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Editorial

This October issue marks the fourth full year that I have been editor of this journal and instead of the usual two to four articles, we have eight contributions over a wide range of topics including geology, statistics, biology, science journalism (a first for us) and Mississippi science news. I hope the increase in articles is a trend that will continue. I assumed the position of editor with a convection that state academies and their journals played an important role in science at the grass roots level. State academy meetings have traditionally been an excellent place for students to give their first professional presentation away from their home institutions. The atmosphere at these meetings is less intimidating than at national meetings where fewer friends and more experts will be in the audience. The meetings are also important to bring together scientists that live within reasonable commuting distance from one another—a situation that can foster convenient and fruitful collaborations. The state academy journal, I thought, was also an excellent place for students to publish a first paper. The peer review is slightly less rigorous than that of national journals and the research can be of more local interest. In fact many studies focusing on the local level could not be published in a national journal, but represent important information never the less. For example, the state academy journal is the place people might begin to look for information about rainfall patterns or butterfly distributions in a particular state.

As you think about summarizing your research during the past year in the form of an abstract to submit for our annual meeting in February, please consider the possibility of writing the information for publication in this journal. For those of you working with graduate and advanced undergraduate students, consider the possibility of having them write up their research. The experience of publishing a refereed article will be invaluable for them.

A glance at the table of contents of this issue will give you some idea of the breadth of types of articles we solicit. Articles can be of general scientific interest or address science news in Mississippi or the Southeast. Articles can be brief communications that put on record something of scientific interest, especially if it relates to Mississippi. General and local research articles are always welcome. This issue contains an article by a high school student who won recognition at our Junior Academy paper competition. This is a regular annual feature. In the past we have featured articles that describe laboratory experiences. I would very much like to see more articles of this type that would be of interest to those of you that conduct high school and college science laboratories.—Ken Curry

Are Journalists Qualified to Write about Health and Science?

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This article examines the preparation of journalists to report on health and science issues. It traces the historical linkage between the news media and health and science and reports the results of a survey of college professors who teach reporting courses at 86 departments and schools of journalism and mass communication. The article, also intended to help explain the journalistic method to scientists, concludes that many young journalists are qualified to cover simple stories about health and science and other topics when they leave college and acquire the skills to report on more complex issues through on-the-job training and specialized journalism programs.

Are journalists qualified to write about health and science? Journalists often ask leading questions about serious topics, some times for comic relief, to prompt reader interest in their work[a]. If this question were on the cover of Rolling Stone, it might prompt an immediate purchase. If it were the substance of a good book, it would be called a page-turner. It is a time-honored journalistic device used to win readers by any means necessary. The device is used here for the same reason and to frame answers from a journalistic point of view within a scientific context, *The Journal of the Mississippi Academy of Sciences.*

Qualifications of journalists to cover health and science and other important, complex issues are intensely debated within the journalism community. Interest in the present article evolved over two years after the author read a report titled: "Are Journalists Too Ignorant To Cover Important News Issues Correctly?" (Giles and Cox, 1997). The report began: "As communities and newspapers begin to feel the effects of the most significant shift in political power and the role of the federal government since the New Deal, thoughtful media observers can't avoid asking a discomforting question. Are today's journalists too ignorant to cover the news correctly? Can they really write with authority about stories as complicated as the implementation of the 1996 welfare reform programs or congressional efforts to privatize Social Security and alter Medicare?"

Journalists are event oriented, and some issues can't be reported as simply as "Something happened yesterday, and it will affect so many people somewhere (the familiar who-what-when-where). Edward R. Murrow, the historical model of what a television journalist should become, said, "It is much easier to report a battle or a bombing than it is to do an honest and intelligible job on the Marshall Plan, the Taft-Hartley Law or the Atlantic Pact." (Emery, 1996)

Such questions and observations, particularly from within the journalism family, raise serious doubts about the quality of journalism education and the practices of the Fourth Estate. They certainly invite further analyses, and this article is one such analysis. It is intended to allay fears in the scientific community about dealing with journalists who dabble in health and science issues. As such, it is intended also to help scientists understand journalism education and the journalistic method. In doing so, this article will explore the historical linkage between American journalism and health and science and summarize a survey of journalism professors about the qualifications of their graduates.

HISTORICAL LINKAGE

From its early days, the American press has run on news—people, events, and other developments with impact, conflict, novelty, prominence, and timeliness (Brooks et al., 1996). Even *Publick Occurrences: Both Foreign and Domestick*, generally regarded as America's first newspaper, seemed to practice this brand of journalism as far back as 1690. However, there was only one issue of *Publick Occurrences* because it was banned after the first issue, having been published without authority at a time when

[a]For example, *USA Today* asked in a lead paragraph: "Can a savvy Internet strategy help save the scandal-torn, cash-poor Salt Lake Olympic Games from financial failure?" (Horovitz, 1999)

British authority was required for publication (Folkerts and Teeter, 1998).

That one issue of *Publick Occurrences* contained items involving Indian raids and conflicts between the French and British and, some say bad taste (but prominence and conflict in journalism) by reporting an immoral affair between the French king and his son's wife (Sloan and Startt, 1996; Emery, 1996). America's first newspaper also carried a report of the smallpox epidemic in Boston, an early indication of the importance (newsworthiness) of science and medicine to journalism.

The first several newspapers that succeeded *Publick Occurrences* generally followed a safe policy of adhering to the wishes of authorities in government and religion until 1721 (Emery, 1996), when James Franklin, Benjamin's older brother, established *The New England Courant*. It was the first of the crusading newspapers, challenging social structure and printing without authority. James Franklin and his editor, an Anglican minister, clashed with Increase Mather and his son, Cotton Mather, the powerful Puritan leaders.

Cotton Mather correctly advocated inoculation for smallpox over the opposition of many Boston doctors who did not consider the experiment scientific. The inoculation experiment used blood from smallpox survivors to prevent spread of the disease (Folkerts and Teeter, 1998). The first issue of *The Courant* attacked Mather over inoculation, and it is speculated that the paper did so not because of any strongly held beliefs about science but because Mather favored it (Sloan and Startt, 1996). Newspapers have not always behaved as a marketplace of ideas (Sloan and Startt, 1996).

Nevertheless, the inoculation issue caused a newspaper war over medical science. The Reverend Thomas Walter, grandson of Increase Mather, published a single sheet, *The Little-Compton Scourge* or *The Anti-Courant*. *The Courant* responded by accusing Walter of drunkenness and continued its attack on inoculation. Other Bostonians who supported the Mathers and inoculation patronized the *Boston Gazette*. Each paper ran articles trying to refute the other's (Folkerts and Teeter, 1998). This was freedom of the press, although not professional journalism or fair journalism.

Coverage of the inoculation issue typified news coverage through most of the 18th and 19th centuries. The local newspaper published nice things about the party in power when the party in power was the paper's party and things not so nice when citizens of a different party were in power. Those with opposing views supported another paper or party. Fairness and detachment in journalism would come later.

Journalists with scientific expertise were rare before this century. Not many journalists before the 20th century went to college, and many who worked as news employees started as printers, apprentices to printers, and postmasters or were trained in other professions. The first journalism school was not created until 1908 at the University of Missouri, although several universities offered a few courses, mostly in printing, before 1908.

Being muckrakers (crusading journalists) at the turn of the last century usually meant looking for abuses, or corpses in news lingo. For example, *Collier's* magazine exposed problems in the patent medicine industry that led to the Pure Food and Drug Act in 1907 (Sloan and Startt, 1996).

Modern journalism is based on late-19th century notions of Joseph Pulitzer. In a statement of policies for his St. Louis newspaper, *The Post-Dispatch*, Pulitzer said his paper would show allegiance to the people over political parties, print the truth, follow no causes but conclusions, criticize the administration rather than support it, oppose all frauds and shams, and advocate principles and ideas (Emery, 1996).

An industry largely dependent on government support and friends in power through most of its history at that point was coming of age as a free and independent force. During the Industrial Revolution, newspapers and magazines emerged as mass media, and independence meant they were mostly beholden to advertisers and subscribers, much as they are today.

In 1898, Pulitzer's *New York World* and William Randolph Hearst's *New York Journal* were so independent and free that many believe they waged a circulation fight that led to America and Spain going to war. By 1945, an independent press was deemed responsible enough to keep state secrets and not report about the atomic bomb before the government was ready. *New York Times* reporter William L. Laurence rode in one of the planes that dropped the second bomb on Japan and wrote a first-hand account. This was his reward for not telling what he knew about the Manhattan Project, which developed the bomb (Emery, 1996). Laurence was considered a science expert and won two Pulitzer prizes, the highest recognition for outstanding journalism established by Joseph Pulitzer.

Two lessons: First, freedom of the press means journalists decide for themselves what to print or hold back in the public interest—influenced, or restrained, by the fear of censorship. Second, journalists need access and voluntarily may suspend their principles of independence to gain access to a good story involving science (the Manhattan Project, for example), but it must be a good story. Those wanting coverage should provide journalists with access. Granting access means sharing data and giving interviews at the journalist's convenience.

Today, there is something called science journalism, which means the major news organizations have health and science reporters with knowledge of the environment, physics, biology, medicine and so forth. Thus, journalists need lots of access to scientists and doctors. Thanks to Pulitzer and the evolution of professional journalism, the news standard dictates coverage rather than adherence to party lines and vested interests, and advances in medical science by the end of the 20th century should preclude both journalism and science being on the wrong side of a good issue.

JOURNALISM EDUCATION UNDER FIRE

Journalism education has come under increasing scrutiny in recent years. On one side are those who believe prospective journalists need a good liberal arts education (Planning for Curricular Change in Journalism Education, 1984). The other side argues for a more practical, professionally-oriented program of study (Dorfman, 1984; Friendly, 1984). The debate about what journalists should be taught is akin to the swirling debate at the start of the century about journalism education. Then, it was some college versus no college or whether anyone could teach a *calling* such as journalism. There is a historical argument that journalists are born, not made (Mirando and Fedler, 1999).

An American Society of Newspaper Editors' survey found that 66 percent of the editors with journalism academic backgrounds and 85 percent without such backgrounds favored increasing student course work outside of journalism (Bales, 1992).

In any event, all seem to worry that many new journalism graduates are not prepared when they leave college (Duhe and Zukowski, 1997), and many challenge journalism educators to steer journalists in the right direction (The Jane Pauley Task Force on Mass Communication Education, 1996).

Others (Giles and Cox, 1997) would require the media to be proactive, concluding: "For the past several years, there has been an effort by some newspapers to reconnect with their communities. That is an important piece of our future. What is needed now is for newspapers to enable reporters and editors to acquire the fundamental knowledge of economics, basic science, the environment and other complex topics that are so much in the news."

There is concern, too, that many stories about science and medical research are hyped, presenting preliminary research as breakthroughs (Nicholson, 1998) and criticism that news organizations pay so little attention to science that their audiences are shortchanged (Hartz and Chappell, 1997).

However harsh the criticism, the literature should not be read as an indictment of journalism or journalism education. Introspection does not mean bad journalism or bad education. It means journalists worry they are not as good as they should be. Making journalism and journalism education better is their intent. Some of the harshest critics say, "The complaints come at a time when medical and science reporting has become better than ever." (Nicholson, 1998).

SURVEY OF COLLEGE JOURNALISM PROFESSORS

The question remains: Are journalists qualified to cover health and science, and other complex issues? College journalism professors, the bridge between the present and future of journalism, will be used to suggest answers to this and related questions.

As a careful reading of employment ads in *Editor & Publisher* and *The Chronicle of Higher Education* would verify, most journalism and mass communication deans and chairs covet professors who have worked in journalism jobs as broadcast and print reporters and editors, preferably with five or more years of professional work experience. Many professors continue to write and report for professional news organizations while holding academic rank.

As such, the professors should be expected to have an understanding of student and professional media qualifications. The Association for Education in Journalism and Mass Communication publishes an annual directory that identifies 200 members of the Association of Schools of Journalism and Mass Communication. The membership directory was used

to identify the various journalism and mass communication programs across the country for this telephone survey of professors who teach reporting courses. Each institutional member was contacted by telephone and asked for the name and telephone number of a professor who teaches reporting at that institution. Professors representing 86 institutional members of the Association were interviewed by telephone. The others could not be reached.

SURVEY RESULTS

All survey respondents teach reporting courses. They are veteran journalists averaging 12.29 years of professional work and experienced teachers averaging 13.46 years of teaching reporting courses.

The professors were asked to rate the importance of teaching their students how to report on 11 typical areas (beats) one would expect to read about in a newspaper or magazine, view on television or listen to on a radio newscast. (Table 1). On a scale of 1 to 10, with 10 being the most important, the professors give local government (8.82 mean) their highest rating and low-revenue sports such as soccer (4.78 mean) their lowest. Health and science (7.86 mean) falls in the middle of the list, slightly above the mean for the list (7.37).

That local government, politics, public schools

Table 1. Mean Rating of News Beats Journalism Professors Say Are Important to Teach Their Students How to Cover and Textbooks Used in Beginning and Advanced Reporting Courses.

	Important to Teach[a]	Beginning Book[b]	Advanced Book[c]
News Beats	Rating	Rating	Rating
Local Government	8.82	5.86	6.46
Politics	8.65	5.78	6.08
Public Schools and Education Issues	8.40	4.64	6.31
Criminal Courts	8.39	6.09	6.35
Economics and Business	8.31	5.25	5.50
Health and Science	7.86	4.55	5.08
Private Schools and Education Issues	7.12	2.89	3.87
International Affairs	7.11	3.10	3.06
Charities	6.19	3.00	4.64
Big-Time Sports	5.48	4.13	3.63
Low-Revenue Sports	4.78	2.47	1.75
Mean =	7.37	4.34	4.70

[a]Question. On a scale of 1 to10, with 10 being the most important, how important is it for journalism departments and schools to offer instruction in coverage of: Local government, criminal courts, not-for-profit organizations such as the United Way, Red Cross and other charities, big-time sports such as football and basketball, low-revenue sports such as soccer, diving, swimming and volleyball, health and science issues, economics and business, public schools and education issues, private schools and education issues, international affairs, politics?

[b]Question. Rate the primary textbook you are using for the beginning-reporting course. Please rate the book on a scale of 1 to 10, with 10 being the highest rating. Rate the book's coverage of: Local government, criminal courts, not-for-profit organizations such as the United Way, Red Cross and other charities, big-time sports such as football and basketball, low-revenue sports such as soccer, diving, swimming and volleyball, health and science issues, economics and business, public schools and education issues, private schools and education issues, international affairs, politics.

[c]Question. Rate the primary textbook you are using for the advanced-reporting course. Please rate the book on a scale of 1 to10. with 10 being the highest rating. Rate the book's coverage of: Local government, criminal courts, not-for-profit organizations such as the United Way, Red Cross and other charities, big-time sports such as football and basketball, low-revenue sports such as soccer, diving, swimming and volleyball, health and science issues, economics and business, public schools and education issues, private schools and education issues, international affairs, politics.

Table 2. Percentage of Professors Supplementing Textbooks with Additional Course Materials for Various News Beats and Percentage Knowing Helpful Courses Outside Journalism.

News Beats	Percentage/Supplement[a]	Percentage/Know Courses[b]
Local Government	89.41	85.37
Politics	80.00	83.33
Criminal Courts	78.82	58.33
Public Schools	67.06	58.23
Economics and Business	67.06	84.71
Health and Science	61.18	68.67
International Affairs	50.00	71.08
Private Schools	37.65	40.51
Charities	35.71	25.64
Big-Time Sports	34.12	34.94
Low-Revenue Sports	18.82	36.59
Mean =	56.35	58.85

[a]Question. In your reporting courses, do you supplement the textbook with lectures, handouts and other materials when discussing the coverage of: Yes or No. Local government, criminal courts, not-for-profit organizations such as the United Way, Red Cross and other charities, big-time sports such as football and basketball, low-revenue sports such as soccer, diving, swimming and volleyball, health and science issues, economics and business, public schools and education issues, private schools and education issues, international affairs, politics?

[b]Question. Do you know of other courses on your campus outside your program that would help students learn to cover? Yes or No. Local government, criminal courts, not-for-profit organizations such as the United Way, Red Cross and other charities, bigtime sports such as football and basketball, low-revenue sports such as soccer, diving, swimming and volleyball, health and science issues, economics and business, public schools and education issues, private schools and education issues, international affairs, politics.

and education and criminal courts hold the top spots for importance should be of no surprise. They represent the core of instruction and reflect media preference for content. The news media find them newsworthy because they produce one or more of the elements of news—impact, conflict, novelty, prominence, and timeliness.

Health and science are more difficult to cover than crime and government. While they beat out the sports beat, that probably does not mean that health and science get better coverage than sports. It suggests that journalism professors do not teach much about sports coverage in beginning and advanced reporting courses. Professors tend to concentrate on hard news, more serious items, in these classes. Many professors assume that students will pick up basic reporting values in these classes and apply them to the Big-Time sports beat, such as basketball, football, baseball and hockey. Some schools have separate sports news classes, and some of the big-time sports would be covered as specialized journalism on a growing number of campuses. Low-revenue sports lack impact, an essential ingredient in determining newsworthiness, and do not attract much media attention unless they do something unusual (win the women's World Cup).

Beginning textbooks average a 4.34 rating for how well they cover the 11 news beats versus 4.70 for advanced textbooks (Table 1), with the health and science area getting a 4.55 rating and 5.08 rating, respectively. The six most important beats (Table 1) also are the six best covered by the textbooks. However, the mean ratings for the textbooks fall far short of the mean rating for importance, 7.37 for all of the beats and 7.86 for health and science (Table 1). The difference between means probably indicates unhappiness with the quality of the textbooks. These responses also help explain Table 2, which indicates that most of the professors supplement their textbooks with lectures and handouts and know of

courses outside journalism (and may recommend them) to supplement areas the professors consider important but are not covered adequately by textbooks.

The mean percentage of professors supplementing textbooks for the 11 news beats is 56.35 percent (Table 2), and the mean percentage of professors who know of courses outside journalism (Table 2) is 58.85 overall and 68.67 for health and science.

So how prepared are journalism graduates to cover specific news stories involving complex issues? The professors believe their new graduates are prepared to cover simple stories that reflect their undergraduate training. Journalism professors primarily train their students to cover uncomplicated meetings, deaths, and crimes involving local government, politics, the courts and public schools (Table 3). Most of the specific stories above the mean rating of 6.76 involve simple news items: speech by the mayor, 8.76; college dean driving drunk, 8.62; death of a philanthropist, 8.24. More complex news items fall below the mean: stock market, 4.76; community college finances, 4.81; charter schools, 5.03; federal support for police, 5.82.

There are probably elements of health and science in each of the news items in Table 3, but the most obvious one is the new AIDS treatment, which ranks 12th with a 6.65 rating, slightly less than the mean for all news items.

Table 3. Rating of Professors on How Prepared Graduates Are to Cover Specific News Stories.

Specific News Stories	Rating[a]	Rank
Speech by Mayor	8.70	1
College Dean's DUI	8.62	2
Death of Philanthropist	8.24	3
United Way Campaign	7.81	4
Gift to University	7.78	5
Board of Trustees	7.60	6
Criminal Trial	7.57	7
Lobby City Council	7.40	8
Public Education Reform	7.02	9
Homelessness	6.73	10
Local Government Budgets	6.68	11
AIDS Treatment	6.65	12
Women's Volleyball	6.41	13
Men's Basketball Game	6.37	14
State Supreme Court	6.18	15
Charity Lose Tax Exemption	5.93	16
Changes in AFDC	5.91	17
Federal Support for Police	5.82	18
Charter Schools	5.03	19
Community College Finances	4.81	20
Stock Market	4.76	21
Mean = 6.76		

[a]Question. Rate the preparation of students graduating from your journalism program using a scale of 1 to 10, with 10 being the most prepared .... How do you rate the preparation of students graduating from your journalism program to cover: Municipal and county budgets, charter schools, financing of community colleges (2-year colleges), homelessness in your community, federal support for local police, changes in Aid to Families with Dependent Children (AFDC), a men's basketball game, a criminal trial, a speech by your mayor, a United Way campaign kickoff, your university's board of trustees meeting, state supreme court arguments, the stock market, a breakthrough in the treatment of AIDS, a large gift to the university, a charity losing its tax-exemption, the death of a local philanthropist, lobbying by a local association before the city council, a women's volleyball game, public education reform, the arrest of your college dean for drunk driving?

DISCUSSION

Overall, this article demonstrates the historical linkage between journalism and health and science and answers several questions about the qualifications of journalists who write about health and science. This discussion clearly shows preparation for coverage of simple issues and raises concerns about preparation for coverage of more complex issues

The fact that many news people question journalists' abilities is encouraging and signals efforts to improve news coverage. Many take courses in the natural sciences and physical sciences. While it is apparent that some journalists are not qualified immediately after leaving college, what group of professionals is? Even new physicists and other scientists must absorb knowledge and mature before accepting the Nobel Prize.

Journalists also learn about coverage of health and science and other complex issues through on-the-

job-training and specialized journalism programs sponsored by various foundations at universities across the country.

There is room for optimism (Liebeskind, 1999). The Accrediting Council on Education in Journalism and Mass Communications has accredited more than 100 college and university journalism programs and requires students to take 90 semester hours of a typical 120 hours outside journalism departments (in such areas as history, economics, political science, natural sciences, and mathematics).

At Northwestern University's Medill School of Journalism, for example, those who concentrate in health and medical journalism visit the medical school, research labs, and the Institute of Health Policy to develop an understanding about such beats. The University of Mississippi Department of Journalism puts on professional-development workshops, including one this fall on health and science coverage.

The Knight Foundation has been funding science journalism fellowships since 1983, and its Science Journalism Fellowships at the Massachusetts Institute of Technology encourage journalists to audit courses at MIT and Harvard. More than 140 professionals have gone through Knight's program. The Kaiser Family Foundation also funds six fellowships a year in health. There are other such programs, too.

Still, a close reading of the survey and journalism community's self-criticism indicates much more work needs to be done both within journalism and outside. Scientists who want press attention and those who just care about the portrayal of science in the media should first learn something about the journalistic method, as journalists learn about the scientific method. They should study the publications and television shows for clues about their news requirements, much as one would study an academic journal before submitting a manuscript. Later, when they have an event that needs publicity, they should use the occasion to help educate reporters. Workshops on journalism would help scientists, too. This article should be the beginning and not the end.

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Vegetative and Reproductive Responses of Cotton to Stage-Specific CO_2 Enrichment and Drought Stress

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This study was undertaken to determine the effects of CO_2 enrichment and drought stress during specific stages of vegetative and reproductive development in cotton (*Gossypium hirsutum* L. cv. DPL 51). Cotton plants were grown from seed in 7.6 L plastic pots containing soil:peat:perlite in equal volumetric proportions. Two levels of CO_2 (ambient, 350 µmol CO_2 mol^{-1} air and high, 700 µmol CO_2 mol^{-1} air) and two soil moisture treatments (well-watered and drought-stressed) were imposed at 50 days after planting (i.e., flower bud or square initiation stage) for 14 and 28 days. Growth parameters such as number of nodes, plant height, and number of flower buds (squares) were significantly higher in plants exposed to high CO_2 compared to plants exposed to ambient CO_2. However, at each CO_2 level, well-watered plants were taller, had more nodes and reproductive parts (squares and flowers) than drought-stressed plants. Likewise, total leaf area, total leaf weight, stem weights, root weights, and reproductive biomass were greater in plants exposed to high CO_2 as opposed to plants exposed to ambient CO_2 atmospheres. Generally, these increases in growth parameters were attributed to higher amounts of photosynthates. Most of these increases in growth parameters due to CO_2 enrichment were negated by the greater impacts of drought stress.

Climatic models show that a doubling of the atmospheric CO_2 concentration can be expected by the year 2050 (Keeling and Whorf, 1994; Schneider, 1989). An increased level of carbon in the atmosphere is potentially beneficial to plant primary production (Cure and Acock, 1986) through its direct effects in increasing the rate of photosynthesis (Begonia et al., 1987b) and reducing stomatal conductance (Acock and Allen, 1985; Chen et al., 1993). The benefit of CO_2 enrichment is commonly exploited by commercial growers in greenhouses to enhance yields. Carbon dioxide is also an important greenhouse gas and any increase in its atmospheric concentration could lead to changes in global climate, including precipitation patterns that could result in increased drought conditions in some areas of the world.

Numerous reviews (Allen, 1990; Bowes, 1991; Cure and Acock, 1986; Dahlman et al., 1985; Farrar and Williams, 1991; Kimball, 1983; Stitt, 1991) have documented the effects of both short- and long-term CO_2 enrichment on photosynthesis and biomass accumulation in both vegetative and reproductive components of several plant species. However, little work has been done to study the combined effects of elevated CO_2 and drought stress imposed at specific stages of growth of the cotton plant. This paper examines the combined influence of two atmospheric CO_2 concentrations (350 and 700 µmol CO_2 mol^{-1} air) and two soil moisture treatments on growth, biomass partitioning and reproductive yield of cotton.

MATERIALS AND METHODS

Plant Culture and Experimental Design—Plants were grown under natural daylight at the Jackson State University glasshouse during the spring of 1997. The daylight period was extended to 12 hrs using high intensity super halide lamps (1000 W H.Y. Lites Horizontal System, High Yield, Inc., Camas, WA). The photosynthetically active radiation (PAR; 400–700 nm) measured at the canopy level was no less than 1800 µmol photons m^{-2} s^{-1} at midday with no clouds. Five seeds of cotton (*Gossypium hirsutum* L. cv. DPL 51) were sown in each 7.6 L plastic pot containing top soil, peat and perlite in equal volumetric proportions. Two weeks after planting, emerged seedlings were thinned out to 2 seedlings per pot. All plants were well watered on a regular basis depending

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on the evaporative demand. An equal amount of full strength nutrient solution (Triplett et al., 1980) was added to each pot once a week for the first 4 weeks; thereafter, 250 ml of a fertilizer solution (Peters 20% N–20% P_2O_5–20% K_2O; 9.5 mg ml^{-1}) were added at weekly intervals.

At 7 weeks after planting (i.e., squaring stage), two CO_2 levels (350 and 700 µmol CO_2 mol^{-1} air) and two soil moisture treatments (well-watered and drought stressed) treatments were imposed. Ambient air (approximately 350 µmol CO_2 mol^{-1} air) was flushed into the base of open-top chambers (0.76 m wide x 1.25 m long x 0.94 m deep) enclosing 10 pots. Except for the bottom and top, all sides of the chambers were covered with transparent (100% light transmission) plastic film. Carbon dioxide enrichment was achieved by metering CO_2 into the air stream to give approximately 700 µmol CO_2 mol^{-1} air during the daylight hours. Carbon dioxide concentrations were monitored with an infrared gas analyzer (LI-COR 6200 portable photosynthesis system, LI-COR, Inc., Lincoln, NE) and were regulated at least twice daily by adjusting a flow meter installed in the CO_2 stream entering the chamber. Drought-stressed plants received only half the volume of irrigation water added to well-watered plants as gravimetrically determined from a preliminary experiment. Each pot containing 2 plants represented a replicate. Experimental units were arranged in split-plot in a Completely Randomized Design with 10 replications. Carbon dioxide and soil moisture treatments were designated as main plots and sub-plots, respectively. To eliminate positional effects, pots within a chamber were rearranged at least three times a week.

Growth, Gas Exchange and Water Potential Measurements—Plant height from ground level to the shoot tip, number of nodes and dead leaves (>50% chlorotic leaf blade), and number of reproductive structures (e.g., squares, flowers and bolls) were monitored on tagged plants at weekly intervals during the treatment period. Two and four weeks after initiation of CO_2 and soil moisture treatments, sample plants were harvested for measurements of dry matter distribution. At each harvest, the plants were separated into leaves; stems which consisted of the main stem, branches and petioles; and reproductive components, then oven-dried at 75°C for 48 hours. Areas of mainstem and branch leaves for each plant were also measured with a LI-COR 3000 portable leaf area meter (LI-COR Inc., Lincoln, NE). During the treatment period leaf elongation rates were monitored from the three youngest leaves (i.e., nodes 8, 9, and 10) at the top of each plant's canopy. Leaf lengths were measured from the base of the leaf blade to the tip of the median lobe using a millimeter ruler. Leaf gas exchange rates and associated parameters were determined for several days between 1000 and 1400 hours (CDT; minimum photon flux density, 1800 µmol photons m^{-2} s^{-1}) from the youngest, most fully expanded leaf using a LI-COR 6200 portable photosynthesis system. Also, water potentials were obtained from leaves of similar morphological age as those used for gas exchange measurements using a pressure bomb (Soil Moisture Equipment Corp., Santa Barbara, CA).

RESULTS

Leaf production, expressed as number of nodes per plant, was similar among plants prior to imposition of CO_2 and soil moisture treatments (Fig. 1A). At different days after treatment, the plants exposed to elevated CO_2 had significantly more leaves than those grown at ambient CO_2. Under a given CO_2 treatment, the number of nodes was greatly reduced in drought-stressed plants compared to well-watered plants (Fig. 1A). Stressed plants stopped producing additional leaves 14 days after CO_2 and soil moisture treatments were imposed.

After treatments were imposed, plant heights were significantly greater under elevated CO_2 than at ambient CO_2 atmosphere (Fig. 1B). Well-watered plants exposed to high CO_2 grew from an average 30.5 cm at 50 days after planting (DAP) to 49.6 cm at 77 DAP, whereas ambient CO_2-grown plants grew from 30.6 cm to 41.8 cm during the same growth period. Within a given CO_2 treatment, cotton height was significantly diminished by drought stress.

Regardless of CO_2 or soil moisture treatment, cotton plants had similar number of flower buds or squares at 50 days after planting (Fig. 1D). With increasing exposure periods, plants grown at high CO_2 had significantly more squares than those grown at ambient CO_2 especially at 77 days after planting. Within each CO_2 treatment, however, well-watered plants produced two times more squares than drought-stressed plants. This indicated that the positive influence of CO_2 enrichment was negated by drought stress.

Flower production was not enhanced by CO_2 enrichment (Fig. 1D). Cotton plants grown in enriched CO_2 atmospheres produced an average 6.3

flowers per plant at 77 days after planting in contrast to 5.9 flowers per plant for ambient CO_2-grown plants. The effects of drought stress on flower production was not evident in high CO_2-grown plants. However, drought-stressed plants grown in ambient CO_2 produced 59% less flowers per plant, compared to their well-watered counterparts.

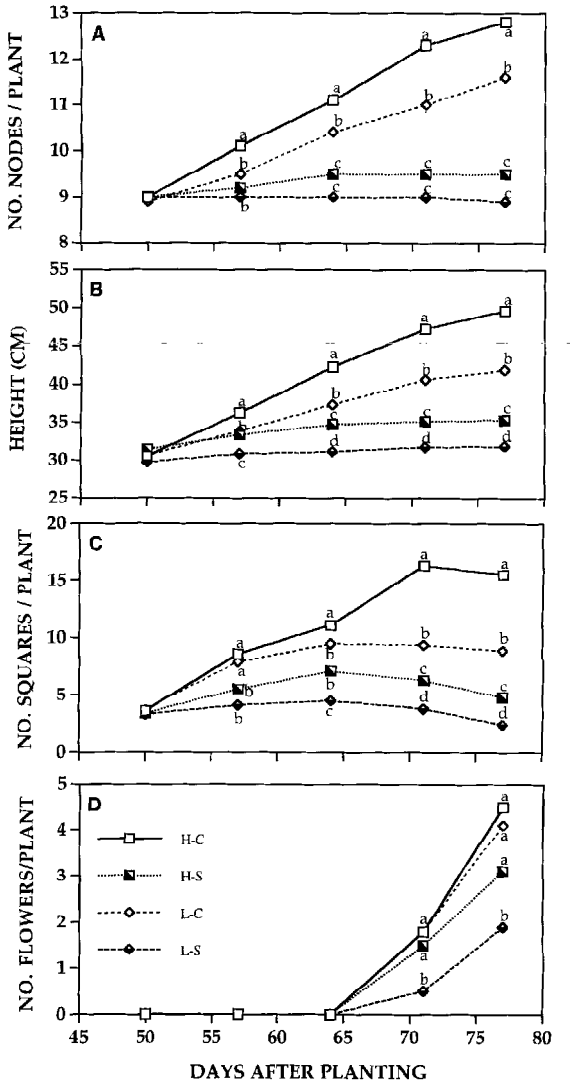

Figure. 1. Number of nodes (A), height (B), number of squares (C), and number of flowers (D) of cotton plants at different days after planting as influenced by CO_2 and soil moisture treatments. Within each observation date, means with a common letter are not significantly different from each other according to LSD test (P 0.05). (H-C= 700 µmol CO_2 mol^{-1} air, well-watered; H-S = 700 µmol CO_2 mol^{-1} air, drought-stressed; L-C = 350 µmol CO_2 mol^{-1} air, well-watered; L-S = 350 µmol CO_2 mol^{-1} air, drought-stressed.)

Total leaf area (cm^2 /plant) at 2 and 4 weeks after CO_2 and soil moisture treatments are shown in Fig. 2A . Leaf areas of CO_2-enriched plants were significantly greater than those of ambient CO_2-grown plants especially after a longer exposure period. Within each CO_2 treatment, well-watered plants had greater leaf areas than plants subjected to drought.

Total leaf biomass (g/plant) at 2 and 4 weeks after CO_2 and soil moisture treatments are presented in Fig. 2B. Similar to the leaf area response, leaf weights were greater in plants exposed to high CO_2 than those grown in ambient CO_2. The impact of high CO_2 on leaf weight was more evident at 4 weeks compared to 2 weeks after initial exposure. Drought stress exerted more influence on leaf weight than CO_2, since drought-stressed plants grown at elevated and ambient CO_2 had 62% and 53% less leaf biomass, respectively, than the well-watered controls.

Based from their stem weights, plants exposed to high CO_2 were bigger and more vigorous compared to those grown at ambient CO_2 especially after a 4-week exposure period (Fig. 2C). High CO_2-grown plants had 37% more stem biomass than ambient CO_2-grown plants. However, the effect of drought was more dramatic. Drought-stressed plants exposed to high and ambient CO_2 had 51% and 42% less stem biomass, respectively, than the well-watered controls.

Carbon dioxide enrichment did not affect photosynthate partitioning to the roots after a 2-week exposure period (Fig. 3A). The effect of CO_2 on root biomass was more evident at 4 weeks after treatment, since high CO_2-grown plants had 40% greater root biomass than ambient CO_2-grown plants.

Carbon dioxide exposure did not play a significant role in the preferential allocation of photosynthates to the roots as opposed to the shoots. This is gleaned from the nonsignificant difference in root/shoot ratios between high CO_2-grown and ambient CO_2-grown plants (Fig. 3B). However, drought stress exerted a greater influence on the partitioning of photosynthates to the roots, and this drought effect was more discernible at 4 weeks after the initial treatment. For instance, drought-stressed plants exposed for 4 weeks to high CO_2 and ambient CO_2 had 28% and 42% greater root/shoot ratios respectively, than the

corresponding well-watered plants.

Biomass of reproductive organs (e.g., squares, flowers, bolls) at 2 and 4 weeks after CO_2 and soil moisture treatments are shown in Fig. 3C. There was no significant effect of CO_2 exposure on reproductive organ biomass at 2 weeks after treatment. However, high CO_2-grown plants had 52% more reproductive biomass than ambient CO_2-grown plants at 4 weeks after initial exposure. The effects of drought stress was more evident since drought-stressed plants grown at high and ambient CO_2 environments had 52% and 67% less reproductive biomass, respectively, than their well-watered counterparts.

The effects of CO_2 and soil moisture on leaf length (i.e., an indicator of leaf expansion) at the three youngest, uppermost nodes are presented in Figures 4A, B, C. Carbon dioxide enrichment did not significantly affect leaf lengths. However, drought stress exerted more negative effects on leaf lengths. Regard-

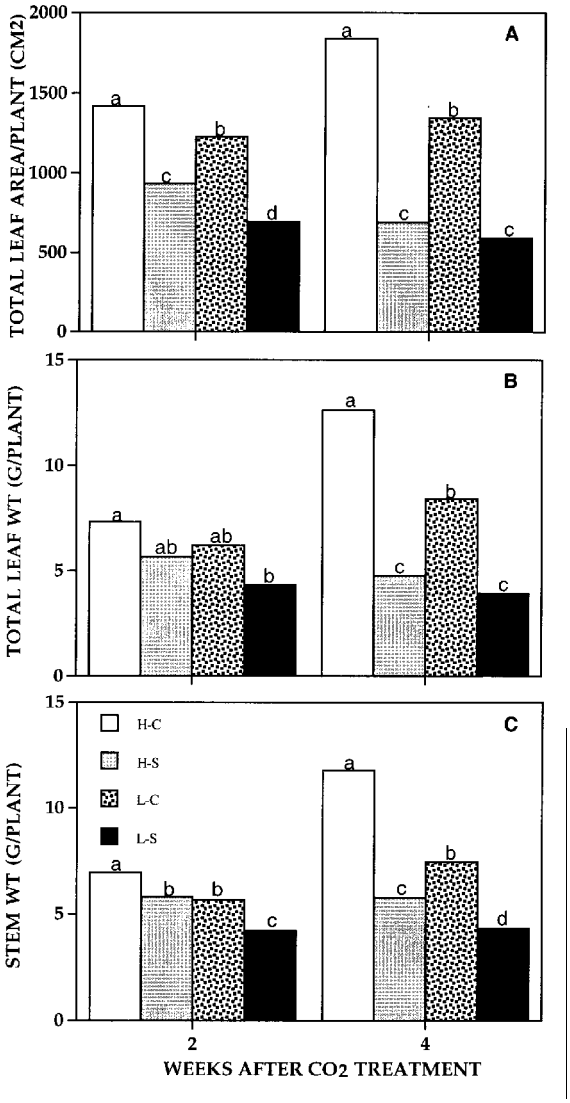

Figure. 2. Total leaf area (A), total leaf weight (B), and stem weight (C) per plant at 2 and 4 weeks after initial CO_2 and soil moisture treatments. Within each observation date, means with a common letter are not significantly different from each other according to LSD test (P 0.05). See Fig. 1 for nomenclature.

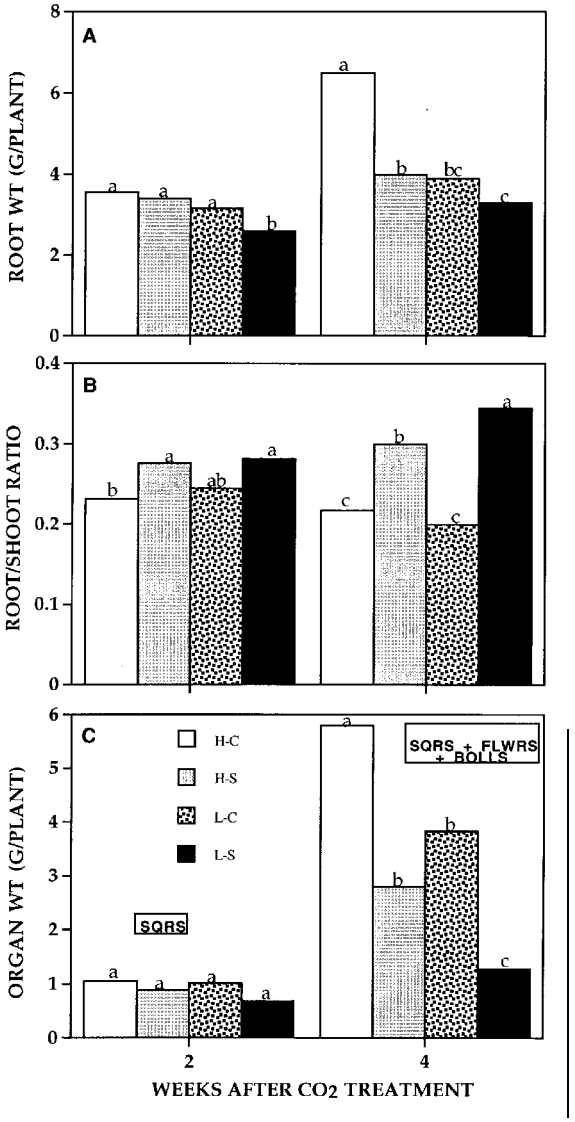

Figure. 3. Root weight (A), root/shoot ratio (B), and organ weight (C) of cotton plants at 2 and 4 weeks after initial CO_2 and soil moisture treatments. Within each observation date, means with a common letter are not significantly different from each other according to LSD test (P 0.05). See Fig. 1 for nomenclature.

less of CO_2 concentration, drought-stressed plants generally had less leaf lengths than well-watered controls. Noticeably, the effects of drought on leaf expansion were more severe in relatively younger leaves (Figs. 4A, B) than older leaves (Fig. 4C). The number of dead leaves as a function of CO_2 and soil moisture treatments are shown in Fig. 4D. Carbon dioxide did not exert any significant influence on leaf senescence. However, drought-stressed plants abscised more leaves than well-watered plants.

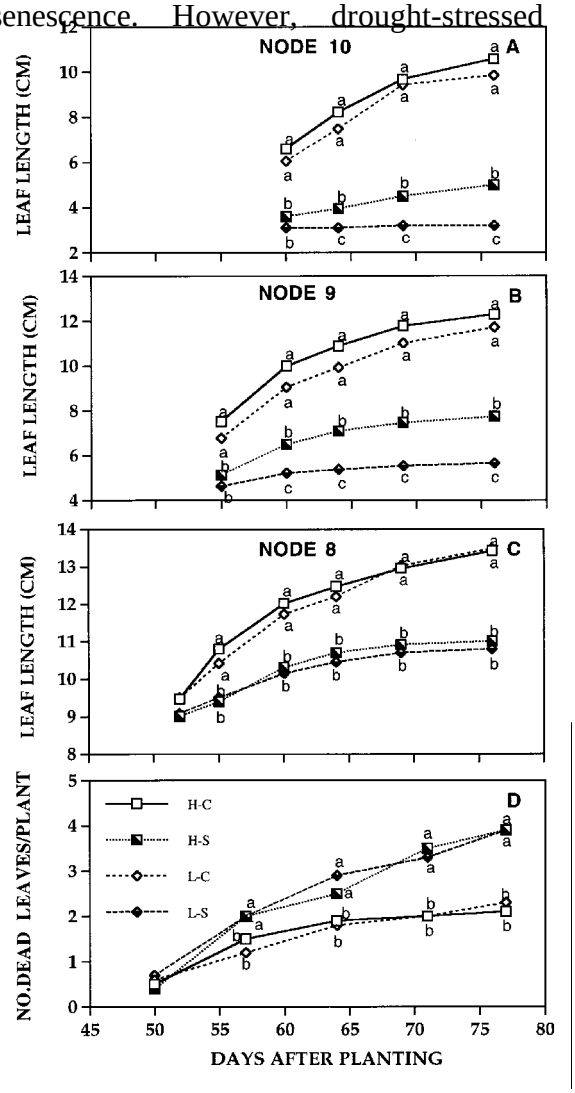

Figure. 4. Leaf lengths at nodes 10 (A), 9 (B), and 8 (C), and number of dead leaves per plant (D) at various days after planting as influenced by CO_2 and soil moisture treatments. Within each observation date, means followed by a common letter are not significantly different from each other according to LSD test (P 0.05). Nodes were counted acropetally, meaning that node 1 is the lowermost node in a plant. See Fig. 1 for nomenclature.

The effects of CO_2 and soil moisture treatments on leaf net photosynthetic rates (Pn) are shown in Fig. 5A. Although there were fluctuations in Pn during the exposure periods, high CO_2-exposed plants had an average 44% more rapid Pn than ambient CO_2-grown plants. The effects of water stress on Pn was more discernible. Under ambient CO_2 conditions, drought-stressed plants exhibited an average 74% reduction in Pn compared to well-watered plants. The effects of drought stress on Pn was less under high CO_2 exposure since drought-stressed plants had only 66% less Pn than the well-watered plants, signifying that high CO_2 slightly counteracted the negative effects of drought stress on Pn.

Carbon dioxide exposure did not alter the leaf water potential of cotton plants as indicated by the non-significant difference in leaf water potentials between high CO_2-grown and ambient CO_2-grown plants (Fig. 5B). Regardless of CO_2 treatments, drought-stressed plants showed more negative water potentials than well-watered plants. It was noted that high CO_2 exposure did not counteract the negative influence of an unfavorable water environment.

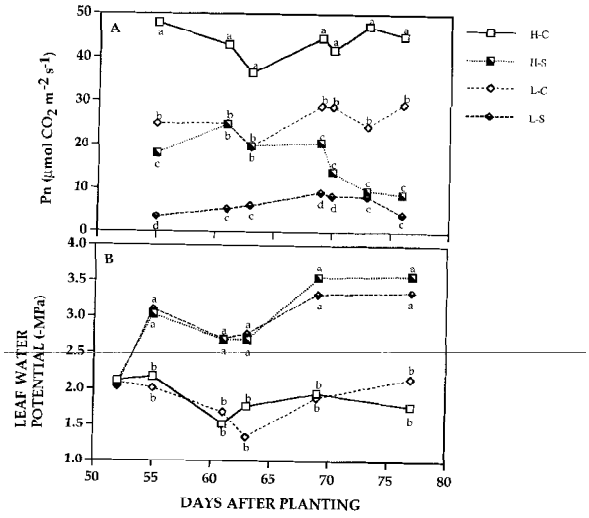

Figure. 5. Leaf net photosynthetic rate (Pn) (A), and leaf water potential (13) of cotton plants at different days after planting as affected by CO_2 and soil moisture treatments. Within each observation date, means followed by a common letter are not significantly different from each other according to LSD test (P 0.05). See Fig. 1 for nomenclature.

DISCUSSION

Some of the morphological changes during growth in enhanced CO_2 may be related to the increased availability of photosynthates which leads to increased development of sinks, or the initiation of new sinks. For example, bushiness (the development of secondary shoots) could be a response to increased carbohydrate (Kramer, 1981). Increased tillering in cereals in enhanced CO_2 (Cloux et al., 1987) could also be a response to increased carbohydrate, which has been reported to modify apical dominance (Wardlaw, 1990). In the present study, the increased availability of photosynthates resulting from CO_2 enrichment favored development of new sinks (i.e., increased rates of leaf initiation or node production). This was the main reason why high CO_2-grown plants had more leaves or nodes than ambient CO_2-grown plants (Fig. 1A). Under a given CO_2 level, however, drought stress suppressed the production of new leaves. Aside from the cessation of leaf production, drought stress also accelerated senescence of existing leaves (i.e., increased number of dead leaves) (Fig. 4D). A previous study by Begonia et al. (1987a) reported a decreased leaf duration (equivalent to accelerated leaf senescence) in some plant species subjected to drought stress.

Main stem height increments in higher CO_2 concentrations resulted from stimulation of internode elongation as well as greater node numbers (Fig. 1A). The increased supply of photosynthates forced the development of new sinks such as leaves, flower buds, and other reproductive organs (Figs. 1A, 1C, 1D). In a previous CO_2 enrichment study, a large number of sinks in many seeds of gynoecious cucumbers had been observed as a positive response to enhanced CO_2 (Kimball, 1983). Also, during reproductive growth, the elevated carbohydrate supply may allow greater floral induction or seed set (Ho, 1977). Reproductive yields of soybean were also enhanced in high CO_2 atmospheres (Rogers et al., 1984). More likely, high CO_2 during grain filling period resulted in less pod abortion (Ackerson et al., 1984).

In the present study, the higher numbers (Figs. 1C, 1D) and biomass of reproductive organs (Fig. 3C) due to CO_2 enrichment were ascribed to greater amounts of assimilates (Fig. 5A). Within a CO_2 level, however, drought-stressed plants had less numbers (Figs. 1C, 1D) and weights of reproductive structures (Fig. 3C) due to unfavorable water status (see Fig. 5B). Cotton plants had been shown to produce less nodes and consequently less fruiting points when they experience drought (Begonia et al., 1986).

Cotton plants grown at 700 µmol CO_2 mol^{-1} air had greater above ground dry biomass than plants grown at ambient CO_2. Increases in above-ground biomass were primarily due to increases in node number, height, leaf area, leaf biomass as well as stem and reproductive organ weights. Cure and Acock (1986) examined data for ten leading crops (8 C_3 and 2 C_4) exposed to doubling of CO_2. Despite the existence of photosynthetic acclimation, nine out of ten species accumulated 30% more biomass. A limitation in the availability of water, as often encountered in the field, can curtail growth responses in elevated CO_2. This present study showed that indeed, drought-stressed cotton plants had reduced biomass compared to their well watered counterparts.

Carbon dioxide enrichment did not play a significant role in the preferential allocation of photosynthates to the roots as opposed to the shoots as evidenced by the non-significant difference in root/shoot ratios between high CO_2-grown and ambient CO_2-grown plants (Fig. 3B). In a literature survey on CO_2 enrichment studies by Cure and Acock (1986), cereal plants often did not show long-term changes in the partitioning of assimilates between root and shoot in response to increased CO_2. Also, in tree saplings provided with sufficient nutrients, there was no change in root/shoot ratio at higher CO_2 concentrations (Eamus and Jarvis, 1989).

However, drought stress exerted a greater influence on the partitioning of assimilates to the roots, and this drought effect was more discernible at 4 weeks after initial treatment. As a survival strategy, drought-stressed plants usually allocate more photosynthates to their roots at the expense of their shoots.

The increase in leaf area per plant (Fig. 2A) due to CO_2 enrichment, resulted primarily from more rapid leaf emergence (i.e., more node number) (Fig. 1A) and from accelerated expansion rates (i.e., greater leaf lengths) (Figs. 4A, 4B, 4C). Increased expansion of leaves due to CO_2 enrichment had been ascribed to increased availability of carbohydrates (Kramer, 1981; Hinkleton and Joliffe, 1980; Cure et al., 1989). On the other hand, the reduced leaf area in drought stressed plants was attributed to less leaf production (Fig. 1A) coupled with more rapid leaf senescence (Fig. 4D). Moreover, the reduction in leaf area was attributed to a decline in leaf water potentials (Fig. 5B) due to

drought stress.

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Analysis of Developmental Toxicity Data with Litter Size Treated as Random

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This paper discusses a procedure based on generalized estimating equations for analyzing data from developmental toxicity studies when litter size is considered to be random. Most well known procedures commonly used condition on litter size. The GEE's provide a means of determining the effect on variance estimation of conditioning on litter size. Also discussed is a means of testing for dose effects on litter size.

In a typical developmental toxicity study females of a certain species are randomly assigned to dose groups and then exposed to fixed levels of a toxin to determine the effects of exposure on their offspring. Typically outcomes such as fetal death, resorption, and malformation are measured on the offspring as binary events. Of interest is the proportional risk of an outcome of interest (typically death or malformation) measured with respect to number of implantation sites or number of live births, either of these quantities being termed litter size. The number of live births may be defined as the number of implantation sites less the number of fetal deaths and resorptions. In many studies the litter size is seen to decline with increasing exposure level, indicating increasing risk. Clearly if exposure occurs after implantation the litter size could be effected by the exposure thereby contributing to the overall risk of the toxin. If exposure occurs prior to implantation, the number of sites implanted could be reduced if the toxin had an effect on fertility.

To illustrate typical developmental studies and how they may vary, consider three published data sets. The first data set was analyzed in Bowman et al., (1995) and involved a study of developmental effects following exposure of hydroxyurea given to mice. The data consisted of one control and three treatment groups corresponding to exposure levels of 0, 150, 200, and 250 ppm. The number of females, or the number of litters, in the four groups is shown in Table 1. The endpoint or outcome of interest in this analysis was death/resorption and the number of implantation sites was measured for each litter. Average number of implantation sites within the four groups are shown in Table 1. For this chemical there does not appear to be a dose effect on the number of implantations. The observed proportions of death/resorption per number of implantations in the four groups are also shown in Table 1 and indicate a clear relationship between the outcome of fetal death and exposure to hydroxyurea. In this study exposure to the chemical hydroxyurea occurred prior to implantation. So if a significant effect of exposure to hydroxyurea is observed on the number of implantation sites, for example if they are seen to decrease with increasing exposure levels, then the number of implantation sites could become an additional outcome of interest when determining the effects of hydroxyurea on fertility.

The second data set is referred to as the Shell toxicology data and was analyzed in Paul (1982). In this experiment pregnant rabbits were exposed to a toxic substance and skeletal or visceral abnormalities were observed on the offspring. The number of litters per dose group is shown in Table 1. Paul does not discuss the actual levels of exposure nor the chemical being studied. The observed proportions of malformation per litter size (here litter size is defined as the number of live fetuses) are given in Table 1. The pattern of the observed malformation rate is not strictly monotonic, but seems to increase to the third dose group and decrease after. The average litter sizes in each of the four groups, given in Table 1, appear consistent with a tendency for litter size to decrease with increasing dose. In this study, litter size is measured as the number of live births. This is the same quantity as the number of implantation sites less the number of fetal deaths and resorptions. In this case, the observed dose effect on litter size can be interpreted as an increased rate of fetal death due to increased exposure levels. The litter size can thus be considered an outcome of the experiment which can be used to measure the risk of fetal death due to

Table 1. Estimates of Mean Response and Average Litter Size.

	Number of Litters	GEE Mean Response	Observed Mean Response	GEE Ave. L.S.	Observed Ave. L.S.
Hydroxyurea Data					
Dose Group l	17	.0069(.076)	.034	10.451(.747	10.3
Dose Group 2	13	.1615(.121)	.107	)	10.8
Dose Group 3	8	.3684(.106)	.451	10.798(.423	12.8
Dose Group 4	19	.6385(.135)	.671	)	10.5
				10.913(.473	
				)	
				11.029(.595	
				)	
Shell Toxicology Data					
Dose Group l	27	.1225(.237)	.1349	7.925(.828)	8.0
Dose Group 2	19	.1584(.336)	.1353	7.338(l.001)	7.0
Dose Group 3	21	.2024(.562)	.3444	6.751(l.527)	7.2
Dose Group 4	17	.2548(.854)	.227	6.164(2.162	5.9
				)	

exposure.

The final data set considered here is from a dominant lethal assay discussed in Luning et al. (1966). A portion of the data was analyzed in Rai and Van Ryzin (1985) where litter size was considered a covariate in the dose-response model, i.e. the authors assumed that litter size affects the response rate. Here male mice of CBA strain were given doses of 0, 300 and 600 rads of radiation and were mated with females of the same strain within the first 7 days after exposure. The number of females in each dose group in order of increasing dose was 683, 604, and 486. The observed response was fetal death. The observed response rates per number of implantation sites for the three dose groups were .0996, .2526, and .3982. Here litter size is the number of implantation sites and average litter sizes were 7.0, 6.6, and 6.2.

The reduction in litter size appears moderate. Since litter size for the radiation experiment refers again to implantation sites, the litter size could be considered an outcome which can be used to measure the effects of radiation on fertility.

In recent years several authors (e.g., Curtis et al., 1988; Donner, 1993; McDermott et al., 1988; Schukken et al., 1991) have discussed measuring treatment effects on animals when whole litters, herds, or flocks are sampled. The responses of animals within the same litter (or herd) tend to be more similar than responses of animals across litters. This litter effect, termed intralitter correlation, is well documented in the statistical literature (Donner, 1993; Kupper, et al., 1986; Ryan, 1992; and Williams,1975) and typically results in over-dispersion in the data, that is, the observed variation is greater than would be expected if the littermates responded independently. Most statistical procedures proposed for analyzing data of this type account for the overdispersion due to the litter effect. These procedures include the beta-binomial model (Williams, 1975), GEE procedures (Lipsitz, Laird, and Harrington, 1991), non-parametric procedures (Gladen, 1979) and adjusted chi-square tests (Donner and Donald, 1988).

Each of the procedures referenced in the previous paragraph which account for overdispersion due to the litter effect implicitly assumes that litter size is fixed, non-random, and not influenced by exposure to the toxin. The variation of the litter size distribution is not considered in the resulting analysis despite the fact that the variation of litter sizes also contributes to the total variation observed in the response variable. Some authors have attempted to address the effects of litter size in a developmental study. Rai and Van Ryzin (1985) propose a model where litter size is treated as a covariate in the analysis. However, Rai and Van Ryzin do not provide for the correlation among litter mates in their analysis, nor do they provide a means for associating litter size with exposure level. Commenting on this procedure, Williams (1987) suggests a model incorporating the intralitter correlation while modeling response as a

function of dose level and litter size, and also accounting for interaction between dose level and litter size. More recently, Bowman and George (1995) construct maximum likelihood estimates of the parameters of a model based on an assumption of exchangeability between litter mates. This estimation procedure does not condition on litter size, but assumes a multinomial distribution for the litter sizes, although they do not provide a means of associating litter size with exposure level.

The focus of this paper is to develop models for analyzing developmental data which incorporate random litter size into the analysis and provide means for estimating dose effects on litter sizes. Intralitter correlation is accounted for in the model although it is not explicitly modeled as a function of exposure (Bowman, Chen, and George, 1995). The method, involving the use of estimating equations, provides a test for treatment effect on the response of interest (death or malformation) and on litter size. The effect of conditioning on litter size in the analysis is also examined. The method is illustrated on the published data sets from developmental studies previously discussed.

MATERIALS AND METHODS

Consider an experiment with g dose levels, $d_1, d_2, \ldots, d_g$. At the ith dose level there are m_i females. In the jth litter of the ith dose group suppose there are observed x_{ij} positive responses out of a litter of size n_{ij} for $j = 1, \ldots, m_i$ and $i = 1, \ldots, g$. Let random variable Y_{ijk} be equal to 1 if the kth offspring in the jth litter of the ith dose group exhibits a positive response (typically death or malformation) and 0 otherwise for $k = 1, \ldots, n_{ij}$, $j = 1, \ldots, m_i$, and $i = 1, \ldots, g$. Then Y_{ijk} is the response random variable. Assume that the moments of the litter size random variable, N_{ij}, are given by $E(N_{ij}) = \ddot{e}_i$ and $Var(N_{ij}) = \hat{o}\acute{\imath}(\ddot{e}_i)$, where $\hat{o}$ is an unknown constant and $\acute{\imath}(\ddot{e}_i)$ is a known function of $\ddot{e}_i$ For example, if the N_{ij} follow a Poisson distribution, then $\acute{\imath}(\ddot{e}_i) = \ddot{e}_i$ and $\hat{o} = 1$.

Assume the following population parameters represent the conditional mean, variance and correlation of Y_{ijk}, the binary random variable of response

$$\begin{aligned} E(Y_{ijk} \mid N_{ij} = n_{ij}) &= \mu_i \\ Var(Y_{ijk} \mid N_{ij} = n_{ij}) &= \mu_i(1-\mu_i) \\ corr(Y_{ijk}, Y_{ijh} \mid N_{ij} = n_{ij}) &= \ddot{o}_i \end{aligned} \qquad (1)$$

for $k \neq h$. Here μ_i is the conditional mean response at dose level i and $\ddot{o}_i$ is the intralitter correlation there. Let $X_{ij} = \sum_{k=1}^{N_{ij}} Y_{ijk}$ so that random variable X_{ij} is the number of positive responses in the jth litter of the ith dose group. It is now possible to derive the unconditional mean and variance of the random variables X_{ij} using properties of conditional expectation (see Bartoszynski and Niewiadomska-Bugaj, 1996, for example). For the derivations see Appendix 1. Then

$$E(X_{ij}) = \mu_i \ddot{e}_i \qquad (2)$$

and

$$\begin{aligned} Var(X_{ij}) = {} & \lambda_i \mu_i (1-\mu_i) + \\ & \phi_i \mu_i (1-\mu_i)(Var(N_{ij}) + \lambda_i^2 - \lambda_i) + \\ & \mu_i^2 Var(N_{ij}). \end{aligned} \qquad (3)$$

Thus the unconditional mean of X_{ij} is equal to the conditional mean times the mean of the litter size distribution and the unconditional variance of X_{ij} is a function of the conditional mean and correlation as well as the mean and variance of the litter size distribution. To determine the effect of conditioning on litter size in the variance of X_{ij}, note that the extra term in $Var(X_{ij})$ due to the randomness of N_{ij} is given by

$$(\phi_i \mu_i (1-\mu_i) + \mu_i^2) Var(N_{ij}) \qquad (4)$$

which is positive if $\ddot{o}_i$ is greater than or equal to zero.

In this paper, following Rai and Van Ryzin (1985), a Poisson variance assumption is made for the litter size distribution. So that

$$\begin{aligned} Var(N_{ij}) &= E(N_{ij}) = \ddot{e}_i \\ Var(X_{ij}) &= \lambda_i \mu_i + \phi_i \lambda_i^2 (1-\mu_i). \end{aligned} \qquad (5)$$

The extra variation due to litter size given in equation 4 for this assumption is

$$ExVar = (\phi_i \mu_i (1-\mu_i) + \mu_i^2) \lambda_i. \qquad (6)$$

Although it has been noted by McCaughran and Arnold (1976) that typically litter size variation is smaller than the Poisson model, simple chi-square

goodness of fit tests for the data sets discussed here indicate that Poisson variation provides adequate fit to the litter size distributions.

To determine the effect of dose and other covariates on positive response and litter size, generalized estimating equations may be derived similar to those given in Bowman, Chen, and George (1995). The specifics of these derivations are given in Appendix 2.

To implement the generalized estimating equations developed in Appendix 2, link functions relating mean response rate to dose level and average litter size to dose level must be specified. In the examples given here for the mean response μ_i, a logistic dose response function, $log(\mu_i/(1-\mu_i)) = \hat{a}_1 + \hat{a}_2 d_i$ was assumed. Here d_i is the dose level in the ith dose group. The logistic link function is a reasonable choice for the mean response since it is the canonical link function for a binomial distribution.

A linear dose response model was assumed for the mean litter size $\ddot{e}_i = \acute{a}_1 + \acute{a}_2 d_i$, where $\acute{a}_1$ may be interpreted as the mean litter size in the control group (exposure level is zero) and $\acute{a}_2$ is the change in average litter size with dose level. The choice of the link function for the litter size distribution was motivated by the suggestions of McCullagh and Nelder (1989) in jointly modeling mean and variance functions, since the focus of this paper is the manner in which the litter size variance contributes to overall variation in the response data. McCullagh and Nelder suggest linear or logarithmic link functions for modeling variance components. Originally the log link was used since it is also the canonical link function for the Poisson distribution, however, identical estimates for average litter size arose from both the log link and the linear link functions. The linear link function was chosen to illustrate the method as it provided more conservative estimates in terms of standard errors.

RESULTS

The procedure for modeling random litter size in conjunction with a binary response of interest is illustrated on the three published data sets from developmental studies discussed in the introduction. Parameter estimates of the link functions are obtained from the generalized estimating equations derived in Appendix 2 using an iterative procedure described there. The estimation procedure was programmed using SAS IML and the code is available upon request.

In each of the data sets, simple chi-square goodness of fit statistics for the number of positive responses, X_{ij} indicated that the model provided adequate fit to the data. In addition for each data set, the parameter relating positive response to dose level, $\hat{a}_2$ was significant, indicating increasing risk of fetal death (or malformation) with increasing dose.

Recall that for the litter size distribution, a linear link function relating mean litter size to dose level was assumed, $\ddot{e}_i = \acute{a}_1 + \acute{a}_2 d_i$. The parameter estimate, $\hat{\alpha}_2$, relating litter size to dose gives a means of testing for a dose effect on litter size by testing the hypothesis $H_0 : \acute{a}_2 = 0$. In the alternative, if $\acute{a}_2 > 0$ litter size increases with increasing dose while if $\acute{a}_2 < 0$ litter size is said to decrease with increasing dose levels. Asymptotic normality of the estimates resulting from the GEE procedure is assumed in order to test the null hypothesis. This assumption seems reasonable in the data sets examined here where there are between 57 and 1773 total litters examined.

In the hydroxyurea data the estimate of $\acute{a}_2$ was 0.231 with a standard deviation of .414 indicating exposure to hydroxyurea did not have a statistically significant effect on litter size. Relating to the previous discussion of the hydroxyurea data, if litter size is considered as an outcome of the experiment designed to measure effects of hydroxyurea on fertility, the conclusion would be that no statistically significant relationship between exposure to hydroxyurea and changes in fertility is evident.

In the Shell toxicology data $\acute{a}_2$ was estimated to be –.587 with standard deviation of .256 indicating that litter size decreases significantly with increased exposure. If litter size is considered as an outcome of the experiment designed to measure effects of the material on fetal death, the results of this procedure would indicate that there is a significant statistical relationship between exposure to the material and reduction in litter size (increase in fetal death).

In the radiation data, the estimate of $\acute{a}_2$ was –.0224 with a standard deviation of .0014, indicating a significant dose effect on litter size. Recall that in the radiation data the litter size was measured as number of implantation sites. The results of this procedure indicate that if litter size is considered as an outcome of the experiment, there is a statistically significant relationship between exposure to radiation and reduction in fertility.

The estimated values of μ_i and $\ddot{e}_i$ together with the observed proportion of positive responses and the observed average litter sizes are given in Table 1 for both the hydroxyurea data and the Shell toxicology

data. Estimates of the standard error of the values are given in parenthesis.

The estimates of mean response for the hydroxyurea data follow the pattern of the observed proportions of mean response fairly well. There seems to be underestimation in the lowest dose group, which may indicate that the logistic link function does not fit particularly well for this data set. In practice other link functions should be tried to obtain a better fit. These results are not included here. In the Shell Toxicology data, the observed proportions of mean response show a downturn in the fourth dose group. The logistic link function specified for mean response is strictly monotonic and may not be flexible enough to pick up a such a downturn. As a result of having an inadequate dose-response model, the standard errors of the GEE estimates are quite large in each dose group. The fit could be improved by selection of a quadratic dose response function with the GEE procedure. For comparison purposes with the other data, this model is not included here.

For the radiation data it is desirable to compare the estimates from the GEE procedure introduced here with those of Rai and Van Ryzin (1985), however their procedure included litter size as a covariate, resulting in different estimates of mean response for different litter sizes. For this reason the radiation data is not included in Table 1. Computation of the Rai and Van Ryzin estimates of mean response at the average litter size within each dose group results in values of .1022, .2505, and .4030 in the three dose groups. The estimates of mean response using the GEE method of Section 2 were .1095, .2281, and .4154 in order of increasing exposure. The estimates are comparable with those of Rai and Van Ryzin. Estimates of average litter size in the radiation data using the GEE procedure were 7.041, 6.582, and 6.154 in order of increasing exposure. Although the change seems small, due to the large number of litters involved the decline is statistically significant.

To determine the effect of conditioning on litter size, Table 2 shows the estimated percent of over-dispersion in the data which may be attributed to the variation in litter size within each dose group. Estimated binomial variation in the data is computed using the formula for binomial variance within each litter, $n_{ij}\,\hat{\mu}_i(1-\hat{\mu}_i)$, where n_{ij} is the observed litter size and $\hat{\mu}_i$ is the estimated probability of positive response. The observed Variance is the sample variance of the response random variables X_{ij}. The extra variation column is simply the difference between the binomial variation and the observed variation and reflects the amount of overdispersion present in the data. The column *ExVar* is an estimate of the amount of the theoretical variance of *X* which is directly due to the variation in litter size as given in equation 6. The percent of over-dispersion due to the litter size variation is given in the last column. Table 2 clearly shows that for each of these data sets the contribution of littersize variation to the observed overdispersion may be quite significant. In the hydroxyurea data the effect was low in the first four dose groups but was 53% in the highest group, while in the Shell toxicology data the procedure estimated that 100% of the variation observed in the second dose level was due to variation in the litter size. In the radiation data, the procedure estimated that the variation in litter size accounted for 100% of the over dispersion in each dose group.

As mentioned previously, this procedure estimated that in the hydroxyurea data from 10 to 53% of the over-dispersion is due to variation in litter size rather than in correlation between littermates. Thus one effect of conditioning on litter size rather than treating it as random in the analysis is potential bias in the estimation of the correlation parameter. When litter size is incorporated as a random variable, estimates of *ö* may be quite different than estimates from procedures which do not treat litter size as random. For example in the Shell toxicology data, estimates of *ö* for the four dose groups using a standard likelihood based procedure, the beta-binomial model, which conditions on litter size were .214, .105, .315 and .113. The GEE procedure gave corresponding estimates of correlation as .261, –.004, .591, and .118, markedly different from the beta binomial in the second dose group where the GEE procedure estimated that 100% of the over dispersion was attributable to variation in the litter sizes.

In the radiation data, the GEE procedure estimated that 100% of the over-dispersion in the data was due to variations in litter size. Corresponding to this, estimates of intralitter correlation were essentially zero. Thus for the radiation data, the intralitter correlation, or the tendency for litter mates to respond more similarly than non-littermates was not a factor. Since exposure to radiation occurred in males prior to fertilization, this result might indicate that intralitter correlation is less important when the indirect fetal exposure occurs prior to fertilization than when it occurs after fertilization (when the female receives the direct exposure).

Table 2. Extra Variation Due to Litter Size

	Binomial Variance	Observed Variance	Extra Variation	ExVar	Percent due to Litter Size
Hydroxyurea Data					
Dose Group 1	0.072	0.456	0.384	0.037	10%
Dose Group 2	1.463	3.753	2.292	0.468	20%
Dose Group 3	2.540	15.703	13.163	2.55	19%
Dose Group 4	2.545	11.785	9.240	4.929	53%
Shell Toxicology Data					
Dose Group 1	0.852	2.744	1.892	0.343	18%
Dose Group 2	0.978	1.132	0.154	0.180	100%
Dose Group 3	1.090	5.681	4.591	0.916	20%
Dose Group 4	1.171	2.407	1.283	0.536	43%
Radiation Data					
Dose Group 1	0.686	0.698	0 .011	0.013	100%
Dose Group 2	1.159	1.206	0 .047	0.052	100%
Dose Group 3	1.494	1.644	0 .150	0.153	100%

DISCUSSION

The methods developed here for incorporation of random litter size into the estimation of mean response provide means for testing for a dose effect on litter size and on mean response by testing the significance of the dose parameter in the link function. A test for dose effect on litter size has applications in evaluating effects of toxins on fertility. The generalized estimating equations discussed here also provide a means of gauging the effect of conditioning on litter size in the estimation of mean response. In many experiments, such as the radiation data given here, a sizeable portion of the observed overdispersion in the data is due to variation in litter size rather than in intralitter correlation as shown in Table 2.

Although the methods in this paper deal specifically with developmental studies, the procedure can be readily applied to any type of binary clustered data where the cluster size is random such as any data gathering situation where the experimental unit is litters, herds, or flocks rather than individuals.

APPENDIX 1

For Y_{ijk} the binary response variable of the *k*th fetus in the *j*th litter of the *i*th dose group and N_{ij} the random variable of litter size, let $X_{ij} = \sum_{k=1}^{n_{ij}} Y_{ijk}$ be the number of responses in the *j*th litter of the *i*th dose group, for n_{ij} the observed litter size there. Let the conditional mean, variance, and correlation of the Y_{ijk}'s be given by equation (1).

To find the unconditional mean and variance of X_{ij}, using properties of expectation and conditional expectation,

$$E(X_{ij}|N_{ij}=n_{ij})=E\left(\sum_{k=1}^{n_{ij}}(Y_{ijk}|N_{ij}=n_{ij})\right)=\sum_{k=1}^{n_{ij}}E(Y_{ijk}|N_{ij}=n_{ij})=\sum_{k=1}^{N_{ij}}\mu_i=N_{ij}\mu_i.$$

So the unconditional mean of X_{ij} is given by

$$E(X_{ij})=E(E(X_{ij}|N_{ij}=n_{ij}))=E(N_{ij}\mu_i)=\lambda_i\mu_i$$

which corresponds to the unconditional mean of equation (2).

In a similar way

$$Var(X_{ij}|N_{ij}=n_{ij})=Var\left(\sum_{k=1}^{n_{ij}}Y_{ijk}|N_{ij}=n_{ij}\right)$$

$$=\sum_{k=1}^{n_{ij}}Var(Y_{ijk}|N_{ij}=n_{ij})+\sum_{k=1}^{n_{ij}}\sum_{h=1}^{n_{ij}}Cov(Y_{ijk},Y_{ijh}|N_{ij}=n_{ij})$$

with the last sum ranging over all pairs k, h such that $k \quad h$. This sum is equal to

$$=N_{ij}\mu_i(1-\mu_i)+2N_{ij}(N_{ij}-1)\mu_i(1-\mu_i)\phi_i.$$

The unconditional variance may then be found using the relationship

$$Var(X_{ij})=E(Var(X_{ij}|N_{ij}=n_{ij}))+Var(E(X_{ij}|N_{ij}=n_{ij}))$$

which gives the expression

$$E(N_{ij}\mu_i(1-\mu_i)+2N_{ij}(N_{ij}-1)\mu_i(1-\mu_i)\phi_i)+Var(N_{ij}\mu_i)=$$
$$\lambda_i\mu_i(1-\mu_i)+2\mu_i(1-\mu_i)\phi_iE(N_{ij}^2-N_{ij})+Var(N_{ij})\mu_i^2$$

which simplifies to

$$\lambda_i\mu_i(1-\mu_i)+2\mu_i(1-\mu_i)\phi_i(Var(N_{ij})+\lambda_i^2-\lambda_i)+\mu_i^2Var(N_{ij})$$

which is the unconditional variance given in equation (3).

APPENDIX 2

For an experiment with g dose groups and m_i litters in the ith dose group for $i = 1, \ldots, g$ let $\mathbf{X} = (X_{11}, X_{12}, \ldots, X_{gm_g})'$ be the random vector of positive response. Let $\boldsymbol{\grave{e}} = E(\mathbf{X}) = (\mu_1 \ddot{e}_1, \ldots, \mu_g \ddot{e}_g)'$ be the unconditional mean response vector and

$$\mathbf{V}_\mathbf{x} = Cov(\mathbf{X}) = diag(Var(X_{11}), \ldots, Var(X_{gm_g}))$$

be the variance covariance matrix of the random response vector. The covariance matrix is diagonal since the random variables of positive response are independent across litters.

Assume that mean response is related to exposure level by a dose response function on the parameters $\grave{e}_i$, the unconditional mean response in the ith dose level. Assuming this link function for $\grave{e}_i$ with parameters $\hat{\boldsymbol{a}}$, let $\mathbf{D}_\mathbf{x}$ be the matrix whose ijth element is $\frac{\P q_i}{\P b_j}$. An estimating equation for $\hat{\boldsymbol{a}}$ is then given by

$$\mathbf{U}_\mathbf{x}(\mathbf{X}, \boldsymbol{b}) = \mathbf{D}_\mathbf{x}' \mathbf{V}_\mathbf{x}^{-1} (\mathbf{X} - \boldsymbol{q}) = \mathbf{0}. \tag{7}$$

A similar estimating equation for $\ddot{e}_i$ may be derived by letting $\mathbf{N} = (N_{11}, N_{12}, \ldots, N_{gm_g})'$ be the random vector of litter size. Then the mean vector and covariance matrix of N are given by

$$E(\mathbf{N}) = \ddot{\boldsymbol{e}} = (\ddot{e}_1, \ldots, \ddot{e}_g)'$$

$$Var(\mathbf{N}) = \hat{o} \mathbf{V}_\mathbf{N}, \tag{8}$$

where $\mathbf{V}_\mathbf{N} = (v(\ddot{e}_1), \ldots, v(\ddot{e}_g))$ and $\hat{o}$ is a scalar. Off diagonal elements are zero since litter sizes are assumed independent. Assume some link function for $\ddot{e}_i$ with parameters $\acute{\boldsymbol{a}}$ relating litter size to dose level and other covariates. Let $\mathbf{D}_\mathbf{N}$ be the matrix whose ijth element is given by $\frac{\P l_i}{\P a_j}$. Then an estimating equation for $\acute{\mathbf{a}}$ may be written as

$$\mathbf{U}_\mathbf{N}(\mathbf{N}, a) = \frac{\mathbf{1}}{t} \mathbf{D}_\mathbf{N}' \mathbf{V}_\mathbf{N}^{-1} (\mathbf{N} - l) = \mathbf{0}. \tag{9}$$

Estimates of $\acute{\boldsymbol{a}}$ and $\hat{\boldsymbol{a}}$ can be obtained using an alternating iterative procedure. Suppose that in the kth iteration, by conditioning on the most recent estimate of, say, $\acute{\boldsymbol{a}}$, $\hat{\boldsymbol{\alpha}}_k$, we obtain a new estimate of $\hat{\boldsymbol{a}}$ as

$$\hat{b}_{\mathbf{k}+\mathbf{1}} = \hat{b}_\mathbf{k} + \left[\hat{\mathbf{D}}_{\mathbf{X}\mathbf{k}}' \hat{\mathbf{V}}_{\mathbf{X}\mathbf{k}}^{-1} \hat{\mathbf{D}}_{\mathbf{X}\mathbf{k}} \right]^{-1} \hat{\mathbf{U}}_{\mathbf{X}\mathbf{k}}(\mathbf{X}, \hat{b}_\mathbf{k}), \tag{10}$$

where $\hat{\mathbf{D}}_{\mathbf{X}\mathbf{k}}$, $\hat{\mathbf{V}}_{\mathbf{X}\mathbf{k}}$, and $\hat{\mathbf{U}}_{\mathbf{X}\mathbf{k}}(\mathbf{X}, \hat{b}_\mathbf{k})$ are evaluated at $\hat{b}_\mathbf{k}$ and $\hat{\boldsymbol{\alpha}}_\mathrm{k}$.

Using the estimate, $\hat{b}_{\boldsymbol{k}+\mathbf{1}}$ a new estimate of $\acute{\mathbf{a}}$ is obtained as

$$\hat{a}_{\mathbf{k}+\mathbf{1}} = \hat{a}_\mathbf{k} + \left[\hat{\mathbf{D}}_{\mathbf{N}\mathbf{k}}' \hat{\mathbf{V}}_{\mathbf{N}\mathbf{k}}^{-1} \hat{\mathbf{D}}_{\mathbf{N}\mathbf{k}} \right]^{-1} \hat{\mathbf{U}}_{\mathbf{N}\mathbf{k}}(\mathbf{N}, \hat{a}_\mathbf{k}), \tag{11}$$

where $\hat{\mathbf{D}}_{\mathbf{N}\mathbf{k}}$, $\hat{\mathbf{V}}_{\mathbf{N}\mathbf{k}}$, and $\hat{\mathbf{U}}_{\mathbf{N}\mathbf{k}}(\mathbf{X}, \hat{a}_\mathbf{k})$ are evaluated at $\hat{b}_{\mathbf{k}+\mathbf{1}}$ and $\hat{\boldsymbol{\alpha}}_\mathrm{k}$. Within each iteration updated moment estimators of $\ddot{\boldsymbol{o}}_{\boldsymbol{i}}$, the intralitter correlation parameter are obtained and input into the model. The iteration continues in this alternating fashion until both estimates converge.

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Geology of the Falkner Topographic Quadrangle, Tippah County, Mississippi

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Within the Falkner, Miss., 7.5 minute quadrangle are portions of the outcrop belts of the Cretaceous Ripley and Owl Creek Formations (Selma Group) and the Tertiary Clayton, Porters Creek, and Naheola Formations (Midway Group) and the Meridian Sand (Claiborne Group). Quaternary flood plain deposits are also present. Limited exposures of the McNairy Sand Member of the Ripley Formation are present in the southeast corner of the study area and consist of medium-grained sands. The Owl Creek Formation unconformably overlies the Ripley and consists of clay, silt, and fine-grained sand. The Tertiary Clayton Formation unconformably overlies the Owl Creek and consists of medium- to fine-grained glauconitic sand. The Porters Creek Formation, which conformably overlies the Clayton, consists of a thick sequence of gray clay and is conformably overlain by the Naheola Formation. The Naheola consists of varied lithologies, and is recognized for the first time in Tippah County. Recognition of the Naheola restricts the area formerly mapped as the Wilcox Group and supports similar revisions suggested in other parts of the state. The Meridian Sand consists of cross-bedded sands and lies unconformably above both the Naheola and Porters Creek Formations in a stratigraphic overstep of successively older units. The Muddy Creek Fault Zone is the major structural component of the quadrangle and forms the potential for hydrocarbon trapping. Mineral resources in the quadrangle consist of sand, clay, lignite and isolated bauxite deposits. Geologic hazards include expansive clays associated with the Porters Creek Formation, the potential for earthquake damage, and flooding.

In 1941, Conant and McCutcheon published a geologic map of Tippah County, Mississippi. This generalized map and the accompanying report have served for the last 58 years as the primary source of geologic information for Tippah County. Since 1941, significant improvements have been made in the knowledge of the state's stratigraphic units, their correlation with equivalent units in other parts of the state, the knowledge of faults and other geologic structures in Mississippi, and the resources available for the construction of geologic maps. The Mississippi Mineral Resources Institute (MMRI) has a continuing program of geological mapping which provides the profession and public with updated interpretations of recently acquired geological data. The geologic map of the Falkner, Miss. quadrangle is part of these efforts.

The geological mapping was conducted at a scale of 1:24,000 using the Falkner topographic map (U.S. Geological Survey, 1982) as a base. This map has a contour interval of 20 feet (6.1 m) and was used to determine elevations, to plot field data, and to project and establish outcrop patterns. This mapping represents the first time the area has been mapped on a topographic base and the first time at a 1:24,000 scale. ARC/INFO (a geographic information system produced by Environmental Systems Research Institute, Redlands, California) was used to construct the geologic map digitally and to derive some of the spatial data used for the project.

AREA OF STUDY

The Falkner quadrangle is entirely within Tippah County, Mississippi (Figure 1). The town of Falkner is in the northern half of the study area and the northern edge of the city of Ripley is in the southern extreme of the study area. Much of the western edge of the study area is within the Holly Springs National Forest. The focus of this study was, of course, the Falkner topographic quadrangle; however, limited field studies were carried out in adjacent quadrangles

in order to assure a smooth continuity of contacts across map boundaries.

STRATIGRAPHY

The oldest stratigraphic unit cropping out in the study area is the Cretaceous Ripley Formation, with the Meridian Sand as the youngest Tertiary unit. Flood plains associated with the existing fluvial systems are currently receiving sedimentation and are mapped as a separate unit. The MMRI-Hill, No. 2 stratigraphic test well was drilled in the SW 1/4, SW 1/4, of section 33, T2S, R3E to a total depth of 440 feet (134 m). The purpose of this well was to sample the down-dip equivalent of units cropping out in the study area and to provide a geophysical log through a known stratigraphic column which could be used for correlation purposes. The formations sampled in this well included the Cretaceous Ripley and Owl Creek Formations, and the Tertiary Clayton, Porters Creek, Naheola, and Meridian Sand (Figure 2). Swann (1996) gave a detailed account of the drilling conditions and stratigraphy encountered in this test well.

The exposures of the Cretaceous Ripley Formation (Selma Group) are limited to areas in the southeastern corner of the study area, along White Oak Creek and other small streams. These small exposures consist of medium-grained, massive sand and have been assigned to the McNairy Sand Member, representing only the upper most Ripley section. The Chiwapa Sandstone Member was not noted in outcrop, but it is present in the northern edge of the adjoining Ripley quadrangle (Swann, Faruque

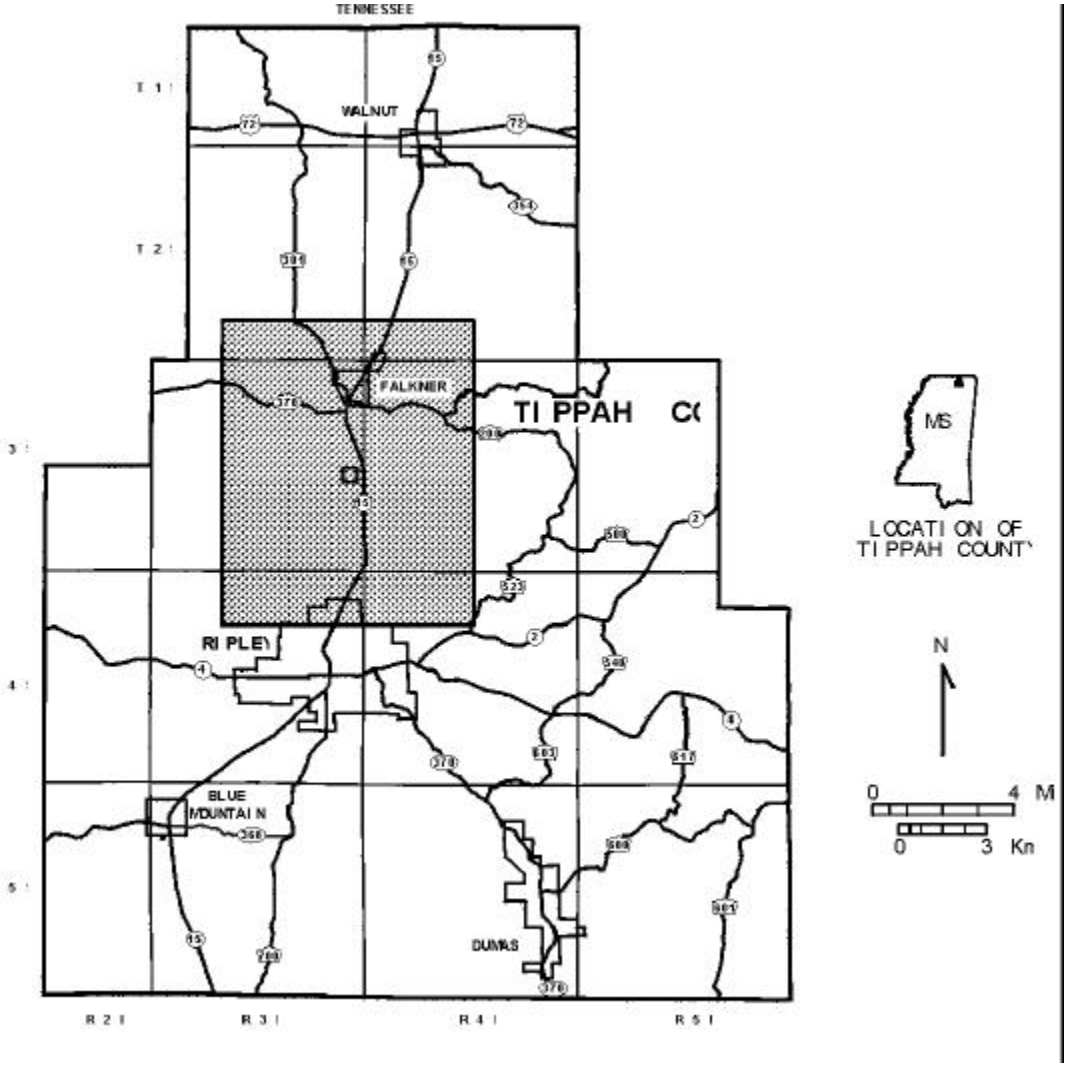

Figure 1. Location map illustrating the study area and adjacent geographic features.

and Harding, 1995) along Owl Creek and was sampled in the MMRI-Hill, No. 2 core. It is likely that this calcareous unit may be locally present in outcrop in the southeastern corner of the study area due to the near proximity of the Ripley quadrangle exposures. The Ripley Formation is distinguished from the younger Owl Creek Formation by its coarser grain size. The Ripley-Owl Creek contact is considered unconformable, but is poorly exposed in the study area.

The youngest Cretaceous unit is the Owl Creek Formation (Selma Group). The Owl Creek is well represented along the eastern edge of the study area and typically consists of fossiliferous, sparsely glauconitic and phosphatic, silty clays, and silty fine-grained sands. Abundant medium-grained mica is an identifying characteristic of the unit. Roadcut exposures in the extreme southeastern corner of section 20, T3S, R4E, contain a more sandy facies consisting of fine- to medium-grained, bedded, micaeous sands, below a highly weathered clay section. This sandy Owl Creek facies was also noted in the adjacent Ripley quadrangle (Swann, Faruque and Harding, 1995). An unusually sandy section was

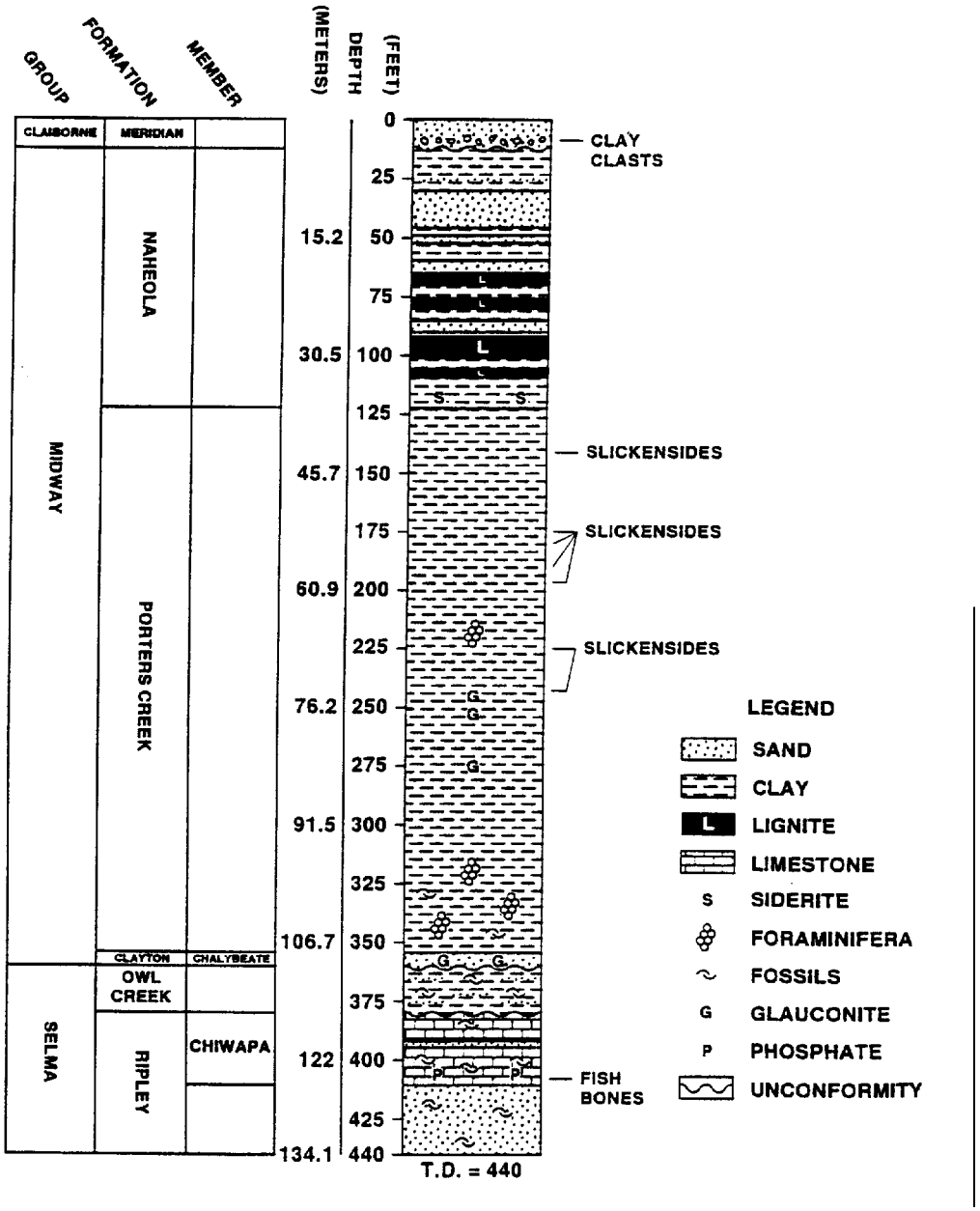

Figure 2. Stratigraphic units assigned to the core of the MMRI-Hill No. 2 stratigraphic test well.

also identified in the MMRI-Hill, No. 2 test well core (Swann, 1996). Fossiliferous beds were noted within the Owl Creek at several locations. These beds contain a diverse fauna including *Baculites* sp., *Exogyra* sp., other bivalves, and small crab fossils. Disseminated, carbonized plant debris was noted near the upper contact both in outcrop and in the core samples.

The thickness of the Owl Creek varies from a maximum of approximately 60 feet (18 m) in the southern edge of the study area (near Ripley), to 20 to 30 feet (6 to 9.1 m) in the northern end of the study area outcrop belt. A total of 19 feet (5.8 m) was assigned to the Owl Creek in the MMRI-Hill, No. 2 core, also in the northern half of the study area. The change in thickness is attributed to the unconformities at both the upper and lower contacts, with the erosion associated with the upper unconformity being more significant.

The Clayton Formation (Midway Group) is the basal Tertiary unit and lies unconformably above the Owl Creek Formation. The Clayton typically consists of a discontinuous, basal limestone unit with an overlying unit of olive gray glauconitic sands. The basal limestone is poorly exposed in the study area, with most of the outcrop belt consisting of sands. The Clayton section in the northeastern corner of the study area contains an unusual coarse-grained, clastic component. These coarse-grained clastics (scattered granules and small gravel) derive from a paleochannel system that contributed clastic materials to the nearshore Clayton system (see Swann, 1997). This clastic input may also account for the paucity of the limestone facies in the study area. The entire Clayton section is mapped as the Chalybeate Member. The Clayton section in the study area contains few fossils and those consist of rare bivalve molds and casts.

The thickness of the Clayton is also influenced by the paleochannel system and, in outcrop, is inversely related to the thickness of the Owl Creek Formation. The section obtains its maximum thickness in the area of the paleochannel and thins to the west and south. The Clayton, for example, is approximately 60 feet (18.3 m) thick in the northeast corner of the study area and thins to only approximately 30 feet (9.1 m) in the southeast corner. The MMRI-Hill, No. 2 well is located opposite the paleochannel in the northwest corner of the study area. The core contains only eight feet of phosphatic sand, which was assigned to the Clayton Formation. The thin Clayton section suggests that the clastics being contributed to the marine system did not exert an influence for any significant distance down the depositional dip. The upper contact with the younger Porters Creek Formation is considered conformable and is placed at the base of the lowest occurring clay bed above the glauconitic sands.

The Porters Creek Formation (Midway Group) consists of two units, a thin basal unit containing glauconitic, sandy, fossiliferous clay and an upper unit consisting of medium to dark gray, laminated, expansive clay. In the upper Porters Creek section, opaline cements impart a conchoidal fracture to fresh clay exposures. The predominately fine-grained nature of the formation makes it easy to identify in outcrop and in geophysical logs. The lower Porters Creek unit is poorly exposed in the study area and the only indication of this section was the glauconitic clays at the base of the formation in the MMRI-Hill, No. 2 core. The upper Porters Creek is a thick clay section that can be divided by the presence of at least two glauconite beds. Only one glauconite bed was sampled in the stratigraphic test well core near the top of the section. Bivalves are typically sparse in the Porters Creek and most common in the lower section where they often consist of molds and casts. Foraminifers were noted in the MMRI-Hill, No. 2 core in the basal 33 feet (10 m) of the Porters Creek section.

The Porters Creek is the thickest Tertiary unit mapped in the study area. In the MMRI-Hill, No. 2, a total of 231 feet (70.4 m) of section was assigned to the Porters Creek between the conformable Clayton and Naheola formations. This thickness is typical for the complete Porters Creek section. The thickness can vary due to the erosion associated with the stratigraphic overstep of the younger Meridian Sand. Where a Porters Creek—Meridian Sand contact is present, the Porters Creek is often significantly thinner. The Porters Creek section, for example, beneath a Meridian outlier at Pine Hill Church, east of Bell Creek (section 29, T3S, R4E), is mapped as only approximately 40 feet (12.1 m) thick. The Porters Creek-Naheola contact is conformable and can be difficult to identify. Where the Naheola consists of alternating beds of sand and clay, the contact is placed at the base of the lowest bed of sand above the typical

dark gray, laminated clays of the Porters Creek Formation. When the Naheola consists of a basal clay section, the contact is placed at the base of the lowest primary kaolinitic bed. Siderite nodules, siderite-rich clays, and lignite are restricted to the Naheola. The Porters Creek-Naheola contact in the MMRI-Hill, No.2 core was identified by the kaolinitic clays and siderite. The Porters Creek-Meridian contact is easily identifiable and very irregular. The basal Meridian often consists of coarse- to very coarse-grained sands which contrast sharply with the clays of the Porters Creek section.

The Naheola Formation (Midway Group) consists of a variety of lithologies and depositional environments. Fine- to medium-grained sands, granules, thick beds of dark gray expansive clay similar to the Porters Creek clays, kaolinitic clays, bauxite, and lignite beds are all included in the Naheola. Naheola exposures in the area of Fourmile, Bowling, and Linebarger branches contain a channel facies with boulder-size blocks of clay within a matrix of medium- to fine-grained argillaceous sand, with well rounded gravel-sized clay clasts marking the base of these channels. Generally, the Naheola section north of West Prong Creek is more argillaceous than south of the creek. In the study area, the Naheola is overstepped by the younger Meridian Sand. In an ideal section, the Naheola should underlie the Wilcox Group, which crops out west of the study area. The Naheola-Meridian Sand contact is typically identified by the coarser grain sizes in the Meridian Sand.

Only the lower Naheola is exposed in the study area, being mapped along its western boundary. The recognition of the Naheola Formation here and in work by Moyse (1999) is the first report of the unit in Tippah, Benton, and Union counties, although Thompson (1999) noted it in other areas of northern Mississippi, and has mapped it along the outcrop belt south of the study area. Mapping the Naheola above the Porters Creek also removes considerable amounts of section from what was previously mapped by Conant and McCutcheon (1941) as the Wilcox Group and places the Naheola in the older Midway Group. Thompson (1999) also found that significant amounts of the southern part of the outcrop belt should be mapped as Naheola rather than Wilcox Group.

The Meridian Sand (Claiborne Group) is the youngest Tertiary unit in the study area and consists of a distinctive unit of cross-bedded, medium- to very coarse-grained, locally gravelly sand. The Meridian is present only as outliers which appear to represent the remnants of large channels extending east of its main outcrop belt. The largest outlier is in the southwestern corner of the study area between Medlock and Bowling branches (section 34, T3S, R3E and section 3, T4S, R3E). Conant and McCutcheon (1941) suspected a stratigraphic overstep of the Meridian ("Holly Springs Formation" of Conant and McCutcheon) and Lusk (1956) mapped the Meridian as extending eastward to the Benton-Tippah County line.

Quaternary flood plain deposits are the youngest unit mapped in the study area. This unit consists of the present flood plains associated with the existing stream system. The lithologic character of these deposits varies widely according to the stratigraphic unit(s) exposed within the stream drainage basin. Flood plain deposits associated with steams draining the Porters Creek outcrop belt, for example, consist almost entirely of fine-grained clay. Drainage basins developed in sandier units are more arenaceous and may develop the typical fining upward cycle associated with fluvial deposits. The unit was mapped using the geomorphic characteristics of flood plains in addition to lithologic characteristics. Unlike the Quaternary deposits in the Chalybeate Quadrangle (Swann, 1997), there were no elevated fluvial terraces recognized within the Falkner Quadrangle.

STRUCTURE

There are several structural features in the study area (Figure 3). The most important is the northerly-oriented, normal fault running down the eastern edge of the flood plains of Muddy and Bell Creeks. This fault is the major component of the Muddy Creek Fault Zone which extends southward from the Mississippi-Tennessee state line (Swann, 1997) along the trend of the Muddy Creek flood plain. Although the actual fault plane was not identified in outcrop, the displacement of the stratigraphic section is evident in both the northern extreme of the study area and the southern end of the study area. Displacement is estimated to be approximately 30 to 50 feet (9.1 to 15.2 m). A second component of the Muddy Creek Fault Zone is mapped in the southern end of the study

area west of the main fault. This smaller fault was mapped northward from the adjoining Ripley quadrangle for approximately 1.5 miles (2.4 km) into the Falkner quadrangle. This normal fault was identified by the displacement of the Owl Creek-Clayton section, and accounts for the locally complex stratigraphy on the northern edge of Ripley, Mississippi. Displacement is estimated at approximately 20 feet (6 m). The northern end of the fault was terminated where displacement could no longer be identified. A third component is located north of the town of Falkner, Mississippi, and represents an extension of a normal fault from the adjoining Walnut quadrangle. Because the fault does not have enough displacement to completely offset the Porters Creek Formation, it is difficult to map. Maximum displacement is estimated at approximately 20 feet (6 m). The extension was mapped southward until no displacement in local beds could be identified.

A fourth normal fault was noted in outcrop in section 26, T3S, R3E. The northeasterly orientation of this fault suggests it is not related to the Muddy Creek Fault Zone, but rather to other structural features. This fault cross-cuts both the Naheola Formation and an outlier of the younger Meridian Sand. It consists of a zone of small, similarly oriented faults in the Naheola, but of only a single fault plane in the Meridian section. The fault could not be mapped in either direction for an appreciable distance, but it was noted that two straight reaches of Bowling Branch are on trend with the orientation of the fault. Displacement appears to be less than 15 feet (4.6 m).

Twelve joints were measured in the study area and are included in Figure 3. These joint measurements were made only on joints filled with iron oxides in order to avoid joints which may have an anthropogenic origin. Although the number of joint measurements in the study area is too small to be of statistical significance, combined with measurements from adjoining areas enough may be obtained to make structural inferences for this area of the state.

UTILITY OF THE GEOLOGIC MAP

The geologic map (Figure 3) can be used to elucidate a number of applied problems and is intended as a tool for planners and local landowners. Another use of the map will be to provide new stratigraphic information for the formulation of a new geologic map for the State of Mississippi.

Mineral Resources—The Porters Creek Formation and the Meridian Sand are both mined within the study area. The Oil-Dri Corporation of America mines the Porters Creek Formation in north Ripley. They use the Porters Creek to produce a variety of products, but primarily as an agricultural carrier. The geologic map provides a guide to the outcrop belt of the Porters Creek, which is, of course, the primary area to explore for additional reserves of clay. Benefield Sand Company produces sand from the Meridian Sand (NW 1/4, sec 3, T4S, R3W). Since the Meridian is present as outliers, the map should be particularly useful as an exploration guide should additional sand resources be required. The locations of the pits of both companies are shown on Figure 3.

Faulting within the study area is of interest to the hydrocarbon industry as geologic structures may form trapping mechanisms for hydrocarbons. The Paleozoic section, several thousand feet below the land surface, holds the greatest potential for production. Presently depressed crude oil prices, unfortunately, do not encourage exploration or further study of this area. Exploration for natural gas may be more attractive as the economic situation is more stable. The closest production is approximately 40 miles (25 km) away and is derived from the Paleozoic section in the Black Warrior Basin.

The Naheola Formation contains lignite resources, which have potential as a source of energy. The younger Wilcox lignites are the energy source for the Red Hills Power Plant in Chotcaw County, currently being constructed to generate electricity for the Tennessee Valley Authority. Bauxite and kaolin are also present in the Naheola, but deposits identified in mapping were too limited in scope to be of economic interest. A drilling program may identify additional resources. The geologic map should be a useful guide to the areas where lignite, bauxite, and kaolin exploration would be most rewarding.

Geological Hazards—The clays of the Porters Creek Formation are expansive (Swann, Faruque, and Harding, 1995; Moyse, 1999). Expansive clays are a source of concern because they shrink and swell according to their moisture content. If this uneven shrink and swell is not considered during construction, structures such as houses can literally break apart. Highways are also susceptible to damage from expansive clays resulting in higher maintenance costs. Many expansive soils problems can be accommodated through engineering techniques employed prior to construction. The geologic map should provide a guide as to where these problems are likely to occur. If new construction is planned within the Porters Creek outcrop belt, a qualified engineer should be retained to evaluate the potential for expansive soils and recommend ways to mitigate their effects.

The geologic map should also be of use in mitigating the potential damage resulting from flooding. The map unit labeled Qal denotes flood plain deposits associated with existing streams. The existence of these flood plains is attributable to past flooding and serves as a guide to future flooding. Urbanization, such as is occurring in the Ripley area, usually results in additional surface runoff which increases flooding potential as existing streams must handle an increased flow of storm water. Ideally, flood plains should be reserved for agricultural uses or recreational uses such as athletic parks, general recreational use areas, walking trails, or wooded areas. It is undesirable to site homes and businesses on an active flood plain, and it is especially undesirable for businesses or industries that produce hazardous materials which can contaminate surface water during a flood. Structures critical to public health and safety, such as hospitals, fire stations, and police stations should be sited well above any flood plains.

Structures within the study area may be damaged by earthquakes originating from the New Madrid Seismic Zone (NMSZ). The southern end of the NMSZ is generally considered to be at Marked Tree, Arkansas, and earthquakes originating from this area could do significant damage to unreinforced masonry structures. The faults illustrated in Figure 3 are important as they may represent a potential source of local seismic activity. Small local seismic events may cause damage to structures, whereas the same size event several hundred miles away would not be felt, much less cause damage. The faults included on the geological map may pose local earthquake hazards, but too little is known about them to make definitive evaluations as to their history of movement and the size of earthquake they may be capable of producing. Additional work needs to be done on these faults to better characterize their seismic potential.

Liquefaction is another hazard initiated by seismically induced ground motion. Reiter (1990, p. 168) defines liquefaction as ". . .the temporary conversion of unconsolidated soils into a medium that behaves like a fluid." During liquefaction, structures may sink, tilt or topple due to the lack of foundation support. Several geological factors influence the susceptibility of soil liquefaction, which include distance from the seismic source, depth to the top of the water table and age of the geological material (Kramer, 1996). In the Falkner quadrangle, the Quaternary flood plains are most susceptible to liquefaction, and can be identified from Figure 3.

Karst is a landform that results from the dissolution of certain types of rock. The result of this dissolution may be the formation of collapse structures often referred to as sinkholes, sinks, or dolines. Considerable damage may occur to structures that are sited over sinkholes as the loss of support beneath the structures may cause the failure of foundations and walls. In the study area, limestone is the rock most likely to result in the formation of sinkholes, and there are two units which may contain limestone. Brown (1948) noted sinkholes in the City of Ripley and attributed them to the limestone in the Clayton Formation; Swann, Faruque, and Harding (1995) identified a karst hazard from the limestones in both the Clayton Formation and the Chiwapa Member of the Ripley Formation. Using Figure 3 as a guide, areas of potential karst can be identified. Areas near the Ripley-Owl Creek contact and the Owl Creek-Clayton contact should be considered areas of potential karst development.

CONCLUSIONS

Six stratigraphic units have been mapped in the area encompassed by the Falkner 7.5 minute topographic quadrangle. These units include the Cretaceous Ripley and Owl Creek Formations, and the Tertiary Clayton, Porters Creek, Naheola, and Meridian Sand. Quaternary flood plain deposits have also been mapped along existing streams.

The Ripley Formation is exposed only in a limited

area in the southeast corner of the study area and consists of sands. The Owl Creek Formation consists of fossiliferous, silty clay and silty sands. The upper and lower contacts are both considered unconformable. The upper contact is the Cretaceous - Tertiary boundary. The Owl Creek Formation is thickest in the southern portion of the study area and thins northward in the area coinciding with a paleochannel system in the basal Tertiary Clayton Formation. The Clayton Formation, basal member of the Midway Group, consists of glauconitic sands except in the northeastern corner of the study area, where the paleochannel system has added coarse-grained clastics to the depositional system. The Clayton-Porters Creek contact is conformable, but poorly exposed in the study area. The Porters Creek Formation is the thickest unit in the study area, consisting of a sequence of gray, sparsely fossiliferous, highly expansive clays. The Porters Creek-Naheola contact is conformable and can be difficult to identify. Typically, the contact was placed at the base of the lowest sand bed, but is here placed at the base of the lowest kaolinitic bed where the Naheola Formation and Porters Creek Formation clays are in contact. The Naheola is the upper member of the Midway Group and consists of a variety of lithologies including fine- to coarse-grained sand, clay, and lignite. The Meridian Sand is the basal unit of the Claiborne Group and unconformably overlies the Porters Creek and Naheola Formations. The lower contact is easily identified by the coarse grain size of the Meridian Sand. Flood plain deposits have also been mapped using a combination of lithologic and geomorphic criteria to delineate their extent.

The geologic map should be of assistance in identifying areas of natural hazards such as the expansive soils of the Porters Creek Formation or flood-prone areas such as the flood plain deposits. The map should also be useful as a guide in exploration for sand, lignite, bauxite, and kaolin resources. The Muddy Creek Fault Zone is a potential zone of hydrocarbon trapping that has not been adequately explored.

ACKNOWLEDGMENTS

Ms. McCullough Moyse is gratefully acknowledged as her assistance in the field and in preparing the digital copy of the geologic map were essential to the completion of the project. A significant amount of the digital work was conducted in the Geographic Information Systems Lab of the Department of Geology and Geological Engineering at the University of Mississippi. The use of their facility is appreciated. The Mississippi Office of Geology has provided aid to this project by drilling the stratigraphic test well. We appreciate the continuing help and assistance provided by the Office of Geology. We acknowledge the help of Mr. Paul Mitchell, MMRI Technical Design Specialist, as he was responsible for preparation of the publication-quality illustrations used herein. The constructive criticism of Ms. Carol Lutken, MMRI Research Associate, and the external reviewers (Dr. Maurice Meylan of the University of Southern Mississipi , Dr. Darrel Schmitz of Mississippi State University and an anonymous reviewer) is also acknowledged as the paper was improved by their suggestions.

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The Design and Testing of a Portable Seismic Telemetry Station

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Phase I of the research focused on the construction of a modified James D. Lehman seismograph, the only seismograph in the state of Mississippi to record the March 25, 1996, Clarke County earthquake—the first earthquake recorded in the state since March 29, 1972. However, certain structural features, such as size and weight, hindered the seismograph's portability and practicality. To improve the device, a more portable model using three ADXL05JH accelerometer sensors with bandpass filtering was constructed in Phase II. Because each sensor can be calibrated to ignore the tilt angle, the portable seismograph does not have to be balanced. In Phase III, the portable seismograph was interfaced with a telemetry system, enabling the seismograph to send outputs to remote locations. Designed to operate on amateur radio frequencies, the system uses a microprocessor controller to activate the system at the detection of a seismic event and also provides automatic Morse code (CW) identification and an auxiliary 440 MHz (7 cm) control link to comply with Federal Communications Commission (FCC) regulations. Some of the unique features incorporated into the design suggest the device will be useful for both seismic and nonseismic research. For instance, it is hypothesized that the device could serve as an environmental monitor (particularly useful to small rural areas) to report weather changes.

In 1987, Richard L. Kroll introduced the possibility that the renowned James D. Lehman seismograph, an instrument that records for a duration of time the motions of the Earth's surface that are caused by seismic waves (Bolt, 1995), was structurally flawed (Kroll, 1987). Discovering this book nine years later and its arguments apparently unsolved, the researcher became interested as to how this problem could be corrected. Phase I of the research began with the construction of a modified Lehman seismograph. Several major structural changes were made to the original design to improve the seismograph's overall performance, but it remained a heavy device, neither quickly transportable nor easily set up. In Phase II, the researcher sought to correct these problems by designing and constructing a reliable portable seismograph that, unlike the modified Lehman, was easily transportable and could be set up in a minimum amount of time. The portable device was built using three Analog Devices ADXL05JH accelerometer sensors (integrated circuits) with bandpass filtering. In Phase III, the researcher developed a telemetry system to be interfaced with the portable seismograph, allowing for the seismograph's outputs to be transmitted to remote locations. The system was designed to operate on amateur radio frequencies (2 m and 7 cm bands), allowing a constant and immediate method of relaying data. This novel technique presents a unique way to measure earthquakes and provides applications beyond seismic research.

MATERIALS AND METHODS

Phase I. According to Kroll, the original Lehman seismograph contained several key components that were flawed and responsible for hindering the device's ability to accurately record earthquakes (Walker, 1979; Kroll, 1987). The researcher modified the flawed design in an attempt to correct the reported problems (Fig. 1). A single laminated ash wood base replaced the two separate bases used in the original design. A ¼-inch-thick by two inch-wide welded frame substituted for the suggested ¾ inch

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steel pipe, which was reported to lack sufficient support and rigidity. In addition, a copper tubing boom replaced the suggested steel boom, thought to have a magnetic influence on the boom's swing (Walker, 1979). An Analog-to-Digital converter board, which sensed the outputs from the seismograph, was interfaced with a personal computer using Seismic Data Recorder (SDR) software that recorded, logged, displayed, and printed the results.

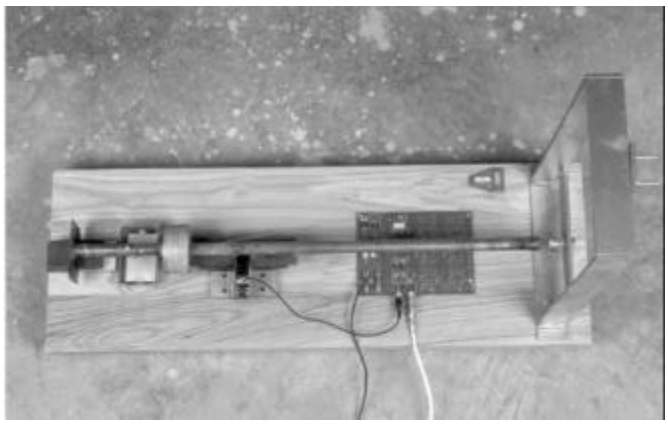

Figure 1. Modified Lehman seismograph.

Figure 2. Clarke County, Mississippi earthquake. March 26, 1996. Magnitude 4.1. Recorded by modified Lehman.

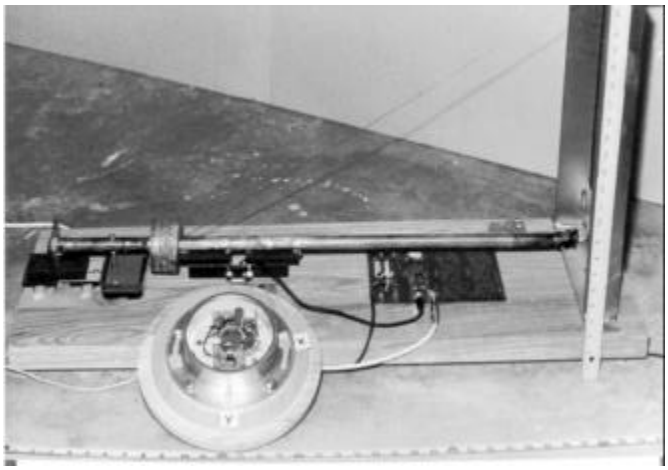

Figure 3. Size comparison of modified Lehman device to portable device.

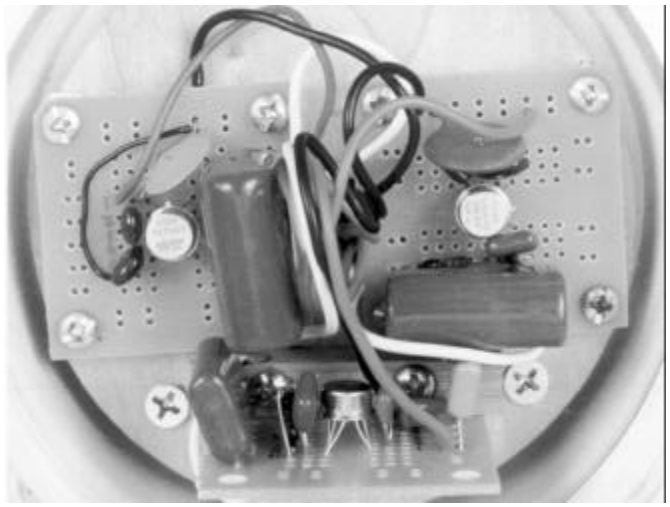

Figure 4. Top view of interior of PVC housing showing positioning of PC boards for x, y, and z axes.

Phase II. Despite its success, the modified Lehman remained a heavy temperamental device (weighing approximately fifty pounds) and demanded a minimum setup time of two hours (with favorable surrounding conditions). Therefore, the task of designing a more portable model became the focus of Phase II. The portable device uses three ADXL05JH accelerometer sensors with bandpass filtering. The accelerometer sensors were originally designed with the purpose of providing motion sensing for industrial and automotive purposes, offering impressive sensitivity and accuracy (Carlson, 1996). The researcher hypothesized that the accelerometer sensors could be adapted to record seismic activity. The accelerometer sensor is a complete accelerometer

Figure 5. Telemetry transmitter top view.

measurement system on a single monolithic integrated circuit (IC). The sensor will measure accelerations with a full scale selectable from either ±5 g or ±1 g. It is a force-balanced capacitive accelerometer with the ability to measure both alternating current (AC) accelerations, which are typical of vibration, and direct current (DC) accelerations, typical of inertial force and gravity. Three external capacitors and three resistors are used in the device's basic configuration, permitting measurement of accelerations up to ± 5 g. In addition, the output buffer amplifier may be configured to set scale factors ranging from 200 mV/g to 1 V/g. Additional resistive/capacitive (RC) networks can be added to achieve low pass and/or high pass filtering. In order to determine if these sensors have the ability to measure earthquakes, the researcher chose to use both low pass and high pass filtering methods to achieve bandpass filtering with a range of 0.1 Hz to 10 Hz (the frequency range associated with most seismic activity). The three accelerometer sensors are oriented orthogonal to each other along x, y, and z axes: x measures East and West; y, North and South (x and y are horizontal accelerations), and z, vertical accelerations. Because of the ability of these sensors to differentiate between AC and DC accelerations, the seismograph can be unbalanced and still record seismic activity.

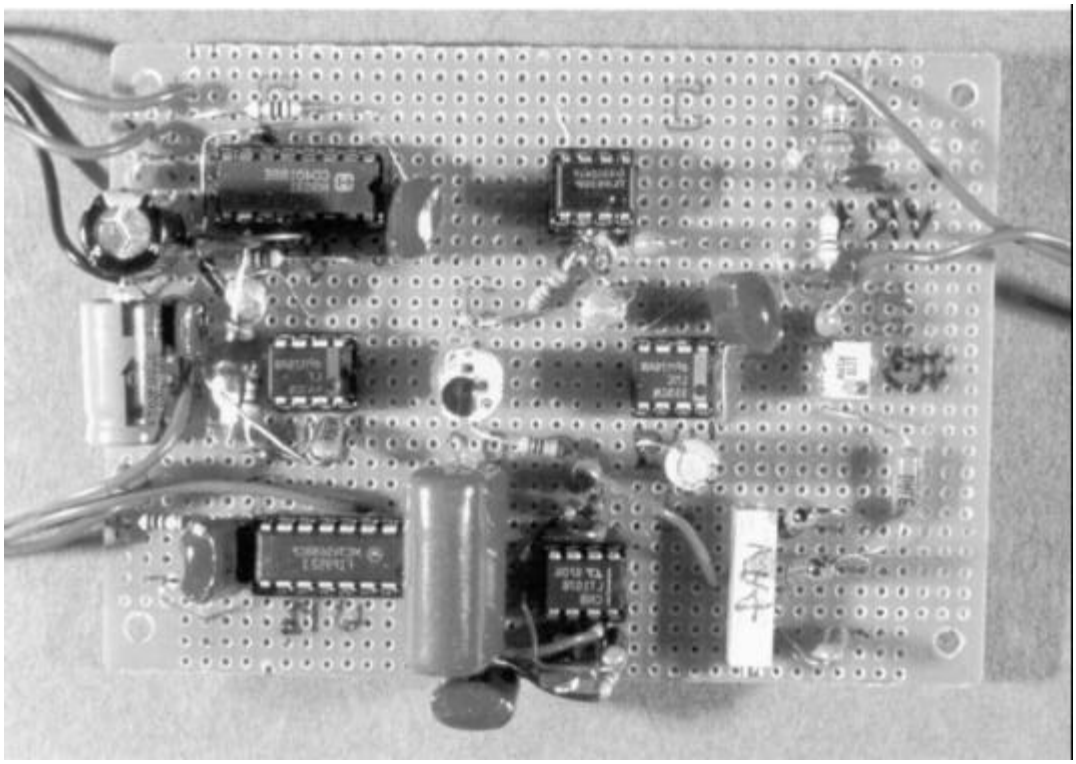

Figure 6. VCO schematic.

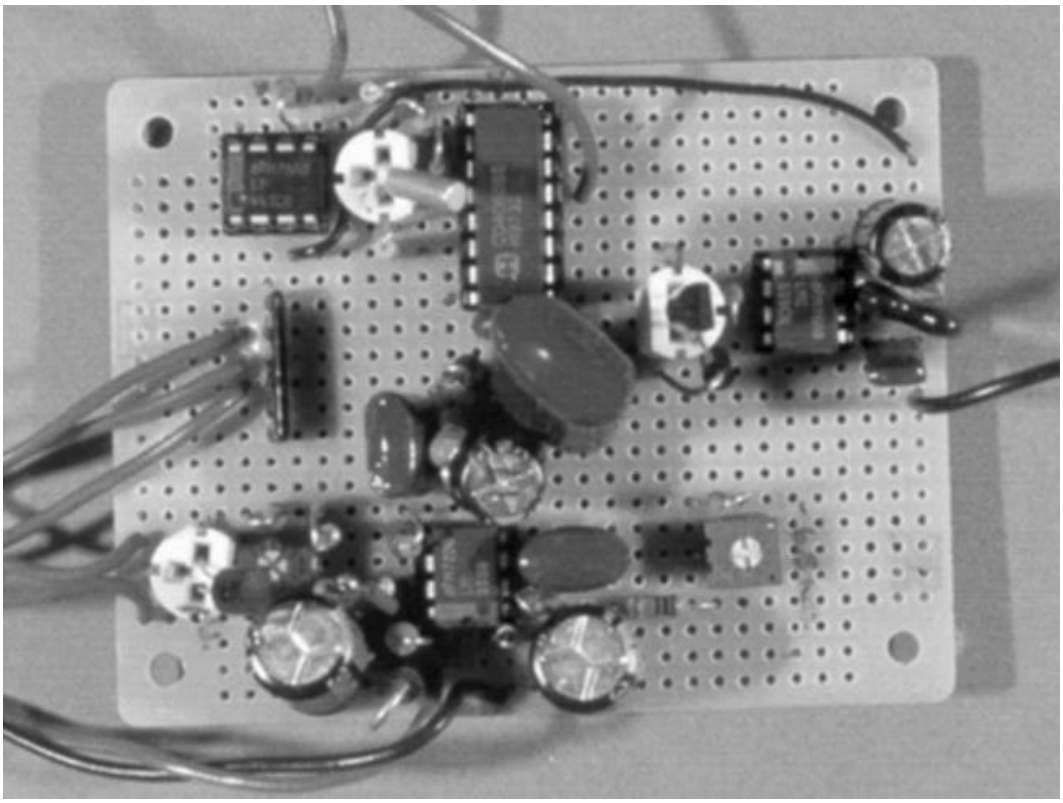

Figure 7. Power supply reference oscillator.

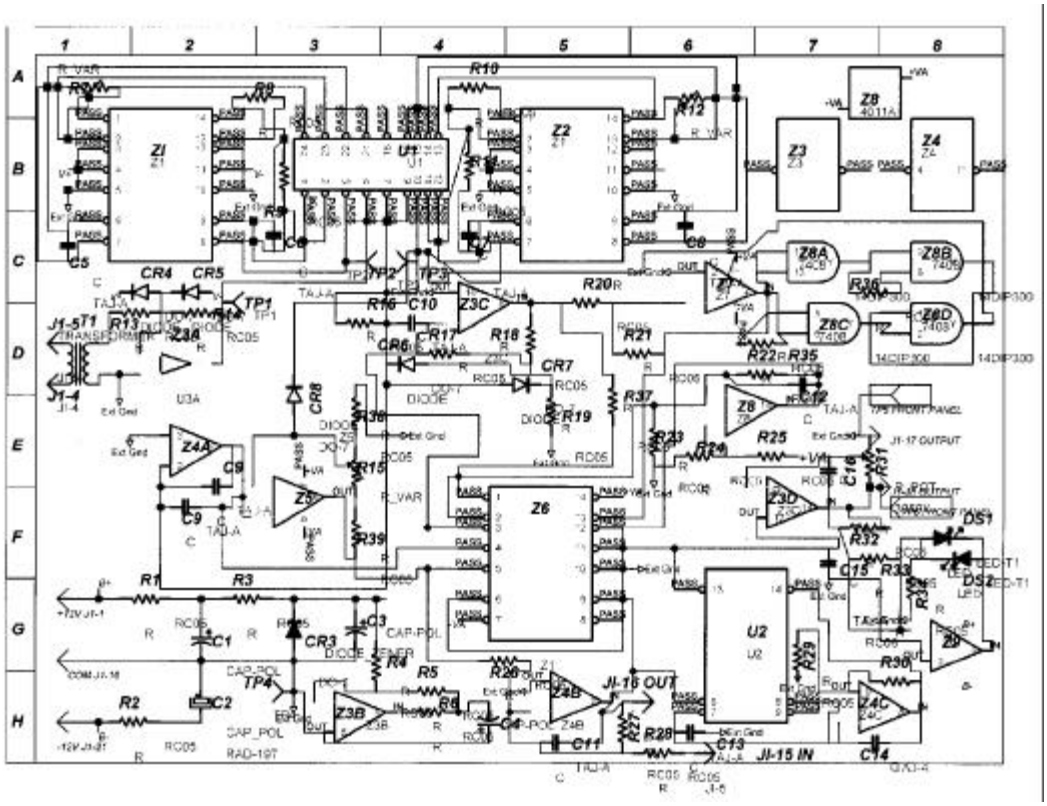

Figure 8. Demodulator schematic.

Construction of the three seismic sensors began by mounting each of the three accelerometer sensors onto a one by ¾ inch predrilled, pre-etched circuit board. Bandpass filtering was used to minimize the amount of local noise and other nonseismic activity. The combination of both low pass and high pass filtering provided for the desired bandpass of 0.1 Hz to 10 Hz. The ADXL05JH manufacturer claims a typical noise floor of 500 mg/square root of Hz, allowing signals below 5 milli-g to be resolved (Carlson, 1996). Three external capacitors and a +5 volt regulated power supply are needed to measure accelerations up to ±5 g. Three resistors are used to configure the output buffer amplifier (which is onboard to the accelerometer sensor) to set scale factors from 200 mV/g to 1 V/g. The insertion of additional RC networks would achieve low and/or high pass filtering. The self-test function, called "Logic 1," tests the sensors by causing an electrostatic force, which in turn generates an approximate negative full-scale output (either 1 g or 5 g, depending on the selected scale). An output change of -1 volt measured at IC pin 7 proved the sensor worked. After testing, the sensors were mounted onto a yellow poplar wood base, coated with marine lacquer, and positioned in a housing fashioned from four-inch PVC pipe-fittings. The wire inputs and outputs were linked to a standard 5-pin DIN connector mounted in the base.

Phase III. In Phase III, features of the portable seismograph were further enhanced by developing a telemetry system to be interfaced with the portable seismograph, thus transmitting its outputs to remote locations. Cellular telephones, citizen band (CB) and family radio, and commercial radio were considered as possible transmission media, but amateur radio was selected for a variety of reasons. Even though cellular telephone equipment is readily obtainable, air time is expensive. In addition, cellular telephones require delays of several seconds while dialing and connecting, presenting a considerable disadvantage for the telemetry system that must be operating at all times. CB and family radio is also disadvantageous due to a lack of available frequency spectrum, making interference a problem. Commercial radios avoid interference problems, but equipment is expensive and a commercial license is difficult to obtain. Amateur radio, however, not only avoids interference and cost concerns but also provides many opportunities for interfacing telemetry transmissions through existing amateur radio repeaters, greatly increasing the range of transmission (Fig. 5).

The Federal Communications Commission (FCC) imposes regulations for automatic and telemetry transmissions over amateur radio. The FCC limits automatically initiated transmissions to three continuous minutes but places no limit on the length of time for transmissions initiated manually by the control operator. The FCC requires the telemetry transmitter to send its FCC call sign (usually in Morse code at a speed of 20 words per minute or less) in ten-minute intervals. In addition, FCC regulations require a remote control link (or auxiliary link) that operates at a frequency of 220 MHz or higher (American Radio Relay League, 1989). Due to the availability of equipment and the proliferation of repeaters on the 144 MHz-band, the researcher chose 2 m as the wavelength to transmit the telemetry signals. For similar reasons, the 7 cm band (440 MHz) was selected as the auxiliary link. Modifications were made to a microprocessor repeater controller circuit board, permitting it to provide automatic Morse code identification every ten minutes and allowing it to act as an interface with the auxiliary link to implement various remote control functions, such as turning the 2 m transmitter on and off.

In addition, a voltage comparator was constructed to sense outputs from the seismic sensor and to automatically activate the 2 m telemetry transmitter. The voltage comparator features a variable threshold, adjustable through a range of a few millivolts to above one volt. When the voltage comparator reaches the predetermined threshold (indicating a level of seismic activity worthy of recording), its circuit sends a Logic "1" signal to the controller that in turn activates the telemetry transmitter.

The voltage controlled oscillator (VCO) functions as the heart of the telemetry system (Fig. 6). The VCO converts the varying voltage output of the seismic sensor to an audio tone that varies in frequency in direct proportion to the output of the seismic sensor. This audio tone may be within any range of frequencies suitable for amateur radio VHF/UHF FM radio transmission. Research indicates that audio tones within a range of 100 Hz to 5000 Hz are best suited for this project's purposes, thus 1020Hz was selected as the center frequency—the same center frequency used by the United States Geodetic Survey. A VCO was constructed from a schematic diagram obtained courtesy of the University of Memphis Center for Earthquake Research and Information (CERI). This schematic was originally

used in a seismic monitoring project of the New Madrid fault and specified 1125 Hz as the center frequency (P. Lane, University of Memphis, personal communication, 1998). Modifications moved the center frequency to 1020 Hz, while retaining the 140 Hz deviation outlined in the CERI schematic.

Stability is a crucial element in a VCO used for telemetry purposes. Although many factors can cause frequency shifts, temperature variations present the main concern. Temperature variations causing frequency shifts can be misinterpreted as seismic activity and distort the accuracy of the transmitted data. Because the telemetry transmitter will likely be exposed to considerable temperature variations, a circuit featuring great temperature stability was needed. Therefore, a phase-locked loop (PLL) circuit using an external crystal reference oscillator was used to keep temperature-related frequency drift to an absolute minimum.

The output from the VCO is fed to the microphone input (through an attenuator pad) of the 2 m FM transmitter. Although the transmitter may be adjusted to operate on any authorized 2 m frequency (144–148 MHz), 146.57 MHz was selected. The microphone push-to-talk (PTT) contacts connected to the microprocessor controller activate the transmitter.

The 7 cm (440 MHz) receiver provides the auxiliary link connection. The audio output of the auxiliary link is connected to the Dual Tone Multi-Frequency (DTMF) input of the microprocessor controller. DTMF or "touch-tone" signals received by the microprocessor controller implement the needed remote controlled functions, such as turning the sensors and transmitter on and off.

A regulated power supply operating from a 12 volt DC source provides power for the seismic sensors, the VCO, and the voltage comparator (Fig. 7). Currently, this source is ten Nickel-Cadmium (Ni-Cad) cells.

Both the 2 m telemetry transmitter and the 7 cm auxiliary link receiver share a single dual-band antenna, which may be elevated to improve transmission. A 2 m receiver (operating at 146.57 MHz) receives the signals transmitted from the telemetry transmitter. The output from the receiver is fed to the input of a demodulator (or discriminator) which acts as a reverse voltage controlled oscillator (Fig. 8). Modifications were made to a surplus Teledyne demodulator designed for oil exploration purposes to receive outputs from the amateur receiver. The varying tones produced by the VCO at the remote location are translated into varying voltages. The varying voltages are intended to duplicate the voltage outputs from the seismic sensors and are fed to the input of the A-to-D converter board, which is interfaced with the personal computer. Once again, the SDR computer software is used.

An amateur radio transmitter operating on the 7 cm band (440 MHz) remotely controls the telemetry system. The transmitter is equipped with a DTMF oscillator (touch-tone pad) which allows remote switching of various channels through the microprocessor controller located at the remote location. Although the system has the capacity to control nine different channels, currently remote control functions are limited to activating or deactivating the transmitter and manually initiating the transmission of data. The remote control operator, according to FCC regulations, must be able to shut down the transmitter should the need arise (American Radio Relay League, 1989).

RESULTS

Phase I. The three changes made to the Lehman seismograph proved successful. The seismograph recorded earthquakes ranging from Mexico to California and was the only seismograph in the state of Mississippi to record the magnitude 4.1 ML, March 25, 1996, Clarke County, Mississippi earthquake—the first earthquake recorded in the state since March 29, 1972 (Department of the Interior, 1998; A.C. Johnston, University of Memphis, personal communication, 1996) (Fig. 2).

Phase II. The portable device is very small, lightweight, and has the ability to be set up in a minimum amount of time. If proven successful and reliable, the seismograph will present a more convenient way to measure earthquakes, and possibly will assist in nonseismic vibration monitoring applications. The seismograph's protective PVC pipe "rain hat" makes the seismograph essentially weatherproof. In addition, the accelerometer sensors can be calibrated to ignore the "tilt angle," proportional to the sensor's voltage output. By ignoring the tilt angle, the seismograph does not have to be perfectly level and has the ability to be thrown or possibly launched while accurately graphing accelerations, movement, and seismic activity. These unique capabilities might have applications to military research related to vibration and motion sensing. Due to its ability to measure and record the intensity and

direction of vibrations and other disturbances, the portable seismograph's outputs could be fed to a modified flight recorder "black box." If so, it is possible that this information could be used to analyze and determine the cause of many in-flight anomalies that lead to various mechanical and structural failures in aircrafts. Furthermore, Dr. Hans Homung of California Institute of Technology agreed with the researcher in that this information might assist in not only predicting but also aid in avoiding these same problems (H. Homung, personal communication, 1997).

The full potential of this device for recording seismic activity is a matter of continuing investigation, but it has the capability of recording both small and large vibrations. However, in comparison to the modified Lehman seismograph built in the first year of research, the portable device seems to work well in many areas.

While seismic activity in the Jackson, Mississippi area, has provided limited opportunities for comparison, the portable device appears promising in several categories. Comparisons with the Lehman device have revealed that the portable seismograph is somewhat less sensitive. However, it is also dramatically less susceptible to local noise interference—most notably that associated with aircraft and automobiles. Also, the modified Lehman is regularly influenced by freight trains passing on the Illinois Central Main Line located some three miles west of the test site. The portable device, however, appears largely immune from this interference. This comparative noise immunity is attributed to the narrow bandpass incorporated into the design. It has also been noted that g-level measurements can be made with great accuracy based on the voltage output of the devices. The ability to equate the forces applied to the sensor to a recognized standard measurement of acceleration offers obvious research advantages over the somewhat arbitrary and merely relative measuring capabilities of the Lehman device. The most obvious advantage of the new device remains its compactness and portability (Fig. 3). Three sensors are contained within a housing weighing only a few pounds and occupying only a fraction of a cubic foot (Fig. 4). Three Lehman sensors would occupy at least nine to twelve square feet of space and would weigh over 100 pounds. Due to the delicacy of the Lehman device and the need for leveling and other adjustments, a setup time of up to two hours is required (assuming the availability of a suitable location and a source of power). On the other hand, the portable seismograph requires virtually no setup, has a protective housing, requires less than one-half of a square foot of space, does not have to be placed on a level surface, and may be battery operated for extended periods of time.

Figure 9. Seismic telemetry transmitter. Weather-proof PVC housing.

Phase III. Initial tests conducted on both a 146.57 MHz simplex frequency and a local repeater, that operates on an input frequency of 147.600 MHz and an output frequency of 147.000 MHz, have demonstrated the overall feasibility of the telemetry system. First, evaluations were conducted at a close range (within 100 feet) using the simplex frequency at low power (300 MW).

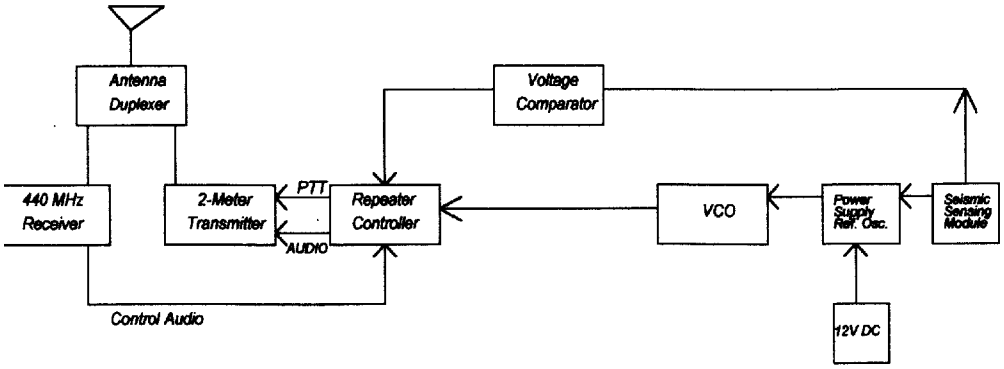

Figure 10. Seismic transmitter block diagram.

Tipping the remote sensor at a 90º angle along the axis of the accelerometer (x-axis) allowed for a momentary 1g response. In order to achieve the desired response, "tweaking" was done at the threshold setting of the voltage comparator to allow triggering of the controller and, in turn, the telemetry transmitter. Initial comparator thresholds were too low, causing delay in triggering the controller which then cut off much of the accelerometer's rising output. Due to low comparator thresholds, it is apparent that this threshold setting will be particularly critical in measuring seismic activity, which may produce accelerometer outputs considerably below the full 90º tilt.

A simple "rubber duck" style dual band antenna attached directly to the dome of the telemetry unit was used for testing purposes (Fig. 9). At 300 MW transmitter output levels, this setup generally worked well for tests at distances of up to a quarter of a mile from the testing site using simplex frequencies. The receiver used a similar antenna for these tests. Connecting the receiver to an elevated antenna with a gain of about 3 decibels helped improve the range, providing a reliable range of approximately 1 mile. However, hills, trees, and other structures in the area surrounding the testing site sometimes hindered operation. These obstacles caused "dead spots" in the transmission, but either elevating the antenna or increasing the transmitter power levels prevented these problems.

Battery life also proved to be a major consideration. Depending on outside temperature, as well as the number and duration of test events, the Ni-Cad batteries would power the remote system for about twenty-four hours. Higher transmitter outputs (i.e., 5–7 watts) drastically shortened this time. Obviously, in a situation where it is difficult to establish a reliable link, notwithstanding the desirability of maintaining compactness and portability, antenna height must first be optimized. Even then it appears that sustained operation will require a solar panel system to keep the batteries charged.

Although only partly successful, operation through the local 2 m repeater provided encouraging results. The test repeater, operated by the researcher's high school amateur radio club, is located on the roof of a medical office building (approximately 175 feet above street level) three miles from the testing site. Unfortunately, the testing site is surrounded by hills and trees that distorted the path of the repeater. Perhaps for this reason, at a 300 MW setting with the "rubber duck" antenna, the transmitter would not reliably "key" the repeater. Switching to a 3 db-gain antenna at a height of six feet cured this problem. Switching the transmitter to the 5 W-output level also corrected the problem but considerably increased battery drain. Therefore, the high-gain antenna at 3 db was used for the remaining repeater tests. Due to the researcher's experience as an amateur radio operator, the hypothesis was made that a telemetry transmitter equipped with a small "rubber duck" antenna would be adequate for flat open terrain areas.

Once it was established that the telemetry transmitter

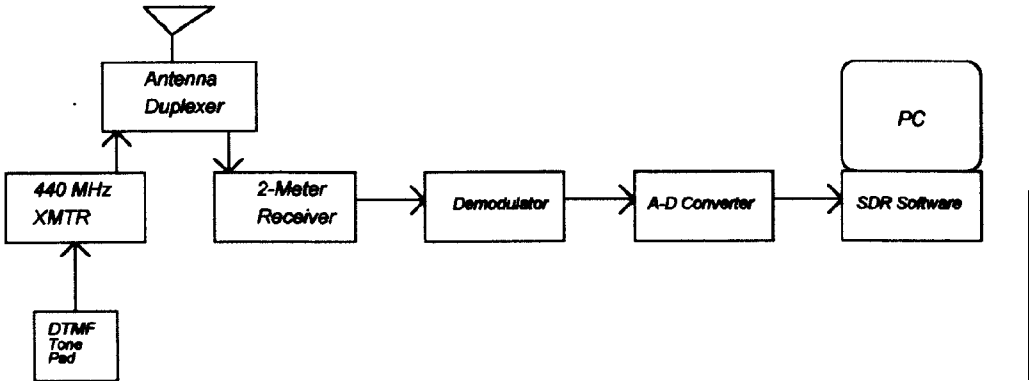

Figure 11. Seismic receiving station block diagram.

could at least "key" or activate the repeater, the researcher modified several repeater control features so that telemetry information could be retransmitted. First, the "anti-kerchunk" feature was turned off. This feature prevents other amateur radio operators from searching for an active repeater by keying their transmitter momentarily, and then waiting to hear a response (i.e., CW identification, squelch tail, etc.). Ordinarily this feature requires a carrier to be transmitted for at least one second before turning on the repeater transmitter, but by deactivating this mode, the repeater responded immediately to a telemetry signal. Also the repeater's DTMF inhibit mode was turned off. This function prevents retransmission of touch-tone control codes used to program the repeater but also interferes with the retransmission of telemetry tones.

Tests were conducted to measure the 90º tilt—1 g response by randomly shaking the telemetry capsule. Although results were encouraging, the repeater (responding to the initial telemetry signal and the keying of the transmitter to re-transmit the signal) caused additional lag time by cutting off the initial response. Decreasing the sensitivity threshold of the voltage comparator would eliminate some of these responses but could also contribute to false triggering.

Activating the repeater's CW identifier and the identifier built into the telemetry controller caused occasional interference. Many of these problems could be reduced or eliminated by modifying the system (i.e., improving repeater response time), but despite these problems the repeater system proved workable. A simplex dedicated link between the telemetry transmitter and the receiver is clearly the most reliable and less prone to receive interference.

As a result of some of the unique features incorporated into this design, it is believed that the telemetry system will be effective for both seismic and nonseismic research applications. Although current telemetry research has been limited to the use of a single channel system (operating on the x-axis), a single radio frequency has the ability to combine as many as nine telemetry channels. Therefore, future research will seek to expand to three telemetry channels (one channel for each seismic sensor) by adding a channel to the y-axis and another to the z-axis. It is also possible to add control functions for monitoring and reporting changes in temperature, wind speed and direction, barometric pressure, river levels, humidity, etc. For instance, in the event of a flood, this telemetry system could be used to monitor changes in river levels and instantaneously relay the readings through amateur radio. This type of environmental monitor would be especially useful in small rural areas where in some cases bridges are not presently equipped with river gauges. If the need should arrive, this system is also adaptable to traditional telephone lines, cellular phones, family and CB radio services, as well as commercial radio (Figs. 10, 11).

DISCUSSION

The evolution in designs from the bulky and temperamental Lehman device to the current telemetry system has been largely successful, although there have been tradeoffs. The current system, based upon the ADXL05JH accelerometer sensors, lacks the range and sensitivity of the Lehman but is more portable, flexible, and in some respects more reliable than the Lehman is. Although the telemetry system works best in a simplex dedicated mode, in an emergency situation the system can be reprogrammed to accommodate fast-rise outputs from the telemetry transmitter.

Battery conservation is a problem, but a solar panel charging system would keep the batteries charged for much longer periods of time. Also, battery drain would be minimized by replacing power levels (which increased battery drain) with adjusted antenna gain and antenna height.

One of the exciting aspects of this investigation has been the continuing realization of its potential applications to other areas of research. Besides being used to further benefit the study of earthquake engineering, the station could also be used as an educational teaching tool in the elementary, secondary, and the university school systems. Relatively inexpensive, the telemetry station could be an affordable addition to numerous science courses. Used as a teaching tool, the portable seismograph would provide an interesting hands-on experience in learning about the fields of seismology, physics, engineering, and geology.

Outside of the classroom, the telemetry station could serve as an environmental monitor, particularly useful in small rural towns that lack a system needed to monitor changes in river levels during flooding conditions. This inexpensive system can be rapidly deployed using existing resources, including trained amateur radio operators and amateur radio equipment.

ACKNOWLEDGMENTS

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The Mississippi Space Commerce Initiative (MSCI)

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In August 3, 1996, NASA Administrator Dan Goldin issued a challenge to the State of Mississippi to "become the nation's leader in commercial remote sensing research, product development and services."

This event lead to the passage of Senate Bill 3154 during the 1997 legislative session, appropriating one million dollars to the Mississippi Research Consortium (MRC) in support of the MSCI on top of NASA's commitment of three million dollars per year for five years.

In April 1998 the MSCI was formally accepted through the signing of the Joint Research Agreement and the University of Mississippi was assigned to be the lead university.

The multi-facet agreement purports to enhance Mississippi's remote sensing infrastructure through technology development initiatives with far reaching implications affecting the work-force development and training.

Specifically, the following agencies will participate in this program and will offer the following services:

- The Institutions of Higher Learning will promote remote sensing course and program implementation at Mississippi's colleges and universities.
- The State Board of Community and Junior Colleges will provide Spatial Information Application Centers through the Skill Tech program at each campus plus degree and certificate programs in remote sensing.
- The State Department of Education will provide awareness and introductory training in remote sensing, geographic information systems and global positioning systems through the existing Tech Prep program and through an academic course titled Spatial Information Science.
- The Mississippi Authority for Educational Television provides production services for public information programs plus access to the electronic classroom network to disseminate information and training statewide.
- The Social Science Research Center at Mississippi State University conducts surveys, needs assessments and program evaluations.

These and other resources are presently being committed to educating students to populate this new industry now and into the next millennium. Not will only remote sensing be part of our college and vocational curriculum, but also it will be taught to elementary, junior high and high school students. This program is one of the most innovative in the industry. And it is ensuring that Mississippi will continue to have its share of the most innovative minds in this industry.

Various phases of this program have already been implemented:

(a) Agreements for the distribution of remote sensing software to all our State Universities and Community and Junior Colleges.
(b) First sets of software have already been distributed.
(c) Faculty from the MRC universities have already attended classes in the use of the software, with more attendees to participate during the fall semester.
(d) Remote sensing courseware are being presently developed by Jackson State University, Mississippi State University and University of Mississippi. The software, once completed (early this fall) will be available via the Internet and other distance learning environments.

Remote sensing applies the technologies of three distinct disciplines in the creation of industries and products that have wide application in our modern technological society.

The area of GIS (Geographic Information Systems) has been with us for quite some time and it provides the mapping and demographic component of this technology.

The GPS (Global Positioning System) technology provides the capability of positioning a person or an area at any place on the earth within feet from its actual position. This capability varies depending on the equipment used and other considerations.

However, it is an extremely invaluable component of the system and it has applications in telemedicine, agriculture, real estate, forestry, transportation, urban planning and others.

The RS (Remote Sensing) involves the capability of using satellite or other imaging sources to photograph the earth with various types of sensors and observe specific areas with phenomenal detail and image content.

The importance of the integration of these technologies has not as yet made its full impact both in the academic and business worlds. It reminds one of the impact that the integration of PCs, telephone and television is about to bring to our society. Both these technological thrusts will dominate the technology of at least the first twenty years of the next millennium.

Mississippi is getting ready to train its work-force resources to meet face-to-face with these demands.

Education Members

Organizations that assist the Mississippi Academy of Sciences in its efforts to promote science in Mississippi

Alcorn State University
Belhaven College
Delta State University
Mississippi-Alabama Sea Grant Consortium
Mississippi Delta Community College
Mississippi Gulf Coast Community College
Mississippi State University
MSU Agric. & Forestry Expt. Station
Mississippi University for Women
Pearl River Community College
University of Mississippi
University of Mississippi Medical Center
University of Southern Mississippi

Ponthieva racemosa (Orchidaceae) in Trace State Park, Pontotoc County, Mississippi

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Two rather large populations, over 100 each, and one small population of *Ponthieva racemosa* (Walt.) C. Mohr (Orchidaceae) were found in Trace State Park in Pontotoc County, Mississippi, during September and October of 1993. Trace State Park is located within the Pontotoc Ridge physiographic region of the state (Fig. 1).

One classification scheme places *Ponthieva racemosa* in Subtribe Cranichidinae, Tribe Cranichideae, Subfamily Spiranthoideae, and Family Orchidaceae (Dressler, 1981; Dressler, 1993). Another scheme places it in Subtribe Cranichidinae, Tribe Goodyereae, Subfamily Neottioideae, and Family Orchidaceae (Luer, 1972).

The genus *Ponthieva* R. Brown includes about twenty-five species which are found in the warmer regions of the Western Hemisphere from southeastern Virginia to Chile, including Mexico, Central America, the West Indies and South America (Correll, 1950). The range of *Ponthieva racemosa* is from southeastern Virginia along the coastal plain to Florida and west to Texas (Gupton and Swope, 1986).

Ponthieva racemosa, which is known by various common names, including Shadow-witch, often occurs in the vicinity of limestone or in calcareous soils in hammocks, on limestone ledges and on the edge of limerock sinkholes in Florida, in damp woods along streams or on the rim of eroded stream banks in wooded ravines and on the edge of muddy sloughs and ponds (Correll, 1950). Our populations were found on moist calcareous slopes with *Juniperus virginiana* L., Eastern Red Cedar, as the dominant woody species.

Ponthieva racemosa has a reddish brown to purplish or greenish scape; thick, fleshy roots; leaves mostly in a basal rosette; and a lax raceme consisting of few to many, wide-spreading, whitish green flowers (Radford et al., 1968). Our specimens fit the detailed descriptions in Manual of the Vascular Flora of the Carolinas.

This orchid appears in early spring as a rosette of satiny green leaves. Later a slender pubescent stem bolts from the center of the rosette. A raceme of small blossoms develops by autumn. Each blossom protrudes laterally from the stem and tilts back to face upward, the peaks of the uppermost lips pointing to the axis of the stem. The green-veined lateral sepals are oriented upward like wings (Luer, 1972).

The two broad petals together form an undulating platform supported by the middle sepal behind like a spring, as if to create a landing platform for some insect. Insects will encounter the beaked rostellum en route to the nectary of the concave lip. Carrot-shaped pollinia will attach to insect visitors and be transported, hopefully, to the next flower. Halictine bees were observed visiting flowers of this species in central Florida in November 1970 (Luer, 1972). Very small flying insects, presumed to be possible pollinators, were observed around flowers of our populations.

In *Ponthieva*, especially, the nonresupinate flowers mimic resupinate flowers, in that the two petals, together, form a sort of "pseudolip." The inconspicuous true lip functions as an elaiophore or nectary, which produces oil, rather than nectar. According to Dressler (1993), the pollinators may be anthophorid bees that gather oil as food for their larvae.

The Shadow-witch is considered rare (Radford et al., 1968) and no mention was made of it in a preliminary check-list of Mississippi's orchids (Pullen, 1966). It was not included among later additions to the Mississippi flora (Pullen et al., 1968). The Thomas M. Pullen Herbarium (MISS) at the University of Mississippi had no specimens of this orchid prior to our collection.

A further search of the literature revealed records of its occurrence in the Ragland Hills area of Forrest and Perry Counties (Rogers, 1977) and in Monroe

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County (MacDonald, 1996). The IBE Collection at Mississippi State University Herbarium contains a record from Clay County and there is a verbal report of two sites in Chickasaw County within the Tombigbee National Forest with one site containing an estimated 5000+ plants (John MacDonald, graduate student, Mississippi State University, personal communication). The Mississippi Natural Heritage Program provided a record of a site called Osborn Prairie in Oktibbeha County and informed us that *Ponthieva racemosa* had been added to the Mississippi Special Plants List in 1994 with a G4, G5, S2? ranking, indicating it is apparently or demonstrably secure globally, though possibly rare in some parts of the range; and, that it is possibly imperiled in the state because of rarity or factors making it especially vulnerable to extinction (Ron Wieland, ecologist, Mississippi Natural Heritage Program, personal communication).

This finding of three populations of Ponthieva racemosa on moist calcareous slopes in Trace State Park suggests that this species may occur in favored habitats throughout the Pontotoc Ridge.

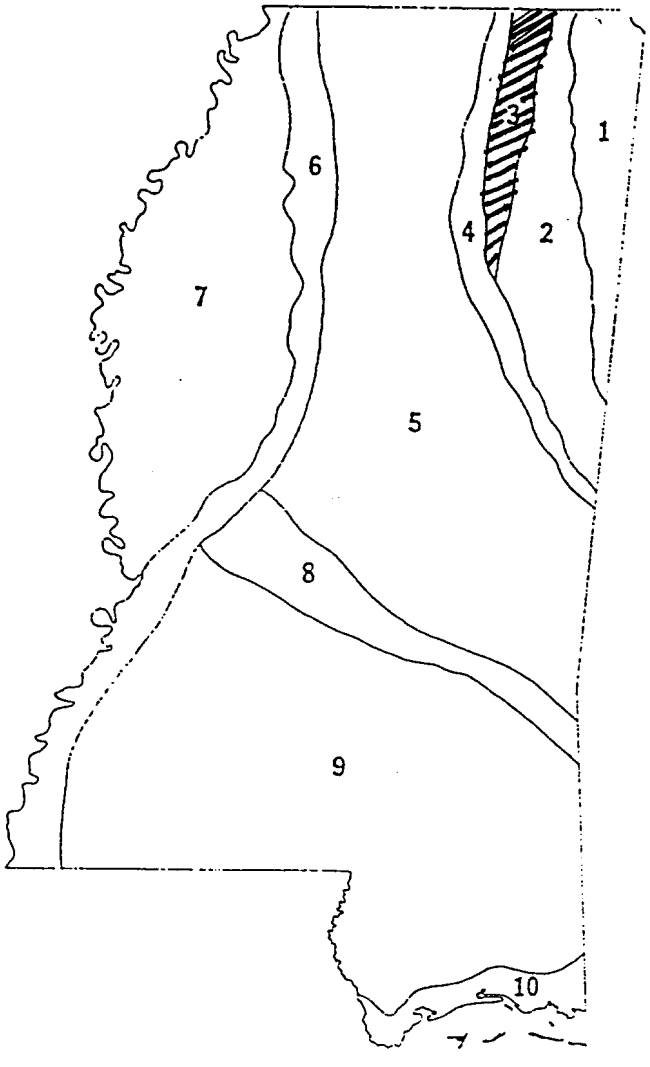

Figure 1. Physiographic regions of Mississippi (adapted from Lowe, 1921; Temple and Pullen, 1968). 1. Tennessee River Hills, 2. Northeast Prairie Belt, 3. Pontotoc Ridge, 4. Flatwoods, 5. North Central Plateau, 6. Loess Hills, 7. Yazoo-Mississippi Delta, 8. Jackson Prairie Belt, 9. Long Leaf Pine Region, 10. Coastal Pine Meadows.

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An Annotated Checklist of Benthic Invertebrates of Lake Yazoo and Yazoo River, Mississippi

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Benthic invertebrates form resident communities of individuals that move very little within a particular reach of a stream or lake throughout their life time in the water (Wells and Demas, 1979). The composition of these communities can be indicative of the hydrologic and water-quality conditions where these organisms live (Mackenthum and Ingram, 1966). Any significant change in hydrology or water quality can change the composition of benthic invertebrate communities. Therefore, the number of taxa of benthic invertebrates at a location as well as the number of individuals within a taxon can yield useful information about the hydrology and water quality of the habitat (Wells and Demas, 1979). Price et al. (1993) reported on the agricultural uses of Yazoo River dredged material with emphasis on dredged material in an old, thick-layer confined disposal facility (CDF) constructed near the Yazoo River Channel. This was in an area adjacent to the Yazoo River levees, located about 9.7/km north of Yazoo City, Mississippi-an area surrounded by productive cotton land. Their objective was to determine the response of cotton to Yazoo River dredged material as a growth medium and to produce a substantial cotton crop on a representative deep-layer CDF. Their study was necessitated by the fact that channel improvement and levee construction in and along the Yazoo River drainage basin were authorized by the U.S. Congress to alleviate flooding of residential areas, towns and farm land in "The Delta"—a fertile area lying between the Mississippi River and Yazoo River. The area also delineates the Yazoo River Basin. It was noted that the lower portion of the Yazoo River was dredged during the 1970s with the dredged material placed in large deep confined disposal facilities constructed near the Yazoo River Channel. Erosion resulting from flooding became a problem in the area with an estimated loss of millions of tons of soil per year carried by the Yazoo River and its tributaries. Also, conversion of bottomland hardwood forests into agricultural lands caused concern for increased loss of soils through loss of catchment basins. In addition, Price et al. (1993) noted that studies conducted during the 1970s indicated pesticide contamination in some areas. So there was special interest in changes in land use and flood control structures that might impact the presence of pesticides and sedimentation rate resulting in reduction in water quality.

Yazoo River has four major tributaries, viz., Yalobusha, Big Sunflower, Coldwater, and Tallahatchie. It arises in the west central part of the State at the confluence of the Tallahatchie and Yalobusha Rivers and flows approximately 190 miles southwest to drain into the Mississippi River. The soil conservation service in 1970 estimated that erosion in the Yazoo River basin was more than 28 million tons per year of which 50% was carried by tributaries of the Yazoo River (U.S. Fish and Wildlife Service, 1979).

Pennington et al. (1991) carried out water quality studies in the Upper Yazoo Project Area characterized by a hill region in the east and a flat delta region of extensive agriculture in the west. One of the objectives was to characterize general water quality in the Yazoo River and another was to provide information on pesticide (insecticide and herbicide) contamination of sediments of the upper Yazoo Project area. It was reported that, on the whole, pesticide concentrations were lower in 1990 than in 1980. It was noted also that the impact of land-use changes on water quality for the Yazoo River Basin was hard to generalize due to changes that the basin was said to be undergoing at the time of the study, namely, the conversion of land to catfish ponds and the conversion of forest land to crop land

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which impact the aquatic system because of the probable increase of suspended sediment load.

A study on nonpoint source contamination of the Mississippi River and its tributaries including the Yazoo River was carried out by Pereira and Hostettier (1993). It indicated that the entire navigable reach of Mississippi River was contaminated with complex mixture of agrochernicals and their transformation products derived from nonpoint sources. This study found that the upper and middle Mississippi River Basin farm lands were the major sources of herbicides applied to corn, soybeans and sorghum and that farm lands in the lower Mississippi River basin were a major source of rice and cotton herbicides. The Mississippi River thus serves as a drainage channel for pesticides-contaminated surface and ground water from the Midwestern United States.

Ford and Hill (1991) carried out studies on the organochlorine pesticides in soil sediments and aquatic animals in the Upper Steel Bayou Watershed of Mississippi. Soil sediments and tissue samples from eight species of aquatic animals were collected on or near Yazoo National Wildlife Refuge and analyzed for organochlorine pesticide residue. Residues of 12 organochlorine pesticides were found in most animal samples, and 0.0 to 4.6 mg/kg of 5 compounds were detected in soil sediments. But the animals sampled did not include benthic invertebrates. Literature review shows that no significant survey of the benthic invertebrates in the lower Yazoo River or Lake Yazoo has been previously carried out.

The purpose of the present study was to collect, identify, and catalog the benthic invertebrates in the Yazoo River and Lake Yazoo. The study was also conducted to enable us to find and select relevant bioturbators (i.e., the animals that live in or on sediment and mix or stir it both horizontally and vertically through activities such as burrowing, sediment ingesting, defecating, tube building and biodepositing [Reible et al., 1996a]) for performing flux measurement experiments which will shed more light on physicochemical transport processes.

Benthic invertebrates were sampled between June 1995 and November 1996 at 12 sites (six in Lake Yazoo, about 96.5/km from Vicksburg, MS and six in the lower part of Yazoo River, about 101.4/km from Vicksburg) in the Yazoo City area (Figs. 1 and 2). The sites were selected at a minimum of 100 meters apart. The river was cut off and rechanneled in 1953 in the vicinity of Jonestown as a flood control measure. The cut-off part is now called Lake Yazoo. The course of the lake in the vicinity of the Yazoo City limit where three industrial corporations are located, namely, Griffin Corporation, Spencer Concrete, and Beasly Lumber Yard, was selected as well as the East bank levee part of the altered river channel where some wood chipping industries (James River Corporation) are located (Fig. 2).

Two sediment samples were taken from each collection site with Peterson grab sampler and Tall Ekman grab sampler from the bank area and at a water depth of 0.5 m to 3 m and three replicates per site to obtain representative samples. The samples were taken at different days (one to two weeks apart and approximately the same time period [between 9 and 11 a.m.]). In each of the three collection times approximately the same amount of sediment was collected, one quarter of the pail full. The sediment samples were put in plastic pails and taken to the laboratory for processing. One sediment sample was used to perform chemical analysis to determine contaminated sediment sites, and to assess and characterize contaminated sediments or substrates (Acholonu et al., 1997). The invertebrates were separated from the second sediment sample by using different sizes of sieves (0.5–2 mm mesh). All organisms seen were removed from the sieve, killed and fixed in 10% formalin. They were sorted with the aid of a dissecting microscope and stored in 70% methyl alcohol pending further processing and identification. The specimens were next mounted directly on slides in CMC-10 medium which also cleared them. They were examined under the microscope for identification. Identifications were made with the help of keys from Beck (1979), Brigham et al. (1982), Klemn (1985), and Pennak (1989). Voucher specimens are kept at the Department of Biological Sciences, Alcorn State University since all appear to be already described species and/or immature specimens

From the lake, seven chironomid genera, two genera of oligochaetes, and some unidentified immature specimens belonging to the Family Glossoscolecidae were recorded. Also a few leeches (*Placobdella* sp., Hirudinidae) were recovered. From the river, eight chironomid genera, three genera of oligochaetes and some unidentified immature specimens of the family Glossoscolecidae were recorded. In addition, some caddis fly (*Hydropsyche* sp. Trichoptera), dragon fly (*Gomphis* sp. Odonata), and water scavenger beetle (*Hydrobius* sp. Coleoptera) larvae, and some fingernail clams

(*Pisidium* sp. Bivalvia) were recovered (Table 1). The dipterans were the most numerous invertebrates recovered from both habitats but they were a little more diverse in the river (9 genera) than in the lake (8 genera). The dominant infauna in both the lake and the river were chironomids (Diptera) and tubificid worms (Oligochaeta). There were, however, more varieties of genera and species from the Yazoo River than from the Yazoo Lake. This does not, however, suggest that all the invertebrates found only in the river do not exist or cannot be found in the lake.

Polypedillum sp. (Diptera) occurred very frequently in the lake and river followed by *Glyptotendipes* sp. (Diptera). *Polypedillum halterale* (Diptera) was the most common species of benthic organisms collected.

The difference in the diversity of organisms between the Yazoo River and Lake Yazoo could be attributed to hydrologic conditions such as substrate type (silt, clay, sand), velocity of water, vegetation, organic detritus, and the overall water quality especially with respect to pollution (Wells and Demas, 1979).

Some of the benthic organisms found, such as the oligochaetes, *Limnodrilus hoffmeisteri*, *Limnodrilus udekemianus*, and *Dero digitata* may serve as bioturbators (Karickhoff and Morris, 1985) and enhance contaminant release. Chironomids and *Lumbriculus* are suspected to have impact on contaminant migration intermediate between the amphipods and tubificids (Reible et al., 1996b). The midge fly larvae according to them, borrow and grow until they emerge as adult flies. They could thus in the process of borrowing stir the sediment vertically.

We plan to evaluate both the tubificids and chironomids found in this study as possible bioturbators. We also plan to culture some of these for conducting flux measurement experiments. The fact that the dominant species found were tubificids indicates that the water bodies were contaminated. Pennak, (1989) indicated that tubificids often dominate benthic microfaunal populations in contaminated sediments. Acholonu et al. (1997) indicated the presence of polyaromatic hydrocarbons (PAHs) in the sediments of both the river and lake thus showing that both bodies of water are polluted in some parts.

It is recommended that this kind of study be continued to widen our scope of knowledge on the benthic organisms in Mississippi freshwater bodies, that sediments in the middle or deeper parts of the river and lake be collected and examined and that the recovered fauna be compared with those from the banks as reported from the present study.

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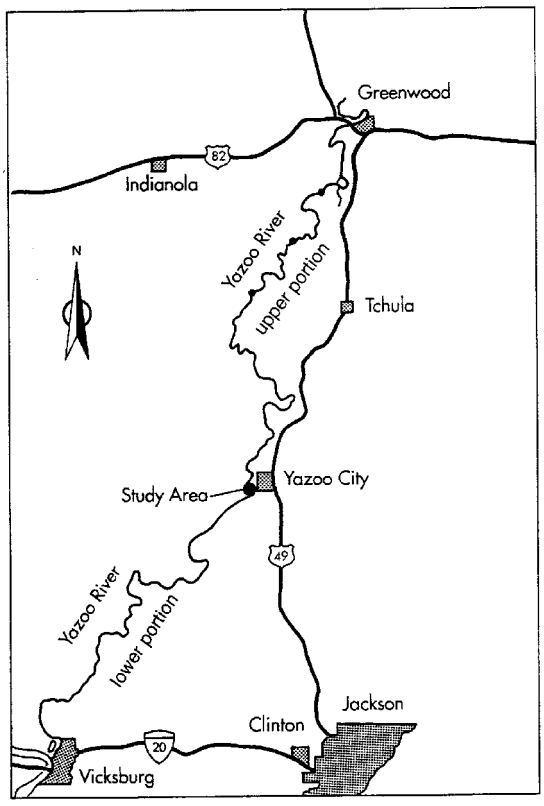

Figure 1. Map showing upper and lower Yazoo River and study area.

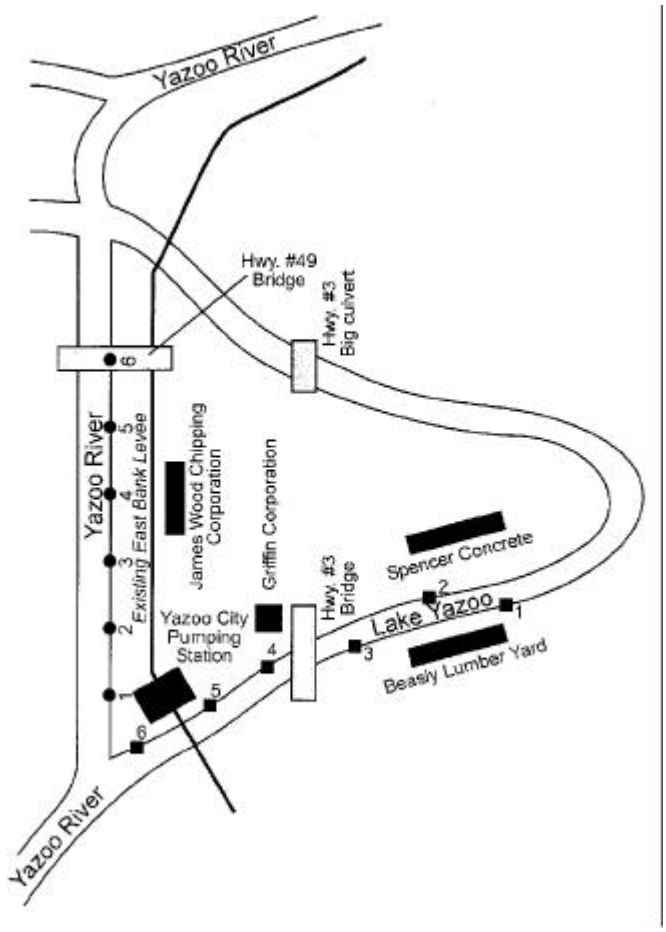

Figure 2. Map showing study sites in the Lake Yazoo and Yazoo River. Collection or sampled sites along the Yazoo River are marked with round dots, those along Lake Yazoo are marked with squares while industrial areas are marked with rectangles. Note the confluence of Lake Yazoo and Yazoo River and the location of the Army Corp of Engineers Pumping station that controls the water levels in the Lake and prevents flooding of Yazoo City.

Table 1. Benthic Invertebrates Collected from Yazoo River and Lake Yazoo Sediments, June 1995–November 1996.

Taxa	Yazoo River	Lake Yazoo
Insecta: Diptera	x	x
Chironomidae: Chironomi (larval midges)		
Chironomus sp.	x	x
Cryptochironomous blarina	x	x
Glyptotendipes sp.	x	x
Goeldichironomus pictus	x	-
Goeldichironomus sp.	x	x
Polypedilum halterate	x	x
Poypedilum sp.	x	x
Stenochironomus sp.	x	x
Cladotanytarsus sp.	x	-
Tribelos sp.	x	-
Tanypodinae		
Procladius sp.	-	x
Pentanura sp.	x	-
Insecta: Coleoptera: Hydrophilidae		
Hydrobius sp. (Beetle larvae)	x	-
Insecta: Odonata: Gomphidae		
Gomhis sp. (Dragonfly larvae)	x	-
Insecta: Trichoptera: Hydropsychidae		
Hydropsyche sp. (Caddis fly larvae)	x	-
Oligochaeta: Tubificidae		
Limnodrilus hoffmeisteri	x	x
L. Udekemianus	x	x
Oligochaeta: Naididae		
Dero digitata	x	x
Oligochaeta: Lumbriculidae		
Lumbriculus sp.	x	-
Oligochaeta: Glossosolecidae	x	x
Hirudinea: Hirudinidae		
Placobdella sp.	-	x
Mollusca: Bivalvia (Pelecypoda)		
Sphaeriidae		
Pisidium sp. (clam)	x	-

x = presence of organism
- = absence of organism

President's Column

I realize that most of us are growing weary of references to the new millennium; however, it seems such an appropriate reference for sharing thoughts about the Academy that I'm going to risk using it…just one more time. It seems that being on the threshold of the new millennium irresistibly calls us to reflect, take stock and review our vision for the future. Reflecting on the history of the Academy since its birth in 1930, we can certainly feel both proud and grateful. We can be proud of the Academy's role in promoting science education and research in Mississippi and beyond. And, we can be grateful for the many working visionaries whose efforts created a state academy that is regarded to be one of the nation's finest. But, it is also a time to take stock. I remember well last year listening to Rob [Rockhold] calling us specifically to "take stock," vision anew our organization's response to the challenges of the future, and be prepared to adapt. If there is one thing upon which we can all agree at this point, it is that change will be in our future. As an organization of scientists and educators, it will be our challenge to guide the role of science in a changing world and articulate that role especially within the communities we serve. At this point, it might be good to include a reminder of the purpose of science and technology, that is, to serve humanity and improve the quality of life. The advancement of scientific knowledge and technology should not be separated from discussions of its impact on improving the quality of all life. Our challenge will be to be mindful leaders of scientific advancement, rather than unthinking followers in the wake of science and technology's forward momentum. Native Americans employ a useful perspective for evaluating decision-making; they ask, "What will be the effect of this decision on the seventh generation?" This might be a good measure to keep in mind as we discuss the Academy's goals and formulate our future action plans.

Speaking of plans and action, I would like to share briefly some of the recent activities of the Academy. In July, the new assemblage of board member gathered to begin planning the 2000 conference and discuss matters relevant to the Academy. Some highlights of this meeting and the summer activities are: 1) Policies governing the Mississippi Junior Academy of Sciences (MJAS) were revised. Discussion of a proposal submitted by the MJAS subcommittee (Steve Case, Joan Messer, Burnette Hamil and Rosalina Hairston) resulted in revisions that will increase the number of MJAS students attending the National Competition and provide travel support for the Youth Activities Chair's attendance at the National Meeting. All of us that have been closely involved with the Junior Academy are excited about these positive changes. 2) Two new committees/chairs were instituted to meet conference needs. A Poster Session Committee that will be chaired by Aleta Sullivan was created. In addition to coordinating the easel set-up and dismantling process, Aleta and her crew will be available during the conference to greet poster exhibitors, provide poster site directions, and answer questions. We feel this committee will facilitate a much more smooth running of a very important component of our conference. Joyce Mullins Applegate has agreed to be publicity chair. Although the publicity committee as such is not new, the responsibilities have been expanded. Joyce will be responsible for assembling the conference brochure, handling all publicity prior to the meeting, and taking pictures at the conference. 3) Two exciting symposia are in the planning stages. Catherine Cotten is organizing presentations on information technology, and John Colonias from IHL in conjunction with NASA is developing a symposium on remote sensing. Not only should these symposia interest many long-time members, but also draw new, non-traditional members to our conference. 4) This summer, two organizations contacted MAS requesting our endorsement of their grant initiatives. The National Institute on the Environment sought our endorsement of a proposal seeking additional funds for an expanded interdisciplinary environmental initiative, and IHL requested endorsement of the Mississippi Mathematics and Science Collaborative for Excellence in Teacher Preparation (MSMS-CETP), a major proposal they are submitting to NSF. Letters of endorsement were sent in support of both initiatives.

In closing, I would like to give voice to the growing sense of optimism I feel concerning the role of the Academy in the future. Recently I spoke with Dr. Bill McHenry, Assistant Commissioner of Academic Affairs at IHL. He expressed his desire that IHL and the Academy find new ways to work

together towards our common goals. This liaison offers many new and exciting possibilities for promoting science and education in our state. Also, our keynote speaker for the February Conference, Dr. David Orr, should open new doors. Dr. Orr, chair of the Environmental Studies Program at Oberlin College in Ohio, is a noted expert on environmental issues, a popular lecturer, and accomplished author. Two of his books, *Earth in Mind* and *Ecological Literacy*, have sold 10,000 copies each—bestsellers, by the accounting of academic publishing. He has the ability to deliver a critical message that concerns us all with intelligence, insight, and hope. Dr. Orr's presentation has the potential of providing a catalyst for our thinking and infusing our organization with new energy. It is my hope that we will come away from the conference inspired, with a clearer sense of pathways through which we might better evaluate and guide our efforts in the 21st century. As the axiom goes, "We may realize we have unparalleled challenges, but we will see them as unparalleled opportunities."—Susan J. Nodurft

Executive Officer's Column

Ordinarily, I use this space to inform the membership about the functioning of the Mississippi Academy of Sciences. I will still do briefly in this paragraph. The MAS has been fortunate in having excellent elected leadership and these leaders have put the Academy on a sound financial footing. Recent increases in Abstract and Membership fees (the first increases in quite a long time) have given us enough of a cushion that we no longer have to use interest from our savings to cover costs incurred during the year. Leadership from Journal Editor Ken Curry has put this periodical on a strong course. Article submissions are up and we have had a positive response to the online version. Please remember that we have another deadline approaching for abstract submissions.

Having taken care of MAS business, it's time to make a plea to care of Science. We are experiencing a time of real turmoil in our pursuit of knowledge. Research has never been more exciting; funding is even stable and perhaps increasing in some areas. However, our future is not bright. We live in time when acceptance of science is drastically declining. Pseudoscience has always been popular as witnessed by daily Horoscope columns. (How many of your newspapers carry daily science columns?) But now we see mainstream examples of fear of science. Try to recall the last movie that had a scientist "good guy."

In the middle of August, the Cassini spacecraft passed near Earth in order to gain a gravitation boost on its way to Saturn. Instead of pointing out the wonders of this mission and the amazing use of conservation of angular momentum involved in using planets to accelerate our probes, the media concentrated on plutonium. It seems the ship carries a thermoelectric generator powered by the heat generated by the decay of plutonium. Concerns were raised during the launch of Cassini and during its flyby that an accident could cause plutonium release with subsequent contamination of some part of the Earth. Predictions were made of increased cancer deaths, etc. This was the lead item in most stories about the mission. The science was secondary or forgotten.

Few people remember that the worst has already happened. Plutonium from man-made space objects has already been showered on the Earth. The Lunar Module (LM) of Apollo 13, the life boat that allowed the astronauts on that stricken mission to return safely home, was powered by an amount of plutonium essential equal to that found on Cassini. This LM reentered our atmosphere, and it, along with its burden of plutonium, disintegrated. There has been no evidence of health or environmental consequences from this event. However, this was not reported as the media highlighted the plutonium hazard of Cassini.

As scientists we need to stand ready to counter the pseudoscience and fear of science trends. Unfortunately, we cannot seem to get the positive attention of the media. It has been practically impossible for the MAS to get any media coverage of our meetings. We did not get into science for the publicity but lack of good publicity may be doing us great harm. We need to become more activists for our work. I hope that the Academy can take a lead in this role; we need your help and suggestions.—John Boyle

MJAS Millennium Call for Papers

The Mississippi Junior Academy of Science (MJAS) endeavors to identify and encourage high school students with potential to become creative scientists, engineers and mathematicians. Without a doubt, the major MJAS program is the annual paper competition. To anyone who has never entered the MJAS competition, it is not only a great learning experience for all participants, but it can be rewarding as well due to the numerous awards are given each year. The site of this year's paper competition will be announced in the December issue of this journal. The site of this year's state-wide paper competition will be announced in the December issue of this journal. The meeting this past year was hosted at Mississippi College. Dr. Rob Hamilton served as the liaison for that meeting. His comments about hosting that meeting are in an article in this journal.

The winner of this competition will represent MJAS at the national convention, under the direction of the American Junior Academy of Science (AJAS). This convention will be held in Washington, D. C. in 2000. Mississippi will be represented on the AJAS national committee by Dr. Joan Messer, the state director of MJAS.

To enter the MJAS annual paper competition the student must submit a typewritten report based on an independent research project. The length of the paper should be limited to ten minutes reading time. Judges will give preference to basic research papers that include a pertinent literature review, research purpose, concise procedures, neatly arranged experimental data, significance of the results obtained, and compete references. Each paper entered must include on a separate page the title of paper, name of student researcher, class and division, school address and telephone number, home address and telephone number, and name of the teacher.

All papers submitted must be postmarked no later than December 1. The Mississippi Junior Academy of Sciences Competition is a statewide contest open to students in grades 9-10 (Class I) and 11-12 (Class II). When submitting papers, please indicate your present grade level and identify the competition category (biology, geology, mathematics, computer science, astronomy, or behavioral science). Please mail to the address above.

An expert panel of scientists selects the written papers for oral competition and judge to oral competitions in each category. From the oral presentations, the judges will select an Overall Winner and the Clyde Q. Sheely Research Award. A Class winner is selected from Class I. Each of the winners will be presented an attractive, personalized plaque. The Overall Winner and the Clyde Q. Sheely recipient will receive an all-expense-paid trip to the Annual Meeting of the Mississippi Academy of Sciences in February.

Judging criteria include:

I. Written paper competition:
   - A. A definite research problem
     1. Identifies and controls variables
     2. Collects data and interprets results
     3. Draws sound logical conclusions
   - B. Use of scientific literature for support
   - C. Understands relevance of data to the problem
   - D. Demonstrates knowledge of the topic

II. Presentation of Paper
   - A. Professional
     1. Professional Attitude
        - a. Confidence in presentation
        - b. Exhibits enthusiasm for a chosen topic
     2. Maintains audience interest
     3. Clarity of diction
     4. Voice volume appropriate
     5. Neat appearance
   - B. Supporting materials (*slides, posters, transparencies, etc.)*
     1. Effective use of audiovisual materials
     2. Support materials clear and concise

A special invitation is being extended to teachers to attend. Remember that you do not have to have a student presenter to attend the oral paper competition. Science teachers might want to attend to see how other science teachers in the state are encouraging their students to become active in research.— Joan Messer

Mail papers to:
1999 MJAS Paper Competition
Dr. Joan Messer
Jones Junior College
Ellisville, MS 39437

Hosting the Mississippi Junior Academy of Sciences

On January 30th 1999, Mississippi College hosted the Mississippi Junior Academy of Sciences Convention. High school students from across the state presented papers based on their own original research in two sessions, where they were judged by a panel of faculty from local universities. The overall first and second place winners received academic scholarships from several colleges and universities throughout the state, including Mississippi College. The papers of first and second place winners were published in the Journal of the Mississippi Academy of Sciences, and received all expenses paid trips to the Mississippi Academy of Sciences Convention, where they presented their work as either an oral or a poster presentation. The overall winner of the Mississippi Academy of Sciences received an all expense paid trip to the American Junior Academy of Sciences Conference.

The format of the convention requires eight intimal sessions of oral presentations, with two judges for each session. The winners of the initial sessions return for a final oral presentation to be judged by a panel of three judges, who select the overall winner. Thus a host must recruit at least 19 judges to meet the requirements of the convention format. I was able to recruit more than enough judges from Mississippi College, Millsaps College and the University of Mississippi Medical Center. Recruiting judges was rather easy, as the judging only required two hours of time on a Saturday from each judge, and involvement with the types of high school students participating was a great pleasure for anyone interested in education.

The format of the convention also required eight rooms for initial presentations and a large lecture hall or auditorium for final presentations. We were able to use a single building consisting of classrooms with a capacity of about 50 students for initial presentations and a lecture hall seating more than 200 people for final presentations. The use of a single building made it quite easy to set up audio visual equipment and provide a central troubleshooting facility for circumstances such as burned out bulbs in projectors or overheads.

The convention also elects officers and board members for the Mississippi Junior Academy of Sciences. All officers and board members are high school students. The officers and board members have a final voice in all decisions made regarding the Mississippi Junior Academy of Sciences. The fact that the Mississippi Academy of Sciences is a grass roots level organization is one of its greatest strengths.

A host must provide a format for a gathering of teachers and students the day before that of the oral presentations. The gathering should include a reception and some sort of activity related to education and research at the high school level. The building that we chose for the presentations had a lounge, which was used for the reception. We served pizza and soft drinks, both in great abundance. The activities that I chose were workshops. I was to present a workshop for high school students discussing methods of preparing and delivering oral presentations while local high school teachers and Mississippi Junior Academy of Sciences Teacher Advisory Board members Virginia Ingram and Sandra Hindsman would present a workshop discussing the development and maintenance of a high school student research program. The concept driving each workshop was to allow participants to relate experiences to each other, rather than sessions dominated by presentations from workshop leaders. Unfortunately, inclement weather greatly limited attendance at the reception that preceded the workshops, with many of those attending clearly worn from the ordeal of driving to the location from their home towns that evening, and thus we decided to cancel the workshops.

A host must provide food service the day of the presentations. Mississippi College provided a continental style breakfast consisting of traditional sweet rolls, coffee and fruit juice in the morning, with lunch available at a cost of less than $5.00 for participants at noon.

The meeting itself went off very well. The meeting opened with remarks from Mississippi College president Howell Todd, Mississippi Junior Academy of Sciences president Katie Underwood and Mississippi Junior Academy of Sciences Director Joan Messer. The initial sessions of oral presentations followed the opening remarks. I had arranged for two students to be available to replace overheads and slide projectors that may have malfunctioned with backup units, rather than repair malfunctioning units during the session; however none of the visual equipment failed.

Following the intimal sessions of oral presentations was a keynote speaker address. The keynote address was delivered by Dr. Janelle Pryor, and focused on the ethical issues associated with information derived from the Human Genome Project. Following the keynote address, the winners of the intimal sessions were announced, with lunch following.

After lunch, the final presentations were made, which was followed by the business meeting, where new board members and officers were elected. Following the business meeting, the winners of the overall competition were announced.

From an organizational standpoint, my task as organizer at the host institution required that I do the following:

1. Put the event on the academic calendar
2. Arrange for facilities
3. Arrange for audio visual equipment
4. Recruit judges
5. Arrange food service
6. Recruit student helpers
7. Recruit a keynote speaker
8. Recruit the highest ranking Mississippi College official possible for introductory remarks
9. Organize a reception and activities for the night prior to the presentations
10. Identify local hotel accommodations for participants
11. Arrange for financial support of the Convention from the college.

I encountered no great difficulty with any of these tasks. Mississippi College was highly cooperative at all levels. Joan Messer and Jesse Burnette Hamil provided excellent support in organizing the presentation sessions and assigning them to available rooms, as well as preparing all documentation associated with the convention. I would gladly facilitate the hosting of a convention of the Mississippi Academy of Sciences at any time in the future. Having done it once, it will be much easier to do again.

As scientists and science educators, we constantly request a great deal of financial support from the public, not only for expenses such as our salaries and the overhead associated with our employment, but to facilitate research and outreach programs. Thus the scientific community places great demands on society in general. The types of individuals who participate in organizations such as the Mississippi Junior Academy of Sciences are among our greatest supporters in society in general. The students in particular are individuals that we can strongly influence with relatively very little effort. While it is true that many of us do support such students as research mentors, there is a lack of proper financial support for MJAS. If we wish to commit any of our time and resources to generating support for science in society in general, there is probably no other vehicle that offers the level of return on such investments as does the MJAS, as the interest in the types of activities supported by MJAS far exceeds the capacity of MJAS to support such activities.—Rob Hamilton

[insert Ohaus advertisement here]

Final call for abstracts for the 2000 Annual Meeting of the Mississippi Academy of Sciences

The Mississippi Academy of Sciences

will hold its **2000** annual meeting
Thursday and Friday, **February 24 and 25**
at the Broadwater Resort East in
Biloxi, Mississippi

Abstracts are due no later than 1 November 1999. A form for abstract submission is included in this issue. You may submit the abstract electronically through the Academy website: http://www.msstate.edu/Org/MAS/MAS.HTML

MISSISSIPPI ACADEMY OF SCIENCES ABSTRACT FORM/MEMBERSHIP FORM

ABSTRACT INFORMATION

Abstract title _____

Name of presenting author(s) _____

Telephone _____ Email _____

Name of Academy member _____

(One author must be a current member of the MAS; 2000 membership dues must be paid.)

Check the division in which you are presenting

___ Agriculture and Plant Science	___ History and Philosophy of Science	___ Science Education
___ Cellular, Molecular and Dev. Biology	___ Math., Computer Sci. and Statistics	___ Social Sciences
___ Chemistry and Chemical Engineering	___ Marine and Atmospheric Sciences	___ Zoology and Entomology
___ Geology and Geography	___ Physics and Engineering	
___ Health Sciences	___ Psychology and Behav. Neuroscience	

Type of presentation

___ Poster presentation ___ Workshop

___ Lecture presentation ___ Invited symposium

If the presenting author for this paper is also presenting in another division, please list the other division: _____

Audio-visual equipment needs

___ 2" x 2" slide projector

___ Overhead projector

Other audio-visual equipment including computers and computer projection equipment must be provided by the speaker.

MEMBERSHIP INFORMATION

New ___ Renewal ___

Mr. Ms Dr. _____

Address _____

City, State, Zip _____

School or Firm _____

Telephone _____ Email address _____

PLEASE INDICATE DIVISION WITH WHICH YOU WISH TO BE AFFILIATED _____

Regular member $25	Student member $5	Life member $ 250
Educational $150	Corporate Patron $1000	Corporate Donor $500

CHECKLIST

The following MUST be DONE:

___ I. Enclose copy of abstract (even if abstract has been submitted electronically)

___ II. Complete and enclose abstract form /membership form(this form)

___ III. Enclose the following payments (make check payable to Mississippi Academy of Sciences):

- ___ $25 per abstract
- ___ $25 regular membership fee OR $5 student membership fee (2000 membership must be paid for abstract to be accepted)

___ IV. You must supply a check # _____ or P.O. # _____ (credit cards are not accepted)

In addition you MAY preregister at this time:

___ Enclose the following payments:

- ___ $12 regular member (Preregistration before Feb. 1, 2000)
- ___ $5 student member (Preregistration before Feb. 1, 2000)

NOTE: Late abstracts will be accepted with a $10 late fee and only if there is room in the appropriate division. They will be published in the April issue of the MAS JOURNAL.

MISSISSIPPI ACADEMY OF SCIENCES—ABSTRACT INSTRUCTIONS
PLEASE READ ALL INSTRUCTIONS BEFORE YOU SUBMIT YOUR ABSTRACT

Your paper may be presented orally or as a poster. Oral presentations are generally 15 minutes. The speaker should limit the presentation to 10–12 minutes to allow time for discussion. Instructions for poster presentations are given on the reverse side of this sheet.

Enclose a personal check, money order, institutional check, or purchase order for $25 publication charge for each abstract to be published, payable to the Mississippi Academy of Sciences. The publication charge will be refunded if the abstract is not accepted.

At least one author must be a member of the Academy at the time the paper/poster is presented. Payment for membership of one author must accompany the abstract.

Attendance and participation at all sessions requires payment of registration. Complete pre-registration information will be sent in January.

Note that two separate fees are associated with submitting a paper for presentation at the annual meeting of the Mississippi Academy of Sciences. An abstract fee is assessed to defray the cost of publishing abstracts and a membership fee is assessed to defray the costs of running the Academy. Preregistration payment ($12 regular; $5 student) may accompany the abstract, or you may elect to pay this fee in January or pay full registration costs at the meeting.

Abstracts may be submitted typed or printed on clean white paper. Abstracts received in this form will be scanned into a computer. Leave ample margins and use a sanserif type font to help minimize errors in scanning.

Abstracts may be submitted as a WordPerfect (Windows or DOS), ASCII, ANSI, or .RTF file on a PC readable diskette. Formatting should be minimal. This abstract submission form and the appropriate fees should be sent by US mail even if a diskette is used for the abstract.

Abstracts may be submitted by e-mail or entered directly through the MAS website. The URL is http://www.msstate.edu/Org/MAS/ MAS.HTML. This abstract submission form and the appropriate fees should be sent by US mail even if the abstract has been submitted electronically.

Submit your abstract and appropriate fees to the Abstracts' Editor, John Boyle, TO BE RECEIVED NO LATER THAN NOVEMBER 1, 1999.

Dr. John Boyle
Mississippi State University
Dept. of Biochemistry
P.O. Drawer 9650
Mississippi State, MS 39762

FORMAT FOR ABSTRACT

Your abstract should be informative, containing: (a) a sentence statement of the study's specific objectives, unless this is given in the title; (b) brief statement of methods, if pertinent; (c) summary of the results obtained; (d) statement of the conclusions. It is not satisfactory to state, "The results will be discussed."

Your abstract, including a concise, descriptive title, author(s), location where work was done, text and acknowledgment, may not exceed 250 words.

The title should be all capital letters. Use significant words descriptive of subject content.

Authors' names start a new line.

The institution where your research was done should include city, state, and zip code. Do not include institutional subdivisions such as department.

The abstract should be one paragraph, single spaced, starting with a 3-space indentation.

Use standard abbreviations for common units of measure. Other words to be abbreviated, such as chemical names, should be spelled out in full for the first use, followed by the abbreviation in parenthesis. Do not abbreviate in the abstract title.

Special symbols not on your printer or typewriter must be in black ink.

Use italics for scientific names of organisms.

Begin authors' names on a new line. Place an asterisk (*) after the presenter(s), if there are multiple authors.

Use superscripts for institutional affiliations where necessary to avoid ambiguity.

Refer to these examples as guides.

EXAMPLES OF TITLES AND AUTHORS:

[single author, no ambiguity about designated speaker or affiliation]

AN EXPERIMENTAL MODEL FOR CHEMOTHERAPY ON DORMANT TUBERCULOUS INFECTION WITH PARTICULAR REFERENCE TO RIFAMPICIN

Joe E. Jones, Mississippi State University, Mississippi State, MS 39762

Abstract body starts here . . .

[two authors, one designated speaker, different affiliations, but no ambiguity]

AN EXPERIMENTAL MODEL FOR CHEMOTHERAPY ON DORMANT TUBERCULOUS INFECTION WITH PARTICULAR REFERENCE TO RIFAMPICIN

Joe E. Jones and Ralph A. Smith*, Mississippi State University, Mississippi State, MS 39762 and University of Mississippi Medical Center, Jackson, MS 39216

Abstract body starts here . . .

[two authors, both designated as speakers, different affiliations, but no ambiguity]

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[three authors, one designated speaker, different affiliations]

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Joe E. Jones[1], Ralph A. Smith[1]*, and Alice D. Doe[2], [1]Mississippi State University, Mississippi State, MS 39762 and [2]University of Mississippi Medical Center, Jackson, MS 39216

Abstract body starts here . . .

GUIDELINES FOR POSTER PRESENTATIONS

The Academy provides poster backboards. Each backboard is 34" high by 5' wide. Mount the poster on the board assigned to you by your Division Chairperson. Please do not draw, write, or use adhesive material on the boards. You must provide your own thumb tacks.

Lettering for your poster title should be at least 1" high and follow the format for your abstract. Lettering for your poster text should be at least 3/8" high.

Posters should be on display during the entire day during which their divisional poster session is scheduled. They must be removed at the end of that day.

Authors must be present with their poster to discuss their work at the time indicated in the program.