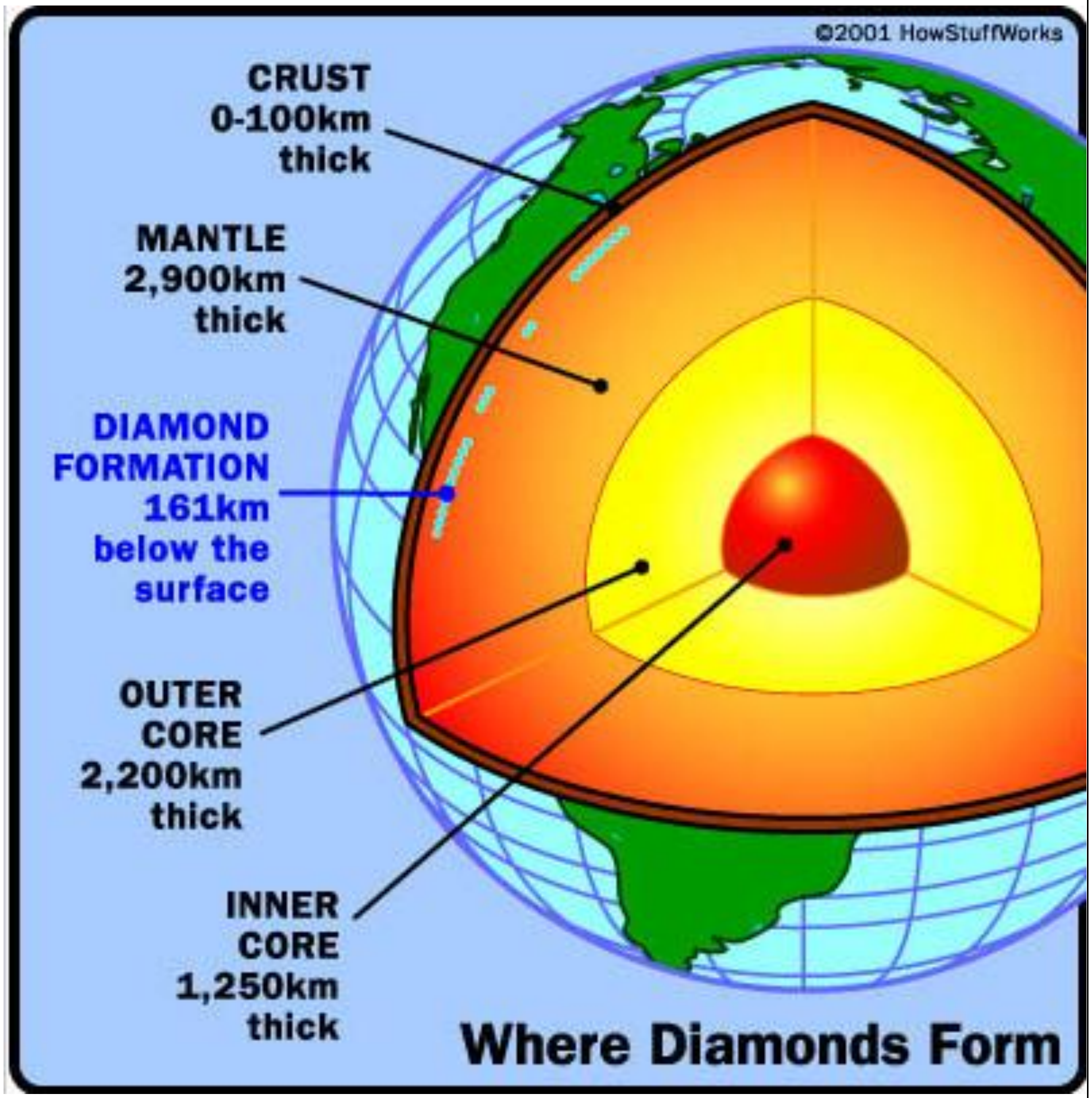
How Diamonds Are Formed

Diamonds are fascinating not just because of their value and beauty. They have unique physical and chemical properties that directly correlate to how they are made. This document briefly explains their origins. Words in **green bold** are found in the index in the back of this document.



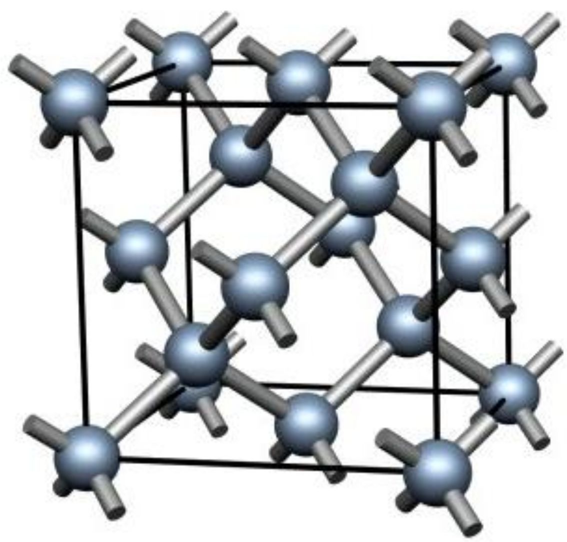
How diamonds are formed is actually unverifiable. It is not possible to directly sample the part of Earth in which they are formed.

The most widely accepted theory is that diamonds are formed at great depth within the earth's **mantle**, at extremely high pressures and temperatures.

Explosive volcanic activity then drives them rapidly to the surface, accompanied by a rapid drop in temperature that stabilizes the diamond structure.

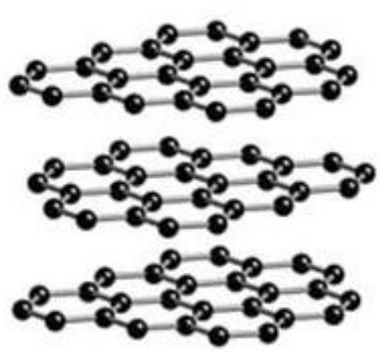
Diamonds are made of carbon. A carbon atom has four bonds available. Under the high temperature and pressure found in the Earth's **mantle**, carbon atoms use all four available bonds to bond to other carbon atoms. Each carbon atom participates in a **covalent bond**, in which the atoms share electrons. This is the most tightly bound crystalline configuration known. It is why diamond is so hard.

The three-dimensional arrangement of carbon atoms in a diamond is known as the *diamond cubic crystal structure*, named after the material. In this illustration, each sphere is a carbon atom, and each rod is the chemical bond. The cube formed by the atoms, shown by black lines, is a repeating unit.

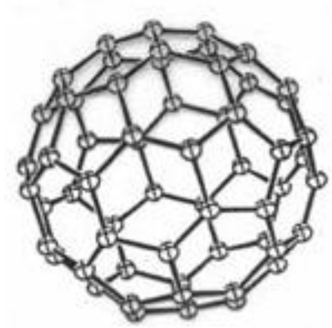


Compare the atomic structure of the two other forms of carbon that are stable at low pressure: **graphite** and **fullerite**. Both are much looser bonds.

Graphite atomic structure

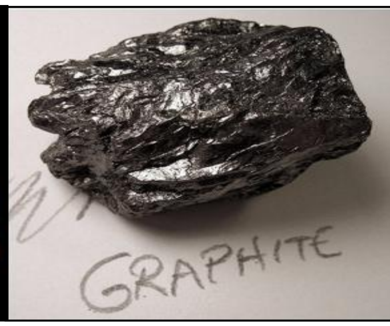


Fullerite atomic structure



To retain the four-way **covalent bond**, diamonds must be driven upward through the earth very quickly – in a matter of hours. The speed is critical to diamond material, because if it traveled too slowly, it would turn to graphite. By moving quickly, the carbon is locked into the diamond atomic formation. The rapid cooling does not leave enough energy to rearrange the diamond structure into graphite, the form of carbon that is stable under low pressures.

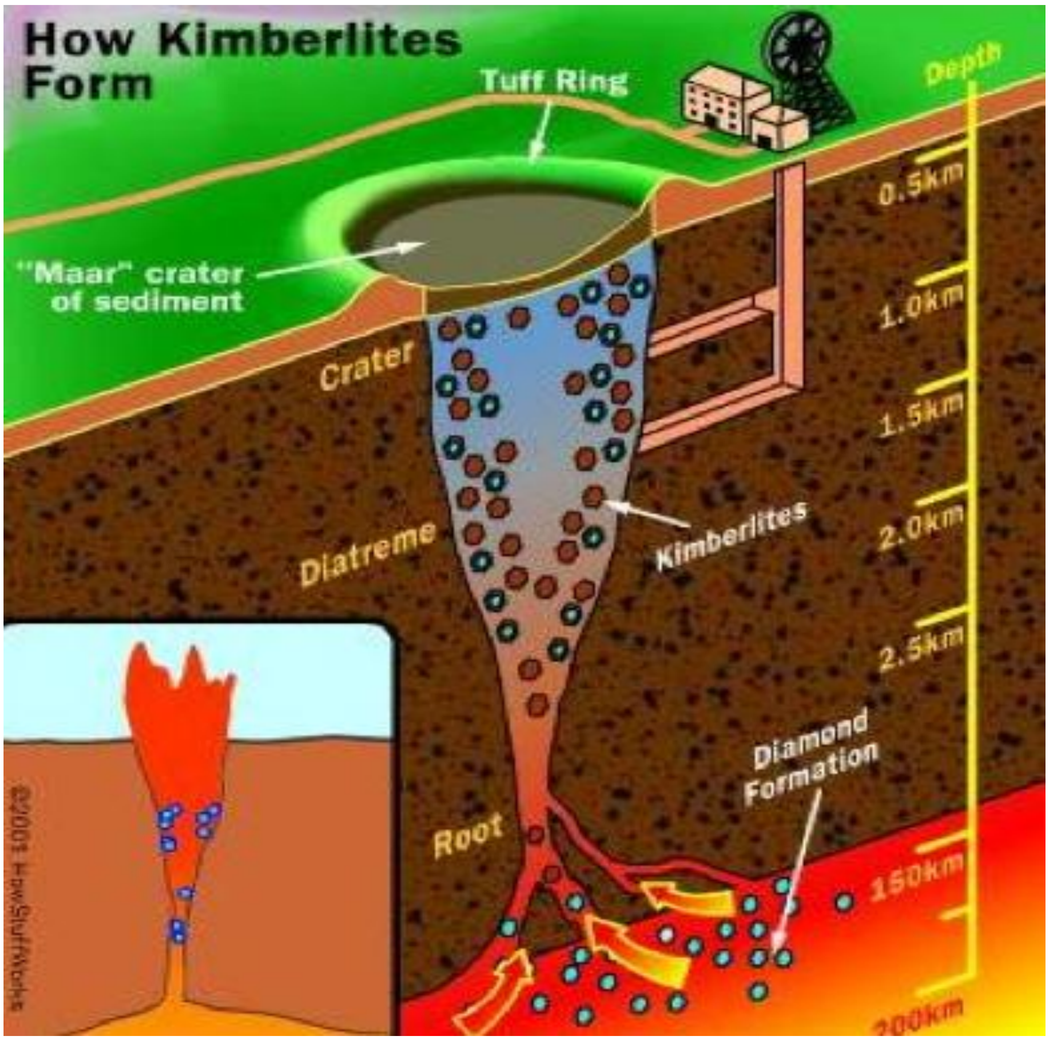
Three naturally occurring forms of carbon: diamond, graphite, and fullerite.



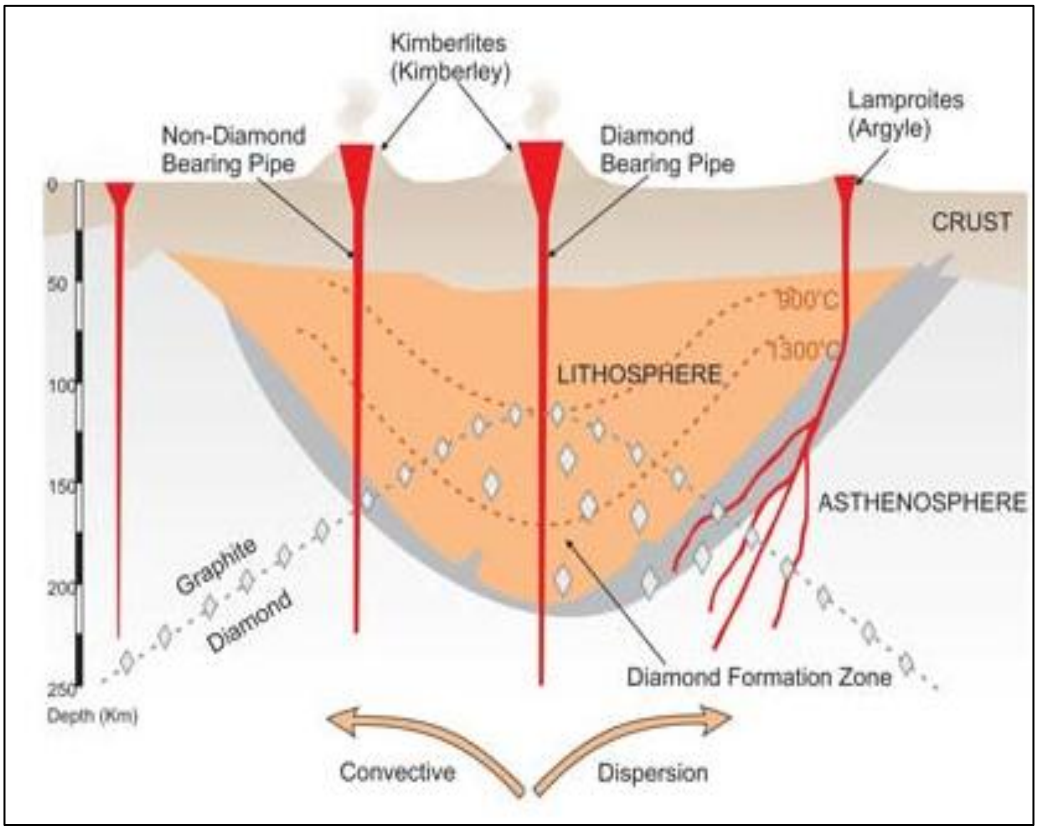
Four processes are thought to be responsible for nearly all natural diamonds that have been found near the Earth's surface. But only one is a significant source: the Earth's mantle.

Geologists believe that diamonds were formed in the **mantle** and driven to the surface by deep-source volcanic eruptions. These eruptions produced **kimberlite** and **lamproite** pipes. This type of eruption is so rare that it has not occurred in the time science has been able to recognize it. Below is a mined-out **kimberlite** pipe at Kimberley, South Africa.

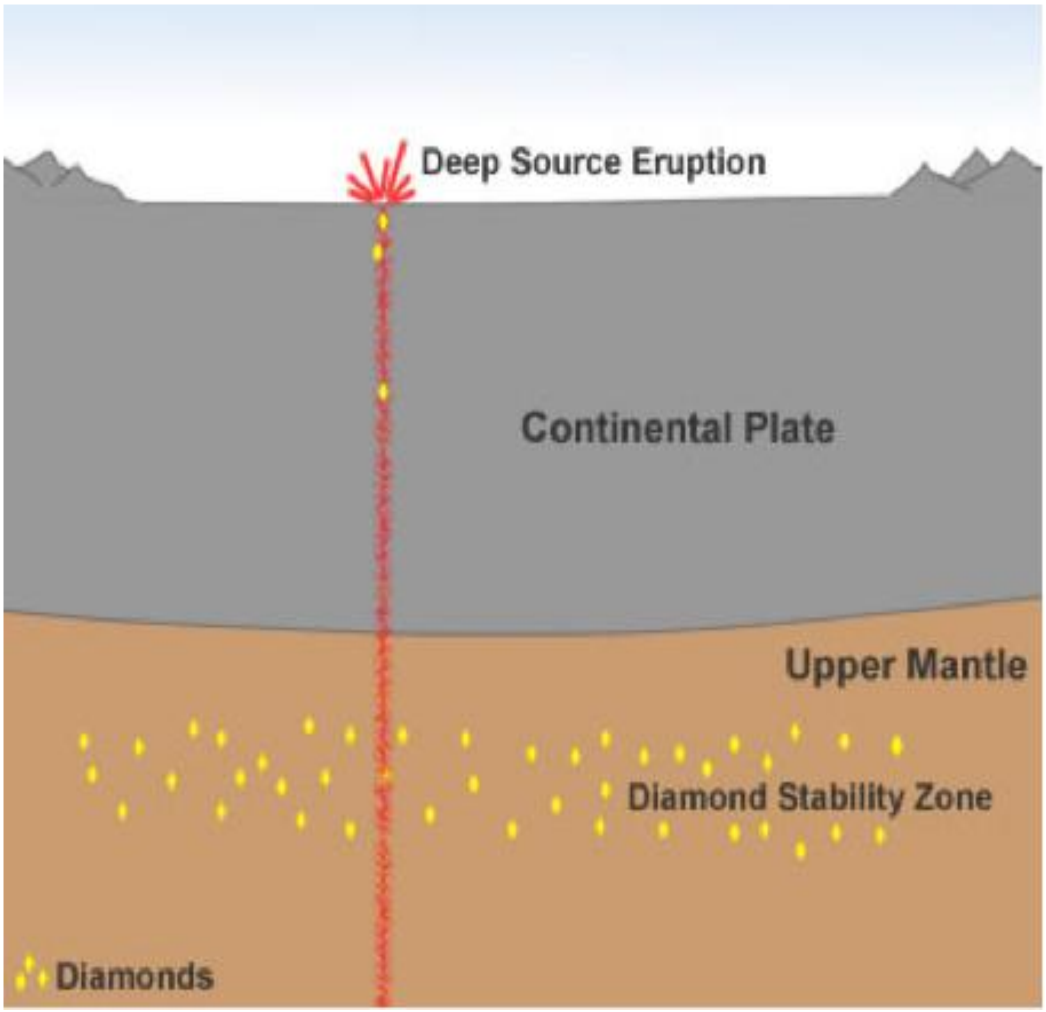
Kimberlite pipes are rare structures (named after the South African town of Kimberly). They are funnel-shaped, a few hundred meters in diameter, becoming a fissure that presumably extends through the Earth's crust into the upper mantle where diamonds are formed. They were produced by a gas-driven eruption the rapidity of which preserved the diamond material. The youngest known Kimberlite pipes are several tens of millions of years old.



Lamproite pipes differ from kimberlite pipes in that the **magma** contains boiling water and volatile compounds that corrode the overlying rock. The result is a broad cone at the earth's surface that narrows into a pipe. Lamproite pipes are a less frequent source of diamonds than kimberlite pipes. Below is an illustration from the Argyle Diamond Mine in Western Australia. Diamonds that eroded from these eruptive deposits are now contained in sedimentary (**placer**) deposits of streams and coastlines.



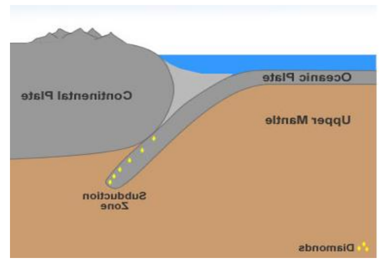
Formation of diamond requires very high temperature and pressure. These conditions occur in limited zone of the Earth's mantle about 90 miles below the surface where the temperatures are at least 2000 degrees Fahrenheit. This environment is thought to be present in the **mantle** only beneath the stable interiors of continental plates.



Diamond formed and stored in these "diamond stability zones" is delivered to the surface through deep source volcanic eruptions. These eruptions tear out pieces of the mantle and carry them rapidly to the surface.

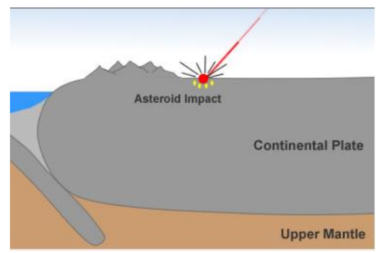
Other sources of diamond formation are:

- ❖ *Subduction*



The movement downward and sideways of a plate of the earth’s crust beneath another plate is called subduction. Diamond formation could occur this way as little as 50 miles below the surface at a temperature as low as 390 degrees Fahrenheit.

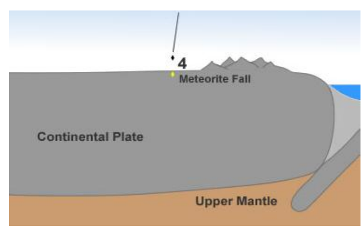
- ❖ *Diamond formation At Asteroid Impact Sites*



At the time of impact, extreme pressure and temperature is produced.

Example: A 6-mile wide asteroid traveling at 9 to 12 miles per second would produce an energy burst equivalent to millions of nuclear weapons and temperatures exceeding that of the sun. These conditions are favorable to diamond formation. Tiny diamonds have been discovered around several asteroid impact sites.

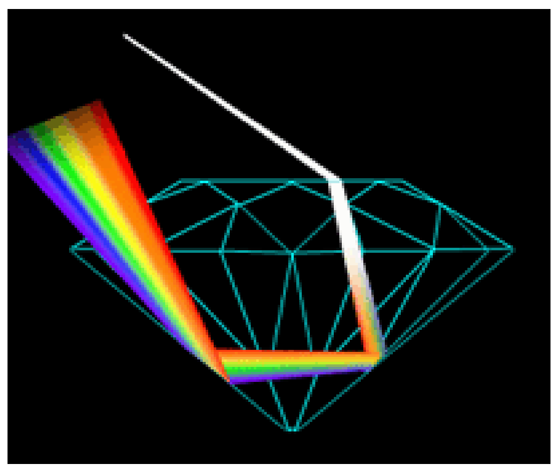
- ❖ *Diamond formation in space*



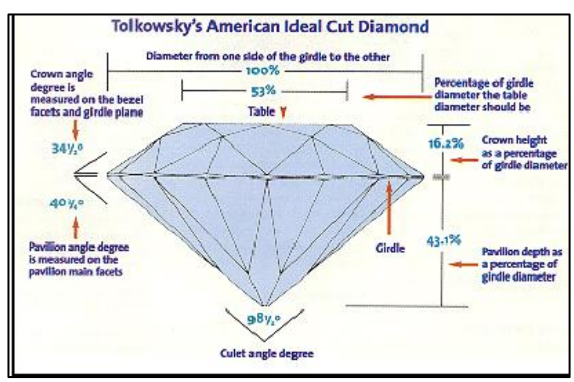
NASA has detected large numbers of nanodiamonds in some meteorites. A nanometer is a billionth of a meter.

Diamonds are extremely dense. The *atomic number density* of diamond at room temperature is 1.763x10^23. A diamond with a volume of about .01 cubic centimeters holds approximately 2,000,000,000,000,000,000,000 carbon atoms. This is two sextillion atoms, about the same number as the grains of sand of all the beaches on Earth. No other substance is so densely packed with atoms.

Light normally travels at 186,000 miles per second, but diamond is so dense that light is slowed to half that speed. This ability to slow light, in conjunction with the ability to bend light (refraction), accounts for the brilliance of faceted diamond. Light entering a faceted stone is broken into its constituent wavelengths.



Diamond’s unique visual properties remained hidden until the 1870s, which saw the development of machines and techniques that more fully exploited diamond’s unique ability to disperse and reflect light. Mathematician Marcel Tolkowsky, in 1919, wrote a groundbreaking Master’s thesis on the proportions for round brilliant cut diamonds. This formed the basis for the “ideal cut” known today.



Glossary

Covalent Bond A chemical bond formed by the sharing of a pair of electrons between two atoms. The electron pair interacts with the nuclei of both atoms and this attractive interaction holds both atoms together.

Crust The outer layer of the earth.

Graphite A soft gray-black form of carbon with metallic luster and a greasy feel.

Fullerite A fullerene is any molecule made up entirely of carbon in the form of a hollow sphere or tube. Fullerite is a crystalline form of a fullerene.

Kimberlite pipe A geological structure formed by the violent supersonic eruption of deep-origin volcanoes. The kimberlite eruption does not form a large aboveground elevation. These pipes are the primary source of diamonds.

Lamproite pipe This is similar to the kimberlite pipe, except that the boiling water and volatile compounds in the magma act corrosively on the overlying rock, which results in a broader outer cone, which is then filled with volcanic ash. This structure appears mostly flat from the surface.

Magma A hot semi-liquid mass of materials below or within the earth's crust.

Mantle The part of the earth's interior that lies between the outer crust and the central core. It is about 2900 km (1800 mi) thick.

Placer A sand or gravel deposit in a river or lake bed, that contains valuable mineral particles.

MORE ABOUT DIAMONDS

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