Bailey Henwood

Tracking the Untraceable: An Assessment of Global Obliteration Techniques on Small Arms

Cranfield Forensic Institute

PhD Defence and Security
Academic Year: 2020 - 2023

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Associate Supervisor: Dr. Rachael Hazael
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This thesis is submitted in fulfilment of the requirements for the degree of PhD Defence and Security

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Academic Integrity Declaration

I declare that:

- the thesis submitted has been written by me alone.
- the thesis submitted has not been previously submitted to this university or any other.
- that all content, including primary and/or secondary data, is true to the best of my knowledge.
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Abstract

The illicit trafficking and proliferation of small arms and light weapons is of international concern to organisations such as the United Nations, state governments, and non-government organisations. Violent extremist groups and organised criminal groups alike sanitise weapons to conceal their identity and undermine forensic tracing operations. These groups demonstrate sufficient forensic awareness to know that serial numbers and other identifying marks are used to track firearms throughout their lifecycles, across porous borders, and through criminal networks, exposing illicit actors to risk of prosecution. Weapon sanitisation remains an area of concern across the globe, with little transnational monitoring of obliteration methodology undertaken. This thesis investigates marks that have been intentionally obliterated from firearms to render untraceable weapons trackable through illicit facilitation routes.

To enable field-based forensic recovery of removed markings, this research explores an emerging magneto-optical technology. A methodology for utilising this kit has been established within this thesis, with the recovery of obliterated markings surpassing the current methods that utilise a chemical etchant (Fry's reagent) by up to 22%. This emerging technology has proven to be a beneficial forensic capability and preserves the integrity of evidence, while highlighting that some marks may never be recovered even using the most effective, current techniques.

To enable the investigations of non-recoverable marks, this thesis undertakes the first known investigation into the tracking of obliterations on a global level by developing a novel, intelligence-led investigative codification tool based on the toolmark analysis of individual obliterations. This unique tool has been designed to ensure that technical analysis is not restricted by location nor forensic capability. The development and methodology of this novel framework to critically analyse the toolmarks within obliterations has been presented. This approach has been proven in this work to be a useful method to track global obliteration trends when coupled with local intelligence, showing physical links between

sanitised weapons documented in Africa, the Middle East, Canada, the United Kingdom, and Australia. 125 unique clusters encompassing 81% of weapons analysed were established in this research, with 82 of these clusters crossing international and continental borders.

The developed methods and techniques, conclusions, and recommendations of this research have been presented to, and adopted by, international research organisations demonstrating the impact of this novel contribution to knowledge.

Keywords:
Firearm, tool mark analysis, sanitisation, non-destructive recovery, intelligence, criminological investigation

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List of Publications and Presentations

Peer Reviewed Journal Papers

An Assessment of a Non-Destructive Magneto-Optical Imaging Technique for the Recovery of Laser Engraved Marks from Steel Plates and Firearm Components. Bailey J Henwood, Aimée Helliker, Rachael Hazael, Katherine Hewins. Science and Justice; 63 (6): 736-42. 2023. https://doi.org/10.1016/j.scijus.2023.10.007

Conference Papers & Presentations

The Assessment of a Novel Non-Destructive Serial Number Recovery Kit on Steel Plates and Firearms. International Symposium on Ballistics. Reno, USA. May 2022. (Paper [Appendix D] and Oral Presentation)

Regional Obliterations Trends: SALW Recovered in an African State. Defence and Security Doctoral Symposium. November 2022. (Paper [Appendix E] and Oral Presentation)

Firearm Mark Obliterations Documented in Afghanistan: A Case Study. Association of Firearm and Toolmark Examiners Annual Conference. Austin, USA. May 2023. (Oral Presentation)

Differentiating Paint Samples from Overpainted Firearm Obliterations; A Pilot Study. Association of Firearm and Toolmark Examiners Annual Conference. Austin, USA. May 2023. (Oral Presentation)

The Non-Destructive Recovery of Obliterated Marks and Identification of Regional Obliteration Trends. Close Combat Symposium. July 2023. (Poster)

Additional Presentations of Work

Analysis of SALW Materials to Enhance Obliterated Mark Recovery. Counter Firearms Threat Science and Technology Working Group (CoFIT) Meeting. June 24, 2021.

Panel Member. Programme of Action on Small Arms and Light Weapons- 7th Biennial Meeting of States. United Nations Office for Disarmament Affairs, New York. July 28, 2021.

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Panel Member. Programme of Action on Small Arms and Light Weapons- 8th Biennial Meeting of States. United Nations Office for Disarmament Affairs, New York. June 2022.

The Assessment of a Novel Non-Destructive Serial Number Recovery Kit on Steel Plates and Firearms. Guest Speaker for Food and Facts (F2) with Association of Firearm and Toolmark Examiners. July 19, 2023.

List of Abbreviations

ATF	Bureau of Alcohol, Tobacco, Firearms and Explosives
ATT	Arms Trade Treaty
CAR	Conflict Armament Research
CBC	Canadian Broadcasting Corporation
CFA	Canadian Firearms Act
CIBIN	Canadian Integrated Ballistics Identification Network
CIFTA	Inter-American Convention Against the Illicit Manufacturing of and Trafficking in Firearms, Ammunition, Explosives, and Other Related Materials
COTEC	Cranfield Ordnance Testing Evaluation Centre
CSI	Crime Scene Investigation
DA	Defence Academy
DNA	Deoxyribonucleic Acid
EBSD	Electron Backscatter Diffraction
ECK	Eddy Current Kit
ECOWAS	Economic Community of West African States
ENACT	Enhancing Africa's Ability to Counter Transnational Crime
EPS	Edmonton Police Service
ESGI	Environmental, Social, and Governance Index
FBI	Federal Bureau of Investigation
GCI	Global Corruption Index
GI-TOC	Global Initiative Against Transnational Organized Crime
GOCI	Global Organised Crime Index
INTERPOL	International Criminal Police Organization
ISIS	Islamic State of Iraq and Syria
ISO	International Organization for Standardization
ITI	International Tracing Instrument
LIT	Lock-In Thermography
LWW	Light Weapons Wing
NATO	North Atlantic Treaty Organization
NAVCENT	U.S. Naval Forces Central Command
NFA	National Firearms Act
NFC	National Firearms Centre
NSW	New South Wales
NSWPF	New South Wales Police Force
PIT	Pulse Infrared Thermography
POA	Implementation of the United Nations Programme of Action to Prevent, Combat and Eradicate the Illicit Trade in Small Arms and Light Weapons in All Its Aspects
PSSM	Physical Security and Stockpile Management
RCMP	Royal Canadian Mounted Police
SADC	Southern Africa Development Community

SALW	Small Arms & Light Weapons
SEESAC	South Eastern and Eastern Europe Clearinghouse for the Control of Small Arms and Light Weapons
SEM	Scanning Electron Microscopy
SHT	Step Heating Thermography
TIT	Transient Infrared Thermography
UK	United Kingdom
UN	United Nations
UNFP	United Nations Firearms Protocol
UNODA	United Nations Office of Disarmament Affairs
US/USA	United States of America

1 Introduction

The movement and trafficking of illicit small arms and light weapons (SALW) is a transnational threat faced by law enforcement, policymakers, and forensic investigators. Defined by the North American Treaty Organization (NATO), *small arms* are designed for use by one individual, whereas *light weapons* are designed for use by two or more individuals operating as a crew [1]. Due to the size of most SALW, they are easily transported, sanitised, and concealed, and therefore susceptible to diversion [2]. In conflict-afflicted zones such as West Africa, the Middle East, and some parts of Eastern Asia, firearms are often left as remnants of war, which are then filtered across regions through trafficking networks. In these areas, firearms of all types are easily available and are at the forefront of armed violence, crime, and insecurity, and are lucrative income-generating commodities [3]. In more developed regions, such as North America and Europe, nearly half of the illicit firearms used in criminal activity are handguns because of their small size and the fact that the long range of rifles is not typically required [4]. These firearms are often sourced legally in the first instance and are subsequently sold into black markets, where they end up in the hands of criminals and are used for intimidation or committing violent crimes [4].

It is not uncommon for firearms to be recovered by law enforcement agencies in a location where they are not expected or legally meant to be [5]. Firearms are often diverted from legal owners or consigners by criminal parties, referred to as “illicit actors” or “actors”. Examples of diversion sources include state collapse, loss from national custody, state-sponsored diversion, battlefield capture, and ineffective physical security and stockpile management (PSSM) [6]. Weapon diversion and misuse ultimately undermine peace and security by negatively impacting the physical safety and security of life and protection of civilians while also limiting the sustainable development of a region [7]. Additionally, The United Nations Office for Disarmament Affairs (UNODA) states that illicit arms transfers and diversions lead to effortless access to weapons and can contribute to crime and human suffering as well as violate international laws, enable political

repression and terror or civilian populations [8]. To counter these impacts, the importance of impeding weapon diversion and enabling the tracing of illicit weapons within and across regions and borders is clear.

The ability to trace firearms globally is paramount for illicit diversion investigations. Firearms tracing efforts are made by a multitude of organisations, including police bodies during criminal investigations and non-government organisations operating in SALW diversion networks. The goal of these efforts is to ascertain the origin of the firearm and piece together the history of its lifetime. Serial numbers and other manufacturing marks are documented through a firearm's lifecycle as a means of record keeping; they are relied upon to identify all the way through manufacturing, consignments, and to end users. Tracing, therefore, relies on the serial number as the only unique identifier marked on the firearm. Diverted and criminal weapons, however, are often sanitised, meaning a criminal effort had been made to conceal the identity of the weapon [9]. When these identifying marks are removed, the firearm becomes anonymous. Depending on the type of investigation and the global region, an attempt may be made to recover any removed marks.

The recovery of identifying marks is a common practice in forensic laboratories when serial numbers and other marks are removed from illicit firearms. This recovery is currently performed using corrosive chemicals, namely Fry's Reagent, to physically strip layers of the surface to expose deeper layers of the material [10]. Fry's reagent is a mixture of deionized water and cupric chloride, combined with hydrochloric acid. When used in serial number recovery on firearms, the surface is damaged through the surface preparation and chemical application [10]. This leads to irreversible destruction of forensic evidence and renders it impossible to re-examine if necessary.

For research organizations that function to trace illicit weapons recovered in conflict zones, the recovery of these obliterated marks is all but impossible. For numerous reasons, including local acquisition of the reagent or the individual

chemical components, logistics of transport, and safety, chemical recovery is either too dangerous or impractical to do in the field. To combat this, organisations have investigated alternate methods of serial number recovery that carry less risk to the user and reduce damage to the firearm.

During forensic investigations, if the evidential value of physical evidence outweighs the intelligence gained from potential recovery, Fry's reagent may not be used to recover obliterated markings at the risk of damaging evidence. This leaves a capability gap in both developed forensic processes and in conflict-zone investigations. In an effort to aid these types of investigations, this research investigates a currently commercially available alternative tool for the recovery of obliterated marks that, to date, has received little scientific investigation or validation.

In more forensically advanced regions of the world the extent to which the marks are removed often does not allow their recovery, ending any ongoing investigation. To combat the lack of capability and limitations presented through the investigation into mark recovery capabilities, this thesis builds on the non-destructive recovery of obliterated marks by proposing a novel intelligence-based methodology using toolmark analysis to identify the possibility of regional trends in obliterations, in leu of formal mark recovery.

1.1 Research Significance

The non-destructive recovery of obliterated marks can be applied in forensic contexts as well as in remote, in-situ trafficking investigations in conflict zones. Using a magneto-optical imaging technique, serial number recovery efforts may be improved and made more accessible to all operators. The limitations of traditional recovery, namely evidence destruction and corrosive chemical exposure, can be avoided almost entirely. Any transport issues traditionally faced are also negated, allowing for greater global capacity and investigation enhancement.

By understanding the strengths and limits of this recovery method, this thesis poses the first investigation into obliteration techniques and trends on a global scale. There does not currently exist a global tracking system for sanitised firearms, or obliteration techniques across the world. By comparing the physical obliteration analysis to regional firearms legislation, the motivation to conceal identity, and local forensic awareness, a greater understanding of firearms concealment efforts and trafficking may be gained. This thesis, therefore, presents the first method of recording obliterations using objective toolmark analysis, which can be used to group similar obliterations to find common sanitisation points within the lifecycle of individual weapons. The results of these groupings, or "clusters", can then add value to the intelligence into firearms diversion and sanitisation investigations. Subsequent chapters in this thesis will identify trends and highlight intelligence-based findings in firearms sanitisation in different regions around the world.

This novel methodology has been presented to investigators and policymakers through presentations given to delegates, researchers, and international policy organisations in the international arms and diversion networks during this project (see page **Error! Bookmark not defined.**). The feedback from these delegates has shown a high impact in the value of the methodology. The outcome of this work will increase the technical capability in the field and increase the industry's knowledge base surrounding serial number recovery possibilities and how obliterations change around the globe.

1.2 Regions of Interest

This research covers both conflict-afflicted and developed countries. A map highlighting each region of interest is shown in Figure 1-1, which includes the specific countries where obliterations were documented. In this research, conflict-afflicted countries are defined as those that have been impacted by the destabilising effects of armed violence, and frequently experience societal and

political upheaval. Developed countries are defined in this work as those where there is no armed conflict, and the criminal use and sanitisation of firearms by civilians is the primary concern. These definitions and categories have been established by the author of this thesis after considering the aforementioned factors. A thorough profile examining each region and country will be presented in Chapters 5-9, with an overall comparison of all regions in Chapter 10.

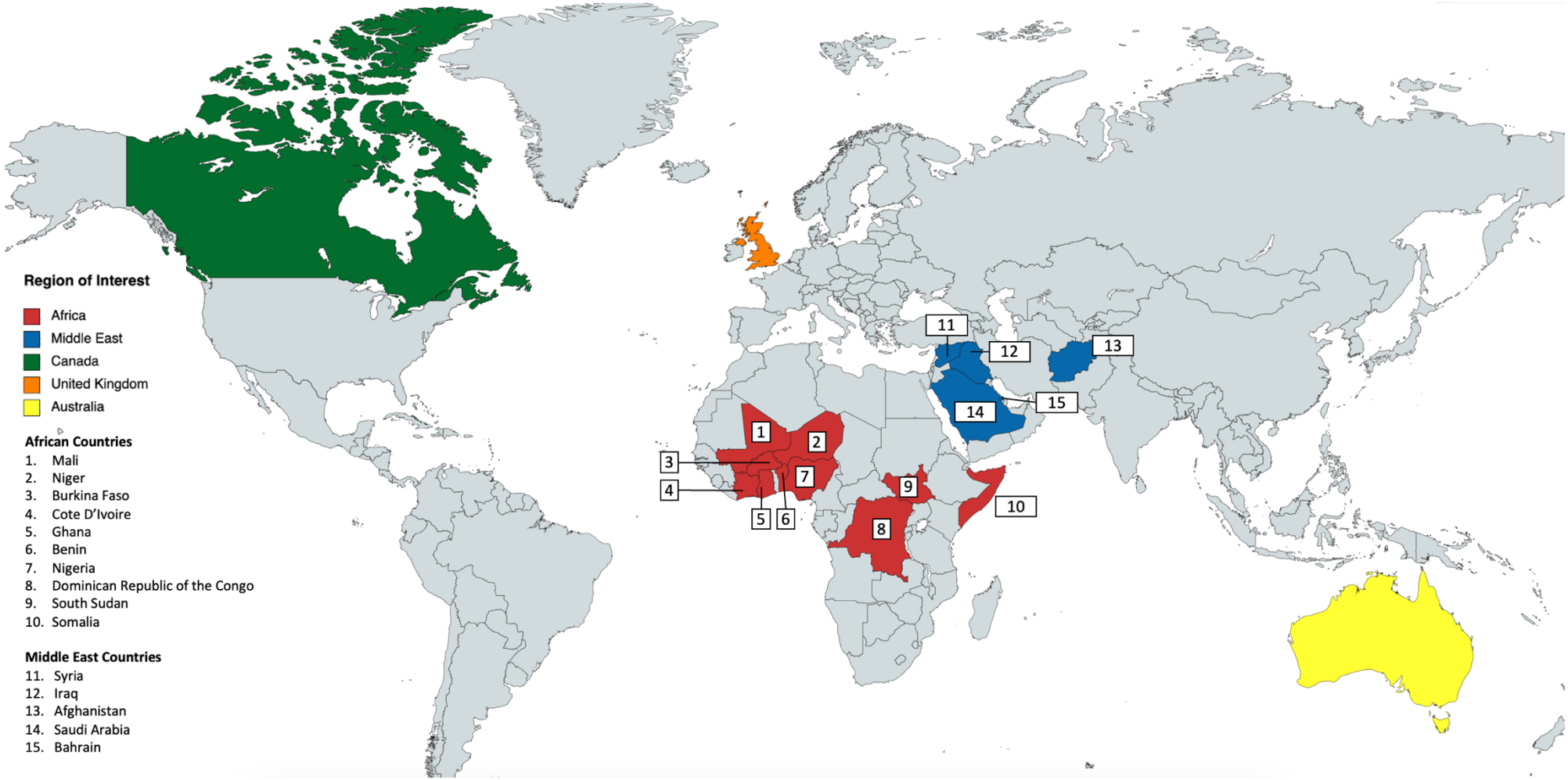


Figure 1-1: A map of the regions and countries of investigation within this study.

1.3 Organisation of Thesis

This project intends to support forensic investigations and weapon tracing efforts. This will first be accomplished through the testing of a non-destructive obliteration recovery technique (ECK), and second, provide a novel methodology for the examination of obliterations. This methodology will be used to enhance intelligence-based investigations based on a region's forensic awareness, technical capabilities, and proliferation networks to ultimately ascertain the efficacy of estimating the region an obliteration was conducted in or trafficking pathways based on obliteration similarities.

The hypotheses guiding this project are:

1. The ECK will provide a statistically comparable solution for obliterated mark recovery to Fry's reagent for use in both forensic labs and the field.
2. The obliteration coding system presented in this work will be able to aid the identification of where an obliteration was conducted, when coupled with intelligence on regions around the world.

The thesis is separated into the following 11 chapters:

- Chapter 1 has provided a brief introduction into the background of the project,
- Chapter 2 reviews the literature on obliterated mark recovery techniques, and the tracking of illicitly diverted weapons,
- Chapter 3 critically reviews and compares two techniques of obliterated mark recovery,
- Chapter 4 outlines the need for and development of a novel coding system for classifying obliteration profile,
- Chapters 5, 6, 7, 8, and 9 explore each region and/or country where obliterations have been documented. Each chapter also provides a review of firearms laws and criminalistics measures local to each region and investigates the obliteration techniques specific to each region,

- Chapter 10 critically analyses the data sets collected from each region and examines the results on a global scale to identify trends and patterns in the obliterations, and
- Chapter 11 presents conclusions, limitations, and recommendations for future research.

This thesis investigates the recovery of obliterated marks from firearms through a comparative analysis of two distinct methods. The first, Fry's reagent, aligns with industry standards, while the second employs an emergent technology (ECK). These results lead to the identification of a capability gap in serial number recovery. To fill this capability gap and allow investigations to thoroughly examine all evidence from within forensic labs and in non-permissive environments, an unprecedented framework for investigating toolmarks documented on sanitised firearms is introduced and used to examine obliterations from five regions around the world.

2 Literature Review

2.1 Introduction

This thesis first investigates an emerging serial number recovery technique, which provides a potential solution for States where traditional serial number recovery may not be a logistically viable or forensically appropriate solution. This work will provide a critical review of a common technique used in forensic laboratories and this emerging, magneto-optical technique. Secondly, this thesis will introduce a novel contribution to knowledge, where this work provides the first intelligence-based investigation into the tracking of obliterations around the world, where recovery is not possible.

This literature review establishes the basis of this thesis, beginning with the introduction of serial numbers, and then the history and development of small arms. The illicit use, diversion, and movement of small arms around the world is explored, followed by the obliteration and methods of recovery of serial numbers and other markings on firearms. A global perspective of firearms is provided in this chapter, however specific laws and policies will be discussed for each region in later chapters. Finally, factors that contribute to the varying perspectives, including corruption levels and forensic science perspectives will be discussed.

2.2 Firearms and Manufacturing

2.2.1 Modern Firearms Materials and Manufacturing

The construction of firearms today is much more complex than that of early weaponry documented through history. The materials firearms are now made from have been developed and improved over time, reflecting the needs and

requirements of the weapon specification, and the component parts of a single firearm depend on the operating mechanism and type of firearm [11,12]

The manufacturing of firearms has evolved as materials and manufacturing processes advance. Where once most firearms were historically made primarily of steel and wood, it is increasingly more common for aluminium and polymers to be the primary materials [11]. The main factors for these changes are due to the cost of the materials and speed of production. More information on these materials will be discussed in the following subsections relating to metal and polymer materials.

There are thousands of firearm manufacturers around the world [13], each with their own material preferences and manufacturing techniques. Generally, these manufacturers produce quality products, that buyers trust will perform as expected to fulfil certain procurement requirements. These requirements may relate to the operation of the weapon itself or the specific task of the intended end user. They also align with legal requirements for marking, which will be discussed later in this chapter. In contrast, and of increasing concern, are illicit manufacturers.

In some cases, weapon designs are illegally copied to satisfy demand for particular types or models [14]. While visibly, a high-level replicate may look like a genuine firearm, the materials used are often of lesser quality, with substandard material properties leading to early failure, or have a different material composition altogether, which may affect the performance of the firearm [15]. The materials used, whether metals or plastics, are high quality when manufactured in a legitimate facility and it has been hypothesised that the quality of the metals will be lower when manufactured in an illicit factory, which if true, may be used as another facet to weapon identification and tracing [14,15]. Small batch gunsmiths in Pakistan have stated that while their Kalashnikov copies are convincing in their appearance, the quality is no match for those made in China

or Russia, and the weapons fail far sooner than those of legitimate production [14].

2.2.1.1 Metals

Mechanical properties of metals, such as the strength, ductility, toughness, and conductivity, are a direct reflection of their microstructure [16–18]. The microstructure of metals, while generally organised into cubic crystal structures, is not perfect and often has inclusions of other elements (or voids) that distorts the lattice structure [17].

Another distortion of the lattice structure is known as a dislocation. Edge dislocations and screw dislocations are the two primary forms, where the latter inserts an extra half-plane of atoms, and the former creates a spiral in the lattice (Figure 2-1).

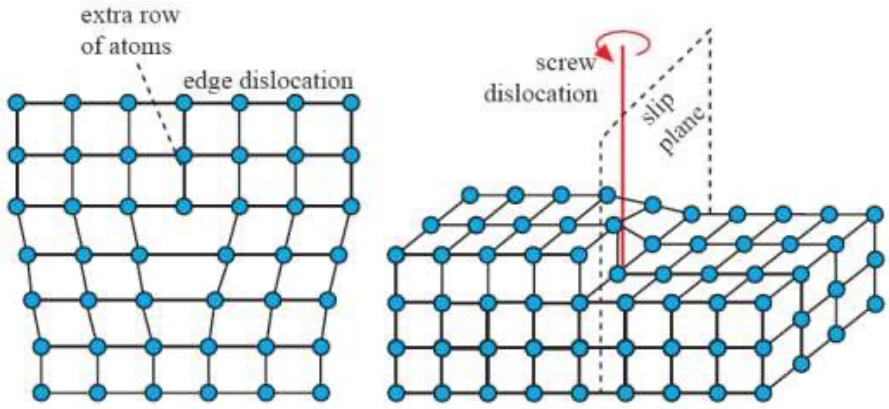


Figure 2-1: A schematic of crystalline dislocations. An edge dislocation (left) forces adjacent atoms outward, while a screw dislocation (right) creates a spiral in the lattice.

Most metals are comprised of many small crystals with varying atomic lattice orientations, known as polycrystalline [16,18]. The crystal units are called “grains”, with the area between the grains known as “grain boundaries”. The orientation of the grains in an unprocessed, and therefore unstrained, metal is random [17]. When the number of grains increases in an area, there are more

opportunities for multiple grain orientations to be observed. The random orientation of the grains is what gives the metal strength, as there is more resistance to dislocation, making a metal harder to manipulate [17].

To alter the shape of a metal, such as forming firearm components or applying markings, it must undergo plastic deformation [19]. When the applied force exceeds the yield strength of the material, but does not exceed the tensile strength, the material cannot return to the original shape [19]. The visible deformation of the material (i.e., the change in the shape) is due to the dislocations piling up at the grain boundaries within the microstructure.

This is a general description of the microstructure of metals. Each type of metal will have different properties based on the type of material. Steel and aluminium are of primary interest in this work and will be discussed in the next two sections.

2.2.1.1.1 Steel

Steel is primarily comprised of iron and carbon in varying percentages depending on the intended use, with traces of other elements [20]. In firearms, a high carbon content is necessary to achieve the required strength to withstand the high amounts of pressure generated inside the chamber during firing [21]. Proof houses ensure each firearm is strong enough to fire the appropriate ammunition through the proofing process [21]. The most common high-carbon steel used in firearms manufacturing is 4140 steel, which is 0.4% carbon, with chromium and manganese [22]. The microstructure of steel can be changed using heat treatments to obtain the desired microstructure. One microstructural form of high carbon steel is pearlite, which exhibits alternating layers of ferrite and cementite [20]. This configuration allows a balance of ductility and strength, which is beneficial during firearms manufacturing [20]. A benefit of steel is its magnetic properties, which allows certain recovery methods to be effective if serial numbers are obliterated, which will be discussed in Section 2.4 of this thesis.

2.2.1.1.2 Aluminium

Another common metal used in firearms manufacturing, aluminium is lightweight and less dense than steel [23]. Because of these beneficial factors, the firearms industry currently relies more heavily on aluminium for frames, magazines, mounts, and other components [24]. The most popular aluminium used in firearms manufacturing is 6061 aluminium alloy, which contains magnesium and silicon and is commonly known as aircraft aluminium and used for its lightweight properties [22]. Another, more expensive aluminium alloy (7075) is used in military-grade weapons such as AR-15 models [22]. A downside to using aluminium for firearms manufacturing is the lack of magnetic property [23]. Within Section 2.4, serial number recovery methods will be introduced that rely on this property for a successful recovery.

2.2.1.2 Polymers

While the recovery of serial numbers from polymers is not considered in this thesis, it is important to note that the use of polymers, or plastics, in firearms manufacturing is becoming increasingly more common [25]. Polymers are lightweight, cost-effective, and resistant to corrosion; all issues encountered when using steel and aluminium in arms manufacturing [25]. They also have an advantageous strength to weight ratio, which allows good elasticity and toughness. As with aluminium, polymers can only be used for some components as they are not strong enough to withstand the pressures required by the chamber, barrel, and other internal components.

2.3 Serial Numbers

Serial numbers are applied to items of value [26]. As a unique identifier, serial numbers are often used to distinguish one item from every other similar item, and for record keeping. Serial numbers were first required to be applied to firearms by the Gun Control Act in the United States of America (USA) in 1968 [27]. The intention of introducing this requirement was to prevent illicit sales and ensure firearms would be traceable in the event of a crime, or diversion.

There are no international requirements for the format of serial numbers, and so many manufacturers use their own conventions when assigning serial numbers and other marks to firearms [28]. Conventions may also change within the same manufacturer if serial number become too long, are to fulfil a specific contract or end-user, a new variant is introduced, or a new factory becomes operational [28]. In some cases, the serial number may contain year of manufacture or other indicators. This also means that there are no standard procedures or locations for other markings on firearms. Sometimes, this can result in the same model of firearm having different markings in the same location. For example, Figure 2-2 shows two AK-pattern rifles. One rifle was manufactured in Russia, showing the factory, year of manufacture and the serial number on the frame, while the second rifle was manufactured in China showing the factory, model and serial number marks in the same location.

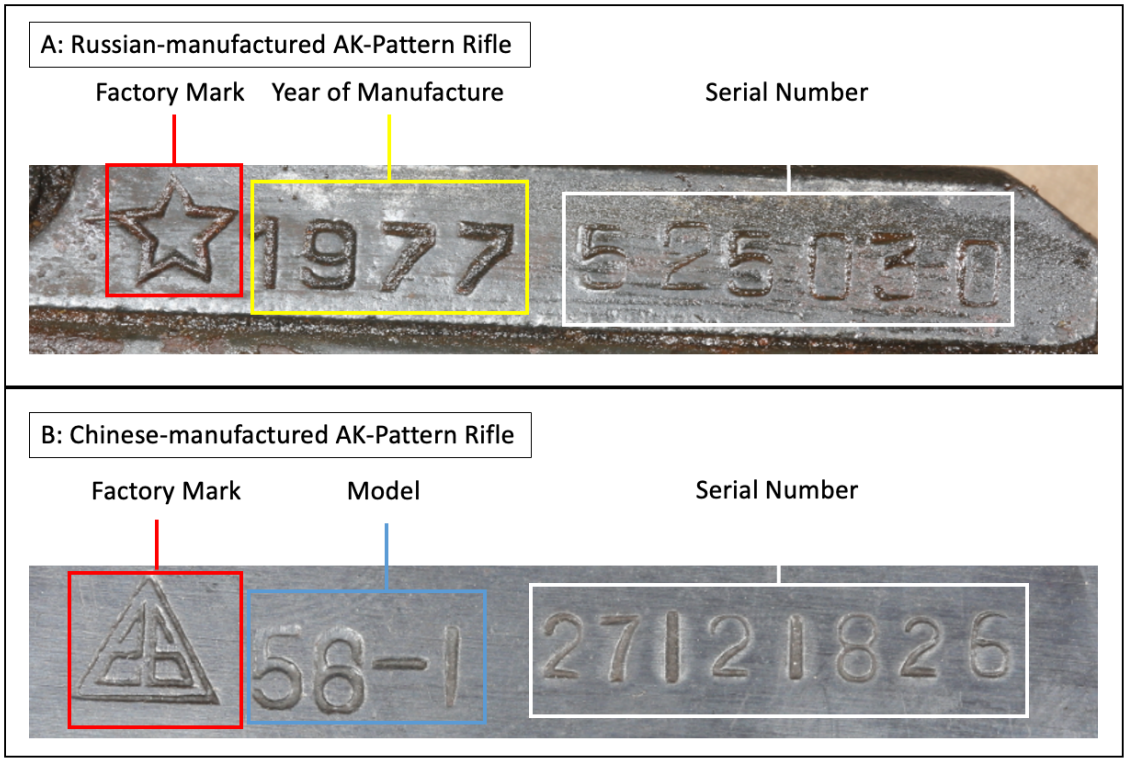


Figure 2-2: Two AK-pattern rifles manufactured in two countries. A) Russian manufactured, showing factory, year of manufacture and serial number marks, and B) Chinese manufactured, showing factory, model, and serial number marks.

As mentioned previously, the materials firearms are made of has evolved over time, depending on requirement, technology, and cost. To evolve with the materials, manufacturing methods have also changed, including how marks are applied [11]. During production, weapons manufacturers apply unique serial number to small arms in addition to the generic manufacturing marks, identifying the factory, year of manufacture and calibre [29]. Serial numbers are applied to support the identification of weapons during manufacturing, onward shipping, and subsequent transfers to end users, throughout their lifecycle [29]. They allow effective record keeping methods to be used by the manufacturer during sales to a variety of customers, such as government forces and resellers. When a consignment reaches the end user, the serial numbers may be used to assign personnel with individual weapons and ensure adequate stockpile management systems are in place. In many countries, local gunsmiths and other registered

firearm traders are required by law to record the serial numbers of the firearms they have in stock for service, storage and for sale [30].

The allocation of serial numbers is not standardised across global manufacturers. Manufacturers typically follow their own internal formats, which can be changed to accommodate consignments, model changes, year of manufacture, and more [31]. For example, Bulgarian serial numbers include the year of manufacture in the serial number through the date code digits, where 1970 is “10” and increases by 1 each year of production [32]. It is common for manufacturers to start a new format for military consignments, which can lead to sequential serial numbers for one group of weapons. This can complicate the estimation of SALW in circulation at any given time, as well as ensuring PSSM practices are efficient.

2.3.1 Additional Marks on Firearms

The marks being analysed in this study will primarily be those applied by the manufacturer; serial numbers, manufacturer, model numbers, calibre, factory identification and potentially proof, import or inspection marks. The purpose and importance of each mark are as follows:

- *Serial number*: These are the unique identifiers of each firearm. They are typically numerical, however, some manufacturers with use alpha-numeric serial numbers or symbols.
- *Manufacturer:* These marks will often be the manufacturer’s logo stamped or engraved into the firearm. This is primarily a branding technique; however, they do help to identify the firearm.
- *Model number:* Discriminates different types of firearms made by the same manufacturer. These model numbers are akin to the various models of cars that one vehicle manufacturer produces.
- *Calibre:* The calibre of the firearm is the type of ammunition it will fire. This is a standard mark included on almost all firearms, as it will ensure the firer is using the correct ammunition. Not only for safety purposes, however,

also aids in identifying the same model that may have been produced to fire multiple types of ammunition,

- *Factory:* This is a mark commonly seen on Chinese produced firearms. They help to discriminate which of the many factories one manufacturer has, improving the chain of custody and traceability of these firearms.
- *Proof mark:* Firearms in some countries, including the UK, require testing to ensure they are fit for use and can withstand the pressure of the intended ammunition, making them physically safe to fire. Each proof house will have a unique stamp they apply to various pressure-bearing components, again improving the chain of custody and traceability of the firearm.
- *Import mark:* These marks are extremely inconsistent, as there is no universal standard or requirement to include them. Some countries will apply importation marks on all firearms, whereas others will only apply them in specific circumstances.
- *Inspection mark:* These are typically added by armourers or weapons inspectors and are often merely for internal record keeping. Often, they are small, random characters and are not routinely victim to obliteration as they do not hold any real identification value, nor is there a recorded keeping system for these marks outside of individual organisations.

Figure 2-3 shows examples of proof, inspection and import marks. An example of a British (Birmingham) proof mark is shown in the top left image, with Spanish inspection marks shown in the top left image. The bottom image highlights an import mark. It is important to note that these types of marks are not regulated internationally and are left to the country of origin to determine the requirements for information included, size, and application method.

Figure 2-3: Examples of proof marks (top left)(authors own image), inspection marks (top right) [33]**, and import marks (bottom)** [33]**.**

The above marks are commonly positioned on the frame, receive, barrel and/or slide, as these are the major components of the weapon. These components may also be subject to legal control in some countries, which require a serial number [28]. In some cases, the marks are also applied on smaller, internal components like the bolt carrier, insert plates, and return spring guides [34,35]. Figure 2-4 outlines the components of a typical pistol (Glock) and a rifle (AK-pattern), where a serial number or other identifying mark would be applied.

Figure 2-4: A Glock pistol (top) and an AK-pattern rifle (bottom), each with the typical locations of marking labelled and the primary serial number circled. Figure authors own.

2.3.2 Mark Application Methods

Licit manufacturers will ensure their markings are made using various tools and techniques, where artisanal copies of genuine firearms are not likely to exhibit the same level of quality [36]. Methods of application include, but are not limited to, dot peening, lasering engraving and stamping, shown in Figure 2-5.

Figure 2-5: Three methods of serial number and mark application. (A) Dot peening, (B) Laser engraving, (C) Stamping. All photographs courtesy of Conflict Armament Research.

When manufacturers apply marks to a firearm, they must consider the effect the application process will have on the material. The process must result in clear, legible marks and not damage the material in a way that affects the physical or mechanical integrity of the firearm [36]. There are four main methods of mark application- stamping, dot-peening, mechanical engraving, and laser engraving- each of which display different characteristics in the material.

Stamping is one of the most common methods of mark application to metal firearms, likely due to the simplicity of the machinery required and the lower cost associated[36,37]. For example, the average stamping machine will cost approximately $10,000-$25,000 USD, whereas a mechanical engraver may cost up to $50,000 USD, and potentially $60,000 USD for a laser engraving kit [37]. The stamp does not remove material but forces it away from the stamp, primarily outward with pressure building below the mark [36]. Stamped marks therefore show material build-up around the edges of the mark (as seen in Figure 2-7), and also exhibit the highest level of compression to the underlying crystalline layers. Due to the microstructure and low tensile strength of the material, stamping cannot be used on polymer or aluminium. This leaves a requirement for alternate marking methods [37].

Dot-peening is the same process to stamping, however, instead of one solid stamp, the mark is made of dots that are stamped into the material. This reduces the amount of stress applied to the weapon components, therefore limiting the damage to underlying layers of crystalline structure [36]. For the same reason stamping is not used on plastics, neither is dot-peening. Figure 2-6 shows a schematic illustrating the side view of microstructural stress and material flow, shown by the dotted lines, when metals are stamped or dot-peened.

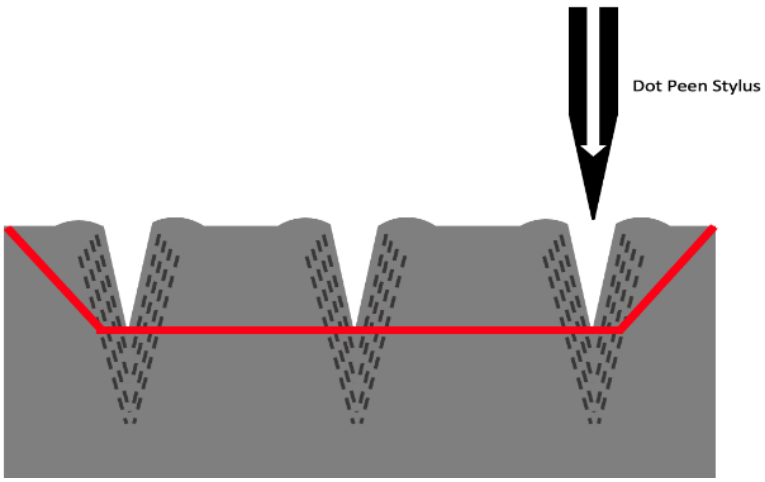


Figure 2-6: The area above the solid red is the area of obliteration, removing visual dots or stamps while leaving regions of stress intact, allowing for recovery (not to scale).

Mechanical engraving, sometimes referred to as “scribing” or “etching”, physically removes material from the marked area, without compressing the underlying microstructure [36]. This is shown in Figure 2-7. A hardened pin or various types of cutters can be used to scribe the desired mark into the material. The benefit of engraving marks into firearms is that the process produces high quality marks, however, it is only useful in metals. The cutter must impact the material with enough force to exceed the elastic limit without causing material failure. The amount of force used must be adjusted for each material, as the physical properties of the materials vary with their specific composition. It also requires continuous maintenance of the pins or cutters, which can be costly over time [36].

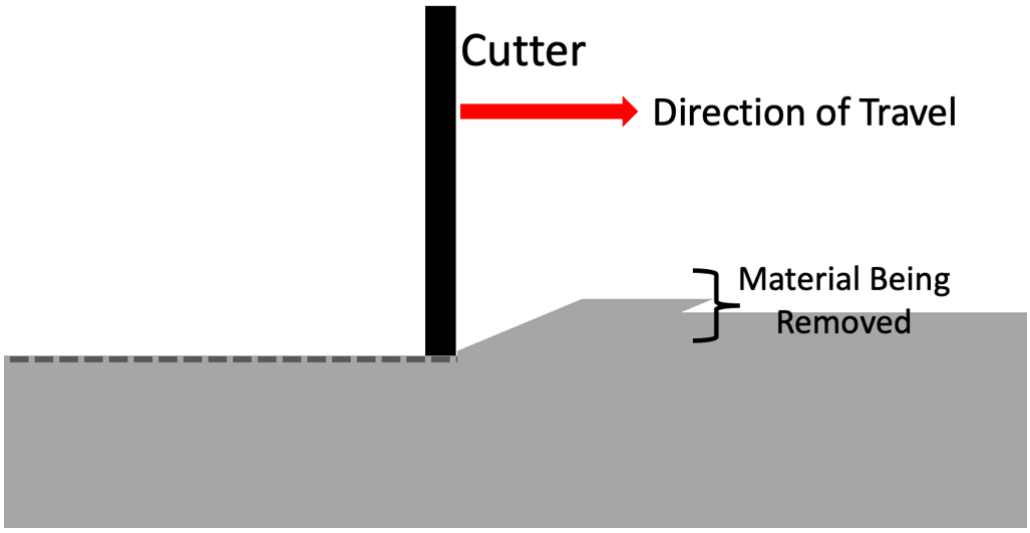


Figure 2-7: A schematic of the effect of mechanical engraving on the structure of metallic firearms.

Laser engraving is a technologically elevated process to mechanical engraving, utilising a fibre laser to remove material from the steel surface instead of a stylus making physical contact [36]. A laser beam passes over the material without making physical contact, resulting in extremely clear marks while not compromising the material. Typical wavelengths of the beam for these laser engraving units range between 780nm and 2200nm, which is effective for

marking materials such as metal, rubber and plastic [38]. A benefit of this process is that it can be used on various materials and requires low maintenance as there is no physical contact between the machine and the material [36]. The downside to this method of application lies in forensic applications; laser engraved marks produce the smallest area of localized deformation in the surrounding material with no toolmarks associated with the application, which makes recovery very difficult, if not impossible, if the mark is obliterated [37]. Laser marking is also used to apply serial numbers and other marks to polymers. The use of lasers allows for the manipulation of heat and intensity of the beam, which impact the depth of the mark [39]. This is examined in more detail in Chapter 4. Figure 2-8 illustrates the differences between mechanical engraving and laser engraving.

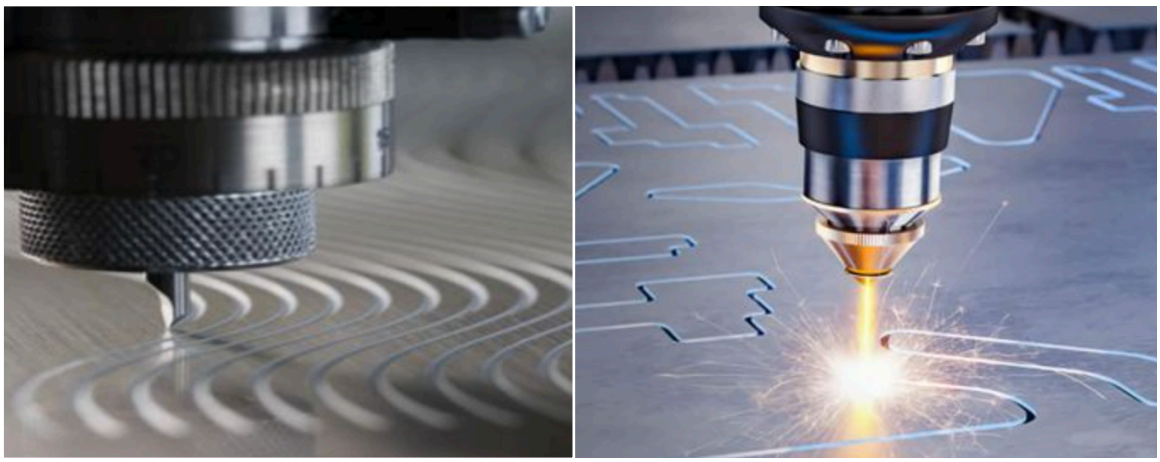


Figure 2-8: Mechanical engraving, where the engraving stylus makes contact with the steel surface, removing material as it moves (left), and the laser engraving of steel, where the laser removes material by the emission of radiation (right). Images from [39].

2.3.3 Firearm Marking Policies

Firearm mark requirements are not standardised across the industry globally [37]. Many countries will impose their own legislation, in coordination with their firearms ownership and sales laws, while others may choose to align with

standards suggested by various political bodies [37]. The firearms regulations for each region examined as part of this thesis will be covered in Chapters 6-9, however, some key global policies are introduced in this current section.

The Bureau of Alcohol, Firearms and Explosives' (ATF) National Firearms Act (NFA) [40] and the Canadian Firearms Act (CFA) [41] are two examples of early federal laws that regulate ownership, possession, use, and importation of firearms. While these Acts are North American legislation, many countries choose to adopt the same, or similar, guidance and requirements for their own legislation. The NFA requires that serial numbers and other identifying marks are placed on conspicuous components to a minimum depth of 0.003 inches (0.0762 mm) and cannot be easily removed or altered. The CFA requires markings to be "permanently stamped or engraved on the frame or receiver of all firearms manufactured in, or imported to, Canada" [42], however, it does not stipulate the depth or method of marking.

Additionally, the International Tracing Instrument (ITI) is a politically binding agreement, which all UN Member States adopted in 2005 [43]. It outlines the challenges faced in illicit weapon tracing and provides measures to better equip tracing operations. Some of the main provisions include additional marking at import and export, utilising emerging technologies to support recovery of obliterations, and improving engagement with manufacturers, law enforcement and end users [43].

In light of the ITI, efforts have been made to increase the capacity and skillsets for serial number recovery in States that could benefit from increased forensic science support to investigators [44]. This may include providing equipment and training for States to recover obliterated serial numbers in-situ, rather than leave investigative gaps when dealing with illicit firearms. While the ITI is not legally binding, it does offer ongoing aid to States who have signed up to the agreement and need additional support to achieve its goals[44].

In addition to the ITI, international law can aid in regulating firearms marking and control. The United Nations Protocol against the Illicit manufacturing of and Trafficking in Firearms, their Parts and Components and Ammunition (Firearm Protocol or UNFP) [45] is the only legally binding instrument covering the regulation of small arms flows and investigation on a global level and aims to strengthen international cooperation. One key provision of the Firearms Protocol is to ensure adequate marking, recording, and tracing of firearms [45]. Non-compliance with legally binding agreements can lead to penalties and sanctions. For example, there are currently 15 sanctioned regimes under the UN Security Council, which are under focus to support political settlement of conflicts and counterterrorism [46]. The measures of these sanctions range from arms embargos and travel bans to commodity restrictions in order to increase support offered to governments and regions working towards peace [46].

With any manufacturing, there are challenges faced that can be difficult to combat regardless of the legal requirements. The potential for marks to be removed always exists, as explored in the next section of this literature review, and there is limited scope for ensuring marks are manufactured to an adequate level that they will be recoverable if obliterated. Some restrictions faced when applying marks to a firearm include the type of material being used in the construction of the firearm, the cost of machining, and finally the financial and time cost of the implementation and enforcement of policies. The lack of standard materials, marking methods and requirements pose new challenges as manufacturing technology advances, which adds complexity to the political stances taken by many States, countries, and organisations.

2.4 Illicit Use, Diversion, and Movement of Firearms

Firearms, even when used legally and responsibly, are a highly controversial topic when considering civilian ownership and use. For civilian use, firearms are often used for recreation and sport where the laws allow. In some regions, firearms are used legally for personal protection and security. For law

enforcement and military use, firearms are tools used to defend and protect. The public perspective on firearms in a region is often tied to the local legislation and how firearms are used in law enforcement [47].

Within first world countries, such as the United Kingdom, the nature of firearms crimes often involves individual citizens. They are being used to aid in committing crimes such as armed robbery, homicide, property damage, and organised gang crime [48–51]. In contrast, firearms are used in conflict zones by armed groups and militaries. The crimes committed in these regions are often on a much larger scale such as war crime, massacre, and ethnic cleansing [5,6,9].

While the legal ownership of firearms can have benefits (such as sport or hunting), the illicit use and movement of firearms must be addressed. The diversion of weapons is the transfer of items from an *authorised* owner to an *unauthorised* user at any time in the life cycle of a weapon from manufacturer to end user [6]. The physical interception of firearms can occur during export, transit, import or allocation. Even after the acquisition by the legal end user, firearms can end up in the hands of another party illegally [6,7,52].

According to Conflict Armament Research (CAR), who specialise in the collection of weapons data, there are six main sources of weapon diversion within conflict zones [6]. These are battlefield capture (30%), loss from national custody (27%), state-sponsored diversion (22%), ineffective PSSM (12%), state collapse (5%) and unknown (4%) [6]. As firearms from these sources disperse within regions and across porous, or low security, borders, it is not uncommon for them to be sanitised by those who have procured them. Common diversion routes are shown in Figure 2-9.

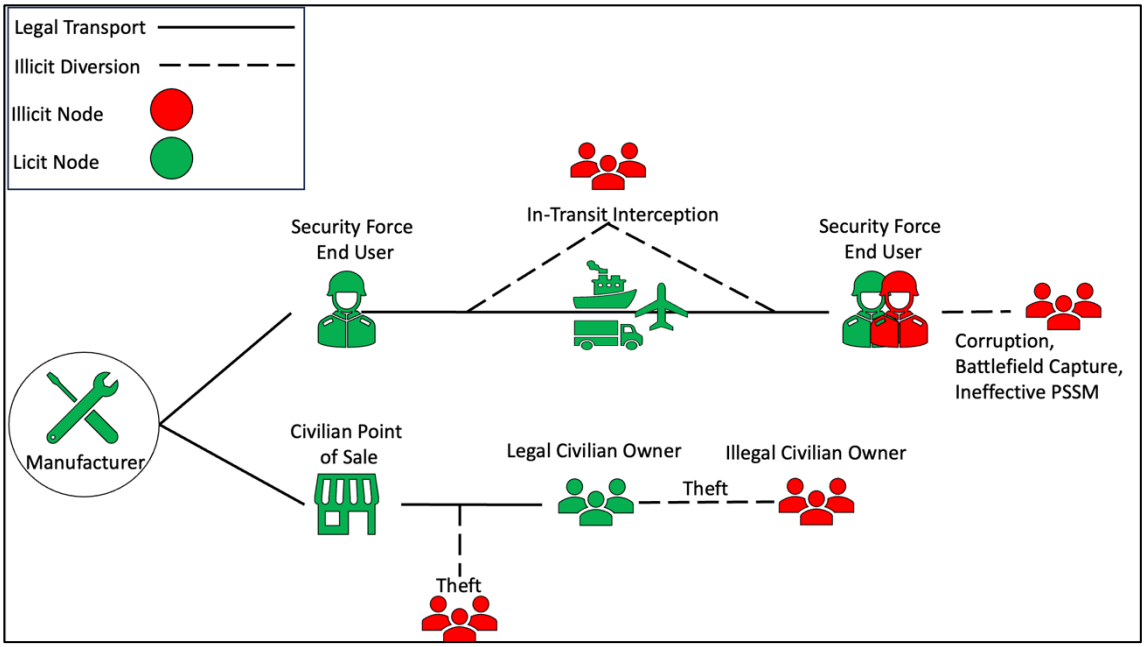


Figure 2-9: A schematic showing the primary licit and illicit routes for firearms movement and diversion, highlighting licit (authorised) nodes and illicit (unauthorised) nodes. Image authors own.

Within first world countries, it is also common for firearms to be stolen or imported illegally, only to end up sanitised within criminal networks [5]. This involves the removal or alteration of identifying marks, like the serial number, factory numbers, country of manufacture, etc. [5]. For forensic investigators and law enforcement, recovering the serial number from these sanitised weapons can provide grounds for prosecution and punishment within the bounds of the local law. Most first world countries have the forensic capacity and tools to recover the serial numbers, however this capability may not exist in many conflict zones. The next section of this literature review introduces and explains mark obliteration and recovery techniques employed by forensic practitioners.

2.5 Mark Obliteration and Recovery

The aim of this section is to understand what method of obliteration are used in forensic cases, and how their examination can be applied to illicit weapons tracing. Methods used for the application, obliteration and recovery of marks will be explored in detail. For the application and recovery of marks, various methods will be explored that are either currently in practice or have been proven ineffective. When discussing the obliteration of marks, different types of tools and the way in which they are used will be pulled from source data of known samples. The analysis of which will be reviewed to obtain the best potential method to apply to the present samples.

The goal of many criminal organizations is to hide the identity of the SALW so it cannot be traced to where it was manufactured [5]. The most obvious way to obscure the identity of a genuine-production weapon is to remove all traces of the manufacturer's information. When a mark is applied to a weapon, the material *around* the mark may also be altered. This is, of course, method dependent.

If the marks are applied using physical force such as stamping and dot peening, the alteration to the layers of material directly below the mark exhibit localized stress [30,36]. If these layers can be exposed, the original mark may be visible after treatment. It is less likely for recovery to be possible when the original marks are applied via laser, as the affected zone is much smaller and only the material directly adjacent to the beam is altered [53,54]. Simplistic methods of obliteration include removal by hand tools, such as screwdrivers, and simple power tools, such as hand sanders. When marks are obliterated by these tools, the damage often does not penetrate deep enough into the metal and it is often possible to polish the surface and recover the marks using various chemical, analytical and visual techniques [55,56]. More advanced obliterations are often done using machines designed to penetrate deep into the material, such as lasers or stamping machines. When the inflicted microstructural changes to the material-

be it metal, wood or polymer- extend below the material altered by the application of the original mark, it may not be possible to recover the markings [55].

It is critical to preserve the integrity of forensic evidence. This means that during the exploitation of a firearm, the attempted recovery of forensic evidence must be conducted in a way that causes the least damage to the item. Ideally, any potential non-destructive testing would be done in the first instance, leading to fully destructive testing only when absolutely necessary [57].

2.5.1 Current Gold Standard: Fry's Reagent

The recovery of serial numbers using Fry's Reagent is the most accepted recovery method in the forensic exploitation of firearms evidence [56]. Fry's Reagent is made by combining 90g Cupric chloride, 120ml hydrochloric acid, and 100ml distilled water [58]. Nitric acid is often used to increase the contrast between the recovered mark and the unmarked metal; however, it is not always required [58]. The application methodology requires the chemical exploitation of the localized crystalline structure deformation below the obliteration. Fry's Reagent works on the premise that deformed metals dissolve more readily than intact samples due to the microcracks formed at grain boundaries due to tension [10]. For this reason, Fry's Reagent requires extensive surface preparation to remove the top layers of damaged material to allow access to a smooth surface. Before Fry's Reagent is applied to the obliteration, the area is polished to a mirror finish and cleaned with acetone. Due to these drawbacks, a lot of training is required for forensic examiners before they can carry out the investigation on firearms. There is a risk of over polishing the surface, removing the underlying microstructure containing the original marking. Even with training, this process is highly destructive and is detrimental to the retainment of forensic evidence. In addition to the destructive nature of the etchant, Fry's Reagent is not effective on aluminium given the speed with which the etching reactions occur [53]. Many

modern weapons are made of aluminium due to its low cost and weight, leaving a gap for recovering serial number obliterated on these firearms [59].

While Fry's Reagent is currently used in many forensic science laboratories as standard practice, for those operating in non-permissible environments, like conflict zones, there are logistical challenges that have yet to be accommodated for. The transport and safe storage of chemicals into these areas via air travel can be logistically difficult, if not impossible (Personal communication, Conflict Armament Research, 2020). While this may not be an issue for certified forensic laboratories, there is still the obvious advantage to not rely on chemicals.

Studies by Bong et al. [59], Baharum et al. [60], Richa et al. [58] and Song [61] have been conducted over the last two decades with efforts to develop a method of chemical etching for the recovery of obliterated firearm serial numbers that rivals the results of the standard Fry's Reagent, without the drawbacks presented by the Reagent. Some of those detriments include the corrosivity, the addition of copper deposits to the sample, potentially affecting future testing, as well as the nitrous acid release during use. No etchant has been found to rival the results of Fry's Reagent, and a major drawback to all chemical etchants is that if the obliteration is too aggressive and deep, the method is often insufficient to recover the serial number [58–61]. These aggressive methods may include over-stamping, dot peening and heat treatments [62]. It has been seen in some instances where firearms are being exposed to structural fires in effort to destroy evidence. The high level of heat causes local stresses in metals to relax, which can remove any trace of a serial number or other mark and make recovery near impossible. Structural fires may lend enough heat to the firearms to remove the internal tensions caused by mark application processes, depending on proximity and exposure time. A typical structural fire can reach over 800 degrees Celsius [63], while the annealing temperature of carbon steel is merely 150-200 degrees Celsius, depending on the alloy [63,64]. Considering the recovery of serial numbers is based on the ability to resurface internal deformation, if the firearm is heated to above its temperature of annealing the serial number may not be

recoverable at all. If Fry's Reagent is used to recover a serial number on a weapon that has been exposed to high levels of heat, there may be no result while still causing physical damage to the firearm. This destroys the integrity of a piece of evidence, rendering it unusable for criminal proceedings.

2.5.2 Alternate Chemical Recovery Methods

The recovery of serial numbers using the most common method- Fry's reagent- requires the chemical exploitation of the plastic deformation below the obliteration. Recent efforts have been made to find a less corrosive, toxic and destructive chemical than the hydrochloric acid and copper chloride mixture that is Fry's reagent. Multiple studies [58,61,65,66] have been conducted in the last two decades with efforts to develop a method of chemical etching for the recovery of obliterated firearm serial numbers that rivals the results of the standard Fry's reagent, without the drawbacks presented by the reagent. Some of those detriments include the addition of copper deposits to the sample, potentially affecting future testing, as well as the nitrous acid release during use [58]. It is important to note that each of the following studies has focussed on various metal types and may not be applicable to *all* metal weapon components. Fry's reagent works on the premise that deformed metals dissolve more readily than intact samples due to the microcracks formed at grain boundaries due to tension[67].

A study by Uli et al.[68] noted that modern firearms are generally made using high strength aluminium alloys, which prove more difficult for chemical etching restoration than steel. Nine reagents were tested, with $NaOH/HNO_3$ proving to be the most effective. This confirmed Bong and Kuppuswamy's study completed in 2009 [59], as well as Baharum et al in 2008[60]. A separate study also found success with HNO_3, however, only when used in conjunction with hydrofluoric acid and acetone [61]. The authors proposed varying factors such as temperature, humidity and the relative concentrations of each reagent element to determine if there can be enhanced recovery.

The aforementioned study by Bong and Kuppuswamy [59] tested five additional reagents on high strength aluminium alloy (AA7010), which some success. Three types of obliteration were tested: erasure, over-engraving and centre punching. The reagents tested were phosphoric acid, hydrochloric acid, sodium hydroxide, a mixture of iron chloride, hydrochloric acid and water, a mixture of sodium hydroxide and water, and a mixture of sodium hydroxide in mercuric chloride and water. All attempts at recovering the original impressions were successful, except when the iron chloride, hydrochloric acid and water mixture was used on erasure samples, however the authors did not provide the reason for failure[59].

In 2013, another chemical etchant was tested for serial number recovery [58]. Acidic ferric chloride was determined to be just as effective as Fry's reagent on steels and copper alloys, without the drawbacks of nitrous acid being released. It was also found to be a faster recovery reagent than Fry's, by about 15 minutes, with the further benefit of not adding copper depositions to the sample [58]. The downside to this technique is the rapid rusting effect that occurs on steel samples.

Various liquid dye penetrants were also tested for serial number restoration using similar methodologies to Fry's Reagent [69]. Liquid dye penetrants are pigments added to carrier oils and were thought to be an alternative as they are commonly used to detect cracks and imperfections in welding and do not share the disadvantages of Fry's. They were found to be ineffective, as the dyes did not settle into any deformed areas where the serial number was applied. It was postulated that there was not enough physical damage in the plastic deformation regions for this to be an effective method of recovery [69].

One drawback to chemical etching is that if the obliteration is too aggressive, one where more than simple hand tools are used to remove a shallow depth of material, the method is often insufficient to recover the serial number as the depth of damage is too great. In cases like these, other analytical techniques and imaging processes are often employed.

Additional limitations to all chemical recovery techniques include the health hazards faced by the users and investigators. Although not an immediate risk to life or health, the reagents are suggested for use only inside of a fume hood, which may or may not be possible depending on the global location and facilities available. User errors must also be considered, where the proper training and time must be invested for successful results.

2.5.3 Analytical Recovery Methods

In addition to chemical methods, analytical techniques have been employed for visualisation of removed marks. Scanning electron microscopy (SEM) was coupled with electron backscatter detection (EBSD) in attempt to visualize die stamped imprints that had been polished away [70]. When a serial number is applied to a firearm, the process damages and/or alters the shape of the crystal structure in the metal. When SEM is coupled with EBSD, the surface of the metal is scanned by a probe and produce a map of the crystallographic orientation, potentially exposing the pattern of the original die stamped marks. White and Keller [70] had success using this method recovering clear imprints up to 140μm, despite the process taking over one hour per digit.

When a serial number is laser engraved, typical recovery using chemical etchants may not be effective. One of the issues surrounding laser applied markings is the small area of metal that is affected. There are no tool marks associated with the application and therefore the only material influenced is the small region where the serial number is applied via laser. The problematic nature of this type of recovery has prompted efforts in relief polishing coupled with reflected light stereomicroscopy [53]. It was found that obliteration marks can be removed with more ease than the serial number, due to the work done on the metal and the resulting difference in hardness. With relief polishing, a soft and slow polish, the

reflected light stereomicroscopy with a cold light source showed success in recovering obliterated serial numbers. The caveat in this study being that if the obliteration damage reached a great depth, the area of serial number application is more likely to be damaged beyond recovery [53].

Raman spectroscopy has recently been investigated as a tool for the recovery of obliterated serial numbers in various polymers. A 2017 study co-authored by Parisien notes that a pixel-by-pixel image creation based on the residual mechanical strain collected through Raman spectroscopy is a valuable tool in obliteration works [71]. The bond polarizability of the photons allows for the development of a spectral fingerprint. This fingerprint can be converted to an image where the original serial number or marking is discernible [71]. A second study, also by Parisien et al., found success in recovering these marks as the plastic deformation created by the application of the original markings was optimal for creating peak intensity ratios sufficient to recover serial numbers using confocal microscopy [72]. Two major benefits to using Raman spectroscopy coupled with confocal microscopy are the lack of pre-treatment requirement and the non-destructive nature of the test, preserving the samples if further testing is required, however has not been proven to work on metallic samples such as firearms.

Magnetic particle restoration and magneto-optical imaging have also been investigated as tools for restoring stamped marks in steel [73–75]. These techniques have proven beneficial to mark restoration and can detect plastic deformation regions from the original markings, even when obliterated using overmarking techniques [75]. Depths up to 670 μm were recoverable using magnetic particle restoration, and 260 μm using magneto-optical imaging, all without sample destruction. While having a lower performance threshold, a benefit to utilising magneto-optical imaging lies in the mobility and versatility for potential field use [75]. Magnetic principles have proven particularly useful for materials where acid etching generally fails, with carbines and submachine guns being specially mentioned [74]. In a baseline study by the Los Angeles Police

Department, samples were polished using steel wool and placed on a vibrating magnet. Fe_3O_4 Magnatite was applied to the surface and effectively revealed the obliterated serial number [74]. These methods are not useful on firearms made from polymer and aluminium, as they are non-magnetic.

A German study from 2010 also explored the use of magneto-optical methods to restore erased marks in metals [76]. Weimar and Herrman state that the Regula Fluidpad, a system which operates using magneto-optical processes and the Faraday Effect [76], was extremely effective in the recovery of erased marks in various types of steel. This system was effective even on austenitic steel, which is not typically ferromagnetic [76]. Since 2010, product research and development has continued to progress. Currently, the Regula Forensics 7517 firearms workstation is proving successful in recovering obliterated serial numbers on firearms [55,77,78]. The system utilizes magnetic properties and eddy currents to scan for internal stressed on thick-walled ferromagnetic objects. Where there is electric resistance, material damage is noted, and computer software visualizes the obliterated marks [77,78]. This system will be tested further on firearms and steel plates in Chapter 3 of this thesis.

2.5.4 Imaging Recovery Methods

In a first approximation study, Ekstrand et al [79] utilized 3D scanning techniques to investigate the comparison of screwdriver tips to marks left on steel plates. Using open-source 3D graphic programming, coupled with an infinite focus microscope and noise reduction processes, the estimated angle of contact was successfully determined within five degrees of the actual angle. This study was useful in the generation of future studies using 3D graphics to map the surface of metals and the characteristics of intentional damage.

Infrared thermography has attracted more attention as of late. Utilizing non-destructive methods has the obvious benefit of not altering the sample, while also

preserving the integrity of the investigation. Unobe et al. [80] used thermal imaging to locate and characterize flaws in the sample by measuring how the applied heat flowed through the metal. In areas where plastic deformation was detected, a heat gradient appeared. This allowed the successful reconstruction of the serial number in all samples, with the assistance of principal component analysis to enhance minute differences [80]. A second study has had similar success. By using active infrared thermography and MatLab to reduce the gaussian noise and add filters, abraded serial numbers in steel were able to be recovered [81].

A technique tested in 2016 on cartridge cases may be applicable to this current study. Navrátil et al.[82] used confocal microscopy with a custom scanning probe to scan the surface of the cartridge casings to conduct a near-field examination. The confocal microscope allowed 3-dimensional optical resolution for both surface topography and internal structure. MatLab was then used to create a 3-dimensional height profile, allowing the visualization of the impressions left in the metal[82].

A study funded by the United States Department of Justice provided insight into three methods of infrared thermography: transient (TIT), pulse (PIT) and lock-in (LIT) [83]. The work outlines the following:

- TIT heats the sample to 250°C and infrared images are taken as the sample cools. The authors found limited results using this method.
- PIT found marginally improved results to TIT. The sample was heated in pulses, and images were taken during the heat pulse. While some success was noted using PIT, the difference between PIT and TIT was not significant.
- LIT, where the images are taken between the heat pulses, was coupled with principal component analysis and returned effective restoration images. While the authors noted that LIT was successful on stamped marks and those laser engraved, on aluminium, steel and stainless steel,

as well as curved and flat surfaces, the most success to restore the marking was on laser engraved serial numbers [83].

A similar study was conducted to investigate the potential of using various infrared thermography techniques; in addition to those above, step heating thermography (SHT) and various post-processing algorithms [39]. Some extras included MatLab, guided filtering, block guided filtering, thermographic signal reconstruction and logarithmic transformation. It was concluded that for marks that are deeply abraded, applying logarithmic transformation to raw PIT images or block guided filters to raw LIT images produce the best results. In general, LIT was the most successful technique even for paint covered samples, confirming previous studies as better thermal contrast is obtained. Overall, SHT was not successful and should not be employed in this field [39].

The limitations of the above imaging technologies are not unlike chemical or analytical techniques. The cost of the equipment and the time required to process a sample hinders the use in a forensic context, due to available resources during police investigations. Additionally, some of these techniques require cutting full firearms into smaller pieces and heating the samples to elevated temperatures. Both of these treatments undermine the preservation of evidence, which must be avoided as best possible.

2.5.5 Magneto-Optical Imaging Recovery

Previous work using the Faraday effect by inducing the interaction between eddy currents and the magnetic field of an item has been proven successful in the recovery of obliterated marks from ferromagnetic items such as steel firearms [84–86]. While the fundamentals of magnetism are not explored in detail, as is beyond the scope of this thesis, it is important to understand basic principles utilised by recovery methods as outlined in this section.

Eddy currents, also known as Foucault's currents, are induced by changing the magnetic field within an item [84]. They are essentially loops of electric current flowing perpendicular to the magnetic field, as shown by Figure 2-10 [84]. Garcia-Marin et al. test the use of eddy currents for non-destructive testing for crack identification and location. Where the eddy current interacts with the crack defect, the optical sensors were used to visualise the result. The results were positive, and investigators were able to locate imperfections with this non-destructive technique.

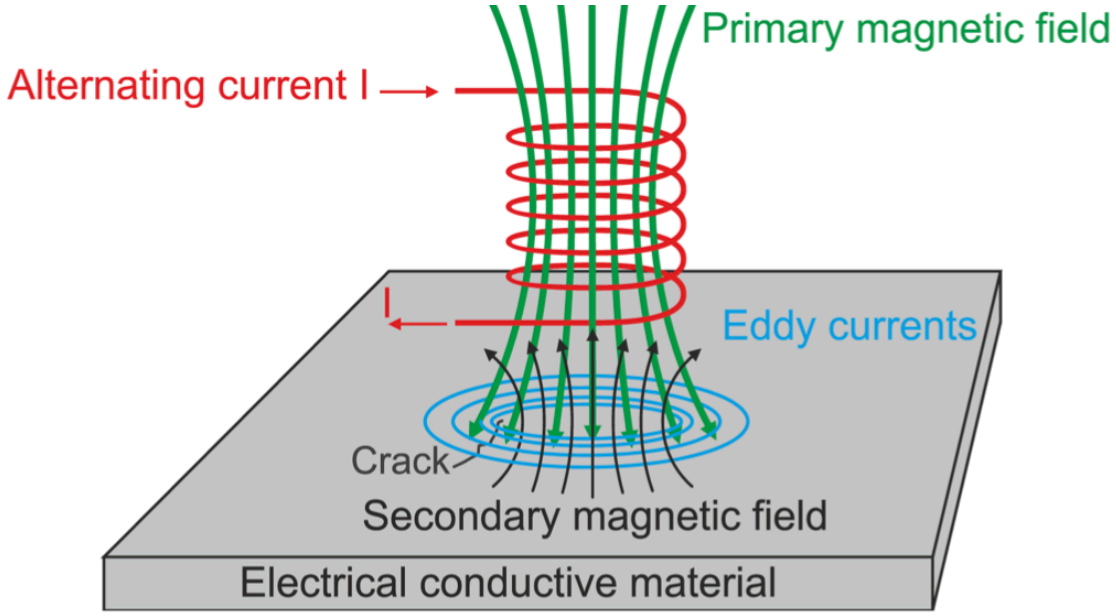


Figure 2-10: A schematic showing the use of eddy currents as non-destructive testing to locate a crack in a material. Photo taken from [84].

An introductory study by Agalidi et al. introduced the coupling of eddy current excitation with magnetography by measuring the leakage of the magnetic field caused by the eddy currents [85]. In this work, the scanner also contained a video camera, allowing the real-time capture of the magnetic field leakage and therefore highlighting defects in the surface of the material [85].

A study conducted by the National Institute of Justice also investigated how the interaction of eddy currents with the induced magnetic field of an object can visualise areas of defect in the microstructure [86]. This study specifically focused

on serial number recovery from firearms using magneto-optical imaging and found positive results. In some cases, the technique proved more capable of recovering obliterated marks than the standard chemical etchants typically used in forensic casework [86].

Recent work by Lima et al. has shown the use of Regula Firearms Examination kit 7517 (referred to as the Eddy Current Kit or ECK in this thesis) to be an effective method of recovering obliterated marks from firearms [75]. This work used sanding and over stamping as a method of obliterating originally stamped marks to ascertain the effectiveness of the kit on isolating overlapped regions of plastic deformation. The researchers found very positive results, with the ECK recovering more obliterated marks with greater clarity than standard chemical etchants in some cases [75]. To build off this work, this thesis endeavours to fill the knowledge gap on whether this technique will work on laser engraved marks, due to the decreased amount of material altered in the marking process.

As discussed in this literature review thus far, serial numbers and other markings are shown to be critical in the tracing of illicit firearms. Because of this, there are a multitude of successful methods for recovering obliterated markings from firearms that have been developed over decades of research, as presented in this review. Also shown in previous work, and through conversations with firearms examiners and intelligence sources, not all marks can be recovered, which renders these firearms untraceable. Considering this, this thesis will provide a new approach to analysing obliterations using toolmarks and intelligence evidence. The following sections of this literature will outline the basis for the investigation.

2.6 Global Firearms Perspective

This section outlines how firearms crimes are perceived and how they are considered in investigations around the world. The concepts discussed in this

section are introductory in nature and will be used and expanded upon in Chapters 6-9 for each specific region.

Also introduced in this section are three global indices, which are each a compilation of data from a vast number of expert international agencies. The indices are the Global Organized Crime Index (GOCI) [87], the Global Corruption Index (GCI) [88], and the Environmental, Social and Governance Index (ESGI) [89]. These metrics are used in this thesis to understand how the intelligence gained on each region can be used to understand the motivation to conceal the identity of a firearm by removing the unique markings.

2.6.1 Laws, Regulations, and Policies

Historically, legal systems and the laws in a region are shaped by cultural, historical, ethical, and political factors [47]. The laws surrounding firearm ownership and use are no different, and so the regulation of firearms around the world varies greatly.

In many developed regions, firearms laws are constantly changing to react to safety concerns, current events, threats, military action, and political perspectives [90]. A notable example of this is the legislation against civilian-owned pistols and handguns in the UK after a school shooting on March 13, 1996 in Dunblane, Scotland [91]. Within 18 months, the change in legislation was introduced.

In contrast, in conflict-ridden areas of the world, the combatant nature of both authority and civilians is often more dominating than the ethical and safety factors relied on in developed regions. Because of this, investigations into firearms crime are handled very differently, with varying repercussions and goals of investigations [92].

Chapters 5-9 present literature regarding how firearms are perceived around the world and how the local laws reflect civilian ownership. Each chapter will

introduce the legislation surrounding ownership in the specific region of interest. In Chapter 10, a global comparison is presented, accounting for the ownership and use of firearms in each region.

2.6.2 International Instruments for SALW Control

Two international instruments have been discussed previously in this literature with regards to firearm marking requirements. In addition to these two instruments, the United Nations Programme of Action to Prevent, Combat and Eradicate the Illicit Trade in Small Arms and Light Weapons (POA) exists to provide a framework to enable States to counter the effects of illicit firearms trading within their own countries [93]. The POA was adopted by all UN member states in 2001 and provides a basis for outreach and collaboration, and for States to request international aid in controlling illicit weapon manufacturing, brokering, and trading. As mentioned, the UNFP is the only legally binding international agreement, while the ITI and POA outline measures that can aid firearms investigations.

2.6.3 Intelligence-Led Investigation

Intelligence-led investigations are not uncommon when considering firearms crimes where there is often an emphasis on trafficking and criminal interception. When serial numbers are obliterated without the potential of recovery, there are still valuable ways to gain insight that can aid intelligence-based investigations. By focussing on each global region as an individual factor in the obliteration, investigations can use tools such as the GCI [88] and the ESGI [89] so data can be used to enhance the understanding of criminal activity, corruption, and weapons trafficking in an area. These indices are based off a multitude of factors measured by various independent bodies which are presented in the following

sections, each offering different information on regions around the world. The following sections outline the purpose of each Index and how they are calculated.

2.6.3.1 Global Organized Crime Index

The GOCI Index was developed based on the Enhancing Africa's Response to Transnational Organised Crime (ENACT) report focused on Africa and expanded as part of the Global Initiative Against Transnational Organized Crime (GI-TOC) [87]. It assesses 193 countries across criminal markets and actors, and resilience. Considerations include (but are not limited to) mafia groups, criminal networks, foreign actors, human trafficking and smuggling, arms trafficking, drug trades, and non-renewable resource crimes. These "criminality indicators" are compared against "resiliency indicators", including law enforcement, political leadership, prevention, government transparency, and more. This index was developed primarily to provide stakeholders and those working on policy a means to measure how effective their interventions are[87].

This index is used to help understand the context of firearms crime, trafficking, and sanitisation. The individual country/region analysis will be conducted in Chapters 6-9, with a global comparison conducted in Chapter 10.

2.6.3.2 Global Corruption Index

The GCI is a measure of the state of corruption around the world. 196 countries and territories are ranked using 43 variables, which include the corruption risk from both the public and private sector [88]. Data is collected from the UN, the Organisation for Economic Co-operation and Development, World Bank, Financial Action Task Force, Transparency International, Global Initiative, World Justice Project, Economist Intelligence Unit, Basel Institute on Governance, the World Economist Forum, and more. They use a strict methodology and translate the z-score calculated and combine the data to give a scale value. This score is given out of 100, where 0 corresponds to the lowest level of risk, and 100 is the highest level of risk [88].

The corruption in a region may be reflective of how prevalent weapon diversion is, the typology of diversion, and how prevalent obliterations are in a region. In the context of this thesis, the GCI will be used as a comparison baseline for the motivation to conceal a firearm's identity in a global comparison conducted in Chapter 10.

2.6.3.3 Environmental, Social and Governance Index

The ESGI collates data from 183 countries in three categories: environment, human rights, and health and safety [89]. The human rights component accounts for 50% of the weighting, and considers factors relating to social, political, and collective rights. These general categories more specifically encompass (but are not limited to) slavery, child labour, education, press freedom, minority rights, measures of peace and rights to self-determination. The environmental component accounts for 30%, and considers air pollution, climate change, biodiversity, and ecosystem health. Health and safety accounts for the remaining 20%, including factors like life expectancy, safe drinking water access, workers safety, social protection and spatial inequality [89].

Many of the sources of raw data are international bodies, such as the UN, World Bank, World Economic Forum, Food and Agriculture Organization of the United Nations, Freedom House, The Global Carbon Project, and more [89].

The raw data is analysed using linear extrapolation, the Last Observation Carried Forward, and Predictive Mean Matching. From these analyses, a z-score is calculated and converted to a common scale for direct comparison across data sets [89]. Similar to the GCI, a scale of 0-100 is used, where 0 represents the lowest level of risk and 100 represents the highest level of risk [89]

The ESGI will be used in this thesis to aid the global comparison for firearms sanitisation presented in Chapter 10.

2.6.4 Forensic Science and Awareness

Forensic science capabilities must be considered in the investigation of firearms crime. In developed regions, where access to advanced equipment is not hindered, the capacity for crimes to be investigated and evidence to be thoroughly examined objectively is often high. Value is placed on the forensic investigation, and holding guilty parties to account for their actions is paramount to the perceived safety of citizens [94]. Many countries have a multitude of training programs, educational degrees, and professional bodies that guide and govern forensic science. These courses train upcoming scientists, policy makers, and technical experts in the field of forensic science and crime scene investigation, which ultimately increases the forensic awareness of a population. Examples of these types of courses are provided in each regional chapter where applicable.

Laboratories in these countries, especially those included in this thesis (Canada, the United Kingdom, and Australia) operate to the International Organization for Standardization (ISO) 17025 [95]. This standard enables laboratories to operate at a level that will produce reliable, repeatable, and valid results that can be validated by laboratories around the world. Each technique used in the examination of forensic evidence is certified to this standard [95].

In contrast, in conflict-ridden regions of the world forensic capacity may be lower, due to the lack of trust and value placed on the justice systems by civilians [96]. In addition to the disparity between citizens and law enforcement, forensic capabilities are often lower, due to the lack of investment into criminal investigations. There are, however, international efforts into gaining forensic knowledge within these regions. For example, the U.S. Naval Forces Central Command (NAVCENT) and Federal Bureau of Investigation's (FBI) Forensic Exploitation Laboratory operates multiple locations in conflict-afflicted zones to analyse evidence of battlefield explosive and firearms crimes [97]. The goal of this type of analysis is to identify key actors in the development, building, and use of weapons (firearms, explosives, drones, and more) in armed attacks to increase

the intelligence-base for the region [97]. These laboratories are built to “Western standards”, often with high specification, state-of-the-art equipment, however as they are not used to investigate traditional criminals, do not tend to proliferate forensic knowledge and capability to civilians and may not reach ISO standards [Personal Communications, NAVCENT Firearms Examiner].

Forensic awareness, or the “CSI Effect” is the theory that as the general public’s understanding of forensic processes increases due to television shows and media coverage of public trials, criminals can evade the law more effectively [98]. For example, knowing that bullets recovered from crime scenes can be traced back to the firearm that discharged it, and ultimately traced back to the person who pulled the trigger would result in more criminals collecting their bullets or brass casings from the crime scene. Researchers have found that there is little proof to support this claim [98,99]. Cole et al. claim that jurors and criminals both hold an unrealistic belief that forensic science is infallible, and that the CSI effect is not a robust theory [98].

Considering the paradox between the CSI-effect theory and the general population’s knowledge on forensic practices, this thesis will put an emphasis on the technology available in reach region over the forensic awareness. The technological advancement and tools used in each region of interest in this work will be expanded upon in Chapters 5-9, with a global comparison provided in Chapter 10.

2.7 Summary

This literature review discussed a brief history of firearms and their manufacture, how markings are applied to firearms, and why they are of critical value in criminal investigations, as well as the international requirements for the unique marking of firearms. Current methods for the recovery of obliterated markings were examined, and why they may not be effective in all circumstances. While the removal of serial numbers and unique marks can be detrimental to tracing operations and criminal investigations, intelligence-based analysis of evidence may prove beneficial. To address this potential, the role of intelligence indices addressing global firearms issues and perspectives is highlighted, with a focus on corruption, organised crime, and weapon trafficking.

This review has shown that there are two major gaps in the current field of investigation:

1. The ability to recover obliterated marks from firearms using non-destructive methods that can be utilised outside of a traditional laboratory environment, and
2. When the marks are not recoverable, there is no existing method to continue investigation.

To address these gaps, the next chapter of this thesis first explores the comparison of two serial number recovery techniques, namely Fry's reagent as the current laboratory standard, and an emerging technology. In the chapters following, this thesis then presents a novel methodology for examining obliterations using objective toolmark analysis and combining those observations with the intelligence-led investigative tools presented in this literature review.

3 Recovery of Obliterated Markings

3.1 Introduction

As mentioned in the previous literature review, serial numbers are used to trace firearms through both licit and illicit networks. In many regions around the world, weapons that were once held legally are diverted into illicit networks and sanitised by actors within these networks [2,5]. With the knowledge that seized weapons can be traced through their lifecycle using their serial number, when the serial numbers are removed, their identity is compromised, and the firearms are rendered untraceable [5].

The magnitude of obliterations is difficult to measure. SALW that are legally held by civilian or government forces can be accounted for by law enforcement agencies around the world, however, the unknown number of weapons lost to diversion make it impossible to estimate the number that are sanitised. Conflict Armament Research has reported approximately 6% of weapons they have documented in nearly 12 years of operation are sanitised [personal communications, CAR researchers]. This value is limited to the SALW they have been given access to, which is limited by the opportunity to access very specific caches of weapons. This may give investigators an estimate on the scale of the issue of obliteration in conflict zones, however criminal sanitisation may be vastly different. Within Chapters 5-9, obliterations from countries around the world are examined, and may also aid in the estimation of the scale of the issue based on sample size.

The recovery of identifying marks is undertaken in forensic laboratories when serial numbers and other marks are removed from firearms involved in criminal proceedings. This recovery is currently done using corrosive chemicals, namely Fry's Reagent, to physically strip layers of the surface to expose deeper layers of

the material, as mentioned in the previous literature review [10]. When used in serial number recovery on firearms, the surface is damaged; both through the surface preparation and the chemical application [10]. This leads to the irreversible destruction of forensic evidence and renders the evidence impossible to re-examine if necessary. During forensic investigations, if the evidential value of the physical evidence outweighs the intelligence gained from potential recovery, Fry's reagent may not be used to recover obliterated markings at the risk of damaging evidence.

Another detriment to using Fry's reagent, or other corrosive chemicals, for the recovery of obliterated markings is the harmful nature of the testing. ISO 17025 requires these tests to be conducted only in fume hoods to protect the investigators [95]. This limits the recovery to be done in appropriate forensic laboratories, and leaves those without access incapable.
In effort to reduce the amount of evidence unnecessarily damaged by corrosive recovery techniques and ensure the health and safety of investigators is protected, this work evaluates an emerging, non-destructive technique that utilises eddy currents and magnetic fields to create magneto-optical images of the original markings. This chapter, therefore, presents the potential for both stamped/dot peened and laser engraved marks to be recovered using this Eddy Current Kit (ECK) in comparison to Fry's reagent. This technique visualises the microstructure of steel and aluminium, therefore, should detect any material differences in the remaining layers of the sample. This includes where marks were added and have altered the physical characteristics of the metal.

Previous work discussed in the previous literature review indicates that this type of magneto-optical imaging has been successful in the past, therefore, it is hypothesised that the ECK will recover more obliterated marks that were stamped or dot peened, as it does not rely on human application like Fry's reagent, and also preserves the integrity of the surface of the firearm. It is also hypothesised that there will be no successful recoveries of laser engraved markings, using

either methodology, based on the limited microstructural changes in laser engraved markings compared to those applied through cold working.

3.2 Eddy Current Kit

To enhance serial number recovery and avoid using a chemical etchant to recover obliterated serial numbers, Regula Forensics® have adapted their existing Vehicle Identification Number reading technology to accomplish serial number recovery in firearms [15]. A magnetising firearm base and magnetised tape are used with specialized scanners to identify internal stress in both ferrous and non-ferrous metals. The schematic in Figure 3-1 shows the process of an eddy current pulse (blue arc in the schematic) moving through the magnetised material from positive to negative (indicated on the schematic, with the magnetic field indicated by waved lines). The scanner is attached to a controller which supplies an electric pulse. This pulsing current leads to the development of an eddy current within the metallic item. As mentioned previously, mark application causes localized stresses and defects in the material. These defects interrupt the flow of the eddy current trajectories and cause resistance in the stray magnetic fields supplied by the magnetic stand. Where these stresses are located, the eddy current signal will be translated into a digital video signal and is processed by software to visualize the serial number in a magneto-optical image [15].

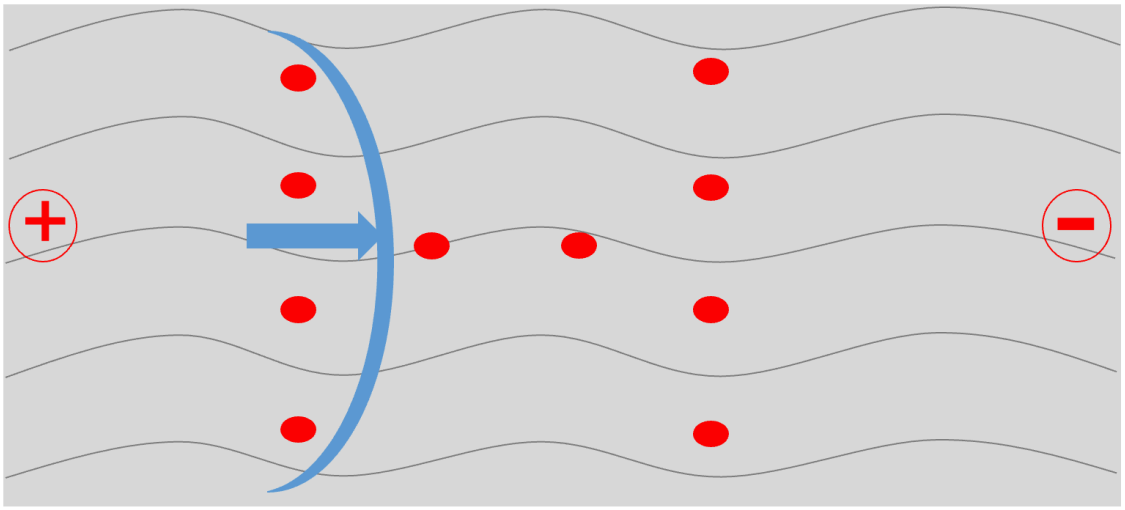


Figure 3-1: A schematic showing the interaction of the microstructure of the ferromagnetic material with the eddy current pulse and the magnetic field. The red dots symbolise the letter "H" as dot peened into the material. The positive and negative indicators show the direction of the magnetic field, symbolised by waved lines moving across the schematic. The blue crescent is the eddy current pulse as it moves through the material in the direction of the arrow from positive to negative sides of the sample (arrow indicates direction of movement).

For the purpose of this study, the dynamic iron scanner was used. The scanner connects directly to the controller which was then moved smoothly along the length of the magnetic tape. The controller delivers a pulsing eddy current through the scanner as it passes over the obliteration, recording interruptions in the eddy current flow and stray magnetic fields onto the tape. Each level is a linear increase of the eddy current strength, as confirmed by the manufacturer, but no quantitative measurements were outlined. The maximum current supplied at level 12 is 150 Amps [78]. The tape is then inserted into the reading device, which is interpreted by a downloadable software, NUCA [16], to visualize the serial number. The components of the ECK are shown in Figure 3-2.

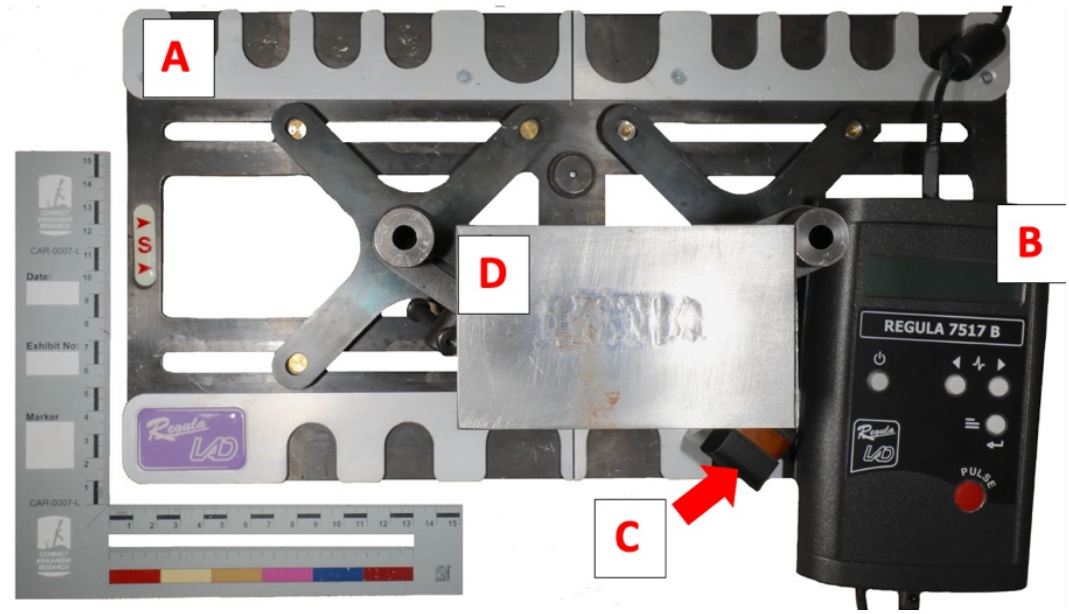


Figure 3-2: The set-up of the ECK. (A) magnetic base, (B) eddy current supply, (C) eddy current scanner, (D) steel plate with an obliterated serial number.

For successful recovery, the magnetization and eddy current pulse strength must be balanced to complement one another. To do this, the surface layer must be magnetically saturated. There is an indicator that is included in the kit, and visually indicates to the operator if the magnetization is of an appropriate strength. If the magnetization is too low, the signal will be too weak and not allow deep enough to penetrate below any superficial scratches [15]. If the item is magnetized too much, it will demagnetize the tape, removing any contrast on the final image. The eddy current pulse works as a magnetic signal amplifier. If the magnetization of the item is too low, there is nothing to amplify, therefore no result would be seen in the image. When the magnetization level is correct, increasing the eddy current strength allows a deeper penetration to visualize layers of the material beneath the surface, although the image may be slightly blurred. If the strength of the eddy current is reduced, a sharp but shallow image will be obtained [15].

3.3 Samples

This chapter presents multiple types of samples used in the testing of the ECK to recover obliterated markings. Steel plates with applied marks, firearm components with original manufacturer marks, and firearm components with post-manufactured marks applied. Each type of sample had either dot peened (stamped) and/or laser engraved marks applied. Steel plates were used in the first instance to establish a baseline for the potential recovery rates on real firearms. Then, actual firearm components were used to understand limitations the ECK would face in actual forensic examination scenarios. Table 3-1 outlines each sample type, the treatment used to create the obliteration, and the methods of recovery attempted.

Table 3-1: The samples used to evaluate the effectiveness of the recovery techniques in recovering obliterated marks, including the respective mark application and obliteration technique.

Sample Type	Number of Samples	Method of Mark Application	Obliteration Technique	Recovery Technique
Steel Plates	60	Dot Peened	Grinding Wheel	ECK Only
Steel Plates	10	Dot Peened	Hand Tools	ECK, Fry's Reagent
Steel Plates	20	Laser Engraved	Grinding Wheel	ECK, Fry's Reagent
Baikal Pistol Slide	1	Laser Engraved	Mill (Criminal)	ECK Only
Steel Insert Plate	1	Stamped	Rotary Tool (Criminal)	ECK Only
AK-Pattern Rifle Frame	1	Stamped	Grinder (Criminal)	ECK Only
Muzzle Device	1	Mechanically Engraved	Grinder (Criminal)	ECK Only
Glock Pistol Slide	1	Stamped, Laser Engraved	Rotary Tool (Lab)	ECK, Fry's Reagent
AK-Pattern Rifle Top Cover	6	Laser Engraved	Rotary Tool (Lab)	ECK, Fry's Reagent

3.3.1 Plates

90 CR4 grade steel plates, each 60mm x 100mm x 2mm, were used to simulate a firearm bearing a serial number applied using two techniques. The thickness of the plate was chosen to reflect the thickness of the frame of firearms; measured across five pistols where the serial numbers were applied from five different manufacturers to ensure a representative thickness was used. A Vickers

hardness test of these plates averaged at 135 HV across a random sample of 20 plates, with a ferrite and pearlite microstructure, shown in Figure 3-3.

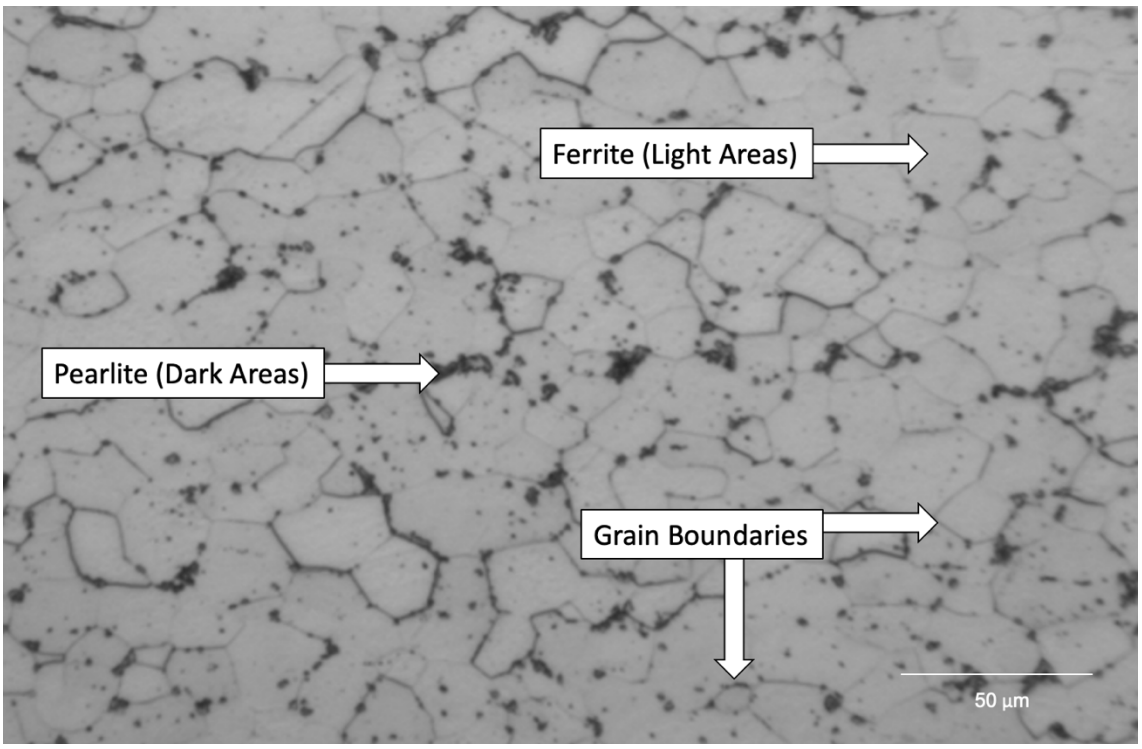


Figure 3-3: The microstructure of the steel plates at 100x magnification, where the pearlite is the dark areas, and the light areas are ferrite.

70 plates had serial numbers applied using a Pryor BenchDot machine. The alphanumeric digits were created using the maximum force setting of 9 using a "varidot" setting, resulting in an average dot depth of 250µm. This is deeper than the required 76 µm dictated by the NFA, as mentioned in the previous chapter [40]. Each digit was 8mm tall. One example of the applied serial number is shown in Figure 3-4. The serial numbers, *ABC123, DEF456* and *GHI789*, were used to include both straight lines and curves in each alphanumeric sequence. In total, 70 steel plates with a total of 420 digits were used.

Figure 3-4: A sample of a dot-peened steel plate (size 60mm x 100mm x 2mm).

The remaining 20 steel plates were laser engraved to an average depth of 230µm using a 30-watt BWM-30F Fibre laser marking machine with a wavelength of 1065nm [100]. Each plate was engraved with twenty marks ("*1234567890*") to allow for increased recovery areas for sampling. The average depth of the engraving on the steel plate was obtained by cross sectioning an engraved area and measured using a calibrated microscope. This was done on 5 different, randomly selected plates to calculate an average. Figure 3-5 shows an entire plate with 20 laser engraved marks, and a cross section of the same plate, highlighting lipping (material flow upward on the edge of the character) from the laser.

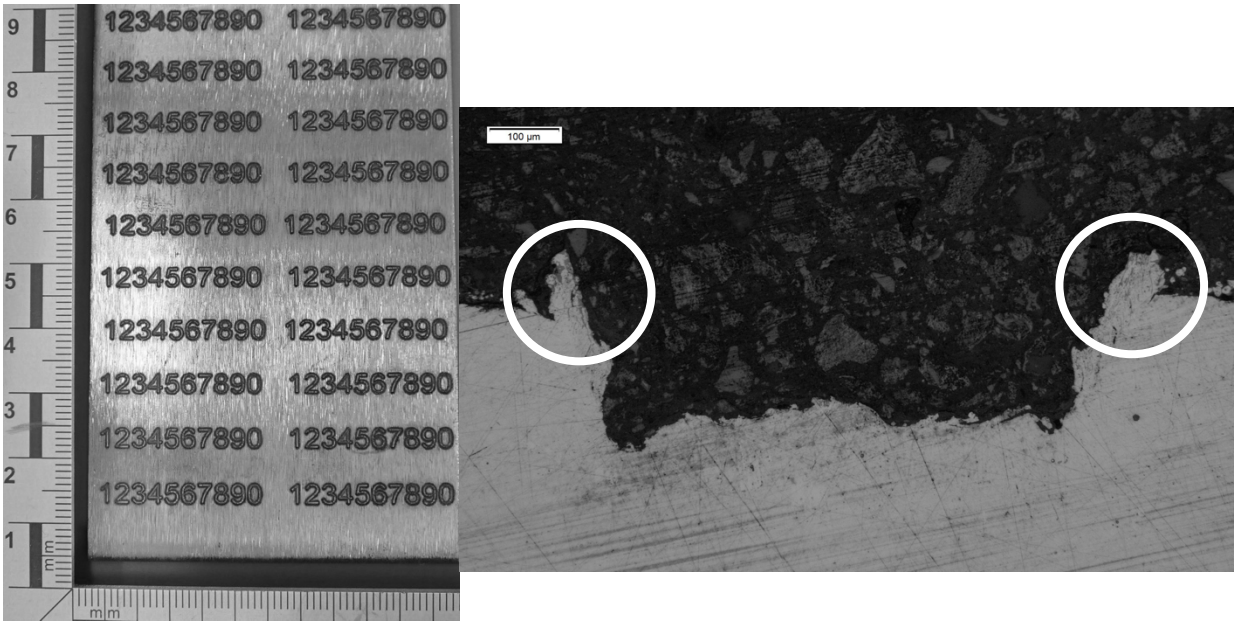


Figure 3-5: One steel plate with twenty laser engraved marks (left) and a cross section (50x magnification) of the same steel plate, showing the depth of the laser engraving (230µm) (right).

3.3.2 Firearms Components

Firearms components used in this work were thin (between 1.5mm and 2mm), flat steel elements. This decision was made to obtain a baseline for comparison to the results obtained from the steel plate samples. The applicability of the ECK to all firearms components with complex geometries was not established in this work due to the vast number of models, with differing component shapes, thicknesses, and material variations.

3.3.2.1 Real Life Sanitised Firearm Components

One Baikal pistol slide showed existing obliterations on the slide. Two markings on the left side were removed using a milling machine (Figure 3-6). The original

markings are laser engraved, matching the visible markings on the top left of the slide. The obliterated regions were compared to other Baikal pistols in the LWW and NFC collections to confirm the presence of additional laser engraved marks.

Figure 3-6: A Baikal pistol slide (left profile), showing one visible original laser engraved mark (*и*Ж-79-8), one stamped mark (LW005) applied by the LWW, and two regions where milling marks are evident, hiding two additional laser engraved marks.

A steel serial number insert plate was also examined using the ECK, which also showed existing criminal obliteration. Figure 3-7 shows the steel plate, which is commonly used on the underside of the barrel in polymer-frame pistols to show the serial number of the firearm. Many manufacturers, including Glock and Steyr, stamp the serial numbers into the steel plates before fixing into the polymer.

Figure 3-7: The obliterated steel plate that houses the serial number for a polymer-framed pistol.

An AK-pattern rifle (Figure 3-8) was documented in a West-African country and recovered to the UK for assessment. The area directly above the obliteration was gently wiped with steel wool to clean the rust from the surface, while avoiding adding additional toolmarks or striations.

Figure 3-8: An AK-pattern rifle, showing an area of obliteration, where a portion of the serial number was removed (circled).

This firearm component originated from a firearm which had every identifying mark removed. The muzzle device of this firearm is shown in Figure 3-9. The remaining “E” mark appears to be scribed, or mechanically engraved, into the steel, however the concealed mark may be applied using a different technique, as the visible gap between the “E” and the obliteration does not allude to one uniformly applied mark. No surface preparation was done on this component.

Figure 3-9: The muzzle device of a rifle with a criminal obliteration.

A steel Glock pistol slide was laser engraved using the BWM-30F Fibre laser marking machine, in addition to the pre-existing manufacturer stamped marks. The average depth of the stamped manufacturing marks was 0.84mm, while the marks applied post-manufacturing with the laser were 0.55mm on average. The depth of these marks was measured using a Vernier caliper, sampled in 6 locations. Figure 3-10 shows both the marks stamped during manufacturing and those added for the purpose of this study. In total, there were 8 stamped marks, and 7 laser engraved marks.

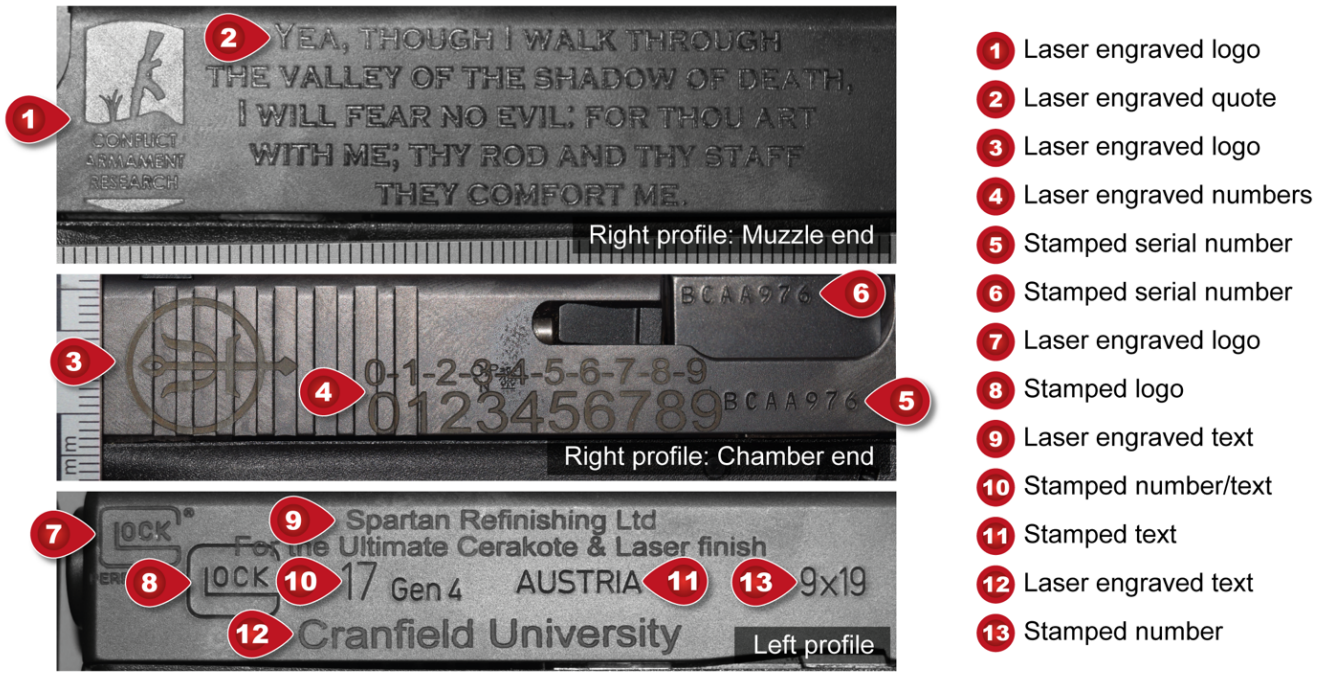


Figure 3-10: The laser engraved and stamped marks removed from the right profile (top, middle) and left profile (bottom) sides of the pistol slide.

Six AK-pattern rifle top covers were also laser engraved, using the same standards and equipment. These top covers each had 17 marks (“1234567890”) applied (Figure 3-11). In addition to the ten pictured on the left side, one was on the back face of the cover, and an additional six marks were engraved on the right side.

Figure 3-11: The left side of an AK-pattern rifle top cover, with ten laser engraved marks (“1234567890”).

3.4 Obliterations

The samples in this work were subjected to two types of obliteration: either the systematic removal of material in measured layers as explained in the following section of this chapter, or by hand tools. The systematic removal of layers of steel allowed for the controlled depths of obliterations to be studied, testing the ability of the ECK and Fry's reagent to work on marks of the same depth with different amounts of material removed. The obliteration by hand tool was unavoidable, as many of the firearm components were delivered already showing obliterations. The additional samples fabricated for this study (the Glock slide and AK -pattern top covers) were used primarily for the investigation into the efficacy of recovering laser engraved markings.

3.4.1 Systematic Obliterations

A surface grinder with an 80-grit aluminium oxide wheel was used to remove 0.01mm of material at a time from the surface of 60 dot peened plates. The samples were flooded in coolant during the grinding process. The force involved in removing such small layers is negligible, so no physical alterations to the microstructure would occur.

To test the abilities of the eddy current kit (ECK) against dot-peened marks, the steel plates were obliterated to varying depths. Ten plates were each obliterated to 100, 150, 200, 250, 300, and 350μm. This method of obliteration ensured the depth of obliteration remained consistent to a level where the marks were no longer visible by eye to two examiners, however the material under the original mark was not disturbed, allowing the best chance of recovery.

In addition, all 20 laser engraved plates were obliterated using a grinding wheel to a depth where the marks were no longer visible to the naked eye.

3.4.2 By-Hand Obliterations

Serial numbers on the remaining 10 plates dot peened plates were obliteration by hand, using a grinding disk on a Dremel®, a hand-file and a rotary grinder. Examples of these methods are shown in Figure 3-12. The obliterations are rough and uneven, due to human tendency. These obliteration methods were chosen and conducted by a single operator to simulate what is most encountered in the field.

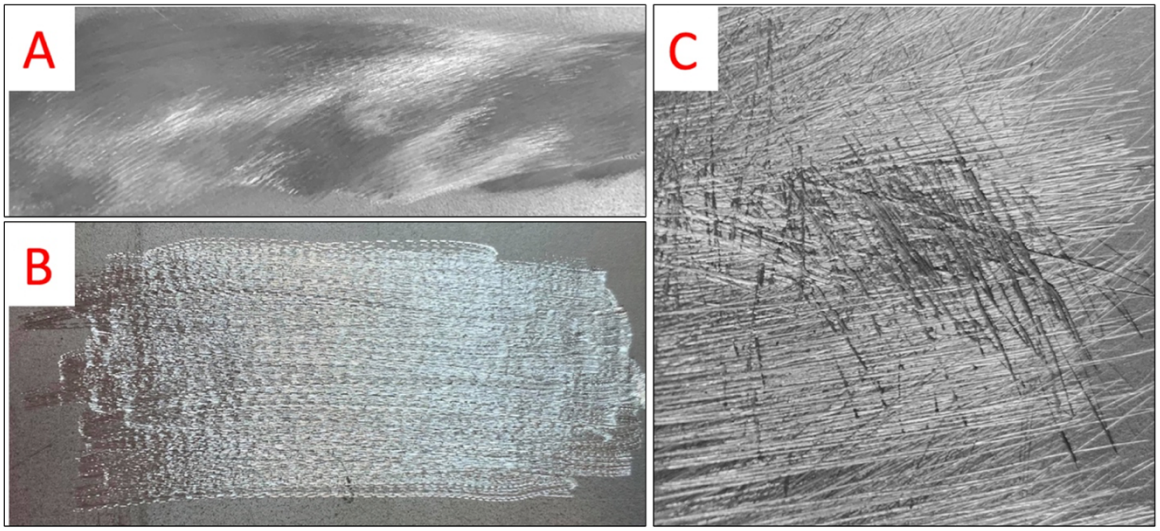


Figure 3-12: The three methods of obliteration using hand tools on 10 steel plates. (A) Mechanical grinder moving from left to right, (B) Polishing stone on a powered Dremel®, tool, moving back and forth from left to right (C) Hand file, showing random striations moving in all directions. (Figure not to scale, used to highlight toolmark characteristics).

A Dremel® rotary tool with a grinding bit was used to remove each mark on the pistol slide. This was conducted by one operator only to a depth where the mark was no longer visible to the naked eye. The original surface was maintained to ensure a datum point remained for measuring the obliteration depth. Figure 3-13 shows the pistol slide and a top cover post-obliteration, where the obliteration depth was 1.20mm. Both sides of the slide had some features (small amounts of text) left unobliterated, to ensure the orientation of the recovery scans. The AK-

pattern top covers were also obliterated by hand using a Dremel® rotary tool, to a level where they were no longer visible to the naked eye.

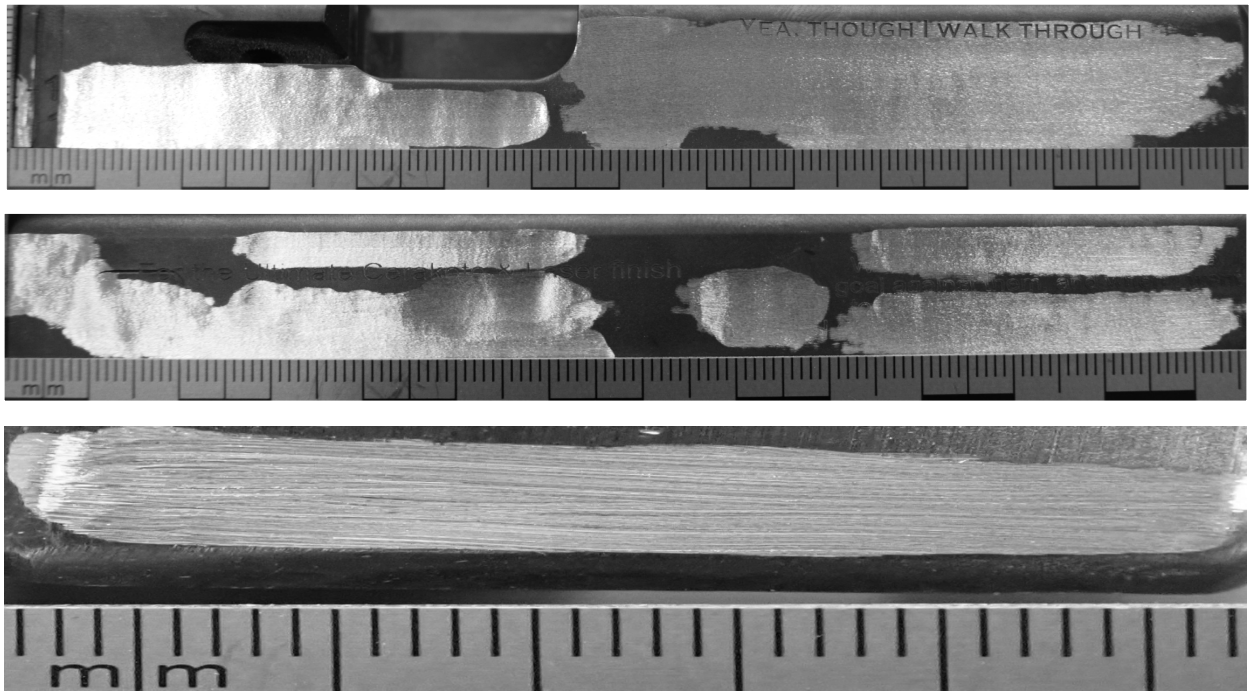


Figure 3-13: Each side of the pistol slide (top, middle) and the back face of a top cover (bottom) after the marks were removed with a Dremel® rotary tool.

3.5 Recovery Methodology

The ECK was used to attempt recovery first as it is a non-destructive method. Fry's reagent was then used, as the forensic industry standard. It was attempted after the ECK, as it is a destructive method of recovery and leads to irreversible damage to the steel.

3.5.1 Eddy Current Kit Recovery

In the first round of testing, no surface preparation was conducted to evaluate the potential for totally non-destructive testing. Each plate was placed on the electromagnetic base, with care taken to ensure all magnets were aligned

appropriately to allow proper current flow. A systematic approach was used to establish the most effective strength of magnetic field and eddy current settings. As this is an emerging technology, the manufacturers suggest using cardboard to create a standoff between the magnetic base and the steel plate to reduce the magnetic field to an appropriate level, as indicated by the included tool. The scanner used has eddy current pulse strength settings 1 to 12, and each setting was evaluated against the 14 hand-obliterated samples. Levels 6-8 gave the clearest image of each serial number.

After the first round of non-destructive testing, a portion of plates required minimal polishing due to the extreme surface damage imparted by the tools used to create the obliterations. These samples were not necessarily those with deeper obliterations, however, they did show increased surface irregularity. After minimal polishing, each plate was retested until a clear result was obtained.

Only the ECK will be used to attempt the recovery of the obliterated marks from these components, as the firearms are part of a formal collection and could not be subjected to Fry's reagent.

3.5.2 Fry's Reagent Recovery

Fry's Reagent was prepared by mixing 5g of copper chloride in 25ml of ethanol and 40ml of hydrochloric acid in 30ml distilled water [101]. This was then applied to the obliterations with a cotton bud. Following the preparation and use guidelines provided by Cranfield university [101], the reagent was brushed on with the cotton bud and allowed to sit for 2 minutes before continuous brushing with the reagent. The process was repeated until the serial number was visible.

Fry's Reagent was not used on the 60 dot peened plates used in the systematic portion of the study, due to the proven success rates of Fry's reagent in previous work [55,67]. However, the 10 plates obliterated by hand were used in the eddy current testing were subsequently used in the Fry's Reagent testing. This allowed

for the direct comparison of the two methods using the same samples, ensuring identical obliteration conditions were used to test each method. As Fry's Reagent is known to be destructive, it was carried out after using the ECK. As the ECK is an emerging technology, not currently employed in the forensic recovery of serial numbers, this methodology has been established as part of this thesis. While allowing for direct comparison of the effectiveness of each technique, it also ensures the ECK is used on samples that have not been exposed to destructive chemicals before use, allowing the best chance at recovery.

Each plate was prepared using a polishing stone on a Dremel® tool to obtain a generally smooth surface and then sandpaper of increasing grades, from 300 to 1200 grit, to bring the surface to a mirror finish. Upon the completion of polishing, each sample was wiped with acetone to preparate the surface for Fry's Reagent.

The second, laser engraved pistol slide was also used to compare the two recovery methods, therefore, was subjected to Fry's reagent after the ECK. The obliterations were polished smooth to ensure even application of the chemical.

3.6 Results

The results of the recovery of obliterated markings are presented in this section. First, the steel plate results are presented, and secondly, the firearms components.

3.6.1 Dot Peened Plates

The dot peened plates were only examined using the ECK, in an effort to establish how effective it is to recover serial numbers that have been obliterated to increasing depths. Table 3-2 shows the overall results.

Table 3-2: The results of the recovery of digits from 60 machine-obliterated steel plates using Fry's Reagent. Depths of obliteration range from 100 to 350µm by increments of 50µm, with 10 plates in each depth category.

Obliteration Depth (µm)	Number of Characters Recovered	Percent Recovery
100	60	100%
150	60	100%
200	26	43%
250	12	20%
300	5	8%
350	3	5%

To allow direct comparison of Fry's Reagent and the ECK, the same 10 plates obliterated using hand tools were used to assess the success of both methods. They were first subjected to recovery attempts using the ECK, followed by Fry's Reagent. A sample result of each method is shown in Figure 3-14. This figure also shows that there is no difference in the clarity of the resulting image from the ECK when the curvature of the characters is different (i.e. straight vs rounded digits).

Figure 3-14: The top image shows the characters visible before obliteration. Traditional recovery using Fry's Reagent (middle) and the non-destructive recovery using the ECK (bottom). Both results show "GHI789", showing a complete recovery of all 6 digits. These results have not been filtered, processed, or altered using any computer software. (Figure not to scale)

The experimental configuration and success rates of each method used to recover marks from the hand-obliterated plates are shown in Table 3-3. The number of successfully recovered digits per obliteration method are shown, in addition to the overall success of each method.

Table 3-3: The respective success rates (number of digits recovered) for Fry's reagent and the ECK from the 10 steel plates (60 digits) obliterated using hand tools.

Obliteration Method	Number of Digits Recovered	
	Fry's Reagent	Eddy Current
Dremel®	12	25
Dremel® & Anneal	4	4
Hand File	12	12
Grinder	8	8
Total Digits Recovered	36	49
Percentage Recovered	60%	82%

The percentage of serial number digits recovered was calculated and compared between the two methods of recovery. A t-test (Table 3-4) was used to identify if there was a significance difference in the recovery rates of Fry's reagent and the ECK. The following hypothesis and alternate hypotheses were established:

- H_0: $t_1 = t_2$ (There is no significant difference in the performance of Fry's reagent and the ECK).
- H_1: $t_1 \neq t_2$ (There is a significant difference in the performance of Fry's reagent and the ECK).

Table 3-4: The hypothesis, test statistic (t-test), p-value and results of the test for significant difference.

Sample	n	Recovered	Test Statistic	p-Value	Decision
Fry's Reagent	60	36	t= 2.92	0.67	Reject H_0
Eddy Current	60	49			

The performed t-test showed that there is a significant difference in the resulting recovery rates of Fry's reagent and the ECK, therefore proving that the ECK is more effective than Fry's reagent when recovering dot peened marks that have been removed from steel after being obliterated by hand tools.

3.6.2 Laser Engraved Plates

0 of the 400 laser engraved marks were recovered from the steel plates using the eddy current recovery technique. Additionally, Fry's reagent did not successfully recover any of the 400 engraved marks from the steel plates.

3.6.3 Firearms Components

The ECK was unsuccessful in the recovery of the laser engraved marks obliterated through milling on Baikal pistol (seen in Figure 3-15, top). The stamped "LW005" is clear on the electromagnetic image, however the laser engraved mark "иЖ-79-8" that was not obliterated was very faintly visible in the scan (Figure 3-15). This suggests that the scan is reaching the microstructure below the surface, as intended, and the removed marks are simply not recoverable.

Figure 3-15: The electromagnetic image (bottom) resulting from the ECK scan, showing two milled areas with no discernable marks underneath, a clearly visible stamped mark (LW005) and a faint laser-engraved mark (иЖ-79-8). The scan was not altered from original using any computer software. (Figure not to scale)

Figure 3-16 shows the successful recovery of part of the serial number stamped into the steel insert plate from the polymer pistol. The image reads “00428”, which matches the first 5 digits of the serial number applied to the barrel of the pistol.

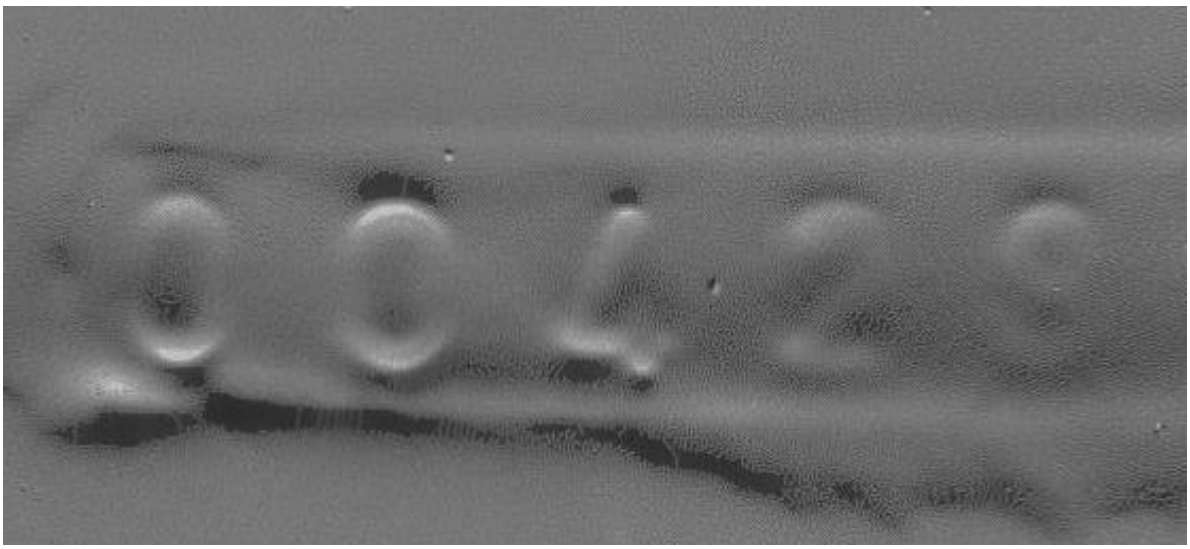


Figure 3-16: "00428" is visualised from the ECK scan of the steel insert plate from the polymer-framed pistol. The scan was not altered from original using any computer software. (Figure not to scale)

The electromagnetic image of the serial number of the real-world obliterated AK-pattern rifle was not as clear as previous results. The contrast was adjusted to allow for easier visualization. Figure 3-17 shows the recovery of the digits "2788" (in boxes). This serial number matched an un-obliterated serial number on the bolt.

Figure 3-17: "2788" (boxes) recovered in the electromagnetic image of the AK-pattern rifle. Image authors own. (Figure not to scale)

The mark “202” was clearly recovered from the muzzle device. It appears to have been stamped, due to the noticeable material build up around the edges of the numbers, compared to the “E”, which was unobliterated. Figure 3-18 shows the recovered mark, beside the existing “E” and the general outline of the muzzle device.

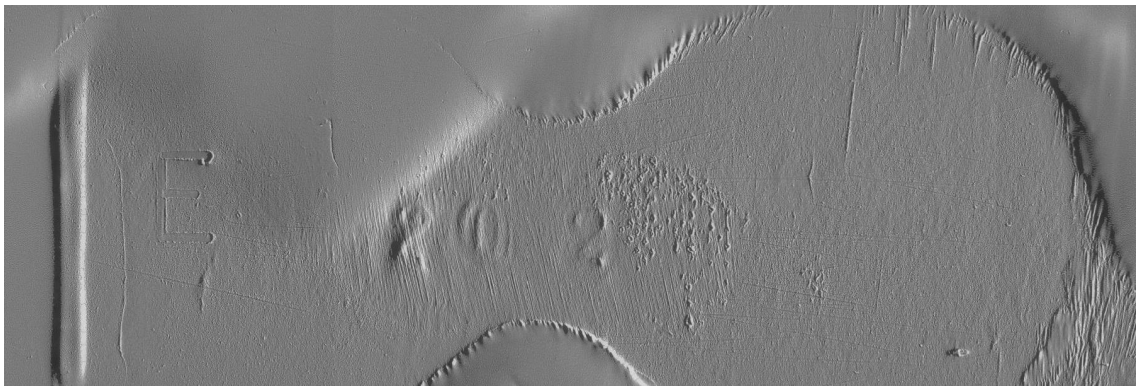


Figure 3-18: The recovered “202” serial number from the muzzle device. This electromagnetic image was not altered or processed in any computer software. (Figure not to scale)

As the Glock pistol slide was laser engraved post-manufacturing for the purposes of this thesis, the ECK was used in attempt to visualise both laser engraved and dot-peened marks.

Using the ECK, the firearm recoveries showed the clearest result at level 8. The results of the ECK showed that only the stamped manufactured marks were visible. The laser engraved marks were not visible. The manufactured marks “17 Gen 4”, “9x19” and “Austria” are highlighted in Figure 3-19, where the blank spaces (dotted rectangle) are where the laser engraved text should have been recovered. The visibility of these marks was confirmed by external examiners, with their annotated results shown in Appendix B (External Expert Examination of Magneto-Optical Image).

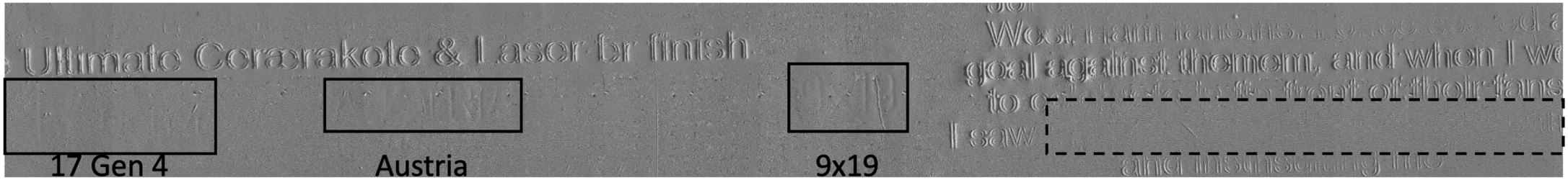


Figure 3-19: The left side of the pistol slide, where the stamped manufactured marks (solid rectangles) are still visible on the ECK scan after obliteration, at level 8. The applied laser engraved marks are no longer visible (dotted rectangle). (Figure not to scale)

3.6.4 AK- Pattern Rifle Top Covers

Six top covers were engraved with 17 marks each. Each mark was removed in the same manner as the pistol slide and recovery was attempted using Fry's reagent and the ECK. No marks were visible in the electromagnetic image, nor recovered using the etchant. Figure 3-20 shows the electromagnetic image of the eddy current scan, where the microstructure disturbance is clear, however no digits are discernible.

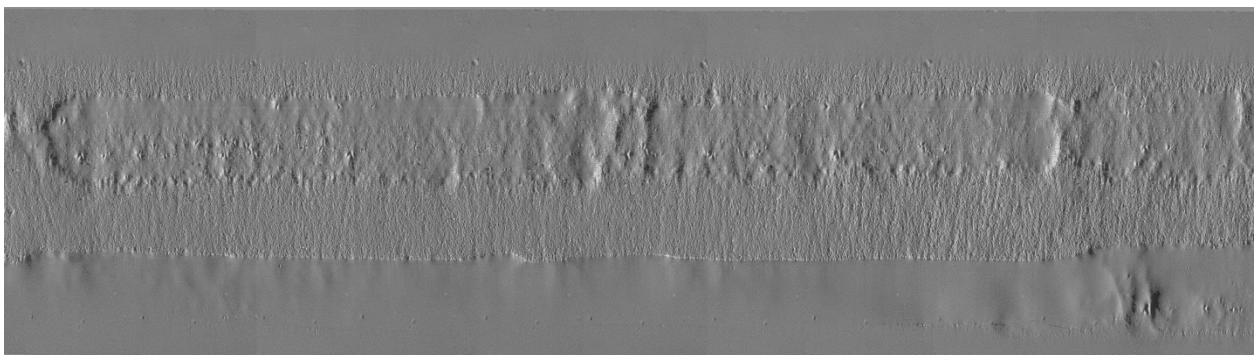


Figure 3-20: The electromagnetic image showing the microstructure of the AK-pattern rifle top cover, where the laser engraved marks were removed by hand using a Dremel® rotary tool. (Figure not to scale)

Fry's reagent was able to successfully recovery all 8 of the stamped marks from the slide, however, did not recover any of the laser engraved marks (n=7). Figure 3-21 shows the Fry's reagent recovery of a stamped mark, while also highlighting one area where the laser engraved marks were applied, but not recovered.

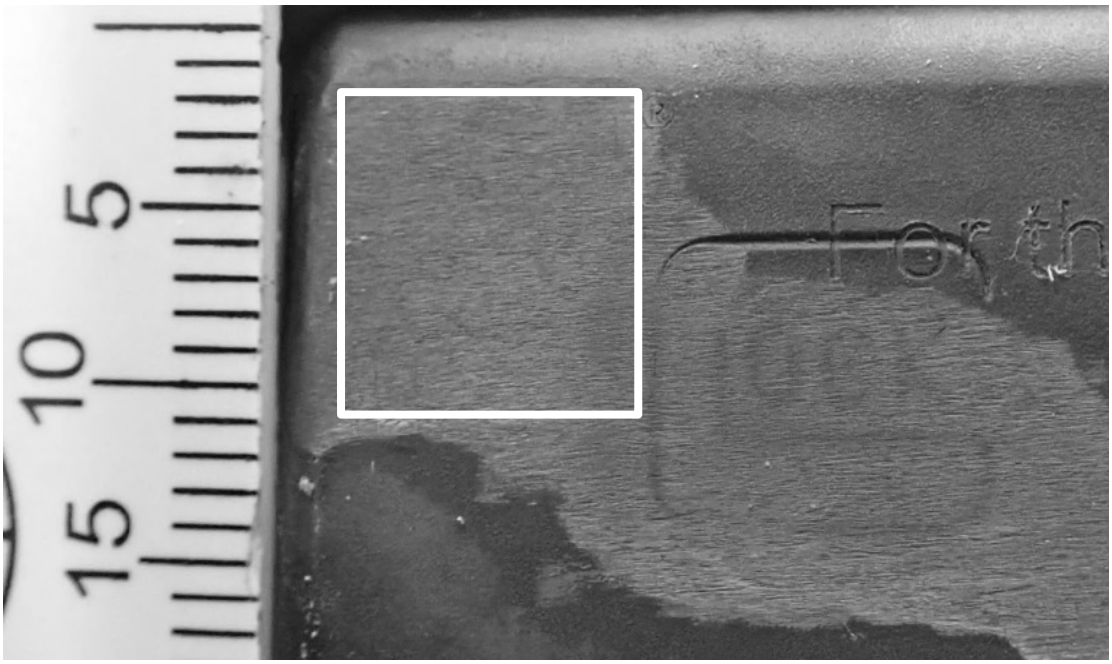


Figure 3-21: The front left side of the pistol muzzle, where the stamped "Glock" logo was recovered using Fry's reagent, and the laser engraved logo was not recovered (box).

3.6.5 Results Summary

Table 3-5 summarises the complete recovery results from all samples analysed in this chapter.

Table 3-5: The results of the recovery of obliterated marks, including the respective mark application and obliteration technique.

Sample Type	Number of Samples	Method of Mark Application	Obliteration Technique	Recovery Technique	Results (% Marks Recovered)
Steel Plates	60	Dot Peened	Grinding Wheel	ECK Only	Between 5% and 100%, depending on obliteration depth (see Table 3-2)
Steel Plates	10	Dot Peened	Hand Tools	ECK, Fry's Reagent	60% (Fry's) 82% (ECK)
Steel Plates	20	Laser Engraved	Grinding Wheel	ECK, Fry's Reagent	0%
Baikal Pistol Slide	1	Laser Engraved	Mill (Criminal)	ECK Only	0%
Steel Insert Plate	1	Stamped	Rotary Tool (Criminal)	ECK Only	100%
AK-Pattern Rifle Frame	1	Stamped	Grinder (Criminal)	ECK Only	100%
Muzzle Device	1	Mechanically Engraved	Grinder (Criminal)	ECK Only	100%
Glock Pistol Slide	1	Stamped, Laser Engraved	Rotary Tool (Lab)	ECK, Fry's Reagent	100% (stamped) 0% (lasered)
AK-Pattern Rifle Top Cover	6	Laser Engraved	Rotary Tool (Lab)	ECK, Fry's Reagent	0%

3.7 Discussion

The recovery of obliterated serial numbers and markings from firearms is an important capability for both forensic investigations and weapon tracing operations. Due to the destructive nature of chemical etchants, the investigative value of the potential results in a forensic examination is weighed against the destruction of evidence. Despite this, Fry's reagent was used in this study to examine the possibility of recovering obliterated laser engraved marks. To potentially find an alternative for this destruction, a non-destructive methodology was also used in this work to determine the efficacy of utilising this technique to recover the same laser engraved marks.

The non-destructive ECK was employed first, to preserve the integrity of the samples for later testing. The method by which the ECK functions is to detect structural differences in the microstructure of the steel and visualising it through magneto-optical digital images. With an example shown in Figure 3-22, all stamped marks (n=8) were recoverable with clear results. This is an expected result, based on previous literature and continuous, proven use in forensic laboratories, and relies on the plastic deformation to the microstructure of the steel below the original mark.

3.7.1 Recovery of Dot Peened or Stamped Marks

The results of the systematic portion of this study were unexpected, especially when compared to the hand-obliterated results. In only 44% of the plates, a full recovery was obtained. It was expected that a higher recovery rate would be noted as in some cases the original dots were still visible due to the shallow obliteration. When a successful full recovery was obtained, the result was visualized as shown in Figure 3-22.

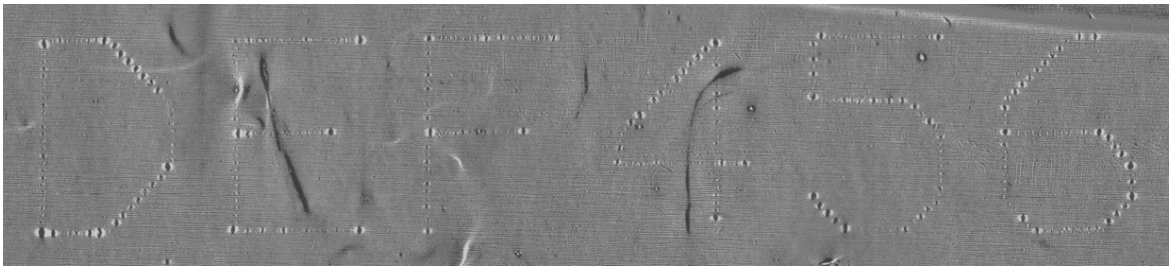


Figure 3-22: A clear, successful recovery showing 'DEF456' that was applied using the dot peen technique. (Figure not to scale)

Of the successful recoveries, some were faint results, likely due to a physical contact issue between the scanning wand and the sample. An example of this faint recovery is shown in Figure 3-23.

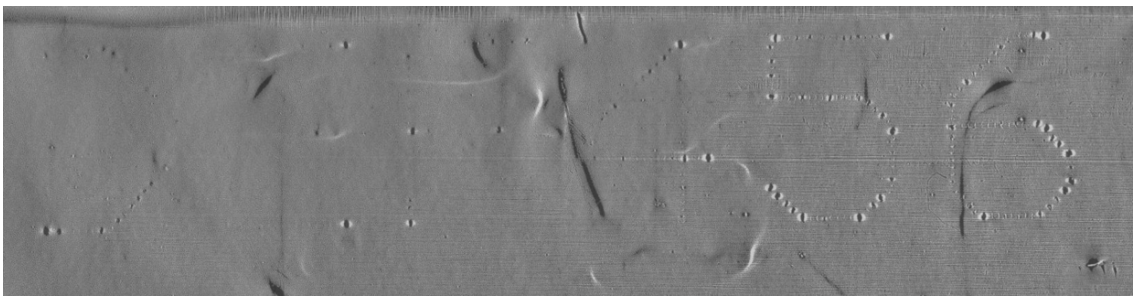


Figure 3-23: An example where poor physical contact between the scanner and the sample results in a faint result. (Figure not to scale)

Considering that using Fry's Reagent is expected to be successful when the obliteration is deeper than the visual serial number, if this kit is to eventually replace Fry's Reagent, it must be as, if not more, effective. The plates that were obliterated beyond 250µm were therefore expected to be recoverable by the ECK as well. The first attempt at these scans showed large amounts of surface noise on all scans so a second polishing with grit papers to 1200-grit were used to obtain a smoother surface. Only 56% (50) of scans were then partially or fully successful. The authors believe that this is still due to the surface finish of the samples. A smoother finish must be obtained to avoid the surface noise, as shown in Figure 3-24.

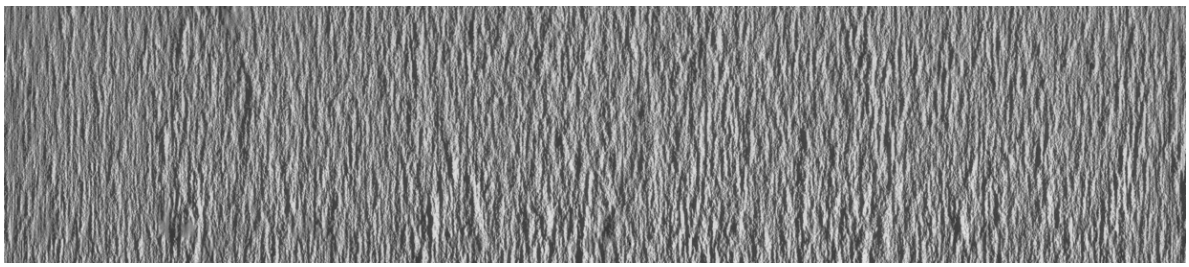


Figure 3-24: An example of a plate with high surface noise, not allowing a successful recovery. (Figure not to scale)

The overall results of this systematic study highlighted some anomalies and should be repeated using a finer grinding paper in the first instance. Even though this kit is meant to be non-destructive, a large amount of polishing was required, negating any benefit this technique has over Fry's Reagent.

To allow for seamless comparison of Fry's Reagent to the eddy current system, the same 14 plates obliterated by hand were used in both recovery trials. When the results are placed side by side, the quality of each method can be assessed.

Both samples in Figure 3-13 in the 'Results' section of this chapter were obliterated using a grinder. In this example, Fry's Reagent is effective, and the resulting serial number recovery is legible. This does rely on how well the surface is polished, therefore impacting the integrity of the forensic evidence. The result of recovery using the ECK system is perhaps not as clear as the recovery with Fry's Reagent, as individual dots are not typically visible, however, the serial number is still visible, which is ultimately the point of the technique. The trade-off of the non-destructive method to preserve evidential integrity must be considered.

Each serial number digit was 8mm tall whereas, in reality, many serial numbers on firearms are only 2-4mm tall depending on the firearm make and model. This height of digit was dictated by the dot peening equipment limitations. Because of this, the success of each method was determined primarily by the number of

serial number digits that could be recovered instead of the entire serial number. The current ISO 17025 method of forensic recovery using Fry's Reagent recovered 62% (n=84) of the total digits. When using the ECK, 81% (n=84) of the digits were recovered. The eddy current method was more effective than Fry's when recovering digits obliterated with a Dremel®, however, the two methods otherwise performed similarly when the obliteration was made with a hand file or a grinder. These obliterations were much shallower than the Dremel®, allowing easier recovery for both methods.

It was determined that there is a significant difference in the recovery rates of Fry's Reagent (60%) and the eddy current method (82%). The null hypothesis is rejected as the calculated value is less than 0.05. In the first phase of this study, only the success of the kit was considered. These results are in support of the hypothesis that there is a significant technical benefit to using the ECK compared to Fry's reagent with regards to the actual recovery of serial numbers.

Of the firearm components that had stamped marks applied at the time of manufacture, each mark was successfully recovered. In total, 8 stamped marks were recovered from the Glock slide, the serial number from both the steel insert plate the muzzle device were very clear in the electromagnetic image, and the AK-pattern rifle serial number was recovered, although not as clear and required post-processing editing.

The recovery of these marks shows the proof of concept that the ECK is a viable tool for the non-destructive recovery of obliterated markings from firearms. Each of these marks, however, were applied to thin, flat pieces of steel. This current work did not test the ECK on aluminium firearms, or those components with complex geometries with air gaps such as machine gun bolts, or barrels.

3.7.2 Recovery of Laser Engraved Marks

The steel plates, pistol slide, and top covers each had laser engraved marks obliterated using either a belt grinder or a Dremel® rotary tool. 0% of these characters were recovered (n=509) using either the ECK nor the etchant. This shows that, despite a very shallow and even obliteration, the heat affected zone within the steel is not deep enough to retain the mark below the obliteration.

As it was found that neither Fry's reagent, nor the Regula Forensics® Eddy Current Recovery kit were successful in the recovery of laser engraved marks from steel plates or steel firearm components, this study has, therefore, shown that marks applied with a laser are not recoverable using two methods that are reliably used in forensic and tracing investigations.

3.8 Comparison of Recovery Techniques

In addition to the quantitative results and success rates, the process and logistics of each technique was considered. The preparation of the samples, time requirement and health and safety considerations were weighed between the two methods to ascertain the viability of use in a forensic laboratory context, as well as implications to the evidential integrity of the samples.

Fry's Reagent is currently used in ISO 17025 accredited forensic laboratories for serial number recovery on steel-framed firearms. It is currently the most effective etchant, although there are obvious drawbacks to using a corrosive chemical on forensic evidence. When using Fry's Reagent for recovery, each sample must be polished to a mirror finish to allow the etchant to work evenly across the surface. Areas that are physically higher than others will require more etchant to remove layers of the metal, while the low points will collect the corrosive liquid. This pooling will cause even more damage to the immediate area. This is destructive to the sample and in a forensic capacity is undesirable, however, currently unavoidable given the recovery techniques available.

Another downside to Fry's Reagent is the corrosive nature and is, therefore, a general health and safety hazard. In laboratories, there is a requirement for a ventilated fume hood. While this is not such a logistical burden on established forensic laboratories, as fume hoods are standard equipment, the health and safety risk of technicians must still be considered. This is also an issue when Fry's Reagent is being use outside of the standard laboratories, such as in field-based investigations.

For firearms in a forensic context, using a destructive method of recovery may not be worth the risk of compromising the integrity of the evidence for the slight chance of recovery. The experience of the examiner is relied upon to make this decision and weigh the likelihood of recovery versus destruction of evidence as there is no test to determine if Fry's Reagent will be effective. Overall, the use of Fry's Reagent in a forensic laboratory can be time consuming in terms of sample preparation and is destructive and unrepeatable by nature, however, is not complicated and is acceptable for use on forensically relevant evidence.

The main benefit to the proposed use of eddy currents and magnetic fields in the recovery of serial numbers from firearms is the non-destructive nature of the test. In theory, this technology can recover serial numbers where the surface has been obliterated with no preparation, such as polishing. In the experiment with hand obliterated numbers, 11 of the steel plates did not need any polishing at all, with very clear results obtained. The remaining three steel plates required some polishing, as they were very deeply obliterated using a grinding disk on the Dremel®, tool. Even though the surface of these plates did require some polishing, which is notably a destructive process, the level of polishing required was minimal in comparison to what is needed for Fry's Reagent to be effective. Despite the obvious consequence of still requiring surface preparation, the level of destruction is lower and may still be attractive to forensic and judiciary services.

While conducting the test is rapid, the training time on the operation of the kit is extensive. The manufacturing company provides a 3-day workshop, however in operation each case is unique, and it can take dozens of cases to be confident and competent in operation. A certain amount of expertise and training is required to understand how to adjust the settings to allow for successful and clear results. In general, by using an ECK setting around 6- on a scale of 1 to 12 for iron-based frames- will give an indication of whether the serial number can be recoverable. The operator can then adjust the eddy current flow to improve the clarity of the image. The benefit to this technology is that the operator can scan the obliterated area an unlimited number of times without altering the evidence, as the eddy currents and magnetic fields will not alter the microstructure of the material. The development of a Standard Operating Procedure by a systematic study will enable a methodological approach to be refined.

Overall, the ECK technology has the potential to be a useful methodology for obliterated serial numbers, with a nearly non-destructive application and no health and safety concerns. The process is not time consuming, however the burden of training is much higher than is required for Fry's Reagent. More extensive testing of this kit must be completed to understand the true limitations, especially on actual firearms.

3.8.1 Limitations

The way in which the steel plates had marks applied and subsequently obliterated was not entirely true to life, however, were necessary to ensure consistent conditions were held across all samples. The marks being applied to the same depth across all 20 plates and 400 marks allowed for systematic obliteration using a grinding belt to a specified depth. The laser engraver used to apply the marks is used within the firearms industry to apply post-manufactured marks, such as internal reference numbers for police forces, however it is not the same strength as those used in the actual manufacturing process. The laser engraving kits used by firearms manufacturers are often of higher intensity and beam strength. This

does not have an impact on the heat affected zone, however, and only changes the depth of the engraving. Additionally, the CR4-grade steel is not weapons-grade, however the cost and availability of more appropriate steel restricted the acquisition. The steel used in this study has similar carbon content, tensile strength, and yield stress to that of weapons-grade steel [102,103].

The laser engraving process for the top covers and pistol slide had the same limitations as the steel plates, where they were not applied by the same equipment used in actual manufacturing processes, however, the application of each mark was consistent and conducted to a standard used in post-manufacturing mark application. By using true firearm components, this was the most accurate way of comparing the potential for recovery to real-life forensic and tracing cases. Additionally, the “by hand” obliteration technique is inherently not consistent, however due to the shape of the components, the belt grinder could not be used. In effort to reduce the effect of this limitation, one operator conducted all obliterations, and only removed enough material until the mark was no longer visible to the naked eye. This was done in shallow layers with little pressure applied to the surface.

As mentioned previously, the ECK was effective on thin, flat steel components of real firearms. It was not tested on components with complex geometries or those made of aluminium. As aluminium is not magnetic, the ECK may not be effective on those types of weapons. Additionally, the operating mechanism of the ECK requires a uniform magnetic field to flow through the samples to produce a clear image. If the geometry of the component is not conducive to this type of magnetic flow, the ECK may not produce clear results.

3.9 Conclusions

The work contained in this chapter has shown that the eddy current technology has the potential to be a useful methodology for obliterated stamped or dot peened serial numbers, with nearly non-destructive application and no health and

safety concerns. The process is not time consuming, however, the burden of training is much higher than what is required for Fry's Reagent. More extensive testing of this kit must be completed to understand the true limitations, especially on actual firearms.

Another significant conclusion was that Fry's reagent, an industry-standard chemical etchant, and Regula Forensics® Eddy Current Recovery kit, were both unsuccessful in recovering any of the applied laser engraved marks. This highlights the need for further refinement of politically binding agreements to clarify the requirements for the marking of firearms by manufacturers.

From these results, forensic practitioners are recommended to avoid attempting the recovery of laser engraved marks, especially using a chemical etchant, to preserve the integrity of forensic evidence. Additionally, to maintain compliance with the ITI and other international legislation, firearms manufacturers in countries subscribing to these political agreements should use more permanent cold working methods (ex. stamping or dot peening) when applying unique identifying marks.

Through the assessment of the efficacy of the technology to recover removed markings from steel plates and firearms, it was found that in many cases these marks cannot be recovered. The potential of recovery depends on a multitude of factors, including the application method and obliteration method. During this portion of the research, firearms with obliterations where the material was entirely removed from the frame of the firearm, leaving zero potential for recovery. This renders firearms with these extensive obliterations to be entirely untraceable. While the marks may not be recoverable, the analysis of the toolmarks themselves could lead to gaining intelligence-based information that would enable forensic and illicit firearms tracing investigations. The following chapter, therefore, outlines a novel methodology established in light of these types of obliterations, exploring how the toolmarks and details of the obliterations can be used to identify trends in the sanitisation of illicit firearms.

4 Methodology: Obliteration Codes

4.1 Introduction

This chapter introduces a novel codification system used to classify obliterations based on the toolmark analysis of obliterations documented on firearms. From the previous chapter and existing literature, it has been established that marks criminally removed from firearms are not always recoverable, and therefore are untraceable. This coding system allows for intelligence to be gained, despite the absence of identifying marks.

4.2 Justification for Novel Methodology

In Chapter 3, during the investigation into the recoverability of obliterated marks using the eddy current technology, it was noted that some removed marks will inevitably not be recoverable using any currently utilised methodology due to the extent of the obliteration. Initial samples intended for recovery provided by both the National Firearms Centre (NFC) (n=12) and the Light Weapons Wing (LWW) of the Defence Academy of the United Kingdom (n=6) showed obliterations where the mark was removed from the firearm by means of drilling out entire sections of the frame. This removed a significant portion of obliterated firearms from the dataset of attempted recoveries using the ECK. The specific firearms with this type of advanced obliteration were all recovered in the United Kingdom, raising the question as to why they were removed so aggressively compared to obliterations documented in other parts of the world.

To understand why obliterations in the NFC and LWW collections were so advanced, this research examined obliteration samples from around the globe, with the aim of understanding the significance of these assiduous obliteration techniques. Individual firearms were treated as a single sample throughout this work. If a firearm possessed more than one obliterated mark, each one was

treated as a discrete observation from the sample. For comparison to samples obtained in the UK, samples were collected from two countries where similar firearms laws, criminal punishment, and technologies exist. Firearms were, therefore, donated from Canada and Australia by two police forces, documented during criminal investigations in highly populous metropolitan areas. In Canada, data was collected from within the City of Edmonton by the Edmonton Police Service (EPS), while the Australian data was collected from the New South Wales (NSW) region by the New South Wales Police (NSWP). For comparison to obliterations done in regions where firearms laws and access to technology are dissimilar to the UK, samples were also donated by Conflict Armament Research that had been documented in fifteen countries, each being a recognised conflict affected zone. Justification for the selection of each of the above regions, as well as the investigation into individual samples and obliteration trends from each region, will be explored in Chapters 5 to 9. Each of these chapters will present the findings from applying this novel methodology to the obliterations documented in the various regions.

The methodology proposed in this chapter was developed utilising the objective toolmark features of obliterations obtained from the global network. To ensure the analysis was being conducted to a high, accurate and unbiased standard, experts in firearm examination, toolmark analysis, and intelligence operations were consulted on the methodology and technical assessment of the conclusions formed during the analysis of each obliteration. These consultations were also had to ensure the methodology would provide conclusions that would be both robust and valuable to investigations. The experts consulted and details regarding their area of expertise are listed in Table 4-1.

Table 4-1: Details of the experts consulted during the development of this methodology.

Expert Name	Organisation	Area of Expertise
Ronald Nichols	Nichols Forensic Science Consulting [104]	Forensic Firearms and Toolmark Examination
Specialist Group Military Intelligence Members	United Kingdom Ministry of Defence (Army) [105]	Technical Intelligence
Alan Barlow, MBE.	Conflict Armament Research, Chief of Technical Services [106]	Investigation of Firearms, Explosives, and Ammunition
David Baldwin	Principal Forensic Services [107]	Marks Analysis and Intelligence

While this coding system is novel, and developed by the author, toolmark analysis applied to codification systems and forensic investigation are not a new concept in general. Work by Gregory Klees and James Cadigan, both of the FBI, introduced the casting of obliterations to aid the toolmark analysis of the removal of VIN from vehicles in auto theft investigations [108]. This casting technique went on to provide a coded library of casts for toolmark comparison during VIN examination work, however the results went unpublished due to ongoing criminal investigations [personal communications, Gregory Klees, 2023].

Observations of an obliterated mark are codified to provide five categories of descriptor, each capturing a notable physical characteristic. The combination of each category gives each individual obliteration a code, which can be compared to other obliterations within a dataset. Matches observed within the dataset can indicate the existence of a common source.

This novel coding system utilises readily interpreted class characteristics within the toolmarks to identify the type of tool used to remove marks from the firearms and the way the tool is used, allowing a robust dataset to be developed. Individual tool mark characteristics are not used, despite being relied on in forensic

examinations, as this methodology does not aim to compare a mark with the specific tool used to create the obliteration. This is primarily because the firearms had often been seized away from workshop environments where tools might otherwise be observed. These obliteration codes will be used during future investigations on illicit weapons to index obliterations and allow searchable codes for comparison between jurisdictions. Coupling these profiles with intelligence on each region, the degree of forensic awareness of illicit networks and motivations for obliteration will also be identified within Chapters 5 to 9.

4.3 Sample Collection

Five locations across the globe were chosen for use in this work: two conflict-afflicted regions, and three developed countries. The justification for the selection of each country/region will be presented in Chapters 5 to 9, where the obliterations from each will be analysed independently.

The conflict-afflicted regions are those where the documentation of the firearms was conducted during a period of armed conflict. These firearms were originally recovered across the regions by local police and militant groups. The identification and documentation of the weapons was conducted in the field by trained and competent firearms specialists. Using macrophotography, obliterations of identifying markings were captured and catalogued for each weapon. In total, 471 firearms with obliterations were documented in conflict zones in Africa and the Middle East by intelligence service field teams between 2011 and 2023. Within Africa, the intelligence teams deployed into ten countries, documenting 249 of these 471 weapons. Documentation of the remaining 222 weapons was conducted in five countries in the Middle East.

The three developed countries in this dataset, Australia [109], Canada [51] and the United Kingdom [49], are not experiencing active conflict at the time of writing this thesis but do encounter significant levels of criminal use of firearms. 388 weapons with obliterations were documented in Australia, 236 obliterations were

documented within Edmonton, Canada, and 41 weapons showing obliterations were documented in the United Kingdom. Obliterations in Australia were documented by the New South Wales Police, and by the Edmonton Police Service in Canada. These firearms were each involved in the commission of a crime and recorded by the respective police force as evidence between the years 2001 and 2023. Those documented in the United Kingdom were taken by the author from three primary locations: the National Firearms Centre, the Light Weapons Wing at the Defence Academy of the United Kingdom and Cranfield Ordnance Test and Evaluation Centre (COTEC). Each of these centres has access to firearms from across the United Kingdom, originating from multiple police forces, border control services and other law enforcement agencies.

In addition to a high-resolution photograph, the following information relating to each firearm was recorded in an Excel ledger:

- Assigned sample number (Firearm Identification),
- Obliteration code (outlined in Section 4.4),
- Country of documentation, and
- Model.

4.3.1 Weapon Type Investigation

The type of weapons documented in each region may provide additional context to add valuable intelligence on weapon sources. It must be noted that the firearms documented in this thesis may not be entirely representative of *all* illicit weapons in a region. Over the course of this three-year thesis, it was not possible to cover all geographical areas, however, this research acts as a clear proof of concept for this novel and impactful intelligence-based investigation. For the purposes of this thesis, the SALW examined were separated into eleven categories. The categories were determined based on abundance and prevalence in various regions. In some cases, general categories, such as “rifle” were made more specific to indicate a particular model, such as “AK-pattern”, or to indicate artisanal manufacturing. To note, a Type 56 Rifle is a subset of AK-pattern rifles,

that is known to have been manufactured in China. Enabling more specific categories allows for an examination into the potential sources of the weapons in each region. The eleven categories, which are dictated by the model of firearm, are:

- Rifle,
- Sniper Rifle,
- AK-pattern Rifle,
- Type 56 Rifle,
- Artisanal AK-Pattern Rifle,
- Handgun,
- Artisanal Pistol,
- Blank Firer,
- Machine Gun,
- Submachine Gun, and
- Shotgun.

4.4 Code Outline

This novel coding system was deduced by examining obliterations and their objective toolmark characteristics. This unique intelligence tool will allow the objective analysis of obliterations to group sanitised weapons, regardless of geographical location. The characteristics selected for the categories were established in consultation with determined based on those that could be objectively analysed by any examiner that has the appropriate level of firearms and toolmark analysis.

The generation of each “obliteration codes” was conducted using the toolmark and obliteration observations. To establish a code, the methodology of sanitisation must be consistent. Figure 4-1 outlines the specifications within each category. The code for each weapon is given as “*T#.S#.M#.D#.C#”,* where:

T: Tool type

S: Level of sanitisation

M: The specific identifying mark that has been removed. If there is more than one mark removed, a "/" is placed between the digits representing the marks.

D: Directionality of the toolmarks

C: Additional concealment

#: The specification within each category

After each weapon was analysed and assigned an obliteration code, those with the same code were grouped together to visualise the key features in discrete folders.

The methodology has intentionally been left open-ended by using numerical categories for each specification allows for continual growth when new features are observed as samples are added in the future.

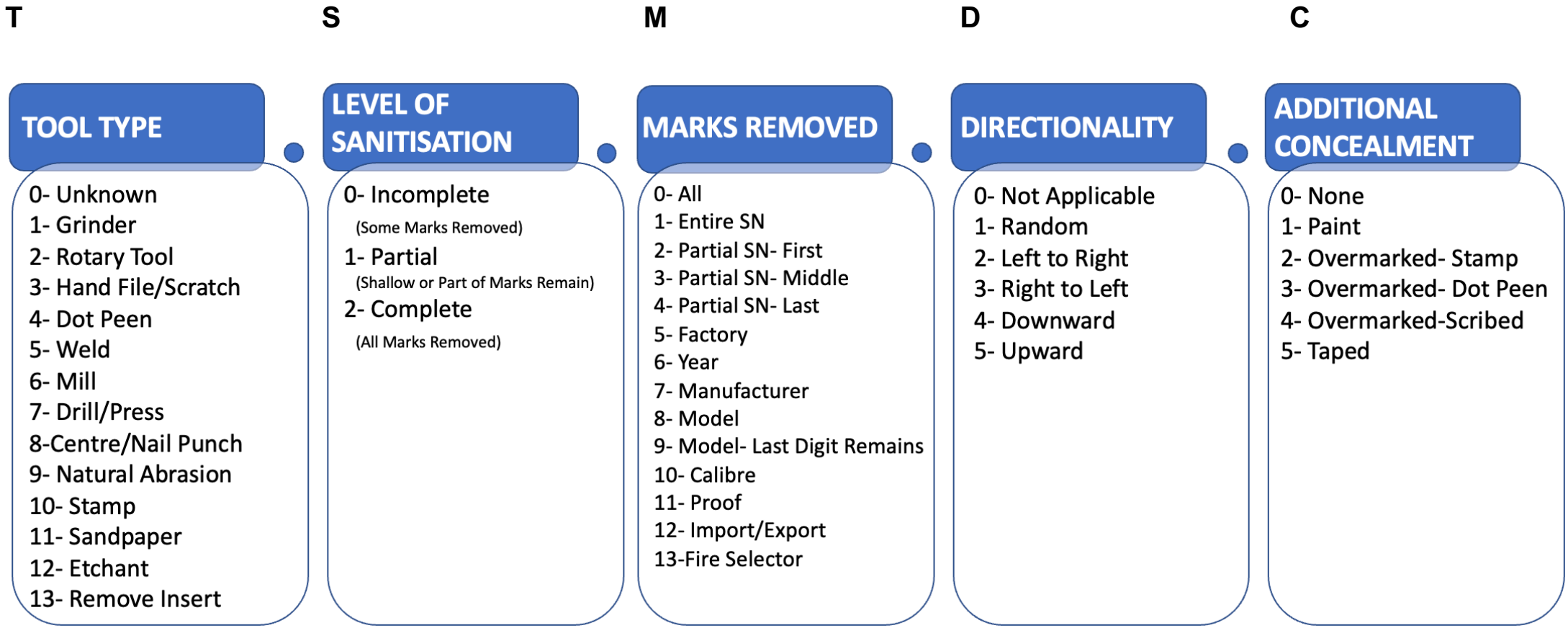


Figure 4-1: The novel methodology developed and followed to assign each weapon with an obliteration code.

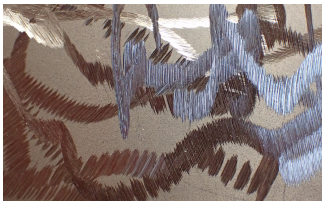
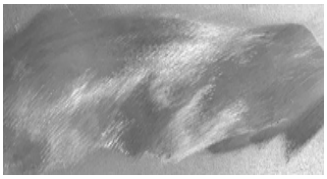
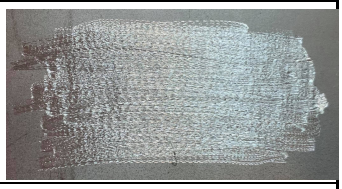
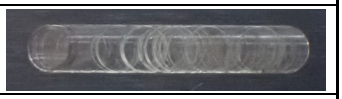
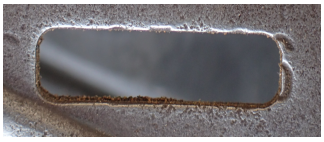
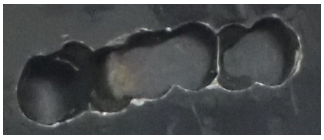
4.4.1 T: Tool Type Determination

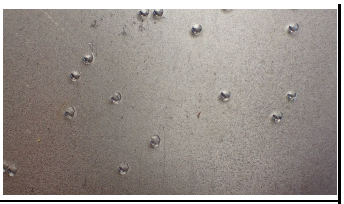
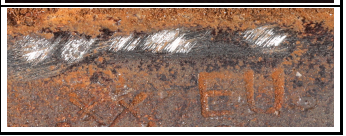
The type of tool used on each weapon was ascertained by examining the class characteristics of the toolmarks found within the obliteration. Class characteristics are those common to a group of tools [110]. An example of this is the size and shape of a hammer leaving a distinctive mark that only is left by a hammer. Individual characteristics, on the other hand, are those unique to one particular tool, typically a result of wear and tear during its lifetime [110]. Examples of individual characteristics are the tread pattern on the soles of shoes, which are unique to the wearer due to their gait and objects stepped on. Unlike traditional forensic investigations, the individual characteristics are irrelevant for this research as the aim of this work is to simply identify the type of tool using the general features observed in the striations, not to compare to known tools for criminal investigations.

To ensure the toolmark identification was accurate, sample plates were made using tools most encountered in artisanal and professional workshops in both conflict zones and developed regions. Identifying these tools may aid the intelligence-based investigation by establishing the technical capability and tool availability in some regions. These sample plates are shown in Table 4-2.

It is recognised that toolmarks can be very difficult to identify and quantify due to the many factors that influence their physical translation from the tool to the surface of the marked item [111]. These factors include the type of tool, the amount of force used, the area and angle of contact, the direction of movement (if applicable), among others.

Table 4-2: Twelve sample plates showing toolmarks from typical workshop tools to differentiate the various class characteristics to aid the identification of the tool used in an obliteration.

Tool Type	Characteristics	Photograph
Grinder (Edge)	Short, uniform marks. Spacing and direction of the marks depend on the speed of rotation and movement. Estimates at the diameter of the disc can be made by measuring the width of the striations.	
Grinder (Flat)	Continuous marks with a slight curve. The curve follows the circular shape of the grinder. The length of the marks depends on the time of contact with the sample.	
Rotary Tool	Thin, short, repeating marks. Spacing and depth depend on speed and force applied. Directionality can be random due to hand operation.	
Dot Peen	Individual dots stamped into the material in a pattern. Dot size and depth depends on the force of application, however material flow around the outside is a common feature.	
Weld	Individual dots, often overlapping, with evidence of heat treatment (colour change) and additional material being deposited. Direction of travel is indicated by the overlapping of marks.	
Mill	Uniform outline with circular striations inside.	
Drill/Press	Complete removal of material. Shape depends on the individual and the type of machine used. Static machines may result in circular shapes, while dynamic machines may remove larger areas of various shapes. There is no directionality associated with this category, as the bit moves up and down and can be difficult to isolate toolmarks by photographs.	 

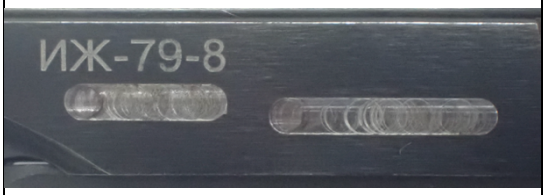
Centre/Nail Punch	Individual circular marks, not penetrating the material. Marks will differ in depth and definition, depending on the punch used and force applied.	
Natural Abrasion	Often results in smooth surfaces and little to no evidence of toolmarks. May be mistaken for an unmarked area of the firearm. These are not criminal by nature, and will only be used in conjunction with other, criminal methods of mark removal.	
Stamp	Size and shape will change depending on the stamp used. Depth and resulting material flow will change depending on the force applied.	
Sandpaper	Thin, continuous striations. Random in direction, due to human interaction. Striation size may change depending on the grit size of the paper.	
Etchant	Often results in colour and/or surface finish changes. Pitting may occur. Rusting may occur.	

In addition to the comparison above, experts were consulted to ensure tool type determinations were accurate by sending a random selection of 50 obliterations for confirmation. These consultations were with toolmark experts and subject matter experts from various police/army forces and forensic laboratories, as mentioned in Section 4.1.

4.4.2 S: Level of Sanitisation

Three levels of sanitisation have been identified, as explained in Table 4-3, with examples. In some cases, the level of sanitisation may indicate the forensic awareness or the motivation for concealment. The intentional and unintentional removal of the identifying marks are both included in the dataset of the thesis. It was important to include the level of sanitisation in the coding methodology as there may both forensic and intelligence implications to these situations, which will be expanded upon in Chapters 5 to 10.

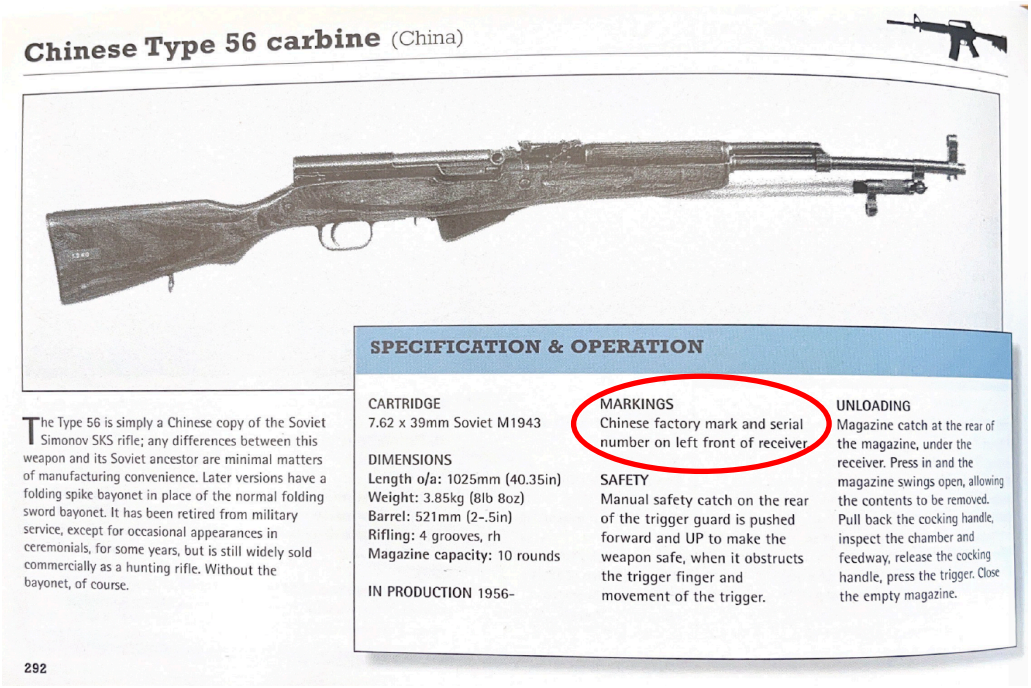
Table 4-3: Sanitisation levels, with descriptions and examples, for use in the obliteration coding system.

Level of Sanitisation	Description	Example
Incomplete	Only some identifying marks were removed, such as serial number or factory mark	
Partial	Marks are removed, however, are still partially visible by the naked eye. This may be due to a shallow obliteration or where identifying remnants of a mark remain.	
Complete	All identifying marks are removed to the point where they are no longer visible to the human eye.	

4.4.3 M: Marks Removed

Identifying marks on weapons differ between models and manufacturers. As discussed in the literature review, the serial number, among many other marks, may be found in different locations, alphabets, or languages, particularly when the same model is manufactured by different countries or factories, or produced by a manufacturer over an extended period. To determine which marks were

removed from each weapon, research was conducted using various resources including the Jane's Guns: Recognition Guide [112], RCMP Firearms Reference Table [113], the INTERPOL Reference Table [114], and two physical reference collections from the LWW and the NFC. Each of these resources has examples of the markings noted on firearms of different manufacture and country of origin. An example of a reference from the literature is shown in Figure 4-2, which has been taken from Jane's Gun Recognition Guide [112].



Chinese Type 56 carbine (China)

The Type 56 is simply a Chinese copy of the Soviet Simonov SKS rifle; any differences between this weapon and its Soviet ancestor are minimal matters of manufacturing convenience. Later versions have a folding spike bayonet in place of the normal folding sword bayonet. It has been retired from military service, except for occasional appearances in ceremonials, for some years, but is still widely sold commercially as a hunting rifle. Without the bayonet, of course.

SPECIFICATION & OPERATION

CARTRIDGE
7.62 x 39mm Soviet M1943

DIMENSIONS
Length o/a: 1025mm (40.35in)
Weight: 3.85kg (8lb 8oz)
Barrel: 521mm (2-.5in)
Rifling: 4 grooves, rh
Magazine capacity: 10 rounds

IN PRODUCTION 1956-

MARKINGS
Chinese factory mark and serial number on left front of receiver

SAFETY
Manual safety catch on the rear of the trigger guard is pushed forward and UP to make the weapon safe, when it obstructs the trigger finger and movement of the trigger.

UNLOADING
Magazine catch at the rear of the magazine, under the receiver. Press in and the magazine swings open, allowing the contents to be removed. Pull back the cocking handle, inspect the chamber and feedway, release the cocking handle, press the trigger. Close the empty magazine.

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Figure 4-2: A Chinese Type 56 Carbine, where the expected marks on each have been highlighted within Jane's Guns: Recognition Guide [9].

In addition to the literature resources, the two physical reference collections were used in two scenarios: the first being as a confirmation of the literature, and the second being if the firearm was not covered in the literature. The physical collections were held by the LWW and NFC. Confirmation of the removed marks through corroboration with the two physical collections allowed for a greater level of certainty for the weapons manufactured in legitimate factories.

Depending on which specific marks were obliterated, the motivation of the sanitisation may be established. For example, when certain manufacturing marks remain after obliteration, such as the factory code, the legitimacy of manufacture is maintained. Additionally, if the year is removed, the supply chain may be trying to obscure the time of procurement to avoid embargos in certain regions. The black-market value will reflect the genuine nature of the weapon [115]. A deeper explanation of the motivation to remove marks in each region is discussed in Chapters 5 to 9 and a global perspective will be prevented in Chapter 10.

4.4.4 D: Directionality

The directionality of each obliteration is noted to assist in intelligence-based investigation. By determining the direction in which the tool moves across the surface of the firearm, investigators can find patterns and link similar obliterations; potentially identifying the presence of common nodes within the illicit trade. Although the current research is not seeking to identify individual perpetrators, including the directionality of the toolmarks from the outset allows for the identification of trends, while considering the handedness and uniqueness of the tool-user for future investigations. Additionally, by including the directionality of the toolmarks in the coding system, a further objective factor is added to the coding system, allowing for more specific filtering for comparisons to be made. This may assist in limiting the number of weapons within an obliteration code to more easily identify those which are visually similar. The results of this category will be presented in each regional chapter; however a thorough analysis will not be undertaken in this thesis as it is intended only as a further discriminatory factor for the coding system, and not to conduct forensic investigations.

There are five mechanisms employed to create toolmarks: compression, tension, shearing, torsion, and bending [111]. Of interest in this work are primarily those created through compressive forces, and those applied using a shearing, or dragging, force across the surface. Tools that are used in a “stamping” capacity

will not have a directionality associated with them and will therefore all fall into the “0- Not Applicable” category of the coding system.

The toolmarks that are created through a dragging force will have a directionality assigned to them in the coding system. As each obliteration is taken independently of the location on the firearm, the directions (random, left to right, right to left, upward, downward) are assigned as the analyst is looking at the obliteration with the firearm oriented on a flat surface with the lowest part of the firearm being at the bottom. Figure 4-3 shows an illustration for clarity.

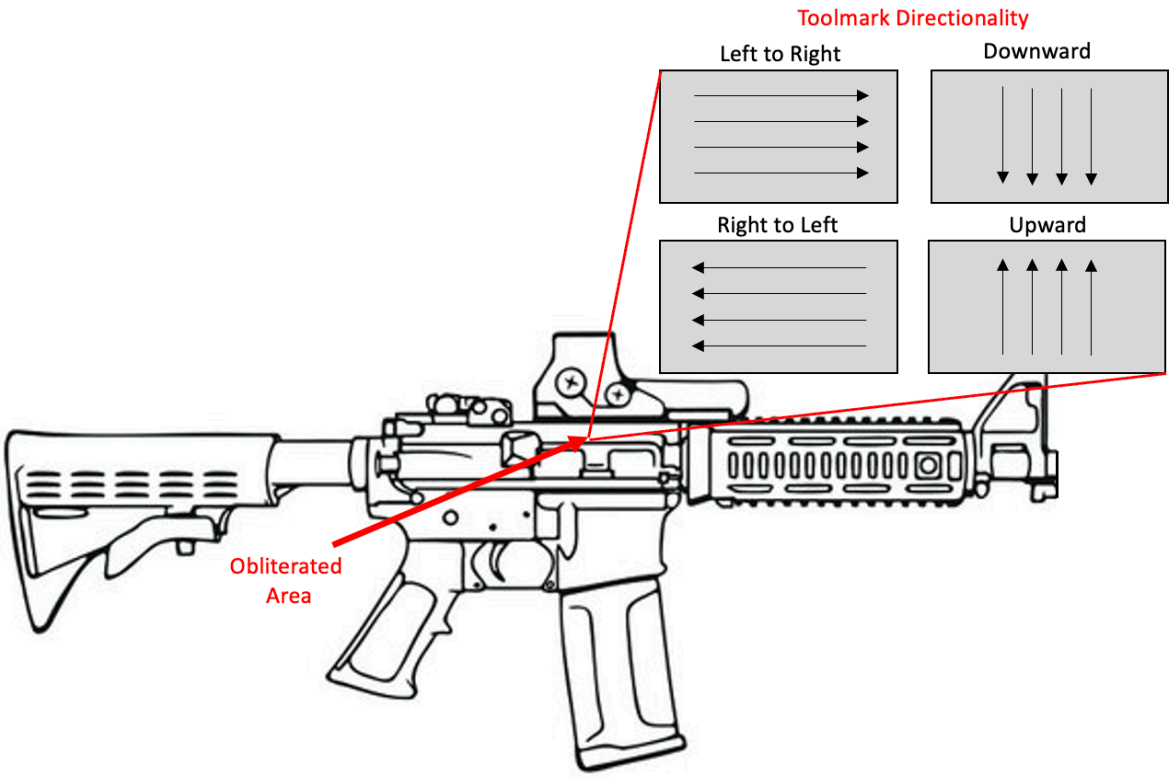


Figure 4-3: This figure shows the standard toolmark directionality, regardless of which side profile the marks are removed from. The lowest part of the firearm is oriented at the bottom of the image.

The directionality of a toolmark can be determined through visual observation of the features and characteristics within the mark. The shape, depth and width of such marks often are indicators of the orientation of the tool during contact with the surface [111]. By assessing overlapping striations and the leading and

following edges, the starting point and lift-off point are routinely identifiable. Figure 4-4 is a labelled sample from this data set to identify the leading edge, uniform striations, and the trailing edge. The trailing edge is where the tool started to lose contact with the firearm and is often non-uniform in length across the width of the toolmark. This occurs as the tool is lifted, different parts of the tool lose contact before others. The uniform striations show that a wide tool was used and there was consistent contact with the surface of the firearm.

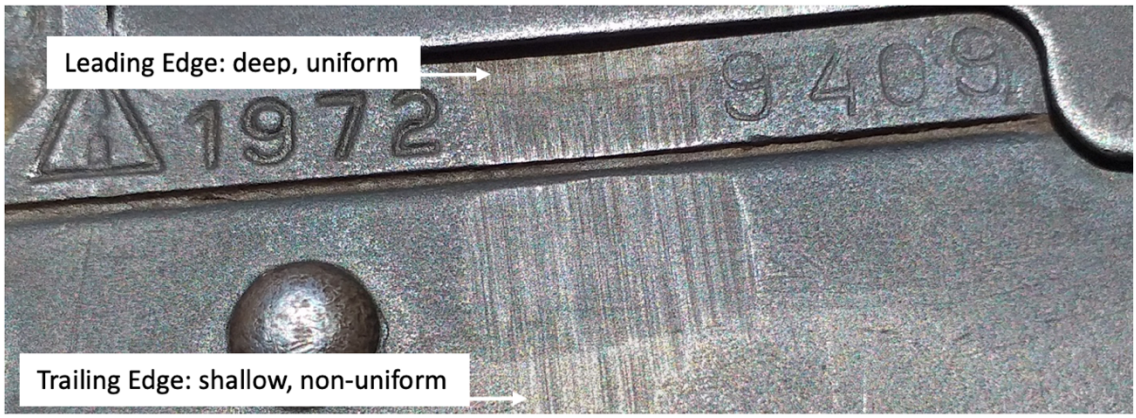


Figure 4-4: An example of a toolmark where the leading and trailing edges are identified, as well as uniform striations, indicating a wide tool passing the surface once.

In contrast, overlapping striations are indicative of multiple contacts of the tool and the firearm surface. Figure 4-5 shows a firearm where the tool, in this case a welding stick, was used to obliterate the marking and overlapped its own previous mark, showing the direction of travel of the tool. The only complete circle is on the left side of the obliteration (highlighted), indicating it was the last weld spot to be done, therefore a directionality of right to left.

Figure 4-5: An example obliteration where the direction of travel from right to left is indicated by the overlapping toolmarks created as the welding stick is moved across the surface of the firearm.

4.4.5 C: Additional Concealment

In some obliterations observed in this dataset, additional measures were seen to be used to camouflage the region where the marks were removed, as the toolmarks often leave the weapon surface altered and easily noticeable. These additional measures may be black paint, over stamping, or dot peening over an existing mark. Like the directionality of toolmarks, additional concealment of the obliterations allows for patterns and similarities to be made between obliterations in effort to link perpetrators and global trends. The specific paint used, if identified through analytical techniques, may inform investigators of where the paint was manufactured, and enable further investigation [116]. Figure 4-6 shows an example of paint being used as additional concealment on a weapon documented in Somalia.

Figure 4-6: An obliteration documented in Somalia, which has been painted black to conceal the area where toolmarks would be obvious.

4.5 Analysis of Obliteration Codes

This section outlines the statistical and qualitative analysis conducted on the dataset based on the obliteration codes assigned to each sample.

4.5.1 Cluster Analysis

Cluster analysis was conducted to establish groups of obliterations, regardless of their geographical documentation location. A hierarchical clustering method [117] was used to approach the dataset, starting with each individual obliteration. After each obliteration was coded, those with the same codes were grouped into a cluster. This type of grouping allowed for the assessment of similarities shared between obliterations sharing the same obliteration code from regions around the world. The established clusters are therefore based on discrete factors rather than observable differences. This removes the subjectivity of relying on visual comparison alone. A manual (visual) check was then conducted on obliterations within each cluster to establish the actual similarity between the obliterations. This check ensured that the coding system was robust enough to isolate similar or identical obliteration techniques. Where obliterations were not visually similar,

despite sharing an obliteration code, will remain within the cluster for potential inclusion in future investigations.

4.5.2 Geographical Analysis

A comparison of obliterations on a global scale was conducted. First, clusters within one region or country were compared. This established a baseline for how significantly similar the obliterations were in one area, or if the obliterations were too different to hold any confidence in conclusions drawn based on the obliteration trends. Second, clusters from different regions or countries were compared. This comparison was used to establish if any obliteration profiles were similar or identical cross-regionally, leading to a final intelligence-based analysis on forensic awareness, motivation to conceal the firearm's identity and technical capability.

4.6 Summary

This chapter outlines how each obliteration was analysed and categorised for direct comparison to other obliterations across the globe. By using the standard categories and multi-factor observations, Chapters 5 to 9 analyse the obliterations documented in each region independently. These chapters explore the tools used, level of sanitisation, which marks were removed, the directionality and additional concealment used in each region to understand the local physical capabilities and forensic awareness. Within each chapter, a cluster analysis of obliterations will be conducted using samples from the respective region. Chapter 10 seeks to conduct a global comparison of all obliterations. These comparisons of obliteration codes will also test the viability of using obliteration codes as a method to determine the geographical location of a single obliteration to a country or regional level. This novel methodology is applied to 1136 firearm's showing obliterations documented in five regions around the world and applied to intelligence-based conclusions.

5 Obliterations in Africa

5.1 Introduction

By exploring the nexus of conflict and the illicit trafficking of weapons within Africa, researchers have examined the factors driving conflict and proliferation of firearms [5,6,9,13,118]. The illicit trading of firearms is seen as a major component of sustaining and exacerbating conflict, due to the ease of access to weaponry [9,118]. This chapter examines weapons documented across ten African countries. By combining the analysis of physical evidence with an intelligence-based review of corruption, terrorism, weapon supply chains and forensic awareness, this chapter provides conclusions on what drives obliteration and weapon sanitisation in African states.

5.2 Countries of Interest

249 weapons from ten African countries were documented with obliterations by intelligence services between 2011 and 2023. The countries and number of weapons documented in each country are presented in Figure 5-1.

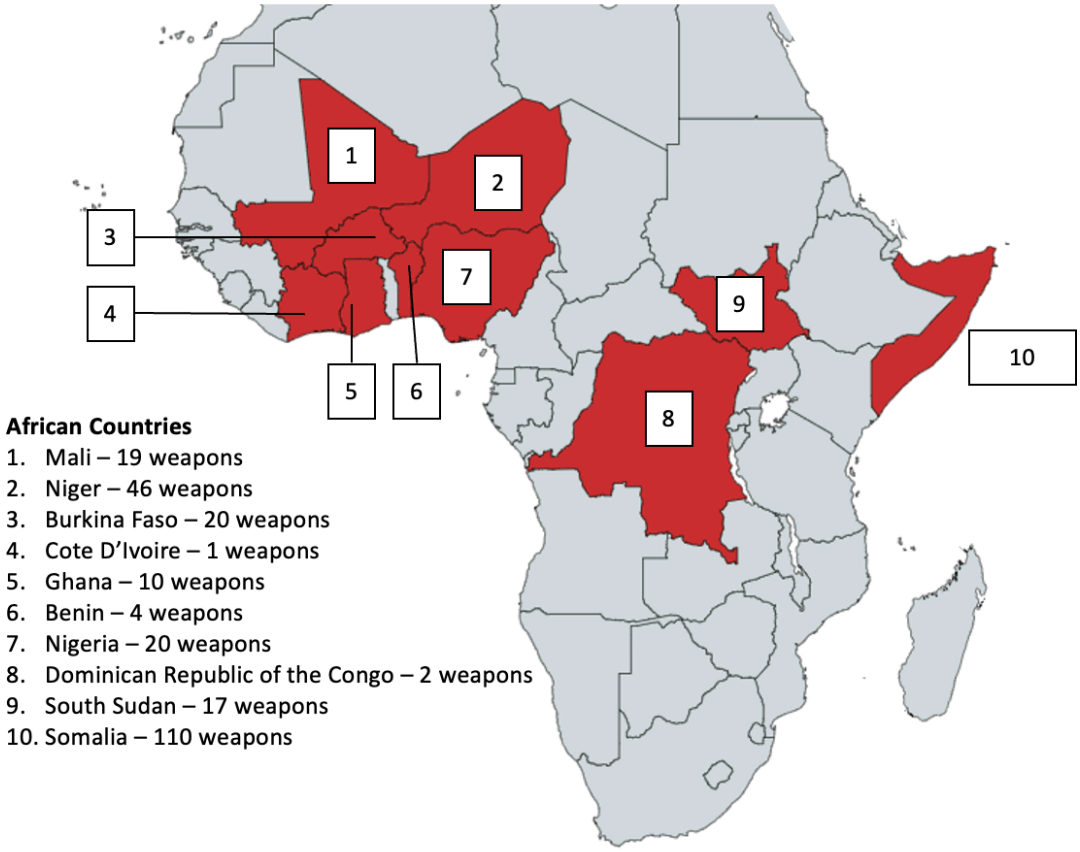


Figure 5-1: The number of weapons with obliterations documented in each African country, with a total of 249 across the region.

These countries are primarily in the Northwestern region of Africa, with the exception of the Dominican Republic of the Congo (Central) and Somalia (Horn of Africa). Each country has its own independent laws, government, military, police, and security forces. Generally, however, the recommendations made within four main Instruments are followed for civilian ownership of firearms, should be included in the firearms laws of each country [119]. The four instruments and their key provisions are:

1. Bamako declaration on an African common position on the illicit proliferation, circulation and trafficking of small arms and light weapons (Bamako declaration) [120].
    - Illegal possession of SALW and related material should be a criminal offence under national law.

2. Protocol on the control of firearms, ammunition and other related materials in the Southern African development community region (SADC firearms protocol) [121].
    - Registration of civilian-owned firearms, provisions on safe storage and use, competency training, firearm licencing, restrictions on civilian ownership.
3. Nairobi protocol for the prevention, control and reduction of small arms and light weapons in the great lakes region (Nairobi protocol) [122].
    - Registration of arms owned by private security companies, prohibition of semi-automatic and automatic rifle and machine gun ownership by civilians.
4. ECOWAS convention on small arms and light weapons, their ammunition and other related materials (ECOWAS convention) [123].
    - Licensing system requirements (age, number of weapons, safe storage and training, criminal record checks), sanctions and penalties for illicit possession and use.

Despite these recommendations and legislative requirements in each country, it is more common for international organisations, such as INTERPOL, to conduct investigations and prosecute and dismantle weapons trafficking organisations than for countries to persecute individual citizens for illicit ownership [124]. While criminal prosecution varies between each country, common challenges are faced across the continent. Many of the judicial systems are weak and undermined by corruption within governments, militaries, and police bodies [7,8,45,125]. This leads to an unbalanced criminal justice system, which is reflected in the low investment into forensic laboratories and requirement for international support from organisations such as INTERPOL and the UN [126].

5.2.1 Illicit Weapon Sources

All ten African countries in this study fall within the top 40 (out of 196) most corrupt countries in the world on the GOCI [88]. This is unsurprising, due to the levels of armed violence, political instability, terrorist groups, and known corruption within security forces. Violent extremism, insurgency, and conflict all rely on weapon and ammunition supply, so it is typical to see violent extremist organisations at the core of illicit weapon trafficking [127]. In many countries, organisations such as the Islamic State of Iraq and Syria (ISIS), Boko Haram, al-Qaeda, and Al-Shabaab are responsible for sustaining illicit weapon flow; both within, and between, African countries [127–129]. These terrorist groups do not often operate solely within the borders of one country and will spread across regions. Boko Haram is known for armed movements, including piracy and banditry, often acting as both a source and an end-user for illicit weapons [128]. Intelligence services have reported on documenting weapons known to have been in national custody, however, were originally seized from ISIS and Boko Haram groups [9]. Another example is ISIS, who are known to be active in African countries such as Libya and Nigeria, in addition to parts of the Middle East, and conduct high profile attacks with sanitised weapons on government facilities and civilians [9,130–132].

In addition to these terrorist groups, corrupt State officials are common sources of illicit firearms. For example, it is common practice in Nigeria for security force members to sell or rent their issued firearms to balance their low levels of pay [128]. This type of transaction has also been noted in Mali [133], Burkina Faso [131] and Niger [134]. In the Sahel Region, which is a belt that stretches from East to West in North Africa, primary weapon sources for the illicit market are theft from police armouries and from corrupt military members [127]. This region includes ten countries, four of which are included in this data set (Mali, Burkina Faso, Niger and Nigeria), further emphasising that criminal actors and trends in weapon sources are not limited to one country and span entire regions. In some

cases, weapons used in high profile attacks were completely sanitised, most likely conducted upon entering the terrorist networks [31].

A third source of illicit weapons are those that begin as a legal transaction that are diverted. Legally acquired weapons (often by government or military bodies) can end up in the hands of criminals through battlefield loss or poor stockpile management [133,135], in addition to the aforementioned State-level corruption. An example of this can be seen in Somalia, where the licit engagement of international stakeholders over decades of conflict is a primary factor in the illicit trafficking of weapons [136]. Poor weapon stockpile management and opposing force attacks are considerable post-shipment diversion factors across Africa [135]. In some cases, weapons diverted from legal sources end up in black-markets for resale.

Finally, a major contributor to the movement of illicit firearms is the high level of border porosity in African countries. Weak political institutions and governments, in addition to certain levels of corruption, enable weak borders, allowing for near-free movement between States by criminal actors [2,124]. Nigeria and Somalia are both known for their ideal transit access, owed heavily to their ocean access [118,128,136,137]. Illicit weapons trafficked from France, Turkey and Iran are common in these countries [127,128]. Niger is considered a major transit corridor for SALW, primarily due to the deterioration of its own security forces [134]. Weapons smuggled from neighbouring countries, which were originally sources from past conflicts and government stockpiles, often move into Niger or across the country onward to other regions in Africa and the Middle East [134]. Burkina Faso is also a major link for SALW between Mali, Niger, and Cote D'Ivoire [131]. This level of weapon trafficking would not be possible if the security of borders was improved across the continent.

In this chapter, weapons that have been sanitised and documented across Africa are examined. 249 firearms with obliterations were coded using the methodology established in Chapter 4 of this thesis and the results and interpretation will be presented here.

5.3 Methodology

All obliterations analysed in this chapter were documented in the field and provided by trained individuals. Each firearm was seized by local police or military units and stockpiled for documentation and tracing, as part of the iTrace program [138]. After documentation, the authority allowing access was responsible for the firearms, and no physical evidence was maintained. The photographs taken are taken to satisfy internal standard operating procedures for weapon documentation and photography. This methodology of documentation highlights the first strength of the codification system, where any investigator around the world can take the photograph and index the obliteration, allowing a simple yet highly effective system.

5.3.1 Application of Obliteration Codes

The coding system outlined in Section 4.4 of this thesis was followed for the obliterations documented in Africa. Each photograph was analysed to determine the type of tool used, the level of sanitisation, which mark(s) had been removed, the direction the tool moved, and if there was any additional concealment over the obliteration.

In total, 249 firearms with obliterations were coded from ten countries within Africa, and the results and interpretation will be presented in this chapter. Each obliteration was coded independently, and without comparison to other obliterations. This ensured no contextual information would interfere with an unbiased assessment of each obliteration.

The five-digit obliteration codes were recorded in an Excel spreadsheet, which also contained each item number and model of firearm. The item number each obliteration reflects the country of documentation using the two-digit country code, followed by a number. The number in each item number is assigned only for organisational purposes and does not reflect the order of documentation or analysis. Table 5-1 shows an excerpt of the spreadsheet used to maintain the records.

Table 5-1: An example of three obliterations and the data held within the Excel spreadsheet, where type of tool (T), level of sanitisation (S), marks removed (M), directionality (D) and additional concealment (C) are recorded..

Firearm Identification	T	S	M	D	C	Country	Model
NI1	2	0	2	0	1	Niger	Type 56-1
SO83	2	0	5/9	2	0	Somalia	Type 56-2
GH2	1	0	1	3	0	Ghana	AKKS

5.3.2 Comparison of Obliterations

After each obliteration was coded, clusters were created by associating those obliterations with the same five-digit code in one group. A cluster was established if there was more than one weapon with the same code. This decision was made to ensure that all similar obliterations could be compared, and no potential intelligence links were missed if the minimum number of matching codes for a cluster was increased.

In this African dataset, the clusters were made across the entire continent, not only within single countries. This was done to understand if the methods for obliterations were similar across borders, similar to the known level and

mechanisms of weapon diversion and movement across porous borders or remained in isolated areas.

Upon cluster creation, the photographs of the obliterations with a shared code were compared by filtering the results through an ArcGIS Dashboard. Figure 5-2 shows an example of the Dashboard filtered showing weapons in Africa with obliteration code 1.0.1.2.0.

Figure 5-2: Obliteration code 1.0.1.2.0 filtered in the ArcGIS Dashboard, to show that weapons in Mali, Niger, Nigeria, Ghana, and Somalia share the same code despite the geographical distance.

5.4 Results

5.4.1 Cluster Analysis

Across Africa, 25 clusters were established. 158 out of the 249 weapons (63%) were grouped into clusters with at least one other weapon (minimum of n=2). The remaining 91 weapons each have a unique obliteration code and are considered clusters of n=1.

Table 5-2 lists each obliteration code observed in Africa as a whole, the number of weapons within the cluster, and the number of weapons documented in countries where that obliteration code was documented.

Table 5-2: The 25 clusters of obliterations documented in Africa, shown with the obliteration code and the countries they were documented in. The number of weapons from each country is given in paratheses after the country name.

Code[1]					Country and Number of Weapons
T	S	M	D	C	
1	0	1/5/6	2	1	Benin (2)
1	0	1	2	0	Ghana (2), Mali (2), Niger (1), Nigeria (1), Somalia (11)
1	0	1	2	2	Burkina Faso (3), Somalia (3)
1	0	1	3	0	Burkina Faso (1), Ghana (1), Mali (3)
1	0	1/5/8	2	0	Ghana (2)
1	0	1/5/8	2	1	South Sudan (3), Niger (2)
1	0	2	4	0	Somalia (17)
2	0	1/5	1	0	Ghana (1), Niger (1)
2	0	1/5/6	2	2	Niger (2)
2	0	1/5/8	0	3	Cote D'Ivoire (1), Somalia (1)
2	0	1/5/8	1	1	South Sudan (2), Benin (1)
2	0	1/5/8	2	0	Mali (2), D.R. Congo (1), Niger (1)
2	0	1/5/8	2	1	Niger (2), Mali (1), South Sudan (1)
2	0	1/7	2	0	Somalia (11)
2	0	5/8	2	0	Somalia (6)
2	0	5/8	2	1	Somalia (17)
2	0	5/9	2	0	Somalia (16)
2	0	5/9	2	1	Somalia (16), Niger (2)
2	0	8	0	0	Niger (3)
2	1	1/5/8	2	0	Mali (2), Niger (1)
3	0	1	1	0	Nigeria (1), Somalia (1)
3	1	1/5	1	0	Nigeria (2)
3	1	1/5/6	1	0	Mali (2), Nigeria (1)
6	0	7/8	0	0	Niger (1), Nigeria (1)
6	1	1/7	0	0	Nigeria (4)

[1] T: tool type, S: level of sanitisation, M: marks removed, D: directionality, C: additional concealment. See Section 4.4 for full details.

As noted in the table above, 11 clusters are isolated to only one country, and 14 share obliteration codes across borders. When n=1 in Table 5-2, there was no weapons with obliterations sharing the same code within one country, however, it was shared across borders. The clusters are shown in Figure 5-3, highlighting the geographic links between clusters. The clusters are represented by a black dot, and the clusters linked cross-border are shown by a black line.

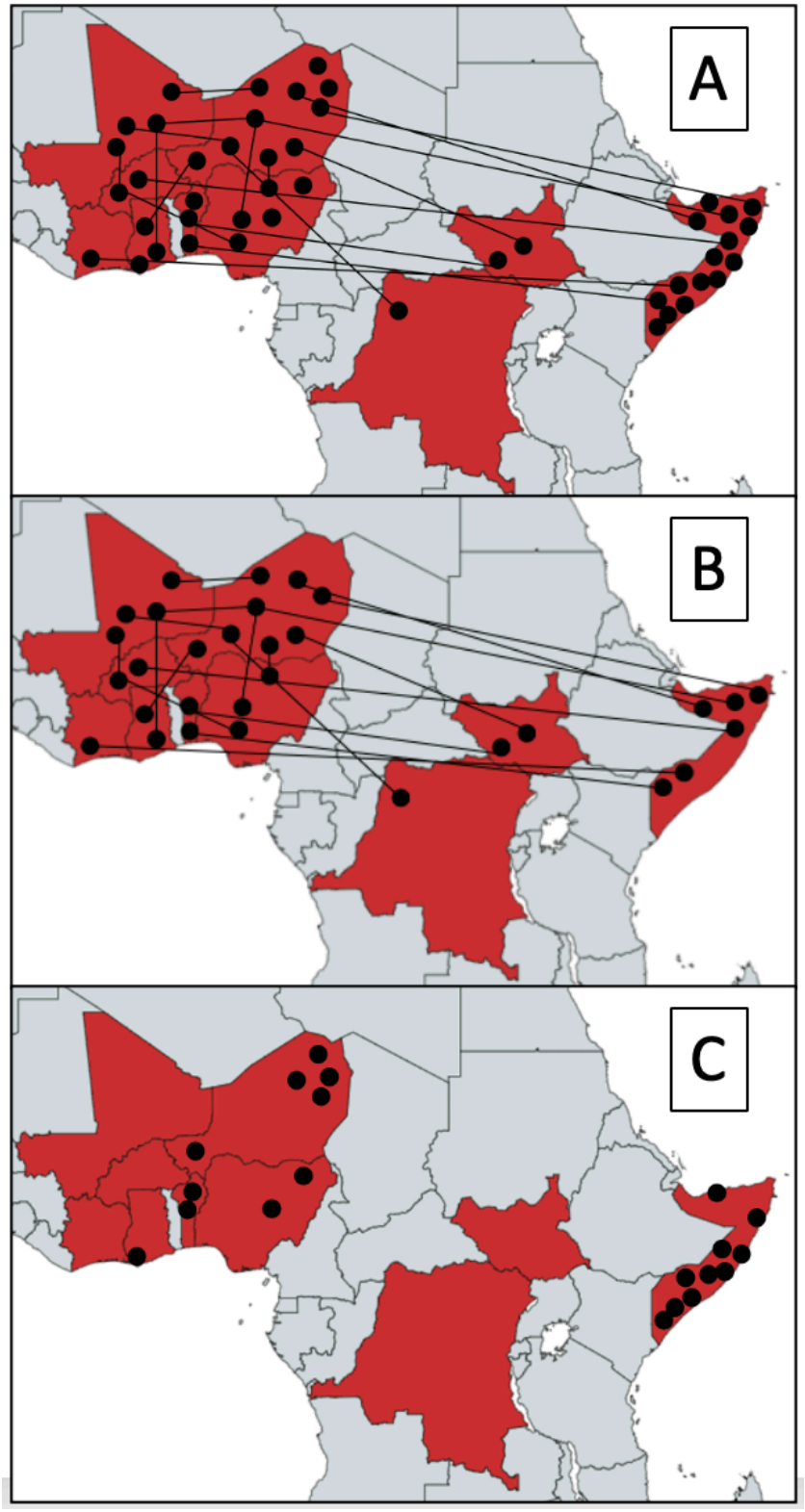


Figure 5-3: The 25 clusters (black dot) established across Africa, where clusters sharing an obliteration code are linked (black line). A) All clusters across Africa, B) Only clusters with cross-border obliteration codes, C) Only clusters isolated to one country.

One example of an obliteration code that is isolated to one country is in Somalia, where the obliteration code is 1.0.4.2.0. This indicates that the weapons had were partially obliterated and the marks were removed using a grinder moving downward. Only the first digits of the serial number were removed, and there was no additional concealment. 17 weapons are in this cluster and each one of them was documented in Somalia. Figure 5-4 shows three examples of obliterations in this cluster.

Figure 5-4: Three weapons documented in Somalia, where the obliteration code for each is 1.0.4.2.0.

An example of clusters created across borders is 2.1.1/5/8.2.0. These obliterations were documented in Mali and Niger. They were created using a rotary tool and left partially visible. The serial number, factory, and model number were each obliterated from left to right, with no additional concealment. One weapon from Mali and one from Niger are shown in Figure 5-5.

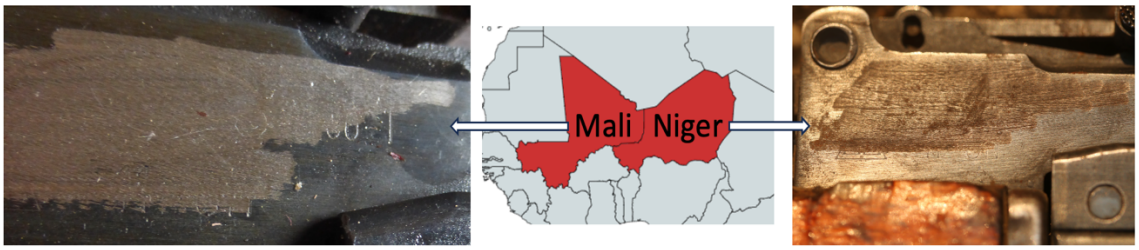


Figure 5-5: Two weapons sharing the obliteration code 2.1.1/5/8.2.0 documented in Mali and Niger.

5.4.2 Weapon Types

Most weapons documented in Africa are Chinese Type 56 rifles (50%, n=125), followed by other AK-pattern rifles (30%, n=74). This group of AK-pattern rifles is comprised of any AK-pattern rifle manufactured outside of China, namely Russia, Germany, and Bulgaria.

Also present, but in much smaller quantities, were handguns (n=18), sniper rifles (n=12), other assault rifles (of unknown or uncommon model) (n=19), and a shotgun (n=1). Figure 5-6 shows a chart indicating the prevalence of each weapon type documented in Africa with obliterations.

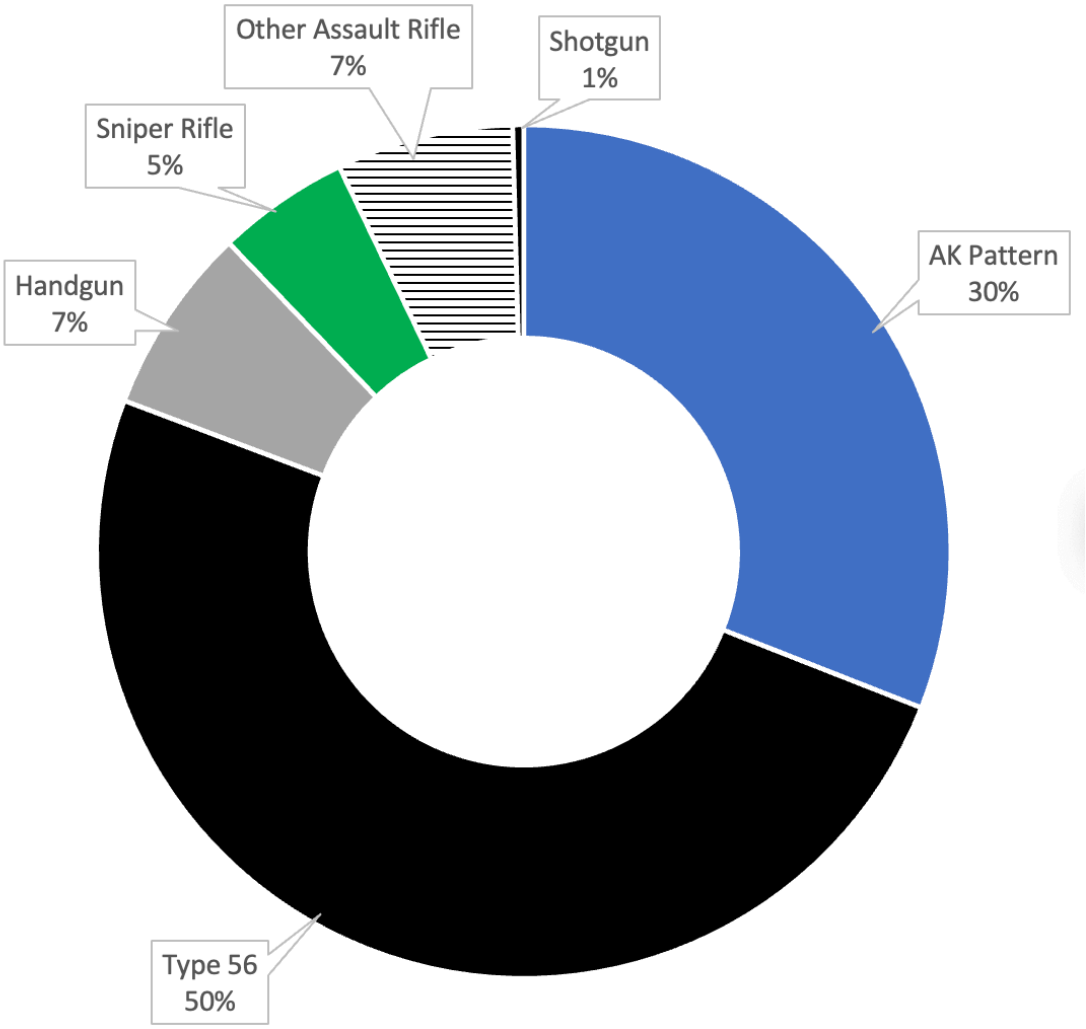


Figure 5-6: The types of weapons documented with obliterations in Africa (n=249).

5.4.3 Tool Types

The types of tools used to obliterate markings from firearms in Africa vary. The two most prominent tool types are two power tools: rotary tools (37%, n=111) and grinders (37%, n=91). Other tool types used include hand files (n=21), mill (n=9), drill (n=6), stamp (n=2), dot peen (n=1), weld (n=1), and nail punch (n=2). Figure 5-7 shows the breakdown of each tool type.

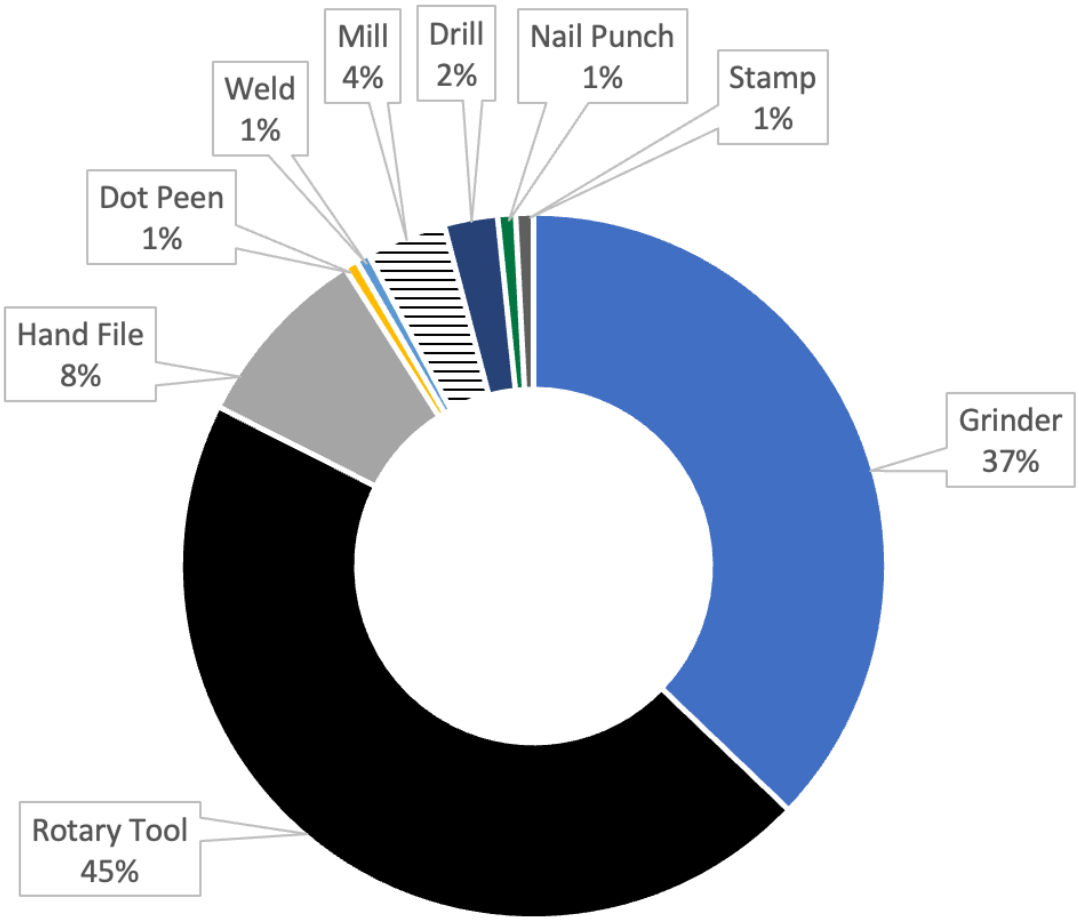


Figure 5-7: The tools used to create obliterations in Africa.

5.4.4 Level of Sanitisation

Few of the firearms were completely sanitised. Only seven (3%) had every identifying mark removed to a point where it was no longer visible. These seven weapons were documented in Burkina Faso, Niger, and Somalia. Only one of these firearms was a handgun, the remainder were rifles of various models.

Fourteen (6%) of the firearms documented were partially sanitised. Partial sanitisations occur when marks are either still visible due to shallow obliterations or only parts of the marks were removed. These partial sanitisations were

documented on weapons from the following weapon types: AK-pattern rifle, Type 56, and Other Assault Rifles.

Finally, most of the firearms (83%, n=207) documented in Africa were incomplete in their sanitisation. This means only some marks were removed, most often the serial number, while other identifying marks remained.

5.4.5 Marks Removed

The marks obliterated may help to indicate the motivation for concealing the identity of the weapon, as mentioned in Chapter 4. This will enable inferences to be made regarding the regional drivers for obliterating the identifying marks within countries around Africa. Figure 5-8 shows the number of observations of each mark being removed from a firearm. In most cases, more than one mark was removed from the firearm, which is indicated by a "/" in the coding system presented in Chapter 4. These have been separated into the individual mark categories for analysis.

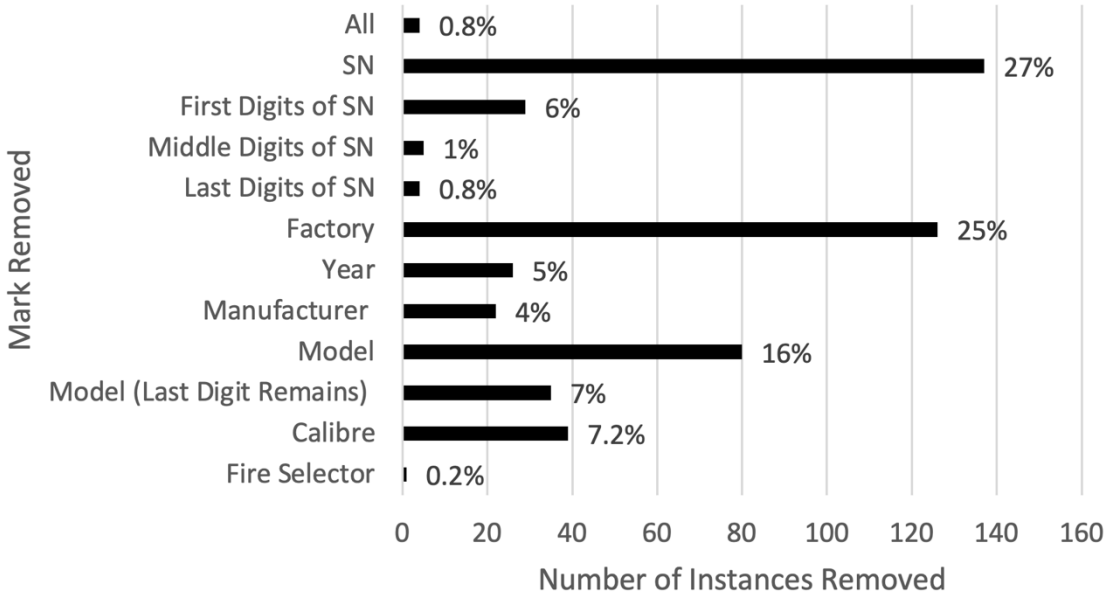


Figure 5-8: The number of times and percentage of overall occurrences specific marks were obliterated from firearms documented in Africa. ("SN" = serial number).

The mark most removed was the serial number, as it was completely obliterated from 137 weapons (57%), as expected, and partially removed from 38 (7.8%). This was expected due to the serial number being the only identifying mark that is unique to only one weapon.

Secondary to the serial number, the factory mark was removed from 126 weapons (25%). The factory mark on firearms may be an obvious indicator of the country of manufacture to investigators. By removing this mark, it becomes more difficult to identify the country of origin, and therefore the source of the weapon.

5.4.6 Directionality

The directionality of mark removal was noted in the obliteration code and provided 6 different directions of tool travel. While the majority of toolmarks indicate left to right tool travel (58%), “random” and “not applicable” (i.e. created using a stamp, drill, or dot peen machine) each show the next most common direction of tool travel at 17% and 10% respectively. Table 5-3 lists each direction and the prevalence of each noted in the 249 obliterations.

Table 5-3: The directionality of tool marks noted in the African weapon documentations.

Direction	Number of Observations	Percentage of Total Data
Not Applicable	24	11%
Random	42	18%
Left to Right	140	57%
Right to Left	9	4.5%
Downward	23	9%
Upward	1	0.5%

5.4.7 Additional Concealment

Additional concealment of obliterations to camouflage the areas of obliteration is not very common in Africa. 65% (n=163) showed no attempt to cover the areas the marks were removed from, and the toolmarks were obvious and noticeable. Black paint was sometimes used in an attempt to camouflage the area of obliteration (22%, n=54); however, the paint was not enough to make the area completely unnoticeable due to the prominent toolmarks. Other methods of additional concealment seen in the African dataset included stamping (n=14, 6%), dot peening (n=7, 3%), and scribing over the area (n=1, 0.5%).

In addition to the analysis above, a MSc thesis undertaken by Rohit Pyngottu analysed 9 paint samples that were analysed taken from 9 of the weapons documented in Africa and the Middle East [116][2]. This project was established to identify the composition of the paint samples in effort to determine common sources of the paint used. 3 samples were taken from Syria, 4 from Mali and 2 from Niger. The paint was sampled by the intelligence services documenting the obliterations and sent for analysis. This project used Attenuated Total Reflectance Fourier Transform Infrared (ATR FT-IR) spectroscopy to identify if the paint used in each case came from the same source based on the chemical makeup of the samples. The results of this work are shown in Figure 5-9, which lists the major constituents of each sample found in each country. The key conclusion from this study were that the major constituents may be similar across some of the paint samples, however they are not affiliated with one country/region. This analysis was not specific enough to differentiate minor components of the paint or identify single paint sources. This project is ongoing, at the time of submitting this current thesis.

[2] This project was an MSc thesis conducted at Cranfield University co-supervised by B.Henwood.

MALI	NIGER	SYRIA
Acrylic/Styrene Co-Polymer Emulsion	Acrylic/Styrene Co-Polymer Emulsion	Alkyd Resin-Based Paint
Acrylic Emulsion	Acrylic Emulsion	Acrylic Emulsion
Acrylic Co-Polymer Emulsion		Acrylic Co-Polymer Emulsion
Conifer Resin, Alkyd Resin-Based Paint		

Figure 5-9: The results of Pyngottu et al. [116]**, showing the major constituents of paint samples taken from 9 weapons with overpainted obliterations in Mali, Niger, and Syria.**

5.5 Discussion

This discussion will expand on the results presented in the previous section. The obliteration analysis that built the clusters will be explained, followed by the types of weapons analysed and the tools used to create the obliterations. The regional drivers will be presented, which relies upon the level of sanitisation and specific marks that had been removed.

5.5.1 Clusters and Obliteration Analysis

Obliteration codes were able to cluster 66% of weapons together from the African dataset. 24 clusters were formed with these 158 weapons, with 11 clusters found to be exclusive to a single country and the remaining 14 clusters were shared across at least two countries. This can be seen in Figure 5-3.

It was noted that the obliteration codes restricted to one country often involved the serial number being only partially obliterated. One example of the serial number being only partially removed was shown in Figure 5-4, where the first digits of the serial number were removed in an identical fashion across multiple

weapons. This shows a unique obliteration that appears to have been done either by one person, or multiple people under the direction of a single actor. A second example can be seen in Table 5-2, where the factory and model (marks 5/8) were removed, but the serial number was left intact. This was only noted in Somalia.

Certain clusters that were shared across borders exhibited the use of rather generic tool types like grinders and rotary tools. This, coupled with the popular tool types noted in the next section of this discussion, indicates that the use of popular tools in the region did not necessarily lead to visually similar obliterations, despite sharing an obliteration code. For instance, Figure 5-5 highlights cases where marks were removed from the rear sight block of weapons in Mali and Niger, using the same tool type and technique. These obliterations, despite being documented in two countries, look visually similar and share an obliteration code. Also of note is the geographical proximity of the two countries, which share a porous border. The significance of documenting these weapons in two different countries may not be of as much interest as if they had been found further apart. It is, however, interesting that each of the weapons within cluster 2.1.1/5/8.2.0 were tied to attacks made on government buildings by ISIS actors [personal communications, CAR field investigators]. This may indicate that the obliterations were, in fact, done by the same individual within the terrorist network in an effort to sanitise weapons being used in high-profile attacks. Therefore, when an obliteration code suggests that the obliterations follow a uniform direction, involving the same tool type, and affect identical components, it is possible that these weapons were batch sanitised at the same time.

It is also noted in this dataset that many of the obliterations did not appear deep enough to hinder attempted forensic recovery. Although forensic awareness in the region may be lower than in more developed regions, it is unlikely that avoiding forensic recovery would be a primary reason for obliterations. Instead, it is proposed that the actors are more concerned with protecting corrupt individuals involved in the procurement process of these illicit weapons, which may be involved in the filtering from licit stockpiles or incoming shipments. Combines with

the context presented in the introduction of this chapter and the results presented in this section, a hypothesis can be formed that these actors may be associated with the military, police, or work at entry ports where the weapons are held legally, only to be diverted through these channels. Thus, the obliterations may be intended to prevent tracing operations from identifying points of diversion, as records primarily use the serial numbers for tracing.

5.5.2 Weapon Types

The data presented in this chapter reflects that the majority of weapons documented with obliterations in Africa are AK-pattern rifles (80%), which includes 50% overall being identified specifically as Chinese Type 56 rifles. The prevalence of these weapons in Africa does not necessarily imply illicit or nefarious activity, as many countries produce and use these rifles for their police and military forces. Additionally, the presence of various international stakeholders and defence contractors in the region further contribute to the abundance of AK-pattern rifles. The significant number of these rifles reflects the historical procurement and donation patterns of weapons acquired during various conflicts in the region.

While other rifles of different models were also documented in lower quantities, handguns accounted for only 7% of the data. The relatively low presence may be attributed to their benefits in specific uses in comparison to rifles. For example, terrorist groups often employ rifles for their longer effective range, visual impact, and firing capacities [130,139]. Handguns, on the other hand, are more discrete, have shorter ranges, and less effective rates of fire if the “goal” is to cause as much harm as possible in a short amount of time. They may be preferred for certain purposes, but when engaging in longer distance attacks, rifles offer greater accuracy and effectiveness. As noted previously, many of these weapons were documented after being seized after attacks against government facilities, further reinforcing this point. There are also potentially more illicit pistols and other

weapon types in the region, however as they are not commonly captured or catalogued, they cannot be considered in this work.

The likely source of these weapons would have been government stockpiles through corrupt actors and supplied to terror networks like ISIS or Boko Haram [9,118,127]. This explains why the AK-pattern rifles dominate the dataset, while the number of handguns, shotguns and other weapon types remain comparatively limited.

5.5.3 Tool Types

Across Africa, the majority of obliterations are accomplished using rotary tools (45%) and grinders (37%). These tools are both user-friendly and easy to operate with minimal experience. Additionally, they are universal in their applications and therefore easily accessible in various workshops and manufacturing facilities. These workshops may, in theory, primarily operate as mechanic shops for vehicles or other common repairs, however, serve a dual purpose for weapon sanitisation. These tool types enable sanitisation of larger numbers of weapons in a limited amount of time. Considering the number of weapons in the clusters presented in the results section of this chapter and their visual similarities, it is reasonable to infer that many of the weapons in these larger clusters were obliterated in batches. There may also be potential for some of these weapons to have been procured from the same diversion point or stockpile, as when the remnants of the serial numbers are considered in those only partially obliterated, many are close in proximity. Due to the similarities presented in this chapter, and context provided throughout this chapter, it may be justified to hypothesize that many of these weapons were actually sanitised by a single actor in an existing “dual purpose” workshop.

On the other hand, equipment such as mills and welding equipment are used much less to obliterate marks from weapons, presumably due to their large size, high cost, lack of portability, and limited availability in small-scale workshops

common around the region. Similarly, hand files were only used in 8% of cases, as the process of obliterating marks using a hand file is exceedingly time consuming and labour-intensive.

5.5.4 Regional Drivers

There were 7 cases where a complete sanitisation was documented where all identifying marks were removed from weapons documented in Africa (3%). Conversely, the remaining 97% of weapons exhibited partial or incomplete sanitisation, primarily focused on obliterating key identifying marks, particularly the serial number. As noted, the serial number holds the most significance in weapon tracing operations, as it can be used to track a weapon through documentation to the original manufacturing facility. Eliminating this singular mark effectively erases the potential for following a paper trail during investigations.

From the marks removed from weapons documented in Africa, the primary motivation for concealing the identity of these weapons is likely to obscure their origin rather than individual identification. Criminal actors within terrorist networks are aware of tracing operations and organisations that attempt to identify points of diversion in their networks. Consequently, they remove marks that could reveal the origin of the weapon, in addition to the serial number as the unique identifier. This was noted in cases where the factory and model marks were removed, complicating the investigation in identifying the identity and origin of weapons. The serial numbers being removed serve as an inhibitor to tracing through import records, export records, and manufacturing records which may reveal entry routes into African countries.

In addition to mark removal, mark alteration was noted in the Sahel and North Africa regions. Notably, Chinese-manufactured weapons have bene documented being “re-badged” with falsified serial numbers to appear of Russian origin, aiming to secure higher values on the illicit market. This capitalises on the higher

manufacturing quality offered by Russian weapons in comparison to those of Chinese origin. This was documented in 13 weapons across the region, where Cyrillic characters were over stamped where Chinese characters should have been.

Across Africa, additional concealment techniques were relatively infrequent, accounting for only 32% of obliterations showing any attempt at camouflaging the area. Black paint was the most common method used, noted in 54 cases; however, it was evident that the paint was not intended to completely conceal the area at a close examination due to the prominent toolmarks still visible through the paint. In 21 cases, new marks were over stamped or dot peened on to the weapon, which may be a practice carried out by state organisations when re-entering weapons into their own stockpiles after capture. This practice is not uncommon; however it should be noted that these operations were executed with shallow markings, indicating the operators of the equipment may not be fully aware of forensic recovery capabilities.

The shallowness of obliterations was a consistent observation across the entire dataset. This may indicate one of two factors; either the actors are unaware of forensic recovery potential and therefore only remove marks until they are no longer visible to the naked eye, or more likely, the individuals conducting the obliterations are simply following directives given to them through the command chain of illicit terrorist networks. In the authors opinion, if access were granted to these weapons, forensic recovery techniques, both traditional and eddy current based, would have significant potential to reveal at least some of the obliterated marks. As mentioned earlier, the convenient and accessible tools used in this region are not creating particularly deep or uneven obliterations, so minimal surface preparation would be required to attempt recovery.

5.6 Conclusions

In conclusion, the analysis of 249 obliteration codes in the Africa dataset provides insight into the patterns and motivations behind the concealment of weapon identities across the continent. The clustering of weapons based on their obliteration codes revealed that a significant portion could be grouped together, with some clusters exclusive to a single country and others being shared across porous borders. Unique obliteration patterns suggest the involvement of individual criminal and terrorist actors from within larger networks. The predominance of AK-pattern rifles, especially Chinese Type 56, reflect historical procurement patterns in the region during previous conflicts, often donated by international stakeholders. The use of rotary tools and grinders, along with relatively shallow obliterations and removal of marks in addition to primary serial numbers, indicate the primary objective in sanitisation to be concealing the weapon origins in addition to individual anonymization. Although additional concealment techniques were periodically encountered, they may have been applied by State-officials and may not be criminalistic in nature. By examining the obliteration codes and resulting clusters, as well as tool mark analysis, the regional drivers for concealing the identity of weapons in Africa has been presented in this chapter.

6 Obliterations in the Middle East

6.1 Introduction

In this chapter, weapons with obliterations documented in the Middle East are examined. The coding system developed and outlined in Chapter 4 is applied to each obliteration in attempt to link obliterations to a common source. Using the same outline as Chapter 5, the types of weapons sanitised, as well as the type of tools used, and to what extent, will be used to understand how available technology, terrorist activity and access to weapons in the region tie to the motivation to conceal a weapon's identity.

6.2 Countries of Interest

Across the Middle East, 222 weapons with obliterations were documented by intelligence service field teams. Countries included in this region are Afghanistan, Bahrain, Iraq, Saudi Arabia, and Syria. These weapons were documented between 2011 and 2023. The specific number of weapons with obliterations documented in each country are listed in Figure 6-1.

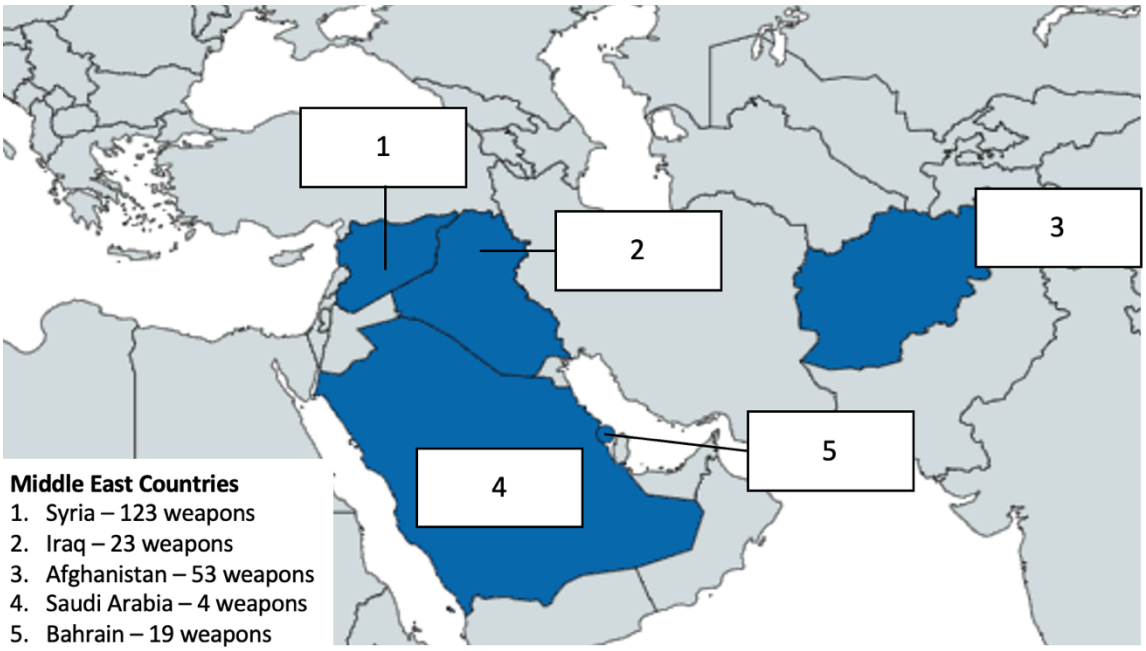


Figure 6-1: Middle Eastern countries where 222 weapons with obliterated markings were documented and analysed in this thesis.

The proliferation and trafficking of weapons in the Middle East is a complex and multifaceted issue. There is a long history of conflict, involving insurgent and terrorist organisations, local governments and militaries, and foreign governments [140]. From civil wars to major international conflict, the Middle East is an extremely active region for weapon trafficking [130,140–143]; highly dependent on illicit firearms trade from black markets, corrupt officials, and smugglers. Similar to the legislation in Africa, civilian firearms laws in the Middle East vary depending on the country. Only one regional instrument- the Arab Model Law on Weapons, Ammunition, Explosives and Hazardous Material [144]- guides the civilian ownership of firearms in the Middle East. This instrument is intended to set broad standards across the region, however, does not set any requirements for punishment. Within this instrument, recommendations are made to require licences for civilian ownership of firearms and limits the number and type of weapons, as well as the amount of ammunition one may possess [144].

Generally, each of the five countries of interest follow these recommendations. Each country requires a background check and a licence or permit to own a firearm [145–149]. Syria, of note, limits the number of firearms a civilian is allowed to own to own one handgun and two rifles [149]. Additionally, each country imposes different lengths of prison time for possession of illicit firearms. In Saudi Arabia, the maximum sentence is 18 months [145], whereas Bahrain is 15 years [147] and Syria is 6 years [149]. Afghani and Iraqi legislation are not clearly defined; however, it has been noted that higher penalties may be imposed if civilians cause additional damage or harm [146,148].

6.2.1 Weapon Sources

With five main sources for illicit weapons, terrorist organisations are at the heart of illicit firearm movement and use in the Middle East. The main sources of illicit SALW are as follows [6,140,150]:

1. Terrorist activity,
2. Proliferation from government stockpiles,
3. Long-term local conflict,
4. Unauthorised reselling,
5. Cross-border smuggling, and
6. Foreign intervention.

Many of these sources are not exploited in isolation and the movement and diversion of SALW relies on multiple facets operating in tandem.

Corrupt government, police and/or military officials allow for low levels of resistance against accessing government stockpiles for distribution on the black market [151–154]. Low wages of military employees often leave individuals finding ways to make money, and will sell their issued weapons, or provide access for criminal and terrorist organisations to government stockpiles [153]. In countries like Syria and Afghanistan, where the government is extremely

unstable, security and control over SALW is lacking. This provides an easily accessible source for weapons to armed groups.

Long-term conflict is a significant common source of illicit weapons entering the black market in the Middle East [153]. There is a huge demand for weaponry and easy access to black markets and unsecured stockpiles. This is noted especially in Syria, where the earliest sources noted for diverted weapons included direct assault of government facilities [129,155]. This is an unsurprising source of weapons, due to decades of civil war and arms embargos from Western countries [31]. It is also common for weapons obtained through disparate sources to be remarked and rebadged to identify fighters [129]. The effect of conflict on weapon prices must also be noted. The start of the civil war in Syria dramatically increased the prices of weapons in Iraq by nearly four times the average price per firearm due to the high demand and low quantity of available firearms [155]. When smuggling routes were established between Syria and Libya by sympathetic groups, the prices lowered again [155]. Similarly, the price of weapons fell rapidly at the downfall of the Republic of Afghanistan, due to the sheer abundance and lack of control. When some level of stability of the country was achieved by the Taliban's formalisation of weapon procurement, the prices gradually increased back to "pre-Taliban" rule costs [156].

The unauthorised re-sale of weaponry is prevalent in the Middle East and reaches into other regions such as North and West Africa [157,158] or directly to terrorist organisations [157]. This dynamic occurs when an end-user legally procures a product (in this case SALW) and diverts the items from their own stockpiles into a subsequent, unauthorised, often corrupt buyer. The weapons may be re-exported with false records or smuggled across borders. This ensures the genuine manufacturers are not implicated and will continue to sell to the end-users [130]. In many cases, the weapons that were legally intended for military use are diverted into civilian hands by corrupt state actors, as mentioned above [152]. It is common for weapons subjected to this type of diversion to be sanitised,

with at least their serial number removed. This allows for the preservation of illicit supplier relationships.

Cross-border smuggling is not limited to the Middle East and is noted in nearly all regions of the world, as noted in this thesis. Countries in the Middle East are also subject to porous borders [151,152], and even when smuggling routes are officially sanctioned, new transport corridors are easily established [155]. Often, weapon trafficking and diversion routes link regions that are otherwise in unconnected conflicts across the Middle East and Africa [130].

Finally, foreign involvement and military aid is a large supplier of SALW in the Middle East. Many Western governments have offered support in the form of weaponry, ammunition, and training to those fighting civil wars. One example is the involvement of the USA in Afghanistan and Iraq, where both countries were the recipient of billions of dollars of equipment [141,152,153]. When the USA was no longer active in these conflicts, much of their equipment (SALW, ammunition, vehicles, etc.) remained in country. Without control measures, the level of diversion of this equipment was very high. The USA also offered support in Syria in 2013, where an operation was launched to train soldiers fighting against the Assad regime, resulting in the proliferation of thousands of weapons [150]. In addition to this influx of American weapons, Russia, China, Belarus, China, and North Korea are all known to historically have provided weapons to the Syrian government [150]. In a similar vein, Saudi Arabia is currently (at the time of writing this thesis) under extreme scrutiny for potential international law violations for their supply of firearms to known corrupt governments, such as Bahrain, who conduct violent attacks on neighbouring countries and civilians [157,158]. In some cases, weapons destined for “opposition forces” never make it to the recipient and end up directly in the hands of terror organisations like ISIS [151].

The activity of terrorist organisations is extremely prevalent in the Middle East. Prominent groups are the Taliban and ISIS, each with long, well documented histories in the region [143,159]. Many high-profile attacks in the Middle East, and

abroad, are claimed by both organisations [159]. Of note, when the Taliban gained control of Afghanistan, the trafficking dynamics of SALW were localised both commercially and politically with primary emphasis of maintaining Taliban control [156]. They formalised licencing requirements for civilians and unauthorised dealers, with the goal of reducing small scale smuggling while maintaining trafficking within the organisation. This is proven through the types of weapons favoured for resale, namely high value American M4 and M16 weapons, compared to the weapons they prioritise for use by their own members (lower value but reliable Soviet-era AK rifles) [142,153]. Due to the far reach of these types of organisations, movement of goods and information between nodes across porous borders is common. Weapons known to have been in custody of militant groups in Saudi Arabia were documented later in Bahrain, indicating a common terrorist-fuelled supply source [160]. Similar situations have occurred in Kobane, Syria, where sanitised Chinese and Russian rifles were documented after being originally destined for South Sudan where one terrorist organisation links both regions [139]. Terrorist organisations will use the above weapon sources to acquire and sell SALW, making them a key component of weapon trafficking in the Middle East.

Using the same methodology of examining obliterations as was used in the previous chapter, and outlined in Chapter 4 of this thesis, obliterations documented across the Middle East will be analysed. Conclusions will be drawn relating to the regional drivers for obliterations and trends noted in the types of tools used and levels of sanitisation of individual weapons.

6.3 Results

6.3.1 Clusters

Across the Middle East, 30 clusters were established where obliterations shared identical codes. To form a cluster, at least 2 weapons must have matching obliteration codes. Within these clusters sits 101 weapons, or 45% of the total 222 weapons. The remaining 121 weapons have obliterations codes that are unique, where they are considered a cluster of n=1 and are not included in the cluster analysis. Each established cluster in the Middle East with the obliteration code is listed in Table 6-1. The number of weapons documented with the corresponding code in each country are also shown in the table.

Table 6-1: The 30 clusters of obliterations documented in the Middle East, shown with the obliteration code and the countries they were documented in. The number of weapons from each country is given in paratheses after the country name.

Code[3]					Country and Number of Weapons
T	S	M	D	C	
1	0	1	1	2	Iraq (1), Syria (7)
1	0	1	2	0	Afghanistan (1), Syria (1)
1	0	1	2	2	Afghanistan (3), Saudi Arabia (1), Syria (1)
1	0	1	2	3	Afghanistan (1), Syria (3)
1	0	1	4	0	Syria (2)
1	0	1	4	2	Afghanistan (2)
1	0	1/5/6	2	0	Syria (2)
1	0	1/5/6	2	2	Iraq (1), Syria (2)
1	0	1/5/8	2	2	Afghanistan (1), Syria (2)
1	0	1/5/8	2	3	Syria (7)
1	0	1/8	1	1	Syria (2)
1	1	1	2	0	Afghanistan (2), Syria (2)
1	1	5/8	2	0	Bahrain (3)
2	0	1	1	3	Bahrain (3)
2	0	1	2	0	Afghanistan (2), Bahrain (1), Syria (1)
2	0	1	2	2	Afghanistan (3), Syria (1)
2	0	1/5/6	2	2	Afghanistan (1), Syria (1)
2	0	1/5/8	2	0	Syria (1)
2	0	1/5/8	2	2	Iraq (1), Saudi Arabia (1)
2	1	1	2	0	Afghanistan (1), Syria (1)
2	2	0	1	0	Bahrain (2)
2	2	0	2	0	Bahrain (6)
3	0	1	1	0	Afghanistan (1), Syria (1)
3	0	1	1	2	Afghanistan (1), Iraq (1)
3	1	1	2	0	Afghanistan (3)
5	0	1	2	0	Syria (3)
5	0	1/6	2	0	Syria (2)
6	0	1	1	2	Syria (3)
6	2	1/8/10	0	1	Syria (10)
12	0	1	0	0	Syria (3)

[3] T: tool type, S: level of sanitisation, M: marks removed, D: directionality, C: additional concealment. See Section 4.4 for full details.

As noted in the Table 6-1, 16 clusters are isolated to only one country, and 45 share obliteration codes across borders. When n=1 in Table 6-1, there was no weapons with obliterations sharing the same code within one country, however, it was shared across borders and creates a cluster shared within the Middle East. Figure 6-2 shows the individual clusters established across the region, where a black dot represents the cluster, and a black line indicates a shared obliteration code across borders.

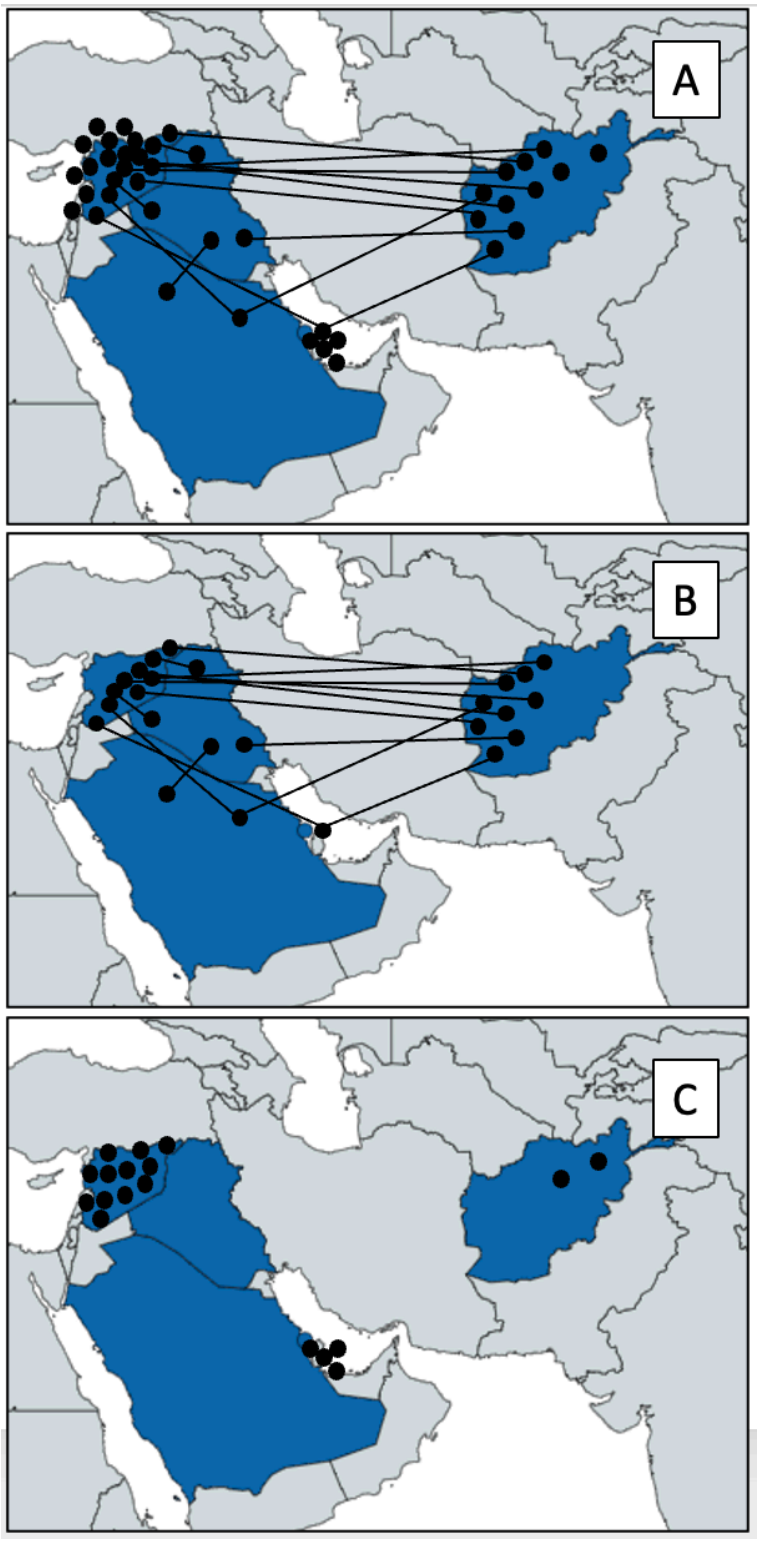


Figure 6-2: The 30 clusters (black dot) containing 101 weapons established across the Middle East, where clusters sharing an obliteration code are linked (black line). A) All clusters across the Middle East, B) Only clusters with cross-border obliteration codes, C) Only clusters isolated to one country.

Within Syria alone, there are 10 unique clusters that do not share an obliteration code cross-border. In addition to these 10 clusters, Syria has cross-border obliteration codes with weapons documented in 12 all five other countries. An example of a cluster within only Syria is the obliteration code 6.2.1/8/10.0.1, which shows the serial number, model, and calibre removed using a mill and painted over. Typically, a mill would leave marks that would allow the directionality to be ascertained, however in this instance, the mill was used to cut away entire sections of the firearms and the paint partially obscures the toolmarks. The weapons within this cluster are all either M16 rifles or CQ rifles, which are a Chinese copy of the M16 rifle. Photographs of some of these rifles are shown in Figure 6-3.

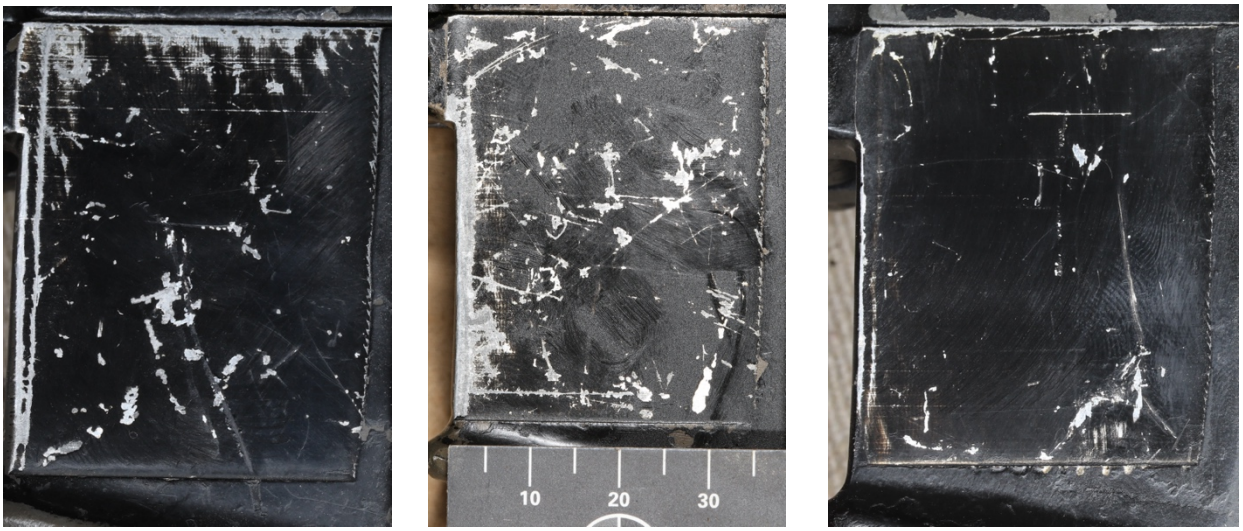


Figure 6-3: Three examples of Chinese CQ rifles documented in Syria with the obliteration code 6.2.1/8/10.0.1.

An example of a cluster of identical obliterations is noted in Bahrain, with the obliteration code 2.2.0.2.0. The photographs in Figure 6-4 show three examples of pistols where every identifying mark was removed using a rotary tool moving from left to right, with no additional concealment. The top two firearms in the figure were documented on the same date and were seized within the same box. The

bottom firearm, however, was documented nearly two years later in a different part of Bahrain.

Figure 6-4: Three weapons showing the obliteration code 2.2.0.2.0 as documented in Bahrain.

6.3.2 Weapon Types

Weapon types seized with obliterations in the Middle East include a variety of makes and models, including 22 artisanal firearms. The most common types of weapons are AK-pattern rifles. General AK-pattern rifles made up 39% (n=82), while specific Chinese Type 56 rifles account for an additional 24% (n=50), and artisanal AK-pattern rifles make up 6% (n=13) of this category. In addition, handguns, artisanal pistols, machine guns, sniper rifles and other assault rifles

were documented with obliterations. The complete breakdown of weapon types is shown in Figure 6-5.

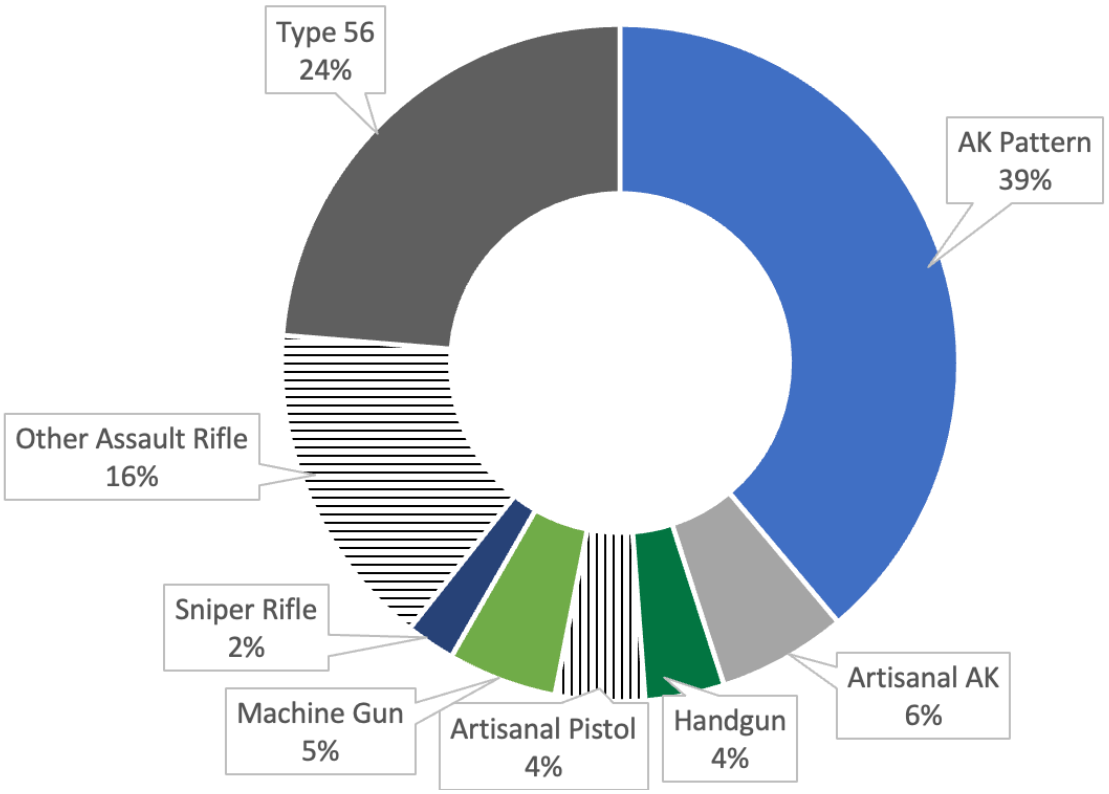


Figure 6-5: The different types of weapons (n-223) documented in the Middle East, which had been seized with criminal obliterations.

6.3.3 Tool Types

Tool types used to create obliterations in the Middle East are varied. The majority of obliterations are done using a grinder (n=97), while rotary tools are the next most prevalent (n=68). Hand files (n=23), mills (n=14), and chemical etchants (n=14) were the next most popular means of removing identifying marks from weapons. In 13 cases, two tools were used to remove the markings, while in the remaining 209 weapons only one tool type was used. Figure 6-6 presents the overall breakdown of tool types used to create mark obliterations in the Middle East.

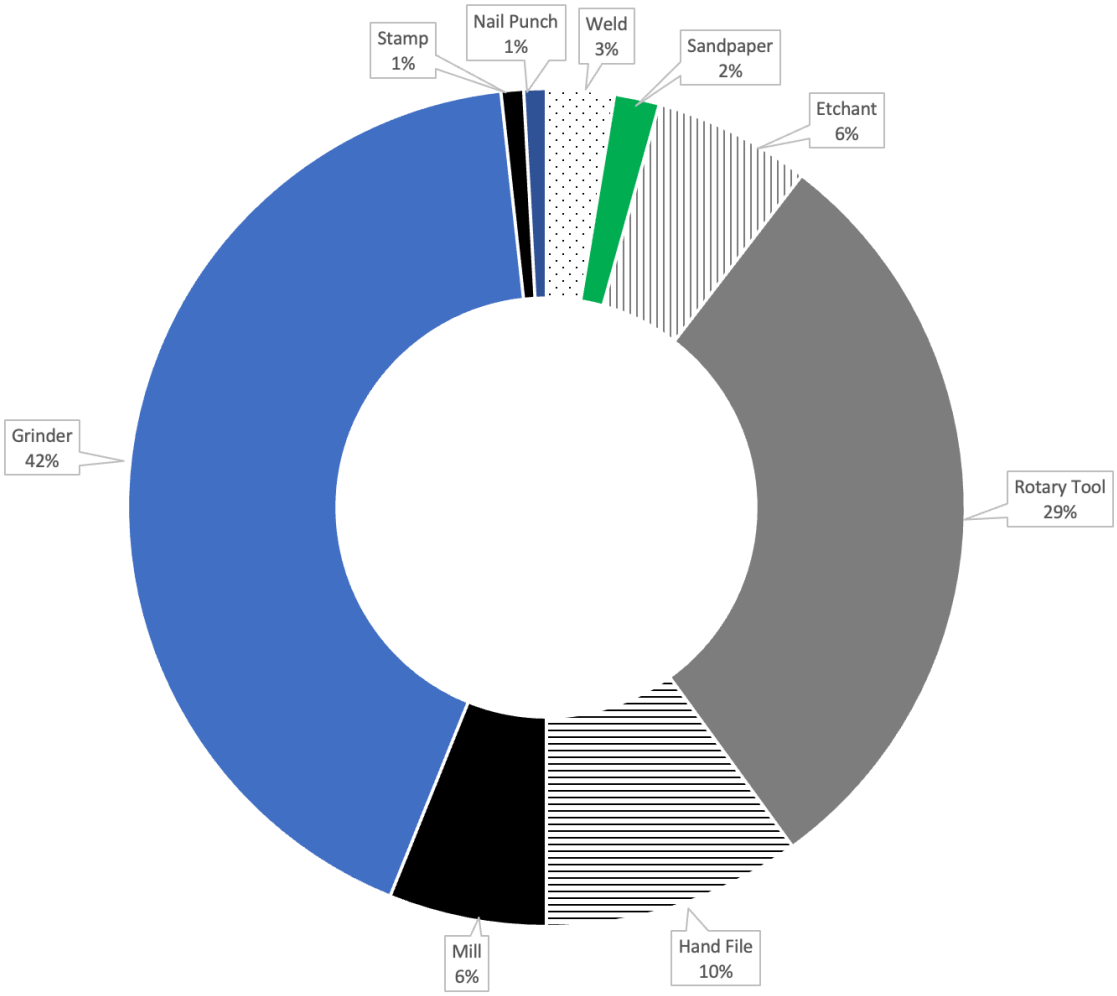


Figure 6-6: The types of tools (n=222) used to obliterate identifying markings from firearms documented in the Middle East.

6.3.4 Level of Sanitisation

In the Middle East, only 10% of firearms had all identifying marks removed (n=22). These weapons were documented primarily in Syria (n=13), while the remaining 10 were documented in Bahrain (n=8) and Iraq (n=1). These completely sanitised weapons were of all different types of rifles and handguns. The types of weapons that were sanitised included handguns, Type 56 rifles, AK-pattern rifles, and Other Assault Rifles.

45 (20%) of the firearms documented in this region were partially sanitised. Among the 45 partially sanitised weapons, 15 of them had the factory, year, and/or model removed in addition to the serial number. In all cases, the serial number was obliterated, however, did remain partially visible due to shallow obliteration. The types of firearms showing partial sanitisation were limited to Type 56 Rifles and AK- Pattern Rifles.

The majority of firearms documented in the Middle East with obliterations were incomplete in their sanitisation. This means only some marks were removed in 156 weapons (70%), most often the serial number, while other identifying marks remained.

6.3.5 Marks Removed

As mentioned in previous chapters, the removal of specific marks may indicate the motivation to conceal the identity of the firearm. Like seen in Africa, serial numbers are the most common mark to be removed, which was observed 184 times in the Middle East. 90 of those weapons also had other marks removed in addition to the entire serial number. In 17 weapons, the serial numbers were only partially removed and were missing either the first digits, middle digits, or last digits.

The factory mark was the next most commonly removed mark with 72 instances of obliteration; however, it was always removed in addition to other marks and never in isolation. The same is true for the year of manufacturer, where it was removed 40 times, however never by itself. Finally, the model number (n=53), calibre (n=10), and the manufacturer (n=1) were each removed in addition to other marks, primarily the serial number. Figure 6-7 shows a visual comparison of the number of times each mark type was removed from a weapon documented in the Middle East.

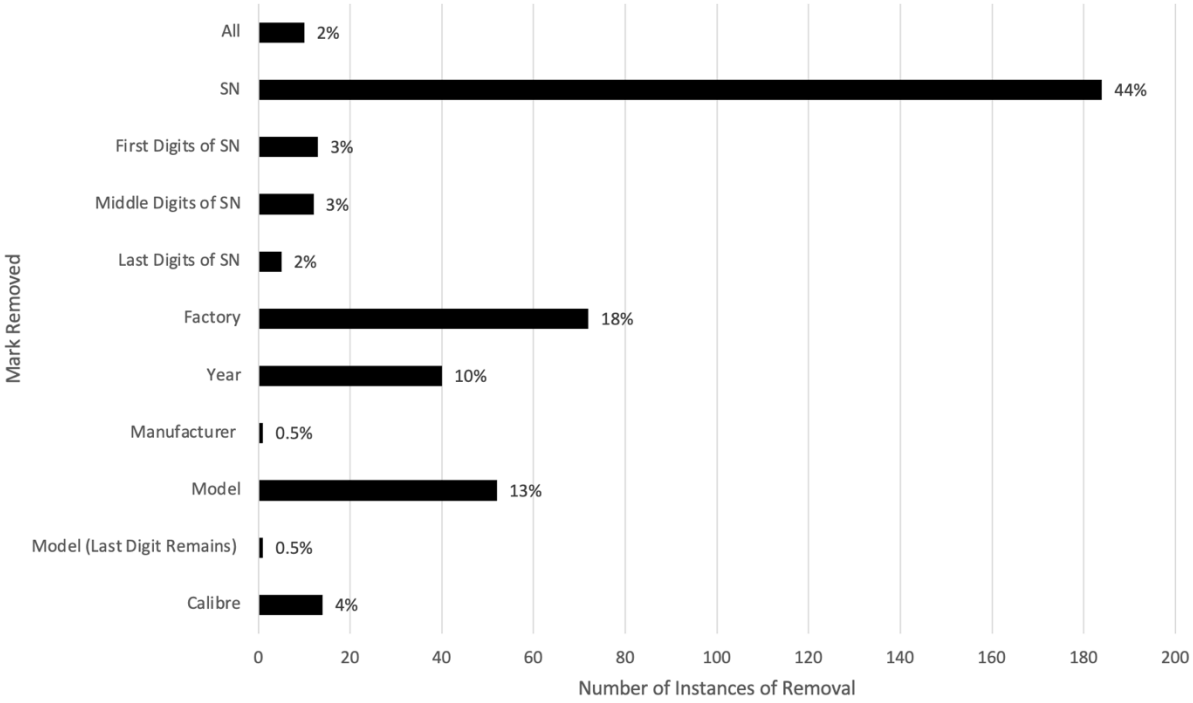


Figure 6-7: The number of instances specific marks were obliterated from 222 firearms documented in the Middle East.

6.3.6 Directionality

The directionality of mark removal was noted in the obliteration code and provided 5 different directions of tool travel. While the majority of toolmarks indicate left to right tool travel (51%, n=112), downward and “not applicable” (i.e. created using a milling machine or a chemical etchant) each show the next most common direction of tool trave with 9% (n=21) and 11% (n=25), respectively. Table 6-2 lists each direction and the prevalence of each noted in the 222 obliterations.

Table 6-2: The directionality of tool marks noted in the Middle Eastern weapon documentations.

Direction	Number of Observations	Percentage of Total Data
Not Applicable	21	9%
Random	60	27%
Left to Right	112	51%
Right to Left	4	2%
Downward	25	11%

6.3.7 Additional Concealment

Over half (n=122, 55%) of the obliterations documented in the Middle East showed some attempt to conceal or overmark the area of obliteration. Most of these concealment attempts were done by over-stamping the area. 29% (n=65) had physical stamps applied over the original obliteration, and an additional 5 weapons were painted *and* stamped. Those weapons that were only painted over account for 26 (12%) of the obliterations. Dot peening was also used to over-mark some obliterations (n=17, 8%), while 2 more weapons were dot peened *and* painted over. Finally, 6 weapons (3%) showed evidence of a mechanical scribe being used to mark over the obliterated area, with 1 more being painted as well.

6.4 Discussion

This section will discuss the different types of obliterations and the resulting clusters documented in the Middle East, as well as offer intelligence-based reasoning for regional drivers to sanitise weapons.

6.4.1 Cluster and Obliteration Analysis

The results section of this chapter outlines the 30 clusters established within the Middle East data set, which encompasses Iraq, Syria, Afghanistan, Saudi Arabia, and Bahrain. 50% of the clusters were found exclusively in a single country, while the remaining 50% spanned across borders. The data revealed that Syria exhibited the highest number of unique clusters, potentially influenced by the significant number of weapons documented in the region; 123 weapons attributed to Syria, 53 to Afghanistan, 19 to Bahrain, 23 to Iraq, and only 4 to Saudi Arabia. The percentages of firearms attributed to clusters in each country is as follows: 47% in Syria, 42% in Afghanistan, 75% in Bahrain, 17% in Iraq, and 50% in Saudi Arabia. The remaining firearms in each country show unique obliteration codes and were not clustered. Nevertheless, each country was represented in multiple clusters, occasionally crossing national borders.

Clusters in the Middle East exhibited a high degree of visual similarity, as depicted in Figures 6-3 and 6-4. These similarities raise the potential for a single individual or coordinated terrorist network may have been responsible for these obliterations. In addition to being visually similar, many of the obliterations documented in the Middle East are more advanced than those seen in Africa. For example, Figure 6-3 illustrates that the obliterations in Syria are more advanced compared to other regions, with Chinese CQ rifles showing consistent patterns of milling and painting over entire sections of the frame. This level of advanced obliterations suggests a degree of technological skill and forensic awareness, indicating that these sanitisations were likely carried out in a professional setting. In contrast, Figure 6-4, which highlights a case of weapons documented in Bahrain, displays a less advanced technique while still exhibiting high visual similarity, with shallow tool markings accomplished using a rotary tool. This shallow obliteration may show potential for forensic recovery of the underlying marks, despite attempt to remove the identifying features.

6.4.2 Weapon Types

The types of weapons documented in the Middle East are more varied than what was seen in Africa. In addition to AK-pattern rifles, both Chinese Type 56 (24%) and other models (39%), assault rifles (16%), machine guns (5%), handguns (4%), and sniper rifles (2%) were documented. These results are unsurprising, as each of these weapon types are used by military, police, and international stakeholders.

Interestingly, it has been noted by field investigators with CAR that AK-pattern rifles in Syria are often illegally sanitised and remarked by civilians. This is due to their legal ownership allowances, enabling civilians to own one AK-pattern rifle in Syria. Often observed, is an individual will own multiple rifles and remove the serial numbers that have not been allocated to them, while stamping the legally owned serial number on to the “extra” rifles [personal communication, CAR field investigator].

Potentially of most interest is the documentation of artisanal pistols (4%) and AK-pattern rifles (6%). These were primarily products of the Khyber Pass workshops between Afghanistan and Pakistan. It was interesting to find these weapons with obliterated markings because artisanal weapons traditionally would not have a serial number applied. This introduces the potential that weapons are being rebadged as something they're not or manufactured from a country with higher manufacturing quality to increase the sale price on the black market.

6.4.3 Tool Types

The types of tools used in the Middle East to create obliterations and remove marks from weapons range from hand tools to larger, more technical kit. The clusters in the Middle East are predominantly formed from grinders and rotary tools, however, hand files, welding, milling, and chemical etchants were also noted, as listed in Table 6-1. A prevalence in the use of grinders (42%) and rotary

tools (29%) indicates a preference for tools requiring minimal training and technical expertise for weapon sanitisation. These tools offer low power requirements and are often easy to access in various types of workshops. A smaller percentage of obliterations were conducted using mills, etchants, and hand files (between 5-10% each). Stamps, nail punches, welding, and sandpaper were used in even smaller numbers (1-2% each). The low rates of documentation of these tool types implies that these tool types demanded higher technical proficiencies or more laborious efforts and were not relied on as heavily as rapid, non-technical techniques like grinders and rotary tools.

6.4.4 Regional Drivers

Considering only 10% of the weapons in this Middle Eastern dataset were entirely sanitised, it becomes apparent that the primary driver for obliterations is more likely to hinder tracing operations than evading individual repercussions or criminal prosecution. It is noted that with the removal of other identifying marks, the origin of the weapon is more effectively concealed, as opposed to if only the serial number is removed. This additional marks being removed helps to limit the investigation into the diversion networks, protecting the illicit actors along the way.

Interestingly, over half of the obliterations in the Middle East exhibited efforts to conceal the region of obliteration on the firearm. 29% of those with additional concealment show re-marking efforts using a stamp, while an additional 8% were dot peened. This leads to the supposition that State-actors may be remarking previously obliterated weapons after capture or procurement so they can be entered into their own physical stockpiles and weapon sources. Previous research has noted that allied groups in other countries in the Middle East have applied additional marks to identify weapons captured as their own, which supports the previous supposition [129]. While this cannot be confirmed at the time of writing this thesis, these firearms showing potential remarking have been left in the dataset and included in the conclusions. Should they be proven to be legally remarked, conclusions may be updated. The presence of additional

concealment contrasts with relatively lower levels in Africa, which will be further compared in Chapter 10, where a comprehensive global comparison of all obliterations will be conducted.

6.5 Conclusion

This chapter has presented and discussed the findings from obliterations documented in five countries in the Middle East. These countries include Syria, Afghanistan, Bahrain, Saudi Arabia, and Iraq. 30 unique clusters were formed from the 222 weapons analysed, with half of the clusters being documented in multiple countries. Many of the clusters show a high level of visual similarity, indicating a possibility that a single criminal actor or a coordinated terrorist network may be responsible for these obliterations. The obliterations were more advanced in Syria than in other Middle Eastern countries, indicating a higher level of technological skill and access to more advanced machinery, as well as a potential higher forensic awareness. It appears that the main regional driver to sanitise weapons lies in the hindrance of tracing operations and protecting illicit procurement networks rather than avoiding criminal prosecution.

7 Obliterations in Canada

7.1 Introduction

This chapter presents the analysis of weapons documented in Canada with criminal obliterations. The analysis presented follows the same methodology as presented in Chapter 4 to analyse weapons and obliterations documented in Africa and Middle East to compare obliterations in conflict zones to those in non-conflict afflicted regions.

Firearms crime is a highly debated topic in Canada and is an issue that is consistently being investigated and studied [51,161]. The complex issue is multifaceted by nature and is in constant flux, responding to firearms incidents stemming from gang-violence, socioeconomic factors, mental health and more [161]. This chapter explores Canadian firearms laws, the status of the country on the GOCI, the perspective on forensic science and investigations, and examines the specific jurisdiction of focus to understand how the conclusions formed can be related to the wider country.

7.1.1 Canadian Firearms Laws

All firearms in Canada are defined and regulated by two pieces of federal legislation; the Firearms Act and Part III of the Criminal Code. The Firearms Act [41] is the authoritative legislation which dictates who may possess firearms and the training and safety requirements in place for civilians. The Criminal Code [162] outlines the definition of a firearm, offenses, and their respective punishments.

Allowances for civilian firearm ownership have fluctuated since the 19th century. For example, when the first Criminal Code was written in 1892, individuals were required to hold a basic permit to carry a pistol unless you had a reason to fear

assault [163]. Venders were also required to keep record of the purchaser, date of sale and information that could identify a gun, which was not specifically defined. Before 1938, there was no mention of serial numbers in the legislation. In 1938, however, it became an offence to alter or deface numbers that happened to be on a firearm, however guns were not required to have a serial number. In 1951, serial numbers were introduced as a legal requirement on firearms[163]. 1977 was the beginning of the licensing system and defining firearms into distinct legal categories when Bill C-51 was introduced proposing age limitations, stricter penalties, and the prohibition of automatic firearms [163]. As the firearm possession and acquisition legislation presents itself today, the RCMP's Canadian Firearms Program oversees the licencing, registration, and safety training for civilian firearm ownership, while Public Safety Canada is responsible for the development of policy, legislation, and requirements for the safe and legal use of firearms [164]. All firearms owners must take part in, and successfully pass, a certified safety course, pass mental illness screenings and regular record checks, and have no history of violence. Civilians are also routinely checked against criminal record databases. General trends indicate that while historically, arms-trafficking depended heavily on the USA imports, the trafficking within criminal networks originate through the illicit sale of legally held firearms [87].

At the time of writing this thesis, the Criminal Code has three categories of firearms outlines in Section 84(1); prohibited, restricted and nonrestricted firearms [162]. Firearms that generally fall within each category are outlined in Table 7-1.

Table 7-1: The legal designations of civilian firearms ownership from the Criminal Code, defined in Section 84 (1).

Category	Firearm
Prohibited	Handguns with a barrel less than 4.1 inches and/or that discharge .25 or .32 calibre ammunition.
	Rifles and shotguns with barrels that have been altered so that the barrel length is less than 18 inches, or the overall length is 26 inches.
	Firearms that are capable of firing in a fully automatic capability.
	Various firearms, similar to the M14, M4, CZ Scorpion EVO 3
	Firearms with a bore diameter of 20mm or more.
	Firearms producing more than 10,000 joules of energy.
Restricted	All handguns that are not prohibited.
	All firearms that are not prohibited that are capable of discharging in a semi-automatic manner and has a barrel length less than 18.5 inches.
	Any firearms that can be fired when the overall length has been reduced to less than 26 inches.
Non-restricted	Any other firearm

Canada has also adopted the following international controls: Geneva Declaration on Armed Violence and Development [165], the ATT [8], the UNFP (not ratified) [45], the POA [125], and the Wassenaar Agreement on Export Controls and Conventional Arms and Dual-Use Goods and Technologies [50].

7.1.2 Firearms Trafficking and Crime in Canada

Compared to the USA, Canadian firearms laws and markets are restrictive and tightly controlled, making cross-border trafficking illicit weapons profitable. Additionally, established smuggling routes are often dual purpose, and are utilised by both firearms and drug operations [161]. These facts, coupled with the fact that Canada and the USA share the longest uncontrolled border in the world, makes the USA the primary source for illicit weapons entering Canada [166]. In

2007, the Firearms Tracing and Enforcement Program traced 69% of illicit weapons to American sources, with Florida and Washington being two notable States of origin [166]. Second to the USA, stockpile leakage accounts for another major source of illicit weapons, where police and military weapons have been seized after being diverted from theft and corruption [166].

Canada saw 2.6% of violent crimes involve a firearm in 2021, including 297 homicides [51]. Between 2020 and 2021, firearms crime was noted to have declined in urban areas and the rural south, however increased in the territories and prairie provinces. For example, the city of Edmonton saw a 9% decrease in firearm related crime between 2020 and 2021 [51]. This may have been a result of the firearms laws changing surrounding the requirement for hunting licences in Northern territories and for aboriginal peoples, however literature surrounding this topic is lacking [167].

7.1.3 Canada's Ranking on the GOCI

Canada's low level of governmental corruption gives it a low score on the GOIC metrics [87]. The overall global ranking is 32nd, with a low index score of 3.67. There has been a slight increase in the corruption of low-level officers in the most recent ten years, according to the GOCI [87], which has led to an influx of smuggled firearm and drugs across borders. Despite this, there is little evidence of state-embedded actors, and most organised criminal actors in Canada belong to mafia-style organisations, such as the Hells Angels and the Outlaws. The focus of these organised crime groups are financial crimes, intimidation of both civilians and officers of the law, extortion of those in power and the trafficking of humans, drugs, and firearms across federal and provincial borders [87]. The GOCI has reported Arms Trafficking, specifically, a score of 2.5, indicating the influence of firearms movement to criminal activity to be non-existent to low[87].

7.1.4 Forensic Awareness & Capability

The forensic capabilities within Canada are advanced, hosting three federal forensic laboratories for nearly all criminal forensic investigations, and many smaller laboratories who focus on cases such as DNA and paternity forensics [168–170]. Due to the well-established forensic science infrastructure, forensic awareness in Canada is relatively advanced compared to other regions of interest in this thesis. Canada has several forensic laboratories, research institutions and professional bodies[168,170]. The Canadian Society of Forensic Science provides training, educational and certification programs for scientists and legal professionals. The Canadian Society of Forensic Science has been at the forefront of promoting forensic awareness and capability development since its inception in 1953 [169].

The RCMP National Forensic Laboratory Service provide services in biology, firearms and toolmarks, anti-counterfeiting, toxicology, and trace evidence [168,170]. Within the firearms and toolmarks section, services include the following: legal classification, mechanical assessments, bullet/cartridge case association to firearms, range determination, serial number restoration, impact assessment, and expert testimony. The RCMP laboratories utilise the Canadian Integrated Ballistics Identification Network as a central reservoir of case work for information sharing purposes [170].

Information on general forensic information is freely available to the public and produced by Canadian agencies. The Canadian Society of Forensic Science produced a documented titled “All You Ever Wanted to Know About Forensic Science in Canada but Didn’t Know Who To Ask!” [168] in 2017, which gives readers information on forensic procedures used in Canada, as well as specific investigation techniques, education requirements, and training available in various disciplines (blood, toolmarks, chemistry, etc.). As mentioned in Chapter 2, the “CSI-Effect” was found to not be a critical factor in the forensic awareness amongst civilians, and therefore, despite the ease of access to Canadian forensic

science processes and information, does not enhance a criminal's ability to avoid the justice system in the country [171–173].

In addition, there are 25 undergraduate level forensic science degrees across Canada. These range from general forensic science to more specific programs like forensic chemistry and forensic anthropology [174]. These courses naturally increase the level of forensic awareness among students, which may propagate through the general public.

7.1.5 Jurisdiction of Focus

The data analysed in this dataset was obtained through the EPS Firearms Unit. Edmonton is a large urban city of the province of Alberta, with a population in 2021 of 1,010,899 [175]. Edmonton is a very diverse city, with a diverse demographic base. It is home to the Metis Nation, as well as those identifying from European, Southeast Asian, African, Latin, Middle Eastern, and Caribbean backgrounds [175,176]. Being such a multicultural metropolitan area, the religious denominations include Christian, Muslim, Sikh, Buddhism, Hindi, Jewish and Aboriginal Spiritualism [175,176]. This cultural pluralism is reflected in many large population centres across Canada, such as Toronto, Vancouver, and Montreal, where Statistics Canada reports that the firearms crime profiles generally follow the same trends[51].

In 2022, the EPS seized 1,127 firearms and reported 165 shootings within the city limits [177]. In the previous three years, shooting occurrences have increased by 10% to an average of 13 shootings per month [177]. Temitope Oriola, a criminologist at the University of Alberta, stated in a 2021 interview with CBC that he believes the data obtained in Edmonton reinforces credible patterns in firearm crime and homicide rates in Canadian crime[178]. Based on the urban profiles of large major cities, combined with this statement from Oriola, the results obtained from this chapter may be justified in being applied to intelligence-based investigations in these other urban regions across Canada.

7.2 Results

7.2.1 Clusters

In Canada, 28 clusters were established. 69% of weapons (163 of 236) fit into these 28 clusters. That leaves 73 (32%) with unique obliteration codes that do not fit into clusters, or clusters of n=1. Each obliteration code documented in Canada and number of weapons within a single cluster are presented in Table 7-2.

Table 7-2: The number of weapons within established clusters in Canada.

Code[4]					Number of Weapons
T	S	M	D	C	
1	0	1	1	0	3
1	0	1	2	1	7
1	0	1	2	0	11
1	0	1	3	0	2
1	0	1	3	1	3
1	0	1	4	0	6
1	0	1	4	1	3
1	0	1	5	0	2
1	1	1	2	0	4
1	2	0	0	0	4
2	0	1	1	0	12
2	0	1	1	1	3
2	0	1	2	0	48
2	0	1	2	1	10
2	0	1	4	0	2
2	0	1	2/4	0	2
2	0	1	3	0	3
2	0	1/10	2	1	3
2	0	1/10	2	0	2
2	1	1	2	0	9
2	1	1	1	0	6
2	1	3	2	0	2
2	2	0	1	1	3
2	2	0	2	0	2
3	0	1	1	0	3
3	1	1	1	0	6
1/11	0	1	1	1	2

[4] T: tool type, S: level of sanitisation, M: marks removed, D: directionality, C: additional concealment. See Section 4.4 for full details.

The cluster 2.0.1.2.0 is the largest, with 48 weapons fitting into the same group. As these weapons share an obliteration code, they do tend to be visually similar, however, the method of mark removal is quite basic and some obliterations therefore do not look identical, as was the case in some of the clusters presented in Chapters 5 and 6. The code 2.0.1.2.0 indicates that only the serial number was removed with a rotary tool until it was no longer visible, with the tool moving from left to right and showed no additional concealment. Figure 7-1 shows a few of the 48 obliterations that fit into this cluster that *are* visually similar, while Figure 7-2 shows some that *are not* visually similar, despite sharing the same obliteration code.

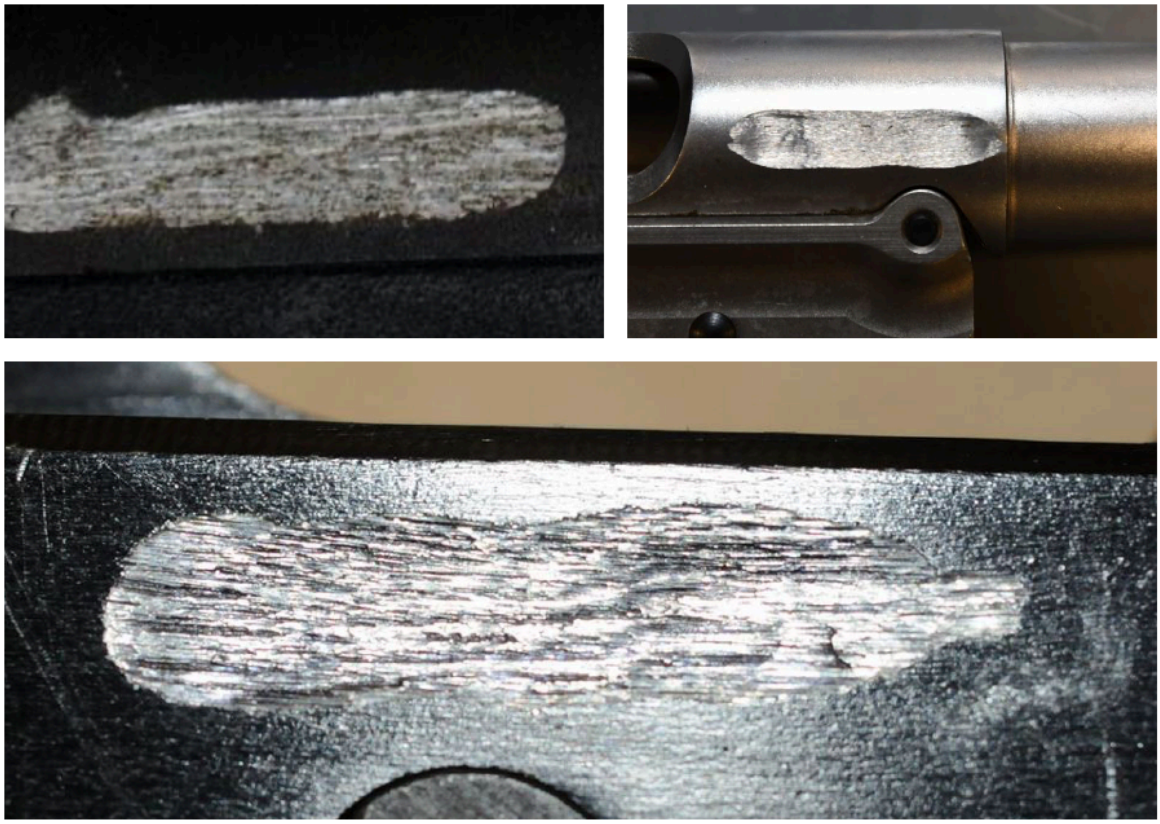


Figure 7-1: Three examples of obliterations sharing the code 2.0.1.2.0 that look visually similar.

Figure 7-2: Three examples of obliterations sharing the code 2.0.1.2.0 that do not look visually similar.

Smaller clusters in this dataset tend to look more visually similar than those in larger clusters. For example, cluster 2.0.1/10.2.1 holds three firearms. These three obliterations look visually similar and have a more specific obliteration technique, where the serial number and the calibre were removed, despite the marks being located in three different places on each firearm. Each one was also painted over in black paint. The three weapons, two Norinco pistols (NP34 and N275) and an Uzi, are shown in Figure 7-3.

Figure 7-3: The three weapons that comprise the cluster 2.0.1/10.2.1.

Another small cluster of only two weapons shows the serial numbers removed with a grinder moving upward. These two weapons are both Remington shotguns obliterated in a similar fashion and are shown in Figure 7-4.

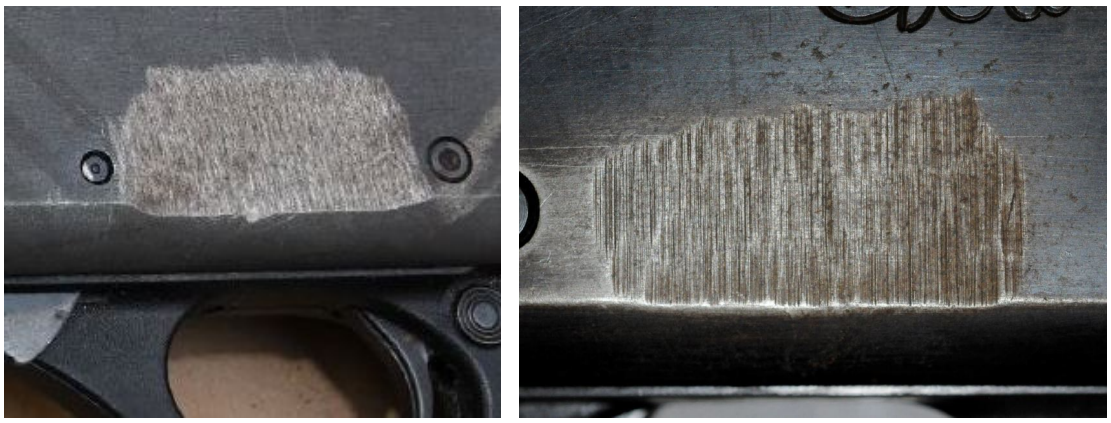


Figure 7-4: Two obliterations making up the cluster 1.0.1.5.0.

7.2.2 Weapon Types

Four types of weapons were documented in Edmonton with obliterations. The majority were handguns (n=121), while shotguns (n=70), rifles (n=42), and submachine guns (n=3) were also seized and documented. Figure 7-5 shows the percentages of each type of firearm that was seized by the EPS and documented with obliterations.

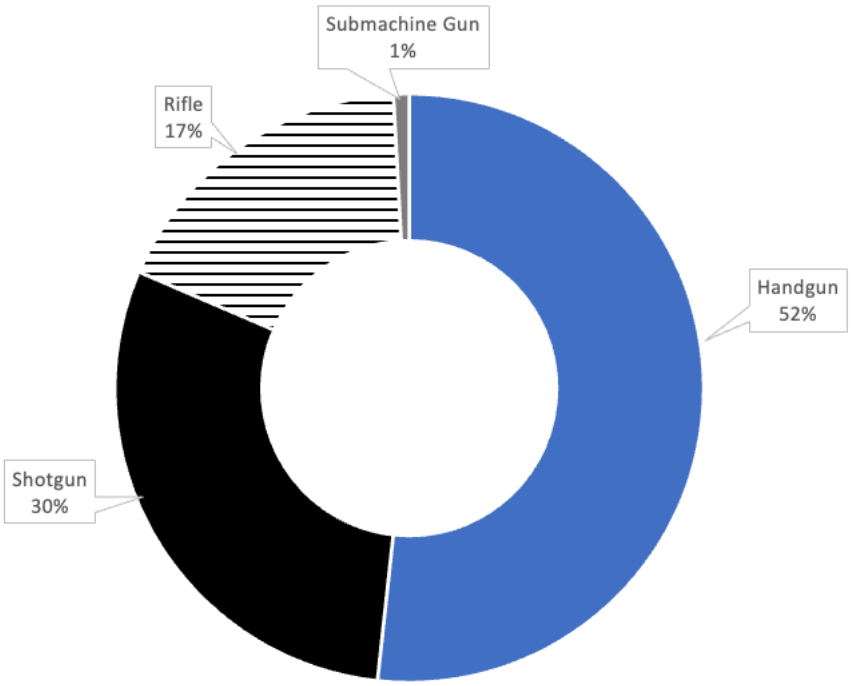


Figure 7-5: The types of weapons (n=236) documented by the EPS after seizure during criminal investigations that had obliterated markings.

7.2.3 Tool Types

Two types of tools were much more predominantly used to create obliterations in Canada than any others. Grinders and rotary tools were seen in 27% (n=62) and 52% (n=123) of cases, respectively. Other tools used included hand files (n=18), mills (n=8), drills (n=9), nail punches (n=2), welders (n=2), and sandpaper (n=7). There were also 3 obliterations where the tool used could not be identified. Figure 7-6 shows the breakdown of each tool type and its prevalence in the dataset.

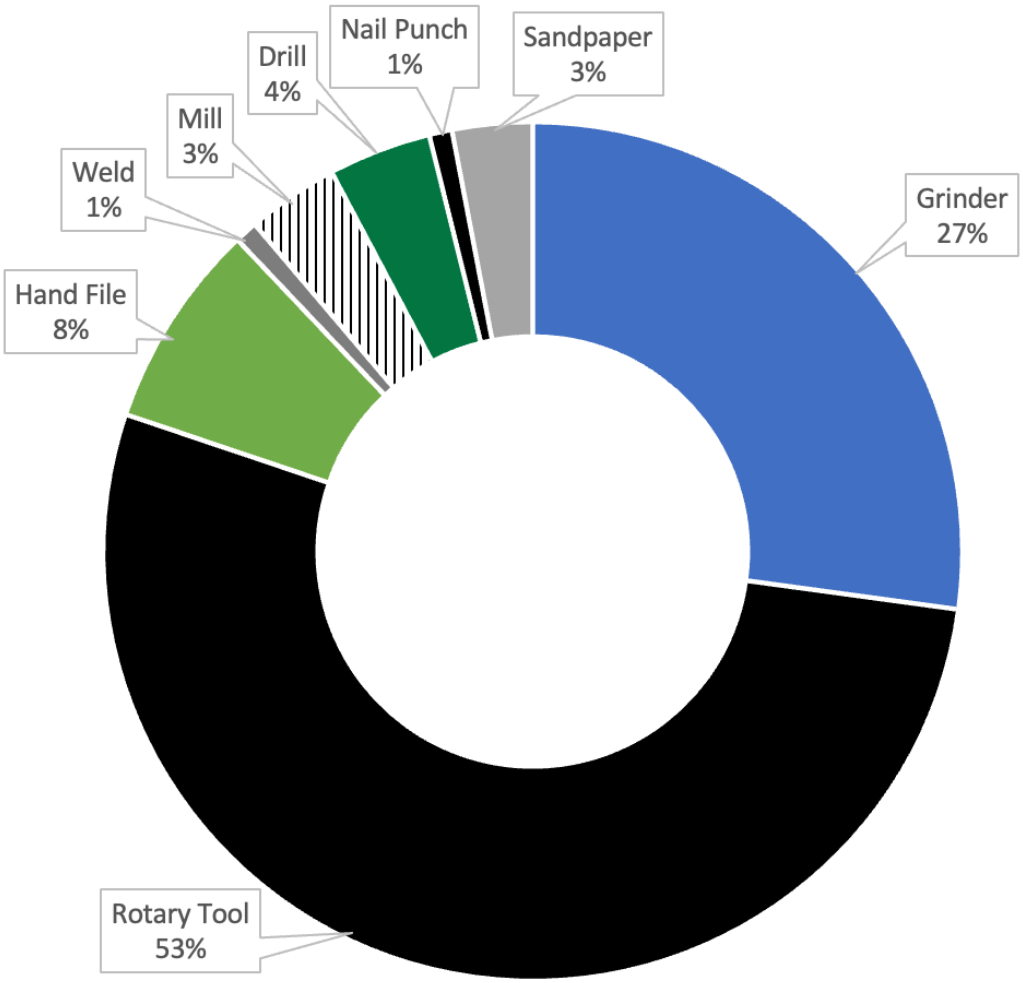


Figure 7-6: The types of tools used to create obliterations on 236 firearms in Canada, with their respective prevalence.

7.3.4 Level of Sanitisation

In this dataset, the number of completely sanitised firearms was low. Only 10% of weapons had all marks removed to a point where they were not partially visible. This reflects only 24 of 236 firearms. The weapons completely sanitised were a variety of weapon types, with no consistent make or model that had all marks removed. 16 of these firearms were hang guns, while the remaining 8 were shot guns or rifles.

51 of the firearms, or 22%, were partially sanitised. In all 51 cases, the serial number was removed. The serial number was still but partially visible in only 5 firearms, while the remaining 46 had the serial number completely removed. In addition to the serial number that was partially visible due to shallow obliterations, there were 6 instances of the calibre being removed, 1 where the factory was removed, 2 that had the model removed, and 2 where the manufacturer was obliterated.

The majority of the firearms were incompletely sanitised. 68% (n=158) only had some marks removed to a stage where they were no longer visible, which were primarily the serial number. Other marks removed in addition to the serial number include 1 instance of the factory mark, and 1 occurrence of the manufacturer mark being obliterated. Some weapons had serial numbers where only some digits were removed instead of the entire serial number (n=9).

7.2.4 Marks Removed

As seen in Figure 7-7, the serial number was the most common mark to be removed in this dataset, with 149 observations where only the serial number was obliterated. In addition to those 149 cases, 38 firearms had additional marks obliterated. There were no cases where a secondary identification mark (factory, manufacturer, model, calibre) were removed if the serial number was not at least partially obliterated as well.

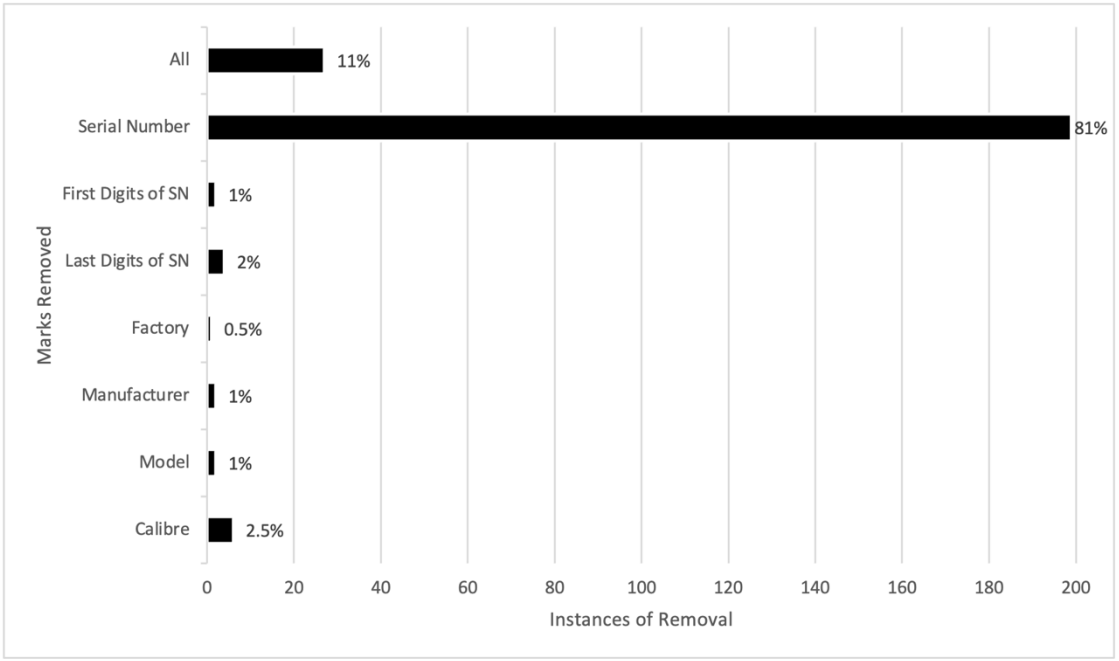


Figure 7-7: The number of times each mark was obliterated from firearms in the Canadian dataset, including the percentage of overall removals (n=236 firearms)

7.2.5 Directionality

The direction the tool moved to remove a mark was noted in the obliteration code. Most marks (n=136) were removed from left to right as seen in Table 7-3, where the tail of the toolmark indicated the final contact position of the tool. The second most common directionality was “random” (n=58), which is where multiple directionalities are noted with no clear pattern. Downward, upward, and “not applicable” were also noted, with 24, 7, and 7 observations, respectively.

Table 7-3: The directionality of tool marks noted in the Canadian Dataset

Direction	Number of Observations	Percentage of Total Data
Not Applicable	7	3%
Random	58	23%
Left to Right	136	57%
Right to Left	10	4%
Downward	24	10%
Upward	7	3%

7.2.6 Additional Concealment

In this dataset, the majority of obliterations did not show any attempt to conceal the area of toolmarks. 181 obliterations (76%) had not been covered by paint, stamping, or any other technique of overmarking. 49 weapons (21%) showed black paint over the obliterations, with an addition 2 weapons that had been painted *and* scribed over. Only 3 weapons showed obliterations that had been stamped (1 weapon) or scribed over (2 weapons). Finally, 3 weapons had tape that was applied over the obliterated area to conceal the region. The forensic exploitation of these three weapons by EPS involved the removal of the tape to reveal the obliteration on the surface of the firearm.

7.3 Discussion

First, an assessment of the clusters formed will also be presented. This section will then discuss the results presented above relating to the significance of the types of weapons analysed, the types of tools used, and the motivation to sanitise weapons based off the marks removed and additional concealment.

7.3.1 Cluster and Obliteration Analysis

In this dataset, 28 clusters were established, holding 163 weapons. Only four of these clusters have more than 10 weapons with the same obliteration codes, while the remaining 24 have only a few weapons with matching obliteration codes. As noted in the results section of this chapter, some of the larger clusters show weapons with similar but not visually identical obliterations, while the smaller clusters are often made up of firearms with obliterations that are actually visually similar (see Figures 7-2 versus 7-1, respectively). This result proves that a smaller number of firearms are sanitised by an individual, placing the root of weapon sanitisation in opportunistic individual criminal hands, instead of larger, organised groups or enterprises who are “batch” importing and sanitising weapons.

The obliterations in this dataset have not been subjected to recovery efforts by the EPS. This may be due to lack of requirement by the investigative process, as recovering the serial number at the detriment of evidence preservation is not valuable enough to the courts. Often, charges for illicit weapon possession or committing crimes with a firearm are sufficient to apply criminal charges to individuals and the serial number of the weapon is not required. In many cases, the extent of the obliteration (i.e. the amount of material removed) is too high for recovery to be plausible. In cases where a tool such as a drill was used, the removal of the material does not allow for even an attempt to recover the serial number, and the forensic awareness in the region is high enough to conclude criminals would be aware of the potential for recovering the serial number should less material be removed. Similarly, marks removing with welding equipment would not be recoverable, due to the addition of material covering the original markings.

7.3.2 Weapon Types

The provenance of the weapons from Canada in this project is unknown, so it cannot be determined if the specific firearms analysed were either illegally imported, legally acquired, and then diverted into the illicit market, or legally acquired and used by the legal owner for criminal activity. This is the case for all firearms, regardless of type (handgun, rifle, shotgun, or submachine gun) in this dataset.

The types of weapons most commonly seized with obliterations within this dataset are pistols and handguns. Pistols, until recently, have been legal to own by civilians in Canada who hold Restricted Possession and Acquisition firearms licences. In an official announcement made in May 2022, national freezes on selling, purchasing, and transferring ownership of handguns in Canada were introduced [179]. While this may influence the types of weapons seized with obliterations in the future, this current dataset ranges from January 2001 and August 2022 and any effect of this legislation would be negligible. As mentioned earlier in this chapter, the process for obtaining these licences is not particularly difficult if the individual has a clean criminal record, no record of serious mental illness, and has taken the safety courses. Considering this, the popularity of handguns in this chapter is a reflection of three factors: 1) the ease of access to handguns by anyone with an appropriate firearms licence, 2) the abundance of handguns owned by the general population, and 3) the ease of concealment both on the body and within vehicles crossing the USA border.

The shotguns and rifles analysed in this chapter are legal for Canadians who hold valid Non-Restricted Possession and Acquisition firearms licence holders to own. Across Canada, 2,236,983 firearms licences are held by civilians [180]. As mentioned previously, while the licencing process is straightforward, civilians are still subject to routine criminal record checks, however the restrictions and training requirements for owning long guns (i.e. rifles and shot guns) are lower than handguns. Similar to the prevalence of handguns in this dataset, shotguns and

rifles would be easily accessible to anyone with a licence, and there is an abundance of legally owned firearms in the country. The largest difference contributing to the popularity of these weapons in this research is the concealment aspect. Whether trying to conceal on the body or within a vehicle crossing a border, these guns are more difficult to hide, hence the lower percentage of involvement in crimes leading to police seizure.

The only firearms analysed in this chapter that are not legal for Canadian citizens to own are the two submachine guns seized. The specific make and model (Heckler and Koch MP5), however, is used by the Special Forces, Close Protection, and Military police units. This increases the potential for a diversion from Government stockpiles, although the specific method of diversion (corruption, theft, etc.) in these two cases is unknown. As the MP5 is also relatively small, compared to rifles, shotguns, and full-size machine guns, there is still potential for these two weapons to have been smuggled into Canada from across the border alongside other handguns.

7.3.3 Tool Types

Rotary tools were used to obliterate 52% of markings in this Canadian dataset. These types of tools are widely available at most hardware stores at accessible prices. Rotary tools, especially when a grinding or polishing bit is used, are very effective for use on small surfaces, such as handgun frames, and require very little training or effort. The only drawback to using a rotary tool for weapon sanitisation is the time to adequately remove the markings with a tool with a smaller surface area.

The second most popular tool is a standard grinder. Grinders are very quick and effective for mark obliterations from firearms. Although not as dextrous as a rotary tool, if the frame of a larger firearm (shotgun or rifle) is being sanitised, a larger tool such as a grinder would be an effective method of mark removal.

The rest of the firearms were sanitised using various other tools in much smaller numbers, as seen in Figure 7-6. Although used in significantly smaller proportions than rotary tools or grinders, they are each common tools in a typical civilian workshop. Drills, welding equipment, mills, hand files, nail punches and sandpaper are all very accessible, especially if workshops primarily for purposes such as automotive maintenance or general manufacturing are acting as sanitisation “hubs”.

This data suggests that, in Edmonton, and by extension other large metropolitan areas in Canada, weapons are sanitised on a more individual basis, unlike in the previously analysed conflict zones where “batch” sanitisation is much more common. This allows a lower time investment on individuals, as they are only sanitising up to a few weapons at a time instead of entire shipments. This factor adds justification to the increased number of established clusters compared to conflict zones, each holding a small number of weapons.

7.3.4 Regional Drivers

Based on the findings and interpretation of the obliterations observed on seized weapons within Edmonton, it appears the motivation to conceal the identity of firearms used in illicit activities is primarily to protect the supply chain of the weapons. This is evidenced most significantly by the specific marks removed.

When serial numbers are removed from weapons, they are no longer traceable to the most recent legal owner. This hinders the ability of investigators to link the firearm to either government ownership (military, security, or police), civilian ownership (firearms dealer or individual), or to an international body (government or individual). Additionally, if the firearm was smuggled across the USA border, there would be no records of the firearm entering the country.

The serial number was removed in all 236 cases, although, in 10 cases only part of it was removed. This alone shows that the primary concern of criminal actors

is removing only the unique identity of the firearm. By removing the only unique mark able to identify the weapon, but maintaining the general production marks such as factory, make, and model, conclusions can be made that there is far less concern for hiding the origin of the weapon, as noted in both the Middle East and Africa. While protecting the supply chain of the illicit weapons is important to maintain the supply for the demand of weapons, the manufacturers information is not relevant to the criminal investigations pursued in the region. In fact, the factory, manufacturer, model, and calibre marks were each obliterated in less than 10 instances across all 236 weapons analysed in this dataset.

The low amount of application of additional concealment (only 62 firearms out of 236), primarily black paint (n=51), shows that hiding the area of the obliteration is not a priority in this region. These 51 obliterations that were covered by black paint were slightly camouflaged, as not to be obvious from a distance, however, during a forensic analysis would be easily visualised.

The other methods of concealment (stamping, scribing and taping) account for only 11 firearms, and appear to be more stylistic than for concealment. For example, one obliteration done using a rotary tool had the word “loser” written over the original serial number using the same tool. This would not add any concealment value to the obliteration, and would, in fact, emphasise the area and potentially be used as a link between other obliterations done by the same person (if they were to be seized as well).

Based on the above assessment, the most significant regional driver to sanitise weapons used in illicit activities in Edmonton, and by extension Canada, is primarily to protect the supply chain of the weapons to ensure demand by the illicit market is fulfilled.

7.4 Conclusions

In summary, obliterations in Canada documented on weapons seized during criminal investigations in Edmonton, Alberta are primarily seen on handguns are done using rotary tools. There is little evidence to suggest that efforts are made to camouflage the obliterations with additional concealment. The motivation to conceal the identity of these weapons lies in the criminal networks required to procure the firearms from legal sources and the illicit, international market.

8 Obliterations in the United Kingdom

8.1 Introduction

This chapter explores the evolution of firearms laws regarding civilian ownership in the United Kingdom. The status of the country on the GOCI is discussed, in addition to the perspective on forensic science and investigations.

8.1.1 United Kingdom Firearms Laws and Ownership

The possession and use of firearms in the UK is highly regulated, where the safety of the public is paramount to policy makers and enforcers. In response to multiple high-profile shooting incidents, namely the Dunblane massacre in 1996 and the Hungerford massacre in 1987, firearms laws have evolved, resulting in some of the strictest firearm laws in the world [181].

Current civilian firearm ownership is regulated by the Firearms Act of 1968 [182], and its amendments. Most importantly, Sections 1, 2, 5 and 7 apply to civilians, with definitions of each below:

- Section 1: Firearms that are not prohibited, including rifles, shotguns, and some air guns.
- Section 2: Shotguns that have a magazine capacity of no more than 2 rounds.
- Section 5: Automatic weapons, machine guns and handguns (with exceptions of muzzle loading and starter pistols).
- Section 7: Antique firearms.

Civilians wishing to own firearms must hold a firearms certificate issued by the police. Before issuing such permission, the police will conduct a background check and assess each individual's suitability to own a firearm [182]. The firearms certificate issued will specify which firearms an individual can hold. In addition to

the ownership restrictions, the Firearms Act of 1968 (and amendments) states *where* firearms can be used [182]. Firearms may be restricted to authorized ranges or private property. As of March 2022, 539 212 people in the UK hold firearms certificates. 522,627 Section 2 (shotgun) certificates were recorded, and 151,218 certificates for Section 1, 5, or 7 firearms were recorded [183].

Most police officers in the UK outside of major cities do not carry firearms, and incidents requiring firearms support will be responded to by dedicated firearms police units called Authorised Firearms Officers [184]. These officers receive enhanced training in high-risk incidents, de-escalation, intelligence gathering, and threat assessment. Firearms officers across the UK are not always issued with the same models across the different jurisdictions. For example, Home Office and Scotland Police forces use a Glock pistol, while smaller jurisdictions such as the Sussex and Essex Police forces use a SIG pistol [185]. The same is true for rifles and submachine guns, where different police units will procure different models based on their individual needs.

While police weapons and legally owned civilian firearms are not commonly used in criminal activity, civilian shotguns and rifles are more prevalent amongst criminals, reflecting the legislation [181]. Illegal firearms often enter the UK through trafficking routes from Europe and are obtained through existing criminal networks. Additionally, the National Crime Agency has reported that while few weapons are sold on the dark web, those that are sold online are typically sent through the postal system [186]. With gun crime on the rise, the demand for illicit weapons is ever increasing, driving the increase in import from mainland Europe [181].

In addition to firearms illegally entering the country, reactivated deactivated firearms pose a threat that is difficult to quantify. Many firearms are deactivated by law-abiding citizens for collection, theatre, décor, or inheritance [187]. In legislation prior to 2018, the technical specifications for deactivation were minimal. During this period, many firearms were ineffectively deactivated and

could easily be reactivated using minimal skill and tooling [187]. Since this legislative change, the loopholes found in deactivation legislation have been closed by requiring only proof houses can provide deactivation certificates and proof marks [187]. This has been an influential change in firearms legislation in the UK, however, firearms deactivated prior to this may still be easily reactivated and used in criminal activity.

8.1.2 Criminal Actors and Organised Crime Groups

Firearm offences and the civilian ownership and use regulations in the UK are highly restricted, as mentioned earlier in this chapter. As such, the illicit firearms market is not particularly lucrative. There are crime groups that facilitate weapons movement; however, the sources are generally located in mainland Europe and Northern Ireland [188]. The firearms routes are often shared with drug channels and operate across county lines by criminal actors.

It must be noted that weapon trafficking trends have increased in the last five years, and there is an emphasis in the black market on converted, modified, and reactivated firearms [188,189]. The ease of converting blank firing pistols and reactivating poorly deactivated weapons allows for criminal actors to acquire less expensive weapons with lower levels of legal classification and restrictions and convert them in to live firing weapons with little resistance [189]. This is one key feature that differs from conflict zone insurgency-based firearms trafficking; smaller numbers of weapons move across county lines with an emphasis on readily convertible firearms or those stolen from legal civilian owners are more common in developed regions, compared to large-scale trafficking of military weapons [119, chap.4].

The corruption levels in the UK are low, compared to other countries around the world. Ranking as the 11th least corrupt nation on the GOCI [190], it is noted that corrupt State-actors embedded in the government and legal systems are less of a concern than criminal actors around the country. Despite the low levels of

corruption, the UK criminal justice system is underfunded and has a low effectiveness in disbanding organised crime groups [188,190]. Researchers have suggested that there should be a greater focus on how to define mechanisms of firearm acquisition and counter the illicit movement of criminal firearms, compared to the actual use of illegal firearms. This leaves a gap in investigation into supply routes and local suppliers [191]. At present, there is a large emphasis on prosecuting perpetrators of gun crime, however the wider issue of supply and trafficking is left unaddressed [119, chap.7,191,192].

8.1.3 Forensic Awareness & Capability

Forensic science as a discipline in the UK is highly advanced, partially owing to the Forensic Science Regulator. This provides oversight of forensic practitioners, both in laboratories and on crime scenes. Practitioners must maintain a specific set of standards relating to the quality and reliability of forensic evidence. Technological advancements within the UK have allowed for efficient evidence collection, analysis, and sample preservation.

This is a major contrast to the forensic systems available in regions of conflict. Equipment is expensive, however, easily accessible otherwise. This is often not the case in the Middle East or Africa, as discussed in previous chapters.

Civilians in the UK are also exposed to forensic science through multiple outlets, such as the media and education. Across the UK, 72 different universities offer 287 undergraduate forensic science courses, with a further 127 master's level courses [193]. These courses expose students to forensic science and the intricacies involved in the collection, analysis and preservation of evidence and court testimony involved in forensic cases. Although studies have shown that the "CSI-effect" does not have an impact on the level of forensic awareness within a population [98,171,173], the exposure of forensic practices is high and easily accessible for the general population.

8.2 Obliteration Acquisition and Analysis

The weapons analysed in this chapter were obtained through multiple organisations. Three main firearms collections were accessed, each with their own sources. Primarily, the National Firearm Centre (NFC) in Leeds provided 29 weapons with obliterations. Each of these firearms was seized through police investigations of criminal activity. The Light Weapons Wing (LWW) at the Defence Academy of the United Kingdom was also used as a source for obliterated firearms. 6 weapons were documented, which were procured from police agencies around the UK during criminal investigations. Finally, Cranfield Ordnance Test and Evaluation Centre (COTEC) operates as a disposal centre for government organisations as a tertiary component of their core operations. The final 8 weapons documented at COTEC originated primarily from unknown police sources across the UK.

Unlike the obliterations documented in conflict zones in Chapters 5 and 6 of this thesis, the author was able to document all 43 of these firearms in person. Macro photography and appropriate forensic scales were used to capture all obliterations on each firearm. After photographing each firearm, the obliterations were subject to the coding system established in Chapter 4.

8.3 Results

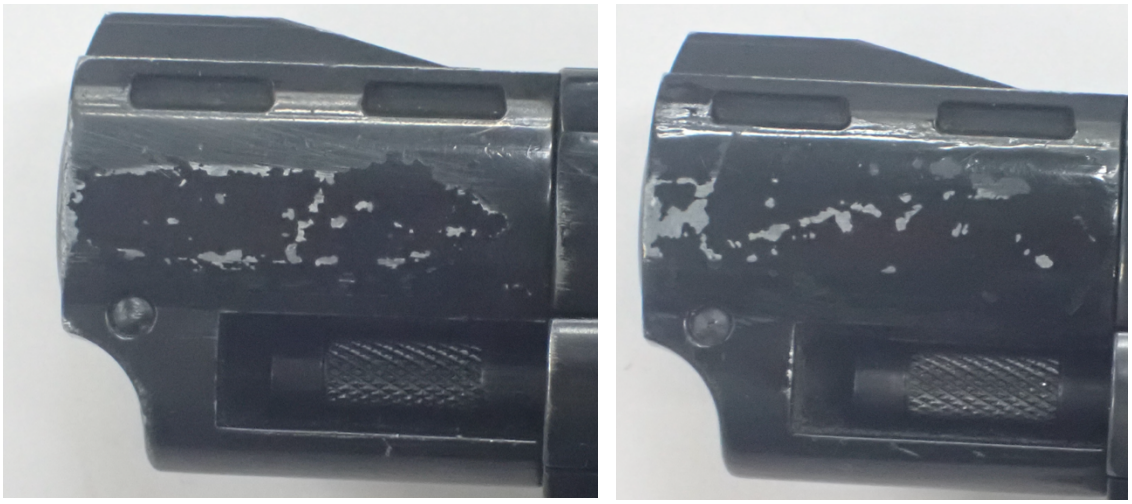
8.3.1 Clusters

In the UK, 6 clusters were established. 37% of weapons (13 of 40) fit into these clusters. 28 obliterations had unique obliteration codes that do not fit into clusters or can be defined as clusters of n=1. Each obliteration code documented in UK and the number of weapons within a single cluster are presented in Table 8-1.

Table 8-1: The number of weapons in each established cluster within the UK.

Code[5]					Number of Weapons
T	S	M	D	C	
2	0	1	2	0	2
2	0	8	2	1	2
5	0	1	0	0	2
6	0	1/8	3	0	3
6	0	1/10	3	0	2
7	0	1	0	0	2

An example of a cluster containing two weapons with the same obliteration code (2.0.8.2.1) can be seen in Figure 8-2. These Brocock pistols are two air pistols that both had only the model mark removed. In this case, the model would indicate to users that the firearm was an air pistol and did not fire real bullets. The serial number on each pistol remained intact.



[5] T: tool type, S: level of sanitisation, M: marks removed, D: directionality, C: additional concealment. See Section 4.4 for full details.

Figure 8-1: Two Brocock air pistols, which had the model number removed to conceal the mark identifying these are air pistols and do not fire live ammunition.

8.3.2 Weapon Types

Six weapon categories were documented in the UK with criminal obliterations. Handguns make up the most common category, with 23 of 40 weapons (57%). The second largest category is shotguns, which account for 27% of the weapons documented (n=11). Other weapon types include submachine guns, AK-pattern rifles, other assault rifles, and air pistols. The prevalence of each type is shown in Figure 8-3.

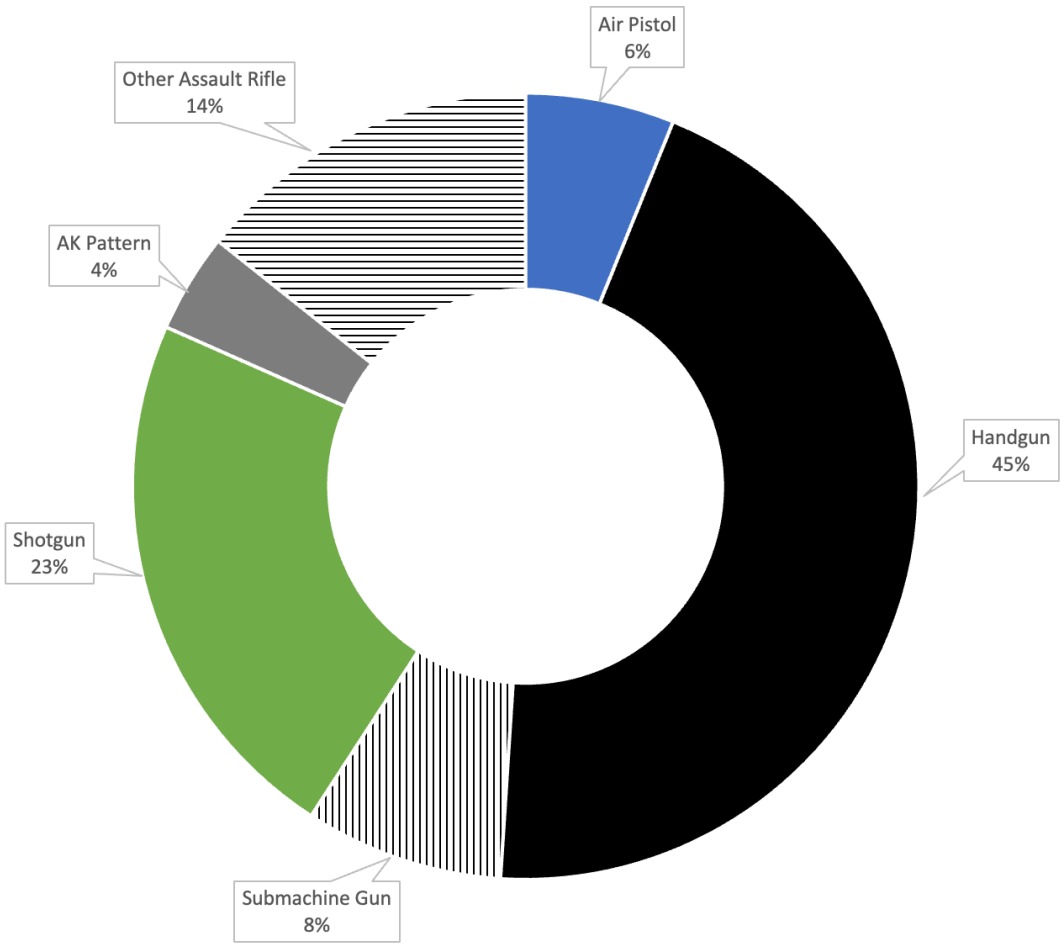


Figure 8-2: The types of weapons, and their prevalence, documented in the UK with criminal obliterations (n=40).

8.3.3 Tool Types

The tools used in the UK to obliterate identifying marks from firearms varies significantly. Almost equally, rotary tools, hand files, welders, and mills were used to create 80% of obliterations (n=8, n=8, n=7, and n=9 respectively). Drills, nail punches, stamps, and grinders account for the remaining obliterations, as shown in Figure 8-4.

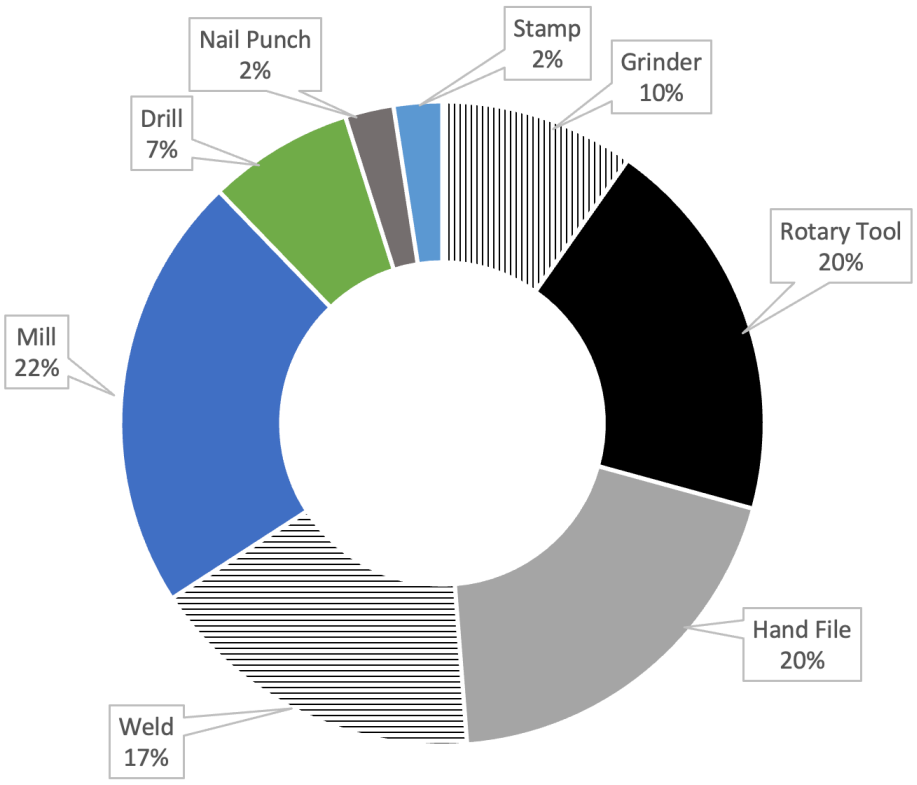


Figure 8-3: The types of tools used in criminal sanitisation of 40 firearms seized and documented in the UK.

8.3.4 Level of Sanitisation

In this dataset, the number of completely sanitised firearms was similar to those in Canada, Africa, and the Middle East. 12% of weapons had all marks removed to a point where they were not visible. This equates to only 5 of 40 firearms. The weapons completely sanitised were a variety of weapon types, with no consistent make or model that had all marks removed.

Only 7% (n=3) weapons were partially sanitised. In each case, the serial number was either partially obliterated (n=1) or fully removed (n=1).

Similar again to other regions, the majority of the firearms were incompletely sanitised. 82% (n=33) only had some marks removed to a stage where they were no longer visible, which were primarily the serial number. Other marks were removed in addition to the serial number on 11 weapons, which will be presented in the next section.

8.3.5 Marks Removed

The majority of weapons had only the primary serial number removed (n=24, 60%). The only other instance where one mark alone was removed from weapons was in the aforementioned case with the Brocock pistols, where the model was removed (n=2). In all other obliterated weapons, marks were removed in addition to the serial number, but not in isolation. These marks include the calibre (n=3), the model (n=4), the factory (n=2), the year of manufacture (2), the manufacturer (n=1). Figure 8-5 shows the number of times a mark was removed from weapons in this dataset.

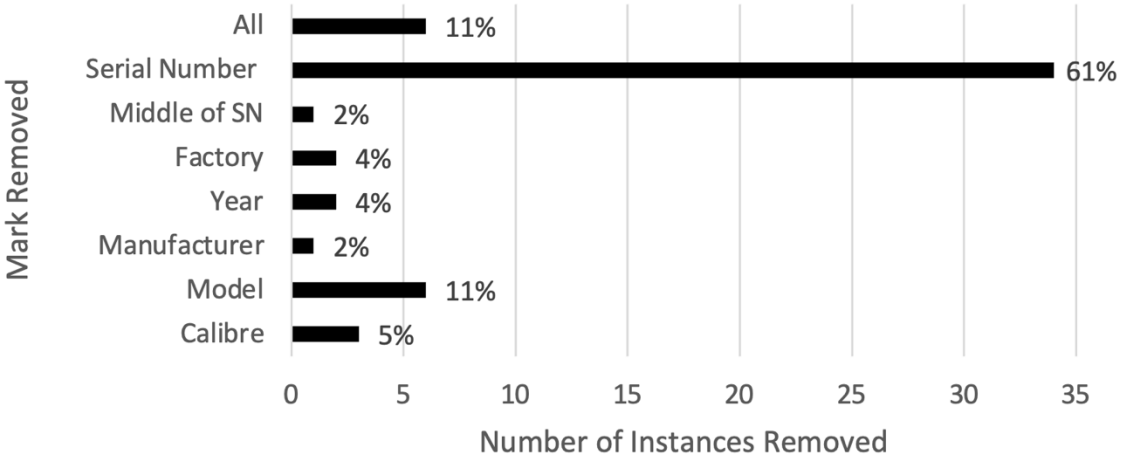


Figure 8-4: The number of times a mark was removed from weapons (n=40) documented with obliterations in the UK. (SN= serial number).

8.3.6 Directionality

Most marks (n=14) were removed from left to right as seen in Table 8-3. This is similar to the other regions presented thus far. The second most common directionalities were “not applicable” and left to right (n=9 for both directions). A downward direction and “random” were also noted, with 2 and 9 observations, respectively.

Table 8-2: The directionality of tool marks noted in the UK Dataset

Direction	Number of Observations	Percentage of Total Data
Not Applicable	9	22%
Random	6	15%
Left to Right	14	36%
Right to Left	9	22%
Downward	2	5%

8.3.7 Additional Concealment

Additional concealment of obliterations is rare in the UK. 78% (n=31) showed no attempt to cover the areas the marks were removed from, and the toolmarks were obvious and noticeable. Black paint was used in an attempt to camouflage the area of obliteration on six weapons (15%); however the paint was flaking off in all six and actually enhanced the area of obliteration. Only three other weapons showed additional concealment; two were over stamped and one by scribing over the area of obliteration.

8.4 Discussion

This section aims to form conclusions relating to the reasoning behind the different types and techniques of obliterations documented on seized weapons from around the UK. An obliteration analysis will be conducted first, then weapon types and tool types will be assessed to offer reasons for their respective popularity. Finally, the regional drivers for obliterating identifying marks from weapons in the UK will be posed based on the marks removed and any concealment noted.

8.4.1 Cluster and Obliteration Analysis

In the UK, 6 criminally obliterated clusters were formed of only 2-3 weapons in each. Weapons within the clusters are consistently visually similar, with an example seen in Figure 8-2 in the results section of this chapter. This leads to conclusions that weapons in the UK are obliterated on a much smaller scale than that seen in the Middle East or Africa, where the clusters are larger with more dissimilar obliterations sharing the same code. The small-scale clusters show proof of a higher number of solitary actors sanitising weapons.

Although this dataset is a small sample of weapons, the consistency in level of sanitisation of these weapons, coupled with the example made from the welrod

pistols, lends to the expectation that this degree of obliteration may be documented throughout the UK. It is also anticipated that a larger number of clusters with fewer weapons will be maintained should this dataset be expanded through continued examination of obliterations across the UK.

8.4.2 Weapon Types

The types of weapons documented in this dataset were more variable than those documented in Canada. Handguns were the most commonly documented in this dataset, followed by shotguns and assault-style rifles. In addition to this majority, blank firing pistols, submachine guns, and AK-pattern rifles were documented.

It is an unsurprising result to find handguns with obliterations in the UK. Although not legal for civilians to own, they are very easy to conceal in vehicles or cargo crossing over from mainland Europe or Northern Ireland. There is also a high demand on the criminal market for handguns, as they are much easier to conceal on the body than long guns. This demand drives the supply of illicit weapons into the country.

Shotguns are legal to own in the UK, so they are generally easier to obtain and in higher abundance around the country. This abundance alone enables illicit procurement for those without legal means to acquire such firearms.

Submachine guns were an interesting weapon type to see in the UK, with two different models being documented: Sterling and Hotchkiss submachine guns. While the presence of the Sterling submachine gun in the UK can easily be explained, the Hotchkiss cannot. Until 1994, the Sterling submachine gun was used by the British Army, and it was noted during documentation that these two specific weapons were diverted into the illicit market during the service period of the weapon, and presumably obliterated at that time. This is a similar situation for the AK-pattern rifles documented, where authorities in Northern Ireland have

used these guns in the past and may have entered the market through stockpile diversion. The Hotchkiss, however, has not been used in the UK by service personnel, and therefore must have been brought into the country illegally.

Air pistols were potentially the most surprising to find within the UK as they weren't documented in any other region within this thesis. They were especially interesting because even other countries with more developed investigation systems like Canada and Australia did not have any in their data sets (see Chapters 7 and 9). It is believed by the author that the reason they were found in the UK is because of the difficulty to obtain pistols by civilians, criminals were trying to sell blank firers on the black market as live firing pistols by removing the caliber but maintaining the serial number to make them look legitimate. These would then sell for a higher value on the black market, and the supplier would "disappear" before the user realised they were blank firers and not true pistols.

8.4.3 Tool Types

The four main types of tools used to obliterate serial numbers in the UK were rotary tools, hand files, mills, and welding kit.

Rotary tools and hand files were both seen in 19% of samples. These are both easily accessible tools and much more economically available than the larger equipment. Although the time required to remove marks from weapons using a hand file is quite high, both tools would be used in individual weapon sanitisations, instead of a large influx of weapons all at once.

Mills and welders were used in 22% and 17% of obliterations, respectively. These types of tools would be used by criminals sanitising weapons in more professional workshops with more developed capabilities. These workshops may operate primarily as manufacturing facilities, metal workshops, or automotive maintenance garages, but serve a dual purpose as firearms sanitisation shops for the illicit market. The obliterations made using these tools are extensive in

terms of the amount of material removed- or added in the case of welding- leading to a lower potential for forensic recovery.

While a popular tool in other regions, grinders were only used in 10% of obliterations in the UK. When compared to conflict zones and the Canadian data this is very low. A potential explanation for this is that the UK population density is much higher than all of these other regions and the noise pollution may have an impact on the tool choice used if the criminal groups are sanitising in their home garages or after working hours of a professional workshop. Grinders are also less controlled on smaller weapons so individuals may opt for a rotary tool instead to be more precise.

8.4.4 Regional Drivers

Only four weapons, all handguns, were entirely sanitised in this dataset. This shows there is not a significant emphasis to remove the origin of the weapon by completely anonymising the firearms. Instead, like in Canada where protecting the supply chains from the USA is critical, intact procurement chains from mainland Europe and Northern Ireland are paramount to ensure demand is met in the UK. Criminals protecting themselves from conviction is not a primary concern because they are using firearms in a secondary role in the commission of other, potentially more serious, crimes so illicit firearms possession would not be the most significant charge should they be convicted. Instead, serial number are removed from illicit weapons in the UK to protect the supply chain.

Additionally, the monetary aspect of illicit weapon sales is a critical component of the drive to sanitise weapons in the UK. This is a conclusion formed on the basis of the blank firers that have been documented in this dataset. The serial numbers were removed, or at least partially removed, from all weapons except two. Those were both air pistols, where the area on the frame that would normally house the caliber on the real live-firing version would be. This was done to make the air

pistols look like live firing weapons with an intact serial number so the purchaser would believe they were purchasing a real weapon and paid the reflecting amount of money. The seller would then “disappear” after collecting the money, leaving the buyer with an ineffective weapon.

8.5 Conclusions

In summary, obliterations in the UK are extensive, with enough material removed to ensure the forensic examination of the firearms would not be able to recover the obliterated serial numbers and other markings. The clusters formed are of few visually similar obliterations, where few weapons sharing unique obliteration codes, showing more isolated actors conducting the sanitisations. The primary regional driver for the sanitisation of firearms in the UK is to conceal history and previous ownership so weapons cannot be traced through supply chains to stop weapon movement across the channel and county lines. A secondary driver is to increase value on black market by selling blank firing firearms disguised as actual lethal weapons.

9 Obliterations in Australia

9.1 Introduction

Legal firearm ownership of firearms in Australia is strictly regulated, especially after the Port Arthur Mass Shooting [194–196]. The National Firearms Agreement was written in response to this tragedy in 1996, where 37 people lost their lives [194]. This Agreement was established to ensure unsuitable people could not easily obtain firearms [197]. A restricted ownership allowance on automatic and semi-automatic centre-fire firearms was established, in addition to magazine capacities [197].

There is still demand for firearms by criminal actors and organised crime groups operating in the country [198]. One significant issue with actors involved in firearms crimes, is that they often are indifferent about the punishment they may receive if caught [197].

It has also been noted by researchers that firearm safety around Australia differs depending on the area of residence. In larger metropolitan areas, such as Sydney, firearm owners are very strict about safe storage practices, while those who live in extremely rural areas are more likely to be less careful [199]. People who use their firearms for land and property protection prioritise easy access to their firearms over secure storage [199]. This cultural difference by civilians may account for differences noted in firearms crime rates in various regions of Australia.

9.1.1 Firearms Laws

In Australia, firearms may be owned by civilians under strict legal guidance. Applicants for a firearm owner's licence must have a genuine reason for possessing a firearm, as well as meet minimum age requirements and pass

continual background checks [200]. There are also firearms safety courses that must be passed, requalification of licences after a set time (up to five years, depending on the type of licence), and limits on the number of firearms, and the amount and type of ammunition one may possess and purchase at one time [200]. Firearms must be registered upon purchase and transfer by civilians, and firearms dealers and manufacturers are subject to maintaining records relating to sales and maintenance [200]. In addition, The National Firearm Trafficking Policy Agreement (2002) created an offence for the altering or defacing of serial numbers and other identifying marks [195]. Since the National Firearms Agreement, licenced firearm owner numbers have decreased in Australia by nearly 75%, with citizens noting that the primary reason for this is lack of need to own a firearm [201].

After the inception of the National Firearms Agreement, nearly 642,000 firearms were surrendered, the majority of these being long guns [201]. Researchers estimate roughly 260,000 firearms remain in the Australian illicit market since the implementation of compulsory registration in 1996. In an effort to reduce this number further, another amnesty was held in 2021, where 17,543 long guns were surrendered across the country in the first year [201].

9.1.2 Weapon Sources

In Australia, researchers and law enforcement agencies have established three markets for firearms procurement: the legal market, the grey market, and the black market. Each market is a contemporary and historical source for illicit firearms in the country. Trafficking network is not as structured as in some nations; however, it is dominated by serious and organised crime groups [195,202]. Often the primary function of these groups is drug trafficking and weapon trafficking is an associated activity [195].

Both suppliers and consumers of illicit firearms tend to lie in a collection of networked organised crime groups and small drug trafficking units [195]. Included

in these networks are outlaw motorcycle gangs, Middle Eastern crime groups, and drug traffickers [196,202]. Maximum jail time for unlawful possession of a firearm is 20 years, which may be reduced depending on jurisdiction and type of firearm [200].

The legal market is comprised of civilians holding gun licences, police, military, and other entities legally allowed to own and use firearms. A report from 2022 suggest that defence forces in Australia hold over 214,500 firearms, while the police hold 69,000 [200]. Police in Australia do routinely carry at least one firearm, which is typically a pistol in their duty belt, but may also be issued a long gun [200]. As the corruption levels in Australia are low, government owned firearms are not often found in the black market or used in the commission of crime [202]. Legally held firearms by civilians are still subject to theft and may be diverted to the black market. For example, 1545 civilian owned firearms were reported stolen between 2004-2009 with only 12-14% recovered [195].

The grey market in Australia consists only of long guns that were subject to legislative change after the 1996 mass shooting at Port Arthur, as handguns were already subject to legislative restrictions [195,199]. Long guns not handed in during the amnesty or those that were poorly and inadequately deactivated are considered to be in the grey market [195]. Many of these firearms are not necessarily owned for criminal use and were not registered due to negligence or other reasons, but may still end up in black market as they are not registered [195,199].

The black market is the largest source of illicit weapons, consisting of firearms illegally imported, illegally manufactured, stolen, or legally owned then diverted from the original owner or government stockpiles.

Of all firearms traced in the Firearms Tracing Program, only about 1% are entering into the country through postage. These are generally firearms ordered from overseas by opportunistic individuals, not organised criminal groups [196].

That 1% is mainly components that look innocent on scanning equipment, such as barrels that appear to be hollow metal tubes [199,203]. In the few instances of firearms successfully entering through the post, it was found that the weapons were typically purchased online using cryptocurrency, such as bitcoin, and originated in the USA [198]. International cooperation of intelligence and policing agencies has enabled these pathways to be closely monitored and disbanded [198]. Although it is unlikely that levels of trafficking seen in the Middle East and Europe will ever be seen in Australia, due to the physical geography of the country and robust borders [202], it has been noted that the proximity of Australia to the Philippines may be concern for illicit import, however, there has been no documented involvement to date [196].

Another significant source of black-market firearms are those subject to legislative loopholes. In addition to long guns that were deactivated poorly after the Port Arthur mass shooting, firearms are commonly legally imported but are deactivated by dealers upon receipt, which do not then require registration. In some instances, the deactivations were substandard by design and are easily reactivated on the criminal market [195].

Illicit manufacturing accounts for a very small number of weapons on the black market. These firearms are generally made to order, not mass produced [195]. Six of eight jurisdictions in Australia have specific legislation against the illicit manufacturing of firearms, while the other two include manufacturing with other criminal charges [195].

Finally, corrupt dealers account for one of the largest sources of black-market firearms, especially when concerned with handguns due to the concealability and high magazine capacity [195].

9.2 Obliteration Acquisition and Analysis

This chapter will address sanitised firearms seized during criminal investigations from New South Wales (NSW). Each obliteration in this dataset was provided by the Science and Research Unit at NSW Police. The weapons analysed were seized through criminal investigations and processed through the NSW Ballistics Section. 384 of the 388 firearms examined in this chapter are pistols and other handguns, which make up only approximately 20% of the case work the NSW Ballistics Section analyses [personal communication, NSW Police]. The reason for this is that handguns are the primary concern for the Firearms Tracing Program, which aims to provide intelligence on the lifecycle of weapons used in criminal activity in Australia. The Program enables the identification and linking of organised crime groups, which tend to favour handguns. The dataset received from NSW Police was easily available and could be collated rapidly, and therefore reflects only about 20% of the total firearms received by the Ballistics Section, the remaining 80% being primarily rifles and shotguns. For this reason, the intelligence relating to the type of firearm observed with obliterations will not be conducted in this chapter.

The obliterations are coded using the methodology outlined in Chapter 4 of this thesis.

9.3 Results

9.3.1 Clusters

In Australia, 41 clusters were established by more than 1 weapon having the same obliteration code. 78% of weapons (303 of 386) fit into these established clusters. That leaves 81 (21%) with unique obliteration codes that do not fit into clusters, or clusters of n=1. Each obliteration code documented in Australia and number of weapons within a single cluster are presented in Table 9-1.

Table 9-1: The number of weapons within 41 established clusters in Australia.

Code[6]					Number of Weapons
T	S	M	D	C	
1	0	1/8	2	0	4
1	0	1	1	0	5
1	0	1	2	0	43
1	0	1	4	0	9
1	1	0	1	0	2
1	1	1	2	0	7
1	1	3/4	2	0	3
1	2	0	1	0	3
1	2	0	2	0	5
2	0	1	1	0	14
2	0	1	2	0	43
2	0	1	2	1	3
2	0	1	2/4	0	2
2	0	1	4	0	6
2	0	1/10	2	0	2
2	1	0	1	0	2
2	1	1	2	0	16
2	1	1	1	0	5
2	2	0	2	0	5
2	2	0	1	0	5
2/6	0	1	2	0	2
2/7	0	1	2	0	2
2/8	0	1	2	0	2
3	0	1	1	0	4
3	1	1	1	0	4
5/6	0	1	1	0	2

[6] T: tool type, S: level of sanitisation, M: marks removed, D: directionality, C: additional concealment. See Section 4.4 for full details.

5/11	0	1	2	0	2
6	0	1	1	0	2
6	0	1	2	0	18
6	0	1	2	2	3
6	0	1	2/3	0	3
6	0	1	3	0	9
6	1	1	2	0	5
7	0	1	0	0	21
7	0	1	2	0	2
8	0	1	0	0	17
8	1	1	0	0	6
8	1	3/4	0	0	2
11	0	1	1	1	3
11	1	1	1	0	2
13	0	1	0	0	8

One example of two weapons of different make and model (one Browning HiPower and one Ruger 22/45) in a cluster with the same obliteration code (2.0.1.2/4.0). These two weapons were seized in the same year (2011), with no provenance information on either pistol, however the Ruger pistol was confirmed to be deactivated. Figure 9-1 shows these two weapons and the obliteration of the primary serial number.

Figure 9-1: Two pistols with the same obliteration code showing the serial numbers removed by a rotary tool moving both left to right and downward with no additional concealment.

Another cluster formed in Australia with the code 2.1.1.2.0 shows 16 firearms that had the serial number partially obliterated. The tool moved left to right, however, there was no additional concealment. Figure 9-2 shows three examples of this code and how visually similar they are.

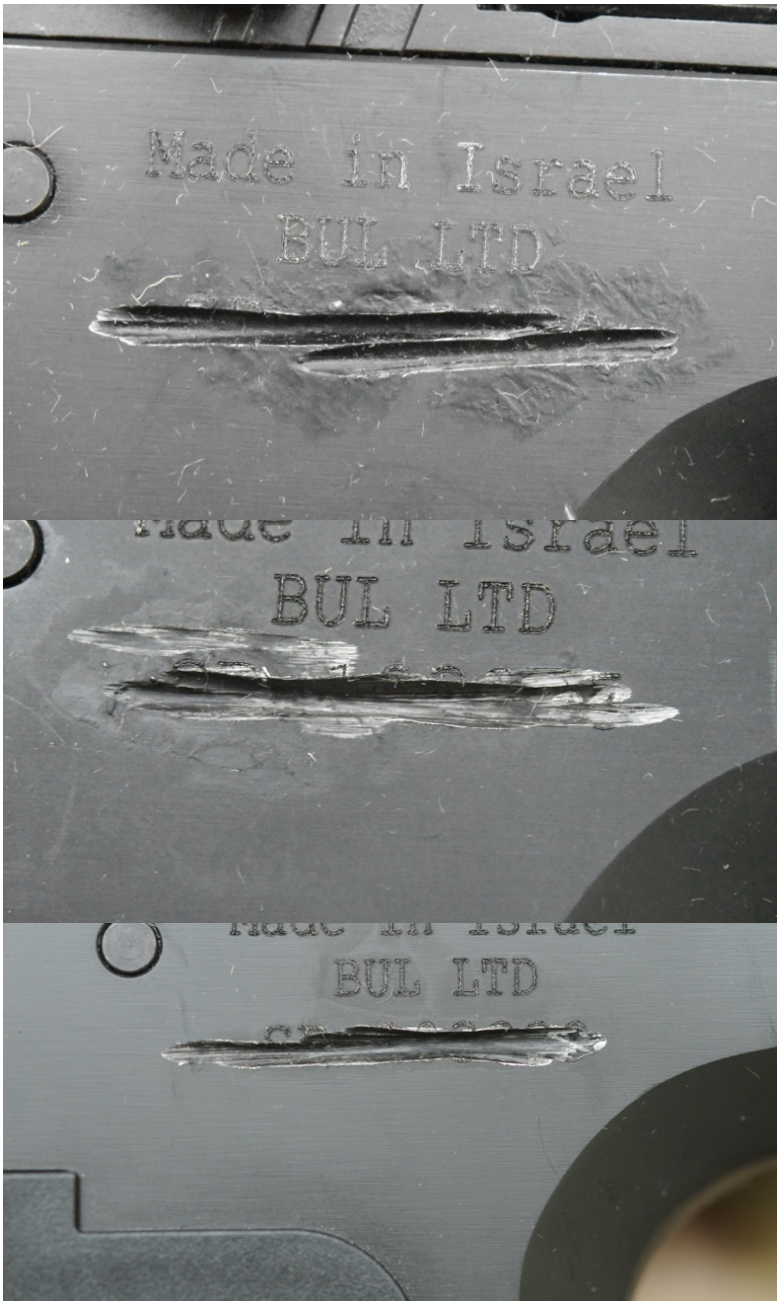


Figure 9-2: Three Desert Eagle pistols documented that are part of the obliteration code 2.1.1.2.0 cluster.

9.3.2 Tool Types

Two types of tools were much more predominantly used to create obliterations in Australia than any others. Grinders and rotary tools were seen in 26% (n=110) and 29% (n=125) of cases, respectively. Other tools used included hand files,

milling machines, welders, drills, nail punches, sandpaper, etchant, and stamps. The prevalence of each tool type is shown in Figure 9-3. In addition to the tool types, a further method of sanitisation observed in Australia, that had not been observed in other datasets in this thesis, was the removal of the metallic insert plate in polymer-framed pistols. This was noted in 12 cases. 41 (11%) weapons had their marks removed using two or more tools.

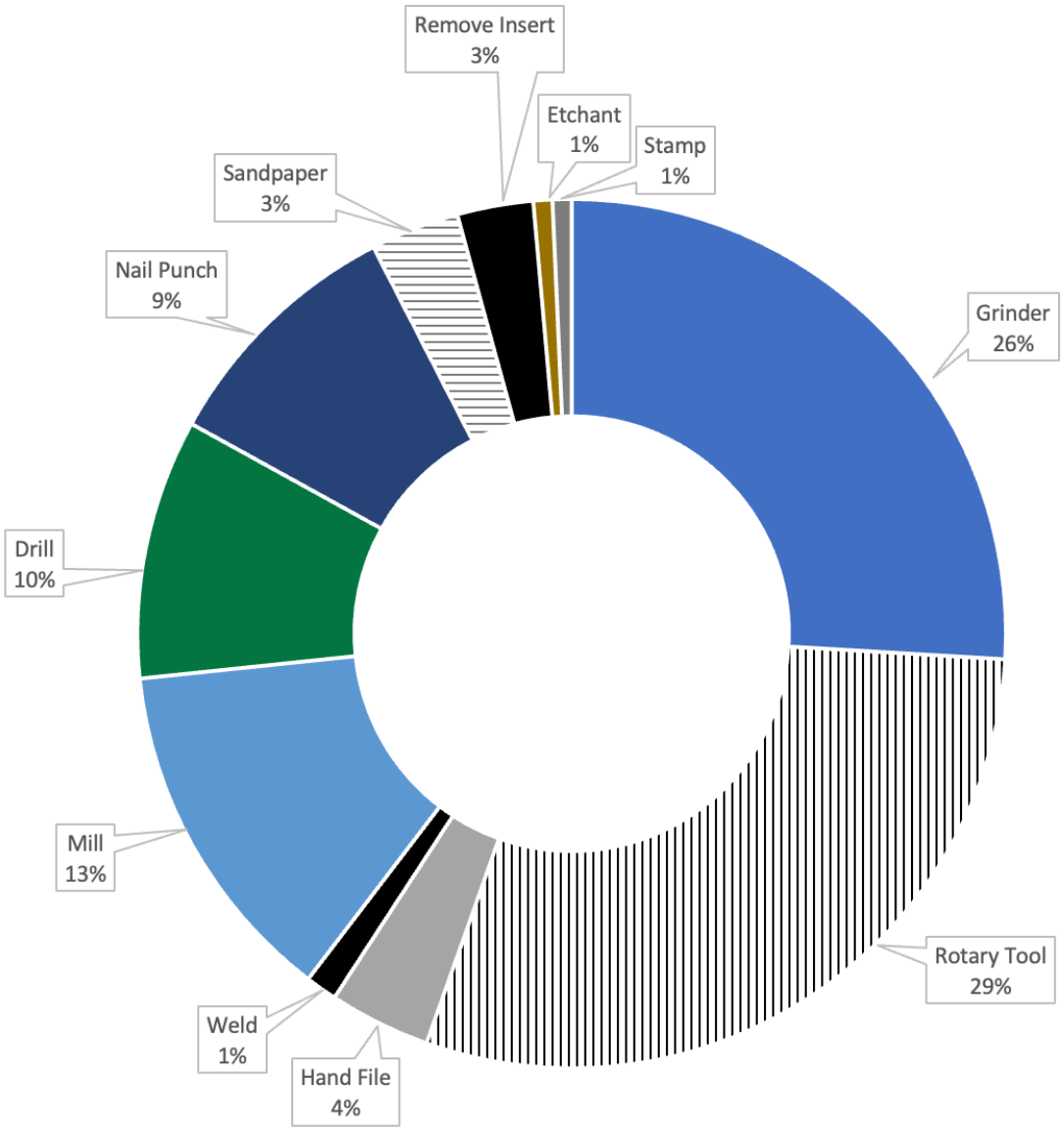


Figure 9-3: The types of tools used to create obliterations in Australia, with their respective prevalence across 388 firearms.

9.3.3 Level of Sanitisation

Considering the number of firearms in the Australian dataset, only 7% were completely sanitised. This is merely 30 weapons that had every identifying mark removed to a point where it was no longer even partially visible.

74 (19%) of the firearms documented were partially sanitised. 12 of these partially sanitised weapons had partially intact serial numbers, where at least 2 digits remained visible. The remaining 62 weapons only had the serial number partially obliterated to a very shallow level.

Finally, most of the firearms (73%, n=282) seized and documented in Australia were incomplete in their sanitisation. This means only some marks were removed, most often the serial number, while other identifying marks remained.

9.3.4 Marks Removed

Serial numbers are also the most common mark to be removed from firearms in Australia, like all four previously investigated regions. The number of firearms where only the serial number was removed was 331 (84%). The remaining 64 weapons also had their serial numbers removed in addition to other markings. The other markings removed include the manufacturer (n=2), the model (n-4) and the calibre (n=2). 39 weapons had all marks removed (including the serial number), with 11 being partially visible and only 30 being entirely non-visible, as mentioned in the previous section. Figure 9-4 shows this breakdown as a visual comparison.

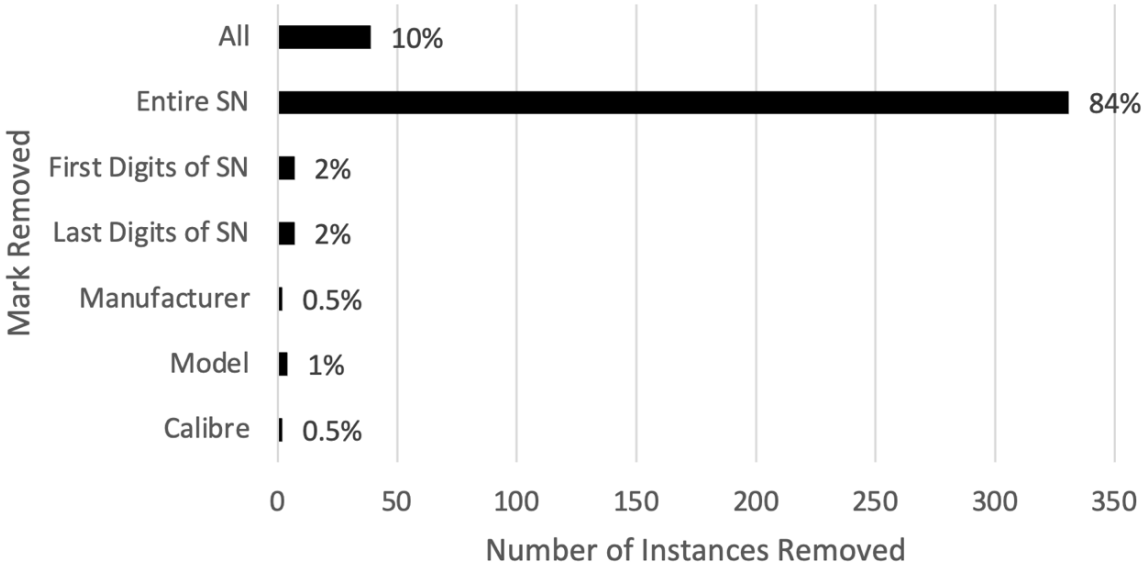


Figure 9-4: The number of instances specific marks were obliterated from 388 firearms documented in Australia.

9.3.5 Directionality

The directionality of mark removal was noted in the obliteration code and provided 7 different directions of tool travel. While the majority of toolmarks indicate left to right tool travel (51%, n=198), 75 obliterations did not have a directionality due to the type of tool used, and “random” toolmarks were observed in 71 cases. Other toolmark directions observed were right to left and downward, each comprising 5% of the dataset. 4 weapons in total showed multi-directional toolmarks. 2 showed toolmarks that were left to right, in addition to “not applicable”, again due to the types of tools used, while two clearly show toolmarks moving left to right, as well as downward. Table 9-2 lists each direction and the prevalence of each noted in the 388 obliterations.

Table 9-2: The directionality of tool marks noted in the Australian dataset.

Direction	Number of Observations	Percentage of Total Data
Not Applicable	75	19%
Random	71	18%
Left to Right	202	52%
Right to Left	18	5%
Downward	22	6%

9.3.6 Additional Concealment

Weapons seized and documented in Australia do not typically show any attempt at additional concealment of the obliterated areas. Only 6% of the data set (n=21) have any additional measures noted; 13 had been painted, 7 were stamped, and 1 showed scribing. The remaining 365 (94%) were left with visible toolmarks. There were no cases were multiple methods of camouflaging the area were observed.

9.4 Discussion

This chapter has presented the results of the obliteration analysis and resulting codes established from weapons provided by the NSW Police. These weapons were seized and documented in New South Wales during criminal investigations. The general characteristics of the obliterations and the resulting clusters will be discussed first, followed by an examination of all factors contributing to the regional factors influencing obliteration in Australia. As mentioned previously, considering the data provided by the NSW Police was limited to handguns, the types of weapons and the significance this may hold on the intelligence of obliteration analysis in the region, this will be omitted in this chapter.

9.4.1 Cluster and Obliteration Analysis

In the data collected from NSW, it was found that 79% of weapons could be coded and classified into 41 discrete and unique clusters. Among these clusters two stood out, being comprised of 43 weapons each. The formation of these clusters was based on the objective analysis using the toolmarks present in each obliteration. In both clusters, the two most popular tools in the data set were used, with serial numbers being the only identifying mark removed. Specifically, one cluster housed obliterations created with a grinder, while the second cluster involved the use of a rotary tool. These tool types and their prevalence will be discussed more in the next section of this chapter. Given the nature of these generic obliteration codes and their consistent directionality (left to right) without additional concealment, the presence of such large clusters was unsurprising. Within each of these larger clusters, there were weapons where the obliterations did exhibit visual similarity and were potentially obliterated by the same person, or a group of people under the same instructions. While, despite sharing an obliteration code, there were many weapons within these large, generic clusters that displayed visual differences in their obliterations. Considering the different techniques or angles possible when using common tools like a grinder or rotary tool, this is not a surprising result.

The remaining clusters consisted of fewer weapons where the obliterations did exhibit higher visual similarity, likely owing to their uniqueness in the tools used, marks removed, and the presence of additional concealment techniques. The benefits of this novel coding system can be seen in two specific cases. One example of where the novel coding system proposed in this thesis worked effectively was shown in Figure 9-2 of this chapter, where the tool directionality was determined to be in two distinct directions and the resulting code was able to pair these weapons together without having been examined prior to being coded.

During the examination of the toolmarks to determine the obliteration code for each weapon, it became apparent that a significant portion of the firearms analysed in this dataset had been obliterated to a depth that rendered the forensic recovery of the marks improbable. This may be a result of either too much material being removed with a drill press, grinder or rotary tool, or the heat treatment and added material of welding. This may be indicative of the motivation to conceal the identity of the weapons, which will be discussed later in this chapter.

As mentioned previously in this thesis, though the directionality of the toolmarks was not relied on to form conclusions on the regionality of obliterations, it did serve as additional criteria to compare similar obliterations to enhance the analysis of the data.

It is also noteworthy that within this dataset, despite the aggressive methods of obliteration, there is a lack of concern for camouflaging the obliterated area with additional concealment. This suggests that while the criminal actors understand the implications of leaving the serial number intact, they are not concerned that the marks have been removed will be analysed as part of the evidence examination.

9.4.2 Tool Types

The two most prevalent tools used in Australia for obliterations were grinders and rotary tools, comprising 26% and 29%, respectively. Both tools are efficient, low effort means of removing marks from weapons. The rotary tool may have been more favourable in this dataset due to the increased control on the small frame of handguns that the grinder does not offer on the compact items. These tools are also highly mobile and are likely present in both professional workshops as well as private, civilian “backyard garages”.

Mills were used in 13% of obliterations, while drills/drill press and a nail punch account for 9% each, indicating a preference for quick tools and techniques over more labour-intensive methods like filing and stamping. Notably in NSW, nail punch usage was considerably higher than other regions, which will be further discussed in Chapter 10.

Within this thesis, Australia stands out as the only country/region where polymer-frame pistols were documented with the steel serial number insert plates were removed entirely. It is, however, important to emphasize that this observation does not necessarily reflect the presence in other areas, but a consequence of the nature of data collection employed for this thesis.

9.4.3 Regional Drivers

The motivation behind concealing the identity of illicit weapons in Australia, particularly NSW, appears to be twofold. The primary objective is to prevent the recovery of the serial numbers. This is obvious due to the extent of obliteration noted in many samples, where the methods used are more extensive and permanent such as welding and drilling through the frame. The depth of obliteration and the methods and techniques employed would inherently hinder the traceability of the firearms. The second motivation for sanitising weapons is akin to the observations made in both Canada and the UK, where protecting supply chains and the criminal networks is critical. Criminals that operate as part of a wider organisation recognise that the possession of illicit weapons may lead to additional criminal charges and intensive investigations, leading the individuals to sanitise the weapons to protect the broader networks.

In all 388 weapons analysed, the serial number was at least partially, if not entirely, removed in all cases. This is in comparison to other regions where there were instances of the serial numbers being left intact in favour of removing other manufacturing marks. This distinction highlights the concern for removing the

evidence of the last legal owner, but not tracing the weapon back to its original manufacturer.

A consideration that must be noted is that the individuals caught with sanitised weapons are not likely the ones who performed the obliterations. Instead, they are likely the customers or lower-level members of organised crime groups, as the source of diversion may anonymise the weapons to protect themselves from identification.

9.5 Conclusions

In summary, the formation of clusters of firearms with matching obliteration codes proved effective in grouping weapons with distinct tool mark features and enabling side by side comparisons to be made. The consistent removal of the serial number in this dataset proves the significance in concealing the history weapon. The regional drivers for weapon sanitisation in Australia involve efforts to protect higher-level individual actors within criminal networks and diminish traceability and accountability during investigations.

10 A Global Comparison of Obliterations

10.1 Introduction

In the previous 5 chapters, regional profiles have been built for different regions of the world. Three of these regions- Canada, Australia and the UK- are developed countries that have formal forensic capacity and are unaffected by domestic armed conflict. In contrast, countries documented within the Middle East and Africa are suffering from active conflict or are recovering from recent conflict events. This chapter will consider a global comparison of obliterations documented in each of these regions, in an attempt to ascertain the potential for establishing where a weapon was sanitised, and in doing so to add to the overall investigative understanding.

10.1.1 International Policy

In addition to the regional instruments previous discussed in the Chapters 5-9, there are global instruments that guide the policy relating to firearm possession, use, trafficking, and sanitisation. As mentioned previously, the ITI and the UNFP guide legislation for UN Member States and have been adopted, even if not formally ratified by all signatories.

The ITI, while politically binding, is not considered international law, and therefore does not claim to be legally binding, nor enforceable through international judicial processes. It does, however, outline the challenges faced in the tracing of illicit weapons and offers recommendations to better enable these efforts [43]. The UNFP, on the other hand, is legally binding for Member States, and can lead to penalties and sanctions if not abided by [45]. Each country discussed in this thesis has at least adopted, if not ratified, these agreements/protocols.

10.1.2 Conflict versus Crime

The dynamics of illicit weapon possession, trafficking, and use are noticeably different in conflict-afflicted regions compared to regions where criminal use is prevalent. These differences may be attributed to the regional drivers of illicit weapon procurement, motivation to conceal the identity of a weapon, forensic awareness, and the criminal prosecution potential civilians face for firearms and weapons crime.

Criminological investigations have shown that a much lower number of weapons are trafficked across borders and are stolen from legal owners/stockpiles, compared to insurgency investigations, which show that primary supply of illicit weapons come from oversupply by international stakeholders [119]. The criminal use of firearms in developed regions, without the threat of war and corruption, acts as a threat to the stability of the region itself [119]. Organised crime groups that operate in these types of political climates are generally structured in a rigid, controlled hierarchy, which rely on intimidation and corruption to establish control over civilians [204]. These actors are less likely to resort to violence, which aid in maintaining covert operations and avoiding the criminal justice systems in place [204].

In regions witnessing insurgent and armed rebellion activity, the demand for firearms by civilians is driven primarily by the lack of stability in the region, including the loss of trust in authorities, terrorism, and civil strife, among other factors [119]. The actors in these regions are more prone to rely on violence as a control mechanism, due to the lack of structure in the authority groups [204].

As mentioned in previous chapters, the motivation to conceal the identity of a weapon may be different depending on where it was sanitised. Developed countries show small batch obliterations, and an aversion to criminal prosecution and protecting supply chains, while conflict-afflicted regions aim to avoid official tracing procedures and protection of corrupt State-embedded actors. This

difference has been shown in the marks removed from different types of weapons, the manner and extent of obliteration and how they differ between each region.

10.1.3 Global Corruption Impact

The impact of state-level corruption is considerable on weapon trafficking and illicit possession and use. In this section, the Global Corruption Index (GCI) [88] and the Environmental, Social and Governance Index (ESGI) [89] are used in addition to the GOCI to understand how the relative level of corruption in a country may aid the investigation into weapon sanitisation and mark obliterations.

The GCI ranks 196 countries as a measure of the state of corruption in country. 43 variables are ranked by Global Risk Profile, following a methodology that carried a 90% confidence level. The scores obtained are translated to z-scores and enables the ranking of all countries relative to one another [88]. The lower the score, the lower the corruption level was calculated to be in the country.

Similarly calculated and ranked, the ESGI considers the environment, human rights, and health and safety of 183 countries based on data obtained from international references like United Nations publications to rank countries in the index. Table 10-1 shows the rankings of each country of interest in this thesis on the GCI and ESGI for comparative purposes. A lower rank indicates a lower level of risk in the country.

Table 10-1: The rankings of the 18 countries of interest in this thesis on the GCI and ESGI.

Continent	**Country**	**GCI (Out of 196)** [88]	**ESGI (Out of 183)** [89]
Oceania	Australia	9	9
North America	Canada	14	11
Europe	UK	11	28
Middle East	Saudi Arabia	74	113
	Bahrain	83	71
	Iraq	173	129
	Afghanistan	187	176
	Syria	196	160
Africa	Ghana	80	131
	Burkina Faso	136	156
	Benin	143	119
	Cote d'Ivoire	148	159
	Niger	159	155
	Nigeria	152	173
	Mali	170	164
	Somalia	186	183
	South Sudan	192	Not Included
	Dominican Republic of the Congo	194	182

These two ranking systems will be used in this chapter to aid the aid the attempted explanation of the regional motivation to sanitise weapons, as well as understanding the sources of weapons.

10.2 Analysis

In the previous five chapters, the analysis of 1136 obliterated firearms documented in regions around the world were analysed. Within these chapters, the regional data was assessed independently, with conclusions proposed based on the legal, historical, social, and forensic context of each region. In this current chapter, all obliterations will be considered. The clusters established in each region will be expanded to include weapons from around the world, the tools used, and specific marks removed will be compared in attempt to understand how and why criminals remove marks from weapons based on their region. Additional concealment of the obliterations will also be compared on a global level, in attempt to understand the regional nuances in a comparative manner between conflict zones and more developed countries.

The categories of analysis remain consistent in this chapter, where the obliteration codes for each obliteration will guide the investigation. The type of tool used, level of sanitisation, marks removed, directionality, and additional concealment form discrete clusters that can be broken down into components to form intelligence-based inferences. By conducting analysis in this manner, chapter will show direct comparisons made between regions and how a state of conflict versus more developed countries can alter obliteration trends.

10.3 Results

10.3.1 Clusters

When considering all of the weapons documented and analysed in the previous 5 chapters, 1136 firearms with obliterations have been codified and placed into clusters restricted to their region or country of origin. In those 5 regions, the following number of clusters have been identified:

- Africa: 25 clusters containing 158 weapons (63%).
- Middle East: 30 clusters containing 101 weapons (45%).
- Canada: 27 clusters containing 163 weapons (69%).
- UK: 6 clusters containing 13 weapons (32%).
- Australia: 41 clusters containing 303 weapons (79%).

This breakdown would indicate that 129 clusters have been identified containing 738 (65%) weapons observed globally. When considering the entire available dataset, which includes all weapons, irrespective of the region in which they were documented, there were, in fact, 125 unique clusters containing 923 weapons (81%) were identified when all obliterations were considered without restricting the analysis to the region of origin. This unfiltered figure includes those clusters that indicate transnational diversion events across borders and between regions, in addition to those which did not transit national borders to provide a complete number of unique clusters seen around the world. In total, 82 clusters cross international or continental borders, with only 43 being isolated to one country. As the number of unique clusters has decreased, this proves that many clusters established within one region share the same unique code as clusters in other regions. The entire list of these clusters with the number of weapons from each region can be found in Appendix C: Global Obliteration Code Clusters.

An interactive ArcGIS Dashboard was created to enable the visualisation of the spread of each cluster. The side panel of the dashboard enables users to filter for obliteration codes with specific features to make up the code. Once filtered,

the map will show the number of obliterations matching the selected obliteration code, as well as each region where the corresponding firearms were documented. The desktop URL link is:
https://cranfield-uni.maps.arcgis.com/apps/dashboards/48d5f5707fb543fc9ca5cab773d4a294 .

This dashboard is also accessible in a mobile-friendly version by following the QR provided in Figure 10-1.

Figure 10-1: The QR code to access the interactive ArcGIS Global Obliterations Dashboard.

To use this interactive map, the filters on the left panel can be selected to reflect the tool type, level of sanitisation, marks removed, directionality, and additional concealment. All weapons with the selected 5 factors will be listed in the middle panel and shown by a red dot on the map in the right panel. An example of this is shown in Figure 10-2. This is a revolutionary tool in understanding and visualising how obliteration techniques can be spread around the world.

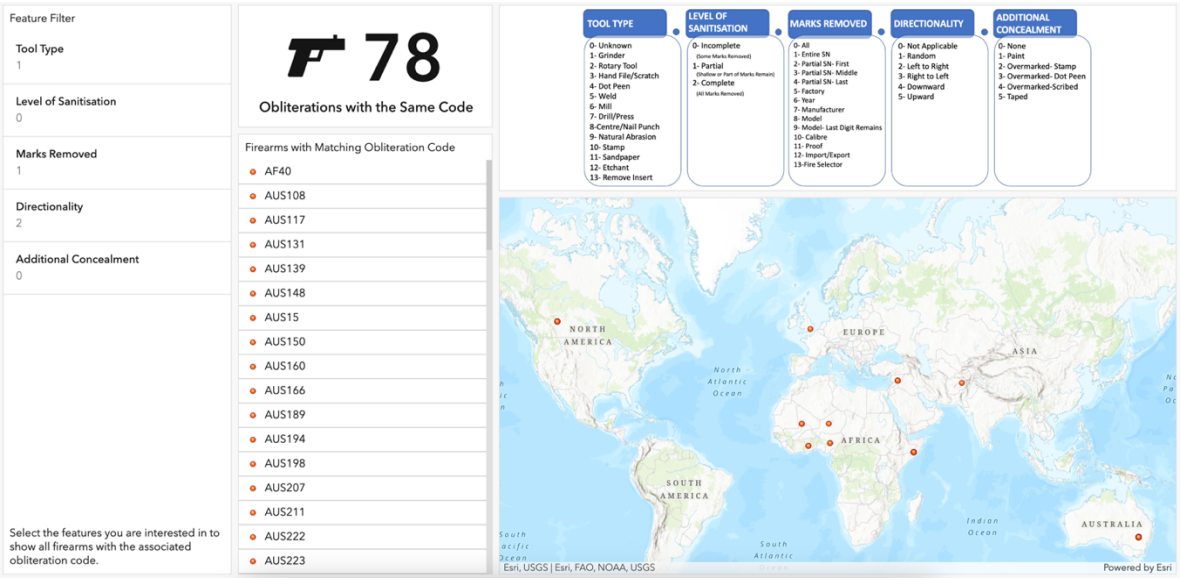


Figure 10-2: An example of the ArcGIS Dashboard that has been filtered to show the locations of all 78 weapons with the obliteration code 1.0.1.2.0.

Some examples of clusters that are formed across borders will highlight how the coding system proposed in this thesis has enabled the linking of weapons documented with obliterations in different regions.

The cluster filtered for in Figure 10-2 (1.0.1.2.0) contains all weapons that had the serial number removed with a grinder moving from left to right. There is no additional concealment, or any additional marks removed. This is a very generic obliteration, with 78 weapons presenting the same obliteration factors. Many of these obliterations are visually similar, while some are not. This is likely due to the ease of access to grinders in all regions of the world but the way in which the tool is used differs, which will be further discussed in this chapter. Figure 10-3 shows some examples of obliterations that are visually similar within this cluster documented in the UK, Canada and Australia, and also some that are not, documented in Syria, Afghanistan, Mali, and Somalia.

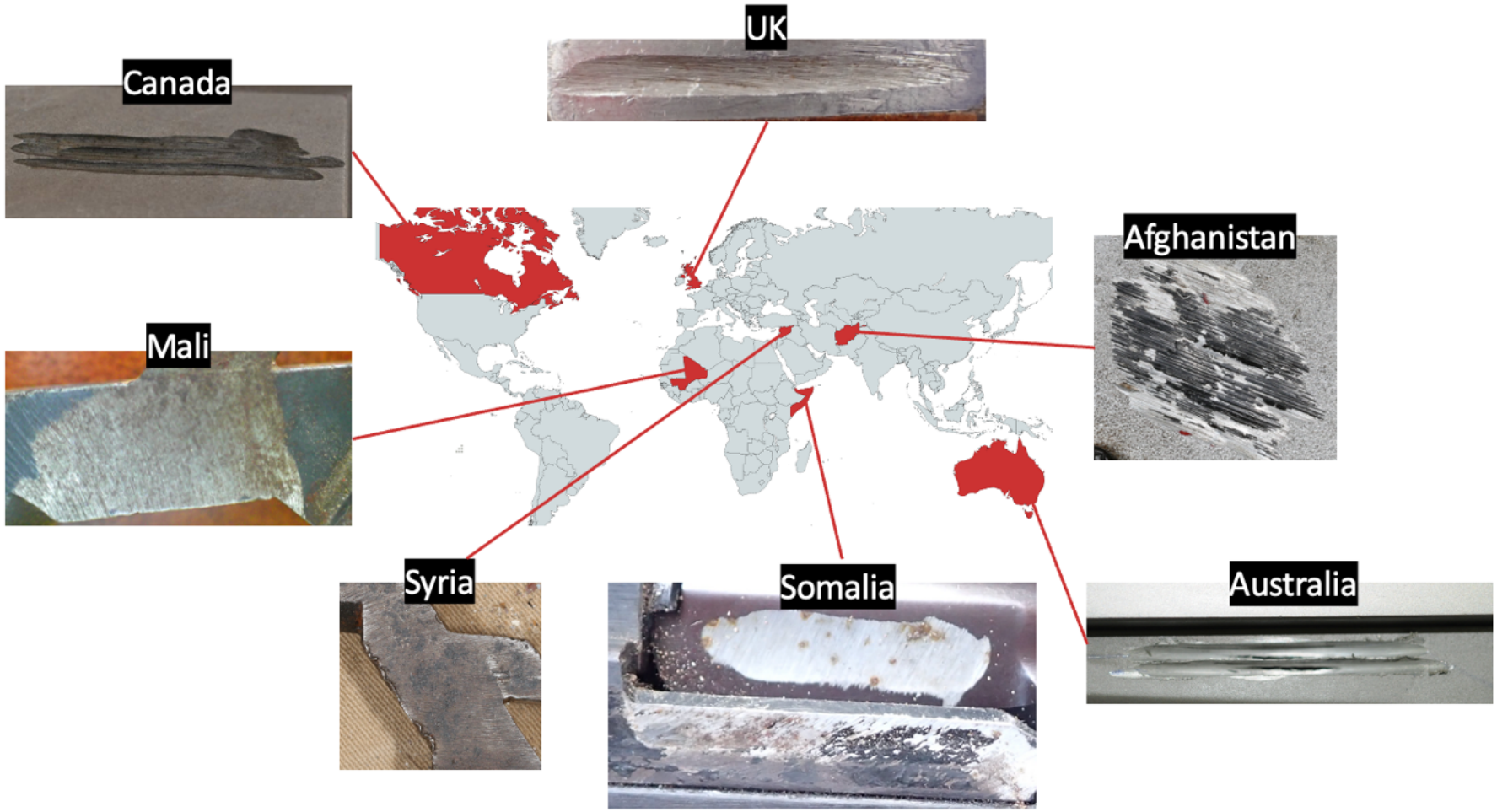


Figure 10-3: Seven obliterations from seven different countries that fit into the cluster 1.0.1.2.0.

The second case study is weapons in the cluster 2.0.1/5/8.2.0. Weapons with these obliteration codes have the serial number, factory, and models marks removed using a rotary tool moving from left to right with no additional concealment. These weapons were documented in Mali and Niger (Africa), and Syria (Middle East). Figure 10-4 shows two examples from this cluster which originated in Mali and Syria. In this case, the last 5 digits of each serial number remain intact, while the factory logo and the model have been removed.

Figure 10-4: Two obliterations documented on weapons in Mali and Syria sharing the obliteration code 2.0.1/5/8.2.0.

Another case study also involved an obliteration code shared between the Middle East and Africa, specifically Syria, Mali, and Niger. In Chapter 5 investigating obliterations in Africa, this code was also seen being shared across Mali and Niger. With a global investigation, Syria also has had weapons with this obliteration code that are, in fact, visually congruous, as shown in Figure 10-5. The obliteration code for these weapons is 2.1.1/5/8.2.0, which is only one factor different from the previous example. The difference in these obliterations is that the digits on these weapons are still partially visible, as noted in the below figure.

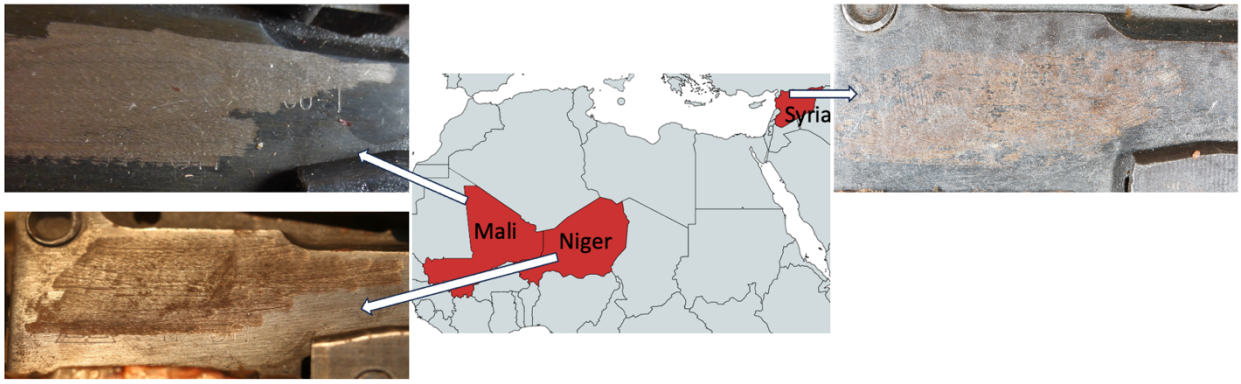


Figure 10-5: Three obliterations documented in Mali, Niger, and Syria sharing the code 2.1.1/5/8.2.0.

A final example of cross-border obliteration code sharing can be seen between Canada, the UK, and Australia. These weapons, 26 in total, had their serial numbers removed using a drill/press. Due to the complete material removal, there is no directionality assigned and no additional concealment. There were no weapons with this obliteration code in the Middle East or Africa. Three of these weapons are shown as an example in Figure 10-6.

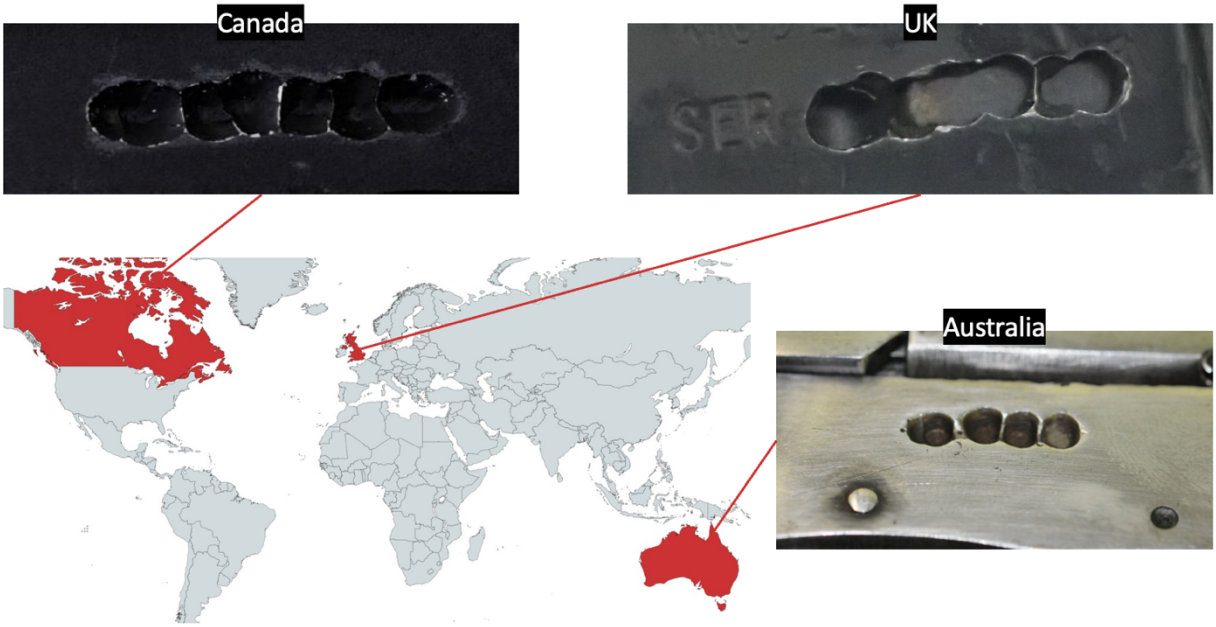


Figure 10-6: Three weapons documented in Canada, the UK, and Australia showing the obliteration code 7.0.1.0.0.

10.3.2 Weapon Types

The types of weapons seized and documented in the different regions around the world vary. Some of the key results are the following:

- Some weapons, such as AK-pattern rifles, sniper rifles, and machine guns, were only documented in conflict zones, while other weapons, such as air pistols and shotguns were only documented in developed regions.
- Artisanal weapons were only documented in the Middle East. This will be discussed further in the discussion of this chapter.
- Where handguns are legal for civilians to own (parts of the Middle East and Africa), they are less commonly documented than countries where pistol ownership is heavily regulated (UK and Canada).

Figure 10-7 shows the different types of weapons documented in each region by percentage of the dataset in each region. Due to the aforementioned bias in the

weapon types in the data set provided (see Chapter 9.2), Australia has been removed from the global weapon type analysis.

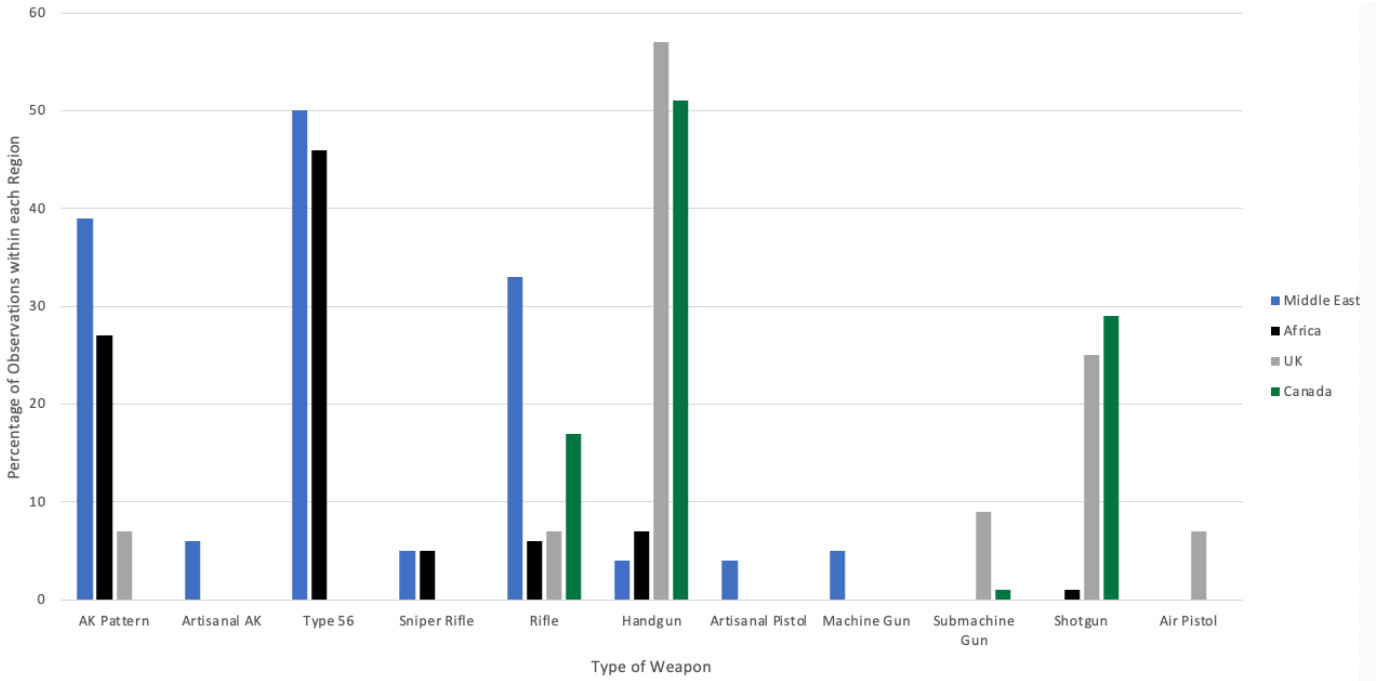


Figure 10-7: The different types of weapons analysed in this thesis and their prevalence in each region.

10.3.3 Tool Types

This global comparison of tool types was conducted to ascertain if particular tool types are more prevalent in specific regions than others. This may enable an understanding into why these tools are chosen over others, and if the tool type can be an indicator of where an obliteration was conducted.

As discussed in previous chapters, grinders and rotary tools are the two most commonly used tools in each region, except for in the UK, where hand files are more commonly used than either rotary tools or grinders. To understand the difference in tool preference and use around the world, Figure 10-8 presents the most common tools in each region on one graph. These nuances will be discussed in the discussion section of this chapter.

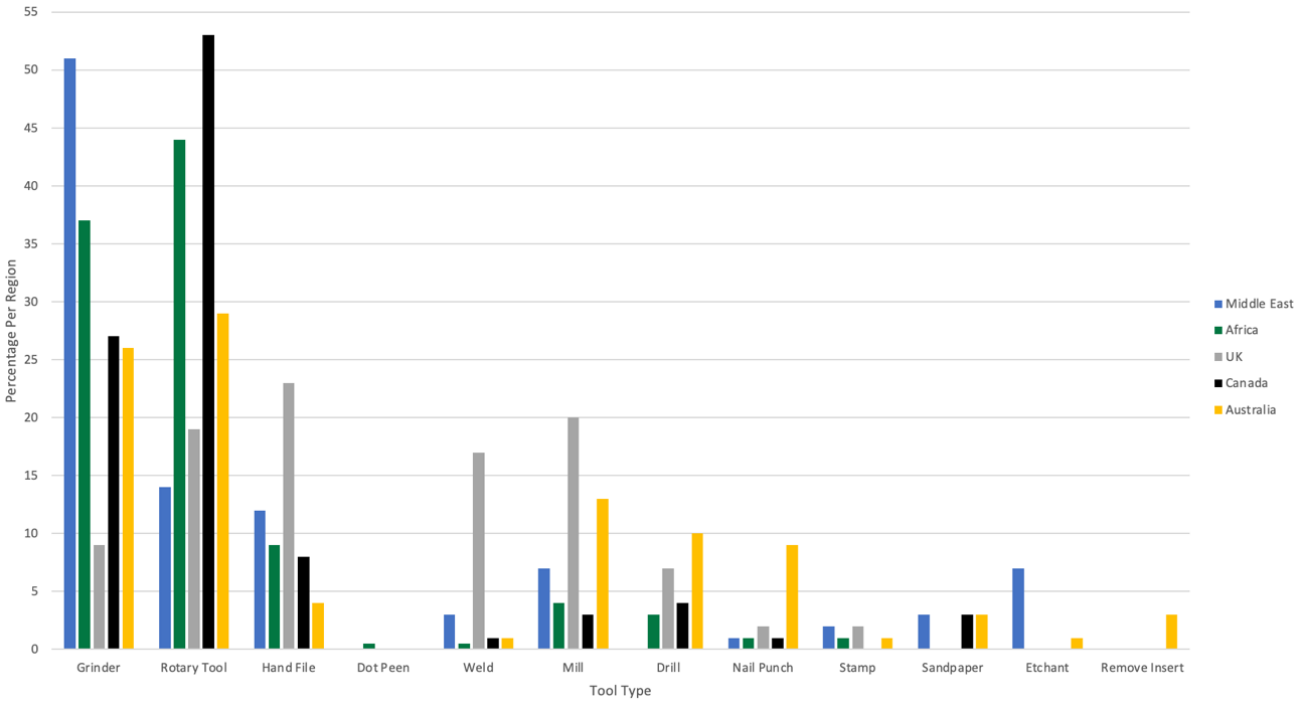


Figure 10-8: The prevalence of tool types used to obliterate markings from 1136 firearms in each region of interest.

10.3.4 Level of Sanitisation

The level of sanitisation around the world is primarily only to an “incomplete” stage. This means most of all weapons in all regions only have some marks removed to a point of being non-visible. At least 67% of the weapons in each region show this level of sanitisation, as shown in Figure 10-9.

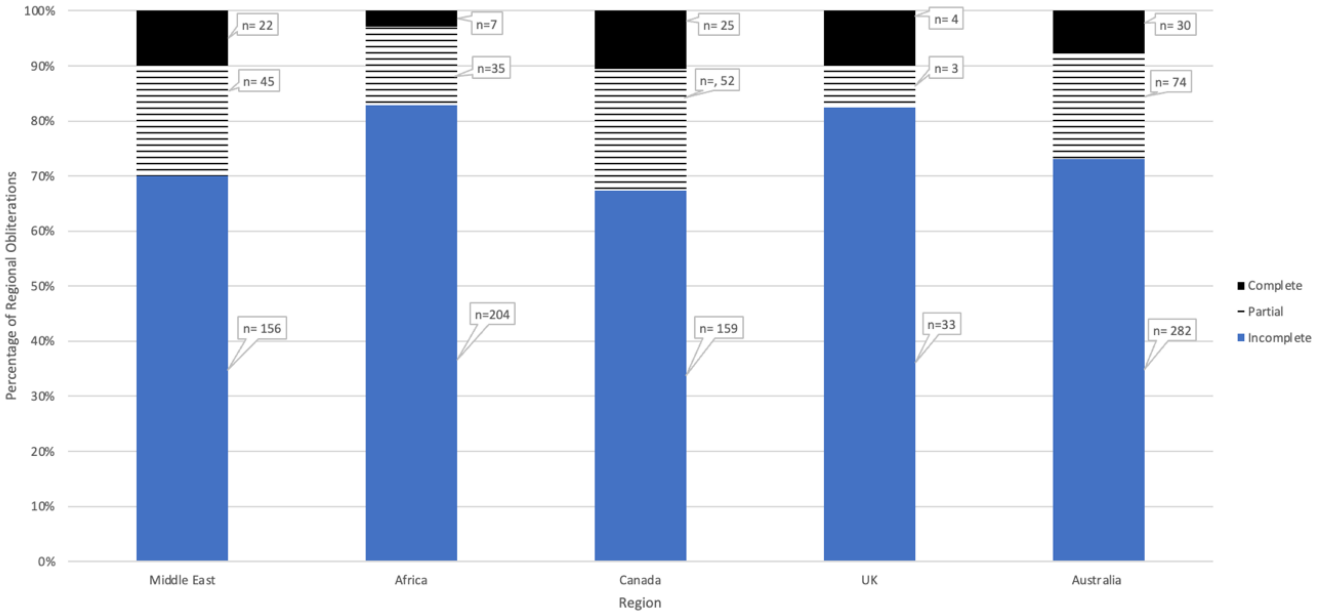


Figure 10-9: The relative level of sanitisation of weapons across the globe. The number of weapons in each category per region are given in each bar section of the graph.

Also highlighted in Figure 10-9, is that the percentage of completely sanitised weapons is the smallest group, compared to that of those partially or incompletely sanitised, except in the UK. In the Middle East, 10% of weapons were completely sanitised, compared to 20% which were partially sanitised and 70% incompletely sanitised. In Africa, even few firearms were completely sanitised, showing merely 5% of weapons to fit this category, compared to 14% being partially sanitised, and 81% incompletely sanitised. Canada and Australia follow similar levels of sanitisation, with 11% and 8% completely sanitised, respectively. This is compared to 67% incompletely sanitised and 22% partially sanitised in Canada, and 73% and 19% in Australia. The UK is the only region where more weapons

were completely sanitised than only partially sanitised, with 10% completely sanitised, 8% partially sanitised, and 83% incompletely sanitised.

The total level of global sanitisation is presented in Figure 10-10. It shows that 74% (n=834) of weapons documented around the world in this thesis were incompletely sanitised, while 8% (n=88) were completely sanitised and had all marks removed. This leaves 18% (n=209) that were partially sanitised where only parts of the identifying marks were removed, or some were left partially visible.

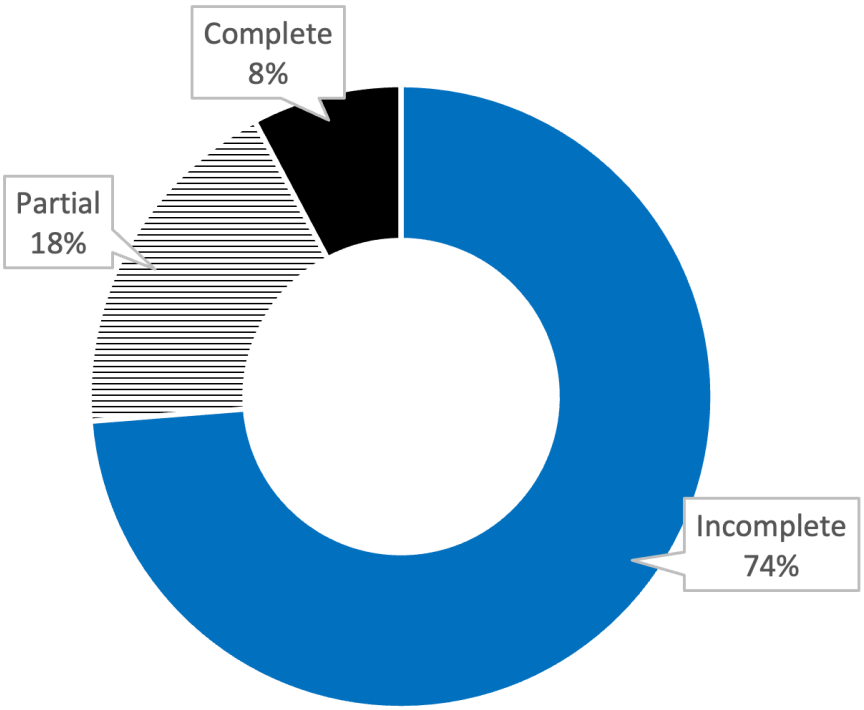


Figure 10-10: The total level of sanitisation of weapons documented in all 5 regions of interest in this thesis.

10.3.5 Marks Removed

Across the world, the prevalence of the specific marks removed changes depending on the region, which may indicate different motivations to conceal the

identity of firearms. Figure 10-11, shows the marks removed in each region, presenting general qualitative regional trends.

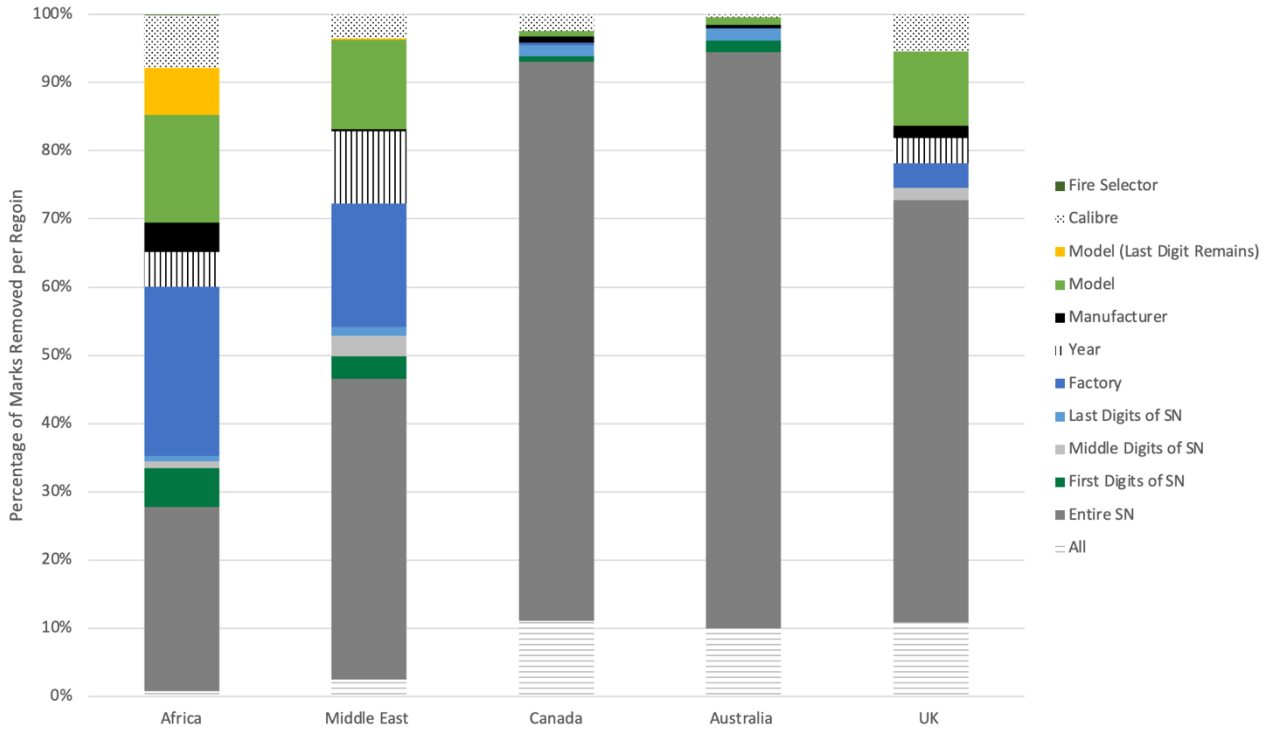


Figure 10-11: The prevalence of the obliteration of each mark in the five regions of interest.

As interpreted from Figure 10-11, some key results to be taken from this breakdown are:

- The serial number is universally the most common mark to be obliterated in each region of the world.
- In developed regions (Canada, Australia, and the UK) approximately 10% of firearms are completely sanitised with all identifying marks removed. In contrast, under 3% of firearms in conflict zones have all identifying marks removed.
- The factory mark is removed more often in conflict zones than developed countries.

While Figure 10-11 allows for the identification of general trends for the marks removed in each region, it is not intended to be used for obtaining quantifiably compared results. Figure 10-12 breaks down the data further into the marks removed in each country to fulfil the comparison of specific marks that have been removed in each region.

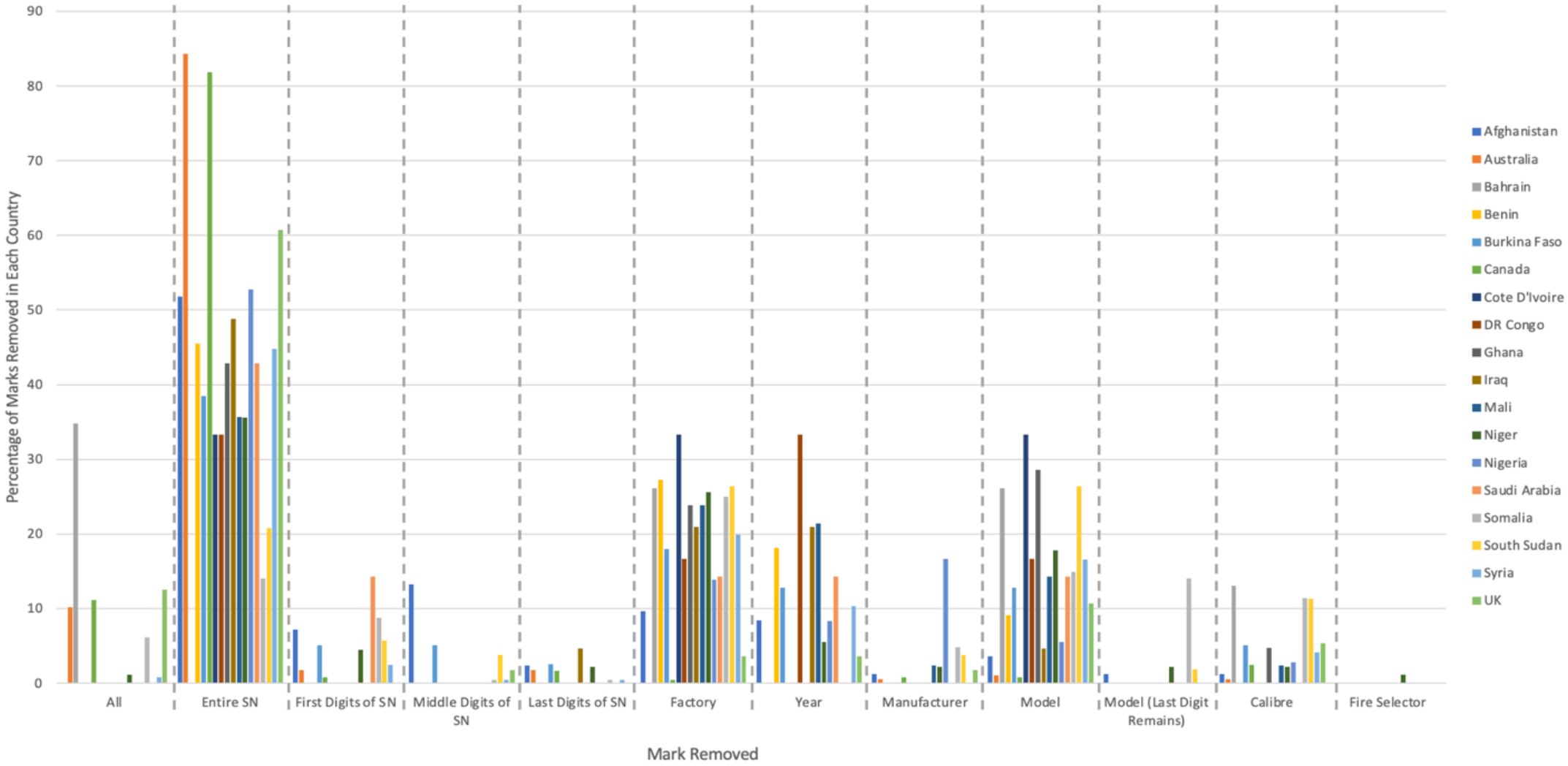


Figure 10-12: The number of instances where specific marks were removed from firearms in each country of interest, given as a percentage of the total mark removals in each country. (SN: Serial Number)

Key results to be taken away from Figure 10-12 include:

- The marks removed in most countries are the serial number, factory, year, and model.
- A very limited number countries have weapons with only part of the serial number removed, compared to removing the entire serial number.
- The manufacturer, calibre, and fire selector marks are rarely (under 15%) removed in any country.
- Bahrain (Middle East) has the highest relative percentage of weapons with all marks removed compared to all other countries. As a point of interest, this is also a country where large caches of weapons were documented, rather than smaller seizures as part of police investigations.

10.3.6 Directionality

As analysed in previous chapters on a regional level, the directionality of the toolmarks is an important component of the obliteration code assignment. Although other components, such as the type of tool and the marks removed, are of greater intelligence value, the directionality of the toolmarks allows further refinement of the obliterations using non-subjective measures. As noted in Table 10-2, a left to right direction is the most documented. This may indicate the handedness of the tool operator and could be of great benefit in criminal investigations, however, does not indicate regionality of obliterations.

Table 10-2: The directionality of tool marks noted in the global dataset.

Direction	Number of Observations	Percentage of Total Data
Not Applicable	156	14%
Random	239	21%
Left to Right	605	54%
Right to Left	50	4%
Downward	76	6%
Upward	8	1%

10.3.7 Additional Concealment

As analysed in each regional chapter, the additional concealment of obliterated areas on the firearm is not seen in the majority of cases. In fact, when all 1136 firearms with obliterations are analysed, only 25% of weapons showed an attempt to further conceal the obliteration. The remaining 848 weapons show no additional concealment, while only 289 have paint, over-stamping, dot peening, scribing, or tape covering the original area of the obliteration. Figure 10-13 shows the breakdown of each type of concealment for those 289 weapons.

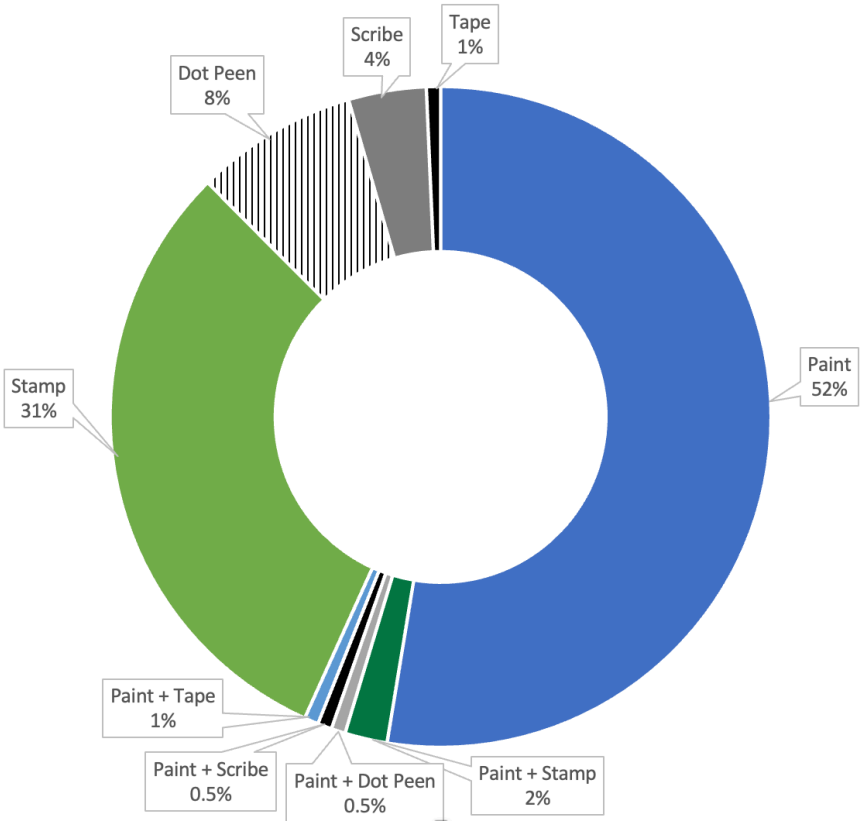


Figure 10-13: The different types of additional concealment seen in the entire dataset of obliterations documented around the world (n=289).

10.4 Discussion

This section aims to present the results of all five regions assessed in this thesis in a comparative manner, to understand the nuances of the results obtained in different parts of the world, as well as to assess the efficacy of using the novel obliteration code system presented in this thesis for investigations.

This discussion will present key findings and critical examples that highlight key differences between conflict-afflicted regions and developed countries. The prevalent weapon types and tools used to obliterate their identifying marks will be discussed, in addition to the extent of obliteration and measures taken to conceal the area of obliteration on the firearms. Finally, a conclusion on the revolutionary application of this novel obliteration coding system will be presented.

10.4.1 Cluster and Obliteration Analysis

The coding of obliterations using the proposed methodology in Chapter 4 allowed for the objective toolmark analysis of 1136 firearms and generation of 125 clusters. These clusters can be easily filtered using the generated ArcGIS Dashboard. The Dashboard enables the five categories of analysis to be selected from drop down menus. The obliterations that match the code specified appear in a list, allowing side-by-side comparison. This strategic approach serves as a mechanism to limit the number of comparisons required to ascertain if two obliterations share a common source. The results section of this chapter highlights a few key examples and will be discussed below.

The obliteration code 1.0.1.2.0 is a very generic code, in the sense that a popular tool was used (grinder) to remove only the serial number from left to right, with no additional concealment efforts. In total, 78 weapons were documented around the world with this code, and therefore were in a shared cluster. Given the prevalence of this obliteration code across the world, it is expected that there may be a high level of visually dissimilarity in the cluster. Seven obliterations are

shown in Figure 10-3, which were each documented in different countries, show this level of dissimilarity. In these larger, more generic clusters, the sharing of obliteration codes may indicate similar techniques, or be coincidental due to the simplicity in the features. For this reason, individual examination by trained examiners must be conducted to compare all obliterations within each cluster.

In contrast, the second example shown in Figure 10-5 highlights the use of a rotary tool to remove the serial number, factory mark, and model from firearms only documented in Mali, Niger, and Syria. Upon comparison and findings of extreme similarities, the author inquired with the field investigators at CAR about their provenance. Their confirmation of common source established that each of these weapons was held by ISIS members and used during attacks on high-profile government buildings in the respective regions. This shows that, at some point, in the history of each of these weapons, they were likely held by a common node within the ISIS network and were likely sanitised before being distributed to those conducting the attacks. The sharing of obliteration codes, and more importantly the visual similarity within these clusters, across borders truly highlights the shared supply networks. The presence in two different continents further proves the geographical spread of terrorist organisations like ISIS, their ability to cross porous borders with illicit weapons unhindered as well as the possibility that some form of criminal syllabus is being shared across the network, to educate illicit actors on how to conduct obliterations. This finding highlights how critical the application of this methodology is to intelligence-based investigations of sanitised firearms tracing operations.

The final example in the results section of this chapter (Figure 10-6) shows examples of obliteration codes shown across borders of non-conflict-based countries. The serial numbers in each of these firearms has been drilled out of the frame. Intuitively, this approach safeguards the integrity of the structure of the firearms, while also ensuring no forensic recovery of the digits would be possible. As mentioned in previous chapters, the advance level of sanitisation noted in the

UK, Canada, and Australia indicate higher levels of forensic awareness, access to complex equipment, and therefore increased levels of technical ability.

10.4.2 Weapon Types

Considering the legal firearms ownership allowances in each region, and the justifications for civilians owning different types of firearms, the specific types of firearms documented in each region may aid in the final conclusions relating to regional drivers to anonymise weapons.

Two main findings have been noted. First, the presence of assault rifles, both AK-pattern and others, are predominantly documented in the Middle East and Africa, while the prevalence of these firearms diminishes in Canada and the UK, where there are more strict firearms laws in place for civilian ownership and no recent conflict event which could lead to the leaking of military grade materiel into domestic illicit markets. Secondly, a noted presence of blank firing pistols, handguns, and shotguns in these developed regions indicates their ease of access, while the absence in conflict zones insinuates limited utility. The types of weapons are highly indicative of the demand required by the illicit market, and by extension the intended use. Firearms intended for insurgent attacks in conflict zones will primarily be longer range, higher rate of fire assault weapons, whereas the criminal markets in developed countries need to be easily concealed and transported.

It is evident that there is a higher documentation rate of handguns in regions where civilian ownership is permitted with the correct licensing. Despite the strict controls in Canada, the UK, and Australia, handguns comprise a large amount of the sanitised market. This is likely due to ease of access once an individual does have authority to purchase a handgun. Intuitively, the more abundant a weapon type is, the more subject to proliferation and diversion it is. This is analogous to the diversion and sanitisation of assault rifles in the conflict zones discussed in

this thesis, where weapons used by military and police forces are those which are primarily diverted due to the vast number in circulation.

An unexpected finding was the artisanal weapons documented in the Middle East with obliterations. This was discussed in detail in Chapter 6, however, is important to note in the global evaluation of weapon types as well. Considering these weapons are manufactured illicitly, they would be untraceable by nature and so the removal of identifying marks is unnecessary. This may indicate that the artisanal weapons produced in the Khyber Pass are of sufficient quality that they convince those who purchase them that they are of legitimate manufacture and must be sanitised to avoid tracing operations.

10.4.3 Tool Types

The two most prevalent tools for the obliteration of identifying marks from firearms are grinders and rotary tools. This is shown in Figure 10-8, where the tool types used in each region are shown as a percentage of the total number of obliterations in the country or region. The only country where a grinder or rotary tool is not the most prevalent tool used was found in the UK, where hand files are more commonly documented. As mentioned in previous chapters, the ease of access and use, as well as rapid, effortless obliterations make the grinder and rotary tools advantageous in firearm sanitisation. There is a disparity noted between the two tool types, however, in that grinders are favoured in conflict-afflicted regions, while rotary tools are favoured in the more developed regions. This is likely due to the prominent weapon types being sanitised in each of these regions. The rotary tools are much smaller and better suited for small areas of obliterations, akin to handgun frames compared to the larger surface area offered by a grinder. Grinders are less precise and cannot achieve the same level of accuracy as a handheld rotary tool, hence are better suited to sanitise larger firearms such as rifles.

It must be highlighted that welding surpasses even the popularity of grinders within the UK. This is most likely linked to the dual-purpose of machining shops, as well as the higher level of forensic awareness. Criminal actors are aware of chemical recovery efforts and understand that the application of material during the welding process will hinder these attempts.

Intuitively, the more laborious obliteration methods such as nail punching, stamping, sandpaper, and acid etching are unanimously less prevalent in all regions of the world. The goal of firearm sanitisation is often to quickly remove identifying marks from the firearms to avoid investigation. In some cases, high number of firearms being “batch sanitised” would limit the methodology and tools used. Even when only individual firearms are being anonymized, the less effort criminals need to expend, the more likely they will be to use those tools.

Conversely, it was surprising to find the removal of steel insert plates in polymer frames was only documented in the Australian dataset. This is a very simple method for removing serial numbers from these pistols, and it is surprising that this method had not been documented elsewhere. However, limited access to entire datasets from each country and jurisdiction may have contributed to this lack of data. Unfortunately, due to the opportunistic method of data collection, many sanitised firearms that are potentially in circulation may not be represented in this thesis.

Finally, the firearms documented with natural abrasion were documented in four out of the five regions, excluding Canada. The highest number of instances was noted in Africa, where weapon stockpiles are known to suffer from poor conditions. In developed regions like the UK, natural abrasion was not documented as often. In fact, the only two cases where natural abrasion was coded in the UK was on two pistols that had been seized in criminal investigations and recovered from being buried underground for concealment.
Overall, the types of tools and methods used to remove identifying marks from weapons changes when considering weapon types and geographical region of

focus. The tools that require more training, space, and financial support are more commonly used in more developed parts of the world, compared to hand tools and those easily acquired and operated. This reflects local technical ability, access to tools and equipment, forensic awareness, and potentially PSSM resources. Further data collection would enhance the understanding of these nuances.

10.4.4 Regional Drivers

Across all five regions of interest in this thesis, the majority of weapons were not completely sanitised; 74% were coded as “incomplete”. This implies that the comprehensive removal of all identifying marks was not a global priority, and the obliteration of some key marks (namely the serial number) was more common. Additionally, in four regions, partial sanitisation was more prevalent than complete sanitisation. Partially sanitised weapons exhibited the removal of marks to a shallow depth, enabling the visualisation of the marks despite attempted obliteration. However, the exception noted within the UK showed a larger number of completely sanitised weapons than partially sanitised.

The aim of sanitisation of weapons in the conflict zones of Africa and the Middle East appear to be twofold. Primarily, actors aimed to obscure the origin of the weapon, and secondarily aimed to anonymise the individual weapon. This nuance insinuates that the prevention of tracing captured or diverted weapons to their original source was paramount for the illicit networks. The motivation behind this strategy is likely to safeguard corrupt actors within State-organisations, who operate in part to provide weapons to the illicit networks and terrorist groups. A parallel can be drawn to developed, crime-based regions. The justification for sanitising weapons in countries like Canada, the UK, and Australia is to protect procurement chains, cross-border sources, and specialist workshops servicing the needs of numerous criminal enterprises. The distinction between the two different objectives lies primarily in the nature of the actors; while those in

developed countries exhibit criminalistic motives, terrorist organisations exploit corruption and fear both within and outside of their networks.

The analysis of removed marks presented in the results section of this thesis reveals that the serial number is universally the most obliterated mark from firearms across the world. The serial number is the most valuable mark to both forensic and tracing operations, due to it being the only unique identifier on a firearm. Interestingly, the factory mark was the second most removed mark in conflict zones. The author believes this is because of the underlying motivations to conceal the identity of firearms in these regions, and the need to undermine tracing operations to the origin of the firearms.

Further examination of the specific marks removed from the firearms in each country showed interesting results. The manufacturer, calibre, and fire selector mark were rarely removed, unless part of an obliteration that completely sanitised the weapon. Also, the serial numbers were typically obliterated entirely, except in African countries, where many cases of parts of the serial number remained sufficiently intact as to be legible. This indicates a possible lower level of technical knowledge on both forensic processes and tracing operations.

Only a global level, 25% of obliterations showed some attempt at additional concealment, indicating a lack of motivation to camouflage the obliterations and tool marks. The most common method of concealment, when documented, was black paint, likely owed to the ease of access globally and cost-effectiveness. Additional concealment methods like over stamping, dot peening, scribing, or taping over obliterations were observed in 32% of cases. In previous chapters, it was suggested that some of these marking methods may be used by State-bodies and are used for “rebadging” weapons legally for introduction into their own stockpiles and personnel [personal communications, CAR investigators]. On the other hand, it was also noted that these methods were also used on artisanal weapons produced in the Khyber Pass to increase the monetary value of copied weapons [personal communications, CAR investigators].

10.4.5 Crime, Conflict and the Impact of Corruption

There is an apparent correlation between the level of corruption in a region and the primary cause of disruption (crime or conflict), indicated by the relationships between GCI and ESGI.

Table 10-1 outlined the scores of the countries of interest in this thesis on the GCI and ESGI (GCI having been discussed in the previous regionally focussed chapters). The scores of the three countries affected primarily by criminal enterprise rather than by armed conflict are considerably lower than the countries in Africa and the Middle East. Together, these indices consider the role of government corruption, perception of civilian safety, border porosity, arms trade, and levels of violence, to create a broad understanding of how levels of corruption can create the permissive environment necessary to facilitate illicit SALW trafficking. This data can be extrapolated to infer the motivation by illicit actors to conceal the identity of weapons through removing of their identifying marks.

Canada, the UK, and Australia score within the lowest 14 of 196 countries on the GCI and the lowest 28 of 183 countries on the ESGI. In all three countries, the levels of corruption are low, and the perception of civilian safety is generally high amongst the populations. As previously discussed, while crime rates and civilian firearms ownership (as well as the laws that govern it) vary in each country, the indices reflect the low levels of corruption and organised crime. This is likely to indicate that the sanitisations conducted in these three regions are more likely to have been conducted by individuals involved in criminal firearms activity, compared to what has been documented in Africa and Middle East and as such may prove a useful metric to monitor when assessing the various risks posed by criminal or state-level corrupt practices.

In contrast, the GCI and ESGI index scores for the countries in Africa and the Middle East, the two regions used to demonstrate the role of conflict on weapon sanitisation in this thesis, are very high. Syria, for example, ranks as the highest

scoring country (that is, the most corrupt) on the GCI, followed closely by Afghanistan and Iraq. A similar trend is shown in the ESGI, where the 5 countries in the Middle East rank within the top 70 poorest countries. Within Africa, all countries besides Ghana (ranked 80) belong to the top 60 most corrupt countries around the world. The ESGI also ranks the African countries within the top 50 ranks, showing a low quality of life as perceived by the public. These rankings show that the level of corruption in the region is very high, which aligns with conclusions made in this thesis that many weapon sanitisations may be either conducted by government, police, or armed force members through PSSM diversion, or enabled by these same members during import, transit, or export. Batch sanitisations are more common due to the ease of access to legal stockpiles.

10.4.6 Application of Codes to Investigations

The impact and usefulness of individual codes is not dictated by the size of the cluster alone, as alluded to in the Results section of this chapter. The context of the tool types, weapon types, and affiliation with crime or conflict will aid in determining how strong the link may be between weapons within one cluster.

As noted previously, common types of tools are often included in large clusters. This may lead investigators to believe all weapons within those clusters are potentially related in origin, however, as the tools such as grinders and rotary tools are used across the world, this may not be the case. In these clusters, human investigation will be required to further isolate weapons that have *visually similar* obliterations for further investigation.

Smaller clusters are more likely to show more unique features in the obliterations, whether only specific marks are removed, or particular concealment techniques are used. This may indicate that smaller clusters with few weapons should be more likely to show connections.

Within these small clusters, the types of weapons and their provenance will be of great value to investigators. If all weapons in one cluster are similar or identical, with each being found in commission of a similar incident, the investigative value of the shared obliteration code increases. This type of scenario was highlighted in Figure 10-5, where a group of weapons were all within one cluster, and then linked to similar acts of terror by one terrorist organisation.

The application of obliteration codes during investigations must be done with care and attention to detail. The confirmation of similarity must be done through human intervention as a matter of quality assurance and accuracy.

10.5 Conclusions

This chapter has presented a comparative analysis of obliterations documented on weapons seized in both conflict zones and developed, but crime-based, societies. The practicality of filtering a multitude of obliterations into small, manageable, visually similar clusters is of great benefit to tracing and criminal investigations. The application of novel obliteration codes to international investigations has shown to be an incredible tool to inform intelligence operations, both within criminal investigations by police forces, and tracing operations globally.

The assessment of tools used, marks removed, and presence of additional concealment measures aided the generation of insights on the regional drivers for obliterations. The significance of removing the serial number lends to both forensic investigations in developed nations, as well as impeding tracing operations across conflict zones. The concealment of the obliterations is not common globally, however, overmarking may indicate re-purposing of captured firearms, or the intent to increase monetary value of artisanal weapons. The author believes that this shows a greater impact of the technological advancement available in a region, compared to the local forensic capability or awareness. Further analysis may be required to better understand these observed trends.

11 Conclusion

This research was concerned with the global intelligence-based investigation of obliterated serial numbers having shown that recovery is not always possible with destructive nor non-destructive techniques. This thesis initially reports on the efficacy of the non-destructive recovery of serial number using an emerging technique and how it compares to the current standard forensic methodology. Having highlighted this, the thesis then addressed the research gap in the intelligence investigation of these untraceable firearms by proposing a new codification system for weapon sanitisation investigations that was designed to be accessible and applicable to any country or jurisdiction around the world.

To investigate Hypothesis 1 (*The ECK will provide a statistically comparable solution for obliterated mark recovery to Fry's reagent for use in both forensic labs and the field*), the first section of this work aimed to understand if the proposed ECK is as effective as the current standard recovery method (Frys' reagent) used in forensic analysis. The work contained in Chapter 3 of this thesis proves that the ECK was more effective than Fry's reagent when recovering marks applied to steel sheets by 22%, or similarly thin and flat firearm components. However, when the geometry of the firearm is complex, the ECK is not as effective. Similarly, if the application method of the marks does not alter the microstructure of the material suitably, the ECK is not able to detect the minute levels of microstructural changes. This is not a detrimental result, as Fry's reagent was shown to also be ineffective, and in fact destructive, in these cases. This portion of the project highlighted a research gap and the loss of investigative intelligence, due to the inability to retrieve obliterated information. This gap led to the development and introduction of a novel codification system, designed to examine the toolmarks found in the obliterations as a source of intelligence. The results from this codification tool adds a novel contribution to the current knowledge on obliterations and obliteration techniques around the world.

The boundaries of current weapon sanitisation investigations were therefore expanded once again by placing obliterations into discrete, non-subjective categories, which enables direct comparison of similar techniques to isolate potential links in origin. This concept, although historically used in other fields of forensic investigation [108], has not been applied to firearms examinations until now.

In Canada, Australia, and the United Kingdom, the combination of obliteration trends and criminalistic practices suggest that the motivation to conceal a firearm's identity is likely to be to protect both the illicit facilitation routes along which firearms transit from abroad, and the identity of local smuggling networks or gunsmiths conducting conversion and modification work. The same cannot be said for conflict-afflicted regions across Africa and the Middle East. In these regions the goal is more likely to be to reduce the traceability of firearms diverted from State-held stocks, ensuring that illicit actor obscure the vulnerable weapon stocks they retain access to, and to protect corrupt state-embedded actors engaged in criminality.

Concerning Hypothesis 2 (*The obliteration coding system presented in this work will be able to aid the identification of where an obliteration was conducted, when coupled with intelligence on regions around the world*), while general trends were noted in each region or country of interest, the presence of obliteration codes in one region alone was not strong enough evidence to isolate the geographical source of the sanitisation. However, when used in addition to other forensic evidence and tracing investigation context, the obliteration codes provide an additional piece of objective toolmark-based evidence that previously has not existed. This highlights the value in continuing to build the dataset fed into the obliteration coding system in the future. By continuously adding observations, the conclusions within and between individual countries and regions can be strengthened.

Key findings from the regionality and tracking of obliterations are as follows:

- 81% of weapons analysed in this research were able to be clustered using the developed codification system, many of which cross international and regional borders. 923 weapons were placed into 125 discrete categories using the developed codification system presented in Chapter 4.4 (Code Outline), allowing for direct, objective comparison.
- The types of weapons sanitised in a region will reflect the weapon sources and regional drivers to conceal the identity of the weapon. Handguns and shotguns were more prevalent in developed regions due to legal civilian ownership and easy concealment. These types of weapons are sanitised to protect supply chains and cross border sources. In comparison, conflict-afflicted regions show a prevalence of AK-pattern rifles and artisanal weapons, which are commonly used in violent extremist attacks and terror activity. These are sanitised to obscure the origin of the weapon and impede tracing operations.
- The tools used in each region reflect the technological advances and ease of access to various types of tools. More advanced and permanent methods of mark obliteration, like welding, milling, and extensive drilling are depended on in developed regions such as Canada, the UK, and Australia when compared to marks obliterated in Africa and the Middle East, which are often shallowly removed using basic hand tools like grinders and rotary tools.

11.1 Limits and Assumptions

As with any research, there are unavoidable limitations to consider in this study. Each section (obliterated mark recovery versus obliteration trends and regionality) is subject to different constraints.

The investigation of the non-destructive recovery of obliterated marks is affected by the technology itself. As the primary researcher did not develop or patent the

ECK, no changes could be made to the hardware or software. As the ECK has not been used, to date, in forensic firearms investigations or in non-permissive environments, the identification and assessment of weaknesses and limitations of the technology allow this to still be a novel contribution to the field.

Access to the physical collections of firearms is another limiting factor for the ECK portion of the study. In the investigation into the “real life” application of the ECK, true firearms with obliterations were required for comparison with the findings using the standardised steel plates. Due to the nature of the firearms collections, only firearms with pre-existing obliterations could be tested, resulting in a limited dataset.

Regional obliteration assessment was restricted to a finite dataset of firearms held within accessible collections. The EPS and the NSWPF were able to share intelligence through photographs of sanitised firearms within their database. Due to potential ongoing criminal investigations, limited context and provenance was available for these firearms. These regions within North America and Oceania are home to police forces that operate in high population density regions in developed countries; therefore, the results may be applicable to other similar regions around the world, such as parts of Europe or the USA, for example. In addition, complete access to an entire database of weapons documented in multiple conflict zones by a research organisation was accessed for analysis. As the organisation has been in operation for 12 years (at the end of this project), this database is extensive and covers many conflict-afflicted regions highlighted in Figure 1-1. While the obliterations examined in this work were analysed by myself after working with toolmark analysts, the obliterations were documented by others working in the aforementioned police units and research organisations. This limited the analysis to 2-dimensional photograph analysis, without having access to the actual firearms.

Finally, there are instances where the obliteration codes match, however the obliterations are not visually similar. For example, the cluster 1.0.1.2.0 is very large and contains 78 weapons around the world, and common tools were used

(in this case a grinder) to create the obliterations. Three weapons held in this is cluster are shown in Figure 11-1 as an example.

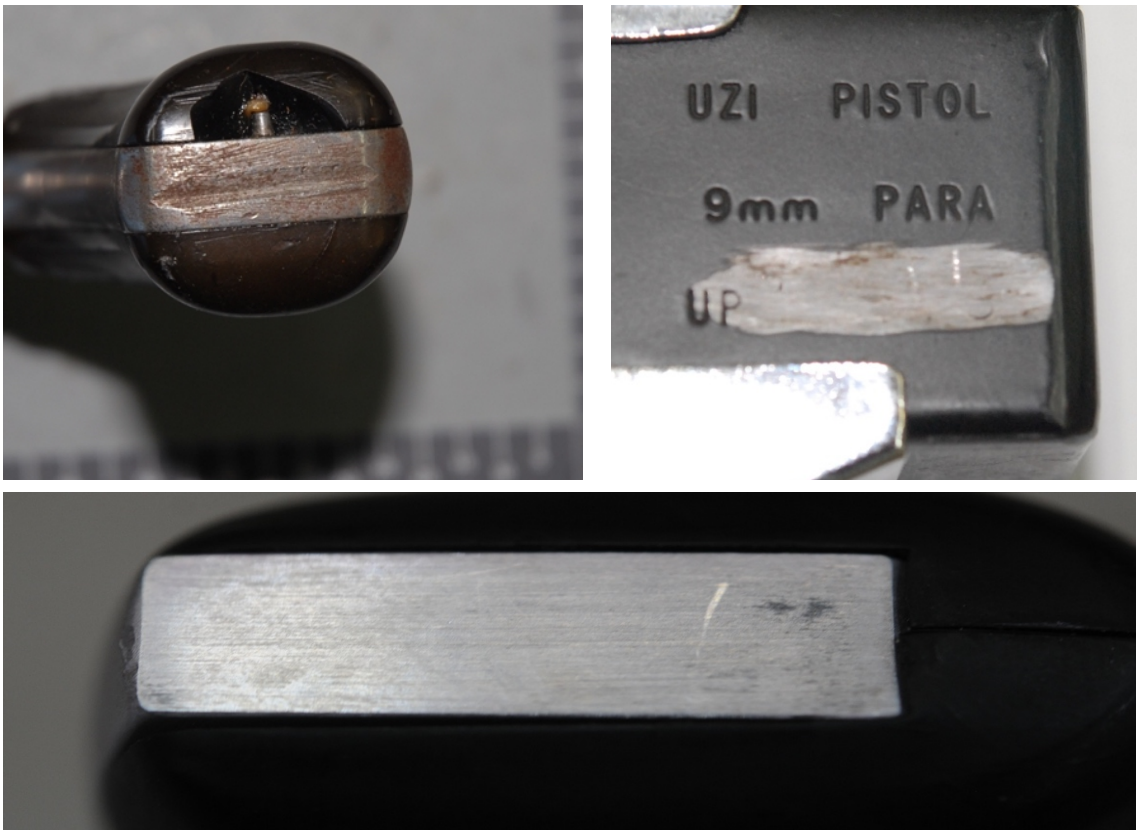


Figure 11-1: Three weapons in the same obliteration cluster that are not visibly similar.

The codification methodology allows for a smaller number of obliterations to be compared from the outset as shown within this research. However, due to the limitation stated above, human intervention is required to analyse the specific obliterations on a case-by-case basis to remove any out-liars and anomalies.

11.2 Future Work

The work presented in this thesis should be continued in the future. Both the recovery technique and the codification system, although strong, have areas that can be improved upon. These are presented below, presented as long- and short-term goals and projects.

11.2.1 Short Term

Throughout this project, the additional concealment of obliterations using paint has inspired the question "*can the chemical analysis of paint identify the source?".* Future projects will aim to answer this, with paint samples already being taken and analysed from weapons documented in Northeast Syria and West Africa, as presented in Chapter 5. This work on additional samples may be undertaken by future MSc and PhD work in years to come.

While the obliteration coding system is robust, especially considering this is the first iteration of the system, improvements should be made in the future to include weapon component parts and consideration of the model of firearm to address the final limitation presented in the previous section of this chapter. The addition of these factors would fill a research gap identified in this work and ensure that obliterations across various models of firearms are not separated based solely on the location of certain marks. Should the frame of the firearm hold the factory, model, and serial number, it would not be automatically isolated from a firearm of the same model but showing the year and serial number, despite having a visually identical obliteration.

Another consideration for future work is the weighting of the factors given in the obliteration code depending on the jurisdiction of interest and purpose of use. For example, where the evidential value of the obliteration is critical for the prosecution of an individual involved in a weapons crime, the directionality and additional concealment may be weighted higher than the type of tool used due to

the individualistic nature of the toolmarks. In contrast, if the intelligence value is higher to isolate weapon trafficking organisations, the general tool type and marks removed would be weighted higher.

11.2.2 Long Term

Refinement of the ECK settings and parameters would allow for more systematic examination of evidence, enabling standardised recovery and potential for integration into ISO certification for forensic practitioners. By working with the manufacturer of the kit, the hardware can be improved to enable more flexible scanning. Additionally, the strength of the magnetic field and eddy current pulses must be more accurately quantified.

As part of a large international effort, the results in attempting to recover laser engraved marks are being presented and included in liaison with international bodies such as the UN and ATF to ensure the requirements of international guiding policies are being upheld. Of primary concern is the ITI, and the requirement for serial numbers to be “recoverable” despite this research proving laser engraved marks to be irretrievable once obliterated.

Finally, one of the main intentions with the codification system is to integrate the framework into big-picture, global investigations. Investigators around the world will be able to utilise the knowledge gained from this research and employ the innovative codification tool during both criminal and weapons tracing operations. A key benefit of this codification methodology is the ability to apply it to samples regardless of their location. The photography of obliterations around the world has enabled this study to expand at a rapid rate and would continue to allow the dataset to grow and reach investigators globally. As the codification method does not require the physical weapon, it allows police organisations and forensic investigators to maintain the chain of custody while still gaining valuable intelligence. The first step to this global initiative is to report the findings of this work to the agencies who provided the photographs of obliterations documented

around the world and present the system to them as stakeholders and potential users. Each agency has requested a report of the findings specific to their region for review, which will be completed within six months of submission of this thesis.

11.3 Summary

Two recovery techniques for serial number obliteration analysis and investigation have been compared in this thesis: one industry standard chemical etchant (Fry's reagent), and one emerging technology. Dot peened marks applied to 90 steel plates showed 60% recoverability using Fry's reagent, and 82% using the ECK. The laser engraved plate samples showed no recoverability by either method. An additional 11 firearm components were used to test the ECK, each with multiple marks applied using stamping techniques, mechanical engraving, and laser engraving. 100% of the marks applied by stamping or engraving were recovered after obliteration, while 0% of the laser engraved marks were recovered. The use of the ECK will allow investigators to conduct field-based mark recovery, without concern for the technician's health and safety or implicating the integrity of the evidence, while maintaining high levels of successful recoveries, surpassing the current industry standard.

When recovery is not an option due to the extent of obliteration or access in non-permissive environments, the analysis of an additional 1136 obliterations using the novel coding system developed in this work enables the clustering of similar obliterations documented in an area. When these obliterations show similarities within one region, intelligence can be gained and added to the investigation into the complex criminal or violent extremist groups responsible. Further, global comparisons and linkages with similar weapon sanitisation marks around the world can be made to create intelligence-based evidence for large-scale investigation support. 125 unique clusters with 923 weapons were established in this research, with 82 of these clusters crossing international and continental borders resulting in furthering the possible levels of global forensic investigation. This type of objective toolmark analysis has never been presented in the firearms

examination profession, therefore filling a large research gap on the tracking of weapons that have been rendered untraceable through criminal activity and will provide revolutionary pathways for future investigations.

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Appendix A Ethical Approval Letter

14 November 2020

Dear Miss Henwood ,

Reference: CURES/12286/2020
Title: A multi-faceted approach to the analysis of weapons recovered in combat zones to differentiate fake from genuine production, and identify patterns of mark obliteration and other common points of alteration

Thank you for your application to the Cranfield University Research Ethics System (CURES).

We are pleased to inform you your CURES application, reference CURES/12286/2020 **has been reviewed. You may now proceed with the research activities you have sought approval for.**

I would like to apologies for the delay in getting this decision to you as I was waiting for feedback from the review team.

If you have any queries, please contact CURES Support.

We wish you every success with your project.

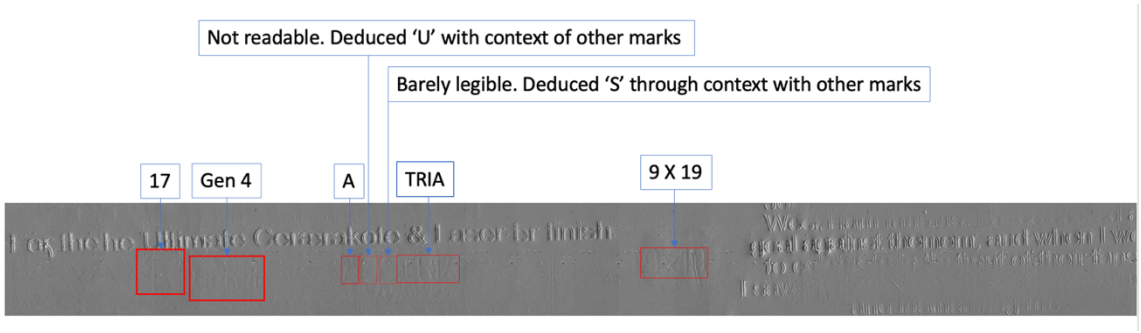
Regards,

CURES Team

Appendix B External Expert Examination of Magneto-Optical Image

This appendix provides the feedback from firearm examiners regarding their examination of a magneto-optical image of the Glock slide, which is Figure 3-20.

Participant 1



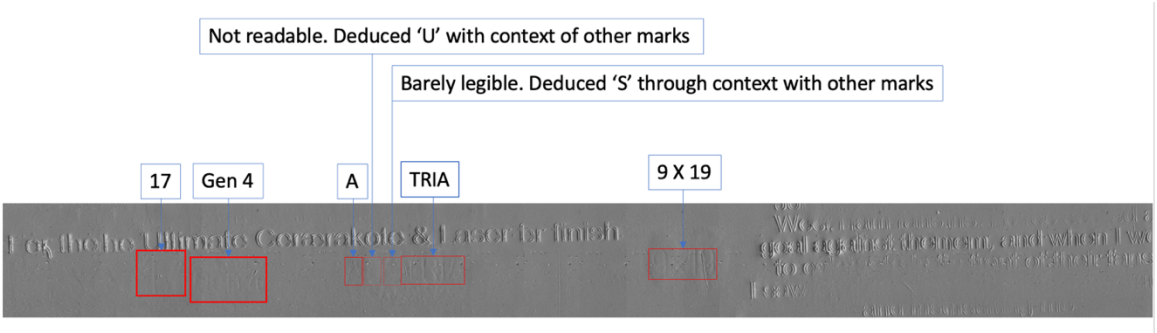
Participant 2

Participant 3

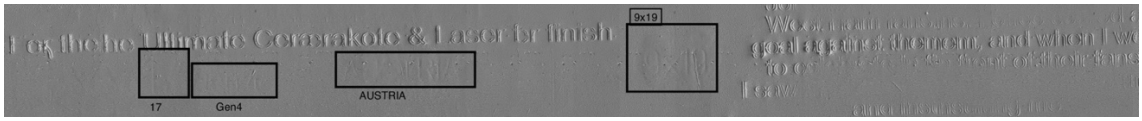
Participant 4

Participant 5

Participant 6



Participant 7



Appendix C Global Obliteration Code Clusters

AU: Australia	AF: Africa	BH: Bahrain	BJ: Benin
BF: Burkina Faso	CA: Canada	CI: Cote D'Ivoire	GH: Ghana
IQ: Iraq	ML: Mali	NI: Niger	NG: Nigeria
SA: Saudi Arabia	SO: Somalia	SS: South Sudan	SY: Syria
UK: United Kingdom	CD: Dominican Republic of the Congo		

Code[7]					Country and Number of Weapons
T	S	M	D	C	
1	0	1	1	2	IQ (1), SY (37)
1	0	1	1	0	AU (5), CA (3), NG (1)
1	0	1	2	4	AU (1), IQ (1)
1	0	1	2	3	AF (1), NI (1), SY (3)
1	0	1	2	2	AF (3), AU (1), BF (3), SA (1), SO (3), SY (3)
1	0	1	2	1	AU (1), CA (7), IQ (1), UK (1)
1	0	1	2	0	AF (1), AU (42), CA (11), GH (2), ML (2), NI (1), NG (1), SOM (11), SY (3), SY (3), UK (1)
1	0	1	3	0	AU (1), BF (1), CA (2), GH (1), ML (1), UK (1)
1	0	1	3	0	CA (2)
1	0	1	4	2	AF (2), AU (1)
1	0	1	4	1	CA (3)
1	0	1	4	0	AU (9), CA (6), NI (1), SY (2)
1	0	1	5	0	CA (3)
1	0	1/5/6	2	0	SY (2)
1	0	1/5/6	2	1	BJ (2), IQ (1)
1	0	1/5/6	2	2	IQ (1), SY (6)
1	0	1/5/8	1	0	GH (1), SY (1)
1	0	1/5/8	2	0	BH (1), GH (2), NI (1), SS (1)
1	0	1/5/8	2	1	NI (2), SS (3), SY (1)
1	0	1/5/8	2	2	AF (1), SY (2)
1	0	1/5/8	2	3	SY (7)
1	0	1/6	1	0	ML (1), NG (1)
1	0	1/8	1	1	SY (2)
1	0	1/8	2	0	AU (4), CAN (1), GH (1), UK (1)
1	0	3/4	4	0	AU (1), CA (1)
1	0	2	4	0	SO (17)

[7] T: tool type, S: level of sanitisation, M: marks removed, D: directionality, C: additional concealment. See Section 4.4 for full details.

1	0	4	4	0	AF (1), SO (1)
1	1	0	1	0	AU (2)
1	1	1	1	0	AU (1), CA (1), SY (1)
1	1	1	2	0	AF (2), AU (7), CA (4), NI (1), SY (2)
1	1	1	4	0	CA (1), SY (1)
1	1	1	2	0	CA (4)
1	1	1/5	2	0	BF (1), CA (1)
1	1	1/5/8	3	0	BH (1), SS (1)
1	1	5/8	2	0	BH (3)
1	1	¾	2	0	AU (3)
1	2	0	0	0	CA (4)
1	2	0	1	0	AU (3), CA (2)
1	2	0	2	0	AU (5), CA (4)
1	2	0	4	0	AU (1), CA (1)
1	2	1/5/8	1	0	BF (1), IQ (1)
1/11	0	1	1	1	CA (2)
2	0	1	1	0	AU (14), CA (12), SY (1)
2	0	1	1	1	AU (1), CA (3), IQ (1)
2	0	1	1	3	BH (3)
2	0	1	2	0	AF (2), AUS (43), CA (48), NI (1), SY (1), UK (2)
2	0	1	2	1	AU (3), CA (10), SA (1), UK (25)
2	0	1	2	2	AF (3), SY (1)
2	0	1	2/4	0	AU (2), CA (2)
2	0	1	3	0	CA (3), NI (1)
2	0	1	4	0	AU (6), BH (1), CA (2)
2	0	1	4	1	CA (1), IQ (1)
2	0	1	5	0	CA (1), IQ (1)
2	0	1/5	1	0	GH (1), NI (1)
2	0	1/10	2	0	AU (2), CA (2)
2	0	1/10	2	1	CA (3)
2	0	1/5/6	2	0	AG (1), UK (1)
2	0	1/5/6	2	2	AF (1), NI (2), SY (1)
2	0	1/5/8	0	3	CI (1), SO (1)
2	0	1/5/8	1	1	BJ (1), SS (2)
2	0	1/5/8	2	0	CD (1), ML (2), NI (1), SY (11)
2	0	1/5/8	2	1	BH (1), ML (1), NI (2), SS (1)
2	0	1/5/8	2	2	IQ (1), SA (1)
2	0	1/7	2	0	SO (11)
2	0	5/8	2	0	ML (1), SO (6)
2	0	5/8	2	1	SO (17)
2	0	5/9	2	1	NI (2), SO (16)
2	0	8	0	0	NI (3)
2	0	8	2	1	UK (2)

2	1	0	1	0	AU (2)
2	1	1	1	0	AF (1), AU (5), CA (6), SY (1)
2	1	1	2	0	AF (1), AU (16), CA (9), NI (1), SY (1)
2	1	1	2	2	CA (1), IQ (1)
2	1	1	4	0	AU (1), CA (1)
2	1	1/5/8	2	0	ML (2), NI (1)
2	1	3	2	0	AU (1), CA (2)
2	2	0	1	0	AU (5), BH (2), CA (1)
2	2	0	1	1	CA (3)
2	2	0	2	0	AU (5), CA (2)
2	2	0	4	4	BH (6)
2/6	0	1	2	0	AU (2)
2/7	0	1	2	0	AU (2)
2/8	0	1	2	0	AU (2)
2/11	0	1	2	0	AF (1), AU (1)
3	0	1	1	0	AF (1), AU (4), BF (1), CA (3), NG (1), SO (1), SY (1), UK (1)
3	0	1	1	1	AU (1), IQ (1), NG (1)
3	0	1	1	2	AF (1), BF (1), IQ (1), UK (1)
3	0	1	2	0	AU (1), CA (1)
3	0	1	4	0	CA (1), UK (1)
3	1	1	1	0	AF (1), AU (4), BF (1), CA (6), NG (1), UK (1)
3	1	1	2	0	AF (3), AU (1), CA (4), NG (1)
3	1	1/5	1	0	NG (2)
3	1	1/5/6	1	0	IQ (1), ML (2), NG (1)
3	2	0	0	1	UK (3)
5	0	1	0	0	AU (1), UK (2)
5	0	1	2	0	SY (3)
5	0	1/6	2	0	SY (2)
5	2	0	2	0	SOM (1), UK (1)
5/6	0	1	1	0	AU (2)
5/11	0	1	2	0	AU (2)
6	0	1	0	0	AU (1), CA (1), UK (1)
6	0	1	1	0	AU (2), CA (1),
6	0	1	1	2	SY (3)
6	0	1	2	0	AU (18), CA (3), UK (2)
6	0	1	2	1	AU (1), CA (1)
6	0	1	2	2	AU (3)
6	0	1	2/3	0	AU (3)
6	0	1	3	0	AU (9)
6	0	1/8	3	0	UK (3)
6	0	1/10	3	0	UK (2)
6	0	7/8	0	0	NI (1), NG (1)
6	1	1	2	0	AU (4), CA (1)

6	1	1/7	0	0	NG (4)
6	1	1	2	0	AU (5)
6	2	0	2	0	CA (1), UK (1)
6	2	1/8/10	0	1	SY (10)
7	0	1	0	0	AU (21), CA (3), UK (2)
7	0	1	2	0	AU (2), CA (1)
8	0	1	0	0	AU (17)
8	1	1	0	0	AU (6)
8	1	3/4	0	0	AU (2)
11	0	1	1	1	AU (3)
11	1	1	1	0	AU (2)
12	0	1	0	0	SY (3)
12	0	1	0	0	AU (8)

Appendix D Conference Paper: International Symposium on Ballistics, 2022

Serial Number Recovery Techniques on Steel Plates; Fry's Reagent and Eddy Current Technology

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SUMMARY

The recovery of obliterated serial numbers is a common process involved in the forensic analysis of firearms confiscated in criminal cases. The current standard method of recovery involves the use of chemical reagents which are highly destructive to the material. The destructive process does not allow subsequent analysis, nor does the test always recover the serial number completely. A new technology that utilizes eddy currents and magnetic fields to recover serial numbers without the use of chemicals has been proposed to allow for an almost non-destructive recovery. This research has shown that the use of eddy currents and magnetic fields is a promising technique for obliterated serial number recovery and that further research may indicate it is a suitable replacement for the currently used Fry's Reagent.

Many criminal organizations attempt to hide the identity of Small Arms and Light Weapons (SALW) so they cannot be traced to a place of manufacture or the last legal owner or consignee. The most obvious way to obscure the identity of a genuine-production weapon is to remove all traces of the manufacturer's information. It is, therefore, not uncommon to find serial numbers and other manufacturer marks obliterated during both forensic investigations and illicit weapons tracing efforts [1]. Serial numbers are typically positioned on the frame, barrel, and slide, if applicable, as these are the major components of the weapon [2, 3]. Licenced manufacturers ensure their markings are made to a specific standard using various tools and techniques which include dot peening, lasering and stamping, as seen in Figure 1. The marks analyzed in this preliminary study will be restricted to serial numbers, as they are the most commonly marking that is obliterated in the field.

Figure 1. Three methods of serial number and mark application. (A) Dot peening, (B) Laser engraving, (C) Stamping. All photographs courtesy of Conflict Armament Research.

If the marks are applied using physical force, such as stamping and dot peening, the alteration to the layers of material directly below the mark exhibit localized property changes [4, 5], as shown in Figure 2. If a stamped or engraved serial number is obliteration by criminal organisations, it is likely that microscopic changes in the underlying material would still be present. Much to the detriment of forensic exploitation, it is less likely for recovery to be possible when the original marks are applied via laser, as the affected zone is much smaller and only the material directly adjacent to the beam is altered [4]. Simplistic methods of obliteration include removal by hand tools, such as screwdrivers and simple power tools, such as Dremel® tools or grinders. When marks are obliterated by these tools, the damage often does not penetrate sufficiently deep to eradicate the microscopic changes to the material under the original serial number. It is often possible to polish the surface and recover the marks using various chemical, analytical, and visual techniques. When the inflicted damage to the material extends below the material altered by the application of the original mark, it may not be possible to recover the markings using traditional methods [6].

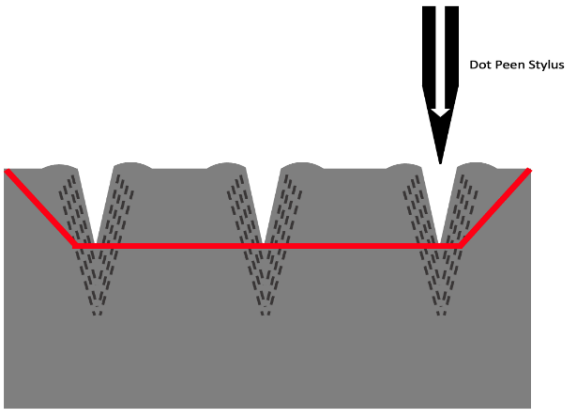

Figure 2. A schematic illustrating the side view of microstructural stress and material flow, shown by the dotted lines, when metals are dot-peened or stamped. The area above the solid red is the area of obliteration, removing visual dots or stamps while leaving regions of stress intact, allowing for recovery (not to scale).

The recovery of serial numbers using Fry's Reagent is the most accepted recovery method in the forensic exploitation of firearms evidence [7]. This methodology requires the chemical exploitation of the localized crystalline structure deformation below the obliteration. Fry's Reagent works on the premise that deformed metals dissolve more readily than intact samples due to the microcracks formed at grain boundaries due to tension [8]. For this reason, Fry's Reagent requires extensive surface preparation to remove the top layers of damaged material to allow access to a smooth surface. Before Fry's Reagent is applied to the obliteration, the area is polished to a mirror finish and cleaned with acetone. Due to these drawbacks, a lot of training is required for forensic examiners before they can carry out the investigation on firearms. Even with training, this process is highly destructive and is detrimental to the retainment of forensic evidence. In addition to the destructive nature of the etchant, Fry's Reagent is not effective on aluminium [4]. Many modern weapons are made of aluminium due to its low cost and weight, leaving a gap for recovering serial number obliterated on these firearms [9].

While Fry's Reagent is currently used in many forensic science laboratories as standard practice, for those operating in situ there are logistical challenges that have yet to be accommodated for. Conflict Armament Research (CAR) is one such organization who conducts serial number recoveries in non-permissive environments. The transport of chemicals into these areas via air travel can be logistically difficult, if not impossible. While this may not be an issue for certified forensic laboratories, there is still the obvious advantage to not rely on chemicals.

Studies by Bong et al. [9], Baharum et al. [6], Richa et al. [10] and Song [11] have been conducted over the last two decades with efforts to develop a method of chemical etching for the recovery of obliterated firearm serial numbers that rivals the results of the standard Fry's Reagent, without the drawbacks presented by the Reagent. Some of those detriments include the corrosivity, the addition of copper deposits to the sample, potentially affecting future testing, as well as the nitrous acid release during use. No etchant has been found to rival the results of Fry's Reagent, and a major drawback to all chemical etchants is that if the obliteration is too aggressive and deep, the method is often insufficient to recover the serial number [6,9,10,11]. These aggressive methods may include over-stamping, dot peening and heat treatments [12]. It has been seen in some instances, especially in conflict-afflicted regions, where firearms are being exposed to structural fires in effort to destroy evidence. The high level of heat causes local stresses in metals to relax, which can remove any trace of a serial number or other mark and make recovery near impossible. Structural fires may lend enough heat to the firearms to remove the internal tensions caused by mark application processes, depending on proximity and exposure time. A typical structural fire can reach over 800 degrees Celsius [13], while the annealing temperature of carbon steel is merely 150-200 degrees Celsius, depending on the alloy [13, 14]. Considering the recovery of serial numbers is based on the ability to resurface internal deformation, if the firearm is heated to above its temperature of annealing the serial number may not be recoverable at all. If Fry's Reagent is used to recover a serial number on a weapon that has been exposed to high levels of heat, there may be no result while still causing physical damage to the firearm.

To enhance serial number recovery and avoid using a chemical etchant to recover obliterated serial numbers, Regula Forensics® have adapted their existing Vehicle Identification Number (VIN) reading technology to accomplish serial number recovery in firearms [15]. A magnetizing firearm base and magnetized tape are used with specialized scanners to identify internal stress in both ferrous and non-ferrous metals. The scanner is attached to a controller which supplies an electric pulse. This pulsing current leads to the development of an eddy current within the metallic item. As mentioned previously, mark application causes localized stresses and defects in the material. These defects interrupt the flow of the eddy current trajectories and cause resistance in the stray magnetic fields supplied by the magnetic stand. The magnetic tape then translates the magnetic fields into a digital video signal and is processed by software to visualize the serial number [15].

For successful recovery, the magnetization and eddy current pulse strength must be balanced to complement one another. To do this, the surface layer must be magnetically

saturated. There is an indicator that is included in the kit, and visually indicates to the operator if the magnetization is of an appropriate strength. If the magnetization is too low, the signal will be too weak and not allow deep enough to penetrate below any superficial scratches [15]. If the item is magnetized too much, it will demagnetize the tape, removing any contrast on the final image. The eddy current pulse works as a magnetic signal amplifier. If the magnetization of the item is too low, there is nothing to amplify, therefore no result would be seen in the image. When the magnetization level is correct, increasing the eddy current strength allows a deeper penetration to visualize layers of the material beneath the surface, although the image may be slightly blurred. If the strength of the eddy current is reduced, a sharp but shallow image will be obtained [15].

To troubleshoot, the first parameter that should be adjusted is the level of magnetization. By increasing or decreasing the strength of the magnetic field, it is much easier to identify how the eddy current pulses enhance or diminishes the resulting image. After the magnetization is optimized, as indicated by the tool included in the kit, the eddy current pulses should be set to a low setting to begin with and increased one step at a time until a clear image is obtained [15].

The overarching goal of this study is to compare results obtained with Fry's Reagent directly to those obtained using this novel eddy current technology on basic workshop steel samples. Factors to be considered will be the ease of use, time requirement, reliability and ultimately the successful recovery of obliterated serial numbers. As this is a preliminary study, steel plates have been used to simulate firearms as a baseline for future research to build upon.

MATERIALS AND METHODS

Sample Description

64 CR4 grade steel plates, each 60mm x 100mm x 2mm, were used to simulate a firearm bearing a serial number. A Vickers hardness test of these plates averaged at 135 HV, with a ferrite and pearlite microstructure, shown in Figure 3.

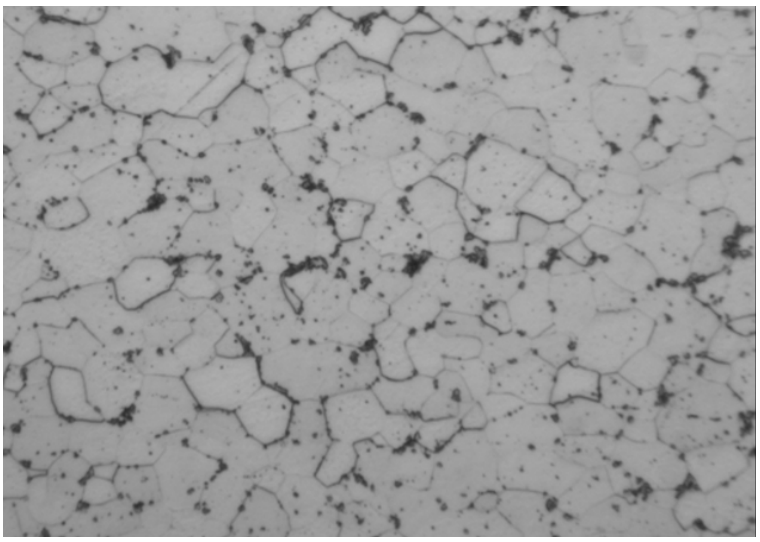

Figure 3. The microstructure of the steel plates.

The serial numbers were applied using a Pryor BenchDot machine. The alphanumeric digits were created using the maximum force setting of 9 using a "varidot" setting, resulting in an average dot depth of 250µm. Each digit was 8mm tall. One example of the applied serial number is shown in Figure 4. The serial numbers, ABC123, DEF456 and GHI789, were used to include both straight lines and curves in each alphanumeric sequence. In total, 64 steel plates with a total of 384 digits were used.

Figure 4. A sample of a dot-peened steel plate (size 60mm x 100mm x 2mm).

Systematic Machine Obliteration

To test the abilities of the eddy current kit (ECK), 50 steel plates were obliterated to varying depths. Ten plates were each obliterated to 100, 150, 250, 300, and 400µm.
A surface grinder with an 80-grit aluminum oxide wheel was used to remove 0.01mm of material at a time from the surface of the plates. The samples were flooded in coolant for each grind to ensure there were no changes to the material due to heat. The force involved in removing such small layers is negligible, so no physical alterations to the microstructure would occur.

Hand Obliterations

Serial numbers on fourteen plates were obliteration by hand, using a grinding disk on a Dremel®, a hand-file and a rotary grinder. Examples of these methods are shown in Figure 5, with sample configuration in Table I. These obliteration methods were chosen and conducted by a single operator to simulate what is most encountered in the field. The obliterations are rough and uneven, due to human tendency. The obliteration depth was measured with vernier calipers, calculating the average depth across the obliteration. To investigate the potential effect of the heat endured by a weapon during a structural fire on the microstructure, two dot-peened plates were subjected to heat at 350°C for one hour.

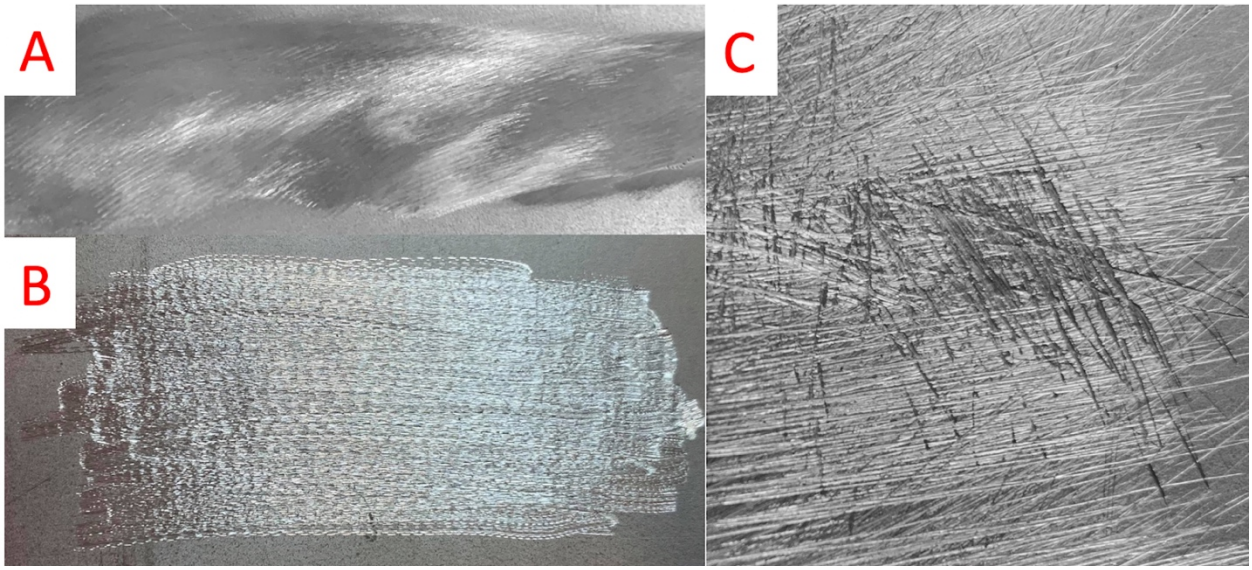

Figure 5. The three methods of obliteration used. (A) Mechanical grinder, (B) Polishing stone on a powered Dremel tool, (C) Hand file.

TABLE I. HAND OBLITERATION SAMPLE CONFIGURATION

Obliteration Method	Number of Plates	Number of Digits Obliterated	Average Depth of Obliteration [µ]
Dremel®	7	42	311
Dremel® & Anneal	2	12	311
Hand File	2	12	293
Grinder	3	18	265

Recovery Using Eddy Current Technology

In the first round of testing, no surface preparation was conducted to evaluate the potential for totally non-destructive testing. Each plate was placed on the electromagnetic base, with care taken to ensure all magnets were aligned appropriately to allow proper current flow. When the field was an appropriate strength, as indicated by the included tool, a piece of magnetic tape was placed directly on top of the obliteration.

For the purpose of this study, the dynamic iron scanner was used. The scanner connects directly to the controller which was then moved smoothly along the length of the magnetic tape. The controller delivers a pulsing eddy current through the scanner as it passes over the obliteration, recording interruptions in the eddy current flow and stray magnetic fields onto the tape. The tape is then inserted into the reading device, which is interpreted by a downloadable software, NUCA [16], to visualize the serial number. The components of the ECK are shown in Figure 6.

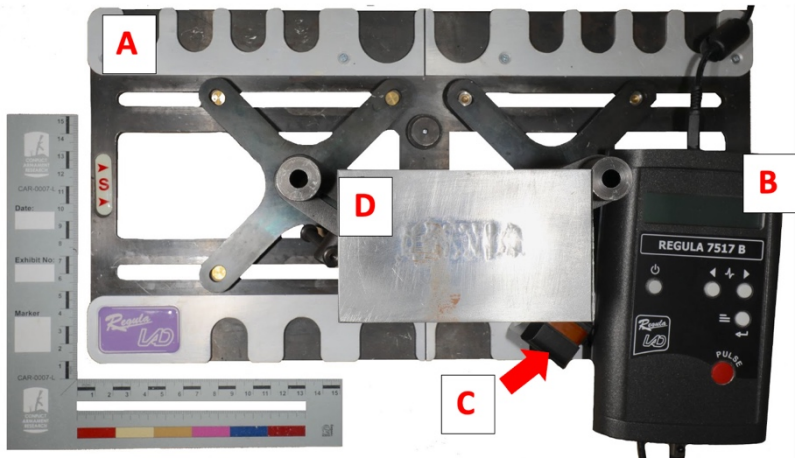

Figure 6. The set-up of the ECK. (A) Magnetic base, (B) Eddy current supply, (C) Eddy current scanner, (D) Steel plate with an obliterated serial number.

A systematic approach was used to establish the most effective strength of magnetic field and eddy current settings. Cardboard was used to create a standoff between the magnetic base and the steel plate to reduce the magnetic field to an appropriate level, as indicated by the included tool. The scanner used has eddy current pulse strength settings 1 to 12, and each setting was evaluated against the 14 hand-obliterated samples. Levels 6-8 gave the clearest image of each serial number.

After the first round of non-destructive testing, a portion of plates required minimal polishing due to the extreme surface damage. These samples were not necessarily those

with deeper obliterations, however, they did show increased surface irregularity. After minimal polishing, each plate was retested.

Recovery Using Fry's Reagent

Fry's Reagent was not used on the 50 plates used in the systematic portion of the study, however, the 14 plates obliterated by hand were used in the eddy current testing were subsequently used in the Fry's Reagent testing. This allowed for the direct comparison of the two methods using the same samples, ensuring identical obliteration conditions were used to test each method. As Fry's Reagent is known to be destructive, it was carried out after using the ECK.

Each plate was prepared using a polishing stone on a Dremel® tool to obtain a generally smooth surface and then sandpaper of increasing grades to bring the surface to a mirror finish. Upon the completion of polishing, each sample was wiped with acetone to preparate the surface for Fry's Reagent.

Fry's Reagent was prepared by mixing 5g of copper chloride in 25ml of ethanol and 40ml of hydrochloric acid in 30ml distilled water. This was then applied to the obliterations with a cotton bud. The Reagent was brushed on with the cotton bud and allowed to sit for 2 minutes before continuous brushing with the Reagent. The process was repeated until the serial number was visible.

Analysis

Statistical analysis included a two independent sample binomial test, conducted using Minitab® 19, Version 19.2.0.0. The total number of digits recovered across 64 plates will be assessed, and a comparison between the two methods of recovery will be evaluated to determine if the methods differ significantly in their success rates.

To compare the practicality of the two methods of serial number recovery, multiple considerations were made. The primary factors were the ease of each method and the time requirement per sample. The ease of each method will include the set-up, preparation, and the recovery itself. Similarly, the time requirement assessment will include the sample preparation and the recovery process.

RESULTS

Machine Obliterated

These plates were only examined using the ECK, in an effort to establish how effective it is to recover serial numbers that have been obliterated to increasing depths. Table II shows the overall results.

TABLE II. THE PERCENTAGE OF SERIAL NUMBER RECOVERIES IN 50 MACHINE-OBLITERATED STEEL PLATES (n=50).

Full Recovery	44.0%
Partial Recovery	16.0%
No Recovery	40.0%

Of the 44.0%, n=50, only 2 recoveries were successful when the obliteration depth was more than 150µm. 1 partial recovery deeper than 300µm was recorded and 0 full recoveries deeper than 250µm.

Hand Obliterated

To allow direct comparison of Fry's Reagent and the ECK, the same 14 plates obliterated using hand tools were used to assess the success of both methods. They were first subjected to recovery attempts using the ECK, followed by Fry's Reagent. A sample result of each method is shown in Figure 7.

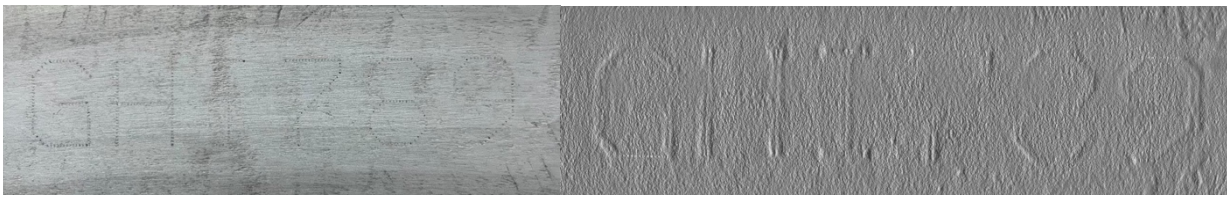

Figure 7. Traditional recovery using Fry's Reagent (left) and the non-destructive recovery using the ECK (right). These results have not been filtered, processed or altered using any computer software.

The experimental configuration and success rates of each method are shown in Table III. The number of successfully recovered digits per obliteration method are shown, in addition to the overall success of each method.

TABLE III. THE RESPECTIVE SUCCESS RATE FOR FRY'S REAGENT AND THE ECK.

Obliteration Method	Number of Digits Recovered	
	Fry's Reagent	Eddy Current
Dremel®	16	32
Dremel® & Anneal	6	6
Hand File	12	12
Grinder	18	18
Digits Recovered	52	68
Percentage Recovered	61.90%	80.95%

Figure 8 shows the number of fully recovered partially recovered and unrecovered digits of serial numbers on the steel plates per method. A full recovery is considered when a single alphanumeric character is positively identifiable, whereas a partial recovery shows only segments of the character, which may result in a misidentification. As the obliterations were conducted by hand, the variation in depth resulted in some serial numbers being partially recovered. Of the six digits per serial number, only some individual digits were recovered, which is why the number of digits recovered was recorded, instead of entire serial number sequences. The eddy current method was able to recover more complete digits overall, including individual digits when the entire serial number was not recovered.

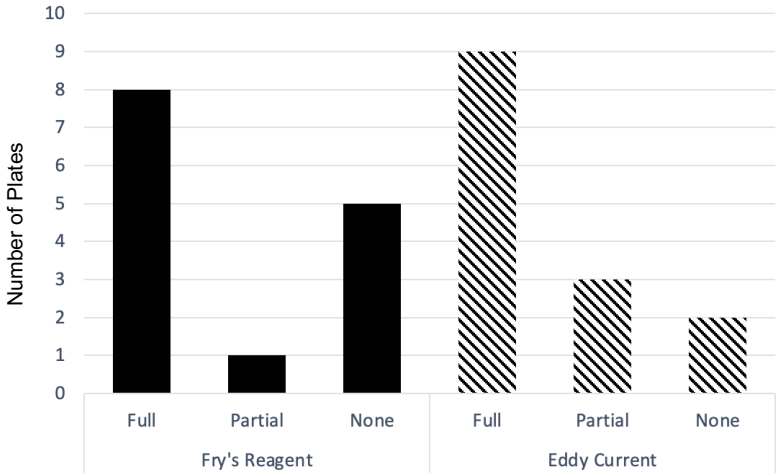

Figure 8. The number of plates showing fully, partially or unrecovered hand-obliterated 6-digit serial number sequences per method.

The percentage of serial number digits recovered was calculated and compared between the two methods of recovery. An individual sample binary test was conducted at p =0.05. The results are reported in Table IV, showing the obtained Fisher's Exact value of 0.01.

TABLE IV. THE HYPOTHESES, P-VALUES AND RESULTS OF THE INDIVIDUAL SAMPLE BINOMIAL TEST.

Null Hypothesis		$H_0 : p_1 - p_2 = 0$	
Alternate Hypothesis		$H_0 : p_1 - p_2 \neq 0$	
Sample	**N**	**Recovered**	**Sample P**
Fry's Reagent	84	52	0.619048
Eddy Current	84	68	0.809524
	Z-Value	**P-Value**	
Normal Approximation	-2.73	0.006	
Fisher's Exact		0.01	

DISCUSSION

The results of the systematic portion of this study were unexpected, especially when compared to the hand-obliterated results. In only 44% of the plates, a full recovery was obtained. It was expected that a higher recovery rate would be noted as in some cases the original dots were still visible due to the shallow obliteration. When a successful full recovery was obtained, the result was visualized as shown in Figure 9.

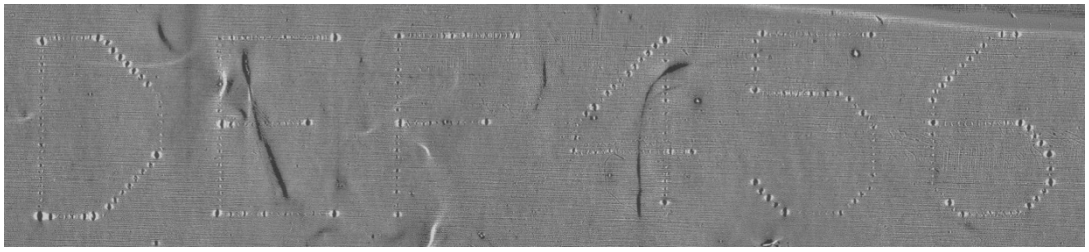

Figure 9. A clear, successful recovery showing 'DEF456'.

Of the successful recoveries, some were faint results, likely due to a physical contact issue between the scanning wand and the sample. An example of this faint recovery is shown in Figure 10.

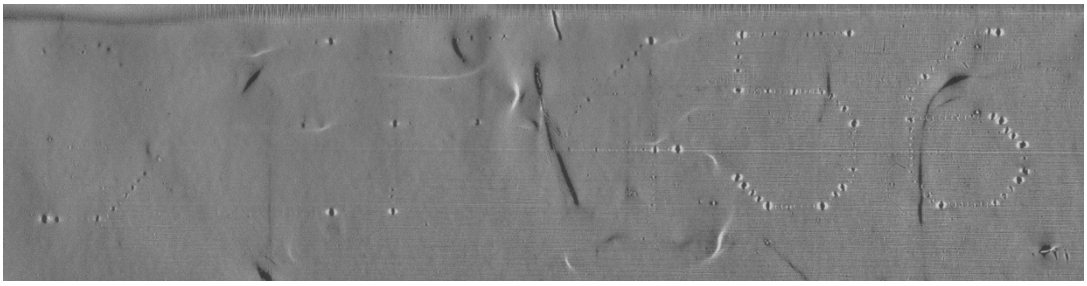

Figure 10. An example where poor physical contact between the scanner and the sample results in a faint result.

Considering that using Fry's Reagent is expected to be successful when the obliteration is deeper than the visual serial number, if this kit is to eventually replace Fry's Reagent, it must be as, if not more, effective. The plates that were obliterated beyond 250µm were therefore expected to be recoverable by the ECK as well. The first attempt at these scans showed large amounts of surface noise on all scans so a second polishing with grit papers to 1200-grit were used to obtain a smoother surface. Only 56% (50) of scans were then partially or fully successful. The authors believe that this is still due to the surface finish of the samples. A smoother finish must be obtained to avoid the surface noise, as shown in Figure 11.

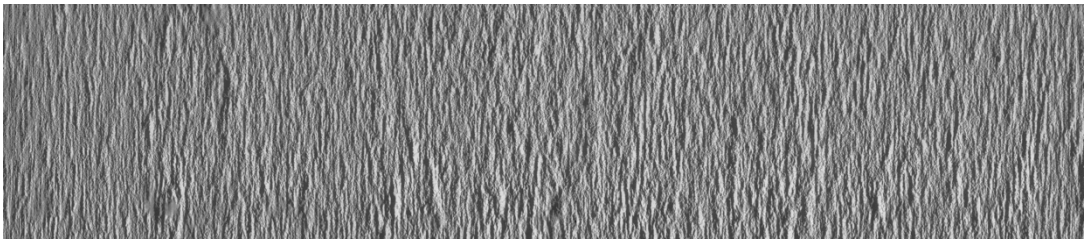

Figure 11. An example of a plate with high surface noise, not allowing a successful recovery.

The overall results of this systematic study highlighted some anomalies and should be repeated using a finer grinding paper in the first instance. Even though this kit is meant to be non-destructive, a large amount of polishing was required, negating any benefit this technique has over Fry's Reagent.

To allow for seamless comparison of Fry's Reagent to the eddy current system, the same 14 plates obliterated by hand were used in both recovery trials. When the results are placed side by side, the quality of each method can be assessed.

Both samples in Figure 7 in the 'Results' section of this paper were obliterated using a grinder. In this example, Fry's Reagent is effective, and the resulting serial number recovery is legible. This does rely on how well the surface is polished, therefore impacting the integrity of the forensic evidence. The result of recovery using the ECK system is perhaps not as clear as the recovery with Fry's Reagent, as individual dots are not typically visible, however, the serial number is ultimately still visible, which is ultimately the point of the technique. The trade-off of the non-destructive method to preserve evidential integrity must be considered.

In this pilot study, each serial number digit was 8mm tall whereas, in reality, many serial numbers on firearms are only 2-4mm tall depending on the firearm make and model. Because of this, the success of each method was determined primarily by the number of serial number digits that could be recovered instead of the entire serial number. The current method of forensic recovery using Fry's Reagent recovered 62% (n=84) of the total digits. When using the ECK, 81% (n=84) of the digits were recovered. The eddy current method was more effective than Fry's when recovering digits obliterated with a Dremel®, however, the two methods otherwise performed similarly when the obliteration was made with a hand file or a grinder. These obliterations were much shallower than the dremel, allowing easier recovery for both methods.

Using an individual sample binomial test, it was determined that there is a significant difference in the recovery rates of Fry's Reagent (62%) and the eddy current method (81%), with a calculated Fisher's exact value of 0.01. The null hypothesis is rejected as the calculated value is less than 0.05. In the first phase of this study, only the success of the kit was considered. These results are in support of the hypothesis that there is a significant benefit to using the ECK compared to Fry's reagent with regards to the actual recovery of serial numbers.

In addition to the quantitative results and success rates, the process and logistics of each technique was considered. The preparation of the samples, time requirement and health and safety considerations were weighed between the two methods to ascertain the viability of use in a forensic laboratory context, as well as implications to the evidential integrity of the samples.

Fry's Reagent is currently used in ISO 17025 accredited forensic laboratories for serial number recovery on steel-framed firearms. It is currently the most effective etchant, although there are obvious drawbacks to using a corrosive chemical on forensic evidence. When using Fry's Reagent for recovery, each sample must be polished to a mirror finish to allow the etchant to work evenly across the surface. Areas that are physically higher than others will require more etchant to remove layers of the metal, while the low points will collect the corrosive liquid. This pooling will cause even more damage to the immediate area. This is destructive to the sample and in a forensic capacity is undesirable, however, currently unavoidable given the recovery techniques available.

Another downside to Fry's Reagent is the corrosive nature and is, therefore, a general health and safety hazard. In laboratories, there is a requirement for a ventilated fume hood. While this is not such a logistical burden on established forensic laboratories, as fume hoods are standard equipment, the health and safety risk of technicians must still be considered. This is also an issue when Fry's Reagent is being use outside of the standard laboratories, such as in the case of CAR's operations and other field-based investigations.

For firearms in a forensic context, using a destructive method of recovery may not be worth the risk of compromising the integrity of the evidence for the slight chance of recovery. The experience of the examiner is relied upon to make this decision and weigh the likelihood of recovery versus destruction of evidence as there is no test to determine if Fry's Reagent will be effective. Overall, the use of Fry's Reagent in a forensic laboratory can be time consuming in terms of sample preparation and is destructive and unrepeatable by nature, however, is not complicated and is acceptable for use on forensically relevant evidence.

The main benefit to the proposed use of eddy currents and magnetic fields in the recovery of serial numbers from firearms is the non-destructive nature of the test. In theory, this technology can recover serial numbers where the surface has been obliterated with no preparation, such as polishing. In the experiment with hand obliterated numbers, 11 of the steel plates did not need any polishing at all, with very clear results obtained. The remaining three steel plates required some polishing, as they were very deeply obliterated using a grinding disk on the Dremel tool. Even though the surface of these plates did require some polishing, which is notably a destructive process, the level of polishing required was minimal in comparison to what is needed for Fry's Reagent to be effective. Despite the obvious consequence of still requiring surface preparation, the level of destruction is lower and may still be attractive to forensic and judiciary services.

While conducting the test is rapid, the training time on the operation of the kit is extensive. A certain amount of expertise and training is required to understand how to adjust the settings to allow for successful and clear results. In general, by using an ECK setting around 6- on a scale of 1 to 12 for iron-based frames- will give an indication of whether the serial number can be recoverable. The operator can then adjust the eddy current flow to improve the clarity of the image. The benefit to this technology is that the operator can scan the obliterated area an unlimited number of times without altering the evidence, as the eddy currents and magnetic fields will not alter the microstructure of the material. The development of a Standard Operating Procedure (SOP) by a systematic study will enable a methodological approach to be refined.

Overall, the ECK technology has the potential to be a useful methodology for obliterated serial numbers, with a nearly non-destructive application and no health and safety concerns. The process is not time consuming, however the burden of training is much higher than is required for Fry's Reagent. More extensive testing of this kit must be completed to understand the true limitations, especially on actual firearms.

Limitations and Recommendations

The methodology used to remove steel to prescribed depths for the systematic review portion of this study left increased noise on the surface of the steel plates. Because of this, the surface of each plate required polishing to obtain a clear magneto-optical image, negating the non-destructive nature of the ECK. In similar future studies, a finer grit tool should be used to obtain a smoother surface finish in the first instance. Due to this surface finish issue, the authors do not feel this is an accurate representation of how the ECK ultimately performs on real samples. We believe this portion of the study should be further examined in future studies with an alternative method of systematic obliteration.

The steel plates used in this study are a good representation of how the eddy current recovery kit can produce clear magneto-optical image results, however, it does not account for the geometry of a real firearm. This preliminary work should be used as an introductory study to build on in the future using real firearms.

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Declaration of Interest
None

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Regional Obliteration Trends: SALW Recovered in an African State

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ABSTRACT

For the first time, a "boots on the ground" approach has been taken to understand obliterations made to Small Arms and Light Weapons (SALW) recovered and documented in an African state, Country X. 126 firearms, primarily AK-pattern, were documented by Conflict Armament Research during a 10-year mission. These weapons were sanitised by local actors by removing identifying markings such as serial numbers and factory marks. Each obliteration was carefully analysed to determine the type of tool used by identifying the class characteristics of the toolmark, and to identify precisely which marks were removed. An "obliteration code" system has been developed, which identifies the tool type, completeness, marks removed, directionality, and any additional concealment. These codes have allowed to development of a database of obliterations and will, in turn, aid the intelligence-led investigation into the local forensic awareness, physical capabilities, and the motivation to obscure the SALWs identity. The results indicate that many of the weapons in each profile were likely sanitised by the same "node"-or were at least under the instruction of one common actor. This study also established that the forensic awareness within Country X is relatively low, as many of these marks may be recoverable using either traditional or novel means, if given the opportunity. The motivation for many of these weapons lies in the maintenance of monetary value, while concealing the identity to evade tracing efforts. This paper utilises a novel approach to understand weapon sanitisation in

Country X, and how methods of obliteration can enhance further investigations in the region.

KEYWORDS

Firearms, Intelligence, Sanitisation, Forensic Awareness

During manufacture, producers apply unique serial number to Small Arms and Light Weapons (SALW) in addition to the generic manufacturing marks, identifying the factory, year of manufacture and calibre (1). Serial numbers are applied to support the identification of weapons during manufacturing, onward shipping and subsequent transfers to end users, throughout their lifecycle (1). They allow effective record keeping methods to be used by the manufacturer during sales to a variety of customers, such as government forces and resellers. When a consignment reaches the end user, the serial numbers may be used to assign personnel with individual weapons and ensure adequate stockpile management systems are in place. Among civilians in many countries, local gunsmiths and other registered firearm traders are required by law to record the serial numbers of the firearms they have in stock for service, storage and for sale (2).

Across the globe, serial numbers are used to trace SALW through both licit and illicit networks. In many regions around the world, weapons that were once held legally have been diverted into illicit networks and sanitised by actors within these networks (3). Knowing that seized weapons can be traced through their lifecycle using the serial number, it is not uncommon to find serial numbers and other identifiers removed from weapons used in illicit activity. When the serial numbers are removed, traceability is compromised (3).

The International Tracing Instrument (ITI) is a politically binding agreement, which UN Member States adopted in 2005 (4). It outlines the challenges faced in illicit weapon tracing and provides measures to better equip tracing operations. Some of the main provisions include additional marking at import and export, utilising emerging technologies to support recovery of obliterations, and improving engagement with manufacturers, law enforcement and end users (4).

In light of the ITI, efforts have been made to increase the capacity and skillsets for serial number recovery in States that could benefit from increased forensic science support to investigators (5). Traditional methods, such as acid etching, and non-traditional methods, such as eddy current recovery and other analytical techniques have been tested and utilised to visualise the material's microstructure (6) (7) (8) (9). In previous research, novel emerging technology using eddy currents and magnetic fields has been tested for serial number recovery (6). The technology proved to be effective, and in some cases, more effective, than traditional recovery using acid etchants (9). It has now been deployed to multiple conflict-afflicted regions to be tested in non-permissible conditions.

In many cases, even where technical capabilities exist, access to these weapons to conduct the recovery efforts, even after capture, can be made difficult by factors such as the geographical location of the seizure, difficulties in recovering exhibits in hostile environments, forensic capacity, availability of resources (analytical kit and reagents) and lack of training (10). Additionally, the prevalent types of weapons recovered and documented from non-state actors can occasionally be indicative of the region they came from. For example, in Afghanistan, a large proportion of weapons are from American and British military sources (11). This may be an effect of the withdrawal of international forces, where many weapon stockpiles were abandoned and left vulnerable to integration into illicit markets. It must be noted that diversion in the region began well before the withdrawal of international forces, so the aforementioned is not an exclusive weapon source (8).

The same situation is not necessarily true around the world. Illicit weapon diversion transpires for many reasons. Sometimes through abandonment, battlefield capture, or cross-border smuggling, as we are beginning to see in the current Ukraine/Russia conflict (12) (13) (14). Sometimes, through what begins as a legal transaction, legally acquired weapons can end up in the hands of criminals through low level corruption or battlefield loss (16). An example of this can be seen in Country X, where the licit engagement of international stakeholders over decades of conflict is a primary factor in the illicit trafficking of weapons (15). Additionally, poor weapon stockpile management and opposing force attacks are considerable post-shipment diversion factors in the region (16).

Some States within Country X are extremely volatile and official government travel advisories state that warlords, violent demonstrations, and piracy are of primary concern in the region (17) (18) (19). Through first-hand interviews with Conflict Armament Research Field Team staff, terrorism and clan conflict are seen as the primary sources of destabilisation in many regions within Country X, and piracy and warlords present a lower current threat. With a Global Corruption Index (GCI) rank in the top ten countries, the destabilisation is not surprising, regardless of the justification. The GCI relies on data from organisations such as the United Nations, The World Justice Project Organisation, Transparency International, and more to display the corruption risk exposure of a country (20). Additionally, the Environmental, Social and Governance Index (ESGI) also provides metrics relating to the environment, human rights and health and safety. Factors include social rights, slavery, child labour, political rights, and peace, among many others. Like the GCI score, Country X rates very poorly on the ESGI, having the one of the lowest ranks on the scale (21).

In the early 2000s, the world was introduced to an ISIS-linked terrorist group when they claimed responsibility for a suicide attack against foreign soldiers in the capital of Country X. During its early years, this organisation strengthened relationships with ISIS and launched violent attacks against international targets within Country X's borders. For the first four years of its existence, the terrorist organisation operated solely in Country X; however, in 2010 it conducted its first international attack outside the country borders. These attacks continued, targeted mainly at civilians, foreign troops, and international peacekeepers (22).

Between the mid 1990s and early 2010s, Country X was under a complete arms embargo due to continuous conflict and lack of formal government, which plagued the country. The United Nations Security Council (UNSC) partially lifted the embargo in 2013, after the establishment of the Federal Government of Country X, who requested support from the international community to defeat the terrorist organisation (23) (24). This modification permitted the federal government to procure weapons, but supplying States were required to submit delivery notifications to the UN Sanctions Committee to maintain oversight and control of weapons in service with governmental forces. Due to the easing of the embargo, there was a massive influx of weapons into Country X in support of operations against the, now, well established terrorist group (25). With the aforementioned level of corruption, it is not surprising to find these legally donated or purchased weapons in the hands of the terror networks. In some cases, these weapons

were completely sanitised, most likely conducted upon entering the terrorist networks. The unique identifying marks- serial numbers, factory marks, year of manufacture, etc.- were removed using a variety of hand and power tools (26). Often, the workshops conducting the sanitisation do not operate primarily as a weapons workshop, but as general mechanical shops who are paid cash to remove certain marks (22).

In addition to the removal of marks, the alteration of marks is also a practice that is not unfamiliar in and around Country X. The Global Initiative Against Transnational Organized Crime released a report titled "The Price of Civil War" which states key findings, among which is the following: Chinese-manufactured weapons have been "rebadged" with falsified serial numbers to appear Russian (27). This practice will secure higher values on the illicit market due to the quality difference in manufacturing. The quality of production is also a factor in obliterations and resale value, which is explored in this study, even if the weapons are not being rebranded.

Conflict Armament Research (CAR), a research organisation, operates to identify and trace such weapons. CAR deploys field teams into conflict-afflicted regions around the world. Its operations in Country X began in 2011 and expanded when the arms embargo was modified in 2013. In eleven years, CAR has documented 1440 weapons, 126 of which show the intentional obliteration of serial numbers. According to CAR, the lack of forensic capacity and resources by Country X organisations, coupled with the hostile and non-permissive environment within its borders, there is no evidence to support the attempt to recover these serial numbers to aid tracing efforts.

These obliterated marks are being investigated in this current research as part of a significantly larger piece of work examining regional trends to establish the possibility of determining where an obliteration was done. The obliteration codes identified of Country X will be compared to other countries and regions around the world. It has been noted in ongoing unpublished research by the primary author that obliterations from regions of the world with advanced forensic science and stringent firearm laws are far more advanced, both in tool type and extent, than regions with lesser knowledge and technical ability.

Unlike traditional toolmark analysis, which aims to identify individual tools this work relies on class characteristics within the toolmarks to identify the tool *types* used in obliterations. Within the obliterations, trends will be analysed; including precisely which

mark components are obliterated and to what extent. This analysis will enable to development of “obliteration codes”. Coupling these profiles with intelligence on each region, the forensic awareness and motivations for obliteration will also be identified within this study. These obliteration codes will be used during future investigations on illicit weapons to index obliterations and allow searchable profiles for comparison.

MATERIALS AND METHODS

Sample Description

126 firearms with obliterations were documented in Country X by Conflict Armament Research field teams. These firearms were originally recovered in various regions of Country X by local police and militant groups. The identification of the weapons was conducted and recorded in situ. Using macrophotography, obliterations of identifying markings were captured and catalogued.

Figure 1 shows typical examples of the obliterated area on the documented firearms. These photographs are the primary data source used throughout this project, in addition to collected contextual information such as recovery location, date, and provenance (if known).

Figure 1: Two examples of the types of photographs examined. A Type 56-1 (top) and an AKM rifle (bottom), both showing partial obliterations.

Analysis Methodology

For each of the 126 weapons, a visual assessment of the obliteration was conducted. A toolmark analysis was performed to ascertain the class characteristics within the marks, which enables the identification of the type of tool used to remove the mark. Features identified include the tool type, level of sanitisation, which specific marks had been removed, directionality, and any additional concealment over the obliterated area.

The type of tool used on each weapon was ascertained by examining the class characteristics of the toolmarks found within the obliteration. Unlike traditional forensic investigations, the individual characteristics are unimportant for this research. The aim of this work is to simply identify the type of tool using the general features observed in the striations. To ensure the toolmark identification was accurate, sample plates were made using tools most encountered in artisanal workshops in many African states. Identifying these tools may aid the intelligence-based investigation by establishing the technical capability and tool availability in some regions. These sample plates are shown in Figure 2.

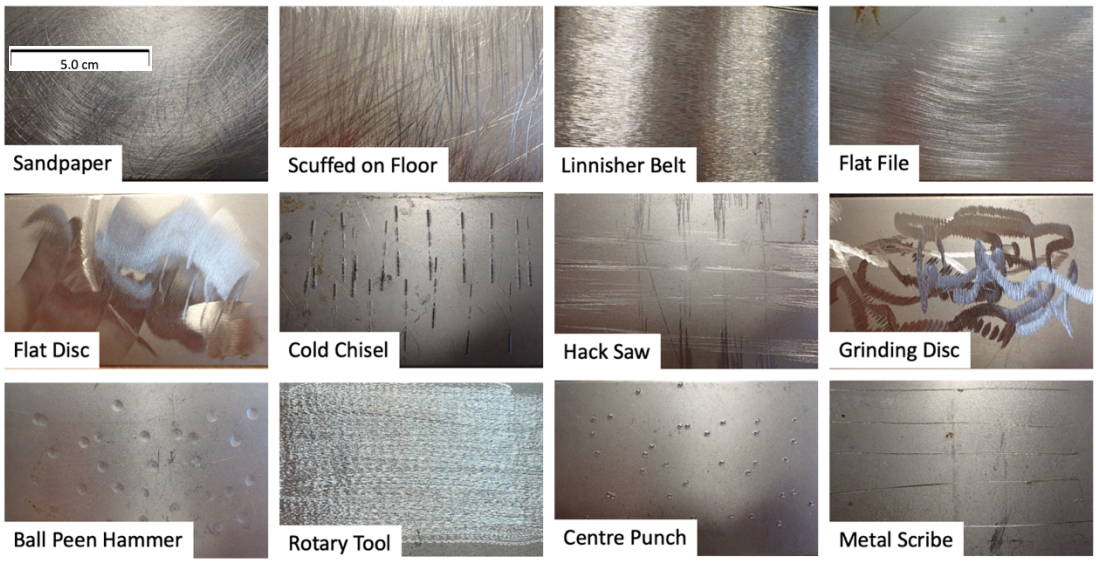


Figure 2: Twelve sample plates showing toolmarks from typical workshop tools to differentiate the various class characteristics to aid the identification of the tool used in an obliteration.

Three levels of sanitisation have been identified. The first is considered “incomplete”, where only some identifying marks were removed, such as serial number *or* factory mark. Secondly, “partial” sanitisations are noted when all identifying marks are removed, however, are still partially visible. This may be due to a shallow obliteration or where small pieces of a mark remain. Finally, “complete” obliteration is when all identifying marks are removed to the point where they are no longer visible to the human eye. In some cases, the level of sanitisation may indicate the forensic awareness or the motivation for concealment.

Identifying marks on weapons differ between manufacturers. The serial number, factory mark, year of manufacture, and other marks, are found in different locations, even when the model is the same. To determine which marks were removed from each weapon, various resources were used including the RCMP Firearms Reference Table (28), the INTERPOL Reference Table (29), and two reference collections from the Defence Academy of the United Kingdom and the National Firearms Centre (Leeds, United Kingdom). Depending on which specific marks were obliterated, the motivation of the sanitisation may be established. If certain manufacturing marks remain after obliteration, the legitimate production of the weapon is obvious and the black-market value will reflect the genuine nature of the weapon (27).

The directionality of each obliteration is noted to assist in intelligence-based investigation. This will enable investigators to find patterns and link similar

obliterations, potentially identifying nodes within the illicit trade. Although the current research is not seeking to identify individual perpetrators, including the directionality of the toolmarks from the offset allows for the identification of trends, while considering the handedness and uniqueness of the tool-user for future investigations.

In some obliterations, as seen in this dataset, paint or overstamping may be used to camouflage the region where the marks were removed, as the toolmarks often leave the weapon surface altered and easily noticeable. Similar to the directionality of toolmarks, additional concealment of the obliterations allows for patterns and similarities to be made between obliterations in effort to link perpetrators and global trends.

The generation of "obliteration codes" was conducted using the above visual observations. To establish a code, the methodology of sanitisation must be consistent. Figure 3 outlines the specifications within each category. The code for each weapon is given as "T#.S#.M#.D#.C#", where:

T: Tool type
S: Level of sanitisation
M: The specific identifying mark that has been removed. If there is more than one mark removed, a "/" is placed between the digits representing the marks.
D: Directionality of the toolmarks
C: Additional concealment
#: The specification within each category

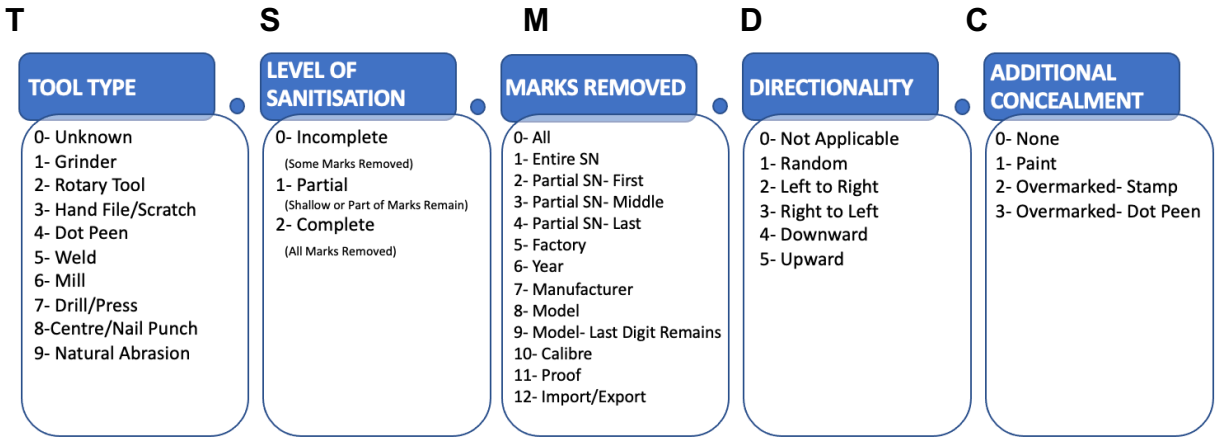


Figure 3: The methodology followed to assign each weapon with an obliteration code.

After each weapon was analysed and assigned an obliteration code, those with the same code were grouped together to understand the key features, and how these may relate to the forensic awareness in Country X and the local technical capability.

RESULTS

Weapon Types

Of the 126 weapons, 5 main model types were documented with 5 or more individual weapons in each category. 9 other weapons were documented outside of the main groups. The breakdown of these groups is shown by percentage in Table 1. As seen in the chart, 39% of the weapons documented were Chinese Type 56-1, which follows an AK-pattern, and an additional 25% were other non-specified AK-patterns. In the minority, GAFAT-1, Npi-KM, MP22 and other Type 56 models were also documented.

Table 1: The breakdown of weapon models showing obliterations documented in Country X.

Model	Sample Count		Model	Sample Count
GAFAT-1	9		Type 56-1	49
NP22	9		Other AK Pattern	35
Type 56	11		Other	13

Obliteration Profiles

Together, the toolmark analysis and identification of removed marks resulted in obliterations falling into twenty codes. Each code is dictated by the type of tool used to remove the mark and which mark(s) have been removed, and to what extent. Any overstamping or overpainting is also considered. These codes aid the intelligence-led investigation into the local forensic awareness, physical capabilities, and the motivation to obscure the SALWs identity. Figure 4 lists the code, an image showing an example of each obliteration code, and the number of weapons given that specific code.

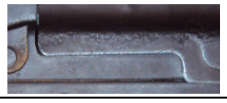
Code	Example Photo	Sample Count	Code	Example Photo	Sample Count
T1.S0.M1.D2.C0		12	T3.S2.M0.D1.C0		1
T1.S0.M1.D2.C2		3	T3.S2.M0.D1.C3		1
T1.S0.M1/8.D2.C3		1	T3.S0.M1.D1.C0		1
T1.S0.M2.D4.C0		17	T4.S0.M1.D0.C0		1
T1.S0.M4.D4.C0		1	T5.S2.M0.D2.C0		1
T2.S0.M1/7.D2.C0		12	T9.S1.M0.D0.C0		10
T2.S0.M5/8.D2.C0		7	T9.S1.M1/8.D0.C0		2
T2.S0.M5/8.D2.C1		18	T9.S1.M8.D0.C0		4
T2.S0.M5/9.D2.C0		16	T9.S1.M1.D0.C0		1
T2.S0.M5/9.D2.C1		16	T9.S1.M0.D0.C0		1

Figure 4: Each of the twenty codes identified within the Country X dataset, showing an example obliteration and the number of weapons with the same code.

Tool Types

Most obliterations in this dataset were obliterated using either a grinding disc (27%, n=34) or a rotary tool (55%, n=69). Only 1 weapon was sanitised using a welding technique, or a dot peening machine. Additionally, only three weapons were scratched in attempt to remove the identifying marks. Finally, 18 weapons were sanitised through

natural or “passive” abrasion. These weapons are not linked to intentional criminal sanitisation, however, may have been subject to inadequate storage, handling, and/or transport.

DISCUSSION

Weapon Types

Most weapons documented in Country X are Chinese Type 56-1 rifles (39%, n=49), closely followed by “unidentified” AK-pattern rifles (25%, n=31). This group of AK-pattern rifles is comprised of any other AK-pattern rifle manufactured outside of China, namely Russia, Germany, and Bulgaria. The prevalence of AK-pattern weapons is not necessarily indicative of nefarious activity, as so many countries both produce and/or use AK-pattern rifles for their police and military forces. As mentioned previously, there are an abundance of international stakeholders and defence contractors who are active in, and around, Country X. Many of these organisations use AK-pattern rifles, and so the sheer number of these weapons in a region with an active illicit weapons market may contribute to the prevalence of this type of rifle in the current dataset.

Tool Types

The prevalent tool types used in these obliterations are grinders and rotary tools, shown in 103 of 126, 82%, weapons. These types of tools have low power requirements and can be run efficiently in the rural areas the workshops tend to be located (22). In contrast, dot peening and welding machines, which account for only 2 out of 126 weapon obliterations combined, are extremely expensive to procure and run, so are very rare to see in regions like Country X. It is, therefore, hypothesised that these weapons may have been sanitised outside of Country X before entering the country through the illicit network and subsequently recovered and documented.

Additionally, hand tools account for only 3 of 126 obliterations, or 2.4%. It is hypothesised this is because completing many weapon sanitisations using hand tools would be very time consuming and labour intensive, where the goal of sanitisation is to be fast and efficient. These conclusions are supported by CAR researchers, with experience in Country X and other regions with similar technical capabilities and weapon trafficking trends.

Obliteration Codes

The coded system allowed for the filtering of observations in advanced investigations. For example, code T2.S0.M5/8.D2.C1 indicates that a grinder was used to remove the serial number and model, from left to right, and then covered in paint. Figure 5 shows multiple examples of weapons with this code, that look to be done either by one individual or multiple individuals under the direction of one actor. This system will connect weapons obliterated within one terrorist node, aiding investigations, and can be applied to any weapon system.

Figure 5: Four examples of weapons with the obliteration code T2.S0.M5/8.D2.C1. The similarity of these weapons may indicate sanitisation by one actor.

With 20 obliteration codes generated within Country X, the identification of individual nodes is possible based on similarities in the obliteration trends. For example, the obliterations shown in Figure 5 are identical to those with the code T2.S0.M5/8.D2.C0 with the addition of black paint. These similarities indicate crossover in the technique, and indicate a similar level of forensic awareness and motivation to conceal the identity

of the weapon. This relationship will be explored in more detail in future work by the primary author.

Motivation to Conceal

In only one case, every single identifying mark was removed. The other 125 weapons saw partial obliterations, where only key marks were removed, most notably the serial number. The serial number is the most important in weapon tracing operations, as they can often be tracked through documentation to the original manufacturing factory. If the serial number is removed, that paper trail disappears.

Legitimate weapons may sell for higher values on the illicit market, leading perpetrators to retain marks that will prove its origin (27). Often, this means serial numbers will be removed, but the factory mark will be retained. This phenomenon has been noted in other regions of the world, including the United Kingdom by curators at the National Firearms Centre (24). The findings in this current research agree with research organisations such as Stockholm International Peace Research Institute (24) and the National Firearms Centre (NFC). The NFC states that “black market” Baikal blank firing pistols sell for similar values to legitimate live-firing pistols as criminals remove the marks denoting that it is a blank firer and retain “Baikal” and “Made in Russia” to lead buyers to believe it will fire live ammunition. This hypothesis, therefore, may hold true in both criminal and terrorist theatres globally.

Forensic and Technical Awareness

One primary observation reflected across the entire dataset is how shallow the obliterations appear to be in the photographs. This is hypothesised to be indicative of two factors;

1. Actors are unaware of forensic recovery capability and therefore only remove the marks to where they can no longer see them by eye, not realising they may be recoverable if not enough material is removed; or more likely,
2. The individuals are simply following directive from their command chain to remove the marks.

In the authors opinion, if access were to be granted to these weapons, forensic recovery of the obliterations would have great potential to reveal at least some of the marks, primarily due to the shallowness of the obliterations and the smoothness of the toolmarks. Typically, when acid etching is used, the surface must be prepared (smoothed) to remove any gauges or knicks. In this dataset, there were no weapons with obliterations that would require extensive surface preparation and could potentially be recovered. As mentioned earlier in this report, these workshops are not always weapon-specific, and so they will use a tool of convenience, such as a grinder, and remove marks from weapons *en masse* as quickly as possible to collect their pay for completing the service.

One weapon model highlights both a lack of forensic awareness and the lack of technical capability. A Chinese Type 56 rifle top cover overhangs the frame of the rifle slightly and the top half of the markings are covered. Often, these weapons show marks that have only had the bottom half of the markings removed. An example is shown in Figure X. This highlights the two potential scenarios if the weapon is intentionally sanitised mentioned above. In some cases, such as in Figure 6, the method of obliteration was natural abrasion, and the bottom half of the markings being worn away simply indicates that the top cover was in place during storage and/or transportation when the abrasion occurred.

Figure 6: An example of a Type 56 rifle where the top cover would have protected the upper half of the digits and natural abrasion of the surface resulted in the passive removal of the bottom half of the digits.

Limitations

The main limitation is that the weapons used in this study were not physically accessed and the analysis was done solely through photographs. Analysing the weapons in person

may have allowed more thorough observations to be made. In a limited number of cases, the photographs were of low quality, making the toolmark analysis more difficult; but not impossible.

Future Work

These considerations have been made with the goal of integrating this work into a global perspective of obliterations. Future work by the primary author will assign codes to obliterations seen in many other regions of the world. The following recommendations will help to guide future documentation and observations.

1. Incorporate documentation sites to identify specific nodes within the regions of interest, and
2. Conduct quantitative analysis and statistical comparison to identify significant differences between obliteration trends within, and between, Europe, North America, and the Middle East.

Conclusion

The sanitisation of weapons in Country X is most often conducted using a handheld rotary tool or a grinding disc. These tools were used in 82% of obliterations. The hypothesised reason for this being the ease of use of these tools, the lower electricity requirement to run these tools- in comparison to others such as welding rigs- and the volume of weapons to be sanitised being fairly high.

The most likely motivation to conceal the identity of the weapons is to avoid tracing operations, while, most importantly, maintaining monetary value. This was established by identifying which marks were removed from each weapon, and if the legitimacy of its manufacture could still be confirmed. Weapons with intact factory marks but no serial number will prove it is of genuine production, and therefore high quality, to preserve the illicit market value while compromising any tracing efforts made.

The use of obliteration codes enables investigators to group weapons with the same characteristics and patterns of sanitisation. For organisations tracking and tracing illicit weapons in support of the International Tracing Instrument, this will assist in the eventual identification of specific nodes conducting the obliterations and sanitisation of weapons. This work will be integrated into a larger piece of work which aims to provide a degree of confidence in identifying a global region where a sanitisation was conducted. The obliteration codes generated in this work will be the baseline for Country X recoveries and compared to other codes and their prevalence around the world.

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Declaration of Interest

None

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