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Tree Defects: A Photo Guide

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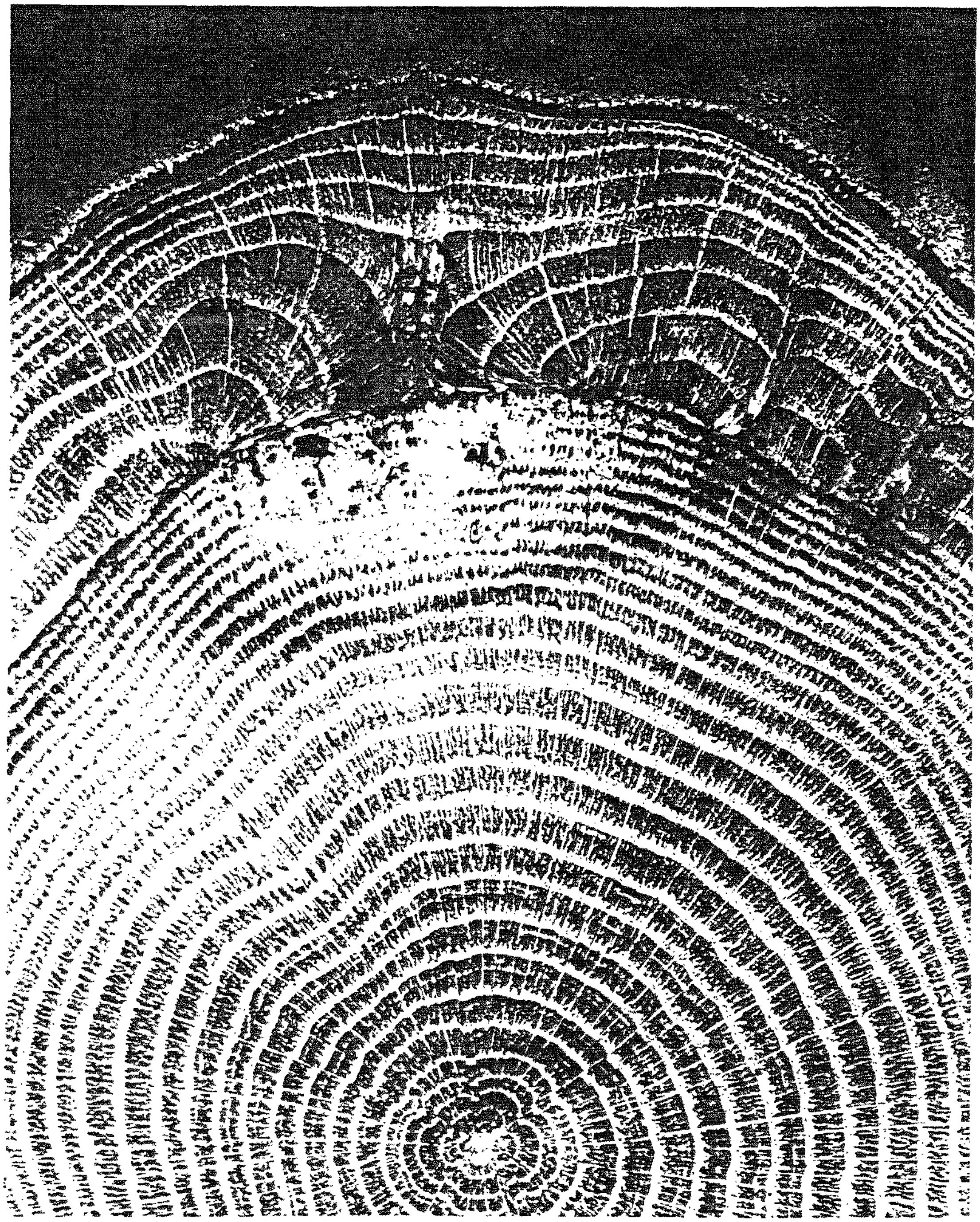

The Author

Alex L. Shigo is Chief Scientist and leader of a USDA Forest Service Pioneering Project on discoloration and decay in trees, with the Northeastern Forest Experiment Station in Durham, New Hampshire.

Dr. Shigo has used a chainsaw to make longitudinal dissections of thousands of trees. He has studied trees throughout the United States, and in Canada, Australia, Europe, and Asia in his research on the response of trees to injury and infection. He has packaged parts of his research findings to reach many audiences worldwide.

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Abstract

Dissections and wounding studies on thousands of trees since 1959 have resulted in an expanded concept of tree decay. A long gradation of events begins after wounding as tree and microorganisms interact. The highly compartmented tree forms boundaries to resist the spread of microorganisms. This defense process is compartmentalization, and CODIT is a model of the process.

The expanded concept of decay and CODIT are used to reexamine many tree problems. Discolored and decayed wood are major tree problems that cause low quality in trees. A better understanding of these defects makes it possible to begin growing healthier and higher quality trees in our forests and cities.

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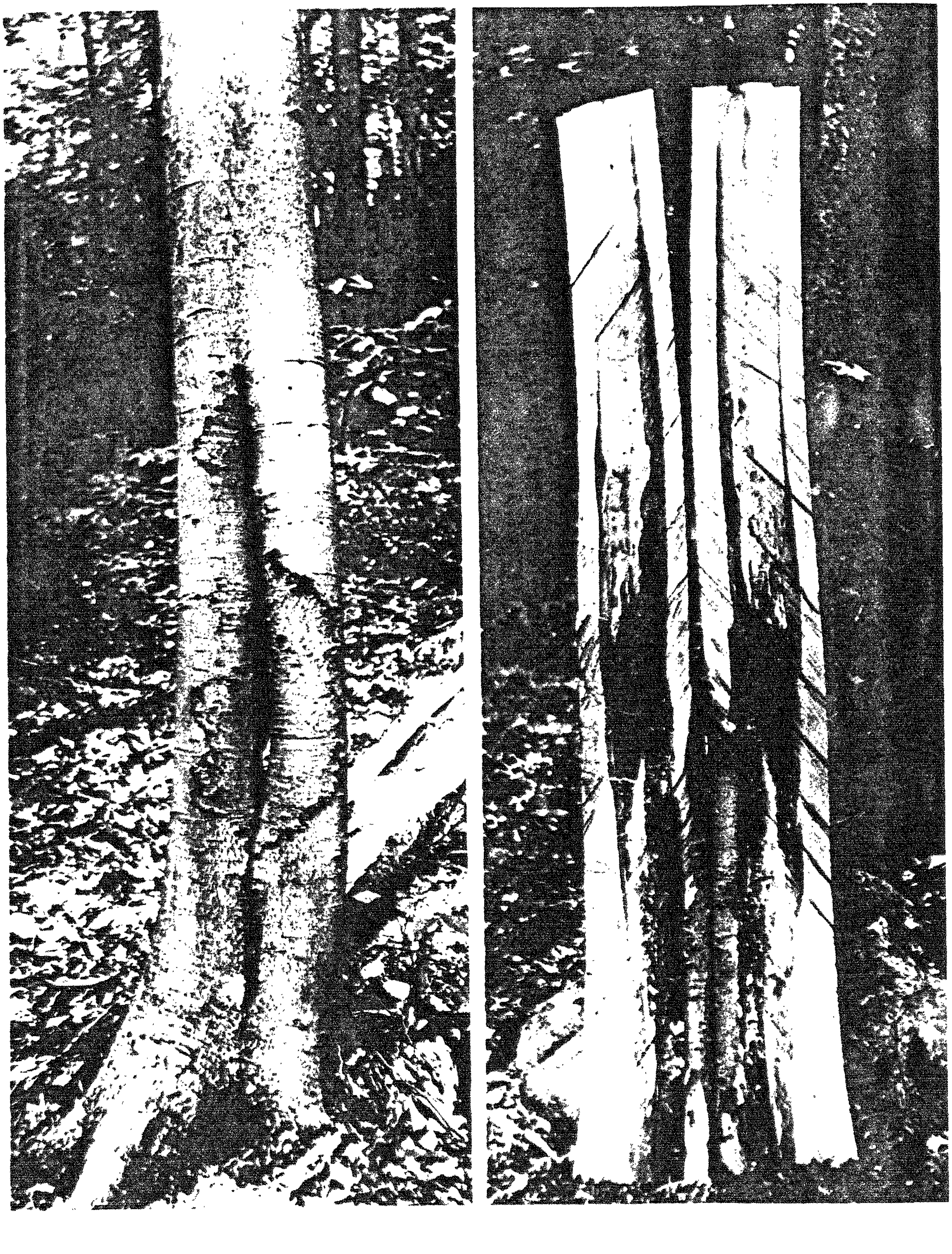
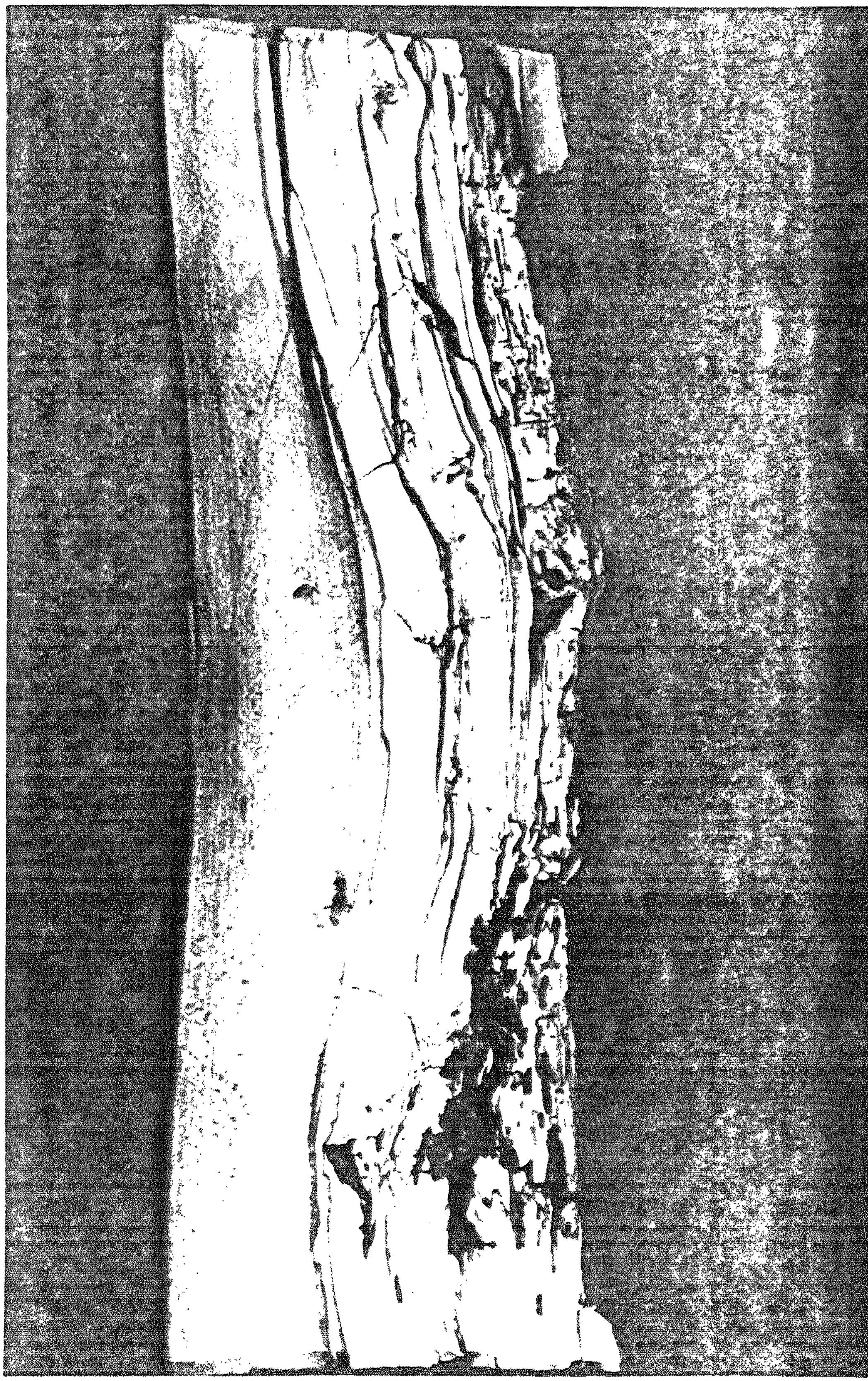
The guide gives an historical pictorial overview of the development of the CODIT model. CODIT is a model of Compartmentalization Of Decay In Trees. CODIT shows how trees are built up in highly ordered compartments. Trees survive after injury and infection so long as they recognize and compartmentalize the injured tissues, confining them to small volumes rapidly and effectively. When trees break down from disease or decay, they do so compartment by compartment.

Field dissections that led to the CODIT model are shown first. The application of the model to many other tree problems is then shown. A constant thread that runs through the photos is that many problems in wood products have their origin in the living tree.

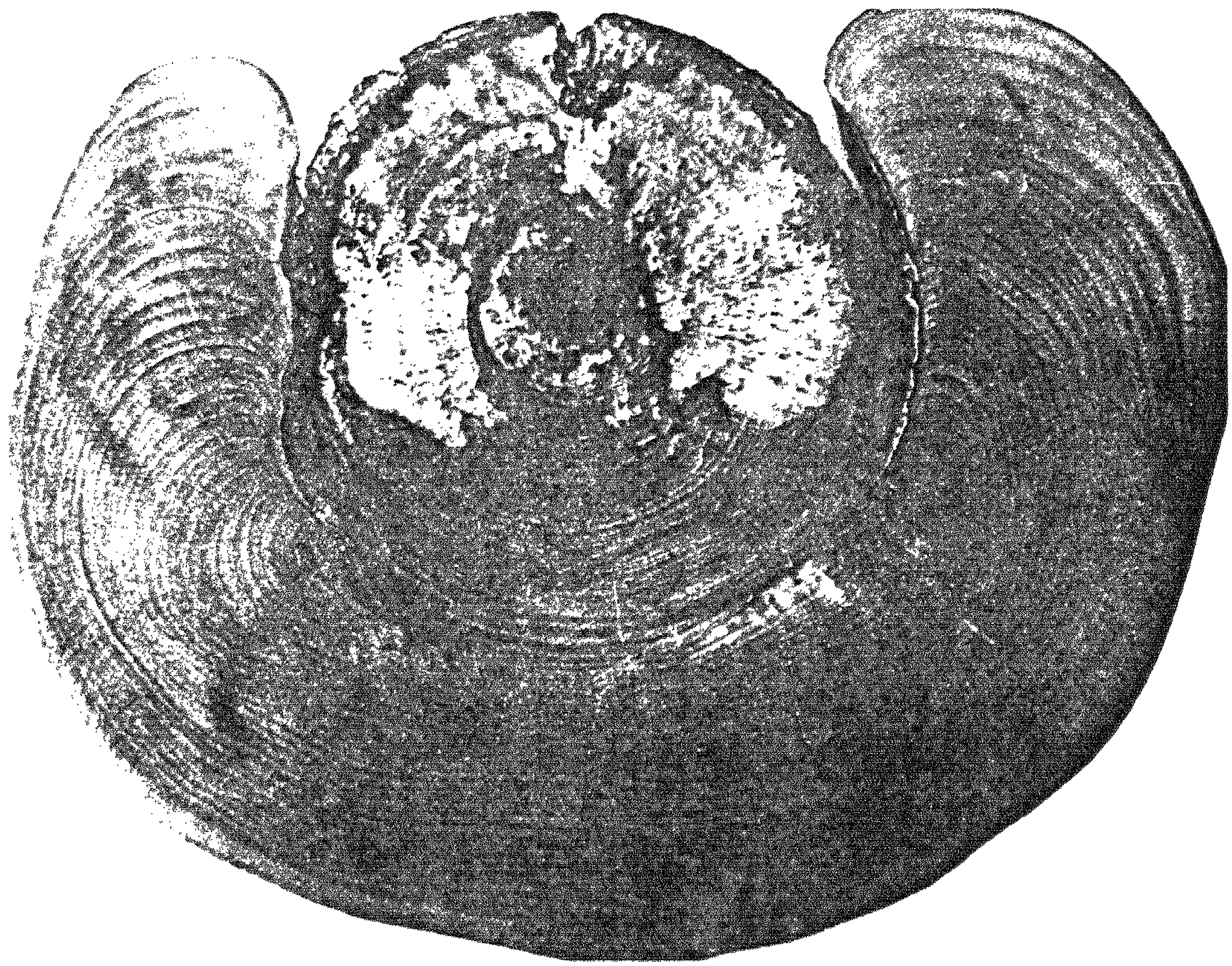
1. Thousands of trees with wounds were dissected longitudinally. The decay did not spread outward into new wood formed after wounding, as this American beech shows.



2. And this beech with decay associated with *Fomes igniarius*.



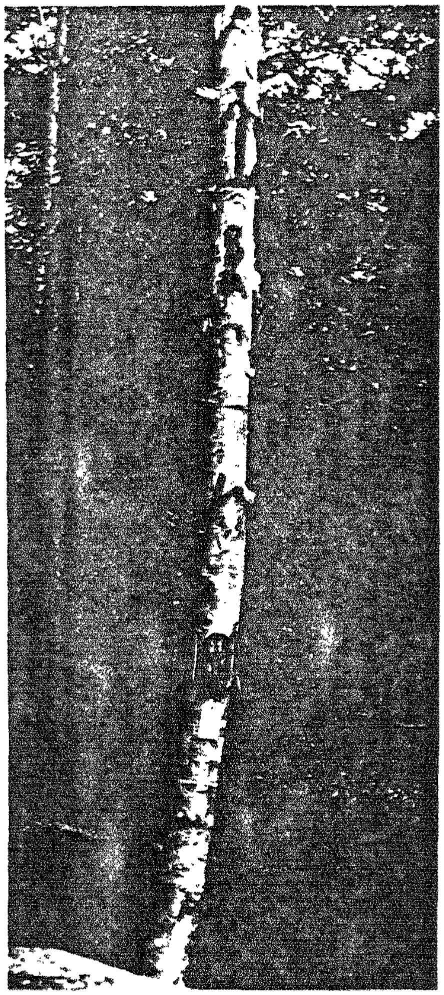
3. Cross-sections of trees showed the same patterns: the decay was confined to the wood present at the time of wounding, as in this yellow birch.

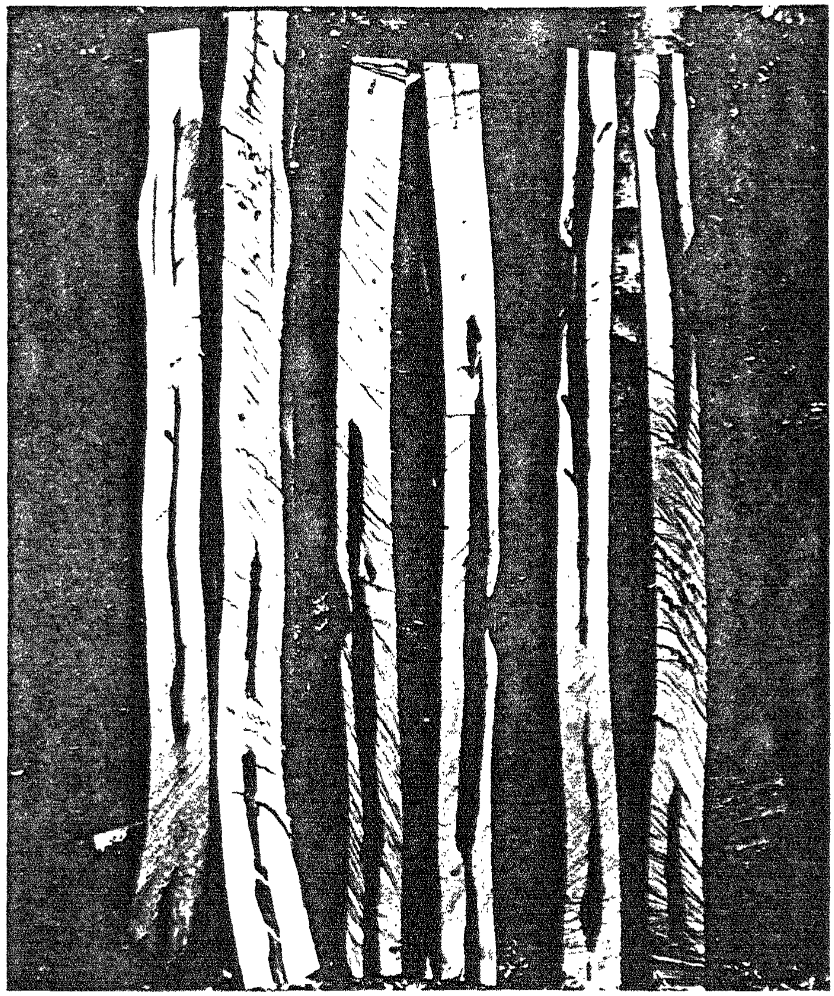


4. New questions arose as more trees were dissected. Dissection of this paper birch showed that the central column of colored wood was associated with the wounds.

   Most birch trees did have a central core of colored wood, but some trees, even large, old trees, had no colored cores. The discolored wood was associated with wounds.

   Dissections showed that some columns of discolored wood associated with the wounds were very small, while others were large. Wound size and depth were important factors affecting size of internal columns of discolored and decayed wood.



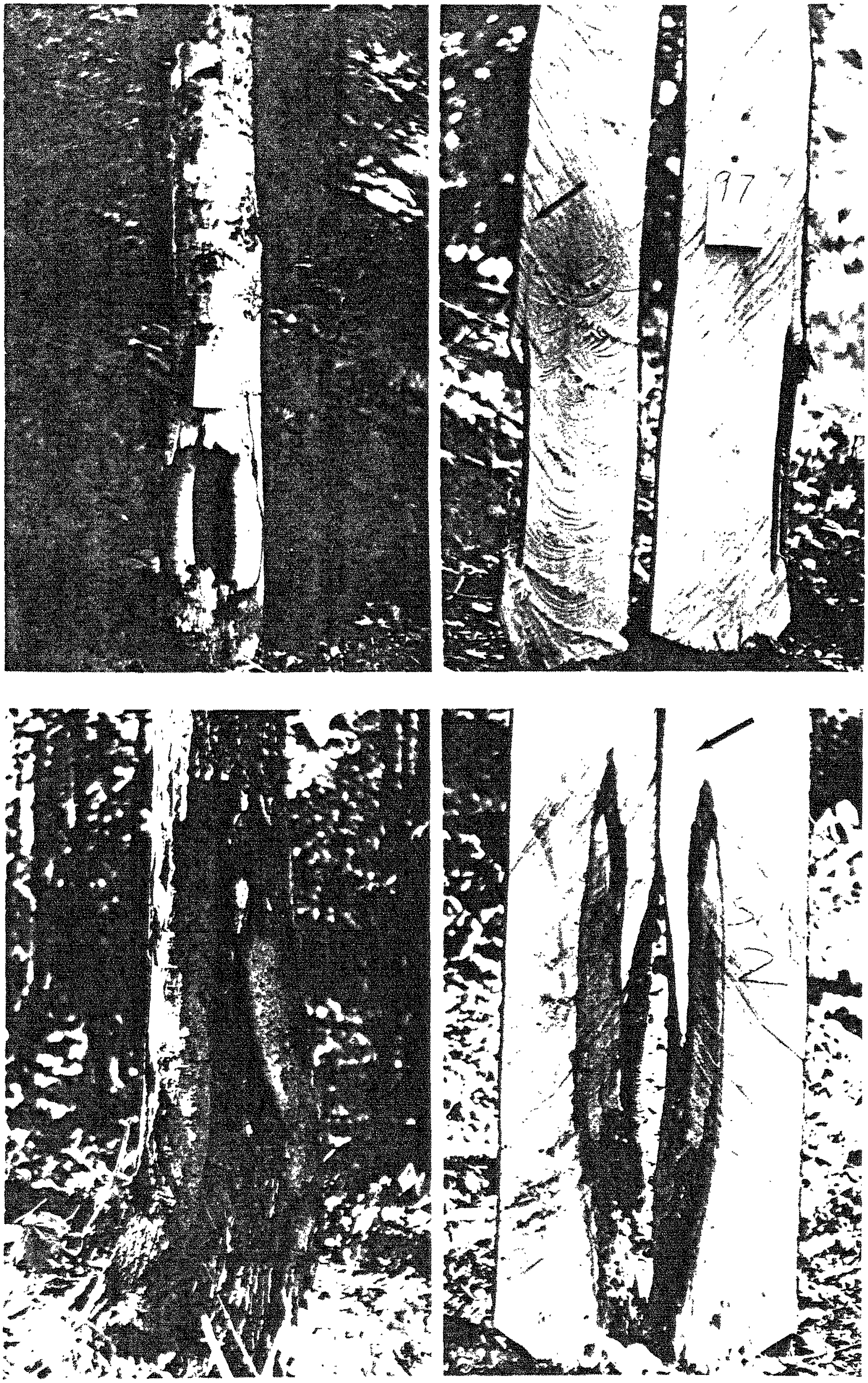


5. The wound on this yellow birch was 50 years old. The large arrows show the size of the discolored core at the time of the large wound. The small arrows show the size of the tree at the time of wounding. The decay did not spread inward into the wood that had been altered by previous wounds, or outward into the new wood that formed after wounding.

6. Patterns were complex in sugar maple, but more dissections revealed their high order. This tree had an old basal wound—over 75 years old. The fruit body was *Fomes connatus*. The large wound above was inflicted by sugar maple borers, *Glycobius speciosus*. The type of decay associated with each wound was different, but the fungi were confined to the wood present at the time of wounding, even after more than 75 years.

7. More and more sugar maple trees with clear wood to the pith were found. The 8-year-old basal wound caused very little defect. A dark line was often seen in the growth ring that formed after wounding (arrow). The question of whether beech, birch, and maple have a normal central core of colored heartwood began to emerge.

8. The dark line (arrow), was first called "barrier cells". The cells formed after wounding, and they separated the infected wood from the sound wood. *Barrier zone* was the term given later to these cells. The barrier zone was easy to see in sugar maple. The pattern of discolored wood forming first, and then decayed wood spreading within the discolored wood, and the pattern of bacteria, non-decay-causing fungi, and decay-causing fungi all began to take shape.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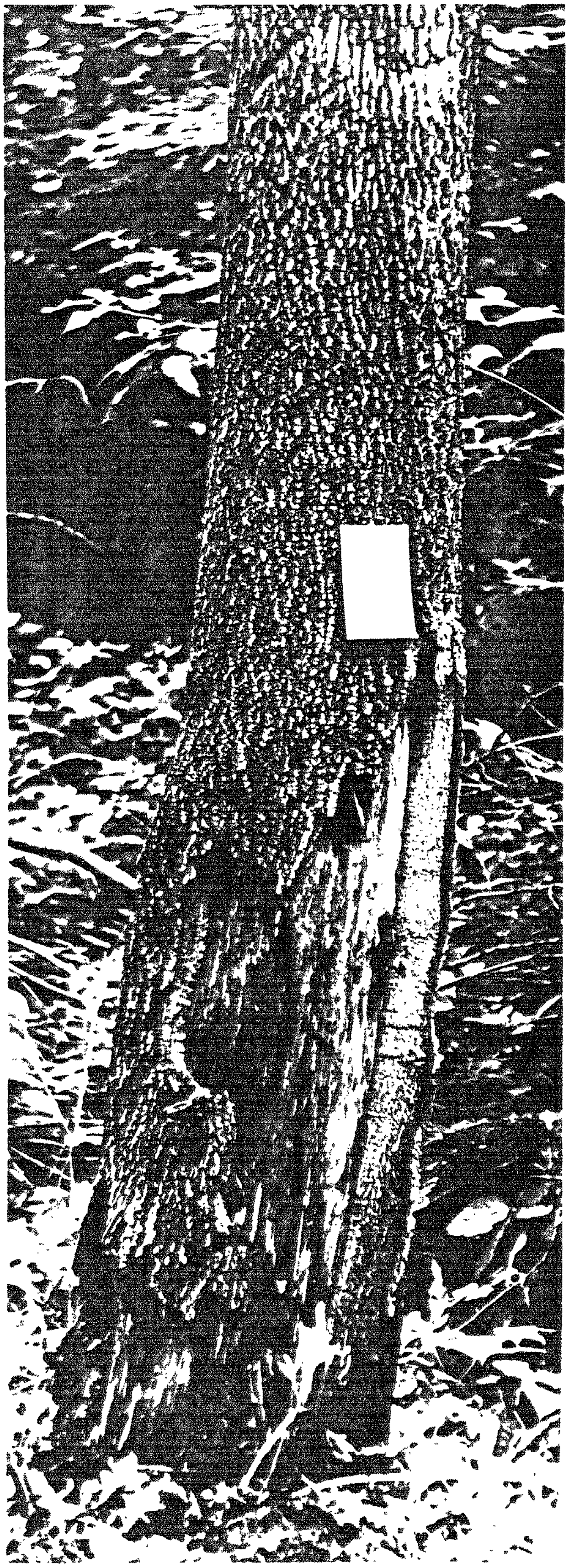
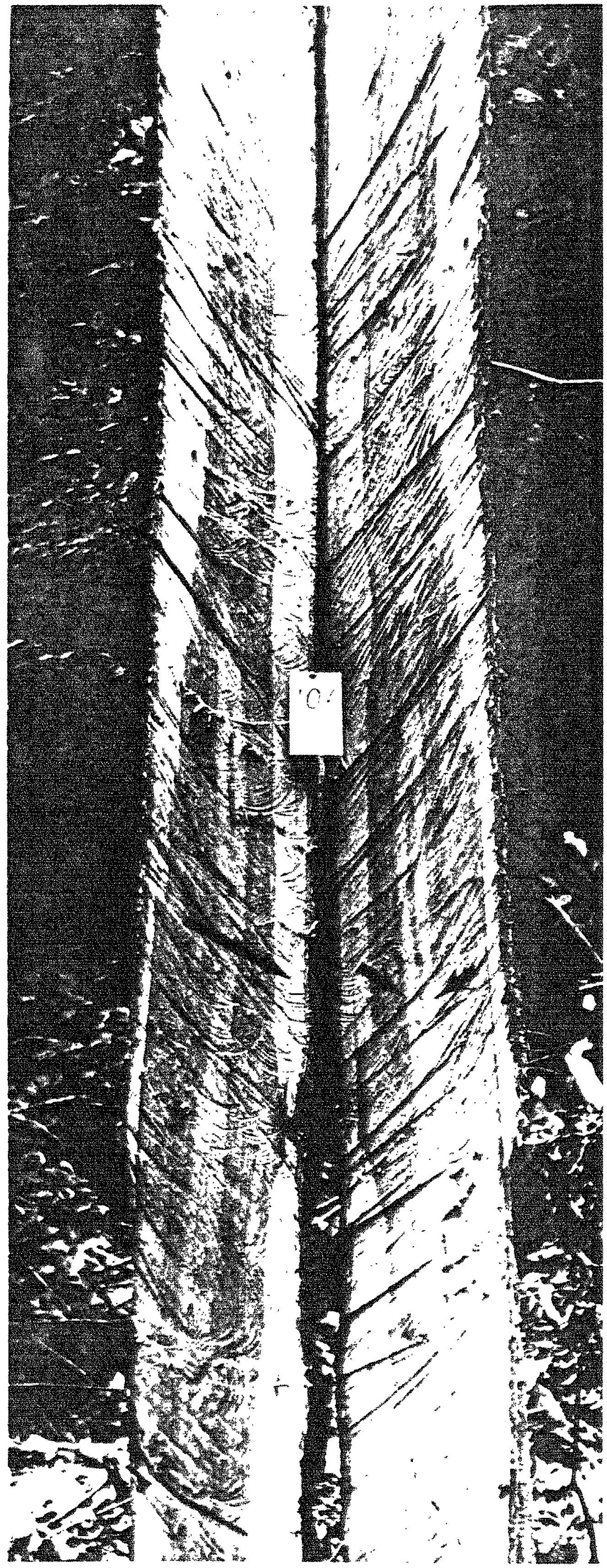
9. Dissections of American ash showed the same internal patterns as the other species of hardwoods. Note the light colored central column (small arrows). This was associated with many small stubs. The large arrow shows a barrier zone.

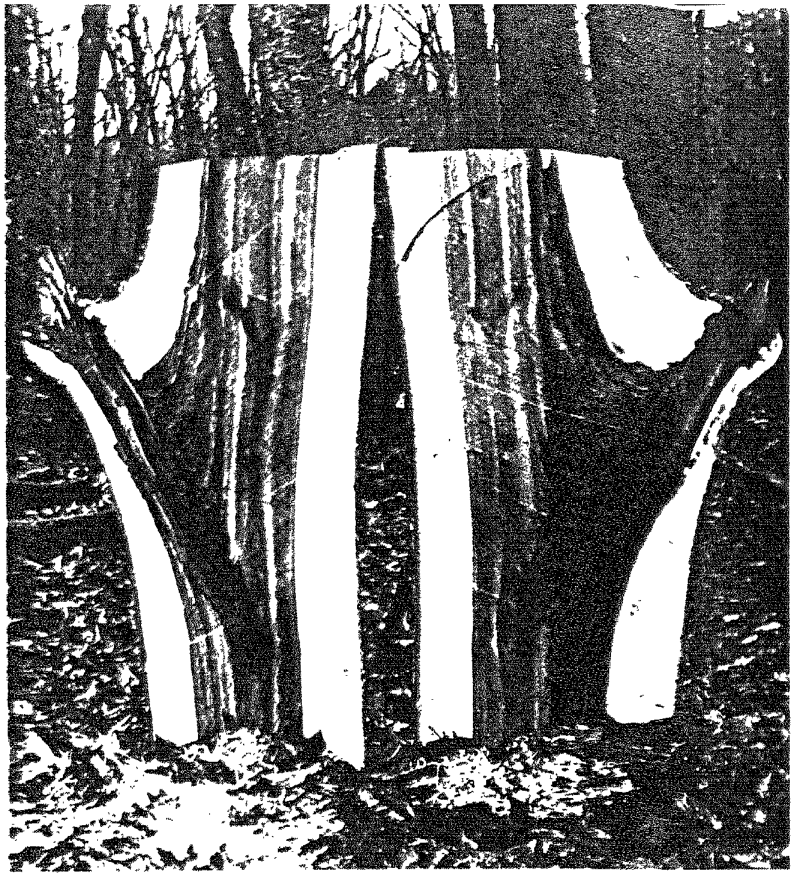


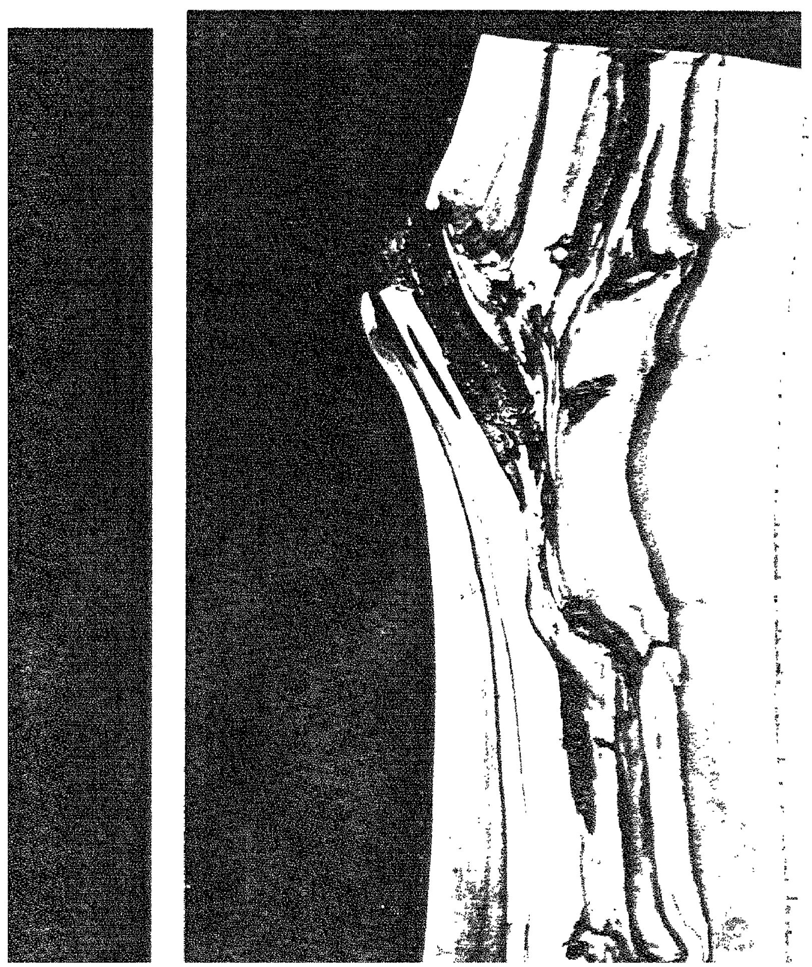


10. Dissections began to focus on branch stubs. Decayed wood associated with large old stubs was confined to the wood present at the time the branch died. Note that the discolored wood associated with the stub on this paper birch does not spread into the central column of discolored wood associated with older branch stubs.

11. This large old stub on a paper birch was "pinched off". The decayed wood is strongly walled off within the old internal branch wood. The decay did not spread outward into the healthy wood.

12. The hollow branch base in this yellow birch was surrounded by a light-colored column of decayed wood. The central column of decayed wood was associated with many branch stubs. Each new column of decayed wood remains separate from the others. This pattern would be impossible to understand from cross sections.

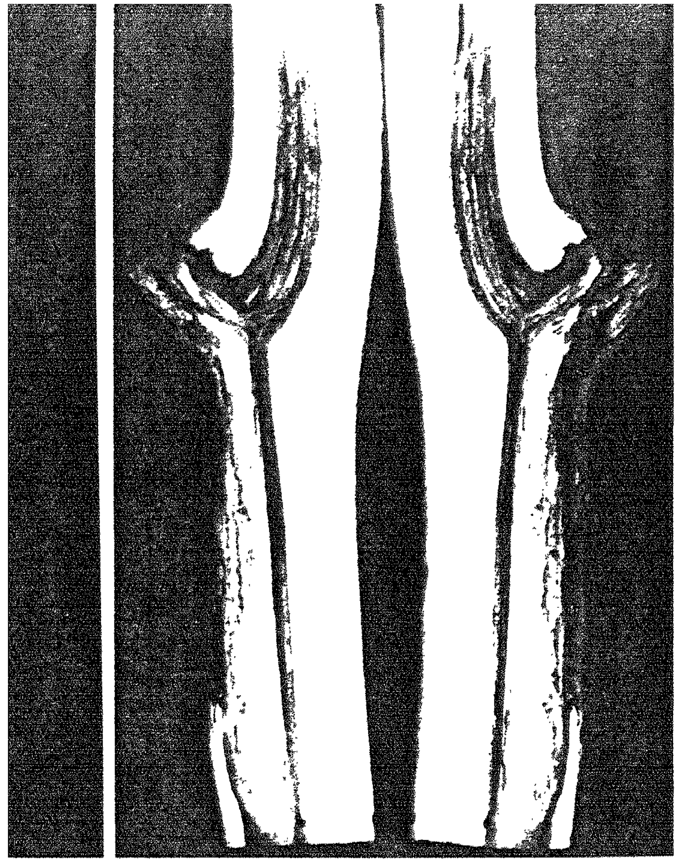


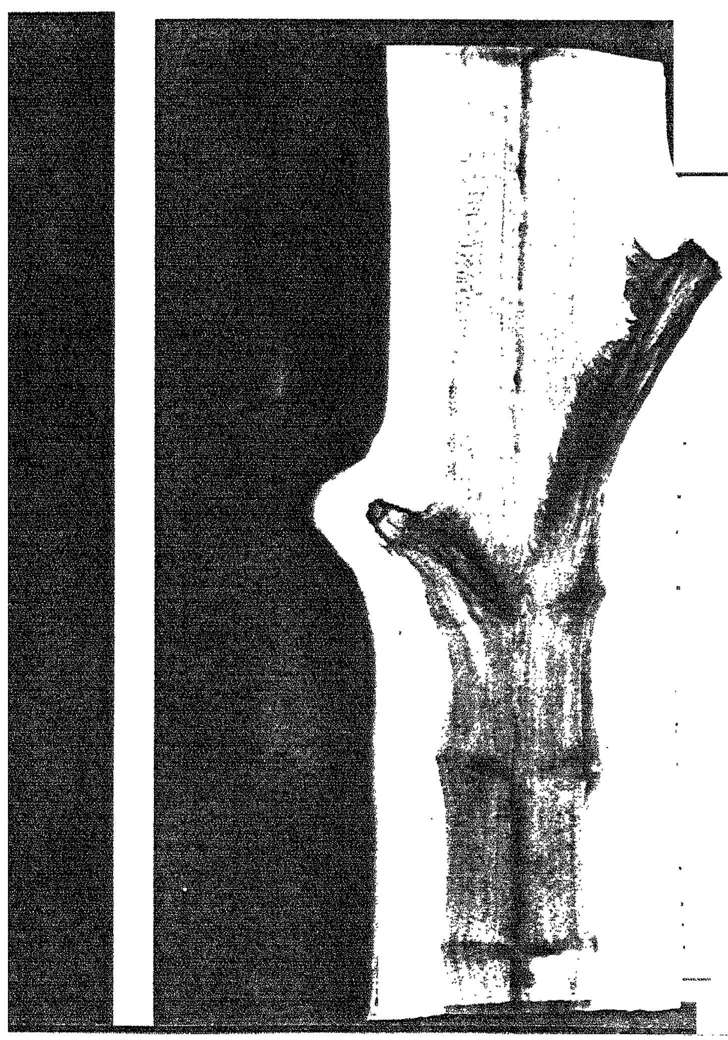


13. The dead spot below this small stub on a red maple indicates that the cambium was injured when the branch tore away from the main stem. The discolored wood was walled off within the wood present at the time the branch died.

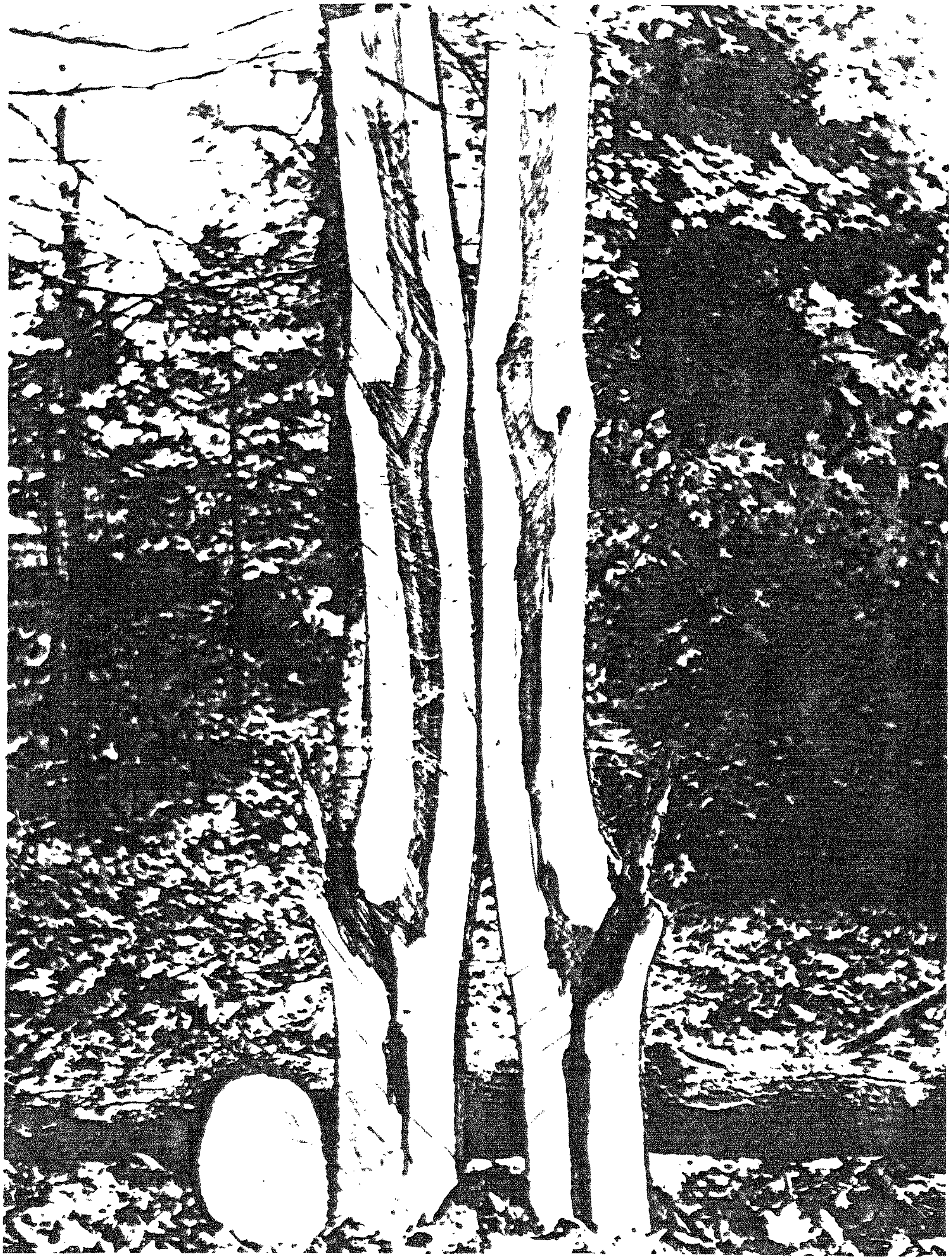
14. Two major leaders died on this yellow birch, and the third leader grew to be the main stem. Note how neatly the leaders are walled off from each other. The decayed socket in stub A was essential for effective shedding. A similar socket of decayed wood is in stub B. The upward extension of discolored wood associated with stub A indicates that the trunk was injured when stub A fell away from the trunk.

15. Two large old branch cores on red maple. Note the tip of decayed wood in the lower branch core. Decayed wood is essential to shedding. The decayed wood extended farther into the inner branch wood in the upper branch. The central core of discolored wood in beech, birch, maple, ash, and many other trees is associated with the death of branches and the alteration (and usually infection) of the wood present at the time the branch died.

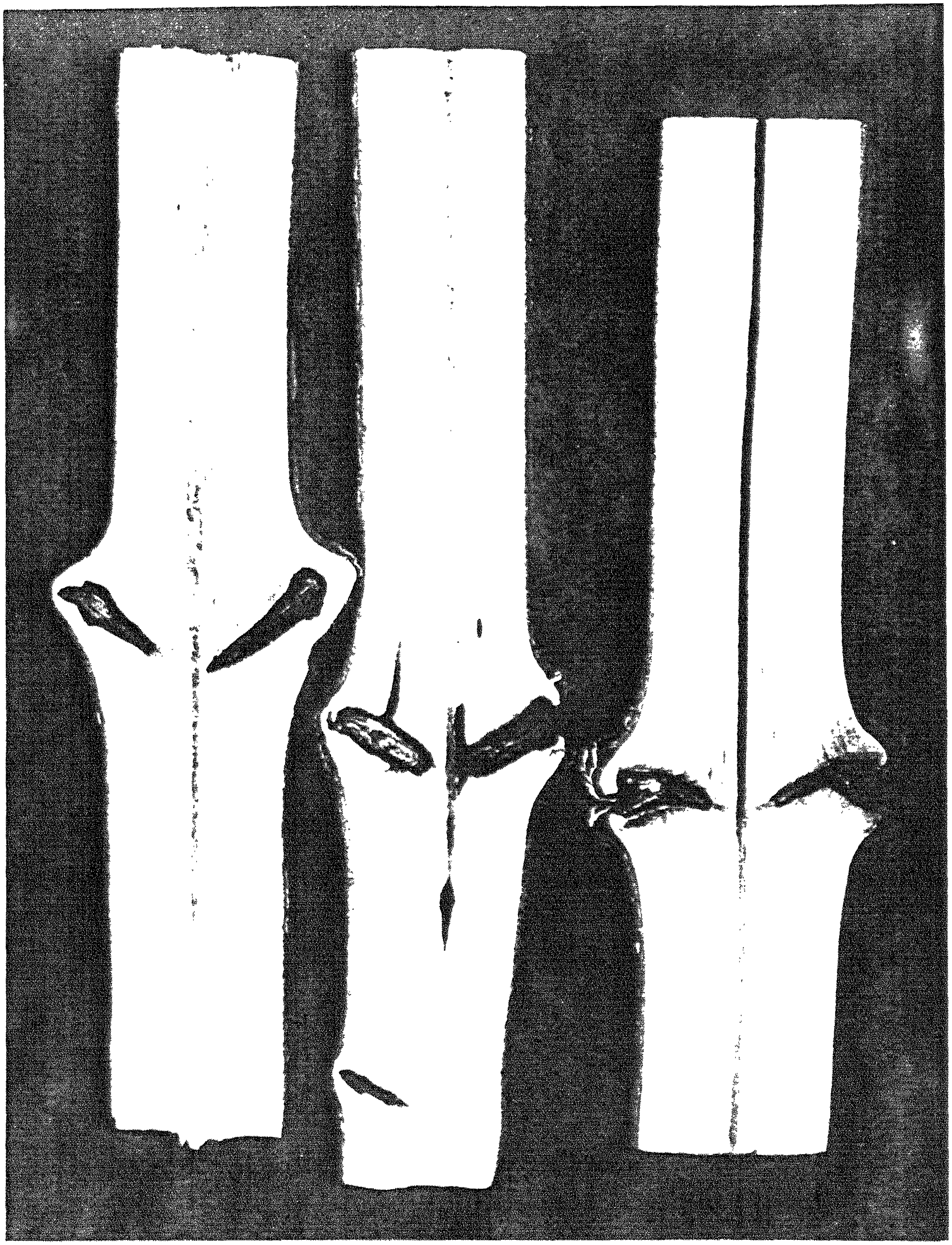




16. Dissection of this sugar maple shows a clear base, but discolored wood associated with branch stubs. The discolored wood in the trees studied yielded many species of bacteria and fungi, usually species in the genus *Phialophora* and closely related genera. The results began to show a succession of microorganisms associated with discolored and decayed wood.



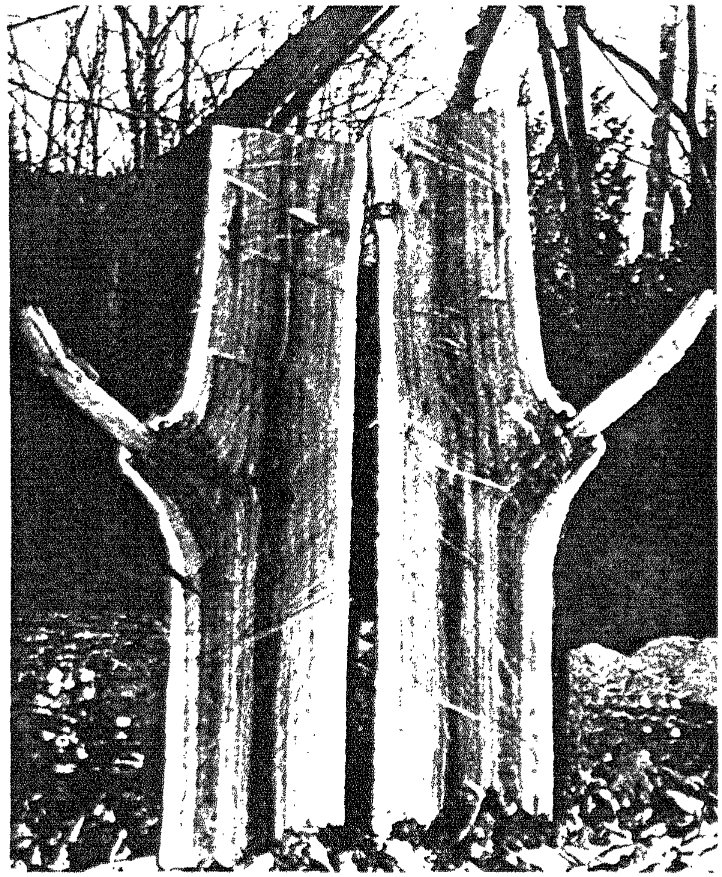
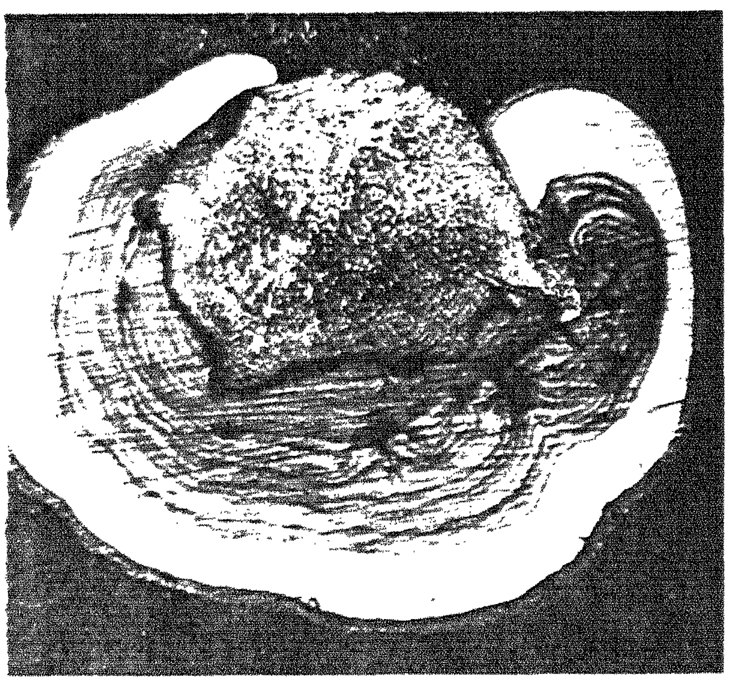
17. Dissection of very small stems showed patterns similar to those of large branches and similar microorganisms were isolated from the discolored wood. The small inner branch cores were walled off. It appeared also that there was a blocking of the pith connection between branches and main stem.



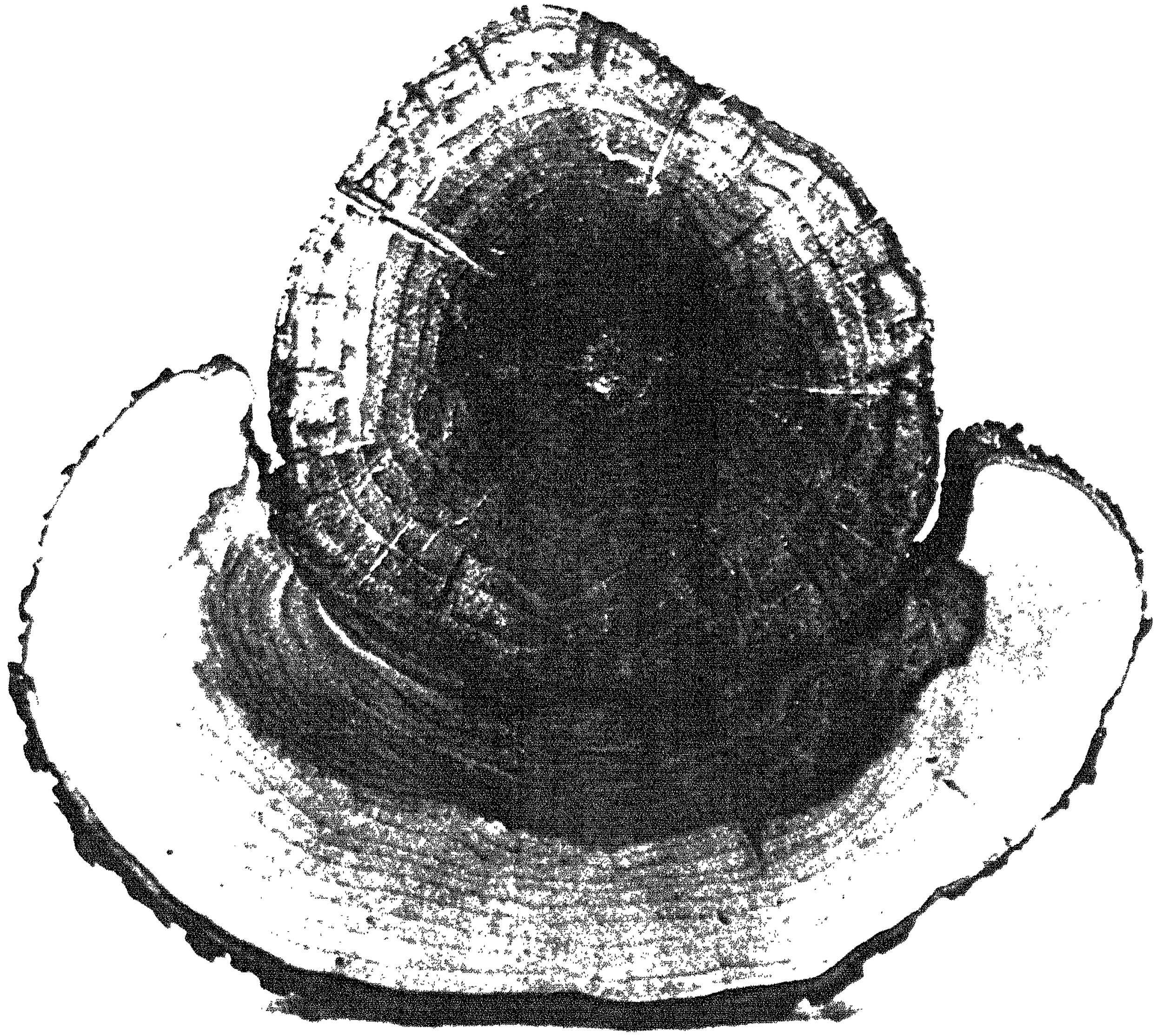
18. Dissections of branch stubs on oaks and other heartwood-forming trees showed patterns similar to those in birch and maple. The discolored wood associated with the dead branch on this red oak was walled off within the wood present at the time the branch died. The discolored wood was discolored heartwood (arrows). Heartwood will wall off defects, and heartwood will discolor. If heartwood is an unresponsive tissue, how can this be?

19. It was time to begin rethinking our beliefs about heartwood. The classical concept of tree decay, the heartrot concept, would have you believe that once heartwood was infected, the fungi would grow at will into a hollow formed by complete digestion of heartwood. It was time to question this concept.

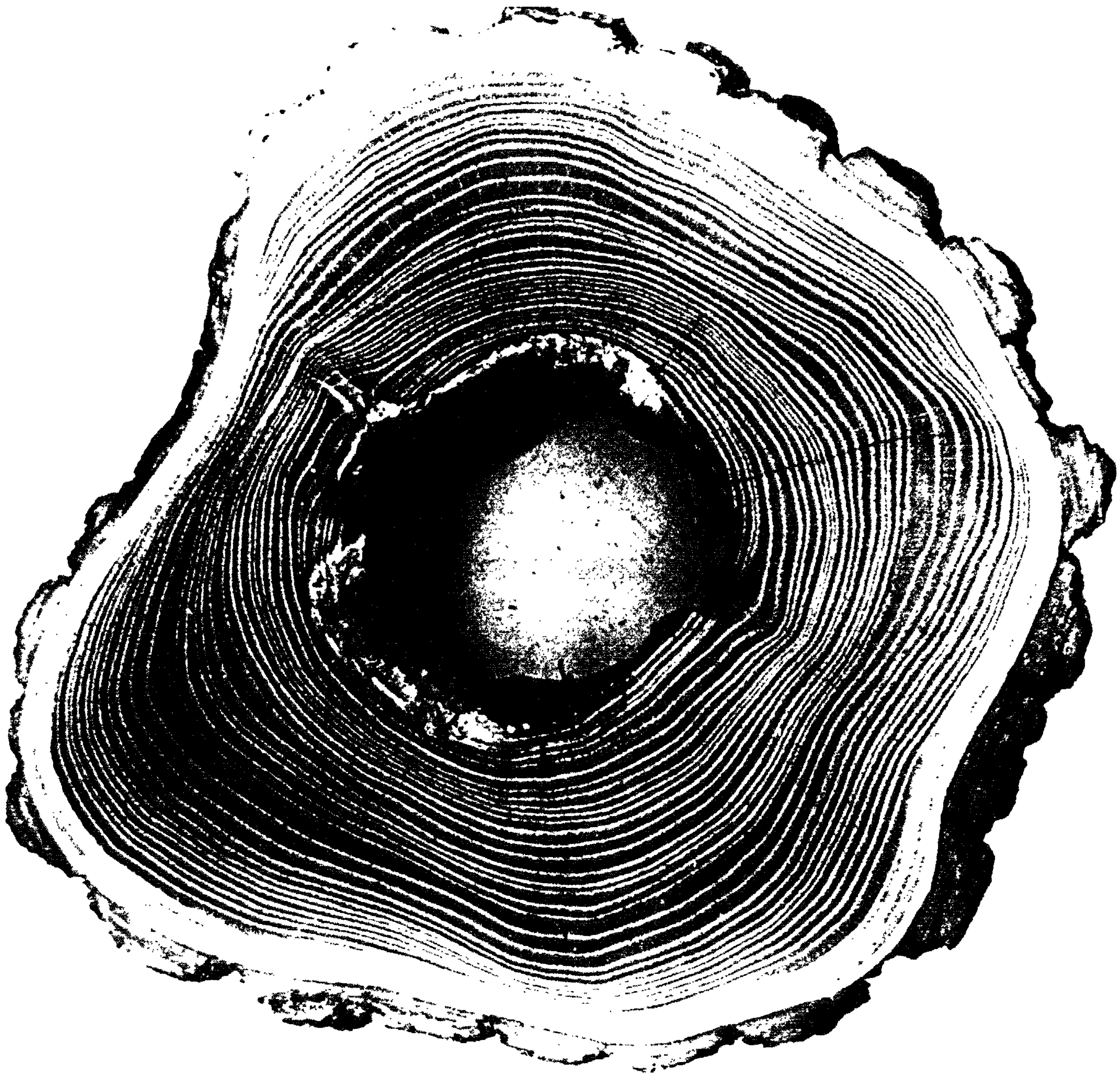
20. Dissection of white pines showed that the diameter of hollows was the diameter of the tree when it was wounded. Sound heartwood surrounded the hollow. How could this be so if the classical heartrot concept were true?

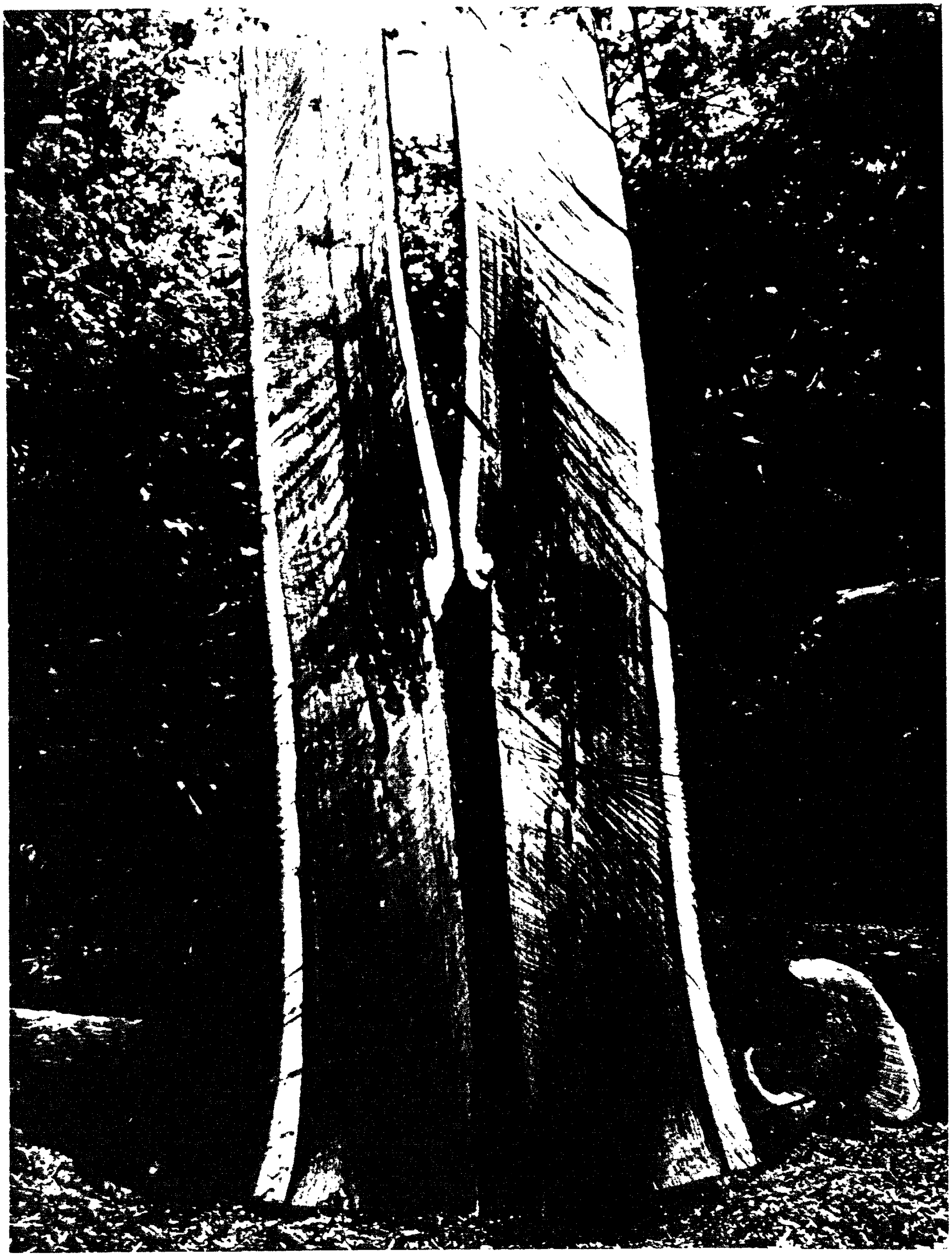

21. Dissections of tree species that have a normal heartwood showed patterns similar to those in birch and maple. The decayed wood in this black cherry did not develop into the surrounding heartwood, even after 20 years. Where small radial cracks formed, the decayed wood did move out, but still only very slightly. It appeared that the heartwood-forming trees also had similar patterns of discolored and decayed wood, even within heartwood.



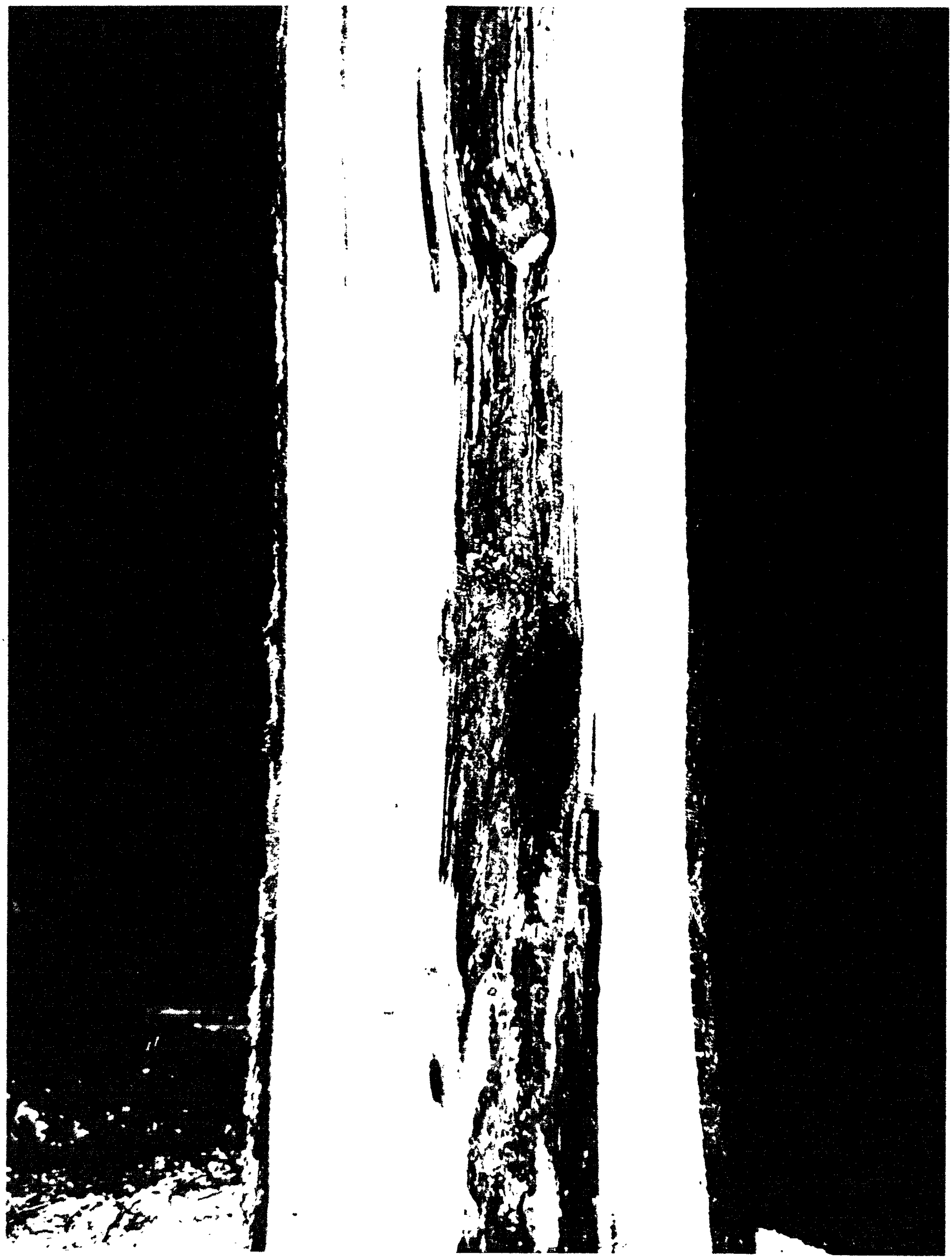
22. Similar patterns were seen in other heartwood-forming trees such as this black locust. The diameter of the hollow was the diameter of the tree at the time of injury. Even after almost 40 years, the so-called "heartwood rotting fungi" did not spread outward into the heartwood that surrounded the hollow. These observations suggested that microorganisms could only infect wood that was first altered by injury.



23. Longitudinal dissections of red oaks strenghthened the developing hypothesis that heartwood does wall off or confine discolored and decayed wood. And even further, that insects such as ants that infest trees also stay within the tissues present at the time of injury (arrow). Microorganisms and wound-infesting insects apparently do not move "at will" in a tree.



24. Ants infested the column of discolored heartwood in this white pine. The discolored heartwood is surrounded by about 75 growth rings of sound wood. Dissections of oaks, cherries, pines, walnuts, and other heartwood-forming trees began to show more clearly that a fundamental survival process may be operating. And, it was highly ordered.



25. Trees were dissected to determine patterns of discolored and decayed wood associated with old dead leaders, or old main stems that had died. A lower branch then began to grow as a new leader. The old leader stub was called a stem stub. The trees that had stem stubs acquired a characteristic curve.

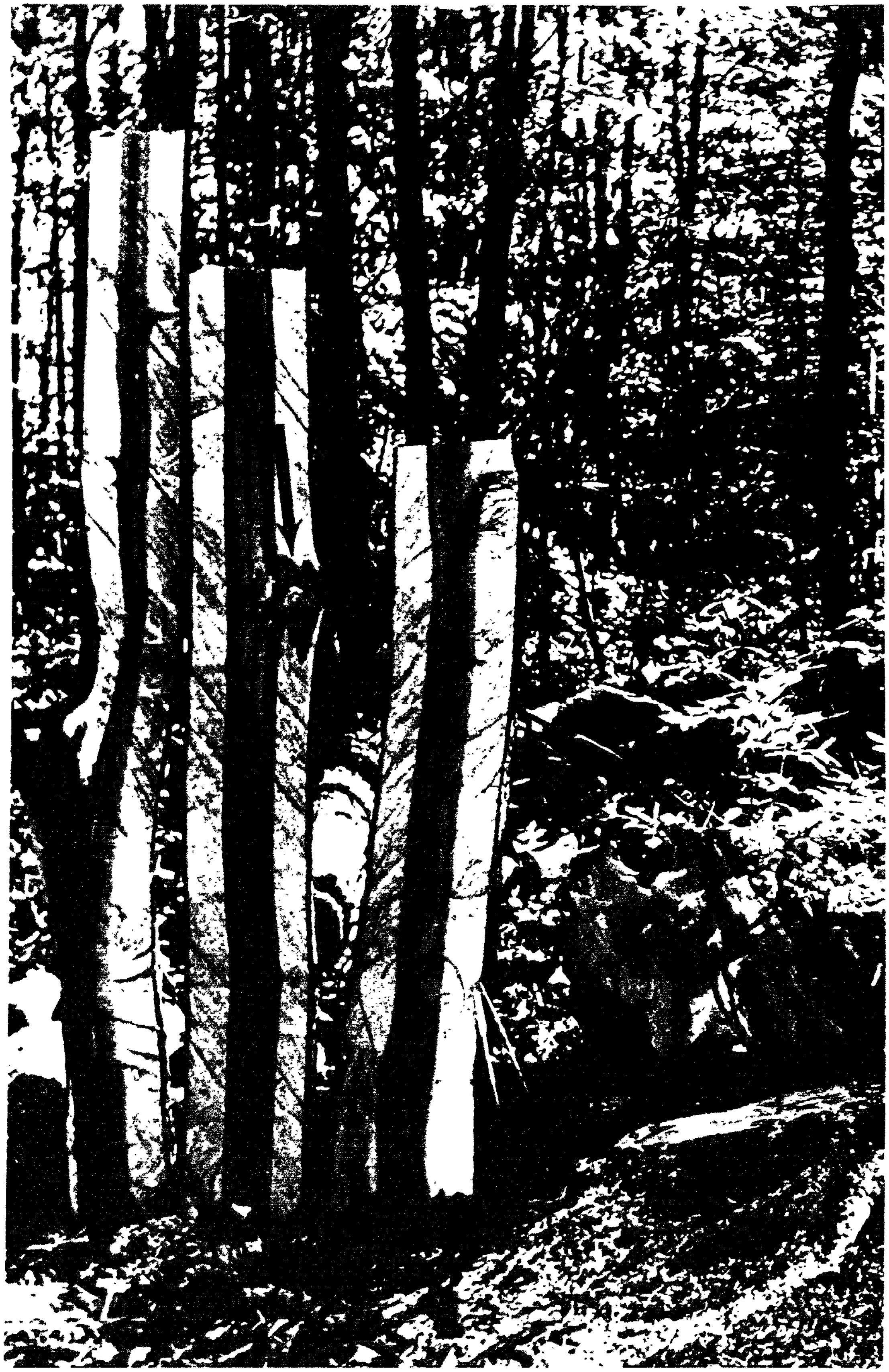
The diameter of the old leader at the time it died was the diameter of the column of discolored and decayed wood, and the column developed mostly downward. Some discolored wood developed upward in the new leader when the branch was large and had a close connection with the old leader. The diameter of the discolored wood in the new leader would be the diameter of the branch at the time the old leader died.

26. The old leader decayed completely on this yellow birch. Discolored wood in the new leader was associated with branch stubs higher in the stem. The decayed wood did not spread outward to the surrounding discolored wood on the inner side, or to the clear wood on the outer side. These observations led to questions about whether it was wise to break the hard rim or barrier zone when cavities are filled in trees.

27 Dissection of beech shows a connection of the decay column from the sprout with the main stem. Note that the decay does not move outward (large arrow). The sprout has been dead for approximately 50 years. Approximately 50 growth rings separate the decay in the trunk from the bark (small arrow).

28 A low sprout on a sugar maple. The sprout did not connect with the main stem aboveground, hence the sprout decay is separated from the main stem.

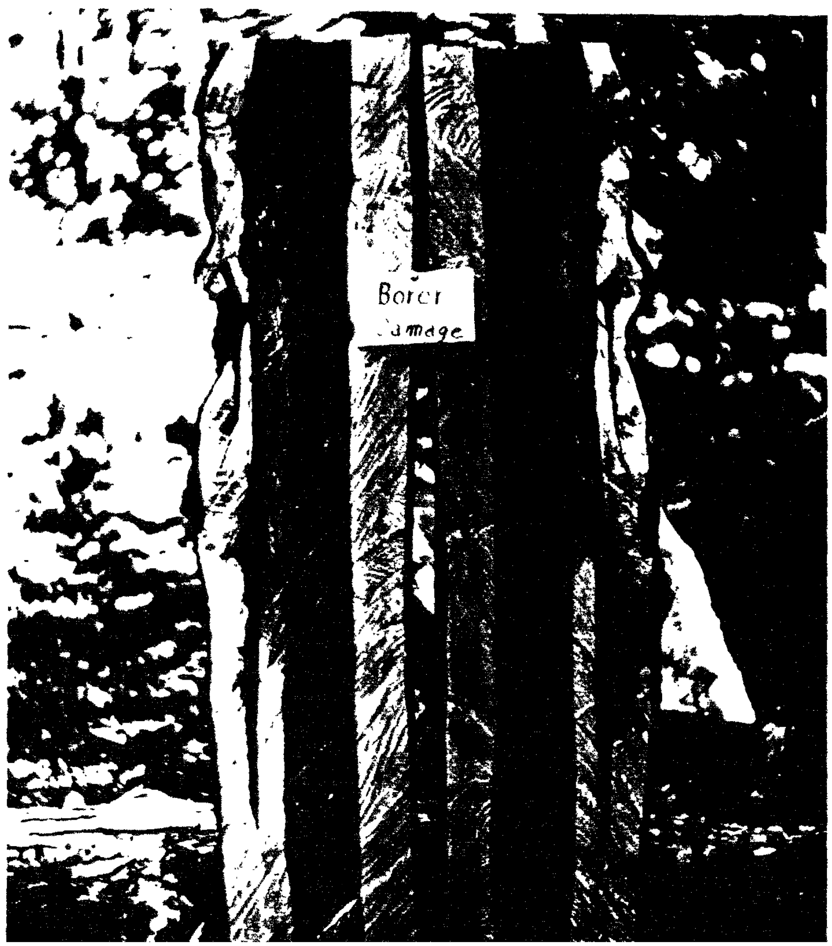
29. Dissections of many large, old red maple sprout clumps showed that decay did not spread from the old parent stump to the sprout stems. Decay did spread from sprout stubs at the base of still-living sprouts. Most of the defects in the sprout stems were associated with old branch stubs. Fungi that cause canker rots, such at *Polyporus glomeratus* (arrow), were associated with the stubs. When a sprout stem is cut, and decay develops in the cut stub, the decay may spread to the still living sprout attached to the stub. The greatest diameter of decay in the still living sprout will be its diameter at the time the connecting sprouts are cut. For example, if a 2 inch diameter sprout is cut from an attached 3 inch diameter sprout, decay could develop later into the 3 inch core of the still-living stem.



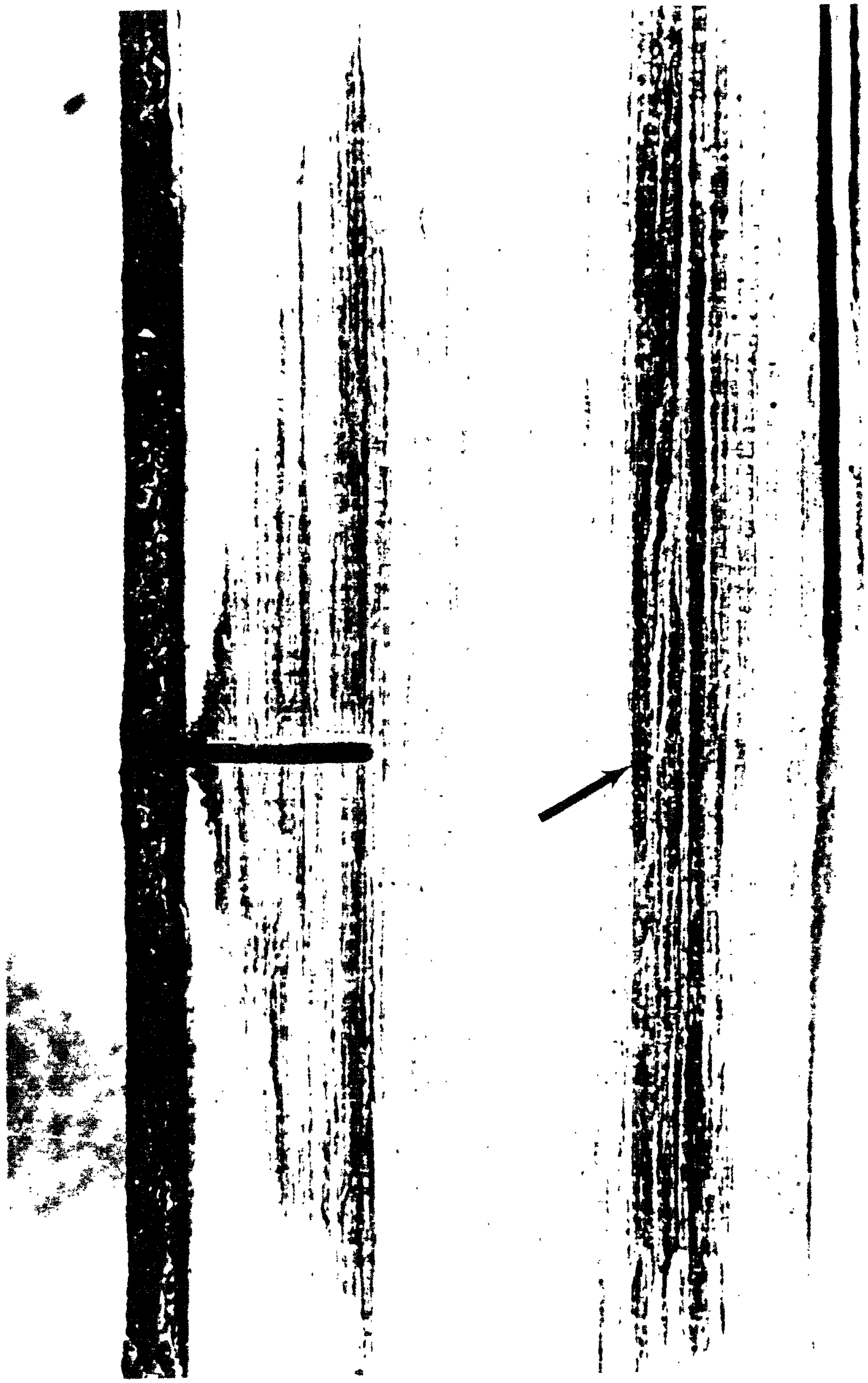
30. Old decaying parent stumps of red oak were dug out and dissected to reveal the attachment of the sprouts. Decay from the stump did not spread into the sprouts. The heartwood attenuated as it developed downward. There was no heartwood in roots. Dissections of many oaks showed that what appeared as a single stem was really the coalescence of several sprouts.

31. As more trees were dissected, the important role of insects and other wounding agents became obvious. Insects infested this yellow birch after it was wounded. At the 4-foot position (section at right), the decay associated with the wound spread inward to meet the already present circular column of discolored wood. At 16 feet above the wound (section at left), the patterns of insect infestation were still obvious. The central column was very small at this height. Note also the slightly darker shade of the wood present at the time of wounding. This wood is slightly pink in birch and maple. No matter how such wood is dried, it will be a darker shade than the wood that continues to form after wounding.

32. The sugar maple borer is a major cause of damage to sugar maple. The beetle has a 2-year life cycle. The discolored wood associated with the beetle wounds often has margins of dark green to orange. The discolored streaks are often called mineral streaks. "Mineral streaks" are columns of discolored wood associated with wounds. In sugar maple, the major wounds that initiate so-called mineral streaks are caused by the sugar maple borer, squirrels, and yellow-bellied sapsuckers. Often these wounding agents occur in clusters.

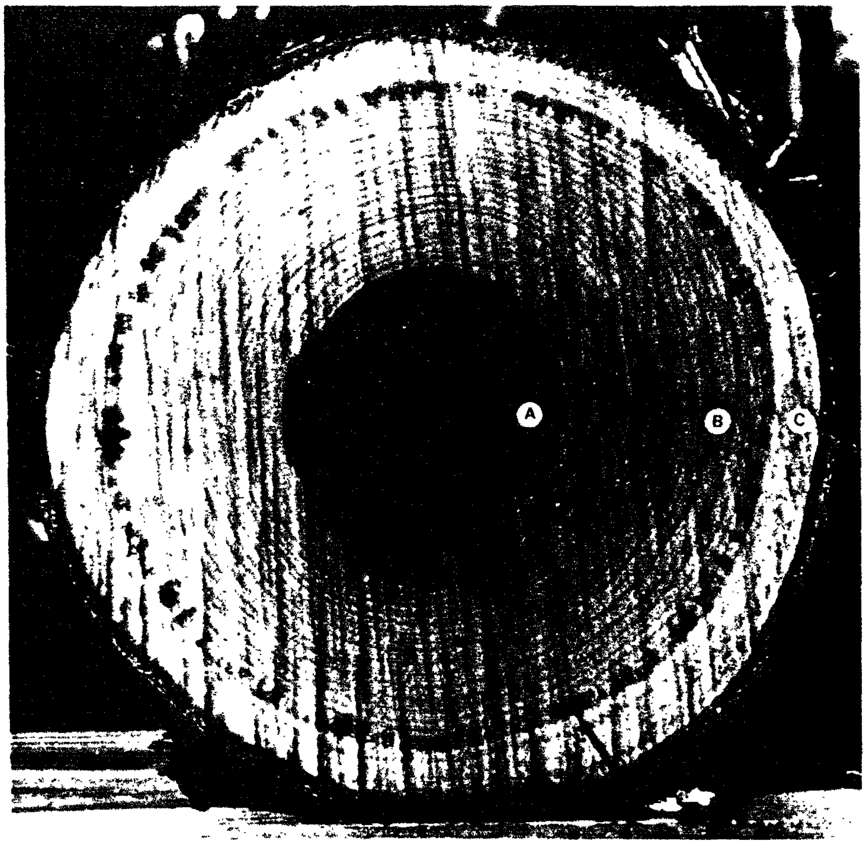

Borer

33. Small ambrosia beetles often bore into trees weakened or stressed by other agents. The small drill-like bore hole in this red maple was caused by an ambrosia beetle. Discolored wood formed above and below the hole. Also in this sample are vessel plugs that form in discolored wood (arrow). The plugs look like small patches of cotton in the vessels.



34. This paper birch was attacked by many ambrosia beetles 4 years before it was cut. Note the many small drill-type holes around the trunk (arrow). The central column of discolored wood is called red heart (A). Bacteria and non-decay-causing fungi abound in red heart wood. The wood on the inner side of the insect attack zone was a light shade of pink (B). The wood that formed after the insect attack was bright (C).

35. Cambium miner, an Agromizid or type of fly, in paper birch. The larvae mine downward in the developing wood, and they leave their tracks as a thin dark line. The arrow shows a circle of darker pink wood associated with another wound.


A
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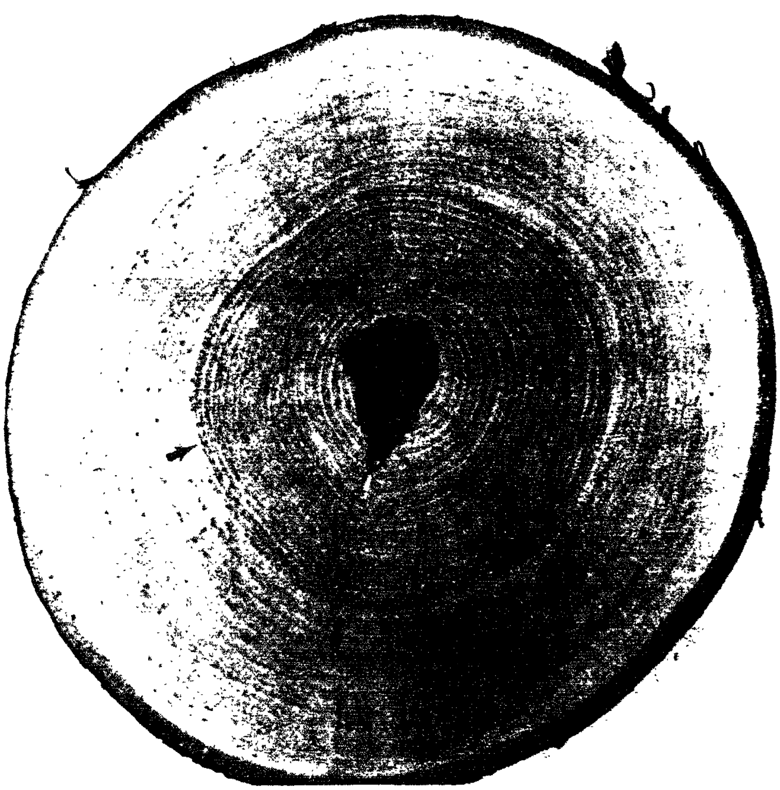

36. Yellow-bellied sapsucker wounds on a Canadian or Eastern hemlock. The wood often separates along the growth ring that has the wounds. Such ring separations are called ring shakes. The ring shakes form only where many peck holes are inflicted, and after at least 15 to 20 years.

37. Another scale insect on beech. *Xylococculus betulae* causes a bark roughening. The scale often becomes established at the base of weak and dying branches. The branch collar is killed, and when the branch is shed, a sunken area remains (left). The roughened bark may also serve to harbor low populations of the beech scale, *Cryptococcus fagisuga* (upper right). The tree walls off the injured areas, but included dead bark may persist as a defect (lower right). Some beech trees are highly resistant to the beech scale, and the Nectria fungi, and even to *X. betulae*.

38. Canker-causing diseases are common on trees, especially on weakened or stressed trees. Swollen dead spots, or cankers, (left) are common on young and old maples. The canker-causing fungi seldom invade far above or below the canker (right). The discolored wood is very hard and heavy and often resists decomposition. Nectria fungi are commonly associated with such cankers. The cankers remain perennial as the fungus reinfects the bark, and a small amount of additional cambium is killed. After the cambium is killed, the tree responds by walling off the infected tissue, hence the circles or bands which give some cankers a target shape.

39. Walled-off Nectria canker on beech.