Aluminium minerals (Ore)

By

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1 – Allanite

Allanite crystals on smokey quartz from the White Mountain Wilderness, Lincoln County, New Mexico, USA

Allanite from Queensland , Australia

Allanite is a sorosilicate group of minerals within the broader epidote group that contain a significant amount of rare earth elements. The mineral occurs mainly in metamorphosed clay rich sediments and felsic igneous rocks. It has the general Formula $A_2M_3Si_3O_{12}[OH]$ where the A sites can contain large cations such as Ca^{2+}, Sr^{2+}, and rare earth elements and the M sites admit Al^{3+}, Fe^{3+}, Mn^{3+}, Fe^{2+}, or Mg^{2+} among others . However, a large amount of additional elements, including Th, U, Zr, P, Ba, Cr and others may be present in the mineral. The International Mineralogical Association lists three minerals in the allanite group, each recognized as a unique mineral: allanite-(Ce), allanite-(La) and allanite-(Y), depending on the dominant rare earth present, cerium, lanthanum or yttrium.

Allanite, also called orthite, contains up to 20 % rare earth elements and is a valuable source of them. The inclusion of thorium and other radioactive elements in allanite results in some interesting phenomena. Allanite often has a pleochroic halo of radiation damage in the minerals immediately adjacent. Also highly radioactive grains of allanite often have their structure disrupted or are *metamict*. The age of allanite grains that have not been destroyed by radiation can be determined using different techniques.

Allanite is usually black in color, but can be brown, brown-violet. It is often coated with a yellow-brown alertation product,[6] likely limonite. It crystallizes in the monoclinic system and forms prismatic crystals. It has a Mohs hardness of 5.5–6 and a specific Gravity of 3.5–4.2. It is also pyrognomic, meaning that it becomes incandescent at a relatively low temperature of about 95 °C.

It was discovered in 1810 and named for the Scottish mineralogist, Thomas Allan (1777–1833). The type locality is Aluk Island, Greenland where it was first discovered by Karl Ludwig Giesecke.

Category	Silicate mineral
Chemical Formula	$(Ce ,Ca ,Y, La)_2 (Al ,Fe^{+3})_3 (Si O_4)_3(OH)$
Crystal symmetry	Monoclinic 2/m
Unit cell	a = 8.927 Å, b = 5.761 Å, c = 10.15 Å; β = 114.77°; Z = 2
Color	Brown to black
Crystal habit	Crystals tabular, prismatic to acicular; granular, Massive; commonly metamict
Crystal system	Monoclinic
Twinning	Polysynthetic, common on {100}
Cleavage	Imperfect to poor
Fracture	Conchoidal to uneven
Tenacity	Brittle
Mohs scale hardness	5.5 – 6
Luster	Vitreous , resinous to sub metallic

Streak	Grey
Diaphaneity	Translucent to opaque
Specific Gravity	3.5 – 4.2
Optical properties	Biaxial (-)
Refractive index	n_α = 1.715–1.791, n_β = 1.718–1.815, n_γ = 1.733–1.822
Pleochroism	X = pale olive-green, reddish brown; Y = dark brown, brownish yellow; Z = dark reddish brown, greenish brown
2V angle	Measured: 40° to 80°
Dispersion	r > v; strong
Other characteristics	May be radioactive

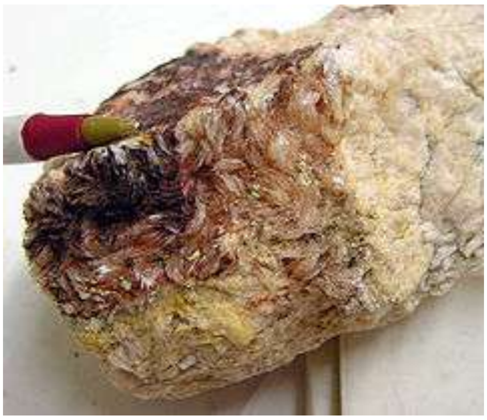
2 – Aluminite

Aluminite is a hydrous aluminium sulfate mineral with Formula: $Al_2SO_4(OH)_4 \cdot 7(H_2O)$. It is an earthy white to gray-white monoclinic mineral which almost never exhibits crystal form. It forms botryoidal to mammillary clay - like Masses. It is very soft Mohs hardness of 1 with a specific Gravity of 1.66—1.7. It forms as an oxidation product of pyrite and marcasite along with aluminous silicates and clays.

It was first described in 1807 from Halle, Saxony-Anhalt, Germany. It is also known as *alley stone* and *websterite* (named after English geologist Thomas Webster).

Aluminite is used by tile & masonry workers to reduce the setting time of cementitious mortars.

3 – Alunite



Alunite from Utah - USGS

Alunite is a sulfate mineral that was first observed in the 15th century in Monti della Tolfa, north of Rome, where it was mined for the manufacture of alum. First called *aluminilite* by J.C. Delamétherie in 1797, this name was contracted by François Beudant in 1824 to alunite.

Distinct crystals of alunite are rarely found in cavities in the Massive material. Alunite crystallizes in the hexagonal system with crystals forming trigonal pyramids that resemble rhombohedra with interfacial angles of 90° 50', so that they resemble cubes in appearance. Minute glistening crystals have also been found loose in cavities in altered rhyolite. Alunite varies in color from white to yellow gray. The hardness is 4 and the specific Gravity is between 2.6 and 2.8. The mineral is a hydrated aluminium potassium sulfate, $KAl_3(SO_4)_2(OH)_6$. Sodium substitutes for potassium and when high in sodium it is called natroalunite. It is insoluble in water or weak acids, but soluble in sulfuric acid. Jarosite is an iron analogue in which Fe^{3+} replaces the aluminium. It occurs as a secondary mineral on iron sulfate ores.

Alunite Marysvale, Utah

Alunite from Slovakia

Alunite occurs as veins and replacement Masses in trachyte , rhyolite , and similar potassium rich volcanic rocks. It is formed by the action of sulfuric acid bearing solutions on these rocks during the oxidation and leaching of metal sulfide deposits. Alunite also is found near volcanic fumaroles. The white, finely granular Masses closely resemble finely granular limestone, dolomite, anhydrite, and magnesite in appearance. The more compact kinds from Hungary are so hard and tough that they have been used for millstones.

Historically extensive deposits were mined in Tuscany and Hungary, and at Bulahdelah, Australia. Currently found at Tolfa, Italy. In the United States it is found in the San Juan district of Colorado; Goldfield, Nevada; the ghost town of Alunite, Utah near Marysvale; and Red Mountain near Patagonia, Arizona. The Arizona occurrence lies appropriately above a canyon named *Alum Gulch*. Alunite is mined as an ore of both potassium and aluminium at Marysvale.[4] Some of the ore deposits were located by airborne and satellite multispectral imaging.

Category	Sulfate minerals
Chemical Formula	$KAl_3(SO_4)_2(OH)_6$
Crystal symmetry	Trigonal 3m or 32/m
Unit cell	a = 6.98 Å, c = 17.32 Å;

	Z=3
Color	Yellow, red, to reddish brown, colorless if pure; may be white , pale shades of gray,
Crystal habit	fibrous to columnar, porcelaneous, commonly granular to dense Massive
Crystal system	Trigonal
Fracture	Conchoidal
Tenacity	Brittle
Mohs scale hardness	3.5 - 4
Luster	Vitreous , some what pearly , earthy if Massive
Streak	White
Diaphaneity	Transparent to translucent
Specific Gravity	2.6 - 2.9
Optical properties	Uniaxial (+)
Refractive index	$n_\omega = 1.572$ $n_\varepsilon = 1.592$
Other characteristics	Strongly pyroelectric

4 – Amblygonite

1 – Introduction :

Amblygonite is a fluorophosphate mineral, $(Li,Na)AlPO_4(F,OH)$, composed of lithium, sodium, aluminium, phosphate, fluoride and hydroxide. The mineral occurs in pegmatite deposits and is easily mistaken for albite and other feldspars. Its density, cleavage and flame test for lithium are diagnostic. Amblygonite forms a series with *montebrasite*, the low fluorine endmember. Geologic occurrence is in granite pegmatites, high-temperature tin veins, and greisens. Amblygonite occurs with spodumene, apatite, lepidolite, tourmaline, and other lithium-bearing minerals in pegmatite veins. It contains about 10 % lithium, and has been utilized as a source of lithium. The chief commercial sources have historically been the deposits of California and France.

2 – History :

The mineral was first discovered in Saxony by August Breithaupt in 1817, and named by him from the Greek *amblus*, blunt, and *gouia*, angle, because of the obtuse angle between the cleavages. Later it was found at Montebras, Creuse, France, and at Hebron in Maine ; and because of slight differences in optical character and chemical composition the names montebrasite and hebronite have been applied to the mineral from these localities. It has been discovered in considerable quantity at Pala in San Diego county, California; Caceres, Spain; and the Black Hills of South Dakota. The largest documented single crystal of amblygonite measured 7.62 x 2.44 x 1.83 m^3 .

Category	Phosphate minerals
Chemical Formula	$(Li,Na)AlPO_4(F,OH)$
Color	Generally white or creamy , but can also be colorless or pale yellow, green, blue, beige, gray, brown or pink.
Crystal habit	Prismatic to columnar form
Crystal system	Triclinic
Twinning	Microscopic polysynthetic twinning common
Mohs scale Hardness	5.5 - 6
Luster	Vitreous to pearly
Specific Gravity	2.98 - 3.11
Polish luster	greasy to vitreous (in gem material)
Optical properties	Double refractive, biaxial, may be either positive or negative
Refractive index	n_a=1.577 - 1.591, n_b=1.592 - 1.605, n_c=1.596 - 1.613
Birefringence	.020 - .027
Pleochroism	weak to none
Ultraviolet fluorescence	very weak green in long wave, light blue phosphorescence in long wave and short wave

3 - Gemology :

Transparent amblygonite has been faceted and used as a gemstone. As a gemstone set into jewelry it is vulnerable to breakage and abrasion from general wear, as its hardness and toughness are poor. The main sources for gem material are Brazil and the U.S.. Australia, France, Germany, Namibia, Norway, and Spain have also produced gem quality amblygonite.

Amblygonite from Taquaral, Itinga, Minas Gerais, Brazil. Scale at bottom is one inch, with a rule at one cm.

5 – Andalusite


Andalusite, Tyrol Austria

1 – Introduction :

Andalusite is an aluminium nesosilicate mineral with the chemical Formula Al_2SiO_5.

The variety chiastolite commonly contains dark inclusions of carbon or clay which form a checker-board pattern when shown in cross-section.

A clear variety first found in Andalusia, Spain can be cut into an interesting gemstone. Faceted andalusite stones give a play of red, green, and yellow colors that resembles a muted form of iridescence, although the colors are actually the result of unusually strong pleochroism.

It is associated with mica schist which increases alkali content in ultimate product and so it has not been exploited economically so far.

Category	Silicate mineral nesosilicate
Chemical Formula	Al2SiO5
Unit cell	a = 7.7980 Å b = 7.9031 Å

	c = 5.5566 Å; Z = 4
Color	Pink, violet, yellow, green, white, gray; in thin section, colorless to pink or green
Crystal habit	As euhedral crystals or columnar aggregates having nearly square cross sections; fibrous compact to Massive
Crystal system	orthorhombic
Fracture	uneven to subconchoidal
Mohs scale hardness	6.5 - 7.5
Luster	Vitreous
Streak	White
Diaphaneity	Transparent to nearly opaque with inclusions
Specific Gravity	3.17 (+ / - .04)
Optical properties	double refractive, biaxial negative; chiastolite has anomalous aggregate reaction .
Refractive index	$n\alpha = 1.629 - 1.640$ $n\beta = 1.633 - 1.644$ $n\gamma = 1.638 - 1.650$
Pleochroism	Weak
2V angle	71 - 86°
Dispersion	$r < v$ strong
Ultra violet fluorescence	Non - fluorescent

2 - Occurrence :

Andalusite is a common regional metamorphic mineral which forms under low pressure and moderate to high temperatures. Called Lapis Crucifer in ancient texts. The minerals kyanite and sillimanite are polymorphs of andalusite, each occurring under different temperature-pressure regimes and are therefore rarely found together in the same rock. Because of this the three minerals are a useful tool to help identify the pressure - temperature paths of the host rock in which they are found.

It was first described and named after the type locality in the Ronda Massif, Málaga, Andalusia, Spain in 1789 .

6 – Annite

Annite sample

1 – Introduction :

Annite is a phyllosilicate mineral in the mica family. It has a chemical Formula of $KFe_3^{2+}AlSi_3O_{10}(OH,F)_2$. Annite is the iron end member of the biotite mica group, the iron rich analogue of magnesium rich phlogopite . Annite is monoclinic and contains tabular crystals and cleavage fragments with pseudohexagonal outlines .

Annite was first described in 1868 for the first noted occurrence in Cape Ann, Rockport, Essex County, Massachusetts, US. It also occurs on Pikes Peak, El Paso County, Colorado. It occurs in igneous and metamorphic rocks that are deficient in magnesium. It occurs associated with fluorite and zircon in the type locality.

2 – Properties :

The relief of a mineral refers to the way a mineral may stand out in plane polarized light. A mineral may be referred to as having a low or high relief. Minerals with a high relief, such as annite, have sharp grain boundaries and display good fracture and cleavage. When viewed under a microscope, this mineral may appear to stick out of the other minerals in the thin section. Relief primarily depends on the index of refraction of the mineral . The index of refraction of a mineral is a measure of the speed of light in the mineral. It is expressed as a ratio of the speed of light in vacuum relative to that in the given mineral. Annite has three indices of refraction known to be n_α = 1.625 - 1.631 n_β = 1.690 n_γ = 1.691 - 1.697. It is also an anisotropic mineral, meaning under the cross polars of a microscope the mineral will become extinct every 90°. However, in plane polarized light, annite appears as a brown or green platy form and is pleochroic, meaning the mineral changes colors under a microscope without the polars being crossed.

3 – Uses :

Annite is a member of the mica group and has very similar properties as other micas such as muscovite and biotite. More importantly, annite is interesting to geologists because it can be used for potassium - argon dating. Because annite contains large amounts of potassium, it can be used to find the absolute age of articles older than 1000 years. This type of dating also preserves a record of the direction and intensity of the local magnetic field, giving field geologists better knowledge of their surroundings.

7 - Axinite

Axinite – Deposit Topotype, France

Axinite is a brown to violet-brown, or reddish-brown bladed group of minerals composed of calcium aluminium boro-silicate, $(Ca,Fe,Mn)_3Al_2BO_3Si_4O_{12}OH$. Axinite is pyroelectric and piezoelectric.

Category	Borosilicates
Chemical Formula	$(Ca,Fe,Mn)_3Al_2BO_3Si_4O_{12}OH$ or $Ca_2(Fe,Mn)Al_2BSi_4O_{15}(OH)$
Color	Reddish brown to yellow to colorless. Blue, violet, grey.
Crystal habit	Tabular, wedge shaped crystals
Crystal system	Triclinic
Fracture	Conchoidal
Mohs scale hardness	6.0 – 7.5
Luster	Vitreous
Streak	White
Specific Gravity	3.18 – 3.37
Optical properties	Biaxial (-)
Refractive index	$n_\alpha = 1.672–1.693$ $n_\beta = 1.677–1.701$ $n_\gamma = 1.681–1.704$

The axinite group includes :

- Axinite - (Fe), ferro-axinite, iron rich, lilac brown to black
- Axinite - (Mg), magnesio-axinite, magnesium rich, pale blue to gray
- Axinite - (Mn), manganaxinite, manganese rich, yellow-orange
- Tinzenite, iron – manganese intermediate, yellow

8 - Bauxite

1 – Introduction :

Bauxite is an aluminium ore and is the main source of aluminium. This form of rock consists mostly of the minerals gibbsite $Al(OH)_3$, boehmite γ-AlO(OH), and diaspore α-AlO(OH), in a mixture with the two iron oxides goethite and hematite, the clay mineral kaolinite, and small amounts of anatase TiO_2. Bauxite was named after the village Les Baux in southern France, where it was first recognised as containing aluminium and named by the French geologist Pierre Berthier in 1821.

2 - Bauxite formation :

Lateritic bauxites (silicate bauxites) are distinguished from karst bauxite ores (carbonate bauxites) . The early discovered carbonate bauxites occur predominantly in Europe and Jamaica above carbonate rocks (lime stone and dolomite) , where they were formed by lateritic weathering and residual accumulation of intercalated clays or by clay dissolution residues of the limestone.

The lateritic bauxites are found mostly in the countries of the tropics.They were formed by lateritization (see laterite) of various silicate rocks such as granite, gneiss, basalt, syenite, and shale. In comparison with the iron-rich laterites, the formation of bauxites demands even more on intense weathering conditions in a location with very good drainage. This enables the dissolution of the kaolinite and the precipitation of the gibbsite. Zones with highest aluminium content are frequently located below a ferruginous surface layer. The aluminium hydroxide in the lateritic bauxite deposits is almost exclusively gibbsite.

3 - Production trends :

Bauxite output in 2005

Estimated numbers for 2008's
total proven bauxite reserves x 1000 tone

Country	Mine production 2007	Mine production 2008	Reserves	Reserve base
Guinea	18,000	18,000	7,400,000	8,600,000
Australia	62,400	63,000	5,800,000	7,900,000
Vietnam	30	30	2,100,000	5,400,000
Jamaica	14,600	15,000	2,000,000	2,500,000
Brazil	24,800	25,000	1,900,000	2,500,000
Guyana	1,600	1,600	700,000	900,000
India	19,200	20,000	770,000	1,400,000
China	30,000	32,000	700,000	2,300,000
Greece	2,220	2,200	600,000	650,000
Iran	—	500	—	—
Suriname	4,900	4,500	580,000	600,000
Kazakhstan	4,800	4,800	360,000	450,000
Venezuela	5,900	5,900	320,000	350,000
Russia	6,400	6,400	200,000	250,000
United States	NA	NA	20,000	40,000

Other countries	7,150	6,800	3,200,000	3,800,000
World total (rounded)	202,000	205,000	27,000,000	38,000,000

In 2007, Australia was one of the top producers of bauxite with almost one - third of the world's production, followed by China, Brazil, Guinea, and India. Although aluminium demand is rapidly increasing, known reserves of its bauxite ore are sufficient to meet the worldwide demands for aluminium for many centuries . Increased aluminium recycling, which has the advantage of lowering the cost in electric power in producing aluminium, will considerably extend the world's bauxite reserves.

In November 2010, Nguyen Tan Dung, the prime minister of Vietnam, announced that Vietnam's bauxite reserves might total 11000Mt; this would be the largest in the world.[3]

4 - Processing :

Bauxite being loaded at Cabo Rojo, Dominican Republic, to be shipped else where for processing; 2007

Bauxite is usually strip mined because it is almost always found near the surface of the terrain, with little or no overburden. Approximately 75% to 85% of the world's bauxite production is processed first into alumina, and then into aluminium by electrolysis. Bauxite rocks are typically classified according to their intended commercial application: metallurgical, abrasive, cement, chemical, and refractory.

Usually, bauxite ore is heated in a pressure vessel along with a sodium hydroxide solution at a temperature of 150 to 200 °C. At these temperatures, the aluminium is dissolved as an aluminate (the Bayer process). After separation of ferruginous residue (red mud) by filtering, pure gibbsite is precipitated when the liquid is cooled, and then seeded with fine-grained aluminium hydroxide. The gibbsite is usually converted into aluminium oxide, Al_2O_3, by heating. This mineral becomes molten at a temperature of about 1000 °C, when the mineral cryolite is added as a flux. Next, this molten substance can yield metallic aluminium by passing an electric current through it in the process of electrolysis, which is called the Hall–Héroult process after its American and French discoverers in 1886.

Prior to the Hall–Héroult process, elemental aluminium was made by heating ore along with elemental sodium or potassium in a vacuum. The method was complicated and consumed materials that were themselves expensive at that time. This made early elemental aluminium more expensive than gold.

9 - Bentonite

Contents

1 – Introduction :

Bentonite is an absorbent aluminium phyllosilicate, essentially impure clay consisting mostly of montmorillonite. There are different types of bentonite, each named after the respective dominant element, such as potassium (K), sodium (Na), calcium (Ca), and aluminum (Al). Experts debate a number of nomenclatorial problems with the classification of bentonite clays. Bentonite usually forms from weathering of volcanic ash, most often in the presence of water. However, the term bentonite, as well as a similar clay called tonstein, has been used for clay beds of uncertain origin. For industrial purposes, two main classes of bentonite exist: sodium and calcium bentonite. In stratigraphy and tephrochronology, completely devitrified (weathered volcanic glass) ash-fall beds are commonly referred to as K-bentonites when the dominant clay species is illite. Other common clay species, and sometimes dominant, are montmorillonite and kaolinite. Kaolinite-dominated clays are commonly referred to as tonsteins and are typically associated with coal.

2 – Types :

2 – 1 - Sodium bentonite :

Sodium bentonite expands when wet, absorbing as much as several times its dry Mass in water. Because of its excellent colloidal properties , it is often used in drilling mud for oil and gas wells and for geotechnical and environmental investigations.

The property of swelling also makes sodium bentonite useful as a sealant, especially for the sealing of subsurface disposal systems for spent nuclear fuel and for quarantining metal pollutants of groundwater. Similar uses include making slurry walls, waterproofing of below-grade walls, and forming other impermeable barriers, e.g., to seal off the annulus of a water well, to plug old wells, or to line the base of landfills to prevent migration of leachate. It is also used to form a barrier around newly planted trees to constrain root growth so as to prevent damage to nearby pipes, footpaths and other infrastructure.

Sodium bentonite can also be "sandwiched" between synthetic materials to create geo-synthetic clay liners (GCL) for the aforementioned purposes. This technique allows for more convenient transport and installation, and it greatly reduces the volume of sodium bentonite required.

Various surface modifications to sodium bentonite improve some rheological or sealing performance in geoenviromental applications, for example, the addition of polymers.

2 – 2 - Calcium bentonite :

Calcium bentonite is a useful adsorbent of ions in solution, as well as fats and oils, being a main active ingredient of fuller's earth, probably one of the earliest industrial cleaning agents. Calcium bentonite may be converted to sodium bentonite (termed sodium beneficiation or sodium activation) to exhibit many of sodium bentonite's properties by a process known as "ion exchange" (patented in 1935 by Germans U Hofmann and K Endell). In common usage, this means adding 5–10 % of a soluble sodium salt such as sodium carbonate to wet bentonite, mixing well, and allowing time for the ion exchange to take place and water to remove the exchanged calcium . Some properties, such as viscosity and fluid loss of suspensions, of sodium-beneficiated calcium bentonite (or sodium-activated bentonite) may not be fully equivalent to those of natural sodium bentonite . For example, residual calcium carbonates (formed if exchanged cations are insufficiently removed) may result in inferior performance of the bentonite in geosynthetic liners.

2 – 3 - Potassium bentonite :

Also known as potash bentonite or K- bentonite, potassium bentonite is a potassium-rich illitic clay formed from alteration of volcanic ash .

3 - Uses :

Much of bentonite's usefulness in the drilling and geotechnical engineering industry comes from its unique rheological properties. Relatively small quantities of bentonite suspended in water form a viscous, shear thinning material. Most often, bentonite suspensions are also thixotropic, although rare cases of rheopectic behavior have also been reported. At high enough concentrations (~60 grams of bentonite per litre of suspension), bentonite suspensions begin to take on the characteristics of a gel (a fluid with a minimum yield strength required to make it move). For these reasons it is a common component of drilling mud used to curtail drilling fluid invasion by its propensity for aiding in the formation of mud cake.

Bentonite can be used in cement , adhesives, ceramic bodies, and cat litter. Bentonite is also used as a binding agent in the manufacture of taconite pellets as used in the steel making industry. Fuller's earth, an ancient dry - cleaning substance, is finely ground bentonite, typically used for purifying transformer oil. Bentonite, in small percentages, is used as an ingredient in commercially designed clay bodies and ceramic glazes. Bentonite clay is also used in pyrotechnics to make end plugs and rocket engine nozzles.

The ionic surface of bentonite has a useful property in making a sticky coating on sand grains. When a small proportion of finely ground bentonite clay is added to hard sand and wetted, the clay binds the sand particles into a moldable aggregate known as green sand used for making molds in sand casting. Some river deltas naturally deposit just such a blend of clay silt and sand, creating a natural source of excellent molding sand that was critical to ancient metal working technology. Modern chemical processes to modify the ionic surface of bentonite greatly intensify this stickiness, resulting in remarkably dough - like yet strong casting sand mixes that stand up to molten metal temperatures.

The same effluvial deposition of bentonite clay onto beaches accounts for the variety of plasticity of sand from place to place for building sand castles. Beach sand consisting of only silica and shell grains does not mold well compared to grains coated with bentonite clay. This is why some beaches are much better for building sand castles than others.

The self - stickiness of bentonite allows high-pressure ramming or pressing of the clay in molds to produce hard, refractory shapes, such as model rocket nozzles. Indeed, to test whether a particular brand of cat litter is bentonite, simply ram a sample with a hammer into a sturdy tube with a close-fitting rod; bentonite will form a very hard, consolidated plug that is not easily crumbled.

Bentonite also has the interesting property of adsorbing relatively large amounts of protein molecules from aqueous solutions. Therefore, it is uniquely useful in the process of wine making , where it is used to remove excessive amounts of protein from white wines. Were it not for this use of bentonite, many or most white wines would precipitate undesirable flocculent clouds or hazes upon exposure to warmer temperatures, as these proteins denature. It also has the incidental use of inducing more rapid clarification of both red and white wines.

Bentonite can also be used as a desiccant due to its adsorption properties. Bentonite desiccants have been successfully used to protect pharmaceutical, nutraceutical and diagnostic products from moisture degradation and extend shelf life. In fact, in the most common package environments, Bentonite Desiccants offer a higher adsorption capacity than silica gel desiccants. Bentonite complies with the FDA for contact with food and drugs.

3 – 1 – Medical :

Bentonite has been prescribed as a bulk laxative, and it is also used as a base for many dermatologic Formulas.

Bentoquatam is a bentonate - based topical medication intended to act as a shield against exposure to urushiol, the oil found in plants such as poison ivy or poison oak.

3 – 2 – In Thai farming :

Application of bentonite clay technology made a big contribution to rejuvenating degraded soils in North east Thailand, which both improved yields and farmer incomes.

Over the past 40 years, North east Thailand has undergone significant changes in land use. Farming systems moved from being subsistence agriculture to being commercial agriculture, typically characterized by paddy rice production in the lowlands and sugar cane / cassava production in the uplands. How ever, the intensification of these production systems degraded soil chemical properties in ways that are best described as nutrient / resource mining operations . As a consequence of these changes, productivity and production systems declined, as soils became depleted of their nutrients and water-retaining properties.

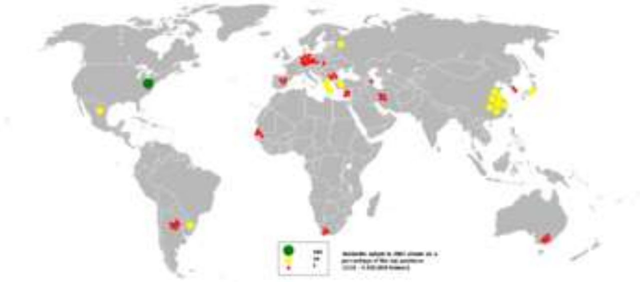
The application of clay technology by farmers in Northeast Thailand, using bentonite clay, has dramatically reversed soil degradation and resulted in greater economic returns, with higher yields and higher output prices. Studies carried out by The International Water Management Institute and partners in 2002–2003 focused on the application of locally sourced bentonite clays to degraded soils in the region. These applications were carried out in structured field trials. Results from these studies showed that applying bentonite clays effectively improved yields of forage sorghum grown under rain-fed conditions.

Cumulative dry matter production over a two-year period ranged from 0.22 tons per hectare under control treatment applying normal fertilizer only, to 23 tons per hectare using an application of 50 tons per hectare of bentonite. Yields rose to 36 tons per hectare when a combination of 50 tons per hectare of bentonite and 10 tons per hectare of leaf litter was applied. These and several other studies conclusively demonstrated that introducing clay-based materials such as bentonite and termite mound materials significantly and persistently improve the productivity of degraded , light – textured soils . Three years after the conclusion of this project, a survey was carried out on 250 farmers, equally split between those farmers that had adopted clay-based approaches versus those that had not. The purpose was to assess the economic effects of the project. Using different methods, an economic assessment was carried out. Although the responses were, in essence, agronomic effects, they also tended to cause major changes in farm economies, especially concerning the type and composition of different agricultural supplies and enhancing market ability. Variations in the quantity and composition of these yield-increasing supplies explain differing productivity levels and the return on investment of farms that used clay applications versus the farms that did not.

Apart from its role of changing the nature and composition of farm supplies, bentonite application also influenced the prices that farmers received for their crops. The average output price for farmers using clay technologies was 18 % higher than that for non-clay users; this suggests that either clay - using farmers go for high value crops (as in vegetable farms) or they receive a higher price for their produce, due to better quality (e.g., from organic rice and integrated farms). Production costs are higher, but, due to more production and the quality of the food, clay farmers could afford to invest and grow more and better food, compared to non clay-using farmers. For example, the average per-hectare cost of clay-using farms was 57% higher than that for non-users, but the per-hectare gross revenue of farms using bentonite clay technologies was twice that of non-clay-using farms. Since the net values of the treated and control groups were compared, clay application led to a net benefit of about 120 % .

4 - History and natural occurrence :

List of countries by bentonite production



Bentonite output in 2005. Click the image for the details.

In 2005, U.S. was the top producer of bentonite with almost one-third world share followed by China and Greece, reports the British Geological Survey.

The absorbent clay was given the name bentonite by Wilbur C. Knight in 1898, after the Cretaceous Benton Shale near Rock River, Wyoming . Other modern discoveries include montmorillonite discovered in 1847 in Montmorillon in the Vienne prefecture of France, in Poitou - Charentes, South of the Loire Valley.

Most high-grade natural sodium bentonite is produced from the western United States in an area between the Black Hills of South Dakota and the Bighorn Basin of Wyoming. Mixed sodium/calcium bentonite is mined in Greece, Australia, India , Russia, and the Ukraine. In the United States, calcium bentonite is mined primarily in Mississippi and Alabama. Other major locations producing calcium bentonite include Germany, Greece, Turkey, India, and China.

It should be noted that, in some countries like the UK and US, calcium bentonite is known as fuller's earth, a term also used to refer to attapulgite, in terms of mineralogy, a distinct clay mineral but one exhibiting similar properties.

10 – Beryl (حجر كريم)

Three varieties of beryl: morganite, aquamarine and heliodor

Contents :

1 - Introduction :

The mineral **beryl** is a beryllium aluminium cyclosilicate with the chemical Formula $Be_3Al_2(SiO_3)_6$. The hexagonal crystals of beryl may be very small or range to several meters in size. Terminated crystals are relatively rare. Pure beryl is colorless, but it is frequently tinted by impurities; possible colors are green, blue, yellow, red, and white.

Category	Silicate mineral
Chemical Formula	$Be_3Al_2(SiO_3)6$
Crystal symmetry	Dihexagonal Dipyramidal
Unit cell	a = 9.21 Å ,

	c = 9.19 Å ; Z = 2
Molar Mass	537.50
Color	Green, Blue, Yellow, Colorless, Pink & others.
Crystal habit	Massive to well Crystalline
Crystal system	Hexagonal
Fracture	Conchoidal
Mohs scale hardness	7.5 – 8
Luster	Vitreous
Streak	White
Diaphaneity	Transparent to opaque
Specific Gravity	Average 2.76
Optical properties	Uniaxial (-)
Refractive index	nω = 1.564 –1.595, nε = 1.568 –1.602
Ultraviolet fluorescence	None (some fracture filling materials used to improve emerald's clarity do fluoresce , but the stone itself does not)

2 - Etymology :

The name beryl is derived from Greek *beryllos* which referred to a "precious blue - green color – of – sea - water stone" the French word *brille* meaning "shine" and the English word *brilliance* .

3 - Deposits :

Beryl of various colors is found most commonly in granitic pegmatites, but also occurs in mica schists in the Ural Mountains, and limestone in Colombia. Beryl is often associated with tin and tungsten ore bodies. Beryl is found in Europe in Norway, Austria, Germany, Sweden (especially morganite), Ireland and Russia, as well as Brazil, Colombia, Madagascar, Mozambique, South Africa, the United States, and Zambia. U.S. beryl locations are in California, Colorado, Connecticut, Idaho, Maine, New Hampshire, North Carolina, South Dakota and Utah.

New England's pegmatites have produced some of the largest beryls found, including one Massive crystal from the Bumpus Quarry in Albany, Maine with dimensions 5.5 m by 1.2 m with a Mass of around 18 metric tons; it is New Hampshire's state mineral. As of 1999, the largest known crystal of any mineral in the world is a crystal of beryl from Madagascar, 18 meters long and 3.5 meters in diameter.

4 – Varieties :

4 – 1 - Aquamarine and maxixe :

Aquamarine

Aquamarine (from Latin: *aqua marina*, "water of the sea") is a blue or turquoise variety of beryl. It occurs at most localities which yield ordinary beryl, some of the finest coming from Russia. The gem - gravel placer deposits of Sri Lanka contain aquamarine. Clear yellow beryl, such as that occurring in Brazil, is sometimes called **aquamarine chrysolite**. When corundum presents the bluish tint of typical aquamarine, it is often termed Oriental aquamarine. The deep blue version of aquamarine is called *maxixe*. Its color fades to white when exposed to sunlight or is subjected to heat treatment, though the color returns with irradiation.

The pale blue color of aquamarine is attributed to Fe^{2+}. The Fe^{3+} ions produce golden-yellow color, and when both Fe^{2+} and Fe^{3+} are present, the color is a darker blue as in maxixe. Decoloration of maxixe by light or heat thus may be due to the charge transfer Fe^{3+} and Fe^{2+}. Dark - blue maxixe color can be produced in green, pink or yellow beryl by irradiating it with high - energy particles (gamma rays, neutrons or even X-rays).

In the United States, aquamarines can be found at the summit of Mt. Antero in the Sawatch Range in central Colorado. In Wyoming, aquamarine has been discovered in the Big Horn Mountains, near Powder River Pass. In Brazil, there are mines in the states of Minas Gerais, Espírito Santo, and Bahia, and minorly in Rio Grande do Norte. The Mines of Colombia, Zambia, Madagascar, Malawi, Tanzania and Kenya also produce aquamarine. The largest aquamarine of gemstone quality ever mined was found in Marambaia, Minas Gerais, Brazil, in 1910. It weighed over 110 kg, and its dimensions were 48.5 cm long and 42 cm in diameter.

4 – 2 – Emerald (زمرد):

 *Rough emerald on matrix*	 *Faceted emerald gemstones*

Emerald refers to green beryl , colored by trace amounts of chromium and some times vanadium .

Emeralds in antiquity were mined by the Egyptians and in Austria, as well as Swat in northern Pakistan . A rare type of emerald known as a trapiche emerald is occasionally found in the mines of

Colombia. A trapiche emerald exhibits a "star" pattern; it has raylike spokes of dark carbon impurities that give the emerald a six - pointed radial pattern. It is named for the *trapiche*, a grinding wheel used to process sugar cane in the region. Colombian emeralds are generally the most prized due to their transparency and fire. Some of the most rare emeralds come from three main emerald mining areas in Colombia: Muzo, Coscuez, and Chivor. Fine emeralds are also found in other countries, such as Zambia, Brazil, Zimbabwe, Madagascar, Pakistan, India, Afghanistan and Russia. In the US, emeralds can be found in Hiddenite, North Carolina. In 1998, emeralds were discovered in the Yukon.

Emerald is a rare and valuable gemstone and, as such, it has provided the incentive for developing synthetic emeralds. Both hydrothermal and *flux-growth* synthetics have been produced. The first commercially successful emerald synthesis process was that of Carroll Chatham . The other large producer of flux emeralds was Pierre Gilson Sr., which has been on the market since 1964. Gilson's emeralds are usually grown on natural colorless beryl seeds which become coated on both sides. Growth occurs at the rate of 1 mm per month, a typical seven-month growth run producing emerald crystals of 7 mm of thickness . The green color of emeralds is attributed to presence of Cr^{3+} ions .

4 – 3 - Golden beryl and heliodor :

Golden beryl can range in colors from pale yellow to a brilliant gold. Unlike emerald, golden beryl has very few flaws. The term "golden beryl" is some times synonymous with *heliodor* (from Greek *hēlios* "sun" + *dōron* – "gift") but golden beryl refers to pure yellow or golden yellow shades, while heliodor refers to the greenish-yellow shades. The golden yellow color is attributed to Fe^{3+} ions. Both golden beryl and heliodor are used as gems. Probably the largest cut golden beryl is the flawless 2054 carat stone on display in the Hall of Gems, Washington, D.C.

 *Golden beryl*	 *Heliodor*

4 – 4 – Goshenite :

Goshenite

Colorless beryl is called *goshenite*. The name originates from Goshen, Massachusetts where it was originally discovered. Since all these color varieties are caused by impurities and pure beryl is colorless, it might be tempting to assume that goshenite is the purest variety of beryl. However, there are several elements that can act as inhibitors to color in beryl and so this assumption may not always be true. The name goshenite has been said to be on its way to extinction and yet it is still commonly used in the gemstone markets. Goshenite is found to some extent in almost all beryl localities. In the past, goshenite was used for manufacturing eyeglasses and lenses owing to its transparency. Nowadays, it is most commonly used for gemstone purposes and also considered as a source of beryllium.

The gem value of goshenite is relatively low. However, goshenite can be colored yellow, green, pink, blue and in intermediate colors by irradiating it with high-energy particles. The resulting color depends on the content of Ca, Sc, Ti, V, Fe, and Co impurities.

4 – 5 - Morganite :

Morganite

Morganite, also known as "pink beryl", "rose beryl", "pink emerald", and "cesian (or *caesian*) beryl", is a rare light pink to rose-colored gem - quality variety of beryl. Orange/yellow varieties of morganite can also be found, and color banding is common. It can be routinely heat treated to remove patches of yellow and is occasionally treated by irradiation to improve its color. The pink color of morganite is attributed to Mn^{2+} ions.

Pink beryl of fine color and good sizes was first discovered on an island on the coast of Madagascar in 1910. It was also known, with other gemstone minerals, such as tourmaline and kunzite, at Pala, California. In December 1910, the New York Academy of Sciences named the pink variety of beryl "morganite" after financier J. P. Morgan.

On October 7, 1989, one of the largest gem morganite specimens ever uncovered, eventually called "The Rose of Maine," was found at the Bennett Quarry in Buckfield, Maine, USA . The crystal, originally some what orange in hue, was 23 cm long and about 30 cm across, and weighed (along with its matrix) just over 23 kg .

Red beryl

4 – 6 - Red beryl :

Red beryl (also known as "red emerald" or "scarlet emerald") is a red variety of beryl. It was first described in 1904 for an occurrence , its type locality, at Maynard's Claim (Pismire Knolls), Thomas Range, Juab County, Utah . The old synonym "bixbite" is deprecated from the CIBJO , because of the risk of confusion with the mineral bixbyite (also named after the mineralogist Maynard Bixby) . The dark red color is attributed to Mn^{3+} ions .

Red beryl is very rare and has only been reported from a handful of locations including: Wah Wah Mountains, Beaver County, Utah; Paramount Canyon, Sierra County, New Mexico; Round Mountain, Sierra County, New Mexico ; and Juab County, Utah. The greatest concentration of gem - grade red beryl comes from the Violet Claim in the Wah Wah Mountains of mid - western Utah, discovered in 1958 by Lamar Hodges, of Fillmore, Utah, while he was prospecting for uranium . Prices for top quality natural red beryl can be as high as $10,000 per carat for faceted stones. Red beryl has been known to be confused with pezzottaite, also known as raspberry beryl or "raspberyl", a gemstone that has been found in Madagascar and now Afghanistan – although cut gems of the two varieties can be distinguished from their difference in refractive index.

While gem beryls are ordinarily found in pegmatites and certain metamorphic rocks, red beryl occurs in topaz - bearing rhyolites. It formed by crystallizing under low pressure and high temperature from a pneumatolitic phase along fractures or within near-surface miarolitic cavities of the rhyolite. Associated minerals include bixbyite, quartz, orthoclase, topaz, spessartine, pseudobrookite and hematite.

11 - Biotite

Contents

1 – Introduction :

Biotite is a common phyllosilicate mineral within the mica group, with the approximate chemical Formula $K(Mg,Fe)_3AlSi_3O_{10}(F,OH)_2$. More generally, it refers to the dark mica series, primarily a solid - solution series between the iron-endmember annite, and the magnesium-endmember phlogopite; more aluminous endmembers include siderophyllite. Biotite was named by J.F.L. Hausmann in 1847 in honour of the French physicist Jean-Baptiste Biot, who, in 1816, researched the optical properties of mica, discovering many unique properties.

Biotite is a sheet silicate. Iron, magnesium, aluminium, silicon, oxygen, and hydrogen form sheets that are weakly bound together by potassium ions. It is sometimes called "iron mica" because it is more iron - rich than phlogopite. It is also sometimes called "black mica" as opposed to "white mica" (muscovite) – both form in some rocks, in some instances side-by-side.

Category	Dark Mica series
Chemical Formula	$K(Mg,Fe)_3(AlSi_3O_{10})(F,OH)_2$
Molar Mass	433.5 g
Color	Dark brown, greenish brown, blackish brown, yellow, white
Crystal habit	Massive to platy
Crystal system	Monoclinic

Fracture	Micaceous
Tenacity	Brittle to flexible , elastic
Mohs scale hardness	2.5 – 3.0
Luster	Vitreous to pearly
Streak	White
Diaphaneity	transparent to translucent to paque
Specific Gravity	2.7–3.1
Density	2.8 – 3.4
Optical properties	Biaxial (-)
Refractive index	n_α = 1.565–1.625 n_β = 1.605–1.675 n_γ = 1.605–1.675
Pleochroism	strong
Ultra violet fluorescence	None

2 - Properties :

Like other mica minerals, biotite has a highly perfect basal cleavage, and consists of flexible sheets, or lamellae, which easily flake off. It has a monoclinic crystal system, with tabular to prismatic crystals with an obvious pinacoid termination. It has four prism faces and two pinacoid faces to form a pseudo hexagonal crystal. Although not easily seen because of the cleavage and sheets, fracture is uneven. It appears greenish to brown or black, and even yellow when weathered. It can be transparent to opaque, has a vitreous to pearly luster, and a grey-white streak. When biotite is found in large chunks, they are called “books” because it resembles a book with pages of many sheets.

Under cross polarized light biotite can generally be identified by the gnarled bird's eye extinction.

3 – Occurrence :

Biotite is found in a wide variety of igneous and metamorphic rocks. For instance, biotite occurs in the lava of Mount Vesuvius and in the Monzoni intrusive complex of the western Dolomites. It is an essential phenocryst in some varieties of lamprophyre. Biotite is occasionally found in large cleavable crystals, especially in pegmatite veins, as in New England, Virginia and North Carolina. Other notable occurrences include Bancroft and Sudbury, Ontario. It is an essential constituent of many metamorphic schists, and it forms in suitable compositions over a wide range of pressure and temperature.

The largest documented single crystals of biotite were approximately 7 m^2 sheets found in Iveland, Norway.

4 - Uses :

biotite: Topotype deposit

Biotite is used extensively to constrain ages of rocks, by either potassium-argon dating or argon-argon dating. Because argon escapes readily from the biotite crystal structure at high temperatures, these methods may provide only minimum ages for many rocks. Biotite is also useful in assessing temperature histories of metamorphic rocks, because the partitioning of iron and magnesium between biotite and garnet is sensitive to temperature.

12 - Boehmite

Boehmite or **Böhmite** is an aluminium oxide hydroxide (γ-AlO(OH)) mineral, a component of the aluminium ore bauxite. It is dimorphous with diaspore. It crystallizes in the orthorhombic dipyramidal system and is typically Massive in habit. It is white with tints of yellow, green, brown or red due to impurities. It has a vitreous to pearly luster, a Mohs hardness of 3 to 3.5 and a specific Gravity of 3.00 to 3.07. It is colorless in thin section, optically biaxial positive with refractive indices of $n\alpha = 1.644 - 1.648$, $n\beta = 1.654 - 1.657$ and $n\gamma = 1.661 - 1.668$.

Boehmite occurs in tropical laterites and bauxites developed on alumino-silicate bedrock. It also occurs as a hydrothermal alteration product of corundum and nepheline. It occurs with kaolinite, gibbsite and diaspore in bauxite deposits; and with nepheline, gibbsite, diaspore, natrolite and analcime in nepheline pegmatites.

It was first described by J. de Lapparent in 1927 for an occurrence in the bauxites of Mas Rouge, Les Baux-de-Provence, France, and named for the Bohemian-German chemist Johann Böhm (1895-1952) who carried out X-ray studies of aluminium oxide hydroxides in 1925[5] (and not for the German geologist Johannes Böhm (1857–1938) as often stated).

Category	Oxide mineral
Chemical Formula	γ-Al O (OH)
Crystal symmetry	Ortho rhombic
Unit cell	a = 3.693 Å, b = 12.221 Å, c = 2.865 Å; Z = 4
Color	White, pale greyish brown; yellowish or reddish when impure; colorless in thin section

Crystal habit	Tabular crystal rare, fine grained in pisolitic aggregates or disseminated
Crystal system	Ortho rhombic dipyramidal
Mohs scale hardness	3.5
Streak	White
Diaphaneity	Translucent
Specific Gravity	3.02 - 3.05
Optical properties	Biaxial (+)
Refractive index	n_α = 1.644 - 1.648 n_β = 1.654 - 1.657 n_γ = 1.661 - 1.668
Dispersion	weak

13 – Celsian

Celsian (transparent / gray in photo) in sanbornite (white) and quartz matrix from Incline, Maricopa County, California

Contents

1 – Introduction :

Celsian is an uncommon feldspar mineral, barium aluminosilicate, $BaAl_2Si_2O_8$. The mineral occurs in contact metamorphic rocks with significant barium content. Its crystal system is monoclinic, and it is white, yellow, or transparent in appearance. In pure form, it is transparent. Synthetic barium aluminosilicate is used as a ceramic in dental fillings and other applications.

The mineral is named after Anders Celsius.

Category	Feldspar
Chemical Formula	$Ba\,Al_2\,Si_2\,O_8$
Crystal symmetry	Monoclinic prismatic H-M symbol:
Unit cell	a = 8.622(4) Å, b = 13.078(6) Å, c = 14.411(8) Å; β = 115.2°; Z = 8
Color	Colorless, white, yellow
Crystal habit	Short prismatic to acicular crystals, Massive
Crystal system	Monoclinic
Tenacity	Brittle
Mohs scale hardness	6 - 6.5
Luster	Vitreous
Diaphaneity	Transparent
Specific Gravity	3.10 to 3.39
Optical properties	Biaxial (+)
Refractive index	n_α = 1.580 - 1.584 n_β = 1.585 - 1.587 n_γ = 1.594 - 1.596
2V angle	Measured: 86° to 90°

2 - Composition

Celsian is a barium feldspar with a chemical composition $BaAl_2Si_2O_8$. It forms part of the feldspar group and belongs to the celsian-hyalophane series and the celsian-orthoclase series. It has some resemblance to anorthite, and it has four distinct polymorphs. The essential elements are Si,Al,O and Ba. Some common impurities in the mineral are Fe, Ti, Mg, K and Ca. Celsian is stable from room temperature up to 1590 °C (Lin and Foster,1968). The most common trace elements are potassium and calcium, in an analysis of the approximate chemical composition of celsian the following wt% were found: • SiO_2—35.1 • Al_2O_3---26.8 • BaO----35.8 • K_2O-----2.3 Total:100.0

3 - Geologic occurrence :

Celsian is of limited occurrence. Most of the barium feldspars are associated with exhalative hydrothermal processes and low-and medium - grade metamorphism . It is also associated with sedimentary and meta sedimentary rocks, manganese, ferromanganese and barite deposits.

Celsian can be found in places like Wales, Zamora (Spain), Alaska, California, Sweden and Japan, also with hendricksite on the Franklin mines in New Jersey.

4 - Structure :

The symmetry in celsian is somewhat different from the symmetry normally found in feldspars. It is monoclinic with a body centered lattice similar to those of anorthite. Insufficient evidence has been found to suggest that celsian lacks a center of symmetry, so its space group is I 2 / c . The space group differs from others of its group like orthoclase, albite and body center anorthite are C2/m, C1bar and I1bar.

X - ray analysis shows that the values for the lattice parameters *a*, *b*, *c* axes and angles are approximately a = 863 pm, b = 131.0 pm , c =1400 pm and β = 116°, θ = 90° (Gay, 1956).

There are 8 Formula units per cell, and the general position is eightfold, so all atoms can lie in general positions .This structure is very similar to that of orthoclase and sanidine but differs in a couple of ways :

1. The distribution of Si and Al.
2. The coordinates of all the atoms.

The distribution of silicon and aluminium along the tetrahedral sites mixed with the nature of the barium atom makes an impact on the surrounding silicate frame work . The Si-Al bonds are partially ordered, and in some cases the aluminium substitute's silicon.

The order in celsian is very simple, each aluminium tetrahedron is surrounded by four silicon tetrahedra, and vice versa . Also there is another type of transformation besides aluminium-silicon, where silicon-poor goes into a silicon-rich network that involves having to simultaneously be a replacement of Al, and Si at other sites.

The barium ion has an irregular configuration close to the one in potassium in the feldspars. Each barium has an oxygen close, and thanks to this configuration it has a strong effect on the silicon - oxygen - silicon bond angles.

4 – 1 – Poly morphism of celsian :

There are four distinctive polymorphs of celsian, two of them are the natural minerals and the other two are synthetic products. The first are paracelsian and celsian, the second ones are hexacelsian and the other one is related to the mineral cymrite . The order of increasing stability is paracelsian → hexacelsian → celsian in a temperature range between 500 °C to the 1000 °C.

As temperature rises from the 1,600 °C to 1,760 °C it goes from celsian to a reversible form of hexacelsian. Paracelsian is less stable than the other two and celsian is the most stable.

5 – Twinning :

Barium feldspars occur in optically uniform crystals where the twinning is poorly developed, except on coarse crystals. Eighteen crystal forms have been identified; eleven of them coincide with those known for orthoclase. Observed twining includes manebach twins on (001) and baveno twins on (021). Some samples of celsian were found to have a rare lamellar twinning .

6 – Properties :

6 – 1 - Physical properties :

Celsian shows a c(001) perfect cleavage and a b(010) good cleavage , which marks the difference with its polymorph paracelsian which has a [110] indistinct cleavage. There are different crystals habits like adularia, larger, stout crystals (Spencer, 1941), and long, slender to acicular. It is usually colorless and transparent with a pearly to non-fluorescent luster.

The density is about 3.31 to 3.33 g / cm³ . This might be the case due to some impurities in the structure of the mineral. It has a hardness of 6 on the Moh's scale, this hardness is due to the short length of the bond in the structure, since is relative short tends to be harder.

6 – 2 - Optical properties

Some other optical properties are the 2V angle which is approximately 88° with a maximum birefringence of 0.014, biaxial with a negative sign . It has a moderate relief.

6 - Uses

The uses of celsian are mostly related to glass and ceramics. This uses are usually achieved by the preparation of pure synthetic monoclinic celsian.

Celsian has very attractive features such as chemical stability and high mechanical resistance, which can be favourably exploited in order to obtain enhanced - performance composites with respect to bulk glass . Many studies shows that by increasing the amount of celsian phases in the glasses results in increased bulk of crytaslization .

14 – Childrenite

Childrenite from Galileia , Minas Gerais , Brazil 2 cm across

1 – Introduction :

Childrenite is a rare hydrated phosphate mineral with elements iron, manganese, aluminium, phosphorus, oxygen and hydrogen. Its chemical Formula is $(Fe,Mn)AlPO_4(OH)_2 \bullet H_2O$ and it has a molecular weight of 229.83 g / mol. Its specific Gravity is 3.2 and it has a Mohs hardness of 4.5 to 5. It is usually translucent and non-fluorescent, with imperfect cleavage. It has a vitreous lustre with a white streak, and is brown or yellow in color. It has a conchoidal, uneven fracture, and an ortho rhombic crystal system.

Category	Phosphate minerals
Chemical Formula	$(Fe^{2+},Mn^{2+})AlPO_4(OH)_2{\cdot}H_2O$
Crystal symmetry	Ortho rhombic dipyramidal H–M Symbol
Unit cell	a = 10.41 Å, b = 13.42 Å, c = 6.92 Å
Color	Yellowish brown , brown, clove - brown; colorless in transmitted light.
Crystal system	Ortho rhombic
Fracture	Irregular / uneven, sub - conchoidal

Mohs scale hardness	5
Luster	Vitreous , resinous
Streak	White
Diaphaneity	Transparent , translucent
Specific Gravity	3.11 - 3.19
Optical properties	Biaxial (-)
Refractive index	n_α = 1.644 - 1.649 n_β = 1.662 - 16.830 n_γ = 1.671 - 1.691
Pleochroism	Visible
Dispersion	r > v strong
Solubility	Soluble in acids.

2 - History and formation :

Childrenite was discovered in 1823 by John George Children (1777 - 1852), who was a prominent English chemist and mineralogist. This secondary mineral was first found in the George and Charlotte Mine near Tavistock in Devon. Its formation is probably from the alteration of granitic phosphates like lithiophilite and triphylite. Childrenite is also found in some ore veins.

3 - Relationship to other species :

Childrenite forms a solid solution series with eosphorite. The chemical composition of eosphorite only differs by being rich in manganese and not in iron. The structures are the same, and differences in properties can be traced to the iron/manganese percentage. Of the two, childrenite is denser. Furthermore, eosphorite is normally pink in color, which can be attributed to manganese.

15 - Chlorastrolite

A small green stone

1 – Introduction :

Chlorastrolite also known as **Michigan Green stone,** is a green or bluish green stone. Chlorastrolite has finely radiated or stellate Masses that have a "turtleback" pattern. The stellate Masses tend to be chatoyant, meaning they have a changeable luster. This chatoyancy can be subtranslucent to opaque. Chlorastrolite is a variety of pumpellyite: $Ca_2(Mg,Fe)Al_2(SiO_4)(Si_2O_7)(OH)_2 \cdot H_2O$. Chlorastrolite was once thought to be an impure variety of prehnite or thomsonite.

2 - Occurrences

Chlorastrolite occurs as amygdaloid structures and fracture fillings in basalt, and when the water and wave action has worn away the basalt, they are found as beach pebbles and granules in loose sediments. It is found in the Keweenaw Peninsula of the Upper Peninsula of Michigan and Isle Royale in Lake Superior. Isle Royale is a National Park, and so it is illegal to collect specimens there. It is difficult to identify an unpolished pebble of chlorastrolite. Most gem quality chlorastrolite stones are very small, and it is rare to find one that is larger than a half inch. The largest gem quality stone is in the Smithsonian and measures 1.5 by 3 inches.

It was first described from Isle Royale, Lake Superior by C. T. Jackson and J. D. Whitney in 1847. Chlorastrolite, also known as greenstone, is the official state gem of Michigan.

3 - Other Names :

- *Green starstone* as found especially in Michigan's Upper Peninsula.
- *Green stone* or *Isle Royale green stone* and *Lake Superior green stone*.
- *Turtle back* is a name some times given because of the overall pattern, particularly in polished pieces, which roughly resembles that of a turtle shell.
- *Uigite* is a variety found on the island of Skye off the coast of Scotland.
- *Zonochlorite* is a misnomer sometimes given rounded Masses of chlorastrolite within or weathered out of amygdaloidal cavities, especially those from the area around Nipigon Bay (on Lake Superior), Ontario, Canada. Confusion may derive from the fact that zonochlorite is sold as faux *chlorastrolite*.

16 – Chrysoberyl

1 – Introduction :

The mineral or gem stone **chrysoberyl** is an aluminate of beryllium with the Formula $BeAl_2O_4$. The name chrysoberyl is derived from the Greek words *chrysos* and *beryllos*, meaning "a gold - white spar". Despite the similarity of their names, chrysoberyl and beryl are two completely different gemstones. Chrysoberyl is the third - hardest frequently encountered natural gemstone and lies at 8.5 on the hardness scale, between corundum (9) and topaz (8).

An interesting feature of its crystals are the cyclic twins called *trillings*. These twinned crystals have a hexagonal appearance, but are the result of a triplet of twins with each "twin" oriented at 120^o to its neighbors and taking up 120^o of the cyclic trilling. If only two of the three possible twin orientations are present, a "V"-shaped twin results.

Ordinary chrysoberyl is yellowish - green and transparent to translucent. When the mineral exhibits good pale green to yellow color and is transparent, then it is used as a gemstone. There are three main varieties of chrysoberyl: ordinary yellow-to-green chrysoberyl, cat's eye or **cymophane**, and **alexandrite**. Yellow-green chrysoberyl was referred to as "chrysolite" during the Victorian and Edwardian eras, which caused confusion since that name has also been used for the mineral olivine ("peridot" as a gemstone); that name is no longer used in the gemological nomenclature.

Alexandrite, a strongly pleochroic (trichroic) gem, will exhibit emerald green, red and orange-yellow colors depending on viewing direction in partially polarised light. However, its most distinctive property is that it also changes color in artificial (tungsten/halogen) light compared to daylight. The color change from red to green is due to strong absorption of light in a narrow yellow portion of the spectrum, while allowing large bands of blue-greener and red wave lengths to be transmitted. Which of these prevails to give the perceived hue depends on the spectral balance of the illumination. Typically, alexandrite has an emerald-green color in daylight (relatively blue illumination of high color temperature) but exhibits a raspberry-red color in incandescent light (relatively yellow illumination) .

Cymophane is popularly known as "cat's eye". This variety exhibits pleasing chatoyancy or opalescence that reminds one of an eye of a cat. When cut to produce a cabochon, the mineral forms a light-green specimen with a silky band of light extending across the surface of the stone.

Category	Oxide minerals - Spinel group
Chemical Formula	$BeAl_2O_4$
Crystal symmetry	Ortho rhombic
Unit cell	a = 5.481 Å, b = 9.415 Å, c = 4.428 Å; Z = 8
Color	Various shades of green , yellow, brownish to greenish black , may be raspberry - red under incandescent light when chromian; colorless , pale shades of yellow , green , or red in transmitted light
Crystal habit	Crystals tabular or short prismatic , prominently striated

Crystal system	Ortho rhombic
Twinning	Contact and penetration twins common, often repeated forming rosette structures
Fracture	Conchoidal to uneven
Tenacity	Brittle
Mohs scale hardness	8.5
Luster	Vitreous
Streak	White
Specific Gravity	3.5 - 3.84
Optical properties	Biaxial (+)
Refractive index	n_α=1.745 n_β=1.748 n_γ=1.754
Pleochroism	X = red ; Y = yellow – orange ; Z = emerald - green
Alexandrite	Color change ; green to red
Cymophane	Chatoyant

2 - Occurrence :

Chrysoberyl forms as a result of pegmatitic processes. Melting in the Earth's crust produces relatively low-density molten magma which can rise upwards towards the surface. As the main magma body cools, water originally present in low concentrations became more concentrated in the molten rock because it could not be incorporated into the crystallization of solid minerals. The remnant magma thus becomes richer in water, and also in rare elements that similarly do not fit in the crystal structures of major rock-forming minerals. The water extends the temperature range downwards before the magma sets solid completely, allowing concentration of rare elements to proceed so far that they produce their own distinctive minerals. The resulting rock, igneous in appearance but formed at a low temperature from a water-rich melt, with large crystals of the common minerals such as quartz and feldspar, but also with elevated concentrations of rare elements such as beryllium, lithium, or niobium, often forming their own minerals, is called a pegmatite. The high water content of the magma made it possible for the crystals to grow quickly, so pegmatite crystals are often quite large, which increases the likelihood of gem specimens forming.

Chrsoberyl can also grow in the country rocks near to pegmatites, when Be- and Al-rich fluids from the pegmatite react with surrounding minerals. Hence, it can be found in mica schists and in contact with metamorphic deposits of dolomitic marble. Because it is a hard, dense mineral that is resistant to chemical alteration, it can be weathered out of rocks and deposited in river sands and gravels in alluvial deposits with other gem minerals such as diamond, corundum, topaz, spinel, garnet, and tourmaline. When found in such placers, it will have rounded edges instead of sharp, wedge-shape forms. Much of the chrysoberyl mined in Brazil and Sri Lanka is recovered from placers as the host rocks have been intensely weathered and eroded.

If the pegmatite fluid is rich in beryllium, crystals of beryl or chrysoberyl could form. Beryl has a high ratio of beryllium to aluminium, while the opposite is true for chrysoberyl. Both are stable with the common mineral quartz. For alexandrite to form, some chromium would also have had to be present. However, beryllium and chromium do not tend to occur in the same types of rock. Chromium is commonest in mafic and ultramafic rocks in which beryllium is extremely rare. Beryllium becomes concentrated in felsic pegmatites in which chromium is almost absent. Therefore, the only situation where an alexandrite can grow is when Be-rich pegmatitic fluids react with Cr-rich country rock. This unusual requirement explains the rarity of this chrysoberyl variety.

3 - Chrysoberyl :

 *Yellow-green chrysoberyl , oval cut.*	 *Yellow chrysoberyl gem stone featuring a brilliant cut crown and step cut pavilion.*

Chrysoberyl was discovered in 1789 and described and named by Abraham Gottlob Werner, in 1790. Werner worked at the Freiberg Mining Academy from 1790–1793 and was well known as one of the most outstanding geologists of his time. He is best known today as the loser in the battle of the Neptunists and Vulcanists that raged in the 1780s.

Chrysoberyl is normally yellow, yellow - green, or brownish with its color being caused by the presence of iron. Spectro scopic analysis will usually reveal a strong band where the violet takes over from the blue. As the color darkens from bright yellowish-green to golden-yellow to brown, this band increases in strength. When the stone has a strong color, two additional bands can be seen in the green - blue. The most common inclusions are liquid - filled cavities containing three-phase inclusions. Stepped twin planes may be apparent in some cases. Some very rare minty bluish-green chrysoberyls from Tanzania owe their color to the presence of vanadium.

Despite the similarity of their names, chrysoberyl and beryl are two completely different gemstones. Members of the beryl group include emerald, aquamarine, and morganite while members of the chrysoberyl group include chrysoberyl, cymophane (cat's eye), and alexandrite. Beryl is a silicate and chrysoberyl is an oxide and although both beryl and chrysoberyl contain beryllium, they are separate gemstone species unrelated in any other way. Because of the confusion between chrysoberyl and beryl, chrysoberyl is relatively unknown in its own right and the alexandrite variety is much more widely recognized. The only well-known natural gemstones harder than chrysoberyl are corundum and diamond.

4 – Alexandrite :

The alexandrite variety displays a color change (*alexandrite effect*) dependent upon the nature of ambient lighting. This color shift is independent of any change of hue with viewing direction through the crystal that would arise from pleochroism. Both these different properties are frequently referred to as "color change", however. Alexandrite results from small scale replacement of aluminium by chromium ions in the crystal structure, which causes intense absorption of light over a narrow range of wavelengths in the yellow region of the spectrum . Alexandrite from the Ural Mountains in Russia is green by daylight and red by incandescent light. Other varieties of alexandrite may be yellowish or pink in daylight and a columbine or raspberry red by incandescent light.

Alexandrite step cut cushion, 26.75 cts.

According to a popular but controversial story, alexandrite was discovered by the Finnish mineralogist Nils Gustaf Nordenskiöld , (1792 – 1866) and named alexandrite in honor of the future Tsar Alexander II of Russia. Nordenskiöld's initial discovery occurred as a result of an examination of a newly found mineral sample he had received from Perovskii, which he identified as emerald at first. The first emerald mine had been opened in 1831.

Alexandrite up to 5 carats (1,000 mg) and larger were traditionally thought to be found only in the Ural Mountains. Other deposits are located in India (Andhra Pradesh), Madagascar, and Sri Lanka. Alexandrite in sizes over 3 carats are very rare.

Some gemstones described as lab-grown (synthetic) alexandrite are actually corundum laced with trace elements (e.g., vanadium) or color - change spinel and are not actually chrysoberyl. As a result, they would be more accurately described as simulated alexandrite rather than synthetic but are often called Czochralski alexandrite after the process that grows the crystals .

Alexandrite lasers are commonly used in laser hair removal for pale skins . They work at 755 nm.

5 - Cymophane :

Translucent yellowish chatoyant chrysoberyl is called **cymophane** or *cat's eye*. Cymophane has its derivation also from the Greek words meaning 'wave' and 'appearance', in reference to the chatoyancy sometimes exhibited. In this variety, microscopic tubelike cavities or needlelike inclusions of rutile occur in an orientation parallel to the c-axis producing a chatoyant effect visible as a single ray of light passing across the crystal. This effect is best seen in gemstones cut in cabochon form perpendicular to the c-axis. The color in yellow chrysoberyl is due to Fe^{3+} impurities.

Although other minerals such as tourmaline, scapolite, corundum, spinel and quartz can form "cat's eye" stones similar in appearance to cymophane, the jewelry industry designates these stones as "quartz cat's eyes", or "ruby cat's eyes" and only chrysoberyl can be referred to as "cat's eye" with no other designation.

Gems lacking the silky inclusions required to produce the cat's eye effect are usually faceted. An alexandrite cat's eye is a chrysoberyl cat's eye that changes color. "Milk and honey" is a term commonly used to describe the color of the best cat's eyes. The effect refers to the sharp milky ray of white light normally crossing the cabochon as a center line along its length and overlying the honey colored background. The honey color is considered to be top - grade by many gemologists but the lemon yellow colors are also popular and attractive. Cat's eye material is found as a small percentage of the over all chrysoberyl production wherever chrysoberyl is found.

Cat's eye really became popular by the end of the 19th century when the Duke of Connaught gave a ring with a cat's eye as an engagement token; this was sufficient to make the stone more popular and increase its value greatly. Until that time, cat's eye had predominantly been present in gem and mineral collections. The increased demand in turn created an intensified search for it in Sri Lanka. Early 20th century prices could go up as high as $8000 for a cut stone .

17 – Clintonite

Clintonite with spinel on orthoclase matrix from Amity, New York

Clintonite is a calcium magnesium aluminium phyllosilicate mineral. It is a member of the margarite group of micas and the subgroup often referred to as the "brittle" micas. Clintonite has the chemical Formula: $Ca(Mg,Al)_3(Al_3Si)O_{10}(OH)_2$. Like other micas and chlorites, clintonite is monoclinic in crystal form and has a perfect basal cleavage parallel to the flat surface of the plates or scales. The Mohs hardness of clintonite is 6.5, and the specific Gravity is 3.0 to 3.1. It occurs as variably colored, colorless, green, yellow, red, to reddish-brown Masses and radial clusters.

The brittle micas differ chemically from the micas in containing less silica and no alkalis, and from the chlorites in containing much less water; in many respects, they are intermediate between the micas and chlorites. Clintonite and its iron-rich variety xanthophyllite are sometimes considered the calcium analogues of the phlogopites.

Typical formation environment is in serpentinized dolomitic limestones and contact metamorphosed skarns. It occurs with talc, spinel, grossular, vesuvianite, clinopyroxene, monticellite, chondrodite, phlogopite, chlorite, quartz, calcite and dolomite.[3]

Clintonite was first described in 1843 for an occurrence in Orange County, New York. It was named for De Witt Clinton (1769-1828).

Category	Phyllosilicate Mica group
Chemical Formula	$Ca(Mg,Al)_3(Al_3Si)O_{10}(OH)_2$
Crystal symmetry	Monoclinic - prismatic
Unit cell	a = 5.204Å, b = 9.026Å, c = 9.812Å; β = 100.35°; Z = 2
Color	Colorless , yellow , orange , red –brown , brown , green
Crystal habit	Tabular pseudohexagonal crystals; foliated or lamellar radiated; Massive
Crystal system	Monoclinic
Twinning	Spiral polysynthetic twinning
Tenacity	Brittle
Luster	Vitreous, pearly, submetallic
Streak	White, slightly yellow-gray
Diaphaneity	Transparent to translucent
Specific Gravity	3.0 - 3.1
Optical properties	Biaxial (-)
Refractive index	n_α = 1.643 - 1.648 n_β = 1.655 - 1.662 n_γ = 1.655 - 1.663
Pleochroism	X = colorless , pale orange, red –brown ; Y = Z = pale brownish yellow, pale green

18 - Coconinoite

1 – Introduction :

Coconinoite is a uranium ore that was discovered in Coconino County, Arizona. It is a phosphate mineral; or uranyal phosphate mineral along with other subclass uranium U^{6+} minerals like blatonite, boltwoodite, metazeunerite and rutherfordine.

Category	Phosphate minerals
Chemical Formula	$Fe^{3+}{}_2Al_2(UO_2)_2(PO_4)_4(SO_4)(OH)_2 \cdot 20\ (H_2O)$
Crystal symmetry	Monoclinic
Unit cell	a = 12.45 Å , b = 12.96 Å, c = 17.22 Å; β = 105.7°; Z= 4
Molar Mass	489 gram / mole
Color	Pale creamy yellow
Crystal habit	As lathlike to platy grains, in microcrystalline aggregates seams and crusts.
Crystal system	Monoclinic
Mohs scale hardness	1 - 2
Luster	Adamantine - pearly
Streak	White
Diaphaneity	Translucent
Specific Gravity	2.70
Optical properties	Biaxial (-)
Refractive index	$n_\alpha = 1.550$

	$n_\beta = 1.588$ $n_\gamma = 1.590$
Pleochroism	X = colorless; Y = Z = pale yellow. Orientation: Y = elongation of laths with positive elongation ; Y at 8°- 25° to elongation of laths with negative elongation.
Other characteristics	Radioactive

2 - Composition :

The chemical Formula is :

$Fe_2Al_2(UO_2)_2(PO_4)_4(SO_4)_4(OH)_2\cdot 20H_2O$.

The chemical Formula was derived from the spectrographic analysis.

3 - Physical properties :

The mineral has a white streak and a pale creamy yellow color. The mineral occurs as microscopic crystals, the largest found is 6 by 20 micrometres. It is a radioactive mineral, but not fluorescent . Upon heating for dehydration it is found the that mineral losses some of its SO_2 at 600 to 800 °C.

4 - Geologic occurrence :

It occurs in the oxidized zone of vanadium-poor Colorado Plateau-type uranium deposits of Utah and Arizona. It occurs in association with gypsum , jarosite , limonite , quartz , clay minerals and coalized wood at the Jomac mine, Utah .

Coconinite was first described in 1966 for occurrences in the Huskon Mines, Cameron, Cameron District and the Sun Valley Mine, Vermillion Cliffs District, Coconino County, Arizona. It was named for Coconino County.

19 – Cordierite

Cordierite from Italy

1 – Introduction :

Cordierite (mineralogy) or **iolite** (gemology) is a magnesium iron aluminium cyclosilicate. Iron is almost always present and a solid solution exists between Mg-rich cordierite and Fe-rich sekaninaite with a series Formula: $(Mg,Fe)_2Al_3(Si_5AlO_{18})$ to $(Fe,Mg)_2Al_3(Si_5AlO_{18})$. A high temperature polymorph exists, indialite, which is isostructural with beryl and has a random distribution of Al in the $(Si,Al)_6O_{18}$ rings.

Category	Silicate mineral
Chemical Formula	$(Mg,Fe)_2Al_4Si_5O_{18}$
Crystal symmetry	Orthorhombic - Dipyramidal
Unit cell	a = 17.079 Å, b = 9.730 Å, c = 9.356 Å; Z = 4
Color	Blue, smoky blue, bluish violet; greenish, yellowish brown, gray;

	colorless to very pale blue in thin section
Crystal habit	Pseudo-hexagonal prismatic twins, as imbedded grains, and Massive
Crystal system	Orthorhombic - Dipyramidal
Fracture	Subconchoidal
Tenacity	Brittle
Mohs scale hardness	7 - 7.5
Luster	Greasy or vitreous
Streak	White
Specific Gravity	2.57 - 2.66
Optical properties	Usually optically (-) , some times (+)
Refractive index	$n_\alpha = 1.527 - 1.560$ $n_\beta = 1.532 - 1.574$ $n_\gamma = 1.538 - 1.578$ Indices increase with Fe content.
Pleochroism	X = pale yellow, green; Y = violet, blue-violet; Z = pale blue
Fusibility	on thin edges
Diagnostic features	Resembles quartz can be distinguished by pleochroism. Can be distinguished from corundum by its lower hardness

2 - Name and discovery :

Cordierite , which was discovered in 1813, is named after the French geologist Louis Cordier (1777 – 1861) .

3 – Occurrence :

Cordierite typically occurs in contact or regional metamorphism of argillaceous rocks. It is especially common in hornfels produced by contact metamorphism of pelitic rocks. Two common metamorphic mineral assemblages include sillimanite-cordierite-spinel and cordierite - spinel - plagioclase – ortho pyroxene . Other associated minerals include garnet (cordierite-garnet-sillimanite gneisses) and anthophyllite . Cordierite also occurs in some granites, pegmatites, and norites in gabbroic magmas. Alteration products include mica, chlorite, and talc. Cordierite occurs in the granite contact zone at Geevor Tin Mine in Cornwall.

4 - Commercial use :

Catalytic converters are commonly made from ceramics containing a large proportion of cordierite. The manufacturing process deliberately aligns the cordierite crystals to make use of the very low thermal expansion seen for one axis. This prevents thermal shock cracking from taking place when the catalytic converter is used.

5 - Gem variety :

As the transparent variety iolite, it is often used as a gemstone. The name "iolite" comes from the Greek word for violet. Another old name is *dichroite*, a Greek word meaning "two-colored rock", a reference to cordierite's strong pleochroism. It has also been called "water-sapphire" and "Vikings' Compass" because of its usefulness in determining the direction of the sun on overcast days, the Vikings having used it for this purpose . This works by determining the direction of polarization of the sky overhead. Light scattered by air molecules is polarized, and the direction of the polarization is at right angles to a line to the sun, even when the sun's disk itself is obscured by dense fog or lies just below the horizon.

Gem quality iolite varies in color from sapphire blue to blue violet to yellowish gray to light blue as the light angle changes. Iolite is sometimes used as an inexpensive substitute for sapphire. It is much softer than sapphires and is abundantly found in Sri Lanka, India, Burma, Australia's Northern Territory, Namibia, Brazil, Tanzania, Madagascar, Connecticut, and the Yellowknife area of the Northwest Territories of Canada.

Geologist Dan Hausel, University of Wyoming, found iolite deposits in Wyoming. These are some of the largest deposits in the world. One iolite that he recovered weighed in at more than 24,000 carats--the largest ever found in the world.

		
Pleochroism of Cordierite	*Facet cut Iolite gemstone*	*Left: rough specimen showing dichroism;* *right: cut stone*

20 – Corundum (ياقوت)

1 – Introduction :

Corundum is a crystalline form of aluminium oxide (Al_2O_3) with traces of iron, titanium and chromium . It is a rock-forming mineral. It is one of the naturally clear transparent materials, but can have different colors when impurities are present. Transparent specimens are used as gems, called ruby if red and padmaraga if pink-orange. All other colors are called sapphire, e.g., "green sapphire" for a green specimen.

The name "corundum" is derived from the Tamil word "kuruntam" meaning "ruby", and related to Sanskrit "kuruvinda".

Because of corundum's hardness (pure corundum is defined to have 9.0 Mohs), it can scratch almost every other mineral. It is commonly used as an abrasive, on everything from sandpaper to large machines used in machining metals, plastics, and wood. Some emery is a mix of corundum and other substances, and the mix is less abrasive, with an average hardness near 8.0.

In addition to its hardness, corundum is unusual for its density of 4.02 g / cm^3 , which is very high for a transparent mineral composed of the low atomic Mass elements aluminium and oxygen.

Category	Oxide mineral – Hematite group
Chemical Formula	Aluminium oxide , $Al_2 O_3$

Crystal symmetry	Trigonal
Unit cell	a = 4.75 Å, c = 12.982 Å ; Z = 6
Color	Colorless, gray, brown; pink to pigeon-blood-red, orange, yellow, green, blue to cornflower blue, violet; may be color zoned, asteriated mainly grey and brown
Crystal habit	Steep bipyramidal, tabular, prismatic, rhombohedral crystals, Massive or granular
Crystal system	Trigonal (Hexagonal Scalenohedral) Symbol
Twinning	Polysynthetic twinning common
Cleavage	None – parting in 3 directions
Fracture	Conchoidal to uneven
Mohs scale hardness	9 (defining mineral)
Luster	Adamantine to vitreous
Streak	White
Diaphaneity	Transparent, translucent to opaque
Specific Gravity	3.95 – 4.10
Optical properties	Uniaxial (–)
Refractive index	n_ω = 1.767–1.772 n_ε = 1.759–1.763
Pleochroism	None
Melting point	2044 °C
Fusibility	Infusible
Solubility	Insoluble

Alters to	May alter to mica on surfaces causing a decrease in hardness
Other characteristics	May fluoresce or phosphoresce under UV
Sapphire	Any color except red
Ruby	Red
Emery	Black granular corundum intimately mixed with magnetite, hematite, or hercynite

2 - Geology and occurrence :

Corundum occurs as a mineral in mica schist, gneiss, and some marbles in Metamorphic terranes. It also occurs in low silica igneous syenite and nepheline syenite intrusives. Other occurrences are as Masses adjacent to ultramafic intrusives, associated with lamprophyre dikes and as large crystals in pegmatites. It commonly occurs as a detrital mineral in stream and beach sands because of its hardness and resistance to weathering. The largest documented single crystal of corundum measured about 65×40×40 cm.

Corundum for abrasives is mined in Zimbabwe, Russia, Sri Lanka and India. Historically it was mined from deposits associated with dunites in North Carolina, USA and from a nepheline syenite in Craigmont, Ontario. Emery grade corundum is found on the Greek island of Naxos and near Peekskill , New York, USA. Abrasive corundum is synthetically manufactured from bauxite.

3 - Synthetic corundum :

In 1837, Gaudin made the first synthetic rubies by fusing alumina at a high temperature with a small amount of chromium as a pigment. In 1847, Ebelmen made white sapphires by fusing alumina in boric acid. In 1877 Frenic and Freil made crystal corundum from which small stones could be cut. Frimy and Auguste Verneuil manufactured artificial ruby by fusing BaF_2 and Al_2O_3 with a little chromium at temperatures above 2,000 °C . In 1903, Verneuil announced he could produce synthetic rubies on a commercial scale using this flame fusion process .

The Verneuil process allows the production of flawless single-crystal sapphires, rubies and other corundum gems of much larger size than normally found in nature. It is also possible to grow gem -quality synthetic corundum by flux-growth and hydrothermal synthesis. Because of the simplicity of the methods involved in corundum synthesis, large quantities of these crystals have become available on the market causing a significant reduction of price in recent years. Apart from ornamental uses, synthetic corundum is also used to produce mechanical parts (tubes, rods, bearings, and other machined parts), scratch-resistant optics, scratch-resistant watch crystals, instrument windows for satellites and spacecraft (because of its transparency from the UV to IR), and laser components.

21 – Creedite

Creedite, Santa Eulalia District,
Municipio de Aquiles Serdán, Chihuahua, Mexico

1 – Introduction :

Creedite is a calcium aluminium sulfate fluoro hydroxide mineral with Formula: $Ca_3Al_2SO_4(F,OH)_{10}\cdot 2(H_2O)$. Creedite forms colorless to white to purple monoclinic prismatic crystals. It often occurs as acicular radiating sprays of fine prisms. It is translucent to transparent with indices of refraction of $n_\alpha = 1.461$ $n_\beta = 1.478$ $n_\gamma = 1.485$. It has a Mohs hardness of 3.5 to 4 and a specific Gravity of 2.7.

Creedite was first described in 1916 from the Creed Quadrangle in Mineral County, Colorado. It is a product of intense oxidation of ore deposits.

Category	Sulfate and halide mineral
Chemical Formula	$Ca_3Al_2(SO_4)(F,OH)_{10}\bullet 2(H_2O)$
Crystal symmetry	Monoclinic
Unit cell	a = 13.91 Å, b = 8.58 Å, c = 10 Å; β = 94.4°; Z = 4
Color	Colorless, white, violet, orange
Crystal habit	Generally appears as anhedral to subhedral in matrix; bladelike prismatic and radial, drusy to granular aggregates

Crystal system	Monoclinic
Fracture	Conchoidal
Tenacity	Brittle
Streak	White
Diaphaneity	Transparent to translucent
Specific Gravity	2.71
Optical properties	Biaxial (-)
Refractive index	$n_\alpha = 1.461$ $n_\beta = 1.478$ $n_\gamma = 1.485$
Luster	Vitreous

2 - Occurrence :

***Creedite**, Qinglong Sb-Au deposit,*
Qinglong County, Guizhou Province, China

Creedite is a rare hydroxylhalide mineral. Creedite usually forms from the oxidation of fluorite ore deposits. Creedite was named after the location where it was discovered in 1916 in the Colorado Fluorspar Co. Mine at Wagon Wheel Gap, located at Creede Quadrangle, Mineral County, Colorado.

It was later found in other fluorite veins near Tonopah, Nye County, Nevada; in the Grand Reef mine, Graham County, Arizona; in the Darwin district, Inyo County, California. It also occurs in the Potosi and other mines of Santa Eulalia, Chihuahua, Mexico. It is also found in La Paz, Bolivia; Pamir Mountains, Tajikistan and Dzhezkazgan, Kazakhstan.

3 - Geologic association :

Creedite, Navidad Mine, Rodeo, Durango, Mexico

Creedite typically occurs with low-grade metamorphic rocks on a fluorite – calcite – quartz matrix or on a sulfide-matrix with its oxidized products. Creedite most commonly found in the form of creedite – carbonate – cyanotrichite – woodwardite – spangolite – kaolinite association. The other less common creedite association is creedite – limonite – kaolinite – hemimorphite – smithsonite – hydrozincite – aurichalcite. Creedite also occurs in skarn formation which usually has association with sulfides, spangolite, brochantite, linarite, limonite, cuprite, wad and kaolinite. In general, creedite usually found as two to three millimeters radial aggregates and less commonly as a single prismatic crystals up to one millimeters long.

4 – Structure :

Creedite structural composition study was conducted by utilizing 1390 Philips diffractometer with Fe – filtered CoK radiation (λ=1.79021Å), 10–90° 2θ range, peak-height relative intensities. It was concluded that the creedite falls into monoclinic crystal system that has space group of C2/c. It was also found that creedite has basal reflections of (2 0 0) and (4 0 0) that are enhanced due to preferred orientation which concur with Michael Fleischer's orientation.

22 – Cryolite

The cryolite mine Ivigtut, Greenland, summer 1940

Cryolite from Ivitut Greenland

1 – Introduction :

Cryolite ($Na_3 Al F_6$, sodium hexa fluoro aluminate) is an uncommon mineral identified with the once large deposit at Ivigtût on the west coast of Greenland , depleted by 1987.

It was historically used as an ore of aluminium and later in the electrolytic processing of the aluminium - rich oxide ore bauxite (it self a combination of aluminium oxide minerals such as gibbsite, boehmite and diaspore) . The difficulty of separating aluminium from oxygen in the oxide ores was overcome by the use of cryolite as a flux to dissolve the oxide mineral(s). Pure cryolite itself melts at 1012 °C , and it can dissolve the aluminium oxides sufficiently well to allow easy extraction of the aluminium by electrolysis. Considerable energy is still required for both heating the materials and the electrolysis, but it is much more energy - efficient than melting the oxides themselves. Now, as natural cryolite is too rare to be used for this purpose, synthetic sodium aluminium fluoride is produced from the common mineral fluorite .

Cryolite occurs as glassy, colorless, white-reddish to gray-black prismatic monoclinic crystals. It has a Mohs hardness of 2.5 to 3 and a specific Gravity of about 2.95 to 3.0. It is translucent to transparent with a very low refractive index of about 1.34, which is very close to that of water; thus if immersed in water, cryolite becomes essentially invisible.[5]

Cryolite has also been reported at Pikes Peak, Colorado; Mont Saint-Hilaire, Quebec; and at Miass, Russia. It is also known in small quantities in Brazil, the Czech Republic, Namibia, Norway, Ukraine, and several American states.

Cryolite was first described in 1799 from a deposit of it in Ivigtut and Arksukfiord, West Greenland. The name is derived from the Greek language words *cryò* = chill, and *lithòs* = stone.[2] The Pennsylvania Salt Manufacturing Company used large amounts of cryolite to make caustic soda at its Natrona, Pennsylvania works during the 19th and 20th centuries.

Category	Halide Mineral
Chemical Formula	$Na_3 Al F_6$
Crystal symmetry	Monoclinic
Unit cell	a = 7.7564 Å, b = 5.5959 Å, c = 5.4024 Å; $\beta = 90.18°$; Z = 2
Molar Mass	$210\ g\ mol^{-1}$
Color	Colorless to white, also brownish, reddish and rarely black
Crystal habit	Usually Massive, coarsely granular. The rare crystals are equant and pseudocubic
Crystal system	Monoclinic
Twinning	Very common, often repeated or polysynthetic with simultaneous

	occurrence of several twin laws
Cleavage	None observed
Mohs scale hardness	2.5 to 3
Luster	Vitreous to greasy,
Streak	White
Diaphaneity	Transparent to translucent
Specific Gravity	2.95 to 3.0
Optical properties	Biaxial (+)
Refractive index	n_α = 1.3385 –1.339, n_β = 1.3389 –1.339, n_γ = 1.3396 –1.34
Melting point	1012 °C
Solubility	Easily soluble in $AlCl_3$ solution, soluble in H_2SO_4 with the evolution of HF, which is poisonous. Slightly soluble in water.
Other characteristics	Weakly thermo luminescent. Small clear fragments become nearly invisible when placed in water, since its refractive index is close to that of water. May fluoresce intense yellow under SWUV, with yellow phosphorescence, and pale yellow phosphorescence under LWUV. Not radioactive.

2 - Pesticide and insecticide :

Cryolite is used as a insecticide and a pesticide .

23 - Cupalite

1 – Introduction :

Cupalite is a rare mineral which is mostly composed of copper and aluminium, but might contain up to several percents of zinc or iron ; its chemical structure is therefore described by an approximate Formula (Cu , Zn) Al or (Cu , Fe) Al. It was discovered in 1985 in placers derived from serpentine, in association with another rare mineral khatyrkite ($CuAl_2$). Both minerals are thus far restricted to the area of Listvenitovyi Stream, in the Khatyrka ultramafic (silicon-poor) zone of the Koryak–Kamchatka fold area, Koryak Mountains, Beringovsky District, Chukotka Autonomous Okrug, Far Eastern Federal District, Russia.[4] The mineral name derives from *cup*rum (Latin for copper) and *al*uminium. Its holotype (defining sample) is preserved in the Mining Museum in Saint Petersburg, and parts of it can be found in other museums, such as Museo di Storia Naturale di Firenze.

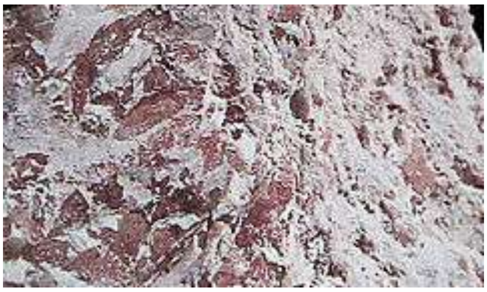
Category	Native element class , alloy
Chemical Formula	(Cu , Zn , Fe) Al
Color	Steel - gray yellow
Crystal system	Orthorhombic
Mohs scale hardness	4 - 4.5
Luster	Metallic
Specific Gravity	5.12 g / cm^3
Other characteristics	Non - magnetic , Non - radioactive

2 - Properties :

Cupalite forms dendritic, rounded or irregular grains, typically below 0.1 millimeter in size, which are intergrown with khatyrkite. They have an orthorhombic crystal structure with a yet uncertain space group and the lattice constants *a* = 0.695(1) nm, *b* = 0.416 (1) nm, *c* = 1.004(1) nm, and 10 Formula units per unit cell. Their Mohs hardness is between 4 and 4.5 and Vickers hardness is in the range 272–318 kg/mm^2 for a 20–50 gram load.

Cupalite and khatyrkite are accompanied by spinel, corundum, stishovite, augite, forsteritic olivine, diopsidic clinopyroxene and several Al-Cu-Fe metal alloy minerals. They are remarkable by containing micrometre-sized grains of the only known naturally occurring quasicrystal – aperiodic, yet ordered structure. The quasicrystal has a composition of $Al_{63}Cu_{24}Fe_{13}$ and icosahedral symmetry. The presence of unoxidized aluminium in cupalite and association with the stishovite – a form of quartz which forms exclusively at high pressures of several tens GPa – suggest that cupalite is formed either upon meteoritic impact or in the deep earth mantle.

24 – Diaspore



Diaspore from Slovakia

Diaspore is a native **aluminium oxide hydroxide**, α-AlO(OH), crystallizing in the orthorhombic system and isomorphous with goethite. It occurs sometimes as flattened crystals, but usually as lamellar or scaly Masses, the flattened surface being a direction of perfect cleavage on which the lustre is markedly pearly in character. It is colorless or greyish-white, yellowish, sometimes violet in color, and varies from translucent to transparent. It may be readily distinguished from other colorless transparent minerals with a perfect cleavage and pearly luster, like mica, talc, brucite, and gypsum by its greater hardness of 6.5 - 7. The specific Gravity is 3.4. When heated before the blowpipe it decrepitates violently, breaking up into white pearly scales.

Category	Oxide mineral
Chemical Formula	α - Al O (OH)
Crystal symmetry	Orthorhombic
Unit cell	a = 4.4007 Å , b = 9.4253 Å , c = 2.8452 Å ; Z = 4
Crystal habit	Platey, elongated to acicular crystals; also stalactitic, foliated, scaly, disseminated and Massive
Crystal system	Orthorhombic dipyramidal

Twinning	Pseudo hexagonal aggregates
Fracture	Conchoidal
Tenacity	Very brittle
Mohs scale hardness	6.5 - 7
Luster	Adamantine, vitreous, pearly on cleavage faces
Diaphaneity	Transparent to translucent
Specific Gravity	3.2 - 3.5
Optical properties	Biaxial (+)
Refractive index	n_α = 1.682 - 1.706 n_β = 1.705 - 1.725 n_γ = 1.730 - 1.752
Pleochroism	Strong
2V angle	Measured: 84° to 86°, Calculated: 80° to 84°
Dispersion	$r < v$, weak
Fusibility	Infusible
Solubility	Insoluble
Other characteristics	Decrepitates releasing water in closed tube on heating

The mineral occurs as an alteration product of corundum or emery and is found in granular limestone and other crystalline rocks. Well-developed crystals are found in the emery deposits of the Urals and at Chester, Massachusetts, and in kaolin at Schemnitz in Hungary. If obtainable in large quantity, it would be of economic importance as a source of aluminium.

Diaspore along with gibbsite and boehmite are the major components of the aluminium ore bauxite.

It was first described in 1801 for an occurrence in Mramorsk Zavod, Sverdlovskaya Oblast, Middle Urals, Russia. The name is from the Greek *to scatter*, in allusion to its decrepitation on heating.

Other names for diaspore include empholite, kayserite, tanatarite and spelling variations of these.

Zultanite is a gem quality form of diaspore from Turkey.

Twinned crystal of diaspore
from Mugla Province , Aegean Region , Turkey

25 - Dickite

Dickite ($Al_2Si_2O_5(OH)_4$) has molecular weight of 258.16 grams. It is a phyllosilicate clay mineral chemically composed of aluminium, silicon, hydrogen and oxygen contributing 20.90 % , 21.76 %, 1.56%, and 55.78 % each respectively. It has the same composition as kaolinite, nacrite, and halloysite, but with a different crystal structure (polymorph). Dickite sometimes contains impurities such as titanium, iron, magnesium, calcium, sodium and potassium.

Dickite occurs with other clays and requires x-ray diffraction for its positive identification. Dickite is an important alteration indicator in hydrothermal systems as well as occurring in soils and shales. It takes its name from Allan Brugh Dick (1833-1926), the Scottish metallurgical chemist who first described it.

Dickite's type location is in Pant-y-Gaseg, Amlwch, Isle of Anglesey, Wales, U.K., where it was first described in 1960.[2] Dickite is scattered across Wales forming occurrences in vein assemblages and as a rock forming mineral. Another occurrence spot, as indicated by Brindley and Porter of the American Mineralogists journal, is the Northerly dickite-bearing zone in Jamaica. The dickite in this zone ranges from indurate breccias containing cream to pinkish and purplish fragments composed largely of dickite with subordinate anatase set in a matrix of greenish dickite, to discrete veins and surface coatings of white, cream and translucent dickite. It appears that dickite in the northerly zone were formed by hot ascending waters from an uncertain origin. Dickite occurrence is well spread among countries like China, Jamaica, France, Germany, U.K., U.S.A, Italy, Belgium and Canada.

Dickite has a monoclinic crystal system and its crystal class is domatic (m). This crystal system contains two non-equal axes (a and b) that are perpendicular to each other and a third axis (c) that is inclined with respect to the an axis. The a and c axes lie in a plane. Dickite involves an interlayer bonding with at least 3 identifiable bonds: an ionic type interaction due to net unbalanced charges on the layers, van der waals forces between layers and hydrogen bonds between oxygen atoms on the surface of one layer and hydroxyl groups on the opposing surface. A hydrogen bond, as the term is used here, involves a long range interaction between hydrogen of a hydroxyl group coordinated to a cation and an oxygen atom coordinated to another cation. The reaction is predominantly electrostatic; hence an ionic bonding model is appropriate. Its axial ratio is a=0.576, b=1, c=1.6135.

Dickite has perfect cleavage in the (001) direction. Its color varies from blue, gray, white to colorless. It usually has a dull clay-like texture. Its hardness on the Mohs scale is 1.5-2, basically between talc and gypsum. This is attributed to its loose chemical bonds. It is held with hydrogen bonds, which are otherwise weak. It leaves a white streak and it has a pearly luster. It has a density of 2.6. Dickite is biaxial, its birefringence is between 0.0050-0.0090, its surface relief is low and it has no dispersion. The plane of the optical axis is normal to the plane of symmetry and inclined 160, rear to the normal to (0,0,1).

Category	Phyllosilicate
Chemical Formula	$Al_2Si_2O_5(OH)_4$
Color	White, with coloration from impurities
Crystal habit	pseudohexagonal crystals, aggregates of platelets and compact Massive
Crystal system	Monoclinic – domatic
Cleavage	Perfect on {001}
Tenacity	Flexible but inelastic
Mohs scale hardness	1.5 - 2
Luster	Satiny to pearly
Streak	White
Diaphaneity	Transparent

Specific Gravity	2.6
Optical properties	Biaxial (+)
Refractive index	nα = 1.561 - 1.564 nβ = 1.561 - 1.566 nγ = 1.566 - 1.570

26 – Dumortierite

Dumortierite from Alpine County, California, USA, possibly pseudomorphic after tourmaline

Dumortierite is a fibrous variably colored aluminium boro - silicate mineral , $Al_7BO_3(SiO_4)_3O_3$. Dumortierite crystallizes in the orthorhombic system typically forming fibrous aggregates of slender prismatic crystals. The crystals are vitreous and vary in color from brown, blue, and green to more rare violet and pink. Substitution of iron and other tri-valent elements for aluminium result in the color variations. It has a Mohs hardness of 7 and a specific Gravity of 3.3 to 3.4. Crystals show pleochroism from red to blue to violet. *Dumortierite quartz* is blue colored quartz containing abundant dumortierite inclusions.

Dumortierite was first described in 1881 for an occurrence in Chaponost, in the Rhône-Alps of France and named for the French paleontologist Eugene Dumortier (1803-1873). It typically occurs in high temperature aluminium rich regional metamorphic rocks, those resulting from contact metamorphism and also in boron rich pegmatites. The most extensive investigation on dumortierite was done on samples from the high grade metamorphic Gfohl unit in Austria by Fuchs et al. (2005).

It is used in the manufacture of high grade porcelain. It is sometimes mistaken for sodalite and has been used as imitation lapis lazuli.

Sources of Dumortierite include Austria, Brazil, Canada, France, Italy, Madagascar, Namibia, Nevada, Norway, Poland, Russia and Sri Lanka.

Category	Boro-silicate mineral
Chemical Formula	$Al_7BO_3(SiO_4)_3O_3$ or $Al_{6.5\text{-}7}BO_3(SiO_4)_3(O,OH)_3$
Crystal symmetry	Orthorhombic
Unit cell	a = 11.77 Å, b = 20.21 Å, c = 4.71 Å; Z=4
Color	Blue, greenish-blue, violet - blue , pale blue , red
Crystal habit	As fibrous or columnar crystals; coarsely crystalline to intimate parallel aggregates of needles; Massive
Crystal system	Orthorhombic - Dipyramidal
Fracture	Fibrous
Mohs scale hardness	7 - 8.5
Luster	Vitreous to dull
Streak	White
Diaphaneity	Transparent to translucent
Specific Gravity	3.3 - 3.4
Optical properties	Biaxial (-)
Refractive index	$n_\alpha = 1.659 - 1.678$ $n_\beta = 1.684 - 1.691$

	n_{γ} = 1.686 - 1.692
Pleochroism	Strong; X = deep blue or violet; Y = yellow to red - violet or nearly colorless; Z = colorless or very pale blue
2V angle	Measured: 20° to 52°, Calculated: 30°
Dispersion	r > v; strong

27 – Emerald (زمرد)

	
Cut emeralds	*Emerald crystal from Muzo,Colombia*

Contents

1 – Introduction :

Emerald is a variety of the mineral beryl ($Be_3Al_2(SiO_3)_6$) colored green by trace amounts of chromium and sometimes vanadium. Beryl has a hardness of 7.5 – 8 on the 10 point Mohs scale of mineral hardness . Most emeralds are highly included, so their toughness (resistance to breakage) is classified as generally poor.

Category	Beryl variety
Chemical Formula	$Be_3Al_2(SiO_3)_6$
Crystal symmetry	Dihexagonal Dipyramidal
Unit cell	a = 9.21 Å, c = 9.19 Å; Z = 2
Molar Mass	537.50
Color	Green shades
Crystal habit	Massive to well Crystalline
Crystal system	Hexagonal
Fracture	Conchoidal
Mohs scale hardness	7.5 – 8
Luster	Vitreous
Streak	White
Diaphaneity	Transparent to opaque
Specific Gravity	Average 2.76
Optical properties	Uniaxial (-)
Refractive index	$n_\omega = 1.564 – 1.595$, $n_\varepsilon = 1.568 – 1.602$
Ultra violet fluorescence	None (some fracture filling materials used to improve emerald's clarity do fluoresce , but the stone itself does not)

2 – Etymology :

The word "Emerald" is derived (via Old French: Esmeraude and Middle English: Emeraude), from Vulgar Latin: Esmaralda / Esmaraldus, a variant of Latin Smaragdus, which originated in Greek : (smaragdos ; "green gem") ; and Arabic: برق barq "lightning" . It is the same source for the names Persian (زمرّد zomorrod) , Turkish (zümrüt) .

3 - Properties determining value :

Emeralds, like all colored gem stones, are graded using four basic parameters – the four Cs of Connoisseurship: *Color*, *Cut*, *Clarity* and *Crystal*. The last C, *crystal* is simply used as a synonym that begins with C for transparency or what gemologists call *diaphaneity*. Before the 20th century, jewelers used the term *water* as in "a gem of the finest water" to express the combination of two qualities, color and crystal. Normally, in the grading of colored gemstones, color is by far the most important criterion. However, in the grading of emerald, crystal is considered a close second. Both are necessary conditions. A fine emerald must possess not only a pure verdant green hue as described below, but also a high degree of transparency to be considered a top gem.

In the 1960s the American jewelry industry changed the definition of 'emerald' to include the green vanadium-bearing beryl as emerald. As a result, *vanadium emeralds* purchased as emeralds in the United States are not recognized as such in the UK and Europe. In America, the distinction between traditional emeralds and the new vanadium kind is often reflected in the use of terms such as 'Colombian Emerald ' .

3 – 1 - Color :

Scientifically speaking, color is divided into three components: *hue*, *saturation* and *tone*. Yellow, blue and red the hues found adjacent to green on the spectral color wheel, are the normal secondary hues found in emerald. Emeralds occur in hues ranging from yellow-green to blue-green. The primary hue must, of course, be green. Only gems that are medium to dark in tone are considered emerald. Light-toned gems are known by the species name, *green beryl*. In addition, the hue must be bright (vivid). Gray is the normal saturation modifier or mask found in emerald. A grayish green hue is a dull green.

3 – 2 - Clarity :

Emerald tends to have numerous inclusions and surface breaking fissures. Unlike diamond, where the loupe standard, i.e. 10X magnification, is used to grade clarity, emerald is graded by eye. Thus, if an emerald has no visible inclusions to the eye (assuming normal visual acuity) it is considered flawless. Stones that lack surface breaking fissures are extremely rare and therefore almost all emeralds are treated, "oiled", to enhance the apparent clarity. Eye-clean stones of a vivid primary green hue (as described above) with no more than 15% of any secondary hue or combination (either blue or yellow) of a medium-dark tone command the highest prices.[6] This relative crystal non-uniformity makes emeralds more likely than other gemstones to be cut into cabochons, rather than faceted shapes.

3 – 3 - Treatments :

Most emeralds are oiled as part of the post lapidary process, in order to improve their clarity. Cedar oil, having a similar refractive index, is often used in this generally accepted practice. Other liquids, including synthetic oils and polymers with refractive indexes close to that of emerald such as *Opticon* are also used. The U.S. Federal Trade Commission requires the disclosure of this treatment when a treated emerald is sold. The use of oil is traditional and largely accepted by the gem trade. Other treatments, for example the use of green-tinted oil, are not acceptable in the trade. The laboratory community has recently standardized the language for grading the clarity of emeralds. Gems are graded on a four step scale; *none*, *minor*, *moderate* and *highly* enhanced. Note that these categories reflect levels of enhancement not *clarity*. A gem graded *none* on the enhancement scale may still exhibit visible inclusions. Laboratories tend to apply these criteria differently. Some gem labs consider the mere presence of oil or polymers to constitute enhancement. Others may ignore traces of oil if the presence of the material does not materially improve the look of the gemstone.

Given that the vast majority of all emeralds are treated as described above, and the fact that two stones that appear to be similar in quality may actually be quite far apart in treatment level, a consumer considering a purchase of an expensive emerald is well advised to insist upon a treatment report from a reputable gemological laboratory. All other factors being equal, a high quality emerald with an enhancement level graded *moderate* should cost 40 – 50 % less than an identical stone graded *none*.

4 - Emerald localities :

Spanish emerald and gold pendant exhibited at Victoria and Albert Museum.

Emeralds in antiquity were mined by the Egyptians and in India and Austria .

A rare type of emerald known as a *trapiche* emerald is occasionally found in the mines of Colombia. A trapiche emerald exhibits a "star" pattern; it has raylike spokes of dark carbon impurities that give the emerald a six-pointed radial pattern . Emeralds come from three main emerald mining areas in Colombia: Muzo, Coscuez, and Chivor. Emeralds are also found in other countries, such as Afghanistan, Australia, Austria, Brazil, Bulgaria, Cambodia, Canada, China, Egypt, Ethiopia, France, Germany, India, Italy, Kazakhstan, Madagascar, Mozambique, Namibia, Nigeria, Norway, Pakistan, Russia, Somalia, South Africa, Spain, Switzerland, Tanzania, United States, Zambia and Zimbabwe. In the US, emeralds have been found in Connecticut, Montana, Nevada, North Carolina and South Carolina. In 1998 emeralds were discovered in the Yukon .

5 - Synthetic emerald :

Emerald is a rare and valuable gemstone and, as such, it has provided the incentive for developing synthetic emeralds. Both hydrothermal and *flux-growth* synthetics have been produced, and a method has been developed for producing an emerald overgrowth on colorless beryl. The first commercially successful emerald synthesis process was that of Carroll Chatham. Because Chatham's emeralds do not have any water and contain traces of vanadate, molybdenum and vanadium, a lithium vanadate flux process is probably involved. The other large producer of flux emeralds was Pierre Gilson Sr., which has been on the market since 1964. Gilson's emeralds are usually grown on natural colorless beryl seeds which become coated on both sides. Growth occurs at the rate of 1 mm per month, a typical seven-month growth run producing emerald crystals of 7 mm of thickness . Gilson sold his production laboratory to a Japanese firm in the 1980s, but production has ceased since; so did Chatham's, after the San Francisco earthquake in 1989.

Emerald showing its hexagonal structure

Hydrothermal synthetic emeralds have been attributed to IG Farben, Nacken, Tairus, and others, but the first satisfactory commercial product was that of Johann Lechleitner of Innsbruck, Austria, which appeared on the market in the 1960s. These stones were initially sold under the names "Emerita" and "Symeralds", and they were grown as a thin layer of emerald on top of natural colorless beryl stones. Although not much is known about the original process, it is assumed that Leichleitner emeralds were grown in acid conditions . Later, from 1965 to 1970, the Linde Division of Union Carbide produced completely synthetic emeralds by hydrothermal synthesis. According to their patents , acidic conditions are essential to prevent the chromium (which is used as the colorant) from precipitating. Also, it is important that the silicon-containing nutrient be kept away from the other ingredients to prevent nucleation and confine growth to the seed crystals. Growth occurs by a diffusion-reaction process, assisted by convection. The largest producer of hydrothermal emeralds today is Tairus in Russia. They have succeeded to synthesize emeralds that have similar chemical composition as emeralds in alkaline deposits in Colombia, hence they are called “Colombian Created Emeralds” or “Tairus Created Emeralds”. Luminescence in ultraviolet light is considered a supplementary test when making a natural vs. synthetic determination, as many, but not all, natural emeralds are inert to ultraviolet light. Many synthetics are also UV inert.

Synthetic emeralds are often referred to as "created", as their chemical and gemological composition is the same as their natural counterparts. The U.S. Federal Trade Commission (FTC) has very strict regulations as to what can and what cannot be called "synthetic" stone. The FTC says: "§ 23.23(c) It is unfair or deceptive to use the word "laboratory-grown," "laboratory-created," "[manufacturer name]-created," or "synthetic" with the name of any natural stone to describe any industry product unless such industry product has essentially the same optical, physical, and chemical properties as the stone named " .

6 - Emerald in different cultures, and emerald lore :

The Gachala Emerald is one of the largest gem emeralds in the world, at 858 carats (172 g). This stone was found in 1967 at La Vega de

San Juan mine in Gachalá, Colombia. It is housed at the National Museum of Natural History of the Smithsonian Institution in Washington, D.C.

Emerald is regarded as the traditional birthstone for May, as well as the traditional gemstone for the astrological signs of Taurus, Cancer and sometimes Gemini. One of the quainter anecdotes on emeralds was by the 16th-century historian Brantôme, who referred to the many impressive emeralds the Spanish under Cortez had brought back to Europe from Latin America. On one of Cortez's most notable emeralds he had the text engraved *Inter Natos Mulierum non sur-rexit mayor* ("Among those born of woman there hath not arisen a greater," Matthew 11:11) which referred to John the Baptist. Brantôme considered engraving such a beautiful and simple product of nature sacrilegious and considered this act the cause for Cortez's loss of an extremely precious pearl (to which he dedicated a work, *A beautiful and incomparable pearl*), and even for the death of King Charles IX of France, who died soon after. "The Attenbury Emeralds" is a detective story in which Lord Peter Wimsey must solve several emerald-related mysteries. In The Wizard of Oz, the Wizard lives in a city made entirely of emerald, known as the Emerald City.

7 - Notable emeralds :

Emerald	Origin
Chalk Emerald	Colombia
Duke of Devonshire Emerald	
Gachala Emerald	
Mogul Mughal Emerald	
Bahia Emerald	Brazil

8 - Gallery :

The Chalk Emerald ring, containing a top-quality 37-carat emerald, also in the U.S. National

The Hooker Emerald Brooch, containing a 75-carat square-cut emerald, also in the U.S. National

Left to right: The Indian Emerald Necklace, the Gachala Emerald crystal and the Mackay Emerald Necklace (167-carat center stone), all pieces from the U.S. National Museum of Natural History

28 - Emery (حجر الصنفرة)

Emery mine on Naxos Island

1 - Introduction :

Emery is a very hard rock type used to make abrasive powder. It largely consists of the mineral corundum (aluminium oxide), mixed with other species such as the iron - bearing spinels hercynite and magnetite, and also rutile (titania) . Industrial emery may contain a variety of other minerals and synthetic compounds such as magnesia, mullite, and silica.

It is black or dark gray in colour, less dense than translucent - brown corundum with a specific Gravity of between 3.5 and 3.8. Because it can be a mixture of minerals, no definite Mohs hardness can be assigned: the hardness of corundum is 9 and that of some spinel-group minerals is near 8, but the hardness of others such as magnetite is near 6.

Crushed or naturally eroded emery (known as *black sand*) is used as an abrasive — for example, on an emery board, as a traction enhancer in asphalt and tarmac mixtures, or as used in mechanical engineering as emery cloth.

The Greek island of Naxos used to be the main source of this industrially important rock type. It has been mined on the eastern side of Naxos for well over two thousand years until recent times. However, demand for emery has decreased with the development of sintered carbide and oxide materials as abrasives.

2 - Grain numbers :

Grain numbers define the size of the grain. The number corresponds to the number of meshes per linear inch in the grading sieve. Common numbers are, from coarse to fine: 10, 12, 14, 16, 18, 20, 24, 30, 36, 40, 46, 54, 60, 70, 80, 90, 100, 120, 150, 180, and 200. Grains finer than 200 are known as "flour" and are designated by the letters: CF, F, FF, FFF, FFFF, and PCF or SF (coarse to fine). Note that the grades for flour are not standardized, so the same grade grains from different sources may differ in size slightly.

29 – Epidote

Epidote from Alaska

Epidote crystals – Deposit topotype

Epidote is a calcium aluminium iron soro silicate mineral, $Ca_2Al_2(Fe^{3+};Al)(SiO_4)(Si_2O_7)O(OH)$, crystallizing in the mono clinic system. Well - developed crystals are of frequent occurrence: they are commonly prismatic in habit, the direction of elongation being perpendicular to the single plane of symmetry. The faces are often deeply striated and crystals are often twinned. Many of the characters of the mineral vary with the amount of iron present for instance, the color, the optical constants, and the specific Gravity. The color is green, grey, brown or nearly black, but usually a characteristic shade of yellowish-green or pistachio-green. It displays strong pleochroism, the pleochroic colors being usually green, yellow and brown. Clinozoisite is white or pale rose-red variety containing very little iron, thus having the same chemical composition as the orthorhombic mineral zoisite. The name is derived from the Greek word "epidosis" which means"addition "

Epidote is an abundant rock-forming mineral, but one of secondary origin. It occurs in marble and schistose rocks of metamorphic origin. It is also a product of hydrothermal alteration of various minerals (feldspars, micas, pyroxenes, amphiboles, garnets, and others) composing igneous rocks. A rock composed of quartz and epidote is known as epidosite. Well-developed crystals are found at many localities: Knappenwand, near the Großvenediger in the Untersulzbachthal in Salzburg, as magnificent, dark green crystals of long prismatic habit in cavities in epidote schist, with asbestos, adularia, calcite, and apatite; the Ala valley and Traversella in

Piedmont; Arendal in Norway; Le Bourg - d'Oisans in Dauphiné; Haddam in Connecticut; Prince of Wales Island in Alaska, here as large, dark green, tabular crystals with copper ores in meta morphosed lime stone.

The perfectly transparent, dark green crystals from the Knappenwand and from Brazil have occasionally been cut as gemstones.

Belonging to the same isomorphous group with epidote are the species piemontite and allanite, which may be described as manganese and cerium epidotes respectively.

Piemontite occurs as small, reddish - black, monoclinic crystals in the manganese mines at San Marcel, near Ivrea in Piedmont, and in crystalline schists at several places in Japan. The purple color of the Egyptian porfido rosso antico is due to the presence of this mineral.

Allanite and dollaseite - (Ce) have the same general epidote Formula and contain metals of the cerium group. In external appearance allanite differs widely from epidote, being black or dark brown in color, pitchy in lustre, and opaque in the Mass; further, there is little or no cleavage, and well-developed crystals are rare. The crystallographic and optical characters are similar to those of epidote; the pleochroism is strong with reddish-, yellowish-, and greenish-brown colors. Although not a common mineral, allanite is of fairly wide distribution as a primary accessory constituent of many crystalline rocks, gneiss, granite, syenite, rhyolite, andesite, and others. It was first found in the granite of east Greenland and described by Thomas Allan in 1808, after whom the species was named. Allanite is a mineral readily altered by hydration, becoming optically isotropic and amorphous: for this reason several varieties have been distinguished, and many different names applied. Orthite was the name given by Jöns Berzelius in 1818 to a hydrated form found as slender prismatic crystals, sometimes a foot in length, at Finbo, near Falun in Sweden. Dollaseite is less common, famous from the Ostanmossa mine, Norberg district, Sweden.

Category	Sorosilicates
Chemical Formula	$\{Ca_2\}\{Al_2Fe^{3+}\}[O\|OH\|SiO_4\|Si_2O_7]$
Color	Pistachio-green , yellow - green, greenish black
Crystal habit	Prismatic with striations , fibrous , Massive
Crystal system	Monoclinic – Prismatic
Cleavage	good in one direction lengthwise
Fracture	Flat regular to uneven
Mohs scale hardness	6 – 7
Luster	Vitreous to resinous
Streak	Greyish white
Diaphaneity	Transparent to nearly opaque
Specific Gravity	3.3 – 3.6
Optical properties	Biaxial (-)
Refractive index	n_α = 1.715–1.751 n_β = 1.725–1.784 n_γ = 1.734–1.797
Birefringence	δ = 0.019–0.046
Pleochroism	Strong

30 – Ettringite

Ettringite , Kalahari manganese fields ,
Northern Cape Province, South Africa

Ettringite , N'Chwaning Mines, Kalahari manganese fields, Northern Cape Province, South Africa

1 – Introduction :

Ettringite is a hydrous calcium aluminium sulfate mineral with Formula: $Ca_6Al_2(SO_4)_3(OH)_{12}\cdot 26H_2O$. It is a colorless to yellow mineral crystallizing in the trigonal system. The prismatic crystals are typically colorless, turning white on partial dehydration.

Category	Sulfate minerals
Chemical Formula	$Ca_6Al_2(SO_4)_3(OH)_{12}\cdot 26H_2O$
Crystal symmetry	Trigonal 3m ditrigonal pyramidal
Unit cell	a = 11.23 Å, c = 21.44 Å; Z = 2
Color	Colorless, pale yellow, milky white
Crystal habit	Striated prismatic crystals; fibrous to cotton like

Crystal system	Trigonal
Mohs scale hardness	2 - 2.5
Luster	Vitreous
Diaphaneity	Transparent to opaque
Specific Gravity	1.77
Optical properties	Uniaxial (-)
Refractive index	$n_\omega = 1.491$, $n_\varepsilon = 1.470$
Solubility	Partially soluble in water
Alters to	Partially dehydration on atmospheric exposure, becomes opaque

2 - Discovery and occurrence :

Ettringite was first described in 1874 for an occurrence near the Ettringer Bellerberg volcano, Ettringen, Rheinland-Pfalz, Germany . It occurs within meta morphically altered lime stone adjacent to igneous intrusive rocks or within xenoliths. It also occurs as weathering crusts on larnite in the Hatrurim Formation of palestine . It occurs associated with portlandite, afwillite and hydro calumite at Scawt Hill, Ireland and with afwillite, hydrocalumite, mayenite and gypsum in the Hatrurim Formation.[2] It has also been reported from the Zeilberg quarry, Maroldsweisach, Bavaria; at Boisséjour, near Clermont-Ferrand, Puy-de-Dôme, Auvergne, France; the N'Chwaning mine, Kuruman district, Cape Province, South Africa; in the USA, at the Crestmore quarry, Riverside County, California and in the Lucky Cuss mine, Tombstone, Cochise County, Arizona.

3 - Occurrence in cement :

In concrete chemistry ettringite is a hexacalcium aluminate trisulfate hydrate, of general Formula :

$$(CaO)_6(Al_2O_3)(SO_3)_3\cdot 32H_2O$$

or

$$(CaO)_3(Al_2O_3)(CaSO_4)_3\cdot 32H_2O.$$

Ettringite is formed in hydrated Portland cement system as a result of the reaction of calcium aluminate with calcium sulfate, both present in Portland cement . Ettringite, the more prominent representative of AFt phases or (Al_2O_3-Fe_2O_3-tri), can also be synthesized in the laboratory by reacting stoichiometric amounts of calcium, aluminium and sulfate in water.

$$C_3A + 3\ CaSO_4 \rightarrow \text{ettringite}$$

In the cement system, the presence of ettringite depends on the ratio of calcium sulfate to tri-calcium aluminate (C3A); when this ratio is low, ettringite forms during early hydration and then converts to the calcium aluminate monosulfate (AFm phase or (Al_2O_3-Fe_2O_3-mono)). When the ratio is intermediate, only a portion of the ettringite converts to AFm and both can coexist, while ettringite is unlikely to convert to AFm at high ratios.

The characters designate standard notations :

$A = Al_2 O_3$
$C = Ca O$
$F = Fe_2 O_3$
$H = H_2 O$
$K = K_2 O$
m = mono
$N = Na_2 O$
$\bar{S} = S O_3$
$S = Si O_2$
t = tri

3 – 1 - AFt and AFm phases

- AFt : abbreviation for "alumina, ferric oxide, tri-sulfate" or (Al_2O_3 – Fe_2O_3 – tri). It represents a group of calcium sulfoaluminate hydrates. AFt has the general Formula $[Ca_3(Al,Fe)(OH)_6 \cdot 12 H_2O]_2 \cdot X_3 \cdot nH_2O$ where X represents a doubly charged anion or, sometimes, two singly charged anions. Ettringite is the most common and important member of the AFt group (X in this case denoting sulfate).

- AFm: abbreviation for "Alumina, Ferric oxide, mono-sulfate" or (Al_2O_3 – Fe_2O_3 – mono). It represents another group of calcium aluminate hydrates with general Formula $[Ca_2(Al,Fe)(OH)_6)] \cdot X \cdot nH_2O$ where X represents a singly charged anion or 'half' a doubly charged anion. X may be one of many anions. The most important anions involved in Portland cement hydration are hydroxyl, sulfate and carbonate.

31 – Gibbsite

Gibbsite from Brazil

1 – Introduction :

Gibbsite, $Al(OH)_3$, is one of the mineral forms of aluminium hydroxide. It is often designated as γ-$Al(OH)_3$ (but sometimes as α-$Al(OH)_3$). It is also sometimes called hydrargillite (or hydrargyllite).

Gibbsite is an important ore of aluminium in that it is one of three main phases that make up the rock bauxite. Bauxite is often thought of as a mineral but it is really a rock composed of hydroxide and oxyhydroxide minerals such as gibbsite, boehmite (γ-$AlO(OH)$), and diaspore (α-$AlO(OH)$), as well as clays, silt, and iron oxides and hydroxides.

Gibbsite has three named structural polymorphs or polytypes: **bayerite** (designated often as α-$Al(OH)_3$, but sometimes as β-$Al(OH)_3$), **doyleite**, and **nordstrandite**. Gibbsite and bayerite are monoclinic, whereas doyleite and nordstrandite are triclinic forms.

Category	Hydroxide minerals
Chemical Formula	Al(OH)3

2 - Structure

The structure of gibbsite is interesting and analogous to the basic structure of the micas. The basic structure forms stacked sheets of linked octahedrons of aluminium hydroxide. The octahedrons are composed of aluminium ions with a +3 charge bonded to six octahedrally coordinated hydroxides with a -1 charge. Each of the hydroxides is bonded to only two aluminium atoms because one third of the octahedrons are vacant a central aluminium. The result is a neutral sheet since +3/6 = +1/2 (+3 charge on the aluminiums divided by six hydroxide bonds times the number of aluminiums) and -1/2 = -1/2 (-1 charge on the hydroxides divided between only two aluminiums); thus the charges cancel. The lack of a charge on the gibbsite sheets means that there is no charge to retain ions between the sheets and act as a "glue" to keep the sheets together. The sheets are only held together by weak residual bonds and this results in a very soft easily cleaved mineral.

Gibbsite's structure is closely related to the structure of brucite, $Mg(OH)_2$. However the lower charge in brucite's magnesium (+2) as opposed to gibbsite's aluminium (+3) does not require that one third of the octahedrons be vacant of a central ion in order to maintain a neutral sheet. The different symmetry of gibbsite and brucite is due to the different way that the layers are stacked.

It is the gibbsite layer that in a way forms the "floor plan" for the mineral corundum, Al_2O_3. The basic structure of corundum is identical to gibbsite except the hydroxides are replaced by oxygen. Since oxygen has a charge of -2 the layers are not neutral and require that they must be bonded to other aluminiums above and below the initial layer producing the framework structure that is the structure of corundum.

Gibbsite is interesting for another reason because it is often found as a part of the structure of other minerals. The neutral aluminium hydroxide sheets are found sandwiched between silicate sheets in important clay groups: the illite, kaolinite, and montmorillonite/smectite groups. The individual aluminium hydroxide layers are identical to the individual layers of gibbsite and are referred to as the *gibbsite layers*.

3 - Etymology

Gibbsite is named after George Gibbs (1776–1833), an American mineral collector. G. Gibbs' collection was acquired by Yale University early in the nineteenth century.

32 – Gmelinite

Gmelinite from Flinders, Victoria, Australia.

Contents

1 - Introduction :

Gmelinite-Na is one of the rarer zeolites but the commonest member of the gmelinite series, gmelinite-Ca, gmelinite-K and gmelinite-Na. It is closely related to the very similar mineral chabazite. Gmelinite was named as a single species in 1825 after Christian Gottlob Gmelin (1792–1860) professor of chemistry and mineralogist from Tübingen, Germany, and in 1997 it was raised to the status of a series. Gmelinite-Na has been synthesised from Na-bearing aluminosilicate gels . The naturally occurring mineral forms striking crystals, shallow, six sided double pyramids, which can be colorless, white, pale yellow, greenish, orange, pink, and red. They have been compared to an angular flying saucer.

Category	Silicate mineral
Chemical Formula	$Na_4(Si_8Al_4)O_{24}\cdot 11H_2O$
Molar Mass	2,000 g

Color	Colorless, white, yellow, orange, pale green, pink, red, brown and grey
Crystal habit	Hexagonal plates, or short prisms, showing hexagonal dipyramids, pyramids and basal pinacoid . May also be tabular or rhombohedral . Crystals are striated parallel
Crystal system	Hexagonal Dihexagonal Dipyramidal
Twinning	Interpenetrant twins common . The twins consist of four individuals , three are at 90° to the other and at 60° to each other
Fracture	Conchoidal
Mohs scale hardness	4.5
Luster	Dull to vitreous
Streak	White
Diaphaneity	Transparent, translucent or opaque
Specific Gravity	2.04 to 2.17
Optical properties	Uniaxial (-)
Refractive index	$n_\omega = 1.476 - 1.494$, $n_\varepsilon = 1.474 - 1.480$
Solubility	Soluble in cold 10 % HCl.
Other characteristics	Piezoelectric. Barely detectable radioactivity. As with all zeolites, water is released on heating, and almost all has been expelled by 400 °C.

2 - Structure :

The aluminosilicate framework is composed of tetrahedra linked to form parallel double six-membered rings stacked in two different positions (A and B) in the repeating arrangement AABBAABB. The framework has no Al-Si order . Within the structure there are cavities with a cross-section of up to 4 Å, and also wide channels parallel to the c axis with a diameter of 6.4 Å Space group : $P6_3 / mmc$. Unit cell parameters : a = 13.72 Å , c = 9.95 Å , Z =4.

3 – Environment :

Generally occurs in Si-poor volcanic rocks, marine basalts and breccias, associated with other sodium zeolites such as analcime, $Na(Si_2Al)O_6 \cdot H_2O$, natrolite, $Na_2(Si_3Al_2)O_{10} \cdot 2H_2O$, and chabazite-Na, $Na_2Ca(Si_8Al_4)O_{24} \cdot 12H_2O$. It also occurs in Na-rich pegmatites in alkaline rocks, and as an alteration product in some nepheline syenite intrusions . No sedimentary gmelinite has been found . It is generally assumed that it forms at low temperatures, less than 100 °C. It is widespread as a hydrothermal alteration product of ussingite, $Na_2AlSi_3O_8(OH)$, associated with gobbinsite, $Na_5(Si_{11}Al_5)O_{32} \cdot 11H_2O$, gonnardite, $(Na,Ca)_2(Si,Al)_5O_{10} \cdot 3H_2O$, and chabazite - K .

4 - Notable localities :

Gmelinite-Na occurs extremely rarely at the Francon Quarry, Montreal, Canada, in sills of the igneous volcanic rock phonolite which are rich in dawsonite, $NaAl(CO_3)(OH)_2$. It occurs both as pure gmelinite-Na and interlayered with chabazite in water-quenched basalts in Western Tasmania .

5 - Distribution :

Type Locality: Monte Nero, San Pietro, Montecchio Maggiore, Vicenza Province, Veneto, Italy. Also found in Australia, Canada, Czech Republic, Germany, Hungary, Japan, Russia, UK and USA.

33 – Halloysite

A sample of Halloysite

1 – Introduction :

Halloysite is a 1:1 aluminosilicate clay mineral with the empirical Formula $Al_2Si_2O_5(OH)_4$. Its main constituents are aluminium (20.90%), silicon (21.76%), and hydrogen (1.56%). Halloysite typically forms by hydrothermal alteration of alumino-silicate minerals . It can occur intermixed with dickite, kaolinite, montmorillonite and other clay minerals. X-ray diffraction studies are required for positive identification. It was first described in 1826 and named after the Belgian geologist Omalius d'Halloy.

Category	Clay kaolinite - group
Chemical Formula	$Al_2Si_2O_5(OH)_4$
Crystal symmetry	Monoclinic domatic H-M symbol : m Space group : Cc
Unit cell	a = 5.14 Å, b = 8.9 Å, c = 7.214 Å; β = 99.7°; Z = 4
Color	White; gray, green, blue, yellow, red from included impurities.
Crystal habit	Spherical clusters , Massive
Crystal system	Monoclinic

Fracture	Conchoidal
Mohs scale hardness	2 - 2.5
Luster	Pearly , waxy , or dull
Diaphaneity	Semitransparent
Specific Gravity	2 - 2.65
Optical properties	Biaxial
Refractive index	n_α = 1.553 - 1.565 n_β = 1.559 - 1.569 n_γ = 1.560 - 1.570

2 - Structure :

Two common forms are found, when hydrated the clay exhibits a 1 nm spacing of the layers and when dehydrated (meta-halloysite) the spacing is 0.7 nm. Halloysite naturally occurs as small cylinders which average 30 nm in diameter with lengths between 0.5 and 10 micrometres . The cation exchange capacity depends on the amount of hydration, as $2H_2O$ has 5-10 m.e / 100g, while $4H_2O$ has 40-50 m.e./100g . "Endellite" is the alternative name for the $4H_2O$ structure .

3 - Occurrence :

The formation of halloysite is due to hydrothermal alteration, and it is often found near carbonate rocks. For example, halloysite samples found in Wagon Wheel Gap, Colorado, United States are suspected to be the weathering product of rhyolite by downward moving waters . In general the formation of clay minerals is highly favored in tropical and sub-tropical climates due to the immense amounts of water flow. Halloysite has also been found overlaying basaltic rock, showing no gradual changes from rock to mineral formation . Halloysite occurs primarily in recently - exposed volcanic-derived soils, but it also forms from primary minerals in tropical soils or pre-glacially weathered materials . Igneous rocks, especially glassy basaltic rocks are more susceptible to weathering and alteration forming halloysite.

Often as is the case with halloysite found in Juab County, Utah, United States the clay is found in close association with goethite and limonite and often interspersed with alunite. Feldspars are also subject to decomposition by water saturated with carbon dioxide. When feldspar occurs near the surface of lava flows, the CO_2 concentration is high, and reaction rates are rapid. With increasing depth, the leaching solutions become saturated with silica, aluminium, sodium, and calcium. Once the solutions are depleted of CO_2 they precipitate as secondary minerals. The decomposition is dependent on the flow of water. In the case that halloysite is formed from plagioclase it will not pass through intermediate stages .

4 – Applications :

A very pure halloysite is mined from a highly altered rhyolite occurrence in New Zealand uses include porcelain and bone china .

Halloysite also has been used as a petroleum cracking catalyst in the past. Exxon has also developed a cracking catalyst based on synthetic halloysite.

Due to its structure, it can be used as filler in either natural or modified forms in nanocomposites.

34 – Hauyne

Haüyne on augite, Somma-Vesuvius Complex, Naples Province Italy

Contents

1 – Introduction ;

Hauyne, **haüyne** or **hauynite** was first described in 1807 from samples discovered in Vesuvian lavas in Monte Somma, Italy, and was named in 1807 by Brunn - Neergard for the French crystallographer René Just Haüy (1743–1822) . It is a tectosilicate mineral with sulfate, with endmember Formula $Na_3Ca(Si_3Al_3)O_{12}(SO_4)$. As much as 5 wt % K_2O may be present, and also H_2O and Cl. It is a feldspathoid and a member of the sodalite group .

Category	Tectosilicate , sodalite group
Chemical Formula	$Na_3Ca(Si_3Al_3)O_{12}(SO_4)$
Crystal symmetry	Isometric hextetrahedral

	H-M symbol 43m Space group: P 43n
Unit cell	Z = 1; a = 9.08 - 9.13 Å
Molar Mass	1,032 g
Color	Blue, white, grey, yellow, green, pink
Crystal habit	Dodecahedral or pseudo - octahedral
Crystal system	Isometric
Fracture	Uneven to conchoidal
Tenacity	Brittle
Mohs scale hardness	5 to 6
Luster	Vitreous to greasy
Streak	Very pale blue to white
Diaphaneity	Transparent to translucent
Specific Gravity	2.4 to 2.5
Optical properties	Isotropic
Refractive index	n = 1.494 to 1.509
Birefringence	None, isotropic
Pleochroism	None, isotropic
Fusibility	4.5
Solubility	Gelatinises in acids
Other characteristics	May fluoresce orange to pink under longwave ultraviolet light

2 - Sodalite group :

Formulae :

- sodalite $Na_4(Al_3Si_3)O_{12}Cl$
- nosean $Na_8(Al_6Si_6)O_{24}(SO_4).H_2O$
- lazurite $Na_3Ca(Si_3Al_3)O_{12}S$
- tsaregorodtsevite $N(CH_3)_4Si_4(SiAl)O_{12}$
- tugtupite $Na_4BeAlSi_4O_{12}Cl$
- vladimirivanovite $Na_6Ca_2[Al_6Si_6O_{24}](SO_4,S_3,S_2,Cl)_2\cdot H_2O$

All these minerals are feldspathoids. Haüyne forms a solid solution with nosean and with sodalite. Complete solid solution exists between synthetic nosean and haüyne at 600 °C, but only limited solid solution occurs in the sodalite-nosean and sodalite-haüyne systems.

3 - Unit cell :

Haüyne belongs to the hexatetrahedral class of the isometric system, 43m, space group P43n. It has one Formula unit per unit cell (Z = 1), which is a cube with side length of 9 Å. More accurate measurements are as follows:

- a = 8.9 Å
- a = 9.08 to 9.13 Å
- a = 9.10 to 9.13 Å
- a = 9.11(2) Å
- a = 9.116 Å
- a = 9.13 Å

4 - Structure :

All silicates have a basic structural unit that is a tetrahedron with an oxygen ion O at each apex, and a silicon ion Si in the middle, forming $(SiO_4)^{4-}$. In tectosilicates (framework silicates) each oxygen ion is shared between two tetrahedra, linking all the tetrahedra together to form a framework. Since each O is shared between two tetrahedra only half of it "belongs" to the Si ion in either tetrahedron, and if no other components are present then the Formula is SiO_2, as in quartz.

Aluminium ions Al, however, can substitute for some of the silicon ions, forming $(AlO_4)^{5-}$ tetrahedra. If the substitution is random the ions are said to be disordered, but in haüyne the Al and Si in the tetrahedral framework are fully ordered.

Si has a charge 4+, but the charge on Al is only 3+. If all the cations (positive ions) are Si then the positive charges on the Si's exactly balance the negative charges on the O's. When Al replaces Si there is a deficiency of positive charge, and this is made up by extra positively charged ions (cations) entering the structure, somewhere in between the tetrahedra.

In haüyne these extra cations are sodium Na^+ and calcium Ca^{2+}, and in addition the negatively charged sulfate group $(SO_4)^{2-}$ is also present. In the haüyne structure the tetrahedra are linked to form six-membered rings which are stacked up in an ..ABCABC.. sequence along one direction, and rings of four tetrahedra are stacked up parallel to another direction. The resulting arrangement forms continuous channels that can accommodate a large variety of cations and anions.

5 - Appearance :

Haüyne crystallizes in the isometric system forming rare dodecahedral or pseudo-octahedral crystals that may reach 3 cm across; it also occurs as rounded grains. The crystals are transparent to translucent, with a vitreous to greasy luster. The color is usually bright blue, but it can also be white, grey, yellow, green and pink. In thin section the crystals are colorless or pale blue, and the streak is very pale blue to white.

6 - Optical properties :

Haüyne is isotropic. Truly isotropic minerals have no birefringence, but haüyne is weakly birefringent when it contains inclusions . The refractive index is 1.50. Although this is quite low, similar to that of ordinary window glass, it is the largest value for minerals of the sodalite group. It may show reddish orange to purplish pink fluorescence under longwave ultraviolet light.

7 - Physical properties :

Cleavage is distinct to perfect, and twinning is common, as contact, penetration and polysynthetic twins. The fracture is uneven to conchoidal, the mineral is brittle, and it has hardness 5½ to 6, almost as hard as feldspar. All the members of the sodalite group have quite low densities, less than that of quartz; haüyne is the densest of them all, but still its specific Gravity is only 2.44 to 2.50. If haüyne is placed on a glass slide and treated with nitric acid HNO_3 , and then the solution is allowed to evaporate slowly, monoclinic needles of gypsum form. This distinguishes haüyne from sodalite, which forms cubic crystals of chlorite under the same conditions. The mineral is not radioactive.

8 - Geological setting and associations :

Haüyne occurs in phonolites and related leucite- or nepheline-rich, silica-poor, igneous rocks ; less commonly in nepheline-free extrusives and metamorphic rocks (marble). Associated minerals include nepheline $KNa_3(AlSiO_4)_4$, leucite $K(Si_2Al)O_6$, titanian andradite $Ca_3Fe^{3+}{}_2(SiO_4)_3$, melilite $(Ca,Na)(Mg,Al,Fe)(Si,Al)_2O_7$, augite $(Ca,Mg,Fe)_2(Si,Al)_2O_6$, sanidine $K(AlSi_3)O_8$, biotite $K(Fe^{2+},Mg)_3AlSi_3O_{10}(OH,F)_2$, phlogopite $KMg_3(Si_3Al)O_{10}(OH)_2$ and apatite $Ca_5(PO_4)_3(F,Cl,OH)$.

9 - Localities :

The type locality is Lake Nemi , Alban Hills, Rome Province, Latium, Italy.

Occurrences include :

Hauyne, Mayen, Eifel Mts, Rhineland-Palatinate, Germany.

- Canary Islands: A pale blue mineral intermediate between haüyne and lazurite has been found in spinel dunite xenoliths from La Palma, Canary Islands.
- Germany : In ejected rocks of hornblende-haüyne-scapolite rock from the Laach lake volcanic complex, Eifel, Rhineland-Palatinate
- Italy: Anhedral blue to dark grey phenocrysts in leucite-melilite-bearing lava at Monte Vulture, Melfi, Basilicata, Potenza
- Italy: Millimetric transparent blue crystals in ejecta consisting mainly of K-feldspar and plagioclase from Albano Laziale, Roma
- Italy: Ejected blocks in the peperino of the Alban Hills, Rome Province, Latium, contain white octahedral haüyne associated with leucite, garnet, melilite and latiumite .
- USA: Haüyne of metamorphic origin occurs at the Edwards Mine, St. Lawrence County, New York.
- USA: Haüyne occurs in nepheline alnoite with melilite, phlogopite and apatite at Winnett, Petroleum County, Montana, USA.
- USA: Haüyne is common in small quantities as phenocrysts in phonolite and lamprophyre at the Cripple Creek, Colorado Mining District, Colorado, USA.

35 – Hessonite

Striated crystals of hessonite

Hessonite or *Cinnamon Stone* is a variety of grossular, a calcium aluminium mineral of the garnet group with the general Formula $Ca_3Al_2Si_3O_{12}$. The name is from the Greek hēssōn, *inferior*, in allusion to its lower hardness and density than most other garnet species varieties.

It has a characteristic red color, inclining to orange, much like that of gem zircon. Indeed it was shown many years ago, by Sir A. H. Church, that many gems, especially engraved gemstones, commonly regarded as zircon, were really hessonite. The difference is readily detected by the specific Gravity, that of hessonite being 3.64 to 3.69, whilst that of zircon is about 4.6. Hessonite has a similar hardness to that of quartz, about 7 on the mohs scale, whilst the hardness of most garnet species can reach 7.5.

Hessonite comes chiefly from [[Sri Lanka]and India where it is found generally in placer deposits, though its occurrence in its native matrix is not unknown. It is also found in Brazil and California.

Hessonite is also called Gomedhaka in Tamil and Sinhalese.

Category	variety of the grossular species
Chemical Formula	$Ca_3Al_2Si_3O_{12}$

Crystal system	cubic
Cleavage	none, sometimes indistinct parting
Fracture	conchoidal to uneven
Mohs scale hardness	7
Specific Gravity	3.64 to 3.69
Polish luster	Vitreous
Optical properties	Single refractive, often anomalous double refractive
Birefringence	none
Pleochroism	none

36 –Heulandite

Heulandite, Lonavala Quarry, Pune District, Maharashtra, India.
Size of individual crystals : 3-5cm .

1 – Introduction :

Heulandite is the name of a series of tecto-silicate minerals of the zeolite group. Prior to 1997, heulandite was recognized as a mineral species, but a reclassification in 1997 by the International Mineralogical Association changed it to a series name, with the mineral species being named :

- heulandite-Ca
- heulandite-Na
- heulandite-K
- heulandite-Sr
- heulandite-Ba (described in 2002).

Heulandite-Ca, the most common of these, is a hydrous calcium and aluminium silicate, $(Ca,Na)_{2\text{-}3}Al_3(Al,Si)_2Si_{13}O_{36}\cdot 12H_2O$. Small amounts of sodium and potassium are usually present replacing part of the calcium. Strontium replaces calcium in the heulandite-Sr variety. The appropriate species name depends on the dominant element. The species are visually indistinguishable, and the series name heulandite is still used whenever testing has not been performed.

2 - Crystallography and properties :

Crystals are monoclinic. They may have a characteristic coffin-shaped habit, but may also form simple rhombic prisms. Frequently, a crust of fine crystals will form with only the ends of the rhombs visible, making the crystals look like wedges. They have a perfect cleavage parallel to the plane of symmetry, on which the lustre is markedly pearly; on other faces the lustre is of the vitreous type. The mineral is usually colourless or white, but may be orange, brown, yellow, brick-red, or green due to inclusions of celadonite. It varies from transparent to translucent. Isomorphous with heulandite is the strontium and barium zeolite brewsterite.

The Mohs hardness is 3 – 4 , and the specific Gravity 2.2. Heulandite is similar to stilbite. The two minerals may, however, be readily distinguished by the fact that in heulandite the acute positive bisectrix of the optic axes emerges perpendicular to the cleavage.

Heulandite, Berufjördur, Suður-Múlasýsla, Iceland. Clusters of pearlescent, curved heulandite crystals cover the vuggy, thin basalt matrix. Heulandite crystals are up to 2 cm.

3 - Discovery and occurrence :

Heulandite was first separated from stilbite by August Breithaupt in 1818, and named by him "euzeolite" (meaning beautiful zeolite); independently, in 1822, H. J. Brooke arrived at the same result, giving the name heulandite, after the mineral collector, Henry Heuland (1778 –1856).

Heulandite occurs with stilbite and other zeolites in the amygdaloidal cavities of basaltic volcanic rocks, and occasionally in gneiss and hydrothermal veins.

Good specimens have been found in the basalts of Berufjord, near Djupivogr, in Iceland, the Faroe Islands and the Deccan Traps of the Sahyadri Mountains of Maharashtra near Mumbai. Crystals of a brick-red colour are from Campsie Fells in Stirlingshire and the Fassa valley in Trentino. A variety known as beaumontite occurs as small yellow crystals on syenitic schist near Baltimore, Maryland.

37 – Hornblende

Amphibole Hornblende

1 – Introduction :

Hornblende is a complex inosilicate series of minerals (ferrohornblende – magnesio hornblende) .

It is not a recognized mineral in its own right, but the name is used as a general or field term, to refer to a dark amphibole.

Hornblende is an isomorphous mixture of three molecules; a calcium-iron-magnesium silicate, an aluminium – iron -magnesium silicate, and an iron - magnesium silicaten . The general Formula can be given as :

$(Ca,Na)_{2–3}(Mg,Fe,Al)_5(Al,Si)_8O_{22}(OH,F)_2$.

2 - Compositional variances

Some metals vary in their occurrence and magnitude:

- Manganese and titanium are often present.
- Sodium is sometimes present and fluorine often substitutes for the hydroxyl in the crystalline structure.

3 - Physical properties :

Hornblende has a hardness of 5 – 6 , a specific Gravity of 2.9–3.4 and is typically an opaque green, greenish-brown, brown or black color.

Its cleavage angles are at 56 and 124 degrees. It is most often confused with the minerals augite and biotite mica, both of which are black and can be found in granite and in charnockite.

4 - Occurrence :

Hornblende is a common constituent of many igneous and metamorphic rocks such as granite, syenite, diorite, gabbro, basalt, andesite, gneiss, and schist.

It is the principal mineral of amphibolites. Very dark brown to black hornblendes that contain titanium are ordinarily called basaltic hornblende, from the fact that they are usually a constituent of basalt and related rocks. Hornblende alters easily to chlorite and epidote.

A rare variety of hornblende contains less than 5% of iron oxide, is gray to white in color, and named edenite, from its locality in Edenville, Orange County, New York.

Other minerals in the hornblende series include:

- pargasite
- hastingsite
- tschermakite

5 - Etymology :

The word hornblende is derived from the German *horn* and *blenden*, to 'deceive' in allusion to its similarity in appearance to metal bearing ore minerals.

38 – Hydrogrossular

Hydrogrossular, is a calcium aluminium garnet series (Formula: $Ca_3Al_2(SiO_4)_{3-x}(OH)_{4x}$, with hydroxide (OH) partially replacing silica (SiO_4)). The endmembers of the hydrogarnet family (grossular, hibschite, and katoite) depend on the degree of substitution (x) :

- Grossular : $x = 0$
- Hibschite : $0.2 < x < 1.5$
- Katoite : $1.5 < x < 3$.

Hydrogrossular is a garnet variety in which a Si^{4+} is missing from a tetrahedral site. Charge balance is maintained by bonding a H^+ to each of the four oxygens surrounding the vacant site. Hydrogrossular is found in Massive crystal habit, sometimes grown in with idocrase.

Hydrogrossular is translucent to opaque, and found in green to bluish green, pink, white, and gray. The cause of the green color is chromium, and possibly iron. Pink hydrogrossular is caused by the presence of manganese. Hydrogrossular may have dark gray to black small inclusions . It has similarities to jade, and has the misnomers *Transvaal jade*, and *African jade*.

Hydrogrossular is sometimes used as a gemstone, being cabochon cut, or made into beads. Sources for green and pink hydrogrossular are South Africa, Canada, and the US. White hydrogrossular is sourced from Burma and China.

Category	Silicate mineral
Chemical Formula	$Ca_3Al_2(SiO_4)_{3-x}(OH)_{4x}$
Color	green to bluish green, pink, white, gray
Crystal habit	Massive
Crystal system	cubic
Cleavage	none
Fracture	conchoidal
Mohs scale hardness	7 - 7.5
Luster	vitreous
Specific Gravity	4.15 (+.05, -.03)
Polish luster	vitreous to subadamantine
Optical properties	Single refractive, anomalous aggregate reaction
Refractive index	1.810 (+.004, -.020)
Birefringence	none
Pleochroism	none
Ultraviolet fluorescence	inert
Absorption spectra	dark green hydrogrossular often shows cutoff below 460nm. Other color stones may show line around 463nm, indicating some idocrase content

39 – Jadeite

	
A selection of antique, hand - crafted Chinese jadeite buttons	*Jadeite*

Jadeite is a pyroxene mineral with composition $NaAlSi_2O_6$. It is monoclinic. It has a Mohs hardness of about 6.5 to 7.0 depending on the composition. The mineral is dense, with a specific Gravity of about 3.4. Jadeite forms solid solutions with other pyroxene endmembers such as augite and diopside (CaMg-rich endmembers), aegirine (NaFe endmember), and kosmochlor (NaCr endmember). Pyroxenes rich in both the jadeite and augite endmembers are known as omphacite.

The name Jadeite is derived (via French: l'ejade and Latin: ilia) from the Spanish phrase "piedra de ijada" which means "stone of the side." It was believed to cure kidney stones if it was rubbed against the side of the afflicted person's body. The Latin version of the name, *lapis nephriticus*, is the origin of the term nephrite, which is also a variety of jade.

Jadeite is formed in metamorphic rocks under high pressure and relatively low temperature conditions. Albite ($NaAlSi_3O_8$) is a common mineral of the Earth's crust, and it has a specific Gravity of about 2.6 , much less than that of jadeite. With increasing pressure, albite breaks down to form the high-pressure assemblage of jadeite plus quartz. Minerals associated with jadeite include: glaucophane, lawsonite, muscovite, aragonite, serpentine, and quartz.

Rocks that consist almost entirely of jadeite are called jadeitite. In all well - documented occurrences, jadeitite appears to have formed from subduction zone fluids in association with serpentinite . Jadeitite is resistant to weathering , and boulders of jadeitite released from the serpentine - rich environments in which they formed are found in a variety of environments.

Jadeite's color commonly ranges from white through pale apple green to deep *jade* green but can also be blue-green (like the recently rediscovered "Olmec Blue" jade), pink, lavender, and a multitude of other rare colors. *Chloromelanite* is a very dark green to black variety . Color is largely affected by the presence of trace elements such as chromium and iron. Its translucence can be anywhere from entirely solid through opaque to almost clear. Variations in color and translucence are often found even within a single specimen. Currently, the best known sources of gem quality jadeite are California, Myanmar, New Zealand and more recently Guatemala; other localities of jadeite include Kazakhstan, Russia, British Columbia, Alaska, Italy and Turkestan.

Over 100 axe heads made from jadeite quarried in northern Italy in the Neolithic era have been found across the British Isles . Because of the difficulty of working this material, all the axe heads of this type found are thought to have been non-utilitarian and to have represented some form of currency or be the products of gift exchange.

Category	Pyroxene group
Chemical Formula	$NaAlSi_2O_6$ or $Na(Al,Fe^{3+})Si_2O_6$
Color	Apple-green, emerald - green, bluish green, leek-green , greenish white , white, may show green spots, rarely blue or violet; colorless in thin section

Crystal habit	Commonly Massive, or fibrous, granular — prismatic crystals rare
Crystal system	Monoclinic prismatic
Fracture	Splintery
Mohs scale hardness	6 - 7
Luster	Subvitreous, pearly on cleavages
Streak	White
Diaphaneity	Translucent
Specific Gravity	3.24 to 3.43
Polish luster	vitreous to greasy
Optical properties	Biaxial (+)
Refractive index	$n\alpha = 1.654 - 1.673$ $n\beta = 1.659 - 1.679$ $n\gamma = 1.667 - 1.693$
Ultra violet fluorescence	*Dark colors* are generally inert. *Light green* - inert to weak white in long wave, generally inert in short wave; *light yellow* - inert to weak green in long wave, generally inert in short wave; *white* - inert to weak in long wave, generally inert in short wave; *light purple* - inert to weak white or weak brownish red in long wave, generally inert in short wave; some *dyed lavender colors* - moderate to strong orange in long wave, weaker in short wave

40 - Jade

Jadeite rock with finished jade Buddha statue, from China, American Museum of Natural History, NewYork City

Jadeite is one of the minerals recognized as the gemstone jade. The other is nephrite. Jadeite from the Motagua Valley, Guatemala, was used by the Olmec and Maya peoples, as well as the indigenous peoples of Costa Rica. Typically, the most highly valued colors of jadeite are the most intensely green, translucent varieties, though traditionally white has been considered the most valuable of the jades by the Chinese, known for their carefully crafted jade pieces. Other colors, like "Olmec blue" jade, which is characterized by its deep blue-green, translucent hue with white flecking, are also becoming more highly valued because of its unique beauty and historical use by the Mesoamerican Olmec and also in Costa Rica;[11] however, this variety was only recently rediscovered and is only being minimally exploited by native Guatemalans. It is thus difficult to obtain and as yet too rare and little known to have attained great value as a gemstone. When purchasing jade, quality is determined by the degree of translucence, cleanness of color, and purity of color. Occasionally, other minerals like serpentine or quartz are sold as jade but the difference can be determined by cleavage and hardness.

Polished Neolithic ax - Museum of Toulouse

41 – Kaolinite (صلصال)

Contents

1 – Introduction :

Kaolinite is a clay mineral, part of the group of industrial minerals, with the chemical composition $Al_2Si_2O_5(OH)_4$. It is a layered silicate mineral, with one tetrahedral sheet linked through oxygen atoms to one octahedral sheet of alumina octahedra . Rocks that are rich in kaolinite are known as **kaolin** or **china clay**.

The name is derived from *Kao-ling* (Chinese : pinyin: *Gaoling*), a town near Jingdezhen, Jiangxi province, China . The name entered English in 1727 from the French version of the word: "kaolin", following Francois Xavier d'Entrecolles's reports from Jingdezhen.

Kaolinite has a low shrink - swell capacity and a low cation exchange capacity (1 - 15 meq / 100 g) . It is a soft, earthy, usually white mineral (dioctahedral phyllosilicate clay) , produced by the chemical weathering of aluminium silicate minerals like feldspar. In many parts of the world, it is colored pink-orange-red by iron oxide, giving it a distinct rust hue. Lighter concentrations yield white, yellow or light orange colors. Alternating layers are sometimes found, as at Providence Canyon State Park in Georgia, USA.

Category	Silicate mineral
Chemical Formula	$Al_2Si_2O_5(OH)_4$
Unit cell	a = 5.13 Å, b = 8.89 Å, c = 7.25 Å; α = 90°, β = 104.5°, γ = 89.8°; Z = 2
Color	White, sometimes red, blue or brown tints from impurities
Crystal habit	Rarely as crystals, thin platy or stacked, More commonly as microscopic pseudohexagonal plates and clusters of plates, aggregated into compact, claylike Masses
Crystal system	Triclinic
Tenacity	Flexible but inelastic
Mohs scale hardness	2 – 2.5
Luster	Pearly to dull earthy
Streak	White
Specific Gravity	2.16 – 2.68
Optical properties	Biaxial (–)
Refractive index	n_α = 1.553–1.565, n_β = 1.559–1.569, n_γ = 1.569–1.570

2 - Structural transformations :

Kaolin - type clays undergo a series of phase transformations upon thermal treatment in air at atmospheric pressure. Endothermic dehydroxylation (or alternatively, dehydration) begins at 550 – 600 °C to produce disordered metakaolin, $Al_2Si_2O_7$, but continuous hydroxyl loss (-OH) is observed up to 900 °C and has been attributed to gradual oxolation of the metakaolin . Because of historic disagreement concerning the nature of the metakaolin phase, extensive research has led to general consensus that metakaolin is not a simple mixture of amorphous silica (SiO_2) and alumina (Al_2O_3), but rather a complex amorphous structure that retains some longer-range order (but not strictly crystalline) due to stacking of its hexagonal layers .

$$2\ Al_2Si_2O_5(OH)_4 \rightarrow 2\ Al_2Si_2O_7 + 4\ H_2O.$$

Further heating to 925 – 950 °C converts metakaolin to a defect aluminium-silicon spinel, $Si_3Al_4O_{12}$, which is sometimes also referred to as a gamma - alumina type structure:

$$2\ Al_2Si_2O_7 \rightarrow Si_3Al_4O_{12} + SiO_2.$$

Upon calcination to ~1050 °C, the spinel phase ($Si_3Al_4O_{12}$) nucleates and transforms to mullite, $3\ Al_2O_3 \cdot 2\ SiO_2$, and highly crystalline cristobalite, SiO_2:

$$3\ Si_3Al_4O_{12} \rightarrow 2\ Si_2Al_6O_{13} + 5\ SiO_2.$$

3 - Occurrence :

Kaolinite is one of the most common minerals; it is mined, as kaolin, in Brazil, Bulgaria, France, United Kingdom, Iran, Germany, India, Australia, Korea, the People's Republic of China, the Czech Republic and the United States.

A kaolin mine in Ruse Province, Bulgaria

3 – 1 - Predominance in tropical soils :

Kaolinite clay occurs in abundance in soils that have formed from the chemical weathering of rocks in hot, moist climates—for example in tropical rainforest areas. Comparing soils along a gradient towards progressively cooler or drier climates, the proportion of kaolinite decreases, while the proportion of other clay minerals such as illite (in cooler climates) or smectite (in drier climates) increases. Such climatically-related differences in clay mineral content are often used to infer changes in climates in the geological past, where ancient soils have been buried and preserved.

In the *Institut National pour l'Etude Agronomique au Congo Belge* (INEAC) classification system, soils in which the clay fraction is predominantly kaolinite are called *kaolisol* (from kaolin and soil).

4 - Uses :

Kaolin is used in ceramics, medicine, coated paper, as a food additive in toothpaste, as a light diffusing material in white incandescent light bulbs, and in cosmetics. It is generally the main component in porcelain.

It is also used in paint to extend titanium dioxide (TiO_2) and modify gloss levels; in rubber for semi-reinforcing properties; and in adhesives to modify rheology.

Kaolin was long used in the production of common smoking pipes in Europe and Asia.

The largest use is in the production of paper, including ensuring the gloss on some grades of paper. Commercial grades of kaolin are supplied and transported as dry powder, semi-dry noodle or as liquid slurry.

Kaolinite can contain very small traces of uranium and thorium, and is therefore useful in radiological dating. While a single magazine made using kaolin does not contain enough radioactive material to be detected by a security-oriented monitor, this could result in the possibility of a truckload of glossy paper occasionally tripping an overly-sensitive radiation monitor.

Kaolinite has also seen some use in organic farming, as a spray applied to crops to deter insect damage, and in the case of apples, to prevent sun scald.

In April 2008, the US Naval Medical Research Institute announced the successful use of a kaolinite-derived aluminosilicate nanoparticle infusion in traditional gauze, known commercially as QuikClot Combat Gauze.

When heated to between 650 and 900 °C kaolinite dehydroxylates to form metakaolin. According to the American National Precast Concrete Association this is a supplementary cementitious material (SCM). When added to a concrete mix, metakaolin affects the acceleration of Portland cement hydration when replacing Portland cement by 20 percent by weight.

In ceramics applications, the Formula is typically written in terms of oxides, thus the Formula for kaolinite is $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$

Using the cement chemist notation this can be even written as AS_2H_2, with the oxides represented as $A = Al_2O_3$, $S = SiO_2$, $H = H_2O$.

Kaolinite was also used as filler in Edison Diamond Discs.

4 – 1 - Medicinal and culinary uses :

Kaolin. (unknown scale)

A folk medicine use is to soothe an upset stomach, similar to the way parrots (and later, humans) in South America originally used it . More recently, industrially-produced kaolinite preparations were formerly common for treatment of diarrhea; the most common of these was Kaopectate, which abandoned the use of kaolin in favor of attapulgite and then (in the United States) bismuth subsalicylate.

In Africa, kaolin is sometimes known as *kalaba* (in Gabon[15] and Cameroon), *calaba*, and *calabachop* (in Equatorial Guinea). It is used for facial masks or soap and is eaten for pleasure or to suppress hunger,[16] a practice known as geophagy. Consumption is greater among women, especially during pregnancy.

This practice is also seen among black women in the Southern United States, especially Georgia . There, the kaolin is called *white dirt*, *chalk* or *white clay*.

42 - Khatyrkite

1 – Introduction :

Khatyrkite is a rare mineral which is mostly composed of copper and aluminium, but might contain up to about 15 % of zinc or iron;[3][5] its chemical structure is described by an approximate Formula $(Cu,Zn)Al_2$ or $(Cu,Fe)Al_2$. It was discovered in 1985 in placers derived from serpentine, in association with another rare mineral cupalite ({Cu,Zn,Fe}Al). Both minerals are thus far restricted to the area of Listvenitovyi Stream, in the Khatyrka ultramafic (silicon-poor) zone of the Koryak–Kamchatka fold area, Koryak Mountains, Beringovsky District, Chukotka Autonomous Okrug, Far Eastern Federal District, Russia. The mineral's name derives from the Khatyrka (Russian: Хатырка) zone where it was discovered.[6] Its holotype (defining sample) is preserved in the Mining Museum in Saint Petersburg, and parts of it can be found in other museums, such as Museo di Storia Naturale di Firenze.

Category	Native element class, alloy
Chemical Formula	$(Cu,Zn,Fe)Al_2$
Color	Gray-yellow (reflection), opaque
Crystal system	Tetragonal , space group I4/mcm
Fracture	Malleable
Mohs scale hardness	5 – 6
Luster	Metallic
Streak	Dark gray
Specific Gravity	4.42 g/cm^3 (calculated)
Other characteristics	non-magnetic , non-radioactive

2 – Properties :

In the initial studies of khatyrkite, a negative correlation was observed between copper and zinc, i.e. the higher the copper the lower the zinc content and vice versa, which is why the Formula was specified as (Cu,Zn)Al_2. It was found later that iron can be substituted for zinc. The mineral is opaque and has a steel-gray yellow tint in reflected light, similar to native platinum. Isotropic sections are light blue whereas anisotropic ones are blue to creamy pink. Strong optical anisotropy is observed when the crystals are viewed in polarized light. Khatyrkite forms dendritic, rounded or irregular grains, typically below 0.5 millimeter in size, which are intergrown with cupalite. They have a tetragonal symmetry with point group 4/m 2/m 2/m, space group I4/mcm and lattice constants a = 0.607(1) nm, c = 0.489(1) nm and four Formula units per unit cell. The crystalline structure parameters are the same for khatyrkite and synthetic $CuAl_2$ alloy. The density, as calculated from XRD the lattice parameters, is 4.42 g/cm^3. The crystals are malleable, that is they deform rather than break apart upon a strike; they have the Mohs hardness is between 5 and 6 and Vickers hardness is in the range 511 – 568 kg / mm^2 for a 20 – 50 gram load and 433–474 kg / mm^2 for a 100 gram load.

Khatyrkite and cupalite are accompanied by spinel, corundum, stishovite, augite, forsteritic olivine, diopsidic clinopyroxene and several Al-Cu-Fe metal alloy minerals. The presence of unoxidized aluminium in khatyrkite and association with the stishovite – a form of quartz which exclusively forms at high pressures of several tens gigapascals – suggest that the mineral is formed either upon meteoritic impact or in the deep earth mantle.

3 - Relation to quasicrystals :

Khatyrkite is remarkable by that it contains micrometre-sized grains of the only known naturally occurring quasicrystal – aperiodic, yet ordered structure. The quasicrystal has a composition of $Al_{63}Cu_{24}Fe_{13}$ which is close to that of a well-characterized synthetic Al-Cu-Fe material. This was the first quasicrystal found in nature and remains the only known naturally occurring example of a quasicrystal.

Quasicrystals were first reported in 1984 and named so by Dov Levine and Paul Steinhardt. More than 100 quasicrystal compositions have been discovered by 2009 – all synthesized in the laboratory. Steinhardt initiated a large-scale search for natural quasicrystals around the year of 2000 using the database of the International Centre for Diffraction Data. About 50 candidates were selected out of 9,000 minerals based on a set of parameters defined by the structure of the known quasicrystals. The corresponding samples were examined with X-ray diffraction and transmission electron microscopy but no quasicrystals were found. Widening of the search eventually included khatyrkite. A sample of the mineral was provided by the Museo di Firenze and was later proven to be part of the Russian holotype specimen. Mapping its chemical composition and crystalline structure revealed agglomerate of grains up to 0.1 millimeter in size of various phases, mostly khatyrkite, cupalite (zinc or iron containing), some yet unidentified Al-Cu-Fe minerals and the $Al_{63}Cu_{24}Fe_{13}$ quasicrystal phase. The quasicrystal grains were of high crystalline quality equal to that of the best laboratory specimens, as demonstrated by the narrow diffraction peaks. The mechanism of their formation is yet uncertain. The specific composition of the accompanying minerals and the location where the sample was collected – far from any industrial activities – confirm that the discovered quasicrystal is of natural origin.

43 –Kyanite

1 – Introduction :

Kyanite, whose name derives from the Greek word *kuanos* sometimes referred to as "kyanos", meaning deep blue, is a typically blue silicate mineral, commonly found in aluminium-rich metamorphic pegmatites and/or sedimentary rock. Kyanite in metamorphic rocks generally indicates pressures higher than 4 kilobars. Although potentially stable at lower pressure and low temperature, the activity of water is usually high enough under such conditions that it is replaced by hydrous aluminosilicates such as muscovite, pyrophyllite, or kaolinite. Kyanite is also known as disthene, rhaeticite and cyanite . Kyanite is a member of the aluminosilicate series, which also includes the polymorph andalusite and the polymorph sillimanite. Kyanite is strongly anisotropic, in that its hardness varies depending on its crystallographic direction. In Kyanite, this anisotropism can be considered an identifying characteristic. At temperatures above 1100 °C kyanite decomposes into mullite and vitreous silica via the following reaction :

$$3(Al_2O_3{\cdot}SiO_2) \rightarrow 3Al_2O_3{\cdot}2SiO_2 + SiO_2.$$

This transformation results in an expansion.

Category	Silicate mineral
Chemical Formula	Al_2SiO_5
Crystal symmetry	Triclinic pinacoidal H–M Symbol: 1 Space group: P1

Unit cell	a = 7.1262(12) Å, b = 7.852(10) Å, c = 5.5724(10) Å α = 89.99(2)°, β = 101.11(2)°, γ = 106.03(1)° Z = 4
Color	Blue, white, rarely green, gray, yellow, pink, orange, and black, can be zoned
Crystal habit	Columnar; fibrous; bladed
Crystal system	Triclinic
Fracture	Splintery
Tenacity	Brittle
Mohs scale hardness	4.5 - 5 parallel to one axis 6.5 - 7 perpendicular to that axis
Luster	Vitreous to pearly
Streak	White
Diaphaneity	Transparent to translucent
Specific Gravity	3.53 - 3.65 measured; 3.67 calculated
Optical properties	Biaxial (-)
Refractive index	nα = 1.712 - 1.718 nβ = 1.720 - 1.725 nγ = 1.727 - 1.734
Pleochroism	Trichroic, colorless to pale blue to blue

2 - Uses of kyanite :

Kyanite is used primarily in refractory and ceramic products, including porcelain plumbing fixtures and dishware. It is also used in electronics, electrical insulators and abrasives.

Kyanite has been used as a semiprecious gemstone, which may display cat's eye chatoyancy, though this use is limited by its anisotropism and perfect cleavage. Color varieties include recently discovered orange kyanite from Tanzania.[*citation needed*] The orange color is due to inclusion of small amounts of manganese (Mn^{3+}) in the structure.

Kyanite is one of the index minerals that are used to estimate the temperature, depth, and pressure at which a rock undergoes metamorphism.

3 - Notes for identification :

Kyanite's elongated, columnar crystals are usually a good first indication of the mineral, as well as its color (when the specimen is blue). Associated minerals are useful as well, especially the presence of the polymorphs of staurolite, which occur frequently with kyanite. However, the most useful characteristic in identifying kyanite is its anisotropism. If one suspects a specimen to be kyanite, verifying that it has two distinctly different hardnesses on perpendicular axes is a key to identification.

4 – Occurrence :

Kyanite occurs in gneiss, schist, pegmatite, and quartz veins resulting from moderate to high - pressure regional metamorphism of principally pelitic rocks. It occurs as detrital grains in sedimentary rocks. It occurs associated with staurolite, andalusite, sillimanite, talc, hornblende, gedrite, mullite and corundum.

44 - Laterite

Monument of laterite brickstones at Angadipuram, Kerala, India, which commemorates where laterite was first described and discussed by Dr. Buchanan-Hamilton in 1807.

Contents

1 – Introduction :

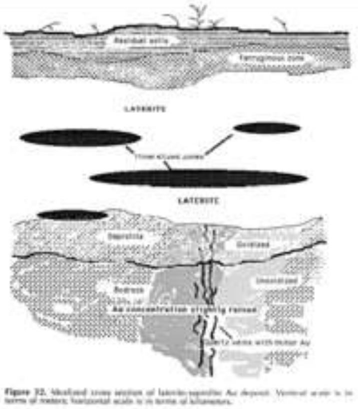
Laterites are soil types rich in iron and aluminium, formed in hot and wet tropical areas. Nearly all laterites are rusty-red because of iron oxides. They develop by intensive and long-lasting weathering of the underlying parent rock. Tropical weathering (laterization) is a prolonged process of chemical weathering which produces a wide variety in the thickness, grade, chemistry and ore mineralogy of the resulting soils. The majority of the land areas with laterites was or is between the tropics of Cancer and Capricorn . Historically, laterite was cut into brick-like shapes and used in monument building. After 1000 CE construction at Angkor Wat and other southeast Asian sites changed to rectangular temple enclosures made of laterite, brick and stone. Since the mid-1970s trial sections of bituminous-surfaced low-volume roads have used laterite in place of stone as a base course. Thick laterite layers are porous and slightly permeable, so the layers can function as aquifers in rural areas. Locally available laterites are used in an acid solution, followed by precipitation to remove phosphorus and heavy metals at sewage treatment facilities. Laterites are a source of aluminium ore; the ore exists largely in clay minerals and the hydroxides, gibbsite, boehmite, and diaspore, which resembles the composition of bauxite. In Northern Ireland they once provided a major source of iron and aluminium ores. Laterite ores also were the early major source of nickel.

2 - Definition and physical description :

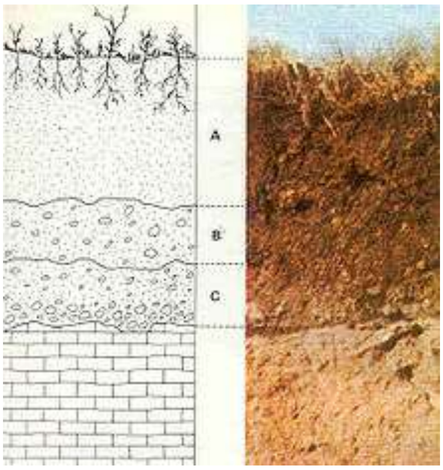
Francis Buchanan-Hamilton first described and named a laterite formation in southern India in 1807.[1]:65 He named it laterite from the Latin word *later*, which means a brick; this rock can easily be cut into brick-shaped blocks for building. The word laterite has been used for variably cemented, sesquioxide-rich soil horizons. A sesquioxide is an oxide with three atoms of oxygen and two metal atoms. It has also been used for any reddish soil at or near the Earth's surface.

Laterite is a surface formation rich in iron and aluminium, formed in hot and wet tropical areas. It develops by intensive and long-lasting weathering of the underlying parent rock. Nearly all laterites are rusty-red because of iron oxides. Laterite covers are thick on the stable areas of the African Shield, the South American Shield and the Australian Shield. In Madhya Pradesh, India, the laterite which caps the plateau is 30 m thick Laterites can be either soft and easily broken into smaller pieces, or firm and physically resistant. Basement rocks are buried under the thick weathered layer and rarely exposed. Lateritic soils form the uppermost part of the laterite cover.

3 – Formation :



Laterite is often located under residual soils.



A represents soil; B represents laterite, a regolith; C represents saprolite, a less-weathered regolith; D represents bedrock

Tropical weathering (laterization) is a prolonged process of chemical weathering which produces a wide variety in the thickness, grade, chemistry and ore mineralogy of the resulting soils . The initial products of weathering are essentially kaolinized rocks called saprolites. A period of active laterization extended from about the mid-Tertiary to the mid - Quaternary periods (35 to 1.5 million years ago). Statistical analyses show that the transition in the mean and variance levels of ^{18}O during the middle of the Pleistocene was abrupt. It seems this abrupt change was global and mainly represents an increase in ice Mass; at about the same time an abrupt decrease in sea surface temperatures occurred; these two changes indicate a sudden global cooling . The rate of laterization would have decreased with the abrupt cooling of the earth. Weathering in tropical climates continues to this day, at a reduced rate .

Laterites are formed from the leaching of parent sedimentary rocks (sandstones, clays, limestones); metamorphic rocks (schists, gneisses, migmatites); igneous rocks (granites, basalts, gabbros, peridotites); and mineralized proto-ores;[3]:5 which leaves the more insoluble ions, predominantly iron and aluminium. The mechanism of leaching involves acid dissolving the host mineral lattice, followed by hydrolysis and precipitation of insoluble oxides and sulfates of iron, aluminium and silica under the high temperature conditions of a humid sub-tropical monsoon climate . An essential feature for the formation of laterite is the repetition of wet and dry seasons. Rocks are leached by percolating rain water during the wet season; the resulting solution containing the leached ions is brought to the surface by capillary action during the dry season . These ions form soluble salt compounds which dry on the surface; these salts are washed away during the next wet season. Laterite formation is favoured in low topographical reliefs of gentle crests and plateaus which prevents erosion of the surface cover. The reaction zone where rocks are in contact with water – from the lowest to highest water table levels – is progressively depleted of the easily leached ions of sodium, potassium, calcium and magnesium . A solution of these ions can have the correct pH to preferentially dissolve silicon oxide rather than the aluminium oxides and iron oxides.

The mineralogical and chemical compositions of laterites are dependant on their parent rocks. Laterites consist mainly of quartz and oxides of titanium, zircon, iron, tin, aluminium and manganese, which remain during the course of weathering. Quartz is the most abundant relic mineral from the parent rock. Laterites vary significantly according to their location, climate and depth. The main host minerals for nickel and cobalt can be either iron oxides, clay minerals or manganese oxides . Iron oxides are derived from mafic igneous rocks and other iron-rich rocks; bauxites are derived from granitic igneous rock and other iron-poor rocks.[10] Nickel laterites occur in zones of the earth which experienced prolonged tropical weathering of ultramafic rocks containing the ferro-magnesian minerals olivine, pyroxene, and amphibole.

4 - Locations :

Yves Tardy, from the *French Institut National Poly technique de Toulouse* and the *Centre National de la Recherche Scientifique*, calculated that laterites cover about one - third of the Earth's continental land area . Lateritic soils are the subsoils of the equatorial forests, of the savannas of the humid tropical regions, and of the Sahelian steppes . They cover most of the land area between the tropics of Cancer and Capricorn; areas not covered within these latitudes include the extreme western portion of South America, the southwestern portion of Africa, the desert regions of north- central Africa, the Arabian peninsula and the interior of Australia .

Some of the oldest and most highly deformed ultramafic rocks which underwent laterization are found in the complex Precambrian shields in Brazil and Australia . Smaller highly deformed Alpine - type intrusives have formed laterite profiles in Guatemala, Columbia, Central Europe, India and Burma . Large thrust sheets of Mesozoic to Tertiary 251- to 65 - million - year- old island arcs and continental collision zones under went laterization in New Caledonia, Cuba, Indonesia and the Philippines. Laterites reflect past weathering conditions; laterites which are found in present-day non-tropical areas are products of former geological epochs, when that area was near the equator. Present - day laterite occurring outside the humid tropics are considered to be indicators of climatic change, continental drift or a combination of both.

5 - Uses :

5 - 1 - Building blocks :

Cutting laterite bricks in Angadipuram, India

When moist, laterites can be easily cut with a spade into regular-sized blocks . Laterite is mined while it is below the water table, so it is wet and soft . Upon exposure to air it gradually hardens as the moisture between the flat clay particles evaporates and the larger iron salts lock into a rigid lattice structure and become resistant to atmospheric conditions. The art of quarrying laterite material into masonry is suspected to have been introduced from the Indian subcontinent.

After 1000 CE Angkorian construction changed from circular or irregular earthen walls to rectangular temple enclosures of laterite, brick and stone structures . Geographic surveys show areas which have laterite stone alignments which may be foundations of temple sites that have not survived . The Khmer people constructed the Angkor monuments – which are widely distributed in Cambodia and Thailand – between the 9th and 13th centuries . The stone materials used were sandstone and laterite; brick had been used in monuments constructed in the 9th and 10th centuries . Two types of laterite can be identified; both types consist of the minerals kaolinite, quartz, hematite and goethite . Differences in the amounts of minor elements arsenic, antimony, vanadium and strontium were measured between the two laterites .

Angkor Wat – located in present-day Cambodia – is the largest religious structure built by Suryavarman II, who ruled the Khmer Empire from 1112 to 1152. It is a World Heritage site . The sand stone used for the building of Angkor Wat is Mesozoic sand stone quarried in the Phnom Kulen Mountains, about 40 km away from the temple . The foundations and internal parts of the temple contain laterite blocks behind the sandstone surface . The masonry was laid without joint mortar.

5 - 2 - Road building :

Laterite road near Kounkane , Upper Casamance, Senegal

The French surfaced roads in the Cambodia, Thailand and Viet Nam area with crushed laterite, stone or gravel . Kenya, during the mid-1970s, and Malawi, during the mid-1980s, constructed trial sections of bituminous-surfaced low-volume roads using laterite in place of stone as a base course . The laterite did not conform with any accepted specifications but performed equally well when compared with adjoining sections of road using stone or other stabilized material as a base . In 1984 US $ 40,000 per 1 km was saved in Malawi by using laterite in this way.

5 - 3 - Water supply :

Bed rock in tropical zones is often granite, gneiss, schist or sand stone ; the thick laterite layer is porous and slightly permeable so the layer can function as an aquifer in rural areas. One example is the

Southwestern Laterite (Cabook) Aquifer in Sri Lanka . This aquifer is on the southwest border of Sri Lanka, with the narrow Shallow Aquifers on Coastal Sands between it and the ocean . It has considerable water-holding capacity, depending on the depth of the formation . The aquifer in this laterite recharges rapidly with the rains of April–May which follow the dry season of February–March, and continues to fill with the monsoon rains . The water table recedes slowly and is recharged several times during the rest of the year . In some high-density suburban areas the water table could recede to 15 m below ground level during a prolonged dry period of more than 65 days . The Cabook Aquifer laterites support relatively shallow aquifers that are accessible to dug wells .

5 - 4 - Waste water treatment :

In Northern Ireland phosphorus enrichment of lakes due to agriculture is a significant problem . Locally available laterite – a low-grade bauxite rich in iron and aluminium – is used in acid solution, followed by precipitation to remove phosphorus and heavy metals at several sewage treatment facilities . Calcium-, iron- and aluminium-rich solid media are recommended for phosphorus removal. A study, using both laboratory tests and pilot-scale constructed wetlands, reports the effectiveness of granular laterite in removing phosphorus and heavy metals from landfill leachate . Initial laboratory studies show that laterite is capable of 99 % removal of phosphorus from solution . A pilot-scale experimental facility containing laterite achieved 96% removal of phosphorus . This removal is greater than reported in other systems . Initial removals of aluminium and iron by pilot-scale facilities have been up to 85 % and 98 % respectively Percolating columns of laterite removed enough cadmium, chromium and lead to undetectable concentrations . There is a possible application of this low-cost, low-technology, visually unobtrusive, efficient system for rural areas with dispersed point sources of pollution.

5 - 5 - Ores :

Ores are concentrated in metalliferous laterites; aluminium is found in bauxites, iron and manganese are found in iron-rich hard crusts, nickel and copper are found in disintegrated rocks, and gold is found in mottled clays.

5 - 5 - 1 – Bauxite :

Bauxite on white kaolinitic sandstone at Pera Head, Weipa, Australia

Bauxite ore is the main source for aluminium. Bauxite is a variety of laterite (residual sedimentary rock), so it has no precise chemical Formula. It is composed mainly of hydrated alumina minerals such as gibbsite [$Al(OH)_3$ or $Al_2O_3 . 3H_2O$)] in newer tropical deposits; in older subtropical, temperate deposits the major minerals are boehmite [γ-$AlO(OH)$ or $Al_2O_3.H_2O$] and some diaspore [α-$AlO(OH)$ or $Al_2O_3.H_2O$] . The average chemical composition of bauxite, by weight, is 45 to 60 % Al_2O_3 and 20 to 30 % Fe_2O_3 . The remaining weight consists of silicas (quartz, chalcedony and kaolinite), carbonates (calcite, magnesite and dolomite), titanium dioxide and water. Bauxites of economical interest must be low in kaolinite. Formation of lateritic bauxites occurs world-wide in the 145- to 2- million-year - old Cretaceous and Tertiary coastal plains . The bauxites form elongate belts, sometimes hundreds of kilometers long, parallel to Lower Tertiary shorelines in India and South America; their distribution is not related to a particular mineralogical composition of the parent rock . Many high - level bauxites are formed in coastal plains which were subsequently uplifted to their present altitude .

5 - 5 - 2 – Iron :

The dark veins are precipitated iron within kaolinized basalt near Hungen, Vogelsberg, Germany.

The basaltic laterites of Northern Ireland were formed by extensive chemical weathering of basalts during a period of volcanic activity. They reach a maximum thickness of 30 m (100 ft) and once provided a major source of iron and aluminium ore. Percolating waters caused degradation of the parent basalt and preferential precipitation by acidic water through the lattice left the iron and aluminium ores. Primary olivine, plagioclase feldspar and augite were successively broken down and replaced by a mineral assemblage consisting of hematite, gibbsite, goethite, anatase, halloysite and kaolinite.

Laterite ores were the major source of early nickel.[5]:1 Rich laterite deposits in New Caledonia were mined starting the end of the 19th century to produce white metal. The discovery of sulfide deposits of Sudbury, Ontario, Canada, during the early part of the 20th century shifted the focus to sulfides for nickel extraction . About 70 % of the Earth's land-based nickel resources are contained in laterites; they currently account for about 40 % of the world nickel production . In 1950 laterite-source nickel was less than 10 % of total production, in 2003 it accounted for 42 %, and by 2012 the share of laterite-source nickel is expected to be 51 % . The four main areas in the world with the largest nickel laterite resources are New Caledonia, with 21 % ; Australia, with 20 % ; the Philippines, with 17 % ; and Indonesia, with 12%.

Irregular weathering of grey serpentinite to greyish-brown nickel-containing literite with a high iron percentage (nickel limonite), near Mayagüez, Puerto Rico.

45 – Laumontite

	
Laumontite crystals	

Laumontite is a mineral, one of the zeolite group. Its molecular Formula is $Ca(AlSi_2O_6)_2 \cdot 4H_2O$, a hydrated calcium-aluminium silicate. Potassium or sodium may substitute for the calcium but only in very small amounts.

It is monoclinic, space group C2/m. It forms prismatic crystals with a diamond-shaped cross-section and an angled termination. When pure, the color is colorless or white. Impurities may color it orange, brownish, gray, yellowish, pink, or reddish. It has perfect cleavage on [010] and [110] and its fracture is conchoidal. It is very brittle. The Mohs scale hardness is 3.5-4. It has a vitreous luster and a white streak. It is found in hydrothermal deposits left in calcareous rocks, often formed as a result of secondary mineralization. Host rock types include basalt, andesite, metamorphic rocks and granites.

The identification of laumontite goes back to the early days of mineralogy. It was first named lomonite by R. Jameson (System of Mineralogy) in 1805, and laumonite by René Just Haüy in 1809. The current name was given by K.C. von Leonhard (Handbuch der Oryktognosie) in 1821. It is named after Gillet de Laumont who collected samples from lead mines in Huelgoat, Brittany, making them the type locality.

Laumontite easily dehydrates when stored in a low humidity environment. When freshly collected, if it has not already been exposed to the environment, it can be translucent or transparent. Over a period of hours to days the loss of water turns it opaque white. In the past, this variety has been called leonhardite, though this is not a valid mineral species. The dehydrated laumontite is very friable, often falling into a powder at the slightest touch.

It is a common mineral, found worldwide. It can be locally abundant, forming seams and veins. It is frequently associated with other zeolites, including stilbite and heulandite. Notable occurrences are India; Paterson, New Jersey; Pine Creek, California; Iceland; Scotland; and the Bay of Fundy, Nova Scotia. Prehnite pseudomorphs after laumontite (epimorphs) have been found in India.

Category	Tectosilicate - Zeolite group
Color	White , colorless , yellowish , brownish ,
Cleavage	Perfect, two directions
Fracture	Uneven
Mohs scale hardness	4

46 – Lawsonite

Sample from the type locality in California with two elongated, lustrous and translucent crystals of pastel pink, lawsonite in mica schist

Contents

1 – Introduction :

Lawsonite is a hydrous calcium aluminium sorosilicate mineral with Formula $CaAl_2Si_2O_7(OH)_2{\cdot}H_2O$. Lawsonite crystallizes in the ortho rhombic system in prismatic, often tabular crystals. Crystal twinning is common. It forms transparent to translucent colorless, white, and bluish to pinkish grey glassy to greasy crystals. Refractive indices are $n\alpha=1.665$, $n\beta=1.672$ - 1.676, and $n\gamma=1.684$ - 1.686. It is typically almost colorless in thin section, but some lawsonite is pleochroic from colorless to pale yellow to pale blue, depending on orientation. The mineral has a Mohs hardness of 8 and a specific Gravity of 3.09. It has perfect cleavage in two directions and a brittle fracture.

Lawsonite is a metamorphic mineral typical of the blueschist facies. It also occurs as a secondary mineral in altered gabbro and diorite. Associate minerals include epidote, titanite, glaucophane, garnet and quartz. It is an uncommon constituent of eclogite . It was first described in 1895 for occurrences in the Tiburon peninsula, Marin County, California. It was named for geologist Andrew Lawson (1861-1952) of the University of California.

Category	Silicate mineral
Chemical Formula	$CaAl_2Si_2O_7(OH)_2 \cdot H_2O$
Crystal symmetry	Orthorhombic dipyramidal H-M symbol: Space group: Ccmm
Unit cell	a = 5.847 Å, b = 8.79 Å, c = 13.128 Å; Z = 4
Color	Colorless, white, pale blue to grayish blue
Crystal habit	Commonly prismatic, tabular; also granular, Massive
Crystal system	Orthorhombic
Tenacity	Brittle
Mohs scale hardness	7.5
Luster	Vitreous , greasy
Streak	White
Diaphaneity	Translucent
Specific Gravity	3.05 - 3.12
Optical properties	Biaxial (+)
Refractive index	$n_\alpha = 1.665$ $n_\beta = 1.672 - 1.676$ $n_\gamma = 1.684 - 1.686$
Pleochroism	Weak; X = blue, pale brownish yellow; Y = deep bluish green, yellowish green ; Z = colorless, yellowish

2 - Composition :

Lawsonite is a metamorphic silicate mineral related chemically and structurally to the epidote group of minerals. It is close to the ideal composition of $CaAl_2Si_2O_7(OH)_2 \cdot H_2O$ giving it a close chemical composition with anorthite $CaAl_2Si_2O_8$ (its anhydrous equivalent), yet lawsonite has greater density and a different Al coordination (Comodi et al., 1996). The substantial amount of water bound in lawsonite’s crystal structure is released during its breakdown to denser minerals during prograde metamorphism. This means lawsonite is capable of conveying appreciable water to shallow depths in subducting oceanic lithosphere (Clark et al., 2006). Experimentation on lawsonite to vary its responses at different temperatures and different pressures is among its most studied aspects, for it is these qualities that affect its abilities to carry water down to mantle depths, similar to other OH-containing phases like antigorite, talc, phengite, staurolite, and epidote (Comodi et al., 1996).

3 - Geologic occurrence :

Lawsonite is a very widespread mineral and has attracted considerable interest over the last few years because of its importance as a marker of moderate pressure (6 - 12 kb) and low Temperature (300 - 400 °C) conditions in nature (Clark et al., 2006) . This mainly occurs along continental margins (subduction zones) such as those found in : the Franciscan Formation in California at Reed Station, Tiburon Peninsula of Marin County, California; the Piedmont metamorphic rocks of Italy; and schists in New Zealand, New Caledonia, China, Japan and from various points in the circum - Pacific orogenic belt.

4 - Crystal structure :

Though lawsonite and anorthite have similar compositions, their structures are quite different. While anorthite has a tetrahedral coordination with Al (Al substitutes for Si in feldspars), lawsonite has an octahedral coordination with Al, making it an orthorhombic sorosilicate with a space group of Cmcm which consists of Si_2O_7 Groups and O, OH, F, and H_2O with cations in [4] and / or > [4]

coordination. This is much similar to the epidote group which lawsonite is often found in conjunction with, which are also sorosilicates because their structure consists of two connected SiO4 tetrahedra plus connecting cation. The water contained in its structure is made possible by cavities formed by rings of two Al octahedral and two Si_2O_7 groups, each containing an isolated water molecule and calcium atom. The hydroxyl units are bound to the edge-sharing Al octahedral .

5 - Physical properties :

Lawsonite has crystal habits of orthorhombic prismatic, which are crystals shaped like slender prisms, or tubular figures, which are form dimensions that are thin in one direction, both with two perfect cleavages. This crystal is transparent to translucent and varies in color from white to pale blue to colorless with a white streak and a vitreous or greasy luster. It has a relatively low specific Gravity of 3.1g/cm3, and a pretty high hardness of 7.5 on Mohs scale of hardness, slightly higher than quartz. Under the microscope, lawsonite can be seen as blue, yellow, or colorless under plane polarized light while the stage is rotated. Lawsonite has three refractive indices of $n\alpha = 1.665$ $n\beta = 1.672 - 1.676$ $n\gamma = 1.684 - 1.686$, which produces a birefringence of $\delta = 0.019 - 0.021$ and an optically positive biaxial interference figure.

6 - Significance of lawsonite :

Lawsonite is a significant metamorphic mineral as it can be used as an index mineral for high pressure conditions. Index minerals are used in geology to determine the degree of metamorphism a rock has experienced. New metamorphic minerals form through solid-state cation exchanges following changing pressure and temperature conditions imposed upon the protolith (pre - metamorphosed rock) . This new mineral that is produced in the metamorphosed rock is the index mineral, which indicates the minimum pressure and temperature the protolith must have achieved in order for that mineral to form.

Lawsonite is known to form in high pressure, low temperature conditions, most commonly found in subduction zones where cold oceanic crust subducts down oceanic trenches into the mantle . The initially-low temperature of the slab, and fluids taken down with it manage to depress isotherms and keep the slab much colder than the surrounding mantle, allowing for these unusual high pressure, low temperature conditions. Glaucophane, kyanite and zoisite are other common minerals in the blueschist facies and are commonly found to coexist . This assemblage is diagnostic of this facies.

47 – Leucite

Leucite crystals in a rock from Italy

1 – Introduction :

Leucite is a rock - forming mineral composed of potassium and aluminium tectosilicate K[AlSi$_2$O$_6$]. Crystals have the form of cubic icositetrahedra but, as first observed by Sir David Brewster in 1821, they are not optically isotropic, and are therefore pseudo-cubic. Goniometric measurements made by Gerhard vom Rath in 1873 led him to refer the crystals to the tetragonal system. Optical investigations have since proved the crystals to be still more complex in character, and to consist of several orthorhombic or monoclinic individuals, which are optically biaxial and repeatedly twinned, giving rise to twin-lamellae and to striations on the faces. When the crystals are raised to a temperature of about 500 °C they become optically isotropic and the twin-lamellae and striations disappear, although they reappear when the crystals are cooled again. This pseudo-cubic character of leucite is very similar to that of the mineral boracite.

The crystals are white or ash-grey in colour, hence the name suggested by A. G. Werner in 1701, from 'λευκος', '(matt) white'. They are transparent and glassy when fresh, albeit with a noticeably subdued 'subvitreous' lustre due to the low refractive index, but readily alter to become waxy/greasy and then dull and opaque; they are brittle and break with a conchoidal fracture. The Mohs hardness is

5.5, and the specific Gravity 2.47. Inclusions of other minerals, arranged in concentric zones, are frequently present in the crystals. On account of the color and form of the crystals the mineral was early known as **white garnet**. French authors in older literature may employ René Just Haüy's name **amphigène**, but 'leucite' is the only name for this mineral species that is recognised as official by the International Mineralogical Association.

Category	tectosilicates
Chemical Formula	$K[AlSi_2O_6]$
Crystal symmetry	Tetragonal 4/m dipyramidal
Unit cell	a = 13.056 Å , c = 13.751 Å ; Z = 16
Color	White to grey
Crystal habit	Commonly as euhedral, pseudocubic crystals; rarely granular, Massive
Crystal system	Tetragonal
Twinning	Common and repeated on
Fracture	Conchoidal
Tenacity	Brittle
Mohs scale hardness	5.5 - 6
Luster	Vitreous
Diaphaneity	Transparent to translucent
Specific Gravity	2.45 - 2.50
Refractive index	$n_\omega = 1.508$ $n_\varepsilon = 1.509$

2 - Leucite rocks :

Rocks containing leucite are scarce, many countries such as England being entirely without them. However, they are of wide distribution, occurring in every quarter of the globe. Taken collectively, they exhibit a considerable variety of types and are of great interest petrographically. For the presence of this mineral it is necessary that the silica percentage of the rock should be low, since leucite is incompatible with free quartz and reacts with it to form potassium feldspar. Because it weathers rapidly, leucite is most common in lavas of recent and Tertiary age, which have a fair amount of potassium, or at any rate have potassium equal to or greater than sodium; if sodium is abundant nepheline occurs rather than leucite.

In pre-Tertiary rocks leucite readily decomposes and changes to zeolites, analcite and other secondary minerals. Leucite also is rare in plutonic rocks and dike rocks, but leucite syenite and leucite tinguaite bear witness to the possibility that it may occur in this manner. The rounded shape of its crystals, their white or grey color, and absence of planar cleavage make the presence of leucite easily determinable in many of these rocks by inspection, especially when the crystals are large.

Pseudoleucite from São João Alkaline Massif, RJ, Brazil

"Pseudoleucites" are rounded areas consisting of feldspar, nepheline, analcite, &c., which have the shape, composition and sometimes even the outward crystalline shape of leucite; they are probably pseudomorphs or paramorphs, which have developed from leucite because this mineral is not stable at ordinary temperatures and can be expected under favorable conditions to undergo spontaneous change into an aggregate of other minerals. Leucite is very often accompanied by nepheline, sodalite or nosean; other minerals which make their appearance with some frequency are melanite, garnet and melilite.

The plutonic leucite-bearing rocks are leucite syenite and missourite. Of these the former consists of orthoclase, nepheline, sodalite, diopside and aegirine, biotite and sphene. Two occurrences are known, one in Arkansas, the other in Sutherland, Scotland. The Scottish rock has been called borolanite. Both examples show large rounded spots in the hand specimens; they are pseudoleucites, and under the microscope prove to consist of orthoclase, nepheline, sodalite and decomposition products. These have a radiate arrangement externally, but are of irregular structure at their centres; it is interesting to note that in both rocks melanite is an important accessory. The missourites are more mafic and consist of leucite, olivine, augite and biotite; the leucite is partly fresh partly altered to analcite, and the rock has a spotted character recalling that of the leucite-syenites. It has been found only in the Highwood Mountains of Montana.

The leucite-hearing dike-rocks are members of the tinguaite and monchiquite groups. The leucite tinguaites are usually pale grey or greenish in color and consist principally of nepheline, alkali feldspar and aegirine. The latter forms bright green moss-like patches and growths of indefinite shape, or in other cases scattered acicular prisms, among the feldspars and nephelines of the ground Mass. Where leucite occurs, it is always euhedral in small, equant, many-sided crystals in the ground Mass, or in larger Masses which have the same characters as the pseudoleucites. Biotite occurs in some of these rocks, and melanite also is present. Nepheline decreases in amount as leucite increases since the abundances of the two reflect the Na:K ratio of the rock. Rocks of this group are known from Rio de Janeiro, Arkansas, Kola (in Finland), Montana and a few other places., In Greenland there are leucite tinguaites with much arfvedsonite, (hornblende) and eudialyte. Wherever they occur they accompany leucite- and nepheline syenites. Leucite monchiquites are fine-grained dark rocks consisting of olivine, titaniferous augite and iron oxides, with a glassy ground Mass in which small rounded crystals of leucite are scattered. They have been described from Czechoslovakia.

By far the greater number of the rocks which contain leucite are lavas of Tertiary or recent geological age. Although these never contain quartz, but feldspar is usually present, though there are certain groups of leucite lavas which are non-feldspathic. Many of them also contain nepheline, sodalite, hauyne and nosean; the much rarer mineral melilite appears also in some examples. The commonest ferromagnesian mineral is augite (sometimes rich in sodium), with olivine in the more basic varieties. Hornblende and biotite occur also, but are less common. Melanite is found in some of the lavas, as in the leucite syenites.

The rocks in which orthoclase (*or sanidine*) is present in considerable amount are leucite-trachytes, leucite-phonolites and leucitophvres. Of these groups the two former, which are not sharply distinguished from one another by most authors, are common in the neighborhood of Rome. They are of trachytic appearance, containing phenocysts of sanidine, leucite, augite and biotite. Sodalite or hauyne may also be present, but nepheline is typically absent. Rocks of this class occur also in the tuffs of the Phlegraean Fields, near Naples. The leucitophyres are rare rocks which have been described from various parts of the volcanic district of the Rhine (Olbrck. Laacher See, etc.) and from Monte Vulture in Italy. They are rich in leucite, but contain also some sanidine and often much nepheline with hauyne or nosean. Their pyroxene is principally aegirine or aegirine-augite; some of them are rich in melanite. Microscopic sections of some of these rocks are of great interest on account of their beauty and the variety of feldspathoid minerals which they contain. In Brazil leucitophyres have been found which belong to the Carboniferous period.

Those leucite rocks which contain abundant essential plagioclase feldspar are known as leucite tephrites and leucite basanites. The former consist mainly of plagioclase, leucite and augite, while the latter contain olivine in addition. The leucite is often present in two sets of crystals, both porphyritic and as an ingredient of the ground Mass. It is always idiomorphic with rounded outlines. The feldspar ranges from bytownite to oligoclase, being usually a variety of labradorite; orthoclase is scarce. The augite varies a good deal in chemnistry and optical character, being green, brown or violet (suggesting high Na and Ti content), but it is rarely high enough in Na and Fe to qualify as aegirine-augite or aegirine. Among the accessory minerals biotite, brown hornblende, hauyne, iron oxides and apatite are the commonest; melanite and nepheline may also occur. The ground Mass of these rocks is only occasionally rich in glass. The leucite-tephrites and leucite-basanites of Vesuvius and Somma are familiar examples of this class of rocks. They are black or ashy-grey in color, often vesicular, and may contain many large grey phenocysts of leucite. Their black augite and yellow green olivine are also easily observed in hand specimens. From Volcan Ello, Sardinia and Roccamonfina similar rocks are obtained; they occur also in Bohemia, in Java, Celebes, Kilimanjaro (Africa) and near Trebizond in Asia Minor.

Leucite lavas from which feldspar is absent are divided into the leucitites and leucite basalts. The latter contain olivine, the former do not. Pyroxene is the usual ferromagnesian mineral, and resembles that of the tephrites and basanites. Sanidine, melanite, hauyne and perovskite are frequent accessory minerals in these rocks, and many of them contain melilite in some quantity, The well-known leucitite of the Capo di Bove, near, Rome, is rich in this mineral, which forms irregular plates, yellow in the hand specimen, enclosing many small rounded crystals of leucite. Bracciano and Roccamonfina are other Italian localities for leucitite, and in Java, Montana, Celebes and New South Wales similar rocks occur, The leucite basalts belong to more basic types and are rich in olivine and augite. They occur in great numbers in the Rhenish volcanic district (Eifel, Laacher See) and in Bohemia, and accompany tephrites or leucitites in Java, Montana, Celebes and Sardinia. The *peperino* of the neighborhood of Rome is a leucitite tuff.

48 – Liddicoatite

Liddicoatite from the Ambesabora pegmatite, Madagascar.

Contents

1 – Introduction :

Liddicoatite is a rare member of the tourmaline group of minerals, elbaite subgroup, and the theoretical calcium endmember of the elbaite-liddicoatite series; the pure end-member has not yet been found in nature . Liddicoatite is indistinguishable from elbaite by X-ray diffraction techniques. It forms a series with elbaite and probably also with olenite . Formulae are

- Liddicoatite $Ca(Li_2Al)Al_6(BO_3)_3Si_6O_{18}(OH)_3F$
- Elbaite $Na(Al_{1.5}Li_{1.5})Al_6(BO_3)_3Si_6O_{18}(OH)_4$
- Olenite $NaAl_9B_3Si_6O_{27}O_3(OH)$

Liddicoatite was named in 1977 after Richard T. Liddicoat (1918 - 2002) gemmologist and president of the Gemological Institute of America , who is well known for introducing the GIA diamond grading system in 1953.

Category	Tourmaline Group
Chemical Formula	$Ca(Li_2Al)Al_6(BO_3)_3Si_6O_{18}(OH)_3F$
Molar Mass	945.8 g
Color	Usually smoky brown, but also pink, red, green, blue, or rarely white.
Crystal habit	Stout prismatic, with a curved convex trigonal outline
Crystal system	Trigonal 3 m, space group R 3m
Tenacity	Brittle
Mohs scale hardness	7.5
Luster	Vitreous
Streak	White to very light brown
Diaphaneity	Transparent to translucent
Specific Gravity	3.02
Optical properties	Uniaxial (-)
Refractive index	$N_o = 1.637$, $N_e = 1.621$
Pleochroism	Strong : O dark brown or pink , E light brown or pale pink
Other characteristics	Not fluorescent , not radioactive

2 - Unit Cell :

Liddicoatite belongs to the trigonal crystal system, class 3 m, space group R 3m. It has a rhombohedral lattice, with unit cell parameters

- a = 15.867 Å to 15.875 Å
- c = 7.135 Å to 7.126 Å
- Z = 3 (there are 3 Formular units per unit cell).

3 - Structure :

Liddicoatite is isostructural with (has the same structure as) all members of the tourmaline group , which are cyclosilicates with the general Formula

- $XY_3Z_6(BO_3)_3Si_6O_{18}(OH,O)_3(OH,F)$.

For liddicoatite, the X sites are occupied by Ca, the Y sites by Li or Al and the Z sites by Al, giving the Formula

- $Ca(Li_2Al)Al_6(BO_3)_3Si_6O_{18}(OH)_3F$.

The Y sites are octahedrally coordinated by oxygen O and hydroxyl OH ions; three octahedra surround the three-fold axis at the origin, and each octahedron shares an edge with each of its two nearest neighbours. The silicon Si ions are tetrahedrally coordinated by O, forming SiO_4 groups. These tetrahedra form six-membered rings, with two of the four Os in each tetrahedron shared between adjacent tetrahedra. So the Formula for the ring is Si_6O_{18}. In each Si tetrahedron an O at one free apex is shared with one of the Y octahedra. The boron B ions occur in triangular coordination, each triangle sharing a common apex with two Y octahedra. This composite unit is linked to others like it by aluminum Al ions at the Z sites, and its outer oxygen atoms are also atoms of the aluminum coordination octahedra. The X sites are sandwiched between the units along the c axis .

4 - Crystal Habits :

Crystals are stout prismatic, with a curved convex trigonal outline, generally elongated and striated parallel to the c axis. Crystals are hemimorphic, meaning that the two ends of the crystal have different forms. Liddicoatite usually has a pedion (a single crystal face) opposite one or two pyramids .

5 - Physical Properties :

A polished slice of liddicoatite from Madagascar.

The color is usually smoky brown, but also pink, red, green, blue, or rarely white. Color zoning is abundant at the type locality, parallel to pyramid faces. This is due to changes in the solution during crystal growth. As the concentration of trace elements that serve as coloring agents changes, there will be areas of less or more color in different parts of the crystal. When the crystal is sliced perpendicular to the c axis, triangular zoning may be seen, together with a trigonal star that radiates from the centre of the crystal, with the three rays directed towards the corners of the triangular color patterns .The pink - red color is due to the manganese Mn^{3+} content, and the green color is due to intervalence charge transfer transactions between iron Fe^{2+} and titanium Ti^{4+} .The streak is white to very light brown, lighter than the Mass color, luster is vitreous and crystals are transparent to translucent . Cleavage is poor perpendicular to the c crystal axis, or it may be totally absent . The mineral is brittle, with an uneven to conchoidal fracture. It is very hard, with hardness 7½, a little harder than zircon, making it suitable for use as a gemstone. Specific Gravity is 3.02, a little lighter than fluorite. It is neither fluorescent nor radioactive.

6 - Optical Properties :

Liddicoatite is uniaxial (-), with refractive Indices N_o = 1.637 and N_e = 1.621 for the type specimen. The refractive indices, however, will vary from specimen to specimen, as they depend on the content of iron and manganese, which are usually present as trace elements . Pleochroism is strong : O dark brown or pink, E light brown or pale pink.

7 - Environment :

Liddicoatite is detrital in soil at the type locality, presumably derived from the weathering of granitic pegmatites . Associated minerals are quartz, elbaite, albite and micas .

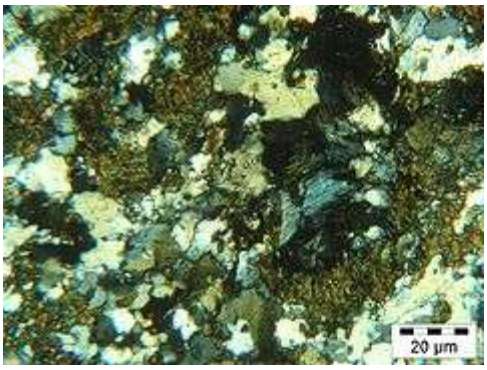
8 - Localities :

*A spectacular radiating spray of **Liddicoatite** crystals, from the Minh Tien Mine, Luc Yen, Vietnam.*

The type locality is Anjanabonoina, Tsilaizina, Antsirabe, Madagascar . Type Material is stored at the National Museum of Natural History, Smithsonian Institution, Washington, D.C., USA, catalogue #135815; further type material is stored at the Natural History Museum, London, the Royal Ontario Museum, Canada and the Geological Survey of Canada .

- Deep brilliant red, highly lustrous, prismatic liddicoatite has been found as large sheaves of near parallel, slightly divergent crystals, at the Minh Tien pegmatite, Luc Yen District, in Vietnam .
- At Ambalabe, Manapa, near Betafo, Madagascar, very lustrous, striated, short prismatic liddicoatite crystals with trigonal terminations have been found, loose or on pegmatite matrix; they are a very dark greenish brown to black, but have rich red internal highlights, and resting on a few of their surfaces are sharp, lustrous, snow-white dodecahedral crystals of londonite .
- In Tsarafara in the Sahatany Valley, Vakinankaratra Region, Madagascar, striated, lustrous, gemmy, color-zoned liddicoatite crystals have been found. Most of these have red tips and green middle zones, some with as many as five distinct color bands. Some of the crystals rest on greyish quartz .

49 – Melilite



Orthite and melilite (blue) with quartz , from a thin section in crossed polarized light

1 – Introduction :

Melilite refers to a mineral of the melilite group. Minerals of the group are solid solutions of several endmembers, the most important of which are gehlenite and åkermanite. A generalized Formula for common melilite is :

$(Ca,Na)_2(Al,Mg,Fe^{2+})[(Al,Si)SiO_7]$. Discovered in 1793 near Rome, it has a yellowish, greenish brown color. The name derives from the Greek words meli "honey" and lithos "stone".

Minerals of the melilite group are sorosilicates. They have the same basic structure, of general Formula $A_2B(T_2O_7)$. The melilite structure consist of pairs of fused TO_4, where T may be Si, Al, B, in bow-tie form. Sharing one corner, the Formula of the pair is T_2O_7. These bow-ties are linked together into sheets by the B cations. The sheets are held together by the A cations, most commonly calcium and sodium. Aluminium may sit on either the T or the B site. Minerals with the melilite structure may show a cleavage parallel to the (001) crystallographic directions and may show weaker cleavage perpendicular to this, in the {110} directions. Melilite is tetragonal.

The important endmembers of common melilite are åkermanite $Ca_2Mg(Si_2O_7)$ and gehlenite $Ca_2Al[AlSiO_7]$. Many melilites also contain appreciable iron and sodium.

Some other compositions with the melilite structure include : alumoåkermanite $(Ca,Na)_2(Al,Mg,Fe^{2+})(Si_2O_7)$, okayamalite $Ca_2B[BSiO_7]$, gugiaite $Ca_2Be[Si_2O_7]$, hardystonite $Ca_2Zn[Si_2O_7]$, barylite $BaBe_2[Si_2O_7]$, andremeyerite $BaFe_2^{+2}[Si_2O_7]$. Some structures formed by replacing one oxygen by F or OH : leucophanite $(Ca,Na)_2(Be,Al)[Si_2O_6(F,OH)]$, jeffreyite $(Ca,Na)_2(Be,Al)[Si_2O_6(O,OH)]$, and meliphanite $(Ca,Na)_2(Be,Al)[Si_2O_6(OH,F)]$

Category	Sorosilicates
Chemical Formula	$(Ca,Na)_2(Al,Mg,Fe^{2+})[(Al,Si)SiO_7]$
Color	Yellowish, greenish brown
Crystal habit	Massive - granular
Crystal system	Tetragonal
Mohs scale hardness	5 - 5.5
Luster	Vitreous - greasy
Streak	white
Diaphaneity	Translucent
Specific Gravity	2.9 - 3.0
Refractive index	$n\omega = 1.632 - 1.669$ $n\varepsilon = 1.626 - 1.658$

2 - Occurrences :

Melilite with compositions dominated by the endmembers akermanite and gehlenite is widely distributed but uncommon. It occurs in metamorphic and igneous rocks and in meteorites.

Typical metamorphic occurrences are in high-temperature metamorphosed impure limestones. For instance, melilite occurs in some high-temperature skarns.

Melilite also occurs in unusual silica-under saturated igneous rocks. Some of these rocks appear to have formed by reaction of magmas with limestone. Other igneous rocks containing melilite crystallize from magma derived from the Earth's mantle and apparently uncontaminated by the Earth's crust. The presence of melilite is an essential constituent in some rare igneous rocks, such as olivine melilitite. Extremely rare igneous rocks contain as much as 70% melilite, together with minerals such as pyroxene and perovskite.

Melilite is a constituent of some calcium- and aluminium-rich inclusions (CAIs) in chondritic meteorites[3]. Isotope ratios of magnesium and some other elements in these inclusions are of great importance in deducing processes that formed our solar system.

50 – Monazite

Contents

1 – Introduction :

Monazite is a reddish - brown phosphate mineral containing rare earth metals. It occurs usually in small isolated crystals. There are actually at least four different kinds of monazite, depending on relative elemental composition of the mineral :

- monazite-Ce (Ce, La, Pr, Nd, Th, Y)PO_4
- monazite-La (La, Ce, Nd, Pr)PO_4
- monazite-Nd (Nd, La, Ce, Pr)PO_4
- monazite-Pr (Pr, Nd, Ce, La)PO_4

The elements in parentheses are listed in the order in which they are in relative proportion within the mineral, so that lanthanum is the most common rare earth in monazite-La, and so forth. Silica, SiO_2, will be present in trace amounts, as will small amounts of uranium and thorium. Due to the alpha decay of thorium and uranium, monazite contains a significant amount of helium, which can be extracted by heating.

Monazite is an important ore for thorium, lanthanum, and cerium. It is often found in placer deposits. The deposits in India are particularly rich in monazite. It has a hardness of 5.0 to 5.5 and is relatively dense, about 4.6 to 5.7 g / cm^3.

Because of the presence of thorium within monazite, it can be radioactive. If samples are kept, they should be placed away from minerals that can be damaged by radiation. Because of its radioactive nature, the monazite within rocks is a useful tool for dating geological events, such as heating or deformation of the rock.

The name monazite comes from the Greek *μοναζειν* (to be solitary), in allusion to its isolated crystals. India, Madagascar, and South Africa have large deposits of monazite sands.

Category	Phosphate minerals
Chemical Formula	$(Ce , La) PO_4$
Color	Reddish brown, brown, pale yellow, pink, green, gray
Crystal habit	Commonly as prismatic or wedge - shaped crystals
Crystal system	Monoclinic
Twinning	Contact twins common
Fracture	Conchoidal to uneven
Mohs scale hardness	5.0 to 5.5
Luster	Resinous, vitreous to damantine
Streak	White
Diaphaneity	Translucent to opaque
Specific Gravity	4.6 –5.7 (4.98–5.43 for Monazite -Ce)
Optical properties	Biaxial (+)

Refractive index	$n_\alpha = 1.770 - 1.793$ $n_\beta = 1.778 - 1.800$ $n_\gamma = 1.823 - 1.860$

2 - Mining history :

Postcard view of a monazite mine in Shelby, North Carolina, showing cart tracks and a bridge

Monazite sand from Brazil was first noticed in sand carried in ship's ballast by Carl Auer von Welsbach in the 1880s. Von Welsbach was looking for a way to obtain thorium for his newly invented incandescent mantles. Monazite sand was quickly adopted as the source of thorium for the mantles and was the foundation of what became the rare earth industry. Monazite sand was also briefly mined in North Carolina, but, shortly thereafter, deposits in southern India were found. Brazilian and Indian monazite dominated the industry before the Second World War, after which major mining activity transferred to South Africa and Bolivia. There are also large deposits in Australia.

Monazite was the only significant source of commercial lanthanides until bastnäsite began to be processed in about 1965. With declining interest in thorium as a potential nuclear fuel in the 1960s and increased concern over the disposal of the radioactive daughter products of thorium, bastnäsite came to displace monazite in the production of lanthanides due to its much lower thorium content. However, any future increase in interest in thorium for atomic energy will bring monazite back into commercial use.

3 - Mineralization and extraction :

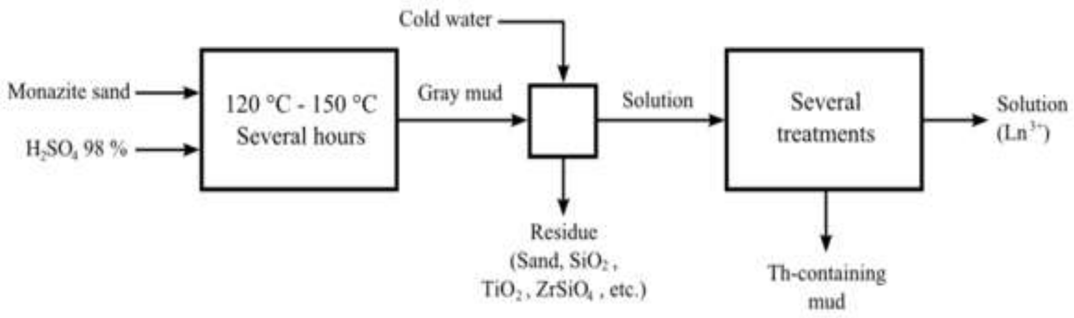
Monazite powder

Because of their high density monazite minerals will concentrate in alluvial sands when released by the weathering of pegmatites. These so-called placer deposits are often beach or fossil beach sands and contain other heavy minerals of commercial interest such as zircon and ilmenite. Monazite can be isolated as a nearly pure concentrate by the use of Gravity, magnetic, and electrostatic separation.

Monazite sand deposits are inevitably of the monazite-(Ce) composition. Typically, the lanthanides in such monazites contain about 45 – 48 % cerium, about 24 % lanthanum, about 17 % neodymium , about 5 % praseodymium, and minor quantities of samarium, gadolinium, and yttrium. Europium concentrations tend to be low, about 0.05 %. South African "rock" monazite, from Steenkampskraal, was processed in the 1950s and early 1960s by the Lindsay Chemical Division of American Potash and Chemical Corporation, at the time the largest producer of lanthanides in the world. Steenkampskraal monazite provided a supply of the complete set of lanthanides. Very low concentrations of the heaviest lanthanides in monazite justified the term "rare" earth for these elements, with prices to match. Thorium content of monazite is variable and sometimes can be up to 20 – 30 %. Monazite from certain carbonatites or from Bolivian tin veins is essentially thorium-free. However, commercial monazite sands typically contain between 6 and 12% thorium oxide.

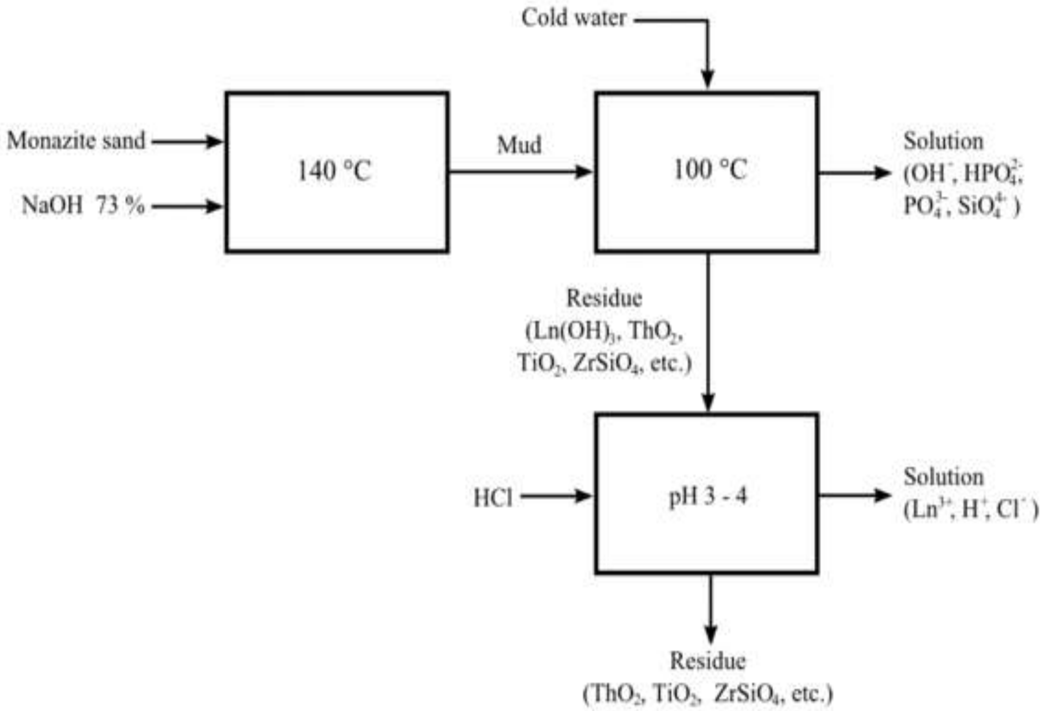
3 – 1 - Acid opening :

The original process for "cracking" monazite so as to extract the thorium and lanthanide content, was to heat it with concentrated sulfuric acid to temperatures between 120 and 150 °C for several hours. Variations in the ratio of acid to ore, the extent of heating, and the extent to which water was added afterwards led to several different processes to separate thorium from the lanthanides. One of the processes caused the thorium to precipitate out as a phosphate or pyro phosphate in crude form, leaving a solution of lanthanide sulfates from which the lanthanides could be easily precipitated as a double sodium sulfate. The acid methods led to the generation of considerable acid waste, and loss of the phosphate content of the ore.



3 – 2 - Alkaline opening :

A more recent process uses hot sodium hydroxide solution (73 %) at about 140 °C. This process allows the valuable phosphate content of the ore to be recovered as crystalline trisodium phosphate. The lanthanide / thorium hydroxide mixture can be treated with hydrochloric acid to provide a solution of lanthanide chlorides , and an insoluble sludge of the less - basic thorium hydroxide .


Cold water
Monazite sand
NaOH 73 %
140 °C
Mud
100 °C
Solution
(OH^-, HPO_4^{2-}, PO_4^{3-}, SiO_4^{4-})
Residue
($Ln(OH)_3$, ThO_2, TiO_2, $ZrSiO_4$, etc.)
HCl
pH 3 - 4
Solution
(Ln^{3+}, H^+, Cl^-)
Residue
(ThO_2, TiO_2, $ZrSiO_4$, etc.)

51 – Muscovite

Muscovite with albite from Doce valley, Minas Gerais, Brazil

Muscovite (also known as **common mica**, **isinglass**, or **potash mica**) is a phyllosilicate mineral of aluminium and potassium with Formula KAl_2 $(AlSi_3O_{10})$ $(F,OH)_2$, or $(KF)_2(Al_2O_3)_3(SiO_2)_6(H_2O)$. It has a highly - perfect basal cleavage yielding remarkably - thin laminæ (sheets) which are often highly elastic. Sheets of muscovite 5 metres by 3 metres have been found in Nellore, India .

Muscovite has a Mohs hardness of 2 – 2.25 parallel to the [001] face, 4 perpendicular to the [001] and a specific Gravity of 2.76–3. It can be colorless or tinted through grays, browns, greens, yellows, or (rarely) violet or red, and can be transparent or translucent. It is anisotropic and has high birefringence. Its crystal system is monoclinic. The green, chromium-rich variety is called **fuchsite**; mariposite is also a chromium-rich type of muscovite.

Muscovite with beryl (var. morganite) from Paprok, Afghanistan

Muscovite is the most common mica, found in granites, pegmatites, gneisses, and schists, and as a contact metamorphic rock or as a secondary mineral resulting from the alteration of topaz, feldspar, kyanite, etc. In pegmatites, it is often found in immense sheets that are commercially valuable. Muscovite is in demand for the manufacture of fireproofing and insulating materials and to some extent as a lubricant.

The name of muscovite comes from Muscovy-glass, a name formerly used for the mineral because of its use in Russia for windows.

Category	Silicate mineral Phyllosilicate
Chemical Formula	$KAl_2(AlSi_3O_{10})(F,OH)_2$
Crystal symmetry	prismatic
Unit cell	a = 5.199 Å, b = 9.027 Å, c = 20.106 Å, $\beta = 95.78°$; Z = 4
Color	White, grey, silvery
Crystal habit	Massive to platy
Crystal system	Monoclinic , space group C
Fracture	Micaceous
Tenacity	Elastic
Mohs scale hardness	2– 2.5
Luster	Vitreous , silky , pearly
Streak	White
Diaphaneity	transparent to translucent
Specific Gravity	2.76 – 3
Optical properties	Biaxial (-)

Refractive index	n_α = 1.552–1.576 n_β = 1.582–1.615 n_γ = 1.587–1.618
Pleochroism	weak when colored

52 – Natrolite

Natrolite

1 – Introduction :

Natrolite is a tectosilicate mineral species belonging to the zeolite group. It is a hydrated sodium and aluminium silicate with the Formula $Na_2Al_2Si_3O_{10} \cdot 2H_2O$. The type locality is Hohentwiel, Hegau, Germany.

It was named natrolite by Martin Heinrich Klaproth in 1803. The name is derived from natron, the Greek word for soda, in reference to the sodium content and lithos, meaning stone. Needle stone or needle - zeolite are other informal names, alluding to the common acicular habit of the crystals, which are often very slender and are aggregated in divergent tufts. The crystals are frequently epitaxial overgrowths of **natrolite**, mesolite, and gonnardite in various orders.

Category	Tectosilicate
Chemical Formula	$Na_2Al_2Si_3O_{10} \cdot 2H_2O$
Crystal symmetry	Orthorhombic
Unit cell	A =18.27, b =18.587, c = 6.56, Z = 8

Molar Mass	380 g
Color	White, colorless
Crystal habit	Acicular
Crystal system	Orthorhombic
Fracture	Irregular, uneven
Tenacity	Brittle
Mohs scale hardness	5 - 6
Luster	Vitreous, Silky, Pearly
Streak	White
Diaphaneity	Transparent to translucent
Specific Gravity	2.25

2 - Properties :

Larger crystals most commonly have the form of a square prism terminated by a low pyramid, the prism angle being nearly a right angle . The crystals are tetragonal in appearance, though actually orthorhombic. There are perfect cleavages parallel to the faces of the prism. The mineral also often occurs in compact fibrous aggregates, the fibers having a divergent or radial arrangement. Natrolite is readily distinguished from other fibrous zeolites by its optical characteristics.

Between crossed nicols the fibers extinguish parallel to their length, and they do not show an optic figure in convergent polarized light. Natrolite is usually white or colorless, but sometimes reddish or yellowish. The luster is vitreous, or, in finely fibrous specimens, silky.

The specific Gravity is 2.2, and the hardness is 5.5. The mineral is readily fusible, melting in a candle-flame to which it imparts a yellow color owing to the presence of sodium. It is decomposed by hydrochloric acid with separation of gelatinous silica.

3 – Environment :

Natrolite occurs with other zeolites in the amygdaloidal cavities of basaltic igneous rocks. It is also common in nepheline syenites.

4 - Notable localities :

Excellent specimens of diverging groups of white prismatic crystals are found in compact basalt at the Puy-deMarman, Puy- de - Dôme, France. Huge crystals have been found on the Kola Peninsula, Russia (30 cm by 13 cm). The walls of cavities in the basalt of the Giants Causeway, in Co. Antrim, are frequently encrusted with slender needles of natrolite, and similar material is found abundantly in the volcanic rocks (basalt and phonolite) of Salesel, Aussig and several other places in the north of Bohemia. Mont St. Hilaire, Quebec has produced large crystals associated with many rare minerals. The Bay of Fundy in Nova Scotia, New Jersey, and Oregon have also produced excellent specimens.

Several varieties of natrolite have been distinguished by special names. **Fargite** is a red natrolite from Glenfarg in Perthshire. **Bergmannite**, or **Spreustein**, is an impure variety which has resulted by the alteration of other minerals, chiefly sodalite, in the augite syenite of southern Norway.

53 – Nepheline

Grayish-white nepheline crystals with dark schorlomite from Bou - Agrao Mt , High Atlas Mts, Morocco

Nepheline, also called **nephelite** (from Greek : "cloud") , is a feldspathoid : a silica – under saturated aluminosilicate, $Na_3KAl_4Si_4O_{16}$, that occurs in intrusive and volcanic rocks with low silica, and in their associated pegmatites. It is often found in mica schist and gneiss.

Nepheline crystals are rare and belong to the hexagonal system, usually having the form of a short, six-sided prism terminated by the basal plane. The unsymmetrical etched figures produced artificially on the prism faces indicate, however, that the crystals are hemimorphic and tetartohedral, the only element of symmetry being a polar hexad axis. It is found in compact, granular aggregates, and can be white, yellow, gray, green, or even reddish (in the *eleolite* variety). The hardness is 5.5 - 6, and the specific Gravity 2.56 - 2.66. It is often translucent with a greasy luster.

The low index of refraction and the feeble double refraction in nepheline are nearly the same as in quartz; but since in nepheline the sign of the double refraction is negative, while in quartz it is positive, the two minerals are readily distinguished under the microscope. An important determinative character of nepheline is the ease with which it is decomposed by hydrochloric acid, with separation of gelatinous silica (which may be readily stained by coloring matters) and cubes of salt. For this reason, a clear crystal of nepheline becomes cloudy when immersed in acid.

Although sodium and potassium are always present in naturally occurring nepheline in approximately the atomic ratio (3:1), artificially prepared crystals have the composition $NaAlSiO_4$; the corresponding potassium compound, $KAISiO_4$, which is the mineral kaliophilite, has also been prepared artificially. It has therefore been suggested that the orthosilicate Formula, $(Na,K)AlSiO_4$, represents the true composition of nepheline.

The mineral is one especially liable to alteration, and in the laboratory various substitution products of nepheline have been prepared. In nature it is frequently altered to zeolites (especially natrolite), sodalite, kaolin, or compact muscovite. Gieseckite and liebenerite are pseudomorphs.

Two varieties of nepheline are distinguished, differing in their external appearance and in their mode of occurrence, being analogous in these respects to sanidine and common orthoclase respectively. Glassy nepheline has the form of small, colorless, transparent crystals and grains with a vitreous luster. It is characteristic of the later volcanic rocks rich in alkalis, such as phonolite, nepheline-basalt, leucite basalt, etc., and also of certain dike-rocks, such as tinguaite. The best crystals occur with mica, sanidine, garnet, etc., in the crystal-lined cavities of the ejected blocks of Monte Somma, Vesuvius. The other variety, known as elaeolite, occurs as large, rough crystals, or more often as irregular Masses, which have a greasy luster and are opaque, or at most translucent, with a reddish, greenish, brownish or grey color. It forms an essential constituent of certain alkaline plutonic rocks of the nepheline syenite series, which are typically developed in southern Norway.

The color and greasy luster of elaeolite (a name given by M. H. Klaproth 1809, from Greek words for oil and stone; German *Fettstein*) are due to the presence of numerous microscopic enclosures of other minerals, possibly augite or hornblende. These enclosures sometimes give rise to a chatoyant effect like that of cats-eye and cymophane; and elaeolite when of a good green or red color and showing a distinct band of light is sometimes cut as a gem-stone with a convex surface.

54 – Orthoclase

Orthoclase (endmember Formula $KAlSi_3O_8$) is an important tectosilicate mineral which forms igneous rock. The name is from the Greek for "straight fracture," because its two cleavage planes are at right angles to each other. Alternate names are **alkali feldspar** and **potassium feldspar**. The gem known as moonstone (see below) is largely composed of orthoclase.

Category	Silicate mineral
Chemical Formula	$KAlSi_3O_8$
Color	Colorless, Greenish, Grayish yellow, White, Pink
Crystal habit	Can be anhedral or euhedral . Grains are commonly elongate with a tabular appearance.
Crystal system	Monoclinic (2/m) space group C2/m
Twinning	Typically displays carlsbad twinning. Baveno and manebach twins have also been reported in orthoclase.
Mohs scale hardness	6 (defining mineral)
Luster	Vitreous, pearly on cleavage surfaces
Streak	White
Diaphaneity	Transparent to translucent

Specific Gravity	2.55 – 2.63
Optical properties	Biaxial (-),
Refractive index	$n_\alpha = 1.518–1.520$ $n_\beta = 1.522–1.524$ $n_\gamma = 1.522–1.525$
Dispersion	relatively strong
Extinction	parallel to cleavage
Diagnostic features	Distinguishable from microcline by a lack in gridiron twinning. Distinguishable from sanidine by a larger $2V_x$.
Other characteristics	Low negative relief

2 - Formation and subtypes :

Orthoclase is a common constituent of most granites and other felsic igneous rocks and often forms huge crystals and Masses in pegmatite.

Typically, the pure potassium endmember of orthoclase forms a solid solution with albite, the sodium endmember ($NaAlSi_3O_8$), of plagioclase. While slowly cooling within the earth, sodium-rich albite lamellae form by exsolution, enriching the remaining orthoclase with potassium. The resulting intergrowth of the two feldspars is called perthite.

Adularia with pyrite incrustations.

The higher-temperature polymorph of orthoclase is sanidine. Sanidine is common in rapidly cooled volcanic rocks such as obsidian and felsic pyroclastic rocks, and is notably found in trachytes of the Drachenfels, Germany. The lower-temperature polymorph of orthoclase is microcline. Adularia is found in low temperature hydrothermal deposits, in the Adula Mountains of Switzerland. The largest documented single crystal of othoclase was found in Ural mountains, Russia. It measured ~10×10×0.4 m^3 and weighed ~100 tons.

3 - Uses :

Together with the other potassium feldspars orthoclase is a common raw material for the manufacture of some glasses, some ceramics, such as porcelain, and as a constituent of scouring powder.

Some intergrowths of orthoclase and albite have an attractive pale lustre and are called moonstone when used in jewellery. Most moonstones are translucent and white, although grey and peach-colored varieties also occur. In gemology, their lustre is called adularescence and is typically described as creamy or silvery white with a "billowy" quality. It is the state gem of Florida.

The gemstone commonly called *rainbow moonstone* is more properly a colourless form of labradorite and can be distinguished from "true" moonstone by its greater transparency and play of colour, although their value and durability do not greatly differ.

55 – Painite

Painite from Myanmar,

1 – Introduction :

Painite is a very rare Borate mineral. It was first found in Myanmar by British mineralogist and gem dealer Arthur C.D. Pain in the 1950s. When it was confirmed as a new mineral species, the mineral was named after him.

The chemical makeup of painite contains calcium, zirconium, boron, aluminium and oxygen ($CaZrAl_9O_{15}(BO_3)$). The mineral also contains trace amounts of chromium and vanadium. Painite has an orange - red to brownish - red color similar to topaz due to trace amounts of iron. The crystals are naturally hexagonal in shape, and, until late 2004, only two had been cut into faceted gemstones.

Category	Borates
Chemical Formula	$Ca\ Zr\ Al_9\ O_{15}\ (\ BO_3\ )$
Crystal symmetry	Hexagonal 6/m
Unit cell	a = 8.72 Å , c = 8.46 Å ; Z = 2
Color	Red, brownish, orange-red
Crystal habit	Elongated crystals, pseudo - orthorhombic
Crystal system	Hexagonal , although earlier reported as

	hexagonal
Mohs scale hardness	8
Luster	Vitreous
Streak	White
Diaphaneity	Transparent
Specific gravity	4.01
Optical properties	Uniaxial (-)
Refractive index	$N_o = 1.8159$, $N_e = 1.7875$
Solubility	Insoluble in acids

2 - Discovery and occurrence :

Striated, euhedral painite crystal

For many years, only three small painite crystals were known to exist. Before 2005 there were fewer than 25 known crystals found, though more material has been unearthed recently in Myanmar.

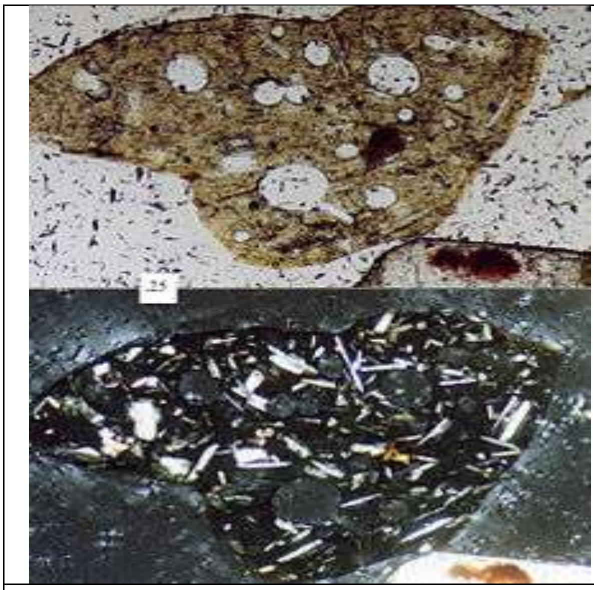
More recently, painite specimens have been discovered at a new location in northern Myanmar. It is believed that further excavations in this area will yield more painite crystals.

Extensive exploration in the Mogok region has identified several new painite occurrences that have been vigorously explored resulting in several thousand new painite specimens . Most of the recent crystals and fragments are dark, opaque, incomplete crystals. A modest number of transparent crystals have been found and have been either saved as crystals or cut into gemstones.

Originally few of the known painite specimens were privately owned. The rest of the stones were distributed between the British Museum of Natural History, Gemological Institute of America, California Institute of Technology and the GRS Gem Research Laboratory in Lucerne, Switzerland.

56 - Plagioclase

A photomicrograph of a plagioclase crystal under cross polarized light. The plagioclase crystal shows a distinct banding effect called a Polysynthetic twinning.

	
In volcanic rocks, fine-grained plagioclase can display a 'microlitic' texture of many small crystals.	*Plagioclase displaying cleavage.*

Contents :

1 – Introduction :

Plagioclase is an important series of tectosilicate minerals within the feldspar family. Rather than referring to a particular mineral with a specific chemical composition, plagioclase is a solid solution series, more properly known as the **plagioclase feldspar** series (from the Greek "oblique fracture", in reference to its two cleavage angles). This was first shown by the German mineralogist Johann Friedrich Christian Hessel (1796 –1872) in 1826. The series ranges from albite to anorthite endmembers (with respective compositions $NaAlSi_3O_8$ to $CaAl_2Si_2O_8$), where sodium and calcium atoms can substitute for each other in the mineral's crystal lattice structure. Plagioclase in hand samples is often identified by its polysynthetic twinning or 'record-groove' effect.

Plagioclase is a major constituent mineral in the Earth's crust, and is consequently an important diagnostic tool in petrology for identifying the composition, origin and evolution of igneous rocks. Plagioclase is also a major constituent of rock in the highlands of the Earth's moon.

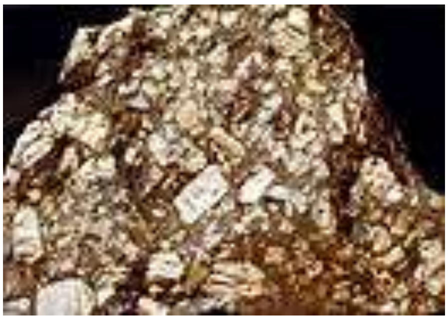
Category	feldspar , tecto silicate
Chemical Formula	$NaAlSi_3O_8 – CaAl_2Si_2O_8$
Crystal system	triclinic
Mohs scale hardness	~ 6
Streak	white
Birefringence	1st order
Pleochroism	none

2 - Plagioclase series members :

The composition of a plagioclase feldspar is typically denoted by its overall fraction of anorthite (% An) or albite (% Ab), and readily determined by measuring the plagioclase crystal's refractive index in crushed grain mounts, or its *extinction angle* in thin section under a polarizing microscope. The extinction angle is an optical characteristic and varies with the albite fraction (% Ab). There are several named plagioclase feldspars that fall between albite and anorthite in the series. The following table shows their compositions in terms of constituent anorthite and albite percentages.

Plagioclase minerals and their compositions

Name	**% $NaAlSi_3O_8$** **(%Ab)**	**% $CaAl_2Si_2O_8$** **(%An)**
 *Albite*	100 – 90	0 – 10
 *Oligoclase*	90 – 70	10 – 30

 *Andesine*	70 – 50	30 – 50
 *Labradorite*	50 – 30	50 – 70
 *Bytownite*	30 – 10	70 – 90
 Anorthite	10 – 0	90 – 100

2 – 1 - Albite :

Albite is named from the Latin *albus*, in reference to its unusually pure white color. It is a relatively common and important rock-making mineral associated with the more acid rock types and in pegmatite dikes, often with rarer minerals like tourmaline and beryl.

2 – 2 - Anorthite :

Anorthite was named by Rose in 1823 from the Greek meaning oblique, referring to its triclinic crystallization. Anorthite is a comparatively rare mineral but occurs in the basic plutonic rocks of some orogenic calc - alkaline suites.

The intermediate members of the plagioclase group are very similar to each other and normally cannot be distinguished except by their optical properties.

2 – 3 - Oligoclase :

Oligoclase is common in granite, syenite, diorite, and gneiss. It is a frequent associate of orthoclase. The name oligoclase is derived from the Greek for little and fracture, in reference to the fact that its cleavage angle differs significantly from 90°. Sunstone is mainly oligoclase (sometimes albite) with flakes of hematite.

2 – 4 - Andesine :

Andesine is a characteristic mineral of rocks such as diorite which contain a moderate amount of silica and related volcanics such as andesite.

2 – 5 - Labradorite :

Labradorite is the characteristic feldspar of the more basic rock types such as diorite, gabbro, andesite, or basalt and is usually associated with one of the pyroxenes or amphiboles. Labradorite frequently shows an iridescent display of colors due to light refracting within the lamellae of the crystal. It is named after Labrador, where it is a constituent of the intrusive igneous rock anorthosite which is composed almost entirely of plagioclase. A variety of labradorite known as spectrolite is found in Finland.

2 – 6 - Bytownite :

Bytownite, named after the former name for Ottawa, Canada (Bytown), is a rare mineral occasionally found in more basic rocks.

57 – Prehnite

		
Sliced Prehnite fragment with calcite core, 9.0 cm diameter	*Prehnite , Epidote*	*Emerald cut Prehnite , 1.85 cm x 1.42 cm, 4.6* grams

1 – Introduction :

Prehnite is a phyllosilicate of calcium and aluminium with the Formula: $Ca_2Al(AlSi_3O_{10})(OH)_2$. Limited Fe^{3+} substitutes for aluminium in the structure. Prehnite crystallizes in the orthorhombic crystal system, and most oftens forms as stalactitic or botryoidal aggregates, with only just the crests of small crystals showing any faces, which are almost always curved or composite. Very rarely will it form distinct, well individualized crystals showing a square-like cross-section, like those found at the Jeffrey Mine in Asbestos, Quebec, Canada. It is brittle with an uneven fracture and a vitreous to pearly lustre. Its hardness is 6-6.5, its specific gravity is 2.80-2.90 and its color varies from light green to yellow, but also colorless, blue or white. In April 2000, a rare orange Prehnite was discovered at the famous Kalahari Manganese Fields in South Africa. It is mostly translucent, and rarely transparent.

Though not a zeolite, it is found associated with minerals such as datolite, calcite, apophyllite, stilbite, laumontite, heulandite etc. in veins and cavities of basaltic rocks, sometimes in granites, syenites, or gneisses. It is an indicator mineral of the prehnite-pumpellyite metamorphic facies. It is the first mineral to be named after someone, and was first described in 1789 for an occurrence in Haslach, Harzburg and Oberstein, Germany, and named for Colonel Hendrik Von Prehn (1733–1785) , commander of the military forces of the Dutch colony at the Cape of Good Hope from 1768 to 1780. Extensive deposits of gem quality Prehnite occur in the basalt tableland surrounding Wave Hill Station in the central Northern Territory, of Australia.

Category	Silicate mineral
Chemical Formula	$Ca_2Al(AlSi_3O_{10})(OH)_2$
Color	Colorless to gray to yellow, yellow-green or white
Crystal habit	Globular, reniform to stalactitic
Crystal system	Orthorhombic - Pyramidal (mm2)
Twinning	Fine lamellar
Cleavage	Distinct on [001]
Tenacity	Brittle
Mohs scale hardness	6 - 6.5
Luster	Vitreous - pearly
Diaphaneity	Semi-transparent to translucent
Specific gravity	2.8 - 2.95
Optical properties	Biaxial (+)
Refractive index	$n\alpha = 1.611 - 1.632$ $n\beta = 1.615 - 1.642$ $n\gamma = 1.632 - 1.665$
Ultraviolet fluorescence	Fluorescent, Short UV=blue white mild peach, Long UV=yellow.

58 - Pyrope

Contents

1 – Introduction :

The mineral **pyrope** is a member of the garnet group. Pyrope is the only member of the garnet family to always display red colouration in natural samples, and it is from this characteristic that it gets its name: from the Greek for *fire* and *eye*. Despite being less common than most garnets, it is a widely used gemstone with numerous alternative names, some of which are misnomers. *Chrome pyrope*, and *Bohemian garnet* are two alternative names, the usage of the later being discouraged by the Gemological Institute of America . Misnomers include *Colorado ruby*, *Arizona ruby*, *California ruby*, *Rocky Mountain ruby*, *Elie Ruby*, *Bohemian carbuncle*, and *Cape ruby*.

The composition of pure pyrope is $Mg_3Al_2(SiO_4)_3$, although typically other elements are present in at least minor proportions -- these other elements include Ca, Cr, Fe and Mn. Pyrope forms a solid solution series with almandine and spessartine, which are collectively known as the *pyralspite* garnets (**pyr**ope, **al**mandine, **sp**essartine). Iron and manganese substitute for the magnesium in the pyrope structure. The resultant, mixed composition garnets are defined according to their pyrope-almandine ratio. The semi-precious stone rhodolite is a garnet of ~70 % pyrope composition.

The origin of most pyrope is in ultramafic rocks, typically peridotite from the Earth's mantle: these mantle-derived peridotites can be attributed both to igneous and metamorphic processes.

Pyrope also occurs in **u**ltra **h**igh-**p**ressure (UHP) metamorphic rocks, as in the Dora-Maira massif in the western Alps. In that massif, nearly pure pyrope occurs in crystals to almost 12 cm in diameter; some of that pyrope has inclusions of coesite, and some has inclusions of enstatite and sapphirine.

Pyrope is common in peridotite xenoliths from kimberlite pipes, some of which are diamond-bearing. Pyrope found in association with diamond commonly has a Cr_2O_3 content of 3-8%, which imparts a distinctive violet to deep purple colouration (often with a greenish tinge) and because of this is often used as a kimberlite indicator mineral in areas where erosive activity makes pin pointing the origin of the pipe difficult. These varieties are known as *chrome-pyrope*, or *G9/G10* garnets.

Category	Nesosilicate
Chemical Formula	$Mg_3Al_2(SiO_4)_3$
Color	Red. Some varieties are very dark, almost black, while others can take tones of purple. Some chromium-rich pyropes are thermochromic, becoming green when heated
Crystal habit	Euhedra typically display rhombic dodecahedral form, but trapezohedra are not uncommon, and hexoctahedra are seen in some rare samples. Massive and granular forms also occur.
Crystal system	Cubic
Cleavage	None
Fracture	Conchoidal
Mohs scale hardness	7 - 7.5
Luster	greasy to vitreous

Streak	White
Specific gravity	3.78 (+.09 -.16)
Polish luster	vitreous[2]
Optical properties	Single refractive, often anomalous double refractive
Refractive index	1.74 normal, but ranges from 1.714 to over 1.742
Birefringence	Isotropic, appears black in cross-polarized light
Pleochroism	none
Ultraviolet fluorescence	inert
Absorption spectra	broad band at 564nm with cutoff at 440 to 445nm. Fine gem quality pyropes may show chromium lines in the red end of the spectrum
Solubility	Insoluble in water, weakly soluble in HF
Mineral association	Olivine, pyroxene, hornblende, biotite, diamond

2 - Mineral identification

In hand specimen, pyrope is very tricky to distinguish from almandine, however it is likely to display fewer flaws and inclusions. Other distinguishing criteria are listed in the table to the right. Care should be taken when using these properties as many of those listed have been determined from synthetically grown, pure-composition pyrope. Others, such as pyrope's high specific gravity, may be of little use when studying a small crystal embedded in a matrix of other silicate minerals. In these cases, mineral association with other mafic and ultramafic minerals may be the best indication that the garnet you are studying is pyrope.

In petrographic thin section, the most distinguishing features of pyrope are those shared with the other common garnets: high relief and isotropy. Garnets tend to be less strongly coloured than other silicate minerals in thin section, although pyrope may show a pale pinkish-purple hue in plane-polarized light. The lack of cleavage, commonly euhedral crystal morphology, and mineral associations should also be used in identification of pyrope under the microscope.

3 - Health effects :

Magnesium aluminum silicate powder is a common ingredient in makeup, pesticide, pharmaceuticals, and other products. Specific health effects depend upon the size, shape, and amount when dust particles are lofted into the air. Fine powder forms clay when water is added. Studies do not exist that indicate increase risk of cancer.

Magnesium aluminum silicate is not considered to be a hazardous substance by US Department of Transportation and US Environmental Protection Agency, and it is not considered to be carcinogenic under California Proposition 65.

Aluminum is one of the non-protein components of amyloid plaque associated with Alzheimer's disease. Silicon is associated with increase risk of cancer and osteoporosis. Magnesium aluminum silicate contains both.

Do not breathe dust. If ingested, seek medical advice immediately and display the container or label to physicians. Respirators are required to prevent inhalation. The treatment after inhalation is to keep airways open and provide oxygen . A self contained breathing apparatus should be used to avoid dust inhalation .

The following are required for large spills :

- Splash goggles.
- Full suit.

- Dust respirator.
- Boots.
- Gloves.

There are several forms, and magnesium aluminum silicate may be identified by several different CAS#, such as 12174-11-7, 1327-43-1, and 12199-37- 0.

Inhaling finely divided dust particles in very small quantities over time can lead to bronchitis, emphysema, or other diseases as the dust becomes lodged in the lungs, reducing lung capacities. In the body, magnesium aluminum silicate particles dissolve slowly and may form mud, which may be expectorated from the lungs and ingested. This exposes the body to silicon and aluminum that can pose health risks. Children, asthmatics of any age, allergy sufferers, and the elderly (all of whom have reduced lung capacity) can be affected in much less time.

3 – 1 - Names

The following names may be used to describe silica dust :

Aluminosilicic acid , magnesium salt	Magnesium Alumino meta silicate	Attapulgite
Magnesium Aluminum Silicate Type 1A	Smectite Clay	Palygorskite
SAluminum Magnesium Silcate Type 1A	Veegum	Pyrope

3 – 2 - Inhalation Risks :

- **Alzheimer's:** Respirable and ingested magnesium aluminum silicate may contribute to Alzheimer's disease.
- **Osteoporosis:** Respirable and ingested magnesium aluminum silicate may contribute to osteoporosis.

- **Non-Malignant Respiratory Diseases (other than silicosis):** Some studies show an increased incidence of chronic bronchitis and emphysema associated with magnesium aluminum silicate .

3 – 3 - Eye Contact :

Magnesium aluminum silicate may cause eye irritation. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes and seek medical attention.

59 – Pyrophyllite

Pearly radial cluster of pyrophyllite from Hillsboro District, Orange County, North Carolina (Size: 11 x 7.3 x 6.6 cm)

Radiating fans of golden-brown pyrophyllite needles from Champion Mine, White Mts, Mono County, California (size: 4.0 x 3.0 x 2.3 cm)

1 – Introduction :

Pyrophyllite is a phyllosilicate mineral composed of aluminium silicate hydroxide: $Al_2Si_4O_{10}(OH)_2$. It occurs in two more or less distinct varieties, namely, as crystalline folia and as compact masses; distinct crystals are not known.

The folia have a pronounced pearly lustre, owing to the presence of a perfect cleavage parallel to their surfaces: they are flexible but not elastic, and are usually arranged radially in fan-like or spherical groups. This variety, when heated before the blowpipe, exfoliates and swells up to many times its original volume, hence the name pyrophyllite, from the Greek *pyros* (fire) and *phyllos* (a leaf),[4] given by R. Hermann in 1829. The color of both varieties is white, pale green, greyish or yellowish; they are very soft (hardness of 1 to 1.5) and are greasy to the touch. The specific gravity is 2.65 - 2.85. The two varieties are thus very similar to talc.

Category	Silicate mineral
Chemical Formula	$Al_2Si_4O_{10}(OH)_2$
Crystal symmetry	Monoclinic / triclinic
Unit cell	a = 5.16 Å, b = 8.966(3) Å, c = 9.347(6) Å; $\alpha = 91.18°$, $\beta = 100.46°$, $\gamma = 89.64°$; Z = 2
Molar mass	360.31
Color	Brown green, brownish yellow, greenish, gray green, gray white
Crystal habit	Compact spherulitic aggregates of needle like radiating crystals; as fine grained foliated laminae, granular, massive
Crystal system	Monoclinic 2 / m - prismatic or triclinic 1 pinacoidal
Tenacity	Flexible inelastic
Mohs scale hardness	1.5 - 2
Luster	Pearly to dull
Streak	white
Diaphaneity	Translucent to opaque

Specific gravity	2.65 - 2.9
Optical properties	Biaxial (-)
Refractive index	n_α=1.534-1.556, n_β=1.586-1.589, n_γ=1.596-1.601
Birefringence	δ =0.0450-0.0620
2V angle	53-62

2 - Occurrence :

Pyrophyllite occurs in phyllite and schistose rocks, often associated with kyanite, of which it is an alteration product. It also occurs as hydrothermal deposits. Typical associated minerals include: kyanite, andalusite, topaz, mica and quartz.[3]

Deposits containing well-crystallized material are found in:[3]

- Russia - pale green foliated masses, very like talc in appearance, are found at Beresovsk near Yekaterinburg in the Urals.
- St. Niklas, Zermatt, Valais, Switzerland
- at Vaastana, Kristianstad, Sweden
- near Ottrje, Ardennes Mountains, Belgium
- Ibitiara, Bahia, Brazil
- Nagano Prefecture, Japan
- Manuels, Newfoundland and Labrador , Canada
- USA
    - It is found near Ogilby, Imperial County at Tres Cerritos, Mariposa County, and the Champion mine, White Mountains, Mono County, California
    - near Quartzsite, La Paz County, Arizona
    - the large deposits at the Deep River region of North Carolina
    - Graves Mountain, Lincoln County, Georgia

It is also reported from South Africa where major deposits of pyrophyllite occur within the Ottosdal region, where it is mined for the production of a variety of manufactured goods and blocks are quarried and marketed as "Wonderstone" for the carving of sculptures

3 - Uses :

The compact variety of pyrophyllite is used for slate pencils and tailors chalk (French chalk), and is carved by the Chinese into small images and ornaments of various kinds. Other soft compact minerals (steatite and pinite) used for these Chinese carvings are included with pyrophyllite under the terms agalmatolite and pagodite.[*citation needed*]

Pyrophyllite is easily machineable and has excellent thermal stability. Therefore it is added to clay to reduce thermal expansion when firing but it has many other industry uses when combined with other compounds, such as in insecticide and for making bricks. Pyrophyllite is also widely used in high-pressure experiments, both as a gasket material and as a pressure-transmitting medium.[5]

60 - Quintinite

Quintinite is a carbonate mineral with the chemical Formula $Mg_4Al_2(OH)_{12}CO_3 \cdot H_2O$.

The mineral was named after Quinitin Wight of Ottawa, Ontario, Canada (b. 1935), who was a significant contributor to mineral studies at Mont Saint-Hilaire.

Quintinite is found as 2H and 3T, or 2-hexagonal and 3-trigonal, poly types, which were originally approved as separate species, but have not been considered species since 1998. These hexagonal and trigonal forms of quinitinite are both from the hexagonal crystal systems, meaning they both have similar lengths of their crystal axes and the same angles between these axes. As a hexagonal mineral, quintinite has three axes of equal length at 60 degree angles to one another and a c axis perpendicular to these three axes of a different length. 2H occurs in carbonatite at Jacupiranga, São Paulo, Brazil, in the Jacupiranga mine and 3T occurs with minerals like gonnardite and donnayite. Both polytypes occur in hydrothermal vents in alkaline rocks. Herg (1977) interpreted the Jacupiranga area as related to a hotspot. The 3T polytype was originally found in the Poudrette quarry at Mont Saint-Hilaire, which is a rare alkaline intrusive complex. The 2H polytype is pleochroic, meaning that the mineral changes colors (in this case yellow and light yellow) when viewed at different angles under a polarizing petrographic microscope. The 3T polytype, however, is not commonly pleochroic but can show green pleochroism if it is high in iron. The 3T polytype has a positive index of refraction whereas the 2H polytype can possess crystals with either a positive or a negative index of refraction.

Category	Carbonate mineral
Chemical Formula	$Mg_4Al_2(OH)_{12}CO_3 \cdot H_2O$
Crystal symmetry	Hexagonal trapezohedral H-M symbol: (6 2 2) Space group: $P\ 6_322$

Unit cell	a = 10.571 Å, c = 15.171 Å, Z = 4
Color	Colorless, deep orange red, orange, pale brown
Crystal habit	Prismatic – crystals shaped like slender prisms
Crystal system	Hexagonal
Mohs scale hardness	2
Luster	Vitreous
Streak	White
Diaphaneity	Transparent
Specific gravity	2.14
Optical properties	Uniaxial (±) for 2H type, uniaxial negative, for 3T polytype, uniaxial negative or positive
Refractive index	1.533 (isotropic)
Pleochroism	For 2H polytype, O = yellow, E=lighter yellow; For 3T polytype, typically nonpleochroic

61 - Ruby

Natural ruby crystals from Winza, Tanzania.

Contents

1 – Introduction :

A **ruby** is a pink to blood-red colored gemstone, a variety of the mineral corundum (aluminium oxide). The red color is caused mainly by the presence of the element chromium. Its name comes from *ruber*, Latin for red. Other varieties of gem-quality corundum are called sapphires. The ruby is considered one of the four precious stones, together with the sapphire, the emerald, and the diamond.

Prices of rubies are primarily determined by color. The brightest and most valuable "red" called pigeon blood-red, commands a huge premium over other rubies of similar quality. After color follows clarity: similar to diamonds, a clear stone will command a premium, but a ruby without any needle-like rutile inclusions may indicate that the stone has been treated. Cut and carat (weight) are also an important factor in determining the price.

Category	Mineral variety
Chemical Formula	aluminium oxide with chromium , Al_2O_3 : Cr
Color	Red, may be brownish, purplish or pinkish
Crystal habit	Varies with locality. Terminated tabular hexagonal prisms.
Crystal system	Trigonal (Hexagonal Scalenohedral) Symbol (− 3 2 / m) Space Group: R-3c
Cleavage	No true cleavage
Fracture	Uneven or conchoidal
Mohs scale hardness	9.0
Luster	Vitreous
Streak	white
Diaphaneity	transparent
Specific gravity	4.0
Refractive index	n_ω=1.768 – 1.772 n_ε=1.760 – 1.763, Birefringence 0.008
Pleochroism	Orangey red, purplish red
Ultra violet fluorescence	red under longwave
Melting point	2044 °C
Solubility	none

Sapphire	Any color except red
Corundum	various colors
Emery	Granular

2 - Physical properties :

Rubies have a hardness of 9.0 on the Mohs scale of mineral hardness. Among the natural gems only moissanite and diamond are harder, with diamond having a Mohs hardness of 10.0 and moissonite falling somewhere in between corundum (ruby) and diamond in hardness. Ruby is α-alumina (the most stable form of Al_2O_3) in which a small fraction of the aluminum^{3+} ions are replaced by chromium^{3+} ions. Each Cr^{3+} is surrounded octahedrally by six O^{2-} ions. This crystallographic arrangement strongly affects each Cr^{3+}, resulting in light absorption in the yellow-green region of the spectrum and thus in the red color of the gem. When yellow-green light is absorbed by Cr^{3+}, it is re-emitted as red luminescence . This red emission adds to the red colour perceived by the subtraction of green and violet light from white light, and adds luster to the gem's appearance. When the optical arrangement is such that the emission is stimulated by 694-nanometer photons reflecting back and forth between two mirrors, the emission grows strongly in intensity. This effect was used by Theodore Maiman in 1960 to make the first successful laser, based on ruby.

All natural rubies have imperfections in them, including color impurities and inclusions of rutile needles known as "silk". Gemologists use these needle inclusions found in natural rubies to distinguish them from synthetics, simulants, or substitutes. Usually the rough stone is heated before cutting. Almost all rubies today are treated in some form, with heat treatment being the most common practice. However, rubies that are completely untreated but still of excellent quality command a large premium.

Some rubies show a 3-point or 6-point asterism or "star". These rubies are cut into cabochons to display the effect properly. Asterisms are best visible with a single-light source, and move across the stone as the light moves or the stone is rotated. Such effects occur when light is reflected off the "silk" (the structurally oriented rutile needle inclusions) in a certain way. This is one example where inclusions increase the value of a gemstone. Furthermore, rubies can show color changes — though this occurs very rarely — as well as chatoyancy or the "cat's eye" effect.

3 - Natural occurrence :

The Mogok Valley in Upper Myanmar (Burma) was for centuries the world's main source for rubies. That region has produced some of the finest rubies ever mined, but in recent years very few good rubies have been found there. The very best color in Myanmar rubies is sometimes described as "pigeon's blood." In central Myanmar, the area of Mong Hsu began producing rubies during the 1990s and rapidly became the world's main ruby mining area. The most recently found ruby deposit in Myanmar is in Namya (Namyazeik) located in the northern state of Kachin.

Rubies have historically been mined in Thailand, the Pailin and Samlout District of Cambodia, Burma, India, Afghanistan and in Pakistan. Rubies have rarely been found in Sri Lanka, where pink sapphires are more common. After the Second World War ruby deposits were found in Tanzania, Madagascar, Vietnam, Nepal, Tajikistan, and Pakistan. A few rubies have been found in the U.S. states of Montana, North Carolina, and South Carolina. More recently, large ruby deposits have been found under the receding ice shelf of Greenland. In 2002 rubies were found in the Waseges River area of Kenya.

There are reports of a large deposit of rubies found in 2009 in Mozambique, in Nanhumbir in the Cabo Delgado district of Montepuez .

Spinel, another red gemstone, is sometimes found along with rubies in the same gem gravel or marble. Red spinel may be mistaken for ruby by those lacking experience with gems. However, the finest red spinels can have a value approaching that of the average ruby.[4]

4 - Factors affecting value :

Diamonds are graded using criteria that have become known as the four Cs, namely color, cut, clarity and carat weight. Similarly natural rubies can be evaluated using the four Cs together with their size and geographic origin.

Color : In the evaluation of colored gemstones, color is the single most important factor. Color divides into three components; *hue, saturation* and *tone*. Hue refers to "color" as we normally use the term. Transparent gemstones occur in the following hues: red, orange, yellow, green, blue, violet, purple and pink. The first six are known as spectral hues; the last two are modified spectral hues. Purple is a hue that falls halfway between red and blue. Pink is a paler shade of red.[5] In nature there are rarely pure hues so when speaking of the hue of a gemstone we speak of primary and secondary and sometimes tertiary hues. In ruby the primary hue must be red. All other hues of the gem species corundum are called sapphire. Ruby may exhibit a range of secondary hues. Orange, purple, violet and pink are possible.

	
Natural ruby with inclusions	*A naturally occurring ruby crystal*
	
A cut ruby.	*Rubies set in jewelry*

The finest ruby is best described as being a vivid medium-dark toned red. Secondary hues add an additional complication. Pink, orange, and purple are the normal secondary hues in ruby. Of the three, purple is preferred because, firstly, the purple reinforces the red making it appear richer. Secondly, purple occupies a position on the color wheel halfway between red and blue. In Burma where the term pigeon blood originated, rubies are set in pure gold. Pure gold is itself a highly saturated yellow. Set a purplish-red ruby in yellow and the yellow neutralizes its complement blue leaving the stone appearing to be pure red in the setting.

5 - Treatments and enhancements :

Improving the quality of gemstones by treating them is common practice. Some treatments are used in almost all cases and are therefore considered acceptable. During the late 1990s, a large supply of low-cost materials caused a sudden surge in supply of heat-treated rubies, leading to a downward pressure on ruby prices.

Improvements used include color alteration, improving transparency by dissolving rutile inclusions, healing of fractures (cracks) or even completely filling them.

The most common treatment is the application of heat. Most, if not all, rubies at the lower end of the market are heat treated on the rough stones to improve color, remove *purple tinge*, blue patches and silk. These heat treatments typically occur around temperatures of 1800 °C . Some rubies undergo a process of low tube heat, when the stone is heated over charcoal of a temperature of about 1300 °C for 20 to 30 minutes. The silk is only partially broken as the color is improved.

Another treatment, which has become more frequent in recent years, is lead glass filling. Filling the fractures inside the ruby with lead glass (or a similar material) dramatically improves the transparency of the stone, making previously unsuitable rubies fit for applications in jewelry . The process is done in four steps :

1. The rough stones are pre-polished to eradicate all surface impurities that may affect the process
2. The rough is cleaned with hydrogen fluoride
3. The first heating process during which no fillers are added. The heating process eradicates impurities inside the fractures. Although this can be done at temperatures up to 1400 °C it most likely occurs at a temperature of around 900 °C since the rutile silk is still intact
4. The second heating process in an electrical oven with different chemical additives. Different solutions and mixes have shown to be successful, however mostly lead-containing glass-powder is used at present. The ruby is dipped into oils, then covered with powder, embedded on a tile and placed in the oven where it is heated at around 900 °C for one hour in an oxidizing atmosphere. The orange colored powder transforms upon heating into a transparent to yellow- colored paste, which fills all fractures. After cooling the color of the paste is fully transparent and dramatically improves the overall transparency of the ruby .

If a color needs to be added, the glass powder can be "enhanced" with copper or other metal oxides as well as elements such as sodium, calcium, potassium etc.

The second heating process can be repeated three to four times, even applying different mixtures . When jewelry containing rubies is heated (for repairs) it should not be coated with boracic acid or any other substance, as this can etch the surface; it does not have to be "protected" like a diamond.

6 - Synthetic and imitation rubies :

In 1837 Gaudin made the first synthetic rubies by fusing potash alum at a high temperature with a little chromium as a pigment. In 1847 Ebelmen made white sapphire by fusing alumina in boric acid. In 1877 Frenic and Freil made crystal corundum from which small stones could be cut. Frimy and Auguste Verneuil manufactured artificial ruby by fusing BaF_2 and Al_2O_3 with a little Chromium at red heat. In 1903 Verneuil announced he could produce synthetic rubies on a commercial scale using this flame fusion process.[11] By 1910, Verneuil's laboratory had expanded into a 30 furnace production facility, with annual gemstone production having reached 1,000 kg (2,205 lb) in 1907.

Other processes in which synthetic rubies can be produced are through the Czochralski's Pulling process, flux process, and the hydrothermal process. Most synthetic rubies originate from flame fusion, due to the low costs involved. Synthetic rubies may have no imperfections visible to the naked eye but magnification may reveal curves, striae and gas bubbles. The fewer the number and the less obvious the imperfections, the more valuable the ruby is; unless there are no imperfections (i.e., a "perfect" ruby), in which case it will be suspected of being artificial. Dopants are added to some manufactured rubies so they can be identified as synthetic, but most need gemological testing to determine their origin.

Synthetic rubies have technological uses as well as gemological ones. Rods of synthetic ruby are used to make ruby lasers and masers. The first working laser was made by Theodore H. Maiman in 1960[12] at Hughes Research Laboratories in Malibu, California, beating several research teams including those of Charles H. Townes at Columbia University, Arthur Schawlow at Bell Labs,[13] and Gould at a company called TRG (Technical Research Group). Maiman used a solid-state light-pumped synthetic ruby to produce red laser light at a wavelength of 694 nanometers (nm). Ruby lasers are still in use. Rubies are also used in applications where high hardness is required such as at wear exposed locations in modern mechanical clockworks, or as scanning probe tips in a coordinate measuring machine.

Imitation rubies are also marketed. Red spinels, red garnets, and colored glass have been falsely claimed to be rubies. Imitations go back to Roman times and already in the 17th century techniques were developed to color foil red—by burning scarlet wool in the bottom part of the furnace—which was then placed under the imitation stone.[14] Trade terms such as balas ruby for red spinel and rubellite for red tourmaline can mislead unsuspecting buyers. Such terms are therefore discouraged from use by many gemological associations such as the Laboratory Manual Harmonisation Committee (LMHC).

7 - Records and famous rubies :

- The Smithsonian's National Museum of Natural History in Washington DC, has received one of the world's largest and finest ruby gemstones. The 23.1 carats (4.6 g) Burmese ruby, set in a platinum ring with diamonds, was donated by businessman and philanthropist Peter Buck in memory of his late wife Carmen Lúcia. This gemstone displays a richly saturated red color combined with an exceptional transparency. The finely proportioned cut provides vivid red reflections. The stone was mined from the Mogok region of Burma (now Myanmar) in the 1930s.
- In 2007 the London jeweler Garrard & Co featured on their website a heart - shaped 40.63 - carat ruby.
- On December 13/14 2011 Elizabeth Taylor's complete jewellery collection will be auctioned by Christie's. Included is a ruby and diamond necklace

8 - Historical and cultural references ;

- An early recorded transport and trading of rubies arises in the literature on the North Silk Road of China, wherein about 200 BC rubies were carried along this ancient trackway moving westward from China .
- Rubies have always been held in high esteem in Asian countries. They were used to ornament armor, scabbards, and harnesses of noblemen in India and China. Rubies were laid beneath the foundation of buildings to secure good fortune to the structure.

62 - Sacrofanite

1 – Introduction :

Sacrofanite is a rare silicate mineral that has the general Formula of $(Na,Ca)_9(Si,Al)_{12}O_{24}(SO_4,CO_3,OH,Cl)_4 \cdot n(H_2O)$. It was approved as a mineral by the International Mineralogical Association in 1980 . Its name comes from the Sacrofano Caldera in the Monti Sabatini from which it was discovered in Latium, Italy.

Category	Cancrinite group, tectosilicate
Chemical Formula	$(Na,Ca)_9(Si,Al)_{12}O_{24}(SO_4,CO_3,OH,Cl)_4 \cdot n(H_2O)$
Crystal symmetry	Hexagonal
Unit cell	a=12.86 Å, c=72.24 Å, V=10,346.52 Å^3; Z = 14
Color	Colorless
Mohs scale hardness	5.5 - 6
Luster	Pearly to vitreous
Streak	white
Diaphaneity	Transparent
Specific gravity	2.423
Optical properties	Uniaxial negative
Refractive index	$n_\omega = 1.505$, $n_\varepsilon = 1.486$ (both ± 0.001)

2 - Structure and optical properties :

It has a hexagonal crystal system, meaning crystallographically it has three horizontal axes of equal length that make an angle of 120° with their positive ends, with a long vertical axis running perpendicular to them. The mineral is anisotropic, meaning the velocity of light through a mineral will vary depending on the direction that the light is going. It has a moderate relief ranging from 1.486 to 1.505. It has a birefringence of 0.019, with birefringence being the decomposition of a light ray into two different rays when light hits a mineral. Sacrofanite is uniaxial negative, meaning it has one optic axis and that the index of refraction for the ordinary ray is greater than the index of refraction for the extraordinary ray.

3 – Occurrence :

Sacrofanite is only found in the Sacrofano Caldera in Italy, yet it represents one of many new minerals found in Italian volcanoes. It can be found on display in The Mineralogical Museum at the University of Rome .

It occurs as a crystal coating within a vug in a rock ejected from the volcano. Other minerals occurring in the rock include sanidine, andradite, fassaite, leucite and hauyne.

63 - Saponite

1 – Introduction :

Saponite is a trioctahedral mineral of the smectite group. Its chemical Formula is $Ca_{0.25}(Mg,Fe)_3((Si,Al)_4O_{10})(OH)_2 \cdot n(H_2O)$.[2] It is soluble in sulfuric acid. It was first described in 1840 by von Svanberg. Varieties of saponite are griffithite, bowlingite and sobotkite.

It is soft, massive, and plastic, and exists in veins and cavities in serpentinite and basalt. The name is derived from the Greek *sapo*, soap. Other names include bowlingite; mountain soap; piotine; soapstone.

Category	Smectite, phyllosilicate
Chemical Formula	$Ca_{0.25}(Mg,Fe)_3((Si,Al)_4O_{10})(OH)_2 \cdot n(H_2O)$
Crystal symmetry	Monoclinic prismatic H-M symbol: (2/m) Space group: C 2/m
Unit cell	a = 5.3 Å, b = 9.14 Å, c = 16.9 Å; β = 97°; Z = 2
Color	White, yellow, red, green, blue
Crystal habit	Granular - Massive
Crystal system	Monoclinic
Tenacity	Brittle dry, plastic when hydrated
Mohs scale hardness	1.5
Luster	Greasy, dull

Streak	White
Diaphaneity	Translucent
Specific gravity	2.24 - 2.30
Optical properties	Biaxial (-)
Refractive index	n_α = 1.479 - 1.490 n_β = 1.510 - 1.525 n_γ = 1.511 - 1.527
Birefringence	δ = 0.032 - 0.037
Pleochroism	X = colorless, light yellow to green-brown; Y = Z = colorless, greenish brown to dark brown
2V angle	Calculated: 20° to 26°

2 - Occurrence :

Saponite was first described in 1840 for an occurrence in Lizard Point, Landewednack, Cornwall, England . It occurs in hydrothermal veins, in basalt vesicles, skarns, amphibolite and serpentinite. Associated minerals include celadonite, chlorite, native copper, epidote, orthoclase, dolomite, calcite and quartz.

Saponite is found in Ząbkowice Śląskie in Silesia, Svärdsjö in Dalarna, Sweden and in Cornwall, UK. The soap stone of Cornwall is used in the porcelain factory. Saponite is also found in the "dark rims" of chondrules in carbonaceous chondrites and seen as a sign of aqueous alteration.

64 - Sapphire ياقوت

The 423- carat (85 g) blue Logan sapphire

Contents

1 – Introduction :

Sapphire (Greek : *sappheiros*, "blue stone") is a gemstone variety of the mineral corundum, an aluminium oxide (α-Al_2O_3), when it is a color other than red or dark pink; in which case the gem would instead be called a ruby, considered to be a different gemstone. Trace amounts of other elements such as iron, titanium, or chromium can give corundum blue, yellow, pink, purple, orange, or greenish color. Pure chromium is the distinct impurity of rubies. However, a combination of e.g. chromium and titanium can give a sapphire a color distinct from red.

Sapphires are commonly worn in jewelry. Sapphires can be found naturally, by searching through certain sediments (due to their resistance to being eroded compared to softer stones), or rock formations, or they can be manufactured for industrial or decorative purposes in large crystal boules. Because of the remarkable hardness of sapphires (and of aluminum oxide in general), sapphires are used in some non-ornamental applications, including infrared optical components, such as in scientific instruments; high-durability windows (also used in scientific instruments); wristwatch crystals and movement bearings; and very thin electronic wafers, which are used as the insulating substrates of very special-purpose solid-state electronics (most of which are integrated circuits).

Category	Oxide mineral
Chemical Formula	aluminium oxide , Al_2O_3
Color	Every color except for red – which is called a ruby – or pinkish-orange (the padparadscha)
Crystal habit	massive and granular
Crystal system	Trigonal Symbol (32/m) Space Group: R3c
Cleavage	none
Fracture	conchoidal, splintery
Mohs scale hardness	9.0
Luster	vitreous
Streak	white
Specific gravity	3.95 – 4.03
Optical properties	Abbe number 72.2

Refractive index	n_ω=1.768–1.772 n_ε=1.760–1.763, Birefringence 0.008
Pleochroism	Strong
Melting point	2030–2050 °C
Fusibility	infusible
Solubility	Insoluble
Other characteristics	coefficient of thermal expansion $(5.0–6.6)\times10^{-6}$/K

2 - Natural sapphires :

The sapphire is one of the two or three gem-varieties of corundum, with another one being the red or deep pink ruby. Although blue is their most well-known color, sapphires are made up of any color of corundum except for red. Sapphires may also be colorless, and they are also found in shades of gray and black.

The cost of natural sapphires varies depending on their color, clarity, size, cut, and overall quality – as well as their geographic origin. Significant sapphire deposits are found in Eastern Australia, Thailand, Sri Lanka, Madagascar, East Africa, and in North America in a few locations, such as at "Gem Mountain", and in or near the Missouri River in the region around Helena, Montana.[2] Sapphire and rubies are often found together in the same area, but one gem is usually more abundant.

2 – 1 - Blue sapphire :

Color in gemstones breaks down into three components: hue, saturation, and tone. Hue is most commonly understood as the "color" of the gemstone. Saturation refers to the vividness or brightness or "colorfulness" of the hue, and tone is the lightness to darkness of the hue. Blue sapphire exists in various mixtures of its primary (blue) and secondary hues, various tonal levels (shades) and at various levels of saturation (brightness).

Blue sapphires are evaluated based upon the purity of their primary hue. Purple, violet, and green are the most common secondary hues found in blue sapphires . Violet and purple can contribute to the overall beauty of the color, while green is considered to be distinctly negative. Blue sapphires with up to 15 % violet or purple are generally said to be of fine quality. Blue sapphires with any amount of green as a secondary hue are not considered to be fine quality. Gray is the normal saturation modifier or mask found in blue sapphires. Gray reduces the saturation or brightness of the hue and therefore has a distinctly negative effect .

The color of fine blue sapphires can be described as a vivid medium dark violet to purplish blue where the primary blue hue is at least 85% and the secondary hue no more than 15 % without the least admixture of a green secondary hue or a gray mask .

The 423- carat (85 g) Logan sapphire in the National Museum of Natural History, in Washington, D.C., is one of the largest faceted gem-quality blue sapphires in existence.

2 – 2 - Fancy color sapphire :

Pink sapphire

Yellow and green sapphires are also commonly found. Pink sapphires deepen in color as the quantity of chromium increases. The deeper the pink color the higher their monetary value as long as the color is trending towards the red of rubies.

Sapphires also occur in shades of orange and brown, and colorless sapphires are sometimes used as diamond substitutes in jewelry. Padmaraga sapphires often draw higher prices than many of even the finest blue sapphires. Recently, more sapphires of this color have appeared on the market as a result of a new artificial treatment method that is called "lattice diffusion".

2 – 3 - Padmaraga :

Faceted padparadscha

Padmaraga is a pink-orange corundum, with a low to medium saturation and light tone, originally being mined in Sri Lanka, but also found in deposits in Vietnam and Africa; Padmaraga sapphires are rare. The name derives from the Sinhalese word for lotus blossom. The rarest of all padmaragas is the totally natural variety, with no sign of treatment.

2 – 4 - Star sapphire :

The Star of Bombay (182 carats (36 g))

A *star sapphire* is a type of sapphire that exhibits a star - like phenomenon known as asterism . Star sapphires contain intersecting needle - like inclusions (often the mineral rutile , a mineral composed primarily of titanium dioxide) that cause the appearance of a six-rayed "star"-shaped pattern when viewed with a single overhead light source.

The Black Star of Queensland is believed to be the largest star sapphire that has ever been mined, and it weighs 733 carats . The Star of India (weighing 563.4 carats) is thought to be the second-largest star sapphire, and it is currently on display at the American Museum of Natural History in New York City. The 182- carat Star of Bombay, located in the National Museum of Natural History, in Washington, D.C., is an example of a blue star sapphire. The value of a star sapphire, however, depends not only on the weight of the stone but also the body color, visibility and intensity of the asterism.

2 – 5 - Color change sapphire :

A rare variety of sapphire, known as color change sapphire, exhibits different colors in different light. Color change sapphires are blue in outdoor light and purple under incandescent indoor light; they may also be pink in daylight to greenish under fluorescent light. Some stones shift color well and others only partially, in that some stones go from blue to bluish purple. While color change sapphires come from a variety of locations, the gem gravels of Tanzania is the main source.

Certain synthetic color - change sapphires are sold as “lab” or “synthetic” alexandrite, which is accurately called an alexandrite simulant (also called alexandrium) since the latter is actually a type of chrysoberyl — an entirely different substance whose pleochroism is different and much more pronounced than color - change corundum (sapphire).

2 – 6 - Source of color :

Rubies are corundum which contain chromium impurities that absorb yellow-green light and result in deeper ruby red color with increasing content . Purple sapphires contain trace amounts of vanadium and come in a variety of shades . Corundum that contains ~ 0.01 % of titanium is colorless. If trace amounts of iron are present, a very pale yellow to green color may be seen. If both titanium and iron impurities are present together, how ever, the result is a magnificent deep - blue color.

Unlike localized ("interatomic") absorption of light which causes color for chromium and vanadium impurities, blue color in sapphires comes from intervalence charge transfer, which is the transfer of an electron from one transition-metal ion to another via the conduction or valence band. The iron can take the form Fe^{2+} or Fe^{3+}, while titanium generally takes the form Ti^{4+}. If Fe^{2+} and Ti^{4+} ions are substituted for Al^{3+}, localized areas of charge imbalance are created. An electron transfer from Fe^{2+} and Ti^{4+} can cause a change in the valence state of both. Because of the valence change there is a specific change in energy for the electron, and electro magnetic energy is absorbed. The wavelength of the energy absorbed corresponds to yellow light. When this light is subtracted from incident white light, the complementary color blue results. Sometimes when atomic spacing is different in different directions there is resulting blue-green dichroism.

Intervalence charge transfer is a process that produces a strong colored appearance at a low percentage of impurity. While at least 1% chromium must be present in corundum before the deep red ruby color is seen, sapphire blue is apparent with the presence of only 0.01% of titanium and iron.

2 – 7 - Treatments :

Sapphires may be treated by several methods to enhance and improve their clarity and color . It is common practice to heat natural sapphires to improve or enhance color. This is done by heating the sapphires in air to temperatures between 500 and 1800 °C for several hours, or by heating in a nitrogen-deficient atmosphere oven for seven days or more. Upon heating, the stone becomes a more blue in color but loses some of the rutile inclusions (silk) . When high heat temperatures are used, the stone loses all of the silk and becomes clear under magnification . Evidence of sapphire and other gemstones being subjected to heating goes back to, at least, Roman times. Un - heated stones are quite rare and will often be sold accompanied by a certificate from an independent gemological laboratory attesting to "no evidence of heat treatment".

Diffusion treatments are somewhat more controversial as they are used to add elements to the sapphire for the purpose of improving colors. Typically beryllium is diffused into a sapphire with very high heat, just below the melting point of the sapphire. Initially (c. 2000) orange sapphires were created with this process, although now the process has been advanced and many colors of sapphire are often treated with beryllium. It is unethical to sell beryllium-treated sapphires without disclosure, and the price should be much lower than a natural gem or one that has been enhanced by heat alone.

Treating stones with surface diffusion is generally frowned upon because when stones chip or are repolished/refaceted the 'padparadscha' colored layer can be removed. (There are some diffusion treated stones in which the color goes much deeper than the surface, however.) The problem lies in the fact that treated padparadschas are at times very difficult to detect, and they are the reason that getting a certificate from a reputable gemological lab (e.g., Gubelin, SSEF, AGTA, etc.) is recommended before investing in them.

According to Federal Trade Commission guidelines, in the United States, disclosure is required of any mode of enhancement that has a significant effect on the gem's value.[15]

3 - Mining :

Sapphires are mined from alluvial deposits or from primary underground workings. The mining locations include Burma, Madagascar, Sri Lanka, Australia, Thailand, India, Pakistan, Afghanistan, Tanzania, Kenya, and China . The Logan sapphire, the Star of India , and the Star of Bombay originate from Sri Lankan mines. Madagascar is the world leader in sapphire production (as of 2007) specifically its deposits in and around the city of Ilakaka . Prior to the opening of the Ilakaka mines, Australia was the largest producer of sapphires (such as in 1987) . In 1991, a new source of sapphires was discovered in Andranondambo, southern Madagascar. That area has been exploited for its sapphires started in 1993, but it was practically abandoned just a few years later – because of the difficulties in recovering sapphires in their bedrock .

In North America, sapphires have been mined mostly from deposits in Montana: fancies along the Missouri River near Helena, Montana, Dry Cottonwood Creek near Missoula, Montana, and Rock Creek near Philipsburg, Montana. Fine blue Yogo sapphires are found at Yogo Gulch west of Lewistown, Montana . A few gem - grade sapphires and rubies have also been found in the area of Franklin, N.C.

The sapphire deposits of Kashmir are still well-known in the gem industry,[21] despite the fact that the peak production from this area mostly took place in a relatively short period at the end of the 19th and early 20th centuries .

4 - Synthetic sapphire ;

	
Synthetic sapphire	*Synthetic star sapphire*

In 1902, the French chemist Auguste Verneuil developed a process for producing synthetic sapphire crystals.[23] In the Verneuil process, named for him, fine alumina powder is added to an oxyhydrogen flame, and this is directed downward against a mantle . The alumina in the flame is slowly deposited, creating a teardrop shaped "boule" of sapphire material. Chemical dopants can be added to create artificial versions of the ruby, and all the other natural colors of sapphire, and in addition, other colors never seen in geology. Artificial sapphire material is identical to natural sapphire, except it can be made without the flaws that are found in natural stones. The disadvantage of Verneuil process is that the grown crystals have high internal strains. Many methods of manufacturing sapphire today are variations of the Czochralski process, which was invented in 1916. In this process, a tiny sapphire seed crystal is dipped into a crucible made of the precious metal rhodium, containing molten alumina, and then slowly with drawn up ward at a rate of one to 100 mm per hour. The alumina crystallizes on the end, creating long carrot-shaped boules of large size, up to 400 mm in diameter and weighing almost 500 kg.

Synthetic sapphire is industrially produced from agglomerated aluminum oxide, sintered and fused in an inert atmosphere (hot isostatic pressing for example), yielding a transparent polycrystalline product, slightly porous, or with more traditional methods such as Verneuil, Czochralski, flux method, etc., yielding a single crystal sapphire material which is non-porous and should be relieved of its internal stress.

In 2003, the world's production of synthetic sapphire was 250 tons (1.25×10^9 carats), mostly by the United States and Russia.[27][28] The availability of cheap synthetic sapphire unlocked many industrial uses for this unique material:

The first laser was made with a rod of synthetic ruby. Titanium-sapphire lasers are popular due to their relatively rare capacity to be tuned to various wavelengths in the red and near-infrared region of the electromagnetic spectrum. They can also be easily mode-locked. In these lasers, a synthetically produced sapphire crystal with chromium or titanium impurities is irradiated with intense light from a special lamp, or another laser, to create stimulated emission.

4 – 1 - Transparent and tough :

One application of synthetic sapphire is *sapphire glass*. Here *glass* is a layman term which refers not to the amorphous state, but to the transparency. Sapphire is not only highly transparent to wavelengths of light between 170 nm (UV) and 5300 nm (IR) (the human eye can discern wavelengths from about 380 nm to 750 nm[29]), but it is also five times stronger than glass and ranks a 9 on the Mohs Scale, and much tougher than tempered glass, although not as much as synthetic stabilized zirconium oxide (such as yttria-stabilized zirconia). Along with zirconia and aluminium oxynitride, synthetic sapphire is used for shatter resistant windows in armored vehicles and various military body armor suits, in association with composites.

Sapphire "glass" (although being crystalline) is made from pure sapphire boules by slicing off and polishing thin wafers. Sapphire glass windows are used in high pressure chambers for spectroscopy, crystals in high quality watches, and windows in grocery store barcode scanners since the material's exceptional hardness and toughness makes it very resistant to scratching.

One type of xenon arc lamp (originally called the "Cermax" its first brand name), which is now known generically as the "ceramic body xenon lamp", uses sapphire crystal output windows that tolerate higher thermal loads – and thus higher output powers when compared with conventional Xe lamps with pure silica window.

4 – 2 - Use as substrate for semiconducting circuits :

Thin sapphire wafers are also used as an insulating substrate in high-power, high-frequency CMOS integrated circuits. This type of IC is called a silicon on sapphire or "SOS" chip. These are especially useful for high-power radio-frequency (RF) applications such as those found in cellular telephones, police car and fire truck radios, and satellite communication systems. "SOS" allows for the monolithic integration of both digital and analog circuitry all on one IC chip.

The reason for choosing wafers of artificial sapphire, rather than some of other substance, for these substrates is that sapphire has a quite low conductivity for electricity, but a much-higher conductivity for heat. Thus, sapphire provides good electrical insulation, while at the same time doing a good job at helping to conduct away the significant heat that is generated in all operating integrated circuits. Thus, the choice of sapphire material for these substrates was not an arbitrary one, but rather, it is a choice that is made for serious electronics engineering reasons.

Once the single crystal sapphire boules are grown they are cored-sliced into cylindrical pieces. Wafers are then sliced from these cylindrical cores. These Wafers of single-crystal sapphire material are also used in the semiconductor industry as a non-conducting substrate for the growth of devices based on gallium nitride (GaN). The use of the sapphire material significantly reduces the cost, because this has about one-seventh the cost of germanium. Gallium nitride on sapphire is commonly used in blue light-emitting diodes (LEDs).

5 - Historical and cultural references :

- Etymologically, the English word “sapphire” derives from Latin *sapphirus*, *sappirus* from Greek *sappheiros* from Old Iranian *sani-prijam,*
- The Greek term for sapphire quite likely was misapplied, and instead used to refer to lapis lazuli.

- During the Medieval Ages, European lapidaries came to refer to blue corundum crystal by its “sapphire-blue” color, whence the modern name for “sapphire”.

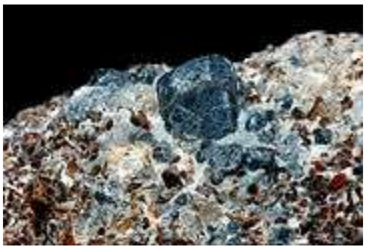
65 – Sapphirine

Indigo-blue sapphirine crystal from Ft. Dauphin, Madagascar

1 – Introduction :

Sapphirine is a rare mineral, a silicate of magnesium and aluminium with the chemical Formula $(Mg,Al)_8(Al,Si)_6O_{20}$ (with iron as a major impurity). Named for its sapphire-like colour, sapphirine is primarily of interest to researchers and collectors: well-formed crystals are treasured and occasionally cut into gemstones. Sapphirine has also been synthesized for experimental purposes via a hydrothermal process.

2 – Properties :



Sapphirine from Madagascar

Typical colours range from light to dark sapphire blue, bluish to brownish green, green, and bluish or greenish gray to black; less common colours include yellow, pale red, and pink to purplish pink.

Sapphirine is relatively hard (7.5 on Mohs scale), usually transparent to translucent, with a vitreous lustre. Crystallising in the monoclinic system, sapphirine is typically anhedral or granular in habit, but may also be tabular or in aggregates: Twinning is uncommon. Fracture is subconchodial to uneven, and there is one direction of perfect cleavage. The specific gravity of sapphirine is 3.54–3.51, and its streak is white.

Sapphirine's refractive index (as measured by monochromatic sodium light, 589.3 nm) ranges from 1.701 to 1.718 with a birefringence of 0.006–0.007, biaxial negative. Refractive index values may correspond to colour: brownish green specimens will possess the highest values, purplish-pink specimens the lowest, and blue specimens will be intermediate between them. Pleochroism may be extreme, with trichroic colours ranging from: colourless, pale yellow or red; sky to lavender blue, or bluish-green; to dark blue. There is no reaction under ultraviolet light.

[edit] Formation and occurrence

While there is evidence of magmatic origin in some deposits, sapphirine is primarily a product of high grade metamorphism in environments poor in silica and rich in magnesium and aluminium. However, sapphirine occurs in a variety of rocks, including granulite and amphibolite facies, calc-silicate skarns, and quartzites; it is also known from xenoliths. Associated minerals include: calcite, chrysoberyl, cordierite, corundum, garnet, kornerupine, kyanite, phlogopite, scapolite, sillimanite, spinel, and surinamite.

Large crystals of fine clarity and colour are known from very few locales: The Central Province (Hakurutale and Munwatte) of Sri Lanka has long been known as a source of facetable greenish blue to dark blue material, and crystals up to 30 mm or more in size have been found in Fianarantsoa (Betroka District) and Toliara Province (Androy and Anosy regions), southern Madagascar. Sapphirine's type locality is Fiskenaesset (Fiskenaes), Nuuk region, western Greenland, which is where the mineral was discovered in 1819.

Other notable localities include: Western Hoggar, Algeria; the Napier complex of Enderby Land and the Vestfold Hills of Antarctica; Delegate, New South Wales and the Strangways Range of the Northern Territory, Australia; Wilson Lake, Labrador; Donghai, Jiangsu province, China; Kittilä, Lapland, Finland; Ariège, Midi-Pyrénées, France; Waldheim, Saxony, Germany; Dora Maira Massif, Province of Cuneo, Piedmont, Italy; Ulstein, Møre og Romsdal, and Meløy, Nordland, Norway; the Messina District of Limpopo Province and the Okiep Copper District of Northern Cape Province, South Africa; Falkenberg Municipality, Halland County, Sweden; Mautia Hill in the Kongwa region of Central Province, Tanzania; Isle of Harris, Outer Hebrides, Scotland; the Bani Hamid area of Semail Ophiolite, United Arab Emirates; the Dome Rock Mountains of La Paz County, Arizona, Stockdale, Riley County, Kansas; Cortlandt, New York; and Clay County, North Carolina.

66 – Scolecite

Scolecite specimen from India

Contents

1 – Introduction :

Scolecite is a tectosilicate mineral belonging to the zeolite group; it is a hydrated calcium silicate, $CaAl_2Si_3O_{10}.3H_2O$. Only minor amounts of sodium and traces of potassium substitute for calcium. There is an absence of barium, strontium, iron and magnesium[1][5]. Scolecite is isostructural (having the same structure) with the sodium-calcium zeolite mesolite and the sodium zeolite natrolite, but it does not form a continuous chemical series with either of them[1]. It was described in 1813, and named from the Greek word, σκώληξ = 'worm' because of its reaction to the blowpipe flame.

2 - Crystal Class :

It is monoclinic m with space group Cc, but crystals are pseudotetragonal. Scolecite, like natrolite and mesolite, usually occurs as acicular (needle-like) and fibrous aggregations. It has nearly the same angles between the crystal faces as does natrolite, but natrolite is orthorhombic and scolecite is monoclinic. The etched figures (figures that arise from the action of a solvent on a crystal face, and indicate its true symmetry) and the pyroelectric character of scolecite show that it crystallizes with a plane of symmetry, but no axis of symmetry, that is to say it belongs to the hemihedral class of the monoclinic system. Scolecite can therefore be distinguished from natrolite by an optical examination, since the acicular crystals do not extinguish parallel to their length between crossed nicol prisms. Twinning on the ortho-pinacoid is usually evident.

3 - Structure :

The structure of the aluminosilicate framework is the same for scolecite, natrolite and mesolite. Scolecite has long ordered chains, rotated 24° round the axis of the chain. One Ca cation and three H_2O molecules are in four ion sites in the channels parallel to the c crystal axis. There is no sign of aluminium ions occupying silicon ion sites .

4 - Unit Cell :s

Scolecite is a monoclinic mineral, with the angle β equal to about 109° and four Formula units per unit cell (Z = 4). Described in this way, various sources give the following values for the parameters of the unit cell, which has one long side and two short ones :

- a = 6.516 to 6.517 Å, b = 18.948 to 18.956 Å, c = 9.761 to 9.765 Å, β = 108.86 to 108.98°
- a = 6.52 to 6.53 Å, b = 18.96 to 18.97 Å, c = 9.76 to 9.78 Å, β = 108.9°
- a = 6.516 Å, b = 18.948 Å, c = 9.761 Å, β = 108.98°

Crystals, however, are pseudotetragonal, and this can be represented by taking a different unit cell, with twice as many Formula units (Z = 8) and two long sides and one short one. The axes are redefined, a and b are very nearly equal and the angle β between the new a and c axes is very nearly equal to 90° (a truly tetragonal crystal would have a = b and β = 90° exactly). The sources give the following values :

- a=18.488 to 18.508 Å, b=18.891 to 18.96 Å, c=6.527 to 6.548 Å, β = 90.64 to 90.75°
- a = 18.508(5) Å, b = 18.981(5) Å, c = 6.527(2) Å β = 90.64°
- a = 18.508(5) Å, b = 18.981(5) Å, c = 6.527(2) Å, β = 90:64(1)°
- a = 18.51 Å, b = 18.97 Å, c = 6.53 Å, β = 90.6°

5 - Crystal Habits :

Scolecite commonly occurs as sprays of thin, prismatic needles, frequently flattened on one side, with slanted terminations and striated parallel to the length of the needles. The crystals appear to be pseudo-orthorhombic or pseudo-tetragonal, and may be square in cross section . It also occurs as radiating groups and fibrous masses. Epitaxial intergrowths (intergrowths of two different crystalline substances in an non-random way) with mesolite, $Na_2Ca_2Al_6Si_9O_{30}.8H_2O$, are common. (Natrolite, $Na_2Al_2Si_3O_{10}.2H_2O$, does not directly form epitaxial overgrowths on scolecite). All three minerals may be developed in the same crystal . Scolecite crystals appear to be monoclinic by X-ray analysis .

6 - Physical Properties :

Scolecite is usually colorless or white, but can also be pink, salmon, red or green. It is transparent to translucent, with a white streak and a luster which is vitreous, or silky for fibrous specimens. It has a Mohs hardness of 5 to 5½ and a specific gravity in the range 2.16 to 2.40. (2.24 to 2.31 2.25 to 2.29 2.16 to 2.4 2.25 to 2.31 . Cleavage is perfect in two directions parallel to the length of the crystals; the mineral is brittle with an irregular fracture. Twinning is common on {100}, twin axis [001], as penetration or contact twins producing V-shaped or fishtail terminations. Scolecite is pyroelectric and piezoelectric, sometimes fluorescent yellow to brown in longwave and shortwave ultraviolet light . It is soluble in common acids . Not radioactive.

7 - Optical Properties :

Biaxial (-) with refractive indices: N_x = 1.507 to 1.513, N_y = 1.516 to 1.520, N_z = 1.517 to 1.521. Pleochroism has been reported, X: colorless Y: colorless Z: colorless .

8 – Environment :

Scolecite is a common zeolite. It is a mineral of secondary origin, and occurs with other zeolites in the amygdaloidal cavities (cavities filled with secondary minerals) of weathered basalts, also in gneisses and amphibolites, and in laccoliths and dikes derived from syenitic and gabbroic magmas, and in contact metamorphic zones. It is a hydrothermal mineral derived from low temperature alteration of basalts and related rocks, associated with other zeolites, calcite, quartz and prehnite. It can be found on top of the calcium zeolites heulandite, stilbite and epistilbite . Associated minerals include quartz, apophyllite, babingtonite, heulandite, stilbite and other zeolites.

9 – Localities :

Scolecite was first described from Kaiserstuhl in Baden-Württemberg in 1813. Divergent groups of prismatic crystals are found in the basalt of Berufjördur near Djupivogr, Suður-Múlasýsla, Iceland and in the Deccan Traps near Pune in India; hence the synonym poonahlite for this species. Other occurrences include Riverside County, California; Skye, Scotland and Santa Catarina, Brazil.

There is no type locality. Most of the world's finest scolecite specimens are found in the Tertiary Deccan Basalt near Nasik, Pune, in the state of Maharashtra, India. The quarries in the Nasik region produce large, colourless sprays of well terminated coarse scolecite crystals that are commonly twinned on {100} to form V-shaped terminations with V-shaped striations on {010}. The scolecite is commonly found alone or on stilbite and is covered with laumontite or colourless, pale green or white fluorapophyllite. It is also found in the region as massive radiating material with powellite, and in cavities in basalt as colourless, flattened crystals in radiating sprays on blocky green apophyllite covered by tiny, thin, colourless apophyllite plates[5].

Scolecite has been reported from many other localities, including Antarctica, Australia, Austria, Brazil, Bulgaria, Canada, Chile, Czechoslovakia, Ethiopia, Faroe Islands, France, Germany, Greenland, Hungary, Iceland, Italy, Japan, Mexico, Mozambique, Nicaragua, Peru, Poland, South Africa, Sweden, Switzerland, Taiwan, United Kingdom, United States and Yugoslavia .

67 – Sodalite

A sample of sodalite

1 – Introduction :

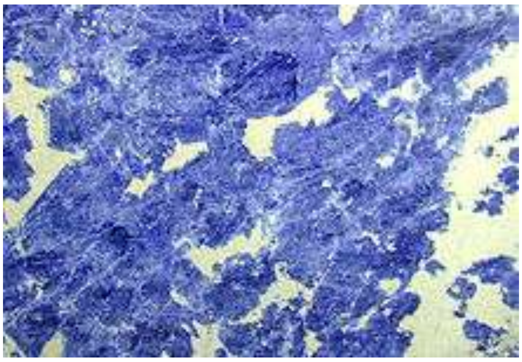
Sodalite is a rich royal blue mineral widely enjoyed as an ornamental gemstone. Although massive sodalite samples are opaque, crystals are usually transparent to translucent. Sodalite is a member of the sodalite group with hauyne, nosean, lazurite and tugtupite.

Discovered in 1811 in the Ilimaussaq intrusive complex in Greenland, sodalite did not become important as an ornamental stone until 1891 when vast deposits of fine material were discovered in Ontario, Canada.

Category	Mineral
Chemical Formula	$Na_8Al_6Si_6O_{24}Cl_2$
Crystal symmetry	Isometric hextetrahedral
Unit cell	a = 8.876 (6) Å ; Z = 1
Color	Rich royal blue, green, yellow, violet, white veining common
Crystal habit	Massive ; rarely as dodecahedra
Crystal system	Cubic
Fracture	Conchoidal to uneven

Tenacity	Brittle
Mohs scale hardness	5.5- 6
Luster	Dull vitreous to greasy
Streak	White
Diaphaneity	Transparent to translucent
Specific gravity	2.27 - 2.33
Optical properties	Isotropic
Refractive index	n = 1.483 - 1.487
Ultra violet fluorescence	Bright red-orange cathodoluminescence and fluorescence under LW and SW UV, with yellowish phosphorescence ; may be photochromic in magentas
Fusibility	Easily to a colourless glass; sodium yellow flame
Solubility	Soluble in hydrochloric and nitric acids
Other characteristics	Odor of H_2S emitted on fracture
Hackmanite	Tenebrescent; violet-red or green fading to white

2 – Properties :



*A sample of **sodalite**-carbonate pegmatite from Bolivia, with a polished rock surface.*

A light, relatively hard yet fragile mineral, sodalite is named after its sodium content; in mineralogy it may be classed as a feldspathoid. Well known for its blue color, sodalite may also be grey, yellow, green, or pink and is often mottled with white veins or patches. The more uniformly blue material is used in jewellery, where it is fashioned into cabochons and beads. Lesser material is more often seen as facing or inlay in various applications.

Although somewhat similar to lazurite and lapis lazuli, sodalite rarely contains pyrite (a common inclusion in lapis) and its blue color is more like traditional royal blue rather than ultramarine. It is further distinguished from similar minerals by its white (rather than blue) streak. Sodalite's six directions of poor cleavage may be seen as incipient cracks running through the stone.

3 – Hackmanite :

Hackmanite dodecahedron from the Koksha Valley, Afghanistan

Hackmanite is an important variety of sodalite exhibiting tenebrescence. When hackmanite from Mont Saint-Hilaire (Quebec) or Ilímaussaq (Greenland) is freshly quarried, it is generally pale to deep violet but the colour fades quickly to greyish or greenish white. Conversely, hackmanite from Afghanistan and the Myanmar Republic (Burma) starts off creamy white but develops a violet to pink-red colour in sunlight. If left in a dark environment for some time, the violet will fade again. Tenebrescence is accelerated by the use of longwave or, particularly, shortwave ultraviolet light. Much sodalite will also fluoresce a patchy orange under UV light.

4 – Occurrence :

Sodalite was first described in 1811 for the occurrence in its type locality in the Ilimaussaq complex, Narsaq, West Greenland.

Occurring typically in massive form, sodalite is found as vein fillings in plutonic igneous rocks such as nepheline syenites. It is associated with other minerals typical of undersaturated environments, namely leucite, cancrinite and natrolite. Other associated minerals include nepheline, titanian andradite, aegirine, microcline, sanidine, albite, calcite, fluorite, ankerite and baryte.[3]

Significant deposits of fine material are restricted to but a few locales: Bancroft, Ontario, and Mont-Saint-Hilaire, Quebec, in Canada; and Litchfield, Maine, and Magnet Cove, Arkansas, in the USA. The Ice River complex, near Golden, British Columbia, contains sodalite.[5] Smaller deposits are found in South America (Brazil and Bolivia), Portugal, Romania, Burma and Russia. Hackmanite is found principally in Mont-Saint-Hilare and Greenland.

Euhedral, transparent crystals are found in northern Namibia and in the lavas of Vesuvius, Italy.

This hippopotamus ornament carved from sodalite demonstrates the mineral's poor cleavage - cracks can be seen throughout the stone.

68 – Spinel

Contents

1 – Introduction :

Spinel is the magnesium aluminium member of the larger spinel group of minerals. It has the Formula $MgAl_2O_4$. **Balas ruby** is an old name for a rose-tinted variety.

Category	Oxide minerals - Spinel group
Chemical Formula	$MgAl_2O_4$
Color	Various, red to blue to mauve. Dark green, brown. Black
Crystal habit	Cubic, octahedral
Crystal system	Isometric
Cleavage	Indistinct
Fracture	Conchoidal, uneven
Mohs scale hardness	7.5 – 8.0
Luster	Vitreous

Streak	White
Diaphaneity	Transparent to translucent
Specific gravity	3.6 – 4.1
Optical properties	Isotropic
Refractive index	1.719
Pleochroism	Absent
Solubility	none
Other characteristics	Nonmagnetic, non-radioactive, sometimes fluorescent (red)

2 - Spinel group :

The **spinels** are any of a class of minerals of general Formulation $A^{2+}B_2{}^{3+}O_4{}^{2-}$ which crystallise in the cubic (isometric) crystal system, with the oxide anions arranged in a cubic close-packed lattice and the cations A and B occupying some or all of the octahedral and tetrahedral sites in the lattice. A and B can be divalent, trivalent, or quadrivalent cations, including magnesium, zinc, iron, manganese, aluminium, chromium, titanium, and silicon. Although the anion is normally oxide, the analogous thiospinel structure includes the rest of the chalcogenides. A and B can also be the same metal under different charges, such as the case in Fe_3O_4 (as $Fe^{2+}Fe_2{}^{3+}O_4{}^{2-}$).

Members of the spinel group include :

- Aluminium spinels:
    - Spinel: $MgAl_2O_4$, after which this class of minerals is named
    - Gahnite: $ZnAl_2O_4$
    - Hercynite: $FeAl_2O_4$
- Iron spinels:
    - Cuprospinel: $CuFe_2O_4$
    - Franklinite: $(Fe,Mn,Zn)(Fe,Mn)_2O_4$
    - Jacobsite: $MnFe_2O_4$

    - Magnetite: Fe_3O_4
    - Trevorite: $NiFe_2O_4$
    - Ulvöspinel: $TiFe_2O_4$
    - Zinc ferrite: (Zn, Fe) Fe_2O_4
- Chromium spinels:
    - Chromite: $FeCr_2O_4$
    - Magnesiochromite: $MgCr_2O_4$
- Others with the spinel structure:
    - Ringwoodite: $(Mg,Fe)_2SiO_4$, an abundant olivine polymorph within the Earth's mantle from about 520 to 660 km depth, and a rare mineral in meteorites

There are many more compounds with a spinel structure, e.g. the thiospinels and selenospinels, that can either be synthesized in the lab or in some cases occur as minerals.

3 - Properties of true spinel :

Spinel crystallizes in the isometric system; common crystal forms are octahedra, usually twinned. It has an imperfect octahedral cleavage and a conchoidal fracture. Its hardness is 8, its specific gravity is 3.5-4.1 and it is transparent to opaque with a vitreous to dull luster. It may be colorless, but is usually various shades of red, blue, green, yellow, brown or black. There is a unique natural white spinel, now lost, that surfaced briefly in what is now Sri Lanka. Some spinels are among the most famous gemstones: Among them is the Black Prince's Ruby and the 'Timur ruby' in the British Crown Jewels, and the 'cote de Bretagne' formerly from the French Crown jewels. The Samarian Spinel is the largest known spinel in the world, weighing 500 carats (100 g).

The transparent red spinels were called spinel-rubies or balas rubies. In the past, before the arrival of modern science, spinels and rubies were equally known as rubies. After the 18th century the word ruby was only used for the red gem variety of the mineral corundum and the word spinel became used. "Balas" is derived from Balascia, the ancient name for Badakhshan, a region in central Asia situated in the upper valley of the Kokcha River, one of the principal tributaries of the Oxus River. The Badakshan Province was for centuries the main source for red and pink spinels.

4 – Occurrence :

Cut spinel

True spinel has long been found in the gemstone-bearing gravel of Sri Lanka and in limestones of the Badakshan Province in modern day Afghanistan and of Mogok in Burma. Recently gem quality spinels were also found in the marbles of Luc Yen (Vietnam), Mahenge and Matombo (Tanzania), Tsavo (Kenya) and in the gravels of Tunduru (Tanzania) and Ilakaka (Madagascar). Spinel is found as a metamorphic mineral, and also as a primary mineral in rare mafic igneous rocks; in these igneous rocks, the magmas are relatively deficient in alkalis relative to aluminium, and aluminium oxide may form as the mineral corundum or may combine with magnesia to form spinel. This is why spinel and ruby are often found together.

Spinel, $(Mg,Fe)(Al,Cr)_2O_4$, is common in peridotite in the uppermost Earth's mantle, between approximately 20 km to approximately 120 km, possibly to lower depths depending on the chromium content . At significantly shallower depths, above the Moho, calcic plagioclase is the more stable aluminous mineral in peridotite, while garnet is the stable phase deeper in the mantle below the spinel stability region.

Spinel, $(Mg,Fe)Al_2O_4$, is a common mineral in the Ca-Al-rich inclusions (CAIs) in some chondritic meteorites.

5 - The spinel structure :

Normal spinel structures are usually cubic closed-packed oxides with one octahedral and two tetrahedral sites per oxide. The tetrahedral points are smaller than the octahedral points. B^{3+} ions occupy the octahedral holes because of a charge factor, but can only occupy half of the octahedral holes. A^{2+} ions occupy 1/8 of the tetrahedral holes. This maximises the lattice energy if the ions are similar in size. A common example of a normal spinel is $MgAl_2O_4$.

Inverse spinel structures however are slightly different in that one must take into account the crystal field stabilization energies (CFSE) of the transition metals present. Some ions may have a distinct preference on the octahedral site which is dependent on the *d-electron* count. If the A^{2+} ions have a strong preference for the octahedral site, they will force their way into it and displace half of the B^{3+} ions from the octahedral sites to the tetrahedral sites. If the B^{3+} ions have a low or zero *octahedral site stabilization energy* (OSSE), then they have no preference and will adopt the tetrahedral site. A common example of an inverse spinel is Fe_3O_4, if the Fe^{2+} (A^{2+}) ions are d^6 high-spin and the Fe^{3+} (B^{3+}) ions are d^5 high-spin.

For many years, crystal field theory was invoked to explain the distribution of the cations within the spinels. As the octahedral and tetrahedral sites in the lattice generate different amounts of CFSE, it was argued that the arrangement of the two types of cation that generated the most CFSE would be the most stable. However, this idea was challenged by Burdett and co-workers, who showed that a better treatment used the relative sizes of the s and p atomic orbitals of the two types of atom to determine their site preference.[5] This is because the dominant stabilizing interaction in the solids is not the crystal field stabilization energy generated by the interaction of the ligands with the d-electrons, but the σ-type interactions between the metal cations and the oxide anions. This rationale can explain anomalies in the spinel structures that crystal-field theory cannot, such as the marked preference of Al^{3+} cations for octahedral sites or of Zn^{2+} for tetrahedral sites - using crystal field theory would predict that both have no site preference. Only in cases where this size-based approach indicates no preference for one structure over another do crystal field effects make any difference — in effect they are just a small perturbation that can sometimes make a difference, but which often do not.

6 - Synthetic spinel :

Synthetic spinel was accidentally produced in the middle of the 18th century, and has been more recently described in scientific publications in 2000 and 2004.

69 – Spodumene

	
Kunzite Nouristan	*Walnut Hill Pegmatite Prospect, Huntington, Hampshire County, Massachusetts, USA*

Contents :

1 – Introduction :

Spodumene is a pyroxene mineral consisting of lithium aluminium inosilicate, $LiAl(SiO_3)_2$, and is a source of lithium. It occurs as colorless to yellowish, purplish, or lilac kunzite , yellowish-green or emerald-green hiddenite, prismatic crystals, often of great size. Single crystals of 14.3 m in size are reported from the Black Hills of South Dakota, United States.

The normal low-temperature form α-spodumene is in the monoclinic system whereas the high-temperature β-spodumene crystallizes in the tetragonal system. The normal α-spodumene converts to β-spodumene at temperatures above 900 °C. Crystals are typically heavily striated parallel to the principal axis. Crystal faces are often etched and pitted with triangular markings.

2 - Discovery and occurrence :

Spodumene was first described in 1800 for an occurrence in the type locality in Utö, Södermanland, Sweden. The name is derived from the Greek *spodumenos* , meaning "burnt to ashes," owing to the opaque, ash-grey appearance of material refined for use in industry.

Spodumene occurs in lithium-rich granite pegmatites and aplites. Associated minerals include : quartz, albite, petalite, eucryptite, lepidolite and beryl.

Transparent material has long been used as a gemstone with varieties kunzite and hiddenite noted for their strong pleochroism. Source localities include Afghanistan, Australia, Brazil, Madagascar, Pakistan, Québec in Canada and North Carolina, California in the USA.

3 - Economic importance :

Spodumene is an important source of lithium for use in ceramics, mobile phone and automotive batteries, medicine and as a fluxing agent. Lithium is extracted from spodumene by fusing in acid.

World production of lithium via spodumene is around 80,000 metric tonnes per annum, primarily from the Greenbushes pegmatite of Western Australia, and some Chinese and Chilean sources. The Talison mine in Greenbushes, Western Australia has an estimated reserve of 13 million tonnes.

Some think that spodumene will become a less important source of lithium due to the emergence of alkaline brine lake sources in Chile, China and Argentina, which produce lithium chloride directly. Lithium chloride is converted to lithium carbonate and lithium hydroxide by reaction with sodium carbonate and calcium hydroxide respectively.

But, pegmatite-based projects benefit from being quicker to move into production than brines, which can take 18 months to 3 years, depending on evaporation rates. With pegmatites, once a mill is built, the production of lithium carbonate is only a matter of days.

Another key advantage that spodumene has over its more popular brine rivals, is the purity of the lithium carbonate it can produce. While all product used by the battery industry have to grade at least 99.5 % lithium carbonate, the make up of that final 0.5 % is important. If it contains higher amounts of iron, magnesium or other deleterious materials it is less attractive to end users.

4 - Gemstone varieties :

4 – 1 – Hiddenite :

Hiddenite is a pale emerald green gem variety first reported from Alexander County, North Carolina, U. S. A.

4 – 2 – Kunzite :

Kunzite is a pink to lilac colored gemstone, a variety of spodumene with the color coming from minor to trace amounts of manganese. Some (but not all) kunzite used for gemstones has been heated to enhance its color. It is also frequently irradiated to enhance the color. Many kunzites fade when exposed to sunlight. It was discovered in 1902, and was named after George Frederick Kunz, Tiffany & Co's chief jeweler at the time, and a noted mineralogist. It has been found in Brazil, USA, Canada, CIS, Mexico, Sweden, Western Australia, Afghanistan and Pakistan.

70 - Staurolite

Contents

1 – Introduction :

Staurolite is a red brown to black, mostly opaque, neso silicate mineral with a white streak.

Category	Silicate mineral
Chemical Formula	$(Fe^{2+},Mg,Zn)_{1.5\text{-}2}Al_9[O_6\vert(OH,O)_2\vert(SiO_4)_4]$
Crystal symmetry	Monoclinic 2/m
Unit cell	a = 7.86 Å, b = 16.6 Å, c = 5.65 Å; β = 90.45°; Z=2
Color	Dark reddish brown to blackish brown, yellowish brown, rarely blue; pale golden yellow in thin section
Crystal habit	Commonly in prismatic crystals
Crystal system	Monoclinic - Prismatic; Pseudo-orthorhombic
Twinning	Commonly as 60° twins, less common as 90° cruciform twins
Fracture	Subconchoidal
Tenacity	Brittle

Mohs scale hardness	7 - 7.5
Luster	Subvitreous to resinous
Streak	White to grayish
Diaphaneity	Transparent to opaque
Specific gravity	3.74 - 3.83 meas. 3.686 calc.
Optical properties	Biaxial (+)
Refractive index	$n_\alpha = 1.736 - 1.747$ $n_\beta = 1.740 - 1.754$ $n_\gamma = 1.745 - 1.762$
Pleochroism	Pleochroism: X = colorless; Y = pale yellow; Z = golden yellow
2V angle	Measured: 88°, Calculated: 84° to 88°

2 - Properties :

It crystallizes in the monoclinic crystal system, has a Mohs hardness of 7 to 7.5 and a rather complex chemical Formula: $(Fe,Mg,Zn)_2Al_9(Si,Al)_4O_{20}(OH)_4$. Iron, magnesium and zinc occur in variable ratios.

A special property of staurolite is that it often occurs twinned in a characteristic cross-shape. In handsamples, macroscopically visible staurolite crystals are of prismatic shape. They are often larger than the surrounding minerals and are then called porphyroblasts.

In thin sections staurolite is commonly twinned and shows lower first order birefringence similar to quartz, with the twinning displaying optical continuity. It can be identified in metamorphic rocks by its swiss cheese appearance (with poikilitic quartz) and often mantled porphyroblastic character.

3 – Name :

The name is derived from the Greek, *stauros* for cross and *lithos* for stone in reference to the common twinning.

4 – Occurrence :

Staurolite is a regional metamorphic mineral of intermediate to high grade. It occurs with almandine garnet, micas, kyanite; as well as albite, biotite, and sillimanite in gneiss and schist of regional metamorphic rocks.

It is the official state mineral of the U.S. state of Georgia and is also to be found in the Lepontine Alps in Switzerland.

Staurolite is also found in Fairy Stone State Park in Patrick County, Virginia. The park is named for a local name for staurolite from a legend in the area.

5 – Use :

Staurolite is one of the index minerals that are used to estimate the temperature, depth, and pressure at which a rock undergoes metamorphism.

71 - Stellerite

Contents

1 – Introduction :

Stellerite has a general Formula of $Ca[Al_2Si_7O_{18}]\cdot 7H_2O$. It is named after Georg Wilhelm Steller (1709–1746) who was a German explorer and zoologist that discovered it . Like most rare minerals, there aren't many commercial uses for stellerite yet. Mineral collectors are lucky to find it in good enough crystal form. Zeolites, including Stellerite, have been studied using a dehydration process to gauge the potential use of their phases as molecular sieves, sorbents, and catalysts.

Category	Mineral
Chemical Formula	$Ca(Al_2Si_7O_{18})\bullet 7H_20$
Color	Colorless to white, pink, orange
Crystal habit	Spherical, Stellate, Tabular
Crystal system	Orthorhombic
Fracture	Uneven
Mohs scale hardness	4.5
Luster	Pearly
Streak	white
Diaphaneity	Transparent to translucent
Specific gravity	approximately 2.2
Density	2.13 g / cm3

Optical properties	Biaxial (-), a =1.4848, b =1.4864-1.4964, g =1.4979

2 - Crystal Habit :

Stellerite is part of the orthorhombic crystal system which means it has three axes of unequal length that intersect at 90° angles. Its crystal class is rhombic-dipyramidal which means it has three perpendicular two-fold rotational axes with perpendicular mirror planes . This would look like a dipyramid cut horizontally along the middle to where the top and bottom halves each have four identical faces that can either be compared to the other faces by the 2-fold rotation axes or the mirror planes . Stilbite, another zeolite, is very similar to stellerite in both chemical composition and physical appearance. Stellerite is more commonly found in rounded radiating clusters or as single crystals and appears more transparent than stilbite does .

3 - Optical Properties :

Stellerite is an anisotropic mineral, meaning that it has different properties in different directions-such as indices of refraction-when light passes through it. A refractive index (n) measures the speed of light in a substance — or in the case of mineralogy — in a mineral. It is expressed as a ratio of the speed of light in a vacuum to that in a mineral. Stellerite has three indices of refraction because it is a biaxial mineral.

4 - Occurrence :

Stellerite lines cavities and fracture surfaces in volcanic rocks altered by hydrothermal solutions. Great examples of Stellerite are on Copper Island, Commander Islands (also discovered by Georg Steller), Bering Sea and at Klichka, Chita region, Siberia, Russia. In the United states, it is located at Ritter Hot Springs, Grant County, Oregon; on Hook Mountain, Rockland County, New York; and at

Fanwood, Somerset County, New Jersey. Large crystals have been found in Australia around Gunnedah, New South Wales, and at Harcourt, Dookie, and Corop, Victoria.

72 – Stilbite

Stilbite from Kiui Island, Alaska, USA

Contents

1 – Introduction :

Stilbite is the name of a series of tectosilicate minerals of the zeolite group. Prior to 1997, stilbite was recognized as a mineral species, but a reclassification in 1997 by the International Mineralogical Association changed it to a series name, with the mineral species being named :

- stilbite-Ca
- stilbite-Na

Stilbite-Ca, by far the more common of the two, is a hydrous calcium sodium and aluminium silicate, $NaCa_4(Si_{27}Al_9)O_{72}\cdot 28(H_2O)$. In the case of stilbite-Na, sodium dominates over calcium. The species are visually indistinguishable, and the series name stilbite is still used whenever testing has not been performed.

Category	Zeolite
Chemical Formula	Stilbite - Ca : $NaCa_4(Si_{27}Al_9)O_{72}\cdot 28(H_2O)$ Stilbite - Na : $Na_9(Si_{27}Al_9)O_{72}\cdot 28(H_2O)$
Strunz classification	8/J.23-30 or 9.GE.10
Molar mass	Stilbite - Ca : 2,840 gm Stilbite - Na : 2,864 gm
Color	Usually colorless, white or pink
Crystal habit	Thin tabular, aggregates sheaf-like or in bow-ties, also fibrous and globular.
Crystal system	Monoclinic 2/m, also triclinic and orthorhombic
Fracture	Conchoidal or uneven
Tenacity	Brittle
Mohs scale hardness	3.5 to 4
Luster	Vitreous, pearly
Streak	White
Diaphaneity	Transparent to translucent
Specific gravity	2.12 to 2.22
Optical properties	Biaxial (-)
Refractive index	Nx = 1.479 to 1.492, Ny = 1.485 to 1.500, Nz = 1.489 to 1.505 Nx = 1.484 to 1.500, Ny = 1.492 to 1.507, Nz = 1.494 to 1.513
Fusibility	Easily fused by blow pipe (~1050 °C) to produce a white "enamel"
Solubility	Decomposes in HCl

2 – History :

At one time heulandite and stilbite were considered to be identical minerals. After they were found to be two separate species, in 1818, the name desmine ("a bundle") was proposed for stilbite, and this name is still employed in Germany. The English name "stilbite" is from the Greek stilbein = to shine, because of the pearly luster of the {010} faces.

3 - Chemistry and related species :

Stilbite shows a wide variation in exchangeable cations (positively charged ions). Silicon, Si, ions and aluminium, Al, ions occupy equivalent sites, and can substitute for each other, but they have a different charge (Si^{4+} and Al^{3+}) so the ions occupying the Na/Ca site have to adjust to maintain charge balance. There is a continuous series between stellerite, whose Formula can be written as $Ca_4(Si_{28}Al_8)O_{72}\cdot 28(H_2O)$, and stilbite, and another a continuous series between stilbite and barrerite, $Na_8(Si_{28}Al_8)O_{72}\cdot 26(H_2O)$.

Epistilbite is a distinct zeolite species unrelated to stilbite.

4 - Crystal class :

Stilbite is usually monoclinic 2/m, meaning that it has one twofold axis of rotational symmetry perpendicular to a mirror plane. The twofold axis is the crystal axis b, and the a and c crystal axes lie in the mirror plane. For a monoclinic crystal a and c are inclined to each other at an angle β which is not a right angle. For stilbite β is nearly 130°. Stilbite crystals, however, appear to be almost orthorhombic, and a larger unit cell can be chosen, containing two Formula units (Z = 2) such that it looks like an orthorhombic cell, with all three crystal axes very nearly mutually perpendicular. The mineral is said to be pseudo-orthorhombic.

Non-endmember forms of stilbite may be triclinic or even truly orthorhombic, indeed the framework can have symmetry ranging from orthorhombic to triclinic in a single crystal.

5 - Habit :

Crystals are typically thin tabular, flattened parallel to the dominant cleavage and elongated along the a axis. Aggregates may be sheaf-like or in bow-ties, also fibrous and globular . Twinning, cruciform and penetration, is extremely common on {001} .

6 - Physical and optical properties :

The color is usually colorless or white, also yellow, brown, pink, salmon, orange, red, green, blue or black. The luster is generally vitreous, and on the perfect cleavage parallel to the plane of symmetry it is markedly pearly. The streak is white and crystals are transparent to translucent. The hardness is 3½ to 4 and the specific gravity 2.12 to 2.22. Cleavage is perfect on {010}, poor on {001}. The mineral is brittle, with a conchoidal or uneven fracture. It is not radioactive.

Stilbite is biaxial (-) with refractive indices:

- Nx = 1.479 to 1.492, Ny = 1.485 to 1.500, Nz = 1.489 to 1.505
- Nx = 1.484 to 1.500, Ny = 1.492 to 1.507, Nz = 1.494 to 1.513

7 - Unit cell and structure :

Where sources give cell parameters for stilbite-Na, they are the same as those for stilbite - Ca.

The unit cell can be considered as a monoclinic cell with β close to 130° and one Formula unit per unit cell (Z = 1), or as a larger pseudo-orthorhombic cell with β close to 90° and Z = 2. Cell Parameters for the monoclinic cell:

- a = 13.595 to 13.69 Å, b = 18.197 to 18.31 Å, c = 11.265 to 11.30 Å, β = 127.94 to 128.1°
- a = 13.63 Å, b = 18.17 Å, c = 11.31 Å, β = 129.166°
- a = 13.60 to 13.69 Å, b = 18.20 to 18.31 Å, c = 11.27 Å, β = 128°

Cell parameters for the pseudo-orthorhombic cell:

- a = 13.595 to 13.69 Å, b = 18.197 to 18.31 Å, c = 17.775 to 17.86 Å, β = 90.00 to 90.91°
- a = 13.595 to 13.657 Å, b = 18.197 to 18.309 Å, c = 17.775 to 17.842 Å, β = 90:05 to 90.91° (Z is doubled to Z = 4 because the Formula unit halved to $NaCa_2Al_5Si_{13}O_{36}.14H_2O$)
- a=13.69 Å, b=18.25 Å, c=11.31 Å, β =128.2°
- a = 13.60 to 13.69 Å, b = 18.20 to 18.31 Å, c = 17.78 to 17.86 Å, β = 90.0 to 90.91°

The framework of stilbite is pseudo-orthorhombic with the open channels typical of zeolites. It has 10-member rings and 8-member rings forming channels parallel to a and pseudo-orthorhombic c respectively.

8 – Uses :

The open channels in the stilbite structure act like a molecular sieve, enabling it to separate hydrocarbons in the process of petroleum refining.

9 - Environment :

Stilbite is a low-temperature secondary hydrothermal mineral. It occurs in the amygdaloidal cavities of basaltic volcanic rocks, in andesites, gneiss and hydrothermal veins. It also forms in hot springs deposits, and as a cementing agent in some sandstones and conglomerates . Stilbite has not been found in sedimentary tuff deposits or deep - sea deposits . Associated minerals are other zeolites, prehnite, calcite and quartz .

10 - Localities :

Stilbite is abundant in the volcanic rocks of Iceland, Faroe Islands, Isle of Skye, Bay of Fundy, Nova Scotia, northern New Jersey and North Carolina. Salmon-pink crystals occur with pale green apophyllite in the Deccan Traps near Mumbai (Bombay) and Pune, India; white sheaf-like groups encrust the calcite (Iceland-spar) of Berufjord near Djupivogr in Iceland; brown sheafs are found near

Paterson, New Jersey in the United States; and crystals of a brick-red color are found at Old Kilpatrick, Scotland.

Iceland is generally considered to be the type locality for stilbite-Ca. It is presumed to be the Helgusta Iceland Spar Mine, along Reydarfjordur. Excellent white bow ties of stilbite are found here on calcite and quartz, associated with heulandite and laumontite in cavities.

The type locality for stilbite-Na is Cape Pula, Pula, Cagliari Province, Sardinia, Italy. Small, lustrous, white or pink, pointed blades of stilbite-Na, and formless masses, up to 5 cm in diameter, have been found there, covering a thin crust of reddish heulandite in large fractures and cavities in the highly weathered volcanic andesite or rhyolite.

The Tertiary Deccan basalts of western India are the most prolific sources of stilbite in the world. Stilbite is the most abundant zeolite in the tholeiitic basalt plateaux near Nasik and Pune and decreases in abundance toward the coast at Mumbai.

73 – Sugilite

Sugilite from Wessels Mine in Northern Cape Province, South Africa

1 – Introduction :

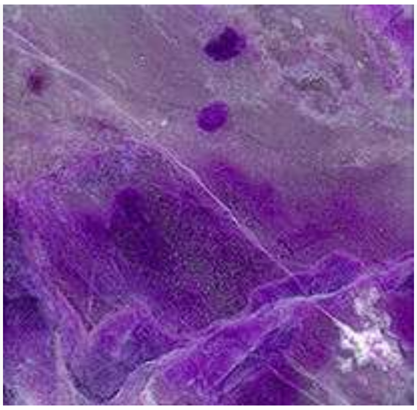
Sugilite (also known as **luvulite**) is a relatively rare pink to purple cyclosilicate mineral with the complex chemical Formula $KNa_2(Fe,Mn,Al)_2Li_3Si_{12}O_{30}$. Sugilite crystallizes in the hexagonal system with prismatic crystals. The crystals are rarely found and the form is usually massive. It has a Mohs hardness of 5.5 to 6.5 and a specific gravity of 2.75 to 2.80. It is mostly translucent.

Sugilite was first described in 1944 by the Japanese petrologist Ken-ichi Sugi (1901–1948) for an occurrence on Iwagi Islet, Japan, where it is found in an aegirine syenite intrusive stock. It is found in a similar environment at Mont Saint-Hilaire, Quebec, Canada. In the Wessels mine in northern Cape Province of South Africa, sugilite is mined from a strata-bound manganese deposit. It is also reported from Liguria and Tuscany, Italy; New South Wales, Australia; and Madhya Pradesh, India.

Note: The mineral is commonly pronounced with a soft "g", as in "ginger". However, as with most minerals, its pronunciation is intended to be the same as the person it is named after; in this case, the Japanese name Sugi has a hard "g", as in "geese": /ˈsuːɡɨlaɪt/ *soo-gi-lyt*.

Category	Mineral
Chemical Formula	$KNa_2(Fe,Mn,Al)_2Li_3Si_{12}O_{30}$
Color	Light brownish-yellow, purple, violet, reddish violet, pale pink, colourless
Crystal habit	Granular
Mohs scale hardness	6 – 6.5
Luster	Vitreous
Streak	White
Diaphaneity	Transparent to translucent
Specific gravity	2.74

Gallery



Sugilite tile

74 – Taaffeite

	
Specimen from Ratnapura, Sri Lanka	*Magnesiotaaffeite-2N'2S* ($Mg_3 Al_8 Be O_{16}$)

Contents

1 - Introduction :

Taaffeite ($BeMgAl_4O_8$) is a mineral named after its discoverer, Count Edward Charles Richard Taaffe (1898–1967) who found the first cut and polished gem in November 1945. As such, it is the only gemstone to have been initially identified from a faceted stone. Most pieces of the gem, prior to Taaffe, had been misidentified as spinel. For many years afterwards, it was known only in a few samples, and is still one of the rarest gemstone minerals in the world. Since 2002, the International Mineralogical Association-approved name for taaffeite as a mineral is **magnesio taaffeite - 2N'2S** .

Category	Oxide minerals
Chemical Formula	$BeMgAl_4O_8$

Color	Colorless, greyish violet, violet red, red, greenish, light green, pink violet, mauve
Crystal habit	Prismatic, alluvial grains
Crystal system	Hexagonal
Cleavage	Imperfect / fair / absent
Fracture	Conchoidal
Mohs scale hardness	8 - 8.5
Luster	Vitreous
Streak	White
Diaphaneity	Transparent to translucent
Specific gravity	3.60 – 3.61
Optical properties	Uniaxial
Refractive index	$n_\omega = 1.722$, $n_\varepsilon = 1.777$

2 - Discovery :

Taaffe bought a number of precious stones from a jeweller in November 1945. Upon noticing inconsistencies between the taaffeite and spinels, Taaffe sent some examples to B. W. Anderson of the Laboratory of the London Chamber of Commerce for identification on 1 November 1945. When Anderson replied on 5 November 1945, he told Taaffe that they were unsure of whether it was a spinel or something new; he also offered to write it up in *Gemmologist*.

3 - Properties :

In 1951, chemical and X-ray analysis confirmed the principal constituents of taaffeite as beryllium, magnesium and aluminium,[6] making taaffeite the first mineral to contain both beryllium and magnesium as essential components .

The confusion between spinel and taaffeite is understandable as certain structural features are identical in both. Anderson *et al.*,[5] classified taaffeite as an intermediate mineral between spinel and chrysoberyl. Unlike spinel, taaffeite displays the property of double refraction that allows distinguishing these two minerals.

4 – Usage :

Because of its rarity, taaffeite is only used as gemstone.

5 - Formation and occurrence :

Taaffeite occurs in carbonate rocks alongside fluorite, mica, spinel and tourmaline. This extremely rare mineral is increasingly found in alluvial deposits in Sri Lanka and southern Tanzania , as well as lower grade taffelite in limestone sediments in China.

75 - Taranakite

1 – Introduction :

Taranakite is a hydrated alkali iron-aluminium phosphate mineral with chemical Formula $(K,Na)_3(Al,Fe^{3+})_5(PO_4)_2(HPO_4)_6\cdot 18H_2O$. It forms from the reaction of clay minerals or aluminous rocks with solutions enriched in phosphate derived from bat or bird guano or , less commonly, from bones or other organic matter . Taranakite is most commonly found in humid, bat inhabited caves near the boundary of guano layers with the cave surface. It is also found in perennially wet coastal locations that have been occupied by bird colonies. The type location, and its namesake, the Sugar Loaf Islands off Taranaki, New Zealand, is an example of a coastal occurrence.

Taranakite forms small white, pale yellow, or gray crystals, which are typically found in pulverulent nodular aggregates, or crusts. Taranakite crystallizes in the hexagonal system, and is noted as having the longest crystallographic axis of any known mineral: the *c*-axis of the taranakite unit cell is 9.505 nanometres long.

Category	Phosphate minerals
Chemical Formula	$(K,Na)_3(Al,Fe^{3+})_5(PO_4)_2(HPO_4)_6\cdot 18H_2O$
Crystal symmetry	Trigonal hexagonal scalenohedral
Unit cell	a = 8.7025 Å , c = 95.05 Å ; Z = 6
Molar mass	1,342 g / mol
Color	White , pale yellow , or gray
Crystal habit	Platy, massive, nodular
Crystal system	Trigonal
Tenacity	Malleable, unctuous

Mohs scale hardness	1 – 2
Streak	white
Diaphaneity	Transparent
Specific gravity	2.12 – 2.15
Optical properties	Uniaxial (−)
Refractive index	n_ω = 1.506–1.510 n_ε = 1.500–1.503
Solubility	Insoluble in water Slightly soluble in acids

2 – Occurrence :

Taranakite was first described in 1866 by James Hector and William Skey . The material had been found by H. Richmond on the Sugar Loaf Islands of Taranaki, New Zealand (in the vicinity of 39°02′57″S 174°01′40″E39.049086°S 174.027708°E), as thin yellowish-white amorphous seams in fissures within trachytic rocks. Within the taranakite, dark yellow-brown seams were observed and thought to be wavellite. Modern X-ray analysis later showed this inclusion to be vashegyite ($Al_{11}(PO_4)_9(OH)_6\cdot 38H_2O$) .

Taranakite itself was initially mistaken for wavellite. Physical differences — its relative softness and ease of fusibility — led Skey, the colonial New Zealand Government analyst , to undertake quantitative chemical analysis which identified the mineral as a double hydrous phosphate of aluminia and potash, with some replacement of aluminium with ferric iron . This identified it as a new mineral species – the first to be discovered in New Zealand .

Hector and Skey identified bird guano as the most likely source of the phosphate required to form taranakite, and speculated on possible advantages of its use in making superphosphate, owing to the absence of carbonate and relatively small amounts of aluminium. Such industrial use was never realized owning to the limited distribution of taranakite.

Taranakite was rediscovered in two cave locations, and given two new names. In 1894, Armand Gautier described a mineral which he called **minervite** from caves at Grotte de Minerve in Hérault, France and argued that it formed from decomposing guano and animal remains reacting with clays. He experimentally justified this by reacting ammonium phosphate with gelatinous aluminium oxide, iron carbonate, and limestone. These reactions yielded a minervatie-like compound, and iron and calcium phosphates similar to what he observed in the caves . In 1904 Eugenio Casoria found a mineral under a guano layer at Monte Alburno, Italy which he called **palmerite** . These two minerals were later identified through X-ray powder diffraction as taranakite and discredited in favor of taranakite by historical priority.

Further occurrences of taranakite include :

- Misserghin, Algeria (as minervite) (1895)
- Jenolan Caves, Australia (as minervite) (1898)

No guano deposits are present in the caves; phosphatization is believed to occur from river water containing organic matter penetrating the cave.

- Réunion, Indian Ocean (as minervite) (1910)

Within a basalt cave in the Saint-Paul district

- Islas Leones, Patagonia (1933)

Associated with a penguin colony

- Pig Hole Cave, near Blacksburg, Virginia (1954)

A limestone cave. Taranakite occurs as a powder near the contact of bat guano and hair with clay, and within fractures in brecciated clay. This was the first discovery of taranakite in the United States.

- Onino - Iwaya cave, Hiroshima Prefecture, Japan (1975)

As a powder associated with gypsum within clay sediments, no more than three centimeters below the surface in areas of bat guano deposits.

- Mezesse Cave near Yaoundé, Cameroon

Coralloid speleothems of regularly alternating taranakite and opal microlayers in a granitic cave. The regular layering of taranakite was explained as the seasonal effect of leaching of guano and flow of clay from upper parts of the cave during the rainy season.

- Cook's Head Rock and Green Island, Otago, New Zealand (2003)

Occurring with leucophosphite as microcrystalline aggregates in jointed and brecciated basalt. Little Blue Penguins on Green Island and gulls on Cooks Head Rock are believed to be the main guano source.

The coastal occurrences, in New Zealand and Patagonia, occur at high latitudes supporting the necessity of humid conditions for the formation of taranakite. In the tropics, rather than taranakite, the minerals that form from guano-derived phosphatization of igneous rocks are variscite ($AlPO_4 \cdot 2H_2O$), metavariscite ($AlPO_4 \cdot H_2O$), barrandite ($(Al,Fe^{3+})PO_4 \cdot 2H_2O$), strengite and phosphosiderite ($Fe^{3+}PO_4 \cdot 2H_2O$) .

3 - Presence in soils :

Tarankaite is observed to form in the reaction zone of fertilizers . **Potassium - taranakite** (synonymous with taranakite) or **ammonium - taranakite** (where the alkali cations are replaced by ammonium) may form in acidic soils treated with potassium or ammonium - containing phosphate-fertilizers. The formation of taranakites, which are relatively insoluble, can act to reduce the bioavailability of phosphorus, potassium, and nitrogen if formed.

This can both hinder plant growth in initial stages by reducing the available cations, and also aid in the long run by extending the presence of these nutrients .

4 – Structure :

Taranakite crystallizes in the hexagonal crystal system (hexagonal scalenohedral , 32 / m) with the space group R3c. The unit cell dimensions are $a = 870.25$ pm and $c = 9505$ pm, enclosing a volume of 6.234 nm^3. The c - axis is the longest of any known mineral .

The unit cell of taranakite contains six layers of composition $K_3Al_5(HPO_4)_6(PO_4)_2(H_2O)_{12}$, each 13.78 Å thick and separated by layers of water. The rigid structure of each layer is built around HPO_4^{2-} groups coordinating three crystallographically distinct aluminium centres, each of which has coordination number six. Near the middle of each layer, an aluminium ion octahedrally coordinates six HPO_4^{2-}. Two other oxygens in each hydrogen phosphate group coordinate the other distinct aluminium centres, which in turn are coordinated octahedral to three hydrogen phosphate groups and three water molecules. This structure forms a Al'–P–Al''–P–Al' linkage nearly parallel to the c-axis, with the other distinct aluminium atom offset, and nearly vertically below a PO_4^{3-} ion.

Taranakite readily loses water when heated. Thermal gravimetric analysis shows two endothermic water loss events occurring in the ranges 80–140 °C and 140–300 °C corresponding to the sequential loss of five and thirteen water molecules to form francoanellite and a noncrystalline material. Heating to 500 °C results in complete dehydration to form $K_3Al_5P_8O_{29}$. In the range 562–595 °C crystalline $AlPO_4$ and $KAlP_2O_7$ form .

76 - Topaz الياقوت الأصفر

A group of topaz crystals on matrix

Contents

1 – Introduction :

Topaz is a silicate mineral of aluminium and fluorine with the chemical Formula $Al_2SiO_4(F,OH)_2$. Topaz crystallizes in the orthorhombic system and its crystals are mostly prismatic terminated by pyramidal and other faces.

Category	Silicate mineral
Chemical Formula	$Al_2SiO_4(F,OH)_2$
Crystal symmetry	Orthorhombic dipyramidal Space group: Pbnm

Unit cell	a = 4.65 Å, b = 8.8 Å, c = 8.4 Å; Z = 4
Color	Colorless (if no impurities), blue, brown, orange, gray, yellow, green, pink and reddish pink
Crystal habit	Prismatic crystals with faces striated parallel to long dimension; also columnar, compact, massive
Crystal system	Orthorhombic
Fracture	Subconchoidal to uneven
Mohs scale hardness	8 (defining mineral)
Luster	Vitreous
Streak	White
Diaphaneity	Transparent
Specific gravity	3.49–3.57
Optical properties	Biaxial (+)
Refractive index	$n_\alpha = 1.606 – 1.629$ $n_\beta = 1.609 – 1.631$ $n_\gamma = 1.616 – 1.638$
Pleochroism	Weak in thick sections X = yellow; Y = yellow, violet, reddish; Z = violet, bluish, yellow, pink
Other characteristics	Fluorescent , short UV = golden yellow, long UV = cream

2 - Color and varieties :

Pure topaz is colorless and transparent but is usually tinted by impurities; typical topaz is wine, yellow, pale gray, reddish-orange, or blue brown. It can also be made white, pale green, blue, gold, pink (rare), reddish-yellow or opaque to transparent/translucent.

Orange topaz, also known as precious topaz, is the traditional November birthstone, the symbol of friendship, and the state gemstone for the US state of Utah.

Imperial topaz is yellow, pink (rare, if natural) or pink-orange. Brazilian Imperial Topaz can often have a bright yellow to deep golden brown hue, sometimes even violet. Many brown or pale topazes are treated to make them bright yellow, gold, pink or violet colored. Some imperial topaz stones can fade on exposure to sunlight for an extended period of time . *Blue topaz* is the US state Texas' gemstone . Naturally occurring blue topaz is quite rare. Typically, colorless, gray or pale yellow and blue material is heat treated and irradiated to produce a more desired darker blue .

Mystic topaz is colorless topaz which has been artificially coated giving it the desired rainbow effect .

3 - Localities and occurrence :

Topaz Mountain, Utah

Topaz is commonly associated with silicic igneous rocks of the granite and rhyolite type. It typically crystallizes in granitic pegmatites or in vapor cavities in rhyolite lava flows like those at Topaz Mountain in western Utah. It can be found with fluorite and cassiterite in various areas including the Ural and Ilmen mountains of Russia, in Afghanistan, Sri Lanka, Czech Republic, Germany, Norway, Pakistan, Italy, Sweden, Japan, Brazil, Mexico, Flinders Island, Australia, Nigeria and the United States.

Some clear topaz crystals from Brazilian pegmatites can reach boulder size and weigh hundreds of pounds. Crystals of this size may be seen in museum collections. The Topaz of Aurungzebe, observed by Jean Baptiste Tavernier measured 157.75 carats . The American Golden Topaz, a more recent gem, measured a massive 22,892.5 carats.

Colorless and light-blue varieties of topaz are found in Precambrian granite in Mason County, Texas within the Llano Uplift. There is no commercial mining of topaz in that area.

4 - Etymology and historical and mythical usage :

4 – 1 - Etymology :

The name "topaz" is derived (via Old French: Topace and Latin: opazus) from the Greek Topázios or Topázion , the ancient name of St. John's Island in the Red Sea which was difficult to find and from which a yellow stone (now believed to be chrysolite: yellowish olivine) was mined in ancient times; topaz itself (rather than *topazios*) wasn't really known about before the classical era.

Pliny says that Topazos is a *legendary* island in the Red Sea and the mineral "topaz" was first mined there. The word topaz might be related to the Arabic word توباز which meant "the subject of the search" or Sanskrit word " tapas " meaning "heat" or "fire " .

4 – 2 - History :

Nicols, the author of one of the first systematic treatises on minerals and gemstones , dedicated two chapters to the topic in 1652 . In the Middle Ages, the name topaz was used to refer to any yellow gemstone, but in modern times it denotes only the silicate described above.

4 – 3 - Biblical back ground , etymology , and analysis :

Many modern English translations of the Bible, including the King James Version mention *Topaz* in Exodus 28:17 in reference to a stone in the Hoshen: "And thou shalt set in it settings of stones, even four rows of stones: the first row shall be a sardius, a topaz, and a carbuncle (Garnet): this shall be the first row."

However, because these translations as *topaz* all derive from the Septuagint translation *topazi[os]*, which as mentioned above referred to a yellow stone that was not topaz, but probably chrysolite, it should be borne in mind that topaz is likely not meant here.[15] The masoretic text (the Hebrew on which most modern Protestant Bible translations of the Old Testament are based) has *pitdah* as the gem the stone is made from; some scholars think it is related to an Assyrian word meaning 'flashed'. More likely, pitdah is derived from Sanskrit words (pit = yellow , dah = burn) , meaning " yellow burn " or , metaphorically , " fiery ".

5 - Gallery :

		
Facet Cut Topaz Gemstones in various colors,	*American Golden Topaz*	*Colorless topaz, Minas Gerais, Brazil*
		
A cut blue topaz	*Imperial Topaz Gem*	*A red topaz*

77 – Tourmaline

Schorl Tourmaline

Contents

1 – Introduction :

Tourmaline is a crystal boron silicate mineral compounded with elements such as aluminium, iron, magnesium, sodium, lithium, or potassium. Tourmaline is classified as a semi-precious stone and the gem comes in a wide variety of colors. The name comes from the Sinhalese word "Thuramali" (තුරමලි) or "Thoramalli" (තෝරමල්ලි), which applied to different gemstones found in Sri Lanka.

Category	Cyclosilicate
Chemical Formula	$(Ca,K,Na,[])(Al,Fe,Li,Mg,Mn)_3(Al,Cr,Fe,V)_6(BO_3)_3(Si,Al,B)_6O_{18}(OH,F)_4$
Color	Most commonly black, but can range from brown, violet, green, pink, or in a dual-colored pink and green.
Crystal habit	Parallel and elongated. Acicular prisms, sometimes radiating. Massive. Scattered grains (in granite).
Crystal system	Trigonal
Cleavage	Indistinct
Fracture	Uneven, small conchoidal, brittle
Mohs scale hardness	7 – 7.5
Luster	Vitreous , sometimes resinous
Streak	White
Specific gravity	3.06 (+.20 -.06)
Density	2.82 – 3.32
Polish luster	Vitreous
Optical properties	Double refractive, uniaxial negative[1]
Refractive index	nω =1.635 – 1.675, nε =1.610 – 1.650
Pleochroism	typically moderate to strong Red Tourmaline: Definite; dark red,light red Green Tourmaline: Strong; dark green, yellow-green Brown Tourmaline: Definite; dark brown, light brown Blue Tourmaline: Strong; dark blue,

	light blue
Ultraviolet fluorescence	pink stones—inert to very weak red to violet in long and short wave
Absorption spectra	a strong narrow band at 498 nm, and almost complete absorption of red down to 640nm in blue and green stones; red and pink stones show lines at 458 and 451nm as well as a broad band in the green spectrum

2 - History :

Brightly colored Sri Lankan gem tourmalines were brought to Europe in great quantities by the Dutch East India Company to satisfy a demand for curiosities and gems. At the time it was not realised that **schorl** and tourmaline were the same mineral.

3 - Tourmaline species and varieties :

- Dravite species: from the Drave district of Carinthia
  - Dark yellow to brownish black—dravite
- Schorl species:
  - Bluish or brownish black to Black—schorl
- Elbaite species: named after the island of Elba, Italy
  - Red or pinkish-red—rubellite variety (from ruby)
  - Dark black—schorl (from indigo)
  - Light blue to bluish green—Brazilian indicolite variety
  - Green—verdelite or Brazilian emerald variety
  - Colorless—achroite variety (from the Greek meaning "colorless")

3 – 1 - Schorl :

The most common species of tourmaline is **schorl**. It may account for 95 % or more of all tourmaline in nature. The early history of the mineral schorl shows that the name "schorl" was in use prior to 1400 because a village known today as Zschorlau (in Saxony, Germany) was then named "Schorl" (or minor variants of this name). This village had a nearby tin mine where, in addition to cassiterite, black tourmaline was found. The first description of schorl with the name "schürl" and its occurrence (various tin mines in the Saxony Ore Mountains) was written by Johannes Mathesius (1504 –1565) in 1562 under the title "Sarepta oder Bergpostill". Up to about 1600, additional names used in the German language were "Schurel", "Schörle", and "Schurl". Beginning in the 18th century, the name *Schörl* was mainly used in the German-speaking area. In English, the names *shorl* and *shirl* were used in the 18th century. In the 19th century the names *common schorl*, *schörl*, *schorl* and *iron tourmaline* were used in the Anglo-Saxon area . The word tourmaline has two etymologies, both from the Sinhalese word *turamali*, meaning "stone attracting ash" (a reference to its pyroelectric properties) or according to other sources "mixed gemstones".

3 – 2 - Dravite :

Black Dravite on a grey matrix

The name **dravite** was used for the first time by Gustav Tschermak (1836–1927), Professor of Mineralogy and Petrography at the University of Vienna, in his book *Lehrbuch der Mineralogie* (published in 1884) for magnesium-rich (and sodium-rich) tourmaline from the village Unterdrauburg, Drava river area, Carinthia, Austro-Hungarian Empire. Today this tourmaline locality (type locality for dravite) at the village Dravograd (near Dobrova pri Dravogradu), is a part of the Republic of Slovenia.[4] Tschermak gave this tourmaline the name dravite, for the Drava river area, which is the district along the Drava River (in German: Drau, in Latin: Drave) in Austria and Slovenia. The chemical composition which was given by Tschermak in 1884 for this dravite approximately corresponds to the Formula $NaMg_3(Al,Mg)_6B_3Si_6O_{27}(OH)$, which is in good agreement (except for the OH content) with the endmember Formula of dravite as known today .

3 – 3 - Elbaite :

A lithium-tourmaline (**elbaite**) was one of three pegmatitic minerals from Utö, Sweden, in which the new alkali element lithium (Li) was determined in 1818 by Arfwedson for the first time . Elba Island, Italy, was one of the first localities where colored and colorless Li - tourmalines were extensively chemically analysed. In 1850 Rammelsberg described fluorine (F) in tourmaline for the first time. In 1870 he proved that all varieties of tourmaline contain chemically bound water. In 1889 Scharitzer proposed the substitution of (OH) by F in red Li-tourmaline from Sušice, Czech Republic. In 1914 Vernadsky proposed the name *Elbait* for lithium-, sodium-, and aluminum-rich tourmaline from Elba Island, Italy, with the simplified Formula $(Li,Na)HAl_6B_2Si_4O_{21}$. Most likely the type material for elbaite was found at Fonte del Prete, San Piero in Campo, Campo nell'Elba, Elba Island, Livorno Province, Tuscany, Italy . In 1933 Winchell published an updated Formula for elbaite, $H_8Na_2Li_3Al_3B_6Al_{12}Si_{12}O_{62}$, which is commonly used to date written as $Na(Li_{1.5}Al_{1.5})Al_6(BO_3)_3[Si_6O_{18}](OH)_3(OH)$. The first crystal structure determination of a Li-rich tourmaline was published in 1972 by Donnay and Barton, performed on a pink elbaite from San Diego County, California, USA.

3 – 4 - Chemical composition of the tourmaline group :

The tourmaline mineral group is chemically one of the most complicated groups of silicate minerals. Its composition varies widely because of isomorphous replacement (solid solution), and its general Formula can be written as

$$XY_3Z_6(T_6O_{18})(BO_3)_3V_3W,$$

Where :

X = Ca, Na, K, vacancy

Y = Li, Mg, Fe^{2+}, Mn^{2+}, Zn, Al, Cr^{3+}, V^{3+}, Fe^{3+}, Ti^{4+}, vacancy

Z = Mg, Al, Fe^{3+}, Cr^{3+}, V^{3+}

T = Si, Al, B

B = B, vacancy

V = OH, O

W = OH, F, O

Large pink elbaite crystal on quartz, Cryo-Genie Mine, San Diego Co., California, USA.

The 14 recognized minerals in the group (endmember Formulas)

1	Buergerite	$NaFe^{3+}{}_3Al_6Si_6O_{18}(BO_3)_3O_3F$
2	Chromdravite	$NaMg_3Cr_6Si_6O_{18}(BO_3)_3(OH)_4$
3	Dravite	$NaMg_3Al_6Si_6O_{18}(BO_3)_3(OH)_4$
4	Elbaite	$Na(Li_{1.5},Al_{1.5})Al_6Si_6O_{18}(BO_3)_3(OH)_4$
5	Feruvite	$CaFe^{2+}{}_3(MgAl_5)Si_6O_{18}(BO_3)_3(OH)_4$
6	Foitite	$(Fe^{2+}{}_2Al)Al_6Si_6O_{18}(BO_3)_3(OH)_4$
7	Liddicoatite	$Ca(Li_2Al)Al_6Si_6O_{18}(BO_3)_3(OH)_3F$
8	Magnesiofoitite	$(Mg_2Al)Al_6Si_6O_{18}(BO_3)_3(OH)_4$

9	Olenite	$NaAl_3Al_6Si_6O_{18}(BO_3)_3O_3OH$
10	Povondraite	$NaFe^{3+}_3(Fe^{3+}_4Mg_2)Si_6O_{18}(BO_3)_3(OH)_3O$
11	Rossmanite	$(LiAl_2)Al_6Si_6O_{18}(BO_3)_3(OH)_4$
12	Schorl	$NaFe^{2+}_3Al_6Si_6O_{18}(BO_3)_3(OH)_4$
13	Uvite	$CaMg_3(MgAl_5)Si_6O_{18}(BO_3)_3(OH)_3F$
14	Vanadiumdravite	$NaMg_3V_6Si_6O_{18}(BO_3)_3(OH)_4$

4 - Physical properties :

4 – 1 - Crystal structure :

Tourmaline belongs to the trigonal crystal system and occurs as long, slender to thick prismatic and columnar crystals that are usually triangular in cross-section. The style of termination at the ends of crystals is asymmetrical, called hemimorphism. Small slender prismatic crystals are common in a fine-grained granite called aplite, often forming radial daisy-like patterns. Tourmaline is distinguished by its three-sided prisms; no other common mineral has three sides. Prisms faces often have heavy vertical striations that produce a rounded triangular effect. Tourmaline is rarely perfectly euhedral. An exception was the fine dravite tourmalines of Yinnietharra, in western Australia. The deposit was discovered in the 1970s, but is now exhausted. All hemimorphic crystals are piezoelectric, and are often pyroelectric as well.

4 – 2 - Color :

Tourmaline gemstones - Mozambique

Tourmaline has a variety of colors. Usually, iron-rich tourmalines are black to bluish-black to deep brown, while magnesium-rich varieties are brown to yellow, and lithium-rich tourmalines are almost any color: blue, green, red, yellow, pink, etc. Rarely, it is colorless. Bi-colored and multicolored crystals are common, reflecting variations of fluid chemistry during crystallization. Crystals may be green at one end and pink at the other, or green on the outside and pink inside; this type is called watermelon tourmaline. Some forms of tourmaline are dichroic, in that they change color when viewed from different directions.

Physics explains color in terms of the wavelength of radiation. A spectrograph that only identifies the position of spectral lines will perfectly differentiate between a radiation at 0.530 µm and another at 0.532 µm, where our eyes will only perceive the same green.

The pink color of tourmalines from many fields is the result of a continued natural irradiation. During their growth, these tourmalines incorporate Mn^{2+}, whereas initially they are by nature very pale. Their granitic environment exposes to them a natural gamma ray exposure due to radioactive decay of ^{40}K, causing the gradual formation of the Mn^{3+} ions responsible for a pink to red color .

4 – 3 - Treatments :

Some tourmaline gems, especially pink to red colored stones, are altered by irradiation to improve their color. Irradiation is almost impossible to detect in tourmalines, and does not impact the value. Heavily-included tourmalines, such as rubellite and Brazilian paraiba, are sometimes clarity-enhanced. A clarity-enhanced tourmaline (especially paraiba) is worth much less than a non-treated gem.

5 - Geology

Tourmaline is found in granite and granite pegmatites and in metamorphic rocks such as schist and marble. Schorl and lithium-rich tourmalines are usually found in granite and granite pegmatite. Magnesium-rich tourmalines, dravites, are generally restricted to schists and marble. Tourmaline is a durable mineral and can be found in minor amounts as grains in sandstone and conglomerate, and is part of the ZTR index for highly-weathered sediments.

Bi-colored tourmaline crystal, 0.8 inches (2 cm) long.

6 - Tourmaline localities ;

Gem and specimen tourmaline is mined chiefly in Brazil and Africa. Some placer material suitable for gem use comes from Sri Lanka. In addition to Brazil, tourmaline is mined in Tanzania, Nigeria, Kenya, Madagascar, Mozambique, Namibia, Afghanistan, Pakistan, Sri Lanka, and Malawi.

6 – 1 - United States ;

Some fine gems and specimen material has been produced in the United States, with the first discoveries in 1822, in the state of Maine. California became a large producer of tourmaline in the early 1900s. The Maine deposits tend to produce crystals in raspberry pink-red as well as minty greens. The California deposits are known for bright pinks, as well as bicolors. During the early 1900s, Maine and California were the world's largest producers of gem tourmalines. The Empress Dowager Tz'u Hsi of China loved pink tourmaline and bought large quantities for gemstones and carvings from the then new Himalaya Mine, located in San Diego County, California.[9] It is not clear when the first tourmaline was found in California. Native Americans have used pink and green tourmaline as funeral gifts for centuries. The first documented case was in 1890 when Charles Russel Orcutt found pink tourmaline at what later became the Stewart Mine at Pala, San Diego .

6 – 2 - Brazil :

Almost every color of tourmaline can be found in Brazil, especially in the Brazilian states of Minas Gerais and Bahia. In 1989, miners discovered a unique and brightly colored variety of tourmaline in the state of Paraíba. The new type of tourmaline, which soon became known as paraiba tourmaline, came in unusually vivid blues and greens. These colors were often described as "neon" since they appeared to glow. Brazilian paraiba tourmaline is usually heavily included. Much of the paraiba tourmaline from Brazil actually comes from the neighboring state of Rio Grande do Norte. Material from Rio Grande do Norte is often somewhat less intense in color, but many fine gems are found there. It was determined that the element copper was important in the coloration of the stone.

6 – 3 - Africa :

In the late 1990s, copper-containing tourmaline was found in Nigeria. The material was generally paler and less saturated than the Brazilian materials, although the material generally was much less included. A more recent African discovery from Mozambique has also produced beautiful tourmaline colored by copper, similar to the Brazilian paraiba. While its colors are somewhat less bright than top Brazilian material, Mozambique paraiba is often less included and has been found in larger sizes. The Mozambique paraiba material usually is more intensely colored than the Nigerian. There is a significant overlap in color and clarity with Mozambique paraiba and Brazilian paraiba, especially with the material from Rio Grande do Norte. While less expensive than top quality Brazilian paraiba, some Mozambique material sells for well over $ 5,000 per carat, which still is extremely high compared to other tourmalines.

Another highly valuable variety is chrome tourmaline, a rare type of dravite tourmaline from Tanzania. Chrome tourmaline is a rich green color due to the presence of chromium atoms in the crystal; chromium also produces the green color of emeralds. Of the standard elbaite colors, blue indicolite gems are typically the most valuable, followed by green verdelite and pink to red rubellite . There are also yellow tourmalines, sometimes known as canary tourmaline. Zambia is rich in both red and yellow tourmaline, which are relatively inexpensive in that country. Ironically the rarest variety, colorless achroite, is not appreciated and is the least expensive of the transparent tourmalines.

6 – 4 - Afghanistan :

Extra fine indicolite (blue tourmaline) and verderite (green tourmaline) are found in the Nuristan region (Ghazi Abad district) and Pech Valley (Pech and Chapa Dara districts) of Kunar province. Gem-quality tourmalines are faceted (cut) from 0.50 – 10 gram sizes and have unusually high clarity and intense shades of color.

78 -Tsavorite

Tsavorite or **tsavolite** is a variety of the garnet group species grossular, a calcium-aluminium garnet with the Formula $Ca_3Al_2Si_3O_{12}$. Trace amounts of vanadium or chromium provide the green color.

In 1967, British gem prospector and geologist Dr. Campbell R. Bridges discovered a deposit of green grossular in the mountains of north-east Tanzania in a place called Lemshuko, 15 km away from Komolo, the first village. The specimens he found were of very intense color and of high transparency. The find interested the gem trade, and attempts were made to export the stones, but the Tanzanian government did not provide permits.

Believing that the deposit was a part of a larger geological structure extending possibly into Kenya, Bridges began prospecting in that nation. He was successful a second time in 1971, when he found the mineral variety there, and was granted a permit to mine the deposit. The gemstone was only known to mineral specialists until 1974, when Tiffany and Co launched a marketing campaign which brought broader recognition of the stone .

Dr. Bridges was murdered in 2009 when a mob attacked him and his son on their property in Tsavo National Park. It is believed that the attack was connected to a three - year dispute over access and control of Bridges' gemstone mines.

The name *tsavorite* was proposed by Tiffany and Co president Sir Henry Platt in honor of Tsavo National Park in Kenya.[4] Apart from the source locality in Tanzania it is also found in Toliara (Tuléar) Province, Madagascar, but so far, no other occurrences of gem material have been discovered.

Rare in gem-quality over several carats (1 carat = 200 mg) in weight, tsavorite has been found in larger sizes. In late 2006 a 925-carat (185 g) crystal was discovered. It yielded an oval mixed-cut 325 carat (65 g) stone, one of the largest, if not *the* largest faceted tsavorites in the world. A crystal that yielded a 120.68-carat (24.14 g) oval mixed-cut gem was also uncovered in early 2006.

Category	Mineral
Chemical Formula	$Ca_3Al_2Si_3O_{12}$
Color	Light to deep green
Crystal system	cubic
Mohs scale hardness	7 - 7.5
Specific gravity	3.60–3.68 [2]
Optical properties	Single refractive
Refractive index	1.740
Dispersion	0.028

79 - Tschermigite

Tschermigite is a mineral form of ammonium alum, Formula $NH_4AlSO_4 \cdot 12H_2O$. *It is found in burning coal seams*, bituminous shale and fumaroles. Because of its extreme water solubility it is unlikely to persist except in the dryest of conditions. Discovered in 1852 at Cermiky, also known as Schermig in Bohemia. It is colorless and named for where it was discovered.

Category	Sulfate minerals
Chemical Formula	$NH_4AlSO_4 \cdot 12H_2O$
Crystal symmetry	m3 (2/m 3) - Diploidal
Unit cell	a = 12.24Å
Color	Colorless, white; colorless in transmitted light
Crystal system	Isometric
Fracture	Conchoidal
Mohs scale hardness	1.5 - 2
Luster	Vitreous, silky
Diaphaneity	Transparent
Specific gravity	1.645
Optical properties	Isotropic

80 – Turquoise (فيروز)

Turquoise (tumble finished) one inch (25 mm) long. This pebble is greenish and therefore low grade

Contents

1 – Introduction :

Turquoise is an opaque, blue-to-green mineral that is a hydrous phosphate of copper and aluminium, with the chemical Formula $CuAl_6(PO_4)_4(OH)_8 \cdot 4H_2O$. It is rare and valuable in finer grades and has been prized as a gem and ornamental stone for thousands of years owing to its unique hue. In recent times, turquoise, like most other opaque gems, has been devalued by the introduction of treatments, imitations, and synthetics onto the market.

The substance has been known by many names, but the word *turquoise*, which dates to the 16th century, is derived from an Old French word for "Turkish", because the mineral was first brought to Europe from Turkey, from the mines in historical Khorasan Province of Persia . Pliny referred to the mineral as *callais*, the Iranians named it "pirouzeh" and the Aztecs knew it as *chalchihuitl*.

Category	Phosphate minerals
Chemical Formula	$CuAl_6(PO_4)_4(OH)_8 \cdot 4H_2O$
Colour	Blue, blue-green, green
Crystal habit	Massive , nodular
Crystal system	Triclinic
Cleavage	Good to perfect – usually
Fracture	Conchoidal
Mohs scale hardness	5 - 7
Lustre	Waxy to subvitreous
Streak	Bluish white
Specific gravity	2.6 - 2.9
Optical properties	Biaxial (+)
Refractive index	$n\alpha = 1.610$ $n\beta = 1.615$ $n\gamma = 1.650$

Fusibility	Fusible in heated HCl
Solubility	Soluble in HCl

2 - Properties of turquoise

Even the finest of turquoise is fracturable, reaching a maximum hardness of just under 6, or slightly more than window glass.[2] Characteristically a cryptocrystalline mineral, turquoise almost never forms single crystals and all of its properties are highly variable. Its crystal system is proven to be triclinic via X-ray diffraction testing. With lower hardness comes lower specific gravity (2.60–2.90) and greater porosity: These properties are dependent on grain size. The lustre of turquoise is typically waxy to subvitreous, and transparency is usually opaque, but may be semitranslucent in thin sections. Colour is as variable as the mineral's other properties, ranging from white to a powder blue to a sky blue, and from a blue-green to a yellowish green. The blue is attributed to idiochromatic copper while the green may be the result of either iron impurities (replacing aluminium) or dehydration.

The refractive index (as measured by sodium light, 589.3 nm) of turquoise is approximately 1.61 or 1.62; this is a mean value seen as a single reading on a gemmological refractometer, owing to the almost invariably polycrystalline nature of turquoise. A reading of 1.61–1.65 (birefringence 0.040, biaxial positive) has been taken from rare single crystals. An absorption spectrum may also be obtained with a hand-held spectroscope, revealing a line at 432 nanometres and a weak band at 460 nanometres (this is best seen with strong reflected light). Under longwave ultraviolet light, turquoise may occasionally fluoresce green, yellow or bright blue; it is inert under shortwave ultraviolet and X-rays.

Turquoise is insoluble in all but heated hydrochloric acid. Its streak is a pale bluish white and its fracture is conchoidal, leaving a waxy lustre. Despite its low hardness relative to other gems, turquoise takes a good polish. Turquoise may also be peppered with flecks of pyrite or interspersed with dark, spidery limonite veining.

3 - Formation

As a secondary mineral, turquoise apparently forms by the action of percolating acidic aqueous solutions during the weathering and oxidation of pre-existing minerals. For example, the copper may come from primary copper sulfides such as chalcopyrite or from the secondary carbonates malachite or azurite; the aluminium may derive from feldspar; and the phosphorus from apatite. Climate factors appear to play an important role as turquoise is typically found in arid regions, filling or encrusting cavities and fractures in typically highly altered volcanic rocks, often with associated limonite and other iron oxides. In the American southwest turquoise is almost invariably associated with the weathering products of copper sulfide deposits in or around potassium feldspar bearing porphyritic intrusives. In some occurrences alunite, potassium aluminium sulfate, is a prominent secondary mineral. Typically turquoise mineralization is restricted to a relatively shallow depth of less than 20 metres , although it does occur along deeper fracture zones where secondary solutions have greater penetration or the depth to the water table is greater.

Although the features of turquoise occurrences are consistent with a secondary or supergene origin, some sources refer to a hypogene origin. The *hypogene* hypothesis, which holds that the aqueous solutions originate at significant depth, from hydrothermal processes. Initially at high temperature, these solutions rise upward to surface layers, interacting with and leaching essential elements from pre-existing minerals in the process. As the solutions cool, turquoise precipitates, lining cavities and fractures within the surrounding rock. This hypogene process is applicable to the original copper sulfide deposition; however, it is difficult to account for the many features of turquoise occurrences by a hypogene process. That said, there are reports of two phase fluid inclusions within turquoise grains that give elevated homogenization temperatures of 90 to 190 °C that require explanation.

Turquoise is nearly always cryptocrystalline and massive and assumes no definite external shape. Crystals, even at the microscopic scale, are exceedingly rare. Typically the form is vein or fracture filling, nodular, or botryoidal in habit. Stalactite forms have been reported. Turquoise may also pseudomorphously replace feldspar, apatite, other minerals, or even fossils. Odontolite is fossil bone or ivory that has been traditionally thought to have been altered by turquoise or similar phosphate minerals such as the iron phosphate vivianite. Intergrowth with other secondary copper minerals such as chrysocolla is also common.

4 - Occurrence :

Massive Kingman Blue turquoise in matrix with quartz from Mineral Park, Arizona

Turquoise was among the first gems to be mined, and while many historic sites have been depleted, some are still worked to this day. These are all small-scale, often seasonal operations, owing to the limited scope and remoteness of the deposits. Most are worked by hand with little or no mechanization. However, turquoise is often recovered as a byproduct of large-scale copper mining operations, especially in the United States.

Cutting and grinding turquoise in Nishapur, Iran, 1973

4 – 1 - Iran :

For at least 2,000 years, the region once known as Persia has remained an important source of turquoise which was named by Iranians initially "pirouzeh" meaning "victory" and later after Arab invasion "firouzeh".[In Iranian architecture, the blue turquoise was used to cover the domes of the Iranian palaces because its intense blue colour was also a symbol of heaven on earth .

This deposit, which is blue naturally, and turns green when heated due to dehyration, is restricted to a mine-riddled region in Nishapur, the 2,012-metre mountain peak of Ali-mersai, which is tens of kilometers from Mashhad, the capital of Khorasan province, Iran. A weathered and broken trachyte is host to the turquoise, which is found both *in situ* between layers of limonite and sandstone, and amongst the scree at the mountain's base. These workings, together with those of the Sinai Peninsula, are the oldest known.

4 – 1 - Sinai :

Since at least the First Dynasty (3000 BCE), and possibly before then, turquoise was used by the Egyptians and was mined by them in the Sinai Peninsula, called "Country of Turquoise" by the native Monitu. There are six mines in the region, all on the southwest coast of the peninsula, covering an area of some 650 square kilometres (250 sq mi). The two most important of these mines, from a historic perspective, are Serabit el-Khadim and Wadi Maghareh, believed to be among the oldest of known mines. The former mine is situated about 4 kilometres from an ancient temple dedicated to Hathor.

The turquoise is found in sandstone that is, or was originally, overlain by basalt. Copper and iron workings are present in the area. Large-scale turquoise mining is not profitable today, but the deposits are sporadically quarried by Bedouin peoples using homemade gunpowder. In the rainy winter months, miners face a risk from flash flooding; even in the dry season, death from the collapse of the haphazardly exploited sandstone mine walls is not unheard of. The colour of Sinai material is typically greener than Iranian material, but is thought to be stable and fairly durable. Often referred to as *Egyptian* turquoise, Sinai material is typically the most translucent, and under magnification its surface structure is revealed to be peppered with dark blue discs not seen in material from other localities.

4 – 3 - United States :

Bisbee turquoise commonly has a hard chocolate brown coloured matrix.

The Southwest United States is a significant source of turquoise; Arizona, California (San Bernardino, Imperial, Inyo counties), Colorado (Conejos, El Paso, Lake, Saguache counties), New Mexico (Eddy, Grant, Otero, Santa Fe counties) Nevada (Clark, Elko, Esmeralda County, Eureka, Lander, Mineral County and Nye counties) are (or were) especially rich. The deposits of California and New Mexico were mined by pre-Columbian Native Americans using stone tools, some local and some from as far away as central Mexico. Cerrillos, New Mexico is thought to be the location of the oldest mines; prior to the 1920s, the state was the country's largest producer; it is more or less exhausted today. Only one mine in California, located at Apache Canyon, operates at a commercial capacity today.

The turquoise occurs as vein or seam fillings, and as compact nuggets; these are mostly small in size. While quite fine material is sometimes found—rivalling Iranian material in both colour and durability—most American turquoise is of a low grade (called "chalk turquoise"); high iron levels mean greens and yellows predominate, and a typically friable consistency in the turquoise's untreated state precludes use in jewellery .

Arizona is currently the most important producer of turquoise by value.[5] Several mines exist in the state, two of them famous for their unique colour and quality and considered the best in the industry: the Sleeping Beauty Mine in Globe, and the Kingman Mine that operates alongside a copper mine outside of the city. Other active mines include the Blue Bird mine, Castle Dome, and Ithaca Peak. The mines at Morenci, Bisbee, and Turquoise Peak are either inactive or depleted.

Nevada is the country's other major producer, with more than 120 mines which have yielded significant quantities of turquoise. Unlike elsewhere in the US, most Nevada mines have been worked primarily for their gem turquoise and very little has been recovered as a byproduct of other mining operations. Nevada turquoise is found as nuggets, fracture fillings and in breccias as the cement filling interstices between fragments. Because of the geology of the Nevada deposits, a majority of the material produced is hard and dense, being of sufficient quality that no treatment or enhancement is required. While nearly every county in the state has yielded some turquoise, the chief producers are in Lander and Esmeralda Counties. Most of the turquoise deposits in Nevada occur along a wide belt of tectonic activity that coincides with the state's zone of thrust faulting. It strikes about N15°E and extends from the northern part of Elko County, southward down to the California border southwest of Tonopah. Nevada has produced a wide diversity of colours and mixes of different matrix patterns, with turquoise from Nevada coming in various shades of blue, blue-green, and green. Some of this unusually coloured turquoise may contain significant zinc and iron, which is the cause of the beautiful bright green to yellow-green shades. Some of the green to green yellow shades may actually be variscite or faustite, which are secondary phosphate minerals similar in appearance to turquoise. A significant portion of the Nevada material is also noted for its often attractive brown or black limonite veining, producing what is called "spiderweb matrix". While a number of the Nevada deposits were first worked by Native Americans, the total Nevada turquoise production since the 1870s has been estimated at more than 600 tons, including nearly 400 tons from the Carico Lake mine. In spite of increased costs, small scale mining operations continue at a number of turquoise properties in Nevada, including the Godber, Orvil Jack and Carico Lake Mines in Lander County, the Pilot Mountain Mine in Mineral County, and several properties in the Royston and Candelaria areas of Esmerelda County.

Untreated turquoise, Nevada USA. Rough nuggets from the McGinness Mine, Austin; Blue and green cabochons showing spiderweb, Bunker Hill Mine, Royston

In 1912, the first deposit of distinct, single-crystal turquoise was discovered in Lynch Station, Campbell County, Virginia. The crystals, forming a druse over the mother rock, are very small; 1 mm (0.04 in) is considered large. Until the 1980s Virginia was widely thought to be the only source of distinct crystals; there are now at least 27 other localities.

In an attempt to recoup profits and meet demand, some American turquoise is treated or *enhanced* to a certain degree. These treatments include innocuous waxing and more controversial procedures, such as dyeing and impregnation (see Treatments). There are however, some American mines which produce materials of high enough quality that no treatment or alterations are required. Any such treatments which have been performed should be disclosed to the buyer on sale of the material.

4 – 4 - Other sources :

China has been a minor source of turquoise for 3,000 years or more. Gem-quality material, in the form of compact nodules, is found in the fractured, silicified limestone of Yunxian and Zhushan, Hubei province. Additionally, Marco Polo reported turquoise found in present-day Sichuan. Most Chinese material is exported, but a few carvings worked in a manner similar to jade exist. In Tibet, gem-quality deposits purportedly exist in the mountains of Derge and Nagari-Khorsum in the east and west of the region respectively.

Other notable localities include: Afghanistan; Australia (Victoria and Queensland); north India; northern Chile (Chuquicamata); Cornwall; Saxony; Silesia; and Turkestan.

5 - History of its use :

The iconic gold burial mask of Tutankhamun, inlaid with turquoise, lapis lazuli, carnelian and coloured glass.

The pastel shades of turquoise have endeared it to many great cultures of antiquity: it has adorned the rulers of Ancient Egypt, the Aztecs (and possibly other Pre-Columbian Mesoamericans), Persia, Mesopotamia, the Indus Valley, and to some extent in ancient China since at least the Shang Dynasty.[9] Despite being one of the oldest gems, probably first introduced to Europe (through Turkey) with other Silk Road novelties, turquoise did not become important as an ornamental stone in the West until the 14th century, following a decline in the Roman Catholic Church's influence which allowed the use of turquoise in secular jewellery. It was apparently unknown in India until the Mughal period, and unknown in Japan until the 18th century. A common belief shared by many of these civilizations held that turquoise possessed certain prophylactic qualities; it was thought to change colour with the wearer's health and protect him or her from untoward forces.

The Aztecs inlaid turquoise, together with gold, quartz, malachite, jet, jade, coral, and shells, into provocative (and presumably ceremonial) mosaic objects such as masks (some with a human skull as their base), knives, and shields. Natural resins, bitumen and wax were used to bond the turquoise to the objects' base material; this was usually wood, but bone and shell were also used. Like the Aztecs, the Pueblo, Navajo and Apache tribes cherished turquoise for its amuletic use; the latter tribe believe the stone to afford the archer dead aim. Among these peoples turquoise was used in mosaic inlay, in sculptural works, and was fashioned into toroidal beads and freeform pendants. The Ancestral Puebloans (Anasazi) of the Chaco Canyon and surrounding region are believed to have prospered greatly from their production and trading of turquoise objects. The distinctive silver jewelry produced by the Navajo and other Southwestern Native American tribes today is a rather modern development, thought to date from circa 1880 as a result of European influences.

In Persia, turquoise was the *de facto* national stone for millennia, extensively used to decorate objects (from turbans to bridles), mosques, and other important buildings both inside and out, such as the Medresseh-I Shah Husein Mosque of Isfahan. The Persian style and use of turquoise was later brought to India following the establishment of the Mughal Empire there, its influence seen in high purity gold jewellery (together with ruby and diamond) and in such buildings as the Taj Mahal. Persian turquoise was often engraved with devotional words in Arabic script which was then inlaid with gold.

Cabochons of imported turquoise, along with coral, was (and still is) used extensively in the silver and gold jewellery of Tibet and Mongolia, where a greener hue is said to be preferred. Most of the pieces made today, with turquoise usually roughly polished into irregular cabochons set simply in silver, are meant for inexpensive export to Western markets and are probably not accurate representations of the original style.

The Egyptian use of turquoise stretches back as far as the First Dynasty and possibly earlier; however, probably the most well-known pieces incorporating the gem are those recovered from Tutankhamun's tomb, most notably the Pharaoh's iconic burial mask which was liberally inlaid with the stone. It also adorned rings and great sweeping necklaces called *pectorals*. Set in gold, the gem was fashioned into beads, used as inlay, and often carved in a scarab motif, accompanied by carnelian, lapis lazuli, and in later pieces, coloured glass. Turquoise, associated with the goddess Hathor, was so liked by the Ancient Egyptians that it became (arguably) the first gemstone to be imitated, the fair structure created by an artificial glazed ceramic product known as faience. (A similar blue ceramic has been recovered from Bronze Age burial sites in the British Isles.)

The French conducted archaeological excavations of Egypt from the mid-19th century through the early 20th. These excavations, including that of Tutankhamun's tomb, created great public interest in the western world, subsequently influencing jewellery, architecture, and art of the time. Turquoise, already favoured for its pastel shades since c. 1810, was a staple of Egyptian Revival pieces. In contemporary Western use, turquoise is most often encountered cut *en cabochon* in silver rings, bracelets, often in the Native American style, or as tumbled or roughly hewn beads in chunky necklaces. Lesser material may be carved into fetishes, such as those crafted by the Zuni. While strong sky blues remain superior in value, mottled green and yellowish material is popular with artisans. In Western culture, turquoise is also the traditional birthstone for those born in the month of December. The turquoise is also a stone in the Jewish High Priest's breastplate, described in Exodus 28.

6 - Culture :

In many cultures of the Old and New Worlds, this gemstone has been esteemed for thousands of years as a holy stone, a bringer of good fortune or a talisman. It really does have the right to be called a 'gemstone of the peoples'. The oldest evidence for this claim was found in Ancient Egypt, where grave furnishings with turquoise inlay were discovered, dating from approximately 3000 BC. In the ancient Persian Empire, the sky-blue gemstones were earlier worn round the neck or wrist as protection against unnatural death. If they changed colour, the wearer was thought to have reason to fear the approach of doom. Meanwhile, it has been discovered that the turquoise certainly can change colour, but that this is not necessarily a sign of impending danger. The change can be caused by the light, or by a chemical reaction brought about by cosmetics, dust or the acidity of the skin.

7 - Imitations ;

The Egyptians were the first to produce an artificial imitation of turquoise, in the glazed earthenware product faience. Later glass and enamel were also used, and in modern times more sophisticated ceramics, porcelain, plastics, and various assembled, pressed, bonded, and sintered products (composed of various copper and aluminium compounds) have been developed: examples of the latter include "Viennese turquoise", made from precipitated aluminium phosphate coloured by copper oleate; and "neolith", a mixture of bayerite and copper phosphate. Most of these products differ markedly from natural turquoise in both physical and chemical properties, but in 1972 Pierre Gilson introduced one fairly close to a true synthetic (it does differ in chemical composition owing to a binder used, meaning it is best described as a simulant rather than a synthetic). Gilson turquoise is made in both a uniform colour and with black "spiderweb matrix" veining not unlike the natural Nevada material.

The most common imitation of turquoise encountered today is dyed howlite and magnesite, both white in their natural states, and the former also having natural (and convincing) black veining similar to that of turquoise. Dyed chalcedony, jasper, and marble is less common, and much less convincing. Other natural materials occasionally confused with or used in lieu of turquoise include: variscite and faustite ; chrysocolla (especially when impregnating quartz); lazulite; smithsonite; hemimorphite; wardite; and a fossil bone or tooth called odontolite or "bone turquoise", coloured blue naturally by the mineral vivianite. While rarely encountered today, odontolite was once mined in large quantities—specifically for its use as a substitute for turquoise—in southern France.

These fakes are detected by gemmologists using a number of tests, relying primarily on non - destructive, close examination of surface structure under magnification; a featureless, pale blue background peppered by flecks or spots of whitish material is the typical surface appearance of natural turquoise, while manufactured imitations will appear radically different in both colour (usually a uniform dark blue) and texture (usually granular or sugary). Glass and plastic will have a much greater translucency, with bubbles or flow lines often visible just below the surface. Staining between grain boundaries may be visible in dyed imitations.

Some destructive tests may, however, be necessary; for example, the application of diluted hydrochloric acid will cause the carbonates odontolite and magnesite to effervesce and howlite to turn green, while a heated probe may give rise to the pungent smell so indicative of plastic. Differences in specific gravity, refractive index, light absorption (as evident in a material's absorption spectrum), and other physical and optical properties are also considered as means of separation.

8 - Treatments :

An early turquoise mine in the Madan village of Khorasan.

Turquoise is treated to enhance both its colour and durability (i.e., increased hardness and decreased porosity). As is so often the case with any precious stones, full disclosure about treatment is frequently not given. It is therefore left to gemologists to detect these treatments in suspect stones using a variety of testing methods—some of which are necessarily destructive. For example, the use of a heated probe applied to an inconspicuous spot will reveal oil, wax, or plastic treatment with certainty.

8 – 1 - Waxing and oiling :

Historically, light waxing and oiling were the first treatments used in ancient times, providing a wetting effect, thereby enhancing the colour and lustre. This treatment is more or less acceptable by tradition, especially because treated turquoise is usually of a higher grade to begin with. Oiled and waxed stones are prone to "sweating" under even gentle heat or if exposed to too much sun, and they may develop a white surface film or bloom over time. (With some skill, oil and wax treatments can be restored.)

8 – 2 – Stabilization :

Material treated with plastic or water glass is termed "bonded" or "stabilized" turquoise. This process consists of pressure impregnation of otherwise unsaleable chalky American material by epoxy and plastics (such as polystyrene) and water glass (sodium silicate) to produce a wetting effect and improve durability. Plastic and water glass treatments are far more permanent and stable than waxing and oiling, and can be applied to material too chemically or physically unstable for oil or wax to provide sufficient improvement. Conversely, stabilization and bonding are rejected by some as too radical an alteration .

The epoxy binding technique was first developed in the 1950s and has been attributed to Colbaugh Processing of Arizona, a company that still operates today. The majority of American material is now treated in this manner although it is a costly process requiring many months to complete. Without such impregnation, most American mining operations would be unprofitable.

8 – 3 – Dyeing :

The use of Prussian blue and other dyes (often in conjunction with bonding treatments) to "enhance"—that is, make uniform or completely change—colour is regarded as fraudulent by some purists, especially since some dyes may fade or rub off on the wearer. Dyes have also been used to darken the veins of turquoise.

8 – 4 – Reconstitution :

Perhaps the most extreme of treatments is "reconstitution", wherein fragments of fine turquoise material, too small to be used individually, are powdered and then bonded to form a solid mass. Very often the material sold as "reconstituted" turquoise is artificial, with little or no natural stone, and may have foreign filler material added to it.

8 – 5 – Backing :

Since finer turquoise is often found as thin seams, it may be glued to a base of stronger foreign material as a means of reinforcement. These stones are termed "backed," and it is standard practice that all thinly cut turquoise in the Southwestern United States is backed. Native indigenous peoples of this region, because of their considerable use and wearing of turquoise, have found that backing increases the durability of thinly cut slabs and cabs of turquoise. They observe that if the stone is not backed it will often crack. Early backing materials included the casings of old model T batteries old phonograph records, and more recently epoxy steel resins. Backing of turquoise is not widely known outside of the Native American and Southwestern United States jewelry trade. Backing does not diminish the value of high quality turquoise, and indeed the process is expected for most thinly cut American commercial gemstones .

9 - Valuation and care

Hardness and richness of colour are two of the major factors in determining the value of turquoise; while colour is a matter of individual taste, generally speaking, the most desirable is a strong sky to "robin's egg" blue (in reference to the eggs of the American Robin).[8] Whatever the colour, turquoise should not be excessively soft or chalky; even if treated, such lesser material (to which most turquoise belongs) is liable to fade or discolour over time and will not hold up to normal use in jewellery.

The mother rock or *matrix* in which turquoise is found can often be seen as splotches or a network of brown or black veins running through the stone in a netted pattern; this veining may add value to the stone if the result is complementary, but such a result is uncommon. Such material is sometimes described as "spiderweb matrix"; it is most valued in the Southwest United States and Far East, but is not highly appreciated in the Near East where unblemished and vein-free material is ideal (regardless of how complementary the veining may be). Uniformity of colour is desired, and in finished pieces the quality of workmanship is also a factor; this includes the quality of the polish and the symmetry of the stone. Calibrated stones—that is, stones adhering to standard jewellery setting measurements—may also be more sought after. Like coral and other opaque gems, turquoise is commonly sold at a price according to its physical size in millimetres rather than weight.

Turquoise is treated in many different ways, some more permanent and radical than others. Controversy exists as to whether some of these treatments should be acceptable, but one can be more or less forgiven universally: This is the *light* waxing or oiling applied to most gem turquoise to improve its colour and lustre; if the material is of high quality to begin with, very little of the wax or oil is absorbed and the turquoise therefore does not "rely" on this impermanent treatment for its beauty. All other factors being equal, untreated turquoise will always command a higher price. Bonded and "reconstituted" material is worth considerably less.

Being a phosphate mineral, turquoise is inherently fragile and sensitive to solvents; perfume and other cosmetics will attack the finish and may alter the colour of turquoise gems, as will skin oils, as will most commercial jewelry cleaning fluids. Prolonged exposure to direct sunlight may also discolour or dehydrate turquoise. Care should therefore be taken when wearing such jewels: cosmetics, including sunscreen and hair spray, should be applied before putting on turquoise jewellery, and they should not be worn to a beach or other sun-bathed environment. After use, turquoise should be gently cleaned with a soft cloth to avoid a build up of residue, and should be stored in its own container to avoid scratching by harder gems. Turquoise can also be adversely affected if stored in an airtight container.

81 -Vauxite

Contents

1 – Introduction :

Vauxite is a phosphate mineral with the chemical Formula $Fe^{2+}Al_2(PO_4)_2(OH)_2\cdot6(H_2O)$. It belongs to the laueite – paravauxite group, paravauxite subgroup , although Mindat puts it as a member of the vantasselite $Al_4(PO_4)_3(OH)_3\cdot9H_2O$ group.[3] There is no similarity in structure between vauxite and paravauxite $Fe^{2+}Al_2(PO_4)_2(OH)_2\cdot8H_2O$ or metavauxite $Fe^{3+}Al_2(PO_4)_2(OH)_2\cdot8H_2O$, even though they are closely similar chemically, and all minerals occur together as secondary minerals . Vauxite was named in 1922 for George Vaux Junior (1863–1927), an American attorney and mineral collector.

Category	Phosphate minerals
Chemical Formula	$Fe^{2+}Al_2(PO_4)_2(OH)_2.6H_2O$
Molar mass	442 g
Color	Blue, becoming greenish on exposure
Crystal habit	Minute tabular crystals, radial aggregates and nodules
Crystal system	Triclinic 1
Cleavage	None observed

Fracture	Brittle
Mohs scale hardness	3.5
Luster	Vitreous
Streak	White
Diaphaneity	Transparent to translucent
Specific gravity	2.39 to 2.40
Optical properties	Biaxial (+)
Refractive index	N_x=1.551, N_y=1.555, N_z=1.562
Birefringence	r > v
Pleochroism	(strong): X , Z colorless , Y blue
Other characteristics	Fluorescent. Not radioactive

2 - Unit cell :

The space group is P1, which means that the only symmetry element for the crystal is a center of symmetry. The crystal is built up of identical units, called unit cells, which are stacked together so that, in the absence of imperfections, they completely fill the space occupied by the crystal. The unit cell is a rhomboid (each face is a parallelogram, and opposite pairs of faces are equal) with side lengths a, b and c. The angles between the sides are denoted by the Greek letters α, β and γ, where α is the angle between sides b and c, β between c and a, and γ between a and b . For vauxite, the reported values of these parameters differ slightly from reference to reference, as different researchers have studied different samples, but all agree that a = 9.1 Å, b = 11.6 Å, c = 6 Å, α = 98.3°, β = 92° and γ = 108°, to the accuracy stated. Detailed reported values of the lattice parameters are :

- a = 9.13 Å, b = 11.59 Å, c = 6.14 Å, α = 98.3°, β = 92°, γ = 108.4°

- a = 9.142 Å, b = 11.599 Å, c = 6.158 Å, α = 98.29°, β = 91.93°, γ = 108.27°

Within each unit cell there are two units of the Formula $Fe^{2+}Al_2(PO_4)_2(OH)_2 \cdot 6H_2O$.

3 - Structure :

The structure of vauxite is characterised by infinite chains parallel to the c crystal axis. One set of chains is built up of octahedra with a ferrous iron ion Fe^{2+} or an aluminium ion Al in the middle, and an oxygen ion O at each of the six vertices. The central ions of these octahedra are alternately Fe and Al, and adjacent octahedra share edges. At each linked edge two oxygen ions are shared between two octahedra, and each octahedron must have two shared edges to form a chain.

Parallel to these edge-linked octahedral chains are vertex-linked mixed chains of alternating octahedra and tetrahedra. The tetrahedra have a phosphorus ion P in the middle, and oxygen ions O at each of the four vertices, and the octahedra have an aluminium ion Al in the middle surrounded by six oxygen ions O, as in the octahedral chains. At each linked vertex one O is shared between a tetrahedron and an octahedron, and each tetrahedron and octahedron must have two linked vertices to form the mixed chain.

Each octahedral chain is flanked by two mixed chains, one on either side, linked through the vertices of the chains, making an infinite triple chain. The triple chains are further interlinked by yet more phosphorus tetrahedra (not the ones in the mixed chains), which share vertices with both kinds of octahedra in the octahedral chains, and with the aluminium octahedra in the mixed chains. Water molecules (H_2O) and hydroxyl ions (OH) are also incorporated into this chain, giving a complex chain with composition $[FeAl_3(PO_4)_4(OH)_4(OH_2)_2]^{5-}$. These complex chains, which are parallel to the c crystal axis, are linked in the direction of the a axis by further aluminium octahedra (not the ones in the chains) and in the direction of the b axis by further Fe octahedra, and there are more water molecules within channels in the structure, giving the final Formula for vauxite as $FeAl_2(PO_4)_2(OH)_2.6H_2O$.

4 - Crystal habit :

Vauxite crystals are very small and tabular, forming sub-parallel to radial aggregates and nodules. The crystals are flattened parallel to the plane containing the a and c crystal axes, and elongated in the c direction , that is along the length of the chains which are the basis of the structure.

5 - Optical properties :

A triclinic mineral, such as vauxite, has all three of its crystal axes of different lengths, and all three interaxial angles of different sizes, with none equal to 60°, 90° or 120°. Consequently the material is anisotropic, and physical properties, including optical properties, vary with direction . The refractive index is the ratio of the speed of light in a vacuum to the speed of light through the medium. Since this varies with the color of the light, a standard color must be chosen when refractive indices are specified. The usual standard is the yellow light from a sodium source, that has wavelength 589.3 nanometres. For an anisotropic substance the refractive index (for light of a given color) varies with direction,[7] and for vauxite the range is from 1.551 for light travelling parallel to the a axis to 1.562 for light travelling parallel to the c axis.

An optic axis is a direction in which light travels through a crystal such that the speed is the same for all directions of polarization for light of any given wavelength (i.e. color). Any direction in an isometric crystal has this property. Trigonal, tetragonal and hexagonal crystals have a single optic axis, parallel to the c crystal axis. They are said to be uniaxial. Triclinic, monoclinic and orthorhombic crystals have two optic axes, and are said to be biaxial. The angle between the two axes is denoted by 2V. Vauxite is biaxial.

5 – 1 - Optic sign :

Unpolarized light travels unchanged through an isometric crystal, whatever the direction of travel. In uniaxial and biaxial crystals, light travelling in any direction other than parallel to an optic axis is broken into two polarized rays, the ordinary ray and the extraordinary ray. The ordinary ray travels with the same speed no matter what the direction; this is a consequence of the plane in which it is polarized. The plane of polarization of the extraordinary ray is perpendicular to that of the ordinary ray, and in general its speed will be different. For rays travelling along an optic axis the speeds of the ordinary and extraordinary rays are equal. For all other directions in uniaxial and biaxial crystals the speeds are different. The crystal is said to be positive if the ordinary ray has a greater speed than the extraordinary ray, and negative if the reverse is true.[7] Vauxite is biaxial (+).

5 – 2 - Dispersion of the optic axes :

The refractive index varies with the wavelength (color) of light, so the positions of the optic axes in biaxial crystals, and the angle 2V between them, will change when the color of the incident light is changed. This phenomenon is usually expressed in the form r > v, indicating that 2V is greater for red than for violet light, or vice versa. For vauxite r > v, 2V is greater for red light than for violet light.

5 – 3 - Pleochroism :

Pleochroism is the phenomenon of crystals appearing to change color as they are rotated in plane polarized light . This is due to differential absorption of light vibrating in different directions. Isometric crystals cannot be pleochroic. Uniaxial crystals (trigonal, tetragonal or hexagonal) may show two, but not three, different colors as they are rotated, then they are said to be dichroic (two colors). Biaxial crystals may show three different colors, and then are said to be pleochroic (many colors). Vauxite is strongly pleochroic, colorless along X and Z and blue along Y.

6 – Environment :

Vauxite is a secondary mineral derived from the alteration of apatite in hydrothermal tin veins. It is found associated with wavellite $Al_3(PO_4)_2(OH)_3{\cdot}5H_2O$, metavauxite and paravauxite at the type locality, Siglo Veinte Mine (Siglo XX Mine), Llallagua, Rafael Bustillo Province, Potosí Department, Bolivia , which is the only known occurrence of this mineral . The type material is conserved at the US National Museum of Natural History, Washington DC: #97561, #103542.

82 – Vermiculite

Contents

1 – Introduction :

Vermiculite is a natural mineral that expands with the application of heat. The expansion process is called exfoliation and it is routinely accomplished in purpose-designed commercial furnaces. Vermiculite is formed by weathering or hydrothermal alteration of biotite or phlogopite . Large commercial vermiculite mines currently exist in Russia, South Africa, China, and Brazil.

Category	Phyllosilicate
Chemical Formula	$(MgFe,Al)_3(Al,Si)_4O_{10}(OH)_2\cdot 4H_2O$
Color	Colorless, white, yellow, green, brown
Crystal habit	Clay, scaly, aggregate, rarely as

	pseudohexagonal crystal plates
Crystal system	Monoclinic Prismatic H-M Symbol (2/m) Space Group: C 2/m
Fracture	Uneven
Tenacity	Pliable
Mohs scale hardness	1.5- 2
Luster	Dull to pearly, bronzy
Streak	Greenish white
Diaphaneity	Translucent
Specific gravity	2.2 - 2.6
Optical properties	Biaxial (-)
Refractive index	n_α = 1.525 - 1.561 n_β = 1.545 - 1.581 n_γ = 1.545 - 1.581
Pleochroism	X in paler shades than Y and Z

2 - Occurrence

Vermiculite was first described in 1824 for an occurrence in Millbury, Worcester County, Massachusetts, USA. Its name is from Latin *vermiculare, to breed worms*, for the manner in which it exfoliates when heated.

It typically occurs as an alteration product at the contact between felsic and mafic or ultramafic rocks such as pyroxenites and dunites. It also occurs in carbonatites and metamorphosed magnesium rich limestone. Associated mineral phases include: corundum, apatite, serpentine and talc. It occurs interlayered with chlorite, biotite and phlogopite.

3 - Structure :

Vermiculite is a 2:1 clay, meaning it has 2 tetrahedral sheets for every one octahedral sheet. It is a limited expansion clay with a medium shrink-swell capacity. Vermiculite has a high cation exchange capacity at 100 -150 meq / 100 g. Vermiculite clays are weathered micas in which the potassium ions between the molecular sheets are replaced by magnesium and iron ions.

4 - Commercial uses :

- moulded shapes bonded with sodium silicate - this process involves the mixing of exfoliated vermiculite with potassium and/or sodium silicate to produce an 'earth damp' mixture. This material is then hydraulically pressed into shape in a mould, and then heat cured at temperatures up to 180° C for up to 24 hours depending upon the thickness of the board. Boards produced in this way can withstand service temperatures of up to 1150° C and are often used in the aluminium smelting industry as back-up insulation behind the carbon cathode in the potcells which contain the molten mixture of cryolite and alumina. These products are used in:
    - high-temperature insulation
    - refractory insulation
    - acoustic panels
    - fireproofing of structural steel and pipes
- calcium silicate boards - exfoliated vermiculite is added to a calcium silicate slurry, this is then dewatered by pressing or by using one of the Fourdriner / Magnani/Hatschek processes to form a flat board which is then heat cured under pressure (typically 10-15 bar) for periods up to 24 hours.
- brake linings - finer grades of exfoliated vermiculite are being used in brake linings primarily for the automotive market The properties of vermiculite that make it an appropriate choice for use in brake linings include its thermal resistance, ease of addition to other raw materials achieve a homogenous mix and its shape and surface characteristics

- roof and floor screeds and insulating concretes - exfoliated vermiculite (typically the finer grades) can be added at site to portland cement and other aggregates, rheological aids and water to produce roof and floor concrete screeds or lightweight concrete which have the benefit of being lightweight and insulating. In many cases vermiculite based roof screeds are often used in conjunction with other insulation materials such as polystyrene board to form a total roofing system. A bituminous binder can also be used with exfoliated vermiculite can to produce a dry, lightweight roof screed which has the advantages of low thermal conductivity, low moisture content and ease of placement by pouring from the bag and then tamping.
- soilless growing media - exfoliated vermiculite is combined with other materials such as peat or composted pine bark compost to produce soilless growing media for the professional horticulturalist and for the home gardener. These mixes promote faster root growth and gives quick anchorage to young roots. The mixture helps retain air, plant food and moisture, releasing them as the plant requires them. These mixes were pioneered by Boodley and Sheldrake
- seed germination - either used alone or mixed with soil or peat, vermiculite is used to germinate seeds. Very little watering is required. When vermiculite is used alone, seedlings should be fed with a weak fertilizer solution when the first true leaves appear. A tablespoon of soluble fertilizer per one imperial gallon (3.78 : 1) of water is the recommended mix
- storing bulbs and root crops - pour vermiculite around bulbs placed in container. If clumps are dug, allow to dry for a few hours in the sun and then place in cartons or bushel baskets and cover with vermiculite. The absorptive power of vermiculite acts as a regulator that prevents mildew and moisture fluctuation during the storage period. It will not absorb moisture from the inside of stored tubers, but it does take up free water from the outside, preventing storage rot.
- soil conditioner - Where the native soil is heavy or sticky, gentle mixing of vermiculite up to one - half the volume of the soil is recommended. This creates air channels and allows the soil mix

to breathe. Mixing vermiculite in flower and vegetable gardens or in potted plants will provide the necessary air to maintain vigorous plant growth. Where soils are sandy, mixing of vermiculite into the soil will allow the soil to hold water and air needed for growth.

- as loose-fill insulation - Exfoliated vermiculite treated with a water repellent is used to fill the pores and cavities of masonry construction and hollow blockwork to enhance fire ratings (eg. Underwriters Laboratories Wall and Partition designs), insulation and acoustic performance.Coarse grades of exfoliated vermiculite can be used to insulate lofts and attics. Exfoliated vermiculite has the benefit of being easy to use with application consisting of pouring the vermiculite between the joists and then levelling
- Refractory/Insulation gunning and castable mixes - exfoliated vermiculite can be combined with high alumina (also known as calcium aluminate) cements and other aggregates such as expanded shale, clay and slate to produce refractory/insulation concretes and mortars. In the early days of their uses these products were batched at or very close to the place of installation, this continues to be the case in some limited circumstances, however more and more use is being made of pre-batched proprietary mixes. Mixes containing vermiculite are used in areas where strength and corrosion/abrasion resistance are of secondary importance, the most important factor being the insulation performance of the in place refractory lining. These mixes find their uses in such areas in industries including iron/steel, cement and hydrocarbon processing
- as a constituent of a coating - vermiculite dispersions are typically either chemically or physically very finely delaminated vermiculite in a fluid medium. These dispersions can be used to make vermiculite ‘paper’ sheet by simply pouring them on to a piece of smooth low surface energy plastic and allowing to dry, the resulting sheet can then be peeled off the plastic .Typical end uses for vermiculite dispersions include in high temperature coatings or binders for construction materials, gaskets, specialty papers / textiles , oxidation resistant coating on carbon based composites, and as barrier coatings for films.
- packing material, valued for its high absorbency

- Waste Treatment - the cation exchange capacity (up to 1000 milliequivalents per Kg) of vermiculite allows it to be used in fluid purification processes for waste water, chemical processing and the pollution control of air in mines and gases in industrial processes. In addition to its ion exchange properties exfoliated vermiculite will retain liquids within the inter-laminar voids of the individual particles as well as between the particles themselves.
- suitable as a substrate for various animals and/or incubation of eggs
- light weight aggregate for plaster, proprietary concrete compounds, firestop mortar and cementitious spray fireproofing - Exfoliated vermiculite is used in both hand and spray applied general building plasters to improve coverage, ease of handling, adhesion to a wide variety of substrates, fire resistance, and resistance to chipping/cracking/shrinkage.
- as an additive to fireproof wallboard
- component of the interior fill for firestop pillows, along with graphite
- carrier for dry handling and slow release of agricultural chemicals
- growing medium for hydroponics.
- ‘Hot Topping’ - both exfoliated and crude vermiculite have been used for ‘hot topping’ in the steel industry. When poured onto molten ‘hot metal’ crude vermiculite exfoliates immediately and forms an insulating layer allowing the material to be transported to the next production process without losing too much heat.
- means to permit slow cooling of hot pieces in glassblowing, lampwork, steelwork, and glass beadmaking
- used in in-ground swimming pools to provide a smooth pool base - Finer grades of exfoliated vermiculite plus portland cement may be combined either on site or a factory premix to provide a base for swimming pool vinyl liners. These mixes are either pumped into place using a rotor stator pump or hand poured.
- used in commercial hand warmers
- used as a sterile medium for the incubation of reptile eggs
- light-weight insulative concrete

- used in AGA cookers as insulation
- used in explosives storage as a blast mitigant
- used to absorb hazardous liquids for solid disposal
- used in gas fireplaces to simulate embers
- used as part of a substrate for fungi cultivation

5 - Commercial manufacture of exfoliated vermiculite :

Vermiculite output in 2005

In 2005, South Africa was the top producer of vermiculite with about 40% world share followed by the USA and China, reports the British Geological Survey.

While some exfoliators focus on only a few of the possible applications, others can provide vermiculite products for all its applications. It is common for vermiculite exfoliators to exfoliate perlite also, as both are often sold together. For those who want to set up a new exfoliation process, it is possible to find expert consultants to advise in the design and construction of the desired facilities. Vermiculite exfoliators have an international trade association called *The Vermiculite Association* to represent the industry's interests and to exchange information. Many of its members also maintain memberships in *The Perlite Institute*.

6 - Fireproofing :

Sprays containing asbestos are still widely used for fireproofing in some parts of the world. These sprays contain aggregates of MMMF (man-made-mineral-fibres) including rockwool and ceramic fibres. The cementitious versions of these fireproofing sprays contain Portland cement and lightweight aggregates of the plaster vermiculite.

Vermiculite ore, particularly those mined from the U.S., usually is contaminated with asbestos. Danger of exposure to asbestos in these sprays is greatly increased when not handling following proper industrial hygiene procedures .

7 - Asbestos contamination :

Although not all vermiculite contains asbestos, some products were made with vermiculite that contained asbestos until the early 1990s. Vermiculite mines throughout the world are now regularly tested for it and are supposed to sell products that contain no asbestos. The former vermiculite mine in Libby, Montana, did have tremolite asbestos as well as winchite and richterite (both fibrous amphiboles) — in fact, it was formed underground through essentially the same geologic processes as the contaminants. A vermiculite mine in Virginia has also been found to be contaminated by asbestos .

Pure vermiculite does not contain asbestos and is non-toxic, but it can become contaminated over long periods if there is a presence of a secondary mineral called diopside. After millions of years of weathering, the biotite turns into vermiculite and the diopside turns into asbestos.

8 - Controversy over health risks :

The largest and oldest vermiculite mine in the United States was started in the 1920s, at Libby, Montana, and the vermiculite was sold under the commercial name Zonolite. The Zonolite brand and the mine was acquired by the W.R. Grace Company in 1963. Mining operations at the Libby site stopped in 1990 in response to asbestos contamination. While in operation, the Libby mine may have produced 80% of the world's supply of vermiculite .

The United States government estimates that vermiculite was used in more than 35 million homes, but does not recommend its removal. Nevertheless, homes or structures containing vermiculite or vermiculite insulation dating from before the mid 1990s—and especially those known to contain the "Zonolite" brand—may contain asbestos, and therefore may be a health concern.

An article published in the *Salt Lake Tribune* on December 3, 2006, reported that vermiculite and Zonolite had been found to contain asbestos, which had led to cancers such as those found in asbestos-related cases. The article stated that there had been a "cover-up" by W.R. Grace Company and others regarding the health risks associated with vermiculite and that several sites in the Salt Lake Valley had been remediated by the EPA when they were shown to be contaminated with asbestos. W.R. Grace Company has vigorously denied these charges.

The vermiculite deposit at the mine in Libby, Montana, was (and is) heavily contaminated with asbestos . Numerous people were knowingly exposed to the harmful dust of vermiculite that contained asbestos. Unfortunately, the mine had been operating since the 1920s, and environmental and industrial controls were virtually non-existent until the mine was purchased by the W.R. Grace Company in 1963. Yet, knowing the human health risks, the mining company still continued to operate there until 1990. Consequently, many of the former miners and residents of Libby have been affected and continue to suffer health problems. Over 200 people in the town have died from asbestos-related disease due to contamination from vermiculite mining from nearby Zonolite Mountain, where soil samples were found to be loaded with fibrous tremolite (known to be a very toxic form of asbestos), and countless others there who insulated their homes with Zonolite have succumbed to asbestos-related diseases, most of whom never were employed in environments where asbestos was an issue .

After a 1999 Seattle Post-Intelligencer story claimed that asbestos-related disease was common in the town, the EPA, in response to political pressure, made cleanup of the site a priority and called Libby the worst case of community-wide exposure to a toxic substance in U.S. history . The EPA has spent $ 120 million in Superfund money on cleanup . In October 2006, W. R. Grace Company tried to appeal the fines levied on them from the EPA, but the Supreme Court rejected the appeal . The United States government is also pursuing criminal charges against several former executives and managers of the mine for allegedly disregarding and covering up health risks to employees . They are also accused of obstructing the government's cleanup efforts and wire fraud. To date, according to the indictment, approximately 1,200 residents of the Libby area have been identified as suffering from some kind of asbestos-related abnormality . Jury selection was to have been completed in February, 2009 . The case ended in acquittals on May 8, 2009n. On June 17, 2009, the EPA issued a public health emergency in and near Libby, there by allowing Federal agencies to provide funding for health care, and for removal of contaminated insulation from affected homes .

83 – Woodhouseite

Woodhouseite from the type locality, the Champion Mine, Mono County, California, USA.

1 – Introduction :

Woodhouseite belongs to the beudantite group $AB_3(XO_4)(SO_4)(OH)_6$ where A = Ba, Ca, Pb or Sr, B = Al or Fe and X = S, As or P. Minerals in this group are isostructural with each other and also with minerals in the crandallite and alunite groups. They crystallise in the rhombohedral system with space group R3m and crystals are usually either tabular {0001} or pseudo-cubic to pseudo-cuboctahedral. Woodhouseite was named after Professor Charles Douglas Woodhouse (1888–1975), an American mineralogist and mineral collector from the University of California, Santa Barbara, USA, and one-time General Manager of Champion Sillimanite, Inc.

Category	Phosphate minerals
Chemical Formula	$CaAl_3(SO_4)(PO_4)(OH)_6$
Molar mass	414.10 g
Color	White, flesh-pink or colourless
Crystal habit	Crystals small, pseudocubic rhombohedral {1012}; tabular at times {0001}, with curved and striated faces.

Crystal system	Trigonal 3 2 / m , Hexagonal Scalenohedral
Mohs scale hardness	4.5
Streak	White
Diaphaneity	Transparent to translucent
Specific gravity	3,00
Optical properties	Uniaxial (+), 2V = 0° to 20°
Solubility	Soluble in acids only after driving off the water in a closed tube.
Other characteristics	Not radioactive.

2 - Environment :

Woodhouseite is a secondary mineral found where wall rock alteration occurred in hydrothermal and disseminated ore deposits; rare in cave deposits, formed from guano. At the type locality it occurs in vugs in quartz veins in an andalusite, Al_2OSiO_4, deposit. This is in pre-Cambrian meta-quartzite that has been intruded by late Jurassic granitic rocks. Woodhouseite is found only near masses of lazulite, $MgAl_2(PO_4)_2(OH)_2$. Associated Minerals at the type locality include topaz, $Al_2SiO_4F_2$, quartz, SiO_2, augelite, $Al_2PO_4(OH)_3$, lazulite, $MgAl_2(PO_4)_2(OH)_2$, tourmaline, baryte, $BaSO_4$, muscovite, $KAl_2(Si_3Al)O_{10}(OH)_2$, and pyrophyllite, $Al_2Si_4O_{10}(OH)_2$, all of which formed before the woodhouseite, which is a late-forming mineral.[5]

3 - Localities :

The type locality is the Champion Mine (White Mountain Mine), White Mountain, Laws, White Mountains, Mono County, California, USA. This is a former sillimanite mine located near Laws; mineralisation is a metamorphic sillimanite deposit hosted in quartzite.

84 - Ye'elimite

Ye'elimite (white) intergrown with Hydroxylellestadite (reddish-brown) in grey Anhydrite from Ronneburg, Thuringia, Germany

1 - Ye'elimite is the naturally occurring form of calcium sulfoaluminate, $Ca_4(AlO_2)_6SO_4$. It gets its name from Har Ye'elim in Israel in the Hatrurim Basin west of the Dead Sea where it was first found in nature. The mineral is cubic, with 16 Formula units per unit cell, and a cell dimension of 1.8392 nm, and is readily detected and quantified in mixtures by powder x-ray diffraction.

2 - Occurrence in cement :

It is alternatively called "Klein's Compound", after Alexander Klein of the University of California, Berkeley, who experimented with sulpho aluminate cements around 1960, although it was first described in 1957 by Ragozina. Ye'elimite is most commonly encountered as a constituent of sulfo aluminate cements, in which it is manufactured on the million-tonne-per-annum scale. It also occasionally occurs adventitiously in Portland-type cements . On hydration in the presence of calcium and sulfate ions, it forms the insoluble, fibrous mineral ettringite, which provides the strength in sulfoaluminate concretes.

It is manufactured by heating the appropriate quantities of finely-ground alumina, calcium carbonate and calcium sulfate to around 1000-1100°C, preferably in the presence of small quantities of fluxing materials. On heating above 1350°C, it begins to decompose to tricalcium aluminate, calcium oxide, sulfur dioxide and oxygen.

85 - Yogo sapphire (ياقوت أزرق)

A 0.43 carat pear-shaped cornflower blue Yogo sapphire

Contents

1 – Introduction :

Yogo sapphires are a special cornflower blue color variety of corundum found only in Yogo Gulch, Judith Basin County, Montana, United States. They are considered among the finest sapphires in the world, and by some gem experts, the finest. Sapphire mining at Yogo Gulch began in 1895, and the term "Yogo" is said to mean "blue sky" in the Piegan Blackfeet language. About $ 25 million of gemstone has been recovered by all mines at Yogo, and at least 28 million carats are estimated to still be in the ground.

The cornflower blue color of the Yogo is provided by trace amounts of iron and titanium. While sapphires were first discovered in Montana in 1865 it was not until 1895 that their quality and value was noticed and serious mining efforts began. Due to the unique nature of the dike that Yogo sapphires are found in, mining efforts at Yogo Gulch have been sporadic and rarely profitable. Yogo sapphires are rarer than diamonds. In 1969 the sapphire was designated the Montana state gemstone, along with Montana agate.

Category	Oxide mineral
Chemical Formula	Aluminium oxide, Al_2O_3
Color	Cornflower blue to purple
Crystal habit	massive and granular
Crystal system	Trigonal
Cleavage	none
Fracture	conchoidal, splintery
Mohs scale hardness	9.0
Luster	vitreous
Streak	White
Specific gravity	3.95 – 4.03
Optical properties	Abbe number 72.2
Refractive index	n_ω=1.768–1.772 n_ε=1.760–1.763,
Pleochroism	Strong
Melting point	2030 – 2050 °C
Fusibility	Infusible
Solubility	Insoluble

2 - Location

Yogo Gulch is located in what today is Judith Basin County, Montana, 19 km southwest (SW) of Utica, Montana and 72 km west-southwest (WSW) of Lewistown, Montana. It lies east of Great Falls, Montana . The area where Yogo sapphires are mined is a region historically inhabited by the Piegan Blackfeet people, and the word "Yogo" is alleged to mean "blue sky" in Piegan Blackfeet , although there is some dispute about this translation . At the time of discovery, this area was in southwestern Fergus County, Montana. Yogo Gulch and Utica are now located in Judith Basin County, which was broken out from western Fergus County and eastern Cascade County, Montana on December 10, 1920 . Yogo Peak (el. 8,625 feet (2,629 m)), Yogo Creek, Yogo Gulch, and the Yogo dike are located in the portion of the Little Belt Mountains that lies within Judith Basin County. The Judith River flows northeast out of the Little Belts towards Utica. East of the river is Pig-Eye Basin—where Jake Hoover, claimed to be the discoverer of Yogo sapphires, had a ranch. The Yogo area to the west. Yogo Peak is about 24 km west of the Judith River. Yogo Creek originates there and flows southeast to its confluence with the Middle Fork of the Judith River a few miles upstream of where the Middle Fork joins the Judith. Yogo Gulch is located along the lower reaches of Yogo Creek, and the Yogo dike originates a few miles north of the stream's confluence, then runs from west-southwest to east - northeast from Yogo Creek to just before the Judith River.

3 – Mineralogy :

Most sapphires found at Yogo Gulch must be mined from hard rock, "in situ". This, plus American labor costs, makes mining Yogos fairly expensive , and keeps them rarer than diamonds . About $ 25 million of gemstone has been recovered by all mines at Yogo to date. However, at least 28 million carats are estimated to still be in the ground.

Sapphires are a form of corundum, which is crystalline aluminum oxide and its chemical Formula is Al_2O_3 . Corundum is the second hardest mineral (rating 9) on the Mohs scale of mineral hardness . Almost all colors of corundum are called sapphires, except those of red corundum, which are called rubies . The term "Yogo sapphire" refers only to sapphires from the Yogo Gulch . The unique cornflower blue color of the Yogo is provided by trace amounts of iron and titanium .

Yogo sapphires are unique among the world's sapphires: they lack color zoning, are free of cavities, do not need heat treating because their cornflower blue coloring is uniform and deep, are generally free of inclusions, and they have high uniform clarity. Unlike Asian sapphires, they maintain their brilliance in artificial light. Because they are found in a lode rather than alluvial deposits where most other sapphires are located , Yogos present an advantage to gemcutters: they retain a perfect or near-perfect crystalline shape, making the work of gem-cutting much easier, as does their lack of inclusions, color zoning, or cloudiness . Yogos also have a trigon pattern , with rhombohedral crystals, a feature which is absent from sapphires from other parts of Montana . These rhombohedrons are almost always less than 1mm in thickness and appear like striations .

	
A 0.37 carat brilliant-cut purple Yogo sapphire. Only about 2 % of Yogo sapphires are purple.	*A 0.19 carat diamond-cut cornflower blue Yogo sapphire.*

The United States Geological Survey considers them among the world's finest sapphires. Some gem experts consider them the finest sapphires in the world. However, Yogo roughs tend to be small and flat, so large cut Yogo gems over two carats are rare. Only about 10% of cut pieces are over one carat. The largest recorded Yogo rough, found in 1910, was 19 carats in size, and was cut into an 8 carat gem. Yogos tend to be beautiful, small, and very expensive. Due to the rarity of large rough, prices for gems begin rising sharply when they are over a half carat, and sky rocket when they are over one carat. About 2 % of Yogos are in colors other than blue, almost always purple , very rarely reddish. Sapphires found in the other parts of

Montana come in a variety of colors, though rubies are rare . It is believed that the reason Yogos are almost always blue rather than coming in as wide variety of colors as other Montana sapphires is that their bedrock had a much longer cooling time. The largest cut Yogo is a 10.2 carat gem held by the Smithsonian Institution.

The Yogo sapphire deposit is located in a silica - poor lamproite igneous rock dike cutting into limestone that intruded a fissure into the earth . It varies from a few feet to almost 30 m in width, averaging 2.4 m wide, is over 8.0 km long, and at least 2,100 m deep. It contains large amounts of biotite and pyroxene. Except for Yogo Gulch and one small site in Kashmir, most other corundum is mined from the sand and gravel created by the weathering of metamorphic rock. These alluvial sapphires are found in the Orient, Australia, and other Montana locations — the Missouri River, Rock Creek, and Dry Cottonwood Creek .

There had been considerable debate over the years about how deep the Yogo dike was and how many ounces of sapphire rough per ton it contained, or "ounces per ton". In the late 1970s and early 1980s Delmer L. Brown, a geological engineer and gemologist, conducted the most thorough scientific exploration of the dike to date and showed it was at least 2,100 m deep and that the amount of sapphire rough was not consistent throughout the deposit. He determined that the dike's erosion was minimal and recent. Brown also showed that the unique characteristics of the Yogo sapphires were due to the way they were formed. Most sapphires are formed under low pressure and temperature over geologically short periods of time, and this is why most non-Yogo sapphires have imperfections and inconsistent coloring. Yogos show crystalline formation over very high temperatures and pressures over geologically long periods of time. These conditions are only possible at great depth. Yogos were formed at great depths, at least thousands of feet, perhaps miles deep, and then carried upwards by slowly thickening magma. As sapphires are heavier then magma, the smaller roughs rose closer to the surface. This is why the Yogos found to date are generally small. Mining at the English Mine confirmed this as the deeper the digging there got, the more likely miners were to find bigger Yogo roughs. Brown also showed that distribution of gem rough through the dike was not consistent, so using an average "ounces per ton" was misleading. What came to be known as the American Mine was built at a part of the dike with significantly lower "ounces per ton" than the English Mine. As a result of Brown's findings, operations at the American Mine were permanently shut down.

4 - Montana sapphires :

An uncut/rough yellow sapphire found at the Spokane Sapphire Mine near Helena, Montana

The term "Montana sapphire" generally refers to gems from Montana locations other than Yogo Gulch, where "Yogo sapphires" is the preferred term . More gem-quality sapphires are produced in Montana than anywhere else in North America . These gems inspired the names of geologic features; the mountains near Rock Creek are known as the Sapphire Mountains. Garnets are also found at some Montana sapphire sites, inspiring the name of the Garnet Range, which lies to the north of the Sapphire Mountains .

The first Sapphires found in the United States were discovered on May 5, 1865 along the Missouri River about 14 miles east of Helena, Montana in Lewis and Clark County, Montana by Ed "Sapphire" Collins . Although Collins sent his find to Tiffany's in New York City and Amsterdam for evaluation, the sapphires he sent did not have very good color or overall quality, so they garnered little notice and initially gave Montana sapphires a bad name . Corundum was also found at Dry Cottonwood Creek near Butte in 1889, Rock Creek near Philipsburg in 1892, and Quartz Gulch near Bozeman in 1894 . By 1890, the British-owned Sapphire and Ruby Mining

Company had bought several thousand acres of land where Montana sapphires were found, but the venture failed after a few years due to fraud perpetrated by the owners .

Sapphires from these three sites are routinely heat treated to enhance color . While millions of carats of sapphires have been mined from the Missouri River deposits, there has been little activity there since the 1990s due to recovery costs and environmental concerns, though small scale "pan-your-own" operations allowing individuals to prospect for sapphires remain in operation . Production at Dry Cottonwood Creek has been sporadic and low-yielding. The Rock Creek area, also known as Gem Mountain, has been the most productive site in Montana by far, even more so than Yogo Gulch, producing over 190 million carats of sapphires .

5 - Mining history :

Although gold had first been discovered at Yogo Creek in 1866, the early prospectors were chased off by local Native Americans. During the Montana Gold Rush of 1878, about one thousand men came to Yogo Creek as a result of a gold strike; Yogo Creek being one of the gold-bearing streams in Montana that had not been actively mined. The mining camp of Yogo City flourished for about three years, but only bits of gold and "blue pebbles" were found. Thus, the population dwindled until only a few people were left.

While on a weight-for-weight basis sapphires are worth more than gold, and the Yogo mines ultimately produced more dollar value than several gold strikes, production of Yogos require hard rock mining and sophisticated marketing, whereas gold was easier to identify and merely required digging and selling . Nonetheless, sapphire mining at Yogo Gulch began in 1895 when someone finally thought to investigate the nature of the "blue pebbles." In that year, Jake Hoover sent a cigar box containing those he had collected while mining gold to an assay office, which in turn sent them via regular, uninsured mail to Tiffany's in New York City for appraisal by gemologist Dr. George Frederick Kunz , the leading American gemologist of the time . Impressed by their quality and color, Kunz pronounced them “the finest precious gemstones ever found in the United States".Tiffany's sent Hoover a check for $3,750 along with a letter that described the blue pebbles as “sapphires of unusual quality.” In February 1896, sheepherder Jim Ettien found the sapphire mother lode, the Yogo dike, while following a line of gopher holes. He sold it to Hoover. Hoover in turn sold his interest in his eight original mining stakes, known as the "New Mine Sapphire Syndicate," to his two partners for $ 5,000. For several years prior to discovering Yogo sapphires, Hoover had a ranch in Pig - Eye Basin. Afterwards he prospected for gold in Alaska and was a deep-sea fishing guide in Seattle, before eventually returning to the Judith Basin .

On July 4, 1896, two other Americans, John Burke and Pat Sweeney, staked mining claims at six sections of western portion of the Yogo dike; areas Hoover had deemed unfit for mining. These claims were known as the "Fourth of July Claim". This mine became known as the "American Mine", bought in 1904 by the American Gem Syndicate and purchased in 1907 by the American Sapphire Company.

Millie Ringold, a former slave born in 1845, had settled in Fort Benton, Montana after having worked as a nurse and servant for an army general. Millie promptly left for the Yogo gold fields, selling her boarding house in Fort Benton and setting up a hotel, restaurant, and saloon. She also sang and played music . Millie became known as a superb cook at the English Mine, but by 1903 she had fallen on hard times. She remained there until she died in 1906, was considered Yogo City's most prominent citizen, and ultimately the last resident of the city . Yogo City also was briefly known as Hoover City, after Jake Hoover, who employed and remained lifelong friends with western painter Charles Marion Russell . Russell stated he learned most of his frontier skills from Hoover . The nearby town of Utica was featured in Russell's 1907 painting *A Quiet Day in Utica*, which was originally known as *Tinning a Dog*. Russell himself, Hoover, and Ringold are all depicted in the painting .

In 1899, gem merchants Johnson, Walker and Tolhurst, Ltd. of London paid $ 100,000 for the New Mine Sapphire Syndicate, which then became unofficially known as the "English Mine " . This site was 5 miles (8.0 km) from Yogo City. One of the Englishmen who came to the area was Charles Gadsden of Berkhamsted. By 1900, there was little left of the gold mine, though Ringold was still working gold claims. By 1902, Gadsden was promoted to resident supervisor of the English Mine and he quickly turned the mine's focus to sapphires.[56] Weight-for-weight rough sapphires are worth much more than gold, and Gadsden's security measures were very tight . The English Mine flourished until the 1920s . Floods so severely damaged the mines on July 26, 1923 that they never fully recovered . The "English Mine" finally succumbed to the aftermath of the floods and hard economic times in 1929. It had recovered more than 16 million carats of rough sapphires that were valued at $2.5 million. Subsequently a series of several other firms mined the sapphires but with marginal success.

Operations at the English Mine were significantly more profitable than at the American Mine, largely because of the mining and management techniques employed, insufficient space and water for ore weathering at their end of the Yogo dike, and inability to market the gems within the United States. Roughs from the English Mine were shipped to London and sold in Europe, often as sapphires from the Far East. The American Sapphire Company, which used less skilled gemcutters from Great Falls, Montana, went bankrupt in 1909 and a new form, the Yogo American Sapphire Company bought the American Mine but went bankrupt in 1913. The American Mine was then bought by New Mine Sapphire Syndicate in 1914, which quickly recouped its purchase price by washing the tailings left behind by the American Mine . Sapphire mining at the other Montana sapphire mines was even less successful because of the very low profit margin in sapphires that are not blue. Blue sapphires are extremely rare at Montana sites other than Yogo Gulch.

Other Montana sapphires were heavily mined during World War II for industrial uses. However, because the Yogo mines were still owned by the British, they were little affected by the war. Hoover remained caretaker of the mines until shortly before his death on

March 11, 1954. For much of the 1930s and 1940s he was the sole employee of the mine and spent $29,000 of his own money to pay the mine's property taxes . The sixth American company to acquire the Yogo dike was the Yogo Sapphire Mining Corporation of Billings, Montana. The firm made its initial offer in 1946 and obtained an agreement with the English in 1949. However, legal wrangling delayed the actual purchase until July 1956. The final price was $65,000 and various stock considerations. Like so many other Yogo ventures, its capital was exhausted. The Yogo Sapphire Mining Corporation then changed its name to the same as the British firm's name: New Mine Sapphire Syndicate. It became known as the "American Syndicate" to distinguish it from the previous "English Syndicate". Production was poor and mining ceased in September 1959. From 1959–1963 the mine was "open" resulting in hobbyists, picknickers, and rockhounds from all over America and Canada coming to gather loose rough. The American Syndicate finally took action to stop this in 1963, with fences and threats of prosecution. The American Syndicate had leased the mine to several operators. One of these was Siskon, Inc. of Nevada, who lost a significant amount of money. They sued and in May 1965 the Montana Supreme Court ruled in Siskon's favor. Siskon bought the mine at a sheriff's sale and in turn leased it to a group headed by Arnold Baron, who had a background in gemcutting and jewelry. Baron organized some German and Thai gemcutters and had success in marketing Yogos in America—the first time that occurred in 50 years. However, due to the difficulty in mining the hard rock site, he did not exercise his option to buy the mine and Siskon sold it in August 1968 when Herman Yaras bought it for $585.000.

Millie Ringold, circa 1900. The structure in the background is a waterwheel that was used to power a crusher at Yogo City's Weatherwax Mine.

Yaras' firm was called Sapphire Village, Inc. Yaras was from Oxnard, California. This eventually led to what is now called Sapphire Village in early 1969, a nearby homesite development where people can gather their own sapphires through limited mining rights. "Mining" on these homesites was limited to hand tools. Meanwhile, Sapphire Village, Inc. did little to mine and market sapphires and it folded. Yaras sold the mine in 1973 to Chikara Kunisaki, an Oxnard, California native and celery farmer. Kunisaki owned one of the original homes in Sapphire Village and named his firm Sapphire International Corporation. Kunisaki then made the first serious effort to mine Yogo Gulch since the early days of the English Mine. He built a modern 3,000 foot tunnel at the site of the old American Mine that became known as the "Kunisaki Tunnel". However, Sapphire International Corporation's operations were so costly that it shut down operations in fall 1976.

Victor di Suvero and his firm Sapphire-Yogo Mines were next in January 1977 with a lease on the mine. Di Suvero was a native-born Italian who grew up in Tientsin, China and had been successful with a jade mine in California. Di Suvero's expertise was in marketing and he formed Sapphire Trading to cut and market the Yogos. He had novel marketing ideas but neglected the mining aspects of business. Consequently he was unable to make payments and this venture folded in fall 1979. At this point, only 4 Americans had been successful at Yogo Gulch and that was early in its mining history. At least thirteen American Yogo mining efforts had failed. Besides financial and hard rock mining difficulties, the Americans did not understand gem marketing. They generally approached the Yogos as if they were gold nuggets; not being able to see past a bag full of sapphire roughs.

Kunisaki then put his mine up for sale, asking $6 million to recoup his expenses. Even though mine profits had been poor over the decades, during this time prices of precious gems were very high due to the world wide oil crises of the 1970s and early 1980s. Four individuals or groups seriously considered Kunisaki's offer. Relying heavily upon the expertise of Brown, Harry C. Bullock and J. R. Edington formed the limited partnership American Yogo Sapphire Limited, the 14th American company to work the Yogo dike. They paid the $6 million price and then raised $7.2 million in funding by October 1981. Bullock and Brown had Yogo mine experience prior to this as they had worked with di Suvero. Bullock's plan included mining, cutting, making jewelry, and marketing—the whole specturm of the business. Brown discovered he could get the best gemcutters for the best price, who were also willing to improve their skills, in Thailand. This is where American Yogo Sapphire Limited set up its network of cutters. Brown also set up a security system that was computerized, thorough, and started at the mine and included the Thai cutters. Bigger roughs were sent to American cutters, specialty cuts were done in Germany, and a few cuts were done in Hong Kong. The vast majority of cuts were done in Thailand. American Yogo Sapphire Limited secured a $5 million line of credit with Citibank. Desiring a more modern name, American Yogo Sapphire Limited changed its name to Intergem Limited in spring 1982. Intergem marketed the Yogo as the Royal American Sapphire. Their first line of jewelry appeared in late summer 1982. Intergem started by marketing the jewelry regionally in the American west and then national marketing. They also developed a system of authorized dealers. Intergem began marketing the Yogo, rather Royal American Sapphire, as the world's only guaranteed untreated sapphire—a claim which rocked the gem trade because by 1982 the issue of heat treating gems had become a major issue in the gem trade. At that time 95 % of all the world's sapphires were being heated to enhance their natural color. The Thais had taken this a step further by buying large quantities of Sri Lankan sapphires that were naturally colorless, known as geuda, and heating them to a totally artificial blue. Compounding the problem, heated gems often fade over time. Trained gemologists can detect a heated gem 95% of the time. Intergem's marketing of guaranteed untreated Yogos set them against many in the gem industry. This issue appeared as a front page story in the *Wall Street Journal* on August 29, 1984 in an article by Bill Richards entitled "Carats and Schticks: Sapphire Marketer Upsets The Gem Industry". In its first 4 years Intergem met with success. In 1984 alone sales were over $3 million. In 1985 there was a movement in Pennsylvania to require disclosure that a gem had been treated. Large numbers of gem professionals were visiting Yogo Gulch. However, problems were brewing.

Intergem had begun planning to dig even deeper into the Yogo dike; which held more known reserves than all the world's other known sapphire deposits combined; albeit deep underground than near the surface like the other known deposits. By this time Sapphire International Corporation had been renamed to Roncor; to which Intergem had made a down payment and agreed to make semi-annual payments. Intergem also had loan and interest payments to make to Citibank. Intergem's sales were steadily increasing, but even still not enough cash was coming in and in May 1985 they missed a $250,000 payment to Roncor. Their collateral with Citibank had declined because their collateral was their own inventory and the value of gems was declining. Citibank called in its loan. Intergem had over $1 million in sales lined up for the 1985 Christmas season but could only fill a tiny portion. In summer 1986 Roncor regained full ownership even though Intergem had sold carats and jewelry worth millions of dollars.

While the various companies attempted mine leasing with Roncor, two local married couples discovered a new site at Yogo Gulch in January 1984 by following a trail to an unused section of the dike that had previously been deemed unsuitable. They began mining the site and named it the "Vortex Mine". The company was named Vortex Mining. The mine shaft went 85 m down and contained two Yogo ore-bearing veins . The mine was successful for years but eventually declined and the Vortex Mine, which was now called Yogo Creek Mining , closed in 2004. The portion of the dike they had mined was an extension of the main dike. In 1992 Roncor found an 11 carat rough .

AMAX Exploration, operating as the Yogo Sapphire Project, signed a 22-month lease with Roncor in March 1993 and had some success in the middle and eastern portions of the dike but decided not to continue after the end of its lease due to the cost of underground mining, depletion of easily accessible Yogos, and the relatively small size of Yogos currently easily accessible. During this time additional dikes were found in the area and low grade rough was found in what is known as the "Eastern Flats Dike".

In 1995 Intergem's stock of gems began to reappear on the market because during its demise Intergem had paid its salesmen in sapphires. After Intergem collapsed, many of its salesmen continued to sell Yogos, especially after AMAX ceased operations. Citibank also had obtained a large stock of Yogo pieces as a result of Intergem's demise reputedly worth $3.5 million and consisting of 200,000 carats of rough, 22,000 carats of cut gems, and 2,000 pieces of jewelry. This sat in the bank's vaults until 1991 when Sofus Michelsen, director of the Center for Gemstone Evaluation and creator of the *Michelsen Gemstone Index*, became interested. In 1992 he and Jim Adair, a Missoula, Montana jeweler who is the world's largest retailer of Yogos, got together and by October 1994 Adair had purchased most of Yogo material Citibank had, which had been stored in 4 sealed bags, which contained a lot of dirt. Only one of the bags was truly valuable. Adair and Michelsen designed custom cutting techniques for Yogos . Then a Canadian company called Pacific Cascade Sapphires operated a mining lease from Roncor in 2000 and 2001 but ran out of funds before becoming successful and their option expired. By this time most of the easily accessible Yogos had been mined and miners were having to dig deeper; further increasing costs.

A new owner bought Vortex in 2008 and is in operation as of late 2011. Its operations are environmentally friendly, using methods such as recycling all water and not using chemicals.[12] As of 2011, there is also mining activity at Sapphire Village, though the Roncor mines are inactive.

6 - State gem of Montana :

The sapphire became one of Montana's two official state gemstones in 1969, 104 years from the time of discovery. Although "Sapphire" Collins recognized as early as 1865 that pebbles he found the Missouri River were of value, he could not convince bankers, merchants, or gem dealers of this since his finds were of lesser quality. It was the discovery of Yogo sapphires at Yogo Gulch in 1895 that spurred investment in sapphire mines throughout the state, mostly by influential people and firms from the eastern United States and England. In the 20th century, when designation of a state gemstone was considered, the Montana Council of Rock and Mineral Clubs supported two nominees: sapphires and Montana agates. Agates were chosen due to their great abundance, particularly in the Yellowstone River basin, which flows from Yellowstone National Park north to Livingston, then east through Montana until its confluence with the Missouri just over the state's boundary with North Dakota. Finally, in 1969, these gems were jointly declared the state gemstones.

There are a number of Yogo sapphires kept at the Smithsonian Institution. The first were noted in its annual report for the year ending June 30, 1899, when the Smithsonian reported that Dr. L. T. Chamberlain gave them 2 cut Yogos and 21 other sapphires, as well as other gems, for its Dr. Isaac Lea gem and mineral collection.[77] In 2006, a representative of the Smithsonian Institution asked Paula Crevoshay, a jewelry designer from Albuquerque, New Mexico, if she would take a set of sapphires from Montana and create a piece of finished jewelry. The gems in question were being donated to the Smithsonian's Gem and Mineral Collection by gemologist Robert Kane of Fine Gems International in Helena, Montana, which has the largest selection of Montana sapphires in the world. He provided 333

Montana sapphires weighing 27.97 carats along with 98.48 grams of 18K yellow gold for the project . Crevoshay felt that a butterfly motif would be excellent to represent America's natural beauty, honor her mother's love of butterflies, and display the wide range of colors found in Montana sapphires. Crevoshay named the brooch "Conchita" in honor of her mother. It is also referred to as the "Sapphire Butterfly Brooch", "Conchita Sapphire Butterfly", and the "Montana Butterfly Brooch". The brooch can also be worn as a pendant or clasp and can be beaded. Two of the sapphires used are cabochon cut and the rest are brilliant cut. Most are from the Rock Creek deposit. The largest one, however, is a blue Yogo used for the butterfly's head. Other colors used are yellow, purple, pink, and orange. Crevoshay and Kane presented it to Smithsonian curator Jeffrey Post on May 7, 2007 in Washington, D. C.

In the earliest years of Yogo sapphire mining, before Yogos achieved their own reputation, Oriental sapphires were sold in Montana with claims they were Yogos while in Europe Yogos were sold with claims of being Oriental sapphires . However, they became notable in their own right. Paulding Farnham (1859–1927) used these stones to great advantage in several jewelry pieces he designed for the 1900 Exposition Universelle in Paris , where Yogo sapphires received a silver medal for color and clarity . Yogo sapphires also won a bronze medal at the 1904 Louisiana Purchase Exposition in St. Louis, Missouri.[85] The most elaborate piece of jewelry ever made with Yogos is the Tiffany Iris Brooch that was designed by Farnham and contains 120 Yogo sapphires . The Tiffany Iris Brooch was first sold on March 17, 1900 for $ 6,906.84 . In 1923 First Lady Florence Harding was given an "all Montana" ring made from a Yogo sapphire and Montana gold. In 1952 Gadsden gave cut Yogos to President Harry Truman, his wife Bess Truman, and their daughter Margaret Truman . While there is no doubt many Yogos have been sold in Europe, there is dispute about whether they are in any of the crown jewels of Europe or whether Lady Diana Spencer's engagement ring sapphire was a Yogo. This same ring was also Kate Middleton's engagement ring. That sapphire has been reported as being 9, 12, and 18 carats .

86 – Zoisite

Yellow zoisite crystal

Zoisite is a calcium aluminium hydroxy sorosilicate belonging to the epidote group of minerals. Its chemical Formula is $Ca_2Al_3(SiO_4)(Si_2O_7)O(OH)$. Zoisite is named after the Slovene scientist Baron Sigmund Zois von Edelstein (Žiga Zois), who realized that this was an unknown mineral when it was brought to him by the mineral dealer Simon Prešern, who had discovered it in the Saualpe mountains (Svinška planina) of Carinthia in 1805. Zoisite was first known as **saualpite**, after its type locality.

Zoisite occurs as prismatic, orthorhombic (2/m 2/m 2/m) crystals or in massive form, being found in metamorphic and pegmatitic rock. Zoisite may be blue to violet, green, brown, pink, yellow, gray, or colorless. It has a vitreous luster and a conchoidal to uneven fracture. When euhedral, zoisite crystals are striated parallel to the principal axis (c-axis). Also parallel to the principal axis is one direction of perfect cleavage. Zoisite is somewhat higher than 6 in hardness and its specific gravity is between 3.10 - 3.38, depending on the variety. Zoisite streaks white and is said to be brittle. Clinozoisite is a more common monoclinic polymorph of zoisite.

Transparent material is fashioned into gemstones while translucent-to-opaque material is usually carved. A metamorphic rock known as anyolite consists of green zoisite with black tschermakite and ruby crystals. These rubies themselves are not of gem quality, but nevertheless their color provides a striking contrast to the green zoisite, and greatly enhances the decorative pieces that are carved from the rock.

Sources of zoisite include Tanzania (tanzanite), Kenya (anyolite), Norway (thulite), Switzerland, Austria, India, Pakistan, and Washington in the USA.

Category	Sorosilicate - epidote group
Chemical Formula	$Ca_2Al_3(SiO_4)(Si_2O_7)O(OH)$
Color	White, gray, greenish brown, greenish gray, pink, blue, purple
Crystal habit	Crystals flattened in an acicular manner, may be fibrously curved and striated. Massive to columnar
Crystal system	Orthorhombic - Dipyramidal
Fracture	Uneven to conchoidal
Mohs scale hardness	6 to 7
Luster	Vitreous, pearly on cleavage surfaces
Streak	White or colorless
Diaphaneity	Transparent to translucent
Specific gravity	3.10 - 3.36
Optical properties	biaxial positive
Refractive index	$n\alpha = 1.696 - 1.700$ $n\beta = 1.696 - 1.702$ $n\gamma = 1.702 - 1.718$
Pleochroism	X = pale pink to red-violet;

	Y = nearly colorless to bright pink or deep blue; Z = pale yellow to yellow-green
Tanzanite	Gem-quality zoisite, blue-purple
Thulite	Pink

87 - Zorite

Zorite is a silicate mineral with the chemical Formula of $Na_2Ti(Si,Al)_3O_9 \cdot nH_2O$. It is named because of its pink color, after the Russian word "zoria" which refers to the rosy hue of the sky at dawn.[4] It is primarily found in Mount Karnasurta, Lovozero Massif, Kola Peninsula, Russia . The Lovozero Massif is an area with an igneous mountain range, home to various types of minerals such as eudialyte, loparite, and natrosilitite.

Crystallographically, zorite belongs in the orthorhombic group, which has 3 axes, a, b, and c that are of unequal lengths ($a \neq b \neq c$) that form 90° with each other. It also belongs in the point group 2/m2/m2/m. The state of aggregation for zorite is acicular. Zorite has perfect cleavage along the planes {010} and {001}, while having poor cleavage along the plane {110} . Zorite is anisotropic, which means that the velocity of light is not the same in all directions. It belongs in the biaxial group, because it is an orthorhombic mineral. [4] Under plane polarized light, zorite displays different colors depending on the angle that the light hits the mineral. This quality is called pleochroism and zorite is rose along the x-axis, colorless along the y-axis, and bluish along the z - axis . The index of refraction of zorite is 1.59 , which is the velocity of light through vacuum over the velocity of light through zorite. Zorite is studied to better understand silicate structures.

In 2003, zorite was looked into to analyze the symmetry and topology of a family of three minerals found in Russia, Nenadkevichite, Labuntsovite, and Zorite . Zorite was also studied to comprehend how silicate structures change when an element is replaced, for example when the sodium is replaced with potassium, caesium[9] and phosphorus . Furthermore, because of its rarity, zorite is one of the collectors' items coveted for its scarcity, as well as it being a valuable source to understanding silicate topology.

Category	Inosilicate
Chemical Formula	$Na_2Ti(Si,Al)_3O_9 \cdot nH_2O$

Unit cell	a = 23.91 Å, b = 7.23 Å, c = 14.24 Å, V=2,461.66 Å^3
Molar mass	1,538 g
Color	Rose red
Crystal habit	Prismic acicular crystals, sometimes radiating
Crystal system	Orthorhombic
Cleavage	Perfect
Mohs scale hardness	3 ~ 4
Luster	Vitreous
Streak	White
Diaphaneity	Transparent
Specific gravity	2.18
Optical properties	Anisotropic, biaxial
Refractive index	n = 1.59
Pleochroism	x = rose, y = colorless, z = blue
Other characteristics	Found in cavities and fractures in alkalic pegmatite