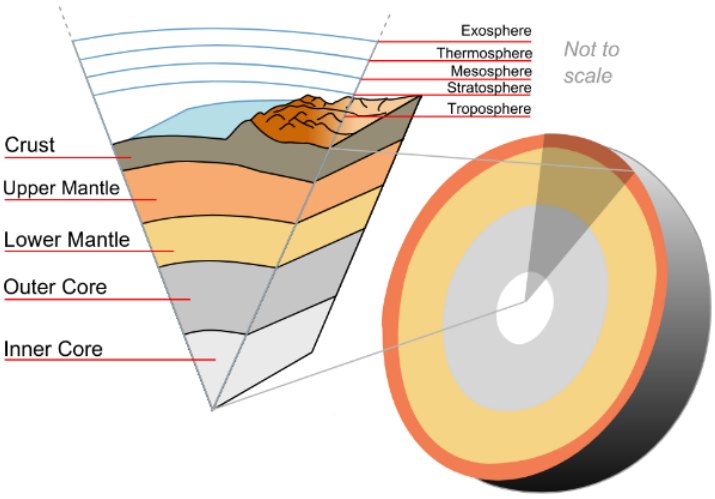
- **The Earth's Lower Mantle** – The next layer of the Earth's interior we shall examine is the **lower mantle** (also known as the mesospheric mantle). This layer represents approximately 56% of Earth's total volume, a large fraction of Earth's interior. The lower mantle is from a depth of about 650 km (400 miles) down to 2,900 km (1,800 miles), and is composed chiefly of magnesium and iron-bearing silicates, including the high-pressure equivalents of olivine and pyroxene. The lower mantle is much less ductile than the upper mantle and transition zone. Although heat usually corresponds to softening rocks, intense pressure keeps the lower mantle solid. Between the upper and lower mantles lies a transition zone extending from 410 to 660km.



Geologists do not agree about the structure of the lower mantle. Some geologists think that subducted slabs of lithosphere have settled there. Other geologists think that the lower mantle is entirely unmoving and does not even transfer heat by convection.

- **Polyhalite** - Beneath the North Yorkshire moors lies the world's largest and highest grade Polyhalite deposit. Polyhalite was formed during the evaporation of the prehistoric 'Zechstein Sea' in the Permian period, around 260 million years ago. The hot and dry conditions of the environment meant the sea evaporated quicker than it could be re-filled, leaving behind Polyhalite. The name Polyhalite is from the Greek words meaning "many salts," and reflects its composition, hydrated sulphates of potassium, calcium, and magnesium. These minerals all nourish crops, especially potatoes, vegetables, and fruit. It is hoped that Polyhalite will replace potash as a plant fertiliser, which takes much more energy and chemicals to process. Polyhalite is a multi-nutrient fertiliser that needs very little processing. It is just mined, crushed, screened then spread onto the fields. Because it's quite an energy efficient process it produces about 85% less carbon than similar fertilisers. Making and using fertiliser is one of the big contributors to global warming - at around 5% of greenhouse gases. The Boulby mine in the North York Moors, is presently the only Polyhalite mine in the world and has been designed to minimise the impact on the environment. The mine tunnel is around 7 km long and extends

A Polhalite crystal

under the North Sea. There is sufficient supply of the mineral to keep the mine operating for the next 100 years. The Polyhalite is mined then transported in a 37 km tunnel to Teesport for shipping around the world. Polyhalite has other uses and can help to remove impurities from water, to soften water, make water less corrosive and as an animal feed additive: adding it to animal feed improves the nutritional value. Polyhalite

- **Mineral Classification** - Chemical formulas form the basis for the standard mineral classification system used today. It is generally called the *Dana System of Mineralogy* and was created in the mid-19th century by American mineralogist, James Dwight Dana. In geology and mineralogy, a **mineral** or **mineral species** is, broadly speaking, a solid substance with a fairly well-defined chemical composition and a specific crystal structure that occurs naturally in pure form. The geological definition of mineral normally excludes compounds that occur only in living organisms. The concept of mineral is distinct from rock, which is any bulk solid geologic material that is relatively homogeneous at a large enough scale. A rock may consist of one type of mineral or may be a mass of two or more different types of minerals. Some natural solid substances without a definite crystalline structure, such as opal or obsidian, are more properly called mineraloids. If a chemical compound occurs naturally with different crystal structures, each structure is considered a different mineral species. Thus, for example, quartz and stishovite are two different minerals consisting of the same compound, silicon dioxide. The International Mineralogical Association (IMA) is the generally recognized standard body for the definition and nomenclature of mineral species. As of July 2023, the IMA recognizes 5,955 official mineral species.

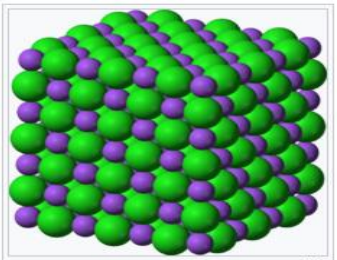
Diopside, garnet, and clinochlore

The **International Mineralogical Association** has established four rules which have been simplified below. The details of these rules are somewhat controversial.

1. ***It must be a naturally occurring substance formed by natural geological processes***, on Earth or other extraterrestrial bodies. Hypothetical substances are excluded, even if they are predicted to occur in inaccessible natural environments like the Earth's core or other planets.
2. ***It must be a solid substance in its natural occurrence.*** A major exception to this rule is native mercury: it is still classified as a mineral by the IMA, even though crystallizes only below −39 °C. Water and carbon dioxide are not considered minerals, even though they are often found as inclusions in other minerals; but water ice is considered a mineral.
3. ***It must have a well-defined crystallographic structure;*** This property implies several macroscopic physical properties, such as crystal form, hardness, and cleavage.

4. ***It must have a fairly well-defined chemical composition:*** Some substances that have a continuous series of compositions, may be arbitrarily split into several minerals. The typical example is the olivine group $(Mg, Fe)_2SiO_4$, whose magnesium-rich and iron-rich end-members are considered separate minerals (forsterite and fayalite).

Crystal structure and habit:


Crystal structure of table salt (sodium in purple, chlorine in green)

Crystal structure results from the orderly geometric spatial arrangement of atoms in the internal structure of a mineral. This crystal structure is based on regular internal atomic or ionic arrangement that is often expressed in the geometric form that the crystal takes.

Crystal habit refers to the overall shape of crystal. Several terms are used to describe this property. Common habits include *acicular*, which describes needle-like crystals, *bladed, dendritic* (tree-pattern, common in native copper), *equant*, (which is typical of garnet), *prismatic* (elongated in one direction), and *tabular*.

The Complete Classification of Minerals

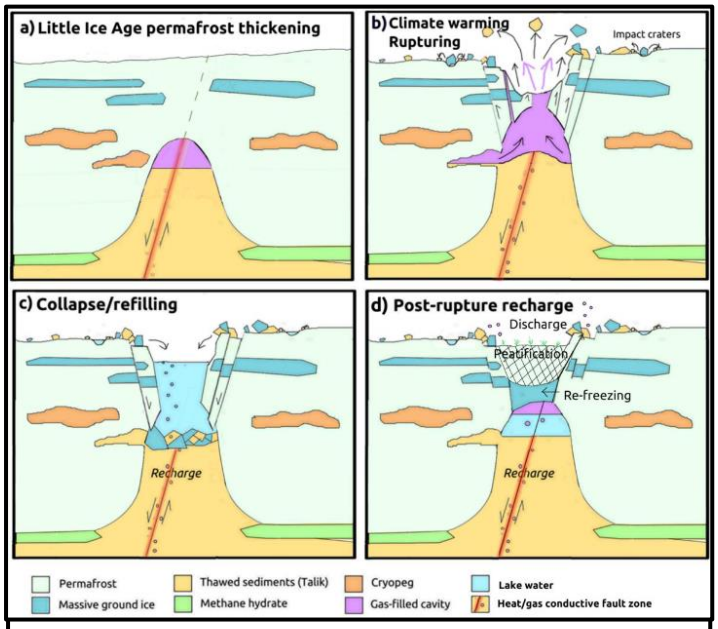
- **Iceland – The land of Fire & Ice.** Located on a rift (a rift is a linear zone where the lithosphere is being pulled apart). Iceland's geologic activity includes geysers and frequent volcanic eruptions. The Reykjanes Peninsula runs along the Mid-Atlantic Rift, where the Eurasian and the North American tectonic plates are drifting apart. Volcanic eruptions at this boundary create new ocean floor and at the same time push the two tectonic plates apart at rates of 1 cm to 20 cm per year, a process known as seafloor spreading. As oceanic plates move apart, rock melts and wells up from tens of kilometers deep producing enormous volcanic eruptions of basalt and building the longest chain of volcanoes in the world. Due to this geological setting, the whole Reykjanes peninsula is extremely volcanically active. Sundhnukagigar are a row of craters just outside the town of Grindavik on the Reykjanes peninsula that erupted in December 2023 and again in February 2024. They previously erupted over 2,500 years ago. Due to strong seismic activity an eruption had been expected for almost 2 months.


The Sundhnukagigar craters are part of a rift that passes under the town of Grindavik - seen to the right hand side

The earthquakes had destructive effects on infrastructure in the nearby town of Grindavik, which was evacuated on the 10th November 2023. Sundhnukagigar may be referred to as a volcano, it's actually an example of a *fissure eruption,* when lava erupts through cracks in the earth's surface rather than a single volcanic vent. When the volcanic fissure opened on December 18th it initially spanned a length of 2.5 miles (4 kilometers) and the lava reached a height of over 328 feet (100 meters). In the first 7 hours the volume of lava flow surpassed the total output of the month-long eruption of the Litli-Hrutur volcano in the summer of 2023. Over the first two days, the surrounding lava field from Sundhnukagigar had reached a size of 4 square miles (3.7 square kilometers). Volcanic rock fragments that were ejected into the air, known as tephra, were blown two to three miles away, reaching the town of Grindavík. A major concern, because of the eruptions, is the possible damage to the Svartsengi power station. This is a geothermal power plant, located 4 kilometres (2.5 mi) north of Grindavík town. It is the world's first combined geothermal power plant for electric power generation and hot water production for district heating. In November 2023, a 9-mile-long dike formed underground, which served as the principal channel for magma to travel through and reach the surface. During the dike formation, magma flowed at an unprecedented rate of 7,400 cubic meters per second. A team of scientists found that fracturing and tectonic stresses played an important part in driving these massive magma flows, even when there's only a modest amount of excess pressure from below. The Mid-Atlantic Ridge in Iceland

The Mid-Atlantic Rift as it passes through Iceland, where the Eurasian and the North American tectonic plates are drifting apart.

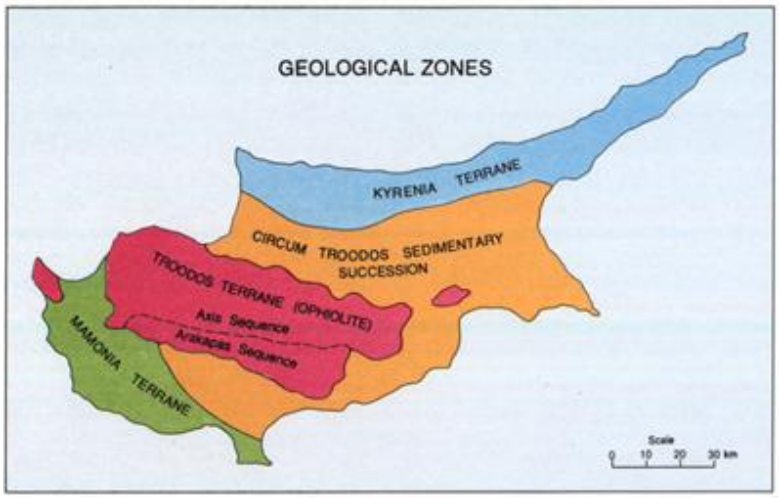
- **Siberia's Exploding Craters** – Large craters, first spotted in 2012, have been appearing in the deserted Siberian permafrost and puzzling scientists. They can be more than 160 feet in depth and 65 feet in width and blasting chunks of debris hundreds of feet away. Permafrost traps a lot of organic material, as temperatures rise it thaws, allowing that mulch to decompose. That process releases methane. It's notably the process that's thought to lead to thermokarsts, lakes that appear in areas where permafrost is melting, which bubble with methane and can be lit on fire. But that doesn't



Model for the formation of Gas Emission Craters, local thinning of permafrost, accumulation of natural gas. The pressure is trapped in the resulting domal structures.

explain why the so-called exploding craters are so localized. Exploding lakes, by contrast, are seen in a wide variety of areas where permafrost is found, including Canada. However, only eight of these exploding craters have been identified so far, all within a very specific area of the Western Siberian Yamal and Gydan peninsulas in Northern Russia. Scientists suggest there's another mechanism at play: hot natural gas, seeping up through a geological fault, is building up under the frozen layer of soil and heating the permafrost from below. Those hot gas plumes would help thaw the permafrost from the bottom, making it weaker and more likely to collapse. The explosion can only happen if the permafrost is thin and weak enough to break. Rising atmospheric temperatures melt the upper layer of the permafrost at the same time. This creates the perfect conditions for the gas to be freed suddenly, triggering either an explosion or a "mechanical collapse" caused by the gas, which is under pressure – this causes the craters. The area is rife with natural gas reserves, which supports the theory. Thermokarst Lakes. Siberia's exploding craters.

- **Cyprus Geology – The Keryneia Terrane.** Continuing our look at the geology of Cyprus, the Keryneia Terrane occupies the northern margin of Cyprus, comprised of a series of narrow, steep-sided mountains stretching from Cape Kormakitis in the west to Cape Andreas in the east. (**Terrane** - a crust fragment formed on a tectonic plate [or broken off from it] and accreted or sutured to crust lying on another plate). The crustal block or fragment preserves its distinctive geologic history, which is different from the surrounding areas. The Keryneia terrane is a sequence of Permian (298.9 Mya to 251.902 Mya) to recent sediments. The carbonate rocks are divided into the *Dhikomo*, the *Hilarion* and the *Sykhari Formation*. These carbonate masses formed in a shallow marine environment on the slopes of a continent, which existed south of the current location of Cyprus. Cyprus Geological Dept-The Keryneia Terrane



- Don’t forget there is an Earth Sciences Glossary of Geology Terms, available on the P3A Earth Sciences website.

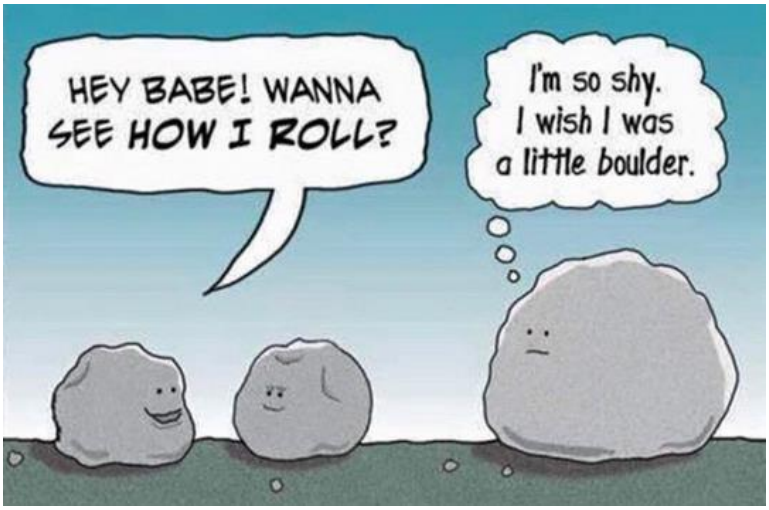
Quizzes

Metals: true or False

The Solid Earth

Weather Quiz

The periodic Table Quiz



Acknowledgements