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In this issue...

Earth Briefs: Mudflows

Shari Kelley

MUDFLOWS are masses of saturated (thoroughly soaked) "mud" that move suddenly and rapidly downslope. Typically a mudflow is composed of at least 50% particles that are silt- to clay-sized and at least 30% water. Commonly, big rocks and trees are entrained as the muddy mass moves downhill. Mudflows are often called mudslides or landslides by the media. The generic term "landslide" describes a range of mass-wasting events, including rockfalls, debris flows and mudflows. Landslides have been categorized into 32 types based on the style of movement (fall, topple, slide, spread, flow, slope deformation) and the material involved (rock or soil).

The U.S. Geological Survey reports that mudflows have occurred in all 50 states in our country. Factors that enhance the formation of a mudflow are steep slopes, loose soil, and heavy rainfall or rapid snowmelt. Within the United States, mudflows are more likely to occur along the Pacific West Coast (Washington State, Oregon, California) and in the Appalachians, the Rocky Mountains and the Colorado Plateau. Storms triggered by El Niño have already caused numerous mudflows along the West Coast this winter season. Areas affected by large forest fires are particularly susceptible to mudflows. Mudflows are also common on steep-sided, active volcanoes that are composed of fine ash; these mudflows could be triggered by melting of snow during an eruption.

Because mudflows can cause devastating loss of life, scientists are working to develop warning systems so that neighborhoods can be evacuated before a mudflow strikes. One system built in England relies on acoustic sensors that detect vibrations as mud starts to move down-slope. Gravel in a steel pipe in a borehole on an unstable slope will amplify the high-frequency vibrations associated with the movement. The vibrations pass up the tube and are detected by a sensor at the surface. If the signal is consistent with mudflow movement, a warning is issued.

Another system that has been tested in an area burned by a forest fire in California uses a combination of weather forecasts and precipitation measurements made by the National Weather

Service and a regional rainfall rate thresholds established by the U.S. Geological Survey. Real-time data from mobile Doppler weather radar systems, rain gauges, topographic data, soil moisture sensors, surface runoff sensors, and video cameras are monitored during a storm. When combinations of these parameters exceed a critical threshold, a mudflow warning is issued to emergency managers in communities that might be affected. The warning system uses outlooks, watches, and warnings, to rate the threat -- much like weather forecasters use.

The U.S. Geological Survey has developed a long-term monitoring system on landslide-prone hills near San Francisco, California, using rain gauges and sensors that measure soil-moisture content and pore-water pressure. The instruments are connected to computers using near-real time telemetry. This network is not yet set up as a warning system, but instead is designed to answer fundamental scientific questions. Based on two years of data, these scientists have learned that rainfall intensity-duration thresholds are inadequate predictors of slope failure. Instead, the saturation of soil by storms that occurred prior to a big storm event is a more reliable predictor. Thus, both short- and long-term monitoring of rainfall and soil moisture content is needed to successfully predict mudslides.

So far, few successful predictions that saved lives have been made. Diligent monitoring of hillslopes in Switzerland using radar led to a road closure hours before the ground gave way. Hopefully with continued research, a reliable warning system for mudflows can be developed. Some current research in this area was highlighted in a 2014 NOVA show on PBS called "Killer Landslides." Until then, exercise caution and watch for warning signs (cracks in the ground, leaning trees) if you are around steep slopes during heavy rainstorms.

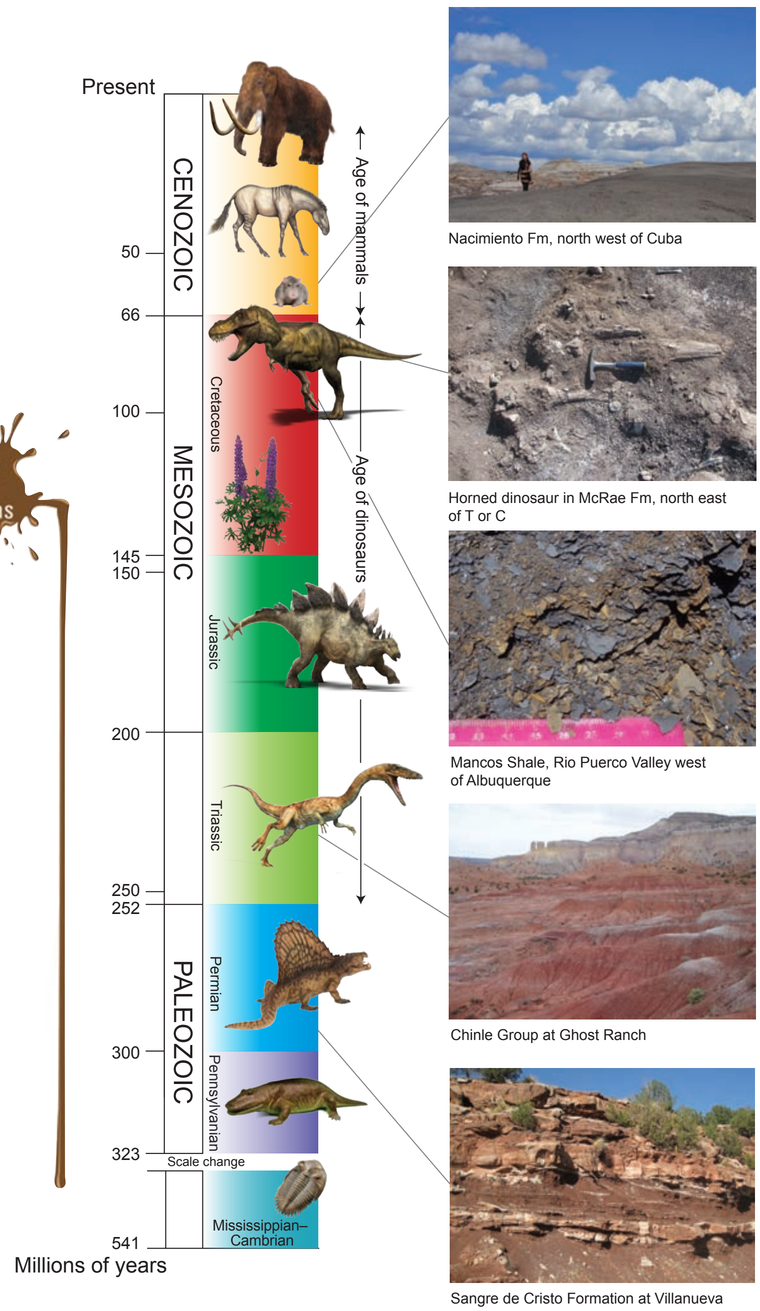
On the cover: Photograph of a mudflow that occurred in La Conchita, California in 2005. The flow took only eight seconds to move downhill, killed 10, and injured dozens. This area was known to be unstable for a decade prior to this event. The photo was taken by Gary Phelps of Ventura County Star (http://www.vcstar.com/news/la-conchita-a-timeline-ep-863804881-349502961.html).

THE MUDS OF NEW MEX- ICO

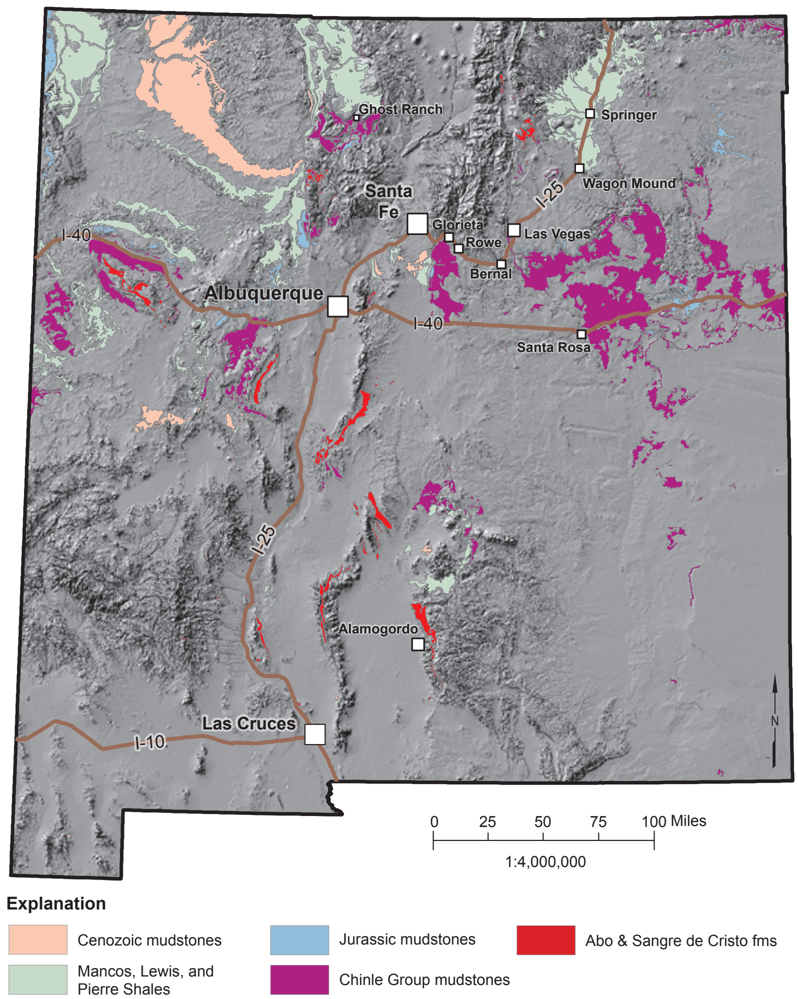
Dan Koning and Spencer Lucas

WE LOVE it when it snows in New Mexico, but hate the muck created when it melts. Slogging around in snowmelt and mud slush in early January got us thinking: where in New Mexico do folks have to deal with this goo every time the ground gets wet? Like so many of life's important questions, the answer can be found in geologic maps coupled with some keen observations. In this article, we will give a run-down of the locations and origins of muddy formations in New Mexico -- by "muddy" we mean a mixture of clay- and silt-size particles. Let's start with older rock formations well known for their mudstones, some of which are quite picturesque, and continue on to modern sediment (moving upwards on the accompanying geology time scale figure).

Mudstone rock formations are relatively few in the early part of the Paleozoic Era (541-252 million years ago), but become more common later on. Most of these geologically older mudstones tend to be grayish shales (hardened mud that breaks into thin plates) interbedded with limestones that were laid down on ancient seafloors. An exception to the grayish shales are the brick-red mudstones of the Permian Abo and Sangre de Cristo formations, which are ancient river deposits. You can see exposures of the Sangre de Cristo Formation along I-25 southeast of Santa Fe, between Glorieta and Rowe and farther on near Bernal (note these exposures, while nicely visible from the Interstate, are too small to plot on the accompanying geology map figure).



Photographs of noteworthy mudstones in New Mexico (right) and their ages on the geologic time scale.



Map of New Mexico showing locations of mudstone-rich rock formations.

Mudstones are common in the dinosaur-age rocks of the Mesozoic (252 to 66 million years ago). Those that formed earlier in that Era, in the Triassic, generally sport a maroon-red color and include formations in the Chinle Group. Those beautiful maroon-red rocks below the cliffs at Ghost Ranch, for example, belong to the Chinle Group. More of these reddish mudstones can be seen in the Santa Rosa area, although not from I-40. Mudstones belonging to the Jurassic Period (middle of the Mesozoic Era) tend to be various pastel shades of green, gray, and brown -- a good example of which can be seen 7 miles southeast of Las Vegas along I-25.

Now we come to the grand-daddy of all mudstones, a >500 ft-thick package called the Mancos and Lewis shales. These muds were deposited 96-71 million years ago on the floor of the Western Interior Seaway, the last ocean to extend across a sizeable portion of North America. In this sea swam ammonites, humungous sharks, and other scary, toothy sea creatures--whose shells, teeth and bones can be found in certain outcrops of this shale. Although not particularly beautiful, this shale is important for New Mexico in two ways: 1) it is a primary source rock for oil and gas in the San Juan Basin, and 2) it forms an aquiclude (a barrier to groundwater flow) where it is buried in the subsurface, commonly separating saltier water below from better-quality water above. This shale package can be observed along NM Highway 64 west of Farmington (at Waterflow) as well as along northern I-25 near Las Vegas, Wagon Mound, and Springer (where it is called Pierre Shale).

After the Western Interior Seaway retreated in the Late Cretaceous, muds were laid down in swamps and on river floodplains. Locally, these muds contain dinosaur fossils, which can be observed in the McRae Formation northeast of Truth or Consequences. Notable muddy formations that were laid down after dinosaur times (Cenozoic Era) include the Nacimiento Formation northwest of the town of Cuba. Younger reddish mudstones, interbedded with tan-yellow sandstones, are seen in the picturesque Garden of the Gods south of Santa Fe.

In geologically young times (within the past 10,000 years or so), muds eroded from older rock formations have been reworked by running water and deposited on floodplains of modern river valleys, including places where many of us live. Aside from the marine Mancos-Lewis shales, the mudstones associated with the much-older formations named above were deposited in a similar manner. Wind also carries and deposits clay and silt; these fine particles can then be incorporated into soils. A striking example of wind-blown clay and silt occurs periodically in Alamogordo when winds pick up enough fine sediment, including gypsum from White Sands, to darken the sky.

So, if you are subjected to gloppy, gooey clay after rains or snows, chances are you are living on a relatively young river floodplain, a high mesa where wind-blown clay and silt has been incorporated into older soils, or on one of the muddy formations shown in the accompanying geologic map. If you can't deal with the mud, use your indispensible friend, a geologic map, to find sandy formations or granitic bedrock on which to make your home.

Mud-amorphosis: The Metamorphic Journey of Mud

Matt Zimmerer

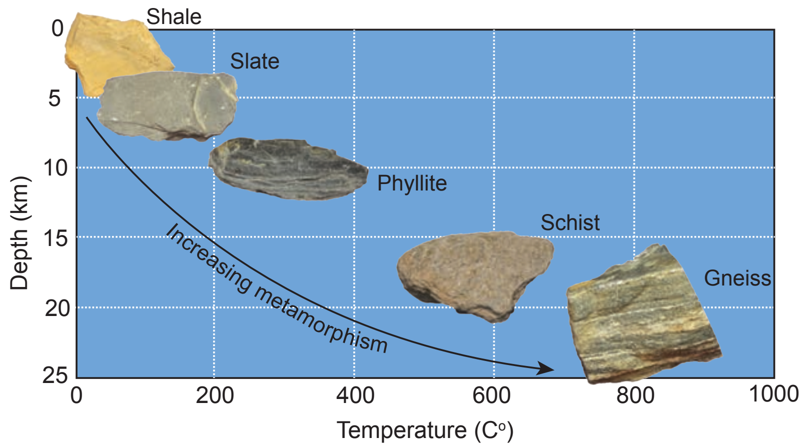


Diagram showing a hypothetical metamorphic path of mud and the approximate temperatures and pressures where each rock type forms. Courtesy of Matt Zimmerer.

DEEP WITHIN the mountain belts of Earth an amazing transformation is happening. This is where mud, the gloppy mixture of water and clay, turns into some of the most beautiful and complex rocks on our planet. In this environment of extreme heat and pressure, rocks are metamorphosed (meaning "to change form"). Metamorphism alters the minerals, textures, and sometimes chemical composition of an existing rock. This is the fascinating journey of mud to rock.

The journey starts with weathering of rocks exposed on the surface of the Earth. Sediment produced from weathering is transported in streams and rivers. During transportation, the coarse and heavy sediment is deposited first, eventually leaving only the finer sediment, such as silt and clay. The silt and clay are later deposited as mud on the floor of oceans and lakes. Compaction from overlying sediment turns the mud into a rock, known as shale or mudstone.

These rocks are transported from Earth's surface into Earth's interior because of plate tectonics. The Earth's crust is broken into about a dozen major plates, which are constantly moving (at about the rate your finger nails grow). Plates can slide beneath one another, called subduction, or crumple up to form large mountains. Both of these tectonic processes are capable of producing metamorphic rocks.

As a rock is moved deeper and deeper into the Earth, the temperature and pressure it experiences increases, and the mud/shale begins the process of metamorphosis. First, the shale is metamorphosed into slate. Slates are usually dark colored and display faint foliation; a preferred alignment of crystals that form in response to increasing pressure. The foliation of slate causes it to break into plates and this rock is commonly used as blackboards, flagstone, and tiles. With increasing metamorphism, the slate transforms into phyllite, a rock similar to slate but with larger crystals and more foliation giving it a glossy appearance. With increasing temperature and pressure the phyllite transforms yet again into a new rock called schist. Schist is easily recognized by its sparkly appearance. The platy crystals begin to grow large enough to see with the naked eye and the foliation takes on a wavy pattern (called schistosity). Finally, if the pressure and temperature continues to increase the schist will turn into gneiss (pronounced "nice"). At this point, the light and dark colored crystals have grown to a coarse grain size and segregated into bands. Continued increase in pressure and temperature may cause the rock to begin melting. Alternatively, uplift may stop the metamorphic process by reducing the temperature and pressure. Uplift of mountains may eventually expose the metamorphic rocks at Earth's surface. At the surface weathering starts to break the rocks down into mud and the journey begins again.

Hoodoo and Neva sporting a fresh coat of mud on the shores of Lake Powell. Photo by Kelsey McNamara.

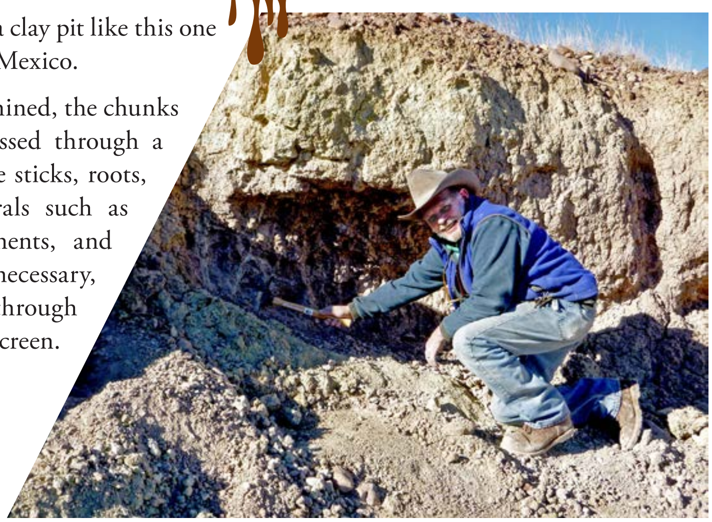
New Mexico Mud in a Potter's Hands: a Photo Essay

Dave Love & Scott Goewey

WHEN "MUD" came up as a topic of interest for Lite Geology, the editorial board thought "adobe" and "pottery" immediately. Fortunately we know Scott Goewey, master potter, sculptor, poet, and multifaceted investigator of many local and international phenomena. Scott has created poetry and ceramic sculptures for more than fifty years, and has begun testing local New Mexico clay sources to create ceramics and glazes. His artworks have been exhibited in many states and from Faenza, Italy, to Nagoya, Japan. Currently some of his larger works are at Vertu Gallery in Socorro, New Mexico (website: http://www.vertuarts.com/). Scott lives in Carrizozo, New Mexico, with his wife, Susan, a painter, fiber artist, gardener, and fiddle player.

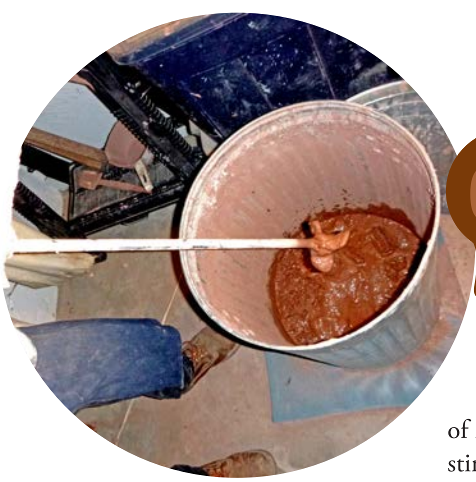
Scott graciously agreed to demonstrate some of the steps involved in making pottery or ceramic sculptures from local "fossil" mud. The following is a photo essay showing some of the steps.

01 Scott Gowey and Dave Love (in photo) locate a local source of clay—you can discover one yourself or ask a geologist.



02 Scott digs clay from a clay pit like this one near Socorro, New Mexico.

After the clay is mined, the chunks of mudstone are passed through a coarse sieve to remove sticks, roots, pebbles, other minerals such as gypsum crystal fragments, and limestone nodules. If necessary, the fine fraction is sieved through an even smaller-diameter screen.



03 Before mixing clay with water, Scott first makes a cellulose suspension by mixing a half pound of newspaper in 20 gallons of water in a trash can and stir vigorously with a motor-driven propeller. Cellulose prevents the clay from cracking when drying later in the process. He stirs in about 5 pounds of raw clay at a time into this mixture, until you have added between 50 and 70 pounds of clay (dry weight). This dilute slurry may be poured through a window screen to remove undesirable particles. Flakes of muscovite mica may be added after the screening process. Then the mixture is stirred again and allowed to settle overnight or longer. Excess water is siphoned or poured off the top.

04

Next, he scoops out some of the gloppy water-mud mixture and put it into a breathable canvas bag to lose water by evaporation. The mixture will become firmer and more dough-like after drying a few days.

05

Scott hangs the bags of wet clay on a drying rack. The two bags on the left are still quite wet. The two on the right have dried longer and are moist, but firm.

06

Clay that is a little too gooey can be mixed with stiffer clay to get a better working consistency.

Here a bag of stiff clay is about to be mixed with sloppy clay on the work bench.

07

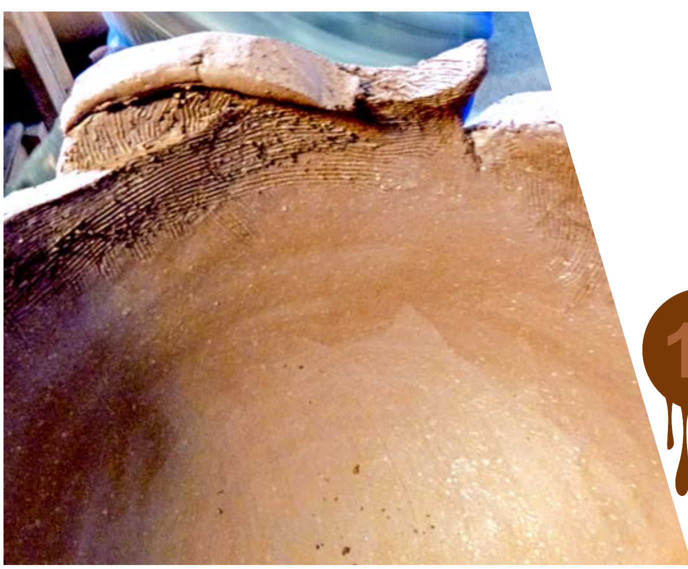
The block of stiff clay is sliced into 1-inch-thick pieces by using a fixed length of strong wire and mixed with the sloppy clay. Then the mixture is sliced and kneaded repeatedly until the combination is one consistency.

08

This clump of clay has an even consistency—medium muddy.

09

He likes to put the molded base on a pottery wheel so that he can rotate the sculpture. Other potters use a pottery wheel to throw pots.



10

Scott adds small amounts of “coiled” clay to his sculpture and pats them down with several tools.

11

Scott roughs up the surface in case he decides to add more to the sculpted rim.

12

Scott smooths the interior of the sculpture to align big flakes of muscovite mica along the edges of the pot.

After the pot is allowed to dry thoroughly, it is placed in a kiln with many other pots to be "fired" or heated to a selected temperature, depending on the type of clay and the desired effects. Firing temperature ranges are listed at this website:

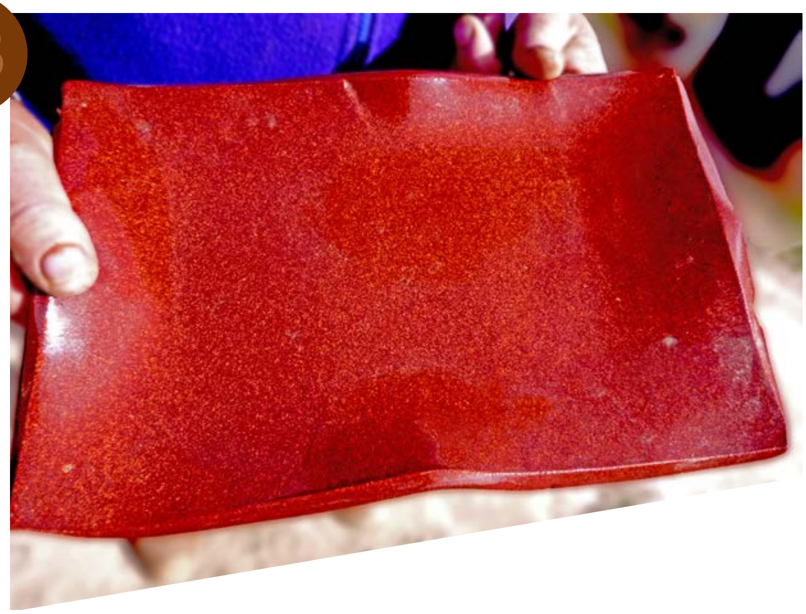
http://www.bigceramicstore.com/info/ceramics/cone-chart.html

If a glaze is desired, the pot is first fired at a lower temperature and the result is called bisque ware. The bisque ware is porous, which allows the glaze (a mixture of clay and flux) to absorb and bond to the pot. After glaze is applied to the pot, both are allowed to dry. Then, depending on the desired effect, the pot is placed in a kiln, fired at a higher temperature and slowly cooled.

A potter may create other effects by changing the firing temperature or the amount of oxygen in the kiln. Some clays and glazes turn one set of colors in an oxidizing atmosphere (with an abundance of oxygen) and turn other colors in a reducing atmosphere (when oxygen is reduced).

Scott holds one of his platters with a locally mined glaze containing iron oxide with 5% tin oxide added.

13

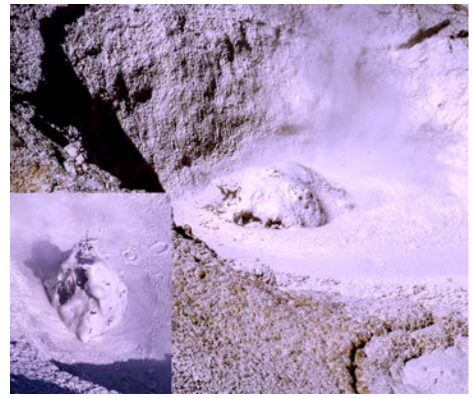


14

This vase has the same locally mined glaze with 1% copper carbonate added.

Mud volcanoes, Yellowstone National Park.

Fossil amphibian tracks left in 280-million-year-old mud, Abo Formation, central New Mexico.



Steam bubbles bursting in boiling mud pots, Yellowstone National Park.

Rolled mud cracks after drying along the Rio Salado, central New Mexico.

Septarian concretion formed in shale of Morrison Formation, central New Mexico. The cracks formed in shrinking mud within the shale and are filled with calcium carbonate precipitated by groundwater.

Small playa with drying mud cracks. Close-up of tiny toad with tail stalking tiny flies on drying mud, beginning to form mud cracks, southeastern New Mexico.

Modern dog paw print in wet sandy mud, Socorro, New Mexico.

Armored mudball in scoured muddy bed with woody roughness element; close-up of armored mudball, central New Mexico.

Laminated gray shale with fossil pectinid clam shells (Dunbarella); inset: transmitted light through thin section of laminated silty shale from the Chagrin Shale (Upper Devonian), Lake County, Ohio. The light laminations are quartz silt. The brown laminations are a mixture of clay minerals and organic matter. The black, opaque areas are authigenic pyrite (fool's gold). There are no clam shells. The width of the photo is about 2.5 mm. Photo taken January 3, 1979, by geologist Ron Broadhead.

Mud Photo Gallery

Dave Love

Two sizes of rain-drop spatter craters and mudcracks, south-central New Mexico. Photo courtesy of Lewis Gillard.

Deep mudcracks formed in thick mud in dried oxbow, west-central New Mexico.

Trail of pocket gopher (Thomomys sp.) burrowing through mud, looking for edible roots beneath 18 inches of snow, Socorro, New Mexico. Burrows can be as much as 150 m long.

New Mexico's Most

Wanted Mineral

Andalusite

Description:

Andalusite is an orthorhombic aluminum silicate with the chemical composition of Al_2SiO_5. It usually forms rectangular prisms with square cross sections but can also be found in massive, columnar, granular, and radiated types. It can display a variety of colors ranging from violet, pink, yellow, green, white, and gray. When small amounts of iron and manganese substitute into the structure, a bright green variety called *viridine* results. The inclusion of carbonaceous impurities sometimes results in the formation of a colored cross or X within the crystal, which is called the variety *chiastolite* or *macle*. Because of its hardness (6.5-7.5 Mohs scale), it has a white streak. The luster varies from vitreous to subvitreous in character. It usually displays one good cleavage and a second poor one. Fracture is uneven to subconchoidal and it tends to be brittle.

Wanted For:

Crystalline andalusite is primarily collected for use as a mineral specimen. Clear varieties are faceted into gemstones. Chiastolite is often cut and shaped into cabochons for use in jewelry. It has been mined as a source of aluminum silicate which is used to make porcelain for electrical insulators and spark plugs. For metamorphic petrologists, it is a very important indicator of temperature and pressure conditions of metamorphism.

Virgil W. Lueth

Hideout:

Andalusite is found in argillaceous (clay-rich) sediments that have undergone contact and regional metamorphism. In metamorphic rocks, it is associated with polymorphs sillimanite and kyanite in addition to garnet, corundum, tourmaline and cordierite. It is rarely found in granites and pegmatites. But when found, it usually forms gem crystals. It is also found in detrital grains in sandstones.

Last Seen At Large:

Andalusite can be found in most modern sands along the Rio Grande. It has also been reported in South Canyon of the Organ Mountains in Dona Ana County. In Hidalgo County, it is reported in skarn rock of the Sylvanite district. It is found in the Capitan area of Lincoln County associated with metamorphism adjacent to igneous dikes intruded into shales. It is also reported in the Iron Mountain No. 2 district of Sierra County. Small amounts have been reported in the Magdalena district of Socorro County and in the Los Pinos Mountains. Evidence for andalusite mineralization has been described from the Manzano Mountains of Torrence and Valencia Counties. Some of the finest specimens of the mineral come from Taos County, especially near the Pilar Cliffs, Harding mine, and Hondo Canyon areas. The variety *viridine*, comes from the Pilar area. Other fine examples come from the Tusas Mountains near Ojo Calente and Petaca.

Aliases:

The name is derived from Andalusia, the first locality noted for the mineral. Viridine is the name for the green variety. *Chiastolite* or *macle* gets its name from the color zonation in the crystal that results in the formation of the letter “X” or “chi” in the Greek alphabet, hence the origin of its name.

New Mexico Enchanting Geology: Clayton Lake State Park

Stacy Timmons

IF YOU have the pleasure of touring through the high plains of northeast New Mexico, be sure to plan a visit to Clayton Lake State Park. This state park features a recreational lake, with impounded waters of Seneca Creek, located approximately 12 miles northwest of Clayton, NM, along Highway 370. The geologic – and mud themed – highlight of this park can be found near the dam spillway on the east side of the park. There you can examine and learn more about 100 million year old dinosaur tracks (from the Cretaceous Period). These tracks are from large herbivore dinosaurs that walked in muddy layers of today's Dakota Group, particularly the Pajarito Shale and the Mesa Rica Sandstone. Many of the tracks at Clayton Lake State Park are from ornithopods, including iguanodons, which were bulky, duck-billed dinosaurs with notable thumb spikes. Other fossilized mud features can be found at the site including worm burrows, plant impressions, ripple marks, and mud cracks.

Besides these fascinating 100 million year old tracks, Clayton Lake State Park also offers camping, seasonal boating, fishing, picnicking, hiking and bird watching. For more information or to plan your visit, please go to:

http://www.emnrd.state.nm.us/SPD/claytonlakestate-park.html

Photos by Rick Kelley

Earth Science Technology Review: Augmented Reality Sandbox (SARndbox)

Andy Jochems

IN 2015, the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) constructed an augmented reality sandbox (SARndbox) to aid in its mission to provide geoscience education to New Mexicans. This captivating tool was developed at the UC Davis W. M. Keck Center for Active Visualization in the Earth Sciences (KeckCAVES) using National Science Foundation funds. It was introduced at the annual meeting of the American Geophysical Union in late 2014 (Reed et al., 2014). The SARndbox combines virtual reality software with a simple sandbox to allow the user to create topography with elevation contours and simulated water flow. The landforms created by the user are limited only by their imagination and the scale of the SARndbox.

The materials used to construct the SARndbox are easily acquired from any hardware store. The box itself is built from simple wooden sides mounted on a metal frame with casters for mobility. Importantly, the sand used is not pure silica, which can cause lung disease when inhaled as very fine dust. Instead, the NMBGMR SARndbox uses gypsum sand collected (with a permit!) from our very own White Sands National Monument. Other SARndboxes use play sand, such as Sandtastik, with no free silica and/or binding agents.

The New Mexico Bureau of Geology SARndbox was built with a wooden box on a Unistrut frame. The CPU is hidden from view behind the sandbox and protected from wayward sand grains by a back board. The 3-D camera and projector are suspended over the sandbox by brackets at the top of the frame. Photo by Matt Zimmerer.

A 3-D camera and projector are fixed to a frame above the sandbox to achieve a 4:3 aspect ratio. The camera is a first generation Microsoft Kinect 3D for Xbox One. The projector, a Beamer BenQ 3D-HDMI ShortThrow, is mounted behind the Kinect camera. Displaying contours and especially water flow on the sandbox requires a robust graphic card; the Bureau's SARndbox uses a 4GB AMD R9 290X card to render high-quality images.

The SARndbox uses a Linux-based system consisting of a topographic map renderer and water flow simulation. The software packages used to create the simulation are the VRUI VR toolkit and SARndbox, both available for free (see website at end of article). The Kinect camera is operated by Kinect3D Video Capture Project software (also free). Both the SARndbox and CPU system were custom-built at New Mexico Tech.

The 3-D camera filters raw depth frames of the topography created in the sand. Topographic contours, a customizable elevation color map, and water flow simulation are then projected back onto the sandbox. Levi Begay, a New Mexico Tech student who helped calibrate the SARndbox, notes that handy shortcut keys allow the user to produce unique effects, such as adding simulated water flow to mimic arid versus wetter environments.

The SARndbox is particularly useful for illustrating the concept of watersheds. Users can easily create topographic divides separating lakes and streams in discrete basins. The construction of volcanos is another popular exercise that helps students visualize the difference between closely spaced elevation contours on the steep sides of a volcanic cone and more distant contours on the flatter plains and benches below.

Although the SARndbox incorporates one of the most recognizable features of the playground–sand–it is anything but a toy. Susie Welch, manager of the Geologic Extension Service at NMBGMR and editor of Lite Geology, has used the sandbox to demonstrate geologic concepts to students of nearly all ages. "In addition to topography and watersheds, the sandbox allows students to create dams, faults, tsunamis, and even the surface effects of growing magma chambers," she says. Who knows—perhaps the next generation of geoscientists in New Mexico will be able to say their love of geology took root in a sandbox!

Sources:

Reed, S., Kreylos, O., Hsi, S., Kellogg, L., Schladow, G., Yikilmaz, M.B., Segale, H., Silverman, J., Yalowitz, S., and Sato, E., 2014, Shaping Watersheds Exhibit: An Interactive, Augmented Reality Sandbox for Advancing Earth Science Education: Abstract ED34A-01 presented at 2014 Fall Meeting, AGU, San Francisco, California, 15-19 December.

For more information on the development of the hardware and software behind the SARndbox, please visit the following website:

http://idav.ucdavis.edu/~okreylos/ResDev/SARndbox/

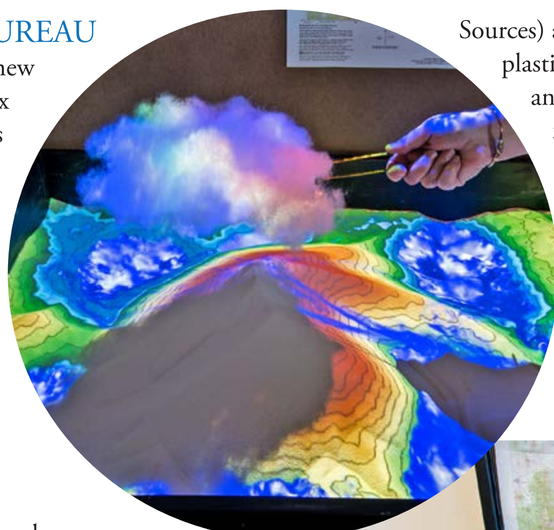
Credits:

Many thanks to the following people who contributed greatly to the development and construction of this model at New Mexico Bureau of Geology: Aaron Curtis, Levi Begay, Niko Ponder, Michael Chavez, Albert Baca, Leo Gabaldon, Bill McIntosh.

Classroom Activity: Geology Applications in the Augmented Reality Topographic Sandbox

Susie Welch
and
Andy Jochems

THE NEW MEXICO BUREAU OF GEOLOGY is using a new interactive topographic sandbox to teach about concepts such as topographic maps, watershed and floodplain issues, faults, volcanoes, tsunamis, and more. This model (SARndbox, developed at University of California at Davis), including both hardware and software components, is described in detail on page 13 of this issue. The basic components for the sandbox include a sturdy frame, a box of sand, a 3-D Kinect camera typically used for video games, and a projector. We also added a printer so we can save and print the 3-D camera images of favorite configurations in the sandbox. The resulting printed map resembles a cartoon, an artifact of the video-game camera, but it represents the sandbox model well.



Sandbox with virtual rain that was generated with the cloud accessory.

Some accessories we developed for the sandbox include wooden blocks with wires to use for creating faults and a cloud tool to generate virtual precipitation. A magma inflation device was a design borrowed from the Flour Box Caldera Model (see Sources) and is made from plastic tubing, a balloon and a rubber band. It is also helpful to have some USGS 7.5 minute topographic maps ("topo maps") for reference when working in the topographic sandbox.

Custom accessories for the sandbox include the fault blocks with wire handles and the magma inflation device. An imaginary cloud made from Styrofoam, polyester fiber fill, and wire can be used to generate water in the model. Assorted blocks are used to construct dams, docks, etc. in the model. An extra board helps to level the sand in the box. Little dinosaurs and other toys give the model extra entertainment value.

Sidebar

Basic Topographic Map Concepts

1) A topographic map is a two-dimensional representation of a three-dimensional landscape.

2) Contour lines follow all points of equal elevation.

3) A contour interval is the difference in elevation between two adjacent contour lines. The contour interval is chosen by the map maker to match the depiction of landforms.

4) Every fifth contour line is an Index contour that is bold and includes the labeled elevation within the line. (Note: The Augmented Reality Topographic Sandbox projection software does not generate labeled Index contours)

5) Some Rules of Contour Lines:

a) All points on a line are of equal elevation.

b) Contour lines do not cross or divide.

c) Contours that are widely spaced indicate a gentle slope.

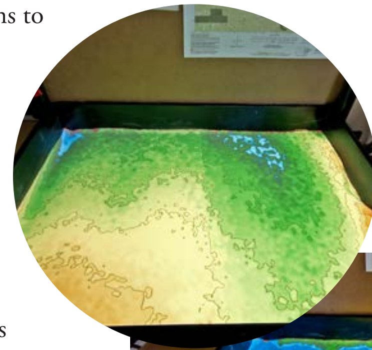
d) Contours that are close together indicate a steep slope.

e) Contours always make a V pointing upstream.

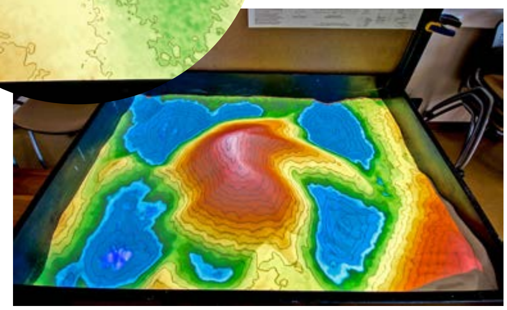
f) Contours always make a V pointing downhill on ridges.

e) Closed contours indicate 1) a peak if elevation increases to that contour, or 2) a depression if elevation decreases to that contour.

Here are some ideas for sandbox lessons to teach basic topographic and geologic concepts:



The sandbox with a flat landscape shows widely spaced contour lines.



Adding higher and lower elevation land features illustrates many of the topographic concepts described in the sidebar.

Topographic Maps

The Augmented Reality Topographic Sandbox model provides an interactive topographic map that is projected onto the sand. Contour lines are generated as the 3-D camera, software, and projector work together to draw a contour map of the sandbox surface. Colored elevation ranges provide visual clues to the elevation differences in the model. Blue represents the lowest elevation and white shows the highest elevation of the sand. As the sand is re-contoured, the interactive topographic map quickly updates to the new configuration.

1) Rules of Contours: A topographic map is a 2-dimensional representation of a 3-dimensional landscape. Build features that illustrate the rules of contours (see Sidebar). Begin with a flattened sand surface to make observations about the contour lines. Then build some mountains and valleys to observe how changes in elevation and shapes of landforms affect the spacing and shapes of the contour lines.

2) Demonstrate the relationship between a 2-dimensional map and a 3-dimensional landform or landscape in the sandbox. Using a USGS 7.5 minute topo map as an example, construct landscape features from the map in the sandbox. Print a new topo map from the sandbox and compare your map to the original topo map.

Watersheds, Flood Plains, Coastlines

This model includes a virtual precipitation feature. Rain is triggered in the model by holding a hand or the cloud tool about a foot above the sandbox. Blue virtual water will rain onto the landscape and pool in low elevations. Assigned keys on the computer keyboard are used to drain the virtual water, and to add a global flood to the model if desired.

1) Build a landscape that contains a watershed, flood plain, dams, diversions, etc. Install a town, farms, roads, etc. Bring on the perfect storm, and print a map. Assess the damage, and remediate the flood hazards by re-locating the damaged facilities, away from natural flood plains. Test with a new storm and print map.

2) To show the effects of sea level rise (or fall), construct a shoreline with low slope and high slope areas and watch the effects of sea level elevation changes on shorelines as you fill (or drain) the virtual sea water.

Volcanoes, Faults, and Tsunamis in Action

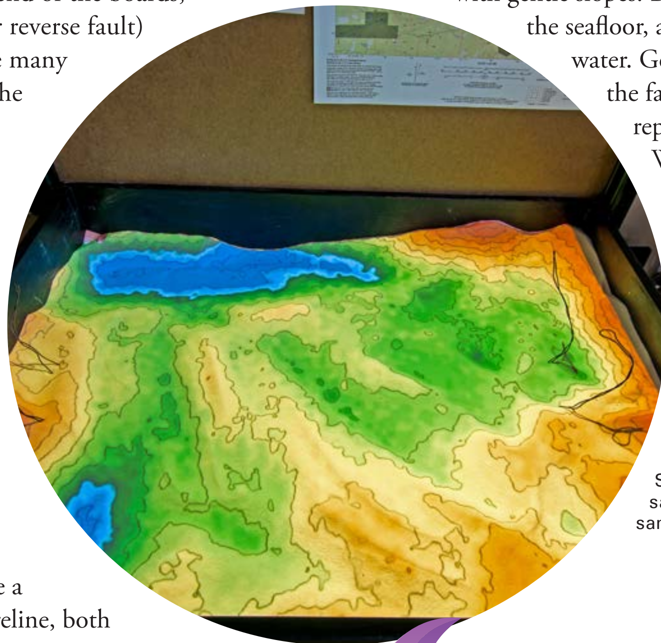
1) Construct a volcano by first burying the balloon end of the magma inflation device under the sand. Then feed the tubing out of the sandbox. Build a volcano in the sand above the balloon. Inflate the balloon, and then let the air suddenly escape to collapse the volcano. Observe the resulting caldera that was formed. Find some calderas on topo maps and build them in the sandbox model.

2) Make some earthquakes by first burying the wooden fault blocks under the sand. Because the sand has a low angle of repose and is unconsolidated, the earthquakes generated won't develop sharp fault features. However, this sandbox model will simulate surface effects from earthquakes, and the low-angle scarps formed do resemble real faults that rupture unconsolidated sediment (similar scarps are seen in parts of New Mexico). Discuss limitations and advantages with using a model of this type.

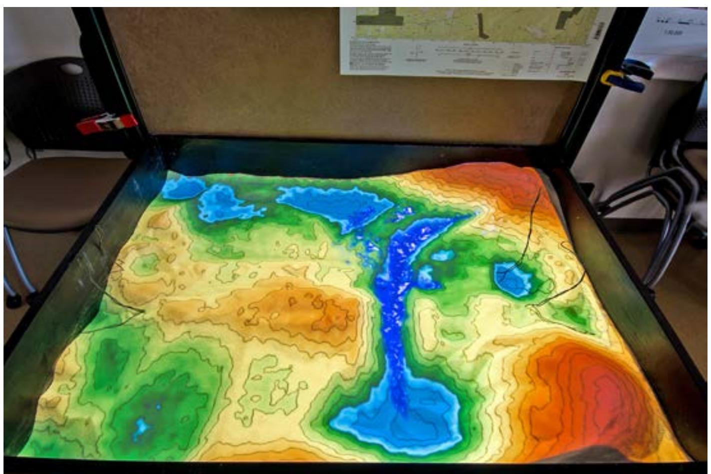
a. Working with a partner at each end of the boards, move one board vertically (normal or reverse fault) or laterally (strike-slip fault) to create many possible fault scenarios, and discuss the results.

b. Demonstrate how strike-slip faults can be identified on topographic maps by shifting one of the fault blocks laterally under a river carved through the sand. The high angles (up to 90°) formed by the river bending along the fault show the nature and direction of lateral movement associated with strike-slip faulting.

3) Tsunamis are giant waves caused by earthquakes, volcanoes or other disturbances on the sea floor. Simulate a tsunami by creating a seabed and shoreline, both with gentle slopes. Bury one of the fault blocks under the seafloor, and then fill the seabed with virtual water. Generate a small earthquake by lifting the fault block vertically about 1 cm to represent a seafloor rupture or bulge. Watch the changes in the sea level at the shoreline. The water may recede first before it runs up onto land, just like a natural tsunami. You may see subsequent waves running up as well. Research some historic tsunamis to understand how they were caused, and compare to the sandbox tsunami.

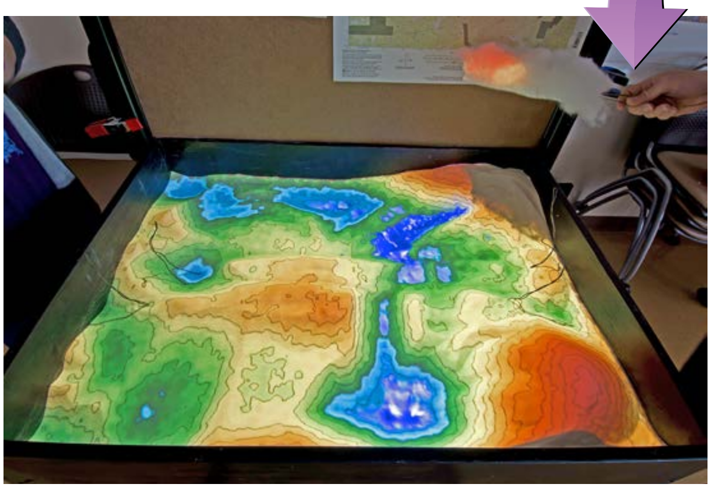


Sandbox with fault blocks buried under the sand (wire handles are protruding from the sand), before creating the normal fault.



Sandbox with a river carved in the sand, and fault blocks buried perpendicular to the river.

After the normal fault occurred, the fault scarp is visible in the sand.



After shifting one fault block laterally, a right lateral strike-slip fault is created. Note the sharp bends due to misalignment of the river along the fault. Further strike-slip movement can create trellis drainage patterns or may completely cut off stream channels upstream of the fault.

Sources:

For a description and instructions for building the Augmented Reality Topographic Sandbox (SARndbox) visit this website: http://idav.ucdavis.edu/~okreylos/ResDev/SARndbox/

A lesson with instructions for building another classroom caldera model, including the balloon magma inflation device, can be found in this article: Building a Flour Box Caldera Model, New Mexico Style on pp. 13-15 in the Spring Issue 33 of Lite Geology. Visit this link:

https://geoinfo.nmt.edu/publications/periodicals/litegeology/33/lg_v33.pdf

Credits

Photos by Matt Zimmerer.

Through the Hand Lens: Profile of a New Mexico Science Teacher

Susie Welch & Jim Sauer

Jim is enjoying the waves at Lost Beach on Oahu, Hawaii. Photo by Diana Tyler-Sauer.

JIM SAUER is a 5th grade teacher at Magdalena Elementary School, where he has taught for 20 years. His first career was in the United States Army. Upon retiring from the military with 20 years of service, Jim became a teacher by utilizing the Defense Activity for Non-Traditional educational Support (DANTES) and the Troops to Teachers programs. Jim holds several degrees in Engineering, Science, and Education, along with a Level III teaching license with the State of New Mexico.

Jim was recently recognized by the Magdalena School Board for his work in cultivating partnerships between his school district and many organizations such as Tuskegee Airmen Inc., StarBase La Luz, New Mexico Tech, New Mexico State University, Bureau of Land Management (Las Cruces Branch), the National Museum of Nuclear Science and History, Las Cruces Museum of Nature and Science. Jim received funding to support his RocketKids club to investigate rocket design and flight, but has expanded the program to cover many other topics. Magdalena schools hold classes four days a week, so the Rocket Kids meet on the off days to do their STEM adventures with Jim.

Educational Background

Georgia Military College—Engineering
Georgia College and University—Biology and Environment Science
George Wallace College—Electronic Engineering
Western New Mexico University—Education

Why is it important for students to learn about Earth Science?

We need the kids who are in school now to be smart, enterprising, intuitive, hard-working and hard-thinking. We need them to be scientists and engineers. Today's youth, are going to have to invent, develop and innovate "fixes" to what my generation broke.

Advice or suggestions for other Earth Science teachers:

Sure, read about it. But then, do it. Kids are losing interest in science and engineering when they only sit behind a desk with their nose in a book. Have them launch a high altitude balloon, collect and quantify a water or soil sample, visit a geological dig site. Track weather, polish rocks, or walk into a dust devil wearing a series of sensors.

Jim Sauer led a field trip with his RocketKids to the Prehistoric Trackways National Monument located northwest of Las Cruces, New Mexico. Photo by Diana Tyler-Sauer.

How did you fall in love with geology?

My love for geology began while in college studying marine geology, where I collected marine fossils along the Macon Fall Line in Georgia. The Oligocene fossils from 12 million years or so ago allowed me to typify marine environments. Even after joining the military, I continued marine fossil hunting along with my children.

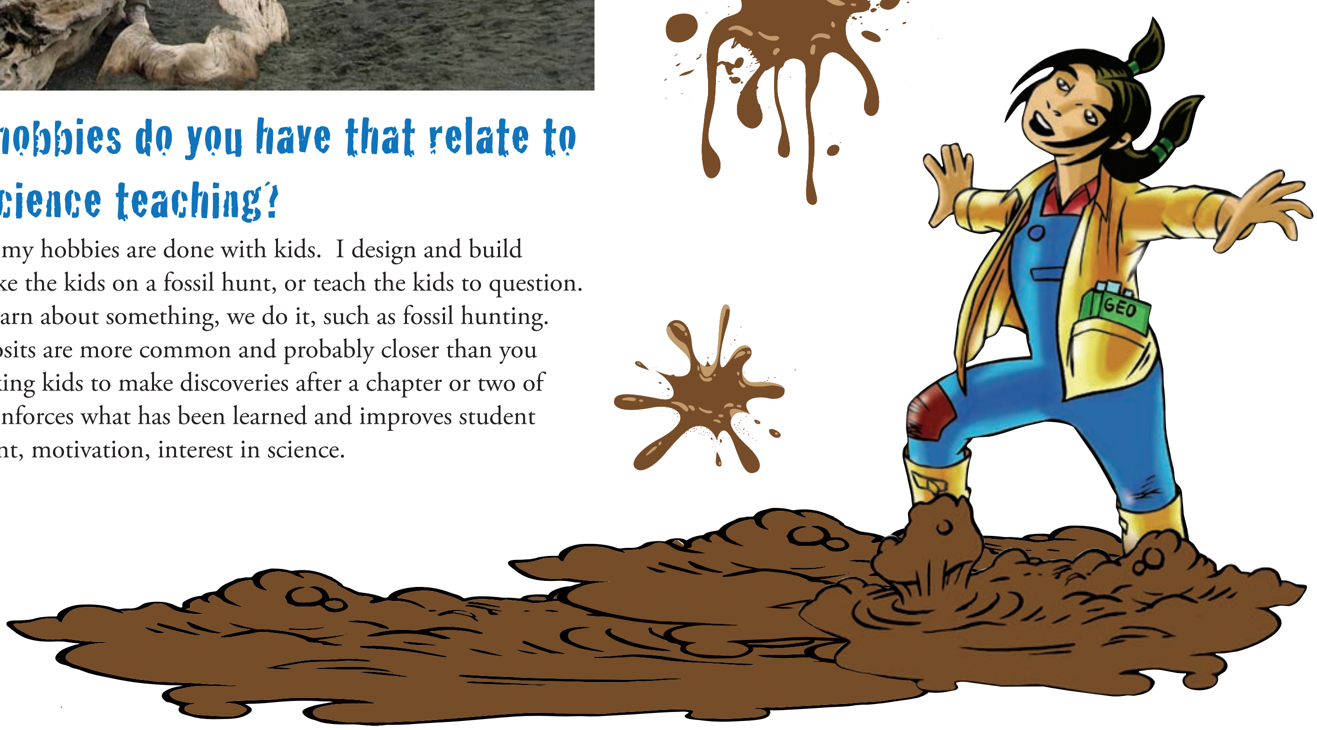
The most emotional event, which really brought geology home was the eruption of Mount Saint Helen's volcano in Washington. At the time, I was an Army Aviator stationed at Fort Lewis Military Base in Tacoma, Washington. Along with another pilot, I flew the only aircraft to conduct Search and Rescue Operations and took more than 750 photos to document the devastation caused by the eruption on the day of the event. As I flew down the Toutle River, I experienced flash backs of geology courses, where we learned about the immense periods of time required to change the courses of a river, or the shape of a valley, the elevation of a ridge or mountain, or a depth of sediment. That day, I decided the "egg-heads" were wrong. It takes but a second.

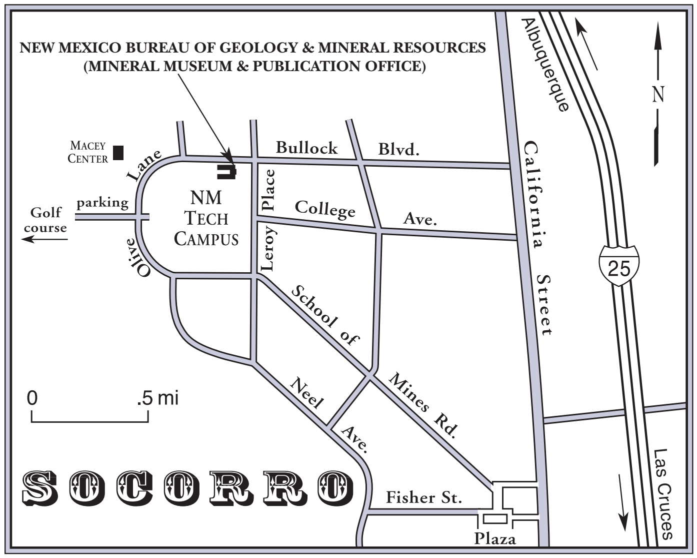
What hobbies do you have that relate to your science teaching?

Most of my hobbies are done with kids. I design and build rockets, take the kids on a fossil hunt, or teach the kids to question. After we learn about something, we do it, such as fossil hunting. Fossil deposits are more common and probably closer than you think. Taking kids to make discoveries after a chapter or two of geology reinforces what has been learned and improves student achievement, motivation, interest in science.

Favorite geologic feature in NM:

Finding fossils on top of the Sandia's is always exciting. While stationed at Kirtland AFB in Albuquerque, I would often take my kids to a site towards the East Mountains that was known for Crinoids. I enjoy poking around some of New Mexico's volcanoes, such as Shiprock, Tome, or those in a neat line that cross the Isleta Pueblo. If you go, don't neglect getting permission or an escort if required. I also enjoy the Valley of Fire lava flow between San Antonio and Carrizozo.





The Mineral Museum is on the campus of New Mexico Tech in Socorro, New Mexico

9 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 new Bureau of Geology building is located at the corner of Leroy Place and Bullock Blvd. on the campus of New Mexico Tech in Socorro (see photo on page 12). Visitor parking on the east side of the building provides convenient access to the Mineral Museum and Publications Sales office.

Mineral Museum

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 5,000 minerals are on display at a time.

For teachers, students, 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 website at: geoinfo.nmt.edu/museum/

Dr. Virgil W. Lueth: Senior Mineralogist and Museum Director

575-835-5140; vwlueth@nmt.edu

Kelsey McNamara: Museum Curator

575-835-5418; kmcnamara@nmbg.nmt.edu

To Schedule a Museum Tour, Contact:

Susie Welch: Education Outreach

575-835-5112; swelch@nmbg.nmt.edu

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