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AN INTRODUCTION TO TOOL MARKS, FIREARMS and the STRIAGRAPH

Though prepared as an "introduction" to the subject, contains many points which will be of interest to the experienced criminalist, including suggested research projects and the like.

THE POLICE SCIENCE SERIES

An Introduction to Tool Marks, Firearms and the Striagraph

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An Introduction to TOOL MARKS, FIREARMS and the STRIAGRAPH

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To my Mother, my Sister,
and the memory of
my Father

PREFACE

CRIMINALISTICS is that branch of police science which deals with the examination and analysis of physical evidence. In his work the criminalist has need to apply a wide variety of physical and chemical testing methods to materials of every conceivable type, form, size and shape. For the most part these analytical methods are borrowed from the more basic sciences or from more specialized laboratories, after which they are perhaps modified to fit the specific needs of the police scientist.

Although a large part of the work of a criminalist consists in the analysis and specific identification of various unknown substances, an equally important phase of his activity is the *comparison* of various specimens. Thus, in many instances, he is not so much concerned with the absolute nature of a material as he is in showing that two specimens are identical between themselves on some significant basis. In a homicide case, for example, he is more concerned with ascertaining whether a fatal evidence bullet was fired from a particular weapon than he is with the composition of the bullet. Again, he may be primarily interested in knowing whether certain tool marks found at two different crime scenes were made by the same tool rather than in ascertaining the nature of the tool itself. Such work involves examination and comparison between two or more specimens. At least one such specimen is known as the "evidence specimen," while the other is referred to as a "test specimen." Although, as in the case referred to above, they may both be evidence in fact, one is nevertheless a "test" as compared with the other.

As a rule, test specimens are obtained only by securing a known sample from the suspected source. A comparison may reveal that test and evidence had an identical source, thus giving legal significance to the source itself.

In a shooting case the final determination is often as to whether a particular weapon fired a certain bullet. The weapon,

or a test bullet known to have been fired from it, is essential to this determination. Many such examples could be given wherein *comparison* of characteristics is paramount.

As in all analytical work, however, there are many instances in which a detailed examination of but one specimen will reveal its general source. Thus in firearms examinations an analysis of a fired bullet may show it to bear features consistent with but one make and model of weapon. Again an examination of the bullet may show it to be of a design consistent with that of but one cartridge factory. These determinations are more often of value from an investigative standpoint than as legal evidence. This fact does not limit the value of such determinations, however, for the information may well lead to the development of more specific data at a later time.

Evidence specimens are frequently obtained considerably in advance of test specimens, due primarily to delay in apprehension of the offender. In such cases it is often the duty of the criminalist to examine a single specimen with a view to providing the investigators with a clue as to its most logical source. An examination of a single bullet may permit the analyst to suggest that the detective search for a .38 caliber Colt revolver and to submit all such suspicious weapons to him for test-firing. If a tool mark is in evidence, the laboratory worker may suggest that any recovered one-inch pry bars be submitted to him for test purposes. These suggestions are made as a result of a determination of the "class characteristics" of the evidence specimen.

Class characteristics are those measurable features of a specimen which indicate a restricted group source. Firearms are manufactured according to certain factory specifications. Each manufacturer has his own general specifications for bore dimensions, groove widths, and angle of twist, which as a "class" are restricted largely to that particular maker. Thus measurements made on an evidence bullet may show it to be consistent with arms from one factory and no other. A "group source" has been arrived at.

The term "class characteristics" is generally applied mainly to firearms, and firearms evidence. Actually, however, the term might be applied to other types of evidence such as tools, in

which the class would differentiate between cutting and scraping tools, hand tools versus machine tools, and so on. Here again, on the basis of class characteristics, the analyst may place the tool utilized in a certain general group type.

In the event the criminalist receives both test and evidence specimens at the same time (as when the suspected weapon is submitted with the fatal bullet), it may be that no separate analysis of the class characteristics is required. So long as the two are found to be identical on a specific basis, identity in class features may be assumed.

In any event, it is the function of the criminalist to make the examination or comparison indicated, and to draw such a conclusion as is justified by the nature and extent of the evidence. He must then be prepared to illustrate or otherwise offer proof of the accuracy of his conclusion in courts of law. The degree to which he succeeds in this demonstration depends upon many factors, not the least of which consists in the methods utilized in his determination.

It is the primary purpose of this book to describe one such testing method developed by the author as an original research project in the field of Criminalistics. The investigation and experimentation which have led to the preparation of this text were begun in March, 1950, and continue at the present time. They have resulted in the development of a specialized instrument known as the "Striagraph," designed to permit certain analyses of firearms and tool-mark evidence not previously possible. Covered by U. S. Patent 2,686,101 issued August 10, 1954, the Striagraph is primarily a measuring, tracing, and recording device suited to the analysis of micro surface-contours—that is, to the detection of microscopic irregularities in surface smoothness. Although not restricted in its application to firearms and tool-mark evidence, nor even to criminalistics problems, it will be considered primarily from that standpoint in this treatment.

Because the contour-tracing technique represents a completely new approach to the subject of firearms and tool-mark identification, there are many questions regarding the process which cannot as yet be answered. It is not so much the purpose of this text to provide specific conclusions as it is to bring to

the attention of other workers some of the possibilities and potentialities of the method. At the same time, in order that the less experienced workers may be placed in a position to compare this method with others, it will be necessary to include a considerable amount of "background material" in firearms and toolmark identification. An attempt will thus be made to provide a brief but fairly comprehensive coverage of the basic features of this type of evidence and methods utilized in its examination, prior to introducing the Striagraph. It is hoped that by such means the work will meet the needs of the student without appreciably detracting from its value to the more experienced worker.

ACKNOWLEDGMENTS

I WOULD LIKE first and foremost to acknowledge the great amount of work performed by my wife, Grace, who has attempted to make from my rough original draft, a manuscript which might be regarded as reasonably satisfactory. But for her efforts in editing, correcting, and re-typing the material at various stages, it would most likely never have been completed.

Also, my thanks to those who have encouraged me to record in book form some of my observations pertaining to contour analysis—particularly to those who have reminded me that a perhaps less-than-perfect book, in print, is somewhat better than the "perfect" manuscript still unwritten.

While they did not aid directly in the preparation of this book, I want to remember E. G. Boden, Experimental Engineer with the Timken Roller Bearing Company, whose cooperation during my early investigations of contour analysis encouraged me to develop methods and techniques described here; and also J. H. Eccleston, a personal friend and amateur machinist, who in 1950 produced from my original sketches, a working model of the instrument I call the "Striagraph."

J. E. D.

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CHAPTER I

INTRODUCTION

WHEN A BULLET is fired through the barrel of a weapon, it is scratched along its length by minute imperfections in the bore. These scratches form straight parallel lines consisting of ridges and valleys (striations) engraved into the surface of the projectile during its passage through the bore. Another bullet fired from the same weapon will be similarly marked. A microscopic comparison of the marks on two bullets may show such a high degree of similarity that it can be safely concluded on this basis alone that they came from the same gun. Compared with bullets from other weapons, no such similarity will be found. In this case the dissimilarity may be so great as to permit the criminalist to state that the two could not possibly have been fired from the same weapon.

Striations are equally important in the comparison of certain types of tool marks.

Tool marks are of two general types. The first of these is the "impression" type which, as its name implies, is little more than a dent. A pry bar may leave an impression-type mark on a window frame to which it is applied. The shape and size of the mark, plus irregularities caused by nicks or breaks in the pry bar, may be such as to permit a positive statement as to its source. Test impressions made with the suspected tool may be so like the evidence impression that an identical source is obvious. Such comparisons are similar to the comparisons of footprints and tire tracks. The straight impression-type tool mark does not contain striations in the ordinary sense.

A "striated" tool mark is left by a tool scraping over an object or surface softer than itself. Thus a pry bar which slips during application may scrape over the jamb of a door, leaving striae. Tin snips or bolt cutters have blades which frequently leave

striae on the edges of metal cut. An axe will leave striae on wood chips, as will an auger or the blade of a plane. Mechanical tools such as the planer, joiner and lathe all have blades or edges which leave striae on chips, shavings, and stock being worked. Many such examples could be given but these are typical of the tools most commonly encountered in criminal investigations. Striated marks are often referred to as "friction marks," "abrasion marks," or simply "scratch marks."

It will be apparent that the striae on bullets are actually nothing more than a special kind of striated tool mark where the barrel of the weapon serves as the tool, acting upon the softer metal of the bullet.

A consideration of these different types of marks will reveal that the tool and object are merely moving relative to one another, and it may be in a given application or circumstance that either the tool or the object (or both) are moving. The "tool" as a practical matter is merely the harder material of the two. The bumper of an automobile may become a tool in effect and scratch a striated area on the fender of a second vehicle. A pry bar being applied to a safe may strike a hard metal plate or pin and itself be scratched. Here the pin or plate becomes the "tool" and the pry bar the marked object.

In each of these cases identifiable striae may be found. Test marks made with the suspected tool and compared with the evidence specimen may reveal identity. The striations resulting from sliding or shearing contact between tool and specimen in such cases vary considerably in size and character. Individual ridges and valleys may be large and clearly visible to the unaided eye, or so small that they can hardly be seen with a microscope. Striae on bullets generally range in height from a few hundred-thousandths to a few ten-thousandths of an inch.

The character of striations such as these depends upon and varies with a number of factors. These factors include (1) the size and shape of the microscopic irregularities on the acting tool; (2) the original surface smoothness of the object acted upon; (3) relative hardness of the two materials; (4) speed of application or rate of relative motion; (5) pressure areas involved; (6) texture and uniformity of material acted upon.

It is quite possible in a given case for a mark to be a combination of the impression and striation types previously described. Thus, if a hammer strikes at a safe door, it is likely to leave an impression shaped generally like the face of the hammer head, which mark may well reveal nicks, dents, or other irregularities of identifiable quality. Should the hammer strike a glancing blow, it is likely that the top of the mark resulting will be an impression of perhaps one-half of the face while the lower part of the mark shows a series of striations where the tool scraped or skidded over the door. Marks of this type offer identification possibilities on the basis of both features.

Some straight impression-type marks appear to be striated because the tool itself had striations upon it as the result of some machining operation. The edge of a bolt-cutter blade is frequently ground in such a way that although it cuts with a semi-shearing action, an impression of the grinding marks (striae) will be left at the bottom of an incomplete cut. Similar marks appear at the bottom of a dent made by the edge of a cold chisel or a punch. A hammer head which had been filed flat would bear striae from the filing process. A straight impression-type mark of this hammer would show negative impressions of these striae which might appear to be scratches made *by* the tool rather than impressions of scratches *on* the tool.

The analysis and examination of such impressed striae depend upon their character. If they are even and regular they may be analyzed as if they were original striae. If they are scattered, or assume various angular positions with respect to one another, they lend themselves better to techniques utilized in any other impression-type mark.

Marks of this type are quite important in firearms identification, as they form some of the most valuable markings to be found on the empty cartridge case from which a bullet has been fired. When a gun is fired, the cartridge case moves toward the rear of the weapon. There it is likely to receive an impression of the striated markings on the breech block. The firing pin itself is likely to leave identifiable striae in the dent it makes in the cartridge primer, for firing pins may also have been turned, filed, or ground to shape and thus bear striations. Impressed striae

markings of this type are often more easily identified than the usual striated scratch mark due to the fact that the angle of application of the tool (or acting part) is indicated by the shape of the total impression. In the case of such marks made by firearms there is usually but one possible position of application so that even less difficulty is encountered.

The experienced worker will rarely have difficulty in distinguishing original scratch-mark striae from impressed striae. A knowledge of tools and how they are used, and a familiarity with weapons, fired cartridge cases, etc., is generally sufficient. An original striated mark, if fresh, will generally be indicated also by the "newness" of the exposed surface, whereas an impression of a striated surface will show no difference in reflectiveness between the "striated" and surrounding areas. As indicated above, however, the analysis or comparison methods utilized depend more on the nature of the markings than on their method of production.

As was mentioned earlier, the subject of firearms identification is really but a specialized aspect of tool-mark work. For various reasons, however, firearms identification problems are generally treated as a distinct and separate subject. It is a large field in itself, and certain aspects of the work are unique to firearms problems. Because firearms are manufactured according to certain specific design, the subject lends itself extremely well to a type of classification which is not so applicable to the broader aspects of tool-mark work. It also necessarily involves a consideration of matters not strictly related to tool marks—for example, powder burns—which removes it a step further from the latter field. Thus it happens that most of the texts on firearms identification treat the subject as relatively isolated and complete within itself. There are a number of excellent books on that subject, which provide a far more complete coverage of it than will be attempted here.

CHAPTER II

IMPRESSION MARKS

General Characteristics. Not all impressions are regarded as tool marks in the ordinary sense. A fingerprint impression left in the soft wax of a candle, for example, would not generally be treated as a tool mark. To the extent that the finger becomes a tool acting upon the softer material of the candle, though, it actually is a tool mark. In like manner, a footprint or shoe print in the sand is a tool mark, as is a tire impression. The comparison of such impressions is made in the same manner as the comparison of the pry-bar marks on a door jamb. An examination is first made to see that the general pattern of the evidence and a test are the same, that the size of both is consistent, and that the gross features match. Following this a detailed search is made for more minute or individual characteristics which would not be found on the impression or "tool" as a class. These individual features may have resulted from peculiar natural formations, uneven wear, or accidental damage to the acting tool. These and other factors give to any tool an individuality which will characterize it, and marks made by it, as distinct from all others.

In many instances, of course, a tool may be so regular, or new in its condition, that it lacks sufficient characteristics of impressionable nature to permit a mark made by it on a given material to be specifically identified. In such instances the examiner may conclude nothing more than that the tool in question "could have made" (that is, is consistent with the shape of) a given mark.

At other times, some individuality will appear, but the number, peculiarity, or clarity of these features may be so slight as not to permit a definite statement to be made. Here we have a "borderline" case in which the specimens show evidence of identity short of positive proof. Instances of this occur in the examination of all sorts of evidence, and in the field of tool marks

and firearms identification are the most frequent cause of a difference of opinion among examiners. Such differences arise primarily through differences in interpretation of the characteristics seen, assignment of greater or less significance to the features observed, variations in methods of analysis utilized, inequalities in experience of the examiners, and other factors. Unlike the field of fingerprint comparison, there is no set number of characteristics required for a positive identification of a tool mark. The characteristics of the latter are the result of too many possible causes, and take on too great a number of forms, to be classified so simply. It thus becomes incumbent upon each examiner to familiarize himself with a great variety of "tools," marks, impressions, and their characteristics. He must be able to distinguish those features which are accidental or otherwise peculiar to the specimen as an individual, and those which are characteristic of the class a whole. Having acquired such information through study and experience, he must then adopt those methods of analysis which will best reveal the identification peculiarities both to his own satisfaction and to that of others.

Because of the difficulty of assigning any sort of numerical "identity value" to specific features found in impression marks, the conclusion reached in such comparisons is of a somewhat different order (of opinion) than the identification of a fingerprint, though it be just as positive, and even granting that numerical assignments to the latter are somewhat arbitrary.

Most impression marks represent a combination of class characteristics and individual characteristics. As a footprint may show evidence of a man's eleven-inch shoe, with composition sole and leather heel in addition to individual characteristics, so may a tool mark show a one-inch blade with a hexagonal shaft, in addition to certain nicks and breaks on the edge. On rare occasions an impression-type mark may show certain individual peculiarities without revealing much in the way of those class features which would typify the tool. Thus a hammer with a rounded face might leave a series of dents on a safe door, each dent bearing identifiable individual peculiarities, yet without a surrounding border which would define the tool. Here the examiner might be unable to state what type of tool was used until he finally

obtained it and was able to identify the specific peculiarities present.

Methods of Examination. In identifying the impression-type mark, two basic methods may be followed. First, a comparison may be made between the impression and the tool itself, and, secondly, the comparison may be made between the impression in evidence and a test impression made by the suspected tool. The latter procedure is almost always followed, for in such case both specimens are of the same form. Otherwise one is a positive and the other a negative wherein the comparison is like showing a mold to have been made by a given pattern, rather than that two molds were made by the same pattern. It is not uncommon, however, to utilize both methods in one demonstration. In comparing footprints it is desirable not only to show the identical features in a test and evidence print, but also to show the source of the features on the shoe sole itself. The same technique may be profitably applied in many instances in the more usual tool-mark case.

Test marks are made with the suspected tool on a substance as nearly like the evidence material as possible. This serves the double purpose of providing specimens of similar reflective quality for illustration, and of demonstrating that the tool is hard enough to impress that type of material bearing the evidence mark. These tests are also made under other conditions which simulate the production of the original evidence marks—that is, the angle of application is made to conform, as are the pressures involved, etc. If the evidence mark is quite deep, for example, a test of like depth would normally be called for. Hence those methods of producing test marks are used which will most nearly duplicate the conditions and circumstances surrounding the evidence specimen.

It may be that the evidence mark is found on a surface or material which represents just about the limit of stress for the tool utilized. In making test marks with this tool the usual procedure is to make the first preliminary tests on a considerably softer material until the proper angle of application has been arrived at. The final tests may then be made on a harder material simulating that of the evidence specimen. By such means,

undue wear and tear on the tool is minimized, and unnecessary damage to the tool avoided. For the usual run of tool-mark cases, lead, type metal, plastics, paraffin, and other soft substances serve as suitable test materials. A reasonable knowledge of the hardness of various tools and materials will suffice to indicate the test conditions. For demonstrative purposes the test marks made on these softer materials may be used quite validly, and the introduction of such comparisons in court would generally be unobjectionable. It may well be better to utilize the softer material throughout, and obtain a true reproduction of the specimen, than to use a harder one with risk of damage to the instrument.

As a rule a number of test marks are made by the criminalist for comparison against the evidence. He has the problem, by trial and error frequently, of matching the angle of application, forces and pressures involved, and other factors which contributed to the appearance of the evidence specimen. It is likely that some tests will show a few of the features and that other tests reveal the remaining ones. Through multiple tests he increases the possibility of making a mark which will more nearly simulate the original, while at the same time obtaining verification from each of the presence or character of individual features. In the ordinary case, from one to a half dozen such tests will generally serve to provide a sample suitable for demonstration purposes.[1]

Following preliminary examination of the tool and production of a series of test marks with it, the problem ahead is to examine and compare the two in order to establish whether an identity exists. Where no identity exists (as when the right tool is not at hand, or where it has been damaged subsequent to its use in the first instance), a reasonable examination of the instrument and marks made by it will usually indicate this fact. When

[1] Attorneys may argue that the "vast number of test impressions made" increases the probability of making an "identification" where none exists. Actually the reverse is true, and in any event if a peculiarity is not present on the instrument, it will not show up in an impression in any number of tests. In fingerprint work it is common practice for a suspect's finger to be printed half a dozen or more times in order that a clear and complete inked print be obtained for comparison in court against an evidence print. Such practices are often objected to by defense counsel. Obviously the objection is without merit, for although a very poor print might be sufficient for the expert, he must be certain that the jury will see the identity as well.

an identity does exist, it is essential that the criminalist recognize it as such and prepare to demonstrate the fact. Recognition of an identity may be "immediate" as when the position, shape, or number of characteristics present stand out clearly, or it may come as the result of tedious observation, microscopy and photography under carefully controlled lighting conditions.

The features upon which such identifications are based are almost exclusively differences in surface contour or elevation of the individual peculiarities.

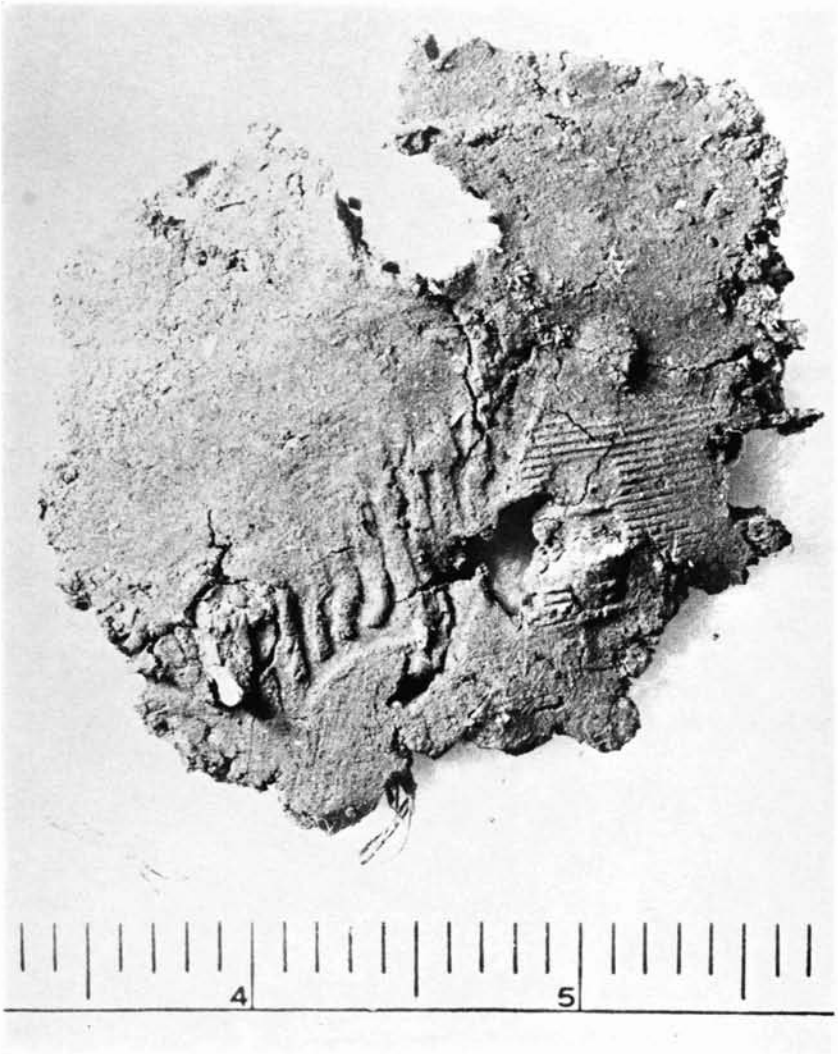
Due to the great variety of marks and traces classifiable as impressions, and the infinite forms and shapes which may be assumed by their individual peculiarities, it would be impossible to provide rules for the examination of each. Generally, however, the test and evidence markings are examined at such magnification as will best reveal the peculiarities (either individually or as a group), after which both are photographed to the same scale and so enlarged as to permit comparative measurements to be made. Many such individualities do not lend themselves to precise measurements, however, and an unusual peculiarity of shape may well be identified without measurement. It is usually the periphery of a dent or raised area in the mark which is observed as a "characteristic" where it forms a map-like figure on the surface. The feature may also have a variable depth contour best illustrated by a careful use of illumination. Here highlights and shadows are utilized to reveal the contour. Oblique illumination (low, slanting light) is generally used in order to emphasize contour variations and to provide a shadow line at the border area of peculiarities. It frequently happens that due to the formation or orientation of these features, they cannot all be illustrated in one photograph. The illumination on one area should perhaps come from the left, while on an adjacent area a right-hand source is needed. In such instances two or more photographs of each specimen are called for. Changes in illumination can thus make some features stand out clearly, but at the expense of others perhaps equally prominent. Two scratches at right angles to one another can easily be lighted so as to make either line prominent independently, or to reveal both at the same intensity. It frequently happens that only after consider-

able experimentation with lighting angles is a feature seen with such clarity that it indicates positive identity. Tool marks often contain so many identification features that the loss of a portion of them in a photograph (due to lighting angles selected) does not appreciably detract from the obvious identity in the comparison.

The usual method of demonstrating impression-mark identification in court is similar to the technique employed in fingerprint cases. Here lines are drawn on the photograph of test and evidence marks, pointing out the characteristics or significant configurations. By numbering the lines on the periphery of each chart the criminalist can easily point out the "identities," and discuss or explain them to the satisfaction of the court.

In some instances it is possible to photograph both test and evidence impressions under the comparison microscope which simultaneously shows both in one photograph, separated only by a prism line. The use of the comparison microscope in impression-type marks is largely restricted to marks or areas of small size where it is more a convenience than a necessity. It is utilized extensively in firearms cases, as will be described later.

Because of the scattered and discontinuous character of the identification features of impression marks, and the variety of shapes which they assume, identification methods are largely restricted to such techniques as have been mentioned above. Various modifications in procedure, or unusual approaches may be called for in a particular instance, but as a rule the methods employed are fairly uniform.



II-1a—Fragment of dried mud left at the scene of a crime bears impressed traces of a rubber heel. Such impressions are essentially the same as impressed tool marks. They may be compared with a suspected source as regards individual identifying characteristics, or in the absence of such suspected source are compared with known standards or samples, II-1b (See page 14), with respect to general class characteristics.

II-1b

→

II-2a—Impressions of tire tracks often constitute valuable physical evidence at the scenes of crime. Their comparison with suspected tires involves the same principles as the comparison of tool impressions, as shown in II-2b, where the lower evidence impression is compared with the upper test mark produced with a suspected pry bar.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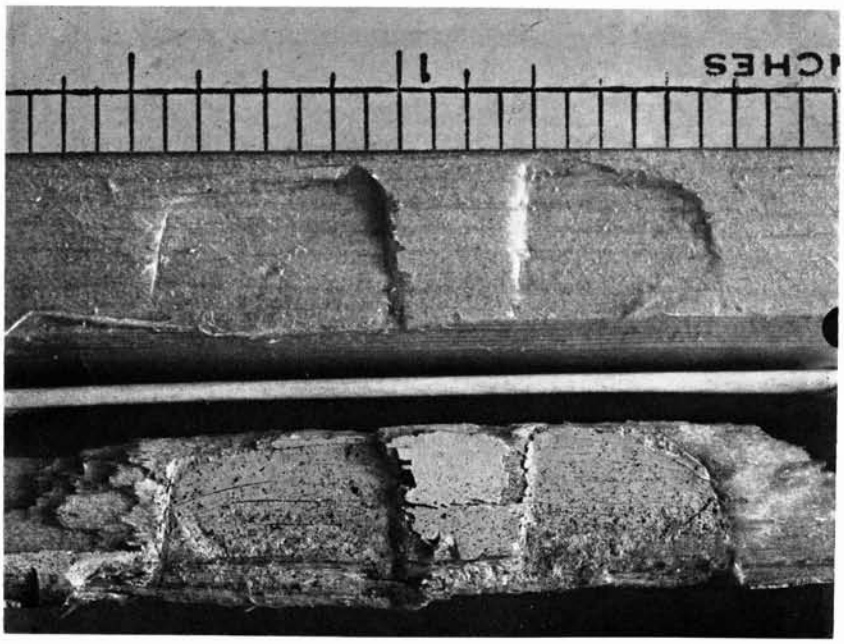

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