Proceedings of the Iowa Academy of Science

Volume 82 | Number

Article 1

1975

Cover - 1975 Centennial

AN|MATERIALS|ENVIRONMENT|ENERGY

The Proceedings of The Iowa Academy of Science

Volume 82 July, 1975 Number 2

Guidelines for Authors

1. The *Proceedings of the Iowa Academy of Science* is a quarterly publication, issued by the Iowa Academy of Science.

2. The *Proceedings* publishes original research in the various fields represented by its membership, short research notes, authoritative review articles, informed commentaries by scientists on topics of general interest, articles dealing with science teaching, and other material of interest to its members. As the publication of a multidisciplinary scientific organization, it welcomes material of general interest to the scientific community. We will not publish previously copyrighted material.

3. Manuscripts should be sent to the editor, Dr. T. E. Rogers, Department of Biology, Cornell College, Mt. Vernon, Iowa 52314.

4. The Editorial staff will examine manuscripts from members of the Academy or from other workers in scientific fields. Papers will be submitted to referees for critical evaluation and accepted or rejected for publication on their recommendations and those of the editors. Preference for space will be given to manuscripts by members, and to papers based on talks delivered at the annual meetings or other meetings of the Academy. Non-members will be subject to a page charge, based on the actual cost of publication.

5. Research notes should consist of a short introductory statement, a brief statement of the materials and methods used, and a report of the new data obtained. They should run no more than three or four double-spaced pages. Longer articles are best handled as regular research papers.

6. The manuscripts must be typewritten, double-spaced throughout, *including tables, footnotes, figure captions,* and *references.* Submit an original and a copy of the manuscript and 2 copies of the illustrations. One of the illustration copies is to send with the manuscript to the reviewer and need not be a top quality reproduction.

Authors should refer to the style manual appropriate to the discipline for details of style, and format. References should be arranged and cited in accordance with the instructions in such style manuals. If doubts exist as to a suitable style manual, it may be necessary to consult the Associate Editor who may be involved in the review and who is named inside the back cover of this journal.

Use italics (indicated by underlining) for generic and specific names, for the titles of books, and for the names of journals.

If abbreviations are used they should conform to those approved in the appropriate abstract service. Chemical terms should be consistent with the system used in the index of the *Chemical Abstracts.*

Use the binomial Latin name of organisms in full when they are first mentioned, underlining them to indicate italics. Subsequently the generic name may be abbreviated, or, if preferred, the common name may be used, if it has been introduced with the full name originally.

The scientific name of a chemical must be used when the compound is first referred to. If abbreviations or popular or trade names are to be used, place them throughout the text.

It is preferable to define the concentration of solutions in terms of normality or molarity, or as the wt of solute in a definite volume of solvent. Use % only to express g/100g of solution. Use % (v/v) to express ml/100 ml of solution.

Extensive footnotes will be treated as an appendix and placed at the end of the text.

Do not write out numbers except at the start of a sentence or where no space is saved by using numbers. Use 2nd rather than "second" in labels, legends, and technical descriptions. Use chemical formulae for common chemicals.

7. Papers dealing with teaching, laboratory techniques, or experiments, should include all pertinent data on apparatus, specifications, suitable brand names, etc. The Academy encourages reviews, descriptions of unusual programs, courses, annotated bibliographies, or other materials which may be of interest to the membership.

Illustrations

Plan illustrations so they will fit, or can be reduced legibly, to a single column or a page. The maximum size of a figure is 182 mm by 232 mm for a whole page and 88mm wide for a single column. If larger illustrations are sent, they must be accompanied by smaller photographs of good quality to permit reviewing.

Drawing and lettering should be in black India ink or white, blue tracing, or blue-lined paper. Letters or numbers should not be less than 1.5 mm high when reduced. Lettering should be done by some dry transfer process or a lettering set of some sort. We strongly discourage free-hand lettering and drawing, Mount photographs on white bristol board or the equivalent. Where possible, group figures to fit a page, allowing room for the figure caption at the bottom. The figure numbers of grouped figures should be drawn at the lower right-hand corner of each figure, large enough to be 3 mm high after reduction. Number all figures in a single series (Figs. 1, 2, 3 . . .) even though grouped on one or several pages. To avoid problems created by reduction, show magnification of figures by a scale on the figure itself.

Please indicate in the typed manuscript the approximate location of each figure.

Where an excessive number of figures is included with the manuscript, the authors may be asked to help defray the cost of engraving. The editor will notify authors in advance, if this is to be the case, and give approximate costs. No color figures can be printed.

Charges

Authors will be subject to page charges should a double-spaced manuscript run over 30 pages. Authors are also subject to charges for changes in the galley proof, other than printers' errors, if they go beyond four lines.

Reprints may be ordered from the editor at the time the gallery proofs are returned. Note the reprint costs as indicated inside of the back cover. Full details on any page charges or costs of illustrations will be sent to the acthor with the gallery proof.

Note to Subscribers

Back copies of the *Proceedings* can be obtained from the Librarian, Iowa State Univ., Ames, Iowa 50010. Annual volumes are priced at $4.00 through 1970. The quarterly issues, beginning in 1971, are $3.00 per issue. The four issues making up a year's printing are priced at $8.00. Orders for back copies should be sent to the Executive Secretary, Dr. Robert Hanson, Dept. of Chemistry, Univ. of Northern Iowa, Cedar Falls, Iowa 50613.

Subscription to the *Proceedings of the Iowa Academy of Science* is included in the membership dues of the Academy. The annual dues are $10.00 for regular members; $4.00 for student members. Application blanks for membership may be obtained from the Executive Secretary, at the address listed above. Any member or subscriber whose address changes during the year should notify the Executive Secretary.

The Proceedings of The Iowa Academy of Science

Volume 82 — July 1975 — Number 2

Table of Contents

The Proceedings of the Iowa Academy of Science, Vol. 82, No. 2, July 1975. Published quarterly by the Iowa Academy of Science. Executive Secretary, Robert Hanson, University of Northern Iowa, Cedar Falls, Iowa 50613.

The History of the Atmospheric Sciences in Iowa

PAUL J. WAITE[1]

The development of the atmospheric sciences in Iowa began in a very simple manner, with the entry of the earliest meteorological and climatological observations into logs, journals and private correspondence and the recording of weather proverbs and lore. These simple environmental records provide virtually all our historical meteorological knowledge until the U.S. Army forts began their systematic, but often short-term (in number of years) daily record of weather in 1819.

Not until 1838 did a private Iowa citizen, the renowned professor Theodore S. Parvin, begin a continuing daily record of weather observations at Muscatine. His was the first climatological gift of service by an Iowan to Iowa, which was later to be duplicated by thousands of Iowans in the years to follow. His 35 years of creative climatological endeavor set the stage for the creation of the Iowa Weather Service in 1875 by another equally brilliant Iowa professor, Gustavus Hinrichs. The Iowa Weather Service, the first state weather service created west of the Mississippi River and now the oldest continuing state weather service in our nation, is also celebrating its centennial in 1975. The Iowa Weather Service functioned alone until it joined with the federal National Weather Service in 1890, to rapidly advance the agricultural climatology and meteorology for our nation—and later joined with Iowa State University and other higher institutions from whence scores of now famous atmospheric scientists have spread around the world.

Pre-Instrumental Record

Written references to Iowa climate were few prior to 1819. One of the earlier inferences about Iowa's climate in the fur trading era prior to instrumental record was presented by the second director of the Iowa Weather Service, J. R. Sage (1907), in an article in the *Cedar Rapids Republican* mentioning that "early records of Jesuits and fur traders from Canada among the Sioux Indians indicate that the winters then were about as they are now."

During this same era, Benjamin Franklin, George Washington and Thomas Jefferson were among those recording or advancing the meteorological knowledge of this nation. Thomas Jefferson, who daily recorded the weather for 40 years (1776-1816) in his *Garden Diary*, instructed Lewis and Clark prior to their famous expedition to the west coast to record the environmental information along their route, which included western Iowa.

From their log we find the earliest known mention of an Iowa tornado entered on June 29, 1804, as they toiled up the Missouri River past the present boundaries of southwestern Iowa. The entry:

> On the S.S. passed much falling timber apparently the ravages of a Dreddful harican [tornado] which had passed oblequely across the river from N.W. to S.E. about twelve months Sinc, many trees were broken off near the ground the trunks of which were sound and four feet in diameter.

Early Iowa Weather Records

The first systematic daily weather observations in the midwest included Fort Calhoun near Council Bluffs, Iowa, along with Fort Snelling, Minnesota, both begun in October, 1819. The *Army Register* (1830) described the action thus:

> In 1819 under the direction of the then Secretary of War, a system of meteorological operation was commenced and zealously prosecuted by the late Surgeon-General [Lowell]; but as the instruments provided never exceeded a thermometer and a rain-gauge, the observations, including those upon the course of the winds and other states of weather have necessarily had a limited range.

Army post records by location and dates of weather data in and near Iowa (Sage, 1890) used to determine our early climate include:

Council Bluffs, Ia.	1819-1826 and occasionally through 1843
Fort Snelling, Minn.	1819-1855
Prairie du Chien, Wis.	1822-1825, 1829-1845
Fort Armstrong (Rock Island, Ill.)	1824-1835
Fort Des Moines, Ia.	1843-1846
Fort Atkinson, Wis.	1844-1846
Fort Dodge, Ia.	1851-1853

According to Blodget (1857) at "Engineer Cantonment" located three miles southeast of the point called "Council Bluff," daily temperature readings were begun on October 22, 1819, and taken thrice daily, at 7 a.m., 2 p.m., and 9 p.m. The average of the three daily readings compares with the present method within about one degree.

The hospital surgeons kept the records because of the initial order issued May 2, 1814, by Surgeon-General Dr. James Tilton that in each case "He shall keep a diary of weather."

In 1817, Josiah Meigs, Commissioner-General of the Land Office, began a system of observation at land offices. The Patent Office also gathered some data, and in 1849, Professor Joseph Henry of the Smithsonian Institution established an extensive network by supplying instruments to telegraph companies. The appearance of telegraph in 1845 made meteorology a practical science. Iowans from some 20 or more localities contributed climatological data to the Smithsonian network. James P. Espy, who served as the first governmental

[1] Former state climatologist of Iowa. Present address: TF 2 JSC-NASA, Houston, Texas 77058.

meteorologist from 1842 to 1857, aided the Smithsonian Institution in the creation of this, the most extensive network to date in the nation, until its deterioration during the Civil War.

During this same era, New York operated our nation's first state weather service, with some 30 weather observers, from 1825 to 1850. Similar but smaller programs were begun in Pennsylvania in 1837 and Massachusetts and Ohio in 1849, but those were of relatively short duration (U.S.D.A. Weather Bureau, 1894a).

To the Honorable Theodore Sutton Parvin (1807-1901) we may confer the title of Father of Iowa Climatology. He arrived in Iowa on July 4, 1838, according to Josiah P. Walton (1899), to serve as the private secretary to the newly appointed governor of the Iowa territory, Robert Lucas. Mr. Parvin's weather records began on December 1, 1838, at Muscatine, where he continued them until his move to Iowa City in October, 1860. He continued his daily record until April, 1874, at Iowa City, in addition to his professional duties at The University of Iowa. J. P. Walton, one of his weather observer successors, typically continued the record from 1863 to past the date of his article in 1899. Professor Parvin read his thermometer three times daily, reported cloudy, clear and partly cloudy days, reported precipitation measurements and in 1850 purchased a barometer.

Professor Parvin is also remembered for having selected the books for Iowa's first library, and for founding the Iowa Masonic Library, located at Muscatine in 1844, but later in Cedar Rapids.

Following Parvin's lead at Muscatine, other weather sites were begun in Iowa during the 1840's and 50's. The U.S. Patent Office and the Smithsonian Institution (1864) listed early Iowa weather sites with beginning dates or tenure if short as follows (county in parentheses): Bellevue (Jackson), 1856; Border Plains (Webster), 1856-59; Burlington (Des Moines), 1859; Camanche (Clinton), 1856-58; Clinton (Clinton), 1856; Davenport (Scott), 1859; Dubuque (Dubuque), 1851; Fairfield (Jefferson), 1855; Fayette Village (Fayette), 1859; Forestville (Delaware), 1859; Fort Madison (Lee), 1848; Franklin (Buchanan), 1856-59; Iowa City (Johnson), 1856; Keokuk (Lee), 1854; Lyons City (Clinton), 1859; Maquoketa (Jackson), 1857; Mt. Vernon (Linn), 1856-57; Muscatine (Muscatine), 1838; Pella (Marion), 1854-56; Poultney (Delaware), 1854-58; Quasqueton (Buchanan), 1857-59; and Rossville (Allamakee), 1857-59. In addition to this listing, additional records were available from Monticello, 1854-1906; Hopkinton, 1852-1895; Farmersburg, 1845; and Sioux City, 1857. During the 1860's the Smithsonian Institution also acquired data beginning in 1861 from Independence, Iowa Falls, Logan, Algona and Mt. Vernon, in 1863 from Mt. Pleasant and Iowa Falls, in 1864 from Onawa, in 1865 from Clarinda and in 1869 from Sac City, Ames and Newton.

Since 1873 the climatological site density was deemed sufficient to determine the Iowa climate in terms of measured temperature and precipitation. State snowfall values begin in 1892.

The bill officially creating the National Weather Service was signed on February 9, 1870, by U. S. Grant. The bill had been introduced in 1869 by Congressman H. E. Blaine (Wis.), a friend of the scholarly Smithsonian observer Increase A. Lapham, to provide for an agency to predict storms and issue coastal warnings. In 1873 a river stage and flood warning service was begun by the U.S. Army Signal Corps Weather Service.

IOWA WEATHER SERVICE

At about this time Iowa's own Professor Gustavus Hinrichs had conceived the need for an Iowa Weather Service, which he established on October 1, 1875, with sixty observers, a revival of the state weather service and the largest of its kind in the nation thus created to date.

The colorful and versatile creator of the Iowa Weather Service, Gustavus D. Hinrichs (1836-1923) was born and educated in Denmark. He arrived in the United States in 1861. His first position came as head of the newly created department of Modern Languages at The University of Iowa. In 1863 Dr. Hinrichs became professor of philosophy, chemistry and physical sciences. In 1871 he became professor of physical sciences and director of the laboratory, until his strong will and forceful opinions created dissention that lead to his departure from the University of Iowa staff in 1886.

Professor Hinrichs was a "brilliant and gifted educator who pioneered in many fields." According to the *Iowa City Press-Citizen* (1953) he was the second college professor in the United States to establish a physical laboratory for students in which they could experiment, and it was during his tenure that The University of Iowa was recognized as having one of the four leading science laboratories in North America. In his lifetime he wrote some 300 publications including 25 books.

When the medical faculty was chosen in 1870, he was one of the original eight members and served as professor of chemistry. The University of Iowa medical historian observed that "in 1872, 290 out of 400 students in the university were registered in his courses. The champions of the classical curriculum grew envious and with the accession of President Thatcher, the scientific course was relegated to a secondary position." His interests ranged across the entire scientific gamut, for his works extended across chemistry, toxicology, astronomy, physics, horticulture and meteorology. It was from this meteorological base that he began his own weather observations in Iowa City in 1873 and proceeded to become the father of the Iowa Weather Service.

Almost immediately he established the Central Weather Observatory, first on campus, but later in 1876 in his own home, which was designed to house both his family and Hinrichs' observatory. The formal organization came in August, 1875, when Professor Hinrichs issued his call to "friends of scientific work . . . to secure as complete a history of the weather of Iowa as possible in order to furnish material for an exhaustive study of the climate of our state. On the first day of October, 1875, actual and regular observations were begun at sixty stations, distributed over all parts of Iowa, though closest together in the more densely populated parts of the state."[2] Dr. Hinrichs described his corps of volunteer observers as largely physicians, but coming from many walks of life, willing to provide without compensation thrice daily observations (8 a.m., noon and 8 p.m.). Professor Hinrichs spent his own money and time to create and operate the service. Within a few months after the establishment of the Iowa

[2] Iowa Weather Service, First Annual Report, Des Moines, Iowa, 1876, p. 499.

Weather Service, the observers bore their own share of the operating expense, for weather was important to them. The observers reported promptly to the Central Weather Observatory in Iowa City no less than three times monthly. Professor Hinrichs issued the reports about Iowa weather between the fourth and seventh of each succeeding month to the Iowa newspapers, "long in advance of the monthly reports issued in Washington, and [which] at the same time, are naturally much more complete so far as our State is concerned" (*Iowa Weather Report*, 1876).[3]

Without official recognition or support, the Iowa weather data, so carefully analyzed by Professor Hinrichs, accumulated at the Central Observatory. However, John R. Shaffer, Secretary of the Iowa State Agricultural Society, requested of the Board of Directors of the Society that the 1875-76 annual report of the Iowa Weather Service be published as an appendix to the State Agricultural Report for the year 1876. The 1877 Annual Iowa Weather Service report was likewise appended to the State Agricultural Report for that year. In the 1877 report Dr. Hinrichs commented upon the considerable expenditure of his own labor and money which he said would be imprudent for him to continue even if possible.

In 1878 the sought-after state support was extended by the 17th General Assembly in the establishment of the Iowa Weather Service with the Central Observatory in Iowa City; Professor Gustavus Hinrichs was named its first director. The act, signed on March 15, 1878, by Governor John H. Gear, also provided "one thousand dollars annually, or so much thereof as may be necessary, for the purpose of meeting the actual expenses in carrying out the provisions of this measure, but no part of said sum shall be used in payment of salaries to any officer or officers, except for clerk hire and only upon the order of the said Director" (Iowa General Assembly; Acts 17:38-39, 1878). The act also specified that the director's duties included the establishment of "volunteer weather stations throughout the state and to supervise the same." Thus the tradition of free weather observations for the state was perpetuated with that act. Dr. Hinrichs also served as the state director without salary throughout his tenure, which lasted until 1889. Because of the diversity of Professor Hinrichs' interests and abilities, the Iowa Weather Service printed earthquake data, magnetic observations and astronomical phenomena in addition to weather data. Professor Hinrichs also observed maximum solar radiation, sunspot numbers and ozone at Iowa City.

National Weather Service

With the establishment in 1870 of the National Weather Service as an arm of the U.S. Army Signal Corps came an emerging nationalized service. The federal service began weather forecasts and observations in 1871 at Keokuk (July 15) and at Davenport (May 24). On July 10, 1873, Dubuque began operation, and on September 30, 1874, Burlington began taking observations for the U.S. Army Signal Corps Weather Service. On August 1, 1878, the Des Moines station was established, and on July 1, 1889, the establishment of a federal station at Sioux City brought the number of Signal Corps weather offices to six. The Signal Corps began utilizing the Smithsonian observers and enlarged their network of weather observers in addition to creating a network of storm reporters. In time, conflict between the state and federal services arose, with Gustavus Hinrichs declaring that the federal service was enticing the state observers away from his network (also without payment for observers), and that the federal weather forecasts were inaccurate. His differences surfaced more often in his later years while he served as the Iowa Weather Service Director.

Professor Hinrichs described the service and some of his problems in the Fifth Biennial Report (1887):

> The Iowa Weather Service has been in continuous operation for over twelve years. . . . When starting this service, there was nothing of the kind in the United States. We had to plan and invent methods. After a few years of work, six other states organized after our plans, mainly through the influence of public spirited men of science, such as my former student and assistant, Professor Francis E. Nipher of Washington University, St. Louis (Mo.). The national weather bureau remained for years, indifferent, if not hostile, to this work of climatological study.

Gustavus Hinrichs narrated further that he had differences with the Signal Corps, that he had made great personal sacrifices in relinquishing his remunerative program in chemistry and toxicology to produce the Iowa Weather Service with all its hard work, no vacation, and reduced living space as records overflowed the observatory annex into his own home.

The U.S.D.A. Weather Bureau International Congress 1894b) noted the creation of the Iowa and other state weather services thus:

> The Iowa Weather Service . . . was a revival of state weather services as had existed before in New York and Pennsylvania and had been attempted in Massachusetts and Ohio. After the creation of the U.S. Signal Corps Weather Service several state weather services came into existence following Iowa's Weather Service.

The State-Federal Weather Service

On April 25, 1890, Governor Boies approved an act by the Twenty-Third Assembly to create the Iowa Weather and Crop Service, to cooperate with the National Weather Service, under the direction of the directors of the State Agricultural Society. The Central Station was relocated in Des Moines and the new director, J. R. Sage, was commissioned by Governor Boies on June 3, 1890. George M. Chappel, M.D., was detailed at the same date as the assistant director by General Greely, Chief of the U.S. Army Signal Corps office. Sgt. Chappel had previously arrived from Omaha to direct the Signal Corps weather station in Des Moines on August 5, 1888, and soon relieved Sgt. P. Connor, who later became well known as the official weather man in Kansas City, Missouri.

At the creation of the joint state-federal weather service for Iowa, thirty other states joined in similar cooperation. Only Iowa has continuously maintained that cooperative arrangement to 1975.

Dr. Chappel was listed in the U.S.D.A. Bulletin 7 (1893) as the elected second vice president of the permanent officers of the American Association of State Weather Services held in Washington, D.C., on August 15 and 16, 1892.

[3] Ibid. p. 500.

Iowa's first crop reporting service was begun by Sgt. Chappel beginning in April, 1889, prior to the official federal-state cooperation.

J. R. Sage served as director of the Iowa Weather Service until December 31, 1907, resigning then due to ill health; Dr. Chappel officially became Iowa's third director of the Weather Service on January 1, 1908, and fittingly the second director of the combined Weather and Crop Service which he had begun nearly 19 years earlier.

In 1889 the initial preliminary cooperation began under the direction of the U.S. Signal Corps observer George M. Chappel of the Des Moines Signal Corps station and an aide of Secretary J. R. Shaffer of the State Agricultural Society. Voluntary observers in nearly every county began collecting weather and crop reports from all parts of the state, the substance of which was embodied in weekly bulletins published and circulated during the crop season for the benefit of producers and consumers. The Twenty-Third General Assembly passed an act establishing the Iowa Weather and Crop Service, the scope and purpose of which are set forth in chapter 29, session laws 1890.

During the Sage era the federal cooperator changed from the U.S. Army Signal Corps to the U.S. Department of Agriculture on July 1, 1891, in response to a bill signed by President Benjamin Harrison on October 1, 1890. Some policies were immediately changed, which included deleting the tornado forecasting service operated by Jno. P. Finley, U.S. Army Signal Corps. The prohibition was imposed against tornado forecasting, a stance which continued until nearly 1950.

In 1895 the total number of weather observers was 104 and weather-crop observers 78. About 900 crop correspondents provided information. In that same year weekly weather and crop bulletins were mailed to some 1,600 locations including newspapers from April 1 through October 1. During 1895 some 29,000 copies of the *Monthly Review of Weather* were printed. The service continued to grow. In 1895 forecasts were telegraphed to 112 locations and distributed therefrom by mail to about 1,000 post offices in Iowa. In 1902 mention is made in the Annual Report of the Iowa Crop Service that about 7,000 farmers were now receiving daily weather forecasts by Rural Free Delivery. By 1906 "about 95,000 patrons of rural telephone lines were receiving forecasts before noon of each working day. This service appears to be highly appreciated by the general public in towns and in the country districts" (Iowa Weather and Crop Service, 1906).

Regarding weather forecast by telephone, the Fort Madison *Democrat* observed (1906) that of the total 222,325 instruments in Iowa according to the first census of telephones in Iowa, 104,524 were rural (farmer's) instruments. It proceeds further that:

> During the past few years the Government Weather Service has arranged for the telephone distribution of forecasts, and a large percentage of these farmers now receive by telephone every morning the forecast of weather for the coming thirty-six hours. This, in fact, has been one strong incentive for the installation of telephones in the homes of farmers of the state.

In 1910 the State-Federal Weather Service, now under the directorate of George Chappel, reported a weather forecast distribution to 177,711 homes daily; 171,389 by telephone, 4,189 by R.F.D., 142 by telegraph and 1,993 by ordinary mail service.

In 1912 specialized frost warnings were issued by arrangement with the Iowa State Horticultural Department during the fruit blossoming season to all orchardists who were prepared to use heaters in case of injurious temperatures. This cooperation was continued each year through at least 1915.

In 1916 Dr. Chappel traveled to the New York weather office to interview their first assistant, Charles Dana Reed, for the position of first assistant and meteorologist. When C. D. Reed arrived during late 1916, he increased the staff to six persons. Other employees included Edward McGann and Carl Hadley, assistants; Ruby Sage, stenographer; and Joseph Franford, messenger.

On April 1, 1918, C. D. Reed became the section director and the fourth director of the Iowa Weather Service. In the quarter century of service following he was to become one of the best known persons in Iowa while achieving considerable stature and reputation as an excellent scientist—although not as versatile as the famous "boat-rocking" Gustavus Hinrichs. Under Reed's direction the State-Federal Weather Service began several agriculturally related research and service programs that accelerated Iowa's progress.

The Iowa Weather and Crop Service Annual Report (1919) described Reed's first major adjustment in the consolidation of the state and federal crop reports into one Iowa report under his direction. Mr. Frank S. Pinney, U.S.D.A., became the agricultural statistician for Iowa. In the following year (1920) the staff totaled eight: four supplied by the U.S. Weather Bureau, two supplied by the U.S. Bureau of Crop Estimates and two by Iowa for the Iowa Weather and Crop Division, which was increased to four in 1921.

In 1921 C. D. Reed began the corn phenology program, later to become world famous, for the numerous studies of this relatively unique data base continued into the mid-1950's.

The operational weather service continued to expand through the creation of a special Highway Weather Service in 1919 by the Weather Bureau in Charles City, which was adopted during part of 1920 in other Iowa Weather Bureau offices. During this same period frost warnings were issued to concerned orchardmen at fruit blossom time.

Early in June, 1922, radio telephone distribution of weather forecasts based on the 1 a.m. observations were begun by the Electrical Engineering Department, Iowa State College, Ames, at 9:30 a.m. and 12:40 p.m. Forecasts were also broadcast that same year from WEAB (Fort Dodge), WKAA (Cedar Rapids) and WEAU (Sioux City).

On July 1, 1923, at the creation of the State Department of Agriculture, the Iowa Weather Service became a bureau in that department.

C. D. Reed was responsible for the computation of the Iowa weather temperature and precipitation as a state-wide value back through 1873. He also computed divisional averages, available since 1890, in the same nine divisions as are presently in use. He described his careful evaluations and use of data with such necessary corrections in the *Monthly Weather Review*, June, 1925.

Reed continued to publish, primarily in agricultural meteorology. His article, "Weather and Corn Maturity in Iowa," in the *Monthly Weather Review* (1927) was often referred to in subsequent studies by others.

In 1928 C. D. Reed began the corn moisture testing program that continued until the mid-1950's. In the same year he began routinely issuing climatological data for the same nine districts used for the crop reporting service. The year 1928 was noteworthy for a total of 45 tornadoes—such a complete account was available because of the excellent storm climatology program which emphasized hail and tornado research.

On October 1, 1929, the Weather Bureau moved to new quarters at the U.S. Court House. Nowhere else in Iowa was there such a structure of design and equipment meriting the term meteorological observatory.

Following the earlier Depression years, considerable climatological data were assembled by workers federally hired for public works programs.

In 1937 the Iowa Weather and Crop Bureau ended as one agency, as it was split on July 1, 1937, into the Iowa Weather Division and the Division of Agricultural Statistics, both reporting to the Iowa Department of Agriculture, respectively through C. D. Reed and Leslie M. Carl, senior statistician. In 1943 the Division of Agricultural Statistics was moved from the U.S. Court House to the Old Colony Building. On December 2, 1944, C. D. Reed worked his last day for the Weather Bureau; his retirement was effective on February 28, 1945, just 46 years to the day after his Weather Bureau career began at Vicksburg, Mississippi. His 28 years in Des Moines had set the meteorological stage for the emergence of a new era in Iowa—that of a growing center of agricultural climatology.

Reed's influence was such that he was considered for the post of President, Iowa State College, Ames, Iowa, being one of 15 persons listed in the *Des Moines Sunday Register* on December 12, 1926. Reputedly in the 1930's he was likewise considered for the position of Chief of the U.S. Weather Bureau. He was listed in *America's Who's Who* and in *American Men of Science*, and held the post of Vice President General of the Sons of the American Revolution.

In 1945 C. D. Reed became a research professor at Iowa State College, where he had previously received his B.Agr. (1894) and M.S. (1896) degrees. He died on October 26, 1945, at the age of 70, ranking with Gustavus Hinrichs as Iowa's most illustrious sons in the meteorological field. He had published extensively, but undoubtedly short of Hinrichs' hundreds of publications.

IOWA METEOROLOGICAL EDUCATION AND RESEARCH ERA

In the 1940's Iowa moved into the academic area of meteorology and climatology to support the need for World War II meteorologists as provided by various Iowa colleges and universities. Iowa State College joined with the Iowa State-Federal Weather Service to advance the state's atmospheric sciences in 1944. In addition to C. D. Reed on the Iowa State College staff, H. C. S. Thom, the newly appointed Iowa Section Director for the State-Federal Weather Service, actively participated in developing the Iowa State College graduate program for agricultural climatologists. The first of the graduates, the now world renowned Dr. Gerald L. Barger, graduated in June, 1948, followed shortly thereafter by the equally famous Professor Robert H. Shaw (now at Iowa State University). Other illustrious early graduates include Paul Waggoner, Wayne Decker and Robert Dale, from among the many agricultural climatologists originating from Iowa State University.

During the past decade Iowa State University has expanded to include a most diversified and talented meteorology staff to specialize now, in addition to agricultural climatology, in various aspects of meteorology.

Atmospheric science in Iowa would be incomplete without a passing note regarding the contribution by Dr. James Van Allen for his pioneering work at The University of Iowa in satellite development and his discovery of the Van Allen radiation belts surrounding the earth.

Applied climatology in recent years continued the impetus in this area provided by C. D. Reed. C. E. Lamoureux, director of the State-Federal Service for 22 years, provided a classical hail study that continues to serve as a valuable resource. Under his direction C. Robert Elford, Iowa's first state climatologist, continued to publish applied climatological studies and served as collaborator at Iowa State University (1955-59). He was followed in the same capacity by Paul Waite, who served Iowa for 15 years with publications about agricultural, applied and storm climatology.

Perhaps one of the more spectacular contributions to Iowa's atmospheric sciences was the discovery, by Newton Weller, and testing for many years of a tornado detection method using ordinary television. The "Weller method" was publicized throughout the nation after its first successful public test in the well known Orange City tornado of September 22, 1968 (see *Popular Mechanics*, March, 1969; *Successful Farming*, May, 1969; *TV Guide*, August 9, 1969, and December 11, 1971; and the *Des Moines Sunday Register*, September 29, 1968). The method was evaluated by Gale Biggs (Iowa State University) and Paul Waite and the successful usage of the "Weller method" was reported in *Weatherwise* (1970). And, even though as of 1974 Weller had realized no remuneration for his invention, he did set off a substantial amount of national research in the area of electromagnetic sensing of tornados, including that by Scouten, Stephenson and Stanford at Iowa State University.

Finally, let it be noted that the history of Iowa's environmental past is continuing to unfold thanks to studies by such scientists as Robert Ruhe (I.S.U.) (Iowa's Quaternary landscape) and Roger Landers (I.S.U.) (inquiry into the past by study of tree rings). Scores and perhaps hundreds of other paleoscientists are patiently assembling the historical and paleoclimatology of Iowa to remind us that once dust storms laid down much of southern Iowa's topsoil, while glaciers lay over much of north and central Iowa. The recovery of Iowa's vegetation from times past tells us of the gradual warm-up after the last glaciers left Iowa some 13 or 14 thousand years ago. The clues are there and the careful, tedious work of Iowa's scientists is regularly adding knowledge to Iowa's history of atmospheric sciences, while other scientists are making history today.

LITERATURE CITED

Army Meteorological Register for the years 1826, 1827, 1828, 1829, 1830 and 1840; Haswell, Barrington, Haswell; Philadelphia.

BIGGS, W. G., and WAITE, P. J., 1970; "Can TV Really Detect Tornadoes?" *Weatherwise*, p. 120-124.

BLODGET, LORIN, 1857; *Climatology of the United States;* Philadelphia.

Fifth Biennial Report of the Central Station of the Iowa Weather Service, 1887; Des Moines.

Fort Madison Democrat, November 26, 1906.

Iowa City Press-Citizen, 1953; "First Weather Station, Iowa City"; p. 13.

Iowa Weather Service, 1876; First Annual Report; Des Moines, Iowa; pp. 499, 500.

Iowa Weather and Crop Service, Annual Report 1906; Des Moines, Iowa.

Iowa Weather and Crop Service, Annual Report 1919; Des Moines, Iowa.

LAMOUREUX, C. E., 1952; "Hail Damage in Iowa, 1923-48"; *Monthly Weather Review;* Vol. 80, pp. 37-44.

LEWIS and CLARK, 1804; *Log of the Lewis and Clark Expedition.*

REED, C. D., 1927; "Weather and Corn Maturity in Iowa"; *Monthly Weather Review;* Washington, D.C., pp. 102-109.

SAGE, J. R., 1891; Annual Report of the Iowa Weather and Crop Service 1890; Des Moines, Iowa; p. 5.

SAGE, J. R., 1907; Iowa Climatological Data, March, 1907; U.S. Weather Bureau and Iowa Weather and Crop Div., Des Moines.

U.S.D.A. Weather Bureau, 1894; Report of the International Meteorological Congress, Chicago, Ill.; Aug. 21-24, 1893; Washington, D.C.; pp. 285-286(a), 259(b).

U.S. Patent Office and Smithsonian Institution, 1864; Results of Meteorological Observations 1854-59 including Vol. 11, Part 1; Government Printing Office, Washington, D.C.

WALTON, J. P., 1899; "A History of the Oldest Continuous Weather Record in the Midwest"; Muscatine *Saturday Mail;* February 18.

Reflections on Women Scientists and the Iowa Academy of Science

LOIS HATTERY TIFFANY[1]

In this centennial year of the Iowa Academy of Science, various facets of scientific activity and development in the state of Iowa and the impact of the Iowa Academy are being examined. With our current awareness of equality, the contribution of women scientists to the Academy is a logical topic for comment. Perhaps in another hundred years it will not seem a necessary separate item to consider.

Women have been active contributors to the Iowa Academy from its earliest days. The first membership list in Volume 1 of the *Proceedings* for the reorganized Academy includes two female members, Nellie Ankeny and Minnie Howe, both of Des Moines. A later membership list for 1892 in the same volume also includes Alice Beach of Ames as a fellow. Included in that volume are four papers by women on diverse topics: "Some experiments for determining the active principle of bread making" by Minnie Howe, "Observations on the pollination of some Compositae" by Mary Alice Nichols, "Notes on the pollination of some Liliaceae and a few other plants" by Mary C. Rolfs and "Additions to the known species of Iowa Ichneumonidae" by Alice Beach.

As the Academy developed, the number of women involved in membership increased, always remaining a small minority. Also, only a limited group of the female members was active in presenting papers at the annual meetings, publishing these in the annual *Proceedings,* and serving on committees involved in the business and expanding interests of the Academy. In the first 80 volumes of the *Proceedings,* including volume 80 in 1973, 275 papers were authored or co-authored by women. Women have frequently served as section chairmen at the annual meetings, less commonly as appointed members of standing committees of the Academy. Smaller still is the group represented in the offices of the Academy. Miss Allison E. Aitchison served as second vice-president in 1916-1917. Dr. Dorothy Miller Matala served as a board member from 1958 until 1962, achieving this position because she was chairman of one of the standing committees, chairmen of which constituted the board at that time. In 1973, Dr. Ruth Siemer and Dr. Lois Tiffany were elected to three-year terms as board members.

The woman with perhaps the greatest impact on the Iowa Academy to date has been Dr. Jessie A. Parish. She presented a paper "The Pyrenomycetes or black fungi of Iowa" at the annual meeting reported in volume 30 of the *Proceedings.* This study was published as "Pyrenomycetes or black fungi of Iowa" in volume 35 of the *Proceedings.* This seems to have been the extent of her active participation in the Academy. She maintained membership in the Academy, however, and was sufficiently concerned to will a 240-acre farm near Reinbeck to the Academy. The history and development of the Parish Farm in relation to the Academy has been discussed by Horner in a paper in number 1, part 1, of this centennial series.

As I have viewed the Iowa Academy of Science history through the mirror of the annual *Proceedings,* reading the accounts of meetings and activities, scanning committee reports, noting the diversity of interests of the women in various scientific disciplines as reflected by the topics discussed in their papers, I have felt a new respect for those women who pioneered as active contributors to Iowa science and to the Academy. Many of the women members were active in the Academy for only a few years, often during a graduate school experience. For example, one of the young women listed in the 1895 membership list was Emma Pammel, Dr. L. H. Pammel's daughter. She had graduated from Iowa State in 1894, and in 1895 was co-author with Emma Sirrine of a paper, "Anatomical studies in leaves of *Sporobolus* and *Panicum,*" published in volume 3 of the *Proceedings.* She completed her Master of Science degree requirements in 1896, and that year presented a paper, "Comparative study of the leaves of *Lolium, Festuca* and *Bromus,*" published in volume 4 of the *Proceedings.* By 1896 she had married N. E. Hanson, moved to Brookings, South Dakota, and no longer actively pursued her scientific interests. Such a sequence of events is certainly not unusual, then or now.

The women who were long-term regular contributors to the Academy or active in its programs are few. These women were typically single; no doubt each would have had her own reasons if one had been so bold as to question her about this situation. A reasonable mix of professional development and a home and family was a rare achievement; it was not a situation that was probable for the early professional women scientists. I would like to introduce very briefly three of these individuals who were involved in the Academy and contributed to it in different ways. As all three of these women were botanists or biologists, I should comment that I have tried to look at women and Academy history in general, not with regard to a particular scientific discipline. However, botany traditionally has been one of the sciences where women have had an opportunity to work and to contribute.

Charlotte M. King was associated with the Botany and Plant Pathology Department at Iowa State from 1894 until her death in 1937. She was the experiment station artist, working particularly in entomology and botany, for 25 years. From 1906 to 1930, Miss King was the seed analyst for the seed testing laboratory associated with the Botany and Plant Pathology Department. After joining the Iowa Academy in 1899, she contributed regularly to the papers presented at the annual meetings. A paper, "Weed survey of Story County, Iowa," in volume 21 of the *Proceedings* marks the beginning of her cooperative work in this area with Dr. L. H. Pammel. A long-time interest in the germination patterns of the seeds of various trees and shrubs is documented by a series of papers by Dr. Pammel and Miss King, beginning with "The germination and juvenile forms of some oaks" in volume 24 of the *Proceedings* in 1917. She was also co-editor with Dr. Pammel of two volumes published by the Iowa

[1] Professor of Botany, Iowa State University, Ames. Dr. Tiffany has been a member of the Academy since 1946; served as chairman of the Botany Section in 1956, as Botany representative on the Editorial Board of the *Proceedings* for 1972, and as a member of the Board of Directors, 1973-76.

Geological Survey, one on the weed flora of Iowa and the other on the honey plants of Iowa.

The second woman scientist that I found to be extremely interesting was Dr. Ada Hayden. Dr. Hayden's career and professional achievements suggest some of the problems encountered by a woman scientist of her era. Beginning with her undergraduate work in botany at Iowa State in 1904, Dr. Hayden was greatly influenced by Dr. L. H. Pammel, an old family friend. After graduation with an M.S. from Washington University at St. Louis in 1910, she was appointed an instructor in botany at Iowa State. In 1918 she earned the first Doctor of Philosophy degree awarded to a woman at Iowa State, and was appointed an assistant professor. She was still an assistant professor at Iowa State at the time of her death in 1950.

Dr. Hayden worked in close cooperation with Dr. Pammel in the Iowa State Herbarium and in the preparation of illustrations, both drawings and photographs, for Dr. Pammel's various publications on the Iowa flora. After Dr. Hayden was appointed a research assistant professor of the Iowa Agricultural Experiment Station in 1934, she spent long hours studying the vegetation of the lakes and marshes of Iowa. She was a physically strong person, handling with ease the transporting and launching of her boat, wading as required to make observations and to take photographs or specimens. She was an excellent photographer, and her reports and research papers on Iowa's wetlands are handsomely illustrated. She utilized her knowledge and talents as a member of the Conservation Committee of the Iowa Academy. Her papers, published in various volumes of the *Proceedings,* deal with aspects of flowering plants and their distributions in the state.

As a child, Dr. Hayden had lived on an Iowa farm which included several acres of virgin prairie. In later years she was instrumental in interesting the Iowa State Conservation Commission in the acquisition of prairie preserves. During her lifetime, the Commission purchased two prairie areas she recommended for preservation. After her death, the Howard County preserve was named the Ada Hayden Prairie in commemoration of her efforts to save some portions of the native flora she knew so well.

The third woman scientist I have chosen for comment was involved with the Academy at a more recent time. Dr. Dorothy Miller Matala worked effectively in Iowa and in the Iowa Academy of Science as a science consultant concerned with science teaching in elementary and secondary schools. Dr. Matala joined the faculty of the State College of Iowa in 1946 after receiving her Doctor of Philosophy degree from Cornell University following teaching experience in high schools and junior colleges in Indiana. She was a staff member of the first Iowa Teachers Conservation Camp and was influential in its program and development. She was a member of the governing board of the American Institute of Biological Sciences and served on its Executive Committee in 1962, the year of her death. She was the first chairman of the Science Teaching Committee of the Iowa Academy, and as its chairman served on the Board of Directors of the Academy from 1957 until 1962.

A year has passed since I was asked the question: "Do you know anything about the contributions of women scientists to the Iowa Academy of Science?" At that time I could only say that I had never really thought about those women who had preceded me in involvement in the Academy. Considering and investigating this question has been a rich opportunity for me to become more aware of this heritage.

EDITOR'S NOTE: Dr. Tiffany has, understandably, been overly modest about her own accomplishments. She has possibly been the most active woman member of the Academy in its history, and many of her contributions still lie in the future. Some indications of her professional activity can be found in the article by George Knaphus in this issue.

Mycology and Plant Pathology in Iowa from 1854 to 1974

GEORGE KNAPHUS[1]

A historical survey such as this cannot be satisfying to the author. It demands too much compression of the incompressible and dictates deletion of many interesting incidents. A mountain of file cards and notes may translate into a tedious listing of authors, titles and sources. It may, on the other hand, capture the spirit of the times and the people. This summary of mycology and plant pathology in Iowa from 1854 to the present tries to do the latter. It is documented sparsely and informally, with most of the information coming from the *Proceedings of the Iowa Academy of Science,* and the *Records and Proceedings* of the Iowa Society of Agriculture. W. F. Buchholtz and Jack Wallin wrote a very interesting and inclusive record, "Plant Disease Research and Extension in Iowa," published in the June, 1951, *Plant Disease Reporter.* This report is a rich source of information and was used extensively in writing this paper.

The disciplines of mycology and plant pathology have been closely intertwined throughout history. Fungi are the most destructive plant pathogens, and dreaded plant diseases such as late blight of potato, rust of wheat and other cereals, ergot of rye, downy mildew of grape and the common rots of potatoes are all fungus diseases. When the early pioneers came to Iowa and began breaking the prairie, the diseases which had plagued them before were soon to harass them again.

Farming was becoming increasingly important in eastern Iowa in the 1850's, and in 1854 the Iowa State Agricultural Society was formed. In the first issue of the *Records and Proceedings* of the Society, there is no mention of fungi nor of plant diseases. George Dixon, in his address to the Society in October, 1854, quoted from the objectives of the Royal Agricultural Society of England. He referred to destruction of insects injurious to vegetable life, to the eradication of weeds, to promoting the discovery of new varieties of grain and other vegetables and to collection of information with regard to the management of wood plantations and fences, but there was no direct reference to plant disease nor fungi. This may seem strange, but the great discoveries of such men as Pasteur, Koch, deBary and Millardet were still in the future and plant diseases were feared but poorly understood. The Irish potato famine was just then subsiding and possibly some of the farmers of eastern Iowa were immigrants fleeing the disaster in Ireland.

In 1855, the *Records and Proceedings* of the Society carried summaries of farming activities from some of the counties of the state as well as the winners of the prizes given at the State Fair. In 1856, incidental references to plant diseases can be found. LeGrand Byington of Johnson County noted that "Spanish wheat" rusted badly and his data indicated a yield of about one-fourth of the yield of other varieties. Potatoes were of excellent quality, "there being lately no complaint of the much dreaded rot." The Mahaska County report of 1857 mentioned blight on apple trees as well as reporting an astounding 138 bushels of corn per acre. In subsequent years, the number of references to plant disease increased with more and lengthier discussions of mildew of grape, potato rot, rusts and blight of apple.

Occasionally personal prejudice intruded into the reports. One example is that of L. J. Young whose somewhat dour report of agricultural possibilities in Chickasaw County was concluded with a criticism of the buying and misuse of farm machinery. Among his pithy comments were: "a mowing machine is a very costly implement for leveling down bogs, uprooting grubs and digging stones" and "agricultural implement dealers have done more to retard progress of Chickasaw County than wet seasons and dry seasons and early frosts and war."

Agriculture continued to grow in Iowa, and in March of 1858 the General Assembly passed an act establishing a "State Agricultural College and Model Farm to be connected with the entire agricultural interests of the State." The first students came in October of 1868. In December of 1869 the position in botany and horticulture was offered to Charles Edwin Bessey of Michigan Agricultural College, and he began his work as Instructor of Botany and Horticulture and secretary of the faculty. Bessey was to devote a lifetime to botany at Iowa State and Nebraska and become one of the most highly regarded plant taxonomists. His first botany student was J. C. Arthur, whose later work on the rusts appeared as the classic books *The Plant Rusts* and *Manual of the Rusts of the United States and Canada.* J. C. Arthur graduated in the first class in November, 1872, and later, in 1877, received the first master's degree from Iowa State College.

Dr. Bessey published the first paper on plant pathology in Iowa in the Sixth Biennial Report of the College. The publication dealt mostly with rusts and smuts and was entitled "On Injurious Fungi." Dr. Bessey collected fungi as well as other plants and established the Iowa State Herbarium containing flowering plants and fungi. He worked on rusts and wood deteriorating fungi, and also helped teach the veterinary medicine students the "rudiments of medical botany."

Bessey was a prodigious worker, and in addition to his research, teaching, and administrative duties, he helped establish the Iowa Academy of Science in 1875. In 1884 he moved to Nebraska.

Dr. L. H. Pammel became the head of the Department of Botany and Bacteriology at Iowa State in March of 1889 and published two papers on diseases of fruit trees in Volume 1, part I, of the *Proceedings of the Iowa Academy of Science* in 1890. Pammel, like Bessey, was a man of broad interests and accomplishments. His major interests were in the fields of taxonomy and economic plants, but he contributed fourteen papers on plant diseases to the *Proceedings of the Iowa Academy of Science.* He also described *Xanthomonas (Bacillus) campestris* as the cause of black rot of rutabaga in 1895 and *Helminthosporium sativum* as the cause of barley blight in 1911.

Pammel and Charlotte King in 1909 published a significant and detailed paper, "Notes on Factors in Fungus Diseases of Plants, with Records of Occurrence of Plant Disease at Ames for a Period of Twenty-Five Years." Pammel's records from 1889 to 1909 had noted prevalance of 81 plant

[1] Professor of Botany at Iowa State University, Ames.

diseases. A summary of these records and such evidence as was available from the previous years back to 1870 are included in this paper. Much of the evidence of those earlier years must be credited to Charles Bessey and Byron Halstead. Pammel began the practice in 1904 of having farmers and horticulturalists report plant diseases in their areas. This has grown into the Iowa Plant Disease Survey. It is apparent at this point that Pammel recognized the importance of plant diseases.

This concern with plant diseases resulted in the employment of Dr. I. E. Melhus in 1916 to be the first full-time plant pathologist. Pammel had developed the first plant pathology course, Botany 66, and Melhus taught this course. Melhus was to play an increasingly dominant role in plant pathology in Iowa for the next 35 years.

Pammel reported in 1919 on barberry in Iowa and adjacent states. The disastrous wheat rust epiphytotics of 1916 and 1917 had stirred great concern regarding wheat rust. Stakman's work in Minnesota had elucidated physiologic specialization in the rust pathogens, and the importance of control of barberry was becoming evident. Pammel served as president of the Iowa Academy in 1892-93 and also in 1923-24. His presidential speech in 1924 was published in the *Proceedings.* It was a history of botany in Iowa, and is an interesting document which is recommended. He retired as head of the Department of Botany and Plant Pathology in 1928 and was succeeded by Melhus.

Meanwhile, at The University of Iowa, Dr. Thomas H. Macbride was making remarkable contributions to the studies of botany. He published five papers on fungi in the *Proceedings of the Iowa Academy of Science* in the period 1895 to 1923, and several more in the *University of Iowa Bulletin of Laboratories of Natural History.* His collections of homobasidiomycetes were the subject of some of these papers, but he also published papers on his collections of his favorite group of fungi, the slime molds, from the Black Hills and New Mexico. His book, *The North American Slime Molds,* was published in 1899. Macbride was the first president of the Iowa Park and Forestry Association, which later became the Iowa Conservation Association. This organization was active in early conservation efforts in Iowa. He served as president of the Iowa Academy of Science in 1897. A scholarship endowment for students attending the summer sessions at Iowa Lakeside Laboratory still perpetuates his memory. Macbride submitted his last paper concerning fungi in 1923. It was entitled "A Collection of Fiji and New Zealand Myxomycetes." We can only imagine how much this remarkable scholar enjoyed this journey.

The Macbride-Pammel botanical era produced other remarkable and interesting contributors. Bruce Fink (how fortunate that his name was not an affliction in those halcyon days) contributed much concerning Iowa lichens. George Washington Carver contributed papers from 1895-1899. J. P. Anderson's 1907 paper on the Iowa Erysiphaceae demonstrated the careful work characteristic of his later studies of Alaskan flora. His work and studies there were to lay the foundation academically and financially for the *Flora of Alaska* by Dr. Stanley Welsh, published in 1974. He continued as a member of the Academy even after moving to Alaska. Guy West Wilson of Upper Iowa University published the first of his ten papers in 1908, entitled "Notes on Peronosporales."

Henry Conard published a brief paper on spore formation in *Lycogola* in 1910. His career at Grinnell College was to span the next 60 years, in which he would receive national recognition as a bryologist and taxonomist. This gentle scholar is venerated by those who knew him. He was also to serve in 1914 as president of the Iowa Academy of Science.

Another illustrious career was also beginning at Iowa State as A. L. Bakke published his first paper on late blight of barley. Bakke's area was plant physiology, but his interests ranged broadly. His early research on the effect of smoke on plants preceded our current concerns by almost 60 years.

As the Macbride-Pammel era reached its peak, a new era in mycology began in Iowa. It was to be dominated by Dr. George Martin of The University of Iowa and Dr. Joseph C. Gilman of Iowa State.

Gilman came to Iowa State from Washington University in 1919 as a plant pathologist. He had worked with L. R. Jones at Wisconsin. His first published contribution to the Academy came in 1922. Gilman was to contribute to plant pathology and mycology locally and nationally for over 40 years. Gilman was the author of 23 papers concerning fungi and plant diseases published in the *Proceedings of the Iowa Academy of Science,* more than any other contributor in this area. Gilman's papers covered a wide range of topics. His series on "illustrations of the fleshy fungi of Iowa" appeared from 1940 to 1947 and included nine papers. His *Manual of Soil Fungi* is a classic reference. He was president of the Iowa Academy of Science in 1945 after serving as secretary of the Academy for many years.

Dr. George W. Martin presented two papers in 1925. One concerned some *Amanita* species from eastern Iowa. The second paper established a long-standing and cherished tradition of Martin's. It was entitled simply "Notes on Iowa Fungi." This series was to continue 35 years and to end with the publication of "Notes on Iowa Fungi XIV" in 1960. Martin contributed a total of 18 mycological papers to the Academy, a total second only to that of his close friend, Joseph Gilman. He was the senior author of the definitive book *The Myxomycetes.* Martin combined exceptional scientific talent with an endearing personality. He may well have been the most loved and respected of any of the many people mentioned in this summary. Many of us can remember sensing the very special aura of gentleness and kindness which surrounded Professor Martin.

The first decade (the 1920's) of the Martin-Gilman era produced some well known contributors. S. M. Dietz had two papers concerning rust of oats. Dietz' career spanned 40 years at Iowa State and Oregon State. J. C. Arthur presented his only paper to the Academy, entitled "The Uredinales of Iowa." Forty years previously Arthur had published a preliminary list of the Uredinales of Iowa containing 134 species. The name Jessie Augusta Parish appears in 1928. Parish's paper, "Pyrenomycetes, or Black Fungi of Iowa," was the only contribution on fungi which she presented and the only paper she contributed to the Academy. The name Parish continues, however, in Academy history and memory because it was Jessie Parish who endowed the Iowa Academy with the Parish Farm near Reinbeck. Donald Rogers, a student of Martin's, was beginning a career of distinction which was to allow him to serve at the New York Botanical Gardens and the University of Illinois.

Dr. J. E. Sass had joined the staff at Iowa State in 1929 and contributed four mycological papers beginning in 1935. His wide range of interest and competence, especially in the areas of plant anatomy and microtechnique, made him a pillar of the Iowa State faculty for almost 40 years. Dr. Myrle

Burk was also a contributor. She is still active and influential in the Nature Conservancy.

Paul Lentz, another Martin student, began contributing in 1942. Horace Barnett reported on Iowa fungi in 1945 based on Shimek's collections at The Universtiy of Iowa. Phyllis Gardner, also a Martin student, contributed an annotated checklist of Homobasidiomycetes of Iowa.

A brief paper in 1946 on producing stromata in *Claviceps* by Lois H. Tiffany marked the beginning of an illustrious career at Iowa State. This was the first of 17 mycological papers (as of 1974) contributed to the Iowa Academy. Only her major professor, Joseph Gilman, and George Martin have contributed more. Her contributions to the Academy, her university and the state are many. She has a record of perfect attendance at Iowa Academy meetings for the past 29 years. She is now a member of the Board of Directors. Her career at Iowa State includes contributions as a remarkable teacher, graduate faculty member, undergraduate adviser, and director of research. She was honored as faculty member of the year by Lampos in 1974. In addition, her patient contributions when the women at our universities were less enthusiastically rewarded was a constant reminder of the merits of women scholars. Many faculty women at Iowa State enjoy the benefits of the prior pioneering and example of Dr. Tiffany. It is indeed fitting that she follows professors Martin and Gilman as the mycological leader of the succeeding era in Iowa Academy of Science history. Her interests have been primarily in the area of lichens and Ascomycetes.

Another major contributor of the 1950's and 1960's was Harold S. McNabb, Jr. His primary concerns are tree diseases, especially oak wilt and Dutch elm disease. Paul Hoffman, Paul Schuldt, and Anthony Marchett also contributed papers to the Academy on tree diseases.

Dr. Martin was succeeded at The University of Iowa by Dr. Constantine Alexopoulos. Alexopoulos was already a well-known and highly respected mycologist when he came to Iowa from Michigan State to become the head of the Botany Department in 1956. His major interest was the Myxomycetes. He was the author of the standard textbook *Introductory Mycology* and was co-author with Dr. Martin of *The Myxomycetes.* Alexopoulos went to the University of Texas in 1962 and was succeeded by Dr. Martin Rosinski, who remained until 1974. Sister Mary Annunciata McManus was a consistent contributor during the 1960's, with seven papers concerning fine structure and physiology of Myxomycetes.

A great many contributions of papers, many of which concerned plant pathogens, came from Iowa State during the 1960's. Some of the contributors included John Dunleavy, Marr Simons, J. Artie Browning, Don Norton, Virgil Howe, Mike Woodward and Karen Juhl.

We now stand, in 1975, looking back 120 years to the beginnings of agriculture and the study of plant diseases in Iowa. We see the late 19th century when Bessey and Macbride and Pammel made the study of fungi an essential part of their wide botanical study. We recognize especially the sagacity of their early work and their ability to sense the real nucleus of the fungus problems which beset them. Later we could afford the luxury of having men like Melhus and his many co-workers at Iowa State devoting energy and resources to combating plant diseases while others like Martin and Gilman were concerned with the fungi themselves on a more academically aesthetic level.

The present finds two members of the Academy who are pursuing research on fungi with much activity. Most prominent is Dr. Lois Tiffany at Iowa State, with basic interests in Ascomycetes and lichens but with a broad range of knowledge based on over 25 years of experience and study. She has taught the basic and advanced mycology courses at Iowa State for 18 years. The other current worker is Dr. Robert Franke, a student of Dr. Alexopoulos, who is also the chairman of the Biology Program at Iowa State. His interests are primarily in fungus physiology and the Myxomycetes.

This history has so far been primarily concerned with mycology. There is, of course, a very pronounced and broad-surfaced interface between mycology and plant pathology. We must now pick up the thread of plant pathology as it began far back in the 1850's and as it became interwoven in the work of Bessey and Pammel in the early years. Finally, with the coming of Melhus to Iowa State in 1916, plant pathology was recognized as a major discipline in its own right. Melhus was a vigorous leader, and soon several programs were developed which contributed remarkably to Iowa agricultural efficiency.

The two major grain crops in Iowa in the period from 1915 to 1940 were corn and oats. It is logical that a vigorous program was established to explore the problem of crown rust of oats. The project was actually inaugurated in 1914, and the Iowa Agriculture Research Station and the United States Department of Agriculture have cooperated in continuing the work for the last 60 years. S. M. Dietz was an early leader from 1917 to 1927, and he was followed by H. C. Murphy, who was responsible for the project until he left in 1958 to work in Washington. Dr. Marr Simons and Dr. J. Artie Browning are now responsible for the work of the program.

Some of the achievements of this program included: the determination of the range of *Rhamnus* species as alternate hosts of *Puccinia coronata;* the development of sources of genetic resistance to crown rust; and the production of Clinton oats which revolutionized oat growing in Iowa twice. They were of Victoria genetic derivation and their excellent yield characteristics made them an almost unanimous choice of the farmers of Iowa in 1945. The second revolution came in 1947 when it became apparent that Clinton oats were very susceptible to *Helminthosporium victoriae.* This genetic factor was tied directly to resistance to *Puccinia coronata,* and Victoria-based oats were dropped in favor of other genetic bases which did not show this linkage. Thus the recurring lesson of plant breeding was taught again: a narrow genetic base for a widely grown crop can be very dangerous.

Corn is king in Iowa and diseases of corn are of great concern.

L. H. Pammel was an early student of the ear rotting diseases. Others involved with ear rotting organisms included L. W. Durrell and W. P. Raleigh. G. L. McNew and George Seminiuk have been major contributors in the study of stalk rots. Dean Foley has also contributed, especially in the study of resistance to stalk rots and stalk breakage.

Root rots are a major corn disease problem in Iowa. Dr. W. F. Buchholtz was the major contributor in this area from 1945 to 1967. He was succeeded by Dr. Charlie Martinson.

Corn smut, purple leaf sheath spot, and Holcus leaf spot are other corn diseases which have received attention. It is, however, interesting that corn generally does not have a single disaster-producing pathogen. Complacency often follows continued success. Thus corn yields in the 1950's and 1960's seemed to climb upwards with little really serious disease damage. Occasionally a leaf blight might damage the crop mildly, but neither farmers nor plant pathologists were prepared for the disastrous invasion of America's cornfields by southern corn leaf blight in 1970. Almost perfect weather conditions were coupled with an unfortunate genetically controlled susceptibility and a 25% yield loss resulted. Martinson, Foley, Wallin, Nyvall, Tiffany, Horner, and Knaphus, as well as other members of the department, were involved in various aspects of this urgent new problem. The major defense lies in changing the genetic makeup of the plant. The experience of 1970 lies in history but it is a grim reminder of the lesson learned previously in 1947 with Clinton oats. A narrow genetic base can be a doorway to disaster.

One of the problems of many crop plants is rotting of the seed before it can establish a vigorous new seedling. Iowa State contributions, especially those of C. S. Reddy, in the development of seed treatments are indeed massive. Many crops, and especially corn, can be planted earlier and a longer growing season utilized if the seeds are treated with fungicides.

The roots of seedlings also are susceptible to attack by fungi. Buchholtz was a long-time leader in studies by several graduate students concerning root rots of sugar beets, barley, corn, and crested wheat grass.

Soybeans are the other major grain crop of Iowa, and their production has grown from almost nothing in 1930 until, in 1973, the cash value of soybeans sold compared with the cash value of corn. A. W. Welch began the legume and forage crop program in 1946. J. M. Crall, J. C. Gilman and Lois Tiffany were active contributors. John Dunleavy and Hideo Tachibana are now the chief contributors in the area of soybean diseases.

Many plant diseases are affected greatly by the vagaries of weather. Iowa State contributions, especially those of Jack Wallin and I. E. Melhus, have elucidated the disease-weather relationships and made possible a "disease-forecasting" program which enables Iowa growers to spray more effectively at the times when disease is most likely to appear. The program is not only very valuable to Iowa, but principles of weather effects on disease spread have been elucidated which aid other researchers in the rest of the world.

Nursery crops are not as prominently recognized as corn or soybeans in Iowa. However, they are important, with large nurseries in southwest Iowa, many commercial orchards and a host of home-grown fruits all needing protection from disease. Fire blight of apple was a problem in 1860 and remains serious today. Melhus worked on nursery diseases in the 1920's. Others who have contributed include J. H. Muncie, D. F. Bliss, G. L. McNew and W. F. Buchholtz. Buchholtz was especially active in studying stone fruit viruses in the 1950's and 1960's.

Shade trees are a part of our lives, and two major diseases of shade trees have caused great concern in the last 25 years. Oak wilt was the earlier disease; it received attention from S. M. Dietz, J. W. Barrett, R. A. Young, G. L. McNew, W. H. Bragonier and H. S. McNabb, Jr. It has not had the disastrous effects which have attended the advent of Dutch elm disease. Dutch elm disease came into Iowa in the late 1950's. H. S. McNabb, Jr., has been the leader in the study of this disease and the battle has been very difficult. The effectiveness of spore transfer by the elm bark beetle, root grafts and the apparently increasing virulence of the pathogen have reduced the elm population, and probably only a few individual trees will be able to survive. The relentlessness of the disease and its decimation of a much-loved tree population does not detract from the dedication and ability of those who have wrestled with this problem, including McNabb and Abraham Epstein.

An arm of plant pathology of great importance has been the Extension Program. Plant pathologists such as Melhus began early the spreading of knowledge about plant diseases and their controls. The Extension Program continued and formalized these procedures. Many disease problems were greatly reduced because of the very active program of education. R. H. Porter, Duke Layton, J. H. Standen, E. L. Waldee, D. M. Coe, A. F. Sherf, Malcolm Shurtleff, Gayle Worff, Robert Lambe, Jim Reynolds, Abraham Epstein and Bob Nyvall have been members of the extension group. E. P. Sylwester, who began work as Extension Botanist in November of 1935, has also contributed to the plant pathology extension work during the past 40 years.

The Ionization Constants for Ethylenediamine

WILLIAM A. DESKIN[1] and GARY LORD

DESKIN, WILLIAM A., and GARY LORD (Department of Chemistry, Cornell College, Mount Vernon, Iowa 52314). The Ionization Constants for Ethylenediamine. *Proc. Iowa Acad. Sci.* 82(2): 100-101, 1975.

The ionization constants for ethylenediamine have been determined at 25° and at a constant ionic strength of 0.2 M (sodium perchlorate). The following values are reported: log $Q_1 = 10.22 \pm 0.02$ and log $Q_{12} = 7.36 \pm 0.04$.

A continuing study in our laboratory has been the determination of formation constants for metal complexes. One of the methods (1) which we have used makes use of a competitive reaction of two ligands for coordination sites on the particular metal ion. The following equilibrium illustrates one of the reactions which has been studied.

$$M(en)_2^{2+} + 2\ dto^{2-} = M(dto)_2^{2-} + 2\ en \qquad (1)$$

In this reaction the metal ion, M^{2+}, is complexed with ethylenediamine, en. An aqueous solution of this complex is mixed with the dipotassium salt of dithiooxalic acid, dto^{2-}. The concentrations of species in the above reaction are adjusted so that the equilibrium proceeds only part way. The ionic strength is adjusted to a prechosen value with an inert electrolyte, usually sodium perchlorate, and the pH of the final solution is either monitored or adjusted to a desired value.

The formation constant, β_2, for the metal-dithiooxalate complex may be calculated from spectral data. Spectra suggest that mixed ethylenediamine-dithiooxalate complexes are not formed. The solutions were assumed to contain the species $M(en)_2^{2+}$, Men^{2+}, en, $M(dto)_2^{2-}$, and dto^{2-}. The extinction coefficients of these species are known and the formation constants of $M(en)_n^{2+}$ are available (2). This information together with knowledge of the total concentration of metal, ethylenediamine, and dithiooxalate allows one to solve for the value of β_2 for the dithiooxalate complex.

If one chooses a pH value which is neutral or acidic the basicity of the ethylenediamine must also be considered. In our experiments we chose to work at an ionic strength of 0.2 *M*. In this medium literature values for the ionization constants for ethylenediamine were not available.

EXPERIMENTAL

The chemicals used in this study were reagent grade. The sodium hydroxide solutions were prepared carbonate-free by standard procedures and standardized using primary standard potassium hydrogen phthalate with phenolphthalein as the indicator. The hydrochloric acid solutions were standardized with primary standard sodium carbonate using modified methyl-orange as the indicator. The ionic strength of all solutions was adjusted to 0.2 *M* by addition of the appropriate amount of sodium perchlorate. Ethylenediamine was purified by refluxing with zinc dust and distilled.

The pH measurements were made with a Brinkman model 102 pH meter, accurate to ± 0.002 pH units, which was standardized with precision buffers prepared by a recommended formula of the National Bureau of Standards. All titrations were made at a constant temperature of 25° under a nitrogen atmosphere to prevent the absorption of carbon dioxide by the ethylenediamine. The activity coefficients of the hydrogen ion and hydroxide ion at an ionic strength of 0.2 *M* were 0.797 and 0.706, respectively (3).

[1] Department of Chemistry, Cornell College, Mount Vernon, Iowa 52314.

RESULTS AND DISCUSSION

The quotients for the protonation of ethylenediamine are defined:

$$H^+ + en = enH^+ \qquad Q_1 = \frac{[enH^+]}{[H^+]\,[en]} \qquad (2)$$

$$H^+ + enH^+ = enH_2^{2+} \qquad Q_{12} = \frac{[enH_2^{2+}]}{[H^+]\,[enH^+]} \qquad (3)$$

Since concentrations were used in the equilibrium constant expressions instead of activities, these expressions are concentration quotients (at a constant ionic strength). An aqueous solution containing ethylenediamine completely protonated by a strong acid was titrated with a strong base. A proton balance equation and a material balance equation, respectively, for ethylenediamine for this system are:

$$T_A - T_B + [OH^-] = [H^+] + [enH^+] + 2\,[enH_2^{2+}] \qquad (4)$$

$$T_{en} = [en] + [enH^+] + [enH_2^{2+}] \qquad (5)$$

$T_A - T_B$ (total acid − total base) represents the amount of hydrogen ions from the acid less the hydrogen ions neutralized by the base. The hydrogen ions from the dissociation of water are represented by $[OH^-]$.

When one assumes that the quotients differ by more than a factor of 100, then $[en] = 0$ in the buffer region of the first half of the titration and $[enH_2^{2+}] = 0$ in the buffer region of the second half of the titration. From these assumptions we may derive an expression for Q_1 and Q_{12}.

$$Q_1 = \frac{T_A - T_B + [OH^-] - [H^+]}{[H^+]\,\{T_{en} - T_A + T_B - [OH^-] + [H^+]\}} \qquad (6)$$

$$Q_{12} = \frac{T_A - T_B - T_{en} + [OH^-] - [H^+]}{[H^+]\,\{2T_{en} - T_A + T_B - [OH^-] + [H^+]\}} \qquad (7)$$

The hydrogen and hydroxide ion concentrations were determined from the pH values and the activity coefficients of both ions. The other terms in equations 6 and 7 were known from the volumes and concentrations of the respective solutions added. A program for the IBM 1130 computer, written in Fortran IV, was used for calculating the quotients.

The results of these titrations reported as log Q_1 and log Q_{12} for ethylenediamine produced the values 10.22 ± 0.02 and 7.36 ± 0.04, respectively. These results are compared to literature values found at both lower and higher ionic strengths; see Table 1.

TABLE 1. PROTONATION QUOTIENTS FOR ETHYLENEDIAMINE AT 25°

Ionic Strength	*log Q_1*	*log Q_{12}*	*Reference*
0	9.87	6.80	(4)
0[a]	9.81	6.79	(5)
0.1[b]	10.03	7.22	(6)
0.2	10.22	7.36	this work
0.5	10.18	7.47	(7)
1.3	10.17	7.44	(8)

[a] At 30°.
[b] At 20°.

Within experimental error, the values determined in this work agree with the pattern of earlier work at lower and higher ionic strength.

ACKNOWLEDGMENT

We wish to thank the Research Corporation for support of this work under a Cottrell College science grant.

LITERATURE CITED

(1) R. G. PEARSON and D. A. SWEIGART, *Inorg. Chem.*, 9, 1167 (1970).
(2) A. E. MARTELL and L. G. SILLEN, *Stability Constants of Metal-Ion Complexes*, 2nd ed., Special Publication No. 17, The Chemical Society, London, 1964, p. 372.
(3) LOUIS MEITES, *Handbook of Analytical Chemistry*, McGraw-Hill Book Company, Inc., New York, 1963, p. I-7.
(4) A. GERO, *J. Amer. Chem. Soc.*, 76, 5159 (1954).
(5) C. R. BERTSCH, W. C. FERNELIUS, and B. P. BLOCK, *J. Phys. Chem.*, 62, 444 (1958).
(6) G. SCHWARZENBACH, *Helv. Chim. Acta*, 35, 2337 (1952).
(7) F. BASOLO and R. K. MURMANN, *J. Amer. Chem. Soc.*, 74, 5243 (1952).
(8) R. N. KELLER and L. J. EDWARDS, *J. Amer. Chem. Soc.*, 74, 1931 (1952).

Blood Parasites from Birds of the Lake Okoboji Region, Iowa[1]

JOHN N. FARMER[2] and DAVID H. VESOLE[3]

FARMER, JOHN N., and DAVID H. VESOLE (Division of Biological Sciences, University of Missouri, Columbia, Missouri 65201). Blood Parasites from Birds of the Lake Okoboji Region, Iowa. *Proc. Iowa Acad. Sci.* 82(2): 102-105, 1975.

Hematozoa are reported from 171 birds, representing 7 orders of 20 families and 33 species, all collected in Dickinson County, northwest Iowa, with the majority of animals being collected at the Iowa Lakeside Laboratory, Milford, Iowa. Blood parasites were observed in 67 birds (39.2%), with an incidence as follows: *Haemoproteus* sp., 45 (26.3%); *Leucocytozoon* sp., 19 (11.1%); *Plasmodium* sp., 4 (2.3%); *Trypanosoma* 3 (1.7%); and microfilariae, 29 (16.9%).

An evaluation of these results indicates a dramatic decrease in the incidence of blood parasites later in the summer. The presence of parasites early in the spring is considered to be a function of relapse in birds returning to the area to build nests and to reproduce. The subsequent decrease in incidence of parasitized birds occurs as the infections run their course and become latent.

A species of *Plasmodium* isolated from a blue jay *(Cyanocita cristata)* was found to be highly pathogenic, since the natural host as well as two other blue jays with induced blood infections died, with over 60% of their erythrocytes being parasitized. Using gametocyte morphology, the number of merozoites in mature schizonts and the punctiform appearance of pigment, the parasite was considered to be *P. relictum*. The blue jay appears to be a new host record for this parasite, at least in Iowa.

INDEX DESCRIPTORS: Avian Blood Parasites, Hematozoa, *Plasmodium relictum*

Surveys of blood parasites of resident and migratory birds in Iowa have been few in number. Moreover, these studies, for the most part, have been restricted to a single avian species. Coatney (1938) examined the blood of 63 birds representing 15 families and 23 species captured or shot during 1935-1936 in the vicinity of the Iowa Lakeside Laboratory on Lake Okoboji. He reported finding only seven birds (1.1%) harboring blood parasites. During the period 1957-1959, Farmer (1960) surveyed the blood of birds, principally of the order Columbiformes, in central Iowa (Ames and Gilbert), and of the 568 examined, 99 (17.3%) were found to be infected with hematozoa. Roslein and Haugen (1962, 1964, 1970) have conducted several surveys in Iowa in order to assess the incidence of blood parasite infections in game bird populations. In 1962, they reported the absence of blood parasites in 364 pheasants and 673 bobwhite quail examined during the period 1957-1961. They indicated (1964) that while examining blood of 168 wood ducks (*Aix sponsa* L.) at the Upper Mississippi River Wildlife and Fish Refuge during 1963, 77 (46%) were found to be infected with *Haemoproteus*. Finally, while studying the blood of wild Rio Grande turkeys stocked in Iowa, they reported (1970) finding 31 of 39 (79%) harboring *Haemoproteus* infections.

The senior author has been a resident at the Iowa Lakeside Laboratory for several summers, and because the examination of birds for the presence of metazoan parasites has been an ongoing project of other investigators at the Laboratory, it has been a simple matter to obtain blood smears from a variety of avian hosts.

The following information represents the results of this study, conducted during the summers of 1967-1974. Because the common grackle (*Quiscalus quiscula*) was being trapped as a part of a recent project, this group represents a major portion (42.1%) of the birds examined. No attempt was made to distinguish between the bronzed, purple and hybrid grackles. The results of the survey were also evaluated in relation to the time of summer that parasites were observed, because initial studies in 1967 indicated a dramatic decrease in the incidence of hematozoa in birds examined later in the summer.

MATERIALS AND METHODS

All birds were captured or shot in Dickinson County, with the majority being collected in the vicinity of the Iowa Lakeside Laboratory during the spring and summer months of 1967-1974. Blood from birds was obtained by nicking a toe or the alar vein of live birds or by using a heparinized capillary tube to collect blood from the heart of killed birds. Blood smears so obtained were air dried, fixed in absolute methanol and stained in Giemsa. Stained slides were examined by low power and oil immersion microscopy. A slide was determined negative if after a 20-minute examination period (under oil immersion) no sign of blood parasites was detected. In only a few cases were attempts made to determine the species of the various blood parasites observed during this study. In one *Plasmodium* infection, observed in the blue jay (*Cyanocita cristata*), blood from the host animal was transferred to two other blue jays that had been captured and held in the animal building. These had been examined a week earlier and had been found to be negative for blood protozoa. Each bird was inoculated with .25 ml of heparinized blood from the host animal with a patent *Plasmodium* infection. Two blood smears were made from each animal twice a day, once in the morning and again in the afternoon. One of each pair of slides was dipped in ether prior to fixation and staining in order to disrupt the erythrocytes to facilitate the counting of merozoites in mature schizonts.

RESULTS AND DISCUSSION

Results of the blood survey are summarized in Table 1. Of

1 This study was conducted at the Iowa Lakeside Laboratory, Milford, Iowa 51351, and supported in part by a Summer Research Fellowship (Biomed) awarded to John N. Farmer by the Research Council of the University of Missouri–Columbia.

2 Division of Biological Sciences, University of Missouri, Columbia, Missouri 65201.

3 Department of Microbiology and Medical Technology, University of Arizona, Tucson, Arizona 85721.

TABLE 1. INCIDENCE OF BLOOD PARASITES FROM BIRDS OF THE LAKE OKOBOJI REGION

Family and Specific Name	Common Name	No. Examined	No. Positive	Parasite H	L	T	P	Mf.
Passeriformes								
Corvidae								
Cyanocita cristata	Blue Jay	9	3	1		1	1	
Mimidae								
Dumetella carolinensis	Catbird	5	1					1
Toxostoma rufum	Brown Thrasher	11	8	8	1			
Tyrannidae								
Tyrannus tyrannus	Eastern Kingbird	2	0					
Contopus virens	Eastern Wood Peewee	1	0					
Paridae								
Parus atricapillus	Black-Capped Chickadee	3	0					
Turdidae								
Turdus migratorius	Robin	8	0					
Vireonidae								
Vireo gilvus	Warbling Vireo	1	0					
Icteridae								
Agelaius phoenicius	Red-Winged Blackbird	15	2	1	1			2
Sturnella magna	Meadowlark	1	1	1			1	
Xanthocephalus xanthocephalus	Yellowheaded Blackbird	1	0					
Euphagus cyanocephalus	Brewer's Blackbird	1	1				1	1
Quiscalus quiscula	Common Grackle	72	47	31	17	1	1	24
Hirundinidae								
Hirundo rustica	Barn Swallow	1	0					
Progne subius	Purple Martin	4	0					
Ploecidae								
Passer domesticus	House Sparrow	1	0					
Troglodytidae								
Troglodytes aedon	House Wren	5	0					
Telmatodytes palustris	Longbilled Marsh Wren	2	0					
Parulidae								
Dendroica dominica	Yellow-Throated Warbler	1	0					
Picadae								
Colaptes auratus	Yellowshafted Flicker	1	0					
Dendrocopos pubescens	Downy Woodpecker	1	0					
Fringillidae								
Spinus tristis	American Goldfinch	3	1	1				
Melospiza melodia	Song Sparrow	4	0					
Melospiza georgiana	Swamp Sparrow	2	0					
Passerherbulus henslowii	Henslow's Sparrow	1	0					
Pheuctius ludovicianus	Rose-Breasted Grosbeak	2	1			1		1
Columbiformes								
Columbidae								
Zenaidura macroura	Mourning Dove	3	2	2				
Gruiformes								
Rallidae								
Fulica americana	Coot	2	0					
Falconiformes								
Accipitiridae								
Buteo jamaicensis	Red-Tailed Hawk	1	0					
Ciconiformes								
Ardeidae								
Ardea herodias	Great Blue Heron	1	0					
Charadriiformes								
Laridae								
Chlidonias nigra	Black Tern	3	0					
Scolopacidae								
Erolia minutilla	Least Sandpiper	2	0					
Strigiformes								
Strigidae								
Bubo virginianus	Great Horned Owl	1	0					
Totals		171	67	45	19	3	4	29

171 birds examined, 67 (39.1%) were positive for some form of blood parasite. The parasites and their incidence were: *Haemoproteus* sp., 45 (26.3%); *Leucocytozoon* sp., 19 (11.-1%); *Plasmodium* sp., 4 (2.3%); *Trypanosoma*, 3 (1.7%); and microfilariae, 29 (16.9%). Of the microfilariae, two distinct forms were recognized, a blunted unsheathed form and an unsheathed form blunted anteriorly and tapered posteriorly.

Multiple infections involving two or more blood parasites were common. Of the total of 67 infected birds observed, 41 (60%) carried single infections, 17 (25%) carried two parasite species, seven (14%) carried three and two (3%) carried four species of parasite. These results suggest that the same vector may be responsible for the transmission of two or more blood parasites, a possibility suggested by Bennett and Fallis (1960).

Grackles represented 42.1% of the total number of birds examined (72 of 171), with 70.1% (47 of 72) being found infected with some type of blood parasite. Incidences of the infections in the grackles were: *Haemoproteus quiscalus,* 31 (68.8%); *Leucocytozoon* sp., 17 (89.4%); *Plasmodium,* one (25%); *Trypanosoma avium,* one (33.3%); and microfilariae, 24 (82.7%).

Contrary to previous studies (Stabler and Kitzmiller, 1970; Wetmore, 1941; Bennett and Fallis, 1960), not one of the eight robins we examined appeared to carry patent infections. On the other hand, eight of 11 (72.7%) brown thrashers were infected with *Haemoproteus beckeri,* with one possessing a *Leucocytozoon* infection as well. This contrast between incidence of infection in grackles and thrashers is puzzling and suggests that either the vectors for transmitting robin-specific parasites are not present in the Okoboji region or that relapses in these animals occur at other times of the year.

Haemoproteus

According to Levine and Campbell (1971), the genus *Haemoproteus* should only include those parasites transmitted by hippoboscid vectors. *Parahaemoproteus,* on the other hand, should be reserved for those haemoproteid forms that are transmitted by *Culicoides.* Since the vectors responsible for carrying blood parasites were not determined during our survey, no distinction was made between these two genera. We retained the genus *Haemoproteus* for all halteridium-type parasites seen in erythrocytes, although future studies might warrant their inclusion in the genus *Parahaemoproteus,* because no hippoboscids were observed on any of the birds we examined.

Haemoproteus sakharoffi was seen in one of nine (11.1%) blue jays; eight of 11 (72.7%) brown thrashers were infected with *H. beckeri;* 31 of 72 (41.8%) common grackles were hosts to *H. quiscalus;* and two of three (66.6%) mourning doves were infected with *H. macallumi.* One of these mourning doves also was host to the characteristic hypertrophied gametocytes of *H. sacharovi.* In addition, *Haemoproteus* was diagnosed from one of three goldfinches, from the only meadowlark examined, and one of 15 red-winged blackbirds.

Leucocytozoon

Leucocytozoon was observed in 19 of 171 (11.1%) birds examined; however, these infections were distributed among only three avian species, the grackle having by far the greatest incidence—17 of 19 (89.4%) infections being recorded from these animals. The two other species carrying *Leucocytozoon* were the brown thrasher and the red-winged blackbird, with one bird of each being infected.

The incidence of *Leucocytozoon* infections in grackles was

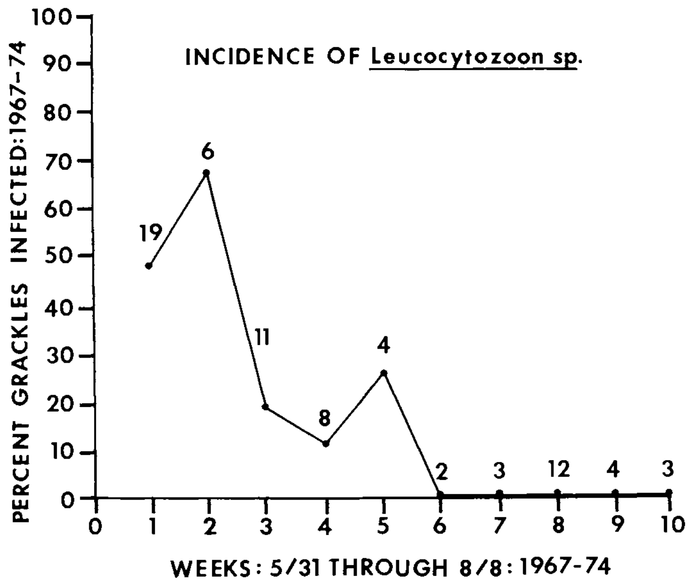


Figure 1. The incidence of *Leucocytozoon* sp. in the common grackle (*Quiscalus quiscula*) relative to the time of year. The birds were grouped according to their date of capture regardless of the year.

far greater in the spring (May) and early summer (June) than later in the summer (mid-July to August). Examination of Figure 1 indicates a dramatic decrease in the incidence of *Leucocytozoon,* with no birds being found with patent infections past mid-July. Bennett and Fallis (1960) attribute monthly variations in the incidence of *Leucocytozoon* infections in ducks to the abundance and prevalence of the appropriate vectors. In their study, the numbers of these intermediate hosts reached their highest level late in May and through the month of June. Furthermore, this period coincides with the breeding phase of the avian hosts. Khan and Fallis (1970) and Rogge (1968) consider that relapse of *Leucocytozoon* infections in previously infected birds is a function of the host's reproductive cycle rather than a function of stress due to migration. The results of our survey appear to corroborate these reports. *Leucocytozoon* infections in grackles are more common during the spring, coinciding with the active breeding phase of these animals. It is assumed that birds returning to this area to breed undergo relapse, causing *Leucocytozoon* to be available for the appropriate intermediate host. The relapse may be initiated by an increase in gonadal hormones in breeding birds (Haberkorn, 1968) or the release of steroids due to the stress of competition for mates and nest-building sites.

Plasmodium

The identification of *Plasmodium* in single blood smears is, at best, a speculative venture. One must be sure that the parasite is *Plasmodium,* because small, uninucleate stages of the various genera of hematozoa are so similar in appearance (i.e., *Haemoproteus* sp.). Only by the observance of segmenting stages can one be sure that the organism is *Plasmodium.*

Accordingly, *Plasmodium* was only clearly identified in four birds, namely blue jay, Brewer's blackbird, grackle and meadowlark. In the *Plasmodium* observed in the blue jay, the smear was obtained from a live bird, enabling a blood transfer to be made to two other jays that had been trapped four days earlier, whose blood had been found free of blood parasites. Fulminating *Plasmodium* infections developed in these animals and the experimental animals died eight days after being infected, each with over 60% of their erythrocytes being infected. The host animals also died with parasitemias almost as high, indicating this species of *Plasmodium* to be highly pathogenic.

Identification of *Plasmodium* usually involves hourly blood examination of infected hosts to determine the timing of sporulation, and the periodicity and synchronicity of the parasite. This was not done; however, the morphology of gametocytes was examined and merozoite numbers in mature schizonts were determined. The parasites displaced host cell nuclei and the rounded gametocytes often caused the extrusion of the host cell nucleus completely. The morphology of pigment granules formed by the parasites was variable although tending to be small and punctiform. The mean number of merozoites per mature schizont was determined to be 16.5 with a range of 13-23. Although these data are scant, they do suggest that the parasite was *P. relictum.* A search of the literature indicates that *Plasmodium* infections in blue jays are rarely reported, if at all. This report appears to be a new host record for *Plasmodium relictum* in blue jays, at least in Iowa.

Trypanosoma

Avian trypanosomes are rarely seen in the peripheral blood smears, so that their incidence has long been considered to be quite low. However, their occurrence is greater than previously suspected, as shown by the study of Stabler (1961), who used bone marrow smears and culture techniques in his study of 79 Colorado birds, with 81% of the birds surveyed by these methods being found to harbor *Trypanosomes,* while only 6% of these same animals yielded positive peripheral blood smears.

Only three *Trypanosoma* infections were observed during our survey, one each from a blue jay, a grackle and a grosbeak. All have previously been reported in the midwest as hosts for trypanosomes (Stabler, 1961). However, their incidence may be much greater, a speculation that can only be verified by utilizing bone marrow smears and culture methods during additional surveys.

One point that was apparent was that in all three hosts, the trypanosomes were found in association with at least one other haemoprotozoan, suggesting that a common vector may be responsible for transmission.

Microfilaria

These blood inhabiting stages of nematodes were observed in approximately 17% of the birds surveyed, with 29 infections being distributed among five avian species. Two morphological types of microfilariae were recognized, namely an unsheathed form blunted at both ends and an unsheathed form blunted anteriorly and tapered posteriorly. The former microfilariae are associated with a *Splendidofilaria* sp. nematode, the adults of which occur in the brain of grackles. Concurrent infections of the two microfilarial types were observed in five grackles. The pointed microfilariae, alone, were reported from three birds: two grackles and a red-winged blackbird. The blunted forms were observed in 26 birds including 22 grackles, one catbird, one red-winged blackbird, one Brewer's blackbird and a grosbeak. The vector for *Splendidofilaria* sp. is considered to be a *Culicoides* (Robinson, 1961), but the transmission of these nematode parasites has never been studied in the Okoboji region.

ACKNOWLEDGMENTS

We wish to thank Edward K. Dykstra, Mary J. Barnett, David W. Frederickson and Robert R. Rankin for their help in collecting these data.

LITERATURE CITED

BENNETT, C. F., and A. M. FALLIS. 1960. Blood parasites of birds in Algonquin Park, Canada, and a discussion of their transmission. *Can. J. Zool.,* 38:261-273.

COATNEY, G. R. 1938. Some blood parasites from birds of the Lake Okoboji region. *Amer. Midl. Nat.,* 20:336-340.

FARMER, J. N. 1960. Some blood parasites from birds in Central Iowa. *Proc. Iowa Acad. Sci.,* 67:591-597.

HABERKORN, A. 1968. Zur hormonellen Beeinflussung von *Haemoproteus*-Infektionen. *Z. Parasitenk.,* 31:108-112.

HSU, CHAO-KUANG, G. R. CAMPBELL, and N. D. LEVINE. 1973. A checklist of the species of the genus *Leucocytozoon* (Apicomplexa, Plasmodiidae). *J. Protozool.,* 20:195-203.

KHAN, R. A., and A. M. FALLIS. 1970. Relapses in birds infected with species of *Leucocytozoon. Can. J. Zool.,* 48:451-455.

LEVINE, N. D., and G. R. CAMPBELL. 1971. A checklist of the species of the genus *Haemoproteus* (Apicomplexa, Plasmodiidae). *J. Protozool.,* 18:475-484.

ROBINSON, E. J., JR. 1961. Incidence of microfilariae in some Ohio birds and data on the habits of a possible vector. *J. Parasitol.,* 47:441-444.

ROGGE, D. 1968. Experimentelle Beeinflussung der *Haemoproteus*-parasitemie beim Grünfinkin *(Carduelis chloris)* durch künstlichen Langtag, *Acta Parasitol. Pol.,* 15(40/50):397-407.

ROSLEIN, D. J., P. L. FORE, and A. O. HAUGEN. 1962. Blood parasites in relation to pheasants and quail in Iowa. *Proc. Iowa Acad. Sci.,* 69:239-244.

——— and A. O. HAUGEN. 1964. Occurrence of *Haemoproteus nettionis* in wood ducks (*Aix sponsa* L.). *Proc. Iowa Acad. Sci.,* 71:235-240.

——— and ———. 1970. Some blood parasites and disease antibody findings in wild Rio Grande turkeys stocked in Iowa. *Proc. Iowa Acad. Sci.,* 77:93-96.

STABLER, R. M. 1961. Comparsion of *Trypanosoma* incidence in blood and bone marrow from 79 Colorado birds. *J. Protozool.,* 8:122-123.

——— and N. J. KITZMILLER. 1970. Hematozoa from Colorado birds. III. Passeriformes. *J. Parasitol.,* 56:12-16.

WETMORE, P. W. 1941. Blood parasites of birds of the District of Columbia and Patuxent Research Refuge vicinity. *J. Parasitol.,* 27:379-393.

The Vertebrate Fauna of the Cayler Prairie Preserve, Dickinson County, Iowa

WILLIAM J. PLATT[1]

PLATT, WILLIAM J. (Department of Biological Sciences, University of Illinois at Chicago Circle, Chicago, Illinois 60680). The Vertebrate Fauna of the Cayler Prairie Preserve, Dickinson County, Iowa. *Proc. Iowa Acad. Sci.* 82(2): 106-108, 1975.
The vertebrate fauna of the Cayler Prairie Preserve, Dickinson County, Iowa, has been compiled from field observations and study between 1971 and 1974. Seventy-two species, including four amphibians, seven reptiles, 35 birds, and 26 mammals, were recorded. The diverse fauna results from the variety of habitats contained in the preserve, as well as the size of the preserve. One key member of the fauna is the badger *(Taxidea taxus)*, which creates microhabitats favorable for small vertebrates while digging for ground squirrels. Few adventive vertebrates have successfully invaded the prairie, and the fauna represents a sizable fragment (larger vertebrates are absent) of the fauna typically associated with tall-grass prairies.
INDEX DESCRIPTORS: Cayler Prairie Preserve, Vertebrates, Badgers, Tall-Grass Prairie.

One of the larger remnants of tall-grass prairie in Iowa is the Cayler Prairie Preserve, located in the northwestern quarter of section 17 of the Lakeville Township, Dickinson County. This prairie, about 160 acres (65 ha) in size, is an esker complex belonging to the Altamont glacial moraine (Salisbury and Knox, 1969), and thus contains considerable topographic relief. Dry ridges are interspersed with potholes and sloughs that contain water during the spring, but frequently are dry during the summer. The flora is diverse, and many species of tall-grass prairie plants, as well as mixed prairie species on the dry ridge tops, are present (cf. Aikman and Thorne, 1956; Platt, 1975). The Cayler Prairie Preserve probably contains the most diverse flora and fauna of any of the larger prairie remnants in Iowa.

The purpose of this report is to provide a species list of vertebrates inhabiting the Cayler Prairie Preserve. Such information ultimately will be of value for scientists wishing to study animal ecology and distribution in tall-grass prairies.

METHODS AND RESULTS

During the past four years I have been engaged in various research projects on the Cayler Prairie Preserve. I have kept notes on the species of vertebrates present on the area. Additional information has been obtained from Dr. Robert Cruden, Edwin L. Freese, and from field biology classes at the Iowa Lakeside Laboratory which utilize the prairie for classwork.

A total of 72 species of terrestrial vertebrates have been recorded from the Cayler Prairie Preserve during the past four years. These species do not include migratory birds that might be present briefly during the spring or fall and do not include transient species that cross or stray onto the prairie. Species breeding and/or foraging on the prairie are listed in Table 1, along with designations of relative abundance. Species were designated as rare if encountered less than five times in the past four years, uncommon if sighted less than twice a year, and common if they were encountered more frequently. Almost all species have been recorded previously from northwestern Iowa (cf. Blanchard, 1923; Tinker, 1914; King, 1946; Stephens, 1938; Scott, 1937; Polder, 1953).

OBSERVATIONS AND DISCUSSION

The considerable topographic relief of the Cayler Prairie Preserve is in part responsible for the large number of species of vertebrates present. Some species tend to be associated with uplands, mesic slopes, or swales. Species typically associated with upland short-grass regions dominated by little blue stem (*Andropogon scoparius*) include *Eumeces septentrionalis, Thamnophis radix, Falco sparverius, Bartramia longicauda, Lanius ludovicianus, Spermophilus tridecemlineatus, Onychomys leucogaster, Zapus hudsonius,* and *Lepus townsendii.* Species typically found on the prairie midslopes dominated by big blue stem (*Andropogon gerardi*) include *Bufo americanus, Rana pipiens, Phasianus colchicus, Tyrannus tryrannus, Sturnella magna, S. neglecta, Dolichonyx oryzivorus, Spiza americana, Ammodramus savannarum, Melospiza melodia, Sorex cinerus, Blarina brevicauda, Reithrodontomys megalotis,* and *Microtus pennsylvanicus.* Species found in the potholes and swales dominated by sloughgrass (*Spartina pectinata*) include *Ambystoma tigrinum, Pseudacris triseriata, Chelydra serpentina, Emydoidea blandingi, Chrysemys picta, Thamnophis sirtalis, Anas platyrhynchos, A. discors, A. crecca, Charadrius vociferus, Cistothorus platensis, Xanthocephalus xanthocephalus, Agelaius phoeniceus, Passerculus sandwichensis, Ondatra zibethicus, Sylvilagus floridanus,* and *Odocoileus virginianus.*

One important member of the vertebrate fauna is the badger (*Taxidea taxus*). Badgers dig holes in pursuit of ground squirrels (cf. Errington, 1937; Snead and Hendrickson, 1942) and in the process excavate mounds of dirt. This habitat modification not only results in distinct plant species associations (Platt, 1975), but also creates microhabitats favorable for small vertebrates. A number of amphibians and reptiles (i.e., *Ambystoma tigrinum, Bufo americanus, Rana pipiens, Eumeces septentrionalis, Thamnophis radix*) spend the winter inside the badger holes. These species may also survive dry spells during the summer inside badger holes. *Eumeces septentrionalis* lays eggs inside burrows dug in the mounds of dirt adjacent to the badger holes; I have observed at least 25 skinks with clutches of eggs in the early summer. Small rodents and insectivores also undoubtedly use badger holes. The large number of badger holes on the Cayler Prairie Preserve has favored large populations of some of these small vertebrates and perhaps is the reason species such as shrews are able to survive in xeric prairie habitats.

The vertebrate fauna of the Cayler Prairie Preserve repre-

[1] Department of Biological Sciences, University of Illinois at Chicago Circle, Chicago, Illinois 60680.

sents a fragment of that present prior to conversion of surrounding land to agricultural use (cf. Tinker, 1914; Stephens, 1938); larger birds and mammals were present at one time. However, invasions by other vertebrates are relatively few. Pheasants (*Phasianus colchicus*) and Hungarian partridge (*Perdix perdix*) presumably have replaced prairie chickens, *Tympanuchus cupido* (cf. Kendeigh, 1941). *Geomys bursarius,* the prairie pocket gopher, and *Scalopus aquaticus,* the eastern mole, are present only in disturbed areas along the periphery of the prairie and are not found in the relatively undisturbed central area of the preserve. Species commonly associated with man, such as the house sparrow (*Passer domesticus*), starling (*Sturnus vulgaris*), house mouse (*Mus musculus*), and Norway rat (*Rattus norvegicus*) are found on nearby farms, but not on the prairie. The existence of a vertebrate fauna fairly typical of that expected for a tall-grass prairie remnant suggests that the prairie is a relatively closed community not likely to be invaded by adventive species. Although larger vertebrates are not present, the community at present contains a relatively intact vertebrate fauna in which the terminal predators are raptors (especially the accipitrid hawks) and mustelids (weasels, badgers). It is worth noting that home ranges of badgers (270-580 ha; Lindzey, 1971) and the larger hawks (80-100 ha; Craighead and Craighead, 1956) are larger than the size of the existing preserve. Thus individuals of these species also forage in areas (now primarily pasture) adjacent to the prairie. I suggest that if this land were to be converted to crop use, an important faunal element of the Cayler Prairie Preserve would be eliminated, or at the least greatly reduced in numbers. Especially in the case of badgers, this would eliminate or greatly reduce rates of habitat modification. Small vertebrate and plant populations dependent upon these habitat alterations also might be eliminated or decrease in abundance.

TABLE 1.

VERTEBRATE FAUNA OF THE CAYLER PRAIRIE PRESERVE

Species classification was taken from Blair, *et al.* (1968) and Jones, *et al.* (1973). Species abundance designations are common (c), uncommon (u), or rare (r).

AMPHIBIA

Urodela
- Ambystomatidae: *Ambystoma tigrinum* (tiger salamander—c)

Anura
- Bufonidae: *Bufo americanus* (American toad—c)
- Hylidae: *Pseudacris triseriata* (northern chorus frog—c)
- Ranidae: *Rana pipiens* (leopard frog—c)

REPTILIA

Chelonia
- Chelydridae: *Chelydra serpentina* (snapping turtle—u)
- Testudinidae: *Emydoidea blandingi* (Blanding's turtle—u); *Chrysemys picta* (painted turtle—u)

Squamata
- Scincidae: *Eumeces septentrionalis* (prairie skink—c)
- Colubridae: *Thamnophis radix* (plains garter snake—c); *Thamnophis sirtalis* (common garter snake—c); *Elaphe vulpina* (fox snake—u)

AVES

Anseriformes
- Anatidae: *Anas platyrhynchos* (mallard—c); *Anas discors* (blue-winged teal—c); *Anas crecca* (green-winged teal—c)

Falconiformes
- Vulturidae: *Cathartes aura* (turkey vulture—u)
- Accipitridae: *Buteo jamaicensis* (red-tailed hawk—c); *Circus cyaneus* (marsh hawk—u)
- Falconidae: *Falco sparverius* (American kestrel—c)

Galliformes
- Phasianidae: *Phasianus colchicus* (ring-necked pheasant—c); *Perdix perdix* (Hungarian partridge—c)

Charadriiformes
- Charadriidae: *Charadrius vociferus* (killdeer—c)
- Scolopacidae: *Bartramia longicauda* (upland plover—c)

Columbiformes
- Columbidae: *Zenaida macroura* (mourning dove—c)

Strigiformes
- Strigidae: *Bubo virginianus* (great-horned owl—u)

Caprimulgiformes
- Caprimulgidae: *Chordeiles minor* (common nighthawk—u)

Apodiformes
- Trochilidae: *Archilochus colubris* (ruby-throated hummingbird—u)

Passeriformes
- Tyrannidae: *Tyrannus tyrannus* (eastern kingbird—c)
- Alaudidae: *Eremophila alpestris* (horned lark—u)
- Hirundinidae: *Riparia riparia* (bank swallow—c); *Hirundo rustica* (barn swallow—c)
- Corvidae: *Corvus brachyrhynchos* (common crow—c)
- Troglodytidae: *Cistothorus platensis* (short-billed marsh wren—c); *Cistothorus palustris* (long-billed marsh wren—u)
- Turdidae: *Turdus migratorius* (American robin—u)
- Laniidae: *Lanius ludovicianus* (loggerhead shrike—u)
- Icteridae: *Molothrus ater* (brown-headed cowbird—c); *Xanthocephalus xanthocephalus* (yellow-headed blackbird—u); *Agelaius phoeniceus* (red-winged blackbird—c); *Sturnella magna* (eastern meadowlark—c); *Sturnella neglecta* (western meadowlark—c); *Dolichonyx oryzivorus* (bobolink—c)
- Fringillidae: *Spiza americana* (dickcissel—c); *Carduelis tristis* American goldfinch—c)
- Emberizidae: *Passerculus sandwichensis* (savannah sparrow—c); *Ammodramus savannarum* (grasshopper sparrow—c); *Melospiza melodia* (song sparrow—c)

MAMMALIA

Insectivora
- Soricidae: *Sorex cinereus* (masked shrew—c); *Blarina brevicauda* (short-tailed shrew—c)
- Talpidae: *Scalopus aquaticus* (eastern mole—u)

Chiroptera
- Vespertiliontidae: *Myotis lucifugus* (little brown bat—u)

Rodentia
- Sciuridae: *Spermophilus tridecemlineatus* (13-lined ground squirrel—c); *Spermophilus franklini* (Franklin's ground squirrel—r)
- Geomyidae: *Geomys bursarius* (plains pocket gopher—c)
- Castoridae: *Castor canadensis* (beaver—r)
- Cricetidae: *Reithrodontomys megalotis* (western harvest mouse—c); *Peromyscus maniculatus* (deer mouse—c); *Onychomys leucogaster* (northern grasshopper mouse—u); *Microtus pennsylvanicus* (meadow vole—c); *Ondatra zibethicus* (muskrat—u)
- Zapodidae: *Zapus hudsonius* (meadow jumping mouse—c)

Lagomorpha
- Leporidae: *Lepus townsendii* (white-tailed jackrabbit—c); *Sylvilagus floridanus* (eastern cottontail—u)

Carnivora
- Canidae: *Vulpes fulva* (red fox—u)
- Procyonidae: *Procyon lotor* (raccoon—c)
- Mustelidae: *Mustela nivalis* (least weasel—c); *Mustela erminea* (short-tailed weasel—c); *Mustela frenata* (long-tailed weasel—u); *Mustela vison* (mink—r); *Mephitis mephitis* (striped skunk—u); *Spilogale putorius* (eastern spotted skunk—u); *Taxidea taxus* (badger—c)

Artiodactyla
- Cervidae: *Odocoileus virginianus* (white-tailed deer—c)

ACKNOWLEDGMENTS

I wish to thank members of field biology classes, especially Jerry Dwyer, for their assistance in preparing the species list. Dr. Robert Cruden and Edwin L. Freese have contributed observations of bird species. Robert Conley assisted me in live-trapping for small mammals. This study was conducted with the cooperation of the Iowa State Preserves Board and Iowa Conservation Commission.

LITERATURE CITED

AIKMAN, J. M., and R. F. THORNE. 1956. The Cayler Prairie: An ecologic and taxonomic study of a northwest Iowa prairie. *Proc. Iowa Acad. Sci.* 63:177-200.

BLAIR, W. F., A. P. BLAIR, P. BRODKORB, F. R. CAGLE, and G. A. MOORE. 1968. *Vertebrates of the United States.* 2nd ed. McGraw-Hill, New York.

BLANCHARD, F. N. 1923. The amphibians and reptiles of Dickinson County, Iowa. *Univ. Iowa Studies Nat. Hist.* 10:19-26.

CRAIGHEAD, J. J., and F. C. CRAIGHEAD, JR. 1956. Hawks, owls and wildlife. Dover Publ., New York.

ERRINGTON, P. L. 1937. Summer food habits of the badger in northwestern Iowa. *J. Mammal.* 18:213-216.

JONES, J. K., JR., D. C. CARTER, and H. H. GENOWAYS. 1973. Checklist of North American mammals north of Mexico. *Occas. Papers Mus. Texas Tech. Univ.* 12:1-14.

KENDEIGH, S. C. 1941. Birds of a prairie community. *Condor* 43: 165-174.

KING, R. L. 1946. Summer birds of the Okoboji region, 1938-42. *Proc. Iowa Acad. Sci.* 51:467-470.

LINDZEY, F. G. 1971. Ecology of badgers in Curlew Valley, Utah and Idaho, with emphasis on movement and activity patterns. M.S. Thesis, Utah State Univ., Logan.

PLATT, W. J. 1975. The colonization and formation of equilibrium plant species associations on badger disturbances in a tall-grass prairie. *Ecol. Monogr.* 45:285-305.

POLDER, E. 1953. A checklist of mammals of present occurrence in Iowa with notes on new additions and distribution since 1937. *Proc. Iowa Acad. Sci.* 60:716-724.

SALISBURY, N. E., and J. C. KNOX. 1969. Glacial landforms of the Big Kettle locality, Dickinson County, Iowa. Iowa State Advisory Board for Preserves, Development Series Report No. 6.

SCOTT, T. G. 1937. Mammals of Iowa. *Iowa State Coll. J. Sci.,* Vol. 12, No. 1.

SNEAD, E., and G. O. HENDRICKSON. 1942. Food habits of the badger in Iowa. *J. Mammal.* 23:380-391.

STEPHENS, T. C. 1938. The summer birds of the Lake Okoboji region in Iowa. *Univ. Iowa Studies Nat. Hist.* 17:273-340.

TINKER, A. D. 1914. Notes on the ornithology of Clay and Palo Alto counties, Iowa. *Auk.* 31:70-81.

Development of Air Passages, and Crystal Distribution, in the Stem of *Bacopa caroliniana* (Scrophulariaceae)

NELS R. LERSTEN and JAMES L. GUNNING[1]

LERSTEN, NELS R., and JAMES L. GUNNING (Department of Botany and Plant Pathology, Iowa State University, Ames, Iowa 50010). Development of air passages, and crystal distribution, in the stem of *Bacopa caroliniana* (Scrophulariaceae). *Proc. Iowa Acad. Sci.* 82(2): 109-112, 1975.
About 20 vertical air passages occur in each internode, separated at each node by a solid diaphragm of parenchyma, in which leaf traces depart. Air passages are schizogenous and begin to form just below the shoot apex. This may be the first report of druse crystals in Scrophulariaceae. Druses become visible in the second nodal plate below the shoot apex. In the mature stem, druses are more common in nodes, but they also occur in internodes. The stele appears to be an ectophloic siphonostele, without separate vascular bundles at any stage of development. This appears to be a good species for further study by electron microscopy.
INDEX DESCRIPTORS: Scrophulariaceae, *Bacopa,* stem anatomy, druse crystals.

The Scrophulariaceae is among the larger dicot families, with 220 genera and 3,300 species (Willis, 1973). Considering its size, anatomical studies have been rather sparse. According to Metcalfe and Chalk (1950), representatives of 63 genera, only slightly more than a quarter of the total, have been examined for various aspects of vegetative anatomy.

One genus that has never been studied anatomically is *Bacopa,* which consists of about 100 species of herbs (Willis, 1973), mostly of warm or tropical regions, including many of aquatic and semi-aquatic habitats (Fernald, 1950). Metcalfe and Chalk (1950) did not mention any work on *Bacopa,* and no anatomical studies were uncovered during an examination of *Biological Abstracts* from the late 1940's through 1974.

We examined several aspects of the anatomy of mature and developing stems of *Bacopa caroliniana* (Walt.) Robins., a rhizomatous perennial herb native to the southeastern United States. Our most important observations were of the development of the characteristic air passages, and crystal formation, below the shoot apex. These are described, along with other anatomical observations.

MATERIALS AND METHODS

Mature stems and stem tips were collected from plants of *Bacopa caroliniana* growing in a greenhouse in the department of Botany and Plant Pathology, Iowa State University, and preserved in formalin-acetic acid-alcohol (Sass, 1958). The material was dehydrated in an ethanol-xylene series, embedded in 56° mp. paraffin wax (Fisher Tissuemat), and sectioned at 8-12 μm. The sections were stained with safranin and counterstained with either fast green or chlorazol black E. Sections were examined under bright field optics, or with polarized light to allow clearer observation of druse crystals. Photographs were taken with an Orthomat automatic camera fitted to a Leitz Ortholux microscope.

OBSERVATIONS

There is no true aerenchyma in the stem, but instead there are several conspicuous air passages that extend the length of each internode (Figures 2, 7). The air passages are separated by uniseriate vertical septa, so that the stem in cross-section appears similar to a wagon wheel. The number of passages per internode varies only slightly, from 19 to 22, based on an examination of 43 internodes. In the inner cortex, between the air passages and the stele, there are also conspicuous intercellular spaces. One is indicated by the lower arrow in Figure 7. The arrowhead in Figure 3 points to another, seen at higher magnification. The air passages are interrupted at each node by a solid diaphragm of parenchyma (Figures 1, 2). Within this diaphragm, a single trace per leaf departs abruptly from the vascular cylinder and separates into three bundles as it enters the base of each of the two leaves per node.

A study was made of the developing air passages from a series of cross-sections, cut 8 μm thick, from the shoot apex downward to the mature stem. The first sign of initiation of air passages was noted at about 56 μm below the apex, at which level there occurred a thickening of walls and a slight splitting between cortical cells (Figure 4). Slightly lower, at approximately 64 μm below the apex, splitting was more obvious (Figure 5). At about 144 μm the cells flanking the spaces had subdivided to form several vertically and periclinally flattened cortical cells (Figure 6, arrow). These cells expanded later to form the radially arranged vertical septa in the mature stem (Figure 7).

The levels in the stem at which the sections shown in Figures 4-6 were taken are indicated in longitudinal view in Figure 1 by the three horizontal black lines at the upper right. The increase in diameter of the developing air passages can also be seen in Figure 1, where the left arrowhead indicates the youngest visible passage, below which there are two larger air passages.

Druse crystals were observed throughout the mature stem, but they tended to be concentrated in the nodal diaphragms (Figures 1, 2) in both the developing and mature stem. Figure 3 shows some detail of individual druses. The first visible crystals were seen, under polarized light, at the level of the second node, approximately 100 μm below the apex (Figure 1, uppermost arrow).

[1] Professor and special topics senior undergraduate student, respectively. Department of Botany and Plant Pathology, Iowa State University, Ames, Iowa 50010.

In addition to what has been described about the developing air passages and druse crystals, there are other features worthy of mention. The stele does not develop as separate vascular bundles, but is initiated instead as a cylinder of procambium. Because of this pattern, any longitudinal section, such as in Figure 1, shows the two sides of the continuous stelar cylinder, which appears at various levels of maturation in Figures 5-7.

There is no sclerenchyma in the stem, which is common among hydrophytes. Small glands develop early on the stem and leaves (Figure 1). They consist of a large basal epidermal cell, a short stalk cell, and four cap cells. Two views of these glands are shown in Figures 8 and 9 and a young gland is seen at left in Figure 9.

Adventitious roots are common, some arising at nodes, others from internodes. Figure 7 shows an adventitious lateral root emerging from the stele in an internode. In mature roots, air passages were seen that appeared quite similar to those seen in the stem.

Discussion

Kaul (1971) included in his introduction some general remarks about internal ventilation in aquatic plants. The various types of inner spaces store and transport oxygen, and such an architectural pattern may also give ". . . the greatest strength with the least tissue . . ." Compared with many other aquatic plants, the vertical internodal air passages of *Bacopa caroliniana* are rather simple internal spaces. They begin to develop quite early, with the first signs of splitting and wall modification detected in the first internode below the youngest pair of leaf primordia. Subsequent development is quite orderly and symmetrical, and mature internodes differ very little from each other in number of air passages. We did not subject the plants to varying growing conditions, so we do not know how closely this pattern is genetically controlled.

Crystal formation in the stem in relation to the shoot apex does not appear to have received much study. In two recent reviews of crystals in plants (Arnott and Pautard, 1970; Arnott, 1973), nothing is included about this. The only paper we uncovered that gives comparable information is that of Scott (1941) on *Ricinus communis* (castor bean), in which "The earliest identifiable druse crystals [under polarized light] occur in the vacuolating cells of the third internode . . ." We noted crystal initiation in *Bacopa caroliniana* at the second node, using polarized light.

Druse crystals were abundant in our material. Metcalfe and Chalk (1950) state that calcium oxalate crystals in the Scrophulariaceae are ". . . rather infrequent, when present nearly always small; prismatic, octahedral or acicular in shape." We have not been able to explore the subsequent literature for reports of crystals, but it is possible that this is the first report of druse crystals in this family.

The small external glands that we have described are common in the family, according to Metcalfe and Chalk (1950). Their secretions are probably responsible for the characteristic lemony odor of this species, although we did not verify it beyond doubt.

Our finding that the stele appears to be an ectophloic siphonostele rather than a eustele needs to be investigated more intensively, but there is no doubt that the procambial cells from their inception are so close together that individual vascular bundles appear to be lacking. Leaf gaps are also virtually lacking; the single trace per leaf departs abruptly in the nodal diaphragm at a 90° angle to the stele, and vascular tissue appears immediately above the place where the trace departs.

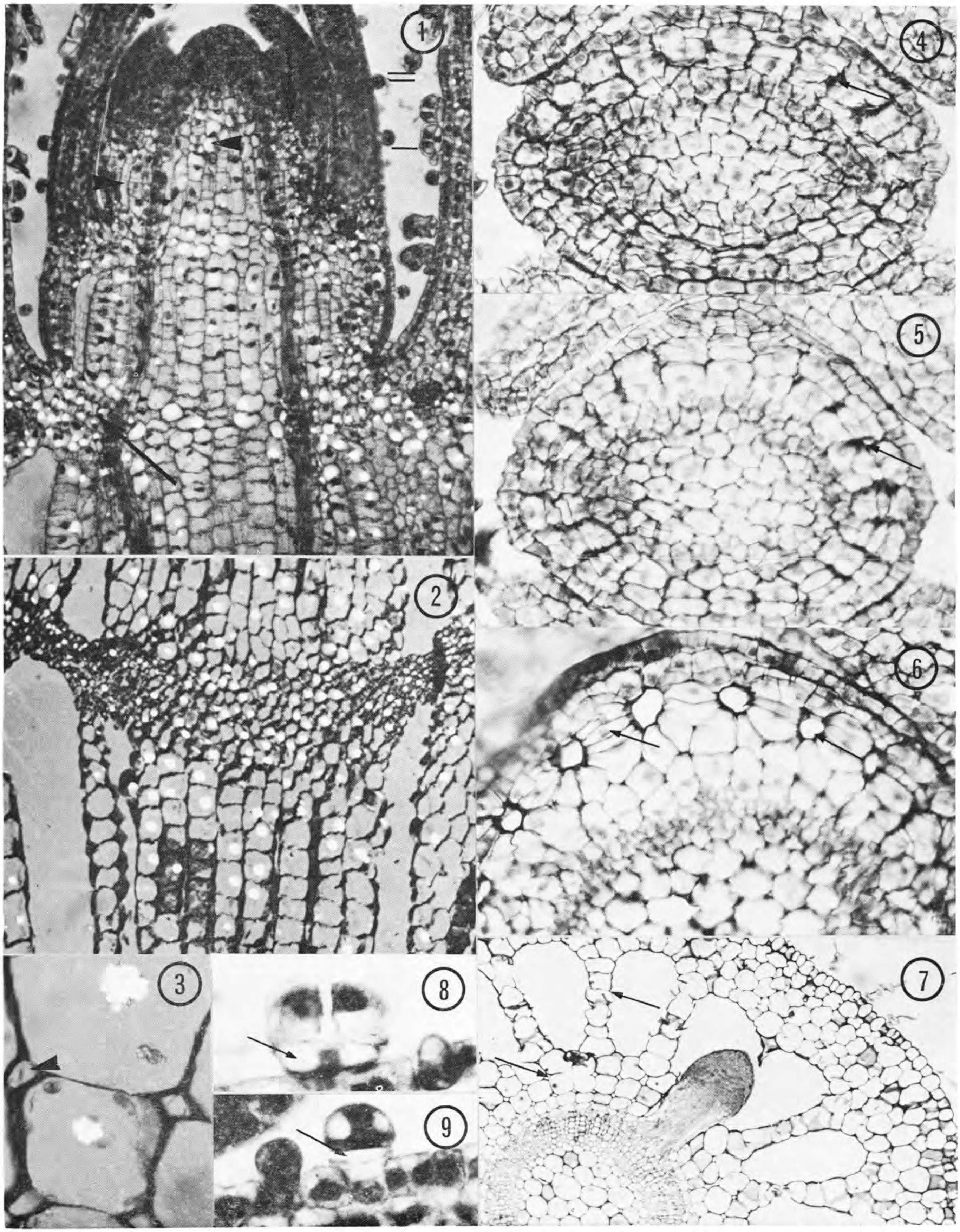
Bacopa caroliniana is a desirable species in which the development of at least three structures can be studied, separately or at the same time, at the fine structure level. Plants of this species are small and easy to grow in the greenhouse, and they rapidly proliferate new branches. Leaf arrangement is decussate, a favorite pattern to provide orientation for longitudinal sections of the shoot tip, and the three structures of interest are initiated just a short distance beneath the apex.

The schizogenous air passages are numerous and predictable in position. The changes in primary wall and middle lamella as cell separation occurs have never been described. Such information could be obtained here in an orderly way.

Crystal initiation and development remains a complex and little understood process (see Horner and Whitmoyer, 1972, for the most complete study and a review of other recent studies using electron microscopy). The peculiar crystal aggregate that makes up a druse has never been investigated. This species seems technically convenient for studying druse crystal development.

Finally, a question that still remains little explored is the series of changes by which procambial cells become distinct from other meristematic cells and gradually take on the characteristics of xylem or phloem. The procambium in *Bacopa*

Figures 1-9. Stem anatomy of *Bacopa caroliniana*. 1. Median longitudinal section of stem tip under partially polarized light. Upper vertical arrow indicates first visible crystal. Upper arrowhead indicates uppermost mature crystal. Left arrowhead is on earliest visible stage of developing air passage. Lower arrow points to a nodal diaphragm with numerous crystals. Three horizontal lines at upper right indicate levels of section in Figures 4-6. X68. 2. Enlarged longitudinal portion of extra-stelar part of stem showing node under partially polarized light. Air passages, nodal diaphragm, and crystals are apparent. X66. 3. Two enlarged cortical cells under partially polarized light. Two druse crystals are seen. Arrowhead indicates a conspicuous intercellular space. X368. 4. Stem cross-section 56 μm below shoot apex (level of upper line in Figure 1). Arrow indicates first visible sign of splitting to form air passage. X368. 5. Stem cross-section at 64 μm (level of middle line in Figure 1). Splitting is more conspicuous (arrow). X357. 6. Stem cross-section at 144 μm (level of lower line in Figure 1). Definite air passages now seen (right arrow). Cortical cells separating passages are dividing periclinally (left arrow). X357. 7. Cross-section of mature stem. Area indicated by left arrow in Figure 6 has developed into a vertical septum like that indicated by upper arrow. Inner cortex has regularly arranged parenchyma cells with prominent intercellular spaces (lower arrow). A young adventitious root is seen extending into two air passages. X51. 8. Enlarged view of a gland. Arrow indicates the stalk cell. X756. 9. Longitudinal view of young (left) and mature (right) gland. Arrow indicates stalk cell, below which the basal cell is located. X756.


1
2
3
4
5
6
7
8
9

caroliniana is initiated as a cylinder, so the possibility of missing individual procambial strands is avoided. This is important when observing the earliest stage of procambial differentiation, where differences among meristematic cells must be very slight.

This rather brief study has contributed some new information to systematic and developmental anatomy, but it is perhaps more important as a preliminary report which points out where further research using electron microscopy could be conveniently undertaken on some questions of current interest.

LITERATURE CITED

ARNOTT, H. J. 1973. Plant calcification. Pages 609-627 *in* I. Zipkin (ed.), Biological mineralization. Wiley and Sons, New York.

———, and F. G. E. PAUTARD. 1970. Calcification in plants. Pages 375-446 *in* H. Schraer (ed.), Biological calcification. Appleton-Century-Crofts, New York.

FERNALD, M. L. 1950. Gray's manual of botany. 8th edition. American Book Co., New York.

HORNER, H. T., JR., and R. E. WHITMOYER. 1972. Raphide crystal cell development in leaves of *Psychotria punctata* (Rubiaceae). *J. Cell Sci.* 11: 339-355.

KAUL, R. B. 1971. Diaphragms and aerenchyma in *Scirpus validus*. *Amer. J. Bot.* 58: 808-816.

METCALFE, C. R., and L. CHALK. 1950. Anatomy of the dicotyledons. Vol. II. Clarendon Press, Oxford.

SASS, J. E. 1958. Botanical microtechnique. 3rd ed. Iowa State Univ. Press, Ames.

SCOTT, F. M. 1941. Distribution of calcium oxalate crystals in *Ricinus communis* in relation to tissue differentiation and presence of other ergastic substances. *Bot. Gaz.* 103: 225-246.

WILLIS, J. C. 1973. A dictionary of the flowering plants and ferns. 8th edition, revised by H. K. Airy Shaw. University Press, Cambridge.

Floristic Composition and Structure of Fen Communities in Northwest Iowa

A. G. VAN DER VALK[1]

VAN DER VALK, A. G. (Department of Botany and Plant Pathology, Iowa State University, Ames, Iowa 50010). Floristic Composition and Structure of Fen Communities in Northwest Iowa. *Proc. Iowa Acad. Sci.* 82(2): 113-118, 1975.
Iowa fens have three distinct, concentric vegetation zones: a border zone, a sedge mat zone, and a discharge zone where ground water supplying the fens comes to the surface. *Calamagrostis inexpansa* Gray, *Viola nephrophylla* Greene, *Scirpus americanus* Pers. and *Carex* spp. are the dominants in the border zone. The composition of this zone is quite variable both within and between fens. The sedge mat is composed primarily of *Rhynchospora capillacea* Torr. Other species normally found in this zone are *Lobelia kalmii* L., *Muhlenbergia racemosa* (Michx.) BSP, *Parnassia glauca* Raf., *Triglochin maritima* L. and *Scirpus americanus.* Although all of the species in this zone are also found in the other zones, this zone is readily distinguishable because of the low stature of the vegetation. The discharge zone is dominated usually by *Carex* spp. or *Calamagrostis inexpansa,* except at one fen where *Phragmites communis* Trin. and *Helianthus grosseserratus* Martens are the dominants. The sedge mat zone on the average has fewer species per quadrat (5.8 versus 6.0 and 8.6), lower Shannon-Weaver index (0.8 versus 1.15 and 1.40) and higher Simpson's index (0.58 versus 0.42 and 0.32) than the discharge and border zones, respectively.
INDEX DESCRIPTORS: Fen, Floristic Composition, Shannon-Weaver Index, Simpson's Index, Vegetation, Zonation.

In the British Isles, a fen is defined as wetland vegetation with alkaline or neutral organic soils whose summer water level is usually just below the soil surface. The alkaline nature of the substrate is a result of the ground water passing through calcareous geologic strata. The vegetation of British fens is generally similar to that of other wetlands except for the presence of a few calcicolous species (Tansley, 1968).

In northwestern Iowa, there are a number of small areas of wetland vegetation which are referred to locally as fens (Anderson, 1943; Hayden, 1943; Holte and Thorne, 1962). These fens have much in common with their British counterparts and fit Tansley's definition of a fen given above. However, Iowa's fens have at least two characteristics which set them apart. First, Iowa fens are small seepage areas (only a few thousand square meters), almost always on the sides of morainic hills, while British fens cover large areas, usually in valley bottoms. Second, well-developed Iowa fens are divided into three distinct zones: a central zone associated with raised areas where calcareous groundwater reaches the surface (discharge cones); a middle zone which consists of a terraced sedge mat containing many small pools; and a border zone. This zonation is made very striking by the short stature of all the sedge mat species. In the British fens, there does not appear to be anything comparable to these terraced sedge mats. A generalized profile of an Iowa fen is given in Figure 1.

Because Iowa's fens are locally an unusual habitat, they have received a great deal of attention. There are published accounts of their protozoa (Hempstead and Jahn, 1939), algae (Gashwiler and Dodd, 1961), diatoms (Shobe et al., 1967), metazoa (Eickstaedt, 1964), vegetation (Shimek, 1915; Anderson, 1943; Conard, 1952; Holte and Thorne, 1962; Holte, 1966) and physical environment (Carter, 1939; Eickstaedt, 1964; Holte, 1966). The vegetation has received the most attention over the years, but all of these studies were primarily simple floristic surveys. As a result, very little is known about the composition and structure of the vegetation in the different zones making up an Iowa fen.

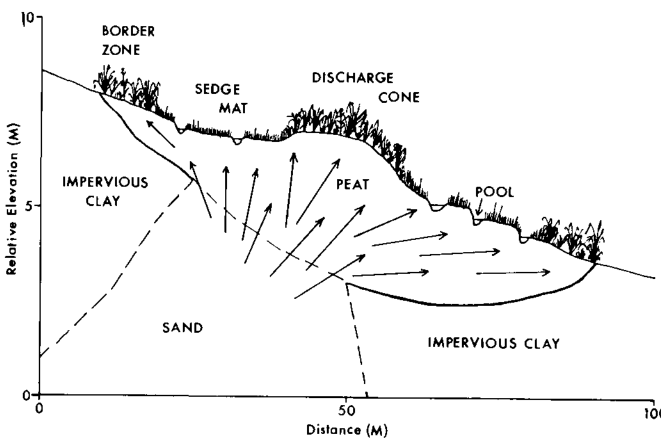


Figure 1. Generalized cross-section of an Iowa fen. The arrows indicate the general pattern of subsurface water movement (see Holte, 1966).

The main purpose of this study was to examine the floristic composition, species richness and floristic structure of the three vegetation zones in as many fens as possible. Species richness is defined as the number of species per unit area (Peet, 1974). Floristic structure refers to the relative abundance of different species in the community. Two indices were used to examine floristic structure: the Simpson's index (C), which is a measure of dominance, and the Shannon-Weaver index (H′), which is a measure of complexity and diversity (Whittaker, 1972; Peet, 1974).

The nomenclature follows Gleason and Cronquist (1963).

STUDY SITES

Attempts were made to relocate all previously reported fen

[1] Department of Botany and Plant Pathology, Iowa State University, Ames, Iowa 50010.

sites. It proved to be impossible to relocate some fen areas, while others had been damaged or destroyed.

Two study sites were used in the study; both were in Dickinson County, northwest Iowa. One site was the Silver Lake fen complex located in the northwestern corner of Section 32, Silver Lake Township. This site is a state preserve and the fens are protected from disturbance. Only the main fen was studied (Eickstaedt, 1964). The second site was the Excelsior fen complex located in the southwest corner of Section 10 and the northwest corner of Section 15, Excelsior Township. All the well-developed fen areas in the complex were sampled, i.e., fens 2, 3, 4, 7, 9, 10 and 11 (Holte, 1966). The Excelsior fens are located in a pasture and, as a result, are subject to grazing. This grazing is only significant around the border of the fens most years, because the cattle will not venture onto the unstable fen surface. In dry years, grazing becomes a problem over the entire fen. During the study no cattle were seen on the fens and there were no signs that the fens were being grazed except around the edges.

Dickinson County has a continental climate with the coldest month (January) having an average temperature of -9 C and the warmest month (July) one of 23 C. The average annual precipitation is around 686 mm (Shaw and Waite, 1964).

METHODS

At the Excelsior fen complex, each fen was sampled using 11 quadrats (20 cm x 50 cm) spaced evenly along a transect line. The transect was positioned so that it started and ended in border areas as little disturbed by cattle as possible and so that it passed through all three zones in a fen. At the Silver Lake fen two random transects passing through the discharge zone were used to sample the fen.

In each quadrat, a list of all the species present was made and the cover of each species was then estimated using a cover-abundance scale modified from Braun-Blanquet (1932) and previously used by van der Valk and Bliss (1971) (see Table 3). All vegetation sampling was done from July 19 to August 9, 1974.

The Simpson's index was calculated from the data for each quadrat using the following formula:

$$C = \sum_{i=1}^{n} P_i^2$$

where

$$P_i = \frac{c_i}{C}$$

c_i = cover of the i th species in a quadrat.
C = total cover of all the species in the quadrat.
n = total number of species in the quadrat.

The Shannon-Weaver index was calculated using:

$$H' = \sum_{i=1}^{n} P_i \cdot \ln P_i$$

where P_i and n are the same as above.

A nested analysis of variance was used to analyze the floristic structural indices (Service, 1972). A logarithmic transformation was used on the Simpson's index. All tests of significance were made at the 95% confidence level.

For each fen, a composite water sample was collected from five or six pools on the sedge mat. These samples were analyzed for calcium and total hardness, conductivity and pH using Hach water analysis equipment.

TABLE 1. FEN POOL WATER CHEMISTRY DATA

Fen[1]	*Hardness (ppm)* $CaCO_4$	*Total*	*Conductivity (micromhos)*	*pH*
E-2	390	680	1,140	7.2
E-3	380	800	1,380	7.1
E-4	440	900	1,550	7.0
E-7	460	940	1,560	7.0
E-9	350	800	1,330	7.5
E-10	430	920	1,400	7.4
E-11	405	740	1,330	7.0
SLF	650	1,580	2,600	7.1

[1] E—Excelsior fen complex; SLF—Silver Lake fen.

RESULTS AND DISCUSSION

Water Chemistry

The water chemistry data (Table 1) for all seven of the Excelsior fens are very similar. Their total hardness ranges from 680 to 940 ppm, about half of which is $CaCO_4$. They have a conductivity of about 1,300 to 1,500 micromhos and a pH which ranges from 7.0 to 7.5. The differences in hardness and pH between the seven fens in Table 1 are smaller than those reported for a transect across a single fen by Holte (1966). The data in Table 1 support Holte's (1966) hypothesis, based on other evidence, that all of the fens in the complex are supplied water by the same aquifer. The hardness and pH values in Table 1 are similar to those previously reported for several Excelsior fens by Holte (1966). However, the $CaCO_4$ percentage of the total hardness values is always higher in Holte's data. This is probably the result of differences in determining the end points of titration.

The Silver Lake fen water has a much higher dissolved mineral content (Table 1). The total hardness and conductivity are both considerably higher, sometimes twice as high. However, the pH values are the same. Eickstaedt (1964) made detailed measurements of the pH of Silver Lake fen pool water. His data indicate that the total hardness and pH values in Table 1 are typical for this fen.

A comparison of the data in Table 1, Eickstaedt (1964), and Holte (1966) for Iowa fens and Bachman's (1965) data on Iowa lakes and reservoirs of the same region clearly demonstrates the unique water chemistry of these fens. On the average, lakes and reservoirs have a conductivity of only 409 micromhos and a total hardness of 199 ppm, while the lowest fen readings are 1,330 micromhos and 680 ppm, respectively (Table 1).

Floristic Composition of Fen Communities

The average cover of all species which were found in any one zone in three or more fens or which had a cover of 5% or more in at least one quadrat in a zone is listed in Table 2.

The border vegetation always has two layers of plants: a tall layer, 50 cm or more in height, usually composed of *Calamagrostis inexpansa*, *Eupatorium* spp., *Lycopus asper*, and *Scirpus americanus*, plus many other species, and a shorter layer of plants which includes *Parnassia glauca*, *Viola nephrophylla* and *Eleocharis erythropoda* (*E. calva* Torr.). Because of disturbance at the Excelsior fens, the border zone often contains a few individuals of some weedy species from

TABLE 2. All Species Found at Three or More Fens or Having a Cover of Five Percent or Higher in a Quadrat in Either the Border, Sedge Mat, or Discharge Zone

SPECIES	E-2[1]	E-3	E-4	FEN E-7	E-9	E-10	E-11	SLF
BORDER ZONE								
Calamagrostis inexpansa	+[2]	+	1	2	+	+		R
Carex aquatalis	+				+			+
Carex hystericina				+	1			P
Eleocharis erythropoda		P		P	P	+	R	
Eupatorium maculatum			1	1	P	1	+	+
Eupatorium perfoliatum	+					+	R	R
Juncus nodosus	+		R	R	P	+	R	P
Lobelia kalmii				P	R	P		P
Lycopus asper	1	+	+	R	R	+	R	
Muhlenbergia racemosa		+	+	R	R		P	R
Parnassia glauca	R		+	1	+	+	P	2
Rhyncospora capillaceae				P		P	P	P
Scirpus acutus	R	P			1			+
Scirpus americanus	R	+	+	+	R	+	+	+
Scutellaria galericulata				P	R			P
Triglochin maritima				R		R		+
Viola nephrophylla	1	+	1	1	R	+	1	R
SEDGE MAT ZONE								
Eupatorium maculatum	P	R		R	R	P		P
Eupatorium perfoliatum				P		+	P	P
Lobelia kalmii	+	+	+	R	+	R	R	R
Lycopus asper		P		P			P	P
Muhlenbergia racemosa	R	P	P	P	R	R		R
Parnassia glauca	+	R	R	+	+	1	1	+
Rhyncospora capillaceae	2	2	3	2	3	2	2	3
Scirpus acutus		R				P	1	
Scirpus americanus	+	+	+		+	P	R	R
Triglochin maritima	+	1	1	1	1	1	1	1
Viola nephrophylla		P	P			R		
DISCHARGE ZONE								
Calamagrostis inexpansa	R		2		P	+		
Carex aquatalis					3	R	1	
Carex hystericina		1				1		
Carex rostrata	3	1	1	1				
Eupatorium maculatum	1	R		1	1	1		
Helianthus grosseserratus								3
Impatiens biflora				1				
Lycopus asper				1		R	+	2
Mentha arvensis		R		1	+			2
Muhlenbergia racemosa	+				R	R		
Parnassia glauca	R	+		P	P	+	+	
Phragmites communis								4
Scirpus acutus							2	
Scirpus americanus	+	R		P	R	R		
Triglochin maritima						1	1	
Viola nephrophylla		1		R	+	1		

[1] E–Excelsior Fen complex (Holte 1966).
SLF–Silver Lake Fen.

[2] P–Present, one individual
R–Rare, several individuals, *ca.* 0.1% cover.
+–Uncommon, *ca.* 0.5% cover.
1–1 to 5% cover.
2–5 to 15% cover.
3–15 to 25% cover.

the surrounding pasture, e.g., *Latuca canadensis, Ambrosia artemisiifolia* and *Hordeum jubatum*. However, grazing at the Excelsior fens does not appear to have produced any major shift in the composition of the border zone (Table 2).

In the border zone, most of the species are widespread wetland species (Table 2), e.g., *Lycopus asper, Carex aquatilis, Eupatorium maculatum, E. perfoliatum, Scirpus acutus* and *S. americanus* (Muenscher, 1944). Four of the species in the border zone are considered to be characteristic of Iowa fens: *Lobelia kalmii, Parnassia glauca, Rhynchospora capillacea* and *Triglochin maritima* (Holte, 1966). Although they are restricted to this habitat in Iowa (Beal and Monson, 1954), all four species are quite widespread in wetlands throughout boreal North America (Gleason and Cronquist, 1963).

There is a great deal of variety in the composition of the border zone from fen to fen (Table 2). Field observations indicate that there is a great deal of variability even around a particular fen border. Only two species (*Scirpus americanus* and *Viola nephrophylla*) were present in the border zones of all the fens (Table 2).

The sedge mat zone, which is dominated by *Rhynchospora capillacea*, was very similar in its floristic composition from fen to fen (Table 2). Four of the eleven most common species are found at all the fens (*Rhynchospora capillacea, Parnassia glauca, Triglochin maritima* and *Lobelia kalmii*). The plants growing in this zone are all about the same height, 25 to 35 cm, except *Scirpus americanus*, which is sometimes 75 to 85 cm tall. All of the species making up the sedge mat were also found as minor species in the border zone (Table 2). However, when these species grew on the mat, their stature was greatly reduced.

The vegetation of the discharge zone is the most variable of all three zones (Table 2). Not one species was present in all the discharge zones. *Parnassia glauca*, the most nearly ubiquitous species, was found in six of the seven Excelsior fens' discharge zones. At the Excelsior fens, the discharge zone vegetation resembled the border vegetation in composition and height. However, it had a higher total cover which was due largely to the abundance of various species of *Carex* (*C. aquatilis, C. hystericina* and *C. rostrata*). At the Silver Lake fen, the discharge zone is dominated by *Phragmites communis* and *Helianthus grosseserratus* and does not in the least resemble the border zone (Table 2). Stewart and Kantrud (1972) consider *Phragmites communis* to be a dominant species in fens undisturbed by grazing in North Dakota, and its absence from the Excelsior fen may reflect past grazing pressure.

Data in previous floristic studies on Iowa fens by Wolden (1926), Anderson (1943), Conard (1952), Holte and Thorne (1962), and Holte (1966) when compared to the data in Table 2 indicate that qualitatively there has been little change in the make-up of fen vegetation. It is more difficult to tell if there have been any quantitative changes in the composition of these fen communities. Holte (1966) ran transects across several fens and estimated the abundance of the species along the transects. He used an abundance measure which is not directly comparable to the cover data in Table 2. Nevertheless, Holte's (1966) data indicate that the composition of the different zones was similar to that found at the same fens in this study. Iowa fens do not appear to be undergoing rapid succession.

In North America, fen vegetation has been described from Wisconsin (Curtis, 1959), Michigan (Cain and Slater, 1948), North Dakota (Stewart and Kantrud, 1972), Missouri (Steyermark, 1938), New York (Zenkert, 1934; Muenscher, 1946), Ohio (Gordon, 1933) and Canada (Sjörs, 1959). However, there is so little quantitative information about these fens in these studies that it is impossible to relate the various studies to each other or to the present study. Iowa's fens have species in common with fens in other regions, especially those in North Dakota. However, much more field work must be done on North American fens before their floristic and ecological relations can be discerned.

Floristic Structure

Table 3 summarizes the floristic structural data for each zone in each fen, and Table 4 contains a summary of the nested analysis of variance done on these data.

Species richness varies significantly from fen to fen and among zones in a particular fen (Table 4). On the average there are 8.6, 5.8 and 6.0 species/quadrat in border, sedge mat and discharge zones, respectively. Although the border zones at some of the Excelsior fens have slightly more species/quadrat than at the Silver Lake fen, there does not seem to be any marked effect of grazing or trampling on the species richness of the border zone (see Table 4).

The Shannon-Weaver indices are slightly higher in all three zones at the Excelsior fens than those at the Silver Lake fen (Tables 3, 4). It is unknown whether this is a result of grazing at the Excelsior fens or due to differences in water chemistry between the two sites (see Table 1). As a plant community's physical environment becomes harsher, its Shannon-Weaver index value decreases (Monk, 1967; Auclair and Goff, 1971; Whittaker, 1972; van der Valk, 1975), i.e., it becomes a simpler community. It is possible that the greater dissolved mineral content of the Silver Lake fen water makes the Silver Lake fen physical environment harsher than that at the Excelsior fens. There is at the present time no direct experimental evidence which could be used to test this hypothesis. However, it has been established that various species of aquatic and marsh plants are found only in habitats within a limited range of water hardness (Moyle, 1945; Olsen, 1950; Seddon, 1972) and that the hardness of the water can influence the growth of aquatic plants (Moyle, 1945).

In the border, sedge mat and discharge zones, the Shan-

TABLE 3. AVERAGE SPECIES RICHNESS, SIMPSON'S INDEX AND SHANNON-WEAVER INDEX FOR EACH ZONE AT A FEN

Zone	*E-2*[1]	*E-3*	*E-4*	*E-7*	*E-9*	*E-10*	*E-11*	*SLF*	*Average*
	Species Richness								
Border[2]	8.5	8.0	7.0	9.5	9.7	9.5	8.5	8.3	8.6
Sedge Mat	6.0	5.6	5.5	5.3	6.7	7.6	5.0	5.5	5.8
Discharge	6.3	6.0	7.0	7.0	6.5	7.5	6.0	2.3	6.0
	Simpson's Index								
Border	0.28	0.33	0.22	0.29	0.31	0.22	0.31	0.43	0.33
Sedge Mat	0.65	0.57	0.63	0.61	0.55	0.39	0.51	0.65	0.58
Discharge	0.43	0.32	0.58	0.42	0.62	0.24	0.43	0.52	0.42
	Shannon-Weaver Index								
Border	1.53	1.45	1.63	1.48	1.44	1.68	1.43	1.17	1.40
Sedge Mat	0.73	0.86	0.71	0.72	0.93	1.18	0.83	0.67	0.81
Discharge	1.17	1.38	0.78	1.18	0.77	1.66	1.17	0.68	1.15

[1] E—Excelsior fen complex; SLF—Silver Lake fen.

[2] There were a total of 23, 58, and 18 quadrats in the border, mat, and discharge zones respectively.

TABLE 4. NESTED ANALYSIS OF VARIANCE OF THE SPECIES RICHNESS, SIMPSON'S INDEX AND SHANNON-WEAVER DATA

Source	*df*	*Species Richness* SS[1]	*Simpson's Index* SS	*Shannon-Weaver Index* SS
Site[2]	1	4.73	0.52	0.64[3]
Fen (Site)[4]	6	43.95[3]	2.67[3]	2.25[3]
Zone (Fen Site)	16	182.46[3]	6.89[3]	7.47[3]
Error	75	187.40	11.82	10.89
Corrected Total	98	418.54	21.90	21.25

[1] SS—sum of squares.

[2] Site—Silver Lake fen and Excelsior fen complex.

[3] Significant at the 95% confidence level.

[4] Fen (Site)—Fen nested within site where fen refers to the seven Excelsior fens and the Silver Lake fen.

non-Weaver indices are 1.40, 0.81 and 1.15 respectively. This pattern is identical with that of species richness. The magnitude of the Shannon-Weaver values for all three fen zones is low compared to those reported for forests (Monk, 1967; Auclair and Goff, 1971), but it is about the same as that for coastal dune grasslands (van der Valk, 1975). This reflects the depauperate floristic condition of these environmentally stressed communities.

The Simpson's index (Tables 3, 4) averages 0.33, 0.58 and 0.42 in the border, sedge mat and discharge zones respectively. The sedge mat zone has the most unequal distribution of cover values. *Rhynchospora capillacea* (Table 2) was the overwhelming dominant in this zone and no other species approached its cover. In the two other zones, species abundance was more even, and often there were two or more equally abundant species.

The structural data show that the sedge mat community when compared with the other two zones is significantly less complex, has fewer species/quadrat and is dominated by only one species (Tables 3, 4). All three conditions indicate that the sedge mat is the zone with the harshest environment (see Monk, 1967; Auclair and Goff, 1971). What environmental differences between the sedge mat and the other two zones are responsible for these floristic structural differences? No definitive answer to this question is possible. However, from some preliminary environmental measurements along transects made by Holte (1966), it is possible to outline some of the major environmental differences among the three zones. His data indicate that, although there is a correlation between soil temperature and the distribution of certain species, e.g., *Cardamine bulbosa,* soil temperature and water chemistry are not major factors influencing the zonation of fen species. Elevation above the water table may be a factor responsible for differences between the composition of the vegetation of discharge cones and the sedge mat zones. This is supported by the results of a simple preliminary experiment done by Holte (1966) which involved changing soil surface levels artificially. Plants growing on the discharge cones probably grow in an area with better soil aeration than those growing closer to the water table on the sedge mat. Plants growing in the border zone are probably influenced by the mineral soils under the fens and, as a result, undoubtedly have a more favorable nutrient status. Cattle trampling has also influenced the Excelsior fen border zones by creating a great deal of microrelief. This has allowed certain weedy pasture species to become established in the zone on the tops of small hummocks. Holte's (1966) field measurements suggest that two important environmental factors (soil nutrients and relief) may be responsible for the zonation found in Iowa fens. These two factors should now be investigated experimentally in the field and laboratory to evaluate their significance.

ACKNOWLEDGMENTS

I would like to thank Craig B. Davis and David Glenn-Lewin for critically reading the manuscript and Jeff Dodd for his assistance in the field. Support for this study was in part supplied by an Iowa State Research Initiation Grant (NSF-GU-3373).

LITERATURE CITED

ANDERSON, W. A. 1943. A fen in northwest Iowa. *Am. Midl. Nat.* 29:787-791.

AUCLAIR, A. N., and F. G. GOFF. 1971. Diversity relations of upland forests in the western Great Lakes area. *Amer. Nat.* 105: 499-528.

BACHMAN, R. W. 1965. Some chemical characteristics of Iowa lakes and reservoirs. *Proc. Iowa Acad. Sci.* 72:238-243.

BEAL, E. O., and P. H. MONSON. 1954. Marsh and aquatic angiosperms of Iowa. *State Univ. Iowa Stud. Nat. Hist.* 19(5):1-95.

BRAUN-BLANQUET, J. 1932. *Plant sociology.* (Ed. and trans. G. D. Fuller and H. S. Conard). McGraw-Hill, New York, 439 pp.

CAIN, S. A., and J. V. SLATER. 1948. The vegetation of Sodon Lake. *Am. Midl. Nat.* 40:741-762.

CARTER, C. 1939. Observations upon bogs of northern Iowa. *Proc. Iowa Acad. Sci.* 46:223-224.

CONARD, H. S. 1952. The vegetation of Iowa. *State Univ. Iowa Stud. Nat. Hist.* 19(4):1-166.

CURTIS, J. T. 1959. *The vegetation of Wisconsin.* Univ. of Wisc. Press, Madison. 657 pp.

EICKSTAEDT, L. 1964. An ecological analysis of Silver Lake fen. I. The aquatic metazoan fauna. *Proc. Iowa Acad. Sci.* 71:486-495.

GASHWILER, K., and J. D. DODD. 1961. Algae from the warm pools of Silver Lake fen. *Proc. Iowa Acad. Sci.* 68:129-131.

GLEASON, H. A., and A. CRONQUIST. 1963. *Manual of vascular plants of northeastern United States and adjacent Canada.* Van Nostrand, New York. 810 pp.

GORDON, R. B. 1933. A unique raised bog at Urbana, Ohio. *Ohio J. Sci.* 33:453-459.

HAYDEN, A. 1943. A botanical survey in the Iowa lake region of Clay and Palo Alto counties. *Iowa State College J. Sci.* 17:277-415.

HEMPSTEAD, D. L., and T. L. JAHN. 1939. The protozoa of Silver Lake fen. *Proc. Iowa Acad. Sci.* 46:413-416.

HOLTE, K. E. 1966. A floristic and ecological analysis of the Excelsior fen complex in northwest Iowa. Ph.D. thesis, Univ. of Iowa, Iowa City. 292 pp.

HOLTE, K. E., and R. F. THORNE. 1962. Discovery of a calcareous fen complex in northwest Iowa. *Proc. Iowa Acad. Sci.* 69:54-60.

MONK, C. D. 1967. Tree species diversity in the eastern deciduous forest with particular reference to north central Florida. *Amer. Nat.* 101:173-187.

MOYLE, J. B. 1945. Some chemical factors influencing the distribution of aquatic plants in Minnesota. *Amer. Midl. Nat.* 34:402-420.

MUENSCHER, W. C. 1944. *Aquatic plants of the United States.* Comstock, Ithaca. 374 pp.

OLSEN, S. 1950. Aquatic plants and hydrospheric factors. I and II. *Svensk Bot. Tidskr.* 44:1-34; 332-373.

PEET, R. K. 1974. The measurement of species diversity. *Annu. Rev. Ecol. Syst.* 5:285-307.

SEDDON, B. 1972. Aquatic macrophytes as limnological indicators. *Freshwat. Biol.* 2:107-130.

SERVICE, J. 1972. A user's guide to the statistical analysis system. Student Supply Store, N.C. State Univ., Raleigh, N. C. 259 pp.

SHAW, R. H., and P. J. WAITE. 1964. The climate of Iowa. III. Monthly, crop season and annual temperatures and precipitation normals for Iowa. *Iowa State Univ. Ag. Home Exp. State. Special Report* 38. 32 pp.

SHOBE, W. R., E. F. STOERMER and J. D. DODD. 1963. Notes on Iowa diatoms. IV. The diatoms in a northwest Iowa fen. *Proc. Iowa Acad. Sci.* 70:71-74.

SHIMEK, B. 1915. The plant geography of the Lake Okoboji region. *Univ. Iowa Bull. Lab. Nat. Hist.* 7(2):1-69.

SJORS, H. 1959. Bogs and fens in the Hudson Bay lowlands. *Arctic* 12:2-19.

STEWART, R. E., and H. A. KANTRUD. 1972. Vegetation of prairie potholes, North Dakota, in relation to quality of water and other environmental factors. USGS Professional Paper 585-D. 36 pp.

STEYERMARK, J. Plants new to Missouri. *Rhodora* 40:249-255.

TANSLEY, A. G. 1968. *Britain's green mantle* (2nd ed. revised by M. C. F. Proctor). George Allen and Unwin, London. 327 pp.

VAN DER VALK, A. G. 1975. The floristic composition and structure of foredune plant communities of Cape Hatteras National Seashore. *Chesapeake Science* 16(2):115-126.

VAN DER VALK, A. G., and C. C. BLISS. 1971. Hydrarch succession and net primary production of oxbow lakes in central Alberta. *Can. J. Bot.* 49:1177-1199.

WHITTAKER, R. H. 1972. Evolution and measurement of species diversity. *Taxon* 21:213-251.

WOLDEN, B. O. 1926. A bog flora of northern Iowa. *Amer. Bot.* 32:6-10.

ZENKERT, C. A. 1934. Flora of the Niagara Frontier region. *Bull. Buffalo Soc. Nat. Sci.* 16:1-314.

Fern Reproduction at Woodman Hollow, Central Iowa: Preliminary Observations and a Consideration of the Feasibility of Studying Fern Reproductive Biology in Nature

DONALD R. FARRAR[1] and ROBERT D. GOOCH[2]

FARRAR, DONALD R., and ROBERT D. GOOCH (Department of Botany and Plant Pathology, Iowa State University, Ames, Iowa 50010). Fern Reproduction at Woodman Hollow, Central Iowa: Preliminary Observations and a Consideration of the Feasibility of Studying Fern Reproductive Biology in Nature. *Proc. Iowa Acad. Sci.* 82(2): 119-122, 1975.
Field observations of spore availability, gametophyte establishment and survival, and sporophyte production were made over a one-year period. Maximum spore release for most species occurred shortly after spore maturation in mid to late summer, but some spores remained on sporophyte fronds through the winter and were available for germination the following spring. Gametophytes of *Cystopteris fragilis, Woodsia obtusa* and *Adiantum pedatum* became established in late summer and fall. Production of sporophytes occurred both in fall and in the following spring. Both gametophytes and juvenile sporophytes survived the winter in relatively unchanged condition. Results indicate that it is feasible and important to correlate field studies with current laboratory studies of fern reproductive biology.
INDEX DESCRIPTORS: Ferns, Fern Gametophytes, Fern Reproduction, Woodman Hollow in Iowa.

The process by which sexual reproduction is accomplished in ferns has considerable bearing upon the interpretation of their past evolution as well as their present distribution and ecology. Our knowledge of sexual reproduction in these plants has increased greatly during the last two decades, but almost entirely from research conducted in the laboratory. Differing conclusions which can be drawn from different aspects of this research leave it unclear as to what methods of sexual reproduction occur in nature. It seems unlikely that these differences will be totally resolved without the aid of field observations. It is the purpose of this investigation to determine the feasibility of conducting field studies on sexual reproduction in the ferns.

The laboratory research of greatest relevance to fern evolution and ecology may be grouped into two categories, the hormonal control of antheridium formation and the genetic response to self-fertilization. Studies in the first area have been conducted primarily by Döpp (1950, 1959), Schraudolf (1966), Näf (1963, 1969), and Voeller (1969, 1971). They have demonstrated conclusively that, in several species of ferns, older or faster growing gametophytes of a population produce a soluble hormone which induces younger or more slowly growing gametophytes to produce antheridia. The end result of this system is the assurance of the simultaneous maturation of male and female gametangia and promotion of cross-fertilization within the population and thus a decrease in the probability of self-fertilization of hermaphroditic gametophytes. An additional effect of the same hormone is the promotion of dark germination of spores which may be buried too deeply in the substratum to germinate alone but which when stimulated by the hormone will produce gametophytes capable of producing additional antheridia.

This hormone system is apparently widespread in the ferns, so much so that it has been possible to set up a phylogeny of the ferns based upon the interaction of various species to the hormones of one another (Voeller, 1971). It is important to note that the effectiveness of this hormone system is dependent upon the close proximity of gametophytes growing in a relatively dense population. Such a system is unlikely to have evolved unless this is a common means of reproduction, i.e., *by relatively dense populations.*

On the other hand, studies by Klekowski (1971, 1973) and co-workers on the genetics of ferns have brought together persuasive evidence suggesting that ferns, throughout their evolutionary history, have reproduced sexually to some extent by self-fertilization of bisexual gametophytes. The principal evidence for this conclusion is the relatively high basal chromosome numbers of ferns, probably the result of ancient polyploidy (Klekowski and Baker, 1966). The selective pressure for this polyploidization is the protection it provides the organisms against the expression of lethals in a totally homozygous state which results from self-fertilization of bisexual gametophytes. If this interpretation is accepted, then one must conclude that the polyploid system in ferns would not have evolved if there were not an appreciable amount of reproduction in nature on the single gametophyte level, i.e., *by self-fertilization of single, bisexual gametophytes.*

These two lines of evidence thus suggest an appreciable degree of reproduction both by cross-fertilization between gametophytes in a population and by self-fertilization of isolated gametophytes. Additional studies in the laboratory may also predict which method predominates for which species. However, verification of these predictions by field observations is lacking, e.g., as stated by Holbrook-Walker and Lloyd (1973) in their study of the reproductive biology of *Sadleria:* "Therefore, further testing of the hypothesis put forward above rests with an ecological study of the gametophyte generation in nature."

Is it possible to study fern gametophytes in nature? The paucity of such studies has been largely ascribed to the difficulties of finding gametophytes in nature and of identification of species in the gametophytic stage. While these difficulties do exist, we feel that the observations presented here indicate that they need not preclude productive field studies if study sites and methods of study are selected carefully.

Growth conditions for gametophytes in the field are unlikely to be similar to those in laboratory studies. Thus it is important to consider as many aspects as possible of the life

[1] Department of Botany and Plant Pathology, Iowa State University, Ames, Iowa 50010.
[2] DuPage County Preserves System, 17 W 315-91st St., Hinsdale, Illinois 60521.

history of gametophytes in nature when making comparisons to laboratory data. One must consider such factors as the growth conditions, the age of reproducing gametophytes, and especially the effectiveness of reproduction. A full understanding of natural reproduction cannot be based solely upon collection of populations of gametophytes at one time of year and analysis of their sexual condition. It is necessary to follow gametophyte and sporophyte growth throughout the year and to determine which gametophytes or populations of gametophytes produce sporophytes that subsequently mature to participate in further reproduction.

PROCEDURE

The study site we have chosen is the Woodman Hollow State Preserve, a relatively isolated canyon in central Iowa. The canyon, cut into glacial till and Pennsylvanian sandstone, is about one-half mile long and 50 to 150 feet deep, with a small intermittent stream. It supports a mature deciduous forest typical of the midwest (Nieman and Landers, 1974) and contains 13 species in 11 genera of ferns (Table 1). Identification of species in the gametophyte stage is most difficult between species of the same genus; this problem is nearly eliminated in Woodman Hollow because only two genera have more than one species present. In these genera (as well as in the remainder of the species) the species could be differentiated by spore morphology and eventually by the sporophytes produced.

TABLE 1. FERN SPORE PRODUCTION AND RELEASE AT WOODMAN HOLLOW STATE PRESERVE, CENTRAL IOWA

Species	*First Release (approx. date)*	*Maximum Release (approx. date)*	*Type of Frond Maturation*
Matteuccia struthiopteris	Mar. 20	April 17	flush
Cystopteris fragilis	May 31	June 10	flush
Dryopteris spinulosa	June 10	July 20	flush
Polypodium virginianum	June 10	July 20-?	sequential
Dryopteris goldiana	June 30	July 20	flush
Botrychium virginianum	June 30	June 30	flush
Athyrium filix-femina	June 30	July 20	flush
Cystopteris bulbifera	July 5	July 20	flush
Osmunda claytoniana	July 5	July 5	flush
Cryptogramma stelleri	July 10	July 20	flush
Woodsia obtusa	July 10	July 20-?	sequential
Adiantum pedatum	Aug. 4	Aug. 20-?	sequential
Asplenium rhizophyllum	Sept. 19	Sept. 30-?	sequential

To outline a procedure of study we posed several questions relative to sexual reproduction of the species in Woodman Hollow. When are spores available for germination? When does reproduction occur and how is it influenced by micro- and macroclimates? When and by what breeding systems are sporophytes produced? Does sexual reproduction occur in nature on a regular basis for all species? To gather data in answer to these questions we began bi-monthly observations in the study area which were continued throughout the year. In addition to recording presence and condition of sporophytes and gametophytes, we began a long-term study of the physical parameters of the habitats in which reproduction occurs. Correlation of reproduction with habitat parameters including temperature, light intensity, relative humidity, and soil characteristics will be reported in a later paper.

OBSERVATIONS

Spore Availability

Information in the literature on spore availability is limited to relatively few accounts of the time of spore maturation and release by various species (Hill and Wagner, 1974; Lloyd and Klekowski, 1970). Times indicated in such listings are precise only for the given area and year in which the observations are made, but they are valid as general indications of the time of first availability of spores from sporophytes of a given season.

Approximate dates of spore release for the species in Woodman Hollow for 1972 are given in Table 1. The period of maximum release is related to type of sporangium, the type of soral maturation, and type of maturation of fertile fronds. In *Botrychium virginianum* and *Osmunda claytoniana* the sporangia are very large and smooth-walled and mature nearly simultaneously. Thus, release of their spores occurs very rapidly after maturation and the dates of first and of maximum spore release are approximately the same. In the remaining species, differential maturation of the sporangia within the sorus, combined with the small size and density of the sporangia, results in a period of maximum release extending usually one to three weeks. Although the fertile fronds mature in a single flush in most of the species, the period of release in *Polypodium*, *Woodsia*, *Asplenium* and *Adiantum* is also extended by the sequential maturation of fertile fronds, which may continue until the time of first frost. *Matteuccia struthiopteris* is a special case because the fertile fronds mature in the fall but spores are presumably not released until the following spring. Although in 1972 first release of spores was observed in March, we have subsequently observed spore release from *Matteuccia* fronds as early as December.

Time of first release and period of maximum release do not give the total picture of spore availability. After release, the spores remain viable in most species for at least a year (Sussman, 1965) (green-spored genera such as *Osmunda* and *Matteuccia* may be exceptions [Lloyd and Klekowski, 1970; Hill and Wagner, 1974]); thus, spores which have landed in a given habitat are available at the time when environmental conditions required for germination are first attained. While most probably occurring soon after release, these conditions may first occur at any time of the year, notably in early spring following a dry fall.

Further complicating the picture of spore availability is the fact that not all spores are shed from the sporophyte fronds during the summer of their maturation. Preliminary examination of the species in Woodman Hollow revealed that in April viable spores remained on the fertile fronds of the previous year (Table 2). In several species 10% or more of the sporangia were unopened, and even in the species where all sporangia were open, spores remained in and on the sporangia and on the frond surface. These were easily dislodged by light tapping of the dried fronds. Figures listed in Table 2 for numbers of spores present are very conservative and can probably be multiplied tenfold in most cases. The old sporo-

TABLE 2. SPORE AVAILABILITY IN APRIL FROM FRONDS OF THE PREVIOUS YEAR

Species	Spores/frond	Spore Viability Relative to 50%	Sporangial Condition—% Opened
Athyrium filix-femina	>1000	+	100
Asplenium rhizophyllum	>1000	–	90-100
Polypodium virginianum	>1000	+	75-90
Woodsia obtusa	>1000	+	75-90
Cryptogramma stelleri	>1000	none	50-75
Matteuccia struthiopteris	>1000	+	actively opening
Cystopteris fragilis	100-1000	+	100
Dryopteris goldiana	100-1000	+	100
Cystopteris bulbifera	<100	+	100
Adiantum pedatum	<100	–	90-100
Dryopteris spinulosa	no fertile fronds found		
Osmunda claytoniana	no fertile fronds found		
Botrychium virginianum	no fertile fronds found		

phyte fronds in the early spring are generally flattened against the substrate and spore release into the air currents would be greatly reduced. Nevertheless, some spores could certainly germinate in the immediate vicinity of the sporophyte frond if a suitable habitat were available.

Gametophyte Establishment

Established populations of gametophytes in Woodman Hollow were first observed in mid-September. They appeared in great numbers in the vicinity of sporophytes of *Cystopteris fragilis, Woodsia obtusa,* and *Adiantum pedatum,* covering exposed as well as protected areas of bare rock or soil. By late September, gametophytes of these species could be found in 23 of 25 one-square-meter plots which were within 10 meters of a fertile sporophyte, and plots within five meters contained 500 to 3000 individuals.

During the month of October, gametophyte numbers were steadily reduced, largely through erosion from exposed sites. By early November, populations of gametophytes were largely restricted to protected pockets of less than 100 cm^2 and contained usually 75 to 100 individuals per 100 cm^2. Most of the gametophytes were mature by November and many had produced the first leaf of the new sporophyte. At this time, one population of *Cystopteris* gametophytes was harvested to determine the feasibility of studying the sexual constitution of natural populations. The gametophytes were examined for presence and type of gametangia. Of the 75 individuals in the population, 67 were sexual, 46 bearing both antheridia and archegonia, and 21 bearing antheridia only. Thus, this population apparently had potential for both cross- and self-fertilization. Hormonal control of antheridial production is also suggested by the large number of male gametophytes, but these observations must be combined with laboratory studies before definite conclusions are drawn. Nevertheless, this observation indicates that correlations between field and laboratory investigations on breeding behavior can be made.

From November through February, temperatures in Woodman Hollow remained near or below freezing and little growth in the gametophytes of juvenile sporophytes could be detected. Many populations became covered with snow in December and remained so into February. In March, when the populations could again be examined, we found that although some gametophytes and sporophytes had been killed, in most populations, 75% or more of the number present at the end of November had survived the winter in essentially unchanged condition. By April, young sporophytes produced in the fall had resumed growth and new sporophytes appeared on other gametophytes which had survived the winter. Through April and May the young sporophytes in most populations grew vigorously and produced dense stands one to three centimeters tall. By June this growth had largely stopped, presumably due to one or more of the factors of high population density, inadequate substrate, and dense shading by an herbaceous canopy. Relatively few individuals in favorable sites continued growth which could be expected to reach maturity.

These observations were made during the fall of 1972, which was wetter than average for central Iowa. This was also the best year for gametophyte establishment in Woodman Hollow we have observed. Yet establishment of gametophytes was observed for only four of the thirteen species present. In addition to the three species mentioned, gametophyte establishment to a much smaller degree was observed for *Dryopteris goldiana.* Although this species produced spores in great abundance, and habitats of bare, moist rock and soil were available, only a few scattered gametophytes were found. Spores of all species were tested in the laboratory and found to be viable. The reasons for the failure of gametophyte establishment are obscure, especially for *Dryopteris goldiana* and *Athyrium filix-femina,* which are very common in the area. However, these are larger, perennial plants which grow in less disturbed areas than do *Adiantum, Woodsia* and *Cystopteris fragilis,* which are colonizers of the most rapidly eroding parts of the canyon. Factors to be considered in explaining the absence of gametophytes of the remaining species include the reduced period of viability of green-spored species, specific requirements for habitats not abundantly available, and occurrence of some species in habitats not as moist as those of *Adiantum, Woodsia* and *Cystopteris.* Establishment of the subterranean gametophytes of *Botrychium virginianum* is of course not readily observable; however, we found young sporophytes with attached gametophytes, indicating that reproduction of this species is occurring in Woodman Hollow.

Regardless of the reasons for lack of gametophyte establishment for certain species, we must conclude that some species reproduce via gametophytes much more readily than others. The species occurring in Woodman Hollow may be tentatively grouped into categories as indicated in Table 3. Weedy species which reproduce annually either sexually or asexually include the two species of *Cystopteris* and the species of *Adiantum* and *Woodsia.* These species may be perennial but are frequently short-lived due to the unstable character of their habitat. *Athyrium* and *Matteuccia* are also weedy species in central Iowa, but individuals are longer-lived, and in Woodman Hollow they apparently do not reproduce annually. The two species of *Dryopteris* and the species of *Osmunda, Polypodium* and *Asplenium* are found only in the most mature forests of central Iowa and cannot be considered weedy, although *Dryopteris goldiana* is very abundant in Woodman Hollow. These species apparently do not reproduce annually here and are also long-lived perennials.

Two species are not included in Table 4, *Botrychium virginianum* because of the difficulty of studying its reproduc-

TABLE 3. FERN REPRODUCTION AT WOODMAN HOLLOW STATE PRESERVE IN CENTRAL IOWA

I. Weedy, short-lived perennials reproducing annually by asexual reproduction
Cystopteris fragilis
Woodsia obtusa
Adiantum pedatum

II. Weedy, short-lived perennials reproducing annually by sexual reproduction
Cystopteris bulbifera

III. Weedy, long-lived perennials not reproducing annually
Athyrium filix-femina
Matteuccia struthiopteris

IV. Non-weedy, long-lived perennials not reproducing annually
Dryopteris spinulosa
Dryopteris goldiana
Osmunda clatoniana
Polypodium virginianum
Asplenium rhizophyllum

tion, and *Cryptogramma stelleri* because of its atypical occurrence here on the extreme southern boundary of its range. *Botrychium virginianum* is weedy in central Iowa and probably reproduces annually. *Cryptogramma stelleri* in Woodman Hollow occurs in three small populations on large, relatively stable cliffs. It is at the extreme southern edge of its range here and although we observed no reproduction, this may not be typical of its behavior further north.

SUMMARY

We have presented here a number of observations which we believe indicate the feasibility of field studies of fern reproduction. Results presented are non-quantitative and will need to be verified by further observation and experimentation not only in Woodman Hollow, but in other areas as well. When a sufficient number of such studies have been completed it should be possible to make a more meaningful integration of present laboratory data on fern reproduction into the study of fern evolution and ecology.

LITERATURE CITED

DÖPP, W. 1950. Eine die Antheridienbildung bei Farnen fördernde Substanz in den Prothallien von *Pteridium aquilinum* (L) Kuhn. *Ber. Deut. Botan. Ges.* 63:139-147.

DÖPP, W. 1959. Uber eine hemmende und eine fördernde Substanz bei der Antheridienbildung in den Prothallien von *Pteridium aquilinum. Ber. Deut. Botan. Ges.* 72:11-24.

HILL, R. H., and W. H. WAGNER, JR. 1974. Seasonality and spore type of the pteridophytes of Michigan. *Mich. Bot.* 13:40-44.

HOLBROOK-WALKER, S. G., and R. M. LLOYD. 1973. Reproductive biology and gametophyte morphology of the Hawaiian fern genus *Sadleria* (Blechnaceae) relative to habitat diversity and propensity for colonization. *Bot. J. Linn. Soc.* 67:157-174.

KLEKOWSKI, E. J., JR. 1971. Ferns and genetics. *Bioscience* 21:317-322.

KLEKOWSKI, E. J., JR. 1973. Sexual and subsexual systems in homosporous pteridophytes: A new hypothesis. *Amer. J. Bot.* 60:535-544.

KLEKOWSKI, E. J., JR., and H. G. BAKER. 1966. Evolutionary significance of polyploidy in the Pteridophyta. *Science* 153:305-307.

LLOYD, R. M., and E. J. KLEKOWSKI, JR. 1970. Spore germination and viability in Pteridophyta: Evolutionary significance of chlorophyllous spores. *Biatropica* 2:129-137.

NÄF, U. 1963. Antheridium formation in ferns—A model for the study of developmental change. *J. Linn. Soc. (Bot.)* 58:321-331.

NÄF, U. 1969. On the control of antheridium formation in ferns. In: Current Topics in Plant Science, J. Gunkel (ed.). Academic Press, Inc., New York.

NIEMANN, D. A., and R. Q. LANDERS. 1974. Forest Communities in Woodman Hollow State Preserve, Iowa. *Proc. Iowa Acad. Sci.* 81(4):176-184.

SCHRAUDOLF, H. 1966. Die Wirkung von Phytohormonen auf Keimung und Entwicklung von Farnprothallien IV. Die Wirkung von unterschiedlichen Gibberellinen und von Allogibberellinsäure auf die Auslösung der Antheridienbildung bie *Anemia pyllitidis* L. und einigen Polypodiaceen. *Plant Cell Physiol.* 7:277-289.

VOELLER, B. R. 1971. Developmental physiology of fern gametophytes: Relevance for biology. *Bioscience* 21:266-270.

VOELLER, B. R., and E. S. WEINBERG. 1969. Evolutionary and physiological aspects of antheridium induction in ferns. In: Current Topics in Plant Science, J. Gunkel (ed.). Academic Press, Inc., New York.

The Oldest Iowa Tree, II: Eastern Red Cedar on Cedar River Bluffs

ROGER Q. LANDERS[1] and DOLORES GRAF[2]

When Anderson (1938) described the oldest tree in Iowa, he was using wood from an eastern red cedar, *Juniperus virginiana* L., which had originated *ca.* 1516 and died *ca.* 1885, presumably near the Schramm family cottage on West Lake Okoboji. Our sample, also from eastern red cedar, is a core from a tree growing on a steep limestone bluff overlooking the Cedar River in Palisades-Kepler State Park. The 16 cm (6¼ in.) core, taken in April, 1965, by Graf and R. Wm. Poulter, was set aside then because the slender tree showed little outward sign of old age compared with gnarled trees nearby (Graf, 1969). The tree was marked with a numbered brass tag. When the study was renewed recently to work on dendrochronology and weather patterns in Iowa, the core was examined and 438 growth rings were counted, well above any age determined previously for a living tree in Iowa. The rings were unusually clear for eastern red cedar despite their narrow growth increment. The severe drought year of 1934 is readily apparent on this core, as it is on other tree samples from this area. This suggests that cross-dating will be successful.

We relocated the tree on January 25, 1975, by identifying it from photographs taken in 1965 and by the numbered brass tag; however, the slope was too icy and steep to take another core. The tree is now ten years older or approximately 448 years old, giving an establishment date of 1523. Because the core was taken *ca.* 50 cm above the base of the tree, it is suggested that an additional several years may be added to its age, corresponding very closely to the possible date of establishment of the Anderson tree. Studies on Iowa's oldest trees are continuing, and even older specimens are anticipated.

[1] Department of Botany and Plant Pathology, Iowa State University, Ames, Iowa 50010.

[2] Division of Biology, Iowa Wesleyan College, Mount Pleasant, Iowa 52641.

Literature Cited

Anderson, W. A. 1938. The oldest Iowa tree. *Proc. Iowa Acad. Sci.* 45:73-74.

Graf, Dolores. 1969. Distribution pattern of eastern red cedar, *Juniperus virginiana* L., in Iowa. Unpublished Ph.D. thesis. Library, Iowa State University, Ames.

Introduction to a New Series of Studies of Ordovician Echinoderms

H. L. STRIMPLE[1]

STRIMPLE, H. L. (Geology Department, The University of Iowa, Iowa City, Iowa 52242). Introduction to a New Series of Studies of Ordovician Echinoderms. *Proc. Iowa Acad. Sci.* 82(2): 124-125, 1975.
A massive collection of Ordovician echinoderms has been accumulated primarily from northeastern Iowa and southeastern Minnesota but including material from other states; it is in process of being studied. A brief history of the inception of the study and the process of bringing the material together is presented. Individuals are named but only brief details are given. Primarily this is a report of a concentrated effort to produce a significant study of echinoderms from Middle and Upper Ordovician strata, the people involved and the methods of obtaining material.
INDEX DESCRIPTORS: Ordovician Echinoderms; Benbolt and Ottosee Formations, Tennessee and Virginia; Bromide Formation, Oklahoma; Platteville Formation; Galena Group; Maquoketa Formation; Decorah Formation, Iowa, Minnesota and Illinois; Kimmswick, Girardeau, Decorah Formations, Missouri.

Considerable attention has been directed toward Ordovician echinoderms of North America in the past few years by many investigators, e.g., Sprinkle, Brower, Lane, Caster, Parsley, Kolata, Kesling, Paul, Bolton and others. A detailed listing would serve no purpose here and would in fact require a report in itself. It is sufficient to note that there is a veritable explosion of material and data which is remarkable enough without considering the great antiquity of the animals and the difficulty in finding them in the field. Although I am more than a little adept at collecting echinoderms, there has been more than one occasion when I was happy to recover one or two specimens in indifferent preservation after an exhaustive search in Ordovician strata. Fortunately it is not always so.

The inception of the presently activated studies of Ordovician echinoderms might be said to be about 1946 or 1947. Wm. T. Watkins, an advanced fossil collector, became my associate and later collaborator on echinoderms of southern Oklahoma. In addition to exposures previously known to Watkins, G. A. Cooper, A. L. Loeblich and W. M. Ham either showed me or told me about many echinoderm-bearing localities in southern Oklahoma, including Ordovician exposures. One of the most prolific exposures of the Bromide Formation, on the West Fork of Sycamore Creek in the eastern portion of the Arbuckle Mountains, was in an area that could only be reached on foot at that time and eluded me for three years, though I did eventually walk it down. The first report I made was on a new pleurocystitid (*Pleurocystites watkinsi* Strimple, 1948) which was subsequently designated the type species of *Praepleurocystis* Paul, 1967 (see also Strimple, 1972; Sprinkle, 1973). Subsequent short taxonomic reports were made, e.g., Strimple, 1952, 1953a, 1953b; Strimple and Watkins, 1949, 1955; Strimple and Graffham, 1955.

It was my intention in 1962 to attempt a large study of echinoderms of the Bromide Formation of Oklahoma, upon completion of the study of Hunton (Silurian-Devonian) crinoids (*Okla. Geol. Survey Bull.* 100, 1963), but the project was assigned to R. O. Fay by Carl C. Branson, who was then Director of the Oklahoma Geological Survey. Fay spent over a year in the field accumulating large collections from Ordovician exposures in southern Oklahoma with the assistance of Allen A. Graffham and his staff; however, the study was eventually shelved, and then revived and organized by James A. Sprinkle in the spring of 1974 to be handled as a team project with Sprinkle as the coordinator. I am not a member of that team and the endeavor has no direct bearing on the studies under discussion.

Subsequent to completion of the forementioned *Okla. Geol. Surv. Bull.* 100, I joined the Geology Department staff at The University of Iowa and became interested in the potential of the Ordovician of northeastern Iowa, in particular the Maquoketa Formation. Both W. M. Furnish and B. F. Glenister were most helpful in my endeavor. Effective collecting in the Maquoketa is only possible when the rocks are moist, which requires close coordination between existing weather conditions and the timing of field expeditions. Through the years considerable collections have been made over and above those described by Slocum (1924), Foerste (1924) and Thomas and Ladd (1926). The major breakthrough in acquisition of Ordovician material was made when Art Gerk, a salesman for Johns-Manville Co., found echinoderms in the Galena Group exposed in his territory in northeastern Iowa.

Art Gerk, Mason City, Iowa, is basically a naturalist who has enjoyed investigations of both living and fossil life in his years of travel in north-central and northeastern Iowa. The fossils and stratigraphy of the Ordovician of northeastern Iowa have occupied his attention for the past several years. In this project he is teamed with C. O. Levorson, Riceville, Iowa, who has been involved with advanced biostratigraphic studies for a longer span of years.

C. O. Levorson, Postmaster, Riceville, Iowa, for many years devoted much of his free time and efforts to collecting fossils and associated biostratigraphic studies of Devonian rocks of north-central Iowa. We became closely associated when I elicited his assistance in production of the "Catalogue of Type Specimens of the Belanski Collection," Strimple and Levorson, 1969, which collection consisted of Devonian fossils mainly from the area around Nora Springs, Iowa. Several joint studies were done on rare Upper Devonian crinoids (Strimple and Levorson, 1969, 1971, 1974). Levorson has concentrated on the Ordovician for the past several years, and in particular on the Galena Group of northeastern Iowa and southeastern Minnesota in cooperation with Art Gerk. A report on the initial stages of their stratigraphic work is available in *Proc. Iowa Acad. Sci.*, Levorson and Gerk, 1972. Their stratigraphic study is now essentially completed and represents an incredible amount of effort, time and just plain work.

[1] Geology Department, The University of Iowa, Iowa City, Iowa 52242.

During the years 1971-1974 they examined in detail 82 localities and made 90 detailed sections in the Galena Group, primarily in northeastern Iowa but extending into Minnesota and Wisconsin on occasion. The echinoderms have been made available and will form the nucleus of the massive studies of Ordovician echinoderms in progress with Strimple, Levorson, et al., as investigators.

Yet another resident of Riceville, Iowa, Glenn Crossman, is an advanced fossil collector who has contributed to the Ordovician echinoderm studies, both in the field and with rare specimens.

Brian Gossman, more or less as a protege of Art Gerk, has worked in the area near Elkader, Iowa, and is now an undergraduate at The University of Iowa. Steve Calhoun, presently a master's candidate at The University of Iowa, is more or less a protege of Glenn Crossman. Both have contributed rare specimens to the Ordovician studies.

Other material which will be used in the present study has been acquired by various means. A collection made in the Benbolt Formation of eastern Tennessee by the author in 1951, and currently reposited in the National Museum of Natural History, has been augmented by a collection made in the fall of 1972. Collections made by Cliff Coney in the Ottosee Formation near Speer's Ferry, Virginia, have been donated to the study through the influence of a University of Iowa alumnus, J. M. Cocke, while a professor at East Tennessee State University. Material from the Girardeau Limestone at Cape Girardeau, Missouri, was donated to the study by Larry Mack while a student at Missouri State College at Cape Girardeau. Mack also guided my wife and me in field work in the area. Crinoids have been recovered by Amel Priest, Mike McGinnis and Glenn Crossman, together with the author, from the Decorah Formation south of Hannibal, Missouri.

Echinoderms from the Kimmswick Formation of Missouri and the Galena Formation at Cannon Falls, Minnesota, have been acquired in a variety of ways. Most of the Kimmswick material is from near the town of Barnhart, south of St. Louis, Missouri. A young amateur, Guy Darrough, guided my wife and me to the area, where we collected, and in addition he exchanged with us a few specimens both from the Kimmswick and from the Galena Formation at Cannon Falls, Minnesota. Darrough is a protege of Bruce Stinchcomb, a teacher at Florissant Valley Community College, St. Louis, Missouri. Both Stinchcomb and Darrough exchange with Allen Graffham (Geological Enterprises), and some of the best specimens were obtained by the author and his wife through outright personal purchase from Geological Enterprises, although Graffham would have made them available through the intricacy of exchange. Some specimens were recovered from Cannon Falls, Minnesota, in November, 1972, after the annual Geological Society meeting in Minneapolis, by a field party consisting of W. M. Furnish, Stan Zawistowski, my wife and me. A rare carpoid, *Scalenocystites strimplei* Kolata, 1973, was subsequently described by Kolata, while a Ph.D. candidate at the University of Illinois, from the Cannon Falls locality.

Dennis Kolata started as an amateur collector while a boy in Rockford, Illinois, and his interest in echinoderms of the Ordovician climaxed with a magnificent study of specimens from Illinois as part of a Ph.D. dissertation. The study is presently in press as a memoir of the *Journal of Paleontology*; Kolata is now a staff member of the Illinois Geological Survey and will be a contributor and principal investigator in many of the current studies.

Robert Wood, a master's candidate at The University of Iowa, recently contributed some excellent pleurocystitids (*Amecystis*) from the Decorah Formation, St. Paul, Minnesota, which will constitute a separate study by Broadhead and Strimple. Tom Broadhead, a doctoral candidate at The University of Iowa, will be principal investigator of the pleurocystitids from Iowa and Minnesota in the current studies.

The studies will thus be a compendium utilizing material housed through the years in museums, and material collected by amateur collectors, advanced collectors, semi-professional collectors, professional collectors, students, professors, private expeditions and University expeditions, as well as material acquired from a reputable fossil company.

Due to the recent tremendous increases in prices of publishing supplies and charges, it will not be possible to produce these studies under one cover, and so it has been elected to make natural groupings and publish whenever and wherever possible. At this stage there has been absolutely no financial support for any part of the project other than that afforded by the normal employment of the parties involved.

LITERATURE CITED

FOERSTE, A. F. 1924. New echinoderms from the Maquoketa beds of Fayette County, Iowa, Part II. *Iowa Geol. Surv.* 29:345-382.

KOLATA, D. R. 1973. *Scalenocystites strimplei*, a new Ordovician belemnocystid solute from Minnesota. *Jour. Paleontology* 47: 969-974.

LEVORSON, C. O., and GERK, A. J. 1972. A preliminary study of the Galena Group of Winneshiek County, Iowa. *Proc. Iowa Acad. Sci.* 79:111-122.

PAUL, C. R. C. 1967. The functional morphology and mode of life of the cystoid *Pleurocystites*, E. Billings, 1854. *Zool. Soc. London Symp.* 20:105-123.

SLOCOM, A. W. 1924. New echinoderms from the Maquoketa beds of Fayette County, Iowa, Part I. *Iowa Geol. Surv.* 29:320-344.

SPRINKLE, JAMES. 1974. New rhombiferan cystoids from the Middle Ordovician of Nevada. *Jour. Paleontology* 48:1174-1201.

STRIMPLE, H. L. 1948. *Pleurocystites watkinsi*, n. sp., from the Bromide Formation of Oklahoma. *Amer. Jour. Sci.* 246:760-764.

———. 1952. Two new species of *Sinclairocystites*. *Jour. Wash. Acad. Sci.* 42:168-169.

———. 1953a. A new species of *Archaeocrinus* from Oklahoma. *Jour. Paleontology* 27:604-606.

———. 1953b. A new carpoid from Oklahoma. *Jour. Wash. Acad. Sci.* 43:105-106.

———. 1963. Crinoids of the Hunton Group. *Okla. Geol. Surv. Bull.* 100:1-169.

———. 1972. A cinderella fossil. *Earth Science*, 25 (2), p. 79-80.

——— and GRAFFHAM, A. A. 1955. A new species of *Cyathocystis*. *Jour. Wash. Acad. Sci.* 45:353-355.

——— and LEVORSON, C. O. 1969. Catalogue of type specimens of the Belanski collection. *Bull. Amer. Paleo.* 56:259-271.

——— and ———. 1971. New flexible crinoids from the Upper Devonian of north-central Iowa. *Proc. Iowa Acad. Sci.* 78:9-11.

——— and ———. 1974. Additional crinoid specimens from the Shellrock Formation (Upper Devonian) of Iowa. *Proc. Iowa Acad. Sci.* 80:182-184.

——— and WATKINS, W. T. 1949. *Hybocrinus crinerensis*, new species from the Ordovician of Oklahoma. *Amer. Jour. Sci.* 247: 132-133.

——— and ———. 1955. New Ordovician echinoderms. *Jour. Wash. Acad. Sci.* 45:347-353.

THOMAS, A. O., and LADD, H. S. 1926. Additional cystoids and crinoids from the Maquoketa shale of Iowa. *Univ. Iowa Studies Nat. Hist.* 11:5-18.

Erisocrinids (Crinoidea-Inadunata) from Middle Pennsylvanian Rocks of Iowa and Colorado

H. L. STRIMPLE[1]

STRIMPLE, H. L. (Department of Geology, The University of Iowa, Iowa City, Iowa 52242). Erisocrinids (Crinoidea-Inadunata) from Middle Pennsylvanian rocks of Iowa and Colorado. *Proc. Iowa Acad. Sci.* 82(2): 126-129, 1975.
Erisocrinus knoxvillensis n. sp. is described from rocks of the Desmoinesian Stage exposed near Knoxville, Marion County, Iowa. Two specimens from the Madera Formation, Desmoinesian Stage, Heurfano Park, Colorado, reported by Tischler, 1963, as belonging to the genus *Erisocrinus* are described as *Exaetocrinus maderaensis* n. sp. and *Pontotocrinus coloradoensis* n. sp. The lectoholotype of *Erisocrinus typus* Meek & Worthen, type species of the genus, is illustrated.
INDEX DESCRIPTORS: Middle Pennsylvanian; Desmoinesian; Madera Formation; Madera County, Colorado; Marion County, Iowa; Crinoidea; Erisocrinidae; *Erisocrinus knoxvillensis; Exaetocrinus maderaensis, Pontotocrinus coloradoensis; Erisocrinus typus.*

The primary purpose of the present paper is documentation of a specimen of *Erisocrinus* found in Desmoinesian rocks near Knoxville, Marion County, Iowa, and mentioned by Knapp, 1969, in discussion of a proposed subfamily Erisocrininae, as well as to consider some related matters. The specimen in question is described as *Erisocrinus knoxvillensis,* n. sp. Subfamilial taxa have not been accepted in the section dealing with the Poteriocrinina, of which *Erisocrinus* is a member, in Section T of the *Treatise on Invertebrate Paleontology* (in preparation) but the remarks of Knapp (*ibid.,* p. 359) affect the family Erisocrinidae Miller, 1889, and are repeated here: "It is possible that *Erisocrinus* may have been derived from a crinoid bearing upflared infrabasals as figured by Tischler (1963, p. 1066, Text-fig. 6A, B) from the Madera Formation. However, recently a cup has been found in the Desmoinesian of Iowa, which is identical to *Erisocrinus* but has a distinct basal concavity." The import of this statement is that Knapp was postulating that the ancestor of *Erisocrinus,* and many other inadunate crinoid genera of Pennsylvanian age, was the Mississippian genus *Phanocrinus* which normally has a distinct basal concavity. In fact Knapp (*ibid.,* p. 351) proposed an order Declinida on this premise. I personally opposed the very concept of the order Declinida and it has been universally rejected.

Strimple and Moore (1971, p. 9) suggested the family Erisocrinidae represents a direct lineage leading from the geologically older family Scytalocrinidae, which is the current concept, and the principal was suggested as an alternative by Knapp. Erisocrinids having mildly upflared infrabasals were referred to *Exaetocrinus* Strimple and Watkins (1969, p. 181); however, those authors thought such forms were regressive because only species of Missourian (Upper Pennsylvanian) age were known at that time. The previously mentioned specimen from the Madera Formation was illustrated with rough line drawings by Tischler, 1963, as *Erisocrinus typus* and was not seriously considered by this writer until examined at first hand. The specimen is now described as *Exaetocrinus maderaensis,* n. sp.

Another specimen, identified by Tischler, 1963, as *Erisocrinus typus* from the Madera Formation, appears to be clearly related to *Paradelocrinus wapanucka* Strimple (1961b, p. 225), which species is from the Wapanucka Formation (Morrowan) of Pontotoc County, Oklahoma. Knapp (*ibid.,* p. 352) proposed the genus *Pontotocrinus,* with *P. wapanucka* as the type species, which was synonomized with *Erisocrinus* by Moore and Strimple (1973, p. 61). Although *Pontotocrinus* will not be accepted as a valid genus in the forthcoming Section T, Echinodermata, of the *Treatise on Invertebrate Paleontology,* this writer considers it to be a viable taxon. The specimen from the Madera Formation is described as *Pontotocrinus coloradoensis,* n. sp.

SYSTEMATIC PALEONTOLOGY

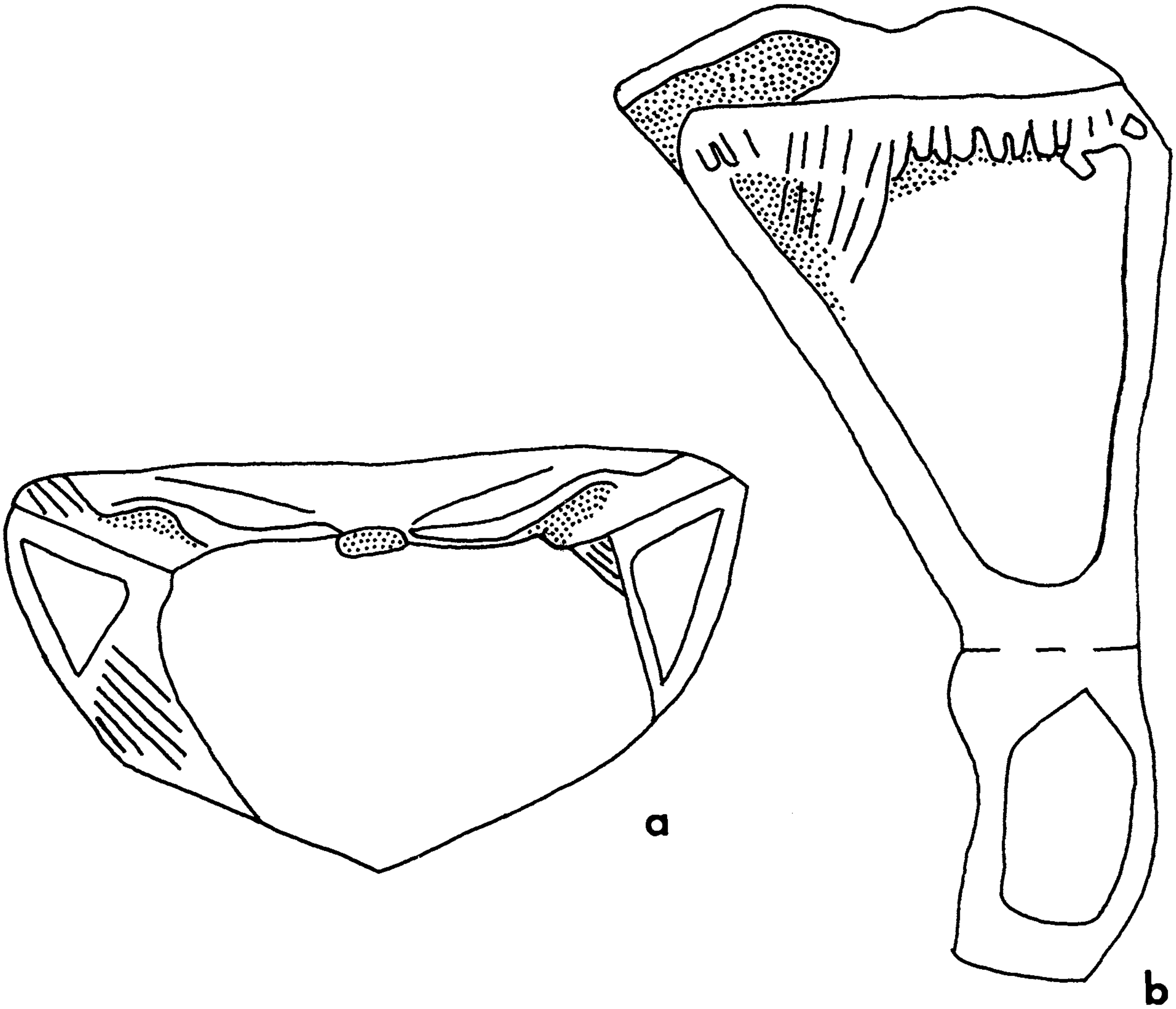
Subclass INADUNATA Wachsmuth and Springer, 1855
Order CLADIDA Moore and Laudon, 1943
Suborder POTERIOCRININA Jaekel, 1918
Superfamily ERISOCRINACEA Wachsmuth and Springer, 1886
Family ERISOCRINIDAE Wachsmuth and Springer, 1886
Genus ERISOCRINUS Meek and Worthen, 1865
ERISOCRINUS KNOXVILLENSIS Strimple, new species
Plate 1, Figures 9-11; Text-Figure 1.

Description—Cup truncate cone-shaped with pronounced basal concavity, regularly pentagonal-shaped when viewed from above or below. Infrabasals downflared and extending only slightly beyond columnar cicatrix. Proximal portions of moderately large basals form walls of basal concavity, flexing to form basal plane of cup and forming part of the lateral cup walls. Large radials form most of cup height but the proximal ends are well above the basal plane. Distal edges of radials are sharply defined. Articular facets are subhorizontal except where elevated to form a socket for the triangular-shaped rudimentary anal plate in the *CD* interray. The columnar cicatrix is slightly impressed and is circular in outline.

Measurements of holotype in millimeters: height of cup 6.0, width 4.1; width of columnar attachment scar 2.9; width of infrabasal circlet 4.3; width of *CD* (posterior) basal 5.0, length 4.7; width of *A* (anterior) radial 9.1, length 4.8; length of *D* radial articular facet at *DE* suture 3.6.

Discussion—*Erisocrinus typus* Meek and Worthen, 1865, is the type species of *Erisocrinus* Meek and Worthen (1865, p. 174); it was based on two syntypes from near Springfield, Illinois. Knapp (1969, p. 360, Text-Fig. 14b) designated the smaller undistorted specimen as the lectoholotype and illustrated it with a cross-section. The specimen is photographi-

[1] Department of Geology, The University of Iowa, Iowa City, Iowa 52242.



Text-Figure 1. Camera lucida sketches of cup plates of *Erisocrinus knoxvillensis,* n. sp. a. Radial plate from interior showing articular facet at top with stippled areas demonstrating slits passing from adsutural area into body cavity, X12. b. Radial plate, with basal plate below, from end showing depressed ligamental areas and fossae, as well as the previously mentioned slit passing under articular facet, X25.

cally illustrated here (Plate 1, Figs. 6, 8). Moore and Plummer (1940, p. 151) considered the horizon of the type of specimens to be lower Middle Pennsylvanian, which equates with Atokan or Lower Desmoinesian age. Knapp (*ibid.,* p. 360) considered it to be "basal Missourian?" in age, which seems more reasonable.

E. knoxvillensis differs from *E. typus* in having a more pronounced basal concavity; the columnar scar is proportionately larger; infrabasals do not extend beyond the cicatrix as far; and the distal ends of radials are further above the basal plane than found in *E. typus.* Most of the characteristics of *E. knoxvillensis* are closely similar to those of *E. georgeae* Strimple and Watkins (1969, p. 180) from the Soldiers Hole Member, Big Saline Formation, Atokan, of Mason County, Texas, with the exception of the basal concavity exhibited by the former species, and the proximal tips of the radial plates, which more closely approach the basal plane than in the latter species.

Holotype—SUI 32481, collected by W. Youngquist, reposited in the Geology Department Repository, The University of Iowa, Iowa City.

Occurrence—Unnamed limestone, Desmoinesian, Middle Pennsylvanian; SE¼ sec. 35, T.76N., R.20W., about three-fourths of a mile northwest of Knoxville, Marion County, Iowa.

The exact age represented by the limestone from which *E. knoxvillensis* was recovered is difficult to ascertain. Mikesh and Glenister (1966, p. 276, 277) in study of *Solenochilus springeri* from northeast of Knoxville concluded that strata in that area lay within the Cherokee Group, and almost certain-

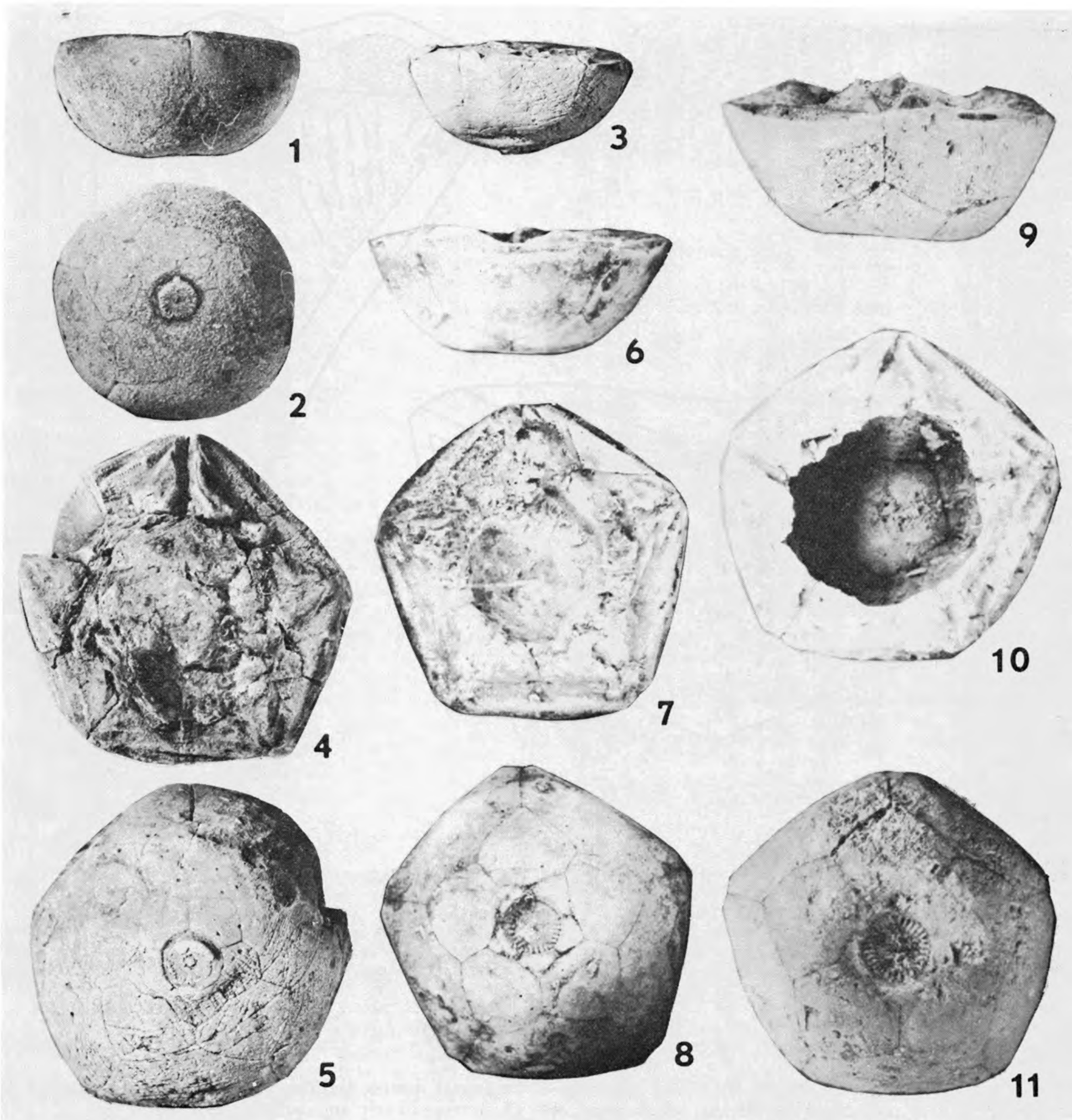


Plate 1. Erisocrinids from Iowa, Colorado and Missouri. 1, 2. *Pontotocrinus coloradoensis,* n. sp., holotype cup from Madera Formation, Colorado, viewed from *CD* interray (posterior) and from base, X3. 3-5. *Exaetocrinus maderaensis* n. sp., holotype cup from Madera Formation, Colorado, viewed from anterior (X2), summit and base, X3. 6-8. *Erisocrinus typus* Meek & Worthen, lectoholotype cup from Missourian Stage, Missouri, viewed from *CD* interray, summit and base, X3. 9-11. *Erisocrinus knoxvillensis,* n. sp. holotype cup from Desmoinesian Stage, Iowa, viewed from *CD* interray, summit and base, X3.

ly belonged in the Lower Cherokee. They further concluded that their fossiliferous horizon was probably Desmoinesian, but did not rule out the possibility of an Atokan assignment. A Lower Desmoinesian age is postulated for *E. knoxvillensis*.

Genus EXAETOCRINUS Strimple and Watkins, 1969

EXAETOCRINUS MADERAENSIS Strimple, new species

Plate 1, Figures 3-5.

Description—Cup bowl-shaped with slightly convex base. Five infrabasals extend well beyond the small columnar attachment area and are slightly upflared. Basals are large with gentle curvature. Radials are very large and are gently curved. The perimeter of the cup is sharply defined by the distal edges of radials when viewed from above and the outline is somewhat pentagonal, almost as pronounced as found in typical *Erisocrinus*. Interarticular notch for rudimentary anal plate is rather large and expands sharply as it approaches the body cavity.

Measurements of holotype in millimeters: maximum width of cup 17.7, height 8.7; width of infrabasal circlet 7.4, height 1.2; width of *AE* basal 5.7, length 4.6; width of *A* radial 9.8, length 6.0; diameter of proximal columnal (preserved in place) 2.5; length of interbasal suture of *A* ray 1.0, *B* ray 1.8.

Discussion—*Exaetocrinus* represents a holdover from the cone-shaped cup of ancestral *Scytalocrinus*. The cup has lost all anal plates and has changed to a low bowl shape as in *Erisocrinus* but the infrabasals have remained slightly upflared. *E. lustrum* (Strimple, 1951) from the Iola Formation, Kansas City Group, Missourian (Upper Pennsylvanian), exposed in the quarry of the Lehigh Cement Company just south of Iola, Kansas, has a taller cup with more evenly expanded sides than found in *E. maderaensis*.

It appears that *E. maderaensis* evolved directly from a species like *Stuartwellercrinus praedecta* Strimple, 1961a, from the Wapanucka Formation, Morrowan of Pontotoc County, Oklahoma. *S. praedecta* has a broad bowl-shaped cup, and large radial plates the proximal tips of which reach the basal plane; an anal plate is retained in the cup. The anal plate has lost contact with the *CD* (posterior) basal. *S. praedecta* is atypical of *Stuartwellercrinus* but is also atypical of *Exaetocrinus*, both of which genera typically have more cone-shaped cups. It seems possible that a divisionary lineage is represented by these two species with *E. lustrum* Strimple, 1951, a possible participant. However, all three species are monotypic so that no action is taken at this time.

Holotype—UMPL 37543, reposited Paleontology Museums, University of Michigan, Ann Arbor, Michigan.

Occurrence—Madera Formation, Desmoinesian, Lower Pennsylvanian; Heurfano Park, Colorado.

Genus PONTOTOCRINUS Knapp, 1969

PONTOTOCRINUS COLORADOENSIS Strimple, new species

Plate 1, Figures 1-2.

Description—Cup moderately low, bowl-shaped with circular outline when viewed from above or below, base planate except for sharply impressed columnar socket. Curvature of cup sides even and gentle. Infrabasals extend well beyond columnar impression. Basals large, extending into lateral walls of cup. Radials very large and long so that proximal tips are close to the basal plane. Round proximal columnal is preserved in place and is slightly smaller than the invaginated socket.

Measurements of holotype in millimeters: normal cup width 13.0; width in anteroposterior radius 12.8; cup height 6.6.

Discussion—The infrabasal circlet is not regularly distributed in that the *D* infrabasal is longer than other infrabasals.

Pontotocrinus coloradoensis differs from *P. wapanucka* in lacking even a slight basal concavity and in the irregularity of infrabasal plates.

Holotype—UMPL 37544, reposited Paleontology Museums, University of Michigan, Ann Arbor, Michigan.

Occurrence—Madera Formation, Desmoinesian, Middle Pennsylvanian; Heurfano Park, Colorado.

LITERATURE CITED

KNAPP, W. D. 1969. Declinida, a new order of late Paleozoic inadunate crinoids. *Jour. Paleontology* 43:340-391, pls. 61-62.

MEEK, F. B., and WORTHEN, A. H. 1865. Note in relation to a genus of crinoids *(Erisocrinus)* from the Coal Measures of Illinois and Nebraska. *Am. Jour. Sci.* ser. 2, 39:350.

MIKESH, D. L., and GLENISTER, B. F. 1966. *Solenochilus springeri* (White & St. John, 1868) from the Pennsylvanian of southern Iowa. *Proc. Iowa Acad. Sci.* 73:269-278, Text-Figure 1.

MOORE, R. C., and PLUMMER, F. B. 1940. Crinoids from the Upper Carboniferous and Permian strata in Texas. *Univ. Texas Pub.* 3945:9-468, 21 pls.

———, and STRIMPLE, H. L. 1973. Lower Pennsylvanian (Morrowan) crinoids from Arkansas, Oklahoma and Texas. *Univ. Kans. Paleo. Contr. Article* 60:84, 23 pls.

STRIMPLE, H. L. 1951. New species of crinoids from the Pennsylvanian of Kansas. *Jour. Paleontology* 25:372-376.

———. 1961a. New species of *Bronaughocrinus* and *Stuartwellercrinus* from the Carboniferous of Oklahoma. *Okla. Geol. Surv. Okla. Geol. Notes* 21:186-189, 1 pl.

———. 1961b. New *Paradelocrinus* from Oklahoma. *Okla. Geol. Surv. Okla. Geol. Notes* 21:225-229, 1 pl.

———, and MOORE, R. C. 1971. Crinoids of the LaSalle Limestone (Pennsylvanian) of Illinois. *Univ. Kans. Paleo. Contr. Article* 55:48, 28 pls.

———, and WATKINS, W. T. 1969. Carboniferous crinoids of Texas with stratigraphic implications. *Palaeontographica Americana* 40:142-275, pls. 30-56.

TISCHLER, H. 1963. Fossils, faunal zonation, and depositional environment of the Madera Formation, Huerfano Park, Colorado. *Jour. Paleontology* 37:1054-1068, pls. 139-142.

Recurrent Community Patterns in Epeiric Seas: The Lower Silurian of Eastern Iowa

MARKES E. JOHNSON[1]

JOHNSON, MARKES E. (Department of the Geophysical Sciences, University of Chicago, Chicago, Illinois 60637). Recurrent Community Patterns in Epeiric Seas: The Lower Silurian of Eastern Iowa. *Proc. Iowa Acad. Sci.* 82(2): 130-139, 1975.
In eastern Iowa, the Llandovery Series (Lower Silurian) consists of the Edgewood and Kankakee formations as well as much of the Hopkinton Dolomite. Outcrops of these rocks provide fossil assemblages of marine benthic invertebrates well suited for reconstructing epeiric sea communities. Results of preliminary field studies in Dubuque, Jackson, Jones, and Delaware counties indicate that an initial *Lingula* Community at the base of the section is succeeded by recurrent patterns of Coral, Pentamerid, and Stricklandid communities. The patterns are interpreted as community response to fluctuations in sea level, estimated to vary between a few and 60 m. At least two repetitions of deepening to shallowing seas are represented, possibly linked to eustatic causes. The orderly sequence of communities, symmetric with respect to reversals in changing water depth, suggests that the local geologic record is reasonably complete. Beds of the Hopkinton Dolomite previously unrecognized as distinct units are described and the first occurrences of the brachiopods, *Cyrtia* and *Ferganella*, from the Lower Silurian of Iowa are reported.
INDEX DESCRIPTORS: Community Patterns; Sea Level Fluctuations; Silurian, Llandovery Series, of Iowa.

During the early part of the Silurian Period, epeiric seas submerged extensive regions of the Canadian, Baltic, and Siberian continental shields. Widespread, generally transgressive conditions may have been caused by eustatic fluctuations in sea level linked to the melting of late Ordovician and early Silurian glaciers (Berry and Boucot, 1972, 1973a and 1973b). Fossil assemblages representing depth-associated communities of marine benthic invertebrates provide a means for the detection and relative measurement of ancient sea level fluctuations. A synchronous change in communities over great distances suggests fluctuations on a global scale, whether due to climatic events or other causes. Conversely, restricted instances of change in communities may reflect regional fluctuations due to localized diastrophic causes.

This paper reports on preliminary field studies of the Llandovery Series (Lower Silurian) in eastern Iowa, and is intended to demonstrate the suitability of the contituent fossil assemblages for community reconstruction. Preservation of recurrent community patterns is interpreted as a local record of depth changes in the epeiric seas which had inundated the North American craton. Correlation with community successions recorded in other areas is discussed and, as a topic of more detailed study, may indicate the extent and nature of sea level fluctuations which occurred during early Silurian times.

COMMUNITY APPROACH

Whittaker (1970) defines a community as a system of organisms living together and linked together by their effects on one another and their shared responses to the environment. The benthic communities reconstructed by Ziegler (1965) from the Llandovery Series of Wales and the Welsh Borderland include *Lingula, Eocoelia,* Pentamerid, Stricklandid, and *Clorinda* communities, listed in order of increasing distance from shore. Different lines of evidence indicate that these communities are depth-associated. When plotted on paleogeographic maps, the communities occur in bands parallel to the ancient shoreline. Especially convincing are localized instances of submarine volcanic flows. When they buried deeper water communities, the flows prepared the way for subsequent colonization of shallower water communities by reducing the height of the water column. Although the community name is derived from the most characteristic member, Ziegler, Cocks, and Bambach (1968) quantitatively defined the communities on the basis of entire, distinctive faunas. Some members are restricted to a single community, while others have a broader environmental tolerance and occur in several communities.

Since the initial work on Llandovery communities, others from regions including the East Baltic states, New York State, and Nevada have been studied in detail, as reviewed by Ziegler and Sheehan (1974). Each of these areas was situated near a continental margin where the slope of the sea floor was sufficient to accommodate several different communities contemporaneously. Those communities near land (Wales, New York) received an influx of clastic sediments. A zoogeographic survey of North America for the Llandovery Epoch (Ziegler and Boucot, 1970) shows that Iowan communities were located in the remote center of the submerged craton, 1,300 to 1,400 km from the nearest shelf margin. The depositional environment in which these communities lived consisted of carbonate sediments, almost to the exclusion of clastic sediments. Development of a platform-like sea bottom over eastern Iowa apparently supported only a single ubiquitous community at a time. Contemporaneous facies, if present, existed in such widely spaced belts as not to be obvious in this particular region. The result was to make shifts in community regime a contingency of fluctuating sea level. Iowan reconstructions include *Lingula,* Coral, Pentamerid, and Stricklandid communities. With few exceptions, the platform communities are similar in faunal composition to counterparts established for continental margin areas. The conformity may provide the opportunity to relate carbonate lithologies to communities previously known mostly in the context of clastic sediments.

The terminology applied to Welsh communities by Ziegler (1965) was permitted to correspond with the nomenclature of chronological genera. Thus the *Stricklandia* Community

[1] Department of the Geophysical Sciences, University of Chicago, Chicago, Illinois 60637.

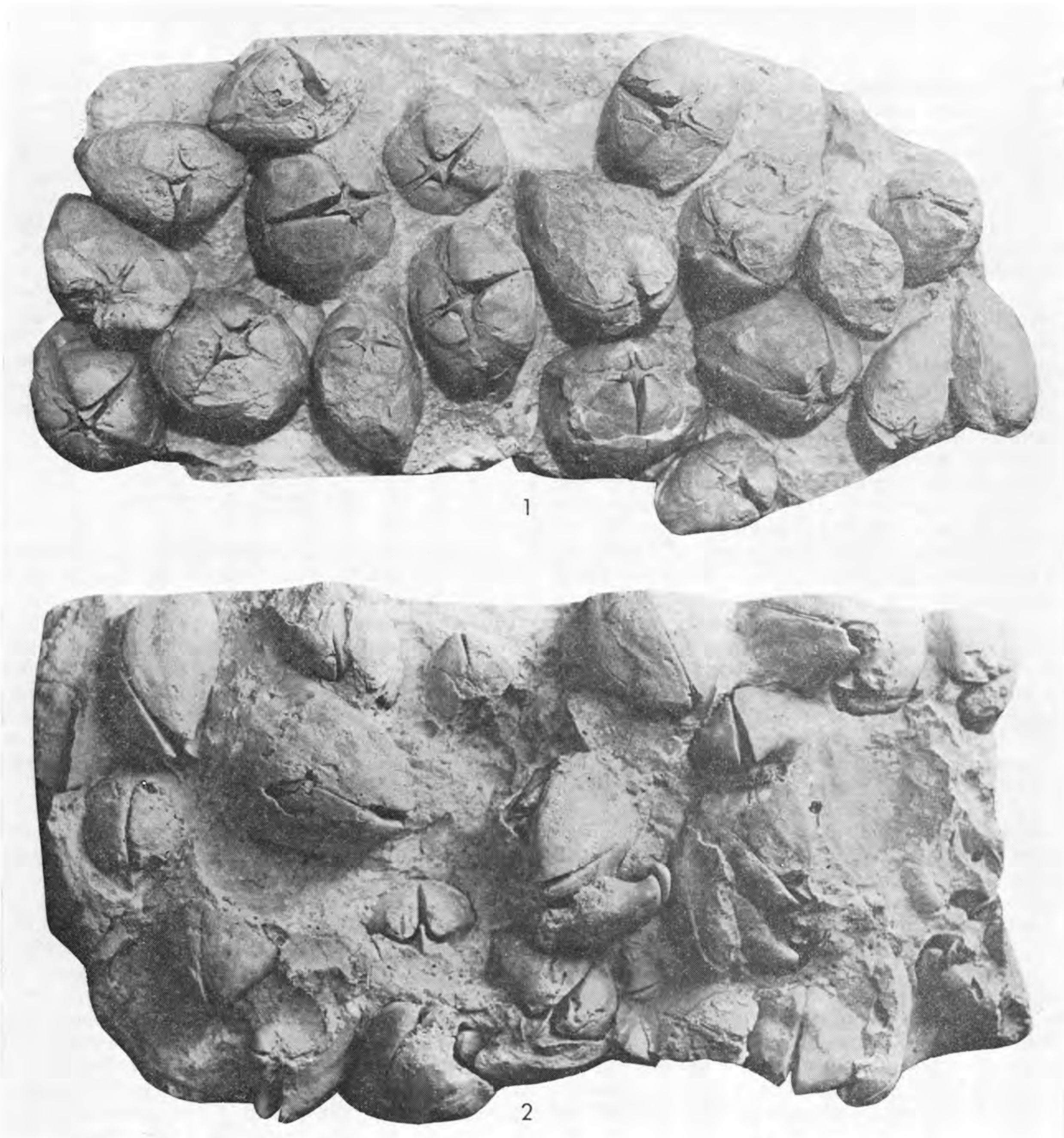


Plate 1. Figures 1, 2. Basal view of contrasting bedding planes from the *Pentamerus* Beds of the Hopkinton Dolomite. 1. Articulated valves (internal molds) of *Pentamerus oblongus* (Sowerby) preserved in life position. 2. Scattered valves (internal molds) of the same species disarticulated after death. The blocks were collected at the B. L. Anderson Maquoketa Quarry located 1.5 km north of Maquoketa in Jackson County (NE¼ NE¼ Sec. 13, T84N, R2E) from horizons 20 cm and 60 cm, respectively, above the base of the *Pentamerus* Beds. Both figures, ½X.

has as a successor the *Costistricklandia* Community, although community composition remains virtually unchanged. Comparable genera in North America are known as *Microcardinalia* and *Plicostricklandia* (Boucot and Ehlers, 1963). In this paper terminology will be restricted to avoid proliferation of community names. The term Stricklandid Community will be applied to assemblages in which any form of stricklandid brachiopod is a common element. Likewise, the term Pentamerid Community will be used for assemblages in which any form of pentamerid brachiopod is a predominant element.

RECONSTRUCTING IOWAN COMMUNITIES

Current usage by the Iowa Geological Survey designates the Edgewood, Kankakee, Hopkinton, and Gower formations as the primary rock stratigraphic units of Silurian age in Iowa. The Llandovery Series is considered to include the first two of these as well as most of the Hopkinton Dolomite. During the summer of 1974, rocks of this series were studied in an outcrop area extending across much of Dubuque, Jackson, Jones, and Delaware counties in eastern Iowa. Interpretation of temporal events as represented by the strata of this region depends critically on the recognition of benthic communities. Johnson (1964) lists three categories of evidence for the identification of ancient communities: (1) field evidence of burial *in situ*, (2) taxonomic analogy with a modern community, and (3) recognition of recurring suites of species analogous to the recurrence observed among modern communities.

Life orientations, particularly those of pentamerid and stricklandid brachiopods, can frequently be observed in vertical cross-section at the outcrops. The undersides of two contrasting bedding planes from the *Pentamerus* Beds of the Hopkinton Dolomite are illustrated in Plate 1. The first slab (Figure 1) shows 19 articulated specimens of *Pentamerus oblongus* preserved in life position. The second slab (Figure 2) shows an accumulation of scattered but relatively unfragmented valves of the same species. Such occurrences are not limited to any specific horizon in the *Pentamerus* Beds. Even immature, oriented specimens, numbering about 50 per square decimeter, are sometimes preserved in a growth stage moderately advanced beyond their spat fall. The stricklandid brachiopod, *Microcardinalia*, also occurs in life position at a particular horizon in the *Pentamerus* Beds. Oriented specimens of *Pentameroides subrectus* can often be observed in the younger *Pentameroides* Beds of the same formation.

The preservation of brachiopods in life position has been documented by Ziegler, Boucot, and Sheldon (1966), who cite occurrences of pentamerid brachiopods from Alabama and stricklandid brachiopods from Scotland. Rudwick (1970, p. 89) develops the explanation that the characteristic orientation is the result of weight stabilization due to differential thickening of the shell in the umbo region. An analogy is drawn to a weighted toy figure which, when displaced, automatically rights itself. For brachiopods such as *Pentamerus*, coping with ontogenetic atrophy of the pedicle, weight stabilization may have been the remedy to the problem of orientation. It should be pointed out, however, that the same orientation could have been arrived at as a function of efficient packing. Thus, surrounding neighbors would help prop up a brachiopod on its umbo simply to achieve utilization of maximum space available to the colony. Orientation by such a method seems a more natural event for immature individuals still possessing functional pedicles.

Despite the thorough dolomitization of the strata in Iowa, internal molds of the Lower Silurian organisms are commonly preserved in fine detail. Even in beds where life orientations are not readily apparent, the faunal associations show few signs of post-mortem disassociation and fragmentation of shells. Among brachiopods of this age, tooth and socket hinges were not well developed for articulation of the valves. The muscle systems were the primary agents for holding the valves together. Unlike the tough resilium of pelecypods, disintegration of the brachiopod tissues after death permitted rapid disarticulation of the shells. Since the ratio of articulated to disarticulated shells is usually quite high at a given horizon, burial must have been swift.

Faunal associations are found to be recurrent, especially in the Hopkinton Dolomite. Stratigraphic control is by reference to phyletic modifications in stricklandid brachiopods. The brachiopods occur at several horizons in the Hopkinton Dolomite, and include forms of *Microcardinalia* sp., *Plicostricklandia castellana*, and *P. multilirata*. Differences most readily observable in hand specimens involve a progressive increase in number of plications, beginning from a smooth shell, and a progressive enlargement of the adductor muscle scar. Berry and Boucot (1970, p. 163) date Iowan occurrences as C_1-C_5, C_6, and Wenlock, respectively. On this basis, deposition of the Hopkinton Dolomite is considered to have spanned the late Llandovery Epoch and continued into the Wenlock Epoch. Evidence of *in situ* burial coupled with the recurrent nature of faunal associations permits reconstruction of communities, as far as members with preservable hard parts are concerned.

HISTORICAL PERSPECTIVE

A gap of 75 years has elapsed since a comprehensive program of research has focused on the stratigraphic paleontology of the area in which the Llandovery Series outcrops in Iowa. The region was first geologically surveyed by D. D. Owen (1840 and 1844), later scrutinized by James Hall and J. D. Whitney (1858), and during the late 1800's and early 1900's drew the attention of several investigators, none as devoted as Samuel Calvin (1896; 1898; Calvin and Bain, 1900; and 1906). Hinman (1968, p. 8) provides a detailed summary of the historical development of Silurian nomenclature in Iowa.

From descriptions and plates in Owen's report of 1844, there can be no doubt that he observed the Chert Beds of the Kankakee Formation and the *Syringopora*, *Pentamerus*, and *Cyclocrinites* Beds of the Hopkinton Dolomite (see Figure 1). These he called the Coralline Beds of the Magnesian Cliff Limestone, properly correlating them with the British Silurian of Murchison (1839). Hall and Whitney (1858), followed by White (1870), did little to subdivide the Silurian of Iowa. For the most part it was simply referred to as the Niagaran limestone strata. By the turn of the century, numerous quarry operations across the Silurian cuesta had been opened for dimension stone and to supply lime kilns. These artificial exposures greatly facilitated expanded study, and A. G. Wilson (1895) became the first to attempt a subdivision of the older Niagaran strata. The system devised by Calvin was developed in its greatest detail for the report on the geology of Dubuque County (co-authored with Bain, 1900, p. 445). His scheme, shown in Figure 1, had Transition Beds of the Maquoketa Shale (now recognized as the lower Edgewood Formation) succeeded by the Basal Beds, Lower Quarry Beds, Chert Beds, *Syringopora* Beds, *Pentamerus* Beds, *Cerionites* (= *Cyclocrinites*) Beds, and finally the Upper Quarry Beds. The entire sequence came to be called the Hopkinton Limestone after the town by that name in Delaware County (Calvin, 1906). The divisions are clearly discernible today, although the stratigraphy is flawed by an error in correlation. Calvin equated the occurrence of *Pentamerus oblongus* from his *Pentamerus* Beds with that of *Pentameroides subrectus* from younger strata. A significant difference between the two genera is that the plates of the brachial valve

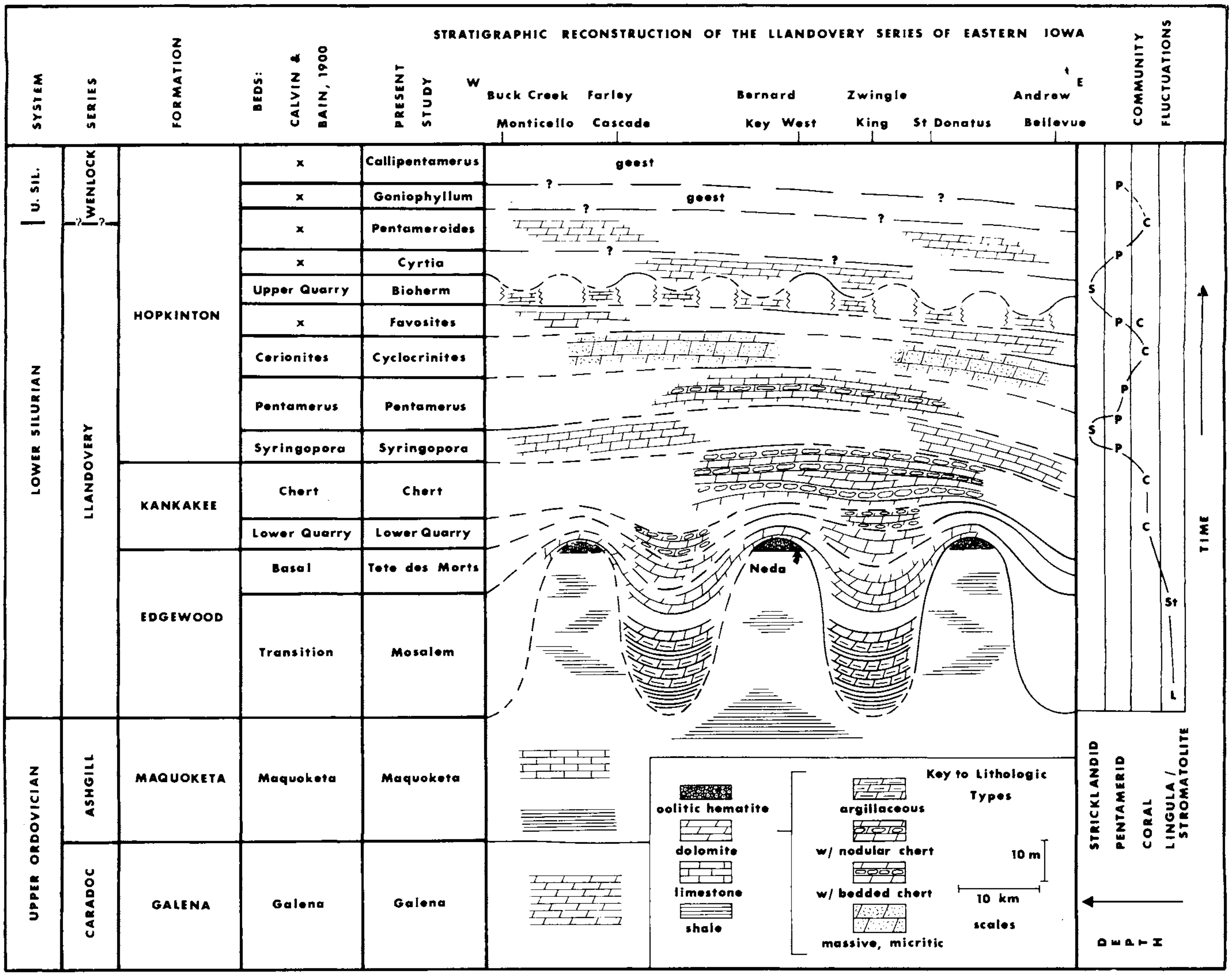


Figure 1. Stratigraphic reconstruction of the Llandovery Series in eastern Iowa, depicting a broad, east-west trending profile across the Silurian escarpment and cuesta. Outcrop evidence for rock stratigraphic contacts is indicated by solid lines. Short dashed lines represent a confident extension of known relationships. Conjectured contacts are shown by long dashed lines.

in *Pentamerus* remain distinct, but fuse in *Pentameroides* (Plate 2, Figures 6 and 7 respectively). Calvin's judgment may have been influenced by the original description of Hall (1894, p. 238) making the later genus a variety of the species *Pentamerus oblongus*. Regardless, the error caused Calvin to exclude several distinctive beds from his stratigraphy. He was perplexed that faunas succeeding what he thought to be the same *Pentamerus* Beds at localities not far separated were so different. This factor Calvin attributed to the inconstancy of life on the Silurian sea bottom.

Later workers revised some of the nomenclature applied by Calvin. Scobey (1935) extended recognition of the Edgewood and Kankakee formations from Illinois to Iowa, thereby restricting the Hopkinton Dolomite to the interval from the base of the *Syringopora* Beds to the base of the Gower Formation. Brown and Whitlow (1960), in mapping the rocks of the Dubuque South Quadrangle, subdivided the Edgewood Formation into a lower Mosalem Member and upper Tete des Morts Member. They found that the Edgewood Formation varies greatly in thickness from locality to locality, as regulated by the underlying Maquoketa Shale. Where the Edgewood Formation is thick, the Maquoketa Shale below is thin, and the converse. Cause of the relationship was determined to be an erosional surface carved into the Ordovician Maquoketa Shale, creating shale hills subsequently filled in by deposition of the Silurian Edgewood Formation. Highly consistent data from the subsurface of Iowa (Agnew, 1955, Figures 4 and 5) show oolitic hematite of the Neda Iron Ore to be capping summits of the shale hills. The iron ore has been assigned to the Maquoketa Shale as the Neda Member on the basis of Ordovician fossils cited by Savage and C. S. Ross (1906, p. 191). Although the description states that the fossils show few signs of abrasion, the possibility exists that the oolites were precipitated as a consequence of shoaling action during earliest Silurian times.

Many authors have studied individual taxa from the rich faunas of the Hopkinton Dolomite, particularly during the last decade. Unique occurrences from selected beds have never been placed within a stratigraphic framework tight enough to enable full comparison with other events which took place during the deposition of the Hopkinton Dolomite. The establishment of such a framework for the whole of the Llandovery Series as represented in eastern Iowa is prerequisite to the interpretation of environmental changes spanning the epoch.

INTERPRETATION OF STRATIGRAPHIC SECTIONS

The stratigraphic reconstruction drawn in Figure 1 depicts a broad profile trending westward from the Mississippi River Valley across the Silurian escarpment and cuesta of Iowa. Although no single locality provides a continuous section incorporating each of the units involved, several different localities expose overlapping sequences. A total of more than 40 outcrop sections examined in Dubuque, Jackson, Jones, and Delaware counties add to the framework upon which interpretation is based.

Edgewood Formation

Mosalem Member and Tete des Morts Member

Age: C. A. Ross (1964) states that diplograptid graptolites from the base of the Edgewood Formation in Iowa are similar to those in Illinois, which Berry and Boucot (1970, p. 145) consider indicative of an early Llandovery age within zones 16-19 of the British graptolite succession.

Lithologies: At localities of varying extremes in thickness, the wavy, thin-bedded, argillaceous dolomite of the lower Mosalem Member can be readily distinguished from the medium grained, massive bedded, vuggy dolomite of the Tete des Morts Member.

Faunas: Diplograptid graptolites occur near the base of the Mosalem Member at a locality where the section is thick. At about this horizon, lingulid and rhynchonellid brachiopods also occur. Stromatolites can be observed near the base of the section, at a locality where the Mosalem Member is very thin. The fauna of the Tete des Morts Member consists predominantly of favositid corals.

Communities: The Mosalem Member contains a fauna suggestive of a *Lingula* Community, while the Tete des Morts Member contains remnants of a Coral Community.

Interpretation: Erosion of the Maquoketa Shale before the close of the Ordovician Period resulted in the development of regional relief. This event may have been induced by the glaciation of the large land mass, Gondwanaland, a portion of which included parts of present day Africa and South America. Resumption of marine conditions during the deposition of the Edgewood Formation led to the drowning of topographic relief. The argillaceous nature of the dolomite in the lower part of the Mosalem Member can be attributed directly to erosion of the shale hills. As the valleys were filled in, the supply of clastic sediments decreased. Replacement of the *Lingula* Community by stromatolites and a Coral Community may have been brought about by a rise in sea level or perhaps nothing more than elimination of the clastic sediment source.

Reference: Thick sections of both members of the Edgewood Formation, bracketed by the Maquoketa Shale below and the Kankakee Formation above, can be observed at the Bellevue State Park in Jackson County (NE¼ NW¼ Sec. 19, T88N, R5E). There the total thickness is about 33 m, with lingulid and rhynchonellid brachiopods first appearing about 3 m above the base of the Mosalem Member. Much thinner sections of both members, totaling 3.75 m, occur at the road cut near the interchange of U.S. highways 151 and 61 in Dubuque County (NW¼ NW¼ Sec. 23, T88N, R2E). There a stromatolite horizon at the base of the Mosalem Member is 35 cm thick.

Kankakee Formation

Lower Quarry Beds and Chert Beds

Age: If there is no evidence of an unconformity at either contact, as previous workers claim (Brown and Whitlow, 1960, p. 40; Scobey, 1938, pp. 215-216), then stratigraphic position above the Edgewood Formation and below the Hopkinton Dolomite suggests a middle Llandovery age for the Kankakee Formation.

Lithologies: The Lower Quarry Beds are distinguished by fine grained, evenly stratified dolomite with nodular chert in the upper part. Succeeding the Lower Quarry Beds, the more conspicuous Chert Beds consist of layered, porcelaneous chert interbedded with dense, fine grained dolomite.

Faunas: Trilobites, cup corals, and orthid brachiopods have been observed from the Lower Quarry Beds. The alternating lithologies of the Chert Beds, however, seem to yield different faunas. The dolomite layers contain silicified *Favosites,* while the chert layers contain gastropods, cup corals, and possibly cryptothyrellid brachiopods.

Community: For the most part, the faunas of the Kankakee Formation suggest variations of a Coral Community.

Interpretation: It is not certain to what degree the two faunas of the Chert Beds are mutually exclusive, but the pattern of secondary cherts might be explained as penecontemporaneous replacement selective for a particular kind of shell deposit.

Reference: Bracketed by the Edgewood Formation below and the Hopkinton Dolomite above, an exposure totaling 16 m occurs at the road cut on U.S. Highway 52 near King in Dubuque County (NW¼ SE¼ Sec. 27, T88N, R3E). The Lower Quarry Beds account for only about 3 m of the basal section. Contact of the Kankakee Formation with the overlying Hopkinton Dolomite is marked by a 5 cm thick shale layer about 0.5 m above the uppermost chert layer.

Hopkinton Dolomite

Syringopora Beds

Age: Deposition of the *Syringopora* Beds probably took place at the beginning of late Llandovery time. Willman (1973, p. 37) reports the stricklandid brachiopod, *Microcardinalia,* from a rock unit in northwestern Illinois which he considers equivalent to the *Syringopora* Beds.

Lithology: The strata are formed of massive bedded, somewhat vuggy dolomite with shale partings.

Fauna: The fauna is decidedly coral dominated, notably by *Syringopora tenella, Halysites catenulatus,* and *Favosites favosus.*

Community: There can be no doubt that the fauna represents a distinct Coral Community.

Interpretation: By this time, the sea bottom had become platform-like with little trace of topographic relief. Seas remained very shallow.

Reference: A full representation of the *Syringopora* Beds, succeeding the Kankakee Formation and preceding the *Pentam-*

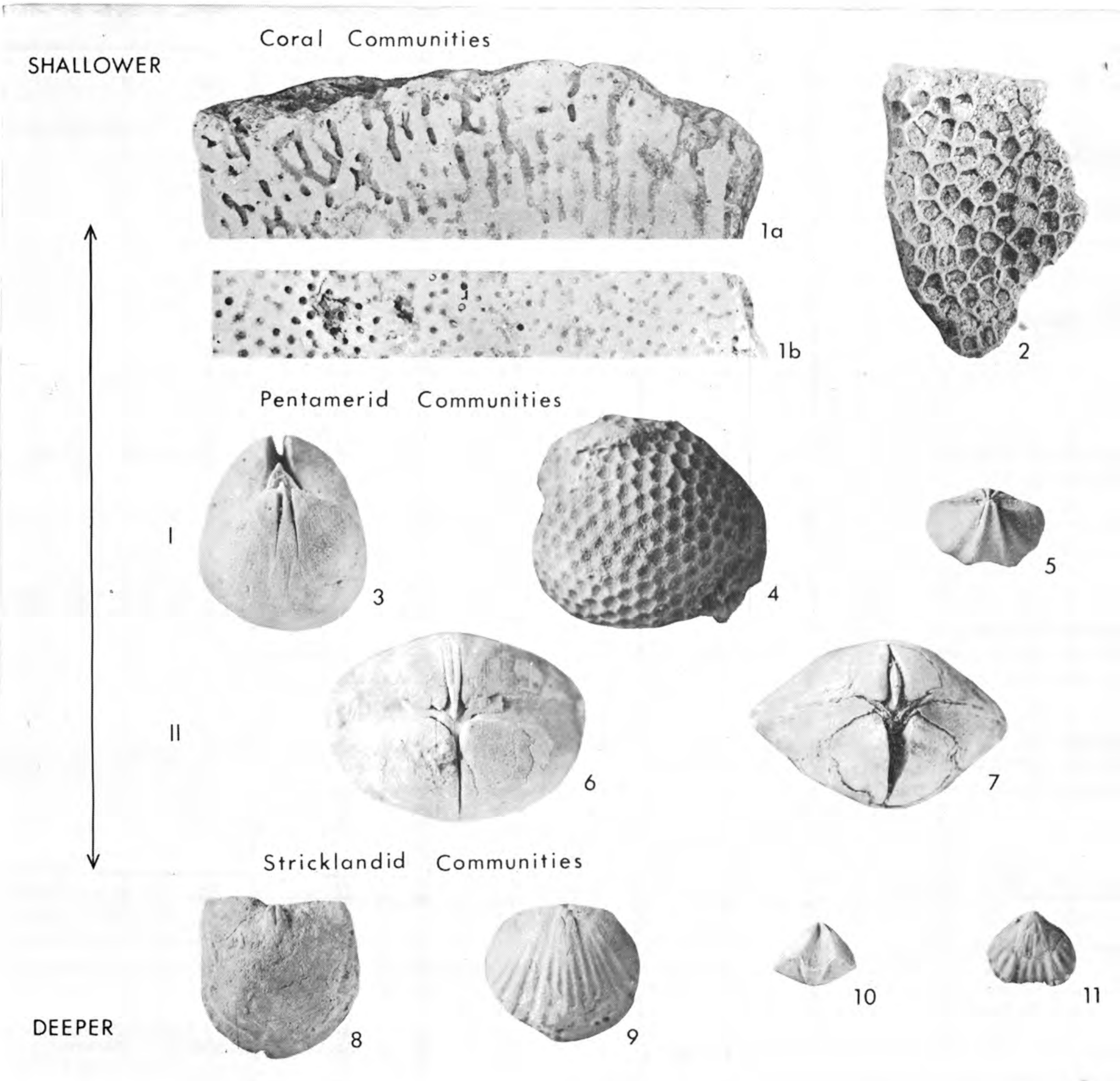


Plate 2. Some diagnostic community elements from the Hopkinton Dolomite. Figures 1, 2. From the *Favosites* Beds. la. Lateral view of *Syringopora* sp. lb. Basal view of the same. 2. *Favosites favosus* (Goldfuss). Figures 3-5. From the *Cyclocrinites* Beds. 3. Brachial view of "*Pentamerus oblongus* var. *maquoketa*" Hall and Clarke. 4. *Cyclocrinites dactioloides* (Owen). 5. *Howellella crispa* (Hissinger). Figure 6. From the *Pentamerus* Beds, *Pentamerus oblongus* (Sowerby). Figure 7. From the *Pentameroides* Beds, *Pentameroides subrectus* (Hall and Clarke). Figure 8. From the *Pentamerus* Beds, brachial view of *Microcardinalia* sp. Figures 9-11. From the *Cyrtia* Beds. 9. Brachial valve of *Plicostricklandia castellana* (White). 10. *Cyrtia exporrecta* (Wahlenberg). 11. *Ferganella* sp. All figures 1X.

erus Beds, can be seen in the road cut on U.S. Highway 151 just north of the Dubuque Municipal Airport in Dubuque County (N½ Sec. 22, T88N, R2E). Total thickness is 9.75 m. The corals are usually replaced by silica. Scattered occurrences of *Microcardinalia* sp. can be found in a zone from 4.5 to 7.75 m above the base of the *Syringopora* Beds.

Pentamerus Beds

Age: Microcardinalia sp., at a horizon in the upper part of the *Pentamerus* Beds, is restricted to a C_1-C_5 date reference but probably represents only the earlier part of the late Llandovery Epoch.

Lithology: The strata are formed of medium bedded dolomite with a cherty zone toward the middle of the section.

Faunas: Beds are crowded by the internal molds of *Pentamerus oblongus* (Plate 2, Figure 6), frequently preserved in life position. Occasionally the brachiopods are associated with such corals as *Halysites catenulatus, Favosites favosus, Cannopora annulata,* and *Heliolites interstinctus.* At the top of the *Pentamerus* Beds, the stricklandid brachiopod, *Microcardinalia* sp. (Plate 2, Figure 8), is predominant.

Communities: Two different communities are indicated, a Pentamerid Community and a Stricklandid Community.

Interpretation: The distinctive, *in situ* faunas of the *Pentamerus* Beds, following that of the *Syringopora* Beds, represent a succession of Coral, Pentamerid, and Stricklandid communities. By analogy to the depth associated communities of sloping continental margins, the early deposition of the Hopkinton Dolomite recorded a central deepening of the water column on the craton. Because the *Microcardinalia* horizon is superseded by beds again containing Pentamerid brachiopods, the rise in sea level must have peaked at a depth compatible to the Stricklandid Community.

Reference: A complete 11.5 m section of the *Pentamerus* Beds, bracketed by the *Syringopora* Beds below and *Cyclocrinites* Beds above, is exposed in the Meloy Quarry 1.5 km north of Bernard on Dubuque County road Y-31 (SE¼ NE¼ Sec. 22, T87N, R1E). Toward the middle of the section, individual beds contain much chert, and from these layers weather delicately silicified specimens of corals and shelled *Pentamerus.* The horizon of *Microcardinalia* is 1.5 m thick, and caps the *Pentamerus* beds. At the locality near the Dubuque Airport, described previously, the lower part of the section can be readily examined. The upper reaches of the unit are most accessible at the Zwingle road cut on U.S. Highway 61 near the intersection with Iowa Highway 246 in Dubuque County (SW¼ SW¼ Sec. 36, T87N, R2E).

Cyclocrinites Beds

Age: A different occurrence of *Microcardinalia* sp. is restricted to the same C_1-C_5 date reference, but because of superposition indicates a slightly younger age for the *Cyclocrinites* Beds.

Lithology: Micritic dolomite with a massive, unbedded appearance is characteristic of the *Cyclocrinites* Beds.

Fauna: Nitecki (1970, 1972) has determined that *Cyclocrinites dactioloides* (Plate 2, Figure 4) belongs to the family Dasycladacea of green algae. The distinctive brachiopod presently known as *"Pentamerus oblongus* var. *maquoketa"* (Plate 2, Figure 3) occurs abundantly in the *Cyclocrinites* Beds and is listed in Berry and Boucot (1970, p. 163) as a yet undescribed new genus and species, *Carmanella maquoketa.* Examples of the associated fauna include the genera *Straparollus, Platyceras, Murchisonia,* and other gastropods; *Ambonychia* and other pelecypods; *Hexameroceras, Kionoceras,* and other nautiloids; *Caryocrinites* and other echinoderms; and *Howellella* (Plate 2, Figure 5), *Platystrophia, Atrypa, Microcardinalia,* and other brachiopods.

Community: The assemblage is considered to represent a shallow Pentamerid Community on the basis of *Howellella,* often an element in the *Eocoelia* Community of continental margin areas, and the abundance of *"Pentamerus oblongus* var. *maquoketa."*

Interpretation: Lithologically the dolomite of the unit is micritic, presumably due to algal contribution to the sediment composition (Blatt, Middleton, and Murry, 1972, pp. 424-425). Massively bedded, the original layering was perhaps obscured by burrowing. The algae may have provided a rich food source for the large molluscan fauna. In the absence of the micritic lithology at other horizons in the Hopkinton Dolomite, the molluscan fauna is much depleted and bedding tends to be well preserved.

Reference: Delimited by the *Pentamerus* Beds below and *Favosites* Beds above, the complete section of the *Cyclocrinites* Beds totaling 9.5 m occurs in the Farmer's Lime Quarry located 3 km northeast of Monticello on U.S. Highway 151 in Jones County (NE¼ NE¼ Sec. 14, T86N, R3W).

Favosites Beds

Age: Stratigraphic position between horizons bearing occurrences of different stricklandid brachiopods dated C_1-C_5 and C_6, respectively, suggests a mid-late Llandovery age for the *Favosites* Beds.

Lithology: Both Calvin (1896, p. 71, p. 76) and Savage (1906, pp. 618-619) mentioned but failed to appreciate the lateral continuity of outcrops here designated as the *Favosites* Beds. The unit is composed of thick bedded, medium grained, vuggy dolomite.

Fauna: The fauna is dominated by corals, mostly *Favosites favosus* (Plate 2, Figure 2), although others such as *Syringopora* sp. (Plate 2, Figure 1) are represented.

Community: The fauna implies a Coral Community.

Interpretation: In succeeding the peculiar Pentamerid Community of the *Cyclocrinites* Beds, the repetition of a Coral Community indicates a resumption of shallower water conditions.

Reference: The 5.75 m thickness of the *Favosites* Beds, bracketed by the *Cyclocrinites* Beds below and Bioherm Beds above, is well exposed in the Martin Quarries 8 km northwest of Cascade on Iowa Highway 136 in Dubuque County (SE¼ NE¼ Sec. 16, T87N, R2W). In contrast to other coral beds, specimens are usually unsilicified.

Bioherm Beds

Age: Dated C_6, the presence of *Plicostricklandia castellana* in the interreef facies gives the Bioherm Beds an age approaching the close of late Llandovery time.

Lithology: Philcox (1970) documented the presence of coral bioherms in the Hopkinton Dolomite. Laterally time equivalent, the Upper Quarry Beds of Calvin are the interreef facies. The term Bioherm Beds is extended to include both phases. Lithologically the interreef facies consists of fine grained, regularly layered beds. According to Philcox, the bioherms include a core of unbedded, micritic dolomite, covered and flanked by coarse crinoidal debris.

Fauna: As Calvin noted (1898, p. 151), his Upper Quarry Beds sometimes yielded a variety of pentamerid brachiopod. The brachiopod is *Pentameroides. Plicostricklandia castellana* can be found as well. Springoperid corals appear to form a large component of the bioherms.

Communities: Although sparse, the fauna of the interreef facies indicates a Pentamerid Community. At the same time, the coral mounds described by Philcox represent a Coral Community. Syringoperid corals appear to form a large component of the bioherms.

Interpretation: As water depth started to increase following deposition of the *Favosites* Beds, coral mounds began to develop, keeping pace with the rising sea level. The habitat region between these mounds supported a deeper water Pentamerid Community.

Reference: Relationship of the coral bioherms of Philcox and the Upper Quarry Beds of Calvin is well demonstrated in the John Creek Quarry about 6.5 km south of Farley on Dubuque County road Y-13 (SE¼ SW¼ Sec. 36, T88N, R2W). Succeeding the *Favosites* Beds and preceding the *Cyrtia* Beds, the entire section of the interreef facies amounts to about 3 m. Comparable strata exposed in an abandoned quarry 2.5 km south of Fulton on U.S. Highway 61 in Jackson County (SW¼ SE¼ Sec. 25, T85N, R2E) yield specimens of *Pentameroides* and *Plicostricklandia* near the base.

Cyrtia Beds

Age: The occurrence of *Plicostricklandia castellana* from the *Cyrtia* Beds is also dated C_6, although superposition with respect to the Bioherm Beds indicates a slightly younger age, nearer the close of late Llandovery time.

Lithology: Recognized in part by Philcox (1970 p. 970), the strata of the *Cyrtia* Beds consist of fine grained dolomite, but are extremely fossiliferous, expecially in contrast with the underlying interreef facies of the Bioherm Beds.

Fauna: The fauna is dominated by brachiopods such as *Plicostricklandia castellana* (Plate 2, Figure 9), *Cyrtia exporrecta* (Plate 2, Figure 10), *Ferganella* sp. (Plate 2, Figure 11), *Eospirifer radiatus,* and *Leptaena rhomboidalis,* but also includes the calyxes of *Marsoupiocrinus* and other crinoids, as well as abundant bryozoans. Neither *Cyrtia* nor *Ferganella* has been reported previously from the Lower Silurian of Iowa. The unit is named the *Cyrtia* Beds because of the common occurrence and distinctive features of that brachiopod.

Community: Faunal composition of the *Cyrtia* Beds is marginal between a Stricklandid and *Clorinda* Community, but lacking the *Clorinda* element, is more like the former.

Interpretation: The deeper water Stricklandid Community marks a peak in the renewal of sea level rise.

Reference: As much as 5.75 m of the *Cyrtia* Beds rest above the Bioherm Beds at the John Creek Quarry.

Pentameroides Beds

Age: A late most Llandovery to Wenlock age may be assigned to *Plicostricklandia multilirata.* However, the occurrence of this brachiopod in the *Pentameroides* Beds, together with what appears to be a species of the coral *Porpites,* suggests that the age of the unit is restricted to the close of late Llandovery time.

Lithology: These are the beds which Calvin miscorrelated with the *Pentamerus* Beds, and properly should be called the *Pentameroides* Beds. The strata consist of fine grained dolomite, often cherty in places.

Fauna: Upper horizons are particularly crowded with the internal molds of *Pentameroides subrectus* (Plate 2, Figure 7), frequently preserved in life position. Much less abundant are specimens of *Plicostricklandia multilirata* and possibly the coral *Porpites.*

Community: The predominance of *Pentameroides* indicates a Pentamerid Community.

Interpretation: If the Pentamerid Community of the *Pentameroides* Beds directly succeeds the Stricklandid Community of the *Cyrtia* Beds, then a decrease in water depth surely took place.

Reference: Although a complete section bridging the *Cyrtia* Beds and the *Pentameroides* Beds has not yet been found, the latter are predicted to succeed the former. At Buck Creek in Delaware County (NE¼ NW¼ Sec. 20, T87N, R4W), a quarry exposes a 16.5 m section, the upper two-thirds of which become increasingly fossiliferous. A similar section amounting to 10 m can be found in the Hanken Quarry 2 km east of Iowa Highway 38, 5 km southeast of Monticello in Jones County (NW¼ NE¼ Sec. 6, T85N, R2W).

Goniophyllum "Beds"

The square coral *Goniophyllum pyramidale* is generally dated Wenlock in age, although an occurrence in Ireland cited by M'Coy (1846, p. 60) may be late Llandovery according to Ziegler, Rickards, and McKerrow (1974, pp. 64-65). In Iowa, *Goniophyllum* is associated with an extensive coral fauna, as reported by Calvin (1896, pp. 79-81). Presently no Iowa locality is known where rock strata may be examined, but in Jones County the silicified corals are recoverable from highly eroded deposits (geest) overlying the *Pentameroides* Beds. The abundance indicates a Coral Community. Environmentally, this reflects a resumption of shallow water conditions.

Callipentamerus "Beds"

From occurrences in subsurface strata of Nebraska, Carlson and Boucot (1967) date *Callipentamerus corrugatus* as very late Llandovery to early Wenlock in age. The distinctive pentamerid brachiopod was first reported by Weller and Davidson (1896) from highly eroded deposits in Jones County, and later redescribed by Boucot (1965). Calvin (1896, p. 73) mentions a locality in that county where a pentamerid variety was found in slumped strata above silicified corals and true *Pentameroides* Beds but the site has not been relocated. On the strength of the record, however, it is postulated that a *Callipentamerus* horizon exists above *Goniophyllum* and *Pentameroides* Beds. If so, the representation of a Pentamerid Community preceded by a Coral Community once again indicates a beginning rise in sea level.

SUMMARY AND CONCLUSION

Early to middle Llandovery deposition of the Edgewood and Kankakee Formations records a changeover from a *Lingula* Community to varying Coral Communities. Recurrent patterns of Coral, Pentamerid, and Stricklandid Communities indicate at least two repetitions of deepening to shallowing seas during the late Llandovery deposition of the Hopkinton Dolomite. In a sequence of deepening waters, a Coral Community is usually followed by a Pentamerid Community succeeded by a Stricklandid Community. The situation is always reversed under conditions of shallowing waters. An orderly sequence of communities, symmetric with respect to reversals in changing water depth, suggests that the regional geologic record in eastern Iowa is reasonably complete. Small breaks in the record, however, are not precluded. These are indicated by such features as planed *Pentamerus* shells with beak regions still in growth position, and the presence of stylolitic seams, or dissolution phenomena. Due to the gradation of community composition, stricklandid brachiopods of the Hopkinton Dolomite are common elements in some communities and minor ones in others. Phyletic development of this brachiopod provides a basis for framing successive depositional events in the perspective of time.

The platform communities now recognized in eastern Iowa may provide the opportunity to relate carbonate lithologies to communities previously associated mostly with continental margin, clastic sediments. Micritic dolomite characteristically occurs with the shallow Pentamerid Community of the *Cyclocrinites* Beds. A similar dense dolomite sometimes appears in various coral beds. Dolomites are more bio-clastic in composition, and generally occur with faunas of deeper water communities, such as the Stricklandid Community of the *Cyrtia* Beds. Difference in the lithologies stemming from shallow water deposition as opposed to deeper water deposition may be related, in part, to the depth range and other conditions under which certain algae best thrive.

Fluctuations in sea level recorded in the Lower Silurian of Iowa varied between depths compatible to Coral and Stricklandid Communities. The platform Coral Community is probably analogous to the continental margin *Eocoelia* Community. Substitution of one for the other may reflect the general preference of corals for carbonate environments remote from sources of clastic sediments. Lauritzen and Worsley (1974) estimate an upper depth limit for the Stricklandid Community, based on the association of *Girvanella* in Llandovery age rocks of Norway. *Girvanella* is thought to be a genus of blue-green algae belonging to the family Oscillatoriaceae. Modern forms of this family inhabit clear waters shallower than 60 m. If the Silurian platform and continental margin communities were restricted to similar depth ranges, then the sea level fluctuations on the North American craton most likely varied between a few and 60 m.

Glaciation, and in turn deglaciation, are two of the most powerful agencies capable of inducing global, or eustatic, fluctuations in sea level. Physical evidence indicates that during the last Pleistocene glaciation, sea level stood 130 m below the present level (Milliman and Emery, 1968). Traces of a late Ordovician glaciation are widespread across North Africa, and are suspected in South America (Berry and Boucot, 1973, 1972). A significant drop in sea level due to glaciation may account for local development of topographic relief in the Maquoketa Shale, and subsequent deglaciation may account for the resumption of marine conditions in the region. On a broader scale, Sheehan (1973) suggests that the same events might explain the disparity between late Ordovician and early Silurian brachiopod faunas in North America. Bennacef *et al.* (1971, p. 2241) report graptolitic shales of the Imirhou Formation (zone 18 or 19 of latest early Llandovery age) in the Algerian Sahara immediately above glacial outwash deposits of a type not prone to preservation if subjected to prolonged exposure. The implication is that deglaciation continued well into the beginning of the Silurian Period. At present, it is uncertain whether additional episodes of deglaciation played any role in causing sea level fluctuations of late Llandovery age. If other than regional factors were involved, it is expected that trends similar to those indicated by community patterns in the Hopkinton Dolomite should be detectable elsewhere in formations of the same age. Comparable strata in New York State (Ziegler *et al.*, 1971) and the Welsh Borderland (Ziegler, Cocks, and McKerrow, 1968) provide community and/or lithologic evidence for fluctuating sea levels. However, the Ross Brook Formation in Nova Scotia, also deposited throughout late Llandovery time, yields faunas belonging to only a single community, the *Eocoelia* Community (Boucot *et al.*, 1974, p. 43).

In conclusion, it is clear that the interpretation of ancient environments through time calls for a thorough, almost bed by bed, assimilation of paleontologic and lithologic data. The prerequisite is not an impossible one to satisfy in the midcontinent region of North America, where geological relationships are relatively uncomplicated. This paper reports only preliminary results from the study of Lower Silurian strata in eastern Iowa. A more comprehensive investigation is in progress with the expectation of clarifying the relationship of platform communities with carbonate lithologies, and establishing the correlation of environmental events between regions of Silurian epeiric and continental margin seas.

ACKNOWLEDGMENTS

To my adviser, A. M. Ziegler, University of Chicago; W. S. McKerrow, Oxford University; and W. M. Furnish, University of Iowa, I am grateful for patiently sharing field experience and providing encouragement. Correspondence with A. J. Boucot and J. G. Johnson, of Oregon State University, has been of benefit. For reviewing various formats of the paper, I am indebted to R. G. Johnson and T. J. M. Schopf, University of Chicago, and M. H. Nitecki, Field Museum of Natural History, although I alone assume responsibility for content. B. D. Rabe graciously took charge of photography. Special thanks are due to my wife, M. Riley Johnson, who assisted with field work, and to my father, C. O. Johnson, who has explored with me many of the localities here described. Work completed during the summer of 1974 was supported, in part, by an N.S.F. grant to A. M. Ziegler, complimented by an A.A.A.S. grant to the author from the Iowa Academy of Science.

LITERATURE CITED

AGNEW, A. F. 1955. Facies of Middle and Upper Ordovician Rocks of Iowa. *Amer. Assoc. Petrol. Geol. Bull.* 39:1703-1752.

BENNACEF, A., S. BEUF, B. BIJU-DIVAL, O. DE CHAPARAL, O. GARIEL, and P. RONGNON. 1971. Example of Cratonic Sedimentation: Lower Paleozoic of Algerian Sahara. *Amer. Assoc. Petrol. Geol. Bull.* 55:2225-2245.

BERRY, W. B. N., and A. J. BOUCOT, editors. 1970. Correlation of the North American Silurian Rocks. *Geol. Soc. Amer. Spec. Paper* 102, 1-289.

———. 1972. Correlation of the South American Silurian Rocks. *Geol. Soc. Amer. Spec. Paper* 133, 1-59.

———. 1973a. Glacio-Eustatic Control of Late Ordovician-Early Silurian Platform Sedimentation and Faunal Changes. *Geol. Soc. Amer. Bull.* 84:275-284.

———. 1973b. Correlation of the African Silurian Rocks. *Geol. Soc. Amer. Spec. Paper* 147, 1-83.

BLATT, H., G. MIDDLETON, and R. MURRY. 1972. *Origin of Sedimentary Rocks*. New Jersey: Prentice-Hall, Inc., 1-634.

BOUCOT, A. J. 1964. *Callipentamerus*, a New Genus of Brachiopod from the Silurian of Iowa. *Jour. Paleontology* 38:887-888.

———, J. F. DEWEY, D. L. DINELEY, R. FLETCHER, W. K. FYSON, J. G. GRIFFIN, C. F. HICKOX, W. S. MCKERROW, and A. M. ZIEGLER. 1974. Geology of the Arisaig Area, Antigonish County, Nova Scotia. *Geol. Soc. Amer. Spec. Paper* 139, 1-191.

———, and G. M. EHLERS. 1963. Two New Genera of Stricklandid Brachiopods. *Contrib. Mus. Paleontology Univer. Michigan* 18:47-66.

BROWN, C. E., and J. W. WHITLOW. 1960. Geology of the Dubuque South Quadrangle, Iowa-Illinois. *U.S. Geol. Survey Bull.* 1123-A, 1-93.

CALVIN, S. 1896. Geology of Jones County. *Iowa Geol. Survey Ann. Rept.* 5:35-112.

———. 1898. Geology of Delaware County. *Iowa Geol. Survey Ann. Rept.* 8:121-192.

———. 1906. Notes on the Geological Section of Iowa. *Jour. Geology* 14:571-578.

———, and H. F. BAIN. 1900. Geology of Dubuque County. *Iowa Geol. Survey Ann. Rept.* 10:381-622.

CARLSON, M. P., and A. J. BOUCOT. 1967. Early Silurian Brachiopods from the Subsurface of Southeastern Nebraska. *Jour. Paleontology* 41:1121-1125.

HALL, J. 1894. Palaeontology: An Introduction to the Study of the Genera of Palaeozoic Brachiopoda. *Geol. Survey State of New York* 8(2), 1-394.

———, and J. D. WHITNEY. 1858. *Report on the Geological Survey of the State of Iowa.* 2 vols., 1-472 and 473-724.

HINMAN, E. E. 1968. A Biohermal Facies in the Silurian of Eastern Iowa. *Iowa Geol. Survey Rept. Inv.* 6, 1-52.

JOHNSON, R. G. 1964. The Community Approach to Paleoecology. *In* J. Imbrie and N. D. Newell, editors. *Approaches to Paleoecology.* John Wiley and Sons, 107-134.

LAURITZEN, O., and D. WORSLEY. 1974. Algae as Depth Indicators in the Silurian of the Oslo Region. *Lethaia* 7:157-161.

M'COY, F. 1846. *A Synopsis of the Silurian Fossils of Ireland.* Dublin: University Press, 1-72.

MILLIMAN, J. D., and K. O. EMERY. 1968. Sea Levels During the Past 35,000 Years. *Science* 162:1121-1123.

MURCHISON, R. I. 1839. *The Silurian System.* London: John Murray. 2 vols., 1-576 and 577-768.

NITECKI, M. H. 1970. North American Cyclocrinitid Algae. *Fieldiana Geol.* 21, 1-182.

———. 1972. North American Silurian Receptaculitid Algae. *Fieldiana Geol.* 28, 1-108.

OWEN, D. D. 1840. Report of a Geological Exploration of Part of Iowa, Wisconsin, and Illinois. 1st ed., *U.S. 26th Cong., Ho. of Reps. Exec. Doc.* 239, 1-161.

———. 1844. Report of a Geological Exploration of Part of Iowa, Wisconsin, and Illinois, 2nd ed., *U.S. 28th Cong., Senate Exec. Doc.* 407, 1-191.

PHILCOX, M. E. 1970. Coral Bioherms in the Hopkinton Formation (Silurian), of Iowa. *Geol. Soc. Amer. Bull.* 81:969-974.

ROSS, C. A. 1964. Early Silurian Graptolites from the Edgewood Formation of Iowa. *Jour. Paleontology* 38:1107-1108.

RUDWICK, M. J. S. 1970. *Living and Fossil Brachiopods.* London: Hutchinson and Co., 1-199.

SAVAGE, T. E. 1906. Geology of Jackson County. *Iowa Geol. Survey Ann. Rept.* 16:565-648.

———, and C. S. ROSS. 1916. Age of the Iron Ore in Eastern Wisconsin. *Amer. Jour. Sci.* 4th ser., 41:187-193.

SCOBEY, E. H. 1938. The Alexandrian Series in Iowa. *Jour. Geology* 46:207-217.

SHEEHAN, P. M. 1973. The Relation of Late Ordovician Glaciation to the Ordovician-Silurian Changeover in North American Brachiopod Faunas. *Lethaia* 6:147-154.

WHITE, C. A. 1870. *Report on the Geological Survey of the State of Iowa.* Des Moines: Mills and Co. 2 vols., 1-391 and 1-443.

WHITTAKER, R. H. 1970. *Communities and Ecosystems.* London: Macmillan Co., 1-158.

WILLMAN, H. B. 1973. Rock Stratigraphy of the Silurian System in Northeastern and Northwestern Illinois. *Illinois State Geol. Circular* 479, 1-55.

WILSON, A. G. 1895. The Upper Silurian in Northeastern Iowa. *Amer. Geologist* 16:275-281.

ZIEGLER, A. M. 1965. Silurian Marine Communities and Their Environmental Significance. *Nature* 207:270-272.

———, and A. J. BOUCOT. 1970. North American Silurian Animal Communities. *In* W. B. N. Berry and A. J. Boucot, editors. Correlation of the North American Silurian Rocks. *Geol. Soc. Amer. Spec. Paper* 102, 95-106.

———, A. J. BOUCOT, and R. P. SHELDON. 1966. Silurian Pentameroid Brachiopods Preserved in Position of Growth. *Jour. Paleontology* 40:1032-1036.

———, L. R. M. COCKS, and R. K. BAMBACH. 1968. The Composition and Structure of Lower Silurian Marine Communities. *Lethaia* 1:1-27.

———, L. R. M. COCKS, and W. S. MCKERROW. 1968. The Llandovery Transgression of the Welsh Borderland. *Palaeontology* 11:736-782.

———, G. NEWALL, M. S. HALLECK, and R. K. BAMBACH. 1971. Repeated Community Sediment Patterns in the Silurian of the Northern Appalachian Basin. *Geol. Soc. Amer. Abstracts with Programs* 3:760-761.

———, R. B. RICKARDS, and W. S. MCKERROW. 1974. Correlation of the Silurian Rocks of the British Isles. *Geol. Soc. Amer. Spec. Paper* 154, 1-154.

———, and P. M. SHEEHAN. 1974. Lower Silurian of Britain, Estonia, New York, and Nevada. *In* R. N. Ginsburg, editor. Principles of Benthic Community Analysis (Comp. Sed. Lab., Univ. Miami). *Sedimenta* 4:10.1-10.6.

The Integration of Self-Descriptions and Descriptions by Outside References in the Evaluation of Job Applicants

JEANETTE M. DOLEZAL and IRWIN P. LEVIN[1]

DOLEZAL, JEANETTE M., and IRWIN P. LEVIN (Department of Psychology, The University of Iowa, Iowa City, Iowa 52242). The Integration of Self-Descriptions and Descriptions by Outside References in the Evaluation of Job Applicants. *Proc. Iowa Acad. Sci.* 82(2): 140-143, 1975.
A study was conducted to determine how different types of information are combined to arrive at evaluations of hypothetical job applicants. Sixty subjects were asked to evaluate nine applicants for the position of elementary school principal. The information describing each applicant included a letter of self-description and from one to three letters from outside references. Results can be summarized as follows: (1) evaluative ratings of job applicants were directly related to the value (level of favorability) of the information contained in the outside letters of reference and the value of the information contained in the self-description; (2) the greater the number of favorable outside letters, the higher was the evaluation; (3) the relative weight or importance of a given self-description or outside reference was dependent upon the other pieces of information with which it was combined. A mathematical model which assumes that subjects average the values of the various types of information provided a good description of the applicant evaluation process.
INDEX DESCRIPTORS: Evaluation of Job Applicants; Self-Descriptions.

This study represents an extension of a current line of research in which subjects are presented several pieces of information from a variety of sources and are required to make a single judgment or decision based on the varied information. In a common task of this type, subjects are asked to form an impression of how much they would like or dislike each of a series of hypothetical persons described by sets of personality trait adjectives (e.g., Rosenbaum and Levin, 1968). The present task is related to this, with subjects being asked to evaluate hypothetical job applicants. This general area of research is known as *information integration* because it is concerned with describing how information is combined or integrated in a variety of judgmental and decision-making tasks. Anderson (1971, 1974) has provided extensive reviews of this research.

The present study employs the methodology and analytic procedures of research on information integration to investigate a class of variables affecting the evaluation of job applicants. Subjects were asked to evaluate hypothetical applicants for the position of elementary school principal. For each applicant the subjects were given a set of information consisting of a self-description written by the applicant himself plus one or more letters of reference from outside sources. These letters of reference will be referred to as "other-descriptions" to contrast them with "self-descriptions." As is typically the case in studies of information integration, the variables of interest—in this case, favorability level of self-descriptions, favorability level of other-descriptions and number of other-descriptions (outside letters of reference)—were manipulated in a factorial design so that each combination of levels of the variables was included. This permits data analyses which determine the effect of each variable and the interactions between variables. These analyses are then used to evaluate the information integration process operative in the present task. Later in this paper, a mathematical model analogous to those used in previous studies of information integration (Levin, 1974a; Levin, Schmidt and Norman, 1971) will be employed as a heuristic device for describing the results of the present study.

PREDICTIONS AND EMPIRICAL QUESTIONS

In some cases, the effects of the variables of interest can be predicted directly on the basis of previous research and common-sense intuition. In other cases, predictions are not so straightforward. Pigage and Tucker (1952) studied job evaluations and found that the more positive the information contained in letters of reference, the more favorable was the response. Brewer (1968) found that an increase in the number of favorable letters of reference produced a more positive response. The same effects were predicted for the present study. However, previous studies of job applicant evaluations have not included self-descriptions as a factor. This is a novel aspect of the present study and a number of outcomes are possible. Subjects evaluating hypothetical job applicants may give higher ratings to applicants with more favorable self-descriptions than to those with less favorable self-descriptions. On the other hand, subjects may tend to discredit persons who appear to be overly self-praising. The information contained in a self-description may be evaluated in terms of whether or not it is supported by the information contained in the other-descriptions, and the effect of this variable would then depend on how the two types of information are combined.

METHOD

Design

A 2 X 3 X 3 factorial design was employed, with variations in content of self-descriptions and other-descriptions, and number of other-descriptions (outside letters of refer-

[1] This paper was based on a master's thesis by the first author under the supervision of the second author. Portions of the paper were presented at the meeting of the Iowa Academy of Science, 1974, Fayette, Iowa. Requests for reprints should be sent to Irwin P. Levin, Department of Psychology, The University of Iowa, Iowa City, Iowa 52242.

ence). In the terminology of information intergration, this latter variable will be referred to as "set size" because it defines the size of the set of information to be evaluated. Type of other-description (high praise, H; moderately good, M; or neutral, N) and set size (n = 1, 2 or 3) were within-subject factors, with each subject receiving all nine combinations of levels of each factor. Different groups of subjects received different levels of self-description. Half of the subjects received a high praise self-description and half received a moderately good self-description. The levels of each factor were determined in a prestudy where actual letters of reference for the job of elementary school principal were modified to achieve varying levels of favorability. A group of 333 students rated the degree of favorability of each letter and the levels chosen for the final study were those that were distinct and discriminable and had high levels of agreement among the judges. The mean ratings on a 20-point scale were as follows: high praise self-description, 18.9; moderately good self-description, 15.2; H other-description, 19.1; M other-description, 15.8; N other-description, 9.3.

Sixty students from introductory psychology classes at The University of Iowa participated in the main study.

Procedure

Each subject in both the high praise and moderately good self-description groups was given nine folders; each folder contained letters describing the qualifications of a different job applicant for the position of elementary school principal. The letters for a given applicant included a self-description plus one to three other-descriptions (letters of reference from other sources).

For the high praise group, each folder contained a high praise self-description. Three of these folders contained the high praise self-description plus one additional letter of recommendation provided by a former employer. This letter was either H, M, or N in value. Three other folders each contained the high praise self-description plus two letters of recommendation, one from a former employer and one from a former professor. These letters were either both H, both M, or both N in value. The final three folders each contained a high praise self-description plus three letters of recommendation, one from a former employer, one from a former professor and one from a colleague. The three letters were either all H, all M, or all N in value.

Each subject in the moderately good group was also given nine folders. The information in these folders differed from the information provided in the folders for the high praise group only in that the letters of self-description were moderately good instead of high praise. The letters of recommendation provided by others were the same as for the high praise group.

Subjects in each group were told that each of the nine folders corresponded to a person who was applying for the position of elementary school administrator (principal). They were asked to consider each person independently of all others and to decide how well each person would serve in the capacity of principal by rating him on a 20-point scale. For example, if they thought the person was very poorly qualified for this position, they were told to rate him 1. On the other hand, if they thought the person was very highly qualified and would be extremely competent in this position, they were asked to rate him 20. For intermediate levels they were to use the numbers between 1 and 20.

Social skills were to be their prime consideration in evaluating each applicant. They were told that in order to serve well in this position the person must be highly competent in getting along with other people, both young and old, since he would be interacting with students, faculty, and parents.

Subjects were instructed that for practical reasons it was not always possible to obtain the same amount of information (outside letters of reference) for each applicant. They were told that all the information about the applicant was contained in a single folder. They worked at their own pace and put their rating of an applicant on the last sheet in the folder. The self-description was always the first item of information in a given folder. The remaining information was shuffled for each subject, as was the order of presentation of folders.

RESULTS AND DISCUSSION

The mean for each cell of the design is presented in Table 1.

TABLE 1. MEANS FOR EACH CELL OF THE DESIGN

		Set Size			
		High Praise Self-Description			
		1	*2*	*3*	
	H	12.600	16.033	17.067	15.233
Other-	M	12.233	14.900	14.800	13.978
Descriptions	N	10.400	12.300	12.133	11.611
		11.744	14.411	14.667	13.607
		Moderately Good Self-Description			
		1	*2*	*3*	
	H	13.567	13.867	17.367	14.933
Other-	M	11.133	11.733	13.400	12.089
Descriptions	N	6.300	6.333	7.767	6.800
		10.333	10.644	12.844	11.274

The effect of level of other-description was statistically significant, $F(2, 116) = 98.84$, $p < .01$, and confirmed predictions. It can be seen in Table 1 that as the favorability of the information in the other-descriptions increased, the subjects' ratings of the applicant also increased.

The effect of level of self-description was also statistically significant, $F(1, 58) = 10.46$, $p < .01$. From an examination of Table 1, it appears that subjects tended to take the self-descriptions at face value rather than discrediting them, since higher ratings tended to be assigned to applicants presenting high praise self-descriptions than to those presenting moderately good self-descriptions. An exception can be seen for H other-descriptions at set size 1. This will be discussed later.

The interaction of other-description and self-description was significant, $F(2, 116) = 14.54$, $p < .01$, and is illustrated in Figure 1. The converging curves show that as the degree of favorability of the other-descriptions increased, the difference between the ratings given to applicants who present different types of self-description decreased, and vice versa. This finding can be explained by assuming that subjects average the information contained in self-descriptions and other-descriptions, thus leading to a tradeoff relationship or balance between the two types of information. When one type of information is extreme in value, that type of information has an increased effect and the other type of information has a diminished effect. This is con-

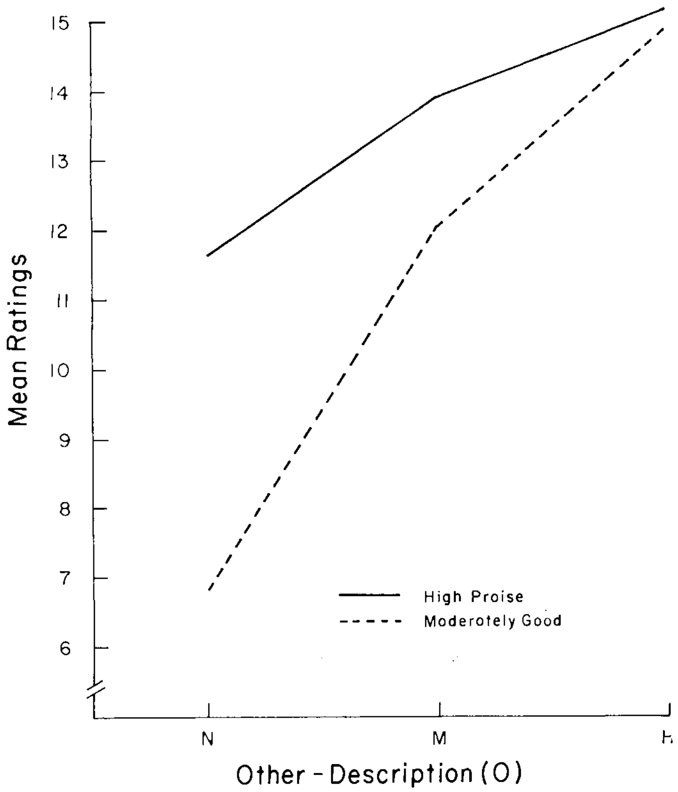


Figure 1. Mean ratings as a function of self-description and other-description.

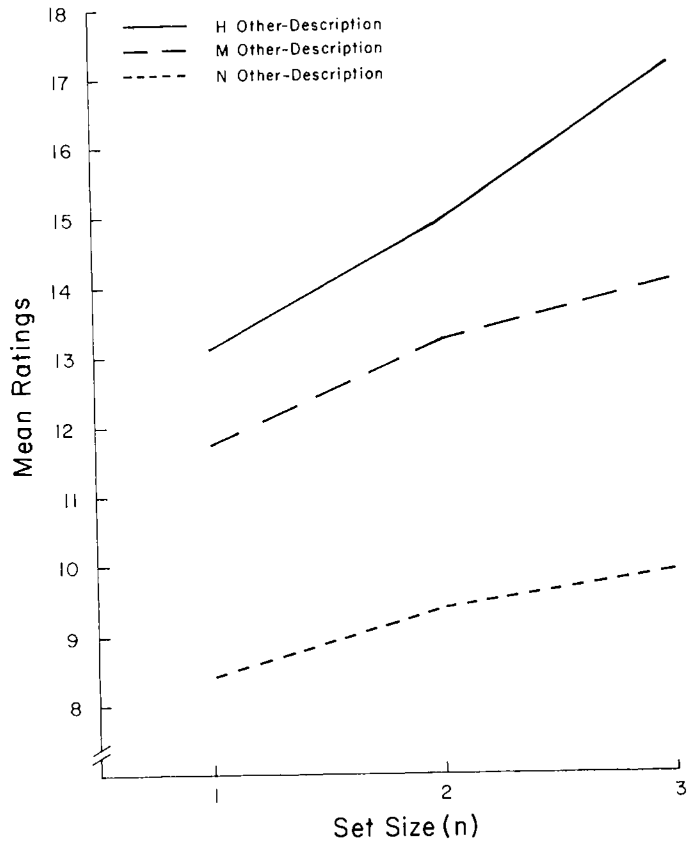


Figure 2. Mean ratings as a function of other-description and set size.

sistent with Anderson's (1967) conclusion that neutral or moderate information has less weight than more extreme information when information of differing values is averaged.

Set size was found to have a statistically significant effect, $F(2, 116) = 34.50$, $p < .01$. As set size increased, the mean rating increased. However, the magnitude of this effect was found to vary depending on the type of other-description and the type of self-description being considered. These interactions are described below.

The interaction of set size and other-description was of borderline statistical significance at the .05 level, $F(4,232) = 2.34$, and appears to be systematic in nature. The interaction is plotted in Figure 2. The diverging curves seen in Figure 2 illustrate the following two points: (1) differences in mean ratings for different levels of other-descriptions increased as set size increased; (2) the degree of increase in mean rating response as set size increased was greatest for high praise other-descriptions and least for neutral other-descriptions. Analogous results have been obtained in studies of personality impression formation and have been explained by assuming that a relatively neutral initial expectancy or response disposition is averaged with the values of the information presented the subjects (Anderson, 1967; Levin, Schmidt and Norman, 1971). The resulting average is thus increased as the number of favorable pieces of information presented is increased. This would account for the present finding.

The interaction of set size and self-description was statistically significant, $F(2, 116) = 7.34$, $p < .01$, and is illustrated in Figure 3. This figure shows that the difference between the high praise self-description group and the moderately good self-description group increased from set size 1 to set size 2 and decreased from set size 2 to set size 3. The decreased difference between groups as set size increased from 2 to 3 is consistent with the assumption that information presented in self-descriptions and information presented in other-descriptions is averaged. As the number of other-descriptions is increased, the relative effect of self-descriptions is diminished. A depressed mean rating at set size 1 for the high praise group (particularly for an H other-description) prevents this effect from occurring when set sizes 1 and 2 are compared. Subjects in the high praise group may have tended to discount the high praise self-description when only one other-description was given, resulting in a relatively low rating at that point.

The set size X other-description X self-description interaction did not approach statistical significance. The relevant graphs are shown in the top part of Figure 3.

CONCLUSIONS

In the present task both self-descriptions and references from outside sources were important in determining eval-

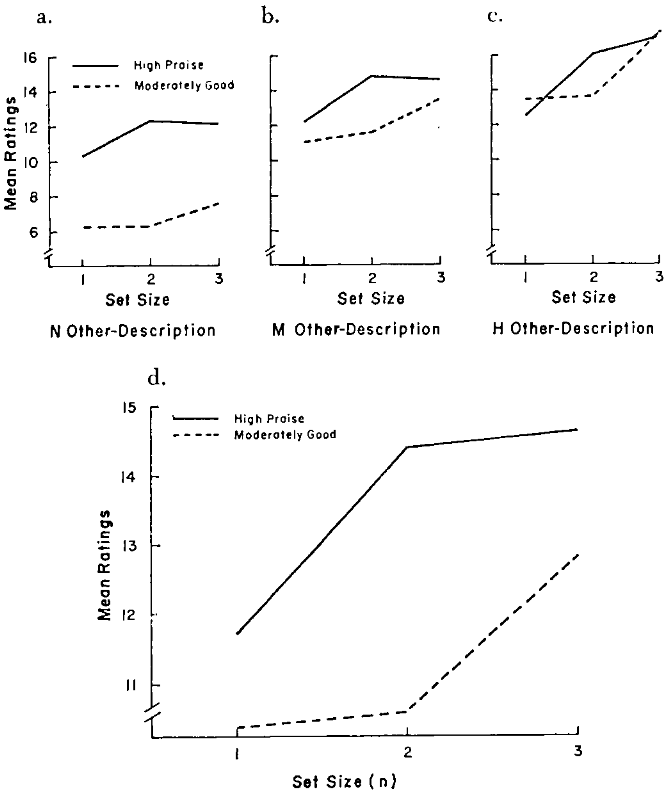


Figure 3. Mean ratings as a function of self-description and set size at each type (N, M and H) of other-description (a, b and c) and summed over other-descriptions (d).

uations of hypothetical job applicants. A tenable hypothesis is that the two types of information are combined through an averaging process. This fits well with recent findings from a variety of judgmental and decision-making tasks. For example, Anderson (1971) concluded that averaging models provide a good description of personality impression formation and certain types of attitude change; Levin (1974a) showed that price information was combined by an averaging process when comparing alternative stores; and Levin (1974b) showed that personal and outside opinions are combined by an averaging rule when arriving at a joint decision. An averaging model which describes the influence on job applicant evaluations of varying levels of self-description and varying levels and numbers of other-descriptions has the following form:

$$R = \frac{w_O I_O + w_S I_S + n\, w_R I_R}{w_O + w_S + n w_R}$$

where R is the evaluative rating response; I_O, I_S, I_R are the favorability levels of the subject's initial expectancy, the information contained in the self-description, and the information contained in the other-descriptions, respectively; w_O, w_S, and w_R are the relative weights or levels of importance of these components of the rating response; and n is the set size. Note that the denominator is the sum of the weights and serves to "normalize" the model so that it has the form of an averaging model and implies that an increase in the influence (weight) of one factor (i.e., self-description or other-description) produces a concomitant decrease in the influence of the other factor. In this form, the model can account for the major findings of the present study. With additional constraints on the parameter values—e.g., by assuming that the weights w_S and w_R are directly related to the values of I_S and I_R—other details can be handled. The model can be used to provide a framework in which to study other variables affecting job applicant evaluations. For example, the credibility of the sources supplying letters of reference can be studied by examining changes in the weight parameter, w_R, as a function of source credibility (Rosenbaum and Levin, 1968).

Studies of the present type are, of course, several steps removed from actual job selection procedures. For one thing, subjects in the present study were not actually evaluating real applicants. Rather, they were making paper-and-pencil responses in a laboratory setting. Secondly, the variables chosen for study represent only a portion of those that are operative in actual job selection. Evaluation of letters of reference is often a screening device to be followed by personal interviews, aptitude tests, etc. Nevertheless, the screening process is an important component of job applicant selections. Subjects in the present study responded systematically to the information presented by putting themselves in the role of an employer. The nature of the information was controlled to a far greater extent than would have been possible in a field setting. It remains for future research to determine the correspondence between laboratory-derived principles of information processing and those principles that apply to decision-making outside the laboratory.

LITERATURE CITED

ANDERSON, N. H. Averaging model analysis of set size effect in impression formation. *Journal of Experimental Psychology*, 1967, 75:158-165.

ANDERSON, N. H. Integration theory and attitude change. *Psychological Review*, 1971, 78:171-206.

ANDERSON, N. H. Information integration theory: A brief survey. In D. H. Krantz, R. C. Atkinson, R. D. Luce, and P. Suppes (eds.), *Contemporary developments in mathematical psychology*. Vol. 2. San Francisco: Freeman, 1974.

BREWER, M. B. Averaging versus summation in composite ratings of complex social stimuli. *Journal of Personality and Social Psychology*, 1968, 8:20-26.

LEVIN, I. P. Averaging processes in ratings and choices based on numerical information. *Memory and Cognition*, 1974, 2:786-790, a.

LEVIN, I. P. Combining personal and outside opinions: An information integration analysis. *Bulletin of the Psychonomic Society*, 1974, 3:44-46, b.

LEVIN, I. P., C. F. SCHMIDT, and K. L. NORMAN. Person preference choices: Tests of a subtractive averaging model. *Journal of Experimental Psychology*, 1971, 90:258-261.

PIGAGE, L. C., and J. L. TUCKER. Job evaluation. *University of Illinois Bulletin*, 1952, 49:44.

ROSENBAUM, M. E., and I. P. LEVIN. Impression formation as a function of source credibility and order of presentation of contradictory information. *Journal of Personality and Social Psychology*, 1968, 10:167-174.

Averaging and Set-Size Effects in Selecting Groups of Movies for a Film Festival[1]

IRWIN P. LEVIN and VALERIE S. HENSLEY[2]

LEVIN, IRWIN P., and VALERIE S. HENSLEY (Department of Psychology. The University of Iowa, Iowa City, Iowa 52242). Averaging and Size Effects in Selecting Groups of Movies for a Film Festival. *Proc. Iowa Acad. Sci.* 82(2): 144-147, 1975.
This paper deals with the *set-size effect* in information processing: the study of how subjective judgments and impressions based on sets of information vary as a function of the amount of information in the set. Subjects rated each of a series of popular old movies to be used in assembling a college film festival. They then rated intact groups of movies of various size and indicated how much money should be spent for each group. Group ratings and money allocations were examined as a function of group size. Group ratings were found to increase in polarity and money allocations were found to increase as the number of movies in the group increased. This supports the general conclusion that the greater the amount of information presented, the more extreme the response. The set-size function in each case was negatively accelerated (i.e., subject to a law of diminishing returns). These results can best be described by an averaging model in which the value of each movie in a group is averaged with an initial neutral expectancy.
INDEX DESCRIPTORS: Set-Size Effects, Information Processing.

In recent years, a number of studies have been concerned with how people combine or integrate diverse pieces of information to make an overall rating or decision (Anderson, 1974). In many instances, support was found for a model that assumes that the respondent *averages* the values of the pieces of information presented to him. Evidence supporting the averaging hypothesis comes from two types of studies. Some studies have employed factorial manipulations of various categories of information and have shown that these categories do not interact (e.g., Anderson, 1962; Levin, 1975). Such findings support a general class of additive models which include both averaging models and adding models (models that assume adding of information values). Other studies specifically tested averaging models vs. adding models by comparing responses to information sets consisting of extreme values only with responses to information sets consisting of the same extreme values plus some additional less extreme values. An adding model would predict that responses to the latter sets would be at least as extreme as responses to the former sets, whereas an averaging model would predict the opposite. Results supported an averaging model in studies ranging from personality impression formation, where subjects are required to indicate their impressions of hypothetical persons described by sets of personality trait adjectives (Anderson, 1965), to simulated shopping decisions, where subjects are required to compare and select grocery stores on the basis of sample price information (Levin, 1974a, Exp. 1). The present study further explores averaging processes in information integration.

The simplest form of an averaging model for information integration would be as follows:

$$R_n = \sum_{i=1}^{n} s_i/n \qquad (1)$$

where R_n is the overall response to a set of n stimuli (items of information) and s_i is the scale value of the ith stimulus. The scale value can be considered as the subject's estimate of the location of the stimulus on the dimension of judgment (e.g., how favorable it is). One implication of Equation 1 is that for homogeneous sets of information—i.e., those where each stimulus has approximately the same scale value—the response should not vary as a function of the "set size," n (the number of pieces of information in the set). However, a number of studies of personality impression formation have shown that responses do vary as a function of set size. Specifically, Anderson (1967) found that impression ratings of persons described by four favorable traits were higher than ratings of persons described by two favorable traits, even though the average trait value was the same in each case. The converse was found when ratings of persons described by four unfavorable traits were compared to ratings of persons described by two unfavorable traits. Analogous findings were obtained by Levin, Schmidt and Norman (1971) when subjects compared two persons described by different numbers of favorable or unfavorable traits and indicated which person they would prefer to have as a friend. The finding that increasing the number of equal-valued stimuli in an information integration task leads to a more extreme or polarized response has been labeled the "set-size effect" (Anderson, 1967; Levin and Kaplan, 1974; Sloan and Ostrom, 1974).

The set-size effect in personality impression formation has been explained by assuming that subjects have a relatively neutral initial impression or expectancy of the person to be evaluated and that this initial impression is averaged in with the information presented. Thus, for example, the greater the amount of favorable information averaged with this neutral value, the higher will be the response. This modified version of the averaging model applied to evaluations based on n items of equal value can be stated as follows:

$$R_n = \frac{w_O I_O + nws}{w_O + nw} \qquad (2)$$

where w and s are the weight (degree of importance) and scale value, respectively, of each item of information; w_O and I_O are the weight and value of the initial impression. In addition to predicting that response polarity should increase with set size, this model predicts that the set-size effect should be a growth function of n with asymptote s. In

[1] Based on a paper read in the Psychology Section of the 86th annual meeting of the Iowa Academy of Science (Upper Iowa College, Fayette, Iowa, April 19, 1974). The research was supported by National Institute of Mental Health Grant MH 23911-01.

[2] Department of Psychology, The University of Iowa, Iowa City, Iowa 52242.

TABLE 1. MEAN RATINGS OF INDIVIDUAL MOVIES (BASED ON A SCALE OF +10 TO −10)

Movie	Rating
Adventure	
Adventures of Robin Hood (Errol Flynn, 1938)	+2.32
African Queen (Humphrey Bogart, Katharine Hepburn, 1951)	+5.56
Gunga Din (Cary Grant, 1939)	− .62
Moby Dick (Gregory Peck, 1956)	+2.91
Mutiny on the Bounty (Clark Gable, Charles Laughton, 1935)	+4.56
Tarzan, the Ape Man (Johnny Weissmuller, 1932)	+4.21
Comedy	
Abbott and Costello Meet Frankenstein (Bud Abbott and Lou Costello, 1948)	+3.00
Adam's Rib (Spencer Tracy, Katharine Hepburn, 1949)	+4.41
The Bank Dick (W. C. Fields, 1940)	+6.27
It Happened One Night (Clark Gable, Claudette Colbert, 1934)	+2.09
A Night at the Opera (Marx Brothers, 1935)	+5.88
Musical	
Anchors Aweigh (Frank Sinatra, Gene Kelly, 1945)	+ .53
Forty-Second Street (Dick Powell, Ginger Rogers, 1933)	− .29
Holiday Inn (Bing Crosby, Fred Astaire, 1942)	+1.06
Singin' in the Rain (Gene Kelly, Debbie Reynolds, 1952)	+ .59
Top Hat (Ginger Rogers, Fred Astaire, 1935)	+ .18
Wizard of Oz (Judy Garland, 1939)	+4.32
Biography	
Lust for Life (Kirk Douglas, Anthony Quinn, 1956)	+1.38
Madame Curie (Greer Garson, 1943)	−1.12
Pride of the Yankees (Gary Cooper, 1942)	− .26
Somebody up There Likes Me (Paul Newman, 1956)	+1.56
Story of Alexander Graham Bell (Don Ameche, 1939)	−1.21
Story of Louis Pasteur (Paul Muni, 1935)	−1.41
Drama	
Citizen Kane (Orson Welles, 1941)	+4.62
The Defiant Ones (Tony Curtis, Sidney Poitier, 1958)	+2.74
From Here to Eternity (Burt Lancaster, Frank Sinatra, 1953)	+3.24
Grapes of Wrath (Henry Fonda, 1940)	+5.21
Of Mice and Men (Burgess Meredith, Lon Chaney, Jr., 1939)	+4.44
On the Waterfront (Marlon Brando, 1954)	+3.59
Mystery-Crime	
The Desperate Hours (Humphrey Bogart, Frederic March, 1955)	+3.22
Hound of the Baskervilles (Basil Rathbone, 1939)	+2.91
Laura (Dana Andrews, Gene Tierney, 1944)	+ .50
Little Caesar (Edward G. Robinson, 1931)	+4.38
The Maltese Falcon (Humphrey Bogart, 1941)	+4.38
Public Enemy (James Cagney, 1931)	+4.76
Science Fiction	
Dracula (Bela Lugosi, 1931)	+3.94
Flash Gordon (Buster Crabbe, 1936)	+2.53
Frankenstein (Boris Karloff, 1931)	+4.82
Invasion of the Body Snatchers (Kevin McCarthy, 1956)	− .76
King Kong (Fay Wray, 1933)	+3.62
The Wolf Man (Lon Chaney, Jr., 1941)	+4.24
War	
All Quiet on the Western Front (Lew Ayers, 1930)	+5.03
Dawn Patrol (Errol Flynn, 1938)	+ .47
For Whom the Bell Tolls (Gary Cooper, Ingrid Bergman, 1943)	+4.47
Red Badge of Courage (Audie Murphy, 1951)	+ .24
Sands of Iwo Jima (John Wayne, 1949)	−1.41
Thirty Seconds over Tokyo (Van Johnson, Spencer Tracy, 1944)	+2.00
Western	
Broken Arrow (James Stewart, 1950)	+ .74
High Noon (Gary Cooper, 1952)	+2.09
Ox-Bow Incident (Henry Fonda, 1943)	−1.26
Red River (John Wayne, Montgomery Clift, 1948)	− .82
Shane (Alan Ladd, 1953)	+ .62
Stagecoach (John Wayne, Claire Trevor, 1939)	− .71

other words, Equation 2 states that increases in response polarity with increases in set size should generate a negatively accelerated curve. This was in fact the case in the studies reported above. Following its establishment as a parameter useful in describing set-size effects, the initial impression was further shown to be an important parameter of impression formation by Kaplan (1972), who related it to individual differences in processing personality information.

One of the goals of the present study is to show that the set-size effect established in studies of personality impression formation holds for other subjective judgment tasks and that, consequently, the assumption of an initial expectancy as a component of the information integration process is tenable for a variety of situations. Some evidence that this is so has been provided by studies of simulated shopping decisions (Levin, 1974a, Exp. 2) and evaluations of job applicants (Dolezal and Levin, 1975).

The present study examines the set-size effect when groups of objects are to be rated. In this case, a group consists of a varying number of popular old movies to be used in assembling a college film festival. One change from previous studies of set-size effects is that the informational stimuli within a set—i.e., the individual movies within a group—are not necessarily homogeneous in value. This requires a slight modification in applying the averaging model stated in Equation 2. The parameter s which represented the scale value of each item of information in a set must now represent the *mean* scale value of items in a group. The modified model then predicts that as group size increases, ratings of groups with positive mean values should increase and ratings of groups with negative mean values should decrease. Furthermore, if the model holds, then the set-size effect should be described by a negatively accelerated growth function.

MATERIALS AND METHODS

Fifty-one students from introductory psychology classes at The University of Iowa who expressed an interest in and familiarity with movies of the 1930's, '40s, and '50s participated in the study. Fifty-four popular old movies were used as stimuli. The same class of stimuli was used in an earlier study of information integration concerning how people combine their own and outside opinions (Levin, 1974b).

Each student was given an alphabetical list of 36 movie titles. Accompanying the list was a booklet giving the stars, year of release, and a brief description of each movie. Students were asked to rate each movie on a scale of + 10 to −10 in terms of how much they thought students at their university would like or dislike the movie.

After completing the initial phase at their own pace and turning in their response sheets, the students were given a new sheet grouping the same 36 movies into the nine categories shown in Table 1. (Mean ratings of individual movies are also given in this table.) For a given student, three of the categories contained two movies, three contained four movies, and three contained six movies. Three different subgroups of 17 subjects each received different lists, so that across subjects each category was represented equally often by set sizes 2, 4 and 6. (That is why a total of 54 movies was needed, even though any one student was given only 36 movies.) Subjects were asked to rate each movie group on a scale of +10 to −10 in terms of how much students would enjoy seeing that group of movies *as a whole*.

The students were then told to assume that they had a total of $9,000 to purchase movies for a college film festival and that they were to indicate how much they would be willing to allocate to each intact group. That is, they could assign whatever amounts they wanted to each of the nine groups of movies, as long as the total was $9,000. (In actuality, some subjects erred in their calculations and the total was not always $9,000.) This part of the study was included to provide a second dependent variable which might reflect on how judgments are affected by set size.

RESULTS AND DISCUSSION

The data of primary theoretical interest are shown in Table 2, where set-size effects for ratings of movie groups and money allocations are summarized. An explanation is needed of how set-size effects for group ratings were obtained. For a given student, the mean response to individual movies within a given category or group was computed and compared with the student's rating of that group as a whole. When the mean rating of the individual movies in a group was positive (e.g., +2) and the group rating was greater than this value (e.g., +3), a *positive* set-size effect was scored. When the mean rating of individual movies in a group was positive (e.g., +2) and the group rating was less than this value (e.g., +1), a *negative* set-size effect was scored. A positive set-size effect was also scored when the mean rating of the individual movies in a group was negative (e.g., −2) and the group rating was less (i.e., more negative) than this value (e.g., −3); and a negative set-size effect was scored when the mean rating of the individual movies was negative (e.g., −2) and the group rating was higher (i.e., less negative) than this value (e.g., −1). In each case, the size of the effect was the difference between the group rating and the mean rating of the individual movies. Thus, the greater the number, the greater the extremeness of the group rating as compared to the average rating of individual movies within the group. For a given student, groups for which the mean rating of the individual movies fell between +1 and −1 were excluded from this particular analysis since they represent neutral sets. For each student, the mean set-size effect was computed for groups with set size 2, groups with set size 4, and groups with set size 6. These values, averaged over subjects, are given in the top half of Table 2.

TABLE 2. SUMMARY OF SET-SIZE EFFECTS

	Set Size		
	2	4	6
Mean Set-Size Effect for Group Ratings*	+ .07	+ 1.05	+ .92
Mean Amount of Money Allocated ($)	1673	3305	4004

* See text for explanation of how this was computed.

It can be seen in Table 2 that the magnitude of the set-size effect for group ratings was greater for set sizes 4 and 6 than for set size 2. For set size 2 the group rating tended to be nearly identical to the average rating of the two individual movies in the group, but for set sizes 4 and 6 the group rating was about one scale point more extreme than the average rating of the individual movies in the group. The difference between set size 2 and set sizes 4 and 6 was statistically significant, $t(50) = 2.34$, $p < .05$, while the difference between set size 4 and set size 6 did not approach statistical significance, $t(50) = 0.39$.

Trend tests across set sizes 2, 4, and 6 were conducted to test the predictions of the averaging model with an initial expectancy (Equation 2). If the model holds, a negatively accelerated growth function should describe the data, and both linear and quadratic trends should be observed. Both the linear and quadratic trends were of borderline significance, $t(50) = 1.93$ and 1.88, respectively, $.10 > p > .05$ in each case. Thus the results provide some support for the model.

The average amount of money allocated to groups of size 2, 4, and 6 are given in the bottom half of Table 2. It can be seen that the mean amount of money allocated increased with set size. The differences between each pair of set sizes were significant. These results are not surprising, since subjects would obviously allocate more money for six movies than for four or two. What is more interesting, however, is that the difference in amount of money allocated for groups of size 4 and 6 is less than the difference in money allocated for groups of size 2 and 4. A law of "diminishing returns" thus seems to be operating. But that is precisely what the averaging model predicts. Trend tests across set sizes 2, 4, and 6 for money allocations resulted in a highly significant linear trend, $t(50) = 9.12$, $p < .01$, and a quadratic trend of borderline significance, $t(50) = 2.00$, $p = .05$. The set size function for money allocations was thus similar to that for rating responses and provides additional support for the averaging model with initial expectancy.

CONCLUSIONS

This study looked for set-size effects when groups of objects were rated. Set-size effects were obtained. Rating responses were more extreme for movie groups of size 4 and 6 than for groups of size 2. Money allocations also increased as group size increased. In each case the function describing the set-size effect approximated that predicted by an averaging model which incorporates a relatively neutral initial expectancy that is averaged with the information presented. Previous support for such a model has been found primarily in studies of personality impression formation. The present results, along with those of other recent projects in the writers' laboratory (Levin, 1974a, Exp. 2; Dolezal and Levin, 1975), suggest that this model may be more generally applicable. The following simple principle of information usage may thus apply to a variety of situations requiring subjective ratings: the greater the amount of information, the more extreme the response.

LITERATURE CITED

ANDERSON, N. H. Application of an additive model to impression formation. *Science*, 1962, 138:817-818.

ANDERSON, N. H. Averaging versus adding as a stimulus-combination rule in impression formation. *Journal of Experimental Psychology*, 1965, 70: 394-400.

ANDERSON, N. H. Averaging model analysis of set-size effect in impression formation. *Journal of Experimental Psychology*, 1967, 75:158-165.

ANDERSON, N. H. Information integration theory: A brief survey. In D. H. Krantz, R. C. Atkinson, R. D. Luce, and P. Suppes (eds.), *Contemporary developments in mathematical psychology*. Vol. 2. San Francisco: Freeman, 1974.

DOLEZAL, J. M., and I. P. LEVIN. The integration of self-descriptions and descriptions by outside references in the evaluation of job applicants. *Proceedings of the Iowa Academy of Science*, 82(2): 140-143.

KAPLAN, M. F. The modifying effect of stimulus information on the consistency of individual differences in impression formation. *Journal of Experimental Research in Personality*, 1972, 6: 213-219.

LEVIN, I. P. Averaging processes in ratings and choices based on numerical information. *Memory and Cognition*, 1974, 2:786-790, a.

LEVIN, I. P. Combining personal and outside opinions: An information integration analysis. *Bulletin of the Psychonomic Society*, 1974, 3:44-46, b.

LEVIN, I. P. Information integration in numerical judgments and decision processes. *Journal of Experimental Psychology: General*, 1975, 104:39-53.

LEVIN, I. P. and M. F. KAPLAN. The set-size effect in personality impression formation is not an artifact. *Bulletin of the Psychonomic Society*, 1974, 3:187-188.

LEVIN, I. P., C. F. SCHMIDT, and K. L. NORMAN. Person preference choices: Tests of a subtractive averaging model. *Journal of Experimental Psychology*, 1971, 90:258-261.

SLOAN, L. R., and T. M. OSTROM. Amount of information and interpersonal judgment. *Journal of Personality and Social Psychology*, 1974, 29:23-29.

EDITORIAL BOARD

PRICES OF LETTERPRESS REPRINTS

(Including postage, handling, insurance)

Copies	1-4 pages	5-8 pages	9-12 pages	13-16 pages	17-20 pages	Covers
100 or less	$24.20	$44.00	$69.30	$89.10	$114.40	$35.20
200	29.70	50.60	82.50	103.40	129.80	47.30
400	40.70	62.20	95.20	117.70	148.20	66.00
600	51.70	74.80	108.90	132.00	160.60	84.70
800	62.76	86.90	122.10	146.30	176.00	105.60
1000	73.70	99.00	135.30	160.60	191.40	113.30
1200	82.50	108.90	146.30	184.80	215.60	139.70

PRICES OF ECONOMY REPRINTS

Duplicated on both sides of 8½ x 11
white bond paper, collated, stapled once.
Two hundred copies, maximum.

Copies	1-2 pages	4 pages	6 pages	8 pages	10 pages	Each additional sheet (2 pages)
25	$.75	$1.65	$2.40	$3.20	$4.00	$.80
50	1.35	3.30	4.80	6.30	7.80	1.50
100	2.70	6.60	9.60	12.60	15.60	3.00
200	4.05	10.55	15.15	19.75	24.35	4.60

THE PROCEEDINGS OF THE IOWA ACADEMY OF SCIENCE

Published Quarterly by the Iowa Academy of Science