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Radial Shakes and "Frost Cracks" in Living Oak Trees

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Abstract

Dissections of hundreds of living, mature oak trees over a 25-year period revealed that radial shakes (or "frost cracks") and ring shakes are associated with a variety of wounds and stubs of branches and basal sprouts. A more intensive study of radial shakes that included dissections of more than 30 oaks confirmed the earlier finds, and provided additional data on radial shakes. Radial shakes were most common in mature oaks that had been wounded, and where basal sprouts died when the dominant tree was less than 20 cm in diameter at 1.4 m aboveground. Radial shakes—frost cracks—are not caused by frost, though frost can be a major factor in their continued development. Radial shakes can be prevented by proper management procedures that minimize basal wounds and by early pruning of branches and basal sprouts.

Auszug

Durch Aufschneiden mehrerer hundert Eichen konnte im Laufe von 25 Jahren festgestellt werden, daß Ring-und Radialrisse im Holz stets mit Wunden verschiedenster Art verbunden sind. Die Befunde der nun vorliegenden Untersuchung, die sich auf die Auswertung won über 30 Eichen beziehen, bestätigen unde ergänzen die bisherigen Erkenntnisse über die Beziehung von Radialrissen zu Wunden. Besonders häufig fanden sich Radialrisse an älteren Bäumen, die vor längerer Zeit eine KambiumVerletzung erlitten hatten, oder die im Jungwuchsalter von absterbenden Stockausschlägen begleitet waren. Durch Verhütung von Rindenschäden sowie durch frühzeitige Beseitigung von überzäligen Stockausschlägen können die Entstehung von Radialrissen und Frostrissen sowie damit verbundene, erhebliche Wertverluste vermieden werden. Frost vermag Radialrisse zwar zu intensivieren; er ist jedoch nicht die eigentliche Ursache.

Introduction

Radial shakes are separations along the radical plane in living trees. Some common names are spider heart, ray shakes, and —when they break out to the surface—"frost cracks." Many reports have been published about these defects. Frost or sudden decreases in temperature were given as the cause of frost cracks, hence the term (Caspary 1855; Hartig 1894; Mayer-Wegelin et al. 1962). Yet frost cracks are not caused by frost (Shigo 1972; Phelps et al. 1975; Phelps and McGinnes 1977).

Radial shakes are often associated with ring shakes, which are separations along the circumferential plane of the tree. Ring shakes are often called "wind shakes," implying that they are caused by wind. But ring or wind shakes are not caused by wind.

Ring and radial shakes are associated with a wide variety of wounds—from fire, logging equipment, small and large animals—and with stubs from the basal portion of dead branches and stump sprouts (Shigo 1963; McGinnes et al. 1971; Shigo et al. 1979). The relationship of wounds to "frost cracks" was first observed by Caspary (1855) in Germany. Although his observations were excellent, they have not been accepted, or it may be that they have been overlooked. Research many years later confirmed his observations (Shigo 1963, 1972).

The high value of oaks, *Quercus* spp., for a great number of products necessitates a reevaluation of the causes of internal shakes. A tree with ring and radial shakes cannot be used for veneer. Boards that are cut will fall apart. It is not possible to cut material for turning stock. From an economic standpoint, defects due to shakes can be much more serious than decayed wood. Because decayed wood usually is compartmentalized in trees, high-quality wood can be cut from around the decayed center of a tree. But with radial shakes, the separations, once formed, continue to move outward to the bark. For this reason, radial shakes pose a major problem where high-quality wood is needed.

This paper includes photographs of dissected trees that show the sequence of events that leads to ring and radial shakes. Because much work already has been done that shows the relationship of ring shakes to wounds and stubs (McGinnes et al. 1971; Shigo 1972), this paper will concentrate on radial shakes in several species of oak.

The Problem

The terms used to describe a defect reflect the state of understanding of that defect. Tree pathology is replete with terms that indicate a lack of understanding of many tree defects. Consider the following: mineral stain, wound heartwood, wind shake, red heart, wetwood, brittleheart, spiderheart, frost crack—and the list goes on and on. It is beyond the scope of this paper to elaborate on all the terms and the confusion they cause. Attention here will be given to the term frost crack which implies that frost causes the crack, and that, because frost is a natural phenomenon beyond the regulation of foresters, defects due to frost cracks must be accepted. This type of thinking is a major reason why so little has been done to prevent or minimize the damage caused by many internal defects. When the correct cause of a defect is understood, proper management decisions can be made to deal with the problem. So it is with radial shakes, or frost cracks. They can be prevented—and they are *not* initiated by frost.

The Oaks

The value of the oaks depends on many factors, but one of the most important is the amount of defect-free wood on the stem. The major defects in oaks are knots, decayed wood, and the ring and radial shakes. Radial shakes appear to be more common on oaks than on other tree species (Shigo 1971).

Oaks, like other trees, are highly compartmented plants that compartmentalize or wall off injured and infected wood associated with wounds (McGinnes et al. 1977; Shigo and Marx 1977; Shigo 1979). By this essential and effective process, defects are confined within the diameter of the tree at the time of wounding, or at the time the branch dies. This means that a defect is not so important if it is restricted to a small volume in the center of the tree. Thus, tree managers, buyers, and the wood industry benefit because quality wood can be obtained from trees with some decayed wood.

For example, if a tree is wounded severely when it is 10 cm in diameter, the worst that can happen is that a 10-cm core of defect will develop. The decayed wood caused by fungi will not spread to the growth rings that form after wounding, even in heartwood (Shigo and Shortle 1979), because after wounding the cambium forms a distinctly different tissue called the "barrier zone" (Sharon 1973; Moore 1978; Mulhern et al. 1979; Tippett and Shigo 1980, 1981).

The barrier zone is a very strong protection against further infection, but it is also a plane of structural weakness, because it has a different anatomical and chemical makeup from normal wood. When internal stresses caused by rapid temperature changes or wind occur near the barrier zone, the wood may separate tangentially and longitudinally along the barrier zone, which results in a ring shake (McGinnes et al. 1977). The ring shake could trigger separations along the radial plane, and radial separations may develop from the inside of the stem outward to the bark. When any stress causes the radial separations to break out to the bark, an obvious external seam or crack results. Surface vertical cracks also may develop above and below wounds or stubs when temperatures drop rapidly. The wounds and stubs interrupt the continuous circumferential surface of the trunk; should any stress—such as frost—occur, the bark will crack along the weakest point. Such cracks seldom penetrate deeply into the wood. Again, wounds and stubs serve as the initiating point for such cracks. Radial shakes are especially damaging because the separations can continue for the life of the tree. Once a radial shake is formed, the tree has no system to compartmentalize it.

Dissections of Trees

Twenty-five white oaks, *Quercus alba* L., and red oaks, *Quercus rubra* L., with obvious basal radial shakes or frost cracks were dissected with a chainsaw in southern Maine. Seven chestnut oaks, *Quercus montana* Willd., with similar defects were dissected in Connecticut. The trees ranged in size from 15 to 40 cm and in age from 40 to 150 years. In addition to the tree dissections, sections were cut for study from the stumps of more than 10 larger oak trees recently cut for fuelwood. Three trees with obviously old, dead basal sprouts were dug out and dissected. Information from dissections of hundreds of other oak trees over a 25-year period also is included in this paper (Shigo 1971).

Many dissections of the trunks were made to reveal the wound and to trace the extent of the shakes. Selected samples were smoothed with a power sander to help reveal details of the shakes. The observations were made immediately after the trees were dissected, and before drying complicated the pattern of the shakes. A photographic record was made of selected samples.

Observations

All radial shakes were associated with wounds, branch stubs, or basal sprout stubs, and with ring shakes at some point in the trunk. Most of the shakes in the Maine trees were associated with wounds that occurred during the serious fire of October 1947. Mechanical wounds inflicted during salvage operations several years after the fire were the starting point of some of the shakes. The initial radial shake started above the wounds as the callus closed the wound. Secondary radial shakes started at the points where the first callus tissue formed at the margins of the wound. Additional radial shakes developed outward from the barrier zone that formed after wounding.

Ring and radial shakes associated with dead basal sprouts started at the base of the trunk. In some trunks this point was belowground. The radial shakes appeared as multiple dark radiating lines from the pith when viewed on the cut stump approximately 30 cm aboveground.

Most of the shakes were associated with wounds on small trees less than 20 cm in diameter at 1.4 m aboveground. Wounds on larger trees usually did not develop into shakes.

The triangular shape of fire wounds seemed to enhance the start of radial shakes as the upper pointed tip set the direction for the wood separations. This occurred after the callus began to close the wound.

Wounds with a blunt or rounded upper margin did not serve as the starting point for the radial shakes. The radial shakes were obvious as dark radiating lines in the heartwood. The lines followed the multicellular large rays common to the oaks. When the radial shakes broke out to the bark, the tree responded by forming new callus to close the wound. It was not possible to establish with certainty the factor or factors responsible for the movement of the radial shakes outward to the bark, or the factor or factors responsible for the periodic reopening of the shakes. Stresses due to normal growth processes, to rapid changes in temperatures, to water content, or to movement due to wind all could play a part in the development of a vertical seam.

In some trunks, the closed callus tissues indicated that the shakes stayed closed for several years, only to reopen at a later time. That the trees were in areas where temperatures in winter can decrease overnight from above 0°C to -20°C does make such changes highly suspect as the major cause for the continued development of the cracks after they are formed in the tree from wounds and stubs. In this sense, frost *does* play a role but only as the factor responsible for the *continuation* of the crack. If the radial shake had not first been "preset" in the tree, no crack would have developed no matter how severe the frost.

The observations and patterns of radial shake formation given here are not restricted to North America. Many mature oaks dissected recently in West Germany showed similar patterns.

Summary and Recommendation

Wounds and stubs—not frost—initiate radial shakes. But once started in the tree, the shakes may persist for the life of the tree because of stresses caused by many factors; in temperate regions, frost is a major factor. Radial shakes have been observed by Shigo in teak, growing in Puerto Rico and in many species of eucalypts growing in Australia. In these areas, frost seldom, if ever, occurs. But in these species, the radial shakes were mostly internal, and did not break out to the bark until subjected to felling stress or drying. The large protruding bulges commonly associated with radial cracks on oak were not seen on teak and only on a few eucalypts.

The large vertical bulges or invaginated seams on oak do indicate a recurring stress. Because teak and ecualypts are subject to stresses associated with wind and growth, as are oaks, but not to frost, it does appear that frost is the major factor responsible for the continuation of the vertical crack, and for the splitting outward of the secondary cracks. In some trees the secondary cracks may be more obvious and prominent than the primary crack associated with the wound or stub. When such a tree is dissected, it may be difficult to accept that the crack started from a wound or stub.

It cannot be emphasized enough that if the shakes are not preset due to wounds and stubs, stress factors due to growth, wind, and frost have little or no part in the development of the crack. Knowing this makes it possible to prevent radial shakes or frost cracks by minimizing wounds, and by proper and early pruning of branches and basal sprouts. The elite tree or dominant tree in a clump should be selected as early as possible, and all other sprouts should be cut. Even before this, management procedures should favor single stems from seeds, rather than single stems from the sprout clumps. Much greater care must be taken not to wound trees, especially during logging operations. In the past, the young, rapidly growing tree was thought to be the tree best suited for responding to wounds. This is true where compartmentalization of discolored and decayed wood is concerned, but not when radial shakes are considered. Thus, greater care must be given to the young growing stock. They should not be considered so tough that nothing will harm them. Yes, they will survive the wounds and shakes, but survival of a tree with many internal defects is not in the best interest of forestry.

Logging operators must be made aware of the serious damage that can result from seemingly minor wounds. Special attention must be given to young trees that receive many basal wounds, or wounds with pointed tips. Trees with such wounds should be removed as soon as possible. Trees with obvious vertical cracks also should be removed as soon as possible.

Radial shakes, like many internal defects in trees, can be prevented or minimized, or recognized early so that the trees can be removed. How effectively this is done depends on how well the causes of the defects are understood.

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Figure 1.—Small radiating cracks normally form at the ends of oak logs as they dry. This drying pattern is typical of oaks that had no major wounds or preset radial shakes associated with wounds and stubs of basal sprouts. Note the large prominent rays that are typical of oaks. Oaks A and D have central columns of compartmentalized discolored heartwood (arrows), while oaks B and C have clear heartwood except for very small columns in the center.

Abb. 1.–Kleine, radial verlaufende Risse auf der Hirnfläche von Stammabschnitten sind typisch und "normal" für holz, das langsam austrocknet. Derartige Trockenrisse entstehen auch an Rundholz, das keine schwerwiegenden Wunden oder basale Fäsale Fäulestellen aufzuweisen hat. Die Eichenabschnitte A und D besitzen ein durch Kompartimentierung hervorgerufenes, verfärbtes Kernholz (Pfeile), wogegen die Abschnitte B und C einen nur kleinen Anteil natürlichen Kernholzes aufweisen.

Figure 2.—Basal wounds on oaks are major starting points for radial shakes. Wounds on young, rapidly growing trees are most likley to lead to internal shakes.

Abb. 2. – Langgestreckte Radialfugen am Stamm sind häufig das Ergebnis einer erfolgreichen "Wundheilung". Solche Wundnähte können allerdings nach vollständiger Überwallung wieder aufreißen und dann als "Frostrisse" in Erscheinung treten.

Figure 3.—Wounds on large trees that seldom close during the life of the tree usually do not lead to internal shakes. Wounds with blunt or rounded upper margins seldom lead to internal shakes.

Abb. 3. – Bei einer Verwundung von älteren Bäumen bleibt eine Rißbildung meist aus, besonders dann, wenn die Wunde noch nicht verschlossen ist. Auch Wunden, deren Wundränder stumpf bzw. abgerundet sind, geben selten Anlaß zu Rißbildungen.

Figure 4.—Vertical shallowwounds close as new wood forms at the sides. This closure process initiates internal cracks which may open many years later. A perfect example of the closure process is shown on this white ash. The same process occurs on oaks.

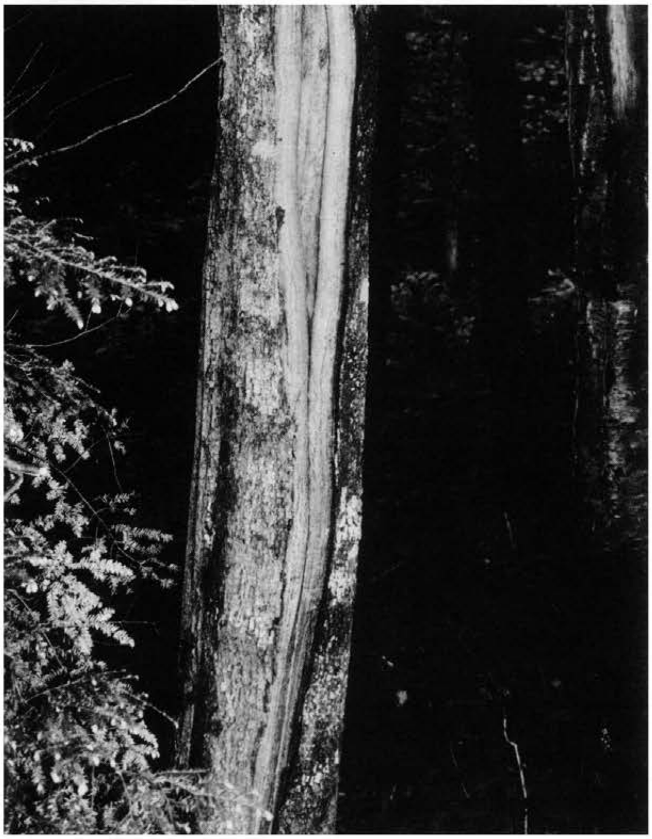

Abb. 4. – Längs am Stamm verlaufende, oberflächliche Verwundungen werden vom Baum meist rasch durch Bildung neuen Holzes überwallt. Bei diesem Prozeß entstehen nicht selten Radialfugen, die später immer wieder aufreißen können. Im vorliegenden Fall handelt es sich um eine Weiß-Esche; der gleiche Vorgang kann aber auch bei der Eiche beobachtet werden.

Figure 5.—After the callus closes the wound, frost or other stress factors may cause the internal, preset radial shake to break out to the bark. The tree responds by closing that wound again with more callus. When this sequence is repeated over many years, a ribbed, swollen, vertical bulge will develop. Often, the bulge will form above the primary wound site, which is at the base of this red oak. This is a major defect.

Abb. 5. – Nach vollständiger Überwallung der Wunde können Frost oder andere Streßfaktoren den im Innern noch vorhandenen Spalt dazu veranlassen, wieder aufzureißen. Der Baum antwortet daraufhin mit erneuter Kallusbildung, so daß sich die Wunde wieder schließt. Wenn sich dieses Wechselspiel mehrere Jahre hintereinander wierderholt, kommt es am Stamm zur Ausbildung rippenartiger, vertikal verlaufender Anschwellungen ("Frostleisten").

Figure 6.—Secondary internal shakes often split out to the bark and multiple swollen ribs result when the closure process is repeated for many years.

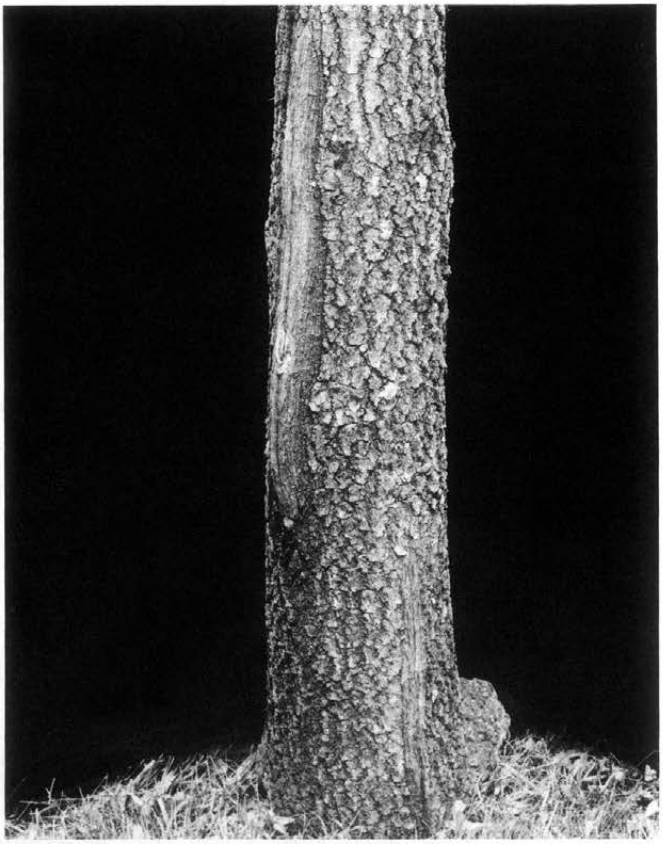

Abb. 6. – Mehrere "Frostleisten" an einem Stamm haben oft den gleichen Ausgangspunkt, auch wenn sie in verschiedener Höhe und auf verschiedenen Seiten des Stammes liegen. Auf dem hier wiedergegebenen Foto erkennt man zwei "Frostleisten", die mit einem faulholzigen Stubben (unten rechts) eines ehemaligen Sproßausschlages in ursächlichem Zusammenhang stehen.

Figure 7.—This chestnut oak shows the relationship of the two "frost cracks" and the basal stub (below right) of an old, decayed sprout.

Abb. 7. – Auch im vorliegenden Fall einer kastanienblättrigen Eiche konnte ein Zusammenhang zwischen den beiden "Frostleisten" bzw. den damit verbundenen Radialrissen im Innern des holzes mit dem Stubben eines Stockausschlages (unten rechts) nachgewiesen werden.

Figure 8.—The swollen rib on this white oak is in a direct line with the primary crack that formed after a 33-year-old fire wound closed.

Abb. 8. – Das Bild zeigt deutlich die Verbindung einer beulenartigen Wundleiste mit einer älteren Kambium-Verletzung im Stamminnern bzw. mit dem davon ausgehenden primären Radialriß. Die Wunde entstand vor 33 Jahren durch Einwirkung eines Bodenfeuers.

Figure 9.—The decayed wood in this white oak is well compartmentalized within the wood present at the time of wounding. The primary shake is well established. Two secondary shakes (arrows) have split out to the bark. This tree had multiple cracks or swollen ribs.

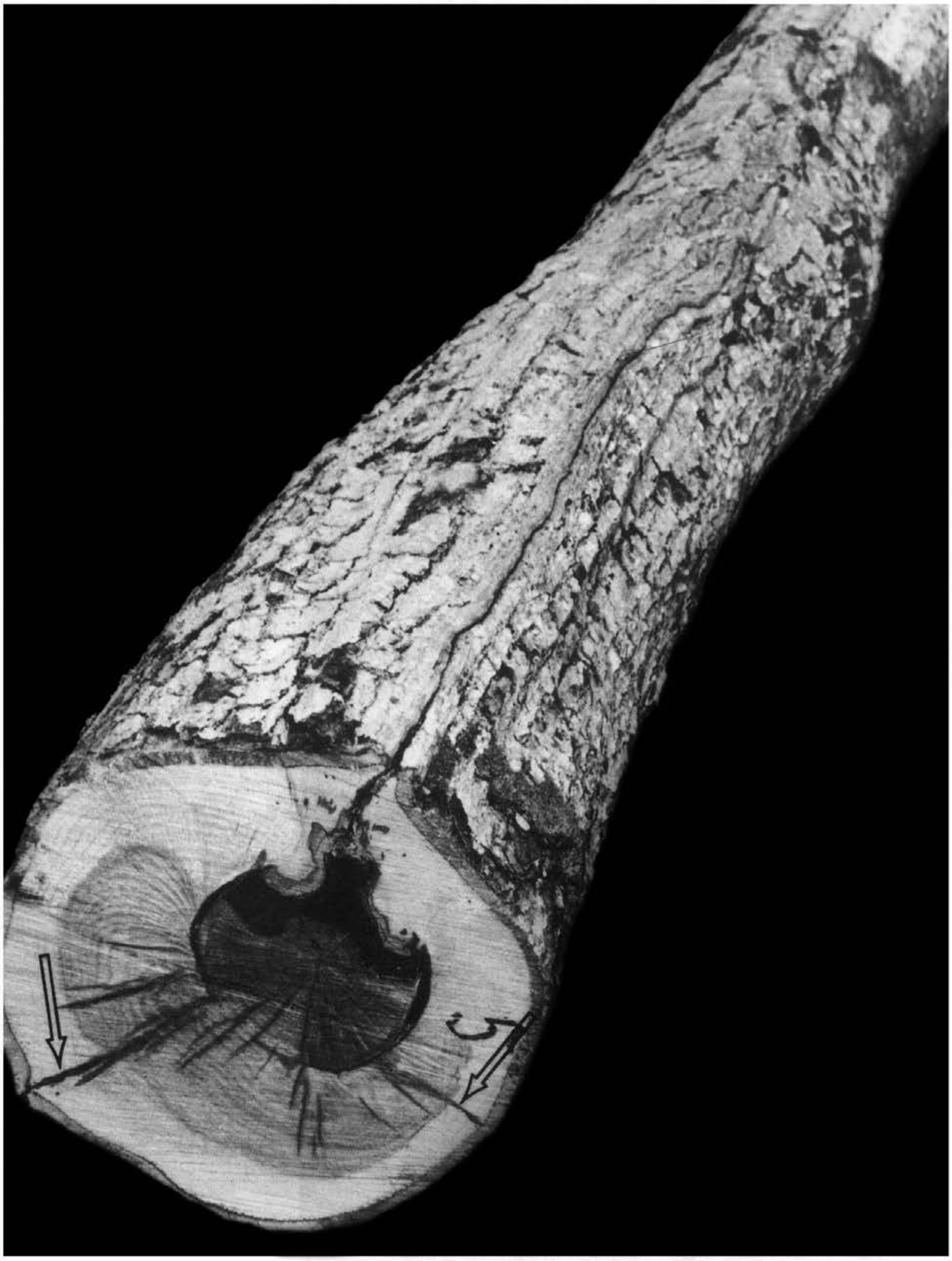

Abb. 9. – Auch das Bild dieser Weiß-Eiche zeigt die Verbindung einer vor längerer Zeit entstandenen Wunde mit der Ausbildung eines Radialrisses, der auf der Stammoberfläche als schmale, schwarze Linie erkennbar ist. Weitere kleinere Risse sind auf der gegenüberliegenden Seite der ehemaligen Wunde entstanden, von denen zwei die Rinde bereits erreicht haben (Pfeile). Beachte die zentral gelegene Fäule, die vom Baum erfolgreich kompartimentiert worden ist.

Figure 10.—When small wounds close on trees, a vertical seam forms where the callus tissues meet (arrows). When no additional stress from frost or drying is inflicted on such a tree, the seam will stay closed and constitute only a minor defect. Note the compartmentalized discolored heartwood associated with the wound.

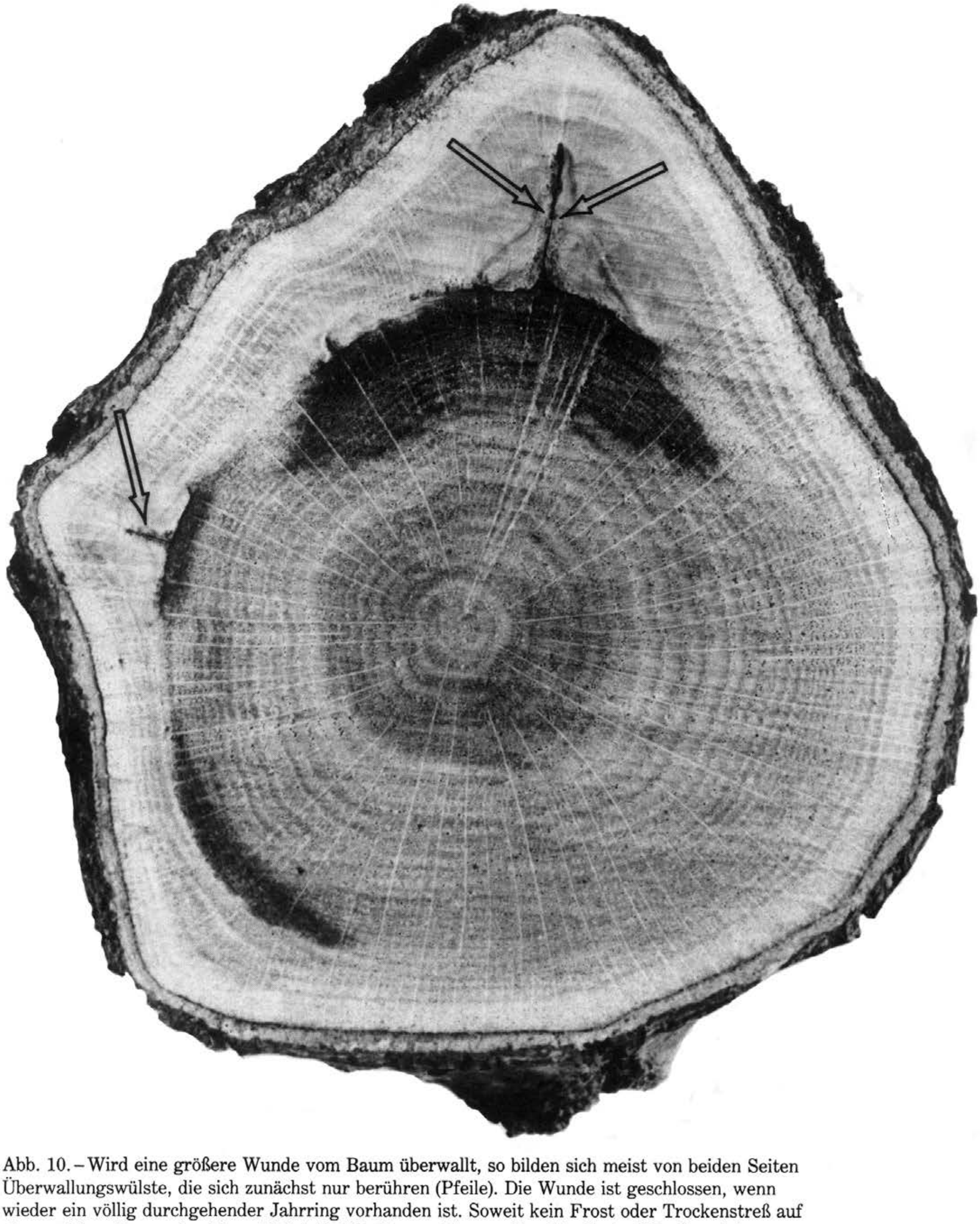

Abb. 10. – Wird eine größere Wunde vom Baum überwallt, so bilden sich meist von beiden Seiten Überwallungswülste, die sich zunächst nur berühren (Pfeile). Die Wunde ist geschlossen, wenn wieder ein völlig durchgehender Jahrring vorhanden ist. Soweit kein Frost oder Trockenstreß auf einen solchen Baum einwirken, bleibt die Wunde geschlossen. Beachte die im Wundbereich aufgetretene Holzverfärbung, die als Anwort (Kompartimentierung) des Baumes auf eine Verwundung aufzufassen ist.

Figure 11.—Small trees wounded at the base are especially vulnerable to radial shakes. On this small white oak, the primary radial shake developed after the callus closed the wound (large arrow). Secondary shakes developed where the callus began to form over the wounds (small arrows). Decayed wood associated with the wound was confined to the wood present at the time of wounding.

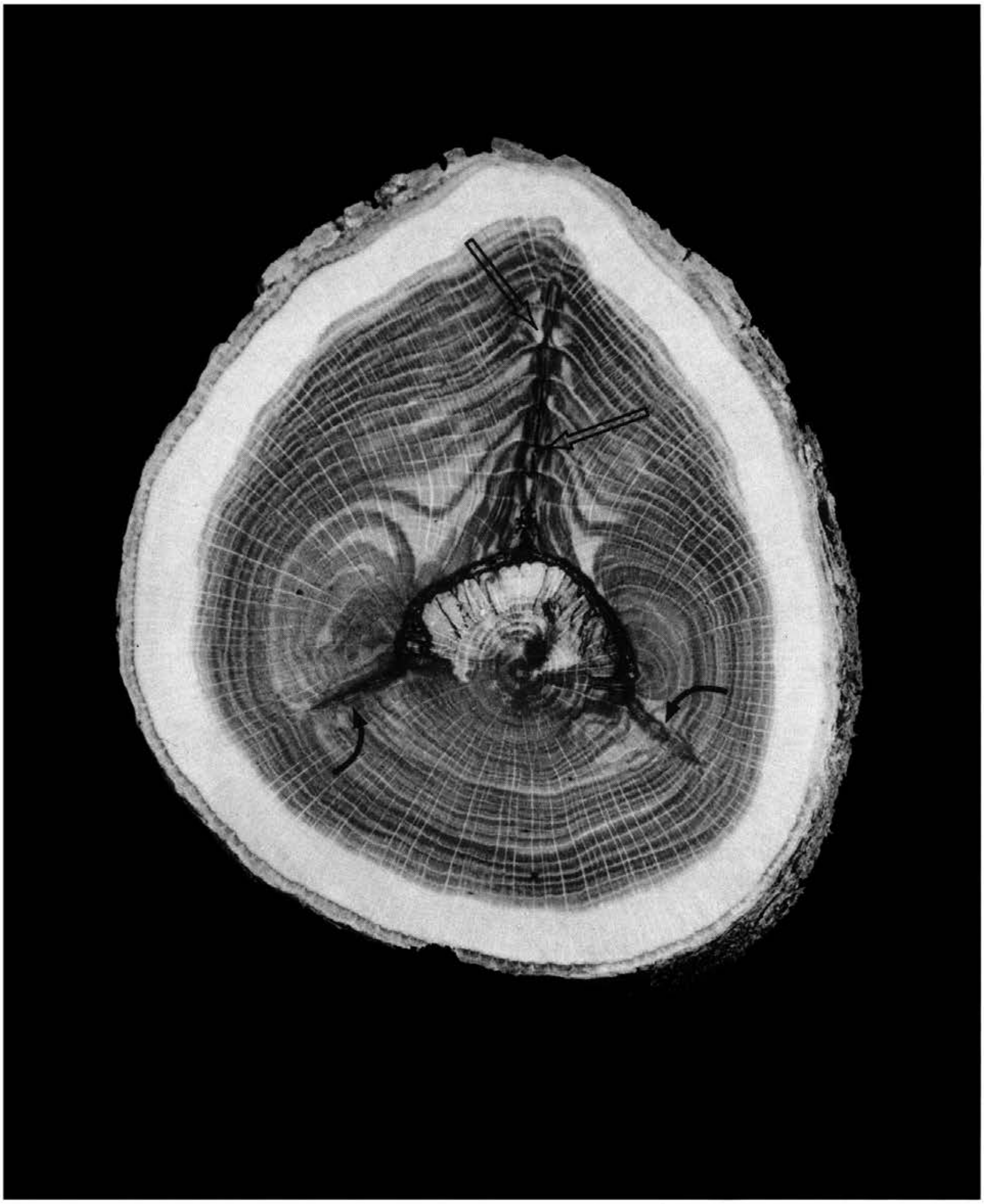

Abb. 11.–Jüngere Bäume, die an der Basis verwundet werden, sind für die Entstehung von Radialrissen besonders anfällig. Bei der hier abgebildeten Weiß-Eiche hat sich ein primärer Radialriß gebildet, lange nachdem sich die Wunde schon geschlossen hatte (großer Pfeil). Typisch für größere Wunden sind auch die beiden sekundären Radialrisse (Kleine pfeile), die sich vom ehemaligen Wundrand in das Holz hineinschieben. Die Holzfäule im Stammzentrum (hell) beschränkt sich auf denjeniegen Teil des Holzes, der zur Zeit der Verwundung vorhanden war. Eine weitere Ausdehnung der Fäule auf das neugebildete Holz findet in der Regel nicht statt.

Figure 12.—A cross section of a swollen rib in this white oak indicates that the shake started after the wound closed. Note the included bark (large arrow). The shake split open several years later and the callus begain to inroll again (small arrow).

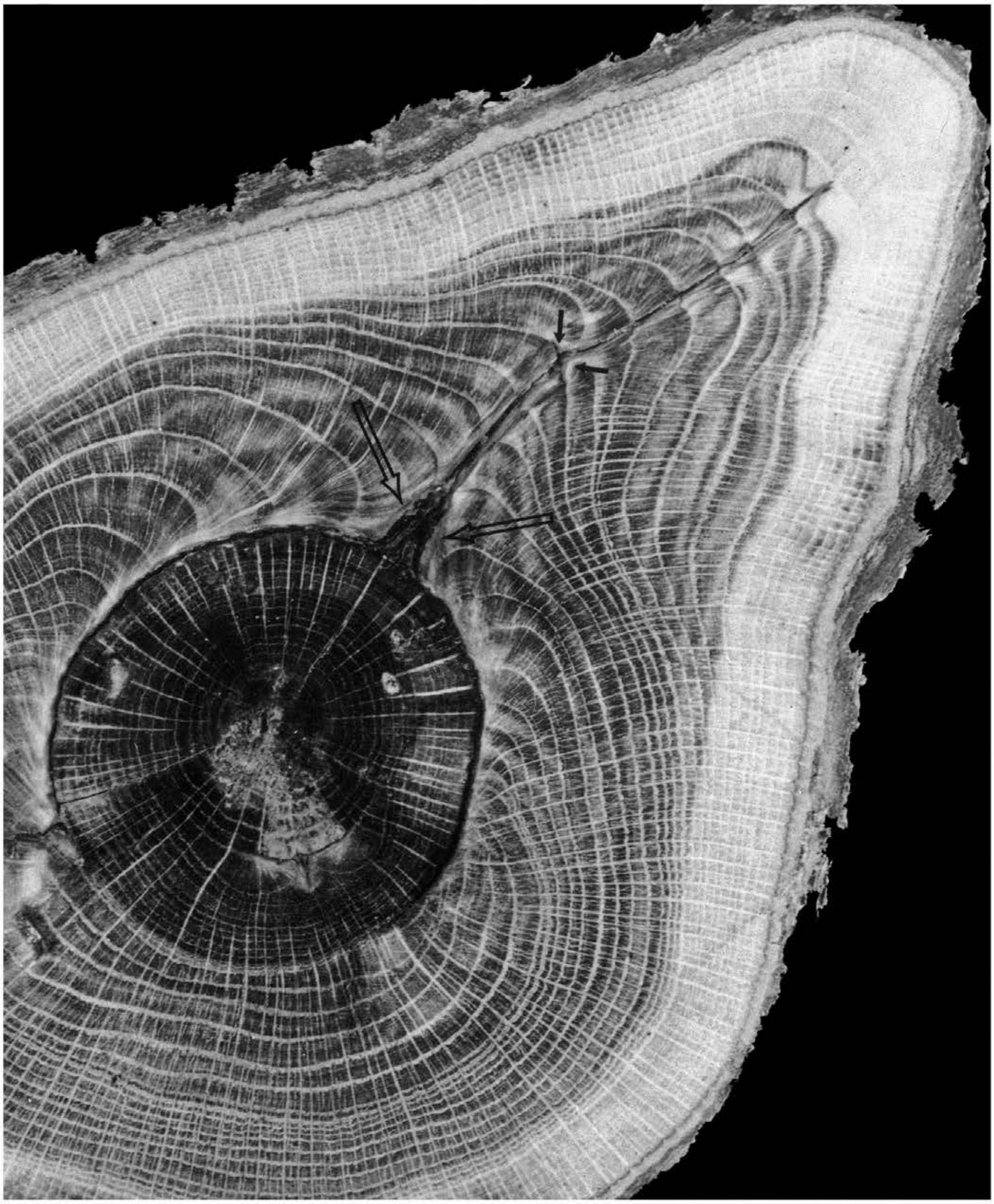

Abb. 12. – Die Entwicklungsgeschichte dieses Stammes läßt zunächst auf einen erheblichen, den halben Stamm umfassenden Kambium-Schaden schließen, der vor 33 Jahren durch Feuereinwirkung enstanden ist. Durch starke Kallusbildung hat sich die Wunde bald geschlossen, erkennbar an den ehemals durchgehenden Jahrringen. (Beachte die durch große Pfeile angedeuteten, eingeschlossenen Rindenreste.) Einige Jahre später ist die Wundstelle besonders weit aufgeplatzt, erkennbar an dem dort eingerollten Jahrring. Auch in den darauffolgenden Jahren hat sich die Rißbildung weiter fortgesetzt.

Figure 13.—The primary shake may split again to form bifurcate cracks; or multiple cracks may develop. This tree will only become more defective as it grows older. Such trees should be cut as soon as possible.

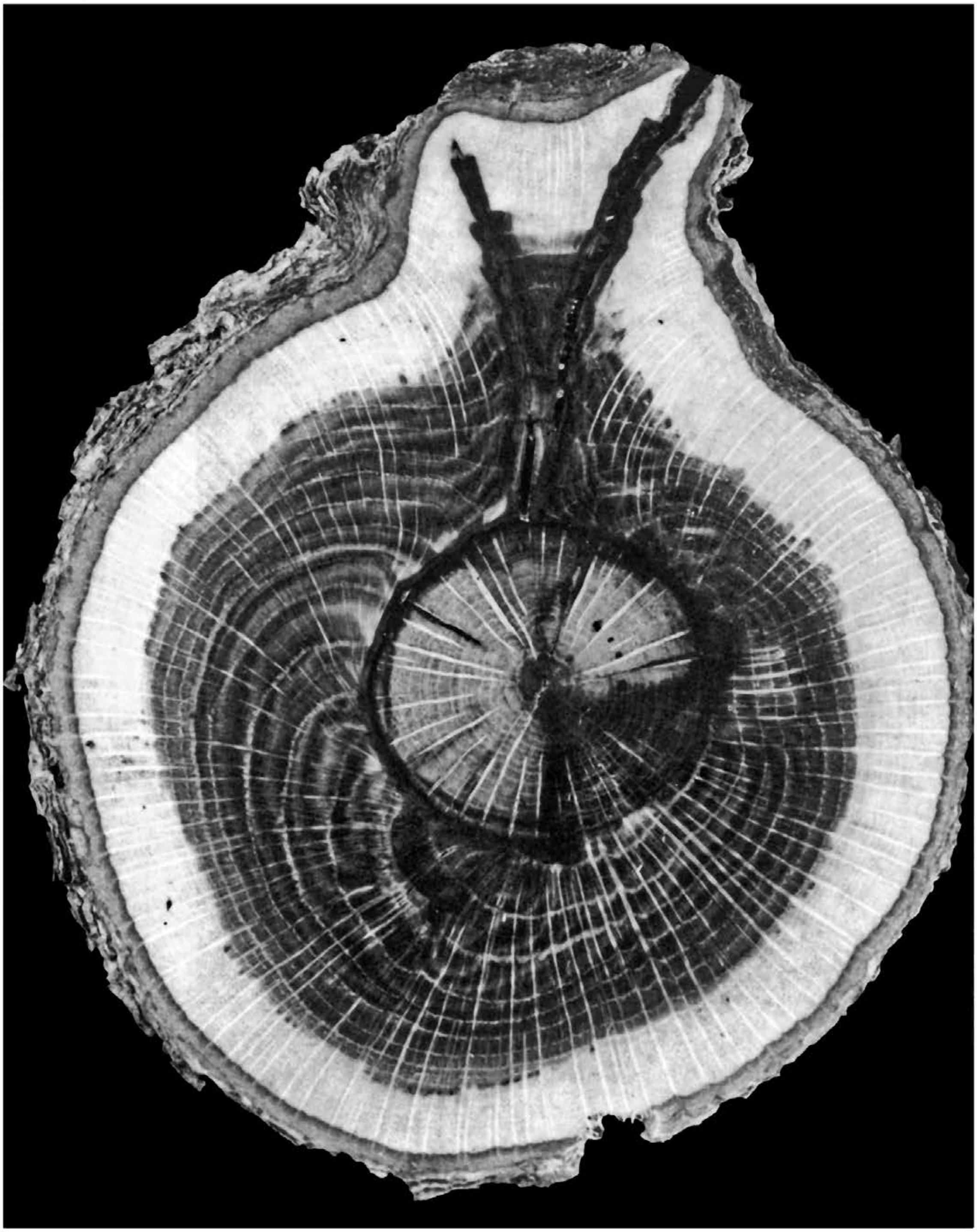

Abb. 13.–Nicht selten verzweigt sich der primäre Riß zu einem gabelförmigen Gebilde. Der hierdurch entstehende Schaden vergrößert sich in dem Maße, wie der Baum an Alter zunimmt. Solche Eichen, die bereits mehrere "Frostleisten" aufweisen, sollten möglichst bald geschlagen werden. Ein Wertzuwachs ist hier kaum mehr zu erwarten.

Figure 14.—Many small radial shakes often start from wounds. It is not known why they start from some wounds and not others. Some of the shakes in this sample have split out to the bark. Note the curved primary shake that opened wide after the sample dried.

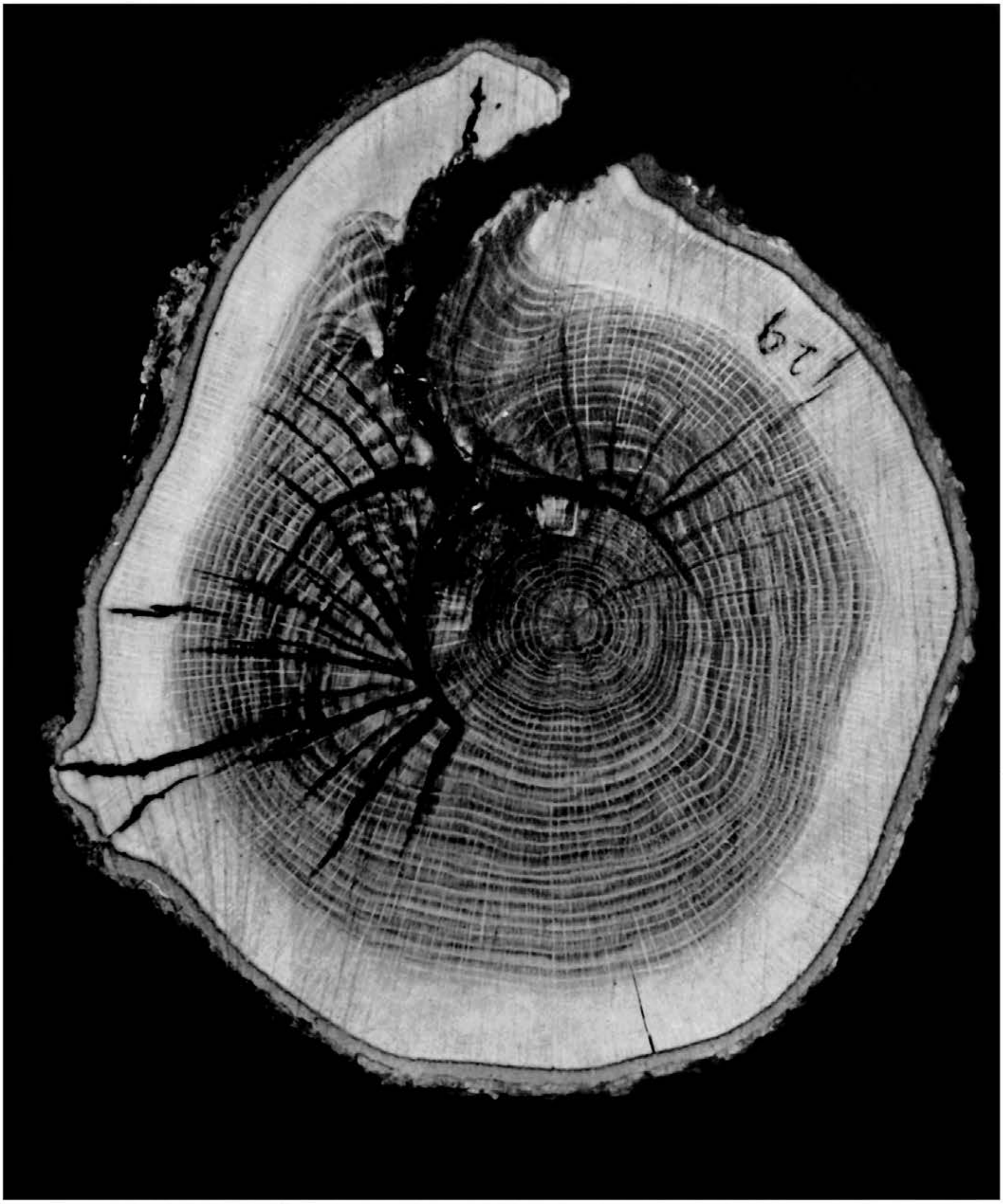

Abb. 14.–Unter bestimmten, bisher unbekannten Voraussetzungen können zahlreiche, kleinere Radialrisse entstehen. Auch diese nehmen ihren Ausgangspunkt stets von ehemaligen Wunden. Aus dem Verlauf der Risse kann man erkennen, daß einige bereits den Rindenmantel durchbrochen haben und damit zu "Frostrissen" geworden sind. Beachte den hier gebogenen, primären Radialriß, der sich durch Austrocknung des Holzes allerdings stark verbreitert hat.

Figure 15.—This white oak had two major wounding periods. The first wounds were inflicted when the tree was less than 4 cm in diameter (small arrows). Many secondary shakes and one obvious primary shake resulted from the injury. Small radial shakes developed later in the life of the tree when several small wounds were inflicted (large arrows).

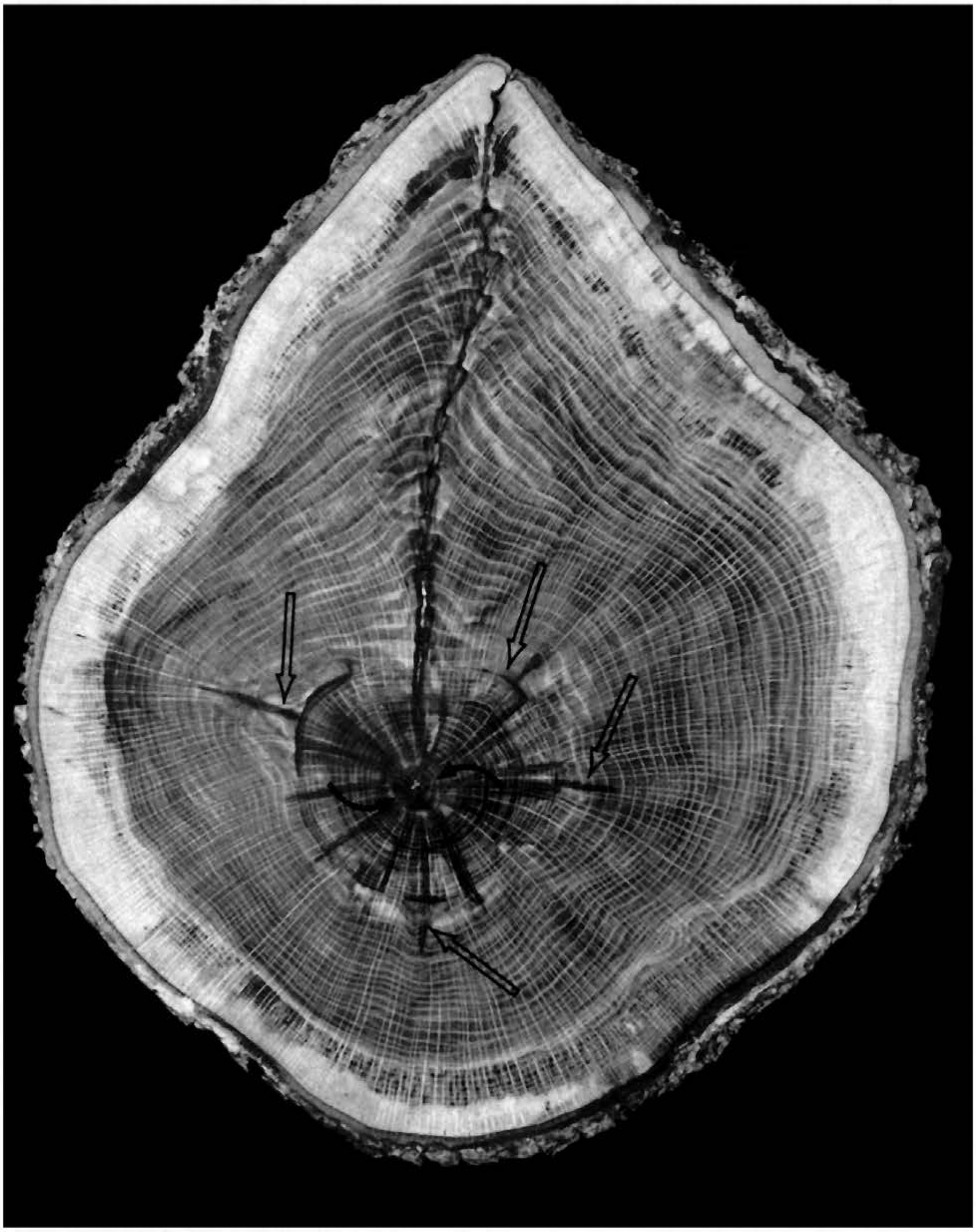

Abb. 15.—Der Querschnitt durch eine ca. 70jährige Weiß-Eiche zeigt zwei bedeutende Verwundungsperioden: Die erste Verletzung erlitt der baum, als er einen Stammdurchmesser von weniger als 4 cm besaß (kleine Pfeile). Die Folgen dieser Verwundungen sind zahlreiche, kleine Spaltén sowie ein großer Primär-Riß, der bereits die Stammoberfläche erreicht hat. Weitere kleinere Radialrisse sind zu einem späteren Zeitpunkt entstanden, als der Baum erneut mehrmals verwundet wurde (große Pfeile).

Figure 16.—Radial shakes that appear to start at the pith in this section actually start slightly out from the pith. This section came from a tree with multiple basal stubs.

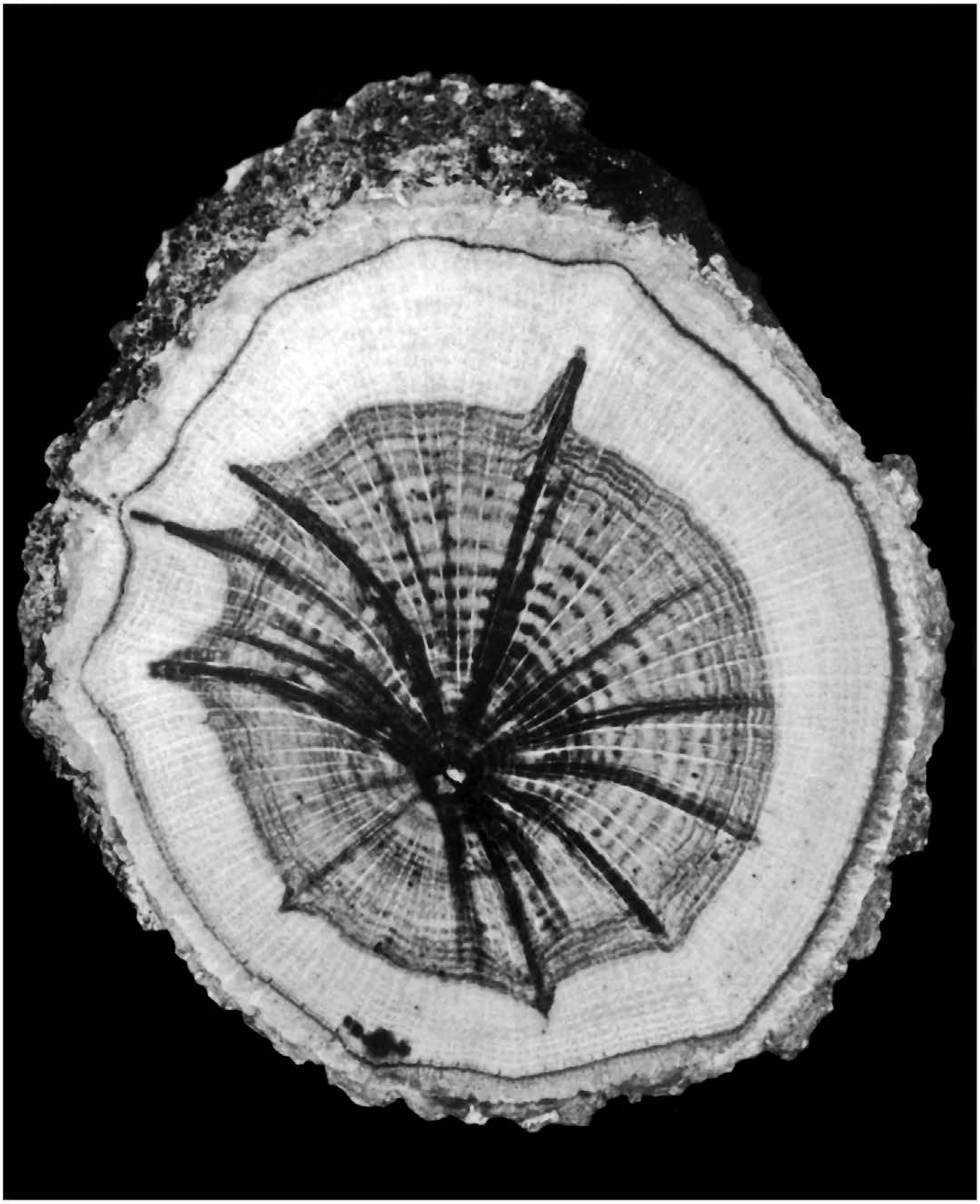

Abb. 16. – Radialrisse, die als "Sternrisse" oder "Spinnenrisse" vom Mark des Stammes ihren Ausgangspunkt zu nehmen scheinen, haben oft einen anderen Ursprung. Der hier wiedergegebene Stammquerschnitt stammt von einem Baum, der von einigen, zum Teil faulholzigen Stümpfen frühzeitig abgestorbener Stockausschläge begleitet war.

Figure 17.—This red oak was cut below ground level to show the multiple radial shakes associated with two basal wounds when the tree was less than 8 cm in diameter. Some of the shakes developed into mulitple ones (arrows).

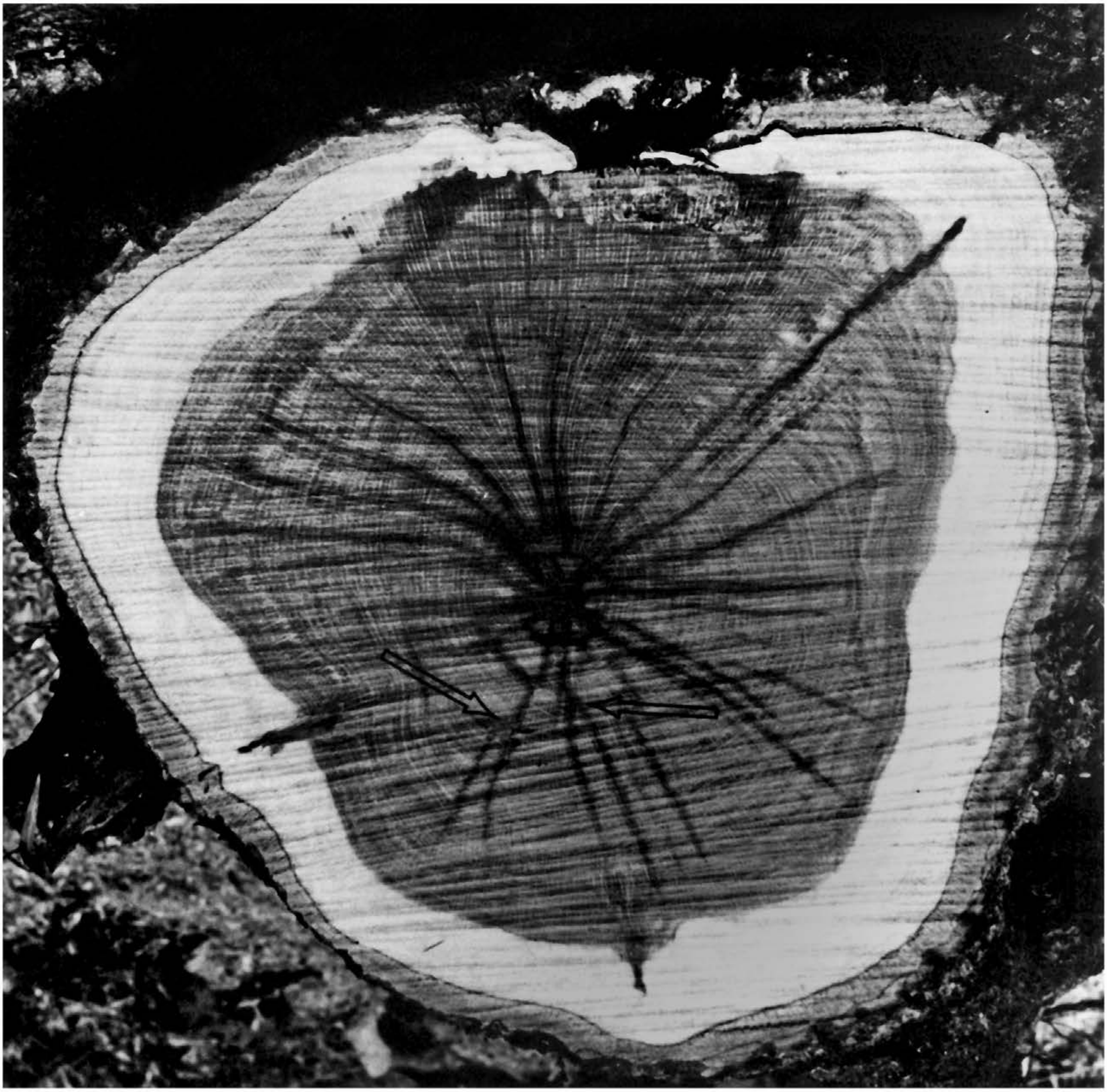

Abb. 17.–Wird bei sternrissigen Eichen der Sägeschnitt tief genug geführt, so kann auch der eigentliche Ausgangspunkt der Radialrisse erkannt werden. Im vorliegenden Fall gehen die Risse von zwei basalen Wunden aus, die entstanden, als der Baum einen Durchmesser von 8 cm hatte. Einige der Risse zeigen eine Aufspaltung in ein Bündel weiterer Strahlenrisse (Pfeile).

Figure 18.—When crosscuts are made at stump height, it often appears that the shakes emerge from the pith.

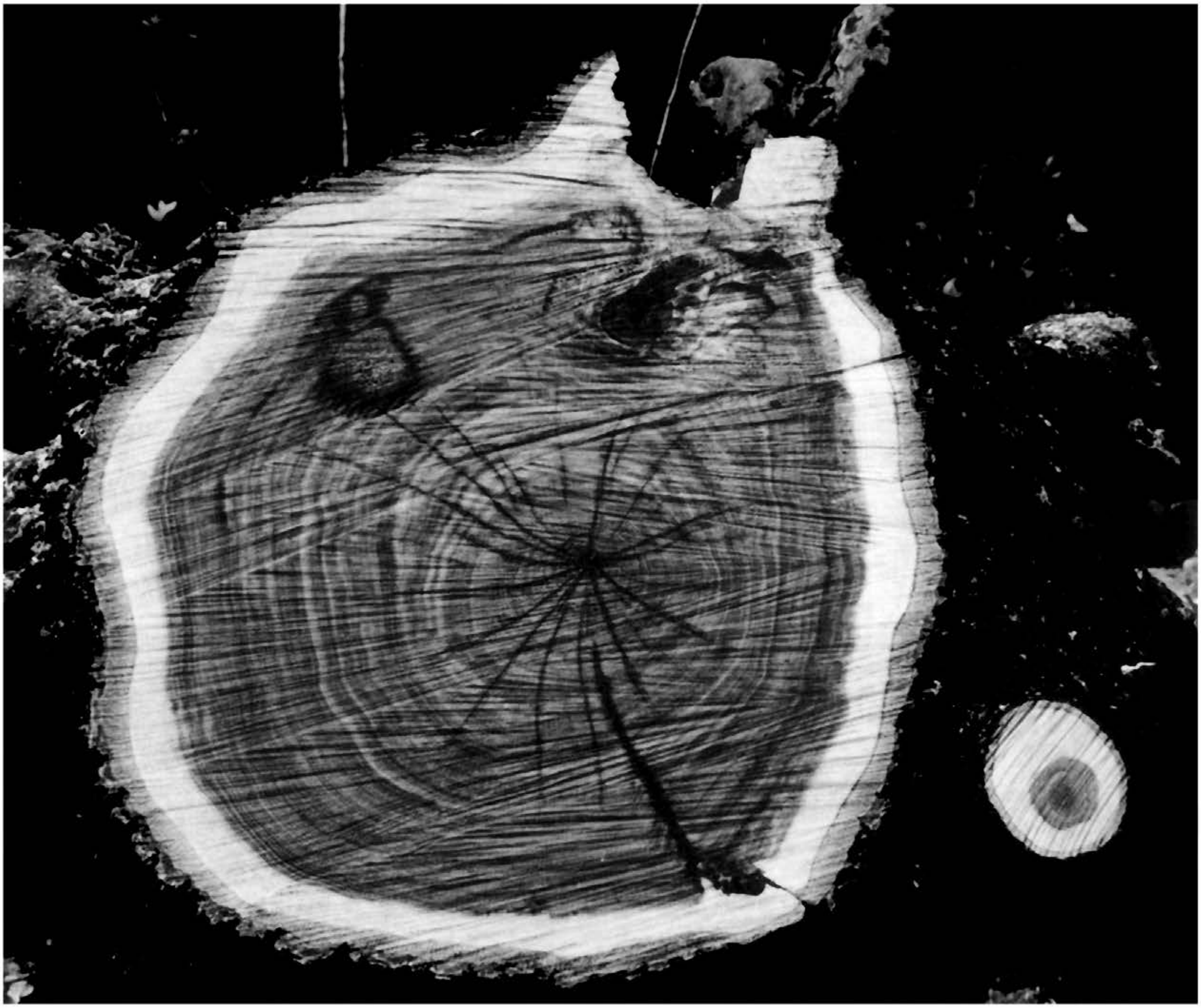

Abb. 18. – Wird der Sägeschnitt zu hoch oder zu tief ausgeführt, verfehlt man oft den eigentlichen Ursprungsort der Radialrisse. So scheinen die Sternrisse im vorliegenden Fall im Mark des Stammes entstanden zu sein (vergl. Abb. 19).

Figure 19.—Dissecting the tree in Figure 11 farther downward revealed that a decayed central core associated with all dead basal stubs was the starting point for the shakes.

Abb. 19.–Ein tief am Wurzelanlauf angesetzter Sägeschnitt zeigt schließlich den eigentlichen Ursprungsort der Radialrisse. Als Ausgangspunkt erkennt man eine zentral gelegene Fäulestelle, die wiederum selbst mit den Resten ehemaliger Stockausschläge in Verbindung steht.

Figure 20.—A radial shake associated with an old, dead sprout stub. The radial crack on the inner side occurred after the sample was dried.

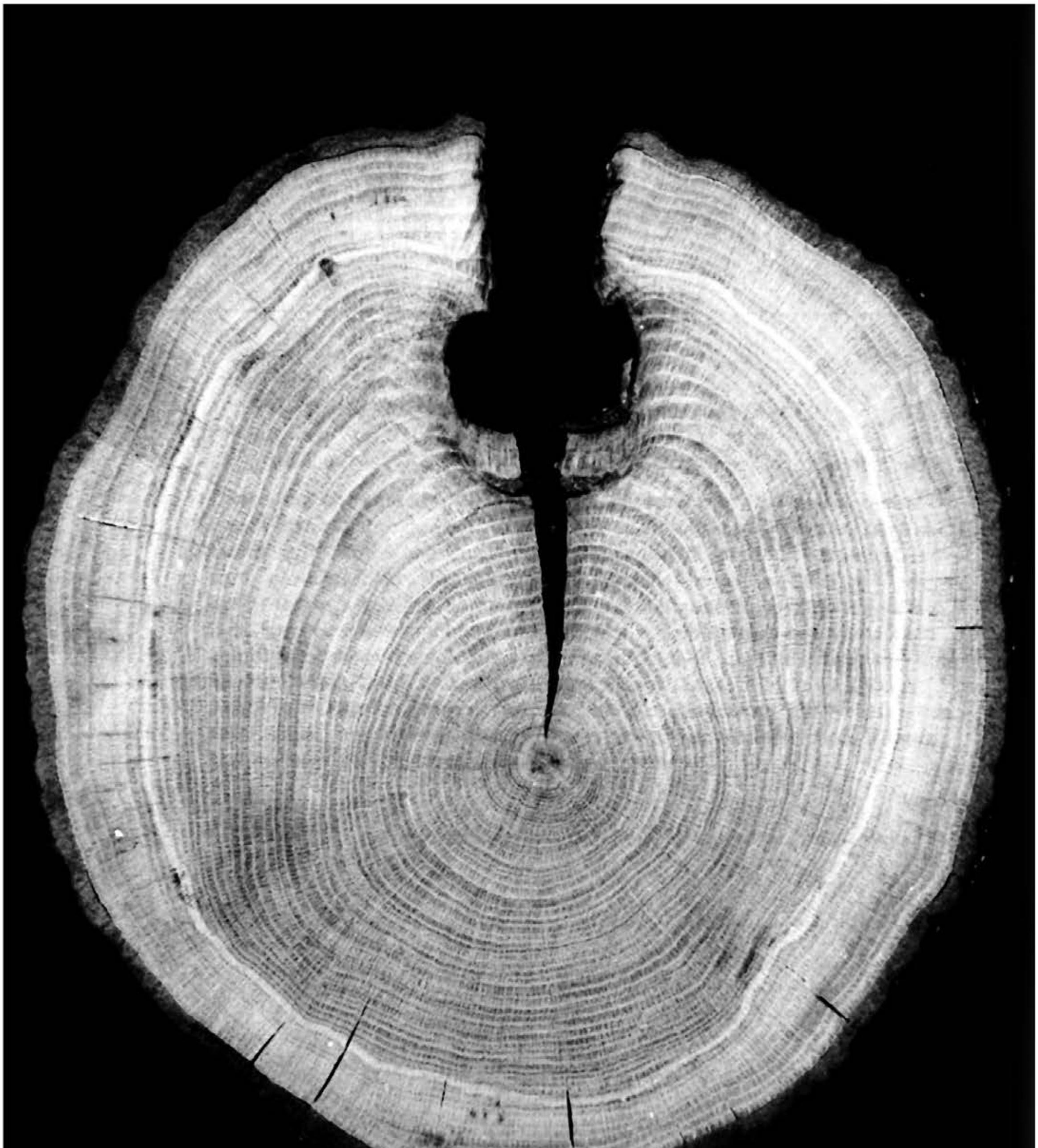

Abb. 20. – Radialrisse können ihren Ausgangspunkt auch von eingewachsenen Totästen aus nehmen. (Der Spalt auf der Innenseite des Astloches entstand nach der Trocknung der Baumscheibe.)

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Butin, Heinz, and Alex L. Shigo.
1981. Radial shakes and "frost cracks" in living oak trees.
Northeast For. Exp. Stn., Broomall, Pa.
21 p., illus. (USDA For. Serv. Res. Pap. NE-478)

Dissections of hundreds of living, mature oak trees over a 25-year period revealed that radial shakes (or "frost cracks") and ring shakes are associated with a variety of wounds and stubs of branches and basal sprouts. A more intensive study of radial shakes that included dissections of more than 30 oaks confirmed earlier findings, and provided additional data on radial shakes. Radial shakes were most common in mature oaks that had been wounded, and where basal sprouts died when the dominant tree was less than 20 cm in diameter at 1.4 m aboveground. Radial shakes—frost cracks—are not caused by frost, though frost can be a major factor in their continued development. Radial shakes can be prevented by proper management procedures that minimize basal wounds and by early pruning of branches and basal sprouts.

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