GEMFIELDS

Understanding the Global Supply of Emerald, Ruby and Sapphire

Market Research

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Table of Contents

I. Scope of this paper

This paper follows on from the report 'Global Emerald & Ruby Supply: Analysing Market Data', written for and published by Gemfields in March 2022. The first report used different sources of data (notably UN Comtrade and USGS) and compared these with miners' direct information (notably from Gemfields, Grizzly and Fedesmeraldas). This research indicated that online data related to coloured gemstone supply is unreliable, often missing, and values are underdeclared.

This new research has three objectives:

1. Restructure and update data from the previous report
2. Add market analysis of sapphire
3. Find new sources of information, working in collaboration with other miners, associations, cooperatives and consultants, to provide stronger statistics on the supply.

It should be noted that this report does not aim to provide an exhaustive list of all the emerald, ruby and sapphire deposits in the world, but rather focuses on the countries that have been and/or are still important sources for these gemstones. In the same way, the report does not aim to provide details of the mining operations (such information can already be found in the literature), but rather provides the names of the main deposits, their discovery, period of activity and a description of their production wherever possible.

The main objective is to provide an overview of coloured gemstone supply, its evolution across the past 40 years, and its current status, in the most accurate way possible. The paper is written in a way that allows the reader to go directly to sections that may be of interest (per country and/or gemstone), therefore some information may be duplicated.

Production data is presented in volume terms (kilograms), and the trade flows are presented in value terms (US dollars). The main sources of information are:

- The United States Geological Survey ('USGS'), the largest agency collecting data on mineral production from all countries in the world, since the 1970s. The information collected is from the mineral yearbooks of the different countries analysed.
- Miners, mining associations and consultants who have participated in the report as collaborators. Some have decided to remain anonymous, while others are mentioned. The collaborators have shared information in the form of data, data ranges and expert opinions.
- When available, minerals statistics from the country's governmental entities, which are usually under the Ministries of Mines.
- The Extractive Industry Transparency Initiative ('EITI') reports, for the countries that participate in the programme.
- Bibliographic research, notably from industry specialised publications like the magazines Gems & Gemology, Journal of Gemmology and InColor.

The collaborative approach to this research allowed production and trade data to be sourced directly from reporters, whether miners, associates, mining cooperatives or consultants. Data sourced directly from actors in the industry ensured greater reliability and challenged the other existing data sources in order to support or disprove reported figures. Of course, the limitation of this principle of collaboration is that it can only work if actors are willing to share their information. Therefore, the information provided in this report will be compiled from data provided by actors, as well as freely available data from USGS and UN Comtrade. In order to preserve the confidentiality of each collaborator's information, the report presents total production and trade flow statistics per country, not per operation or deposit.

Another new objective compared to the previous report is to include information about the Artisanal and Small-scale Mining (ASM) sector. This is especially challenging as artisanal and small-scale mining is often informal, without any formal record of production or sales. Some ASM producers have figures, but do not want to share information to avoid governments accessing their data. Some ASM data are officially reported to the government, but most usually remains undeclared. Collaborating with associations, consultants and miners of all scales has enabled this research to provide a better estimate of the share of global supply attributable to ASM. Therefore, the report attempts to give an estimate of the undeclared portion of production.

II. Collaborative work and acknowledgements

As mentioned above, this report aimed to collect information from various types of collaborators. Approximately 100 people and companies have been contacted for this report. We wish to thank all of those who have agreed to participate. Some collaborators have decided to remain anonymous, and their names will not be disclosed here. Others have agreed to be quoted, namely:

- Gemfields Group Limited
- Alpha Ntayomba of the Population Development Initiative (PDI) of Tanzania
- Gabriel Angarita & FEDESMERALDAS
- Harimala Tsiverisoa Herizo, consultant, Madagascar ASM specialist.

Although many have been contacted, there has been a notable resistance to collaborate and share information. There are multiple reasons for this, notably:

- Data confidentiality: it should be stressed that this research was done by an independent consultancy company, and all discussions and data sharing were carried out under NDAs. Data is presented at a country level only, so no personal or company details are presented, and no reader can trace the information back to its source. Nevertheless, this procedure was not sufficient to reassure some of the people contacted.
- Fear of providing information to governments: although governments are already aware of smuggling and under-declaration in their countries, contacted parties were often concerned about the impact the report could have on their governments.
- Fear of devaluing the product by talking about quantity: because the volume of coloured gemstones produced is never clearly disclosed, this contributes to the rarity and desirability of the gemstones. However, for other precious commodities, like diamonds and gold, volumes are very-well known, and this knowledge does not impact their value. In fact, the findings of this report actually reinforce the rarity of fine-quality gemstones.
- As coloured gemstone data is highly unreliable, many did not see any value in attempting to compile it, leading to a classic vicious circle. The lack of data and scarcity of information about production are factors that make it more difficult to increase the scale of the industry. This has a direct impact on development and investment in the sector, and therefore on the strength of the supply chain. Companies who want to promote both minerals and responsible practices, but who do not wish to share their data, even under conditions of confidentiality, are failing in their pledges of transparency, engagement and more sustainable practices.

The aim of such a collaborative work is to promote coloured gemstones globally and allow individuals, companies and organisation to have access to reliable information. This is summed up in a quote from a

high-quality report by the consultancy Levin Sources: 'An industry that is organised, harmonious and speaks with one voice is better able to influence government and communicate its development needs[1]'

III. Challenges

Before drawing conclusions from the data presented herein, readers are alerted to the significant challenges involved in obtaining data and information about coloured gemstone supply and the downstream market.

The major challenge when trying to assess global coloured gemstone production is the lack of available data. The previous report highlighted that available online data usually reflects exports, rather than production, and is mostly reported in value terms rather than volume. Furthermore, export numbers could be re-exports and exports of gemstones produced much earlier in time. Also, these data are almost always reported for total emeralds, rubies and sapphires, rather than for each individual gemstone. A further complication arises in that export data is often published for 'worked' gemstones (those that have been cut and polished), instead of for rough gemstones.

These challenges in data availability result from various factors:

- Large scale miners do not always disclose their production figures, as there is no obligation to do so, and this is considered to be sensitive information.
- Artisanal and small-scale miners are normally informal and do not have reporting standards in place.
- Gemstone mining occurs in many less-economically-developed countries, which do not have strong reporting standards in place.
- In more-economically-developed countries, like Australia, the reporting of gemstone production is not that important to authorities, as the gemstone industry is fairly insignificant compared to the rest of the mining sector.

Readers should also be aware that, within the gemstone sector, quality is key. Any quantities reported cannot directly indicate market share or size, without specifying the quality of the gemstones in question. Similarly, values will not reflect volumes, either for production or trade flows, because two gem parcels of the same weight can be worth wildly differing amounts depending upon the quality of the gemstones contained within each parcel.

Production information is typically declared either in terms of quantity or of value, but very rarely with both sets of data together. This is a major obstacle when trying to see the full supply-side picture, because providing quantity with value gives a clearer picture of gemstone quality and pricing. Unlike with many commodities, gemstone pricing is enormously sensitive to subtle changes in colour and quality. For example, it is difficult to talk about the ruby market as a whole, as the market covers quality and price ranges ranging from red corundum to fine exceptional rubies reserved for high jewellery, and the price per carat can vary by a factor of 30 million! This feature of coloured gemstones also has profound implications for deposit-hosting nations: allowing the price to be set at the point of export from the host country inevitably leads to acute under-pricing, as the value is so subjective. This, in turn, highlights the fact that official export data is likely to seriously understate the true value of the gemstones.

Another important challenge when trying to assess supply-side developments is the lack of consistent reporting following the history of a discovery, deposit or mine. Usually, when a discovery is made, and a mine or a rush happens, there will be several reports on the subject issued within the next three years. Then, no follow-up reports are issued, sometimes leaving gaps of decades with no information on the status of

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

production. While researching information for this report, the author clearly noticed that older reports – those issued before the 1990s – almost always presented sections on mining and production, giving some estimated figures of recovery. At the time, these data often came from interviews or field work. Conversely, in more recent years, production estimates have disappeared from gemmological reports, and it is notable that talking about production, or traded volumes, is perceived as intrusive and sensitive nowadays. This contrast in information disclosure between periods is particularly striking, as most of the current suppliers, whether miners or traders, are now seeking higher transparency and responsibility in the trade.

Considering the above challenges, it should be kept in mind that the data collected and used in this report are, unfortunately, often inconsistent and far from robust. Yet, these are the only data sources readily available for analysis and interpretation, and they allow a useful, if somewhat fuzzy, picture to be formed.

Note on trade flows and UN Comtrade data

UN Comtrade data is widely used in this report to reflect all of the trade flows, exports and imports for each country of interest. It is important to properly understand what these numbers are and how they are captured.

UN Comtrade is the shorter name for United Nations Commodity Trade Statistics Database. It is the largest database for trade flows, exports and imports, covering a period from 1962 to date[2]. Information is provided by more than 170 countries. The reliability and quality of the data depends on the reporting country. All information is reported per country and per commodity type, and the traded values are all in US dollars. Commodities are classified as per the Harmonised System (HS).

The HS is a standardised numerical system, which classifies products traded between countries. During an export, the seller must choose the appropriate code to describe the product being exported. Customs authorities around the world use this code to charges duties and taxes. The HS code information can be used to calculate industry statistics on trade flows.

For the purpose of this study, two HS codes will be looked at:

- 710310 - Stones; precious (other than diamonds) and semi-precious stones, unworked or simply sawn or roughly shaped, not strung, mounted or set
  ⇨ Can be interpreted as rough gemstones
- 710391 - Stones; rubies, sapphires and emeralds, worked (other than simply sawn or roughly shaped), not strung, mounted or set
  ⇨ Can be interpreted as pre-formed, cut and polished rubies, sapphires and emeralds

These codes are not specific to any one variety of gemstone; however, knowing which gemstones are produced in a given country, they can still be helpful in estimating the flows of specific gemstones. Also, the definitions are not very clear, and it should be noted that there are some inconsistencies between reporters in the choice of which HS code to use for the same product. For example, some countries do not have significant processing factories and are known to export mostly rough gemstones, but nevertheless the majority of exports from these countries may be reported under HS code 710391, which should be used for 'worked' gemstones instead of rough.

The HS code is a six-digit code, but countries can use extra levels by adding digits, to be more specific about which products they are importing and exporting. In the gemstone industry, Thailand has implemented two

[2] https://unstats.un.org/wiki/

extra digits on the HS codes 710391 and 710310, to give information regarding the gemstone variety, allowing more precision and analysis. In-depth analysis of Thai trade flows is presented in chapter 7.

When capturing and reporting trade data, the United Nations Statistics Division recommends using the country of origin for an import, and the last known destination for an export. Ideally, imports and exports mirror each other, meaning that if country A is importing something from country B, the same export movement should be reported by country B. In reality, this is not always the case due to[3]:

- The difference in trade values between imports and exports: imports are reported CIF (including insurance and freight costs), whereas exports are reported FOB (free on board). This means that imports are usually higher in value than exports.
- Imports are often more accurately recorded as this information is used to generate revenues from taxes and customs fees.
- Different HS codes can be used by importers and exporters.

As an example of this, for the HS 710391, Mozambique reported a total export to Thailand of $97.8M for the ten-year period from 2012 to 2021. Conversely, Thailand only reported a total import from Mozambique of $30.2M. This is a significant difference, which can also be explained by the fact that Thailand uses a Special Trade System, while most other countries are using the General Trade System. With the Special Trade System, when a country is importing from a freezone, the country of origin before the transit via a freezone can be lost, and the importing country is then importing from itself. This is why the main importer for commodity HS 710391 to Thailand is actually Thailand itself.

For each country of interest in this study, the data from UN Comtrade will be presented as the graph below, showing both HS commodity codes, for exports and imports. It is good to keep in mind that the scale of value will vary greatly per country.

The overall trend for trade flows for the world, from 1995 to 2023, presented in the graph below (Figure 1), is very similar to the ones from Thailand, the USA, Hong Kong and Switzerland. Indeed, these four countries alone account for 57% of all the export and import values, explaining how these countries can greatly impact the general health of the trade (Figure 2).

[3] wits.worldbank.org/wits/wits/witshelp/Content/Data_Retrieval/T/Intro/B2.Imports_Exports_and_Mirror.htm

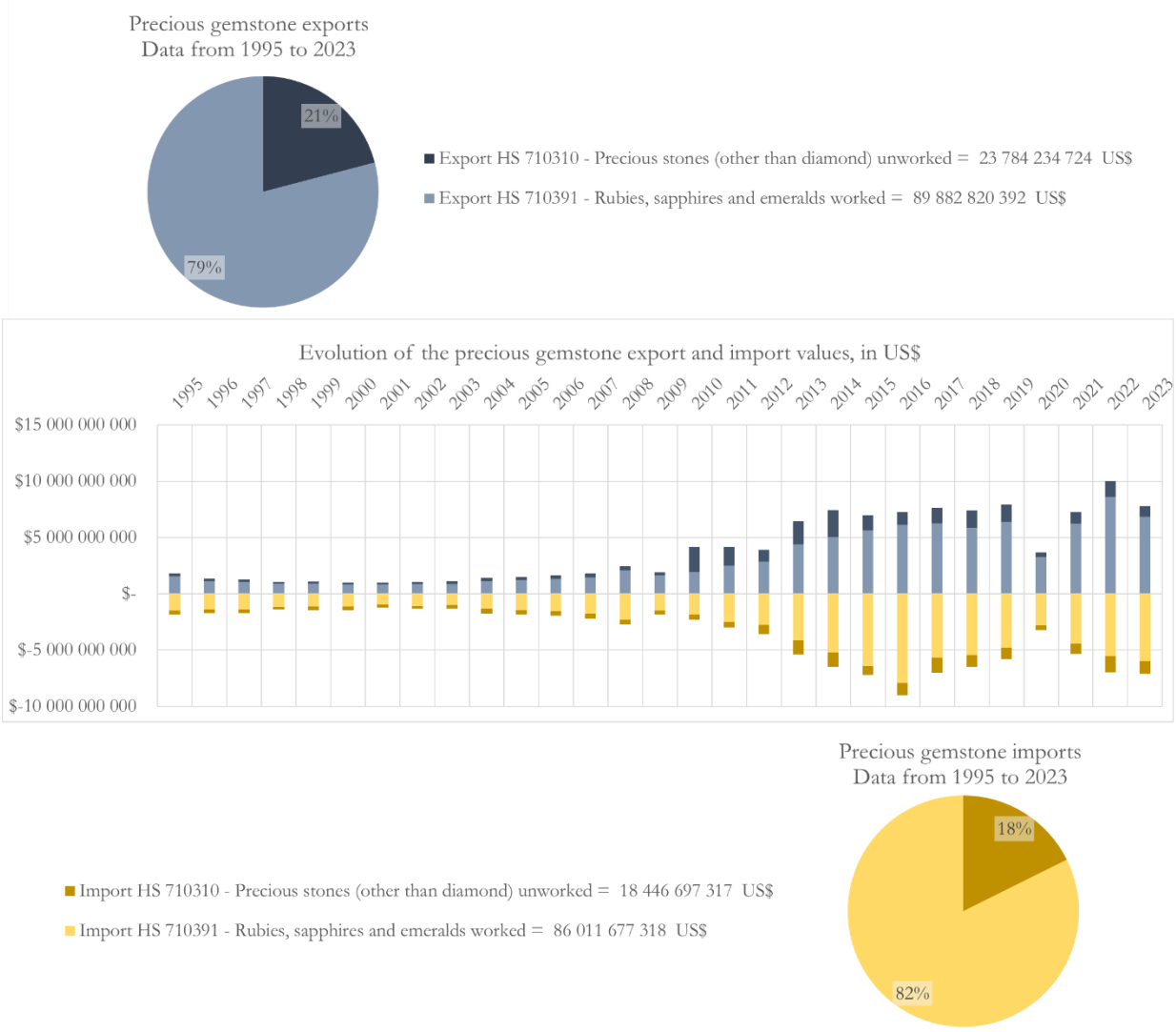

Figure 1: Global precious gemstones imports and exports values

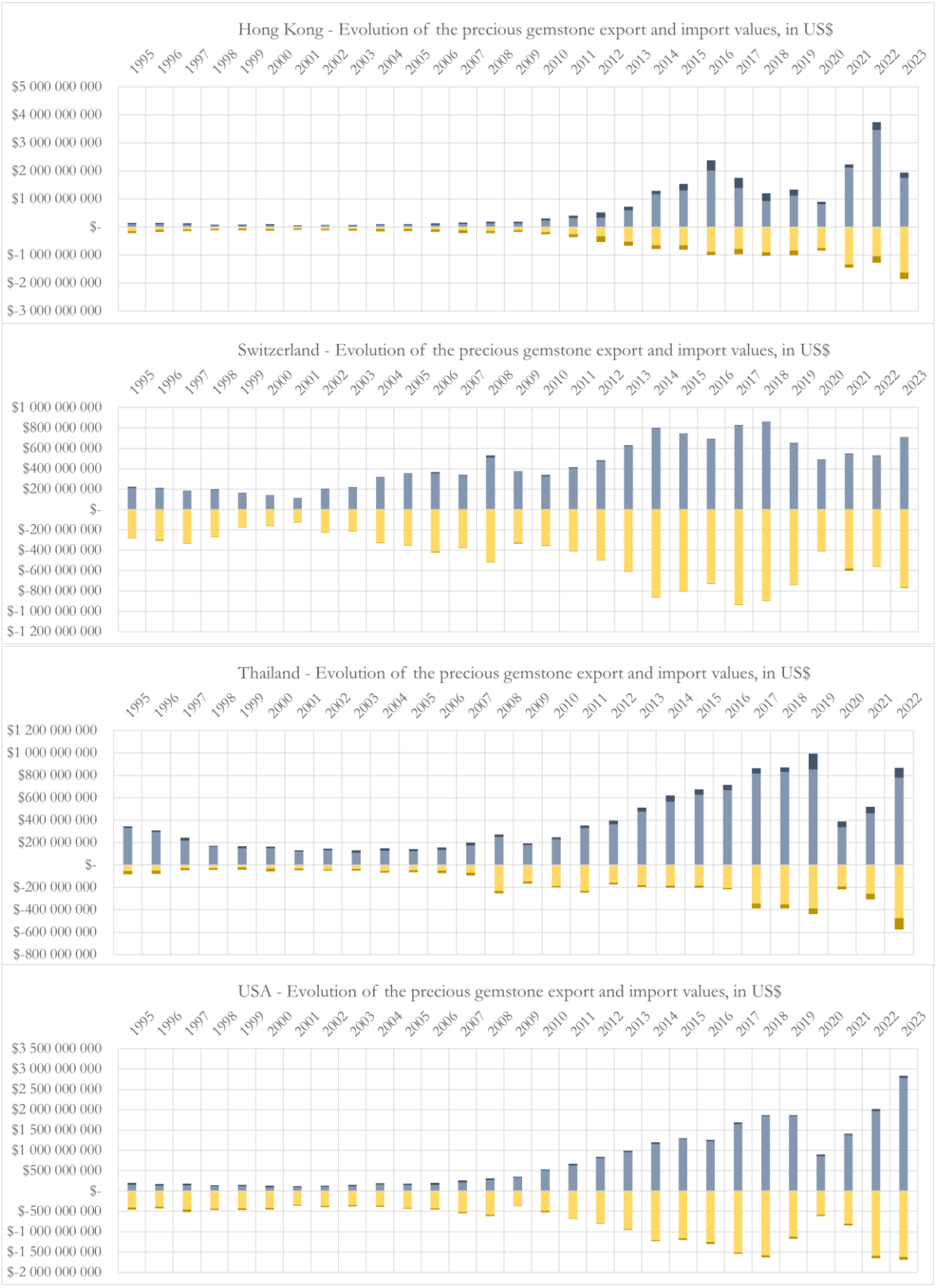

Figure 2: Precious gemstones imports and exports values: four prevailing countries.

IV. Global supply of rubies

1. Introduction

Ruby is the most important coloured gemstone in the trade, in terms of value. The landscape of ruby mining and trading has greatly evolved over the last 20 years with the discovery of many new deposits, the depletion of ancient ones, and the start of large-scale mining in African countries.

This chapter compiles research on the volume of rubies produced yearly since 1980, for fourteen countries which have been, or still are, important source of rubies. Production numbers are difficult to find, as there is little reporting from both mining companies and governments. Exports can sometimes provide a good picture of the production dynamics; however, exports are very often only reported in value terms, with volumes not being captured. Production volumes presented in this report come from various sources including: USGS (United States Geological Survey) yearly mineral industry reports; declared miners' production and sales data; annual surveys of national economic statistics; and EITI (Extractive Industries Transparency Initiative) reports. Due to delays in the publication of these reports, production volumes are only presented up to 2020.

After looking at each individual country, the final section compiles production data from the fourteen countries to attempt a visualisation of global supply dynamics. A 'quality factor' has been applied, to allow a clearer view of the supply of facet-quality rubies. Overall, the report highlights the positive impact of new discoveries on supply. Prior to the 1990s, production figures are highly unreliable, but it can be safely assumed that global production volume has increased over the past 40 years, especially for fine-quality rubies with the rise of Mozambique. Thanks to these new discoveries and mines, supply has been fairly consistent, with production from 'long-term' deposits (like the ones in Myanmar, Mozambique and Tanzania), coupled with deposits being exploited more sporadically (like the ones in Malawi, Madagascar and in Central Asia).

For each country, export and import figures, mostly from the UN Comtrade database, have also been presented. It is worth noting that some countries, such as Thailand, provide more detailed information on this market segment, which permits their trade to be analysed in greater detail.

2. *Kenya*

a) Ruby Production

Ruby production in Kenya comes mainly from one deposit, discovered in 1973 in the Taita-Taveta district, in the area of Mangare. The deposit was first named for one of its discoverers: the 'John Saul mine'. However, geologists lost control of the site; mining was sporadic and completely ceased in 1989. Operations started again in 1995, after the acquisition of the rights and permits by Rockland Kenya[4]. Production from the John Saul mine has been reported to be between 100kg and 500kg per month[33,5].

A more recent deposit was found in the Baringo district. Michelou reported in 2006 that operations there were about to start[6]. However, no production data for this deposit were found.

In Kenya, only a small proportion of the production from the John Saul mine yields facet-quality rubies[7]. In 1999, John Emmett reported that top-quality material represented between 5% and 10% of production[33]. Gemdat notes that only 1% of the production is facetable[8], and during its mine visit in 2008, Laurs did not witness any facet-quality gemstones[34].

The history of production presented in the graph (Figure 4) has been drawn by collecting data from various sources, including bibliography, USGS, the economic survey of the Kenya National Bureau of Statistics[9] and the Mining Annual Review[10]. Several reports estimate that about 60% of gemstone production comes from artisanal and small-scale mining[11,12]. However, rubies are found in one main deposit, which is exploited by a mechanised operation, therefore the 'estimated undeclared' ruby production has been reduced to 20%.

b) Ruby Trade Flows

Kenya produces a variety of gemstones, which makes interpretation of the UN Comtrade data more difficult. Moreover, Kenya does not take part in the Extractive Industry Transparent Initiative (EITI), often a good source for official production and export data. However, it is clear that Kenya exports mainly unworked gemstones, rather than cut and polished ones (Figure 3). This means that the country does not benefit from the full value of its resources, as is the case in most gemstone-producing countries in Africa.

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[4] Emmett, J.L., Prairie, B., (1999). An update on the John Saul ruby mine. Gem News. Gems & Gemology. Winter 1999

[5] Laurs, B.M. (2008) An update on the John Saul ruby mine, Kenya. Gem News International. Gems & Gemology. Fall 2008

[6] Michelou J.C., Ed. (2006) ICA 2006 World Gemstone Mining Report. InColor, Spring.

[7] Shor, R., & Weldon, R. (2009). Ruby and sapphire production and distribution: A quarter century of change. Gems and Gemology, 45(4), 236-259.

[8] https://www.gemdat.org/loc-26484.html

[9] https://www.knbs.or.ke/publications/

[10] Opiyo-Akech, N. (2000). Mining in Kenya: Mining annual review 2000.

[11] Barreto, M. L., Schein, P., Hinton, J., & Hruschka, F. (2018). Economic contributions of artisanal and small-scale mining in Kenya: Gold and gemstones. Pact & ARM.

[12] https://sustainable-asm.com/the-gemstone-mining-sector/

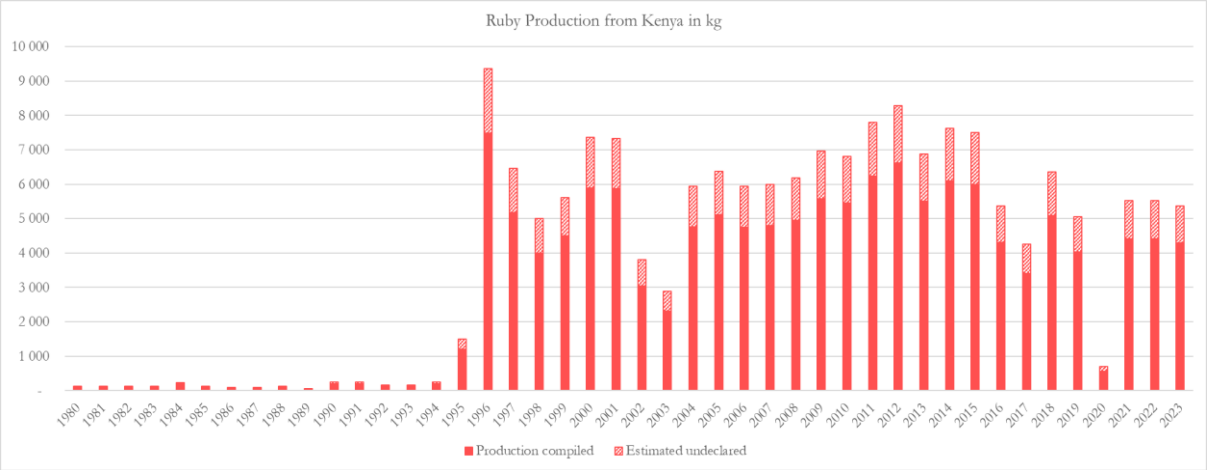


Figure 4: Ruby production from Kenya, in kg

Kenya's government has started to create value-addition centres, notably in Voi in Taita-Taveta district, in order to cut and polish gemstones before they are exported[13].

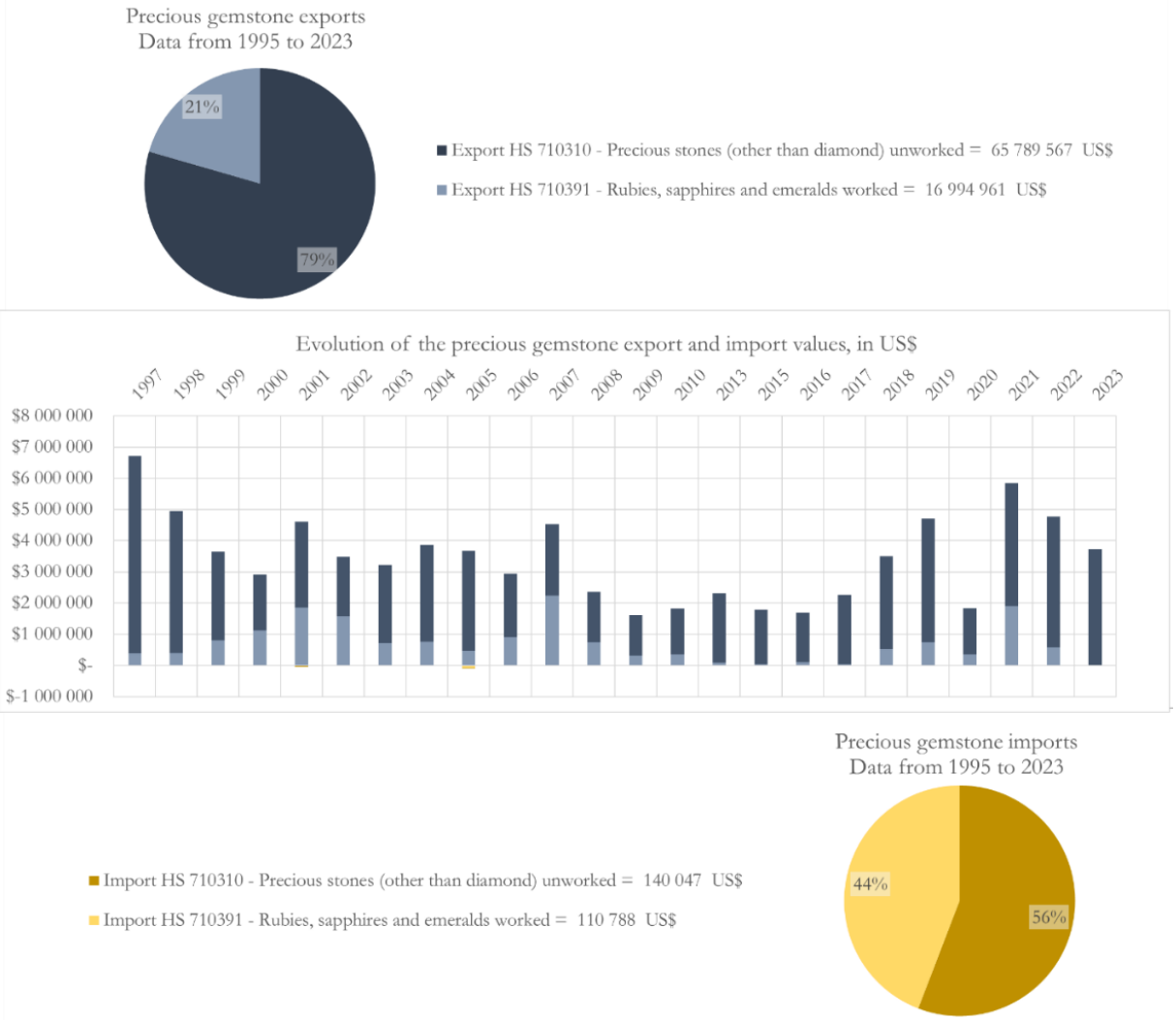


Figure 3: Precious gemstones imports and exports values from Kenya

[13] Anyona, S., & Rop, B. K. (2022, March). The Proposed Gemstone Centre and its Likely Impacts on Small Scale Mining Industry in Taita Taveta County. In Proceedings of the Sustainable Research and Innovation Conference (pp. 98-108).

3. *Madagascar*

a) Ruby production

Madagascar is a land of gemstones, where almost every coloured gemstone can be found. Mining activities here have been ongoing since 1900. However, the history of gem-corundum mining is much more recent, with the main sapphire discoveries occurring only at the end of the last century. Rubies have been known to be present since the 1950s (at the Gogogogo deposit), but their production only started to have a significant market impact in the early 2000s[14], with the discovery of the Vatomandry and Andilamena deposits[15].

It is worth mentioning that the mining conditions in Madagascar are linked to serious environmental and social challenges. Indeed, gemstone discoveries have led to massive rushes and boomtowns. This recurring dynamic has encouraged large numbers of independent miners and their families – sometimes tens of thousands of people – to move across the country, which has been conducive to the development of criminal networks and an increase in violence and corruption. It has also negatively impacted public health, notably due to water pollution and prostitution[16]. Moreover, the deposits are often located within natural reserves, bringing some harmful environmental impacts, especially given that Madagascar has a very unique and endemic flora and fauna[17]. The mine's location in the jungle can be difficult to access and to control. This dynamic of rushes has also meant that mining usually comes and goes relatively quickly, with the government trying to control and regulate the activity. The vast majority of production is smuggled out of the country, which makes it difficult to estimate. Madagascar has enormous potential in terms of its sapphire resources, and it is now thought to be supplying up to 60% of the world's sapphires[18]. Ilakaka would have produced up to 40% of the market supply during the peak of production in the early 2000s[19]. However, these numbers are impossible to prove, and the lack of governance, with bans on rough exports occurring, means that Madagascar can, unfortunately, still not be considered as a reliable and consistent source of supply.

The first significant ruby mine was Vatomandry, discovered in September 2000, which led to a rush of artisanal miners. The mining area was shortly closed by the government, and by 2005 the mining activity was nearly non-existent[42]. This discovery was important because the quality of the rubies recovered was very

[14] Shor, R., & Weldon, R. (2009). Ruby and sapphire production and distribution: A quarter century of change. Gems and Gemology, 45(4), 236-259

[15] Schwarz, D., Schmetzer, K. (2001). Rubies from the Vatomandry area, eastern Madagascar. The Journal of Gemmology, Volume 27 No. 7

[16] Duffy, R. (2007). Gemstone mining in Madagascar: transnational networks, criminalisation and global integration. The Journal of Modern African Studies, 45(2), 185-206.

[17] Ralimanana, H., Perrigo, A. L., Smith, R. J., Borrell, J. S., Faurby, S., Rajaonah, M. T., ... & Antonelli, A. (2022). Madagascar's extraordinary biodiversity: Threats and opportunities. Science, 378(6623), eadf1466.

[18] Expert's interview, Harimalala Tsiverisoa Herizo, ASM country specialist for gemstones. 7 October 2022.

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

fine, with about 30% of the gemstones not requiring any heat treatment. Leuenberger estimated in 2001 that more than 70kg of gemstones had been produced in less than a year of mining activity[20].

At almost the same time, a second promising deposit was discovered near Andilamena, in a remote location within the rainforest. Quantities were much higher than those at Vatomandry. Leuenberger estimated that two tonnes could have been produced in less than a year[48], but the quality was much lower. In 2004, a new rush in the region occurred, at the Moramanga mine, and large quantities of rubies started to arrive on the market. The rubies were also of poor quality, but suitable for the lead-glass filled treatment. The treated rubies are not very durable, because the lead glass is brittle, unstable at high temperatures and sensitive to chemicals[21].

Other deposits were mined in the region, but the next major rush was in 2012, with the discovery of the Didy deposit, found in the jungle[22]. The mine produced rubies and blue sapphires. Finally, a rush occurred in 2015 in the Zahamena National Park.

As mentioned, a significant portion of the rubies are exported illegally to Thailand and Sri Lanka. The below production profile (Figure 5) is compiled from USGS data and bibliography, taking into account the history of the discoveries, rushes and closures of mines. Considering the substantial illegal trade, the estimated undeclared production is based on a ratio of 70% of gemstones being smuggled, which is a relatively low threshold.

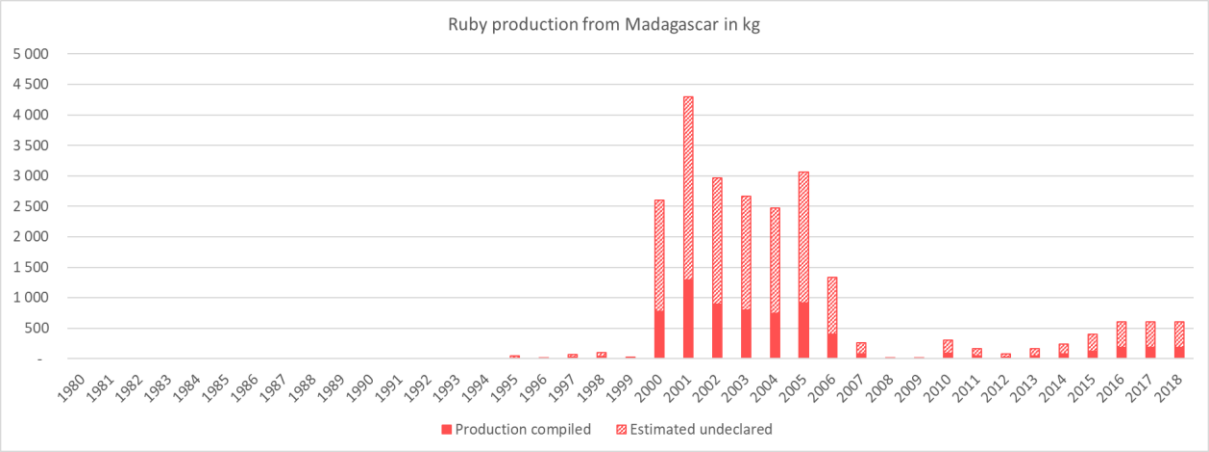


Figure 5: Ruby production from Madagascar, in kg

b) Ruby Trade Flows

Madagascar is also an important producer of gemstones other than rubies and sapphires, like amethysts, tourmalines and garnets. The vast majority of its gemstone exports fall under the category of 'precious stone unworked', and therefore no direct correlation with rubies and sapphires can be made. Overall, the total value exported for unworked gemstones has increased over the years and is at a yearly average of $15.6M since 2011, with the exception of a massive increase reported in 2022. In 2001, the total exports of all gemstones other than diamonds, unworked and worked, was $9.4M[23]. However, the annual production was

[20] Leuenberger, A. (2001). The new ruby deposits in eastern Madagascar: Mining and production. Gems & Gemology, 37, 147-149.
[21] Pardieu, V., Lomthong, P., & Sturman, N. (2010). Lead glass-filled star rubies reportedly from Madagascar.
[22] Pardieu, V., & Rakotosaona, N. (2012). Ruby and sapphire rush near Didy, Madagascar (April-June 2012). GIA Research News.
[23] UN Comtrade

estimated to be $400M, meaning that only 2% of the production value was declared[24]. The drop in exports in 2008 and 2009 (Figure 6) is related the ban on rough exports that was declared by the government in February 2008 and lifted in July 2009. This ban was declared by the president at the time in response to the export of a 536kg emerald named 'Heaven's Gift Emerald', which he claimed was illegal[25].

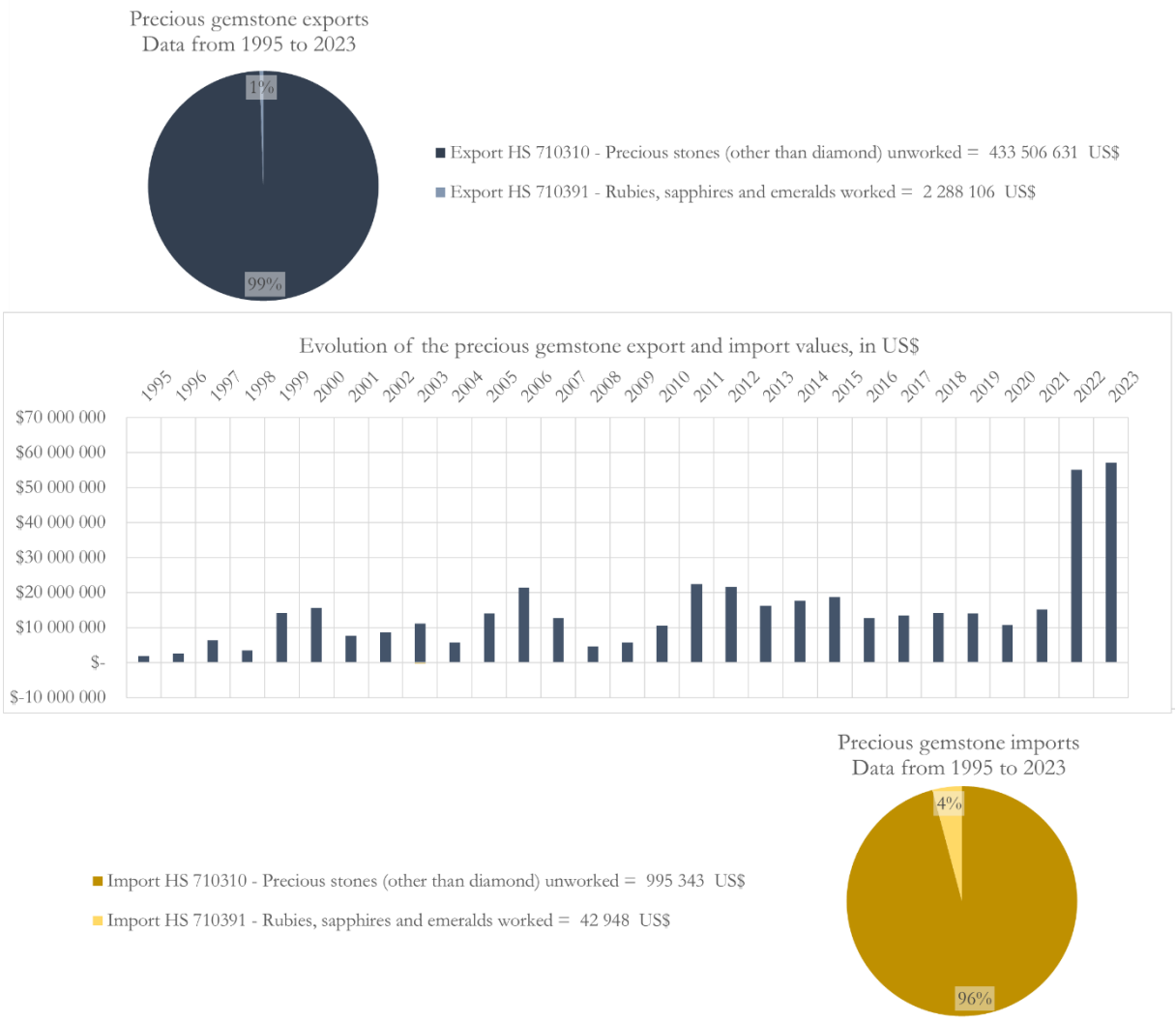
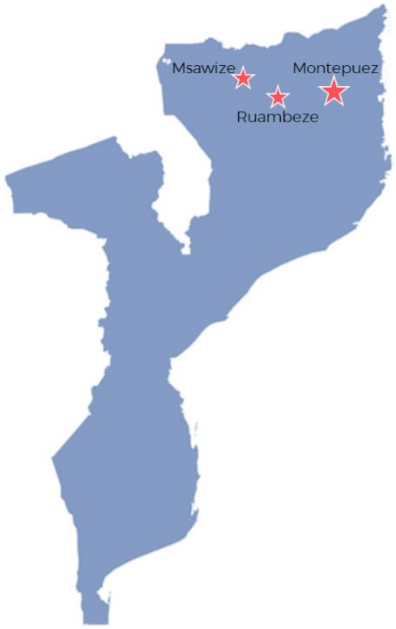


Figure 6: Precious gemstones imports and exports values from Madagascar

[24] Van der Wal, S., & Haan, E. D. (2010). Rough Cut: Sustainability Issues in the Coloured Gemstone Industry. Available at SSRN 1557705.
[25] Shor, R., & Weldon, R. (2010). An Era of Sweeping Change in Diamond and Colored Stone Production and Markets. Gems & Gemology, 46(3).

4. *Mozambique*

a) Ruby Production



Rubies have been present in Cabo Delgado province since 1991[26], when ruby mining was reported in Ruambeze, with an increase in production recorded in 2005[27]. However, the history of ruby mining in Mozambique really started and grew with the discovery of the M'sawize deposit, in the Niassa province, in 2008, but due to its remote location, in a natural reserve, and the authorities clamping down on illegal mining, it was rapidly abandoned. This is correlated with the discovery of a new deposit in 2009 near Montepuez.

It is reported that by 2010, rubies from the Montepuez area were already traded in Bangkok[6]. Yet, no official production data was reported before 2012, which corresponds to the first year of production from Montepuez Ruby Mining. This is easily explained, as most rubies at the time of discovery were mined by unlicensed miners who could not legally export the gemstones. Foreign buyers in Montepuez bought the gemstones from citizen-mining (also locally called 'garimpeiros'), and smuggled them out of the country, most likely to Thailand and Sri Lanka. This illegal practice is still common, as it is in other gemstone-producing countries where artisanal and small-scale mining takes place.

All of the rubies from Ruambeze and M'sawize were extracted by artisanal mining. No reported quantities can be found, as the entire production was illegally removed from the country. It is believed that most of these gemstones left through Tanzania[7].

Nowadays, rubies from Mozambique come from three main sources: Montepuez Ruby Mining (MRM), operated by Gemfields[28]; the ruby licences owned by Fura Gems[29]; and artisanal mining. In the past three years, a new actor, GemRock, has also started exploration and sampling with the aim of operating their licence in an industrial way within the coming years.

The production profile presented (Figure 7) is a compilation of data from different sources, including bibliography, USGS and miners. The 'estimated undeclared' production, from illegal mining activities, is based on experts' opinions and the history of the rushes, notably the number of miners reported in M'sawize and Montepuez. The production decrease observed after 2017 can be related to a shift in the areas of production of one of the main suppliers, MRM. MRM produces rubies from two types of deposit within their concession: one primary deposit, referred to as Maninge Nice, and one secondary deposit, referred to as Mashamba, or Mugloto. Maninge Nice was the first area exploited and produces large quantities of low-quality rubies. Conversely, Mugloto has a lower incidence of rubies in ct/t, but the average quality of the rubies there is much higher, which makes it a more profitable area to mine. It is worth noting that at MRM, and the other mines in the area, sapphires (mostly pink) actually account for 40% to 60% of production. This sapphire element has been removed from the production profile above.

[26] Vertriest, W., & Saeseaw, S. (2019). A decade of ruby from Mozambique: a review. Gems & Gemology, 55(2).
[27] Pardieu, V., Jacquat, S., Bryl, L. P., & Senoble, J. B. (2009). Rubies from northern Mozambique. InColor, 12, 32-36.
[28] https://gemfields.com/about/our-mines-and-brands/montpuez-ruby-mine/
[29] https://www.furagems.com/mine-travel/mozambique

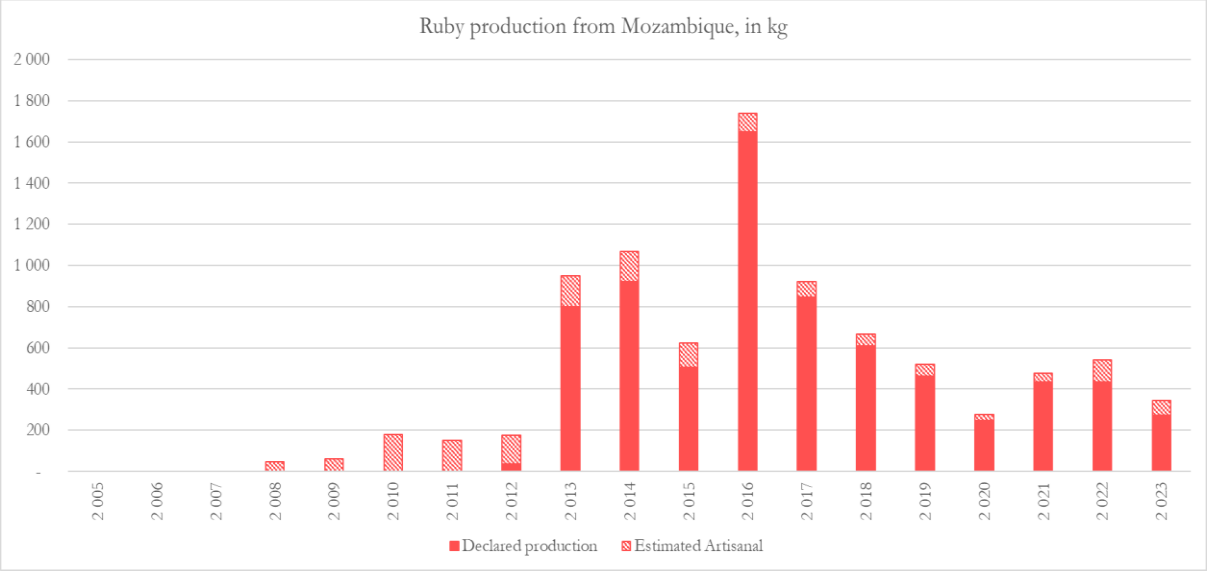


Figure 7: Ruby production from Mozambique, in kg

b) Ruby Trade Flows

As Mozambique is not a producer of emeralds or blue sapphires, the UN Comtrade data (HS 710391) can be considered to reflect the exports of rubies and pink sapphires from northern Mozambique only (Figure 9).

Imports of gemstones into Mozambique is almost non-existent, and therefore negligible. Mozambique does not have a strong beneficiation industry within the country, meaning that the vast majority of the gemstones produced in Mozambique would be exported as rough gemstones. However, when looking at the exports of precious gemstones from Mozambique, 99% of the value comes from the exports of worked rubies, emeralds and sapphires (HS 710391), whereas total rough precious gemstones represent only 1% of export values. Also, when looking at the evolution of the export values, it is clear that the exports started in 2014, which corresponds to the first auction sales of rubies by Montepuez Ruby Mining. The drop in exports value in 2020 can be explained by the Covid-19 crisis.

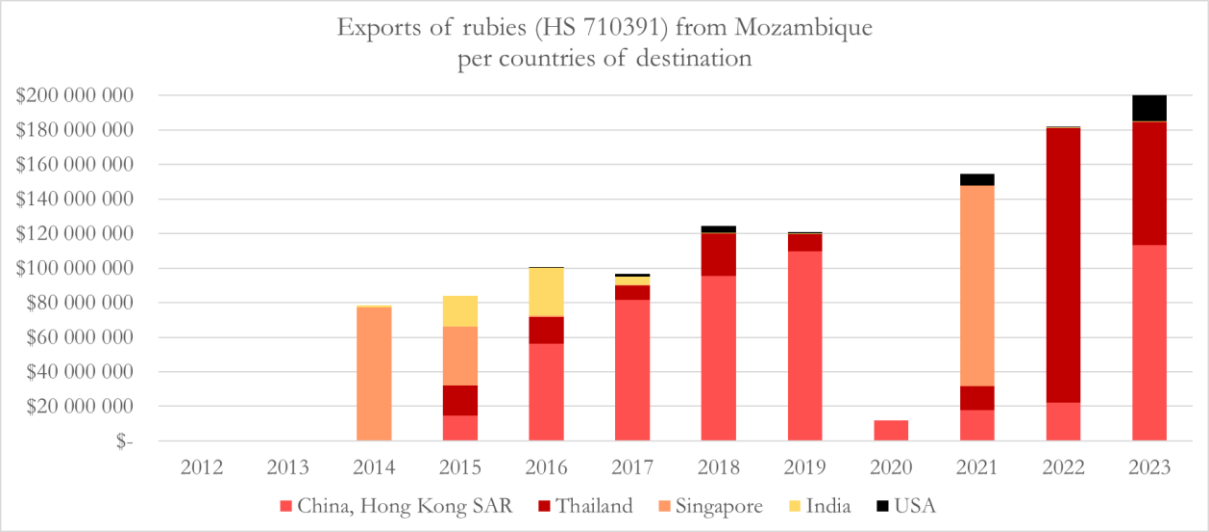


Figure 8: Importing countries of rubies from Mozambique

Mozambique does not export gemstones to many countries. In fact, just four countries account for 94% of the total value of Mozambique's gemstone exports: these are Hong Kong, Singapore, Thailand and India (Figure 8). Hong Kong, Thailand and India are major trading centres, where rubies are going to be cut, polished and, if necessary, treated, before being sold. Gemfields' auction system explains why these countries account for almost all of the exports: MRM initially held its auctions in Singapore; the increase in Thailand's share of exports in 2021 and 2022 is directly related to Gemfields' auctions taking place in Bangkok, rather than Singapore, in those years.

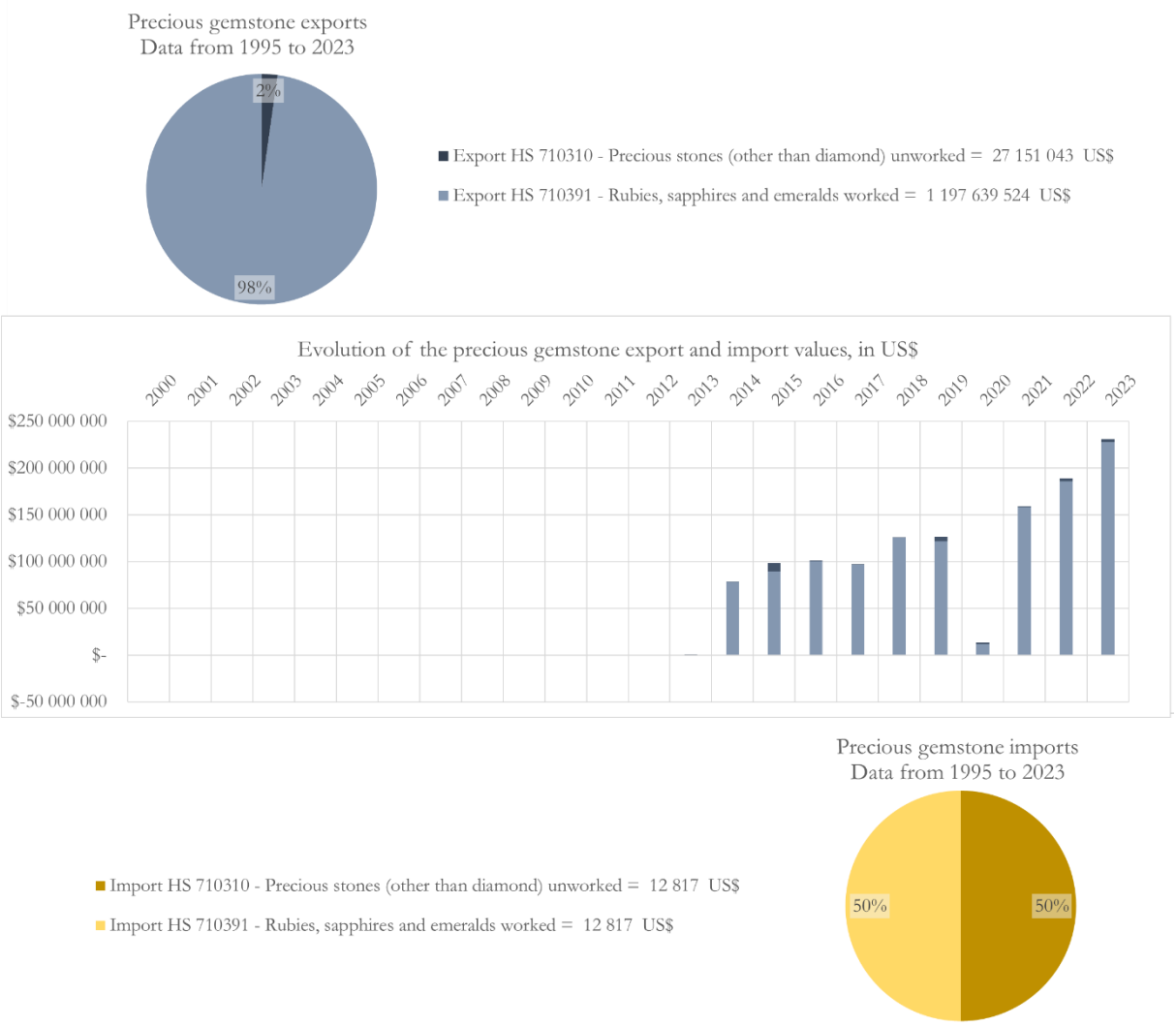


Figure 9: Precious gemstones imports and exports values from Mozambique

When comparing total export values from UN Comtrade with total export values from Montepuez Ruby Mining, who have collaborated with this study, the results follow the same trend and range (Figure 10). In some years, the figures reported by the miner are above the ones from UN Comtrade, which can be explained by a delay in payments and exports following the sales via auctions, especially for end-of-year auctions. This graph highlights the importance of MRM on the export of rubies from Mozambique, with this source representing 88% of the total export value since 2014.

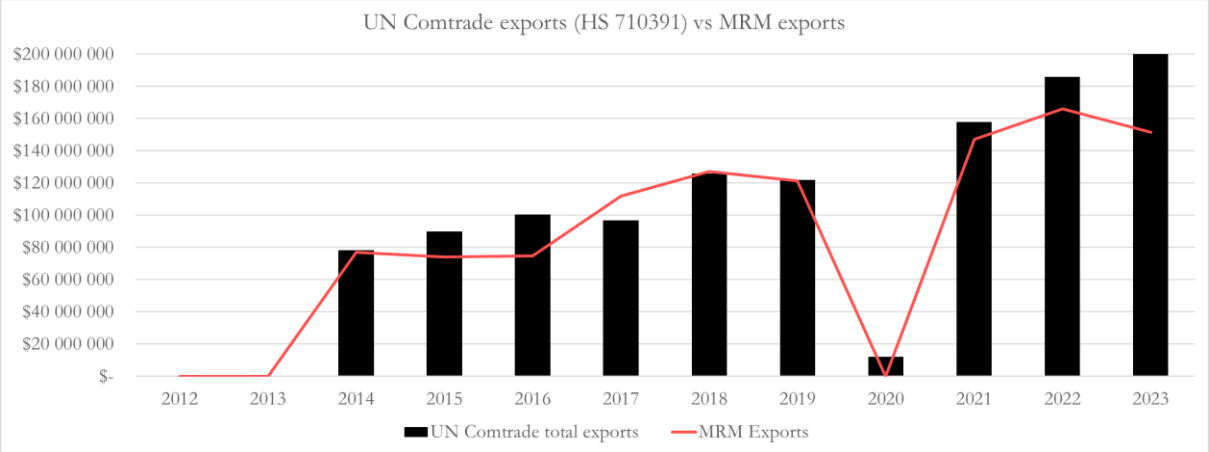


Figure 10: UN Comtrade exports data compared to MRM exports

5. *Myanmar*

a) Ruby Production

Myanmar ('Burma') is the most historical and sought-after source of fine-quality rubies. For centuries, Rubies have been known and exploited in the region of Mogok in Myanmar. Mogok is a land of many gemstones, but its reputation primarily comes from its production and trade of very high-quality rubies. A good indicator of the popularity of Burmese rubies is the record sales they have achieved at auction houses: as of 2009, more than 90% of the rubies with a price above 50kUS$/ct auctioned at Christies were from Mogok[30].

Production of rubies from Myanmar has come from two main areas: Mogok and Mong Hsu. As with other gemstone-producing countries, illegal and citizen mining has been significant and difficult to control. It is a particularly sensitive topic in Mogok, because the city's history is intrinsically linked to the gemstones produced in the area (referred to as the 'Mogok Stone Tract'), and people have been exploiting this land for centuries. All families in Mogok have a history with gemstones, and the entire dynamic and culture of the region revolves around this trade.

In order to control illegal mining, Mogok's gemstone mines were nationalised in 1963, and in 1990 joint-venture mining leases with the Myanmar Gems Enterprise (MGE) were authorised for citizens[31]. However, MGE has ceded operation to private and military-controlled companies[32], and as of 2016, 98% of production permits were held by private companies[33]. After the nationalisation of the mines, mining operations increased and methods evolved, thus, all types of mining operations have occurred in Mogok, from small-scale mining in alluvial deposits in rivers, to large, mechanised operations. Informal citizen miners, known as Kanase, are also allowed to collect gemstones from the waste of larger companies.

The Mong Hsu deposit was discovered in 1992 and quickly provided large volumes of gemstones. Their quality was notably lower than the rubies from Mogok, but the development of treatments enabled these gemstones to reach the market. Mong Hsu was considered to be the world's largest supplier of rubies in the mid-1990s, but production since 2004 has dropped considerably [86].

It is believed that Myanmar has supplied up to 90% of the world's rubies in some periods[34]. Thanks to its renown, the Mogok Stone Track (named for the mining district of Mogok) has a well-documented history. However, volumes of production, both historic and current, remain a challenge to assess, because the area

[30] Newman, M. (2018). Multifaceted: Governance and Conflict Risks in Myanmar's Ruby Industry. Natural Resource Governance Institute

[31] Kane, R. E., & Kammerling, R. C. (1992). Status of ruby and sapphire mining in the Mogok Stone Tract. Gems and Gemology, 28(15), 274.

[32] Shortell, P., & Irwin, E. (2017). Governing the gemstone sector: Lessons from global experience. Natural Resource Governance Institute. UK Department of International Development and Australian Department of Foreign Affairs and Trade.

[33] Kyaw Thu. (2019). Gem Mining and Sustainability in Myanmar. Myanmar Gems Forum 2019 at Yangon International Gems & Jewellery Fair.

[34] Shor, R., & Weldon, R. (2009). Ruby and sapphire production and distribution: A quarter century of change. Gems and Gemology, 45(4), 236-259.

is restricted and official reports are hard to come by. The Natural Resource Governance Institute (NGRI) report of 2018 estimates that 60% to 80% of Myanmar's gemstones are undeclared[15]. Some think that the joint-venture system implemented in 1990 has drastically reduced smuggling; prior to this, the country had control of only about 5% of production[35]. Indeed, data prior to 1990 was more sporadic and harder to come by. The below production profile (Figure 11) is a compilation from bibliography, USGS mineral yearbooks, statistics from Myanmar[36,37] and other sources like Pala Gems[38]. Based on bibliography and expert's opinion, the 'estimated undeclared' production is considered to be: 95% up to 1995; 25% between 1995 and 2014; and 60% after 2014. The decrease in production observed since 2010 can be explained by the depletion of the deposits, as well as by the increase of privately owned mines, which do not have the obligation to report production[39].

It is worth mentioning that Myanmar uses a fiscal year running from April to March, the figures used are allocated to the end of the fiscal year (for example, figures from the fiscal year 2007-08 are reported under the year 2008).

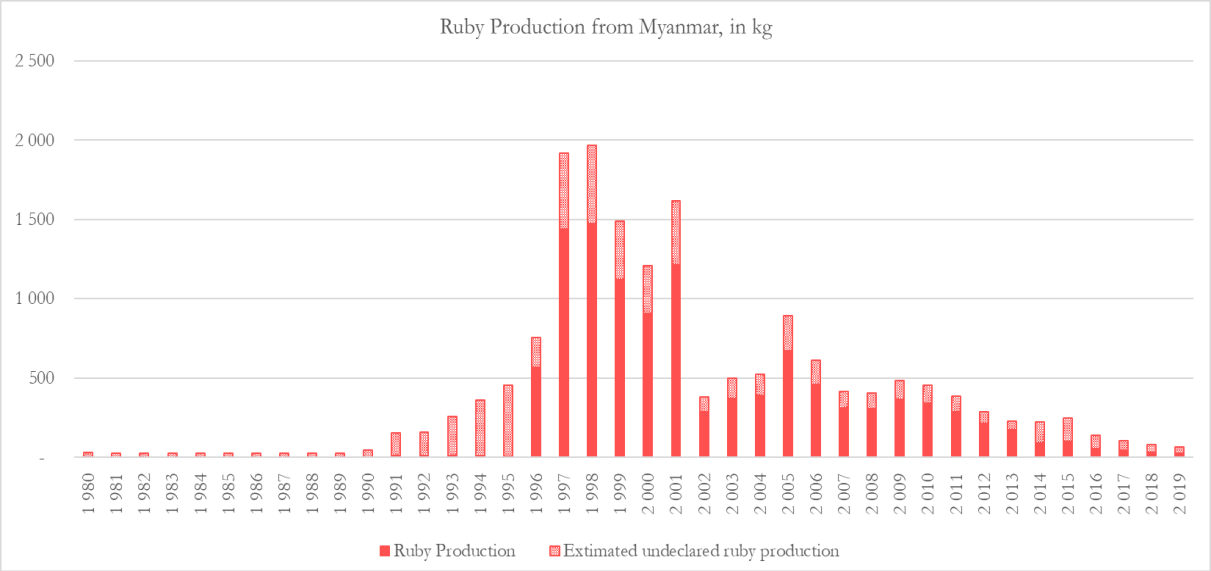


Figure 11: Ruby production from Myanmar, in kg

Once again, Myanmar produces many other gemstones besides rubies, notably sapphires, spinels and peridots. Data from the Myanmar Statistical Information Service[21], from 2005 to 2016, shows the share of production per gemstones type (excluding jade). Over these 12 years, rubies represented 7% of the total volume of gemstone production (Figure 12). However, it is likely that rubies had the highest share in terms of value, although no data can support this assumption.

[35] Kammerling, R. C., Scarratt, K., Bosshart, G., Jobbins, E. A., Kane, R. E., Gübelin, E. J., & Levinson, A. A. (1994). Myanmar and its gems—an update. Journal of Gemmology, 24(1), 3-40.
[36] http://mmsis.gov.mm/
[37] https://myanmareiti.org/en/publication-category/meiti-reports
[38] http://www.palagems.com/gem-news-burma-stats
[39] Newman, M. (2018). Multifaceted: Governance and Conflict Risks in Myanmar's Ruby Industry. Natural Resource Governance Institute

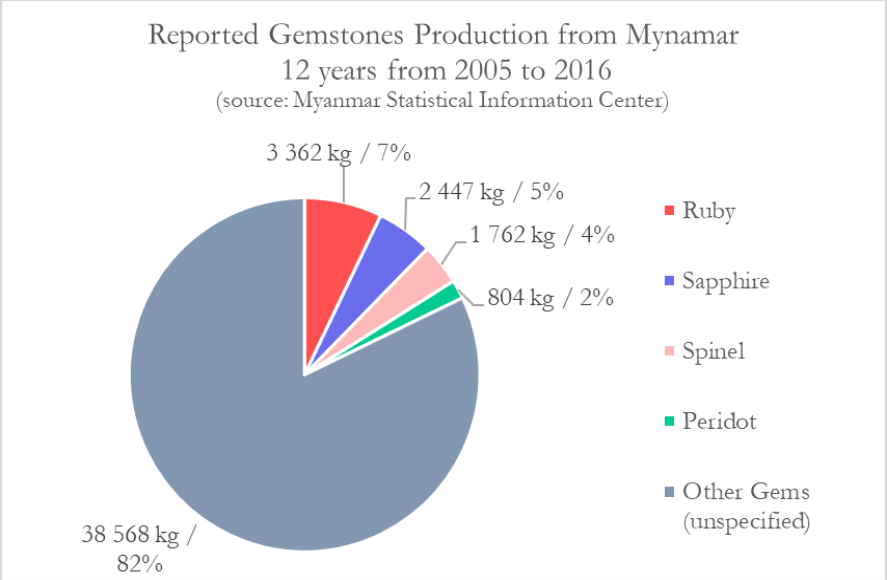


Figure 12: Myanmar gemstone production per type of gemstones

b) Ruby Trade Flows

One cannot discuss the gemstone trade flows from Myanmar without mentioning the related political issues. The implication of the military in the gemstone sector, and the documented human rights abuses have given a bad name to Burmese gemstones, leading to international actions. In 2003, the USA declared a ban on the import of all gemstones from Myanmar. In 2008, this sanction was extended to ruby and jadeite originating from Burma, regardless of the export country. The ban was officially lifted in 2016, but sanctions were imposed again, after the military coup in 2021, on three Myanmar-based gem-producing companies. Considering that it is still difficult to assess the country of origin of a gemstone (laboratories only provide opinions, rather than proof), such sanctions are hard to implement, and some will argue that it encourages smuggling, and disadvantages the population who rely on this sector for a living, rather than effectively punishing the country's political decisions.

Another important dimension of the gemstone trade in Myanmar is the place of the Myanmar Gems Enterprise (MGE) in the sector. MGE is a state-owned company involved in many steps of the trade: it is in charge of the issuance of mining and trading licences and tax collection, as well as sales via the annual Gems Emporiums. It is also worth mentioning that several military-affiliated companies are dominating ruby extraction, notably the Union of Myanmar Economic Holdings Limited (UMEHL) and Myanmar Economic Corporation (MEC). Irwin explains that the gemstone-producers can sell their gems via three channels[40]:

1. Formally through the Gems Emporium.
2. Formally through direct sales to buyers.
3. Informally through direct sales to buyers.

The formal declaration involves the payment of royalties and taxes, and Irwin estimates that these channels represent 20 to 40% of sales, as opposed to the informal trade which represents 60 to 80% of the trade.

[40] Irwin E. (2016). In support of Myanmar EITI, Gemstone Sector review: Summary Version.

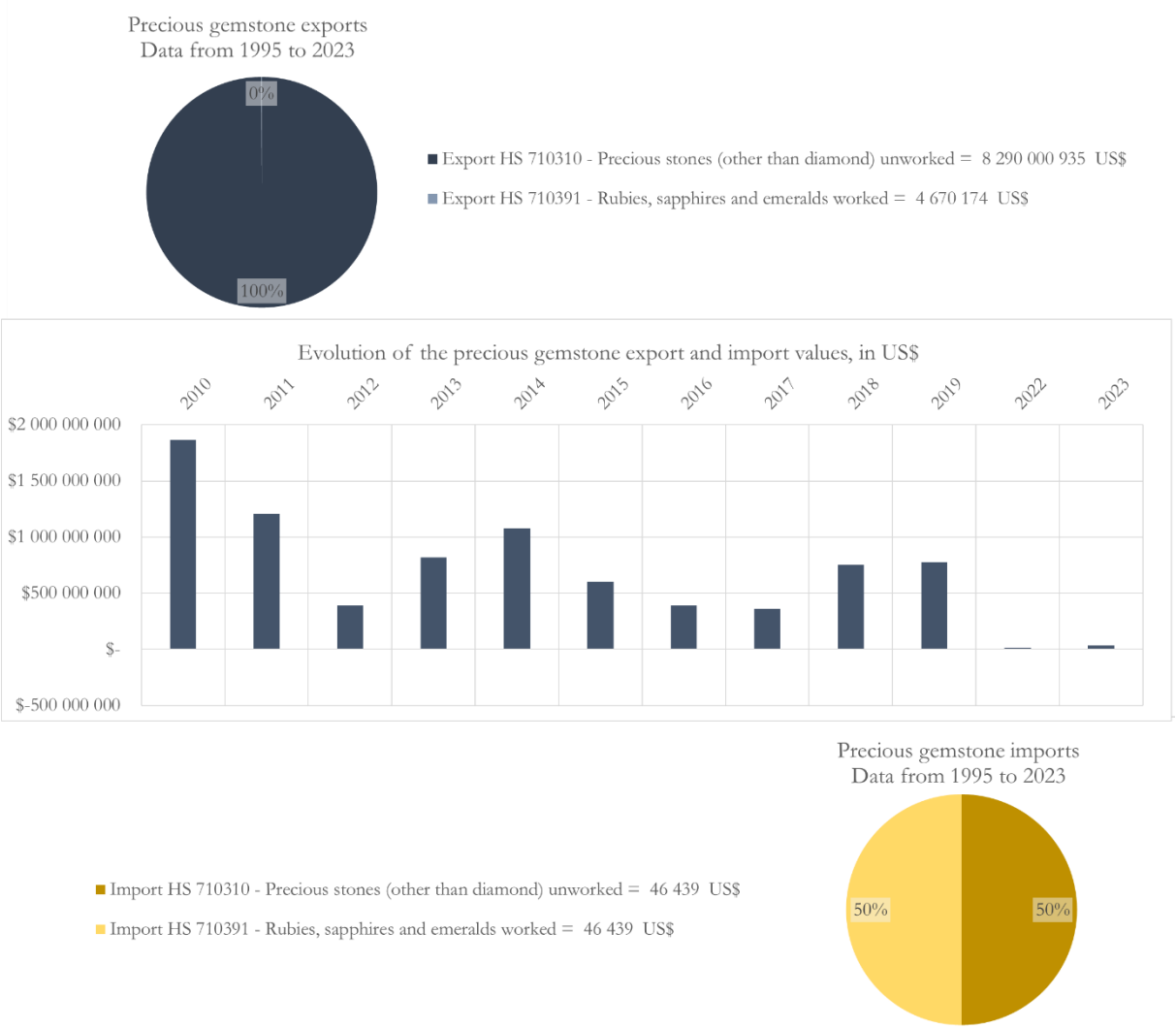


Figure 13: Precious gemstones imports and exports values from Myanmar

Myanmar became a member of the EITI in 2014, however the companies selected for the report on production and sales were the ones selling through the Gems Emporiums only, which is not the main channel for gemstones sales, meaning that there is still a clear lack of transparency[25]. The sale of gemstones from the Emporium was about US$ 5.3 million per year between 2015 and 2018, at an average of 4 US$/ct. This is indeed a very low number when considering the gemstone production and high value of Burmese rubies and sapphires. If we consider that the Gems Emporium sales represent 10 to 20% of the total sales, the real value of the gemstone trade would be between US$ 53 and 27 million per year.

UN Comtrade data for exports only starts in 2010 (Figure 13), and it is believed that the figures reflect more of the jade trade than the gemstone trade (Figure 14). The jade industry in Myanmar is much bigger than the gemstone trade, as Myanmar supplies about 90% of the world's jade[41]. In 2016, 85% of the active mining permits were for jade.

[41] Lin, Y. N., Park, E., Wang, Y., Quek, Y. P., Lim, J., Alcantara, E., & Loc, H. H. (2021). The 2020 Hpakant Jade Mine Disaster, Myanmar: A multi-sensor investigation for slope failure. ISPRS Journal of Photogrammetry and Remote Sensing, 177, 291-305.

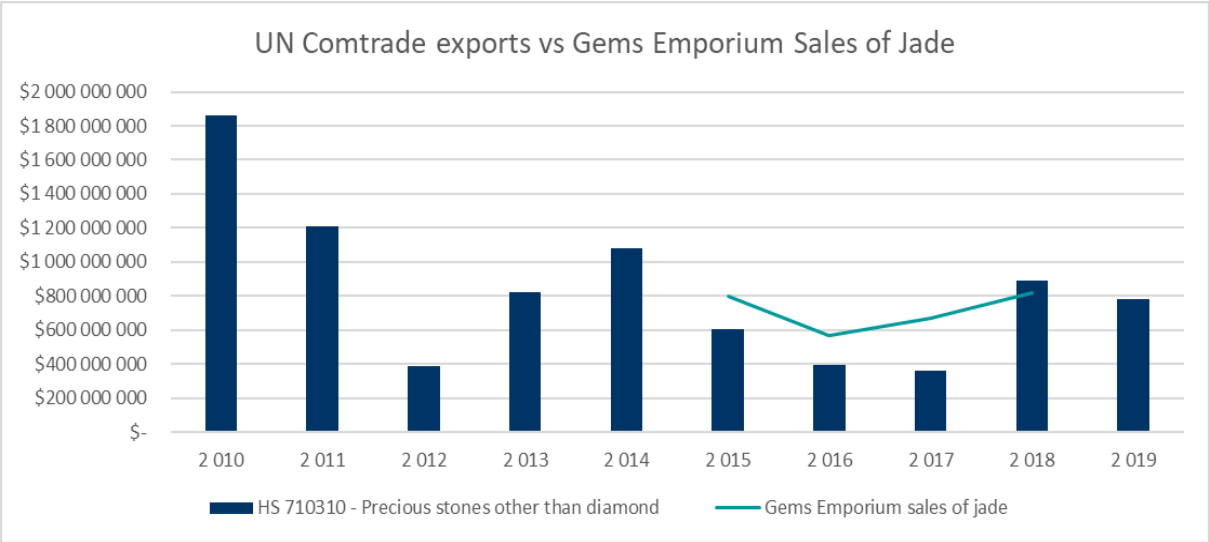


Figure 14: UN Comtrade exports compared to declared jade sales from the Gems Emporium

6. *Tanzania*

a) Ruby Production

Tanzania is now a major producer of rubies and sapphires. Deposits there have been recorded since the beginning of the 20th century[42], although mining activities only really developed in the 1960s[43]. In response to the increase in people and private companies involved in gemstone mining, the Tanzanian government nationalised the mines in 1971. This seriously impacted production, and several mines were closed until the mid-1980s[43] as a result. Overall, the mines in Tanzania have been active only sporadically[44], depending on new discoveries and rushes.

Ruby mining in Tanzania started at the deposit of Longido, which was discovered in the early 1900s in the north of the country. Longido is the oldest ruby mine known in Africa, and its rubies are easily recognised, as they are typically found in a green rock named anyolite. The vast majority of production is low-quality, cabochon-grade at best, but some facet-grade material, requiring heat treatment with borax, has been reported more recently, in 2016[45]. The Longido mine was closed between 1971 and 1988, and when it reopened production was estimated to be around 12 tonnes per year[55].

The second ruby discovery in Tanzania was in the Umba valley in the 1950s[46]. This area is best known for its sapphire production, with large quantities of the gemstone present in an extensive palette of colours[47]. The Kalalani area of the Umba valley has been particularly exploited, with major sapphire discoveries in 1989 and 1990. In 1999, the total overall production for the area was estimated to be 400kg. The rubies were of cabochon quality[48], with less than 1% of them facet-grade. This data suggests that the annual production of rubies from the area must not have exceeded 1kg.

The third main producing area for rubies is the Morogoro region in the centre of Tanzania. This region is vast with many deposits, the most famous ones being Kitonga, Lukande, Matombo and Mahenge. Rubies from Morogoro have been known to exist since the 1970s[55], but the gemstone only came to the market in the 1980s[49], with the peak of production happening between the mid-1980 and mid-1990s[50]. Production in

[42] Shor, R., & Weldon, R. (2009). Ruby and sapphire production and distribution: A quarter century of change. Gems and Gemology, 45(4), 236-259

[43] Dirlam, D.M., Misiorowski, E.B., Tozer, R., Stark, K.B., Bassett, A.M. (1992). Gem Wealth of Tanzania. Gems & Gemology, Summer 1992, Volume 28, No. 2

[44] Michelou J.C., Ed. (2006) ICA 2006 World Gemstone Mining Report. InColor, Spring.

[45] Pardieu, V. (2019). Thailand: The undisputed ruby trading kingdom: A brief history. InColor. Spring, 42, 14-22.

[46] Pardieu, V., Vertriest, W., (2016). Update on colored gemstone mining in Tanzania. Gems News. Gems & Gemology. Fall 2016

[47] Hänni, H. A. (1987). On corundum from Umba Valley, Tanzania. Journal of Gemmology, 20(5), 278-284.

[48] Seifert, A. V., & Hyrsl, J. (1999). Sapphire and garnet from Kalalani, Tanga province, Tanzania. Gems Gemol, 35, 108-120.

[49] Hänni, H. A., & Schmetzer, K. (1991). New rubies from the Morogoro area, Tanzania. Gems & Gemology, 27(3), 156-167.

[50] Hughes, R. (2008) Gem Hunting in Mahenge & Tunduru. https://www.ruby-sapphire.com/articles/798-tanzania-ruby-sapphire-spinel

1992 was estimated to be around 200kg per month, with quality being, again, mostly cabochon and carving grade[55,51].

In 1992, a major sapphire deposit was discovered in Songea, followed, in 1994, by the Tunduru deposit, both in the south of Tanzania[52]. Rubies are rarely found in these areas[53].

The last major discovery of rubies in Tanzania was made in 2007 in Winza. Unlike the other Tanzanian deposits, Winza produces rubies of the fine quality, which do not require treatment.

New deposits continue to be discovered in the country, like the one reported in 2016 in the Kilindi area (between Winza and Umba)[64], underlining the importance of Tanzania to the international gem-corundum market. Quantities produced are difficult to estimate, and reported data is sometimes very contradictory. For example, the early 1990s is estimated to have been a high-production period in Longido and Morogoro, with as much as 14 tonnes a year produced. However, the reported production figure from USGS for 1995 is only 3.5 tonnes[54], which seems quite low, even taking into account the reduction of activity in these two areas at this time. The Tanzania EITI report for 2019 provides production figures of 52 tonnes of rubies and 5 tonnes of sapphire. In the EITI report for 2020, the production figure for rubies is 2.8 tonnes, with 270 tonnes of sapphires, which is a completely different range and ratio from the previous year. The attempted production profile below compiles data from different sources and adds an undeclared portion of production up to 45%. This ratio is based on the smuggled production estimated by the US Agency for International Development in 2001[55], but the undeclared volumes are, of course, impossible to know and bound to have varied over time.

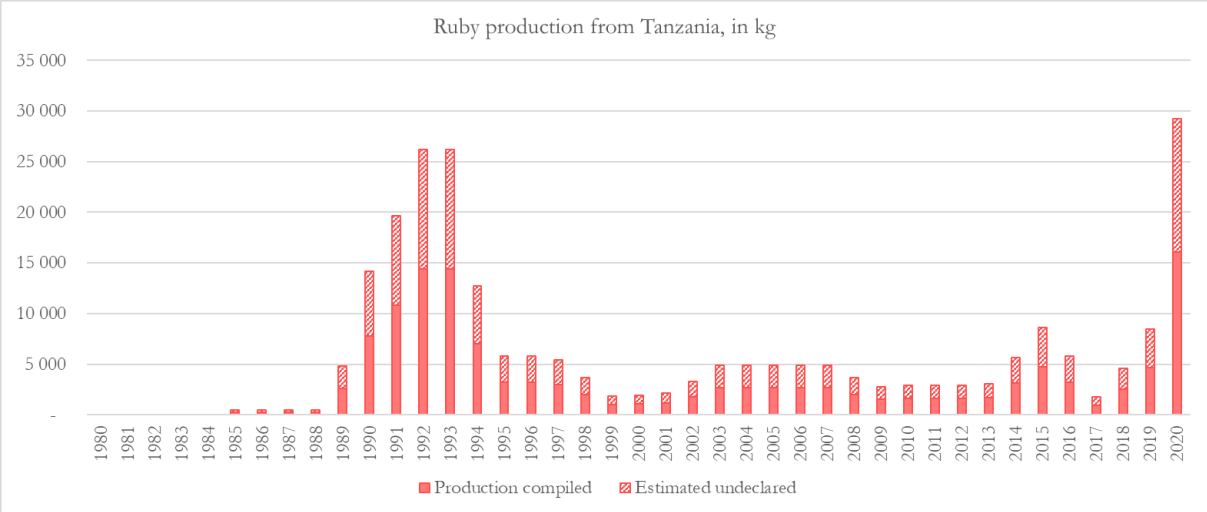


Figure 15: Ruby production from Tanzania, in kg

[51] Schwarz, D., Pardieu, V., Saul, J. M., Schmetzer, K., Laurs, B. M., Giuliani, G., ... & Ohnenstetter, D. (2008). Rubies and sapphires from Winza, central Tanzania. Gems & Gemology, 44(4).

[52] Pardieu, V., Vertriest, W., (2016). Update on colored gemstone mining in Tanzania. Gems News. Gems & Gemology. Fall 2016

[53] Chitty, W. (2009). A study of sapphires and rubies from Tanzania's Tunduru district (Doctoral dissertation, Kingston University, London).

[54] Yager, T. R., Menzie, W. D., & Olson, D. W. (2008). Weight of production of emeralds, rubies, sapphires, and tanzanite from 1995 through 2005. US Geological Survey.

[55] https://www.gemstones-and-jewellery.com/white_papers/letting-it-shine-governance-in-coloured-gemstone-supply-chains/

The Tanzanian Mining Commission reports a drastic increased of the volumes of gemstones produced in 2020, which is reflected in the production profile (Figure 15), however there is no apparent reason nor explanation for it[56].

b) Ruby Trade Flows

Tanzania is also an important producer of other gemstones besides rubies and sapphires, like garnets and tanzanites. The vast majority of its gemstone exports fall into the category of 'precious stone unworked', and therefore no direct correlation with rubies and sapphires can be made. Overall, there was an increase in exports between 1997 and 2013, and a slowdown since then (Figure 16). The decrease in exports could be related to the ban of exports on rough tanzanite above 1ct.

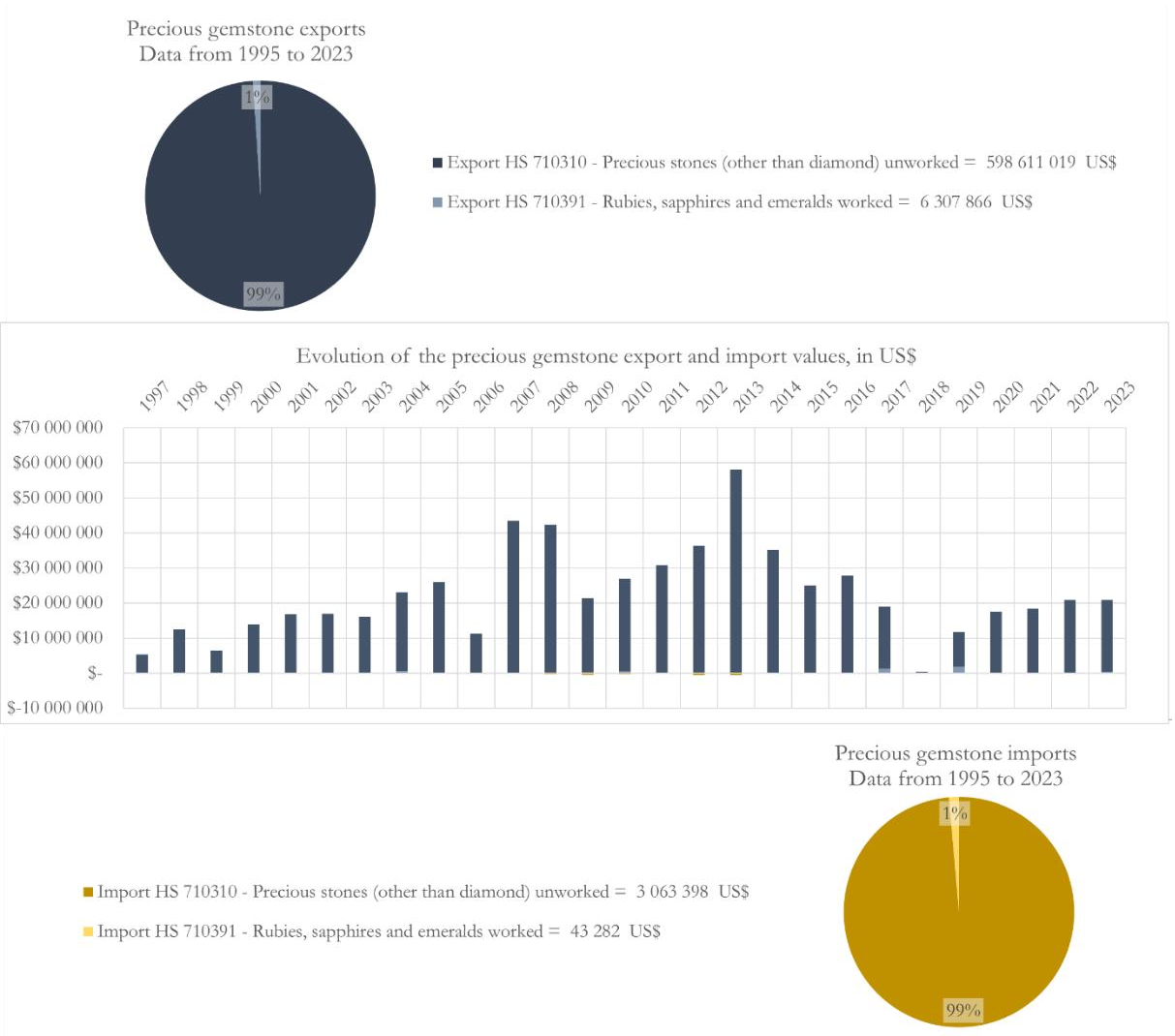


Figure 16: Precious gemstones imports and exports values from Tanzania

[56] https://madini.untsolutions-tz.com/publications/report/

7. *Thailand*

a) Ruby Production

Thailand has been an important source of rubies since the 19th century. The main deposits are in the Chanthaburi-Trat area, close to the Cambodian border. Following the drop in ruby production in Burma, related to the nationalisation of the Burmese deposits in 1963, Thailand became the world's main supplier in the 1970s. It is reported that Thailand provided up to 70% of high-quality rubies in early 1980s. The same article reports that, in 1980, production of rubies and sapphires was estimated at 8 tonnes[57]. Considering that about 10% of the country's production of gem-corundum is accounted for by rubies (an observed ratio from the USGS data[59]), then the estimated production for the early 1980s is about 800kg.

However, Thailand's 'leading-producer' position changed quickly with the depletion of its deposits[58]. By the 1990s, its production was only a hundredth of what it had been a decade before[59]. As per the USGS reports, rubies represented about 10% of Thailand's total gemstone production . This ratio was used to extrapolate and estimate ruby production from the 1990s to 2021 (Figure 17). It is believed that there is currently no production of rubies in Thailand.

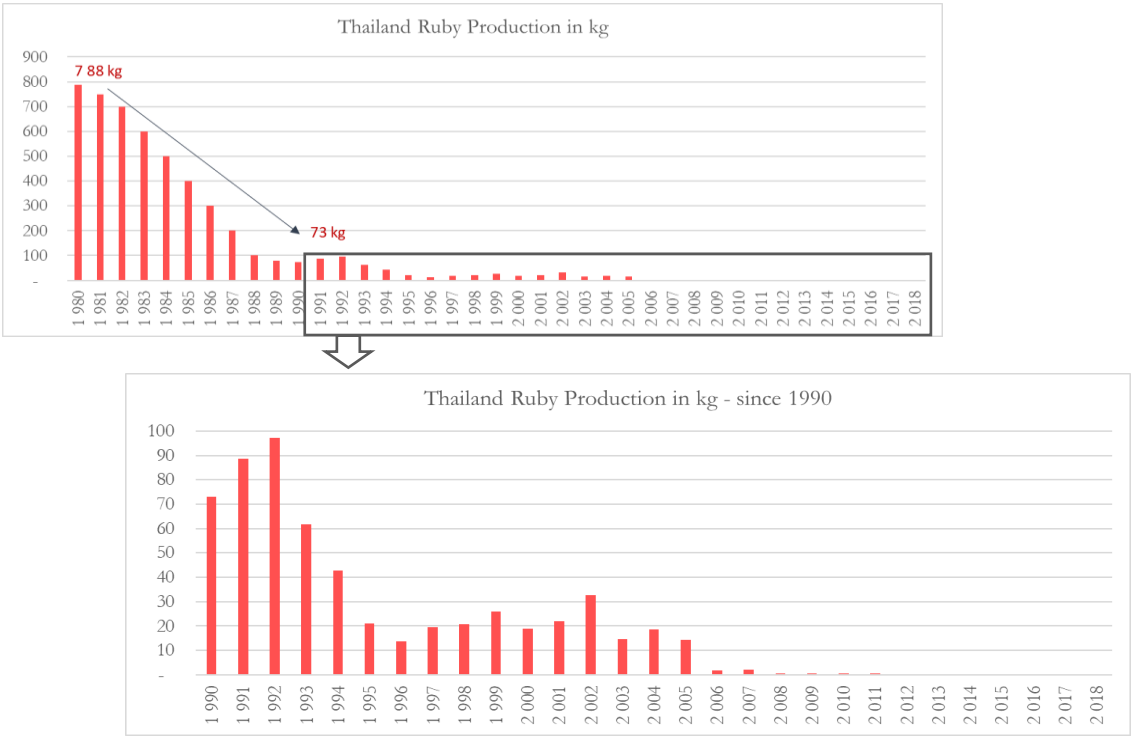


Figure 17: Ruby production from Thailand, in kg

[57] Keller, P. C. (1982). The Chanthaburi-Trat gem field, Thailand.
[58] Pardieu, V. (2019). Thailand: The undisputed ruby trading kingdom: A brief history. InColor. Spring, 42, 14-22.
[59] Yager, T. R., Menzie, W. D., & Olson, D. W. (2008). Weight of production of emeralds, rubies, sapphires, and tanzanite from 1995 through 2005. US Geological Survey.

b) Ruby Trade Flows

Although the direct production of rubies from Thailand diminished and near to non-existent, Thailand has remained one of the world's most important marketplaces for rubies since the 1970s. This is due to the knowledge acquired by Thai traders regarding heat treatments. Thais are also renowned for their cutting skills. Thanks to these value addition processes, rubies and sapphires from all the major deposits in the world (Australia, Madagascar, Mozambique, Burma, etc.), still flow through Thailand.

The graphs below (Figure 18) show that rough, precious stones (HS 710310) represent about 10% of the export and imports value, whereas 'worked' rubies, emeralds and sapphires (HS 710391) represent 90% of the total value. Both imports and exports have consistently increased since the years 2006-2008. This can be correlated with the discovery of several ruby and sapphire deposits in Africa (cf. Mozambique and Tanzania sections). In 2020, the massive drop in traded values is related to the Covid-19 crisis.

Although imports (reported as CIF) are usually higher in value than exports (reported as FO), in UN Comtrade, it is clear that Thailand's import values for precious gemstones are much lower than its export values. On average, over the past ten years, the export values for rubies, emeralds and sapphires are almost twice as high as their import value. As explained, Thailand has not been a significative producer since the early 1990s, so this difference in value should not be interpreted as a difference in volume. More likely, this value gap is related to the beneficiation processes happening in Thailand.

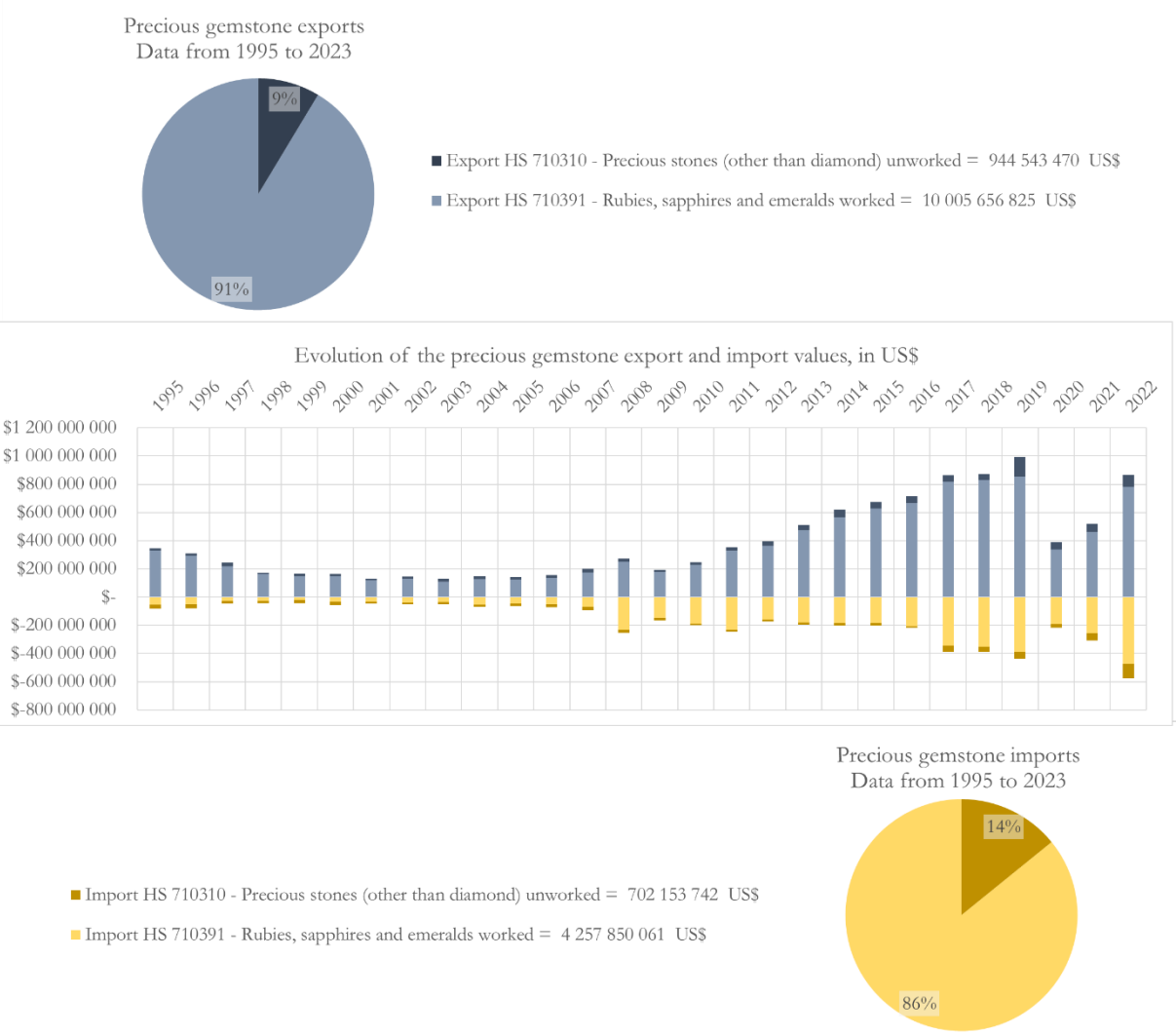


Figure 18: Precious gemstones imports and exports values from Thailand

Thailand has gone one step further in their recording systems for imports and exports of gemstones. They not only use the standard six-digits HS codes, they have also created two extra digits to capture information per variety of precious gemstone. The data is available online via the Gem and Jewelry Institute of Thailand (GIT) database system[60], for the period 2012 to 2023. This enables the country to have high-level detailed analysis of trade flows, which they report monthly on infographics via the GIT infocenter[61]. However, their reports cater to the entire gem and jewellery sector, and therefore show statistics for commodities from gold to gemstones, with 'polished precious stones' as a whole category.

For the purpose of this report, two infographics presented in the following pages have been created with the data from the GIT database.

The first one (Figure 19) presents trade flows, imports and exports for the HS code 710391 ('rubies, sapphires and emeralds otherwise worked'), clearly showing the share of traded values of rubies, emeralds and sapphires. Over the past twelve years, ruby and sapphire export values have been very similar, both more than twice as high as emerald export values. This can be explained by two facts: 1. Thailand is not a main trading centre for emeralds, compared to India, Israel or Hong Kong; 2. The average value of emeralds is below the average value of rubies. When looking at the destination of exports, three countries are responsible for about 70% of the total traded value: Hong Kong, the USA and Switzerland. Hong Kong is the main recipient, representing 46% of all exports. On the import side, the total value is evenly split between the three gemstones, and this trend has been consistent over the years. Three countries import more than half of the total traded value. Interestingly, the major partner is Thailand itself. This can be explained by the fact that Thailand used the 'special trade system' (cf. chapter V, Note on trade flows and UN Comtrade data), meaning that a country can 'import' to itself if the product arrives at a Free Zone, hence the information on the country of origin has been lost. Hong Kong being the second major importer is easily explained as many Thai traders and cutters have operations in Hong Kong. India is the third main importer, mostly for emeralds.

The second infographic (Figure 20) displays imports of unworked gemstones, under the HS code 710310. As Thailand is a major beneficiation centre for coloured gemstones, it is interesting to look at the country's rough imports in detail. However, it should be noted that it is likely that a lot of rough material has in fact been reported under HS code 710391. The import of rough material shows a drastic increase, with a significant increase in ruby imports in 2022, followed by an increased in emerald imports in 2023. The main country of import is Mozambique, representing 47% of total ruby imports. Moreover, the second two import countries for rubies are Singapore and Hong Kong, neither of which are producer countries. This suggests that the share of rubies originating from Mozambique could be much higher, with many of them transiting through Singapore and Hong Kong. Regarding sapphires, Sri Lanka and Australia are the main sources of rough sapphires coming into Thailand. This highlights the negligible share from Madagascar, which accounts for less than 2% of the value imported. Finally, most of the rough emeralds imported to Thailand are from Colombia, however almost all these imports happened between 2022 and 2023. Previously, Zambia and Hong Kong were the most important sources of emerald, whereas imports from Colombia were negligible. . As the volumes of production from Colombia are not known to have increased, and nor have Colombian export figures, this must reflect a change in the trade habits: either Thailand is becoming a more important value addition centre for emeralds, and/or value declarations have improved.

[60] https://www.git.or.th/infocenter-stat/?Lang=EN

[61] https://infocenter.git.or.th/en/infographic/marketing

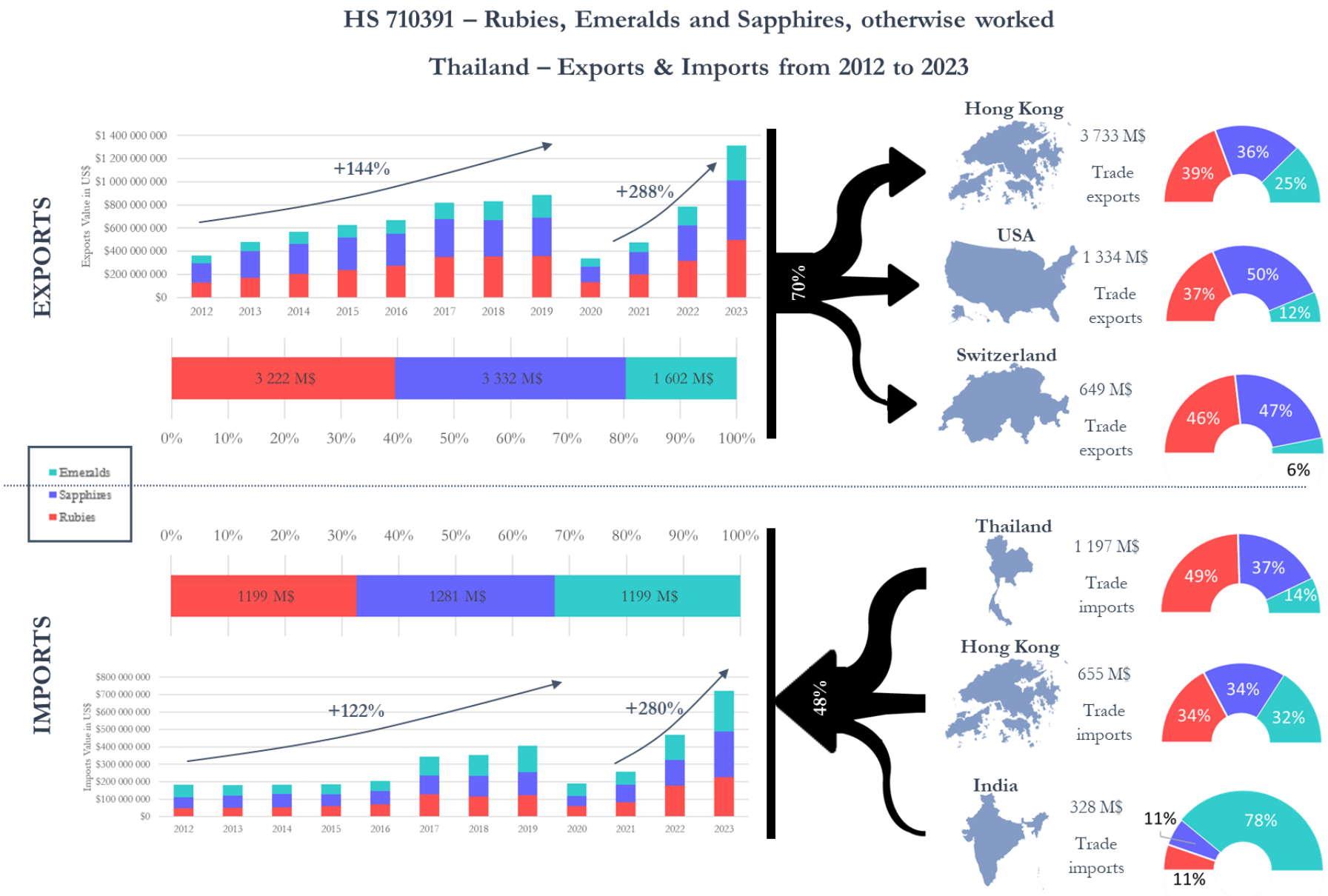


Figure 19: Thailand infographic 1

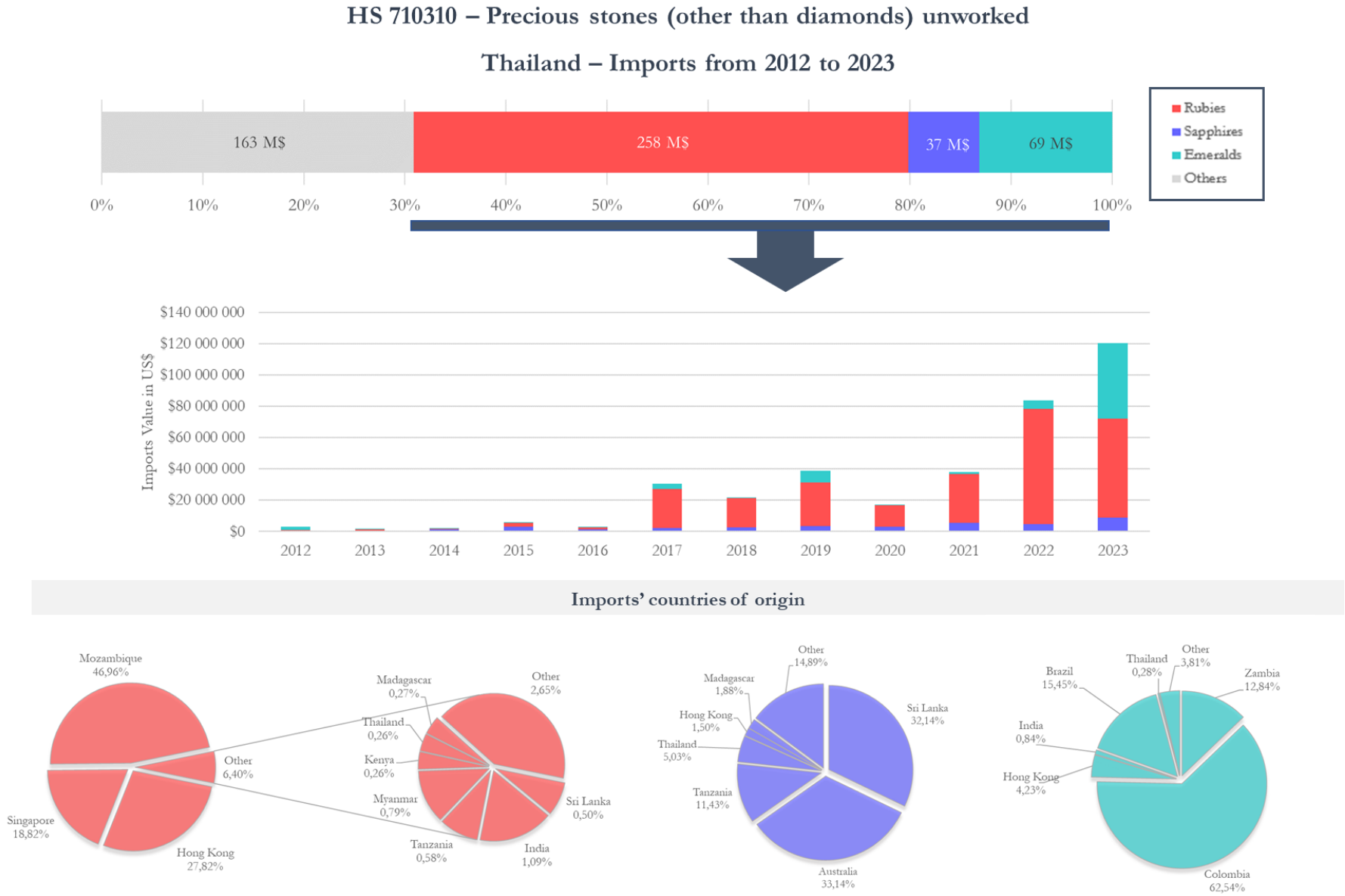


Figure 20: Thailand infographic 2

8. Other countries

a) Malawi

Gem-quality corundum was discovered in Malawi in 1958, at Chimwadzulu Hill, located in the Ncheu district [62]. Exploitation of rubies and sapphires at Chimwadzulu started quickly, and the mine has been operating since the 1960s, although the history of its ownership has been complex. Malawi has a small mining sector, and most of the gemstones there are extracted by artisanal and small-scale miners, with the exception of the Chimwadzulu mine. Chimwadzulu, which is mechanised, is one of the most important mines in Malawi [63,64]. Since 2008, Columbia Gem House, a USA-based gemstone manufacturer and seller, has had an exclusive agreement with the mine owner (at the time Nyala Mines Ltd), to treat, cut, market and sell rubies and sapphires from the Chimwadzulu mine. The gemstones are sold in the USA, under the trade name 'Nyala rubies' [65], with the designation of 'Fair Trade Gemstones' [66]. In October 2017, the Malawian Minister of Natural Resources rejected the renewal of Nyala Mines' mining licence [67]. In 2018, the mining licence was given to a new operator, Mwalawanga Mining Limited; however, Columbia Gem House expressed their desire to continue the fully-integrated supply chain [68].

It is not clear whether production from the Chimwadzulu mine has been consistent since its discovery. Sources mentioned that the deposit is of low-grade, and that gem-quality gemstones are rare, only accounting for about 10% of production [69]. Rubies represent 30% of gem production, with the rest categorised as sapphires (including padparadscha, pink, orange and lavender) [70]. Regarding quantities, reports between 2006 and 2009 mentioned an annual production between 4kg and 5kg [67,69]. However, this does not match the USGS data, nor the latest EITI reports [71],[72], which report yearly production of 180kg in 2005, 309kg in 2015 and 400 tonnes in 2017. There could have been an increase in production due to the installation of a new washing plant around the year 2004-2007 [73,74]. Another possibility for this difference in reported production could be that the average of 4.5kg per year represents only the gem-quality portion of the production (about 10% of production), whereas the figures from EITI are representative of the total production of the mine. The production profile below (Figure 21) comes from USGS mineral yearbook, EITI reports, data and estimated figures.

[62] Shor, R., & Weldon, R. (2009). Ruby and sapphire production and distribution: A quarter century of change. Gems and Gemology, 45(4), 236-259.
[63] Paling, S. (2007) TI-UP Enquiry: The Gemstone Sector in Malawi
[64] Michelou J.C., Ed. (2006) ICA 2006 World Gemstone Mining Report. InColor, Spring.
[65] https://columbiagemhouse.com/
[66] Craig, D. (2017) Gems&Jewellery Spring 2017. Volume 26 No. 1
[67] Malawi extractive Industries Transparency Initiative (MWEITI) Reports. (2020 to 2021)
[68] https://www.nyasatimes.com/wadis-mwalawanga-ltd-roll-mining-nyala-rubies-shaping-malawi-economy-mining/
[69] Paling, S. (2007) TI-UP Enquiry: The Gemstone Sector in Malawi
[70] Vermiculite, C., Ore, I., & Sulphide, I. (2009). Mineral potential of Malawi.
[71] Yager, T. R., Menzie, W. D., & Olson, D. W. (2008). Weight of production of emeralds, rubies, sapphires, and tanzanite from 1995 through 2005. US Geological Survey.
[72] Malawi extractive Industries Transparency Initiative (MWEITI) Reports. (2017 & 2019)

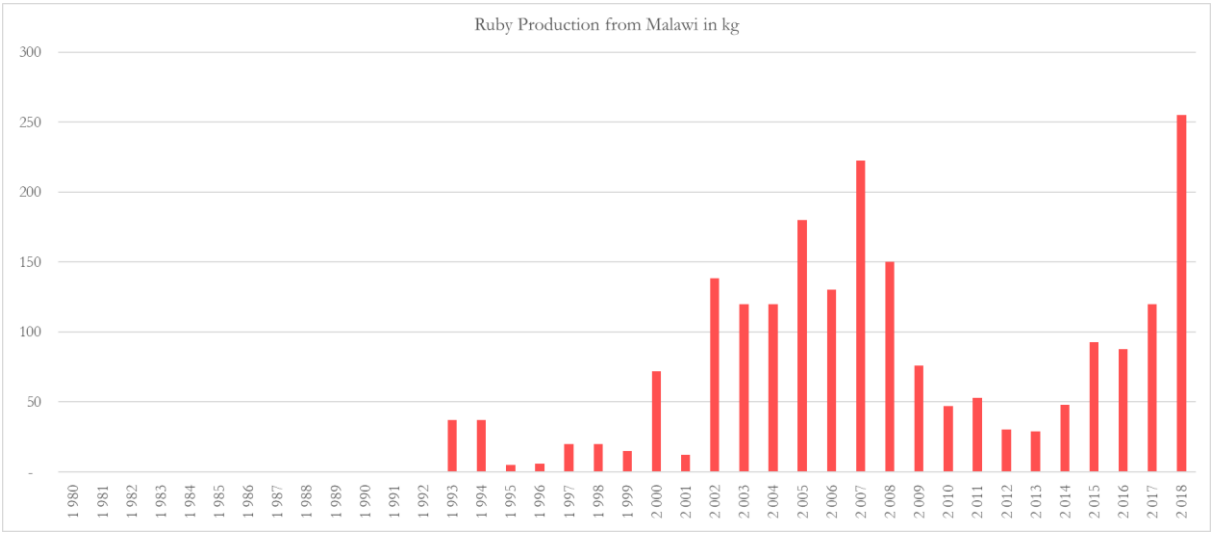


Figure 21: Ruby production from Malawi, in kg

b) India

India has been the source of many gemstones, and rubies have been found in different regions of the country, notably the Karur region[73]. However, no official production has been reported since 1999, neither in the USGS mineral yearbook nor in the official reports from the Indian Bureau of Mines[74]. The production profile below (Figure 22) is based only on the USGS data from 1995 to 1999, with historical values being averaged out.

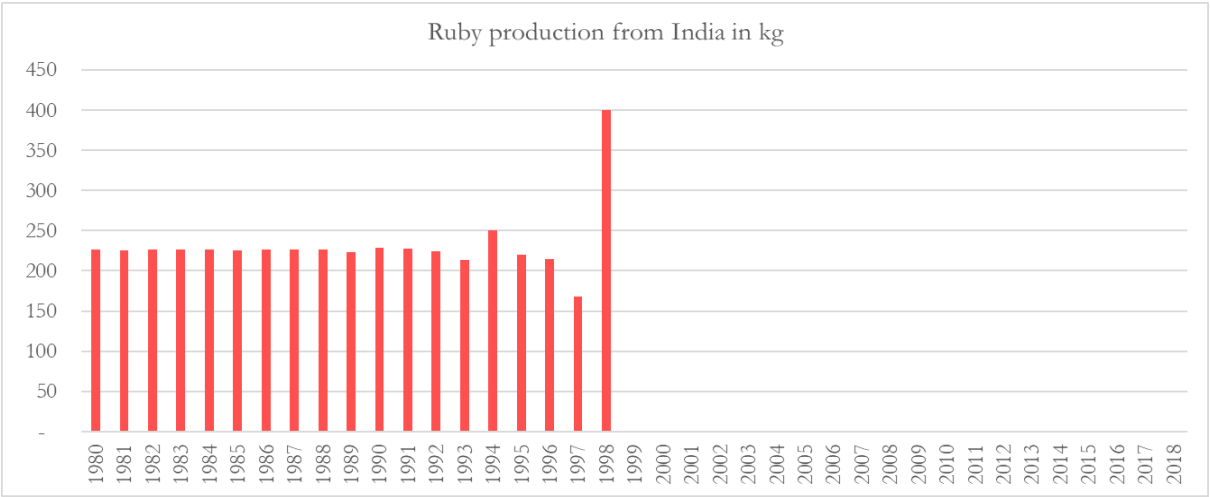


Figure 22: Ruby production from India, in kg

[73] Shirole, P., Mookherjee, A., Marathe, T., Makki, M.F. (2014) Indian Ruby Mining. Gems & Gemology, Spring 2014, Vol. 50, No. 1

[74] https://ibm.gov.in/

c) Vietnam

High-quality rubies were discovered in Vietnam in 1987, in the Luc Yen district of the Yen Bai region, in the north of the country[75]. Organised mining operations started there in 1989[76], but these rapidly slowed down, with some mechanised operations closing in 1994, because the deposits were no longer economic[77]. In Yen Bai, another major discovery was made in 1990 in Tan Huong (about 80 km south of Luc Yen). Together, Luc Yen (also referred as Truc Lau area) and Tan Huong make Yen Bai the most important source of rubies and sapphires from Vietnam, although gem-quality corundums are found in many other regions of the country[78]. The peak of mining activity is believed to have occurred in the 1990s (Figure 23), with hundreds of kilogrammes of gems being produced[80,81,79]. In 2011, Khoi reported that ongoing production was about 10kg per month[80].

Another deposit that produced significant quantities in the 1990s is Quy Chau. This area attracted thousands of artisanal miners, and a few mechanised operations were installed in 1992. The largest company reported a monthly average of 4.5kg of rubies and sapphires extracted in 1992[80].

Rubies in Vietnam are found in both primary and secondary deposits, although the vast majority of mining takes place in secondary gravels. Mining from other areas in the country is sporadic and small-scale[82].

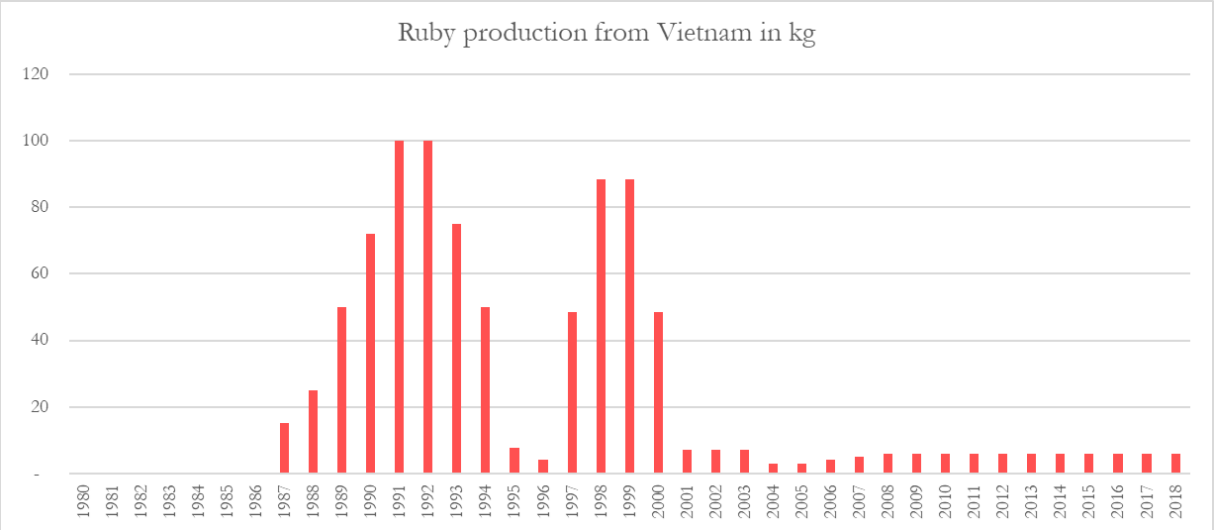


Figure 23: Ruby production from Vietnam, in kg

[75] Van Long, P., Pardieu, V., Giuliani, G. (2013) Update on Gemstone Mining in Luc Yen, Vietnam. Gems & Gemology, Winter 2013, Vol. 49, No. 4

[76] Kammerling, R.C., Keller, A.S., Scarratt, K.V., Rapetto, S. (1994) Update on Mining Rubies and Fancy Sapphires in Northern Vietnam. Gems & Gemology Summer 1994

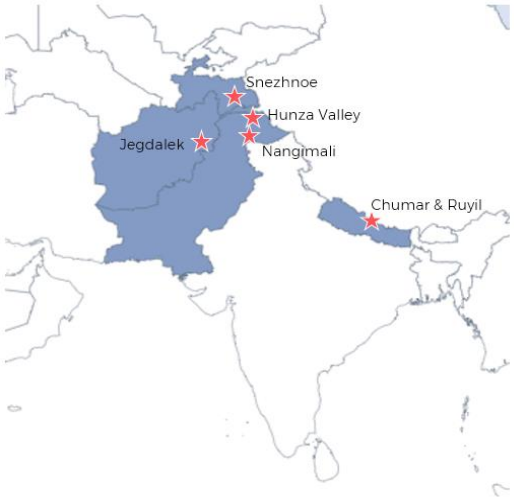
[77] Shor, R., & Weldon, R. (2009). Ruby and sapphire production and distribution: A quarter century of change. Gems and Gemology, 45(4), 236-259.

[78] Huong, L. T. T., Häger, T., Hofmeister, W., Hauzenberger, C., Schwarz, D., Van Long, P., ... & Nhung, N. T. (2012). Gemstones from Vietnam: An Update. Gems & Gemology, 48(3).

[79] Van Long, P., Quang Vinh, H., Garnier, V., Giuliani, G., Ohnenstetter, D., Lhomme, T., ... & Trong Trinh, P. (2004). Gem corundum deposits in Vietnam. Journal of Gemmology, 29(3), 129-147.

[80] Khoi, N. N., Sutthirat, C., Tuan, D. A., Van Nam, N., Thuyet, N. T. M., & Nhung, N. T. (2011). Ruby and Sapphire from the Tan Huong-Truc Lau Area, Yen Bai Province, Northern Vietnam. Gems & Gemology, 47(3).

d) Central Asian deposits (Afghanistan, Pakistan, Tajikistan, Nepal)



Rubies have been extracted from deposits in Central Asia for hundreds of years. The mines are located in mountains between 2,000 and 4,500 metres above sea level. Their elevations mean they are difficult to access and big mining equipment cannot be brought on site. The rubies are mostly found in their host rocks, which are marbles. For these reasons, operations can only be conducted on a small scale.

In Afghanistan, the Jegdalek region is the only known producing area for rubies, with mines there operated by local people. Sapphires account for the majority of production sapphires, with 15% of production being ruby. It is also reported that only 3% of the production is facet-quality[81]. Rubies from Afghanistan are extremely hard to obtain and, although it is believed that mining has been ongoing for several hundred years, it has probably been affected by the political situation there.

In Pakistan, rubies originate from the Nangimali mountain, as well as from the Hunza Valley. The Nangimali deposit was discovered in 1979, but actual production only began in the 1990s. Production in Hunza Valley is reported to be small[82]. The gemstone industry in Pakistan is promising, as mentioned by various sources over the past 40 years[83,84,85], but this potential does not seem to result in real growth, probably due to the complex political situation in the country, the location of the mines, which are difficult to access, and the lack of investment. The Pakistan Bureau of Statistics has not reported any gemstone production since 2005[86].

Rubies have been reported to be present in Tajikistan since the 1930s, but the main deposit, Snezhnoe, was only discovered in 1980. It was exploited until the collapse of the Soviet Union in 1991, when all formal mining activity ceased for 15 years[87]. Tajik rubies became more available to the market in 2006, as reported by Pardieu in 2007[88], but official production figures are not available.
In Nepal, rubies and sapphires were discovered at Chumar and Ruyil, in Dhading district, around 1981. Official mining activity started in 1985 but was quickly abandoned. Most mining is unofficial and sporadic, so production data is difficult to find or to estimate[89].

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[81] Bowersox, G. W., Foord, E. E., Laurs, B. M., Shigley, J. E., & Smith, C. P. (2000). Ruby and sapphire from Jegdalek, Afghanistan. Gems and Gemology, 36(2), 110-126.
[82] Shor, R., & Weldon, R. (2009). Ruby and sapphire production and distribution: A quarter century of change. Gems and Gemology, 45(4), 236-259.
[83] https://www.nation.com.pk/28-Feb-2022/pakistan-s-potential-in-gemstones-vital-for-prosperity
[84] https://phys.org/news/2017-10-rubies-treasures-pakistani-kashmir.html
[85] Gübelin, E. J. (1982). Gemstones of Pakistan: emerald, ruby, and spinel. Gems Gemol., 18(3), 123-139.
[86] https://www.pbs.gov.pk/energy-and-mining-tables
[87] Sorokina, E. S., Litvinenko, A. K., Hofmeister, W., Häger, T., Jacob, D. E., & Nasriddinov, Z. Z. (2015). Rubies and sapphires from Snezhnoe, Tajikistan. Gems and Gemology, 15, 160-175.
[88] Pardieu, V. (2007). Tajikistan: Gems of the roof of the world. InColor Spring 2007.
[89] Smith, C. P., Gübelin, E. J., Bassett, A. M., & Manandhar, M. N. (1997). Rubies and fancy-color sapphires from Nepal. Gems & Gemology, 33(1), 24-41.

The production profile below (Figure 24) is largely based on USGS data between 1995 and 2005[90], with extended averages. It also takes into account production figures and the reported history of mining activity from the bibliography.

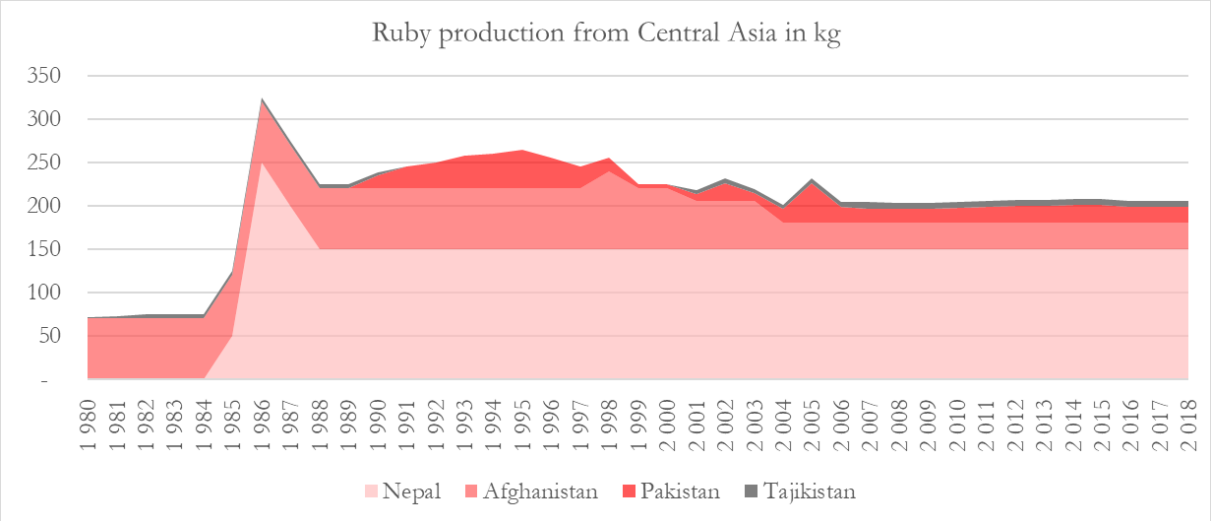

Figure 24: Ruby production from Central Asia, in kg

e) Greenland

Gem-corundum rubies and pink sapphires were discovered in Greenland in the 1960s, although it took decades, until 2014, for mine construction work to begin. In the meantime, small-scale activity by independent miners took place[91], but the gems never reached the global market. The deposit, in the southwest of Greenland, is now referred to as Aappaluttoq, meaning 'red' in Greenlandic. True North Gems Inc. (a Canadian junior exploration company) was the first company to obtain a mining licence and permit in 2014, after several years of exploration work. The mine changed ownership in 2016 and it was operated by LNS Greenland, part of the Leonhard Nilsen & Sonner group, a Norwegian company. The rubies and sapphires had then been marketed under the brand Greenland Ruby. Production officially started in May 2017[92]. However, the mine closed in mid-2023, due to financial difficulties[93]

The mining conditions in Greenland are challenging, mainly due to the weather and the remote location[94,95]. The gem-corundum crystals are

[90] Yager, T. R., Menzie, W. D., & Olson, D. W. (2008). Weight of production of emeralds, rubies, sapphires, and tanzanite from 1995 through 2005. US Geological Survey.
[91] Smith, C. P., Fagan, A. J., & Clark, B. (2016). Ruby and Pink Sapphire from Aappaluttoq, Greenland. Journal of Gemmology, 35(4).
[92]https://www.greenlandruby.gl/press-releases/greenland-ruby-announces-the-official-opening-of-its-ruby-and-pink-sapphire-mining-operation-at-aappalutoq-greenland/
[93] https://nationaljeweler.com/articles/12266-greenland-ruby-has-shut-down-its-mine
[94] Vertriest, W. (2019). Greenland ruby update. Gem News International. Gems & Gemology
[95] https://www.greenlandruby.gl/about-us/

found trapped within their host rock, which has been protected from weathering by the icecap. Extraction from the host rock is complicated: it requires blasting in the open-pit and various steps of processing at a highly mechanised plant, designed to maximise production.

Although production started in 2017, some recovery was made during the exploration and testing phase by True North Gems. They reported sending several kilogrammes of material for trial cutting and polishing. Previous production numbers from ASM are not available but are believed to be minimal considering the location and the geological context. The pre-feasibility technical report of the mine, made in 2015, estimated the total resources (indicated and inferred) at 81 tonnes of corundum (about 405 million carats), giving the mine a life of about ten years, with a yearly production between 4 and 12 tonnes[96]. It was reported that about 5% of this total production would be gem, 20% near-gem and the remaining 75% non-gem (commercial grade) corundum[97]. Rubies represent 20% of the gem production, with the vast majority of the balance being pink sapphires. Blue, lavender and colourless sapphires are also found in small quantities. All of the gemstones produced by Greenland ruby were heat-treated with borax, an industry standard. Treatment and sorting were done in Thailand, while much of the commercial material was cut and polished in India and Sri Lanka.

Production numbers were not disclosed and, considering the low quality of the production, no production from Greenland was added to the final global estimation of ruby supply.

[96] Reggin L. and Horan M. (2015). An Updated Pre-Feasibility Report on the Aappaluttoq Ruby Project, Greenland National Instrument 43-101 Technical Report. True North Gems, Vancouver, British Columbia, Canada, 170 pp., www.truenorthgems.com/wp-content/uploads/2015/05/ Aappaluttoq-PFS-report-2015.pdf.
[97] http://promin.no/en/project/lns-greenland-commissioning-start-up-and-optimization/

9. *Compiled data*

a) Global Ruby Production

The following graph represents the production of gem-corundum ruby from all of the aforementioned locations, but it does not take quality into account, meaning that the figures encompass facet, cabochon, carving and commercial grades.

It should be kept in mind that this profile does not aim to be a perfect representation of the reality; it is acknowledged by the author that there is not enough reliable recorded data to do so.

Earlier years (1980 to 1990) are particularly challenging when it comes to collecting data. Records show that Thailand was one of the main suppliers during this period, which is confirmed by the literature[98], but it is likely that there were more rubies coming from other countries, notably Burma and Tanzania, than are shown on this graph. Moreover, total production volumes before 1990 seem extremely low. Between 1990 and 1995, the graph presents Tanzania as the main supplier of rubies. This jump in production from Tanzania is partly due to the reopening of Longido in 1989 The mines in the Morogoro region were also at their peak between the mid-1980s and the mid-1990s. Information on the quantities produced from these

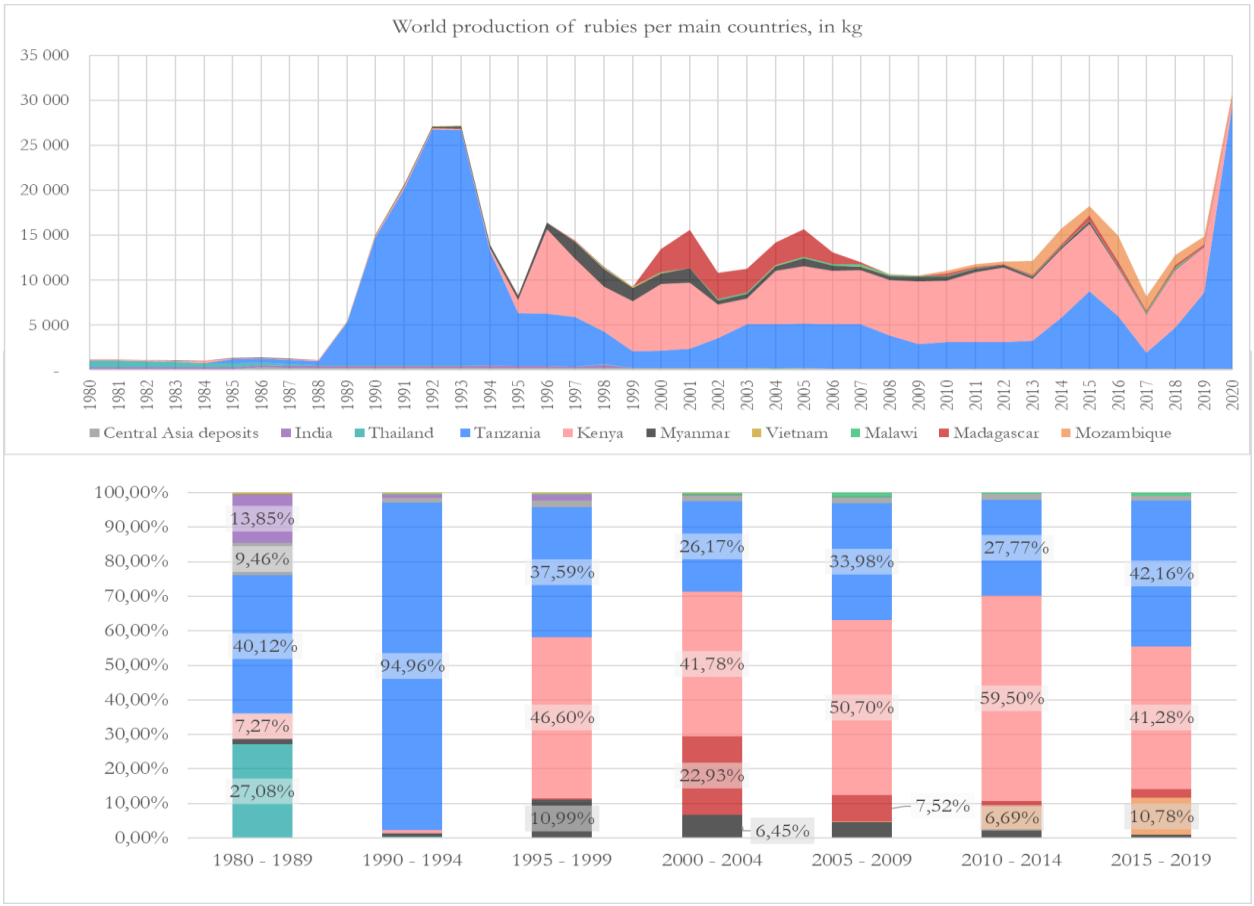

Figure 25: World production of rubies, in kg

[98] Keller, P. C. (1982). The Chanthaburi-Trat gem field, Thailand.

areas was mentioned in a paper from 1992.[99] but, since then, no information on volumes per area has been reportedThe lack of follow-up information on mining activity is a major issue when trying to track the history of ruby supply, especially when many deposits are used only sporadically.

Nevertheless, this profile (Figure 25) provides useful insights into production dynamics:

1. The supply of rubies has shifted between different countries over the years, with the discovery of new deposits and the depletion of others. Moreover, there have been significant fluctuations in the volumes of production. These two parameters, taken together, highlight the difficulty of ensuring a constant supply of gemstones of consistent quality from one year to the next.
2. The volumes produced from deposits in Central Asia, Vietnam, India and Malawi are anecdotal, with a high percentage of undeclared material.
3. The profile includes an estimate of the undeclared volumes of production for almost all the countries. The average yearly volume across the 39 years presented is eleven tonnes, with a minimum of 1 tonne and a maximum of 31 tonnes. These numbers should not be taken as exact figures, but we can safely say that the yearly world production of rubies must rarely exceed 20 tonnes, even with all of the varying qualities taken together;
4. Tanzania and Kenya are the main producers of rubies in terms of volume, but these gemstones are mainly cabochon and carving grades.

b) Quality Considerations

As mentioned above, the graph does not take quality factors into account, which is why Tanzania and Kenya appear so dominant. A quality factor coefficient has been applied in order to assess the history of fine-quality ruby supply. In this document, 'fine-quality' is taken to mean faceted grade, either un-treated or only traditionally heated without flux. The coefficients used vary depending on both the country and the deposit. For example, the percentage of fine rubies from Longido is not the same as for Morogoro or other Tanzanian regions. The same logic applies to Mogok and Mong Hsu in Myanmar, and to Vatomandry and Andilamena in Madagascar. In Mozambique, data and expert observations have established that the recovery of fine-quality rubies is much higher in a mechanised operation than in an artisanal one; the percentages applied to MRM and the neighbouring, undeclared artisanal and small-scale (ASM) operations are therefore different. The factors used are presented in the table below.

Country	Mine taken as a reference	% of fine quality
Central Asia	Jegdalek	3%
Greenland	Greenland Ruby	0.1%
India	NA	0.1%
Kenya	John Saul	1%
Madagascar	Vatomandry & Others	30%
	Andilamena Region	1%
Malawi	Chimwadzulu	10%
Mozambique	MRM	30%
	ASM production	3%
Myanmar	Mogok	30%
	Mong Hsu	5%
Tanzania	Longido	0.1%
	Other (Morogoro & Winza)	5%
Thailand	NA	5%
Vietnam	Luc Yen	10%

The new production profile (Figure 26) is considered to be much more representative of the reality of the market, with Myanmar being the main producer up until the discovery of Montepuez rubies in Mozambique.

According to this profile, approximately 270kg of fine-quality rubies were formerly produced every year on average, significantly increasing in recent years due to the introduction of rubies from Mozambique.

[99] Dirlam, D.M., Misiorowski, E.B., Tozer, R., Stark, K.B., Bassett, A.M. (1992). Gem Wealth of Tanzania. Gems & Gemology, Summer 1992, Volume 28, No. 2

Although figures are not exact, it appears that less than 1 tonne of fine-quality rubies is produced every year, which is less than 5% of the total volume of rubies. This highlights the rarity of these fine-quality gemstones.

Comparing these results, the coloured gemstone market report presented by Guild Gem Laboratories during the ICA congress of 2023 mentioned the share of Burmese rubies to be 45%, and Mozambican rubies to be 42% in 2021.[100]. This highlights the fact that the gemstones transiting through the laboratories are not always representative of the total production, as only those of a high quality, and from certain locations, will be sent to a laboratory for grading. The report mentions that the Mozambican market share is more likely to be 60% to 70%, confirming the results of this study.

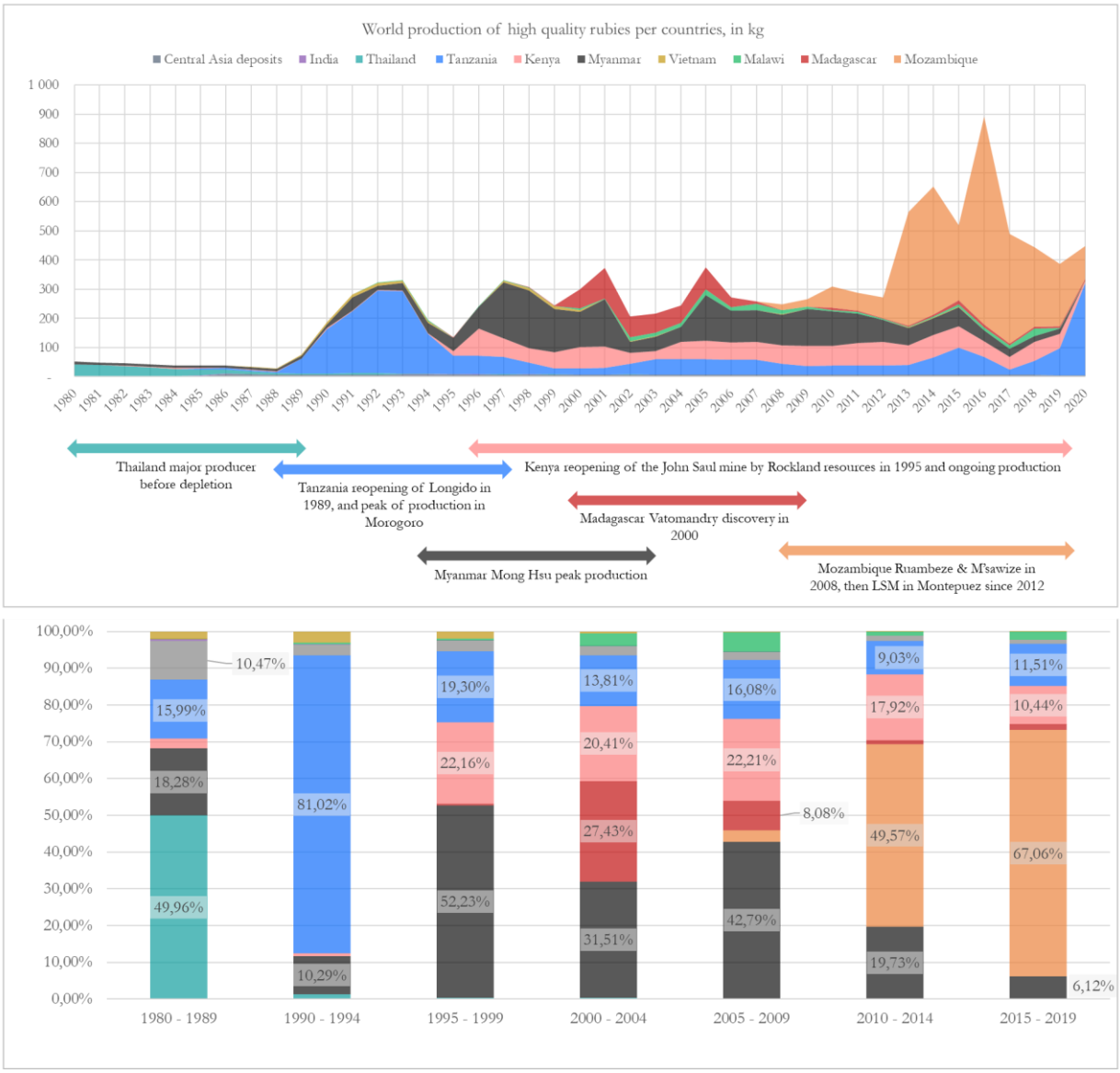

Figure 26: World production of high-quality rubies, in kg

[100] Lucas, A., Lui, R. (2023) Guild 2022 China Colored Gemstone Market Report. Special edition for 2023 ICA congress Dubai. Guild Gem Laboratories

V. Global supply of emeralds

1. Introduction

Emerald is the second most important coloured gemstones in the trade, in terms of value. The history of the global emerald market has been heavily influenced by important historical deposits that are still being actively exploited nowadays, such as the mines in Colombia.

This chapter presents the compilation of research on yearly production volumes since 1980, for eleven countries which have been (or still are) important sources of emeralds. Production numbers are difficult to find, as there is little reporting from either mining companies or governments. Exports can sometimes provide a good picture of production dynamics. However, exports are very often reported solely in value terms, with volume figures not being captured. Production volumes presented in this report came from various sources including: USGS (United States Geological Survey) yearly mineral industry reports; miners' declared production and sales data; national annual economic and statistical surveys; EITI (Extractive Industries Transparency Initiative) reports. Due to the delay in the publication of these reports, production volumes are only provided up to 2020.

After looking at each individual country, the final section compiles the production data from the eleven countries to attempt a visualisation of the global supply dynamic. A 'quality factor' has been applied to allow a clearer view of facet-quality emerald supply. Overall, the report highlights that the supply of emeralds has been fairly consistent over the past 40 years. The three main producing countries are Brazil, Colombia and Zambia, with extensive, long-lasting deposits. One main highlight of the report is the dominant position of Zambia in the global supply of emeralds, especially those of high quality. Although production data are always difficult to obtain, the figures for Zambia and Colombia are considered more accurate because they are provided by mining companies, as well as well important industry bodies like Fedesmeraldas. Although a portion of production is always undeclared, the order of magnitude is correct, positioning Zambia far above Colombia in volume terms.

2. *Brazil*

a) Emerald Production

Brazil is a land of gemstones, and emeralds were discovered here in the early 1910s[101]. However, large-scale exploitation only started in the 1960s, in Bahia state. Brazil then became a significant emerald producer in the 1980s[102].

Emeralds are found and exploited mainly in three Brazilian states:

- Bahia, in the deposits of Carnaíba and Socotó;
- Minas Gerais, in the Itabira/Nova Era belt (Belmont, Piteiras and Capoeirana deposits);
- Goiás, in the Santa Terezinha deposit.

Each of these states produces very different qualities and volumes of emeralds.

In volume, Bahia is probably the main producer. In 1990, Guiliani reported that Carnaíba accounted for 135 tonnes of emerald production in 16 years[103], between 1970 and 1986, an average of 8.4 tonnes per year. 22 years later, in 2012, Lucas reported that Bahia state produced between 500kg and 1000kg per month, averaging 9 tonnes per year[104]. However, the quality of the emeralds is lower than at the other deposits, and these emeralds are mainly used for lower-quality cabochons and carvings. Although gemstone mining in general is often sporadic and discontinuous, it seems that Bahia has consistently produced several tonnes of low-quality emeralds per year for an extended period. Interestingly, when looking at the emerald production numbers from the USGS and the 'Departamento Nacional de Produção Mineral' (DNPM) of Brazil, they do not seem to record Bahia's emerald production, as their numbers are far too low. Incidentally, the DNPM reports that more than 90% of emerald production comes from Itabira (Minas Gerais), and often specifies that the production comes from the Belmont mine[105].

In Minas Gerais, the Belmont Mine has been the most documented active mine since the early 1980s. Different sources report different production quantities, varying from 40kg to 360kg annually.[100,101,106,107] The mine has also evolved over time due to mechanisation and the development of an underground operation[108].

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[101] Lynch, E. P., Costanzo, A., Feely, M., Blamey, N. J. F., Pironon, J., & Lavin, P. (2014). The Piteiras emerald mine, Minas Gerais, Brazil: fluid-inclusion and gemmological perspectives. Mineralogical Magazine, 78(7), 1571-1587.

[102] Groat, L. A., Giuliani, G., Marshall, D. D., & Turner, D. (2008). Emerald deposits and occurrences: A review. Ore Geology Reviews, 34(1-2), 87-112.

[103] Giuliani, G., Silva, L. J. H. D., & Couto, P. (1990). Origin of emerald deposits of Brazil. Mineralium Deposita, 25(1), 57-64.

[104] Lucas, A. Brazil's emerald industry. Gems & Gemology, Spring 2012, Volume 48, No. 1. 2012

[105] Departamento Nacional de Produção Mineral (DNPM), sumario mineral 2010 to 2018

[106] Hänni, H. A., Schwarz, D., & Fischer, M. (1987). The emeralds of the Belmont Mine, Minas Gerais, Brazil.

[107] Puppim De Oliveira, J. A. P., & Ali, S. H. (2011). Gemstone mining as a development cluster: a study of Brazil's emerald mines. Resources Policy, 36(2), 132-141.

[108] Lucas, A., Pay, D., McClure, S., Ribeiro, M., Hsu, T., Padua, P. (2015). The Belmont Mine and an Emerald's Journey from Mine to Market. GIA

The Piteiras mine is also known to be a source of good quality emeralds in Minas Gerais, with production here starting around 2001. Production quantities are unclear, with some sources mentioning that it was sporadic[109], and others stating that production was consistent[110]. Overall, it can be assumed that Piteiras produced emeralds in the range of 80kg to 200kg a year, between 2001 and 2008, when operations ceased[111]. In Minas Gerais, the Capoeirana and Montebello mines are also important producers, but production data for these is extremely hard to find.

The last important producing area is Santa Terezinha, in Goiás. In 1984, this area was reported to be the centre of Brazil's emerald production, with an average yield about 50 times higher than the Belmont Mine[112]. Interviews conducted by Puppim de Oliviera in 2011 suggest that the region produced 44 tonnes of emeralds in 2003[113], but no other source corroborates this quantity. Conversely, Lucas reports little production from this area since the 1990s [114].

The production profile below (Figure 27) compiles information from the different sources quoted above, as well as estimated figures for informal mining. The scale starts at 8 tonnes. It is estimated that production from Bahia is 9 tonnes per year for the entire period.

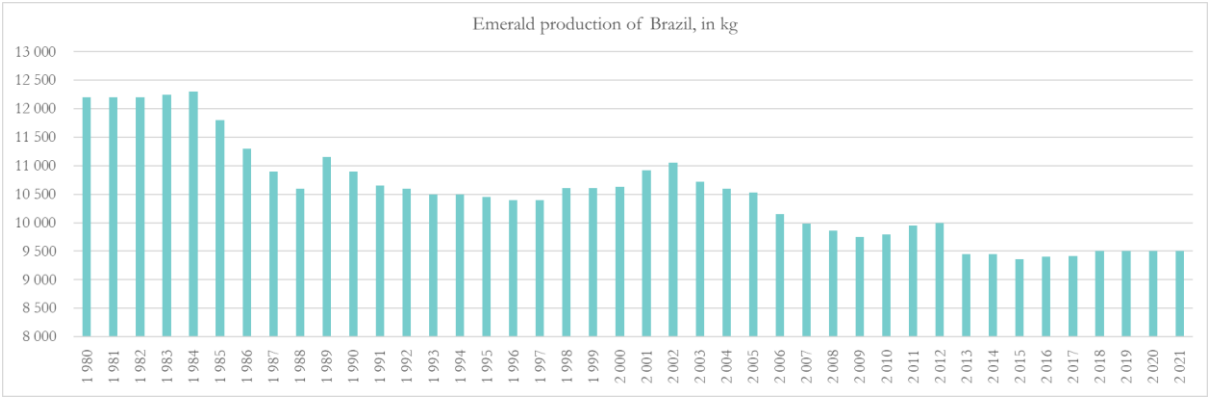

Figure 27: Emerald production from Brazil, in kg

b) Emerald Trade Flows

Coloured gemstone exports from Brazil are difficult to interpret because of the wide variety of gems produced in this country. However, as Brazil is not a large producer of rubies and sapphires, HS code 710391 can be assumed to represent exports of cut emeralds only (Figure 28). These 'worked emerald' exports increased in the early 2000s, which could correspond to the Piteiras production period. From 2003, they dropped to an average of US$10M per year, only to increase again in the 2010s to a yearly average of US$20M, which could be linked to the development of cutting facilities at Belmont. Over the period 1995 to 2023, the USA has been the main importer of Brazilian emeralds, accounting for 42% of the country's

[109] Rondeau, B., Notari, F., Giuliani, G., Michelou, J. C., Martins, S., Fritsch, E., & Respinger, A. (2003). La mine de Piteiras, Minas Gerais, nouvelle source d'émeraude de belle qualité au Brésil. Reveu de Gemmologie, 147, 1-18.
[110] https://emrlibrary.gov.yk.ca/minerals/review-of-the-emerald-industry-2004.pdf
[111] Lynch, E. P., Costanzo, A., Feely, M., Blamey, N. J. F., Pironon, J., & Lavin, P. (2014). The Piteiras emerald mine, Minas Gerais, Brazil: fluid-inclusion and gemmological perspectives. Mineralogical Magazine, 78(7), 1571-1587.
[112] Cassedanna, J.P., Sauer, A. The Santa Terezinha de Goias Emerald Deposit. Gems & Gemology, Spring 1984, Vol. 20, No. 1. 1984
[113] De Oliveira, J. A. P., & Ali, S. H. (2011). Gemstone mining as a development cluster: a study of Brazil's emerald mines. Resources Policy, 36(2), 132-141.
[114] Lucas, A. Brazil's emerald industry. Gems & Gemology, Spring 2012, Volume 48, No. 1. 2012

exports. Hong Kong was the second-largest importer. However, it is important to note that, between 1995 and 2002, Japan was Brazil's most important partner for exports of worked emeralds.

When looking at rough exports, HS code 710310, the export value has increased over the years, and in 2021 the total export value was 2.3 times higher than it had been 20 years before, in 2001. The main importer over the period was Hong Kong, which accounted for 27% of total export value. However, in the last ten years, the USA and China have been increasing their imports and, since 2021, they both imported twice as many unworked gemstones as Hong Kong.

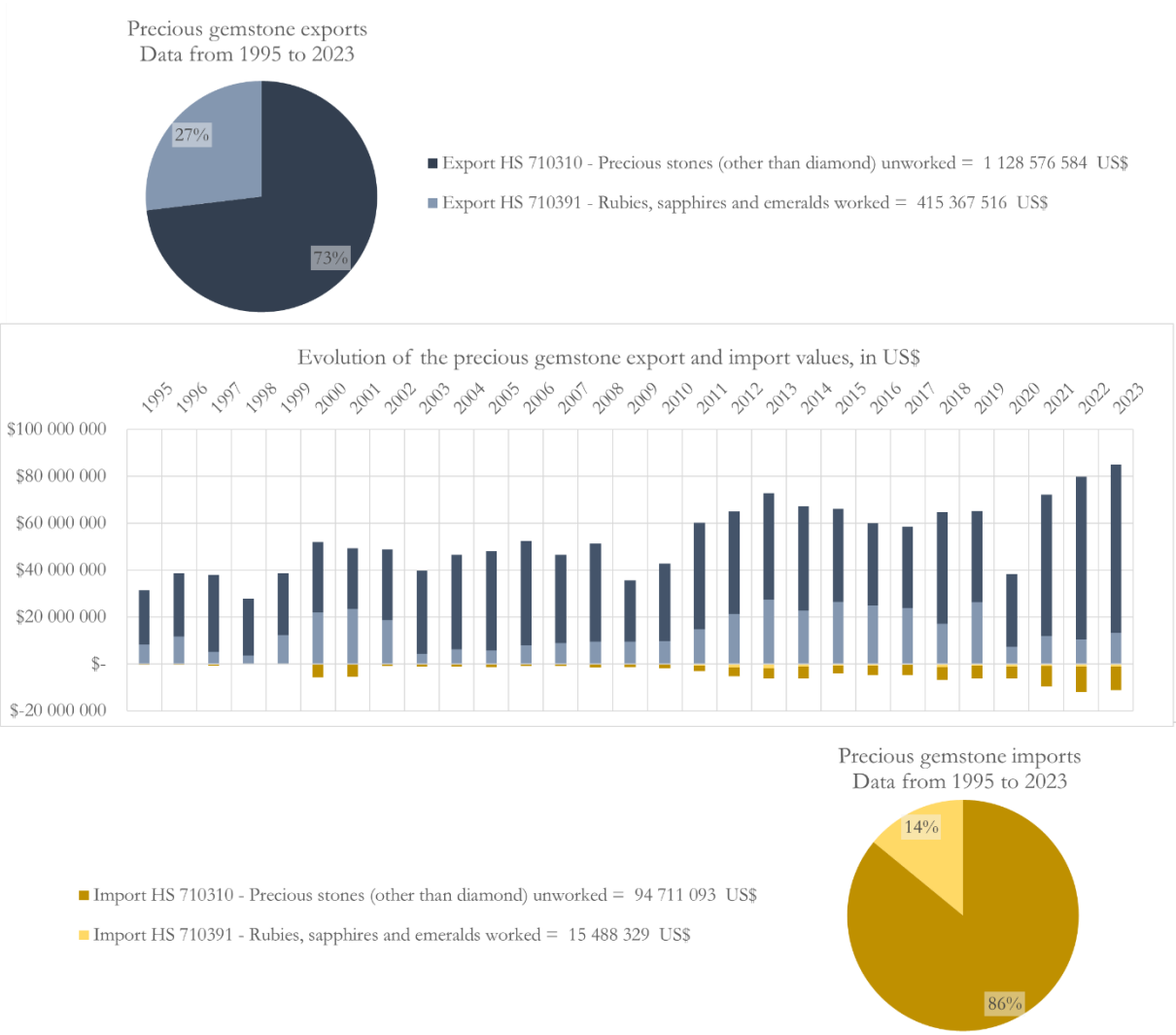

Figure 28: Precious gemstones imports and exports values from Brazil

3. *Colombia*

a) Emerald Production

Emeralds have been produced in Colombia for centuries, with mining efforts dating back to 1000 BC, long before the Spanish colonisation in the 16th century[115]. The country's emerald deposits are located in the Boyacá region, particularly in two districts on the western and eastern side of the Andean Cordillera Oriental. There are more than 200 emerald deposits within these two districts, the most notable being:

The western district (also referred as the Vásquez-Yacopí[116], or Coscuez-Muzo-Yacopí[117], district), which includes, amongst others, the Coscuez, Muzo, Maripí, Peñas Blancas and Yacopí mines;

The eastern district (also referred as the Guavio-Guateque[112], or Chivor-Gachalá[113], district), which includes, amongst others, the Chivor, Gachalá and Macanal mines.

After colonisation, the mines remained Spanish royal property until independence in 1810, when they came under the control of the Colombian government. The privatisation of the mines started only in the late 1970s. Between 1960 and 1990, the situation in the country was very tense due to the 'Green War', a conflict between the main emerald-mining families, who often used paramilitary forces to defend their territories against guerrillas and drug traffickers[118]. Victor Carranza, also known as the 'Emerald Czar', was a big figure in this mafia-like trade: he controlled up to 40% of Colombia's emerald production until his death in 2013[119]. The 'Green War' caused thousands of deaths; it ended in the 1990s with the signing of a peace deal, brokered with the help of Carranza and the Catholic Church[120]. This peace deal, as well as bringing in new mining regulations, promoted the privatisation of the sector. However, allegations against owners of emerald mines continued: for example, the prosecution of Carranza in 2012[121] over the financing of paramilitary groups, or the accusations against the company Esmeracol for drug-money laundering in 2010[115]. Instability and violence in the country continued, and another peace agreement was signed in 2016 between the Colombian government and the FARC guerrilla group[122]. It is worth mentioning that none of these political and social issues have affected the reputation of Colombian emeralds over the years: they are still considered to be the world's most sought-after emeralds. However, mining activities were affected, and Colombia lost its world-leading producer position in the 2000s. This context of violence and instability, as well as the mafia-like organisations within the mining sector, prevented foreign investment for many years, and operations

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115 Fortaleché, D., Lucas, A., Muyal, J., Hsu, T., & Padua, P. (2017). The Colombian Emerald Industry: Winds Of Change. The Quarterly Journal Of The Gemological Institute Of America, 53(3), 332-358.
116 Groat, L. A., Giuliani, G., Marshall, D. D., & Turner, D. (2008). Emerald deposits and occurrences: A review. Ore Geology Reviews, 34(1-2), 87-112.
117 Branquet, Y., Giuliani, G. (2022) Géologie et exploration de l'émeraude colombienne. Émeraudes, tout un monde !
118 https://www.mining.com/former-gemfields-exc-led-firm-grabs-coscuez-emerald-mine-colombia/
119 https://thecitypaperbogota.com/business/coscuez-the-dark-side-of-gemstones/
120 https://colombiareports.com/amp/assassination-emerald-baron-sparks-fear-new-green-wars/
121 https://www.bbc.co.uk/news/world-latin-america-16882779
122 https://www.iss.europa.eu/content/implementing-peace-agreement-colombia

remained very manual and labour-intensive, although the vast majority of mining is done underground[123]. Over time, factors such as the peace agreement, a new generation of miners, and the growing global expectation of sustainability and transparency in mining operations have encouraged the Colombian emerald sector to evolve and remove barriers to investment[124].

The three most historical and famous mining areas are Chivor, Coscuez and Muzo, considered to be responsible for most of the production volumes[125]. More recent mines, including La Pita (where mining started in 1999), Consorcio (where mining started in 1999) and Cunas (where mining started in 2001), are also important deposits nowadays, especially in terms of quantities produced[119].

Coscuez has been a historical source of very fine-quality emeralds, as well as large crystals. Some reports mention Coscuez as the source of about 70% of Colombia's emeralds in the 1970s[126]. Its exploitation remained very artisanal until international mining companies became interested. Gemfields PLC engaged in the acquisition of 70% of the Coscuez mine in 2015, after geological studies performed between 2013 and 2014[127]. Gemfields withdrew from the deal in May 2017, and Fura Gems acquired 76% of the mine in late 2017[128]. Fura has operated the mine since 2018, launching their first emerald auction in 2021[129].

The Muzo mine is the other most renowned source of fine-quality emeralds from Colombia. In 2009, The Muzo Companies was founded as a vehicle to invest in modern mining practices and promote Colombia as a source of sustainable and responsible emeralds. The Muzo mines have a mine-to-market business model, offering mining operations, cutting and polishing, gemstone treatment, laboratory grading, and trading via partnership with designers[130].

Despite the growing interest of multinational companies and the investment in formalisation and mechanised operations, the Colombian government estimates that about 63% of Colombian mining activities are still informal[115].

The production profile below (Figure 29) is a compilation of information from the Sistema de Información Minero Colombiano ('Simco')[131], data provided by the National Federation of Emeralds of Colombia (FEDESMERALDAS) and USGS. The Simco is the official online portal for mineral statistics, under the Colombian Ministry of Mines. FEDESMERALDAS is a trade body founded in 1988 with the aim of developing, representing and guiding the Colombian emerald industry. FEDESMERALDAS links a large number of formal actors in the Colombian emerald production chain and administers the National Emerald Fund, which collects by law a paraphysical tax of 1% of the value of all emerald exports. The USGS data reported in the mineral yearbooks is equivalent to the Simco production data. Data from FEDESMERALDAS, between 2009 and 2021, is closely aligned to the two other sources.

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[123] Michelou J.C., Ed. (2006) ICA 2006 World Gemstone Mining Report. InColor, Spring.

[124] Inestroza, J. (2022). The Mineral Industry of Colombia. 2017-2018 Minerals Yearbook. USGS

[125] Shigley, J. E., Dirlam, D. M., Laurs, B. M., Boehm, E. W., Bosshart, G., & Larson, W. F. (2000). Gem localities of the 1990s. Gems & Gemology, 36(4), 292-335.

[126] https://www.emeraude.info/la-renaissance-de-coscuez-la-plus-emblematique-mine-demeraudes-de-colombie/

[127] https://www.gemfieldsgroup.com/wp-content/uploads/2018/08/20150910_Gemfields_RNS_Acquisition_of_controlling_interests_in_two_emerald_projects_in_Colombia_FINAL.pdf

[128] https://www.nationaljeweler.com/articles/5399-fura-gems-acquires-coscuez-emerald-mine-in-colombia

[129] https://www.furagems.com/trade-info

[130] https://muzo.co/pages/the-mine

[131] https://www1.upme.gov.co/simco/Cifras-Sectoriales/Paginas/esmeraldas.aspx

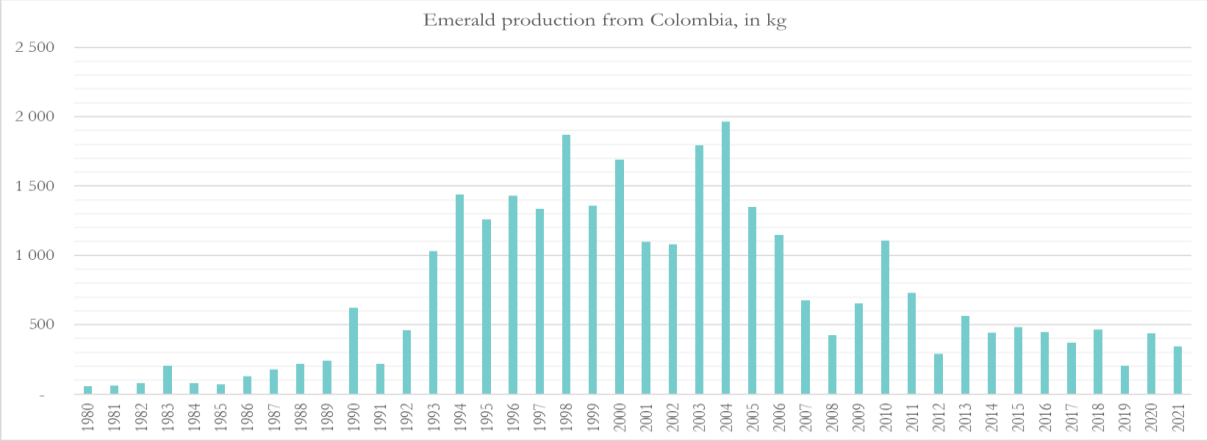

Figure 29: Emerald production from Colombia, in kg

b) Emerald Trade Flows

Colombia is a major producer of emeralds, and does not produce very much of any other gemstone. This makes it possible to approximate the export data from UN Comtrade as emerald exports only (Figure 31). This is also confirmed by the available emerald export data from Simco, which is 99% similar to the UN Comtrade export data. FEDESMERALDAS also provided export data for both rough and worked emeralds, which align very well with the UN Comtrade statistics, as presented in the graph below (Figure 30).

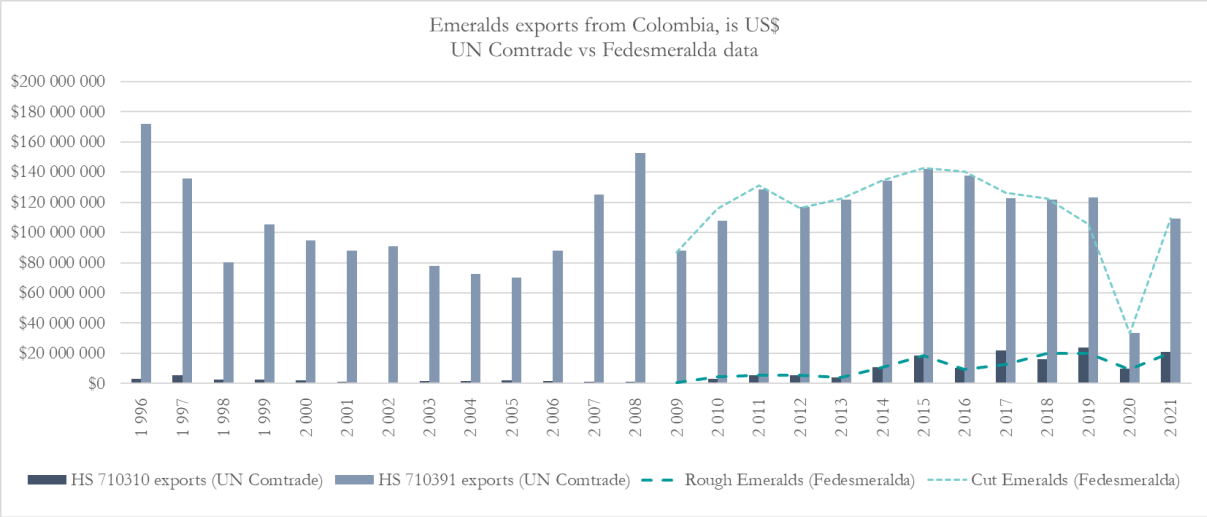

Figure 30: UN Comtrade exports compared to FEDESMERALDA exports

In terms of value, Colombia exports many more worked emeralds (cut and polished) than rough. This is entirely related to the difference in unit prices between rough and worked emeralds. Between 2009 and 2021, Colombia exported more than 5 tonnes of rough emeralds, at an average price of US$5.6/ct, and about 880kg of cut and polished emeralds at an average price of US$340/ct[132]. Although the unit prices have fluctuated over the years, there has been a net increase in the past decade for both rough and worked emeralds (Figure 32).

[132] FEDESMERALDAS data

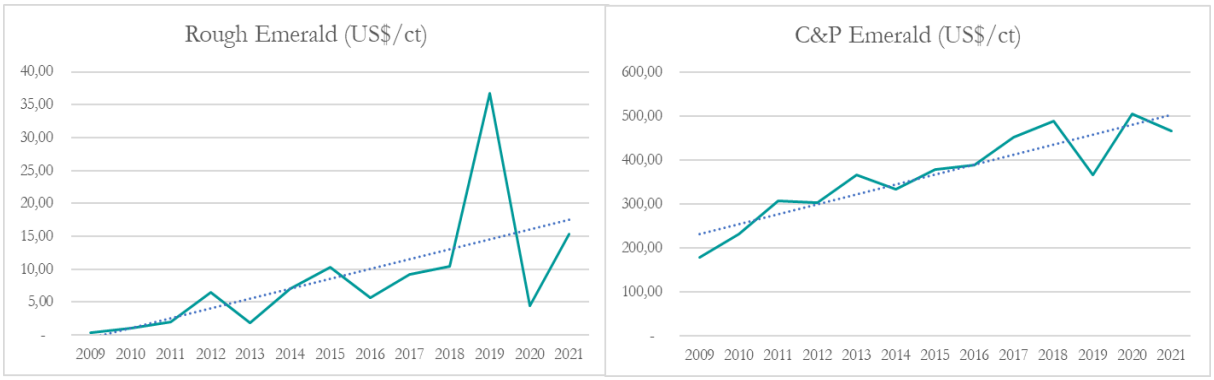

Figure 32: Rough and cut emeralds exports unit prices

Most of Colombia's emerald production is exported. In 2001, USGS estimated that 10% of emeralds were sold in the country, a percentage that dropped to just 2% in 2005.[133]. Colombia has a good beneficiation industry, with several companies cutting and polishing emeralds in Bogotá. Some factories are established in the Bogotá free trade zone, explaining why most of the rough 'exports' since 2010 are going to Colombia.

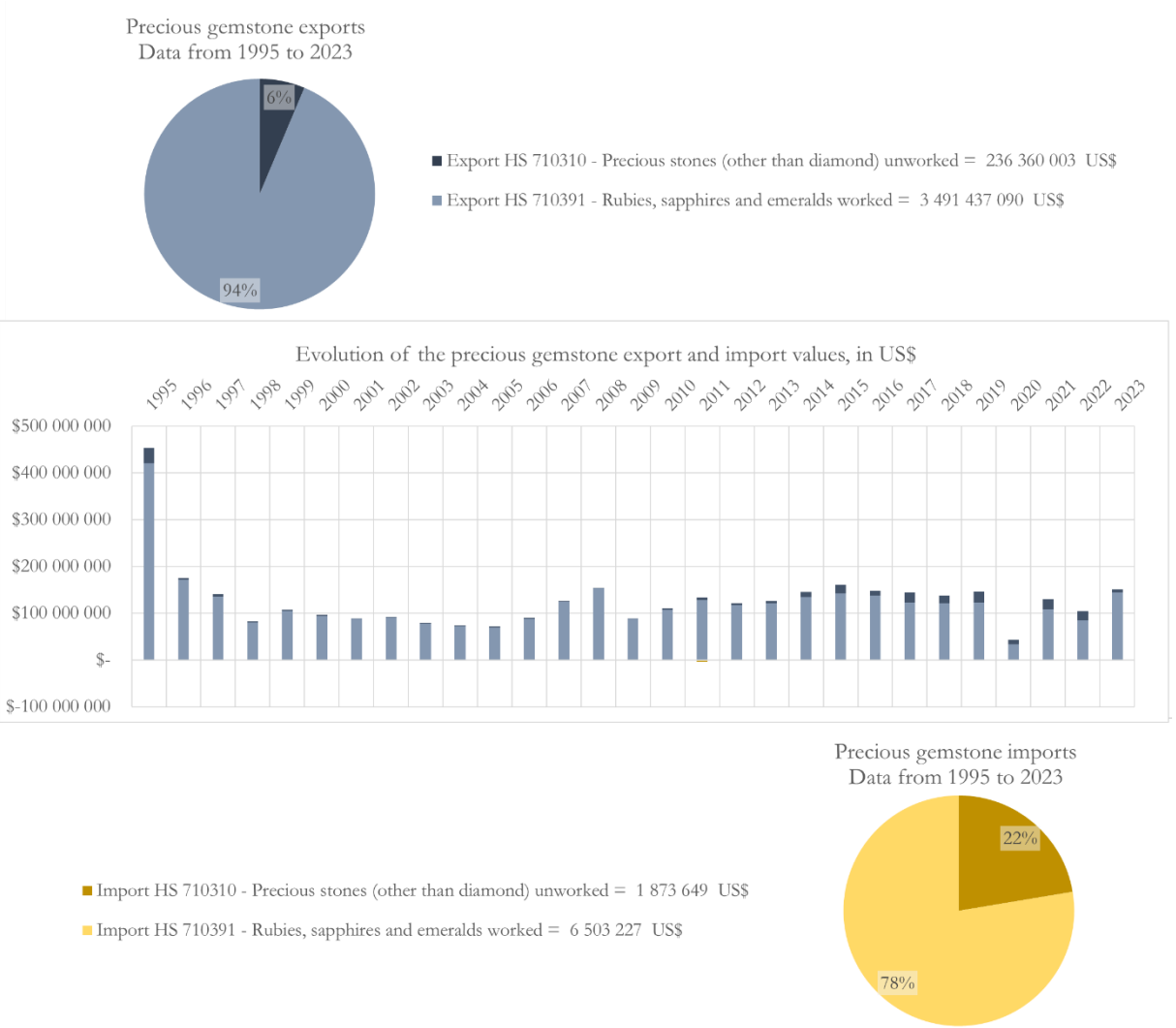

Figure 31: Precious gemstones imports and exports values from Colombia

[133] Torres, I. (2005). The Mineral Industry of Colombia. 2005 Minerals Yearbook. USGS

This is presented in the infographic on the next page (Figure 33). Another striking insight from this analysis is the very low export value of rough between 1995 and 2010: an unstable period, as mentioned earlier. Rough exports started to increase in 2010, which correlates with the development of more mechanised operations (like Muzo and Coscuez), as well as exports for cutting and polishing into the Bogotá Free Trade Zone. In terms of total worked emerald exports, the value has been stable for the past 20 years, with an annual average of US$107 billion. Japan's share of worked emerald import values has decreased over the past 27 years, while Hong Kong's imports have increased significantly. The USA remains the major importer of worked emeralds from Colombia.

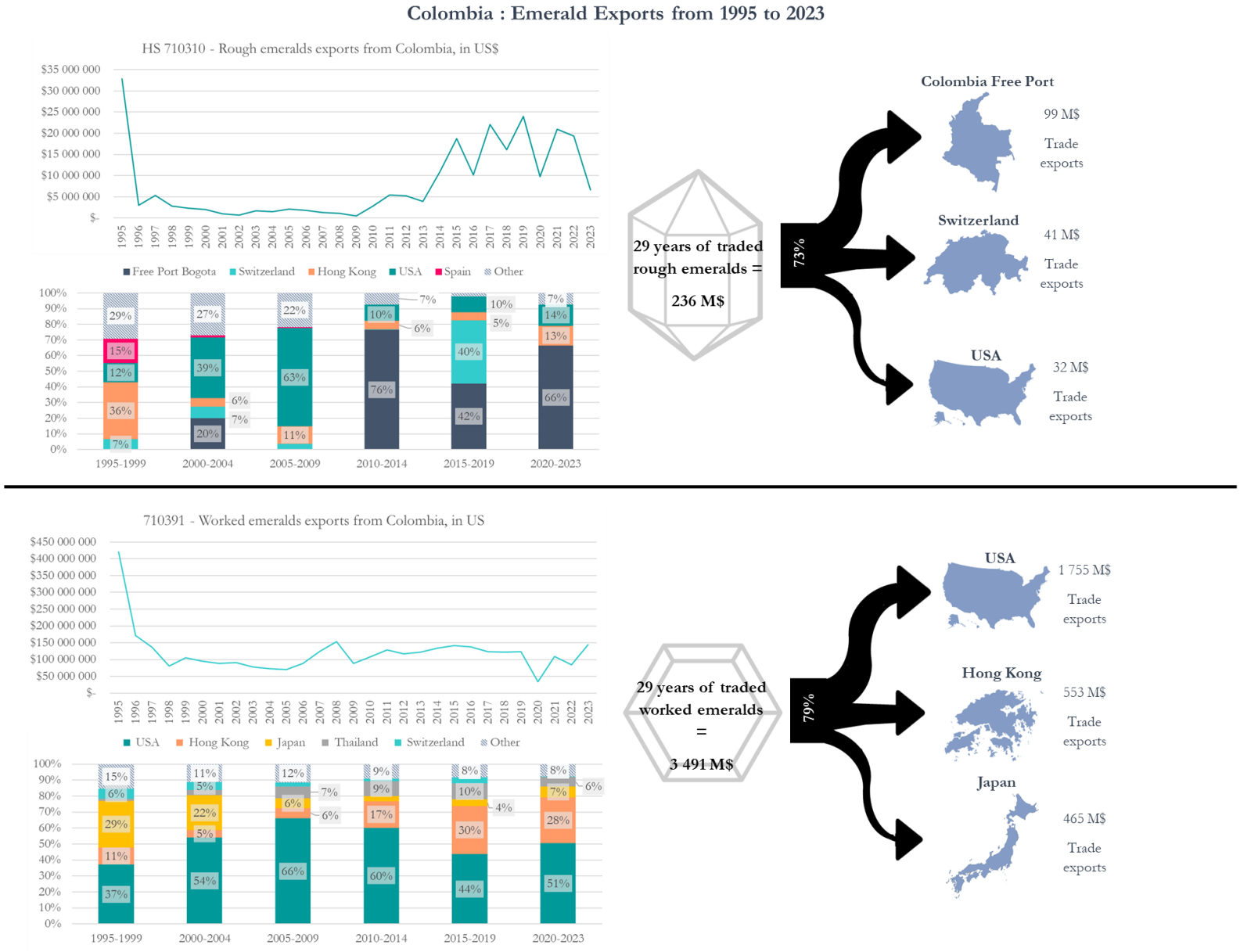

Figure 33: Colombia infographic

4. *Russia*

a) Emerald Production

Emeralds were discovered in Russia in the early 1890s, in the Izumrudny Kopi district within the Ural Mountains. Several mines were opened, of which Malysheva (also called Mariinski), was the most important (accounting for 80% of reserves)[111]. It is estimated that this district was the world's largest producer of emeralds from 1918[134] until the 1930s. It provided up to 2.5 million carats annually, more than Colombia[135]. Between the 1940s and the 1970s, the mines were primarily operated for the extraction of beryllium ore, and emeralds became a by-product (3-4 million carats per year). Emeralds became the main product again in the 1970s when newer, more profitable deposits for beryllium were discovered. In 1995, Laskovenkov[112] reported that, after this shift in focus, production was as high as 8 to 10 million carats annually. However, it's more likely that the estimated capacity of yearly emerald production was around 3 million carats. This figure correlates with the number reported by Richard Hughes in an article he wrote following his mine visit in 2006[136], which states that between 1987 and 1993 yearly production was 3.35 million carats.

Mining operations stopped in 1995, after the collapse of the Soviet economic system. Since this period, the mine has changed owners multiple times. USGS reports that the mine was reopened in 2001 and produced a total of 3,844kg of emeralds between 2001 and 2006[137]. However, multiple sources argue that production was very unclear and, by 2010, the company exploiting Malysheva, TZAR Emerald, was failing to submit reports about production[138]. One of the latest articles mentioning the Malysheva Mine reports that the entire management team was replaced in 2016, with the aim of investing in and developing the mine[139]. In a 'Gem News International' article published by the GIA in 2020, authors Tao Hsu and Jennifer Stone-Sundberg mentioned that the Malysheva mine was once again active and producing emeralds. However, these emeralds are still rarer on the market than their Colombian or Zambian counterparts[140].

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[134] Groat, L. A., Giuliani, G., Marshall, D. D., & Turner, D. (2008). Emerald deposits and occurrences: A review. Ore Geology Reviews, 34(1-2), 87-112.

[135] Laskovenkov, A. F., & Zhernakov, V. I. (1995). An update on the Ural emerald mines. Gems & Gemology, 31(2), 106-113.

[136] https://www.lotusgemology.com/index.php/library/articles/298-emeralds-from-russia-a-closer-look

[137] Yager, T. R., Menzie, W. D., & Olson, D. W. (2008). Weight of production of emeralds, rubies, sapphires, and tanzanite from 1995 through 2005. US Geological Survey.

[138] https://www.rusbiznews.com/news/n1011.html

[139] https://tsarinajewels.com/47-emeralds-of-the-urals/

[140] https://www.gia.edu/doc/SP20-GNI-v2.pdf

The Malysheva mine has always been exploited in an industrial way, with mechanised equipment, and as an open-pit with tunnels. However, the technologies used might be outdated and badly maintained[115,116]. Some sources also report that theft and illegal production have been problems in Russia[116].

The production profile (Figure 34) presented below is a combination of the above-mentioned sources, with numbers from 2005 being estimated.

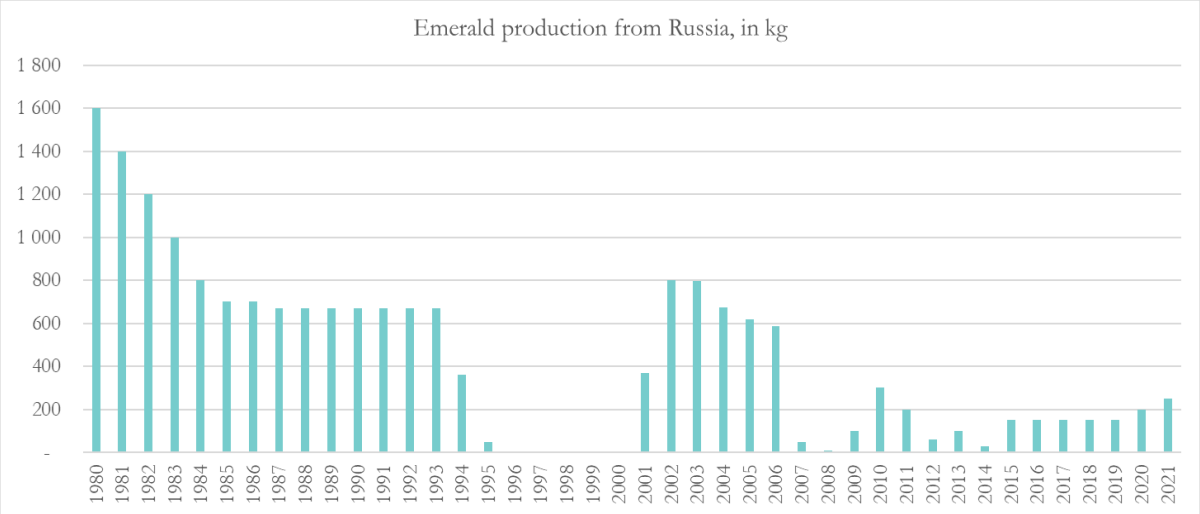


Figure 34: Emerald production from Russia, in kg

b) Emerald Trade Flows

About 99% of Russian precious gemstone exports (excluding diamonds) are in the form of rough gemstones (Figure 35). Russia is not only a producer of emeralds: it is also a major producer of alexandrite, amber and a wide range of other coloured gemstones such as amethyst, citrine, topaz, etc. Therefore, export data from UN Comtrade would include all of these gemstones taken together. More than 93% of Russia's exports go to China, Hong Kong and India. This reflects the fact that Russia does not have a significant processing, cutting and polishing industry for coloured gemstones within its borders.

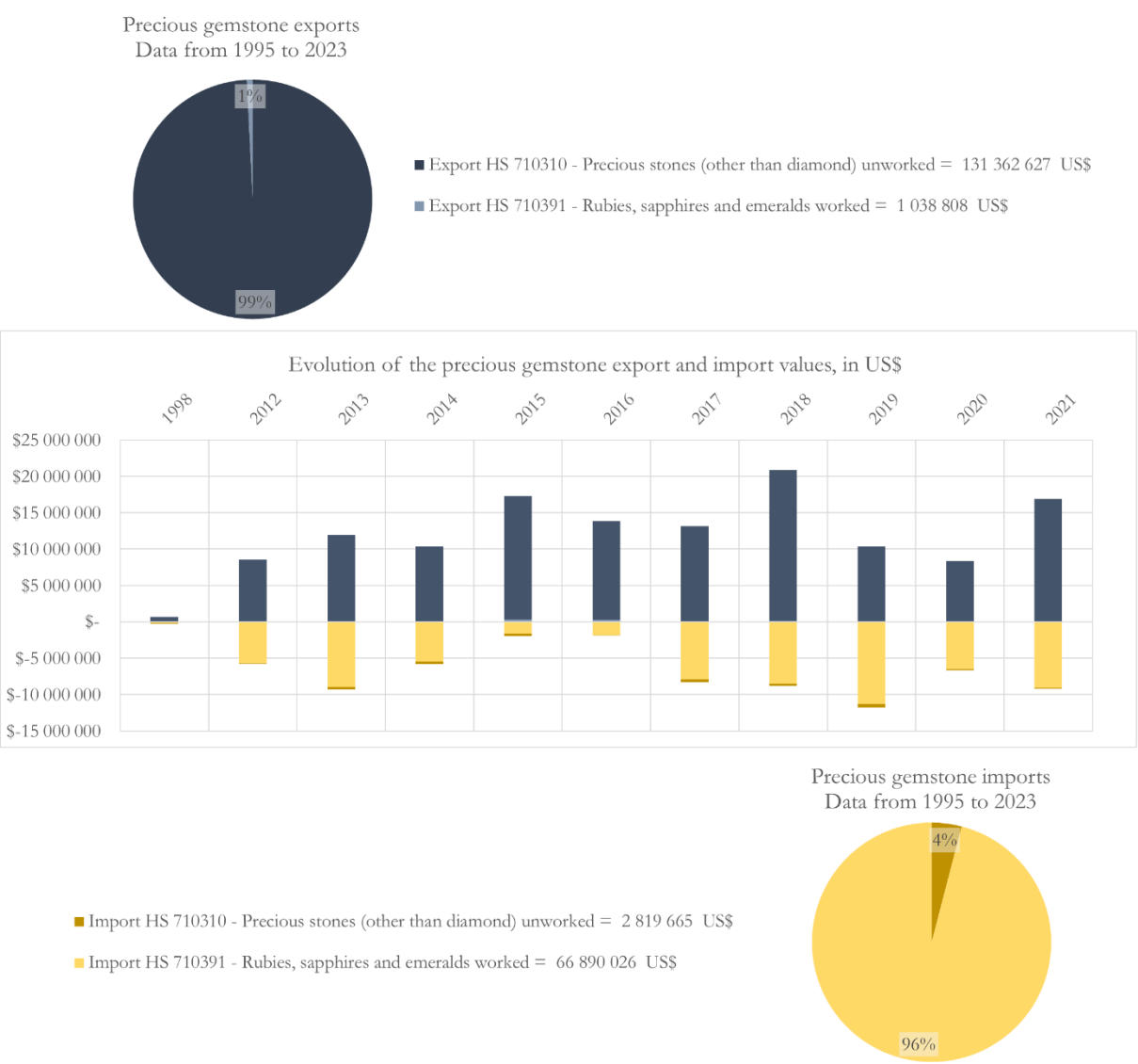
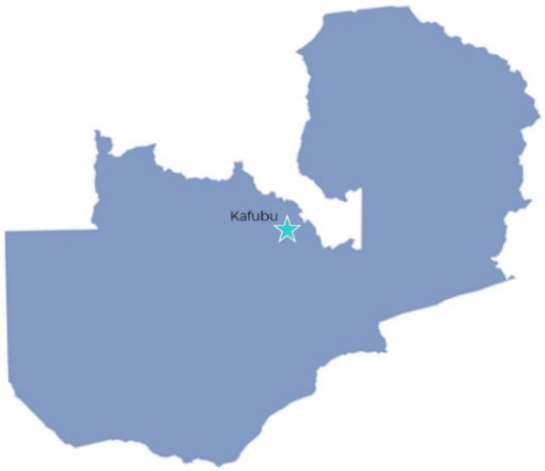


Figure 35: Precious gemstones imports and exports values from Russia

5. *Zambia*

a) Emerald Production



Emeralds in Zambia were first recorded in 1928. However, Zambia has been a significant producer only since the 1970s[141]. Exploration took place for years under different companies, but small-scale mining was only started in 1967 by Miku Enterprises[142]. Mindeco Limited, owned by the Zambian government, took over the mine in 1971, and production increased in 1974 with the discovery of new deposits of higher quality. The advances in production in the 1970s were also related to the establishment of the restricted zone 'Ndola Rural Restricted Area' (NRERA), created by the government in order to control illegal activities and increase the economic potential of the emerald deposits. The NRERA covers about 800 square kilometres[143]. The mines are located in the Kafubu area, Lufwanyama district, in the Copperbelt Province of Zambia. There are several identified deposits which have been and/or are still in operation, including: Chibolele, Chantete, Kamakanga, Fwaya-Fwaya, Pirala, Libwente, Chama, Fibolele, Dabwisa, Kanchule, Lunshingwa and Nkabashila.

Gemfields acquired the Kagem mine in 2008, in co-ownership with the government of Zambia. The Kagem mine is now an amalgamation of several deposits, notably the Mbuva-Chibolele licence (Fwaya-Fwaya-Pirala), Chama, Fibolele, Libwente and Kamakanga. Since Gemfields started mining in 2008, the average quantity of emeralds produced per month has been about 650kg, four times higher than the production reported by Zwaan in 2005[127]. This explains the significant increase in production observed in the past 15 years (Figure 36).

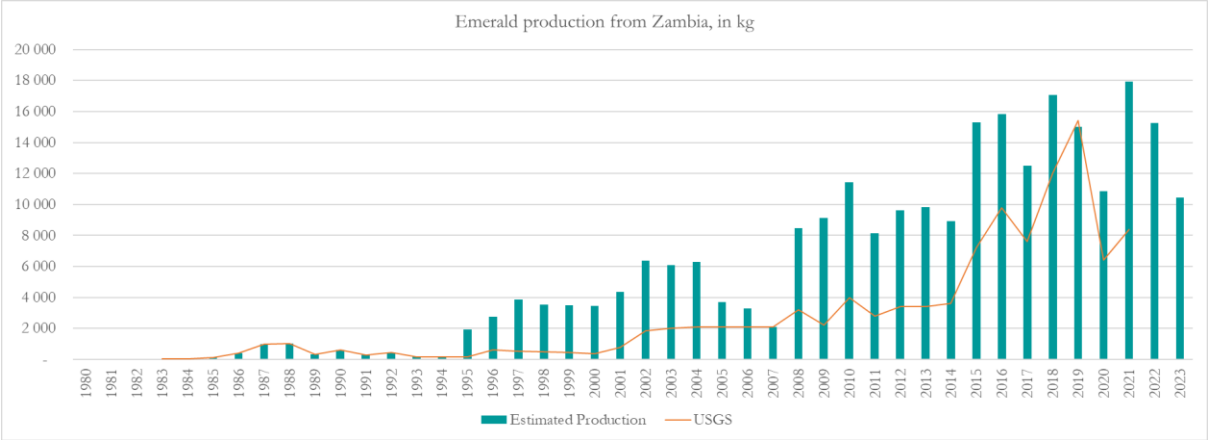


Figure 36: Emerald production from Zambia, in kg

[141] Zwaan, J. H., Seifert, A. V., Vrána, S., Laurs, B. M., Anckar, B., Simmons, W. B. S., ... & Garcia-Guillerminet, H. (2005). KAFUBU AREA, ZAMBIA. Gems & Gemology, 41(2), 116-148.

[142] Sliwa, A. S., & Nguluwe, C. A. (1984). Geological setting of Zambian emerald deposits. Precambrian Research, 25(1-3), 213-228.

[143]https://www.gemfieldsgroup.com/wp-content/uploads/2018/08/02-10-2012_JORC_compliant_Minerals_Resource_and_Reserve.pdf

Grizzly Mining was incorporated in Zambia in 1997. They have been actively mining in NRERA since then, expanding operations and pits. In 2023, they reported to the press that they were producing about 60 million carats per year[144].

In 2005, Zwaan reported that the Chantete mine was active and producing between 150kg and 300kg a month. However, in 2022, the association 'Emerald Production Watch of Zambia' (EPWZ) stated that only the Kagem and Grizzly mines were active, whereas many licences were dormant[145].

In the early 2000s, a new emerald deposit was discovered in Central Zambia, in the district of Solwezi. The production of these emeralds from Musakashi started in 2006 in small quantities (Manyepa and Mutambo report about 20kg produced over 4 years)[146]. However, this deposit is worth mentioning since there have been recent reports of increased production of high-quality emeralds from this area[147].

b) Emerald Trade Flows

The UN Comtrade data for Zambia shows some inconsistencies, notably a lack of data between 2014 and 2018 (Figure 38). Before 2014, exports of precious unworked gemstones were increasing whereas, since 2019, the vast majority of recorded exports have been of worked emeralds. It should be noted that Zambia is a producer of several other precious gemstones besides emeralds, therefore this total figure for the value of 'unworked precious stones' encompasses more than simply rough emeralds. However, Zambia is not a producer of high-value rubies or sapphires, therefore the 381 million dollars of exports for 710391 can be largely attributed to the exports of cut emeralds for the period.

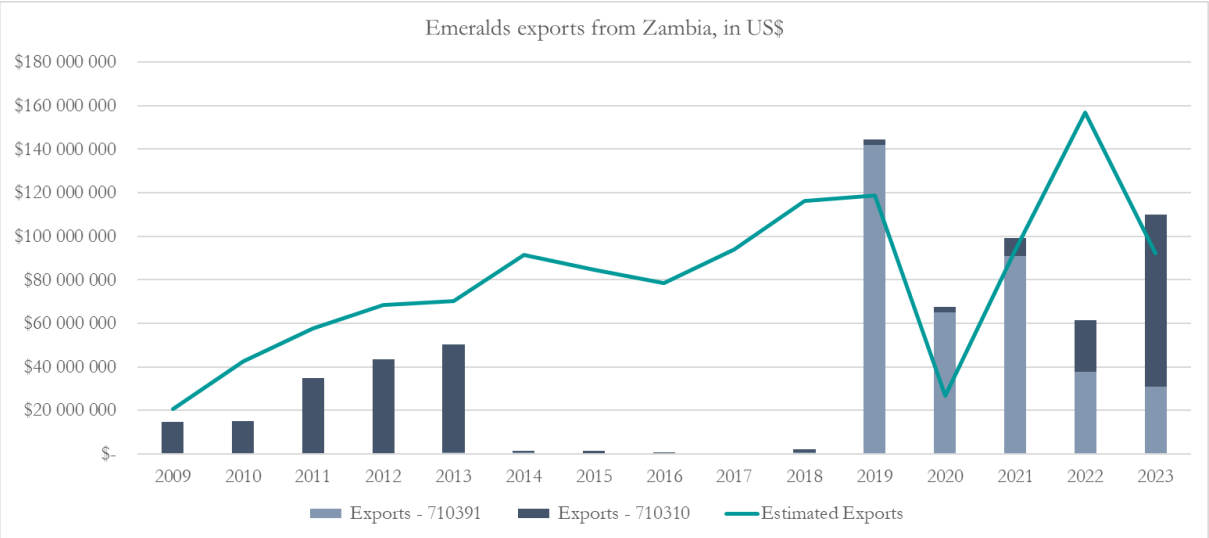


Figure 37: UN Comtrade exports compared to exports reported from other sources (including miners)

[144]https://rapaport.com/news/grizzly-mining-records-highest-ever-emerald-sales/?utm_source=rss&utm_medium=rss&utm_campaign=grizzly-mining-records-highest-ever-emerald-sales
[145]https://www.lusakatimes.com/2022/07/31/repossess-mining-licences-owned-by-several-dormant-emerald-mining-firms/
[146] Manyepa, J., & Mutambo, V. P. (2021). Approaches for Designing Extraction Methods for Randomly Occurring Pocket Formation of Gemstones: A Case of Musakashi Emerald Area, Solwezi, Zambia. *Journal of Mining and Environment*, *12*(3), 605-618.
[147] Krzemnicki, M. S., Wang, H. A., & Cartier, L. E. (2021). New Emeralds from Musakashi, Zambia, Appear on the Market. *The Journal of Gemmology*, *37*(8), 769-771.

The UN Comtrade data has been compared against estimated export values from other sources, including figures sourced from miners collaborating with this report (Figure 37). The general trend between 2009 and 2022 is the same, but it appears to show that the reporting of data has shifted, and product that had been exported under the HS code 710310 before 2013 is now mostly being reported under the HS code 710391.

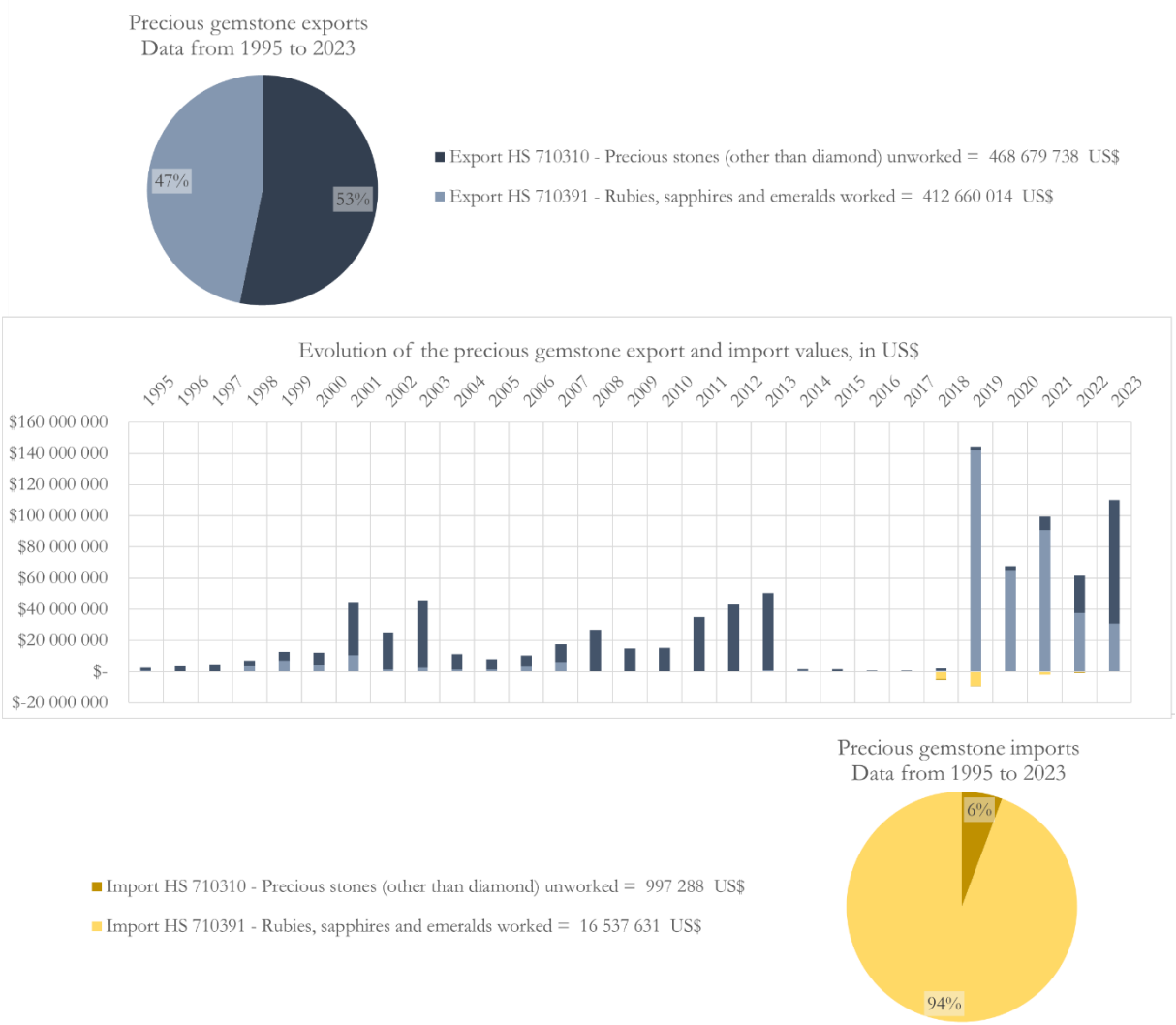


Figure 38: Precious gemstones imports and exports values from Zambia

6. *Zimbabwe*

a) Emerald Production

Zimbabwe produces a variety of gemstones including, amongst others, diamonds, emeralds, amethysts, aquamarines and tourmalines.

Emeralds were discovered in Zimbabwe in 1956, in an area named Sandawana, in the southeast of the country[148]. There were, and still are, numerous occurrences of emeralds and beryl being reported in this area, with more than 50 geological occurrences reported by the Zimbabwe Geological Survey[149]. About 70% of these are located within the Mberengwa district, including the main production mine, Sandawana, also called Zeus mine.

Between 1959 and 1993, the mine was owned by Rio Tinto Zinc (RTZ, 53%) and the Zimbabwean public (47%). During this period, production was reported to be sporadic. In 1993, RTZ sold the mine and the Zimbabwean Government became a minor shareholder. Zwann reports that production then increased and became more consistent[150], until the acquisition of the mine by the ZMDC (Zimbabwe Mining Development Corporation) in 2006[151]. However, this doesn't fit with the production numbers from USGS and the Zimbabwe Geological Survey, which show a significant decrease in production from 1998[152]. Since 2012, the mine has been closed on a 'care and maintenance' basis[153]. ZMDC explained that the emeralds extracted were no longer of commercial value[154].

Another mine, Machingwe, was exploited in a simple but mechanised way between 1984 and 1993 and provided good quantities of emeralds[155].

The Zeus mine started to be exploited as an open pit, before being developed underground through several shafts. The mine was mechanised for both extraction and processing, using modern equipment like crushers and trommels. Since its closure, the shafts have still been used by artisanal miners. Zimbabwean legislation on mining and export licences is onerous and costly, making mining inaccessible to the vast majority of small-scale operators, who extract gemstones as a part-time job. The result is that gemstones extracted by ASM are smuggled through other countries, therefore remaining undeclared and unaccounted for. In an interview, a member of the Zimbabwe Gemstone Association declared that up to 90% of emerald production could be leaving the country illegally[156].

[148] Zwaan, J. C. (2006). Gemmology, geology and origin of the Sandawana emerald deposits, Zimbabwe. Scripta Geologica, 131, 1-212.
[149] M. T. Hawadi, L. S. Mafara. Gemstone deposits of Zimbabwe. Zimbabwe Geological Survey, 2018
[150] Zwaan, J. H., Kanis, J., & Petsch, E. J. (1997). Sandawana Mines, Zimbabwe. Gems & Gemology, 33(2), 80-100.
[151] http://www.emeraldmine.com/old/2012Archive.htm
[152] Yager, T. R., Menzie, W. D., & Olson, D. W. (2008). Weight of production of emeralds, rubies, sapphires, and tanzanite from 1995 through 2005. US Geological Survey.
[153] https://zmdc.co.zw/assets/files/ZMDC-ANNUALREPORT2020.pdf
[154] https://www.radiovop.com/zims-largest-emerald-mine-shutdown/
[155] Kanis, J., Arps, C. E. S., & Zwaan, P. C. (1991). 'Machingwe': a new emerald deposit in Zimbabwe.
[156] Interview on 25/10/2022

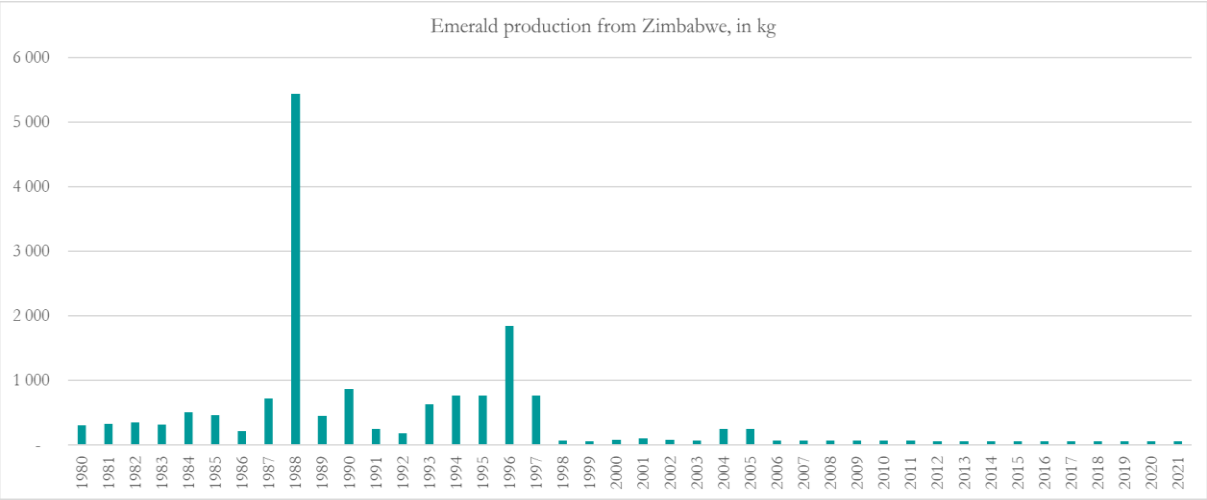


Figure 40: Emerald production from Zimbabwe, in kg

The production profile presented (Figure 40) is a combination of production numbers from the bibliography (sources mentioned in the footnotes), and notably from the geological survey of 2018. It has been supplemented with an estimated value of the quantities produced by ASM and undeclared mining. It is worthwhile noting that, in 1988, the Zimbabwe Geological Survey reported a total production for Sandawana of almost 54 tonnes, which is an inexplicable number given that production never exceeded 1.2 tonnes for any of the other years. This number has been reduced by a factor of ten, on the assumption that 5.4 tonnes is much more realistic.

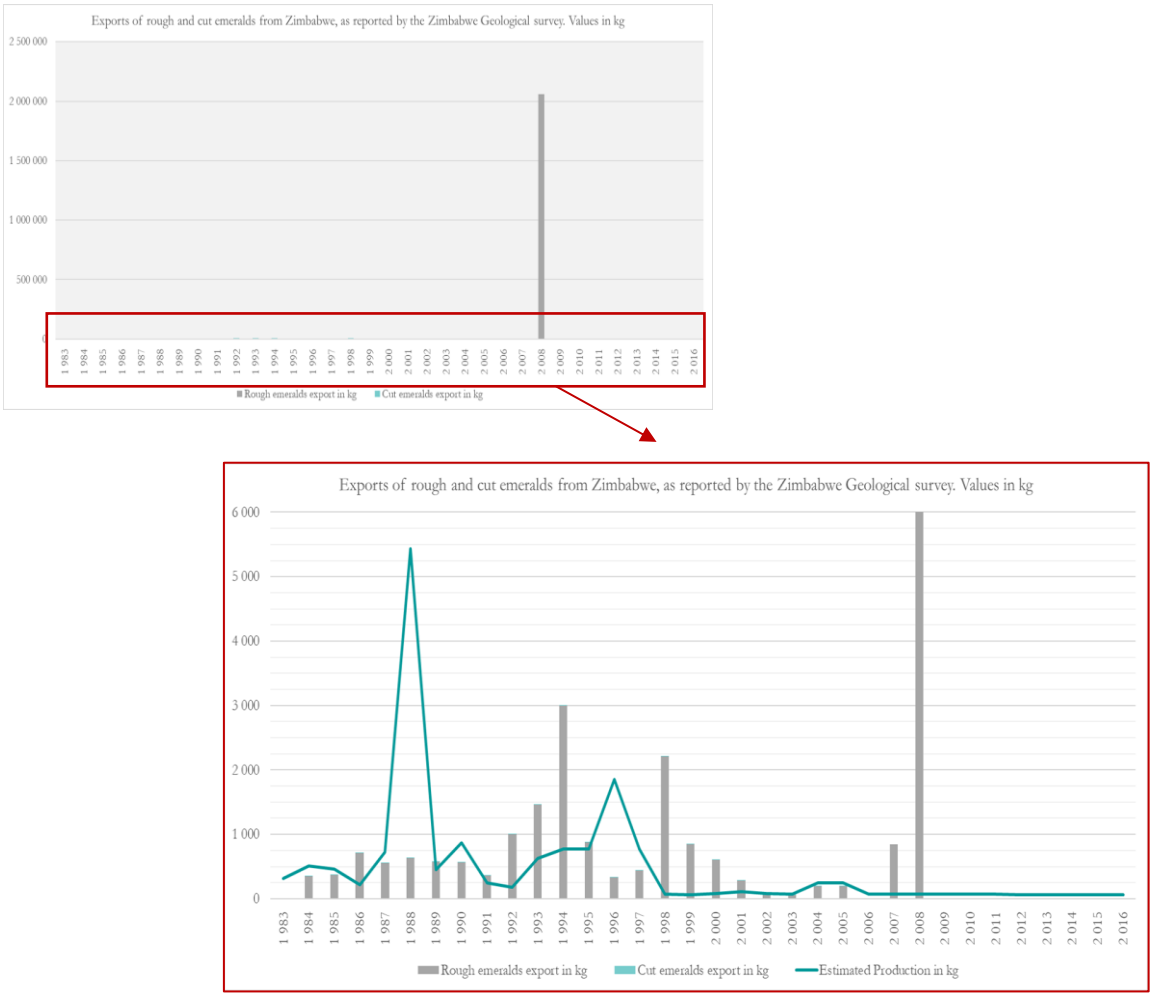


Figure 39: Reported rough and cut emeralds exports, as per the Zimbabwe Geological Survey

The Zimbabwe Geological Survey provides export quantities for rough and cut emeralds between 1983 and 2016. Cut emerald exports were 16kg over this 34-year period, which is negligible (Figure 39). Rough emerald exports were 2,074 tonnes, of which 2,057 tonnes were exported in one year, 2008. This significant export was of particularly low value (0.16 US$/kg) compared to the average value of all the other exports (US$ 1,228 /kg). It is also the last large quantity export recorded. Considering the year of 2008, and the low value, we assume that it corresponds to the Sandawana mine exporting its low-quality stock before its closure.

When comparing the estimated production profile with the rough exports, the general trend is not far off, but the estimated production is often much lower than the export quantity (Figure 41). Given that a significant proportion of Zimbabwe's gemstones are believed to be leaving the country on an undeclared basis, we would expect production figures to be greater than exports. With this in mind, the estimated production profile has been readjusted, as per the graph below. Overall, there has been a clear impact on the quantities produced by Sandawana and Machingwe, and it is estimated that, since 2006, only the ASM sector has been active, producing less than 100kg of emeralds per year.

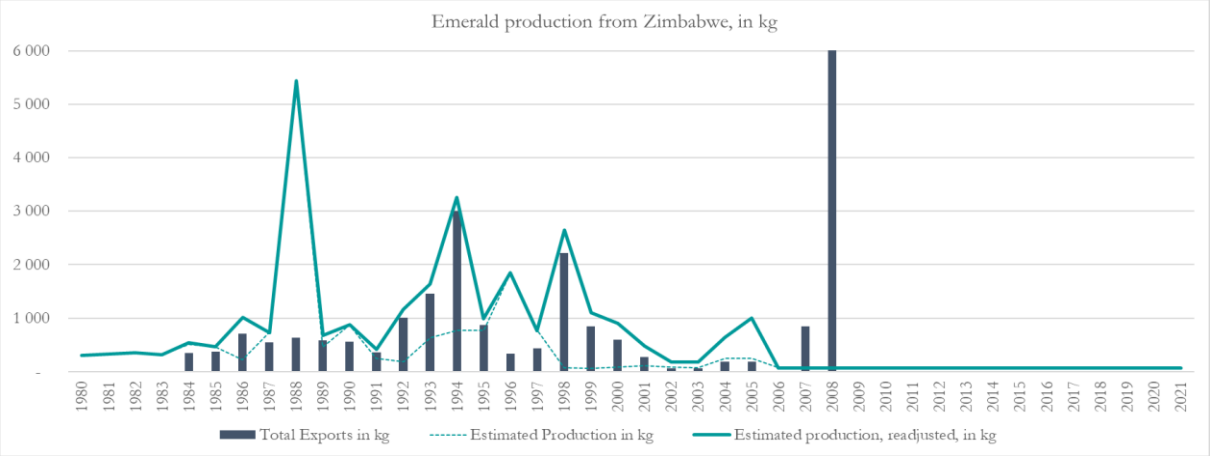


Figure 41: Declared exports from the Zimbabwe Geological Survey compared to the estimated production

b) Emerald Trade Flows

Trade data from UN Comtrade for Zimbabwe is sporadic and seems unreliable (Figure 42). Notably, one export to the United Arab Emirates in 2010 was responsible for 85% of the total export values of unworked precious stones for the period from 1995 to 2021.

The Zimbabwe Geological Survey provides export values for rough and cut emeralds between 1983 and 2016. The graph below shows that UN Comtrade data between 2000 and 2008 aligns well with the declared exports (). The history of Zimbabwe's emerald exports also reflects the known history of Zimbabwean mining, with a significant decrease from the end of the 1990s and almost non-existent exports from 2006, when Sandawana was acquired by the ZMDC and slowly placed under care and maintenance.

The average value for exported rough emeralds for the period from 1983 to 2016 is US$9.93/kg. However, if we exclude the 2008 exports, which represent 99% of the total weight but were valued at only US$0.16/kg, the overall unit price for exports increases to US$1,228/kg. The export value for rough material fluctuated between US$141/kg and US$61,590/kg.

For emeralds, the total quantity exported for the period was minimal (16kg), and the average value was US$188/ct. The export value of cut emeralds fluctuated between US$89/ct and US$882/ct.

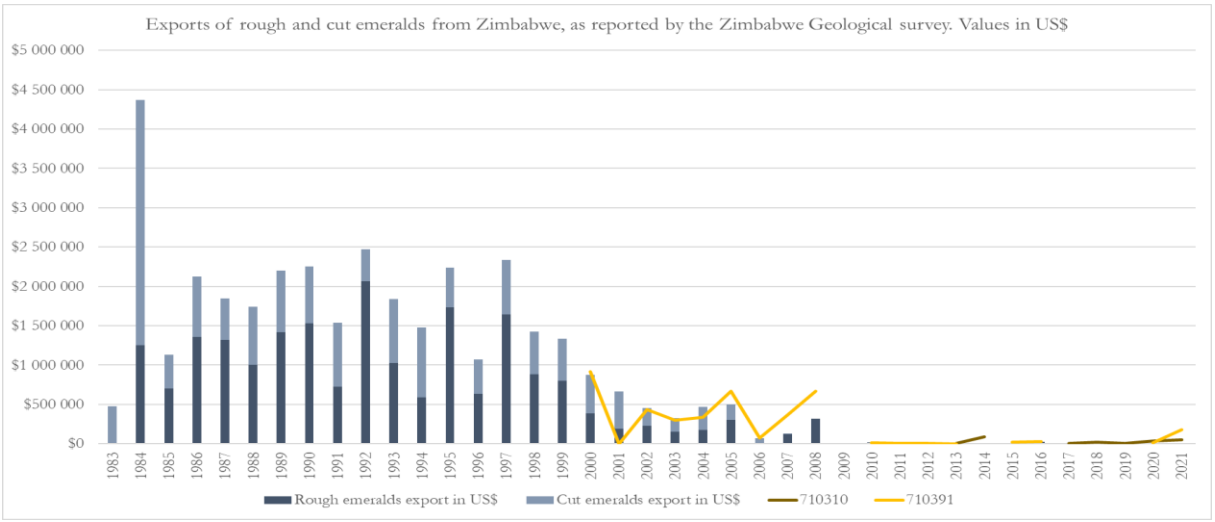


Figure 43: UN Comtrade exports values compared to the reportd exports from the Zimbabwe Geological Survey

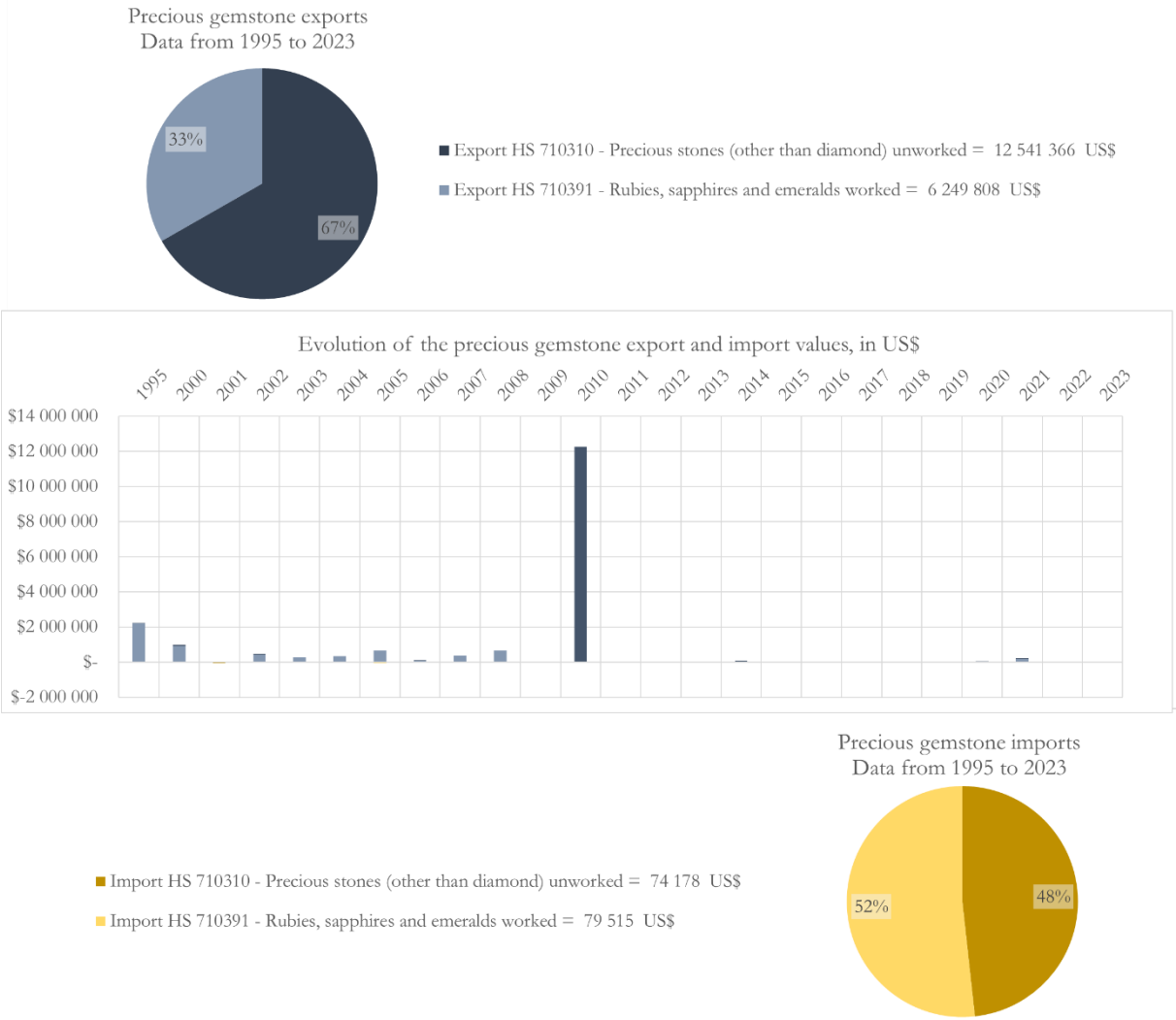


Figure 42: Precious gemstones imports and exports values from Zimbabwe

7. *Other countries*

a) Ethiopia

Ethiopian emeralds were introduced into the global market in around 2011-2012[157]. However, it was only at the end of 2016, and especially during the Tucson show of 2017, that significant quantities of high-quality emeralds were reported there[158],[159] .

All of the emeralds have been found in the south of the country. They were first discovered near Dubuluk, and in 2016 a better deposit emerged near Shakiso, about 200km north of Dubuluk. Mining activity has been carried out entirely by artisanal miners, organised into associations[160]. At the peak of activity, more than 10,000 miners were working in the area[131]. According to the Ethiopian Ministry of Mines, Petroleum and Natural Gas, about 100kg were produced in less than a year, between the end of 2016 and spring of 2017[161]. Gem dealers interviewed by Laurs mentioned that, over the same period, they had purchased more than 300kg of commercial-grade emeralds, and that production was between 6kg and 8kg of gem quality emeralds per month[133]. However, mining appeared difficult to control and the government closed and reopened the area, restricting buying activities several times in the space of a few months[134]. Since 2017, no major production has been reported, although mining activities must have taken place sporadically.

Gemfields attempted to establish a mechanised operation in the country, after acquiring 75% of an Ethiopian company, Web Gemstone Mining plc, and starting exploration in June 2015. Bulk-sampling

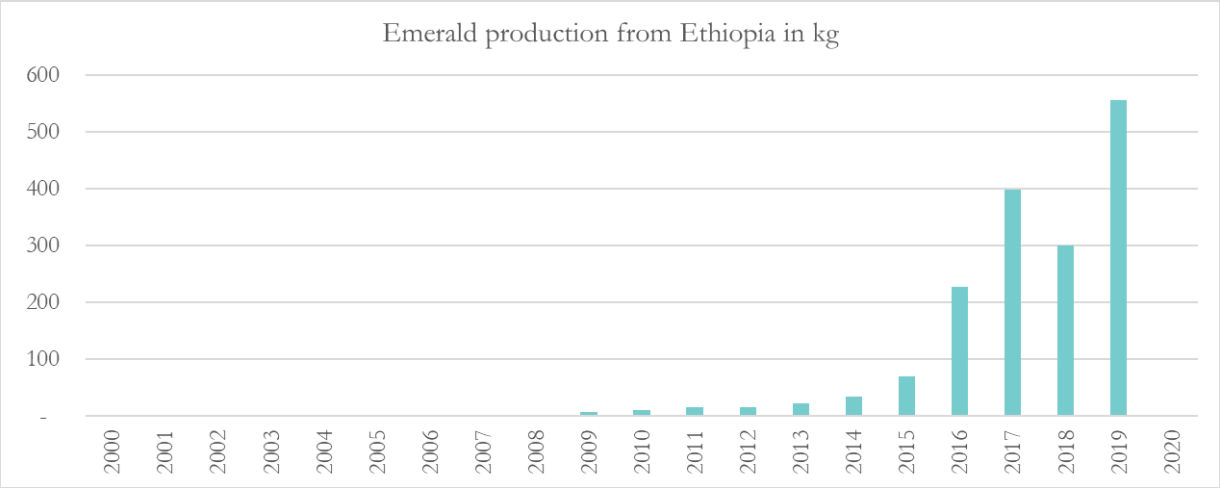


Figure 44: Emerald production from Ethiopia, in kg

[157] Vertriest, W., Girma, D., Wongrawang, P., Atikarnsakul, U., Schumacher, K. (2019). Land of origins: a gemological expedition to Ethiopia. Field Report. Gems & Gemology. Spring 2019

[158] Schluessel, R., & Schuessel, N. H. (2018). Emeralds from Ethiopia. Gemworld International, Gemguide, 1-5.

[159] Laurs, B. M., & Strack, E. (2017). New Production of Emerald from Ethiopia. The Journal of Gemmology, 35(5), 386-388.

[160] https://www.nationaljeweler.com/articles/838-5-things-to-know-about-ethiopian-emeralds

[161] Renfro, N., Sun, Z., Nemeth, M., Vertriest, W., Raynaud, V., Weeramonkhonlert, V. (2017). A new discovery of emeralds from Ethiopia. Gem news international. Gems & Gemology. Spring 2017.

operations began in August 2017[162]; however, the mine was overrun by an armed group one year later, in June 2018[163]. The operations remain on hold due to this unstable situation.

b) Madagascar

Emeralds are mainly found in the Mananjary region of Madagascar. They were first unearthed in the Mananjary region in the 1970s, when Jeannot Andrianjafy came upon the deposits[164]. Numerous mines are present in this area, operated both by independent miners and small mechanised operations[165]. Activities can be sporadic due to the rainy season. Commercial exploitation of the Mananjary deposits increased in the 1980s[166]. Notably, the company Le Quartz Cie, owned by the Andrianjafy family, has been

extracting emeralds from these deposits for the past 50 years. The Sanapatrana mine reported that more than 7 tonnes of emeralds were produced over about 30 years[138]. This gives an annual production capacity much higher than the figure reported in the mineral yearbook of the USGS, which estimated emerald production capacity from the region at 150kg[167].

Moreover, it is well-known that a significant portion of the gemstone production in Madagascar is undeclared. As with the ruby production, the below production profile has been topped-up with an estimate of undeclared production, based on a ratio of 70% of gemstones being smuggled (Figure 45). The spike in

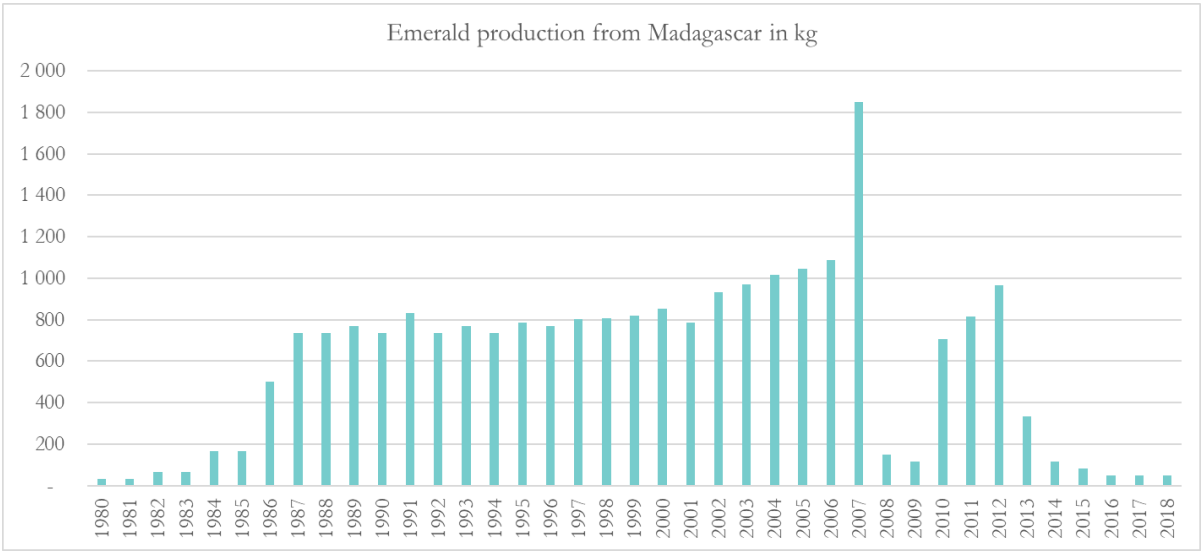


Figure 45: Emerald production from Madagascar, in kg

[162] https://www.gemfieldsgroup.com/assets/web-gemstone-mining-emerald/
[163] https://www.mining.com/gemfields-operation-ethiopia-siege-armed-groups/
[164] Pardieu, V., Sangsawong, S., Cornuz, L., Raynaud, V., & Luetrakulprawat, S. (2020). Update on Emeralds from the Mananjary-Irondro Area, Madagascar. Journal of Gemmology, 37(4).
[165] Schwarz, D. (1994). Emeralds from the Mananjary Region, Madagascar: Internal Features. Gems & Gemology. Summer 1994.
[166] Schwarz, D., & Henn, U. (1992). Emeralds from Madagascar. Journal of Gemmology, 23(3), 140-149.
[167] Yager, T. R. (2003). The mineral industry of Madagascar. Minerals Yearbook, 3, 18.

production in 2007 is related to the production and export of the Heaven's Gift Emerald, a 536kg piece of rough emerald on mica matrix.

c) Central Asian deposits (Afghanistan, Pakistan, Tajikistan, Nepal)

Emeralds in Afghanistan are found in the Panjshir valley[168]. Although emeralds from this part of the world have been reported in the literature for centuries, commercial production only commenced upon the discovery of the Buzmal mine in the 1970s[169]. All of the mines in the Panjshir valley are located in the mountains, at high altitude, and are therefore difficult to access. They are operated mainly by independent miners, using dangerous, archaic and unsystematic mining methods[162]. This includes blasting with dynamite, which tends to fracture and break emerald crystals[170]. However, in 2015, Bowersox, a gemmologist specialising in Afghan gemstones, reported a net improvement in mining methods, notably a reduction in the usage of explosives and better water control[171]. Production volumes are very hard to obtain. Bowersox reported seeing about 1kg of production during a three-week visit in 1985[172]. Emerald production must have also been impacted by the political context, although mining activities never completely stopped[168]. Nevertheless, the Afghanistan geological survey concludes that the majority of gemstones produced in the country are exported illegally, estimating that 90% to 95% of those produced cross the border to Peshawar in Pakistan[173].

In Pakistan, emeralds are found in four districts, the most important of these being the Swat valley. The discovery of these emerald deposits is usually dated to around 1958.[174] However, research on ancient jewellery indicates that emerald mining may have been taking place in this area since antiquity[175]. The recent history of mining activity at the Swat mines is strongly influenced by the political context. In 1969, the mines became to property of the Government of Pakistan, but they were closed between 1970 and 1972 due to a lack of control of the mining. In 1974, in the nationalisation movement, the 'Gemstone Corporation of Pakistan' was created to manage the gemstone industry. This boosted production, until privatisation in the early 1990s. The mines were inactive until 1995, when they fell under the control of the local government. They then closed again in 1998 for 12 years, until companies started operating again in 2010. Between 2007 and 2009, the Taliban gained control in the Swat region and illegally mined some deposits. Production data

[168] Groat, L. A., Giuliani, G., Marshall, D. D., & Turner, D. (2008). Emerald deposits and occurrences: A review. Ore Geology Reviews, 34(1-2), 87-112.
[169] Bowersox, G., Snee, L. W., Foord, E. E., & Seal, R. R. (1991). Emeralds of the Panjshir valley, Afghanistan. Gems and Gemology, 27(1), 26-39.
[170] Lucas, A., Hsu, T. (2017). Emerald Dealing in Afghanistan. Gem News International. Gems & Gemology, Spring 2017, Vol. 53, No. 1
[171] Bowersox, G. (2015) The Emerald Mines of the Panjshir Valley, Afghanistan. InColor. Winter 2015
[172] Bowersox, G. W. (1985). A status report on gemstones from Afghanistan. Gems & Gemology, 21(4), 192-204.
[173] McIntosh, R., & Benham, A. J. (2007). Minerals in Afghanistan: gemstones of Afghanistan. Afghanistan Geological Survey website.
[174] Makki, M., & Ali, S. H. (2019). Gemstone supply chains and development in Pakistan: Analyzing the post-Taliban emerald economy in the Swat Valley. Geoforum, 100, 166-175.
[175] Schwarz, D., Giuliani, G. Emeralds from Asia. Pakistan, Afghanistan, and India – Historically significant deposits? https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers21-03/010030130.pdf

from Pakistan is also very hard to obtain. One report from the geological survey of Pakistan mentions that production, at the peak of activity in 1990, would have been around 16kg[176] from one mine (the Mingora mine). Makki reports that production during the 1980s would have totalled around 50kg[167].

The presented production profile (Figure 46) is largely based on USGS data between 1995 and 2005[177], with extended averages. It also considers the few production figures and the reported history of mining activities from the bibliography. For Afghanistan, the production figures have been augmented, based on the assumption that 90% of production is not declared.

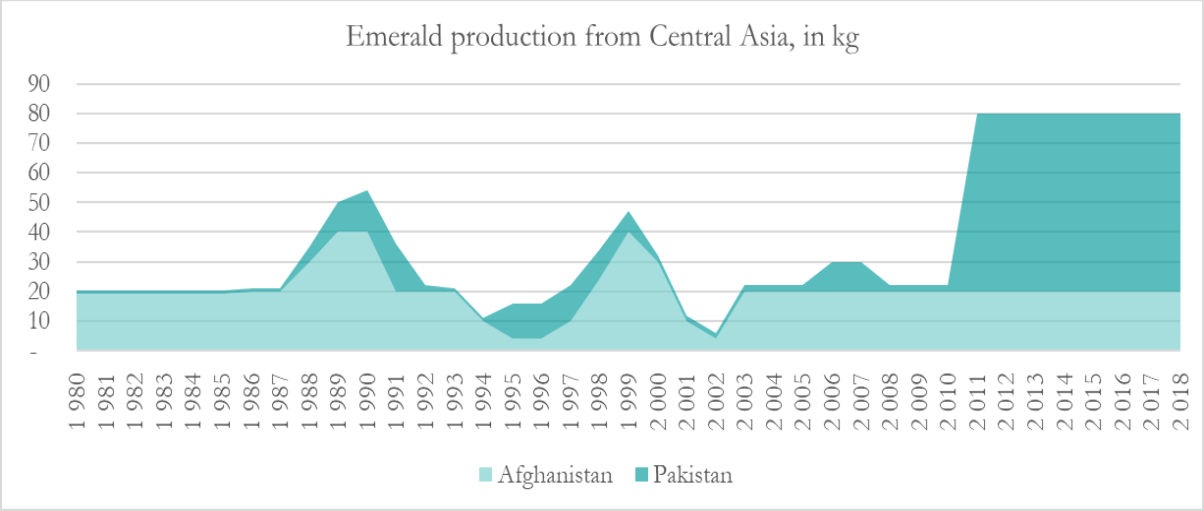


Figure 46: Emerald production from Central Asia, in kg

[176] Malkani, M. S., Mahmood, Z., Somro, N., & Arif, S. J. (2017). Gemstone and Jewelry Resources of Pakistan. Geological Survey of Pakistan, Information Release, 1004, 1-28.
[177] Yager, T. R., Menzie, W. D., & Olson, D. W. (2008). Weight of production of emeralds, rubies, sapphires, and tanzanite from 1995 through 2005. US Geological Survey.

8. *Compiled data*

a) Global emerald production

All of the production figures presented have been compiled in the graph below. The graph represents the production of gem-grade emerald, but does not take quality into account, meaning that the volumes include facet, cabochon, carving and commercial grades.

It should be borne in mind that this profile does not aim to be a perfect representation of reality: it is acknowledged by the author that there is insufficient reliable recorded data available to do so.

The lack of follow-up on mining activity is a major issue when trying to document the history of emerald supply, especially when many deposits are sporadically mined.

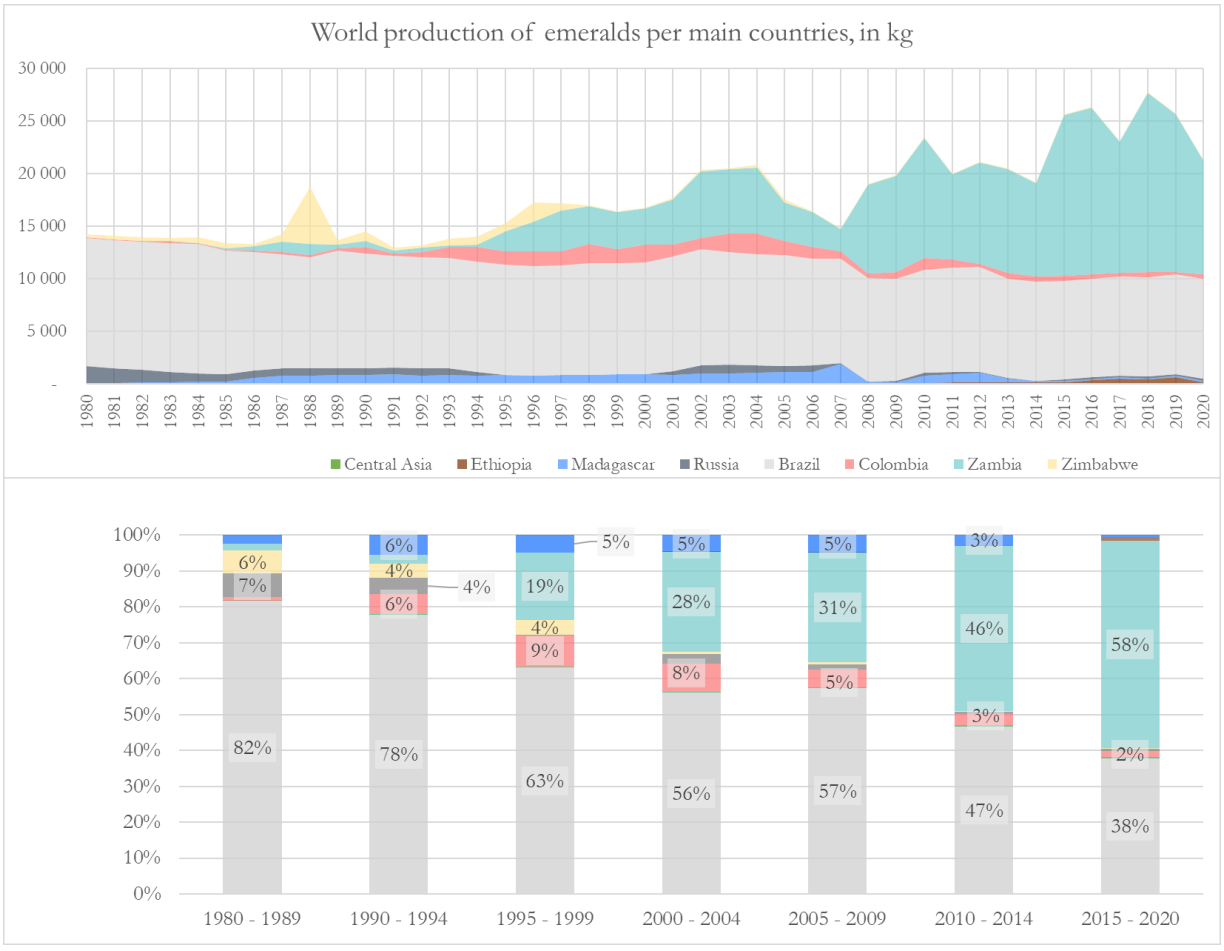


Figure 47: World production of emeralds, in kg

Nevertheless, this profile (Figure 47) provides some useful insights on emerald production dynamics:

1. Over the past 40 years, the supply of emeralds has consistently come from a limited number of countries. No major discoveries have dramatically changed this dynamic. The key factors affecting volume and supply have been changes in mining activities: namely, a shift towards larger, more mechanised and formalised operations.
2. Global emerald supply is dominated by three countries: Brazil, Colombia and Zambia.

3. Brazil has been the most important source of emeralds; however, this is mainly related to the production of large volumes of low-quality emeralds in the state of Bahia.
4. The deposits from Central Asia, Russia and Ethiopia produce relatively little, in volume terms.
5. The average yearly volume across the 40 years presented is 18 tonnes, with a minimum of 13 tonnes and a maximum of 28 tonnes. These numbers should not be taken as exact figures, but we can safely say that the yearly world production of emeralds rarely exceeds 25 tonnes, even with emeralds of all qualities taken together.
6. Colombia, although reported as the world's leading supplier in numerous articles and papers, has never dominated the market in terms of volume. This is because Colombia produces very high-quality emeralds, rather than large quantities of commercial grade gems.
7. The development of mining in Zambia, notably large-scale mining under Gemfields and Grizzly, has made Zambia the world's most important supplier in recent years.

b) Quality considerations

As explained, the graph presented above does not take quality into account, which is why Brazil appears so dominant. A quality factor has been applied in order to depict the history of fine-quality emerald supply. 'Fine quality' here is considered to represent faceted grade, not those gemstones that have been treated or only traditionally oiled. The used factor depends on the country, but also the deposit. For example, the percentage of fine emeralds from Brazil is different from the one for Bahia and other Brazilian regions. The quality factor is referenced in the bibliography; however, not all deposits and countries have provided information on the percentage of facet-grade production, in which case the factor is based on the expert's opinion. The factors used are presented in the table below.

Country	Mine taken as a reference	% of fine quality
Brazil	Piteiras, Capoerina, Belmont	10%
Central Asia	Swat Valley, Panjshir Valley	17%
Colombia	Muzo, Coscuez	30%
Ethiopia	Shakiso	10%
Madagascar	Mananjary	10%
Russia	Malysheva	0.25%
Zimbabwe	Sandawana	10%
Zambia	Kagem	10%

The new production profile (Figure 48) is much more representative of the reality of the market, with Colombia being the main producer, along with Zambia in recent years.

From this profile, on average, 1000kg of fine-quality emeralds are produced every year, although this has significantly increased with Zambian supply. Again, numbers are not exact figures, but less than 1.5 tonnes of fine-quality emeralds are produced every year, accounting for about 5% of the total volume of emeralds. This highlights the rarity of these gemstones.

In contrast to these results, the coloured gemstone market report presented by Guild Gem Laboratories during the ICA congress of 2023 mentioned the share of Colombian emeralds to be 42% and Zambian emeralds to be 25% in 2022[178]. This highlights the fact that the gemstones passing through laboratories are not always representative of total production, as only high-quality gems from certain locations are likely to

[178] Lucas, A., Lui, R. (2023) Guild 2022 China Colored Gemstone Market Report. Special edition for 2023 ICA congress Dubai. Guild Gem Laboratories

be sent for certification. The reports mention that Zambia's share is more likely to be 60 to 70%, confirming the results of this study.

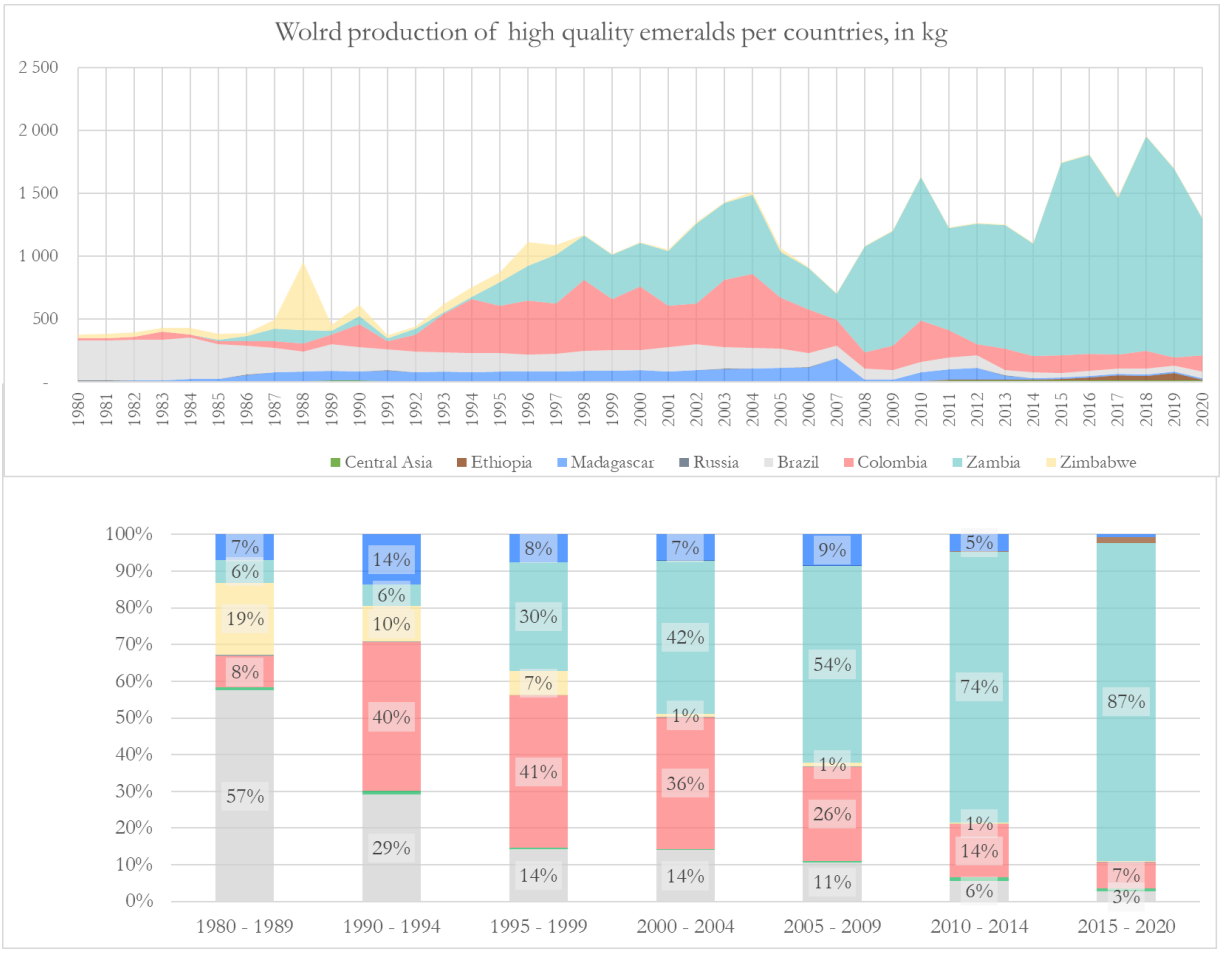


Figure 48: World production of high-quality emeralds, in kg

VI. Global supply of sapphires

1. Introduction

If researching the coloured gemstone market and production is a challenging task in itself, it takes on an even more complicated dimension when it comes to sapphires. The primary reason is simply because they represent a smaller market value than rubies and emeralds and fewer statistics are available. This is especially striking when looking at mineral reporting from well-developed countries, such as the USA and Australia, which *do* have strong information systems in place, yet which either do not report their sapphire production at all or only report it in terms of value, with no mention of volumes.

Additionally, the inherent definition of sapphires is problematic for a market study. Sapphires are defined as corundum of any colour except red (red corundum being ruby). This variety of colours has two main impacts: first, it is difficult to talk about one single market for sapphires, as each colour will have its own price range, customer profile, cultural value, etc. Notably, the price point of a blue sapphire will usually be significantly higher than for other colours. This has led to a bias in data interpretation, as it is often unclear if reports are focusing on blue sapphires only, or on all sapphires. A deposit can also produce more than one colour; in fact, each deposit is different and will have its own range of colours and qualities. Although every deposit is unique, deposits may share a similar geological context, which makes determining their origin an arduous task. This is particularly true for basalt-related sapphires[179],[180]. This specific origin-determination problem has a massive impact on market dynamics and makes it nearly impossible to estimate production. As with emeralds and rubies, the geographical origin of a sapphire has an impact on its value. The challenge of determining origin has increased the general tendency in the coloured gemstone market to mislead, fail to disclose or lie about the provenance of sapphires. This is the reason why many experts argue that a large number of sapphires sold in the 1980s that were labelled from Thailand actually came from Australia. The same debate continues today regarding sapphires labelled as 'Sri Lankan', a portion of which are strongly suspected to originate from Madagascar.

Finally, sources indicate that more than 90% of sapphires are treated [181],[182], with a variety of treatments (low- and high-temperature, glass-filled, beryllium diffusion, etc.). The prevalence of treatments necessitates greater movement of gemstones across borders, adding to the difficulty of properly tracing these gemstones.

Due to these challenges, the compiled data section of this chapter will only present a global estimation of production, without an estimate specifically for 'fine quality' sapphires. For this report, production and trading data research was performed for fifteen countries.

[179] Pardieu, V., Sangsawong, S., Muyal, J., & Sturman, N. (2014). Blue sapphires from the Mambilla Plateau, Taraba State, Nigeria. A preliminary exploration. GIA News from Research, GIA Laboratory Bangkok.
[180] https://eighthdimensiongems.com/origin-opinions
[181] https://www.buygemstone.info/sapphire-treatment-guide
[182] https://www.thenaturalsapphirecompany.com/t-treated_vs_untreated_sapphires/

2. Australia

a) Sapphire Production

Australia is well-known for its production of opals and diamonds, but it is also an important producer of sapphires.

Sapphires were first discovered in Australia around 1854, near Inverell in the New England district of New South Wales. However, exploitation started only about 40 years later, in the Anakie fields in Queensland[183]. These two regions remain the country's main production centres for sapphires. Between the end of the 19th century and the late 1960s, sapphire production in both of these regions was sporadic, and mainly carried out by self-employed miners and small corporations[183,184]. The position of Australia as a major global supplier of sapphires from the 1970s is inherently related to the previous decade's global dynamics. At the time, Asian sources, like Cambodia and Myanmar, were experiencing declining production due to mine exhaustion and political issues[185]. In the 1960s, Thai dealers also started to develop and optimise heat-treatment processes. Indeed, Australian sapphires were known to be too dark and silky[186]. The boom in Australian sapphires in the 1970s is, therefore, related to a drastic increase in demand from Thai dealers, who even established operations in the Anakie fields[186,184], financed large-scale mining and paid higher prices[184]. It is believed that, by the early 1980s, Australia was the source of 70% to 80% of the world's sapphires[183,186,187]. The apogee of Australia's sapphire production did not last very long, with a decrease in production reported to have started between 1980 and 1985[183] and a significant reduction in supply by the end of the 1980s[188]. This is explained by several factors. Firstly, sapphire prices decreased[187], possibly due to overproduction. Increased mining costs, environmental regulations[186] and the depreciation of the Australian dollar would also have been contributing factors. Moreover, in 1987, Thailand lifted in-country restrictions on mechanised mining operations, resulting in many Thai dealers leaving Australia[189]. Australia's share of the world's sapphires decreased to just 20% to 30% in the 1990s, and declined further by the early 2000s. In 2020, Fura Gems purchased two large-scale operations in Queensland, and these operations are expected to produce 80% of the country's production of sapphires, amounting to about 6 million carats (1,100kg)[190].

Fura Gems notes that, when Australia was at its peak of production in the 1980s, it produced nine-tenths of the world's sapphires: about 30 million carats a year[190]. However, 7,000kg of sapphires seems like a very

[183] Coldham, T. (1985). Sapphires from Australia. Gems & Gemology, 21(3), 130-146.
[184] Teghe, D., & McAllister, J. (2004). The Demise of Central Queensland's Small-scale Sapphire Miners: 1970–1995. Queensland Review, 11(1), 83-95.
[185] Broughton, P. L. (1979). Economic geology of the Anakie sapphire mining district Queensland. J. Gemmol, 16, 318-37.
[186] Shor, R., & Weldon, R. (2009). Ruby and sapphire production and distribution: A quarter century of change. Gems and Gemology, 45(4), 236-259.
[187]https://www.ga.gov.au/education/classroom-resources/minerals-energy/australian-mineral-facts/sapphire#heading-4
[188] Shigley, J. E., Dirlam, D. M., Laurs, B. M., Boehm, E. W., Bosshart, G., & Larson, W. F. (2000). Gem localities of the 1990s. Gems & Gemology, 36(4), 292-335.
[189] Olson, D. & Brioche A.. (2018). 2015 Minerals Yearbook. US Geological Survey.
[190] https://www.furagems.com/mine-travel/australia

low estimate of global production at the time, especially considering that Thailand and Sri Lanka were still producing several tonnes per year (cf. related sections). The 2008 USGS reports estimated global production of almost 27 tonnes in 1995, and bibliographic research supports the hypothesis that global production of sapphires decreased between the mid-1980s and the mid-1990s.

It is also worth noting that Australian sapphires are often associated with low-quality material, although high-quality sapphires are also produced. It is common for high-quality sapphires from Australia to be wrongly labelled as Thai, Sri Lankan or Burmese. In 1985, Coldham estimated that 50% of the sapphires labelled as Asian in Thailand actually came from Australia[183].

The ratio of production between Queensland and New South Wales must have varied over time and it is hard to obtain figures for this. The New South Wales resources regulator reports that, during the 1980s production peak, New England represented more than 50%.[191], yet New South Wales has not provided any statistics, and other bibliographic references mention Queensland as the main producer[185]. Queensland's annual reports on mineral production statistics provide sapphire production data from 1983 to 2012, and from 2016 to 2021 (Figure 49Figure 49). The data solely refers to production from Queensland and is reported in value terms (AUD). The data has been converted to USD using yearly historical conversion rates and is presented in the graph below. Although it does not give volumes, it shows the dynamic of production from the Anakie fields. It also shows that the economic value of the industry for the Queensland region was almost non-existent in 2021, with a total output value of $51.5k, even though it had been as high as $13.5M in 1983.

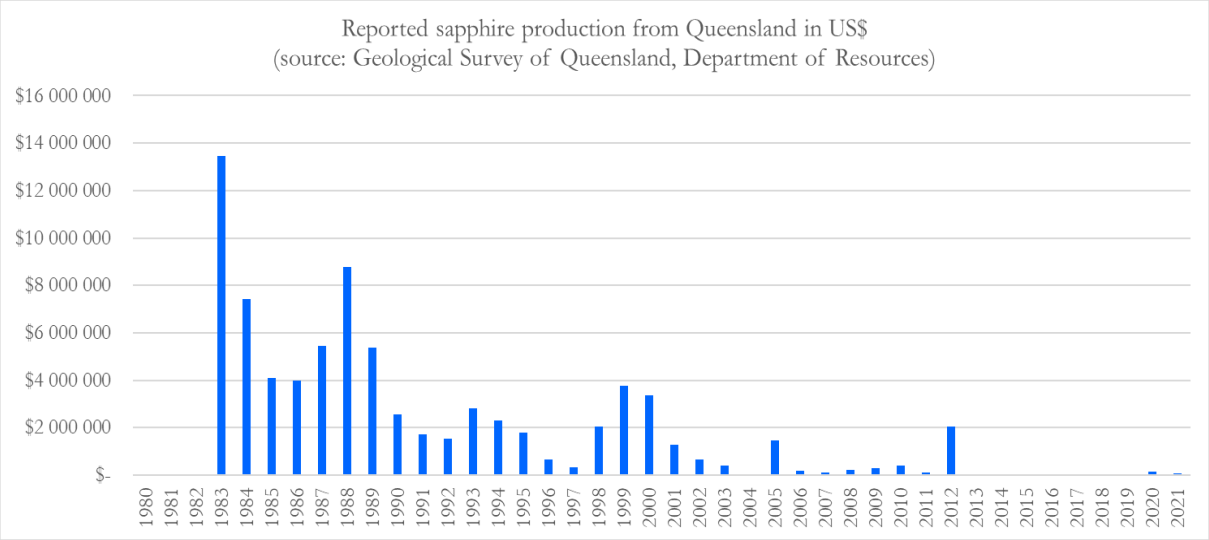


Figure 49: Sapphire production from Queensland in US$

For gemstones, it is impossible to translate production value figures into volume figures, because unit prices vary with quality. Moreover, gemstone prices have varied significantly over the last 40 years. Nevertheless, the graph below (Figure 50) is an attempt to estimate the volume of sapphires produced in Australia, using data from literature referenced herein, USGS data and statistics from Queensland and New South Wales.

[191] https://meg.resourcesregulator.nsw.gov.au/sites/default/files/2022-11/sapphire.pdf

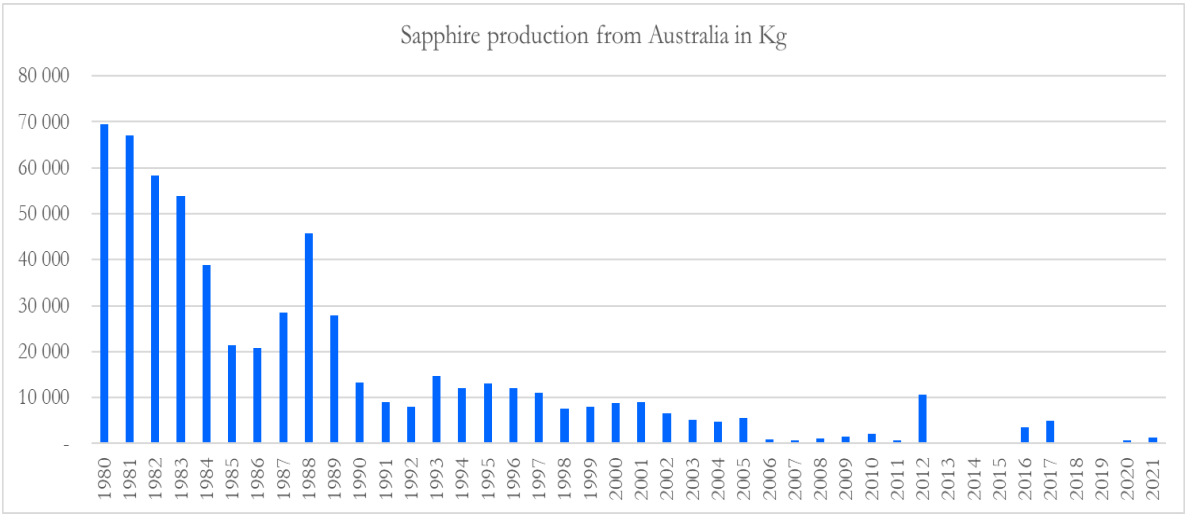


Figure 50: Sapphire production from Australia, in kg

b) Sapphire Trade Flows

As Australia is a major producer and exporter of opals, it is important to remember that UN Comtrade data represents the total for all coloured gemstones (Figure 51). However, in 1997 Australia experienced a significant decrease in exports, both in terms of the total volume of unworked gemstones (excluding diamonds) and worked rubies, emeralds and sapphires. This could be related to a significant drop in sapphire production volumes, although the decline had started about a decade before, in the late 1980s.

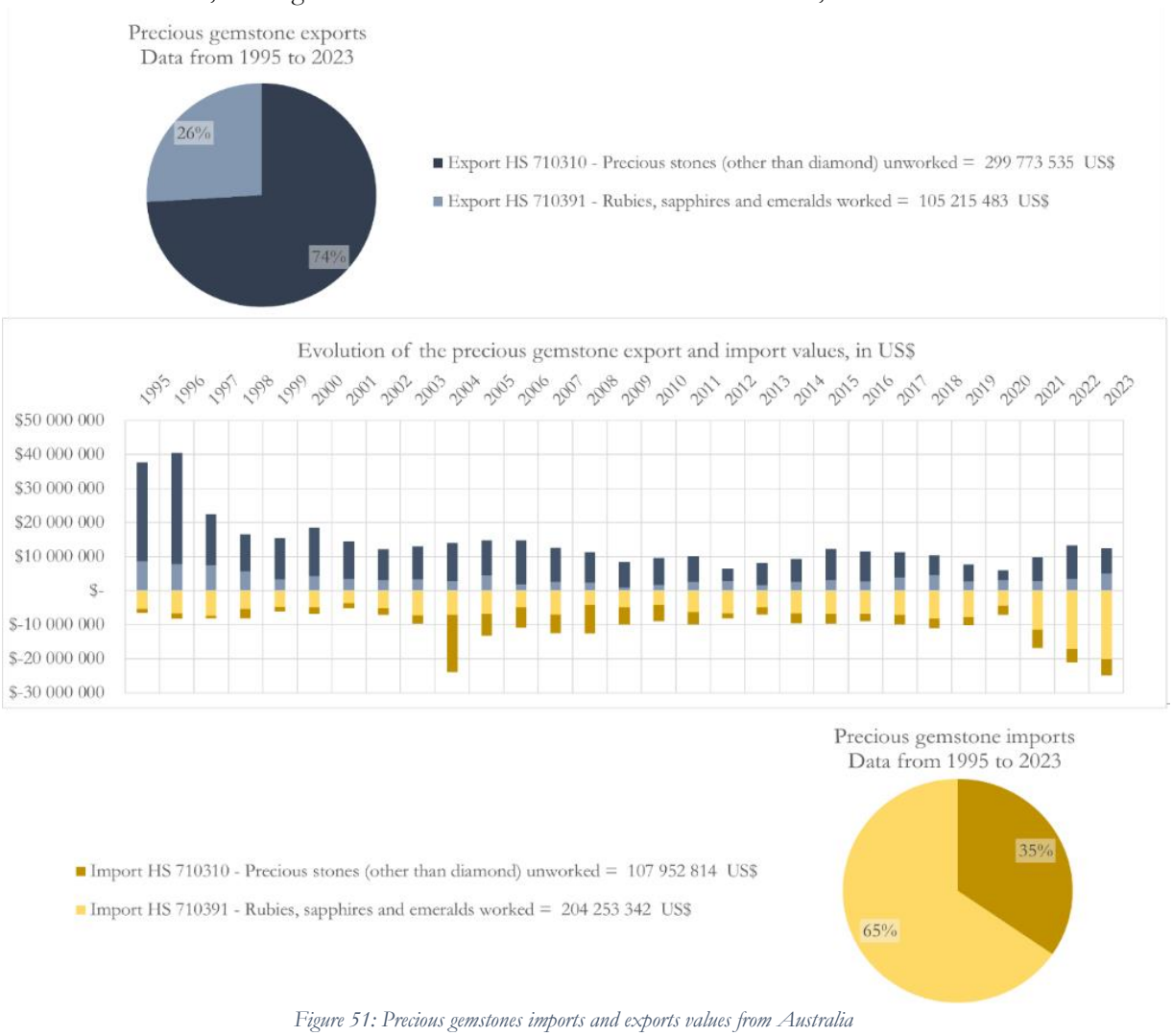


Figure 51: Precious gemstones imports and exports values from Australia

3. Kenya

a) Sapphire Production

There are two main sources of sapphires in Kenya. The first is the Rockland mine, formerly the John Saul Ruby mine, which is located in the south-east of the country. As in all ruby mines, pink sapphires are also produced here. The deposit was discovered in 1973, but production was sporadic until 1995, following the acquisition of rights and permits by Rockland Kenya [192].

The second most important source of sapphires is in Garba Tula, located in central Kenya. The main deposit, named Dusi, is the most important deposit for blue and yellow sapphires in Kenya [193]. It should be noted that sapphires from this area are challenging to identify using standard origin-determination methods[194]. Several other sapphire sources are also found in the Garba Tula area, such as the Kina deposit[195].

A third area, in the east of Kenya near Mount Kenya, produces pink sapphires. It produced between 7kg and 50kg per year of good-quality pink corundum from1989 to 1993 [196]. It is unknown if the deposit is still active.

The production history outlined in the graph below (Figure 52) was compiled using data from various sources, including bibliography, USGS, the Kenya National Bureau of Statistics and the mining annual report [197]. Several reports estimate that about 60% of gemstone production comes from artisanal and small-

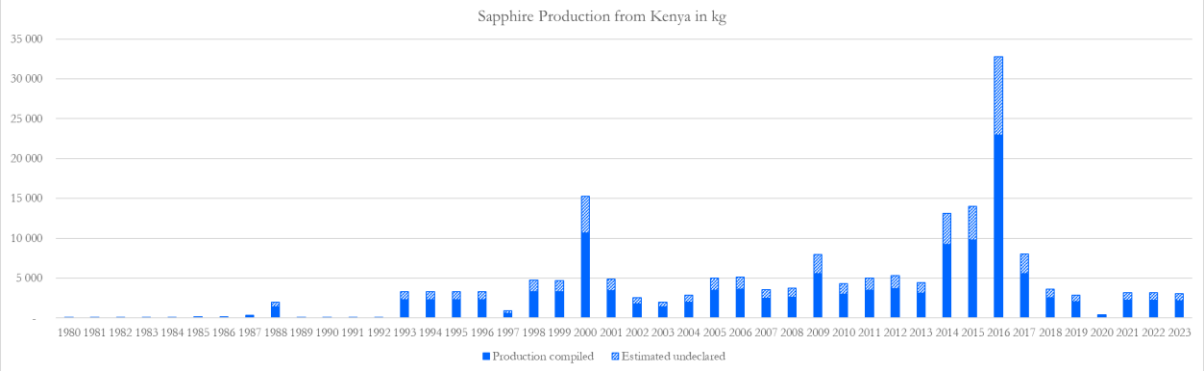


Figure 52: Sapphire production from Kenya, in kg

[192] Emmett, J.L., Prairie, B., (1999). An update on the John Saul ruby mine. Gem News. Gems & Gemology. Winter 1999

[193] Simonet, C., Paquette, J. L., Pin, C., Lasnier, B., & Fritsch, E. (2004). The Dusi (Garba Tula) sapphire deposit, Central Kenya—a unique Pan-African corundum-bearing monzonite. Journal of African Earth Sciences, 38(4), 401-410.

[194] Atikarnsakul, U. (2021). Multi-Color Sapphires Reportedly from the Garba Tula District, Isiolo County, Kenya. Gem News International. Gems & Gemology, Summer 2021, Vol. 57, No. 2

[195] Mayerson, W. M. (2015). Sapphires from kina, Kenya. The Journal of Gemmology, 34(8), 662-664.

[196] Barot, N., Harding, R. (1994) Pink corundum from Kitui, Kenya. The Journal of Gemmology, 24(3), 165-172.

[197] Opiyo-Akech, N. (2000). Mining in Kenya: Mining annual review 2000.

scale mining[198],[199]. However, considering that sapphire production in Kenya mainly yields pink sapphires, a sub-product of the Rockland mine, which is a mechanised operation, the 'estimated undeclared' figure for sapphire production has been kept at a conservative figure of 30%.

b) Sapphire Trade Flows

Kenya produces a variety of gemstones, which makes interpretation of the UN Comtrade data difficult (Figure 53). Moreover, Kenya does not take part into the Extractive Industry Transparency Initiative (EITI), often a good source for official production and export data. However, it is clear that Kenya exports mainly unworked gemstones, rather than cut and polished ones. This is also the case in most gemstone-producing countries in Africa. Kenya's government has started to create value-addition centres, notably in Voi in Taita-Taveta district, in order to cut and polish gemstones before they are exported[200].

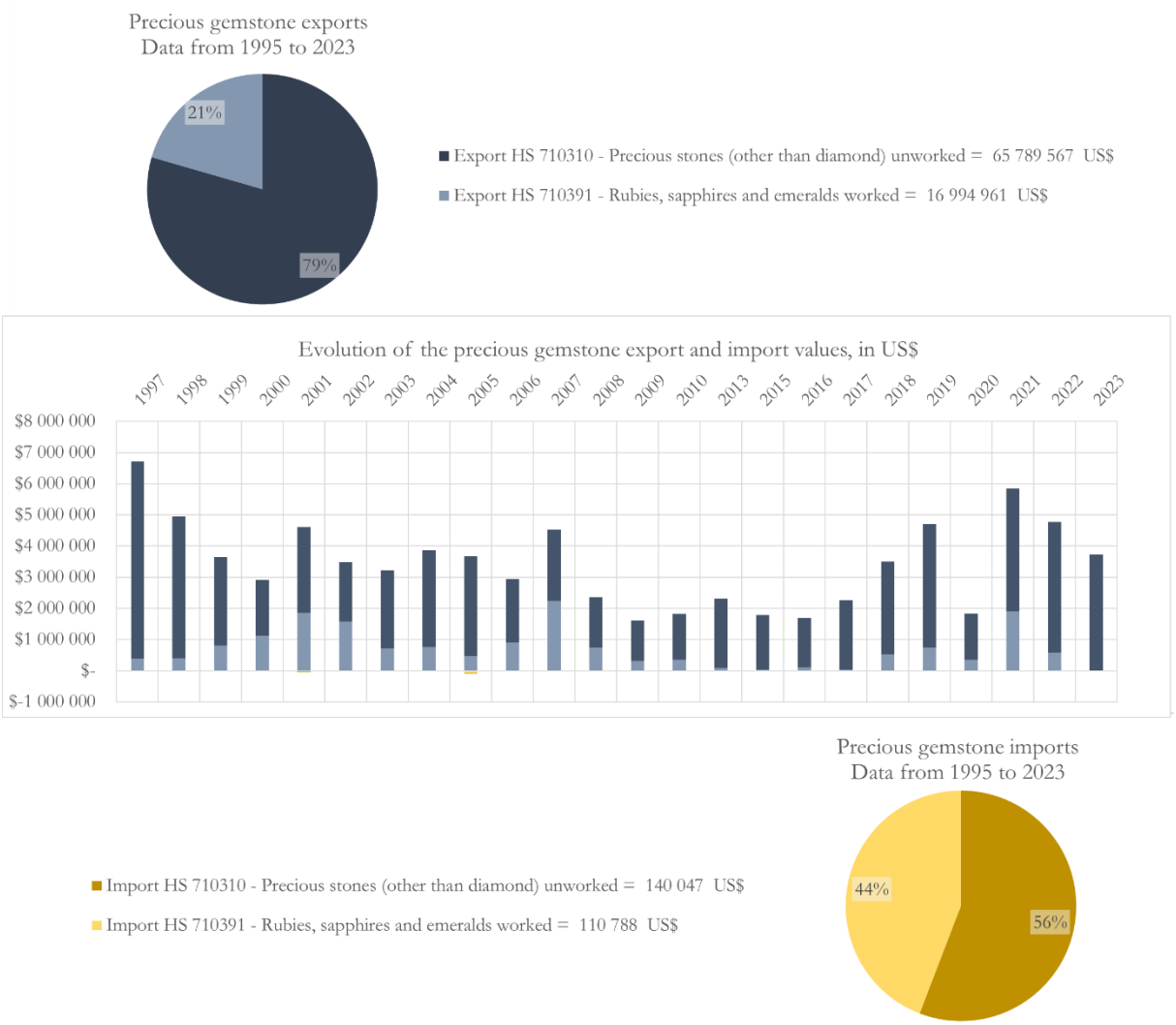


Figure 53: Precious gemstones imports and exports values from Kenya

[198] Barreto, M. L., Schein, P., Hinton, J., & Hruschka, F. (2018). Economic contributions of artisanal and small-scale mining in Kenya: Gold and gemstones. Pact & ARM.

[199] https://sustainable-asm.com/the-gemstone-mining-sector/

[200] Anyona, S., & Rop, B. K. (2022, March). The Proposed Gemstone Centre and its Likely Impacts on Small Scale Mining Industry in Taita Taveta County. In Proceedings of the Sustainable Research and Innovation Conference (pp. 98-108).

4. Madagascar

a) Sapphire Production

Madagascar is a land of gemstones, where almost every coloured gemstone variety can be found. Mining has been taking place here since 1900. However, the history of gem-corundum mining is much more recent, with the main sapphire discoveries occurring towards the end of the last century.

It is worth mentioning that mining conditions in Madagascar are linked to serious environmental and social challenges. Indeed, gemstone discoveries have always created massive rushes and boomtowns. This recurring dynamic encourages large numbers of independent miners and their families – sometimes several tens of thousands of people – to move across the country, which may be conducive to the development of criminal networks and may also induce violence and corruption. It also negatively impacts public health, notably due to water pollution and prostitution[201]. Moreover, the deposits are often located within nature reserves, thereby causing harmful environmental impacts, which is especially worrying given that Madagascar has unique endemic flora and fauna[202]. Mines located in the jungle are also difficult to access and to control. This dynamic of rushes also means that mining usually comes and goes relatively quickly, with the government trying to control and regulate activity. The vast majority of production is smuggled out of the country, which makes it difficult to estimate. Madagascar has enormous sapphire resource potential, and the country is currently thought to be supplying up to 60% of the world's sapphires[203]. Ilakaka would have produced up to 40% of the market supply during the peak of production in the early 2000s[204]. However, these numbers are impossible to prove, and the lack of governance, with bans on rough exports, means that Madagascar can unfortunately still not be considered as a reliable and consistent source of supply.

The first significant discovery of sapphires happened in the south of the country at Andranondambo. Sapphires were reported there in the 1950s, but mining activity became significant between 1992 and 1995[205]. This locality is especially famous for its fine-quality blue sapphires, which are comparable to the best Kashmir, Burmese or Sri Lankan sapphires[206]. Schwartz reports that about 1,200kg of rough sapphires were exported from this location every year between 1994 and 1996, and almost all the gem-quality material is heat-treated[205]. The deposit was still providing fine quality sapphires as recently as 2016[206].

[201] Duffy, R. (2007). Gemstone mining in Madagascar: transnational networks, criminalisation and global integration. The Journal of Modern African Studies, 45(2), 185-206.

[202] Ralimanana, H., Perrigo, A. L., Smith, R. J., Borrell, J. S., Faurby, S., Rajaonah, M. T., ... & Antonelli, A. (2022). Madagascar's extraordinary biodiversity: Threats and opportunities. Science, 378(6623), eadf1466.

[203] Expert's interview, Harimalala Tsiverisoa Herizo, ASM country specialist for gemstones. 7 October 2022.

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

[205] Schwarz, D., Petsch, E. J., & Kanis, J. (1996). Sapphires from the Andranondambo region, Madagascar. Gems & Gemology, 32(2), 80-99.

[206] https://www.lotusgemology.com/index.php/library/articles/455-madagascar-ruby-sapphire-ruby-sapphire-a-gemologist-s-guide

In 1996, a discovery occurred in the north of Madagascar, at Ambondromifehy. The recovered sapphires were mainly blue, yellow and green. The discovery led to a massive rush, with the local population multiplying by a hundred in two years. This ended with a ban on sapphires from this locality in 1998[207].

Probably the most important discovery in the country was Ilakaka, which was discovered in late 1998 and is currently considered to be the world's largest sapphire deposit[208]. This new deposit radically changed the worldwide dynamic of the sapphire market, quickly becoming the main source of supply. The deposit yields sapphires of all colours and in large quantities[209], and is believed to have been responsible for 40% to 50% of the world's supply[204, 210]. The 2008 USGS report broadly supports these production estimates for Ilakaka and Sakara, stating average production of 6,000kg per year between 1998 and 2005. Production declined significantly in 2008 due to a ban on rough exports.

Following this, several other discoveries were made, include fine blue sapphires in Andrebabe[211], near Andilamena, in 2002; pink sapphires in Ambohimandroso[206] in 2004; blue sapphires from Didy in 2012[211]; and sapphires of various colours from Bemainty in 2016[212]. It is worth noting that the latter deposit has been providing blue sapphires of fine quality resembling and sharing characteristics of the ones from Kashmir[213], and many were identified as Kashmir sapphires by some laboratories[214].

The estimated production profile below (Figure 54) compiles data from different sources, and also assesses the undeclared portion of the production at up to 70%, which may be on the low side, considering that the World Bank estimated that the country realised 5% or less of the revenue from its sapphire exports[210]. The decreases in 2008 and 2009 are related to a rough gemstone ban announced by the government: this was intended to encourage dealers to open cutting factories in the country, but severely impacted artisanal miners trying to make a living in the sector.

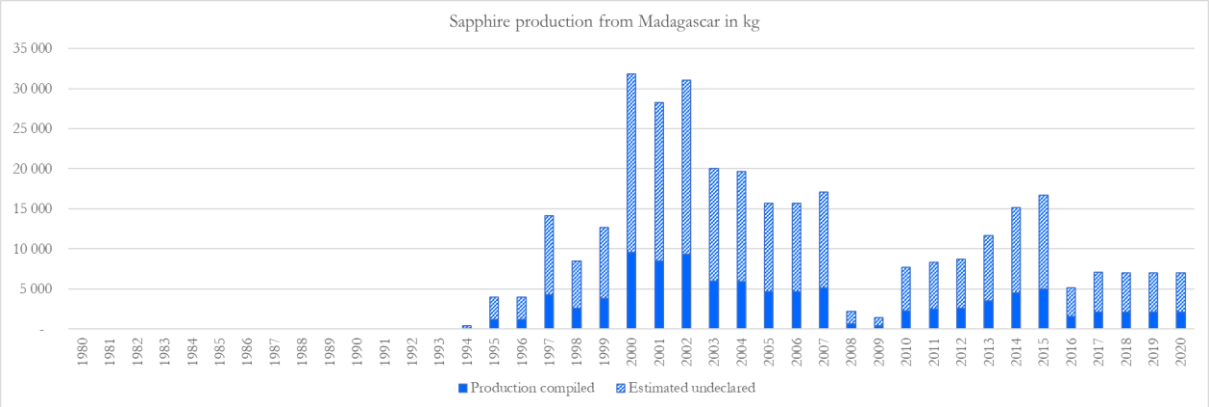


Figure 54: Sapphire production from Madagascar, in kg

[207] Cushman, T. A. (1999). The short life and death of a Sapphire Boomtown. Gems & Gemology, 35, 142.
[208] Michelou J.C., Ed. (2006) ICA 2006 World Gemstone Mining Report. InColor, Spring
[209] Milisenda, C. C., Henn, U., & Henn, J. (2001). New gemstone occurrences in the south-west of Madagascar. Journal Of Gemmology-London-, 27(7), 385-394.
[210] Shor, R., & Weldon, R. (2009). Ruby and sapphire production and distribution: A quarter century of change. Gems and Gemology, 45(4), 236-259
[211] Pardieu, V., & Rakotosaona, N. (2012). Ruby and sapphire rush near Didy, Madagascar (April-June 2012). GIA Research News.
[212] Pardieu, V., Vertriest, W., Weeramonkhonlert, V., Raynaud, V., Atikarnsakul, U., & Perkins, R. (2017). Sapphires from the gem rush Bemainty area, Ambatondrazaka (Madagascar). GIA Research News.
[213] Krzemnicki, Michael S. New Sapphires from Ambatondrazaka, Madagascar. The Journal of Gemmology, 2017, vol. 35, no 5, p. 391-393.
[214] https://eighthdimensiongems.com/origin-opinions

b) Sapphire Trade Flows

Madagascar is an important producer of gemstones other than rubies and sapphires, such as amethysts, tourmalines and garnets. The vast majority of its gemstone exports fall under the category of 'precious stones unworked', therefore no direct inferences can be made regarding rubies and sapphires (Figure 55). Overall, the total value for exported, unworked gemstones has increased over the years and has been at a yearly average of $15.6M since 2011, with the exception of a massive increase reported in 2022. In 2001, total exports of all gemstones other than diamonds, unworked and worked, was $9.4M[215]. However, annual production was estimated to be $400M, meaning that only 2% of the production value was declared[216]. The drop in exports in 2008 and 2009 is related to a ban on rough exports declared by the government in February 2008, which was subsequently lifted in July 2009. This ban was decided by the president at the time, in response to the export of a 536kg emerald named 'Heaven's Gift Emerald', which he described as illegal[217].

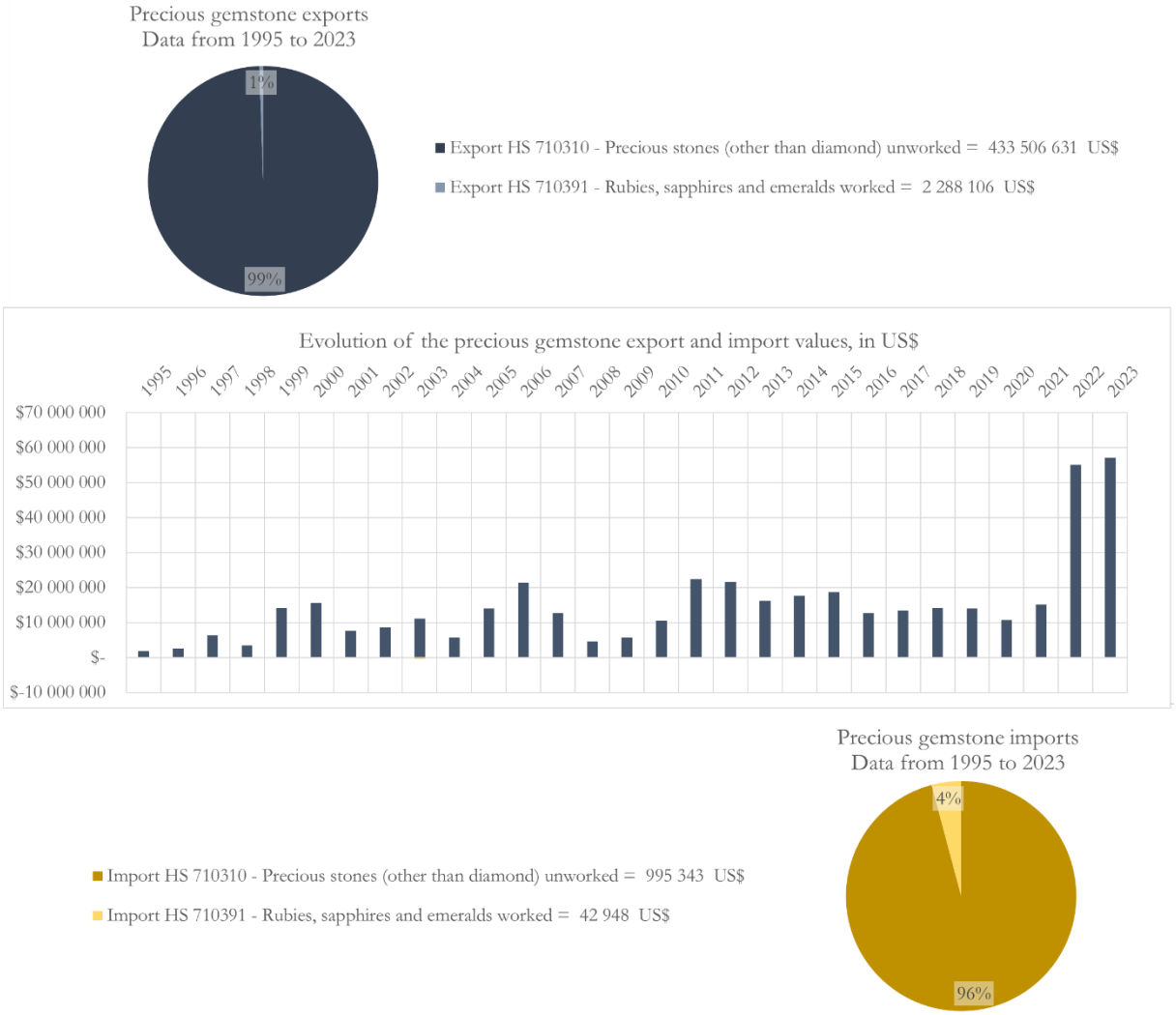


Figure 55: Precious gemstones imports and exports values from Madagascar

[215] UN Comtrade

[216] Van der Wal, S., & Haan, E. D. (2010). Rough Cut: Sustainability Issues in the Coloured Gemstone Industry. Available at SSRN 1557705.

[217] Shor, R., & Weldon, R. (2010). An Era of Sweeping Change in Diamond and Colored Stone Production and Markets. Gems & Gemology, 46(3).

5. Myanmar

a) Sapphire Production

Myanmar's rubies and sapphires both mostly come from the Mogok area, a famous 'land of gemstones'. Mogok is renowned for its exceptional blue sapphires, often of large size. However, other sapphire colours are also produced. The widespread presence of rutile 'silk' entails significant production of star sapphires as well. Gemstone production from the Mogok Stone Tract has centuries of history, and it is believed that blue sapphires were once mined in places like Bernardmyo and Changyui. Around 2008, Baw Mar, a new location in the Mogok Stone Tract, started to produce large quantities of blue sapphire[218], causing an increase in production which is depicted in the profile presented below. Sapphire production volumes are intrinsically linked to ruby mining activities, and also to the political and economic context, as discussed in the 'Myanmar – Ruby production' section.

It should also be noted that pink sapphires must be produced from the ruby operations, therefore Mong Hsu must also produce significant volumes of sapphires.

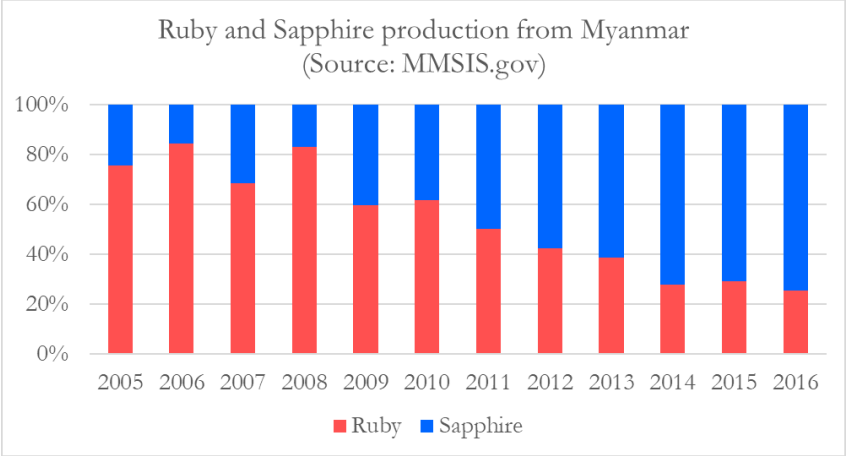


Figure 56: Share of ruby and sapphire production in Myanmar

It remains a challenge to assess the volumes of Myanmar sapphire production, both historic and current, because the area is restricted and official reports are hard to come by. In 1992, Kane explained that the nationalisation (in 1963) of the mines contributed to a massive gap in information, although data from 1992 suggests that Mogok was going through a peak of activity and production at the time[219]. An article by Hughes mentioned that sapphires would form only 10% to 20% of the total output of production in Mogok[220]. This correlates with the Myanmar Statistical Information Service data (MMSIS) until 2009, when

[218] Kan-Nyunt, H. P., Karampelas, S., Link, K., Thu, K., Kiefert, L., & Hardy, P. (2013). Blue Sapphires From The Baw Mar Mine In Mogok. Gems & Gemology, 49(4).
[219] Kane, R. E., & Kammerling, R. C. (1992). Status of ruby and sapphire mining in the Mogok Stone Tract. Gems and Gemology, 28(15), 274.
[220] https://www.lotusgemology.com/index.php/library/articles/287-burmese-sapphire-giants

the trend started to reverse (Figure 56). This is explained by the significant decrease in ruby production due to the depletion of resources, whereas production of sapphires remained steadier.

The Natural Resource Governance Institute (NGRI) report of 2018 estimates that between 60% to 80% of Myanmar's gemstones are undeclared[15]. Another source mentioned that the joint-venture system implemented in 1990 must have drastically reduced smuggling, whereas prior to this the country might have had control of only 5% of its production[221]. Indeed, data prior to 1990 was much more sporadic and harder to find. The production profile (Figure 57) is a compilation from bibliography, USGS mineral yearbooks, statistics from Myanmar[222, 223] and other sources like Pala Gems[224]. Based on bibliography and expert opinions, the 'estimated undeclared' production was considered to be 95% up to 1995, 25% between 1995 and 2014, and 60% after 2014. The decrease in production observed since 2010 can be explained by the depletion of the deposits, as well as by an increase in privately-owned mines, which are not obliged to report production[225].

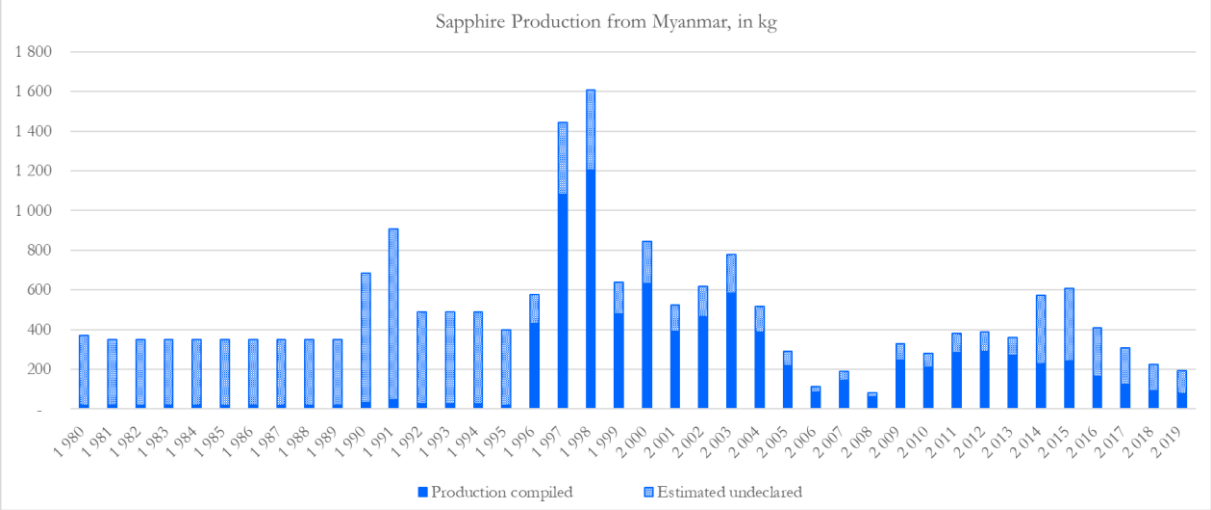


Figure 57: Sapphire production from Myanmar, in kg

It is worth mentioning that Myanmar uses an April-to-March fiscal year, so the fiscal year figures have been allocated to the end of the calendar year (for example figures from fiscal year 2007-08 are reported under the year 2008).

b) Sapphire Trade Flows

One cannot discuss gemstone trade flows from Myanmar without mentioning political issues. Human rights abuses and the involvement of the military in the gemstone sector have given Burmese gemstones a bad name, leading to international sanctions. In 2003, the USA declared a ban on the imports of all gemstones from Myanmar. In 2008, this was extended to all ruby and jadeite originating from Burma, regardless of the country of export (or the processing country in which the material had been worked/polished). The ban was officially lifted in 2016 but, in 2021, after the military coup, sanctions were re-implemented against three

[221] Kammerling, R. C., Scarratt, K., Bosshart, G., Jobbins, E. A., Kane, R. E., Gübelin, E. J., & Levinson, A. A. (1994). Myanmar and its gems—an update. Journal of Gemmology, 24(1), 3-40.
[222] http://mmsis.gov.mm/
[223] https://myanmareiti.org/en/publication-category/meiti-reports
[224] http://www.palagems.com/gem-news-burma-stats
[225] Newman, M. (2018). Multifaceted: Governance and Conflict Risks in Myanmar's Ruby Industry. Natural Resource Governance Institute

Myanmar-based gem-producing companies. Considering that it is still difficult to assess the country of origin of a gemstone (laboratories only provide opinions, rather than proof), such sanctions are hard to implement, and some will argue that the sanctions encourage smuggling, and negatively affect local people trying to make a living from this sector, rather than effectively punishing the country's political decisions. The UN Comtrade information below (Figure 58) is believed to be heavily influenced by data referring solely to the trade in jadeite jade.

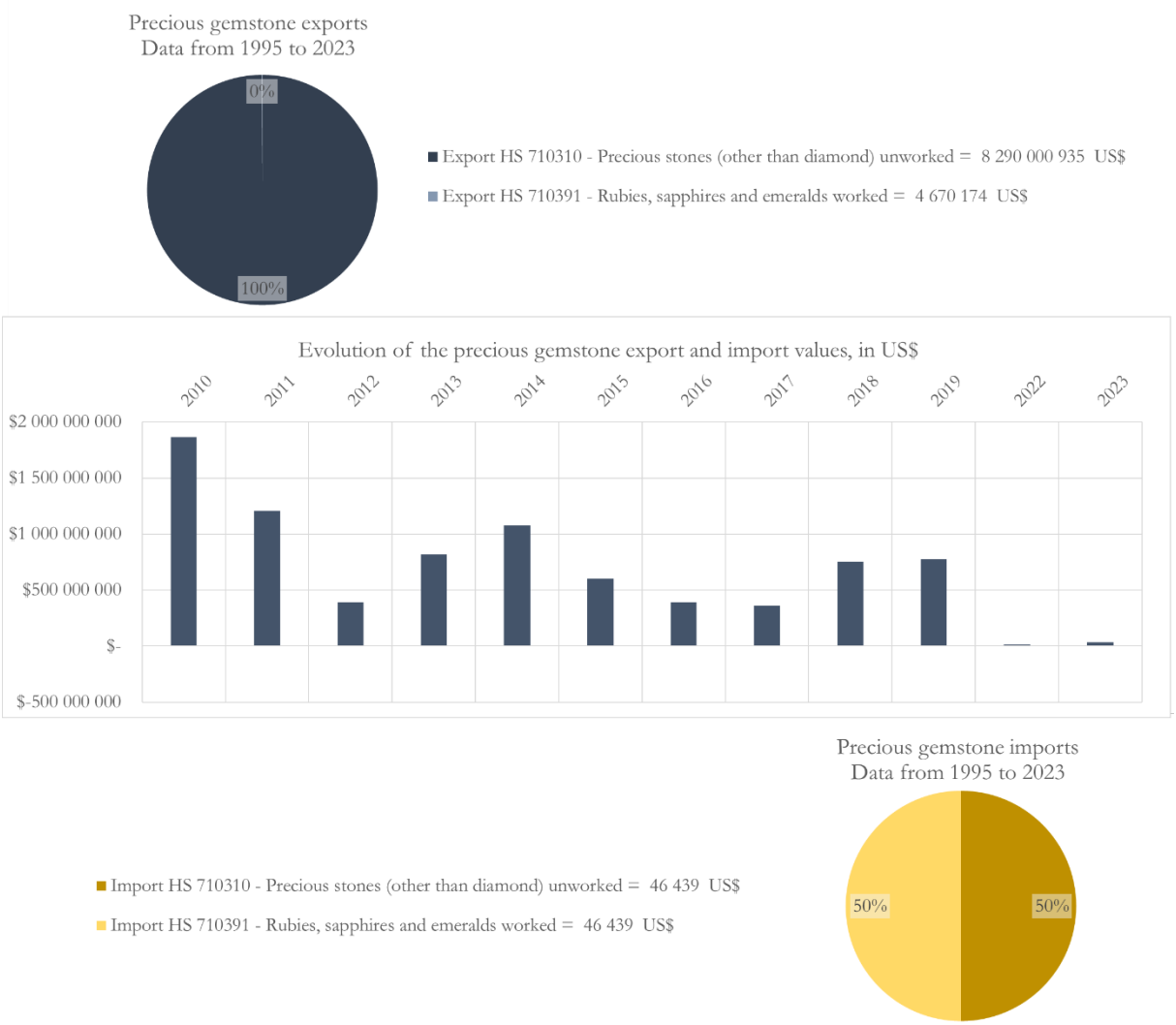


Figure 58: Precious gemstones imports and exports values from Myanmar

Please refer to the section 'Myanmar - Ruby trade flows' for more information about Myanmar's gemstone exports.

Another important issue regarding Burmese sapphires is the difficulty in determining geographical origin for blue sapphires. This is especially true when it comes to distinguishing between blue sapphire of metamorphic origin from Myanmar, Sri Lanka and Kashmir.[226]. Burmese sapphires are usually higher in price than Sri Lankan ones, which means there is a possibility that many blue sapphires sold as Burmese on the market have actually come from Sri Lanka.

[226] https://lotusgemology.com/index.php/library/articles/459-world-sapphire-market-update-2020-lotus-gemology

6. Sri Lanka

a) Sapphire Production

Sri Lanka has one of the longest-known gemstone production histories, with early records dating as far back as 334 BCE[227]. Sri Lanka not only produces sapphires, it is also the source of many other gem-quality minerals. It is believed that 25% of the surface of Sri Lanka is gem-bearing.

Mining here is fairly straightforward, because most deposits are secondary alluvial and eluvial, of metamorphic origin[228]. The sapphire deposits yield well-rounded gemstones, indicative of long weathering and transport processes. The sapphires are typically found in gravel beds lying between 3m to 25m deep[227, 229]. Although all mining operations are small-scale (as decreed by the government), the island's historic mining traditions follow well-established procedures. The government's policy is to keep mechanisation levels in the sector low. This has enabled the country to consistently employ large numbers of people: there were approximately 65,000 mine-workers in 2014[229]. Sri Lanka's principal mining industry is based upon pit-mining. This involves digging vertical shafts, stabilised with wooden framework, to reach the gravel beds which contain the gemstones[229]. Surface mining also occurs[227], but this is less common: for example, in 2013, more than 90% of gem mining licenses were issued for pit mining[229].

The two main sapphire producing areas are Ratnapura and Elahera. Ratnapura is the most productive and is considered to be the gemstone trading centre of the country. Archaeological research suggests that Elahera was an active area for gemstone mining many centuries ago, before being forgotten. Sapphires from Elahera started to reach the market again in the 1950s after being rediscovered by construction workers[230]. Two other gem-bearing areas worth mentioning are Tissamahorama[227], and Okkampitiya[231].

Sri Lanka is famous for its 'Ceylon sapphires', a term which traditionally evoked very high-quality blue sapphires, but which is used nowadays as a trade description for any sapphire produced in Sri Lanka, regardless of quality. 'Ceylon' was the former colonial name of Sri Lanka until 1972. Sri Lanka produces every colour of sapphire, but two are the most important in terms of market value: blue and 'padparadscha' (orange-pink). The famous Ceylon blue sapphires are reported to be mostly mined from the Elahera region[232]. The best shade of blue is called 'cornflower blue'. Sri Lanka is known for producing large quantities of low-quality greyish material ('geuda' sapphires), which used to be difficult to sell but which are now known to react well to heat-treatment, which turns the greyish stones into commercially-viable blue sapphires. There are various rumours around the creation and development of heat treatments, but Thai dealers are known to have started purchasing this low-quality material from Sri Lanka in the 1970s, to be

[227] Zwaan, P. C. (1982). Sri Lanka: the gem island. Gems and Gemology, 18(2), 62-71.
[228] Dissanayake, C. B., & Rupasinghe, M. S. (1995). Classification of gem deposits of Sri Lanka. Geologie en Mijnbouw, 74, 79-79.
[229] Lucas, A., Sammoon, A., Jayarajah, A. P., Hsu, T., & Padua, P. (2014). Sri Lanka: Expedition To The Island Of Jewels. Gems & Gemology, 50(3).
[230] Gunawardene, M. & Rupasinghe, M. (1986). The Elahera Gem Field In Central Sri Lanka. Gems & Gemology, 81.
[231] Herath, J. W. (1984). Geology and occurrence of gems in Sri Lanka.
[232] https://www.srilankabusiness.com/gem-diamond-and-jewellery/about-sri-lanka-gems/ceylon-sapphire.html

exported and heat-treated in Thailand[233]. It took about two decades for the Sri Lankan market to adapt and implement the treatment processes within the country[234]. Nowadays, Sri Lanka is probably the most important centre in the world for sapphire treatment, cutting and polishing.

Sri Lanka is one of the few countries in the world to have devoted significant government effort to actively develop the gemstone sector. In 1971, the State Gem Corporation (SGC) was created to promote and regulate the market[231, 235]. The SGC became the authority issuing mining and trading licenses, which helped to reduce the illegal export of gemstones. Indeed, Zwaan indicates that annual reported figures before 1960 might have represented only 10% of actual production[227]. The SGC also enabled the development of a strong beneficiation industry by training cutters[236]. In 1993, the National Gem and Jewellery Authority (NGJA) took over the SGC[237]. One interesting aspect of Sri Lanka's governance is the strict ban on foreign companies and investors. A change in import policy in the 1990s was another industry milestone. This allowed Sri Lankans to import gemstones from other countries for processing; previously, only domestically-mined product had been allowed. Consequently, many Sri Lankan buyers started to establish themselves in other producing countries, mainly in Africa, importing sapphires to be treated and cut in Sri Lanka. Nowadays, the NGJA promotes Sri Lanka as a destination with traditional, ethical mining methods, minimal accident numbers and environmentally-friendly operations[238].

Although Sri Lanka has had a government body regulating the sector for over 50 years, production numbers remain difficult to obtain, and all quantities reported by the government are for export, rather than production. One article from 1986 estimated that the Elahera region contributed 35% of gemstone exports, of which 64% were sapphires, adding up to 15,000kg. The same article mentioned that the numbers from 1980 must have been double this. In 2009, Shor[239] mentioned that the production of blue sapphires in 2006 was 95kg, dropping to 31kg in 2007. This suggests that production has been declining since the 1990s.

USGS data is available from the mineral yearbooks from 1998 to 2021, as well as the Yager report from 2008[240]. The two sets of data are not in agreement, providing completely contrasting pictures (Figure 59). According to the 2008 report, Sri Lanka produced between 2,700kg and 4,000kg per year, increasing between 1995 and 2005. On the other hand, the mineral yearbooks show a much smaller number, with an average of 91kg of sapphires produced between 1998 and 2005, which matches the estimated numbers from articles. The reported quantities exported from the NGJA Export performance reports[241] match the USGS mineral yearbooks for 2017-2021 perfectly (no prior NGJA reports are available). This would suggest that 'sapphire production' reported by the USGS actually refers to export figures. If the exports equalled production, then it would mean that Sri Lanka has produced, on average, 300kg of sapphire per year (ranging from 30kg to more than 700kg per year), amounting to 30% of the total gemstone production from Sri Lanka since 1998.

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233 History of Ruby & Sapphire Heat Treatment, Richard Hughes: https://www.ruby-sapphire.com/index.php/component/content/article/10-articles/830-brief-history-heat?Itemid=101
234 https://www.crescentgems.com/information/reading/heat_treating_gemstones
235 https://ngja.gov.lk/wp-content/uploads/2020/05/1.jpg
236 Shortell, P., & Irwin, E. (2017). Governing the gemstone sector: Lessons from global experience. Natural Resource Governance Institute. UK Department of International Development and Australian Department of Foreign Affairs and Trade.
237 https://ngja.gov.lk/our-history/
238 https://ngja.gov.lk/gems/gemstone-mining-industry/
239 Shor, R., & Weldon, R. (2009). Ruby and sapphire production and distribution: A quarter century of change. Gems and Gemology, 45(4), 236-259.
240 Yager, T. R., Menzie, W. D., & Olson, D. W. (2008). Weight of production of emeralds, rubies, sapphires, and tanzanite from 1995 through 2005. US Geological Survey.
241 https://ngja.gov.lk/corporate_profiles/statistics/

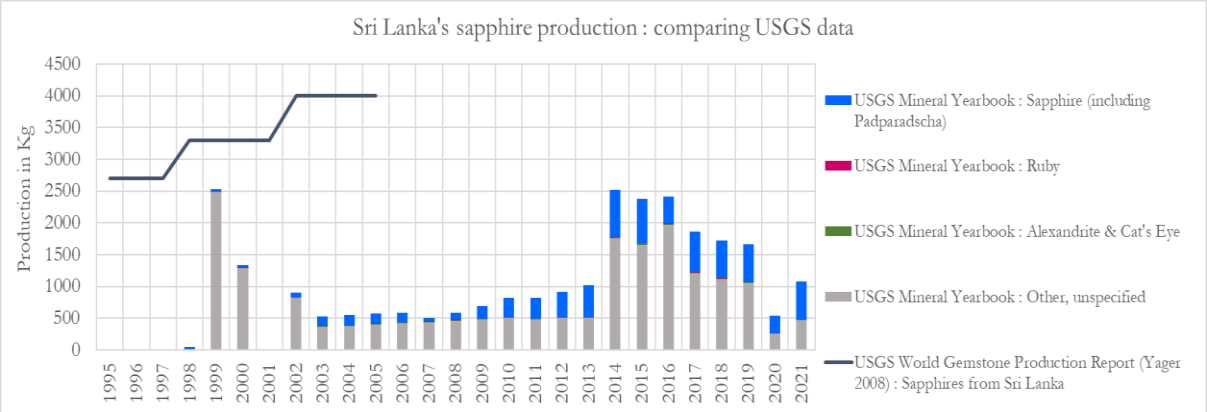


Figure 59: USGS detailed gemstones production data from Sri Lanka

The most commonly-encountered scenario for coloured gemstones is for production and exports to be underestimated, due to artisanal (sometimes illegal) mining activities and also smuggling. The Sri Lankan situation is complex because of its massive imports of sapphires from other countries: in-country production could actually be overestimated. In the production profile (Figure 60), compiled from several data sources, the increase in production from the 2000s could be related to the discovery and development of African deposits.

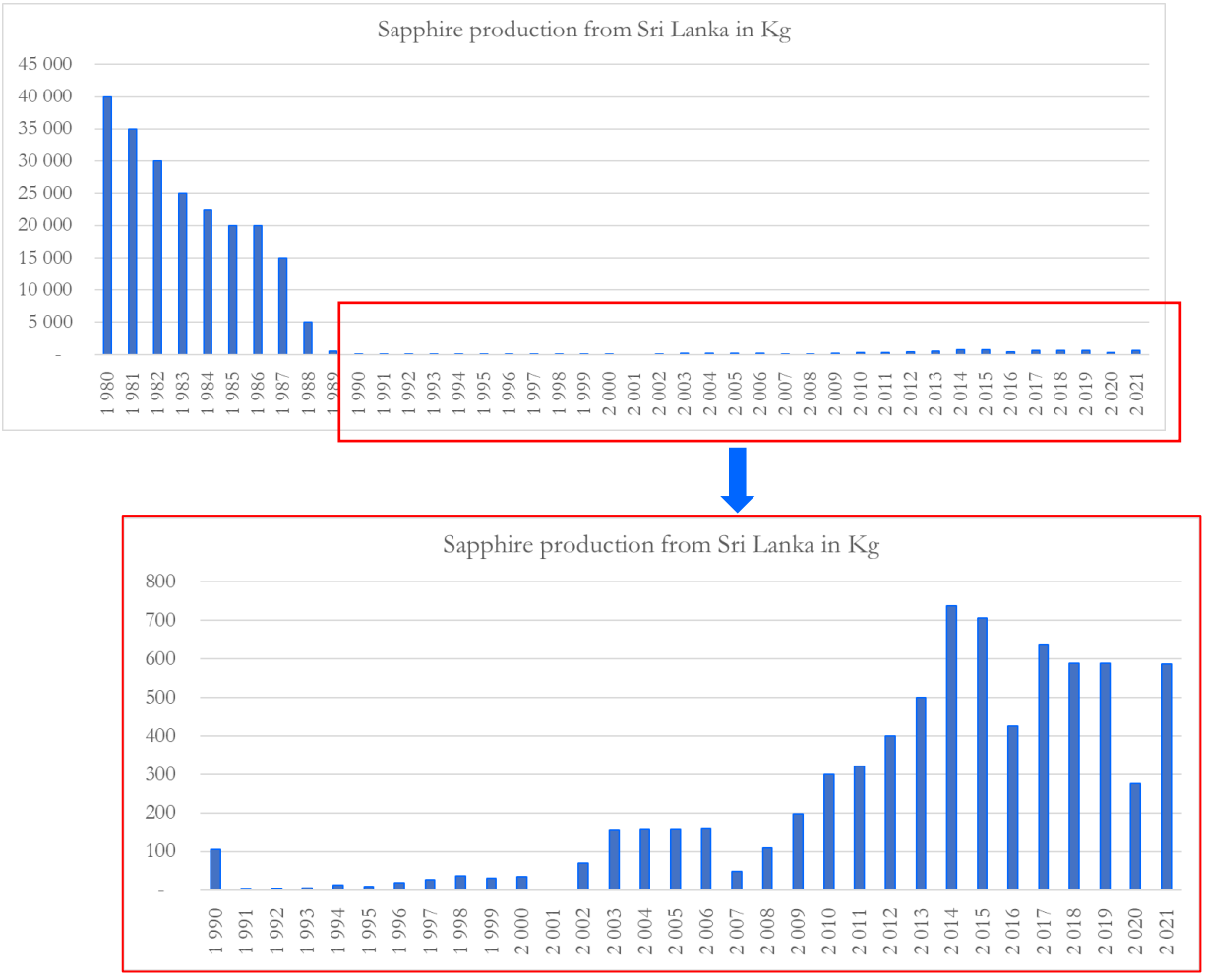


Figure 60: Sapphire production from Sri Lanka, in kg

b) Sapphire Trade Flows

The UN Comtrade data shows that the majority of gemstones are exported under the category HS 710391 ('Rubies, sapphires and emeralds worked'; Figure 61). The trend over the last 30 years shows a strong increase in exports from the early 2000s through 2010, which can be put down to several factors: the creation of the NGJA and, therefore, a reduction in smuggling and enhanced data-capture; the commencement of imports from other countries and, consequently, an increase in gemstone quantities and values in and out of Sri Lanka; and an increase in average gemstone prices over the years. Since 2010, the yearly export value has varied significantly year on year, hovering at around $100M, on average.

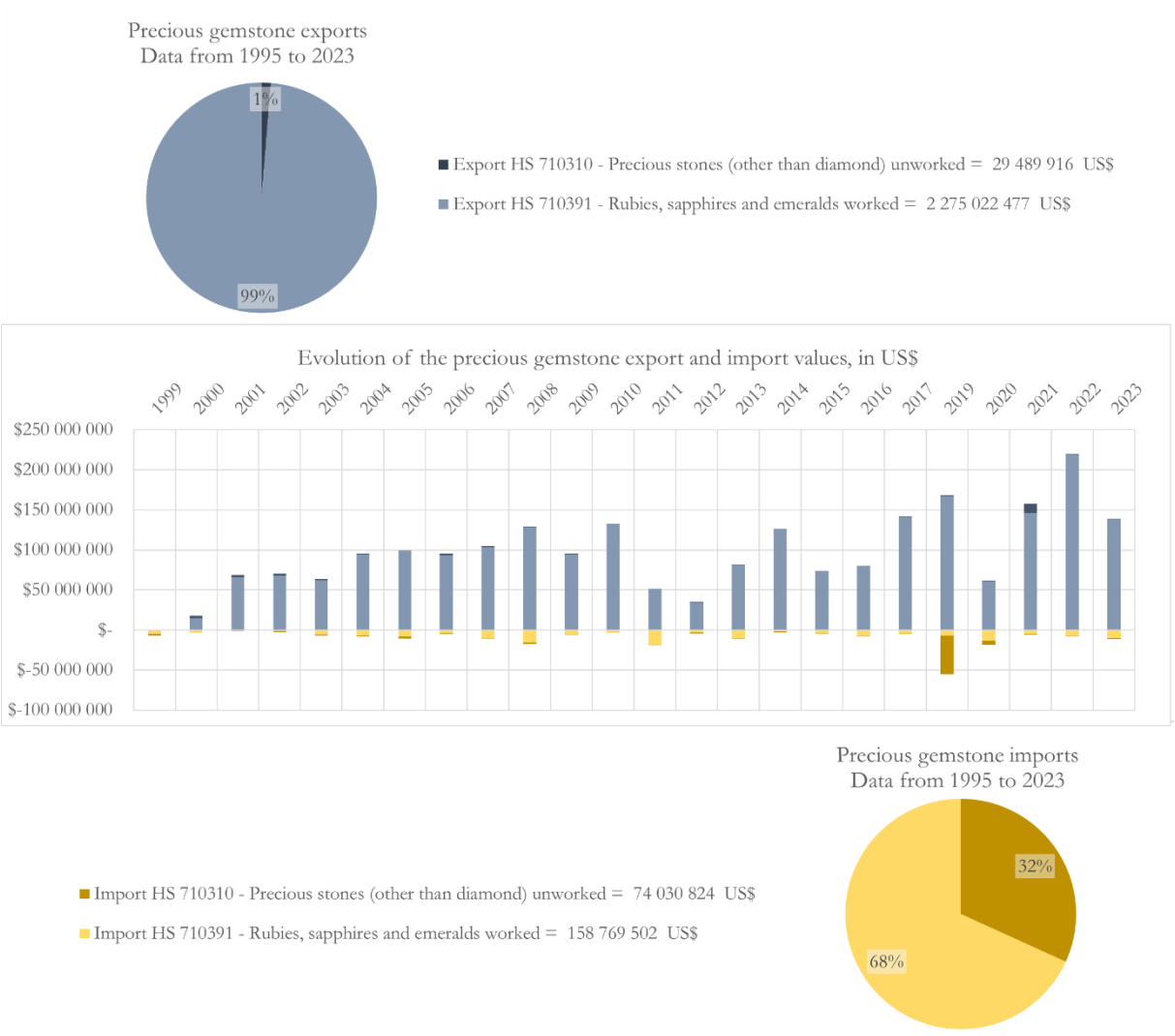


Figure 61: Precious gemstones imports and exports values from Sri Lanka

It should be noted that the import value has remained extremely low over the years, and that almost all imports have been made under the same category of 'worked' gemstones. It is known that Sri Lankan dealers import gemstones to carry out the beneficiation process in the country. Given that production from Sri Lanka cannot explain the massive difference between import and export values on its own, this highlights the importance of the value-addition process. It is also believed that a large proportion of imported gemstones are undeclared.

The NGJA provides another source of information with their 'Export performance reports', which are available online. The reports provide statistics for exports per gemstone between 2017 and 2022[242]. Prior reports were unavailable. The data is reported in both quantity and value and can be broken down by gemstone variety. The analysis in the infographic (Figure 64) shows that blue sapphires account for almost half of the total value of gemstone exports (47%), although they only represent 7% of the quantity exported between 2017 and 2023. All sapphires taken together (blue and other colours) account for 83% of total exports, by value. The available data do not provide details of which gemstones are exported where, but the three major international importers in terms of value are Hong Kong, the USA and Thailand, whereas India, Thailand and China are the most important countries with regard to quantity.

The average price-point, measured in US dollars per carat, shows that padparadscha sapphires are almost three times more valuable than blue sapphires (Figure 62). However, they only account for a tiny proportion of exports (0.13% of all sapphires exported). Their price has also varied greatly over the most recent five years, whereas blue sapphire prices have remained steadier, at an average of around US$ 140/ct.

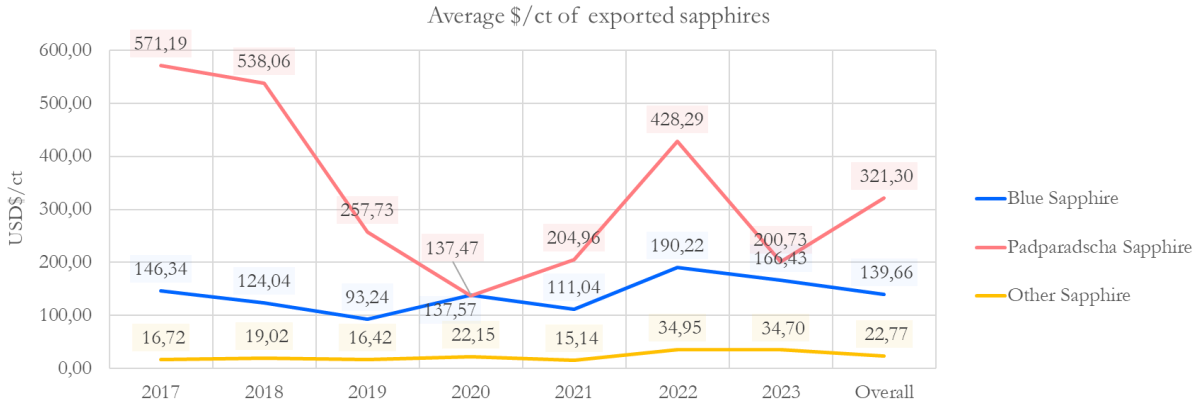


Figure 62: Unit prices of exported sapphire

The Sri Lankan Export Development Board (EDB) provides an online database for trade flow data to and from Sri Lanka, following HS codes, hereby referred to as EDB Trade Statistics[243]. The values from the EDB are reported in both carats and Sri Lankan rupees (LKR). A conversion rate for each year was used to convert the LKR into USD. The EDB data and the UN Comtrade data are very similar, except for two years: 2010, for which The UN Comtrade is much higher, and 2018, which is missing in UN Comtrade (Figure 63).

Both EDB data and NGJA export performance reports are issued by governmental bodies of Sri Lanka, but the values do not match and can have significant differences, such as in the year 2019.

[242] https://ngja.gov.lk/corporate_profiles/statistics/
[243] https://www.srilankabusiness.com/edb/trade-statistics.html

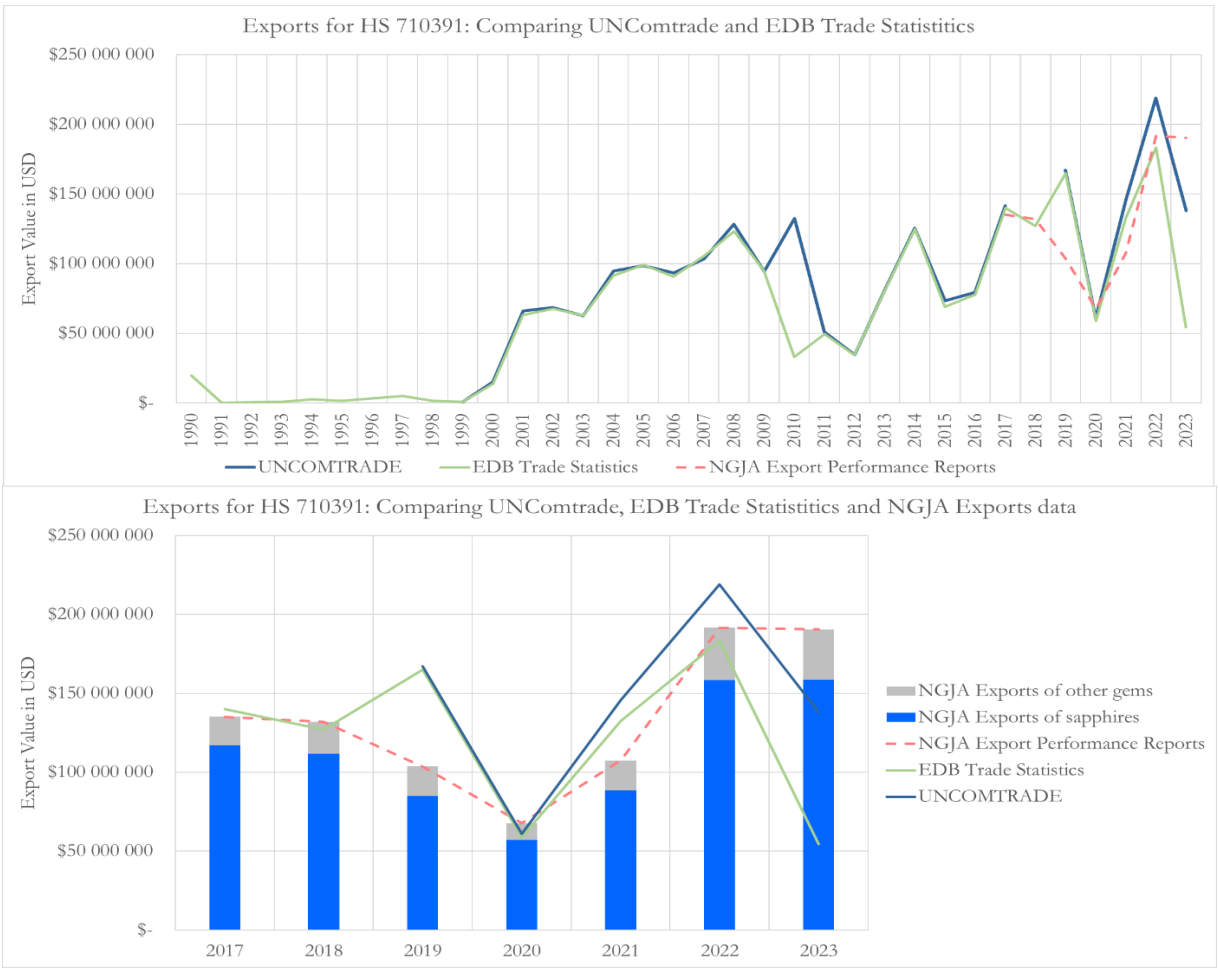


Figure 63: UN Comtrade exports compared to NGJA and EDB exports

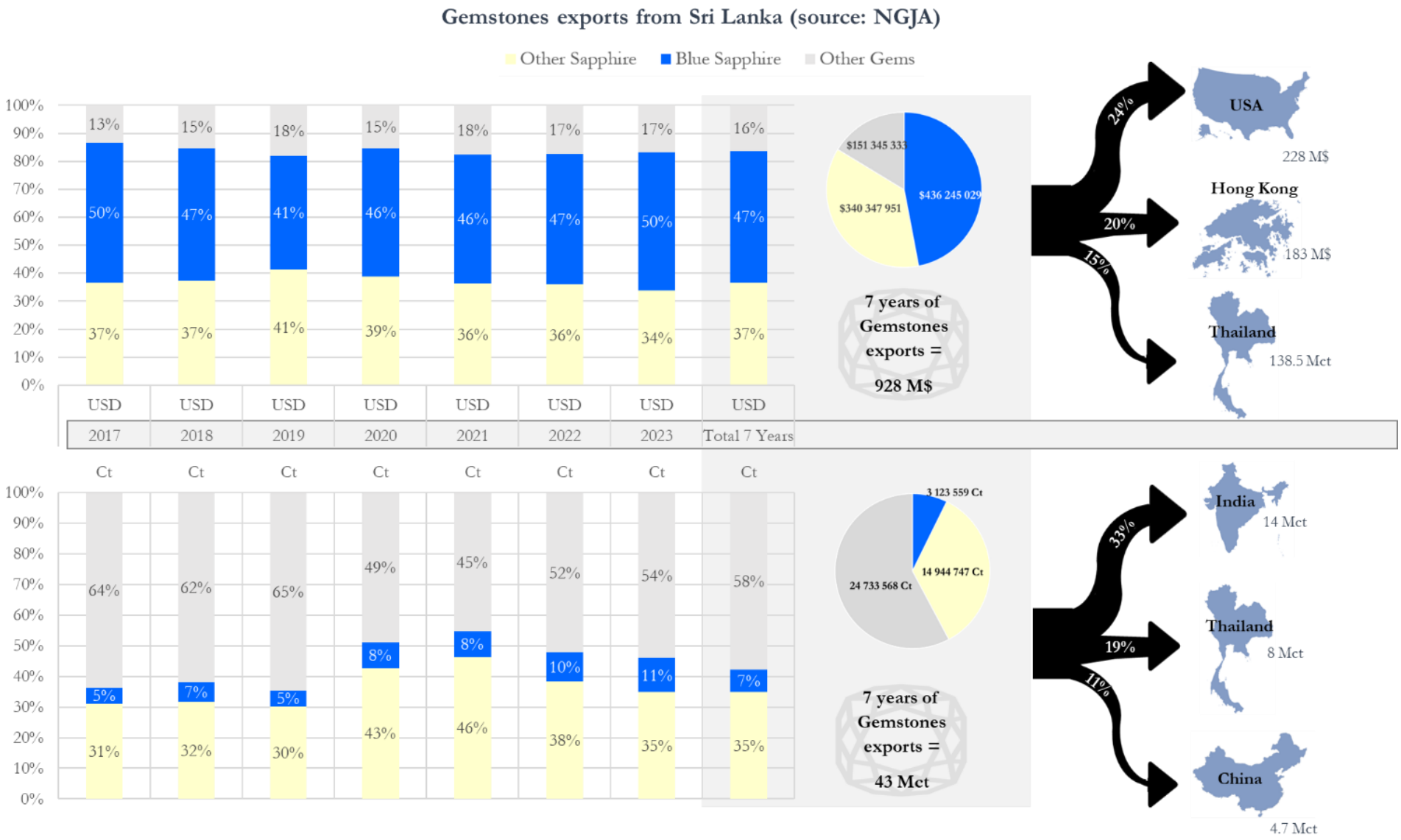


Figure 64: Sri Lanka infographic

7. Thailand

a) Sapphire Production

Thailand has been an important source of gem corundum since the 19th century. The main deposits are in the Chanthaburi-Trat area, close to the Cambodian border. Mining activity in Thailand was particularly strong in the 1960s due to a slowdown in production from Myanmar and Cambodia, related to their political issues[244].

Most of the sapphires mined come from the western and central zones of Chanthaburi-Trat province, rarely from the eastern zone. It has been reported that production in 1980 was estimated at 8 tonnes of rubies and sapphires[245]. Considering that sapphires represent about 90% of the global production of gem-corundum (an observed ratio from the USGS data[246]), then the estimated production for the early 1980s is about 7 tonnes (Figure 65).

Kanchanaburi is the second province where sapphires have been found in Thailand, more specifically in the Bo Phloi district. Mining activity intensified in the 1980s, with the development of mechanised operations. The sapphires recovered are mainly blue, with small quantities of green and yellow[247]. In 1996, activity at the main mining site was still ongoing, producing between 200g and 2kg per day[248]. In 2015, this mine was closed, and replaced by a tourist attraction including a lake in the former open pit, a golf course and a holiday resort. The production of blue and fancy-colour sapphires from the area has massively decreased[249], and only small mining operations remain[250].

[244] Saeseaw, S., Sangsawong, S., Vertriest, W., Atikarnsakul, U., Raynaud-Flattot, V. L., Khowpong, C., & Weeramonkhonlert, V. (2017). A study of sapphire from Chanthaburi, Thailand and its gemological characteristics. GIA Research News.
[245] Keller, P. C. (1982). The Chanthaburi-Trat gem field, Thailand.
[246] Yager, T. R., Menzie, W. D., & Olson, D. W. (2008). Weight of production of emeralds, rubies, sapphires, and tanzanite from 1995 through 2005. US Geological Survey.
[247] Kammerling, R. C. (1990). 'Gem News: Update on sapphire mining in Kanchanaburi.' Gems & Gemology, 26 (4): 302-303.
[248] Kammerling, R. C. (1996). 'Sapphire mining in Kanchanaburi'. Gems & Gemology, 32 (2): 134-135.
[249] Leelawatanasuk, T., Sripoonjan, T., Susawee, N., Wathanakul, P., & Pisutha-Arnond, V. (2017). Rare Fancy Sapphires from Bo Phloi Gem Field, Kanchanaburi, Western Thailand. In Proceedings of the 35th International Gemmological Conference (IGC 2017), Windhoek, Namibia (pp. 156-158).
[250] Atichat, W., Promwongnan, S., Saengbuangamlam, S., Pisutha-Arnond, V., Leelawatanasuk, T., Maneekrajangsaeng, M., ... & Buathong, A. Review of Rubies and Sapphires from Chanthaburi-Trat and Kanchanaburi Gem Fields, Thailand.

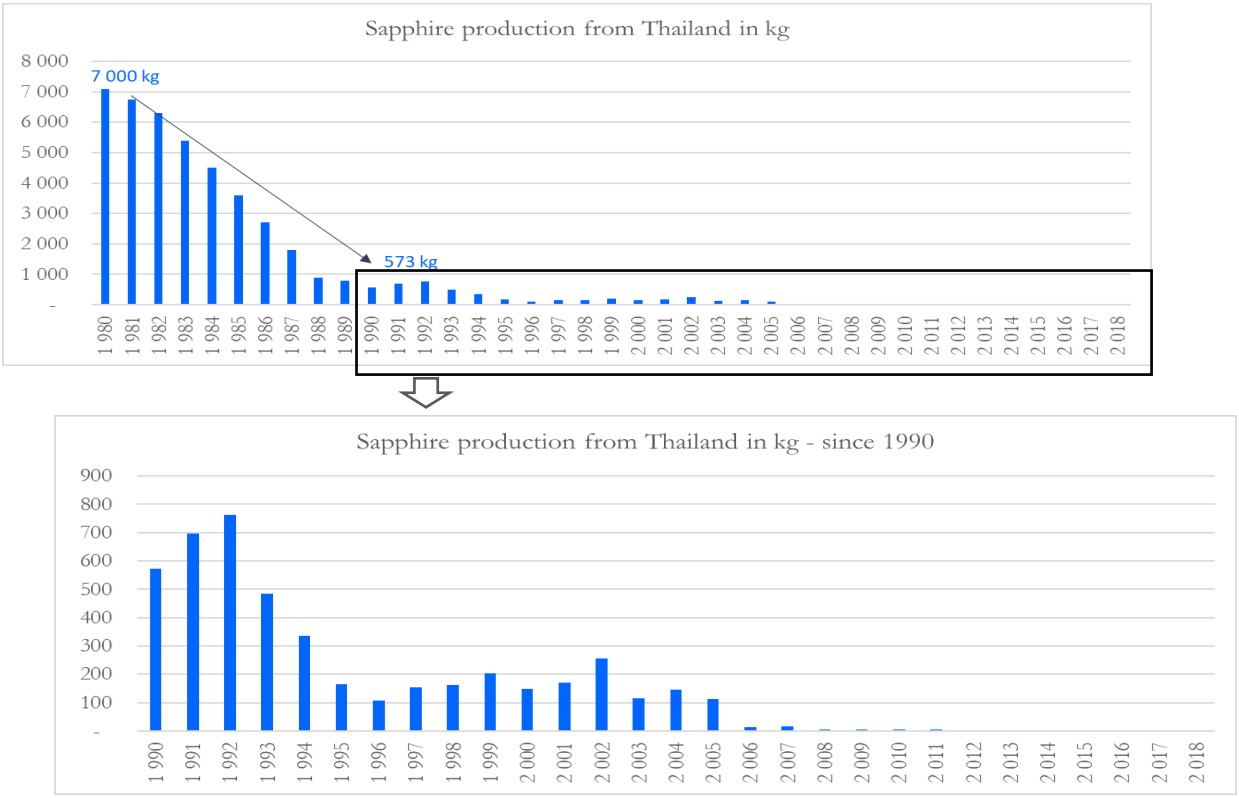


Figure 65: Sapphire production from Thailand, in kg

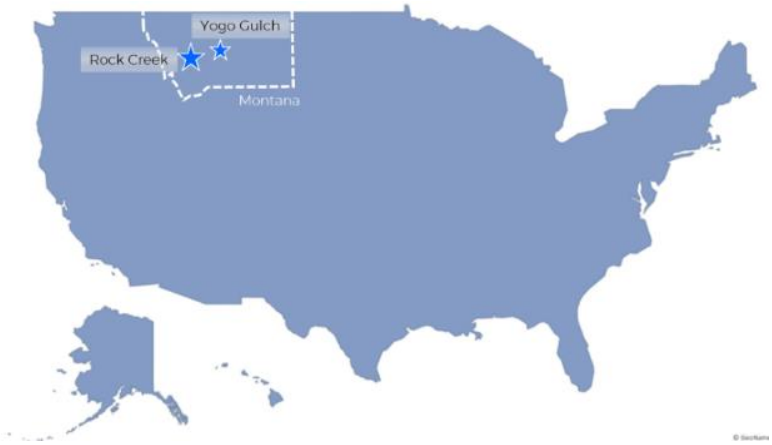
b) Sapphire Trade Flows

The section 'Thailand – Ruby trade flows' already presented information regarding gemstone flows in and out of Thailand, including sapphires, and the information will therefore not be repeated here.

However, one important addition to the above is to mention that Thailand has developed as a major trading, treatment and cutting centre for sapphires. Data from the Sri Lankan authorities (NGJA) shows that Thailand is the second main importer of gemstones from Sri Lanka, in terms of quantity, and third most important in terms of value. Expert opinions also suggest that large quantities of Australian sapphires were sold as Thai between the 1960s and the 1970s[251]. In the 1970s, Thai dealers started to source low-quality sapphires from Sri Lanka for heat-treatment[252]. The same dynamic applied to production from the south of Tanzania (Songea-Tunduru area), where mining activities were given a boost in 2002, when Thai dealers sourced sapphires that were suited to the new beryllium diffusion treatment[253]. A report from 2020 suggests that most sapphires in Thailand originate from Madagascar and transit via Sri Lanka[254]. The high-profile presence of Sri Lankan and Thai dealers in corundum-producing African countries supports this hypothesis.

[251] https://www.gia.edu/UK-EN/gia-news-press/gem-gathering-bangkok-may-2015
[252] History of Ruby & Sapphire Heat Treatment, Richard Hughes: https://www.ruby-sapphire.com/index.php/component/content/article/10-articles/830-brief-history-heat?Itemid=101
[253] Chitty, W. (2009). A study of sapphires and rubies from Tanzania's Tunduru district (Doctoral dissertation, Kingston University, London).
[254] A Rough Cut Trade: Africa's Coloured-Gemstone Flows to Asia. Hunter M. Lawson L. (2020) Research report Global Initiative Against Transnational Organized Crime

9. *USA*



The United States of America produces many gemstones, including the famous Montana sapphires. Sapphires in this state are found in four main deposits: namely Rock Creek, Missouri River, Dry Cottonwood Creek and Yogo Gulch. The latter is the only primary deposit, while the other three are all alluvial and located close to each other. In order to differentiate between the two types of sapphires, the alluvial ones are often referred to in the market as 'Montana sapphires', whereas those from Yogo are referred to as 'Yogo sapphires'.[255]. Sapphires from Montana occur in a large colour palette, including pink, orange, lavender, yellow, green and blue.

Sapphires in Montana were discovered at the end of the 19th century, and were extensively mined up until the early 1940s, mostly for industrial use, such as watch manufacturing.[256]. Between 60 and 70 tonnes of sapphires were recovered during that period, of which production from Rock Creek represented more than 85% of the total.[257]. After that, the area was only mined sporadically up until the 1990s, mainly for local jewellery and tourist fossicking (searching for gemstones by hand). Indeed, only about 15% of the production resulted in marketable colours.[258]. The development of heat-treatments enabled the deposits to become economical, by increasing the percentage of marketable colours to 80%.[259]. The majority of sapphires from Montana require treatment, and the gems are mainly of small sizes, below 1ct. In terms of production, 89kg were reported yearly between 1989 and 1991, and 800kg of gem-quality sapphires were mined from 1994 to 1996[257]. In 2011, Potentate Mining purchased its first land in Rock Creek, followed by a second acquisition in 2014. In 2014, they reported recovering 10kg of sapphires.[260].

For the purposes of this report, Montana's production has not been added to the global estimated supply of sapphires, because it has been sporadic, and quantities have been small over the last 40 years. However, Montana represents an interesting source of sapphires, because local miners are able to produce consistent quantities and bring them to market with a short-supply-chain business model, using responsible practices.

[255] Zwaan, J. C., Buter, E., Mertz-Kraus, R., & Kane, R. E. (2015). Alluvial Sapphires From Montana: Inclusions, Geochemistry, And Indications Of A Metasomatic Origin. Gems & Gemology, 51(4).
[256] Emmett, J. L., & Douthit, R. (1993). Heat Treating The Sapphires Of Rock Creek, Montana. Gems & Gemology, 29(4), 250-272.
[257] Berg, R., (2014) Sapphires in the southwestern part of Rock Creek sapphire district, Granite country, Montana. Montana Bureau of Mines & Geology. Bulletin 135.
[258] Boyd, W., & Barron, K. (2015). Update on Rock Creek Sapphire deposit. Gem News International. Gems & Gemology. Summer 2015. p215
[259] Barron, K. M., & Boyd, W. F. (2015). The Rock Creek Sapphire Mine of Montana–A new era. InColor Spring (28), 2-12.
[260] http://www.potentatemining.com/rock-creek-montana-sapphires-new-age-mining-begins/

10. Other African Countries

a) Nigeria

Nigeria has never been a major producing country for sapphires, but sapphires from Nigeria have been reported to have reached the market in the past 50 years.

The first sapphires were supposedly discovered in the late 1960s to early 1970s in Kaduna province, in the central region of Nigeria. However, these first gemstones were too dark, and it was only in the mid-1970s that they started to appear on the market, with a significant increase from 1984[261, 262]. This period could be related to the beginning of mining operations in the Mambilla Plateau (Taraba state), although the deposit's discovery and activity are poorly-documented[263]. Mambilla Plateau was also the site of a better-known discovery of sapphires in early 2013[264], which produced blue sapphires of good quality and size, although almost all them required treatment[265]. In 2017, operations in this area were still reported to be active and growing, with the installation of more mechanised and organised operations (washing plant, grading system, etc.)[266]. The same year, sapphires coming from new sources around Antang and Gombe were also reported[267].

All the sapphire deposits in Nigeria are basalt-related, comparable to Australian deposits[261], and produce the usual associated range of colours (blue, yellow and green). The development of heat treatments has helped sapphires from Nigeria to reach the market.

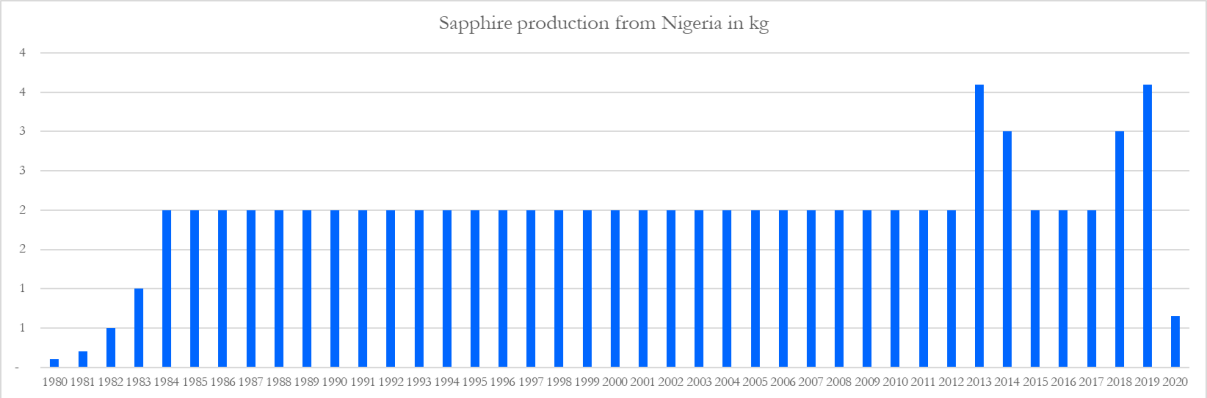
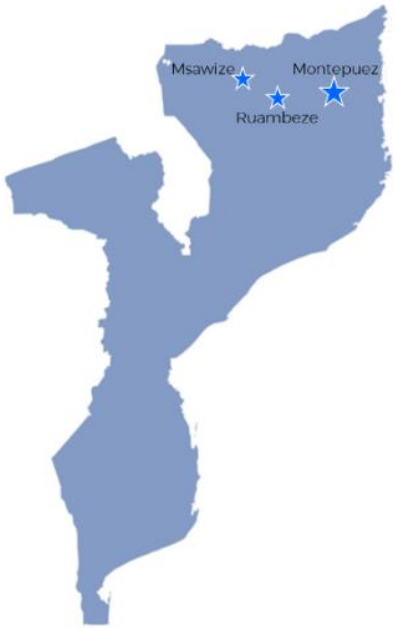


Figure 66: Sapphire production from Nigeria, in kg

[261] Kanis, J., & Harding, R. R. (1990). Gemstone prospects in central Nigeria. J Gemmol, 22, 195-202
[262] Kiefert, L., & Schmetzer, K. (1987). Blue and yellow sapphire from Kaduna Province, Nigeria.
[263] Olade, M. A. (2021). Gemstones of Nigeria: An Overview of Their Geological Occurrence, Provenance and Origin. Achievers Journal of Scientific Research, 3(1), 1-22
[264] Oruonye, E. D. (2015). Socio-economic impact of artisanal mining of blue sapphire on the Mambilla Plateau. Research on Humanities and Social Sciences, 5(1), 54-61
[265] Pardieu, V., Sangsawong, S., Muyal, J., & Sturman, N. (2014). Blue sapphires from the Mambilla Plateau, Taraba State, Nigeria. A preliminary exploration. GIA News from Research, GIA Laboratory Bangkok.
[266] Tourmaline and sapphire from Nigeria. Gems & Gemology Gem News International, Spring 2017, p134
[267] Yellow, green, and blue sapphires reportedly from Antang and Gombe, Nigeria. Gems & Gemology Gem News International, Fall 2017, p380

Production statistics have been reported by Nigeria's National Bureau of Statistics for 2016, and for 2019 to 2021. These quantities vary from 100g to 2kg per year[268]. Interestingly, production is reported from Plateau state, and not Kaduna nor Taraba. It is estimated that 95% of gemstone production from Nigeria comes from illegal activities by artisanal and small-scale miners[264], with more than 80% of production leaving the country undeclared. The gemstones are smuggled out of the country by foreign traders, mainly from Senegal, Mali[261] and Cameroon[267].

b) Mozambique



Because rubies and sapphires are the same mineral, with colour being the only difference between them, every ruby deposit will also provide sapphires. At Montepuez Ruby Mining, sapphires account for between 40% to 60% of production, and it is believed that this ratio is applicable to other mines and ASM production. Sapphires from northern Mozambique are mostly pink, orangy or near-colourless.

For the history of the mines, please refer to the Mozambique section in the 'Global Supply of Ruby' chapter.

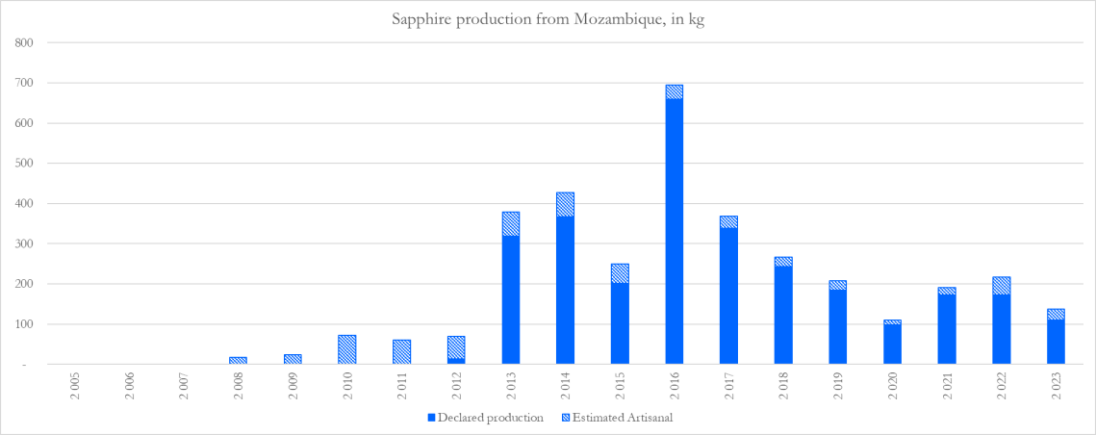


Figure 67: Sapphire production from Mozambique, in kg

268 https://nigeria.opendataforafrica.org/zdejvjb/mining-and-quarrying-solid-minerals-production-output-in-tons-2016

c) Malawi

Sapphires from Malawi come from the Chimwadzulu mine, which supplies rubies and sapphires. Sapphires represent 70% of the mine's gem production and include padparadscha, pink, orange and lavender.[269].

For the history of the mine, please refer to the Malawi section in the 'Global Supply of Ruby' chapter.

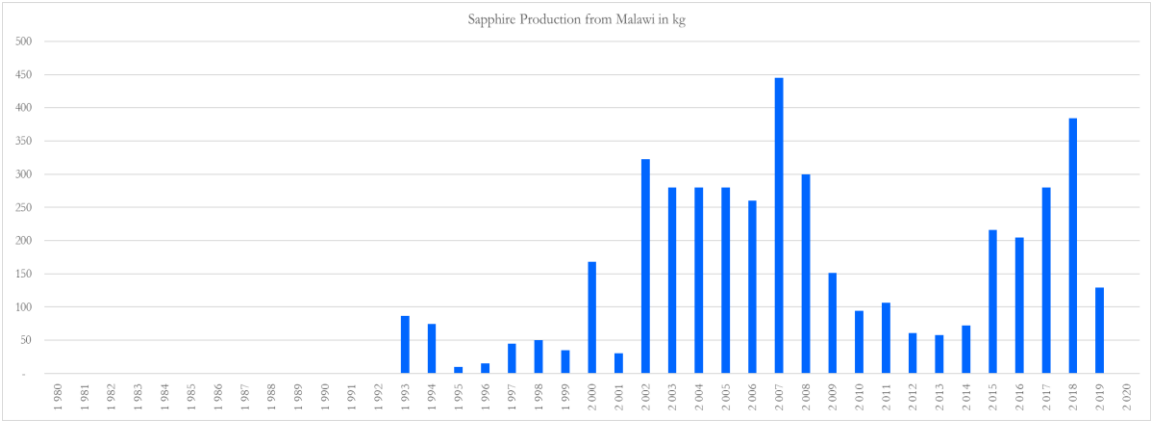


Figure 68: Sapphire production from Malawi, in kg

[269] Ministry of Energy and Mines of Malawi (2009). Mineral potential of Malawi. https://core.ac.uk/download/pdf/58929.pdf

11. Other Asian Regions

a) Kashmir

Kashmir's sapphire production is ancient history now, but given the importance of these gems to the trade, with their incredibly high value, it is worth mentioning the deposit's history in this report.

Kashmir is a region in the Himalayas, currently disputed by India, Pakistan and China. At the time of the sapphire discovery in the Paddar region in 1881[270], Kashmir was a suzerainty of the British Crown[271]. The main mining activities there lasted until 1887, when the primary deposit (to the east of the Line of Control) was exhausted. Thereafter, exploration and small mining activities continued. There was a small rebound in production in 1927, but it ceased within a few years[272]. Sporadic and limited production persists: it is estimated that Kashmir provided an average of 3kg per year between 1998 and 2007[273]. Recently, it has been reported that blue sapphires were found in Azad Kashmir[274] (to the west of the Line of Control), as well as pink and purple sapphires from the Batakundi area (to the north-west of the Line of Control)[275]. However, it is believed that volumes of production from these deposits are currently insignificant in terms of the global sapphire market.

The high reputation of the deposit is due to the extremely fine quality of some of the blue sapphires discovered there. 'Classic' Kashmir sapphires from the original deposit are still considered today to be the most desirable sapphires, with prices that can be five times higher than for Sri Lankan or Burmese sapphires[276]. Moreover, the lack of access to the deposit, due to its remote mountainous location, the beauty of the surrounding landscape and the lack of information made available to foreigners are thought to have greatly contributed to the mystery and fantasy surrounding these stones[270]. Albeit 'Kashmir sapphire' is now used as a synonym for exceptional quality, it should be noted that a gemstone deposit typically produces a wide range of qualities[277], with a pyramidal production profile, where the top quality (the 'tip of the pyramid') often represents less than 10% of the volume. As with any blue sapphire, determining origin is a challenge[276], but even more so for Kashmir sapphires, because much of the mining activity happened 100 years ago, and so the scientific data in origin-determination databases are based on a limited number of verified samples. Previously, it had long been believed that any blue sapphire with a 'velvety' appearance

[270] Atkinson, D., & Kothavala, R. Z. (1983). Kashmir sapphire. Gems and Gemology, 19(2), 64-76.
[271] https://en.wikipedia.org/wiki/Kashmir
[272] https://www.thenaturalsapphirecompany.com/blog/history-kashmir-sapphires
[273] Shor, R., & Weldon, R. (2009). Ruby and sapphire production and distribution: A quarter century of change. Gems and Gemology, 45(4), 236-259.
[274] Huang, T., & Gao, Y. (2022). Blue Sapphires Reportedly from Azad Kashmir. The Journal of Gemmology, 38(2), 122-124.
[275] Pardieu, V., Thirangoon, K., Lomthong, P., Saeseaw, S., Thanachakaphad, J., & Du Toit, G. Sapphires Reportedly from Batakundi/Basil area.
[276] https://eighthdimensiongems.com/origin-opinions
[277] Krzemnicki, M.S. (2013). Kashmir sapphire. SSEF Facette 2013

was likely to be from Kashmir[278]. One good example is the trade alert published in 2017, when the SSEF observed that blue sapphires from a recently-discovered deposit in Madagascar shared similar characteristics with Kashmir sapphires[279], and consequently a number of gemstones had been wrongly identified in that time period by other laboratories[276].

d) China

China has numerous gemstone deposits, and sapphires are found in several locations. The major deposit is in Changle, in Shandong province[280]. It was discovered in the late 1980s and produced an estimated volume of 10kg between 1988 and 1991[281]. Sapphires from this deposit are dark blue, often with colour-zoning, and they can occur in large sizes.

In 1986, Keller reported that the main source of Chinese sapphires at the time were the deposits of Penglai on Hainan Island and Mingxi in Fujian province, although the mines were not well-developed[282] The Mingxi deposit had been discovered in 1980, and produced about 1.2kg over the following six years[283]. Sapphires in Penglai were discovered by a farmer in the 1960s, but exploration work only started in 1982[284]. Sapphires in China have also been reported from Muling since 1985, but activities started in the late 1990s, when Thai traders invested in mining machinery there[285]. Production is still limited due to the remote location and weather conditions[286].

All the sapphire deposits in China are identified as basalt-related and display the typical blue, yellow and green colours, with the exception of Muling, which produces more rubies than sapphires[286]. Previously, commentators had often described Chinese production as being of low quality, with dark colours and strong colour-zoning. However, this deposit, which produces a wide range of colours, has real potential to supply finer-quality material[285].

[278] https://lotusgemology.com/index.php/library/articles/459-world-sapphire-market-update-2020-lotus-gemology
[279] Krzemnicki, Michael S. New Sapphires from Ambatondrazaka, Madagascar. The Journal of Gemmology, 2017, vol. 35, no 5, p. 391-393.
[280] Yu, X. Y., Long, Z. Y., Zhang, Y., Qin, L. J., Zhang, C., Xie, Z. R., ... & Wan, J. X. (2021). Overview of gemstone resources in China. Crystals, 11(10), 1189.
[281] Guo, J., Wang, F., & Yakoumelos, G. (1992). Sapphires from Changle in Shandong Province, China. Gems & Gemology, 28(4), 255-260.
[282] Keller, P. C., & Fuquan, W. (1986). A survey of the gemstone resources of China. Gems and Gemology, 22(1), 9-10.
[283] Keller, A. S., & Keller, P. C. (1986). The sapphires of Mingxi, Fujian Province, China. The Quarterly Journal of the Gemological Institute of America.
[284] Wang, F. (1988). The sapphires of Penglai, Hainan Island, China. Gems & Gemology, 24(3), 155-160.
[285] Liu, Y., & Lu, R. (2022). Sapphire Beneath The Rich Black Soil Of Muling, Northeastern China. Gems & Gemology, 58(3).
[286] Liu, Y. Lu, R. (2016). Ruby and sapphire from Muling, China. Gems & Gemology. Spring 2016. Gem News International p98-100

In their report of 2008, Yager et al. place China as the fifth most important producer of sapphires in 2005, with 12% of global production[287]. However, production data are hard to find, and the Ministry of Natural Resources of China does not even mention gemstone production in any of its yearly Mineral Resources reports[288]. The reports on the various deposits suggest production ranges from 1kg to 10kg per year[286,283,281,284], but some other sources report production from Changle alone in the region of 3 tonnes per year[289]. Considering the experts' opinions about the development of China as an important producer, the latter estimate has been incorporated in this report (Figure 69).

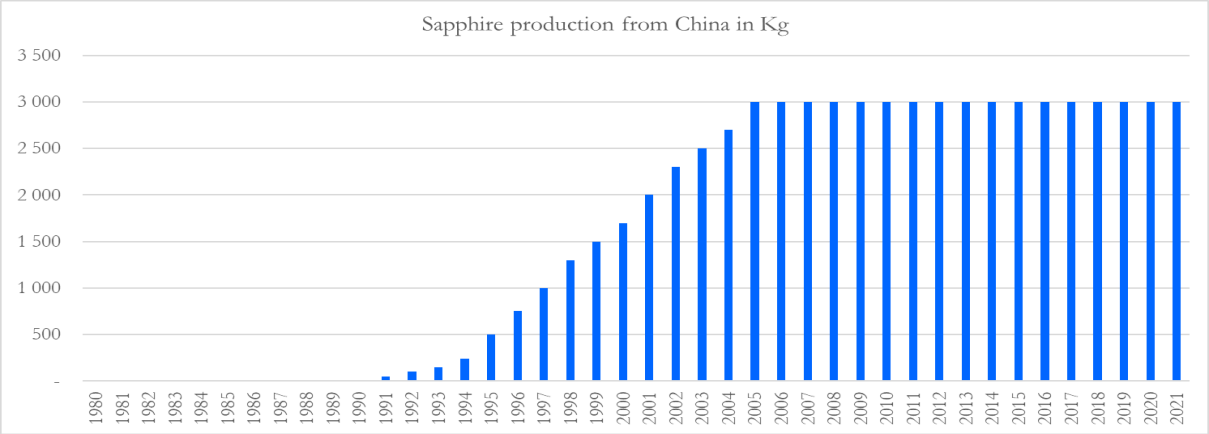


Figure 69: Sapphire production from China, in kg

c) Vietnam

Sapphires in Vietnam are found, along with rubies, in the deposits of Luc Yen and Quy Chau. For more information about these production districts, please refer to the 'Vietnam' section of the 'Global Supply of Ruby' chapter.

Sapphires were also discovered in the south of Vietnam in the late 1980s, in the Phan Thiet and Di Linh district. The sapphires are mainly dark blue, but their quality is low, with only 5% to 10% of the production being good enough to cut. The sapphires occur in gravels. Mining was highly active in the early 1990s[290].

[287] Yager, T. R., Menzie, W. D., & Olson, D. W. (2008). Weight of production of emeralds, rubies, sapphires, and tanzanite from 1995 through 2005. US Geological Survey.
[288] http://chinageology.cgs.cn/news_list_en.htm?column=data
[289] Michelou J.C., Ed. (2006) ICA 2006 World Gemstone Mining Report. InColor, Spring.
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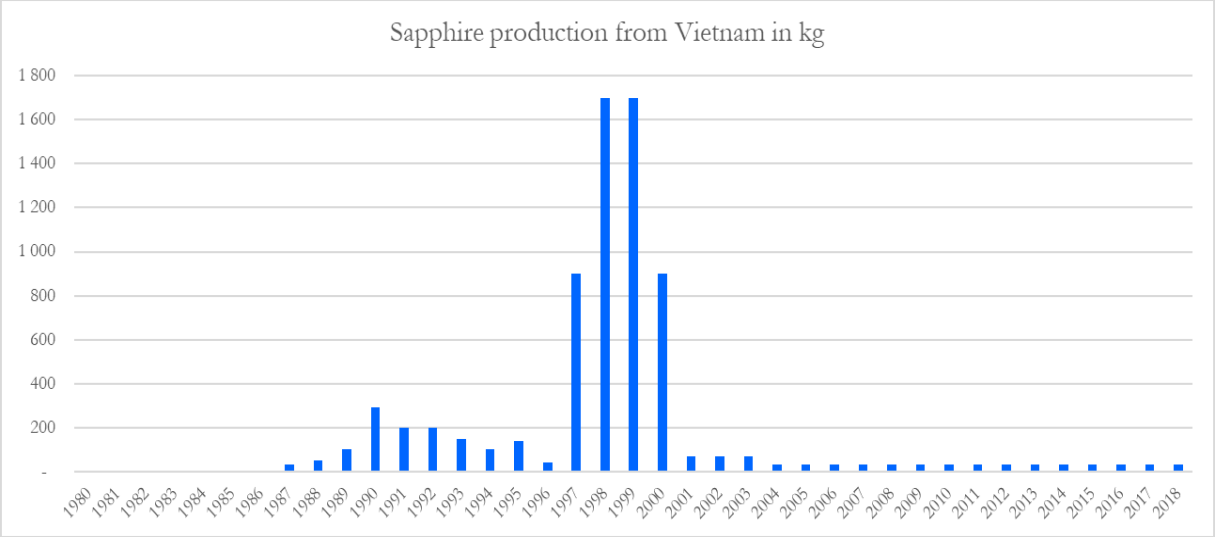

Figure 70: Sapphire production from Vietnam, in kg

e) Nepal

In Nepal, rubies and sapphires were discovered at Chumar and Ruyil, in Dhading district, in around 1981. Official mining activity started in 1985, but did not last long and was quickly abandoned. Most mining is unofficial and sporadic, so production data are difficult to find and estimate[291].

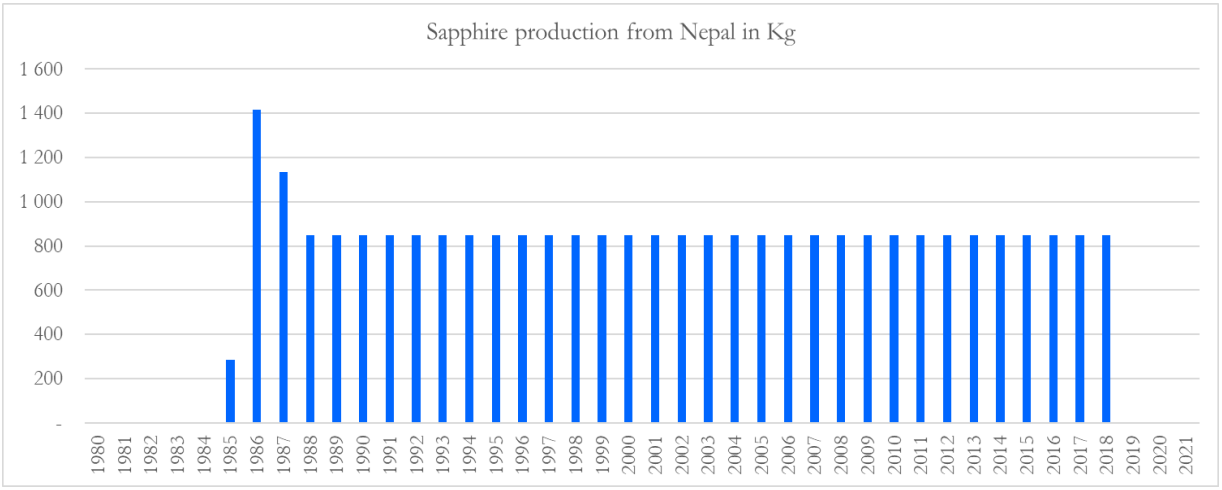

Figure 71: Sapphire production from Nepal, in kg

[291] Smith, C. P., Gübelin, E. J., Bassett, A. M., & Manandhar, M. N. (1997). Rubies and fancy-color sapphires from Nepal. Gems & Gemology, 33(1), 24-41.

12. Compiled Data

All the production profiles presented here have been compiled into the graph below. The graph represents the production of gem-corundum sapphire, but it does not take quality into account, so volume figures incorporate facet, cabochon, carving and commercial grades.

It should be kept in mind that this profile does not aim to be a perfect representation of reality. It is acknowledged by the author that there is not enough reliable recorded data available to do so.

The lack of follow-up information on mining activity is a major issue when trying to chronicle the history of gemstone deposits, especially when many deposits are only worked sporadically.

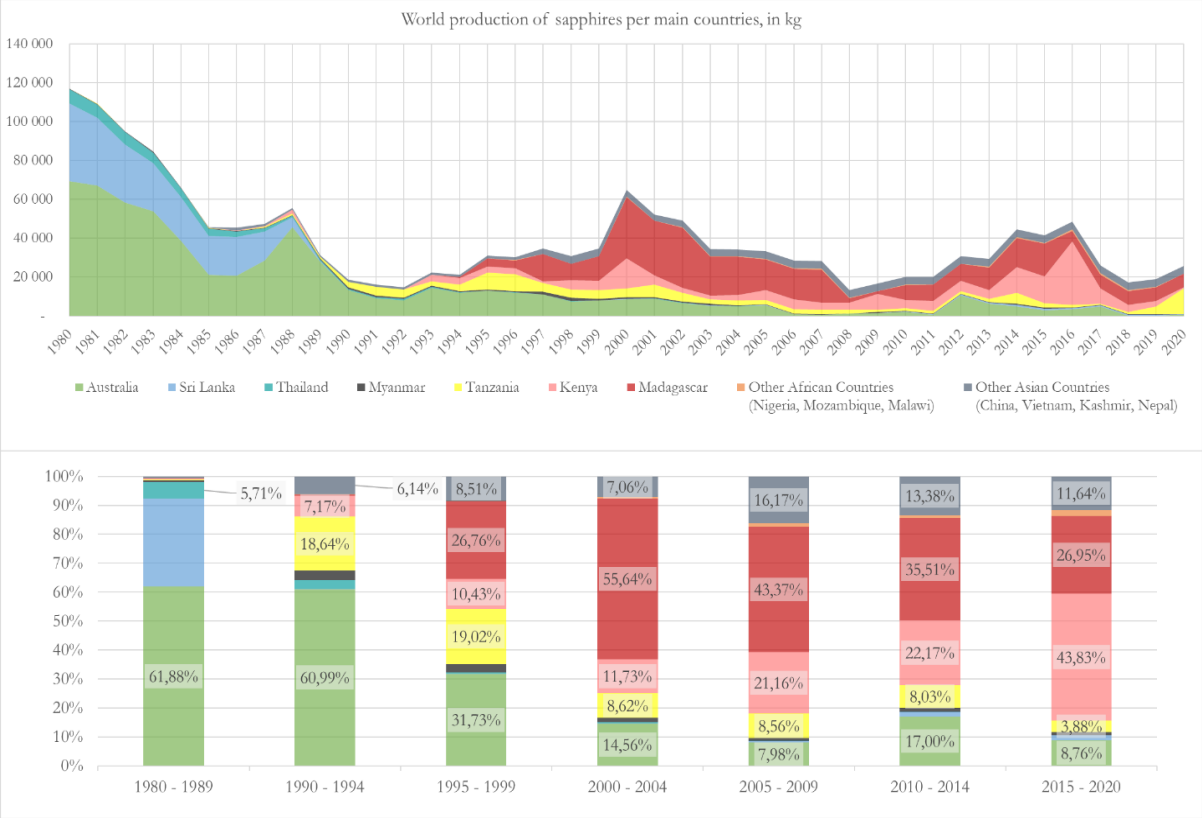

Figure 72: World production of sapphire , in kg

Nevertheless, this profile (Figure 72) provides some useful insights on production dynamics:

1. The overall supply of sapphires has been far from consistent across the 40 years covered in this research. New discoveries and mine depletion have driven ups and downs.
2. Australia and Sri Lanka were the main sources of supply between 1980 and 1990.
3. Although Australia remains an important source of sapphire today, Sri Lanka seems insignificant in terms of volume produced over the past 30 years. This does not accord with general market sentiment, whereby many commentators still refer to Sri Lanka as a major producer. However, it should be noted that Sri Lanka could indeed be a major producer for a specific quality of sapphire, but the available data does not allow to make an analysis on production volumes per quality type.
4. Compared to the ruby market, the global supply of sapphires originates from a larger number of countries, with the most important ones being in Africa.

5. Either the importance of Kenya to supply is probably overestimated, or the published figures might predominantly refer to lower qualities.
6. Volume figures for deposits in Central Asia, Russia and Ethiopia are anecdotal.
7. The average yearly volume across the 40 years presented is 40 tonnes, with a minimum of 13 tonnes and a maximum of 117 tonnes. These numbers should not be taken as exact figures, but we can safely assume that the global yearly production of sapphires rarely exceeds 60 tonnes, even considering the whole range of qualities in aggregate.
8. The overall quantity of sapphires available has decreased significantly since the 1980s.

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VIII. NOTES TO EDITORS

About The Author

Lauriane Pinsault is a mining engineer specialising in the extraction of coloured gemstones. After spending several years working in the field in both Asia and Africa, Lauriane developed strong expertise in data analysis, as well as a profound interest in the topics of ethics and traceability in the gemstone sector. In 2022, Lauriane, together with two other PhD geologists, founded the consultancy firm GeoGems, based in France. GeoGems aims to work towards increased sustainability and transparency in the sector, providing services that include market research, competent person reports for mines, gemstone identification and gemmological training.

GeoGems

About Gemfields

Gemfields is a world-leading responsible miner and marketer of coloured gemstones. The operator and 75% owner of both the Kagem emerald mine in Zambia (believed to be the world's single largest producing emerald mine) and the Montepuez ruby mine in Mozambique (one of the most significant recently discovered ruby deposits in the world), Gemfields believes that those who mine gemstones should do so with transparency, legitimacy and integrity.

Gemfields introduced a technologically advanced coloured gemstone sort house at its operation in Mozambique, with state-of-the-art equipment, like optical sorting machines. In addition, a proprietary grading system, a pioneering auction platform and an active marketing presence have all contributed to Gemfields playing a significant role in the rise of African gemstones. Underlying this achievement has been the strong belief that coloured gemstones should create a positive impact for the country and community from which they originate.

Responsible mining for Gemfields means implementing industry-leading policies and practices across operations, transparency in its auction sales process, an active role in working groups to modernise the sector, projects to improve health, education and livelihoods for the communities around its mines and conservation efforts (#conservationgemstones) to protect Africa's great wildlife and biodiversity.

Gemfields Foundation is the charitable arm of Gemfields, through which donors can contribute funding to directly support community and conservation projects in Africa, magnifying the scale of the work already carried out by Gemfields itself.

Fabergé – an iconic name with an exceptional heritage – is a member of the Gemfields Group. The beauty of Fabergé's designs and craftsmanship helps to raise consumer awareness of responsibly mined coloured gemstones.

As well as supplying a significant share of the world's rough rubies and emeralds, Gemfields initiates activations to build desire for coloured gemstones: for example, collaborations with international jewellery brands and other creative partners. Often surprising, unexpected and unique, these collaborations are chosen to promote consumer awareness and increase the appeal of coloured gemstones, raising their profile, and, in turn, providing greater benefit to their place of origin in Africa.

Gemfields