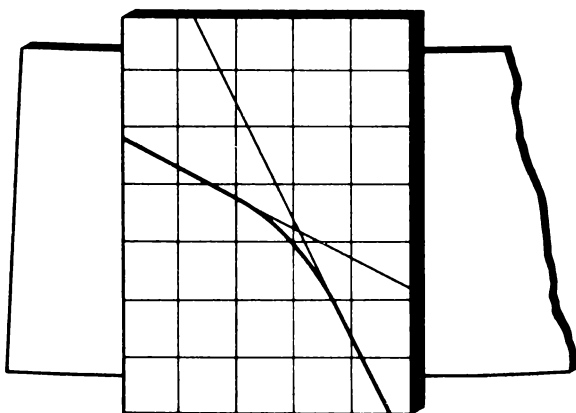


PROCEEDINGS
of the
NORTH DAKOTA
ACADEMY OF SCIENCE

ABSTRACTS



70th Annual Meeting

APRIL 28-29

University of North Dakota, Grand Forks, North Dakota

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1977-78

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70th Annual Meeting

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EDITOR'S NOTE

The abstracts are arranged in the order in which they were presented at the annual meeting. The number assigned to each abstract corresponds to the number assigned the paper in the meeting program. An author index to all authors may be found starting on page 51.

1. VEGETATION OF WETLANDS IN SOUTHWESTERN NORTH DAKOTA. G. W. Fulton and William T. Barker. Dept. of Botany, N.D. State Univ., Fargo, N.D. 58102

The plant communities of fourteen wetlands in southwestern North Dakota were mapped and sampled during July and August, 1976 and 1977. Species composition was determined by estimates of frequency, cover, and density from 0.25m² quadrats randomly located within the communities. Estimates of standing crop were obtained by clipping and oven drying sampled quadrats. Water samples, taken at the time of sampling, were analyzed in the field for pH, chloride, sulfate, calcium, magnesium, total hardness, and specific conductance. Of the 93 species present in sampled quadrats, those with the highest frequencies were: Scirpus acutus 86%; Hordeum jubatum 86%, Typha latifolia 79%, and Eleocharis palustris 79%. Standing crop averages for vegetation zones were: wet meadow 2841 lbs/acre, shallow marsh 5076 lbs/acre, deep marsh 7552 lbs/acre, and submerged 5534 lbs/acre. Salinity of water ranged from 875 to 5500 micromhos/cm. Relationships of vegetation zonation, species composition, and water chemistry were found to be similar to those of wetlands in glaciated regions of the state.

2. VEGETATION STRUCTURE AND SUCCESSION OF COTTONWOOD (*POPULUS DELTOIDES*) COMMUNITIES IN WESTERN NORTH DAKOTA. *Keith T. Killingbeck.* Dept. of Biol., Univ. of N. Dak., Grand Forks, N.D. 58202

Cottonwood communities along the Little Missouri River in Billings, Dunn, McKenzie, and Slope Counties were studied to determine vegetation structure and successional trends. Cottonwood (*Populus deltoides*) dominated the overstory and accounted for 97% of the tree stratum basal area. Green ash (*Fraxinus pennsylvanica* var. *subintegerrima*) was the only other tree found at more than 10% of the study sites. Total tree stratum density was 142 stems/ha, basal area was 15.5 m²/ha, canopy height ranged from 12-20 m, and stratum diversity was 11 species. The shrub stratum was dominated by western wild rose (*Rosa woodsii*) and white sweet clover (*Melilotus alba*). Shrub stratum basal area was 69.1 m²/ha and diversity was 17 species. Of the 49 herb stratum species, over 30% were grasses. Canada wild-rye (*Elymus canadensis*) had the highest frequency (66%) in this stratum. The mean age of cottonwoods was 62 years and most stands already showed signs of deterioration (maximum growth occurs to 40-50 years). Cottonwood seedlings were not found in the herb stratum and composed only 1.4% of shrub stratum stems. However, cottonwood regeneration was apparent outside of the forest canopy at several sites. Thanks to R.H. Bares and E.J. Crompton for computer/field work. Support: N.D. Regional Environmental Assessment Program grant to M.K. Wali

3. NITROGEN FRACTIONS IN NATIVE RANGE GRASSES AS AFFECTED BY FERTILIZERS. Metha Wanapat, D. O. Erickson and H. Goetz. Dept. of Animal Science, NDSU, Fargo, ND 58102

Nitrogen fractions were investigated in some common native range species: Stipa comata, Agropyron smithii and the composite shortgrass (Bouteloua gracilis, Carex eleocharis and Carex pennsylvanica). The fertility levels included: no fertilizer (control); 75 kg N/ha every year and every other year; 112 kg N/ha every year and every other year; 224, 336 and 448 kg N/ha only one time, three years prior to collection; 56 kg P/ha every year; 56 P + 75 N kg/ha every year; 56 P + 75 N + 224 kg K/ha every year and 224 kg K/ha every year. Total and true protein contents increased ($P < .05$) in all grasses, as well as the NPN contents in Stipa comata and in the composite shortgrass when the fertilizers were applied up to 112 kg N/ha. The total protein of Stipa comata and the NPN of the composite shortgrass increased ($P < .05$) when the grasses were fertilized up to 112 kg N/ha every year compared to every other year. Grasses sampled three years after a one time nitrogen fertilization up to 448 kg N/ha were relatively constant in nitrogen fractions, indicating there was no apparent nitrogen carryover in the soil. Applying phosphorus and potassium fertilizers alone did not increase the N fractions in any of the grasses. The highest NPN content was .268% in the composite shortgrass fertilized with 112 kg N/ha every year.

4. NITROGEN FRACTIONS IN NATIVE RANGE GRASSES AS AFFECTED BY GROWTH STAGES. D. O. Erickson, Metha Wanapat and H. Goetz. Dept. of Animal Science, NDSU, Fargo, ND 58102

Four Species of native grasses common to western North Dakota were sampled for three years at seven physiological growth stages and analyzed for various nitrogen fractions. The total protein and true protein in Stipa comata were about 13% and 11% respectively during the early heading stages with these values decreasing ($P < .05$) to about 7% and 6% near the end of the season. Non-protein nitrogen (NPN) in Stipa comata ranges from a high of .25% during anthesis down to ($P < .05$) .11% at the end of the season. The nitrogen fractions in Agropyron smithii and the short grasses followed a similar pattern of decreasing with advancing maturity. The N fractions were higher ($P < .05$) at most growth stages when comparing grasses fertilized with N to those with no N.

5. PONDEROSA PINE IN SOUTHWESTERN NORTH DAKOTA: HISTORY AND ECOLOGY. Richard H. Bares. Project Reclamation, Univ. of N. Dak. 58202.

As one of the only two naturally occurring species of pine in the state, *Pinus ponderosa* is unique and of biological interest. This was recognized during the early 1900's and resulted in a Presidential Proclamation by Theodore Roosevelt which set aside, as the Dakota National Forest, about 1590 ha of ponderosa pine in northern Slope County. Unfortunately, due to high cost of administration and poor results in a reforestation program, the Dakota National Forest was abolished in 1917.

Southwestern N. Dak. represents the northeastern extent in the geographical range of ponderosa pine. These outlying stands are most commonly found on "scoria" buttes ranging from 750 to 850 m in elevation. Tree stratum associates were Rocky Mountain juniper and green ash. Skunk bush was common in the shrub stratum whereas Indian ricegrass and bluebunch wheatgrass were characteristic of the herb stratum. Soils were characterized by "scoria" and relatively low content of mineral nutrients and organic matter. Mean pH ranged from 7.3 for the A layers to 7.8 for the C horizons. Mean replaceable major nutrients (equiv./m³) corrected for bulk density and stoniness were: Ca 129; Mg 39, K 4; Na 0.7. Trace elements and anions (g/m³) were: Mn 2.1; Cu 0.6; Fe 12.1; Zn 0.3; Cl 11; SO₄ 158; P 0.8; N 870.

Supported by REAP Grant No. 7-01-1.

6. THE ROLE OF PIONEERING VEGETATION IN ECOLOGICAL SUCCESSION OF SURFACE MINED AREAS IN NORTH DAKOTA. L. R. Iverson and M. K. Wali, Project Reclamation, UND, Grand Forks, ND 58202.

Pioneering vegetation plays an important role in the establishment of desirable species on surface mined areas in western North Dakota. Several species, such as *Kochia scoparia*, *Chenopodium album*, *Salsola collina* and others colonize the disturbed areas in the first year after mining. As time proceeds, these species decline, being replaced completely in 4 years in areas that have been re-seeded. In areas not re-seeded, the natural immigration of seeds and propagules not only determines the character of subsequent vegetation, but also takes a longer time to exhibit a desirable plant composition. Allelopathy, intra- and interspecific competition all seem to be involved in the elimination of the pioneering species. The allelopathic compounds usually inhibit the growth of the pioneering species whereas the growth of desirable species seems unaffected. High fecundity of pioneering species leads to intense intraspecific competition in the second year, and the r-type selection of these species renders them poor interspecific competitors. Thus these pioneering species, as our studies show, may in fact be both desirable and critical in the revegetation process. Specific data on these phenomena will be presented. (Supported by Grant No. G0264001 from the U.S. Bureau of Mines).

7. THE ADVANTAGES OF ATMOSPHERIC FLUIDIZED-BED COMBUSTION OF LIGNITES--THE NEXT GENERATION OF POWER PRODUCTION SYSTEMS. Richard W. Fehr. DOE, Grand Forks Energy Research Center, Grand Forks, N. Dak. 58202

Atmospheric fluidized-bed combustion (AFBC), the burning of fuel in a bed of finely-divided particles suspended in a stream of air, promises to become an alternate source of steam for power generation. AFBC produces lower levels of SO_2 and NO_x through lower combustion temperatures and the use of sulfur-absorbing materials such as limestone. A 6-inch experimental AFBC at GFERC is being used to study the sorbent properties of the ash in Western coals. These high-ash alkali, low-sulfur Western coals are uniquely suited to AFBC and may meet the current Federal New Source Performance Standard of $1.2 \text{ lb SO}_2/10^6$ when fired in this manner. AFBC's lower combustion temperatures may also reduce the potential for ash fouling. At GFERC, a variety of Western coals were burned in tests to determine the effect of ash composition and various operational parameters on SO_2 and NO_x emissions. Tests showed sulfur retention varied from approximately 30% to 60% and was strongly related to combustion temperature and sulfur-alkali ratio. Most of the lignites tested could meet the current NSPS when burned in the GFERC AFBC.

8. CHARACTERIZATION OF WASTE SOLIDS FROM A SCRUBBER OPERATED ON NORTH DAKOTA LIGNITE. A.F. Volesky and S.Y. Johnson. Dept. of Energy, Grand Forks Energy Research Center, Grand Forks, N. Dak. 58202

Column studies are being performed to assess the trace element leaching potential of scrubber sludge generated on a 5000-acfm pilot scrubber employing fly ash alkali to remove sulfur dioxide from a power plant flue gas. Physical characterization of the sludge materials include moisture content, surface area, unconfined compressive strength, permeability, porosity, and density.

Column leachates are analyzed for twenty-two (22) elements, using an inductively coupled argon plasma (ICAP) spectrometer. Results will be presented for the following elements: arsenic, beryllium, chromium, copper, zinc, and cadmium. To date, after fifty (50) days of leaching, a total of 0.09 pct chromium, 0.13 pct copper, 3.9 pct zinc, 0.18 pct arsenic, 2.4 pct beryllium, and 5.85 pct cadmium has been leached from the total amount available.

CHEMISTRY OF SULFUR DIOXIDE SCRUBBERS USING FLY ASH FROM A NORTH DAKOTA LIGNITE. Bruce D. Keifenheim and Grant L. Scheikoph. DOE Grand Forks Energy Research Center, Grand Forks, N. Dak. 58202

Wet scrubbing of flue gas sulfur dioxide using fly ash alkali have been performed using a 130-scfm pilot plant located at the Grand Forks Energy Research Center, and a 5000-acfm pilot plant located at the Milton R. Young Generating Station (Center, N. Dak.). Parameters investigated are liquid-to-gas ratios (L/G), stoichiometric ratios (CaO/SO₂), and level of recirculated suspended solids.

Test results indicate that utilization of the fly ash alkali is highly dependent on liquor pH; however, the absorption of sulfur dioxide is affected by solution pH. Discussion will be concerned with optimizing the fly ash alkali-sulfur dioxide absorption relationship, and the effects of pH on trace elements present in the fly ash.

PRODUCTION OF C₁-C₄ HYDROCARBONS IN THE GASIFICATION OF SOME NORTH DAKOTA LIGNITES. Jacquelyn K. Olson and Harold H. Schobert. Grand Forks Energy Research Center, Grand Forks, N. Dak. 58202

Modification of a standard commercial gas chromatograph by addition of a cryogenic oven allows determination of C₁-C₄ hydrocarbons. This instrument is used for routine analysis of the product gas from the Grand Forks Energy Research Center fixed-bed slagging gasifier. Determination of these light hydrocarbons is of interest because such gases could pass through gas clean-up units and become an emissions problem. Results from gasification of North Dakota lignites show that the amount of these gases produced is independent of the operating conditions. Data will be presented showing quantities of gas produced, types of lignite used, and the range of conditions used in the gasification experiments.

11. CO-STEAM PROCESS: BATCH AUTOCLAVE SAMPLING. Curtis L. Knudson. DOE, Grand Forks Energy Research Center, Grand Forks, N. Dak. 58202

Studies concerning the liquefaction of lignite via the CO- Steam Process (reactions of carbon monoxide and water with a coal slurry) have taken place at the Grand Forks Energy Research Center for the past three years. These studies have involved both gas phase and slurry phase sampling of batch autoclaves at up to 500° C and 5000 psi. Sampling at these high temperatures and pressures presents unique problems: 1) The high temperatures cause quantities of relatively non-volatile compounds such as phenanthrene to be found in the gas phase of the autoclave; 2) At cooler points in the sampling train, the compounds readily condense and plug the sampling tube. This presentation will cover the design and limitations of the equipment used for these studies.

12. LIQUID AND SOLID WASTE EFFLUENTS OF LURGI COAL GASIFICATION PROCESS. Yung-Tse Hung and Charles A. Adeniji. Dept. of Civil Engr., Univ. of N.Dak., Grand Forks, ND 58202

In recent years the coal gasification has become a potential process through which the depleting supplies of natural gas can be augmented. The major components of Lurgi gasification plants are gasification unit, scrubbing unit, shift conversion unit, cooling unit and methanation unit. Liquid waste streams contain phenols, fatty acids, sulfur compounds, dissolved ammonia, tar and tar oils, and cyanide. Solid waste streams consist of quench ash, stack gas scrubber sludge, raw water treatment sludge, and wastewater treatment sludge. After treatment the liquid streams are reused in the gasification plants. After sludge dewatering the solid wastes are buried in the mine sites. No liquid effluent is discharged to the surrounding environment. Various methods of treating and disposing of the waste streams are described.

THE TECHNIQUE OF STEREOMICROSCOPY APPLIED TO SCANNING ELECTRON MICROSCOPY. Bruce Persky. Dept. of Anat., Sch. of Med., Univ. of N. Dak., Grand Forks, N. Dak. 58201

This technique session will show how to establish stereomicroscopy in a laboratory. A step by step procedure for those aspects fundamental to stereomicroscopy will be both explained and illustrated. Mounting of tissue onto stubs, taking photographs on the scanning electron microscope, negative developing, printing, photocopying, and slide projecting will be included. A stereo demonstration illustrating the effectiveness of stereomicroscopy on choroid plexus tissue of the brain will follow. A handout will be distributed at the session containing the following: (1) a procedural flow sheet of items fundamental to stereomicroscopy, (2) a list of special equipment needed, (3) a list of suppliers for the equipment, and (4) the current prices of the equipment. Supported by USPHS Grants NS 09363 and NS 12106 from the Institute of Neurological and Communicative Disorders and Stroke.

CHROMOSOMAL ANALYSIS OF SOME PATIENTS AT THE GRAFTON STATE SCHOOL FOR THE MENTALLY RETARDED. D. R. Engbrecht and S. M. Jalal. Dept. of Biology, Univ. of N. Dak., Grand Forks, N. Dak. 58202

Twenty-nine patients have been studied and the total number is expected to increase as the investigation progresses. All of the patients had physical traits characteristic of Down's syndrome. The I.Q. in each case was well below 100.

Fifteen patients have been karyotyped. Thirteen of these had trisomy 21, one had a G-G translocation and one D-G translocation. These institutionalized patients with G_1 trisomy had a sharp increase of occurrence at maternal ages of 20-25 and 35-45 years. Translocation induced syndromes are age independent and are expected to have a familial transmission.

Nine patients and four normal individuals have been C-banded. Preliminary data indicates that C band polymorphisms exist in chromosomes 1, 3, 9, 16 and Y.

15. TRANSFER OF MACROMOLECULES TO THE IMPLANTING RAT BLASTOCYST. Christopher A. Bates and Donald L. Matthies. Dept. of Anat., School of Med., Univ. of N. Dak., Grand Forks, N. Dak. 58202.

Endometrial edema at the implantation site in rats has previously been shown to be associated with the transfer of macromolecules from the maternal vasculature to the surrounding extracellular space. Utilizing the macromolecule ferritin, as a tracer, electron microscopy has revealed the presence of capillary fenestrations in the region of the implantation site and the passage of ferritin across these fenestrations. The present study attempted to determine if any of the tracer material was demonstrable in the trophoblast. On days 6 and 7 of pregnancy, Long-Evans rats were anesthetized and injected intravenously with 1 ml. of ferritin (90 mg.). The ferritin circulated for 60 minutes to four hours, whereupon the animal was perfused with fixative via the left ventricle. Implantation sites were dissected out and prepared for routine electron microscopy. Ferritin was observed within the uterine epithelial cells, within trophoblast cells, and also in the uterine lumen. Uptake by trophoblast cells from intercellular fluid appeared to occur by pinocytotic vesicles. Direct epitheliotrophoblast contact may provide an additional site of transfer to the blastocyst. Such findings could associate a nutritive role with the uterine capillary fenestrations.

16. THE BINDING OF PROTEINS DERIVED FROM THE ACCESSORY GLAND SECRETIONS TO RAT SPERMATOZOA, M.S. Joshi (Dept. of Anatomy, U.N.D.).

The uterine contents of rat soon after mating are in the form of a gel formed mainly by a protein derived from coagulating gland secretion. The spermatozoa carry with them the coagulating gland fluid protein in sufficient quantity to cause post-coital gelation. The gelation is brought about by the bicarbonate in the uterine secretion.

The epididymal spermatozoa incubated with seminal vesicle fluid, coagulating gland fluid, rat blood plasma and saline are washed with saline to remove non-specifically bound proteins. The proteins adhering to the sperm membrane are solubilized in sodium dodecylsulfate and analyzed by acrylamide gel electrophoresis. The spermatozoa incubated with coagulating gland fluid and seminal vesicle fluid show the presence of additional protein bands. The interaction of the accessory gland fluid proteins and the uterine peptidase will be discussed.

MECHANORECEPTOR INTERACTIONS WITH THE CAROTID BAROREFLEX MECHANISM. F.J. Sepe* and H.O. Stinnett, Univ. of North Dakota, Grand Forks, ND 58202.

In 13 pentobarbital anesthetized aortic denervated rabbits, controlled increases in expiratory resistance (ER) reduced the mean arterial pressure (MAP) and increased heart rate (HR) responses to controlled step changes in isolated carotid intrasinus pressure (ISP). ISP was changed in increments of 12.5 mm Hg (range 50 to 140 mm Hg) and ER was increased in increments of 2.5 mm H₂O (range 0 to 7.5 cm H₂O). At each ER level, significant ($p < .05$) changes in mean right atrial pressure were averaged before (1.8, 2.2, 3.3 and 3.5 mm Hg) and after (1.5, 1.9, 2.8 and 3.7 mm Hg) vagotomy, respectively. In the ISP range of 75 to 100 mm Hg the ratio(S) of change in MAP to change in ISP ($S = \Delta \text{MAP} / \Delta \text{ISP}$) was calculated. Control S values averaged 1.5 before and 1.0 following vagotomy. At ER levels of 7.5 cm H₂O, S values averaged 1.0 before and 0.6 after vagotomy. HR responses to each ISP level were elevated with each increase in ER prior to vagotomy. Following vagotomy these responses were diminished. These results demonstrate modification of carotid cardiovascular baroreflex mechanisms during increased expiratory resistance. These results further suggest that both vagal and nonvagal pathways are involved. (Supported in part by NIH Grant HL 05939-04 and Am. Heart Assoc., Dakota Aff. Inc.)

Videotape Simulations in Experimental Physiology. J.A. Ward. Division of Science, Minot State College, Minot, N. Dak. 58701.

The objectives of this study were to explore the use of electronic media as a means to improve instruction in physiology laboratory. Three videotape simulations of physiology experiments were prepared. Both the videotaped demonstrations and the resultant electrophysiological signals were stored simultaneously on the tape. Students are able to observe the demonstrations and record the signals when the tapes are played back. This reduces the time spent in preparation of experiments, (which in some cases takes up to 75% of the laboratory time), allows for the use of a wider range of experiments, permits students to work in smaller groups, and allows more time to be spent on interpretation and discussion of results. Supported in part by NSF (LOCI Grant SER 77-03201).

19. EFFECTS OF LOW PRECIPITATION ON GRASSLAND VEGETATION ON THE SHEYENNE NATIONAL GRASSLANDS. Llewellyn L. Manske and William T. Barker. Dept. of Botany, N.D. State Univ., Fargo, N.D. 58102

The native grassland vegetation was studied during the growing seasons of 1976 and 1977. The area received less than 30% of the 40-year mean precipitation during the 1976 growing season. The vegetation was sampled using 12 paired plots constructed across the three grassland communities (upland, midland, and lowland) on identical soil series. Four parameters were measured: species composition, biweekly phenological development, biweekly above ground productivity, and biweekly soil moisture. The number of grass and shrub species did not change between the two years but the number of annual forbs greatly increased. The total percent of basal cover for the grasses decreased by more than 50%. The total density for the shrubs decreased slightly and the total density for the forbs greatly increased due to annual and biennial species. The 1977 grass leaf heights were shorter but each had a higher percentage of living material and the flower stem heights were greatly increased. The productivity of the forbs increased in 1977 in all three plant communities with the greatest increase in the upland. The 1977 productivity for the grasses increased in the upland but decreased in the midland and lowland communities.

20. VEGETATION OF FOREST PATCHES IN SOUTHEASTERN NORTH DAKOTA AND WEST-CENTRAL MINNESOTA. Gary Clambey. Dept. of Botany, N. Dak. State Univ., Fargo, N.D. 58102

The vegetation of 65 forest patches (shelterbelts, tree claims and natural forest patches) in southeastern North Dakota and west-central Minnesota was inventoried during a 10-week period of summer 1977. Of 226 vascular plant species found, over half were infrequent inhabitants, and the vegetation is described in terms of common trees, shrubs and vines, forbs and graminoids. Among the constituents were numerous species from adjacent non-forested agricultural areas. For plants these sites are not islands in the strictest sense because they are not isolated from the surrounding matrix. Although the sites vary in species richness, that incomplete isolation and subtle site-specific factors obscure diversity patterns related to patch area and distance from source regions. Evidence is provided for dispersal of forest species, including 48 cases documented for tree species. The prominence of plants producing fleshy fruits and stick-tight fruits attests to the effectiveness of endozoochory and ectozoochory, strategies insuring comparatively long-range, directional seed transport. Supported by the Eastern Deciduous Forest Biome Project, USIBP, funded by the National Science Foundation.

21. SECONDARY SUCCESSION OF A MIXED GRASS COMMUNITY IN THE NORTHERN GREAT PLAINS. M. D. Brand and H. Goetz. Dept. of Botany, N. Dak. State Univ., Fargo, N. Dak. 58102

In 1976, paired sites were selected on a sandy range site in Billings Co., N. Dak. to study the recovery of vegetation after 39 years of excluding cattle. In 1976 and 1977, production and average height of selected species were recorded in 10 random-systematically placed 0.5 m² quadrats. Forb density was determined with 12 random-systematically placed 0.125 m² quadrats while the point frame method was used for per cent basal cover. Per cent soil moisture was obtained to a depth of 122 cm. The vegetation of both sites was the grama-needlegrass-sedge type although they were essentially short-grass in character. The grazed site was dominated by Bouteloua gracilis while Carex filifolia dominated the ungrazed site. The intervening successional vegetation was mixed grass due to the high relative cover of Stipa comata. Total above ground herbaceous production was not significantly different between sites although grass and grass-like species produced significantly more in the ungrazed site. There is also an almost total lack of overlap in forb composition and an incomplete soil moisture recharge below 60 cm. in the grazed site. Therefore, both heavy grazing by cattle and the exclusion of cattle resulted in more of a shortgrass aspect in the grama-needlegrass-sedge type although the similarity was only superficial.

22. BIOMASS DYNAMICS OF THREE GRASSLAND COMMUNITIES IN SOUTHERN ILLINOIS. B. Dziadyk. Dept. of Botany, N. Dak. State Univ., Fargo, N. Dak. 58102

The dynamics of above ground vegetation at a railroad right-of-way prairie, an old field, and a hill prairie in southern Illinois were studied during the growing season of 1975. Randomly placed square meter quadrats were used in harvesting herbage and mulch biomass at bi-weekly intervals. The lowest peak standing crop (474 g/m²) was noted at the hill prairie where the plant cover was dominated by Andropogon scoparius, Sorghastrum nutans, and Bouteloua curtipendula. The railroad prairie, completely dominated by Andropogon scoparius, and the old field, wherein A. virginicus was the ecological dominant, attained similar peak standing crop values (1007 and 1047 g/m², respectively). However, the railroad prairie displayed a greater mean total biomass (1270 g/m²) than did the old field (904 g/m²) for the growing season. This difference reflects the high mulch accumulation at the railroad prairie (41.1% of total biomass) compared to the old field (25.2% of total biomass). The greater productivity, faster mulch decomposition, and general successional nature of the old field account for much of the variation between it and the railroad prairie. The relatively low total biomass (493 g/m²) at the hill prairie reflects a low effective moisture at this site.

23. ALGAE AS AN EDAPHIC FACTOR IN WESTERN NORTH DAKOTA. L. E. Shubert, T.L. Starks and S. B. Mercil. Dept. of Biology, Univ. N. Dak., Grand Forks, ND 58202

Soil formation involves both abiotic and biotic processes. Soil algae play a role as producers of organic matter, soil aggregates and fixers of available nitrogen. Extensive studies of soil algae conducted in western North Dakota have documented their presence in a variety of habitats, including prairie, woodland and shrub communities and denuded strip mined areas.

Microclimatic conditions and the chemical-physical properties of the soils determine the diversity and abundance of soil algae. Algae are an integral part of the soil and should be considered as an edaphic factor in ecological studies.

Supported by Project Reclamation and Project SAFARI.

24. COMPARATIVE PHYSIOLOGY OF SOIL ALGAE. J. M. Wenker and L. E. Shubert. Dept. of Biology, Univ. N. Dakota, Grand Forks, ND

Soils were collected aseptically from woodland and shrub communities in western North Dakota and cultured in an enrichment medium for algae growth. This study focused on the identification and physiology of the coccoid green algae, such as Chlorococcum, Chlorosarcinopsis and Tetracystis. Algae were sprayed on a nutrient agar medium weekly from the enrichment cultures. Algal colonies were isolated into axenic cultures. The life cycles of the coccoid greens were studied in dilute and concentrated defined inorganic media for their physiological, morphological and taxonomical characteristics. Analysis of the soil samples by the enrichment culture and axenic isolation methods demonstrated that many species of coccoid green algae were present and that in vitro succession occurred.

25. NITROGEN-FIXATION BY SOIL ALGAE. C. J. Winter and L. E. Shubert. Dept. of Biology, Univ. N. Dakota, Grand Forks, ND
Soils were collected aseptically from the burning coal vein in western North Dakota and cultured in an inorganic medium for the presence of algae. Blue-green algae were isolated into axenic culture for studies on their nitrogen-fixing activities. Nitrogen-fixation was determined on a gas chromatograph by the acetylene reduction method. Nitrogen-fixation rates of Nostoc commune were greater in nitrogen-free media. Rates of nitrogen-fixation varied with the addition of different nitrogen sources. The importance of free-living blue-green algae in soils will be discussed.

26. ALGAL COLONIZATION AND SUCCESSION ON A RECLAIMED STRIP-MINE TEST PLOT. T.L. Starks and L.E. Shubert. Dept. of Biol., Univ. N. Dak., Grand Forks, N. Dak. 58202

Several test plots have been established in the western part of North Dakota to study the effect certain soil amendments have on the reclamation of strip-mined lands. Soil samples from one of these test sites were collected aseptically during the last three growing seasons and analyzed for algal species present, chlorophyll a and phaeophytin a. A trend analysis performed on these data showed no significant effect by any soil amendment on any of the parameters tested. Time demonstrated a significant effect on the number of species present, chlorophyll a and phaeophytin a with these parameters increasing over time. These data were then compared to the above ground biomass for the various sampling dates. A possible correlation between nitrogen-fixing bacteria and algae was tested. These results and their effect on algal succession will be discussed.

Supported by Grant No. G0264001 from the BSDI, Bureau of Mines.

27. MAJOR INFESTATION OF Petrova metallica Busck IN A PONDEROSA PINE PROVENANCE PLANTING. M. E. Dix and J. L. Van Deusen. USDA Forest Service Shelterbelt Lab., Bottineau, N.D. 58318

Attack behavior of P. metallica, along with pattern and frequency of attack and consequences of infestation to tree form were surveyed at Watertown, S.D. in April 1975. Infestation levels in 8-year-old tree crowns varied significantly among 8 isodata clusters of the 73 Great Plains provenances. The plantation average was 4.7 pitch nodules per tree. On a plot basis, average number of attacks per terminal did not vary significantly among provenances. Plantation trees shorter than 1.4 meters were least likely to be attacked. Tree height of provenances and number of pitch nodules in the crown were significantly correlated. The 1973 damage to tree form appeared as open-faced crown (51.9%), multiple terminal leaders (33.1%), or forked tops (15.0%). Trees with sparse crowns were less likely to be infested than trees with normal or bushy crowns. Needle angle did not affect infestation level.

28. MALVACEAE OF THE GREAT PLAINS. Joan Colette Thompson and William T. Barker. Dept. of Botany, N.D. State Univ., Fargo, N.D. 58102

Members of the Malvaceae family in the Great Plains number 26 species within 10 genera. Three of the genera are native to the Western Hemisphere: Anoda Cav., Callirhoe Nutt., and Malvastrum Gray. The genera Althea L. and Malva L. have been introduced from the Old World. Abutilon Mill., Hibiscus L., Malvella Jaub. and Spach., Sida L., and Sphaeralcea St.-Hill. are genera found in both hemispheres. Malvella is a recent segregate from Sida, based on a combination of characteristics. Herbarium studies of specimens from the University of Kansas, University of Nebraska-Lincoln, University of South Dakota, and North Dakota State University have been made. Specimens from all the Great Plains states have been observed. Descriptions and keys have been written for the genera and species as found in the Great Plains. Distribution data for each species have been mapped.

29. THE GENUS SALIX IN NORTH DAKOTA. G. E. Larson and William T. Barker. Dept. of Botany, N.D. State Univ., Fargo, N.D. 58102
- Field and herbarium research has shown that fifteen species of willow occur in North Dakota. These include Salix amygdaloides, S. alba, S. bebbiana, S. candida, S. discolor, S. exigua ssp. interior, S. fragilis, S. humilis, S. lucida, S. maccalliana, S. pedicellaris, S. pentandra, S. petiolaris, S. rigida, and S. serissima. Of these species, S. maccalliana is a new record for North Dakota. S. alba, S. fragilis, and S. pentandra are introductions from Europe which occasionally escape from cultivation. Key taxonomic characters used to identify willows include capsule vestiture, stamen number, the presence or absence of glands on the petioles, and leaf shape and vestiture. Taxonomic revisions have involved nomenclatural changes in some of our native species, including S. exigua ssp. interior (S. interior), S. rigida (incl. S. missouriensis, S. cordata Muhl, not Mich., S. lutea), and S. humilis (incl. S. tristis). Spring and summer field collecting have added new information on the distribution of willows in North Dakota.
30. THE EFFECT OF ADP AND ATP ON THE ELECTRON TRANSPORT RATES OF ISOLATED WHEAT CHLOROPLASTS. R. D. Zabrocki and M. E. Duysen. Dept. of Botany, N.D. State Univ., Fargo, N.D. 58102
- Etiolated wheat seedlings, 7 days old, were illuminated with 24 or 48 hours of continuous light. The isolated chloroplasts were measured for state 2 (basal) and state 3 (phosphorylating) whole chain electron transport rates with methylviologen as the electron acceptor. A technique was developed to elicit high state 3 rates. ADP concentration was varied and the stimulation of the state 3 rates was monitored. The effect of ATP on state 2 and state 3 was also measured.
- Higher concentrations of ADP did not appreciably increase the state 3 rate, but did affect the length of the stimulation. ATP had no significant effect on either state 2 or state 3. The basal and phosphorylating rates of the 48 hour light developed chloroplasts were slower than the rates of the 24 hour light developed chloroplasts, but the ratios of the phosphorylating rate/basal rate in each case were comparable.

31. SEASONAL FLUCTUATIONS IN THE NUTRIENT QUALITY OF NINE SELECTED SHRUBS. Rick L. Williamson, William T. Barker, and D. O. Erickson. Dept. of Botany, N. D. State Univ., Fargo, N.D. 58102

Nine shrub species were sampled on a biweekly basis from the first of June through the last of August, 1977. Each species was collected from two different sites at each sampling date and separated into leaves, twigs (current year's growth), and fruits when present. These plant parts were then dried, ground, and analyzed for the following constituents: percent ash, lignin, acid detergent fiber, crude protein, calcium, phosphorus, magnesium, potassium, and IVDMD (in vitro dry matter digestibility). The species sampled were leadplant (Amorpha canescens), willow (Salix interior), Juneberry (Amelanchier alnifolia), prairie wild rose (Rosa arkansana), buckbrush (Symphoricarpos occidentalis), skunk bush (Rhus trilobata), buffaloberry (Shepherdia argentea), Woods' rose (Rosa woodsii), and chokecherry (Prunus virginiana). Preliminary results indicate that with advancing maturity there is an increase in fiber and lignin along with a decrease in crude protein and IVDMD. There are also evident changes in the calcium, phosphorus, magnesium, and potassium content of these plants as the growing season progresses.

32. MULTIMETHOD ANALYSIS OF COAL LIQUEFACTION PRODUCTS. Bruce W. Farnum. DOE, Grand Forks Energy Research Center, Grand Forks, N. Dak. 58202

Analysis of the composition of coal liquefaction products requires prior separation of process solvent. Separation techniques in use include vacuum distillation, column chromatography on alumina, and solvent separations with hexane, toluene, and tetrahydrofuran. Analysis of the fractions is carried out by low voltage mass spectrometry, gel permeation high pressure liquid chromatography, non-aqueous titrations for weak acids and weak bases, gas chromatography, computerized infrared analysis, and solution viscosity. The problems in distinguishing coal depolymerization products from the coal-derived process solvent will be discussed.

33. USE OF A SCANNING AND ANALYZING MICROSCOPE IN LIGNITE RESEARCH. Willis Beckering. DOE, Grand Forks Energy Research Center, Grand Forks, N. Dak. 58202

A computer controlled scanning electron microscope equipped with an energy dispersion system is a valuable tool in a research laboratory. During the past year the Grand Forks Energy Research Center has used such an instrument to:

1. Scan a polished coal surface to determine the size and composition of minerals in Western coals.
2. Determine the mode of occurrence of the inorganic elements in lignite.
3. Examine the distribution and composition of minerals in a CCl₄ sink fraction of lignite.
4. Examine and analyze probe deposit particles in conjunction with a heated stage microscope.

The above techniques will be described and their significance discussed

34. THE INDUCTIVELY COUPLED ARGON PLASMA SPECTROMETER--A NEW ANALYTICAL TOOL IN LIGNITE RESEARCH. Robert D. Roppel. DOE, Grand Forks Energy Research Center, Grand Forks, N. Dak. 58202

The inductively coupled argon plasma spectrometer (ICAP) is the newest state-of-the-art method for simultaneous multi-element analysis. Its capability to analyze trace elements at sub-ppm levels and speed of analysis are the two main advantages of the ICAP over conventional methods of analysis. This paper describes the ICAP and the properties that make it useful in lignite research.

The ICAP has often been compared to atomic absorption. Although the accuracy is comparable, the ICAP suffers little from the problems that are common to A.A. To determine its accuracy, Beulah-2 coal, NBS1633 fly ash, and NBS1632 coal were analyzed. The results were well within the range for those values that were certified. A full discussion of results will be presented.

35. GPC ANALYSIS OF PRECIPITATES FORMED DURING STORAGE OF COAL LIQUEFACTION PRODUCTS. D.J. Twedt. DOE, Grand Forks Energy Research Center, Grand Forks, N. Dak. 58202.

The formation of precipitates with time has been observed in THF soluble fractions of coal liquefaction products. This THF soluble fraction was initially filtered to 0.5 μm and stored as a 1.0 wt. pct. solution. With time, however, a precipitate formed which was THF insoluble and greater than 0.5 μm . Various methods were employed to resolublize these precipitates: heated and stirred THF, THF acidified with (acetic, sulfuric, H_2S), THF made basic with (NH_3 and KSCN), other bases such as aniline, NH_4OH , and amines. These techniques failed to yield adequate results. Pyridine, one of the best solvents of high MW material in coal-derived products, yielded a slightly greater resolubilization of this precipitate. Results similar to those of pyridine were obtained with quinoline. However, a refluxed solution of THF and pyridine led to a sharp increase in the high MW material brought back into solution. The degree to which this high MW material is resolubilized is dependent upon the ratio of THF to pyridine. This increased solubility indicates that a complex, formed during storage, was broken down to a greater degree by the combination of nucleophiles (THF and pyridine) than by either individually. Future work is aimed at a better understanding of the nature of this complex.

36. EMISSION SPECTROSCOPY OF DISUBSTITUTED BENZENES. Paresh J. Kothari and V. I. Stenberg. Dept. of Chemistry, Univ. of N. Dakota, Grand Forks, N. Dak. 58202.

The fluorescence and phosphorescence spectra of various substituted acetophenones were recorded in polar and nonpolar solvents at 77°K. The fluorescence spectra were also recorded at room temperature. In general, the m-isomers emit at longer wavelengths than the p-isomers. The aminoacetophenones were found to fluoresce and phosphoresce at longer wavelengths than the hydroxy- and methoxyacetophenones. When the aminoacetophenones were converted to the corresponding hydrochlorides, substantial blue shifts were observed whereas conversion of the hydroxyacetophenones to their sodium salts showed red shifts in the singlet-singlet transitions. The change in solvent polarity caused small red shifts in the fluorescence spectra of all at room temperature whereas no substantial shifts were observed at 77°K. In the phosphorescence spectra, the amino- and methoxyacetophenones showed red shifts on increasing the solvent polarity whereas the hydroxyacetophenones did not show any significant shift. When the temperature was changed from room temperature to 77°K the fluorescence spectra of the m-aminoacetophenones showed blue shift whereas m-hydroxy- and m-methoxy acetophenones showed red shifts. Supported in part by NIH grant GM21590.

37. STUDIES ON THE ASSIGNMENTS OF C-13 NMR SPECTRA OF STRYCHNINE AND BRUCINE. S.P. Singh, V.I. Stenberg, S.S. Parmar and S.A. Farnum. Departments of Physiology and Chemistry, University of North Dakota, Grand Forks, North Dakota 58202.

The natural abundance carbon-13 NMR spectra of strychnos alkaloids, brucine and strychnine, were obtained in deuteriochloroform. The proton-noise decoupled spectrum of brucine gave fourteen separate signals for the aliphatic carbons in the upfield region (26-78 ppm) and nine separate signals for the aromatic, carbonyl and vinylic carbons in the downfield region (101-169 ppm). Eleven separate signals for aliphatic carbons in the upfield region (26-78 ppm) and nine separate signals for the aromatic, carbonyl and vinylic carbons in the downfield region (116-170 ppm) were obtained from the proton-noise decoupled spectrum of strychnine. The single-frequency off-resonance decoupled (SFORD) spectra of both compounds differentiated the methyl, methylene, methine and quaternary carbons. The quaternary carbons were also isolated from protonated carbons by recording the proton-noise decoupled spectra of various pulsing sequences. The chemical shifts of various carbon resonances have been assigned on the basis of chemical shift theory, signal intensity, multiplicity generated in SFORD spectra and carbon shift assignments of model compounds. (Supported in part by NSF Grant CHE 76-05678 and NIDA Grant 7-R01-DA01893)

38. CARBONMONOXIDE RADICAL FORMATION ON MgO SURFACE SITES. R. M. Morris, R. A. Kaba and K. J. Klabunde, Department of Chemistry, University of North Dakota, Grand Forks, North Dakota 58202

Electron spin resonance is being used to investigate CO radical systems adsorbed on MgO. CO adsorbed (ca. 150 torr) on MgO, heat treated in vacuo at temperatures 300 to 1000°C, produced a radical with an unsymmetrical g-tensor. The maximum limit of radical growth, at least in part, appears to be a function of heat treatment temperature. The pattern of radical growth as a function of the heat treatment temperature can not be explained by changes in the surface area. It appears that thermal activation of the MgO surface produces a specific active site. The following data has been observed: 1) CO radical growth occurs even if the CO gas is only allowed ca. 10 min. contact with the MgO; 2) if CO₂, a Lewis acid, is adsorbed prior to CO, no radical is observed; 3) if H₂, a non-polar molecule, is adsorbed prior to CO, radical growth will occur; 4) the number of reducing sites was determined with nitrobenzene anion radicals which correlates with the CO radical growth data. It appears both Lewis basic and reducing sites are important for CO radical formation. Other organic compounds are being adsorbed on MgO so as to learn more of the nature of the site. Supported by ERDA-FE(E(49-18)-2211) and NSF.

39. SOLVATED METAL ATOMS USED FOR THE LOW TEMPERATURE PREPARATION OF HIGHLY DISPERSED ZERO VALENT METAL CATALYSTS. Kenneth J. Klabunde*, Daniel Ralston, Robert Zoellner, Hideshi Hattori†, and Yashutaka Tanaka†, *Department of Chemistry, Univ. of N. D., Grand Forks, N.D., 58202 †Dept. of Chemistry, Hokkaido Univ., Sapporo, Japan.

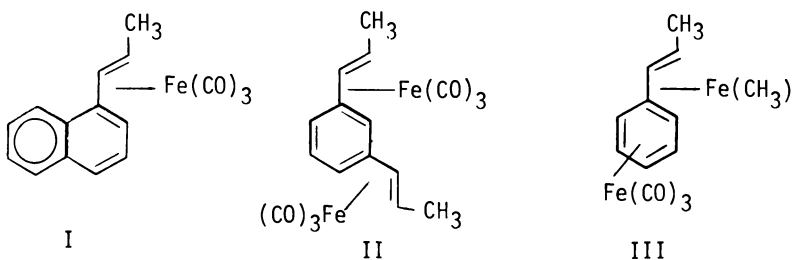
Metal atoms dispersed in weakly complexing solvents yield "solvated metal atoms" which can be used to permeate catalyst supports. This method serves as a new way of preparing zero-valent highly dispersed catalysts at low temperatures in the absence of H₂O or O₂ and eliminates the need for an H₂ reduction step. The catalyst properties are characterized by x-ray diffraction, scanning electron microscopy, vacuum pyrolysis, low pressure H₂ reduction, and unsaturated compound hydrogenation at both low and high pressures. The new technique has advantages over normal organometallic procedures in that a wide range of different dispersing solvents are available, catalysts may be rapidly prepared, preparation requires lower temperatures (as low as -90°C), and large scale production is feasible.

40. MECHANISTIC ASPECTS OF RHODIUM PROMOTED CYCLIZATION AND DECARBONYLATION OF UNSATURATED ALDEHYDES. R.E. Campbell, Jr., K.P. Vora and R.G. Miller. Department of Chemistry, University of North Dakota, Grand Forks, N. Dak. 58202

It has been reported that $\text{RhCl}(\text{PPh}_3)_3$ catalyzes the decarbonylation of saturated aldehydes. It can be now reported that $\text{RhCl}(\text{PPh}_3)_3$ also catalyzed the decarbonylation of unsaturated aldehydes, while at the same time catalyzes the intramolecular addition of the aldehyde functional group in cis & trans-4-Hexenal to C-C double bonds to generate cyclic ketones. On treatment with $\text{RhCl}(\text{PPh}_3)_3$ in C₆H₆ or CHCl₃, cis & trans-4-Hexenal are converted to 2-methylcyclopentanone as major product and to small amounts of unsaturated decarbonylation products. Addition of ethylene to the reaction mixture increases the yields of the 2-methylcyclopentanone product. Results from the conversion of deuterio-trans-4-Hexenal derivatives to deuterio-2-methylcyclopentanones have provided information regarding the mechanism of intramolecular isomerization and decarbonylation processes.

41. THE REACTIONS OF SOME ALLYLAROMATICS WITH IRON CARBONYLS.
Philip Boudjouk and See Lin. Dept. of Chemistry, North Dakota State University, Fargo, ND 58102.

Allylnaphthalene and m-diallylbenzene react with iron carbonyls to form two new vinyl-cyclohexatriene iron tricarbonyl complexes I and II respectively. The isomerization is stereospecific giving only the trans- β -methyl complex in each case. Allylbenzene and $\text{Fe}(\text{CO})_5$ react only under photochemical conditions to give the known bis-iron complex, trans- β -methylstyrene trans-bis(tricarbonyliron), III.



42. ELECTROCHEMICAL REDUCTION OF BENZYL HALIDES: RADICAL VS. CARBANION FORMATION. D. A. Koch and D. E. Bartak, Dept. of Chem., Univ. of N. Dak., Grand Forks, N.D. 58202

The electrochemical reductions of benzyl chloride, benzyl bromide, and benzyl iodide were studied on platinum in acetonitrile. These studies are of importance to establish an electron transfer mechanism on an inert platinum electrode, as contrasted to previously reported studies on mercury electrodes where organomercury intermediates were formed. The establishment of the intermediacy of the benzyl radical vs. the benzyl carbanion during the electron transfer process is particularly relevant. Cyclic voltammetric data for benzyl iodide showed two reduction waves, in contrast to the single reduction wave seen for benzyl chloride and benzyl bromide. In none of the three cases was a corresponding oxidation wave seen, indicating that the reduction products undergo rapid follow-up chemical reactions. The nature and yield of the products were studied using controlled-potential coulometry and gas chromatographic analysis. Chronoamperometric data indicated an overall one electron reduction process for benzyl chloride and benzyl bromide. However, an n-value somewhat greater than one was indicated for the reduction of benzyl iodide. In its entirety, the data can be interpreted as a one-electron reduction to an unstable anion radical ($k > 10^4 \text{ sec}^{-1}$) which decomposes to a benzyl radical and a halide ion.

43. THE CHEMISTRY OF TOLUENE-BIS(PENTAFLUOROPHENYL)NICKEL: A NOVEL ARENE Ni(II) COMPLEX. R. G. Gastinger, B. B. Anderson and K. J. Klabunde. Chem. Dept., Univ. of N. Dak., Grand Forks, N.D. 58202

The complex toluene-bis(pentafluorophenyl)nickel (1) has been synthesized by the metal-atom technique, i.e., the cocondensation of nickel atoms with a bromopentafluorobenzene/toluene mixture at -196°C followed by warmup to room temperature. This complex was found to react with a variety of substrates. Reactions with 1,5-cyclooctadiene and norbornadiene gave stable crystalline compounds via displacement of the toluene ligand by the diene. In the latter case a polymer, polynorbornadiene, was formed as well. Reaction of cyclopentadiene with the arene nickel complex gave a compound which could not be completely characterized. Spectroscopic and chemical evidence suggest the presence of a π -cyclopentadienyl(pentafluorophenyl)nickel group as well as a complexed cyclopentadiene. Reaction of (1) with carbon monoxide yielded decafluorobiphenyl and $\text{Ni}(\text{CO})_4$. Addition of TIF to (1) gave a compound which probably can be formulated $(\text{C}_6\text{F}_5)_2\text{Ni}(\text{THF})_n$. The role of (1) as a versatile source of Ni(II) has been demonstrated.

44. CARBON-13 NMR ANALYSIS OF SOME BENZODIAZEPINES. S.A. Farnum, S.P. Singh, S.S. Parmar and V.I. Stenberg. Departments of Chemistry and Physiology, University of North Dakota, Grand Forks, North Dakota 58202.

The present study is concerned with Carbon-13 NMR analysis of diazepam (Valium), chlonazepam (Clonopin), flurazepam (Dalmane) and chlorodiazepoxide (Librium). Both the proton-noise decoupled and single-frequency off-resonance decoupled (SFORD) spectra of these antianxiety drugs (minor tranquilizers) were recorded in suitable solvents using Fourier transform technique. The quaternary carbon resonances were isolated from the protonated carbon resonances with the help of SFORD spectra and the measurement of relaxation times (T_1). The chemical shifts of the carbon resonances of diazepam (34-170 ppm), chlonazepam (57-170 ppm), flurazepam (11-169 ppm) and chlorodiazepoxide (27-153 ppm) were assigned on the basis of the chemical shift theory, measurement of the relaxation time, multiplicities observed in the SFORD spectra and comparison with the chemical shifts of the model compounds. These studies will aid in the characterization of benzodiazepine metabolite(s) obtained in biotransformation studies. (Supported in part by NSF Grant CHE 76-05678 and NIDA Grant 7-R01-DA01893)

45. CLIMATIC CHANGE: IMPLICATIONS FOR NORTH DAKOTA'S AGRICULTURE.
W. A. Dando. Dept. of Geog., Univ. of N. Dak., Grand Forks,
N. Dak. 58202

Weather and climate are not constant and evidence of climatic fluctuations in North Dakota over all scales of time is conclusive. Since settlement by north Europeans, the most significant factors influencing the state's weather and climate are variations in Pacific Ocean surface temperatures, geographic patterns of jet stream movements and associated storm tracts, and changes in land use. Temperatures increased from 1892 to 1973 approximately 1° C.; precipitation fluctuated erratically while trends remained relatively stable; and violent storm tracts shifted southward nearly 110 km. Long-term temperature and precipitation trends since 1974 have been disrupted, as have the spatial patterns of recorded weather elements. Agriculture in North Dakota would benefit from cooler temperatures and increased precipitation. Albeit, preliminary studies suggest a return to the many-year, slightly warming trend with little or no variation in average precipitation receipts. Reductions in moisture efficiency related to temperature increases could lower state average wheat yields nearly five per cent. Corn and soybean yields could vary annually three to four per cent, there would be a gradual northward shift in the planting area.

46. EQUATORIA PROVINCE SUDAN: LAND USE CHANGE IN THE AFTERMATH OF CRISES. Frederick L. Bein. Dept. of Geography,
Univ. N. Dak., Grand Forks, N. Dak. 58202

War has always had a spatial impact upon people and places; civil war in a developing African nation as a greater impact for ethnic animosities can lead to general and total destruction of culture. The civil war in southern Sudan (1955-1972) led to mass out-migration, total disruption of economic activities, and destruction of life styles. With peace restored in Equatoria Province, where the rebellion was most strong, people are returning with a new outlook toward national identity, economic growth, and land use practices. Still isolation, tribalism, tradition and lack of infrastructure: transportation, markets, and capital inhibit development. Personal interviews show that although the Addis Ababa peace agreement is generally accepted, the indigineous inhabitants are finding it difficult to break with spatially restricted subsistence agriculture and develop a more diversified land use.

47. PETROLOGY OF A METAMORPHIC AUREOLE, BOUNDARY WATERS AREA, MINNESOTA. Odin D. Christensen and Joyce M. Miley. Dept. of Geology, Univ. N. Dak., Grand Forks, North Dakota 58202

A sequence of amphibolite facies metamorphic rocks is exposed along the northern edge of the Vermilion granite-migmatite massif. Outcrops were examined in the field from Namakan Lake to Lac La Croix along the Minnesota-Ontario border. The Vermilion massif is a 2680 million year old granite-migmatite complex consisting predominantly of quartz, microcline, plagioclase, muscovite, and biotite in varying proportions. The contact is broadly gradational across marginal migmatite zones up to several miles wide. Critical metamorphic assemblages developed within the thermal aureole involving the phases quartz (Q), plagioclase (P), microcline (K), biotite (B), muscovite (M), garnet (G), staurolite (S), sillimanite (A), cordierite (C) and hornblende (H) include QPBGCA, QPBGSA, QPBMC, QPBMG, QPBKH, AND QPBGH. The metamorphism was of the high-temperature, low-pressure Abukuma type. Estimated conditions of metamorphism are temperatures of 630-675°C and pressures of 4-5.5 kilobars.

48. COMPUTER INTERPRETATION OF GEOPHYSICAL LOGS OF WILLISTON BASIN SHALLOW PALEOCENE SEDIMENTS. L. M. Winczewski, Univ. of N. Dak., Grand Forks, ND 58202

Computer-assisted interpretation of geophysical logs should promote effective use of subsurface data. Logic is presented for a program that uses the digitized traces of natural gamma, gamma density, self-potential, and resistivity logs, as well as a driller log.

After log trace deflections are normalized to the maximum deflection for each log, deflection values are interpolated for each user-specified depth interval. Lithologic unit boundaries are established at depths midway between value maxima and minima. Unit lithology assignment is based on relative deflection of the natural gamma trace, with consideration of discriminating evidence from the other logs. Lithologies of gradational units and other special cases are arbitrarily assigned. The program is initially calibrated by comparing all log displacements with manually interpreted lithologies for several holes.

Output consists of the original digitized data, the driller log, a printed reproduction of the log traces, and the interpreted lithologic column. Storage of results is optional. Supported in part by NDGS and USDA, USFS.

49. NEW RECORDS OF BIVALVIA FROM THE FOX HILLS FM. OF N. AND S. DAK. WITH SOME PALEOGEOGRAPHIC SPECULATIONS. J.M. Erickson. Geol. Dept., St. Lawrence Univ., Canton, N.Y. 13617

Refinement of Late Cretaceous molluscan distributions is continued by recording new geographic and stratigraphic ranges of Bivalvia in the Fox Hills Formation (Maestrichtian).

Clisocolus moreauensis, Cuspidaria ventricosa, and Periploma subgracilis are recorded from Emmons Co., N. Dak. for the first time. C. moreauensis was taken from a fossil-rich concretion zone also containing many Sourimis equilateralis and Hoploscaphtes nicolleti, in a silty shale very low in the section. The fauna is characteristic of the Lower nicolleti Assemblage Zone and constitutes the first biostratigraphic evidence supporting recognition of the lower Trail City Member in N. Dak.

Arctica cf. A. ovata, a Cannonball species, is first recorded in the Fox Hills by specimens from Emmons and Sioux Cos.

Two bivalves are northern faunal elements. Early Maestrichtian faunas of N. Dak. originated from "Atlantic," Pacific, and Gulf Coast lineages. Fox Hills-Hell Creek deposition split the withdrawing seaway into northern and southern basins at 45° latitude at which time the Pacific and Gulf connections ended. Paleocene faunal affinities with the Paris Basin document Atlantic opening and a circumpolar(?) "French connection" for the Cannonball Sea. Terrestrial climate was harshened.

50. Contrasting Styles of Late Cretaceous Sedimentation and Tectonics, Western Interior, U.S.A. T. A. Cross. Dept. of Geology, Univ. North Dakota, Grand Forks, N.D. 58202

A sea level rise of 310 m is required to explain the extent of N. America submergence during the Late Cretaceous. Loading by water and sediment results in ~750 m of crustal subsidence and, thus, limits the thickness of sediment which could accumulate under isostatic subsidence alone. N. America, maximum thickness of U. Cretaceous strata is of this magnitude except for a broad region centered in Colorado in which >5 km of sediment accumulated. This relation dictates that a tectonic process, other than gravitational loading, was responsible for anomalous subsidence in the Colorado locus. Analysis of thickness and distribution of U. Cretaceous strata shows two distinct basinal trends. The earliest (100-80 mybp) is an elongate trough co-linear with the Sevier Highlands; subsidence is attributed to isostatically compensated flexure in front of these highlands. From 80-70 mybp, a broader, sub-circular region subsided and >3 km of sediment accumulated. Subsidence is attributed to a shallowly subducted oceanic plate which displaced less dense asthenosphere and cooled the continental lithosphere. Following detachment of the subducted plate, this region rose isostatically. Preliminary studies indicate that positions of subsequent maximum uplift coincide with those of former maximum sediment accumulation.

51. NORTH DAKOTA COAL LANDS ARCHAEOLOGY. L.L. Loendorf. Anthro/Arch Univ. N. Dak., Grand Forks, N. Dak., 58201

During the summer of 1975 archaeological research was undertaken at the site of a proposed coal gasification plant in Dunn County, North Dakota. The work was accomplished by the Department of Anthropology and Archaeology, University of North Dakota and sponsored by Natural Gas Pipeline Company of America, Chicago, Illinois. The main thrust of the research was to search a 33,000 acre tract of land for evidence of archaeological sites.

A total of 144 archaeological sites were located and recorded during the work. Seventy-five percent of these sites were areas of scattered chipped stone debris while the remaining twenty-five percent were quarry sites, rock alignment sites and cache sites. The quarry sites are areas where Knife River Flint was removed from the ground to be used in the manufacture of chipped stone tools. They are very important sites; five quarry sites have been recommended for inclusion on the National Register of Historic Places.

One interesting discovery during the research was the absence of occupation sites in the area of the flint quarries. This lack of living sites is unique within the quarry area; archaeological surveys in adjacent areas have revealed numerous occupation sites. The absence of occupational debris in the quarry area may suggest a supernatural significance to the quarries.

52. THE ARIKARAS AS SLAVE TRADERS: A STUDY OF INTERTRIBAL ECONOMICS ON THE PROTOHISTORIC NORTHERN PLAINS. James J. Berry. Department of Anthropology and Archaeology, University of North Dakota, Grand Forks, ND 58202.

Ethnological studies of diffusion have tended to oversimplify the mechanisms by which traits are transmitted across cultural boundaries. The treatment of the diffusion of the horse on the Great Plains in the seventeenth and eighteenth centuries is typical of this approach. There has been insufficient appreciation for the role of intertribal trade in the dissemination of horses on the Plains. Arikara case study material demonstrates that horses could have been initially obtained only in exchange for human beings--slaves--for which there were markets in Spanish New Mexico and French Louisiana. Thus it is probable that warfare for the purpose of taking captives may have been widespread on the northern Plains and that the initial diffusion of the horse followed existing trade routes.

53. EVANS: A PREHISTORIC CAMPSITE IN NORTHWESTERN NORTH DAKOTA. F. Schneider. Dept. of Anthropology, Univ. N. Dak., Grand Forks, N. Dak. 58202.

Archaeological investigation of the Evans Site, 32MN301, located near the Little Knife River, Mountrail County, North Dakota, reveals the presence of two distinct prehistoric cultural components. An early unspecified Woodland component containing cord-roughened, grit-tempered ceramics, Avonlea projectile points, and evidence of bison hunting is radiocarbon dated as existing at sites reported elsewhere outside of North Dakota in the Northern Plains is identified as belonging to the Mortlach Aggregate. This component contains the ceramic Mortlach Check-Stamped, Plains Side-Notched and Triangular projectile points, and evidence of bison hunting. The component has a radiocarbon date of A.D. 1555.

The investigations provide further insight as to the temporal and spatial parameters as well as the subsistence and settlement patterns of these two prehistoric cultures.

54. THE EFFECT OF PROLONGED EXPOSURE TO HYPERBARIC He-O₂ UPON TESTICULAR DEVELOPMENT. Zogg, Carl A., S.J. Brumleve, B. DeBoer, T.K. Akers and M.R. Magnusson. Department of Physiology, University of North Dakota, Grand Forks, ND 58202.

A growth study was conducted of rats continuously exposed to ambient air, 1 ATA He-O₂, or 11 ATA He-O₂ environmental conditions. The exposure period was 4, 8, 12, 16, 20 and 24 weeks. The environmental temperature was appropriately adjusted to maintain a zone of thermal neutrality and the diet was also appropriately adjusted to compensate for increased nutrient requirements previously determined of rats exposed to similar environmental conditions. Testicular development was determined by several methods. Visual inspection of the testes, as removed from the rats at time of slaughter, showed no gross abnormalities nor differences in the size, vascularization, texture, and general appearance of the testes. The grams of dry matter content of these testes revealed an increase in the size of the testes up to 20 weeks of exposure (177 days of age) which corresponds to normal growth rate of rats. Histological examination of these testes revealed normal development and functional germinal epithelium in all the rats. In no case was the germinal epithelium lost due to some stress factor. Environmental conditions of hyperbaric He-O₂ exposure (11 ATA) for 4 to 24 weeks does not appear to produce permanent, if any, lesions to testicular tissues.

55. THERMOREGULATION IN THE DOG IN A HIGH TEMPERATURE HELIUM-OXYGEN ENVIRONMENT. Paul M. Stein* and H.E. Ederstrom. Dept. Physiol. School of Med., Univ. N. Dakota, Grand Forks, ND 58202.

Bodily heat transfer rarely has been studied at high ambient temperatures in a helium-oxygen milieu. The thermoregulatory abilities of small, clipped, unanesthetized, and unrestrained mongrel dogs were studied when they were exposed for one hour in a sealed chamber at temperatures of 23, 33, or 43° C in air, or in 80% helium-20% oxygen atmospheres. In air respiratory rates increased from 15 to 133, to 322 breaths per minute. In helium-oxygen atmospheres respiration increased from 13 to 48, to 335 breaths per minute. Heart rates in air increased from 68 to 82, to 102 beats per minute. In helium-oxygen heart rates were 78, 69 and 97 per minute in the three temperature zones studied. No significant changes in rectal temperature occurred in any of the environments studied. The results indicated that a helium-oxygen atmosphere was a more favorable environment for heat dissipation by panting in dogs exposed to 33° C, but not to 43° C, as indicated by respiratory and heart rate changes.

56. CAFFEINE AND ITS INFLUENCE ON REPRODUCTION IN THE EARLY POST-PUBERAL FEMALE RAT. R.D. Allrich, R.M. Weigl and J.E. Tilton. Ani. Sci. Dept., N. Dak. State Univ., Fargo, N. Dak. 58102

Ninety-eight early post-puberal female rats (NDSU breeding) were utilized in an experimental design consisting of 4 levels of dietary caffeine (DC) (0, 110, 220 or 330 mg/l H₂O). A 12-day treatment was imposed. After caffeine treatment, female rats were exposed to breeding males for 10 days. Sacrifice occurred 18 days after initial male exposure with the following measurements being noted: packed cell volume, number of fetuses in utero, fetal bulge length and number of resorptions. This experiment was divided into 2 trials. In trials 1 and 2, conception rate(%) was not significantly affected by any level of DC (trial 1: 45, 88, 50 or 90% for 0, 110, 220 or 330 mg/l, respectively; trial 2: 93, 86, 93 or 93% for 0, 110, 220 or 330 mg/l, respectively). Number of fetuses were not significantly affected by any level of DC. Number of fetuses were 9.2, 10.0, 11.8 or 10.9 for 0, 110, 220 or 330 mg/l, respectively (trial 1) and 11.0, 12.9, 10.5 or 10.5 for 0, 110, 220 or 330 mg/l, respectively (trial 2). In trial 2, the number of resorptions decreased linearly with increasing levels of DC (0.54, 0.33, 0.15 or 0.08 resorptions for 0, 110, 220 or 330 mg/l, respectively). In conclusion, DC as administered in this experiment did not affect conception rate or number of fetuses.

57. SYNTHESIS, CHARACTERIZATION AND ANTIINFLAMMATORY ACTIVITY OF SUBSTITUTED TETRAZOLES. V. Kishore, S.S. Parmar and S.J. Brumleve. Department of Physiology, University of North Dakota School of Medicine, Grand Forks, North Dakota 58202.

Ten 2-(2-acetoxy-3-substituted carbamido)-5-phenyl tetrazoles were synthesized and characterized by IR and NMR spectra. NMR spectra revealed the formation of a small amount of 1-(2-acetoxy-3-substituted carbamido)-5-phenyl tetrazoles along with the formation of the corresponding 2-isomer. Antiinflammatory activity was determined in albino rats against carrageenin-induced edema. All tetrazoles (100 mg/kg, ip) provided protection 6-41% as compared to oxyphenbutazone which showed 48% antiinflammatory activity. Four of these tetrazoles were further evaluated for their effectiveness against cotton pellet-induced granuloma formation. These tetrazoles showed low activity of only 1-12%. Antiproteolytic activity of these tetrazoles was determined by their ability to inhibit trypsin-induced hydrolysis of bovine serum albumin. The degree of *in vitro* inhibition of trypsin activity by tetrazoles (1 mM) was 6-66% which, however, was not related with their antiinflammatory activity. These results have provided specificity in the antiinflammatory activity of substituted tetrazoles. (Supported in part by NIDA Grant 7-R01-DA01893 and NIH Grant 1-T01-HL-05939)

58. MEMBRANE STABILIZING PROPERTY OF NEWER ANTIINFLAMMATORY AGENTS. J.S. Davis, V. Kishore, G.J. Yutrzenka and S. S. Parmar. Department of Physiology, University of North Dakota School of Medicine, Grand Forks, North Dakota 58202.

Antiinflammatory agents stabilize and thus protect erythrocyte membrane. The present study is concerned with the evaluation of antiinflammatory activity of 2-methyl-3/6-substituted-4-quinazolones which was reflected by their ability to provide protection against carrageenin-induced edema in albino rats. All substituted quinazolones (100 mg/kg, ip) provided protection of 29-40%. The increase in the concentration increased the antiinflammatory activity. All substituted quinazolones (1 mM) possessed *in vitro* antihemolytic activity by providing protection against hypo-osmotic hemolysis in dog red blood cells. Reduction in antihemolytic activity observed in the presence of bovine serum albumin indicated preferential binding affinity of substituted quinazolones for albumin. Antihemolytic activity of these substituted quinazolones was concentration dependent and biphasic in nature. These studies have indicated some possible relationship between antiinflammatory and antihemolytic activity of these substituted quinazolones. (Supported in part by NIH Grant 5-T01-HL05939 and NIDA Grant 7-R01-DA01893)

59. STUDIES ON THE MECHANISM FOR THE ANTICONVULSANT ACTIVITY OF BENZODIAZEPINES. G.J. Yutrzenka, J.S. Davis, S.S. Parmar and S.J. Brumleve. Department of Physiology, School of Medicine, University of North Dakota, Grand Forks, North Dakota 58202.

The possible involvement of neurohumors (catecholamines, 5-hydroxytryptamine) in the mechanism of anticonvulsant activity of diazepam (7-chloro-1,3-dihydro-1-methyl-5-phenyl-2H-1,4-benzodiazepin-2-one) was investigated. Anticonvulsant activity was determined by the ability of diazepam to provide protection against pentylenetetrazol (80 mg/kg, s.c.)-induced convulsions in male, CFl mice (Sprague Dawley). The ED₅₀ value for diazepam ranged from 1.4-1.7 mg/kg (Mean = 1.54 mg/kg). Pretreatment with reserpine (2 mg/kg, ip, 24 hr) or disulfiram (200 mg/kg, ip, 1 hr) increased the anticonvulsant activity of diazepam as reflected by a decrease in ED₅₀ to 1.3 mg/kg and 1.4 mg/kg, respectively. Significant increase in the anticonvulsant activity of diazepam was observed by the administration of dibenzyline (20 mg/kg, ip, 1 hr) or p-chlorophenylalanine (100 mg/kg, ip, x 2 days) which decreased the ED₅₀ values of diazepam to 0.95 mg/kg and 0.80 mg/kg, respectively. These results have provided evidence for the involvement of neurohumors in the mediation of the anticonvulsant activity of diazepam. (Supported in part by NIH Grant T01-HL05939 and by NIDA Grant 7-R01-DA01893.)

60. ANTICONVULSANT PROPERTY OF SUBSTITUTED TRIAZOLES. H.A. Pakola, S.J. Brumleve, R.K. Jaiswal and S.S. Parmar. Department of Physiology, University of North Dakota School of Medicine, Grand Forks, North Dakota 58202.

Anticonvulsant activity of nine 5-(3,4,5-trimethoxyphenyl)-4-substituted phenyl-3-hydrazinoacarbonylmethylthio-1,2,4(H)-triazoles was determined in male albino mice. All triazoles (100 mg/kg, ip) provided 20-90% protection against pentylenetetrazol (90 mg/kg, sc)-induced convulsions. The degree of protection, a measure of anticonvulsant activity, increased with the introduction of a substituent in the phenyl moiety, attached at position 4 of the triazole nucleus. In these studies greater anticonvulsant activity of triazoles was associated with their ability to provide greater protection against pentylenetetrazol-induced 24-hr mortality in experimental mice. All triazoles (1 mM) inhibited monoamine oxidase activity of rat brain homogenates and the degree of inhibition ranged from 41-81% using kynuramine as the substrate. Such an inhibition of monoamine oxidase was unrelated with the anticonvulsant activity and hence cannot account for the biochemical mechanism of action of these triazoles. (Supported in part by NIH Grant 1-T01-HL05939 and NIDA Grant 7-R01-DA01893)

61. RAT TESTICULAR TISSUE METABOLISM IN THE PRESENCE OF DELTA-9-TETRAHYDROCANNABINOL. Michael Lame' and Syed Husain. Department of Pharmacology, University of North Dakota, Grand Forks, ND 58202.

In order to study the effects of delta-9-Tetrahydrocannabinol (THC) on glucose metabolism, rat testicular tissues were incubated at 37° for 100 min in Warburg Flasks containing 25 mM Tris buffered medium with NaCl (145 mM), KCl (4.83 mM), MgSO₄·7H₂O (1.33 mM), CaCl₂·2H₂O (1.22 mM), KH₂PO₄ (1.2 mM) and 5.5 mM glucose 6-C¹⁴. Immediately prior to incubation, delta-9-THC dissolved in ethanol, was introduced into the medium in the following concentrations, 0.2 mM (6 µl), 0.3 mM (9 µl) and 0.4 mM (12 µl). Controls for each dose received the equivalent amount of ethanol. To trap the ¹⁴CO₂ evolved from the testicular tissues, 3.5 N KOH was placed in the center well. The ¹⁴CO₂ was trapped for 60 min after perchloric acid was added to the medium to terminate the 100 min incubation period. Samples (0.1 ml) from the center well were then added to 10 ml of Permafluor II and counted in a Packard Scintillation Counter. Counts obtained were converted to µ moles of CO₂ produced/gram of dried tissue for 100 min incubation. Results obtained from this study indicate a significant inhibitory effect of delta-9-THC on rat testicular glucose metabolism. The percent inhibition from 0.2, 0.3 and 0.4 mM delta-9-THC was 18%, 20% and 30%, respectively. (Aided by Biomedical Research Support Grant RRO 5407 from USPHS)

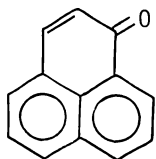
62. BREEDING, FEEDING AND OTHER UTILIZATION OF SEWAGE LAGOONS BY WATERFOWL. G.A.Maxson. Dept. of Biol., Univ. of N. Dak., Grand Forks, ND 58202.

The Grand Forks Sewage Lagoons were studied to ascertain their attractiveness to waterfowl and record species and numbers. Alternate day censusing from late March to late November 1976 and '77 yielded 33 species (loon, 5 grebes, pelican, cormorant, swan, 3 geese, 9 dabblers, 11 divers, coot). Mallards, Gadwalls, Pintails, Shovelers and Blue-winged Teal produced 480 ducklings or 1.8 ducklings/ha/year. Eleven other species were non-breeding summer residents. Abundant and constantly available food supplies were provided by cladocerans and chironomids. Aquatic flowering plants were virtually absent.

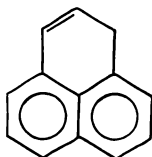
Maximum utilization occurred in spring and fall (average 1500 ducks/day, maximum 3500). Divers were most numerous early and late in the year. The resident summer population was 450 adults (50% Ruddy Ducks, 35% dabblers, 15% divers). Major lagoon attractions in this region are constant availability of areas of water and abundant food supply.

63. ALANE, BORANE AND SILANE REDUCTIONS OF PHENALENONE. Paul D. Johnson and Philip Boudjouk. Dept. of Chemistry, North Dakota State Univ., Fargo, ND 58102.

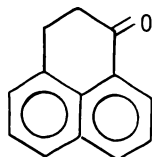
The reactions of borane, alane, and siloxane reducing agents with phenalenone(I) will be discussed. It was found that diisobutylaluminum hydride gives the 1,2-addition product, phenaleno!, which disproportionates to phenalene(II) and starting material. Attempts to intercept this disproportionation will be described. Tetramethyldisiloxane gives the 1,4-addition product which is hydrolyzed to phenalanone(III). The reduction of I with boranes gave II and/or III.



I



II



III

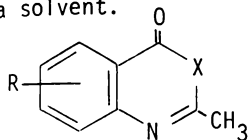
64. MOLD CONTROL IN INSECT REARING MEDIA. L. R. Ludemann and B. R. Funke. Dept. of Bacteriology, N. Dak. State Univ., Fargo, N. Dak. 58102

Eighteen humectant type food additives were screened for antifungal effects for possible use as mold control agents in insect rearing media. Aspergillus niger, the most common contaminant in insect rearing media, was the test mold and Heliothis virescens was the test insect. Propylene glycol, in three concentrations, was selected for testing in vivo. This approach, i.e., mold control by "water activity" was not successful due to toxicity to larvae.

Thirty-five agricultural type antifungal agents were screened for effectiveness against A. niger. Eight of these were selected for testing for effectiveness in the presence of larvae. Trichoplusia ni was the test insect used in this series of experiments.

65. SYNTHESIS OF SOME 3-BENZYL AND 3-TOLYL SUBSTITUTED 2-METHYL QUINAZOLONES. M. D. Green, S. S. Parmar, and V. I. Stenberg. Dept. of Chemistry and Dept. of Physiology, Univ. of N. D., Grand Forks, North Dakota 58202

Various 3-benzyl and 3-tolyl substituted 2-methyl quinazolones were synthesized as possible antiinflammatory and anticonvulsant agents by the method of Parmar (Can. J. Chem., 44: 2100, 1966 and J. Med. Chem. 7: 831, 1964). The quinazolones were synthesized from substituted anthranilic acids in two steps. The first step to produce the acetantranile (I, X = O) is accomplished by refluxing the appropriate anthranilic acid in acetic anhydride. The quinazolone (I, X = NR') is formed by reacting the acetantranil with the amine, R'NH₂, by warming in the absence of a solvent.



R = H, R' = benzyl, o,m,p-methoxybenzyl,
m-hydroxy

R = 7-NO₂, R' = o-tolyl, m-trifluoromethyl-
phenyl

R = 6:7 benzo, R' = o-tolyl, m-trifluoro-
methylphenyl

These compounds were analyzed by IR, mass spec., and proton NMR. Sponsored in part by the National Science Foundation Undergraduate Research Participation program. (Grant SMI-76-03971A02).

66. PHARMACOKINETICS OF GOLD IN RABBITS. D. Schoepp and S. Melethil. Dept. of Pharmaceut. Pharm. Prac., Coll. of Pharmacy, N. Dak. State Univ., Fargo, N. Dak., 58102.

The purpose of this study was to study the absorption and distribution characteristics of parenterally administered gold in rabbits. The blood concentration-time profiles of gold were determined following the i.v. and i.m. administration of 2 mg/kg doses of Myochrysine^R. Drug concentrations in whole blood were determined using graphite furnace atomic absorption spectrophotometry. In the i.v. study (n=2), gold concentrations declined in a biexponential manner with a short initial or distribution phase (t_{1/2}=0.35 and 1.2 hrs) and a long terminal or elimination phase (t_{1/2}=43.1 and 58.8 hrs). The calculated mean volume of the central compartment (0.35 liters) is a good approximation of the blood volume in the rabbit. Following i.m. administration, gold was rapidly absorbed (mean t_{1/2}=9.9 min, range 5.5-12 min, n=4). Peak blood concentrations were in the range 5-7.4 mcg/ml and occurred within 0.5-1.8 hrs. Total body clearances were calculated to be 8.3 and 6.0 ml/hr for the i.v. route and 6.9, 8.0, 9.4 and 10 ml/hr for the i.m. route. The mean fraction of the i.m. dose that was absorbed was 0.83 (range 0.67-1.02, n=4).

Thanks to Mr. R. N. Reopelle, Dept. of Pharmacol. for providing rabbits and Myochrysine^R.

67. CARBON MONOXIDE-HYDROGEN-WATER: REDUCTION OF ANTHRACENE, DIHYDRO-ANTHRACENE, AND QUINOLINE. V. I. Stenberg, J. Wang, R. J. Baltisberger, K. J. Klabunde, R. Van Buren, and N. F. Woolsey. Dept. of Chem., Univ. of N. Dak., Grand Forks, N.D. 58202. J. E. Schiller and D. J. Miller, Grand Forks Energy Research Center, Grand Forks, N.D. 58201

Anthracene is reduced by $\text{CO-H}_2\text{O}$, $\text{CO-H}_2\text{O-H}_2$ or H_2 at 425°C and an initial pressure of 1,500 psi to dihydroanthracene, 1,2,3,4-tetrahydroanthracene and methylbenzohydrindene. Dihydroanthracene converts back to anthracene under the reaction conditions. Hydrocracked products and dimers are formed to a minor extent. Hydrogen proved superior as a reducing gas. The presence of water and sodium carbonate reduces the conversions and yields of all products except dihydroanthracene.

The principal reduction product of quinoline under similar conditions is 1,2,3,4-tetrahydroquinoline. Fragmented aniline derivatives, dimeric quinoline species, and methylated compounds are also found in the reaction mixture. Hydrogen is most effective as a reducing gas, and carbon monoxide must have water present to accomplish the reduction. Iron sulfide and sodium carbonate promote the carbon monoxide reductions. The hydrogen donor solvent, tetralin, does not influence conversions.

68. HOUSE DUST MITE (DERMATOPHAGOIDES PTERONYSSINUS) IN NORTH DAKOTA Theresa A. Maertens. Dept. of Entomol., NDSU, Fargo, North Dakota

Dermatophagoides pteronyssinus was first discovered in N. Dak. on Aug. 28, 1977. The European house dust mite is believed to be cosmopolitan and a common inhabitant of the home; although, there are no records of these mites in neighboring states. These mites are of medical importance because they cause some house dust allergies.

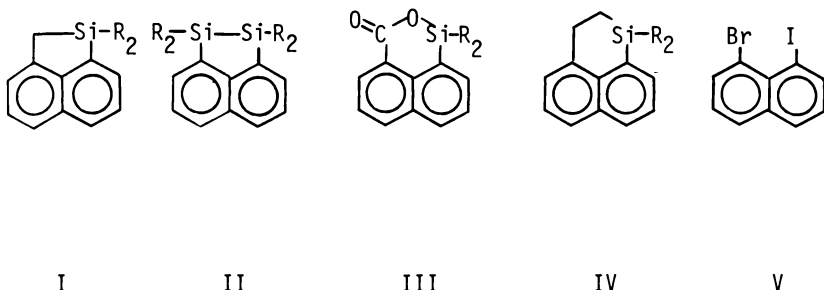
Mite samples were taken with a portable vacuum cleaner at several homes in Fargo, Strasberg, Williston, and Cooperstown, N. Dak. Cut up nylon stockings were used as collectors with one end tied and placed in the vacuum cleaner hose. Samples were then teased apart with forceps under a dissecting microscope. Consequently, they were only found in a trailer house couch on a farm near Cooperstown, N. Dak., the couch was the only piece of furniture infested with mites; however, later on mites were found elsewhere throughout the trailer house.

D. pteronyssinus feed mainly on sloughed human skin, but are also known to inhabit some bird and mammal nests. The most favorable niche in the home is the bed, but they also inhabit carpets, couches, stuffed pillows, bare floors, and curtains.

The mites found in these samples are now being cultured in a mixture of house dust and human skin flakes at 25°C and 70-80% relative humidity.

69. THE SYNTHESIS OF ORGANOMETALLIC PERI-BRIDGED NAPHTHALENE HETEROCYCLES. John S. Kiely and Philip Boudjouk, Dept. of Chemistry, North Dakota State Univ., Fargo, ND 58102

The synthesis of peri-bridged naphthalene heterocycles I, II, III, and IV, all of which are derived from the common starting material 1-bromo-8-iodonaphthalene, V, will be presented



70. CARDIAC ARRHYTHMIAS INDUCED BY COOLING AND CORONARY OCCLUSIONS IN DOGS. M.R. Towarnicky and H.E. Ederstrom. Dept. of Biol. and Physiol., U.N.D., Grand Forks, ND 58202.

Cold is known to protect tissue from ischemia. Experiments were done to find if hearts could tolerate coronary occlusion longer when cooling of the myocardium was done. Adult dogs were anesthetized with pentobarbital, the chest opened, and respiration maintained with a pump. The left anterior descending coronary artery and vein were ligated close to their origin. A cannula was inserted into the pericardial sac, and the heart lavaged with 1° C saline. Controls were similarly prepared, with coronary occlusion omitted. In controls, bradycardia, blood pressure fall, and ventricular fibrillation resulted from cooling. Prolongation of P-R, QRS, and Q-T intervals, T wave reversal, and S-T elevation or depression were typical. Coronary ligation resulted in ECG that resembled the cooled heart, but T wave and S-T deviations occurred before cooling. Ventricular fibrillation occurred when coronary occluded hearts had a temp. of 22.5° C. Cooling failed to protect myocardial tissue from ischemia. (Supported in part by American Heart Association, Dakota Affiliate.)

71. BIOAVAILABILITY OF ZINC - THE DETECTION OF ZINC(II) BINDING LIGANDS IN HUMAN AND RAW COW'S MILK, R. W. Ames and J. G. Brush-miller, Department of Chemistry, University of North Dakota, Grand Forks, North Dakota 58202 and G. W. Evans and P. E. Johnson, U.S.D.A. Human Nutrition Laboratory, Grand Forks, North Dakota 58201

A modified gel filtration technique was developed which detects the presence of labile Zn^{++} complexes in aqueous solution. The basic chemical theories on which the test rests will be explained. The technique was tested using ^{14}C tagged lysine, ^{14}C tagged cystie, and glutathione. The test cases showed that both the ligand and its zinc complex eluted simultaneously from the column as predicted by the theory. Samples of human breast milk and raw cow's milk were filtered to remove solute particles with molecular weights above 10,000 daltons. The low molecular weight fractions were examined for zinc binding ligands using the modified gel filtration technique. Zinc binding ligands were found in both samples but at different elution volumes. This is interpreted as meaning that the zinc binding ligand in human milk is different from the zinc binding ligand in raw cow's milk.

72. BENTHIC INVERTEBRATES OF FELTON CREEK, MINNESOTA. D. Feick and J. J. Peterka. Zoology Dept., N.D.S.Univ., Fargo, ND 58102.

The Red River of the North has many small tributaries, many of which are channelized, dammed, or altered by man. These streams are important sources of benthic invertebrates for food of resident fishes, and for the young of many fishes which spend most of their adult lives in larger streams but spawn in small tributaries. To assess possible effects of channelization upon benthic invertebrates in one small stream, we measured standing crops and kinds of benthic invertebrates found in the upstream (unchannelized) and in the downstream (channelized) area during the summer and fall, 1974, in Felton Creek, Clay County, Minn. Mean biomass, numbers and kinds of benthic invertebrates were greater in the upstream than in the downstream area of Felton Creek by nearly 7, 11 and 2 fold, respectively. The mean biomass and numbers of organisms in four samples collected at an unusual site in the downstream area where large rocks were found near a bridge were 10.6 g/m^2 (range $8.2-14.3 \text{ g/m}^2$) and $2237 \text{ organisms/m}^2$ (range $1143-3121 \text{ organisms/m}^2$), nearly the same as the mean standing crop in the upstream area. Apparently, the reduction in variability of stream substrate types by channelization is important in influencing crops and diversity of benthic invertebrates. Supported in part by undergraduate research grant, NSF.

73. BENTHIC MACROINVERTEBRATE FAUNA OF LAKE SAKAKAWEA. Phyllis A. Guthrie, Robert L. Newell, and E. A. Wells. Environmental Sciences Division, Stearns-Roger Inc., P.O. Box 5888, Denver, Colo. 80217.

The benthic fauna of Lake Sakakawea was studied for one year to determine its taxonomic composition, density and diversity and the effect of depth on these aspects of the benthic communities.

Samples were collected seasonally from Renner and Beaver Bay area of the reservoir using a Ponar grab.

Chironomidae and Oligochaeta were the most abundant groups, respectively. Benthic populations at greater depths were less diverse and dominated by Oligochaeta and *Procladius*, respectively. Many taxa were found at shallow depths where various Chironomidae composed the majority of the fauna. Slightly higher numbers and organisms less tolerant of organic pollution were also characteristic of the shallow water zone.

Characteristics of the benthic populations of Lake Sakakawea are indicative of a slightly eutrophic lake with generally good water quality conditions and typical of other impoundments in the area. Financial support was provided by Basin Electric Cooperative.

74. DISTRIBUTION AND ABUNDANCE OF ZOOPLANKTON IN LAKE SAKAKAWEA, NORTH DAKOTA. C.C. Garlasco, E.A. Wells, and R. L. Newell. Stearns-Roger Inc., Environmental Sciences Div., Denver, Colorado 80217

A year long study was undertaken to examine the abundance and distribution of the zooplankton of Renner Bay, Lake Sakakawea, N.D. Duplicate samples were collected with a 30 liter Schindler Patalas zooplankton trap (30 micron mesh net). Six depths were sampled at each of three deep bay stations, while at three shallow bay stations surface samples only were taken. Twenty eight species of zooplankters were identified in this study. The copepod group, especially the calanoid copepods was most abundant throughout. This study shows the dominance of *Mesocyclops edax* and *Diaptomus forbesi* that had not been reported previously. *Daphnia pulex* was the most abundant cladoceran and *Polyarthra* sp., was the most abundant rotifer. Depth density profiles showed an overall decline in zooplankton numbers in the fall and winter with relatively homogeneous distribution of zooplankton through the water column. Spring and summer depth density profiles showed an increase in numbers, with low surface densities, an increased density at 5 meters, then in most cases, a decline in zooplankton densities with increasing depth. Financial and field support was provided by Basin Electric Power Cooperative, Bismarck, N. D.

75. SEASONAL OCCURRENCE OF LAKE SAKAKAWEA PHYTOPLANKTON, 1976-1977. D. D. Hultgren, E. A. Wells and D. S. Dennis. Stearns-Roger Inc. Environmental Sciences Div., PO Box 5888, Denver, CO 80217

An environmental baseline study designed to assess the chemical, physical and biological characteristics of Renner and Beaver Bays of Lake Sakakawea was conducted from 1976 to 1977. Six sampling stations were sampled at various depths for phytoplankton on seven occasions. Duplicate, unconcentrated phytoplankton samples were preserved with a modified Lugol's solution. After settling, the phytoplankton were identified and enumerated.

Contrary to the results of other Missouri River main stem reservoir investigations, Bacillariophyta (diatoms) were not generally the dominant algal group found in this study. Cryptophyta or Cyanophyta had the highest densities during most sampling periods. Only May samples were dominated by diatoms. The greatest phytoplankton concentrations were found during May while the lowest densities occurred in January. Species composition and organism concentrations were not generally depth-dependent throughout the study. The financial and field support of Basin Electric Power Cooperative, Bismarck, ND, is acknowledged.

76. SEASONAL AND SPATIAL VARIATIONS OF ALGAL PRODUCTIVITY IN THE DEVILS LAKE ECOSYSTEM. C. M. Conway and L. E. Shubert. Dept. of Biology, Univ. N. Dak., Grand Forks, ND 58202.

Primary productivity determinations were made with the bioassay method under controlled environmental conditions. The green alga, Selenastrum capricornutum, a standard assay organism, was grown in sterile-filtered Devils Lake water for a period of 7 days with frequent transfer into fresh sterile medium. Growth was determined daily by in vivo chlorophyll a fluorescence measurements. Growth limitation was assessed by additions of phosphorus and nitrogen either alone or in combination. Spatial and temporal variations in both algal growth potential and nutrient limitation as well as relationships with other nutrients will be discussed.

Supported by Grant #A-053-NDAK, USDI, OWRR.

77. TEMPORAL CHANGES IN THE PHOSPHORUS CYCLE OF DEVILS LAKE. S.B. Mercil and L.E. Shubert. Dept. of Biology, Univ. N. Dak., Grand Forks, ND 58202

This study was conducted on Creel Bay, Devils's Lake, the most heavily used recreational area. Creel Bay receives periodic discharges from the sewage lagoon. The bay has dense algal blooms during the late summer. Intensive sampling was conducted during the 1977 growing season, and surface, bottom and column samples were taken.

Analysis of ambient levels of chlorophyll a, phosphorus (T-P, TDP, o-P, P-P, H-P) and nitrogen (NO_3 , NH_3) showed a seasonal trend. The concentrations of chlorophyll a, phosphorus and nitrogen were very high and were calculated at a mean of 100 on Carlson's Trophic State Index scale. Phosphorus cycling in Creel Bay will be discussed.

Supported in part by a Faculty Research grant.

78. CHANGING Mg/Ca RATIO AS A MEASURE OF LAKE PRODUCTIVITY. J. K. Neel. Dept. of Biology, Univ. N. Dak., Grand Forks, N. Dak. 58202

Increases in Mg/Ca ratios relative to water residence time demonstrated comparative productivity ranking in a sewage pond and associated lake chain in Minnesota, and in a more highly mineralized lake in North Dakota. All bodies were holomictic for all or nearly all of the open water seasons. Magnitude of photosynthate production depended upon nutrient loading and environmental conditions in individual water bodies, the latter at times suppressing the potential of the former, but a general positive association with nutrient loading was evident. Major photosynthate production in these waters was by aquatic flowering plants and associated filamentous algae. N and P seemed non-limiting in all lakes and ponds, and other elements in a wastewater effluent appeared responsible for the highest productivity noted. Nutrient loading represented productivity potential and the TSI introduced here showed accomplishment. The potential was not always realized.

79. BREWER LAKE PRIMARY PRODUCTIVITY MEASUREMENTS AND EFFECTS OF BOTTOM DISCHARGE DURING YEARS OF PRECIPITATION EXTREMES. G. W. Comita. Dept. Zool., N. D. St. Univ., Fargo, N. D. 58102

Four seasonal cycles of gross productivity (GP) and selected nutrients in Brewer Lake have been monitored (1974 - 1977 incl.) with bottom discharge being done during the last three. Precipitation extremes were: 8.84 inches in 1976 (record low) 32.28 inches in 1977 (second wettest on record). GP's were 1.68 (1974), 2.31 (1975), 1.24 (1976) and 1.83 kg C m⁻² period⁻¹ in 1977, a 48 % increase over 1976. GP occurred as five algal blooms at approximately monthly intervals. Amounts of water discharged (m³) were: 427,314 (1975), 275,810 (1976) and 89,496 (1977) resulting in an i-PO₄ decrease: 0.82 (1974), 0.31 (1975), 0.30 (1976) but an increase to 0.40 kg m⁻² period⁻¹ occurred in 1977 (+ 33 %), indicating that GP increases with increases in precipitation; GP vs precipitation: $r = 0.78$, $N = 4$. Amounts of ammonium (kg m⁻² period⁻¹) were: 0.50 (1974), 0.43 (1975), 1.11 (1976), which reduced to 0.58 in 1977, a 48 % decrease from 1976. For GP vs ammonium, $r = -0.92$ *, indicating that ammonium is preferentially utilized by the algal populations as a primary source of nitrogen. Fluctuations in solar and sky radiation on a period-1 basis were without effect but transparency closely followed GP: $r = -0.97$ **. Supported in part by N. D. State Game & Fish Dept

80. KARYOTYPIC EVOLUTION OF GROUND SQUIRREL (RODENTIA: SPERMOPHILUS) POPULATIONS OF THE U.S. NORTHERN PLAINS. P. J. Stupca, J. C. Pigage, and S. M. Jalal. Dept. of Biology, Univ. of N. Dak., Grand Forks, N. Dak. 58202

Four subspecies are recognized for Richardson's ground squirrels. Nadlar and others have described two karyotypic forms in these subspecies with $2n = 34$, and $2n = 36$. This investigation confirms earlier diploid chromosome counts for Spermophilus richardsonii richardsonii and S. r. elegans as 36 and 34, respectively. By G- and C-banding we have identified the telocentric pairs 1 and 2 from richardsonii in the formation of the metacentric pair 7 of elegans. We tend to favour Robertsonian fusion rather than centric fission for the divergence of the two karyotypes. In addition, morphological differences in the X and Y exist in the two forms. Based on the karyotypic divergence as well as the cranial, baculum and pelage characteristics we support the proposal that S. richardsonii be relegated to a new species and S. r. elegans be regarded as a separate species with three subspecies.

81. LIGHT-INDUCED CHANGES IN MOSQUITO RETINULA CELLS. J. D. Brammer.
Dept. of Zoology, North Dakota State University, Fargo, N. Dak.
58102.

In mosquito compound eyes rhabdom membrane is continuously being lost into the cytoplasm via coated vesicle (CV) and multi-vesicular body (MVB) formation. Rate of loss is dependent upon conditions of illumination. The number of CVs and MVBs formed increases with increasing intensity and/or duration of illumination, and total rhabdom volume simultaneously decreases. During periods of steady state illumination rhabdom volume remains constant.

Light adaptation also causes an increase in protein synthesis within photoreceptor cells. Much of this protein is opsin--the apoprotein of the visual pigment rhodopsin, and the major membrane protein of the eye. The kinetics of H^3 -leucine incorporation into the rhabdom has been observed autoradiographically, and correlated with its appearance in electrophoretically isolated rhodopsin.

Data support the hypothesis that opsin is first formed in the perinuclear rough ER and then processed through the Golgi. It (or rhodopsin) is then randomly inserted into the rhabdom. Rhodopsin is lost from the rhabdom via CV and MVB formation. Light increases rate of formation and rate of loss. (Supported by USPHS Grant R01 01150-03 from the National Eye Institute.)

82. EXOGENOUS HORMONE TREATMENTS TO INCREASE PRODUCTION IN SHEEP.
J.F. Zidon, J.E. Tilton and M.R. Light. Ani. Sci. Dept., N. Dak.
State Univ., Fargo, N. Dak. 58102

Out-of-season lamb production in sheep was attempted using progesterone pessaries and gonadotropins. A total of 60 ewes were treated with progesterone pessaries (PP) and gonadotropins (GTH) with 30 ewes serving as controls. The intravaginal devices were inserted into 4 ewes at 2-day intervals beginning April 1 until all 60 ewes had been treated. After 12 days the pessaries were removed and the ewes were injected intramuscularly with a gonadotropic hormone and exposed to rams fitted with marking crayons to detect estrual activity. Subsequent lambing dates were recorded. The results indicate that PP and GTH treatments stimulated 63% of the ewes to exhibit estrual activity compared to 18.7% of the control group. There was no significant difference in estrual activity between breeds. The overall conception rate was 40% in the treated animals vs. 6.25% in the control. Treated ewes that mated had a 68% conception rate with a 178% lambing rate, indicating the fecundity of the ewes was quite high. Of the 8 control ewes exhibiting mating activity 2 (25%) conceived with a subsequent lambing rate of 200%. These results would suggest that lamb production can be increased by exogenous hormones during the anestrus period of sheep.

83. FIELD OBSERVATIONS OF A NEW, ACTIVE MIMICRY IN LARVAL SPHINGIDAE (LEPIDOPTERA). *J.M. Erickson, R.J. Erickson and G.E. Erickson. *Geol. Dept., St. Lawrence Univ., Canton, N.Y. 13617.

Intricate, co-evolved, relationships between phytophagous insects and host plants result from strategies developed to relieve stresses between the insect and host populations. Superimposed on this struggle are predatory stresses focused on the insect. Added strategies must be employed to elude predators. Such conditions are pertinent for larval Lepidoptera.

Over the past 20 years we have made careful field observations of more than 30 spp. of N. Amer. larval Sphingidae. Most show a variety of color polymorphs which are genetically programmed by instar. We have observed that some possess the ability to actively adjust pigmentation to mimic subtle color changes reflecting foodplant condition as governed by local climate. Ceratonia undulosa, C. amyntor, Dolba hyloeus, and Hemaris thysbe each demonstrates this ability to alter normal coloration when host plants undergo chlorophyll breakdown to produce crypsis.

This process should be regarded as a new type of active, phytochromic, cryptic mimicry of which other distinct types are yet to be defined. In larval sphingids color change is triggered by ingesting leaves undergoing phytochemical changes, precisely matches foodplant hues, maintains crypsis, and is irreversible. We have tested this cause-effect relationship experimentally.

84. FISHES AND FISHERIES OF THE SHEYENNE RIVER, NORTH DAKOTA. John J. Peterka. Zool. Dept., N.D.S.Univ., Fargo, ND 58102.

The purpose of this paper is to describe the fishes and fisheries of the Sheyenne River, mostly from Lake Ashtabula to the mouth of the river. The Sheyenne River has a diverse fish fauna when compared to the Red River drainage; there are 53 species (51 species excluding the rainbow trout and muskellunge which do not reproduce in the Sheyenne) of fishes in the Sheyenne and 70 species in the entire Red River drainage. New records for the Sheyenne are Moxostoma anisurum, Moxostoma erythrurum, and Chrosomus (Phoxinus) eos. Notropis heterolepis was found in the Sheyenne Delta in two spring-fed streams and one site in the Sheyenne at the mouth of one of the spring-fed streams. This is the first record of this species in the Sheyenne drainage since 1929. The spring-fed streams in the Sheyenne Delta may provide refuges for species such as C. eos, N. heterolepis and Rhinichthys atratulus that require clean-water conditions. The most abundant fishes in seine collections in 1977 downstream from Lake Ashtabula were N. spilopterus, N. stramineus, and M. macrolepidotum. Fishes associated with gravel or rubble substrates such as darters and smallmouth bass were common in the Drift Prairie area and were rare in the Sheyenne Delta area where substrates were sand. Channel catfish were common in the Sheyenne Delta area. Funds from U.S. Corps of Engineers (CES, NDSU, Fargo).

85. TERRESTRIAL VERTEBRATES OF SOUTHWESTERN NORTH DAKOTA: STATUS OF SELECTED SPECIES. R. W. Seabloom, R. D. Crawford and M. G. McKenna. Institute for Ecological Studies, University of N. Dak., Grand Forks, N. Dak. 58202

A study of representative terrestrial vertebrates in the portion of the Missouri Slope south and west of the Missouri River, and McLean County in North Dakota was undertaken in the summers of 1976 and 1977. Of the 224 species of terrestrial vertebrates observed there were 8 amphibians, 12 reptiles, 156 birds and 48 mammals recorded by distribution, significant habitats, and abundance. Bird counts were compared for areas also censused in 1967. A few species (i.e. McCown's Longspur, several swallows) seemingly are reduced from surveys conducted 8-10 years ago, while counts of upland game birds, flycatchers, thrushes, warblers, blackbirds and sparrows were higher. There are 273 confirmed prairie dog towns in the project area, having a mean size of 38 acres. Prairie dog populations appear to be increasing, presumably due to cessation of control measures. The general habitats of Ponderosa/Limber Pine, Riparian Woodland, Hardwood Draw, Deciduous Forest and Wetlands contributed greatly to species diversity and total faunal components, considering their limited extent in total geographic area.

86. HOST AND DISTRIBUTION RECORDS FOR THE PULMONARY FUNGUS, EMMONSIA. Nile R. Fellows. Dept. of Biol., Univ. of N. Dakota, Grand Forks, ND 58202.
- Lungs from 249 deer mice (Peromyscus maniculatus) and 201 red-backed voles (Clethrionomys gapperi) collected from May 1976-April 1977 in Grand Forks County, North Dakota, were examined for parasites. Five deer mice (2%) and 4 red-backed voles (2%) possessed lungs which contained hard, white lesions. Tissue sections of such lesions revealed the presence of adiaspores of the fungus, Emmonsia sp. These spores varied from 0.23 to 0.29 mm in diameter, and possessed walls 0.025 mm in thickness. Emmonsia sp. is a world wide genus that has been found in the lungs of 5 orders of mammals. It is an unusual pathogen in that it does not seem to reproduce within the host, but rather does so in the soil. Infected animals were found only during March-May. This appears to be the first known record of Emmonsia sp. from Grand Forks County and it also seems to be the first report from deer mice and red-backed voles in the state of North Dakota.

87. MYOFIBROGRANULOMA IN NORTH DAKOTA WALLEYE, STIZOSTEDION VITREUM. M. D. Forstie and H. L. Holloway, Jr. Biol. Dept., U of North Dakota, Grand Forks, 58202, and C. E. Smith, Fish Cultural Development Center, Fish and Wildlife Service, Bozeman, MT. 59715.

One Stizostedion vitreum, obtained from Wood Lake, exhibited a generalized muscular anomaly. Gross examination of a fillet revealed myopathy typical of myofibrogranuloma, as described by Economon(1970). Myofibrogranuloma is characterized by extensive hypertrophy of trunk musculature with muscle fibers in various stages of dystrophy. Abnormal trunk tissue was histologically examined using representative sections stained with hematoxylin and eosin. North Dakota walleye myopathy is compared pathologically to the previously described walleye muscle disorder. The etiology of the dystrophy will be examined although the precise causative factors are unknown. This is the first report of myofibrogranuloma in North Dakota fishes. It was previously described in Minnesota and Nebraska. Walleye is the only piscine species known to exhibit this myopathy.

88. THE EFFECT OF SODIUM CHLORIDE AND SPERMIDINE ON THE IN VITRO METHYLATION OF HISTONES IN RAT BRAIN NUCLEI.

J.C. Wallwork and J.A. Duerre, Dept. of Microbiology, School of Medicine, UND Grand Forks, North Dakota, 58201.

When isolated nuclei from 10-day-old rat brain were incubated with S-adenosyl-L-[methyl-³H]-methionine in the presence of 1.0 mM MgCl₂ and 0.32 M sucrose at pH 7.0, significant amounts of ³H-methyl were incorporated into lysyl residues in histones H3 and H4. Sodium chloride (0.1 M) was found to stimulate methylation of histones whereas 1.5 mM spermidine inhibited methylation. The V_{max} in the control reaction and in the presence of 0.1 M NaCl or 1.5 mM spermidine were 5.7, 5.4 and 3.8 pmol of ³H-methyl incorporated/min/mg histone H3, respectively. The V_{max} in the control reaction and in the presence of 0.1 M NaCl or 1.5 mM spermidine were 1.3, 3.0, and 0.4 pmol of ³H-methyl incorporated/min/mg histone H4, respectively. When NaCl or spermidine was added to the reaction mixtures the K_m of the enzyme for S-adenosyl-L-methionine with histone H3 (7.7 μmol ± 2.0) or histone H4 (7.0 μmol ± 1.8) as methyl acceptor was not altered significantly. Since NaCl and spermidine are normal constituents of the cell, the results observed in vitro may also have some physiological significance.

Supported by Grant NS-09725-05 from National Institute of Neurological Diseases and Strokes.

89. THE INCIDENCE OF STAPHYLOCOCCUS AUREUS AMONG NURSING HOME EMPLOYEES. James R. Waller and David B. Almquist. Department of Microbiology, University of North Dakota, Grand Forks, North Dakota. 58202

Swab samples from the external nares of employees from 11 nursing homes were planted onto blood agar plates, grown for 48 hours at 35C and examined for the presence of Staphylococcus aureus. Typical colonies from each plate were identified as S. aureus if they were catalase +, coagulase +, Gram+ cocci. Nursing home carrier rates varied from 33% to 52% with an overall rate of 41%. The carrier rate in a control population was 19.3%. DNase production occurred in 83% of the control strains and in from 46-100% of the nursing home strains. Strains from CNC facilities (directly attached to a hospital) averaged 95% DNase positive. DNase activity of 251 S. aureus isolates determined with the methyl green technique resulted in 10.4% false negatives and 4.4% false positives when compared to the HCl precipitation technique. Additional studies performed on all strains included antibiograms by the K-B method, fermentation of lactose, maltose, mannitol and mannose, AMC production and a comparison of coagulase reactions by the slide reaction and coagulase-mannitol medium.

90. RESISTANCE IN BALB/C MICE TO HERPES SIMPLEX VIRUS CONFERRED BY CORYNEBACTERIUM GRANULOSUM. Gabrielson, D.A., J. Varani, J.J. Kelleher. Department of Microbiology, University of North Dakota, Grand Forks, ND 58202.

A heat-killed, formalin-treated preparation of Corynebacterium granulosum has been shown to inhibit tumor growth. We have found that this same Corynebacterium preparation prevented lethal encephalitic Herpes Simplex Virus (HSV) infections in mice. C. granulosum administered by tail vein injection one week prior to challenge with HSV reduced fatal encephalitic infections by 50%. Best protection was observed when C. granulosum was administered prior to HSV. Analysis of blood samples indicated that there was an increase in the total number of leukocytes as well as an increase in activated lymphocytes. Blast transformation assays of spleen cells indicated that C. granulosum-stimulated-animals had about a four-fold greater stimulation index. Treatment of mice with anti-lymphocyte or anti-thymocyte serum decreased but did not eliminate the protection conferred by C. granulosum. Transfer of peritoneal macrophages from C. granulosum treated adults to suckling mice failed to protect them from subsequent HSV infections. We presently believe that protection conferred by C. granulosum against HSV involves several components of the immune response rather than a preferential stimulation of an individual component in the immune system.

91. AN IMMUNODIFFUSION TEST FOR DIAGNOSIS OF BRUCELLOSIS. G. W. Allmaras, D. K. Anderson and K. J. McMahon. Dept. of Bacteriol., N. Dak. State Univ., Fargo, N. Dak. 58102

An immunodiffusion test for detection of Brucella antibodies was developed, and results were compared with those obtained with the standard tube-agglutination test. Brucella abortus strain 1119-3 plate antigen obtained from the USDA, National Animal Disease Laboratory, Ames, IA was sonicated, and 70 μ l were placed in a center well 7 mm in diameter made in Noble agar with borate buffer on a slide. Equal amounts of human sera obtained from the State Hygienic Laboratory, Iowa City, IA were placed in wells 3 mm from the antigen.

Of 305 sera tested, 92 had an agglutination titer of 1:20 or higher. Twenty-one of 24 sera with a titer of 1:160 or higher were positive by immunodiffusion in 8-24 h. Nine of 12 sera with a titer of 1:80 were positive by immunodiffusion in 24-72 h. All sera with titers of 1:20 and 1:40 were negative by immunodiffusion.

An agglutination titer of 1:160 or higher is considered indicative of Brucella infection, and results suggest that a high percentage of positive sera would be detected by the immunodiffusion technique.

92. ANTIBIOTIC RESISTANCE IN SALMONELLAE ISOLATED FROM WESTERN NORTH DAKOTA RIVER SEDIMENTS. T. L. Johnson and M. C. Bromel. Dept. of Bacteriology, N. Dak. State Univ., Fargo, N. Dak. 58102

River and lake sediments have been widely reported to act as "sinks" concentrating bacteria and viruses as well as organic and inorganic chemicals. The sediment "sinks" can then maintain large populations of microbial pathogens because of these high organic concentrations. If the sediment is disturbed, it may act as a source of contamination for drinking water.

Sediment from the Knife River and Spring Creek of Western North Dakota as well as overlying water was analyzed for Salmonellae and Shigellae. Pathogen occurrence was 3x higher from sediment than water. Antibiotic sensitivities to six antibiotics were performed by minimal inhibitory concentration (M.I.C.) on the obtained isolates. A high degree of multiple resistance was found in many of the isolates.

The waters of the Knife River and Spring Creek are impacted by grazing, cropland, and municipal usage. The study was part of a one-year baseline study to provide a comparison for future assessments of water quality under expanded coal development and subsequent population growth.

93. GROWTH PROMOTING CONCENTRATIONS OF FATTY ACIDS FOR LEPTOSPIRA SP. IN RIVER SEDIMENTS. R. C. Taylor and M. C. Bromel. Dept. of Bacteriology, N. Dak. State Univ., Fargo, N. Dak. 58102

River sediment fatty acid concentrations utilizable by pathogenic leptospirae were determined at five sites along the lower Sheyenne River. Fatty acid concentrations of from 70.8 $\mu\text{g/ml}$ to 394.5 $\mu\text{g/ml}$ were present at all sites. After extraction and methylation only the 14 to 22 carbon chain length fatty acids were analyzed by liquid-gas chromatography.

Correlation of concentrations and types of fatty acids with sediment soil types and sources of pollution was determined.

94. VARIATIONS IN THE GROWTH RESPONSE OF LACTOBACILLUS CASEI TO RIBOFLAVIN, FMN AND FAD INDUCED BY HEAT AND MEMBRANE FILTER STERILIZATION. James R. Waller and Richard A. Remark. Department of Microbiology, University of North Dakota, Grand Forks, ND.

Responses of Lactobacillus casei to Riboflavin, FMN and FAD can vary significantly depending on the method of sterilization. In addition, heat treatment of FAD has been shown to convert that flavin to 4.5 cyclic phosphate. Filter sterilized flavins produce widely variable growth responses in L. casei. Triplicate determinations of a single concentration often varied by 50 to 100%. Autoclaved sterilized flavins did not show significant variability. The maximum growth of flavins sterilized by autoclaving was significantly higher than the response to filter sterilized flavins. Heating FAD at 130 C for 60 min. converts this flavin to 4.5 cyclic phosphate. Separation of the two forms by thin layer chromatography followed by bioassay of the fractions obtained demonstrated that riboflavin 4.5 phosphate produced the same growth response in L. casei as did the parent FAD. Autoclaving FAD for 10 min. at 121 C resulted in about a 5% conversion to the cyclic form. Boiling FAD in water for 10 min. did not cause any conversion to the cyclic form.

95. EFFECT OF 1-AMINO-D-PROLINE ON PURIFIED ASPARTATE AMINOTRANSFERASE FROM ESCHERICHIA COLI B. D. D. Burkholder and B. P. Sleeper. Dept. of Bacteriology, N. Dak. State Univ., Fargo, N. Dak. 58102

Aspartate aminotransferase (AAT) from Escherichia coli B was purified by $(\text{NH}_4)_2\text{SO}_4$ precipitation, Biogel P-4, DEAE-Sephadex, and hydroxylapatite chromatography. Finally, iso-electric focusing (I.P. of 4.3) gave 56% recovery of crude extract activity with 238-fold purification. Gel electrophoresis showed one band of AAT activity corresponding to main protein band. AAT was multispecific, but there was 12x more activity with aspartate than with aromatic amino acids. There was no activity without the cofactor pyridoxal-5'-phosphate (PLP).

1-Amino-D-proline (DAP) completely inhibited the holoenzyme and gave a new absorption peak at 335 nm. Holoenzyme maxima at 320 and 385 nm remained as shoulders. The PLP-DAP complex added separately to apoenzyme gave the same spectrum and no activity. Once bound to the coenzyme, DAP did not dissociate from PLP, nor did the PLP-DAP complex readily dissociate from the enzyme. Kinetic studies showed the DAP inhibition of AAT was neither strictly competitive nor noncompetitive. The kinetics observed are compatible with the expected results for an irreversibly binding inhibitor.

96. INEFFECTIVE MUTANTS OF RHIZOBIUM PHASEOLI. Peter Feng and D. L. Berryhill. Dept. of Bacteriology, N. Dak. State Univ., Fargo, N. Dak. 58102

The bacterium Rhizobium phaseoli is capable of forming a dinitrogen-fixing symbiotic association with bean plants. Establishment of this association is dependent upon three bacterial properties: host specificity, infectiveness (ability to induce nodule formation), and effectiveness (ability to fix dinitrogen). Cells of R. phaseoli 14482 were exposed to acridine orange or ethidium bromide, and pure cultures of survivors were obtained. Each culture was used to inoculate a Pinto bean seedling grown aseptically in vermiculite. After 25 days, the plants were examined for nodule formation, and effectiveness was determined by the acetylene reduction technique. The treatment of cells with either acridine orange or ethidium bromide resulted in a complete loss of effectiveness in more than 20% of the survivors. All ineffective mutants retained infectiveness; however, nodules formed were small and white, whereas normal nodules are pink due to the presence of leghemoglobin. Because acridine orange and ethidium bromide are known to eliminate extrachromosomal genetic elements, it is possible that genes governing effectiveness in R. phaseoli are extrachromosomal.

97. TEACHING EXPERIMENTS APPLIED TO CARBOHYDRATE METABOLISM.
F.A. Jacobs, M.J. Boyer, and F.J. Sepe. Dept. of Biochem. and
Physiol., Sch. of Med., Univ. of N. Dak., Grand Forks, ND 58202.

The purpose of this paper is to report a series of experiments used to reinforce and emphasize certain biochemical events under the influence of the hormones epinephrine and insulin. The influence of these hormones upon the blood sugar as well as glycogen in a number of tissues has been shown. Adult rats were anesthetized with sodium pentobarbital; the tissues were analyzed by standard procedures. Students gained experience in a number of techniques related to biochemistry, physiology, and pharmacology, making this an interdisciplinary experience; namely, the handling of animals, collection of samples, performance of chemical measurements, and analysis of data. Results of such experiments support textbook descriptions of the metabolic reactions, i.e., effects of insulin and epinephrine on the blood sugar of the test animals, and changes related to these responses seen in the tissue. Thus, the concepts of carbohydrate metabolism are strengthened in the mind of the student, as an experience, rather than as a textbook remark in the didactic part of his training. These are but a few of a series of experiments which can be carried out by students in any one of the three disciplines mentioned. Specific data cited came from student experiments.

98. THE LONG-EVANS LABORATORY RAT - CHANGES IN SEXUAL MATURATION OVER 50 YEARS. K. C. Kraft and D. L. Matthies. Department of Anatomy, School of Medicine, University of North Dakota, Grand Forks, North Dakota 58201.

In studies in recent years involving reproductive endocrine functions of laboratory rodents, it has become apparent that there is an earlier appearance of external signs of sexual maturation in some of these animals. Notably with regard to the Long-Evans (L-E) strain of rat, which has been used to a great extent for this purpose, it was natural to consult the historical monograph written by Profs. Long and Evans in 1922. They reported that vaginal opening (vag. op.) occurred between days 45 and 145 with a mean of day 76.5. The first ovulation occurred in association with vag. op. In our study it has been observed that vag. op. can occur at earlier stages, which range from days 34 to 62 with a mean of day 44.1. The mean age shows an advance in sexual maturity of 32 days over the past 50 years since the original Long-Evans report. These observations are presented for information to investigators who might be relying upon a maturation schedule derived from the original Long-Evans Treatise "The Oestrous Cycle in the Rat and its Associated Phenomena." Memoirs of the Univ. of Calif., A.O. Leuschner, ed. Vol. 6, Univ. Calif. Press, Berkeley, 1922.

99. CHARACTERIZATION OF THE NUCLEOTIDASE ACTIVITY OF S_1 NUCLEASE. A. E. Oleson and M. Sasakuma. Dept. of Biochemistry, N. Dak. State Univ., Fargo, ND 58102.

S_1 nuclease, an enzyme previously reported to have no activity on mononucleotides (T. Ando, BBA 114, 158, 1966), was purified from Aspergillus oryzae by a procedure designed to eliminate traces of nonspecific phosphatase. The nearly homogeneous enzyme was found to be a glycoprotein with an IEP of ~ 3.5 and a MW of $\sim 40,000$. At pH 4.5 the enzyme hydrolyzed single-stranded DNA, 3'-AMP, and 2'-AMP at relative rates of 100, 13, and 0.03, respectively. No activity was detected with 5'-AMP or p-nitrophenyl phosphate. Several lines of evidence indicated that the same protein possesses both nucleotidase and nuclease activities. The enzyme acted on 3'-AMP, 3'-CMP, 3'-GMP, and 3'-UMP at similar rates, but was much less active on deoxyribo-3'-NMPs. The K_m of S_1 nuclease for 3'-AMP at pH 4.5 was $42 \mu M$, and the reaction was inhibited by ATP. This fungal nuclease has many properties similar to those of plant nuclease I, which has been characterized in this and other laboratories.

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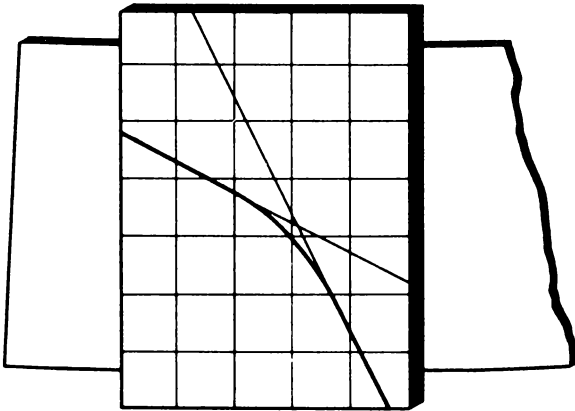
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PROCEEDINGS
of the
NORTH DAKOTA
ACADEMY OF SCIENCE
PAPERS



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NORTH DAKOTA ACADEMY OF SCIENCE

(Official State Academy; founded December, 1908)

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Editor's Notice

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

Volume XXXII will be the last to follow the practice of two-part publication. Rising costs, diminishing proportion of use by author's presenting papers, and increasing difficulty with the editorial process all led the Academy to reconsider its publication program.

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

Each presentation at the annual meeting will be represented by a full page "Communication" which will be more than an abstract, but less than a full paper. The communications will contain results and conclusions, and permit data presentation. The communication will convey much more to the reader than did an abstract, but still provide the advantage of timeliness and ease of production. The communications will be reviewed by the Editorial Board prior to acceptance and publication.

A. William Johnson
Editor

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. 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.
4. 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.*
5. 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.
6. Only essential references should be cited, and should be indicated in the text by numerals and quoted at the end of the communication. Up to three authors' names may be cited in full; with four or more authors only the first should be cited. The following form of citation should be used:

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

Books: Batstone, 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

7. 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.
8. Abbreviations: Only standard abbreviations should be used, and should be written out the first time used with the abbreviation following in parentheses.
9. 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.
10. Session Assignment: In order to assist the program committee in organizing the presentations, please indicate on the reverse of the blue-line form your 1st, 2nd, and 3rd preferences for the topical classification of your paper.
11. 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.

IN MEMORIAM

Ya Pin Lee

1924-1978

Dr. Ya Pin Lee, physician, educator and scientist

Dr. Lee was born October 23, 1924 at Taipei, Taiwan, the son of Mr. and Mrs. Kan Lee of Taiwan. Ya Pin entered science at an early age and obtained his M.D. degree from National Taiwan University in 1949. He married Lin Lin on December 7, 1950. He served as a Medical Officer in the Army of Taiwan for three years. Ya Pin immediately began medical research the year after graduation from Medical School and published his first research publication entitled "The influence of some catecholamine derivatives on blood sugar" that same year. This dedication and pursuit of knowledge continued throughout his life.

Dr. Lee was author of five research publications before he went to Ky-u-shu University (Japan) and obtained a Doctor of Medical Science degree in 1956.

Dr. Lee came to the United States in 1955 and spent two years as Research Assistant Professor, Department of Biological Chemistry, Washington University School of Medicine, St. Louis, working in the Department with the famous Nobel Prize winners Carl and Gerty Cori. While there he published three research papers on the enzyme "Adenylic Acid Deaminase" in the Journal of Biological Chemistry. He was the first to isolate and identify the properties of this enzyme in muscle.

His interest in enzymes, these biological catalysts which carry out reactions in the cell, led him to accept an appointment at the Institute for Enzyme Research at the University of Wisconsin in 1959 working with Dr. Henry Lardy, one of the world's most distinguished enzymologists. At the University of Wisconsin Dr. Lee isolated and purified another enzyme of the cell. While at the University of Wisconsin he began his research on the action of the thyroid hormone.

In 1963 the Hill Foundation awarded the second Hill Professorship in Biochemistry for "Cellular Research" to the University of North Dakota, Biochemistry Department. Dr. Lee was highly recommended by Dr. Henry Lardy, Professor of Biochemistry at Wisconsin, and Dr. Carl Cori, Professor of Biochemistry, Washington University, for this position. On June 1, 1963 Dr. Lee was appointed to the University of North Dakota Medical School faculty as a Hill Research Professor which he served for ten years. Dr. Lee transferred his research grants from the University of Wisconsin to the University of North Dakota. His research projects over the past 15 years at the University have brought in over \$258,000 in grant awards. Many of these awards were made by the National Institutes of Health and National Science Foundation, and the

funds provided scientific equipment, chemicals, supplies and funds for graduate and post-graduate students.

Dr. Lee's major contribution in Biochemistry since he has been at the University of North Dakota has been his research work investigating the action of the thyroid hormone. He was a national and international authority on the thyroid hormone and was the first scientist to determine the action of the hormone on an enzyme found in the mitochondria in the cell involved in the production of energy.

Dr. Lee was one of the most dedicated scientists that we have had at the University. He always expected this of his students. Ya Pin spent long hours at the laboratory bench, always seeking the unknown.

Dr. Lee has made a major contribution in graduate education at the University. He has supervised the research and training of 17 graduate students - 8 doctoral students and 9 master's students. He has also trained four post-doctoral students in Biochemistry since he joined the Department in 1963. Dr. Lee has published over 40 scientific articles and contributed a chapter to a book on enzymology.

Dr. Lee's major contribution in teaching was chiefly in graduate courses for the Department. His questions always required the students to think.

As national recognition for his research on enzymes he was elected a member of the American Society of Biological Chemists in 1963. As recognition for his research on the thyroid hormone he was awarded a Travel Award to attend the International Biochemistry Congress in Tokyo in 1965 to present a research paper. As further recognition for his research, in 1963 the University of North Dakota gave him the Sigma Xi award for excellence in research.

As a scientist and educator he set a good example with high standards, integrity, and dedication. He has made an imprint on our University and has helped to put our medical school on the map. He was a dedicated family man and was extremely proud of his three sons, Andrew, Nicolas and Benedict.

I am proud to have had a man of this caliber as a colleague and friend. His students are a living memorial to his dedication to science for the betterment of mankind.

W. E. Cornatzer

A SURVEY OF BENTHIC INVERTEBRATES OF FELTON CREEK, MINNESOTA

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Grand Forks, North Dakota 58201
and

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Fargo, North Dakota 58105

ABSTRACT

Standing crops and kinds of benthic invertebrates found upstream (unchannelized) and downstream (channelized) were measured during the summer and fall, 1974, in Felton Creek, Clay County, Minnesota. Mean biomass, numbers and kinds of benthic invertebrates were greater upstream than downstream in Felton creek by nearly 7, 11 and 2 fold, respectively. The mean biomass and numbers of organisms in four samples collected at an unusual site in the downstream area where large rocks were found near a bridge were 10.6 g/m² (range 8.2-14.3 g/m²) and 2237 organisms/m² (range 1143-3121 organisms/m²), nearly the same as the mean standing crop in the upstream area. We believe the channelized reach could be made much more productive for benthic invertebrates by construction of artificial riffles.

INTRODUCTION

The Red River of the North has many small tributaries, many of which are channelized, dammed, or otherwise altered by man. These streams are important sources of benthic invertebrates for food of resident fishes, and for the young of many fishes which spend most of their adult lives in larger streams but spawn in small tributaries. In this survey, we measured standing crops and kinds of benthic invertebrates found in the upstream (unchannelized) and in the downstream (channelized) reaches of one such tributary, Felton Creek, Clay County, Minnesota, during the summer and fall, 1974.

DESCRIPTION OF THE STUDY SITE

Felton creek is 32-37 km long flowing through portions of Keen, Flowing, and Viding townships of Clay County, Minnesota. The creek is a tributary of the Wild Rice River, which is a major tributary of the Red River (Fig. 1).

In its unchannelized upstream 5 km, Felton Creek flows through a deep ravine formed as the stream passes through the beaches of glacial Lake Agassiz. Wooded vegetation lines the stream banks and the adjacent pasture was heavily grazed. The stream gradient in this reach was approximately 12 m/km. Maximum depths in riffle areas sampled ranged from 22-33 cm; the average wid-

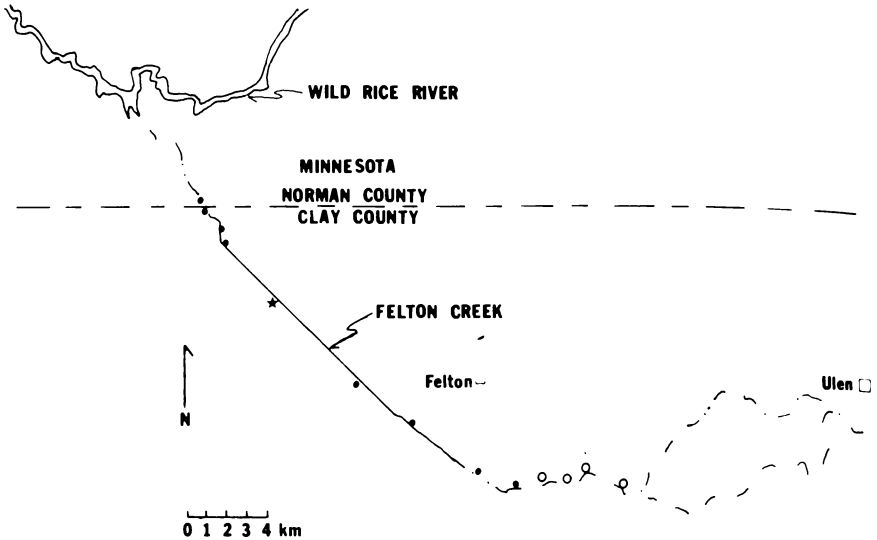


FIGURE 1. Sampling sites in Felton Creek. Open circles are upstream and closed circles are downstream sampling sites. The star is the location of a special site near a bridge.

th was 2 m. Pools and riffles were well defined, the latter containing gravel or rock substrates. This portion of the stream is spring-fed, and the cool water temperatures and sustained flows provide a brook-trout fishery managed by the Minnesota Department of Natural Resources.

The 32 km downstream reach of the stream is in the lake bed of glacial Lake Agassiz. Of this reach, the upper 23 km portion has been straightened and channelized. Stream gradient in the channelized area was approximately 0.8 m/km; pools and riffles were not well defined. In riffle areas, maximum depths were 16-17 cm and average stream width was 3 m. In the channelized reach, sand was the major substrate in the upper portion and clay-silt in the lower portion. Grasses were the dominant vegetation along the stream banks, with adjacent land flat and heavily cultivated. The lower 9 km section of the stream was not sampled.

The discharge of Felton Creek in the summer and fall was usually 3-5 m³/min. For the entire stream, pH ranged from 7.5-8.5, methyl orange alkalinity from 350-550 mg/l CaCO₃, conductivity (25°C) from 410-655 μmhos/cm, and turbidity (JTU) from 18-61. Water temperatures were about 10°-12°C in the upstream area and slightly warmer downstream.

METHODS

Benthic invertebrates were collected from 18 July to 8 November 1974, with a sampler described by Waters and Knapp (1961) that sampled an area of 0.1 m².

Four sites (riffles) were sampled in the upstream reach (Fig. 1). We collected invertebrates from two or three of these sites on each of three sampling dates (18 July, 13 August and 20 September). Two or three samples were taken from the center of the stream in each riffle sampled; the number of samples collected on each date was 4, 9 and 6, respectively.

In the downstream reach, of a total of eight sites sampled (Fig. 1), one to four sites were sampled on each of four sampling dates (18 July, 20 September, 10 October and 8 November). On each date, 2, 4, 13 and 8 samples, respectively, were collected. In addition, four samples (two on 18 July and two on 10 October) were collected from one unusual site in the downstream reach where rocks and rubble were found near a bridge (Fig. 1). Data from this site are treated separately.

Invertebrates from each sample were preserved in 10% formalin, counted, and identified. Weights were determined by centrifuging organisms to remove excess moisture and then determining their volume (no shells or cases were measured) by water displacement (Myers and Peterka, 1974).

Because of the rather large variation in numbers and biomass of organisms among samples collected at a site and because of the limited number of samples taken, data for all dates were combined for the upstream and for the downstream reaches of the stream. The coefficient of variation for the 19 samples collected from the upstream reach was 46% for numbers of organisms and 72% for biomass; for the 27 samples collected in the downstream reach, the coefficients of variation were 130% and 114%, respectively. The greater coefficient of variation among samples collected in the downstream reach was largely because 7 of the 27 samples contained no organisms; all samples from the upstream reach contained organisms.

To compute relative importance, we multiplied the per cent each taxon represented of the total weight of all organisms in a reach by its per cent of total numbers. For example, for *Tipula*, which comprised 32.9% of the average biomass in the upstream reach and only 0.7% of the numbers, the relative importance value is 23.0 (Table 1).

RESULTS

In the upstream 5 km of stream, biomass of 19 samples taken ranged from 1.3-35.6 g/m², with a mean of 11.5 g/m² (Table 1). Numbers of organisms ranged from 368-2926/m², with a mean of 1362/m². The number of taxa collected at any one station ranged from 9-16. Diptera comprised 44% (*Tipula* 33%) and Trichoptera 23% of the biomass of all samples. Elmidae comprised 32%, Diptera 21%, Ephemeroptera 19% and Trichoptera 18% of total organisms. The relative importance was 324 for Coleoptera (Elmidae), 234 for Trichoptera (largely *Hydropsyche* and *Cheumatopsyche*), 98 for Ephemeroptera (largely *Baetis* spp.), and 80 for Diptera (Fig. 2).

In the downstream 23 km of stream, the biomass of 27 samples taken ranged from 0-6.9 g/m², with a mean of 1.7 g/m². Numbers of organisms ranged from 0-732/m², with a mean of 128/m². Number of taxa collected at any one station

TABLE 1. Mean wet weight and numbers of organisms in upstream and downstream reaches of Felton Creek, Minnesota, 1974.

	UPSTREAM ^a				DOWNSTREAM ^b					
	Weight g/m ²	% of Total	Number no./m ²	% of Total	Relative Importance Value	Weight g/m ²	% of Total	Number no./m ²	% of Total	Relative Importance Value
Plecoptera	0.56	4.9	21	1.5	7.4					
<i>Acroneuria</i>	0.10	0.9	11	0.8	0.7	0.01	0.6	2	1.6	1.0
<i>Isoperla</i>										
Ephemeroptera	0.10	0.9	36	2.6	2.3					
<i>Ameletus</i>	0.70	6.1	213	15.6	95.2	0.01	0.6	10	7.8	4.7
<i>Baetis</i>	+		+		+					
<i>Caenis</i>	+		+		+					
<i>Heptagenia</i>	+		+		+					
<i>Hexagenia</i>	+		+		+					
<i>Stenonema</i>	0.03	0.3	5	0.4	0.1	0.05	3.0	4	3.1	9.3
Trichoptera										
<i>Brachycentrus</i>	0.29	2.5	19	1.4	3.5	0.23	13.7	26	20.3	278.1
<i>Glossosoma</i> sp	+		+		+					
<i>Helicopsyche</i>	+		+		+					
Hydropsychoidea	1.63	14.1	216	15.9	224.2	+		+		+
(<i>Hydropsyche</i> and <i>Cheumatopsyche</i>)										
<i>Oecetis</i>	+		+		+					
<i>Pycnopsyche</i>	0.70	6.1	15	1.1	6.7					

Diptera	0.27	2.3	180	13.2	30.4	0.03	1.8	28	21.9	39.4
Chironomidae										
Rhagionidae	0.57	4.9	45	3.3	16.2	0.06	3.6	6	4.7	17.0
<i>Atberix</i>										
Simuliidae	0.03	0.3	16	1.2	0.3	0.05	3.0	5	3.9	11.7
<i>Simulium</i>										
Tabanidae	0.44	3.8	38	2.8	10.6	0.02	1.2	6	4.7	5.6
Tipulidae										
<i>Hexatoma</i>	+				+					
<i>Tipula</i>	3.80	32.9	10	0.7	23.0	0.50	29.8	6	4.7	140.0
Coleoptera	1.16	10.0	441	32.4	324.0	0.05	3.0	20	15.6	47.0
Hemiptera	+				+					
Gerridae	0.02	0.2	22	1.6	0.3	0.12	7.1	2	1.6	11.4
Annelida										
Mollusca	0.14	1.2	5	0.4	0.5	0.54	32.1	12	9.4	301.7
Sphaeriidae	0.40	3.5	57	4.2	14.7	0.01	0.6	1	0.8	0.5
Amphipoda	0.30	2.6	2	0.2	0.5					
Decapoda	0.30	2.6	10	0.7	1.8					
Miscellaneous	0.30	2.6	10	0.7	1.8					
Total	11.54	100.1	1362	100.1		1.68	100.1	128	100.1	

^a - Number of samples = 19, standard deviation = 623.8 for numbers of organisms and 8.3 for weight of organisms/m².

^b - Number of samples = 27, standard deviation = 169.0 for numbers of organisms and 2.0 for weight of organisms/m².

^c - Presence indicated by a +.

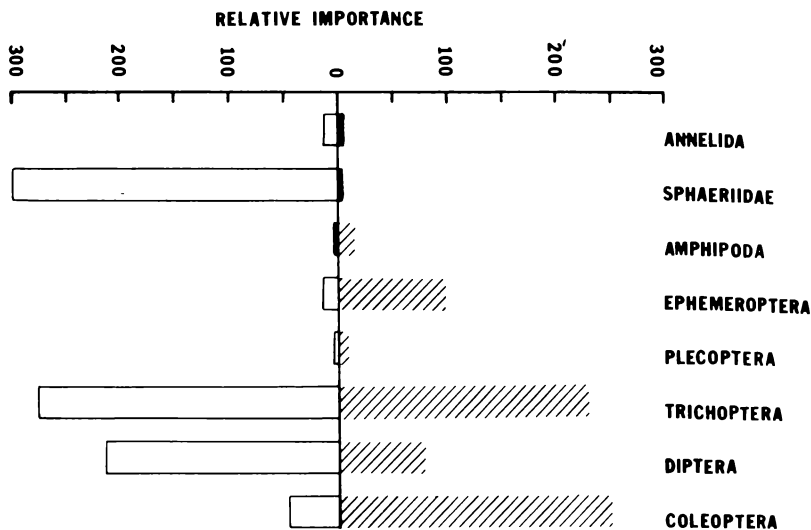


FIGURE 2. Relative importance of benthic invertebrates in upstream (hatched bars) and downstream (open bars) reaches of Felton Creek, Minnesota.

ranged from 0-10. Sphaeriidae comprised 32%, Diptera 39% (*Tipula* 30%) and Trichoptera (*Brachycentrus*) 14% of the biomass of all samples. Trichoptera (*Brachycentrus*) comprised 20%, Diptera 40% and Coleoptera (Elmidae) 16% of total organisms (Table 1). The relative importance was 302 for Sphaeriidae, 278 for Trichoptera (*Brachycentrus*) and 214 for Diptera (*Tipula* was 140).

Although the relative importance for trichopterans was similar both upstream and downstream, *Brachycentrus* was dominant downstream, and *Hydropsyche* and *Cheumatopsyche* were dominant upstream. Sphaeriidae and *Hexagenia*, important downstream (where silt substrates were common), were of little importance in the upstream reach. Upstream, 27 taxa were collected; only 14 taxa were collected from the downstream reach.

DISCUSSION

Mean, biomass, numbers and kinds of benthic invertebrates were greater upstream than downstream in Felton Creek by nearly 7, 11 and 2 fold respectively.

Because there were no data for the kinds and amounts of invertebrates present before channelization we could not establish whether the low standing crop and diversity of benthic invertebrates found in the downstream (channelized) reach of the stream resulted from the effects of channelization or from the natural low stream-gradient and the silt-sand substrate. However two factors support our belief that the channelized reach could be made more productive for benthic invertebrates by the construction of artificial riffles. First, in an unusual site in the

channelized section where there were large rocks there was a large standing crop of invertebrates, the mean biomass and numbers of organisms in four samples were 10.6 g/m^2 (range $8.2\text{-}14.3 \text{ g/m}^2$) and $2237 \text{ organisms/m}^2$ (range $1143\text{-}3121 \text{ organisms/m}^2$), nearly the same as the mean standing crop in the upstream (unchannelized) reach. Second, in a study of a small river in Ohio artificial riffles produced numbers and kinds of benthic invertebrates far superior to those produced in conventionally channelized areas (Woods, 1977).

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BENTHIC MACROINVERTEBRATES OF THE RENNER-BEAVER BAY AREA, LAKE SAKAKAWEA, NORTH DAKOTA

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ABSTRACT

The benthic fauna of Lake Sakakawea was studied for one year to determine its taxonomic composition, density, diversity and the effect of depth on these aspects of the benthic community. Samples were collected quarterly from the Renner and Beaver Bay area of the reservoir using a petite Ponar grab. Chironomidae and Oligochaeta were the most abundant groups. Many taxa were found at shallow depths where various Chironomidae composed the majority of the fauna. Slightly higher numbers and organisms less tolerant to organic pollution were also characteristic of the shallow water zone. Benthic populations at greater depths were less diverse and dominated by Oligochaeta and *Procladius*, respectively. Characteristics of the benthic populations of the Renner Beaver Bay area are indicative of a slightly eutrophic lake with generally good water quality conditions, typical of other impoundments in the area.

INTRODUCTION

Lake Sakakawea, one of six impoundments on the Missouri River, is in west-central North Dakota (Figure 1). This reservoir was completely filled in 1955, is 286 km long with a shoreline of 2,574 km, an area of 1,490 km² and an average capacity of 30 km³. The maximum depth is about 55 m (Benson and Cowell, 1961).

No investigations have been published on the benthic macroinvertebrates of Lake Sakakawea; however, benthic studies of other mainstem Missouri River reservoirs are available. Benthic macroinvertebrates were reported by Schmulbach and Sandholm (1962), Cowell and Hudson (1968) and Hudson (1971) for Lewis and Clark Reservoir, South Dakota; by Cowell and Hudson (1968), Hudson

(1971) and Benson and Hudson (1975) for Lake Francis Case, South Dakota; and by Jones and Selgeby (1974) for Lake Oahe, South Dakota. Peterka (1972) investigated the benthic macroinvertebrates in Lake Ashtabula, a North Dakota reservoir on the Sheyenne River.

MATERIALS AND METHODS

Benthic macroinvertebrate samples were collected from stations in Renner Bay and one station in Beaver Bay in July and October 1976, and January and May 1977 (Figure 1). Four replicate samples were taken per station using a petite Ponar grab, which samples an area of 0.023m^2 (0.25ft^2). Samples were cleaned in the field using a No. 30 mesh wash bucket (0.595 mm openings). The retained material was placed in prelabeled jars and preserved with 70% ethanol. In the laboratory, samples were washed of all silt in a No. 30 mesh sieve, diluted and the macroinvertebrates picked using a dissecting microscope. The organisms from each sample were stored in vials containing 70% ethanol until they were identified.

Organisms were identified to genus or species when possible. Chironomid larvae and oligochaetes were mounted on glass slides in CMC mountant and examined under a compound microscope. Because many of the oligochaetes were immature and could not be positively identified, they were placed in one of two categories: (1) immature tubificids without capilliform setae and (2) immature tubificids with capilliform setae.



FIGURE 1. The Renner and Beaver Bay area of Lake Sakakawea showing sampling stations.

The number of benthic organisms in each sample was converted to number per square meter using the conversion factor of 43.06. Mean number per square meter was then calculated by station.

Water depths at all sampling stations varied approximately 4 to 6 m due to water level fluctuations in the reservoir. Stations 1, 2 and 3 were designated shallow water stations since their depths ranged from 0.3 m to 5.5 m with a mean depth of 3 m. Stations 4 through 8 were deep water stations. Their depths ranged from 16 m to 40.5 m with depths becoming progressively greater proceeding toward the center of the bay. Depth at Station 4 fell within the shallow water zone in January and May 1977. Station 9 was of intermediate depth with a range of 7 to 12.5 m.

RESULTS AND DISCUSSION

Thirty-four taxa were collected from Renner and Beaver Bays. All taxa were common at depths of 5.5 m or above, but only 17 taxa were collected from each of the remaining depth zones (Table 1). Ten of the 17 taxa collected from the deep

TABLE 1. Benthic macroinvertebrates collected from Renner and Beaver Bays of Lake Sakakawea and their depth-zone of collection.

Taxa	Depth Zone*
Annelida	
Oligochaeta	
Plesiopora	
Naididae	
<i>Nais</i> sp.	SI
Tubificidae	
<i>Limnodrilus hoffmeisteri</i> Claparede	SDI
<i>Tubifex tubifex</i> (Muller)	SDI
Immature without capilliform setae	SDI
Immature with capilliform setae	SDI
Arthropoda	
Crustacea	
Amphipoda	
Talitridae	
<i>Hyaella azteca</i> (Saussure)	S
Insecta	
Ephemeroptera	
Caenidae	
<i>Caenis</i> sp.	SD
Ephemeridae	
<i>Hexagenia limbata</i> (Serville)	SI

Hemiptera	
Corixidae	
<i>Hesperocorixa</i> sp.	S
Coleoptera	
Elmidae	
<i>Dubiraphia</i> sp.	SI
Trichoptera	
Leptoceridae	
<i>Oecetis</i> sp.	S
Diptera	
Ceratopogonidae	
<i>Palpomyia</i> cf. <i>jonesi</i> Grogan and Wirth	SDI
Chironomidae	
Chironomini	
<i>Chironomus decorus</i> type	SD
<i>C. plumosus</i> (L.)	S
<i>Cryptochironomus blarina</i> (Town.)	SD
<i>C. fulvus</i> type	SDI
<i>Cryptocladopelma</i> sp.	S
<i>Cryptotendipes casuarius</i> (Town.)	SDI
<i>C. darbyi</i> (Subl.)	S
<i>C. pseudotener</i> (Goetgh.)	SD
<i>Dicrotendipes</i> sp.	SD
<i>Endochironomus</i> sp.	S
<i>Harnischia curtilamellata</i> (Mall.)	SI
<i>Paratendipes</i> sp.	SDI
<i>Polypedilum (Tripodura)</i> sp.	SI
<i>Pseudochironomus prasinatus</i> type	SI
Tanytarsini	
<i>Paratanytarsus</i> sp.	S
<i>Stempellina</i> sp.	S
<i>Tanytarsus</i> sp.	S
Tanypodinae	
<i>Procladius (Procladius)</i> sp.	SDI
<i>Procladius (Psilotanypus) bellus</i> (Loew.)	SDI
<i>Tanypus neopunctipennis</i> (Subl.)	S
Ephydriidae	SD
Arachnoidae	
Hydracarina	SDI

*S = Shallow water zone 0.3 to 5.5 m.

D = Deep water zone 16 to 40.5 m.

I = Intermediate water zone 7 to 12.5 m.

water zone were represented by only one or two specimens and, therefore, contributed very little to the deep water benthic community. This agrees with Jónasson's (1972) findings that shallow areas of lakes support a diverse fauna with high oxygen demands while fewer taxa are found at greater depths. Oxygen, food supply, and other factors limit the profundal macroinvertebrates to a few specialists that can tolerate the extremes of this environment.

Chironomidae were the most important benthic macroinvertebrates collected as they comprised 69% (971/m²) of the total numbers and were represented by 20 taxa (Figure 2) (Table 1). Greatest densities of the chironomids were found at shallow and intermediate depths where they made up 80% of the benthic fauna. Dominance by chironomids decreased with depth so that only 46% of the deep water fauna were of this family. Chironomids have been reported to dominate the benthic macroinvertebrates in other mainstem Missouri River reservoirs (Schmulbach and Sandholm, 1962; Cowell and Hudson, 1968; Benson and Hudson, 1975; Hudson, 1971). Jones and Selgeby (1974) found chironomids dominated to depths of 10 m in Lake Oahe, the reservoir immediately downstream from Lake Sakakawea. Peterka (1972) reported that chironomids were the most abundant benthic organism in Lake Ashtabula, a nearby North Dakota reservoir. The chironomids collected in this study were similar to those found in Lake Francis Case, Lewis and Clark Lake, and Lake Oahe (Hudson, 1971; Jones and Selgeby, 1974).

Procladius, the most abundant chironomid in the reservoir, preferred the deeper areas but was common at all depths (Figure 2). This Tanypodinae averaged 532/m² and comprised 38% of the total benthic fauna. Ninety percent of all chironomids collected below 5.5 were *Procladius* spp.; however, only 37% of the chironomids from the shallow water zone were of this genus. Tudorancea and Green (1975) also found *Procladius* evenly distributed throughout Lake Manitoba. High numbers of this profundal chironomid in deep areas of lakes have been reported by Saether (1970), Hilsenhoff and Narf (1968), Jónasson (1972) and Brinkhurst (1974). Hudson (1971) found *Procladius* (*Psilotanypus*) *bellus* to be the most numerous chironomid in Lewis and Clark Lake. *Procladius bellus* was also found in this study along with *Procladius* (*Procladius*).

Chironomid of the *Harnischia* complex, other Chironomini, and Tanytarsini had high densities at shallow depths but were rarely collected from deeper stations (Figure 2). The *Harnischia* complex was represented in the reservoir by seven taxa and had a mean density of 178/m² (356/m² at shallow and intermediate depths). *Cryptotendipes casuarius* was the most abundant member of this complex; *Cryptochironomus blarina* and *Cryptochironomus fulvus* type were common; *Cryptotendipes darbyi*, *Cryptotendipes pseudotener*, *Harnischia curtilamellata*, and *Cryptocladopelma* were also collected. These chironomids of the *Harnischia* complex are generally found in eutropic or mesotrophic lakes; however, they require a dissolved oxygen concentration greater than 5.0 mg/l (Beck, 1977; Weber, 1973; Jones and Selgeby, 1974; Mason, 1975).

Other Chironomini occurring in the shallow water zone were *Dicrotendipes*, *Endochironomus*, *Polypedilum* (*Tripodura*), *Paratendipes*, and

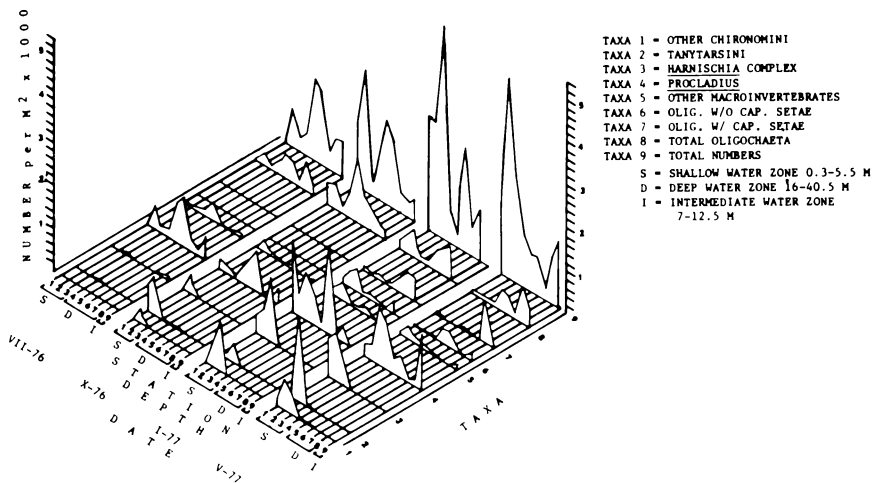


FIGURE 2. Standing crop (no./m²) of benthic macroinvertebrates from the Renner and Beaver Bay area of Lake Sakakawea, by sampling station and period.

Pseudochironomus prasinatus type. These midges are common inhabitants of reservoirs and can tolerate moderate organic enrichment if oxygen levels remain above 5.0 mg/l (Beck, 1977).

Chironomus decorus (= *attenuatus*) type were collected from all depths. This agreed with findings of Sublette (1957) who showed this species to have the least depth preference of any chironomid collected from Lake Texoma. Only one specimen of *Chironomus plumosus* was found, and from a depth of 1 m. These two species of *Chironomus* are often found in highly eutrophic waters with low dissolved oxygen (Saether, 1975; Beck, 1977; Mason, 1975). Hilsenhoff and Narf (1968) reported, however, that *C. attenuatus* cannot tolerate highly eutrophic conditions and occurred in the profundal zone of only the least eutrophic of the 14 Wisconsin lakes studied. Mean density of other Chironomini was 110/m² (216/m² at shallow and intermediate depths).

Tanytarsini were represented by three taxa and had a mean density of 143/m² (291/m² shallow and intermediate depths). *Paratanytarsus*, *Tanytarsus*, and *Stempellina* were collected. Certain species of *Tanytarsus* have been used to characterize profundal waters of ultra-oligotrophic lakes (Brundin, 1958; Saether, 1975); whereas, other species of *Tanytarsus* can tolerate low oxygen levels and mild organic pollution (Saether and McLean, 1972). Peterka (1972) found that *Tanytarsus* did not occur below 10 m in Lake Ashtabula and may be a good indicator of accumulating organics and oxygen depletion. Saether (1970) stated that Tanytarsini are generally found in oligotrophic to mesotrophic lakes; however, species identifications are necessary before *Tanytarsus* can be used as an indicator organism.

Oligochaetes were the second most abundant group collected; they numbered 365/m² and composed 26% of the total macroinvertebrate density. Oligochaete distribution was opposite to that of the chironomids since oligochaetes comprised only 16% (244/m²) of the fauna at depths of 12.5 m or above but 50% (512/m²) of the deep water benthos (Figure 2). This depth distribution with chironomids dominating shallow areas and oligochaetes dominating greater depths is typical of many lakes and reservoirs and was also reported in Lake Oahe by Jones and Selgeby (1974).

Most of the oligochaetes were Tubificidae; however, a few Naididae (*Nais*) were collected from shallow areas near macrophyton growths. Tubificids without capilliform setae were more abundant in shallow water areas; whereas, tubificids with the capilliforms dominated the deep water zone (Figure 2). Immature tubificids without capilliform setae were primarily *Limnodrilus hoffmeisteri* and immatures with capilliform setae were *Tubifex tubifex* since these two species were identified from mature specimens resembling the respective immatures.

Limnodrilus hoffmeisteri and *Tubifex tubifex* are a normal component of all freshwater biotopes and indicate low oxygen concentrations and organic pollution only when they occur in very large numbers with few other species present (Saether, 1970). In polluted stations of Skaha Lake and Osoyoos Lake, Saether (1970) found either densities of *L. hoffmeisteri* greater than 1,000/m² or less than three species of invertebrates. In the present study, the maximum density of oligochaetes was 1,399/m² at Station 5 in October from a depth of 25 m. This was an unusually high density however, and was not typical of the oligochaete fauna collected during most of the study.

Other macroinvertebrates comprised only 5% of the total numbers and were primarily collected from depths above 12.5 m (Figure 2). Hydracarina were the most numerous. Ephemeroptera (*Caenis* and *Hexagenia limbata*), other Diptera (*Palpomyia* cf. *jonesi* and Ephydriidae), Amphipoda (*Hyalella azteca*), Hemiptera (*Hesperocorixa*), Coleoptera (*Dubiraphia*), and Trichoptera (*Oecetis*) were also found in the samples. Many of these same organisms were reported from reservoirs in the area (Jones and Selgeby, 1974; Schmulbach and Sandholm, 1962; Peterka, 1972).

The total number of organisms averaged 1,409/m² for the entire study. Mean densities of 843/m², 1,164/m², 1,988/m² and 1,706/m² were collected in July, October, January, and May, respectively. Mean densities from Lake Sakakawea were less than those reported for Lake Francis Case (Benson and Hudson, 1975) where total numbers collected over an 8-year period averaged 3,009/m² for September collections and 2,922/m² for May collections. Higher numbers were also found in Lake Oahe (Jones and Selgeby, 1974) where mean densities were 4,235/m² in October and 3,198/m² in June. Fewer macroinvertebrates were found in Lewis and Clark Lake (Schmulbach and Sandholm, 1962) with a mean density of 431/m² for June, July and August collections.

The mean density in shallow water zones in Lake Sakakawea was higher than that from intermediate and deep water zones (1,982/m² versus 1,024/m² and 1,018/m²). In general, a peak in total numbers occurred at 5.5 m or above, a low

was encountered between 16 m and 22 m and a smaller peak was found between 24 m and 27 m (Figure 2). This trend was especially evident in January when the highest mean numbers for the study ($5,203/m^2$) were collected from Station 3 at a depth of 5.5 m, a low ($217/m^2$) was found at Station 5 from 22 m and a smaller peak ($2,562/m^2$) occurred at Station 6 from 24 m (Figure 2). Such depth distribution is apparently typical for lake benthos. Jónasson (1972) and Brinkhurst (1974) both stated that two peaks of benthic abundance occur in lakes with one in the littoral zone and another in the profundal zone. The peak in the profundal zone is lower, but its height depends upon the trophic condition of the lake (Brinkhurst, 1974). Eutrophic lakes have a higher density in the profundal zone than mesotrophic lakes. Mean density curves in Lake Sakakawea appeared to be intermediate between those of eutrophic and mesotrophic lakes (Figure 2).

The organisms collected during the study were those normally found in eutrophic or mesotrophic lakes and were common in other Missouri River reservoirs. Many macroinvertebrates found in the shallow water zone require dissolved oxygen concentrations greater than 5.0 mg/l; whereas, those abundant at great depths have often been reported to tolerate large amounts of organic pollution and low oxygen levels. Although the oligochaetes were second in abundance to chironomids, these worms were not as numerous as found in highly polluted waters. These aspects of the benthic communities in addition to the relative abundance of organisms in the shallow water zone to those at greater depths indicate that the Renner-Beaver Bay area of Lake Sakakawea is slightly eutrophic but with generally good water quality conditions, especially at depths of 5.5 m or greater.

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ABUNDANCE AND DEPTH DISTRIBUTION OF ZOOPLANKTON IN RENNER AND BEAVER BAYS, LAKE SAKAKAWEA, NORTH DAKOTA, 1976-1977

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ABSTRACT

A year long study was undertaken to examine the abundance and distribution of the zooplankton of Renner and Beaver Bays, Lake Sakakawea, North Dakota. Duplicate samples were collected with a 30 liter Schindler Patalas zooplankton trap (30 micron mesh net). Six depths were sampled at each of three deep bay stations, while at three shallow bay stations surface samples only were taken. Twenty-eight species of zooplankters were identified in this study. The copepod group, especially the calanoid copepods was most abundant throughout. This study shows the dominance of *Mesocyclops edax* and *Diatomus forbesi* that had not been reported previously. *Daphnia pulex* was the most abundant cladoceran and *Polyarthra* sp. was the most abundant rotifer. Depth density profiles showed an overall decline in zooplankton numbers in the fall and winter with relatively homogeneous distribution of zooplankton throughout the water column. Spring and summer depth density profiles showed an increase in numbers, with low surface densities, an increased density at 5 meters, and in most cases, a decline in zooplankton densities with increasing depth.

INTRODUCTION

Lake Sakakawea was formed in 1953 with the completion of the Garrison Dam, north of Bismarck, North Dakota, and is one of several Missouri River main stem reservoirs constructed for multiple use. Hydrographic features of the lake and water quality data have been published by Benson and Cowell (1961). Lake Sakakawea, along with the large deeper upstream reservoir, Fort Peck, have not been studied extensively. The zooplankton of Lake Sharpe and Lake Oahe were examined by Rada (1970), and Lake Oahe was studied by Selgeby (1974). The plankton of the lower two main stem reservoirs (Lewis and Clark Lake and Lake Francis Case) have been investigated several times (Siebrass, 1961; Tash, Swanson, and Seifert, 1966; Hudson and Cowell, 1966; Cowell, 1967; and Selgeby, 1968).

The purpose of the present study was to examine diversity, depth distribution, seasonal abundance, and percent composition of zooplankton in Renner and Beaver Bays along the south shore of Lake Sakakawea. Six sampling stations were established, three in the shallow bay areas and three deep lake stations (Figure 1). The study was conducted between July 1976 and June 1977.

Benson and Cowell (1961) described Lake Sakakawea as being deep (mean = 17 m; maximum = 57 m) and exhibiting slow pronounced summer stratification, with a water exchange rate greater than one year. Benson (1968) indicated that thermal stratification develops in many areas of Lake Sakakawea, but that strong

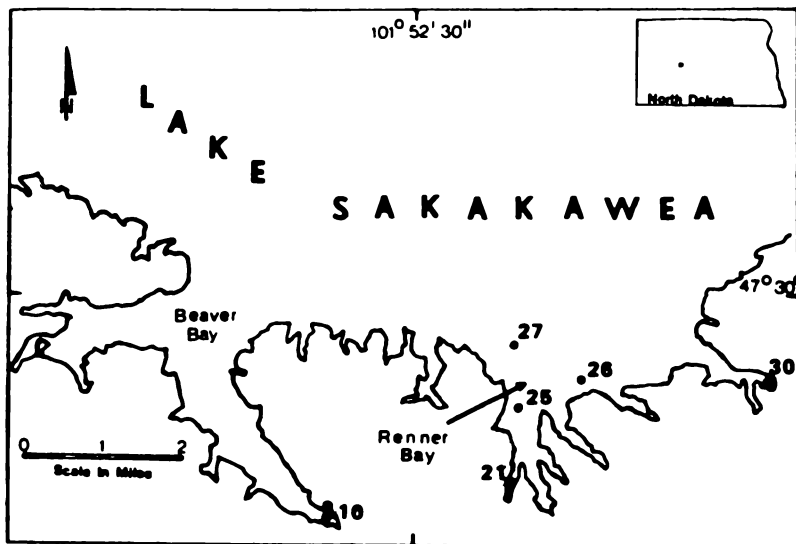


FIGURE 1. Study area, Renner Bay, Lake Sakakawea, North Dakota.

winds usually mix the water layers within a few weeks following stratification. He also reported that temperatures above 21°C were present only in late July and August, with temperatures within the 15.5°C to 21°C range mostly in the upper 15 meters of water. By October, water temperatures became homothermous, and decreased uniformly until ice formed in late November to December.

MATERIALS AND METHODS

Duplicate zooplankton samples were collected from one to six different depths (0, 2, 5, 10, 15 m, bottom) at each of six stations on July 24 and October 27, 1976, and on May 11, 1977; from four stations on August 29 and September 23, 1976, and on June 13, 1977; and from five stations on January 25, 1977 (see Figure 1). Samples were obtained with a 30-liter Schindler-Patalas zooplankton trap equipped with a 30-micron mesh net. Zooplankton samples were preserved with 4% formalin solution.

In the laboratory, each sample was examined with a stereo microscope and all organisms were identified and enumerated except in very dense samples. In the latter case, subsampling took place until at least 300 individuals were enumerated. All counts were converted to number per cubic meter. Zooplankton that could be identified positively using this method were dissected and mounted for detailed examination with a compound microscope.

Copepods were identified to species. Copepodid stages were grouped as either Diaptomidae or Cyclopidae copepodids, since the fifth leg necessary for identification was not fully developed. Organisms in the fifth copepodid stage were

identified to species if the caudal seta arrangement in the adults was distinguishable. Nauplii of calanoids and cyclopoids were grouped together. Cladocera were keyed to species except for some individuals of the family Chydoridae, which is presently undergoing taxonomic revision. The rotifers were keyed to the lowest possible taxon (usually genus).

RESULTS AND DISCUSSION

Twenty-eight taxa of zooplankters were identified during this study. Copepods representing eight species in the samples, comprised approximately 80% of the total number of organisms identified. There were eight species of Cladocerans and twelve taxa of rotifers, comprising 15% and 5%, respectively, of the total zooplankton examined. A list of taxa identified follows:

Rotifera

Brachionus quadridentatus Hermann

Brachionus urceolaris Muller

Kellicottia longispina (Kellicott)

Keratella cochlearis (Gosse)

Asplanchna sp.

Lecane sp.

Cephalodella sp.

Ascomorpha sp.

Gastropus sp.

Polyarthra sp.

Synchaeta sp.

Filinia sp.

Cladocera

Leptodora kindtii (Focke)

Diaphanosoma sp.

Daphnia galeata mendotae Birge

Daphnia pulex Leydig

Bosmina coregoni Baird

Bosmina longirostris (O. F. Muller)

Chydorus sphaericus (O. F. Muller)

Leydigia quadrangularis (Leydig)

Copepoda

Diaptomus ashlandi Marsh

Diaptomus forbesi Light

Diaptomus sicilis Forbes

Diaptomus siciloides Lilljeborg

Cyclops bicuspidatus thomasi Forbes

Eucyclops agilis (Koch)

Macrocyclops albidus (Jurine)

Mesocyclops edax (Forbes)

The copepod nauplii were the most abundant group found throughout the study. Overall, the nauplii accounted for 45% of the copepod group, and in some samples for more than 90% of the copepods.

Calanoid Copepods. — The calanoid copepods occurred in greater numbers than the cyclopoids at most stations. Immature diaptomids accounted for nearly 70% of the calanoid group.

Diaptomus ashlandi. — *D. ashlandi* was the second most abundant calanoid copepod, comprising 10.5% of the group. The concentration of this species peaked in August, declined rapidly through September and October, increased slightly in January and reached its lowest concentration in May. The population started increasing in June. Studies on Lake Oahe (Selgeby, 1974) showed *D. ashlandi* to be the dominant calanoid species where calanoid copepods comprised only 18% of the copepods, in contrast to the 22% attributed to cyclopoid copepods. Cowell (1967) reported that *D. ashlandi* was the most abundant calanoid copepod in Lewis and Clark Lake. However, in Cowell's study, calanoid species were most abundant at the upper end of the reservoir.

Diaptomus forbesi. — This species was the most abundant calanoid copepod comprising 12% of the group. The concentration of *D. forbesi* increased from July through August and reached an asymptote in September. Population numbers steadily decreased through the fall and winter sampling periods and achieved their lowest concentration in May. A slight increase in numbers occurred in June. Maximum abundance was reached only after *D. ashlandi* and *D. sicilis* began to decline. Selgeby (1974) noted a similar occurrence in Lake Oahe.

Diaptomus sicilis. — *D. sicilis* was the most abundant calanoid captured in the July samples, but its concentration rapidly declined to its lowest point in October.

Diaptomus siciloides. — This species was first identified in September but its population remained at a low concentration until June when its numbers more than doubled.

Cyclopoid copepods. — Highest concentrations of cyclopoid copepods appeared in May and June. Immatures made up 70% of all cyclopoids collected.

Mesocyclops edax. — *M. edax* was the dominant species collected comprising 15% of all cyclopoids. The highest concentration of this species occurred in August when numbers exceeded 2,000/m³. The concentration of *M. edax* decreased through September to October and it was not collected in the January and May samples.

Cyclops bicuspidatus thomasi. — This species was present at every collecting station throughout the study and was the second most abundant cyclopoid copepod, comprising 12.4% of the group. *Cyclops bicuspidatus thomasi* concentrations achieved a high of 200/m³ in August, declined throughout the fall and winter and increased to 100/m³ in June. This species and *Mesocyclops edax* commonly are found together in large deep lakes in North America (Rawson, 1956; Davis, 1966). While concentrations of *C. bicuspidatus thomasi* usually exceed those of *M. edax* (Selgeby, 1974; Cowell, 1967; Tash, 1966) this dominance was not pronounced in this study.

Eucyclops agilis. — *E. agilis* was first collected in January at Station 10, a shallow water station. In May this species was present in low concentrations at all collecting stations. In June *E. agilis* had increased in number and became the most abundant cyclopoid.

Cladocera. — Of the eight species of cladocerans identified, *Daphnia pulex* was more abundant at every station throughout the study in many samples it was the only cladoceran present. *D. galeata mendotae*, *Diaphanosoma* sp. and *Leptodora kindtii* were common, but were found in relatively low numbers. Other species were collected infrequently in relatively low numbers.

Daphnia pulex. — *D. pulex* reached a population peak in August (450 individuals/m³), doubling the levels found in July, and then the numbers declined through September to October. January samples showed a small increase in density of *D. pulex* numbers while May numbers were low. June concentrations were similar to those of July, with an average of 200 individuals/m³.

Previous studies also have found *D. pulex* to be abundant in Missouri River reservoirs (Benson and Cowell, 1966; Cowell, 1967; and Tash, 1966). However, species found in low numbers during this study previously have been reported as occurring in appreciable numbers. For example, *Bosmina longirostris* were relatively abundant throughout Tash's (1966) study, and was reported as common in Lewis and Clark Lake by Benson and Cowell (1961) and Cowell (1967); yet this species occurred infrequently during the present study.

Rotifera. — The Rotifera accounted for only 5% of all zooplankters, but this group exhibited the greatest number of taxa. *Polyarthra* sp. was the most abundant rotifer present, and during some months comprised 100% of the Rotifera. *Brachionus*, *Keratella* and *Asplanchna* occurred frequently, but generally were found in fewer numbers than *Polyarthra*. Hudson and Cowell (1966) found *Polyarthra* and *Asplanchna* to be most abundant in Lewis and Clark Lake, and *Keratella*, *Brachionus* and *Synchaeta* appeared frequently. During the present study, *Synchaeta* and *Kellicottia* occurred rarely.

The total number of zooplankton collected showed significant changes during the study year. In general, the zooplankton declined in abundance from July through October but an overall increase of zooplankton occurred in June. January and May showed low numbers for some species. A compilation of total numbers of zooplankton collected from the surface of each station over the study year is presented in Table 1. This table indicates a similarity in abundance of zooplankton for the three deep lake stations (25, 26 and 27). Stations 10, 30 and to some extent 21, showed greater concentrations, particularly from October through May. The higher January values could be attributed to the influence of ice cover on the bays. Since water levels were already low, ice formation could cause a denser population in the relatively small amount of water remaining. It also is possible that the higher densities at Stations 10, 21 and 30 reflect an ecological preference for a shallow water environment by the zooplankton.

While the total numbers of zooplankton generally were decreasing from August to October, the percent composition of the Copepoda reached a peak, comprising over 90% of the zooplankton. The Rotifera and Cladocera populations

TABLE 1. Mean number of zooplankters per duplicate samples, surface only ($10^3/m^3$)

Date	Station					
	10	21	25	26	27	30
July 1976	8,466	2,750	16,132	15,950	27,166	15,466
Aug. 1976	*—	37,099	16,832	8,883	14,932	—
Sept. 1976	—	16,300	8,950	9,950	7,866	—
Oct. 1976	10,466	4,150	2,083	2,250	2,417	7,100
Jan. 1977	32,987	25,015	13,849	2,966	4,516	—
May 1977	10,883	6,500	3,850	28,314	5,732	8,749
June 1977	—	10,466	46,759	60,593	30,751	—

* Indicates no samples were obtained for these stations.

TABLE 2. Percent composition of zooplankters per duplicate sample, surface only.

Date		Station					
		10	21	25	26	27	30
Jul 76	R	5.9%	17.6%	7.3%	4.6%	0.9%	*2.3%
	C	4.7	16.4	18.8	14.9	13.7	11.3
	Co	89.4	66.0	73.9	80.5	85.4	86.3
Aug 76	R	a—	5.0	17.1	9.4	7.5	—
	C	—	*29.3	*19.5	3.4	36.9	—
	Co	—	65.6	63.3	87.2	55.6	—
Sept 76	R	—	13.1	8.1	12.4	37.6	—
	C	—	9.6	16.0	9.5	5.7	—
	Co	—	77.3	75.9	78.1	56.7	—
Oct 76	R	2.6	0	1.6	0.7	2.8	3.8
	C	3.5	2.9	2.5	0.7	0	6.1
	Co	93.9	97.1	95.9	98.6	97.2	90.1
Jan 77	R	13.8	38.6	12.0	46.6	43.2	—
	C	45.1	9.1	4.5	5.6	2.2	—
	Co	41.1	52.3	83.5	47.8	54.6	—
May 77	R	14.4	0.8	13.9	1.6	1.4	1.7
	C	2.3	11.8	4.3	1.3	1.2	8.8
	Co	83.3	87.4	81.8	97.1	97.4	89.5
June 77	R	—	4.8	6.2	1.9	1.8	—
	C	—	15.3	10.6	4.8	1.2	—
	Co	—	79.9	83.2	93.3	97.0	—

R — Rotifera, C — Cladocera, Co — Copepoda

* 0.1% other than Rotifera, Cladocera or Copepoda.

a - indicates no sample collected.

declined, each comprising less than 3% of the zooplankton collected. Table 2 gives the percent composition for the Rotifera, Cladocera and Copepoda from the total numbers presented in Table 1. All three groups had declined in October (for example, rotifers had decreased to less than 10 organisms/m³). The Copepoda still were represented by species having densities of over 80 individuals/m³.

In January, the percent composition of the Rotifera and Cladocera increased. The copepods, in contrast, declined to less than 60% of the total zooplankton. Rotifera population levels increased to over 80 individuals/m³ and the Cladocera showed similar population increases. Individual copepod species remained at low levels of 85 to 170 individuals/m³. Copepod nauplii numbers declined sharply, inasmuch as the January low of 1,170 individuals/m³ was preceded by an August peak of 5,100 individuals/m³.

Copepods increased in May and June, while the Cladocera and Rotifera made up less than 10% of the zooplankton. The Rotifera and Cladocera showed a decline in numbers for May, and then doubled in June. In contrast, several copepod species exhibited a steady increase in numbers from January through June. The copepod nauplii increased from January to a high of over 10,300 individuals/m³ in May to 28,800 individuals/m³ in June. Thus, the Copepoda greatly exceeded the rate of increase for the Rotifera and Cladocera, and comprised a greater percentage of the zooplankton collected.

The large, rapid increase in copepod nauplii from May to June contributed to the high zooplankton numbers, as seen in Figures 2 through 4. The depth distributions for the three deep lake stations showed similar zooplankton distributions. Surface densities for the summer sampling periods were low at the surface, but increased at 5 meters. Generally, zooplankton numbers declined with depth. However, at Station 25 during June, July and May, and at Station 26 in June, an increase in numbers occurred at lower depths.

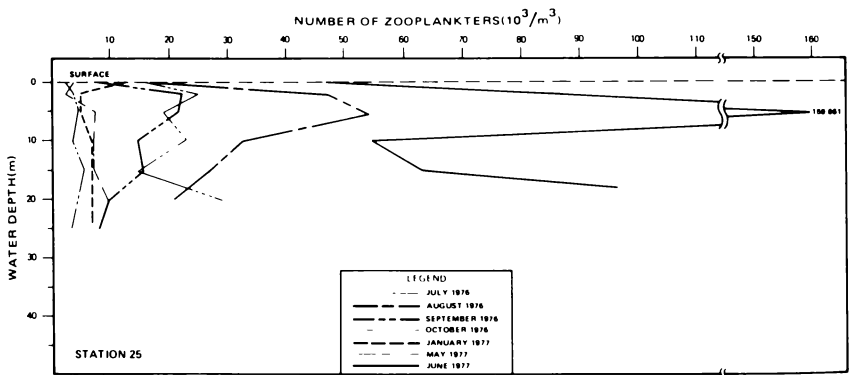


FIGURE 2. Depth distribution for Station 25.

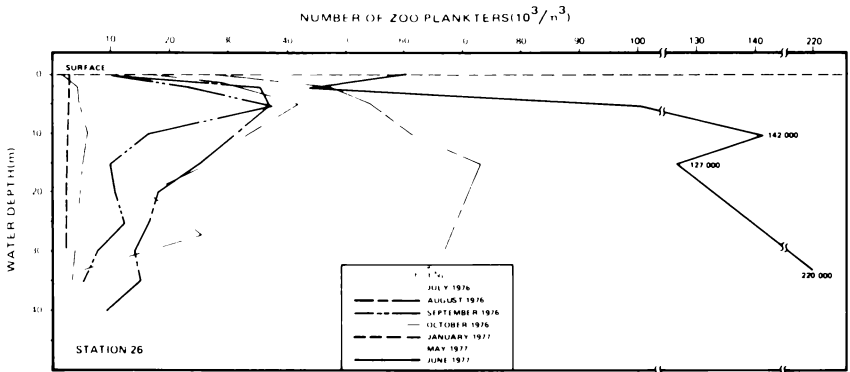


FIGURE 3. Depth distribution for station 26.

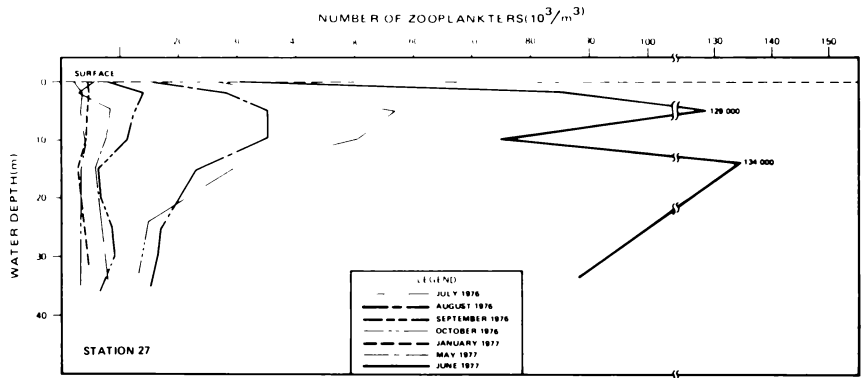


FIGURE 4. Depth distribution for Station 27.

The depth-density profiles shown in the figures also indicate an overall decline in zooplankton numbers through the fall, and lowest densities occurred in October and January. The autumn depth profiles show a relatively homogeneous distribution of zooplankton through the water column, which very likely is the result of lake mixing due to strong autumn winds. The three deep water stations showed essentially the same pattern.

The fauna identified during this study are common throughout the Missouri River main stem reservoir system and in most large, deep lakes in North America. However, the present study showed numerical dominance of two species, *Mesocyclops edax* and *Diaptomus forbesi*, that had not been reported previously. Zooplankton densities in the deep lake stations showed normal depth-distribution profiles with numbers greatly increased during the summer pulse and

greatest densities occurring at 5 meters. October and January samples indicated a decline in zooplankton and even depth distribution, with the latter attributed to lake mixing.

ACKNOWLEDGMENTS

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FISHES AND FISHERIES OF THE SHEYENNE RIVER, NORTH DAKOTA

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ABSTRACT

The purpose of this paper is to describe the fishes and fisheries of the Sheyenne River, mostly from Lake Ashtabula to the mouth of the river. The Sheyenne River has a diverse fish fauna when compared to the Red River drainage: there are 53 species (51 species excluding the rainbow trout and muskellunge which do not reproduce in the Sheyenne) of fishes in the Sheyenne and 70 species in the entire Red River drainage. New records for the Sheyenne are *Moxostoma anisurum*, *Moxostoma erythrurum*, and *Phoxinus eos*. We also recorded hybrids of *Notropis rubellus* x *Notropis cornutus* at one site. *Notropis heterolepis* was found in the Sheyenne Delta in two spring-fed streams and one site in the Sheyenne at the mouth of one of the spring-fed streams. This is the first record of this species in the Sheyenne drainage since 1929. The spring-fed streams in the Sheyenne Delta may provide refuges for species such as *P. eos*, *N. heterolepis* and *Rhinichthys atratulus* that require clean water conditions. The most abundant fishes in seine collections in 1977 downstream from Lake Ashtabula were *N. spilopterus*, *N. stramineus*, and *M. macrolepidotum*. Fishes associated with gravel or rubble substrate such as darters and smallmouth bass were common in the Drift Prairie area and were rare in the Sheyenne Delta area where substrates were sand. Channel catfish were common in the Sheyenne Delta area. In 1974 and 1975 about 15% of North Dakota anglers who fished rivers fished in the Sheyenne River, exclusive of Lake Ashtabula where the angling effort was 4.6 times that spent in fishing the river. Fishing success was about 10 fish per man-day in Lake Ashtabula and about 4 fish per man day in the Sheyenne River.

INTRODUCTION

The purpose of this paper is to describe the fishes and fisheries of the Sheyenne river, mostly from Lake Ashtabula to the mouth of the river.

The total length of the Sheyenne River is 914 km (568 miles). In the upper 36 km, flows are highly intermittent, and they are commonly intermittent as far downstream as Cooperstown where there was zero discharge for 5 of the 10 years from 1955 to 1965 (Cvancara, Norby and Van Alstine, 1976). Except in 1936, flow was always present from 1929 to 1974 at West Fargo, downstream from Lake Ashtabula (U.S. Bureau of Reclamation, 1976); a substantial increase in discharge occurs where the river crosses the Sheyenne Delta due primarily to groundwater inflow from the sandy delta deposits (Cvancara, et al. 1976). The average slope of the river is 0.28 m/km (1.5 ft/mi) (Cvancara, et al. 1976).

From the headwaters to near Anselm, the bottom sediments vary from bouldery sand to silt and clay, sand and gravel and marine shales as the river passes through glacier-related sediments and shales of late Cretaceous age (Cvancara, et al. 1976). Downstream from Anselm to Kindred the Sheyenne cuts into sand and silt associated with the Sheyenne Delta; bottom sediments are primarily well-sorted sand (Fig. 1). Downstream from Kindred to the mouth, the river cuts

into silt and clay of the plain of glacial Lake Agassiz; bottom sediments are muddy sand and mud. Turbidity generally increases downstream as the bottom sediments become finer (Cvancara, et al. 1976).

Fishes. — Early collections of fishes in the Sheyenne River were made by Woolman (1896); Hankinson (1929) made collections in a two-month period at

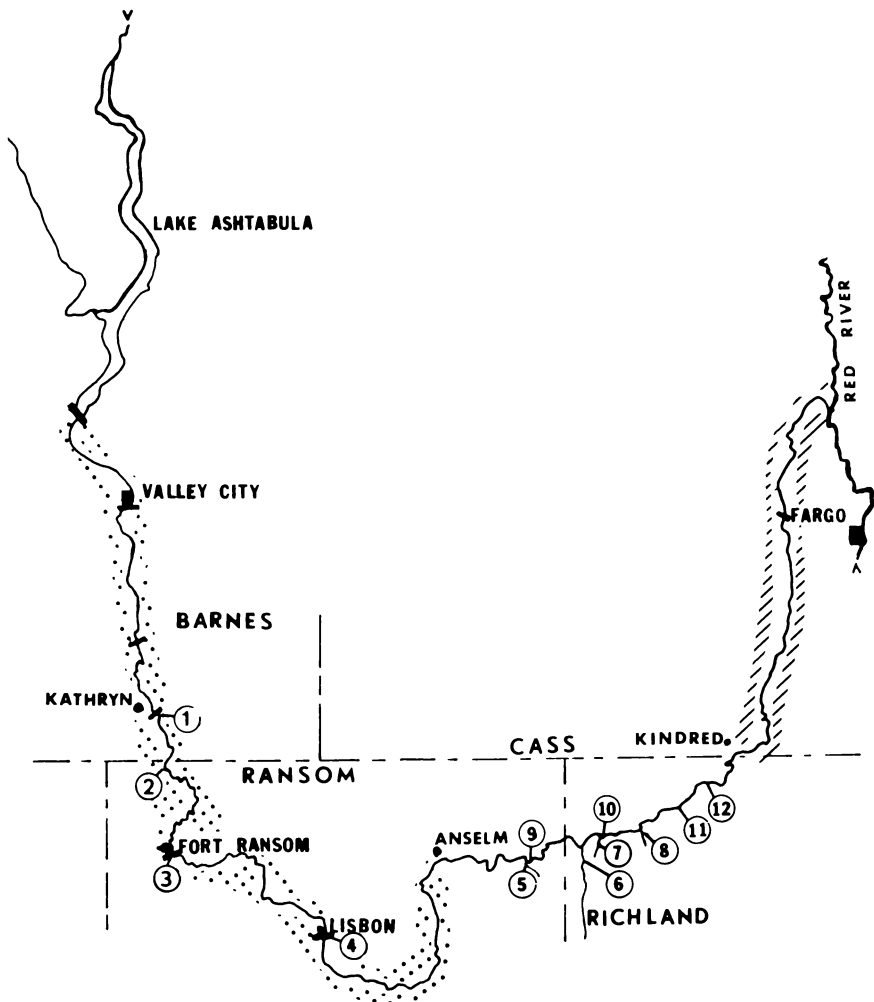


FIGURE 1. Sample sites, June-August 1977, Sheyenne River, N.D. Sites 1-4 are in the Drift Prairie area (stippled); sites 5-12 are in the Sheyenne Delta area; the lake Agassiz area is indicated by diagonal lines. Dams are indicated by heavy lines across the river. The broken lines indicate county boundaries.

Pekin, Valley City and Lisbon and summarized earlier studies. Fishes upstream from Baldhill Dam were collected in the summer of 1949 by Wilson (1950) just prior to the river's impoundment in July of that year. Tubb, Copes and Johnston (1965) collected fishes from 25 stations located from near the headwaters to near the mouth of the Sheyenne River (three of the stations were in Baldhill Creek, a tributary to the Sheyenne). Russell (1975) sampled 18 stations in a study to assess affects of the proposed Garrison Diversion project on fish distribution. The North Dakota Game and Fish Department (NDGFD) periodically samples the Sheyenne and Lake Ashtabula. The most recent NDGFD study was done by Van Eeckhout (1976) who collected fishes downstream from Baldhill Dam to near the mouth of the river. NDGFD test netting surveys of Lake Ashtabula were summarized by Owen and Russell (1975) in a study for the U.S. Bureau of Reclamation to assess effects of the Garrison Diversion Unit on fish distribution in North Dakota; Owen, et al. (1975) also prepared a report on environmental requirements, life histories and distribution of fishes in North Dakota.

A number of studies have been made in Lake Ashtabula for management purposes. Knutson and Peterka (1969) and Ragan (1970) described age and growth of yellow perch. Owen and Wahtola (1970) described effects of a commercial fishery on the black bullhead population. Farmer (1974) described age and growth and relative abundance of several fish species and Ober (1975) described food habits of the principal game fishes. Owen and Duerr (1972) reported on the feasibility of removing nutrient accumulations in Lake Ashtabula by harvesting yellow perch and bullheads. Ryckman (1977) continued studies of Owen and Duerr of the feasibility of a commercial fishery for nutrient removal.

Peterka and Reid (1968), Peterka and Knutson (1970) and Peterka (1972) related primary productivity, phytoplankton, zooplankton and benthic invertebrates to water quality in Lake Ashtabula.

Fisheries. — Fisheries of the Sheyenne River include sport fishing and a small commercial fishery, mostly for bullheads, in Lake Ashtabula. Information on angling in the Sheyenne River, which occurs mostly below Baldhill Dam, and in Lake Ashtabula was collected by mail surveys conducted by NDGFD in 1969, 1970, 1974 and 1975 (Duerre; 1972, 1977). A 1971 creel census at Lake Ashtabula was reported by Owen and Ruehle (1972). Ryckman (1977) provided harvest information of the commercial fishery in Lake Ashtabula from 1953 to 1976.

The U.S. Fish and Wildlife Service operates a fish hatchery at Valley City. The hatchery has produced smallmouth and largemouth bass, muskellunge, and bluegills from adult fish kept at the hatchery and usually collects eggs of northern pike and walleye from fish caught in Lake Ashtabula. Fish from the hatchery are distributed to waters under control of the federal government and to waters of the state open to public fishing. Lake Ashtabula and the Sheyenne River have received frequent stocks of northern pike and walleyes produced at the hatchery. Other species stocked from hatchery operations are smallmouth and largemouth bass, bluegills (Lake Ashtabula and Sheyenne River); channel catfish (Sheyenne River); and muskellunge (Lake Ashtabula).

The NDGFD at one time operated a state hatchery at Lisbon and they have attempted to develop fish rearing facilities in the Sheyenne Delta. The 205 ha (507.6 acre) Mirror Pool area was purchased by the department to ensure state ownership of two flowing springs which would supply cold water for a trout hatchery (Henegar, 1968).

METHODS

At North Dakota State University we have collected fishes in the Sheyenne River basin at varying intervals since 1966. Since 1974 we have also sampled fish from four (sites 5-8) of the many small spring-fed streams that enter the Sheyenne River in the Sheyenne Delta area (Fig. 1). No collections from these streams are reported in the literature, yet the streams are unique areas for fishes and other aquatic organisms that require clear water; the Sheyenne River is usually very turbid.

All North Dakota State University collections were made with seines: in the Sheyenne River a 9m (30 ft.) seine, 1.8m (6 ft.) deep, with a bag of 0.3cm ($\frac{1}{8}$ inch) mesh was used; in smaller tributary streams we used a 4.6m (15 ft.) seine, 1.2m (4 ft.) deep, with a bag of 0.6cm mesh. Because of the variety and differences in relative intensity of collecting gear used by various investigators, it is difficult to assess relative abundance and standing crops of fishes. The number of sites at which any one species was collected may give some clues as to relative abundance, however, emphasis here is on species occurrence.

RESULTS

Fishes. — A total of 53 species of fishes have been reported in the Sheyenne River basin from collections made from 1964 to date (Table 1). Of the 53 species, carp, rainbow trout, smallmouth bass, largemouth bass, white bass and muskellunge were introduced by stocking. Except for the rainbow trout and muskellunge, for which there are no records of reproduction, the stocked species now reproduce in the Sheyenne River basin. Carp were absent upstream from Baldhill Dam when it was closed in 1949 and have not been collected upstream from the dam to date. Russell (1975) reported that carp were collected at a site just downstream from Baldhill Dam. White bass were stocked in Lake Ashtabula in 1953 (NDGFD, stocking records; personal communication, James Ragan) and now provide excellent fishing in that reservoir. Smallmouth bass were stocked in 1965, 1967, 1968, 1970 and 1974; Farmer (1974) reports that the status of these fish in Lake Ashtabula is not known. In June 1977 we collected young-of-the-year smallmouth bass at Kathryn, Fort Ransom and Lisbon and young-of-the-year white bass at Fort Ransom, indicating successful reproduction in the Sheyenne River downstream from Baldhill Dam (low water in 1977 probably prevented any escape of young-of-the-year from Ashtabula). Copes and Tubb (1966) report that the largemouth bass is an introduced species collected only in reservoirs in North Dakota. Although the largemouth bass was reported in the Sheyenne River at Lisbon by Hankinson (1929), recent collections indicate it occurs only up-

TABLE 1. Fishes found upstream and downstream from Baldhill Dam, Sheyenne River, North Dakota, 1964 to 1977. An "X" indicates that the fish was present; the numbered superscript indicates the earliest published source.

	Upstream	Downstream
rainbow trout ⁵ (<i>Salmo gairdneri</i>)	X ¹	
mooneye (<i>Hiodon tergisus</i>)		X ³
northern pike (<i>Esox lucius</i>)	X ¹	X ¹
muskellunge ⁵ (<i>Esox masquinongy</i>)	X ²	
carp ⁵ (<i>Cyprinus carpio</i>)		X ¹
golden shiner (<i>Notemigonus crysoleucas</i>)	X ¹	X ²
creek chub (<i>Semotilus atromaculatus</i>)	X ¹	X ¹
longnose dace (<i>Rhinichthys cataractae</i>)	X ²	X ¹
blacknose dace (<i>Rhinichthys atratulus</i>)	X ²	X ⁴
emerald shiner (<i>Notropis atherinoides</i>)		X ¹
rosyface shiner (<i>Notropis rubellus</i>) ⁶		X ¹
common shiner (<i>Notropis cornutus</i>)	X ¹	X ¹
bigmouth shiner ⁷ (<i>Notropis dorsalis</i>)		X ¹
spottail shiner (<i>Notropis hudsonius</i>)	X ¹	X ¹
spotfin shiner (<i>Notropis spilopterus</i>)		X ¹
sand shiner (<i>Notropis stramineus</i>)	X ¹	X ¹
blacknose shiner (<i>Notropis heterolepis</i>)		X ⁴
brassy minnow (<i>Hybognathus hankinsoni</i>)		X ¹
bluntnose minnow (<i>Pimephales notatus</i>)		X ¹
fathead minnow (<i>Pimephales promelas</i>)	X ¹	X ¹
northern redbelly dace (<i>Phoxinus eos</i>)		X ⁴
silver chub (<i>Hybopsis storeriana</i>)		X ⁴
bigmouth buffalo (<i>Ictiobus cyprinellus</i>)		X ¹
quillback (<i>Carpiodes cyprinus</i>)		X ¹
northern redbreast (<i>Moxostoma macrolepidotum</i>)		X ¹
greater redbreast (<i>Moxostoma valenciensi</i>)		X ¹
golden redbreast (<i>Moxostoma erythrurum</i>)		X ⁴
silver redbreast (<i>Moxostoma anisurum</i>)		X ⁴
white sucker (<i>Catostomus commersoni</i>)	X ¹	X ¹
black bullhead (<i>Ictalurus melas</i>)	X ¹	X ¹
brown bullhead (<i>Ictalurus nebulosus</i>)	X ¹	
channel catfish (<i>Ictalurus punctatus</i>)		X ¹
tadpole madtom (<i>Noturus gyrinus</i>)	X ¹	X ¹
stonecat (<i>Noturus flavus</i>)		X ²
trout perch (<i>Percopsis omiscomaycus</i>)	X ²	X ¹
brook stickleback (<i>Culaea inconstans</i>)	X ¹	X ¹
freshwater drum (<i>Aplodinotus grunniens</i>)		X ¹
white bass ⁵ (<i>Morone chrysops</i>)	X ¹	X ²
smallmouth bass ⁵ (<i>Micropterus dolomieu</i>)	X ¹	X ²

largemouth bass ⁵ (<i>Micropterus salmoides</i>)	X ¹	
green sunfish (<i>Lepomis cyanellus</i>)	X ¹	X ¹
orangespotted sunfish (<i>Lepomis humilis</i>)	X ¹	X ¹
pumpkinseed (<i>Lepomis gibbosus</i>)	X ¹	X ¹
bluegill (<i>Lepomis macrochirus</i>)	X ¹	X ²
rockbass (<i>Ambloplites rupestris</i>)		X ¹
white crappie (<i>Pomoxis annularis</i>)	X ¹	X ¹
black crappie (<i>Pomoxis nigromaculatus</i>)	X ¹	X ¹
sauger (<i>Stizostedion canadense</i>)		X ¹
walleye (<i>Stizostedion v. vitreum</i>)	X ¹	X ¹
yellow perch (<i>Perca flavescens</i>)	X ¹	X ¹
blackside darter (<i>Percina maculata</i>)	X ¹	X ¹
johnny darter (<i>Etheostoma nigrum</i>)	X ¹	X ¹
iowa darter (<i>Etheostoma exile</i>)	X ²	X ⁴
	Total	31
		49

¹Tubb, Copes and Johnston (1965)

²Russell (1975)

³Van Eeckhout (1975)

⁴Peterka

⁵Introduced species. The rainbow trout is not stocked in the Sheyenne River; only one specimen was collected by Tubb, et al (1965).

⁶We recorded two specimens of *N. rubellus* x *N. cornutus* hybrids at site 2.

⁷Reported by Wilson (1950) to be upstream prior to the closure of Baldhill Dam.

stream from Baldhill Dam. Largemouth bass were stocked in Lake Ashtabula in 1951, 1954, 1974 and 1976.

In 1974-1977 we collected the blacknose shiner at sites 5, 7 and 10 in the Sheyenne Delta area (Fig. 1 and Table 2), the first record of this species in the Sheyenne River basin since early records by Hankinson (1929). The first record since 1929 was reported for the blacknose dace in Baldhill Creek (above Baldhill Dam) by Russell (1975); in 1974-1977 we collected the blacknose dace in Iron Springs (site 6) and in the Sheyenne River (sites 9 and 10). The northern redbelly dace, the first record for the Sheyenne River, was collected in 1974-1977 from a pool in the NDGFD Mirror Pool Game Management area (site 7), from Iron Springs (site 6), and from a small impoundment in a spring-fed stream near Owego Cemetery (site 5).

The golden and silver redbhorse are reported here for the first time. We found the golden redbhorse at various sites downstream from Baldhill Dam since 1968, including collections at Kathryn, Fort Ransom, Lisbon and Kindred in 1977. The species is common and it is a puzzle why it had not been reported before. Most of the silver redbhorse specimens were juveniles.

The bigmouth shiner was reported by Wilson (1950) to be present in the Sheyenne River upstream from Baldhill Dam before it was closed; it is absent in

TABLE 2. Fishes collected downstream from Baldhill Dam, Sheyenne River and spring-fed sites¹, North Dakota, May-August, 1977.

Species	Drift Prairie				Sheyenne Delta							
	River Sites				Spring-fed Sites				River Sites			
	1	2	3	4	5	6	7	8	9	10	11	12
Northern pike		X ⁰								X ⁰		
golden shiner				X*			X ⁰					
creek chub	X*	X*	X ⁰		X ⁰							
longnose dace		X*		X*					X ⁰			
blacknose dace					X ⁰	X ⁰			X ⁰	X ⁰		
rosyface shiner		X+		X*								
common shiner	X*	X+		X*								
spottail shiner	X ⁰	X*	X*									
spotfin shiner	X*	X+	X*	X+					X+	X+	X+	X+
sand shiner	X+	X+	X ⁰	X*					X+	X+	X*	X*
bigmouth shiner									X*	X*	X*	
blacknose shiner					X ⁰		X ⁰			X*		
brassy minnow					X ⁰	X ⁰			X ⁰			
bluntnose minnow	X+	X*	X+	X*	X ⁰				X*	X*	X*	
fathead minnow	X*	X ⁰			X+	X+	X+		X ⁰		X ⁰	X ⁰
northern redbelly dace					X*	X ⁰	X ⁰					
silver chub												X ⁰
quillback									X ⁰		X ⁰	
northern redhorse	X*	X*	X*	X*					X*	X*	X*	X*
golden redhorse	X*	X*	X*	X*						X ⁰	X ⁰	
white sucker	X+	X*			X+	X+			X*	X*	X*	X*
silver redhorse				X ⁰						X ⁰	X ⁰	X ⁰
black bullhead		X ⁰	X*						X ⁰			
channel catfish									X ⁰	X*	X ⁰	X ⁰
tadpole madtom	X ⁰			X ⁰								
stonecat									X ⁰			
trout perch	X*	X+	X ⁰						X ⁰		X ⁰	

brook stickleback					X ⁰	X ⁰	X ⁰	X ⁰	X ⁰			
freshwater drum					X ⁰							
white bass					X ⁰							
smallmouth bass	X*	X ⁰	X*	X*								
orangespotted sunfish	X*		X ⁰	X ⁰								
pumpkinseed sunfish								X*				
rockbass		X ⁰	X ⁰	X ⁰					X ⁰		X ⁰	
white crappie					X ⁰							
black crappie	X ⁰	X ⁰		X ⁰								
walleye												X ⁰
yellow perch											X ⁰	
blackside darter	X*	X+	X*									
johnny darter	X*	X+	X*	X ⁰		X ⁰					X ⁰	
iowa darter	X ⁰	—	—	—	—	X ⁰	—	—	—	—	—	—
	18	20	17	16	9	8	6	1	17	14	14	8

+abundant in sample

*common in sample

⁰occasional in sample

¹See Fig. 1 for general site locations. In Barnes County: Site 1 (T.137N, R.58W, Sec. 13). In Ransom County: Site 2 (T.136N, R.58W, Sec. 2); Site 3 (T.135N, R.58W, Sec. 12); Site 4 (T.134N, R.56W, Sec. 1); Site 5 (T.135N, R.53W, Sec. 15); Site 9 (T.135N, R.53W, Sec. 15). In Richland County: Site 6 (T.135N, R.52W, Sec. 17-18); Site 7 (T.135N, R.52W, Sec. 8); Site 8 (T.135N, R.52W, Sec. 2); Site 10 (T.135N, R.52W, Sec. 8); Site 11 (T.136N, R.51W, Sec. 28-27); Site 12 (T.136N, R.51W, Sec. 13).

collections made from 1964 to present. Apparently this is the only native species of fish recorded before the closing of Baldhill Dam which has not been recorded after.

The most abundant fish in our seine hauls made in the river were spotfin shiners, sand shiners, and northern redhorse (Table 2). In the Drift Prairie area, bluntnose minnows, golden redhorse, blackside and johnny darters, and smallmouth bass were common at nearly all sites; rosyface shiners, trout perch and white suckers were abundant in at least one site. In the Sheyenne Delta area, white suckers were common at nearly all sites and channel catfish were present at all sites.

Fisheries. — The estimated number of man-days of fishing in Lake Ashtabula in 1974 and 1975 was about 4-6 times the effort expended in fishing in the Sheyenne River (Table 3). In 1974 about 1.1% of the estimated 1,511,000 man-days of fishing in North Dakota were spent on the Sheyenne River; in 1975 about 0.6% of the estimated 1,383,000 man-days occurred on the Sheyenne River. Similar values for Lake Ashtabula were 6.3% and 2.5% in 1974 and 1975. In 1969 and 1970 about 17% of the estimated man-days fished in the state were on rivers; in 1974 and 1975 about 7% of the anglers fished rivers (Duerre, 1977). Winter ice fishing in Lake Ashtabula comprised 14% of the total angling effort in 1971 (Owen and Ruehle, 1972); there is little winter ice fishing in the Sheyenne River.

Fishing success was about 10 fish per man-day in Lake Ashtabula and about 4 fish per man-day in the Sheyenne River (Table 3). About 15% of the fish caught in 1974 and 1975 in the Sheyenne River were northern pike and walleye; in Lake Ashtabula about 11% of the catch in 1974 and 3% of the catch in 1975 were northern pike and walleyes (Duerre, 1977). In 1969 and 1970, northern pike and

TABLE 3. Estimated man-days spent fishing, numbers of fish caught by angling, number of fish caught per man-day, and expenditures by licensed anglers on fishing and associated recreation in Lake Ashtabula and in the Sheyenne River.

Lake Ashtabula					
1969 ¹	1970 ¹	1971 ²	1974 ³	1975 ³	
52,338	24,687	18,661 ⁴	95,028	34,626	man-days
162,248	54,805	137,832 ⁵	715,035	458,206	# of fish caught
3	2	7	8	13	# of fish/man-day
—	—	—	1,784,608	646,030	expenditures (\$)
Sheyenne River					
			16,770	7,836	man-days
			66,778	33,060	# of fish caught
			4	4	# of fish/man-day
			626,080	293,664	expenditures (\$)

¹Duerre (1972)

²Owen and Ruehle (1972)

³Duerre (1977)

⁴estimated from data of Owen and Ruehle (1972) by using 6.6 hrs. for the average time per angler trip as reported by Duerre (1972) for 1969, 1970.

⁵estimated weight of fish caught was 37,121 kg (81,668 lbs.).

walleyes comprised about 24 to 30% of the total numbers of fish caught in Lake Ashtabula. These shifts in percent composition of the catch probably reflect good and poor years of reproduction and perhaps stocking success. Channel catfish comprised less than 1% of the catch from the Sheyenne River: 293 were estimated to have been caught in 1974 and none in 1975 (Duerre, 1977).

Of the numbers of fish caught in 1971 in Lake Ashtabula, about 87% were yellow perch, 4% were bullheads, 3% were northern pike, 1% were walleyes and 5% were other species (Owen and Ruehle, 1972). Van Eeckhout (1976) mentioned that "yellow perch and black bullheads — comprise the largest proportion of species brought to creel" in the Sheyenne River.

The only harvest data by weight for the sport fishery were reported by Owen and Ruehle (1972) for the 1971 creel census in Lake Ashtabula: yellow perch comprised 54% of the catch by weight, northern pike 28%, white bass 7%, black bullheads 6% and walleye 5%. The estimated yield in 1971 for the angling catch in Lake Ashtabula was 16.8 kg/ha (15 lbs/acre); the estimated average yield of the commercial fishery in Lake Ashtabula from 1953-1976 (excluding 5 years when there was no commercial fishing) was 32 kg/ha (28 lbs/acre) (computed from Ryckman, 1977).

The estimated expenditures by licensed anglers on fishing and associated recreation in Lake Ashtabula were \$1,785,000 in 1974 and \$646,000 in 1975; Sheyenne River expenditures were \$626,000 in 1974 and \$294,000 in 1975 (Table 3). These expenditures do not include the value of fish removed. To estimate the value of the sport fishery, we used harvest by weight estimates for Lake Ashtabula for 1971 (Owen and Ruehle, 1972), and the following values per kilogram of fish as listed in an unpublished preliminary report prepared by the Monetary Values of Fish Committee, North-Central Division, American Fisheries Society (Donald Duerre, committee chairman, personal communication, 1977): bullheads (\$1.10), yellow perch (\$2.20), northern pike (\$7.70), walleyes (\$7.70), and white bass (\$4.40). The values per kilogram reflect current retail market values and costs of raising fish to various sizes. The estimated value of the 1971 harvest by angling in Lake Ashtabula was \$152,000 or an average of \$4.09/kg (\$1.86/pound) of fish removed.

DISCUSSION

Fishes. — Dams along the Sheyenne undoubtedly are barriers to upstream movement of fishes, especially during low water years. Upstream from Baldhill Dam, the largest dam on the river, 31 species of fishes were reported in collections from 1964 to date; 49 species have been reported downstream from the dam (Table 1). The absence of carp and redhorses above the dam, but their presence immediately below it, is a good indication that the dam restricts upstream movement of fishes. Smaller dams at Valley City, Kathryn, Fort Ransom, Lisbon and West Fargo, all downstream from Baldhill Dam, may also restrict fish from moving upstream. Russell's (1975) site immediately downstream from the Lisbon Dam had the greatest number of fish species of any station during his survey,

which he indicated may suggest the dam is a barrier to most fishes. The absence of carp and redborses upstream from the Valley City Dam prior to the construction of Baldhill Dam is another indication these lowhead dams influence fish movement.

Of the 49 species recorded in downstream reaches of the Sheyenne River, mooneye, largemouth buffalo, quillback, greater redhorse, silver chub, freshwater drum and sauger are usually associated with large rivers. These species collected in the Sheyenne were probably recent immigrants from the Red River of the North. In most cases only adult specimens were collected, most near the mouth of the Sheyenne River; however, in our 1977 collections several young-of-the-year quillback were collected. Goldeye (*Hiodon alosoides*), common in the Red River (Peterka, unpublished) have not yet been recorded in the Sheyenne River.

The 53 species of fishes (51 species excluding the rainbow trout and muskellunge which have not been reported to reproduce) reported in the Sheyenne River drainage is about twice the number of species found in any other North Dakota stream tributary to the Red River of the North (Table 4). The Sheyenne River has a diverse fish fauna with 51 of the 70 species recorded for the entire Red River drainage in Minnesota and North Dakota (Eddy, Tasker and Underhill, 1972), yet the Sheyenne drainage comprises only 24% of the Red River drainage. Only 48 species of fishes which reproduce in North Dakota have been reported to occur in Lake Sakakawea (Missouri River) (Owen and Russell 1975).

TABLE 4. Number of species of fishes collected in streams tributary to the Red River of the North, North Dakota

<u>Streams</u>	<u>Number of Species</u>
Pembina	27 ¹
Tongue	17 ¹
Park	25 ¹
Forest	26 ¹
Turtle	21 ¹
Goose	24 ¹
Elm	6 ¹
Rush	14 ¹
Maple	21 ¹
Sheyenne	53 ³
Wild Rice	12 ^{1,2}

¹Copes and Tubb (1966)

²Russell (1975)

³Copes and Tubb (1966) reported 44 species; additional sampling in the Sheyenne has added 9 more species.

Probably one of the principal reasons for the great diversity of fishes is that the Sheyenne is a long river; most of the river is in glacial till where pools and gravel riffles provide a great diversity of habitats for aquatic organisms. Most of the other North Dakota tributaries of the Red River lie within the boundaries of old glacial Lake Agassiz, where the substrate, silt and mud, does not offer much variety in habitats. Other factors which may be important downstream from Baldhill Dam are: a) the constant flow of water and the additional flow of groundwater into the Sheyenne River from the Sheyenne Delta prevents depletion of dissolved oxygen during low-flow periods, and b) the many small spring-fed springs in the Sheyenne Delta may provide unique clean-water conditions required for certain fishes. The occurrence of the blacknose shiners, blacknose dace, and red-bellied dace in some of the springs and near their mouths in the Sheyenne River is a good indication that the springs are refuges for these species.

Cvancara, et al. (1976), reported the most diverse mollusk fauna (31 species) in the state was in the Sheyenne River. Studies are not available for other aquatic organisms.

We noted in our 1977 seine collections that standing crops of fishes in the Drift Prairie area were much greater than those in the Sheyenne Delta area. From data of Van Eeckhout (1976), the mean number of fish caught, excluding minnows and young-of-the-year fish, per unit effort of one overnight set of a gill net and a frame net was 59, 14 and 16 in the Drift Prairie, Sheyenne Delta and Lake Agassiz Basin areas, respectively; their mean weights were 302, 334 and 496g. With the assumption that catch of fish per unit of effort was indicative of their abundance, the estimated total weight of fish per unit of effort was about 18, 5 and 8kg in the Drift Prairie, Sheyenne Delta and Lake Agassiz Basin, respectively. It is likely that the sand substrate in the Sheyenne Delta area is not as productive, especially for fishfood organisms, as the gravel-rubble substrate in the Drift Prairie area. Apparently the diversity of fishes is not affected, as 28 species were found in the Drift Prairie area and 25 species were found in the Sheyenne Delta area river sites (Table 2).

Important factors affecting fishes and other aquatic organisms in the Sheyenne River are rate of flow and fluctuation of discharge, and the availability of suitable substrates and shelter. Rate of flow is important in maintaining dissolved oxygen concentrations. Because there is usually some flow in the Sheyenne River downstream from Lake Ashtabula, it is unlikely that dissolved oxygen would become low enough to cause death of fishes. Lowest dissolved oxygen concentrations recorded at Kindred from July 1976 to August 1977 were 5.0 mg/l on 20 June and 6 July 1977 (U.S.G.S. records, Grand Forks, personal communication). While these concentrations are adequate for fish survival (the recommended minimum for aquatic organisms is 4 mg/l dissolved oxygen, E.P.A., 1973), they are low enough to suggest that, should flow stop, oxygen demand is great enough to cause dissolved oxygen concentrations to drop to levels which could restrict fish movement or cause fish kills. Low or zero flows occurring in the Sheyenne upstream from Lake Ashtabula, mostly during winter months, cause low dissolved oxygen concentrations; we recorded no oxygen at 1 and 3m (bottom) in the upper

end of Lake Ashtabula on February 21, 1969, at a site near Luverne (Peterka, unpublished). Low dissolved oxygen and periods of no flow are important factors contributing to the low species diversity of fishes in the upper reaches of the Sheyenne compared to that in the reaches below Baldhill Dam.

Fluctuations in discharge in the Sheyenne appeared to influence relative and absolute abundance of fishes. Many of the species are minnows which are short-lived and have high reproductive potentials. Because some are spring spawners, others spawn through the summer, and still others are late summer spawners, the times and durations of flooding may cause marked changes in reproductive success from year to year. In our 1977 collections downstream from Baldhill Dam, we found excellent populations of rosyface shiners at two sites, spotfin shiners at all sites, and young-of-the-year smallmouth bass at all sites sampled in the Drift Prairie area. These species were not mentioned as being numerous in previous studies. The low water and no flooding during 1977 may have provided ideal conditions for reproduction of these species.

Some fishes require specific substrates; many species of darters are found in riffle areas with gravel substrates and smallmouth bass require gravel-sand substrates for spawning. Two species of darters and the smallmouth bass were abundant downstream from Baldhill Dam in the Drift Prairie area (Fig. 1) where gravel and boulders were present, especially in riffle areas; very few darters and no smallmouth bass were collected farther downstream where there were only sand and mud substrates.

Fisheries. — The major sport fishery and only commercial fishery in the Sheyenne River basin is in Lake Ashtabula. In 1974 and 1975 about 1% of the total North Dakota anglers fished in the Sheyenne River (excluding Ashtabula). Since, during those same years, about 7% of the state's total estimated anglers fished rivers, the angler effort in the Sheyenne was 15% of the total angler effort spent in river fishing in the state. Probably a good portion of the river fishing takes place near the small dams. A creel census, however, is not available. Van Eeckhout (1976) reported that yellow perch and bullheads made up the major portion of angler catches from the Sheyenne River which indicates catches were coming from impounded areas as yellow perch are unusual in collections made in unimpounded river sites.

The monetary value of sport fishing (includes expenditures associated with fishing and value per kilogram of fish taken) in the Sheyenne River (excluding Lake Ashtabula) is substantial: \$0.7 million in 1974 and \$0.3 million in 1975 (computed from Table 3 — value of fish caught was estimated from data from Lake Ashtabula for 1971). The monetary value of sport fishing in Lake Ashtabula was 3.5-3.7 times that of the Sheyenne River: \$2.6 million in 1974 and \$1.2 million in 1975 (Table 3). By comparison, the monetary value of sport hunting in the lower Sheyenne River basin, from Baldhill Dam to the mouth of the river (about a third of the length of the Sheyenne), was estimated as \$0.4 million for 1974 (Leitch and Nelson, 1976).

In spite of the importance of sport fishing in the Sheyenne River it may only be a small portion of the river's recreational use if results from a survey made in the

upper James River, South Dakota, are indicative of use in the Sheyenne. Of the 150 river miles surveyed in the James River, total recreational use from September 1975-September 1976 was 357,590 hours, consisting of 19,410 trips by 56,000 people (Hansen, 1977). Non-consumptive uses accounted for about 67% of total trips, 75% of the people and 87% of the hours. Sight-seeing comprised the greatest number of all trips and people, and camping contributed the most use in terms of hours. Fishing (the largest consumptive use) accounted for 26% of the trips, 20% of the people and 11% of hours of all uses. Recreation users were primarily local residents who drove 25 miles or less to get to the river.

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PETROLOGY OF A METAMORPHIC AUREOLE, BOUNDARY WATERS AREA, MINNESOTA

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ABSTRACT

A sequence of amphibolite facies metamorphic rocks is exposed along the northern border of the Vermilion massif, a 2680 million year old granite-migmatite complex. This margin is broadly gradational across migmatite zones up to several kilometers wide. Exposures were examined along this contact from Namakan Lake to Lac La Croix along the Minnesota-Ontario border. Two distinct metamorphic rock types were distinguished based upon the presence or absence of hornblende. Amphibolites appear to be the product of the metamorphism of a granodioritic parent rock. Biotite schists containing quartz, plagioclase, muscovite, garnet, staurolite, cordierite, and sillimanite have formed from pelitic sedimentary rocks. Estimated conditions of metamorphism are temperatures of 630-675°C and pressures of 4.5-5.5 kilobars. We interpret the contact zone schists, amphibolites, and migmatites to be the result of high-temperature, low-pressure metamorphism associated with the emplacement of the composite Vermilion granitic body. The migmatite appears to be the result of intrusion and replacement with some formed locally by anatexis.

INTRODUCTION

The Vermilion granite-migmatite massif is a large complex of Early Precambrian granitic rocks. Underlying an area of about 55 km by 125 km, it is the largest body of granitic rocks exposed within the state of Minnesota. The complex and its bordering metavolcanic and metasedimentary rocks lie within the Quetico subprovince of the Archean Superior province of the Canadian shield (Stockwell et al., 1970). Southwick (1972) has summarized the petrology of the Vermilion massif and proposed a model for its history. He concluded that the massif is primarily a plutonic intrusive complex consisting of multiple phases of synorogenic quartz dioritic to granitic intrusives and that migmatite was formed by injection of granitic magma into contact rocks and by large-scale metasomatism of wall rocks with feldspar components. It was the purpose of this study to examine the metamorphic rocks bordering the complex as another means by which to interpret the geologic history of this area.

METHODS OF STUDY

The area of study lies along a portion of the northern border of the Vermilion massif within the Minnesota-Ontario boundary waters area (Figure 1). Exposures were examined and a reconnaissance geologic map constructed along two separate traverses in the vicinity of Namakan Lake and Lac la Croix.

Petrographic examination of 30 thin sections was used for the determination of metamorphic mineral assemblages and characterization of the plagioclase feld-

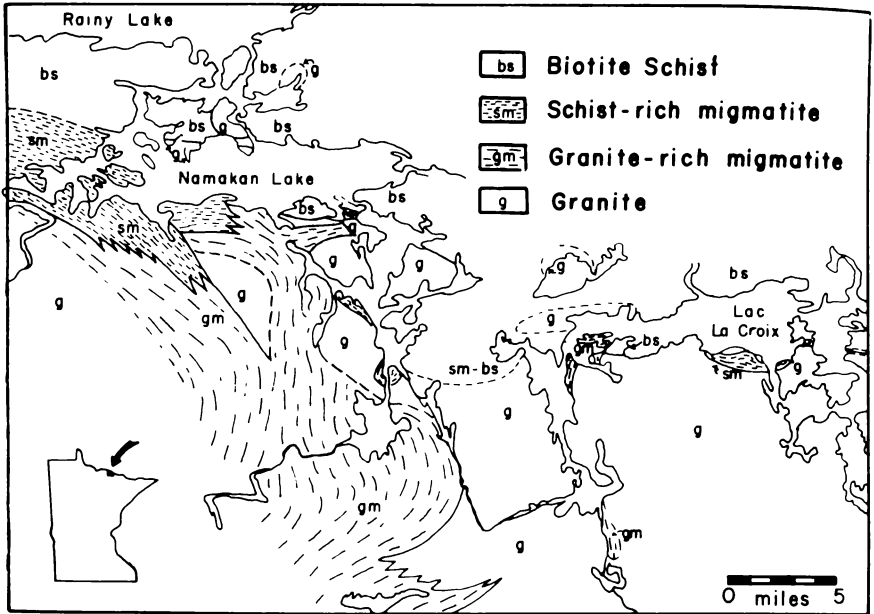


FIGURE 1. Simplified geologic map of part of the contact zone of the Vermilion massif. The form lines portray in a general way the structure of the migmatite parts of the complex. Modified after Southwick (1972) and Ontario Department of Mines Map 2115.

spar. Optical and x-ray diffraction methods (Wones, 1963; Gower, 1957; and Hutchison, 1974) were used to estimate the chemical composition of biotite, garnet, and alkali feldspar.

GEOLOGIC SETTING

Within the central portions of the body, away from the contact zones and areas of migmatite, the Vermilion massif is predominantly igneous-looking, massive, grayish pink, medium-coarse grained granite with a hypidiomorphic granular to allotriomorphic granular texture. The granite contains nearly equal parts of quartz, plagioclase ($An_{20}-An_{30}$), and perthitic microcline, with lesser amounts of deep olive green biotite and muscovite. Low-grade metamorphism has resulted in the sericitization of plagioclase and chloritization of biotite.

The contacts of the massif are broadly gradational across migmatite zones. Within any outcrop, the relative proportions of granitic material and biotite schist vary greatly. As the contact is approached, the proportion of granitic material gradually increases from biotite schist to schist-rich migmatite, granite-rich migmatite, and granite. The granitic neosome of the migmatite is essentially con-

formable to the structures within the older schistose paleosome. Interlayering of the granitic and schistose rocks occurs on all scales, from stringers as thin as one millimeter to massive sills and inclusions tens of meters thick.

PETROLOGY

Biotite schists and amphibolites lying outside of the borders of the granite-migmatite massif as well as the schistose paleosomes of the migmatite were studied. Characteristically these rocks are gray to dark gray, medium- to coarse-grained, biotite-rich rocks which are well-foliated and lineated. The rocks typically have well-developed relict bedding that strikes east-west and dips north, roughly parallel to the adjacent contact. Two distinct rock types were distinguished based upon the presence or absence of hornblende.

Amphibolitic rocks comprise a minor portion of the metamorphic rocks within the study area. These rocks are coarse-grained with a pronounced gneissic texture and prominent feldspar augen. They are composed principally of plagioclase, ($An_{25}-An_{35}$), blue-green hornblende, microcline, dark olive-green biotite, and quartz with lesser amounts of garnet, chlorite, and epidote. The texture is marked by the prominent deformed and zoned plagioclase and hornblende megacrysts. These are interpreted to be relict crystals from a granodioritic parent rock. Feldspar crystals have been partially altered to fine-grained aggregates of epidote, chlorite, and sericite. These rocks may represent early phases of intrusion of the synorogenic Vermilion massif which were deformed and metamorphosed by the later major pink granite, or they may be pre-metamorphic igneous material associated with the metasedimentary rocks.

The most abundant rocks within the metamorphic aureole are medium- to coarse-grained biotite schists. They are composed principally of red-brown biotite, quartz, and sodic plagioclase with lesser muscovite, garnet, cordierite, staurolite, sillimanite, and accessory iron oxides, apatite, tourmaline, and zircon. Texturally, the schists are granoblastic to foliated. Compositional layering observed on a thin-section scale is interpreted to be relict bedding.

Cordierite, garnet, staurolite, and sillimanite schists occur throughout the metasediments of the aureole, although many rocks contain biotite as the only ferromagnesian phase. The following mineral assemblages have been identified:

- biotite + garnet + staurolite + sillimanite
- biotite + garnet + cordierite + sillimanite
- biotite + cordierite + muscovite
- biotite + garnet + muscovite
- biotite + garnet + cordierite
- biotite + garnet
- biotite + muscovite
- biotite

Quartz and plagioclase occur in all assemblages. Muscovite and chlorite can generally be identified as retrograde phases associated with sericitization of feldspars, chloritization of biotite, or pinitization of cordierite.

X-ray diffraction analysis of the biotites indicate that the Fe/Fe + Mg ratio varies from about 0.40 to 0.47. The composition of a single garnet was estimated from x-ray diffraction and optical properties. The measured properties are consistent with a member of the almandine-pyrope solid-solution series with a composition approximately Alm₆₇-Pyr₃₃.

In the following discussion, it is assumed that the observed coexisting phases were in chemical equilibrium at the time of metamorphism. Two observations support this assumption:

(i) textural disequilibrium was not observed in thin sections. All phases were observed to be in physical contact with all other coexisting phases without intervening reaction products.

(ii) tie lines between compositional plots of coexisting phases do not intersect, suggesting phase rule equilibrium.

Phase relations between the phases biotite, cordierite, garnet, microcline, muscovite, sillimanite, and staurolite are shown in Figure 2. The compositions of all phases were not determined in this study and hence the precise locations of phases in the diagram are approximate. Determination of the compositions of coexisting AKFM phases in other studies indicate that the ratio Mg/Mg+Fe decreases in the order cordierite > chlorite > biotite > staurolite > garnet (Henson, 1971; Albee, 1972; Thompson, 1976). Tie lines have been constructed consistent with the observed assemblages. Quartz, plagioclase, and an aqueous fluid are assumed to be ubiquitous phases.

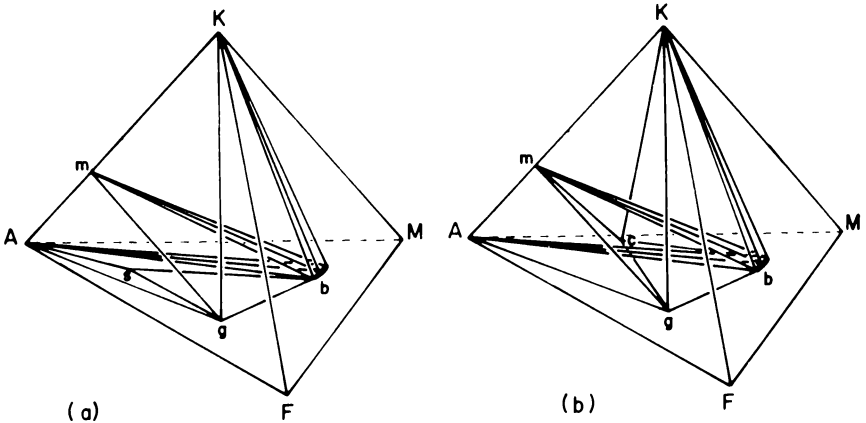
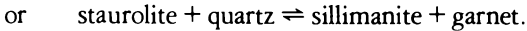
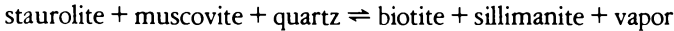
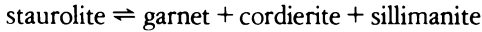


FIGURE 2. Phase relations between biotite (b), cordierite (c), garnet (g), K-feldspar (K), muscovite (m), sillimanite (A) and staurolite (s) in the AKFM tetrahedron:

- (a) below the staurolite breakdown reaction,
- (b) above the staurolite breakdown reaction.

In many pelitic rocks, the presence of muscovite in all assemblages permits projection of phases from the muscovite point to create the ternary AFM diagram of Thompson (1957). The absence of muscovite from most assemblages prohibits this simplification in this study. Biotite, however, is a ubiquitous phase, and was used to project mineral compositions to construct a stereographic projection by the method of Grant (1976). Figure 3 demonstrates that the observed mineral assemblages appear to belong to two distinct metamorphic zones, separated by reactions such as



The common occurrence of muscovite and the ubiquitous presence of quartz in the schists make one of the latter two reactions most likely. The samples containing staurolite were collected at a greater distance from the contact and are interpreted to be of a lower temperature origin. Within each zone, the assemblages are consistent with phase rule equilibrium. The absence of muscovite and K-feldspar from most assemblages is attributed to the low potassium composition of the rocks.

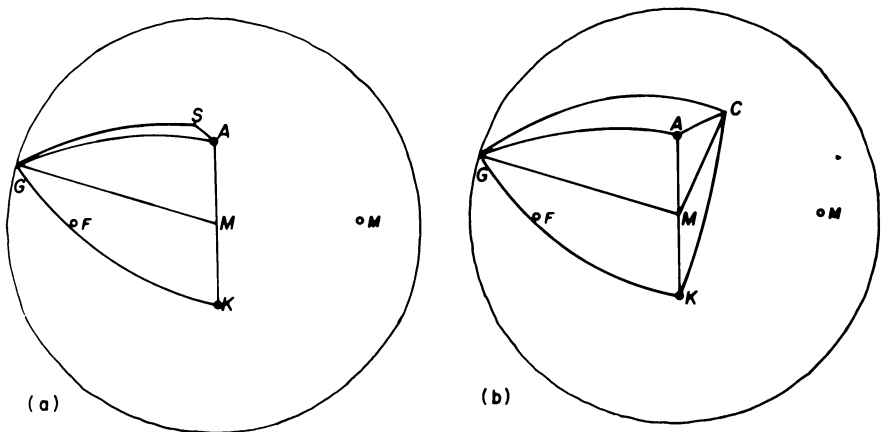
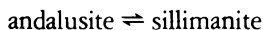


FIGURE 3. Stereographic projections of the four phase assemblages with biotite, based on the tetrahedra of Figure 2. Biotite lies at the center of the sphere with the AK edge oriented horizontally in a north-south direction above it. A biotite composition with $\text{Fe}/\text{Fe}+\text{Mg} = 0.5$ is used for projection. A = sillimanite, C = cordierite, G = garnet, K = K-feldspar, M = muscovite, S = staurolite. Points of projection of the apices of the tetrahedra are represented by closed and open circles for upper and lower hemisphere projection points respectively.

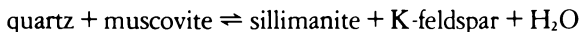
PHYSICAL CONDITIONS OF METAMORPHISM

The observed assemblages are consistent with a metamorphic system in chemical equilibrium and may be used to estimate the conditions of metamorphism. The pressure-temperature conditions for several pertinent reactions involving the observed phases are shown in Figure 4.

The presence of sillimanite places the metamorphic conditions above the first sillimanite isograd (Richardson, Gilbert & Bell, 1969)



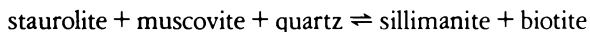
but the observed coexistence of quartz and muscovite restricts temperatures to below the second sillimanite isograd (Chatterjee and Johannes, 1974).



The location of this reaction curve on Figure 4 requires the assumption that $P_{\text{H}_2\text{O}} = P_{\text{total}}$. If $P_{\text{H}_2\text{O}} < P_{\text{total}}$, the position of the curve may be decreased by 100°C or more (Holdaway and Lee, 1977). The plotted position of this reaction curve then marks the maximum stability of this observed assemblage.

Cordierite and almandine are common in metapelitic rocks in low and medium pressure metamorphic terranes respectively. Reactions in the system $\text{K}_2\text{O-MgO-Al}_2\text{O}_3\text{-SiO}_2\text{-H}_2\text{O}$ involving cordierite have been determined by Schreyer (1968) and Schreyer and Siefert (1969) and several are shown on Figure 4. Again, these curves represent the maximum stability range of cordierite, since the presence of Fe will decrease the stability field of cordierite (Holdaway and Lee 1977). The stability of garnet depends upon the oxidation potential of the environment as well as the composition of the mineral. In general, almandine garnets are stable at temperatures above about 600°C throughout the range of pressures considered.

Staurolite forms over a wide range of rock pressures. The actual reactions for staurolite formation depend upon the associated minerals, $P_{\text{H}_2\text{O}}$, and f_{O_2} . We may estimate the stability range to lie at temperatures below the reactions



Staurolite-bearing assemblage (1) must lie immediately below these reactions, and the other staurolite-free garnet-cordierite-sillimanite-biotite assemblage (2) at temperatures just above them. These are also shown on Figure 4 after Hoschek (1969). Again, the precise conditions for these reactions depend upon other intensive variables of the environment.

From these reactions, we estimate the conditions of metamorphism in the contact zones of the Vermilion massif to have been pressures of from 4.5 to 5.5 kb and temperatures of from 630 to 675°C. The geothermal gradient implied is 35-45°C/km. This estimate is similar to estimates made by Harris (1976) for garnet-cordierite assemblages from near Sioux Lookout Ontario, or by McRitchie and Weber (1971) for the Manigotagan gneiss belt, southeastern Manitoba. The im-

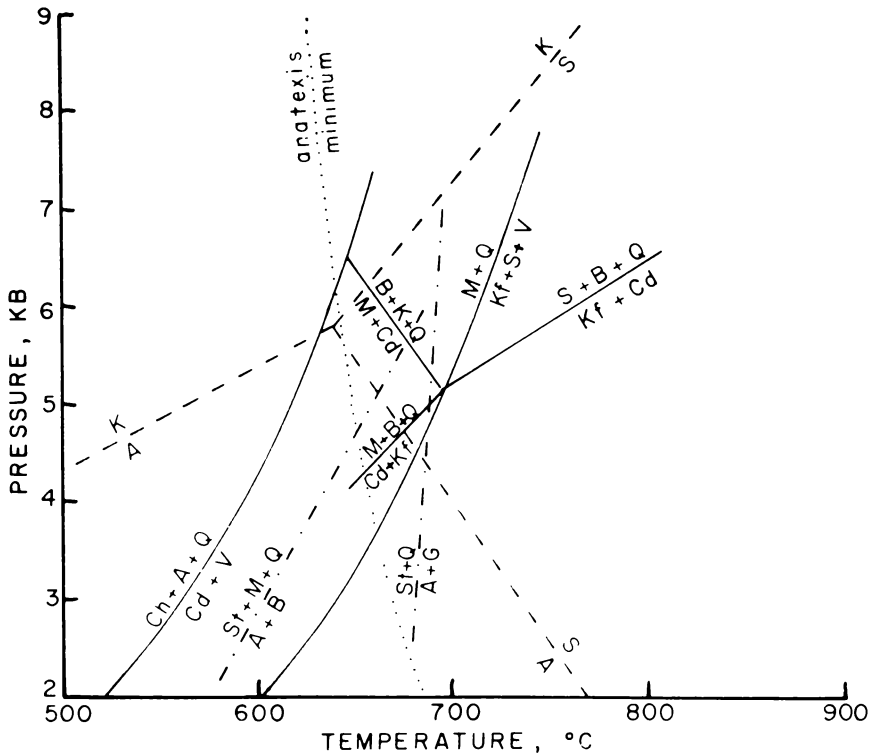


FIGURE 4. Pressure and temperature fields for reactions between andalusite (A), biotite (B), cordierite (Cd), chlorite (Ch), garnet (G), K-feldspar (K), muscovite (M), quartz (Q), sillimanite (S), staurolite (St), and aqueous vapor (V). Also shown is the location of the minimum granite solidus after Winkler (1967). Aluminosilicate triple point from Richardson et al. (1969); cordierite reactions after Schreyer (1968) and Schreyer and Siefert (1969); staurolite reactions after Hoschek (1969); muscovite breakdown reaction after Chatterjee and Johannes (1974).

plied geothermal gradient and the observed assemblages are indicative of a low pressure baric type of metamorphism similar to rocks of the Abukuma Plateau in Japan (Miyashiro, 1973).

As an independent check on these estimated conditions, we attempted to apply two frequently used geothermometers to the granitic rock near the contact. The two-feldspar geothermometer of Whitney and Stormer (1977), based on the partitioning of $\text{NaAlSi}_3\text{O}_8$ between coexisting microcline and plagioclase feldspars indicated equilibration at less than 400°C . The iron-titanium oxide geothermometer of Buddington and Lindsley (1964), based on the partitioning of titanium between hematite-ilmenite and magnetite-ulvospinel minerals, likewise

indicated equilibration between these phases at temperatures less than 500°C. Our interpretation is that these phases continued to reequilibrate during slow cooling to temperatures well below the solidus temperature, whereas the metamorphic mineral assemblages formed during prograde metamorphism were not severely affected by retrograde reactions.

It is evident from Figure 2 that the coexistence of garnet + cordierite + sillimanite + biotite is possible below the muscovite-quartz breakdown reaction for a narrow rock composition field only. The absence of muscovite or K-feldspar from most observed mineral assemblages suggests that these rocks are unusually potassium deficient. Harris (1976) observed similar K-deficient rocks in the Sioux Lookout area, and estimated that the K-poor gneisses had been subjected to higher grades of metamorphism than the K-rich biotite gneisses in that area. He suggested that it was the higher metamorphic grade which caused the potassium loss and consequent formation of garnet and cordierite.

The estimated conditions of metamorphism are somewhat above the wet granite solidus. Above this temperature metamorphism may be accompanied by melting of plagioclase, quartz, potassium feldspar or muscovite. Migration of the granitic liquid would leave behind a restite impoverished in both water and potassium. The garnet-cordierite gneisses should then have significantly higher proportions of mafic minerals, and the granitic liquid could have migrated to form the neosome of associated migmatite and granitic bodies.

Are the granites and migmatites of the Vermilion massif then of intrusive origin and the cause of the associated contact metamorphism, or are these migmatites the result of regional metamorphism? The various granitic phases of the massif have variant compositions which are in general not far from the 5 kb minimum melt composition (Southwick, 1972) which would be expected were they of an anatectic origin. Similarly, the intimate centimeter-scale interlayering of granitic neosome and schistose paleosome is best explained as a result of metasomatism or local anatexis. We believe, however, that this is a local phenomenon and not of widespread importance. Several observations are inconsistent with a model involving widespread anatexis for the origin of the Vermilion massif. First, it is observed that the width of the metamorphic aureole is limited: greenschist facies rocks outcrop less than 2 km from the contact zone (Southwick, 1972). The observed sequence of intrusives from more mafic to more felsic rocks is just the opposite of what would be expected for a metamorphic origin. And finally, our field observations of interrelationships between the neosome and paleosome suggest in most instances a clearly intrusive relationship.

SUMMARY

We interpret the migmatites and schists associated with the granitic rocks of the Vermilion massif to be the products of high-temperature, low-pressure metamorphism associated with the emplacement of this synorogenic, composite igneous body. The migmatite appears to be a result of replacement and intrusion with perhaps some formed locally by anatexis. The adjacent metasedimentary

rocks have been metamorphosed to amphibolite facies assemblages indicating temperatures of 630-675°C and pressures between 4.5 and 5.5 kilobars.

ACKNOWLEDGMENTS

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VEGETATION DYNAMICS OF THREE GRASSLAND COMMUNITIES IN SOUTHERN ILLINOIS

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ABSTRACT

The dynamics of aboveground plant biomass at a railroad right of way prairie, an old field, and a hill prairie in southern Illinois were studied during the growing season of 1975. Herbage (production plus standing dead) and litter biomass were harvested at biweekly intervals from randomly placed square meter quadrats. The lowest peak standing crop (474 g/m^2) was noted at the hill prairie where the cover was dominated by *Schizachyrium scoparium*, *Sorghastrum nutans*, *Bouteloua curtipendula*, and *Andropogon gerardii*. The railroad prairie, dominated by *Schizachyrium scoparium*, and the old field, wherein *Andropogon virginicus* was the dominant species, attained similar peak standing crop values (1007 and 1047 g/m^2 , respectively). However, mean total biomass at the railroad prairie (1270 g/m^2) was 29% greater than at the old field (904 g/m^2) and 61% greater than at the hill prairie (493 g/m^2). These differences reflect the high litter accumulation at the railroad prairie compared to the other two study areas. The high productivity of the old field is related to the rapid growth of the successional species of that site. The relatively low productivity at the hill prairie reflects at least partly the low effective moisture of the steep bluff which supports the prairie.

INTRODUCTION

The tall grass or true prairie of North America, at the time of white settlement, extended from southern Manitoba to Texas and from the drier and sparser grassland of the Great Plains to the deciduous forest in the east (Weaver, 1954). In the midwest a pronounced lobe or Prairie Peninsula extended across the northern two-thirds of Illinois into northwestern Indiana (Transeau, 1935). True prairie areas in southern Illinois were discontinuous and much more localized at the time of settlement, about 1810 to 1820 (Anderson, 1970) (Figure 1). The remainder of the area was largely forested.

Most of the prairies of Illinois have been destroyed through cultivation. In the southern portion of the state, prairies are restricted to long ribbons of vegetation found along highways and railroad rights-of-way and to xeric bluffs bearing hill prairies (Voigt and Mohlenbrock, 1964). Since prairie remnants are slowly being engulfed by urbanization, it was decided to study the structure and function of selected grasslands in southern Illinois while such remnants are still available for study.

The objective of this investigation was to study the quantitative changes in aboveground vegetation throughout a growing season in three communities dominated by grasses. The study areas included a prairie strip along a railroad right-of-way (railroad prairie), an abandoned agricultural field (old field), and a hill prairie (Figure 1).

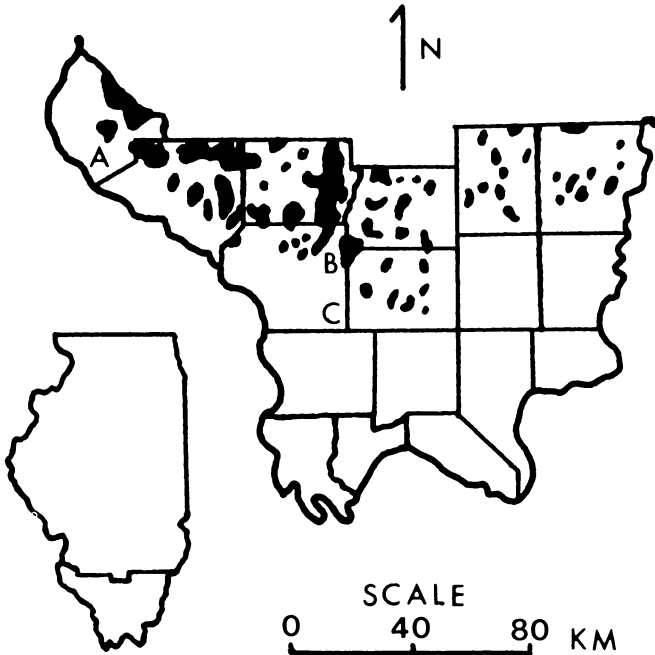


FIGURE 1. Extent of prairies in southern Illinois at the time of white settlement (modified from Anderson, 1970). Location of study areas: A, hill prairie; B, railroad prairie; C, old field.

DESCRIPTION OF THE STUDY AREAS

The railroad prairie is located 3.8 km north of the town of De Soto, Jackson County. This prairie, situated between the Illinois Central Railroad tracks and a blacktop road, extends about 0.8 km in a north-south orientation. Maximum width is about 60 m, and the total area is approximately 1.2 ha. The railroad was originally constructed in the mid 1850's and it is possible that the prairie has been largely undisturbed since construction. The soils at this study area belong to the Ava-Bluford-Wynoose complex (Alfisols). They are light colored with good development and were formed under forest vegetation from 0.45 to 1.21 m of loess on Illinoian drift (Fehrenbacher *et al.*, 1967).

The abandoned agricultural field (old field) is situated adjacent to Crab Orchard Lake 5 km east of Carbondale, Jackson County. This site is roughly circular in shape and occupies approximately 4 ha. The field was formerly cultivated for the production of row crops but was abandoned 11 years prior to this study due to severe spring flooding. The soils at the old field belong to the Belknap-Wakeland Association (Inceptisols). These soils are formed of acidic to neutral medium tex-

tured alluvium more than 1.21 m in depth on 0 to 2% slopes. Both series are light colored with little or no development (Fehrenbacher *et al.*, 1967).

The one relatively undisturbed grassland of this study is located 2.5 km southwest of the village of Fults, Monroe County. The study area is situated on an east-west oriented limestone bluff that rises as high as 115 m above the floor of the Mississippi River floodplain. The aspect is predominantly SSW. Forest divides this prairie into two major segments with a combined area of 1.1 ha. The prairie is located on highly varying topography with slopes ranging from 17% to more than 80%. The major soils of hill prairies in southwestern Illinois belong to the Stookey series (Alfisols). They are light colored and moderately developed. Hill prairie soils have characteristically developed on thick deposits of loess (Evers, 1955).

A policy of periodic burning, administered by the Illinois Nature Preserves Commission, is in effect at many hill prairies to help control encroachment by woody species. The Fults hill prairie was last burned in early spring 1974, one year prior to this study.

The climate of southern Illinois is determined by its mid-continental location with generally hot summers and cool to cold winters. January is normally the coldest month with a mean of 0°C and July is warmest with all of southern Illinois averaging over 25°C. The area experiences about 200 frost-free days per year. Precipitation averages approximately 100 cm with early spring being the wettest period and September being the driest month of the growing season (Page, 1949).

METHODS

The field work for this study was conducted from April to November, 1975. Each study area was sampled at approximately two week intervals for a total of 15 periods each during the growing season. Vegetation sampling was by the community peak standing crop method (Malone, 1968; Kelly *et al.*, 1974), but sampling continued beyond the "peak" until the end of the growing season at each area.

On each sampling date three randomly-selected quadrats (1.0 m²) of above-ground plant biomass were harvested at each of the three study areas. All standing herbage (living plus dead) was clipped at approximately 1 cm above ground level with grass-clipping shears. Only plant tops rooted within the boundary of the m² quadrats were harvested. The current season's twig growth of woody species occurring in quadrats was clipped and included in the herbage fraction of the quadrat. All unattached litter material lying upon the soil surface was collected separately.

Clipped herbage and litter were oven-dried at 50° C to constant weight, and the dry weights of herbage and litter were determined to the nearest gram. Values for the three quadrats at each area were averaged to represent mean herbage and mean litter weights for every sampling period.

From sampling periods 11 through 15 at each study area, plant cover (the fraction of the quadrat occupied by a canopy projection of the collective individuals of the species) was estimated for each species prior to clipping. Frequent

cy for all species was determined by dividing the number of quadrats of a species occurrence by the total number of quadrats sampled (e.g., if a species were present in each quadrat sampled during periods 11 through 15 it was assigned a frequency of 100%).

Nomenclature of plants collected follows Mohlenbrock (1975).

RESULTS

Twenty-two species of vascular plants were encountered in the sampling quadrats at the railroad prairie (Table 1). The dominant species of this site was *Schizachyrium scoparium* (= *Andropogon scoparius*), which exhibited an average cover of 58.37% and a frequency of 100%. In some areas the growth of *S. scoparium* was so dense that only two or three other species were found in the quadrats. *Solidago nemoralis* also had a frequency of 100% yet its average cover was only 6.80%. Individuals of *S. nemoralis* were often encountered as low rosettes 30 to 40 cm across growing under the *Schizachyrium* canopy.

A third species with high frequency (73.3%) was *Potentilla simplex*. *P. simplex*, *Sorghastrum nutans*, and *Desmodium paniculatum* all exhibited a relatively high average cover of about 4.0%. *D. paniculatum* had a fairly high frequency (53.3%) but *Sorghastrum nutans* was more restricted in distribution (frequency 20.0%), occurring in abundance in only one area of the railroad prairie. Of the remaining 17 species, each had an average cover of less than 2.0% and a relatively low frequency.

Of the 24 species encountered at the old field, *Andropogon virginicus* was the dominant (Table 2). It was the only species at this site that exhibited a frequency of 100%, and its average cover (53.13%) was greater than the coverage of all other species combined. However, half a dozen or more minor species were almost always present in the sample quadrats. *Juncus tenuis* and *Campsis radicans* both had very high frequency (93.3% for both), but only *Juncus* had a high average cover (21.13%) making it the second major species at this site. *Solidago canadensis* was fairly important in the old field (average cover 3.40% and frequency 66.7%), however it was less important than was *S. nemoralis* at the railroad prairie. All other species at the old field had cover values of less than 2.0%.

At the hill prairie no disturbance other than burning was evident. Although only 20 species were noted in the sample quadrats (Table 3), no species was strongly dominant as was the case at the railroad prairie and the old field. The cover consisted primarily of four grasses, *Schizachyrium scoparium* (22.80%), *Sorghastrum nutans* (13.60%), *Bouteloua crutispendula* (9.93%), and *Andropogon gerardii* (4.93%). *Schizachyrium scoparium* was particularly important on the steeper, drier 40-80% slopes. *Sorghastrum nutans* assumed dominance on gentler 15-25% slopes where precipitation runoff was probably lower. *Bouteloua crutispendula* was common on more level areas, although it also occurred on steep grades. *Andropogon gerardii*, though fairly common throughout the prairie, never assumed as high a coverage as did the other major grasses.

TABLE 1. Percentage composition of cover on five sampling dates and frequency of species (in 15 quadrats) at the railroad prairie.

Species	Cover %					Frequency %	
	9/14	9/28	10/12	10/25	11/11		Average
<i>Schizachyrium scoparium</i>	57.66	59.00	54.33	53.66	67.33	58.37	100.0
<i>Solidago nemoralis</i>	9.33	5.33	7.33	8.66	3.33	6.80	100.0
<i>Sorghastrum nutans</i>	3.00	6.66	—	—	10.66	4.06	20.0
<i>Desmodium paniculatum</i>	—	1.33	5.66	9.66	3.33	4.00	53.3
<i>Potentilla simplex</i>	3.66	5.66	4.33	1.33	4.66	3.93	73.3
<i>Rhus copallina</i>	1.33	—	3.33	5.00	—	1.93	26.7
<i>Pycnanthemum tenuifolium</i>	2.00	0.66	—	2.66	1.66	1.40	33.3
<i>Panicum</i> spp.	—	1.00	0.66	2.00	2.77	1.26	46.7
<i>Solidago canadensis</i>	—	—	2.33	1.00	1.66	1.00	26.7
<i>Carex</i> spp.	—	4.00	0.33	—	—	0.87	20.0
<i>Lespedeza repens</i>	3.66	—	0.66	—	—	0.86	26.7
<i>Rubus flagellaris</i>	—	—	1.66	—	—	0.33	6.7
<i>Juncus interior</i>	—	—	—	0.33	1.33	0.33	20.0
<i>Asclepias syriaca</i>	—	—	—	1.33	—	0.27	6.7
<i>Lespedeza capitata</i>	—	1.00	—	—	—	0.20	6.7
<i>Cassia fasciculata</i>	—	—	—	1.00	—	0.20	6.7
<i>Aristida oligantha</i>	—	—	—	—	1.00	0.20	6.7
<i>Setaria lutescens</i>	0.66	—	—	—	—	0.13	6.7
<i>Oenothera biennis</i>	—	—	—	0.66	—	0.13	6.7
<i>Oxalis violacea</i>	—	—	0.33	—	—	0.07	6.7
<i>Eragrostis spectabilis</i>	—	—	—	—	—	0.07	6.7
<i>Allium</i> spp.	—	—	—	—	0.33	0.07	6.7
TOTAL COVER	81.33	84.64	80.95	87.62	97.95	86.48	

TABLE 2. Percentage composition of cover on five sampling dates and frequency of species (in 15 quadrats) at the old field.

Species	Cover %					Average	Frequency %
	9/15	9/30	10/14	10/28	11/9		
<i>Andropogon virginicus</i>	54.00	61.00	47.33	48.33	55.00	53.13	100.0
<i>Juncus tenuis</i>	8.00	17.66	32.33	28.33	19.33	21.13	93.3
<i>Campsis radicans</i>	3.66	3.00	4.00	4.66	3.33	3.73	93.3
<i>Solidago canadensis</i>	0.33	7.00	2.00	4.00	3.66	3.40	66.7
<i>Liquidambar styraciflua</i>	—	1.00	2.33	2.66	3.00	1.80	40.0
<i>Digitaria sanguinalis</i>	2.33	0.33	1.66	1.00	2.33	1.53	66.7
<i>Acer saccharinum</i>	1.33	2.33	3.66	—	—	1.46	40.0
<i>Fraxinus americana</i>	1.00	1.00	1.66	1.00	—	1.26	53.3
<i>Acer rubrum</i>	—	—	—	1.00	1.66	1.07	26.7
<i>Verbena hastata</i>	0.66	0.33	0.66	1.66	2.00	1.06	53.3
<i>Acalypha virginica</i>	—	—	2.00	1.33	1.33	0.93	53.3
<i>Pycnanthemum tenuifolium</i>	—	3.33	—	—	—	0.67	13.3
<i>Chamaesyche maculata</i>	2.00	1.33	—	—	—	0.67	20.0
<i>Carex</i> spp.	—	—	—	2.66	—	0.53	6.7
<i>Cyperus strigosus</i>	0.66	—	0.33	—	1.33	0.46	33.3
<i>Gerardia tenuifolia</i>	—	—	1.33	0.33	0.66	0.46	20.0
<i>Aster</i> spp.	1.00	—	0.33	—	0.66	0.40	20.0
<i>Echinocloa crus-galli</i>	1.00	0.33	0.33	—	—	0.33	20.0
<i>Platanus occidentalis</i>	—	—	—	—	1.66	0.33	6.7
<i>Desmodium paniculatum</i>	—	—	—	1.66	—	0.33	6.7
<i>Panicum</i> spp.	—	1.00	—	—	—	0.20	6.7
<i>Ulmus rubra</i>	—	—	—	—	0.66	0.13	6.7
<i>Asclepias incarnata</i>	—	0.33	—	—	—	0.07	6.7
<i>Oenothera biennis</i>	—	—	—	0.33	—	0.07	6.7
TOTAL COVER	75.97	99.97	99.95	99.95	99.94	95.15	

TABLE 3. Percentage composition of cover on five sampling dates and frequency of species (in 15 quadrats) at the hill prairie.

Species	Cover %					Frequency %	
	9/13	9/27	10/11	10/26	11/8		Average
<i>Schizachyrium scoparium</i>	35.00	28.33	23.00	11.00	16.66	22.80	80.0
<i>Sorghastrum nutans</i>	11.66	—	25.00	26.66	5.00	13.67	40.0
<i>Bouteloua curtipendula</i>	5.66	3.66	4.33	7.00	29.00	9.93	80.0
<i>Andropogon gerardii</i>	7.00	10.00	1.33	2.33	4.00	4.93	46.7
<i>Gerardia aspera</i>	1.66	7.00	2.66	4.33	1.66	3.46	60.0
<i>Lespedeza capitata</i>	6.66	3.33	3.00	2.00	2.33	3.46	66.7
<i>Solidago nemoralis</i>	2.66	4.66	4.33	1.00	3.33	3.20	60.0
<i>Cornus drummondii</i>	1.66	1.33	2.66	6.66	3.33	3.13	40.0
<i>Desmodium ciliare</i>	2.00	2.00	2.33	2.00	4.00	2.47	53.3
<i>Echinacea pallida</i>	1.33	4.00	—	1.66	0.66	1.53	33.3
<i>Houstonia nigricans</i>	—	1.66	1.00	3.33	0.66	1.33	40.0
<i>Lespedeza virginica</i>	1.33	0.66	2.66	0.66	0.66	1.19	33.3
<i>Rudbeckia hirta</i>	—	—	—	—	4.66	0.93	6.7
<i>Croton monanthogynus</i>	—	—	4.00	—	—	0.80	6.7
<i>Euphorbia corollata</i>	—	—	2.33	—	1.00	0.67	13.3
<i>Rhus copallina</i>	—	1.66	1.00	—	—	0.53	13.3
<i>Asclepias viridisflora</i>	—	—	—	2.33	—	0.47	6.7
<i>Liatris cylindracea</i>	1.66	—	—	—	—	0.20	13.3
<i>Cassia fasciculata</i>	—	0.66	—	0.33	—	0.20	13.3
<i>Eragrostis spectabilis</i>	—	—	—	0.66	—	0.13	6.7
TOTAL COVER	78.22	68.95	79.63	71.95	76.95	75.16	

The forbs *Lespedeza capitata*, *Gerardia aspera*, and *Solidago nemoralis* at the hill prairie had frequencies (60.0% or greater) comparable to the dominant grasses and cover values greater than all other forbs. *Desmodium ciliare* and *Houstonia nigricans* were also common associates of the grasses throughout much of the hill prairie.

Considerable variation was noted in the vegetation dynamics among the study areas (Figure 2a, b). During the first two sampling periods in the early spring most of the herbage component consisted of standing dead vegetation that had persisted from the previous growing season. This was true at all three areas but it was especially striking at the railroad prairie. Here, the standing dead herbage at the first sampling (704 g/m^2) was 70% of the maximum weight of herbage recorded during the peak (1007 g/m^2) at this site in late July. Herbage values at the railroad prairie (other than during the peak) remained somewhat more stable during the growing season relative to the other two sites (Figure 2a).

Herbage biomass exhibited much greater fluctuation at the old field. Standing dead material at the first sampling period (364 g/m^2) represented only 35% of the maximum weight attained during the herbage peak (1047 g/m^2) in mid-September. Although initial herbage weights were lower than those at the railroad prairie, biomass production was so rapid at the old field (average $89 \text{ g/m}^2/\text{biweekly interval}$) that mean herbage at this site surpassed that at the railroad prairie between the eighth and ninth sampling periods (mid-August) and remained higher for the rest of the season.

Herbage production at the hill prairie displayed relatively minor fluctuation. The production peak (474 g/m^2) occurred at the beginning of September or nearly the same time as at the old field. Mean seasonal herbage at the hill prairie (334 g/m^2) was 50% of that observed at the old field (677 g/m^2) and 45% of that at the railroad prairie (748 g/m^2).

Some distinctive trends were observed in the litter components compared to herbage during the growing season (Figure 2b). At the railroad prairie maximum litter values were observed during August, following the herbage peak noted in July. This may have reflected some transfer of the recent peak production into the litter component. The ratio of litter to herbage was generally very high during the season at this site. Mean litter for the season (522 g/m^2) was approximately 70% of the mean herbage value at the railroad prairie.

At the hill prairie greatest litter values coincided with or slightly preceded the herbage peak in early September. The weight of litter remained consistently high at this site throughout July and August but decreased steadily toward the end of the season. Average litter during the growing season (159 g/m^2) was 48% of mean herbage.

A striking contrast between herbage and litter was observed at the old field. Despite the high productivity at this site relatively little herbage was transferred into the litter component during the growing season. In fact, litter at the old field exhibited the least fluctuation of either component at any of the three study areas. Mean seasonal herbage at the old field was 66% greater than mean litter (228 g/m^2).

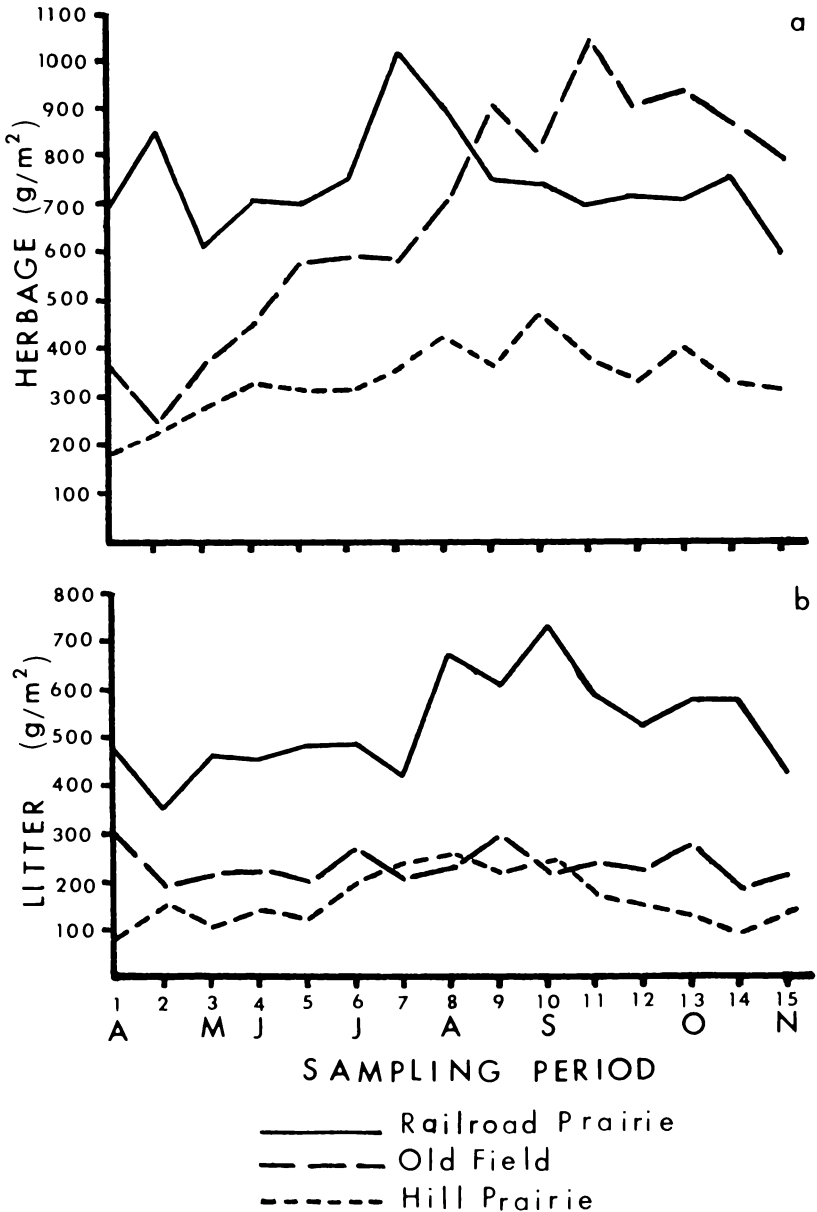


FIGURE 2a,b. Seasonal dynamics of biomass at the study areas during 1975. a, herbage biomass (live plus standing dead); b, litter (unattached dead). A . . . N: months from April to November.

Although the greatest total biomass (herbage plus litter) fluctuation of the growing season was observed at the old field, the railroad prairie exhibited the highest total biomass. Mean aboveground biomass at the railroad prairie (1270 g/m²) was 29% greater than at the old field (904 g/m²) and 61% greater than at the hill prairie (493 g/m²).

DISCUSSION

The grassland communities examined in this study were seen to differ significantly in both species composition and biomass dynamics during one growing season. Several aspects of these communities may be considered in an attempt to account for some of the variation.

The mulch or litter layer has important effects on the functioning of grassland ecosystems. Mulch increases soil moisture, stabilizes soil moisture and soil temperature, and promotes seed germination and seedling development and growth (Tomanek, 1969). However, an excessive accumulation of litter may delay growth in spring and decrease the total number of stems produced late in the season, thus decreasing the total productivity of a community (Weaver and Bruner, 1948). Also heavy mulch accumulations may result in pure stands of species like *Andropogon gerardii* or *Panicum virgatum* in true prairie (Weaver and Rowland, 1952). Sampson (1921) concluded that in Illinois prairies seldom disturbed by man and where the dead grass remained from year to year, the dominant plants may exist in relatively pure stands and secondary species may become insignificant.

The detrimental effects of litter accumulation appear to have retarded primary production at the railroad prairie. Mean litter biomass at the railroad prairie was 56% greater than mean litter at the old field and was 6% greater than mean total biomass at the hill prairie. The thick litter layer may account for the relative lack of herbage fluctuation, except for the period of the peak standing crop. (An early increase in the herbage component in late April appears to have been a sampling artifact. See Figure 2a.) The complete dominance of the railroad prairie community by *Schizachyrium scoparium* also appears to reflect the tendency of some unburned or unharvested grasslands to form nearly pure stands.

Unlike the railroad prairie, the old field exhibited rapid productivity which peaked in mid-September. Golley (1965) found that an old field dominated by *Andropogon virginicus* in South Carolina also attained its peak standing crop in early autumn. He also found that the litter component exhibited relatively minor seasonal fluctuation relative to herbage biomass, as was the case at the old field of this study.

The slow transfer of standing dead vegetation into the litter layer is related to the growth characteristics of the dominant species at this site. *A. virginicus* is a successional species very common in abandoned field in southern Illinois. Bazzaz (1968) has shown that *A. virginicus* dominates fields by the fourth year after abandonment and continues to dominate even in open areas of 40 year old fields. The thick, woody culms of this grass may persist for more than one season before

falling and decomposing. Since *A. virginicus* had probably not been dominant in this field for more than six or seven years prior to this study, a thick litter layer had not accumulated.

Both the herbage and litter components at the hill prairie exhibited relatively uniform fluctuation during the growing season. That is, increases and decreases for these components were relatively synchronized. The vegetation at the hill prairie appeared to have achieved a relatively stable climax since it was characterized by true prairie grasses and forbs (Evers, 1955; Kilburn and Ford, 1963). Though total biomass at this prairie was much less than that observed at the other study areas, it is consistent with the value (400 g/m^2) that Risser (1976) considers average for peak standing crop in true prairie.

The existence of hill prairies is believed to be primarily due to the xeric nature of the bluffs they occupy. The bluffs are primarily south or southwest facing and at an angle to intercept most directly the insolation of the midday sun (Evers, 1955). Thus these small prairies exist usually surrounded by deciduous forest. Effective moisture can be expected to be lower at hill prairies than at grasslands on level areas assuming the same amount of precipitation.

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SECONDARY SUCCESSION OF A MIXED GRASS COMMUNITY IN SOUTHWESTERN NORTH DAKOTA

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ABSTRACT

In 1976, two study areas, one grazed and the other ungrazed, were selected on a sandy range site in Billings Co., North Dakota, to study successional changes after 39 years of excluding cattle. In 1976 and 1977, production and average height of selected species were recorded in each site with random-systematically placed 0.5 m² quadrats. Forb density was determined in each site with 12 random systematically placed 0.125 m² quadrats while the point frame method was used for percent basal cover. The vegetation of both sites was similar to the grama-needlegrass-sedge type although they were essentially short grass. The grazed site was dominated by *Bouteloua gracilis* while *Carex filifolia* dominated the ungrazed site. The intervening successional vegetation was mixed grass due to the high relative cover of *Stipa comata*. Total herbage production was not significantly different between grazed and ungrazed sites although grass and grass-like species produced significantly more in the ungrazed site. There was also a relative lack of overlap in forb composition and an increase in forb density in the grazed site. Therefore, both heavy grazing by cattle and the exclusion of cattle resulted in the development of a short grass aspect in the grama needle-grass-sedge type.

INTRODUCTION

Literature directly concerned with the response of upland mixed grass prairie to exclusion from grazing is limited. Most of the information considers the effect of various intensities of grazing on native vegetation by comparing it to vegetation found within exclosures. This provides an indirect concept of the successional changes associated with the lack of grazing, however, research directly related to secondary succession is needed. In 1976 a project was initiated to elucidate some of these changes. A portion of that project is the subject of this paper.

LITERATURE REVIEW

The mixed grass prairie is an extensive and therefore important range resource in western North Dakota. Its principle species are *Bouteloua gracilis* (H.B.K.) Griffiths (blue grama), *Carex filifolia* Nutt. (thread-leaved sedge), *Agropyron smithii* Rydb. (western wheatgrass) and *Stipa comata* Trin. and Rupr. (needle-and-thread) (Whitman, 1953). The structural response of mixed grass prairie to exclusion from grazing is generally recognized as a shift towards a mixed grass community (Clements, 1934 and Whitman and Wali, 1975). This was also observed by Smoliak (1965) and Whitman (1974) who reported a characteristic increase in midgrasses on ungrazed range. However, this trend may not always be unidirectional since *S. comata* has been observed to increase under "intermittent use" and "moderate" grazing pressure (Larson and Whitman, 1942 and Rauzi, 1963). Therefore, it may not be able to maintain itself under complete protection

from grazing (Larson and Whitman, 1942). In addition to the increase in midgrasses, the shortgrass, *B. gracilis*, decreases under exclusion from grazing while upland sedges increase, resulting in a mixed grass aspect on ungrazed ranges (Larson and Whitman, 1942 and Rauzi, 1963). Production is also generally reported as increasing on ungrazed ranges, although Bjugstad (1965) reported an increase in yield on some ranges in fair condition in southwestern North Dakota due to a large increase in shortgrasses and forbs.

Forbs, as a group, decrease with the exclusion of cattle in the mixed grass prairie (Larson and Whitman, 1942 and Whitman, 1974). More specifically, Bjugstad (1965) observed that perennial forbs were highest in density and percentage of total yield on ranges in good condition as compared with ranges in excellent or fair condition in southwestern North Dakota. He also reported a general increase in annual forbs as grazing intensity increased.

Several microclimatic and edaphic effects are evident as a result of grazing the mixed grass prairie. Rauzi and Hanson (1966) and Zeller (1963) observed an inverse relationship between intensity of grazing and infiltration while Hanson *et al.* (1970) demonstrated lower seasonal runoffs on lightly grazed range as compared with heavily grazed ranges. Whitman (1974) also reported higher percent soil moisture, but decreased air temperatures, soil temperatures, wind movement and evaporative conditions on ungrazed versus grazed ranges.

Exclusion from grazing may therefore result in more of a mixed grass aspect and less xerophytic conditions on the mixed grass prairie.

SITE DESCRIPTION

In August, 1937, a 3 wire cattle enclosure of 1.7 ha was established on sec. 5, T.138N., R.101W., Billings Co., North Dakota to determine successional changes in vegetation resulting from the exclusion of cattle. The enclosure is located on the unglaciated portion of the Missouri Plateau in the Badlands of North Dakota. The substrate is the Tongue River Formation, a member of the Fort Union Group, laid down 55-70 million years ago (Bluemle, 1975). Presently the enclosure is classified as a sandy range site located on a 3-5% north facing slope. The soil is a combination of Telfer fine sandy loam and loamy fine sand.

The climate is a dry-semiarid type receiving over 75% of its average annual precipitation during the April-September growing season (Ramirez, 1973). The mean annual precipitation for Medora, the closest reporting station, is 356 mm with a maximum mean monthly precipitation of 91 mm in June and a minimum mean monthly precipitation of 6 mm in December. The mean annual temperature is 4.6°C with a mean maximum of 20.6°C in July and a mean minimum of -12.3°C in January.

The vegetation of the enclosure and immediate area most closely resembles a grama-needlegrass-sedge type as described by Hanson and Whitman (1938). The dominant species in this type are *B. gracilis*, *S. comata* and *C. filifolia* with the subdominants being *A. smithii*, *Carex eleocharis* Bailey (needleleaf sedge) and *Koeleria pyramidata* (Lam.) Beauv. (= *cristata*) (Junegrass). Ocular estimates in-

dicade that in the area adjacent to the enclosure, grazing has removed an average of 42% of the herbage annually. This level of grazing is maintained by congregation of cattle at the site due to the presence of a stock dam located about 127 meters to the west of the enclosure and a salt lick between it and the enclosure.

MATERIALS AND METHODS

In 1976, paired sites, one grazed and the other ungrazed, were established to determine the effects of 39 years of exclusion of cattle from the grama-needlegrass-sedge type of community (Figure 1). The ungrazed site was essentially the east half of the previously described 1.7 ha enclosure and was 1.0 ha while the grazed site was 0.4 ha and was located immediately outside the north fence of the enclosure. Homogeneity of the vegetation was considered to be of primary importance in site selection to prevent confusion in interpreting the results.

Vegetation sampling began in late June in 1976 and early July in 1977. Percent basal cover was determined using an inclined 10 pin point frame systematically placed 300 times for a total of 3,000 points in each site. A "hit" was interpreted as the intersection by a pin with a living stalk or crown and the soils surface. For *Selaginella densa* Rydb. (small club moss), a "hit" was recorded when the point intersected prostrate, living tissue. Density was determined for forbs to compensate for the inadequacy of the point frame values. In July, twelve 0.125 meter² quadrats were randomly chosen along systematically placed tran-

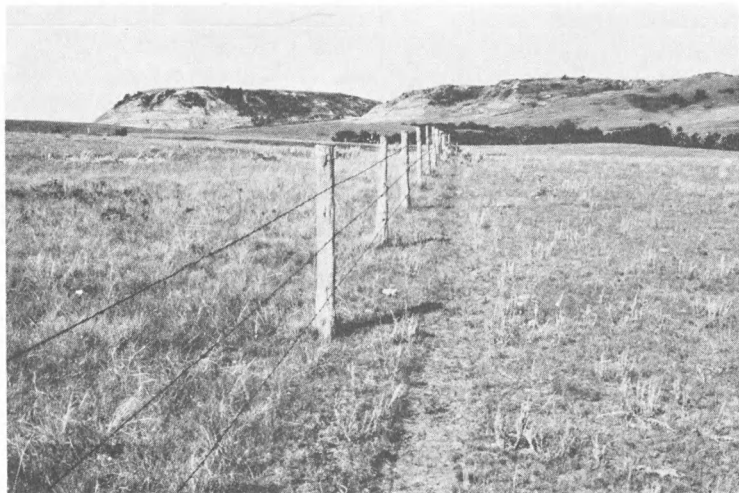


FIGURE 1. Fence line contrast of the grazed site to the right of the fence and the ungrazed site to the left.

sects in each site (hereafter referred to as random-systematic placement) and the number of stalks for rhizomatous species such as *Solidago mollis* Bartl. (soft goldenrod) were counted while the number of plants were counted for individual forbs. In August, after the main growth period had terminated, ten 0.5 meter² random-systematically placed quadrats were clipped at ground level in each site and oven dried at 66°C. Before clipping, the average height of selected species was measured and species composition by weight was estimated using doubling sampling. The clipped quadrats were protected from grazing by placing cages over them at the beginning of the grazing season. After clipping the quadrats, mulch, which included both standing dead from the previous year and litter, was collected and oven dried at 66°C.

Soil temperatures were obtained with a probe type soil thermometer at depths of 7.6 cm and 15.2 cm. The readings were taken at six systematically chosen sample locations in each site on June 23, 1977. Soil bulk density was obtained with a hydraulically operated soil corer and a 3.5 cm diameter tube to a depth of 4 feet in three systematically chosen locations in June, 1977.

Nomenclature used in this paper is based on McGregor *et al.* (1977).

RESULTS AND DISCUSSION

The vegetation on the grazed site has remained remarkably constant in composition since 1950 despite large fluctuations in weather and possible fluctuations in usage (Table 1). This makes interpretation of the ungrazed vegetation simpler in that changes in composition can be linked with a fair amount of certainty to the exclusion of cattle. Based on the stability of the grazed vegetation, it may also be assumed that the grazed vegetation approximates the pre-exclosure condition of the ungrazed vegetation.

The composition of the ungrazed vegetation indicates that by 1950, 13 years after fencing, it had not stabilized (Table 2). A more stable composition was probably reached before 1959 when the response of *S. comata* between years became similar in both the grazed and ungrazed sites as did the responses of *B. gracilis* and *C. filifolia*. Inspection of Tables 1 and 2 also reveals that *S. comata* was lowest in relative cover in both the grazed and relatively stable, ungrazed communities. The highest cover of *S. comata* occurred during succession towards the "stable", ungrazed community and not in it, assuming that the grazed vegetation approximates the successional beginning point of the ungrazed vegetation (Table 2, 1950 and 1951).

The absolute cover of *C. filifolia* and *Carex heliophila* Mack. was higher and *B. gracilis* was lower in the ungrazed site as compared to the grazed site (Table 3). *K. pyramidata* and *Calamogrostis montanensis* Scribn. (plains reedgrass) also comprised a smaller portion of the ungrazed vegetative cover resulting in a lesser variety of subdominant species and a lower total cover of grasses, grass-like species and forbs in the ungrazed community.

In comparing the lowest strata of vegetation it was apparent that the cover of *S. densa* Rydb. (small clubmoss) was similar in the two sites although there has

TABLE 1. Yearly variation of relative basal cover (%) of the grazed vegetation.^a

Species	1950	1951	1952	1959	1976	1977
<i>Carex filifolia</i>	6.6	11.2	11.9	3.4	9.0	12.8
<i>Bouteloua gracilis</i>	57.7	70.4	66.1	76.1	66.3	51.7
<i>Carex heliophila</i>				1.1	3.0	1.7
<i>Carex eleocharis</i> & <i>heliophila</i>	0.9	2.9	3.7			
<i>Carex eleocharis</i>				1.9		9.4
<i>Stipa comata</i>	2.3	4.9	6.3	5.9	2.4	2.2
<i>Agropyron smithii</i>	30.9	5.3	6.0	4.2	2.4	1.1
<i>Calamagrostis montanensis</i>	0.4	0.5	0.4	1.2	4.2	6.1
<i>Koeleria pyramidata</i>			0.4	0.8	6.6	8.9
Misc. grass	0.2	1.3	0.0	3.1	0.6	1.1
Forbs	1.1	3.4	5.2	2.4	5.4	5.1
Total	100.1	100.0	100.0	100.1	99.9	100.0

^a Data from 1950-1959 was provided by Dr. W.C. Whitman, Fargo.

TABLE 2. Yearly variation of relative basal cover (%) of the ungrazed vegetation.^a

Species	1950	1951	1952	1959	1976	1977
<i>Carex filifolia</i>	23.4	38.5	40.8	33.8	52.0	58.4
<i>Bouteloua gracilis</i>	32.6	18.1	22.6	26.8	27.0	18.4
<i>Carex heliophila</i>				17.7	18.0	12.0
<i>Carex eleocharis</i> & <i>heliophila</i>	7.1	13.7	14.8			
<i>Carex eleocharis</i>				2.6		1.6
<i>Stipa comata</i>	23.4	21.4	9.6	8.2		1.6
<i>Agropyron smithii</i>	3.3	3.3	4.8	7.0	1.0	0.8
<i>Koeleria pyramidata</i>	0.8		1.3	0.3		1.6
<i>Calamagrostis montanensis</i>	1.7			0.5	1.0	
Misc. grass	0.8	1.7	0.0	0.7	0.0	1.6
Forbs	6.7	3.3	6.1	2.6	1.0	4.0
Total	99.8	100.0	100.0	100.2	100.0	100.0

^a Data from 1950-1959 was provided by Dr. W.C. Whitman, Fargo.

been an increase in the lichen, *Cladonia chlorophaea* (Florke) Spreng. in the ungrazed site (Table 3). The net result was a total vegetative cover value which was similar in both sites.

Herbage production in the grazed and ungrazed communities was not significantly different although grass and grass-like species produced significantly more in the ungrazed community (Table 4). Increased forb production compensated for the decreased production of grass and grass-like species in the grazed site. There was also little difference in the production of *B. gracilis* between the grazed and ungrazed sites. This was unexpected since its cover was larger in the grazed site (Table 3). The similarity was probably due to the significantly increased height of *B. gracilis* in the ungrazed site (Table 5). *C. filifolia* and *C. heliophila* both produced more herbage in the ungrazed site. This is attributable to the increased cover of these two species and also the increased height of *C. filifolia*

TABLE 3. Absolute basal cover (%) of the grazed and ungrazed vegetation.

Species	Treatment	
	Ungrazed ^a	Grazed ^a
<i>Carex filifolia</i>	2.1	0.6
<i>Bouteloua gracilis</i>	0.8	3.4
<i>Carex heliophila</i>	0.6	0.1
<i>Koeleria pyramidata</i>	0.1	0.5
<i>Calamagrostis montanensis</i>	0.1	0.3
<i>Carex eleocharis</i>	0.1	0.3
<i>Stipa comata</i>	0.1	0.1
<i>Agropyron smithii</i>	0.1	0.1
Misc. grass	0.1	0.1
Forbs	0.1	0.3
Subtotal	3.8	5.8
<i>Selaginella densa</i>	13.5	13.8
<i>Cladonia chlorophaea</i>	3.0	1.1
<i>Parmelia chlorochroa</i>	0.1	0.2
<i>Bryum argenteum</i>	0.1	
Subtotal	16.5	15.0
Total	20.3	20.8

^a Average of 3,000 points in each of the years 1976 and 1977.

TABLE 4. Average herbage production (g m⁻²).

Species	Treatment	
	Ungrazed ^a	Grazed ^a
<i>Carex filifolia</i>	37.1	12.5
<i>Carex heliophila</i>	34.6	3.0
<i>Bouteloua gracilis</i>	26.0	34.5
<i>Agropyron smithii</i>	8.5	4.5
<i>Stipa comata</i>	5.2	5.6
<i>Koeleria pyramidata</i>	3.4	5.1
<i>Calamagrostis montanensis</i>	0.1	4.1
Misc. grass	0.8	1.5
Total grass and grass-like species	115.8 ^b	70.6
Forbs	7.1 ^b	34.1
Total herbage production	122.9	104.7
Mulch	220.1 ^b	42.4

^a Average of ten 0.5 m² quadrats in each of the years 1976 and 1977.

^b Significantly different from grazed value at the 0.001% level.

TABLE 5. Heights (cm) of selected species.

Species	Treatment	
	Ungrazed ^a	Grazed ^a
<i>Carex filifolia</i>	21.6 ^b	8.9
<i>Bouteloua gracilis</i>	16.6 ^b	7.3
<i>Agropyron smithii</i>	31.0 ^b	20.1

^a Average of not less than 19 measurements per species in each of the years 1976 and 1977.

^b Significantly different from the grazed value at the 0.001% level.

(the height of *C. heliophila* was not measured). The net result of the increased production of *C. filifolia* and *C. heliophila* was a more equitable distribution of above ground biomass among the forage producing species within the ungrazed site. Mulch production was also significantly greater in the ungrazed than grazed vegetation.

The dissimilarity between the grazed and ungrazed sites was further exemplified by the relative lack of overlap in forb composition (Table 6). The tendency in the ungrazed site is towards taller, perennial forbs while the grazed community was dominated by forbs which are either unpalatable [*Artemisia frigida* Willd. (prairie sagewort)], resistant to grazing [*Aster ericoides* L. (white aster)] or too short to be grazed [*Antennaria parvifolia* Nutt. (pussytoes) and *Phlox hoodii* Rich. (Hoods phlox)]. A large increase in forb density in the grazed site was apparent and may be due to decreased mulch. This response was observed in the ungrazed community as an increase in forb density from 1976 to 1977 with a concurrent decrease in mulch from 309 g m^{-2} in 1976 to 131 g m^{-2} in 1977.

Exclusion from grazing has also resulted in lower soil temperatures at both 2.5-7.5 cm and 10.2-15.2 cm (Table 7). Along with the lower soil temperatures in the ungrazed site there was also a lower bulk density in the 0-15 cm level although no consistent trend was present below this level (Table 8). The significance of these edaphic effects is not clear. Additional soil moisture and infiltration data are necessary to characterize the edaphic effects of grazing in this site.

SUMMARY AND CONCLUSION

Forty years of excluding cattle from a sandy range site in mixed grass prairie resulted in a short grass community dominated by *C. filifolia* with the subdominants being *B. gracilis* and *C. heliophila*. The grazed vegetation, located on the same range site, was also shortgrass in character with *B. gracilis* dominating and *C. filifolia*, *K. pyramidata* and *C. montanensis* being subdominants. Successional vegetation leading to the ungrazed composition exhibited an initial increase in the midgrass *S. comata* and its subsequent decline with the climax being attained within 22 years.

The grazed and ungrazed sites were not significantly different in herbage production, although the ungrazed site produced significantly more total grass and grass-like species and mulch and significantly less forbs than the grazed site. There were also species production differences resulting in a more equitable distribution of biomass among the forage species within the enclosure.

Forb densities and composition were dissimilar between the two sites. Preferential grazing probably accounts for the differences in composition while the decreased density in the ungrazed site may be due to the increased cover of mulch.

The successional status of these two communities is similar. Both the grazed and ungrazed communities are near climax since the species composition was relatively constant under the present environmental conditions. Whether the grazed community is retrogressive or a disclimax is speculative in view of the in-

completeness of our knowledge about the structural and functional attributes of a mature ecosystem. Heady (1973) and Whittaker (1953) both hesitate in labeling a community as retrogressive when it differs from the expected potential vegetation. This is reinforced by our knowledge of the pristine vegetation in the Northern Great Plains as pointed out by Larson (1940) and England and DeVos (1969) and the interpretation of the factors leading to shrub invasion in the semi-desert grass and shrub ranges (Humphrey, 1954).

TABLE 6. Density of forbs (number per m²).

Species	Ungrazed ^a		Grazed ^a	
	1976	1977	1976	1977
<i>Solidago mollis</i>	10.7	22.7		
<i>Artemisia ludoviciana</i>	10.0	11.3		2.0
<i>Lactuca oblongifolia</i>	8.7	29.3		
<i>Gaura coccinea</i>	4.0		29.3	1.3
<i>Rosa arkansana</i>	3.3	1.3		
<i>Symphoricarpos occidentalis</i>	2.0			
<i>Tragopogon dubius</i>	1.3			
<i>Sphaeralcea coccinea</i>	0.7	2.0	0.7	2.0
<i>Lygodesmia juncea</i>	0.7	2.0	0.7	2.0
<i>Chenopodium desiccatum</i>	0.7			
<i>Psoralea argophylla</i>		1.3		0.7
<i>Aster ericoides</i>		7.3	8.7	33.3
<i>Antennaria parvifolia</i>			25.3	14.7
<i>Artemisia frigida</i>			22.7	10.0
<i>Phlox hoodii</i>			7.3	19.3
<i>Penstemon gracilis</i>			5.3	
<i>Lithospermum incisum</i>			4.0	4.0
<i>Ratibida columnifera</i>			1.3	1.3
<i>Oxytropis lambertii</i>			1.3	1.3
<i>Petalostemon purpureum</i>			0.7	4.0
<i>Coryphantha</i> spp.				2.0
Misc. forbs			2.8	2.7
Total	42.1	77.2	110.1	100.6

^a Average of twelve 0.125 m² quadrats in each of the years 1976 and 1977.

TABLE 7. Soil temperatures ($^{\circ}\text{C}$) under grazed and ungrazed sites. The skies were clear until 1 hr. before the readings and then a complete overcast developed. Readings were taken at approximately 12:30 M.S.T. on June 23, 1977.

Depth (cm)	Soil Temperature ($^{\circ}\text{C}$)	
	Ungrazed ^a	Grazed ^a
2.5-7.6	24.5	28.8
10.2-15.2	21.7	24.3

^a Average of six measurements at each depth.

TABLE 8. Soil Bulk density (g cm^{-3}).

Depth (cm)	Bulk Density (g cm^{-3})	
	Ungrazed ^a	Grazed ^a
0-15	1.12	1.29
15-31	1.38	1.38
31-46	1.34	1.31
46-61	1.39	1.40
61-76	1.37	1.45
76-91	1.44	1.48
91-122	1.37	1.37

^a Average of three samples in 1976 at each depth.

Regardless of the successional interpretation of the grazed community, it is ecologically beneficial. The vegetation's resistance to grazing is a major factor in the preservation of the site under perennial heavy use by cattle and is an example of the establishment of a balanced relationship between the grazing animal and range vegetation.

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BIVALVE MOLLUSK RANGE EXTENSIONS IN THE FOX HILLS FORMATION (MAESTRICHTIAN) OF NORTH AND SOUTH DAKOTA AND THEIR IMPLICATIONS FOR THE LATE CRETACEOUS GEOLOGIC HISTORY OF THE WILLISTON BASIN

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ABSTRACT

The marine bivalves *Clisocolus moreauensis*, *Cuspidaria ventricosa*, and *Periploma (Aelga?) subgracile* are recorded from the Fox Hills Formation (Maestrichtian) in Emmons County, North Dakota, for the first time. *C. moreauensis* was taken from a fossil-rich concretion zone, also containing many *Sourimis equilateralis* and *Hoploscaphites nicolleti*, in a silty shale very low in the section. The fauna is characteristic of the lower *nicolleti* Assemblage Zone and constitutes the first biostratigraphic evidence supporting recognition of the lower Trail City Member in the state. *Arctica* cf. *A. ovata*, typically a Cannonball (Paleocene) species, is recorded for the first time in the Fox Hills Formation in Emmons and Sioux Counties, North Dakota. This species, in consort with *Periploma subgracile*, increases the already high degree of similarity between Fox Hills and Cannonball bivalve faunas. *C. moreauensis*, *S. equilateralis*, *P. subgracile*, and *A. ovata* are elements of the North American Boreal Faunal Province and indicate close ties with Late Campanian-Maestrichtian faunas of Canada, although in the Fox Hills they are mixed at times with species having Gulf Coast origins. Presence of *Arctica* indicates temperate water conditions existed in North Dakota above the *Sphenodiscus lenticularis* ammonite zone.

Linkage with the Gulf Coast ceased late in Fox Hills time when deltaic deposition along and against the Sioux Arch joined the eastern and western strands. The Dakota Isthmus, a broad tidal floodplain dominated by brackish faunas, resulted from this union and separated the regressing sea into northern and southern basins at 45° latitude. Northward marine connections through the Canadian Arctic and Hudson Bay were terminated, but the Hudson Bay connection was re-established in Paleocene time providing a marine entry to the Williston Basin across the Canadian Shield. The resulting Cannonball Sea had a temperate fauna with a composition similar to those of the Paleocene Paris Basin.

INTRODUCTION

Through the efforts of several workers the fossil fauna of the Upper Cretaceous (Maestrichtian) Fox Hills Formation in North and South Dakota has been thoroughly examined over the past fifteen years. Because they are generally well-preserved and dominate collections, the Bivalvia have received most attention. Speden (1970) described 58 bivalve species in 49 genera from the formation in the Missouri Valley of South Dakota, and in 1972, Feldmann listed 42 species in 25 genera from the equivalent region in North Dakota. Feldmann and Kammer (1976) have subsequently redescribed one of the North Dakota taxa as *Crassatellina hollandi*.

Most of the paleontologists participating in this work have noted that Fox Hills faunas seem to be less diverse and less abundant in the North Dakota sections. Small-and-large-scale paleogeographic reconstructions which rely upon both knowledge of sediment distributions and upon dispersion of contained faunas require precise geographic and stratigraphic occurrence data to be successful. Because such reconstructions are of continuing interest to geologists it is deemed appropriate herewith to document newly recognized bivalve finds for the Fox Hills in North Dakota and to note their significance.

SYSTEMATICS AND LOCALITY DATA

Expediency dictates that this report follow the most recent thorough faunal revision. Systematics employed follow Speden (1970) with few exceptions.

Localities from which specimens were collected for this study are listed below according to the St. Lawrence University Geology Department Accession File numbers. These reference numbers will be utilized throughout the subsequent text.

- A103 NE1/4, Sec. 28, T.133N., R.77W., Emmons Co., N. Dak. *Tellinimera* concretion zone (?) in Timber Lake Mem., Fox Hills Fm.
- A116 NW1/4, Sec. 15, T.131N., R.80W., Sioux Co., N. Dak. Weathered from sand of Timber Lake Mem., Fox Hills Fm.
- A120 Sec. 11, T.130N., R.79W., Emmons Co., N. Dak. Fossils in place in Timber Lake Mem., Fox Hills Fm.
- A134 NE1/4, Sec. 5, T.129N., R.80W., Sioux Co. Stream cut in Timber Lake Mem., Fox Hills Fm.
- A142 NW1/4, Sec. 32, T.131N., R.77W., Emmons Co., N. Dak. Fossils in 2 ft.-thick indurated ledge in Timber Lake Mem., Fox Hills Fm.
- A187 Sec. 13, T.132N., R.76W., Emmons Co., N. Dak. Fossils from concretions dug from silty shale of Lower *nicolleti* Assemblage Zone, Trail City Mem., Fox Hills Fm.

BIVALVE RANGE EXTENSIONS

Sourimis equilateralis (Meek and Hayden). — For its bearing upon clarification of Fox Hills stratigraphy it is appropriate to introduce the combination *Sourimis equilateralis* to the North Dakota literature. Feldmann (1972) recorded *Tellina equilateralis* Meek and Hayden from North Dakota. Speden (1970) erected the genus *Sourimis* designating *T. equilateralis* Meek and Hayden as its type species. *Sourimis equilateralis* (Figure 2d and e) was collected both from the Timber Lake Member, in which it is rare, and from a fossil-rich concretion

zone well below the Timber Lake Member, in which it is abundant. Significance of the latter occurrence is discussed later in this report.

Arctica cf. *A. ovata* (Meek and Hayden). — Record of a species of *Arctica* from the Fox Hills Formation is made here for the first time. It is based upon two complete specimens from Emmons County (Figure 1a-d; Figure 2a) and one poorly preserved valve from Sioux County (Loc. A134). Meek and Hayden's literature contains description of *A. ovata* found near the mouth of the Heart River with Fox Hills rocks suggested as the origin of their material, but Cvancara (1966) verified that the Paleocene Cannonball Formation, not the Fox Hills, was the source of their specimens. Speden (1970) did not record *Arctica* during his research.

A. ovata is a common species in the Cannonball, yet it has also been mentioned as common in Upper Cretaceous units of Alberta (Russell and Landes, 1940). Today the only extant species, *Arctica islandica*, is restricted to cold temperate waters of the North Atlantic (Nicol, 1951).

Material here designated *A. cf. ovata* was taken from the Timber Lake Member approximately 3 meters above a zone of the cephalopod *Sphenodiscus lenticularis* (Owen). Double-valved specimens were in good condition, showing no sign of post-mortem transport. They agree well with the range of morphological features presently ascribed to *A. ovata*. It is notable, however, that valves are slightly more massive and inflated, teeth somewhat stronger, and the hinge plate slightly more curved than on specimens of *A. ovata* from the Cannonball Formation.

Clisocolus moreauensis (Meek and Hayden). — This inflated, thick-shelled bivalve superficially resembles the common Fox Hills species of *Cucullaea*, but its heterodont hingement and non-buttressed adductor insertions immediately distinguish it from that genus. Speden (1970) found *Clisocolus moreauensis* to be an abundant element in faunas of the lower Trail City Member in South Dakota although it has not been previously recorded in North Dakota.

Figure 2b and c illustrates two specimens of *C. moreauensis* which are well preserved steinkerns from a concretion zone toward the base of the Emmons County section. Several additional specimens were recovered from the locality although much of the scientifically important material, demonstrable from shattered remains and empty molds, had been carelessly plundered by amateurs prior to my arrival. *C. moreauensis* belongs to a group of Late Campanian-Maestrichtian species described from eastern Wyoming, South Dakota, Alberta, and the Socia Islands region of the Pacific Coast. Speden (1970) noted a high degree of similarity among the species and suggested probably synonymy of the Western Interior forms with *C. moreauensis*.

Periploma (Aelga?) subgracile (Whitfield). — Based upon 17 specimens, most from the Timber Lake Member, Speden (1970) diagnosed *Periploma subgracile*, a rare element in the Fox Hills bivalve fauna of South Dakota. Similar scarcity of the species is apparent in North Dakota, as it was not found during Feldmann's thorough study, nor have I encountered it more than once. In Emmons County it occurs in a thin (0.3m) indurated lense of very fine sandstone a few meters above

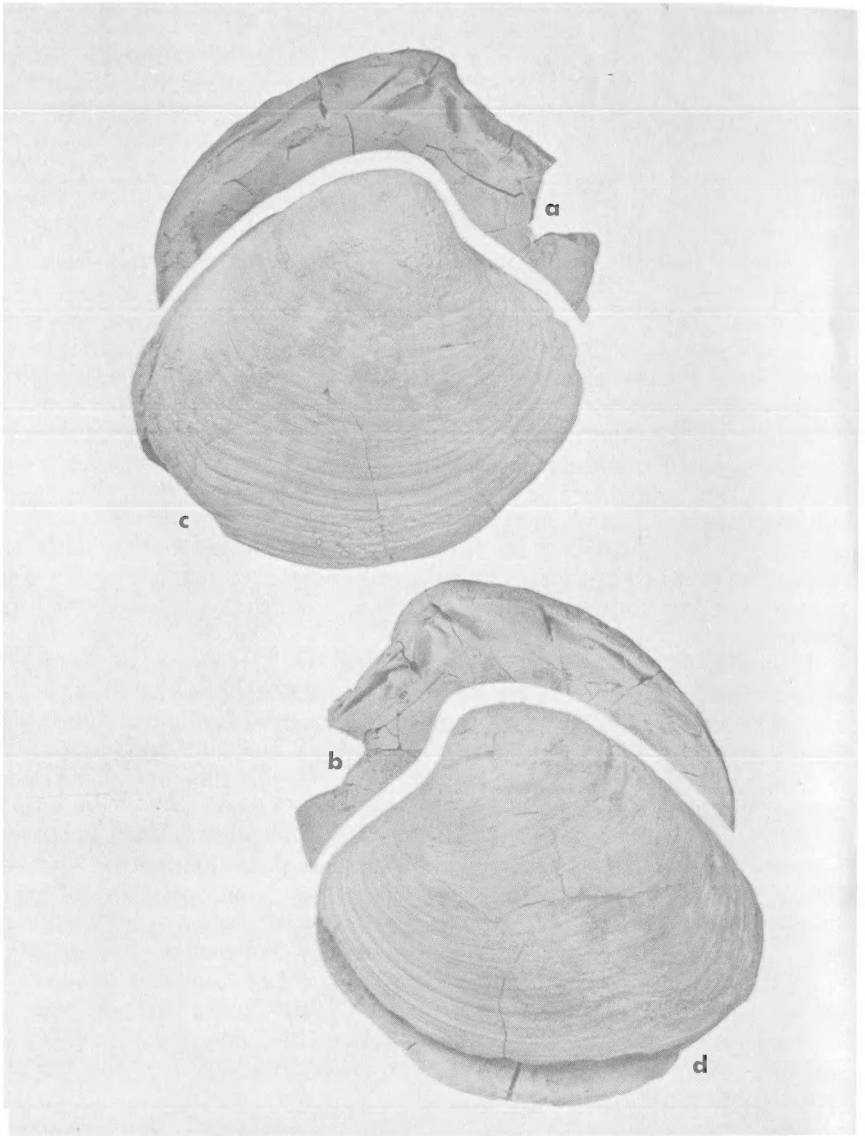


FIGURE 1. Dentition and exterior of *Arctica* cf. *A. ovata*, Fox Hills Fm., N. Dak. Left (a) and Right (b) valve dentition, SLU 505, Loc. A120, X 1; Exterior of Right (c) and Left (d) valves, SLU 506, A120, X 1. (Specimen Numbers refer to St. Lawrence University Geology Department Faculty Research Collection: Locations are listed in text.)

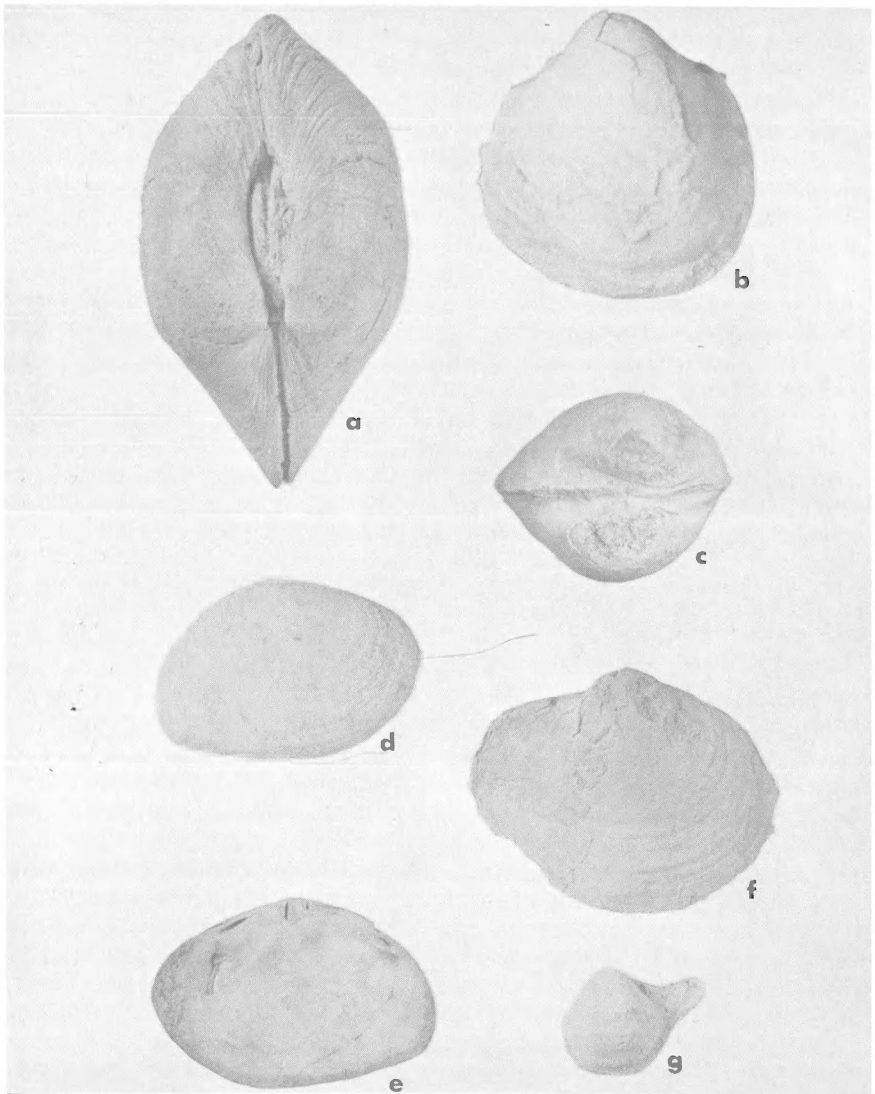


FIGURE 2. Dorsal view (a) *Arctica* cf. *A. ovata*, SLU 506, X 1; Right valve (b) *Clisocolus moreauensis*, SLU 501, A186, X 1; Dorsal view (c) *C. moreauensis*, SLU 502, A186, X 1 (both specimens partially decorticated steinkerns); Exterior (d) and interior (e) Rt. valve of *Sourimis equilateralis*, SLU 507, A116, X 1; Exterior (f) (posterior decorticated exposing mold of pallial sinus) of Rt. valve of *Periploma* (*Aelga*?) *subgracile*, SLU 504, A142, X 1.2; Steinkern (g) Lt. valve of *Cuspidaria ventricosa*, SLU 503, A103, X 2.

weathered sandstone concretions containing fragments of *Sphenodiscus*. All six specimens of *P. (A?) subgracile* (Figure 2f) from this unit are double-valved, very thin-shelled, and slightly to highly crushed.

Speden (1970) reassigned with doubt *Laternula? subracilis*, described by Cvancara (1966) from the Cannonball Formation, to *Periploma* indicating it to be conspecific with Fox Hills specimens. If this assignment proves valid in the future, it appears that *P. subgracile* should be additionally assigned to *Periploma (Aelga)* (*sensu* Cox *et al.*, 1969) rather than to *P. (Periploma)*, a decision I base upon general valve shape and depth of pallial sinus in the Fox Hills material. If correct the stratigraphic range of *P. (Aelga)* cited by Cox, *et al.*, as Oligocene to Miocene, and the geographic range (N.E. Asia), must be extended into the Maestrichtian of the Western Interior of North America. *P. johnsoni* Landes (in Russell and Landes, 1940) from the Foremost Formation (Campanian-Maestrichtian) of Alberta may be conspecific with *P. subgracile* as suggested by Speden.

Cuspidaria ventricosa (Meek and Hayden). — One specimen of this diminutive taxon is represented by a mold of the interior of the left valve taken from a Timber Lake Member sandstone concretion (Loc. A103) in Emmons County. The thick, but fragile, shell decorticated during preparation, but the specimen (Figure 2g) satisfies Speden's (1970, p. 155) description of *C. ventricosa* from South Dakota quite closely. He found the species in both Trail City and Timber Lake sediments in South Dakota, but this is its first mention from North Dakota.

STRATIGRAPHIC IMPLICATIONS

From the Missouri Valley of South Dakota northward the expanse of Fox Hills outcrop decreases, and with it decreases the ability to trace facies boundaries and thus to define stratigraphic units clearly. Because the Trail City Member, basal in the Fox Hills sequence, crops out in a limited number of locations, Feldmann (1972) suggested that it was not sufficiently developed in North Dakota to be recognized. In part this was due to lack of fossil assemblages deemed characteristic of the lower Trail City (Waage, 1968).

Erickson (1974) expressed the opinion that, although rich lower Trail City faunas were not everywhere present, several outcrops do contain demonstrable thicknesses of Trail City sediments in both Sioux and Emmons Counties. The Upper *nicolleti* Zone of Waage (1968) was the only Trail City assemblage documented in the state at that time. Other workers (Cvancara, 1976; Klett and Erickson, 1976) have accepted the existence of Trail City lithologies in the North Dakota section yet remained mindful that the unit does not manifest the full suite of facies and assemblages defined by Waage.

Waage's (1968) lowest assemblage zone in the Trail City, the "Lower *nicolleti* Zone", contains an abundant molluscan fauna of more than a dozen species. Prominent among them are the ammonite, *Hoploscaphites nicolleti*, and bivalves *Sourimis equilateralis*, *Clisocolus moreauensis* and several protobranch species. Speden (1972, p. 111) noted that *C. moreauensis* is "virtually restricted

to the Trail City Member, with 67.2 percent of specimens coming from the Lower *nicolleti* Assemblage Zone." About *S. equilateralis* he wrote (p. 135), "A rare species virtually restricted to the Lower *nicolleti* Assemblage Zone (94.7%). The remaining two specimens . . . came from the *Protocardia-Oxytoma* Assemblage Zone." Although restriction of this latter species is not as complete as Speden's statement implies the strength of his data is most significant.

During this study [numerous specimens of *C. moreauensis* and *S. equilateralis* were taken from a zone of dense, silty, limestone concretions near the base of the Fox Hills section in Emmons County. They were accompanied by many *H. nicolleti*, several species of nuculacean bivalves, *Protocardia subquadrata*, rare specimens of *Pseudoptera subtortuosa*, *Tellinimera scitula*, *Oxytoma nebrascana*, and gastropods *Graphidula* sp., *Drepanochilus evansi*, *Serrifusus dakotaensis*, and *Oligoptycha concinna*, all in approximate order of abundance. The assemblage in which these taxa dominate is indicative of the Lower *nicolleti* Assemblage Zone and demonstrates that the light gray, silty shale in which it was found represents the Lower Trail City Member in Emmons County and further justifies use of that unit in North Dakota stratigraphy.

PALEO GEOGRAPHIC SPECULATIONS

Although the general Late Cretaceous paleogeographic setting of the northern mid-continent is rather well understood from both fossil and sediment distributions, a precise interpretation of the closing events and corresponding paleogeography has not been formulated. Recent expansive treatments of the Late Cretaceous seaway that crossed the North American continent, include those of Kauffman (1973), Jeletzky, (1968, 1971), Sohl (1967, 1971), and Williams and Stelck (1975). In the local region Gill and Cobban (1973), Erickson (1973), and Klett and Erickson (1976) have presented a variety of observations bearing on Fox Hills paleogeography. Each of these studies has been enlightening; yet as they focus attention upon the last strandlines of that seaway, each has provided more questions than answers.

Faunal studies clearly demonstrate the presence of representatives from two biotic provinces "mixed" in Fox Hills rocks, but none demonstrates conclusively when mixing occurred, from whence the various elements immigrated nor their migrational pathways during the Maestrichtian. Careful mapping of the regressive strandline (Gill and Cobban, 1973) has been accomplished through the ammonite zone of *Baculites clinolobatus* in the Lower Maestrichtian — below Fox Hills deposits in North Dakota — without resolving the position of the eastern strand (perhaps an insoluble question) and without discussing final regressive pathways. Such questions may appear inconsequential except that there is as yet no conclusive evidence for the route of returning seas which produced the Paleocene Cannonball marine deposits in North Dakota.

Maestrichtian molluscan faunas of Canada are not yet known with enough precision to permit full answers to questions of faunal migration routes. Cephalopods, bivalves, and gastropods all demonstrate an increasing degree of

latitudinal provincialism at this time (Jeletzky, 1971; Erickson, 1973) and provincial overlap is strong in the Fox Hills type area. Four of the bivalves discussed in this report, *C. moreauensis*, *S. equilateralis*, *P. subgracile*, and *Arctica ovata* offer direct linkage with the North American Boreal Province (Jeletzky, 1971) and markedly increase the cooler water "appearance" of Fox Hills faunas in North Dakota.

Arctica is a particularly significant addition to the fauna. After an extensive survey of the distribution of the only living species, *Arctica islandica*, Nicol (1951, p. 104) concluded that *Arctica* is a genus with boreal, but not Arctic, distributions in the North Atlantic. In Campanian and Early Maestrichtian rocks of Canadian North America *Arctica ovata* is a frequent element (Russell and Landes, 1940) indicating a temperate oceanic climate during their deposition (Jeletzky, 1971). That relatively cool water condition may be extended now into southern North Dakota during Timber Lake time based upon the presence of *Arctica* described herein.

Arctica cf. *A. ovata* and *Periploma subgracile* in the Fox Hills create a second important relationship. Because both are elements of the Paleocene Cannonball bivalve fauna (Cvancara, 1966) they increase faunal similarities between these formations and indicate the temperate character of the Cannonball seaway. Common presence of *Arctica ovata* in Cannonball sediments demonstrates conclusive ties of that seaway with north Atlantic waters of the opening Atlantic ocean.

Two routes seem available for that connection, one through the Arctic Ocean, the other through Hudson Bay crossing the Canadian Shield. Williams and Stelck (1975, p. 17) have proposed the operation of each of these arteries during Early Maestrichtian time. Similarities between Fox Hills ammonites and those of West Greenland (Birkelund, 1965) lend credence to a direct migration route across the shield via Hudson Bay but precise chronologic chorography of the events is still lacking.

Based upon both sedimentologic and paleontologic data I suggest (Figure 3) the following geologic history for the demise of the Fox Hills sea above the *Sphenodiscus lenticularis* assemblage zone:

1. Rapid deposition of the Pierre-Fox Hills delta platform sequence (see Pettyjohn, 1967) along and onto the Sioux Arch (probably maximum extent of Sheridan Delta of Gill and Cobban, 1973).

2. Merger of eastern and western strands of Fox Hills seaway along and over the Sioux Arch at 45° latitude, resulting in a temperate Dakota Sea to the north and a subtropical-to-tropical Mississippi Embayment Sea to the south during Maestrichtian time.

3. A very broad, tidal floodplain having complex coastline, strong estuarine influence supporting rich oyster populations, and perhaps with deltaic distributaries to both northern and southern seaways resulted from this merger. This "sea level" plain is here called the DAKOTA ISTHMUS (see Figure 3).

4. Regression continued with Hell Creek terrestrial sediments filling the Williston Basin. Similar deposition may have closed the passage to the Canadian

Arctic ocean in several areas. Fundamental northern midcontinent drainage patterns were established (subsequently altered somewhat by glaciation as noted by Bluemle in 1972).

5. Renewed tectonism (Early Paleocene), including downwarping of the Williston Basin and north Atlantic spreading with crustal disturbance on the Canadian Shield and in West Greenland (presence of Danian conglomerates and basalts mentioned by Birkelund in 1965). This permitted a marine invasion of the Williston Basin by the Cannonball Sea through Hudson Bay without a Paleocene connection to the Gulf Coast. This marine invasion brought faunas having greatest similarities to those of the Paris Basin (Cvancara, 1966). At maximum extent the Cannonball Sea may have occupied the Wind River Basin in Wyoming,

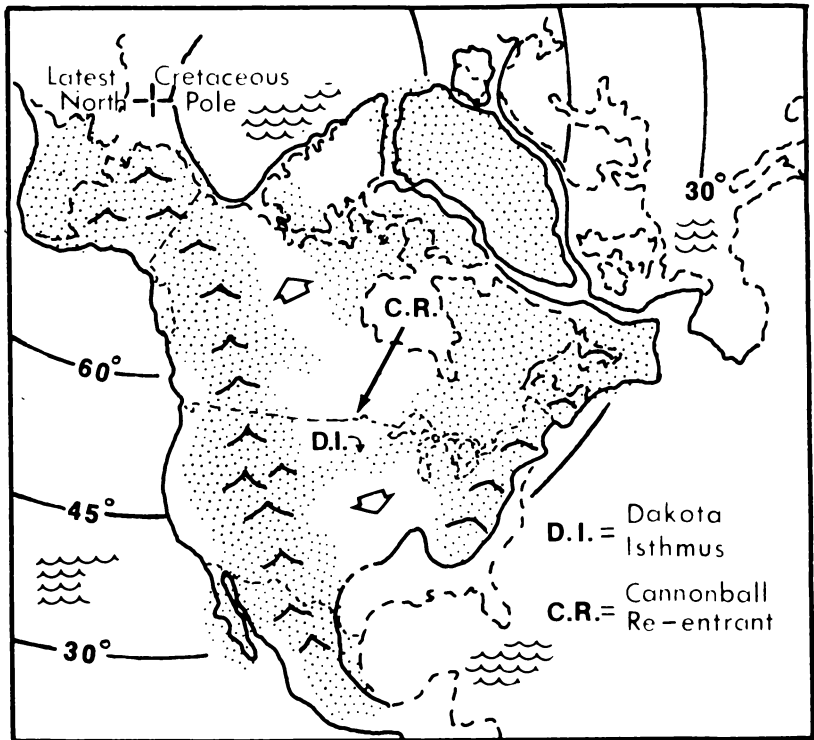


FIGURE 3. Maestrichtian paleogeography above the *Sphenodiscus lenticularis* Zone in North Dakota. Open arrows denote regressional Cretaceous seas divided by Dakota Isthmus, a deltaic platform prograding against Sioux Arch. Origin and direction of Cannonball (Paleocene) marine transgression indicated by solid arrow. (Pole and continental massing after Sloan, 1971; land configuration modified from Williams and Stelck, 1975).

perhaps temporarily drowning a Paleocene "Fort Union" drainage across the Powder River Basin, to produce the brackish Waltman Shale within the Tongue River Formation of Wyoming (Keefer, 1961).

6. Termination of the Hudson Bay connection and basin infilling by the Slope, Bullion Creek, and Sentinel Butte fluvial and deltaic facies (Clayton, *et al.*, 1977; Cherven, 1978) resulted in final exclusion of marine waters from the central midcontinent. Bullion Creek-Sentinel Butte relationships demonstrate further Paleocene downwarping of the Williston Basin in a cyclic manner but, with no further marine connection, lacustrine conditions seem to have prevailed.

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HORSES FOR SLAVES: SOME OBSERVATIONS ON ARIKARA PARTICIPATION IN THE TRADE OF THE PROTOHISTORIC NORTHERN PLAINS

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ABSTRACT

Ethnological studies of diffusion have tended to oversimplify the mechanisms by which traits are transmitted across cultural boundaries. The treatment of the diffusion of the horse on the Great Plains in the seventeenth and eighteenth centuries is typical of this approach. There has been insufficient appreciation for the role of intertribal trade in the dissemination of horses on the Plains. Arikara case study material demonstrates that horses could have been initially obtained only in exchange for human beings — slaves — for which there were markets in Spanish New Mexico and French Louisiana. Thus it is probable that warfare for the purpose of taking captives may have been widespread on the northern Plains and that the initial diffusion of the horse followed existing trade routes.

INTRODUCTION

The introduction and diffusion of horses among the Plains Indians is one of the better-studied aspects of Plains history. Since Clark Wissler's (1914) essay, much scholarly research has been directed toward discovering the source of these animals, the time and place of their introduction, the manner in which they were first acquired by the Indians, and the direction and rate of their movements across the Plains, as well as their impact on the cultures of the Plains Indians. Despite extensive research on this subject, however, comparatively little attention has been given to the mechanisms by which this diffusion was accomplished. This paper is intended to be a brief examination of some of the factors, particularly economic constraints, that may have served to facilitate or inhibit the movement of horses from tribe to tribe on the Great Plains.

The concern here is with the manner in which horses were obtained for the first time by the northern Plains tribes, with special attention given to the acquisition of horses by the Arikara Indians. It should be noted at the outset that there is no evidence presently available to pinpoint when or how the Arikaras obtained their first horses. Rather, portions of Arikara history will be used to illustrate some of the difficulties facing the Plains tribes in their efforts to get horses. The discussion will lead to the framing of a testable hypothesis concerning the diffusion of horses on the northern Plains.

Haines (1938a,b), Denhardt (1947), Roe (1955), Ewers (1955), and others have compiled a great deal of information documenting the introduction and diffusion of horses in North America. It is now considered well-established that at the beginning of the seventeenth century the Spaniards brought these animals to

their settlements near Santa Fe and that some years later Indian groups of the region took up the mounted life. As the numbers of Indian-owned horses in the Southwest increased, they began to be passed from tribe to tribe northward into the Great Basin and the Plains. By the last quarter of the eighteenth century, horses had diffused as far north as the present-day Canadian border and as far east as the Mississippi River. According to Secoy (1953), the greatest concentrations of Indian-owned horses at all times existed nearest the Spanish source of supply, from which there formed a declining gradient extending northward and eastward from New Mexico. Complementing this distribution of horses was the French fur trade, which by the beginning of the eighteenth century had pushed from Montreal to the eastern margins of the Plains. The French traders supplied firearms and other elements of iron technology to the Indians who trapped for beaver. Like the distribution of horses, says Secoy, that of firearms also formed a gradient, plentiful in the northeast and sparse in the southwest. Both of these introductions, horses and guns, were necessary to the tribes who were taking up the new life emerging on the Plains: horses for successful adaptation to the buffalo and guns for the military advantage they conferred over potential competitors. As the distribution of these two traits met and overlapped on the northern Plains, beginning after the year 1725 (Ewers 1955: 17), the "classic" Plains nomads came into being. In addition, both trading and warfare were greatly stimulated. Trade was enhanced when the Indians began to equate the value of the horse and gun for purposes of exchange. Warfare escalated as competing nomads raided each other for horses and for control of territory.

Despite the detailed knowledge accumulated by these historians, much remains to be learned. Ethnological studies of diffusion suffer from biases which inhibit a clearer understanding of the subject at hand. First of all, traditional American ethnology has tended to approach the diffusion of the horse on the Great Plains largely as a trait-distribution study: a problem to be solved in terms of time, distance, and velocity. The historiography of Plains diffusion studies can be represented as a sequence of increasingly refined maps. The result has been a neglect of the mechanics of cross-cultural transmission. Second, the horse by its very nature is unlike the majority of subjects of diffusion analysis, like ceramic design and basketry techniques, because of its inherent value; that is to say, being greatly desired by the Indians and existing in short supply, it was an economic commodity. Third, Plains ethnologists, for whatever reasons, have tended to characterize the spread of horses over the Plains as a rapid process. In fact, horses diffused very slowly, taking a century-and-a-half to be transmitted over much the same territory that the Ghost Dance covered in but a few years (Ewers 1955; Roe 1955). Too little account has been taken of factors retarding, rather than promoting, diffusion. Lastly, there has been a strong temptation in the literature to regard the horse as if it diffused itself from culture to culture, perhaps because of its obviously independent means of locomotion. But the migration of the horse, a natural process pertaining to the animal in the wild, must not be confused with its diffusion, a cultural process wherein humans controlled the animal's movements. A revised account of the diffusion of the horse should take greater ac-

count of the mechanics of the diffusion process. In order to illustrate some of the critical factors shaping the diffusion of the horse, some aspects of Arikara history will be singled out.

DISCUSSION

The Arikaras were a relatively recent offshoot of the Skidi band of the Pawnees who migrated from the Central Plains to the Upper Missouri River in South Dakota sometime in the fifteenth or sixteenth century. There they pursued a mixed subsistence strategy, tending their gardens in the river bottoms in the spring and fall and hunting the buffalo during the remainder of the year. They customarily built their villages on defensible terraces above the river, usually at the confluence of the Missouri and one of its tributaries. Situated as they were along these major "highways" of the northern Plains, the Arikaras were well-placed for trade. Prior to the advent of the horse and the fur trade, the Arikaras are believed to have maintained a small-scale trade with neighboring pedestrian nomads (see Wood 1972). This trade seems to have been based upon a natural division of labor between the two groups. Most probably the women of both groups were the principal traders, exchanging the products of the garden for the products of the hunt (Wood 1972:159). It is not known whether men were engaged in trade at all during this period. Many of the imperishable artifacts recovered from early Arikara components have their origins far from the Upper Missouri region (Lehmer 1954:163; George 1949:18, 36; Johnston and Hoffman 1966:51, 57), indicating that even in prehistoric times the Arikaras were linked to a transcontinental trade network.

Although it will probably never be possible to fix the date of the first Arikara horses with certainty, an approximation can be made. The archaeological record is not helpful here, for horse bones are poorly represented in Arikara components, even in later occupations when the Arikaras are known to have had horses. The French explorer La Verendrye (Burpee 1927:337) reports Arikara horses in 1738, but there is evidence that this tribe had acquired them somewhat earlier. The Dakota winter counts, pictographic mnemonic devices kept to mark the significant events of the previous year, provide some useful information in this context. Battiste Good's Winter Count relates that Dakota groups "Brought-home" Arikara horses in 1718-1719 (Mallery 1893, I:297). Although it is not indicated whether the Dakotas got their horses by raiding or trading for them, the fact that they bothered to go to the Arikaras to get them indicates that, by 1718, the Arikaras had a sufficient number of horses to make such a trip worthwhile. Moreover, if the Arikaras were well-mounted in 1718, the date of the horse's first appearance among them must have come considerably earlier if they were to have time to become familiarized with the animals and to have built up sufficient numbers. In sum, a date of 1700-1710 for the first Arikara horses does not seem unreasonable, although it is admittedly speculative. Considering the northerly location of the Arikaras, this would seem to be a rather early date of adoption. The Blackfeet did not get their first horses until after 1725 (Ewers 1955:17),

while the Mandans did not receive any until after 1743, since they had none at the time of La Verendrye's visit (Burpee 1927). There would seem, then, to have been factors other than distance from the source affecting the date of horse-acquisition.

Concerning the source of the first Arikara horses, two possibilities that the Arikaras obtained them through raiding or the capture of wild horses, can be disposed of immediately. Denhardt (1947:103-04) refutes the myth that the Plains tribes obtained their first horses through capture: in order to handle, care for, and train even domesticated (let alone wild) horses, it is first necessary to be familiarized with them. The same restriction applies to raiding for horses (Ewers 1955:14). That the Plains tribes learned horsemanship only from other Plains tribes or from the Spaniards — and not independently, as would be expected if they had tamed wild horses — is suggested by the fact that Plains horsemen widely followed the Spanish custom of mounting from the right side (Roe 1955:63-65); the probability that such a uniform practice could have arisen by chance is small.

If it is true that the Arikaras did not acquire their first horses either by capture or by raiding, they would almost certainly have obtained them peacefully from some people already knowledgeable about them. Moreover, that source would have had to own sufficient numbers in order to be willing to dispose of some of them, or else to have wished to gain something equally valuable. There are several potential sources of the first Arikara horses: the Siouan villagers living downstream from the Arikaras, the closely related Skidi Pawnees, and the buffalo-hunting nomads with whom the Arikaras had been trading since prehistoric times. For reasons given below, these nomadic trading partners would seem to have been the likeliest of the three. Who these people were is unknown, but in the subsequent protohistoric period they have been tentatively identified as the Kiowas, Padoucas (Apaches), Gatakas (Kiowa-Apaches), and Ietans (perhaps a Ute-Apache group) (Secoy 1951:529; Hyde 1959:149). These tribes are believed to have made expeditions to the south for Spanish trade goods and horses (Hyde 1959:172).

While nomadic tribes were already linked to the Arikaras through a prehistoric tradition of trade and may have been sufficiently well-supplied with horses in 1700, it would require something more to persuade them to part with these valuable animals. It is unthinkable that they would have given away what they are known to have held so dear in later times. Some writers seem to have more or less automatically assumed that the Arikaras exchanged garden produce and tobacco for their first horses — that the protohistoric trade pattern was an extension of prehistoric practices and that horses simply became an additional article in that trade (see Hyde 1937:17). But this is improbable economics. Two considerations must be interjected: spheres of exchange and equivalency of value. Spheres of exchange refer to bounded cycles of production and exchange which are the products of both normative and non-normative constraints on these activities (Barth 1967). While the evidence for Arikara spheres of exchange is

fragmentary (Chittenden 1902, I: 117; Ewers 1950: 203), there are nevertheless indications that certain classes of items were exchangeable only for other classes of items. The women's trade in foodstuffs and clothing appears to have comprised such a sphere, for there is no mention in the nineteenth-century fur traders' journals of food or clothing having been traded for other kinds of articles. A second sphere involving the exchange of horses for firearms and ammunition seems to have been well-established by the protohistoric period. This sphere was the domain of the men, but it appears that the initial negotiations with the nomadic tribes were handled and the prices fixed by the chiefs (Thwaites 1904, V: 129-30, VI: 111; Abel 1939: 137-46). A third sphere, pertaining to the fur trade and also engaged in by the men, was established by the late eighteenth century (Thwaites 1904, V: 130, 132, VI: 114; Thwaites 1904-05, VI: 89; Beaugard 1912; Drumm 1920; Abel 1939). If the horse-trade had been confined to a separate sphere of exchange, governed by customary and perhaps religious constraints, many categories of items might have been prohibited from exchange.

Second is the matter of equivalency. After 1750, the Arikaras would have had no difficulty finding something to exchange for horses: it became customary throughout the Plains for a horse to be traded for a muzzle-loader and a hundred rounds of ammunition, or some multiple of that combination (Abel 1939: 158; Ewers 1968: 27). But in the era before the presence of firearms on the northern Plains there is some difficulty identifying an article valuable enough to exchange for a horse. Garden produce would have been clearly inadequate, for how many measures of corn or tobacco would have been considered equal to a horse? Moreover, the sheer bulk involved would have made transporting it prohibitively difficult. The two kinds of articles simply were not suited to easy exchange. It therefore seems highly improbable that the Arikaras ever established a horse-trade in this manner.

ANALYSIS

In searching for some other medium of exchange with which horses could have been procured, two would seem plausible. The first is women. It is possible that the Arikaras were giving their women to the nomads or to the Skidi in return for bridewealth in the form of horses. However, it would then be necessary to look for conditions under which the horse-trading tribes would consider themselves poor in women. Such conditions do not readily come in mind, since it is likelier in the case of the buffalo nomads that the sex ratio would have favored females, owing to the hazards of warfare and male occupations. And while it is true that, under fur trade circumstances, having multiple wives became advantageous for processing buffalo robes (see Lewis 1942: 38), there was no widespread trade in robes at this early date.

A second and likelier possibility is that the Arikaras were engaged in the slave trade. Slavery as an institution on the Plains antedates European contact (Magnaghi 1971: 46-51). The Spaniards are also known to have practiced

slavery, and soon after settling in the Southwest they were enslaving conquered Indians to work on the *encomiendas* and in the mines (Magnaghi 1971:11-21, 153-56). But a large-scale trade in slaves developed only after 1964, when the Navahos discovered that the Spaniards would pay good prices for their war captives (Magnaghi 1971:68-69). By 1700, the Indians were regularly trading their slaves (as well as kidnapped Spaniards) for Spanish horses, manufactured goods, and agricultural products, while the French in Louisiana were willing to exchange arms and ammunition for Indian slaves (Magnaghi 1971:73, 140). Taos, Pecos, and the Wichita villages became centers of this trade (Hyde 1959:102-03; Magnaghi 1971:135). This business in slaves was a profitable one for both the Spaniards and the French, although it was necessary to disguise it as the ransoming of unfortunate captives and thus keep it secret from their respective governments in Europe (Hyde 1959:81-82).

Many of the Plains tribes raided for slaves, and virtually all were victims at one time or another (Jablow 1950:24; Secoy 1953:38, Ewers 1955:311; Hyde 1959:15, *et passim*). On the southern Plains the principal slave traders at various times were the Navahos, Utes, Apaches, and Pawnees (who traded with the French) (Hyde 1959:44, 46, 78, 135; Magnaghi 1971:25-29, 131). But the foremost were the Comanches, who sold large numbers of captives to both the Spaniards and the French, in the latter case through Wichita middlemen (Magnaghi 1971:34, 161).

Outside the southern Plains there is little documentation for a trade in war captives, but occasional instances of slave raiding and trading are recorded in the northern Plains. In a situation much like that suggested here for the Arikaras, Secoy (1953:38) writes of the Shoshones during the period, 1735-1765, that:

The pressing need of this tribe for European metal goods, horses, and mules was partially satisfied by direct trade in New Mexico and by trade with Comanche kinsmen to the south who acted as middlemen. The tribe's main problem was to find a commodity of exchange which was sufficiently valuable, transportable, and plentiful to support this trade in some volume. Buffalo hides were not satisfactory, because their relatively low value and large bulk made their transportation for such a tremendous distance hardly worth while. The solution appears to have been a trade in war captives, for such a commodity was not only valuable but, in addition, could transport itself to market. And the need for captives further stimulated the warfare with the surrounding tribes that had originally been started by the physical expansion of the Snake into the Northern Plains. The Snake raided for captives continuously and on a large scale, in order to exchange them for goods and horses in the south, while the victimized tribes raided for vengeance and to acquire badly needed horses, so that they might equip themselves fully for war and the mounted, nomadic hunting life.

This is not the only example of such practices. At a later date the Blackfeet were selling female slaves to the British (Lewis 1942:49-50). The Arikaras, too, are reported by Brackenridge (Thwaites 1904, VI:128) to have owned slaves in 1811, although there is nothing to indicate that they were trading in anything but prostitution at that time.

CONCLUSIONS

The evidence, then, concerning an Arikara slave trade in the early eighteenth century is circumstantial. The need for extensive knowledge about horses would have almost compelled the Arikaras to obtain their first horses through trade with a friendly source. Before the Arikaras obtained their first guns, they would have little to offer in exchange for horses other than human beings. Markets for Indian slaves and a trade in such war captives did come into existence on the Plains near the end of the seventeenth century. The formation of this trade coincided roughly with the period of Arikara horse-acquisition. The Arikaras are known to have maintained peaceful trading relations with equestrian tribes having frequent access to the markets of Santa Fe and Taos. At least one other northern Plains tribe, the Shoshone, is known to have sold war captives for horses at these markets, via Indian middlemen. And finally, the Arikaras are known to have kept slaves during the historic period.

Beyond the circumstantial evidence, there is little to the case for Arikara slave-trading other than the expression of possibilities. The Arikaras could have been carrying on a trade in captives with the Pawnees or one of the equestrian tribes living in the Black Hills region. Who might have been the victims of such Arikara slave raids is completely open to speculation: Dakotas, Mandan-Hidatsas, Omahas, Poncas — it could even have been other Arikara villages.

In the absence of historical evidence for Arikara slave-trading, what remains is to suggest an hypothesis: that in order to obtain their first horses, the northern Plains tribes were forced to exchange human beings, having no other article suitable for trade until the introduction of firearms. With a broader range of societies in which to search for information the potential for confirming or disconfirming the hypothesis is increased. If found to be correct, it would help to explain the relative slowness of the horse's diffusion: a tribe's need to build up a supply of livestock for its own use in hunting, warfare, and transportation would result in a lengthy interval between the time it received its first horses and the time it began trading some of them away to more northerly tribes. The relatively early acquisition date of the Arikaras could be accounted for by their participation in what appears to have been an old and central trading network, one with important connections in Southwestern markets. By extension to other cases, this could point to the relatively greater importance of trade connections over simple geographical location in the early years of horse diffusion. The current picture of Plains history would also be modified somewhat to represent warfare and slave-raiding as endemic in the areas just beyond the frontier of horse-ownership. Thus not only would the horse have intensified warfare among the Plains tribes after its adoption, but before it as well.

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