Sand Lab

Adapted from *The Fluid Earth / Living Ocean*

What comes to mind when you think of sand? Close your eyes and imagine a beach. What does it look like? The chances are that you've imagined a sandy beach, probably white or light in color. However, once you actually start looking at beaches, you'll quickly see that they are made of particles of many sizes and colors. Sand is a common substance, but few people take time to look at it. Scientists who specialize in the study of sand are called **arenologists**. (You are probably familiar with a similar word, **arena**. Long ago in Greece sports arenas were covered with sand.) Sand is of interest to geologists and oceanographers who seek to learn more about the earth and its ocean basins. It can also be valuable to forensic scientists who use it as evidence in criminal investigations. Additionally, sand is the home of numerous small organisms, called meiofauna, who live in the spaces between the sand grains.

Where does sand come from?

Explore a small sample of sand using a hand lens and make some observations about it.

What are some of the things you notice about the sand? You probably noticed many different things, and while you were noticing them, you might have been forming some hypotheses about the area where this sand came from. When arenologists study sand, there are certain qualities of the sand that are particularly useful and informative. Think back to your observations of the sand. What kinds of things were you noticing that seemed like they might be helpful to you if you were going to categorize the sand, or try to identify what kind of beach it might have come from?

You probably listed things like the types of *organisms* found there, the *colors* of the sand, how *large* the grains were, and what their *texture* was like. In general you can probably divide your observations into three broad categories, observations about **size**, observations about **shape**, and observations about the probable **source** of the sand. These “3 S’s” of sand are informative about the beach that it came from. The three main informative features of sand are size, shape and source.

Size

The Wentworth scale shown in Table 1 is one system used to classify sediments by particle size. To classify a rock using the Wentworth Scale, it doesn’t matter what kind of rock it is, it only matters what size. Notice that the term **sand** is used for particles between 0.25 mm and 2 mm in diameter. Smaller particles are classified as **mud**, larger particles as **gravel**. **Sediment** is a general term for all particles, including boulders, gravel, sand, and mud.

The size of the sand is informative about the slope of the beach. As a general rule, the steeper the beach, the larger the particle size. This is because on steep beaches larger particles can be cast higher by the waves and tend not to be rolled and broken into smaller pieces like they are on flatter beaches.

Table 1. Wentworth grain-size scale

Diameter (mm)	**Sediment Particle**
>256	Boulder
>64	Cobble
>2	Pebble
>1/16	Sand
>1/256	Silt
<1/256	Clay

Particles can be separated into size groups by shaking them through a set of sieves. **Sieves** are containers with mesh bottoms. Graduated geology sieves usually stack, the one having the largest mesh openings on top and the one having the smallest mesh openings on the bottom. As sand falls through the sieves, the larger particles stay in the levels with the larger mesh.

Shape

The shape of sand particles are important too because they reveal information about their history and are informative about their origins. Rough, irregular particles are younger than rounded, smooth ones. Pure, distinctly shaped crystals are rarely found. Rough or sharp-edged particles become rounded and polished through **weathering**, which includes changes caused by waves, wind, and rain. When wind or waves move particles, the particles rub against each other, wearing down rough edges and smoothing surfaces. Water from waves or rain also acts to change particles by dissolving out soluble ions. Mature, rounded sand particles are more worn and smaller, containing fewer types of chemicals than less mature, angular particles. The amount of wave action at a beach influences particle shape as well. Sand particles from beaches with lots of wave action are smoother than those from beaches with little wave action.

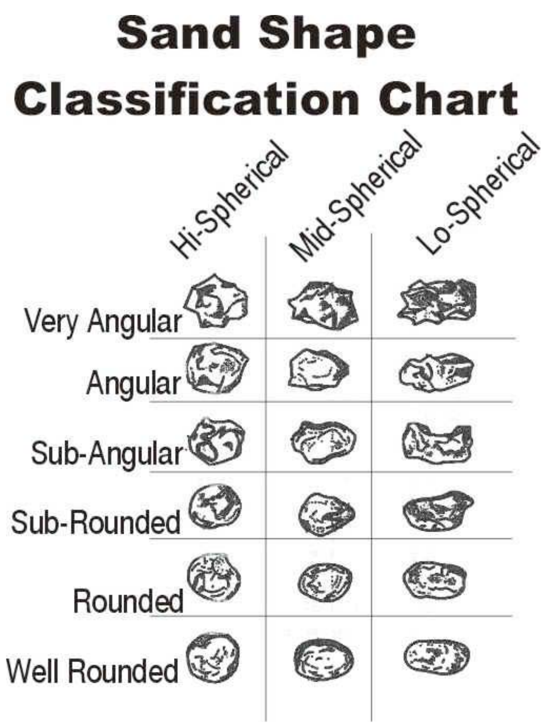


Fig. 2. Magnified sand particles showing classification of sand by shape (Source: www.theworkshop.ca.)

Source
By identifying the components of sand, we can tell what sand is made of and where it probably came from. Sands can be broadly classified by their source into two types. The first type, called **abiogenic sand**, is made of eroded pieces of rocks. The second type, called **biogenic sand**, is made of the skeletal remains of plants and animals. Bio = living, genic = originating from; a = not or without.

Abiogenic sands are inorganic mineral sands. Abiogenic sand particles are formed as rocks break down through weathering and erosion. Abiogenic sands are formed from rocks in the continental crust or the oceanic crust of the earth. The continental crust includes most of the major, dry landmasses of the world. Mountains in the continental crust are composed mostly of **granite**. Mineral sands formed by the breakdown of granite usually contain **quartz** and **feldspar.** Quartz and feldspar break down more slowly than **mica** or dark minerals like **magnetite**, which are also common in granite. Because they resist chemical and physical breakdown, quartz and feldspar are referred to as **resistant minerals**. The sands of most beaches along the coasts of the continental United States are called **quartz sands** because quartz is their most abundant, resistant component. Where continental volcanoes form, **olivine** and **obsidian** (volcanic glass) may also be found. The attached microscope page shows some perfect crystal structure components of abiogenic sand. Perfect crystals are rare in sand deposits. Over time these crystals are worn down, as was shown in Fig. 2.

The oceanic crust contributes to another type of abiogenic sand. The oceanic crust is made up of volcanic material called **basalt**. Volcanic islands, lava from volcanic eruptions, and the bottom substrates of the ocean basins are all made of basalt. Basalt is denser than granite and darker (black, gray, or brown) because it is richer in minerals containing heavy metals such as iron and manganese. Basalt contains no quartz, but it does contain resistant minerals (olivine) and glassy basalt sands (obsidian). Smaller amounts of other less resistant inorganic minerals are also found in basalt sands. Components of abiogenic sand are listed in Table 9–3.

Table 2. Common components of abiogenic sand

Basalt. Black lava flows are basalt. As they erode, they may form dull black, gray, or brownish red grains of gravel and sand. ***Feldspar***. Feldspar is clear, yellow, or pink squarish crystals with smooth, glossy, or pearly luster. ***Garnet***. Garnets are usually amber or beer-bottle color, but some are light pink. Perfect crystals have 12 faces. (Perfect crystals are rare because the ocean waves round off the edges rapidly.) Garnet is often used in making sandpaper. ***Granite***. Grains are usually light-colored to pink, with a salt-and-pepper pattern of mineral crystals all about the same size. ***Magnetic mineral grains***. These may be grains of iron ore (magnetite) or other metals. **Magnetite** crystals resemble a double pyramid. These grains are dense and tend to accumulate at the botton of containers. They are attracted to a magnet.

Mica. Mica forms shiny, paper-thin, translucent flexible sheets. It is light-colored or white and may appear iridescent.

Olivine. Olivine is a shiny crystal that can be various shades of olive-green to almost brown. It may be transparent or translucent and often contains specks of other crystals. It is found in basalt.

Quartz. Quartz grains are clear or transparent, resembling small pieces of broken glass. Quartz comes from granite and sandstone erosion. It is the most abundant mineral found in continental sand.

Volcanic glass. Hot, black lava forms black, shiny, irregular but sharp-edged particles when rapidly cooled; continental volcanoes form obsidian.

Other. "Beach glass" is formed when broken shards of manufactured glass are rounded and frosted by wave action. Other manmade substances (especially plastics) may also be found on the beach.

The skeletal remains of plants and animals are a second source of sands. **Biogenic sands** are also called **organic sands** or **biological sands**. Sands that come from a living source, such as coral, mollusk shells, worm tubes, or sea urchin spines, are made primarily of Calcium Carbonate; $CaCO_3$. Many organisms are able to remove Ca^+ and CO_3^- ions from the water and incorporate them into their hard structures as the compound $CaCO_3$. When the organisms die, they leave their hard parts behind, and tumbling by waves, grinding by other organisms, like parrotfish or sea urchins, or other processes wear them down into sand. These sands are sometimes called **calcium sands** (or limey sands) because the chemical composition of most skeletal remains is calcium carbonate (CaCO3), the material our bones are made of.

Weird Science: Parrotfish and sand

Scientists estimate that 75% of sand around reefs in the Caribbean has been processed by parrotfish. Parrotfish bite chunks of coral and grind it in a special set of toothplates in their jaws called a pharyngeal mill (pharyngeal = relating the pharynx or throat). The fish aren't actually interested in the coral as much as the fine filamentous algae that grows in the tight little spaces of the coral skeleton, but they have to break down the coral to get it. The ground-up coral passes through their digestive tract and is expelled as fine white sand. Kind of makes you re-think building that sand castle, doesn't it?

It isn't always easy to tell if sand is biogenic just by looking at it because weathering processes can turn identifiable structures into smooth grains. The interesting thing about $CaCO_3$ is that it reacts with acid, even weak acids like vinegar (also known as acetic acid) to produce bubbles when the carbonate is broken down by the hydrogen ion from the acid and carbon dioxide is released. Sand that does not come from a living source, like quartz sand (from glass or silicate- SiO_2), does not react with weak acids like vinegar. A simple chemical test for distinguishing calcium (biogenic) sands from inorganic (abiogenic) sands is to drop vinegar or other acid onto a pinch of sand particles. If the sand contains calcium carbonate, the particles react with the acid to form bubbles of carbon dioxide. So, if you are unsure as to the origin of a sand sample, you can conduct a simple test by dripping vinegar on the sand. If it bubbles, it is biogenic-it is of living origin.

Most biogenic sands are composed of fragments of corals, coralline algae, and mollusks. Usually biogenic sands are described by their most abundant component—for example, coral sand or coralline algae sand. Some of the components are the skeletal remains of entire organisms, such as the micromollusks or the single-celled foraminifera. Biogenic sands also include other resistant biological fragments, such as sea urchin spines and sponge spicules. Fossil remains such as tiny teeth and parts of jawbones are sometimes found in beach samples. Some biogenic sand components are listed in Table 3.

Table 3. Common components of biogenic sand

1. Barnacle fragments. Pieces of the calcareous plates that form the carapace (shell) of a barnacle, the only sessile group of crustaceans; may be white, yellow, pink, orange, lavender, or purple. Occasionally they have a striped or notched pattern. (Earlier biologists mistakenly thought that barnacles were mollusks; hence the carapace was called a shell.)
2*. *Bivalve mollusks. Entire bivalve shells or pieces of clam, oyster, or mussel shells may appear white, gray, blue, or brown; usually not shiny; slow to dissolve in acid.
3. Calcium-depositing algae. **Calcareous algae** are those green or brown algae that secrete small amounts of calcium carbonate to form delicate or finely branched skeletons. An example is ***Halimeda*** with its short branches of articulated blades that when dried look like oatmeal. **Coralline algae** are marine algae that secrete large amounts of calcium carbonate to form stronger, more robust skeletons. Encrusting coralline algae appears rose or lavender when alive and white when dried. Solitary clumps of coralline algae are often mistaken for coral.
4. Coral. Fragments of dull-white coral rubble are common in tropical sand. Larger, uneroded pieces from the outer layer of coral may be identified by their many small holes (cups) where individual coral polyps once lived.
5. Foraminifera. The skeletons of one-celled animals (protozoans). They may be white, dull or shiny, or be covered with tiny sand grains. They look like tiny shells except that their apertures are small and slitlike or porelike. "Forams" have a small hole where the living animal extended its false feet to trap food.
6. Gastropod mollusks. Entire snail-like shells or fragments, varying widely in color, shape, and pattern. Juvenile shells are more fragile than their adult forms and may differ in appearance. Eroded fragments may reveal internal spiral growth patterns. **"Cat's eyes,"** white disks, round on one side and flat on the other, are intact operculums from turban shells. The cat's eyes are trapdoor-like structures used to close the outer opening when the foot is withdrawn into the shell. **"Puka" shells** are the tops of eroded cone shells that appear as stout, light-colored disks with a hole in the center. Their slightly concave undersides sometimes show concentric rings. (*Puka* is Hawaiian for "hole.") A few years ago puka shells were collected, strung, and sold as necklaces all over the United States.
7. Sea urchin fragments. Spines may be white, purple, black, beige, or green. Viewed under a

microscope, some have crystalline matrices that look like ornate corn-on-the-cob structures from the side or like concentric growth rings from the top. **Tests** are the inner skeletons of sea urchins. Test fragments have tiny holes and raised knoblike structures arranged in regular sequences; they appear dull white or lavender.

8. Sponge spicules. Spicules are usually clear and transparent or whitish; large triaxon sponge spicules may resemble the three-pointed logo of the Mercedes-Benz automobile. They make up the internal skeletal support structure of some sponges.

9. Worm tubes. Pieces of calcareous tubes secreted by worms. They are white or brownish and look ring-shaped when viewed from the top.

10. Other. Biogenic sand may contain other animal parts such as pieces of crabs or shrimps, or the colonial animals known as bryozoans.

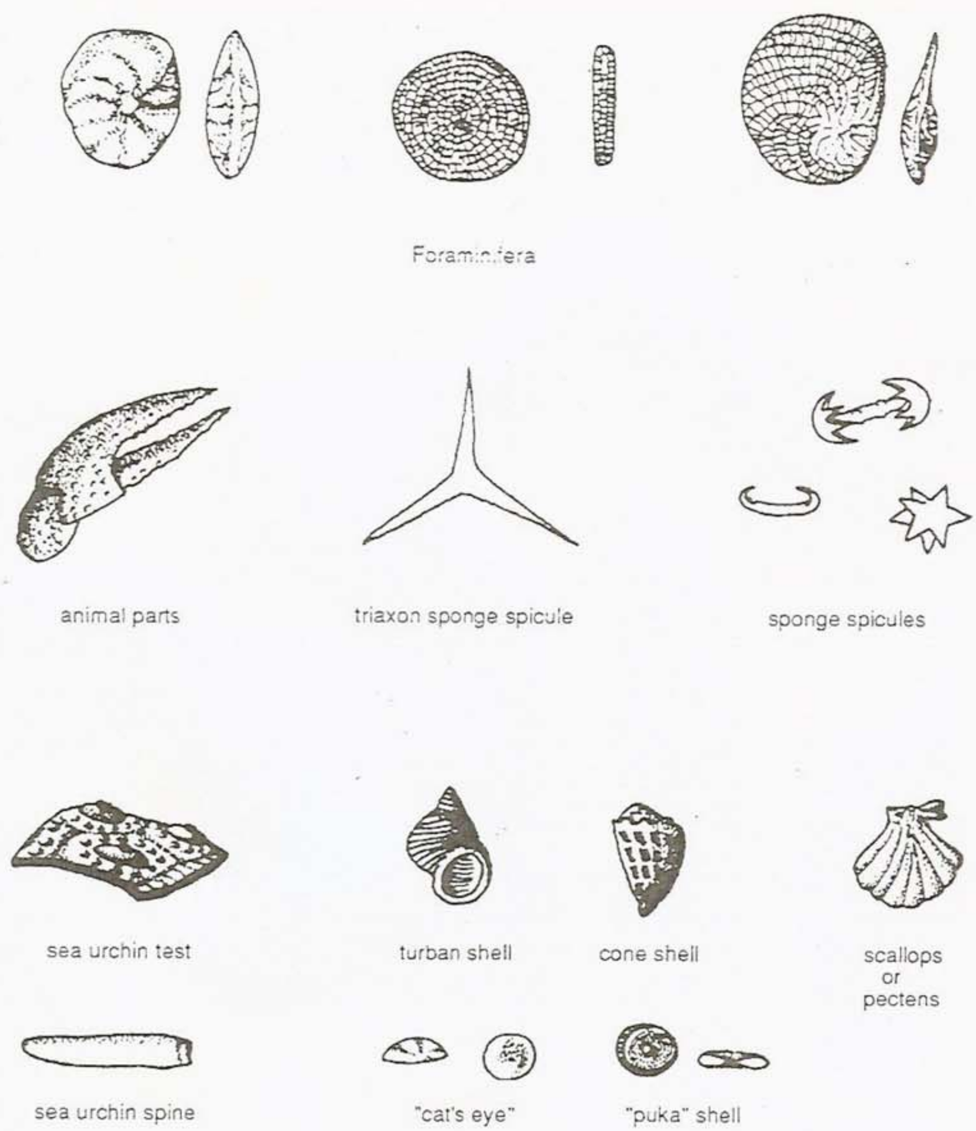
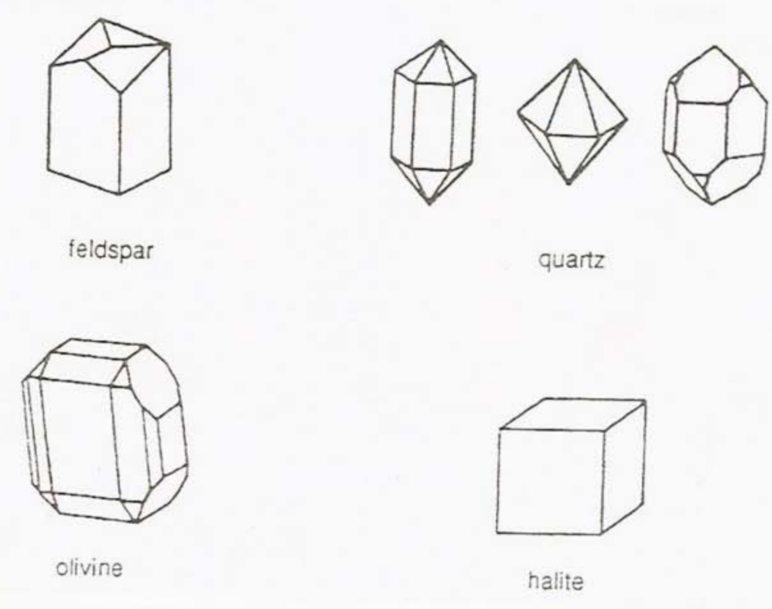


Fig. 9–5. Biogenic sand components



Name___________________________

Sand Lab

1. Investigate several sand samples. For two samples, record the source of the sand on the attached table. Also, describe the sand's size and shape. Based on this evidence, and using the information in the attached handout, hypothesize what kind of environment the sand may have come from (e.g. a steep beach in the tropics with high wave energy).

Sand Sample #1:

Sand Sample #2:

2. Meiofauna are small organisms between 62 um and 0.5 mm in size that live in the spaces between sediment grains. What features of different beaches/different types of sand might affect the abundance and diversity of meiofaunal organisms living there? How?

Material developed for the University of Hawaii-Manoa GK-12 program (NSF grant #05385500).
Website: www.hawaii.edu/gk-12/evolution. Duplication for educational purposes only.

microbus

take a microscopic trip

Applications

Sand Analysis

What is sand? Sand is defined as granular material that passes through different sizes of strainers or "sieves". According to the classification parameters, material of which 50% or more is coarser than the #200 sieve but which 50% or more is finer than the #4 sieve, is classified as sand. The #200 sieve has openings of 75 microns (.075mm) of diameter while the #4 openings are 4.75 millimeters in diameter. If there are large amounts of particles smaller than 75 microns, the material is called clay, or silt. If there are large amounts of particles bigger than 4.75 mm, the material is called gravel.

Have you ever looked at sand with a microscope? If not then start collecting! You will find that sand is one of the most fascinating things to look at under a microscope. In fact, sand is somewhat of a fingerprint for the beach it comes from. When observing samples, the best type of microscope to use is a stereo zoom with magnifications of 10X to 40X. A dual power 10X / 30X or 20X / 40X stereo would also be a good choice. For some interesting effects, try using a bright flashlight and illuminate the sample from the side. It will cast long shadows and bring out the definition and color of many minerals. If you only have a compound (biological type) microscope, use the 4X objective only, put your sample on white or black paper and illuminate from above with a bright light. Are you ready? Jump on the Micro-Bus and journey to some of the most exotic beaches of the world below!

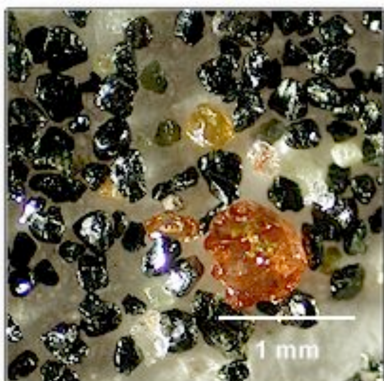
Lake Powell (Utah)

The mighty rivers like the Colorado wear away the rocks as water passes on it's way to the sea. Tiny bits of decomposed rock are carried along in the water. When water reaches a lake, it slows down and some of the sand particles are deposited to make beaches. We start with this image of sand from Lake Powell to illustrate some of the basic things you should look for when investigating sand. First, the size of the grains is always important. Put a metric ruler under your microscope to get an idea of their size. The shape of the material is also important. Is it smooth or rough? Third, can you identify the material that makes up the sand? Is it made from minerals like quartz, feldspar or mica or is it made from tiny bits of broken shells?

Lake Powell Sand

Some samples are best observed on a white background and others on a black background. Try both to see which is best.

Here we see the same sample, magnified more on a black background. See how different it looks. Sand is a byproduct of weathering. The particles in sand are usually very small bits of something very large upstream, like a huge mountain. But not all sand is deposited from rivers. On some beaches, wave action on coral underwater deposits tiny bits of coral on the beach. From a distance, the color of the sand is related to the composition of the individual particles. Lots of quartz will produce a shiny white beach. Lots of feldspar will make a more orange colored beach. Common black minerals in sand are mica and hornblend.



California Black Sand

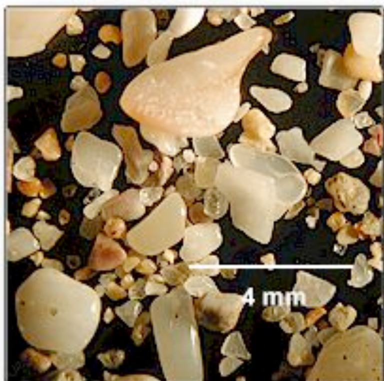
One winter day I found this expanse of black sand on a beach north of San Diego. The waves had been big for a few days and most of the lighter sand with quartz and feldspar had washed out to sea leaving this heavy material behind. I took a sample back to my lab for analysis. It was very pretty with many interesting minerals. It was also quite heavy as compared to regular sand. I wondered why it was so dense so I grabbed a magnet off my refrigerator door and ran it through the sample.

California black sand after magnet

Many of the black particles stuck to the magnet. Those metallic particles are called magnetite. I looked at what was left. There was still some black minerals. My guess is that they are hornblende. The green crystals could be olivine.

Waianapanapa, Maui Sand

If you ever drive the road to Hana on the island of Maui (Hawaii) be sure to stop at Waianapanapa Beach (3 miles before Hana). It is a gorgeous black sand beach. Unlike the sand above, you can see that these particles are dull in color and likely made from something other than magnetite or hornblende. The sand here is composed of basalt (lava) which is weathered by waves and wind at the oceans edge. At Waianapanapa you will also see many photogenic volcanic arches and sea stacks at the oceans edge. This is a good clue as to why the sand on the beach is black.



Cabo, Baja Mexico Sand

Some beaches aren't made of minerals at all but rather tiny bits of broken shells. Notice the size scale here. These particles are quite large. When you walk on a beach like this you can feel the coarseness of the sand under your feet. Because there is very little rain in Baja, there is very little transport of material from the land. As one might guess, the sand must be made from some material other than decomposed rock. After time, wave action will smooth out the sharp edges of the shells. In this picture you can see some smooth and some sharp pieces

St. Maartin, Caribbean Sand

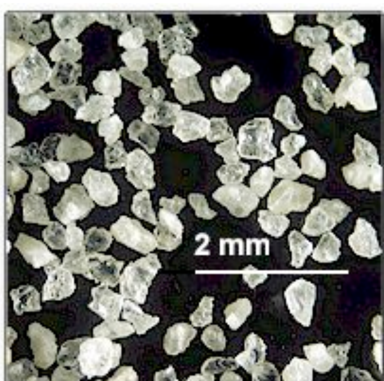
Another example of a beach made of shell fragments. If you spend some time sifting through the sample you should find some less eroded material. You could eventually start to identify and classify each particle and make a hypothesis as to what type of mollusk that particle originally came from.

North Shore, Oahu, HI Sand

Like the two samples above, Hawaiian beach sand is primarily made up of the shells of micromolluscs (tiny snails) and broken and worn pieces of larger shells and corals. On beaches with intense wave action (like this North Shore sample), the shell pieces are rounded by the energy of the waves. On more protected Hawaiian beaches the sand is coarser and the particles are more defined (compare to the Cabo sample above).

Huahini, Tahiti Sand

In French Polynesia there are no big rivers that flow to the sea nor is there freezing of rock to break it up. Some of the minerals (mostly volcanic) find there way to the beach but the beaches in Tahiti are predominantly very white and made up of bits of coral. The islands are mostly protected by barrier reefs so there is little wave action. The sand particles are generally not smooth like those of the North Shore above and from this sample you can see why the beaches in Tahiti are so very white and soft.

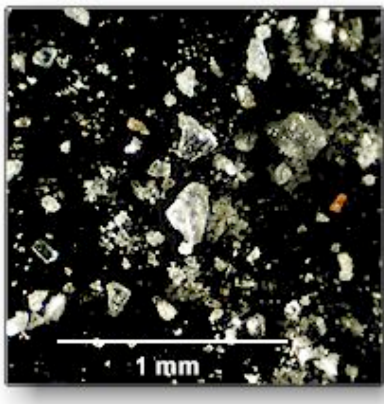


Lumber yard

You don't have to live near the beach to collect sand. Take a trip to your local lumber company and go to the area where bricks and concrete are sold. Likely you will find the big bags of sand used for sandblasting or to mix with cement. Some is very fine and white, almost pure quartz. Look around the floor. There will surely be a spill from one of the bags. Take a sample. Hmmmm, I don't think it would be shoplifting but never cut open a bag for a sample! From our scale, notice how small these particles are.

Guam, green sand!

Yes, it really is green sand. It is strange to walk on a green beach and there are very few green sand beaches in the world. One is on the island of Guam and another is found on the big island of Hawaii (2 hour hike from South Point). The beach formed by the erosion and concentration of olivine crystals derived from a surrounding lava cone. Olivine is a mineral commonly found in basalt lava. The waves removed the lighter grains of sand leaving the denser olivine crystals behind to form the beach.



Mt. St. Helens

This is not sand because the particle size is too small. It is called ash and is presented here as a reference. Like dust, the particles are extremely small but on close inspection (40X) we see very tiny bits of quartz (Silica) and other minerals, all with very rough edges. It was ejected from the Mt. St. Helens volcano on May 18, 1980. Can you explain why the grains aren't smooth?

If you are considering purchasing a microscope to study sand, we recommend the zoom model 420 (10X-40X) or the model 446TBL-10 from MicroscopeWorld.com (see "suppliers" at the top). The 446TBL-10 is a stereo microscope with two powers 10X and 30X. You might also choose a 446TBL-15 with 15X and 45X. Stereo is best as it gives a 3-D effect. If you are really getting excited about sand then jump back on the Micro-Bus and head over to the sand collectors information page your resource to sand other sand collection websites.

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