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WALDORF SCIENCE

NEWSLETTER

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Reading the rocks

By Chet Raymo

In his book *Conversations With the Earth*, German geologist Hans Cloos described the moment when he "became a geologist forever." It did not happen at university. It did not happen with the passing of an exam or the awarding of a degree. It happened one morning in Naples, Italy, when Cloos opened the window in his hotel room, and saw the smoking cone of Vesuvius looming above the still sleeping city. At that moment he had the realization that motivated a lifetime of creative work in geology: The Earth is alive.

Cloos had a special, gift for reading the story of the past in the rocks of the present. I thought of him - and of the living Earth - as I inspected some massive sandstone boulders on a hill near my home in Easton, Massachusetts.

The sandstone was layered in delicate alterations of a fine red sand, known to geologists as the Wamsutta formation, and a coarser gray sand, known as the Rhode Island formation. The sands had been deposited in a low-lying basin nearly 300 million years ago, and subsequently consolidated into stone.

On the face of one of the largest boulders was a beautiful example of "crossbedding," layers of sand that did not lie flat in parallel planes, but instead swept upward in banked curves that were truncated by other layers curving upwards in quite different directions. Crossbedding of this sort spoke of the deposition of the sands by currents, at a place where spirited streams gave up their suspended sediments and tumbled gravels to the sluggish waters of a lake or shallow sea, quite possibly at the delta of an ancient river that flowed from high mountains.

Tropical New England

The Wamsutta and Rhode Island sandstones contain interbedded coals and black slaty shales of a vegetative origin: the place of their deposition was swampy. The image that came to mind was wild, wet, more like the basin of the Amazon than present-day New England.

In fact, 300 million years ago New England lay in equatorial latitudes. North America was part of a unified land mass that embraced all of the present continents, a supercontinent geologists call Pangaea (all-Earth). The supercontinent had been assembled south of the equator by collisions of drifting continental fragments, and was itself slipping slowly northward as part of the ongoing movements of the "eggshell" plates that make up the Earth's crust. The

mighty ancestral Appalachians stood along the suture where the component land masses had been joined, and from these mountains vigorous streams carried sand and gravel into swampy basins.

How can geologists be so confident in telling this story of a time when New England, lay athwart the equator? The answer has to do with the Earth's magnetic field.

The lines of force of the magnetic field come out of the Earth near the south magnetic pole, sweep around the curve of the Earth above the equator, and plunge back into the Earth near the north magnetic pole. Near the poles, the inclination of the field is perpendicular to the surface of the Earth. Near the equator, the field lies parallel to the surface. In general, the inclination of the field varies with latitude.

Rocks reveal latitude

Volcanic rocks have a way of preserving a record of the orientation of the Earth's magnetic field at the time they are formed. When the rocks are still in the molten state, iron minerals in the rock line up with the Earth's field like iron filings near a magnet. When the rock solidifies, the magnetic field is frozen into place.

Today, geologists collect samples of volcanic rock from the Earth's continents. These specimens, drilled from the rock, are about the size of a roll of quarters. They are returned to a properly equipped lab and the direction of their magnetism is measured. The result gives an approximate latitude for the rocks at the time of their formation. The 300 million-year-old volcanic rocks of North America speak eloquently of horizontal fields and, therefore, tropic latitudes.

So, the Earth is alive. The continents move. Climates change. Mountains are raised by colliding continents and are worn away by water and time. Mountains are tumbled into lowland basins. Mountains are crumbled into sand and deposited as crossbedded sediments in swampy river deltas. Continents shift and bend and buckle, and ancient tropical swamps are lifted onto the tops of northern hills, where they lie today.



Mathematician solves 40 year old riddle

A Michigan mathematician has spent 10 years and three gigabytes of computer space figuring out what every 17-year-old grocery clerk already knows: The best way to stack fruit is in a pyramid.

Thomas Hales, a professor at University of Michigan, used computers and an equation with 150 variables to conclude that when stacking spherical objects, the fruit-stand arrangement is the most efficient use of space.

Stacking spherical objects directly on top of one another in a cubic configuration uses just over half of the cube's space. Stacking them in a pyramid, with the objects resting off-center in the cracks between spheres, fills 74 percent of the overall space.

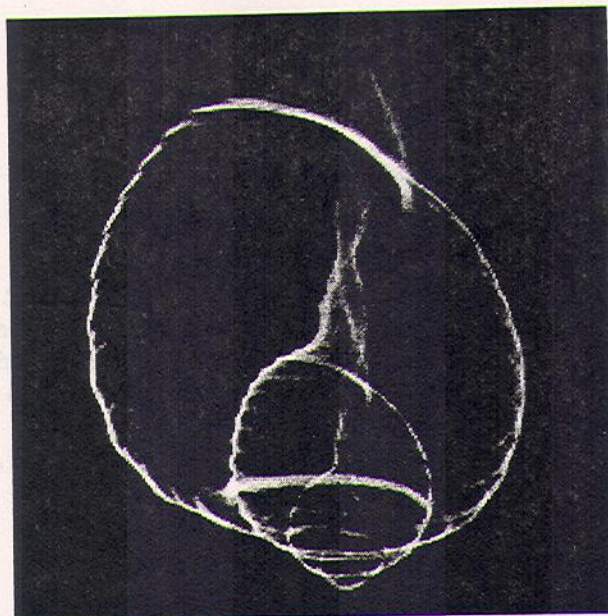
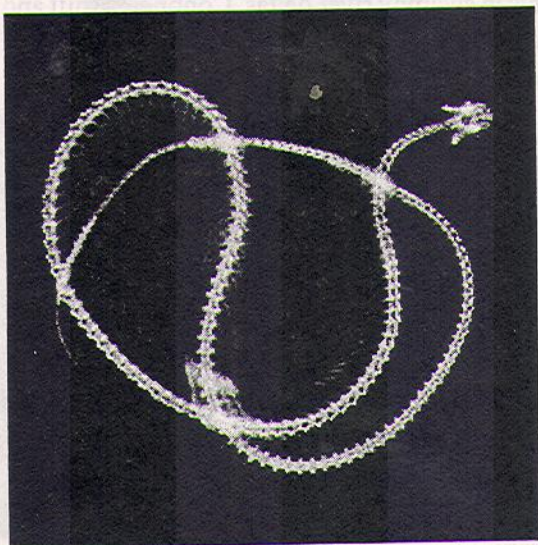
"The problem seemed simple to me," said Hales, 40. "But the more I studied the problem, the more I saw the complexities."

Of course, oranges and grapefruits are stacked in pyramids in the grocery store not because it's an efficient use of space, but because it keeps them from rolling onto the floor.

For about 400 years, mathematicians have been trying to figure out the most efficient way to pack spheres. In the 16th century, Sir Walter Raleigh wrote to the English mathematician Thomas Harriot, asking him to find a quick way to estimate the number of cannonballs in a pile.

German astronomer Johann Kepler, who came up with scientific laws describing the motion of planets in the solar system, proposed the proof in 1611.

But testing all the different possible combinations of stacking has been beyond pencil-and-paper approaches. Hales' finished proof runs to 250 pages.



Why the Arts are Important to Science

By K.C. COLE

What's art got to do with it? A lot more than people generally think

To educators fighting over school budget, art and music frequently are viewed as frills that drain funds from more serious subjects like math and science. But scientists and mathematicians know different. In fact, they often rely on aesthetics to guide their research, filter their perceptions and help them visualize patterns in the sometimes impenetrable chaos of data.

That's why recent moves by Los Angeles and Orange counties to put the arts back into the schools is such good news for science education. Among the children who will benefit most are the future scientists and mathematicians — and the people who come to use their discoveries and inventions. Artistic training can sometimes play a critical role in scientific success.

Of course, scientists have long said that the best of their breed are artistically inclined. Most everyone has seen photos of Einstein with his violin and physicist Richard Feynman with his bongos. I've sat next to physicist Frank Wilczek while he played silent Bach piano concertos on his knees during professional talks. Nobel Prize-winning chemist Roald Hoffmann writes highly praised poetry (only sometimes about molecules).

Put four mathematicians in a room, the old saying goes, and you're sure to have a string quartet.

In fact, artistically inclined scientists tend to win more awards than their less diversified colleagues, according to several studies. Michigan State University physiologist Robert Root-Bernstein and his psychologist mother, Maurine Bernstein, found that most Nobel Prize winners and members of the National Academy of Sciences had arts-related hobbies.

"Their less successful colleagues did not share either their arts interests or their arts-related thinking skills," the authors concluded.

This finding, replicated in several similar studies, seems a logical extension of other research conducted at U.C. Irvine suggesting that exposure to music actually enhances intellectual ability. Not only does listening to Mozart improve test performance (at least temporarily), preschoolers who play piano do better at science and math than their counterparts who don't.

Why should this be so? Why should painting or playing piano or writing poetry have anything to do with math or science? One obvious reason is that scientists, like artists, must learn to pay close attention – both to detail and to the broader context. Scientists, like artists, are people who notice things. They not only see things that other people often ignore, they also see the frequently hidden links among disparate aspects of reality.

Scientists and engineers, says Root-Bernstein, "must learn to observe as acutely as artists and to visualize things in their minds as concretely. They must learn to recognize and invent patterns like composers or poets . . . and play their high-tech instruments with the same virtuosity as musical performers."

Another art-science connection may lie in the relationship between our hands and our brains. A new book by California neurologist Frank Wilson, *The Hand: How It Shapes the Brain, Language and Culture*, argues that people who use their hands are privy to a way of knowing about the world inaccessible to those not schooled in manual arts.

Speaking on National Public Radio's "All Things Considered" recently, Wilson told of a car mechanic who got a call from a vice president at a big computer company, complaining that his MIT-educated engineers couldn't solve problems as well as the older engineers at the company. It turned out, Wilson said, that 70% of older engineers fixed their cars, and 20% had some experience with wrenches. Of the young hotshots, none had ever held a wrench. As a result, they weren't as good at understanding complex systems.

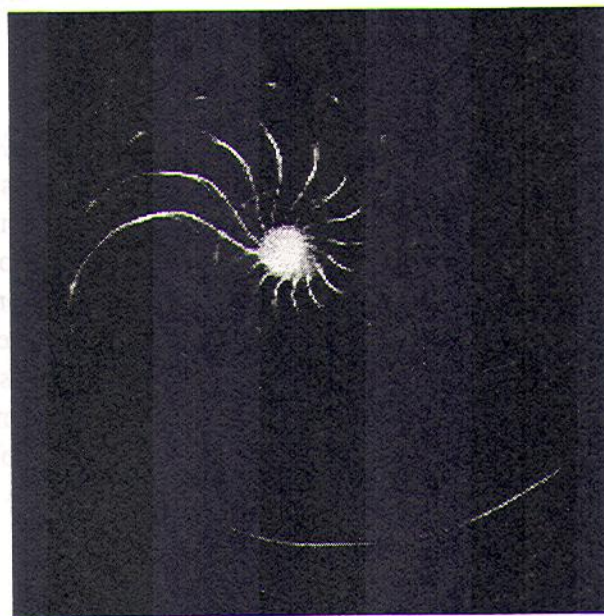
The hand's knowledge about the world, according to Wilson, actually teaches the brain new tricks. The hand's touching, exploring, and manipulating can rewire the brain's neural circuitry.

Finally, logic alone is sometimes insufficient to solve really complex problems. Even Einstein said that imagination was more important to a scientist than knowledge. Physicists on the forefront of discovery often talk about being guided by "smell" or instinct. They talk about the "aesthetic" appeal of ideas.

According to French physicist Henri Poincare, aesthetics was "a delicate sieve" that helped scientists sort through the confusion of facts and theories. The physicist P.A.M. Dirac observed: "It is more important to have beauty in one's equations than to have them fit experiments."

Painting, piano playing and poetry help put things in context, sharpen details, hone observations. They sort the essential from the peripheral, forge connections, find patterns and discover new ways of seeing familiar things.

These are exactly the tools any good scientist needs.



THE THREE GROUPS OF ROCKS

IGNEOUS – SEDIMENTARY – METAMORPHIC

IGNEOUS -

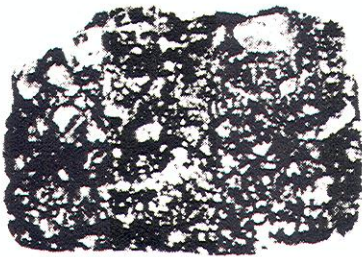
means made from fire or heat. Deep down in the earth it is very hot- so hot that rock and mineral is in a fluid state. This is called magma. When magma cools beneath the surface it forms igneous rock. Granite and Basalt are examples of igneous rock. Granite is our most common rock; it is made up of three minerals quartz, feldspar and mica.



Basalt is an igneous rock which can form crystal pipes.

SEDIMENTARY -

rocks were formed under water. Mud, sand, and rock settled to the bottom to form sediment. Layers built up year after year and century after century. The weight of the layers presses down and the bottom layer is compressed together and rock results. Sandstone and limestone are examples of sedimentary rock. Limestone forms from the millions and millions of shells from snails and clam shells which have been compressed under the weight of an ocean or lake. It takes millions of years for nature to make limestone.



Puddingstone is a conglomerate of rounded pebbles.

METAMORPHIC -

rocks are rocks that have been changed in some way. They began as either igneous or sedimentary rock but have undergone a change as a result of tremendous heat or pressure. When limestone is heated through the mighty warmth of a volcano it becomes marble. Shale is metamorphosed into slate.



Marble is metamorphosed limestone.

Introduction to Geology

by

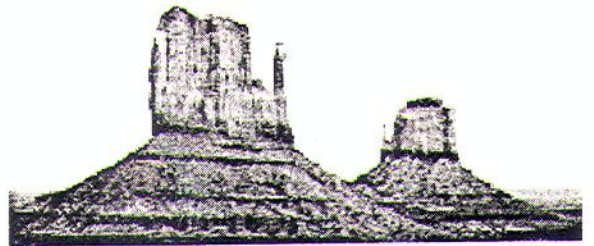
Giselher Wulff

(Photographs by David Mitchell)

Last year, I took my class on a class trip to the valley of Untersulzbach, nearby Grossvendigel. During one of our excursions through the mountains, surrounding the valley, we were fortunate enough to discover some semiprecious minerals. This unexpected discovery made it possible for me to see how these transparent, colorful crystals touch the children's hearts and souls. The excitement of the treasure we discovered and the eager search by classmates for further hidden treasures left the children in awe and reverence for the hidden treasures of nature.

By coincidence, an older man happened to cross our path. Obviously, he was a knowledgeable collector of rocks and crystals. He picked up a splinter of Epidote (a dark green iron silicate) and showed it to some children, saying: "Now, when the sun shines, it will be easier to find these rocks, because they will sparkle in the layers of clay." A few minutes later, we were able to observe this impressive relationship between sunlight and this dark, almost greenish-black mineral, firsthand.

The children weren't mostly fascinated by the material value reflected in these rocky pieces. Their fascination was linked with the dark, thick rock strata, the walls of rock surrounding them. They felt that there was something magical hidden in the rock faces and crevices. They felt that these magical treasures had something to do with the light, breaking up into a kaleidoscope of colors, with the purity and crispness of the air and the transparent nature of water.



Considering amazement, reverence, and humility are powerful building blocks of education, we should pose the question of what position the study of rocks, minerals and precious stones (geology) should take within the middle school curriculum.

The world of rocks and stones should not be studied too early in life. Plants and animals are alive and breathing, and in this respect, are much closer to the psyche of a child. The study of rocks and minerals becomes more meaningful to the child after the twelfth year of life. In one of his lectures, held in Ilkley, England, Rudolf

Steiner refers to the cause and effect thinking, necessary for the understanding of inanimate nature:

*One can begin to understand and grasp the essence of rocks and minerals by approaching them through cause and effect thinking. In this way, the world of physics can be made tangible. Once you enter the plant world, it seems impossible to gain a true understanding of everything through logic, reasoning, or the intellect."*¹

In the sixth grade, children start to become mature enough to process cause and effect thinking. In their earlier years, they have been exposed to lively presentations which create inner pictures that foster their imagination and strengthen their thinking and feeling. Only after this experience, at this developmental threshold, a child should be introduced to scientific processes that follow mechanical laws.²

This is why the subject of physics is introduced to the children in the sixth grade, entering the curriculum in form of geometry and geology. However, the world of rocks and minerals should never be studied in isolation. Geology needs to be experienced in its natural context, embedded in geography.³ With this in mind, rocks and minerals are replaced by larger geological formations. Moreover, individual, characteristic rock samples should be introduced and shown to the children only after they have a mental picture of a granite rock, a sandstone cliff or a volcanic region.



But how do we manage to develop an introduction to geology for sixth graders that makes sense in geological terms and is simultaneously sensitive to the children's development? Once you study books about rocks and minerals, there is little hope for children to connect to the joy and magic captured in the beauty of rocks. Textbooks list formulas about the chemical constitution of rocks and minerals and show the mathematics of their crystal formations.

Furthermore, you will be confronted with many diverging theories about chemical and physical processes, aiming to explain the evolution of today's rock formations.

Already during Goethe's life time scientists debated about the evolution of rocks and minerals. Neptunists claimed that rocks and minerals developed from 'oceanic forces' (watery sedimentation processes, see A. G. Werner) while Plutonists believed that they evolved from a primeval fiery state (Leopold von Buch).⁴

To begin, it doesn't make much sense to place granite and basalt in the same category of igneous rock formations, because they are very different. Granite is a very firm and primeval rock formation that has not changed over time, and basalt is a rock formation that often developed in more recent geological eras. For class teachers, it is convenient to divide rocks into four major groups:

1. "Primeval" (ancient) rocks
2. Slate and limestone
3. Volcanic rocks
4. Sedimentary and metamorphic rock formations.

European Geography offers vast samples of primeval rock formations, slate, limestone as well as volcanic rock formations. The subject of geology should be studied and taught within a relevant geographic context.

1. Primeval Rocks

Goethe wrote the following about primeval rocks:

Every path into an unknown mountain range confirms the ancient wisdom that the highest peaks and deepest rock formations are made of granite. This rock type is different from all other rocks in that it forms the foundation of our earth on which all other rock formations rest. It gives the earth inner form, stability and structure. It rests within the earth's metabolic system and forms the earth's backbone, which extends into such great height that its peaks were never submerged in water.⁵



Goethe calls this rock of primeval age also "*the oldest, most solid, deepest submerged and least changed son of nature.*"⁶

Granite outcrops are known for their comparatively smooth, rounded formations. Numerous boulders rise to rounded hill rocks that bend toward the horizon. These rock masses are cleft, weathered, have shifted and fallen down. A scenery like that can be observed in the Granite Alps, the Bavarian Forest, or the Swedish and Norwegian coastal rock formations. Goethe's writings about his geological excursions into Bohemia are also useful, stimulating materials for such descriptions.⁷

Only after having established a firm inner picture of granite mountain ranges, should the teacher bring large, heavy, shiny-granular pieces of granite into the classroom. Rudolf Steiner describes this introduction in one of his lectures to teachers during his methodology and pedagogy seminar in greater detail. He said:

It is more useful to start out with granite and gneiss, and then go on to the minerals which make up granite and gneiss, than to tell and show children the individual elements that form the rocks: this is quartz, this is mica, this is feldspar and so on, and then, show how those elements are part of granite and gneiss. Particularly, when studying rocks, you can go from the whole picture into the details of a rock, from the formation of mountain ranges into the mineralogy. This approach is helpful to the child.⁸

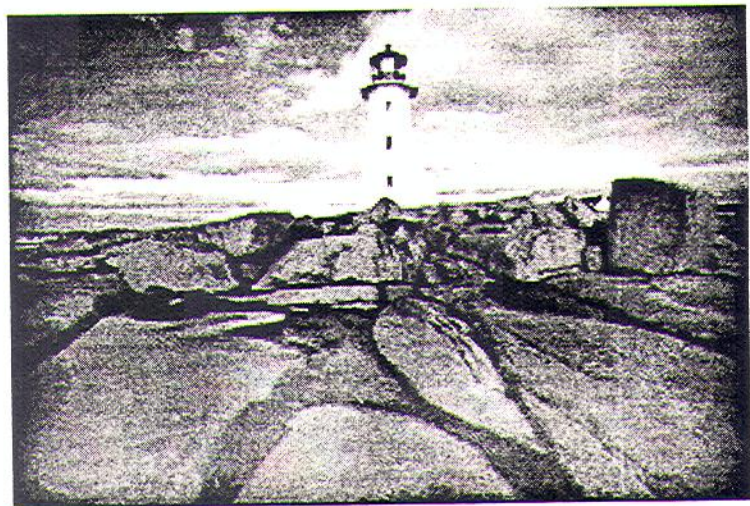


With that in mind, we first examine the surface and structure of a piece of granite. Feldspar gives it the overall white or pinkish color, mica is dull and varies the rock's tint of lightness or darkness, while quartz gives the rock a shininess as if it was covered with a layer of lacquer, giving it stability and hardness. But from where does the granite receive its crystalline graininess?

Now, we can vividly describe how the earth once was liquid and more flexible, and slowly turned into solid matter, over the course of thousands of years. Feldspar was one of the first elements crystallized out — it coagulated and developed into a crystalline solid. Quartz, on the other hand, was one of the last liquid elements to harden and become solid. In this stage, between liquid and solid material, a myriad of mineral combinations were possible. In granite, the trio of feldspar, mica and quartz dominate. Gneiss has less feldspar. Consequently, we observe less grains and more smooth layers, which is characteristic for gneiss. In porphyry, there is only a trace of mica.

How much detail the class teacher wants to go into with these differences between primeval rocks remains his personal judgment. More important becomes the question about the level of purity of our three minerals. How can we talk about quartz without looking at its purest form, the rock-crystal? How can we restrain from showing a shining mica piece with beautiful layers? And how can we forget to show the orthoclase to demonstrate the beauty of pure feldspar? This threefoldness of minerals contained in granite, is a meaningful introduction to the study of crystals. Amazement and intense attentiveness spread through the classroom when the teacher shows these beautiful rocks.

We start out with pure feldspar crystals: blue amazonite, sodalite, pink plagioclase and white



orthoclase. Looking at these crystals, we can admire all lime formations and lime processes on earth. In general, however, feldspar is not very evident in our landscapes. Nevertheless, it is the most represented mineral group on our planet. Feldspar comprises almost sixty percent in the crust of our earth.

The most beautiful form of feldspar is perhaps an orthoclase twin, in which nature shows the potentials of its geometric formations to the highest degree. One of these pieces, not too small, should be part of every school's rock collection.

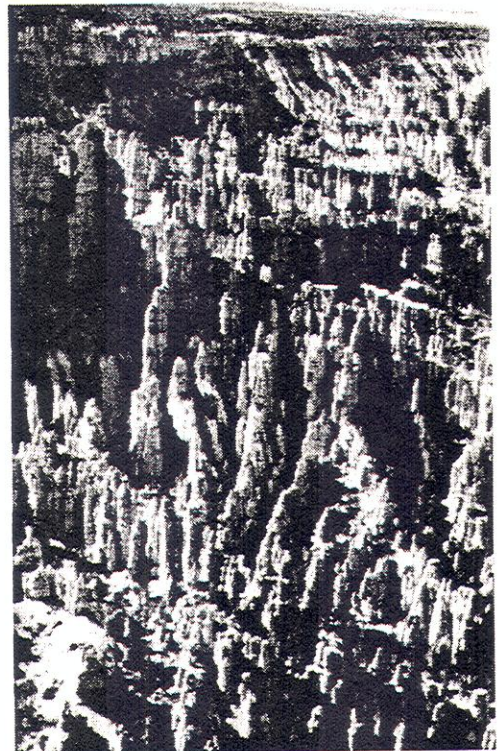
Most interesting are always the encounters with quartz crystals, especially because there are so many forms to choose from: Rose quartz, agate, tiger-eye, are all still amorphous, but their formless masses are reaching for form. One of the most beautiful, metamorphic processes of the mineral world is the formation of crystals from amorphous masses. Only rock crystal, smoky quartz, amethyst or citrine are crystal forms of quartz, and exhibit the formation of beautiful druses. On that level quartz tends to be hexagonal. On the scale of hardness quartz ranks seven, and there are no harder or softer varieties of quartz.⁹ Furthermore, quartz is a light source on our earth, being captured within each little pebble of silica. Although this quality of quartz should be mentioned, it can only be elaborated on and studied in high school.

The encounter with mica is always accompanied with signs of decay. Holding and handling a piece of mica, you will experience this first-handed, because by mere touch, mica leaves small traces of its particles behind. Mica is soft, easily breakable, porous and elastic. In nature, it disintegrates into clay which is used for burning bricks. Sometimes, mica is even overlooked, although it often forms the foundation on which the purest, most precious stones and crystals are rested. For example, a large piece of mica on which green garnet rests has a mesmerizing effect on the observer. We also can find smagrite, rubies and sapphires between layers of mica.¹⁰

2. Slate and Limestone

With slate and limestone we enter the medieval period of the earth's evolution. Traveling northern Italy, south of Bozano, one will stay with the following, impressive and memorable pictures in mind: steep, precipitous and bizarre silhouettes of mountains reign to the right and left side of a wide valley. The whitish, gray of limestone appears cold and chilling with its sharp cutting and edgy cliffs. The neighboring Dolomites, with their towers and pinnacles, sit majestically higher than the rest of mountains.

However, outside of the Alps we find other impressive limestone formations. For instance, on Spanish maps we find the name "sierra" occurring over and over again. Sierra



means literally saw, and the Spanish sierras tell us how sharply cut, sliced and chopped these mountain ranges of limestone and chalk are. Other limestone formations are the Swiss Jura mountains and the southern Alps.

Slate is less obvious in landscapes; it usually occurs intermingled with other rocks. However, the conscious observer will notice the flaky, brittle layering of mica which we first observed in gneiss, shows up in mica schist and phyllite, until it finally becomes slate. Slate is a rock which breaks into thin, even sheet like layers. In the evolution of the earth, during the formation of slate, this liquid mineral combination seems to have been closely connected to the plant world. Numerous fossil traces of plant life can be observed in slate sheets and hard coal. Examples of such fossilized plant life should be brought to the class room to demonstrate the relationship between earth, stone and the plant world.



Lime, on the other hand, shows a relationship to the animal world. Where phosphorous limestone is found in nature, we can find lots of fossils of prehistoric animals. This can again be demonstrated in the classroom with some samples.

The lime process, which is already active in the feldspar of granite and becomes intensified in the porphyry, seems to have initiated enormous life forming processes for animals during the Cretaceous period. This becomes obvious in the previously mentioned mountain ranges as well as on the island of Gotland.

Are there rock formations that include more than one kind of precious stones? The commonly known form is perhaps 'iceland spar' (calcite), the most common and purest crystal form in all the lime group. Also marble, lapis lazuli and the valuable dolomite belong to this group.

3. Volcanic Rocks

During the youngest geological era extrusive rocks formed, starting with basalt up to contemporary volcanic rocks. Where are the regions, typical for volcanic rocks, with their rounded, conical mountains? In Germany, we have the Vogelberg and the Eifel. However, our description becomes more alive when we move toward regions with still active volcanoes, such as Vesuvius and Etna, or the island of Iceland where we encounter hot water springs, sulfur holes, geysers and hollow ground. In these regions, new rocks and minerals form and old sediments and rocks are being transformed from liquid into solid masses and vice versa, on a daily basis. In volcanic regions,

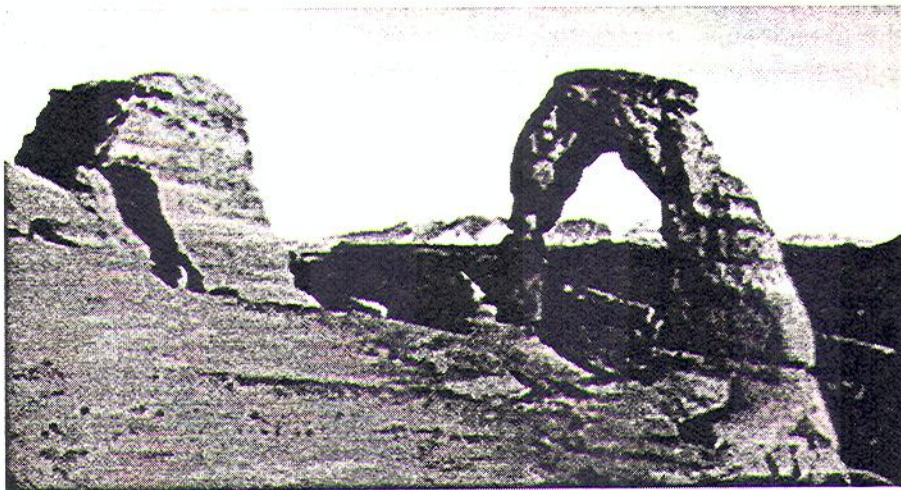
our earth stayed young and the ground is very fertile. The mountain slopes of Etna and Vesuvius prove of that, because they flourish with the sweetest grapes and noblest fruits.



Now, we closely examine hard basalt. We can find basalt in almost conical formations, because it once formed into large pillars when it cooled down. Today, it is used for gravel, in the construction of dikes and harbors. Also, lightweight rock formations like tuff, pumice stone, and lava rock are part of the volcanic rocks.

Perhaps, it may seem surprising that we find even precious stones and crystal formations derived from volcanic rocks. Obsidian, a mixture of feldspar and quartz, shows black depth and is occasionally used in jewelry. Some pure quartz formations were melted by fire and transformed into volcanic glass, crystals of different colors.

One of the youngest precious stones of the mineral world is the opal. The Opal is the “baby” of all gems and doesn’t show any crystallization. It is also incredibly flexible, because it can absorb water and release it in dry air, changing colors.¹¹ And lastly, we need to mention the influence of sulfur which takes part in all fire processes, and has its own beautiful crystal formations.



4. Sedimentary and Metamorphic Rocks

Not all rocks and rock formations can be classified into the three previously established groups. Next to fire processes, other changes have occurred and influenced the formation of rocks, minerals, and crystals. Some of these sedimentary and metamorphic rocks have been of great importance in the evolution of man. One of them is flint, also referred to as "fire stone", from which tools and weapons were made. Another one is sandstone, which has been employed over centuries for the building of enormous architectural structures and highly artistic sculptures.

Perhaps the most commonly known sedimentary formations are the curious stalactites and stalagmites that we encounter in drip stone caverns. The crystal formations of this last group include formations as common as salt as well as rare and precious stones such as diamonds. Salt is common and essential to human survival and has very impressing crystal formations. The diamond is the hardest crystal formation known to us (with a degree of hardness of 10), and at the same time it is the most transparent crystal of all.

At the very end, we might place the tourmaline. It comes in all shades of colors that are possible and has a beautiful conical form. This stone is not easily classified, and yet it seems to tell us, in its own way, about the primeval times, when the power of the sun brought life to and into our earth.¹²

The following words, taken from a note of Rudolf Steiner, let us think further about this evolution:¹³

In porphyry the inanimate world freezes. In slate the plant world freezes, in lime hardens the animal world, and with salt the human existence dies out. The other polarity is sulfur, in which minerals are formed and transformed by being burned.

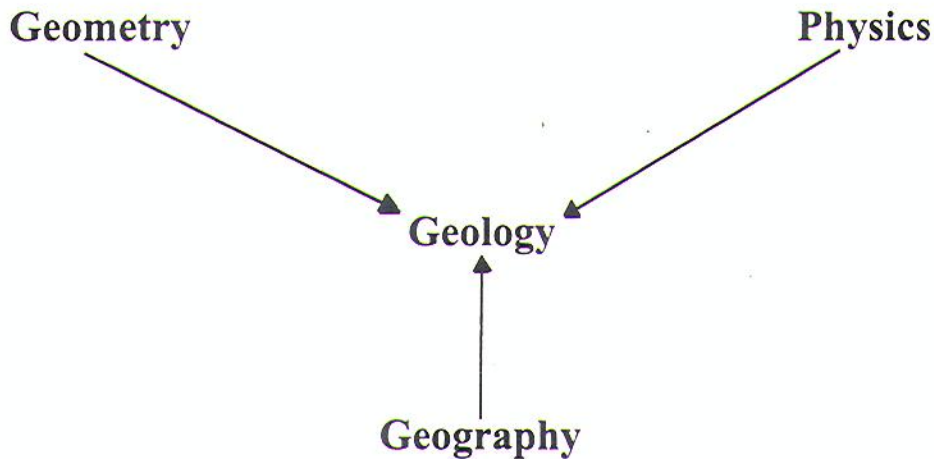
Besides the beauty captured in rock and mineral formations, there are several other topics connected to the study of rocks which the teacher needs to incorporate into their lessons. The teacher should awaken the children to examine their surroundings and observe landscapes in greater detail and with a deeper awareness, trying to discover two-dimensional, symmetrical forms and laws. Cubes, octagons, pentagons and hexagons, studied in a previous block, should be recognized and discovered in nature.

Holding a rock crystal against the light we can observe the phenomena of refraction. Moreover, the phenomena of refraction offers a very natural transition and introduction to physics. In respect to the developmental stage of twelve year olds, Rudolf Steiner said in one of his lectures:

Then it is time to move along to the mineral world, the world of rocks, orienting ourselves on geometric configurations. The world of rocks is deeply connected to the world of physics, which in turn can be applied to the physiology of man: refraction and the lens of the human eye.¹⁴

This statement, then moves geology to the core of the sixth grade curriculum:

Descriptions of landscapes with their typical rock formations belong to the realm of geography. But, if you want to truly do justice to sixth grade geology, you should link the geography block with a one or two week geology block.



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¹ Rudolf Steiner, *Modern Art of Education*, lecture on August 16th, 1923, GA 307.

² More detailed reasoning based on the physical and emotional development of the child is given by Rudolf Steiner in the so-called Christmas lectures: *Soul Economy and Waldorf Education*, lecture 11, January 2nd, 1922, GA 303.

³ See Rudolf Steiner, *Practical Advice to Teachers*, lecture 11, September 2nd, 1919, GA 294.

⁴ Kurt Schleucher: Alexander Humboldt. Darmstadt 1984, especially pages 84 and 273.

⁵ Johann Wolfgang Goethe: Writings about Mineralogy and Geology. Chapter "About Granite".

⁶ Ibid.

⁷ Johann Wolfgang Goethe: "Getting to Know the Bohemian Mountain Ranges: about geology, especially of Bohemia."

⁸ Rudolf Steiner: *Practical Advice to Teachers*. Lecture 11, September 2nd, 1919, GA 294.

⁹ Rudolf Borner: *What kind of Rock is that?* Tables for the determination of the most important rocks and minerals. Stuttgart 1952. p.14-87.

¹⁰ Walter Cloos: *A Small study of Crystals*. Schaffhausen 1989. p. 110.

¹¹ Ibid. p. 48.

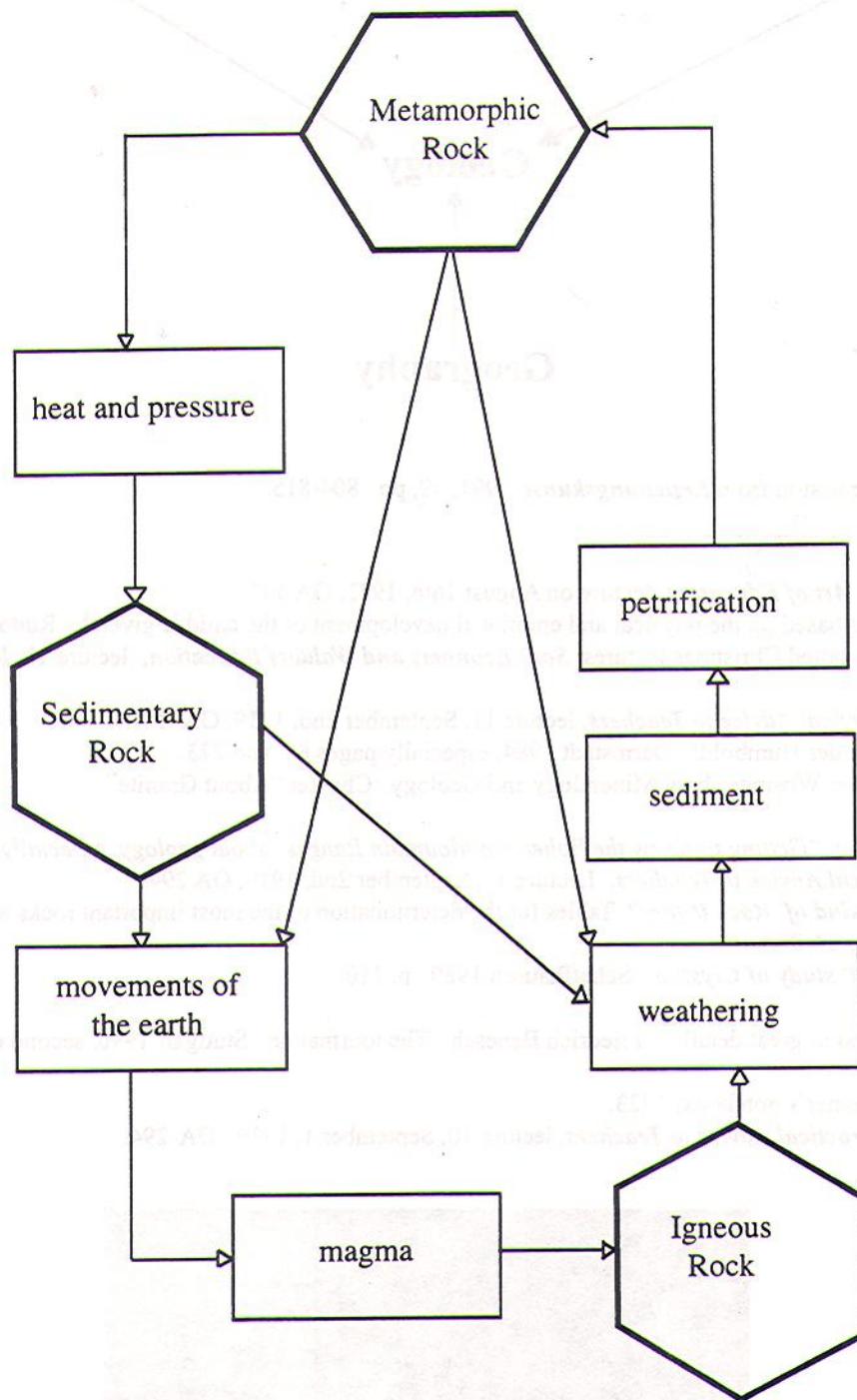
¹² Tourmaline is discussed in great detail by Friedrich Benesch: *The tourmaline*. Stuttgart 1990, second edition 1991.

¹³ Taken from Rudolf Steiner's notebook, 1923.

¹⁴ See Rudolf Steiner: *Practical Advice to Teachers*, lecture 10, September 1, 1919. GA 294.



THE ROCK CYCLE



D.S.M.

Mineralogy for Grade Six

BACKGROUND NOTES FOR THE BLOCK

by

John Petering & David Mitchell

Rudolf Steiner give only a brief indication for the key themes of a Grade 6 Mineralogy block:

"In geography, continue studying other regions of the earth and try to find a link between the climactic conditions and astronomical conditions . . . one should proceed to the study of minerals. But this study should be absolutely a part of geography."

This presents us with the central theme of mineralogy studies, but embedded in a study of the geographic and geologic character of regions, and the characteristic resources of each geographic region.

ARCHETYPAL GROUPINGS OF THE STONES & ROCK TYPES

The most basic and archetypal rock found at the surface of the earth is granite. Geologists describe granite as a crystalline rock, homogeneous in composition, having three groups of minerals in roughly equal amounts: gem-like, transparent quartz, earthy, buff-colored feldspars, and dark minerals rich in the metals iron and magnesium. *Goethe* wrote a short but rich essay on granite. Since granite is so foundational, it might be appropriate to take our direction from this threefoldness, and group the rocks and minerals into "species," using granite as the 'trunk' of a diverse tree of derivative rocks.

In his fascinating book, *Living Earth*, Cloos builds a typology of rock types around this triad. And, a further, more detailed grouping along these lines can be found in *"Earth's Countenance & Earth's Body"* by *H. Knauer*. He developed three seven-fold clusters for the rock types, the minerals, metals and ores. Lastly, Rev. *Fredrich Benesch* has explored the interconnections of the lore of precious and semiprecious minerals and gems, largely using the Old and New Testament as a guide¹⁶ as translated elsewhere in this edition of the Waldorf Science Newsletter

So, rather than simply arranging rocks or minerals based on the chemical composition and molecular structure — which is as yet unknown to the students, a simple typology which can be connected to observable characteristics may be useful. The following table is a synopsis of all of the key elements from the above sources, and is intended to allow such a clear overview. It could be one arrangement for the mineralogy lessons. Semiprecious gem minerals are **in bold**.

Mineral Groups

1) Silicates;

a) *Pure quartz*: rock crystal; amethyst; citrine, smoky quartz,

massive quartz types: milky quartz, rose quartz, tiger's eye

- b) The *agate-chalcedony group* (metamorphosis into cryptocrystalline-fibrous, oval forms) includes **chalcedony** (reddish-brown), **carnelian** (pink), **sard** (red), **heliotrope** (green), **sardonyx** (layered); **jasper** (opaque, makes up petrified wood); **moss agate**, chert and flint;
- 2) Dark 'ferro-magnesian' group
 - a) *Micas*: muscovite (light-colored, magnesium rich), biotite (dark-colored); hornblende, augite
 - b) metamorphosis of mica: **serpentine**, **jade**; chrysolite; **tourmaline**
- 3) The "spar" group
 - a) feldspar: albite, microcline, plagioclase
 - b) relatives: **garnet**; epidote, **beryl**; staurolite (cross-form); **emerald**
- 4) The ores of the classic seven metals: lead, tin, iron, gold, copper, mercury, silver
Hyacinth (similar to zircon, with rare earths)
- 5) The clays (similar to ores, but richer in silica); bauxite; kaolinite, montmorillonite; metamorphosis of clays (rich in alumina); **ruby**, **sapphire**; corundum;
- 6) The Lime (Calcium) group; calcite (dogtooth spar, **iceland spar**); marble; oolite & coral;
- 7) The salts (halogen compounds); halite, **fluorite**; apatite; gypsum; topaz; carbon minerals (coal, diamond, etc.).

TERMS

The following terms are often used in technical books on mineralogy. We would like to use them as descriptions of phenomena describing specific characteristics, but not necessarily implying an atomic or molecular explanation.

Crystalline: showing shiny, lustrous crystal "faces" or "cleavage planes." A beautiful characteristic, unique expression of the mineral kingdom. The clarity of crystals calls forth feelings of beauty; our modern thinking consciousness has a great affinity with both the solidity and the clarity of crystals.

Granular: composed of discrete grains, like sand-size to microscopically small.

Laminar, layered: made up of noticeable layers, e.g., mica. These characteristics remind us of one of the most notable characteristics of the plant kingdom: the flat, "laminar" leaf.

THE PROPERTIES OF STONES

The following, taken in part from Amethyst Galleries, Inc. website:

><http://mineral.galleries.com/><

helps us to understand the nature and individual properties of stones.

CLEAVAGE

When a mineral breaks it does so by either fracturing or by cleaving. Cleavage is a smooth break producing what appears to be a flat crystal face. The tendency for minerals to cleave or not and in which directions, is very characteristic and therefore important to the

identification of minerals. Cleavage is described in terms of how easy the cleavage is produced. From easiest to hardest to produce the terms are: perfect, imperfect, good, distinct, indistinct, and poor. Cleavage is said to be basal when it occurs perpendicular to the major axis of the mineral and prismatic when it occurs parallel to the major axis. Multiple cleavages that produce geometric polygons are referred to using the name of the geometric polygon, such as octahedral cleavage in the mineral fluorite. Cleavage occurs in minerals that have specific planes of weakness. These planes or directions are inherent in the structure of the mineral and form from a variety of factors.

The phyllosilicates are a group of minerals whose structure is based upon stacked layers. A natural cleavage plane is produced between these layers. Other minerals may have cleavage planes that are more related to bond strength. Weak bonds that all lie in a plane will produce a cleavage direction.

Cleavage, being related to structure, is important sometimes to distinguish symmetry. Cleavage must follow the symmetry of the mineral and must be parallel to a possible crystal face. A mineral of the isometric symmetry class can either have no cleavage or at least three directions of identical cleavage. A mineral of a uniaxial class (trigonal, tetragonal or hexagonal) will potentially have a cleavage perpendicular to the dominant axis and or prismatic cleavage of either 3, 4 or 6 directions respectively, running parallel to the axis. A biaxial mineral, those belonging to orthorhombic, monoclinic or triclinic classes, can not have more than two identical cleavage directions.

The angle between cleavages is also important to note and maybe diagnostic. The pyroxene and amphibole groups of minerals are distinguished primarily by cleavage angle with the pyroxenes having a more acute angle. The angle may also help identify the type of cleavage. Three identical directions of cleavage in one mineral can only be either cubic cleavage, rhombic cleavage or prismatic (forming six sided prisms). If the angle between cleavage faces is 90 degrees, then the cleavage is cubic. If the angle is 60 degrees, then the cleavage is prismatic. Also, if the angle is something else and there are three identical cleavages, then the cleavage is rhombic.

PARTING IN MINERALS

Parting is a property that often gets confused with cleavage. An there is good reason for that. Parting is a break along structural planes and is parallel to a possible face, just like cleavage. However, parting differs from cleavage in many important ways. It can not be found in every specimen as is true of cleavage for every cleavable mineral. It is not absolutely repeatable or reproducible as is cleavage down to theoretically the very atomic layers that cause cleavage. Parting is caused by pressures that are applied to a crystal or by twinning. The pressure breaks the crystal on a plane of weakness. The plane between twins in a crystal can also break and form a parting plane, but areas between these twin planes will break with a fracture, not a parting plane. Often with pressure parting the actual break formed long before the crystal was excavated from the ground and may be due to tectonic or isostatic pressures that have been forced on the crystal. Most parting is seen as fracture lines that are incomplete or healed (the crystal continued to grow and sealed the break) and might appear as striations. As stated above, parting is nota consistent property, but when it is seen it can be a great aid in identification.

The best examples of parting occur in some specimens of:

Chromite (octahedral)

Corundum (rhombohedral)
Cryolite (cubic)
Hematite (two planes)
Magnetite (octahedral)
Monazite (basal)
Parisite (basal)
Pentlandite (octahedral)
Pyroxenes (basal)
Tourmalines (basal)
Zincite (basal)

HARDNESS

Hardness is one of the most important and reliable physical properties. A good property in mineral identification is one that does not vary from specimen to specimen. In hardness, specimens may vary slightly but are generally consistent. Hardness is a measure of the strength of the structure of the mineral as it relates to the strength of the chemical bonds and their positions. It is not the same as brittleness, which is another measure of strength but is not related to the chemical bonds.

Hardness can be tested through scratching. A hard mineral can scratch a soft mineral, but a soft mineral can not scratch a hard mineral. Therefore, a relative scale can be established to account for the differences in hardness simple by seeing which mineral scratches another. That is exactly what mineralogist Friedrich Mohs proposed almost one hundred and seventy years ago. The Mohs' Hardness Scale starting with talc as 1 and ending with diamond as 10, is universally used around the world as a way of distinguishing minerals. The higher the number the harder the mineral and a mineral can scratch any other mineral with a lower number.

Below is the Mohs' Hardness Scale:

1. Talc (can be crushed between fingers)
2. Gypsum (can be scratched by a finger nail)
3. Calcite (can be scratched by a nail)
4. Fluorite (can be scratched by glass)
5. Apatite (can be scratched by a pen knife)
6. Orthoclase (can be scratched by quartz)
7. Quartz (can be scratched by a hardened steel file)
8. Topaz (can be scratched by an emerald)
9. Corundum (can only be scratched by a diamond)
10. Diamond (the hardest mineral)

In order to use this scale, it is necessary to have on hand some of the minerals in the scale. If you wish to test an unknown mineral for hardness you might want to start with a specimen of apatite to see if it can scratch it. If the unknown mineral scratches the apatite, then it has a hardness of 5 or more. If the apatite can scratch the unknown mineral, then the mineral has a hardness of 5 or less. If they can scratch each other, then the unknown mineral has a hardness of 5. You will need to perform other tests to narrow down the hardness. If it is softer than apatite, try calcite, etc., etc. until you have a min-

eral it can scratch and an adjacent mineral that can scratch it. One word of caution for inexperienced collectors: do not scratch over nice crystal faces! A broken or cleaved or inconspicuous part of these minerals will still give a good hardness test and not damage a potentially wonderful specimen.

Remember, this is a relative scale and a mineral that can scratch a mineral that has a hardness of 4.5 may be given a hardness of 5, but it still might be softer or harder than apatite. Also, what if you do not have the minerals listed above? Well, a collector might keep a few items of known hardness in a "hardness kit" just in case they are needed.

The Mohs' Hardness Scale is only relative. An absolute hardness scale looks a little different. Using diamond's hardest surfaces as a standard at 1000, a comparison can be found using sensitive equipment.

Below is an absolute hardness scale:

1	Talc
3	Gypsum
9	Calcite
21	Fluorite
28	Apatite
41	Orthoclase
83	Quartz
125	Topaz
250	Corundum
1000	Diamond

The simpler Mohs' hardness scale is much easier to remember and use.

Here are a few hints on how to use hardness to identify a mineral:

Keep in mind that minerals usually have small differences in hardness according to the direction of the scratch and the orientation of the scratch and that some minerals such as kyanite and diamond, have a marked difference in hardness with respect to these factors.

A massive specimen will probably be softer than a single crystal and really hardness should only be used on individual crystals.

Some minerals will have a range of hardness due mostly to impurities or substitution of certain ions.

Don't be fooled by a dust trail from a soft mineral after being rubbed across a harder mineral. It may look as if the softer mineral scratched the harder mineral (always blow air over the scratch to be sure it's a scratch).

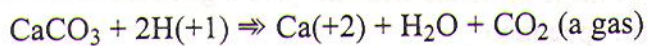
Another clue to relative hardness is ease of scratching (both diamond and quartz scratch glass, but diamond scratches glass like a knife through butter).

To remember the scale try remembering this phrase: The Geologist Can Find An Ordinary Quartz, (that) Tourists Call Diamond!

THE REACTION TO ACIDS

One of the more important properties in minerals is that some react to acids. All the minerals that have some reaction to acids tend to be carbonates or minerals that contain

significant amounts of carbonate ions. The reaction is written as follows for calcite the mineral for whom this test is made famous:



The carbon dioxide gas (CO_2) is given off as bubbles and the calcium simply dissolves in the left over water. The bubbles or effervescence is the reaction we are looking for and indicates the presence of carbonate ions. Two hydrogens attack the carbonate ion (CO_3) and detach one oxygen leaving the CO_2 gas. The hydrogens are supplied by the acids which are generally dilute hydrochloric acid (10% solution) or dilute acetic acid (vinegar). Other acids can be used with similar results but these two are the most user friendly as they are relatively mild. The key to this property is not the fact that the mineral reacts, although that is diagnostic, but how well it reacts. With calcite and aragonite, the two most common carbonate minerals, the reaction to a cold, dilute acid is easily accomplished and is often so energetic that it is associated with a fizzing noise. For dolomite and other carbonates the reaction is less vigorous and may only produce a small reaction when the mineral is powdered or the acid is heated.

In some cases, the reaction is very slow and is only seen at all in the eventual dissolution of the mineral.

THE SCENT OF A MINERAL

Yes some minerals do have odors! In fact there are quite a few of them. Generally the odor is not strong unless the mineral has been struck or is freshly excavated. The most renown smelly mineral is sulfur to no ones surprise. Other minerals that smell are generally sulfides, arsenic based minerals or clays.

The sulfide mineral Pyrite gives off a noticeable sulfur-like odor and the arsenic sulfide mineral arsenopyrite gives off a garlic smell when these minerals are struck or crushed. The smell in the sulfide minerals comes from the reaction of oxygen in the air to the sulfur; forming odious scented molecules such as sulfur dioxide, SO_2 . Arsenic minerals tend to have a garlic scent as is consistent with the element and poison arsenic. The clay minerals have, for lack of a better term, a clay-like smell that is sometimes called earthy. Occasionally a mineral will have a rather distinct and therefore diagnostic odor, but this is a fairly uncommon property and not reliable in general.

MINERALS HAVE A DISTINCTIVE FEEL

Minerals that have a distinctive feel are generally low in hardness, but not always. Several metallic minerals such as copper have a jagged feel due to minute, sharp protrusions. Minerals such as molybdenite, graphite, serpentine, talc and several other clay minerals have a greasy or oily feel. At times feel can distinguish two minerals, but because feel is so subjective it is impossible to tell a person how a mineral should feel in comparison to another. But experience with these minerals can be productive in determining their characteristic "feels".

THE SOLUBILITY OF MINERALS

Minerals do dissolve. In very idealistic terms, pure water can dissolve any mineral at least partially.

Water is known as the "universal solvent". However most minerals do not dissolve in water to any great extent that we can detect in a short period of time and without quantitative

chemical tests. The ones that do dissolve rapidly are therefore considered soluble and this can be diagnostic. Most soluble minerals are nitrates, borates, some carbonates, some sulfates and some phosphates as well as some organic minerals. At times the degree to which a mineral is soluble is important as there are several closely related minerals (such as parisite and its relatives) that dissolve with much different speeds making for easier identification.

Solubility is not just limited to water. Many acids are capable of dissolving minerals where water has no effect. Carbonates are especially susceptible to acids (see reaction to acids). Some metals, even gold, can be dissolved in a mixture of one part nitric acid and three to four parts hydrochloric acid called "aqua regia". Of course, identification of minerals using solubility is a test that could destroy the specimen, if it is soluble. An unneeded fragment can be used for such tests.

MINERALS BY CLASS

Minerals can be organized, mainly according to their chemistry, into the following classes:

Elements Class: The Metals and their alloys and the Nonmetals.

Sulfides Class: The Sulfides, the Selenides, the Tellurides, the Arsenides, the Antimonides, the Bismuthinides and the Sulfosalts.

Halides Class: The Fluorides, the Chlorides and the Iodides.

Oxides Class: The Oxides and the Hydroxides.

Carbonates Class: The Carbonates, the Nitrates and the Borates.

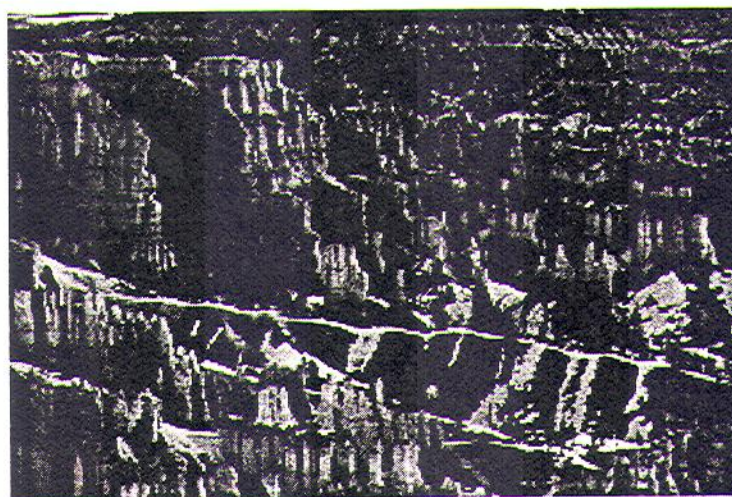
Sulfates Class: The Sulfates, the Sulfites, the Chromates, the Molybdates, the Selenates, the Selenites, the Tellurates, the Tellurites and the Tungstates (or the Wolframates).

Phosphates Class: The Phosphates, the Arsenates, the Vanadates and the Antimonates.

Silicates Class: The Silicates (the largest class).

The Organics Class: The "Minerals" composed of organic chemicals!

The Mineraloids: The "Minerals" that lack crystal structure!



METALS AND MINERALS

(from the book: *Living Metals* by L.F.C. Mees)

One can look at minerals to find and compare the following qualities:

1. Luster
2. Conductivity of heat.
3. Heaviness
4. Malleability, plasticity
5. Conductivity of electricity

One should also bear in mind that the whole is always more than the sum of the parts. In other words there has to be an organizing principle before the qualities mentioned above can be used. Or, first there is an idea; a product is an idea which has made visible.

The use of minerals throughout the ages:

Stone age	- no use of minerals
Copper age	- copper
Bronze age	- tin and copper
Iron age	- iron
	-lead and mercury (quicksilver) came later.

Gold is the only mineral which can be found in a readily usable state. This was known to mankind very early. All other minerals can not be used as found in nature; they have to be taken out of the ore and refined. To do this one needs to use energy. If you leave the minerals out in the open they revert to the earth (iron rusts).

The resistance to conductivity of heat and electricity increases as follows: 1. lead, 2. tin, 3. iron, 4. gold, 5. copper, 6. mercury, 7. silver. (Mercury forms an exception unless it is in a stable frozen form). One could say that the first three are useful and the last three are beautiful - gold is in the middle.

We will look at the minerals in pairs.

IRON (Mars) and COPPER (Venus)

Iron is used in: - rails, bridges, construction.
- tools (as in: saws, hammers).
- weapons (formerly a sign of courage).

Iron has the power to support. Activity and courage are soul qualities with which man connects himself with iron. 'Masculine' qualities.

Copper is used for: - roofs of temples, churches.
- electronics, telephone
- water taps - they fit well but also let go easily.

Copper encloses and surrounds. Enveloping, connecting and adaptability are soul qualities with which man connects himself with copper. 'Feminine' qualities.

There is a lot of iron in blood - especially in the red blood corpuscles - haemoglobin. But the blood serum contains about 100 millipercents iron and 100 millipercents copper. Men have slightly more iron, women slightly

more copper. During pregnancy women have up to three times that amount of copper in the blood serum. The embryo has up to three times the amount of iron (both the male and the female embryo).

Iron is found on the Northern hemisphere and copper is found in areas around the Pacific Ocean.

LEAD (Saturn) and SILVER (Moon)

Lead is mostly found in the Western hemisphere (especially in the Andes mountains in South America). Silver is found everywhere - also in solution as silver salt in sea water. But it is mainly found in lead ore.

Lead is used in:

- printing (also in pencils)
- roofing
- water pipes
- coffins
- red-lead paint
- protection against x-rays

Lead has a sealing-off, protecting-against function. This can also be seen in printing - an idea which is changeable has been cut off and given an unchangeable form. Also printing protects the idea from getting lost.

Lead brings an action to a standstill. For instance lead poisoning makes one age very fast and vitality decreases to zero.

Lead as a mineral usually has a dirty grey color. If you cut it, it will shine for a moment before oxydizing immediately (it seals itself right away).

Silver is used in:

- mirrors
- photography
- jewelry

As an analogy one can say it opens up to the outside world without criticism. It is the world of images: mirror image, photographic image. A mirror is unthinkable without light, photography is unthinkable without a dark room. So the interaction of light and darkness and the image without influencing.

While mirroring, the silver itself is invisible. When one looks at a mirror one sees oneself. Asking questions of the mirror. ('Mirror, mirror on the wall...'). The answer is irreversible for the moment. (How often do you stick out your tongue at the mirror or wrinkle your nose?). A mirror not only shows you yourself but also the space behind you (metaphorical: the past as an image).

MERCURY (Mercury) and TIN (Jupiter)

Mercury is a heavy metal and at the same time it is a liquid. This goes against one's normal feeling of the way things should be. If one drops a little ball of mercury it splatters into many little balls and then can come together again as if nothing has happened. It makes you want to laugh.

Mercury is used in:

- thermometers
- barometers
- blood pressure meters
- quicksilver lamps
- sun lamps
- medicinal purposes (formerly more than now).

Alchemists used to especially watch the transitions from solid to liquid, etc. These transitions were called: 'sal' (from solid to liquid), 'mercur' (from liquid to gaseous) and 'sulphur' (from gaseous to a state of

heat). So mercury was in the middle area. In plants one would say: 'sal' -roots, 'mercur' - the leaves winding around the stem, 'sulphur' - the flower.

Mercury is very mobile. It is a liquid that does not wet its surroundings. But all metals dissolve in it except iron and iron-related metals. It has a shiny silver color and in a liquid state one never gets to take a look at the inside.

Tin. Every metal becomes softer through heating. But though tin first does become softer, from 1600 C it becomes much harder, even brittle. The other way around: when chilled, tin falls apart to powder. At -500 C, the normal mineral form cannot exist. When one heats tin up to 2320 it becomes liquid which is the lowest melting point of all heavy metals (except mercury). Lead melts at 3270 and boils at 17000. The boiling point of tin is 23000. Tin 'resists' heating up. Melting always goes together with the losing of form. Mercury does not want to be made into a form; tin does not want to lose its form.

Tin is used in:

- making of letters (influences the legibility)
- solder
- essential for making bronze (93 % copper and 7 % tin)
- adds form staying power to the structure
- formerly used for plates, cups, etc.
- tin cans (preservation).

There is but little tin in the human body and it is not spread out. There is tin in the muscle of the tongue and in the mucous membrane of the tongue. Also in the skin. The tongue not only tastes, but investigates the texture of food.

Tin is also used in silver paper to wrap up chocolate, etc. (Silver paper = stanniol; tin = stannum in Latin). It gives contour to the already existing form. Skin gives contour to the body.

To laugh is quicksilver; to cry is tin (to become rigid).

GOLD (Sun)

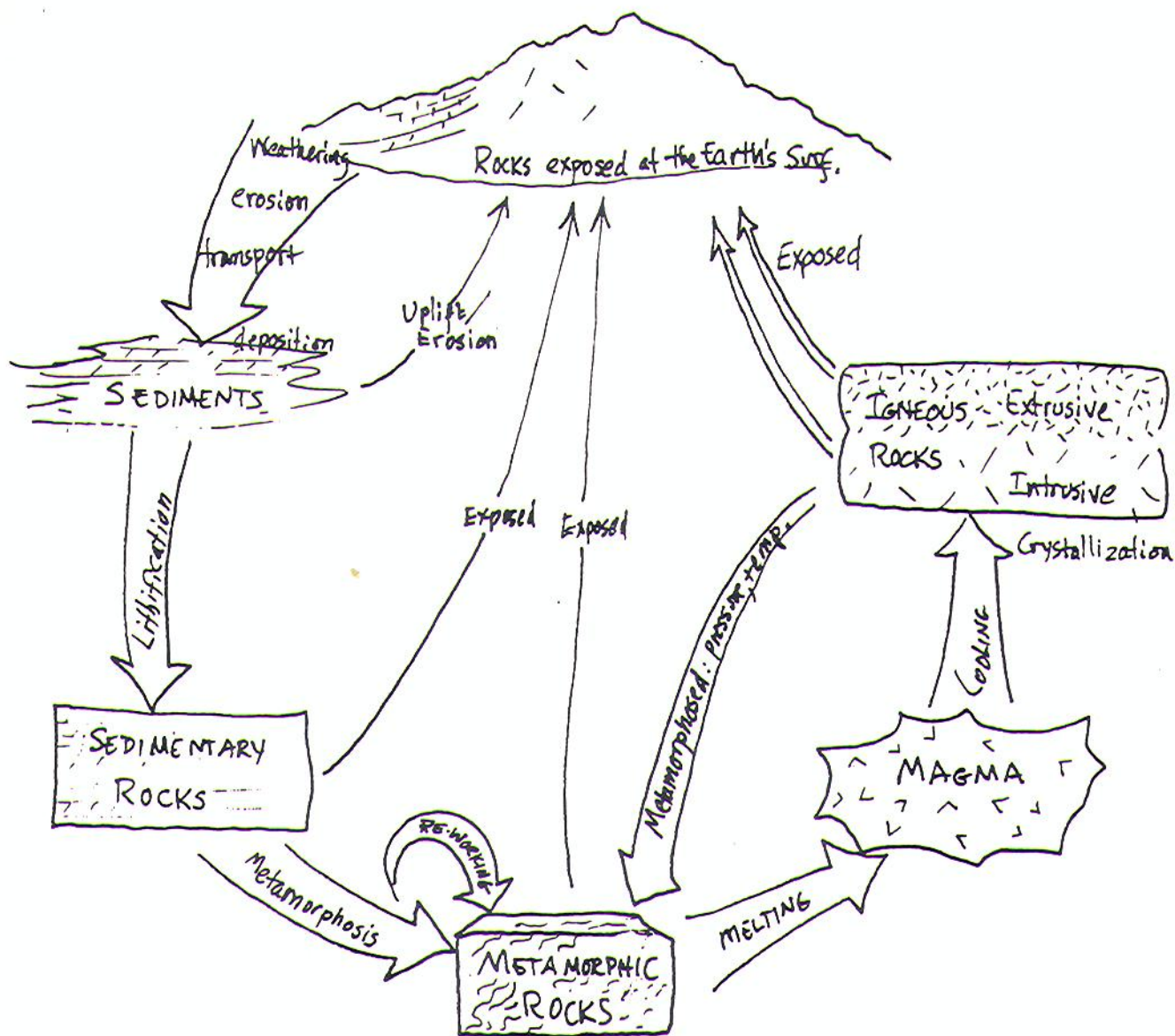
Gold is something 'to look at'. It used to be a symbol for regal power. Now one finds it in underground safes. In a way gold is bound up with the spreading of 'culture'. Think of the gold rushes.

If you hold gold leaf against the light between two pieces of glass it has a greenish color. Gold is used to 'intensify' in the making of colors.

Gold is the heaviest of all minerals: SG = 19.

Gold can be flattened so much that 10,000 leaves of gold are less than 1 mm thick.





The following article is not for students! It is for teachers to read to gain a deeper and esoteric insights for their minerology preparation . – Eds.

Precious Stones

Their Meaning for Earth, Human Being & Cosmos

by

Dr. Friedrich Benisch

On earth, there are only about 2,400 to 2,500 individual types of minerals. They form the constituents of the solid, fluid, and gaseous mineral earth and are the organs and organelles of its living body.

Among these thousands, there are a few dozen which are called “semi-precious” stones; but this term is hard to define precisely. It does express an aspect of the emotional influence which seeing these minerals exerts on the soul; we are astonished over the possibility that a ‘rock’ can be so transparent, pure, well-formed, colored, shining and glittering – so “gloriously beautiful.” That astonishment goes over into awe, the awe into enthusiasm, and this enthusiastic delight into the feeling of value or preciousness (in feeling, not in price). This experience points out the need to understand better how it can be that something which seems so totally material, can simultaneously present itself to the senses so paradoxically, mysteriously and wonderfully. To a dispassionate observer, the stone’s appearance stirs a deep intimation of a higher question for which our consciousness — schooled in the methods of conventional science — can find no answer. For, neither the knowledge of crystallographic form, chemical associations, crystalline refractive index, geochemical origin or association, occurrence, or a knowledge of commercial value can provide details which explain the feelings of the astonished beholder.

We could actually even say: any single common mineral, i.e., just a piece of rock or stone basically already reveals the same characteristics – it is complete in itself. It is an individualized, immobile, motionless, undesired being, possessing only existence: what it is or has become; but, it is chaste, pure, and complete in itself. Nevertheless, as an instance of a material thing (solid, fluid, or gaseous), its existence would be impossible without a connection to the earth,

the solar system, or even the cosmos. So, perhaps, what common minerals conceal of this pure being, is usually revealed in the transparent form, sparkle, refractivity, hardness and color of the semiprecious and precious stones – partly manifesting what one mineral can generally embody and partly concealing what one mineral must conceal. Perhaps this “manifest concealment” constitutes the essence of precious gems.

Many people preserve traditions. Such lore goes back a long way, and gives indications about the origin, feeling-character, soul-spiritual characteristics, qualities, forces and activities which are imparted to the precious stones. The modern scientific consciousness, however, sees this as an anthropomorphizing (attributing a human, subjective quality to the thing), as superstition, illusion, as error. Thus, on the one hand, the attributes are sometimes very specific, and consequently are preserved through centuries or millennia. On the other hand, these various traditions can be so complicated, imprecise and contradictory, that it seems impossible to rationally penetrate their meaning.

In addition, precious stones also play an important role in the Christian religious documents of the Old and New Testaments. Thus, for example, twelve precious stones are prominently mentioned in the Old Testament – built into the breast-plate of the high priest Aaron; their designation and arrangement was transmitted to Moses out of direct, divine revelation from the Jave-Godhead itself; it originated as spiritual knowledge (Exodus 2). And, in the New Testament in St. John’s Apocalypse, a different twelve precious stones are named in his supersensible spirit-vision of a new heaven and a new earth, which the present cosmos will become. They appear as a part of his vision of a city, the “new Jerusalem.” In it sun, stars, earth, and humanity are transfigured in a spiritual-organic way into an image of the future. The spiritual building materials are seen as twelve “foundation stones,” with “precious stones” in soul-colors, “decorated” or “adorned” with spiritual forces as moral qualities and identified with the names of precious stones.

The Greek word is *Kekosmæmenoi* (Κεκοσμημένοι); we could express this as “decorated” or “adorned”, or else we might say “cosmologized” if there is such a word (Rev. 21: 19-20). The twelve foundation stones “decorated” via these images of “precious stones,” simultaneously carry the names of the twelve Apostles of the Lamb (Rev. 21: 14).

There is a tradition also, that says precious gems are the bearers of mysterious soul-spiritual forces (drives, inclinations). They have an invisible “soul” and magical forces within them, which are passed on the bearer – whether it is a person, a dress, an apparatus, or a piece of jewelry. They have a kind of “inner spirit” or individuality connected to the specific crystal; they are the bearer of protective, healing but also dangerous forces. They have a life, which also can be utilized medically. They are an external image or symbol: they have power to mediate. Generally, they are connected with one of the twelve zodiac signs or the seven planets; they have a cosmic correspondence, a cosmic origin, which makes them the vehicle for cosmic-spiritual realms and beings. Mystical, magical, mythic, religious, a cult object, symbolic, representative, cosmic, astrologic, amulet, talisman, medicament – a whole world of esoteric occult traditions surround the world of precious stones, even today.

All these domains – our direct sense-experiences, the scientific and material-mechanistic research, the occult tradition – all these lie unconnected, or else stand in sharp contrast to each other.

But now, there is the possibility to form connections. The best attempt thus far, to fashion a bridge between these disparate realms by means of Goethean methods or spiritual indications, is the book *A Little the Lore of Precious Stones* by Walther Cloos. In the background are the spiritual-scientific results of Rudolf Steiner's research, which discuss the common supersensible origin of the cosmos as well as the human microcosm (see, *An Outline of Esoteric Science*). The world – components of the cosmos, as well as of the human organization – have the same spiritual origin and have differentiated over time through stages of spiritual, soul, and living, up to the material phase. Correlation between these cosmic developments (micro- and macrocosm) are still evident, today. The sun in our cosmos corresponds to our heart and the "I"-ego within our spiritual reality; the earth corresponds to our head and our conscious aspects; the planets relate to the inner organs and our soul-forces; the fixed stars (especially the zodiac) represent the limbs of our form, and fundamental 'types' for the whole of humanity. Each member of the animal kingdom is a one-sided expression of an aspect of our human soul-life in compressed form; plant life is a summation of life-forces; and the mineral world bears within it transformed images of the whole human being. Particular minerals originated at the same time as certain human organs or aspects of our organization, and developed into human organs on the microcosmic level, and particular beings on the macrocosmic level. This primal common origin of minerals, plants and animals with mankind is the true reason for the curative powers that certain natural elements have for particular human ailments and illnesses. Here is the cosmic rationale for a renewed method of preparing remedies and therapies.

Essentially, ultimately we are dealing with individual, supersensible spirit-beings, since everything in our world a material body but also has life, soul-life and individual spirit. Modern, conventional science has immense difficulty with this.

This central idea of the kinship between the cosmos and the human being, directs us also toward the future of world-evolution. We are not talking about material world-mechanisms of modern science such as the law of entropy, but also about the continuous intervention of spiritual beings, including mankind. The world's decline into a material state, will evolve into a stage in which world elements are re-connected and become "ensouled" again, because our existing, material world is constantly influenced and reshaped by spiritual beings, whose strongest and most influential representative is the Christ-spirit. Only by keeping this in mind does the image of the heavenly Jerusalem makes sense, where the twelve primary rocks and precious stones are related to the twelve names of the apostles. Distinct elements such as precious stones, human beings and the world of fixed stars, to spiritual perception, will be reconnected and reunited in a future reality. This, however, would not be possible if this future was not already active today.

From a myriad of possible combinations, we have selected for this cal-

endar to present the twelve months and the four festivals of the year (Christmas, Easter, St. John's and Michaelmas) corresponding to twelve and four precious stones along with representative colored photographs of them.

This poses the question of classification. Over and over it has been emphasized that there is quite a discrepancy between the traditional astrological divisions of the year, the calendar months of a year, as well as the actual position of the sun within the [sidereal] zodiac constellations. Due to the shifting position of the spring equinox with the Platonic "year," the designation of the sun's position differs greatly from the astrological and astronomical viewpoints. According to the astrological calendar, the sun stands "in Aries" (as astrologers call this tropical sign) between March 21st and April 20th. However, the spring sun stands in the constellation of "the Fish" (Pisces) from March 12th to April 18th in real-astronomic terms. The sun reaches [the constellation of] "the Ram" (Aries) only around April 19th. From an astronomical standpoint, the equal-division zodiac is purely a convention of science, taking particular spherical-geometric areas of the ecliptic and naming each with ancient, mythological terms without explaining any sort of reality for these divisions. Also, astronomically, the band of the zodiac has no reality except that the ecliptic [sun's path] lies there, which in turn is only an optical projection of the apparent course of the sun against the background of the fixed stars. Further, those stars that make up an astrological sign could be part of several different galaxies, and may not stand in any special spatial relation to each other, beyond being apparent neighbors that form an image, when viewed from the earth. So, from an astronomical view point, attaching influences or characteristics to those star-groups (signs), seems not only arbitrary but even ridiculous. The interpretation of astrologers that the sun "stands in the sign of Aries," while it actually passes through the constellation of the Fish (Pisces) during the end of March and early April, appears completely absurd.

This contradiction becomes only resolved when the twelve spatial directions of the zodiac are not conceived as only a material extrapolation of a merely conceptual possibility. From a spiritual-scientific viewpoint, these images of the zodiac make up a readable script of signs for spiritual regions from which stream definite activities of spiritual beings. The images formed by the arrangement of the visible stars next to one another, are signs for these spiritual beings. According to Steiner's Spiritual Science, they appear as twelve "world-initiators," reconfirming or correcting the old astrology. They are the true meaning of the zodiac. In essence, it comprises the cosmic sphere of the first hierarchy, of the Seraphim, Cherubim and Thrones, particularly, however, of the Cherubim. To supersensible perception, these higher spiritual beings appear in the form of animal imaginations.

There was a time, when the astronomical constellations and the animal signs of the astrological zodiac fell together into the same arrangement with respect to the position of the sun. During that period, the spring equinox of the sun occurred when the sun stood within the constellation of the Ram (Aries). Also during this time falls the earthy journey of the Christ being in the person of the man Jesus, and the mystery of Golgatha. With the descent of the Christ being down to earth, the influence of the Cherubim was split up. One aspect of

the Cherubim's influence stayed cosmic and manifests in the shifting (precession) of the spring equinox, continuously bringing about the new epochs of the Ram, and then the Fish. With this activity, the sun passes through constellation Pisces between March 21st and April 20th. Another part of the activity of the Cherubim has been connected with life on earth, and with humanity, by the leadership of the Christ being. Thereby has arisen a kind of 'birth horoscope' for the Christ impulse, which has been decisive for human destiny. For the spiritualizing and 'christing' of the earthly realm which leads into the future, the sun "stands" in the "sign" of Aries from March 21st through April 20th.

With this background knowledge we can now attempt to arrange the precious stones of the Apocalypse and relate them to the months of the year and the signs of the zodiac. The arrangement in this Weleda calendar relates a precious stone to each month, and then the sign of the zodiac with the month in which it lasts the longest time for that respective "sign," like: Chalcedony - January - Capricorn.

Because the "civil" year begins in January, this calendar starts out with that month. However, the 'spiritual year' starts with the spring equinox (March 21st = 1° astrological Aries). On the other hand, Passover and the Easter celebration fall on different dates each particular year. We always should remember that with the first of January we enter a terminating year and declining season.

In the *Apocalypse of St. John*, the enumeration of the images of precious stones begins with Jasper. The affiliation and equivalence of the twelve stones with the cosmic images of the zodiac is then reversed; it begins with the Jasper for Pisces, continues with Aquarius, Capricorn, up to Aries. This sequence does not coincide with the course of the sun, but the eastward movement of the spring equinox through the zodiac during the Platonic year of 26,000 years. The completely spiritual world moves in the opposite direction of the material world.

Discussions for the pictures for each month will include a synopsis of scientific research results. More detailed information then can be found in almost any book about mineralogy.¹⁷ A thorough description from a Goethean anthroposophical perspective, can be found in Walter Cloos' books.¹⁸ The connection between precious stones and the months of the year, with the zodiac, as well as seasonal festivals, can only be truly understood when the relationships are not only seen from a material viewpoint as relations of objects, but are also viewed within their spiritual context, looking at the origins and goals within the spiritual world. Rudolf Steiner's Spiritual Science has given us a basis for doing exactly that. The spiritual reality of the hierarchy of the Cherubim allows for minerals, people, and the starry world to have a common origin. The creative impulses of the Cherubim are differentiated through lesser spiritual beings and are embodied in a material cosmos. The creative powers of the Cherubim differentiate the twelve main types and characters of the zodiac, the animal- and plant world. They form the twelve parts of the human body, the twelve senses and the twelve constitutions of human character types. This twelve-foldedness is also related to the Christ having been surrounded by twelve apostles. The connections between human beings and the cosmic realities (i.e. star constellations) were known in all the ancient mysteries. The highest essence of all the twelve-fold divisions (of which there are many) only surfaces when we rise to soul-

spiritual virtues and the fundamental powers of spirit-beings. Rudolf Steiner unfolded the connection between the twelve "moods" and the twelve virtues in his lectures on Eurythmy, and related those virtues, then, to the zodiac in *Indications for Esoteric schooling and Self-development*.

In this area one comes closest to the core of spirit beings, because it is spiritual beings in reality that shine within us as our highest ideals. On the other hand, minerals are the last external material creations of these beings. And, precious stones are mineral derivatives, yet images of the creative forces of higher spiritual beings. Arranging precious stones and relating them to particular signs of the zodiac has been problematic, because precious stones are not twelve-fold, and the seven planets and their spirit influence each of the signs of the zodiac. We can speculate, then, that there are 7 x 12 precious stone types. This assumption does not exclude that some precious stones have so many characteristics that they can appear in more than one twelve-foldedness. These types, then, would be influenced by many creative forces.

The twelve-foldedness represented in this calendar, is that of the Apocalypse. Since the apocalyptic picture entails future vision, it can be assumed that this twelve-foldedness is influenced by and aspires to aspects of the future spiritual heaven. Going beyond the other (7 x 12) planetary possibilities previously mentioned, there is perhaps an eighth, 'apocalyptic twelve-foldedness.' Once again, this does not preclude some stones being part of other twelve-fold groups. Only those rocks carrying and connecting past as well as future characteristics within them can then belong to this group of cosmic and apocalyptic stones. It is striking that half of the apocalyptic stones are semiprecious minerals belonging to the 'quartz group,' and that precious stones such as rubies, diamonds, garnets, tourmaline, as well as rock crystal are not among this group.

The twelve spiritual beings of the zodiac appear to spiritual perception in form of animal images. That is also the case in the Apocalypse (Rev. 4:6-8). On the other hand, in the futuristic vision of the Holy City the twelve beings of the zodiac appear in images of animal characters, twelve foundation-stones, and twelve precious stones as well as twelve "pearl gates," which are described with the twelve names of the future tribes and the names of the twelve apostles. The future aspect is entailed in the co-operation of distinct creative powers from different hierarchies: the mineral world, groups of people (community) and that of individual human beings.

How can we make a connection between the mineral and the human world? The golden thread between them is purely spiritual, a spiritual kinship. The human being has twelve senses that connect them to the world, and each forms a specific realm of existence. The individual will which enters and leaves each person through their senses, is penetrated by a definite realm, comprised of world will. This is the reality of sense perception. The earthly will of the first hierarchy, the Seraphim, Cherubim and Thrones, are active in the spiritual zodiac in the four leading Cherubim: the Bull, the Lion, the Eagle (or Scorpion as it is now seen), and Aquarius. Each of those primary Cherubim is accompanied by two neighboring images. The four Cherubim and their neighbors is the reality of the zodiac. As the human being, in developing particular ideals and vir-

tues, comes inwardly into a spiritual-soul connection with these beings from the one side, so from another side, through sensory perception, they can also come into connection with the revelation of these same beings in the mineral kingdom. Therein we see how the creative activity of the spiritual beings can be directed totally outwards, and have its revelation in the mineral, plants, and animals. Or, on the other hand, can proceed totally inwards, where the activity appears as morality, achieved in the human being. In the minerals lies the end of the creative activity of the Cherubim, and in virtues lies the beginning. In between lies field of their creating in the members and organs of the human form and the kingdoms of nature.

In both his fundamental works, Walter Cloos described the creation and formation of precious stones out of primeval stages of a living earth. He showed that precious stones were not only the result of cooling magma masses, but a hardening and extensive "de-vitalization" of early plant-minerals and plant-animals. On the one hand, through "de-vitalization" this process created minerals; and created lower fauna on the other. He also points out how individual stones come forth in a particular way. For example, quartz, which is more common than most other precious stones, can be found in many parts of the world and embodies ten combinatorial laws of crystal formation; diamond reaches outer extremes in some of its qualities; tourmaline is very strongly related to the plant world; the garnet family is known for its numerous chemical forms, which are almost all precious stones with almost identical crystal forms.

If we now survey the twelve apocalyptic stones, we notice that half of them belong to the group of semi- precious stones of the quartz-silica group (amethyst, chrysoprase, sard, sardonyx, chalcedony and jasper). Following Rudolf Steiner's indications, Cloos shows the importance of the silica-quartz process for the earth, plants, animals, as well as human sensory processes. In the quartz group of crystals, a relationship arises between the human sensory system and the formation of these crystals more clearly than in any other group. The word "semiprecious" captures the sense of something not quite pure, not quite completed. And, at the same time, it points at the future to something that will be reached once the process is completed, leaving the "half-crystal" and "semiprecious" stones, half-way into the process of pure crystal formation. This brings us back again to the twelve-folded nature of apocalyptic crystals which carry future powers within themselves. According to Rudolf Steiner, six of those futuristic stones have developed alongside our sense of self, the sense of hearing, of smell, movement, touch and warmth. The remaining six crystals of the apocalypse also conceal characteristics of semiprecious stones. The relationship between the hyacinth to zircon, of topaz to the other fluoride minerals, beryl in relation to aquamarine, chrysotile to olivine, ruby [smaragdite] to beryl, and sapphire to ruby, all touch on borderline qualities. In these six crystals of the apocalypse, appear the future powers of the other human senses: vitality (sense of aliveness), balance (sense of equilibrium), sense of thought, sense of the other person, sense of the word, and sense of taste. This classification is future oriented; it entails future aspects of the senses. The basis of an entirely different arrangement of the senses in relation to the zodiac will not be discussed any further in this article.

If we try to venture to the birthing place of the twelve world initiators, we will first look for the moral qualities, the virtues that penetrate into and emanate from each being. More detailed instruction on the internalization of virtues can be found in Rudolf Steiner's indications for meditative life, where he states that an inner movement is expressed and every virtue in itself can reach far beyond its original qualities, when sufficiently elaborated and contemplated about. For example, the virtue of devotion that is part of the Aries impulse, develops with the influence of future powers into the virtue of sacrifice in mankind. Through internalization of such processes one can learn to see the inner orientation of crystals and precious stones. One can then move freely from the spiritual world to the material world and from the material world to the spiritual one. This inner flexibility (movement) within a single hierarchy leads then also to transitional movements from one hierarchy to another. This flexibility of movement within and between different spheres is important and should not be ignored. In fact, the cosmic expression for that is the course of the planets, especially that of the sun, through the zodiac.

One movement follows the seasons of the year, starting with Aries, going counter-clockwise to Pisces. The second movement starts with Pisces clockwise to Aries, as the movement of the spring equinox. The third movement follows the apocalyptic pictures and starts at Pisces, moving toward Aries. A fourth one is found in Rudolf Steiner's instructions to Eurythmy and the movements for the zodiac (*Eurythmy as Visible Speech*). The fourth movement is entirely projected onto mankind. It has two points of origins: one is the Leo, starting with the gesture "flaming enthusiasm", going counter-clockwise over the Virgin, up to Capricorn, with the gesture of "contemplation about the world." The other starting point is Cancer, with the gesture of "will for action" and goes clock-wise over Gemini up to Pisces, with their gesture "the event has become destiny."

Similar movements can be projected onto pictures of precious stones so that they show correlations and connections which correspond to the names of the spirits of harmony.

Observing our worldly crystals, attributing them to a particular spiritual sphere, a mood or part of a human organization, we need to acknowledge and respect the transitions from one matter into another in a sensible fashion. This way we can develop a flexibility of thinking and a (deeper sense) of observation, which does not solely rely on logical and typological explanations but also can capture the experience and describe the lively intellectual, spiritual and physical changes.

EXPERIMENT 1

Growing Crystals

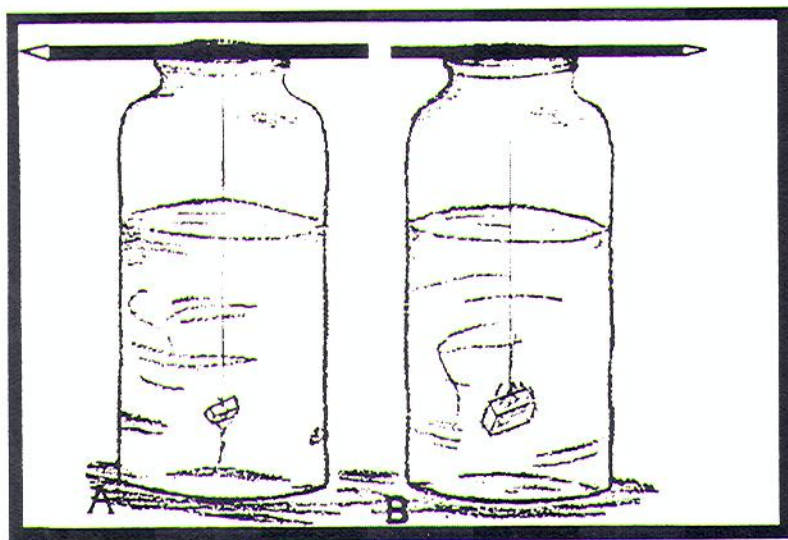
PROCEDURE:

Obtain several clean jars, then in a clean pan. Boil $\frac{3}{4}$ cup of water. While the water is boiling, gently stir in the salt or sugar, little by little, until no more will dissolve. *This is a saturated solution.* Remove from the heat. Continue to stir and observe so that you make a fully saturated solution. **BE SURE to ADD THE INGREDIENTS SLOWLY WHILE STIRRING.** You will come to a point where one more grain will cause the solid to "snow" out and precipitate to the bottom, *this is a super-saturated solution.*

Pour the solution into a glass or clean jar. Put a spoon in the glass or jar – this will absorb the heat and keep the glass or jar from breaking or cracking. Now remove the spoon.

While the solution is hot, lay a pencil across the top of the glass or jar. In the middle of the pencil tie a piece of clean cotton string. Hang the string into the saturated solution. In order for the string to sink to the bottom you may have to tie a small clean metal weight such as a paper clip onto it. (Figure A)

Set the glass or jar in a quiet **warm** place, where it won't be moved or in any way disturbed. The solution will cool and then evaporate slowly leaving behind large crystals hanging on the string. When the crystals have stopped growing (2 or 3 days) take the largest to use as a "seed" crystal. Place this crystal carefully back into your saturated solution and it should grow much larger (Figure B)



The following salts (available at either a pharmacy, a food store, or from the chemistry lab supply room) can be used:

sodium chloride (table salt)
alum
crome alum
sodium bromate
copper sulphate
rochelle salt
nickel sulfate hexahydrate

potassium ferricyanide
lithium trisodium chromate hexahydrate
calcium copper acetate hexahydrate
sucrose (table sugar)
Copper acetate monohydrate
alum grown on Chrome alum
strontium formate dihydrate

EXPERIMENT 2

Grade 10 Chemistry

Salt Crystal Symmetry

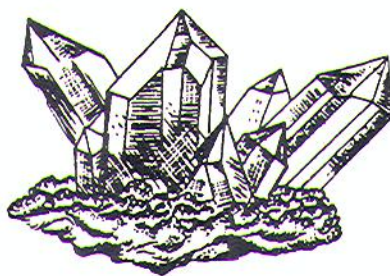
Finding Symmetry in Crystal Models

Making Crystal Polyhedra Models

Almost all minerals are crystalline in structure, having a great degree of order in their inner substance. Even tiny fragments of minerals reveal an order when X-rays are passed through them. Crystal shapes are regular geometric solids bounded by flat faces. The angles between adjacent faces remain similar whether the crystal is large or small, perfectly symmetrical or distorted.

In this investigation, you will construct crystal models typical of six crystal systems. Each system contains many different crystal forms. You will be working with the simplest forms representative of each system - two forms (the cube and octahedron) for the isometric system and one form for the other five systems. All of these models will help you recognize actual crystals that occur in nature.

You can observe crystal symmetry in the models you construct. Symmetry is the similarity of form on either side of a dividing line or plane. It is also the repetition of a form when an object is rotated about an axis. When you rotate the crystal models around their axes, you will be able to see how the same faces are repeated in different crystal forms.



MATERIALS: scissors, transparent tape or glue stick, toothpicks (colored if possible), copies of 8 crystal model patterns on cardstock. Optional: Goniometer, crystal specimens of quartz, pyrite, and garnet

Assembly Procedure

1. Make sure you have a copy of each of the 8 crystal model patterns.

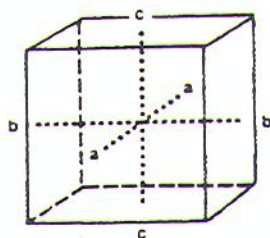
With scissors or X-acto knife, **carefully cut out** each pattern; only the solid lines are for cutting, and the dotted lines are for folding. Score the fold lines. Assemble the models, placing the flaps inside; glue (or tape) the flaps on each model securely closed, so that it retains its shape.

2. Draw diagonal lines across each of the six faces of the cube; the intersection of the diagonals is the center of each face. Push the toothpick through the center of one face so that it comes out through the center of the opposite face. Repeat with other toothpicks on the other face pairs, following the axis lines in figure below.

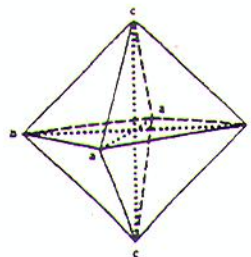
Exploration Questions

1. Hold the cube by the ends of one toothpick; **slowly rotate** 90°. Describe the shape of the face that reappears and record how many times you observe it.

Shape Re-appears



Cube axes



2. Insert the three toothpick axes 'into the octahedron. Slowly rotate the octahedron as you did with the cube. Repeat this procedure with each of the other crystal models, rotating them on the longest vertical axis. Describe the shape of the face (square, rectangle, triangle) and record how many times it reappears during one rotation.

Octahedral crystal:	Face Shape	Reappears	<u>symmetry elements</u>
Tetragonal			
Orthorhombic			
Hexagonal			
Monoclinic			
Triclinic:			

3. During rotation, a repeating pattern of similar faces indicates symmetry. Which model(s) show the most frequent repetition of faces- around the central axis'?
- Which models show the fewest similar faces?
- Which crystals, therefore, are the most symmetrical?

Crystallographic Symmetry

There are two types of symmetry: an axis (repetition when rotated about an axis) and-mirror plane, (similarity on either side of a dividing line or plane). If, for example, an axis has 4-fold symmetry, and is also symmetrical top and bottom, in crystallographic terms we designate it "4/m," meaning a 4-fold axis With a **mirror plane**. Other possibilities are: 3/m, 2/m; also simple axes with no reflection top-bottom are designated: 3⁻, or 2⁻ (this is read bar- three, etc.).

4. Fill in all the types of crystallographic symmetry in each of the crystal models above. Look for more than one axis of symmetry if it exists!

Conclusions

What does your investigation reveal?

1. Name the six crystal systems.

- | | | |
|----|----|----|
| a) | b) | c) |
| d) | e) | f) |

2. What is meant by-crystal symmetry?

How does the rotation of a crystal indicate symmetry? (What: did you see?)

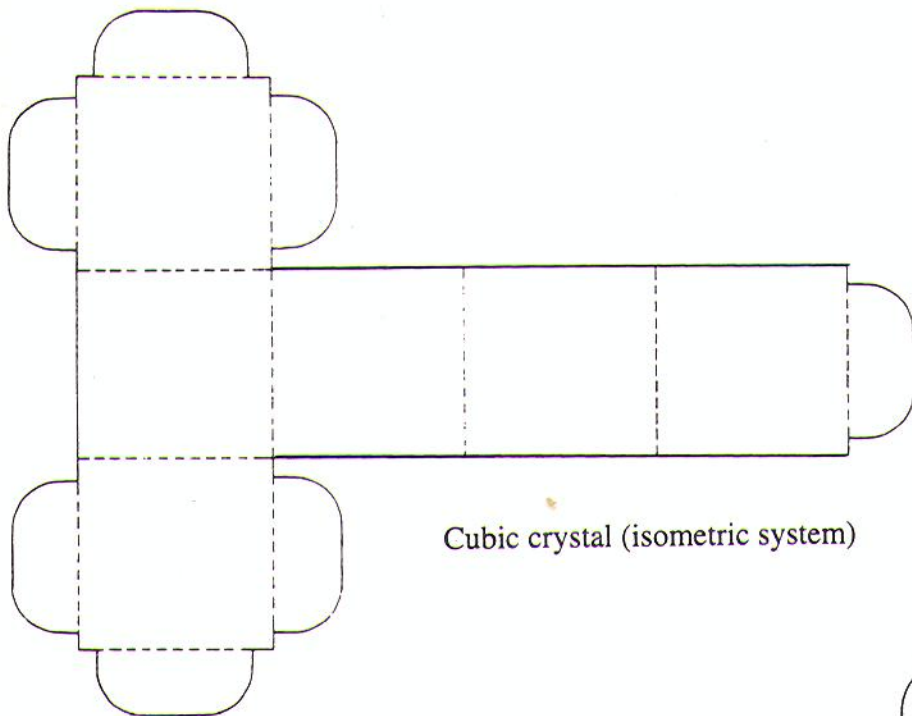
4. How does the angle between corresponding faces in different crystals indicate order in crystals?

5. Describe the symmetry of a cubic crystal. (What symmetry elements are present?)

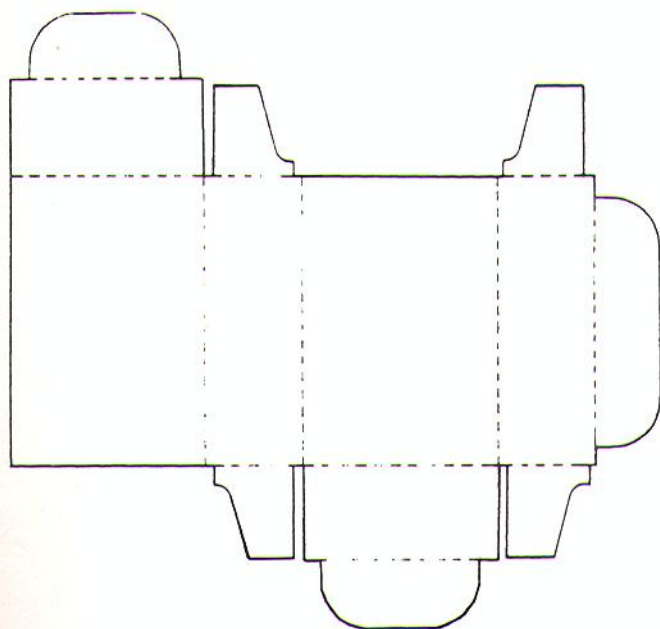
Crystal Symmetry

Polyhedra Model Templates

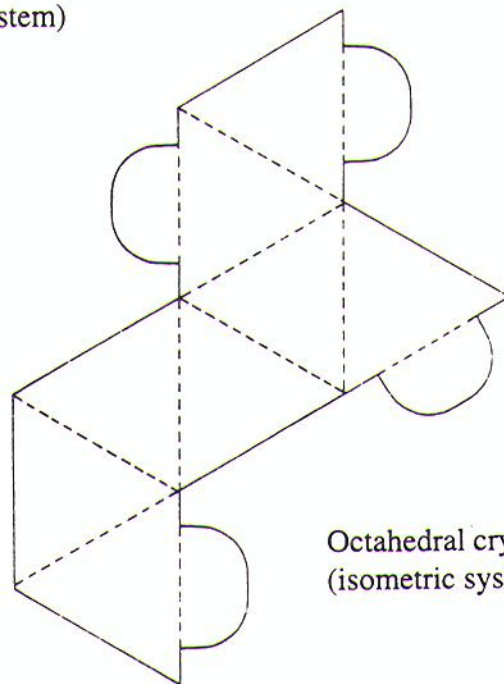
You will have to enlarge the templates. Cut on the solid lines, fold on the dotted lines.



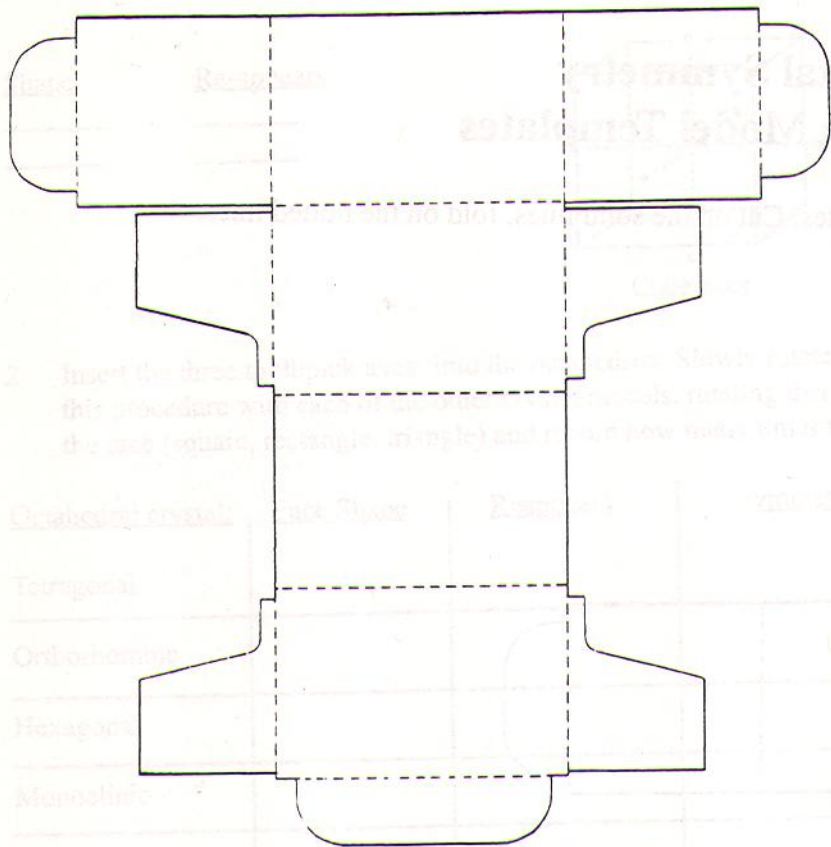
Cubic crystal (isometric system)



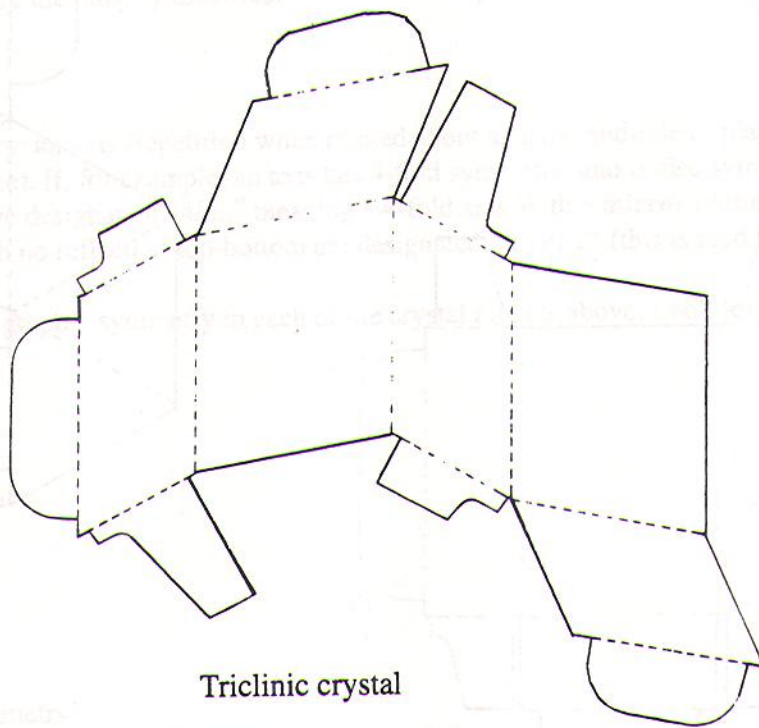
Orthorhombic crystal



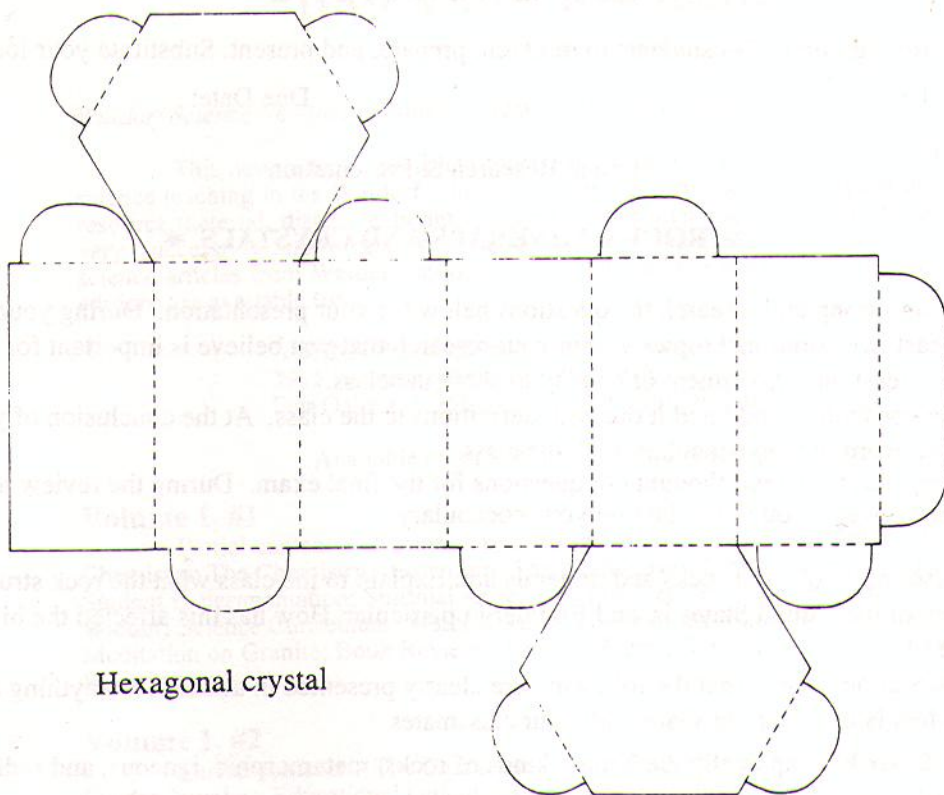
Octahedral crystal
(isometric system)



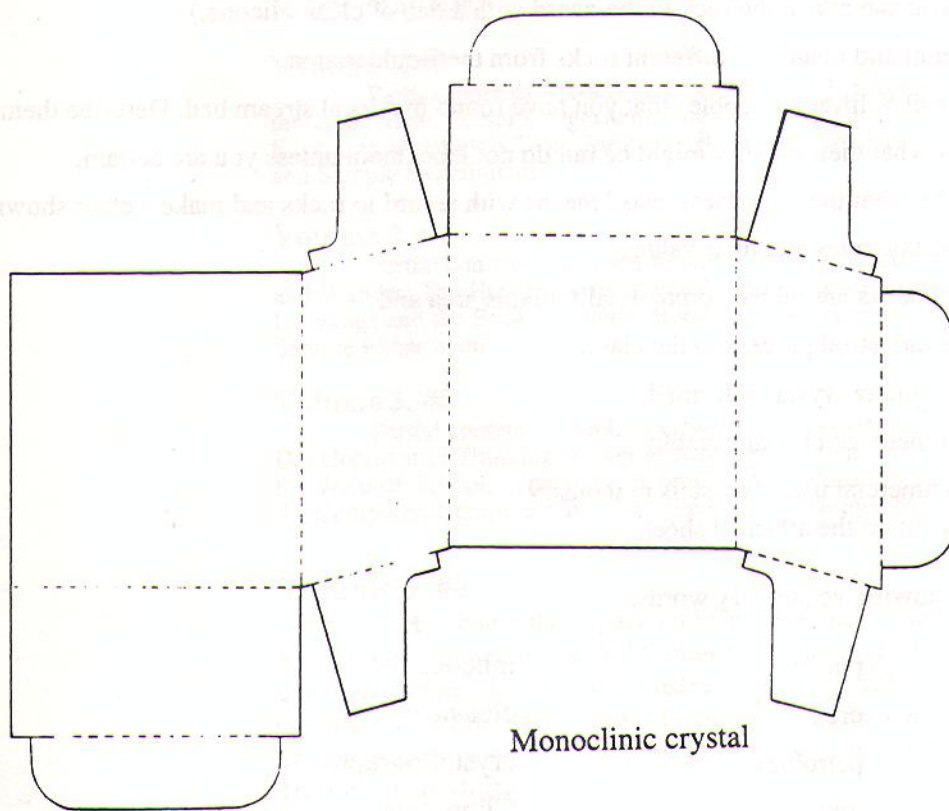
Tetragonal crystal



Triclinic crystal



Hexagonal crystal



Monoclinic crystal

EXPERIMENT 3

This worksheet is for a group of 3-4 students to research, prepare, and present. Substitute your locality for "Boulder."
EARTH SCIENCE 10 Due Date:

Group Research & Presentation

* ROCKS, MINERALS AND CRYSTALS *

1. Divide amongst your group and research the questions below for your presentation. During your research you should each discover at least two additional topics within your research that you believe is important for the class to know.
2. You should have at least one experiment or display to show the class.
3. You must type the vocabulary and hand it out with definitions to the class. At the conclusion of your presentation you should go over each word in the vocabulary with the class.
4. You must have prepared four, well thought out questions for the final exam. During the review next morning you will ask these questions as well as quiz the class on your vocabulary.

Prepare a description of what rocks and minerals are. Explain to the class what the rock structure underlying Rocky Mountain area of the United States is, and Boulder in particular. How has this affected the history of the people who have lived here?

In your presentation be sure that the following are clearly presented in addition to anything else about your topic that you, as a group feel is important to share with your classmates

Describe graphically the 3 main kinds of rocks, metamorphic, igneous, and sedimentary.

Explain the difference between a rock and a mineral.

On a board mount and label (typed on white paper) 5 minerals from around

Boulder. (You can attach the rock to the board with a dab of clear silicone.)

On a board mount and identify 7 different rocks from the Boulder area.

On a board mount 5 different pebbles that you have found in a local stream bed. Describe them to the class. Guess what their identity might be but do not label them unless you are certain.

Explain what the "hardness tests" means with regard to rocks and make a chart showing the accepted examples and their values.

Determine what rocks are mined commercially in this area and describe the industrial process to the class.

Describe how a quartz crystal is formed.

Explain the geometry of crystallography.

Explain the commercial use of crystals in industry.

Do the experiment on the attached sheet.

Define and give examples of the following vocabulary words:

vein

vug

geode

pegmatite

hydrothermal

sedimentary

metamorphic

placer

ore

petrology

dike

shist

fluorescence

geothermal

igneous

cleavage

crystallography

Clino-axis

saturated solution

spectography

hexagonal system