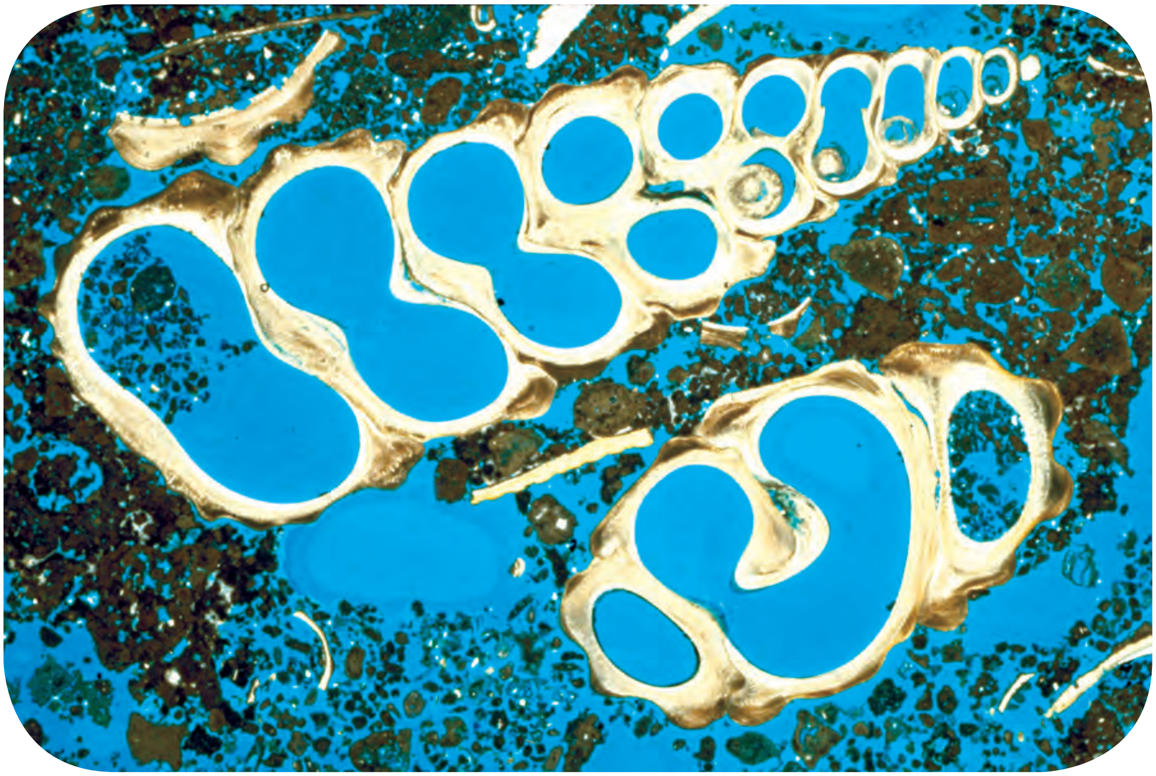
Lite Geology

Magnification

SPRING 2011 ISSUE 29



Gastropod, Abu Dhabi. This is a thin section of shells of modern snail-like gastropods that lived in a coastal lagoon. Contrary to appearances, the interior spiral chamber where the animal lived is not segmented, but continuous. The image was taken using an optical microscope. The largest gastropod here is approximately 14mm long. *Image courtesy of Peter Scholle and Dana Ulmer-Scholle.*

In This Issue…

New Mexico Bureau Of Geology & Mineral Resources a division of New Mexico Tech

http://geoinfo.nmt.edu/publications/periodicals/litegeology/current.html

The Evolution of Magnification

Virgil W. Lueth

Magnification involves enlarging an image of an object beyond its actual size. The first magnifiers were probably suspended droplets of water that magnified the objects behind them. Classical Greco-Roman literature first describes the use of lenses as a glass globe filled with water. Very little is known about early magnification, but the application of the technology began in earnest during the 13th century with the advent of glass grinding.

The Simple Lens

The placement of a lens in front of the eye allows you to place an object closer to the eye than the eye can focus. When the eye focuses through the lens, a much larger object is perceived. Unfortunately, the stronger the lens, the more distortion it creates. If you have a magnifying glass, you will notice the object is in best focus in the center of the lens. The outer portions tend to be blurry due to aberrations caused by refraction (light bending) and diffraction (color separation through a prism). Most simple lenses operate at magnifications from four times the original size (4x) to 10x. With 10x, an object the size of a millimeter appears to be a centimeter in size.

Precision Magnifiers (Hand Lens)

These magnifiers are composed of multiple lenses, some of which are ground to correct the aberrations of the others, allowing greater magnification than single lenses. Some use two lenses (doublets), and others use three (triplets). These types of lenses are commonly found in 10x to 40x varieties, the 40x hand lens being quite small.

Microscopes

The very first microscopes were really nothing more than a hand lens mounted on an apparatus to hold a sample. Compound microscopes use multiple lenses to collect light from the sample, and then a separate set of lenses to focus the light into the eye or camera. The increased number of lenses used in their construction, along with more significant engineering to minimize aberrations, increases their cost.

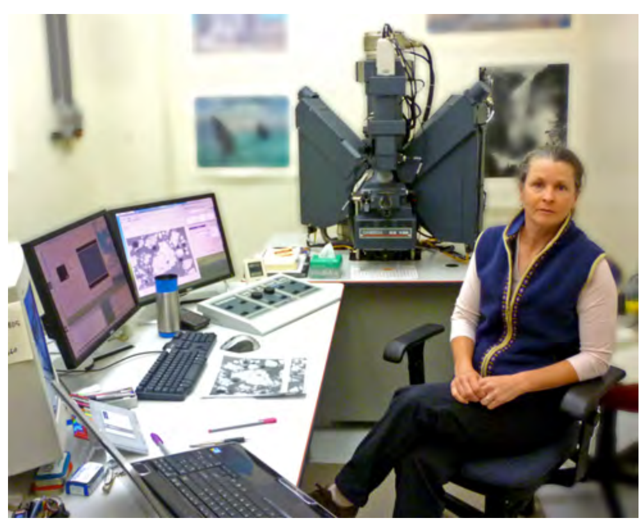
Two main lenses are responsible for magnification. The ocular lens (eyepiece) focuses on the back of the main magnifier, the objective lens. Use in air can achieve reliable magnification up to 400x. However, this can be increased by immersing the lens in oil, which reduces the amount of refraction between the sample and the objective, achieving good magnification up to 1,000x. Light microscopes are limited by diffraction and can only resolve objects down to 200 nanometers (nm).

Transmission Electron Microscope (TEM)

Since the use of light is limited to object sizes larger than 200 nm, other energy sources must be used to "get smaller." Scientists turned to electrons to generate the image. A TEM works much like a slide projector, where a beam of light transmits through the slide and is then projected onto the viewing screen, forming an enlarged image. In many ways the TEM is built like an optical microscope but uses electrons in place of light, electromagnets instead of glass lenses, and some type of imaging device such as photographic film or charge-coupled device (CCD). The TEM can see the shadows of atoms and can resolve objects down to 0.5 angstroms (or magnification up to 50 million x!).

Scanning Electron Microscope/ Electron Microprobe (SEM)

Unlike a TEM, an SEM images a sample by moving a beam of electrons over the sample (a raster scan). The interaction of the electrons and the sample produces a variety of



signals. Detectors measure these interactions and produce images we see on screens. The electron microprobe can also fix the beam (keep it in one place, no rastering) so it can generate data that are used to determine compositions and concentrations of elements. The very best SEMs can image particles as small as 0.4 nm (500,000x).

Please click on the Web link below, then the video link at the bottom of the web page, to see a short video that explains various SIZES, giving examples of things that are the size of a meter (large rectangular pizza), centimeter (pen), and so on, down to microscopic size. *Photographs in this section courtesy of Leo Gabaldon.* **http://www.bbc.co.uk/news/science-environment-12612209**

The Role of Magnification in Solving a Geologic Problem—The Mystery of Argentiferous Galena

Virgil W. Lueth

The question: "How is silver 'dissolved' in the mineral galena (lead sulfide)?" perplexed scientists and miners for 300 years. This mystery could not be solved until scientists developed better and better ways of magnifying the very minute crystal structure of galena, invisible to the human eye.

Many economic ore deposits are valuable not only for the main metal they produce, but also for other metals bound within their crystals. Since the earliest days of mining, silver was observed with lead in many ore deposits where galena (PbS) is the most common mineral. Some deposits contained few or no obvious silver minerals, although they produced significant amounts of silver after the ore was melted (smelting). The early metallurgists coined the term *argentiferous galena* (silver-bearing galena) as the "carrier" of silver in these types of deposits. It was a reasonable idea because silver mixes with lead in the "bullion" during the smelting processes, but at much higher temperatures than found within the earth. However, not all galena contains silver, so something about argentiferous galena was not completely understood. It wasn't until many deposits were studied and experiments conducted in the laboratory that it was confirmed: Very little silver can actually be dissolved into galena at the temperatures at which the deposits formed. Obviously, something controls the ability of silver to be carried by galena, but what is it?

A rounded galena crystal from the Hansonburg mining district, Socorro County, New Mexico. This crystal contains almost no silver. This specimen is typical of a sedimentary lead deposit. *Photo courtesy of Debra Wilson, New Mexico Bureau of Geology museum specimen #11454.*

Early mineralogists hypothesized that silver-rich galena might show specific crystal shapes rather than the simple cube, which is the most common shape for galena. They thought that the appearance of additional faces on the corners of the cube (the octahedron faces) or other unusual shapes were a sign of silver. This idea was reasonable because placing atoms of different sizes into crystal structures should cause them to grow a particular way. However, after the study of hundreds of deposits and thousands of crystals, it was determined that crystal shape had nothing to do with silver content. What exactly causes the development of certain crystal faces instead of others remains a mineralogical mystery well worth future study.

This galena crystal from Missouri shows the classic cube shape with modifications at the corners called octahedral faces. They are called octahedral faces because if allowed to extend outward until they meet, they would create an eight-sided diamond-like shape we know as an octahedron. This crystal is from a sedimentary lead deposit, and it contains very little silver. *Photo courtesy of Jeff Scovil.*

Although crystal shape did not reflect the silver content of galena, some researchers speculated that distortion of the crystal (due to different sizes of atoms) was a sure sign of silver content. Many highly deformed galenas were found to have significant silver content. However, the silver content had nothing to do with crystal distortion. Perhaps it had more to do with the geologic setting of the deposit and deformation (from force applied outside the crystal). Some deposit types (like the Pecos, New Mexico, deposit) that discharge hydrothermal fluids directly into seawater, also known as black smokers, typically contain silver-rich galena. The preservation of these deposits depends on geologic forces that transport them from the sea floor onto the continents. During the geologic transport process, the deposits are subjected to high temperature and pressure, which causes them to become deformed (metamorphosed). However,

Sparkly, “steely” silver galena contains significant silver, as in this deformed galena schist from the Pecos mine, San Miguel County, New Mexico. *Photo courtesy of Virgil W. Lueth, museum specimen #12444.*

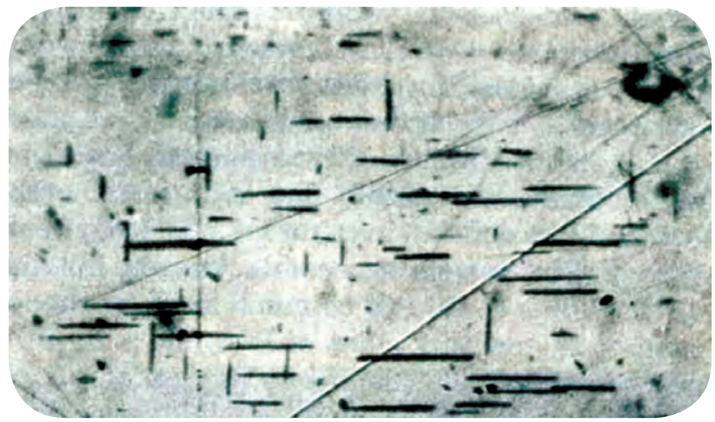
researchers discovered that the amount of silver in galena has nothing to do with the deformation either. Instead, the silver was inherited from the original environment of formation.

Scientists continued studying the phenomenon of silver in galena by making synthetic crystals in the lab. These experiments showed that you cannot put much silver sulfide into galena at temperatures likely to be found in nature. However, later experiments with more ingredients did show that significant amounts of silver can be “dissolved” into galena.

A microscopic image of a metamorphosed galena sample magnified 100x. A standard optical microscope is limited in the amount of magnification it can produce because of lens distortion. A lens bends light, and more bending (higher magnification) results in more distortion and diffraction (separation of light), especially on the edges of the lens. With high magnification, you must look through the middle for the best image. *Image modified from Ramdohr 1969, The ore minerals and their intergrowths, 3rd ed., Pergamon Press, New York, 1,174 pp.*

By adding the elements antimony or bismuth in amounts equal to the silver, it was discovered that more silver would go into the structure of galena. When scientists dissolved whole crystals of natural silver-rich galena, they found all these same ingredients. This indicated that in order to put silver into the galena structure, you needed an equal amount of antimony or bismuth to be present at high temperature. This process is called a “coupled substitution”. Understanding exactly how this happens had to wait for more magnification. It did explain why ore deposits associated with molten magmas (like black smokers) contain abundant silver and sedimentary types do not: Sedimentary deposits don’t contain much antimony or bismuth.

If the microscope lens and sample are immersed in oil, less distortion is produced, allowing clear images with even higher magnification. Studies of silver-rich galena using oil



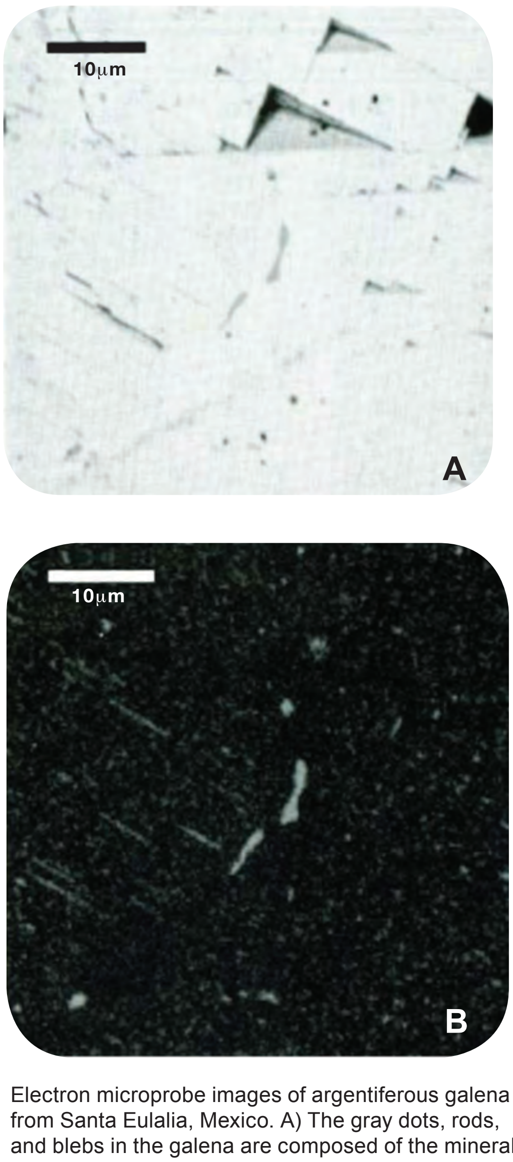
“Silver-bearers” in a galena crystal magnified 550x by an oil immersion lens. Light bent through a lens gets more distorted at higher and higher magnification. By using oil that covers both the lens and sample, the light does not get bent as strongly, and you can use greater magnification before distortion destroys the image. This marks the limit of standard optical microscopy. *Image modified from Ramdohr 1969, The ore minerals and their intergrowths, 3rd ed., Pergamon Press, New York, 1,174 pp.*

immersion lenses revealed “dots and rods” of minerals, but they were still too small to positively identify. These dots and rods were specifically oriented within the galena crystals, and petrologists (scientists who specialize in the study of rocks) of the day called these rods “silver-bearers.” The petrologists were left to guess what the rods were made of, but they correctly theorized that they contained the silver.

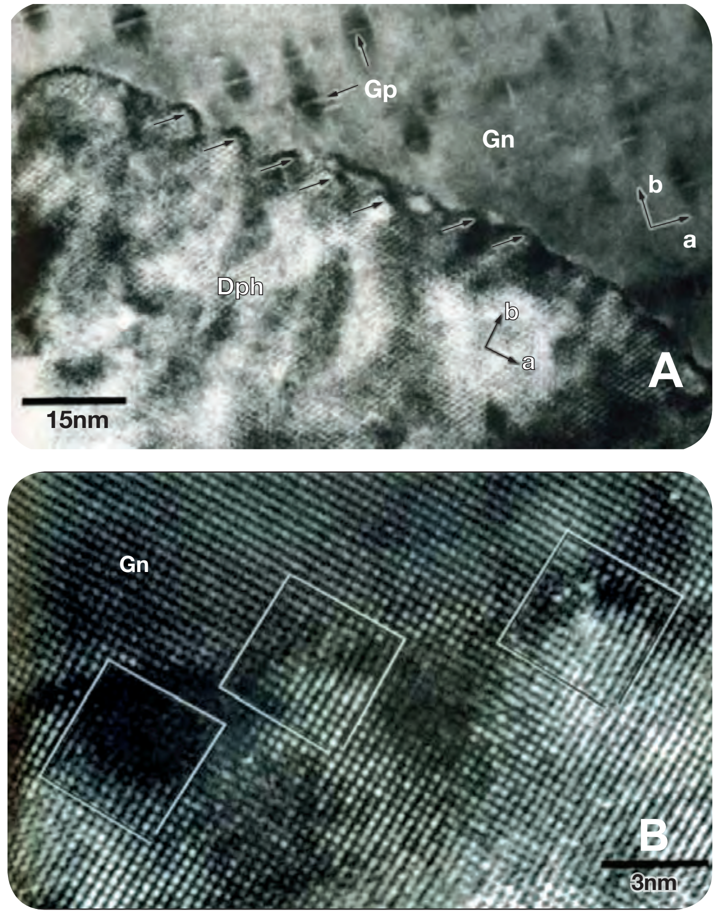
In the late 1950s–1960s, electrons and X-rays came to the magnification “rescue” when scanning electron microscopes and electron microanalyzers were invented. These machines use electron beams, allowing scientists to look more closely at the “silver-bearers.” These instruments allowed the compositions of the rods to be analyzed, which indicated that the amount of silver in the rods is equal to the amount of antimony or bismuth, just like the experimental studies found. Because very small spots could be analyzed and the compositions matched known minerals, the “silver-bearers” could be positively identified, in some cases, as the mineral diaphorite ($Ag_3Pb_2Sb_3S_8$).

Transmission electron microscopes also use electron beams, but they are used to produce the shadows made by atoms, allowing researchers to image structures at the atomic scale. During this analysis, individual atoms and crystal defects can be seen but only in one plane on a very thin sample. Various orientations of the sample are required to see in three dimensions—a technique called “electron crystallography.” In our example, we can see how diaphorite fits into the galena crystal lattice with very little deformation. At higher temperatures of crystallization, these elements fit randomly in the galena. At lower temperatures, the silver and antimony unmix, or exsolve, from the galena, like oil and water. This process is called “exsolution.” The diaphorite forms only in places where it best fits into the galena crystal, which is only along certain crystal directions. This is why the rods are lined up.

The mystery of argentiferous galena was solved after almost three centuries of advances in magnification technology. The next step is “seeing” the interactions of electrons between bonded atoms, something we are just now studying using mass accelerators. The frontiers of magnification continue to be explored at smaller and smaller size scales not only to understand natural materials, but also to allow us to fabricate better materials for our increasingly technological society.

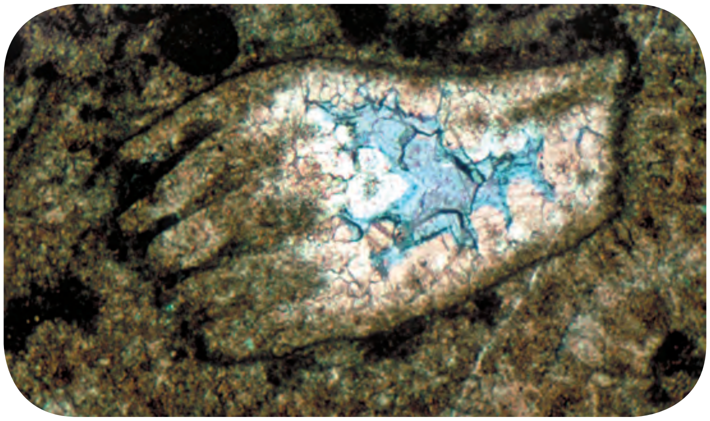


Electron microprobe images of argentiferous galena from Santa Eulalia, Mexico. A) The gray dots, rods, and blebs in the galena are composed of the mineral diaphorite ($Ag_3Pb_2Sb_3S_8$), which contains equal amounts of silver and antimony. B) Silver X-ray map highlighting the “silver-bearer” shown in A now seen as the bright areas. Scale is in microns (µm) *Author figure.*

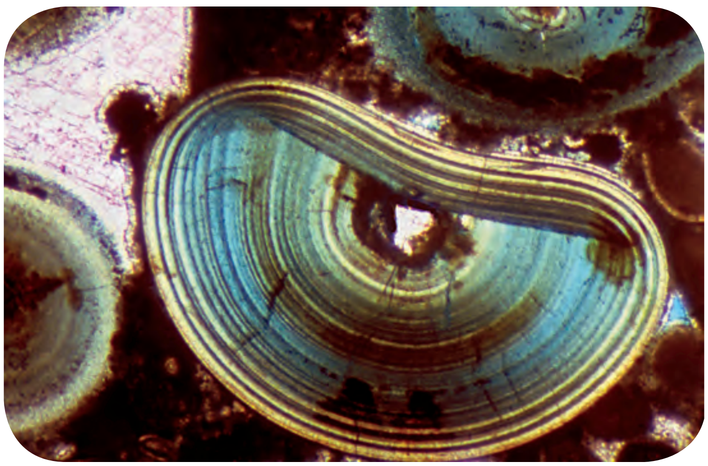


High-resolution transmission electron microscope images of argentiferous galena from Mexico illustrating how diaphorite fits in the galena structure. Bright areas correspond to areas of no or few atoms (i.e., holes) and dark areas are the shadows where atoms block the beam from passing through. A) Notice the “jagged” yet uniform interface between the diaphorite (Dph) and galena (Gn) and how closely the two structures “line up.” This is an indication of how well the diaphorite fits into the structure. B) Close-up of the interface and how the structures of the two minerals follow completely across the interface with very little deflection, again corresponding to a good fit among the atoms. Scale is in nanometers (nm). *Figure modified from Sharp, T.G., and Buseck, P.R., 1993, The distribution of Ag and Sb in galena: Inclusions versus solid solution: American Mineralogist, v. 78, pp. 85–95.*

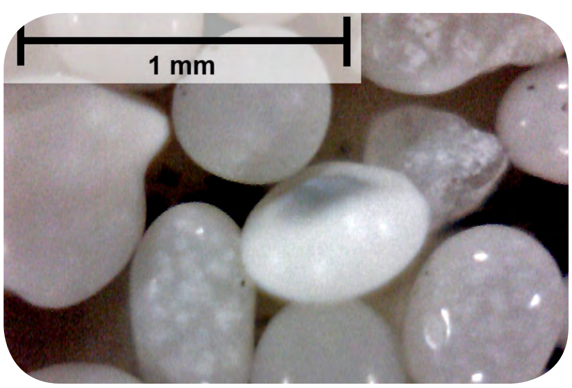
Photo Gallery



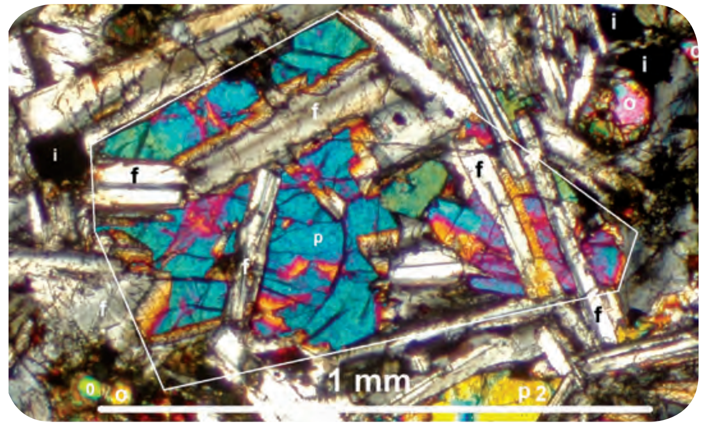
This unidentified shell from a 200-million-year-old rock formation from Greenland has been thinly sliced (called a thin section) so light can be transmitted through it like a window, revealing minute details. This image from an optical microscope is of an area approximately 2 millimeters (mm) wide. *Image courtesy of Peter Scholle and Dana Ulmer-Scholle.*



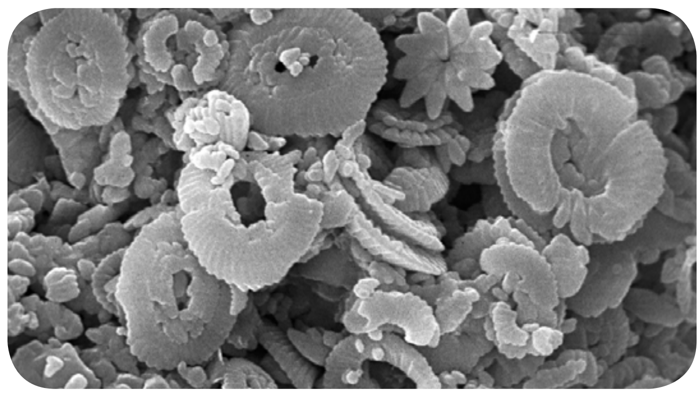
Ooid thin section, Russia. The ooid is approximately 1 mm across. An oolite, or ooid, has a shell of concentric layers of calcium carbonate that precipitated around a nucleus or central core. The nucleus is usually a tiny brine shrimp, fecal pellet, or a mineral fragment. This image shows an ooid that developed many concentric layers, was broken, and then grew further with additional layers. *Image courtesy of Peter Scholle and Dana Ulmer-Scholle.*



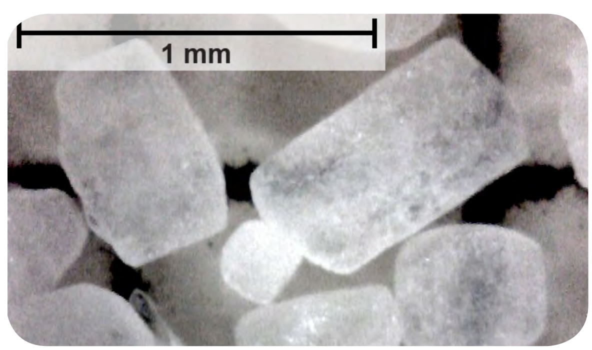
Oolitic sand, Great Salt Lake, Utah. Oolites form in shallow, wave-agitated water, rolling along the lake bottom and gradually accumulating more and more layers. *Image courtesy of Susie Welch using a digital optical microscope.*



Basalt thin section, New Mexico. Here, thin section colors are created by light polarizing filters. Ophitic texture is the association of many slender lath-shaped crystals of plagioclase feldspar (f) embedded in, or partially embedded in, large single crystals of pyroxene (p). When viewed in three dimensions, pyroxene crystals are multifaceted prisms. A thin white line shows the projected boundaries of the 1-mm-long pyroxene crystal. Some feldspar crystals (on right) clearly extend outside the boundaries of the blue pyroxene crystal. Essentially all of these crystals were formed rapidly at the surface of the earth as the very hot lava flow was quenched against the cold ground surface. *Image courtesy of Virgil W. Lueth, information courtesy of Richard Chamberlin.*



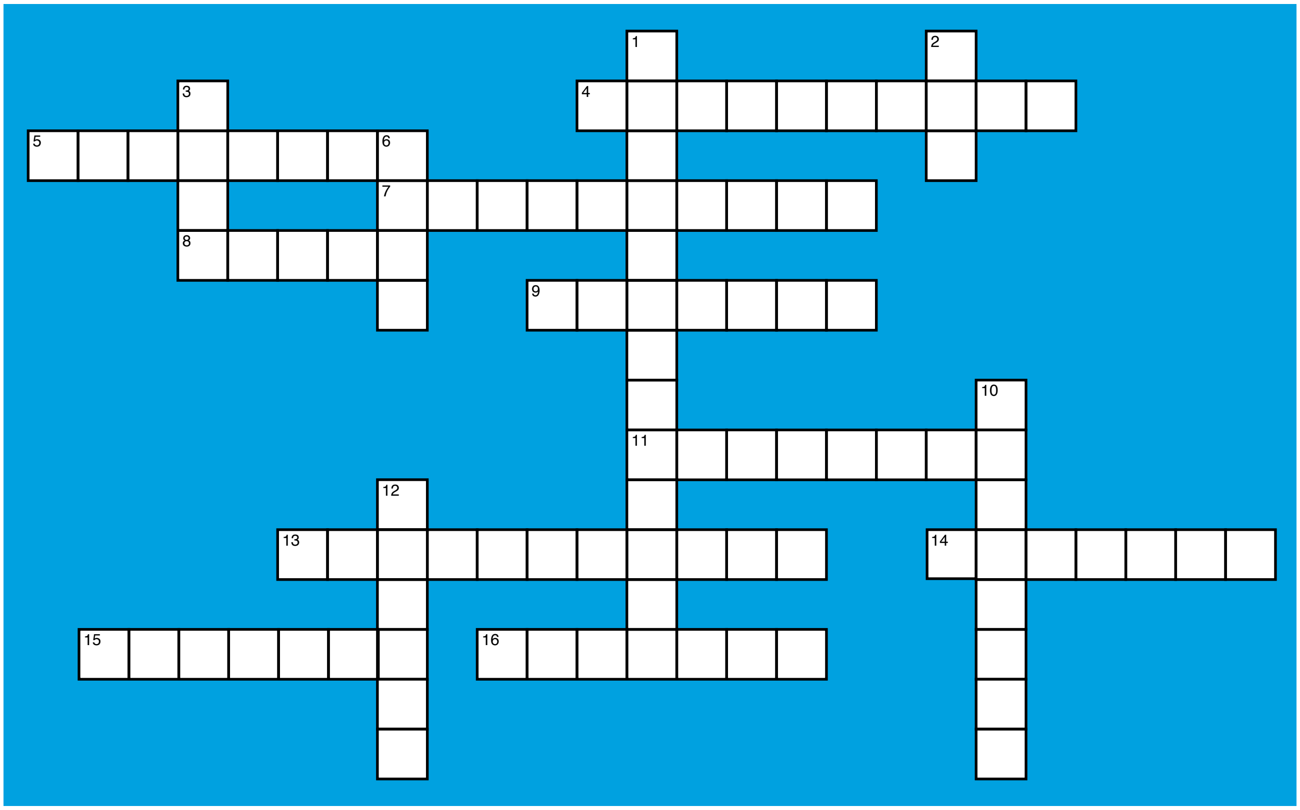
Chalk composed of North Atlantic Ocean floor ooze. This image, taken with a scanning electron microscope (the image is of an area approximately 22 microns across), shows coccoliths, which are extremely tiny plates and shell fragments formed by certain marine algae. *Image courtesy of Peter Scholle and Dana Ulmer-Scholle.*



Sand composed of gypsum particles from White Sands National Monument, New Mexico. This wind-blown dune sand is well sorted, and even though the grains are rounded due to erosion, the original gypsum crystal shapes are evident. *Image courtesy of Susie Welch using a digital optical microscope.*

Crossword Puzzle

Douglas Bland and Virgil W. Lueth



Across

4. collector of sand
5. metamorphosed
7. 8-sided shape
8. to melt ore
9. type of microscope
11. type of microprobe
13. hydrothermal fluids flowing into sea water
14. element found with silver in galena, Bi
15. unmix
16. a cube of galena is this

Down

1. ore that contains silver
2. substance that reduces distortion of a magnified image
3. “silver-bearers”
6. more“silver-bearers”
10. element found with silver in galena, Sb
12. mineral containing lead, PbS

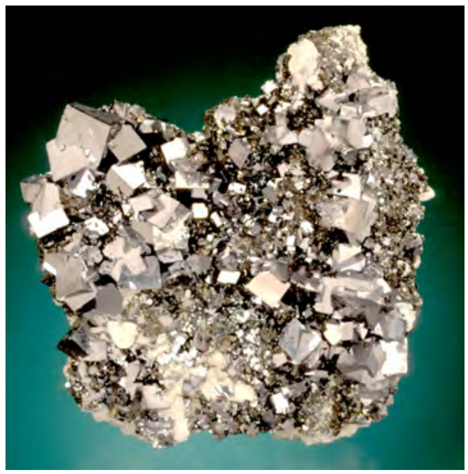
The answers to the clues (with one exception) are found in the Argentiferous Galena article in this issue of *Lite Geology*.

The solution to the puzzle is found on the last page of this issue.

New Mexico's Most WANTED MINERALS

Virgil W. Lueth

GALENA



A three-inch tall mass of cubic galena crystals, with lesser amounts of the minerals quartz (light gray) and sphalerite (black), from the Groundhog mine, Grant County, New Mexico. *Photo courtesy of Jeff Scovil, New Mexico Bureau of Geology museum specimen #15296.*

DESCRIPTION: Galena has a very bright, eye-catching metallic gray luster. The most common crystal shape is a perfect cube. More rarely it is found as cubo-octahedrons or as octahedrons. The mineral's perfect cubic cleavage, the same as table salt, mimics the cubic crystal shape. It is relatively soft, with a Moh's Hardness between 2.5 and 2.75, so it can be scratched easily with a metal point. It has a dark-gray streak when tested on unglazed porcelain, such as the back of a piece of tile.

WANTED FOR: Galena is the most common source of lead. Lead is one of the oldest metals used in human culture with some lead products dated from 7,000 B.C. Most lead is used in batteries, castings, chemical pigments, and alloy metal (most commonly as solders in electronics).

HIDEOUT: Galena is one of the most common minerals found in metallic ore deposits associated with hydrothermal (hot water) activity. It is found in deposits associated with magmas and in sedimentary deposits.

LAST SEEN AT LARGE: New Mexico has many ore deposits, and most of them contain galena. Look on old mine dumps (don't ever enter a mine opening, they are very dangerous) for shiny silver sparkles. You might confuse galena with hematite, but the perfect cubic cleavage and a dark-gray streak test will quickly solve your problem (hematite commonly forms flakes and has a red-brown streak). In some mines, galena crystals can be a large as automobiles, but most of the time they are less than an inch in size.

ALIASES: Galenite, Lead Glance.

Classroom Activity Susie Welch and Virgil W. Lueth

LARGER THAN LIFE: MAGNIFICATION OF SAND

Grade Level: Grades 5–8 and 9–12

NM Science Standards: See Supplementary Materials

Objectives

Students will:

1. Explore samples of sand from different localities without magnification, and then examine the same sands at several magnifications.

2. Make and record observations describing what the enhanced details of the magnified images reveal about the composition, texture, and ultimately the source of the materials.

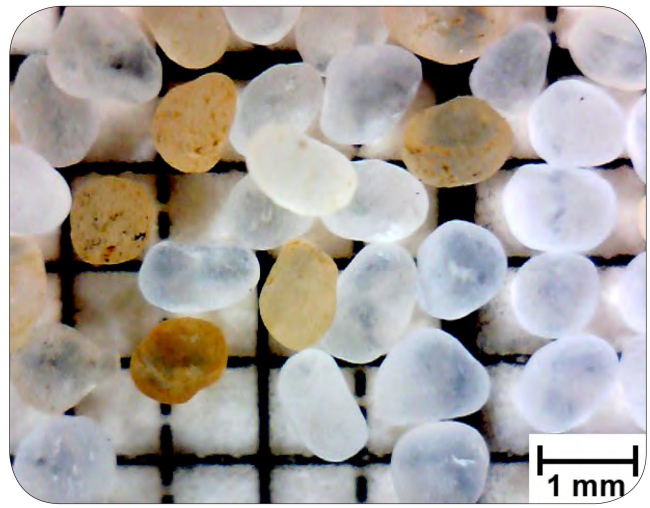
Background

Sand is defined as granular material with grains that are smaller than gravel but larger than silt, between 2 millimeters and 0.0625 millimeters in diameter. Sand is created by the disintegration of rocks or minerals through weathering processes such as chemical reactions, freezing and thawing, and abrasion by wind or water. Sand particles can be transported away from their source rocks by wind or water, which continues to wear the particles into characteristic rounded shapes. Immature sand is one that is freshly weathered and has not been transported far, so the grains retain much of the original mineral shapes, typically have sharp, angular edges, and have larger average sizes. Mature sands are typically of uniform size, finer grained, and spherical (this is because spheres represent a geometry of minimum surface area).

Wind-transported deposits—A sand particle that has been windblown for a considerable distance will tend to have a higher degree of roundedness than one transported by water, and may have a frosted appearance on its surface (think of sandblasting). These particles will also be smaller and well sorted, of similar size. This is because the larger, heavier grains tend to remain in place while the lighter ones are carried away by the wind.

Water-transported deposits—Water-deposited sands commonly have a wide range of particle sizes within the deposit, which is described as a poorly sorted deposit. However, particle sizes of water-deposited sands reflect specific conditions of transport and deposition (think energy)—from well-sorted sand in migrating ripples in a stream to poorly sorted sand in a turbulent flood deposit. Beach sands tend to be well sorted, but the size of the grains will change as conditions vary from the gentle lapping of small summer-time waves (small grains) to roaring surf in winter-time storms (large grains).

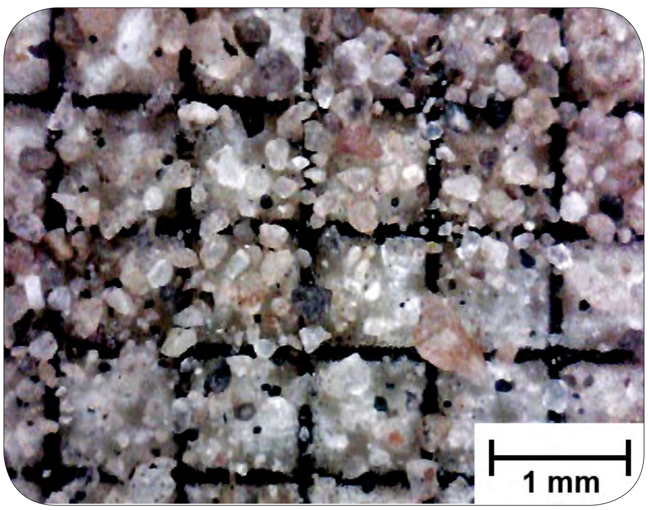
Examining sands from a variety of deposits can be useful in comparing the source (provenance) and transport history of the different materials. These sands may appear similar without magnification. However, viewing the sands with a hand lens, digital scanner, or microscope will reveal clues about their origin, and, in many cases, the journey from their source to the location where the sand particles were found.



Example of a frosted, well-rounded, and well-sorted sand, which is typical of a wind-transported deposit. This Ordovician-age sand is from the St. Peter Sandstone in La Salle County, Ottawa, Illinois.

This immature sand, or grus, formed from crumbling granite. It has not been transported away from the base of the granite boulder where it was collected. It shows no signs of being worked by either wind or water and is very poorly sorted, with very angular grains. Sample is from the base of the Sandia Mountains, Albuquerque, New Mexico.

This Rio Salado stream deposit sand is poorly sorted, with angular grains. Sample is from the Rio Salado west of I-25 and the area where the Rio Salado dune sand was collected.



This Rio Salado dune sand has well-sorted, tiny grains, and is typical of a wind-transported sand. The grains are only slightly rounded compared to the Ordovician sand, indicating less erosion and shorter transport. Sample is from the dunes near the rest stop on I-25 just north of the Rio Salado, Socorro County, New Mexico.

Method overview

Samples of various sand grain materials will be viewed first with the unaided eye, then at different levels of magnification starting with a hand lens, which typically magnifies the image about 10 times, or 10x. For greater magnification, a flatbed document scanner or digital microscope is used. The digital images can be projected for students to view and study.

Materials:

1. Sand samples—Gather samples from as many different sources and locations as possible, such as sand from beaches, rivers, lakes, anthills, deserts, gravel pits, dunes, and even play sand or blasting sand sold at home improvement stores. Be creative about finding interesting samples to magnify. Document the location and environment of the sand deposit, along with the date when it was collected.

2. Hand lens

3. Either a **digital microscope** or a **flatbed document scanner** with a high resolution along with a computer to process the scanned images.

4. Template for scale to be scanned with the sand sample (see supplementary materials for download).

5. Observation chart for making observations (see supplementary materials).

6. White paper for displaying samples for unmagnified and low magnification observation.

Method

On the observation chart, record the sample names before beginning.

Unmagnified and low magnification observations:

For each of the following observations, look for these characteristics: color, size, shape, markings on the grains, how uniform the size and shape of the grains are, and other features.

1. Prepare each sample by spreading a small amount on a white piece of paper.

2. Using your unaided eye, view and make observations about each sample. Record your observations on the chart.

3. Using your hand lens, view and make observations about each sample. Record your observations on the chart.

Digital scanner or microscope magnification observations:

Using a digital scanner—Place an acetate scale template, if using, on the flatbed scanner glass. Carefully place the sample grains on the template to cover a 2cm^2 area so that grains are close to the scale marks on the template. Cover the samples with a piece of clear acetate and close scanner lid. Select a high resolution setting and scan the sample.

Using a digital microscope—Place a sand grain sample on the scale template, if using, and collect images at a high magnification setting.

Save the scanner or microscope images in a gallery and explore image processing options, such as further magnification or image enhancement. Compare the digital images of each sample. Make observations and record on your chart.

Consider the following questions:

Questions:

1. How would you describe the grains in this sample?

2. What are the average sizes of the grains (remember your magnification!)

3. Are the grains well sorted (mostly the same size, typical of wind-deposited sands) or poorly sorted (various sizes, more typical of water-laid deposits)?

4. How can you tell if the sand grains are shaped by wind or water action?

5. Can you assume that the sand found at a particular location was formed locally? Why?

6. Can you see any crystal structure evident in the grains?

7. How many different minerals do you think are present in the sample?

8. If grains are sharp and angular, what does this angularity tell you about the minerals contained in the grains?

9. Are you an arenophile (someone who collects sand)?

Expanded inquiry

What other substances or materials can you think of to explore through magnification? Examples of different materials to examine might include soils, fossils, diatomaceous earth, chalk, table salt, and dust. Other ideas: Sugar vs. salt, rocks, leaves, sliced fruit, your hand, hair, feathers, etc. You can also check for the presence of magnetite by running a magnet under the paper containing the sand sample. Magnetite will collect against the paper.

Supplementary materials:

Links to a **chart for observations** and a **template for a scale** (to be printed on acetate) in downloadable Pdf format are found on the Sand Magnification exercise page at:
http://geoinfo.nmt.edu/education/exercises/sandmag

New Mexico Science Standards—Strands and Benchmarks

Strand 1: Scientific Thinking and Practices

Standard 1: Understand the processes of scientific investigations and use inquiry and scientific ways of observing, experimenting, predicting, and validating to think critically.

Grade 5–8 Benchmark I: Use scientific methods to develop questions, design and conduct experiments using appropriate technologies, analyze and evaluate results, make predictions, and communicate findings.

Grade 9–12 Benchmark I: Use accepted scientific methods to collect, analyze, and interpret data and observations and to design and conduct scientific investigations and communicate results.

(*Source: August 2003 Public Education Department Science Content Standards, Benchmarks, and Performance Standards*)

Other resources

Colorful and artistic collection of magnified sand grains:
http://www.sandgrains.com/Sand-Grains-Gallery.html

Sample lessons on sand from the U.S. Forest Service:
http://www.fs.fed.us/outdoors/nrce/iye/unique/chdunes.pdf

Sample lessons on comparing minerals and soils under magnification using the **ProScope Digital USB Microscope**:

Lesson using mineral samples:
http://www2.vernier.com/sample_labs/BD-PS-mineral_matters_es.pdf

Lesson using soil samples:
http://www2.vernier.com/sample_labs/BD-PS-analyzing_soil.pdf

Additional content by Patty Frisch, Dave Love, Douglas Bland, Ed Munsell, Carla Burns, Becky Kerr, Leo Gabaldon.

Through the Hand Lens Susie Welch

PROFILE OF A NEW MEXICO EARTH SCIENCE TEACHER

Sarah Wilson teaches 9th grade geology at Sandia Preparatory School in Albuquerque, New Mexico. Sarah began her teaching career in the public schools and taught at Eldorado High School for 27 years before joining the faculty at Sandia Prep in 2006. While working for the public schools, Sarah pursued her fascination with earth and planetary science by participating in field courses offered by several universities and space science organizations. As a graduate student in the Masters of Science for Teachers (MST) program at New Mexico Tech, she studied paleontology, geology, seismology, and mining. In addition to exploring and developing curricula about the Rio Grande rift near home, Sarah has traveled extensively around the state to study the geology of places including the Bisti Badlands, El Malpais volcanic field, Carlsbad Caverns, and the Valles caldera. Some out-of-state geology adventures include trips to Hawaii, Alaska, Utah, Wyoming, Texas, Colorado, Washington, and Arizona.

Sarah Wilson on the Mt. St. Helens caldera rim with Spirit Lake and Mt. Rainier in the background. *Photo courtesy of Sarah Wilson.*

As a teacher representative through the University of New Mexico, Sarah served with a team of scientists to develop the Grand Canyon Trail of Time in Arizona, (**http://tot.unm.edu**), which recently opened to the public. In a joint project with JPL, NASA, and UNM, she gained field experience in a program called The Great Desert: Geology and Life on Mars and in the Southwest, which included stops at the Grand Canyon and the great Meteor Crater in Arizona, as well as the Jemez Mountains volcanic field in New Mexico. Not just a geologist, Sarah is an adventurer, too. Studying geology in the field has involved hiking, backpacking, river trips, and even walking out onto the volcanically active area around Pu'u Oo on the island of Hawaii. She has spent time studying the unique geology at Mt. St. Helens volcano where she climbed to the top of the volcano. In preparation for her role with the Outdoor Leadership Program at Sandia Prep, Sarah took the 80-hour Wilderness First Responder course at the Grand Canyon.

Educational background:

- Bachelors of University Studies at University of New Mexico, 1977
- Coursework in the Masters of Science for Teachers program at New Mexico Tech
- Specialties in teaching: Geology, with a focus on field instruction

How did you decide to become a science teacher? I grew up with a mother who taught high school science in a small private school, so she had a big influence on my decision to teach science.

When did you fall in love with geology? I have always loved being outdoors so geology was the thing I was exposed to when I was hiking.

Did you have a teacher or professor who inspired you to learn about geology? When I was taking MST courses, Dr. Bill Chavez at New Mexico Tech was the professor from whom I learned the most.

How easy is it to network with professionals in the scientific community to support science teaching in New Mexico? You can find whatever you need by just calling one of the university science departments. If their faculty doesn't have the expertise, they can refer a teacher to an expert in that field. Also, being part of the state-wide science listserve that posts science resources is a big help. Anyone can subscribe to the list and then post or receive announcements by visiting the Web site at:
http://lists.aps.edu/cgi-bin/mailman/listinfo/science

Are you aware of any of your former high school students who went into science or engineering? Yes, several of my students went into science, and one female student became a NASA engineer and worked on the space shuttle program.

Why is it important for students to learn about earth science? Students go through a huge growth curve when they enter geology as a 9th grader. They initially think the class will be about rocks, but as the year progresses they begin to put the entire picture together with all the topics covered from plate tectonics, rock cycles, structure, volcanology, mapping, and paleontology. They come out of the class with a solid understanding of geology that gives them the basis for understanding biology, which they study next. When environmental issues are discussed, including climate change, they actually have the science background to understand this.

What is your favorite activity in earth science? With the small class size at Sandia Prep I can take my students on several field trips during the year. We take advantage of the geology that is right outside of our classroom. One unit is the field trip to the Albuquerque volcanoes. This is a large unit and includes preliminary discussions on volcanology, igneous rocks, plate tectonics, and rift systems. It includes pre-field trip prep, taking field notes, observations, and analysis during the three hours in the field. Post-field trip work involves drawing a cross section of the Rio Grande rift. Students also model eruptions of the volcano flows, followed by core sampling, measurements, and mapping.

The supplementary materials (listed below) for this activity are available through Pdf links on the Albuquerque Volcanoes Field Exercise home page: **http://geoinfo.nmt.edu/education/exercises/ABQvolcano**

- Materials and instructions
- Field notes form
- Geologic map
- Cover sheet for report
- Sample cross section by student

What is your favorite Web link? I like the New Mexico Museum of Natural History and Science at: **http://www.nmnaturalhistory.org/**

What are your favorite resources? For teaching geology in New Mexico, the actual structures around us are some of the best resources. Local geologists, other teachers, and college professors are always great resources too.

Do you have any advice or suggestions for other earth science teachers? Experience what you are teaching before you teach it. Go out in the field and know what is in the area that represents each topic that is covered in class. Connect the students to the local geology and then go global. Do as much hands on lab work as you can. Make sure all the basic lab skills are practiced in many different ways. Application and analysis are critical. Be passionate and have fun.

Sandia Prep students on a field trip to the Albuquerque volcanoes. *Photo courtesy of Sarah Wilson.*

What is your favorite geologic feature in New Mexico? I have many favorite geologic features, such as the Valles caldera in the Jemez Mountains, Sandia Mountains, the Rio Grande rift, the El Malpais area, Tent Rocks, Taos canyon, and White Sands.

Another important use of magnification is to peer deep into space with telescopes to explore the universe. The Kepler space telescope magnifies light from distant stars.

The following job opening announcement is fictional, but the information about the Kepler space mission is true.

Job Opening:

Date: June 1, 2012

Geologist wanted to explore earth-like planets that may host life

The U.S. National Aeronautics and Space Administration (NASA) is looking for a geologist to join a team of scientists and engineers who will study Earth-like planets orbiting nearby stars in the Milky Way galaxy. The goal of this project is to analyze data collected by the Kepler and James Webb space telescopes and other sources, and design a deep-space probe that will travel to one or more planets that may harbor life.

Background information on the mission

For centuries humans have wondered if we are alone in the universe. Are there other intelligent beings beyond Earth, or even primitive life forms of some kind? Until recently we had no way to find planets beyond our solar system that might have the right conditions for life as we know it to evolve. Now, for the first time in history, astronomers have found such planets. Some scientists call this the most important scientific discovery of the past century. The first confirmed extra-solar planet, or exoplanet, was discovered in 1995 when astronomers detected a wobble in the motion of the nearby star 51 Pegasi, located in the constellation Pegasus. The wobble is caused by the gravitational tug of the planet. Between 1995 and 2010, more than 500 other planets were discovered. The easiest to find are very large and close to their sun, which means they are very hot. Because many of them are similar in size to Jupiter, the largest planet in our solar system, they are called "hot Jupiters."

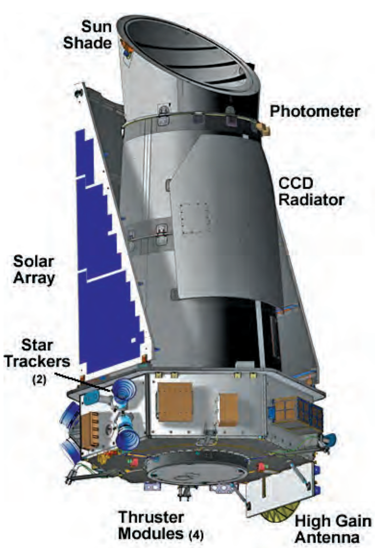


Image courtesy of NASA.

The next step was to find rocky planets more like Earth.

In 2009 NASA launched the Kepler space mission. Its goal is to locate planets that orbit their stars in the habitable zone, meaning at a distance where planet surface temperatures allow liquid water to exist. An orbit too close to the star would make it too hot, and an orbit too far away would leave it too cold. To have liquid water, it must be in the "Goldilocks zone." To find them, the Kepler space telescope searches for planet signatures by measuring tiny decreases in the brightness of a star caused by a planet passing in front of it, an event known as a transit.

On February 1, 2011, NASA announced that Kepler had identified 1,235 new potential planets based on the first four months of observations of a planned three-year mission. Additional ongoing observations by Kepler and other telescopes are needed to confirm these planets, but NASA expects the vast majority will be confirmed. Of these planets, 68 are approximately Earth-sized, and 288 are so-called "Super Earths," meaning they are as much as twice the size of Earth. Larger planets are likely to have a very thick hydrogen-helium atmosphere similar to Jupiter or Neptune, rendering them uninhabitable. Of these discoveries, 54 are in the "Goldilocks" habitable zone, and five are near Earth-sized. However, even large planets in the habitable zone may have moons that contain liquid water and life. Scientists expect to find many more such planets as the mission continues. The James Webb space telescope, currently scheduled for launch in 2015, will help to identify additional planets near us. It will be able to determine the components of their atmospheres, which will indicate which ones are most likely to support life.

Job requirements

The geologist on this team will use knowledge of geologic processes on Earth such as plate tectonics, volcanism, and the weathering cycle of rocks to investigate similar processes on exoplanets. A geologist's unique understanding of how these processes play out over billions of years of planetary evolution, using the 4.6-billion-year history of Earth as an example, is essential. The successful applicant will help determine which planets should be explored by the spacecraft, and will choose or design instruments most useful for gathering geologic data throughout the voyage. Minimum job requirements include a Ph.D. in geology, or a M.S. in geology plus five years work experience in a related field. Experience in extraterrestrial geology is highly desirable.

Would you like this job, and would you qualify?

New Mexico's Enchanting Geology

Douglas Bland

WHERE IS THIS?

Photo courtesy of U.S. Bureau of Land Management

The Organ Mountains form a stunning spine of jagged spires on the eastern skyline of Las Cruces, New Mexico, that soar almost a mile above the Rio Grande valley to the west and the Tularosa Basin to the east. They are part of a 150-mile-long range of mountains that extends northward from El Paso, Texas. Shown here are the Rabbit Ears, elevation 8,150 feet, in a section called the Needles. About 33 million years ago, a large volcanic caldera formed when eruptions created deposits of ash-flow tuff. Some of the magma remained in the magma chamber below the surface, and it cooled and crystallized into a rock called quartz monzonite. Later, tectonic forces associated with the Rio Grande rift uplifted these rocks and turned the caldera on its side. The rocks are now exposed at the surface due to erosion by wind and water. Today you can walk through the ash-flow tuffs found on the eastern flank of the Organ Mountains, down through the floor of the caldera, to the frozen remains of the magma chamber that form the Rabbit Ears. The monzonite is composed mostly of impressive gray and white crystals of the minerals quartz and feldspar. The hot desert landscape at the base of the mountains gives way to spectacular steep-walled canyons filled with abundant wildlife, towering trees, and springs. Hiking and rock climbing are popular activities.

The Needles are located 10 miles east of Las Cruces, but can be seen for many miles in all directions. Recreational access on the east side of the range is available from Aguirre Springs Road, and from the west on Dripping Springs Road.

Short Items of Interest to Teachers and the Public

THE MINERAL MUSEUM ON THE CAMPUS OF NEW MEXICO TECH IN SOCORRO, NEW MEXICO

Hours:

8 a.m. to 5 p.m., Monday through Friday

10 a.m. to 3 p.m., Saturday and Sunday

Closed on New Mexico Tech holidays

The Mineral Museum is located in the Gold Building on the campus of New Mexico Tech in Socorro. The bureau's mineralogical collection contains more than 16,000 specimens of minerals from New Mexico, the United States, and around the world, along with mining artifacts and fossils. About 2,500 minerals are on display at a time.

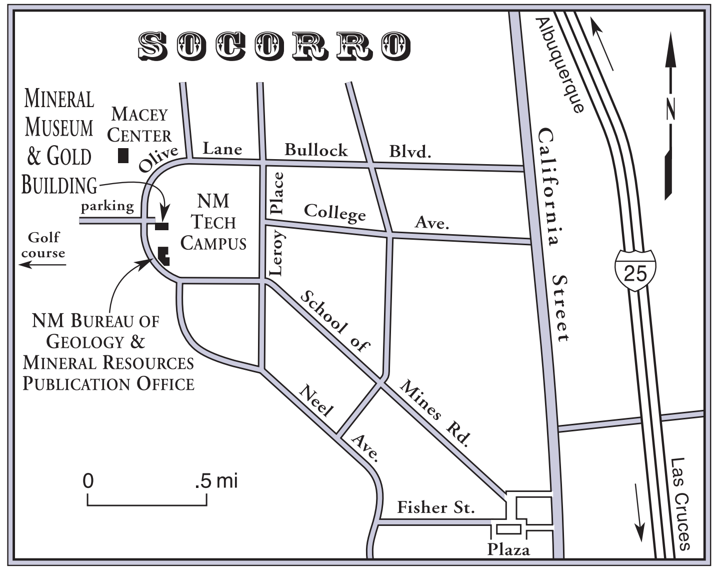
For teachers and other groups, we offer free tours of the museum. We like to show off our home state minerals, as well as give students an idea of how minerals end up in products we use every day. Museum staff can also identify rocks or minerals for visitors. Please call ahead to ensure someone will be available. For more information on the museum, please visit our Web site at: **http://geoinfo.nmt.edu/museum/**

Dr. Virgil W. Lueth
Senior Mineralogist and Curator
vwlueth@nmt.edu
575-835-5140

Bob Eveleth
Senior Mining Engineer and Associate Curator
beveleth@gis.nmt.edu
575-835-5325

To schedule a tour, contact:

Susie Welch
Manager, Geologic Extension Service
susie@nmt.edu
575-835-5112



THE PUBLICATION SALES OFFICE AT THE NEW MEXICO BUREAU OF GEOLOGY AND MINERAL RESOURCES ON THE CAMPUS OF NEW MEXICO TECH

Open 9 a.m. to 4 p.m. (closed for lunch from 12 to 1), Monday through Friday.

Call 575-835-5490 for phone orders or information, or visit our Web site at: **http://geoinfo.nmt.edu/publications**

The Publication Sales Office has many resources for teachers, including publications on New Mexico's geology. Many are written for the amateur geologist and general public.

We offer:

- Topographic maps for the entire state of New Mexico
- Geologic maps for selected areas of New Mexico
- U.S. Forest Service maps
- A 20% discount for teachers

UPCOMING EVENTS FOR TEACHERS AND THE PUBLIC

Rockin' Around New Mexico

July 5–8, 2011

Location: Jemez Springs, Valles Caldera National Preserve Science Education Center

Teachers will explore the geology around Jemez Springs and the Valles caldera in the Jemez Mountains. Topics will include the geologic history of the area, discussions on volcanic and seismic hazards, and safety awareness. An optional one hour of graduate credit through the Masters of Science for Teachers program at New Mexico Tech is available. Teachers can request an application to participate by sending an e-mail to **susie@nmt.edu**

National Earth Science Week

October 9–15, 2011

AGI invites you to take part in Earth Science Week 2011, which will encourage people everywhere to explore the natural world and learn about the geosciences. This year's theme "Our Ever-Changing Earth" will engage young people and the public in learning about the natural processes that shape our planet over time. Find out how to participate by visiting the Earth Science Week Web site at: **www.earthsciweek.org**

Space Mission Summer Camps for Kids

June, July, August 2011

Registration is open for summer space mission adventures for kids at the Challenger Learning Center of New Mexico. Simulated space missions are available for school aged students in grades 2–12. Check out the summer camp schedule at:

http://www.challengernm.org/summer-camp-programs.php

Missions for teachers and the public are offered as well. Visit the Challenger Learning Center Web site at:
http://www.challengernm.org/learning-communities.php?layer=community

Challenger Learning Center New Mexico is located at the Unser Discovery Campus at:

1776 Montaño Road NW
Los Ranchos de Albuquerque, NM 87107
Phone: (505) 248-1776
E-mail: info@challengernm.org

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