Testimony in Wood: Analysis of the Rail 16 evidence in the Lindbergh Kidnapping

Summary Report 1.2

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Figure 1: The kidnap ladder. Rail 16 is the upright on the far right. Photo courtesy Forest Products Laboratory, Madison, Wisc.

I. Introduction

"Trees and stones can teach you that which you can never learn from masters"

-St. Bernard of Clairvaux

On a cold night in 1932, a baby boy disappeared from his crib in Hopewell, New Jersey. Two and a half months later he was found dead. The child was Charles Lindbergh Jr., son of the famous aviator; his kidnapping and death shocked the nation[1] and was called the "Crime of the Century."[2] The subsequent investigation led to the arrest and execution of Bruno Richard Hauptmann. Yet from the beginning, doubts have been raised about Hauptmann's guilt. The investigation was a complex and colorful affair, and accusations have been made of police coercion, planted evidence and false testimony.

One crucial piece of evidence in the case was a piece of wood from a homemade ladder found on the grounds of the Lindbergh Estate on the night of the kidnapping (Figure 1). The ladder was built in three sections, held together with wooden dowels. The top section included an upright, or rail, of southern yellow pine. This particular rail, afterwards identified as "Rail 16," had knots and distinctive grain patterns, and was hand-planed along both edges. According to the police, it also had 4 extraneous nail holes in its face.[3]

For two years after the crime the police searched for the kidnappers without success. In May of 1933 they enlisted the help of Arthur Koehler, a forestry professor at the Department of Agriculture's Forest Products Laboratory, who conducted an in-depth analysis of the wood from the ladder. Then, in September of 1934, Hauptmann was arrested after passing a ransom bill at a Bronx gas station. At his trial, Detective Louis Bornmann testified that, while searching Hauptmann's attic on September 26, 1934, he noticed that part of an attic board had been cut away. He testified that he and Koehler subsequently brought Rail 16 up into the attic, and that the four nail holes in the face of Rail 16 lined up with four nail holes in the attic joists[4] (Figure 2). Koehler testified that there was a 1-5/16" gap between Rail 16 and the remaining section of attic board--labeled "S-226" during the trial--but "there were a number of points of similarity between the two" that convinced him they had been one piece.[5]

Figure 2: Rail 16 in the attic. The tip of S-226 is visible on the far left. Photo courtesy New Jersey State Police Museum, W. Trenton.

Koehler's work on the case has been applauded by many as groundbreaking forensic science. Others, however, have decried Koehler as inept, or accused him and Bornmann of planting Rail 16 in the attic in order to help the prosecution obtain a conviction. A reopening of the case in 1935 by Governor Harold G. Hoffman fueled further controversy. Over the years the case has been debated in books, magazines and Internet websites, and doubts about the validity of the Rail 16 evidence remain.

The kidnap ladder, the attic board in question, and other evidence still exist. For the last three years, the author has coordinated a reexamination of this evidence, with the assistance of wood scientists, lumber professionals, historians and others. What follows is a summary of the results of this project.

Research objectives

The Rail 16 evidence connects the kidnap ladder found at the crime scene with Hauptmann's attic, and therefore is a tangible physical link between the crime and the accused. In order to evaluate the validity of this link, this study focused on three key tasks:

1. Establish whether or not the current Rail 16 was the original ladder rail.
2. Determine the true relationship between Rail 16 and the attic board (S-226).
3. Examine the relationship between Rail 16 and the rest of Hauptmann's attic floor.

The alleged attic position of the evidence boards

The police claimed that when Rail 16 was cut out of the attic, an 11-foot long section of floorboard was left behind. Detective Bornmann stated that during the investigation he pulled this board up by hand. As he did so, he said, the board split in the vicinity of a large knot,[6] creating a short piece, about 22 inches long, and a longer piece, a little over 9 feet long. Prior to the trial, the police cut this 9' long piece down further, and presented as evidence a section that was 80-¾" long. This piece was designated evidence number "S-226." Along with Rail 16, S-226 is on display at the New Jersey State Police Museum. The remaining sections of this board (two pieces of wood with a combined length of 55 inches) were recently rediscovered in the evidence warehouse of the New Jersey State Police. In this report, these additional sections of wood are collectively termed "**S-226X**" or "**S-226 Extension.**" The arrangement of Rail 16 and S-226 that was claimed by the police to be their original relationship in the floor is referred to here as the "**alleged attic position**" (Figure 3).

II. Is the current Rail 16 the same board as the one found on the ladder on the night of the kidnapping?

The first question addressed in the study was whether the police replaced the original Rail 16 with a substitute board. Photographic evidence demonstrated that this was not the case. The author sought out and found photographs taken immediately after the kidnapping; one photo, a detailed picture of Rail 16, was apparently taken by a photographer named William B. Springfield on March 2, 1932[7] (Figure 4). This photo appeared in

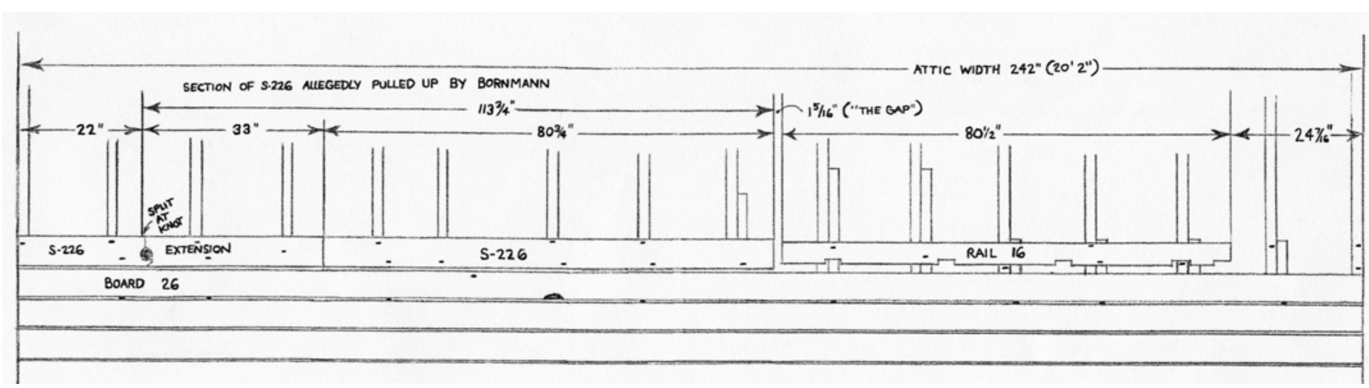


Figure 3: Author's diagram of the arrangement of boards in the attic. Attic floor continues at bottom, with "Board 26." "S-226" was the evidence number for the section of attic board (center) used in the trial. In the text, the two extension pieces of S-226 (far left) are referred to as "S-226X."

newspapers around the country in the week after the kidnapping[8]. A second photo, found in the New York Daily News, showed the opposite side of the rail.[9]

The author set up the current Rail 16 in the same position as the early photograph and created comparison images (Figure 4). An examination found very clear and unique match-ups in the knots and surface grain, establishing that the current Rail 16 is the same rail that was found on the ladder at the time of the kidnapping.

III. Determining the true relationship between Rail 16 and S-226 (the attic board)

The second task of the study was to determine the true relationship between Rail 16 and S-226. The author focused on six areas of comparison: milling characteristics; general natural characteristics; knot patterns; surface grain patterns; relationship between end grain and surface grain; and end grain comparisons.

Comparison of the milling characteristics of Rail 16 and S-226

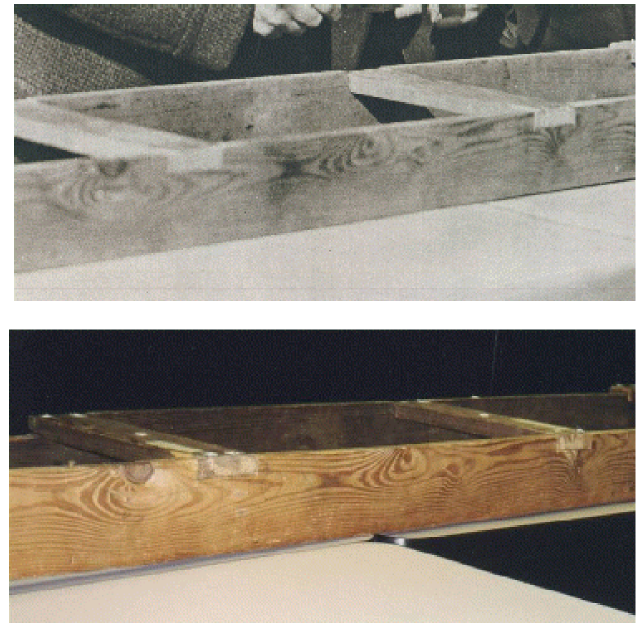


Figure 4: Comparison photos of Rail 16, pith side. Top: Detail from copy of Springfield photo, 3/2/32. Bottom: Photo of Rail 16 taken by author, 6/1/2001. Top photo courtesy of New Jersey State Police Museum.

In order to bring the two boards from their natural state to usable lumber, Rail 16 and S-226 were milled. Typically this process involves cutting the tree, rough-sawing the wood into boards, and then planing the surfaces. Machine planing is typically done by a "planer" or a "molder," machines with sets of rotating blades. These spinning blades cut into the sides of the wood, and sometimes the edges, as it passes through the machine. The resulting surface is not exactly flat, but consists of a series of small, closely-spaced grooves (Figure 5). Each groove represents a pass of a planer knife, and so the resulting grooves are called "knife marks." Planing machines vary in the speed of the planer knife rotations, the number of knives on each cylinder, and the speed at which the boards are fed through the planer. Irregularities can also occur.

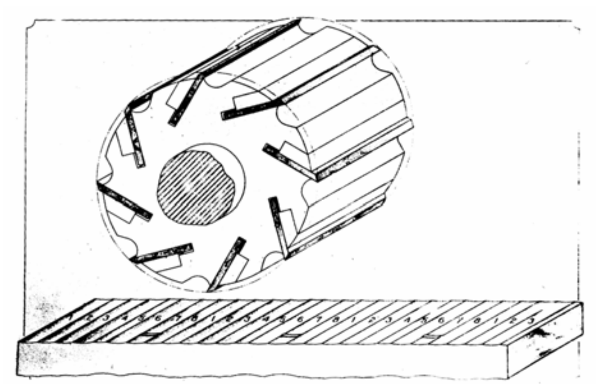


Figure 5: Diagram by Koehler, illustrating the cuts (or "knife marks") made by a machine planer. In this diagram, Koehler shows the effect of a small defect in one of the eight knives, visible in the drawing as a periodic horizontal mark on the board. Irregularities such as this help to determine the number of knives on the cylinder. Diagram courtesy Forest Products Laboratory.

An examination found that Rail 16 and S-226 had matching milling characteristics. Both boards were "plain sawed," meaning that they were cut in a manner that the sides are perpendicular to a given radius of the tree.[10] A series of measurements taken along the edges and ends of the boards found them to be virtually identical in thickness. Both boards were found to average eight knife marks per inch on both the bark and pith sides, with some irregularities in the spacing. When photographed under side lighting, both boards showed sequences in which every sixth knife mark was darker and more distinct (Figure 6). This phenomenon was only faintly visible in a few places on the bark (outer tree) side of Rail 16 but was more apparent on the pith (inner tree) side of both boards and the bark side of S-226. These marks were typically spaced ¾" and six knife marks apart, indicating that both boards were planed on a machine with six knives per cylinder on both sides, with one knife offset from the others on both cylinders.

Both boards have raised grain, a common phenomenon in which the latewood rings swell above the surface of the wood. Both boards have torn grain near the knots, and the arrangement of the torn grain is consistent in direction, indicating that both boards were planed in the same direction, from down-tree to up-tree.

Photographs of the planer marks were inspected by Alden Witham of Contractor's Millwork in Sharon Springs, NY, and Hendal Price of the Southern Pine Inspection Bureau in Pensacola Florida. Mr. Witham teaches woodworking techniques and runs a mill, using old-fashioned, belt-driven planing equipment. Mr. Price inspects and diagnoses problems with machine planers in southern lumber mills. According to Hendal Price, the severity of the torn grain on these two boards suggests that both boards were most likely planed while they still had high moisture content.

On sections of both boards, the knife marks are not evenly spaced, but occur in sequences of two close together. Both men identified that the coupling of the knife marks into sequences of two was a phenomenon known as "wavy dressing". Mr. Witham suggested that wavy dressing is sometimes created by a loose adjustment of the pressure bar, which holds the wood down: if the bar is loosely adjusted, it may allow the wood to vibrate, and cause wavy dressing. According to Mr. Price, wavy dressing is a fairly common characteristic of poorly-dressed lumber. On the evidence boards, however, these sequences tend to merge more in the same direction, toward the groove edge of S-226, and the comparable edge of Rail 16.

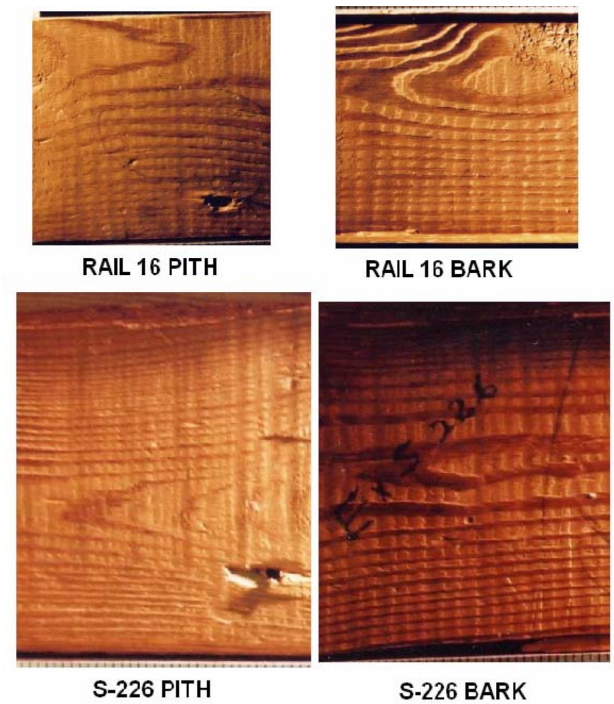


Figure 6: Periodic deep knife marks visible along the surfaces of Rail 16 and S-226.

General natural characteristics of Rail 16 and S-226

Species: Photographs of the end views of Rail 16 and S-226 were sent to Dr. Warren Thompson, Dean Emeritus of the College of Forest Resources at Mississippi State University, and a former Director of the School's Laboratory of Forest Products Research. Dr. Thompson identified the two specimens as southern yellow pine (sometimes called "North Carolina Pine.") This is a group of species that includes loblolly, shortleaf, longleaf, and others.[11] Because these species are alike in structure, definitive identification of the specific species of a southern yellow pine cannot be made on the basis of the inspection of a board alone. [12]

Color: A couple of weeks after the kidnapping, Rail 16 was stained with silver nitrate, in an effort to find fingerprints.[13] Remnants of this stain remain today, giving the board a grayish tint. Over the years, however, the board has been subject to a certain amount of wear and damage, which has exposed untreated areas. In these places the color of the wood is similar to S-226.

Heartwood and sapwood: After the trial an investigator for Governor Hoffman, Archibald Loney, made the claim that Rail 16 contained heartwood and S-226 was completely sapwood.[14] An inspection of the boards found no basis for this claim. Neither board shows any evidence of the darkening that occurs when southern yellow pine cells evolve into heartwood; both boards appear to be completely sapwood. S-226 does have a long dark streak visible on both side surfaces, but the streak appears to be a resin pocket.

Origin on trunk: Measurements of the arcs of the rings of both boards suggested that both boards come from an area near the center of the tree, within about 1-½" to 2" from the pith at the closest point. (Because of the irregularity in tree shapes, however, this is not a definitive test).

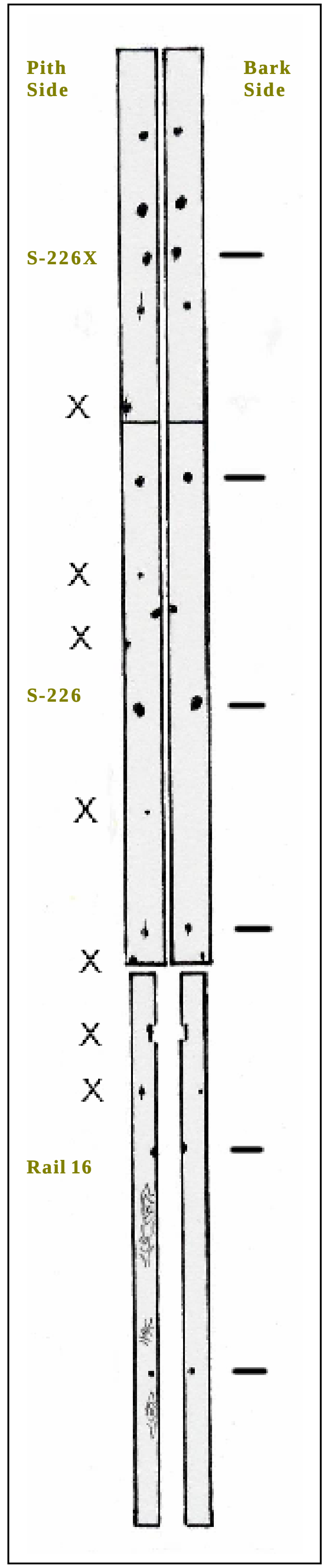


Figure 7: The pattern of the knots on Rail 16 and S-226. Knots that are in the process of self-pruning are marked with an "X". The lines on the right denote the regular spacing between many of the remaining knots. Whorls on the piths side of Rail 16 are also drawn in. Only one of the Rail 16 mortises is shown.

Diagram by author, based on measurements taken on the actual boards.

The patterns of the knots

The number and location of the knots on the two boards was a point of contention during the trial. A defense witness named Charles J. DeBisschop testified that he found "the lower rail [Rail 16] has three [knots] and the top one [S-226] has seven, which is contrary to anything that ever was."[15] A review of literature, however found DeBisschop to be incorrect. Knots are the bases of branches.[16] Young trees, with little or no shading, often have lots of small branches. As the tree grows, however, upper branches cast a shadow on the branches below, which may then experience slower growth, wither, and eventually die.[17] These dead branches then deteriorate and break off, leaving knots in the trunk. This process is called "**self-pruning.**" On a typical forest tree, then, larger knots are more likely to develop higher up in the tree, and lower knots are likely to be smaller. This evolution of branch growth also means that the number of knots in a specific board will depend on its distance from the pith: the clearest wood is farther out on the lower part of the tree, and the knottiest wood closest to the pith, or center of the tree.[18] Often too, the pattern of sunlight and shading will lead to an evolution in the branch pattern in which the branches grow at fairly regular intervals.

For this study, the locations of the knots on Rail 16 and all of the sections of S-226 were measured and mapped (Figure 7). When the boards were set in the alleged attic position, the knots on both boards were closer to the far end of S-226 ("far end" meaning away from Rail 16) on the bark (attic top) side than on the pith side. This indicates that the boards are consistent in tree growth direction: for both boards, "up-tree" would be towards the far end of S-226 (East side of attic in alleged attic position), and S-226 would be above Rail 16 on the tree.

The overall pattern of the knots on the combined boards was found to be consistent with the growth of a forest tree. A series of knots and whorls on the pith side of Rail 16 suggest the location of a series of small branches, which would have been lower on the tree, and most of which self-pruned by the time the tree grew to the thickness that included the pith side of the board. The knots on the pith side of both boards display a pattern of branches developing farther up the trunk, which would have overshadowed the branches represented by the knots and whorls on Rail 16, inhibiting their growth. On the bark side of the boards, several of the lower knots have self-pruned, or are in the process of self-pruning. The remaining knots display a pattern that includes a cluster of knots up towards the tree's crown (the S-226X area) and a series of more widely spaced knots below. Some of these knots are spaced at regular intervals.

The pattern of the knots was reviewed by Dr. Warren Thompson. He wrote, "I have reviewed in depth the knot pattern on the three board sections [including the S-226 extension], as depicted in the photographs and knot map that you supplied. I discovered nothing during my review that is inconsistent with the hypothesis that R16 and S-226 are sections of the same board...One would generally expect fewer knots in the lower than the upper portion of a southern pine tree, which typically undergoes relatively rapid self-pruning. One would also expect, considering how knots originate in the pith of a tree, that there should be some consistency in their vertical spacing along the bole [trunk] of the tree, and hence longitudinally in boards cut from that tree. You found both of these 'expected' results in your analysis of Rail 16 and S-226."[19]

Surface Grain Patterns of Rail 16 and S-226

The author set the boards up vertically on blocks and clamps and compared the surface grain on both sides of the boards simultaneously (Figures 8 & 9). The alignment was based on a Forestry Department picture taken in the attic in 1934, showing the boards fixed in place with nails. Near the end of S-226 a large knot is visible, which distorts the rings in the areas closest to the groove edge. Away from the knot, however, the curves in the surface grain of the two boards were found to be in alignment across the gap: rings from specific years of growth on one board aligned with the same yearly rings on the other board. A plausible pattern, with a ring-for-ring match, existed on both sides of the boards, indicating that the relationship of the layers of tree growth was continuous throughout the boards. In addition, in examining the two boards the author also noted that both appear to have had a split in the cambium on the pith sides. This split is visible as a series of V's on both the sides and ends of the boards. When the boards are placed in the alleged attic position, the two grooves appear to follow a somewhat irregular but continuous curve around the knot on S-226 (Figure 9).

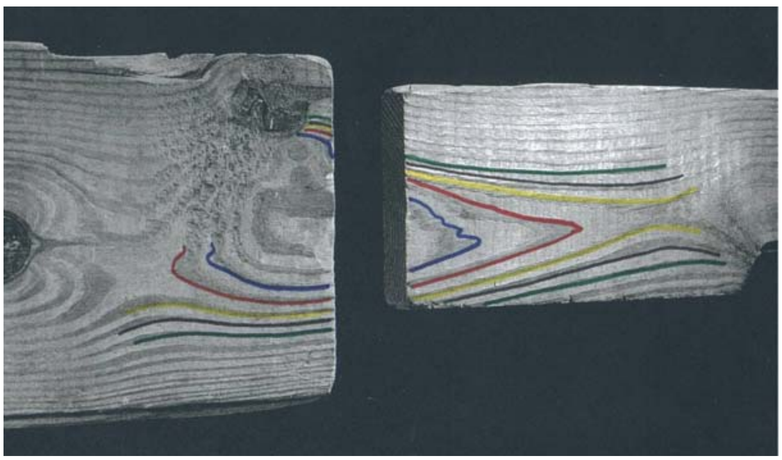


Figure 8: Comparing the bark (attic top) side surface grain of Rail 16 and S-226 in the alleged attic position. Rings have been color-coded on outer edge of latewood, which is the dividing line between annual rings.

Colors of rings: Blue=Ring 15; Red=Ring 16; Yellow=Ring 17; Black=Ring 18; Green=Ring 19.

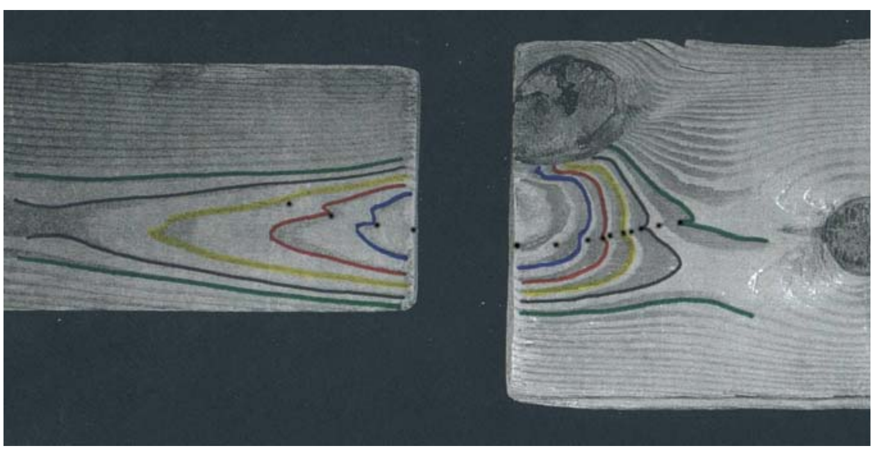


Figure 9: Comparing the pith side surface grain of Rail 16 (left) and S-226 in the alleged attic position. Photo taken with boards in same position as in Figure x. Rings have been color coded on the outside edge of the latewood, which is the dividing line between annual rings. In addition, the locations of the V-grooves on the surface and end grain have been plotted.

Color of rings: Blue=Ring 3; Red=Ring 4; Yellow=Ring 5; Black=Ring 6; Green=Ring 7. (NOTE: Early photographs show one additional ring on the pith side of S-226, just below the knot; this small chip of wood apparently has fallen off since. For this reason, the numbering system begins with #2.)

Relationship between end grain and surface grain

During the trial, Arthur Koehler provided a demonstration: he cut off one half of a picture of the end view of Rail 16 and laid it over S-226 (Figure 29). This was done in order to show the similarity in the sequence of rings. However, critics have sometimes pointed out that in order to make the match, the image of Rail 16 had to be lifted up above S-226. This has been claimed to be proof that Koehler fabricated evidence.[20]

This assertion, however, is based on a misconception. It assumes that rings travel straight up a tree, and maintain the same distance from the pith (the center of the tree) all along the trunk. In reality, this is not the case. Tree trunks are irregular in shape, and the growth layers follow these irregularities. The curves and whorls often visible on the surface grain of boards are, in fact, examples of this change in relative location. In Koehler's photo,

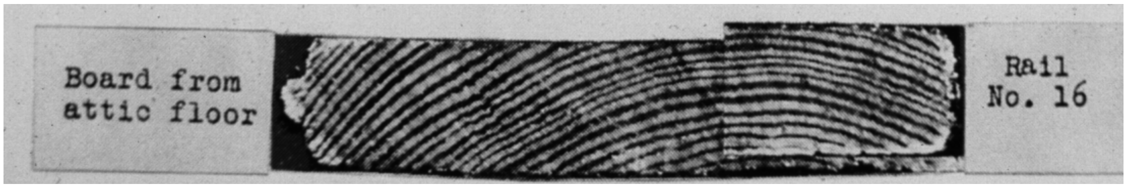


Figure 10: Koehler's photo of the end views. Photo courtesy of Forest Products Laboratory, Madison, Wisc.

the end view sequence is offset by two rings. This was found to be consistent with the surface grain, where two inner rings are visible on the bark side surface of S-226, at a swell near a knot at the end of the board, but are not visible on the surface of Rail 16[21] (Figure 8). Therefore the offset of the rings that is visible in Koehler's demonstration photograph is not a discrepancy. In reality it displays consistency between the side surface grain and end grain patterns, and demonstrates that the combined ring patterns of the two boards create a plausible three-dimensional relationship.

End Grain Comparison

The knots and surface grain represent patterns in the vertical growth of a tree. The end grain allows for comparison in a completely different dimension, the horizontal thickening of a tree. The light and dark rings visible in the boards represent changes in patterns of cell growth. Early in the season, trees produce "**earlywood**" (light rings) in which the cells have thin walls, large diameters, and a lighter appearance. Later in the season the tree produces "**latewood**" (dark rings) in which the cells have thick walls, small diameters, and a darker appearance. Generally (but not always) there is one light and one dark ring produced in a year, and the "**annual**" ring is a combination of one earlywood and one latewood ring.[22] The variations in ring thickness result from a variety of factors: age of the tree; local climate during the growing season; disturbances from within or from outside the forest stand, and other factors.[23] Additionally, not all rings within a given stand of trees show the same amount of variation. A tree high up on a hill, for example, may be more "sensitive" to changes in rainfall patterns, as it depends on the rain fall for moisture. A tree that is down the hill, along the edge of a stream--a more dependable source of water--may be more "complacent", and show less variation in ring thickness from year to year. Tree ring patterns, then, vary from tree to tree.

Rail 16 is narrower than S-226, and a knot at the end of S-226 distorts the grain near the groove edge, rendering comparison in that area meaningless. The author used the remaining section, an area about 1-5/16" wide was used. Since tree ring scientists typically work with a "core sampling" about 3/16" in diameter,[24] the 1-5/16" end view samplings of Rail 16 and S-226 were considered to be more than sufficient, and allowed for a wider range of comparison than typical core sampling. For this study, four avenues for comparison of the end views were explored: variations in thickness in the rings along the arcs; specific points of similarity; variation in the shape of the arcs; comparison of the thicknesses of the series of rings.

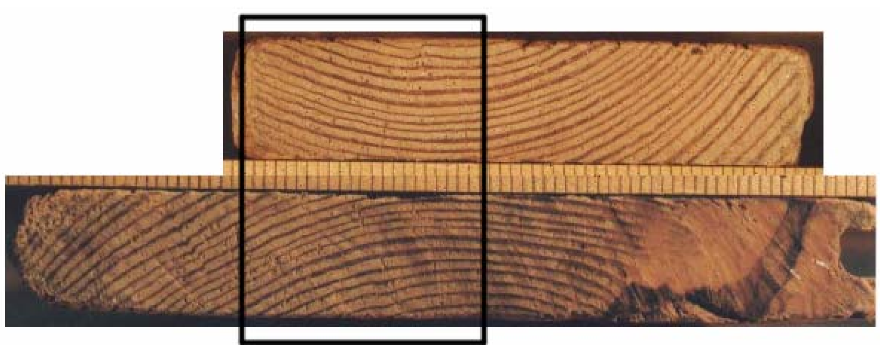


Figure 11: End views of Rail 16 and S-226, in alleged attic relationship. Rail 16 is on top. Rectangle indicates sampling area used by author for comparison (Figure 12). Note that Rail 16 has been stained with silver nitrate; consequently the color is lighter. Photos were taken with unfiltered tungsten lighting. Slight variation in scale.

Variations in thickness in the rings along the arcs (see Figure 12): Tree rings often vary in thickness around the circumference of the tree, depending on grown patterns in each section of the tree. Both samplings revealed similar variations in ring thickness around the arcs. In both samplings, the latewood sections of rings #6, #7, #8, #10 and #11 were thicker at the tops of the arcs than farther down to the left. In the case of latewood ring #12, both boards exhibited the same variations: the ring was thick at the top of the arc, thinner to the right of the top of the arc, and then thicker again farther to the left.

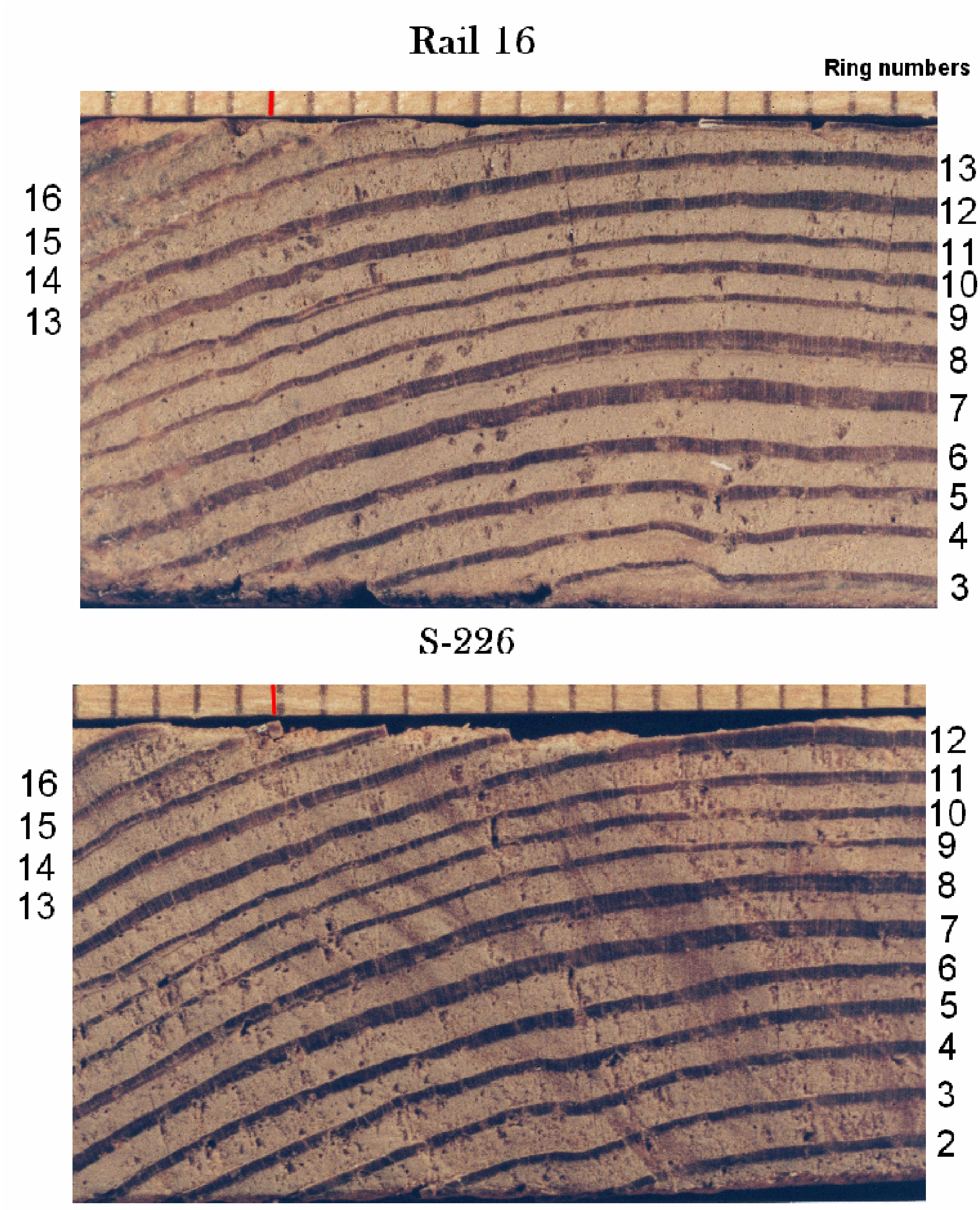


Figure 12: Sample areas of Rail 16 (top) and S-226 (bottom). Image of Rail 16 has been reversed in order to show it in correct alignment with S-226. The spacing marks on the ruler visible in the photos are in 1/16" increments. The red marks on the rulers indicate the approximate alignment of the two pieces when the boards are in the alleged attic position. Rail 16 is slightly lighter due to staining with silver nitrate. Slight variations in scale may occur between both photos. Photos unretouched except for alignment marks.

Specific similarities: One identifiable characteristic in cambium growth is the occurrence of "false rings." These are unusually narrow areas of what appears to be latewood. They generally occur towards the (outer) end of the earlywood area. False rings may be the result of late frost, insect infestation, periods of draught followed by heavy rain, or other causes.[25] False rings tend to be less clearly delineated that true latewood rings.[26] False rings are specific to locale, and not every tree in an area will have false rings in the same location. An inspection of Rail 16 and S-226 revealed false rings in the same locations on both boards:

- Ring #8 appeared to have two: a very thin false ring, barely visible in the earlywood, and a somewhat thicker false ring in the lower part of the latewood section. On both boards the thin ring was less visible farther down the arcs.
- Ring #11 appeared to have small areas of false ring at the top of the arcs, and long partial false ring areas on the far left sides of the sample areas.
- Ring #13 had some partial false ring areas in the vicinity of the red alignment marker.
  Ring #14 had a false ring, but its full extent on Rail 16 could not be determined due to wear on the surface.

Both boards also exhibited a series of v-shaped curves in the lowest rings (#3 & #4). These V's were not in horizontal alignment in the two end view pictures. However, it should be recalled that the paths of the grooves along the surface are curved (see Figure 9); the V-groove locations in the end view are consistent with that curve.

Comparison of the curve of the arcs and thickness of the rings

In order to compare the arcs of the rings, a photographic overlay was set up. High contrast images of both end views were created. The images were transferred to transparencies. When the transparencies were laid over each other and tilted slightly, an alignment was created in which the rings on the two boards were almost perfectly consistent in arc and thickness over most of the sample area (Figure 13). Anatomical similarities, such as the thick latewood section of ring #12 and the partial false ring area on the far left on ring #11 were in alignment. The diminishing thickness of rings #7 and #8 also aligned.

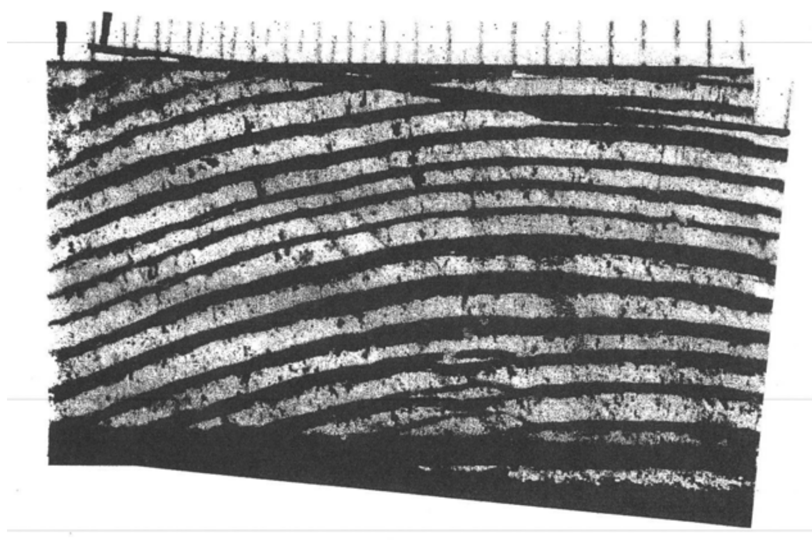


Figure 13: Overlay of transparencies of scaled, high contrast images of the sampling areas of Rail 16 and S-226. Photo by author.

Dr. Warren Thompson was asked about the validity of tilting of the two photos in the composite. He suggested that the shift could be attributed to a change in the shape of the trunk as it approaches a knot area.[27] He noted that tree ring arcs often change in angle along the length of a tree trunk. Wood specimens examined by the author showed this same tendency.

The transparency overlay test demonstrated the almost perfect match-up of the thickness of the rings in the sampling area. In the overlay, one can see directly through the lighter earlywood rings on both transparencies. This could only occur if every annual ring in the sequence, and every earlywood and latewood section of each ring matched in thickness over the entire sequence. If even one of the rings varied to any substantial extent, the transparency match-up would be out of alignment.

Professional comparison of the Rail 16 and S-226 ring thickness patterns, and of the end views

For this study, macro-photographs of the end views were sent to Dr. Allan Drew of the State University of New York School of Environmental Science and Forestry (SUNY-ESF). Dr. Drew measured a sampling of the earlywood and latewood rings' thicknesses to the nearest 0.5 mm and developed regression printouts for the measurements. Dr. Drew wrote, “The correlations were about what I would expect if the two boards were from the same tree. Had the boards come from separate trees, the R squared [regression] values would have been a lot lower.”[28] Dr. Drew summarized his conclusions by saying, “It is highly unlikely that these two boards came from separate trees. How unlikely is that? Quantitatively, if you sampled 1 million trees where their growth rings showed the same degree of complacency/sensitivity as R16 and S-226, you might find that in one of those trees you could conclude that the two end views were not from different trees. Even that may be to0 conservative a figure, given the conditions.”[29]

A portfolio of photographs of the end views and surface grain comparisons was examined by Dr. Gordon Jacoby, a Dendrochronologist at the Lamont-Doherty Earth Observatory of Columbia University. Dr. Jacoby and Ms. Nicole Davi, a Research Technician, used a densitometer to analyze the patterns of the rings. Dr. Jacoby and Ms. Davi wrote:

> “There are only 17 rings common on each board. This number is not usually enough to make a series of ring widths that would have a unique pattern of growth. However the patterns of ring width variations match and support the idea that the two pieces are from the same board. In addition to the total width of annual rings, the width of the latewood within each of the rings can be compared. The latewood widths also match between the two pieces of wood. Under magnified examination one can see thin bands in several rings on each photograph. The presence of the thin bands or “false” rings matches between Rail 16 and floorboard S-226. Photographs of the two piece of wood at the same scale can be aligned visually to show the correspondence between the rings and anatomy.
>
> “The combination of agreements between ring widths, latewood widths, curvatures, and false rings strongly supports the hypothesis that they are from the same board. Also the direct photographic comparison is strong graphical evidence of anatomical matching. Our conclusion is that they are from the same board.”[30]

A similar portfolio of photographs was sent to Dr. Warren Thompson. After he had been given a chance to examine the photos alone, he was sent the reports by Dr. Drew, Dr. Jacoby and Ms. Davi. He wrote,

> “I should state up front that I agree fully with the conclusion reached by Drs. Jacoby and Drew that R16 and S-226 are sections of the same board. The correspondence of grain pattern...supports that conclusion. However, the most convincing evidence is...the end grain of the two sections. The correlation of annual ring, earlywood and latewood widths between the two sections is such that it is extremely unlikely that they represent two different boards....The level of agreement is such that it is unlikely to have occurred by chance, and provides convincing evidence in support of the hypothesis that R16 and S-226 are sections of the same board.”[31]

Discussion and conclusions regarding the relationship between Rail 16 and S-226

The true relationship between Rail 16 and S-226 could be one of three possible realities: (a) coincidental similarity; (b) a faked relationship; (c) two sections from one original board. Clearly the number of similarities identified in this research rule out the plausibility of coincidence. But could the relationship have been faked?

The notion that the police could go to a lumberyard—or even a series of lumberyards—and find these very exact matching patterns in a separate piece of wood is extremely problematic. Tree ring patterns are very specific to locale; if such a similar end view ring pattern did exist, it would almost certainly have to come from the same stand of trees. Yet identifying the local origin of the Rail 16 board would be a daunting task. It is not even possible to determine the exact species of Rail 16, and the various species of southern yellow pines have different ranges. Loblolly, for example, grows in regions from Texas to New Jersey, and in a range of climates, such as the Mississippi Alluvial Flood Plain; the Cumberland Plateau; the coastal areas of South Carolina; and the high elevations of the Appalachian Mountains.[32] Within each region, the climatic factors that affect tree ring growth, such as sunlight or rainfall, will vary.

If somehow the police identified the stand of trees from which Rail 16 originated, it would very likely be long gone, if all the trees were clear-cut when the Rail 16 tree was harvested, years before the arrest. The wood from this stand could be anywhere, and in various forms of boards; if any similar arcs of rings existed, they very probably would have a different location in the end views of any other boards.

Yet if the police were somehow able to find trees with the same end view ring patterns, this would not be enough. The samples from Rail 16 and S-226 share a number of very minute and specific similarities, such as the variations in ring thickness, and the false rings in matching locations. According to Dr. Drew, one may have to examine at least a million boards with "the same degree if complacency/sensitivity" to find such a similar end view. Trees from the same stand with a different amount of exposure to sunlight or moisture would not match.

A search for such an end view would be complicated by other factors. The end cuts on stacked lumber are often not very smooth or readable. In order to see the very fine details of the end views, such as the false rings, the police might have to trim or sand the ends of boards they would encounter in their search. The police would require some means of measuring or comparing these minute details to Rail 16. The police would be limited to the down-tree end of the boards—since the knots would have to grow in the same direction, and the gap end of Rail 16 is the up-tree end of the board. Trees with heartwood would have to be eliminated. Finding a board with an exact match of tree rings then, or even a fairly similar set, would be an extraordinary feat.

Yet if, in spite of all of these obstacles, such a precise match of the end views were found, the problem would not yet be solved. The surface grain patterns exist on a totally different dimension from the end view grain; they represent the vertical growth of the tree as opposed to the horizontal. There are an infinite number of possible arrangements here as well. Even if the very specific patterns in the end view were miraculously duplicated on another board, there could be no guarantee that the surface grain patterns would align into a plausible pattern. If the police found the "one-in-a-million" end view match-up, they would most likely have to search through many, many of these "one-in-a-million" match-ups to find plausible surface patterns alignments on the bark side. If they found it, they still would not be through; *the pith side surface grain must align as well.* If at any of these steps, the wood does not match up, they would have to start all over again, most likely having to search through millions of boards for a new piece.

Further, there is the problem of the planing patterns. Photographs document that Rail 16 was never re-planed.[33] S-226 would have to be replaned to match the thickness of Rail 16, and the characteristics of the torn grain, raised grain, etc. would also have to be added. Planing would change the location of the surface grain; if one found the perfect match of end-views, one would have to plane the two side surfaces and hope that, after the planing, the patterns display a ring-for-ring alignment on both the bark and pith sides.

In conclusion, an analysis of the physical evidence demonstrates that finding and dressing a board to make it appear to be a continuation of Rail 16, matching the characteristics of the Rail in the number of ways that S-226 does match, would virtually impossible. The only plausible explanation for the true relationship between Rail 16 and S-226 is that they were once the same board.

IV. Examining the relationship between Rail 16 and Hauptmann's attic floor

For this study, four aspects of the relationship were explored:

- The question of pre-existing nail holes in the face of Rail 16
- General characteristics in Hauptmann's attic
- Construction patterns of the attic floor
- Planing characteristics of Rail 16/S-226 and the attic boards

The question of pre-existing nail holes in the face of Rail 16

One essential question that has been debated over the years is the number of nail holes that were present in the side of Rail 16 on the night of the kidnapping. Currently there are four (Figure 14). They are rectangular, and are consistent with the shape of nail holes created by old-fashioned cut nails: wedge-shaped nails cut out of stamped iron, which leave rectangular holes. The nail holes on Rail 16 are wider on the attic top/bark side. This indicates that this side was the entry side for the nails, since cut nails are wedge-shaped.

During the trial, Dr. Erastus Mead Hudson, testifying for the Defense, claimed that when he worked with the ladder in March of 1932, there was only one such nail hole.[34] Hudson's testimony and other comments have since fueled speculation that Rail 16 was planted in the attic. However, the author found four memos, all dating from the period prior to the arrest, and all mentioning multiple cut nail holes in Rail 16:

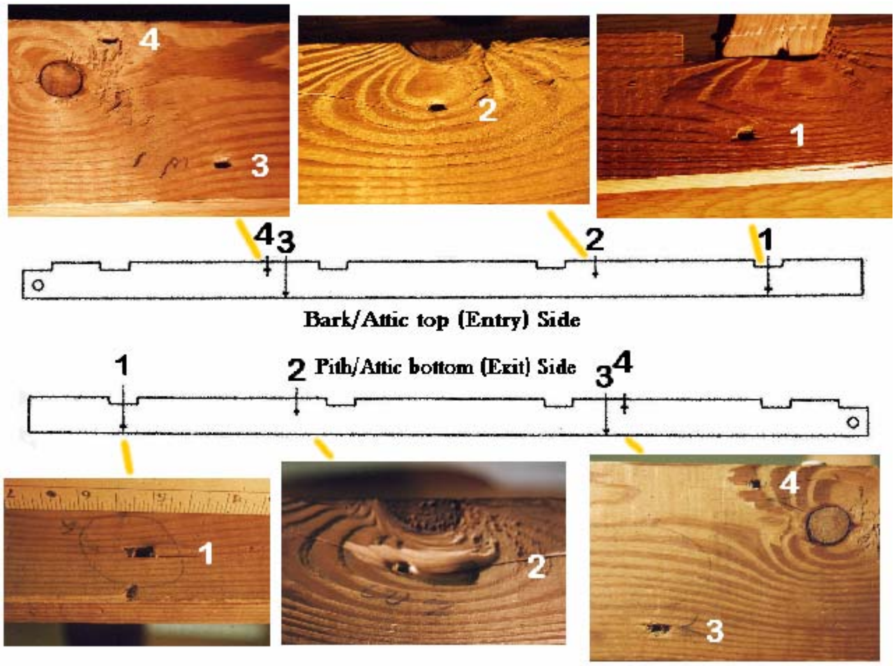


Figure 14: Left, Photographs and locations of the four nail holes currently in the face of Rail 16. Photos vary in scale. The diagram is adapted from a drawing by Arthur Koehler. The nail hole numbers have been assigned numbers by the author. Nail #2 chipped out a piece of wood on the exit side (bottom center). The small dark spot below nail hole #1 on the pith side is not a nail hole but a small area of compressed wood along the edge. Nail hole #1 was identified and circled by Dr. Erastus Meade Hudson during the trial. His small "H" is visible in the upper left. Below, cut nails from Hauptmann's attic.

- A Forest Service report, dated, June 1, 1932, written by H. S. Betts, describes 4 cut-nail holes on Rail 16.[35]
- Arthur Koehler's preliminary report, dated March 4, 1933, mentions 4 cut-nail holes on Rail 16.[36]
- A handwritten letter by Koehler, dated December 10, 1933, mentions multiple cut-nail holes on Rail 16.[37]
- A preliminary FBI report, dated 2/16/34, mentions multiple cut-nail holes on "the sides of the top section" of the ladder.[38] Rail 16 was part of the top section of the ladder; since Rail 17 (the other rail in the top section of the ladder) has no cut-nail holes, the report appears to be referring to Rail 16.

The author also found that a number of photographs from the period prior to the arrest of Hauptmann displayed images of nail holes in the locations of the present ones. Among these photos were the following:

- The Springfield photograph (Figures 4 & 15) contains images in the location of nail holes 2, 3 & 4. (Nail hole #1 would be out of camera range.)

- Police photograph of the ladder against white wall (Figure 15). This photo is not dated. However, in the photograph Rung #11 (bottom) is shown to be split but complete. According to memos and photos by Koehler, one half of this rung was missing by the time he began investigating the ladder in 1933.[39] The picture, then, appears to pre-date Koehler's involvement. In this photograph, distinct images of nail holes #2, #3 and #4 are clearly visible. Nail hole #1 is out of view behind rung #11.

- New York Daily News, March 5, 1932 (not shown[40]). This photograph appeared in the Daily News on March 6, 1932. The original was found in the New York Daily News Archives. In this photo, nail hole #1 is visible. This is the one nail hole recognized by Dr. Hudson during the trial. Hudson's nail hole can be identified as #1 because he circled and initialed it during the trial[41]. The circle and initial are still visible on the board today (Figure 14).

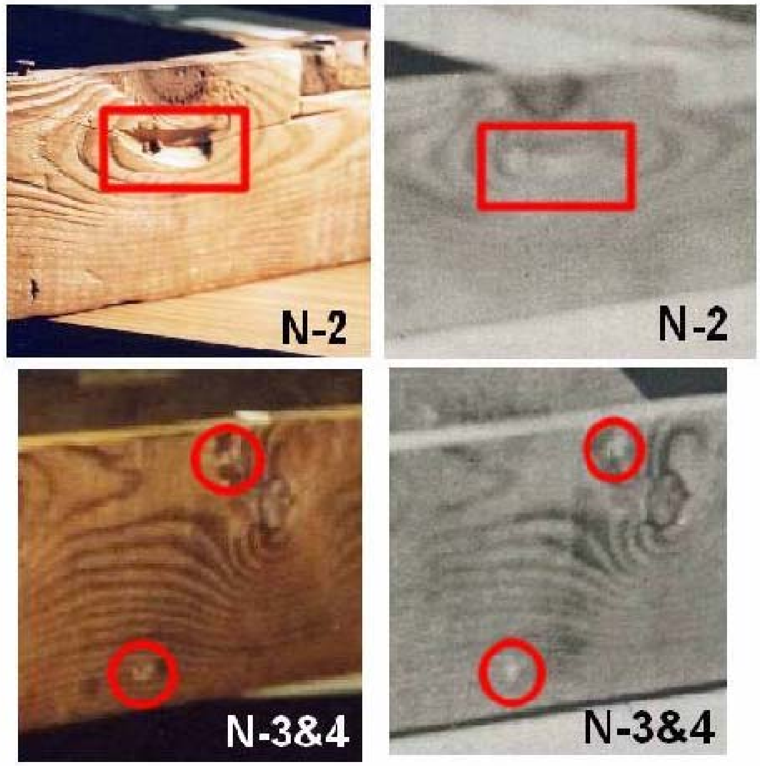
In summary, recurring images of nail holes appear in photographs taken prior to the arrest. Taken as a whole, the photographic evidence and written reports verify that all four of the current nail holes were present in Rail 16 in the days immediately after the kidnapping, and prior to the arrest of Hauptmann.

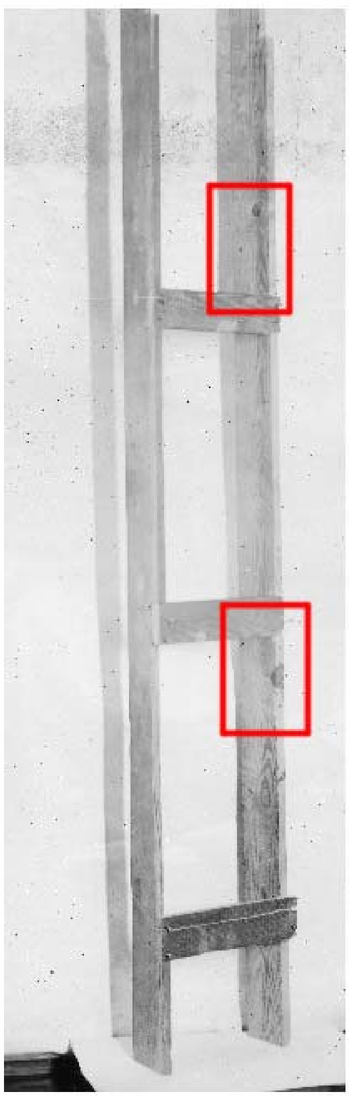
Figure 15: Pre-arrest photographs showing images of the nail holes.

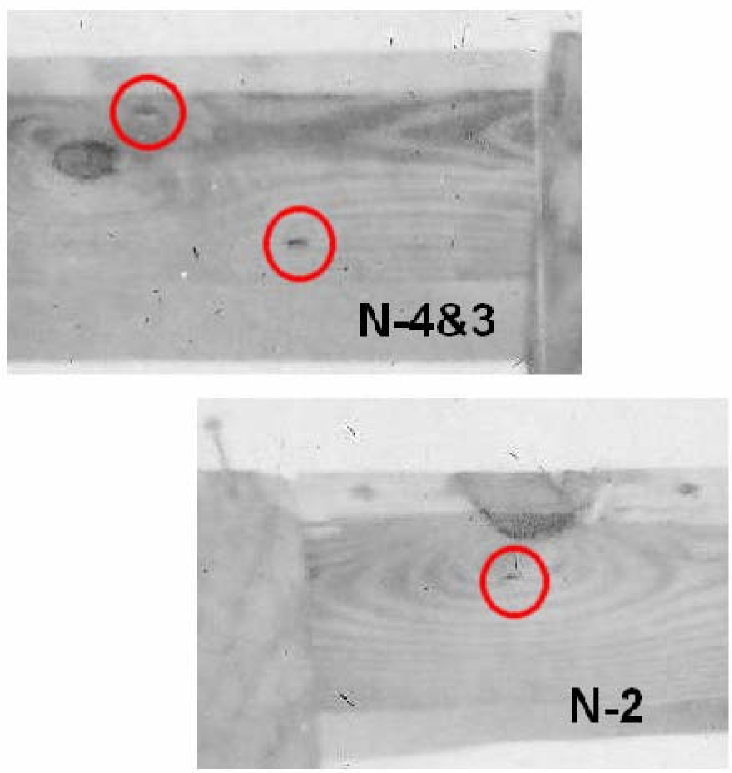
<u>Top Two Rows</u>: Recent photos of nail holes (left) compared to Springfield photo (right and Figure 4).
<u>Lower Left</u>: Police photo of ladder. Section of Rung #11 (bottom), lost prior to March of 1933, is still in place, indicating photo was taken before that date.
<u>Lower right</u>, details from police photo, showing images of nail holes.

Nail hole #1 is out of range in Springfield photo, and behind rung 11 in police photo.

Police photo courtesy New Jersey State Police Museum.







General characteristics of Hauptmann's attic

Hauptmann lived in an upstairs apartment in a two-story house in the Bronx. Access to the attic was gained from a small hall closet in his apartment. The house was atypical, in the sense that the roof line followed the short width of the house, rather than the longer length; consequently, the attic floor joists ran from front to back. Because long floor joists were required, the joists were spliced, meaning that shorter lengths of wood were used but overlapped and nailed together. This is typically done over a strongly supported, or "load bearing" wall.

The attic was partially floored. According to a Koehler memo, the carpenter left the boards long in order to "facilitate handing them up through the attic window."[42] An inspection of period photographs of the attic corroborates this statement; except for those in the vicinity of the attic hatch, no cuts are visible on the boards, and the surface grain is uninterrupted. (If shorter boards were used, the surface grain patterns would change at the points where the boards meet.)

The floorboards were described by Koehler as "1 x 6 Matched N. C. Pine."[43] "1 x 6" is a nominal size indicating wood dimensions before the boards were planed. In reality the boards were about ¾" thick and generally a little over 5" wide. "Matched" is a technical term, meaning that the lumber has a tongue-and-groove joint on either the edges or the ends.[44] "N.C. Pine" is an abbreviation for "North Carolina pine", another term for southern yellow pine. The floor was nailed down with 8-penny cut nails, and some of these are still embedded in samples of attic boards kept at the New Jersey State Police archives.

Hauptmann's apartment, then, included a number of general characteristics that were necessary for a relationship with Rail 16/S-226:

- His apartment building had an attic.
- His apartment had access to the attic.
- The attic had a floor.
- The floor was southern yellow pine.
- The floor boards were about ¾" thick.
- The boards were nailed with old-fashioned cut nails.
- The boards were nominally 6" wide.
- The boards were tongue and groove.

The first 6 characteristics could not have been altered by the police, unless they replaced the entire floor. Interviews conducted by the author of professional insulators working in the Bronx indicated that this combination of attic characteristics were only present in a very small percentage of Bronx attics.

Figure 16: Hauptmann's attic. S-226 is in the foreground on the left. Rail 16 is not installed; it would go above S-226 in the picture. Grooves edges of the boards are towards the left side of the photo. Boards appear to be uncut along their entire lengths. Photo courtesy New Jersey State Police Museum.

Implications of the tongue and groove floor

The patterns in the construction of the tongue and groove floor offered another avenue for testing the relationship between Rail 16/S-226 and Hauptmann's attic. If Rail 16/S-226 was originally part of the attic floor, the installation patterns should include the rail board. If the board was planted in the attic, the remainder of the boards should demonstrate a plausible installation pattern that is not dependent on Rail 16/S-226. As a planted board, Rail 16/S-226 would either have been an *additional* board inserted into an existing attic floor, or a *replacement* for a board previously existing at the end of the floor.

The police presented Rail 16 as having come from the southwest corner of Hauptmann's attic floor. (The south side of the house was the front.) There were 26 other floorboards in the attic, and so Rail 16/S-226 would make a 27th.[45] Below the location of the 27th board was a load bearing wall[46] and a splice in the floor joists.

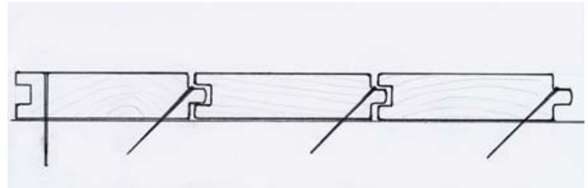


Figure 17: Typical nailing pattern for tongue and groove flooring. The first board laid, on the left, is the "toe-board". This toe-board is face nailed at the groove edge. The other edge of the toe-board and the other board are "blind-nailed".

When installing a tongue-and-groove floor, the first board lain is called the "**toe board**". This board is typically "**face nailed**", meaning that nails are driven directly down through the face of the board into the joists or sub-floor below. Sometimes the entire toe board is face nailed; more often, only the groove edge is face nailed (Figure 17). Typically, each subsequent board is laid with its groove interlocking with the tongue of the previously installed board. A nail is driven into the shoulder of the tongue of this new board, which is then covered by the groove of the next board. This technique is called "**blind nailing**". Because the boards interlock, a board that is blind nailed in the middle of the floor is also held down by the nails in the board ahead of it. Consequently, inner boards that are blind nailed need fewer nails.

Leon Hoage, investigator for Governor Hoffman, identified 24 cut-nail holes in the Rail 16/S-226 area.[47] One of these was found to be very shallow--about a half inch deep[48]--and so apparently was not related to the construction of the floor. Of the remaining 23 nail holes, 14 align with nail holes in S-226 and S-226X, 4 align with the nail holes in Rail 16, and 5 exist in the areas around or beyond Rail 16 (see Figure 3). These 23 nail channels are all close to vertical, and appear in locations in the joists that are consistent with face nailing. The 26 other floorboards were generally blind nailed. According to Koehler, approximately 10 face nails exist in various other locations across the attic floor.[49] The floorboards are oriented with the tongues pointed away from the south (Rail 16) side of the attic. This indicates that the first board lain, the toe board, would have been on the Rail 16/S-226 side of the floor, since blind nailing is done into the shoulder of the tongues.

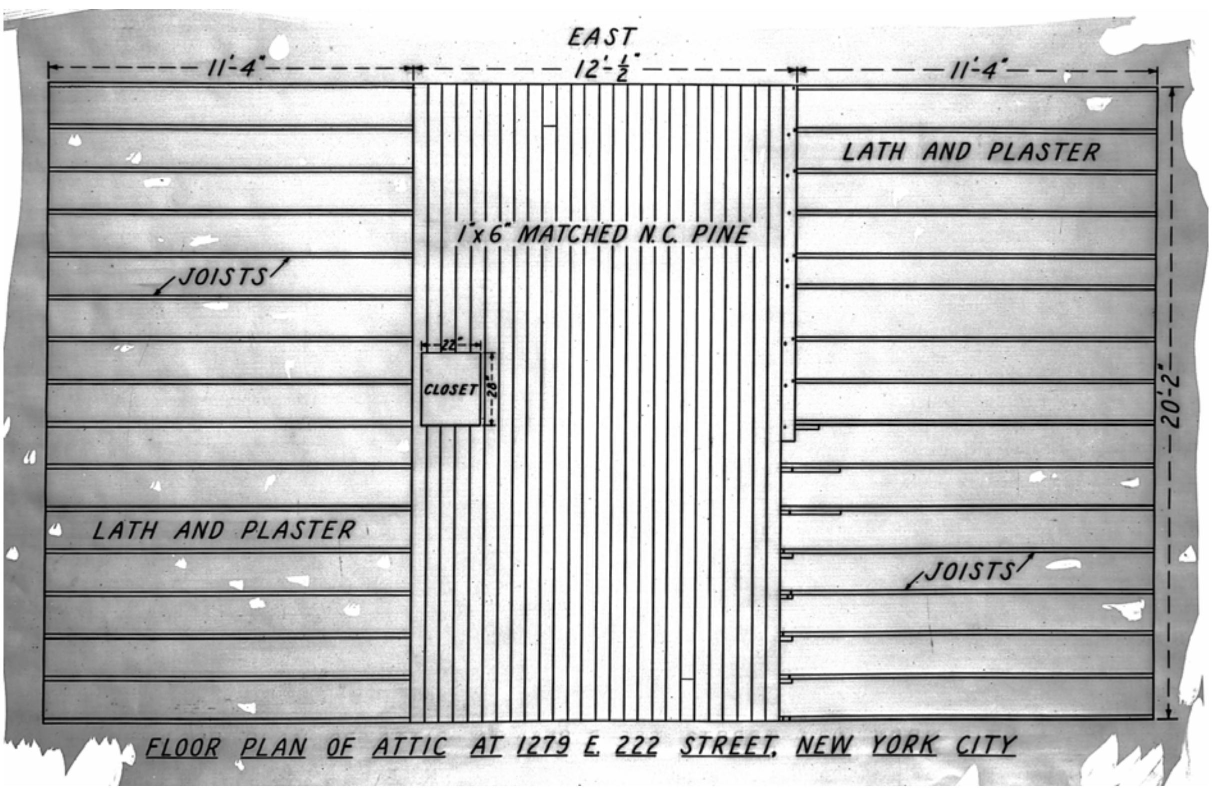


Figure 18: Koehler's diagram of Hauptmann's attic. S-226 is the partial board on the right. Rail 16 is not shown. Photo courtesy Forest Products Laboratory.

Rail 16/S-226 as the original toe board

With Rail 16/S-226 in the alleged attic position, the nailing pattern presents an attic floor with a toe board face nailed with 23 nails, and 26 other floorboards that were generally blind nailed, and occasionally face nailed. The nailing pattern of the attic floor was inspected by Ben Greico of Benjamin's Fine Flooring in Greenwich, New York. Grieco considered it an appropriate pattern, "the way he would nail it down". Grieco suggested that occasional face nails may have been inserted into the other 26 boards due to bumps or irregularities in the wood.

The four pre-existing nail holes in Rail 16 are not spaced at even intervals (Figure 19). Three of them are close to 16 inches apart, a fairly common spacing in construction, since wall studs and floor joists are frequently spaced at 16" intervals. However, the fourth (nail hole #3) is offset, and only matches Hauptmann's attic because the joists are spliced in this location. The pattern of the pre-existing nail holes in Rail 16, then, is consistent with the notion that Rail 16 was part of a toe board, face nailed into spliced joists in Hauptmann's attic. The pattern also indicates that one of the only locations where Rail 16 could be planted into an attic floor would be in a situation where the suspect has a face-nailed board at the location of a splice in the joists. According to Bronx insulation workers interviewed by the author, this is a rare occurrence.[50]

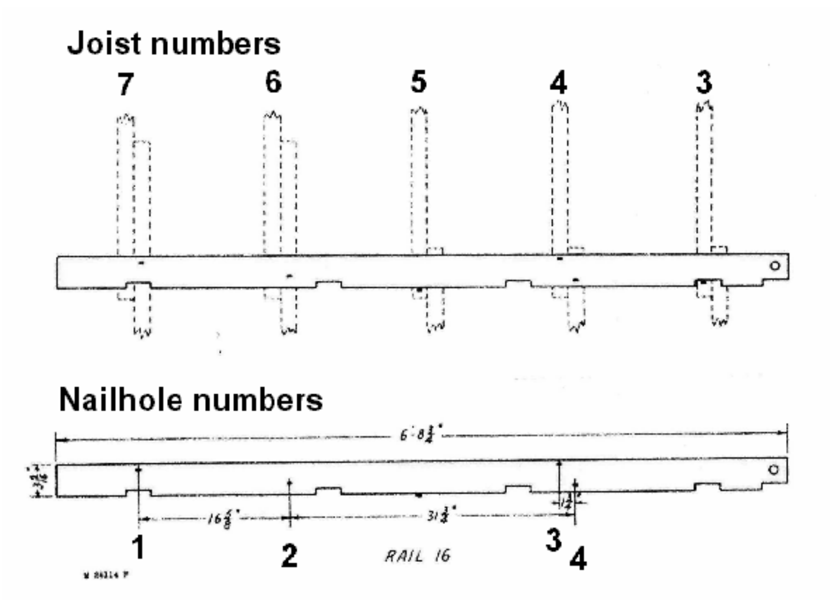


Figure 19: A diagram by Arthur Koehler. (Numbers added to diagram by author.)

Top: Illustration of the alleged relationship between Rail 16 and the attic joists. Note the splices in the joists below the rail, visible in photos of the attic. The joists were assigned numbers when they were split open (see text.) The "A" side is on the left, the "B" side is on the right. This diagram shows only the Rail 16 joist area.

Bottom: Koehler's measurements of the nail hole spacings. The author's own measurements of the nail holes came very close to Koehler's.

Diagram courtesy of New Jersey State Archives.

Rail 16/S-226 as an additional board

Investigators for Governor Hoffman pointed out that Koehler's attic diagram includes an error: the attic is much closer to symmetrical when Rail 16/S-226 not included.[51] This has led to speculation that the attic originally only had 26 boards. However, Board 26—the next board over from Rail 16--has been preserved at the archives of the New Jersey State Police, and the author was able to examine the nailing pattern of this board. There were only nine nail holes along the entire length of the board; eight of them are in the shoulder of the tongue (see Figure 3). There were no nail holes at the ends of the board: at one end the closest nail hole was 15-½" from the end; and on the other, the closest nail was 18-¾" from the end. There were no nail holes along the groove edge, except one face nail, which was a little over an inch from the groove edge in an area where there was a bump in the wood. According to Greico, a carpenter would put nails at the ends and along both edges of a toe board. Overall, he thought that the nailing pattern of Board 26 was that of an inner board. The nailing pattern of Board 26, then, does not support the hypothesis that it was a toe board in a 26-board attic.

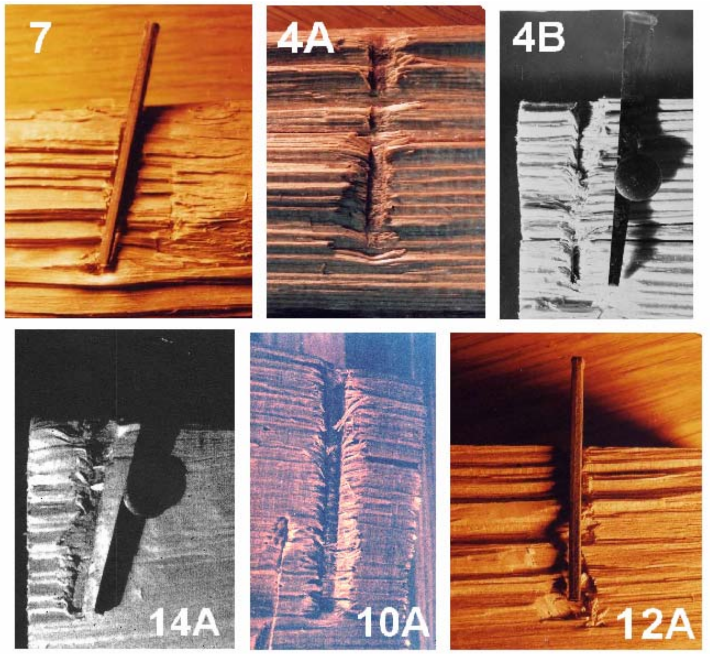


Figure 20: Nail channels in the attic joists. Joist numbers are shown. The joists were numbered from west to east in the attic, which would be right to left in Figure 26. "A" is the left (East) joist, "B" is the right (West). The top three joists correspond to Rail 16 Nail holes #1 (Joist 7), #3 (Joist 4A) and #4 (Joist 4B). The bottom three joists correspond to nail holes in S-226.

Photos 4B and 14A courtesy of Forest Products Laboratory.

Rail 16/S-226 as a replacement board

If Rail 16/S-226 was not added onto a 26 board attic, it might theoretically have been a replacement for a previous toe board, a 27th board that existed in the location where the police presented Rail 16 and S-226. If there had been a board in this place, it would necessarily have used some or all of the 23 cut-nail channels in this area.

Any previously existing nail holes in the Rail 16 area would not only have to match the four nail holes in Rail 16 in joist location, but also in the three angles of the nail channels: left-to-right, front-to-back, and rotation angle of the rectangular shape of the nail. Taken together, this is highly implausible; therefore if Rail 16 replaced a previous toe board in this location, it is highly unlikely that any previous nail holes existed in the joists in the locations of the Rail 16 nail holes.

During Governor Hoffman's investigation, ten of the floor joists were removed and split open.[52] These were inspected by the author. Although they showed signs of wear from multiple insertions (the nails were removed and replaced a number of times during the investigation), none of the split joists revealed multiple channels, or channels varying to any appreciable angle (Figure 20). Therefore if the police wanted to plant Rail 16/S-226 into this space, and if nail channels already existed from a previous toe board, they would have to create nail channels in S-226 that matched pre-existing joist channels in location, front-to-back angle, left-to-right angle, and nail rotation. Moreover, they would have to do this blind, since the nail channels in the joists would be covered by S-226. They would have to nail down through S-226 from above, hoping to hit the unseen, previously existing nail channels dead-on. This process would have to be repeated up to fourteen times--in the author's opinion, an extraordinary feat. They could not make a mistake, because the nail channels in the joists were literally attached to the house.

The wood evidence, then, does not support the theory that Rail 16/S-226 was a replacement for a previously existing board in this location.

Previously-existing nail holes in S-226

The nail hole evidence raised another question: if Rail 16/S-226 was planted, what would have been the nailing pattern of the entire board prior to the arrest? Photographs and memos established that Rail 16 had four cut-nail holes in its face at the time of the kidnapping. The only nail holes in S-226 corresponded to nail holes in the joists of Hauptmann's attic. None of the joists have two nail holes close together. Further, the joists are not all at regular intervals; some of the joist spacings are wider or narrower than the rest (see Figure 3).

Therefore if Rail 16/S-226 was planted, the original board would have to have been a long board, at least 18 feet in length. It would have had four nail holes at one end (Rail 16), and few if any along the rest of the length. Any additional nail holes that did exist on S-226 would have to coincidentally correspond with locations directly over the spliced joists in Hauptmann's attic where no other previous nail holes existed.

Pre-existing wire nails in Joist 7

An inspection of photographs revealed further evidence that supported the claim that Rail 16's originated in the attic. Photographs taken after the arrest show the heads of three common wire nails[53] in Joist 7. They are located in the area where Rail 16 would set if placed in the alleged attic position. The nail channels for these nails are visible in the pieces of the split joist block that was removed from the attic in 1936. They do not appear to relate to the installation of the floor, as the attic floor was installed with cut nails, and no other wire nails were present in the joist blocks retrieved from the attic.[54] Other wood in the attic shows signs of previous usage[55] and it is possible that the wire nails were related to some earlier use of this board. All three nails were angled towards the east end of the attic; because of this, the eastern sides of the nail heads protrude more that the western sides. The top nail in the photos (southern-most) protrudes more than the other two; the bottom (northern-most) nail head appears to be largely embedded (Figure 21).

The appropriate section of Rail 16 was examined for marks from these nail heads. Impressions were found on the surface of the rail in the areas that correspond to the nail heads (Figure 21). At the location of the southern-most nail head (top in photos) Rail 16 was found to have an area of compressed wood with a semicircular imprint, which corresponds in shape and location to the protruding eastern edge of the southern-most nail. Since the police set the rail on top of these nail heads during their investigation in 1934, imprints could have been created at that time. Significantly, however, the imprint of compressed wood on the edge of Rail 16, corresponding to this southern-most nail head, is visible on the New York Daily News photograph taken on March 5, 1932. [56]

Thirty months before the arrest, then, Rail 16 exhibited an imprint that aligned in size and location with a nail head in a joist in Hauptmann's attic when the board was set in the alleged attic position.

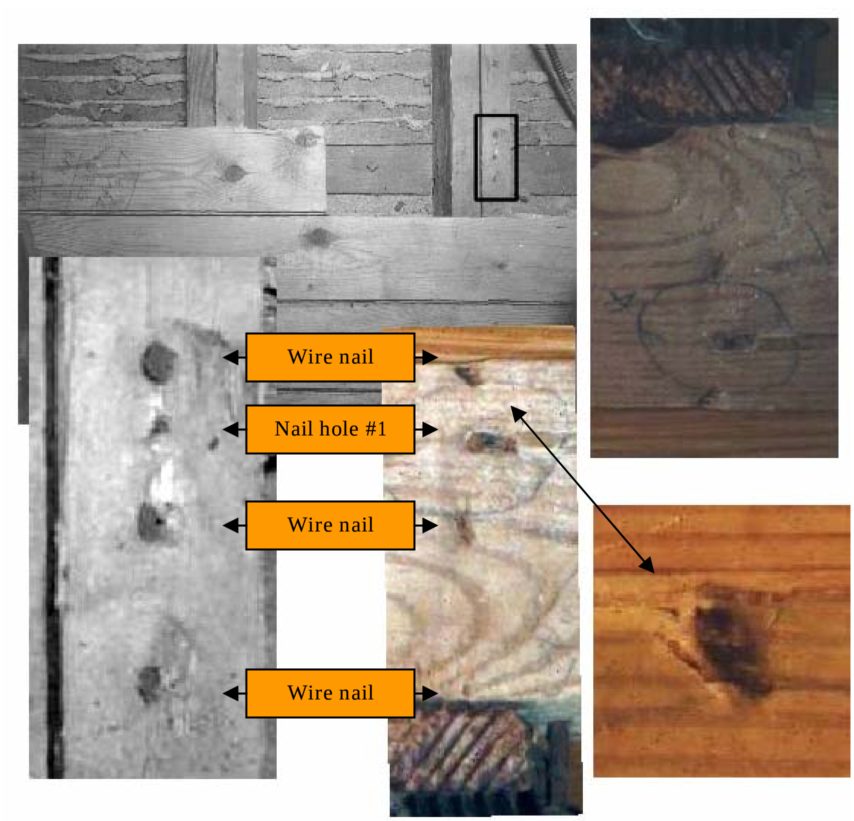


Figure 21: Nail head impressions in Rail 16.

Top left, old police photo taken after the arrest. Rail 16 is not in place. Three nail heads are visible (black box) in Joist 7 below, in the vicinity of cut Nail hole #1.

Lower left, close up of the black boxed area shows that the top nail head protrudes slightly.

Bottom middle, the comparable area of the underside of Rail 16. IMAGE REVERSED IN ORDER TO SHOW ITS ALIGNMENT WHEN SET IN PLACE. Marks are visible in all three places, and most prominently at the edge (top).

Bottom left, close up of the edge mark, showing semicircular shape. This is a section of photo of the Nail hole #1 area in Figure 14. IMAGE REVERSED.

Upper right, this area of Rail 16 as it appears today. An image of an imprint of the same size and location is visible in a New York Daily News photo, taken March 5, 1932 (not shown-see Footnote #9).

Police photo courtesy New Jersey State Police Museum.

Comparing Rail 16/S-226 with boards from Hauptmann's attic

The characteristics and planing patterns of the attic boards offer further avenues for evaluating the claim that Rail 16 originated in Hauptmann's attic. During this study the author attempted to gain access to Hauptmann's attic. This request was turned down by the present owners, who understandably prefer privacy[57]. However, the author did have access to samples of some of the boards from the attic floor:

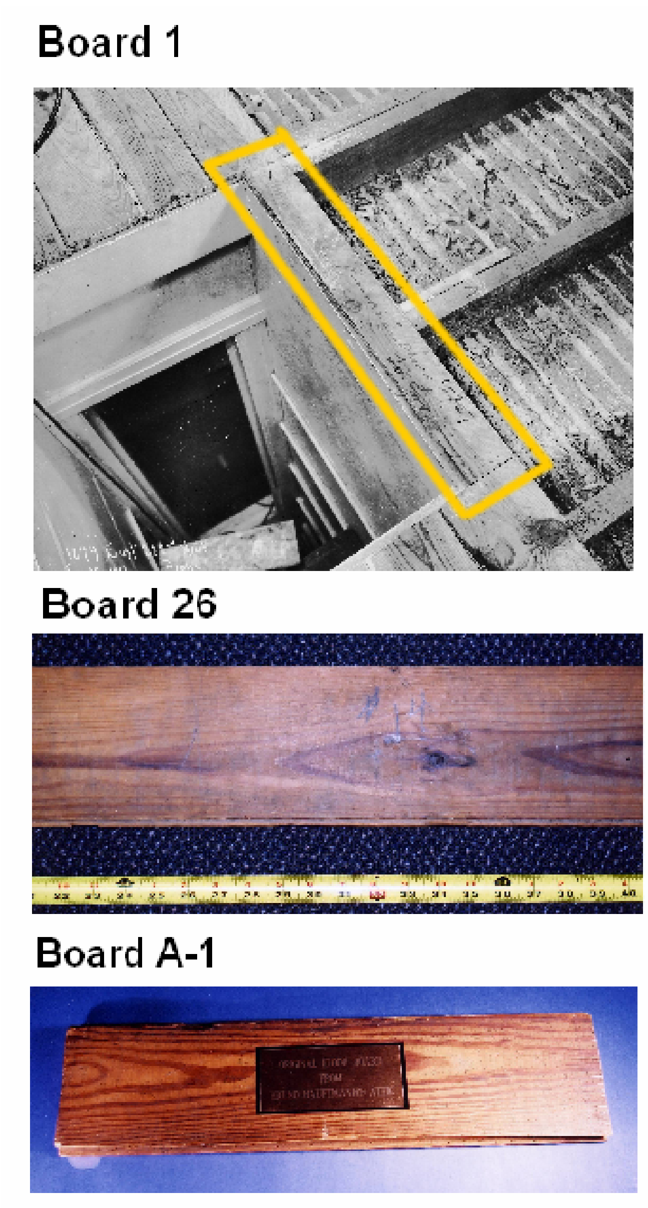


Figure 21: Boards from Hauptmann's attic.

Top, Photo of hatch area taken in January of 1937. On this occasion, Leon Hoage removed a section of Board 1 from the edge of the attic hatch (yellow rectangle). Note saw cuts in corners of hatch area. Arrows and writing are on photo, not board. Middle, Section of Board 26. Bottom, Board A-1. A small plate has been mounted on the board.

Top photo courtesy of New Jersey State Police Museum.

Board 1: A small piece of this board, about 27" long, was removed from the attic by Leon Hoage in 1937.[58] This piece came from the opposite side of the floor from Rail 16. It had been located at the edge of the attic hatch and had been narrowed for the opening; a couple of inches of width, including the groove edge, were removed.

Board 26: Hoage also removed the entire length of Board 26, the next board over from the alleged attic position of Rail 16/S-226.

Board "A": Prior to the author's attempts, two other researchers, along with a friend, were able to visit the attic in 1999. They were given this board, about 25" long, which was evidently one of a series of remnants created when the owners added a pull-down stairwell. The surface grain of the boards, visible in photos taken during the visit, indicate that this board was most likely Board 11, although a definitive determination could not be made. Board A was cut into three pieces in order that the three researchers could share the board. For this study they are termed Boards "A-1", "A-2" and "A-3."

General characteristics of the boards

<u>Species</u>: Dr. Thompson identified Board A as a southern yellow pine. Boards 26 and Board 1 look like southern yellow pines in appearance, but the coarseness of the saw cuts at the ends did not allow for a conclusive identification.

<u>Heartwood and Sapwood</u>: Both Board 26 and Board 1 appear to have heartwood in the center of the boards. Board A and Rail 16/S-226 appear to be completely sapwood.

<u>Color</u>: The wood of Boards 26 and Board 1 is generally more pinkish in color than the other two boards, especially in the heartwood areas.

<u>Nails</u>: During the investigation, 8-penny cut nails from the attic were found to fit into the holes in Rail 16/S-226.[59] Board 26 and Board 1 both still have 8-penny cut nails embedded in them. Board A-1 has one nail hole, and an 8-penny cut nail inserted by the author fit the nail hole.

Thickness: Measurements along the edges found the boards to be similar in thickness, ranging from .738" to .747" in average thickness.

Width: The boards all have one groove wall slightly longer than the others. The widths of the boards[60] were measured, from the tongue edge to the end of the longer groove wall. S-226 and Board A-2[61] were virtually identical in average thickness (5.13" and 5.15" respectively; Figure 22) and Board 26 was slightly narrower (5.09").

Comparing the tongue-and-groove profiles

All of the boards with grooves were found to have one groove wall that is longer than the other. The tongues on all of the boards were also found to be slightly offset to one side. These characteristics are consistent with a "standard match" tongue-and-groove flooring pattern.[62] According to Jim Paustian of Miles Lumber, when a standard match pattern is used for flooring, the longer groove wall is intended to go on top, so that the boards will still appear snug even if small irregularities in the wood make a tight fit difficult. This longer groove is typically thicker to allow for sanding and wear (See Figure 24).

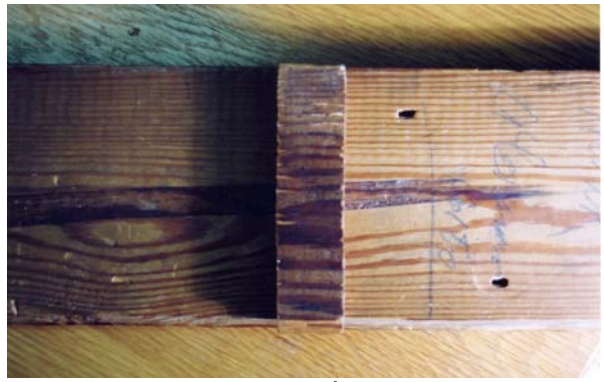


Figure 22: Board A-2 on top of S-226.

On Boards S-226, 26 and A, the tongue is slightly closer to the pith sides of the boards, and the longer groove wall is on the bark side. The bark side of these boards, then, would be the "pattern-top" side. The sample of Board 1 does not have a groove, since it was narrowed for the attic hatch. The tongue of this board is slightly closer to the bark side. When Board 1 is set with the planer marks pointed in the same direction and with the tongue edge on the same side as the other boards, the bark side planning direction of Board 1 aligns with the pith sides of the other boards. This led the author to conclude that if Board 1 was planed with the other boards, it must have been run through the planer with its pith side as the pattern-top side. Based on this assumption, in the following section, the planing patterns of the bark side of Board 1 are compared to the planing patterns of the pith sides of the other boards, and vice-versa.

Board A-2 was used by the author to create molds of its tongue and groove profiles, which were then inserted into the grooves and over the tongues of the other boards. The molds were found to fit the profiles of the other boards (Figure 23).

In the author's experience, in upstate New York, tongue-and-groove profiles in old sheathing boards vary considerably in size, angles and shape. The degree of profile design variation in old Bronx attic flooring was not determined. Nevertheless, an examination revealed that all of the boards with grooves (Boards S-226, 26 and A) had the same three irregularities:

1. The longer groove wall was thinner, rather than thicker, than the shorter groove wall.
2. Specifications typically call for the lower groove wall to be of the same thickness as the space below the tongue. This creates a strong fit, as the lower groove wall is set under the tongue of the board before it. In the case of Boards S-226, 26 and A, however, the groove wall was thicker than the space below the tongue. According to Hendal Price, this variation is called a "mismatch".
3. The lower corner of the groove was somewhat rounded, and there is tear-out along the grooves in this area due to damage or irregularities in the groove-cutting knives (Figure 24).

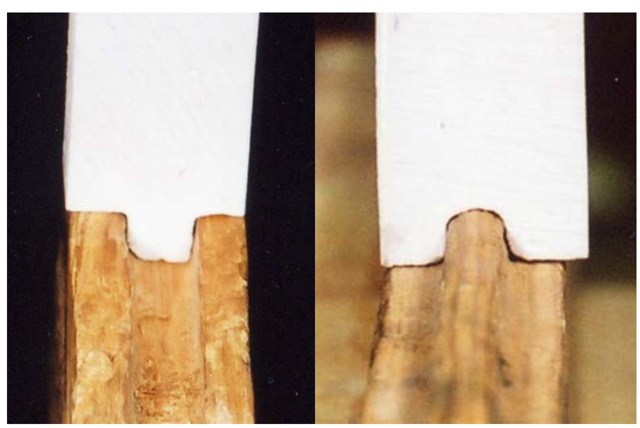


Figure 23: Molds created from Board A inserted over S-226 (left) and S-226 extension (right).

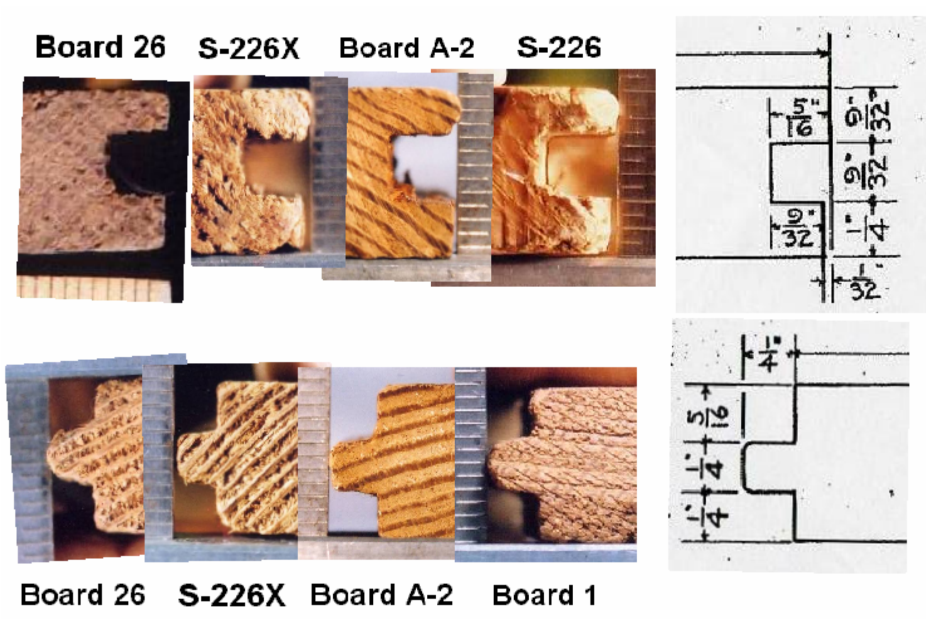


Figure 24: Tongue and groove profiles, of the boards. These corners are often damaged; S-226 is badly deteriorated at the tongue corners and so was not included here. Molds used on inner sections of the edges (Figure 23) provided more accurate comparison. The tongues and grooves are compared here with specifications from the "1926 Official Inspection Rules of the North Carolina Pine Association, Inc." This guide was used in mills in Virginia, Maryland and the Carolinas. The guide illustrates two specification details still in use on standard match patterns today: (1) the longer (upper) groove wall is also thicker; (2) the shorter (lower) groove wall is the same thickness as the space below the tongue. See text for details.

In addition, all of the boards, including Board 1, have the same planer defect along the tongue edge: a thin, scratch-like groove on the pattern underside close to the tongue (Figure 25).

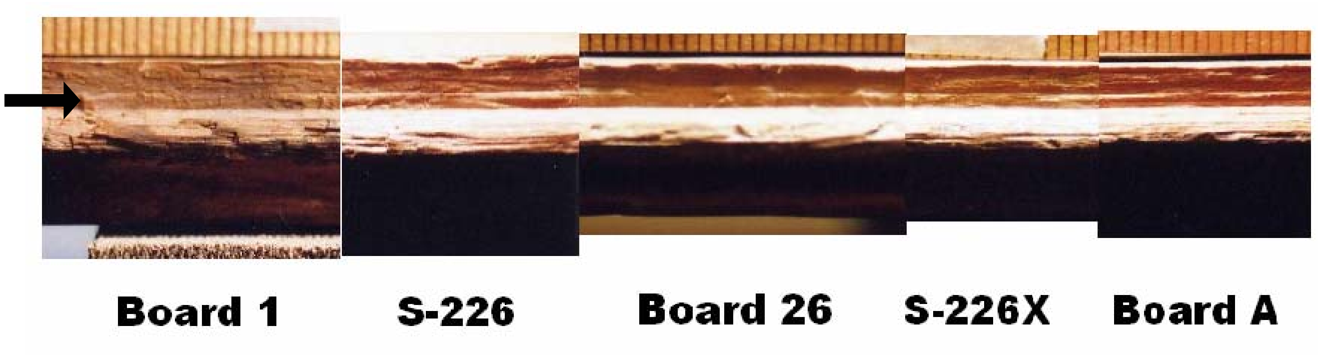


Figure 25: Thin groove-like defect on tongue edge. In this photo, the pattern-bottom side is up, and the groove is visible just above the tongue. Photos to scale.

Comparison of the tongue and groove rotation marks

As a board passes through a planer, the rotation of the tongue and groove knives creates a series of cuts along the edge of the board. If the knives are set up correctly, the cuts are evenly spaced, and close together. This is not the case with the evidence boards. On the groove edge, wide and generally distinct cuts are visible, averaging 0.71" on samplings from boards S-226, 26 and A. On the tongue side, wide cuts are also visible, but they are less pronounced and irregular in spacing. Averages of samplings on the tongue sides varied, as follows: S-226, 0.73"; Board A, 0.70"; Board 26, 0.74"; Board 1, 0.73". The rotation marks were more difficult to measure on the tongue side, as the curves were more rounded, and less distinct. All of the tongue sides had sequences where every second cut was somewhat more pronounced than the ones in between.

Comparison of the side surface planing characteristics

Inspection of the boards found that Boards 1, 26 and A had the same general planing characteristics as Rail 16 and S-226. All of the boards were found to have eight knife marks per inch, with occasional irregularities. As in the case of Rail 16 and S-226, side-lighting of the other boards revealed sequences on both sides in which every sixth knife mark was visibly wider (Figures 27 & 28). The pattern is most visible in areas with little or no wavy dressing. This pattern indicates that all of these boards were dressed on a planer with six knives on both the top and the bottom cylinders. On both sides, one of the knives was offset from the others, and so created the wider groove. All of the boards with knots had significant torn grain in close proximity to knot areas, suggesting that all of these boards were milled at a point when they had high moisture content. Board A does not have any knots, but has some moderate torn grain in the vicinity of surface grain curves near the end of Board A-1. All of the boards have areas of significant raised grain, and areas of wavy dressing.

According to Hendal Price, the irregularity of the knife marks suggests that the knives had uneven, or "wiry" edges. According to Mr. Price, a common technique for improving the quality of the planing is "jointing": an abrasive stone, called a "jointer", is passed over the blades as they are rotating. This technique results in knife marks that are smoother and more uniform. The periodic deep knife marks and jagged edges suggest to Mr. Price that some of the knives may not have been jointed before planing.

Planer defects on the under-pattern side of the boards

In the areas of the sides of the boards close to the edges, where there are a large number of rings, the raised grain and wavy dressing often distort or obliterate the planing marks. Upon inspection, however, the author noted a consistent irregularity on the under-pattern side of the boards (visible on some of the boards towards the bottom in Figure 27). Close inspection revealed this to be a pattern of planer defects, in the form of grooves and ridges, extending approximately 1-5/8 to 1-3/4" in from the tongue edge. (The width of the boards, and of the defect pattern, varies slightly due to board irregularities and shrinkage.) This defect series was most clearly visible on Board 26, which appeared to have come from a somewhat crooked tree; because of this irregularity, some sections of Board 26 that are close to the tongue edge have very few rings, and hence little raised grain. The defect series consisted of a pattern of grooves and ridges on the pith side of the board. The defects are not visible along the entire length of Board 26, as they are often obliterated by raised grain, damage and other factors (Figure 26).

An inspection of S-226 and Board A found remnants of defects that matched the characteristics of those on Board 26. Vague similarities were also found in the appropriate location on Board 1, but the condition of the planer marks was poor.

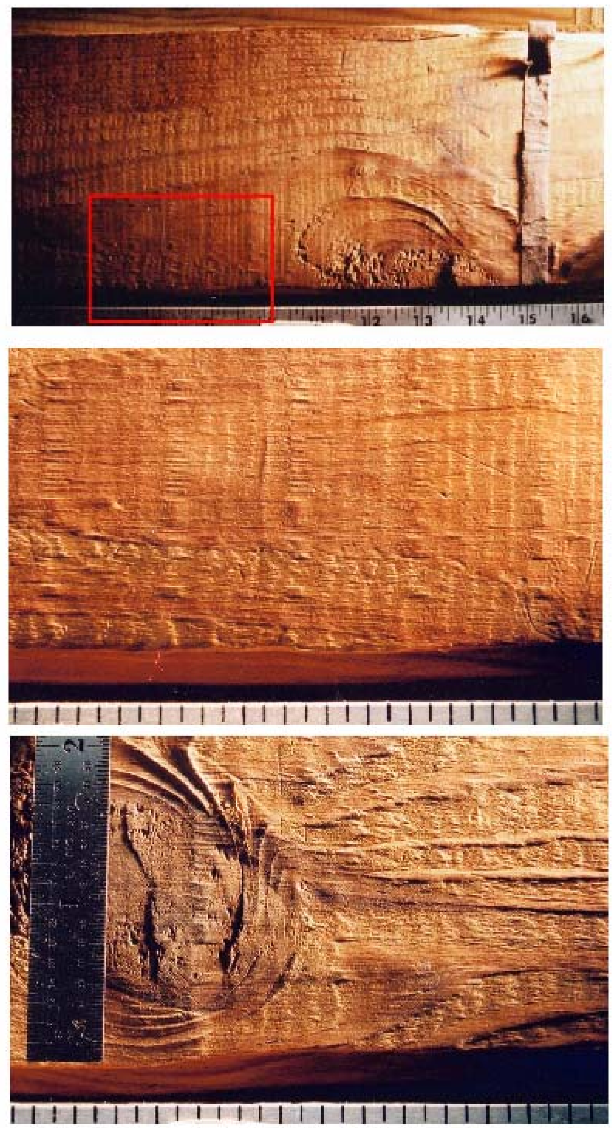


Figure 26: Planer defects on Board 26. Top: Section of Board 26 photographed in oblique lighting, with defect area highlighted. Middle: close-up of defect area from top photo. Bottom: Close-up of another section of Board 26. Note how defect is visible in knot area, but obscured nearby. In all photos planing went from left to right (down-tree to up-tree). Tongue edge at bottom.

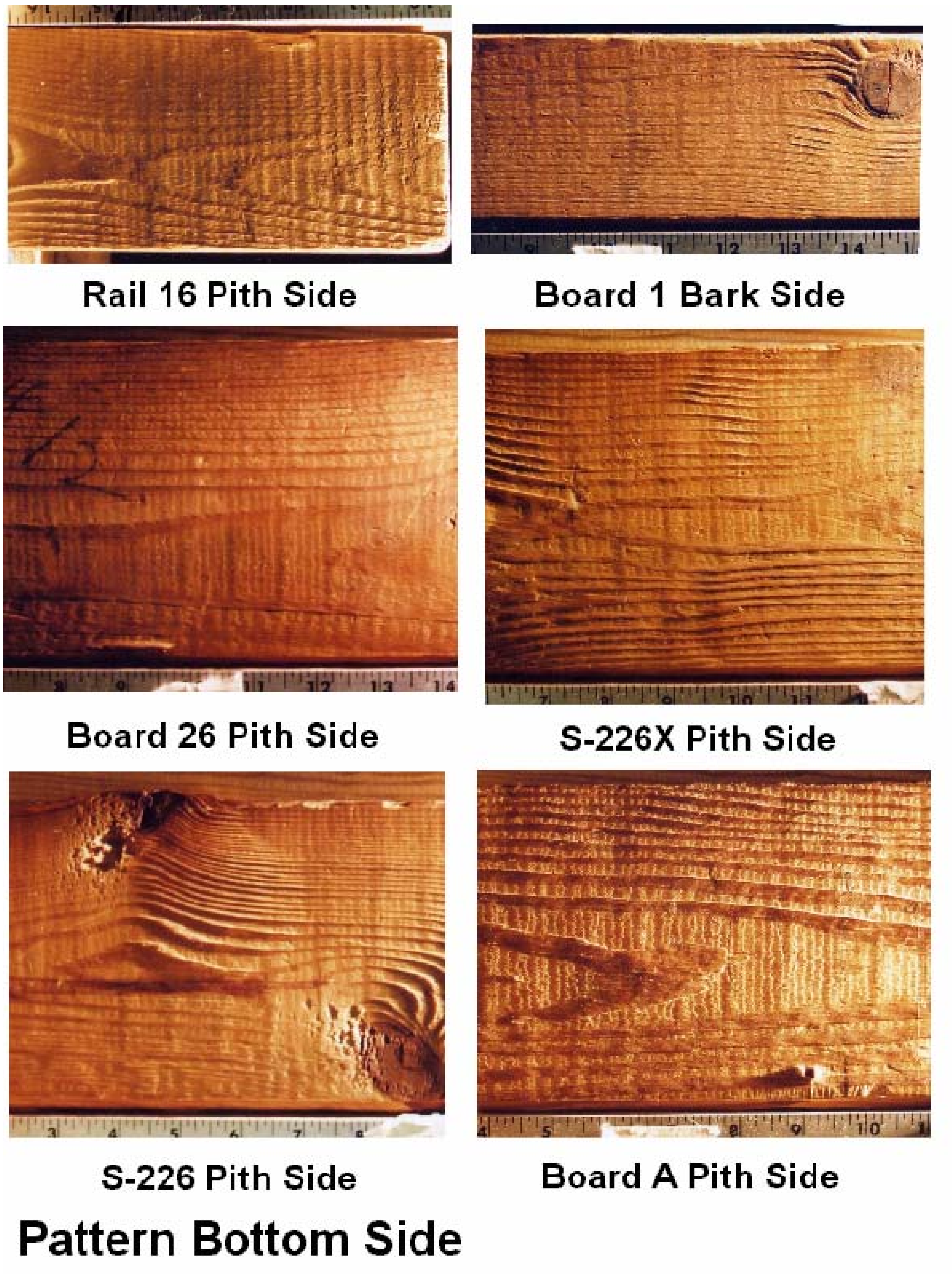
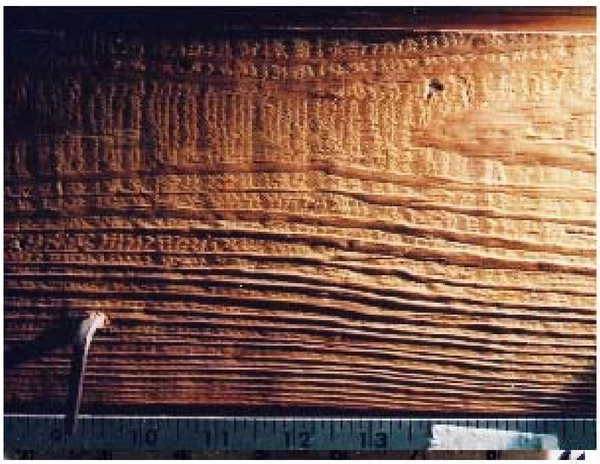


Figure 27: Planing details on the pattern-bottom sides of the boards. The photos are presented to scale, but slight variations may occur. Planing from left to right. Tongue edges down. The photos vary in lighting, condition of the boards and quality of the images.

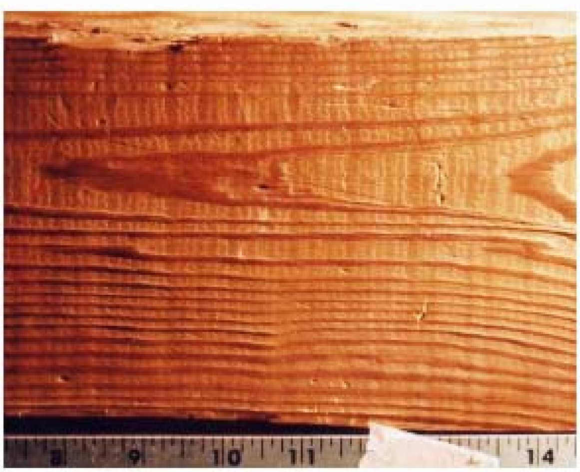
Rail 16 Bark Side

Board 1 Pith Side



Board 26 Bark Side

S-226X Bark Side

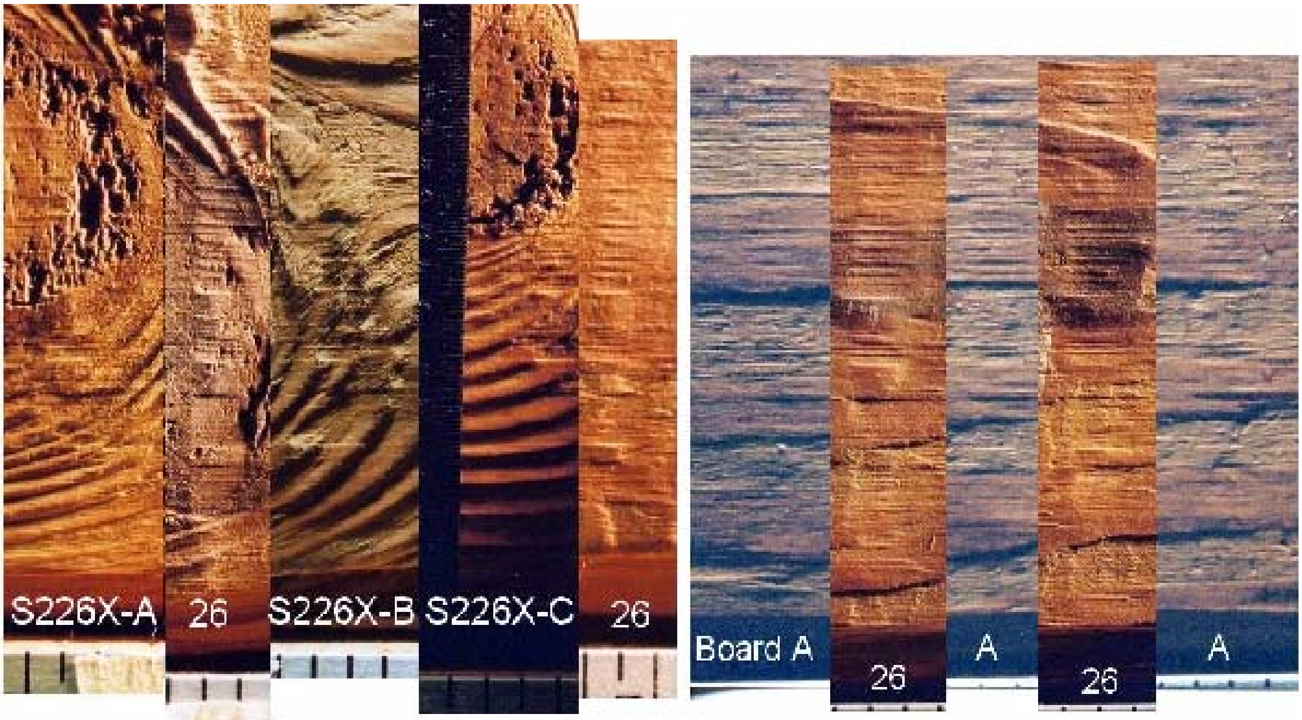


S-226 Bark Side

Pattern Top Side

Board A Bark Side

Figure 28: Planing details of the pattern-top sides of the boards. The photos are presented to scale, but slight variations may occur. Planing from left to right. Tongue edges up. The photos vary in lighting, condition of the boards and quality of the images.



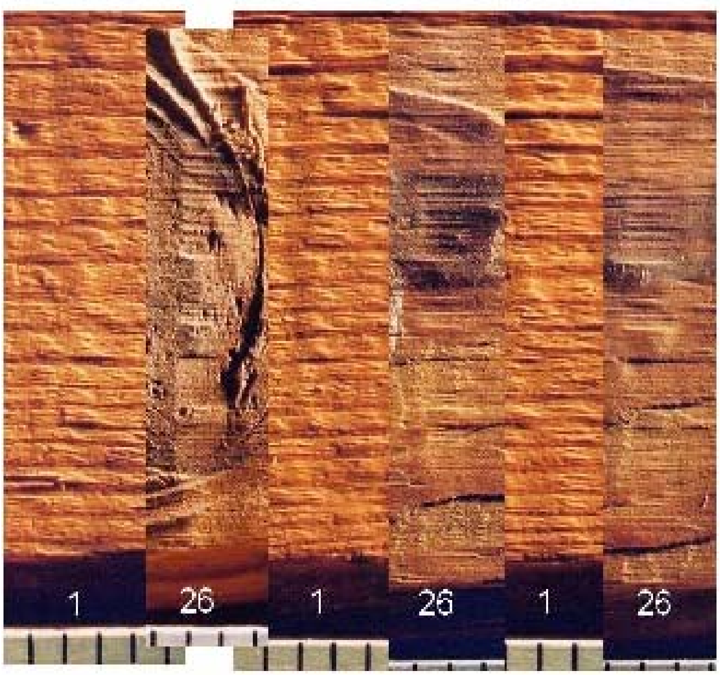


Figure 29: Comparing the planing defect patterns on Boards 26, S-226. A and 1. All comparisons to scale, with occasional slight variations.

Upper left: Samples from the extension section of S-226, compared with Board 26. The knife marks near the tongue edge of S-226 are largely obliterated due to raised grain and damage. However, the author found remnants on the more-protected S-226 extension piece that included several defects consistent with the defect series on Board 26.

Upper right: Remnants of planer defects on Board A, compared with the defect series on Board 26. Again several of the defect patterns are repeated.

Bottom: Remnants of planer defects on Board 1, compared with the defect series on Board 26. Occasional similarities are visible, but the overall quality of the planers mark detail on Board 1 is poor.

When Rail 16 was cut from the S-226 board, a little over an inch was trimmed off of the tongue edge, which narrowed Rail to the width of the other rails. Consequently a large part of the defect area on Board 26 could not be compared to Rail 16. However, the series of planer defects on the wider boards does extend far enough in from the edge that one section can be compared to the ladder rail. In this area, on the pith side of Rail 16, close to the edge that would be comparable to the tongue edge of S-226, the author found sequences of planer defects matching the inner section of the defect series on the other boards. The clearest examples were found in an area of latewood, approximately 66” to 70” from the gap (Figures 30 & 31). The author also discovered at least three additional sequences of this planer defect series along the rest of the rail, in the same relative location.

On the pith sides of Boards S-226 and A, the author also discovered sequences of planer defects very similar in characteristics to the inner series of defects on Board 26 and those on Rail 16, at a comparable distance from the tongue edge (Figures 31 & 32). Similar irregularities were found on the bark side of Board 1, but the read-ability of the planer marks in this area was very poor due to the condition of the wood (Figure 32).

The clearest samples of the inner section of the defect series found on the boards (Figure 33) included the following defects:

A. A rectangular ridge, 0.07” wide.
B. A very thin ridge is sometimes visible trailing off of the end of this rectangular ridge on the up-tree side (i.e., the upper right in the enclosed photographs). This thin ridge follows the rectangular ridge in the planing sequence, and possibly represents a thin defect on the planing knife that immediately follows the one that created the rectangles.
C. A second rectangular ridge, 0.03” wide. The two rectangular ridges are separated by a space of 0.05”. The second rectangular ridge sometimes appears to have a thin groove in the middle.
D. A series of thin ridges.
E. A rounded groove, intermittent along the boards, and sometimes at a slight angle. This groove extends beyond the knife cuts. It may have been caused by a burr in the planer’s pressure bar, which holds down the boards; according to Alden Witham, such burrs can cause a continuous or intermittent groove along the surface of a board.

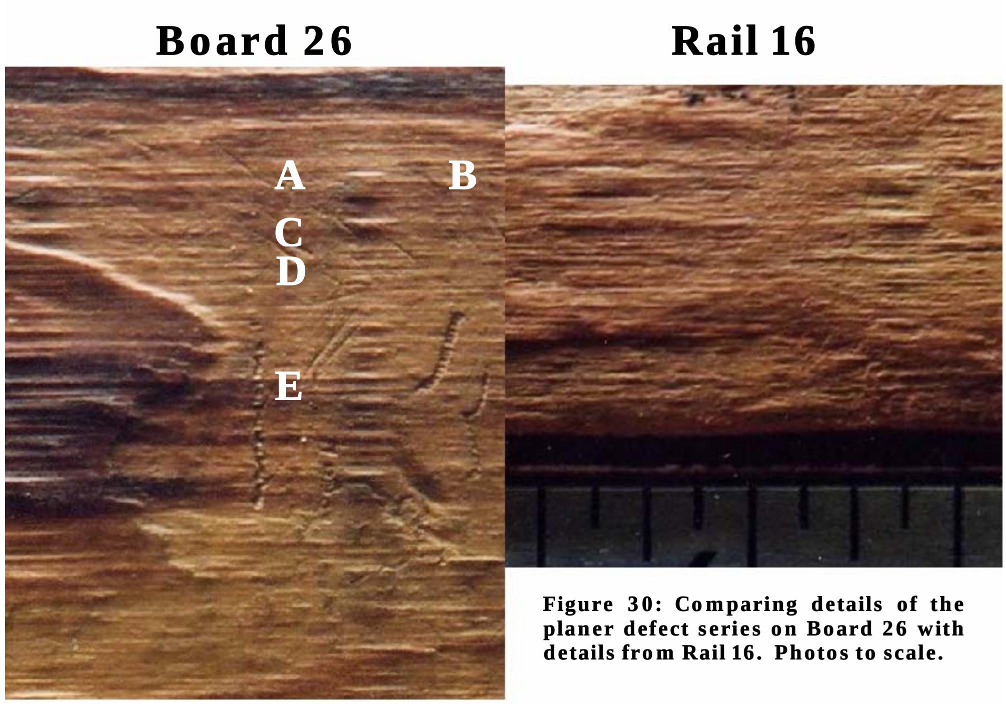


Figure 30: Comparing details of the planer defect series on Board 26 with details from Rail 16. Photos to scale.

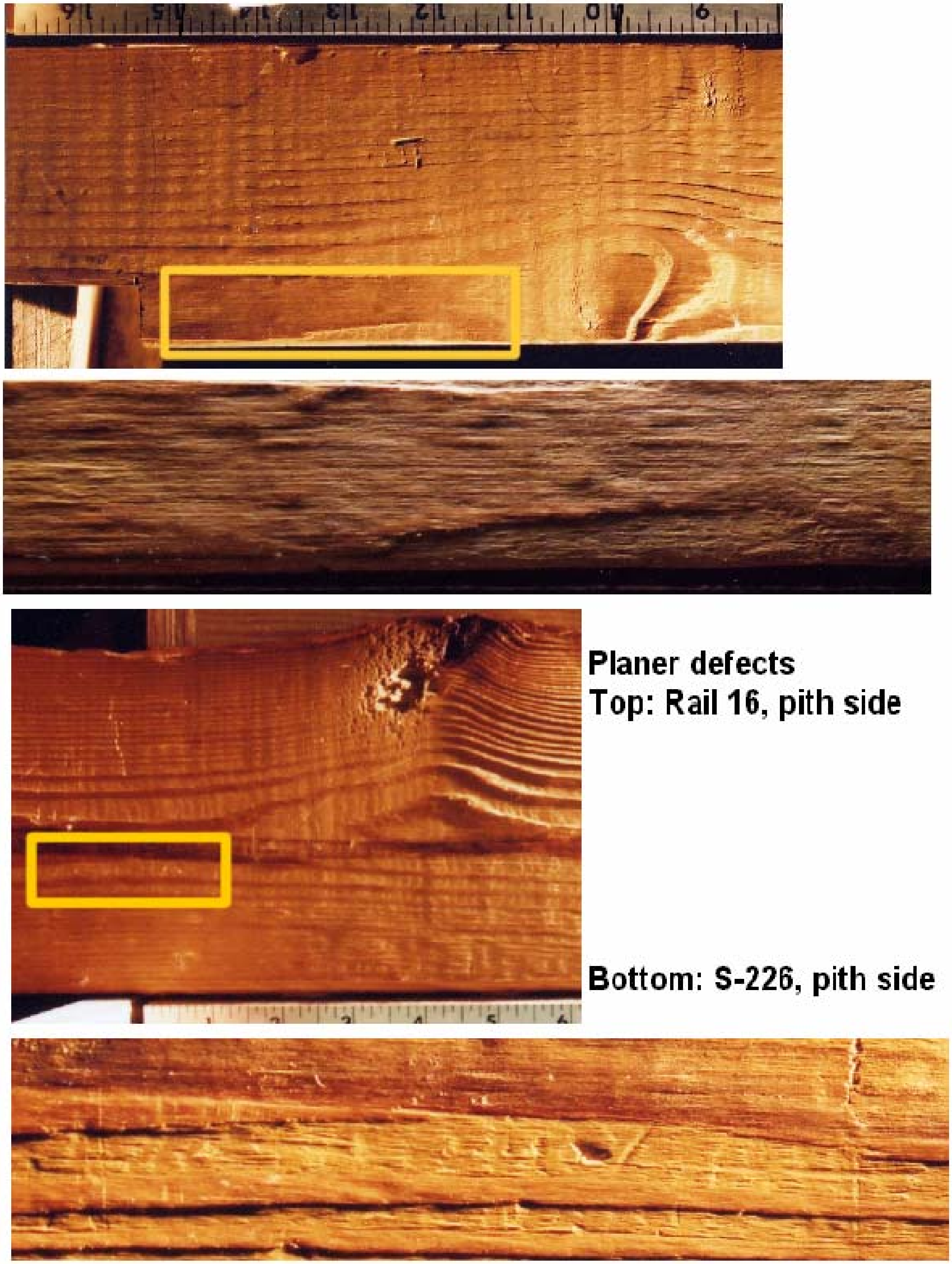


Figure 31: Sequences of planer defects on the pith sides of Rail 16 and S-226. Variations in scale.

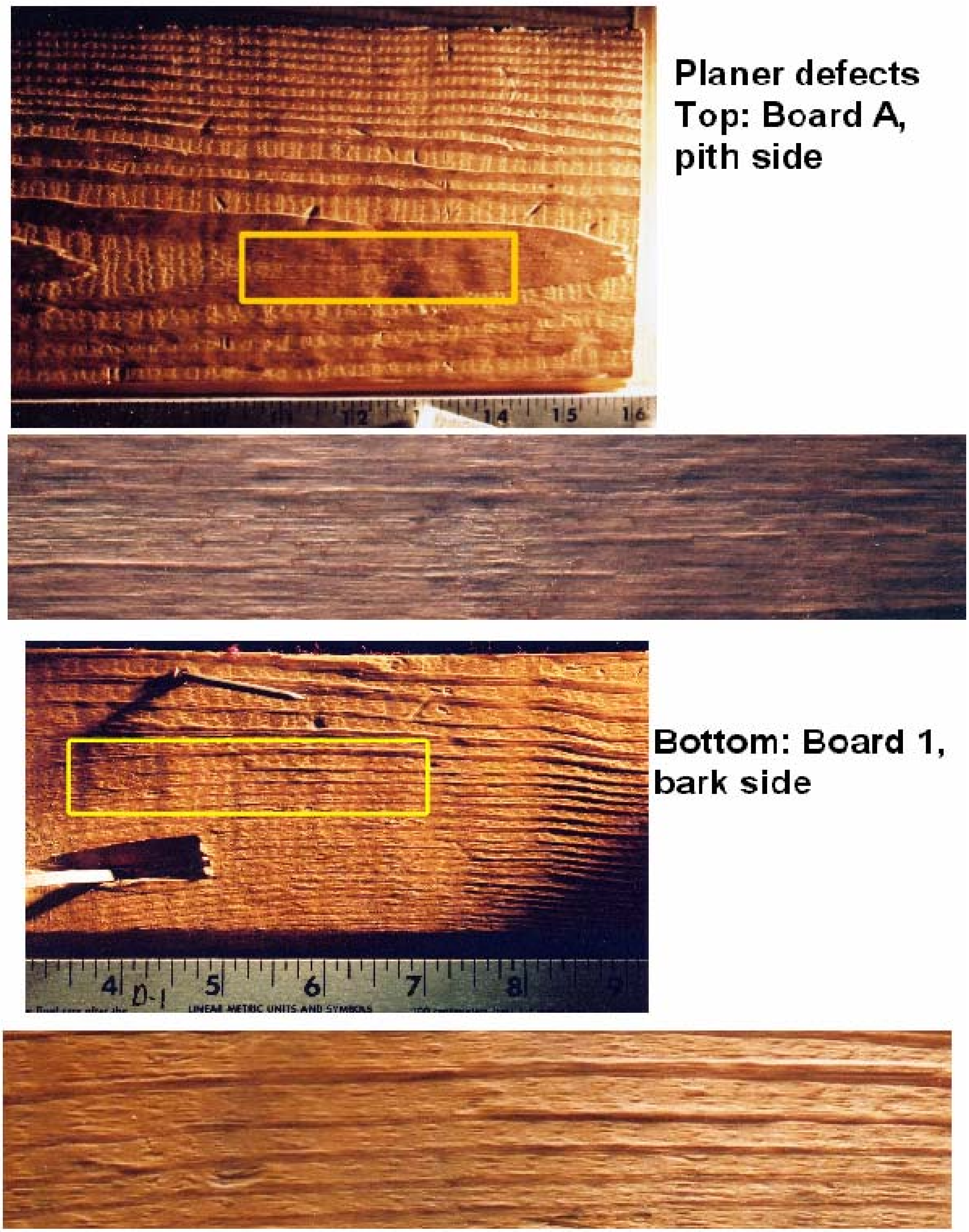
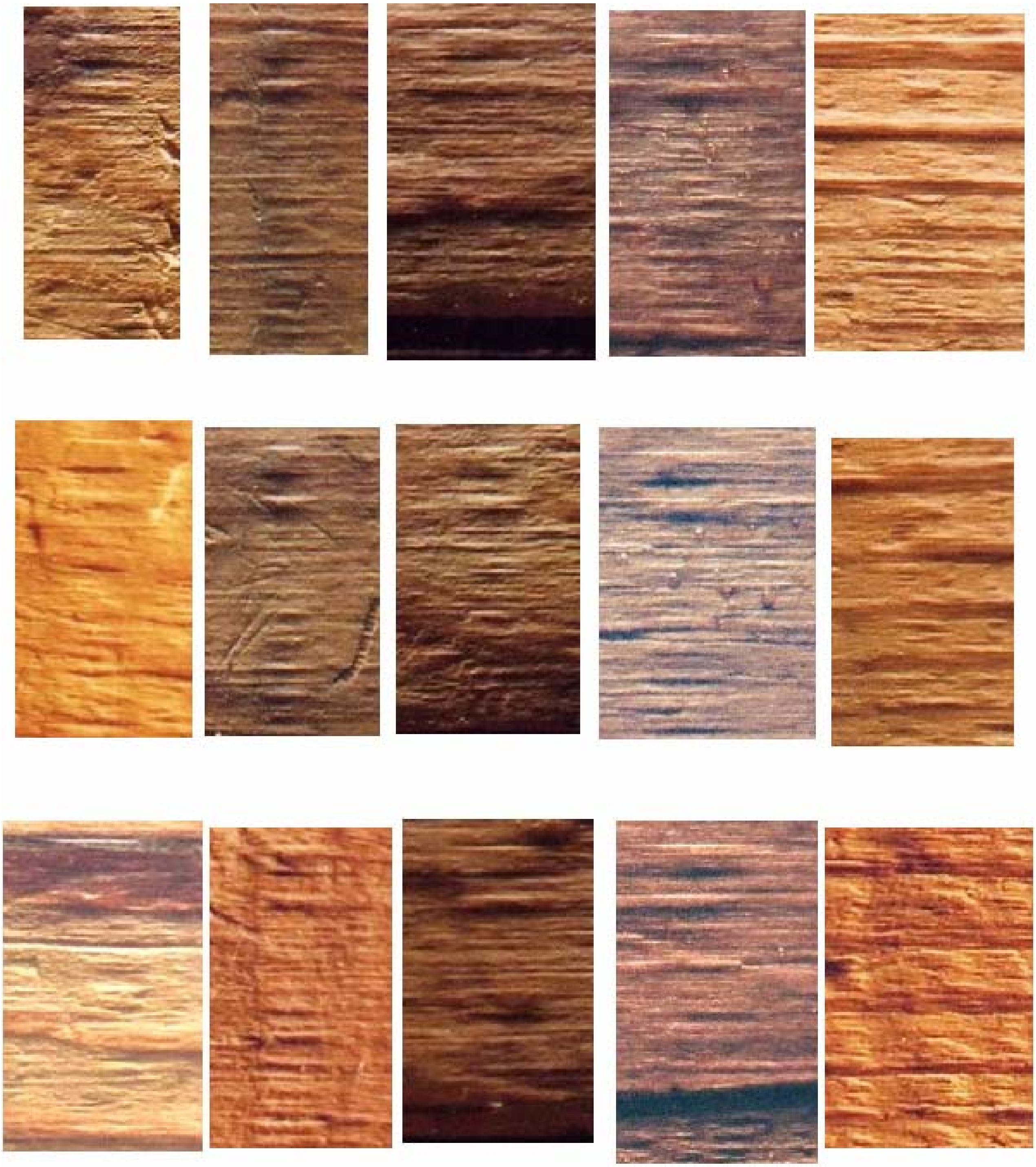


Figure 32: Sequences of planer defects on Board A and vague remnants on Board 1. Variations in scale.



S-226 Board 26 Rail 16 Board A Board 1

Figure 33: Samples of some of the clearest examples of the inner defect series on the boards. The boards vary in condition and shrinkage. Board 1 has the most deterioration, and Board s-226 appears worn, with little detail in this area. The photos vary in lighting and quality. While the author was careful to adjust all of the images to the same scale, some slight variations may occur.

As a further test of the relationship between Rail 16 and S-226, the author compared the relative locations of the two rectangular defects on the two boards. This test was performed using the actual boards as well as photographs. In both cases, when Rail 16 and S-226 were arranged in the alleged attic position, the series of defects on the two boards were found to be in alignment.

V. Discussion and conclusions

What was the true relationship between Rail 16 and Bruno Richard Hauptmann's attic? Was Rail 16 part of the attic floor prior to the kidnapping, or could it have been planted into the attic after Hauptmann's arrest? Which of these two realities does the physical evidence support?

General Characteristics of the attic: Hauptmann lived in a house that had an attic, with an access hatch from his apartment to that attic, and an attic floor built from ¾" southern yellow pine, nailed down by 8-penny cut finish nails. These characteristics are consistent with the hypothesis that Rail 16 originated in the attic. A survey conducted by the author indicated that this combination of characteristics only existed in a small percentage of apartments in the Bronx. Since the police did not target Hauptmann, and could not choose or create these characteristics, theories that the board was planted are dependent on the notion that all of these characteristics existed in the suspect's attic by random luck.

The nail holes in Rail 16: Claims have been made over the years that some or all of the nail holes in Rail 16 were added by the police after the arrest. However, photographs and documents establish that four cut-nail holes existed in the side of Rail 16 immediately after the kidnapping. The nail holes are irregular in spacing, are in the face of the board, and consistent with the notion that Rail 16 was part of a toe board nailed in place at a splice in the joists. According to the author's survey, this is a very rare combination. If the police wanted to plant Rail 16, they could only do so if the suspect happened to have a splice in the joists at or near the end of the floor, with joists spaced in such a way as to accommodate the pre-existing nail holes in Rail 16. Again, theories of planted evidence would have to depend on additional and extraordinary random luck.

The nailing pattern of the floor: When Rail 16 and S-226 are set in the alleged attic position, the nailing pattern of the attic boards is consistent with typical carpentry practice: a toe board that is well face nailed and 26 other boards that are blind nailed, with occasional face nails used where irregularities, such as the bump in Board 26, require additional support. The nail channels cut out of the floor do not support claims that Rail 16/S-226 was added to the attic as a replacement board, as there are not indications of previous cut-nailing in this area or reuse of nail channels. The nailing pattern of the next board over, Board 26, is that of an inner board, and so does not support claims that this board was the first board lain in a symmetrical, 26-board attic. Further, an area of compressed wood along the edge of Rail 16, visible in a photograph taken immediately after the kidnapping, was found to correspond exactly with the location of a protruding nail head in a joist in Hauptmann's attic, when the rail was set in the alleged attic position.

S-226: The fact that S-226 is a continuation of Rail 16 has important implications. Since there is no record of S-226 prior to the arrest, the police would have had to have found this board somewhere during the investigation and kept its existence a secret. The author knows of no evidence to support this concept. The combined length of S-226 and Rail 16 creates a long board, about 18 feel long. This is consistent with the long boards in Hauptmann's attic, although questions remain about the last missing two feet beyond Rail 16. S-226 had no pre-existing nail holes inconsistent with the attic floor; the only nail holes in S-226 occur in locations at or near the middle of the joists in Hauptmann's attic, some of which are irregular in spacing. Therefore claims that Rail 16 was planted depend on the notion that the original Rail 16/S-226 board was coincidentally at least 18 feet long, with four face nails near one end (the Rail 16 area) and few or none along the rest of the board—an unusual nailing pattern.

The planing patterns of the boards: The tongue-and-groove profiles on Boards 1, A, 26 and S-226 all match. Additionally—and significantly--these profiles share four irregularities: a thinner long groove wall, a mismatch in which the lower groove wall is too thick for the space beneath the tongue, tear-out in the corner of the groove, and a thin planer defect along the tongue edge. All of the boards, including Rail 16 have the same basic side surface planing patterns: all were planed at the rate of eight knife marks per inch. All were planed with a planer with 6 knives on both the top and bottom cylinders; on both sides, one of the knives was offset from the others. All have torn grain, raised grain and wavy dressing. In addition, Rail 16, S-226, Board 26 and Board A exhibit a series of minute and specific surface defects. The series of defects on Rail 16 align with similar defects on S-226 when the two boards are set in the alleged attic position, and match the characteristics of similar defects on Boards 26 and A. Board 26, S-226 and Board A all exhibit remnants of a wider series of matching defects. The planing marks on Board 1 are vague; however generally irregularities exist in areas that correspond to the locations of the more detailed irregularities on the other boards.

It is important to note that planer defects are completely random events. On some runs they may not occur at all; on others, multiple defects may occur. They can vary enormously in size, shape, location, number and appearance. As noted above (Figure 30), at least five different defects are visible on the inner sections of the defect series found on Rail 16, S-226, Board 26 and Board A, and vaguely visible on Board 1. The odds against these five defects occurring randomly on different runs of boards from different mills, yet matching in size, characteristics and location, are astronomical. The more extended series of defects, remnants of which are visible on the S-226 extension, Board 26 and Board A, is even more complex.

As noted earlier, the many surface details of the pith side of Rail 16—the side where the defects exist—and visible in the Springfield photo document that this board was not replaned, and so the defects could not have been added after the arrest. The three additional boards inspected by the author were, in essence, random selections from different parts of the attic floor. One of them—Board A—was removed from the attic in 1999, and carries the same series of defects as Rail 16. Taken as a whole, the planing characteristics offer conclusive proof that Rail 16 and S-226 share a common origin with the remainder of Hauptmann's attic floor.

In conclusion, the wood evidence demonstrates that the accusations that Rail 16 was planted into Hauptmann's attic are based on a very complex and implausible series of coincidences combined with feats of carpentry that would be, in practical terms, impossible to perform. Instead, the evidence supports the following scenario:

> Some time around 1926, a stand of southern yellow pines was harvested and cut into boards. Some of the trees were older and had heartwood; some did not. The mill workers did not wait until the wood was fully seasoned; instead, they milled the boards while they still had relatively high moisture content. The boards were planed on a planer with six knifes per cylinder. The mill workers did not adjust the knives correctly, and neglected to joint the knives; consequently the planing cuts were irregular. On both sides of the boards, one knife was offset from the others. On one side, one of the knives was badly damaged before or during the run, and the jagged edge left a series of defects on the boards near the tongue edge. A burr on the pressure bar also left an intermittent groove in this area as the wood pressed beneath it. Because of the high moisture content and possibly due to the condition of the knives, the planing knifes tore out the grain near the knots, and created raised grain along the boards. Because the wood was irregular, with twists and bumps, the mill workers left the pressure bar loosely adjusted. This adjustment may have reduced stalling, but created areas of wavy dressing as the boards vibrated in the planer.
>
> The tongue and groove blades were also damaged. At least one of the tongue knives (or possibly a pressure bar) had a burr that left a long thin groove along the edge. At least one of the groove knives had some irregularity in the corner, tearing out the grain instead of cutting it cleanly. The tongue knife and the groove knife were not aligned correctly; consequently the upper groove wall was too thin, and the lower groove wall too thick to fit under the tongue.
>
> The boards—over 20 feet long--were shipped to New York City, and sold to a carpenter named Koski. He had been building a house in the Bronx and the owner decided that he wanted an attic floor. Because the walls were already up, Koski left the boards long, so that they could be handed up into the attic through the attic window. The boards were cut to the width of the attic: 20' 2". Because of the slope of the eaves, it was decided not to cover the entire floor; instead, Koski started the floor by installing the toe board at a point where splices in the joists created additional opportunities for nailing. He used 23 face nails on the toe board. Then he added 26 more boards, which brought the floor to a point just beyond the attic access hatch. He blind nailed these additional boards, using old-fashioned cut nails to hold the floor together, and using occasional face nails in areas where the wood was irregular, such as the bow in Board 26.
>
> Some time before March of 1932, Rail 16 was cut out of the toe board of this attic. A little over an inch of wood was trimmed off one end in order to square the cut (the end of S-266 was not cut square). Two feet were cut off of the other end. The grooves were planed off of one edge, and about an inch of wood trimmed off of the other. This piece of wood was inserted onto the kidnap ladder and then carried to and abandoned at the Lindbergh home.

During the trial Reporter Adele St. Johns wrote, "If you were working one of those jigsaw puzzles, and you were looking for the piece in color, size, and grain to fit that missing space in Hauptmann's attic, you would put that sixteenth rail from the kidnap ladder right in there and heave a sigh of relief."[63] This study has gone far more extensively into comparisons between Rail 16, S-226 and other boards from Hauptmann's attic than anything presented at the trial and has verified that Ms. St. Johns was correct.

Trees are complex life forms, consisting of many specific characteristics. The carpentry processes used in transforming trees into boards add further individual characteristics. The intricate combination of all of these qualities in Rail 16, S-226 and the other attic boards precludes any possibility of a faked relationship, and demonstrates irrefutable evidence that Rail 16 was indeed part of Bruno Richard Hauptmann's attic floor prior to the kidnapping.

Implications of this research

What conclusions can one draw from the connection between Rail 16 and Bruno Richard Hauptmann's attic?

Hauptmann became connected with the Lindbergh Kidnapping Case after he was found to be in possession of a large portion of the ransom money two years after the crime. Hauptmann himself acknowledged possession of the money.[64] Having the money does not, by itself, constitute absolute proof of guilt of the crime. Indeed, Hauptmann offered an innocent explanation—that the money was left in his home by a friend named Isidor Fisch. However, the fact that wood from his attic was used to create the ladder that was found on the grounds of the Lindbergh estate on the night of the kidnapping makes Hauptmann's relationship to the crime more than coincidental.

It is also important to consider other evidence in the case. Hauptmann quit his job the same weekend that the ransom money was paid.[65] Hauptmann and his wife existed for two years after the crime—during the Depression--without any consistent employment, during a period when Hauptmann's investments in the stock market showed net losses.[66] He and his wife made lavish purchases and traveled during this period.[67] Hauptmann was German, and the writing in the ransom notes suggested German ancestry. Hauptmann was a carpenter. Hauptmann had a keg of nails in his garage of the same make and size as those used to make the ladder.[68]

Yet is it possible that Hauptmann was only paid to make the ladder, and may have been oblivious to its intended use?

The wording of the ransom notes clearly indicates that the writer was aware of the nature of the crime. If Hauptmann was the writer, he is clearly implicated as a conscious participant. During the trial, eight handwriting experts testified that the handwriting was Hauptmann's.[69] Another expert, James Vreeland Haring, wrote a book making the same claim.[70] More recently a professional document examiner named Michael Krakowski, of Scientific Examination of Documents, came to the same conclusion. [71] Further, the amount of money found to be in Hauptmann's possession thirty months after the kidnapping—about $14,000—also suggests that Hauptmann was more than a minor participant.

In the author's opinion, all of this evidence, taken together, leaves no room for reasonable doubt that Hauptmann's was a conscious and active participant in the kidnapping. The real question of the Lindbergh Kidnapping Case, then, is not whether Hauptmann was guilty, but rather whether he worked with accomplices, and exactly what role he played in the kidnapping and death of the baby boy. It remains to be seen whether such questions will ever be completely answered.

The Rail 16 evidence presented here has implications concerning another alleged crime: the claim that Louis Bornmann, Arthur Koehler and others conspired to commit fraud by planting Rail 16 into Hauptmann's attic. This accusation is very serious, since this evidence led to Hauptmann's electrocution. It has been surprising to the author that writers who have professed serious concerns about justice in the Hauptmann case have themselves neglected to carefully examine and evaluate the Rail 16 evidence before making their own accusations against Koehler, Bornmann, and others. It is hoped that readers who carefully review the evidence presented in this report will see the importance of exonerating Koehler and Bornmann, who have for decades been accused of a crime that they could not possibly have committed.

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For Further information:

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Footnotes:

[1] Berg, S. (1998). Lindbergh. New York: G. P. Putnam's Sons. P. 276.
[2] Brittingham, W. C. (2001) Hopewell's crime of the century. Kingston, N.Y.: Tri-State-Litho. p. 11.
[3] Koehler, A. (March 4, 1933). "Report on examination of ladder for the New York State Police". New Jersey State Police Archives, W. Trenton, New Jersey.
[4] *State of New Jersey vs. Bruno Richard Hauptmann*, Trial transcript, p. 2153-2157.
[5] Trial transcript, p. 2210.
[6] Bornmann, L. (March 24, 1936). "Transcript of stenographer's notes of examination of STATE TROOPER BORNEMAN (sic), taken at the School of the New Jersey State Police, Wilburtha, New Jersey, on Tuesday, March 24, 1936, and in the presence of Governor Harold G. Hoffman, R. William Lagay, Secretary to the Governor, Mr. Hoge (sic), Colonel Schwarzkopf, Captain Snook, and Lieutenant Keaton." Hoffman Files, New Jersey State Police Archives, W. Trenton. p. 8.
[7] A memo in the New Jersey State Police archives, dated January 6, 1936, and signed by Mr. Springfield, states that Mr. Springfield took a photograph of the ladder on March 2, 1932. However, the photograph mentions a man in a doorway in the background, and no doorway is visible in the croppings of the photo that the author has seen, so it is unclear whether the memo refers to this picture or another. Nevertheless, the photo used here was sometimes credited in newspapers as an Acme photo (New York World-Telegraph, March 4, 1932, p. 14), and Mr. Springfield stated in the memo that he worked for Acme, so it appears likely that he took this photo on this date. Certainly it was taken prior to March 4, 1932, as it appeared in newspapers on this date (see next footnote).
[8] For example: Syracuse Herald, March 4, 1932, p. 18; Daily Press (White Plains, N.Y.), March 4, 1932, p. 6; New York World-Telegraph, March 3, 1932, p. 14; Springfield (Massachusetts) Republican, March 5, 1932, p. 18.
[9] Due to copyright restrictions relating to use on the Internet, New York Daily News photographs were not included in this summary report. These photos are available on the Internet through Dailynewspix.
[10] Arno, J. (1995). The woodworker's visual handbook. Emmaus, PA: Rodale Press. p. 187.
[11] Panshin, A. J, and DeZeeuw, C. (1970). Textbook of wood technology, volume 1 (3rd ed.) New York: McGraw Hill. p. 456.
[12] Panshin and DeZeeuw, p. 458.
[13] Trial transcript, pp. 3791-3792.
[14] Koehler, A. (March 28, 1936). "Report of investigation carried on in co-operation with the New Jersey State Police." New Jersey State Police Archives, W. Trenton. p.1.
[15] Trial transcript, p. 3997.
[16] Panshin and DeZeeuw, p. 279.
[17] Wilson, B.F. (1984). The growing tree. Amherst, MA: U. of Massachusetts Press. p. 12.
[18] Hoadley, R.B. (2000). Understanding wood: a craftsman's guide to wood technology. Newtown, CT: Taunton Press. p. 214.
[19] Thompson, W.S. Private correspondence, dated October 21, 2002.
[20] Scaduto, A. (1976). Scapegoat: the lonesome death of Bruno Richard Hauptmann. New York: G. P. Putnam's Sons. Photo caption after p. 320.
[21] To be exact, one of these two rings, Ring 14, just touches the surface of Rail 16 on the tip of the arc in the end view, and is just visible right at the end of the board in the side view.
[22] Wilson, B. F. p. 95.
[23] Web.utk.edu.
[24] Stokes & Smiley, p. 31.
[25] Panshin and DeZeeuw, p. 52-53.
[26] Stokes, M. A. & Smiley, T. L. (1996). An introduction to tree-ring dating. Tucson: U. of Arizona Press. p. 17.
[27] This shift is consistent with the knot at the end of S-226. For example, note on Figure 12 how the thick area of growth in the latewood of Ring 12 of S-226 is up and to the left of the similar area of thickness on Rail 16.
[28] Drew, A., Unpublished letter to the author, dated December 22, 2001.
[29] Drew, A. 2001.
[30] Jacoby and Davi, Unpublished letter to the author, dated June 26, 2002.
[31] Thompson, W. (2002). Private correspondence with author, dated October 21, 2002.
[32] Schultz, R. P. (Ed.). (1979). Loblolly pine: the ecology and culture of loblolly pine. Agricultural handbook #713. Washington, D. C. : U.S. Department of Agriculture Forest Service. p. 3.4.
[33] A more detailed description of the author's analysis of this question is included in the full report.
[34] Trial transcript, p. 3810.
[35] Betts, H. S. p. 4.
[36] Koehler, March 4, 1933, p. 6.
[37] Koehler, A. (December 10, 1933). Letter to Captain Lamb. New Jersey State Police Archives, W. Trenton.
[38] Sisk, T. H. (2/16/34). "Summary report, kidnapping and murder of Charles A. Lindbergh, Jr." Divisi0n of Investigation, File NY-62-3057.
[39] Koehler, 3/4/32, p. 6. Note: in the memo, Koehler refers to this as "cleat #12". Since no 12th rung exists, it would appear that he was referring to rung 11.
[40] See footnote 9. The original, available from the Dailynewspix archives, shows the nail hole very clearly.
[41] Trial transcript, p. 3856.
[42] Koehler, A. & Davis E. (1/3/35). "Report on examination of lumber in Hauptmann's house by Arthur Koehler and E. M. Davis." New Jersey State Police Archives, W. Trenton.
[43] Koehler, A. Caption from diagram of attic. Date unknown.
[44] Graham, F. P. (1968). Audels carpenters and builders guide No. 4. Publisher unlisted.
[45] Kennedy, L. (1985). The airman and the carpenter. New York: Viking Penguin Inc. p. 389.
[46] House Blueprints. New Jersey State Police Archives, W. Trenton.
[47] Hoage, L. (3/22/36). Memo titled "Hauptmann attic". Hoffman files, New Jersey State Police Archives, W. Trenton.
[48] Measurement checked by author.

[49] Koehler, A. (3/28/36). Report on investigation carried on in co-operation with the New Jersey State Police. New Jersey State Police Archives.
[50] More details regarding these interviews are included in the author's full report.
[51] Using old photographs of the attic the author was able to verify that they were correct.
[52] Joists 4A&B, 5, 7, 10A&B, 12A&B, and 14A&B. Joist 6 was also removed but never split open.
[53] A "wire nail" is a type frequently used today, with a cylindrical body, and a pointed tip. A "common" wire nail typically has a large, flat, round head.
[54] However, one wire nail head may be visible in one of the police photos in Joist 8, beyond the edge of S-226. See Figure 21.
[55] A section of joist from the opposite end of the attic, kept at the New Jersey State Police Archives, shows signs of previous use.
[56] See footnote 9
[57] It is hoped that researchers who wish to pursue the issues presented here further will respect the concerns of the family. First and foremost, the house is their home.
[58] Hoage, L. (1/29/37). Untitled memo to Governor Hoffman. Hoffman files, New Jersey State Police Archives, W. Trenton.
[59] Koehler, A. (10/4/1934). "Report of examination of tools and lumber from Hauptmann's garage and house by Arthur Koehler." New Jersey State Police Archives, W. Trenton. p. 2.
[60] Both Rail 16 and Board 1 had been narrowed, and so were not included in this comparison.
[61] Board A-1 was missing the longer groove wall and so could not be measured for this comparison.
[62] North Caroline Pine Association (1926). 1926 Official inspection rules of the North Carolina Pine Association, Inc. Portsmouth, Va: Printcraft Press, Inc. In this rulebook there are no specifications the tongue-and-groove profiles for sheathing boards. Hendal Price speculated that the miller most likely used flooring knifes for these boards. The author's research on this point, however, was not exhaustive.
[63] St. John, A. R. (1/24/34). Washington Herald.
[64] Trial transcript, p. 2449.
[65] Trial transcript, p. 2636.
[66] Waller, p. 358.
[67] Waller, p. 264.
[68] Corey, Robert W. Letter to Chief, Intelligence Unit, Bureau of Internal Revenue, dated December 20, 1932. The letter states that the 8-penny wire nails used to construct the ladder were identified as coming from the Pittsburgh Steel Company by Hubert F. Hanks, of that firm. This was the brand of a keg of 8-penny wire nails found in Hauptmann's garage. See also "Identification of Lindbergh Ladder Nails" by Stanley Keith. Iron Age, October 17, 1935. p. 22.
[69] Fisher, J. (1999) The ghosts of Hopewell. Carbondale, IL: Southern Illinois University Press. p. 119.
[70] Haring, J. V. (1937). The hand of Hauptmann. Plainfield, NJ: The Hamer Publishing Co.
[71] M. Krakowski, private conversations. Mr. Krakowski has also posted details of his analysis on the following websites: www.lindytruth.net and forum.onecenter.com/yz12.