An Introduction to the Geology of Gem Materials

The division of the sciences into various subjects, such as biology, chemistry, geology and physics, is convenient for their study, and for teaching purposes.

Indeed, these subjects are themselves so vast that they are further subdivided into many sections. However, the division into apparently separate subjects is, to some extent, illusory and the overlap into other topics can vary considerably. To study any of these subjects effectively, the student should have, at least, some knowledge and understanding of the related sciences.

Gemology is no exception to this and a basic understanding of the geology and mineralogy of gemstones will be helpful.

The Structure of the Earth

The CRUST: The crust of the continent on which we live varies from about 25 km (15 miles) to about 70 km (45 miles) in thickness. Under the oceans it averages about 6km (4 miles).
Much of the crust has a thin covering composed chiefly of sedimentary material,. This is material which has been deposited by wind, rain, rivers, seawater or by chemical precipitation, and then cemented or compressed to form rocks. These sedimentary rocks are chiefly lime stones, clays, shales and sandstones.

Granites, basalts and metamorphic rocks form the major part of the crust. The first two have been formed by the solidification of molten rock (magma) and are termed “igneous” rocks. Metamorphic rocks are any rocks that have undergone change (metamorphism) in the solid state, principally by heat or pressure in the depths of the earth.

The Intermediate Zone or MANTLE: Beneath the curst lies the mantle with a thickness of about 2,900 km (1,800 miles). It is very hot and, in contrast to the cooler and more rigid crust is subject to slow circulation even though it is solid.

The CORE: The core extends about 3,500 km (2,150 mils) from the mantle to the centre of the Earth. Scientists are uncertain as to its temperature and its composition. The inner core is solid.

The core, mantle and crust each have different physical characteristics The core is under the highest pressure, and its temperature is higher than those of the mantle and crust. Because of these differences there are discontinuities and relative movement between these regions.

It is these factors, particularly the circulating movement of the mantle, that are responsible for such natural phenomena as volcanic eruptions, earthquakes, the slow drift of the continents, the compressions and tension in the crust of the Earth to form mountain ranges and valleys, and the formation of rocks and minerals, including gem materials.

The surface features of the Earth are produced by two sets of opposing forces-destructive and constructive.

The destructive forces, such as those due to wind, rain, rivers, glaciers and the action of the sea break down the rocks, which form the feature of the Earth's crust.

The constructive forces, form new features. Some of these changes may be relatively rapid, as in the case of volcanoes, whilst others may take millions of years, as with the gradual movement of the continents.

The Composition of the Earth

There are 92 naturally occurring elements in the Earth's crust and of those, eight account for approximately 98% of the crust:

Oxygen	46.60%
Silicon	27.70%
Aluminium	8.10%
Iron	5. 00%
Calcium	3.60%
Sodium	2.80%
Potassium	2.60%
Magnesium	2.10%

It should be realized, however, that the elements forming the Earth are not evenly distributed through the crust. Basalt has a composition different from granite, and both these differ from limestone. The concentration of materials containing these elements varies from place to place, due to the ways in which the crust has formed.

These natural elements combine together chemically to form compounds, and some of these chemical compounds are minerals.

A mineral is therefore, a naturally-formed inorganic substance, which possesses a definite chemical composition and a crystalline atomic structure.

A mineral may consist of just one element (e.g. diamond is composed of just carbon) or of several elements, chemically combined to forma compound (e.g. almandine garnet is a compound make up of iron, aluminium, silicon and oxygen atoms).

Rocks, however, consist of mineral particles which have grown together, or which have become cemented together by chemical processes or by heat and pressure, and have formed aggregates. Some rocks, which possess desirable texture and colour (such as lapis lazuli) are used as gemstones or for decorative purposes.

Most gem materials are minerals, but some owe their origins to plants and animals, such as pearl, coral and ivory. These are not minerals, although many organic substances are partially composed of crystalline materials such as calcite an aragonite.

The Classification of Rocks

Rocks can be classified according to the way in which they have been formed. There are three main divisions: igneous, Sedimentary, Metamorphic. Igneous Rocks: These are rocks which have formed on cooling of molten rock material called magma. They may be subdivided into two types, depending on where the magma cooled viz:

Volcanic (Extrusive) Rock: This is the rock which has formed at the surface of the Earth. In contact with air, or seawater, molten rock cools rapidly an, in consequence, either quenches to a glass (eg. Obsidian), or forms very small crystals (e.g. basalt).

Plutonic (Intrusive) Rock: When the molten rocks, or magma, solidifies below the Earth’s surface, then it cools slowly, and forms plutonic rocks, with larger crystals.

During slow cooling, different minerals may form at different temperatures. Olivine (Peridot) forms at higher temperatures than quartz, for example, and in some circumstances, minerals may become concentrated.

Two of the most common igneous rocks are granite and basalt.

Granite is a coarse-grained intrusive rock containing the minerals quartz and feldspar, usually with mica or hornblende. Many granite intrusions are exposed at the Earth's surface because they are raised by earth movements, and exposed by erosion of the overlying rocks.

As granite cools, the primary minerals, such as hornblende, mica and feldspar, solidify, while the remaining fluids are left with varying amounts of quartz, feldspar and rarer elements. These fluids are also commonly rich in water and gases such as fluorine (found in topaz and fluorite). As these eventually crystallize, they often produce a series of different minerals.

Among the residual fluids to be formed, often in veins penetrating the surrounding rocks, are minerals of the pegmatite group. Some pegmatites contain large transparent crystals, and are a valuable source of gemstones. Of course, the varieties of minerals present depend on the chemical elements present in the original magma and left in the residual fluids.
Thus, granites are the primary source of many gemstones.

Basalt is an extrusive rock, and is fine grained due to its rapid cooling. It largely consists of tiny feldspar and pyroxene crystals, but some basalts contain gem minerals.
The corundum gems (ruby and sapphire), zircon and garnets found is some basalts represent crystals (or parts of larger crystals) plucked ,by the basaltic magma, from rocks it has invaded on its way up though the Earth's crust and crystals formed by reaction of the magma with surrounding rocks.

A variety of volcanic igneous rocks, which is chemically different from basalt, is called Kimberlite,. This is best known in the form of the Kimberlite pipes of Africa, USSR and other parts of the world. Other gemstones may also be present, and their occurrence is often a useful indicator of the presence of a diamond.

Gem minerals in Kimberlite have been formed deep down in the Earth and have been transported towards the surface during volcanic eruption.

For better and further understanding how diamonds are born, please refer to “Diamonds” written by the same author on this website.

Sedimentary Rock

Rocks are won away by the action of wind and water. The particles produces are carried away by running water, and are eventually deposited in lakes and seas,. When these particles eventually settle, they form gravels, sands or clays. They may become cemented and compressed, to form sedimentary rocks, such as conglomerates, sandstones and mudstones.

Chemical action in the environment leads to some material dissolving in water. Eventually the water may evaporate and deposits of borax and other slate evaporates may form in this way.

Most lime stones are formed by biochemical action. Much limestone is used as ornamental material, and is frequently mis-termed as “marble”. Plant and animal remains are commonly incorporated among the rock fragments, and these may be preserved as fossils.

Metamorphic Rock

When Earth movements occur, or when magma is intruded, solid rocks can change in texture or chemical composition. Thus, as a result of heat, pressure or chemicals from within magma, existing rocks change into new types of rocks. These are known as metamorphic rocks. They are often harder and denser than the original material.

During metamorphism the rocks are re-crystallized while remaining solid. For example slate is formed from shale, and limestone is converted into marble. The mineral garnet and jadeite form during metamorphism under very high pressure.

Gem Minerals

Heat and pressure, and the chemical elements are not evenly distributed throughout the earth.
Owing to the nature of the forces at work and the variation in the Earth’s crust, the natural phenomena, such as Earth movements and volcanic activity, only produce noticeable effects in certain areas during any one period of time.

Many gems form in areas of active earthquakes, volcanoes and mountain—building.
These factors control the development of the various minerals and only in a few places are economically recoverable quantities found.

Gemstones are found in all three rock groups and similar species may occur in each group.

The largest variety of gemstones occurs in association with igneous rocks, particularly the granites,. The final crystallization of granitic fluids (which may contain such elements as beryllium, fluorine, chlorine, boron and zirconium) in the presence of water, gives rise to pegmatites which contain gem minerals as beryl, topaz tourmaline and zircon.
The fluids in this process are much less viscous than the original magma, and can produce very large crystals in rock cavities and faults. Some crystals of beryl weigh many tons, but little of this of gem quality.

At high temperatures and pressures, and particularly under acid condition, water is capable of dissolving many minerals which at atmospheric temperature and pressure are regarded as being soluble.

When these mineral-rich solutions percolate through gaps and fissures in rocks, they form hydrothermal veins an vugs (a hollow cavity in the rock) lined or filled with crystals.
Gem materials such as opal, turquoise chalcedony and varieties of quartz are often formed in this way.

Sedimentary rocks are also sources of gem materials.

Many gemstone are found in alluvial deposits. These deposits, most of gravel, sand and silt, have their origins in the destruction of the original rocks and the transportation of the resulting material by rivers and floods. During this movement, the heavier minerals tend to remain relatively close to the source, whilst lighter materials are carried further a field.

The harder and chemically resistant materials do not wear away as quickly as the soft or easily altered materials and tend to retain more of their crystal shape. Stones such as a as sapphire and topaz do not suffer so much abrasion from the softer minerals such as quartz.

However, due to the continuous grinding and tumbling over a period of time, a large number of durable gem minerals are found as rounded “water-worn” pebbles. Denser minerals tend to accumulate where water velocity and volume are decreased. Gem gravels may contain a wide variety of such minerals.

Because of their supreme hardness many diamonds survive the sedimentary processes and may be found in alluvial deposits.

Many of the softer minerals and those which cleave easily or have incipient flaws, are usually fragmented by transport and erosion processes. The minerals which survive this treatment and which possess the required colour and clarity are potential gem material.

To Be Continued...

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