heater core exchanger on the Buick V-6 test engine. Ambient temperature with the exchanger was -23.4°F and without the exchanger was -22.3°F. Both tests were run at 2000± 100 RPM and a load of 12± 0.5 hp applied. The reference temperature has been measured in the intake manifold water jacket near the thermostat. The data indicates that with the heat exchanger installed, warm-up time, as indicated by cycling of the engine thermostat, was decreased approximately 20% from 7 to 5.5 minutes. Initial fuel consumption data indicate approximately equal fuel consumption for both runs.



ENGINE WARM-UP RATE

Data obtained using the automobile under actual driving conditions indicates that a temperature rise of 13-18°F can be obtained across the shell and tube exchanger under fully warmed up conditions at 55 MPH. During take-off from a cold start 50-60°F rises have been noted. Temperature rise at idle is considerably lower. Fuel savings have been noted but exact data is not yet available.
CONCLUSION: Tests to date indicate that warm-up time is decreased by the system under consideration. Fuel consumption data point toward fuel savings but further testing is underway at this time to refine measurement techniques allowing better conclusions to be drawn. Fuel savings are expected to be approximately 5-8% on warm-up. Low mass flow rates of exhaust gas at idle results in low heat transfer limiting the effectiveness of the warm-up system. Under load, exhaust gas mass flow increases and significant reduction in warm-up time can be observed.

24. LIVESTOCK-WILDLIFE INFLUENCE ON THE COVER, DENSITY AND AGE STRUCTURE OF GREEN ASH (*Fraxinus pennsylvanica*) IN THE NORTH DAKOTA BADLANDS.

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The activities of various animals influence the composition and structure of plant communities. The degree of influence is largely dependent on the intensity of use. In the Badlands of southwestern North Dakota, livestock production is the principal industry and contributes greatly to the local economy. The area also supports a sizeable population of wildlife, including antelope, mule deer, white tail deer and upland game birds, as well as countless nongame birds and small mammals. The major source of food and cover for the wildlife is provided by the various woodland communities, which also provide forage for cattle during stress periods and shelter form wind, heat, cold and insect pests. The most common woodland community occurring in the Badlands is that dominated by green ash.

In May, 1980, a study was initiated to investigate the impact of cattle utilization on the condition and trend of such communities. This paper is a preliminary report concentrating on the effect of cattle on the overstory. Two sites were selected for investigation. A site located within the boundries of Theodore Roosevelt National Park represents the ungrazed site, as it has been excluded from grazing for about 35 years and is now only used by native fauna. The second site is located in the Little Missouri National Grasslands and is managed by the U.S. Forest Service and the Medora Grazing Association for livestock grazing.

Belt-transects were placed systematically 10 m apart and were designed to dissect the community. The belts were 6 m in width with a meter tape running lengthwise through the center. Length and number of transects per site varied depending on the extent of the community. The portion of the community influenced by the overstory was defined as the distance between the vertical projection of the crown of the first tree encountered to the last tree encountered on the transect. The interceptions of tree and sapling crowns over 1.8 m in height were used as an estimate of cover. Density estimates of mature trees were obtained by counting the number of individuals with diameter at breast height (dhb) $\geq$ 7.5 cm occurring within the strip. Basal area estimates and increment cores to determine age structure were taken from all trees within the transect with dbh $\geq$ 7.5 cm. Saplings are defined as those trees greater than 1.8 m in height but with a dbh of less than 7.5 cm.

The ungrazed site contains a larger number of smaller stemmed individuals with substantially more cover than the grazed site (Table 1). The grazed site is represented by a more open canopy with a smaller number of larger trees. Sapling density was greater in the ungrazed site with 1158.9 stems per hectare compared to 709.1 stems per hectare occurring in the grazed site.

The effects of cattle on the age structure of the community is superimposed on other factors such as drought, fire and long term changes in the physical enviroment. Figure 1 illustrates the percentage of the population sampled occurring in various age classes. This does not take into account the individuals with dbh less than 7.5 cm that might fall into the 0-20 or 21-30 age classes. The majority of the trees from the two sites fall into the 31-40, 41-50 age classes. Since the ungrazed site has only been protected from grazing by cattle since the park was established in 1947, inferences about the influence of cattle on the age structure could not be conclusive. A clearer depiction of the influence of cattle on these communities might be obtained by investigation of the shrub and herbaceous components.

Table 1. Density, cover and basal area of green ash in one grazed and one ungrazed site.

| Site | Density stems/ha | Cover % | B. A. $cm^2/ha$ | Average B. A. $cm^2$ |
|---|---|---|---|---|
| Grazed | 411.2 | 75.2 | 91,123.4 | $221.6_{SEM=24.572}$ |
| Ungrazed | 428.9 | 98.6 | 68,162.3 | $158.9_{SEM=25.393}$ |

SEM (Standard Error of the Mean)

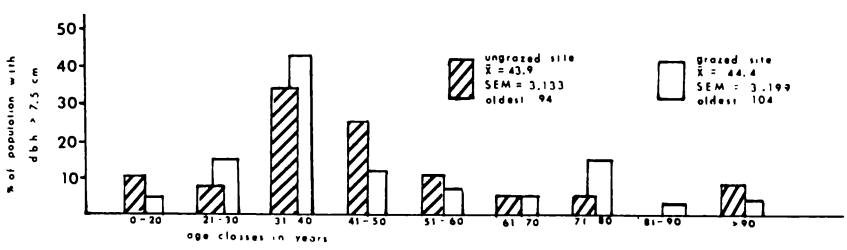


FIGURE 1 AGE DISTRIBUTION OF GREEN ASH

25. DETERMINATION OF THE LOCATION OF THE HISTONE METHYLASES IN CHROMATIN WITH NUCLEASES

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The histone lysine methyltransferases catalyze the transfer of the methyl groups from S-adenosyl-L-methionine to specific $N^{\epsilon}$-lysyl residues in the N-terminal regions of histone H3 and H4. These enzymes are located exclusively within the nuclei and are firmly bound to chromatin (1). The enzymes can be solubilized by limited digestion of brain chromatin from 4-6-day-old rats with nucleases. The majority of these enzymes can be solubilized after 5% digestion of the chromosomal DNA, while maximum release was obtained after 12-14% digestion (Figure 1). Exhaustive digestion of rat brain chromatin with micrococcal nuclease solubilized 40-45% of the DNA, leaving a limit-digest particle (nucleosome) which contains 150-160 base pairs. Thus indicating that these enzymes are associated with the linker region of the chromatin.

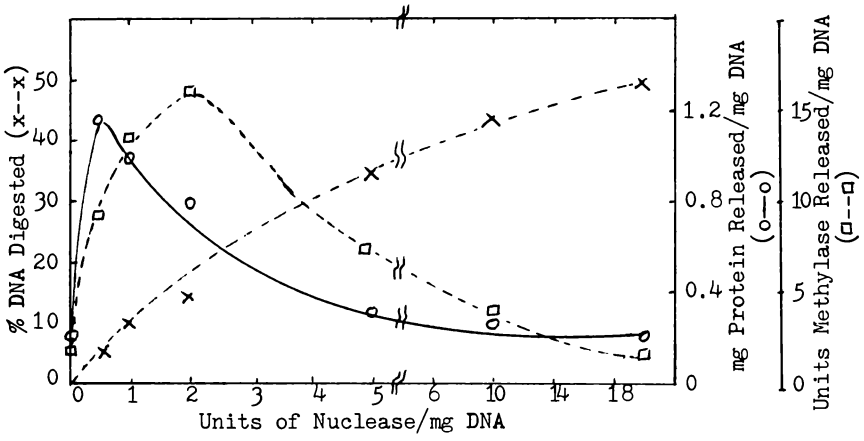


Figure 1
Nuclease Digestion of 4-6-day-old Rat Brain Chromatin

After digesting 15% of the chromosomal DNA with micrococcal nuclease the nucleosomes and protein aggregates were removed by centrifugation and the soluble chromosomal fragments concentrated on an Amicon YM-10 filter. These fragments were fractionated on a Sepharose 6B-100 column and with ammonium sulfate (20-45%). The fragments rich in histone methyltransferase contained 12% DNA and 88% protein.

The molecular weight of the fragments between 1 million to 2 million. Electrophoresis on standard polyacrylamide gel revealed some 17-20 non-histone proteins associated with the short DNA segments. Sodium dodecyl sulfate polyacrylamide gel electrophoresis indicates that there are 28-30 polypeptides associated with these segments.

If the DNA fragments are removed by complete digestion with either micrococcal nuclease or DNAase I, all the proteins aggregate. Aggregation can be prevented with the addition of 0.45 M NaCl, however, methylase activity is lost. If the DNA fragments are bound to DEAE-cellulose, the non-histone proteins can be selectively eluted with NaCl. The histone lysine methyltransferases are resolved into two distinct peaks, one specific for histone H3 and the other specific for histone H4.

The enzyme specific for histone H3 has a pH optimum of 8.2-8.7. The other enzyme, specific for histone H4, has a pH optimum of 7.3-7.6. The histone-H4-lysine methyltransferase was homogeneous on polyacrylamide gel electrophoresis, while histone-H3-lysine methyltransferase was contaminated with at least three other proteins. Both enzymes are extremely unstable in 50 mM Tricene-HCl buffer (pH 7.5)-1 mM dithiothreitol. However, when they are associated with DNA fragments, they are quite stable. (Supported by N.I.H. Grant NS09725-10)

1. Wallwork, J.C., Quick, D.P. and Duerre, J.A. (1977) J. Biol. Chem. 252, 5977-5980.

26. NON-EXCLUSION OF BACTERIA BY REVERSE OSMOSIS OF DOMESTIC WATER ON NORTH DAKOTA FARMS

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Two reverse osmosis water filtration systems were installed on two farms in rural North Dakota. The systems consisted of a spiral-wound cellulose acetate membrane and an Aramid nylon hollow fine fiber membrane. The systems were designed to provide low mineral content as well as bacteriologically safe water for domestic use at a relatively low cost.

Testing procedures included: a three-tube lactose broth, Most Probable Number test for coliform determination; a three-tube lauryl sulfate broth, Most Probable Number test for coliform determination; an Elevated Temperature test with E. C. Broth for Escherichia coli determination; and a Standard Plate Count on Standard Plate Count agar for total aerobic bacterial determination. Tests were conducted according to Standard Methods.

The standard plate count on the cellulose acetate spiral wound membrane has ranged from 2,270 to 380,000 organisms per ml, while the Aramid nylon hollow fine fiber membrane ranged from 70 to 79,000 organisms per ml. Standard plate counts at the beginning of this research were 25 organisms per ml from the Aramid nylon hollow fine fiber membrane and 517 organisms per ml from the cellulose acetate spiral wound membrane. The present counts are 1,813 organisms per ml from the Aramid nylon hollow fine fiber membrane and 312,000 organisms per ml from the cellulose acetate spiral wound membrane.

The cellulose acetate membrane is subject to hydrolysis by high pH water. Hydrolysis involves the breakdown of cellulose acetate to cellulose and acetic acid, causing loss of membrane integrity. Bacterial exclusion by the hydrolyzed membrane may be severely compromised in addition to providing a substrate (cellulose) for bacterial growth within the membrane. Exclusion of dissolved solids and organics by the cellulose acetate spiral wound membrane may also be compromised and provide additional substrates for bacterial growth within the system. The total dissolved solids from the cellulose acetate spiral wound membrane at the beginning of this research was 170 ppm and is now 550 ppm. The Aramid nylon hollow fine fiber membrane is not subject to hydrolysis but the total dissolved solids have increased from 55 ppm at the beginning of this research to 400 ppm at present.

These data show that the cellulose acetate membrane, which may even enhance bacterial growth, is less efficient than the Aramid nylon membrane for bacterial exclusion.

27. TWO METHODS FOR THE DETECTION OF ROTAVIRUS IN FRESH-WATER SYSTEMS

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Rotaviruses were first described in 1969 as the etiological agent of neonatal calf diarrhea (1). Since then, rotaviruses have been shown to be a cause of gastroenteritis in most other mammals, including man.

Rotaviral infection has been demonstrated to be a major cause of economic loss in the cattle industry (2). Present methods of detection involve the testing of animals showing signs of infection. However, demonstration of rotaviral infection at this point is too late to avoid production losses. For these reasons, two methods for the detection of rotavirus sources in the environment were developed.

For the concentration of rotavirus from sediments: 150 ml of glycine (pH 9) was added to 50 ml of aseptically collected sediment. The mixture was sonicated (2.5 min @ 100 watts), homogenized (5 min @ low in a Waring blender) and centrifuged, first at 6000 x g for 10 min, then at 12,000 x g for 30 minutes. The supernatant was adjusted to a pH of 7. Antibiotics were added. The fluid was dialyzed against polyethylene glycol (5000-7000 molecular weight) for 12 hours. The concentrate was stored at 4°C until tested.

For the concentration of rotavirus from water: 3 sterile gauze pads were folded 4 times, secured with monofilament and suspended in a flowing water source for 6 days. At the end of this time the pad was collected aseptically and transported on ice. The liquid surrounding the pad was adjusted to a pH of 8 and decanted into a centrifuge tube. Ten ml double distilled water was added to the pad, mixed by squeezing and decanted. Next 10 ml of pH 8 calcium-magnesium-free phosphate buffered saline (CMF-PBS) was added, mixed, and decanted. The solution was centrifuged (12,000 x g for 30 min) after which the supernatant was decanted and saved. The pellet was resuspended in 10 ml CMF-PBS and recentrifuged at 12,000 x g for 30 min). The supernatants were mixed, antibiotics added, and pH adjusted to 7. Dialysis against 5000-7000 m.w. polyethylene glycol for 12 hours was performed on the fluid. The concentrate was stored at 4°C until tested.

Detection of rotavirus in both sediment and water concentrates was accomplished by the standard direct fluorescent antibody technique. Due to the nature of the concentrated material, the procedure was slightly modified. Fixation was extended to 10 minutes in -20°C acetone. The fluorescein isothiocyanate conjugated antibodies were diluted 1:2 in CMF-PBS to reduce non-specific fluorescence. Positive, negative, and absorption controls were employed.

Using these techniques, rotavirus has been found in the water of the Sheyenne River of eastern North Dakota, the raw sewage and the effluent from the Moorhead Minnesota waste treatment plant, and in the sediment of a drainage ditch used for cattle watering on the campus of North Dakota State University.

The presence of rotavirus in fresh water and its associated sediments indicates that water may be a mode of transmission for rotavirus.

1. Mebus, C.A., et al. (1969) Agr. Expt. Stn. Research Bull., no. 233, College of Agriculture, Lincoln, Neb.

2. Halvorson, Eldon. (1981) N. Dak. Farm Research 38:6

28. DISEASE EFFICIENCY AND LESION SIZE AS CRITERIA FOR SCREENING BARLEY GENOTYPES FOR RESISTANCE TO NET BLOTCH (PYRENOPHORA TERES)

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Net blotch of barley, caused by the fungus Pyrenophora teres (Died.) Drechsl. is found throughout the world wherever barley (Hordeum vulgare L.) is grown. Under favorable conditions the disease causes considerable reduction in foliage which results in low yields and grain of poor quality (2). To date, the screening of barley genotypes for resistance to P. teres has been based upon the subjective evaluation of lesion size or the disease proportion (area of tissue showing disease symptoms to total leaf area). Genotypes are evaluated 6 to 7 days after a spore suspension of P. teres is applied (1,3).

The disease proportion is a function of not only lesion size but also of lesion number, i.e. lesion size (area) x lesion number = area showing disease symptoms and area showing disease symptoms/total leaf area = disease proportion. More immediate progress towards the development of genotypes resistant to P. teres might be made if disease efficiency (the number of lesions which result in relation to the number of spores applied) was evaluated in addition to lesion size. A lower disease efficiency (DE) on one genotype relative to other barley genotypes would slow the infection rate of P. teres.

It has been reported that the disease proportion of barley inoculated with P. teres increases as the period of leaf wetness (LW) is increased (1). Whether this is due to an increase in lesion size or lesion number is not known. Our purpose was to determine the relative DE of 10 6-row spring barley genotypes and to determine if the duration of LW following inoculation affects primarily lesion size or lesion number.

Spores from 10-day old cultures of P. teres grown on barley leaf agar were applied uniformly to 10-day old seedlings using an artist's airbrush. Inoculated seedlings were placed in a moisture chamber for treatment periods ranging from 6 to 30 hours at a temperature of 20 $\pm$ 1 C. Plants were then transferred to a growth chamber (20 C) and the size and number of lesions were recorded 6 days later. There were 4 replications per treatment, 10 plants per replication. To determine relative DE, plants were inoculated in the same manner as above with the exception that plants were removed from the moisture chamber 15 hours after inoculation and there was a minimum of 25 plants per replication. The experiment was repeated 5 times.

The number of lesions on all genotypes increased as the period of LW was extended (Table 1). Periods of LW between 9 and 30 hours after inoculation did not affect the relative size of lesions on the 5 genotypes, however lesion sizes were smaller when the LW period was 6 hours and were larger if the LW period was greater than 30 hours. Genotypic effects on lesion numbers were more apparent at 15 hours duration, hence this duration of LW was used to determine the relative DE of 10 barley genotypes (Table 2). Although Glenn is considered to be moderately resistant to P. teres based on lesion size, more lesions developed on Glenn. Relative DE was lowest for ND B112.

These experiments suggest that disease proportion is a function primarily of lesion number for periods of LW up to 30 hours after inoculation. Selection of genotypes for both small lesion size and low DE (a more objective evaluation) should result in improved resistance to P. teres.

TABLE 1. EFFECT OF DURATION OF LEAF WETNESS (HOURS) ON THE NUMBER OF LESIONS FOLLOWING INOCULATION WITH PYRENOPHORA TERES.

| | Duration of Leaf Wetness (hours) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Genotype | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 30 |
| Glenn | 3a | 11a | 28a | 50a | 51a | 62a | 72a | 77a |
| Morex | 4a | 9a | 23a | 46ab | 43a | 56a | 62a | 71a |
| Larker | 4a | 6a | 22a | 36bc | 35b | 40b | 44b | 65a |
| Dickson | 2a | 7a | 18a | 27cd | 35b | 38b | 42b | 42b |
| B112 | 2a | 5a | 7b | 23d | 22c | 24c | 26c | 33b |

Values in columns followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$)

1. Berglund, D. and Pederson, V. D. (1981) Phytopathology 71:1115.
2. Dickson, J. G. (1956) Diseases of Field Crops, pp. 37-40. McGraw Hill, New York. 517 p.
3. Holtmeyer, M. G. and Webster, R. K. (1981) Phytopathology 71:881.

TABLE 2. RELATIVE DISEASE EFFICIENCY AND LESION SIZE OF TEN 6-ROW SPRING BARLEY GENOTYPES INOCULATED WITH PYRENOPHORA TERES[1]

| Genotype | Relative Disease Efficiency[2] | Lesion size[3] |
|---|---|---|
| Glenn | 100a | 6.0 |
| Bumper | 92a | 5.7 |
| Morex | 81 b | 6.7 |
| Park | 76 b | 6.0 |
| Larker | 66 c | 7.0 |
| Nordic | 61 c | 5.0 |
| Dickson | 57 c | 5.0 |
| Beacon | 51 d | 5.5 |
| Norbert | 48 d | 3.0 |
| ND B112 | 36 e | 3.0 |

1. Values followed by same letters are not significantly different according to Duncan's multiple range test ($P \leq 0.05$).
2. All values relative to Glenn.
3. Based on subjective rating scale of 1 to 9 where 1 = fleck and 9 = maximum lesion size.

29. KINETIC ASSAY OF CATALYZED PEPTIDE HYDROLYSIS WITH O-PHTHALALDEHYDE REAGENT

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Automatic titration or the use of ninhydrin reagent have been the most popular methods used to study peptide hydrolysis. Recently, ortho-phthalaldehyde (OPTA) has come into wide use as a very sensitive reagent for the fluorometric detection of primary amines (1,2), particularly amino acid analysis. The purpose of this paper is to report how OPTA can be used as a colorimetry reagent to assay the catalytic activity of alpha-chymotrypsin towards the hydrolysis of a dipeptide.

PEPTIDE SYNTHESIS: The dipeptide (N-acetylphenylalanylglycine ethyl ester) was synthesized according to the procedure by Smart, Young, Williams (3,4).

KINETIC ASSAY: OPTA was found to be sensitive to minute quantities of oxygen present in water. Therefore, the master solution of OPTA was made in a nonaqueous media by dissolving 0.8046 g ($6 \times 10^{-2}$ M) of OPTA in 100 ml of absolute methanol in the presence of 2.42 ml mercaptoethanol (3 ml/g OPTA). This solution was found to preserve the OPTA for 2 months. The reagent solution for kinetic assay consisted of first adding 25 ml of twice distilled boiled water to 25 ml of 0.1 M phosphate buffer pH 8.0. This solution was mixed with 25 ml of the master solution containing OPTA, this prevented precipitation, and must be made fresh everyday. OPTA-alpha-amino acids showed a lambda max at 335 nm and glycine ethyl ester (Gly-OEt) was found to have an extinction coefficient of $8.196 \times 10^3$. Solutions of dipeptide or enzyme were made in .1 M phosphate buffer at the desired pH. The rate of hydrolysis of the dipeptide was assayed over approximately a half hour period by removing samples at zero time and then every five minutes. Corrections for background due to the enzyme (E°) and the substrate (S°) were made as follows. The reagent solution of OPTA as described above was used as a blank in the reference cell. Exactly 50 ul of the E°, S°, or Rxn was pipetted into 3 ml of the reagent solution and mixed for 15 s in the sample cell. The maximum absorbance of these solutions at 335 nm were read and recorded within 150 to 300 s. The absorbance due to the release of product, Gly-OEt, is then equal to A(Gly-OEt) = Arxn-Ae-As. Where Arxn, Ae, and As are the absorbance of the reaction, enzyme, and substrate respectively. Thus, the rate at any time (t) may be found. For comparision, we performed similar assays by titrimetry in the presence of .1 M KCl. The substrate concentrations (S°) in both methods were varied between $5 \times 10^{-3}$ M to $2.7 \times 10^{-4}$ M, the enzyme concentration was kept constant at $4.03 \times 10^{-5}$ M. A correction was made at each pH for the absorption of hydrogen-ion by the alpha-amino group of Gly-OEt. The results using Lineweaver-Burk plots for both methods compare very favorably as shown in the Table below.

APPARENT RATE CONSTANTS AND MICHAELIS CONSTANTS FOR ACETYL PHENYLALANYL GLYCINE ETHYL ESTER AND ALPHA-CHYMOTRYPSIN IN 0.1 M KCl

| | COLORIMETRY METHOD | | TRITRATION METHOD | |
|---|---|---|---|---|
| pH | $k_2 \times 10^2 (s^{-1})$ | km $\times 10^2$(M) | $k_2 \times 10^2 (s^{-1})$ | km $\times 10^2$(M) |
| 7.00 | 3.01 ± 0.17 | 1.00 ± 0.06 | 2.99 ± 0.26 | 1.14 ± 0.10 |
| 7.10 | 3.21 ± 0.18 | 0.60 ± 0.03 | 3.27 ± 0.23 | 1.20 ± 0.09 |
| 7.40 | 4.25 ± 0.25 | 1.10 ± 0.06 | 4.20 ± 0.23 | 1.01 ± 0.06 |
| 7.60 | 5.29 ± 0.50 | 1.20 ± 0.12 | 5.13 ± 0.35 | 1.14 ± 0.08 |
| 7.70 | 6.02 ± 0.79 | 1.51 ± 0.20 | 6.06 ± 0.79 | 1.62 ± 0.21 |
| 7.80 | 5.09 ± 0.38 | 1.23 ± 0.09 | 5.30 ± 0.52 | 1.27 ± 0.13 |
| 8.00 | 4.04 ± 0.34 | 0.91 ± 0.08 | 4.31 ± 0.32 | 1.04 ± 0.08 |
| 8.10 | 3.83 ± 0.41 | 1.05 ± 0.11 | 3.75 ± 0.32 | 1.22 ± 0.10 |
| 8.20 | 3.33 ± 0.28 | 0.67 ± 0.05 | 3.42 ± 0.29 | 0.78 ± 0.07 |
| 8.40 | 2.51 ± 0.30 | 1.11 ± 0.13 | 2.45 ± 0.30 | 0.65 ± 0.08 |
| 9.00 | 2.37 ± 0.30 | 0.35 ± 0.04 | 2.07 ± 0.28 | 0.82 ± 0.11 |

ADVANTAGES OF COLORIMETRY METHOD

(1) Assays may be done using a UV spectrophotometer; these are readily available.
(2) There is no $CO_2$ interference as in titrimetry.
(3) A hydrogen-ion correction factor is not required at each pH.
(4) Assays may be done conveniently over a wider range of pH values.
(5) Only small quantities of enzyme and substrate are needed.
(6) OPTA reagent is easier to prepare than ninhydrin, it neither requires a closed system nor a high temperature.

DISADVANTAGES: This method may not be feasible for fast reactions, but with minor modification a stop flow technique may be used. Temperature may effect the development of the OPTA color.

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30. INHIBITION STUDIES OF THE TRYPSIN-CATALYZED HYDROLYSIS OF L-LYSINE METHYL ESTER

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In nature, trypsin is a specific proteolytic enzyme responsible for the cleavage of protein at points with basic side chains. Our laboratory has taken trypsin out of its natural environment and have observed along with others the activity of trypsin with substrates other than protein molecules. Trypsin has a negatively charged carboxyl group in the active site, which makes the positively charged lysine methyl ester (Lys-OMe) molecule a suitable substrate (1).

Our research has focused on the effect of surface interactions on the activity and inhibition of trypsin. Crystallographic studies (2) suggest that soybean trypsin inhibitor (STI) binds to the active site, which implies competitive inhibition. Our results reveal inhibition to be more non-competitive than competitive with both native and chemically modified enzymes.

Using the procedure of Johnson et al (3), the surface carboxyl groups of trypsin were chemically modified with glycine ethyl ester (Gly-OEt). The rate of hydrolysis of the substrate, Lys-OMe, was measured at pH 6 by following the release of hydrogen-ion by automatic titration. Readings were taken every 30 s with an accuracy for ± 0.001 ml of the volume of NaOH added. Compared to native trypsin, the modified enzyme retained approximately 10% of its original activity towards Lys-OMe.

Both native and modified trypsin were incubated for 24 hr with known amounts of STI. In each case, Lineweaver-Burk plots of 1/rate versus 1/substrate (Lys-OMe) concentration gave a common intercept on the negative abscissa, which indicates non-competitive. Using methods of Laidler (4), the non-competitive inhibition constants, $K_i$, were determined by plotting the slopes, from Lineweaver-Burk plots at various concentrations of inhibitor, versus inhibitor concentration. The values of $K_i$ for native and modified trypsin were determined to be $5.29 \times 10^{-8}$ M and $1.82 \times 10^{-6}$ M, respectively.

Since $K_i$ is defined as: $K_i = [E][I]/[EI]$ where [E], [I] and [EI] are the concentrations of enzyme, inhibitor and enzyme-inhibitor complex, respectively, the smaller the $K_i$ value the more stable is the enzyme-inhibitor complex. Therefore, the smaller value of $K_i$ for the native enzyme indicates that it forms a more stable complex with STI than does the modified enzyme.

Chemical modification at pH 4 with Gly-OEt does not block interior carboxyls (3). Trypsin has three interior carboxyls (5), two of which have been implicated to be involved in catalysis. Our results suggest that surface carboxyls (anionic groups) affect both catalytic efficiency and inhibitor binding. Modified trypsin retains only 10% of its catalytic activity and its enzyme-inhibitor complex constant, $K_i$, is only 3%, when compared to the native enzyme.

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31. SULFUR PROMOTED HIGH TEMPERATURE REACTIONS OF N,N-DIMETHYLANILINE

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The presence of sulfur in the form of hydrogen sulfide ($H_2S$) or elemental sulfur (S°) has been known to increase the rate of nitrogen removal and promote the rate of reduction of the nitrogen-containing aromatic ring in heterocyclic model compounds (1,2). However, there is a large hydrogen requirement for denitrogenation both in the absence and presence of sulfur.

In the present study, $H_2S$ and S° are added to N,N-dimethylaniline (DMA) to investigate the cleavages of the C-N bonds at 425°C. DMA is a valuable model for denitrogenation study because it posesses two types of C-N bonds. The major bond cleavage observed is that of the alkyl C-N bond, and the products of this bond rupture are N-methylaniline (NMA) and aniline (3) (Table 1). The aryl C-N bond ruptures at a rate comparable to the aliphatic C-N bond cleavage under an atmosphere of $H_2$ at this temperature in the absence of sulfur compounds. The addition of $H_2$ to the reaction of DMA with $H_2S$ or S° causes a decrease in the amount of aniline formed and an increase in the NMA yield. A study in which the reaction time was varied demonstrates that aniline is formed via NMA. Elemental S° is more active than $H_2S$ in the demethylation of DMA. The maximum yield of aniline is obtained from DMA with three gases present simultaneously: CO, $H_2O$ and $H_2S$. At the reaction temperature, water is above its critical point. A preliminary gas analysis indicates that the methyl groups on DMA appear in the product mixture as methane and carbon dioxide. The overall stoichiometry of the DMA reaction with S° at 425°C is represented in the equation 1.

$$PhNMe_2 + 2S° + 2H_2O \longrightarrow PhNH_2 + CH_4 + CO_2 + 2H_2S \qquad (1)$$

Table 1

Reactions of N,N-Dimethylaniline with S° and its Precursors at 425°C

| | Products (Mole %) | |
|---|---|---|
| Condition | NMA | $PhNH_2$ |
| $H_2S$, $H_2O$ | 44.2 | 29.8 |
| S°, $H_2O$ | 10.1 | 54.1 |
| $H_2$, $H_2S$, $H_2O$ | 52.2 | 11.9 |
| S°, $H_2$, $H_2O$ | 36.3 | 40.3 |
| CO, $H_2O$, $H_2S$ | <5.6 | 76.1 |

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# OBITUARIES (1981-82)

## Donald W. Bolin (1897-1981)

Donald W. Bolin died April 4, 1981 in Fargo.

Bolin was born May 4, 1897. He obtained his undergraduate education in Wisconsin, and was awarded the bachelor's degree with a major in agricultural chemistry from the University of Idaho in 1932. After teaching chemistry and physics in high school in Wisconsin, he joined the faculty of the University of Idaho in 1929. He came to NDSU in 1945 as an associate nutritionist in the Agricultural Experiment Station. After 22 years of research in animal nutrition, Bolin retired from NDSU in 1967 as Associate Professor of Animal Science. He joined the Academy of Science in 1946.

Professor Bolin married Margaret Knudson in 1929. His wife survives him, now residing in their home in Fargo.

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| JOHNSON ARNOLD R | 1966MINOT STATE COLLEGE | MINOT | ND58701 |
| JOHNSON, ROBERT E | 1969RR 1 BOX 20 | FARGO | ND58103 |
| JOHNSON, A WM | 1961416 TERRACE DR | GRAND FORKS | ND58201 |
| JOHNSON, PHYLLIS E | 1978HUMAN NUT LAB | GRAND FORKS | ND58202 |
| JONES, MICHAEL L | 1981BOX 8213 UNIV STATION | GRAND FORKS | ND58202 |
| +JORDE, DENNIS | 1979240 NUTTING HALL U OF ME | ORONO | ME04469 |
| KANNOWSKI PAUL B | 1960BIOLOGY DEPT UND | GRAND FORKS | ND58202 |
| KANTRUD, HAROLD A. | 1980ROUTE 7 | JAMESTOWN | ND58401 |
| KARNER FRANK R | 1963GEOLOGY DEPT UND | GRAND FORKS | ND58202 |
| KEHEW, ALAN E | 1979315 LEONARD HALL UND | GRAND FORKS | ND58202 |
| KELLEHER JAMES J | 1972MICROBIOLOGY DEPT UND | GRAND FORKS | ND58202 |
| KEMP, JUDY B | 1978748 VIKING DR | VALLEY CITY | ND58072 |
| KIESLING RICHARD | 1961PLANT PATH DEPT NDSU | FARGO | ND58102 |
| KIRBY, DON | 1980BOTANY DEPT NDSU | FARGO | ND58103 |
| KLEVAY LESLIE M | 1973223 27TH AVE S | GRAND FORKS ND | 58201 |

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| KNOBLICH, JEROME | 1958 | BOX 63 | ELDRIDGE | ND58435 |
| KNUDSON, CURTIS L | 1978 | DCE ENGR RSCH/BOX 20 UND | GRAND FORKS | ND58202 |
| KOCH, FRANK | 1979 | 315 SATURN DRIVE | BISMARCK | ND58501 |
| *KOENKER, WM. E. | 1958 | 6403 GARRET RD | DURHAM | NC27707 |
| *KOHANOWSKI, N | 1949 | GEOLOGY DEPT UND | GRAND FORKS ND | 58202 |
| KOLSTOE RALPH H | 1962 | PSYCHOLOGY DEPT UND | GRAND FORKS | ND58202 |
| +KOPONEN, MARK A. | 1975 | BOX 381 | MINOT | ND58701 |
| +KORDONOWY, RHODA | 1981 | HARRIS HALL NDSU | FARGO | ND58105 |
| KRAFT DONALD J | 1970 | BEMIDJI STATE COLLEGE | BEMIDJI | MN56601 |
| KRESS WARREN D | 1958 | GEOGRAPHY DEPT NDSU | FARGO | ND58102 |
| +KRUGER, ROBERT M | 1982 | DEPT OF ENTOMOLOGY NDSU | FARGO | ND58105 |
| *KRUSCHWITZ, EARL H | 1947 | 431 6TH ST SW | VALLEY CITY | ND58072 |
| KUBE WAYNE R | 1949 | CHEM ENG DEPT UND | GRAND FORKS | ND58202 |
| KUCERA HENRY L | 1966 | AGR ENG DEPT NDSU | FARGO | ND58102 |
| +KUKLA, JEFF L | 1982 | 161 JOHNSON HALL, NDSU | FARGO | ND58105 |
| *LAIRD WILSON | 1941 | 1807 WAINWRIGHT DR | RESTON | VA22070 |
| LAMBETH, DAVID | 1979 | 1909 20TH AVE S | GRAND FORKS | ND58201 |
| LANA EDWARD P | 1957 | HORTICULTURE DEPT NDSU | FARGO | ND58102 |
| +LARSON, PAUL | 1981 | ENTOMOLOGY DEPT NDSU | FARGO | ND58105 |
| LARSON OMER R | 1964 | BIOLOGY DEPT UND | GRAND FORKS | ND58202 |
| LEAGUE, LARRY | 1981 | DICKINSON STATE COLLEGE | DICKINSON | ND58601 |
| LECHNER, TERESA | 1982 | 715 N 40TH #204 | GRAND FORKS | ND58201 |
| LEFEVER, RICHARD D | 1980 | GEOLOGY DEPT UND | GRAND FORKS | ND58202 |
| LEITE, M B | 1981 | PO BOX 1822 | MINOT | ND58701 |
| LI KAM W | 1968 | MECHANICAL ENG DEPT NDSU | FARGO | ND58102 |
| LIPP, WILLIAM V | 1972 | 3024 N 10TH ST #19 | FARGO | ND58102 |
| +LOBDELL, FREDERICK | 1980 | GEOLOGY DEPT., UND | GRAND FORKS | ND58202 |
| +LOCKER, HOWARD J. | 1982 | P.O. BOX 209 | DRAKE | ND58736 |
| LOENDORF, LAWRENCE L | 1973 | ANTHRO DEPT UND | GRAND FORKS | ND58202 |
| LOGUE, MARSHALL W | 1979 | DEPT OF CHEMISTRY NDSU | FARGO | ND58105 |
| LORENZ RUSSELL J | 1962 | N GREAT PLAINS RES CNTR | MANDAN | ND58554 |
| LOWE, STEPHEN | 1981 | DIV OF SCIENCE & MATH MSC | MINOT | ND58701 |
| *LOW, FRANK N. | 1964 | 2511 ST CHARLES AVE | NEW ORLEANS | LA70301 |
| +LUNN, ERIC | 1981 | MANITOBA AVENUE APT #4 | GRAND FORKS | ND58201 |
| +LURA, CHARLES L | 1981 | 1014 15TH ST N | FARGO | ND58102 |
| MACCARTHY, RONALD F | 1968 | 1116 19TH AVE S #18 | GRAND FORKS | ND58201 |
| +MACK, STEVEN | 1981 | BOTANY DEPT, NDSU | FARGO | ND58105 |
| MADHOK OM P | 1967 | MINOT STATE COLLEGE | MINOT | ND58701 |
| *MAGNUSSON, ADELYNN M | 1951 | 1703 S 20TH ST | GRAND FORKS | ND58201 |
| MARKELL CLARK | 1972 | MINOT ST COLLEGE | MINOT | ND58701 |
| +MARTIN, GWEN | 1981 | BOX 122 | WILLISTON | ND58801 |
| MARTIN DEWAYNE C H | 1962 | 2104 7TH AVE NW | MINOT | ND58701 |
| MARWIN RICHARD M | 1949 | MICROBIOLOGY DEPT UND | GRAND FORKS | ND58202 |
| MASON, HARRY | 1951 | P.O. BOX 1116 | JAMESTOWN | ND58401 |
| +MASTEL, JEROME A. | 1980 | BOTANY DEPT., NDSU | FARGO | ND58105 |
| MATHSEN, DON | 1970 | MECH ENGR DEPT UND | GRAND FORKS | ND58202 |
| MATTHIES DONALD L | 1973 | ANATOMY DEPT UND | GRAND FORKS ND | 58202 |
| MAYER, JANET F | 1982 | 1602 N 10TH ST | FARGO | ND58102 |
| MCDONALD CLARENCE E | 1965 | CEREAL TECHNOLOGY NDSU | FARGO | ND58102 |
| +MCDONNELL, TIMOTHY | 1978 | ANATOMY DEPT UND | GRAND FORKS | ND58202 |
| MCKENNA, MICHAEL G | 1976 | 1601 S COLUMBIA | BISMARCK | ND58501 |
| MCMAHON KENNETH J | 1970 | BACTERIOLOGY DEPT NDSU | FARGO | ND58102 |
| *MCMILLAN WILLIAM W | 1947 | 407 7TH ST W | GRAFTON | ND58237 |
| *MELDRUM, ALAN | 1957 | 512 COLUMBIA RD | GRAND FORKS | ND58201 |
| +MERCER, STEPHAN | 1982 | 509 10TH STREET NE | MINOT | ND58701 |
| +MERCURY, MICHAEL G | 1979 | 615 39TH ST N #204A | GRAND FORKS | ND58201 |
| MERRILL, STEPHEN D. | 1982 | N.G.P.R.C. BOX 459 | MANDAN | ND58554 |
| MESSENGER, THEO | 1976 | PHIL DEPT UND | GRAND FORKS ND | 58202 |
| MEYER DWAIN W | 1970 | AGRONOMY DEPT NDSU | FARGO | ND58102 |
| MILLER, JAMES E | 1964 | 3807 MICHAEL LANE | GLENVIEW | IL60025 |
| MILLER, DAVID | 1979 | ENERGY RESEARCH CTR UND | GRAND FORKS | ND58202 |
| MITCHELL E N | 1960 | 220 GLENHILL LN | CHAPEL HILL | NC27514 |
| MITCHELL, MARTHA J. | 1982 | P.O. BOX 8011, UNIV STAT | GRAND FORKS | ND58202 |
| MOLLAND, GIBBS | 1979 | 1205 N 22ND ST | BISMARCK | ND58501 |
| MONTGOMERY, GEORGE G | 1979 | BOX 76 | MANVEL | ND58256 |
| +MOORE, MARGARET M | 1981 | BOX 16 STEVENS HALL NDSU | FARGO | ND58105 |
| MOORE WILLIAM L | 1973 | VALLEY CITY STATE COLLEGE | VALLEY CITY ND | 58072 |
| +MORLOCK, BRADLEY J | 1982 | 1530 - NORTH 9TH ST | FARGO | ND58102 |
| MOWERY, GARRY B | 1979 | 334 FOREST AVE N | FARGO | ND58102 |
| MUNSKI, DOUGLAS | 1981 | UND GEOGRAPHY DEPT | GRAND FORKS | ND58202 |
| +MURPHY, KATHLEEN A | 1979 | MICROBIOLOGY DEPT UND | GRAND FORKS | ND58202 |
| MUTH, EDITH ANN | 1980 | | ARDOCK | ND58213 |
| NALEWAJA JOHN D | 1963 | AGRONOMY DEPT NDSU | FARGO | ND58102 |
| *NEEL, JOE K | 1969 | BICLOGY DEPT UND | GRAND FORKS | ND58202 |
| NELSON, HARVEY K | 1967 | 10515 KELL AVE S | BLOOMINGTON | MN55437 |
| +NELSON, WALLACE T | 1981 | 2217 10TH ST N | FARGO | ND58102 |
| *NELSON C N | 1972 | NDSU BOTTINEAU BRANCH | BOTTINEAU | ND58318 |
| NELSON DELBERT R | 1961 | 218 E OWASSO LN | ST PAUL | MN55112 |
| NELSON DENNIS R | 1964 | MET & RAD RES LAB NDSU | FARGO | ND58102 |
| NIELSEN, FORREST H | 1974 | USDA HUMAN NUTR LAB UND | GRAND FORKS | ND58202 |
| NILSON, DAVID J | 1981 | BOX 337 | STANTON | ND58571 |
| NORDLIE ROBERT C | 1962 | BIOCHEMISTRY DEPT UND | GRAND FORKS | ND58202 |
| NOYCE, MICHAEL D | 1981 | 1206 ROCK CANYON DR | KATY | TX77450 |
| NYREN, PAUL | 1980 | DICK. ENGR. STA., BX 1117 | DICKINSON | ND58601 |
| O'CONNELL JAMES W | 1973 | 535 8TH AVE SW | VALLEY CITY ND | 58072 |
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| OLSON, EDWIN S | 1981223 CIRCLE HILLS DR | GRAND FORKS | | ND58201 |
| ORING LEWIS # | 1971BIOLOGY DEPT UND | GRAND FORKS | | ND58202 |
| ORR, PAUL H. | 19821010 RIVER DR SE | EAST GRAND FORKS | | MN56721 |
| ORTH, JAMES A | 1970C.P. 1076 SCHEFFERVILLE | QUEBEC, CANADA | G0G2T0 | |
| OWENS THOMAS C | 1970CHEM ENGR DEPT UND | GRAND FORKS | | ND58202 |
| OWEN, JOHN B | 1966BIOLOGY DEPT UND | GRAND FORKS | | ND58202 |
| *OWEN, SHUBEL D | 19588000 PANORAMA RD | PANORA IA | | 59216 |
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| PARK, CHUNG S | 1979DEPT OF ANIMAL SCI NDSU | FARGO | | ND58105 |
| PARMAR, SURENDRA | 1977PHYS & PHARM UND | GRAND FORKS ND | | 58202 |
| PARRILL, CLARK C | 1977BOX 19 NORTHLAND TEL CT | BOTTINEAU | | ND58318 |
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| PEDERSON A ROBERT | 1972414 20TH AVE N | FARGO | | ND58102 |
| PEDERSON VERNYL D | 1968PLANT PATHOLOGY NDSU | FARGO | | ND58102 |
| PERSON, DONALD A | 19613022 WINSLOW | HOUSTON | | TX77025 |
| PETERKA JOHN J | 1968ZOOLOGY DEPT NDSU | FARGO | | ND58102 |
| PFISTER, PHILIP C | 196830 MEADOWLARK LANE | FARGO | | ND58102 |
| PRATT GEORGE L | 1961AGRICULTURAL ENGR NDSU | FARGO | | ND58102 |
| PRESZLER, DALE A | 19781717 E INTERSTATE AVE | BISMARCK | | ND58501 |
| PRUNTY, LYLE | 1981318 23RD AVE N | FARGO | | ND58102 |
| RAND ROGER W | 1975542 5TH AVE SW | VALLEY CITY ND | | 58072 |
| *RATHMANN, FRANZ H | 1955NDSU CHEM DEPT | FARGO | | ND58102 |
| RAWAT, BANMALI | 1992DEPT ELECTRICAL ENG UND | GRAND FORKS | | ND58202 |
| RAY PAUL D | 1968BIOCHEMISTRY DEPT UND | GRAND FORKS | | ND58202 |
| REICHMAN GEORGE A | 1962306 6TH AVE NW | MANDAN | | ND58554 |
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| REIFF, THEODORE R | 1978DEPT OF MEDICINE UND | GRAND FORKS | | ND58202 |
| +REISKIND, JEREMY | 1978GEOLOGY DEPT UND | GRAND FORKS | | ND58202 |
| RICHARDSON, J L | 19781245 N 9TH | FARGO | | ND58102 |
| RIES, RONALD E | 1979908 2ND AVE NW | MANDAN | | ND58554 |
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| *ROGLER GEORGE A | 1962BOX 459 | MANDAN ND | | 58554 |
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| RUSTAN, JERRIL H | 1979BOX 140 DSC | DICKINSON | | ND58601 |
| *SANDAL, PAUL | 1955AGRONOMY DEPT NDSU | FARGO | | ND58105 |
| *SANDS F H | 1946COLL OF CHEMISTRY NDSU | FARGO ND | | 58102 |
| SAPGEANT ALAN B | 1972N PRAIRIE WILDLIFE RES | JAMESTOWN | | ND58401 |
| SAUMUR JEAN H | 1975PATHOLOGY DEPT UND | GRAND FORKS ND | | 58202 |
| SCHAFER, JOHN E | 1979140 11TH AVE W #1 | DICKINSON | | ND58601 |
| SCHEIBE, PAUL | 19603 SHIRLEY LANE | WOODSIDE | | CA94062 |
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| SCHMIDT, CLAUDE H | 1980SEA-AR RM 419 FED BLDG | FARGO | | ND58102 |
| SCHNEIDER FREDERICK | 1973SOC & ANTHRO DEPT UND | GRAND FORKS ND | | 58202 |
| SCHOBERT, HAROLD | 1978DOE ENGR RSCH BOX 20 UND | GRAND FORKS | | ND58202 |
| SCHULZ, JOHN T. | 1960ENTOMOLOGY DEPT NDSU | FARGO | | ND58105 |
| SCHWERT, DONALD P | 1981GEOLOGY DEPARTMENT NDSU | FARGO | | ND58102 |
| SCOBY DONALD R | 1968BOTANY DEPT NDSU | FARGO | | ND58102 |
| SEABLOOM ROBERT W | 1962BIOLOGY DEPT UND | GRAND FORKS | | ND58202 |
| +SEARS, SHEILA | 1977MRR LAB NDSU | FARGO ND | | 58102 |
| +SEIDEL, JIMMY LEE | 1981UNIV OF UTAH DEPT OF CHEM | SALT LAKE CITY | | UT84112 |
| SEVERSON ARTHUR L | 1970U S BUREAU OF MINES UND | GRAND FORKS | | ND58202 |
| SEVERSON D E | 1949CHEMICAL ENGR DEPT UND | GRAND FORKS | | ND58202 |
| SEVERSON ROLAND G | 1958CHEMISTRY DEPT UND | GRAND FORKS | | ND58202 |
| SHELTON, DAVID R | 1978BOX 5195 NDSU | FARGO | | ND58102 |
| SHELVER, WILLIAM | 1979COLLEGE OF PHAR NDSU | FARGO | | ND58105 |
| SHUBERT L ELLIOT | 1974BIOLOGY DEPT UND | GRAND FORKS ND | | 58202 |
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| SLEEPER BAYARD P | 1952BACTERIOLOGY DEPT NDSU | FARGO | | ND58102 |
| *SMITH, GLENN S | 19301115 N 14TH ST | FARGO | | ND58102 |
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| STACK, ROBERT W. | 1980PLANT PATH.. NDSU | FARGO | | ND58105 |
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| +STOTTS, BRYAN | 1981BOX 4 | MEDORA | | ND58645 |
| STOY, W. MICHAEL | 19801826 N. BELL ST. | BISMARCK | | ND58501 |
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| SUGIHARA JAMES M | 1965GRADUATE SCHOOL NDSU | FARGO ND | | 58102 |
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| +TAYLOR, RAYMOND | 1980PLANT PATHOLOGY NDSU | FARGO | | ND58105 |
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| VAN DEUSEN JAMES L | 1975USFS SHELTERBELT LAB | BOTTINEAU ND | 58318 |
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| WALLWORK, JAMES C | 1979HUMAN NUTRITION LAB UND | GRAND FORKS | ND58202 |
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| WANEK WALLACE J | 1965RT 1 BOX 307 | BEMIDJI | MN56601 |
| *WARDNER, C ARTHUR | 19583518 CHERRY ST | GRAND FORKS | ND58201 |
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| WICKS ZENO W | 1974POLYMRS & COAT DPT NDSU | FARGO ND | 58102 |
| WIEDERANDERS R E | 1968HARMON PARK CLINIC | WILLISTON | ND58801 |
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| WILLIAMS, DEAN | 1981305 4TH ST SW | DICKINSON | ND58601 |
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| +WILLIAMS, RICHARD L | 19812333 20 1/2 AVE S, #22 | FARGO | ND58103 |
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| WILSON, RUSSELL H | 19666218 WALNUT HILL LN | DALLAS TX | 75230 |
| +WINCZEWSKI, LARAMIE | 197712614 VINDON DR | HOUSTON | TX77024 |
| WINGER, MILTON | 1973MATH DEPT UND | GRAND FORKS | ND58202 |
| WITZ RICHARD L | 1960AGRI ENGR DEPT NDSU | FARGO | ND58102 |
| +WOLFSON, ALAN | 1979530 TULANE DR #206 | GRAND FORKS | ND58201 |
| WOLF, EDWARD G | 19771436 TIPPERARY | BOULDER | CO80303 |
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| WORTHAM KENNETH E | 1975BIOL DEPT-STATE COLLEGE | MAYVILLE ND | 58257 |
| WOSICK, FREDERICK D | 1975569 SUNSET PLACE | BISMARCK | ND58501 |
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| WYMORE, ROBERT W | 1977350 1ST ST NW | MAYVILLE | ND58257 |
| ZIEMAN DALE M | 1961DICKINSON ST COLLEGE | DICKINSON | ND58601 |
| +ZOELLNER, ROBERT | 1978CHEM DEPT KS STATE UNIV | MANHATTAN | KS66506 |
| ZOGG, CARL | 1979PHYSIOLOGY DEPT UND | GRAND FORKS | ND58202 |
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