



**ADDIS ABABA INSTITUTE OF TECHNOLOGY, CENTER FOR
ETHIO MINES DEVELOPMENT (MENG IN MINERAL
PROCESSING**

**PROCESS ENHANCEMENT OF SAPPHIRE GEMSTONE FROM
BORENA ZONE, OROMIA REGION, SOUTHERN ETHIOPIA**

A GRADUATE PROJECT SUBMITTED TO THE CENTER FOR ETHIO-MINES
DEVELOPMENT IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF ENGINEERING IN MINERAL ENGINEERING

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Declaration of Originality

I declare that this project is my original graduate work, conducted under the supervision Dr. Mulugeta Sisay, School of Chemical and Bio Engineering, AAiT of Addis Ababa University and the Co-Guide, W/ro Aselefech Mitiku (MSc), from the Ethiopian Mineral, Oil and Biofuel Organization, at the Center for Ethio-Mines Development. Furthermore, I affirm that this work has not been submitted to any other institution for similar purposes, such as the attainment of any degree or certification. All sources and materials referenced in this project have been duly acknowledged with proper citations.

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Approval Sheet

This project, entitled "Process Enhancement of Sapphire Gemstone from Borena Zone, Oromia Region, Southern Ethiopia," has been submitted to fulfill the requirements for the Master of Engineering degree in Mineral Processing. It adheres to the university's standards and aligns with established principles of innovation and excellence.

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Abstract

The Borena Zone in the Oromia Region of Southern Ethiopia has recently emerged as a significant source of sapphires. Despite the region's potential, local processing methods remain rudimentary, often relying on manual labor and traditional techniques that limit the quality and market value of the gemstones. This study explores the current state of sapphire processing in the Borena Zone and proposes technological enhancements to improve the efficiency and quality of the final product. From Mining Engineering point of view, integrating advanced processing techniques, such as cabochon style and Faceting, the sapphire industry in this region can significantly elevate its quality of the mineral; Sapphire. Successful case studies from other regions, including Sri Lanka and Madagascar, highlight the transformative impact of modern processing technologies. Implementing these advancements in the Borena Zone has the potential to not only increase the value of Ethiopian sapphires but also foster the quality. and strengthen the local gemstone industry's global competitiveness. This project work underscores the critical need for technological investment and skill development to achieve substantial process enhancements in the Ethiopian gemstone sector.

Key words: Cabochon method, Faceting style, Enhanced Sapphire, Jewelry, Market

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Table of Contents

Abstract.....	iii
List of Figure.....	vii
List of Table.....	viii
Abbreviation	ix
CHAPTER ONE.....	1
INTRODUCTION	1
1.1. Background	2
1.2. Statement of Problem.....	3
1.3. Objective	3
1.3.1. General Objective	3
1.3.2. Specific Objectives	3
1.4. Significance of the Study	4
1.5. Scope of the Study.....	4
CHAPTER TWO	5
LITERATURE REVIEW	5
2.1. Overview of Gemstones.....	5
2.1.1. General Properties of Gemstones	5
2.1.2. History of Gemstones	7
2.1.3. Incidence of Gemstones.....	8
2.2. Gemstones in Ethiopia and the Current Use Tendency.....	9
2.3. Geographic Source Determination of Corundum.....	10
2.4. Sapphire Gemstone Processing	13
2.5. Current State of Sapphire Processing in Ethiopia	14
2.6. Challenges in Sapphire Processing	14

2.7. Technologic Advancements in Gemstone Processing	14
2.8. Impact of Improved Processing Techniques	15
2.9. Case Studies of Successful Process Enhancements	15
CHAPTER THREE	16
THE PROJECT WORK METHODOLOGY	16
3.1. Source of the Rough Sample	16
3.2. Materials Used in Sapphire Processing Enhancement	17
3.3. Sapphire Processing Methods	17
3.4. The Cabochon style	17
3.5. Faceting style.....	21
3.6. Steps in the Processing.....	23
3.6.1. Cabochon Making.....	23
3.6.2. The use of Faceting.....	23
CHAPTER FOUR.....	24
FINDINGS AND DISCUSSIONS	24
4.1. Out Comes.....	24
4.1.1. Enhancing the Rough Sapphire Gemstone Process.....	25
4.1.2. Cutting and polishing of sapphire.....	26
4.1.3. Faceting	26
4.1.4. Shining.....	27
4.2. Sapphire Gemstone Process Improvement Description	27
4.2.1. The Geological Setting	27
4.2.2. Social and Economic Impacts.....	29
4.2.3. Environmental Considerations	29
4.2.4. Modern Processing Methods	29
4.2.5. Advances in Technology	29
4.2.5.1. Color	29
4.2.5.2. Clarity	31
4.2.5.3. Cut	31
4.2.5.4. Weight	32
CHAPTER FIVE	33

CONCLUSIONS AND RECOMMENDATIONS	33
5.1. Conclusion.....	33
5.2. Recommendations	34
REFERENCES	36

List of Figure

Figure 1: Production stages of colored gemstone jewelry.....	8
Figure 2:Ga/Mg versus Fe discrimination diagram for sapphires (From Voudouris et al.2019...)	13
Figure 3: Rough sapphire mineral at site when sample was collected.....	16
Figure 4: From left to right Hitch Diamond the Hi-Tech Diamond Slant Cabber model, the Diamond Pacific GENIE model, and the All-U-Need model.....	20
Figure 5: A busy cabochon polishing machine	20
Figure 6:Faceting Machine with activity.....	22
Figure 7: Swat cutting, Faceting, and Polishing Machines with activities.....	24
Figure 8: Rough sapphire is sorted and measured before being processed using a digital gram and light.....	24

List of Table

Table 1: Unit Price Export of Ethiopian Rough Sapphire (Source: From EMPBC).....	9
Table 2: Sapphire gemstone enhancement.....	25
Table 3: Weight (in grams) differentiates between improved and rough sapphire.....	26
Table 4: Rough and Enlarged Sapphire Cost in the Borena Zone (Source:EMPBC).....	30

Abbreviation

OMDA.....	Oromia Mineral Development Authority
ASM.....	Artisinal and Small Mining
CAD.....	Computer-Aided Design
CAM.....	Computer-Aided Manufacturing
USD.....	United States Dollar
ETB.....	Ethiopian Birr

KG.....Kilogram

EMPBC.....Ethiopian Mineral, Petroleum and Biofuel Corporation

CHAPTER ONE

INTRODUCTION

Gemstone mining emerged with the discovery of a precious chocolate opal in north Shewa province near Mezzezzo town in the 1990s. In 2008, yet more stable and valuable white opal was found in Wollo province, more precisely in the Delanta area, near Wogeltena and Tsehay Mewcha towns [1].

As it is well stated by [2] Ethiopia's economy is diversified from agriculture by mining. Industrial minerals, gemstones, and gold are principal commodities in the nation's export-driven development strategy. Ethiopia is well endowed with natural resources and has a wide variety of unexploited minerals; Gemstones and petroleum have also been found. The reserve amount and degree of deposits are not known even though the gemstone has evidently high economic values and has been found in many locations. A successful and lucrative mining operation is certain once a very competent and determined labor force is teamed with a precious material.

The Borena Zone, located in the Oromia Region of Southern Ethiopia, is renowned for its rich deposits of sapphire gemstones. Despite the abundance of these precious stones, the current processing techniques remain rudimentary, resulting in suboptimal quality and limited market reach [3].

A gemstone, often called a precious or semi-precious stone, is a beautiful mineral specimen that is used in the manufacture of jewellery after cutting and polishing. A few of the minerals used as gems include opal, aquamarine, garnet, olivine, tourmaline, topaz, sapphire, ruby, amethyst, agate, jasper, etc. Its natural beauty, its scarcity, its hardness and durability, and the skill with which it has been cut and polished are the four main factors that determine its value [4]. Gemstones like sapphire minerals are graded based on the criteria which called —four C's and these four C's in gemstones are Color, Clarity, Carat and Cut [5].

Process enhancement, or the improvement and enhancement of a mineral carried out by a company prior to selling the minerals, is essential to obtaining the right benefits from the gemstone industry. It combines lowering a mineral's production costs with enhancing its value (often a gemstone) through processing or treatment to increase its market worth.

The process of value addition has fundamental advantages to the company, local people and the government at large [5]. In addition, it is the link that can help effectively convert minerals to financial returns. Ethiopia currently has a major challenge in the values addition field. Although the country is rich in minerals, the economy is still crippled, and selling the raw materials abroad wouldn't largely and radically change the scenario. Since the exports are priced low, the government receives relatively less cash, and the foreign nations receive the most. By transforming the raw materials that were imported into finished goods, the foreign nations impart more value to them [6].

The African countries then import these products at high prices. As a result, this creates a huge gap between the developing countries and the developed in terms of wealth. The unlike statistical distribution of financial condition has contributed to the underdevelopment or slow rate of development in developing nations, particularly Africa. So, the same holds true for Ethiopia in general but for the purpose of this paper particularly for gemstones.

1.1. Background

Ethiopia's Borena Zone is home to a rich deposit of sapphires, particularly in the southern part of the Oromia Region. These sapphires have recently gained attention for their exceptional quality, attracting interest from international gemstone markets. Despite this potential, the local gemstone industry faces significant situation owed to the demand of modern processing facilities and techniques [7].

The traditional methods employed by local miners involve manual extraction and basic processing technique. This often results in lower quality gemstones that are less competitive in the global market [8]. The absence of advanced cutting and treatment technologies further exacerbates the issue, as the gemstones fail to reach their full potential in terms of quality and value [9].

The use of CAD and CAM technologies has allowed for greater precision in cutting, while heat treatment processes have enhanced the color and clarity of the gemstones. These advancements have significantly improved the marketability and value of gemstones from these regions [1].

By drawing insights from these successful case studies, this research seeks to propose similar enhancements for the sapphire processing industry in the Borena Zone. The goal is to highlight

the critical need for technological investment and skill development to elevate the quality and market position of Ethiopian sapphires. Implementing these advancements could not only increase the value of the gemstones but also contribute to economic growth and job creation in the region [10].

1.2. Statement of Problem

Despite the region's natural wealth, the current processing practices are outdated and inefficient, resulting in substandard gemstones that fail to meet international market demands. This inadequacy not only diminishes the economic value of the sapphires but also restricts the socio-economic development of the local communities [11]. The existing mining techniques are primarily manual and lack the technological advancements necessary to produce gem-quality stones without damage. Consequently, many sapphires are either damaged or lose their gem quality during processing. Moreover, the lack of proper mining and resources abuse by local artisans further worsens the problem, leading to inconsistent quality and a higher rejection rate in global markets.

Addressing these issues is imperative to enhance the processing methods of sapphires in the Borena Zone. By implementing modern technologies and providing adequate training to local artisans, it is possible to significantly enhance the quality of the Sapphire in Oromia Regional State Borena Zone [12].

1.3. Objective

1.3.1. General Objective

The general objective of this project is to enhance the processing and production techniques of sapphire gemstone from the Boreza Zone, Oromia region, southern Ethiopia.

1.3.2. Specific Objectives

Specific objectives will be:

- To enhance the color, clarity, and general quality of sapphires
- To identify appropriate cutting method of the sapphire
- To introduce the correct way of faceting of the sapphire

1.4. Significance of the Study

The significance of enhancing process of sapphire extends beyond economic benefits; it also offers opportunities for local development and skill enhancement. By leveraging advanced technologies and methodologies, the research can address existing challenges in the processing chain and establish a model that can be replicated across other gemstone-rich regions in Ethiopia. The study on the process enhancement of sapphire gemstones from the Borena Zone, Oromia Region, Southern Ethiopia holds considerable significance for several reasons:

Economic Development: By improving the processing techniques of sapphires, this study aims to enhance the quality and market value of Ethiopian gemstones. This has the potential to boost the local economy by increasing revenue from gemstone exports. Higher-quality sapphires can attract better prices in the international market, providing substantial economic benefits to the local communities and the country as a whole.

Competitive Advantage: By adopting advanced processing techniques, Ethiopian sapphires can meet and exceed international standards. This will enhance their competitiveness in the global gemstone market, positioning Ethiopia as a significant player in the industry. A strong international presence can lead to increased market share and recognition for Ethiopian gemstones.

In summary, this research project remains important by way of it addresses the critical need for technological and skill enhancements in the sapphire processing industry in the Borena Zone. By highlighting the potential economic, social, and environmental benefits, the investigation delivers a comprehensive framework for leveraging Ethiopia's natural resources to achieve sustainable development and global competitiveness.

1.5. Scope of the Study

The scope of this project is only the enhancement of the Sapphire mineral quality found in Borena zone. In the Processes the sample was cut appropriately and Mineralogical processing like application of Cabochon and faceting was done.

CHAPTER TWO

LITERATURE REVIEW

2.1. Overview of Gemstones

2.1.1. General Properties of Gemstones

Any valuable or semiprecious stone that can be cut and polished to be employed in ornaments is known as a gemstone. Like semi-precious gemstones, precious gemstones are scarce, attractive, and long-lasting. Therefore, compared to precious gemstones, semi-precious gemstones are of lower quality but more common. Brilliance, shape, and size are some other characteristics that define the value of a gem. After being cut and polished, gemstones are employed in jewelry or other ornaments [13] .

Any mineral, rock, or organic material that can be cut, polished, or otherwise prepared for use as jewelry or other ornaments is a natural gemstone. A precious gemstone possesses beauty, durability, and rarity, whereas a semiprecious gemstone possesses one or two of these characteristics.

Gemstones are precious or semi-precious stones. It is a mineral crystal that differs in type, color, and grades. Topaz, garnet, amethyst, ammolite, benitoite, zircon, labradorite, kyanite, sapphire, ruby, aquamarine, turquoise, emerald, diamond, and many more are a few of the examples of gemstones. Although some rocks, such as lapis lazuli, fall under gemstones and can still be used to make jewelry, they are not minerals like amber. Because of their unique characteristics, gemstones are always treasured and coveted regardless of the purpose. They are usually wear-resistant and require washing and polishing prior to use, especially in decorations.

A unique class of non-metallic minerals (rocks) known as gemstones (gems) are prized for a variety of reasons and are used to make jewelry and other personal accessories. Jewelers cut, facets, and polish them before selling for comparatively exorbitant rates. The majority of gemstones are minerals that naturally occur in rocks as crystals, albeit occasionally. Most gemstones are naturally occurring minerals in rock as well-formed crystals, sometimes stunning objects of beauty; they are precious because of their rarity and strong enough to provide their owners considerable service over the years. Some gems are rocks (like lapis lazuli) or animal products (like amber and pearl), but most are minerals. Due to people wishing to possess them as

jewelry, they form gemstones.[13] , also defined in his revision that above binary hundred mineral deposits were referred to as gemstones but less than 10% of them are commercially available and handled worldwide. A mineral must possess some attributes in order to be considered a gemstone, for example, beauty and deep color, luster and transparency (no inclusions), hardness and toughness, and complete rarity. These traits have so escalated the price of gemstones that they are a luxury for both payment and the prosperous. Though the masses do enjoy gemstones, they are only able to afford the lower-priced varieties or the substitutes provided by technology. Average gemstone prices range between a few dollars and over \$15,000 per carat (1 carat=200 mg). Blue diamond, the world's most expensive gem, is available for purchase at approximately \$4 million a carat.

In terms of mineralogy, gemstones are mostly silicates that are distinguished by their distinct physical characteristics, such as brilliant color, high Mohs hardness, improved specific gravity, superb cleavage, and dazzling brilliance. Mineral groups (such as beryl, corundum, garnets, and tourmalines), chemical properties (such as organic and inorganic), and commercial worth (such as precious and semiprecious) are some of the factors used to classify gemstones. Jewelers and marketers continue to utilize the most popular classification, which was developed in the 1800s and is based on quality and value. Precious and semi-precious stones are the two categories that have been distinguished.

These four minerals that make up precious stones—sapphire, ruby, emerald, and diamond—are extremely valuable and attractive. The most interesting and valued of all the gemstones is the diamond composed of recrystallized carbon, typically radiant and colorless or weakly highlighted. The mineral beryl ($\text{Be}_3\text{Al}_2(\text{SiO}_3)_6$) has a green multiplicity called emerald. Ruby is a pink to blood-red variety of the mineral corundum (Al_2O_3). White sapphire is a royal blue variety (polymorph) of the same mineral corundum. The different colors are recognized to different trace element content. The semi-precious stones comprise all other gemstones; mostly colored gems that are considered less valuable or less appealing. Examples include tourmaline, topaz, zircon, garnets, amethyst, aquamarine, and peridot (olivine) [13].

2.1.2. History of Gemstones

Since more than 25,000 years ago, gemstones have been used. They were known by a variety of names in antiquity, including mood stones, healing stones, crystals, and healing crystals. Nonetheless, gemstones come from diverse regions. Around 4000 BC, the Egyptians are known to have imported obsidian gemstones, which they used to make jewelry and weaponry. Gemstones were utilized to manufacture jewelry and implements in China circa 3600 BC. Nephrite jade was popular among the Chinese. Up to the twenty-first century, gemstones were recycled by Indians, Greeks, Romans, Europeans, Africans, and a widespread of others through the world, particularly for artistic and restorative purposes [14]. Nigeria nonstop estimated toward obligate developed a significant producer of sapphire, topaz, tourmaline, and aquamarine in the middle-1980s after initial hearsays of original gemstone finds in Central Nigeria generated to screen into the international glob. Rare belongings stay now known about production masses, the area, and the paragenesis of these gem deposits, and furthestmost of these gemstones have been run out of the country. Topaz and aquamarine are typically found alongside the edges of younger granite masses. Pegmatite of the older granite bodies is originated with tourmalines. Eluvial deposits above weathered alkali basalts have yielded sapphires and zircons. The range of gem-quality zircons is red to colorless, and stones in this range have been subjected to chemical studies. The gemstone's discovery marks the beginning of the gemstone route.

As stated by [15]. Devising awareness of the geological location and environment in which certain gemstones are found can lead to discoveries, as gemstones are several of the more precious substances on earth's surfaces and ground. Beginning from the investigation stage to the final client, the gemstone passes through a series of geographically and organizationally dispersed activities known as the gemstone pipeline [13]. A gemstone travels long distances and from hand to hand among miners, gem traders, and stakeholders done this procedure. Panning, cleaving, bruiting, polishing, and final inspection are the huge treating steps that the gemstone has to go through to be organized for the final customer as a portion of jewelry because gemstones in their natural state have very irregular geometry and are full of many contaminations [16].

2.1.3. Incidence of Gemstones

Due of the rare conditions that facilitate their production and the generally limited expanse of the lithology they are connected with, gemstones are not very common. As a result, unlike metallic minerals, which form huge ore deposits, gemstones often exist in modest quantities. Therefore, in this context, the phrase "gem deposits" will refer to natural gemstone concentrations where individual mineral crystals can have a value of millions of dollars. Gem deposits are characterized by their value rather than their size. Small deposits are frequently mined because of the high value of gemstones. Groups of microscopic aggregates or tiny hydrothermal veins and cavity fills in host rocks, whose crystallization spans from syngenetic to epigenetic, are the most common forms of major gem deposits. They can either be thinly spread or scattered over a lot of rock (like diamonds in kimberlites). The alluvial transport of primary minerals, erosion, and chemical weathering all contribute to the alluvial deposits' proximity to the source regions. Because of their comparatively high specific gravity and solidity, gems can resist both physical abrasion and chemical breakdown, preserving their original shape and attrition resistance for extended periods of transit. Moreover, stream gravels with meditations of gemstone crystals tend to be microscopic, and they occur on a stream bed as small lenses or pockets of gravel. In decomposed rock, gemstones can be more than a few rhythms under the superficial, necessitating the pitting or trenching of overburden. Compaction also cementation of sedimentary buildups can result in the formation of paleoplacer gemstone deposits [13].

Gemstones are ranked according to the so-called "Four" C's and in them gemstones, color, clarity, carat, and cut are the four Cs [5].The steps that a gemstone goes through on its journey from the mine stage to being sold as jewelry to the final consumer are the same for all gemstones, notwithstanding the complexity of supply chains for colored gemstones. These steps can be summed up as follows:

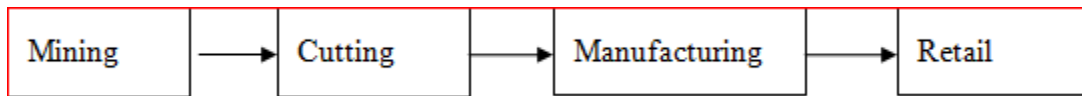


Figure 1: Production stages of colored gemstone jewelry

2.2. Gemstones in Ethiopia and the Current Use Tendency

Opals, emeralds, sapphires, amazonite, amber, rubies, tourmaline, aquamarine, chrysoprase, peridot, chalcedony, obsidian, agate (scapolite agate), jasper, petrified wood, and different varieties of quartz, including precious quartz, are among the many varieties of high-quality gemstones found in Ethiopia [17]. There are significant deposits of opal, corundum, beryl, garnet, peridot, species of quartz, and tourmaline in the country. The highest-priced beryl of all, emerald, was recently discovered in the Guji Zone of the Oromia Region in the Seba Boru area. The latest unit price of Ethiopian rough sapphire exports is shown in the table below.

Table 1: Unit Price Export of Ethiopian Rough Sapphire (Source: From EMPBC)

S. No.	Grade (depend on 4C's Grading)	Updated Export Price in USD /Ct
1	A	300
	B	185
	C	70

One could infer from the preceding data that Ethiopia exports sapphire gemstones at extremely low prices in their unpolished state.

Process improvement is essential to reaping the full benefits of the diamond industry. Value addition involves both lowering the cost of producing a mineral and adding value to it (mostly gemstones for the purposes of this project work) by processing or treating it to increase its selling price. Value addition is the improvement and enhancement of a mineral that a company does before selling the minerals [5]. The government, the community, and the business all gain from it. Additionally, the connection that can most effectively help transform the wealth of minerals into economic wealth is value addition. Currently, African countries that are labeled as developing countries—Ethiopia being among them—are hit by a severe problem as a result of value addition of minerals and extractives [5].

Despite the mineral wealth of the nations, poverty has been steadily rising. All of this is demonstrated by the fact that raw minerals extracted in emerging nations are transferred to other nations. Due to the low prices at which the exports are sold, the government receives relatively

little cash, and foreign nations benefit the most. By processing and turning the imported raw resources into finished goods, the foreign nations give them more value [22]. These goods are then expensively imported by the African nations. As a result, there is a significant wealth disparity between emerging and established nations. The underdevelopment or sluggish rate of development in developing countries, especially in Africa, has been exacerbated by the unequal distribution of income. The same is true for Ethiopia as a whole, but specifically for gemstones in the context of this research.

According to the report by [18], there are currently no well-documented studies on gemstone mineral deposits, which is a step backward because that is the primary parameter used to determine the overall analysis and the strategy. To address this issue, we have prioritized the commodity using production data that has been exported and export revenue. The ministry's mineral market development and value chain directorate has provided various market studies to aid in the process improvement. According to the industry profile study, artisanal miners in Ethiopia are responsible for all gemstone unearthing activities. For instance, when compared to all non-opal gemstones combined, opal leads the gemstone industry in income generation, with a marginally greater margin of 50%. This indicates that opal is produced in large quantities and is in high demand worldwide. According to this analysis, opal existed before the gemstone industry. When rough opal is exported in greater quantities than polished opal, the export earnings is marginally less than that of polished opal. This suggests that improving the process ought to be the strategy's top focus.

2.3. Geographic Source Determination of Corundum

Establishing the source of corundum and specifically blue sapphires, is a challenging issue [19]. To begin with, corundum from different deposits has several microscopic features in common. As such, when utilizing this information to make origin identification or to establish when the inclusion data are too vague to be utilized in origin determination, it is essential to scrutinize the inclusion features carefully. Epitaxial rutile, which is crystallographically aligned to the host corundum, is the most prevalent inclusion in corundum. Along with boehmite intersection tubules connected to the intersection of twinning planes, twinning is another prevalent feature seen in corundum all over the world.

The inclusions observed in blue sapphires of igneous origin such as Ethiopia, Nigeria, Thailand, Cambodia, and Australia could be characteristic of the host rock and growth conditions. Colorless feldspar crystals are one of the more common minerals encountered in blue sapphires of volcanic origin, but also glassy melt inclusions which are very suggestive of igneous origin can be present, and other mineral inclusions such as pyrochlore and columbite.

Negative crystals, or voids with the crystallographic structure of the host corundum, are frequently found in sapphires from metamorphic deposits like those found in Myanmar, Sri Lanka, or some localities in Madagascar. These voids are filled with carbon dioxide fluid, diaspore, and occasionally graphite. Phlogopite mica, carbonate crystals, green spinel, and black cubes of uraninite are other solid minerals that are occasionally found. (Note that a subsequent article will explain the precise criteria used to differentiate blue sapphires according to their inclusion properties; [19] of this issue.)

A geographic origin is rarely identified by a solitary inclusion category. A good exception is pargasite and tourmaline in Kashmiri sapphires. These types of inclusions are unusual and cannot always be relied upon to support an origin determination.

Inclusions found in rubies are generally indicative of the host rock or geologic environment that produced them. Some of these include spherical grains of protogenetic calcite, which frequently are present in rubies occurring in marble deposits. Graphite, apatite, phlogopite, and rutile are among other mineral inclusions typical of such an environment. Inclusions in rubies of basalt-related origin, like those of Thailand and Cambodia, are a whole lot different from those of stones derived from metamorphic or metasomatic deposits. In the case of volcanic rubies, glassy melt inclusions form one of the most prevalent and distinctive inclusions. Metal sulfides or other minerals may be present in these rocks as well.

Elongated rods of pargasite inclusions, which are indicative of their geological origin, are frequently found in rubies from metasomatic deposits, such as those connected to amphibolite (such as the Montepuez deposit in Mozambique). Provides more information on the precise standards used to differentiate rubies of different geographical origins. It should be noted in; [19] of this issue.

Because the species and concentrations depend on (1) the elements' source and (2) the genesis of the deposits that contain corundum, such as crystallization from a magma (syenite) or fluid-rock interaction through metamorphic reactions (amphibolite), trace elements are frequently used to determine the origin of corundum.

The path toward determining the origin of corundum based on chemical composition was begun by [20], who compared trace elements in 283 natural and synthetic rubies from 12 producers and 14 sources using energy-dispersive X-ray fluorescence. They discovered that almost all synthetic rubies could be distinguished from natural rubies by the Ti, V, Fe, and Ga contents taken together as a trace element signature.

This signal can also be utilized to suggest a ground origin and, in the process, establish the geological setting under which a ruby should have formed (figure 2). They have determined, for example, that marble-hosted rubies from Afghanistan, Myanmar, Nepal, and China are V-rich and Ga- and Fe-poor, except for those in Afghanistan and some from China, Nepal, and the Mogok mines in Myanmar, whereas rubies from basalts from Thailand and Cambodia are Fe-rich and V- and Ga-poor. Trace element concentrations in meta-somatic rubies found in different kinds of rocks and in different types of geological settings varied over a wide range [12]. Used LA-ICP-MS on corundum of various geological situations and optional use of the contents and ratios of Fe, Ti, Cr, Ga, and Mg (e.g., Ga/Mg, Fe/Ti, Fe/Mg, and Cr/Ga) to decide the origin of the sapphires. This finding is supported by the Fe vs. Ga/Mg map in Figure 2, which shows that most Naxos sapphires are dispersed in the metamorphic sapphire field, with blue and some pink sapphires overlapping the Yogo Gulch, Montana, magmatic sapphire field. The Naxos example demonstrates the complexity and uncertainty of applying trace element chemistry. There is a larger overlap between metamorphic and magmatic blue sapphires than had been thought, according to observations in GIA's colored stone reference database for blue sapphires [4]. The following types of blue sapphires were distinguished based on the parameters in [21] for those found in alkali basalts: (1) Fe-rich (average 2000–11000 Fe ppmw), Ga-rich (>140 ppmw), and Mg-poor (10); and (2) metamorphic pastel blue sapphires with low average Ga/Mg ratio (asites resulting from metasomatism of pegmatites) that are Fe-poor (average Fe 60 ppmw).

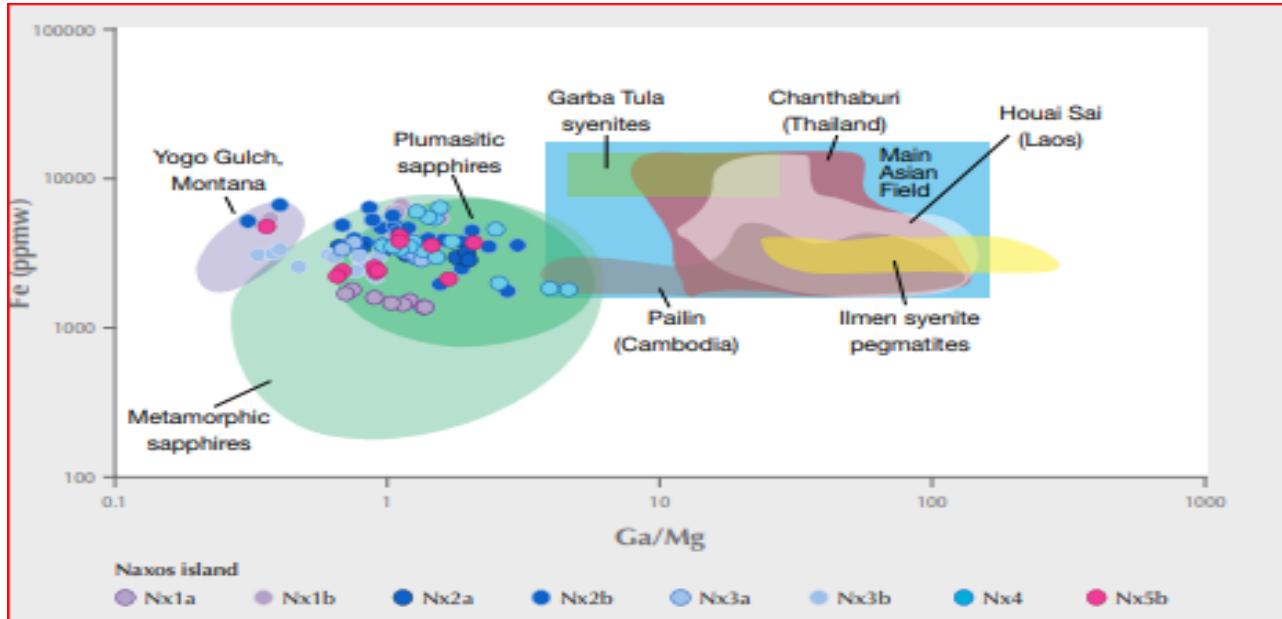


Figure 2: Ga/Mg versus Fe discrimination diagram for sapphires (From Voudouris et al. 2019)

2.4. Sapphire Gemstone Processing

The sapphire, a valuable gemstone of changing color, but with blue being the most sought after, belongs to the corundum family. The rough sample of the sapphire will be gathered from various regions with known gemstone deposits around the area if possible; otherwise, activities will be conducted on the given sample from the Ethiopian Mineral, Petroleum and Biofuel Corporation workshop with interest in the corporation's welfare.

Sapphire is subjected to different processes such as extraction, sorting, cutting, polishing, and grading. The market value of the final product and its quality depend greatly on each of them. Sophisticated cutting technology and heat treatment have been shown to improve the quality and appearance of sapphires and thus make them competitive in the global market. But problems like output undervaluation, lack of regulation, general illicit mining, and rough, non-standard treatment persist in the colored gemstone ASM industry [22]. It is no accident that, in contrast to other mining operations, the colored gemstone sector has been sluggish to address the sustainability issue [23].

2.5. Current State of Sapphire Processing in Ethiopia

Ethiopia has recently emerged as a notable source of high-quality sapphires, particularly from the Borena Zone. However, the local processing methods remain rudimentary, often relying on manual labor and traditional techniques. Studies indicate that the lack of modern equipment and insufficient training among local artisans result in lower quality gemstones, which struggle to meet international standards [12]. This gap offers a substantial opportunity for process improvement to improve the standing of Ethiopian sapphires in the international market.

2.6. Challenges in Sapphire Processing

Formal or informal mining operations that primarily use simplified methods of exploration, extraction, processing, and transportation are known as artisanal and small-scale mining (ASM), which is generally low capital and labor intensive [24].

Men and women who labor alone, in family groupings, in partnerships, or as members of cooperatives or other legal entities and businesses that employ hundreds or even thousands of miners can all be considered ASM. ASMs are among the most significant sources of income for low-income individuals worldwide. Particularly in developing nations like Ethiopia, where this type of mining is one of the most prevalent activities among the populace residing in the nation's rural areas [14]. The processing of sapphire in the Borena Zone faces a number of issues:

Limitations of Technology: The results are unsatisfactory when high-end cutting and polishing equipment is not available.

Skills Deficiencies: Local artisans may lack the education and exposure to use sophisticated processing methods.

Quality Control: To maintain the uniformity and marketability of treated sapphires, strict quality control is essential.

Economic Constraints: The development of extensive training programs and the purchase of contemporary processing equipment are limited by a lack of finance.

2.7. Technologic Advancements in Gemstone Processing

Studies identify various technological innovations that have transformed gemstone processing around the world. For example, advancements in computer-aided design (CAD) and computer-aided manufacturing (CAM) technologies have improved the accuracy and effectiveness of

cutting gemstones. Furthermore, heat treatment techniques are now being applied as common practice to enhance the quality of sapphire color and clarity. These technologies are important guides for possible improvements that can be made in Ethiopia's sapphire processing sector [25].

2.8. Impact of Improved Processing Techniques

Research has shown that improved processing techniques can significantly enhance the value of sapphires. For instance, well-heated and well-cut sapphires receive higher premiums in the global market. Additionally, improved processing can lead to more employment opportunities and economic development in regions where there is an abundance of gemstones. Implementing these methods in the Borena Zone would see the local gemstone industry significantly transformed and the population enjoy considerable economic benefits [26].

2.9. Case Studies of Successful Process Enhancements

Ethiopia can reap the benefits of successful development of gemstone processing capabilities elsewhere. Sri Lanka and Madagascar, for example, have enhanced market standing and provided higher-quality gemstones through access to modern processing technology and training [25]. These case studies illustrate how talent development and technology investments must be in place to achieve substantive process improvements.

This literature analysis highlights the urgent need for process improvement in the sapphire gemstone sector in the Borena Zone, Oromia Region, by combining these findings. Such advancements could have far-reaching advantages, including increased economic growth, the creation of jobs, and a more powerful position in the world gemstone market [30].

CHAPTER THREE

THE PROJECT WORK METHODOLOGY

The objective of this project is Borena rough sapphire, which is the focus of process improvement for enhancing its jewelry value and by extension, its unit price. To produce a faceted gem or cabochon, the naturally occurring precious sapphire mineral is cut and polished to produce a gem product with added worth. This is achieved through a detailed review of the literature and methods of treatment of gemstones.

3.1. Source of the Rough Sample

The Borena zone, one of the 21 zones that make up the Oromia Region, is 570 kilometers from Addis Ababa and is where the rough sapphire sample was taken. This area, located in southern Ethiopia and going southwards to Kenya, takes its name from one of the two larger Oromo subgroups. This area is renowned for its varied landscape, where national parks, savannas, and mountains exist [28].



Figure 3: Rough sapphire mineral at site when sample was collected

3.2. Materials Used in Sapphire Processing Enhancement

Below is a discussion of some of the materials used in the production of sapphire gems.

1. Slurries for Polishing: Slurries of alumina and silica are employed with the intention to create a free-defect, smooth surface for sapphire. The slurries are specially formulated such that they react to sapphire's hardness and crystal direction.

2. Nano-Abrasives: In CMP processes for more precise polishing outcomes, nano-abrasives are utilized. These materials ensure the removal of surface defects as well as provide a high-quality surface finish [35].

3. Completing agents and pH regulators: are chemical reagents utilized in CMP slurries to control pH and improve polishing efficiency. They help in reducing surface defects and material removal uniformly.

3.3. Sapphire Processing Methods

In order to enhance the properties of sapphire and bring it to the desired quality, processing involves several methods. Some of the key methods for Sapphire enhancement processing include:

Ultrasonic Vibration-Assisted Machining (UV-A): It is a method that employs ultrasonic vibrations to enhance surface quality and decrease cutting forces in the machining process. Since sapphire is hard and brittle, UV-A machining is particularly useful in cutting and shaping it [29].

Chemical-Mechanical Polishing (CMP): CMP is a method that employs both chemical and mechanical forces to provide sapphire with a perfect, smooth surface. The process is widely applied in the production of high-quality sapphire wafers in electronics and optics industries [30].

EFG stands for edge-defined film-fed growth, a technique for the growth of complex and bulk sapphire crystals. It is suitable for a number of high-technology applications since it allows close control of size and shape of the sapphire crystal during the process of growth [31].

3.4. The Cabochon style

Sapphires are typically cut in the Cabochon style, particularly when the natural color and beauty of the stone are to be maximized. It is one of the methods gemstones are cut to achieve a curved

surface that is polished and smooth. In its most basic form, it has an unpolished flat back and an open domed top. This is a summary of the process:

- 1. Rough Sapphire Selection:** First, a raw sapphire that can be cut into cabochon is chosen. This is the process of choosing a stone with few imperfections and nice color.
- 2. Dome Shape:** The rough sapphire is then shaped into a dome with a grinding wheel or other cutting tools. The idea is to create a smooth, rounded, symmetrical surface.
- 3. Polishing:** A number of abrasive substances are used to polish the cabochon sapphire to a brilliant luster after the dome form is attained. In order to enhance the natural color and texture of the stone, the process is done.
- 4. Treatment Methods:** Sapphires are also treated to enhance their color. Titanium diffusion is one of the most popular treatment methods, where the blue hue of the sapphire is darkened by subjecting it to heat with titanium.

Because of their rounded and smooth surface, which emphasizes the natural beauty of the gemstone rather than its brilliance, cabochon-cut sapphires have a distinctive and original appearance [32]. This cut is often used on larger stones and can yield a very attractive subtle play of light and color. Cabochon machines cut and polish gemstones on a number of diamond wheel grits [29]. These are talked about as follows.

A. Coarse Grits (80-260): These do material removal and shaping. The objective while operating on the sapphires on a cabochon machine with coarse grits (100-260) is to shape the rough sapphire into a manageable shape. What follows is a step-by-step explanation of the process:

First Shaping: To cut away a lot of material quickly, begin with the 100 grits wheel. In this process, the rough sapphire is reduced in size and the overall shape of the cabochon is determined.

Refining Shape: Move to the 260 grit wheel to further refine the shape. This grit is still coarse but finer than 100 grit, allowing you to smooth out the rough edges and start forming the final outline of the cabochon.

Water Supply: Ensure a steady supply of water to both wheels for lubrication and cooling. This helps prevent overheating and reduces dust.

Safety Precautions: Always wear protective gear, such as safety glasses and gloves, to protect you from flying debris.

Regular Inspection: Frequently check the progress of your work to ensure you're achieving the desired shape and size. Once you've completed the shaping with coarse grits, you move on to medium and fine grits to further smooth and polish the sapphire.

B. Medium Grit (280–600): Used to further smooth and shape the stone's surface. Used during the sapphire enhancement process when it is in the cabochon machine.

Smoothing: The cabochon shape is polished and rough edges smoothed with medium grits (280–600) after the first rough shaping with coarse grits. The heavy scratches created with the coarser grits are removed in this step.

Form Refining: These grits assist in further refining the shape of the cabochon. Between 280 and 600 grit, the surface of the sapphire is smoother and more formed.

Transition to Polishing: Medium grits prepare the stone for the polishing stage and the finer grits. They get the cabochon as close to the final shape as possible and reduce any remaining flaws to a minimum.

Consistency: To prevent unevenness or introducing new scratches, it's best to apply pressure and motion with these grits at a steady rate.

Application of Coolant: Avoid overheating and to remove the small particles produced during grinding, maintain a constant flow of water or coolant. The sapphire's actual brilliance and luster will become apparent during the last stages of polishing, which are successfully determined with medium grits.

C. Fine Grits (e.g., 1200–3000): These are used to polish the stone and hone its shape. A smooth pre-polished surface is the ultimate goal when using fine grits (1200–3000) on a cabochon machine during the sapphire enhancement process. Here is a detailed review of the process:

Fine Shaping: Begin with the 1200 grit wheel. This will remove any last imperfections and continue to shape the cabochon further.

Pre-Polishing: The sapphire is then ready for the final polishing phase by moving up to a higher grit, i.e., 3000 grit. There should now no longer be scratch marks and the surface will be extremely smooth.

Minimal Pressure: To prevent forming new scratches, apply minimal pressure during this phase. The objective is to smooth the surface gradually.

Coolant Use: In order to avoid the wheel and stone from warming up and also to remove any minute particles, keep using a stream of coolant or water.

Inspection: Check regularly how the progress of the work is going. The surface is supposed to become smoother and more reflective as time passes. Sapphire is now ready to be given the final polish, which will reveal its natural brilliance and beauty, once fine grits have been achieved [30]. Examples of capping tools used to create cabochons are:

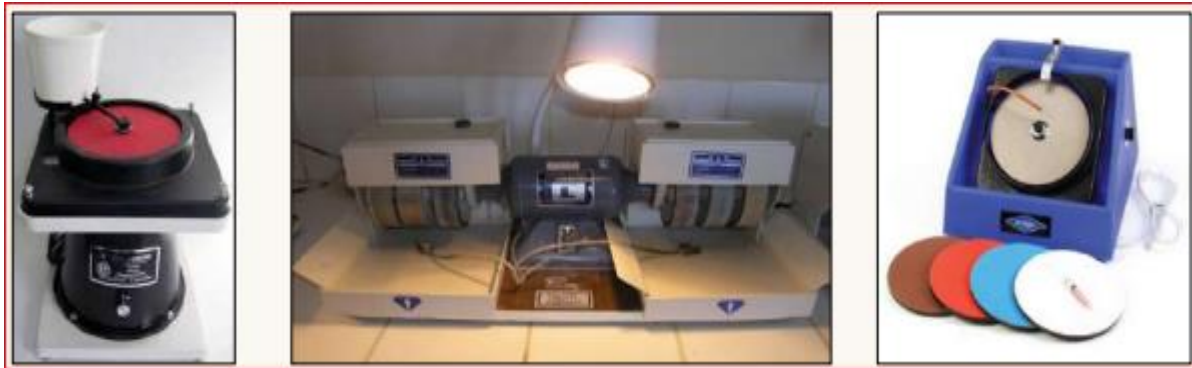


Figure 4: From left to right Hitch Diamond the Hi-Tech Diamond Slant Cabber model, the Diamond Pacific GENIE model, and the All-U-Need model



Figure 5: A busy cabochon polishing machine

The following materials are needed for the cabochon making process:

- Get the sapphire mineral rough.
- A sawing machine with lubricants and a blade
- Molds or templates (standard shapes),
- A trim saw that consists of a blade and lubricants (gas oil or water),
- Dope stick (wood or metal),
- Polishing wheels and grinding and polishing machine
- A pencil, an ink pen, tracing paper, and a ruler (for using templates to make various forms),
- Glue, cleaning materials with various pincers, a small gas cylinder or torch and packing materials.

3.5. Faceting style

One of the most important processes to increase sapphires' beauty and worth is faceting. In order to prepare a final gemstone of the highest brilliance and clarity, the rough sapphire stones need to be cut and polished [33]. Faceting methods produce very smooth and regular small faces, or facets, on the surface of the gemstone, in contrast to a cabochon cut. Facets can be flat or curved. In terms of faceting styles, two strong determinants are:

For smaller- to medium-sized sapphires, foreign faceting is a popular option. The stones are exported to countries such as Sri Lanka, where there is an excellent lapidary industry, to be cut and polished. This results in high-quality cuts at an affordable price.

Montana Faceting: Local Montana faceting is ideal for larger, more valuable sapphires. Individualized cutting and designing are achievable through this method, guaranteeing maximum output for irreplaceable stones.

Some examples of the faceting machines utilized for creating faceted objects are the following:



Figure 6: Faceting Machine with activity

Faceting sapphires raise their worth in addition to enhancing their beauty. The following sequential steps are included in this sapphire mineral processing method:

- In order to get facet raw stone, the rough sapphire is sorted and/or graded.
- Eliminating poor sources or trimming to the correct size
- Doping

The upper and lower surfaces of the sapphire sample are polished and faceted by spinning the discs in line with the ultimate form that will be needed. Faceting is carried out with the use of the following: -

- ✓ Rough sapphire mineral face
- ✓ The Physical Fact Cut Project
- ✓ Nobble stick; glue or Amir;
- ✓ Faceting machine with different plates and water;
- ✓ Diamond residue and/or olive oil/diamond plate;
- ✓ Packing materials and Trim saw machine with blade and lubricants

3.6. Steps in the Processing

3.6.1. Cabochon Making

The subsequent step-by-step processes are needed for the sapphire mineral processing technology of cabochon making:

- The boulder stone of the sapphire mineral is cut to size in slabs or gravels using templates as a guide
- The stone is then cut using a trim saw and doped on a dope stick (doping)
- The stone is then ground and polished using six stages of different grits of grinding and polishing wheels, starting from the initial rough surface smoothening and finishing to final polishing and shining stages.

3.6.2. The use of Faceting

The following series of operations is a part of faceting sapphire gemstones:

- Sorting and/or grading of the raw sapphire to get rough stone facet
- Removing low-quality or irrelevant sources or condensing to the desired length
- Doping - Altering the discs based on the ultimate form that will be necessary to facet and polish the sapphire sample (top and bottom).

CHAPTER FOUR FINDINGS AND DISCUSSIONS

4.1. Out Comes

The following photos illustrate sapphire process enhancement lapidary machinery and operations taken at the Ethiopian Mineral, Petroleum and Biofuel Corporation Gemstones work shop center during part work.



Figure 7: Swat cutting, Faceting, and Polishing Machines with activities

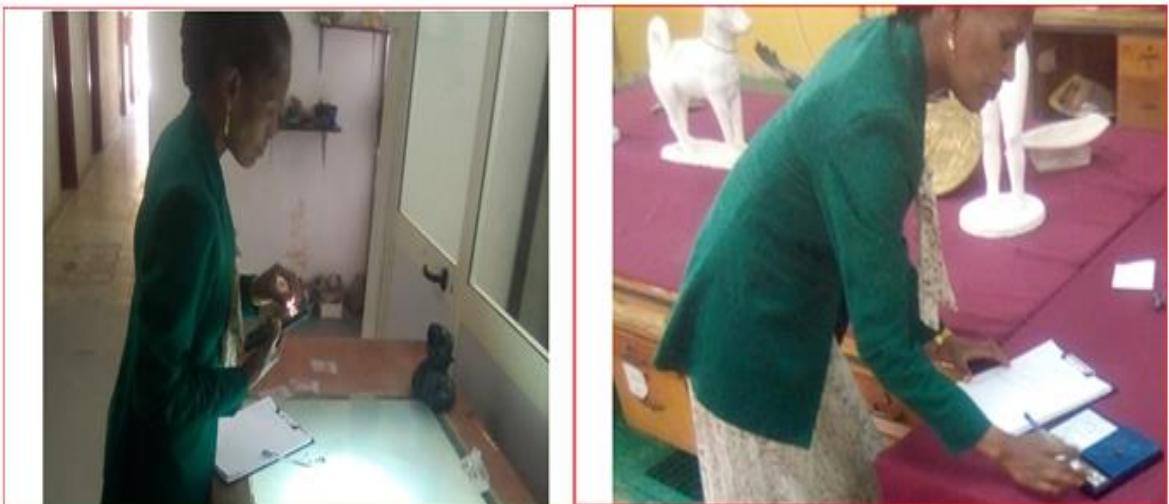





Figure 8: Rough sapphire is sorted and measured before being processed using a digital gram and light

Table 2: Sapphire gemstone enhancement

S.No.	Rough gemstone name	Place of Origin	Process of enhancement applied	Immediate advantage	Images of enhanced Gemestone
1	Sapphire	Oromia Region in Borena Zone	Grading and Sorting	Better surface rough stone to apply faceting	
			Cutting then Polishing by Cabochon machine	To have required size or removal of poor quality faces	
			Faceting	Attractive shape and faces	

4.1.1. Enhancing the Rough Sapphire Gemstone Process

The improvement process starts as soon as the sapphire mineral is mined. To add value and increase its price, the sapphire undergoes several phases of processing. Sorting and grading the Sapphire is the initial task in the improvement task. Artisanal sapphire miners in the region are, however, not currently doing anything regarding sorting sapphire. As can be noted from the current situation, a majority of the artisanal miners are engaged in sorting, which is the manual separation of valuable sapphire from the lesser quality stones. While the valuable stones are retailed or sold to brokers directly by the cooperatives, the worthless stones are rejected. We found that the existing processing techniques in the Borena Zone were largely manual and traditional. These techniques, with the use of rudimentary hand tools and equipment, constrain the efficiency and accuracy of cutting and treatment of sapphires. While local artisans possess a rich traditional knowledge, they are constrained by their access to traditional technologies in delivering quality jewels. Marketability and value of the sapphires are affected because they generally don't comply with international specifications.

This project work proposes the application of polishing or cabochon cutting and faceting for grading to enhance the miner's process improvement. There is a use of simple technology and moderately priced equipment in this process, which reduces the expense of selling value-added sapphire over rough sapphire. The price of the sapphire is affected positively by the process improvement. A sapphire that is process-improved certainly more expensive.

4.1.2. Cutting and polishing of sapphire

The faceting, a method of sapphire cutting, is discussed in this project. Faceting is the fine art of wounding sapphire fine rough into beautiful finished ones. A facet rough crystal is the source for cutting. Sapphire comes in a variety of shapes and forms. Some, for example, can be in their natural state, while others have been damaged during the process of mining. The brilliance of a gemstone can be enhanced by cutting, shape and polishing, all of which greatly add to its cost. Cutting requires a lot of skill because the goal is to lose as little weight as possible and to get the largest final sapphire size from a rough sapphire.

Table 3: Weight (in grams) differentiates between improved and rough sapphire

Sample Code	Rough sapphire	Enhanced	Technology type	Deference (based on Four C's)
SBA1	0.7	0.4	Faceting	Clarity increases by losing poor materials then Color change from tone to saturate
SBA 2	1.4	0.7	Cabochon	Shaping is increased
SBA 3	1.00	0.5	>>	Color is changed from tone saturated
SBA 4	2.5	1.4	>>	Color become shining
SBA 5	1.85	0.9	>>	Decrease inclusion in case of clarity
SBA 6	1.55	0.8	>>	High saturated color
SBA 7	2.20	1.20	Faceting	Shape become symmetry

4.1.3. Faceting

Faceting is the cutting and polishing of a rough gem, like a sapphire, to create a highly finished gem that is appropriate for jewelry. The gem is cut to create facets, or polished surfaces, that reflect light and enhance the color and fire of the stone.

In particular, none of the gemstones possess any useful points that can be applied. Due to the shifting fundamental points, all of the pearls have different demands. The fundamental concept is the simplest plot possible for a feature to reflect light back into the pearl. All of the diamonds should be aware of the fundamentals in order to prevent any undesirable light spills. This is when the light creates a disturbance outside of the central location in the town.

4.1.4. Shining

Polishing is a surface finishing method that employs abrasive and polishing wheel to eliminate surface irregularities of a work piece surface. With high-speed polishing machinery, it is possible to get a mirror-flat and defect-free finish and surface. The coarse to fine machining strategy is where the abrasives start in this method.

Making cabochon or cleaning entails sapphire and other gemstones are crushed and cleaned (this is accomplished using six stages of different maize meal crushing and cleaning wheels, starting with rough surface smoothing and ending with the last necessary cleaning and shining phases).

4.2. Sapphire Gemstone Process Improvement Description

To render the appearances more appealing and dazzling, the raw sapphire gemstone has undergone worth-expansion operations i.e. manual setting, cutting, faceting and cleaning. Cutting machines, cleaning machines and faceting machines along with their respective synthetics and consumables are a few examples of process equipment that are worth investing in. Wonderful transformations occur in the process of worth expansion, i.e. evaluation, removal of undesirable elements and increased splendor or beauty.

Thanks to the faceting machine-created faces, the sapphire, which is an exceptional gem, even more shines while being faceted, looking quite lovely.

Several critical factors are involved in the characterization of sapphire mineral process enhancement in the Borena Zone, Oromia Region, Southern Ethiopia:

4.2.1. The Geological Setting

The Precambrian basement rocks that make up the southern Ethiopian plateau are typified by the Borena Zone. The area is defined by a diverse geological setting consisting of both igneous and metamorphic rocks [34]. The following are important facts regarding the geological environment of the Borena Zone:

Geological composition: The geology of the region comprises medium to high-grade poly-deformed gneisses of igneous and sedimentary origin. Multiple phases of deformation have produced foliations, veins, fractures, and mesoscale folds in these rocks.

Mineralization: Gold, nickel, cobalt and base metals are some of the mineral deposits that make the Borena Zone famous. The mineralization is commonly linked with joints and fractures of the rock structures.

Economic Minerals: The zone contains extensive base metals, nickel, tantalum, platinum group elements (PGE), and gold. Some of the notable mining companies in this zone is the Lega Dembi gold mine [35].

Geological History: The rocks within the Borena Zone form part of the old geological complexes known as the Arabian-Nubian Shield and the Mozambique Belt. The current structure and makeup of the rocks are the products of geological processes taking place over millions of years.

Research and Studies: Numerous studies have been done to investigate the geological and geochemical aspects of the Borena Zone. The objectives of the studies include finding the geological history of the region as well as areas of possible mineral exploration.

The composition of minerals: In the Borena Zone, sapphire minerals are found in association with other minerals. The mineral corundum, which is Al_2O_3 (aluminum oxide) chemically, makes up the majority of it. Pyrite, magnetite, goethite, and hematite are not likely to be present in any great amounts. Though they would not be a characteristic of the sapphire itself, minor amounts of these minerals might possibly be included as inclusions in a sapphire gemstone.

The following chemical compositions of minerals reflect the geological mechanisms responsible for sapphire deposit formation and concentration:

1. Pyrite: Iron Sulfide (FeS_2)
2. Magnetite: iron oxide (FeO_4)
3. Goethite: Iron Oxyhydroxide ($\text{FeO}(\text{OH})$)
4. Hematite: Iron oxide (FeO_3)

4.2.2. Social and Economic Impacts

Enhancing the techniques can enhance the income of local communities and create more job opportunities. A better gemstone can benefit the local economy and provide better living conditions for miners and their families.

4.2.3. Environmental Considerations

Environmental foot print of the mining activity can be minimized and raw material waste can be lessened through the use of new processing technology. Long term sustainability for the regional gem trade will rely on implementing sustainable strategies.

4.2.4. Modern Processing Methods

The Borena Zone employs the traditional processing techniques that rely mostly on human muscle and rudimentary handheld equipment. Such techniques tend to produce unequal quality along with impaired gemstone value on the market.

4.2.5. Advances in Technology

The accuracy and consistency of sapphire cutting and treatment can be greatly improved through the application of sophisticated technologies. By improving their color and clarity, these treatments can increase their value on the global market. To progress their presence, sapphire gemstones can be subjected to a variety of treatments, including heat treatment to increase hue and clarity and irradiation to change or deepen color [36]. If properly done, these improvements can greatly enhance the worth of the gem. When assessing the quality and worth of sapphire gemstones, the four Cs—color, clarity, cut, and carat weight—are significant considerations [37]. A brief description of each factor and how it adds to sapphires' beauty and worth is presented below:

4.2.5.1. Color

The most important consideration for sapphires is color. Variety, quality and fullness are the main concerns of sapphire grading. The preferred hue is a saturated medium-to-dark blue and that color is most often known as "cornflower blue." Sapphires are also found in rosy, buttery, olive or caroty.

A. Hue: The true color of the sapphire. Sapphires stay originates in a variety of hues, but they can include blue, pink, yellow, green, etc. Clear and vibrant colored sapphires are considered the best ones.

B. Tone: States to the weightlessness or nightly of the color. Sapphires must be of a medium tone that is neither rich nor bright.

C. Saturation: This is the intensity or purity of the color. Low saturation gives the color a washed-out look, while high saturation gives a vivid and dramatic color. High saturation is a quality of the finest sapphires that helps make them more brilliant.

Gemstone's worth is greatly impacted by the color's intensity and saturation. Variety is among the models by which gemstones are assessed. Thus, it is practical to consider variation both in principle and in regards to the accumulation of esteem. Here, the sapphire, a gemstone, has a richer color of brilliance that glows regardless of whether the unpleasantness was glaring and brilliant or not. After esteem expansion, it shows a variety of excellence that really seemed appealing in appearance, brilliant in light-moving variety and highly appealing in general.

Raw sapphires, depending on their size, color, and clarity, can range widely in price. The following are some rough and enhanced sapphire prices:

Table 4: Rough and Enlarged Sapphire Cost in the Borena Zone (Source:EMPBC)

S. No.	Weight (Carat) (Ct)	Grading Color	Rough sapphire Price in (USD)	Enhanced sapphire Price in (USD)	Difference
1	1	Blue (Top grade)	\$185.60	\$1,100-\$5,500	\$914.4-\$5,314.4
2	1	Pink	\$168.20	\$350-\$1,650	\$181.2-\$1,481.8

From the above table, it is clear that selling process-improved sapphire is a lot less expensive than selling unpolished sapphire.

Prices of treated sapphire gemstones in Borena rely largely on several parameters, such as the quality, carat weight, and inherent treatments of the gemstone.

Better than Average: Because of their better color and clarity, high-quality sapphires that are improved tend to fetch higher quality.

Treatment Location: Borena sapphires are also exported to specialty labs like Sri Lanka and Thailand to undergo heat-treatment, which adds on the cost as a result of import charges and treatment charges. An ungraded rough sapphire will be cheaper than a graded sapphire, and that

is cheaper than a good-cut and polished sapphire. Additionally, the process that brings jewelry from the enhanced sapphire hybridization will be most expensive by far.

4.2.5.2. Clarity

When sapphires are graded for explicitness, inclusions and blemishes (internal and external defects), respectively are quantified. These are the highlights:

Inclusions: Internal flaws present while the sapphire was forming, such as crystals, gas bubbles, or other minerals. Zoning of color, feathers, crystals and needles (rutile silk) are typical inclusions in Borena sapphires. While sapphires have inclusions, clarity and value of the stone are increased through the amount and type of inclusion present. Inclusions might degrade transparency and appearance of the diamond. Gem clarity will typically look to topographic properties that affect the diamond. As problems are defined as anything that tends to prevent light from a faceted diamond in free passage, the sapphire gem that is faceted has an evident, uncomplicated range of light that appears pleasing aesthetically. Thus, sapphire's worth is added value, and it can be incorporated into ornaments on a vast number of applications.

Blemishes: These are surface defects on the stone, such as nicks or scratches.

4.2.5.3. Cut

Slice is the state of the gemstone. In addition to being among the primary factors involved in diamond testing, the Slice also plays an extremely crucial function in the look of a sapphire. Based on what kind of gem is to be used and how good of quality pearl is to be required, a gemstone can be brought into shape. This makes the clever exclusion of the things that are unwanted. Since sapphire is used in both the ring and the neckband by being combined with other materials, it has been mostly cut for these purposes.

The sapphire's cut has an influence on both its general beauty and brilliance. A sapphire which is well-cut will deepen the color and bend light in a lovely way. The size and shape of the stone are also included in the cut.

For sapphires, cut grading entails assessing the cut quality of the gemstone, which impacts the overall appearance and brilliance of the gemstone. These are the highlights:

Proportions: Angles and dimensions of facets of the sapphire. Well-proportioned facets sapphires reflect light in a most efficient manner and appear brighter.

Symmetry: Regularity and proportion in the facets. Symmetrical sapphires appear more lovely.

Polish: The evenness of the sapphire's surface. The brilliance and fire of the gemstone are enhanced by a higher polish.

4.2.5.4. Weight

In addition to carat weight, general quality of the gemstone—incorporating color and clarity—affects beauty and worth. It is also a unit used to estimate pearls' weight. One carat is 200 mg. or 1/5g. Since numerous gemstones occur in limited sizes only, superior gemstones are extra pursued after and thus priced higher per carat. Therefore, a gemstone of different carats will cost differently; for instance, a gemstone of a larger carat will be more costly compared to one of a smaller carat. This is independent of whether the gemstone has the same variety, clarity, and cutting grades. It can be observed from this that the heaviness of a diamond increases with price. Either way, when a large pearl is too big to be of any value in gems, it could lose considerably in value. Most importantly, each class of gem has its own weight for carats. Even though two pearls can possibly share similar characteristics, they may have different weights. Their different gravity in particular is the direct cause of this. Therefore, the valuable gemstones (opal, jasper, agate, valuable stone quartz, and both black and green obsidian) in question during the process of handling are determined by taking into account the requirement of the gem's carat approximation. Measurement of a sapphire gemstone is measured by its carat weight. 0.2 grams is equal to one carat. And that's the rundown.

Weight vs. Size: A 1-carat sapphire may appear lesser than one carat (1ct) diamond because the sapphire is heavier than most gemstones like diamonds. Although both of them weigh the same in carats, they may appear smaller.

Measurement of Carat Weight: The carat weight is weighed on precise scales. It is usually the practice to round the figure to the nearest hundredth of a carat.

Value Impact: The weight of a sapphire in carats has a large impact on its value. Although color and clarity are also factors to consider, bigger sapphires stay fewer besides; therefore more valuable.

Calibrated Sizes: For enabling the manufacture of corresponding stones for rings, earrings, and similar jewelry, sapphires are cut into precise sizes (calibrated stones).

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusion

The procedures used in the project include collecting rough sapphire, sorting, cutting, polishing, faceting, characterization, and cost estimating of the sapphire. These procedures provide important information to meet the study objectives. The conclusions of the research are as follows:

1. According to this project, Ethiopia's gemstone potential is faced with a set of challenges including the use of contemporary mining and lapidary technology and market analysis and price. Process improvement needs to be initiated on the sapphire to contribute towards playing a role in the national development roadmap plan.
2. The conclusion of this project work is consistent with the literature review that Ethiopia is endowed with gemstone deposits, among which sapphire may be a basis for development. The economic contribution of gemstone mining should not be underrated for the purpose of developing the country.
3. Development of an improvement facility that will only be focused on sapphire processing prior to selling and giving people added-value technology will make selling sapphires easier in the country or abroad to achieve greater government profits and guide participants. Therefore, the right legislation of the country banning raw gem dealing should be enacted in order to make improvement on the sapphire compulsory.
4. By the improvement of the process, the nation will be able to gain foreign exchange, increase the proportion of the industry in the net GDP, and assist in fulfilling its own contribution towards achieving sustainable development throughout the nation and in assisting in eradicating the unemployment issue.
5. To use the resource to its fullest, training in the nature of gemstones and process improvement is also necessary. Therefore, the government must take proper steps to enable education.

5.2. Recommendations

The following suggestions are submitted to the Ethiopian government and relevant sectors based on this report.

- The study recommends that government authorities and stakeholders offer small-scale miners financial subsidies and incentives to enable them to embrace current processing methods such as heat treatment, diffusion treatment, polishing grits (8,000–14,000) on a cabochon, CAD, and CAM. Such steps can lower the startup costs and improve broader usage.
- There must be a scientific assessment of the nation's existing gem resources as there is no standard by which the resources are measured, e.g., deposit quality, quantity, or gemstone estimation or valuation. Therefore, there is no grading of the gems and hence branding is prevented.
- Since there is no standard basis on which the country's current gem resources are measured, for example, by deposit size, quality, or gemstone estimation or valuation, the resources' scientific evaluation becomes a necessity. As a result, branding is evaded because the stones remain ungraded.
- Establishing sapphire minerals process development facilities in or close to their source locations to buy them directly from the miners in an effort to avoid both the sale of rough and middlemen at the same time. All sapphire miners should be legally required to add value to the gemstones they mine before selling them, either locally or internationally, if possible. Otherwise, it must be a requirement that they sell their rough gems they have mined to the available local gemstone value-adding centers.
- Recruit foreign investors and request them to begin developing the processes of sapphires in the country and teaching people how to work with sapphires.
- To look into the long-term financial effect of process enhancement on the sapphire gemstone sector is most appropriate in the future. It encompasses learning possible marketplace growth and looking for fresh means of enlargement.

- It is also significant to include technology advancements that enhance the effectiveness and quality of processing sapphire. Competing in the global market will be facilitated by research and development

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