Fossil Woods and Resin-like Substances from the Lee Creek Mine

Francis M. Hueber

ABSTRACT

The spoil heaps at the Lee Creek Mine, near Aurora, Beaufort County, North Carolina, are a source of limited quantities of fossil woods and resin-like substances. The woods are permineralized (Schopf, 1975:29) with quartz in crystalline or opaline form. Eight specimens of the woods were examined for this report. The stratigraphic sources of only three of the eight were established on the bases of foraminiferal assemblages and matrix composition. The specimens came from the lower 4 to 10 feet (1.2 to 3 m) of the early Pliocene Yorktown Formation. The gymnospermous genera *Pinus* Linnaeus, *Juniperus* Linnaeus, and *Taxodium* Richards are identified and the remaining five specimens belong to the angiospermous family Caesalpiniaceae. Their generic identity is tentatively resolved and *Gleditsia* Linnaeus is suggested. The biological source of the resin-like substances has not been determined, nor has the stratigraphic source been established for any but one of the 42 specimens examined. Its occurrence is in the upper lower or lower middle part of the Yorktown Formation at a point higher in the section than that of the woods. Fragments of bark, liquid-filled cavities, quartz-like crystals, and pyrite are the inclusions found in three of the specimens; the others are barren. The identity of the fossil woods with modern genera and species suggests their contemporaniety with the deposition of the sediments in which they are found as opposed to being reworked from older sediments. A better stratigraphic control on the occurrences of the woods in the section, as well as their age relationship to the resin-like substances, remain as the most important objectives in any meaningful, additional studies of these entities found at the Lee Creek Mine.

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Introduction

Fossil woods can be found in nearly all of the states along the east coast of the United States but never in the quantity nor of the quality of preservation so typical of localities in several of our western states. Most commonly the fossil woods in the east occur as lignitized logs, twigs or drifted fragments and least commonly as permineralized remains. If permineralization is the mode of preservation, quartz is the primary embedding mineral while pyrite, marcasite, limonite, or hematite are secondary in order of occurrence. Calcite is rarely encountered as the preserving agent, except in Pleistocene or Recent tuffs derived from spring deposits.

Fossilized resins, broadly referred to as amber, are found in the Atlantic Coastal Plain. They are restricted in occurrence to the various formations of Cretaceous age ranging geographically from Marthas Vineyard, Massachusetts, southward to near Goldsboro, North Carolina. Most of the specimens are quite small, droplet-like pellets, while larger ones are generally found adhering to or embedded in fragments of lignitized bark or wood. This latter occurrence suggests association of the resin with wounds or wound areas on the

trunks of the source trees. The resin source of the amber has been attributed to gymnosperms, with the exception of one occurrence where analysis indicated an angiosperm source (Langenheim and Beck, 1968:86). The amber at all of the localities is too limited in quantity and quality to be of commercial significance.

For a number of years permineralized wood, with quartz as the embedding mineral, and lumps of thoroughly solidified resin-like substances have been collected from the spoil heaps at the Lee Creek Mine. The number of specimens has never been very great; however, many of the specimens weigh several kilograms. This brief note is based on the study of eight specimens of wood and 42 specimens of resin-like material.

ACKNOWLEDGMENTS.—I wish to express my gratitude to the following collectors who have generously donated to the paleobotanical collections of the National Museum of Natural History specimens of fossil wood and resin-like material from the Lee Creek Mine: Gerard Case, Peter J. Harmatuk, James Kaltenbach, Earl Mason, Jack H. McLellan, Royal Mapes, James G. Mead, Franklin Pearce, Robert Purdy, Clayton E. Ray, Donna Ray, Clyde Swindell, and James Westgate.

I am particularly appreciative of Thomas G. Gibson's help in establishing the horizons from which four specimens (3 fossil wood, 1 resin-like specimen) were obtained.

James P. Ferrigno produced the excellent photographs and photomicrographs. The scanning electron microscope photographs were made possible through the very capable work of Susann Braden and Mary-Jacquelyn Mann of the National Museum of Natural History SEM laboratory.

Materials and Methods

All of the fossil wood specimens from the Lee Creek Mine thus far donated to the Smithsonian paleobotanical collections, represent silicified, well-eroded, and rounded fragments of secondary wood derived from trunks of trees. No branches, twigs, or shrub-like material have been observed.

Transverse, radial, and tangential sections were obtained by making appropriate cuts of the material with a standard 8-inch (20-cm) diamond saw. The sawed surfaces were ground to smoothness with 600 grit carborundum powder on a glass plate, etched with concentrated hydrofluoric acid for 10 to 30 seconds, carefully rinsed by dipping into several changes of fresh water, air dried, and peeled by means of the Joy, Willis Lacey, technique (1956) using acetone and 76.2 μm (0.003 in) thickness cellulose acetate paper. The resulting peels were mounted in Canada balsam on standard glass microscope slides.

Specimen USNM 267213, *Pinus* species cf. *P. palustris* Miller, is so porous and thoroughly mineralized that it was necessary to prepare standard ground thin-sections that were then stained in acid Bismarck Brown solution in order to differentiate detail. This technique was described by Bartholomew, Matten, and Wheeler, 1970.

The specimens of resin-like substances comprise pieces from 3 × 2 × 1 cm to 30 × 36 × 11.5 cm in overall dimensions. All 42 in the collections at this time represent eroded fragments from larger masses, even in the case of the largest specimen. Ground thin-sections were prepared from one particularly well-banded specimen (USNM 267217) for microscopic study. Epoxy 220 resin was used to attach the sections to standard glass microscope slides, and they were then ground on a glass plate to smoothness and necessary thinness, using water and 1200 grit aluminum oxide. The sections were covered with high-viscosity Canada balsam in order to prevent swelling of the epoxy mounting medium. A glass coverslip was used to seal the mount.

Surfaces of some of the transluscent to transparent resinous specimens were ground and polished to permit better examination of their interiors for possible inclusions. Sanding on a 220 fixed grit belt sander followed by a worn 600 fixed grit belt produced a surface that could then be finished to a high luster, using a soft cloth impregnated with titanium oxide final polishing compound. Unfortunately, although the polish

was bright, it was temporary. The surfaces became dull with any handling and soon became opaque. Freshly broken surfaces showed the same changes with time.

Fragments of plant tissue found in one specimen of the resinous material and portions of mineral-filled cavities in another were attached to aluminum stubs using white glue (Elmer's brand). They were then coated with carbon and gold-palladium to a thickness of ~500 Å, and observed and photographed in a Cambridge Stereoscan Mark II A scanning electron microscope.

Stratigraphic Occurrence of Specimens

The stratigraphic sources have been established for only four of the fifty specimens considered in this report. Analyses by T.G. Gibson of the foraminiferal assemblages and the sedimentary characteristics of matrix removed from protected cavities in three specimens of the fossil woods and from the fillings of shells of barnacles attached to the surface of one specimen of the resin-like substance (Plate 2: figure 10) are quoted here and serve to date those particular specimens.

Matrix from fossil wood specimen USNM 267218 contained: *Nonionella auris* d'Orbigny, *Elphidium clavatum* Cushman, *Buliminella elegantissima* (d'Orbigny), *Cassidulina laevigata* (d'Orbigny), *Nonion pizarrense* Berry, *Bulimina elongata* d'Orbigny, *Bolivina paula* Cushman and Ponton, *Hanzawaia concentrica* Cushman, *Globigerina falconensis* Blow, small grains of secondary phosphate, and echinoid spines. This assemblage and the sedimentary characteristics indicate that this fossil wood specimen is from the lower part of the Yorktown Formation, in the lower 10 feet (3 m) of the Lee Creek Mine section.

Matrix from fossil wood specimen USNM 298768 contained: *Bulimina elongata* d'Orbigny, *Buccella frigida* (Cushman), *Buliminella elegantissima* (d'Orbigny), *Elphidium clavatum* Cushman, *Cibicides lobatulus* (Walker and Jacob), *Epistominella pontoni* Cushman, *Globigerina bulloides* d'Orbigny, *Hanzawaia concentrica* Cushman, *Bolivina paula* Cushman and Ponton, *Virgulina fusiformis* Cushman, and small grains of secondary phosphate. This assemblage and the sedimentary characteristics indicate that this fossil wood specimen is from the lower part of the Yorktown Formation, in the lower 10 feet (3 m) of the section at the Lee Creek Mine.

The matrix from fossil wood specimen USNM 298767 contained: *Elphidium clavatum* Cushman, *Cibicides lobatulus* (Walker and Jacob), *Cassidulina laevigata* d'Orbigny, *Nonionella auris* d'Orbigny, *Buccella frigida* (Cushman), and medium to large phosphate grains. This assemblage and the sedimentary characteristics indicate that this specimen of fossil wood is probably from within the lower 4 feet (1.2 m) of the Yorktown Formation in the Lee Creek Mine section.

Matrix filling the barnacle shells attached to the specimen of resin-like substance USNM 267220 contained: *Elphidium clavatum* Cushman, *Uvigerina subperegrina* Cushman and Kleinpell, *Buliminella elegantissima* (d'Orbigny), *Cibicides lobatulus* (Walker and Jacob), *Globigerina falconensis* Blow, *Rosalina floridana* Cushman, *Bolivina floridana* Cushman and Ponton, *Nonionella auris* (d'Orbigny), *Lagena substriata* Williamson, *Angulogerina occidentalis* (Cushman), *Bolivina plicatella* Cushman, and echinoid spines. This assemblage and the sedimentary characteristics indicate that this specimen would come from the upper lower to middle part of the Yorktown Formation in the Lee Creek Mine section.

The remainder of the specimens in this study were collected from the spoil heaps of the mine and were either clean when collected or were subsequently washed free of any matrix before donation to the museum collections. As a result no precise stratigraphic occurrence can be established for them.

Systematics

Division PINOPHYTA
Class PINOPSIDA
Order PINALES
Family PINACEAE

Genus *Pinus* Linnaeus
Family CUPRESSACEAE
Genus *Juniperus* Linnaeus
Family TAXODIACEAE
Genus *Taxodium* Richards
Division MAGNOLIOPHYTA
Class MAGNOLIOPSIDA
Order FABALES
Family CAESALPINIACEAE
Genus *Gleditsia* Linnaeus

Genus *Pinus* Linnaeus

Pinus species cf. *P. palustris* Miller

PLATE 1: FIGURES 1–5

This description is based on a single specimen (USNM 267213) collected and donated by J. Kaltenbach. It is 17.5 cm long and 9.5 cm wide, the latter dimension measured along the radial section of the wood. Virtually all of the organic matter of the wood has been replaced by quartz. Subsequent leaching by ground water has removed any remaining organic matter and has made the specimen quite porous. The nature of the pitting in the tracheid walls as well as in the cross-field contacts of the ray parenchyma were particularly difficult to demonstrate because of the replication in quartz of the cell walls.

Twelve rather broad growth rings are clearly visible in the cross-section of the wood, the early wood being the broadest and most evenly textured. The late wood is narrower and clearly defined by the presence of numerous longitudinal resin canals (Plate 1: figure 1). There are a few resin canals distributed unevenly through the early wood. The transition from early to late wood is gradual. Rays are very fine and can be seen only where a horizontal resin canal is included in the ray.

Tracheids in cross-section are 22 to 64 μm in diameter (average 35 μm). Bordered pits are found on the radial walls in single rows or less commonly in two rows arranged oppositely (Plate 1: figure 5). No pits were observed on the tracheids in tangential section in the preparations at hand.

Ray parenchyma with one, rarely two, large unbordered pits per cross-field is not well preserved (Plate 1: figure 4). The rays are of two types, uniseriate and fusiform (Plate 1: figure 3) and 1 to 20 cells high (average 8). The fusiform rays contain a horizontal resin canal (Plate 1: figure 3 at arrows). It has not been possible to determine the presence of ray tracheids in this specimen.

The longitudinal resin canals are large, 156 to 180 μm in diameter, and have poorly preserved remains of a thin-walled epithelium lining the walls (Plate 1: figure 2). The horizontal resin canals are much smaller, ranging from 48 to 70 μm in diameter (average 54 μm) and are also lined with an epithelial layer or remnants of tyloses.

Although the cell structure in this specimen is somewhat obscured by the effects of preservation, the detail that has been obtained compares favorably with sections of modern wood of *Pinus palustris* Miller (longleaf pine) from the collections of the Smithsonian Division of Plant Anatomy. Comparison of cell dimensions and clearer detail of ray structure is precluded. The stratigraphic source of this specimen is not known.

Genus *Juniperus* Linnaeus

Juniperus sp. cf. *J. virginiana* Linnaeus

PLATE 2: FIGURES 1–4

USNM 267215 has distinct growth rings marked by a dense, narrow band of late wood and a less dense broad band of early wood; transition between early and late wood abrupt. Rays are numerous and fine. Parenchyma scattered and gum filled (Plate 2: figure 1). Resin canals not present.

Tracheids small, 23 to 35 μm in diameter; bordered pits in one row on radial walls (poorly preserved) (Plate 2: figure 3 at arrows). Rays uniseriate, low, 1–10 cells high (mostly 4 or 5) (Plate 2: figure 2), homogeneous, cross-field pits single and large (Plate 2: figure 4) or smaller and

paired but more specific details not determined because of poor preservation of the material.

Comparisons of the anatomical details of this specimen with those of sections from modern *Juniperus virginiana* Linnaeus (eastern red cedar) in the collections of the Smithsonian Division of Plant Anatomy suggest close agreement in the identification with that species. Positive identification is precluded by the rather poor preservation of finer anatomical detail in the fossil material.

This specimen was collected by J.H. McLellan and bore his original collection number 237. The fragment is 3.5 × 2.75 × 2.5 cm in overall dimensions. The stratigraphic source of this specimen is not known.

Genus *Taxodium* Richards

Taxodium distichum Richards

PLATE 1: FIGURES 6–8

USNM 267214 has quite distinct growth rings marked by a narrow band of late wood and a very broad band of early wood. The transition between the early and late wood is abrupt (Plate 1: figure 6). Rays are conspicuous. Parenchyma is scattered randomly through the early wood and is quite obvious because of the dark resinous contents of the individual cells (Plate 1: figure 6).

Tracheids 48 to 68 μm in diameter with bordered pits in single, commonly double, and only occasionally three rows on the radial walls. When in multiples the pits are opposite, and crassulae are present between vertical pairs (Plate 1: figure 8).

Rays are uniseriate, 2 to 13 cells high, composed wholly of parenchyma and exhibit 1 to 3 bordered pits per cross-field area (Plate 1: figure 8).

Longitudinal parenchyma is diffused randomly through the wood and is clearly differentiated from other cells because of the dark material filling the cell lumens (Plate 1: figures 7, 8).

This specimen was collected by C.E. Ray. It is 30.5 × 17.75 × 7.5 cm in overall dimensions. Mineralization of the specimen is more of an opal-like form of quartz rather than the crystalline type found in the other fossil wood samples examined here.

The cellular detail in this specimen is excellently well preserved, and because of this the identification to species (bald cypress) is made with full confidence. Comparison with slides prepared from modern examples of the species housed in the collections of the Smithsonian Division of Plant Anatomy, substantiated the identification. Unfortunately, the horizon from which this specimen was obtained is not known.

Genus *Gleditsia* Linnaeus

Gleditsia species

PLATE 2: FIGURES 5–7, PLATE 3: FIGURES 1–4

The remaining specimens of fossil wood in this limited study belong to the Magnoliopsida, that is, to dicotyledonous broad-leafed trees. Initial examination of the specimens, following the first cutting with a diamond saw, gave the impression that all of the specimens were identifiable with at most two genera, each one in a different family. Subsequent microscopic examination of cellular detail led to the conclusion that only one genus may be represented from the family Caesalpiniaceae. This family comprises mostly tropical genera; however, our native *Gleditsia* Linnaeus (honey locust) and *Gymnoclaudus* Lamarck (Kentucky coffee tree) are examples of temperate climate members. Of the two genera, *Gleditsia* is the most likely one represented by the fossil woods in the present study. Structural characteristics of each of the specimens overlap so strikingly that they may be identical, and for that reason I have chosen to describe and illustrate only two (USNM 267216 and 267218) of the five specimens representing the Magnoliopsida.

The specimens illustrated by means of photomicrographs of cellulose acetate peel sections in Plate 2: figures 5–7 (USNM 267216) and Plate 3:

figures 1–4 (USNM 267218) were donated by Mr. Peter Harmatuk. Before sectioning, the former was 19 cm long, 8 cm wide, and 5 cm thick. It represents a well-rounded fragment from the trunk of a tree that was at least 66 cm (26 in) in diameter as determined by projecting into a complete circle the arc of the growth rings along the outer margin of the specimen. It was probably a much larger tree. The latter specimen was 28 cm long, 10.5 cm wide, and 3.5 cm thick and represents a fragment of a trunk at least 102.6 cm (40 in) in diameter. The wood is ring porous (Plate 2: figure 5; Plate 3: figure 1) and the transition between early and late wood is abrupt. Vessels are medium- to large-sized, 95–265 μm in diameter, mostly round in cross-section, solitary but forming a band 2 to 5 cells wide in the early wood. Late wood vessels small, 70–100 μm wide, solitary or in small clusters (Plate 3: figure 1). Paratracheal parenchyma conspicuous (Plate 3: figure 1) around vessels and in late wood passing over into the succeeding early wood layer. Vessel members are truncate (Plate 2: figure 7), lack ligulae, and have simple perforation plates (Plate 3: figure 3). Intervascular pitting crowded, angular (Plate 2: figure 7) pits 4.4–5.2 μm in diameter. Rays are high, measured up to 2.4 mm long, multiseriate 4 to 8 cells wide, occasionally uniseriate (Plate 2: figure 6, Plate 3: figure 2), homogeneous and unstoried. A very commonly observed characteristic is the evidence of dark gums filling many of the vessels (Plate 2: figure 5) in large areas of the woods. This is true of all of the specimens examined.

Variation from the discription given above is only slight among the specimens observed. Widths of growth rings, which are quite variable, allow for changes in number of vessels per unit area, minor differences in diameters of the vessels, more prominent parenchyma distribution, at least in wider growth rings, and in some instances the appearance of semi-ring porous structure to the wood. But the microscopic anatomical details remain to unite the group as a whole.

The age of specimen USNM 267216 could not be determined; however, USNM 267218 came from the lower 10 feet of the Yorktown Formation of the Lee Creek Mine. Interestingly, one of the other dated specimens (USNM 298768) came from the same horizon, while USNM 298767 came from the lower 4 feet of the formation.

Comparisons made between the fossil woods and slide preparations of modern woods from the genera *Gleditsia*, *Robinia* Linnaeus, *Gymnocladus* and even *Hymenaea* Linnaeus in the collections of the Division of Plant Anatomy support the assignment of the fossils to *Gleditsia*. The gross, but probably insignificant, variations seen in the fossil woods are not all readily observable in the modern material. The finer anatomical details, however, are supportive to the determination of the genus.

Resin-Like Substances

The collection of resin-like substances in the Smithsonian from the Lee Creek Mine comprises 42 whole or freshly broken and fragmented specimens. On visual examination, there appear to be four basic forms: (1) transparent, lustrous, yellow to very light reddish brown, approach most closely the appearance of amber; (2) transluscent to nearly opaque, lustrous, massive to well-banded, dark reddish brown (Plate 3: figures 5, 6, 8); (3) opaque, dull to waxy luster, light golden, well banded, and generally with a porous texture (Plate 3: figure 9); and (4) transparent to transluscent on thin edges, waxy luster, very dark brown to black in massive pieces, coarsely banded or swirled patterning.

In all but form 1, the odor of freshly broken or slightly heated surfaces is bituminous and rather unpleasant. In form 1 the odor is not bituminous nor does it have the fragrance characteristic of most ambers when heated. Thus far it has not been possible to define the source or type of organic substances represented by these resin-like materials.

The stratigraphic occurrence of the resin-like substances has been determined for only one specimen (Plate 3: figure 6), USNM 267220, and that is the top lower or lower middle part of the

Yorktown Formation. The specimen is younger than any of the fossil woods from the mine for which ages have been determined.

All of the specimens are fragments of even larger masses as evidenced by the banding that is abruptly truncated at the margins of the specimens (Plate 3: figure 8). The swirled patterns are also in sectional view (Plate 3: figure 9).

It is obvious that the resin-like substances were well solidified before transport into the marine environment of deposition. Evidence of the borings of marine organisms (?Pholadidae) and the attachment of barnacles (*?Chthalmus*) and bryozoans to the surfaces of some specimens is illustrated by specimen USNM 267220 (Plate 3: figures 6, 7, 10).

At the outset of this study the resin-like specimens were examined for inclusions, such as plant debris, insects, and pollen. All of the banded patterning that would suggest inclusion of foreign matter (Plate 2: figure 8; Plate 3: figures 6, 8, 9) has proved to be alternating densities of small spherical bodies (Plate 2: figures 9, 10, 11) that are neither liquid nor gas filled. Instead, they are solid and appear to be a different phase of the resin-like substance itself.

In one specimen, a form 1 type as described above, donated by Mr. Swindell (USNM 267223), fragments of bark were found (Plate 4: figures 1, 2). No identification is possible as to the type of tree from which the bark could have come. It does, however, represent the only inclusion of plant material found in any of the 42 specimens in the study collection and establishes the possibility that the form 1 type of resin-like substance is of plant origin.

Bubble-like cavities are present in most of the specimens in the collection. The cavities usually are empty. However, in one specimen of form 1 material (USNM 267225) the cavities are liquid filled and in another specimen, form 3 material (USNM 267224) quartz-like crystals are present in some of the cavities and pyrite in others (Plate 4: figures 3–7). These liquid and mineral inclusions merit additional study.

The entire collection of resin-like substances will be stored in the paleobotanical collections of the Smithsonian Institution and will be available for additional research to qualified specialists.

Discussion

At the outset of this study there was hope to establish a relationship between the resin-like substances and the fossil woods found at the Lee Creek Mine. The first assumption that proved wrong was that the woods were permineralized by phosphates. Quartz proved to be the permineralizing agent. The questions arose as to the source of the quartz and why the woods were the only fossil remains to be preserved by that mineral. There were no immediately satisfying answers to these questions. Further the well-rounded nature of the specimens (as if tumbled, perhaps during fluvial transport) and the lack of borings by marine organisms suggest that the woods were silicified elsewhere at an earlier time, then redeposited at the present site. Further, the one piece of resin-like substance that could be dated proved to be younger than any of the dated woods, placing in limbo any possible relationship between the two materials. Thus, when it became apparent that there was no stratigraphic control on most of the specimens at hand, further efforts to identify the woods and analyze the resin-like substances seemed unwarranted.

It would be presumptive to assume that all of the fossil woods and resin-like substances found at the mine were originally from the Yorktown Formation of the Lee Creek section. Some of the specimens have been arbitrarily labelled as from the Pungo River Formation. It is to be hoped that special efforts will be made in further collecting at the mine to obtain specimens of known or determinable stratigraphic occurrence. The analyses of the matrix will establish horizons bearing the wood and resin-like substances and some clear picture may develop that will answer some of the questions posed.

The results of this study suggest that the woods and resin-like substances are probably not much older than the sediments in which they are found. Clearly the woods are identifiable with modern

genera, and, even more significantly, they are close to, if not identical to, modern species. That the resin-like substances are of plant origin still cannot be proved.

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Plates 1–4

PLATE 1

Pinus species cf. *P. palustris* Miller, USNM 267213

1. Transverse section showing resin canals and general texture of the wood. Growth ring exceeds height of photograph, lower three resin canals mark the end of early and beginning of late wood, × 50.
2. Transverse section of longitudinal resin canal. Thin-walled cells lining the canal are poorly preserved. Radiating fibrilar structure in the canal is mineral growth, × 150.
3. Tangential section showing short, predominantly uniseriate rays except in those rays containing horizontal resin canals (arrows), × 50.
4. Radial section, in which ray cell walls are poorly preserved and accordingly cross-field pitting (arrows) is difficult to illustrate, × 50.
5. Radial section showing single and double rows of circular-bordered pits; pits arranged oppositely when in two rows, × 200.

Taxodium distichum Richards, USNM 267214

6. Transverse section showing abrupt change from summer to spring wood. Scattered, resin-filled parenchyma cells are readily visible as dark spots, × 45.
7. Tangential section showing uniseriate rays and resin-filled longitudinal parenchyma, × 145.
8. Radial section showing arrangement of bordered pits, cross-field pits in the ray parenchyma (upper arrow) and crassulae (lower arrow), × 150.

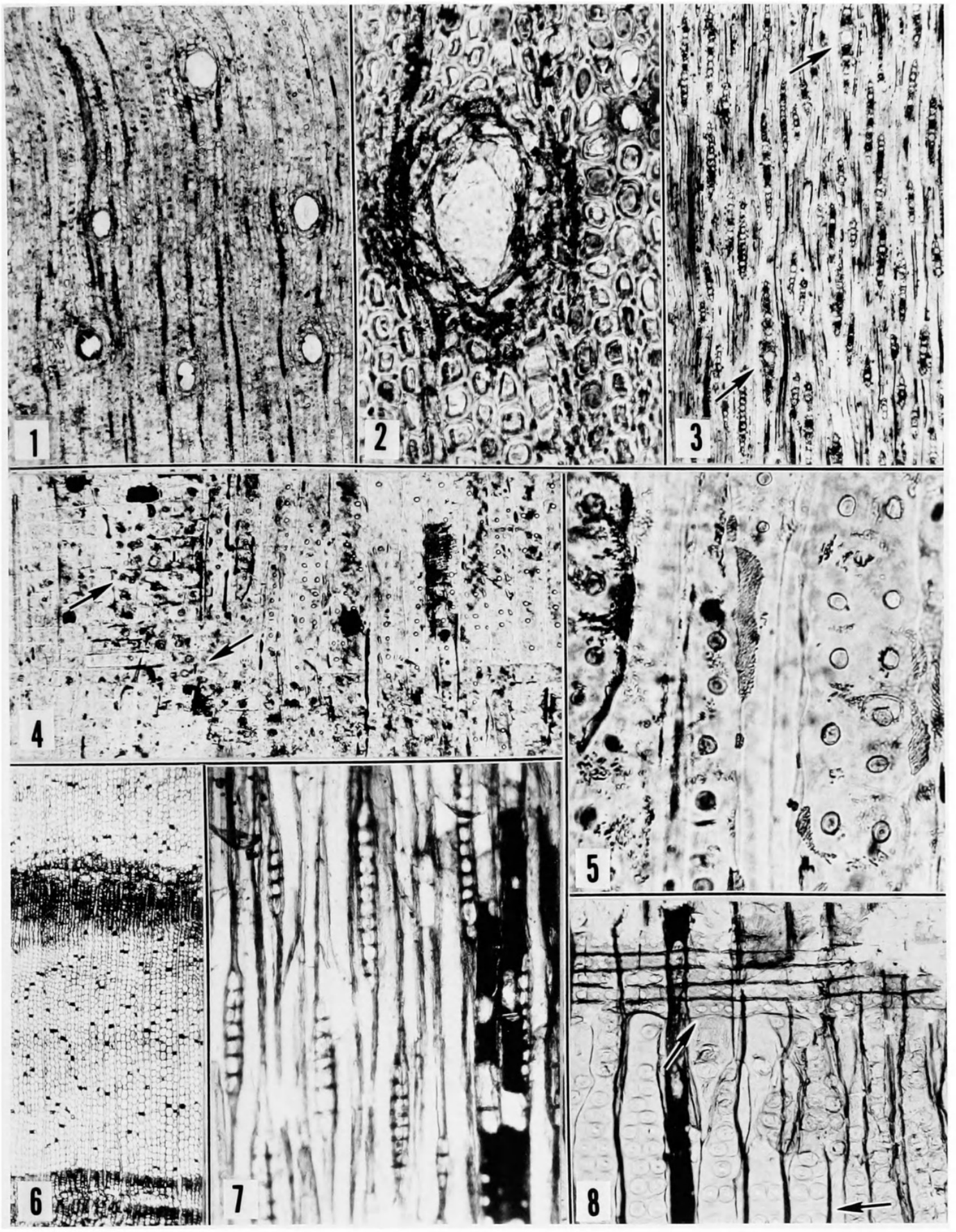
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PLATE 2

Juniperus species cf. *J. virginiana* Linnaeus, USNM 267215

1. Transverse section showing growth rings and general texture of the wood, × 50.
2. Tangential section showing short, uniseriate rays, × 80.
3. Radial section showing remnants of circular bordered pits (arrows) in single rows, × 150.
4. Radial section showing single, large cross-field pits (arrows) in the ray parenchyma, × 80.

Gleditsia species, USNM 267216

5. Transverse section showing growth ring (between upper and lower arrows) and general texture of the wood, × 27.
6. Tangential section showing high multiseriate rays, × 40.
7. Tangential section showing truncate vessel members with fine, angular intervascular pitting, × 105.

Resin-like substance, USNM 267217

8. View of broken and eroded surface of resin-like substance showing banding, × 34.
9. Polished thin-section of dense, light-colored band in the specimen showing small spheres; spheres are solids, not liquid or gas, × 250.
10. Polished thin-section of area between dense bands showing diminution of numbers of spheres, representing a clear area in the substance, × 250.
11. Polished thin-section showing variability in sizes and density of numbers of the spheres, which results in the banding of the resin-like substance, × 250.

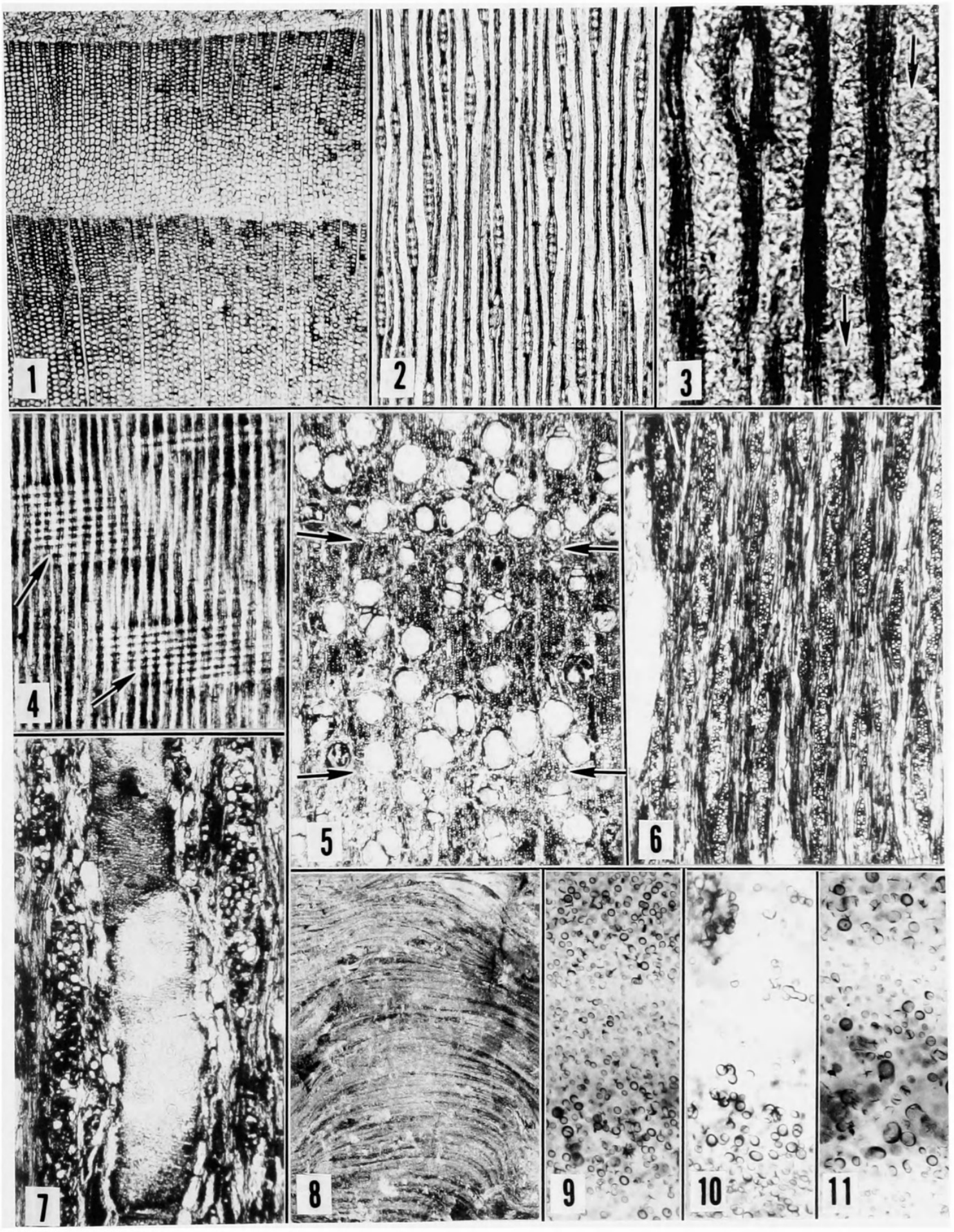
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PLATE 3

Gleditsia species, USNM 267218

1. Transverse section showing growth rings and general texture of the wood, × 40.
2. Tangential section showing early vessels (right) and late vessels (upper left), and morphology of the uniseriate and multiseriate rays, × 40.
3. Radial section showing simple perforation plate in vessel member, × 40.
4. Radial section showing storied paratracheal parenchyma associated with vessel members, × 40.

Resin-like substances and associated fauna

5. USNM 267219, lustrous broken surface of nearly homogeneous resin-like substance with large bubble cavities, × 1/2.
6. USNM 267220, broken surface showing luster, color banding and section through borings made by marine organisms (?Pholadidae), × 1.
7. USNM 267220, enlargement of borings seen in figure 6, × 2.
8. USNM 267221, fragment of banded resin-like substance, banding parallel and truncated at ends of specimen, × 1/2.
9. USNM 267222, broken surface of resin-like substance showing peculiar swirled pattern of banding, × 1/2.
10. USNM 267220 (same as in figures 6 and 7) showing barnacles (*?Chthalmus* sp.) attached to the surface of the resin-like substance; bryozoans are also present at the right margin of the specimen, × 2.

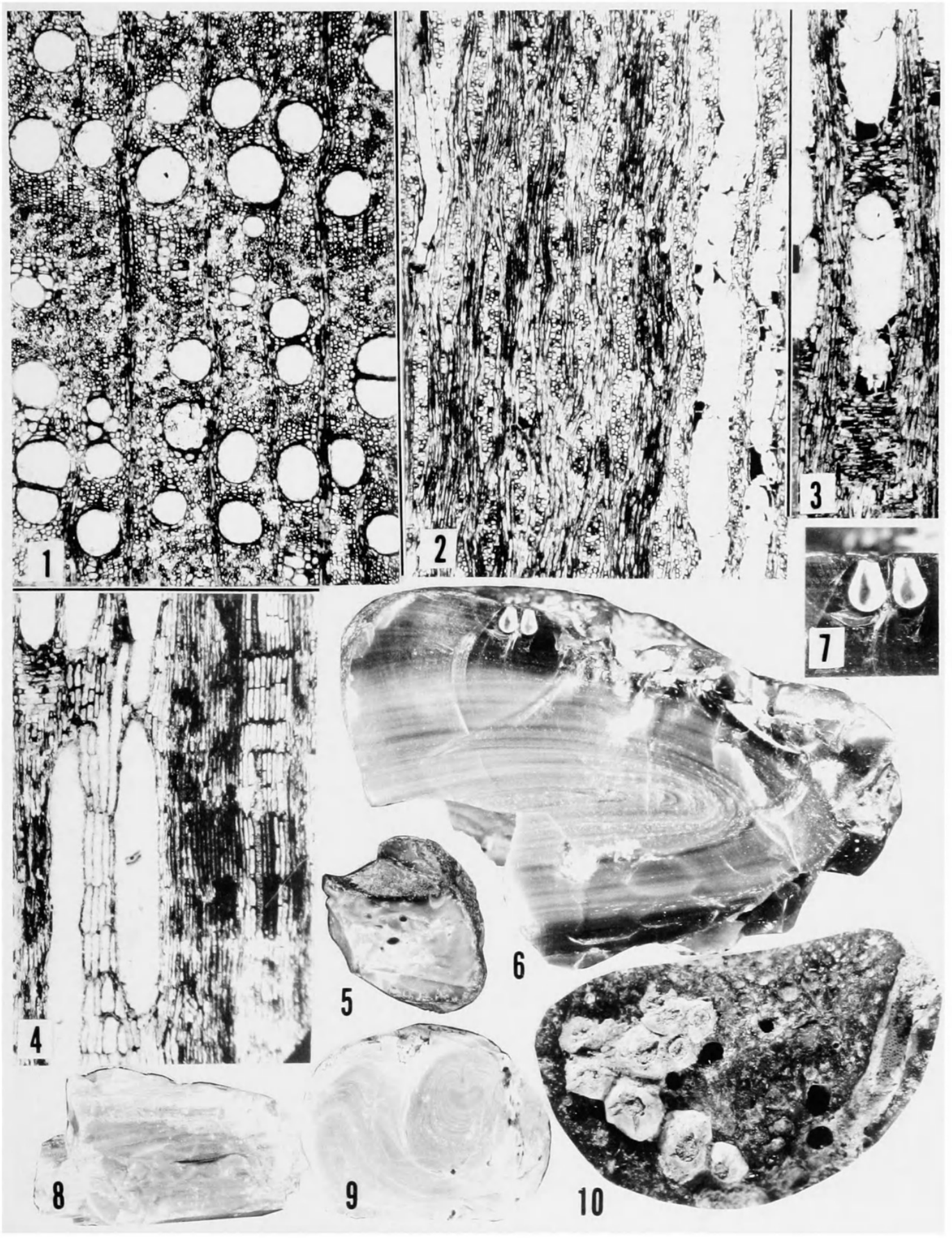
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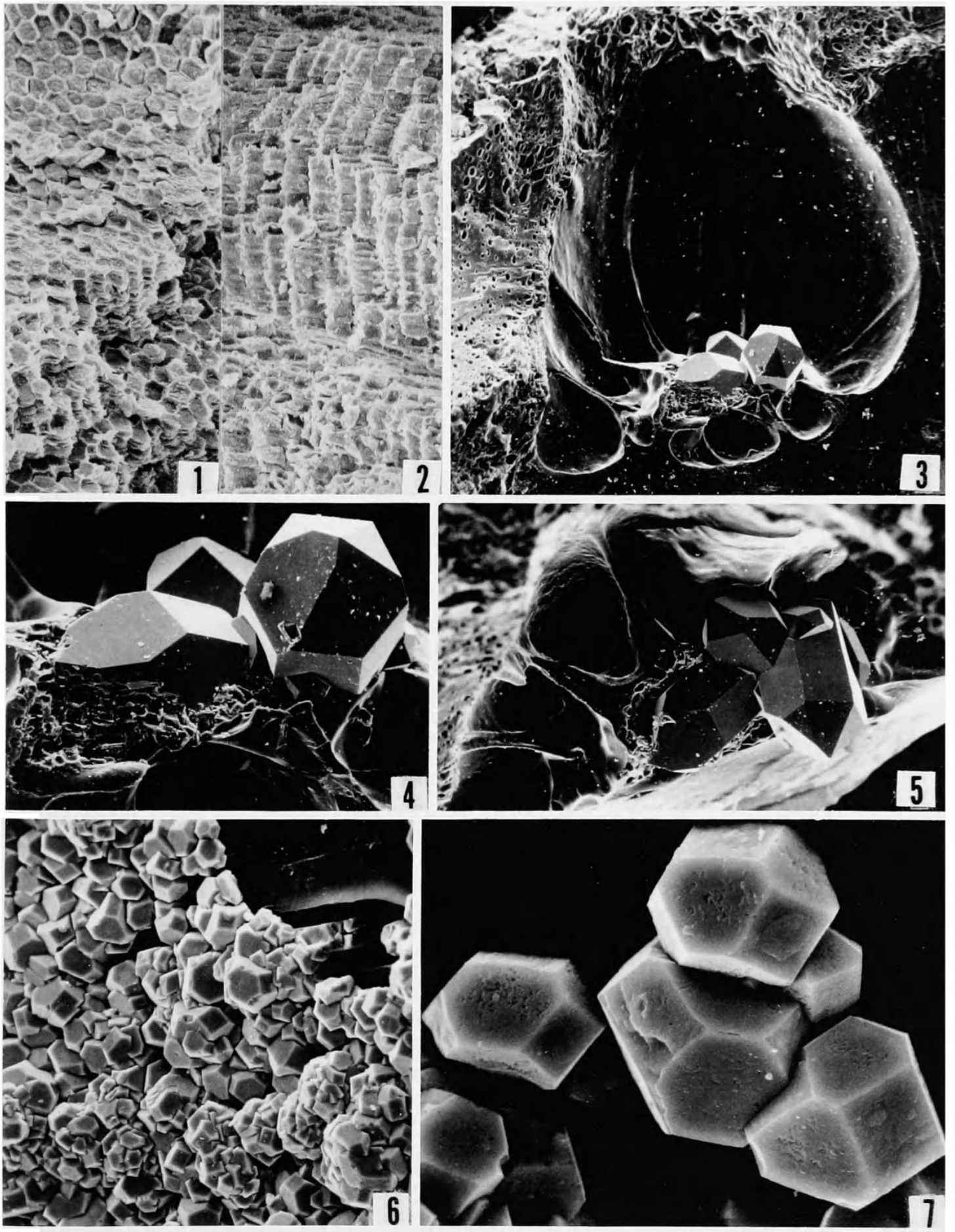
PLATE 4

Inclusions in resin-like specimens, all SEM photographs

1. USNM 267223, fragment of bark; surface in tangential section, × 250.
2. USNM 267223, same fragment as in figure 1; surface in transverse section, × 249.
3. USNM 267224, quartz-like crystals included in bubble cavity in resin-like substance, × 30.
4. USNM 267224, side view of quartz-like crystals in figure 3, enlarged view, × 85.
5. USNM 267224, vertical view of quartz-like crystals in figure 3, × 38.
6. USNM 267224, pyrite crystals coating inner wall of bubble cavity in resin-like substance, × 620.
7. USNM 267224, pyrite crystals enlarged from same cavity as figure 6, × 3800.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