December 2001 Stone of the Month: Moldavite

Scientists have concluded that about 15 million years ago, a meteorite more than half a mile wide crashed violently into southern Germany. In a fraction of a second, surface rocks were melted and thrown a couple hundred miles into the western Czech Republic! We invite you to read of the discovery of the origin of our mysterious moldavites.

PHYSICAL PROPERTIES

Chemistry: High silica content with oxides of calcium, aluminum, iron, and magnesium
Class: Not a mineral. Natural Glass   Group: Tektite
Crystal System: None, amorphous
Habits: Usually small; scarred surfaces and irregular shapes
Color: Lime green to olive green, bottle-green to brown, occasionally bicolor
Luster: Vitreous to dull
Transparency: Translucent to transparent
Streak: White
Refractive Index: 1.48-1.52
Cleavage: None
Fracture: Conchoidal; Brittle
Hardness: 5.5
Specific Gravity: 2.34-2.4
Luminescence: No reaction to ultraviolet light, but exhibits a yellow-green glow under X-rays
Distinctive Features and Tests: Characteristic shapes, Scarring; Color; Unique localities

NAME

Pronounced mŏl′-da-vīt, the name comes from the Moldau river in the Czech Republic. After World War II, the Czechs called the river Vltava, (Moldau is a German word,) and the moldavites "vltavites." The name does not come from the territory of Moldavia, which is now part of Romania. When biologist Joseph Mayer of the Charles University in Prague first described these unique stones in 1788, he named them "chrysolites," and they have also been called pseudochrysolites, water chrysolites, and bottlestones (German *bouteillenstein*.) Fortunately, the name chrysolite did not stick, as it would probably have led to confusion, as chrysolite is from the Greek word khrysolithos, meaning "gold stone," and was used in ancient times to denote any yellow-colored gem, and now refers to olivine of a yellow-green color, or is sometimes used in the gem trade to describe yellow, transparent chrysoberyl.

COMPOSITION

A mineral is defined as a naturally occurring inorganic element or compound having an orderly internal structure and characteristic chemical composition, crystal form, and physical properties. Tektites, of which moldavite is the variety found in the Czech Republic, meet all these criteria but two: they do not have an orderly internal structure and, as a result, they do not have a characteristic crystal form. So according to the current definition, a tektite is not a mineral but a **natural glass**.

What, then, is meant by "natural glass?" It is defined as a state of matter intermediate between the close-packed, highly ordered array of a crystal, and the poorly packed, highly disordered array of a gas. Obviously, our tektite specimen is much more like a crystal than a gas. Natural glass, like tektite and obsidian, forms when molten (melted) rock is cooled quickly and does not have sufficient time to organize into an orderly internal structure, as it would if it cooled more slowly. Such a substance lacking a crystal structure is called **amorphous**. Natural glass and manufactured glass are classified as supercooled liquids. We do not usually think of something that seems immobile like glass to be liquid, but technically it is: we have heard reports of centuries-old window glass ever so slowly flowing and accumulating at the bottom of the pane! The scientific distinction between glass and liquid is based on **viscosity**, the property of a substance to offer internal resistance to flow; liquid water offers little internal resistance and flows easily, motor oil less easily, molasses even less, and while glass has tremendous resistance to flowing, it can flow, as noted above. Substances that fit the definition of a mineral will not flow, unless heated to their respective melting points, at which point they would be classified as liquids.

Tektites are composed mainly of silica (silicon dioxide, SiO_2) and various oxides. (See the October 2001 write-up on jasper under *Composition* for more about silica.) A typical moldavite contains 79% SiO_2 (Silica), 11% Al_2O_3 (Aluminum oxide), 2% Fe_2O_3 (Iron oxide), 1% MgO (Magnesium oxide), 2% CaO (Calcium oxide), and 5% other oxides. Inclusions are common in moldavites, especially a bubbly or foamy silica glass called **lechatelierite**.

Tektites are different in significant ways from other types of natural glass found on Earth, such as obsidian, pumice, volcanic bombs, and fulgurites, a fact some point to as proof of their extraterrestrial origin. They contain almost no water (OH) content, averaging 0.01-0.0001%, while obsidian has 0.1 to more than 1%. Also, tektites evidence inner structure, though not in the orderly way a crystal does, as K. Nassau, Ph.D. explains in *Lapidary Journal*: “Although superficially tektites look like uniform glass, examination of thin sections shows considerable structure. The main characteristic observed is a variation of refractive index. There are fine scale compositional variations within the glass ranging all the way from multicomponent glass to almost pure lechatelierite (silica glass.) The regions may be stretched and twisted, with much flow structure and strain birefringence. The glass was not melted for a long enough period to become completely mixed, and may have become further distorted during its path through the atmosphere.”

These unique properties make tektites a much purer, higher quality glass than most manufactured glass we see around us, and as well as other forms of natural glass. Researchers can recognize tektites from various localities by their typical composition. For a discussion of the four theories of tektite formation and areas where tektites are found, please see our November 1999 write-up on tektites.

COLLECTING LOCALITIES

Moldavites are found at just two localities, both in the Czech Republic, as seen on the map. Our pieces come from the western locality near Ceske Budejovice, in part of the former kingdom of Bohemia that now makes up about the westernmost two thirds of the Czech Republic. The average weight of moldavites from this region is 6 to 7 grams, or 30 to 35 carats, and rarely are pieces bigger than 2 to 3 centimeters found. The largest found here so far weighs 110 grams, or almost four ounces.

The other portion of the Czech strewnfield is south of Trebic, in the former region of Moravia, between Bohemia and Slovakia. Moldavites found here average about 13-14 grams, and the largest known weighs 265.5 grams, about 9½ ounces.

The National Museum in Prague, the capital and largest city of the Czech Republic, boasts a collection of more than 120,000 mineral specimens, 25,000 rocks, 13,000 gemstones, 400 meteorites, and 15,000 moldavites, by far the largest moldavite collection in the world, unless one of us catches up!

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JEWELRY & DECORATIVE USES

Moldavite is the only tektite of gem quality, and is very much *en vogue* for lovers of unusual jewelry and for crystal power believers. Natural stones, especially the more translucent, bottle-green colored ones, are used alone or with other exotic stones in innovative pendants, earrings, and the like, though moldavite is considered too brittle for daily wear in rings. Light lime-green moldavites are faceted into gorgeous gems of high value, resembling peridot and chrome diopside in color, though most of the stone is lost in cutting and stones exceeding fifteen carats are rare. Moldavite takes a high polish, and the most popular cuts are the emerald, the octagon, and the oval. Cabochons and small carvings are also made. In the Czech Republic, moldavite is often combined in jewelry with Bohemian garnets.

HISTORY & LORE

Appreciation for mysterious moldavites dates to the earliest humans living in northern Europe, who collected and utilized them for both tools and decoration. At Willendorf, Austria, a few moldavite splinters have been found, chipped in the same manner as the thousands of flint tools also found there, where one of the oldest known sculptures, the Venus of Willendorf, was discovered. We can be sure that from then until now, those fortunate to live in the two moldavite strewnfields of the Czech Republic have continued to enjoy these mysterious marvels!

To New Age adherents, moldavite is among the most powerful and sought-after stones. It is said to be “a stone to serve the inhabitants of this planet” and to possess the ability to carry a person “beyond the mirage of life, to a home from which one has been absent, providing the image of eternity and the vision and energy to translate the image into reality,” among other things. An entire book has been devoted to its powers.

ABOUT OUR SPECIMENS

As you can probably imagine, the mystery of the origin of moldavites has long fascinated scientists and naturalists of northern Europe. Through the 18^{th} and early 19^{th} centuries, scientists debated whether they were a natural occurrence or just leftovers from an old glass-making operation, found in a region famous for just that! One investigator pointed out that the chemical composition of moldavite is very close to sedimentary rocks, especially sandstone. Another pointed out that no large deposit of moldavite had been discovered, that moldavites were found only lying loose in the soil. Yet another pointed out that moldavites must have cooled very, very quickly after formation, as there were no microcrystals and no water found in them, as there usually is in obsidian, the natural glass formed when silica-rich magma erupts at the Earth’s surface and cools quickly. So where did they come from?

In the 1960's, the space race was on, and the United States was determined to land a man on the moon. Huge budgets were in place for NASA and others to research and explore anything that might be geologically related to the surface of the moon, and to decide once and for all, Could tektites, including moldavite, be bits of the moon blasted to Earth? Attention was fixed on the Ries Kessel (basin) in Germany, about 70 miles northwest of Munich. Should this basin, about 18 miles in diameter and encircled by a rim of highly disturbed bedrock, be more accurately called the Ries crater, the product of a large extraterrestrial object colliding with the Earth? Long a subject of intense fascination, scientists and astronauts converged on this basin to determine its origin.

It was obvious that some major force has hewn out the low-lying, sediment-rich basin in the midst of layers of ancient limestones and marlstones, over a bed of metamorphic granite and gneiss. The first clue was found in an extremely unusual type of rock called suevite. This strange rock is made up of bits and fragments of rock types that according to accepted science should never be found together. Yet, suevite, which is so far unique to the Ries basin, contains bits of igneous, sedimentary, and metamorphic rock, much of it crystalline, cemented together by a foamy natural glass! How could such a rock be formed?

The next clue was the one that really proved that the Ries basin was indeed a crater, or **astrobleme**, as geologists call it. In the suevite, scientists found tiny crystals of the minerals coesite and stishovite, both forms of SiO_2 that form only under extreme conditions. Coesite was discovered in 1953 by Dr. Lorning Coes, Jr. (hence the name) while experimenting on the crystallization of minerals at extremely high pressures. Coesite could only be formed under the kind of pressure found about 60 miles below the Earth's surface, or the kind of pressure caused for a few moments by a blast of tremendous force. Stishovite was named for Sergei Mikhailovich Stishov (1937–), who first synthesized it in 1961. It is formed only through high transient shock pressure and high temperature, such as that caused by the impact of a large meteorite with the Earth. Both these extreme forms of silica were first found in nature at Meteor Crater, Coconino County, Arizona in the early 1960's. Their presence was the definitive proof that the Ries crater and the nearby Steinheim crater were the result of a hypervelocity impact of a pair of stony iron meteorites (or a single meteorite that broke up while passing through the atmosphere), about 1 kilometer and 100 meters in diameter, respectively!

Scientists came to the conclusion that the larger meteorite struck with so much force that it penetrated more than half a mile into the ground before it was stopped by the underlying crystalline rocks. In the fraction of a second of impact, energy of about 18,000 megatons was released, about 250,000 to 300,000 times the energy released by the first atom bombs! Temperatures of 18,000° to 54,000° and pressures between 5 and 10 million times that of normal atmosphere were reached in an instant! The meteorite and most of the rock it struck exploded and were immediately vaporized, and thrown straight up as a mushroom cloud. The bits of melted rock, including both the sedimentary layers of limestone and marlstone and a portion of the crystalline rock underneath, fell back to earth, most of it in and around the crater. This is how the suevite was formed, a process scientists now designate as **shock metamorphism**, and suevite is classified as an **impactite.** Scientists have even found tiny diamond grains in the suevite, converted from graphite to diamond by the almost inconceivable force of the collision, in just a few billionths of a second! Radiometric dating techniques point to an age of 14.87 million years (plus or minus .36 million years) for the date of this cosmic cataclysm, and the age of our moldavites.

But what about the moldavites? They were formed at the very first instant of the collision, when sedimentary surface rocks were melted in a very small fraction of a second, and then thrown more than 180 miles to the east to the Czech strewnfield. It was during their travel through the atmosphere and/or space that most of the deep grooves and flow lines are believed to have formed on the molten glass. After the initial melting that occurred by means of the blast, tektites that left the atmosphere would harden in the coldness of space, and then melt again as they passed through the atmosphere. The overall shape of the tektite would be affected by the rate at which it rotated during its journey, as explained in our 1999 Tektite write-up. Some of our moldavites show deep furrows that run much of the length of the piece. They were probably caused by gas trapped in pockets as the glass began to harden. Due to intense pressure brought on the moldavite as it fell through the atmosphere, the pocket might lengthen until a long groove is formed in the moldavite, until the outside edge of the pocket was blown off, revealing the furrow. If we could examine the inside of our pieces, we would probably find many small gas pockets.

Want to collect some moldavites for yourself? A trip to Ceske Budejovice would be a good place to start, as the western strewnfield lies next to it, as seen on the map. Collecting after a heavy rain would be your best bet, as moldavites might be revealed by the washing away of topsoil. Keep in mind, though, that most pieces you find will be small, broken fragments of larger pieces that shattered on impact. However, if you are really diligent, or lucky, or both, you might find a nice sized piece of what writers Si & Ann Frazier called "the outgrowth of two different worlds in the fleeting but spectacular contact of collision."

While on your trip, you might visit the eastern part of the strewnfield, south of Trebic in the former Moravia. We have seen very few moldavites from this area, which have a slightly different chemical composition from those found in the former Bohemian area. Both strewnfields are elliptical in shape, with a distinct gradation in size, with specimens from the northwest end about three times as heavy, on average, as those from the southeast end.

And certainly your trip must include a visit to the medieval walled city of Nördlingen, inside the Ries crater, which boasts the best preserved city-wall in Germany. Here you will find the Ries crater museum, housed in a renovated 16th century barn, where you will find an extensive audio/visual display, tracing the journey of the meteorite through space to its final destination. And while in Nördlingen, you might visit the tower of St. Georges church, which, like much of the rest of Nördlingen, is built of suevite! And why not schedule your trip in October, so you can visit the "Mineralientage München," or Munich Mineral, Gem & Fossil Show, held every year in October. Anyone care to plan a trip for us all? Or at least give us a report when you return!

We were able to contact a Czech supplier, who purchases moldavites found by local collectors, and arrange to obtain about 200 pieces between six and eight grams for Deluxe Club members at a special quantity price. We have had in the past a few larger pieces weighing up to 10 grams that were over 1½" in length and sold for well over $100. Specimens 10 grams or more are quite rare.

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