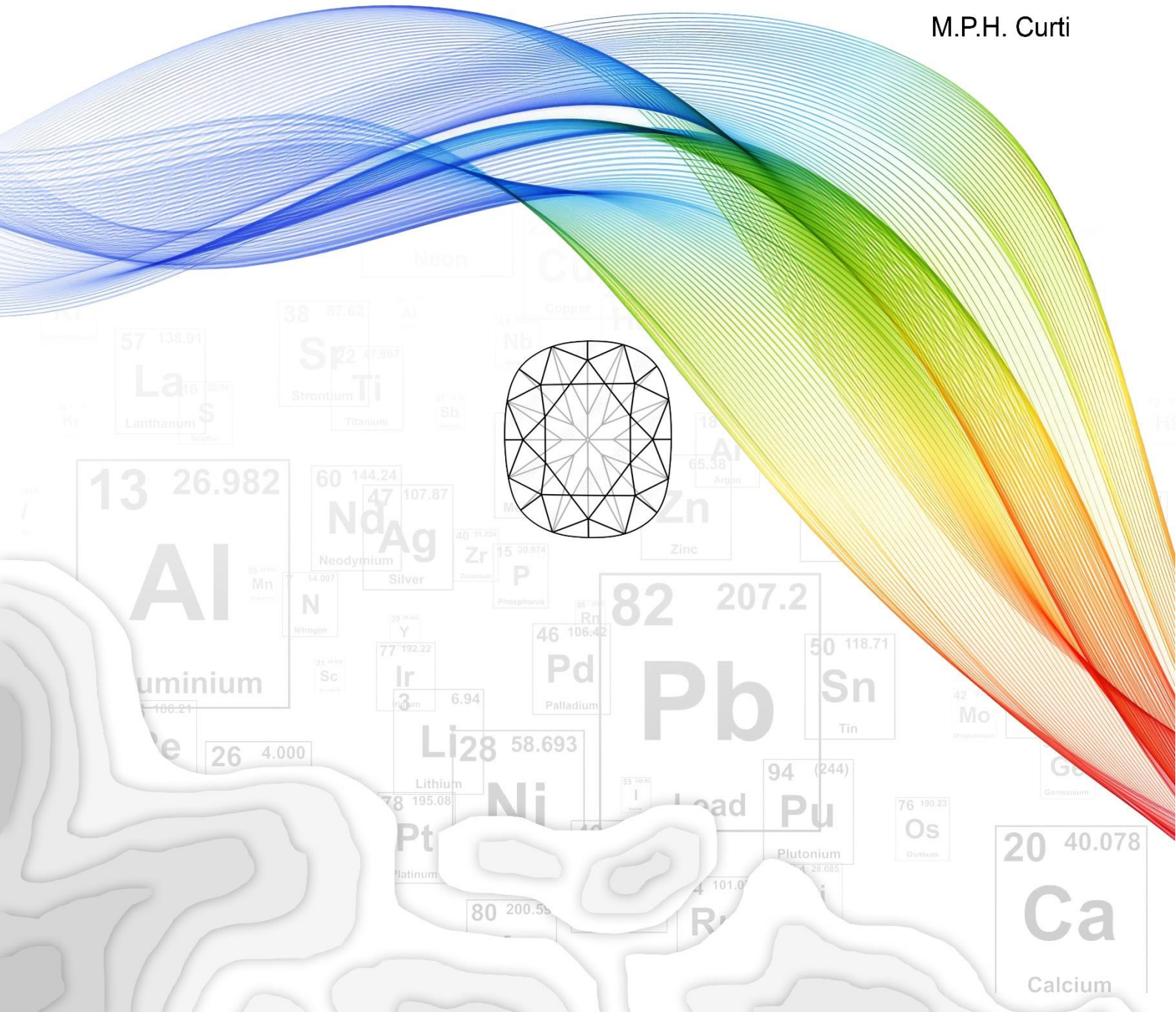
Bellerophon Gemlab

Colored Gemstones

Nomenclature

M.P.H. Curti



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CONTENT

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INTRODUCTION

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This booklet is intended for gemologists, gemstone merchants, hobbyists, connoisseurs, or anyone interested in colored gemstones, as understanding the conclusions written on a gemological report may not be as straightforward as one suppose. Moreover, a deeper understanding of the science behind every single line in a gemological report can only be beneficial to everyone.

Transparency has always been a core value at Bellerophon Gemlab, as such we are delighted to define as clearly as possible and share with you the choice of wording we are using, their meaning and detailed explanation. More importantly why such information may be useful to you, your client or theirs.

We will also dive not too deep into how we collect the data, and how we interpret it to reach any of these conclusions present on a gemological report.

In the pages below you will find information that may seem futile at first sight such as the definition of weight and the implications of the carat unit mass when weighing a gemstone, will also find details listing of the most common treatments per gemstone variety, all treatments doable on a mineral to date, the limitations of a gemological laboratory, the challenges it also faces when doing provenance determinations and much more…

My goal with this booklet is to give you the really essential information and concepts that you would face when confronted with a gemological report. A lot of topics are omitted on purpose, as this booklet is designed to give you the essentials.

Here is a couple of conventions & icons you find in the Colored Gemstones Nomenclature Chart:

Bold text marks words that have been defined already in this book.

Italic is to emphasize new technical terms with an easy-to-understand definition.

🎯 This icon alerts you of really important things you should pay attention to.

ℹ️ This icon points out the easiest way to understand a particular concept or definition.

In addition, I've tried to organize this booklet in approximately the same order of topics found in our gemological report. Whatever your reasons for using this booklet, feel free to go right to a chapter and section that interest you, and/or start from the beginning.

DESCRIPTION

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The “Description” part of the report provides a very basic representation of the object being analyzed in the report. The main objective is to define the analyzed object, for a loose stone it may seem trivial, but should you have a report with a jewelry and many gemstones, the description with visual guided arrows will help you making sure of which gemstones has been analyzed and which may not be.

It is common to receive a whole necklace or ring with numerous gemstones on it, in which case we may be asked to authenticate only the center piece or a specific amount of set gemstones in it. If you have any doubt about which gemstones have been analyzed by us, the description part on your report will guide you.

The description encompasses the amount of stones present in the conclusions, as well as their states during the analysis. Such as loose, mounted, set in a ring, pendant, necklace, earrings etc…

Definition:

Gemstone: *A mineral and/or organic object used for ornamental purposes.*

Description part is here to clearly numbered the amount of gemstone(s) authenticated in the gemological report.

WEIGHT

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The weight of a gemstone may at first sight seem trivial to be defined. However, weight in physics involves an important concept, and in practice measuring the weight of a gemstone carries important financial implications.

In the operational definition, the weight of a gemstone is the force measured by the operation of weighing it, which is the force it exerts on its support. Since the weight is the downward force on the gemstone by the center of earth and there is no acceleration in the gemstone, there exists an opposite and equal force by the support on the gemstone. Also, it is equal to the force exerted by the gemstone on its support (the scale) because action and reaction have same numerical value and opposite direction.

Details can make a considerable difference, for example, a gemstone in free fall exerts little if any force on its support, a situation that is commonly referred to as weightlessness. However, being in free fall does not affect the weight according to the gravitational definition of weight.

Therefore, the operational definition is refined by requiring that the object be at rest. However, this raises the issue of defining "at rest": In our case being at rest with respect to the Earth is implied by using standard gravity.

Using this definition, one may see that the weight of a gemstone at rest on the surface of the Earth is lessened by the effect of the centrifugal force from the Earth's rotation. Meaning a slightly different weight depending on your latitude on earth.

The operational definition, as usually given, does not explicitly exclude the effects of buoyancy, which reduces the measured weight of an object when it is immersed in a medium such as air. Meaning a gemstone might weight slightly differently based on atmospheric conditions.

Carob seeds from which the term Carat derive have been used throughout history to measure gold, gemstones, and diamonds, because it was believed that there was little variance in their mass distribution. However, this was a factual inaccuracy, as their mass varies about as much as seeds of other species.

In the past, each country had its own carat definition. Beginning in the 1570s, it was used to measure weights of diamonds and gemstones.

An international carat was proposed in 1871 by the Syndical Chamber of Jewelers, in Paris, and accepted in 1877 by the Syndical Chamber of Diamond Merchants in Paris. A metric carat of 200 milligrams – exactly one-fifth of a gram – had often been suggested in various countries and was finally proposed by the International Committee of Weights and Measures, and unanimously accepted at the fourth sexennial General Conference of the Metric Convention held in Paris in October 1907. One carat may further be divided into a hundred points.

Definition:

Weight: *The force acting on a gemstone **mass** at rest relative to the measurement device due to earth gravity.*

Mass: *The quantity of matter within a **gemstone**.*

Carat: *A unit of **mass** equal to 200 mg.*

Density: *A **gemstone mass** per unit of volume*.

Specific gravity: *Also called relative density is the ratio of the **density** of a **gemstone** to the **density** of water.*

Point: *A unit of **mass** equal to 0.01 carat.*

MEASUREMENTS

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Measurement is the determination of the size or magnitude of a gemstone. By comparing that unknown volume with some standard quantity, known as measurement unit. The act of measuring a gemstone is an integral part of a gemological report. As a general rule the millimeter is used as the unit of measurement. A millimeter is defined as one thousand of a meter, itself defined as the distance that light travels in 1/299,792,458 of a second.

The measurement of a gemstone almost always includes three numbers: first its length, second its width and lastly its depth. The first two may be exactly the same in a perfect round shaped gemstone, while the last one: its depth, may not be measurable if mounted in jewelry. The proper measurement of a gemstone depends on its shape and cutting style, all measurements are taken based on a gemstone face-up, defining the face-up therefore will change the distanced measured. The definition of length for example may change depending on the shape, for a faceted oval shaped gemstone its length will be the longest distance between two points on its girdle, while for a cushion shaped gemstone its length will be the distance at 90º from its width, itself defined as the shortest distance between two points on its girdle using parallel lines.

The act to take measurements the way we do originated from jewelers, girdles and face up dimensions as well as depth carries important information for the making of the future jewelry surrounding the gemstone. Weight matters when you buy or sell a gemstone, but its measurements matter more if your task is to incorporate this volume in jewelry, even more when there is layout of multiple matching gemstones.

Lastly the acts of writing these dimensions on a gemological report enable anyone with fairly proper measuring device to check it by itself, making the fraudulent act of swapping a gemstone with another report much more difficult, as one has to match its weight and its volume. As such the extreme complexity required to match exactly a colored gemstone weight and measurement with another help to protect everyone along the chain by linking a report to its gemstone.

Definition:

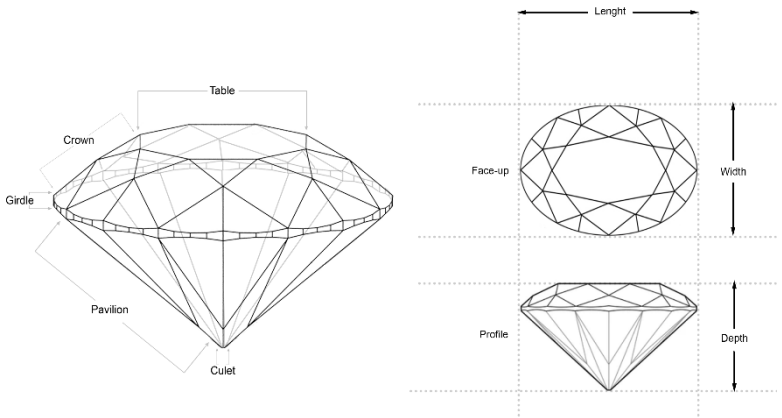
Measurements: *The determination of the size of a **gemstone**.*

Length: *The 90º **measurement** of a **gemstone** end to end from its **width** using parallel lines.*

Width: *The shortest **measurement** of a **gemstone** between two points on its girdle using parallel lines.*

Depth: *The longest **measurement** of a **gemstone** from end-to-end of its profile.*

Millimeter: *A metric unit equal to one thousandth of a meter.*



Example of a measurement on a faceted oval gemstone.

CUT & SHAPE

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The Cut of a gemstone refers to a process by which rough crystal is turned into polished, transparent, and brilliant gemstones, as we commonly know them to be. Both of these attributes – cut and shape – work together to unveil the color, clarity, and shine of the gem. However, there is an important amount of confusion regarding the nomenclature used in cuts; some words define a faceting style, while others a shape, and others may include both of them.

Gemstone faceting, as we understand it today, has its roots somewhere in 15th century Europe. Presumably, the origin of this tedious work was to correct defects in certain crystals and make them closely resemble their perfectly angular mineral counterparts. However, we soon realized that once made, the jewel came to life through the play of light that occurred. Thus began a whole new quest: maximizing the beauty of gemstones through the art of cutting.

For every gemstone, the lapidary is seeking the best compromise between a beautiful appearance, the best retention of weight, the best color, the best clarity, and the best return of light. These compromises pose a great intellectual challenge to the cutter. Color often appears to be the primary focus, followed by either clarity or weight retention.

An easy way to distinguish between cuts and shapes, and the relationship between the two, is that gemstone cuts differ in the style, sizes and amounts of facets, or lack of facets or presence of carving into the gem's surface within each category of shapes.

Definition:

Cut:

Rough: *Shaped and surface finish from nature.*
Cabochon: *Rounded top polished oval, pear, or round* ***gemstone****.*
Sugarloaf: *Rounded pyramidal top polished square, baguette, octagonal or cushion* ***gemstone****.*
Faceted: *Cut with numerous facets.*
Polished: *Polished* ***gemstone,*** *not falling in* ***cabochon*** *or* ***sugarloaf*** *category.*
Carved: *Polished* ***gemstone*** *with recognizable carved pattern or object.*

Shape:

Round: *Shaped like a circle, with most of the points in the perimeter equidistant to the center.*
Oval: *A rounded but elongated perimeter (length is the longest distance between two points on its girdle).*
Cushion: *Rounded corner square or rectangle (length is not the longest distance between two points on its girdle).*
Heart: *Shaped as a heart.*
Pear: *Teardrop-like shape.*
Octagonal: *Square or rectangle with cut corners.*
Triangle: *Triangular shape.*
Trillion: *Triangle with curved perimeter*.
Baguette: *Rectangular shape.*
Marquise: *A boat-like shape.*
Hexagonal: *A shape comprised of six sides*.
Shield: *Shield-like shape.*
Fancy: *Any shapes that do not fall in any definition above*

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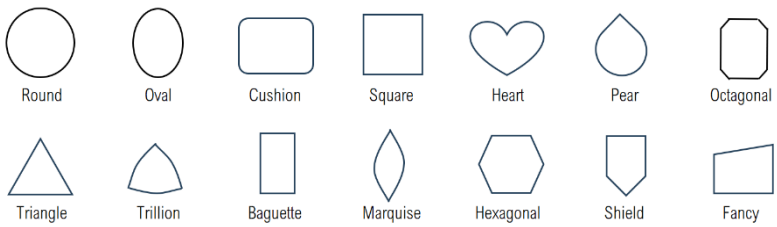

IDENTIFICATION

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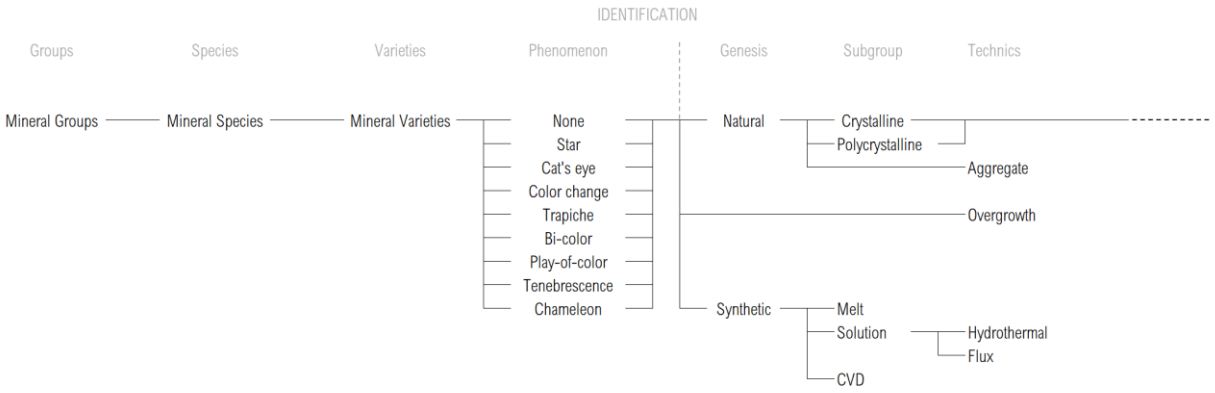
The systematic identification of gemstones has come a long way since the days when any attractive red stone was called a ruby. It was not long ago that we discovered the difference between a spinel and a ruby. What once was an art has now become science.

Cut gemstones possess all the physical properties of the mineral from which they are cut, apart from the crystal habit that is no longer directly visible. Therefore, when talking about gemstones that are mineral, they are identified using the same scientific methods used in mineralogy, the only difference rest in their value, as such no destructive tests are permitted on gemstones, and scientific instruments may be devised especially for testing gemstones, to either take advantage of their forms, such as their cut in a refractometer, or to facilitate handling. Every type of gemstone specie has a unique set of physical and optical properties, and each gemstone variety has a unique profile.

That is where gemology strays away from mineralogy: In its identification a gemologist may include the gemstone mineral specie, but also its variety, and gemologist may have different variety than mineralogy, and/or different criteria for a same variety name. We also include optical phenomena to the identification and more importantly the genesis: The needs to distinguish a naturally formed mineral from its lab-grown human made synthetic counterpart.

A synthetic gemstone is chemically and structurally equivalent to its natural counterpart, the only difference is that it is made in a laboratory.

Mineral Identification Nomenclatures Chart:



"Natural" in the identification part of the report refers only to the formation of the gemstone. It means that this gemstone properties correspond to those formed in Nature. A gemstone can be formed naturally and still be treated.

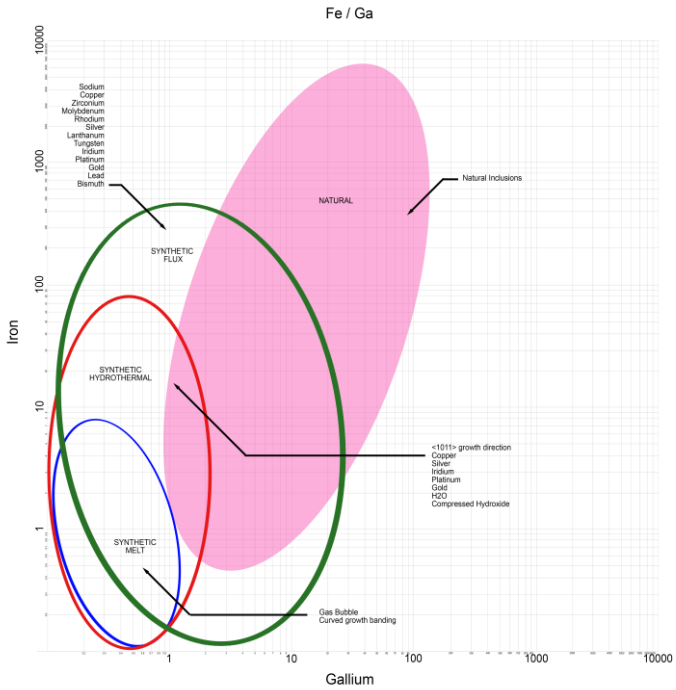
Definition:

Mineral Species: *A solid with a well-defined chemical composition and a specific crystal structure. Excluding compounds that occur only in living organisms.*
Mineral Variety: *A subset of a **mineral species** with some special characteristic(s).*
Naturally formed Gemstone: *A **gemstone** formed entirely by a natural process or a combination of natural processes.*
Lab-grown Gemstone: *A **gemstone** formed entirely or in part by a man-made process or a combination of man-made processes.*
Natural Gemstone: ***Gemstone** whose **gemological properties** correspond to those found in nature.*
Synthetic Gemstone: ***Gemstone** whose **gemological properties** correspond to those found in man-made laboratory grown.*
Crystalline Gemstone: *An orderly repetitive atomic arrangement throughout the **gemstone**.*
Polycrystalline Gemstone: *Consisting of many **crystalline gemstones** either of the same **family** or a combination of families that are randomly oriented with respect to each other.*
Aggregate gemstone: *Consisting of a structure formed from a mass of the same gemstone **family** fragments assembled together.*
Melt (Synthetic): *A **synthetic gemstone** formed by crystallization from its melted constituent.*
Solution (Synthetic): *A **synthetic gemstone** formed by crystallization from a solution (homogenous mixture of one or more solutes dissolved in a solvent).*
CVD (Synthetic): *A **synthetic gemstone** formed by crystallization from a chemical vapor deposition.*
Synthetic Overgrowth Gemstone: *A **synthetic gemstone** formed over a **natural gemstone**.*
Hydrothermal Synthetic Gemstone: *A **synthetic gemstone** formed by crystallization from a water-based **solution**.*
Flux Synthetic Gemstone: *A **synthetic gemstone** formed by crystallization from a non-water-based **solution**.*
Gemological properties: *The combined data with or without their interpretation, of a **gemstone**. Such as chemical, physical, and spectroscopical data.*

Notes On Genesis

The term Natural refers to a gemstone whose gemological properties correspond to those formed by nature without any influence from human, actually most natural mineral formed before homos sapiens walked this earth. These would be gemstones mined from the earth as well as those discovered naturally such a meteorite. Whilst a gemstone is natural, it could have still undergone treatments and enhancements to change its appearance. Synthetic gemstones are physically almost identical to their natural gemstone counterparts that are mined from the Earth. They have the same physical properties and chemical composition as naturally occurring gemstones. The sole difference is that these are gemstones that are grown and manufactured in laboratories under controlled environments by humans, they may also undergo treatment to change their appearances.

Keep in mind that they are almost exactly the same, like a very good printed poster of a famous painting, however, the key difference lies in their rarity. Today it is relatively easy and cost effective to produce synthetic gemstones for less than a hundred dollars, whose natural counterparts are exceedingly rare and will cost you millions should you be able to find it.



Example of a small part of genesis determination in Ruby using Iron and Gallium concentration. Bellerophon Gemlab Research

Phenomenon

Phenomenal gemstones are gemstones that possess striking optical effects. These optical effects make a gemstone exceptional or rather unusual. Each Phenomena has its causes such as inclusions, optical structures and others, the presence of a phenomena is indicated in the "identification" part of your report before the variety name and after the genesis, exception made for multicolored, bi-colored, and color-change gemstone indicated on their "color" part. Chameleon will be disclosed in the "Color Stability" part as well as in the "comment" section of your report.

From left to right: Star Ruby; Cat's eye Chrysoberyl; Trapiche Emerald; Color Change Alexandrite; Bi-color Ametrine; Play-of-color Opal. Bellerophon Gemlab reference collection.

Phenomenon:

Star*: Also called "Asterism phenomenon effect" when a **gemstone** displays four, six or twelve rays of light evenly spaced and well centered that reflects from intersecting needles or needle-like inclusions.*

Cat's Eye: *Also called "Chatoyancy phenomenon effect" when a **gemstone** displays a concentrated band of light across the gemstone that reflects from parallel needle-like inclusions or hollow tubes.*

Color Change: *When a **gemstone** displays a change from a cold to a warm body color when they are exposed to a cold and a warm light.*

Trapiche: *When a **gemstone** displays three, four, six or twelve fixed star-like patterns evenly spaced and well centered that contrast from its body usually due to natural inclusions and/or natural foreign features.*

Bi-color: *When a **gemstone** displays two different evenly distributed colors.*

Multi-color: *When a **gemstone** displays two or more than two different evenly or unevenly distributed colors.*

Play-of-color: *When a **gemstone** displays patches of colors different from its body due to a light diffraction mechanism.*

Tenebrescence: *Also called 'reversible photochromism" is the repeated ability of a **gemstone** to change **color** when exposed to sunlight and lose it in its absence.*

Chameleon: *The ability for a **gemstone** to change **color** repeatedly after light exposure and/or gentle heat or lack of it. It includes **tenebrescence**.*

COLOR

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Color is a continuum that can be defined and described in terms of three attributes:

1. Hue, the attribute of colors that permits them to be classed as, for example, red, yellow, green, blue, or anything in between. Hues are expressed in degree from 0 to 360.

2. Saturation, the strength or purity of the color. (the intensity of the hue). Saturation is expressed in percentage, with 0 being no saturation (white) and 100 being the most saturated (vivid).

3. Brightness is the relative impression of lightness to darkness of the color. (the white and black component of the color). Brightness is expressed in percentage as well, with 0 being black and 100 being fully illuminate.

When Bellerophon Gemlab establishes the color of a gemstone or compare the colors of two gemstones side-by side, several factors must be considered:

1. Use a consistent, standard source of light with known illumination characteristics.

2. The observation should take place in an appropriate surrounding environment that is neutral in its color appearance.

3. A defined geometry should be used between the light source, the object, and the observer.

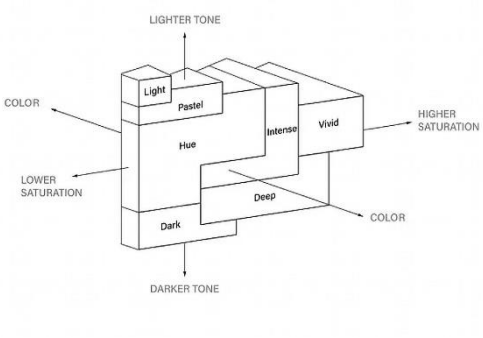
4. If the gemstone color is to be compared to that of another gemstone, the latter should be a standard color reference.

5. Observations must be made by a person with normal color vision. Because any of these factors can influence the visual perception of a gemstone color, they all must be controlled if accurate and consistent results are to be obtained.

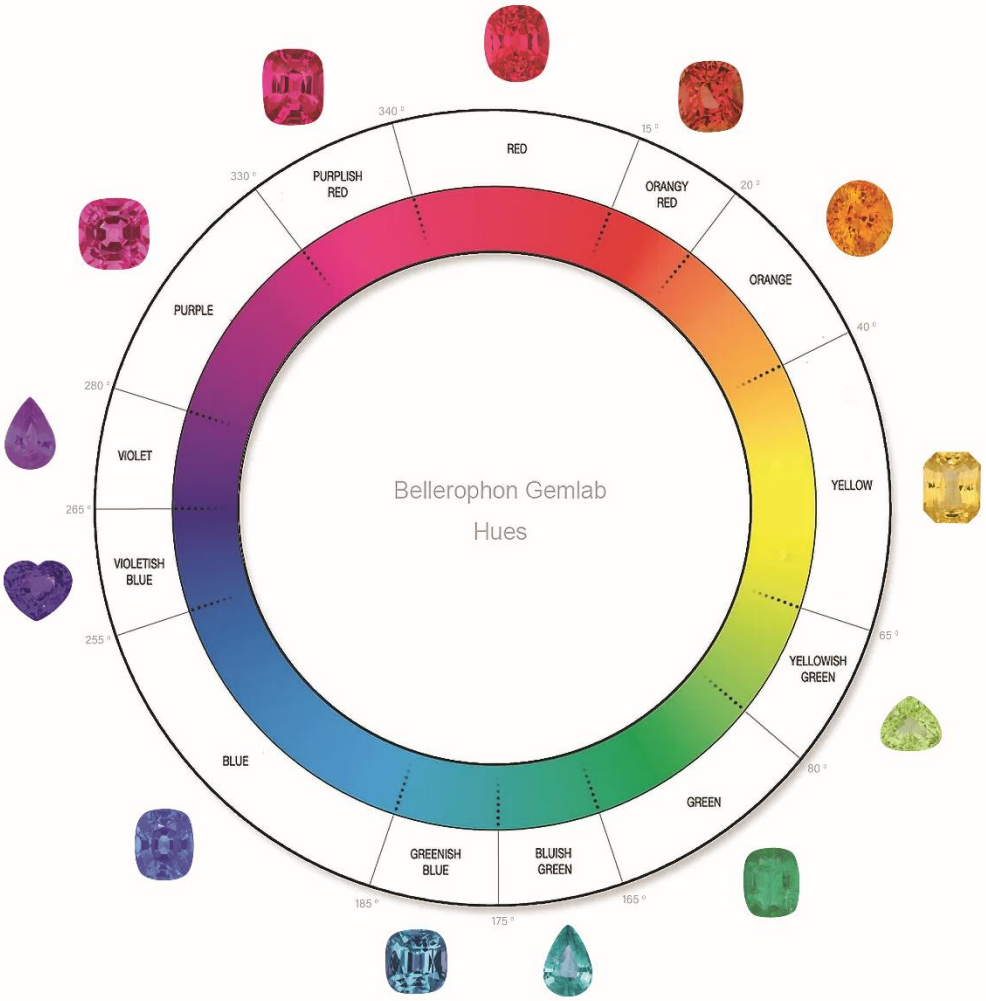
The Bellerophon Gemlab system describes a single color as being “the main color” of the gemstone as a whole (except in case of bi-colored or multi-colored gemstone). We define this single color as the overall color sensation seen when the stone is viewed face-up. Obvious surface reflection and dispersion are not graded, while windowing (see through areas), and/or extinction areas are averaged with the main hue. To help determine the characteristic color, the grader moves the gemstone slightly by rocking the tray. This process of moving the gemstone through a slight angle minimizes the effects of surface reflection, dispersion, windowing, and extinction.

The “color” that a colored gemstone receives on a Bellerophon Gemlab laboratory report is a description of this characteristic color using standardized terms. All hues are divided by the combination of saturation and brightness. Some color defined as hue may be a different saturation and brightness of a main hue. Such as Pink being a lower saturation and lighter tone of Red, the same is true of Brown and Orange. Therefore, there is no pastel Red and no Deep Pink.

Should you be interested to learn more about color grading we invite you to download our dedicated book on Colored Gemstone Color Reference Chart on our website.



Color grades in relation to hue, saturation, and brightness.



Gemstone color grading is a science and an art by itself, discover all about it on our dedicated book on color on our website:

www.gemlabanalysis.com

COLOR ORIGIN & TREATMENT

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The color origin part of the report states the source of the color. In this part you will discover whether the color of the gemstone is entirely natural, if it has been treated or if we are unable to tell the difference.

Gemstone treatments are in constant evolution, but their goals have only one end: improve the value of the gemstone. To this end, treatments are intended to enhance either one or a combination of the following: the color, clarity, weight, and/or phenomenon. These objectives can be obtained by modifying the gemstone through one or a combination of the following mechanisms: heat, pressure, diffusion, irradiation and/or adding foreign matter on, around and/or inside the gemstone.

Many of these treatments can be used alone or in combination, and their results may improve more than just the color. For this reason, you will always find a comment describing in plain English in detail the treatment found providing an accurate and objective basis for consumers who are going to buy the gemstone.

Treatments Nomenclature Chart

COLOR ORIGIN

CLARITY MODIFICATION

		HEAT		PRESSURE		FOREIGN MATTER		
		Natural	Heat	HPHT	Diffusion	Dyed	Coating	Irradiation
PHYSICAL	Natural	Natural No indications of any treatment	Heated This gemstone has been heated to change its color	HPHT This gemstone has been heated at high temperature and high pressure to change its color.	Artificially Diffused This gemstone has been artificially diffused with ***element*** to change its color.	Dyed This gemstone has been dyed to change its color	Coated This gemstone has been coated to change its color	Artificially Irradiated This gemstone has been artificially irradiated to change its color.
	Heat	Natural This gemstone has been quench crackled to change it clarity	Heated This gemstone has been heated to change its color & clarity A minor amount of residues from healing is present	-	-	-	-	-
	Drilling	Natural This gemstone has been laser drilled to change its clarity	-	-	-	-	-	-
FOREIGN MATTER	Oil	Natural This gemstone has been minorly oiled to change its clarity	-	-	-	Dyed This gemstone has been minorly oiled and dyed to change its color & clarity	-	-
	Resin	Natural This gemstone has been minorly resined to change its clarity This gemstone has been impregnated with resin to change its clarity	-	-	-	Dyed This gemstone has been minorly resined and dyed to change its color & clarity	-	-
	Glass Filling (Lead)	Natural This gemstone has been cavities filled with lead glass to change it clarity & weight	Heated This gemstone has been heated with lead glass to change its weight, color & clarity	-	Artificially Diffused This gemstone has been artificially diffused with cobalt and heated with lead glass to change its weight, color & clarity.	-	-	-

Color Origin and its comment will tell you if your gemstone has been treated or if it is natural, or in some rare cases if we are unable to tell the difference.

Treatments Nomenclature & Meaning

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Color Origin:

Natural……This gemstone presents no indications of any treatment related to its color.

Heated……This gemstone has been heated to change its color.

HPHT……..This gemstone has been heated at high temperature and high pressure to change its color.

Artificially Diffused……This gemstone has been artificially diffused with **element** to change its color.

Dyed……This gemstone has been dyed to change its color.

Coated……..This gemstone has been coated to change its color.

Artificially Irradiated……This gemstone has been artificially irradiated to change its color.

None……Color origin is currently undeterminable.

Clarity Modification:

Natural……This gemstone presents no indications of any treatment related to its clarity.

Heated……This gemstone has been heated to change its color & clarity. *minor/moderate/significant* amount of residues from healing is present.

Drilled……This gemstone has been laser drilled to change its clarity.

Oil……*Insignificant/minor/moderate/significant* amount of oil is present to change the clarity.

Resin (Filling)……*Insignificant/minor/moderate/significant* amount of resin is present to change the clarity.

Resin (Impregnation)……This gemstone has been impregnated with resin to change its clarity.

Resin (Fracture Sealed)……This gemstone has been fracture sealed to change its clarity & integrity. The resin filling also keeps the structural integrity of this gemstone.

Clarity Modification……..*Insignificant/minor/moderate/significant* amount of clarity modification is present. The nature of the filler is currently undeterminable.

Glass Filling (Filling)……This gemstone has been heated with lead glass filling to change its color, clarity & weight.

Glass Filling (Cavities)……This gemstone has cavities filled with lead glass to change its clarity & weight.

NATURAL

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Natural color origin is exceedingly rare. It means that your gemstone color is due only to natural processes, and as such the color of this gemstone was found as it is in the ground. A gemstone may have a natural color origin and still be treated for its clarity in which case you will find its corresponding clarity modification written on the comment section. Should the gemstone be completely untreated this comment will be written on the report: “This gemstone presents no indication of any treatment”.

Definition:

Natural Color: *Gemstone with indication(s) of color due only to natural process(es). It must not have any indications of man-made color modifier, including one or a combination of the following: indications of heating (exemption for quench crackling thermal chock noted separately), presence of dye, colored filler, refractive and/or colored coating, artificial irradiation, artificial lattice diffusions of foreign element, and/or high-pressure high temperature.*

Natural Clarity: *Gemstone with indication(s) of clarity due only to natural process(es). It must not have any indications of man-made clarity modification, including one or a combination of the following: Presence of residues within healed fissures and/or cavities following a thermal treatment, presence of any kind of man-made fillers such as oil, resin, glass filling and/or drilled holes by laser, mechanics, or any other forms. Human oil/fat present as trace amount due to handling will not be considered as a clarity modification to a reasonable extent. Any natural clarity modifier due to natural processes such as orange stains and/or inclusions are not considered as clarity modification. Internal features such as exsolved particles or solid foreign crystal being modified by thermal expansion and/or changed phase or nature due to heat are not included as clarity modification to a reasonable extent.*

Gemstone with a natural color origin and no indications of any treatment are incredibly rare. World record for the most expensive colored gemstone, this 55-carat ruby natural color origin can be seen all the way from its rough state.

Bellerophon Gemlab

HEAT

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Heat increases the motions of the atoms in a mineral, an increase in the motion of the atoms competes with the attraction between atoms and causes them to move further apart. From this seemingly trivial effect two important reactions are to be noted: A mineral expands (or in very rare cases reduces) its volume when heated, known as thermal expansion, and atoms may move and/or assemble themselves differently throughout the **lattice**. As heat increases a mineral may completely rearrange himself in a process known as lattice rearrangement, in which case its **mineral phase** and as such its nature may become different. A mineral subjected to a certain amount of heat will also melt therefore becoming a liquid and may recrystallize into something different upon cooling.

Many minerals are formed under high pressure and high temperature with a specific surrounding environment. And regardless of their rapidity of growth most if not all of them are cooled over a very long-time frame (millennia if not millions of years).

Man-made heating processes usually operate under different surrounding environment in term of pressure, temperature, atmosphere, and specially time frame. Therefore, man-made heat treatment often leaves in a gemstone clue in the form of peculiar **crystallographic defects**, tension due to thermal expansion between two minerals, modification of existing mineral, creation of new mineral or structures, changes in internal pressure or exchange of foreign ions with the surrounding atmosphere.

A gemologist heat treatment detection is based on the comparison of the gemological properties of the gemstone before and after heat treatment at different temperatures, its **crystallographic defects**, and the inclusions with their **phases** present. Your gemstone gemological properties are then compared to known references to reach a conclusion on its heat treatment results.

The surrounding oxygen or lack of it in the atmosphere when heated, may change the number of bonds certain defects within a crystal formed with their neighbors, enabling a change in color. However, it is possible if heated enough close to the mineral melting point that the thermal expansion induced, forces fissure together and heal them partially, changing the gemstone clarity as well. A catalyst such as borax may also be use for this end, enabling a reduce localized melting point of the mineral producing a better healing process, but leaving some amount of residues.

Definition:

Atom: *The smallest particle of a chemical element that can exist.*

Ion: *An **atom** or a combination of atoms with a net electric charge due to the loss or gain of electrons.*

Lattice: *The repeating pattern of an arrangement of **atoms** or **ions** that are located at regular points.*

Mineral Phase: *The phase of a **mineral** that becomes physically different through its molecular or crystal structure when induced by a set of conditions such as temperature and/or pressure.*

Crystallographic Defect: *An interruption of the regular patterns of arrangement of **atoms** in a **mineral**.*

Heat treatment is a very common enhancement for a colored gemstone, being traditionally practiced for thousands of years, it is widely accepted and may mimic or complete processes that could occurs naturally by enabling hidden color within the gem to be revealed.

Definition Heat Treatment Detection:

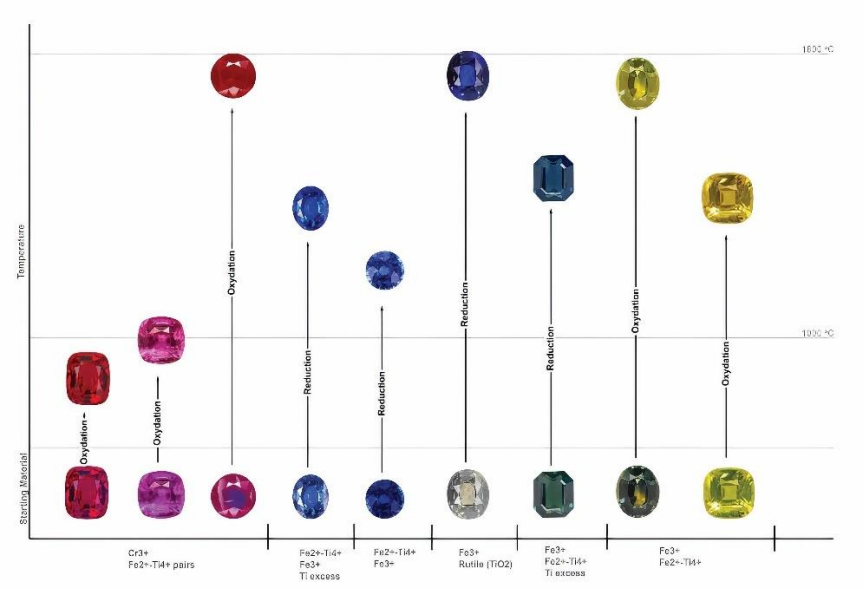
Heated Color Origin: *Gemstone with indication(s) of being heated by a man-made process with or without the intent to change its color. Heat that may be generated by the cutting and/or the jewelry manufacturing process are not included to a reasonable extent. Indications of heat treatment are dependent upon the mineral variety, as well as a minimum temperature and a minimum duration to be relevant in terms of treatment/enhancement as well as detection.*

Clarity Modification due to Heat: *Gemstone with indication(s) of being heated by a man-made process where fissures and/or cavities flux assisted healing has occurred leaving residues with or without the intent to change its clarity. Healed fissures by natural processes such as re-deposition of primary solution during crystal growth is not considered clarity modification. Healed tension crack/fissure surrounding inclusion due to thermal expansion and without the presence of residues is not considered clarity modification.*

Common Heat Treatment per Variety:

Varieties	Low Heat	High Heat
Aquamarine	Yes	-
Citrine	Yes	-
Demantoid	Yes	-
Diamond	Yes	Yes
Kunzite	Yes	-
Morganite	Yes	-
Paraiba	Yes	-
Ruby	Yes	Yes
Sapphire	Yes	Yes
Spinel	Yes	Yes
Tanzanite	Yes	-
Topaz	Yes	-
Tourmaline	Yes	-
Zircon	Yes	-

Common Heat Treatment of Ruby and Sapphire:



Effect of heat treatment on ruby and sapphire at different temperatures and atmospheres conditions.

Bellerophon Gemlab Research

PRESSURE

-

Pressure is the physical force exerted on an object by something in contact with it, measured by the magnitude of the force per unit area. On an atomic scale pressure is the effect of the motion of the atoms on their surroundings. At constant temperature and volume, the pressure is directly proportional to the number of atoms, and for a fixed volume pressure is directly proportional to the temperature.

Therefore, pressure almost always comes from, with and/or produces heat when used for gemstone enhancement. Rare cases where pressure alone is used exist such as compressing organic gemstone or reduced pressure (vacuum) for better fissure filling result.

As such a gemologist pressure treatment detection is almost always directly related to heat treatment detection. Man-made pressure and heat treatment often leaves in a gemstone clue in the form of peculiar **crystallographic defects** related to the matrix pressure proportional to the surrounding pressure it has been exposed to. It is important to note that indications of pressure treatment may be removed by post-**annealing**.

Common Pressure Related Treatment per Variety:

Varieties	Low Pressure	High Pressure
Amber	Yes	-
Diamond	-	Yes
Ruby	Yes	-
Sapphire	Yes	Yes
Emerald	Vacuum	-

Definition:

Annealing: *Heat that is allowed to cool slowly.*

Definition Pressure Related Detection:

HPHT: *Gemstone with indication(s) of being subjected by a man-made process of high pressure and high temperature with or without the intent to change its color. High pressure and high temperature are defined as a surrounding pressure higher than ~800 bar with a temperature higher than ~800 C°.*

ARTIFICIAL DIFFUSION

-

Diffusion treatment in gemology refers to **lattice** diffusion, a process where foreign atoms are inserted into the mineral by thermal activation. Diffusions are directly proportional to the temperature and the atoms sizes.

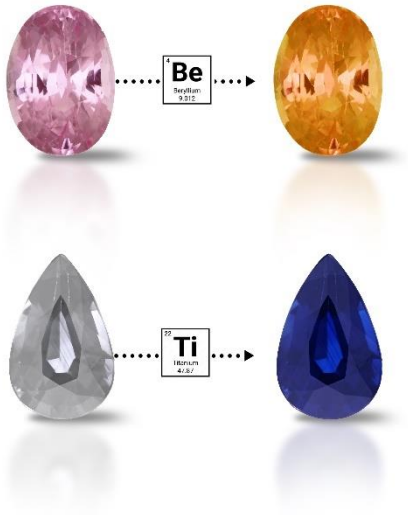
Therefore, diffusion almost always comes with high temperature heat treatment. As such a gemologist diffusion treatment detection is always directly related to heat treatment detection.

Man-made diffusion treatment will leave in a gemstone clue in the form of chemical anomalies, like atoms that are not supposed to be present in the mineral natural state, or by quantity and distribution of the diffused atoms throughout its volume, as well as peculiar **crystallographic defects**.

Hydrogen diffusion for corundum is not considered as artificial diffusion, reasons being that hydrogen diffuses naturally in almost any surfaces given enough time, that its diffusion is a byproduct of regular heat treatment processes to create a reducing atmosphere and that it may not play a direct decisive role in the color modification process, we could also add that hydrogen defects may also be widely present in natural gemstones.

Common Diffusion per Variety:

Varieties	Diffused Element(s)
Andesine	Copper
Opal	Carbon
Ruby	Hydrogen
	Beryllium
	Chromium
Sapphire	Hydrogen
	Beryllium
	Titanium
	Cobalt
Spinel	Cobalt



From top left to bottom right: Sapphire before beryllium diffusion, sapphire after beryllium diffusion; sapphire before titanium diffusion, sapphire after titanium diffusion.

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Definition Artificially Diffused Treatment:

Artificially Diffused: *Gemstone with indication(s) whose lattice has been diffused by a man-made process with any foreign element other than Hydrogen with or without the intent to change its color.*

ARTIFICIAL IRRADIATION

-

Irradiation treatment in gemology is the process by which a gemstone has been exposed to ionizing radiation, meaning exposed to radiation powerful enough to ionize atoms by detaching electrons from them, subsequently creating a **color center** assuming the correct precursor **defects** within the gemstone. This radiation is usually in the form of gamma rays and/or X-rays. It is important to note that heating usually permits the detached electron to return to its original place, therefore for the purpose of gemstone treatment, heating and irradiation are usually opposite in terms of results.

Irradiation may have the capacity to change the **valence** of certain defects within certain minerals as well as the atomic structure of the gemstone's lattice, greatly enhancing the optical properties, including its color. The defects induced by irradiation may not be stable depending on the matrix irradiated.

It is important to note that many irradiation defects can be reversed by heat and/or light exposure. Also, the artificial irradiation process within a mineral can induce defects that exist in natural stone, and/or that may have been induced by natural irradiation within the earth crust during the formation of the gemstone.

Therefore, irradiation treatment is particularly challenging for a gemologist. Gemstones irradiated by man may become radioactive for a short range of time, providing an important clue for detection in the event of authentication during this time frame, artificial irradiation may leave in a gemstone clue in the form of peculiar crystallographic defects as well. Moreover, for gemstone with unstable irradiated induced defect, a **color fading test** may remove all irradiation, naturally and/or man-made induced **color center**.

Definition:

Valence: *Relating to electrons involved in or available for chemical bond formation.*

Vacancy: *A missing **atom** from the lattice of the mineral.*

Color Center: *A type of **defect** in the crystal **lattice**, consisting of one or more electrons trapped at an ionic **vacancy** in the **lattice**.*

Color Fading Test: *A test conceived to remove all color centers with shallow to medium energy gap by light and/or gentle heat exposure for a certain period of time. The test usually consists of placing the stone on a metallic reflecting plate for ~3 hours under strong halogen fiber optics, color is analyzed before and after the test and then compared.*

Definition Artificially Irradiated Treatment:

Artificially Irradiated: *Gemstone with indication(s) of being irradiated by a man-made process to change its color. Irradiation is defined as the man-made process by which the color of a gemstone is changed by exposure to ionizing radiation (gamma-ray to x-ray). Exposure to radiation for analytical purposes that does not change the color of the gemstone is not considered irradiation. Irradiation due to natural process(es) is not considered artificial irradiation. Unstable color caused by artificial and/or natural irradiation that has been removed by light exposure and/or heat is not considered irradiation.*

Irradiation Common Occurrence & Stability of Color Center:

Varieties	Induced color	Natural	Irradiation
Color fades by light at room temperature and/or fade with gentle heat.			
Hackmanite	Red	Yes	Yes
Topaz	Yellow or Brown	Yes	Yes
Kunzite	Green & Violet	Yes	Yes
Rubellite	Red	Yes	Yes
Tourmaline	Yellow or Brown	Yes	Yes
Tourmaline	Purple	Yes	Yes
Maxixe Beryl	Blue	Yes	***No***
Maxixe Type Beryl	Blue	***No***	Yes
Maxixe Type Beryl	Green	***No***	Yes
Sapphire (Pink)	Orange	Yes	Yes
Sapphire (Colorless)	Yellow	Yes	Yes
Color is stable to light at room temperature but fade with consequent heat.			
Topaz (Cr)	Orange	Yes	Yes
Topaz (Cr)	Blue	Yes	Yes
Quartz	Smoky	Yes	Yes
Amethyst	Purple	Yes	Yes
Rubellite	Red	Yes	Yes
Tourmaline	Yellow or Brown	Yes	Yes
Tourmaline	Purple	Yes	Yes
Irradiation not involving color center, fade with consequent heat.			
Heliodor	Yellow	Yes	Yes
Beryl	Green	Yes	Yes
Pearl	Blue	***No***	Yes
Diamond	Green & Blue	Yes	Yes

Medium Energy Gap

Deep Energy Gap

From top left to bottom right: Topaz before irradiation, Topaz after artificial irradiation; Quartz before irradiation, Quartz after artificial irradiation.

Bellerophon Gemlab Research

Artificial irradiation may be extremely complicated and in some case impossible to detect and/or separate from natural irradiation. However, a color stability test will remove all unstable irradiations induced color to protect you.

OIL, RESIN & OTHER FOREIGN MATTER

-

Gemstone treatment involving foreign matters can be divided into 3 subgroups: Foreign matter placed on the stone, such as cavity filling; foreign matter placed around the stone such as coating and foreign matter placed inside the stone such as fracture filling and impregnation. These treatments are plentiful and numerous in their application, nature, and combination with others. It goes from simple waxing around the stone to high temperature lead glass filling, it may enhance the luster, clarity, weight and/or color of the gemstone.

Nevertheless, this class of treatments are detectable by their very nature. As its name implies, foreign matter does not belong to the matrix structure therefore its detection opportunity by a gemologist is usually solved by its identification.

Definition:

Fissure Filling: *The act of filling with foreign material fissures presents in the stone. (Oil, Resin, or Glass)*

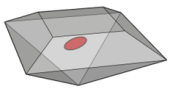
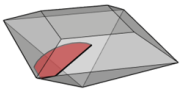
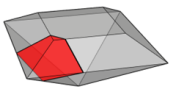
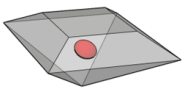
Fracture Filling: *The act of filling with foreign material fractures presents in the stone. (Resin or Glass)*

Impregnation: *The act of closing and sealing the voids between the gemstone's structures. (Resin)*

Cavity Filling: *The act of filling with foreign material cavities presents on the stone. (Resin or Glass)*

Coating: *The act of covering the gemstone with a thin layer of foreign material. (Wax, Metals etc…)*

Features definition related to clarity modification:

	Cracks & Tensions	Fissures	Fractures	Cavities
Microscopic Visual Inspection:	A long, narrow opening within a crystal. A crack cannot reach the surface of the gemstone.	A long, narrow opening in a crystal. Must reach the surface of the gemstone and cannot separate a crystal into two.	A long narrow opening that completely separates a crystal into two.	A empty space on the surface of a crystal. Must be >500 µm wide.
Visual description:				

Oil vs Resin:

Emeralds are almost always filled with resin or oil, or both. Resin is by far the most common filler due to its superiority in optics by hiding fissures, as well as in stability by staying within the fissures and by keeping its transparency over time. However, due to the resin polymerization strength it is possible to seal/glue a fracture within an emerald. The modern treatment that is resin at the beginning of its filler uses for emerald saw a lot of jewelers unhappy with the fact that a gemstone may separate into two when cleaned by ultrasonic or gently heated by a jeweler torch. As such oil usually commands a higher price, being also the most traditional and old approach, it will not be possible to seal a fracture with oil. Nevertheless, should we see that a gemstone has been fracture sealed with resin, it will be disclosed on the report in the comment section as "fracture sealed/glued".

Definition Foreign Filler Clarity Modification Treatment:

Oil: *Gemstone with indication(s) of being fissure filled with oil by a man-made process to change its clarity. Oil is defined as a non-polar substance composed primarily of hydrocarbon without nitrogen bond (N-H and/or N-CH_2), that is hydrophobic (does not mix with water) and lipophilic (mix with other oils). Any presence of natural oil trapped within a crystal will not be considered a clarity modification. Human oil present as trace amount due to handling will not be considered as a clarity modification to a reasonable extent.*

Resin: *Gemstone with indication(s) of being fissure and/or fracture filled and/or impregnated with resin alone or combined with oil by a man-made process to change its clarity. Resin is defined as a highly viscous and/or a solid substance convertible and/or converted to polymer.*

Glass filled: *Gemstone with indication(s) of being fissures and/or fracture filled with transparent and/or colored glass by a man-made process to change its clarity. Common glass fillings include lead and/or silica glass for high refractive index. Glass fillings can be colored and may diffuse within the lattice such as Cobalt Lead glass. Glass filling is commonly combined with a heat treatment but may be used without the need for heating the matrix such as in cavities filling. Any vitreous non-crystalline solid residues formed during flux assisted healing heat treatment are not considered as glass filling to a reasonable extent.*

Drilled: *Gemstone with indication(s) of being drilled by a man-made process with the intent to change its clarity. Drilling may be done by laser, and/or any kind of man-made kinetic motion. Natural growth tubes and/or any other natural processes that may resemble drilling are not considered as clarity modification. Laser inscriptions are not considered as clarity modification. Man-made full and/or half drilling for settings and/or jewelry making purposes are not considered as clarity modification to a reasonable extent.*

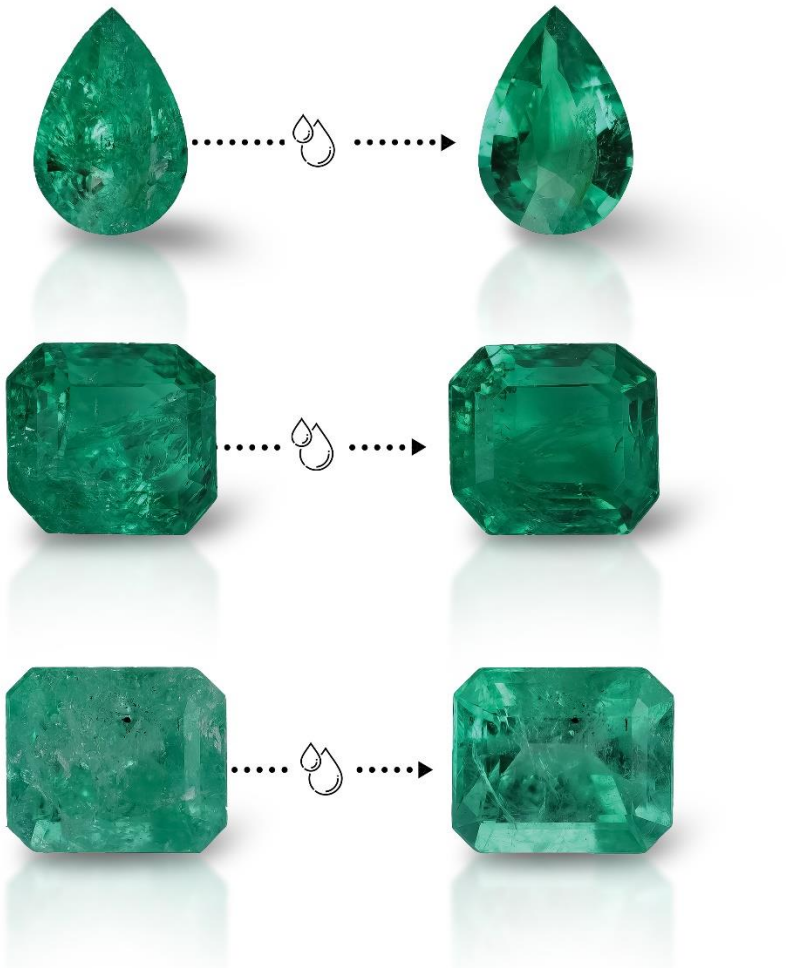
Dyed: *Gemstone with indication(s) of being dyed by a man-made process with the intent to change its color. Any natural color modifier due to natural processes such as orange stains and/or colored inclusions are not considered as dyes.*

Coated: *Gemstone with indication(s) of being coated by a man-made process with the intent to change its color and/or light behavior. Colorless extremely thin layers of organic substances that may be removed with a cleaning cloth such as oil and/or fat and/or wax are not considered coatings to a reasonable extent.*

Common Foreign Matter Treatment per Variety

	Inside		Outside	
Varieties	Impregnation	Fissure Filled	Cavity filling	Coating
Emerald	-	Oil & Resin	Resin	-
Jade	Resin & dyed	-	-	Wax
Opal	Resin & dyed	-	-	-
Paraiba	-	Oil	-	-
Ruby	-	Oil, Heat, Glass: Lead & Silicate	Glass: Lead & silicate	-
Sapphire	-	Glass: Lead & Silicate	Glass: Lead & silicate	
Spinel	-	Oil	-	-

Emerald clarity modification before and after:



Emerald clarity modification (Oil), before on the left and after on the right.
Reference collection Bellerophon Gemlab

UNDETERMINABLE COLOR ORIGIN

-

Treatment detection or lack of it, of a gemstone is based mainly on comparative analysis of internal features and relevant chemical and physical characteristics. Absolute, non-opposable results are attainable in some instances. However, it may not be the case for all treatment detection.

A treatment or a lack of treatment is defined by numerous criteria, such as visual indications, spectral evidence, chemical anomalies, peculiar crystal defects and many more. Each of these criteria may have a different coefficient of reliability, some extremely high others not, it is possible that a gemstone authenticated displays conflicting indications, unknown one or no indications at all. Lastly it is possible that a treatment closely resembles a natural process.

When cases happens where our confidence level are not high enough to provide an accurate conclusion you will see the following Color Origin result followed by the comment:

Color Origin……None

Color origin is currently undeterminable.

Common Undeterminable Color Origin per Variety

Variety	Treatment(s)	Undeterminable Color
Amethyst:	*Irradiated to change its color*	Always
Apatite:	*Heated to change its color*	Common
Aquamarine:	*Heated to change its color*	Common
Citrine:	*Heated to change its color*	Common
Demantoid:	*Heated to change its color*	Possible
Emerald:	*Filler's ID to change its clarity*	Rare when mounted
Heliodor:	*Irradiated to change its color*	Always
Kunzite:	*Irradiated and/or heated to change its color*	Always
Morganite:	*Irradiated and/or heated to change its color*	Always
Paraiba:	*Heated to change its color*	Possible
Quartz green, yellow:	*Heated & irradiated to change its color*	Always
Quartz smoky:	*Irradiated to change its color & clarity*	Always
Rubellite:	*Irradiated to change its color*	Always
Tanzanite:	*Heated to change its color*	Possible
Topaz blue :	*Heated & irradiated to change its color*	Always
Topaz orange, brown, green :	*Irradiated to change its color*	Always
Topaz pink, red violet :	*Heated to change its color*	Possible
Tourmaline pink:	*Irradiated to change its color*	Often
Tourmaline green & blue:	*Heated to change its color*	Possible
Zircon:	*Heated to change its color*	Common

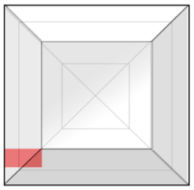
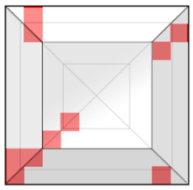
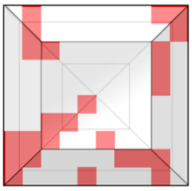
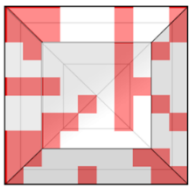
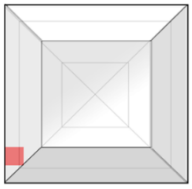
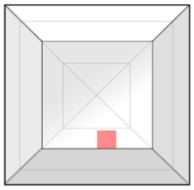
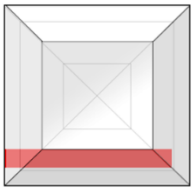
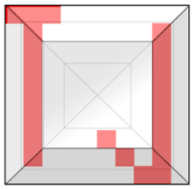
Some color origin of some gemstone will currently always be undeterminable to date due to their close resemblance with natural processes and our inability to distinguish them.

QUANTIFICATION OF CLARITY MODIFICATION

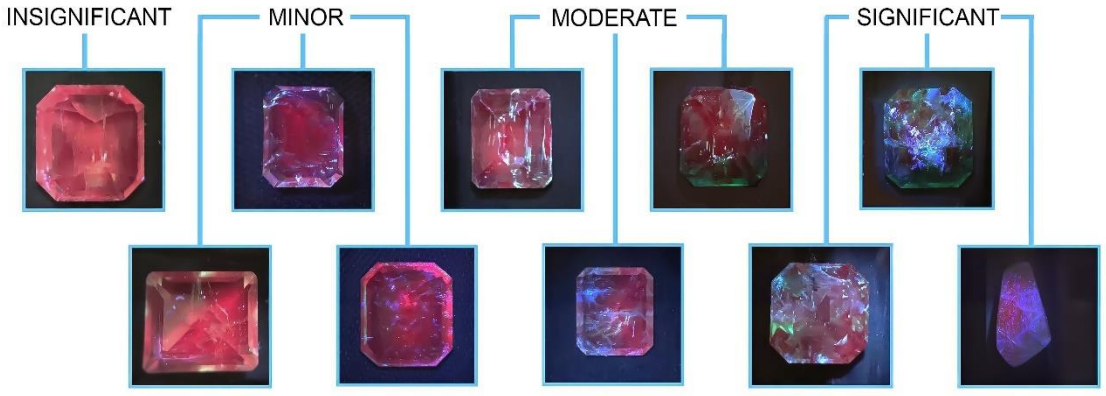
-

The quantification of treatment is applied only to clarity modifications; this quantification consists of assigning a value to a physical quantity of clarity modifications. The amount of the filler is estimated by spatial measurements in relation to the gemstone face up as well as their places on the face, the closer a filler is to the center of a table the more weight it carries in relation to its clarity impact. For gemstones with a cut without table such as sugarloaf or cabochon the table is defined as approximately 50% of its area from the center of the face up. For fancy cut where no orientation prevails for a defined face-up, the face with the most prominent clarity modification will be chosen.

Clarity Modification Grading:

	Insignificant	Minor	Moderate	Significant
Microscopic Visual Inspection:	Never directly under the table.	Fissure max length must be less than 80% of the stone width.		No max for this grade.
% of face up fill:	<2%	<10%	10 to 25%	>25%
Max filling for the grade:				
Minimum filling for the grade:				

Visual Grading Example of Oil in Emerald Using Fluorescence Imaging:



Emeralds under ultraviolet light. The blue fissures reveal the fillers quantity.

Adjective such as minor or significant estimate the impact of the filler on the gemstone's clarity.

TREATMENT STABILITY

-

Stability is the property to resist chemical and/or physical deterioration. It includes a treatment ability to withstand exposure to light, humidity, pressure, temperature, and chemical products. Stability as a whole is an important part of the durability of a gemstone, that includes hardness as well as toughness. The last two are rarely tempered with by a treatment. However, some treatments will change the gemstone stability, these treatments may improve or diminish a gemstone durability. These properties play an important role in the longevity of a gemstone and should be disclosed, as treated gems might require special care.

Heat Treatment: *Heat treatment in almost all gemstones is durable and permanent under regular day to day handling conditions. These treatments do not affect in any significant way a gemstone durability, heat treatment with fissures healing may actually slightly improve a gemstone toughness.*

HPHT: *HPHT treatment is durable and permanent under regular day to day handling conditions. These treatments do not affect in any significant way a gemstone's durability. Questions as arisen regarding the toughness in HPHT treated sapphire, but no measurable change was ever noticed.*

Artificial Diffusion: *Lattice diffusion is durable and permanent under regular day to day handling conditions. These treatments do not affect in any significant way a gemstone's durability.*

Artificial irradiation*: Artificial irradiation may be durable and permanent under regular day to day handling conditions for some gemstones variety, while for others it may fade upon light exposure in a short amount of time.*

Dye Treatment: *Dyes can be applied to porous materials or as a coloring agent in fissures filling. The dye may be long lasting but ultimately depend on the physical properties of the dye itself: they range from very poor stability, as it may leak out of the gems, be removed by contact with a solvent like alcohol or be unstable and fade overtime, to very good stability when sealed within a filler.*

Coating Treatment: *Coating stability ultimately depends on the coating itself: they range from very poor such as in simple ink marker on a gemstone to good stability using metal oxide thin films. However, coating is usually softer than the gemstone making them susceptible to being scratched and deteriorating.*

Acid Bleaching: *When applied alone, acid bleaching treatment may weaken the structure of the materials and increase their susceptibility to breaking. Impregnation is typically used after bleaching to increase durability.*

Impregnation: *The treatment of a porous gemstone being permeated with wax, resin or plastic may actually improve a gemstone's stability and durability. However, due to the poor heat resistance of many fillers used an impregnated gemstone can be susceptible to heat damage.*

Filling (Cavities; Fissures & Fractures): *Filling ultimately depends on the filler itself: Oil and waxes are less durable than resin who is less durable than glass. However, when talking about filling usually the more durable the fillers imply the less durable the matrix is without it. As such glass filling will almost always result in poor durability due to its deterioration combined with the very low-grade material commonly used for this treatment. It should be noted that the ability to remove a filler also implicitly reveals the durability issues of the gemstone before the treatment.*

Drilling: *Drilling is almost always done by laser to drill microscopic holes to remove a visible inclusion. They are very often filled after. Laser drilling is durable and permanent under regular day to day handling conditions.*

Stability of Common Treatment per Gemstone Variety:

Variety	Treatment(s)	Stability
Amethyst:	*Irradiated to change its color.*	Excellent: *Can be removed by consequent heat.*
Aquamarine:	*Heated to change its color.*	Permanent.
Citrine:	*Heated to change its color.*	Excellent: *Can be reversed by irradiation.*
Demantoid:	*Heated to change its color.*	Permanent.
Emerald:	*Oiled to change its clarity.*	Good: *Can be removed by soft solvent and/or changes in pressure.*
	Resined to change its clarity.	Excellent: *Can be removed by strong solvent.*
Heliodor:	*Irradiated to change its color.*	Excellent: *Can be reversed by heat.*
Jade:	*Impregnated to change its clarity.*	Excellent: *Can be removed by strong solvent.*
	Impregnated & dyed to change its color & clarity.	Excellent: *Can be removed by strong solvent.*
	Dyed to change its color.	Poor to very good: *Can be removed by soft solvent or water.*
Kunzite:	*Irradiated and/or heated to change its color.*	Excellent to poor: *Color may fade under the sunlight.*
Morganite:	*Irradiated and/or heated to change its color.*	Good.
Opal:	*Impregnated to change its clarity.*	Permanent.
	Impregnated & dyed to change its color & clarity.	Permanent.
	Carbon diffusion to change its color & clarity.	Permanent.
Paraiba:	*Heated to change its color.*	Permanent.
	Oiled to change its clarity.	Good: *Can be removed by soft solvent and/or changes in pressure.*
Quartz green, yellow:	*Heated & irradiated to change its color.*	Excellent.
Quartz smoky:	*Irradiated to change its color & clarity.*	Poor to Good: *Color may fade under the sunlight.*
Rubellite:	*Irradiated to change its color.*	Excellent: *Can be removed by heat.*
Ruby:	*Heated to change its color.*	Permanent.
	Heated to change its color & clarity.	Permanent.
	Heated with Lead glass to change its weight, color & clarity.	Poor: Impossible to remove and will be *degraded by soft solvent.*
	Heated with foreign ions (Be or Cr) to change its color.	Permanent.
	Oiled to change its clarity.	Good: *Can be removed by soft solvent and/or changes in pressure.*
Sapphire:	*Heated to change its color.*	Permanent.
	Heated with foreign ions (Be; Ti; or Co) to change its color.	Permanent.
	Cavity filling with Lead glass to change its clarity.	Poor: *Can be removed and will degrade*
	Irradiated to change its color.	Poor: *Color will fade after exposure to light.*
Spinel:	*Oiled to change its clarity.*	Good: *Can be removed by soft solvent and/or changes in pressure.*
	Heated to change its color.	Permanent.
	Heated with foreign ions (Co) to change its color.	Permanent.
Tanzanite:	*Heated to change its color.*	Permanent.
Topaz blue:	*Heated & irradiated to change its color.*	Permanent.
Topaz orange, brown, green:	*Irradiated to change its color.*	Excellent: *Can be reversed by consequent heat.*
Topaz pink, red violet:	*Heated to change its color.*	Excellent: *Can be reversed by irradiation.*
Tourmaline:	*Heated to change its color.*	Excellent: *Can be reversed by irradiation.*
	Oiled to change its clarity.	Good: *Can be removed by soft solvent.*
	Irradiated to change its color.	Excellent: *Can be reversed by consequent heat.*
Zircon:	*Heated to change its color.*	Excellent: *Can be reversed by irradiation.*

TREATMENT TRACEABILITY

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The detection of treatment is relevant only at the time the gemstone has been tested in our laboratories. Although extremely rare, it is possible to enhance a gemstone after its authentication, even rarer it is also possible to remove some filler after their authentication.

Treatments done after analysis are not applicable to all enhancement, for example most high temperatures heating, and HPHT require a repolishing of the gem, therefore changing the gemstone weight and/or measurements characteristics from the report, making their identification fairly easy by anyone.

More Importantly many treatments done after a gemological report by Bellerophon Gemlab is issued will be easily identified by comparing the photography and the 360 videos of the gemstone done at the time of testing with the actual item by noticing if the clarity and/or the color has been changed.

Emerald has been the most touched gemstone by this issue, by submitting an emerald for a report and oiling it after its analysis, or by submitting an oiled emerald and removing its oil to fill it with resin after. Recently artificially irradiated orange and yellow sapphire after their analysis as also arisen, although less of an issue for the final consumer due to their unstable color who will fades after couple of days, weeks, or maximum months under regular daylight.

Lastly we keep a complete record of your gemstone gemological properties, its internal features places, and states. In case of any doubts resend your item to one of our laboratories.

Traceability Process:

Traceability comparison process for post treatment identification. We compare all these data collected during the first analysis with the same one collected during re submission.

COLOR DISTRIBUTION

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Color distribution refers to the level of homogeneity of the color in the gemstone, if the color is the same hue, and/ saturation at every point on the gemstone face-up. If its color is uniform without irregularities. Color homogeneity is an important aspect of a colored gemstone quality.

Many if not most colored gemstones are allochromatic, meaning they derive their colors from impurities and/or crystallographic defects within their structure. Therefore, in a pure scientific context, a gemstone is never truly homogeneous in so far as it is composed of different atoms and molecules. However, when talking about color distribution we refer to the homogeneity of the whole gemstone color experience in the normal level of our everyday world.

Color distribution is commonly assessed using a comparison method to a standard for qualitative visual inspection. The homogeneity of a color can also be assessed by using spectroscopic methods. Brightness distribution or deviation resulting from the cut due to the optical effect of the numerous facets, including windowing area and extinction is already implicitly included in the grading of the color. Therefore, for the purpose of color distribution it is to some degree partially disregarded.

The cutting of the gemstone is still indirectly highly relevant as color zoning may be accentuated or masked depending on the cutting axis, also a color concentration in a gemstone if well placed may be reflected evenly all around the gem face-up.

Two grades are available when the color distribution of a gemstone is assessed: Even or uneven. Bi colored gemstone is defined by two even colors present in the gemstone face-up, as such there is no bi colored uneven gem. In the case where two colors unevenly distributed are present in a stone it will be defined as “multi-colored” with an uneven color distribution grade.

Definition:

Color distribution: *The uniformity of the color throughout a gemstone. The color homogeneity may depend on a combination of color distribution and/or light behavior from the cutting angles.*

Color Distribution Grades:

Uneven: *Hues within a gemstone with a deviation superior to 30º.*

Even: *Hues within a gemstone with a deviation inferior to 30º.*

COLOR STABILITY

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Gemstones are very often colored by impurities; some of these impurities may not be stable in regard to light exposure or heat exposure. Although rare it is possible for a gemstone to lose its color over time under normal conditions, whether it is the effects of a natural defects or treatment by heat or irradiation, it is important to make the distinction between gemstone whose color are stable and those that fade. One exception is chameleon gemstone also technically called reversible photochromism, these gemstones have the ability to fade and regain their color repeatedly after light exposure and/or heat or lack of it.

At present, the only practical way for a gemologist to separate these three materials is by an extended exposure to light (~3 hours) or by some sort of gentle heating test (~200°C for a few minutes), all gemological laboratory chooses the first as the latter may potentially present a problem with heat treatment detection.

Yellow, orange and padparadscha sapphire, as well as hackmanite and maxixe are the most commonly touched gemstones varieties by the issue of their color stability.

Definition:

Stable: *The present color grade in the report described the most stable color of the gemstone.*

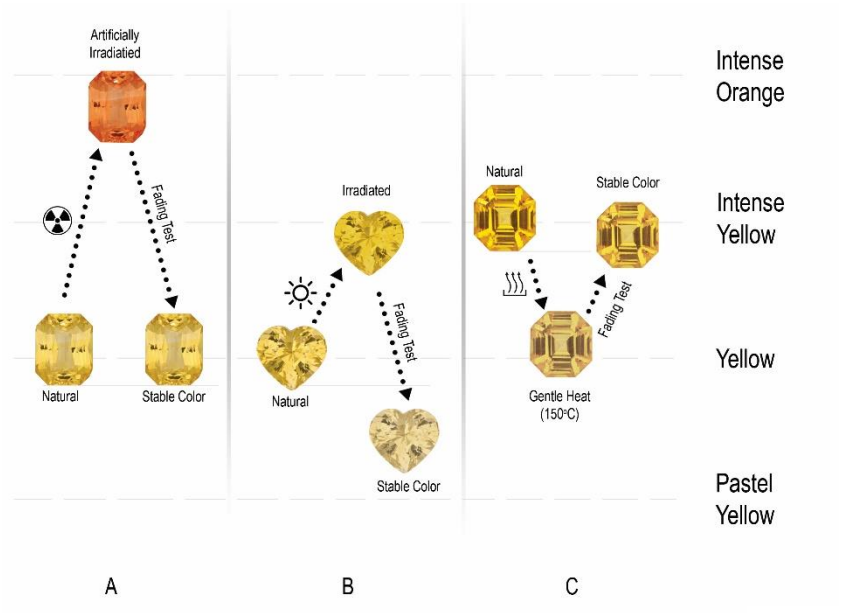
Unstable: *The gemstone has been submitted for a color fading test or not, the present color grade on the report does not describe the most stable color of the gemstone, there is a high probability that the color will fade with time under normal day to day conditions.*

Chameleon: *The ability for a **gemstone** to change **color** repeatedly after light exposure and/or heat or lack of it.*

Chameleon may be accompanied by the following comment:

This gemstone displays the so-called "reversible photochromism" effect also known as "Tenebrescence". This chameleon like color change is extremely rare.

Fading Test results on some Yellow Sapphire:



Results and causes of fading test on different unstable color in Yellow Sapphire.

A: Yellow sapphire artificially irradiated with gamma ray then submitted to Fading test. Stable color same as original color.

B: Yellow sapphire left under the sun for 3 days and short-wave ultraviolet light for 24 hours then submitted to a Fading Test. Stable color lower than original color.

C: Yellow sapphire gently heated at 150°C for 2 hours than submitted to Fading test. Stable color slightly lower than original color.

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Color stability inform you if the color of your gemstone will change overtime.

CLARITY

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Clarity is the quality of a gemstone that relates to the visual appearance of its internal characteristics. The clarity of a gemstone depends on internal factors including its inclusion, color concentration, chemistry, homogeneity, and crystallography.

Inclusions are solids, liquids, or gases that were trapped in a mineral during its formation. They may be crystals of a foreign material, or may have produced structural imperfections, such as tiny cracks. The number, size, color, relative location, orientation, and visibility of inclusions can all affect clarity. Gemstones with higher clarity are usually more valued, with the exceedingly rare "Flawless" graded gemstone or diamond fetching the highest price.

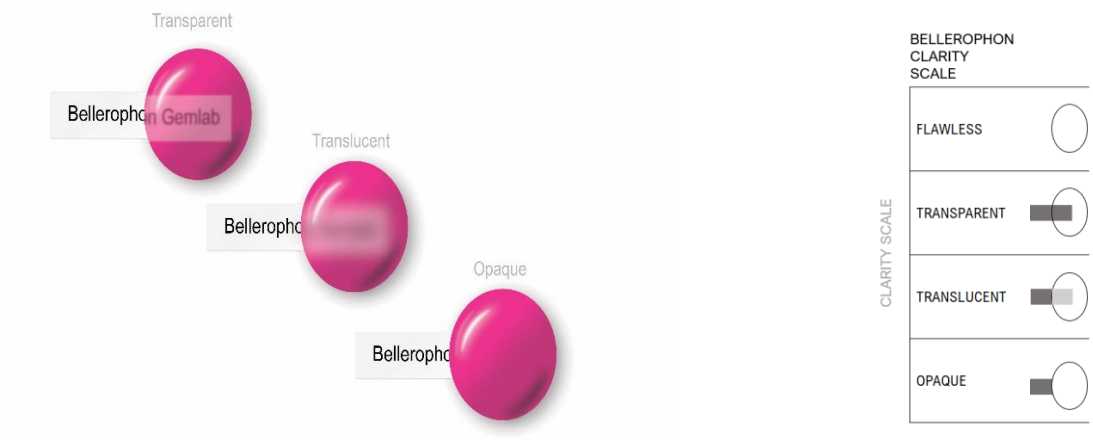
However, minor inclusions or blemishes may be useful, as they can be used as unique identifying marks analogous to fingerprints and may even be welcomed as well as sought after in some colored gemstones, such as horsetail in Demantoid, and many other inclusions responsible for a gemstone phenomenon. As such clarity as discussed here is applicable only to colored gemstone, clarity in diamond is graded differently.

Gemstones can contain solid inclusion consisting of particles of many different sizes. These small solid particles cause the crystal to appear turbid: Turbidity is the cloudiness or haziness of a gemstone caused by large numbers of individual particles that are generally invisible to the naked eye, they may also be due to the gemstone **polycrystalline** structure. In many gemstones variety the purer the crystal the better its quality, but again this rule does not apply to all, some faint amount of haziness in a blue Sapphire gives him a velvety appearance that is highly sought after, also a Jadeite Jade top quality will be defined as translucent and not flawless.

There are several practical ways of assessing a gemstone clarity, the most direct being some measure of attenuation, that is, reduction in strength of light as it passes through a gemstone.

Definition:

Flawless: *No turbidity and no inclusions visible at 10x magnification face-up under darkfield illumination.*
Transparent: *Gemstone that allows light to pass through its crystal, object behind can be distinctly seen.*
Translucent: *Gemstone that allows a portion of light to pass through its crystal, object behind cannot be distinctly seen.*
Opaque: *Gemstone that does not allow any light to pass through its crystal, object behind cannot be seen.*



FLUORESCENCE

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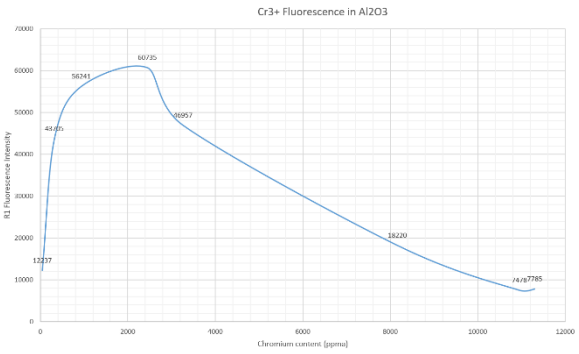
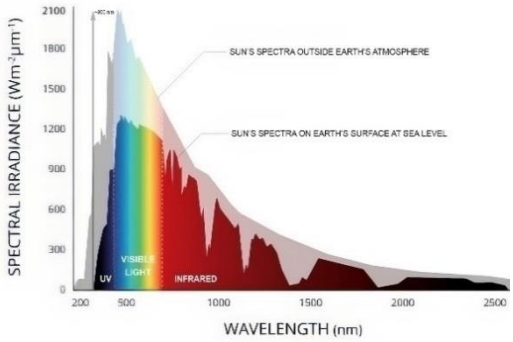
Many gemstones display fluorescence. Fluorescence is the emission of light by a gemstone that has absorbed light. Usually when talking about fluorescence in a gemstone for color grading the absorbed light is in the form of long wave ultraviolet light. Fluorescence in some gemstones plays a very impactful role in their color, therefore, grading a gemstone with or without ultraviolet light component may yield very different color grades. Therefore, we grade the gemstone fluorescence separately, as its influence on a gemstone's overall color grading can depend on the light environment it is exposed to. The stronger the fluorescence the stronger its impact on the color.

A gemstone fluorescence is often link to certain crystal defects and/or absence of defects, such as the red fluorescence in rubies due to the presence of a certain amount of chromium ion, and the absence of iron, seen as a positive feature and highly sought after, expressed by the premium it commands as well as its almost mandatory presence in the grading of the color trade name pigeon's blood. The red fluorescence in rubies created by the absorption of ultraviolet light produces an additional layer of pure red, boosting greatly its color when activated by the lighting environment.



Red fluorescence (R1) intensity in relation to chromium content in ruby and sapphire. Bellerophon Gemlab internal research.

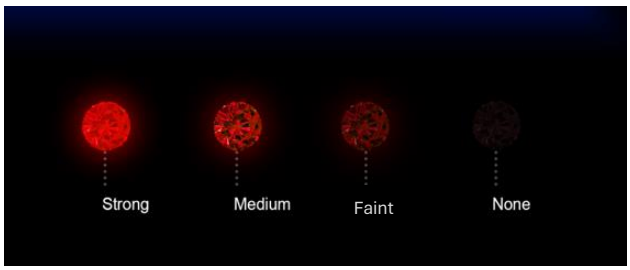


Light emitted by the sun vs light received on earth.

The sun emits a particular spectrum with long and short-wave ultraviolet components, however the short-wave ultraviolet is completely filtered by the atmosphere and does not reach the earth's surface. On the contrary plenty of long-wave ultraviolet reaches us. As such using short-wave ultraviolet provides important chemical information but is completely irrelevant for color grading on the surface of our planet.

Definition:

None: *No influence of the fluorescence on the gemstone body color.*
Faint: *Faint influence of the fluorescence on the gemstone body color.*
Medium: *Medium influence of the fluorescence on the gemstone body color.*
Strong: *Strong influence of the fluorescence on the gemstone body color.*



Fluorescent grades of rubies under long wave ultraviolet light.

The fluorescence grade on a report informs you of the impact of your gemstone fluorescence on its color and how it may changes depending on the different light's environment.

PROVENANCE

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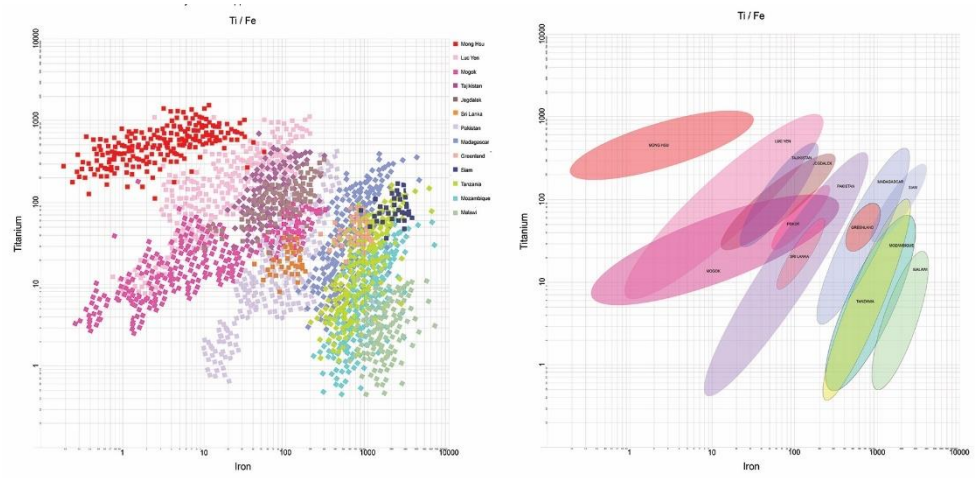
Origin or provenance determination of a gemstone is a comparative science. Its foundation is based on the fact that gemstone properties may be a function of its geological environment. Therefore, deducing that a part of a gemstone's gemological property is correlated to its local geology, a proper referencing of all known pertinent deposits of a gemstone variety with their gemological properties must be referenced and compared to deduce if a geographical origin determination can be statistically relevant. Most colored stone deposits are the direct result of mountain-building events (orogenic events), with the intense heat, pressure, and fluid movement generated acting as the catalyst for crystallization of many gemstones. However, some of these gems were formed much deeper within the earth at more extreme conditions making origin determination even harder or impossible.

To date, a few mostly crustal gemstones, gemstones formed in the earth's crust (<35 km deep), provides sufficient relevant characteristics to pretend to be separated by geographical origin. However, gemstone gemological properties being a function of its geology and not its geography, the gemological properties derived from a gemstone geology may result in broad, overlapping similarities between many geographic origins. Therefore, distinguishing gemstones that are from the same type of geological setting but from different geographic locations persists as a great challenge. The result regarding the provenance of a gemstone may be subjective and not be easily verified.

Multiple layers of evidence, mostly geochemical and inclusion characteristics, must be combined in order to determine a gemstone's origin. Determining trace element concentration within gemstones may allow a statistical correlation to the geological setting they formed in, potentially allowing their geographic origin to be determined.

It is important to emphasize the fact that origin determination does not necessarily ascertain the provenance of a gemstone. Rather it discloses that this particular gemstone gemological properties (chemistry, inclusions, and sometime age) correspond to those found in the referenced country or groups of countries. Due to important overlapping similarities between geographic origin from the same geological settings, gemological science defined populations fields of a geographical origin often by trimming outsider judged to be non-statistically relevant representations of the nominated group. This enables a much clearer definition of a provenance as well as a higher statistical pertinence in origin determination, making the whole provenance determination feasible. However, the flip side is that the more defined is your origin the more outsider you get, giving rise to undeterminable provenance.

Ruby & Pink Sapphire Population Fields Definition Example:



The definition of a population field carries important weight in all future origin determination. The balance lays between the precision and the size the population includes.

Left: Raw geochemical data plotting of referenced geographic origins.

Right: Defined population field of the deposits based on the raw data.

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In practice a comparative origin determination means that we reference all known deposits and when you submit a gemstone we compare its gemological properties against our database. This brings three very important notions regarding our science: First and foremost, it is generally speaking not absolute, but a statistical analysis. Secondly all the referenced geochemical data are linked to a gemstone formation, and not its country of mining, assuming you find two gemstones in a river's delta, there is no guarantee that they were formed together, it is not uncommon that they formed thousands of kilometers and millions of years apart, later carried by the multiple river's tributaries to the same spot. This brings the last important part, a ruby found in a deposit today might not match a ruby found in the same deposit tomorrow, a reference collection worthy of the name is not just about space (geography) but also about time (date of mining). Therefore, a reference collection is a never-ending quest for as long as humans will mine gemstones.

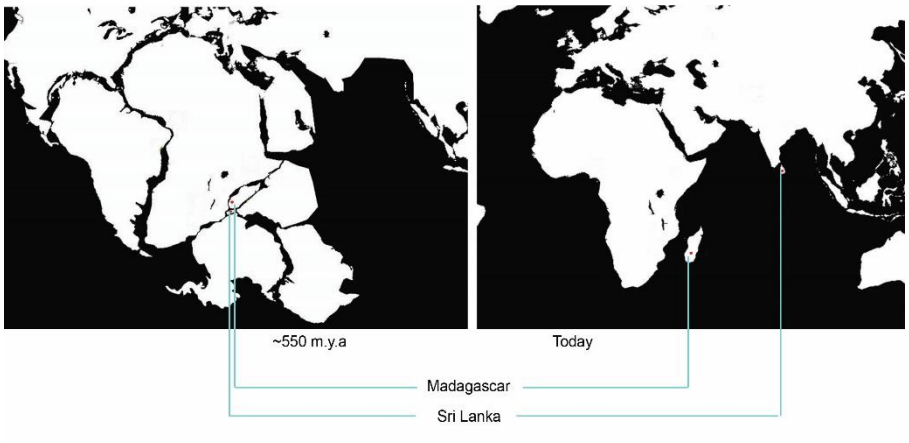
Provenance Correlation & Data Comparison:

	Formation					Determination			
	Geology					Orogeny	Geography		
	Matrix	Depth	Pressure	Temperature	Fluid	Age	Chemistry	Inclusion	Internal Pressure
Description	Rocks surrounding the gemstone. Correlation with chemistry pressure and temperature.	Depth of formation is relevant to surrounding local chemistry. Correlation with pressure and temperature.	Surrounding pressure during formation. Correlation with temperature and depth.	Temperature during formation. Correlation with pressure and depth.	Surrounding fluid(s) carrier. Correlation with inclusion.	Date of formation. Correlation with chemistry & inclusions.	Trace elements concentration. Correlation with Geology.	Internal features. Correlation with geology & chemistry	Crystal internal pressure. Correlation with geology & chemistry.

Origin determination faces important day to day challenges, the trade values gemstone differently based on their countries of mining, while the science compares the data mostly resulting from their formations. Blue sapphire from Sri Lanka and from Madagascar for example shares almost identical characteristics, probably formed togethers and separated by continental plates drifting, as such and to answer the ever-growing demand, gemological laboratories created each their own standard type for each origin, statistically more or less relevant, giving rise to some unharmonized conclusions.

Provenance, at least the geological one remains an extremely important and necessary part in a gemstone analysis, especially in our increasing understanding of gemstone formation. Treatment detection can be intrinsically link to its provenance, a gemologist can easily confuse a heat resulting from a magmatic geological setting with a man-made heat treatment in a corundum should he has not assessed it provenance.

Lastly a gemological laboratory can only compare against what he knowns. Should a new deposit be discovered and not referenced, it may be possible to confuse it with a known one. As such a laboratory must always keep a look out for new deposits and unprecise correlations in a submitted gemstone.



Left: Location of Madagascar and Sri Lanka at the time of formation of most metamorphic sapphire found there.

Right: Location of Sri Lanka and Madagascar deposit as mined today.

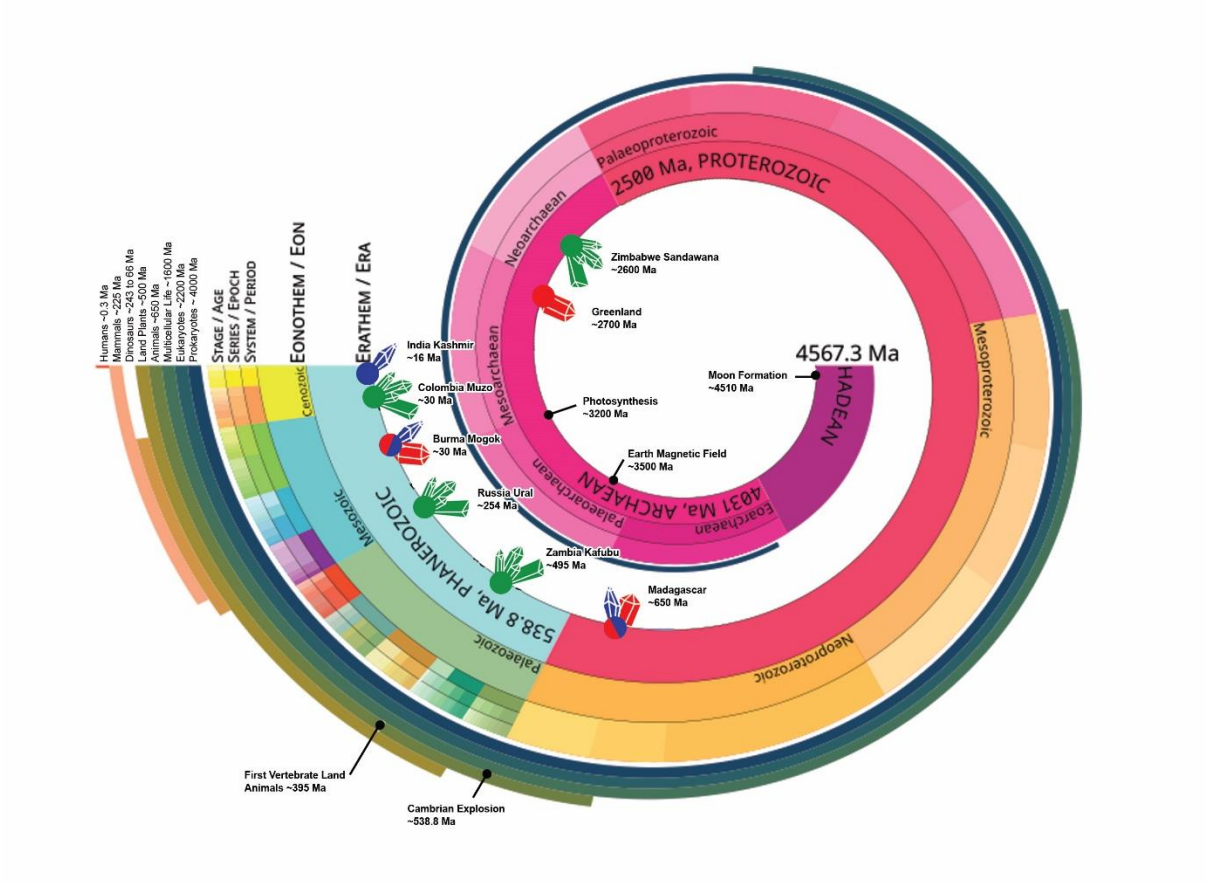
Age of Provenance

The ability to date the age of a gemstone can be tremendously important, especially for origin determination. As two deposits formed millions of years apart and thousands of kilometers away from each other may share identical geochemistry and extremely similar inclusions, such as the famous blue sapphires from Kashmir in India from the recently discovered Bemainty deposit in Madagascar, or the Elahera deposit in Sri Lanka and the renowned Mogok mine in Burma. Should an approximate age be determined, the distinction between these deposits is enormously simplified.

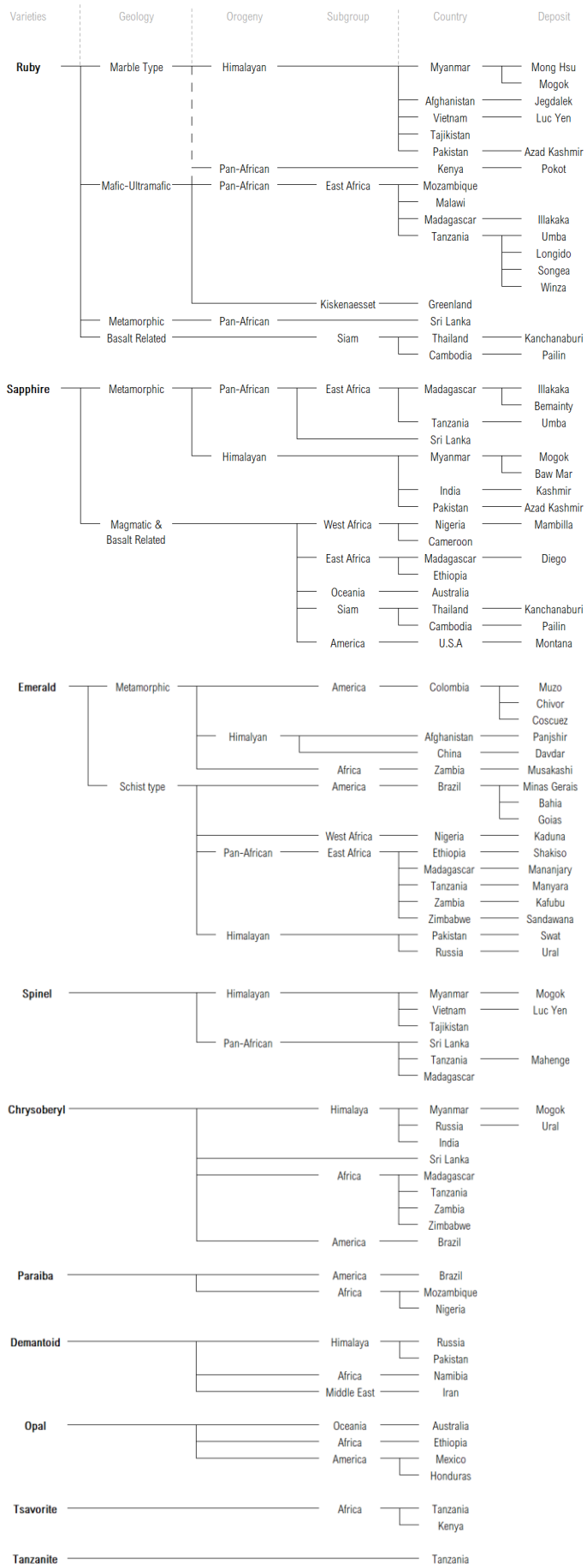
Age determinations for a gemological laboratory conducing non to quasi-nondestructive tests are almost never a direct measurement of the gemstone's age, but rather an indirect measurement through the radioactive decay of minute inclusions that may be found inside the gemstone. For sapphires and rubies, the most common approach is through the estimation of a zircon structural order who is dependent on its radioactive decay, therefore its age, by Raman micro spectrometry. A more direct and precise approach is by radiometric age dating, especially the use of radioactive decay of Uranium to Lead in Zircon as well, by laser ablation inductively coupled plasma mass spectroscopy, although much more precise this technique is much rarer as the gemstone will need to present an available zircon on its surface to be ablated.

You will almost always find the approximated age of formation of a gemstone in its deposit below the provenance. This age may be calculated indirectly or directly by the method above or derived from the provenance through origin determination as well.

Example of Emerald, Ruby & Sapphire age of formation on a Geological Time Frame:



Common Referenced Provenance per Gemstone Variety:



COMMENT

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The comment section includes any clarity modification found, as well as any important note that should added to your gemstone on a report. The complete exhaustive list is enormous and not the subject of this section, but it may include color trade name, peculiar facts about your gemstone, tests not applied due to either technical limit or a request from the gemstone owner as well as rarity award and more.

Color trade name are adjectives used to describe a gemstone, for some since generations, although their actual meaning and color description may have drift based on the different cultures and time using them, they remain today, first as very present wording used in the gem trades, and secondly as an overall gage of quality by merchant, connoisseur, and hobbyist to describe a gemstone. Trade name implies a gemstone identity and variety such as Pigeon Blood for rubies only, some trade name goes as far as to be confused with actual mineral variety like the Padparadscha sapphire, they also describe a specific color in terms of hue, saturation, and brightness as well as color homogeneity. They add a fluorescence characteristic for some, implies clarity and cut grades. They are even limited to specific treatments or lack of it and go as far as to be directly or indirectly through the necessary criteria requirement to be origin specific. In conclusion, trade name presupposes a combination of high quality and rarity based upon the mineral color, with the incorporation of clarity, cut and treatment criteria.

On the other end a gemstone variety is a subset of mineral species with special characteristics, such as specific impurities or crystal defects. Trade names and varieties are very often confused with each other, varieties are a subset of a gemstone species related most of time to its chemistry while trade names imply many facets such as its chemistry, but also its clarity, treatments, and origin, as such there is no notion of quality in a mineral variety. Such as the variety of ruby being defined as a red corundum, while the trade name pigeon blood is a very specific red, with a specific return of light from its cut, a lack of treatments or only a traditional treatment, a specific clarity and sometime a specific origin, same goes for Padparadscha.

A ruby is a ruby wherever it is found, its genesis and no matter his treatments, this does not hold true for a padparadscha sapphire. You will always find a gemstone variety on the identification part of your report, while the trade name will be on the comment section.

Below you will find some color trade name definitions as well as some variety.

Definition:

Mineral Species: *A solid with a well-defined chemical composition and a specific crystal structure. Excluding compounds that occur only in living organisms.*

Mineral Variety: *A subset of a **mineral species** with some special chemical characteristic(s).*

Color Trade Name: *A subset of a natural **mineral variety** with some special color and quality characteristics.*

Some Variety Definition:

Cuprian Tourmaline: *A tourmaline with a detectable presence of copper as trace element.*

Indicolite Tourmaline: *A tourmaline without detectable presence of copper as trace element, whose color is pastel blue; blue; intense blue; vivid blue; deep blue; dark blue; neon blue; intense neon blue; vivid neon blue; pastel greenish blue; greenish blue; intense greenish blue; vivid greenish blue; or deep greenish blue.*

Cobalt Spinel: *A spinel with detectable presence of cobalt as trace element and as a chromophore.*

Ruby: *A corundum colored mainly by chromium impurities. Ruby must be red; purplish red; pinkish red; orangy red; intense red; vivid red; deep red or dark red only. Bi-color corundum whose color falls within the ruby variety may be called "Bi-color ruby & sapphire".*

Sapphire: *A corundum whose color is not red; purplish red; pinkish red; orangy red; intense red; vivid red; deep red or dark red.*

Emerald: *A beryl colored mainly by chromium and/or vanadium impurities. Emeralds must be light green; pastel green; green; intense green; vivid green; deep green; dark green; pastel bluish green; bluish green; intense bluish green; vivid bluish green; or deep bluish green*.

Green Beryl: *A beryl not colored by chromium and/or vanadium impurities. Green beryl must be light green; pastel green; green; intense green; vivid green; deep green; dark green; pastel bluish green; bluish green; intense bluish green; vivid bluish green; or deep bluish green*.

Tsavorite: *A grossular garnet colored mainly by chromium and/or vanadium impurities. Tsavorite must be green; intense green; vivid green; deep green; or dark green.*

Demantoid: *An andradite garnet colored by chromium impurities. Demantoid must be pastel green; green; intense green; vivid green; deep green; dark green; pastel yellowish green; yellowish green; intense yellowish green; vivid yellowish green; or deep yellowish / brownish green.*

Color Trade Name:

Pigeon Blood: *Applicable to Natural Ruby with a combination of hue between 345° and 15° with a saturation between 80 to 100%; and brightness from 100 to 80% with one of the following color grades: Intense red; vivid red or deep red; an even color distribution, a medium to strong fluorescence, a flawless to transparent clarity without pronounced visible inclusions below the table, a good return of light without major windowing or extinction area, and a natural or heated color origin.*

Padparadscha: *Applicable to Natural Sapphire with a combination of hue between 0° to 40° with a saturation between 20 to 60% and brightness of 100% with one of the following color grades: Light orangy pink; pastel orangy pink; or orangy pink, an even color distribution, a flawless to transparent clarity without pronounced visible inclusions below the table, a good return of light without major windowing or extinction area, and a natural or heated color origin.*

Royal Blue: *Applicable to Natural Sapphire with a combination of hue between 220° to 265° with a saturation between 80 to 100% and brightness from 100 to 60% with one of the following color grades: Intense blue; vivid blue or deep blue, an even color distribution, a flawless to transparent clarity without pronounced visible inclusions below the table, a good return of light without major windowing or extinction area, and a natural or heated color origin.*

Cornflower: *Applicable to Natural Sapphire with a combination of hue between 195° to 240° with a saturation between 80 to 100% and brightness from 100 to 80% with one of the following color grades: Intense blue; or vivid blue, an even color distribution, a transparent clarity with a small amount of turbidity for a "velvety appearance" without pronounced visible inclusions below the table, a good return of light without major windowing or extinction area, and a natural or heated color origin.*

Lavender: *Applicable to Natural Sapphire with a combination of hue between 260° to 285° with a saturation between 60 to 100% and brightness from 100 to 60% with one of the following color grades: Intense violet; vivid violet or deep violet, an even color distribution, a flawless to transparent clarity without pronounced visible inclusions below the table, a good return of light without major windowing or extinction area, and a natural or heated color origin.*

Teal: *Applicable to Natural Sapphire with a combination of hue between 160° to 190° with a saturation between 60 to 100% and brightness from 100 to 60% with one of the following color grades: Bluish green; intense bluish green; vivid bluish green; deep bluish green; greenish blue; intense greenish blue; vivid greenish blue; or deep greenish blue, a flawless to transparent clarity without pronounced visible inclusions below the table, a good return of light without major windowing or extinction area, and a natural or heated color origin*

White: *Applicable to Natural Sapphire with a colorless color grade, a flawless to transparent clarity without pronounced visible inclusions below the table, a good return of light without major windowing or extinction area, and a natural or heated color origin*

Paraiba: *Applicable to Natural Cuprian Tourmaline with a combination of hue between 160° to 215° with a saturation between 20 to 100% and brightness from 100 to 60% with one of the following color grades: Pastel bluish green; bluish green; intense bluish green; vivid bluish green; deep bluish green; pastel greenish blue; greenish blue; intense greenish blue; vivid greenish blue; deep greenish blue; pastel blue; neon blue; intense neon blue; vivid neon blue; blue; intense blue or deep blue, an even color distribution, a flawless to transparent clarity and a natural or heated color origin.*

Santa Maria: *Applicable to Natural Aquamarine with a combination of hue between 190° to 205° with a saturation of 20 to 100% and a brightness of 100 to 60% with one of the following color grades: Pastel greenish blue; greenish blue; intense greenish blue; vivid greenish blue; deep greenish blue; pastel blue; neon blue; intense neon blue; vivid neon blue; blue; intense blue or deep blue, an even color distribution, a flawless to transparent clarity and a natural color origin.*

Muzo Green: *Applicable to Natural Emerald with very low to no presence of ion Fe^{2+} and a combination of hue between 110° to 160° with a saturation of 80 to 100% and a brightness of 100 to 60% with one of the following color grades: Intense green; vivid green or deep green, an even color distribution, a flawless to transparent clarity, a natural color origin and none to a minor amount of clarity modification.*