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Research Article

Assessment on Gemstone Mining for Artisanal Miners in South Omo Zone, Ethiopia

Demeke Assefa*, Ashenef Kassaye, Getahun Meseret

Mineral Industry Development Institute (MIDI), Ministry of Mine, Addis Ababa, Ethiopia

Abstract

The gemstone mining sector in Ethiopia's South Omo Zone is predominantly characterized by traditional, artisanal practices with minimal use of modern equipment and negligible integration into organized market structures. Despite the region's abundance of valuable gemstone resources-including corundum (sapphire, ruby), beryl, and other semi-precious stones-especially in Hammer and Bena Tsemay woredas, the sector remains underdeveloped. Artisanal miners often operate with rudimentary tools, lacking technical training, access to finance, and support infrastructure such as transportation and water supply. The absence of geological surveys, reserve estimations, and standardized gemstone valuation exacerbates inefficiencies and limits market potential. Moreover, the lack of transparent benefit-sharing mechanisms and formal registration systems has led to widespread informal extraction and trade, reducing government and community revenues. The resulting information asymmetry creates tension between miners and exporters. Environmental and safety standards are largely unregulated, and institutional support is minimal. To address these challenges, this study recommends the implementation of structured interventions, including gemstone identification and valuation training, establishment of regional trading centers, promotion of public-private partnerships for value addition, and development of a transparent governance framework. Without strategic reform, the sector's economic and developmental potential will remain untapped, risking unsustainable exploitation and limited local benefit.

Keywords

Gemstone, ASM, Mining Technology, Lithology

1. Introduction

A gemstone is the naturally occurring crystalline or non - crystalline form of a mineral, which is desirable for its beauty, valuable in its rarity, and durable enough to be enjoyed for generations [1]. Ethiopia has a huge gemstones potential and nowadays the demand for the country's gemstones increase from time to time in local as well as international markets.

Ethiopia is one of the few countries in the world with a diversity of gemstone deposits within its borders [2]. There exist over 40 different varieties of colored stones. Mining in Ethiopia is predominantly controlled by low skilled, small-scale miners utilizing traditional tools and equipment's for mining purpose. South Omo zone is host for one of the precious type of gemstones known for corundum.

Corundum is a mineral species best known for its two popular gemstone varieties, sapphire and ruby [3]. All colors of corundum except red are known as sapphire. The term

*Corresponding author: assefademeke619@gmail.com (Demeke Assefa)

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sapphire, when used without any modifiers, refers to only the blue variety of corundum. Red stones are known as ruby. Materials that are not matured gemstones are simply known by the name corundum.

Ruby and sapphire are the most commonly known corundum varieties because of their well-known application in jewelry. Due to this they have kept a high price market in relation to other gemstones [4]. However due to their popularity a large majority has been heat treated to emphasize their color. However, corundum can also occur in other colors, including colorless, pink, yellow, gray, golden-brown, and even pink-orange. Corundum is a hard, durable, crystalline mineral made of aluminum oxide (Al_2O_3).

Corundum, as a mineral, is encountered in a range of rocks [5].

It is relatively common in many metamorphic rocks of varied lithologies and its *P-T* stability domain is vast. For example, this mineral appears during forest fires on bauxite soils (at atmospheric pressure), and is observed as a high-pressure phase in diamonds [6] and eclogites [7].

The mineral deposits are classically separated into primary and secondary deposits. Primary corundum deposits are subdivided into two types based on their geological environment of formation: (1) magmatic and (2) metamorphic.

Geology and Genesis of Primary Magmatic Corundum Deposits in magmatic deposits was found in plutonic and volcanic rocks. In *plutonic* rocks, corundum is associated with rocks deficient in silica and their pegmatites, namely syenite [8] and nepheline syenite [9].

The corundum formed by direct crystallization from the melt as an accessory mineral phase. In volcanic rocks, sapphire and occasionally ruby are found in continental alkali basalt [10]. The corundum occurs as xenocrysts in lava flows and plugs of sub alkaline olivine basalts, high-alumina alkali basalt, and basanite [11]. These magmas occur in crustal extensional environments impacted by the rise of upwelling *mantle plumes*. The sapphires are either blue-green-yellow) or pastel-colored, and the deposits have economic importance only because advanced weathering in tropical regions concentrates the sapphires in eluvial and especially large alluvial placers [12].

Climate is the major factor in the formation of secondary deposits. In tropical areas, rocks are exposed to meteoric alteration, resulting in an assemblage of clay minerals, iron and manganese oxides, and other supergene phases [13]. Corundum and zircon are resistant minerals found in soils, *laterite*, and gravelly levels overlying bedrock.

Corundum occurs in metamorphic and magmatic rocks as a detrital relic, metamorphic or igneous mineral, met somatic precipitate or pseudo morph, and xenocryst [14]. It requires conditions of growth at low silica activity and at temperatures above the stability of gibbsite and diaspore (*i.e.* > 400 to 450°C).

Corundum is a high-temperature mineral that forms naturally by metamorphism of alumina-rich rocks under amphibolite and granulite facies conditions, and at temperatures between 500° and 800°C [8]. Metamorphic gem corundum deposits are located in metamorphosed marble, quartzite, gneiss, and Metapelite complexes that were heated either regionally or by thermal anomalies generated by local plutonic intrusions [15]. The various formation mechanisms depend on either isocheimal metamorphism (i.e., regional metamorphism) or *met somatic* metamorphism (i.e., contact and/or hydrothermal-infiltration processes affecting the lithology).

Ruby and sapphire are gem varieties of the mineral corundum. The chromospheres are chromium (Cr^{3+}) in ruby, and iron and titanium (Fe^{2+} and Ti^{4+}) in blue sapphire. All other colors are termed *fancy sapphires* and are named on the basis of color (e.g., yellow sapphire*)* [16].

South Omo Zone, located in the South Ethiopian region is emerging as a significant but underdeveloped region for gemstone resources. Thearea is geologically favorable, with Precambrian metamorphic and igneous rocks known to host a variety of gemstones. Artisanal and small-scale mining (ASM) is the dominant form of extraction, particularly in Hamer, Bena Tsemay, and Keyafer woredas.

Southern Ethiopia region is home to a variety of precious and semi-precious gemstones, including corundum, beryl, ruby, amethyst, Sapphire, Agate and others. Even if the region has potential resources of corundum, beryl and ruby are precious gemstones that can make beneficiary mostly the local people and as well as the government, up to date the local miners /associations are not exploit the resource with their full potential due to different problems.

Mining operations within the south Ethiopia regional state are expected to be an important economic catalyst for the government's export-oriented development strategy. The sector of gemstones in this region is highly unorganized and lacks an updated profile. To make the contribution of gemstone highly worthy than ever, all artisanal and small-scale gemstone miners should produce with their full potential. Due to this fact, the research was concerned on identification of major problems of artisanal miners and suggest for the recommended solutions for identified challenges.

Location and Accessibility

The assessment area is found in southern Ethiopia region at south omo zone at hammer woreda gembela, buska kebele and at key afer woreda Benatsemay kebele. The study area can be accessed through Addis Ababa via South Ethiopia region water, mining and energy office at Dilla city and then to Ari zone Jinka city to south Omo zone Turmi covers 1080km. The second option is *Addis Ababa* to *gambala* via *Arba Minch*, Konso, Key Afer, Turmi covers 996Km.

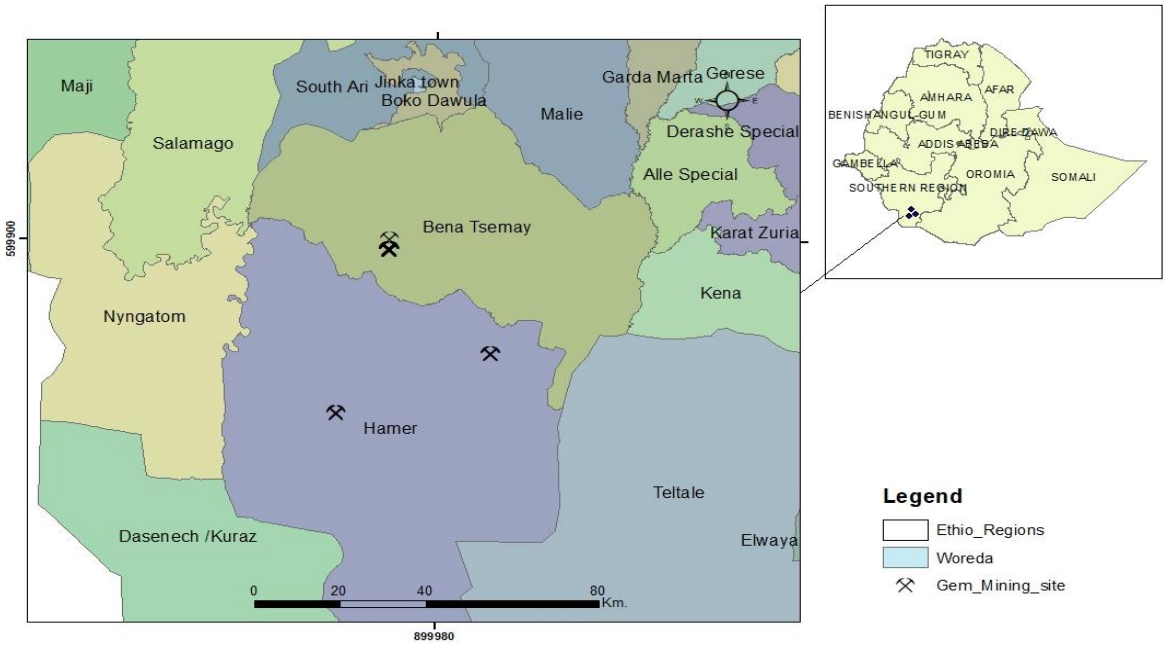

Figure 1. Location Map of the study area.

2. Methodologies

To conduct an assessment and identify major challenges of artisanal miners located in south omo zone and thoroughly to understand the challenges in depth, the following methods were employed:

1) Reviewed relevant documents and previous studies on gemstone development.
2) Developed structured data collection sheets for consistent information recording.
3) Conducted open-ended interviews and surveys with artisanal gemstone miners and key stakeholders.
4) Held focus group discussions with mining bureau staff, experts, and representatives of miner associations.
5) Carried out expert-led site visits to mining areas, facilitating in-depth discussions on current practices, challenges, and opportunities.

2.1. Data Collection

The data was collected with an intense stakeholder focus group discussions and direct field visit to the target area that mine different types of colored stones artisanal. The focus group discussion was carried out with regional, woreda and Keble level mining office experts, miners, suppliers and exporters focusing on the mining methods, mining tools, marketing issues and other infrastructural problems. Semi Structured questionaries' was also used as a means of data collective tool from artisanal miners and specified expertise groups in addition to the oral interviews and focus group discussions. Additionally, the field visit was carried out to observe the mining methods currently they practiced, mining tools they used, and at which condition they mine.

2.2. Data Analysis

Most of the data's are collected in qualitative form from different stakeholders and data's are analysed with an integrative write up skills that can clearly define the major problems and suggested solution.

3. Results and Discussion

3.1. Geology of Corundum Deposit in South Omo Zone, Hammer Woreda Gembela Locality

The lithological units are volcanic & magmatic sequences of basalt. Gem mineral at this area is mainly corundum (sapphire and ruby), beryl, amethyst, emerald, and others. The sapphire potential site in the Hammer woreda is located at specific locality called Gembela. This area is part of corundum mining site which is previously discovered and studied by Hammer woreda individual incentive person in 2016 E. c. The type of corundum at hammer Woreda Turmi kebele Gembala locality is blakish blue type of sapphire. The host rock mineral association suggests secondary corundum hosted in a quartz-dominated vein or hydrothermally altered metamorphic rock. These are typical settings where secondary-type sapphire or ruby is found injected along quartz veins, possibly with mica or feldspar remnants.

Figure 2. Corundum hosted in quartz (hammer woreda Turmi Kebele Gembala site).

3.2. Geology of Beryl Deposit in Hammer Woreda Buska Locality

Beryl is a single mineral with many varieties that are distinguished by their color. Few other minerals have so many known varieties specifically identified by their color. Many of the Beryl varieties are very important gemstones. In fact, all the transparent varieties of Beryl have been used as gemstone jewelry although Emerald and Aquamarine are by far the most important and well-known varieties.

Mountain in Southern Ethiopia is located at specific locality called Buska. This area is part of beryl mining site, which is previously discovered and studied by Hammer woreda in 2016 E. c. This beryl is light green color and the occurrence is typical for aquamarine-bearing pegmatites, where gem-bearing pegmatite dikes cut through older metamorphic and basement rock Often associated with mica-rich zones (e.g., biotite schist).

Figure 3. Aquamarine hosted in quartz (hammer woreda Buska site).

3.3. Geology of Ruby Deposit in Bena Tsemay Wered Dizi & Bori Locality

Figure 4. Ruby samples Bena Tsemay wered Dizi & Bori kebele locality.

Ruby crystals occur

The Dizi and Bori localities in Bena Tsemay Woreda are part of the Southern Ethiopian Shield, composed primarily of Precambrian metamorphic rocks, including amphibolite's, gneisses, schist's, and met sedimentary sequences. These rocks have undergone medium- to high-grade regional metamorphism, creating suitable conditions for the formation of corundum, including ruby. Ruby occurs both in situ (within weathered and fresh host rocks) and in secondary alluvial deposits formed by erosion and transport of ruby-bearing rocks.

3.4. Artisanal Miners in South Omo Zone

3.4.1. Hammer Woreda

In Hammer woreda there are artisanal miners/ associations that mine Corundum and Beryl minerals. There are two (2) enterprises, which are placed at different locations called Genbela and Top mining enterprise. Both artisanal miners use the most traditional mining equipment's, like Doma, Akafa, Digino, Medosha (hammer), konchera, Jerican and others. This traditional Ming equipment's challenge the miners to mine with their full potential.

Figure 5. South Omo zone technology based gemstone mining process.

Most of the time beryl group gemstone minerals and industrial beryl minerals are hosted in pegmatite veins which is very hard rock to excavate with traditional mining equipment's mentioned above. So, to make the artisanal miners more productive, at least they need excavator & jack hammer that can make possible to mine the target mineral with the required depth.

3.4.2. Bena Tsemay Woreda

There are also artisanal miners in this woreda that mine mainly ruby. There are five (5) enterprises actively mine in Bena tsemay woreda that mine ruby with a very tradition way of mining methods. The most common equipment's they used for mining are: Akafa, Konchera, Meterebiya, Madaberiya, digno and doma. Local miners that found in this woreda are mine in a very retarded way of mining equipment's. Most Rubies are hosted in a very depth place of quartz and mica sheet this makes the mining technique is hard as compared to pegmatite hosted corundum group minerals. So, to increase their productivity, local miners need jackhammer, drilling machine, Diamond tester, grading tester, excavator and others for a better production.

3.5. Major Problems Identified in the Sector

3.5.1. Absence of Geological Data

The absence of reliable and detailed geological data on gemstones in south omo zone remains a major constraint to sector growth. Bridging this gap through systematic exploration and documentation is critical for attracting investment, formalizing artisanal mining, and unlocking the full economic potential of the country exploding diverse gemstone resources. Most gemstone occurrences in south omo zone were discovered through artisanal mining activity, rather than formal exploration. As national and zonal-level, there is no registered database that compiles known gemstone occurrences, reserves, and its quality standard.

3.5.2. Illegal Mining and Smuggling

Illegal Mining and Gemstone Smuggling in south omo despite being endowed with a wide range of high-value gemstones such as amethyst, ruby, beryl, sapphire, garnet, and others gemstone faces serious challenges related to illegal mining and smuggling. These illicit activities undermine the country's economic potential, reduce government revenue, degrade the environment, and disrupt formal sector development. The majority of gemstone mining in Ethiopia is done by artisanal and small-scale miners.

Most miners are unaware or unable to obtain legal mining licenses due to bureaucratic barriers, lack of awareness, or poverty. Regional and zonal Government capacity is limited to monitor remote mining areas due to limited number of expert and vehicle. Cross-Border Smuggling a significant volume of Ethiopian gemstones, especially rubies, sapphires, and emeralds, are smuggled into neighboring countries such as Kenya and, Sudan and re-exported as products of the destination country, resulting in loss of origin recognition and national branding.

The Ethiopian government loses millions of dollars annually in untapped tax revenue and foreign currency earnings due to gemstone smuggling. The formal gemstone sector remains underdeveloped and unattractive to investors due to uncontrolled supply chains. In some regions, illegal mining has led to conflicts between communities, miners, and authorities, and is sometimes tied to informal militia activity or armed groups Establish gemstone checkpoints and trade control

zones near known mining areas. Require documentation of origin, weight, type, and buyer at every stage of the supply chain.

3.5.3. Lack of Training

The lack of training in gemstone identification, valuation, and mining safety in south Ethiopia region, south omo zone is a critical barrier to the formalization and development of the gemstone industry. Strategic investment in grassroots training and technical education will empower miners, reduce exploitation, and unlock greater economic value for Ethiopia's gemstone-rich communities.

A major constraint facing at south omo zone artisanal and small-scale mining (ASM)-is the absence of technical training center for miners. Most miners operate without formal knowledge of gemstone types, identification techniques, valuation principles, or basic safety protocols. There are no gem-cutting and polishing training centers to educate miners, lapidaries and traders on the legal process and benefits of formal trade. Due to this, all artisanal miners sell their products without any value addition or in rough form. Most artisanal miners cannot distinguish type of gemstone and this resulting in discarding or misidentifying valuable stones Overreliance on middle men. This resulted due to:

1) Absence of local technical training institutions focused on gemology and mining safety.
2) Limited government outreach and lack of mobile extension services in rural mining areas.
3) Limited integration of gemstone-related modules in vocational or community education programs.

3.5.4. Lack of Market Chain

The absence of a structured gemstone market chain in south omo zone severely undermines the potential of the sector and this affects contribution to national development. By investing in market infrastructure, policy reform, and value addition, Ethiopia can transition from a raw material supplier to a regional leader in ethical and high-quality gemstone trade.

One of the most significant structural challenges facing in south omo zone gemstone sector is the absence of a well-organized and transparent market chain. Despite the abundant gemstone resources and increasing artisanal mining activities, the country lacks the infrastructure and systems required to move gemstones efficiently and profitably from mine to market. This results in low earnings for miners, loss of national revenue, and missed opportunities for value addition and branding. The gemstone supply chain in south omo zone is dominated by informal and uncoordinated transactions. There is no integrated system that connects miners to buyers, processors, or exporters in a transparent and traceable manner and does not have a centralized gemstone market center where stones can be fairly traded and priced. This creates a parallel black market, distorting pricing and market data.

3.5.5. Grading and Standardized Price

The gemstone sector in south omo zone including as a country lacks a formal, transparent, and standardized system for grading and pricing gemstones. This gap causes inconsistent valuation, loss of market trust, and exploitation of artisanal miners, while also limiting Ethiopia's competitiveness in global gem markets. Ethiopia currently does not have an official grading system for gemstones based on internationally accepted criteria. Most gemstones are traded in raw form, ungraded form using visual inspection by buyers, who often lack technical knowledge.

Gemstone prices are set arbitrarily by local brokers and middlemen without reference to global benchmarks. Artisanal miners and small-scale traders often have no access to current market prices, leaving them vulnerable to exploitation. This makes Artisanal gem miners highly exposed for deceiving/fraud by the buyers. With an average they sell one kg of beryl maximum of 150 birr. It is known that mining is the most difficult task and highly energy intensive especially for artisanal miners. Selling one kg of beryl with 150 birr is not feasible for miners and due to this they are forced to stop to mine until good price set up is available for them.

3.5.6. Mining Equipment's and Technology

Gemstone mining in south omo is predominantly carried out using traditional, manual techniques by artisanal miners. These methods rely on basic tools, limited geological knowledge, and minimal safety standards, often resulting in low recovery efficiency and environmental degradation. Despite their limitations, these practices remain widespread due to the absence of access to modern mining technologies, capital, and training.

These make most miners challenging to mine with their full potential. Especially Artisanal miners, which found in hammer woreda are cease to mine due to lack of advanced mining equipment's like, Jack hammer that can penetrate hard rocks and make possible to liberate target gemstone from its host rock quartz. Currently the most common traditional mining equipment's they used for mining are: Akafa, Doma, Digino, Hammer and other supportive equipment. However, at South Omo Zone the communities are pastorals/animal breeders, so they don't have mining knowledge. They need mining technique and other capacity building training.

4. Conclusion

The current mining practice in Ethiopia particularly south omo zone is dominated by traditional methods with limited involvement of modern equipment and organized market chain. Mining activities in the area are predominantly traditional, with minimal use of mechanized tools and no structured market linkage. There is no established system that clearly shows the benefit share of the gemstones for the gov-

ernment and the community. Currently there is lack of transparent benefit-sharing mechanism for raw gemstone revenues among local communities and government entities. It is observed that, there is significant volume of gemstone resources extracted and sold without legal registration. Significant volumes of gemstones are reportedly extracted and traded outside legal frameworks, by passing formal registration systems. Miners Engage in surface-level extraction using rudimentary tools are faced to lack of technical and financial support.

Generally, South Omo zone is a home of different types of gemstones at different woreda, but there is lack of resource identification and reserve estimation study. In south Omo zone there are plenty of corundum (sapphire, ruby), beryl and other semi-precious variety of gemstones especially in Hammer and Bena tsemay woreda. Even if there are a lot of resources, artisanal gem miners that found in different woreda follow very traditional way of mining methods and they use very retarded mining equipment's that hindering their productivity. Not only this, local miners had major problem related to mining ability, capacity building training, marketing chain, gem grading and standard, mining equipment's (modern technology), accessible finance and accessible transport and water to their mining sites. The selling prices of those gem minerals are not well known. Due to these there is a conflict of interest between miners and exporters.

Despite this natural endowment, the sector faces major challenges: lack of geological data, weak technical capacity among miners, limited access to markets, and absence of value addition infrastructure. Furthermore, environmental and safety standards are largely unregulated, and institutional support for local miners remains minimal. Without strategic intervention, the region's gemstone resource will be highly exploited without delivering long-term economic benefits to local communities.

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Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Schumann, W. (2009). Gemstones of the World. Sterling Publishing Company, Inc.

[2] Kyngdon-McKay, Y., Jorns, A., Wheat, B., Cushman, T., & Nemomissa, S. (2016). An Analysis of the Commercial Potential of Ethiopia's Coloured Gemstone Industry.

[3] Simonet, C., Fritsch, E., & Lasnier, B. (2008). A classification of gem corundum deposits aimed towards gem exploration. Ore Geology Reviews, 34(1-2), 127-133.

[4] Saminpanya, S. (2024). The Origins and Analyses of Gem Corundums.

[5] Hausel, W. D. (2006). Gemstones of the world: Geology, occurrence and exploration (with a chapter on opal and chalcedony by W. M. Sutherland). Wyoming State Geological Survey.

[6] Watt, G. R. (1994). Experimental studies on the high-temperature stability of corundum. American Mineralogist, 79(1-2), 34-42.

[7] Dawson, J. B. (1968). Garnet peridotite, eclogite and websterite nodules from the kimberlite pipe at Mwadui, Tanganyika. Journal of Petrology, 9(2), 260-274.

[8] Simonet, C., et al. (2004). Geology and origin of gem corundum and spinel deposits. Ore Geology Reviews, 25(1), 1-16.

[9] Sorokina, E. S., et al. (2017). Nepheline syenite and the genesis of magmatic corundum. Geology of Ore Deposits, 59(1), 27-39.

[10] Sutherland, F. L., et al. (1998). Gem-quality sapphire and basaltic magmatism. Mineralogical Magazine, 62(1), 659-671.

[11] Saminpanya, S. (2000). Mineralogy and origin of gem corundum associated with basalt in Thailand. The University of Manchester (United Kingdom).

[12] Arafa, A. A., & El-Shibiny, N. H. (2017). Origin and Economic Importance of Corundum.

[13] Upadhyay, R. K. (2025). Rocks and Their Formation. In Geology and Mineral Resources (pp. 351-421). Singapore: Springer Nature Singapore.

[14] Giuliani, G., et al. (2020). The geochemistry and genesis of ruby and sapphire. Elements, 16(2), 115-120.

[15] Giuliani, G., Ohnenstetter, D., Garnier, V., Fallick, A. E., Rakotondrazafy, M., Schwarz, D., & Groat, L. A. (2007). The geology and genesis of gem corundum deposits. Geology of gem deposits, 37, 23-78.

[16] Saminpanya, S. (2024). The Origins and Analyses of Gem Corundum. Cambridge Scholars Publishing.