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THE SCIENTIFIC INVESTIGATION OF FOSSIL WOOD

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INTRODUCTION

Sufficient interest has developed in fossil wood in the southeastern United States to suggest that information on how to approach its study is in order. This paper consequently deals with a number of topics directly related to the scientific investigation of fossil wood, including: how to collect and curate specimens, how wood is fossilized (i.e., the preservation states), how fossil wood is thin-sectioned for microscopic examination, and how it is studied and photographed under the microscope. Information on literature and publication of results is also given. It is hoped that this paper will not only provide information about how to study fossil wood, but will as well stimulate interest in its study.

COLLECTION AND CURATING OF SPECIMENS

In all cases, careful collection practices concerning fossil wood specimens, or any specimens for that matter, are important. Accurate collecting information about the source of the wood can be as valuable as the identification of the wood itself. Collecting specimens first-hand and recording exact information about locality, date, conditions, etc., is generally more reliable than accepting an account of where the material came from from a second party. Taking photographs of the wood "in place" in the field is a sound practice. A permanent record book should be kept. It is well to label each specimen of fossil wood with an identifying mark (number and/or lettering system) and keep such information in the record book. It is often possible to write directly on the specimens in pen or pencil. We have found the best way to store specimens is in brown paper sandwich bags, which may be labelled as well. It is a good idea to keep all bags from a given collection site together in a labelled box, or on the same paleontology cabinet tray if such is available. If you do not wish to maintain collections personally, then well labelled, curated specimens are often of interest to a professional museum. Such a museum, however, would generally not be interested in specimens lacking good data.

Understanding the geologic age and source (geologic stratum) in which the wood occurs (or occurred) is valuable. If you know precisely the locality from which the wood came, and what the "formation" or geological unit from which it was obtained looked like, then help on the geology is available at your state geological survey. In Mississippi that is the Mississippi Bureau of Geology, 2525 North West Street, P.O.

Box 5348, Jackson, Mississippi 39216. The Bureau of Geology has many bulletins available on the geology of Mississippi, and also a variety of geologic maps. These may be purchased for a very reasonable price. The staff members at the Bureau are willing to help. However, try to be as informed as possible before you ask their assistance. If wood occurs in place in a particular formation, then noting the position of the specimens in the formation, and using photography to this end, can be very significant. If wood is washed out into a creek bed, such as that in Thompson Creek, Yazoo County, Mississippi (Blackwell and Dukes, 1981), it is often possible to deduce the formation from which it came by study of the formations in the area, in consort with study of bulletins pertaining to that area available at the Bureau. Fossil wood in Mississippi may be of a variety of geologic ages, varying from Pleistocene, as that of Thompson Creek and Bayou Pierre, to Cretaceous (Blackwell and Dukes, 1981; Blackwell, 1983; Blackwell and others, 1983; Blackwell, 1984; Dockery, 1987; Blackwell, 1989). Accurately determining the stratum (formation) and relative age of your fossil wood adds greatly to the study.

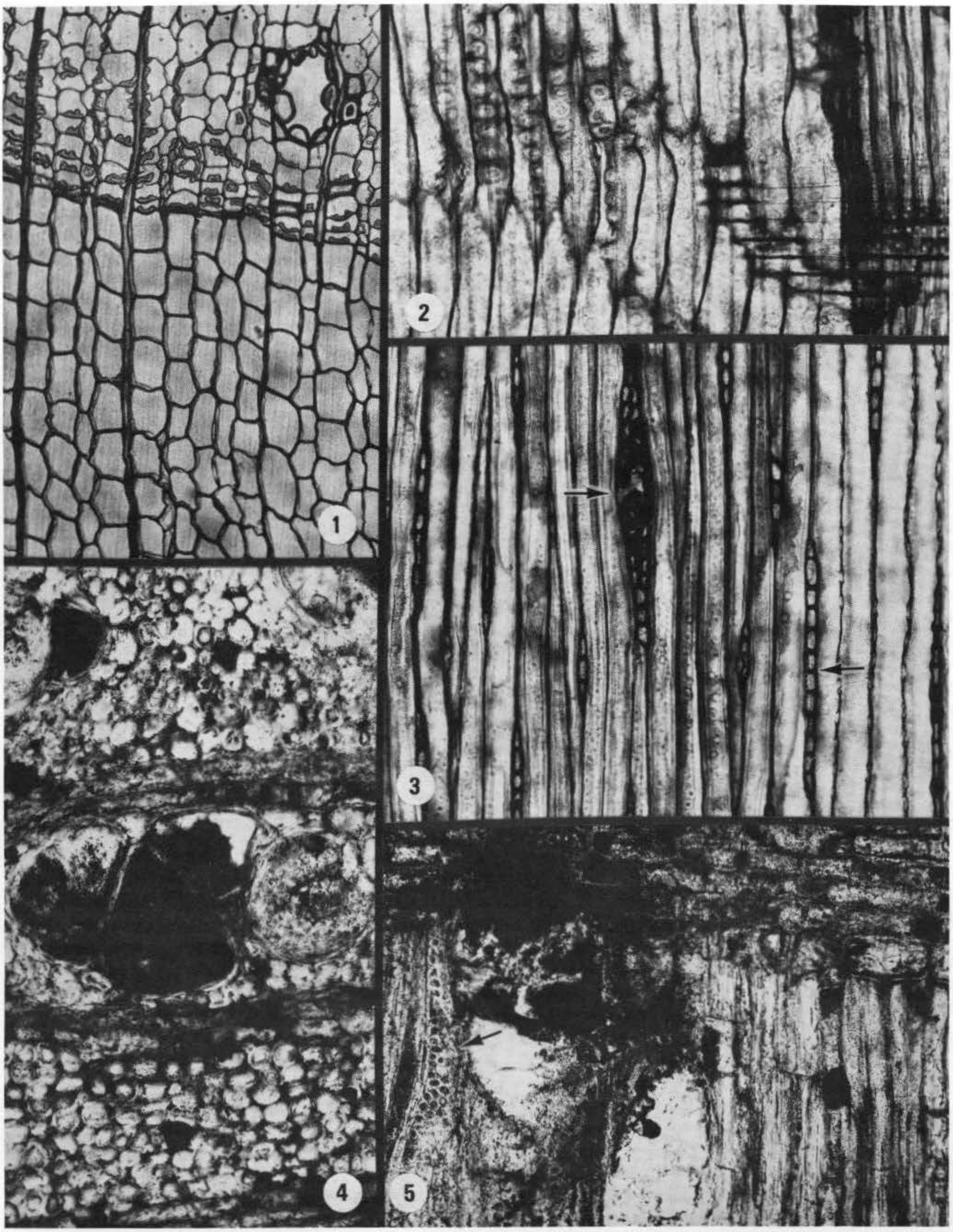
HOW FOSSIL WOOD IS PRESERVED
(Types of Preservation States)

In work on fossil wood in Mississippi and Ohio, we have observed that wood is usually preserved in one of three ways. Perhaps most typically in Mississippi, and as one usually thinks of it, the preservation occurs as siliceous petrifactions, i.e., as wood "turned to stone" or "petrified." Fundamentally, the structure of the wood has been either replaced or more likely heavily coated (emplaced) with silica (silicon dioxide). Indeed in most cases there is still organic (wood) substance trapped within the petrifactions (Delevoryas, 1962; Leo and Barghoorn, 1976). The cold water (as opposed to volcanic) silicates that infiltrate wood buried in sandy formations here and there throughout Mississippi often show up in the wood as minerals, either chalcedony or opal; such wood is sometimes referred to respectively as agatized or opalized. Although it may also be opaline, some silicified wood from western states forms through the action of volcanic silicates. Although petrified wood is the most common type of fossil wood encountered, and has been designated the state stone of Mississippi, it is not the only form of fossil wood in the state. Lignitized (or coalified) wood, i.e., wood which has in effect turned to a soft coal (lignite), may also occur, such as that which has been found in a bentonite layer of the Tombigbee Sand, Upper Cretaceous (David Dockery, personal communication). A third main way that fossil wood may be preserved is simply as buried wood which is otherwise unaltered; this category is referred to as "mummified wood." Although mummified wood doubtless occurs abundantly in Mississippi and a number of other states in the Southeastern United States (Brown, 1938), we are most familiar with it in Ohio, buried in various Pleistocene till banks in the southwestern part of the state (Burns, 1958). All three categories of wood discussed may show comparably good states of preservation of characteristics of wood; see for example Figures 1-9 for comparison of sections of mummified and silicified wood. Silicified wood is readily sectionable without preliminary treatment or preparation; it may, however, occasionally show some distortion or exaggeration of cell wall structure due to impregnation of silica. Additional techniques are typically required for the sectioning of lignitized and mummified wood, as compared with silicified wood, as will be discussed.

There are ways in which fossil wood may be preserved (especially petrified) additional to those mentioned above, including wood which has been pyritized or calcified (Hoskins and Blickle, 1940). But these modes of fossilization are not as commonly encountered as those already discussed, especially in Mississippi. Further, the preservation of detailed wood structure when replaced by either iron disulfide (iron pyrite) or calcium carbonate (calcite) is often not particularly good nor especially durable (Leo and Barghoorn, 1976), and tends to suffer dissolution in the environment. These additional modes of preservation will not be further dealt with in this discussion.

PLATE 1
Legend for Figures 1-5

Figures 1-3, photomicrographs, X 200, of sections of mummified coniferous wood (spruce, *Picea*) from late Pleistocene of southwestern Ohio (collected from a till bank, Butler County, near Oxford): (1) Cross section; note resin duct (upper right) near transition from earlywood to latewood zone. (2) Radial longitudinal section; note typical circular coniferous pitting (upper left) and portion of wood ray seen longitudinally (lower right). (3) Tangential longitudinal section; note rays transected (arrows), one in upper left-center containing a small resin duct. Figures 4-5, X 200, sections of silicified angiosperm (dicot) wood (hop-hornbeam, *Ostrya*) from earlier Pleistocene of Mississippi (Perry Creek, Yazoo Co.): (4) Cross section; note vessel cluster (center) flanked above and below by rays, and then by zones of fibers. (5) Radial section; note pitting on vessel (extending above the number 5, arrow).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SECTIONING OF FOSSIL WOOD FOR MICROSCOPIC EXAMINATION

A. Silicified (Petrified) Wood

It is rare that the identity of any specimen of fossil wood may be determined solely by macroscopic (external) surface examination; fossil palm may often be identified as being fossil palm by external viewing, but even in this case it is typically impossible to assert which type of palm it might be (Blackwell, 1989). For more standard fossil wood, it is often very difficult to tell even whether it is that of a gymnosperm (e.g., conifer) or a dicot simply by external examination. Thus, it is necessary to make thin sections of the wood if it is to be identified. Figures 4-9 illustrate the detailed structure of a type of silicified wood (hop-hornbeam) found in Mississippi.

A good general reference on paleontological techniques is that by Kummel and Raup (1965). However, a detailed account of exactly how to prepare microscope slides of fossil wood per se seems generally lacking in the literature, and, since peels are vastly inferior to slides of fossil wood, the present account of slide preparation would seem in order. Silicified specimens, regardless of size, are generally sectioned initially with some type of rock saw. Any good rock saw will have a diamond-studded blade. Larger specimens of fossil wood may have to be sectioned with a slab saw (one carrying a 20" to 24" blade). Trim saws, as those with a 10" blade are, however, sufficent for most specimens encountered. Gem saws, bearing a 4" blade, may be necessary for very small specimens. As far as cost, neither trim saws nor gem saws are very expensive; larger (slab) saws may cost considerably more, however. In general, you will not want to begin with a specimen which is too large, unless you have a way of breaking it up or else slabbing it. Better quality rock saws come equipped with a vise holder and automatic specimen feed. Such a holding system offers a real advantage, since precise hand-holding of specimens while cutting on a rock saw can be difficult and dangerous. Regardless of the saw used, you will want to section your pieces of petrified wood in such a size as to fit onto 2" x 1" glass microscope slides. Water is generally used as a cutting (antifriction) solvent, although coolant additives are available, and indeed, some saws utilize kerosine as a cutting fluid. Nice and reasonably priced trim and gem saws may be purchased from Raytech Industries, P.O. Box 6, Stafford Springs, CT 06076.

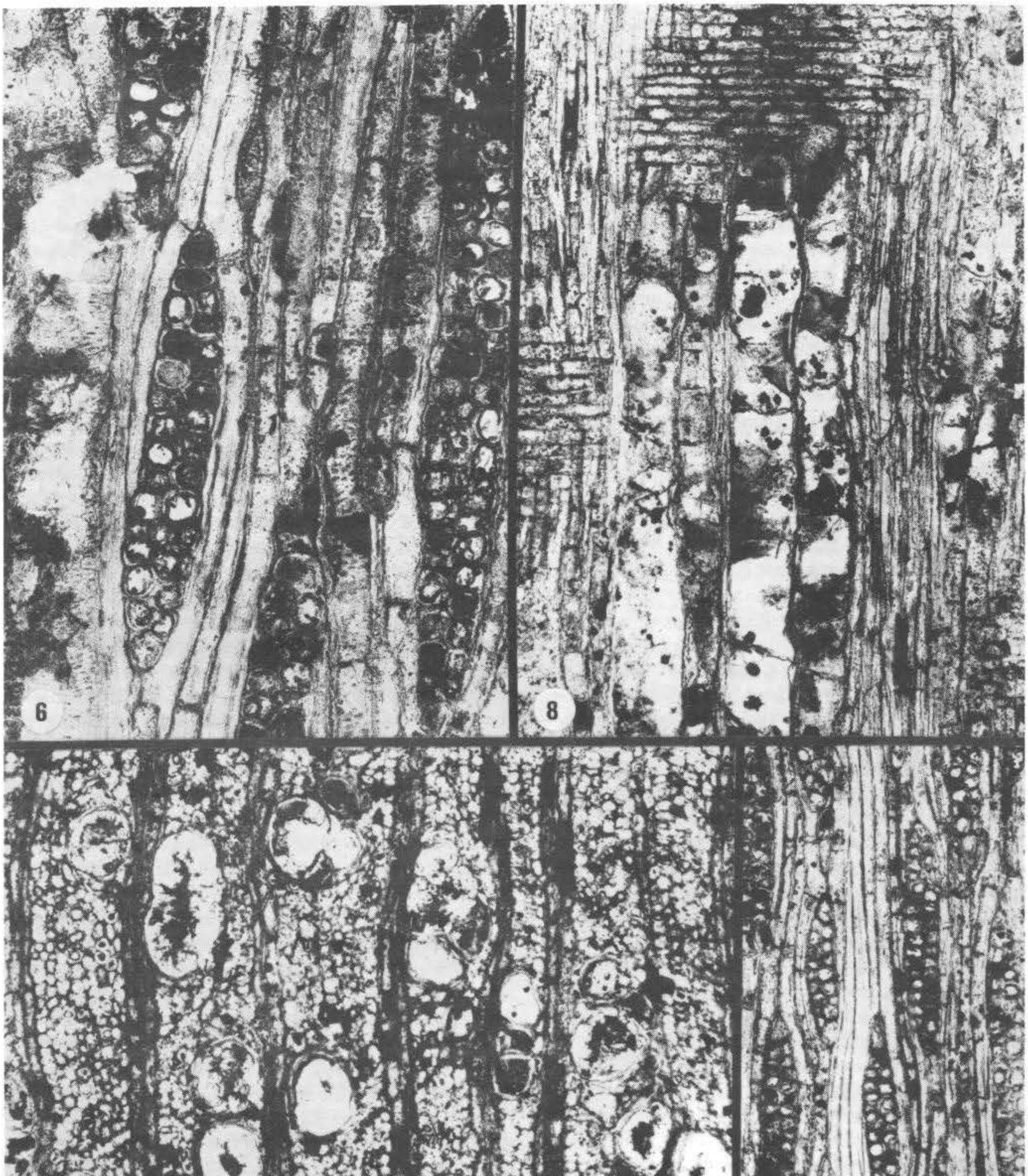
When using a rock saw, your material should be sectioned in the plane of three standard wood sections: cross (transverse) section, radial section (longitudinal section paralleling the wood rays), and tangential section (longitudinal section at right angles to the rays). This is best done by cutting at least two cross sectional pieces first, and then examining the flat faces of these to determine the direction in which the rays occur--one or both cross sections then can be used to prepare the two types of longitudinal sections. A dissecting microscope or hand lens may be necessary to see the direction of the rays. It is perhaps advisable to mark the cutting planes, prior to sawing, with a pencil. Help on understanding the three basic planes (sections) of wood is available in almost any introductory general botany text. Simply refer to the section detailing the three planes (sections) for viewing wood structure (as through a microscope).

After your sections (slugs) are cut, then polish the sectioned face of each (i.e., the face you wish to examine). This is done on a lapidary machine or "lap wheel." Some workers use silicon carbide grit (in a graded series, say 120 through 1000, with several intermediate particle sizes) on a turning, cast iron lap head to grind (polish) the sections. Salt shakers can be used to hold and apply each grit level. Using silicon carbide grit can become a bit messy, so the use of detachable diamond studded discs (three of them--70 microns, 45 microns, and perhaps 15 microns in diamond particle size) instead may be preferable. These can be temporarily (or semi-permanently) attached to inexpensive aluminum lap heads. Regardless of the method, polish the cut face of your specimen (fossil wood slug) until it appears shiny, even when relatively dry. Grinding is done from coarse to fine (in terms of particle size); i.e., if using grit, start with 120 and finish with 1000 (the final stage perhaps being completed upon a smooth glass plate); if using diamond discs, begin with the larger micron size (say 70) first, and finish with the small size (15). In either case, water must be dripped or squirted onto the grinding surface of the lap head during polishing.

Petrified wood slugs are generally cut to a depth of ¼ to ¾ inch (i.e., to fit on a 1" high slide). Some depth is necessary for microscopic examination of longitudinal sections. But, in having depth, the slugs will doubtless contain and hold moisture; and, they are often cut and polished in aqueous solvent, adding to any moisture already present. Consequently, it is desirable, after washing the polished surface, to heat them at a bit more than 212° F (100° C) for one hour. This

PLATE 2
Legend for Figures 6-9

Figure 6, X 200, photomicrograph of tangential longitudinal section of silicified hop-hornbeam (*Ostrya*); note rays transected, upper left, left-center (complete ray visible) and right (larger ray). Figures 7-9, sections of wood of hop-hornbeam at magnification of 100X: (7) Cross-section. (8) Radial section; note portion of ray seen longitudinally at top and at left and vessels extending vertically through left-center of the photograph. (9) Tangential section showing a number of rays with fibers coursing between.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can be done in an electric skillet or on a hot plate. Even a petrified wood specimen already apparently dry will be seen to change color when dried in this fashion, indicating a further release of moisture.

As the specimens are cooling, but while they are still warm to the touch, epoxy should be applied smoothly and evenly to the polished face; a slight excess of epoxy does not hurt. We use Hillquist mounting epoxy, which comes in two parts: the epoxy per se (lighter in color) and the darker epoxy (employed as a hardener). This type of epoxy is mixed in a ratio of 7 parts epoxy to 3 parts hardener epoxy. It is not necessary to be totally precise in mixing this ratio. Simply squeeze the epoxy onto the surface of a lined index card, using 7 lines to measure the epoxy and 3 lines to measure the hardener; attempt to keep the width of each band equal. The bands should be thoroughly but gently mixed. If excess air bubbles are encountered in the epoxy, heating it in a water bath for twenty minutes prior to use (with the lid off) will often solve the problem. However, be careful to keep the water out of any direct contact with the epoxy; and allow the epoxy to cool before use, at least to the point that it is warm, not hot. Hillquist Co. is located at 1545 Northwest 49th Street, Seattle, Washington 98107. Avoid excess skin contact with this or any other epoxy resin.

Mount the epoxy-applied face of the rock slug on the frosted surface of the microscope slide. Prefrosted, 2" x 1" (petrographic size) microscope slides are preferable, as available from Wards Earth Science, 5100 West Henrietta Road, P.O. Box 92912, Rochester, New York 14692. This size slide is sure to fit on essentially any style petrographic sectioning machine (whereas, a regular sized 3" x 1" microscope slide may or may not, depending on the machine). Mount the slug near the middle of the slide. Cure these mounted slugs at about 175° F (not substantially more or less) for 30 minutes to one hour. Apply a downward pressure during this time, as with a lead weight. The epoxy will typically fully harden in less than one hour. However, before removing slides from the skillet, check the edges of the epoxy (with a probe) to see if it has totally hardened. If still slightly sticky and pliable, let the slides cure a few more minutes. Hillquist epoxy mixture can also be cured at room temperature for 24 hours; however, some initial heating and downward pressure to drive out air bubbles is still a good idea.

You will now have polished slugs (polished face down) of petrified wood attached firmly to glass slides. At this stage one truly needs a thin-section saw of some sort. These are of course more expensive than slab and trim saws. Thin-section saws are constructed so that the back of the glass slide is held onto a small head, by either vacuum or water surface tension, while the saw slowly cuts through the rock, near the mounted surface. After thin-sectioning, the specimen must typically be ground even thinner, and polished. Thin-section saws (machines) may have a grinding wheel on the side of the machine arbor opposite the saw blade. Here, the slide is held in a similar way, and the remaining rock face is polished down virtually flush with the slide. In general the polished thin-section should be clearly visible to the naked eye, but relatively transparent, since you will eventually be viewing it with a microscope. As a preliminary check, an inexpensive petrographic (mineral) microscope may be used to examine mineral color during the grinding down process--generally when silicates turn from yellow to blue, the appropriate thinness is being approached. It may actually be an advantage if your slide specimen has regions which are slightly thicker than others. If your thin-section (wafering) saw is not equipped with a grinding wheel (or even if it is), the specimen may be finished off (ground/polished) on a regular lapidary wheel by either of the procedures discussed in connection with "lap wheels," i.e., by grit or by diamond disc. However, in this case you will need to be able to hold your slide (specimen face down) on a turning lap head. This can be done only with the aid of a petrographic slide holder, available at about $30.00. It is impossible to hold a glass slide face down on a turning disc without the aid of such a holding device. It is of course possible to hand-hold and polish a slide on a stationary lap head, or upon a glass plate, but the time required to achieve a good polish is much longer. A good supplier for a variety of petrographic equipment, such as petrographic slide holders, lap discs, thin-section (especially wafering) saws is Buehler Ltd., 41 Waukegan Road, P.O. Box One, Lake Bluff, Illinois 60044.

Wash your slides thoroughly (especially if grit was used), then dry the water out of the thin section for 10-15 minutes at 212° F. As the slide cools, mount a coverslip (#1 thickness) over the thin rock slice with epoxy, basically in the way described above when the slug itself was mounted to the slide. Silicified wood may be stained prior to application of epoxy by methods described by Bartholomew and others, 1970. Although results can be interesting, this step is typically unnecessary; in fact, the natural color variation of the minerals of silicified wood often lends a nice contrast under the microscope. After mounting the coverslip, downward pressure (with some heat) helps flatten the slip onto the slide while pressing air bubbles out from the edge. Use the rubber eraser end of a pencil to help press air bubbles out the sides of the coverslip. The epoxy is hardened in a bit more than 30 minutes at 175° F. As indicated, a downward pressure is advisable, at least through the first few minutes of this process. A lead weight (small enough to not overhand the edge of the coverslip) may be left on top of the coverslip until the epoxy has cured, but one must watch a weighted coverslip initially to make sure it does not "drift" over the epoxy when under heat and pressure.

The slides should be labelled when they cool. Each slide should be given some sort of labelling code which corresponds to the numbering/lettering system written on the specimen, bags or boxes, and in the record book. The frosted surface of the slide, along one edge, may be written upon directly with a #2 pencil. This works well and is essentially as permanent as anything. Of course, slide labels or stick-on-squares can be used if you don't wish to write directly on the slide. A diamond scribe may also be used if you want to engrave the slide permanently. Next, the slide should be cleaned with lens paper, and filed in a labelled petrographic slide box (such as those available from Wards). Any comments about a particular slide can be entered into the record book. Cross-referencing between specimen (and its containing sack or box), slides, slide box, and record book is extremely important for future reference.

B. Lignitized and Mummified Wood

As discussed, the preservation states of these types of fossil wood are quite different from silicified (petrified) wood. Although ultimately the sectioning and processing of these are essentially the same as with petrified wood, additional initial preparation steps are necessary because of the relatively fragile nature of these materials. Essentially, techniques for working with lignitized and mummified woods are similar to certain techniques involved in the preservation of stone (Gauri and Rao, 1978). The material, which may be crumbly, cannot be sectioned (cut with a saw) unless it has first been supported from the inside out, i.e., embedded in some type of workable plastic resin. The wood structure must be thoroughly infiltrated or impregnated with the resin to provide continuity and support. For harder tissue, and even rock materials, what we have found best is Spurr Low-Viscosity Embedding Media (Polysciences, 1986). It has the advantages of (1) low viscosity, (2) high penetration capability, and (3) it can be cured to the hardness desired after embedment. Spurr's is actually a mixture of epoxies or expoxide resins, which can be mixed in varying amounts (Polysciences Data Sheet, 1986). Mix (gently but thoroughly) the following three components first, in the amounts indicated: vinylcyclohexene dioxide (VCD), 10.0 gm; diglycidyl ether of polypropyleneglycol (D.E.R. 736), 6.0 gm; and nonenyl succinic anhydride (NSA), 26.0 gm. The VCD is the polymer, D.E.R. serves as a flexibilizer, and NSA acts as a hardener. If not used immediately, these should be retained in an atmosphere as anhydrous as possible. Just prior to use a fourth ingredient, dimethylaminoethanol (DMAE), should be added (use 0.4 gm); this agent serves as an accelerator in the curing process. Skin contact or breathing of any of these ingredients can be dangerous, especially the DMAE. Prepare the materials under a vented laboratory hood, using vinyl gloves. Spurr's epoxy kits (containing all four chemicals mentioned above, with instruction sheet) may be obtained from Polysciences, Inc., 400 Valley Road, Warrington, PA 18976-2590.

In contrast to mummified wood, lignitized wood should be kept moist to prevent splitting or cracking until you are ready to begin the embedding procedure. However, prior to embedding in Spurr's resin mixture, both mummified and lignitized wood samples (presumably cut with a scalpel, razor blade, or pen knife to a size which will easily fit on 2" x 1" petrographic microscope slides) must be completely dehydrated. This is accomplished not by heating but by passing the samples through three changes of anhydrous acetone; the first and third immersions in acetone should be for several hours, the second being left overnight. The embedding procedure, in increasing concentrations of plastic, may then be carried out stagewise in glass vials, each stage left overnight, as follows: (1) 1 part Spurr's/3 parts acetone, (2) 1 part Spurr's/1 part acetone, (3) 3 parts Spurr's/1 part acetone, (4) 100% Spurr's (2 changes). Spurr's should be made afresh at the beginning and for the final changes. A vacuum (using 5 to 10 pounds of negative pressure) is useful in enhancing infiltration of epoxy, especially in the final stages. Once created, if the vacuum is released slowly (over an interval of an hour or so), infiltration is enhanced, and air bubbles will often be seen to leave the specimens. After infiltration, the Spurr's should be cured (hardened) for 24 hours at 60° C (as for example, in a paraffin oven). Spurr's resin containing the specimens is best cured in smallish, square plastic holders, as for example ice cube trays designed to produce small ice cubes. The cured squares of Spurr's may be "popped out" after curing. Perhaps better is the use of tear-away plastic holders (peel-away molds) available from Peel-A-Way Scientific, 1800 Floradale Ave., South El Monte, California 91733.

After curing, the fossil wood embedded in plastic may be sectioned essentially as in the method described above for silicified wood. The Spurr's (prepared as indicated above) has a consistency resembling that of calcite and may be readily sectioned on a trim or gem saw, then polished on a lap wheel, cleaned, dried, mounted (in Hillquist epoxy mixture), cured, and thin-sectioned (and polished). A mask should be worn, however, while sectioning or polishing the Spurr's to prevent inhalation of dust or vapors. Water is a good solvent in which to cut the hardened resin as Spurr's resists "wetting." Nonetheless, drying at 60° C for a few hours is important before mounting the coverslip (with epoxy) upon the polished section. Prior to mounting, a drop of toluidine blue stain, allowed to dry with low heat upon the section, then rinsed with water (and dried thoroughly), can enhance the definition of certain structures in the wood (such as the boundaries of pits between cells in the wood which once functioned in water conduction, or the cells composing rays coursing between water conducting cells). Regardless of any staining procedure, Hillquist epoxy is a good mounting medium (epoxy) for cured Spurr's. However, only moderate temperatures can be used, and then only initially, to drive the air bubbles out of the Hillquist, because extended temperatures exceeding 60° C may damage the Spurr's. After initial heating and pressure, allow the Hillquist to cure overnight (with a lead weight on top if desired) at room temperature. The final product with this preparation will resemble very closely that obtained with standard sectioning of petrified wood. Figures 1-3 illustrate the detailed structure of a type of mummified wood found in southwestern Ohio.

MICROSCOPIC STUDY AND PHOTOGRAPHY OF FOSSIL WOOD

To examine sectioned fossil wood adequately will require a compound, light microscope. Any good microscope, even student grade, will suffice for this purpose. However, you will note some additional comments about microscopes under the discussion of photography below. The powers of a microscope most useful in examining wood sections are 40X, 100X, 200X, and 400 (or 440)X, although oil immersion (1000X) is occasionally useful. Most microscopes are not equipped with a 20X objective (i.e., with 200X power per se); yet, this is one of the most useful magnification levels in examining and photographing fossil wood. So, when purchasing a microscope, or in adding objectives to an existing microscope, it is well to keep the 20X objective in mind.

Identification of your wood may be attempted with various books; however, a good one to start with is *Textbook of Wood Technology,* 1980, by A.J. Panshin and Carl de Zeeuw. Identification guides to both hardwoods and softwoods are contained within. Another excellent text on wood is that by F.W. Jane, 1970, *The Structure of Wood,* second edition revised by K. Wilson and D.J.B. White. Be warned, however, that if your wood is not of relatively recent age in terms of geologic time (say Pleistocene or Recent), or if it is a tropical type of wood (rather than having originated in the temperate zone), a variety of highly specialized literature sources may have to be consulted--too voluminous and tentative to list here. However, one additional useful reference relating to modern and fossil woods is *Identification of Modern and Tertiary Woods,* by Barefoot and Hankins, 1982.

The last decade has seen the development of computer programs and data bases for achieving wood identification. These are available for personal as well as mainframe computers. Regarding software for personal computers (PC's), perhaps the first such program available is IDENT produced by Regis Miller (1980) at the U.S. Forest Products Lab in Madison, Wisconsin. Developed more recently is the program GUESS by LaPasha and Wheeler (1987) at North Carolina State University. Both systems provide, with some user effort, ready identification by computer of more common types of woods. A manual (Wheeler and others, 1986) is available to assist in understanding wood features and characteristics used in computer-assisted identification.

Since many woods can be difficult to identify, eventually you may have to contact specialists in wood identification, such as Dr. Regis Miller, Wood Anatomy Lab, U.S. Forest Products Laboratory, One Gifford Pinchot Drive, Madison, Wisconsin 53705; and Dr. Elizabeth A. Wheeler, Department of Wood and Paper Science, Box 8005, North Carolina State University, Raleigh, North Carolina 27695.

If one can visit the U.S. Forest Products Lab in Madison, access may be obtained to their over 100,000 microscope slides prepared from extant woods, available for comparison of unknown woods (including fossil woods). However, arrangements must be made well in advance. It is of course always a good idea to have put as much time and effort as possible into achieving wood identification yourself, before contacting the above or other specialists. Their time is valuable, as is your own.

If you are successful in determining fossil wood from a previously unstudied location and/or in determining new and interesting features of fossil wood, publication of results is possible. Manuscripts on fossil wood in the Southeast may be submitted to several journals. One periodical in particular whose editors are interested in fossil wood and other aspects of paleontology in Mississippi is the journal in which this paper appears, *Mississippi Geology,* published at the Bureau of Geology in Jackson. An international journal for the publication of results of studies on wood anatomy also exists; this is IAWA (International Association of Wood Anatomists) Bulletin, devoted to studies of wood structure, including both extant and fossil woods. IAWA is located at the Institute of Systematic Botany, P.O. Box 80.102, 3508 TC Utrecht, The Netherlands.

Publication of results typically involves black-and-white photography. For black-and-white photographs, I prefer intermediate or faster speed films such as Plus-X or Tri-X. Slower speed films such as Pan-X, though finer grained, can present difficulties in photographing through a microscope under higher magnifications (usually necessarily involving conditions of relatively low light intensity). If you want to make a slide presentation, then take color photos using slide film through a microscope. Ektachrome 200 or Kodachrome 64 are good to try for starters for photographing in color through a microscope. Tungsten film (such as Ektachrome 50) may give results superior to daylight films (such as Ektachrome 200 or Kodachrome 64) if one is fortunuate enough to have a microscope outfitted with a halogen light source. Automatic camera/microscope systems such as those produced by Olympus or Nikon are ideal for doing either black-and-white or color photomicrography of fossil wood; however, a simpler system using a single-lens-reflex camera adapted to a phototube of a standard student microscope can also give good results.

If you have an interest in fossil wood, and especially in undertaking a scientific investigation of fossil wood, we hope this paper has provided you with helpful information. Getting involved first-hand in such a project can hardly fail to stimulate interest and enthusiasm; it will perhaps lead to discoveries new to science. If you require information additional to that presented in this paper, you may contact Will Blackwell care of the Botany Department at Miami University (Ohio). Please note that the methods described above and the vendors mentioned are those, respectively, developed and utilized by the authors. Other good methodologies and vendors may be available as well.

REFERENCES CITED

Barefoot, A.C., and F.W. Hankins, 1982, Identification of Modern and Tertiary Woods: Oxford, Clarendon Press, vii + 189 p.

Bartholomew, R.L., L.C. Matten, and E.F. Wheeler, 1970, Staining silicified woods: Journal of Paleontology, v. 44, no. 5, p. 905-907.

Blackwell, W.H., 1983, Fossil wood from "Sand Hill," western central Mississippi: Bulletin of the Torrey Botanical Club, v. 110, no. 1, p. 63-69.

Blackwell, W.H., 1984, Fossil ponderosa-like pine wood from the Upper Cretaceous of north-east Mississippi: Annals of Botany, v. 53, p. 133-136.

Blackwell, W.H., 1989, Fossil palm stem from Bayou Pierre, Copiah/Claiborne Counties, Mississippi: Mississippi Geology, v. 9, no. 3, p. 9-13.

Blackwell, W.H., and G.H. Dukes, 1981, Fossil wood from Thompson Creek, Yazoo County, Mississippi: Mississippi Geology, v. 2, no. 2, p. 1-6.

Blackwell, W.H., M.J. Powell, and G.H. Dukes, 1983, Fossil wood from Bayou Pierre and White Oak Creek, southwest-central Mississippi: Mississippi Geology, v. 4, no. 2, p. 1-6.

Brown, C.A., 1938, The flora of Pleistocene deposits in the western Florida parishes, West Feliciana Parish, and East Baton Rouge Parish, Louisiana, *in* Contributions to the Pleistocene History of the Florida Parishes of Louisiana: Louisiana Geological Survey, Bulletin 12, p. 59-96.

Burns, G.W., 1958, Wisconsin age forests in western Ohio II, vegetation and burial conditions: The Ohio Journal of Science, v. 58, no. 4, p. 220-230.

Delevoryas, T., 1962, Morphology and Evolution of Fossil Plants: New York, Holt Rinehart and Winston, ix + 189 p.

Dockery, D.T., III, 1987, Petrified palm "wood" from Thompson Creek, Yazoo County, Mississippi: Mississippi Geology, v. 8, no. 2, p. 10-11.

Gauri, K.L., and M.V. Appa Rao, 1978, Certain epoxies, fluorocarbon-acrylics, and silicones as stone preservatives, *in* E.M. Winkler, ed., Decay and Preservation of Stone: Geological Society of America, Engineering Geology Case Histories, no. 11, p. 73-79.

Hoskins, J.H., and A.H. Blickle, 1940, Concretionary *Callixylon* from Ohio Devonian black shale: American Midland Naturalist, v. 23, p. 472-481.

Jane, F.W., 1970, The Structure of Wood (second edition): London, Adam & Charles Black. (Jane's first edition, 1956, was completely revised by K. Wilson and D.J.B. White in 1970).

Kummel, B., and D. Raup, 1965, Handbook of Paleontological Techniques: San Francisco, W.H. Freeman, xii + 852 p.

LaPasha, C.A., and E.A. Wheeler, 1987, A microcomputer based system for computer-aided wood identification: IAWA Bulletin, n.s., v. 8, no. 4, p. 347-354.

Leo, R.F., and E.S. Barghoorn, 1976, Silicification of wood: Botanical Museum Leaflets, Harvard University, v. 25, no. 1, p. 1-47.

Miller, R.B., 1980, Wood identification via computer: IAWA Bulletin, n.s., v. 1, no. 4, p. 154-160.

Panshin, A.J., and C. de Zeeuw, 1980, Textbook of Wood Technology (fourth edition): New York, McGraw-Hill, xiii + 722 p.

Polysciences, Inc., 1986, Spurr low-viscosity embedding media for biological, material and mineralogical specimen: Data Sheet # 127. (400 Valley Road, Warrington, Pennsylvania 18976).

Wheeler, E.A., R.G. Pearson, C.A. LaPasha, T. Zack, and W. Hatley, 1986, Computer-Aided Wood Identification, Reference Manual: Raleigh, The North Carolina Agricultural Research Service, Bulletin 474.

PUBLICATION SERIES OF THE MISSISSIPPI BUREAU OF GEOLOGY

Michael B.E. Bograd
Mississippi Bureau of Geology

The Mississippi Bureau of Geology is charged with disseminating the information generated by its researches into the geology and mineral resources of Mississippi. The most efficient method of accomplishing this task is through publication. Some work is published in outside publications, such as paleontological or petroleum geology journals. Most of the work of the Bureau staff is published and sold by the Bureau of Geology. The purpose of this article is to describe the various publication series of the Bureau of Geology.

LIST OF PUBLICATIONS

A list of the publications available from this agency, with prices and instructions for ordering by mail, is available free of charge. The mailing address is:

Mississippi Bureau of Geology
P.O. Box 5348
Jackson, MS 39296

EARLY PUBLICATIONS

In the mid-nineteenth century this agency, then known as the Mississippi Geological Survey, published three reports on the geology of Mississippi in book form. These reports, by B.L.C. Wailes (published in 1854), Lewis Harper (1857), and Eugene W. Hilgard (1860), are out of print.

BULLETINS

The bulletin is the flagship of the Bureau's publication fleet. Number 1 in the series, on cement materials in Mississippi, was published in 1907; it is still available for sale for 50¢. The latest addition, Bulletin 127, is a detailed report on the geology of Tishomingo County, containing an excellent geologic map of the county. For many years most of the work of the agency was published in the bulletin series. A large variety of subject matter has been covered, including, as a sampling: various mineral resources (such as lignite, clays, bentonite, oil, and iron ore), forest resources, water resources, fossils, stratigraphy, county reports (for half of Mississippi's counties), coastal processes, and the Tupelo tornado of 1936. In recent years, most of the bulletins published have been detailed county reports and studies of fossils useful for geologic mapping. Over 100 titles in the series are still in print and available for purchase. Bulletins are printed with a light brown cover.

INFORMATION SERIES

The Information Series was published from 1971 to 1985. Topics included catalogs of electrical logs on file at the agency, a catalog of core holdings, and a history of the agency. This series had no distinct mission and the reports were not numbered consecutively; there are no plans to add additional titles. The reports already published will continue to be sold as long as supplies last. The types of reports published in this series will be published in future in the two series discussed next. The Information Series had blue covers.

REPORTS OF INVESTIGATIONS

Publication of Reports of Investigations commenced in 1989 with a report on coal and coalbed gas in Clay County, within the Black Warrior Basin of northeastern Mississippi. Reports in this series are detailed, technical reports of research into specialized subjects. The color of the covers is light gray.

CIRCULARS

The circular series was started in 1988 and is intended to include numbers that are either collections of data or non-technical summaries of various geological matters. The first two circulars illustrate the types of reports to be published in this series. Circular 1 is a non-technical report about the nature and extent of the Yazoo Clay and construction problems on this swelling clay; it should be of interest to many home-owners in central Mississippi. Circular 2 is the latest edition of the Mineral Producers Directory. Future circulars will be on a diversity of subjects that will provide background data for the researcher and informative reading for the non-specialist. Circulars have green covers.

ENVIRONMENTAL GEOLOGY SERIES

Environmental geology is the study of the interaction between man and the natural geologic processes and hazards on the earth's surface. Three atlas-type reports have been published in this series illustrating how geology relates to slope stability, flooding, and landfill site suitability in the Jackson area and in Adams County. These publications are non-technical and are intended to inform and assist decision-makers and the general public in land-use planning and living with nature.

PAMPHLETS

A pamphlet series has been started to facilitate distribution of information about the geology of Mississippi and the Bureau of Geology. The first pamphlet describes the work and responsibilities of this agency. Pamphlet 2 describes the value of geologic mapping in Mississippi. Future topics in the series will cover commonly asked questions about the geology and mineral resources of Mississippi and the work of the Bureau of Geology.

CROSS SECTIONS

Five cross sections showing subsurface stratigraphy and structural features have been published. A north-south cross section from Tennessee to the Gulf of Mexico is eight feet long. A second cross section runs east-west across northern Mississippi, and the other three are detailed sections of Jurassic sediments in the salt basin.

MAPS AND CHARTS

Geology is a visual science, so much of the Bureau's work is published as maps and charts. Of leading importance is the state geologic map, which is available at the scale 1:500,000 and in a generalized, page-size version. Some of the other titles are Elevation Map of Mississippi, Compilation of Producing Formations in Mississippi, Stratigraphic Column of Mississippi, Economic Minerals Map of Mississippi, and Structural Features of Mississippi. (Note: The many topographic maps sold by the Bureau of Geology are published by the U.S. Geological Survey.)

OPEN FILE REPORTS

Certain research projects of the Bureau result in reports that are of interest to a limited number of specialists or would be prohibitively expensive to prepare and print as publications. The Bureau makes such reports available for examination or purchase by reproduction through the series of open file reports. Available reports are about geothermal energy, deeply buried coal, and hydrologic testing at Tatum Salt Dome. A series of geologic quadrangle maps of Tishomingo County (each at a scale of 1:24,000) is available as open file reports; this is a spin-off of the county mapping project published as Bulletin 127. The Bureau intends to make available quadrangles that are mapped in the future in the course of research projects.

MISSISSIPPI GEOLOGY

The Bureau of Geology publishes a quarterly journal about Mississippi's geology, paleontology, and mineral resources. *Mississippi Geology* contains technical articles, general interest articles for the interested layman or amateur fossil collector, and news of new publications and other developments. Since 1980 this journal has published dozens of articles that might otherwise not have been printed and shared with the public. Many *Mississippi Geology* articles have been contributed by professionals outside the Bureau; this has the effect of "extending" our staff and accomplishments.

PUBLICATION POLICIES

The Bureau of Geology is charged with disseminating information collected in the course of its work, which is done mainly through publication. Therefore, most of the agency's work is published in one of the forms described above, and most of these publications are authored by Bureau staff geologists. There is no prohibition on outside authors publishing through the Bureau of Geology, and most of the series have had contributions by outside researchers. However, the Bureau of Geology is *not* seeking unsolicited manuscripts for any series except the quarterly journal *Mississippi Geology*. Outside contributions to *Mississippi Geology* are welcome.

Prices of Bureau publications are kept reasonable in order to encourage their purchase and use. Most publications are priced to recover printing costs if most copies are sold. It would be impossible to recover the entire cost of doing a project through sales of the report. For example, considering the number of copies printed and sold (1000 to 2000) and the cost of performing a county mapping project (on the order of $250,000), copies of the bulletin would sell for over $125 each. This would make it unavailable to the public and the private industries it was intended to serve. Prices are not raised once they are established. Some bulletins published before World War I are still sold for 50¢ or $1.00 — price-wise, a better bargain now than then.

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Mississippi Geology is published quarterly in March, June, September and December by the Mississippi Department of Environmental Quality, Bureau of Geology. Contents include research articles pertaining to Mississippi geology, news items, reviews, and listings of recent geologic literature. Readers are urged to submit letters to the editor and research articles to be considered for publication; format specifications will be forwarded on request. For a free subscription or to submit an article, write to:

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