# A SCIENTIFIC *World* IN A GRAIN OF SAND

*Investigating local sand samples on a shoestring budget*

*To see a world in a grain of sand,*
*And a heaven in a wild flower,*
*Hold infinity in the palm of your hand,*
*And eternity in an hour.*

—William Blake, *Auguries of Innocence*

**Renee Clary and James Wandersee**

At first glance, sand is ubiquitous! It's found along river and stream banks, comprises dunes in arid regions, and forms beaches along the world's coasts. It also has many commercial applications—it's used in construction, ceramics, filtration systems, and abrasives.

When we look at sand, we typically think of it as a collection of homogeneous quartz grains. In reality, it's anything but uniform. Careful observation reveals the various rock materials from which it came, and the weathering, erosion, and transportation processes that produced this unique collection of granules.

Each sand sample holds the clues to a scientific mystery that can serve as the basis for inquiry investigations in Earth science, geology, or biology:

- What is the parent material for the sand?
- What tectonic forces emplaced the original rock and subsequently altered it?
- What happened to the rock—over thousands and millions of years—to produce the small pieces we collect today?

A classroom investigation of local sand samples reveals a fascinating Earth history that can address a variety of interdisciplinary scientific topics, provide rich inquiry experiences, and move beyond the science classroom to integrate history, culture, and art. This article describes these investigations in more detail.

## The science of sand

Sand comes in many varieties—and each tells a story of weathering, transportation, and deposition that reflects a unique geographic and geologic location. Silica, especially in the form of quartz, is the most common constituent because of its hardness and stability. But sand can have other components, as well, such as small fragments of rocks or minerals, the remains of once-living organisms, and even small pieces of man-made objects!

What can a sand sample tell us? It reveals not only the rocks that provided the grains, but the weathering processes that acted upon them. For example, sand formed from granite initially contains an assortment of grains, including feldspars, quartz, and biotite (i.e., black mica). When subjected to chemical weathering, the less stable minerals decompose to form clay minerals. The presence of less stable minerals, such as feldspars and evaporites (e.g., gypsum), in a sand sample indicates less intense chemical weathering environments. The shape of the individual sand grains is another clue: Rounded particles indicate more intense weathering, and angular grains indicate less weathering and transportation.

The word *sand* refers to a size classification of sediments, which fall between larger, gravel-size particles and smaller, silt-size particles (see photo, p. 32). Sand typically has a diameter of between 0.0625 and 2 mm. The classic Wentworth Grade Scale (see "On the web") further divides sand into five subcategories that range from "very coarse" to "very fine." Diagrams, such as Folk's and Shepard's Classification Systems (see "On the web"), help researchers categorize

**FIGURE 1**

### Soil diameter chart.

Students can use this simple chart to estimate the size of local sand particles based on their diameters. (**Note**: Only numbers 1–5 represent sand-size components.)

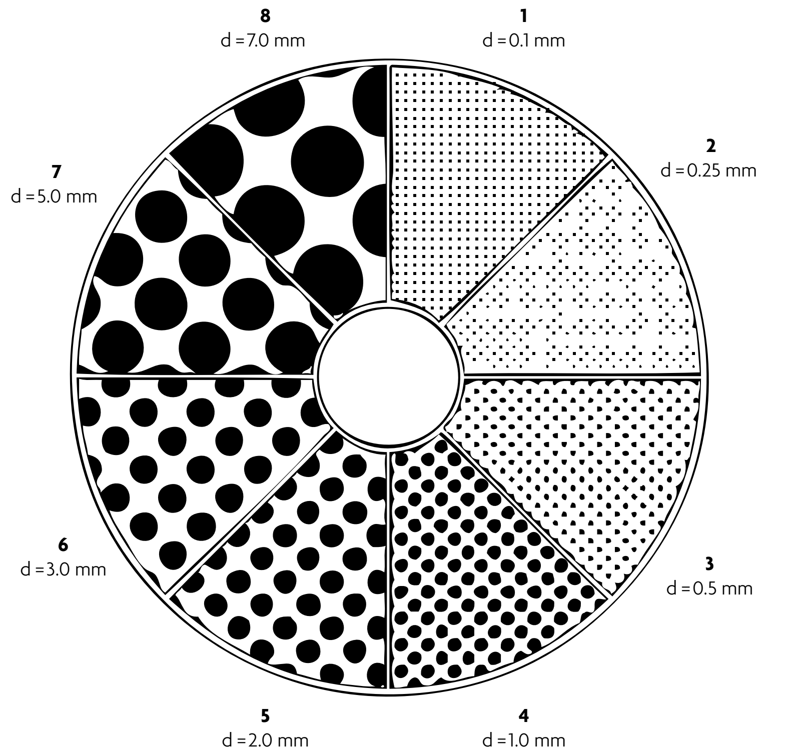



IMAGE COURTESY OF U.S. DEPARTMENT OF AGRICULTURE

sediments by their proportions of mud, sand, silt, and clay. A list of additional classroom sand resources is available online (see "On the web").

Using a microscope to see the individual particles that make up a sand sample is part of what makes this activity so engaging for students—they never fail to appreciate the "wow!" factor.

## Local sand history

Whether from beaches, river sandbars, desert dunes, or glacial moraines, natural sand deposits are available to most classrooms. Our initial sand investigation is usually a local one: Students collect naturally deposited sand and then conduct a regional, in-depth investigation of its "Earth journey" through mineralogy, weathering, and transportation processes.

Past research confirms that students relate more to familiar landforms and features, though exotic, far-away elements can pique their interest (Clary and Wandersee 2008). In this activity, students use weathering processes to trace local sand from its rock origins to its current, but not final, location.

This activity requires between four and seven 50-minute class periods and can be conducted as an individual assignment or a group activity with two to four students per group.

### *Step 1: Locate the sample*

We use Google Earth (see "On the web") to locate potential sand-collecting sites and pinpoint their latitude and longitude coordinates. We then provide students with a list of sand-collecting sites we have visited and approved, such as river channels, point bars, dunes, glacial outwash areas, lakes, or beaches. (We avoid construction sites and commercial stores.) When visiting these sites, students must be supervised by a parent or guardian. We caution students and their families to use care when retrieving their sand samples and to secure permission from private sites. A small amount of sand can support several classroom activities, so our students collect samples in snack-size plastic bags. We always procure a sand sample or two, as well, in case of problems with student collection.

### *Step 2: Sorting and rounding*

The size and shape of sand particles can reveal a lot of information about their Earth journeys! If soil sieves are available in the classroom, student groups can mechanically separate a sample into its size constituents (see photo, p. 32). An easy, inexpensive alternative to soil sieves is wire mesh—such as that used for screen doors or sifting flour—and nylon stockings. Students can sieve the sample through the wire mesh to capture the larger rock particles, and wash the sample through a section of nylon to concentrate the smaller sand-size particles. (The finer silt and mud grains are washed away.)

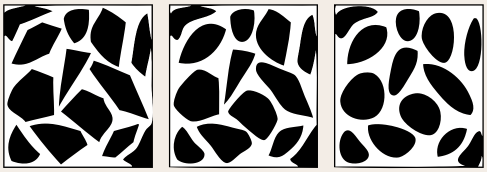
Student groups use a variety of magnifying instruments—such as jeweler's loops, magnifying glasses, and microscopes—to investigate their sorted samples. Metal picks are helpful to separate sand grains under magnification, and toothpicks work well with larger grains. Students identify the sizes of the magnified sand grains using a soil diameter chart (Figure 1). Standard grain-size pocket scale cards are also available from science supply stores.

It is important to note the uniformity of the grain sizes: Well-sorted sands tend to have one grain size; poorly sorted samples have different-size clasts. A grain-size uniformity diagram is available on Brooklyn College's geology website (see "On the web").

**FIGURE 2**

### Rounding diagram.

The basic shape of a sand grain reveals how much mechanical weathering it has experienced.



Angular Medium Rounded

IMAGE COURTESY OF THE UNITED STATES GEOLOGICAL SURVEY

Students also examine the grains' shapes to reveal clues about mechanical weathering and transportation. A basic diagram can help them determine the degree of rounding (Figure 2). A more detailed classification scheme is available on Eastern Illinois University's Sedimentary Rocks web page (see "On the web").

## *Step 3: The ingredients*

In our experience, this step is the most problematic. Unless the sand sample has a fairly uniform composition with an obvious mineral assemblage, student groups typically do not have the background knowledge needed to identify the fragments. We suggest that students research the local geology, and identify the types of rocks exposed at the surface. Once these potential source rocks are identified, they can list their mineral constituents. Microfossils add another dimension—students can investigate the environment in which these tiny organisms lived.

There will be times when the mineralogy of the sand and the locally exposed rocks do not match. In these cases, we ask students to consider the transportation of the sand grains, and whether they were perhaps moved from their source materials via running water or glacial ice. We also have students consider chemical weathering processes, which can result in the decomposition of original rock to clay minerals—only the most stable minerals remain.

## *Step 4: Reconstructing your sand's history*

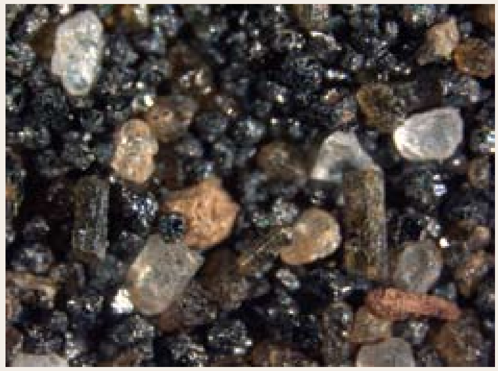
Students determine the basic weathering history of their sand sample through the size of its particles, the uniformity (or lack thereof) of its grain sizes, and the shape of the granules. They compare their sample to local rock outcrops and other sand images to develop a basic list of constituent minerals and possible microorganisms. Then, students weave this information together to form their sand sample's Earth journey.

We have found that the best way to facilitate a local tectonic journey is to locate the nearest national park, or one that mirrors your basic geographic setting. The National Park Service website (see "On the web") provides basic geologic overviews of the landscape in U.S. parks. These resources are helpful when student groups reconstruct their sand's rock origins, tectonic stresses, and weathering and transportation processes. Because interpretation is involved in this activity, the reconstructed histories vary. Sand has been a "work in progress" for thousands, and potentially millions, of years.

**FIGURE 3**

### Washington vs. New York sand.

Sand samples from north-central Washington (47°53'05.80" N, 119°09'48.07" W) reveal a combination of dark minerals with quartz.



A sand sample from New York (40°34'39.35" N, 73°57'41.69" W) reveals a variety of colored minerals, including garnet.

PHOTOS COURTESY OF THE AUTHORS, MAGNIFICATION 30×

Students share their Earth journeys with classmates in a 5–10 minute presentation (a rubric is available online [see "On the web"]). Each group presents its sand's history—including its rock origins and tectonic forces—through its weathering and transportation journey. Groups justify this history with supporting evidence. After the presentations, students individually vote on the most plausible history, and the winner is announced the next class period.

## Around the world with sand

After students investigate local sand, we extend the activity and invite direct comparisons to other locations. When a sand investigation is extended beyond the local area, the

## Safety note.

The following safety precautions are required for this activity:

- Obtain sand samples from a site listed on the teacher-approved list, and make sure animal wastes or toxins have not contaminated them. Commercial sand for sandboxes may contain higher levels of silica and should be avoided.
- Students must be supervised by a parent or guardian when collecting sand from the study site. Parents or guardians must also sign a safety acknowledgment form, noting the potential hazards at such sites and ways to avoid them.
- Sand can be laced with mold, bacteria, and other potential pathogens, so it should be sterilized before use in the classroom. To dry-heat sterilize the sand, thoroughly rinse it in warm water. Then, place it on flat pans in the oven and bake it at 150°C for 2.5 hours.
- Safety glasses or goggles must be worn.
- Use caution in handling wire mesh—it can be sharp and pierce or cut the skin.
- Students must wash their hands with soap and water after completing this activity.

samples reveal a diversity of minerals, organisms, rounding, and sorting processes. With local sand, students determine the composition of their sand sample through similarities with posted internet photographs, but now their focus is the contrast between geographic locations.

We challenge students to compare homogeneous samples of sand that, at first glace, appear to be similar. For example, the white gypsum sands of New Mexico have a similar appearance to white quartz sands from Florida. However, the New Mexico gypsum sand can only exist in an arid environment; wetter climates chemically weather the gypsum and carry it away in solution. The Florida quartz sands have been weathered over millions of years from the Appalachians. Most of the minerals have dissolved and decomposed, resulting in smaller particles that are carried from the system—so what remains is primarily quartz. Though the New Mexico and Florida grains may be the same relative size, they are actually quite different.

Sand can be heterogeneous as well, and we challenge students to suggest reasons for its color and shape variations. For example, sand from north central Washington is primarily black in color with some elongated crystal shapes, but upper New York sand is lighter and more colorful (Figure 3, p. 31).

The OceanGLOBE project at the Marine Science Center at the University of California, Los Angeles (see "On the web") outlines an activity in which students compare sand samples and plot latitude and longitude coordinates on a world map. Teachers can request classroom samples from traveling friends and relatives or obtain a kit from the International Sand Collectors Society (see "On the web") for a fee. Teacher conferences are another good resource. The National Science Teachers Association (NSTA) conferences, for example, typically host share-a-thon sessions in which teachers bring local sand samples and participate in informal "sand swaps." (More information on NSTA conferences is available online [see "On the web"].)

PHOTO COURTESY OF THE U.S. DEPARTMENT OF TRANSPORTATION

**Sand particles range from 0.0625 mm to 2 mm in diameter. When sediments are mechanically separated by sieves, sand (middle image) falls between larger gravel clasts (right images) and silt and clay (left images).**

## Extending sand investigations

The classroom focus can include other scientific aspects of sand, including its angle of repose (i.e., the steepest slope that a sand pile can maintain when it is on the verge of slipping) in comparison to other materials and the amount of water necessary for liquefaction (i.e., when the sand pile can no longer maintain its shape and behaves like a liquid). Although Clay Robinson's (2005) sand castle activities were developed for a middle school audience, they can be adapted to the high school classroom (see "On the web").

Sand investigations do not have to end with scientific studies, either. Our students investigate the economic uses of regional sand and the role it has played throughout history. There are several interesting forensic cases involving sand. Osborn (1984, p. 50) describes its role in World War II: Between 1944 and 1945, the Japanese filled thousands of balloons with incendiary devices, aiming to set fire to U.S. forests. However, they used sand as a ballast to control the altitude of the balloon, and not all of the balloons ignited. The United States analyzed the sand's composition and determined that it could have only originated from five locations in Japan. After surveying these areas, the United States located the launching site and destroyed it.

Sand used to be a blotting mechanism, as well. It drew excess ink from the surface of documents and hastened the drying process (Hopen, D'Errico, and Milke 2008). It is also a creative medium for Zen gardens, sand castle competitions, and sand paintings. With sand mandalas, or Tibetan sand paintings, millions of colored sand grains are carefully placed in a design. The entire process can take days or weeks, depending on the intricacy of the design. When completed, the sand is collected and placed in a river or stream to symbolize the impermanence of all that exists (Drepung Loseling Monastery 2011).

## Discussion

Sand is beautiful, interdisciplinary, inexpensive, and fascinating. Although students suspect that their sand samples are homogeneous, this activity reveals that sand is a much more complicated assortment of mineral and rock fragments. A world of scientific information is contained in local sand grains—they hold clues to the region's rock sources, weathering and erosion processes, and tectonic events. And sand samples are usually free!

Investigations beyond local sand samples can reveal an incredible diversity on a small scale. Sand investigations can even be extended into interdisciplinary arenas, such as history, culture, and art. Our students react positively to classroom sand investigations, particularly the clues offered by local sand samples, and the incredible diversity revealed in sand samples around the world. We encourage our colleagues to explore the Earth through classroom sand investigations! ■

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### On the web

Additional resources for the Earth journey activity: *www.nsta.org/highschool/connections.aspx*

Brooklyn College's geology website: *http://academic.brooklyn.cuny.edu/geology/leveson/core/topics/rocks/rock_texture/rock_texture.html*

Clay Robinson's sand castle activities: *www.wtamu.edu/~crobinson/DrDirt/sndcstl.html*

Folk's Classification System: *http://pubs.usgs.gov/of/2003/of03-001/htmldocs/images/folk.gif*

Glendale Community College's sand lab: *http://gccweb.gccaz.edu/earthsci/imagearchive/sands1.htm*

Google Earth: *www.google.com/earth/index.html*

International Sand Collectors Society: *www.sandcollectors.org/Picture_Gallex.html*

National Park Service: *www.nps.gov/index.htm*

National Science Teachers Association (NSTA) conferences: *www.nsta.org/conferences*

OceanGLOBE project: *www.msc.ucla.edu/oceanglobe/pdf/sandybeachesestuary/sandy_sand.pdf*

The Science of Sand: *www.scienceofsand.info/sand/sandintro.htm*

Sedimentary Rocks: *www.ux1.eiu.edu/~cfjps/1300/sed_rxs.html*

Shepard's Classification System: *http://pubs.usgs.gov/of/2003/of03-001/htmldocs/images/shephard.gif*

Wentworth Grade Scale: *http://pubs.usgs.gov/of/2003/of03-001/htmldocs/images/chart.pdf*

### References

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Drepung Loseling Monastery. 2011. Mandala sand painting: Mystical arts of Tibet. *www.mysticalartsoftibet.org*

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### Addressing the Standards.

The following National Science Education Standards (NRC 1996) are addressed in this activity:

Science as Inquiry (p. 173)
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Physical Science (p. 176)
- Structure and properties of matter
- Conservation of energy and increase in disorder

Life Science (p. 181)
- Biological evolution
- Behavior of organisms

Earth and Space Science (p. 187)
- Geochemical cycles
- Origin and evolution of the Earth system