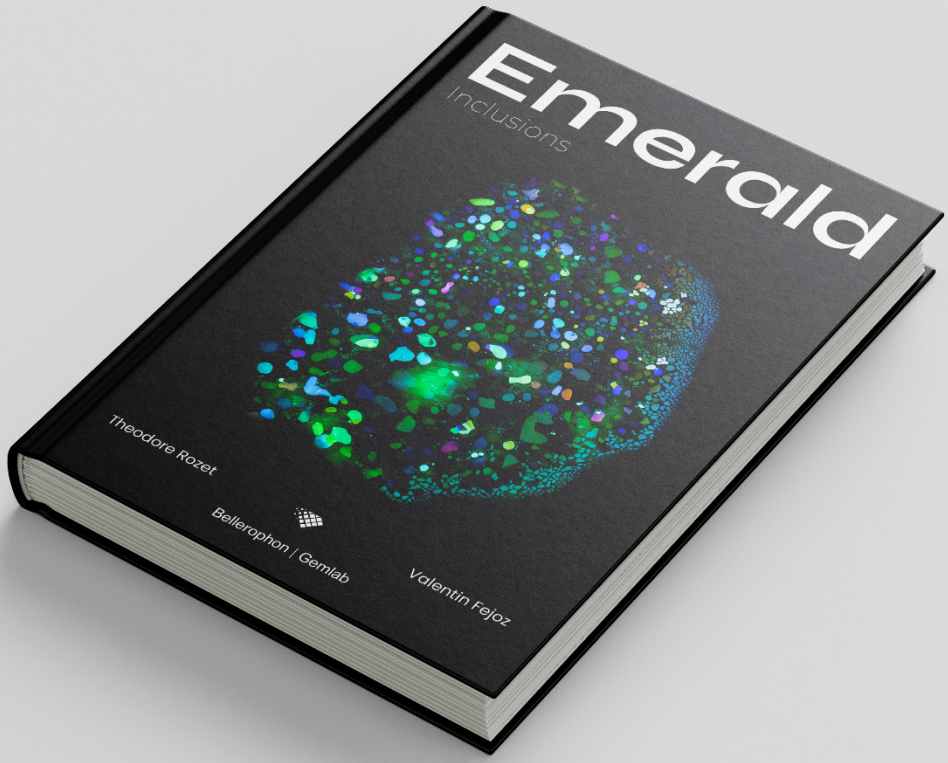
EMERALD INCLUSIONS

Theodore Rozet & Valentin Fejoz



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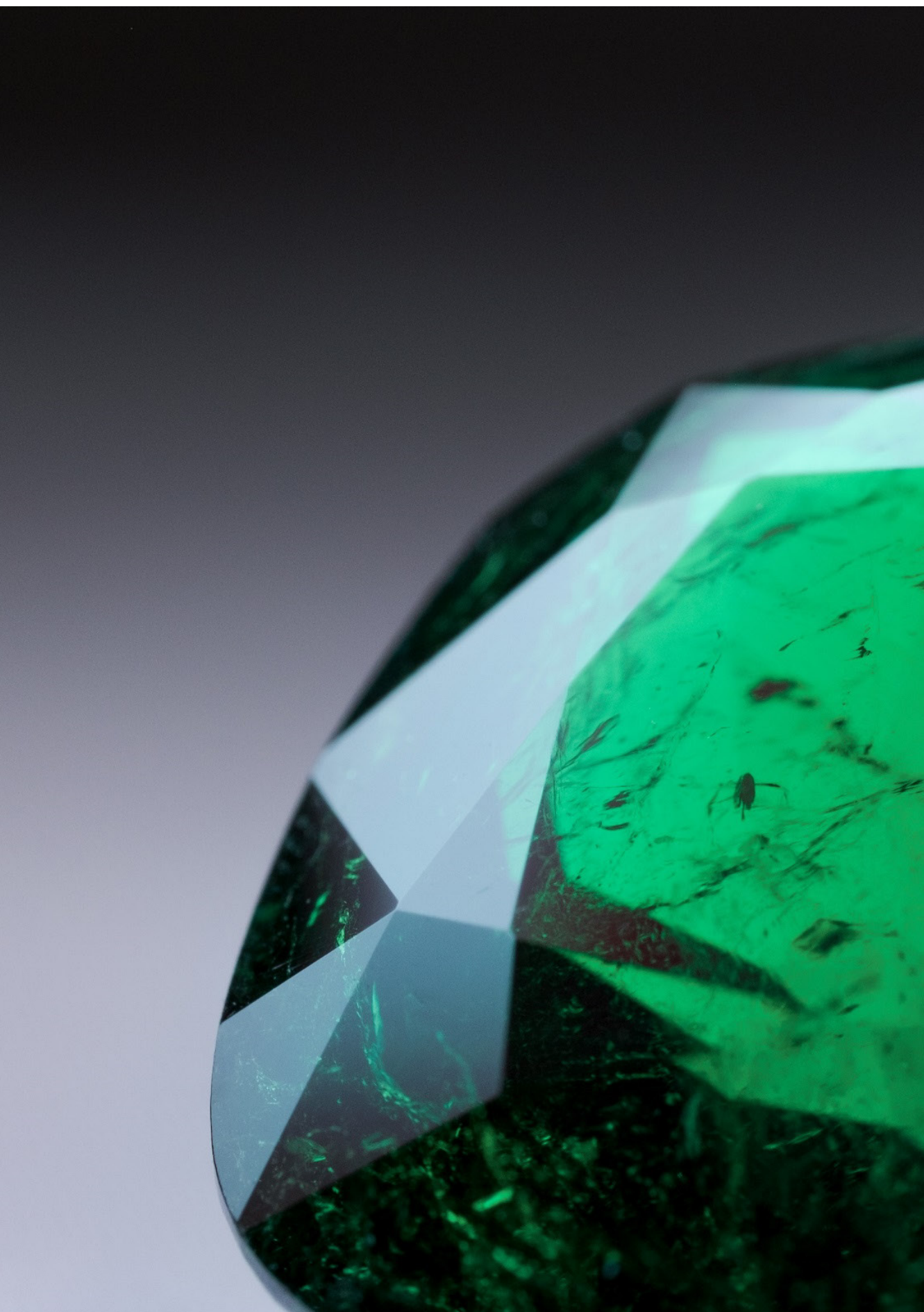
This in-depth book highlights how these natural imperfections, often considered flaws, play a crucial role for gemologists in identifying the origin and authenticity of emeralds. Inclusions, ranging from liquid-filled cavities to mineral crystals, provide valuable information about the geological conditions under which emeralds formed, making them essential tools for gemologists. Beyond their scientific utility, this book celebrates the aesthetic allure of inclusions, showcasing how these unique internal features enhance the emeralds' charm and individuality.

Each inclusion tells a story of the earth's history, adding depth and character to the gemstone. Illustrated with stunning photomicrography, this book invites readers to appreciate the intricate patterns and natural artistry within emeralds, transforming our understanding of these precious gems from mere adornments to works of natural art.



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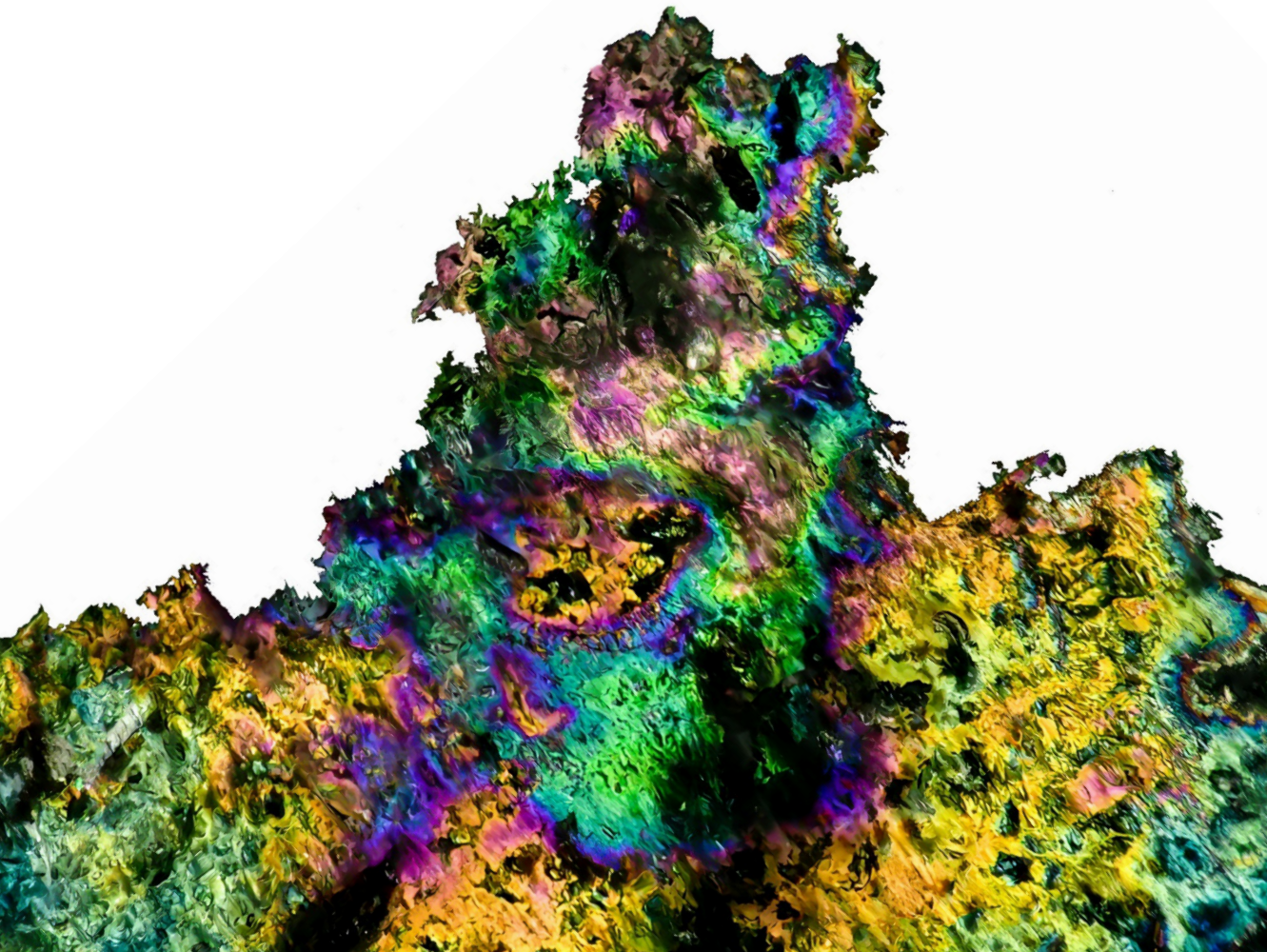


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1

GENERAL OVERVIEW OF EMERALDS

Emerald, a precious gemstone of rare beauty, holds a special place among the four precious stones alongside diamond, ruby and sapphire. Its renown comes from its vivid green hue, rarity and cultural history dating back thousands of years.

Beryl – Emerald

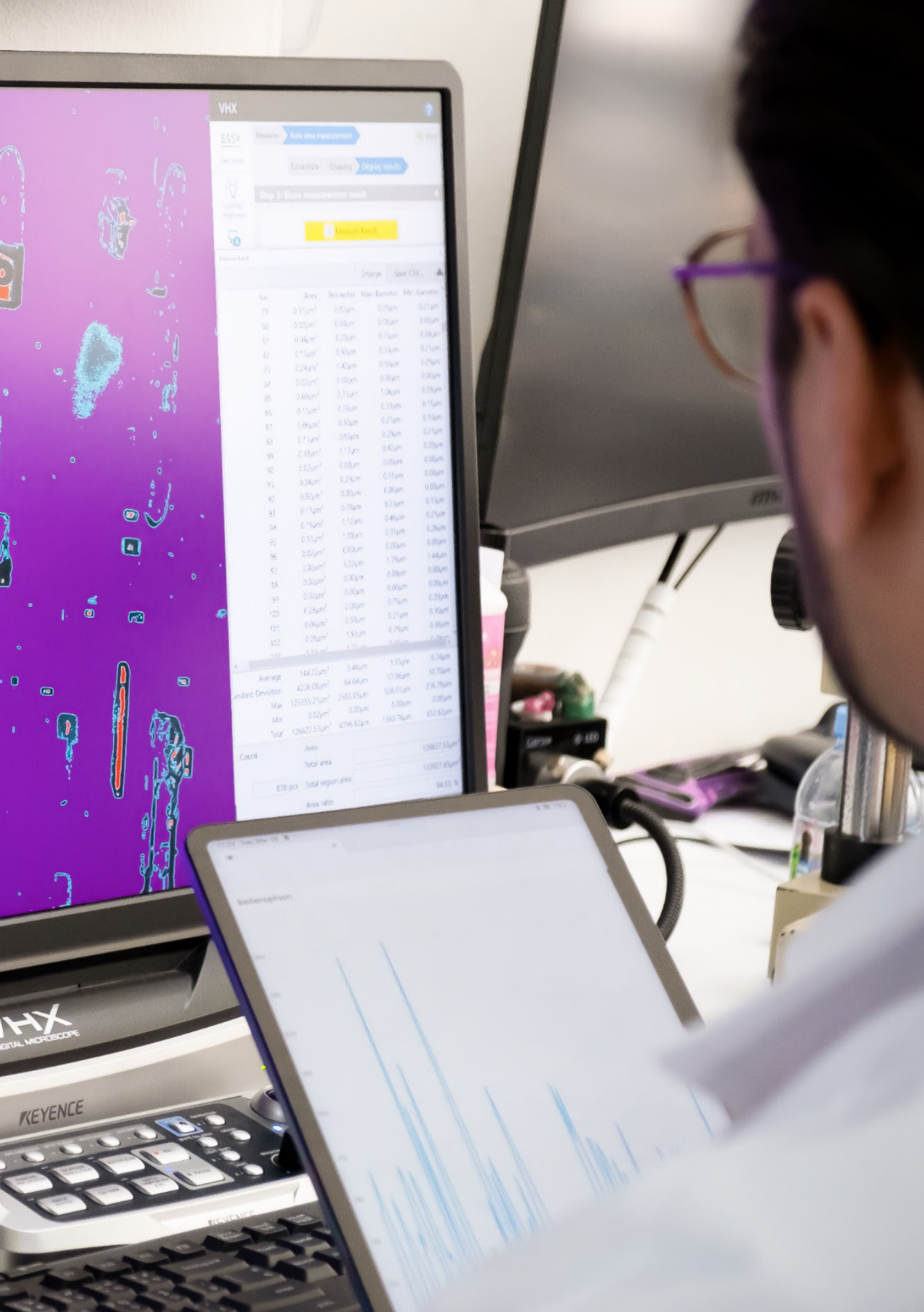
Beryl, with the chemical formula $Be_3Al_2Si_6O_{18}$, is a mineral from the cyclosilicate family, known for its diverse colors and gem varieties. It crystallizes in the hexagonal system, forming elongated prisms. Its hardness is 7.5 on the Mohs scale and its density ranges from 2.63 to 2.92 g/cm^3. The crystalline structure of beryl is organized into hexagonal rings, with each ring consisting of six SiO_4 tetrahedra (each tetrahedron containing one silicon atom surrounded by four oxygen atoms). These rings are stacked on top of one another, forming channels aligned along the crystal's main axis (C-axis). These channels are not completely sealed, allowing them to accommodate ions (Na^+, K^+, Cs^+, etc.) and molecules such as H_2O, $2H_2O$, or CO_2. Pure beryl is colorless, but the incorporation of chromophore ions into its structure generates its many-colored varieties: - Aquamarine (blue to blue-green) derives its color from traces of iron (Fe^{2+} Fe^{3+} IVCT).

- Heliodor (yellow to golden-yellow) owes its hue to iron (Fe^{3+}) in its crystalline structure.

- Morganite (pink to salmon-colored) gets its color from manganese (Mn^{2+}).

- Goshenite, the colorless form of beryl, is pure and lacks chromophore elements, though it may contain traces of alkali metals or iron that do not affect its color.

- Green Beryl color is primarily due to the presence of Fe^{2+} and Fe^{3+}. Unlike emerald green beryl are not colored by chromium and/or vanadium.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2

EMERALD PATTERN RECOGNITION

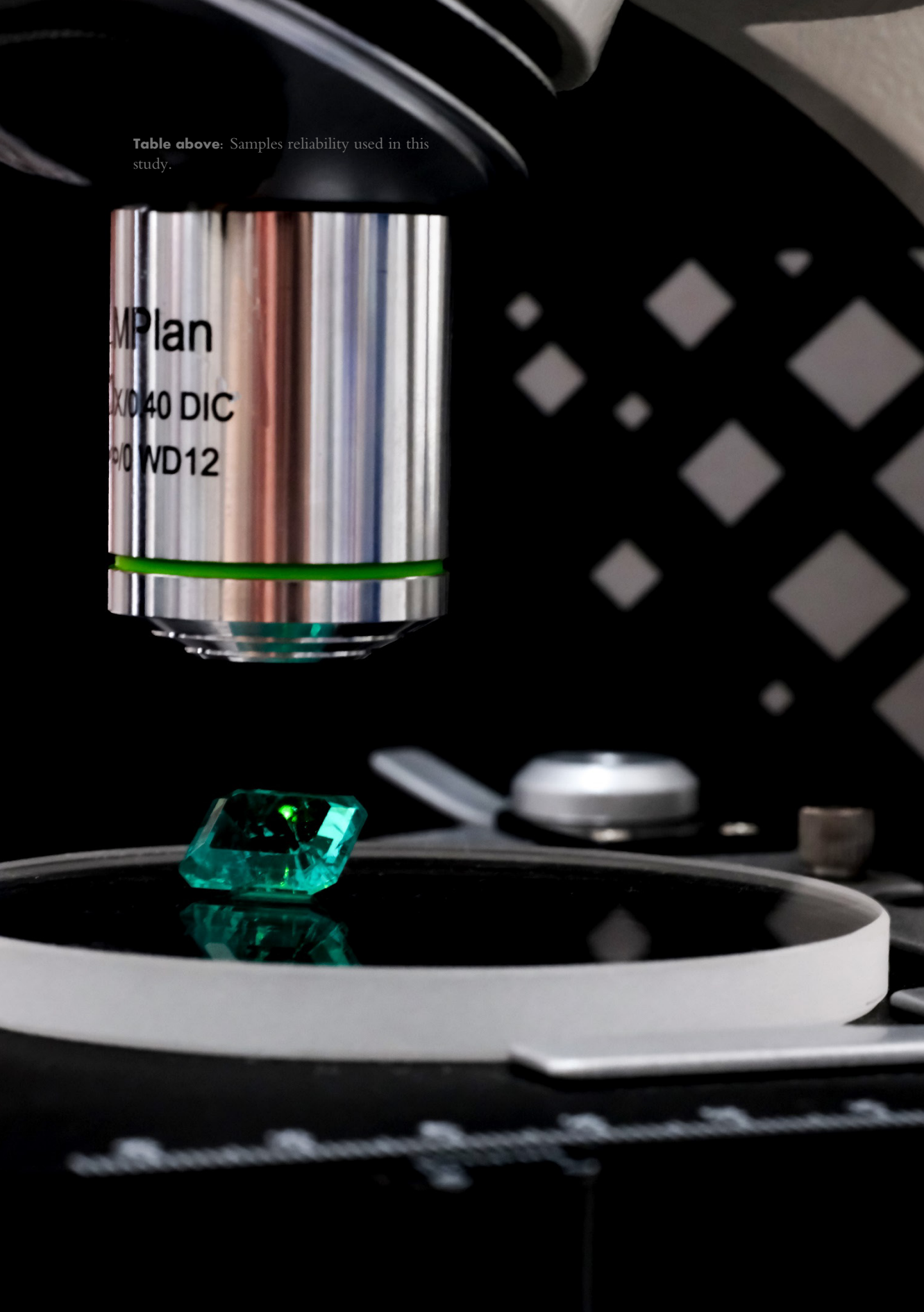
In parallel with the writing of this book, new techniques were developed at Bellerophon Gemlab, based on the analysis of the shapes and dimensions of inclusions for the purpose of determining the geographical origin of emeralds. The study of fluid inclusions presented in this book is built upon this nomenclature, which forms one of the fundamental pillars of its structure. The microscope remains one of the most important tools for gemologists, particularly for origin determination. An experienced gemologist, using the microscope, relies on the brain's ability to recognize and compare patterns such as shapes, sizes and colors of inclusions, as well as the distances, numbers and relief between internal features. All of this information, coupled with state-of-the-art technologies, supports conclusions about a gem's provenance. However, the human factor in pattern recognition is likely the single most significant source of subjective error. Advanced analytical techniques greatly reduce human error, but do not eliminate it entirely. Research aimed at quantifying pattern recognition is not new, but the practical, day to day measurement of internal features has only recently become feasible thanks to technological advances in digital microscopy and software. Finally, proper pattern studies offer a much more effective way to transfer knowledge to new generations of gemologists and may also enable artificial intelligence to receive visual data directly from the microscope.

EMERALD SAMPLE TRACEABILITY GRADING

	Sample	Grades			
	n	AAA	A	B	C
Colombia (Muzo & Chivor)	101	4	78	19	-
Musakashi (Zambia)	100	-	-	82	18
Afghanistan (Panjshir)	100	-	28	66	6
Zambia (Kafubu)	100	-	81	19	-
Ethiopia (Shakiso)	100	-	-	28	72
Madagascar (Mananjary)	100	2	18	-	80
Russia (Malysheva)	100	8	29	-	63
Nigeria (Kaduna)	100	-	-	5	95
Australia (Torrington)	18	-	-	-	18
Swat (Pakistan)	100	-	59	-	41
Chitral (Pakistan)	100	-	82	-	18
Minas Gerais (Brazil)	100	-	78	-	22
Goias (Brazil)	16	-	16	-	-
Bahia (Brazil)	100	-	69	-	31
India (Rajasthan)	100	-	-	60	40
Tanzania (Manyara)	100	-	12	-	88
Zimbabwe (Sandawana)	100	-	22	-	78

AAA: Extracted the gem from the ground.
A: Got the gem at the mine from the miner.
B: Got the gem from the miner not at the mine.
C: Got the gem from trusted contact in the market.

Table above: Samples reliability used in this study.



3

DETERMINATION OF EMERALD ORIGIN THROUGH THE IDENTIFICATION OF SOLID INCLUSIONS

The study of solid inclusions remains one of the most relevant sources of information for determining the geographic origin of gemstones. Depending on the local geology and the nature of the host rocks, certain minerals may become trapped as inclusions within emerald crystals from specific deposits, while being absent in others. Through micro-Raman analysis of a large reference collection of emeralds, combined with an exhaustive review of the scientific literature on mineral inclusions in this gemstone, we were able to identify significant markers that support the reliable attribution of geographic origin.

Left page photo: Micro-Raman 532 nm performed on an emerald at Bellerophon Gemlab Bangkok.

Table below: Samples reliability used in this study.

Origin	Sample
Afghanistan (Panjshir)	112
Australia (Emmaville/Torrington)	4
Australia (Poona)	-
Australia (Riverina/Menzie)	-
Australia (Wodgina/Curlew)	1
Austria (Habatchal)	17
Brazil (Bahia)	110
Brazil (Goiás)	137
Brazil Minas (Gerais)	142
China (Davdar)	-
China (Malipo)	2
Colombia	176
Ethiopia (Shakiso)	86
India (Jharkhand)	-
India (Rajasthan)	26
Madagascar (Mananjary)	108
Madagascar (Ianapera)	17
Norway	-
Pakistan (Chitral)	39
Pakistan (Khaltaro)	-
Pakistan (Swat)	97
Russia (Malysheva)	112
South Africa	22
Tanzania	77
Zambia (Kafubu)	156
Zambia (Musakashi)	48
Zimbabwe (Sandawana)	139
TOTAL	**1628**

4

AFGHAN EMERALD

Afghanistan, located in Central Asia, is a landlocked country known for its mountainous landscapes and rich cultural history. Its capital is Kabul and the country has a population of approximately 40 million people. Bordered by Pakistan, Iran, Turkmenistan, Uzbekistan, Tajikistan and China. Afghanistan features diverse landscapes ranging from the high mountains of the Hindu Kush to arid plateaus and fertile valleys. Its natural resources are abundant, including copper, iron, lithium and gemstones such as lapis lazuli, ruby and various types of tourmalines.

Since ancient times, Afghanistan has been a major source of lapis lazuli, extracted from the Sar-e-Sang mines in the Badakhshan province, which are among the oldest in the world.
The Afghan emeralds, originating from the Panjshir Valley, are renowned for their exceptional quality. The mines are located 113 km northeast of Kabul, near a small village called Khenj.

The Panjshir Valley, also known as the "Valley of the Five Lions", is situated in the Hindu Kush Mountain range, along the Panjshir River.

The emeralds are nestled in a rugged, mountainous region that is difficult to access, with altitudes ranging from 2,100 to 4,270 meters.
Their commercial exploitation truly began in the early 1980s, following field surveys conducted by Russian geologists a few years earlier, which had revealed the presence of this precious mineral.

Mentioned since antiquity by authors such as Theophrastus (314 BC) and Pliny the Elder (77 AD), these emeralds were known as "Smaragdus of Bactria" a region that is believed to includes present-day Afghanistan, Pakistan and part of China, all of which are emerald producing countries.
Even today, uncertainty remains. It's possible that the Russian geologist's discovery in the late 1970s was, in fact, merely a rediscovery of this deposit.

Photo on the left page: Rough emerald from the Panjshir Valley, Afghanistan, 4.652 carats, Bellerophon Gemlab collection.

5

AUSTRALIAN EMERALD

Australia is located in the Southern Hemisphere, is the largest country in Oceania. Its capital is Canberra and the country has a population of approximately 26 million people. This vast island continent is surrounded by the Indian and Pacific Oceans. Geographically the country offers a diverse range of landscapes from the mountains of the Great Dividing Range to the arid deserts of the Outback, as well as tropical forests and coral reefs including the Great Barrier Reef.

Australia's subsoil is extremely rich in natural resources, including iron, coal, gold, copper, uranium and gemstones such as diamonds, sapphires and opals. In 1869, the discovery of a 69 kg gold nugget, named "Welcome Stranger," marked the beginning of the gold rush, attracting thousands of prospectors. This rush was not limited to gold; the influx of miners quickly expanded exploration to include other mineral resources such as copper and gemstones.

Australia is a notable producer of colored diamonds, particularly the pink diamonds from the Argyle mine. This mine played a major role in the colored diamond market until its closure in 2020. Australia is also home to emerald deposits, which are less renowned internationally but have played a role in the history of emerald mining. Although Australia is not a major emerald producer, several deposits have been mined over the past century.

Four main sites stand out: Emmaville/Torrington, in New South Wales, located about 350 km from Brisbane in the eastern part of the country, as well as three deposits in Western Australia: Menzies/Riverina, Poona/Aga Khan and Wodgina/Curlew, situated approximately 720 km, 750 km and 1,450 km from Perth, respectively. The number of deposits places Australia among the countries with the most emerald deposits in the world, on par with Pakistan.

Left page photo: Emerald from Australia Torrington 1.640-carat, Bellerophon Gemlab collection.

7

BRAZILIAN EMERALD

Brazil is the largest country in South America, with a vast territory covering approximately 8.5 million square kilometers, making it the fifth-largest country in the world by area. The capital of Brazil is Brasília, a planned city located in the center of the country, symbolizing Brazil's development and modernity since its inauguration in 1960. Geographically, Brazil occupies a strategic position, bordered by the Atlantic Ocean to the east and sharing borders with almost all South American countries, except Chile and Ecuador.

Brazil's territory boasts remarkable geographical diversity, including the immense Amazon rainforest in the north, which is home to unparalleled biodiversity, as well as plateaus and mountain ranges such as the Serra do Mar and Serra da Mantiqueira in the southeast. Brazil is also one of the world's richest countries in natural resources, making it a key player in the global commodities market. Its vast mineral reserves include significant deposits of iron, bauxite, manganese, nickel, copper and gold.

In addition to these resources, Brazil is famous for its gemstones, including large amethyst geodes, as well as topaz, tourmaline and emeralds. The state of Minas Gerais, in the southeast of the country, is particularly renowned for producing these gems. Although Brazil was historically famous for agate, tourmaline and aquamarine, emerald is now the country's most important precious stone.

The first expeditions of Portuguese explorers, known as the "bandeirantes" in the 16th century, aimed to find gold, emeralds and other precious stones. However, they never actually discovered emeralds only green tourmaline.

Brazil only became a major emerald producer in the 1960s, with the discovery of a deposit in the state of Bahia. Today, three main mining areas stand out:

- The Socotó deposits in the state of Bahia.
- The Santa Terezinha deposits, sometimes called Campo Verde, in the state of Goiás.
- The Belmont deposits in Minas Gerais.

Left page photo: 487-gram carved buddha emerald from Minas Gerais, courtesy of Thanaporn.

8

CHINESE EMERALD

China is a country located in East Asia, sharing borders with 14 countries, including India to the south, Russia to the north and Pakistan to the west. Covering an area of approximately 9.6 million square kilometers, it is the third-largest country in the world. China is characterized by remarkable geographical diversity, including towering mountains, vast deserts, high plateaus, fertile plains and a long coastline along the China Sea. In the southwest of the country lies the Himalayan Mountain range, home to Mount Everest, the highest mountain in the world. The western regions are dominated by the Tibetan Plateau, often referred to as "the roof of the world," while the eastern part of the country is marked by the expansive plains of the Yangtze River and the Yellow River, two of the nation's most significant waterways. China is rich in mineral resources, boasting a wide variety of minerals, many of which are essential to industry.

The country is a major producer of coal, iron, copper, zinc, lead and rare earth elements, the latter being crucial for the production of electronic goods. China is especially renowned for its jade, particularly nephrite jade from the Xinjiang region, which has been highly valued in Chinese culture for millennia. Jade is used in the creation of jewelry, sculptures and art objects. In addition to jade, China also has ruby deposits in the Yunnan province. While the exploitation of these gemstones is less developed than that of industrial minerals, it is growing and China appears to have the geological potential to become a significant producer of gemstones in the future.

Photo on the left page: Confucius (551-479 BC) was a Chinese philosopher whose teachings deeply influenced the culture of China.

9

COLOMBIAN EMERALD

Introduction

Colombia is located in the northwest of South America. It shares land borders with five countries: Panama to the north, Venezuela and Brazil to the east, Peru and Ecuador to the south. Bordered by the Pacific Ocean and the Caribbean Sea, Colombia has access to two major maritime expanses on either side of its territory, making it a strategic commercial hub in Latin America. This unique geographical position not only enhances its role in regional trade but also connects it to some of the most biodiverse ecosystems in the world, including the Amazon. The Amazon region, located in the far southeast of the country, is covered by a dense tropical rainforest, while the La Guajira Peninsula, in the northeast, is a semi-arid area. Colombia's landscape is dominated by the imposing presence of the Andes, which are divided into three main mountain ranges: the Eastern Cordillera, the Central Cordillera and the Western Cordillera. These ranges have formed high plateaus and fertile valleys.

Colombian emeralds are famous for their stunning color and incredible clarity. Their rich history is just as captivating as their beauty

Even before the arrival of the Spanish conquistadors in the early 16th century, emeralds were already being mined by pre-Columbian civilizations such as the Aztecs and the Incas. Exceptional handcrafted pieces made of gold and emeralds are exhibited at the Gold Museum in Bogotá. Later, the conquistadors, particularly Hernán Cortés and Francisco Pizarro, sought precious metals and natural riches during the conquest of the Americas. During their exploration, they discovered significant emerald deposits, especially the Muzo mines, which quickly became known for their high productivity. The exploitation of these mines by the Spaniards marked the beginning of their international fame. Over the centuries, Colombian emeralds have gained prestige not only in Europe but also in Asia, becoming symbols of wealth and power. Their brilliance and unique color have made them highly sought after by royal courts and the wealthy bourgeoisie. Even today, Colombia remains one of the world's leading producers of emeralds.

Left page photo: Rough emerald from the Muzo mine in Colombia.

10

EGYPTIAN EMERALD

Introduction

Egypt is a country located in the northeast of Africa and is bordered to the north by the Mediterranean Sea along the coast of the city of Alexandria, to the east by the Red Sea. Its borders are shared to the south with Sudan, to the west with Libya and to the east with Israel. Its landscapes are dominated by desert, with arid stretches covering most of the territory. However, the Nile, the longest river in Africa, flows through the country from south to north, creating a fertile valley that forms the agricultural heart of Egypt. Egyptian history is one of the oldest and richest in the world. It is the cradle of one of the first great civilizations, marked by the pharaohs, the pyramids and ancient majestic temples. Famous monuments such as the Giza site, the Sphinx and the Karnak sanctuary are a testament to the ingenuity and power of the ancient Egyptians. The Egyptian emerald mines, known as "Mons Smaragdus" or "Mountain of Emeralds," are located near Sikait, between Luxor and the ancient Roman port city of Berenice, on the Red Sea. These mines were a major source of emeralds during Antiquity, first exploited by the Egyptians (from 500 to 30 BC) and then more intensively during the Roman occupation. After the naval victory at Actium, Octavian, the future Emperor Augustus, annexed Egypt to the Roman Empire. The death of Cleopatra VII marked a turning point in the use of Sikait emeralds in jewelry. Under ancient Rome, they were highly prized as a symbol of power in loose stone or in jewelry. The emeralds were often left in their natural form, sometimes lightly polished and pierced to be mounted into necklaces or earrings. Some were cut into cabochons or roughly rounded beads.

Photo on the left page: Egyptian frescoes depicting figures often adorned with jewelry as a symbol of power and wealth.

11
ETHIOPIAN EMERALD

Introduction

Ethiopia is located in the Horn of Africa and covers an area of approximately 1.1 million square kilometers, making it the 27th-largest country in the world. It is a landlocked country, having lost access to the sea following Eritrea's independence in 1993. Ethiopia shares borders with six countries: Eritrea to the north, Djibouti and Somalia to the east, Kenya to the south and Sudan and South Sudan to the west. This geographical position makes it a strategic crossroads between East Africa and the Gulf region. Ethiopia's landscape is dominated by the Ethiopian Plateau, which rises to an average altitude of 2,500 meters and is one of the country's most defining features. The highest peaks, such as Ras Dashen (4,550 meters) in the Simien Mountains in the northwest, contrast sharply with the lowlands, including the Afar Depression, which lies below sea level. This region is known as one of the hottest places on Earth, with an arid climate and extreme temperatures.

Ethiopia is also rich in natural resources. The country's subsoil contains significant deposits of gold, platinum, and tantalum, as well as other precious metals and gemstones. Among these are sapphires and opals, which are primarily found in deposits located in the Wollo region.

These resources have significant economic potential, although their exploitation remains limited due to underdeveloped infrastructure. The first mentions of Ethiopian emeralds in literature date back to the early 1800s. However, it was not until the end of 2016 that mines near the villages of Kenticha began producing emeralds in sufficient quantity and quality for Ethiopia to become a major player in the global market.

Contrary to popular belief, these emeralds do not come directly from the locality of Shakiso. The mines are located more than two hours away by road from this town, provided that access conditions are favorable. In reality, Shakiso is a trading hub where many merchants gather to buy and sell gemstones. The mining area is organized into several associations, each managed by a supervisor responsible for the extraction and distribution of raw emeralds. After an initial sorting, the stones are transported to Shakiso before being shipped to Addis Ababa, the capital, located approximately 12 hours away by road.

Left page photo: 11-carat cushion emerald from the Shakiso mine in Ethiopia, courtesy of Crown Color.

12

INDIAN EMERALD

Introduction

India is located in South Asia and is the seventh-largest country in the world by area, covering approximately 3.28 million square kilometers. It is bordered by Pakistan to the west, China and Nepal to the north and Bangladesh and Myanmar to the east.

India's landscape is diverse, ranging from the snow-capped peaks of the Himalayas in the north, which include some of the highest mountains in the world, notably Kangchenjunga, which reaches an altitude of 8,586 meters. The country is also dotted with the vast, fertile plains of the Ganges, the arid deserts of Rajasthan and the Deccan Plateau.

India is rich in mineral resources, including coal, iron, bauxite and manganese, which contribute significantly to the national economy.

India has a long and rich tradition of gemstones, deeply rooted in its history, religion and art. Gemstones have always held a prominent place in society, symbolizing power, prosperity, and spirituality.

Indian kings and emperors wore lavish ornaments adorned with precious stones.

Moreover, India is known as one of the world's most renowned centers for gemstone cutting and trade. Jaipur, the capital of Rajasthan, is one of the largest global hubs for gem cutting and trading.

The country is also famous for its historic diamonds, particularly those mined in Golconda, in the present-day state of Telangana. These diamonds, including the famous Koh-I-Noor and Hope Diamond, have adorned crowns and royal collections.

Furthermore, India is also renowned for its Kashmir sapphires, a historically significant region in the north of the country. This area has produced exceptional gemstones of the highest quality, distinguished by their unique and velvety blue hue.

Left page photo: Rough emerald from Rajasthan (India), courtesy of Sukhadia Stones.

13

MADAGASCAN EMERALD

Introduction

Madagascar is an island located in the Indian Ocean off the southeastern coast of Africa. With an area of approximately 587,000 square kilometers, it is the fifth-largest island in the world. Geographically the island occupies a unique position, separated from the African continent by the Mozambique Channel.

The Malagasy territory is distinguished by its exceptional geographical diversity, featuring tropical forests in the east, volcanic plateaus in the center and semi-arid regions in the southwest. The island is also rich in natural resources particularly gemstones making it a major player in the global gem industry. Madagascar is especially known for its sapphires, which account for a significant share of global production. It is also a notable source of rubies, tourmalines, garnets and beryls, including emeralds.

Moreover, Madagascar is one of the few places in the world where grandidierite, a rare and valuable gemstone prized for its unique blue-green hue, can be found. The island is also home to pezzottaite, an even rarer gemstone with shades ranging from pink to orangey pink. Pezzottaite is a cesium-rich variety of beryl unique to Madagascar. This abundance of gemstones, some of which are found nowhere else, makes Madagascar an essential destination for geologists and gemologists worldwide.

Madagascar has been renowned for its gemstones since the 16th century. In 1547, Captain Jean Fonteneau is believed to have been the first to describe the island's minerals. A century later, in 1668, the "*Compagnie des Indes*" sent Joseph-François Charpentier de Cossigny de Palma, a French engineer and explorer to assess Madagascar natural resource potential.

Left page photo: A 3.524-carat rough emerald from Mananjary (Madagascar), Bellerophon Gemlab collection.

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NIGERIAN EMERALD

Introduction

Nigeria is located in West Africa covering more than 923,000 square kilometers, it is the most populous country on the African continent. Nigeria stands out as a major producer of gemstones offering a wide variety of gem minerals. Deposits of aquamarine, copper-bearing tourmaline, garnet, topaz, sapphire and emeralds can be found in the country.

Emeralds are found in central Nigeria, approximately 100 kilometers in a straight line from the capital Abuja. Two main mining areas produce these emeralds: the first known as Gwantu is located in Kaduna State, while the second is near Nassarawa Eggon in Plateau State about 70 kilometers south of Gwantu. Emeralds from Kaduna and Plateau States are much rarer than aquamarine which is mined on a large scale.

Despite the research conducted in Nigeria by Dr. D. Schwarz in the early 1990s the origin of chromium, a crucial element in the coloration of emeralds remains unknown. Even today scientists continue to debate this issue. Studies have determined that Nigerian emeralds are approximately 144 to 190 million years old and are believed to have formed at temperatures ranging from around 400 to 500°C.

Left page photo: 2.332-carat oval faceted sample from Nigeria (Kaduna), Bellerophon Gemlab collection.

15

NORWEGIAN EMERALD

Introduction

Norway is located in the Nordic region of Europe covering an area of approximately 385,000 square kilometers. This Scandinavian country is bordered by the North Sea to the southwest, the Norwegian Sea to the west and the Arctic Ocean to the north. It shares land borders with Sweden, Finland and Russia. Its coastline shaped by countless fjords and its predominantly mountainous terrain are interspersed with vast plateaus. Norway is also rich in natural resources. Its subsoil contains significant deposits of oil and natural gas primarily exploited in the North Sea. Additionally, Norway has substantial reserves of minerals such as iron, titanium, copper, nickel and zinc. In the late 19th and early 20th centuries the Byrud deposit located in southern Norway about 60 kilometers from Oslo, emerged as an important source of gem-quality emeralds.
Commercially exploited during that period this deposit yielded an abundance of high-quality specimens, often incorporated into jewelry pieces.

Mining operations began in 1899 involving up to 30 miners in its early years of activity. Some Norwegian emeralds were displayed in Paris at the "*Exposition Universelle*" in 1900. A cut emerald from Byrud is said to have been incorporated into a piece of jewelry belonging to the British royal family in honor of King Edward VII's coronation in 1902. In 1909 underground mining ceased due to a lack of profitability. Today Norwegian emeralds are extremely rare and primarily sought after by collectors.

Photo on the left page: The shores of Lake Mjøsa around which the Eidsvoll mines are located in Norway.

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PAKISTANI EMERALD

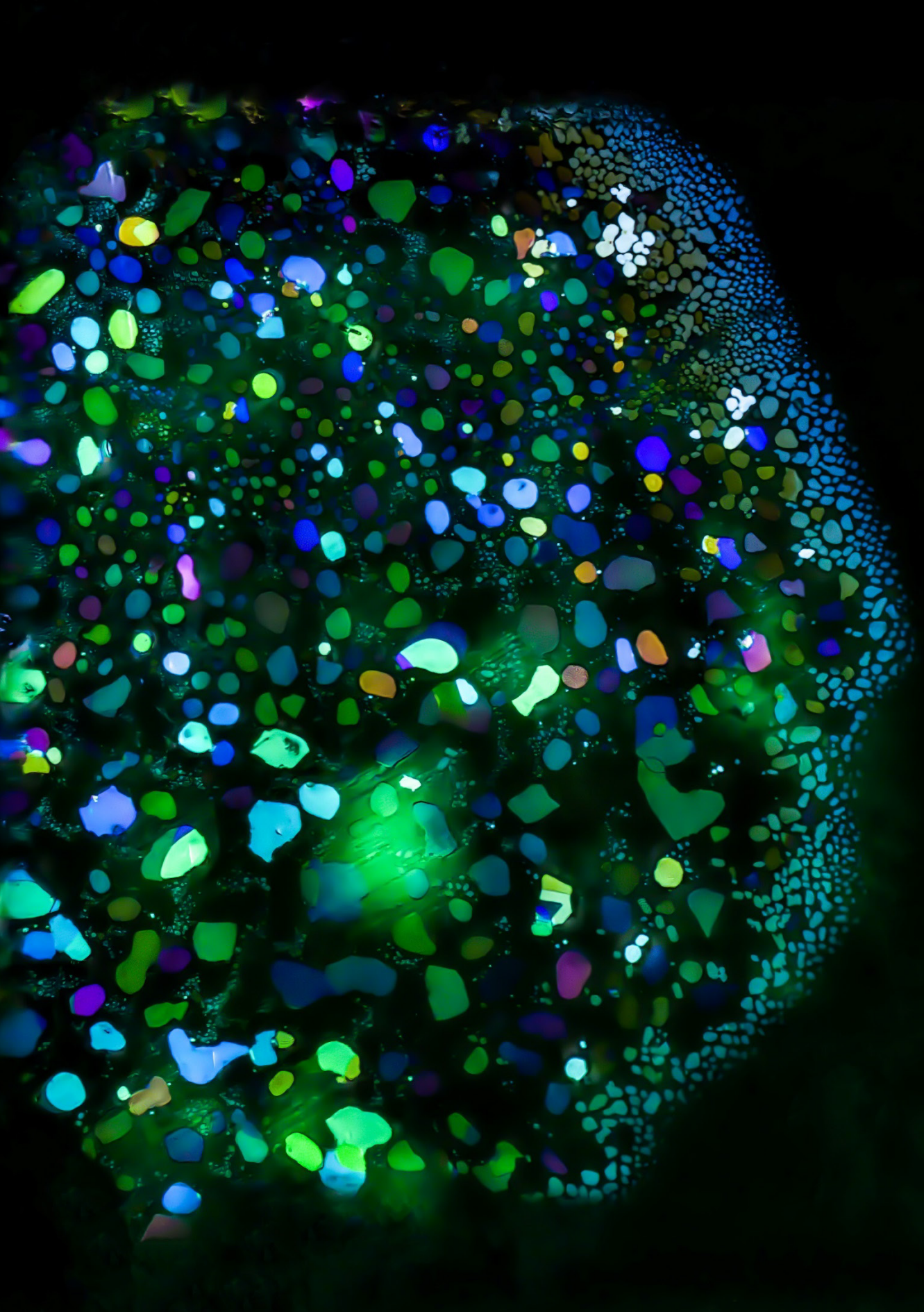
Introduction

Pakistan is a country located in South Asia sharing borders with India to the east, Afghanistan and Iran to the west and China to the north. It is characterized by great geographical diversity including mountainous regions, arid plateaus, fertile plains and a coastline along the Arabian Sea. In the north the Karakoram and Himalayan Mountain ranges are home to some of the world's highest peaks, including K2 the second-highest mountain in the world. The northern regions are known for their glaciers and rugged landscapes, while the south is dominated by the Balochistan Plateau and the Indus Plains.

Pakistan is a major player in gemstone production with significant deposits of tourmaline, topaz, aquamarine, garnet, ruby, sapphire and emerald. Today, the country is recognized for the quality of its gems and ranks alongside Brazil among the world's leading producers of gem minerals. The first historical references to Pakistani emeralds date back to around 300 BCE, as mentioned in the historical and mythological accounts of Alexander the Great.

Although the treasures accumulated during his conquests are often shrouded in mystery and legend, several experts believe that the emeralds described could have originated from the Swat Valley in Pakistan. At that time the regions that are now Pakistan and Afghanistan, including the valleys of Kabul, Swat and Peshawar were part of the Kingdom of Gandhara. Major trade routes such as the Silk Road passed through these valleys. In particular the route connecting Pakistan to Afghanistan ran along the Swat River, with the Mingora outcrop (now an active emerald mine) clearly visible from this road. While it is not possible to confirm with certainty that Swat emeralds were part of Alexander the Great's treasure, it is well established that they have been used in jewelry for over a millennium.

Left page photo: Rough emerald from Swat (Pakistan) with a pyrite crystal in the surface, courtesy Pretty Little Gem.



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RUSSIAN EMERALD

Introduction

Russia is the largest country in the world, covering approximately 17 million square kilometers. Stretching from Eastern Europe to the Pacific Ocean, it boasts great geographical diversity. The Ural Mountains, which run through the country, form a natural boundary between Europe and Asia. Russian landscapes are also characterized by the Caucasus Mountains in the south, the Siberian Mountain ranges, the vast plains of Western Siberia, the taiga and the immense expanses of tundra.

Russia possesses significant natural resources, including abundant reserves of oil and natural gas. The country also has deposits of iron, copper, nickel and coal. In addition to its vast raw material resources, Russia is renowned for its production of precious stones.
The diamond deposits in Yakutia, located in northeastern Siberia, are among the largest in the world, with notable mines such as Mir, Udachnaya and Aikhal, which collectively account for approximately 30% of global production.

Russia is also famous for its alexandrite (a variety of chrysoberyl), a rare gemstone discovered in the early 19th century in the Ural Mountains. This stone is remarkable for its color change, shifting from green in daylight to red or purple under incandescent light. Named in honor of Tsar Alexander II, Russian alexandrite is now one of the most sought-after and rarest gemstones on the market. Additionally, the country is home to deposits of demantoid garnet, renowned for its vivid green color, exceptional brilliance and beauty.
Russia's emeralds primarily come from the Malysheva deposit, located in the Ural Mountains. This mountain range stretches approximately 2,500 kilometers from north to south, extending from the Arctic Ocean to the southern steppes. The mines are situated in the southern part of the range, about 350 km from the border with Kazakhstan.

Left page photo: Impressive snakeskin effect in an emerald from Malysheva (Russia), Bellerophon Gemlab collection.

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SOUTH AFRICAN EMERALD

Located at the southernmost tip of the African continent, South Africa has Pretoria as its administrative capital and a population of over 60 million. It shares borders with Namibia, Botswana, Zimbabwe, Mozambique and Eswatini, while completely surrounding Lesotho. Geographically the country spans vast interior plateaus with coastlines bordered by the Atlantic Ocean to the west and the Indian Ocean to the east. It features diverse landscape ranging from rugged mountains to arid deserts and savannas. Its subsoil is exceptionally rich in natural resources including minerals such as gold, platinum, chrome, manganese and iron, as well as diamonds. In 1869 an 83.5-carats stone known as "The Star of South Africa" was discovered, attracting thousands of prospectors and investors. These discoveries led to the founding of the city of Kimberley, an iconic location in the diamond industry. The country also played a pivotal role in the rise of the De Beers company, which dominated much of the global diamond production for decades. South Africa also hosts emerald deposits whose specimens, though less known today had a significant impact on the gemstone market for several decades. The Gravelotte-Leydsdorp emerald deposit located in the Limpopo province in the northern part of the country, approximately 120 kilometers from the Mozambique border is considered one of the oldest in the world, with a geological formation dating back approximately 2.88 to 2.97 billion years.

Photo on the left page: Wild young male elephants from South Africa.

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TANZANIAN EMERALD

Introduction

Tanzania is located in East Africa, it's a vast country covering approximately 945,087 km^2, making it one of the largest countries on the African continent. Its geography is diverse, consisting of coastal plains, plateaus and mountains, including Mount Kilimanjaro, which is the highest peak in Africa, reaching an altitude of 5,895 meters. To the east, Tanzania has access to the Indian Ocean with a coastline stretching approximately 1,424 km giving it a significant maritime frontage. Tanzania shares borders with several neighboring countries: to the north, Kenya and Uganda; to the west, Rwanda, Burundi and the Democratic Republic of the Congo; and to the south, Zambia, Malawi and Mozambique.

The country is rich in natural resources. In addition to its fertile agricultural lands, Tanzania is known for its gold one of its main mining exports, as well as nickel, coal, iron and uranium. Tanzania is globally renowned for its precious gemstones thanks to its diverse geology that fosters the formation of numerous minerals.

The country is especially famous for tanzanite, a unique blue-violet gemstone found exclusively in the Merelani Hills near Mount Kilimanjaro. Spinel, particularly from the Mahenge region in the southeast, is prized for its shades ranging from bright pink to pink-red and even cobalt blue. Tsavorite garnet, discovered in the 1960s and known for its brilliant green color is often compared to emerald. It is also mined in Tanzania in the Merelani region near the Kenyan border. Other varieties of garnet such as rhodolite with shades of pink and red-violet, are also highly valued.

Tanzania is also home to renowned deposits of rubies and sapphires recognized worldwide. Additionally, the Williamson Mine located in Mwadui in the north, is one of the largest and oldest diamond mines in the world. The country also produces other valuable minerals such as tourmaline and exquisite zircons.

Left page photo: Flamingos in Lake Manyara during the migration season.

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ZAMBIAN EMERALD

Introduction

Zambia is located in Southern Africa and covers an area of 752,618 square kilometers. Its capital, Lusaka, situated on the central plateau is the country's largest city and serves as a major cultural and economic hub. The country shares borders with eight neighbors: the Democratic Republic of the Congo, Tanzania, Malawi, Mozambique, Zimbabwe, Botswana, Namibia and Angola. The terrain is characterized by vast plateaus interspersed with hills and mountains, offering remarkable natural diversity. The landscapes range from savannas to lush tropical forests. Among the major rivers the Zambezi and the Kafue play a crucial role in Zambia's environment and agriculture. Rich in natural resources, particularly copper, the country's economy relies heavily on mining. The Copperbelt region known for its abundant deposits, has shaped Zambia's industrial history and solidified its position in the global market for primary resources. .

Renowned for its emeralds, Zambia's main deposits are in the Kafubu mining area which is highly industrialized with large mining companies such as Gemfields. Another deposit though less significant, has been identified a few hundred kilometers north in Musakashi. These two sites produce high-quality emeralds prized for their vivid green color, attributed to a high concentration of chromium and vanadium. Although the geological formation conditions differ significantly between these two deposits, their emeralds are recognized for their excellence and can compete with those from Colombia, which are considered the most famous in the world.

Photo on the left page: A large parcel of high-grade Zambian emeralds at the Gemfields auction in Bangkok.

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ZIMBABWEAN EMERALD

Introduction

Zimbabwe is a landlocked country in Southern Africa, bordered by several nations: Zambia to the north, Mozambique to the east, South Africa to the south and Botswana to the west. Its capital, Harare is the largest city in the country and serves as its administrative, commercial and cultural center. Zimbabwe is characterized by several plateaus, particularly the central plateau, which has an average altitude of approximately 1,250 meters. The Eastern Highlands Mountain range, located in the east, forms the border with Mozambique and is the country's highest region, reaching around 2,500 meters at Mount Nyangani.

The country is also crossed by several rivers, including the Zambezi River in the north which marks the border with Zambia and is famous for Victoria Falls. Zimbabwe is rich in mineral resources, with significant deposits of platinum, gold, chrome, nickel, coal and diamonds. In 2021 alone, the country produced 4.23 million carats of diamonds valued at several hundred million dollars.

In the mid-1950s, a significant emerald deposit was discovered in the Sandawana region, located in the far south of the country. Emerald extraction spans a strip of approximately twenty kilometers, dotted with seven mines: Orpheus, Eros, Vulcan, Juno, Zeus, Aeres and Machingwe. For several decades Zimbabwe's mines supplied the jewelry industry with very high-quality emeralds, although they were small in size and primarily used for pavé settings and watchmaking. In 1958, Dr. E.J. Gübelin described the discovery of this mine as an "immense surprise," which revolutionized the global market at the time.

Left page photo: Polarized actinolite and mica in a 2.874-carat wafer emerald from Sandawana (Zimbabwe), Bellerophon Gemlab reference.


Adel
Zendero
Machudas
Loango
Ruengas
Pemba
Zanzibar
Monfia
Gamore
Anjouan
Mayotte
Mozambique
Canal de Mozambique

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SPORADIC OR NON-COMMERCIAL PRODUCTION

EMERALD FROM ITALY

Italy is not a globally prominent source of emeralds, unlike countries such as Colombia, Brazil or Zambia, but it does have notable occurrences in the Val Vigezzo region of the Verbano-Cusio-Ossola Province Piedmont in the Western Alps. These emeralds are of mineralogical significance rather than commercial importance; they have been documented since the 1970s. They are characterized by modest color and clarity, making them more significant for mineral collectors and researchers than for commercial jewelry markets. Specimens from Piedmont are considered rare and collectible due to their limited occurrence.

Photo above: Rough emerald crystal on matrix from the Val Vigezzo region, courtesy of Antonio Miglioli.


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EMERALD TREATMENTS

Treatment. (noun) [tʁɛt. mɑ̃] A set of operations performed to improve or modify a product or material.

The purity of an emerald is naturally affected by cleavage planes, healed fissures, fractures and numerous crystalline and/or fluid inclusions. These imperfections, which are almost inevitable, may be poetically referred as "emerald garden".

Furthermore, no common process can eliminate crystalline inclusions (although laser drilling and acid removal of some solid inclusions have been attempted), heat treatments are in almost all cases not applicable to emeralds due to their coloring agents which do not change under heat, as well as the water content in their structure, which can damage the crystal. Open fractures that reach the surface of the stone usually contain air, causing light entering the emerald to be reflected by these fractures like a mirror due to the significant difference in their respective refractive index, making them highly visible. By filling these fractures with a substance that has a refractive index close to that of the emerald, light can pass through without significant deviation within the fractures.

This practice, mentioned by Pliny the Elder in his work *Natural History* in 77 AD, dates back more than two millennia:

"*Emeralds, when they are in poor condition, are repaired by artificial means. Some fractures are filled with oil, others with resin [natural] and there are methods to make defects disappear by immersing them in liquid substances".* [*Natural History (Book XXXVII, Chapter 56)]*

A modern treatment involves placing the stone in a vacuum chamber while it is immersed in the filler under gentle heat (~60 °C), making the filler liquid. The air expands under vacuum and leaves the fissures, while the oil or resin takes its place. It is also common to use moderate pressure (~500 bar) instead of a vacuum to force the oil into the cracks. A combination of both processes is also a common occurrence. Some merchants may quench the stone (gentle heat followed by cold water) to expand fissures that do not reach the surface, making them larger but accessible to the clarity enhancement process.

Photo on the left page: Cedar oil bottles ready for use in the treatment of three Colombian emeralds. Research and Development Department, Bellerophon Gemlab.


Bellerophon Gemlab
Bellerophon
Theodore

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SYNTHETIC EMERALD

The term "synthetic" refers to a substance made by chemical synthesis (the production of compounds by reaction from simpler materials), especially to imitate a natural gemstone. A synthetic Emerald means that it has been created by a man-made process, in a laboratory to replicate the chemical composition, structure and properties of a natural Emerald.
The scarcity of high-quality natural emeralds has always posed a challenge for those who seek to possess these precious gems. This scarcity, combined with advancements in science, led to one of the most significant breakthroughs in the gemstone industry: the creation of synthetic emeralds. Emerald was first synthesized by Ebelman in 1848 with a flux process which unlocked a new chapter in the world of gemstones.

Through carefully controlled processes, scientists were able to replicate the formation of emeralds in a laboratory, producing synthetic gems often with better clarity and color as their natural counterparts.

These man-made marvels offer a more accessible, affordable alternative to natural emeralds. This chapter delves into the fascinating world of synthetic emeralds, tracing the science behind their creation, their history and their inclusions.

Photo above: 0.849-carat Flux Gilson, Bellerophon Gemlab collection.

Left page photo: Extraction of an autoclave after cooling by Theodore Rozet.