

TENNESSEE BUREAU OF INVESTIGATION

Forensic Services Division

Microanalysis Standard Operating Procedures Manual

Footwear Impression Analysis and Comparison



Footwear Impression Analysis and Comparison

1. Scope

The purpose of conducting a footwear examination is to associate/eliminate a pair of shoes/boots with questioned impressions from the scene of a crime. Objectives of the footwear impression examination conducted in the laboratory may include the following:

Comparison of the questioned impression with the tread pattern of the footwear for agreement in class characteristics (i.e. tread pattern, size, and general wear).

Comparison of the questioned impression with the tread pattern of the footwear for a positive identification through individual characteristics (i.e. cuts or gouges found in the tread, and in the impression).

Comparison of the questioned impression with the tread pattern of the footwear resulting in elimination due to size, wear or tread design inconsistencies.

Examination of the questioned impression in order to supply investigative information such as type of footwear, manufacturer and model.

Comparison of the questioned impressions with submitted Officer/Emergency personnel footwear impressions for elimination.

2. Terms and Definitions

Outsole – The sole of a shoe next to the ground on which wear occurs

Ball – Refers to the area on the shoe that corresponds with the fleshy part on the bottom of the foot (back of toes).

Heel – Rear part of the shoe

Upper – A term applied collectively to the upper part of the shoe.

Adhesive lifter - any of a variety of adhesive coated materials or tapes used for lifting shoe print evidence.

Casting – The filling of a three dimensional impression with a material that takes on and retains the characteristics which were in the impression.

Class characteristic – an intentional or unavoidable characteristic that takes on and retains the characteristics which were left in that impression.



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Combined class characteristics – The combination of two or more independent class characteristics.

Dental stone – a gypsum product used in casting footwear impressions.

Distortion – An unclear or inaccurate representation of a mark due to interference with the impression marking process or the retrieval.

Electrostatic lifting device – A device consisting of a high-voltage supply used with a special conductive film (Mylar) to electrostatically transfer a dry impression from the substrate to the film.

Enhancement – Rendering an impression clearer or more visible through physical, electronic, photographic or chemical means.

Examination quality images – are close-up photographs taken of footwear impressions, in a manner to capture the maximum detail so that they can later be used in a scientific comparison.

Gelatin lifter – A gelatin material laid on a pliable backing that can be applied to lift an impression. The lifters can be black, white or clear.

Individual or identifying characteristic – A particular characteristic, individual to a specific shoe, that resulted from an occurrence that randomly added or removed something from the shoe outsole which caused or contributed to making that shoe outsole unique.

Identification – This is the highest degree of association expressed by a footwear examiner. The questioned impression and the known footwear must share sufficient agreement of observable class and individual characteristics. In the opinion of the examiner, the particular known footwear was the source of and made the questioned impression.

Oblique light – Light that is positioned at a low angle of incidence relative to the surface being photographed. This is also referred to as side lighting.

Test impression – An impression made utilizing a known shoe for the purposes of using it in a footwear impression examination.

Three-dimensional impression – An impression with the dimension of length, width and depth. This is also referred to as a shoe track.

Two-dimensional impression – An impression with the dimension of length and width. This is also referred to as a shoe print.

Wear – The erosion of the outsole due to frictional and abrasive forces that occur between the outsole and the ground.

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Wear characteristics – Changes in the surface of the outsole that are observable in the impression and/or the known shoe and that reflect the erosion of the surface of the outsole.

Wear pattern – The position of wear on a shoe(s)

Elimination prints – Impressions from a known shoe used for the purpose of elimination.

Schallamach pattern – A unique and identifiable wear pattern caused by abrasion to the outsole of some shoes which is continually changing. (also known as feathering)

Stippling – A texture or pattern which is mechanically struck into the surface of a mold by individually striking a steel die with a hammer.

SWGTHREAD – Scientific Working Group for Shoeprint and Tire Tread Evidence

3. References

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Hussain, J.I., and C. Anthony Pounds, CRE Report No. 649, “The enhancement of Marks in blood Part 1 - 5-Sulphosalicylic Acid: A convenient and Effective Fixative for Marks on blood”, Central Research Establishment, Home Office Forensic Science Service, United Kingdom, Feb. 1988

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4. Examination Procedures

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4.1. Evidence Types

Evidence includes but is not limited to: photographs, negatives and/or digital images of impressions and/or footwear, casts of impressions, lifts of impressions, objects that contain impressions, known shoes from subjects or victims, and known elimination prints from those present at a crime scene.

4.2. Equipment

- Camera with RAW storage capability
- Tripod or camera stand
- Lighting (fluorescent light bar, flash, flashlight, etc.)
- Measuring scale
- Color filters
- Flatbed scanner
- Computer system
- Imaging software (includes Adobe Photoshop with Foray Calibration filter)
- Printer
- High quality photography paper
- Gelatin lifters
- Electrostatic lifter with Mylar
- Adhesive acetate paper
- Non-adhesive acetate paper
- Fingerprint powder, brushes and tape
- Spray bottle
- Dental stone, water, and plastic zip lock bags
- Soft bristle and/or tooth brush
- Internet
- Biofoam
- Vacuum box with accessories
- Shoeprint Image Capture and Retrieval database
- MikroTrack (Bubber)

4.3. Reagents and Chemicals

- Potassium Thiocyanate
- Ammonium Thiocyanate
- Fixative Solution - 2% w/v 5-Sulphosalicylic Acid
- 0.2% w/v Amido Black in 0.1M Citric Acid
- Leucocrystal violet
- Acetone



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Concentrated Hydrochloric acid
2N Nitric Acid
5-Sulphosalicylic acid
3% Hydrogen Peroxide
Sodium Acetate

All chemicals and reagents shall be ACS grade with the exception of 3% Hydrogen Peroxide that may be USP grade.
All chemical enhancement mixtures shall be verified before using on evidence.

4.4. Reagent Preparation

4.4.1. Potassium Thiocyanate

Dissolve 10g of potassium thiocyanate in 10mL of purified water. Add 80mL of acetone and slowly add 10mL hydrochloric acid. A white precipitate will form. Allow the mixture stand until the precipitate settles to the bottom. A clear liquid will remain at the top. The liquid is the reagent. Carefully decant the liquid into a separate container and discard the bottom residue. If the liquid reagent has a reddish tinge, the reagent is contaminated with iron. It shall be discarded and fresh reagent made. Properly label reagent container and document reagent preparation in the Microanalysis Reagent Logbook. (*International Symposium, 1994*) Verify the reagent is working properly prior to use in casework by spraying a small soil stained area not associated with the print or a sample prepared in the laboratory with dirt. The soiled area should turn red/pink. If the reagent does not react, try another soiled area or a sample prepared in the laboratory with dirt. If this area does not react, discard reagent, remake reagent with original chemicals and retest. Remake reagent with new chemicals and retest. Consult with Unit Supervisor as to next steps should the reagent fail again.

4.4.2. Ammonium Thiocyanate

Dissolve 2g of ammonium thiocyanate in 90mL of acetone. Add 10mL of nitric acid (2N or dilute) to the ammonium thiocyanate. No precipitation will result. The entire mixture should be sprayed onto the impression. Properly label reagent container and document reagent preparation in Microanalysis Reagent Logbook (Bodziak, FBI Academy, 1989) Verify that the reagent is working properly prior to use in casework by spraying a small soil stained area not associated with the print or a sample prepared in the laboratory with dirt. The soiled area should turn red/pink.



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If the reagent does not react, try another soiled area or a sample prepared in the laboratory with dirt. If this area does not react, discard reagent, remake reagent with original chemicals and retest. Remake with new chemicals and retest. Consult with Unit Supervisor as to next steps should the reagent fail again.

4.4.3. Leucocrystal violet

Combine 10g of 5-sulfosalicylic acid with 500mL 3% hydrogen peroxide and place into a 500mL bottle. Add and dissolve 4.4g sodium acetate. Add and dissolve 1.1g of leucocrystal violet. The working solution should be stored in amber glassware and refrigerated. Properly label the reagent container and document the reagent preparation in the Microanalysis Reagent Logbook. The working solution should last approximately 3 months. The working solution shall be verified before use. (Bodziak, Footwear Impression Evidence, p.145, 146, 163.)

Verify the reagent is working properly prior to using in casework by applying reagent to a small blood stained area not associated with the print or a sample prepared in the laboratory with blood. The blood stained area should turn purple. If the reagent does not react, try another blood stained area or a known blood stain made in the laboratory. If this area does not react, discard reagent, remake reagent with original chemicals and retest. Remake with new chemicals and retest. Consult with Unit Supervisor as to next steps should the reagent fail again.

4.4.4. Fixative Solution

Prepare a 2% w/v aqueous solution of 5-sulphosalicylic acid (2g in 100mL of purified water, 20 grams in 1000mL of purified water, etc.) in glass container. Properly label the container and document reagent preparation in Microanalysis Reagent Logbook. The fixative solution is used in conjunction with Amido Black reagent. No verification is required prior to use. Should the fixative not perform properly with blood stained items then the solution shall be remade and retested. Consult with Unit Supervisor as to next steps should the reagent fail again.

4.4.5. Amido Black Staining Solution

0.1M Citric Acid

Dissolve 10.5g of citric acid in 500mL of purified water.

0.2% w/v solution of amido black in 0.1M citric acid.



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Dissolve 1g of amido black in the citric acid solution. Properly label the reagent container and document the reagent preparation in the Microanalysis Reagent Logbook. Verify the reagent is working properly prior to use in casework by applying the reagent to a small blood stained area not associated with the print or a sample prepared in the laboratory with blood. The blood stained area should turn bluish in color. If the reagent does not react, try another blood stained area or a stain made with known blood. If this area does not react, discard reagent, remake reagent with original chemicals and retest. Remake with new chemicals and retest. Consult with Unit Supervisor as to next steps should the reagent fail again.
(CRE Report No. 649,1988, and CRE Report No. 684, 1989)

4.5. Procedural and Chemical Precautions

Refer to the TBI Safety Manual for general safety requirements and hazard information regarding the use of reagents and solvents, and overall safety guidelines.

Protective attire, including laboratory coat, mask, gloves and eye protection should be used when working with clothing and/or bloodstained items.

Decontamination of a scientist's work area should be performed after each use, but shall be done after analyzing bloodstained items.

Hazardous chemicals shall be used in a chemical fume hood.

When handling concentrated acids, eye protection and laboratory coats shall be worn.

When diluting acids, always add acid to water.

When necessary, consult section and laboratory Material Safety Data Sheets (MSDS) regarding any chemical used in the Microanalysis section.

Label all generated solutions and reagents with appropriate warning stickers.

4.6. Limitations

Investigative information (i.e. type of footwear, manufacturer, model or general type) is limited to running the shoe impression through the Shoeprint Image Capture and Retrieval (SICAR) database and/or our section's reference



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footwear test impressions made from shoes/boots previously submitted in other cases and/or information found on the internet.

When performing comparisons using photographs, the scientist's examination and results may be limited by the quality of the images submitted.

When using chemical enhancements, the examiner may need to be aware of the following:

- Color of substrate and color of enhancement chemical,
- Porous or nonporous substrate,
- Over development by allowing the solution to remain in contact too long,
- Leaching of the impression with excess liquid, and
- Background development that lowers the contrast.

4.7. Examination Procedure

Document submitted samples according to *Microanalysis Quality Assurance Policy*.

4.7.1. Footwear Impression on an item

Footwear impressions on an item shall be photographed first for comparison purposes and may also be captured by a flatbed scanner when applicable. The image should be imaged using RAW format or another suitable high resolution format. The camera shall be mounted on a camera stand or tripod to prevent movement. The camera should be adjusted as close to the image as possible allowing for focus to be able to fill the frame. The image plane shall be centered over and parallel to the scale. When using a flatbed scanner, place the evidence on the scanner, along with a scale and make a preview scan. Crop the image appropriately and rescan. Capture the image and evaluate it. When these images are transferred to the computer an original file is made and a working file is made. The original file is never opened or changed. All enhancements made in Adobe Photoshop will be in the working file. These files will be backed up on the external hard drive and a DVD will be made (both these processes occur when space is needed on the internal hard drive). The DVD will be stored in a secure location in the Microanalysis section.

Depending on the substrate, the shoe impression may be lifted or enhanced. (See below)

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4.7.2. Enhancement

Footwear impressions made from dirt residue on a porous surface may be enhanced using Potassium or Ammonium Thiocyanate. Spray a small soil stained area not associated with the print or a sample prepared in the laboratory with dirt. The soiled area should turn red/pink. Spray the area associated with the impression. If the footwear impression is enhanced it shall be re-photographed. If there is no change in the impression, it does not need to be re-photographed.

Footwear impressions in blood may be enhanced using 0.2% w/v amido black. The blood print is immersed in the fixative solution for approximately 5 minutes. The fixed blood print is then immersed in the amido black staining solution for approximately five minutes and then rinsed with water. A small blood stained area not associated with the print or a sample prepared in the laboratory with blood shall be processed with the impression. The stain should turn bluish in color. The footwear impression shall be re-photographed after enhancement. If there is no change in the impression, it does not need to be re-photographed. The solution can also be applied by spraying the impression and rinsing it with water.

Footwear impressions in blood may also be enhanced using Leucocrystal violet. Apply reagent to a small blood stained area not associated with the print or a sample prepared in the laboratory with blood. The blood stained area should turn purple. Spray the impression area with the reagent solution. After the color enhancement, the impression shall be re-photographed. If there is no change in the impression, it does not need to be re-photographed.

4.7.3. Lifting

Some impressions may be enhanced using fingerprint powder lightly applied with a fingerprint brush. The impressions shall be re-photographed after enhancement. If there is no change after the addition of fingerprint powder, the impression does not need to be re-photographed. Test fingerprint powder on a known impression prior to using on casework.

An attempt should be made to lift impressions from a surface of an item using an electrostatic lifter, gelatin lifters, clear latent lifters/tape and/or vacuum box. If successful, the lifted print shall be photographed when using the electrostatic lifter, gelatin lifts or the vacuum box.

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A footwear impression may be lifted from virtually any surface, porous and non-porous, but works best on dry dust or dry residue impressions on surfaces that are relatively clean. The above listed methods may be used to lift latent impressions from surfaces where suspected footwear impressions may be present. Comparison photographs of the impression shall be taken before any lifting attempt is made.

Fingerprint powders can be used to enhance footwear impressions that resulted from damp or wet footwear tracking across waxed or polished surfaces, plastic or painted surfaces, and other clean, nonporous surfaces. The color of powder should contrast with the color of the surface. A very small portion of the impression should be powdered first, to determine if the technique would be successful. If it is, the remainder of the impression should be powdered. The powdered impression shall be photographed and lifted. Latent footwear impressions are often discovered during the processing of surfaces for latent fingerprint impressions and should follow the above procedure.

If the electrostatic lifter is needed on a dusty impression, attach the probe and the ground wires (color coded) to the base unit. Attach the ground to a metal surface (i.e. latch on case). Cut a piece of Mylar film to fit the impression. Place the Mylar black side down on the impression. Turn on the unit and touch the Mylar with the probe. The film should be pulled down tightly against the impression surface. If this doesn't happen, use one of the metal plates along the side of the impression for conduction. Use the roller to go across the film to get rid of any bubbles. Turn off the unit and touch the probe to a metal surface. Lift the film and place it black side up into a flat box. Tape the film to the box.

Gelatin or adhesive lifting material should normally be used only after photographs are taken. To use a gelatin lifter, remove the plastic covering and place it in the center of the impression and let both ends roll down across the impression. Rub your hand across the back of the lifter to make sure the impression comes in contact and adheres to the lifter. On the back of the lift, write down case number, initials and where the lift was located on the item. Place the protective covering back on the gelatin lifter.

Adhesive lifts should be placed at the edge of the impression and rolled across the print. If more than one lifter is needed to lift the complete print, the 2nd lifter should overlap the first and so on. When you pull the lifters

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off the item, start with the first lift applied. Lift the adhesive up and place it on a clear piece of acetate or on a piece of paper that contrasts with the print residue.

In cases where it is suspected that impressions may be present on papers but are not visible, the vacuum box may be used to recover the prints. Place the item with the impression on the vacuum box and cover it with the clear Type SP plastic film. Switch on the fan and the vacuum will eliminate air gaps. Charge the film with the corona unit (wand) for 10 to 15 seconds. Switch off the unit and take the film into the photography room and look for footwear impressions using side lighting. If any are observed, photograph them.

4.7.4. Casts of Footwear Impressions

Footwear impression casts with adhering dirt and debris should be cleaned before analysis. A soft bristle tooth/scrub brush may be used to remove debris. Care should be taken not to use a brush that is so abrasive as to damage the cast surface. Photograph the impression cast after cleaning. Photographs may be used for comparison or documentation purposes. If the photographs are for comparison purposes, enlarge photographs to scale.

4.7.5. Photographs/negatives/digital images of an impression(s) submitted from an outside agency

Determine if the photographs/negatives/digital images are of examination quality. Images shall contain a measuring device and be taken from a 90-degree angle to the impression with the camera back parallel to the impression.

If the impression(s) and footwear have a similar tread pattern, produce black and white images of the impression to actual size. If the tread patterns are inconsistent, then it is not necessary to enlarge the images or to make test impressions of the shoes. A negative report can be generated without further analysis.

In the event that digital photographs of question impression(s) are submitted that are similar in tread design to the submitted shoes, to scale enlargements for comparisons will be generated using Adobe Photoshop software with the Foray Calibration filter. This program will size the images at a true, accurate and life-size scale. These images will be



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printed and compared with a similar type of ruler to insure they are to scale.

4.7.6. Test Impressions

A test impression of the known footwear shall be made when a comparison is necessary.

Ensure the outsole is thoroughly dry.

Evenly dust the whole outsole with fingerprint powder.

Tap the footwear on its side to shake off any loose or excess powder, if necessary.

Place a clear adhesive sheet with the adhesive side up on a flat surface. Press the outsole of the footwear carefully against the adhesive surface, taking care to avoid slippage.

Lift the footwear with the adhesive sheet adhering to the bottom of it.

Press the adhesive sheet onto all of the remaining areas of the outsole using either a clean fingerprint roller or fingers.

Place a transparent cover sheet over the adhesive sheet. This will permanently cover and protect the impression.

This method can also be used while the footwear is being worn. The adhesive material should be laid on the floor. The footwear, after being dusted with the powder, is carefully placed on the foot and pressed against the adhesive sheet, beginning with the heel and completing the impression as if one were taking a step.

Impressions in substrate (i.e. blood, grease, etc.)

If the examiner can determine what the substance is that the impression is in (i.e. blood, grease, etc.), a test impression may be made using that or a similar substance, if necessary. Also, additional test impressions can be made using a similar substrate as the substrate of the questioned impression.

Three Dimensional Impressions

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Three-dimensional test impressions of footwear may be necessary for comparison to submitted casts. A substrate similar to the substrate that made the original impression (i.e. dirt, sand, snow, etc.) should be used to make the impression. Biofoam or MikroTrack (Bubber) may also be used as a substrate for making a three dimensional impression. Cast the three dimensional test impression with dental stone. See casting instructions under “Analysis and comparison of Tire Impressions”.

If an impression is submitted to the laboratory where the officer is requesting manufacturer information, then the impression can be run through the SICAR database and/or compared to the TBI standard reference library containing test impressions of all footwear having been submitted in past cases. An internet search may also be performed.

To scale photographs and footwear impressions cannot be included as part of the case file notes because of their size, therefore, these will be maintained in a secure location in the Microanalysis Section. Each envelope will be labeled with the case number and a brief inventory of its contents. This envelope will be referred to in LIMS as TP1. It will contain the test impressions from the shoes submitted and all photographs that were enlarged to scale and used in the examination. If during the examination, lifts or casts are made, these will also be associated with this packet. It will be the examiners responsibility to set up the TP1 in the LIMS system under the case number. The chain of custody starts with the examiner and continues until it is stored into the test impression secured cabinet in the Microanalysis section.

4.7.7. Analysis and Comparison

Analyze question impressions for comparison quality. Document suitability of the impressions for comparison in case notes.

Compare question footwear impressions with the test impressions by any of the following methods:

Overlaying the test impression on the actual shoe impression (only after photographing the impression)

Overlaying the test impression on latent lift(s).

Overlaying the test impression on photographs of electrostatic lift, gel lifts or vacuum box lifts.



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Overlaying the test impression on a cast or photograph of a cast.

Overlaying the test impression on submitted to scale photographs of footwear impressions.

Assess the question and known impressions for class characteristics. The question and known impressions are compared with respect to size, shape, tread design, manufacturer's characteristics and wear.

Determine if individual characteristics exist in the question impressions and the known footwear and test impressions. Individual characteristics are cuts, tears, wear marks and randomly placed nails and flaws acquired after manufacturing. These individual/accidental characteristics result when something is randomly added to or taken away from a shoe outsole that either causes or contributes to making that shoe outsole unique. Random infers that the size, shape, and/or position of the characteristic depend, to some degree, on chance. The value each characteristic should receive towards a positive identification will depend on clarity of the characteristic, its reproducibility in the test impression, the random occurrence on the shoe and its degree of uniqueness.

4.7.8. Verifications

All impression evidence comparison cases will be blindly verified. A qualified impression examiner will get the case from the analyst that worked it without knowing their results. Since this will encompass all results from elimination to identification, the verifier shouldn't have any preconceived idea to the outcome. The verifier will use the photographs, test impressions, shoes and any other evidence necessary to render an opinion. The verifier will fill out the verification sheet with the required information. After the examination is finished, the examiner and the verifier will compare their answers. Upon agreement, the examiner will enter their results into the LIMS system and the technical review and administrative review will be completed per regular procedure. If there should be minor discrepancies (example: enough detail present, etc.) these can be discussed until an agreement between the two examiners is reached. If a major discrepancy develops (example: identification), the two examiners will either come to a compromise that both agree with (example: A lesser association that they can agree upon) or a third examiner or supervisor will become involved until an agreeable outcome is reached.



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5. Measurement Traceability

Any reference to size is solely based on comparison of question to known. No measurements are taken.

6. Reference Materials

TBI generated library of footwear tread patterns
Shoeprint Image Capture and Retrieval (SICAR) database

7. Reports

The following are possible results concluded from the examination:

Physical comparison of the known shoe with the impression from the crime scene revealed them to be consistent with respect to size, shape, tread design and individual characteristics. Therefore, the impression was made by this shoe.

Physical comparison of the known shoe with the impression from the crime scene revealed them to be consistent with respect to size, shape, tread design, wear and one or more individual characteristics. However, these are not sufficient for an identification. Therefore, this impression could have been made by this shoe or other shoes with these same unusual characteristics.

Comparison of the known shoe with the impression from the crime scene revealed them to be inconsistent with respect to (name one or any combination of size, shape, wear pattern or tread design). Therefore, the impression could not have been made by the shoe.

Due to the condition of (name evidence), a comparison could not be performed.

Insufficient detail was present in the questioned impression for a meaningful comparison.

Detail exists in the impression but the features preclude a definitive opinion.

The comparison was inconclusive due to the condition of the photograph or the evidence. A physical comparison was not possible, however the footwear and the impression appear to have a similar tread design.

Comparison of the known shoe with the impression from the scene revealed them to be consistent with respect to (and or all of the following: size, shape and tread

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design). Therefore, it is possible that the impression could have been made by the shoe. However, the lack of individual characteristics precludes a more conclusive comparison.

Analysis of the submitted footwear impression revealed it to be similar to a (manufacturer's brand and footwear name).