

Research on soils, stone products and rocks – selected cases of opinions issued by the Central Forensic Laboratory of the Police in Warsaw

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Summary

Research on soils, stone products and rocks is part of a scientific discipline known as forensic geology. Among the police forensic laboratories, this type of studies are performed only at the Chemistry Department of the Central Forensic Laboratory of the Police (CFLP) in Warsaw and comprise approximately 2% of all opinions issued annually. Despite a relatively low workload in recent years, the interest of law enforcement agencies in the use of this type of analyses in the criminal proceedings is on the rise. This article presents three exemplary opinions issued in recent years at the CFLP. The first opinion relates to murder, whereby concrete slabs were used to commit the criminal act. The second is related to an agricultural machinery fire, whereby evidence included soil samples recovered at the scene and from the suspect's clothing. The last opinion concerns the falsification of semi-finished products used for amber jewelry craftsmanship.

Key words: forensic geology, concrete, soil, amber, microscopic studies, X-ray diffraction, SEM analysis, FTIR analysis

Introduction

Topics related to the research on soils, stone products and rocks for the purpose of modern forensic science are part of a scientific discipline known as forensic geology. According to the *Encyclopedia of Geology* (Selley et al., 2004), forensic geology is a discipline "... related to the use of geological data and methods to solve legal cases...". This discipline emerged in world forensic science as early as the late 19th century, and is considered to have been pioneered by the Austrian Hans Gross (1847–1915), who was a professor of forensic science. In his publication *A Manual for Judges* (Gross, 1893), he pointed out that the soil and mud residues present on the shoes and clothing of the perpetrator of the crime committed are of great importance to the case under investigation. Shortly thereafter, in 1904, Georg Popp, a German professor of chemistry working at the Johann Wolfgang Goethe University in Frankfurt am Main, conducted a pioneering geological examination, whose results were subsequently used in the trial (Thorwald, 2011). In 1910, French criminologist, Edmond Locard, formulated a basic law of forensic geology, named the exchange principle, according to which: "Whenever two objects come into contact, there is always a transfer of material. The methods of detection may not be sensitive enough to demonstrate this, or the decay rate may be so rapid that all evidence of transfer has vanished after a given time. Nonetheless, the transfer has taken place." (Selley et al., 2004). He also developed many procedures for analyzing geological materials collected from the crime scene (Gałuszka, Migaszewski, 2006).

The advancement of forensic geology in the 20th century has led to the solving many criminal cases worldwide, including the United States, Japan, Switzerland, France, Germany, and the United Kingdom (Murray, 2004; Ruffell, McKinley, 2005). In addition, numerous government agencies around the world have established their own laboratories to conduct forensic geology research. These include the US Federal Bureau of Investigation (FBI), the UK Metropolitan Police Forensic Science Laboratory in London, and the Japanese National Research Institute of Police Science (Gałuszka, Migaszewski, 2006). As far as Polish forensic science is concerned, the use of forensic geology is currently at a moderate but nevertheless noticeable level. Among the police forensic laboratories, such examinations are performed only at the Chemistry Department of the Central Forensic Laboratory of the Police (CFLP) in Warsaw. Annually, about 10–15 cases involving forensic geology are handled, which constitutes about 2% of all forensic opinions issued by the Chemistry Department of CFLP. However, in recent years, law enforcement agencies have become increasingly interested in the use of such examinations in the course of criminal proceedings.

Selected cases handled by the Central Forensic Laboratory of the Police

Case 1

The case involved:

Murder – a woman's corpse was found in the Pilica River near the city in southern Mazovia. The corpse was weighted down with a piece of concrete.



Fig. 1. Evidence material – concrete block, top surface.



Fig. 2. Evidence material – concrete block, bottom surface with visible mortar.



Fig. 3. Comparative material – 3 pieces of concrete blocks, top surface; designated as MP1, MP2, MP3.

Fig. 4. Comparative material – 3 pieces of concrete blocks, bottom surface with visible mortar; designated as MP1, MP2, MP3.

The aim of the study was to answer the question (original spelling):

“Is the chemical composition of the object described as a fragment of a concrete block and the chemical composition of the mortar found on the object marked as No. 1, secured on 2.04.2017 in in the Pilica River during the examination of the site of discovering the corpse of unidentified woman, consistent with the chemical composition of the objects described as concrete edging and the chemical composition of the layers of concrete marked as No. 1, No. 2 and No. 3, secured on 5.04.2017 from from the property on street in”.

The evidence material consisting of a fragment of concrete block smoothed on the top surface (Fig. 1) with visible mortar on the bottom surface (Fig. 2) was designated as MD1 for further studies.

The comparative material consisted of three fragments of concrete blocks smoothed on the top surface (Fig. 3) with visible mortar on the bottom surface (Fig. 4). The blocks were designated as MP1, MP2, and MP3 for further studies.

Preliminary information on forensic examination of concrete

According to the *Polish Language Dictionary*, concrete is a mixture of sand, gravel or other aggregate with a solution of binding materials. Therefore, concrete represents a type of anthropogenic rock, albeit containing a natural component, namely mineral aggregate. The binding material in concrete is cement, an industrial product obtained in cement plants from minerals such as limestone, marl or clay. Thus, concretes contain for the most part natural ingredients. In view of the above, the concrete examination can be treated like the examination of natural rocks (e.g. granite or porphyry) and petrological-geochemical methods can be applied to the analyses. According to The American Society for Testing and Materials (ASTM), forensic examination of concretes conducted primarily to compare specific evidentiary samples with concrete

from a known production site. This is to identify similar characteristics of a given class or to determine the source of the concrete. It is possible owing to the fact that the aggregate material (ranging in size from sand to larger fragments) is usually locally sourced and can indicate the locations where the concrete was produced. The chemical composition of aggregates and cement binder are also examined for comparative purposes or in order to assess their potential effect on human health and life, e.g. in terms of the asbestos content (ASTM, C856/C856M-20).

In the case described herein, the forensic examination of the concretes constituting evidentiary and comparative material was limited to the analysis of the chemical composition of the samples provided, in accordance with the questions contained in the court's decision on the admission of expert evidence.

Methodology for handling evidence and comparison material:

Microscopic studies

Initially, a small amount of mortar was scraped from the underside of the mortar-covered evidence and comparison material. The sample was set aside for further examination.

All concrete blocks were then washed with running water to remove surface dirt that could impede macroscopic identification.

After drying, the concrete blocks were subjected to thorough macroscopic examination under natural and artificial fluorescent light. Both evidence MD1 (Fig. 5) and comparative material MP1, MP2, MP3 (Fig. 6–8) were found to be concrete blocks, polished, elongated in shape, grayish-pink in color, porphyritic in texture (unevenly grained) with visible light-colored inclusions. The underside of each block was covered with dried gray mortar, also porphyritic in texture.

Considering the macroscopic features mentioned above, it can be concluded that both the evidence (MD1) and the comparison material (MP1, MP2, MP3) are macroscopically similar.



Fig. 5. Evidence material designated as MD1 (after washing and drying) – top surface.



Fig. 6. Evidence material designated as MP1 (after washing and drying) – top surface.

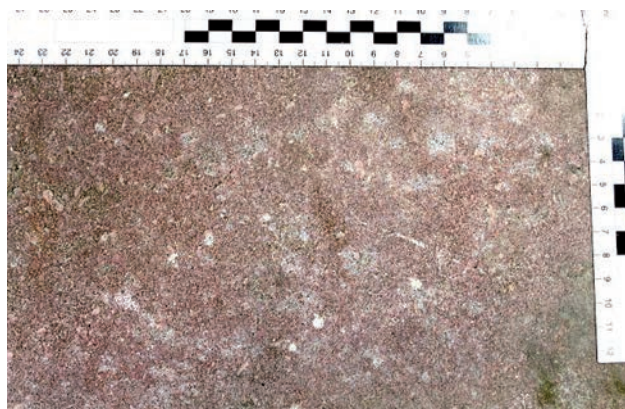


Fig. 7. Evidence material designated as MP2 (after washing and drying) – top surface.

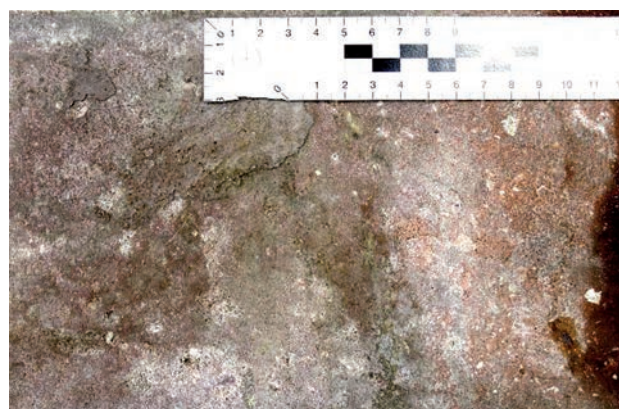


Fig. 8. Evidence material designated as MP3 (after washing and drying) – top surface.

Instrumental studies

Fresh samples were collected from the evidence (MD1) and comparative material (MP1, MP2, MP3) by drilling a hole approximately 2 cm deep in each block, using a special diamond-coated micro-core drill. The resulting borehole cores were separately ground in an agate mortar.

A small proportion of mortar obtained earlier was similarly ground. The prepared bulk samples were subjected to further instrumental examinations.

The first stage of instrumental examinations involved an **X-ray diffraction (XRD)** performed using the CFLP's Seifert FPM XRD-7 X-ray diffractometer. The following measurement conditions were applied: tube with Cu anode; generator: 30 kW, 20 mA; measurement range: 10–66° 2 θ ; scintillation detector. Analysis of the results obtained revealed an identical mineral composition of samples derived from concrete blocks, i.e. quartz (SiO₂), calcite (CaCO₃) and dolomite (CaMg(CO₃)₂). No other components were detected by the method used. This means that the concrete blocks constituting the evidentiary and comparative material were manufactured from the same mineral material. Moreover, the mineral composition of the mortars from both the evidentiary and comparative material was similar and consisted of quartz (SiO₂) and calcite (CaCO₃), occasionally with a small admixture of magnesium (Mg). In addition, two mortar samples from the comparative material (MP1 and MP3) contained a small admixture of hydrated magnesium sulfate (MgSO₄ × H₂O). This means that the mortar composition of the comparative material MP2 was the closest to that of the evidentiary material. The results of the above described analyses are summarized in Table 1.

The next stage of instrumental studies involved subjecting preparations from samples ground in an agate mortar to electron microscopy examination. For this purpose, a small proportion of each sample was applied onto a special microscope stage that was next inserted into the chamber of a SEM Tescan Mira 3 LMU electron microscope equipped with an

Oxford Instruments X-Max^N detector. The elemental composition of selected mineral crusts was then determined using the aforementioned device. Analysis parameters: electron source – Shottky emitter, electron beam accelerating voltage in SEM – 20 kV, working distance – 10 mm, reflected electron detector BSE – atomic contrast registration, EDX detector with 80 mm² SDD type area and 124 eV resolution at K_a line for manganese. Selected data were converted to elemental oxides and matched to the chemical composition of major rock-forming minerals. As a result of the SEM analysis, it was found that all the samples derived from concrete blocks had similar chemical composition of mineral crusts, i.e. mainly quartz (SiO₂), calcite (CaCO₃), occasionally with an admixture of magnesium (Mg), and dolomite (CaMg(CO₃)₂). Similar results were obtained for mineral crusts originated from mortars, which mostly contained quartz (SiO₂) and calcite (CaCO₃), occasionally with an admixture of magnesium (Mg), and small amounts of potassium feldspar (K[AlSi₃O₈]). Subsequently, the quantities of selected chemical elements were converted into oxides and the results were compared on two-dimensional (XY) graphs – the so-called Harker variation diagrams¹. As a result of the comparisons, it was determined that:

- the relationship between silica (SiO₂) and calcium oxide (CaO) (Fig. 9) for all samples derived from concrete blocks is inverse and linear (correlation coefficients R² range from 0.59 to 0.74), that is, as the

¹ Harker variation diagrams are two-dimensional diagrams where the vertical ordinate represents the weight percentage of major or minor oxide components, such as FeO, MgO, CaO, while the horizontal abscissa represents the weight percentage of SiO₂. The purpose of the diagrams is the concise presentation of changes in the concentration of a given oxide, relative to changes in SiO₂. This allows to infer general trends of changes in the major chemical elements. The diagrams were developed in 1909 by English petrologist Alfred Harker and are still used today in the geochemical characterization of rocks (Allaby, 2013).

Tab. 1. Summary of XRD analyses.

Sample	Quartz (SiO ₂)	Calcite (CaCO ₃)	Dolomite (CaMg(CO ₃) ₂)	MgSO ₄ × H ₂ O
MD1 (block)	+	+	+	-
MP1 (block)	+	+	+	-
MP2 (block)	+	+	+	-
MP3 (block)	+	+	+	-
MD1 (mortar)	+	+	-	-
MP1 (mortar)	+	+	-	+
MP2 (mortar)	+	+	-	-
MP3 (mortar)	+	+	-	+

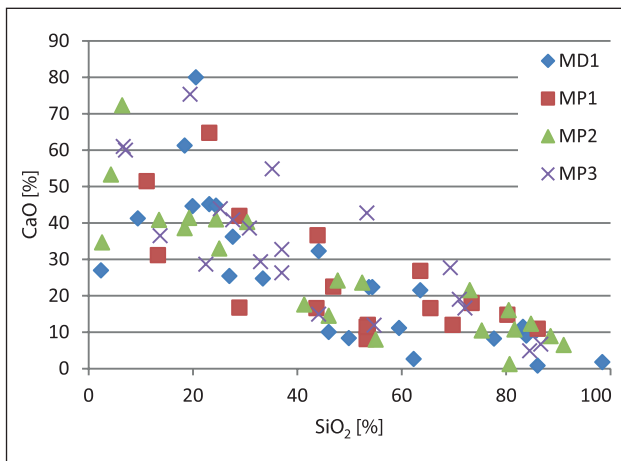


Fig. 9. Relationship between samples derived from concrete blocks (SiO₂ v. CaO).

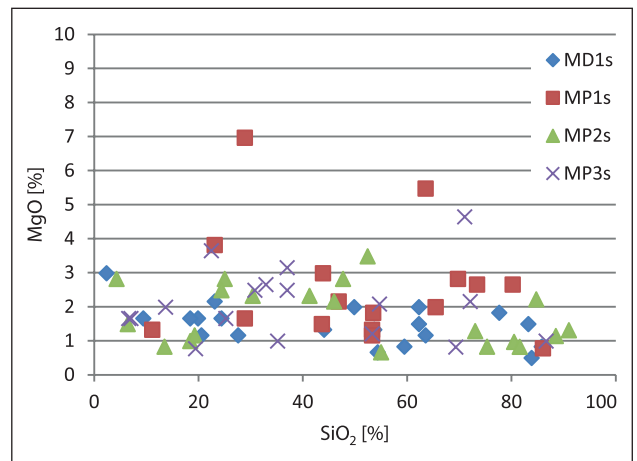


Fig. 10. Relationship between samples derived from concrete blocks (SiO₂ v. MgO).

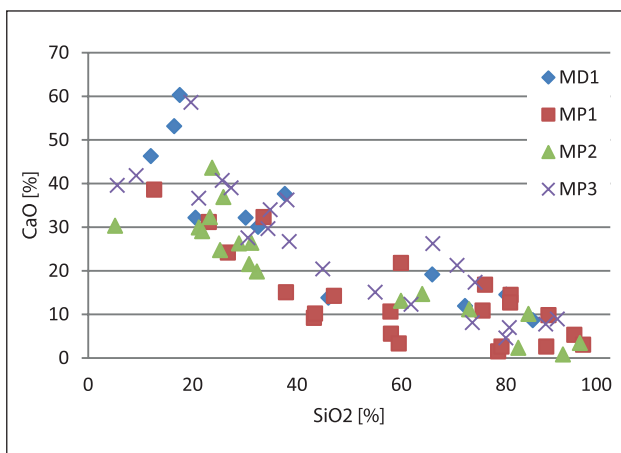


Fig. 11. Relationship between samples derived from mortars (SiO₂ v. CaO).

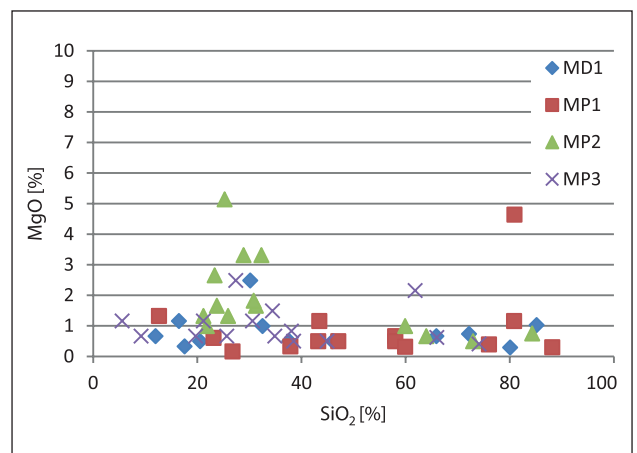


Fig. 12. Relationship between samples derived from mortars (SiO₂ v. MgO).

SiO₂ content increases, the CaO content decreases, meaning, according to the assumptions of Harker diagrams, that the composition of the tested samples derived from all concrete blocks is similar;

- the magnesium oxide (MgO) content of the concrete blocks is virtually constant at about 1–3% for both the evidentiary and comparative material (Fig. 10);
- the relationship between silica (SiO₂) and calcium oxide (CaO) (Fig. 11) for all mortar-derived samples is inverse and linear (correlation coefficients R² range from 0.58 to 0.82), that is, as the SiO₂ content increases, the CaO content decreases, indicating that the composition of the mortar-derived samples is similar;
- the magnesium oxide (MgO) content of mortars is virtually constant at about 0.5–2.0% for both the evidentiary and comparative material (Fig. 12) – slightly less than in the case of concrete blocks.

The remaining elements present in the samples, such as potassium (K), sodium (Na), aluminum (Al), and iron (Fe), are not part of the major minerals that build concrete blocks and mortars and, therefore, cannot provide indicative data to characterize the entire population of the mineral crusts subjected to testing. In conclusion, based on the SEM analysis, the chemical composition of concrete blocks and mortars was similar.

Study conclusions

In terms of the macroscopic features of the concrete blocks, both the evidentiary and comparative material, proved to be similar. The mineral and chemical composition of the samples derived from concrete blocks was the same for both the evidentiary and comparative material, and consisted of quartz (SiO₂), calcite (CaCO₃) and dolomite (CaMg(CO₃)₂), meaning that the tested concrete blocks were produced from the same mineral material. Similarly, the mineral and chemical composition of the mortars from both the evidentiary and the comparative material was much alike and consisted of quartz (SiO₂) and calcite (CaCO₃), occasionally with a small admixture of magnesium (Mg). However, the samples from the comparative material MP1 and MP3 additionally contained a small admixture of hydrated magnesium sulphate (MgSO₄ × H₂O), meaning that the composition of the evidentiary mortar sample most closely resembled that of a comparative mortar MP2.

Postscript

Forensic opinion issued by the CFLP in connection with the above described case has contributed to the conviction of the perpetrator of the criminal act (Fig. 13–15), who was sentenced to 25 years in prison for murder. The judgment is final.

25 LAT ZA ZABÓJSTWO ŻONY

■ Choć proces był poszlakowy, sąd uznał, że poszlaki jednoznacznie wskazują na winę Piotra W., i skazał go za zabicie żony i utopienie jej zwłok w Pilicy na karę 25 lat pozbawienia wolności. Skazany ma w więzieniu przejść terapię

MALGORZATA RUSEK

– Łańcuch poszlak jest zamknięty, ustalenia nie budzą wątpliwości i prowadzą do jednego wniosku: to Piotr W. zabił swoją żonę – mówiła w uzasadnieniu wyroku skazującego sędzia sprawozdawca Iwona Gałek.

Chodzi o głośną w Radomiu sprawę zabójstwa Danuty W. Kobieta zaginęła w niedzielę, 11 grudnia 2016 r. Po południu odwiedziła córkę w szpitalu przy ul. Bohaterów, a potem nie dawała znaku życia. Zaginięcie zgłosił policji dzięk. Córka ujawniła mediom, że trzy dni po zaginięciu mamy w sądzie miała się odbyć sprawa rozwodo-

wa rodziców. Rodzina i policja rozpoczęli poszukiwania, jednak nie przyniosły one efektu. Znalaziono jedynie osobiste rzeczy kobiety, m.in. torebkę i klucze od domu w okolicach miejscowości Brzezce nad Pilicą. Na początku kwietnia 2017 r. ciało kobiety pływające w wodzie odkryli wędkarze.

Prokuratura oskarżyła męża Danuty W. – Piotra W. – o zabójstwo. Mężczyzna nie przyznał się do winy i odmówił składania wyjaśnień. Jak ustalono w czasie śledztwa, Danuta W. i Piotr W. od kilku lat byli w separacji, mieszkali jednak w jednym domu, na różnych jego piętach. Kobieta 11 grudnia pojechała odwiedzić córkę do szpitala, po wizycie wróciła do domu, co potwier-

dzały nagrania z monitoringu miejskiego. Zdaniem śledczych na podwórku została zaatakowana przez męża. Mężczyzna zadął jej kilka silnych ciosów w głowę tępym narzędziem, powodując obrażenia zagrażające życiu i w efekcie zgon. Następnie Piotr W. zapakował ciało żony do swojego samo-

chodu i pojechał nad Pilicę w okolice Białobrzegów. Tam ciało obciążył betonowymi bloczkami i wrzucił je do rzeki. Gdy wjechał, został zatrzymany w okolicach Białobrzegów przez policjantów drogowki, którzy wypisali mu mandat za jazdę z nadmierną prędkością.

– Oględziny wewnątrz samochodu z użyciem luminolu ujawniły dużo śladów krwi mieszczącej co najmniej dwie osoby. Sąd uznał, że ślady DNA kobiety i Piotra W. Bloczki betonowe, które znaleziono przy ciele, według biegłych pochodzą z tej samej linii produkcyjnej co te, które znaleziono na podwórku państwa W. – wymieniła sędzia sprawozdawca.

Sąd skazał Piotra W. na karę 25 lat pozbawienia wolności. Mężczyzna

ma też zapłacić po 200 tys. zł tytułem zadośćuczynienia trójce swoich dzieci, które w procesie występowały jako oskarżyciele posiłkowi. Mężczyzna w więzieniu ma zostać poddany terapii. Wyrok nie jest prawomocny.

Obrońca skazanego zapowiedział złożenie apelacji.

– Nie zgadzamy się z wyrokiem. Twierdzimy, i w tym zakresie sąd podzielił nasze stanowisko, że mamy do czynienia z procesem wyłącznie poszlakowym. W naszej ocenie żadna z poszlak nie przemawia w sposób bezpośredni za winą oskarżonego – mówił obrońca Piotra W., mecenas Daniel Stańczyk. ◻

Danuta W. zaginęła w niedzielę, 11 grudnia 2016 r. Po południu odwiedziła córkę w szpitalu, a potem nie dawała znaku życia.

Fig. 13. Press report on the judgment related to the opinion issued by the CFLP (*Gazeta Wyborcza*, November 23, 2018).

ów krwi należącej do Danuty W., a także ślady DNA kobiety i Piotra W. Bloczki betonowe, które znaleziono przy ciele, według biegłych pochodzą z tej samej linii produkcyjnej co te, które znaleziono na podwórku państwa W. – wymieniła sędzia sprawozdawca.

Fig. 14. Excerpt from a press report directly related to the opinion issued by the CFLP (*Gazeta Wyborcza*, November 23, 2018).

Wyrok za zabójstwo Danuty W. już prawomocny

Sąd Apelacyjny w Lublinie utrzymał w mocy wyrok skazujący Piotra W. na karę 25 lat więzienia za zabójstwo żony Danuty.

Kobieta zaginęła w niedzielę, 11 grudnia 2016 r. Córka ujawniła mediom, że trzy dni po tym w sądzie miała się odbyć sprawa rozwodowa rodziców. Poszukiwania nie przyniosły efektu. Znalezione jedynie osobiste rzeczy kobiety, m.in. torebkę i klucze od domu w okolicach miejscowości Brzeźce nad Pilicą. Na początku kwiet-

nia 2017 r. ciało Danuty W. pływające w rzece odkryli wędkarze.

O zabójstwo żony został oskarżony mąż Danuty - Piotr W. Mężczyzna nie przyznał się do winy i odmówił składania wyjaśnień. Jak ustalono w czasie śledztwa, małżonkowie od kilku lat byli w separacji, mieszkali jednak w jednym domu. 11 grudnia 2016 r. kobieta na podwórku została zaatakowana przez męża, który zadał jej kilka silnych ciosów w głowę tępym narzędziem, powodując ob-

rażenia i w efekcie zgon. Następnie Piotr W. przeniósł ciało żony do samochodu i pojechał nad Pilicę. Tam ciało obciążył betonowymi bloczkami i wrzucił do rzeki.

Jesienią ub. roku Sąd Okręgowy w Radomiu skazał Piotra W. na 25 lat więzienia. Mężczyzna ma też zapłacić po 200 tys. zł tytułem zadośćuczynienia trójce dzieci, które w procesie występowały jako oskarżyciele posiłkowi. W więzieniu zostanie poddany terapii. ● MAR

Fig. 15. Press report on the judgment related to the opinion issued by the CFLP becoming final (*Gazeta Wyborcza*, May 21, 2019).

Case 2

The case involved:

act vandalism to two agricultural tractors CASE and ZETOR with a total value of PLN 190,000 committed to the detriment of a natural person, i.e. constituting a criminal offence under Article 288 § 1 of the Penal Code.

The aim of the study was to answer the question (original spelling):

“Are the soil traces on the secured two pairs of shoes and trousers identical to the soil samples collected as comparative material from the property in and from the field where the clothing in question was discovered?”

The *evidentiary material* consisted of two pairs of athletic shoes (Fig. 16–17) and jeans trousers (Fig. 18–19). Both, the shoes and trousers showed visible signs of wear and tear and were heavily soiled.

The *comparative material* consisted of two samples of a sandy substance: one collected directly from the

property associated with the fire, and the other one collected in a field at a distance of 1500 m from this property.

Preliminary information on forensic examination of soil

The purpose of soil forensic analysis is to link soil, rock, or mineral samples collected from an object, such as shoes, clothing, a spade, or a vehicle, to a specific location. Soils are very good contact (presence) traces that can be helpful in criminal proceedings. Forensic examination of soil typically involves the collection of one or more soil samples and subsequent characterization, supported by instrumental analysis. The samples collected are classified as: (1) evidentiary soil samples of unknown origin or evidentiary samples found on the suspect or victim; (2) control (comparative) soil samples of known origin (e.g., from a crime scene), and (3) alibi soil samples of known origin, providing a measure of the distinctiveness between the evidentiary and comparative sample. Soil characterization often (but not



Fig. 16. Evidentiary material – a pair of light gray athletic shoes with gray speckles.



Fig. 17. Evidentiary material – a pair of blue athletic shoes.



Fig. 18. Evidentiary material – jeans trousers; front view.



Fig. 19. Evidentiary material – jeans trousers; rear view.

always) requires a four-step approach that combines descriptive, analytical, and spatial information. This approach includes: (1) preliminary characterization for sample screening, including morphological description; (2) semi-specific characterization, including semi-quantification of minerals and organic matter after sample selection and grain size fractionation; (3) detailed characterization and quantification of minerals and organic matter using additional analytical techniques and/or sample preparation, separation, or concentration methods such as size or magnetic fractionation or heavy mineral fractionation²; (4) integration and extrapolation of soil information from one scale to another to build a coherent model of soil information from micro (microscopic observation) to macro (landscape) scale, which often includes geologic (including soil) maps and occasionally geophysics. The course of soil forensic analysis at each of the four stages will depend on the amount of sample available and the results of the early stages of examination. Sometimes examination comprising of all four stages is not necessary and it can be narrowed down to the selected stages (Fitzpatrick, 2013).

Methodology for handling evidentiary and comparative material:

Microscopic studies

After a thorough visual inspection of the evidence, in order to obtain material for further examination, scraped soil samples were collected from the shoes (mainly from the heels), which were designated as MD1a, MD1b (a pair of light gray shoes with gray speckles), and MD2 (a pair of blue shoes – considered as a single object of evidence because of the common packaging). The trousers were shaken over a sheet of paper to obtain a shakeout sample, which was designated as MD3. The sandy substance comparative material was designated as MP1 and MP2, respectively. The resulting samples of loose material (MD1a, MD1b, MD2, MD3, MP1, MP2) were subjected to further instrumental analysis.

² Heavy minerals include, inter alia, magnetites, hematites, zircons, spinels, garnets and apatites.

Instrumental analysis

In the first stage of the study, the soil scraped samples from the shoes, the shakeout samples from the trousers and the comparative sandy substance obtained from the preliminary examinations were subjected to microscopic examination using a Leica MZ APO stereo microscope, at 10× magnification. It was found that:

- MD1a (left shoe, light gray with gray speckles) – is a multi-grained (fraction from dusty to gravelly), moderately angular material, light brown with visible large gray and black crumbs and fragments of plants, mainly with a fibrous structure (Fig. 20);
- MD1b (right shoe, light gray with gray speckles) – is mostly fine-grained, moderately angular material, light brown in color with visible larger gray and black crumbs and fragments of plans, mainly with a fibrous structure (Fig. 21);
- MD2 (a pair of blue shoes) – multi-grained material (fraction from dusty to gravelly) moderately angular, light brown with visible large gray and black crumbs and fragments of plants, mainly with a fibrous structure (Fig. 22);
- MD3 (jeans trousers) – fine-grained material, highly angular, light brown, resembling quartz sand with visible, not too numerous grains of dark minerals (Fig. 23);
- MP1 (sandy substance from the property) – multi-grained material (fraction from dusty to gravelly), partially aggregated, moderately angular, light brown with visible larger gray and black crumbs (Fig. 24);
- MP2 (sandy substance collected at a distance of 1,500 m from the property) – multi-grained material (fraction from dusty to gravelly), partially aggregated, moderately angular, light brown with visible larger gray and black crumbs (Fig. 25).

Based on the above analysis of the evidentiary and comparative material, it can be concluded that MD1a and MD2 samples, as well as MP1 and MP2 samples, are similar. The remaining samples (MD1b and MD3) are distinct in terms of grain size (being more fine-grained); however, they do have the same color as the others.

The next stage of the study involved making special preparations from all the samples for examination by scanning electron microscope (SEM). Similarly to



Fig. 20. Scraped soil sample designated as MD1a (left shoe, light gray with gray speckles) (10× magnification).

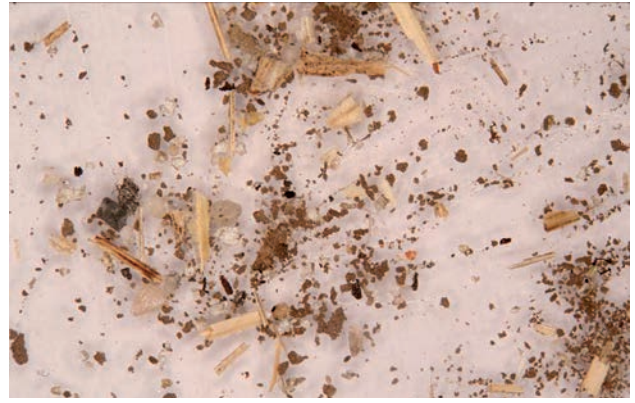


Fig. 21. Scraped soil sample designated as MD1b (right shoe, light gray with gray speckles) (10× magnification).



Fig. 22. Scraped soil sample designated as MD2 (a pair of blue shoes) (10× magnification).



Fig. 23. Shakeout sample designated as MD3 (jeans trousers) (10× magnification).

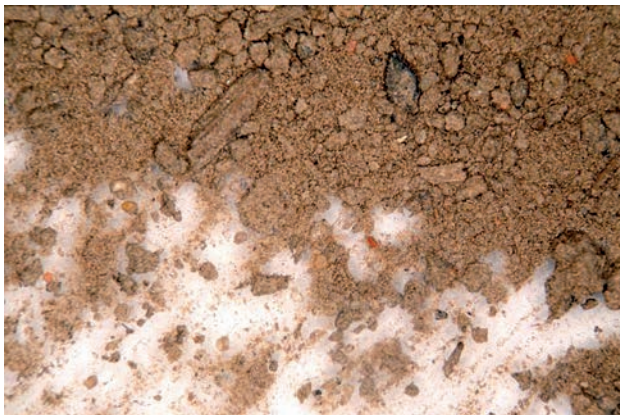


Fig. 24. Sand sample collected from the property (MP1) (10× magnification).

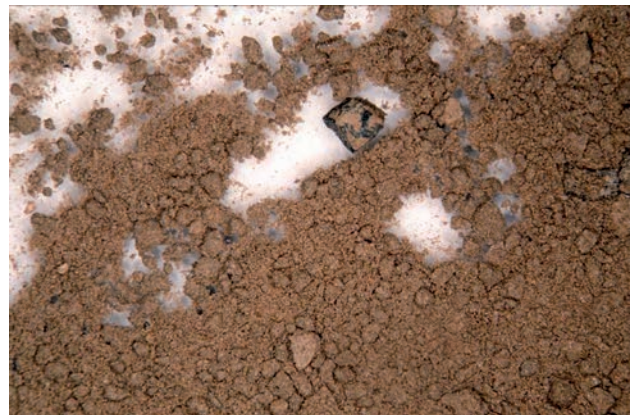


Fig. 25. Sand sample collected at a distance of 1500 m from the property (MP2) (10× magnification).

the Case 1, each sample was applied onto a special microscope stage (Fig. 26, 27), which was introduced into the chamber of a SEM Tescan Mira 3 LMU electron microscope equipped with an Oxford Instruments X-Max^N detector. The elemental composition of selected mineral grains was then determined using the aforementioned device. Selected data were converted to elemental

oxides and matched to the chemical composition of major rock-forming minerals. All samples were found to have mineral composition typical of sandy soils, i.e. consisting mainly of quartz (SiO_2), potassium feldspars (KAlSi_3O_8), occasionally sodium ($\text{NaAlSi}_3\text{O}_8$) or calcium ($\text{CaAl}_2\text{Si}_2\text{O}_9$), clay minerals, mainly from the kaolinite group ($\text{Al}_4[\text{Si}_4\text{O}_{10}](\text{OH})_6$), and iron oxides. Additionally,



Fig. 26. View of the special stage for SEM studies.



Fig. 27. Exemplary material applied to a stage for SEM studies.

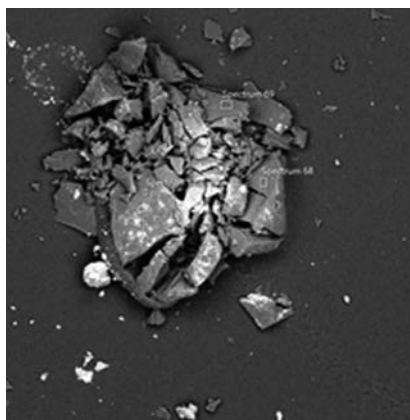


Fig. 28. Carbon grains from MD2 sample (a pair of blue shoes) – SEM microscopic image.

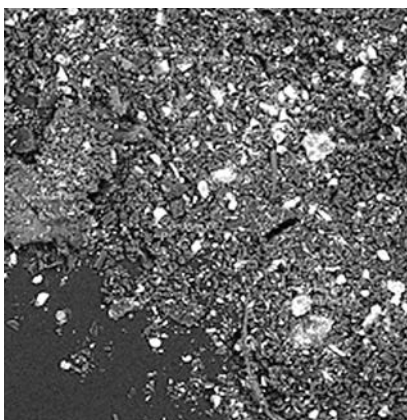


Fig. 29. Carbon grains (dark color) from MD1a sample (left shoe, light gray with gray speckles) – SEM microscopic image.

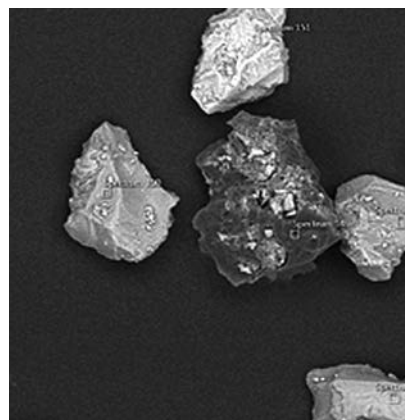


Fig. 30. Carbon grain (dark color) from MD3 sample (jeans trousers) – SEM microscopic image.

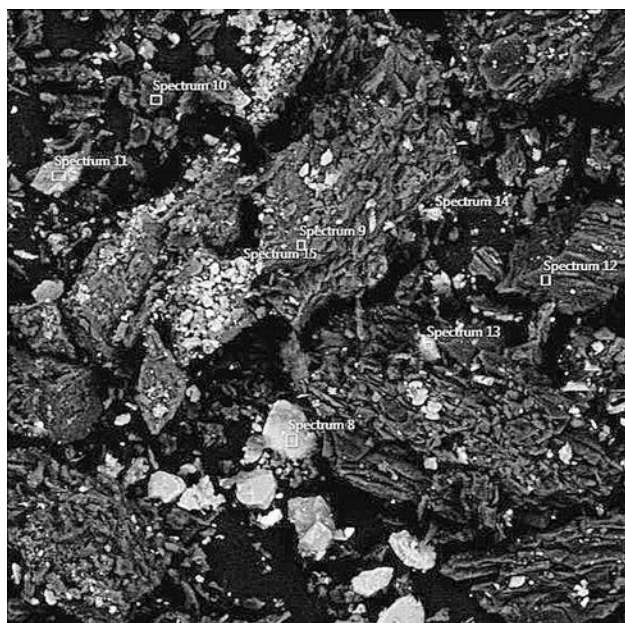


Fig. 31. Carbon grains (dark color) from MP1 sample (sandy substance collected from the property) – SEM microscopic image.

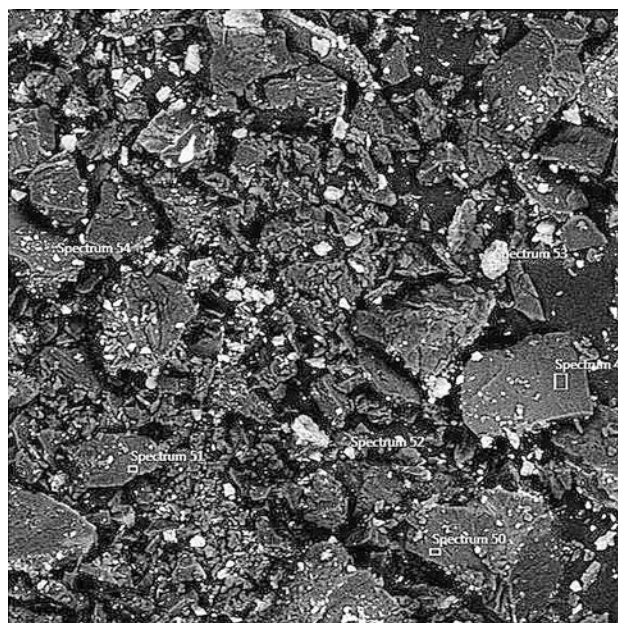


Fig. 32. Carbon grains (dark color) from MP2 sample (sandy substance collected at a distance of 1500 m from the property) – SEM microscopic image.

samples from the MP2 comparative material also contained calcium carbonate (CaCO_3). Moreover, samples designated as MD1a (left shoe, light gray with gray speckles), MD2 (a pair of blue shoes), MD3 (jeans trousers), and the two comparative samples of sandy substance (MP1 and MP2) were found to contain black-colored coal or charcoal crumbs in their composition (Fig. 28–29) – material foreign to their original mineral composition.

Study conclusions

Examinations of the evidentiary and comparative material indicated that the mineral and chemical composition of the scraped samples, shakeout samples and comparative material in the form of sandy, partially aggregated, beige-colored substance was typical for soils of the loamy sand type, which occur over a wide area of Poland. In view of the above, it cannot be categorically stated that the scraped samples, shakeout samples and comparative material originated from the same place. In such a situation, it is important to note unusual, foreign components, whose presence may indicate links between the evidentiary and the comparative material. In the case described herein, such components were crumbs of coal or charcoal, present both on shoes, trousers and in soil samples

collected as comparative material. This may indicate that the person wearing the shoes and trousers in question came into contact with the area where the comparative material was collected. However, it should be remembered that coal and charcoal are also relatively popular soil components in Poland, which precludes which precludes the possibility of issuing a categorical opinion.

Case 3

The case involved:

Fraud by attempting to incite an individual to disadvantageous disposal of property in the amount of 36,000 PLN while selling amber, i.e. an act under Art. 286 § 1 of the Penal Code.

The aim of the study was to answer the question (original spelling):

“Are the semi-finished products in the form of stones for jewelry craftsmanship, secured on from, natural amber?”

The *evidentiary material* consisted of polished cream-colored, yellow, and light brown semi-finished products for jewelry craftsmanship (Fig. 33), uncut beads of various sizes and 3 pieces of cream and light brown colored cubes (Fig. 34–35) – a total of 119 pieces.



Fig. 33. Evidentiary material – polished stones.



Fig. 34. Evidentiary material – beads of various sizes.



Fig. 35. Evidentiary material – beads of various sizes and 3 cubes.

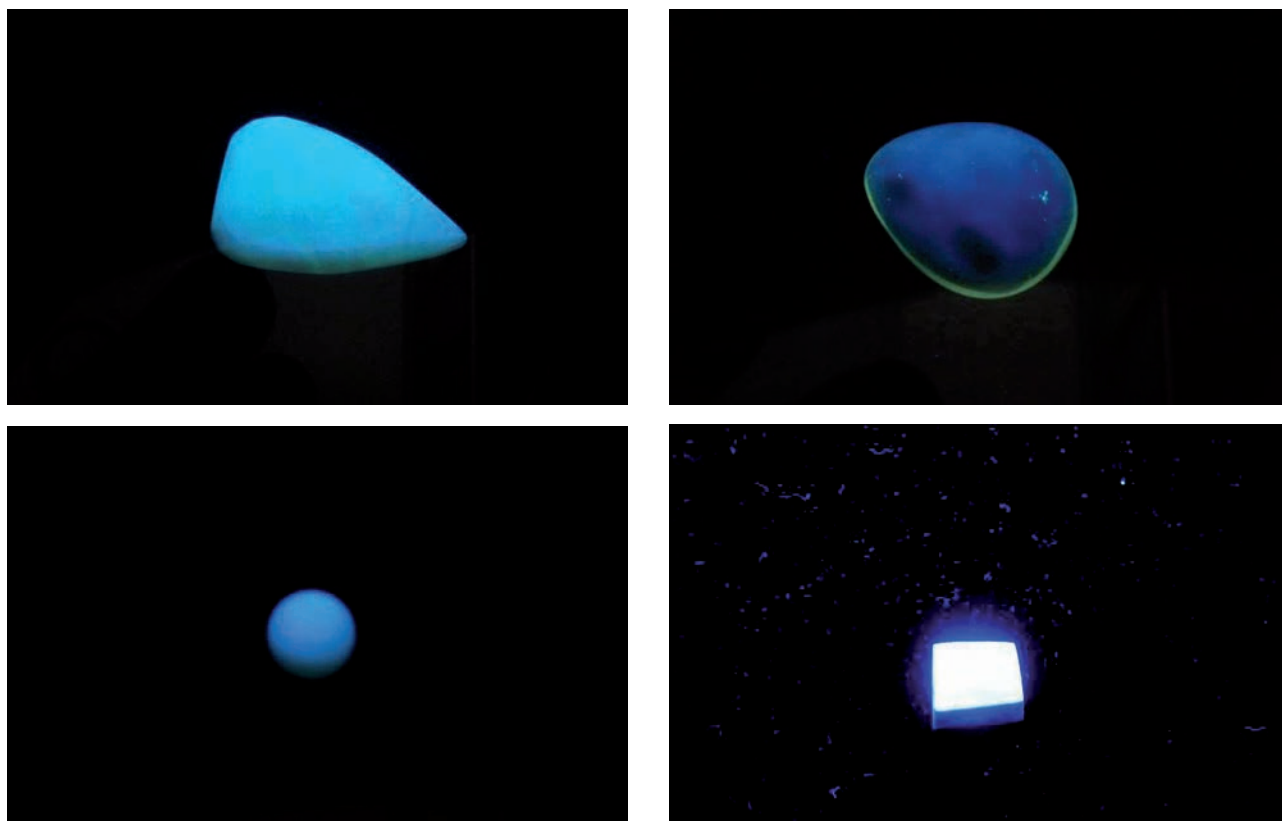


Fig. 36. Randomly selected amber; visible fluorescence under UV light ($\lambda = 365$ nm).

Preliminary information on amber

According to the *Polish Language Dictionary*, amber is a fossil resin of coniferous trees, occurring in the form of yellow or brown lumps. Thus, it is neither a rock nor a mineral. Its name comes from the German word *Bernstein*, meaning a stone that burns. The geological name for amber is succinite, from the Latin word *succinum* meaning sap or resin of a tree.³ The oldest ambers date back to approx. 400 million years ago and come from Canada. Baltic amber, found in Poland among other places, is about 40 million years old. There are also resins similar to amber, but younger – those less than 5 million years old are called copal⁴. The largest amber deposits in the world are located in the Kaliningrad region of Russia (about 90% of the world's resources). The chemical composition of amber is a mixture of dozens of different compounds with an average content of about 67–81% carbon and about 1% sulfur; the remaining components are oxygen and hydrogen. One of the components is succinic acid with a maximum content of 8%.

³ <https://www.gemur.pl/wiedza-o/bursztyn.html> (accessed on 19/03/2021).

⁴ <https://www.amber.org.pl/> (accessed on 19/03/2021).

Methodology for handling evidentiary material

The question posed in this case concerns amber, so at first it should be explained how natural amber is identified and distinguished from artificial, so-called “amber-like” products. According to literature data, natural amber shows an intensive blue-green fluorescence under ultraviolet (UV) radiation at $\lambda = 365$ nm (van der Werf et al., 2017). In addition, it has a unique infrared spectrophotometry (FTIR) spectrum – a distinctive feature of amber (Guiliano et al., 2007). Currently, the FTIR method is widely used to identify and confirm the authenticity of amber. Moreover, the so-called Baltic amber variety is distinguishable from other types of amber, such as that from Romania (Teodor et al., 2009), due to the broad band visible in the infrared spectrum, the so-called Baltic arm, between 1250 and 1175 cm^{-1} with an absorption maximum at 1159 cm^{-1} (Beck, 1986).

Instrumental analysis

In the first stage of the study, randomly selected pieces of evidentiary material were placed under a special lamp emitting ultraviolet (UV) light with a wavelength of $\lambda = 365$ nm. A visible fluorescence effect in the form of blue illumination was observed (Fig. 36).

The next stage of the study involved instrumental measurements by infrared spectroscopy (FTIR). A Thermo Scientific Nicolet IS50 spectrometer was used, and measurements were taken using the Attenuated

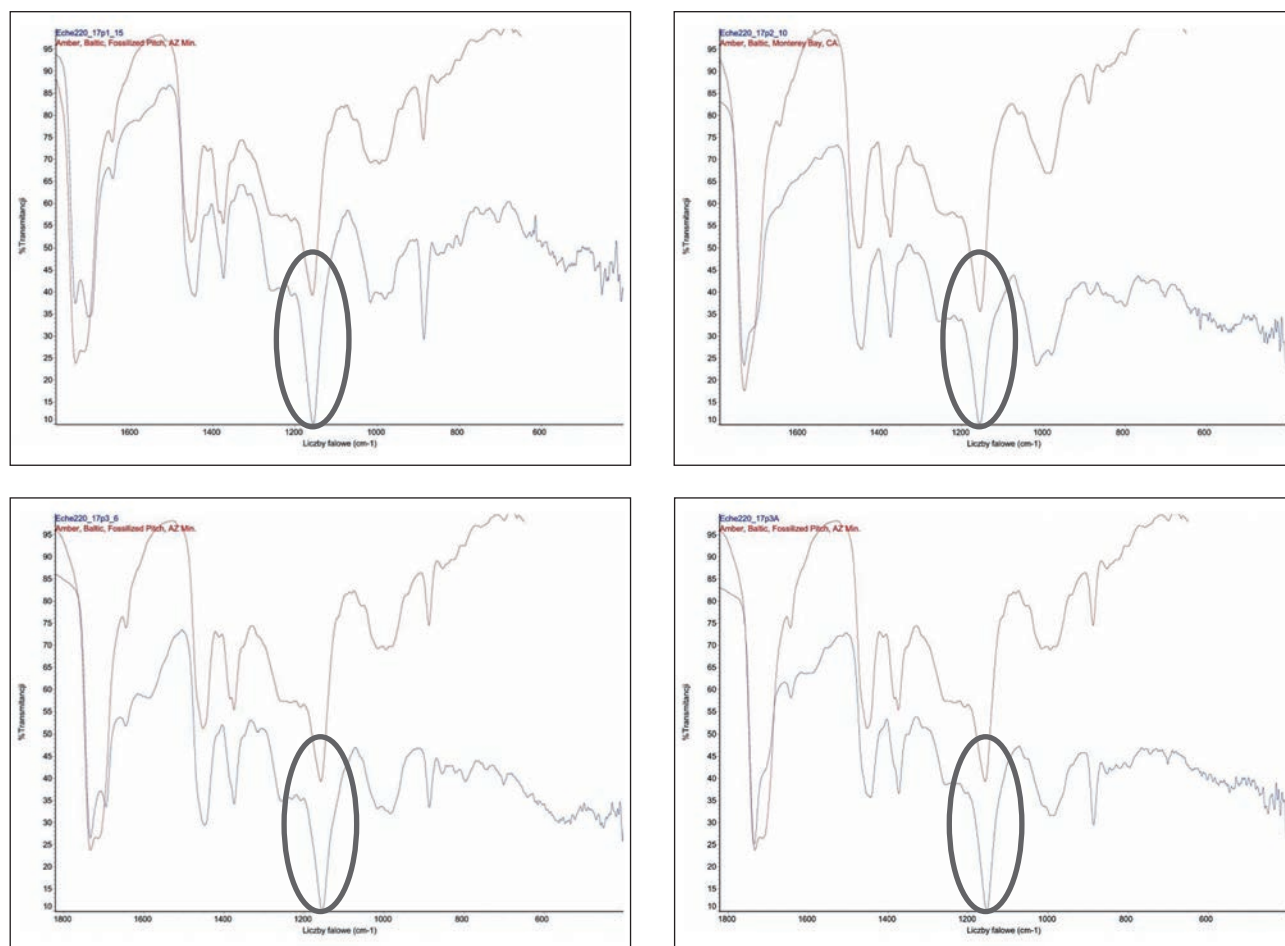


Fig. 37. FTIR analyses of selected ambers (blue) in comparison with the reference (red); marked area represents a spectrum fragment characteristic of Baltic amber.

Total Reflection (ATR) technique, directly from the surfaces of all the ambers. The analysis revealed that each of the ambers examined had the same spectrum as the Baltic amber present in the database, with a visible characteristic band with maximum absorption at 1159 cm^{-1} . Examples of the analyses are shown in Fig. 37.

Study conclusions

Examination by infrared spectrometry, which is indicative mainly of amber, has shown that all the secured semi-finished products for jewelry craftsmanship were Baltic amber. It should be mentioned that the amber identification method applied for the purpose of this case is recommended by the International Amber Association (Międzynarodowe Stowarzyszenie Bursztynników, MSB) in Gdańsk.⁵

Summary

Three examples of forensic opinions in the field of examination of soils, stone products and rocks issued

by the Central Forensic Laboratory of the Police were discussed in detail in this article in order to illustrate the diversity of this forensic discipline. Each of the opinions cited related to a different issue, involved a variety of topics, requiring experts to take a very broad analytical and scientific view. The opinions in question are neither schematic, nor as unambiguous as those involving personal identification, but rather they require a broad range of knowledge, inquisitiveness, and a diverse research workshop, based on modern, interdisciplinary knowledge, mainly in the field of geology, chemistry, and occasionally biology.

Sources of Figures and Tables:

Fig. 1–37: CFLP

Tab. 1: Author

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