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Gems and man: a brief history

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From shell beads in the Palaeolithic and stone beads in the Neolithic to beautiful artificial gems in modern times, the history of gems has roughly paralleled that of humans. In the beginning, myths and folklore about the healing properties of gemstones dominated the story. Today, the story is about scientific techniques making larger or more colourful gems and newly discovered mineral deposits revealing gemstone treasures. In the western world the written history of precious and semiprecious stones begins with the *On Stones* of the Greek philosopher and naturalist Theophrastus (*ca.* 315 BC) followed by the *Natural History* of the Roman historian Pliny (77 AD), which was the standard work on gems and minerals for more than a thousand years. The gemstones of the Old Testament and those of ancient East Asia tell their separate stories. Following a brief summary of these early works, this paper continues with individual descriptions of the major gems and semiprecious stones, focusing on their two most important attributes – colour and hardness – as well as where they are found. This is followed by a brief discussion of altered gems and a summary of modern interactions of gems and man. This paper concludes with some personal experiences of the author and a brief introduction to the geology of gem deposits.

1. Introduction

This article includes certain minerals in addition to those narrowly defined as gems because there exists a great deal of overlap (and confusion historically) among precious stones, semiprecious stones, and minerals that are considered valuable and sought after by collectors. It seems quaint today, but until the last few hundred years gems were sought as much for their healing or magical properties as for their value as ornaments (Fig. 1).

We begin with two early aspects of gems and man that are part of written history: (1) the first text on minerals and gems in the western world, the book *On Stones* written by the Greek Theophrastus *ca.* 315 BC, and (2) gems mentioned in the *Old Testament*. Both the ancient Egyptians (Lucas, 1962) and inhabitants of Mesopotamia (Moorey, 1985) used glazed minerals as beads and objects of adornment, but this short article cannot do more than mention this. We continue with a review of the main gems and minerals used by man, listing their hardness, colours, and the most significant localities where they have been found, beginning in antiquity. The final sections look at very recent times, including the development of synthetic gems, some personal experiences of this author, and a note on the geology of gem minerals.

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Figure 1. Serpentine dish with inlaid goldfish, pearls and other gemstones, 1st century BC or AD, with 9th century AD mounts from the Court of Charles the Bald. Not all gemstones were used for body ornaments.

The definition of a gem does not have the specificity of definition that is given to other earth materials, for example, a mineral. A gem (including precious and semiprecious stones**)** can be a mineral, or a rock (such as lapis lazuli), or a natural organic material (such as amber or pearl) that is used to make jewellery or other adornments. In his popular book on gemstones of North America, Sinkankas (1997) includes nearly everything that humans have carved, for example catlinite, an argillite used by Native Americans to make smoking pipes. There does not seem to be a limit to what polishers will polish into decorative objects, even graphic granite (unique intergrowths of quartz and feldspar). Most gem minerals are hard and durable, but even extremely hard substances such as rock crystal (quartz) have been painstakingly carved into elaborate objects such as jewellery and sealstones. The Babylonians carved seals into cylinder-shaped gems they used as ornaments (Whitlock, 1934). Some softer minerals have been used because of their colour, lustre, or other physical property that gives them aesthetic value. Rarity also lends value to a gemstone.

Many mineral names have changed over time. As a result, not all gems and minerals mentioned in early texts can, with confidence, be given modern names. This article uses modern names or else clarifies. Numerous references are readily available to sort out mineral and gem names (Bauer, 1968; Kunz, 1971; Roberts *et al.*, 1990; Blackburn and Dennen, 1997; de Fourestier, 1999; Bayliss, 2000). In addition, some minerals have many different names. For example, gemmologists use the name iolite, but geologists and mineralogists prefer the name cordierite. This same mineral has also been called dichroite and water sapphire. Early accounts sometimes ascribe the source(s) of gems and minerals, but often these were hearsay. This article discusses only source localities of which the author is reasonably confident.

Gemstones very early became associated with folklore and superstition. Nearly all early references to gems and minerals up through the Middle Ages (1066–1492) noted the magical or healing properties of the gem or mineral. Georgius Agricola (1494–1555) was perhaps the first major author to reject the attribution of magical or healing properties to gems and minerals (Agricola, 1546/1964). Colour, even among

the most knowledgeable, was the dominant way to identify gems and minerals through the Middle Ages. Without knowledge of mineral formation or chemical composition, people developed myths as a way to explain the colours of gemstones.

Gemstone deposits certainly are not ubiquitous. Some, such as lapis lazuli, come from only one, or a very few, localities in the world. Although Afghanistan was the only known source of this mineral during antiquity, lapis artefacts have been found throughout the Old World (Herrmann, 1968), confirming that gemstones were a trade commodity from earliest times. The wealthy urban centres sought gemstones from around the world. For example, the Harappa of the Indus valley sent carnelian to the powerful kings in Mesopotamia following the Silk Road. Every conceivable commodity was traded along this famous route, including rock crystal (quartz). Thus gemstones have served archaeologists as valuable indicators of trade patterns.

2. Early works

2.1. Theophrastus

Theophrastus (*ca*. 371–287 BC), a Hellenistic Greek philosopher, composed treatises on many subjects. His treatise on stones (minerals, rocks and gemstones), variously known as Περί λίθων or *De Lapidibus* (Theophrastus, 1956), remained a definitive reference on the subject throughout the Middle Ages. Theophrastus described only sixteen minerals, but he laid the foundation for the sciences of mineralogy and gemmology, and the minerals he described led to the discovery of many of the chemical elements. He was an avid collector and stressed the importance of observation and of obtaining samples. He acquired information on the minerals of many regions of Asia Minor, Egypt, Nubia and the Persian Gulf. His treatise is composed of several sections that discussed primarily precious and semiprecious minerals. He focused on observable properties, such as size, colour, hardness, smoothness, reaction to fire, ability to attract magnetically and the location where the minerals were found. Theophrastus made the first known reference to the phenomenon of pyroelectricity; he noted that the mineral tourmaline becomes charged when heated. He described the precious stones emerald, amethyst, onyx, jasper. He also included what he considered to be a variety of sapphire that was blue with veins of gold; this was probably lapis lazuli. He mentioned only rarely the magical properties with which the ancients believed stones were endowed. He also devoted sections to organic materials such as amber, coral, pearl and ivory that were classified by the ancients in the same category as gems and minerals. He noted that pearls come from shellfish. He also considered the practical uses of various stones, such as which were necessary for the manufacture of glass, and the use of the touchstone for assaying gold and gold alloys. For good reason he is often called the father of mineralogy and gemmology.

2.2. Pliny

Gaius Plinius Secundus, better known as Pliny the Elder or just Pliny, was a Roman author, naturalist and natural philosopher. Pliny's last work was the *Naturalis Historia*,

a thirty-seven volume work published in 77 AD, which served as an encyclopaedia of the world's knowledge at that time (Pliny, 1989). A number of different editions are available worldwide, including the Harvard Loeb Classical Library edition. Pliny compiled the work from a reported two thousand sources. He lumped minerals together by colour, mining location and – of questionable value – attributes passed on in legends. Pliny attempted to classify gems according to colour as the most observable attribute, which led him to the practice of lumping all stones of similar colour into the same category. For example, he classified most green stones as varieties of emerald. Regarding gemstones described earlier by Theophrastus, Pliny added very little scientific information beyond what he gleaned from his Greek predecessor. The reason for including this note on Pliny is that he became the most often quoted author on gems and minerals for nearly thirteen centuries.

2.3. Minerals of the Old Testament

The King James Version of the *Bible* has 1,704 references to gems and minerals under 124 Greek and Hebrew names (Wright and Chadbourne, 1970). Many of these gems and minerals cannot be identified from the biblical text, and others are obscure. One of the most detailed descriptions in the Old Testament is of a breastplate worn by the high priests of the temple; it contained twelve gemstones representing the twelve tribes of Israel. These gemstones were mounted in four rows. The first row was ruby, chrysolite and beryl; the second row was turquoise, sapphire and emerald; the third row was jacinth, agate and amethyst; the fourth row was topaz, onyx and jasper. In medieval times these same twelve gems became affiliated with the twelve signs of the zodiac. The modern custom of birthstones is derived from this tradition.

2.4. Ancient East Asia: China, Japan and India

In ancient China many precious and semiprecious stones were used in medicinal preparations. These included diamond, ruby, sapphire, emerald, jade, peridot (an olivine) and lizardite (a serpentine mineral). Minerals and rocks exploited for more than 3,000 years, at least back to the Late Shang at Anyang (Wang and Shen, 1986), included marble, turquoise, topaz, garnet, rock crystal, aquamarine, lapis lazuli, tourmaline, moonstone (a variety of feldspar), chrysoberyl, pearl and coral. Turquoise objects are known from the T'ang period (Laufer, 1974). In his multi-volume work on ancient China, Needham (1959), in sections 23 (geology) and 25 (mineralogy), discussed geodes, jade and precious stones. Rock crystal and agate were favourite semiprecious stones throughout early China. Favoured gemstones, like other customs, changed with time and place.

Japan is situated in a volcanic zone within the Pacific Ring of Fire. As a volcanic archipelago with a limited range of rock types, the range of gemstones is quite narrow. However, a number of unusual gemstones are found in Japan, including sugilite, a relatively rare pink to purple silicate mineral. One gemstone common to volcanic areas is obsidian. Indeed, there are >80 archaeological obsidian sources in Japan. In addition,

transparent greenish grey topaz crystals are found on Honshu Island. It is worth noting that quartz crystals have been mined in Japan since the eighth century AD. In modern Japan there is a lively market in gems and semiprecious stones including topaz and pearl.

India was the source of many gems that were highly desired by Romans. Jade carving developed in India with the advent of the Mughal emperors, who brought knowledge of the craft from east central Asia and Iran. Diamonds in India were exploited for millennia, at least from the seventh century BC. However, according to Bauer (1968), most of the diamonds remained in India until the tenth century AD, when invaders plundered the area. India has also been the source of outstanding emeralds.

3. Gems and semiprecious stones

See Rapp (2008) for more complete descriptions and an abundant reference section. Much of the mineral data in the following sections are taken from that book. Hardness is based on the non-linear Mohs scale in which talc is the softest mineral with a hardness of one and diamond is the hardest at ten. Modern stainless steel has a hardness between four and five, and the hardness of glass is approximately 5.5.

3.1. Quartz family minerals

Quartz is the second most common mineral in the earth's crust, after feldspar. It is also the most widely distributed of all minerals in the near-surface environment. Quartz is truly ubiquitous, occurring in nearly all geological environments and in nearly all geographic areas. Since earliest antiquity, quartz in all of its many forms has been a common semiprecious gemstone often called rock crystal. It has a hardness of seven on the Mohs hardness scale. It was mined in Egypt as early as the Predynastic period (beginning ~6000 BC) and by the eighth century AD in Japan. The earliest lapidaries in India, *ca*. 1500 AD, dealt mainly with quartz gems.

3.1.1. Amethyst

Amethyst is quartz characterized by various shades of purple or violet. In Roman mythology, amethyst was believed to have been coloured purple by the god of wine and was thought to offer protection against drunkenness. It derives its name from a Greek word meaning not to intoxicate. Amethyst was mined in Egypt as early as the First Dynasty (2920–2770 BC) (Lucas, 1962). It is found in many areas. The large crystal clusters and geodes exploited today come mainly from Brazil. Catherine the Great of Russia was extremely fond of amethyst and amassed a large collection from mines in the Ural Mountains. Religious leaders still wear amethyst gems in rings.

3.1.2. Citrine

Citrine is pale yellow, yellow to yellow brown or light reddish brown quartz. These colours can be bleached with heating. It is transparent to translucent. The name originates from the French *citron* (lemon). It is sometimes erroneously called topaz.

Citrine has been used since antiquity as gems and seal stones. Much of the citrine available on the market today may be heat-treated amethyst.

3.1.3. Chalcedony

Chalcedony (Fig. 2) is a cryptocrystalline variety of quartz that can be white, greyish, blue, brown or black. It has a waxy lustre and is transparent to translucent. The name is derived from Chalcedon, an ancient city located in what is now part of Istanbul, Turkey. Ancient sources of the mineral included India, Yemen, Iraq, Egypt's Eastern and Western Deserts, and the Sinai. It was used there as a gemstone as early as Predynastic times, which began about 6000 BC.

3.1.4. Chrysoprase

Chrysoprase is a green cryptocrystalline quartz, a variety of chalcedony. Usually jade green, its colour can vary from olive green to a pale sea-green. The green colour is imparted by small amounts of nickel. Chrysoprase has a hardness of 6–7, which adds to its value as a gemstone. It has been identified in ancient Egyptian artefacts, some of which have been dated to the Predynastic period (Lucas, 1962). The first significant deposit of chrysoprase was found in Szklary, Poland, in 1425 AD.

3.1.5. Carnelian

Carnelian is a translucent, red to reddish brown cryptocrystalline quartz. It has been used since the third millennium BC in the wide region from Mesopotamia to India. Carnelian was used for beads by the early second millennium BC; since then it has been used as gems, amulets, seal stones and as inlay for jewellery.

3.1.6. Agate

Agate is a varicoloured microcrystalline quartz, often with irregular or concentric coloured bands. It is one of the most widely distributed materials at the earth's surface.

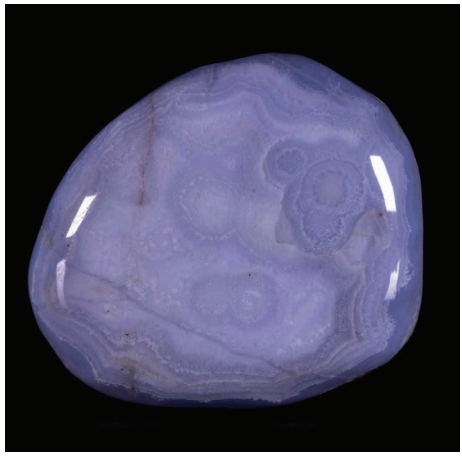

Figure 2. Cut and polished chalcedony gemstone. Like all high-silica minerals chalcedony takes a high polish.

The earliest evidence for working with agates comes from Mesopotamia, where agate ornaments and tools have been recovered. Theophrastus stated that the name was taken from one of the principal sources for the stone, the Achates River in Sicily. Wright and Chadbourne (1970) pointed out that early civilizations used semiprecious stones such as agate amulets blessed by a priest to ward off dangers from everything from thunderstorms to poisonous spiders. During the Classical period of the Eastern Mediterranean, agate was a popular stone for carved signet rings and for objects of art. The Greeks and Romans colourized agates by soaking in sugar solution followed by acid treatment. The Roman emperor Nero was a collector of agate cups. Sources of agate mentioned by Pliny include Crete, India, Phrygia, Egypt, Cyprus, Persia and various places in Greece. The area of Idar-Oberstein in Germany may be the oldest gem-cutting centre in the world. It supplied cut and polished agate to the Greeks and Romans and remained an important centre for agate carving and polishing through the Middle Ages

3.2. Non-quartz silicate minerals

3.2.1. Beryl

Beryl has a hardness of 7.5—8. Common beryl is green, pale green or pale greenish blue and is often opaque. It may occur in gem forms as emerald (green), aquamarine (blue) or morganite (red). Beryl is highly weather-resistant, so it is commonly found as one of the weathering products of pegmatites. The colour of beryl can be altered by irradiation or heating.

Emeralds were Cleopatra‘s favourite gemstone. The earliest emeralds were mined from the legendary Cleopatra’s Mines in the Sikait-Zabara region of Egypt. Until the Europeans discovered emeralds in the New World (Colombia and Brazil), Egypt was the only source. In India’s most famous temple, dedicated to the goddess Minakshi, her idol is made of emerald, probably carved out of a single crystal.

Aquamarine is a beautiful sea-blue variety of beryl (Fig. 3). The colour is caused by iron ions within the crystals. Aquamarine can appear either blue or colourless when viewed from different angles. Gem-quality aquamarine is found as flawless hexagonal crystals, which may have striations along the length of the crystal. The best of the gem-

Figure 3. Aquamarine (blue beryl) crystal. Sri Lanka and Burma were the major sources of these gems in antiquity. (Photo of aquamarine sample from Pakistan, collection of the Museum of Mineralogy, Università di Padova.)

quality aquamarine is found in Brazil, where it occurs in pegmatites and associated alluvial deposits of gravel. Other localities include Russia's Ural Mountains, Afghanistan, Pakistan, India and Madagascar. Some aquamarines are heated to high temperatures to enhance the colour or heat-treated to change a blue green or teal gemstone to a pure blue. This results in a permanent colour change.

3.2.2. Topaz

Topaz has a hardness of 8. It is transparent to translucent and occurs in a wide range of colours from colourless to white, grey, bluish, greenish, yellowish, orange, purple, and pinkish to reddish. The name topaz is derived from the Sanskrit word for fire. Note that the topaz of the biblical Old Testament may have been chrysolite (an olivine). The Romans believed topaz had power to improve eyesight, and the ancient Egyptians wore it as an amulet to protect them from injury. The classic localities of Mursinka in the Ural Mountains and Schneckenstein in Germany were discovered only in the seventeenth century.

3.2.3. Garnet

Garnets are a group of silicates with Mohs hardness between 6.5 and 7.5. The gem varieties are grossular (also named rosolite, hessonite), almandine, pyrope, andradite, spessartine and uvarovite. Colour is the most obvious feature of gem garnets. The garnet group shows one of the widest varieties of colour in the mineral world, ranging from colourless, through white, grey, yellow, yellowish green, green, yellowish brown, brown, pink, red and black. Only blue is extremely rare. Principally used as a gemstone, the name grossular originates from the Latin *grossularium* (gooseberry). During the Middle Ages, deep blood-red almandine garnet was preferred as a gemstone for decorating religious artifacts. Gem-quality garnets commonly develop as a result of regional metamorphism.

3.2.4. Zircon

Zircon has a hardness of 7.5 and is quite durable. It also has been known as cyrtolite, and its ancient name was jacinth or hyacinth. Zircon is widespread as an accessory mineral in silicic igneous rocks. Because of its durability, gem varieties are often found in gravel deposits. The high refractive index and the optical dispersion of zircon result in a brilliancy approaching that of diamond. The colourless variety looks more like diamond than any other natural stone because of this brilliance and light dispersion. The variety hyacinth includes the clear and the transparent red, orange and yellow varieties. Gem-quality zircon occurs in Australia, Cambodia, Myanmar, Sri Lanka, Thailand and many other countries.

3.2.5. Tourmaline

Tourmaline (Fig. 4) is a chemically complex silicate that occurs in several varieties as a result of chemical substitution. Chromium ions colour tourmaline green, which sometimes causes it to be mistaken for emerald. It has a hardness of 7 to 7.5. Practically

Figure 4. Tourmaline crystal.

all gem-quality tourmalines occur in rocks formed in the last stages of granite pegmatite crystallization. The use of tourmaline as a gemstone is documented in ancient Greece and Rome after Alexander the Great's conquests in the East provided a source. The Egyptians wore it as an amulet to protect them from injury. The Romans believed it had power to improve eyesight.

3.2.6. Jade

Jade is the gem term used for two different minerals: jadeite and nephrite. When worked and polished, jadeite and nephrite can usually be distinguished by their appearance. The lustre of nephrite is oily, while the lustre of jadeite is vitreous. The apple-green or emerald-green varieties are usually jadeite. Jades have been worked into implements and ornaments since Neolithic times in China.

Nephrite is an actinolite amphibole with a hardness of 5 to 6. It is light green to greenish black in colour. A number of ancient Egyptian artefacts have tentatively been identified as nephrite. For a mineralogical study of Chinese nephrite jade, see Wen and Jing (1996). Laufer's (1974 reprint) extensive treatise on Chinese jade was first published in 1912, so it is quite dated. The ancient Chinese acquired their nephrite from Burma (Myanmar) and Turkestan. It was used in China from the Neolithic in the eighth millennium BP through the Han Dynasty. Nephrite has been employed for carvings, decorative and ceremonial objects, personal ornaments, and gems. In North America the Canadian province of British Columbia is the major source of nephrite.

Jadeite is a pyroxene mineral with a hardness of 6–7. It is usually light to dark green. The Aztecs, Mayas, and other precontact peoples of Mexico and Central America carved green jadeite for ornaments and amulets. Only the Montagua Valley of Guatemala has been established definitively as a source for pre-Columbian jadeite in the New World. There is considerable speculation and research directed at the identification of other Mesoamerican sources, but none has yet been confirmed.

3.2.7. Opal

Opal has a hardness varying from 5.5 to 6.5. In its chemically purest form, opal is milky white to colourless. However, through admixture of pigmenting material it can be almost any colour, including yellow, brown, orange, green and blue, usually in pale shades (Fig. 5). The principal gem variety, termed precious opal, shows a rich internal play of colours in reflected light and has a pearly opalescence if it is viewed from different angles. The name opal may have derived from Sanskrit *upala*, meaning precious stone. The use of precious opal appeared in ancient Greece and Rome after Alexander the Great's conquests in the East. For the Romans, opal ranked second only to emerald among noble gems. From the fifth century BC on, many of the opals from ancient Europe came from Slovakia near Dubnik. Pliny described the opals from this area, >1,000 km from Rome. Unfortunately, these opals became known as Hungarian (possibly because a second site of production was located in northern Hungary). Production from Slovakia continued through the Middle Ages. The ancient cultures of Mexico had access to many deposits of precious opal including those of Queretaro. Mexican opal was taken back to Europe by explorers as early as 1520, where it was used for engraved gems. Fire opal gets its 'fire' from the diffraction of light where units of silica are arranged in a geometric pattern of the proper size to diffract light entering the material. Fire opal first came from Europe centuries ago, with Hungary providing the best material.

3.2.8. Opalite

Opalite should not be confused with opal. Opalite has been used as a name for two different gem stones: neither is the mineral opal. One type of opalite is a rock composed of dolomite and opalized fluorite and may contain quartz and chalcedony. It is prized for its dramatic colours, particularly dark purple and lavender. It forms as mineralized nodules. The other type is a modern synthetic opalized glass that simulates the mineral opal, it became widespread from the 1960s.

3.2.9. Lapis lazuli

Lapis lazuli has a hardness of 5–5.5. It is known for its blue colour, which can vary from deep blue, indigo blue, azure blue, and violet blue to greenish blue. Its name is derived from the Latin word for stone and a Persian word for blue colour. In the fifth century AD, the mineral was introduced into Europe with the name *ultramarinum*, which became ultramarine. A word of caution: the word *lapis* comes from the Latin for stone, so it has been used as a part of many gemstone names (*e.g. lapis indicus* is

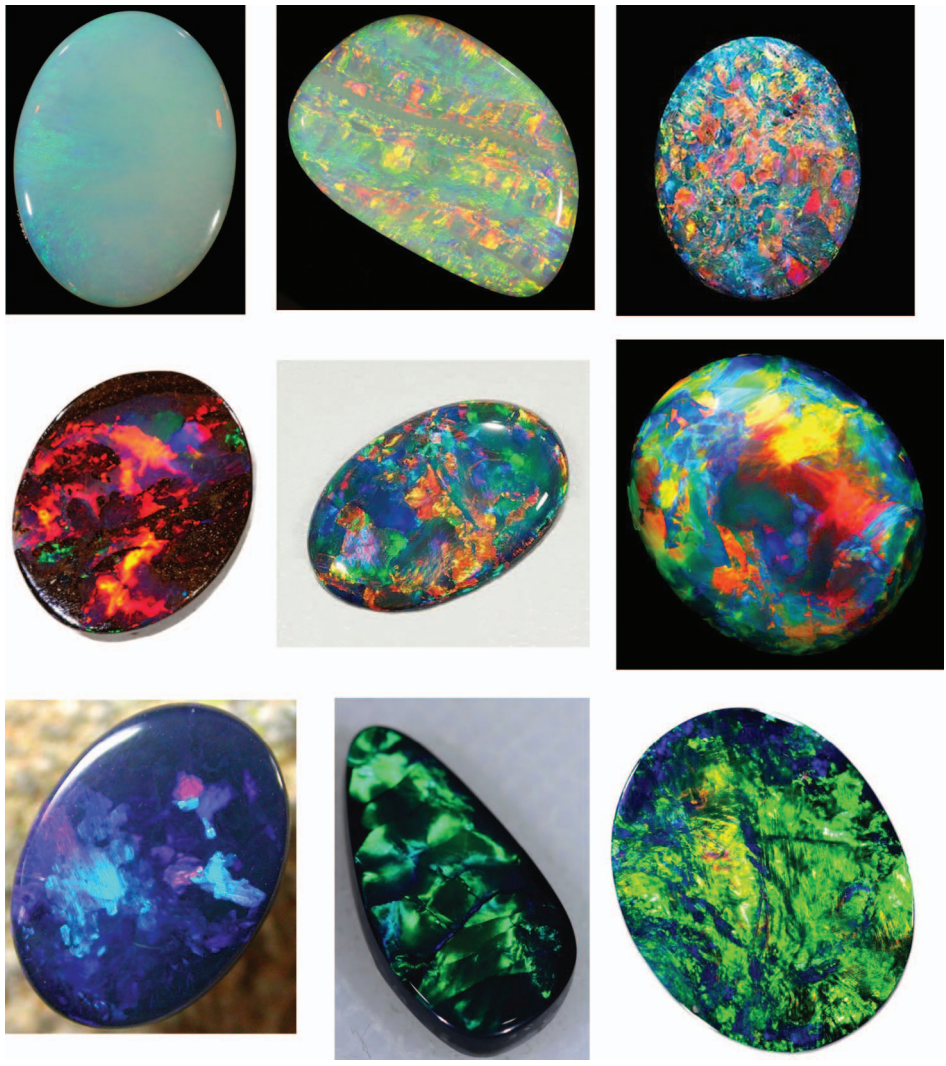

Figure 5. Cut and polished opal. Gem quality opal occurs in many parts of the world.

nephrite). The only proven ancient source of lapis lazuli in the Old World is Badakshan, Afghanistan. Badakshan is mentioned in Chinese writings as early as the sixth century AD. Lapis from Badakshan is almost always associated with pyrite. Lapis lazuli found its way to the Indo-Pakistani region by Neolithic times. The mines of Badakshan were described by Marco Polo, who (reputedly) visited them in the thirteenth century (Bauer, 1968). Importation of lapis began as early as the Third Dynasty at Ur for cylinder seals and beads. It found its way into Egypt by Predynastic times. The Romans believed lapis to be an aphrodisiac.

3.3. Non-silicate minerals

3.3.1. Diamond

Diamond, with a hardness of 10, is the hardest natural mineral. It can be colourless, but it is also found in white to blue white, grey, various shades of yellow, brown, orange, pink, red, lavender blue, green and black. Diamond's name originates from the Latin word *adamas* (invincible). From that name we get *adamantine* lustre. Pliny stated that there were as many as six different stones called *adamas*. However, it is unlikely that all of these were mineralogically diamond. Craftsmen in India used diamonds to drill holes in hard gems like beryl to make beads. Europeans were not aware of India's diamonds until Marco Polo visited the area in the thirteenth century AD. Because diamond forms in a rare igneous rock called kimberlite, its occurrences are limited. The United States Geological Survey estimates that the average diamond in an engagement ring is the product of the removal and processing of 200 to 400 million times its volume of kimberlite. Diamond is highly resistant to weathering, so it is often found in alluvial deposits. Africa currently produces most of the world's diamonds, largely from the countries of South Africa, Angola and Botswana. The diamonds from Sierra Leone in Africa have been labelled 'blood diamonds' because they have funded one of the most savage rebel movements in modern history. Russia is the largest producer in Asia; some diamonds still come from India. Only a small percentage of modern diamond production comes from the rest of the world.

3.3.2. Corundum

Corundum, with a hardness of 9, is one of the hardest minerals known. It is found in two gem varieties: ruby and sapphire. It occurs in crystalline limestone and dolomite, schists and gneisses, and granitic igneous rocks, although gem-quality material is relatively rare in igneous rocks.

Ruby is red in colour and takes its name from the Latin *rubeus* (red). According to medieval Arab scholars, this stone was mined in Sri Lanka. Pliny referred to red stones by the general term *carbunculus*. He listed sources as India, North Africa, Caria, Ethiopia, Miletus, Orchomenos, Chios, Corinth, Troezen (in the northeastern Peloponnese, Greece), Marseilles and Lisbon. Although ruby was mentioned in some translations of the Old Testament, there is no evidence that this mineral was known to the ancient Hebrews. Nevertheless it was widely available as a gemstone. A discontinuous band of marble formed along a tectonic belt running 1,800 miles along the southern slope of the Himalayas from Tajikistan through Afghanistan, Pakistan, and Nepal to China contains many important ruby deposits.

Sapphire is found in shades of blue and sometimes yellow. Sapphire is dichroic – in other words, the colour changes with the angle from which it is viewed. Very minute, regularly arranged inclusions of the mineral rutile are responsible for the asterism of star sapphire. Sapphire is an ancient term of uncertain origin, possibly related to Hebraic *sappir* and Sanskrit *sanipruja*. Sapphire was used as a gemstone beginning in the early first millennium BC. Pliny's *chrysolithus* from India may have been yellow sapphire. According to Pliny, *hyacinthus* (blue corundum) came from Ethiopia,

although India may have been its original source. *Nilos* may have also have been blue corundum. Pliny listed its source as India, Galatia and Egypt. Today sapphires are found in Africa, India, Sri Lanka, Burma, Australia, Nigeria, Madagascar, Kenya, Thailand, Cambodia, Vietnam, Brazil and the USA. Sapphire is particularly abundant in Sri Lanka. It has been mined in Australia for >100 years. Gem-quality sapphires in the United States are found in the state of Montana. Because of its hardness and durability, many gem sapphires have been found in gravels and placer deposits.

3.3.3. Fluorite

Fluorite, sometimes called fluorspar, has a hardness of 4 and a perfect octahedral cleavage. Fluorite can be colourless, but it is also found in shades of purple, blue, green, yellow, white, pink, crimson to brownish red, brown and bluish black (Fig. 6). Its name comes from the Latin *fluor* (to flow). It is widely distributed geologically and has long been used as a gemstone. Predynastic Egyptian beads of fluorspar are known (Lucas, 1962). Beads of fluorspar have been found in the ancient ruins of Tiahuanaco, near Lake Titicaca, on the Bolivian high plateau (Bauer, 1968). One of the most famous fluorite localities is in Derbyshire, England. This gemstone is called Derbyshire Blue John. It is a purple blue fluorite extracted from several mines or caves, including the famous Blue John Cavern. In the nineteenth century, this fluorite was highly valued as an ornamental gemstone.

3.3.4. Chrysoberyl

Chrysoberyl, with a hardness of 8.5, has long been a favourite gemstone because of its beauty and hardness. It is found in two varieties, Alexandrite and cat's eye. It has an extensive colour range and can be found in various shades of yellowish green, yellow, grey, brown, blue green and emerald green. Its name is taken from the Greek word

Figure 6. Green fluorite crystals on a quartz-amethyst matrix. The word fluorescence comes from the brilliant blue luminescence found in fluorite specimens from England.

χρυσος (golden) and from the mineral beryl, in allusion to its colour and beryllium content. This may be the mineral Pliny called *chrysoprasus*; however, he listed no source where it was found. The variety Alexandrite is unique because the colour depends on the light source. It is green or blue green in daylight and under fluorescent light, but shades of red when seen in incandescent light. Alexandrite was discovered in the 1830s in Russia's Ural Mountains and named after the future Czar of Russia, Alexander II.

3.3.5. Turquoise

Turquoise has hardness between 5 and 6. The colour varies from bright blue, pale blue, sky-blue, bluish green, apple-green, to greenish grey. Turquoise is one of the oldest known talismanic and curative gems, prized by many cultures worldwide. Its name originates from the French word for Turkish. The famous Persian turquoise mines were located near Nishapu in the province of Khorasan. Turquoise was used in ancient Egypt prior to the First Dynasty with mines operated in the Sinai Peninsula by the fourth millennium BC. Pliny mentioned green stones that may have been turquoise, but there seems to have been some confusion between lapis lazuli and turquoise. Turquoise was mentioned by the Arab mineralogist ibn-Mansur in 1300 AD (Bauer, 1968). Turquoise has been used in China for more than 3,000 years, at least back to the late Shang at Anyang. There are a significant number of turquoise deposits in the southwestern United States that have been worked since Pre-Columbian times. Perhaps the most exploited is located near Chaco Canyon, New Mexico, where over 56,000 pieces of turquoise were recovered from two burials at Pueblo Bonito. Much additional turquoise has been recovered from other sites in Chaco Canyon dating from the period 900–1150 AD (Mathien, 2001). Turquoise was a major commodity in Mexico from the late first millennium BC through modern times. Cortez reported that Aztec chieftains wore turquoise stones in their lower lips. There were numerous turquoise mines operating in northern Mexico. In pre-Columbian Mesoamerica worked turquoise artefacts are abundant throughout its prehistory beginning in the early Preclassic (*ca.* 2000–1000 BC). Its possession signified the status of nobility. It was prized for gems and jewellery.

3.3.6. Malachite

Malachite, a copper hydroxycarbonate, has hardness between 3.5 and 4. It is bright green to dark or blackish green in colour. Its name is derived from the Greek μολοχιτις. It often occurs with distinctive bands in varying shades of green. It is quite soft for a semiprecious stone, which makes it easy to carve into beads, gems and other decorative objects. Malachite was used in the Old World at least as early as the fifth millennium BC. It was used by the ancient Egyptians, Greeks and Romans to make jewellery and amulets. Pliny mentioned a number of minerals that could have been malachite. The most important deposits exploited in early modern times were in the Ural Mountains of Russia. Currently the Democratic Republic of the Congo is the most important malachite producer. The richest deposits are found in Katanga Province.

3.4. Organic gem materials

3.4.1. Amber

Amber is not a mineral, but rather fossilized resin exuded by the conifer *Pinites succinifer* (see Angelini, 2010). The name is taken from Arabic '*anbar*'. Its varieties are called succinite and retinite. Amber has a hardness of only 2.5–3.0. Artefact amber is quite susceptible to weathering and to poor conservation techniques. The colour ranges from golden yellow through orange, red, brown, green, violet and black. It can be transparent to opaque. Amber from various sources, when exposed to ultraviolet light, will fluoresce with different colours including red, green, blue and yellow. Most modern amber from the Dominican Republic is golden brown or iridescent blue depending on whether it is viewed under or against direct sunlight.

Ornaments found in Sixth Dynasty (3200 BC) Egyptian tombs have been labelled amber. Although there are several early references to amber artefacts in Egypt dating as early as 3500 BC, the analyses of Lucas (1962) showed that these were resins derived from coniferous trees in the Levant other than *Pinites succinifer*. In Mesopotamia, amber has been found in sites dated as early as the mid-third millennium BC. By the Bronze Age amber was traded throughout Europe, including the British Isles. The best European amber is found around the shores of the Baltic Sea; however, it has also been found in Sicily and Romania. The Phoenicians traded bronze for amber with the Ligurians (Liguria is a coastal region in northwest Italy) between the thirteenth and sixth centuries BC. The Etruscans traded in amber as early as 1500 BC. Homer wrote about amber beads in the *Odyssey*. Most amber found in the Aegean area and Italy came from the Baltic region. The earliest true amber found in Greek sites was from Mycenae and Pylos at the end of the Middle Helladic period (*ca.* 1900–1600 BC). Amber artefacts have been found in Crete, other Aegean islands, Cyprus and Syria dating to the end of the Late Helladic (*ca.* 1500–1100 BC). In the Western Hemisphere in recent times Chiapas State in Mexico and the Dominican Republic have been major suppliers of amber. The deposits in Mexico have been exploited since pre-Columbian times (Sinkankas, 1997).

3.4.2. Pearl

Pearl is composed of the calcium carbonate mineral aragonite produced within the soft tissue of a living shelled mollusc. The highest quality pearls come from the genus *Pinctada.* Pearls are characterized by their translucence and lustre with an intricate play of surface colours. The iridescence results from the interference and/or diffraction effects of light through many layers. The colour of pearls varies with the type of mollusc species as well as the water environment it grew in. Pearls can be found in white, yellowish white, pinkish white, bluish white, reddish and blackish grey. The name originates from Latin *perma* (a type of shellfish). Although pearls have long been a valued gem, they generally were not used in Egypt until Ptolemaic times. The earliest use of pearl as a gem appears to be in Europe and dates from the Palaeolithic. Pearls were highly prized on the Arabian Peninsula where there was a highly developed pearl diving and trading industry. Freshwater pearls were used by Native Americans. For

example, they have been found in the ancient burial mounds of the Hopewell people in Ohio. Conversely, aboriginal peoples of Australia regard pearls as a nuisance because they occasionally cracked their teeth on them while dining on north coast oysters (Ward, 1985). Pearl-oysters and pearl-mussels are found on the Red Sea coast of Egypt, in the Persian Gulf and off the coast of Sri Lanka. Freshwater pearls have also been found in rivers in the British Isles and continental Europe. In modern times, saltwater pearls (mostly cultured) are harvested from the northwestern Pacific Ocean, particularly the waters around Japan. The technique for growing cultured pearls was developed by the Japanese in the early twentieth century.

3.4.3. Shell

Shell ornaments are found throughout the world. The origin of the name is from the Teutonic root *skal* (to peel off or separate), the Icelandic *skel* (a tile) and Middle English *schelle*. Shell disk beads have been found at ancient Egyptian sites, which were occupied until the Twenty-second Dynasty (943 BC). Shell ornaments were also favoured throughout precontact North America, and evidence of their use extends into the continental interior, suggesting heavy trade. Shell was used for beads and other personal ornaments.

Mother of pearl, also called nacre, is an iridescent material from the shell lining of many molluscs including pearl-oysters and abalone. Nacre was used as an inlay in jewellery. Mother of pearl comes in many natural colours but frequently is bleached and dyed for gemstone use.

Abalone is a gastropod shellfish. Gemstones made of its shell are sometimes referred to as mother of pearl because they often display an iridescence superior to that found in any other molluscs. Abalone shell is extremely tough and durable due to its unique structure of calcium carbonate clusters held together by a tough, sticky protein. These shell gems have been found in archaeological sites around the world. One site in South Africa is dated at 75,000 BP. There also is a rare gem called abalone pearl, found only in nature. These are not spherical but have odd shapes and are multi-coloured in intriguing patterns.

Ammolite is a gemstone made of the fossilized shells of ammonites. These gemstones, which resemble opal, are composed primarily of aragonite.

3.4.4. Jet

Jet, an organic material related to coal, was just one of a range of black lithic materials used in ancient times for jewellery. Jet is a lustrous black substance that is easily worked and will take a high polish (Fig. 7). Its hardness can vary from 2.5 to 4.0. According to Pliny (*De natura fossilium*), the word jet derives from *gagates* and then from Gagas, a river of Lycia on the southern coast of Turkey. It has sometimes been called black amber, and the term ‘jet black’ comes from this material. Jet occurs as sporadic lenticular masses and is derived from pieces of drifted wood that were buried in isolation and did not pass through a peat phase. Such material was not coalified, but rather underwent decomposition and retained a cellular structure. Good jet has been a

Figure. 7. Left: a polished jet stone. Right: A Victorian cameo carved from jet.

minor gemstone for amulets and pendants since Roman Britain. According to Pliny, jet was procured from Pamphylia and Lycia.

3.5. Other semiprecious stones

3.5.1. Obsidian

Obsidian is not a mineral; it is a glassy volcanic rock that forms as the result of rapid quenching of dacitic and rhyolitic magmas. It has been used as a semiprecious stone for millennia. Obsidian has the hardness of high-silica glass: 5–5.5. It is normally black or brown and has a vitreous lustre. It sometimes contains inclusions that create a silver or gold sheen. Some obsidian contains needle-like inclusions, gas bubbles or cristobalite crystals that look similar to snowflakes, giving rise to the name 'snowflake obsidian'. According to Pliny the name *obsianus* came from Obsius who discovered the material in Ethiopia. This may well be hearsay. In addition to its use as a tool because it has a sharp cutting edge, obsidian was used to manufacture ceremonial objects, beads and gems. The ancient Egyptians used obsidian as early as Predynastic times (5500–3100 BC). It was not available locally and so was imported, probably from Abyssinia (Lucas, 1962). A gold and obsidian necklace, dated to 1810–1700 BC, was excavated by Howard Carter and is now displayed at the New York Metropolitan Museum of Art. Obsidian deposits are plentiful in the USA and Mexico. In North America, rounded nodules of obsidian called 'Apache tears' were highly valued by the indigenous people. Apache tears look opaque in reflected light, but translucent when held up to light. Obsidian gemstone beads can be made with ease by modern technology. Shirataki, Hokkaido, Japan is one of the largest obsidian sources in northeast Asia.

3.5.2. Jasper

Jasper is impure red chert, 75% to 95% silica in the form of cryptocrystalline or microcrystalline quartz of roughly equidimensional crystals. It is normally red and often opaque. Its name is derived from Latin *iaspis*, corresponding to the Persian *iashm* and *jashp*. Pliny called the many varieties of agate or jasper in use at that time *iaspachates*. Because of its large silica content, gem jasper takes a high polish. It is

widely distributed geographically, which partly accounts for its popularity. For thousands of years black jasper was in use to determine the gold content of gold-silver alloys. Rubbing the alloys on the jasper produced a streak, the colour of which indicated the gold content. Jasper was plentiful in the Egyptian Eastern Desert (Lucas, 1962) and exploited in Egypt since Predynastic times. Jasper has been used since prehistoric times in North America and Japan. Like most precious and semiprecious stones it has its own legends, myths and purported medicinal properties. One legend says that jasper would drive away evil spirits and protect against snake and spider bites. In the fourth century AD it was used in attempts to bring rain.

4. Altered, fake and counterfeit gems

Rocks and minerals that have been altered by humans are found throughout the archaeological record from very early periods (Nassau, 1984). For example, the ancient Romans valued darker chalcedony over lighter varieties, and they learned that burning light-coloured chalcedony would cause it to darken. To prevent fracturing, this had to be done carefully, without heating or cooling the stone too quickly (Nassau, 1994). Methods for heat-treating gemstones became a closely guarded trade secret. In dealing with the colour of minerals in antiquity we do not know when early artisans discovered that the colour of many minerals could be changed by heating. Normally it is not possible to distinguish a naturally coloured gem mineral from a heat-treated one with the naked eye, but laboratory analysis can reveal microscopic fractures that result from exposure to high temperatures.

Examples of altered colour can also be found in obsidian and tourmaline. Obsidian occurs naturally in black, grey, brown and as the snowflake variety. It does not generally occur in reds, blues or greens, but such colours can be found in rock shops. Colourless tourmaline can be turned pink by radiation although the colour will fade with time, particularly if exposed to sunlight. Alexandrite may be natural, *i.e*. a rare variety of the mineral chrysoberyl, or synthetic. The synthetic one is made of corundum laced with vanadium to produce the colour change, it is also known as alexandrite. Pale to medium blue topaz is enhanced by irradiation to produce a more intense blue colour.

The first German editions of Bauer's monumental two-volume work on precious stones in 1895 and 1896 included a discussion of artificial and counterfeit gems (Bauer, 1968). Modern technology, driven by large industrial research laboratories, has provided a host of methods to duplicate natural gems and semiprecious stones. All manner of gem crystals from beads to large pendants can be produced on a massive scale. For example, Peruvian blue opal is the national stone of Peru. It is found only in the Peruvian Andes, but in recent years dyed stones have been mass marketed by some dealers as Peruvian Blue Opal.

The belief in the healing power of gems and crystals is not limited to the pre-scientific era. Today one can buy books with titles such as: *Healing Crystals and Gemstones; Gemstones and Crystals to Reduce Stress, Attract Money, and Increase Energy; Gemstone Healing; Lucky Gemstone and Crystal Talismans, Charms, and Amulets for*

Health, Wealth, and Happiness. As the market for mineral crystals has developed, people have found ways to simulate many types of crystals. Perhaps one of the easiest is fluorite. Perfect fluorite crystals grow as octahedrons, and the cleavage is also octahedral. With practice one can take a specimen of fluorite and cleave it into perfect octahedrons, but these are not crystals with naturally occurring faces, they are only cleavage fragments. Natural fluorite crystals are always attached to some matrix, so the best way to spot cleavage fragments is to look for matrix. If no amount of attached matrix is present, it is a cleavage octahedron.

5. Recent times

Being able to identify fake gems and semiprecious stones is theoretically easy as each has a unique set of physical and chemical properties. The synthetics are designed to have the look and colour of a natural gemstone, but most do not have either the chemical or physical characteristics of the natural material. It remains possible to identify the fakes with the proper scientific equipment, particularly optical, but it is difficult if the only equipment is the unaided eye with a 10-power hand lens, a hardness set of some sort, and a way to accurately measure the density. Highly polished and highly reflecting materials such as gemstones are especially difficult to identify without analytical tools. As every gemmologist and mineralogist knows, by far the most difficult job is to try to identify a gem or mineral from a photograph. College, university and museum mineralogists are also regularly asked if a specimen is an example of some local variety name used by collectors (*e.g.* Maw-Sit-Sit from Burma). Local variety names must run into the hundreds of thousands, and few professionals keep those names in their head. Large computer databases may help to alleviate this problem.

Artificial gemstones are made to imitate natural gemstones. For example, several synthetic minerals look similar to diamonds. A cubic zirconium oxide known as cubic zirconia is manufactured to simulate diamond (this is not artificial zircon, which is a zirconium silicate, though the similarity of names may cause confusion) . Another example is synthetic moissanite. Moissanite is silicon carbide and occurs as a rare natural mineral. Moissanite has a higher refractive index than diamond, so it has more sparkle than the diamond, and so it is sold as a diamond look-alike. Other synthetic gems currently made to simulate diamond are made of high refractive index glass, and even an organic acrylic glass of high reflectivity.

Artificial gemstones may have a more vivid colour than their natural counterparts. Synthetic corundum, including those simulating ruby and sapphire, cost only a fraction of the natural gemstones and can be manufactured to have chemical and physical characteristics that are identical to the naturally occurring gemstones. Artificial amethyst can be produced if some iron is included with the silica and the resulting crystal irradiated with gamma rays (O'Donoghue, 1987).

In >60 years as a (sometimes) mineralogist I have visited more than three dozen mineral dealers (rock shops) in perhaps a dozen U.S. states and a few foreign countries (*e.g.* Egypt). The Geological Society of America, at its annual meetings, has a large

exhibit hall where two or more mineral dealers exhibit for sale a broad range of minerals including gems, semiprecious stones and related minerals of interest to collectors. I cannot recall an exhibit where there was not at least one altered mineral, usually altered colour. Perhaps it is fitting that the book *Encyclopedia of Fraud* is published by Obsidian Publishing (Wells, 2002). Although obsidian is a volcanic rock (not a mineral), it is found in most private mineral collections. Readers interested in gems and man might want to read *Fifty Minerals that Changed the Course of History* (Chaline, 2012).

6. A note on the geology and geography of gem mineral deposits

Precious and semi-precious minerals form in many rock types: pegmatites (a coarse-grained intrusive igneous rock), metamorphic rocks (*e.g.* garnets are commonly found as crystals in gneiss and mica schist), hydrothermal veins (*e.g.* emerald deposits of Colombia), and both primary (*e.g.* agate) and secondary (*e.g.* beaches and placers) sedimentary deposits.

Gemstones are rare in part because they tend to be scattered sparsely throughout relatively large rock masses or to occur as small aggregates filling veins and small cavities. My own limited experience with precious and semiprecious stones has been with pegmatites in Minas Gerais State in Brazil and the Black Hills in the U.S. state of South Dakota (Roberts and Rapp, 1965), and with surface deposits in the states of South Dakota and Minnesota as well as small amethyst workings in northern Minnesota.

Brazil is especially rich in precious and semi-precious mineral deposits, with more than 100 gemstone deposits with significant output of emerald, ruby, sapphire, tourmaline, topaz, amethyst, citrine, agate, opal and diamond. Many of the gem minerals come from pegmatites, which are the final product of the last fluid of a crystallizing magma. The final magmatic liquid is rich in chemical elements that did not find a place in the more common minerals. This liquid contains most of the minor elements such as lithium and beryllium, so pegmatites generate gem minerals including beryl, tourmaline, topaz and sometimes spessartite garnet. Gem pegmatites have a somewhat different overall composition from non-gem pegmatites, including lower silica contents. Most gemstones in pegmatite are found in relatively small vugs or cavities. However, pegmatites contain the largest crystals of any geological deposit, including many spectacular gem minerals. The largest gem crystal I had seen (until I visited the giant crystal exhibit at the Earth and Man Museum in Sofia, Bulgaria) was the famous imperial topaz of Oro Preto, Brazil, found in the heart of the Minas Gerais pegmatites.

Not all countries have pegmatites, but surface and near-surface sediments that host mineral deposits are ubiquitous. Tourmaline, beryl and other precious and semiprecious minerals are often concentrated in stream deposits. Sapphires have been recovered from gravels being worked for gold. Namibia's Atlantic shore beach deposits and sediments carry appreciable quantities of diamond. Fluvial reworking of glacial sediments in British Columbia, Canada, has concentrated sapphires and garnets.

A significant diamond deposit in China's Hunan Province was formed in an alluvial regime. Agates are frequently found in glacial gravels and beach deposits of lakes.

Afghanistan is famous as the source of the world's finest lapis lazuli, which has been mined there continuously for >6000 years. But Afghanistan also has other important gem minerals, notably emerald, ruby, tourmaline, aquamarine, amethyst and turquoise. Most of these gemstones come from northeast Afghanistan. While the mining of lapis lazuli goes back millennia, the mining of emerald, ruby and tourmaline began in only the early 1970s. Afghanistan has become known for its blue tourmaline and sea-foam blue green tourmaline, but exploitation of gem deposits has been hampered by decades of war.

7. Conclusion

Humans have valued gems and precious stones since the Palaeolithic. Favoured gems have changed over time as fashions, availability and new discoveries vary the picture. Beauty, hardness and availability determine which gemstones will dominate the market at any one time and place. The increasing skills of gemsmiths have also broadened and enriched the story of gems and man. Today, artificial gemstones are popular. In the next decade – who knows? – they may be called ersatz or fakes and devalued. The only thing sure is that humans seemingly will always fancy ornaments as part of the good life.

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