Rock types are classified into three major groups –
Igneous, Sedimentary and Metamorphic; then subdivided into several divisions based on their chemistries, origin and physical character.

Igneous rocks are formed by cooling from a molten state. When extruded on or near the Earth's surface by volcanoes (such as the Yellowstone Super-volcano) they cool quickly, forming fine-grained, dark rocks like **basalt** (iron & magnesium rich) and **rhyolite** (silica & aluminum rich). **Plutonic** rocks cool slowly at great depth, allowing large crystals to grow over time and are only exposed today on Earth's surface by tectonic upheavals and deep erosion. Plutonic **Granite** is the most common rock type of the Earth's crust, made up primarily of light-colored Quartz and Feldspar crystals (SIALIC) with minor amounts of dark (MAFIC) minerals.

A large pluton exists deep beneath the active Yellowstone caldera, but is not entirely molten any longer. These late-stage pockets of molten rock can form **pegmatites** of fine, large crystals, and can also become concentrated in rare elements producing rare gemstones.
Pegmatites could be growing now beneath the Yellowstone caldera is it slowly cools.

Sedimentary rocks have been exposed on the Earth's surface, broken down by weathering and deposited in layers as strata, cemented together again over time. Any rock type can be torn apart and deposited as sediments, typically in alternating layers of different grain size (**sandstone** and **shale** are basic examples). Most sedimentary rocks contain either quartz or calcite. Deposited in the ocean, **limestone** is made of micro-granular calcium carbonate, often including shells of marine organisms. Precambrian age rocks denote the time period before fossilized skeletons of life forms are found in sediments (~540 million years ago). Precambrian rocks underlie most of North America today, with a thin veneer of sediments and volcanics covering the surface.

Metamorphic rocks have been profoundly "changed" from their original form, typically as a result of deep burial over time, where moisture, oxygen and carbon dioxide are pressed out of the original minerals and re-crystalized <u>in place</u> (without re-melting), preserving the original texture. Conditions of stress, heat and pressure favor the formation of a new group of minerals including **garnet,** amphibolite and the kyanite-staurolite series. Together with mica and other minerals with a flattened structure, oriented to the stress fields, these mineral assemblages are characteristic of highly metamorphosed rocks. Metamorphosed limestone becomes marble.

Regional Geology
The **Yellowstone Super-volcano** lies over an active hotspot where lighter, hot, molten rock from the mantle has risen toward the surface over the last 2 million years. Repeated violent explosions have ejected thousands of cubic miles of **rhyolite, dust and volcanic ash** into the sky and across the region. The surface expression is a depression or **Caldera**, formed where the overlying land has collapsed above the emptied magma chamber. The volcanic hotspot is responsible for large scale volcanism in Oregon, Nevada, Idaho, and Wyoming. Non-explosive eruptions of **basalt lava** have occurred as recently as ~70,000 years ago, and smaller, steam eruptions even more recently. Volcanic activity is currently exhibited via **geothermal vents** scattered throughout the Yellowstone region, such as the **Old Faithfull Geyser**.

Dramatically exposed in **Glacier National Park** are billion year old (Precambrian) sediments, widespread across Idaho, Montana & Canada, which were thrust upward by the tectonic forces creating the Rocky Mountains (80-50 million years ago). This package of ancient mudstones thicken to the west (>18km), buried deeply over hundreds of millions of years and subjected to repeated tectonic events against the ancient continental margin.

These same ancient sediments (**Belt Supergroup**) exposed in **Glacier National Park**, exhibit intense folding, fracturing and high-grade metamorphism when exposed further west in Idaho. Superimposed on the regional metamorphism was the intrusion of a large granitic pluton, the Idaho Batholith, which pushed upward to the surface, further altering the surrounding metamorphosed sediments.

No Precambrian age rocks exist west of the Rocky Mountains, contributing to the evidence that the continental margin of ancient North America was once far inland from the Pacific shoreline we recognize today. Equivalents to North American **Belt Supergroup** rocks are thought to be present in what is now **Korea, Northeast China,** and **Eastern Siberia,** suggesting that an ancient Precambrian super-continent has broken apart as the Pacific Ocean was established and expanded over the eons, creating a "Ring of Fire" with currently active continental margins.

Idaho is known as "**the gemstone state**"

…with mountains of igneous and metamorphic rocks containing veins of gold, silver, lead, zinc, cobalt, copper and precious minerals including sapphire, topaz, zircon, garnet, tourmaline, jade, opal, jasper and is one of only two locations in the world where six-ray Star Garnets are found.

High grade, gem-quality **garnet crystals** are concentrated in soft, muscovite schist at Bechtel Butte in Shoshone County, Idaho. Throughout this area, "**Star Garnet**" (Idaho's State Gemstone) can be found as intact crystals, up to the size of a golf ball. The star quality, or "asterism" originates from the internal reflection of light from minute rods of needle-like rutile (TiO_2) crystals, formed as inclusions within garnet crystals, oriented along the three crystal axes.

Garnet is a mineral group with a range of chemistry and the same crystal structure.
Crystal structure is **isometric**, meaning equal-dimensional in three directions at 90 degrees.
Basic chemistry of Garnet is an **aluminum silicate** with other heavy elements that substitute for each other in a continuous "solid solution". Garnets from northern Idaho are primarily iron-dominated **Almandine**, with lesser percentage of magnesium-rich Pyrope garnet.

Rhodolite is an intermediate between almandine and pyrope garnet, and highly desired as a gemstone when clear and exhibiting a rose-pink color. The term **Garnet** is derived from the Latin "granatus" meaning like a grain, due to the resemblance in size and color to the seeds of the pomegranate. Garnets from Bechtel Butte are found as dodecahedron (12 faces) and trapezohedron (24 faces) crystals. Clusters of crystals also grow together, sometimes as "twins". Idaho garnets have exceptional hardness (8 Mohs) compared to 7 typically.

Asterism is a phenomenon whereby minute crystals of rutile (titanium oxide TiO_2)align themselves along the crystal planes of the host crystal, such that light is reflected back as a "star". Garnets from Idaho are one of only two locations world-wide where 6-ray stars are found, the other being Sri Lanka. Sapphire is also well known to exhibit "stars".

The bulk of the Earth's crust is made of Silica and Aluminum (Sialic), heavier elements like Iron and Magnesium (Mafic) are concentrated in the molten mantle and are more minor constituents of the surface crust. Ultra-mafic rocks on the surface are known to have originated in deep crust.

Garnets from Bechtel Butte are dug from the ground and separated from the soft soil under supervision of the US Forest Service, under terms of a mining lease to a US Vietnam War Veteran.