TENACITY: BREAKING, BENDING, STRETCHING

Tenacity (from the Latin *tenacitus*, to hold fast) refers to how a mineral will break, bend, cut, or crush it. This property is the reason many ores are mined to manufacture important products, such as copper wires and gold and silver jewelry. Some minerals behave differently under different stresses: they may break when hit with a hammer, but can be cut with a knife.

Brittle: Mineral that breaks into fragments when hammered or crushed, are *brittle*. Calcite and quartz can be broken into small pieces. The combination of abundance and brittleness of quartz accounts for its dominance in beach sand.

Malleable (from the Latin *malleus*, a hammer or mallet): Mineral that, when hammered or rolled, do not break, but simply change shape, are said to be *malleable*. Malleable minerals can be pounded or rolled into thin sheets. Examples of malleability include native metals as copper, gold, silver, and lead. Romans made pipes out of lead (Latin, *plumbum*), giving us "plumbing."

Ductile (from the Latin *ductilus*, drawing out): Copper and other metals can be drawn into wires. Many minerals that are malleable are also ductile. But some, like lead, which can be hammered cannot be pulled in wires.

Sectile (from the Latin *sectilus*, a cut): Minerals that can be cut into thin pieces with a knife are *sectile*. Many soft minerals (H < 3) can be easily cut. Examples include graphite and gypsum.

Elastic: Elastic minerals can bend without breaking, and will return to the original shape when the force is released. Thin sheets of mica are the classic example of this. But if bent too far, the sheet can snap.

Flexible: Flexible minerals, like an elastic ones, bent without breaking, but remain permanently bent when the force is released. Thin plates of gypsum provide examples of flexibility.

ACTIVITIES

Tenacity in household objects

Tenacity does not, of course, apply only to minerals, so students can understand its importance using a wider variety of common household materials is demonstrated. We recommend that the teacher provide a collection of items to be damaged (and not suggest students try these activities at home!)

Materials needed:

You will need some of the following:

- a candle or two
- various items made of plastic
- a lead fishing sinker
- a short piece of copper pipe
- a clay pot
- a ceramic dinner plate
- a stainless steel spoon
- a piece of linoleum
- a length of rubber hose
- anything else that may be handy

You should provide a fairly wide selection of metal, ceramic, plastic, and other objects, to see how they behave under stress. Glass objects should be avoided because they are a safety hazard, but the teacher could demonstrate this inside by placing the glass object in a strong plastic bag. Also avoided are composites made of more than one type of material.

You will also need:

- hammers, knives, and pliers (for bending and crushing)
- plywood, or thick sheets of cardboard to protect desks and tables from damage.

Procedure

1. Hammer, cut, crush, bend, fold, poke, etc. .
2. Record what happens, listing in categories: metals, ceramics, plastics, organic, etc..
3. Discuss the results. You will probably find that metals are malleable, ceramics brittle, and plastics brittle when struck but (for some) elastic or flexible when bent. This can lead into discussions of how scientists and engineers select different materials for different purposes.
4. The same material can exhibit different behaviors under different kinds of stress. A wax candle, will break into fragments if struck by a hammer, but the wax is sectile when cut. A plastic drinking glass will shatter if hit by a hammer, but is elastic when slightly bent.

Tenacity versus temperature

Temperature greatly changes the response of many materials to stress,. You can show this effect using two candles. Place one in a freezer and gently warm the other in a tub of warm water. Then bend the candles. The cold candle snaps, but the warm one can be bent into a curve.

DISCUSSION

Engineers and others who build things must be aware of how different materials respond to the types of stress anticipated during use. Attention to temperature effects can be important as well. Here are two examples for classroom discussion and investigations.

1. Gold, the most malleable of metals, can be pounded into sheets so thin that a stack of 280,000 of them measures only an inch high. Gold in this form is referred to as "gold leaf" and has long been used in the decorative arts and in architecture, for large surfaces can be covered using only small amounts of gold.

2. Iron and steel become more malleable when hot. This is why blacksmiths heat iron before hammering it into horseshoes and other products. “Hot working” in mills produce steel sheets. The composition of steel must be carefully adjusted to the anticipated temperature range of its use. Most steel is exceedingly strong and somewhat elastic, properties that make it ideal for such applications as skyscrapers, where the support beams must be able to bend slightly in strong winds, and then recover their original shape. At low temperatures, some steel becomes brittle. Engine blocks of cars occasionally fracture at subzero temperatures.

Adapted from: “Tenacity” By Earl R. Verbeek, Sterling Hill Mining Museum, Ogdensburg, NJ, USA