Proceedings of the NORTH DAKOTA Academy of Science

April 1981 Volume 35

THE PROCEEDINGS OF THE NORTH DAKOTA ACADEMY OF SCIENCE is published annually by the Academy. This issue is published with the support of the University of North Dakota, North Dakota State University, and Valley City State College, the provision of which is gratefully acknowledged. The Proceedings contains communications representing papers submitted for oral presentation at the April annual meeting of the Academy, and appear in April of each year. Printing is by the University of North Dakota Press. Instructions for submission of communications are obtained by writing to the secretary of the Academy (see below).

SUBSCRIPTIONS: Members of the Academy receive the Proceedings. Annual dues are $10.00 for regular members and $5.00 for student members. Copies of the Proceedings may be purchased at $5.00 per copy. Correspondence concerning subscriptions, as well as instructions to authors and other related matters, should be directed to: North Dakota Academy of Science, Office of the Secretary, Box 8123, University Station, Grand Forks, North Dakota 58202.

PROCEEDINGS
of the
NORTH DAKOTA
ACADEMY OF SCIENCE

Volume 35 April 1981

NORTH DAKOTA ACADEMY OF SCIENCE

(Official State Academy; founded December, 1908)

1980-81

73rd ANNUAL MEETING

April 24-25, 1981

Dickinson, North Dakota

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 communications presented in the Professional section of the 1981 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. Professional communications are numbered 1-46.

The second 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. Collegiate communications are numbered 47-55.

Readers may locate papers by presentation number 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 two 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 test 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 of 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.

1. A COMPARISON OF FERTILIZATION AND INTERSEEDING ON NATIVE MIXED GRASS PRAIRIE IN WESTERN NORTH DAKOTA

Paul E. Nyren*, Harold Goetz, and Dean E. Williams, Botany Dept.,
Dickinson Experiment Station, Box 1117, Dickinson, N.D. 58601

The application of plant nutrients (fertilization) and the introduction of seed into an established vegetative cover (interseeding) are two important range improvement practices. Much work has been done to evaluate the effect of these improvement practices on different vegetative communities.

In 1969 a study was undertaken at the Dickinson Experiment Station to evaluate the forage production and species composition changes effected by the application of various rates of fertilization and by interseeding different species of grasses and legumes. The study site was located on silty loam soils supporting a native mixed grass plant community.

The fertilization study consisted of a randomized block design with 12 treatments, 3 replications, and plots measuring 9 x 30 M. The treatments included various combinations of nitrogen (N), phosphorus (P), and potassium (K), nitrogen and phosphorus alone; heavy one-time nitrogen applications; and alternate year nitrogen applications. The interseeding trial consisted of a randomized block design including 11 treatments, 3 replications, and plots measuring 15 x 46 M. The treatments included interseeding crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.); smooth brome (*Bromus inermis* Leyss. L); green needlegrass (*Stipa viridula* Trin.); Russian wildrye (*Elymus junceus* Fisch.); Travois, Ladak and Vernal alfalfa (*Medicago sativa* L.); Eski sainfoin (*Onobrychis viciaefolia* Scop.) and Emerald crownvetch (*Coronilla varia* L.). In addition to the above species, plots treated with the machine but not seeded (check-plowed) and 1 set left untreated as a check were also included.

Table 1. Average yields (kg/ha) for the interseeding-fertilizer trial from 1971-1978.

Treatments	Mid grasses	Short grasses	Perennial forbs	Annual forbs	Interseeded species	Total production
Crested wheatgrass	1232g 1/	542def	398bcdef	59bc	278c	2507d
Smooth brome	1790bcd	408f	270gh	27c	285c	2779cd
Check interseeded	1323fg	880a	367cdefgh	35bc	-	2606d
Check fertilized	1438efg	793ab	244h	51bc	-	2528d
Check plowed	1493defg	465ef	359defgh	42bc	232c 2/	2587d
Ladak	1841bc	426f	324fgh	33c	953b	3572a
Green needlegrass	1484efg	515def	436abcde	67b	89d	2589d
Travois	1605cdef	217g	254h	52bc	1444a	3572a
Vernal	1722bcde	421f	247h	33c	1039b	3463a
112N 3/	1887bc	601cde	543a	55bc	-	3089bc
112N 4/	2508a	535def	495ab	37bc	-	3499a
224K	1330fg	891a	306fgh	63bc	-	2591d
224N	1674bcde	604cde	296fgh	49bc	-	2627d
336N	1977b	701bc	389bcdefg	35bc	-	3092bc
448N	1984b	594cde	477abcd	34bc	-	3091bc
56P	1245g	778ab	383bcdefg	136a	-	2536d
56P75N	2432a	654bcd	454abcd	43bc	-	3584a
56P75N224K	2475a	422f	470abcd	50bc	-	3391ab
75N 3/	1622cdef	645bcd	495abc	28c	-	2795cd
75N 4/	2274a	523def	488abc	36bc	-	3304ab

1/ Values in the same column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.
2/ Interseeded species yields for the check-plowed treatment are for the vegetation re-invading the center 2 inches of the interseeded furrow.
3/ Applied every other year.
4/ Applied every year.

Average forage production for the 8-year trial was highest for the treatment fertilized with 56 kg/ha P and 75 kg/ha N every year. This was not significantly different (at the 5% level) from the Ladak, Travois and Vernal alfalfa interseeded or the plots receiving annual applications of 112 kg/ha N.

The Ladak, Vernal and Travois alfalfa interseeded plots were the highest producing in the interseeding trial. In 1971 and 1972 their production was less than the high N treatments. In 1973 and 1975-1978 their yields were not significantly different from the highest yielding fertilized treatments.

The application of 75 or 112 kg/ha N with or without P changed the mixed grass community to one composed mainly of single stocked cool season grasses. The shortgrass component of the community was effected differently by the fertilization than the interseeding treatments. On the interseeded plots, shortgrass production declined the first year due to destruction by the interseeder and slowly recovered on all but the alfalfa and smooth brome treatments. On the plots given yearly application of N the shortgrass production slowly declined during the 8-year trial. Perennial forb production was higher on plots receiving N fertilizer than on the interseeded plots. Annual forb production remained nearly the same on all treatments in both trials with the exception of the 56 kg/ha P treatment which nearly tripled the production.

2. PRAIRIE CHICKEN HABITAT USE ON THE SHEYENNE NATIONAL GRASSLANDS, NORTH DAKOTA

L.L. Manske* and W.T. Barker
Botany Department, North Dakota State University
Fargo, N.D. 58105

The north unit of the Sheyenne National Grasslands (SNG) includes 27,244 hectares of federal land and 25,593 hectares of private land. This area has the largest population of prairie chicken (Tympanuchus cupido pinnatus) in North Dakota and it is steadily increasing. This increase has been attributed to the wise range management used in cooperation by the U.S. Forest Service and the Sheyenne Valley Grazing Association under the multiple-use concept. Detailed data on prairie chicken habitat use through the entire year is needed for future "fine tuning" of this range management.

Prairie chicken habitat use by actual observation has been recorded from March 1975 to February 1981. The habitat associations and types on the Sheyenne National Grasslands have previously been described quantitatively by topographic, edaphic and vegetative characteristics with acreages of each (1). The Robel habitat use index (2) (% of bird locations/% of study area) was used to indicate relative habitat usage. A habitat use index greater than 1.0 indicates that the selection for that habitat type is greater than expected if the bird exhibited no preference. A value less than 1.0 indicates selection against a habitat type. A value of zero indicates avoidance of that habitat type.

Table 1. Prairie chicken habitat use index.

Habitat Association Habitat Type	% of SNG	Spring (n=3650) 1 Apr-15 Jun			Summer (n=638) 16 Jun-31 Aug		Fall (n=780) 1 Sep-15 Nov	Winter (n=3524) 16 Nov-31 Mar
		courtship	nest	nonnest	brood	nonbrood		
Hummocky Sandhills								
Upland Grassland	26.34	1.66	0.0	0.94	1.27	0.94	0.55	0.14
Midland Grassland	12.68	3.35	6.45	4.57	3.12	3.94	0.42	0.34
Lowland Grassland	9.76	0.76	0.0	1.19	1.12	1.69	0.17	0.01
Cropland	1.36	0.95	13.37	0.0	1.41	6.06	11.13	6.11
Shelterbelt	0.03	0.0	0.0	0.0	0.0	0.0	0.0	55.67
Deltaic Plain								
Upland Grassland	0.01	0.0	0.0	290.00	0.0	0.0	0.0	295.00
Midland Grassland	11.09	0.40	0.0	0.26	0.46	0.0	1.71	0.99
Lowland Grassland	4.13	0.14	0.0	0.0	0.62	0.14	2.51	0.89
Cropland	11.39	0.01	0.0	0.0	0.52	0.0	2.14	3.68
Shelterbelt	3.08	0.0	0.0	0.0	0.0	0.0	0.0	5.56
Choppy Sandhills	14.69	0.0	0.0	0.0	0.0	0.0	0.0	0.0
River Terrace	5.46	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transport. Routes								
Railroad	0.08	0.0	0.0	0.0	0.0	0.0	68.88	59.25
Gravel Road	0.52	0.0	0.0	0.0	0.0	0.0	7.88	1.04

The prairie chicken used a wide diversity of habitat types. The habitat use was variable with activity and season. The only habitats not used at some time of the year were from the Choppy Sandhills and River Terrace Habitat Associations. Most of prairie chicken activity was in the Hummocky Sandhills Habitat Association in the spring and summer and then shifted to the Deltaic Plain Habitat Association in the fall and winter.

The spring courtship rituals were conducted on areas of short native vegetation primarily on the upland and midland grassland habitat types and some on the lowland habitat type that had been manipulated by mowing. Most of the display grounds had areas of dense cover adjacent or very near to the ground. Some feeding was still being done on cropland. All ofthe nest sites in native vegetation were in switchgrass (Panicum virgatum) of the midland habitat type. A few nests were found in cropland (alfalfa). Nonnesting birds spent most of the time in the midland habitat type.

In the summer, broods used many habitat types but usually with a high amount of shrubs and forbs which produce good canopy cover and relatively open understories. Intensive feeding by broods was observed to be on areas of short vegetation that had been mowed or grazed with adjacent areas of dense residual vegetation. Broods also used cropland (alfalfa) for food and cover. Nonbrooding adults were also found to use a wide variety of habitat types during the summer.

The general shift from habitat use in the Hummocky Sandhills Habitat Association to the Deltaic Plain Habitat Association began in the fall. Small flocks formed around the fall display grounds. These flocks were very mobile. Cropland and the spilled wheat on the railroad right of way were used for food. The small flocks joined together to form large packs when the weather turned colder. Cropland and adjacent shelterbelts were the primary habitat types used in winter. Spilled grain and crop residue were used for food. Trees in shelterbelts were used for cover and the buds were used by choice as part of the daily food. When the snow was deep, standing corn or sunflowers along with tree buds became the main food.

Management for prairie chicken on the Sheyenne National Grasslands should provide a diversity of prairie and cropland habitat types for courtship, nesting and roosting, brooding and winter food and cover.

1. Manske, L.L. (1980) Ph.D. Thesis, North Dakota State University.
2. Robel, R.J., et al. (1970) Journal of Wildlife Management 34,286-306.

3.

RECLAIMING SEASONALLY BALANCED NATIVE GRASSLANDS AFTER STRIP MINING

Rick L. Williamson *
Regional Reclamation Biologist, Consolidation Coal Company
Englewood, Colorado

Consolidation Coal Company is conducting a study to reestablish seasonally balanced grasslands on its Glenharold Mining Reserve, approximately 50 miles NW of Bismarck, North Dakota, within the mixed grass prairie region of the Northern Great Plains. The study areas were surface mined, reshaped, and then resurfaced with approximately 46 cm. of a subsoil-topsoil mixture during the mid-1970s. Six native grass species were seeded into two 16-hectare study sites in the first two weeks of June 1979. The species consisted of three warm-season varieties--little bluestem (Schizachyrium scoparius), blue grama (Bouteloua gracilis), sideoats grama (Bouteloua curtipendula)--and three cool-season varieties--western wheatgrass (Agropyron smithii), slender wheatgrass (Agropyron trachycaulum), and green needlegrass (Stipa viridula). Study area 1 was seeded to heavily favor sideoats grama (419 pure live seeds/M^2), and Area 2 was seeded to heavily favor little bluestem (408 PLS/M^2). These were the only two species that varied as to seeding rates for both study areas. The other seeding rates/M^2 were slender wheatgrass (75 PLS), western wheatgrass (86 PLS), green needlegrass (86 PLS) and blue grama (172 PLS). Both study areas were irrigated in 1979 but not in 1980. The study areas were sampled for percent basal ground cover, vegetative density, species frequency, and vegetative productivity. Soil samples were taken and analyzed within both sites in 1979 and 1980.

The data indicate that area 1 progressed better than 2, which was infested with annual grasses in 1979 and 1980. Area 1 had practically no weeds in 1980. The problem in Area 2 seemed to be little bluestem, which had not established itself, and being the most favored in Area 2, it left a void in the first and second years which was filled by annual grasses.

In 1980 sideoats grama was the most frequently occurring warm-season perennial species, occurring in 82% of samples taken in area 1 and 78% in area 2. Slender wheatgrass was the most frequently occurring cool-season grass species, occurring in 98% of the samples in Area 1 and 74% in Area 2. Both species had approximately the same density levels within both study areas. Area 1, however, had significantly ($P<.05$) higher densities/M^2 of both species (23 and 20) compared to Area 2 (17 and 16.7). Area 1 had higher basal ground cover at 5.3% when compared to area 2 at 4.2%. In both areas sideoats grama contributed the most in basal cover. Area 1 produced 2,047 kg./hectare of oven-dried forage, while Area 2 produced 2.206 kg./hectare in 1980. Even at this early stage, these productivity levels are comparable with some of the most productive native range sites. A nearby native area, classified as a "silty" range site (USDA-SCS, 1978), was sampled and found to produce 2,231 kg./hectare of forage for the same year. For both sites the warm-season perennial grass contributing the highest individual productivity was sideoats grama, and the cool-season perennial grass contributing the highest individual productivity was slender wheatgrass. There was no significant difference in the yields of sideoats grama and slender wheatgrass in either site.

After two growing seasons, the study areas are dominated by sideoats grama and slender wheatgrass, indicating the outstanding capabilities of slender wheatgrass to establish itself. Slender wheatgrass, seeded at only 75 PLS/M^2, has still become a co-dominant with sideoats grama (seeded in excess of 215 PLS/M^2 in both sites). Slender wheatgrass, a short-lived perennial, will probably not remain a co-dominant species for very long. Green needlegrass and western wheatgrass were hardly detectable the first year, but were very evident contributors in the second growing season. Blue grama was apparent in 1979, but greatly increased to become a major contributor in all three parameters in 1980. Little bluestem was rarely detected in 1979 or 1980. The annual weed problem, which is common in newly seeded areas, appears to be decreasing as the desirable perennial species increase. Soils data indicate a slight increase in pH from 1979 to 1980 at two depths: 0-15.2 cm. = from 7.59 to 7.91, 30.5-45.7 cm. = from 7.69 to 7.81. Electrical conductivity decreased at both depths: 0-15.2 cm. = from 1.85 to 0.56, 30.5-45.7 cm. = from 1.26 to 0.71 mmho/cm^2. The sodium adsorption ratio also generally decreased from 1979 to 1980 at both depths: 0-15.2 cm. = from 1.32 to 0.81, 30.5-45.7 cm. = from 2.13 to 2.08. The soils are silty loams.

The data thus far indicate that by using specific reclamation techniques, a native, seasonally balanced grassland can be established. Three practices appear to be important: (1) seeding in early summer, in the first two weeks of June, instead of early spring, (2) using irrigation during the first growing season to ensure that moisture will be available at the critical time, and (3) balancing the seed plan ratio to favor the establishment of warm-season species. The data presented here is preliminary. Data collection will continue for a minimum of two more growing seasons.

USDA-SCS (1978) Soil Survey of Mercer County, North Dakota

4. NUTRITIONAL COMPOSITION OF COMMON SHRUBS IN NORTH DAKOTA

D. O. Erickson*, W. T. Barker,
S. Wanapat and R. L. Williamson
Animal Science and Botany Departments,
North Dakota State University,
Fargo, ND 58105

Shrubs on rangelands provide important nutritional inputs of the diets of big game animals as well as domestic ruminants. Management of game and domestic animals as well as range management practices can be improved with more knowledge of the nutritional composition of the rangelands throughout the year. The major objectives of this research were to determine the nutritional composition of shrubs throughout the year, to compare the nutritional composition between two locations in the state, and to compare nutritional composition of leaves, stems and berries (if present). The study areas selected were the Sheyenne National Grasslands (area 1) in the southeastern part of the state and the Badlands (area 2) in the western part of the state. Area 1 consisted of two sites. Site 1 was located 3.4 miles north and 6.5 miles west of McLeod and site 2 was located 3 miles north and 7 miles west of McLeod, both in east-central Ransom County. Area 2 also consisted of two sites, both in Billings County. Site 1 was located 6.5 miles south and 4.5 miles west of Fryburg and site 2 was located 6.5 miles south and 1 mile west of Fryburg. The average annual precipitation was 26 and 18 inches, respectively, for 1977 and 1978 in the Sheyenne Grasslands and 23.1 and 17.6 inches, respectively, for 1977 and 1978 in the Badlands.

The 11 selected shrubs (western snowberry, *Symphoricarpos occidentalis*; serviceberry, *Amelanchier alnifolia*; lead plant, *Amorpha canescens*; woods rose, *Rosa woodsii*; prairie wild rose, *Rosa arkansana*; buffaloberry, *Shepherdia argentea*; skunk bush, *Rhus trilobata*; chokecherry, *Prunus virginiana*; sandbar willow, *Salix interior*; winter fat, *Eurotia lanata*; and big sagebrush, *Artemisia tridentata*) were analyzed for protein, *in vitro* dry matter digestibility (IVDMD), acid detergent fiber (ADF), acid detergent lignin (ADL) and mineral contents (phosphorus, potassium, calcium and magnesium). Samples were taken biweekly from early June to September and the remaining part of the year on a monthly basis in 1977 and 1978. Western snowberry, chokecherry and serviceberry were collected for two years from both the Sandhills (southeastern North Dakota) and the Badlands (southwestern North Dakota). Prairie wild rose, lead plant and sandbar willow were sampled only in the Sandhills both years. The other shrub species (skunk bush, buffaloberry and woods rose) were collected from the Badlands in both years. Winter fat and big sagebrush were sampled only from the Badlands for one year.

Chokecherry, western snowberry and serviceberry contained more protein (12.3 vs. 10.7, 8.5 vs. 7.2, and 10.6 vs. 9.6, respectively) ($P<.05$). Digestibilities were higher (44.5 vs. 41.6, 49.1 vs. 42.1, and 39.4 vs. 34.2, respectively) ($P<.05$) but lower (.131 vs. .285, .119 vs. .174, and .123 vs. .222, respectively) ($P<.05$) in phosphorus in the western part of North Dakota, based on seasonal averages. ADF and ADL percentages were higher ($P<.01$) in lead plant from the eastern part than from the western part.

With advancing maturity, protein, IVDMD and phosphorus contents decreased ($P<.01$) while ADF and ADL contents increased ($P<.01$) in all species. The protein contents in buffaloberry, chokecherry, serviceberry, woods rose, prairie wild rose and lead plant (leaves and twigs combined) are sufficient to meet the maintenance requirements of sheep and cattle during the growing season. Phosphorus percentages in chokecherry and big sagebrush met the maintenance requirements for cattle during the growing season. Calcium percentages from all species met the requirements for sheep and cattle for the entire year. The highest IVDMD values among the 11 species were 67% in big sagebrush during late June and 62% in lead plant in September. The ADF and ADL values were negatively correlated ($P<.01$) with IVDMD for all species. The IVDMD values were positively correlated ($P<.05$) with protein.

Supplementation of protein and phosphorus should be considered for grazing cattle and sheep during periods of slow or no vegetation growth based on these data as well as data published from North Dakota and elsewhere on native grass species.

5. IMPROVING SPECIES COMPOSITION AND SEASONAL VARIETY ON RECLAIMED STRIP MINED GRASSLANDS THROUGH SELECTIVE GRAZING INTENSITIES AND TIME PERIODS

Rick L. Williamson*
Regional Reclamation Biologist, Consolidation Coal Company
Englewood, Colorado

Consolidation Coal is conducting a grazing study on its Glenharold Mining Reserve, approximately 50 miles NW of Bismarck, North Dakota, within the mixed grass prairie region of the Northern Great Plains. The study area was strip mined during the early 1970s. Following mining, the spoils were reshaped and resurfaced with approximately 76 cm. of a topsoil-subsoil mixture. The site was seeded to native grasses during spring 1975, whereupon slender wheatgrass (Agropyron trachycaulum), a cool-season species, became the overwhelming dominant.

Three sites were set up to test the effects of three grazing intensities (heavy, moderate, and light) on reclaimed grasslands, with a fourth site serving as the ungrazed control. Basal ground cover and vegetative productivity measurements were taken during the 1979 and 1980 growing seasons. Plant tissue chemical analysis was performed in 1979. Average daily gains (ADG) and beef production per hectare were obtained using 15 yearling hereford steers. The grazing pens were stocked at 0.2 hectares/steer in Pen 1, 0.5 hectares/steer in Pen 2, and 0.8 hectares/steer in Pen 3. Grazing began on June 2 and ended July 14, 1979. No grazing took place in 1980 because of a severe spring drought. Soil analysis in 1979 indicates that the loamy soils varied in pH from 7.5 to 8.1, EC from 0.42 to 3.7 mmho/cm^2, and the SAR from 0.3 to 22.0 but averaged 7.5.

Pen 1: At this site 84.9% of the grazeable material was removed by grazing in 1979. Basal ground cover significantly decreased ($P < .05$) in 1980 within all sites except for Pen 1, which had a significant increase ($P < .05$). In 1979 all sites were equal in cover, while in 1980 Pen 1 was significantly higher ($P < .05$) in cover than all other sites. The increase was due to some important changes in species composition and numbers which occurred after the first year of heavy early-season grazing. Six species made up the basal ground cover in 1979; in 1980 this increased to nine species. Two grass species--sideoats grama (Bouteloua curtipendula) and western wheatgrass (Agropyron smithii)--increased significantly ($P < .01$), from 0 to 2.7%, and from 0.3 to 2.1%, whereas slender wheatgrass decreased significantly ($P < .01$) (from 4.2 to 1.4%). Sideoats grama, which was not even detected in 1979 cover measurements, is now the most prevalent single component of the ground cover. Vegetative productivity also increased, from 1,592 kilograms/hectare in 1979 to 1,991 kilograms/hectare in 1980. This was mostly due to an increase in warm-season perennial grass species.

Pen 2: At this site 28.3% of the grazeable material was removed in 1979. Cover decreased, primarily because slender wheatgrass decreased dramatically from 1979 to 1980--from being the most prevalent (5.3%) to being the least prevalent (0.1%) cover species. Species numbers rose from three in 1979 to six in 1980. Slender wheatgrass decreased in cover, whereas five other species increased. Vegetative productivity decreased.

Pen 3: At this site grazing removed 9.1% of the grazeable material. As in Pen 2, cover decreased significantly ($P < .01$), from 5.8% to 2.6%. The decrease, however, was even more severe. Vegetative production also decreased. One new species--green needlegrass--turned up in 1980 sampling. One species--western wheatgrass--increased measureably (from 1% to 2%) in cover.

Control Site: At this site base ground cover decreased significantly ($P < .01$), as did vegetative productivity, from 1979 to 1980. This can be attributed to two factors: (1) lack of grazing, which allowed vegetal litter to build up and choke out the living material and (2) the spring drought of 1980, which dramatically affected the highly mesic slender wheatgrass (this factor also explains the total cover and production decreases in Pens 2 and 3). Five species were detectable in 1979 within the control site, while only three species were detected in 1980.

Forage nutrient quality data indicate that the grass tissues have average percentage values of 15.6% for crude protein, 28.8% for acid detergent fiber, 2.5% for acid detergent lignin, 3% for potassium, 0.13% for magnesium, 0.29% for calcium, and 0.21% for phosphorus. There were 46.7 kg. of beef produced in Pen 1, 129.8 kg. in Pen 2, and 154.8 kg. in Pen 3. The Pen 3 steers had a much higher average weight gain per steer, as did those in Pen 1; however, the Pen 1 steers produced more beef/hectare than did those of Pen 3. The highest ADG was 950 grams for a steer in Pen 3, and the lowest value was 90 grams for a Pen 1 steer. These gains are similar to those of Hofmann *et al* (1978).

Data from this study indicate that the more intensely the site was grazed, the more the vegetation changed. All changes that occurred within the grazed areas demonstrate positive trends, while the condition of the control site seemed only to decline.

It appears that one or perhaps two seasons of the heavy early-summer grazing followed by moderate to light season-long grazing in the years afterwards may be the best method of manipulating and managing the reclaimed grassland sites, both agriculturally and from a bond release point of view. The data to date indicate (1) that grazing can be used as a management tool for improving the seasonal variety and species diversity within reclaimed grassland areas (2) that nutritionally good quality forage can be produced on reclaimed grasslands, and (3) that good beef gains can be obtained from livestock grazing reclaimed grasslands.

Hofmann, L., Ries, R.E., Power, J.F., and Lorenz, R.J. (1978) Farm Research, Vol. 36, No.1, pp. 3-5.

6. ABOVE GROUND BIOMASS OF SELECTED WETLANDS ON THE MISSOURI COTEAU

G.W. FULTON* and W.T. Barker
Department of Botany, North Dakota State University
Fargo, North Dakota 58105

Carex atherodes, *Polygonum coccineum*, *Scolochloa festucacea*, and *Sparganium eurycarpum* are common dominant emergent species of seasonal ponds and lakes in North Dakota (5). Yields of these species have been reported (1, 2, 3), but seasonal production has been reported for only *S. festucacea* (4). The present study examines changes in above ground biomass for all four species.

During the summer of 1980 ten wetlands on the Cottonwood Lake Waterfowl Production Area, located 32 kilometers (20 miles) northwest of Jamestown, were sampled with 0.25 m^2 quadrats on radial transects. Length and number of transects varied with size and distribution of plant communities. Plants were clipped at ground level and dried to a constant weight at 65°C (150°F). Sampling began in early June when a distinct pattern of communities had developed, and continued through September past peak biomass (Table 1). Standing water was present on sites 2, 4, 6, 7, 9, 10 and 11 on June 12 but was gone from all sites except sites 6 and 7 by June 28. Water disappeared from these sites by July 20. Precipitation totaled 35 cm (13.8 inches) from June through September.

Carex atherodes produced the highest site biomass (1055 g/m^2) and the highest average species biomass (819 g/m^2). *Sparganium eurycarpum* had the lowest site biomass (174 g/m^2) and the lowest average species biomass (447 g/m^2). The average production of *Polygonum coccineum* (107 g/m^2) on June 12 was the lowest of all species, but with 227 percent and 73 percent increases during the first two sampling intervals biomass reached the levels of the other species. *Carex atherodes* had the highest average biomass (328 g/m^2) on June 12 and the lowest increases during the same sampling intervals (87 and 26 percent respectively). Peak production occurred on August 14 for 14 sites and on July 20 for 8 sites. *Sparganium eurycarpum* had the earliest production peaks followed by the most rapid decline of the four species.

Table 1. Above ground biomass (g/m^2) harvested at six sampling dates in 1980 (n = number of quadrats, biomass = mean ± standard error).

Species	Site	n	June 12	June 28	July 20	Aug 14	Sept 3	Sept 27
Carex atherodes	2	9	287± 38	599± 46	886± 62	801± 61	684± 50	--- --
	3	9	308± 33	680± 62	788± 55	877± 42	876± 61	601± 35
	4	6	313± 59	633± 59	757± 40	756± 92	903±105	383± 50
	5	3	351± 89	737±220	825± 69	935±177	699±174	--- --
	6	9	460± 43	736± 38	892± 69	1055± 94	889± 90	--- --
	7	4	423± 57	826±117	989±129	845±127	553± 55	--- --
	9	9	292± 49	469± 59	575± 88	701± 65	562± 56	494± 44
	10	6	327± 31	427± 85	463± 31	558± 76	511± 22	440± 50
	11	9	354± 29	419± 50	614± 85	647± 85	647± 49	389± 44
	14	3	163± 30	423± 36	641±118	497± 88	563± 75	425± 36
Polygonum coccineum	4	4	--- --	442± 23	593±121	648± 82	741± 78	430± 17
	5	8	79± 14	274± 38	539± 83	510± 54	454± 76	--- --
	6	9	88± 19	297± 47	476± 61	674± 58	579± 78	--- --
	9	9	152± 28	418± 45	814± 93	632± 90	584± 74	435± 48
	10	8	108± 13	374± 29	640± 63	762± 90	694± 75	444± 36
	11	9	--- --	212± 30	386± 63	554± 62	520± 61	255± 33
Scolochloa festucacea	2	4	150± 12	364± 10	593± 59	628± 92	530± 37	--- --
	4	9	187± 24	534± 82	506± 60	671± 65	706± 96	566± 40
	5	8	186± 48	449± 79	624±109	745±138	608± 45	--- --
	6	8	302± 34	601± 62	705± 42	890±110	698± 86	--- --
	7	9	251± 54	550± 90	609± 58	633± 82	636± 68	331± 37
Sparganium eurycarpum	2	4	--- --	119± 18	174± 14	169± 19	108± 26	--- --
	6	9	158± 24	432± 21	537± 44	582± 38	310± 34	--- --
	7	9	169± 32	440± 56	606± 46	472± 54	497± 37	239± 11
	9	9	115± 16	300± 17	430± 61	367± 32	213± 26	--- --
	10	9	121± 16	445± 18	434± 33	343± 19	84± 15	--- --

1. Barker, W.T. and Fulton, G. (1979) N.D. Regional Environmental Assessment Program Project No. 79-15.
2. Barker, W.T. and Larson, G. (1976) Wildlife, Biological and Vegetational Resources of the Dunn County Coal Gasification Project Study Area: Aquatic Plant Communities. N.D. Agric. Expt. Sta.
3. Cosby, H.E. (1964) *J. Range Manage.* 17, 266-269.
4. Smith, A.L. (1973) *J. Range Manage.* 26, 117-120.
5. Stewart, R.E. and Kantrud, H.A. (1971) U.S. Bur. Sport Fish and Wildl. Res. Pub. 92.

7.

Ecology of *Kochia scoparia* on Surface Mined Lands

Louis R. Iverson* and Mohan K. Wali

Department of Biology, and Project Reclamation
University of North Dakota, Grand Forks, ND 58202

Kochia scoparia (L.) Shrad. (Chenopodiaceae) is the most dominant colonizer on western North Dakota surface mined lands. We studied (1, 2) a series of topsoiled, contoured, and seeded mined lands near Beulah, ND, and found that *Kochia* showed dominance in first year areas, an extremely high density but very low vigor in second year areas. and virtual elimination by the third year after mining (Table 1).

Table 1: Frequency, biomass, density and height of *Kochia* plants during the first three years after reclamation.

Year after Mining	Frequency* (%)	Biomass** (g m^{-2})	Density** (Plants m^{-2})	Height** (cm)
1	100	222.5	52	53.7
2	98	70.8	10464	11.3
3	10	0.01	5	0.2

* based on 50 randomly placed 0.5 x 0.5 m quadrats at each site.
** averaged from 5 replicates x 7 sampling periods over the 1977 growing season.

Kochia exhibits several traits which enable it to flourish on newly reclaimed areas: (a) C_4 metabolic pathway, which allows for greater biomass production under high temperature and low moisture conditions; (b) increased efficiency of nutrient uptake; (c) tremendous plasticity, where it can produce over 50,000 seeds per plant under favorable conditions and about 5 seeds per plant under stress conditions; (d) "tumbleweed" dispersal mechanism via stem abscission (3) which allows for efficient spread of seeds over large barren areas. In a separate study on the seed "banks", a grazed and a nongrazed area as well as fresh and 1- year old stockpiles of topsoil were analyzed and found to contain no *Kochia* seeds, showing that most of the *Kochia* seeds are blown in after respreading of the topsoil, and that "tumbleweed" and wind storm (4) dispersal mechanisms are very important for early colonization. *Kochia* also has (e) early spring germination and (f) resistance of seedlings to freezing (5) (thus *Kochia* is established before other plants emerge); (g) salt tolerance (6); (h) drought resistance; (i) rapid growth rate; and (j) possible resistance to insect predators.

However, interspecific and intraspecific competition, loss of suitable germination sites, and the phenomenon of autotoxicity in *Kochia* all combine to remove *Kochia* from prominence in the second and third year after reclamation. Decaying shoots and roots of the large first year *Kochia* plants (which release known phytotoxins such as chlorogenic, caffeic and ferulic acids, myricetin and quercitin (7) inhibit the growth of their offspring in the following spring. A field experiment showed that when *Kochia* plants in Year 2 (density >10,000 plants m^{-2}) were thinned down to approximately the density of first year areas (about 50 plants m^{-2}), growth of *Kochia* plants did not differ significantly by the end of the year. This provides strong evidence for autotoxic influence. In addition, several growth chamber experiments showed that decaying *Kochia* leaves and roots inhibit *Kochia* growth but not the growth of other test species (*Agropyron caninum* and *Melilotus officinalis*). Chemical analysis of soils and tissue from growth chamber experiments supports the hypothesis that the inhibition may be due to nutrient absorption imbalances which cause severe fluctuations in P/Zn and P/Mn ratios in the tissue.

Some speculations as to why *Kochia* would produce phytotoxins which inhibit its own offspring can be presented: (a) there may be a greater selective advantage in producing these compounds as a defense mechanism than selective disadvantage from the effects of the substance on the short-lived populations of the species itself (8). Evidence for this is provided by cocklebur weevil larvae which were found much less frequently in the stems of *Kochia* (40%) than six other colonizing species (73-100%). (b) There may be an interaction between plants and the climatic conditions as *Kochia* plants stunted by autotoxicity seem to be affected less severely by drought conditions. Stunted plants may be able to produce sizable numbers of viable seed for subsequent years, while taller, uninhibited plants, especially those growing in high densities, use a greater proportion of their available water for maintenance, hence seed production is reduced.

(1) Wali, M. K. and L. R. Iverson. (1978) *Amer. Assoc. Adv. Sci. Publ.* 78-2:121-122.

(2) Iverson, L. R. and M. K. Wali. (1979) *Amer. Assoc. Adv. Sci. Publ.* 79-2:109.

(3) Becker, D. A. (1978) *Amer. J. Bot.* 65:375-383.

(4) King, L. J. (1966) *Weeds of the World*, Interscience Publication, New York.

(5) Erickson, E. L. (1947) *South Dakota Agr. Expt. Sta. Bull.* 384:1-27.

(6) Monk, R. W. and H. H. Wiebe. (1961) *Plant Phsiol.* 36:478-482.

(7) Lodhi, M. A. K. (1979) *Can. J. Bot.* 57:1083-1088.

(8) Whittaker, R. H. (1975) *Communities and Ecosystems*, MacMillan Publishing Company, New York.

8. PHYSICAL AND ENVIRONMENTAL FACTORS OF WOODLAND ECOSYSTEMS ON THE GLENHAROLD MINE RESERVE IN WESTERN NORTH DAKOTA

R.L. Williamson,* Consolidation Coal Company, Englewood, CO; J.L. Richardson, North Dakota State University, Fargo; G. Clambey, NDSU, Fargo; B.J. Bermes, Geraghty and Miller, Inc., West Palm Beach, FL; and W. Keammerer, Stoecker-Keammerer and Assoc., Boulder, CO

This study was conducted within a coal strip mining reserve located approximately 50 miles NW of Bismarck, North Dakota. Recoverable coal deposits lie beneath gently rolling upland surfaces broken by numerous narrow drainages. These drainages, referred to as "wooded draws", are important for their contribution of tree and shrub vegetation in a region dominated by grassland. Research concerning the ecology of these woodland ecosystems was undertaken in 1979 to identify why the wooded draws are there. This information was vital for developing a woodland reclamation plan for the draws that will be disturbed by mining.

Six study sites were selected within the reserve for botanical, soils, landscape, and hydrogeologic investigations. The woodlands vary from 0.4 to 40.5 hectares, with three major vegetation types: low shrublands (LS), tall shrublands (TS), and deciduous woodlands (DW). The LS are dominated by western snowberry (Symphoricarpos occidentalis) or silverberry (Eleagnus argentea). The TS are dominated by serviceberry (Amelanchier alnifolia), buffaloberry (Shepherdia argentea) and chokecherry (Prunus virginiana). The DW communities occur on the most mesic sites and consist primarily of trees such as ash (Fraxinus pennsylvania), box elder (Acer negundo), elm (Ulmus americana) and aspen (Populus tremuloides). In the DW communities ash, box elder, elm and aspen had sample frequency values of 87%, 12%, 36%, and 13% and averaged densities of 1,019, 57, 306, and 405 plants/hectare. The TS communities had sample frequency values of 35%, 53%, and 32% for serviceberry, buffaloberry and chokecherry, with density averages of 10,115, 7,111, and 4,649 stems/hectare. The LS communities had sample frequency values of 100% and 6% for western snow and silverberry, and averaged densities of 300,939 and 10,227 stems/hectare.

The woodlands occur along well defined drainages and retreating escarpments. The slope steepness varies but averages around 15 to 25%. Soils found were: Amor, Werner, Temvik, Linton, Parshall, Mandan, Manning, Flaxler, Cabba, and Sens. The uplands are Pachic and Typic Haploborolls. The shoulder and upper backslope soils are Ustorthents. The lower backslopes are dominated by Lithic and Entic Haploborolls. Typic and Pachic Haploborolls do occur in coves, however. Footslopes uninfluenced by the water table are usually Pachic and Typic Haploborolls. Footslopes influenced by the water table are Aeric and Cumulic Haplaguolls. The valley bottoms are usually Fluvaquents. The principal difference between sites was the texture and parent material of some soils. Two of the sites tended to be more sandy because of the sandy loess-like upland. The soils in residuum of shale and siltstone were high in very fine sand, silt or clay. Nitrate nitrogen was low, averaging less than one ppm. In all cases phosphorus was low, while potassium was at acceptable levels. The soil organic matter was high in all soils under woody vegetation. The north and east aspect had more organic matter than the other aspects (north 9.55%, east 7.48%, south 5.35%, and west 4.47%). The summit and shoulder averaged 3.54%; backslope, 6.67%; footslope, 8.49%; and floodplain, 8.66%. The organic matter picked up progressively with distance from the summit to the valley. The prediction equation of the surface 25 cm. for organic matter regressed against clay $Y = 1.34\ (X) + 8.4$ $r = .50^{**}$ where Y = % clay and X = % organic matter. Soil types and properties plus slope gradient did not correlate with woody vegetation except with respect to landscape position and shape. The study sites generally have long concave slopes or numerous hill-like bulges of old slump blocks moving slowly downslope. The slump blocks are especially evident on escarpment areas. These concave sites and slump block areas catch and retain moisture and are where most of the woody vegetation is found growing. Regional aquifers were found to be a relatively unimportant source of water to the woody vegetation in the draws. Data indicate that the flow, generated locally within the draws, is approximately 30 times greater than flow to the draws via coal seams of the upper hydrogeologic unit. Recharge from local infiltration within the draws is thus likely to be a more important source of water

Three factors are important for the presence of woody vegetation on the reserve: (1) landform (2) slope aspect, and (3) shallow watertable outcrops. Of these three factors, landform and aspect are the most important. The most advantageous combination is a north- or east-facing slope in conjunction with a concave land configuration. The correct landform and aspect greatly affect the survival of woody vegetation by providing sites which efficiently retain soil moisture, which is the major limiting factor for woody vegetation in the Northern Great Plains. The watertable outcrop factor is independent of the other two factors. If it is present, regardless of aspect or landform, woody vegetation can and does exist, unless the water is saline. In all sites studied, aspect and landform was important for the presence of woody vegetation, while the "watertable outcrop" factor was important only in a few areas of the study sites. This study indicates that the moisture conservation and retention needed for reclamation of perpetual woodlands can be attained through topographic manipulations; i.e., by constructing the correct land configurations after mining and by using the appropriate slope aspects.

**Significant at the 0.01 probability level.

9. EVOLUTION OF WESTERN NORTH DAKOTA'S REGIONAL SLOPE AND DRAINAGE NETWORK

Eric N. Clausen *
Division of Science and Mathematics, Minot State College
Minot, North Dakota

The northeast-trending regional slope of North Dakota and adjacent states is the result of glacial erosion in glaciated areas and the adjustment of topography in nonglaciated regions to the reduction in baselevel caused by glacial erosion. Southeast-trending river valleys in North Dakota such as those of the Heart, Knife, and Cannonball Rivers originated as segments of a southeast-trending drainage network which was initially formed on a topographic surface equal to or higher in elevation than the highest buttes in the state today. Meltwater from early Pleistocene glaciers flowed on that higher surface. Outwash plains consisting of sheets of sand and gravel were deposited adjacent to and downstream from the margins of those early glaciers. Some of the outwash plains are preserved today as gravel-capped plateaus. These plateaus include the Cypress Hills, the Wood Mountain Upland, and the Flaxville Plain. While the gravels were being deposited the soft Mid and Late Tertiary sediments, which were exposed at those higher elevations, were being rapidly eroded. Coarse grained material from those sediments, including fossils, became incorporated in the stream alluvium and can be used to identify the sedimentary layers which were exposed on the surface at the time of gravel deposition. Rivers charged with glacial meltwater also carried the gravel for considerable distances downstream. Today alluvium from those meltwater rivers can be found in such southeast-trending valleys as those of the Heart, Cannonball, and Grand Rivers. The alluvium can also be found today as strips of gravel litter crossing uplands in southwestern North Dakota and adjacent states.

A large portion of the northern Great Plains and Rocky Mountain region was significantly altered by deep Pleistocene erosion. The eroded area includes the entire Yellowstone-Missouri drainage basin north and west of Nebraska, the entire Red River drainage basin south of the Canadian Shield, and the Saskatchewan River basin south and west of the Canadian Shield. The eastern and northern boundaries of the eroded region are not determined in this paper. The erosion of this large region appears to have been initiated by glacial removal of several hundred meters of soft sedimentary rock to the north and east of a line approximately corresponding to the position of the present-day Missouri Escarpment. The intensity of this erosion probably increased in a northeastward direction. This lowering of baselevel appears to have been accomplished by relatively thin sheets of ice which filled major river valleys and which were not confined laterally by the easily eroded claystones of the valley walls. This stripping of the soft sedimentary cover by unconfined valley glaciers probably began on a topographic surface much higher in elevation than any present-day landforms in the glaciated portion of North Dakota. The process was most likely repeated several times prior to the cycle of stripping which produced the present arrangement of escarpments and lowlands north and east of the Missouri Escarpment (1).

Both the southeast-trending drainage network and the early Pleistocene topographic surface of southwestern North Dakota were significantly altered by the lowering of baselevel in the glaciated areas to the north and east. The southeast-flowing rivers were first impacted by what appears to have been a sharp lowering of baselevel to the east in the vicinity of present-day Minnesota and Wisconsin. The southeast-trending valleys were rejuvenated as knickpoints produced by the lower baselevel worked their way headward, cutting rapidly through the soft sedimentary bedrock. Evidence for the rejuvenation of these valleys can be found in the varying topographic positions of the various strips of gravel litter in southwestern North Dakota.

Next, new north- and northeast-flowing rivers, including the present-day Little Missouri, began to intersect the southeast-trending drainage network through a process of headward erosion and stream capture. Evidence for this headward growth along the Little Missouri includes an asymmetrical drainage divide to the east, barbed tributaries which enter from the west, and east- and southeast-trending strips of gravel litter which are cut by the north-trending Little Missouri trench. Elbows indicating capture of southeast-flowing streams by northeast-flowing streams can be found on several rivers in North Dakota, including the Heart and the Cannonball. Similar elbows of capture can be observed as far south as Nebraska. The headward growth of these new north- and northeast-trending rivers produced the modern northeast-trending regional slope of North Dakota. This regional slope had already been developed by the time of the glacial advances which produced the modern ice-marginal Missouri River. Rivers such as the Missouri resulted when late Pleistocene glacial advances blocked the new north- and northeast-flowing rivers and diverted them along the ice margins (2). Pleistocene erosion of western North Dakota was so extensive that the only remnants of the preglacial topographic surface preserved today, if any remnants are preserved at all, are the tops of the highest buttes in southwestern North Dakota.

1. Clausen, Eric (1980) Proc. N. D. Acad. Sci. 34, p.37

2. Bluemle, J.P. (1972) Geol. Soc. Am. Bull. 83, pp. 2189-2193

10. THEORY OF SATURATED GROUNDWATER FLOW FOR A REGION WITH A PERIODIC SURFACE PROFILE OR WATER TABLE USING THE GRAM-SCHMIDT APPROACH

Lyle Prunty*
Soils Department, North Dakota State University
Fargo, ND 58105

Analysis of groundwater flow by solution of steady state boundary value problems has been useful in gaining an understanding of situations ranging from regional groundwater flow (2, 5) to agricultural field drainage (4). The modified Gram-Schmidt method developed by Kirkham (3) and others has proven particularly useful when dealing with flow regions that are significantly non-rectangular. A class of such situations that has not previously been analyzed is represented in Fig. 1. The line CD represents the locus of zero pore water pressure, commonly called the "water table". The line AB represents an impermeable barrier to flow. The shape of CD is given by the periodic function $f(x) = f(x + p)$. If a soil is underlain by a barrier, the soil profile is saturated and steady rainfall maintains saturation at the surface, then Fig. 1 also represents the soil profile with CD being the surface. Such a situation could exist in an agricultural soil that has been shaped into ridges to promote optimum seedbed conditions, as has been suggested (1).

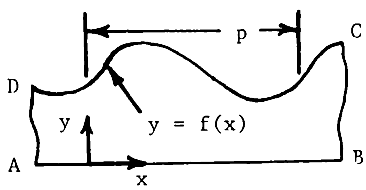


Figure 1. Generalized concept of a region with a periodic surface profile.

The groundwater flow pattern in region ABCD of Fig. 1 can be found by solving Laplace's equation and obtaining the distribution of hydraulic head in the region. Along CD the boundary condition is that hydraulic head must be equal to the elevation at each point, or $h(x, f(x)) = f(x)$ where $h(x, y)$ represents hydraulic head. The boundary condition along AB is that the partial derivative of h perpendicular to AB must be zero because no flow can cross AB, thus $\partial h/\partial y = 0$. After applying the boundary condition on AB and considering the periodicity of the function $f(x)$, one can use the Gram-Schmidt method (3) to find constants A and E(n) such that

$$h(x, f(x)) = A + \sum_{n=1}^{\infty} E(n)\, U(n, x, f(x)) \qquad [1]$$

where $U(n, x, y) = \cosh[(n + 1)\pi y/p] \cos[(n + 1)\pi x/p]$ for $n = 1, 3, 5 \ldots$
and where $U(n, x, y) = \cosh[n\pi y/p] \sin[n\pi x/p]$ for $n = 2, 4, 6 \ldots$
After the constants A and E(n) are found then $h(x, y)$ is simply given by Eq. 1 except with y in the place of $f(x)$.

Fig. 2 shows the shape of the region for which the problem was actually solved. The relative dimensions correspond to suggested planting ridge geometry (1). The solution showed that the division point for subsurface flow in this situation does not correspond to the surface drainage divide. Water seeping into the soil at the point indicated by O will split and appear as seepage at points X. Seepage rates to the left of O are in general about twice as great as to the right of O. The solution also indicated consequences for conceptualizing basin and regional groundwater flow as discussed in Toth (5). Namely, water entering a water table having a gradient does not necessarily move in the same direction as the gradient. It can conceivably move in the opposite direction.

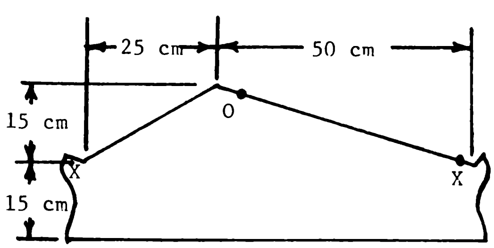


Figure 2. Shape of the flow region that was actually used in calculation. See text for explanation of points O and X.

1. Affleck, Stephen B., Kirkham, Don and Buchele, Wesley F. (1976) Proc. 7th Conf. Int. Soil Tillage Res. Org., ISTRO, Uppsala, Sweden, June 15-18, pp 1:1-1:5.

2. Freeze, R. A. and Witherspoon, P. A. (1966) Water Resour. Res. 2, 641-656.

3. Kirkham, Don, and Powers, W. L. (1972) Advanced Soil Physics, pp 140-160. John Wiley and Sons, New York.

4. Powell, Norris L. and Kirkham, Don (1976) Soil Sci. Soc. Am. J. 40, 625-630.

5. Toth, J. (1963) J. Geophys. Res. 68, 4795-4812.

11. DEFLATION BASIN STRATIGRAPHY, SLOPE COUNTY, NORTH DAKOTA: PROGRESS REPORT

Robert E. Seidel* and John R. Reid
Geology Department, University of North Dakota
Grand Forks, North Dakota, 58202

Numerous basins exist in areas of southwestern North Dakota. Those that are elongated in a NW-SE direction are believed to be of deflation origin; perhaps all are. All lie beyond the glacial boundary, but close enough to it that during glaciations there existed a steep climatic gradient which must have affected the sediments accumulating in these basins. One of the major purposes of this study, therefore, is to determine the origin and the geologic/climatic history of these basins. A second necessary purpose, is differentiation of the underlying Tertiary bedrock from the similar, more recent, basin sediments.

Core and auger samples have been taken from a number of these basins in eastern Slope County and western Hettinger County. This report, however, deals specifically with samples from two basins approximately 4 km south-southwest of West Rainy Butte in eastern Slope County.

A number of preliminary studies have been done on these samples, especially the cores. Visual and microscopic examination of the cores reveals that the sand-size fraction of the sediments is primarily fine, characteristic of eolian environments. The silt/clay fraction, which comprises, on the average, 53 percent of the sediment, is being analyzed by standard pipette techniques. These finer sediments are typical of a quiet water origin.

The most striking feature of the samples is the presence of laminar structures, on the order of millimetres thick. Because the core sites are presently dry, except for occasional periods of high water table or surface runoff conditions, the laminae represent the existence of former intermittent bodies of water. X-ray radiography and photography are planned to better delineate the significance of these laminae.

The presence of pollen in the samples was looked to as a critical element in interpreting the former climates in this area. However, preliminary pollen analysis at one site revealed two problems. First, the pollen in the samples is primarily Tertiary in age. If the sediments are Pleistocene, the environment of deposition either was not conducive to pollen preservation or pollen was not particularly abundant during this time. A third possibility is that the sediments are really Tertiary in age. More pollen analyses are planned to determine the correct answer.

The second problem concerns radiocarbon dating. The single sample processed so far was reported as 32,370 $\pm$ 755 radiocarbon years old. The material was a muck sample from a depth of 2.25 m near the edge of one of the basins. The date seems too old for this depth, and probably is contaminated by the Tertiary pollen or lignite deposits in the area. Additional radiocarbon analyses are planned to determine whether the contamination is genuine.

Faunal remains are another element important to a paleoclimatic evaluation of the area. Although no faunal remains have been discovered so far, with the exception of one gastropod in an auger sample from western Hettinger County, these will continue to be sought to provide additional clues as to the environment of deposition in these basins.

Finally, analysis of the core mineralogy, grain size variations, clay content, sedimentary structures and moisture content are being undertaken to differentiate the bedrock from the basin sediments. The problem is, the basin sediments were derived from poorly consolidated bedrock of quiet water origin, too. The presence of lignite beds, until now, has been the primary basis for determining when bedrock has been reached. This differentiation is needed to be able to delimit accurately the areal and vertical extent of the basin sediments.

12. LATE QUATERNARY INSECT ASSEMBLAGES ASSOCIATED WITH THE DES MOINES LOBE. I.

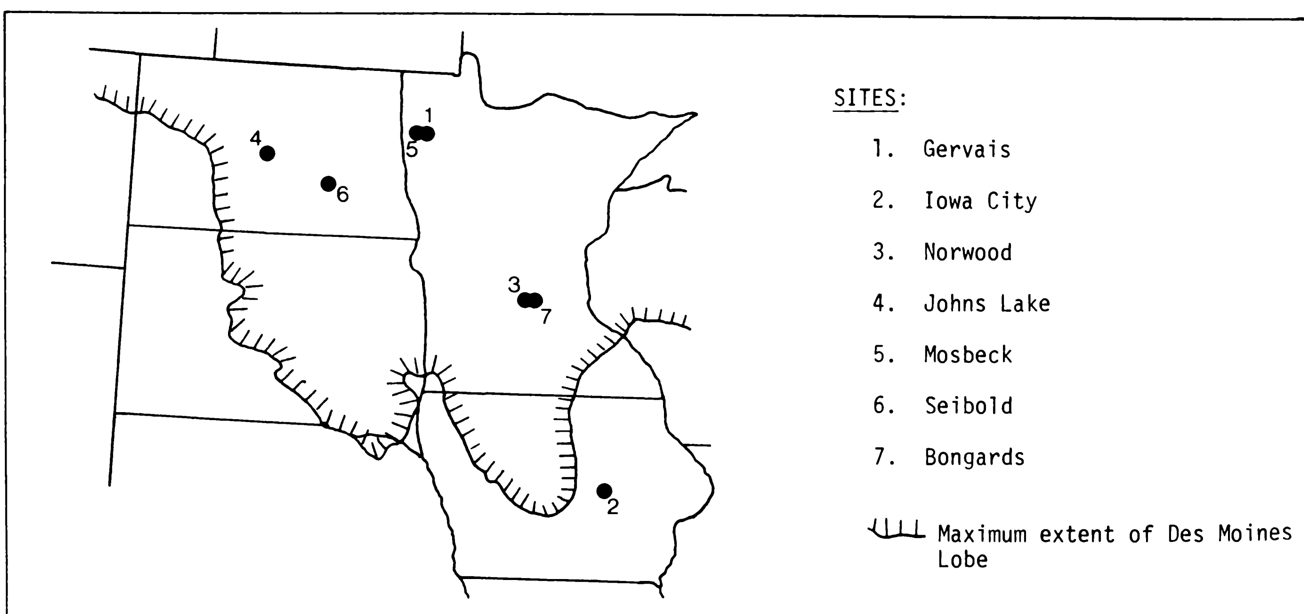
Donald P. Schwert* and Allan C. Ashworth
Geology Department, North Dakota State University
Fargo, N.D. 58105

At its maximum ca. 14,500 yr B.P., glacial ice of the Des Moines Lobe, including the James Sub-lobe, covered much of Minnesota, north-central Iowa, and the eastern Dakotas. With climatic warming, large areas of the ice sheet stagnated, creating numerous ponds and lakes. Insects rapidly colonized the newly available terrain, and their durable, chitinous remains are preserved within lacustrine sediments. These fossils include dragonflies, ants, wasps, bugs, leafhoppers, flies, and over 200 extant taxa of aquatic and terrestrial beetles. Insights into the climatic and environmental history of the region once covered by the Des Moines ice are being obtained through comparative studies of the existing distributions and habitat requirements of these taxa.

The oldest assemblage, from the Gervais Formation of western Minnesota, predates glacial maximum and is isolated in time from the other assemblages by at least 30,000 years. This assemblage, demonstrably > 46,900 yr B.P. and estimated to be Early Wisconsinan (1), is characteristic of a lake with spruce woodland and open areas on the margins. The majority of the species are presently known from Minnesota, but from coniferous forests and not the prairie. At least three species, the ground beetles *Pterostichus haematopus* Dej. and *P.* (*Cryobius*) *brevicornis* Kby. and the weevil *Lepidophorus lineaticollis* Kby. have predominantly northern, treeline distributions and indicate a climate with significantly cooler summers than at present. The Gervais assemblage is the only known midcontinental location in which fossils of the rare weevil *Vitavitus thulius* Kiss. occur. This species, whose fossils occur in Pliocene to Middle Wisconsinan (but not Late Wisconsinan) assemblages from Alaska and Yukon, is presently known from only two localities in the Northwest Territories.

Fossils of insect species that inhabited central Iowa during maximum glaciation are being studied from a 17,000 year old site near Iowa City. Unlike other assemblages studied from the midcontinental region, this one accumulated in loess and is consequently proportionally high in species of terrestrial affinity. The fossils are dominated by ground beetles, including several species of the arctic-subarctic ground beetle subgenus *Cryobius*. The distinctive ground beetle *Diacheila polita* Fald., an inhabitant of tundra in the Northwest Territories, Alaska, and Siberia, is represented by numerous, well-preserved fossils. Remains of northern scarabs, elaterids, weevils, byrrhids, and coccinellids are also present. Treeline elements dominate the assemblage and are evidence that a cold parkland environment, rather than open tundra, bordered the southern edge of the Des Moines Lobe at this time.

1. Ashworth, A.C. (1980) *Quat. Res.*, 13, 200-212.



13. LATE QUATERNARY INSECT ASSEMBLAGES ASSOCIATED WITH THE DES MOINES LOBE. II.

Allan C. Ashworth* and Donald P. Schwert
Geology Department, North Dakota State University
Fargo, ND 58105

Four late-glacial insect assemblages associated with the northward recession of the Des Moines Lobe have been analyzed. The oldest site, 12,400 yr B.P., is near Norwood (1) in south-central Minnesota. Over 100 beetle taxa within 25 families have been identified, and they comprise a series of boreal assemblages that have no modern analogues. The largest faunal element at Norwood consists of species with widespread boreal distributions, at least ten of which do not overlap in range with the beetles Helophorus arcticus Brown and Cymindus unicolor Kby., the only two tundra or tundra-forest species represented. In addition to the boreal and tundra-forest elements are two species with restricted western distributions: Opisthius richardsoni Kby. and Carphoborus andersoni Sw. Faunal analyses indicate that no climatic change occurred during sedimentation and that the transition from an unstable, open environment to a stable, coniferous forest represented a steady and rapid succession of plant and insect communities. Temperatures at this time reflected those of the present Boreal Forest south of the tundra-forest transition zone.

A succession similar to Norwood is recorded at Johns Lake, a younger site on the Missouri Coteau of Sheridan County, ND. The initial open-ground fauna at Johns Lake does not have the Norwood diversity, but the spruce forest fauna that replaced it at 10,800 yr B.P. is richer. The fauna includes nine species of bark beetles that inhabit white spruce. The tundra-forest species that occurred at Norwood are not present at Johns Lake.

The Johns Lake and Norwood sediments accumulated on stagnant ice terrain, which is also the origin of the 9750 yr B.P. Seibold sediments of Stutsman County, ND (2). The Seibold fauna, however, does not have the northerly aspect of either Norwood or Johns Lake and represents spruce woodland with prairie-like openings.

The Mosbeck fauna of Pennington County, MN, is the only Late Wisconsinan assemblage that has been studied from an environment not associated with stagnant ice; this fauna inhabited the eastern margin of Lake Agassiz at 9900 yr B.P. (3). The assemblage, however, like those from the stagnant ice sites, is dominated by boreal species and represents a fauna for which there is presently no analogue.

In sharp contrast to these "mixed" Late Wisconsinan assemblages, an analogue probably exists today in the midcontinental region for the 3500 yr B.P. insect assemblage examined from Bongards, MN. Over 100 taxa of aquatic and terrestrial beetles within 26 families have been identified from the sequence. An eastern element is evident in the fauna, and the site presently lies at or near the western limits for the ranges of nine of the fossil species; several of these species rarely occur on the prairie, suggesting that the prairie-forest transition zone was at or west of Bongards 3500 years ago.

In summary, the fossil insect assemblages studied indicate the following about the Late Quaternary climatic history of the midcontinent: 1. Wisconsinan summers were generally more cool and moist than those of today; 2. the coldest conditions in the Late Wisconsinan occurred 17,000 years ago at glacial maximum, when central Iowa had summer temperatures comparable to those at the treeline in Canada today; 3. by 13,000 years ago, summer temperatures had ameliorated by several degrees and were comparable to those in the mid-Boreal Forest today; 4. from 13,000 to 9,500 years ago, summer temperatures warmed slightly to those now recorded at the southern margins of the Boreal Forest; whether this warming occurred gradually or in steps cannot yet be determined; 5. conditions became markedly drier 9500 years ago, with the introduction of prairie elements into the spruce woodland; 6. from 3500 years ago until present, the climatic patterns varied little from those of today.

The faunal colonization that accompanied the Late Wisconsinan warming and ice recession cannot be envisioned as a steady northward movement of biotic zones but rather as a series of localized successions. Insect species emigrated at different rates producing a continuously changing fauna that has no modern analogue. Whether analogous faunas ever existed during the Wisconsinan or whether they occurred only during periods of deglaciation still remains a zoogeographic puzzle.

1. Ashworth, A.C., et al. (1981) Quat. Res., in press.
2. Ashworth, A.C. and Brophy, J.A. (1972) Bull. Geol. Soc. Amer., 83, 2981-2988.
3. Ashworth, A.C., Clayton, L., and Bickley, W.B. (1972) Quat. Res., 2, 176-188.

14. LATE LLANQUIHUEAN CLIMATIC HISTORY OF SOUTHERN CHILE DEPICTED BY FOSSIL BEETLE ASSEMBLAGES

John W. Hoganson* and Allan C. Ashworth[a]
Geology Department, University of North Dakota
Grand Forks, N.D. 58202
and
North Dakota State Geological Survey
Grand Forks, N.D. 58202
[a]Geology Department, North Dakota State University
Fargo, N.D. 58105

Glacial and pollen studies in southern Chile have produced conflicting interpretations concerning the timing and duration of late-glacial climatic events especially from 13,000 to 10,000 years ago. Pollen studies show a marked deterioration of climate from ca. 11,000 to 10,000 years ago interpreted to be coeval with the European cold Younger Dryas Stade (1). In contrast, studies of ice-marginal variations from the same area reflect significant differences between southern Chile and western Europe during that period (2). Those data reflect a rapid amelioration of climate beginning at 13,000 yr B.P., with glaciers reaching their present diminutive state by 11,000 yr B.P. and full, stable interglacial conditions persisting during the 11,000 to 10,000 yr B.P. interval. The problem presented by the incompatibility of botanical and geological interpretations is being investigated through studies of fossil beetle assemblages.

Interpretations of ecological conditions, specifically the thermal environment, reflected by the fossil assemblages, are based on knowledge of the distribution of the existing coleopteran species. Because elevational distribution generally reflects thermal tolerances, it was necessary to systematically collect the existing coleopteran fauna along an elevational transect from sea level to alpine tundra. Sites were established at approximately 100-m intervals in Valdivian Rain Forest, Patagonian Rain Forest, Subantarctic Deciduous Forest, and Treeline and Tundra biomes. A variety of standard collecting techniques were employed, host plant records kept, and detailed habitat notes taken at each locality. Although numerous sites were in forest habitats, most of the collections were from water-marginal and aquatic habitats because of potential similarity to fossil depositional environments. In excess of 9000 individuals representing 484 taxa from 47 beetle families were collected. Patterns of similarity between beetle faunas from the collecting sites were established by using cluster analysis of similarity coefficients. Three elevational groupings or zones were defined by this method. The elevational range of each taxon was plotted to further refine the zonation. Additional geographic distribution information was obtained from specimens in major North American museums, private collections, correspondence with experts, and from scientific literature. This reference collection and distributional data were used to aid in identification of the fossils and attach climatic significance to the fossil assemblages.

Interpretations are based on several thousand exceptionally well-preserved fossils extracted at 10-cm intervals from a 4.5-m sequence of lacustrine silts, clays and organic debris collected at a cutbank exposure along the Rio Caunahue near Llifen, Valdivia Province, southern Chile. At this site essentially continuous deposition occurred from 14,635 to 4,535 years ago. Comparison of those specimens to the modern zonation and additional distributional data were used to detail the late-glacial/early Holocene climatic history of southern Chile. Apterous leaf-litter weevils, phytophagous scarabs, wood-boring scolytids and weevils, forest-dwelling ground beetles and other forest inhabiting species from numerous families dominate the fossil assemblages. All live today in the temperate, low elevation, Valdivian Rain Forest; the dominant forest type in the Lake Region of southern Chile today. Faunal composition remained essentially unaltered from 14,635 to 4,525 years ago in the Rio Caunahue site area, implying that the thermal environment also remained unchanged during that time. These results indicate that final deglaciation occurred prior to 14,635 yr B.P., although it was previously thought to have taken place about 13,000 yr B.P. Also, no evidence was found that cold conditions existed in the area during the "Younger Dryas Stade" as previously inferred from palynological studies; this corroborates ice-marginal geological investigations which have found no indication of glacial advance at that time.

1. Heusser, C.J. and Streeter, S.S. (1980) Science, 210, 1345-1347.

2. Mercer, J.H. (1976) Quat. Res., 6, 125-166.

15. SHORELINE EROSION, ORWELL LAKE, MINNESOTA: A PROGRESS REPORT

John R. Reid* and Gary D. Winbourn
Department of Geology, University of North Dakota
Grand Forks, ND 58202

Orwell Lake, a flood-control and water management impoundment about 7 miles SSW of Fergus Falls, Minnesota, was first placed into operation in 1954. Since that time, a considerable amount of bank and shore erosion has occurred. A project, funded by the U.S. Army, Cold Regions Research and Engineering Laboratory was initiated in 1980 to identify and quantify those processes responsible for the erosion along the shore of the lake, and especially those processes operating during the cold months of the year.

Preliminary studies have revealed that the significant processes include wave action, raindrop impact, sheetwash, stripewash, rillwash, mass movement, and mass transport. Less important processes identified thus far include deflation, frost desiccation, and ice shove.

In an effort to measure each of these processes, a series of control and measurement stations was installed during the summer and fall of 1980. Of most value so far have been erosion stations. These are sites of varying slope angle and exposure direction at strategic sites around the lake. At each station a set of 9-15 spikes (140 mm long) and washers was inserted normal to the surface. On the steeper slopes the spikes and washers were inserted flush with the surface; on the gentler slopes the head of the spikes were left protruding up to 30 mm above the surface with the washers resting on the surface. In this way both erosion and deposition events are recorded. Most erosion on these slopes has occurred during intense rainstorms. The gentler slopes have been eroded the most (an average of 15 mm/spike) because rillwash is greater there. The average total erosion for all spikes was about 10 mm (equivalent to 8-11 kg of sediment removed from a strip 1 m wide and the height of the average bank).

Erosion of the banks temporarily ceased when the rainy season came to a close. A second period of bank erosion began in late winter when sediment particles, frozen together since Fall, began to loosen as sublimation reduced the interstitial ice. The result was an accumulation of sediment on top of the winter snow at the base of steep exposures. The relative significance of this process has yet to be determined.

Although wave erosion is certainly a major factor in shoreline erosion here, attempts to measure the rates of such erosion failed. Lines, with pebbles spaced at 10 cm intervals, were established at several sites, starting at the water edge. In some cases the erosion was greater than had been anticipated, and the lines of pebbles were destroyed. In other cases, a line coincidentally fell along a developing rill which undercut it and made it invalid. Although further efforts will be made this summer, it is already apparent that the most serious wave erosion occurs during the two periods of high pool level each year.

Deflation does not appear to be a significant erosion process at Orwell Lake. During intense summer storms (winds up to 130 km/hr) some sand-size grains were observed in transit. The effectiveness of this process is highly variable, but at no station were the results distinguishable from raindrop impact or stripewash.

During the winter, expansion of the lake ice upon freezing (plus additional expansion following cold contraction and filling of the cracks with water) results in occasional ice shove ridges. Some of these ridges last through the summer, but they are all well below the base of the banks and involve only a small volume of sediment.

Parameters that are being measured and evaluated to determine their relationship to the erosion processes and their rates include sediment properties, ground water fluctuations, soil moisture variations, the rate and depth of frost penetration, and micrometeorology at ground level.

16. POSTGLACIAL OSTRACOD DISTRIBUTION AND PALEOECOLOGY, DEVILS LAKE BASIN, NORTHEASTERN NORTH DAKOTA

J. B. Van Alstine*
Geology Department, University of Minnesota, Morris
Morris, MN. 56267

The Devils Lake Basin, northeastern North Dakota, has undergone several drastic changes in salinity and depth during recorded history, as well as during the Pleistocene Epoch. These changes have been recognized in the geochemistry of the lake sediment (1) and in the diatom flora (2). The purpose of this study was to determine the vertical distribution and paleoecology of ostracod populations in the postglacial sediments of lakes within the Devils Lake Basin, and from a control lake, outside of the basin. The distributions of the ostracod populations were compared to the distribution of the diatoms, and the paleoecology of the ostracod fauna was compared to environmental interpretations based on the sediment geochemistry.

Sediment cores were taken from Main Bay and Creel Bay of Devils Lake (in 1975 and 1976) and East Devils Lake (in 1978) within the basin, and from Red Willow Lake (in 1979), a control lake outside the basin. The cores were taken with a piston coring apparatus to minimize disruption of the sediment. Through the use of casing and extension rods, continuous lengths of core up to 8.5-m in length were recovered. Cores were sampled, for the recovery of the ostracods, at 10-cm intervals.

Fifteen species of ostracods were present in the cores: 8 candonids, 1 cyclocyprid, 3 cyprids, and 3 limnocytherids. Two distinct faunas are recognized. The Devils Lake-East Devils Lake fauna consists of Candona lactea, C. rawsoni, Cyprinotus glaucus, Potamocypris smaragdina, Limnocythere (Limnocytherina) ceriotuberosa, and L. staplini. The Red Willow Lake fauna consists of Candona acutula, C. candida, C. caudata, C. decora, C. ohioensis, C. lactea, C. pronopa, C. rawsoni Cypridopsis vidua, Cyclocypris ampla, and Limnocythere (Limnocytherina) itasca. Only two species are in common with the two faunas.

The paleoecology of the Devils Lake-East Devils Lake fauna indicates that the lakes have remained shallow, with little aquatic vegetation, through time. Elevated levels of sulfate have always been present, with levels of total dissolved solids always being greater than perhaps 10,000 ppm. Faunal diversity, similarity and equitability indices were calculated and plotted, along with simple abundance of species with depth. The measured indices fluctuated greatly with depth, but the fauna did not become more complex or diverse with time. Variations in the measured indices are used to interpret major episodes of environmental disruption. In the Devils Lake-East Devils Lake system, the nature of the disruption is interpreted to be periods of greatly increased salinity, or dessication. Using previously determined sedimentation rates for Main Bay, of Devils Lake, (1) the episodes of environmental disruption are interpreted to have occurred at 7,000, 1,500, 1,200, and 900 years B.P. Because of lack of sedimentation rates for the other cores within the basin, the times of disruptive events recognized in those cores could not be determined.

The paleoecology of the Red Willow Lake fauna indicates that the lake has remained cool and relatively deep, with abundant aquatic vegetation through time. The sulfate concentration has always been low, and the levels of total dissolved solids have always remained below 6,000 ppm. The same indices were measured for the Red Willow Lake fauna as for the lakes in the basin. The indices fluctuated greatly throughout the length of this core as well. The nature of the environmental disruption is unknown. There is no indication of elevated levels of salinity in the history of Red Willow Lake. None of the episodes recognized in Red Willow Lake correlate with episodes recognized in the Devils Lake Basin.

In the Devils Lake cores, only two periods of disruption, at 7,000 and 1,500 years B.P., correlate with evidence from diatoms (2) and the geochemistry of the lake sediment (1). The paleoecology of the ostracods compares favorably with general interpretations based on diatoms for the Devils Lake Basin through time.

1. Callender, E. (1968) University of North Dakota unpublished Ph.D. dissertation, 312 p.

2. Stoermer, E. F., Taylor, S. M. and Callender, E. (1971) Trans. of the American Micro. Soc. 90. 195-206

17.

CONTINENTALITY: A MEASURE OF THERMAL HARSHNESS IN NORTH DAKOTA

Ted J. Alsop*
Department of Geography, University of North Dakota
Grand Forks, N.D. 58202

One of North Dakota's most well-known facts is its geographic centrality to the North American continent. Located approximately nine kms west of Balta, the geographic center of the North American continent has been surveyed to be $48^{\circ}10'$ North Latitude and $100^{\circ}10'$ West Longitude (1). One of the most dramatic effects of this continental centrality is the landmass' imposition of large temperature ranges in every part of the State of North Dakota, a phenomenon known as continentality.

Because of the thermal differences between a unit of land and a unit of water, i.e., specific heat, heat capacity, thermal conductivity, and shared thermal conductive capacities, land surfaces heat and cool more rapidly than water surfaces. In an effort to quantify this relationship, Johannson (2) developed an index of continentality which, slightly modified, is defined by $K = (1.6A/\sin L^{\circ}C) - 14$ where K is the continentality in percent, A the temperature range in degrees centigrade, and L the latitude in degrees.

Annual continentality values were calculated for each of 117 meteorological (met) stations in North Dakota for the year 1978 (see Figure 1). This year was selected for its most recent and complete data record. The one absolute minimum temperature of the year at each met station was subtracted from the one absolute maximum temperature of the year at each met station in order to calculate the yearly temperature range at each station. The large bold numbers in Figure 1 represent the average continentality value for that district.

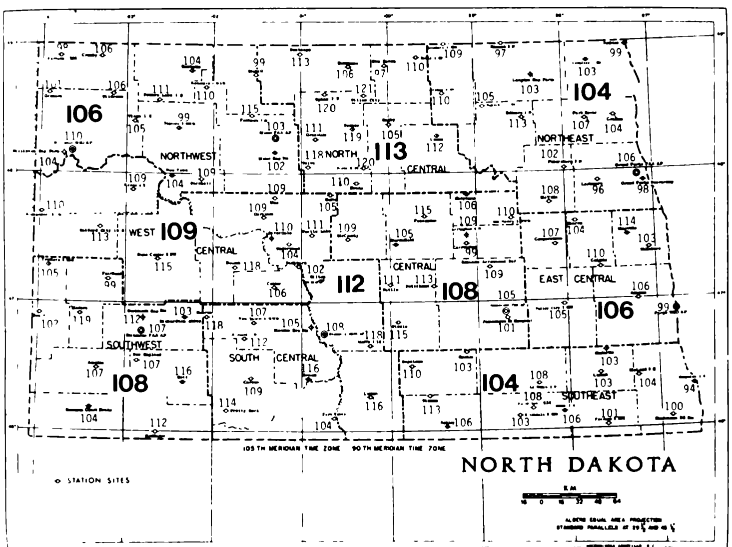


FIGURE 1
Continentality values for 1978

Monthly temperature ranges were calculated in the same manner as the yearly but with the month as the basic unit. An analysis of the monthly values revealed the most continental months of 1978. November was found to be the month with the greatest proneness to large temperature ranges followed closely by March. In November, minimum temperatures plunged to $-29^{\circ}C$ ($-20^{\circ}F$) from minimums of $-07^{\circ}C$ ($20^{\circ}F$) in October. March's continentality is mainly explained by an increase in maximum temperatures which were $16.6^{\circ}C$ ($30^{\circ}F$) higher in March than in February. The months of the year listed in order of decreasing continentality values for the year 1978 are November, March, September, December, August, January, February, October, May, June, April, and July.

The North Central District which contains the geographic center of the North American Continent not only had the highest average continentality but also the station (Willow City) with the highest single continentality. The site with the lowest continentality was the station most distant from the geographic center (Wahpeton) located in the Southeast District which had one of the two lowest average continentalities by district. Simple correlation revealed the relationship between continentality and distance from the geographic center of the North American continent. Correlation coefficients by district varied from -0.0810 in the North Central District which contains the geographic center to -0.7091 in the Southeast District which is one of the two farthest districts from the geographic center. The physiographic roughness of southwestern North Dakota imposes anomolously high continentality values in the West Central, Southwest, and South Central Districts. The sign of the correlation coefficients indicates the inverse relationship between continentality and distance from the geographic center. Further, correlation coefficients increment with distance from the geographic center of the continent.

1. The World Almanac. (1981) p. 459. Newspaper Enterprise Association, Inc., New York.

2. Johannson, O.V. (1976) in The Visualization of Climate, (Engleman, J.R.) pp. 7-8. Lexington Books, Massachusetts.

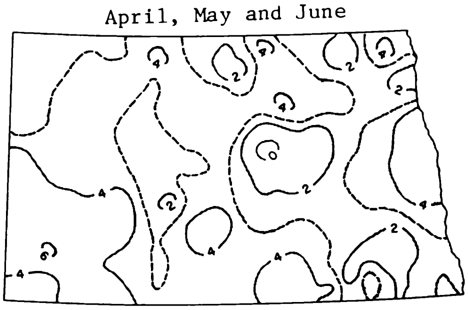
18. THE NORTH DAKOTA DROUGHT OF 1980

William A. Dando and Floyd C. Hickok*
Department of Geography, University of North Dakota
Grand Forks, N.D. 58202

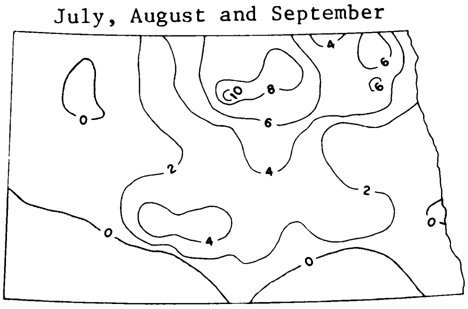
Since late 1979, a period of abnormally dry weather sufficiently prolonged for the lack of moisture and high temperatures to cause a serious hydrologic imbalance has created a drought of a magnitude not experienced for more than forty years in areas of the state. A deviation from long term weather patterns, specifically from October 1979 to August 1980 and dominated by a series of stronger than normal high pressure cells, produced extended periods without rain and unseasonably high temperatures that had a disastrous effect upon agricultural production. A blocking ridge of high pressure to the west and to the south prohibited the movement of moist, maritime air masses into the state. General weakening of the circumpolar vortex at the 700 mb level (approximately 18,000 feet) and the general strengthening of the zonal current at the state's latitudes helped to maintain fast moving dry and warm zonal westerly winds. Cyclonic activity that normally brought moisture into the state tracked generally south or east of the climatologically expected path. Both the westerlies that advect moisture from the Pacific Ocean in the late fall, winter and early spring, and the southeasterlies that advect moisture from the Gulf of Mexico in late spring, summer, and early fall deviated from their normal positions. Over North Dakota an edge of a large and extensive ridge of high pressure produced strong divergence and subsidence, abnormal heating and drying of the air, suppressed clouds and convectional precipitation, increased solar radiation receipts and baked the ground dry. Growing season precipitation departed from the fifty year average as much as six inches in April, May and June, and exceeded the fifty year average as much as ten inches in July, August and September (see maps). Water year deviations (October 1st to September 30th) from the fifty year average ranged from a -9.06 at Hettinger to a +6.19 inches at Towner.

1980 GROWING SEASON PRECIPITATION
IN INCHES OF DEPARTURE
FROM 1931 to 1980 AVERAGE

April, May and June



July, August and September



Below Normal

These meteorologically quantitative and economically qualitative spatially interdependent macro-scale drought conditions had an adverse impact upon the economic viability of the state and has drawn attention to the critical dependence of agriculture and related industries to the highly variable rainfall in sub-humid and semi-arid North Dakota. Dando, in his research of moisture problems in semi-arid agricultural regions where dry-farming is practical, has studied long term precipitation and temperature records from all existing weather stations in the state and has concluded that total state annual precipitation has declined slightly and annual temperatures have increased in the past ninety years (1). Droughts are common in North Dakota and the long term probability for drought ranges from one year out of four in the northwest to one year in twenty in the northeast (2). The spatial patterns (see map) of the 1980 growing season precipitation deviation from the 1931 to 1980 precipitation average help to illustrate the severity and extent of meteorological drought conditions which encompassed the state.

High air temperatures, lack of precipitation and precipitation receipt at an improper time for plant growth, development, maturation or harvesting exacted a heavy economic toll in the state. Abnormal weather patterns associated with a drought year and drought were primarily responsible for a reported statewide 53 percent drop in oil sunflower production, 43 percent loss in flax, 37 percent decline in soybeans harvested, 20 percent decrease in the production of corn, 17 percent drop in corn silage harvested, 55 percent loss in hay cut, 29 percent decline in all wheat combined, 13 percent drop in oats production, and a 65 percent loss in harvested rye (3).

1. Dando, William A. and Chang, Kang-tsung. (1979) A Working Model Computer Map Atlas of Economic Development in North Dakota, University of North Dakota, Grand Forks, N.D., 4-18.

2. Dando, William A. (1977) Drought in North Dakota, The Great Plains-Rocky Mountain Journal, Vol. 6, 197-203.

3. Dando, William A. and Hickok, Floyd C. (1981) The 1980 North Dakota Drought (Phase I), EDA Contract #80-09(A), University of North Dakota, Grand Forks, N.D., 43-44.

19. EFFECT OF PHYSICO-CHEMICAL PRETREATMENT ON THE BIOLOGICAL OXYGEN CONSUMPTION OF COAL GASIFICATION WASTEWATERS

Yung-Tse Hung and Bill D. Priebe*
Civil Engineering Department, University of North Dakota
Grand Forks, North Dakota 58202

One method of utilizing coal as an energy resource is to thermochemically convert it into gaseous fuel. Wastewaters generated during this conversion contain various pollutants and will require treatment prior to discharging to receiving waters or reuse in production processes. Emphasis has been placed on biological wastewater treatment technologies since they are generally the most cost effective method for removal of organic pollutants in high strength wastewaters which are amenable to biological treatment. Coal gasification wastewaters contain contaminants that are toxic or inhibitory to microorganisms in biological waste treatment systems. Raw gas liquor chemical oxygen demand (COD), phenol, and ammonia concentrations can reach 30,000, 7300 and 7000 mg/l, respectively. Pretreatment methods can be used to prepare wastewaters for biological waste treatment.

The objective of this investigation was to determine the influence of physico-chemical pretreatment on the biological oxygen consumption of coal gasification wastewaters. The Warburg respirometric technique was used to determine the biological oxygen consumption (1). Pretreatment included lime precipitation, ammonia-stripping, dilution, and solvent extraction. Methyl isobutyl ketone (MIK) and isopropyl ether (IPE) were used in the extraction of phenols from the ammonia-stripped wastewaters. The Warburg apparatus used in this experiment accommodated 18 independently operated manometer and flask units. Each flask contained 5 ml of pretreated wastewater and acclimated microorganisms. As oxidation proceeded, the dissolved oxygen in the water was consumed and the carbon dioxide that was produced was absorbed by an isolated sample of 20% KOH. A decrease in partial pressure of O_2 in the flask was measured on the manometer and recorded. The barometric pressure and temperature changes were corrected by monitoring two thermobarometers. All samples were examined in duplicate at 21°C.

The oxygen consumption of the pretreated gas liquor over a 120 hour period is shown in Table 1. Raw, lime precipitated, and 90% strength ammonia-stripped gas liquor showed only chemical oxygen consumption, due to toxic concentrations of ammonia and phenol. Reducing contaminant concentrations in the ammonia stripped wastes by dilution increased oxygen consumption. Oxygen consumption for 90, 50, and 30% strength ammonia-stripped gas liquor was 105, 966, and 1249 mg O_2/l, respectively, after 120 hours of Warburg run. Solvent extraction reduced over 90% of the phenol and 60% of the COD from the ammonia-stripped wastewater following four stages of extraction using a solvent to gas liquor ratio of 1:10. After solvent extraction pollutants which are toxic or inhibitory to biological treatment were reduced to acceptable levels. The oxygen consumption increased significantly for gas liquors which have been solvent-extracted. The IPE and MIK solvent extracted samples utilized 1530 and 1355 mg O_2/l. IPE would appear to be a more biologically acceptable solvent as the oxygen utilization was the highest.

This investigation indicates that gas liquor can be biologically treated at full strength following pretreatment by ammonia-stripping and solvent extraction.

Table 1

Oxygen Consumption Summary of Coal Gasification Wastewaters

Time (hr.)	Control	Raw Gas Liquor	Lime Ppt.	NH_3-Strip 90%	NH_3-Strip 50%	NH_3-Strip 30%	Stage 4 MIK Solv.Ext. (1:10)	State 4 IPE Solv.Ext. (1:10)
20	61	749	382	67	83	169	631	647
40	77	817	432	75	131	427	1142	1100
60	110	869	478	80	347	855	1285	1333
80	144	900	507	92	601	1063	1338	1423
100	201	935	539	98	863	1213	1355	1497
120	231	955	559	105	966	1249	1355	1529

1. Hung, Y.T. and Eckenfelder, W.W. 1976. Comparison of Warburg and Marais methods of determining oxygen uptake rate constants. Water and Pollution Control, Vol. 114, No. 2.

20. UTILIZATION OF ANAEROBIC FILTERS FOR TREATING COAL GASIFICATION WASTEWATERS

Yung-Tse Hung and Shyh-Tzong Lee*
Civil Engineering Department, University of North Dakota
Grand Forks, North Dakota 58202

Coal is projected to make a substantial contribution to energy supplies and in effect reduce energy requirements and reliance on imported oil. In order to minimize undesirable environmental effects, coal must be processed into less polluting fuels. Gasification reduces the environmental impact of using coal as a source of fuel but creates large quantities of gaseous and liquid wastes. A full scale plant capable of producing 250 million standard cubic feet per day of synthetic natural gas can produce up to about 2 million gallons of wastewater per day. Gasifier liquid effluents are produced from gas scrubbing to remove soluble substances, quenching to control operating temperatures, steam condensation, and quenching of ash or slag. Gas liquor, which generally contains large concentrations of chemical oxygen demand (COD), phenol, and ammonia (NH_3), is the total liquid stream from condensing or scrubbing in the total gasification process. This wastewater has a high pollution potential if released untreated or even after pretreatment for phenol and ammonia removal.

The objective of this study was to evaluate the feasibility of using anaerobic filters in the removal of organic pollutants from pretreated gas liquor. Anaerobic digestion is normally considered a two-phase process. In the first phase facultative acid-forming organisms convert complex organic matter to acids such as acetic, propionic, and butyric. In the second phase anaerobic methane-forming organisms convert these acids to methane gas and carbon dioxide. The main advantages of using anaerobic biological treatment versus aerobic biological treatment methods is that a high degree of waste stabilization can be accomplished with relatively low production of biological solids with the possibility of methane gas recovery (1). This would reduce effluent suspended solid levels and reduce sludge disposal costs.

Two bench scale anaerobic filters of 3 in. inside diameter and 2 ft. height were used in this study. The void volumes of the columns were approximately 2.5 l when packed with 5/8 in. diameter Raschig rings. The hydraulic detention time for each filter was an average of 6.3 days at an influent flow rate of 1.0 l/day. Pretreatment consisted of lime precipitation, air-stripping, and dilution to reduce alkalinity, ammonia, and phenol concentrations. Gas liquor was fed at 10 and 3% strength for filters 1, and 2, respectively. The performance summary is shown in Table 1.

The pretreated undiluted gas liquor samples, used as feed to the anaerobic filters, had average COD, phenol, and ammonia levels of about 20,000, 4000, and 4000 mg/l, respectively. The two filters exhibited similar removal rates for COD and ammonia, ranging from 54 to 60% for COD and 27 to 30% for ammonia. However, anaerobic filter 2 removed 90% of phenol, approximately 25% more than filter 1. Due to the lower feed strength used in filter 2, higher removals of COD, phenol, and ammonia were obtained. This is common for wastewaters containing compounds toxic or inhibitory to microorganisms. Anaerobic treatment, under the operating conditions chosen in this study, did not produce an effluent capable of being released or reused. However, anaerobic treatment can be used as a pretreatment method for coal gasification wastewaters prior to secondary and tertiary waste treatment.

Table 1

Performance Summary of Anaerobic Filters

Reactor	Hydraulic Detention Time (day)	COD Infl.	COD Effl.	COD % Removal	Phenol Infl.	Phenol Effl.	Phenol % Removal	NH_3-N Infl.	NH_3-N Effl.	NH_3-N % Removal
1	6.32	1776*	814	54	382	136	64	211	155	27
2	6.26	645	261	60	137	14	90	187	131	30

Reactor	Alkalinity Infl.	Alkalinity Effl.	Alkalinity % Removal
1	343	258	24.8
2	145	157	-

*All values in mg/l unless stated otherwise.

1. DeWalle, F.B., and Chian, E.S. (1976) Kinetics of substrate removal in a completely mixed anaerobic filter. Biotechnology and Bioengineering. Vol. XVIII, pp. 1275-1295.

21. FEASIBILITY OF TERTIARY TREATMENT OF COAL CONVERSION WASTEWATERS USING SUBMERGED ANAEROBIC FILTERS

Yung-Tse Hung and Shahin Rezania*
Civil Engineering Department, University of North Dakota
Grand Forks, North Dakota 58202

There is an ever-increasing need for effective treatment of coal conversion wastewaters brought about by more stringent discharge regulations, an increasing national awareness of the effects of pollution, the concern for fixed nonrenewable natural resources, and the possible economic feasibility of in-plant water reuse. Secondary biological treatment processes do not yield an effluent which is free of organic and inorganic contaminants. Tertiary treatment may provide a means of reducing pollutant concentrations (1). The objectives of this study were to determine the effectiveness of using submerged anaerobic filters in the tertiary treatment of coal conversion wastewaters, and to determine the effect of filter media on the filter performance.

Four bench scale submerged anaerobic filters were operated for 3 months to determine their effectiveness in the removal of chemical oxygen demand (COD), and total organic carbon (TOC) from coal conversion wastewaters. Each column had an inside diameter of 1 inch and a length of 2 feet. The first two columns were packed with sand and the second two contained crushed lignite. Filters 1 and 3 were used in treating coal liquefaction wastewaters, while filters 2 and 4 were used in treating coal gasification wastewaters. The wastewaters used for the anaerobic filter treatment were subjected to pretreatment and secondary treatment. The lignite liquefaction wastewater was lime precipitated, ammonia-stripped, and subjected to activated sludge treatment at 10% of its original strength. The coal gasification wastewater was lime precipitated, ammonia-stripped, solvent extracted, and subjected to activated sludge treatment at full strength. Influent tertiary treatment flow rates averaged 1.0 l/day for all filters.

Table 1 summarizes the performance of the anaerobic filters on coal liquefaction wastes. The average feed strength to both columns was 305 mg/l of COD and 117 mg/l of TOC. During the 3 months of operation the average organic removal rates were 16% for the sand column and 21% for the crushed lignite column, on a COD basis, and 11% for the sand column and 17% for the lignite column on a TOC basis. Effluent COD values were still over 200 mg/l and effluent TOC levels were over 90 mg/l. Results for the tertiary treatment of coal gasification wastewaters are shown in Table 2. Average influent COD and TOC values were 1944 and 947 mg/l. These levels are higher than the coal liquefaction wastewaters since full strength pretreated wastewaters were used in the activated sludge treatment. The removal rates for COD and TOC in the sand column were approximately 6 and 3%, respectively. The lignite column removed 9% of COD and 7% of TOC. The wastewater effluents still contained over 1700 mg/l of COD and over 900 mg/l of TOC. High concentrations of toxic substances present in the gasification wastewaters may have inhibited anaerobic biological oxidation and reduced organic removal efficiencies.

Based on this study, crushed lignite was superior over sand as packing media for submerged anaerobic filters. Submerged anaerobic filters showed low removal rates of organic pollutants from coal conversion wastewaters. Methods to minimize the inhibitory effect of toxic substances present in the coal conversion wastewaters should be investigated.

Table 1
Coal Liquefaction Wastewater Treatment Performance

		Sand Column		Lignite Column			Sand Column		Lignite Column	
Time (month)	Feed COD	Effl. COD	% Removal	Effl. COD	% Removal	Feed TOC	Effl. TOC	% Removal	Effl. TOC	% Removal
1	432*	336	22	299	31	138	110	20	93	33
2	228	207	9	203	11	88	86	2	79	6
3	254	211	17	202	20	128	115	10	112	13
Aver.	305	251	16	235	21	117	103	11	95	17

Table 2
Coal Gasification Wastewater Treatment Performance

		Sand Column		Lignite Column			Sand Column		Lignite Column	
Time (month)	Feed COD	Effl. COD	% Removal	Effl. COD	% Removal	Feed TOC	Effl. TOC	% Removal	Effl. TOC	% Removal
1	1974*	1921	3	1840	7	948	952	3	887	10
2	1900	1771	7	1713	10	999	949	5	942	6
3	1957	1814	7	1757	10	858	844	2	808	6
Aver.	1944	1835	6	1770	9	947	900	3	906	7

*All values in mg/l unless stated otherwise.

1. Witt, E.R., and Humphrey, W.J. Full scale anaerobic filter treats high strength wastes. Presented at the Purdue University Industrial Waste Conference. West Lafayette, Indiana. May 1979

22. ACTIVATED SLUDGE TREATMENT OF SYNTHETIC SUGAR BEET PROCESSING WASTEWATERS

Yung-Tse Hung and Ardeshir Asadi-Rad *
Civil Engineering Department, University of North Dakota
Grand Forks, North Dakota 58202

More than three million tons of refined sugar are produced each year from sugar beets raised in 29 states in the U.S.A. The total waste load from a factory capable of processing 2,000 tons of beets per day is roughly equivalent to that from a city of 250,000 people. For many years research has been devoted to the development of applicable methods for the disposal or reuse of industrial wastes. One single wastewater treatment design cannot be adapted to all beet factories due to variations in processing conditions, raw materials and climatic conditions. Biological treatment processes have been commonly used in treating this type of wastewater due to reduced costs and high performance. Tertiary treatment using coagulation/flocculation was proposed by Leentvaar and Koppers (1979) (1). The objective of this investigation was to utilize the activated sludge process in the treatment of synthetic sugar beet processing wastewaters.

Three bench scale completely mixed activated sludge reactors were used in this study to investigate the effects of the aeration tank hydraulic detention time on the removal of organics. Wastewater samples, simulating sugar beet processing effluents, were prepared by dissolving 5 gm/l of powdered table sugar in tap water. This wastewater did not contain sufficient nitrogen and phosphorous for biological treatment. Therefore, it was necessary to add nutrients in the form of Na_2HPO_4, $NaH_2PO_4 \cdot H_2O$, and NH_4Cl, to yield a BOD_5:N:P ratio of 100:5:1. Reactors 1, 2, and 3 had hydraulic detention times of 24, 48, and 72 hours, respectively.

The activated sludge reactor performance data is presented in Table 1. The removal of organics, measured by chemical oxygen demand (COD), improved with increasing hydraulic detention time. The feed wastewater had an average COD level of 5000 mg/l. The effluent of reactors 1, 2 and 3 contained average COD concentrations of 1000, 550, and 250 mg/l, corresponding to 87, 92, and 97% removal. The mixed liquor suspended solids (MLSS) and the mixed liquor volatile solids (MLVSS) were observed to decrease with increasing aeration tank volumes. Increasing aeration tank volumes decreases the food concentration available to microorganisms in the system. The values for effluent total suspended solids (TSS) and effluent volatile suspended solids (VSS) ranged from 150 to 920 mg/l and 290 to 500 mg/l, respectively. The effluent TSS and VSS were lowest in reactor 3 with the longest hydraulic detention time.

In conclusion, the activated sludge process could effectively reduce the COD concentration in the sugar beet processing wastewaters. In order to reuse or release this wastewater additional treatment would be necessary to reduce residual COD, TSS and VSS concentrations.

Table 1

Activated Sludge Reactor Performance Summary

Reactor	Hydraulic Detention Time (hr)	Infl. COD (mg/l)	Effl. COD (mg/l)	% Removal	MLSS (mg/l)	MLVSS (mg/l)	Effl. TSS (mg/l)	Effl. VSS (mg/l)
1	24	5000	1000	87	17000	9000	920	500
2	48	5000	550	92	14500	8400	600	300
3	72	5000	250	97	12275	7000	150	290

1. Leentvaar, J.L., and Koppers, H.W. (1979). Coagulation/flocculation of beet sugar wastewaters. Jour. Water Pollution Control Federation, 51 (10): 2457 - 2466.

23.

FLUORIDE REMOVAL FROM WATER SUPPLIES USING ACTIVATED ALUMINA ADSORPTION PROCESS

Yung-Tse Hung and Bill D. Priebe*
Civil Engineering Department, University of North Dakota
Grand Forks, North Dakota 58202

Natural water contains fluorides in varying amounts. Consumption of water that contains fluoride in concentrations of approximately 1.0 to 1.5 mg/l is effective in reducing tooth decay. Although dental health is probably of primary concern for the control of fluoride in water, the more severe effects of excessive levels make it necessary to reduce the concentrations of fluoride present. The chronic toxic effects of excessive intake of fluoride are usually observed as skeletal and teeth abnormalties or damage (1). The current U.S. Public Health Service Drinking Water Standard, 0.8 to 1.7 mg/l, allows for regional maximum daily air temperatures, since the amount of water, and consequently the amount of fluoride ingested, is primarily influenced by the air temperature of the area.

The primary objective of this study was to examine the feasibility of removing fluoride ions from water by continuously fed upflow activated alumina columns. Factors which affect the performance of the activated alumina process were investigated. These included pH of feed water, hydraulic loading, and the weight ratio of fluoride to activated alumina. Three columns of 0.5 inch inside diameter and 2 feet length were constructed using clear plexiglass tubing. Within each reactor various amounts of activated alumina of 8 to 14 mesh sizes was packed between glass wool to prevent activated alumina washout during the course of each experiment. Two Masterflex variable speed pumps were used to feed the reactors at flow rates ranging from 20 to 60 ml/min. The synthetic feed water was prepared by dissolving predetermined amounts of sodium fluoride in distilled water to simulate the raw waters treated in municipal water treatment plants. The pH was adjusted to 5, 7, and 9 with sodium hydroxide or sulfuric acid. Influent and effluent samples from each column were collected at different time intervals and analyzed for fluoride ion concentration by the specific ion electrode method using a model 407A Orion Research Ionalyser. TISAB buffer was used to maintain the proper pH and eliminate the effects of complexing ions. The influence of flow rate (Q) on fluoride removal is illustrated in Figure 1A. Operating conditions included flow rates of 20, 40, and 60 ml/min with corresponding hydraulic loading of 158, 316, and 478 $l/min/m^2$, 10 gm of activated alumina in each column, a pH of 7, and an initial fluoride concentration of 10.7 mg/l. It was observed that lowering flow rates increased fluoride removal rates. At 80 minutes of column run the concentration of fluoride removed was 2, 1.0, and 0 mg/l for flow rates of 20, 40, and 60 ml/min, respectively. Figure 1B depicts the fluoride removal efficiencies at various weights of activated alumina in the adsorption columns. Feed water containing 10.7 mg/l fluoride, at pH 7, was pumped at 20 ml/min to three columns packed with 5, 10, and 15 gm of activated alumina. The sites for adsorption of fluoride ions on to the activated alumina particles became exhausted much more rapidly in the column packed with the least amount of alumina. An equilibrium between adsorption and desorption of F^- ion appeared to be established at higher effluent F^- concentrations for columns containing lower amounts of activated alumina. In addition to Q and quantity of activated alumina, the pH value also has an important effect on the fluoride removal as shown in Figure 1C. Residual F^- concentrations are shown in relation to time at pH values of 5, 7, and 10. Operating conditions consisted of 10 gm activated alumina in all columns, a flow rate of 20 ml/min, and an initial F^- level of 11.4 mg/l. Of the pH values examined, pH 5 appeared to be the best in terms of establishing the lowest effluent equilibrium level of F^-.

Based on results obtained in this study, the activated alumina process was effective in removing fluoride from water supplies. Regeneration techniques will need to be employed to keep it cost competitive with other methods on a full scale basis.

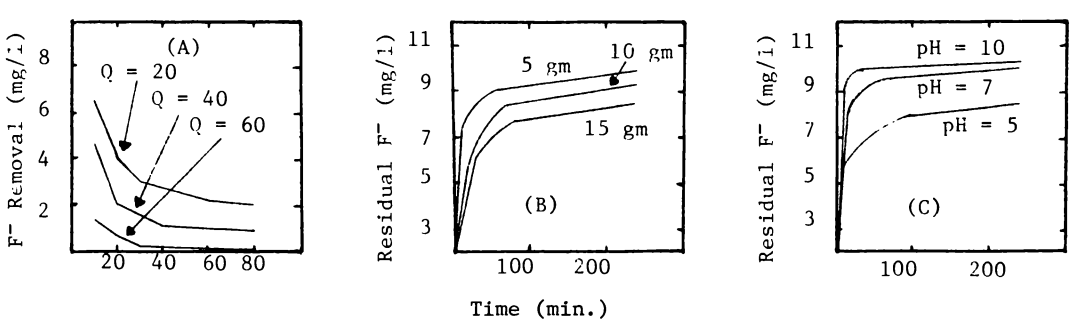


Figure 1. Performance of Activated Alumina Process

1. Choi, W.W., and Chen, K.Y. (1979) The removal of fluoride from waters by adsorption. Jour. American Water Works Association 72 (10): 562 - 570.

24. EFFECT OF POWDERED ACTIVATED CARBON ADDITION ON THE ACTIVATED SLUDGE TREATMENT OF POTATO PROCESSING WASTEWATERS

Yung-Tse Hung and Lih-In Wang*
Civil Engineering Department, University of North Dakota
Grand Forks, North Dakota 58202

Wastewaters from potato processing originate from a variety of sources depending on the specific processes employed. The composition will depend on process technology, operating conditions, and the nature of the raw materials. While great variations exist, the potato processing wastewater effluents are generally considered to be high in suspended and dissolved organic pollutants.

Different water management schemes exist for given processing conditions and depend upon the exact nature of the particular waters and the quality constraints for which waters will be reused or released. The objective of this study was to investigate the effect of powdered activated carbon (PAC) addition on the performance of the activated sludge process in treating primary effluent from a potato processing plant.

Primary settled potato processing wastewaters were fed at a rate of 3.6 l/day to four bench-scale continuous completely mixed activated sludge reactors. Each reactor consisted of an aeration tank and a settling tank separated by a removable baffle. The aeration tank volumes were equal to 0.9 l and the settling tanks had a volume of 0.45 l. Diffused air completely mixed the aeration tanks while providing sufficient oxygen for biological oxidation. The hydraulic detention time for all reactors averaged 6.0 days, while the sludge age was maintained at 5 days. PAC was added to aeration tanks 1, 2, and 3 to enhance the chemical oxygen demand (COD) removal through the physico-chemical adsorption and the on-site biological regeneration of exhausted activated carbon (1). PAC also provides surfaces for biological growth. The PAC levels in aeration tanks 1, 2, and 3 were 2, 4, and 6 mg/l, respectively. Reactor 4 served as a control without PAC additions.

The performance data of the activated sludge reactors is summarized in Table 1. Increasing aeration tank PAC concentrations improved COD removal efficiencies. With an average influent COD of 1592 mg/l the effluent COD for reactors 1, 2, and 3 were 171, 150, and 130 mg/l. This corresponds to removal efficiencies of 89, 91, and 92%. Reactor 4 without PAC addition had an effluent COD of 219 mg/l or a 86% removal efficiency. Nitrification, which is the oxidation of ammonia (NH_3) to nitrites and nitrates by nitrifying bacteria, may have been inhibited slightly by the addition of PAC. The influent NH_3 level averaged 91.4 mg/l. The greatest oxidation rate of 58% occurred in reactor 4. Reactors 1 through 3 ranged from 50 to 56% of NH_3 removed. Phosphate removal was not appreciably affected in this investigation with reduction rates ranging from 2% to 10%. The mixed liquor suspended solids (MLSS) and volatile suspended solids (MLVSS) increased with increasing concentrations of PAC. This trend was also observed in the effluent total suspended solids (TSS) and volatile suspended solids (VSS). The control reactor averaged about 40% and 15% lower in mixed liquor and effluent suspended solids concentrations, respectively.

Based on this study, PAC was found to be effective in enhancing the COD removal in the activated sludge process. Economic considerations will have to be employed in the determination of its practicality in full scale operations.

Table 1

Performance Summary of Activated Sludge Reactors

Reactor	Hydraulic Detention Time (hr.)	MLSS	MLVSS	Effl. TSS	Effl. VSS	Oxygen Uptake (mg/l-day)
1	6.0	4391*	3607	1446	1211	1277
2	6.0	5178	4181	1593	1317	1630
3	6.0	7324	5864	1749	1424	1681
4	6.0	2683	2153	1203	1000	1600

	COD			NH_3			PO_4		
Reactor	Infl.	Effl.	% Removal	Infl.	Effl.	% Removal	Infl.	Effl.	% Removal
1	1592	171	89	91.4	46.1	50	18.5	16.6	10
2	1592	150	91	91.4	42.8	53	18.5	17.6	5
3	1592	130	92	91.4	40.6	56	18.5	18.0	2
4	1592	219	86	91.4	38.0	58	18.5	18.0	2

*All values in mg/l unless stated otherwise.

1. Gatti, L.B. Upgrading existing sewage treatment plants with powdered activated carbon. Presented at the 2nd Annual Eastern Water Pollution Treatment Test Seminar. Nov. 3, 1977.

25. X-RAY DIFFRACTION METHODS FOR IDENTIFICATION OF MINERALS IN COAL LIQUEFACTION REACTOR SOLIDS

Diane K. Rindt* and David Schott
Grand Forks Energy Technology Center (GFETC)
Grand Forks, N.D. 58202

Liquefaction research facilities at GFETC include a 2.26 kg (5-lb) coal/hour continuous process unit (CPU) for studying lined-out operation in various reactor flow configurations,[1] including either a 3.78 liter (1 gal) stirred autoclave or a tubular reactor. Reaction temperatures where solid samples were collected were between 455°-470°C and pressures ranged from 13.78 - 27.56 MPa (2000-4000 psi). Samples were collected after unit shutdown. Reactor gas was either synthesis gas (H_2/CO) or H_2 or CO. Coals that have been tested include Beulah, N.D. lignite and Powhatan bituminous coal.

Reactor solids can be subdivided into three distinct categories: a) carbonaceous materials formed by mechanisms akin to coking; b) minerals and unreacted coal macerals; and c) $CaCO_3$ precipitates (oolite formations) agglomerated during the processing of low-rank coals.[2] Sodium has also been observed to agglomerate in low-rank coals.[3] Minerals observed in studies of reactor solids by Jenkins are predominantly composed of reduced forms of pyrite (pyrrhotite and troilite), quartz, anhydrite and calcite. There are several reasons why it is necessary to study reactor solids: a) solids formation reduces reactor volume, thereby possibly affecting conversion and/or throughput; b) buildup on reactor walls can act as an insulator and reduce reaction temperatures; c) in a serious case solids could totally plug the reactor or cause a shutdown; and d) some of the minerals may act as catalysts,in the case of spherical free-flowing reactor solids. This paper deals with the results obtained upon studying several reactor solids samples from the CPU for mineralogical characterization.

Automated powder x-ray diffraction (XRD) was the major approach utilized to study the mineral matter present in the reactor solids samples. A Philips APD3600-02 version x-ray diffractometer with a standard goniometer and generator, graphics display devices, a hard copy unit, and a Data General Nova 4 computer was used. Software programs produced lists of peaks, d-spacings and intensities for each sample. Search and match routines were available to reduce the data as was a comparison program to compare the spectrum with bar graphs of standard compounds.

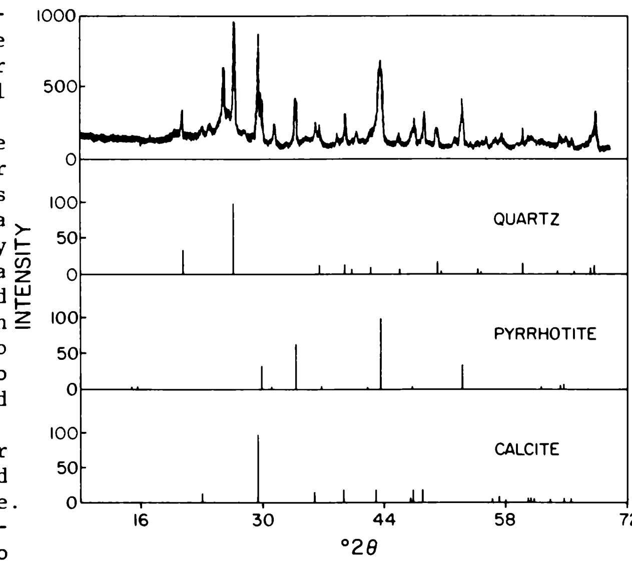


Fig. 1 XRD Diffractogram of Coal Liquefaction Reactor Solids

Figure 1 shows a sample diffractogram of reactor solids with bar graphs of quartz, pyrrhotite and calcite, the major phases identified in this sample. Anhydrate was also noted in this sample. Difficulties arise in identifying calcite by XRD due to the overlapping of the major calcite peak and a lesser pyrrhotite peak. The pyrrhotite peak is broad and tends to mask any calcite present. Most samples analyzed did not show the separation shown here of the calcite/pyrrhotite peaks. In most cases the major calcite line was not identifiable, and as the other lines of calcite were small, a positive identification could not be made from them.

An XRD study using avicel (an organic compound, $C_6H_{10}O_5$, with no XRD pattern) as the matrix showed that the lowest detection limit of calcite was from 2-5%. In this study, XRD results did not identify calcite in most of the samples analyzed. However, thermal gravimetric analysis (TGA) of the samples for carbonate showed between 6 and 24 percent total carbonates present ($CaCO_3$ and $MgCO_3$). These amounts should have been detectable by XRD, if the calcite was in a crystalline form. In the samples studied it appears that the carbonate present was poorly crystallized or non-crystalline and therefore not readily detected by XRD.

In summary, the major mineralogical species identified by XRD in liquefaction reactor solids were quartz and pyrrhotite, with lesser evidence of calcite and anhydrite present. Little evidence of $CaCO_3$ oolite formations were found in these samples, by either XRD or visual observation, due to the amorphous form of the carbonate.

1. Willson, W.G., Knudson, C.L., and Baker, G.G. (1979) Ind. Eng. Chem. Prod. Res. Dev., v. 18, No. 4, 297-310.
2. Jenkins, Robert G. Unwanted Deposits in Liquefaction Reactors (1979) Short Course on Coal Characteristics and Coal Utilization, Penn State University, Oct 22-26.
3. Sondreal, E.A., et al. 9th Biennial Lignite Symposium, (1977) Grand Forks, N.D., May 18-19,p. 20.

26. X-RAY FLUORESCENCE TECHNIQUES FOR ANALYSIS OF FLUIDIZED BED COMBUSTION SAMPLES

Arthur L. Severson* and Steven A. Benson
Grand Forks Energy Technology Center, Department of Energy
Grand Forks, North Dakota 58202

At the Grand Forks Energy Technology Center an atmospheric fluidized-bed combustor (AFBC) is used to study its applicability to low-rank coal combustion. AFBC is an alternative solution to the SO_2 control problem in that AFBCs permit sulfur to be absorbed in the combustion process by adding sorbent to the bed. This, in turn, reduces the need for wet scrubbers to remove the SO_2 from the exhaust gases. The AFBC used in this study was a 2.25 sq. ft. fluidized bed combuster, burning a Texas lignite.

In an AFBC coal is burned in a bed of non-combustible particles consisting of alkali material (which absorbs SO_2) and silica sand suspended in highly turbulent motion by an upward flow of air. Heat transfer tubes in the bed recover the heat generated. Fluidized bed combustors operate at bed temperatures between 1300° F and 1800° F which is more than 1000° F lower than the peak temperatures in a conventional furnace (1).

Since all of the flow streams in the combustor are solids, with the exception of the flue gas, x-ray fluorescence spectrometry (XRF) is a good method for the analysis of these samples. Both qualitative and quantitative techniques were utilized. Quantitative analysis for the lighter elements Na to S used direct excitation from a rhodium x-ray tube operated at 4 KV and 0.30 MA. Germanium secondary excitation at 20 KV and 1.5 MA was used for the analysis of elements K to Fe. The accuracy and precision for the analysis of the major elements Na, Mg, Al, Si, P, S, K, Ca, Ti and Fe has been discussed in earlier studies (2). For sulfur analysis at 2-10% concentration the relative standard deviation is .24%.

Results of the analysis of bed material and some of the flow streams are given in Table 1. These data show a great diversity of composition for the range of concentrations of the different elements. In order to obtain acceptable precision and accuracy in the analysis of samples having such a range of concentrations the standard computer software was modified to account for the different background corrections which result from certain of the elements being at quite low concentrations. Since the bed material has a composition very different from typical lignite ash, U.S. Geological Survey standard reference materials were used to establish instrument calibrations. Table 2 provides an indication of the accuracy of the XRF on samples of widely differing concentration.

Sulfur retention is a key issue in AFBC application to lignite combustion so it is necessary to obtain a material balance on sulfur. Using the data from the AFBC a sulfur balance was made over the whole system and gave a closure of around 60%. This poor closure illustrates that a sulfur balance is a very demanding task since all the ash fractions must be accounted for, and an experimental combuster does not usually operate at a steady state but may involve cyclic operations such as removal of bed material or ash recycle.

Table 1. Fluidized Bed Ash Analysis, %

	Bed material				
	Beginning	End of run	Primary ash	Secondary ash	Baghouse ash
Na_2O	-	-	-	0.82	-
MgO	-	-	0.49	0.62	0.51
Al_2O_3	-	12.94	7.58	8.25	7.76
SiO_2	67.90	51.72	33.31	23.21	22.46
P_2O_5	-	-	0.22	0.59	0.57
SO_3	0.61	7.41	8.04	18.14	17.14
CaO	5.7	34.44	35.68	39.33	40.19
K_2O	0.05	0.26	1.05	0.81	0.61
TiO_2	0.08	0.18	0.41	0.59	0.59
Fe_2O_3	0.66	1.44	2.54	3.97	3.84

Table 2. XRF Analysis of Standards, %

	Std ash 13		USGS Std AGV-1	
	Std	XRF	Std	XRF
Na_2O	7.0	6.7	4.31	4.21
MgO	10.0	10.1	1.55	1.63
Al_2O_3	10.0	9.9	17.22	16.81
SiO_2	20.0	21.7	57.92	57.99
P_2O_5	1.0	1.2	0.50	0.26
SO_3	20.0	20.5	0.01	0.00
CaO	20.0	19.5	5.00	5.30
K_2O	1.0	0.9	2.93	3.40
TiO_2	1.0	1.0	1.05	1.18
Fe_2O_3	10.0	9.9	6.73	6.75

1. Goblirsch, G.M., Sondreal, E.A. (1979) 10th Biennial Lignite Symposium, Grand Forks, ND, May 30-31, p. 1-5.

2. Benson, S.A., Severson, A.L., and Beckering, W. (1980) Am. Lab. Vol 12, No. 11, pp. 35-40.

27. H↔D EXCHANGE IN BCA (BOVINE CARBONIC ANHYDRASE) DUE TO INTERACTION WITH D_2O OR H_2O

Wasyl S. Hnojewyj *
Physics Department, North Dakota State University
Fargo, North Dakota 58105

The dialyzed and lyophilized samples of BCA obtained from Sigma Chemical Co., were pretreated with adsorption of H_2O vapors up to 30%, followed by complete desorptions in high vacuum at 10^{-7} mm of pressure and 30-35° until no changes in weights were observed.

Then, each sample was exposed to a series of D_2O-vapor adsorptions, even at lower temperatures, followed by complete desorptions at 30-35° in vacuum.

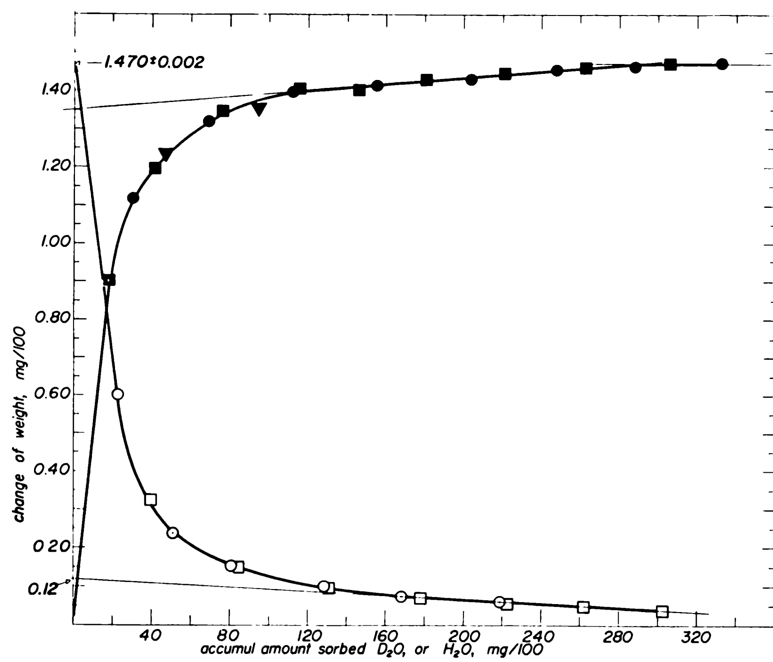
Each cycle of sorption-desorption showed an increase in original weight due to exchange of "labile" hydrogen of BCA by deuterium of D_2O. The "labile" H-atoms are considered to be only from functional groups: -OC-NH-,-COOH,=NH, etc. The repetitions of sorption-desorption cycles were continued until the maxima of weight-change of original BCA sample were reached, indicating a completion of deuterizations.

Further, the use of H_2O vapor for sorption-desorptions on a deuterized BCA in a similar way causes reversible processes of entdeuterizations. Details of procedure are described elsewhere (1,2). The experimental results are shown in the figure, from which maxima of weight-change due to H↔D exchange are all evaluated to be equal to 1.470 ± 0.002 mg/100 of the original weight of BCA.

There is still a question: Are all the "labile" H-atoms of BCA exchanged or not?

Referring to the amino-acid composition of BCA, and assuming an incorporation of Zn-atom through two histidines (3), its molecular weight was estimated to be 29,500 and containing 497 "labile" H-atoms. The theoretical increase of BCA weight due to H↔D exchange should be equal to 1.695 mg/100. Therefore, it seems that the experimental H↔D exchangeability reached only ~87%. It is interesting that the incorporation of 25 NH_3 (3) into BCA in the form of ammonium salts, with respective correction of molecular weight causes the experimental data of H↔D exchange to coincide with theory.

Since the BCA (produced by Sigma Co., and investigated here) represents a mixture of the fractions of activities designated: BCA-I, -II, and -III, which may have some different amino-acid profiles, their ratios could influence H↔D exchangeability. This was recently proved by preliminary checks of H↔D exchangeability on BCA-II, separated electrophoretically in the Biochemistry Department, NDSU, which was found to be ~15% higher than in the original BCA. Further, since our experience with H↔D exchange on similar enzyme-proteins (insulin, hemoglobin) is proven to be the most reliable test of amino-acid composition as related to the molecular structures, therefore, we concluded that all "labile" H-atoms in the BCA investigated are exchanged.



H↔D exchange effect on BCA (bovine carbonic anhydrase) due to adsorption of D_2O or H_2O vapors followed by complete desorption at 35°

sample I: ●○ - forward & reverse runs; sample 2: ■□ and ▼-2nd runs respectively.

1. Reyerson, L. H. and Hnojewyj, W. S. (1961). J. Phys. Chem. 65, 1694.
2. Hnojewyj, W. S. (1971). Proc. N. Dak. Acad. Sci. XXIV, 84-102.
3. Lindskog, S., et al. (1971). The Enzymes, 3rd Edition, Vol. 5, pp. 587-665, Academic Press, N.Y.

28. CHARACTERIZATION OF COMPONENTS IN GASIFICATION TAR BY CAPILLARY GC AND 200 MHz ^{1}H NMR

Edward F. Bitzan*, Sylvia A. Farnum and Bruce W. Farnum
Department of Energy, Grand Forks Energy Technology Center
Grand Forks, North Dakota 58202

Byproduct lignite tar, sample RA 73-1047-1, from the GFETC 25 ton/day slagging fixed-bed gasifier was collected just before conclusion of an 8½-hour run on Indian Head lignite (Mercer County, ND) at 2.1 MPa operating pressure, 170 m^3/hr oxygen flow rate, and 1.0 O_2/steam mole ratio. Identification of components in the tar was carried out to define possible environmental or workplace hazards, assemble a data base on tar composition relative to feed coal and operating conditions, and identify compounds that may be of interest as chemical feedstocks.

Silica gel column chromatography was used to separate the tar into fractions with minimal interferences in assignments of the NMR spectra. A 1 gram sample of the tar was slurried with chloroform and a small amount of activated silica gel. The chloroform was evaporated before the transfer of the sample to the pentane-saturated column. The 19 mm column was packed with 43 cm of neutral silica gel (60-200 mesh) activated at 260°C in an oven overnight. Eluants used were 250 milliliters (ml) of pentane, 100 ml of 5 percent (%) benzene-pentane, 100 ml of 15% benzene-pentane, 100 ml of 20% benzene-20% ethyl ether-60% methanol, and 150 ml of methanol. Twelve fractions of 50 ml each (except 150 ml for fraction 12) were collected in preweighed 250 ml flasks. The fractions were evaporated under vacuum to remove solvent and weighed.

Approximately 170 standard compounds were run as reference standards on a Varian Model 3700 gas chromatograph having a methyl silicone fluid, Carbowax deactivated Hewlett-Packard fused silica capillary column (50 m x 0.2 mm). Total theoretical plates were 200,000. Standards and fractions were programmed at 4°C per minute (min), 100° to 280°C and run for a total time of 55 min where necessary.

^{1}H NMR Spectra were run at 200 MHz on 6-25 milligram samples dissolved in 1 ml of $CHCl_3$-d containing tetramethylsilane. The spectra were taken at 20°C with a flip angle of 45°, a delay of 5 seconds and 16K data points. The spectra were compared with 300 standards run under the same conditions. Assignments were made on the basis of chemical shift, peak intensity and peak pattern matching. Special emphasis was placed on key resonances that occur in less heavily populated regions of the spectrum.

Alkanes and alkenes (6%), naphthalenes, acenaphthenes, phenanthrenes and fluorenes (17-18%), and polynuclear aromatics (PNAs) (7-8%) were identified by GC and NMR. NMR reveals that phenolics and other polar compounds were almost entirely in fraction 12, as shown in Table 1.

Experimental techniques have been developed for the separation of by-product tars from lignite gasification and for the analysis of major components by capillary GC and NMR. Some of the compounds reported here have not been previously reported in these tars. They include the series of terminal olefins, hexamethylbenzene, phenyl ether, and 4,5-methylene phenanthrene. This method will be used as the basis for further reports giving additional results relating to other coals, to other gasification conditions, and to waste treatment studies.

Table 1

Fraction	%	Compound, Compound Type
C-1		dead volume
C-2	3.0	alkanes, terminal olefins
C-3	2.7	terminal olefins, alkanes
C-4	0.6	mixed, some higher alkanes
C-5	0.9	some naphthalenes, hexamethylbenzene
C-6	1.9	naphthalene, methyl- and dimethylnaphthalenes, acenaphthene, acenaphthalene, phenyl ether, dibenzofuran, pyrene
C-7	2.0	biphenyl, dimethylnaphthalenes, acenaphthalene, acenapthene, dibenzofuran, phenanthrene, anthracene, methyl- and methylenephenanthrenes, pyrene
C-8	5.8	biphenyl, acenaphthalene, acenaphthene, dibenzofuran, fluorene, phenanthrene, anthracene, methyl- and methylenephenanthrenes, fluoranthene, pyrene, benzofluorenes, methylpyrenes
C-9	6.3	acenaphthene, dibenzofuran, fluorene, methylfluorenes, phenanthrene, anthracene, methyl-, methylene- and dimethylphenanthrenes, fluoranthene, pyrene, benzofluorenes, methylpyrenes
C-10	4.7	fluorene, fluoranthene, benzofluorenes, benz(a)anthracene, chrysene, methylbenz(a)-anthracenes, dibenz(a,h) anthracene
C-11	2.5	much like C-10
C-12	59.5	phenolics, cresols, other polars

29. SORPTION OF H_2O VAPOR ON SOLID BCA (BOVINE CARBONIC ANHYDRASE) AT 25 AND 35°

Wasyl S. Hnojewyj*
Physics Department, North Dakota State University
Fargo, North Dakota 58105

We used a lyophilized sample of BCA obtained from Sigma Chemical Co., P.O. Box 14508, St. Louis, MO 63178 USA, and labeled as: carbonate dehydratase, carbonate hydro-lyase; E.C. No. 4.2.1.1, lot 69C-9335. It was exposed many times to H_2O-vapor up to 30% in a gravimetric-vacuum system (Fig. 1), followed by complete desorptions at 10^{-7} mm of pressure, until it finally achieved a constant weight. On each sample the sorption isotherms were determined at 25 and 35°, the procedure for which is described elsewhere (1,2). The results are presented in Fig. 2, from which is evident the following: (a) the adsorption isothermic values are markedly lower than those of desorption, demonstrating hysteresis, which is most probably due to activation energy of the protein + H_2O reaction as suggested elsewhere (2). (b) It is remarkable that the extensions of the upper slopes of isotherms to the respective saturation pressures for both temperatures are found to be of the same values, equal ~27 mg/100 H_2O sorbed (points i-i'). These amounts may be considered as experimental values of the total monolayer coverage as suggested elsewhere (2). Also it indicates that in this temperature range no structural alteration of this protein occurs.

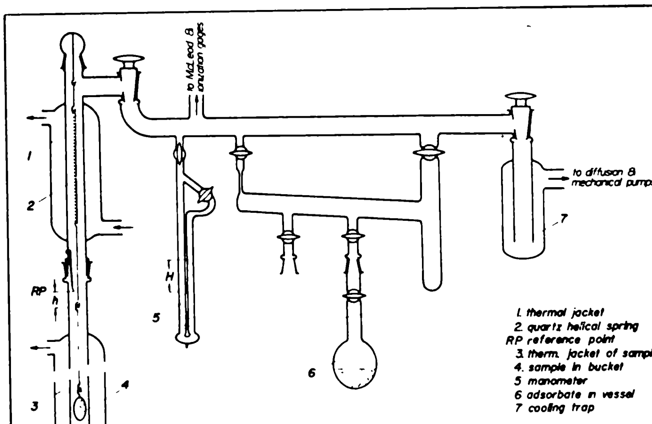


FIG. 1. SCHEME OF GRAVIMETRIC SORPTION SYSTEM

From the amino-acid composition of BCA (Table III) (3) including Zn, the molecular weight is evaluated to be 29,500. It contains 431 functional groups which at the condition of monolayer coverage may hold 431 $H_2O + 2H_2O$ terminal + $2H_2O$ attached to Zn by coordination, as suggested. Therefore, theoretically, one molecule of BCA at the monolayer condition may have 435 molecules of H_2O, which gives 26.78 mg/100 of sorbed H_2O, compared to ~27 mg/100 as approximated from the isotherms. The small difference in the monolayer coverage between theoretical and experimental data demonstrates the relationship between the monolayer coverage and the composition structure of BCA, as we attempt to stress in this investigation.

Differential heat-enthalpies of sorption were calculated by means of the Clausius-Clapeyron relation from isothermic data. These are initially 22 Kcal/mole, decreasing to 14 Kcal/mole at 4 mg/100 of sorption, indicating chemisorption. Then their values decrease linearly, approaching 10.50 Kcal/mole, only slightly above H_2O vaporization at 25-35°, characterizing the physical sorption.

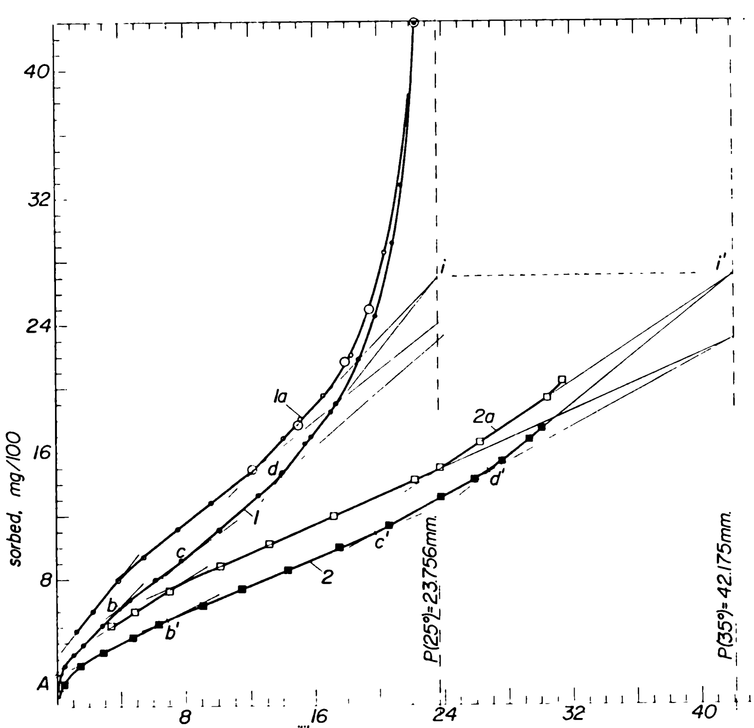


Fig. 2. Sorption Isotherms of H_2O Vapor on BCA (Bovine Carbonic Anhydrase) at 25 and 35°. (1) adsorption, (1a) desorption at 25°, (2 and 2a respectively) at 35°.

1. Reyerson, L. H. and Hnojewyj, W. S. (1961) J. Phys. Chem. 65, 1694.
2. Hnojewyj, W. S. (1971), Proc. N. Dak. Acad. of Sci. XXIV, Part II, 84-102.
3. Lindskog, S., et al., The Enzymes. (1971), 3rd Ed., Vol. 5, pp. 587-665, Academic Press, N.Y.

30. MASS SPECTROSCOPIC AND CAPILLARY GAS CHROMATOGRAPHIC STUDIES OF A LIGHT OIL FROM THE GASIFICATION OF A LOW-RANK COAL

David J. Miller*, Edwin S. Olson, and John W. Diehl
Grand Forks Energy Technology Center, Department of Energy
Grand Forks, North Dakota 58202

Researchers at the Grand Forks Energy Technology Center are operating a 900 kg/hr slagging fixed-bed gasifier. This study considers one portion of the effluent stream from this process. Light oils are defined as organics from a side-stream sampler (1) condensing at less than 10° C and those organics that distill from the tar at 145° C and 0.9 Pa pressure. The light oil sample used in this study was from gasifier run RA-87 which used Indian Head lignite (Mercer County, ND), gasified at 2.1 MPa pressure, 153 m^3/hr oxygen feed rate, and 0.9 oxygen/steam molar ratio. The work reported here is an extension of previous studies of gasification effluents (2). The overall objective is to develop an understanding of the effects of coal feedstock and processing conditions on the composition of the effluents, since effluent composition relates both to design of treatment schemes for pollution abatement and to workplace hygiene and toxicology.

Samples of as received light oil were separated by a modified API column chromatographic method (3) using 25 cm of alumina and 25 cm of silica gel was used to separate the light oil into 23 fractions. This method separated the oil into aliphatic, mono-nuclear aromatics, dinuclear aromatics, polynuclear aromatics, and polar compounds. Table 1 shows the solvent series used for this procedure.

Table 1. Column Chromatography Solvent Series.

Fraction	Eluant	Elution Volume, ml	% of Total
1 - 5	Pentane	250	3.09
6 - 10	5% Benzene/95% Pentane	250	1.82
11 - 15	15% Benzene/85% Pentane	250	17.14
16 - 18	Benzene	150	4.67
19 - 20	60% Methanol/20% Ether/ 20% Benzene	100	0.00
21 - 23	Methanol	150	40.01
Unrecovered material			32.27
			100.00

Mass spectral analysis was performed with a KRATOS MS-30 double focusing mass spectrometer operating in a low-voltage (10 eV) mode. This technique was used to obtain quantitative results from the analysis of mixtures (4). Gas chromatography was performed using a Varian 1400 gas chromatograph and a 60 meter SE-54 fused silica capillary column.

Each fraction from the column chromatographic separation was analyzed by low-voltage mass spectroscopy and by capillary gas chromatography. Fraction 1 was essentially the dead volume of the column. Fractions 2 thru 4 represented the aliphatic material of RA-87 light oil. The major components of this group of fractions were alkanes and alkenes (by NMR) with the majority of the alkanes appearing in fraction 3 and alkenes in fraction 4. These aliphatic components ranged from C_{10} to C_{23} for the alkanes and C_{10} to C_{20} for the alkenes. Pristane was present in fraction 3 and pristene in fraction 4. The mono-aromatic elute in fractions 10 and 11 with some carryover to 12. Major components are the benzene series (C_nH_{2n-6}) ranging in molecular weight from 92 to 204 (C1 to C9); also present in significant quantity were indan/tetralin series (C_nH_{2n-8}, m/e 118-202, CØ-6) and the indene series (C_nH_{2n-10}, m/e 116-200, CØ-C6). Fractions 12 thru 16 were composed primarily of naphthalene series (C_nH_{2n-12}, m/e 128-198, CØ-C5) with a significant amount of indan/tetralin and indene carryover. Fractions 15 and 16 contained compounds of a series corresponding to $C_nH_{2n-10}O$ and the acenaphthene/biphenyl series appears in fraction 15. Polynuclear aromatics begin to elute in fractions 17 and 18. Components identified include fluorene, phenanthrene, and pyrene. The remaining fractions (21-23) contained polar material such as phenols, benzofurans/indenols, pyridines/anilines, and quinolines. Although the light oil is only a portion of the by-product stream from this process, its analysis is of interest because it shows the presence of a rich diversity of organic compounds which may be potential substitute industrial feedstocks or which are of concern as potential environmental pollutants.

1. Hajicek, D.R. (1979) Sym. on Instru. and Control for Fossil Energy Proc. Aug 20-22, 110.
2. Miller, D.J., and others. (1980) Preprints, Div. Fuel Chem., Am. Chem. Soc., 25-1, 256-263.
3. Sawatsky, H. and others. (1976) FUEL, 55, 16-20.
4. Miller, D.J. (1979) Proc., 71st Meeting of NDAS, Aberdeen, SD, April 20-21, 59.

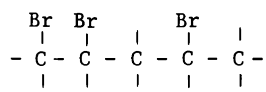
31. MASS SPECTRA OF POLY-HALO-PHENOLS CONTAINING TWO OR MORE HALOGENS, CYANO- OR NITRO-GROUPS

Franz H. Rathmann*
Department of Chemistry, North Dakota State University
Fargo, North Dakota 58105

A variety of poly-halo-phenols containing at least two or more different halogen elements--fluorine, chlorine, bromine and iodine--or halogen-like groups such as cyano, nitro, etc., were prepared by further chlorination, bromination, and/or iodination of simpler, more or less readily available, halophenols such as fluoro-, chloro-, and bromo-, etc. phenols, 3,5-dimethyl-4-chloro-phenol, 2-chloro-4-phenyl-phenol, 2-bromo-4-phenyl-phenol, as well as cresols, nitro-phenol, cyano-phenol, methoxy-phenols, 2,5-dichloro-hydroquinone, and some naphthols, and then carefully recrystallized, usually from acetic acid and/or ethanol, and/or hexane-heptane.

The mass spectra of these mixed poly-halo-phenols were examined for the relative ease with which the different halogen atoms as well as other substituent groups, such as CH_3, OCH_3, NO_2, CN, etc., were knocked off of the benzene ring by electron impact. These results were compared and contrasted with the much earlier results of pioneering studies made by Hunter and his students (1) on the relative loss of halogen as silver halide, or of other groups, when the silver salts of poly-halo-etc. -phenols were decomposed by heating, or on treatment with various reagents or catalysts.

In the electron bombardment of poly-halo-phenols, iodine is usually lost first, then bromine, then chlorine, then fluorine. After the loss of one or two of the halogens the ring is frequently split, with the loss of the C-OH phenol group, leaving an open-chain halogenated residue such as



from tetra- or penta-bromo-phenol.

As an example, 3,5-dimethyl-2,4,6-tri-iodo-phenol gave a parent peak at 500; other strong peaks at 373(-1I), 246(-2I), 119(-3I), 345(-(I + COH)), 217(-(2I + COH)), 91(-(3I + COH). Other lesser peaks indicate loss of OH and CH_3 groups, and of single H-atoms. Penta-bromo-phenol yields a sextet isotope parent peak at 488, quintet at 408, quartet at 329, and other group-peaks around 459, 381, 299, 220, — indicating loss of COH as well as of bromine. 2,5-Dichloro-4,6-di-bromo-phenol yields a quintet parent peak around 320, quartets at 284(-1Cl), 242(-1 Br), 256(-(1 Cl + 1 COH), and 213 (-(1 Br + 1 COH).

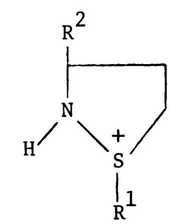
Tetra-bromo-hydroquinone yields a parent quintet at 426, a quartet at 348(-1 Br), a triplet at 264(-2 Br), a low quartet at 317(-(1 Br + COH)), a strong triplet at 237(-(2 Br + COH)) and 208(-(2 Br + 2 COH)). p,p'-Biphenol yields peaks at 186(P), 157(- COH) etc. 2,6-Di-bromo-4-phenyl-phenol yields a triplet peak at 328, a doublet at 248, a singlet at 168(-2 Br) and a very strong singlet at 139, presumably due to loss of both Br atoms and the COH group. 2,6-Dibromo-4-nitro-phenol yields, as principal peaks, a triplet at 297(P), doublet at 217(-Br), a small triplet at 251($-NO_2$), a doublet at 171(-(Br + NO_2)), doublet at 143 (loss of (1 Br + NO_2 + COH)).

I wish to thank Mr. Mark Carlson for his conscientious care in running the mass spectra on the new (Varian MAT. CH 5 D F) instrument in the USDA Metabolism and Radiation Research Laboratories, NDSU, Fargo, N.D.

1. For review and earlier references, see: Rathmann, Franz H., and Hunter, William Hammett. Proceedings North Dakota Academy of Science (1979), Vol. 33, p. 34.

32\. Formation and Properties of Isothiazolidinium Salts from Methionine and Other 3-(amino)thioethers

D.W. Swank* and D.O. Lambeth
Biochemistry Department, University of North Dakota
Grand Forks, ND 58202



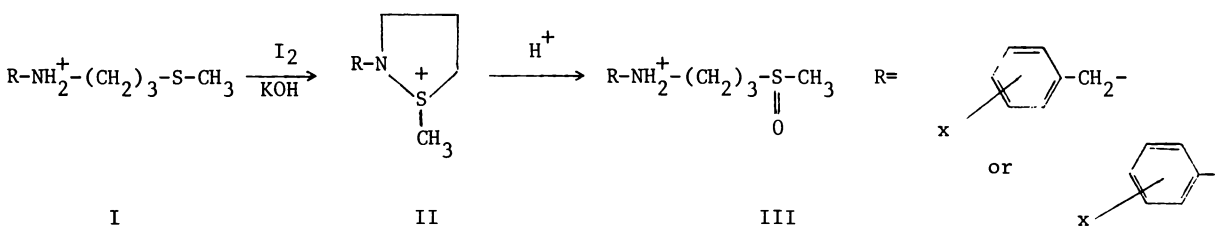
R^1 = alkyl, phenyl, benzyl

R^2 = H, COO^-, $CONH_2$

FIGURE 1

Amine and thioether functional groups are ubiquitous in the biological sphere. Although chemists have explored the combining of these two to form the sulfilimine or azasulfonium functionality, the implications of this chemistry in biological systems has received little attention. Both groups are present in methionine and Lavine first provided evidence (1) that the azasulfonium functionality forms intramolecularly when methionine is oxidized by iodine. We have since shown that a number of compounds containing a primary amine separated from a thioether sulfur by a trimethylene bridge will undergo a similar cyclization reaction (2). The products (Fig. I) are the first known examples of isothiazolidines or isothiazolidinium salts and they appear to be far more stable than azasulfonium salts in general. Their stability is due to incorporation of the azasulfonium linkage into a five-membered ring and several labile bonds have been observed by others to be similarly stabilized. Iodine oxidation of sulfides normally yields the sulfoxides but the extremely rapid formation of isothiazoldinium salts from 3-(amino)thioethers is due to the nucleophilic amine group favorably oriented to compete with water for the iodosulfonium intermediate.

We have now extended the cyclization reaction to include secondary amines in order to probe the influence of neighboring electron-donating and withdrawing substituents on the ease of formation and the stability of the azasulfonium functionality. A series of N-benzyl and N-phenyl 3-(amino)-thioethers with OCH_3, CH_3, Cl or NO_2 substituents at the para- or meta- position of the phenyl ring were prepared by reacting the appropriate aldehyde and amine in the presence of sodium cyanoborohydride as a reducing agent. The resulting aminothioethers(I) were found to readily undergo cyclization upon iodine oxidation to give the respective isothiazolidinium salts (II).



Acid hydrolysis of II yields the sulfoxide (III). Base hydrolysis of II in the N-phenyl series also gives sulfoxide while in the N-benzyl series only part hydrolyzes to sulfoxide. The remainder probably undergoes an elimination reaction to form a Schiff's base which subsequently hydrolyzes to form the parent benzaldehyde and 3-methylthiopropylamine.

Derivatives I, II, and III in the N-benzyl series have been isolated as crystalline chloride salts and each has been characterized by elemental analysis, melting point, high pressure liquid chromatography and proton NMR. For the N-phenyl derivatives, only I and III have been so characterized. However, we have indirect evidence (by HPLC) that II does form in solution and efforts to isolate II are being continued.

The rates of reaction of I with iodine have been found to be pH dependent in a manner consistent with the rate-limiting step involving attack of the unprotonated amine nitrogen on the iodosulfonium center. Thus, the rates level off at pH values above 9 in the case of the N-benzyl derivatives (pK's range from 8.4 to 9.6) and above pH values of 5 for the N-phenyl derivatives (pK's range from 4.3 to 5.5).

Our results lead us to believe that the azasulfonium functionality could form and would be moderately stable under biological conditions. We also believe that the chemistry of the azasulfonium group can be exploited in the synthesis of novel analogues of naturally occurring substances.

1. Lavine, T.F. (1945) Fed. Proc., Fed. Am. Soc. Exp. Biol., 4, 96.
2. Lambeth, D.O. and Swank, D.W. (1979) J. Org. Chem. 44, 2632-2636.

33. REVERSIBILITY OF HYDROGEN-DEUTERIUM EXCHANGE IN TURKEY CARBONIC ANHYDRASE

Wasyl S. Hnojewyj*
Physics Department, North Dakota State University, Fargo, ND 58105

The high molecular compounds of enzymatic character, like lysozyme (1), hemoglobin (2), insulin (3) in the lyophilized solid state, when exposed to the D_2O vapor after desorption, showed the exchange of hydrogen by deuterium from adsorbed D_2O. H→D exchange of labile hydrogen occurs only in functional groups (-CO-OH, R-OH, -CO-NH-, etc.) and is measured as a function of sample weight by use of a McBain gravimetric balance combined with a high vacuum system (1,2). Complete or maxima of exchange is reached on the successive adsorptions followed by complete desorptions to the new constant weights in a vacuum of 10^{-7} mm pressure. Schematically, the procedure in forward steps can be presented finally: $P_{rt}H(D)_{n-1}+D_2O \rightarrow P_{rt}D_n$-comp. deut. + DHO-pumped off. If H_2O is used on a deuterized sample, a reverse D→H exchange is obtained in a similar way.

Data on H→D exchange is found to have a relation to molecular composition structure, and attracted many branches of science since its application was "discovered" in Karlsberg's Laboratories. However, the original methods are not based on direct measurements (differ from ours) but on deduced data of changes of density, radioactivity, etc. Also, the enzyme-proteins were investigated in the presence of buffers, which complicated the actual H→D exchange, leading to the erroneous interpretation of results, concerning completion of H→D exchangeability.

Now there is an important question, namely: Could the complete deuterization be achieved if it uses D_2O of a purity less than 100%, as some authors are claiming? To answer this question as well as to determine H→D exchange, the newly purified Turkey Carbonic Anhydrase—designed TCA, was used. The amino acid composition for TCA was determined by P. R. Lemke and G. Graf (4). As a remark, the carbonic anhydrases are the enzymes catalyzing the reversible hydration of CO_2. It contains the Zn-atom and is widespread in the plant and animal kingdom (for details see (5)).

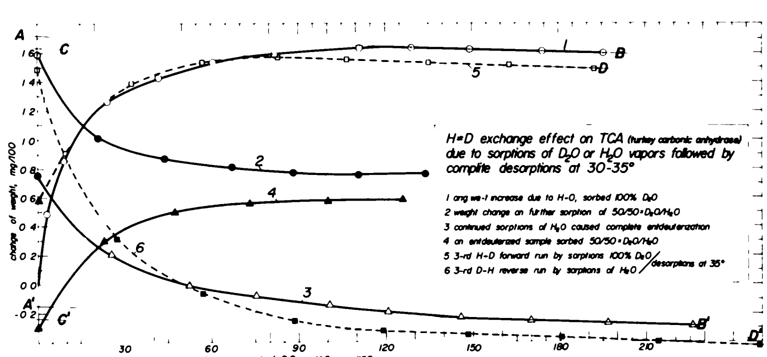
Investigations in our laboratory were done on lyophilized TCA that was originally exposed many times to H_2O vapor, followed by desorptions in high vacuum for two weeks until a weight loss was compromised at 0.002-0.004 mg/100/hr. The results are shown in the figure. The first run of H→D is shown by curve 1. It reaches a maxima of weight increase, then declines, adjusting to the slope AB indicating slight constant loss, caused most probably by sublimation or decomposition. Further, adsorption-desorptions of a mixture $50/50 = D_2O/H_2O$ caused the lowering in H→D exchange (curve 2).

On continuation of the sorptions of H_2O, the reverse D→H exchange was observed, which finally reached the lower slope A'B' of curve 3. It is remarkable that both slopes are nearly parallel, so that their extension to the left vertical coordinate gives the total change of sample weight due to H→D exchange, which equals (1.870-0.094) = 1.776 mg/100. The losses of original weight during H→D are compensated by D→H runs, where 0.094 mg/100 is the correction for loss during the run presented in curve 2.

The repeated runs of H↔D are represented by successive curves 4, 5 and 6 demonstrating practically the same results.

The molecular weight for TCA evaluated from amino-acid composition (4) incorporating 26 NH_3 in the form of ammonium salt was found to be 29,650, containing 524 of labile H-atoms in functional groups. Therefore, the theoretical change of weight (increase) could be expected to equal 1.778 mg/100, which is ~0.15% lower to the experimental value of 1.776 mg/100. However, it is surprising if compared to Bovine Carbonic Anhydrase, on which H→D was done at similar conditions but without observation of the weight loss. The observed weight loss suggests that the amino acid composition should be rechecked.

Further, the use of a $50/50 = D_2O/H_2O$ mixture on the original TCA does not provide completion of deuterization (curve 4) and if used on deuterized sample, it does not cause complete entdeuterization (curve 2). These results are answering the above stated question, namely: that the complete H→D exchange can be achieved only at use of 100% D_2O. However, from equilibrium positions, of curves 4 and 2, it is easy to evaluate the favorable deuterization phenomena as compared to entdeuterization in a ratio 1:0.9. This phenomena may be of technological interest.



1. Reyerson, L. H. and W. S. Hnojewyj, J. of Phys. Chem. 65, 1694 (1961).
2. Hnojewyj, W. S., Proc. N. Dak. Acad. of Sci., Vol. XXIV, pp. 84-102 (1971).
3. Hnojewyj, W. S., Proc. N. Dak. Acad. of Sci., Vol. XXIX, p. 67 (1978).
4. Lemke, P. R. (G. Graf, advisor), Ph.D. Thesis, North Dakota State University, Oct. 1974.
5. Lindskog, S. et al., The Enzymes, (1971) 3rd Ed., Vol. S, pp. 587-665, Academic Press, New York.

34. FOURTH DERIVATIVE UV SPECTROSCOPIC METHODS AND APPLICATIONS TO THE ANALYSIS OF LOW-RANK COAL GASIFICATION TARS

Edith Ann Muth*, Sylvia A. Farnum, and Bruce W. Farnum
Grand Forks Energy Technology Center, Department of Energy
Grand Forks, North Dakota 58202

Tars produced from slagging fixed-bed gasification of low-rank coal contain a complex mixture of organic compounds, including high molecular weight aromatics which are suspect carcinogens. Analysis of these products is an important step toward determining their effect on the environment and on industrial hygiene. A quick and relatively inexpensive method being developed for use in these analyses is fourth derivative UV spectroscopy. The sample discussed in this paper is a by-product tar produced in the slagging fixed-bed gasification of Indian Head lignite (Mercer County, ND) at 2.1 MPa operating pressure, 170 m^3/hr oxygen feed rate, and 1.0 oxygen/steam molar ratio (1).

The UV spectroscopy was performed with a Perkin-Elmer Hitachi 340 Recording Spectrophotometer and Model 340 Micro-Computer Datahandler. The fourth derivative was chosen for its well-defined peaks whose maxima may be used to determine λ_{max} values. The wavelength increment ($\Delta\lambda$ = 7 nm) gives the best fourth derivative peak resolution for the coal products being studied. The solvent, methylene chloride, dissolves these samples very well and has a relatively low UV cutoff (231 nm). Spectra of pure compounds were compared with the spectra of gasification tar samples to enable assignment of peaks.

Figures I and II illustrate an application of this method, using silica gel column fractions of gasifier tar (2). The standard pyrene peaks at 238.0, 269.7 and 332.3 nm match well with the corresponding fraction #7 peaks at 238.5, 270.1, and 332.5 nm. The standard fluoranthene peaks at 233.6 and 283.8 match with the fraction #9 peaks at 233.4 and 283.7 nm. These peak assignments and the others shown are consistent with the compounds identified by ^{1}H NMR and determined as major components by capillary GC. The spectrum of the whole tar indicates the presence of the following compounds: fluoranthene, pyrene, phenanthrene, chrysene, fluorene and acenaphthene.

Although this method cannot "stand alone," it does provide a quick method to identify some probable components of a mixture which are of environmental or industrial hygiene concern. It could also provide a quick comparison of tar fractions from gasification runs using different coals and different processing conditions.

Figure I
Assignment of pyrene peaks
in gasifier tar fraction #7

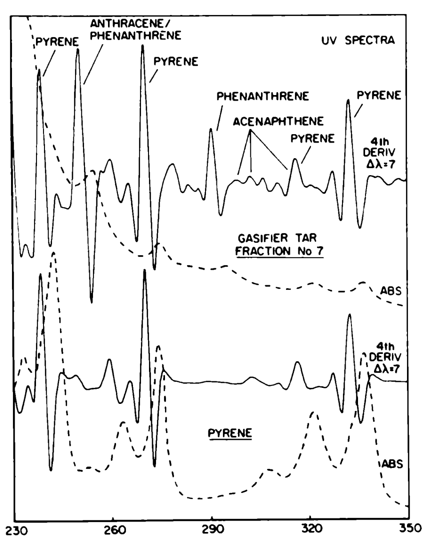
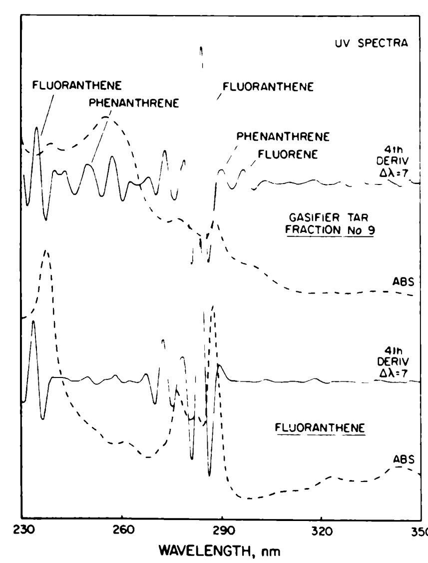


Figure II
Assignment of fluoranthene peaks
in gasifier tar fraction #9



1. Ellman, R.C., Paulson, L.E., Hajicek, D.R., and Towers, T.G. (1979) Proceedings of the Tenth Biennial Lignite Symposium, Grand Forks, ND 236.
2. Bitzan, E.F., Farnum, S.A., and Farnum, B.W. (1981) Proceedings of the North Dakota Academy of Science (in press).

35.

MINERALOGICAL CHARACTERIZATION OF SINK FRACTIONS FROM 14 U.S. LOW-RANK COALS

David W. Schott* and Michael L. Jones
Grand Forks Energy Technology Center (GFETC), Department of Energy
and Department of Geology, University of North Dakota
Grand Forks, N.D. 58202

The suitability of a particular coal for combustion is dependent upon a variety of factors including boiler fouling, slagging, pollution problems and coal cleaning. The minerals in coal contain much of the noncombustible components and so will affect these processes. From a geochemical standpoint, the mineralogy of a particular coal provides a key to the understanding of the mechanisms by which coal is formed and an understanding of the environment of deposition for that coal (1).

In the present study, an attempt has been made to qualitatively and quantitatively characterize the mineral content of 14 low-rank U.S. coals. The primary method of investigation has been polarized light microscopy (PLM) with semiquantitative determinations of mineral phases being made through point count analysis. Mineral phases identified and semiquantitative concentrations were verified by x-ray diffraction (XRD) analysis. In addition, electron microprobe techniques were used for the identification of phases. The mineral phases were separated from coal by the float/sink method. Samples from 14 low-rank coals stored at GFETC were pulverized and sized in the range -50 mesh by +140 mesh. They were then subjected to gravity separation using CCl_4 at 25°C. Sink fractions drawn off a glass chromatography column from the bottom were then used in the study.

The total amount of mineral matter in a particular sink fraction as determined by point count work varied from 25.5% to 78.0% and averaged 51.5% with a standard deviation of 14.85%. Minerals commonly occurring in the sink portions of the 14 low-rank coals investigated are quartz, calcite, kaolinite, pyrite, gypsum, and iron-stained and non-stained aggregates. Minor constituents found include illite, montmorillonite, jarosite, hornblende, barite, oligoclase, andesine, albite, orthoclase, dolomite, aragonite, hematite, muscovite, biotite, szomolnokite and marcasite. In general, clays were identified using XRD methods (2).

Computer aided quantitative determinations of the concentrations of quartz, pyrite and calcite by XRD were obtained through areal intensity versus concentration curves. A comparison of the absolute amounts of these three phases as determined by point counting and quantitative XRD shows that in general, the concentrations as determined by XRD were less than those found through point counting (Fig. 1). This is probably because some phases, particularly the finely divided clays are more easily resolved by XRD methods. Since phase concentrations in this study are expressed as percentages of the total amount of phases found, the method which can detect more phases will express each individual phase as a smaller concentration. Both methods can determine relative coal-to-coal differences in the concentration of a particular phase contained in the sink fractions investigated. One example of this can be seen in the figure below, where by both methods it was determined Texas lignite contained 25% more quartz than Beulah lignite in the sink fractions investigated.

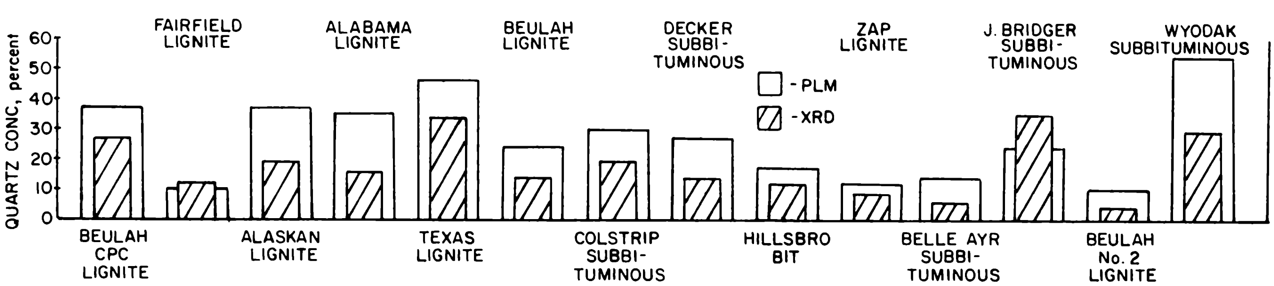


Figure 1. - Comparison of quartz concentrations as determined by XRD and PLM

1. Gluskoter, H.V. and Mitchell, R.S. (1976) Fuel, 55, 90-96.

2. Strach, E. (1975) Coal Petrology, pp. 121-132. Gebrüder Borntraeger, Berlin, Stuttgart.

36. 2,4-D Metabolism in Soybean Cell Suspensions

David G. Davis*and Gerald L. Lamoureux

USDA, SEA, AR, Metabolism and Radiation Res. Lab., State University Station, Fargo, ND 58105

This study is part of an ongoing program to determine the usefulness of plant tissue culture methods in studies on the fate, metabolism and effects of agricultural chemicals in plants. Soybean (Glycine max Merrill (L.) 'Wilkin') cell suspension cultures derived from root callus and maintained on 2,4-dichlorophenoxy acetic acid (2,4-D) were treated with 4.5 μM [2-^{14}C]-2,4-D. At 3 and 8 days the ^{14}C-activity was extracted from the medium and the cells (separately) and partitioned between ether and water. Ether soluble radioactivity was identified tentatively by thin layer and high performance liquid chromatographic methods. Water soluble ^{14}C from the cells was partitioned between n-butanol and water. n-Butanol soluble products were hydrolyzed with β-glucosidase, separated into ether and water soluble fractions and partially characterized. After 3 days only 28% of the ^{14}C was recovered from the cell extract and 67% was recovered from the medium (Table 1); however, after 8 days the ^{14}C recovered from the cell extract increased to 48% and the ^{14}C in the medium decreased to 40%. The water soluble metabolites (cells and medium) were only 17% of the ^{14}C after 3 days, but increased to 43% after 8 days (Table 1). The hydrolyzed water soluble metabolites yielded hydroxylated forms of [^{14}C], 2,4-D and presumably, free sugars. They were not identified. The ether soluble fraction contained 2,4-D and amino acid conjugates of 2,4-D; the amino acids were mostly aspartic and glutamic acid, and were a total of about 5% at 3 days and 10% at 8 days (Table 2). From these preliminary results, using cell suspensions initiated and maintained on 2,4-D, from a single experiment using callus cultures initiated and maintained without 2,4-D, and from literature reports of 2,4-D metabolism in cell cultures from other laboratories, we believe that the amount of 2,4-D metabolism is a function of both the growth rate and the type of culture (i.e. callus compared to cell suspensions) and that the products formed may be similar in cell suspensions, callus or whole plants. Work is underway to evaluate the influence of growth regulators on the metabolism of 2,4-D in cell cultures. The metabolism and effects of several agricultural chemicals by plant cell suspensions of several different species have been conducted over the past several years. We believe that cell cultures systems are useful for this type of research, but caution must be exercised to avoid extrapolating the data too far. One major advantage of cell cultures is the potential for generating large amounts of metabolites of xenobiotics for isolation and identification. Also, because the cultures are aseptic, all metabolic conversions are the result of plant cell metabolism. Acknowledgment: We gratefully acknowledge the technical assistance of Mr. Kendall Dusbabek in this study.

Table 1. Distribution of ^{14}C recovered from soybean cell suspensions treated with 4.5 μM [^{14}C]-2,4-D (percent of recovered ^{14}C).

Fraction	Partitioned into	Time (days) 3	8
Medium	Ether	64 ± 6.9	34 ± 0.5
	Water	3 ± 0.9	6 ± 0.3
Cell extract	Ether	14 ± 2.8	11 ± 0.9
	Water	14 ± 1.8	37 ± 3.4
Cell residue	-----	3 ± 1.2	12 ± 2.3

Table 2. Distribution of ether soluble ^{14}C based on HPLC comparisons to standards (percent of recovered ^{14}C).

Fraction	Product	Time (days) 3	8
Medium	2,4-D	64 ± 7	30 ± 2
	Aspartic and Glutamic acid Conjugates	0.6 ± 0.3	2 ± 1
Cell extract	2,4-D	9 ± 4	2 ± 0.2
	Aspartic and Glutamic acid Conjugates	4 ± 7	8 ± 1

37. STEREOLOGY AS A TOOL IN THE DETERMINATION OF CHLOROPLAST PARAMETERS

N.H. Olson,* T.P. Freeman, and M.E. Duysen
Botany Department, North Dakota State University
Fargo, N.D. 58105

Stereology is a geometric process by which three-dimensional data may be obtained from the measurement of two-dimensional surfaces. In the study of chloroplast structure, changes resulting from normal growth or treatment may demonstrate visually imperceptible but statistically significant changes which may only be detected by stereology. Volume density (Vv) is the percent volume that a component has of a total containing volume. In this application, it was the percent of total plastid volume occupied by thylakoid membranes. Volume density was also used to measure the percent of plastid volume of the cell. This parameter is measured by a point grid system (2) where: $Vv = Pi/Pt$; Pi = component volume points, Pt = total volume points. The second parameter, numerical density (Nv) is calculated and includes factors on shape, size distribution, number of particles per unit area, and Vv. Numerical density was used to obtain the number of plastids per μ^3 of cell volume. Other parameters used include plastid length and cell volume.

Two separate tests were run on wheat seedlings. One test utilized only the primary leaf of the seedlings and data was obtained from leaf sections taken at 1mm, 7mm, 15mm from the seed, and 1cm from the tip of the leaf. The other test utilized both the primary and secondary leaves with sections taken only at 1cm from the leaf tip.

In the various regions of the primary wheat leaf (Table 1-A), stereology showed an increasing volume percentage of thylakoids as the tissue matured. This increase is primarily due to the increase in granal thylakoids. The Nv of plastids showed an eight-fold decrease over the range, while the Vv of plastids increased greater than three times. Concurrently, cell volume doubled. This trend is probably due to the increase in the individual plastid size although a possible change in number per cell cannot be eliminated.

Two methods of counting the number of plastids per cell were used. The first method utilized direct light microscope counts (1). Due to the resolution available, this method is only acceptable when measuring mature plastids. In the second method Nv was multiplied by the estimated cell volume but the results obtained were deemed unacceptable due to difficulties in obtaining an accurate measurement of cell volume.

Table 1-B indicates few differences between the primary and secondary leaves at the age examined (avg. length 16.8 and 14.3 cm respectively). No significant differences in plastid thylakoids were noted at either age. Plastid length and plastid length-width ratios were also similar which would suggest no change in plastid volume. The Vv of the plastids and the Nv did change, and both were greater in the secondary leaf. This is related to the plastid number per cell (light microscope) and the cell volumes. The former showed no change while the latter approximately doubled.

The changes that occur in chloroplasts are easily measured by use of the volume density and numerical density parameters. These stereological techniques, along with the use of light microscopy and various other measurements yield a great deal of information concerning the dynamics of plastid development.

Table 1. Measurements of plastid development in the primary and secondary leaves of wheat

leaf section	Vv1(%)	Vv2(%)	Vv3(%)	P.L.(μ)	L/W	Vv4(%)	Nv(#/μ^3)	C.V.(μ^3)	#/cell
A									
1mm from	8.39	5.00	3.39			7.3	.0477	7411	
seed	0.71	0.56	0.54			0.9			
7 mm from	14.07	14.18	2.90			15.0	.0131	6918	
seed	1.56	1.55	0.39			1.6			
15 mm from	25.87	23.48	3.43			19.7	.0063	8565	
seed	1.27	1.66	0.67			2.2			
1 cm from	27.96	23.11	4.52			22.9	.0058	16057	
tip	2.24	1.46	0.90			3.2			
B									
primary	30.96	24.71	6.25	4.90	2.46	25.6	.0070	28094	69.24
leaf	2.84	2.46	0.82	0.10	0.07	2.0			4.89
secondary	28.07	22.13	6.18	5.03	2.54	44.6	.0119	10687	70.65
leaf	2.02	1.77	0.85	0.13	0.07	2.8			5.21

Vv1--total thylakoids, Vv2--granal thylakoids, Vv3--stromal thylakoids, P.L.--plastid length, L/W--plastid length-width ratio, Vv4--plastid to cell volume, C.V.--cell volume, #/cell--light microscope plastid counts. Each set of paired data represents the mean and the standard error of the mean.

1. Lamppa, G.K., Elliot, L.V., and Bendich, A.J. (1980) Planta 148, 437-443.
2. Weibel, E.R. (1973) pp. 237-296 in M.A. Hayat, ed. Principles & Techniques of Electron Microscopy Vol. 3. Van Nostrand Reinhold Co., N.Y.

38. THE EFFECT OF ESTRADIOL ON SKELETAL MUSCLE DURING GLYCOLYTIC BLOCKADE

Frances C. Garb* and Jeffery W. Gerst
Department of Zoology, North Dakota State University
Fargo, N.D. 58105

Among reported cases of human myophosphorylase deficiency (McArdle's disease) there is a prevalence in males of approximately 4:1. An animal model of this disease has recently been described (1) using sodium iodoacetate (IOA), which selectively inhibits the glycolytic enzyme glyceraldehyde-3-phosphate dehydrogenase. This study was undertaken to determine if there is a sex difference in the response of rat skeletal muscle to glycolytic blockade by IOA and, if so, to determine the influence of estradiol on this difference.

Male and female Wistar/Furth rats were used. IOA was delivered to anesthetized animals by injection into the abdominal aorta at a dose of 22-25 mg/kg. One hour after injection of IOA the hindlimb muscles were exercised ischemically. Ischemia was produced by applying traction to a ligature around the abdominal aorta. Exercise was accomplished by supramaximal electrical stimulation of the sciatic nerve using .075 msec voltage pulse at a frequency of 5 Hz. A contractured limb is typified by a foot that remains firmly fixed in a hyper-plantar flexed position with the toes spread to varying degrees. Three pre- and post-exercise aspects of the hindlimbs were compared to assess the degree of contracture: 1) the angle through which the foot could be moved; 2) the distance between the fourth and fifth digit; 3) the distance from the base of the nail on the first digit to the base of the nail on the fifth digit over the ventral surface of the foot. A more intense degree of contracture is indicated by a decreased angle of movement and an increased distance between digit 1 and 5 and between digit 4 and 5. Male rats undergo a more intense contracture when exposed to IOA than female rats (Table I).

Table I: Percent of Change in Hindlimbs of Male and Female Rats Exposed to IOA

	Angle of Movement	Distance Digit 1 to Digit 5	Distance Digit 4 to Digit 5
Males	-87 ± 1.8 (8)	+63 ± 7.9 (8)	+239 ± 36.1 (8)
Females	-56 ± 9.9 (7)	+24 ± 11.2 (7)	+ 78 ± 36.3 (7)

Results are expressed as mean ± standard error (number). All female means are significantly different from male means (P<.05, Student's t Test).

Ovarectomized rats injected with 10 μg/day/animal beta-estradiol over a ten day period were compared with solvent-injected pair fed ovarectomized rats to assess the influence of estradiol on degree of contracture (Table II). The presence of estradiol is thus shown to be positively related to a decreased degree of contracture following glycolytic blockade.

Table II: Percent of Change in Hindlimbs in Ovarectomized Rats

	Angle of Movement	Distance Digit 1 to Digit 5	Distance Digit 4 to Digit 5
Ovarectomized; Estradiol replaced	-73 ± 3.0 (13)	+29 ± 4.5 (13)	+122.6 ± 26.5 (13)
Ovarectomized; No Estradiol	-85 ± 2.6 (9)	+56 ± 7.0 (9)	+224.8 ± 44.5 (9)

Results are expressed as means ± standard error (number). All estradiol replaced means are significantly different from no estradiol means (P<.05, Student's t Test).

Investigations of this sex difference and the influence of estradiol using beta-estradiol and alpha-estradiol, an inactive isomere, and estradiol receptor-blocking agents (MER-25 and CI-628) are in progress.

1. Brumback, R.A. (1980) J. Neurol. Sci. 48:383-398.

39. EFFECT OF ZINC DEFICIENCY ON BRAIN CATECHOLAMINES AND AMINO ACID CONCENTRATIONS IN THE RAT

J.C. Wallwork* and H.H. Sandstead

USDA, SEA, Human Nutrition Center
Grand Forks, N.D. 58202

A high protein Zn-deficient diet causes anorexia and cyclic feeding behavior in rats. Brain neurotransmitters are probably involved in the control of appetite. The ratios of tryptophan (tryp) or tyrosine (tyr) to other large neutral amino acids influence the entry of either tryp or tyr into the brain and the formation of serotonin and catecholamines (1,2). Therefore, brain catecholamine and amino acid concentrations were measured in Zn-deficient rats. Weanling rats were fed a 20% sprayed egg white biotin enriched diet containing <1 ppm Zn: one group was fed ad libitum and given distilled deionized water (ZD); a second group was individually pair-fed (PF); a third group was fed ad libitum (AL); a fourth group was also fed ad libitum, but was fasted overnight prior to sacrifice (OF). Groups 2-4 were given 25 ppm Zn (Zn acetate) in the water. After 9 or 10 days, the rats were decapitated and the brains extracted by 10 strokes in a Potter-Elvejhm homogenizer either with 3/1 (V/W) 10% 5-sulfosalicylic acid (for amino acid analysis using an automatic amino acid analyzer) or 9/1 (V/W) 5-sulfosalicylic acid or 3/1 (V/W) 0.1 M $HClO_4$ (for reverse phase HPLC and electrochemical detection for the measurement of tryp or catecholamines, respectively). Brain catecholamines were measured in three separate repeat experiments. Femur Zn levels were also assayed (3).

Femur Zn of the ZD rats on day 10 were 135 ± 11 compared to 249 ± 16 and 254 ± 13 μg/g for PF and AL controls. Brain tyr levels were significantly higher when more food was consumed in the ZD rats ($P < 0.05$) and the AL-OF group ($P < 0.001$). This trend was also evident in the PF group. Brain amino acid ratios, tyr:phenylalanine, and tyr:Σ large neutral amino acids minus tyr, were significantly ($P < 0.05$) higher in ZD, PF and AL groups when the rats were eating more food. Brain tryp levels were also significantly ($P < 0.05$) higher in the AL vs OF group, whereas, the PF rats at the bottom of the feeding cycle had significantly ($P < 0.05$) higher tryp levels than at the top of the feeding cycle. Brain tryp levels did not correlate with food intake in the ZD rats. Also, the tryp:Σ large neutral amino acids minus tryp did not correlate with food intake in the ZD and AL groups. This ratio was increased in PF rats at the bottom versus the top of the feeding cycle.

In the three separate experiments brain norepinephrine levels were significantly ($P < 0.05$) higher in ZD versus both AL-OF and PF zinc adequate controls. Brain dopamine levels were less consistent. In experiment 1, the ZD rats had significantly higher brain dopamine levels than either AL or PF controls. However, there were no significant differences in brain dopamine levels between the groups in experiments 2 or 3. In contrast to dietary Zn neither the food intake nor the sex of the animals appeared to influence the levels of brain catecholamines. Also there was no correlation between brain tyr and brain catecholamine concentrations. The reason for the increase in brain catecholamines observed in Zn deficiency is unknown. One possible explanation involves alcohol dehydrogenases (E.C.1.1.1.1 or E.C.1.1.1.2), which are in the degradative pathway of catecholamines. If these enzymes were Zn-dependent enzymes, like liver alcohol dehydrogenase (4) and retinene reductase (5), then their activities might be reduced during Zn deficiency, causing an increased concentration of brain catecholamines. If each alcohol dehydrogenase needed different concentrations of Zn for maximum activity, this could explain some of the inconsistencies in levels of brain dopamine.

These findings and our previous studies (3) suggest that appetite control of ZD rats is not modulated by brain tyr or catecholamines, but is influenced by Zn. The increase in brain norepinephrine concentration observed in the ZD rats may in part explain behavioral and neurophysiologic abnormalities that have been observed in ZD animals (6,7). Perhaps the increase in brain norepinephrine also has relevance for the neurophysiologic abnormalities that occur in severely Zn-deficient humans (8,9).

1. Fernstrom, J.D., Larin, F. and Wurtman, R.J. (1973) Life Sci. 13, 517-524.
2. Wurtman, R.J., Larin, F., Mostafapour, S., et al. (1976) Science N.Y. 185, 183-185.
3. Wallwork, J.C., Fosmire, G.J. and Sandstead, H.H. (1981) Brit. J. Nutr. 45, 127-136.
4. Drum, D.E., Harrison, J.H., Ting-Kai, Li, et al. (1967) Proc. Natl. Acad. Sci. 57, 1434-1440.
5. Huber, A.M. and Gershoff, S.N. (1975) J. Nutr. 105, 1486-1490.
6. Sandstead, H.H., Strobel, D.A., Logan, G.M., Jr., et al. (1978) Am. J. Clin. Nutr. 31, 844-849.
7. Halas, E.S., Heinrich, M.D. and Sandstead, H.H. (1979) Physiol. Behav. 22, 991-997.
8. Henkin, R.I., Patten, B.M., Re, P.K., et al. (1975) Arch. Neurol. 32, 745-751.
9. Geliebter, A.A., Hashim, S.A. and Van Itallie, T.B. (1981) Am. J. Clin. Nutr. 34, 119-120.

40. ZINC DEFICIENCY AND EPIPHYSEAL GROWTH IN THE WEANLING RAT

A. Suwarnasarn,* F.N. Low, G.I. Lykken, J.C. Wallwork and H.H. Sandstead

USDA, SEA, Human Nutrition Center
and
Departments of Anatomy and Physics, University of North Dakota
Grand Forks, N.D. 58202

Skeletal abnormalities are a regular and conspicuous feature of zinc deficiency in growing birds (1-3). Zinc deficiency also affects collagen cross-linking in the skin (4), cartilage and bone metabolism (5,6) and the fetal skeleton (7) of rats. This study investigated the effect of zinc deficiency on the shearing strength, histological changes and proline metabolism of the epiphyseal plate in the tibia of the weanling male rat. The rats were fed a 20% biotin enriched sprayed egg white diet containing less than 1 mg/kg Zn (8). Two groups of rats were studied: a zinc-deficient (ZD) group which were fed the ZD diet _ad libitum_ and were given distilled deionized water; pair-fed (PF) rats who were individually fed the same weight of ZD diet as consumed the previous day by the ZD rats with whom they were paired and the drinking water was supplemented with 25 ppm Zn. This regimen lasted for 27 days. After 8 days an animal was sacrificed daily alternating between ZD and PF control rats. The rats were anesthetized with diethyl ether, bled by cardiac puncture and the plasma recovered by centrifugation. The liver and femurs were removed at this time. Tibiae were removed within 5 min to prevent autolysis. The shearing procedure used to measure the strength of the epiphyseal plate was similar to Hillman (9). The tibia epiphyseal cap was fixed in 2% glutaraldehyde and processed as described by Suwarnasarn _et al._ (10) before examination in a scanning electron microscope and images were recorded on photographic film.

In a separate experiment ZD and PF rats were maintained on the same regimen for 16 to 22 days. L-[^{14}C(U)]-Proline (225 mCi/m mol, New England Nuclear, Boston, MA, 3.25 μCi/100 g rat) (11) was injected intraperitoneally into ZD and PF rats sequentially. After 140 min, the rat was anesthetized with diethyl ether, bled by cardiac puncture and the tibiae epiphyseal plates were removed. Whole blood (0.1 ml) or plasma (0.1 ml) was incubated with Protosol (N.E.N.):ethanol (1:2 v/v) (0.5 ml), and each tibia epiphyseal plate was incubated with Protosol (1.0 ml), overnight at 37°C. The samples were decolorized with H_2O_2 and Aquasol (N.E.N.) (15 ml) added. The mixture was acidified with 0.5 ml of either 0.5 M HCl (blood) or 1 M Tris (pH 4, epiphysis), shaken, and stood overnight at 0°C in the dark. A liquid scintillation spectrometer was used to measure radioactivity. Plasma, liver and femur Zn concentrations were measured by atomic absorption spectroscopy (12).

The force required to displace the epiphysis of a ZD rat was always less than that required for a PF control rat of comparable age. For the first few days of zinc deficiency, this force decreased, it subsequently increased with longer treatment time. In contrast, the force required to displace the epiphysis of a pair-fed control rat increased as a function of treatment time and approached a constant value of 8.5 Newtons. After 18 days of treatment this force was approximately 15% higher than that required to displace the epiphysis of the paired ZD rat. The thickness of the outside compact bone next to the epiphyseal plate region as determined from scanning electron micrographs was thicker in a ZD rat than in a PF control of comparable age. Epiphyseal plates narrowed as the rats aged and were clearly discernible in PF controls but not in ZD rats. ZD epiphysis (1.53 ± 0.32 10^6 cpm/g) contained significantly ($P < 0.01$) less ^{14}C than PF epiphysis (1.82 ± 0.16 10^6 cpm/g). The amount of ^{14}C in whole blood and plasma was similar in the ZD and PF animals so that availability was not the problem. In summary, zinc deficiency had an adverse effect on the shearing strength, histological appearance and uptake or incorporation of ^{14}C(U)-proline into the epiphyseal plate of young male rats.

1. O'Dell, B.L., Newberne, F.M. and Savage, J.E. (1958) J. Nutr. 65, 503-533.
2. Ziegler, T.R., Scott, J.L., McEuoy, R., et al. (1962) Proc. Soc. Exp. Biol. Med. 109, 239-242.
3. Fox, M.R.S. and Harrison, B.N. (1964) Proc. Soc. Exp. Biol. Med. 116, 256-259.
4. McClain, P.E., Wiley, E.R., Beecher, G.R., et al. (1973) Biochem. Biophys. Acta 304, 457-465.
5. Bergman, B., Friderg, U., Lohmander, S., et al. (1970) Odont. Rev. 21, 379-399.
6. Anon. (1978) Nutr. Rev. 36, 152-153.
7. Hickory, W., Nanda, R. and Catalanotto, F.A. (1979) J. Nutr. 109, 883-891.
8. Luecke, R.W., Olman, M.E. and Baltzer, B.V. (1968) J. Nutr. 94, 344-350.
9. Hillman, J.W. (1959) Tensile properties of epiphyseal growth zone, a study of several responses. M.S. dissertation, Vanderbilt University Hospital, Tennessee.
10. Suwarnasarn, A., Low, F., Lykken, G., et al., in preparation.
11. Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture, and does not imply its approval to the exclusion of other products that may also be suitable.
12. Wallwork, J.C., Fosmire, G.J. and Sandstead, H.H. (1981) Brit. J. Nutr. 45, 127-136.

41. SENSITIVE RAPID ASSAY OF TRYPTOPHAN IN TISSUES BY USE OF HPLC AND ELECTROCHEMICAL DETECTION

J.C. Wallwork*

USDA, SEA, Human Nutrition Center
Grand Forks, N.D. 58202

In recent years, tryptophan has been measured in various mammalian tissues, particularly brain. The concentration of tryptophan in plasma and brain has been reported to affect the serotonin content of the brain (1). Serotonin is of importance because it is a putative neurotransmitter and has been implicated in the control of protein intake (2). In physiological samples tryptophan has been quantitated mainly by fluorescent assays that involve extraction with a deproteinizing reagent. The native fluorescence of tryptophan at pH 11 then was measured as described by Udenfriend (3). In an alternative more sensitive assay the extract was reacted with formaldehyde, in the presence of ferric chloride, and formed a fluorophore, norharman (9H-pyrido[3,4-b]indole), that was measured (4). This method is suitable for the assay of plasma tryptophan (5) but use of this technique to measure tissue tryptophan, is fraught with problems such as interfering native fluorescent substances and non-linearity of reaction (6). In some procedures interfering fluorescent compounds were removed from brain extracts by ion exchange chromatography (7). In other methods tryptophan was separated on ion exchange resins and its reaction with ninhydrin was measured (8). Other methods of assay included partitioning between two phases of solvent and subsequent removal of the aqueous layer for assay of tryptophan (9) or the extraction of norharman with butyl acetate (10). More recently electrochemical detection was used for the measurement of tissue tryptophan after passage through Dowex AG-50 and reverse phase HPLC (11). Most of procedures mentioned are time consuming and have several steps where errors might be introduced. The method outlined is rapid and has few steps.

The rats were bled by cardiac puncture with heparinized syringes and whole blood (1.0 ml) was added to a Potter-Elvejhm homogenizer containing 10 ml of ice-cold 10% 5-sulfosalicylic acid plus 1.354 μg, α-methyltryptophan per ml. Tissues (brain, kidney, liver and muscle) were quickly excised and weighed in either a Potter-Elvejhm homogenizer or a 30-ml glass centrifuge tube containing about 10 volumes of 10% 5-sulfosalicylic acid plus 1.354 μg α-methyltryptophan per ml. The tissue was homogenized either with 10 strokes of the Potter-Elvejhm homogenizer (brain, kidney and whole blood) or for 30 seconds with a Polytron (Brinkman Corp., Westbury, NJ) (12) homogenizer (muscle and liver). The homogenate was centrifuged at 600 x g for 20 minutes at 4°C and the supernatants were filtered through a Swinnex (Millipore Corp., Bedford, MA) filter assembly (0.45 μm). The filtrates were added to 1-dram vials that were placed in the automatic sample injector (Model WISP 710A, Waters Assoc., Milford, MA). The pump (Model 6000A, Waters Assoc.) was set to deliver 2.0 ml per min and the detector potential was set at +1.00 v. The automatic sample injector was used to load 25 μl of each solution onto a reverse phase HPLC column (Bio-Sil, ODS-10, 250 mm x 4 mm, Bio-Rad Laboratories, Richmond, CA). A computing integrator (Model SP-4100, Spectra Physics, Santa Clara, CA) recorded column profiles, peak heights and concentrations for tryptophan and α-methyltryptophan. The concentration of tryptophan per g tissue or ml blood was calculated. Tryptophan concentrations (Mean ± SD, nmol/g or ml for blood) in rat tissues were: hind leg skeletal muscle (30.3 ± 2.5); liver (50.4 ± 7.2); kidney (54.4 ± 3.6) and whole blood (26.8 ± 2.9). These concentrations are similar to reported values in the literature (4-10).

The use of HPLC and amperometric detection eliminates such problems as interfering compounds and non-linearity of reaction (8). This procedure is sensitive at the picogram level unlike other methods (4,5). The simplicity of this procedure, in contrast to other methods (6-11), minimizes the introduction of errors. The use of an internal standard, α-methyltryptophan, not described in other chromatographic procedures (8,11), was included as a check on any variations due to recovery.

1. Fernstrom, J.D. (1974) Ann. Rev. Med. 25, 1-8.
2. Anderson, G.H. (1977) Adv. Nutr. Res. 7, 145-165.
3. Udenfriend, S. (1962) Fluorescence Assay in Biology and Medicine, pp. 162-164. Academic Press, New York.
4. Hess, S.M. and Udenfriend, S. (1959) J. Pharmacol. Exp. Ther. 127, 175-177.
5. Denckla, W.D. and Dewey, H.K. (1967) J. Lab. Clin. Med. 69, 160-169.
6. Gaitonde, M.K., Evans, G. and Hartmann, M.K. (1979) Anal. Biochem. 92, 338-344.
7. Thierry, A.-M., Fekete, M. and Glowinski, J. (1968) Eur. J. Pharmacol. 4, 384-389.
8. Gaitonde, M.K. (1974) Biochem. J. 139, 625-631.
9. Weinberger, S.B., Knapp, S. and Mandell, A.J. (1978) Life Sci. 18, 1595-1602.
10. Yuwiler, A., Oldendorf, W.H., Geller, E., et al. (1977) J. Neurochem. 28, 1015-1023.
11. Koch, D.H. and Kissinger, P.T. (1979) J. Chromatog. 164, 441-455.
12. Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture, and does not imply its approval to the exclusion of other products that may also be suitable.

42. A MODIFIED NITROBLUE TETRAZOLIUM (NBT) SLIDE TEST FOR EVALUATION OF GRANULOCYTE PHAGOCYTIC POTENTIAL

J.J. Kelleher and K.A. Murphy*
Department of Microbiology
School of Medicine
University of North Dakota
Grand Forks, North Dakota 58202

A comparative study of granulocyte preparations obtained with the original endotoxin-stimulated NBT Slide Test of Ochs and Igo (1) and a modification of the NBT Slide Test developed in our laboratory was performed on human and murine peripheral blood samples. The modified method was a definite improvement over the original procedure, consistently resulting in NBT-positive cells which were morphologically intact and intensely stained. In contrast, the procedure of Ochs and Igo yielded cells which were poorly stained and exhibited morphological alterations.

The NBT slide Test is a simple, rapid micromethod for evaluating the phagocytic response of peripheral blood granulocytes. The test assays the ability of granulocytes to phagocytize the yellow dye, nitroblue tetrazolium, and reduce it, intracellularly, to an insoluble blue, crystalline form. Reduction of nitroblue tetrazolium occurs primarily via superoxide anion generated during the burst of oxidative metabolism in stimulated phogocytic cells. Superoxide anion is also the source of hydrogen peroxide and other highly reactive oxygen radicals which, in turn, impart microbicidal activity to phagocytic cells. Thus, granulocyte reduction of nitroblue tetrazolium is indicative of the ingestion and microbicidal capabilities of the cell and is a useful tool in detecting abnormalities of phagocyte oxidative metabolism.

The NBT Slide Test was developed by Gifford and Malawista (2) and later modified by Ochs and Igo (1) to include granulocyte stimulation by E. coli endotoxin. Further modifications of the endotoxin-stimulated NBT Slide Test were developed in this laboratory. Our procedures differ from the original procedure in three respects: (1) heparinized blood was used in place of whole blood; (2) coverslips with adherent granulocytes were flooded with NBT solution, rather than inverted on a drop of NBT solution on a glass microscope slide; and (3) a different counterstain (nuclear fast red) was used.

The average percentage of NBT-positive cells obtained with the modified endotoxin-stimulated NBT Slide Test was 95.65 ± 3.13 (humans) and 79.54 ± 9.77 (BALB/c mice). The NBT reduction potential of granulocytes from normal human subjects as determined by the modified procedure was quantitatively the same as that reported by Ochs and Igo (1). Distinct qualitative differences were apparent in the cell preparations obtained with the original and modified NBT Slide Tests. In addition, this is the first report of an assay of NBT reduction potential in normal mice.

A comparison of human and murine granulocyte preparations obtained with the earlier vs. the newer, modified NBT Slide Tests shows that the modified method is an improvement over the original procedure. The method of Ochs and Igo resulted in cell preparations containing many distinct NBT-positive and negative cells. However, some of the cells appeared morphologically altered, as seen by partial or complete displacement of the nucleus from the cytoplasm. In addition, the safranin counterstain used in this procedure did not provide a strong contrast between NBT-positive and negative cells. The nuclei of NBT-positive cells and both the nucleus and cytoplasm of NBT-negative cells were stained weakly. Our modification of the NBT Slide Test resulted consistently in granulocyte preparations which were morphologically intact and more intensely stained. In addition, the size difference between NBT-positive and negative cells was greater, thereby enhancing the distinction between the two cell types. The proposed modifications of the NBT procedure not only improved test results, but rendered the interpretation of those results much easier.

1. Ochs, H.D. and Igo, R.P. (1973) *J. Pediatrics* 83, 77-82.

2. Gifford, R.H. and Malawista, S.E. (1970) *J. Lab. Clin. Med.* 75, 511-519.

43. DIFFERENTIATION OF GROUPS A, B AND D STREPTOCOCCI ON A PRIMARY PLATING MEDIUM

Bette R. Wojack* and James R. Waller
Department of Microbiology, University of North Dakota
Grand Forks, North Dakota 58202

Members of the genus Streptococcus are responsible for producing a wide variety of clinical diseases in man ranging from superficial skin infections to serious systemic diseases. The majority of human pathogens belong to groups A, B and D. Identification of streptococci requires primary isolation followed by further evaluation involving one or more tests.

The purpose of this research was to develop a primary isolation medium that could be used to select for and differentiate colonies of groups A, B and D streptococci. Columbia-CNA agar base was modified to include 0.1% esculin, 0.05% ferric ammonium citrate and 10 µg neomycin/ml. Esculin is hydrolyzed by groups A and D streptococci to esculetin which forms a dark brown or black complex with iron. Group B streptococci do not hydrolyze esculin and do not cause the formation of a dark complex. This medium, which we call CNNE (Table 1), is selective for Gram positive cocci and differential for groups A, B and D streptococci. CNNE agar plates were inoculated and incubated at 35-37 C in increased CO_2 for 18-24 hrs. Colonies grown in 10% CO_2 were larger and easier to visualize then when grown in air.

TABLE 1. COMPOSITION OF CNNE MEDIUM

COLUMBIA BLOOD AGAR BASE*	
COLISTIN SULFATE*	10 µg/ml
NALIDIXIC ACID*	15 µg/ml
NEOMYCIN	10 µg/ml
ESCULIN	0.1%
FERRIC AMMONIUM CITRATE	0.05%
DEFIBRINATED SHEEP BLOOD	5%

* THESE INGREDIENTS ARE PACKAGED COMMERCIALLY AS COLUMBIA CNA AGAR

TABLE 2. ESCULIN AND CAMP REACTIONS OF GROUPS A, B AND D STREPCOCOCCI

	ESCULIN POSITIVE	CAMP POSITIVE
GROUP A	95.5% (19/20)	0%(0/20)
GROUP B	0% (0/31)	93.6%(29/31)
GROUP D	100 % (27/27)	0%(0/27)

The data in Table 2 indicates that not all group A streptococci were esculin positive. Since about 98% of group B streptococci are CAMP positive and other beta-hemolytic streptococci are CAMP negative, a modified CAMP test was used to differentiate colonies of group B streptococci from other occasionally occurring esculin negative colonies of similar morphology. One drop of beta-lysin solution was placed approximately 5 mm from a suspected colony. The plate was then incubated aerobically at 35-37 C for 30-60 minutes. A positive CAMP reaction consisted of complete clearing of the medium within that portion of the beta-lysin drop zone near the colony in question. All of the group A (0/20) and group D (0/27) streptococci were CAMP negative and 29 of 31 group B streptococci were CAMP positive.

TABLE 3. COLONY DESCRIPTIONS OF GROUP A, B AND D STREPTOCOCCI ON CNNE MEDIUM

A	Brown colony, 2 mm, with a large zone of beta-hemolysis surrounded by a zone of brown-black color in the medium.
B	White colony, 1 mm, with a small zone of beta-hemolysis. No darkening of the medium.
D.	Dark, black colony, 1 mm, dense blackening of surrounding medium. No hemolysis visible.

Initial studies with CNNE and the modified CAMP test indicate that groups A, B and D streptococci can be differentiated on this medium. The selectivity of CNNE greatly reduces or eliminates most non-streptococcus organisms including staphylococci, allowing the streptococci to grow and be seen more easily. The colony characteristics outlined in Table 3 provide presumptive identification of groups A, B and D streptococci without further testing. An important differentiating feature of this medium is the degree of blackening (intense, light, none) in the medium. Group B streptococci can be accurately identified by their reactions on CNNE. White or translucent colonies exhibiting a positive modified CAMP test are confirmed as group B streptococci with an accuracy of 93-98%. CAMP negative, esculin negative colonies are identified as non-group A, B or D streptococci. The esculin negative group A strains (Table 2) constitute less than 5% error in identification as group A. Group C streptococci occasionally encountered in clinical specimens are esculin and CAMP negative and would be identified as non-group A, B, or D.

The use of CNNE medium to identify potentially pathogenic beta-hemolytic streptococci in throat specimens could be difficult if the pathogens were present in small numbers. Many people harbor esculin positive, alpha-hemolytic streptococci as part of their normal oral flora which could darken the medium enough to observe a few beta hemolytic foci within a mass of colonies. However, the benefit of using CNNE for isolation and rapid differentiation of organisms present in numbers sufficient to provide isolated colonies should make it useful.

44.

RARE MYCORRHIZAL FUNGI FRUITING IN NORTH DAKOTA IN 1980

Robert W. Stack*
Plant Pathology Department, NDSU
Fargo, North Dakota 58105

Mycorrhiza is the term for the symbiotic association of plant roots and fungi. Several types of mycorrhiza are known, each confined to particular plant families and fungi. The type called 'ectomycorrhiza' is found among forest trees in association with basidiomycetes of the order Agaricales, the gilled and poroid fleshy mushrooms (2).

In nature, the ectomycorrhizal association is obligate in both plant and fungus. Trees in the Salicaceae, Betulaceae, Fagaceae and Pinaceae are always mycorrhizal and the ectomycorrhizal fungi occur only in association with their respective hosts. Although the only direct proof of a mycorrizal association is pure culture synthesis, once a species of fungus has been demonstrated to be mycotrophic, all its natural occurrences may be considered to be in this relationship (4).

Many native North Dakota trees are ectomycorrhizal species but basidiocarps of ectomycorrhizal fungi are seldom found or found in such small numbers as to belie the widespread occurrence of the mycorrhizal association. The seasonal timing of this mushroom production is a characteristic of the particular species but the intensity of fruiting is environmentally controlled. Generally, these ectomycorrhizal fungi fruit once annually, many of them in mid to late summer, a normally dry time in North Dakota (1,3).

The year 1980 was unusual because many parts of North Dakota received abundant mid-to-late-summer rainfall. This paper reports the profuse fruiting and occurrence of large numbers of species of ectomycorrhizal fungi in two of these areas in 1980.

Table 1. Mycorrhizal fungi collected in North Dakota native woodlands in 1980.

Name	Loc.[a]	Freq.[b]	Comments
Amanita virosa	LY	1	Lethal
A. muscaria	TR	3	Poisonous
" "	LY	2	" "
Lactarius piperatus	LY	2	
L. torminosus	LY	1	Poisonous
L. uvidus	TR	2	Poisonous
Russula foetens	TR	2	
R. lutea	TR	3	
R. emetica	TR	3	Poisonous
R. virescens	TR	2	
Cortinarius collinitus	TR	2	
C. glaucopus	LY	3	
Hebeloma crustuliniforme	LY	2	Poisonous
Suillus luteus	LY	4	
Leccinum aurantiacum	LY	1	
" " "	TR	1	
Boletus crassipes	TR	2	
B. luridus	LY	3	Poisonous
B. vermiculosus	TR	2	

a) Location: LY = Little Yellowstone State Park; TR = Tongue River Game Management Area.
b) Frequency: 1 = occasional individuals to 4 = very abundant.

The sites were Little Yellowstone State Park (LY) in Ransom County and the Tongue River Game Management Area (TR) in Cavalier County. At LY, three collections were made between 25 July and 30 August 1980; at TR, a single collection was made on 8 August.

Fungi were identified from freshly collected specimens. Seventeen species in eight genera were recognized and identified (Table 1). Only two of the species identified were common in both locations. The intensity of fruiting at both locations was much greater than the author had observed in these locations in any of four previous seasons and was reminiscent of the profusion of these fungi to be found in wetter climates. It is suggested that the paucity of mushrooms of ectomycorrhizal species in most seasons in North Dakota native woodlands is a response to unfavorable moisture conditions which are customary at this time in North Dakota rather than indicating infrequent occurrence of the ectomycorrhizal association.

Nearly half of the species in Table 1 are poisonous, several quite seriously so. From time to time the author has heard remarks that "there are no poisonous mushrooms in North Dakota". These results clearly indicate that this is a dangerous fallacy.

Literature Cited

1. Graham, V. O. 1944. Mushrooms of the Great Lakes Region. Chicago Acad. Sci. (reprint Dover Press 1970).
2. Harley, J. L. 1969. The Biology of Mycorrhiza. Leonard Hill, London.
3. Miller, O. K., Jr. 1972. Mushrooms of North America. Dutton, New York.
4. Trappe, J. M. 1962. Fungus associates of ectotrophic mycorrhizae. Bot. Rev. 28:538-606.

The author acknowledges the assistance of NDSU graduate students in his Field Mycology course in preparing these results.

45.

VITAMIN PRODUCTION AND UTILIZATION IN AN AERATED SEWAGE LAGOON

K.R. Robinson* and J.W. Vennes
Department of Microbiology, University of North Dakota
Grand Forks, N.D. 58202

The distribution of vitamins in aquatic environments and their production and utilization by microorganisms is important in the ecologic makeup and efficiency of aquatic systems. A past study (1) has observed the presence of vitamin B12 and biotin in the Grand Forks lagoon. The purpose of this research was to investigate the ecological importance of the vitamins biotin, B12 and riboflavin, and to determine if any production or utilization occurred in aerated sewage.

Biotin, vitamin B12 and riboflavin concentrations were determined in the raw influent and aerated sewage of the Grand Forks lagoon. The sewage was assayed for vitamin B12 using *Lactobacillus leichmannii*, for biotin using *Lactobacillus plantarum*, and riboflavin using *Lactobacillus casei*. Physical and chemical determinations were also made of the raw influent and aerated sewage according to Standard Methods (2). These included temperature, dissolved oxygen, biochemical oxygen demand, flow rates, and pH. Microbial counts for total populations of aerobic, facultative anaerobic, coliforms, and fecal streptococci were also made. Several microorganisms were isolated from the lagoon and examined for their ability to produce vitamins in assay medium and lagoon filtrate.

Table I shows weekly concentrations of biotin, vitamin B12, and riboflavin, and weekly temperatures of both the raw and aerated sewage of the Grand Forks lagoon. Biotin showed a reduction in concentration from the raw sewage to that in the aerated sewage. The average weekly reduction was seven fold. B12 concentrations also decreased in the aerated sewage from that in the raw sewage, with an average weekly reduction of 1.7. Riboflavin, on the other hand, increased in concentration from the raw sewage to the aerated sewage by about two times.

Several microorganisms isolated from the aerated sewage, were shown to be producers of biotin and riboflavin in their respective assay medium. *Klebsiella pneumonia* was shown to be a producer of biotin, with one biotype producing 30 ng/l. Six species were isolated that produced riboflavin, with biotypes of *Escherichia coli* and *Enterbacter agglomerans* being the major producers; 22,400 ng/l riboflavin was produced by one biotype of *Enterobacter agglomerans* and one biotype of *Escherichia coli* was shown to produce up to 23,900 ng/l.

Table I.
Biotin, B12, Riboflavin Concentrations and Temperature in Raw and Aerated Sewage

Date	Biotin		B12		Riboflavin		Temperature	
	ng/liter						°C	
1980	Raw	Aerated	Raw	Aerated	Raw	Aerated	Raw	Aerated
7-25	150	12	350	180	2900	11700	21.0	21.0
7-30	100	15	320	160	3700	9700	23.0	23.0
8-6	120	25	200	200	3500	6300	22.0	20.0
8-12	90	15	300	100	3300	3300	21.0	20.0
9-5	75	16	165	120	6100	7100	22.0	21.0
9-17	50	17	150	130	1500	5000	20.0	18.0
9-29	75	7	200	110	2500	4300	18.0	15.0
10-16	45	6	120	90	1700	3000	18.0	14.0
11-1	60	3	130	70	1700	3500	17.0	13.0
11-10	55	4	140	75	1900	2500	16.0	11.0

(1) Choy, Y.M. (1972) *M.S. Thesis*, University of North Dakota, Grand Forks, ND

(2) Rand, M.C., ed. (1975) *Standard Methods for the Examination of Water and Wastewater*, 14th edition. American Public Health Association Inc. Washington, D.C.

46. GIFTED ELEMENTARY SCHOOL CHILDREN: ATTITUDES TOWARD SCIENCE AND MATHEMATICS

Eric N. Clausen*
Division of Science and Mathematics, Minot State College
Minot, North Dakota

The Campus Laboratory School at Minot State College began operating a summer program for gifted elementary school children in 1979. Sixty-seven children were admitted the first year and fifty-four were admitted in 1980. The program was developed with an open classroom philosophy where children, sometimes with parental guidance, were free to select from a diverse range of academic activities. Data collected from initial applications for admission to the program, parent and child entrance interviews, and child evaluations of the program provide an opportunity to observe the attitudes of the children toward instruction in various disciplines including science and mathematics.

Children were admitted to the special summer program on a basis of recommendations submitted by teachers, school administrators, parents and others. Frequently, but not always, test scores were included with recommendations to support the child's application. The recommendation forms used requested an evaluation of the child's interests and abilities on twenty specific items. Items receiving the highest ratings for the group of children that were admitted were: the child has good oral expression, the child has strong reading ability and the child is a logical thinker. Items receiving the lowest ratings were: the child shows unusual mechanical ability and the child shows unusual interest in science.

Prior to the start of the program all children and their parents were asked independently with an open ended question to comment on the child's interests in school. Responses were then grouped into disciplines and were tabulated as favorite and least favorite activities. A summary of the number of responses obtained in each category is presented in Table I.

Table I

	Favorite		Least Favorite	
	Children	Parents	Children	Parents
Art	39	23	1	1
Language Arts	39	24	34	19
Mathematics	52	55	29	32
Music	18	31	6	6
Physical Education	21	8	7	10
Reading	50	61	6	5
Science	39	39	5	11
Social Science	7	15	17	11

Once in the program children were given an opportunity to work with a diverse group of teachers with backgrounds in such disciplines as art, language arts, music, science, social studies, and mathematics (including computer programming). Children were given the opportunity to either sample from several different disciplines or to work exclusively on one project. Most children chose to explore a variety of different subjects. At the conclusion of the 1980 program children were asked with an open ended question to state their single greatest accomplishment of the summer and also to list those activities which they especially enjoyed doing in the summer program. Table II summarizes the number of responses received in each category.

Table II

	Greatest Accomplishment	Especially enjoyed
Art	17	32
Science	11	20
Math (includes computer)	8	21
Social Science	3	5
Music	7	14
All other responses	4	14

This group of gifted elementary children, which was not selected on a basis of special interest in science and mathematics, appears to have had a generally favorable attitude toward science and mathematics instruction. Other programs for academically gifted elementary school children may also find the children to be especially receptive to instruction in science and mathematics.

47. GORHAM
PRAIRIE BIRD STUDY

M. L. Freeman, N. J. Braddock, and S. R. Hamre*
Department of Biology, Dickinson State College
Dickinson, N. D. 58601

The 1980 bird survey started in the Badlands 22 miles north of Belfield and 5 miles west of Highway 85. The last stop was 13 miles north of Belfield and 2 miles east of Highway 85. Most of the survey was conducted along section lines and back roads, crossing Highway 85 one time.

The physical makeup of the area consists of Badlands and short grass upland prairie. Within this area there are scoria buttes and some small stock dams. Sixty percent of the annual precipitation, which is 14-15"/year, falls in the late spring and early summer months.

The survey procedure was followed as designed by starting one-half hour before sunrise and making 50 stops, each one-half mile apart. Each stop was 3 minutes long, and audible and visual observations were made within one-quarter mile radius.

The 7 most common birds found in the survey area this year include (listed from most common to least common):

Western Meadowlark
Red-winged Blackbird
Horned Lark
Brown-headed Cowbird
Lark Bunting
Mallard
Mourning Dove

Over the past 13 years, from 1968 to 1980, this survey has been conducted in the same specific area of North Dakota. The 7 most common birds found in this area over the past 13 years include (listed from most common to least common):

Lark Bunting
Western Meadowlark
Horned Lark
Red-winged Blackbird
Brown-headed Cowbird
Mourning Dove
Ring-necked Pheasant

During the 1980 survey, 6 new species were added to the 13-year study. These include:

Ruddy Duck
American Kestrel
Tree Swallow
Rough-winged Swallow
Black-capped Chickadee
Canadian Geese

Over the past 13 years, 89 different species have been found in this Gorham Prairie Bird survey area of North Dakota. Twenty-seven species have not been seen in the past 3 years. The average number of birds counted each year is 782 in which there are 41 different species.

1. Peterson, Roger, (1980), A Field Guide to the Birds East of the Rockies, Houghton Mifflin Co., Boston.

2. Robbins, S., (1966), Birds of North America, Western Publishing Co., Inc.

3. Stewart, Robert E., (1975), Breeding Birds of North Dakota, Tri-College Center for Environmental Studies.

48. COMPARISON OF *IN VIVO* RABBIT BARORECEPTOR NERVE ACTIVITY TO AORTIC TRANSMURAL PRESSURES: WITH ANALYSIS OF SPATIAL ATTENUATION. A. Billon* and H.O. Stinnett, UNDSM, Grand Forks, ND

The purpose of this study was to investigate the hypothesis that changes in left aortic baroreceptor nerve activity are proportional to changes in aortic transmural pressure (TMP) in the intact thorax rabbit. The rabbit's aortic nerve is composed of afferent Aδ and c multifibers (> 300 fibers/nerve) that transmit aortic pressure information to the brain (3). Previous investigators have demonstrated that in *in vitro* preparation changes in activity of some single fibers in this nerve correlate to changes in aortic TMP (1). Others have shown that the amplitude of electronically integrated recordings of aortic multifiber activity reflect changes in aortic blood pressure during hemorrhage or blood volume expansion (2). Electronically integrated recordings provide information on temporal summation, or the additive effect of simultaneous fiber activity. However, prior studies using integrated recordings have not assessed the loss of activity due to spatial attenuation. Thus, included in the design of the experiments reported here were techniques to evaluate spatial attenuation or the loss of activity due to differences in fiber distance from the recording electrodes.

In nine anesthetized rabbits steady state levels of heart rate, mean right atrial pressure (MRAP), and mean arterial pressure (MAP) were measured following section of both aortic nerves. TMP was estimated as the difference between MAP and MRAP. The distal end of the cut cervical left aortic nerve (LAN) was placed on a recording bipolar platinum electrode, LAN activity was then amplified and counted on a two-channel digital pulse counter. The counter was triggered by setting the signal voltage thresholds at 4 μV and 2 μV at the nerve. Activity, counts per sec., were essentially constant over a voltage range of 3.5 μV to 20 μV. The lower threshold was used to estimate the extent of signal loss (spatial attenuation) at the electrode-nerve junction. Animals were ventilated using a Harvard animal respirator and as part of the protocol 5.0 cm H_2O positive end expiratory pressure was used to increase extramural pressure (low TMP), while carotid occlusion (OCC) was used to increase intramural pressure (high TMP).

Results are summarized in the table below:

Aortic transmural pressure and left aortic nerve activity

Condition	n	TMP	Nerve activity thresholds 4 μV	2 μV
		mm Hg	Counts/sec.	Counts/sec.
Baseline Control	9	97.9 ± 5.8	431.1 ± 41.1	491.1 ± 49.0
PEEP (5.0 cm H_2O)	9	63.0 ± 8.2*	278.4 ± 24.6*	367.1 ± 35.0*
Carotid Occlusion	9	120.7 ± 3.7*	522.0 ± 41.5*	627.1 ± 52.3*

Values are means ± 1 S.E.M., n is number of animals, and PEEP is positive end expiratory pressure. *Indicates the average is significantly ($P < 0.05$) different from the baseline control average. Please see text for additional explanations.

Data from nine animals were averaged. Statistical evaluation included paired 't' test and linear regression analysis in order to determine the degree of correlation of nerve activity to TMP. PEEP resulted in a significant decrease and carotid occlusion resulted in a significant increase in TMP and nerve activity (Table). A linear relationship of nerve activity to TMP was found at both electronic thresholds (all correlation coefficients exceeded 0.97). While activity averaged 85 c/sec more for the low threshold channel the change in activity per change in TMP (slope) was 4.08 ± 0.46 (c/sec)/mm Hg and not significantly different from that of the high threshold channel value of 4.12 ± 0.47 (c/sec)/mm Hg.

It was concluded that aortic multifiber nerve activity increases or decreases proportionally with corresponding changes in aortic transmural pressure. Since changes in activity per unit change in TMP were not significantly different at 2 μV and 4 μV thresholds, it was also concluded that signal loss at the recording electrodes due to spatial attenuation was minimal. Had the low threshold slope been significantly greater than the high threshold slope then spatial attenuation of nerve activity would have been present. It was also considered that the high threshold activity was primarily from the A fiber types since the highest aortic pressures we investigated were still below those pressures reported to elicit c fiber responses (3). The low threshold recorded activity would include either background noise or a constant activity level from fibers with low voltage action potentials. These results are consistent with the literature (3) and support the use of electronic integration methods (2) to determine multifiber nerve activity provided the electronic threshold levels at the recording electrodes are selected to minimize spatial attenuation of fiber activity.

1. Angell James, J.E. (1971 b) Journal of Physiology 214, 89-103.
2. Kumada, M., Sagawa, K. (1970) American Journal of Physiology 218, 961-965.
3. Kirchheim, H.R. (1976) Physiology Reviews 56, 100-176.

Supported in part, UND Fac. Res. Com. Grant #1813 and AHA Dakota Aff. Grant-in-Aid 79-606.

49. Ground Water Quality in Northwestern North Dakota

J. L. Seidel*, K. Baldridge, J. Boatz, C. Hall, M. Heupel
A. King, J. Kostenko, G. Martin, K. Olson, and D. Slind
Division of Science and Mathematics, Minot State College
Minot, N.D. 58701

Ground water quality in northwestern North Dakota was evaluated by sampling 368 rural water wells during June and July of 1980. All wells sampled were within a ten mile radius of the communities of Crosby, Deering, and Towner. Crosby was chosen because of a recent surge in oil related energy development and the current soil fertilization practices in the region. The Towner region is located in part on the former glacial Lake Souris beds and is an area with shallow water wells. These conditions made ground water contamination from the numerous cattle ranches and farm land irrigation projects in that region a possibility worth investigating. Deering is an area used predominantly for small grain farming and is located in part on sediments from former glacial Lake Souris. Geologic similarity to Towner and proximity to Minot made Deering a good study area.

Ten chemical parameters were evaluated for each of the wells using standard Environmental Protection Agency methods. Four of the ten parameters were determined at the well site; these were pH, alkalinity, hardness, and dissolved oxygen. In the laboratory titrimetric chloride and turbidity were determined manually, while the total phosphate, sulfate, iron, and nitrite concentrations were determined using an Autoanalyzer I system. Statistical analysis of the data was performed using the Statistical Analysis System Library on the North Dakota Higher Education Computer Network and locally designed programs on Minot State's Tektronix 4051.

Many of the wells studied exceeded Environmental Protection Agency limits for desirable drinking water in one or more of the chemical parameters tested. In Crosby 28% of all the chemical tests performed exceeded the Environmental Protection Agency limits, while at Deering and Towner 27% and 23% respectively of all the tests exceeded the limits.

Wells in each of the three areas were subdivided into wells in glacial deposits and wells penetrating the bedrock. The glacial deposit wells were also subdivided on the basis of surface geology in the area. For example, the Deering area was divided into outwash and channel fill, lake sediment, and ground moraine wells. Bedrock formations were used to subdivide the bedrock wells. Statistical parameters from the chemical tests were compared for each of the well subgroupings. Principal conclusions were:

1) The pH, alkalinity, and chloride concentrations were higher in the bedrock.
2) Hardness values were lower in the bedrock.
3) Wells in the outwash and channel fill subgroup generally have the "best" water in terms of lower mean ion concentrations and number of wells exceeding the Environmental Protection Agency desirable drinking water standards.

Analysis using well depth as a variable indicated that mean glacial deposit well depth in the Crosby and Deering areas was about 23 meters, while the glacial deposit wells in Towner averaged only 12 meters. Bedrock wells in the Crosby area were found to be about 30% deeper on the average than those in the Deering area. The pH, alkalinity, and chloride ion concentrations generally tended to increase as well depth increased.

Analysis undertaken to seek relationships between various parameters revealed:

1) Iron and turbidity are related in a statistically significant linear fashion.
2) Sulfate and hardness correlated well in a linear fashion.
3) Mean pH, dissolved oxygen, and phosphate concentrations were about the same for all three areas.
4) Water quality in the Deering and Towner areas is similar.

Data from this study should prove useful as baseline data for long term water quality changes in northwestern North Dakota. The project was supported by National Science Foundation grant number SPI-8004019.

50.

THE DESIGN OF LOAD CARRYING JOINTS BETWEEN PLASTIC AND METALLIC STRUCTURAL MEMBERS

Dennis A. Moon,* Mark L. Schow, Hans J. Goettler
Department of Mechanical Engineering & Applied Mechanics
North Dakota State University
Fargo, N.D. 58105

Engineering structures and machines consist of many individual parts which are joined together to form the structure or the machine. Loads must be transferred from one member to another across the connecting joints. The design of joints between structural, i.e. load carrying, members is one of the basic tasks in mechanical engineering design. Historically, metals have been used almost exclusively for machine members. As a consequence, the design of joints between metallic members has been thoroughly researched and the results have been compiled in machine design texts and handbooks. These sources give the designer reliable information, saving time and money. Until recently, the use of plastics in engineering design has been restricted to coverings, decoration, or other minor or no-load applications. Engineering plastics have been developed with load carrying capabilities that make them useful for structural design. In light of decreasing supplies of energy and metallic materials their excellent strength to weight ratio makes them highly desirable in applications where weight reduction or material substitutions is needed, as e.g. in the transportation industries.

There are, however, limitations to the use of plastics, and in most cases it is necessary to work with a combination of plastic and metal parts. Therefore, joints between plastic and metallic members must be designed that can safely and efficiently transfer the required loads. The discontinuity of physical properties at the metal-plastic interface poses challenging problems. Presently, little, if any help is available to the designer in the form of proven design procedures or standards.

This investigation dealt with double lap joints between aluminum and a glass-fiber, randomly re-inforced plastic. The joints were tested with a tensile test machine, with the load applied perpendicular to the bolt axis. Different bolt sizes were investigated, in one and two bolt configurations. Parameters kept constant were: overall dimensions of the joint members, clamping pressure, and the rate at which the load was applied. Standard stress-strain curves were measured for the materials to determine their primary mechanical properties (elastic modulus, yield strength, ultimate strength).

The ratio of stiffness to strength of engineering plastics is much lower than that of metals. Thus if a joint is designed for equal strength in the plastic and metal members, the plastic component will have a much lower stiffness. Conversely, if the joint is designed for equal stiffness, the plastic component will be greatly overdesigned from the standpoint of strength. The joints tested were designed on an equal strength basis.

The single bolt joints were found to present no problems that were due specifically to the mixed material nature of the joint. The strength decreased with increasing bolt diameters due to the decrease in cross-sectional area in the margins of the bolt hole. In all cases tensile failure occurred in the plastic.

The double bolt joints showed an average increase in strength over the single bolt joints for the same bolt size of 6.0 to 8.5%. This contrasts with the expected increase for a metal to metal joint of about 30%. It was argued that the vast difference in elastic moduli (stiffness) of the materials contributed to an uneven distribution of the load between the two bolts. A simple spring model was developed to estimate the effect that the moduli of elasticity of the materials have on distribution of the load between the bolts. The spring constants of the joint members are functions of material properties and the geometry of the joint. Another model was developed, using the principles of stress concentrations, to analyse the relationship between the load distribution and the maximum load carrying capacity of the joint.

Based on these models, the expected increase in strength for the tested joints of the double over single bolt configuration is approximately 5.5%, which agrees in trend and order of magnitude with the experimentally observed increases.

51. SHOOT ELONGATION OF SCOTS AND PONDEROSA PINE IN RESPONSE TO VARIOUS CHILLING REGIMES.

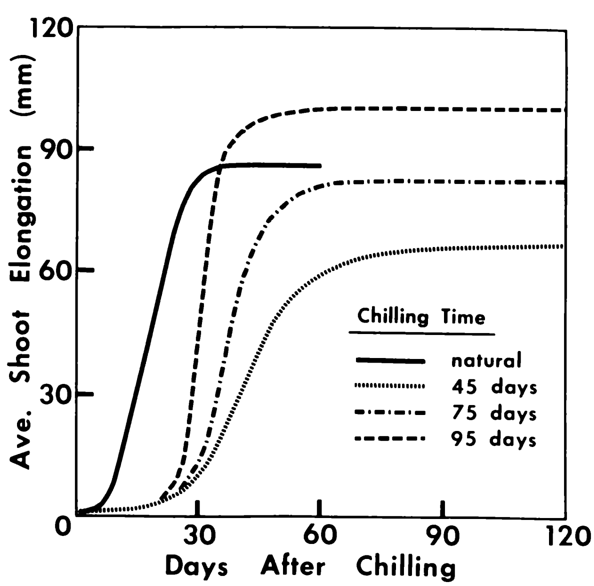
Timothy R. Meyer* and Robert W. Stack
Department of Plant Pathology, NDSU
Fargo, North Dakota 58105

Alternating periods of growth and dormancy characterize many different tree species. The patterns of this alteration can be grouped according to types of seasonal shoot growth. North temperate species such as Pinus sylvestris (scots pine) or P. ponderosa (ponderosa pine) show a 'single-flush' pattern in which shoot elongation potential for the next growing season is established in the current season's shoot apex (2). In trees of this growth pattern, shoot elongation ('flushing') occurs during a relatively short period, followed by terminal bud formation.

The onset of dormancy is preceeded by the formation of this resting bud. Fully dormant buds develop a chilling requirement, and exposure to cold temperatures is required to remove the inhibitors in the plant that hold the buds dormant. Temperature and duration of chilling in conjunction with flushing temperature are considered the major factors in bud burst response (1). This study deals with the duration of chilling for controlling dormancy in scots and ponderosa pine with application to the development of an accelerated growth system in the study of perennial diseases.

Potted 2-year-old scots and ponderosa pine seedlings were allowed to naturally mature outdoors until mid-November. Then they were given a 45 day chilling treatment at 2°C with an 8 hour photoperiod after which these seedlings were grown in a 20°C greenhouse under a 14 hour photoperiod until bud development was satisfactory. A control or natural growth response was determined from these seedlings. Then the seedlings were transferred back into the 2°C, 8 hour photoperiod environment.

Figure 1. Pine shoot elongation following chilling treatments.



At intervals of 45, 75 and 95 days the seedlings were removed to the greenhouse. The 2°C environment served a dual purpose by inducing cold hardiness and providing the chilling requirement. Nutrients were applied in the irrigation water (3).

Growth response to the different chilling treatments is shown in Fig. 1. Growth initiation and subsequent bud development were much earlier for the naturally hardened trees, possibly indicating some environmental factors were not optimum in the induced hardening-chilling procedure. Addition of nutrients increased both growth rate and final shoot length of treated trees compared to natural growth. As the chilling period increased from 45 to 95 days, the shoot growth pattern more nearly approximated the pattern of naturally hardened seedlings.

Literature Cited
1. Campbell, R. K., and A. I. Sugano. 1979. Genecology of bud-burst phenology in Douglas-fir: Response to flushing temperature and chilling. Bot. Gaz. 140: 223-231.
2. Lanner, R. M. 1976. Patterns of shoot development in Pinus and their relationship to growth potential. in M. R. G. Cannell and R. T. Last, ed. Tree Physiology and Yield Improvement. Academic Press, New York. p. 223-243.
3. Tinus, R. W., and S. E. McDonald. 1979. How to grow seedlings in containers in greenhouses. USDA For. Serv. Gen. Tech. Rep. RM-60, 256 p. Rocky Mt. For. and Range Exp. Stn.

52.

THE TIGER BEETLES OF NORTH DAKOTA (COLEOPTERA: CICINDELIDAE)

Paul R. Larson
Department of Entomology
North Dakota State University
Fargo, North Dakota 58105

Of the four genera of Cicindelidae in the United States, Amblycheila, Omus, Megacephala, and Cicindela, only the latter is found in North Dakota. The few scattered published records for North Dakota are vague and incomplete. There have been 26 species and subspecies of Cicindela collected in North Dakota (Table 1), more than have been collected in adjacent Manitoba - 22 (1), Minnesota - 20 (2), and South Dakota - 23 (3). An additional species C. longilabris Say might also occur in North Dakota because it has been collected in all areas surrounding the state.

Tiger beetle adults are active, predaceous insects. In North Dakota, they range in size from 1/3" (C. cursitans LeConte) to 3/4" (C. formosa manitoba Leng) and vary in color hue and intensity. The markings or patterns on the elytra can be complete, reduced or lacking, even in the same population. While most species fly well, C. cursitans is flightless and uses its fast running ability to escape.

TABLE 1

TIGER BEETLES KNOWN TO OCCUR IN NORTH DAKOTA

Cicindela Linnaeus, 1758
- C. cinctipennis LeConte, 1848
- C. circumpicta johnsoni Fitch, 1856
- C. cuprascens LeConte, 1852
- C. cursitans LeConte, 1859
- C. decamnotata Say, 1817
- C. denverensis conquisita Casey, 1914
- C. duodecimguttata Dejean, 1825
- C. formosa formosa Say, 1817
- C. formosa gibsoni Brown, 1940
- C. formosa manitoba Leng, 1902
- C. fulgida Say, 1823
- C. hirticollis Say, 1817
- C. lengi W. Horn, 1908
- C. lepida Dejean, 1831
- C. limbalis Klug, 1834
- C. limbata nympha Casey, 1913
- C. montana LeConte, 1861
- C. nevadica knausi Leng, 1902
- C. punctulata Olivier, 1790
- C. purpurea Olivier, 1790
- C. pusilla Say, 1817
- C. repanda Dejean, 1825
- C. scutellaris scutellaris Say, 1823
- C. scutellaris lecontei Haldemann, 1853
- C. sexguttata Fabricius, 1775
- C. tranquebarica Herbst, 1806

The larvae are predaceous and live in vertical burrows in dry soil. They seize prey in strong traplike jaws while anchoring themselves in the burrow with hooks located on the 5th abdominal segment.

Many species are restricted to highly specific habitats. Some prefer shady areas, while others prefer the banks of rivers and lakes. Still other species seem to require a specific slope to the habitat or seem to prefer areas having sparse vegetation. Each North Dakota species show a definite preference for a particular soil type: 1) predominantly sandy soils, 2) gravelly or sand loam to clay soils, and 3) alkaline or saline soils.

The taxonomic status of some Cicindela species remains to be determined. C. terricola Say is considered by some to be a synonym of C. pusilla Say, while others give it specific or subspecific status. C. cinctipennis LeConte is considered by many to be a subspecies of C. pusilla. The describing of species has been complicated by the reliance of color patterns and markings as diagnostic features, characters known to be variable and influenced by environmental conditions (4). More accurate descriptions of species based on genitalia, habitat associations, and life histories could form a sound basis for a future study.

Several North Dakota localities are prime tiger beetle collecting areas: 1) the Pembina sandhills, 2) the sandhills in Richland and Ransom Counties, 3) the saline flats west of Grand Forks, 4) the river and creek banks of the Badlands, 5) the buttes in western North Dakota, especially those in Slope County, and 6) the remaining Missouri River bottomlands and sandbars.

The author wishes to thank Jack R. Powers, Moorhead, MN, for his suggestions and comments.

1. Wallis, J. B. (1961) The Cicindelidae of Canada. Univ. Toronto Press. 74 pp.
2. Dawson, R. W., and Horn, W. (1928) Minn. Agr. Exp. Sta. Tech. Bull. 56, 13 pp.
3. Kirk, V. M., and Balsbaugh, E. U., Jr. (1975) S. D. Agr. Exp. Sta. Tech. Bull. 42, 139 pp.
4. Shelford, V. E. (1917) Ill. Biol. Monographs 3, 1-134.

53. ENTEROTOXIN PRODUCTION BY STAPHYLOCOCCUS AUREUS OBTAINED FROM NURSING HOMES

Gregory D. Greek* and James R. Waller
Department of Microbiology, University of North Dakota
Grand Forks, North Dakota 58202

Certain strains of Staphylococcus aureus produce exoproteins known as enterotoxins that are responsible for staphylococcal food poisoning. Staphylococcal food poisoning accounts for 25-40% of all incidents of food borne disease.

Five different enterotoxins A, B, C, D, and E have been identified. Enterotoxins A, D, and E are similar chemically, structurally and antigenically as are enterotoxins B and C. The amount of enterotoxin A required to cause an emetic response in humans is approximately 1 μg, where as 20-25 μg of enterotoxin B is required to induce the same response. Of all food poisonings due S. aureus 75-85% are enterotoxins A and D.

The employees and residents of several nursing homes within a 90 mile radius of Grand Forks were cultured for S. aureus in 1977 and in 1980. In 1977 only employees of the nursing homes were cultured. In 1980 both employees and residents were cultured. Cultures were taken from the external nares. All S. aureus isolates were tested for the production of each enterotoxin. Each isolate was grown in brain heart infusion medium using a sac culture technique.[1] Bacterial laden culture fluid was centrifuged at 4,100 X g for 30 minutes and tested for the presence of enterotoxin by a microslide technique employing an agar-gel, double-diffusion, antibody antigen reaction.

TABLE 1. Incidence of enterotoxin production by Staphylococcus aureus isolates.

Source	Number of Strains	Enterotoxin Positive No.	(%)	A	B	C	D	E	AB	AC	AE	BC	BD	CD	ABD	ADE
1977 Control	36	9	(25.0)	1	4	0	1	1	0	0	0	0	0	0	2	0
1977 Employees	209	49	(23.4)	2	17	12	5	5	1	1	1	0	1	1	0	1
1980 Employees	164	39	(23.8)	2	22	1	5	1	1	0	3	1	1	2	0	0
1980 Residents	106	27	(25.5)	2	13	3	4	0	0	0	2	0	1	2	0	0
Total	515	124	(24.1)	7	56	16	15	7	2	1	8	1	3	5	2	1

The enterotoxin most commonly produced was enterotoxin B (64 of 124). 44 of 124 enterotoxin producing isolates produced either enterotoxin A or D or both. The strains producing A and D toxins are of particular interest because A and D toxins are very potent and cause most of the staphylococcal food poisoning.

The relatively high number of enterotoxin C producers seen in the employees tested in 1977 (12) was due primarily to one nursing home. This home accounted for 7 of 12 enterotoxin C producing isolates. No one home in either year showed such a predominance for specific enterotoxin producing organisms. The home was retested again in 1980 and only one enterotoxin C producing isolate was obtained.

Table 2. Percent of enterotoxin positive Staphylococcus aureus from area nursing homes.

Group	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
1977 emp.	13.8	44.0	30.0	15.8	15.0	0.0	41.7	10.0	5.9	26.1	44.4
1980 emp.	19.2	25.0	20.0	--	19.0	--	35.3	21.4	--	26.9	--
1980 res.	26.1	36.0	--	--	--	--	--	18.8	--	25.0	--

(Columns I–XI: Nursing Home)

The data in Table 2 shows the distribution of toxin producing S. aureus among the various homes and for the two years and groups tested. In 1977 a wide range of rates of enterotoxin producing isolates (0-44.4%) occurred among the various homes. The incidence of enterotoxin producers in 1980 (18.8 to 36.0%) was much less variable.

These results along with the identification of specific enterotoxin producers from each home indicate a large turnover in enterotoxin producing strains which may colonize in a certain home. However, the incidence of enterotoxin producing staphylococci throughout the entire population tested (Table 1, Column 3 - %) remained at 23-25% even though many conditions within these rather isolated populations may vary greatly from one home to the next. These results also tend to indicate that the employees and residents harbor common S. aureus organisms.

[1]Donnelly, C.B., Leslie, J.E., Black, L.A., and Lewis, K.H. (1967) App. Micro. 15:1382-1387

54\.

CHARACTERIZATION OF CARBONIC ANHYDRASE FROM *Rhodospirillum rubrum*

P. J. Fedorka* and B. P. Sleeper
Department of Bacteriology, North Dakota State University
Fargo, ND 58105

In 1963 Veitch and Blankenship reported that certain strains of *Neisseria sicca* had high concentrations of carbonic anhydrase (CA). While few other bacteria have been reported to contain CA, the soluble *Rhodospirillum rubrum* CA has been purified and characterized (Fedorka and Sleeper, unpublished). *R. rubrum* was grown photosynthetically in modified yeast extract-glutamate medium. The soluble cytoplasmic CA was obtained by passage of cells through the French pressure cell. The CA was purified 815 fold by 60% $(NH_4)_2SO_4$ precipitation, passage through Sephacryl S-200, and isoelectric focusing, first at pH 3.5 to 10 and then at pH 5 to 7. A molecular weight of 55,000 was determined by gel filtration with Sephacryl S-200 superfine polydextran beads. Sucrose density gradient centrifugation according to Martin and Ames (1961), gave a sedimentation coefficient of 2.81. Earlier experiments indicated that addition of bovine serum albumin (BSA) was required for stabilization of the purified enzyme. More recently zinc sulfate ($ZnSO_4$) has been substituted for the BSA. Assays were in the direction of CO_2 hydration for which the Km was 3.4×10^{-2} M. CA exhibited mixed inhibition kinetics with acetazolamide (Ki 1.3×10^{-9} M) and noncompetitive inhibition kinetics with sulfanilamide (Ki 4.8×10^{-6} M), sodium iodide (Ki 6.4×10^{-3} M), and ferric chloride (Ki 5.7×10^{-2} M). Purified carbonic anhydrase retains approximately 95% of its activity at 4°C for at least 6 months, but only 6% remains at 22°C after 4 days. The pH optimum for CO_2 hydration was 7.5. *R. rubrum* CA did not exhibit esterase activity.

Fedorka, P.J. and Sleeper, B.P., unpublished work.

Martin, R.G. and Ames, B.N. (1961) *J. Biol. Chem.* 236, p. 1372.

Veitch, F.P and Blankenship, L.C. (1963) *Nature* 197, p. 76.

55. COMPUTER-AIDED DESIGN FOR POWER PLANT COOLING TOWERS

Bradley Oachs* and Dr. Kam Li
Department of Mechanical Engineering and Applied Mechanics
North Dakota State University
Fargo, North Dakota 58105

As the number of power plants has increased in coal producing areas such as North Dakota, the management of waste heat from these plants has become necessary. The challenge has been to find the heat rejection method that is not only environmentally acceptable, but also efficient and economical. One approach is the use of evaporative cooling towers. In fact, a majority of the power plants constructed in the future are expected to make use of evaporative cooling towers.

This paper is intended to present a computer model for the purpose of design, performance simulation and distribution analysis. The design model enables the engineer to quickly size the tower fill matrix (packing) and estimate the fan power requirements for either the counterflow or crossflow arrangements. The performance simulation model is used to estimate the tower exit water temperature for given operation conditions. The program generates the tower performance curves in the form recommended by the Cooling Tower Institute [1]. The distribution analysis program determines the enthalpy and temperature distribution throughout the cooling tower. The evaporation loss, drift loss, tower blowdown, and tower makeup are also calculated by this program.

Presented below is an illustrative case study by the computer modeling. A tower is to be designed to remove 1705.1 MBTU/hr from a 225 MW fossil fuel power plant. The ambient temperature and relative humidity at the plant site are 96°F and 48%, respectively. Based upon the overall cooling system analysis, the tower is expected to have a tower approach of 13°F, cooling range of 23.5°F and the so-called fill type F from Kelly's Handbook [2]. In the design, the tower water loading, air velocity and configuration parameter were chosen to be 6500 lb/hr/ft^2, 525 ft/min and 0.5 respectively. The computer output is presented as:

Tower Fill Matrix Height	36 Ft.
Tower Fill Matrix Depth	18 Ft.
Tower Fill Matrix Length	622 Ft.
Tower Fill Matrix Volume	400,700 Ft.^{3}
Total Water Flow Rate	145,000 gals/min
Total Static Pressure Drop	0.36 inches of water
Total Air Flow Through Fans	12,094,500 Ft.^{3}/min
Total Fan Static Brake Horsepower	920 hp.

Using a tower fan diameter of 28 feet, there will be 9 double-row crossflow tower cells with each cell being 68 ft. wide by 44 ft. tall by 36 ft. long. Through the use of the distribution analysis program it was found that the tower evaporation and blowdown would be 3095 gals/min and 2950 gals/min respectively. Taking the drift loss into consideration, the makeup is approximately 6190 gals/min. The water temperature distribution throughout the tower fill is determined below:

Water Flow (↓) / Air Flow (→)

115.5*	115.5	115.5	115.5	115.5	115.5
103.3	107.1	109.7	111.5	112.8	113.6
96.2	100.6	104.1	106.8	108.9	110.5
91.4	95.8	99.4	102.4	104.9	107.0
88.2	92.2	95.7	98.7	101.4	103.7
85.8	89.4	92.6	95.6	98.2	100.6
84.1	87.2	90.2	92.9	95.5	97.8

*All temperatures are in degrees F.

The computer modeling can be used to determine the effects of varied water loadings and air velocities on the tower fill size. It was found that as the water loading increased so did the fan power, but at the same time the fill size decreased. Similar results were obtained as the air velocity increased. The modeling can also be used to generate the information necessary to determine the optimum configuration and matching between the cooling tower and condenser. The computer modeling is currently in the interactive mode and has been thoroughly tested on an IBM 370/158 computer. The documents for the programs can be found in reference [3].

1. Cooling Tower Institute (1967) Cooling Tower Performance Curves. Houston, Texas.
2. Kelly, Neil W. and Associates. Kelly's Handbook of Crossflow Cooling Tower Performance Curves. Kansas City, Missouri.
3. Oachs, Bradley and Li, Kam W. (1981) Computer Modelling of Evaporative Cooling Towers. Internal Report, Dept. of Mechanical Engineering, North Dakota State University, Fargo, N.D. 58105

OBITUARIES (1980-81)

Earl A. Helgeson (1897-1979)

Dr. Earl A. Helgeson died August 27, 1979 at his home in Tucson, Arizona.

Helgeson was born on November 23, 1897 at Northwood, Iowa. He received his B.S. degree from Oregon State University in 1927 and his Ph.D. in 1930 from the University of Wisconsin. He taught at the University of Wisconsin for four years and then joined the faculty of North Dakota State University as an Assistant Professor of Botany, later becoming Professor and Department Chairman until retiring in 1963. Helgeson was a pioneer in the testing and use of herbicides and published extensively on weed control. He served the United Nations Food and Agriculture Organization both as a consultant and on assignment in Chile. He was a member of the North Dakota Academy of Science from 1936 until his death.

Helgeson is survived by his wife, Marguerite, and three sons.

Katharine O. DeBoer (1909-1980)

Dr. Katharine O. DeBoer died December 22, 1980 at her home in Grand Forks.

Katharine O. Mills was born February 23, 1909 at Grant City, Missouri. She graduated from the local high school and received a bachelor's degree, master's degree, and doctor's degree in Zoology from the University of Missouri (Columbus). She was married to Benjamin DeBoer in 1939 and together they came to Grand Forks in 1951 where she taught Physiology at the University of North Dakota Medical School. Dr. DeBoer was a member of the North Dakota Academy of Science since 1963.

Dr. DeBoer is survived by her husband, one son, three daughters, two sisters, and six grandchildren.

Ruth MacKichan (1913-1981)

Ruth MacKichan died January 12, 1981 in Grand Forks.

MacKichan was born August 3, 1913 at Charleston, South Carolina. She received her college education in South Carolina and Michigan. She married Keith MacKichan in 1938 at Charleston and they later moved to Grand Forks where he was a building contractor. Mrs. MacKichan was a Professor of Mathematics at the University of North Dakota from 1948 through 1974. She was a member of the Academy of Science since 1958.

MacKichan was preceded in death by her husband in 1974. She is survived by two sons, six grandchildren, and one sister.

Arthur Saiki (1899-1980)

Dr. Arthur Saiki died in September 1980 at his home in Grand Forks.

Saiki was born in Hawaii where he obtained his undergraduate education. He came to the University of North Dakota in 1924 to enter medical school and after completion of the two years at UND he transferred to the University of Nebraska from which he received his M.D. degree in 1928. Immediately thereafter Saiki returned to UND as a faculty member in the Department of Pathology where he taught Pathology and Bacteriology to medical students. Dr. Saiki joined the Academy in 1949.

In 1955 the Department of Pathology initiated the first residency program in the University of North Dakota Medical School, and the principal instructor in this program was Dr. Saiki.

Dr. Saiki is survived by two sons, George Saiki in Bismarck and Dr. Jack Saiki in Albequerque, New Mexico, one brother and one sister, and seven grandchildren.

Membership of North Dakota Academy of Science

ADOMAITIS VYTAUTAS A	1966	301 16TH AVE NE	JAMESTOWN	ND58401
ALBRECHT, STEVEN	1979	JAMESTOWN COLLEGE	JAMESTOWN	ND58401
ALESSI JOSEPH	1962	N GREAT PLAINS RES CENTE	MANDAN	ND58554
ALSOP, TED J	1981	GEOGRAPHY DEPT UND	GRAND FORKS	ND58202
ANDERSON EDWIN M	1962	213 20TH AVE N	FARGO ND	58102
ANDERSON ORDEAN S	1972	RURAL ROUTE 1	NEW PRAGUE MN	56071
ANTES, JAMES R	1979	3524 7TH AVE N	GRAND FORKS	ND58201
ASCHBACHER PETER W	1958	MET & RAD RES LAB NDSU	FARGO	ND58102
ASHWORTH, ALLAN C	1974	GEOLOGY DEPT NDSU	FARGO	ND58105
AUYONG THEODORE	1963	MEDICAL SCHOOL UND	GRAND FORKS	ND58202
BALTISBERGER RICHARD	1969	CHEMISTRY DEPT UND	GRAND FORKS	ND58202
BANASIK ORVILLE J	1947	CEREAL TECH DEPT NDSU	FARGO	ND58102
BARKER WILLIAM T	1968	BOTANY DEPT NDSU	FARGO	ND58102
BARNEY WILLIAM G	1957	MECH ENGR DEPT UND	GRAND FORKS	ND58202
BARNHARD, MARY DIX	1975	315 ALEXANDER	BOTTINEAU	ND58318
BARRON GEORGE	1972	JAMESTOWN HIGH SCHOOL	JAMESTOWN	ND58401
BARRY, DAVID G	1980	445 10TH ST E	DICKINSON	ND58601
BARTAK, DUANE	1977	CHEMISTRY DEPT UND	GRAND FORKS	ND58202
BEHM, MARLA	1980	MARY COLLEGE, APPLE CR RD	BISMARCK	ND58501
*BEHRINGER, MARJORIE	1969	8014-A PINEDALE COVE	AUSTIN	TX78578
BELINSKEY CAROL R	1958	MINOT STATE COLLEGE	MINOT	ND58701
BELKNAP, JOHN K	1979	DEPT OF PHARM-UND	GRAND FORKS	ND58202
BENSON, STEVEN A	1979	ENERGY TECH CENT BOX 8123	GRAND FORKS	ND58202
BENZ LEO C	1962	1407 N 23RD ST	BISMARCK ND	58501
BERKEY GORDON B	1970	SCIENCE DIVISION MSC	MINOT	ND58701
BERRYHILL DAVID L	1973	BACTERIOLOGY DEPT NDSU	FARGO ND	58102
BIRNKRANT, MILTON	1979	VETERANS ADMIN CENTER	FARGO	ND58102
BITZAN EDWARD F	1952	U S BUREAU OF MINES UND	GRAND FORKS	ND58202
*BLISS, HAROLD N	1951	MAYVILLE STATE COLLEGE	MAYVILLE	ND58257
BLUEMLE JOHN P	1963	N D GEOLOG SURVEY UND	GRAND FORKS	ND58202
*BOLEY, CHARLES	1967	1827 QUAIL ST #9	LAKEWOOD	CO80215
*BOLIN DONALD W	1946	1425 N UNIV DR	FARGO	ND58102
*BOLIN F M	1948	1505 6TH ST S	FARGO	ND58102
BOLONCHUK, WILLIAM W	1981	HPER DEPT UND	GRAND FORKS	ND58202
BOTTOMS, CHARLES L	1979	940 BOX AVE	DICKINSON	ND58601
BOUDJOUK, PHILIP	1978	CHEMISTRY DEPT NDSU	FARGO	ND58102
BRAMMER, J D	1978	ZOOLOGY DEPT NDSU	FARGO	ND58102
BRAND, MICHAEL	1976	1116 SO 3RD ST #2	BISMARCK	ND58501
BREKKE, DAVID	1979	GEOLOGY DEPT., UND	GRAND FORKS	ND58202
BROMEL MARY C	1969	BACTERIOLOGY DEPT NDSU	FARGO	ND58102
BROPHY JOHN A	1960	GEOLOGY DEPT NDSU	FARGO	ND58102
BROPHY, LAURA	1980	1401 9TH AVE N	GRAND FORKS	ND58201
BROSCHAT, MYRON D	1976	203 E CHANNING AVE	FERGUS FALLS	MN56537
BROWN RALPH C	1972	GEOGRAPHY DEPT UND	GRAND FORKS	ND58202
BRUMLEVE STANLEY	1958	PHYSIOLOGY DEPT UND	GRAND FORKS	ND58202
*CALLENBACH JOHN A	1954	ENTOMOLOGY DEPT NDSU	FARGO ND	58102
CAMARA, MICHAEL	1978	11723 CLEARGLEN AVE	WHITTIER	CA90604
CARMICHAEL, VIRGIL W	1979	1013 N ANDERSON ST	BISMARCK	ND58501
CARLSON KENNETH	1960	320 2ND AVE NW	MAYVILLE	ND58257
CARTER JACK F	1950	AGRONOMY DEPT NDSU	FARGO	ND58102
CASSEL J FRANK	1954	ZOOLOGY DEPT NDSU	FARGO	ND58102
+CELLA, JANE	1979	818 8TH AVE N	FARGO	ND58102
+CELLA, JOSEPH	1979	818 8TH AVE N	FARGO	ND58102
+CHENG, STEPHEN	1980	WEST HALL 102B UND	GRAND FORKS	ND58202
CHERIAN, SEBASTIAN	1971	BIOLOGY DEPT JAMESTOWN CO	JAMESTOWN	ND58401
CHRISTOFERSON, LEE A	1952	700 1ST AVE S	FARGO	ND58102
CLAMBEY, GARY K	1975	BOTANY DEPT NDSU	FARGO ND	58102
CLAUSEN ERIC N	1968	MINOT STATE COLLEGE	MINOT	ND58701
COLLINS CHARLES C	1962	ELECT ENGR DEPT NDSU	FARGO	ND58102
COMITA GABRIEL W	1954	ZOOLOGY DEPT NDSU	FARGO	ND58102
CONNELL MARVIN D	1972	2606 5TH AVE N	GRAND FORKS	ND58201
CORNATZER WILLIAM E	1952	BIOCHEMISTRY DEPT UND	GRAND FORKS	ND58202
+COSTABAL, HERNAN	1980	166D UNIV VILLAGE	FARGO	ND58102
COWARDIN LEWIS M	1967	310 16TH AVE NE	JAMESTOWN	ND58401
CVANCARA ALAN M	1963	GEOLOGY DEPT UND	GRAND FORKS	ND58202
DAFOE, ARTHUR W	1963	551 3RD ST NE	VALLEY CITY	ND58072
DANDO WILLIAM A	1975	GEOGRAPHY DEPT UND	GRAND FORKS ND	58202
D'APPOLONIA BERT L	1968	CEREAL TECH DEPT NDSU	FARGO	ND58102
DAVIS DAVID G	1973	MET & RAD RES LAB NDSU	FARGO ND	58102
DAVY, JOEL A	1981	MINOT STATE COLLEGE	MINOT	ND58701
*DEBOER, BENJAMIN	1952	312 ALPHA	GRAND FORKS	ND58201
+DEVLIN, EDWARD	1981	3411 CHERRY LANE #14	FARGO	ND58102
DINGA GUSTAV P	1961	CONCORDIA COLLEGE	MOORHEAD	MN56560
DINUSSON WILLIAM E	1950	ANIMAL SCIENCE DEPT NDSU	FARGO	ND58102
DISRUD DENNIS T	1963	413 HILLCREST DR	MINOT ND	58701
DOERING, EUGENE	1966	9308 CHERRY HILL RD #507	COLLEGE PARK	MD20740
DOGGER, JAMES R	1958	RM 313 BLDG 003 BARC W	BELTSVILLE	MD20705
+DOOD, STEVEN	1978	BIOL DEPT UND	GRAND FORKS	ND58202

+ Student member
* Emeritus member

*DOUBLY, JOHN A	1950306 23RD AVE N	FARGO	ND58102
DOYLE, DARYL J	1978RURAL ROUTE 2	VALLEY CITY	ND58072
+DRAVLAND, J ERIC	1977ANATOMY DEPT UND	GRAND FORKS	ND58202
DUERRE JOHN A	1965MICROBIOLOGY DEPT UND	GRAND FORKS	ND58202
+DUH, SHOW-HONG	19798 BISON CT	FARGO	ND58102
+DUNHAM, DAVID M.	19801030 RIVERVIEW DR	VALLEY CITY	ND58072
DURICK, MARY ANN	1979RURAL ROUTE #1	BISMARCK	ND58501
DUYSEN MURRAY E	1966BOTANY DEPT NDSU	FARGO ND	58102
*EDERSTROM, HELGE E	1953903 N 26TH ST	GRAND FORKS	ND58201
EDGERLY CHARLES G M	1955DAIRY SCIENCE DEPT NDSU	FARGO	ND58102
EGINTON, CHARLES T	1979VETERANS ADMIN CENTER	FARGO	ND58102
ELLIS, LEE	1981SOC DEPT MINOT STATE COLL	MINOT	ND58701
+ERDMANN, GARY	19801540 15TH ST S	FARGO	ND58103
ERICKSON, DUANE	1961ANIMAL SCIENCE NDSU	FARGO	ND58102
ERICKSON J MARK	1966ST LAWRENCE UNIV	CANTON	NY13617
EVANS GARY W	1975HUMAN NUTRITION LAB UND	GRAND FORKS ND	58202
EVANS HAROLD W	19612624 OLSON DR	GRAND FORKS	ND58201
*FACEY, VERA	1948801 BOYD DRIVE	GRAND FORKS	ND58201
FARNUM, BRUCE	1965BOX 8213 UND	GRAND FORKS	ND58202
FARNUM, SYLVIA	1966BOX 8213 UND	GRAND FORKS	ND58202
+FEDORKA, PAULA J	1981BACTERIOLOGY DEPT NDSU	FARGO	ND58105
FEGLEY, MELVIN M	1961908 SANDERS	LARAMIE	WY82070
FEIL VERNON J	1964MET & RAD RESEA LAB NDSU	FARGO	ND58102
+FENNO, CLINTON, JR.	19801510 S. 16TH	FARGO	ND58102
FILLIPI GORDON M	19721005 S 20TH ST	GND FORKS ND	58201
FISCHER, DAVID	19802851 CHEROKEE	CASPER	WY82601
FISH, HAROLD F	1975BOX 338	WATFORD CITY	ND58854
FIVIZZANI, ALBERT J	1979BIOLOGY DEPT	GRAND FORKS	ND58202
*FLEETWOOD CHARLES W	1948CHEMISTRY DEPT NDSU	FARGO	ND58102
FLETCHER ALAN G	1970COLLEGE OF ENGR UND	GRAND FORKS	ND58202
FOSSUM GUILFORD O	1957CIVIL ENGR DEPT UND	GRAND FORKS	ND58202
*FOWKES, WALTER W	1957422 W FARMER	INDEPENDENCE	MO64050
FRAASE, RONALD G	1973PO BOX 223	BISMARCK	ND58501
*FRANK RICHARD E	19491020 BOYD DR	GRAND FORKS	ND58201
FRANCKOWIAK, JEROME	1979AGRONOMY DEPT NDSU	FARGO	ND58105
FREEMAN MYRON L	1961DICKINSON STATE COLLEGE	DICKINSON	ND58601
+FULTON, GARY W	19781128 17TH ST N	FARGO	ND58102
FUNKE B R	1966BACTERIOLOGY DEPT NDSU	FARGO	ND58102
GABRIELSON, DAVID	1979BACTERIOLOGY DEPT., NDSU	FARGO	ND58105
GANO, DAVID	1968MINOT STATE COLLEGE	MINOT	ND58701
GARDNER RUSSELL JR	1975700 1ST AVE SO	FARGO ND	58102
GASSNER, GEORGE	1977MRR LAB UNIV STA NDSU	FARGO ND	58102
GARVEY, ROY	1967CHEMISTRY DEPT NDSU	FARGO	ND58105
GILMER, DAVID S	1978ROUTE #4 MEADOWLARK LN	JAMESTOWN	ND58401
GION, EUGENE R	19793017 MADISON AVE	FARGO	ND58102
GLASSER, ROY G	1973BOX 65	REGENT	ND58650
+GLUCK, WILLIAM	1980352 6TH AVE. S., #4	FARGO	ND58103
GOETTLER, HANS J	1979MECH ENGR DEPT NDSU	FARGO	ND58105
GOETZ HAROLD	1968BOTANY DEPT NDSU	FARGO	ND58102
GRENDA, JAMES C	1973PHYSICS DEPT, ANGELO S U	SAN ANGELO	TX76909
GRIFFITT, DANIEL M	19791101 W CAPITOL AVE #40	BISMARCK	ND58501
GROENEWOLD GERALD	1970ND GEOL SURVEY UND	GRAND FORKS ND	58202
GRONHOVD, GORDON H	1957US BUREAU OF MINES	GRAND FORKS	ND58202
+GROSS, THERESA	1978ENTOMOLOGY DEPT., NDSU	FARGO	ND58105
+GROSZ, KEVIN	1980556 2ND AVE. SW	DICKINSON	ND58601
GUSE, PAUL A	1979SCHOOL OF PHARMACY NDSU	FARGO	ND58105
*GUSTAFSON BEN G	1939421 PRINCETON ST	GRAND FORKS ND	58201
+HARRISON, STEPHEN	1979BIOLOGY DEPT., UND	GRAND FORKS	ND58202
HASSETT, DAVID J	197920 FENTON AVE	GRAND FORKS	ND58201
*HAUNZ, EDGAR A.	19511029 LINCOLN DR.	GRAND FORKS	ND58201
+HEIDT, JEFFREY	1980130 3RD AVE. SE	DICKINSON	ND58601
HEINRICH, MICHAEL	19787 KACHINA TRAIL	FLAGSTAFF	AZ86001
HELENBOLT, KENNETH S	19643563 LONGFELLOW RD	FARGO	ND58102
HENDERSON, WILLIAM	19793014 N ELM ST	FARGO	ND58102
+HEUCHERT, JOAN C	1976923 GRADUATE HOUSE EAST	W LAFAYETTE	IN47906
HICKOCK, FLOYD	19812520 9TH AVE SO #33	GRAND FORKS	ND58201
*HNOJEWYJ, WASYL S	1964COLLEGE OF CHEM NDSU	FARGO	ND58105
HODEK, DONALD	1979PO BOX 9363	MISSOULA	MT59807
*HOEPPNER, JEROME J	19492518 9TH AVE N	GRAND FORKS	ND58201
*HOFFMAN CHARLES A	1958MINOT STATE COLLEGE	MINOT ND	58701
+HOFFMAN, DENNIS	1979DEPT OF BIOCHEMISTRY-UND	GRAND FORKS	ND58202
+HOGANSON, JOHN W	1978GEOLOGY DEPT UND	GRAND FORKS	ND58202
HOLLAND FRANK D	1961GEOLOGY DEPT UND	GRAND FORKS	ND58202
HOSTETTER, TERRY L	19802261 HUDSSON ST	DENVER	CO80207
HOWARD, DALE B	19811 IRMA CT	MINOT	ND58701
HOWELL, FRANCIS L	1970PHYSICS DEPT UND	GRAND FORKS	ND58202
HUNG, YUNG-TSE	1975CIV ENG DEPT UND	GRAND FORKS	ND58202
+HUNT, CURTISS	1978524 STATE ST	GRAND FORKS	ND58201
HUSAIN, SYED	1977PHYS & PHARM DEPT UND	GRAND FORKS	ND58202
+IVERSON, LOUIS	1978PROJ RECLAMATION UND	GRAND FORKS	ND58202
JACOBS FRANCIS A	1955BIOCHEMISTRY DEPT UND	GRAND FORKS	ND58202
JALAL SYED M	1965BIOLOGY DEPT UND	GRAND FORKS	ND58202

JENKINS, DENNIS R	1975493 MCMULLIN DR	GRAND JUNCTION	CO81501
JENSEN, GORDON	1980111 MEDORA AVE BOX 366	MANDAN	ND58554
JOHANSEN ROBERT H	1955HORTICULTURE DEPT NDSU	FARGO	ND58102
JOHNSON, A WM	1961416 TERRACE DR	GRAND FORKS	ND58201
JOHNSON ARNOLD F	1966MINOT STATE COLLEGE	MINOT	ND58701
JOHNSON LESTER E	1969	BOTTINEAU	ND58318
JOHNSON, PHYLLIS E	1978HUMAN NUT LAB	GRAND FORKS	ND58202
JOHNSON ROBERT E	1969624 SINCLAIR	BOTTINEAU	ND58318
JONES, MICHAEL L	1981BOX 8213 UNIV STATION	GRAND FORKS	ND58202
+JORDE, DENNIS G	1978BIOLOGY DEPARTMENT UND	GRAND FORKS	ND58202
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	1978253 COLLEGE SW #3B	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
KNOBLICH, JEROME	1958BOX 63	ELDRIDGE	ND58435
KNUDSON, CURTIS L	1978DOE ENGR RSCH/BOX 20 UND	GRAND FORKS	ND58202
KOCH, FRANK	1979315 SATURN DRIVE	BISMARCK	ND58501
*KOENKER, WM E	19589039 SLIGO CRK PKWY 1812	SILVER SPRING MD	20901
*KOHANOWSKI, N	1949GEOLOGY DEPT UND	GRAND FORKS ND	58202
KOLSTOE RALPH H	1962PSYCHOLOGY DEPT UND	GRAND FORKS	ND58202
+KOOB, MICHAEL D	1979BIOLOGY DEPT UND	GRAND FORKS	ND58202
+KOPONEN, MARK A.	1975BOX 381	MINOT	ND58701
+KORDONOWY, RHODA	1981HARRIS HALL NDSU	FARGO	ND58105
KRAFT DONALD J	1970BEMIDJI STATE COLLEGE	BEMIDJI	MN56601
KRAUS OLEN	1969PHYSICS DEPT UND	GRAND FORKS	ND58202
KRESS WARREN D	1958GEOGRAPHY DEPT NDSU	FARGO	ND58102
KRUSCHWITZ EARL H	1947431 6TH ST SW	VALLEY CITY	ND58072
KUBE WAYNE R	1949CHEM ENG DEPT UND	GRAND FORKS	ND58202
KUCERA HENRY L	1966AGR ENG DEPT NDSU	FARGO	ND58102
*LAIRD WILSON	19411807 WAINWRIGHT DR	RESTON	VA22070
LAMBETH, DAVID	19791909 20TH AVE S	GRAND FORKS	ND58201
LANA EDWARD P	1957HORTICULTURE DEPT NDSU	FARGO	ND58102
+LARSON, LAURN	19804 N 21ST ST	GRAND FORKS	ND58201
LARSON OMER R	1964BIOLOGY DEPT UND	GRAND FORKS	ND58202
+LARSON, PAUL	1981ENTOMOLOGY DEPT NDSU	FARGO	ND58105
LEFEVER, RICHARD D	1980GEOLOGY DEPT UND	GRAND FORKS	ND58202
LEOPOLD ROGER A	1970BROOKTREE PK	HARWOOD	ND58042
LI KAM W	1968MECHANICAL ENG DEPT NDSU	FARGO	ND58102
+LINDBERG, GARY	1980434 7TH AVE. S., #1	FARGO	ND58105
LIPP WILLIAM V	197295 28TH AVE N	FARGO ND	58102
LITTLEFIELD, LARRY L	1979BOX 5012 PLANT PATH	FARGO	ND58105
+LOBDELL, FREDERICK	1980GEOLOGY DEPT., UND	GRAND FORKS	ND58202
+LOEFFLER, PETER	19801114 SUNSET DR	GRAND FORKS	ND58201
LOENDORF, LAWRENCE L	1973ANTHRO DEPT UND	GRAND FORKS	ND58202
LOGUE, MARSHALL W	1979DEPT OF CHEMISTRY NDSU	FARGO	ND58105
LORENZ RUSSELL J	1962N GREAT PLAINS RES CNTR	MANDAN	ND58554
LOW FRANK N	1964ANATOMY DEPT UND	GRAND FORKS	ND58202
+LUNN, ERIC	1980812 N 12TH ST	BISMARCK	ND58501
MACCARTHY, RONALD F	19681116 19TH AVE S #18	GRAND FORKS	ND58201
+MACK, STEVEN	1981BOTANY DEPT, NDSU	FARGO	ND58105
*MACKICHAN RUTH J	1958MATH DPT UND	GRAND FORKS ND	58202
MADHOK OM P	1967MINOT STATE COLLEGE	MINOT	ND58701
*MAGNUSSON, ADELYNN M	1951703 S 20TH ST	GRAND FORKS	ND58201
MALAND HARTLEY B	1969LAKE REGION JUNIOR COLLG	DEVILS LAKE	ND58301
MANZ, OSCAR	1970CIVIL ENGR DEPT UND	GRAND FORKS	ND58202
MARKELL CLARK	1972MINOT ST COLLEGE	MINOT	ND58701
MARTIN DEWAYNE C H	19622104 7TH AVE NW	MINOT	ND58701
MARWIN RICHARD M	1949MICROBIOLOGY DEPT UND	GRAND FORKS	ND58202
+MASTEL, JEROME A.	1980BOTANY DEPT., NDSU	FARGO	ND58105
MATHSEN, DON	1970MECH ENGR DEPT UND	GRAND FORKS	ND58202
MATTHIES DONALD L	1973ANATOMY DEPT UND	GRAND FORKS ND	58202
MCDONALD CLARENCE E	1965CEREAL TECHNOLOGY NDSU	FARGO	ND58102
+MCDONNELL, TIMOTHY	1978ANATOMY DEPT UND	GRAND FORKS	ND58202
+MCKENNA, MICHAEL	19762121 LOVETTE AVE	BISMARCK	ND58501
MCMAHON KENNETH J	1970BACTERIOLOGY DEPT NDSU	FARGO	ND58102
*MCMILLAN WILLIAM W	1947407 7TH ST W	GRAFTON	ND58237
*MELDRUM, ALAN	1957512 COLUMBIA RD	GRAND FORKS	ND58201
+MERCURY, MICHAEL G	1979615 39TH ST N #204A	GRAND FORKS	ND58201
MESSENGER, THEO	1976PHIL DEPT UND	GRAND FORKS ND	58202
MEYER DWAIN W	1970AGRONOMY DEPT NDSU	FARGO	ND58102
MILLER, DAVID	1979ENERGY RESEARCH CTR UND	GRAND FORKS	ND58202
MILLER, JAMES E	19643807 MICHAEL LANE	GLENVIEW	IL60025
MITCHELL E N	1960220 GLENHILL LN	CHAPEL HILL	NC27514
MOLLAND, GIBBS	19791205 N 22ND ST	BISMARCK	ND58501
MOORE WILLIAM L	1973VALLEY CITY STATE COLLEGE	VALLEY CITY ND	58072
MOWERY, GARRY B	1979334 FOREST AVE N	FARGO	ND58102
+MURPHY, KATHLEEN A	1979MICROBIOLOGY DEPT UND	GRAND FORKS	ND58202

MUTH, EDITH ANN	1980	ARDOCK	ND58213
NAISMITH DONALD P	1958MECH ENGR DEPT UND	GRAND FORKS	ND58202
NALEWAJA JOHN D	1963AGRONOMY DEPT NDSU	FARGO	ND58102
NAYES, JAMES B.	1980PLANT PATH., NDSU	FARGO	ND58105
NEAL, DEAN	19772000 STEVENS DR #108	RICHLAND	WA99352
*NEEL, JOE K	1969BIOLOGY DEPT UND	GRAND FORKS	ND58202
*NELSON C N	1972NDSU BOTTINEAU BRANCH	BOTTINEAU	ND58318
NELSON DELBERT R	1961218 E OWASSO LN	ST PAUL	MN55112
NELSON DENNIS R	1964MET & RAD RES LAB NDSU	FARGO	ND58102
NELSON, ERIC	1980WESTVACO CORP BOX 458	WICKLIFFE	KY42087
NELSON, HARVEY K	196710515 KELL AVE S	BLOOMINGTON	MN55437
+NELSON, WALLACE T	19812217 10TH ST N	FARGO	ND58102
NEWMAN, JOEL	1979VA MED CTR 3200 VINE ST	CINCINNATI	OH45220
NIELSON, FORREST H	1974USDA HUMAN NUTR LAB UND	GRAND FORKS	ND58202
NILSON, DAVID J	1981BOX 337	STANTON	ND58571
NORDLIE ROBERT C	1962BIOCHEMISTRY DEPT UND	GRAND FORKS	ND58202
NOYCE, MICHAEL D	19811354 B WILLOW AVE	GRAND FORKS AFB	ND58205
NYREN, PAUL	1980DICK. ENGR. STA., BX 1117	DICKINSON	ND58601
O'CONNELL JAMES W	1973535 8TH AVE SW	VALLEY CITY ND	58072
OGAARD, LOUIS	1976AGRIC ECON DEPT NDSU	FARGO	ND58105
OLESON, ARLAND E	1973BIOCHEM DEPT NDSU	FARGO	ND58102
OLSON, EDWIN S	1981223 CIRCLE HILLS DR	GRAND FORKS	ND58201
OLSON, JACQUELYN K	1978DOE ENGR RSCH CTR BOX 20	GRAND FORKS	ND58202
+OLSON, NORMAN	1979162 D COURT UNIV VILL	FARGO	ND58102
ORING LEWIS W	1971BIOLOGY DEPT UND	GRAND FORKS	ND58202
ORTH, JAMES	1970CP 1076 SCHEFFERVILLE	QUEBEC CANADA	
OWEN ALICE K	1966BIOLOGY DEPT UND	GRAND FORKS	ND58202
OWEN, JOHN B	1966BIOLOGY DEPT UND	GRAND FORKS	ND58202
*OWEN, SHUBEL D	19588000 PANORAMA RD	PANORAMA IA	59216
OWENS THOMAS C	1970CHEM ENGR DEPT UND	GRAND FORKS	ND58202
PARK, CHUNG S	1979DEPT OF ANIMAL SCI NDSU	FARGO	ND58105
PARMAR, SURENDRA	1977PHYS & PHARM UND	GRAND FORKS ND	58202
PARRILL, CLARK	1977BOX 18	NEWBURG	ND58782
+PARSONS, MICHAEL	19802300 E 18TH ST, #434	CASPER	WY82601
+PASTIAN, RUSS	1128 17TH ST N	FARGO	ND58102
PEARSON, MARGARET A	19771105 N 11TH ST #3	FARGO	ND58102
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
RAY PAUL D	1968BIOCHEMISTRY DEPT UND	GRAND FORKS	ND58202
REICHMAN GEORGE A	1962306 6TH AVE NW	MANDAN	ND58554
REID JOHN R	1962GEOLOGY DEPT UND	GRAND FORKS	ND58202
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
RINDT, DIANE	1979BOX 8213 UNIV STATION	GRAND FORKS	ND58202
RIES, RONALD E	1979908 2ND AVE NW	MANDAN	ND58554
+ROBINSON, KIM R	1981MICROBIOLOGY DEPT UND	GRAND FORKS	ND58202
*ROGLER GEORGE A	1962BOX 459	MANDAN ND	58554
+ROHDE, MONICA	19791507 N. UNIVERSITY	FARGO	ND58102
ROTHENBERGER, STEVE J	MIDLAND LUTHERAN COLL	FREMONT	NE68025
RUDESILL JAMES T	1958COLL OF CHEM & PHYS NDSU	FARGO	ND58102
+RUESS, ROGER	1980BIOLOGY DEPT UND	GRAND FORKS	ND58202
RUSTAN, JERRIL H	1979BOX 140 DSC	DICKINSON	ND58601
SANDAL PAUL C	1955AGRONOMY DEPT NDSU	FARGO	ND58102
*SANDS F H	1946COLL OF CHEMISTRY NDSU	FARGO ND	58102
SARGEANT ALAN B	1972N PRAIRIE WILDLIFE RES	JAMESTOWN	ND58401
SAUMUR JEAN H	1975PATHOLOGY DEPT UND	GRAND FORKS ND	58202
SCHAFER, JOHN E	1979412 8TH AVE W #4	DICKINSON	ND58601
SCHEIBE, PAUL	19603 SHIRLEY LANE	WOODSIDE	CA94062
SCHIMMELPFENNIG, D	1978PROJECT RECLAMATION UND	GRAND FORKS	ND58202
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	ND58102
SCHWERT, DONALD	1981GEOLOGY DEPT NDSU	FARGO	ND58105
SCOBY DONALD R	1968BOTANY DEPT NDSU	FARGO	ND58102
SEABLOOM ROBERT W	1962BIOLOGY DEPT UND	GRAND FORKS	ND58202
+SEARS, SHEILA	1977MRF LAB NDSU	FARGO ND	58102
+SEIDEL, JIMMY LEE	1981519 N 14TH ST	BISMARCK	ND58501
SEILER, GERALD J	CROP PROD & CONS LAB	BUSHLAND	TX79012
SEPE, FRANK	1978DEPT OF SURGERY UND MED S	GRAND FORKS	ND58202
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
SILVERMAN LOUIS B	19572524 OLSON DR	GRAND FORKS	ND58201
SIMS, RODGER L	1979718 25TH ST N	GRAND FORKS	ND58201
SLEEPER BAYARD P	1952BACTERIOLOGY DEPT NDSU	FARGO	ND58102
+SLIND, DARLA	19791025 DEL MAR CT #4	MINOT	ND58701
*SMITH, GLENN S	19301115 N 14TH ST	FARGO	ND58102
SMITH HARRY C	1968BOX 145	SAWYER	ND58781
*SNOOK, THEODORE	1954ANATOMY DEPT UND	GRAND FORKS	ND58202
SOMERVILLE MASON H	1974MECH ENGINEERING UND	GRAND FORKS ND	58202
SOUBY ARMAND M	1973CHEMICAL ENGR UND	GRAND FORKS ND	58202
STACK, ROBERT W.	1980PLANT PATH., NDSU	FARGO	ND58105
STANISLAO, JOSEPH	1979ENG & ARCH-NDSU	FARGO	ND58102
*STARCHER GEORGE W	19543605 JAFFA DR	SARASOTA	FL33579
STARKS, THOMAS	1978503 S ASH	CROOKSTON	MN56716
STATLER GLEN D	1970PLANT PATH DEPT NDSU	FARGO	ND58102
+STEFANOVSKY, GARY	1980923 B N 20TH	GRAND FORKS	ND58201
STENBERG VIRGIL I	1961CHEM DEPT UND	GRAND FORKS	ND58202
STEWART JAMES A	1960CHEMISTRY DEPT UND	GRAND FORKS	ND58202
STINNETT, HENRY O	1978PHYSIOLOGY DEPT UND	GRAND FORKS	ND58202
+STOTTS, BRYAN	1981BOX 4	MEDORA	ND58645
STOY, W. MICHAEL	19801826 N. BELL ST.	BISMARCK	ND58501
+STROH, KEVIN	1980346 6TH AVE W	DICKINSON	ND58601
SUGIHARA JAMES M	1965GRADUATE SCHOOL NDSU	FARGO ND	58102
*SUMMERS, LAWRENCE	1951UND CHEMISTRY DEPT	GRAND FORKS	ND58202
+SWANK DARRELL W	1981BIOCHEMISTRY DEPT UND	GRAND FORKS	ND58202
SWANSON GEORGE A	19671727 4TH AVE NE	JAMESTOWN	ND58401
SWANSON RICHARD J	1972507 3RD ST CT	WEST FARGO	ND58078
+TAYLOR, RAYMOND	1980PLANT PATHOLOGY NDSU	FARGO	ND58105
THOMPSON CLARENCE E	19751526 COTTONWOOD ST	GRAND FORKS ND	58201
THOMPSON MICHAEL B	19702208 CRESCENT DR	MINOT	ND58701
TILTON JAMES E	1966ANIMAL SCI DEPT NDSU	FARGO	ND58102
TIMIAN ROLAND G	1954PLANT PATH DEPT NDSU	FARGO	ND58102
TIMPE, RONALD C	1973MAYVILLE STATE COLLEGE	MAYVILLE	ND58257
TODD ROBERT G	1962DICKINSON STATE COLLEGE	DICKINSON	ND58601
+TRUMPOWER, RAY F	1980BOX 1541	DICKINSON	ND58601
VANALSTINE JAMES B	1975DIV OF SCI&MATH UNIV MN	MORRIS MN	56267
VAN DEUSEN JAMES L	1975USFS SHELTERBELT LAB	BOTTINEAU ND	58318
VENNES JOHN W	1957MICROBIOLOGY DEPT UND	GRAND FORKS	ND58202
VINCENT MURIEL C	1957COLL OF PHARMACY NDSU	FARGO	ND58102
+VOLESKY, JERRY D	1981BOX 2, BOTANY DEPT, NDSU	FARGO	ND58105
WAHTOLA, CHARLES H	1970457 PARK AVE	PEWAUKEE	WI53072
WALI MOHAN K	1970BIOLOGY DEPT UND	GRAND FORKS	ND58202
WALLER JAMES R	1971MICROBIOLOGY DEPT UND	GRAND FORKS	ND58202
WALLWORK, JAMES C	1979HUMAN NUTRITION LAB UND	GRAND FORKS	ND58202
WALSH ROBERT G	1968MINOT STATE COLLEGE	MINOT	ND58701
WANEK WALLACE J	1965RT 1 BOX 307	BEMIDJI	MN56601
*WARDNER, C ARTHUR	19583518 CHERRY ST	GRAND FORKS	ND58201
WATREL, ALBERT A	19791071 W 5TH ST	DICKINSON	ND58601
WEISSER WILBUR O	1957PHYSICS DEPT UND	GRAND FORKS	ND58202
WERTH RICHARD G	1964CONCORDIA COLLEGE	MOORHEAD	MN56560
WETSCH, JOHN R.	1977BOX 277	KILLDEER	ND58640
*WHEELER, GEORGE C.	1927326 LAUREL RIDGE RD.	SAN ANTONIO	TX78253
WHITE GLYNDON	1972BOX 1394	JAMESTOWN	ND58401
WHITMAN WARREN C	1950BOTANY DEPT NDSU	FARGO	ND58102
WICKS ZENO W	1974POLYMRS & COAT DPT NDSU	FARGO ND	58102
WIEDERANDERS R E	1968HARMON PARK CLINIC	WILLISTON	ND58801
*WIIDAKAS WILLIAM	1946AGRONOMY DEPT NDSU	FARGO ND	58102
WILLIAMS NORMAN D	1965AGRONOMY DEPT NDSU	FARGO	ND58102
+WILLIAMS, RICHARD L	19812333 20 1/2 AVE S, #22	FARGO	ND58103
WILLIAMSON, RICK L	1981#2 INVERNESS DR E, CONSOLENGLEWOOD		CO80110
WILLMAN, CLYDE A	1968620 10TH ST S	FARGO	ND58102
WILSON, RUSSELL H	19666218 WALNUT HILL LN	DALLAS TX	75230
+WINCZEWSKI, LARAMIE	19772300 LIBRARY LANE #104	GRAND FORKS	ND58201
WINGER, MILTON	1973MATH DEPT UND	GRAND FORKS	ND58202
WITZ RICHARD L	1960AGRI ENGR DEPT NDSU	FARGO	ND58102
WOLF, EDWARD G	19771436 TIPPERARY	BOULDER	CO80303
+WOLFSON, ALAN	1979530 TULANE DR #206	GRAND FORKS	ND58201
WORTHAM KENNETH E	1975BIOL DEPT-STATE COLLEGE	MAYVILLE ND	58257
WOSICK, FREDERICK D	1975569 SUNSET PLACE	BISMARCK	ND58501
WRENN WILLIAM J	1970BIOLOGY DEPT UND	GRAND FORKS	ND58202
WYMORE, ROBERT W	1977350 1ST ST NW	MAYVILLE	ND58257
ZIEMAN DALE M	1961DICKINSON ST COLLEGE	DICKINSON	ND58601
ZIMMERMAN, EMIL	1979	RICHARDTON	ND58652
+ZOELLNER, ROBERT W	1978CHEM DEPT UND	GRAND FORKS	ND58202
ZOGG, CARL	1979PHYSIOLOGY DEPT UND	GRAND FORKS	ND58202
ZUBRISKI J C	1955SOILS DEPT NDSU	FARGO	ND58102

AUTHOR INDEX

The number corresponds to the number listed on the Communication (upper left-hand corner), which is the number assigned in the program for the meeting, and also to the page number in this issue of the Proceedings.