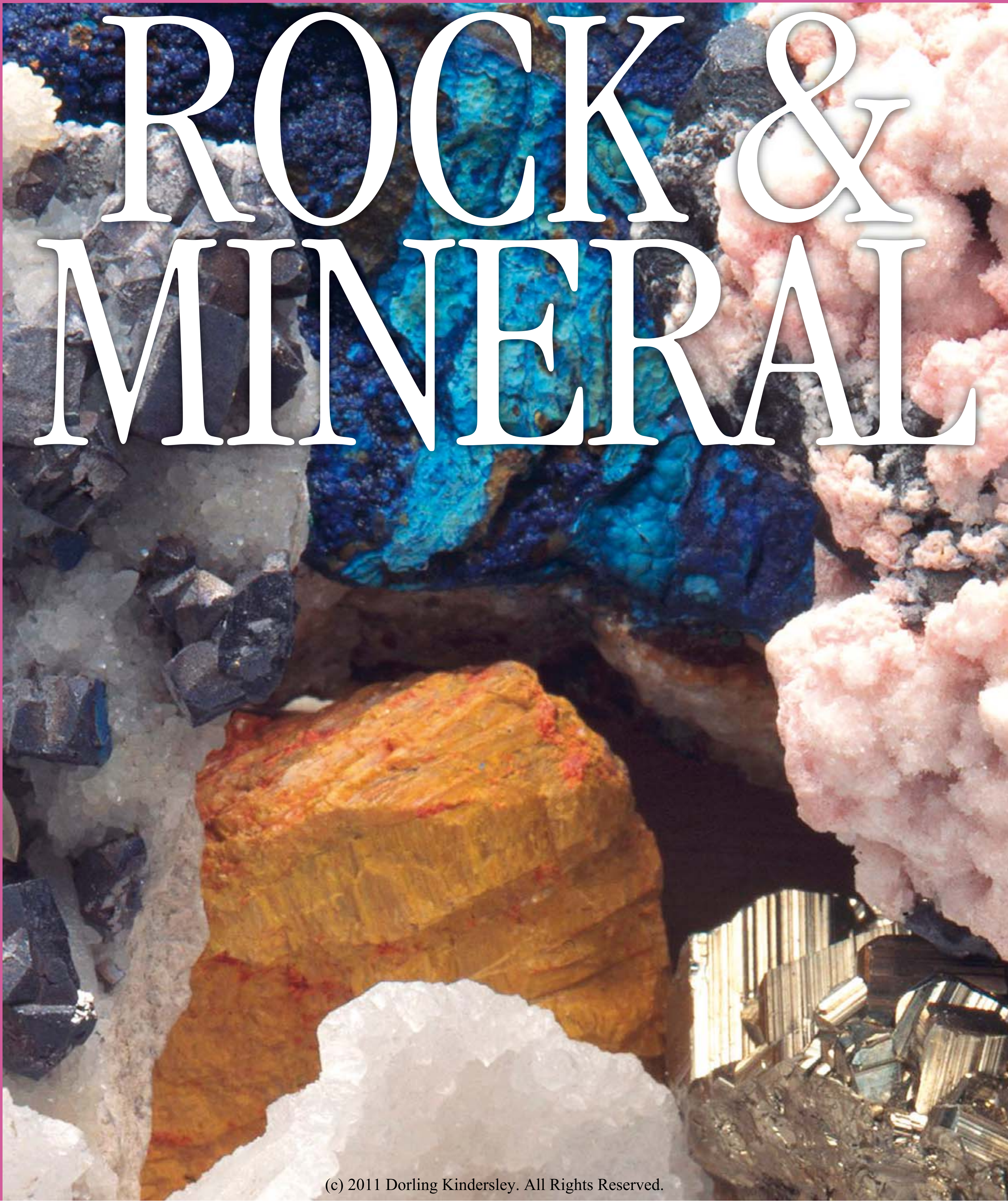
DK Eyewitness

ROCK & MINERAL



Eyewitness

ROCKS & MINERALS


Slice from
septarian nodule
Garnet-chlorite schist
Cinnabar
Hematite
Granite
Gypsum desert rose
Wenlock limestone
with triolobite fossils

Opal

Eyewitness

Cut tourmalines

ROCKS & MINERALS

Written by
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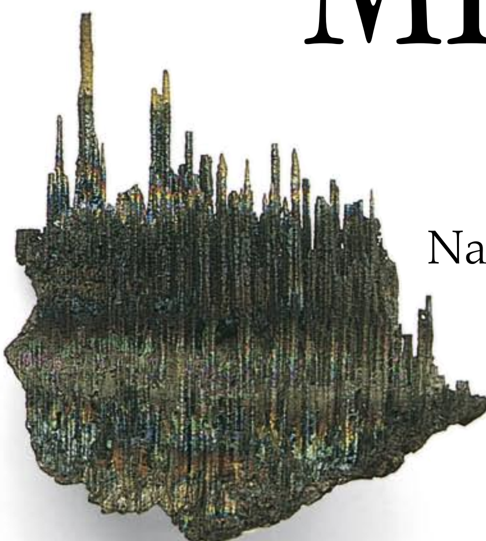
and the staff of the
Natural History Museum,
London



Geothite

Obsidian

Pyrite

Nephrite "tiki"

Labradorite

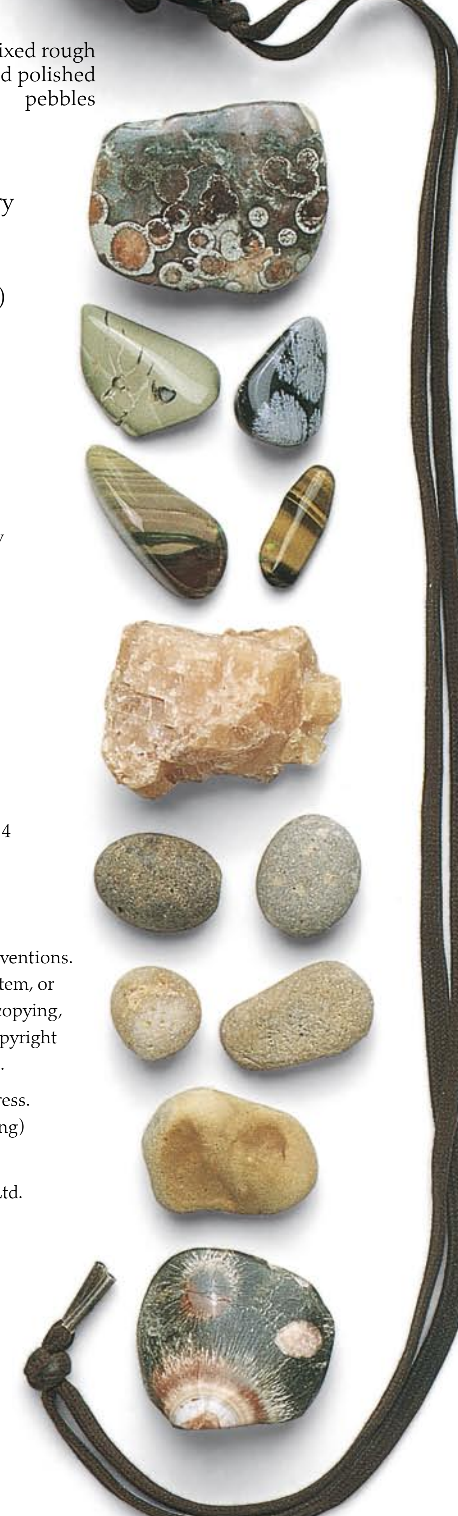
Sulfur

DK Publishing

Magnifying lens

DK

LONDON, NEW YORK,
MELBOURNE, MUNICH, and DELHI



Mixed rough and polished pebbles

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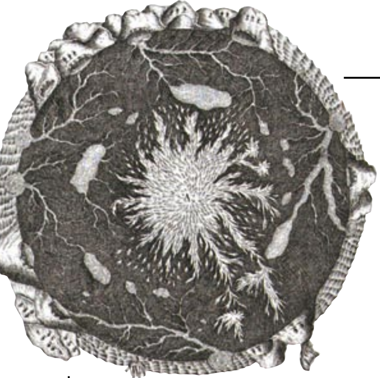
Chisel

Geologist's hammer

Chalcedony cameo

Contents

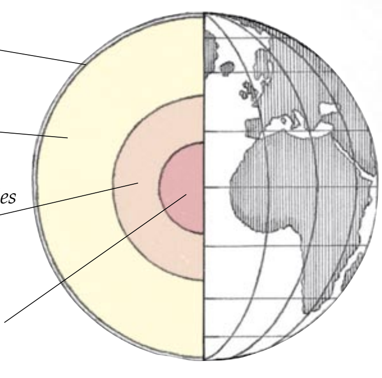


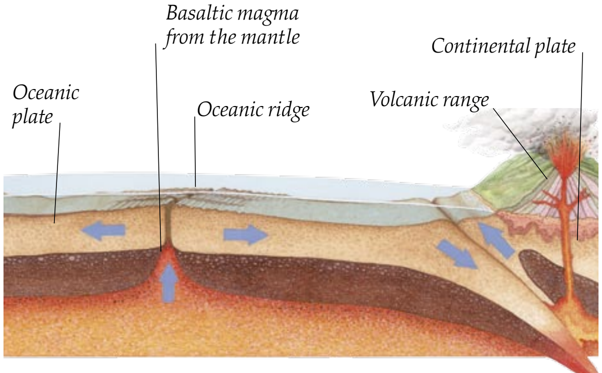
Early view of Earth with a central fire

The Earth

ONE OF THE NINE known planets that revolve around the Sun, the Earth is thought to be about 4.6 billion years old. Geology is the study of the history of the Earth. Because rocks can provide valuable information about the Earth in previous times, geologists study them and work out the processes and events that produced them. As we can currently bore only a few miles into the crust, or outer shell, we cannot sample rocks from the mantle (the inner shell) directly. The rocks and minerals shown here come from many locations and introduce important features that are explained in more detail later in the book.

THE STRUCTURE OF THE EARTH
The Earth consists of three major parts: the core, the mantle, and the crust. The crust and upper mantle form continental and oceanic "plates" that move slowly over the mantle beneath. The closer to the center of the Earth, the greater the temperature and pressure.





MOVING PLATES
Where plates collide, mountain ranges like the Himalayas may form. In the ocean, material from the mantle fills the gap between plates to form a ridge. In other areas, oceanic plates are forced down beneath continental plates, causing volcanic activity.

PRECIOUS METALS
Platinum, silver, and gold are rare and valuable metals. *For more information, see pages 58-59.*

SEASHORE PEBBLES
These are formed by the weathering of larger rocks by wave action. *For more information, see pages 14-15.*

Gold in quartz vein

CRYSTAL HABITS
The shape and size of a crystal is known as its habit. *For more information, see pages 46-47.*

Cubes of pyrite

MINERAL ORES
These are the source of most useful metals. *For more information, see pages 56-57.*

Cassiterite (tin ore) from Bolivia

Cut citrine, a variety of quartz

Diamond in kimberlite

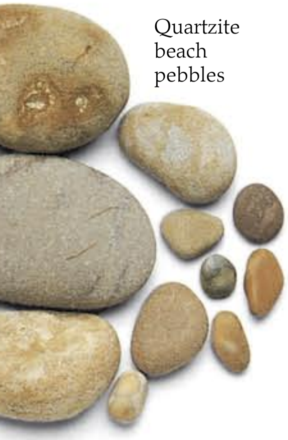
GEMSTONES
Rare, hard-wearing, and attractive minerals may be cut as gemstones. They are used mainly in jewelry. *For more information, see pages 50-55.*

Quartz crystals from France

CRYSTALS
Many minerals form regular-shaped solids with flat surfaces, known as crystals. *For more information, see pages 44-47.*

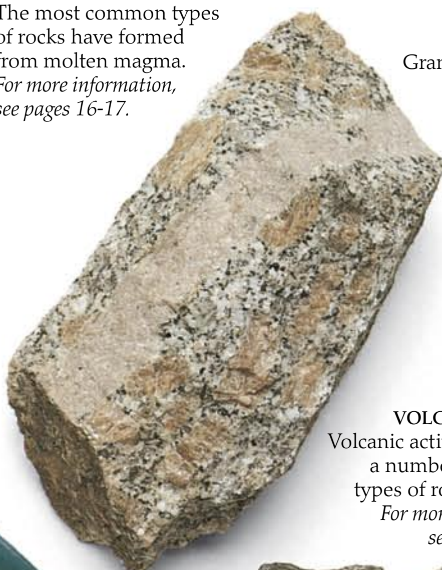
Shelly limestone

FOSSILS
These rocks contain the remains of, or impressions made by, former plants or animals. *For more information, see pages 38-39.*



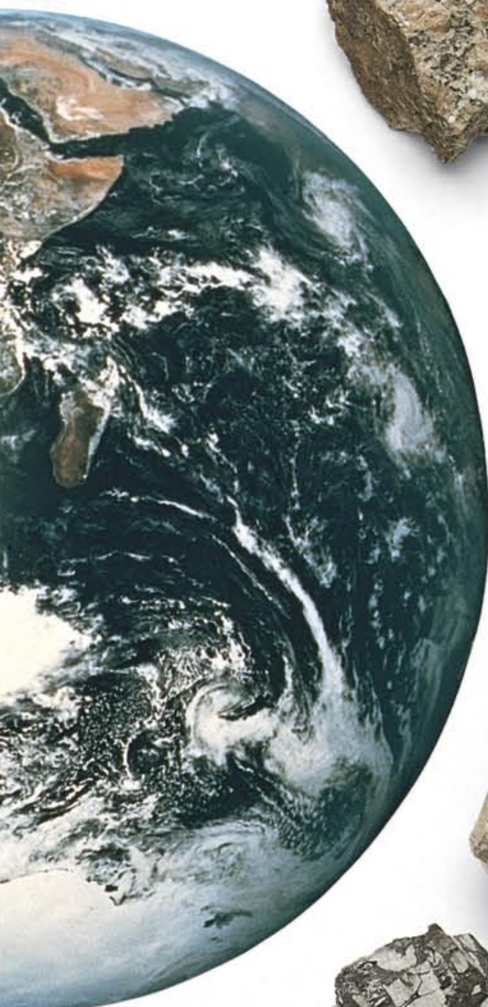
Quartzite beach pebbles

IGNEOUS ROCKS
The most common types of rocks have formed from molten magma. *For more information, see pages 16-17.*



Granite

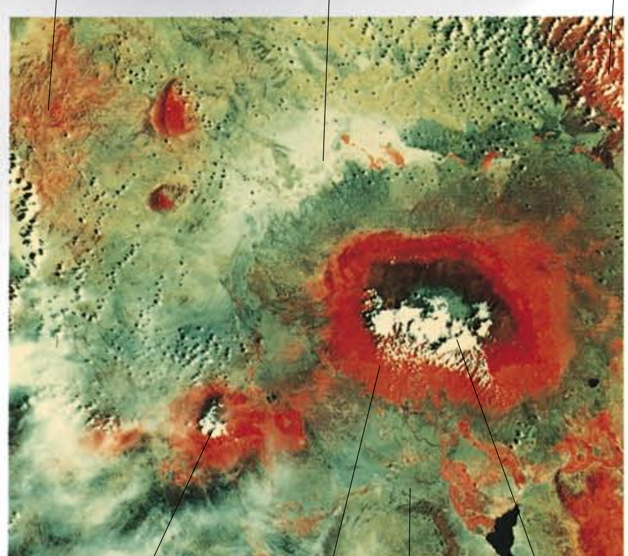
SATELLITE PICTURE OF NILE RIVER AND DELTA
The Nile River carries rock debris eroded from rocks in central Egypt and deposits it in the delta and the sea, where it may eventually form sedimentary rocks (pp. 11 and 20).



VOLCANIC ROCKS
Volcanic activity produces a number of different types of rocks and lava. *For more information, see pages 18-19.*

Hawaiian ropy lava

Carboniferous Limestone



SATELLITE PICTURE OF EAST AFRICA
This area shows a range of landscapes, formed from different rocks. For example, volcanic rocks (p. 18) forming volcanic Mount Kilimanjaro, and evaporites (p. 21) in dried-up lakes.

SEDIMENTARY ROCKS
These have formed from sediment that's been created by the erosion of other rocks and packed together. *For more information, see pages 20-23.*

Anthracite, the hardest form of coal

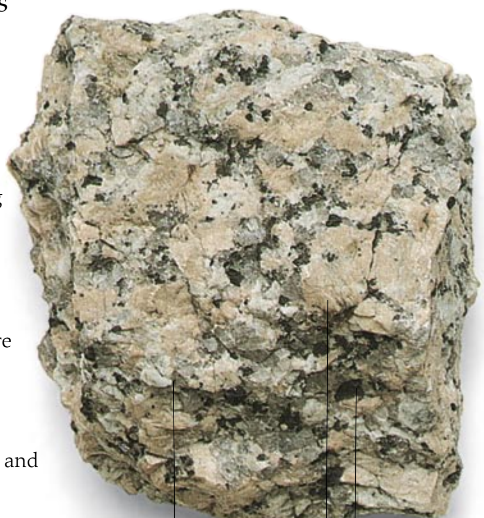
COAL
A sedimentary rock, coal has formed from the fossilized remains of plants. *For more information, see pages 36-37.*

What are rocks and minerals?

James Hutton (1726-97), one of the founders of modern geology

ROCKS ARE NATURAL AGGREGATES or combinations of one or more minerals. Some rocks, such as quartzite (pure quartz) and marble (pure calcite), contain only one mineral. Most, however, consist of more than one kind. Minerals are inorganic (nonliving) solids that are found in nature. They are made of elements such as silicon, oxygen, carbon, and iron. Here, two common rocks - granite and basalt - are shown with individual specimens of the major minerals of which they are formed. Rock-forming minerals can be divided into several groups - these are described in more detail on pages 42-43.

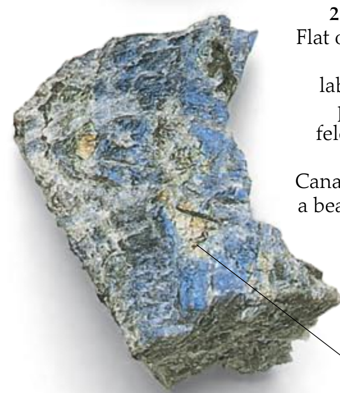
GRANITE AND ITS MAJOR MINERALS
Usually, several kinds of minerals are present in a rock, their size and texture varying according to how the rock formed. In granite, a coarse-grained, igneous rock, the three major minerals are visible to the naked eye. They are quartz (gray areas), feldspars (pink and white), and mica (black).



BASALT AND ITS MAJOR MINERALS
Basalt consists mainly of three minerals - olivine, pyroxene, and plagioclase feldspar. But because it is fine-grained, it is not always possible to tell them apart with the naked eye. This olivine basalt is from the crater of the Kilauea volcano in Hawaii.

1 QUARTZ
Well-developed quartz crystals, like this group, may have milky, etched faces.

1 OLIVINE
Transparent green crystals of olivine are comparatively rare, and are known as peridot (p. 54).



2 FELDSPAR
Flat or polished crystals of labradorite, a plagioclase feldspar from Labrador, Canada, display a beautiful play of colors.

2 MICA
Black biotite (a type of mica) crystals can be split into wafer-thin sheets.

3 FELDSPAR
Crystals of orthoclase (a feldspar) may be milky white or pale pink.

3 PYROXENE
This well developed, single black crystal of augite (a pyroxene) comes from Italy. Augite crystals are found in various igneous rocks.

The scope of rock forms

Rocks and minerals occur in many different forms. Rocks do not necessarily have to be hard and resistant; loose sand and wet clay are considered to be rocks. The individual size of minerals in a rock ranges from millimeters, in a fine-grained volcanic rock, to several yards in a granite pegmatite.

ROCKS FORMED WITHIN ROCKS
This sedimentary rock specimen is a claystone septarian nodule. Nodules (knobs) such as this are formed when groundwater redistributes minerals within a rock in a particular pattern. Nodules are sometimes known as concretions. Here, the pattern of veins is formed of calcite.

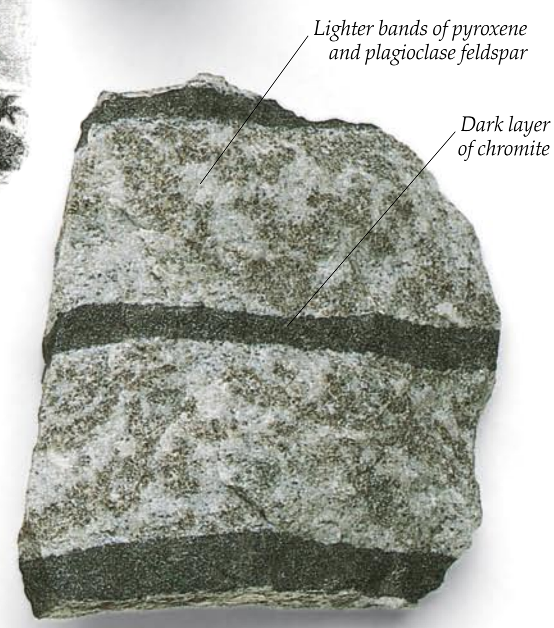
CRYSTALS FROM MINERAL ORE
Orange-red crystals of the mineral wulfenite from Arizona are formed in veins that carry lead and molybdenum.

ROCKS FORMED BY EVAPORATION
Stalactites are formed from substances that are deposited when dripping water evaporates (p. 22). This spectacular pale blue stalactite is composed entirely of the mineral chalcanthite (copper sulfate) and formed from copper-rich waters in a mine.

Section of a mine roof colored with deposits of the copper mineral, chalcanthite

Eruption of Mount Pelée, Martinique, on August 5, 1851

ROCKS FROM VOLCANIC ERUPTION
Despite its extraordinary appearance, "Pele's hair" is technically a rock. It consists of golden-brown hairlike fibers of basalt glass that sometimes enclose tiny olivine crystals, and was formed from the eruption of basaltic magma as a lava spray.



ROCKS THAT FORM IN LAYERS
Norite is an igneous rock composed of the minerals pyroxene, plagioclase feldspar, and the chromium-rich mineral chromite. In this specimen from South Africa, the dark and light minerals have separated from each other so that the rock is layered. The dark chromite layers are an important source of chromium.

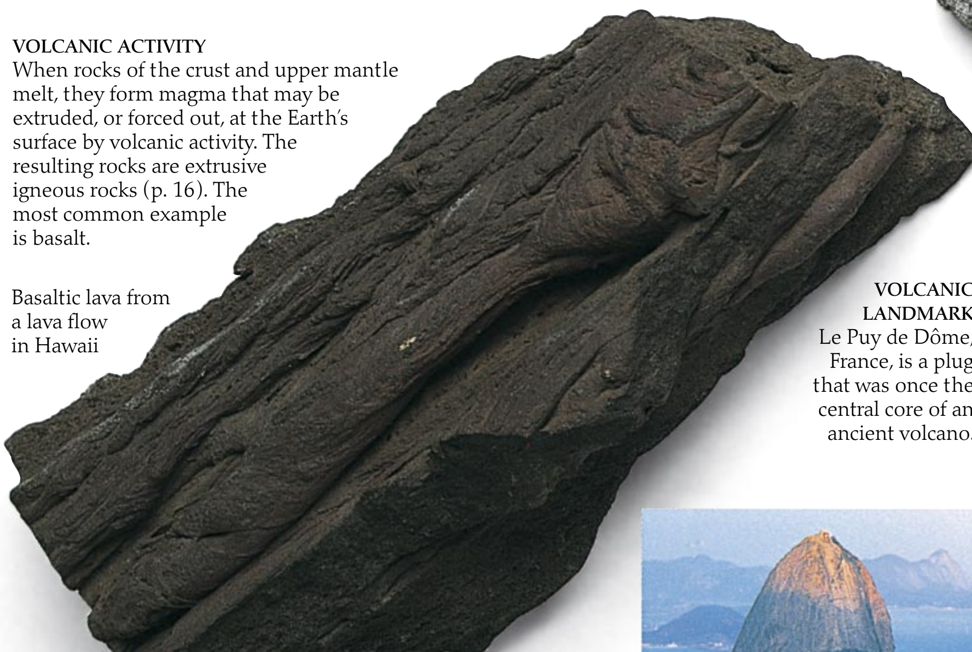
How rocks are formed

Geological processes work in constant cycles - redistributing the chemical elements, minerals, and rocks within and at the surface of the Earth. The processes that occur within the Earth, such as metamorphism (changing) and mountain building, are driven by the Earth's internal heat. Surface processes, such as weathering, are activated by the Sun's energy.

Andesite formed from a volcanic eruption in the Solomon Islands in the Pacific

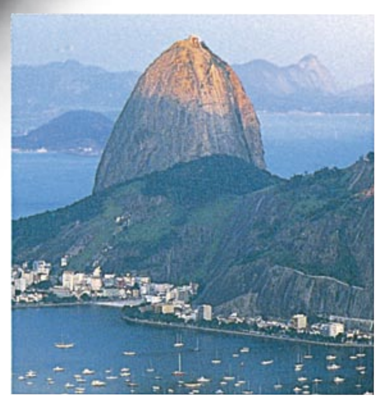
Pure quartz sand formed from weathered granite or sandstone

VOLCANIC ACTIVITY
When rocks of the crust and upper mantle melt, they form magma that may be extruded, or forced out, at the Earth's surface by volcanic activity. The resulting rocks are extrusive igneous rocks (p. 16). The most common example is basalt.

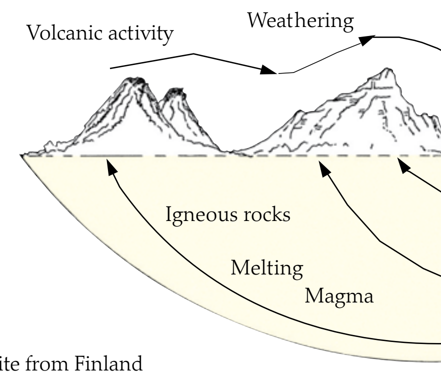


Basaltic lava from a lava flow in Hawaii

VOLCANIC LANDMARK
Le Puy de Dôme, France, is a plug that was once the central core of an ancient volcano.



IGNEOUS ROCKS
Sugar Loaf Mountain, Brazil, consists of intrusive igneous rocks that have gradually reached the surface when rocks covering them were weathered away.



Gabbro, the coarse-grained equivalent of basalt, from Finland

Granite, containing large crystals of pink feldspar, from northern England

Migmatite from Finland

MELTING *right*
Occasionally, high temperatures and pressures cause rocks to partially melt. If the rock is then squeezed, snakelike veins may form. Migmatites are mixed rocks consisting of a metamorphic "host" such as gneiss or schist, cut by veins of granite. They demonstrate the passage of rocks from the metamorphic state to the molten or igneous

ROCKS FROM MAGMA
Rocks formed within the Earth from molten magma are called intrusive igneous rocks (p. 16). They are also known as plutonic, after Pluto, the Greek god of the underworld. One such rock, granite, can form enormous masses called batholiths in mountain belts.

WEATHERING
As the weather acts on rocks it may lead to chemical changes or cause the rocks to fragment (p. 12) and form sediments. For example, sand grains are produced when quartz-bearing rocks are broken down, and clays form from weathered rocks full of feldspar.

Clays produced by weathering become important parts of soils

DEPOSIT OF SEDIMENTS
Sediments are carried by rivers, or by the wind in desert regions. When the wind or water slows down as, when a river runs into a lake, the sediment is deposited into layers of different sized particles. When these are compacted (pressed) together they form sedimentary rocks (p. 20).

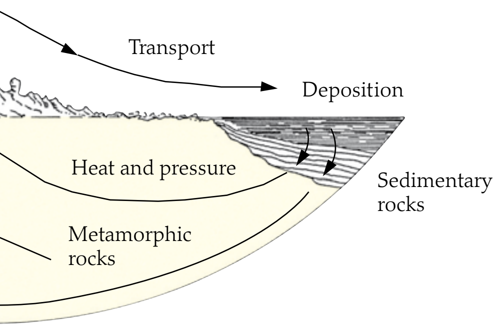
Layered sandstone from Arkansas

RIVER TRANSPORT
Rivers such as these (seen from space) carry rock fragments from one area to another. The Mississippi alone deposits thousands of tons of debris into its delta each day.

Banded claystone from Uganda, East Africa

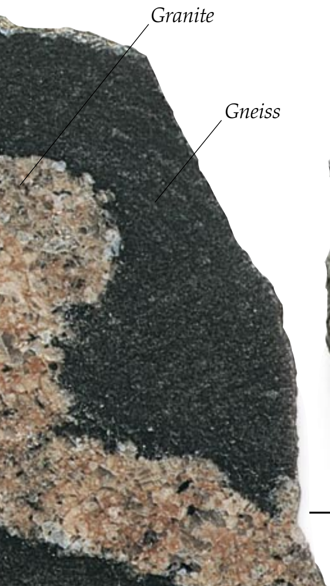
200-million-year-old desert sandstone from Scotland

THE ROCK CYCLE
There is no starting point in this cycle which has been going on for millions of years.

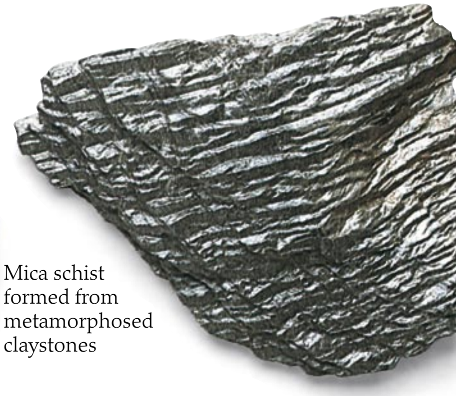


METAMORPHIC ROCKS
Quartz veins stand out in this schist rock face in Scotland. The area contains many metamorphic rocks.

Quartzite, an altered sandstone, formed by pressure and heat beneath the Earth's surface



Gneiss, a banded metamorphic rock



Mica schist formed from metamorphosed claystones

METAMORPHISM
The deeper a rock is within the Earth, the greater the pressure exerted on it from the rocks above it, and the higher the temperature. Pressure and heat cause the rocks to change or "metamorphose" as the minerals recrystallize. The new rocks are called metamorphic rocks (p. 24).

Weathering and erosion

ALL ROCKS BREAK DOWN at the Earth's surface. When rocks break down without movement (as they stand), this is called weathering. Weathering is either chemical or mechanical. If rocks break down during movement or by a moving medium, such as a river or glacier, this is called erosion.

Wind erosion

Constant attack by sediment in wind may slowly grind away at a rock and erode it.

MONUMENT VALLEY, ARIZONA
Large-scale abrasion by the wind produces huge, protruding landforms called buttes.

ABRASION BY THE WIND
The abrasive action of the wind wears away softer layers of rock and leaves the harder ones sticking out, as in this desert rock from East Africa.

SAND BLASTING
Faceted desert pebbles, formed by sand constantly being blown against them, are called dreikanters.

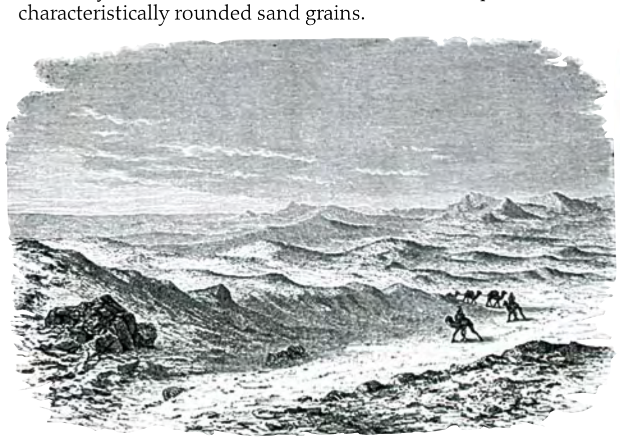
Weathering caused by temperature changes

Rock expands and contracts as the temperature changes, causing it to break up. Shattering is also caused when water in the rock freezes and expands.

Sandstone composed of sand collected 200 million years ago in a desert environment

Sand from a present-day desert in Saudi Arabia

DESERT EROSION
Rocks formed in desert conditions, where sediment is carried by wind, are often reddish in color and composed of characteristically rounded sand grains.



DESERT ENVIRONMENT
Wind and temperature changes cause continual weathering and bizarre, barren landscapes in the Sahara Desert.

ONION-SKIN WEATHERING
In this type of weathering, changes in temperature cause the surface layers of rock to expand, contract, and finally peel away from the underlying rock.

Fine-grained dolerite

Onion-skin weathered dolerite

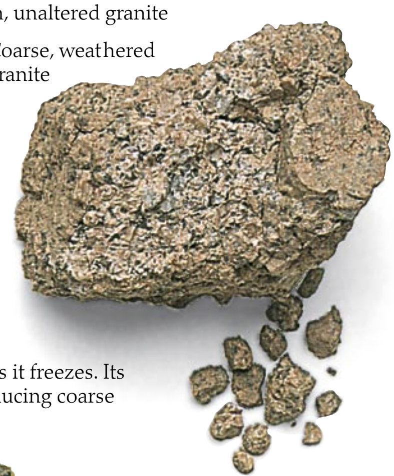
Peeling layers like onion skins, caused by changes in temperature

Chemical weathering

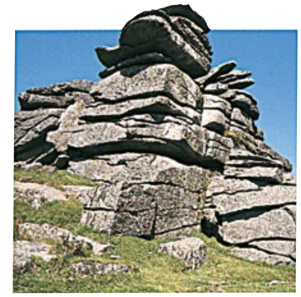
Only a few minerals can resist weathering by rainwater, which is a weak acid. Minerals dissolved at the surface may be carried down and redeposited in the soil and rock below.

Fresh, unaltered granite

Coarse, weathered granite



ALTERED MINERALS
Granite is split by the expansion of water as it freezes. Its minerals are then chemically altered, producing coarse rock fragments.



GRANITE TORS
Tors, weathered rounded rocks, are formed of the remains left when the surrounding rocks have been eroded away. This example is on Dartmoor, England.

Gossan altered by groundwater

Secondary minerals

CHEMICAL CHANGES
Chemical weathering of an ore vein may cause redistribution of minerals. The bright-colored minerals were formed from deposits of minerals that dissolved from rocks at higher levels. They are called secondary deposits.

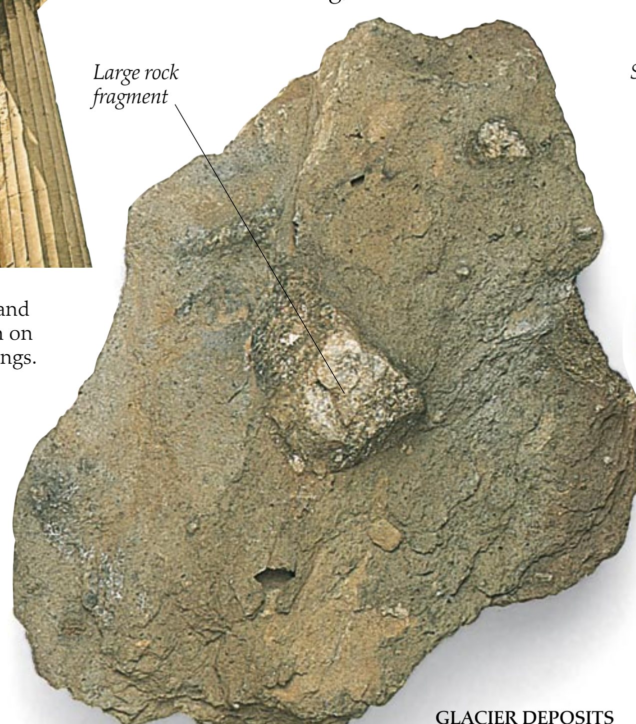
TROPICAL WEATHERING
In certain tropical climates, quartz is dissolved and carried away, while feldspars are altered to clay minerals that may collect on the surface as a thick deposit of bauxite (p. 56).

PARTHENON, ATHENS, GREECE
Chemicals in the air can react with stone and cause drastic weathering. This can be seen on the Parthenon and on gargoyles on buildings.

Ice erosion

As glaciers move they pick up fragments of rock which become frozen into the base of the ice. The moving, frozen mass causes further erosion of underlying rocks.

Large rock fragment



GLACIER DEPOSITS
A till is a deposit left by a melting glacier and contains crushed rock fragments ranging from microscopic grains to large pebbles. Ancient tills that have become packed into hard rock are called tillite. This specimen is from the Flinders Range in South Australia, which was covered with glaciers some 600 million years ago.

Scratches caused by a glacier

SCRATCHED ROCK
The deep gouge marks on this limestone from Grindelwald, Switzerland, were caused by abrasive rock fragments contained in the glacier that flowed over it.

MORTERATSCH GLACIER, SWITZERLAND *left*
Glaciers are a major cause of erosion in mountainous regions.

Rocks on the seashore

Pebbles on Chesil Beach, England

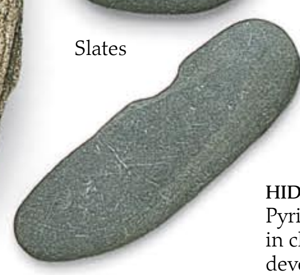
At the seashore, geological processes can be seen taking place. Many seashores are backed by cliffs, beneath which is a deposit of coarse material that has fallen from above. This is gradually broken up by the sea and sorted into pebbles, gravel, sand, and mud. Then the various sizes of sediment are deposited separately - this is the raw material for future sedimentary rocks (p. 20).

GRADED GRAINS
On the beach, these pebbles are sorted by wave and tide action. The sand comes from a nearby area. It is pure quartz; the other rock-forming minerals were washed away by constant wave movement.

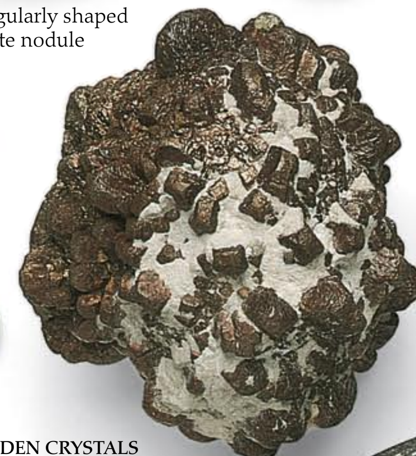
Large, coarse pebbles

SKIMMING STONES
As every school child knows, the best stones for skimming are disk-shaped. They are most likely to be sedimentary or metamorphic rocks, since these split easily into sheets.

Mica schist



Slates



Irregularly shaped pyrite nodule

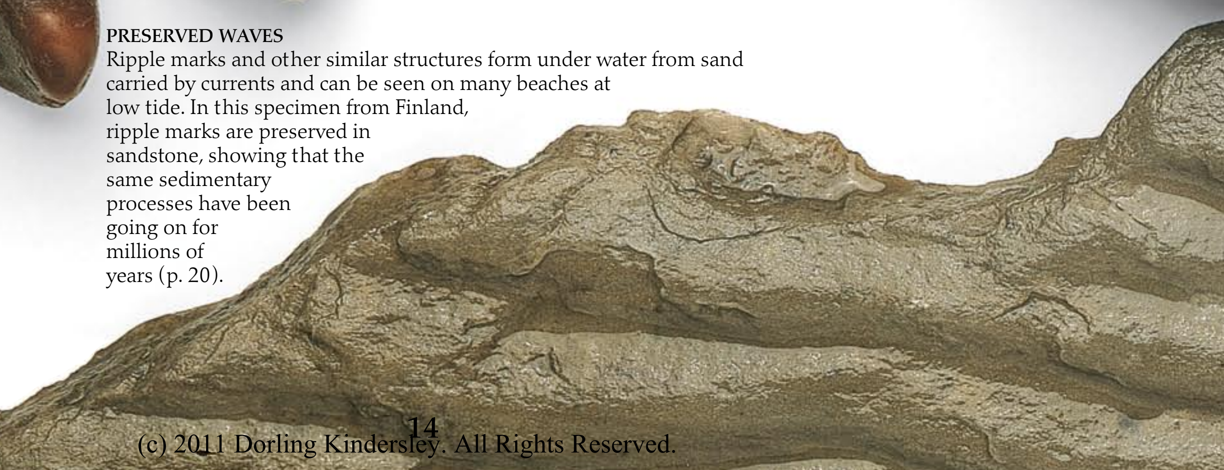
LOCAL STONES
These pebbles reflect the local geology, all coming from the rocks of the immediate neighborhood of the beach where they were collected. They are metamorphic rocks that have been worn into flat disks.

HIDDEN CRYSTALS
Pyrite nodules are common in chalk areas. They may develop interesting shapes The dull outside breaks to reveal unexpected, radiating crystals inside.

SHELLY PEBBLES
Empty sea shells are subjected to continuous wave action. In time, the sharp edges of broken shells may become smoothed and form pebbles. These are from a beach in New Zealand.

AMBER PEBBLES
Amber is the fossil resin of extinct cone-bearing trees that lived thousands of years ago. It is especially common along the Baltic coasts of Russia and Poland.

PRESERVED WAVES
Ripple marks and other similar structures form under water from sand carried by currents and can be seen on many beaches at low tide. In this specimen from Finland, ripple marks are preserved in sandstone, showing that the same sedimentary processes have been going on for millions of years (p. 20).



BLACK SANDS
In areas of volcanic activity, beach sand may contain dark minerals and often no quartz. The olivine sand comes from Raasay, Scotland; the magnetite-bearing sand is from Tenerife, an island off the northwest coast of Africa.


Dark olivine sand


Magnetite-bearing sand


Black volcanic ash beach on north coast of Santorini, Greece


Medium-size coarse pebbles

Small, fine pebbles

Finest pebbles

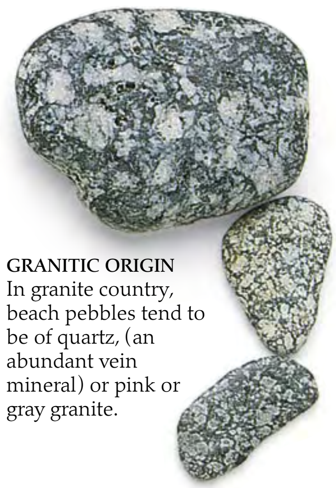
Quartz sand


Nodule of marcasite with knobby exterior

Interior of marcasite reveals glistening crystals radiating outward

DISCOVERED IN CHALK
Because flint nodules are hard, they resist abrasion (scraping) and can be seen on beaches in Chalk areas, sucn as those below the famous White Cliffs of Dover, England.

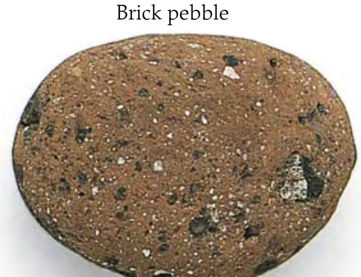

Chalk cliffs often produce pyrite and flint nodules


GRANITIC ORIGIN
In granite country, beach pebbles tend to be of quartz, (an abundant vein mineral) or pink or gray granite.


Flint nodules (knobs) from below Chalk cliffs


FOREIGN MATERIAL
Not all beach rocks are from local areas. This porphyritic igneous rock was probably carried across the North Sea from Norway to England by ice during the last Ice Age, c. 18,000 B.C.


Assorted glass pebbles


Brick pebble

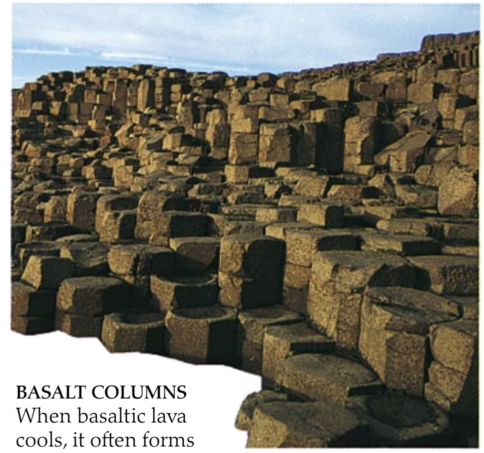
SYNTHETIC PEBBLES
Apart from the usual natural minerals and rocks, man-made objects may be washed ashore, possibly from ships, or dumped on the beach. Some of them may eventually become rounded by wave action.


PROTECTING THE BEACH
Man-made jetties keep pebbles and sand from drifting.

Basalt needle, St. Helena

Igneous rocks

THESE ROCKS are formed when molten magma from deep within the Earth's crust and upper mantle (p. 6) cools and solidifies (hardens). There are two types: intrusive and extrusive. Intrusive rocks solidify within the Earth's crust and only appear at the surface after the rocks above them have eroded away. Extrusive rocks are formed when magma erupts from a volcano as lava, then cools at the surface.



BASALT COLUMNS
When basaltic lava cools, it often forms hexagonal columns. This spectacular example is the Giant's Causeway in Northern Ireland.

Biotite granite

Black grains are biotite, a form of mica (p. 42)

Graphic granite

Long, angular quartz crystals look like ancient writing against the larger pale pink feldspar crystals

Pink granite

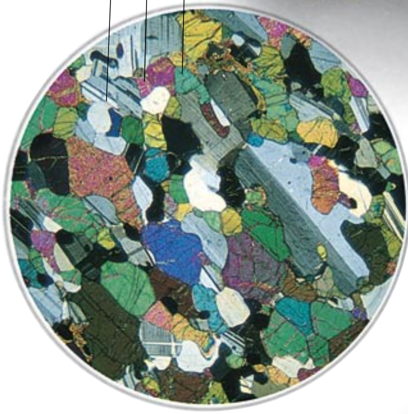
Pink coloring due to the high level of potassium feldspar in the rock

GRANITE
A very common intrusive rock, granite consists mainly of coarse grains of quartz, feldspar, and mica (p. 8). The individual grains are large because they formed as the magma cooled slowly deep in the earth. Granite is usually speckled and varies in color from gray to red according to the different amounts of minerals. Granite is found in many parts of the world. The biotite granite shown here comes from Hay Tor, an outcrop at the highest point on Dartmoor in southwest England (p. 13).

PITCHSTONE
Formed when volcanic lava cools very quickly, pitchstone contains some small crystals of feldspar and quartz and has a dull, resin-like appearance. Pitchstone may be brown, black, or gray, and large crystals of feldspar and quartz are sometimes visible.

OBSIDIAN
Like pitchstone, obsidian is a glass formed from rapidly cooled lava. It forms so quickly that there is no time for crystals to grow. The sharp edges shown on this sample from Iceland are characteristic of obsidian, hence its use as an early tool (p. 29).

FELDSPAR PORPHYRY
Porphyries are rocks that contain large crystals called phenocrysts within a medium-grained rock. This particular sample contains feldspar crystals and comes from Wales.



THIN SECTION OF GABBRO
When a very thin slice of rock is viewed under a microscope using a particular kind of light, hidden features, such as crystal shape, are revealed (p. 42). Here, the highly colored grains are minerals called olivine and pyroxene, and the gray mineral is plagioclase feldspar.

GABBRO
An intrusive rock, gabbro consists of dark minerals such as olivine and augite. It has coarse grains, as large crystals formed when the magma slowly cooled. This sample is from the Isle of Skye, Scotland.

BASALT
Formed from hardened lava, basalt is the most common extrusive rock. It is similar in composition to gabbro but has finer grains. When the lava cools, it may split into many-sided columns. Among the most well known of these spectacular structures are the Needle on St. Helena, an island in the Atlantic, and the Giant's Causeway in Ireland.

Vesicular basalt

Amygdaloidal basalt

VESICULAR VOLCANIC ROCKS
Both rocks are basalts that were formed when bubbles of gas were trapped in hot lava scum. The vesicular basalt is light and full of holes known as vesicles. In amygdaloidal basalt, the holes were later filled in with minerals such as calcite. These rocks were collected from Hawaii, an area of great volcanic activity.

PERIDOTITE
A dark, heavy rock mainly containing minerals called olivine and pyroxene, peridotite is presumed to lie under layers of gabbro six miles (10 km) beneath the ocean floor. This sample was found in Odenwald, West Germany.

SERPENTINITE
As its name suggests, the dominant mineral in this coarse-grained red and green rock is serpentine. It is streaked with white veins of calcite. Serpentinite is common in the Alps.

Ejection of lava from Eldfell, Iceland, in 1973

Volcanic rocks

ROCKS THAT ARE FORMED by volcanic activity can be divided into two groups: pyroclastic rocks, and acid and basic lavas. Pyroclastic rocks are formed from either solid rock fragments or bombs of lava blown out of the throat of a volcano. The bombs solidify as they fly through the air. Rocks formed from hardened lavas vary according to the type of lava. Acid lavas are thick and sticky, flow very slowly, and form steep-sided volcanoes. The more fluid, basic lavas form flatter volcanoes or may well up through cracks in the sea floor. Basic lavas are fast-flowing and so quickly spread out to cover vast areas.

Pyroclastic rocks

Pyroclastic means "fire-broken," an apt name for rocks that consist of rock and lava pieces that were blown apart by exploding gases.

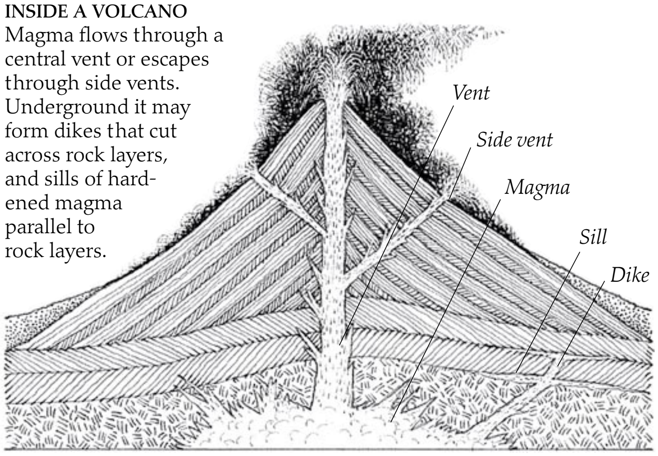
VOLCANIC BOMBS
When blobs of lava are thrown out of a volcano, some solidify in the air, landing on the ground as hard "bombs." Bombs can be round or irregular. These two specimens are shaped like footballs.

Intrusion breccia formed within a vent

Agglomerate formed close to a vent

JUMBLED PIECES
The force of an explosion may cause rocks to fragment. As a result, a mixture of angular pieces often fills the central vent or is laid down close to vents. The fragments form rocks known as agglomerates.

INSIDE A VOLCANO
Magma flows through a central vent or escapes through side vents. Underground it may form dikes that cut across rock layers, and sills of hardened magma parallel to rock layers.



Bedded tuff (a hardened ash)

Ash

WIND-BLOWN PARTICLES
Tiny fragments of volcanic ash can travel for thousands of miles in the atmosphere. Where it settles and hardens it forms tuff. This ash erupted from Mount St. Helens, Washington, in 1980. The coarse grains were blown three miles (five km) from the crater; the fine particles were carried by the wind for 17 miles (27 km).

Eruption of Mount St. Helens, 1980

Acid lavas

Thick, sticky acid lavas move slowly and may harden in the volcano's vent, thereby trapping gases. As pressure builds up, the gases may explode to form pyroclastic rocks.

ERUPTION OF VESUVIUS
The famous eruption in A.D. 79 produced a *nuée ardente*, a fast-moving cloud filled with magma and ash. The Roman town of Pompeii was destroyed in this event.

FLOATING ROCKS
Pumice is hardened lava froth. Because the froth contains bubbles of gas, the rock is peppered with holes, like a honeycomb. Pumice is the only rock that floats in water. This sample is from the Lipari Islands, Italy.

NATURAL GLASS
Although chemically the same as pumice, obsidian (p. 16) has a totally different glassy texture. Because of its sharp edges, early people used it for tools, arrowheads, and ornaments (p. 29).

CARAMEL-LIKE LAVAS
This light-colored, fine-grained rock is called rhyolite. The distinctive bands formed as the thick, sticky lava flowed for short distances.

Aphthitalite

Aphthitalite

ROCKS FROM GASES
Inactive volcanoes are said to be "dormant." Even when volcanoes are dormant or dying, volcanic gases may escape and hot springs form. These colorful rocks were formed in this way at Vesuvius.

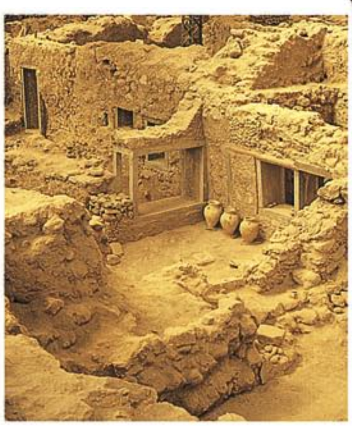
Basic lavas

These lavas flow smoothly, and may cover vast distances with a thin layer. As a result, the vent does not get choked and gases can escape, so that although there is plenty of lava, few pyroclastic rocks are formed.

WRINKLED ROCKS
When lava flows, the surface cools and forms a skin, which wrinkles as the fluid center keeps on flowing. The resulting rocks are called ropy lavas.

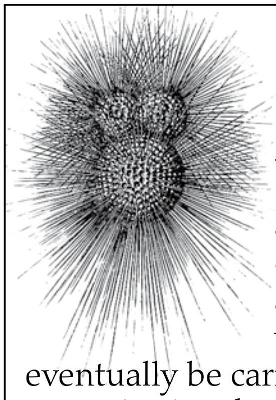
RUNNY LAVAS
Basaltic lavas are fast-flowing and spread out quickly to cover vast areas. This specimen of basalt (p. 17) was deposited by the Hualalai Volcano, one of the many volcanoes on Hawaii.

MULTI-COLORED BASALT
Sparkling points in this basalt include green olivine and black pyroxene crystals.



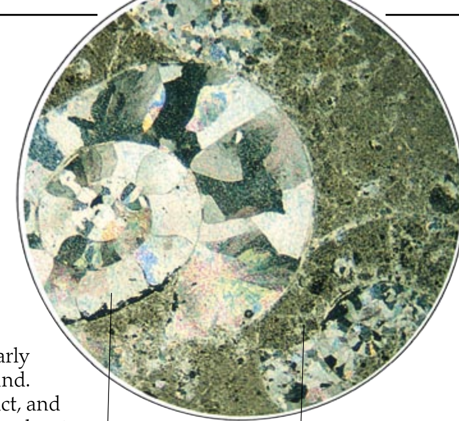
DESTRUCTION OF AKROTIRI
This town on Santorini, Greece, was buried by volcanic ash, c. 1450 B.C.

Sedimentary rocks

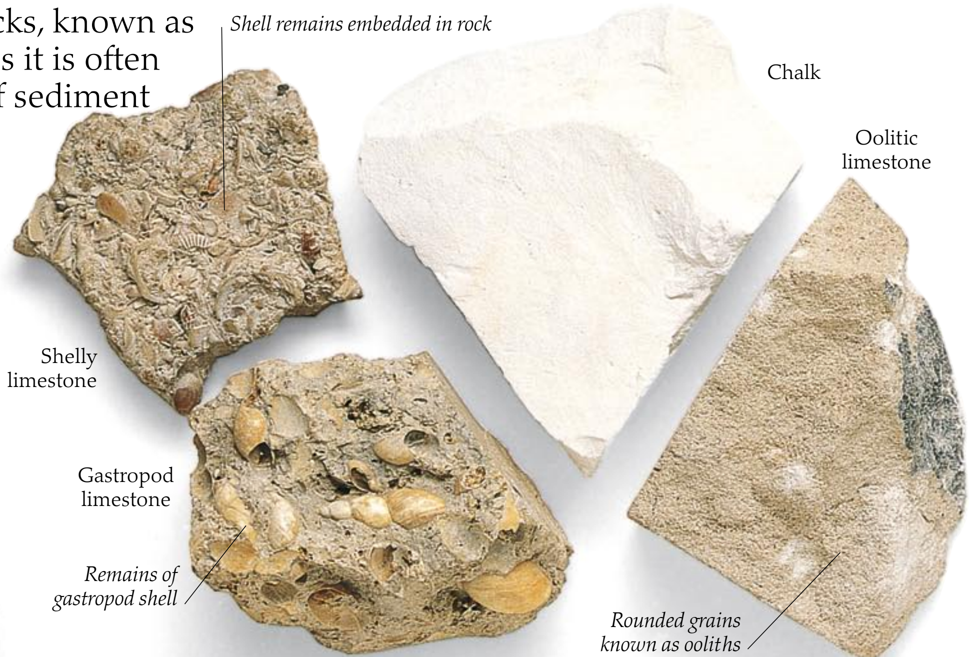


When rocks are weathered and eroded (p. 12) they break down into smaller pieces of rock and minerals. This ma-terial, which is called sediment, may eventually be carried to a new site, often in the sea or in river beds. The sediments are deposited in layers which become buried and compacted (pressed down). In time the particles are cemented together to form new rocks, known as sedimentary rocks. In large outcrops it is often possible to see the various layers of sediment with the naked eye.

RAW INGREDIENTS *above*
Foraminifera are marine organisms that discharge lime. Although rarely bigger than a pinhead, they play an extremely important part in rock building. When they die the shells fall to the ocean floor, where they eventually become cemented into limestone.

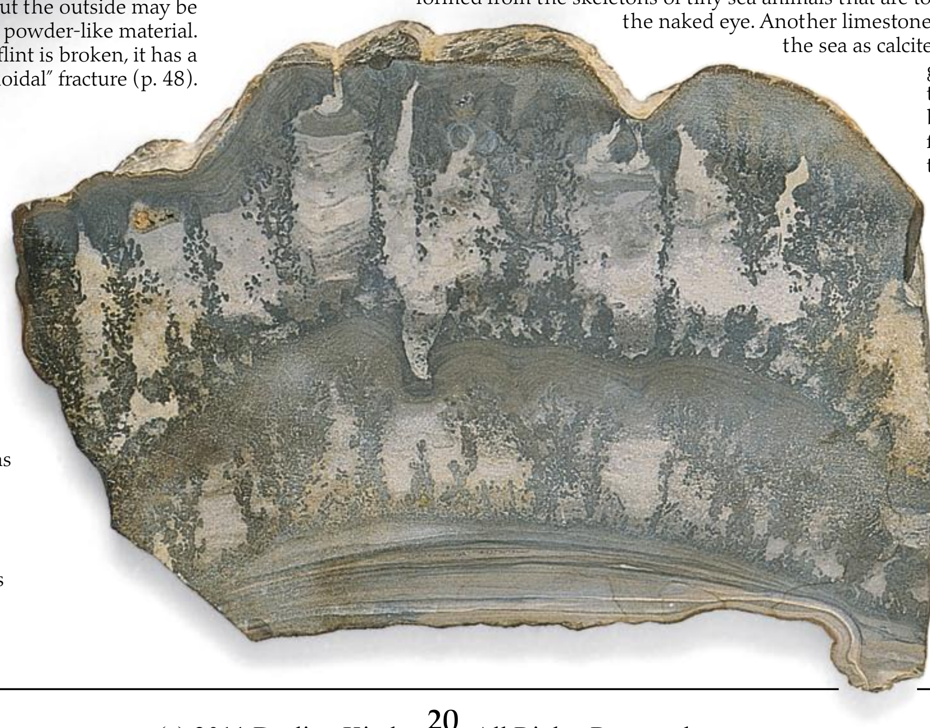


THIN SECTION OF LIMESTONE
Under the microscope (p. 42), fine details in this ammonite limestone are revealed. The ammonite shells (p. 38) show up clearly against the mud background. Ammonites are now extinct, and we know this rock must be about 160 million years old.



LIMESTONES
Many sedimentary rocks consist of the remains of once-living organisms. In some, such as these shelly and gastropod limestones, the remains of animals are clearly visible in the rock. However, chalk, which is also a limestone, is formed from the skeletons of tiny sea animals that are too small to see with the naked eye. Another limestone, oolite, forms in the sea as calcite builds up around grains of sand. As the grains are rolled backward and forward by waves, they become larger.

FLINT
A form of silica (p. 42), lumps of flint are often found in limestones, especially chalk. They are gray or black, but the outside may be covered in a white powder-like material. Like obsidian (p. 16), when flint is broken, it has a "conchoidal" fracture (p. 48).



ALGAL LIMESTONE
So-called "muddy" limestones like this are often referred to as landscape marbles. This is because when the minerals crystallize they may produce patterns in the shape of trees and bushes.

Hole-filled, irregular-shaped rock

CALCAREOUS TUFA
This extraordinary looking porous rock is formed by the evaporation of spring water and is sometimes found in limestone caves (p. 22).

EVAPORITES
Some sedimentary rocks are formed from the evaporation of saline waters. Examples of these include gypsum and halite. Halite is also known as rock salt, from which we get table salt. Gypsum is used to make plaster of Paris, and in its massive form is called alabaster. Both halite and gypsum are minerals that can be found in large deposits worldwide at sites where evaporation of sea water has occurred.

Gypsum crystals growing from a central point like daisy petals

Gypsum

Single crystals of rock salt are not found as often as massive samples

Halite

Reddish cast caused by impurities in the salt

THE GRAND CANYON
This spectacular scenery was formed by the erosion of red sandstone and limestone.

Grit

Red sandstone

SANDSTONES
Although both these rocks are made by the cementing together of grains of sand, their texture varies. The red sandstone was formed in a desert, where the quartz grains were rounded and polished by the wind. The grains in grit are more angular, as they were buried quickly, before they could be smoothed by rubbing.

CLAY
Formed of very fine grains that cannot be seen by the naked eye, clay feels sticky when wet. It may be gray, black, white, or yellowish. When it is compacted and all the water forced out of it, it forms hard rocks called mudstone or shale.

BEDDED VOLCANIC ASH
In many sedimentary rocks it is possible to see the individual layers of sediments because they form visible bands. Here, the stripes are layers of volcanic ash. The surface has been polished to highlight this feature.

Flint pebble

CONGLOMERATE
The flint pebbles in this rock were rounded by water as they were rolled about at the bottom of rivers or seas. After they were buried, they gradually became cemented together to form a rock known as conglomerate.

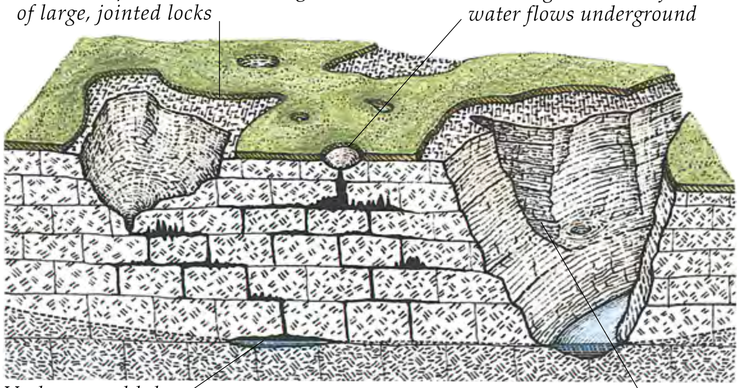
Large rock fragment

BRECCIA
Like conglomerate, breccias contain fragments of rock. However, these are much more angular because they have not been rounded by water or carried far from their original home - often the scree (broken rocks) at the bottom of cliffs.

Limestone caves

SPECTACULAR CAVES, lined with dripping stalactites and giant stalagmites, are perhaps the best-known of limestone wonders. The caves are formed as a result of slightly acidic rainwater turning the carbonate into bicarbonate; this material is soluble in water and is carried away. In addition to caves, this process also produces several other characteristic features, including limestone pavements and karst landscapes.

STALACTITES
Stalactites are formed in caves by groundwater containing dissolved lime. The water drips from the roof and leaves a thin deposit as it evaporates. Growing down from the roof, stalactites increase by a fraction of an inch each year and may eventually be many yards long. Where the water supply is seasonal, stalactites may show annual growth rings like those of tree trunks.

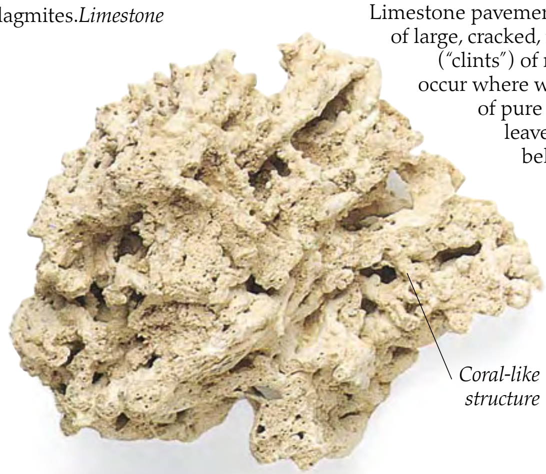


LIMESTONE LANDSCAPES *above*
Rainwater dissolves calcite in limestone, producing deep, narrow structures ("grikes"). In time, the water dripping down such cracks enlarges them into passages. Although the surface remains dry, flowing water dissolves the rock and produces "swallow holes" at the junctions between grikes. Underground streams flow through caves and form subterranean lakes. Some calcite is redeposited in the caves to form stalactites and stalagmites.*Limestone*

PLAN DE SALES, FRANCE
Limestone pavements consist of large, cracked, flat blocks ("clints") of rock. They occur where weathering of pure limestone leaves nothing behind, such as clay, to make soil.

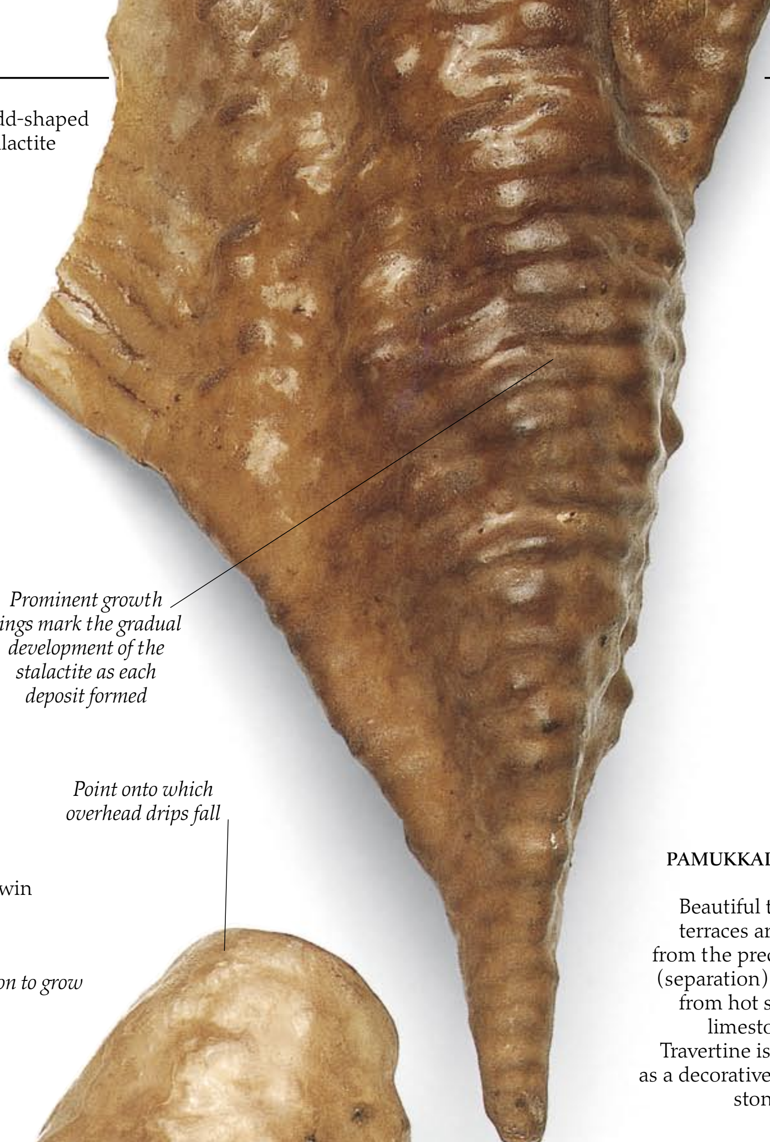
EASE GILL CAVES, ENGLAND
The fine stalactites and stalagmites in this cave form the most spectacular part of a much larger, complex cave system under the hills of the Lancashire Pennines. In fact, this is the largest cave system in Great Britain.

TUFA
Known as a precipitate, tufa (p. 21) forms when lime is deposited from water onto a rock surface in areas of low rainfall. If a man-made object is left in lime-rich waters it may become coated in tufa.



Orange twin stalactite

Last section to grow



Odd-shaped stalactite

Prominent growth rings mark the gradual development of the stalactite as each deposit formed

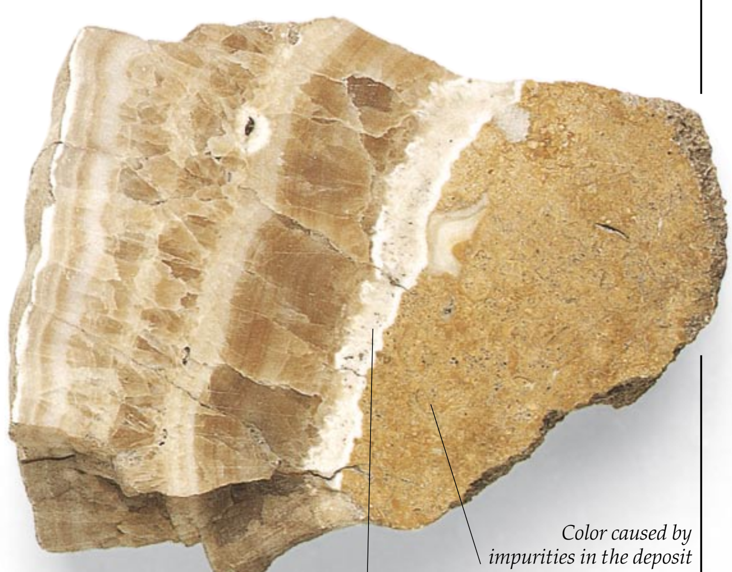
Point onto which overhead drips fall

End attached to floor of the cave

STALAGMITES
Stalagmites are formed on the floor of caves where water has dripped from the roof or a stalactite above. Like stalactites, they develop as water containing dissolved lime evaporates. Stalactites and stalagmites can grow together and meet to form pillars. These have been described as "organ pipes," "hanging curtains," and "portcullises."

STONE FOREST, CHINA
The staggering landscape of the Hunan Province of China is typical of karst scenery. Named after the limestone area of Karst in Yugoslavia, the term is applied to many limestone regions, including the Cumberland Plateau, U.S.A., parts of the Blue Mountains, Australia, and the Causses, France.

PAMUKKALE FALLS, TURKEY
Beautiful travertine terraces are formed from the precipitation (separation) of calcite from hot springs in limestone areas. Travertine is quarried as a decorative building stone (p. 27).



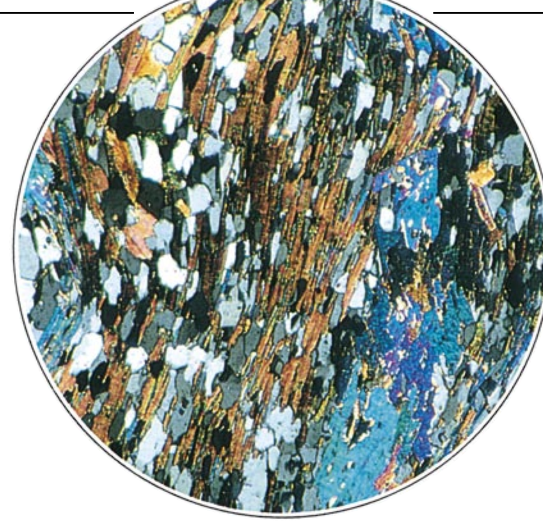
Color caused by impurities in the deposit

Layer of relatively pure calcite

INSIDE A STALACTITE
This specimen has been sliced through the center to reveal colored bands. The different colors show how the stalactite formed from deposits of lime with varying degrees of purity. The purest parts are the whitest.


Schist

Metamorphic rocks



THIN SECTION OF GARNET-MICA SCHIST
Seen through a petrological microscope (p. 42), this Norwegian rock reveals brightly colored, blade-shaped mica crystals. Quartz and feldspar appear as various shades of gray; garnet appears black.

THESE ROCKS get their name from the Greek words *meta* and *morphe*, meaning "change of form," and are igneous (p. 16) or sedimentary (p. 20) rocks that have been altered by heat or pressure or both. Such conditions can exist during mountain-building processes (p. 6); buried rocks may then be subjected to high temperatures and may be squeezed or folded, causing minerals in the rocks to recrystallize and new minerals to form. Other metamorphic rocks are formed when rocks surrounding a hot igneous mass are "baked" by the heat.

Saccharoidal marble


Evenly sized grains give a sugary appearance

MARBLES
When limestone is exposed to very high temperatures, new crystals of calcite grow and form the compact rock known as marble. It is sometimes confused with quartzite, which looks similar. However, marble is softer and may easily be scratched with a knife. Some medium-grained marble looks sugary and is called saccharoidal. This specimen comes from Korea. The other two marbles are formed from limestone containing impurities, such as pyroxene.


Knobby gray marble


Impure marble


Aggregates of carbon
Spotted slate

Chiastolite slate

Long chiastolite crystals

Spotted hornfels


FROM SLATE TO HORNFELS
The irregular speckles in spotted slate are small groups, of carbon crystals, formed by heat from an igneous intrusion. In rocks nearer the intrusion, the temperature is much higher and needle-like crystals of chiastolite form in the slate. The rocks very close to the intrusion become so hot that they completely recrystallize and form a tough new rock called hornfels.

SLATE
During mountain building, shale was squeezed so hard that the flaky mineral mica recrystallized at right angles to the pressure. The resulting rock, slate, splits easily into thin sheets.

Garnet-muscovite-chlorite schist

Red garnet crystals

Blue, bladelike crystals of kyanite

Kyanite-staurolite schist

19th-century slate quarry

SCHISTS
An important group of metamorphic rocks is termed schist. These medium-grained rocks formed from shale or mud but at a higher temperature than slate. For example, the garnet-muscovite-chlorite schist shown here must have been exposed to temperatures of at least 932°F (500°C) because garnet crystals do not grow at lower temperatures. Kyanite-staurolite schist forms under high pressure, 6-9 miles (10-15 km) below the Earth's surface.

Crystals of a green variety of pyroxene

Red garnet crystals

ECLOGITE
A rock produced under very high pressure, eclogite is extremely dense and is thought to form in the mantle (p. 6) - considerably deeper than most other rocks. It contains pyroxene and small red crystals of garnet.

Black biotite crystals

Blue kyanite crystals

Biotite-kyanite gneiss

Light-colored layer containing quartz and feldspar

Dark band of biotite

Banded gneiss

GNEISSES
At high temperatures and pressures, igneous or sedimentary rocks may be changed to gneisses. They have coarser grains than schists and are easy to identify because the minerals often separate into bands. These layers may be irregular where the rock has been folded under pressure.

MIGMATITE
Under intense heat parts of rocks may start to melt and flow, creating swirling patterns. This is very often shown in migmatites. They are not composed of one rock but a mixture of a dark host rock with lighter colored granitic rock. This sample is from the Scottish Highlands.

Dark host, rock

Pink granitic rock

Marble

STRICTLY SPEAKING, marble is a metamorphosed limestone (p. 24). However, the term "marble" is often used in the stone industry for a variety of other rocks. All are valued for their attractive range of textures and colors, and because they are easily cut and polished. Marble has been widely used for sculpture, particularly by the ancient Greeks; its use in building reached a peak under the Romans.

IN THE RAW *below*
A true marble, this unpolished, coarsely crystalline specimen of Mijas marble is from Malaga, Spain. Looking at uncut rock, it is hard to imagine the patterns a polished sample will reveal.

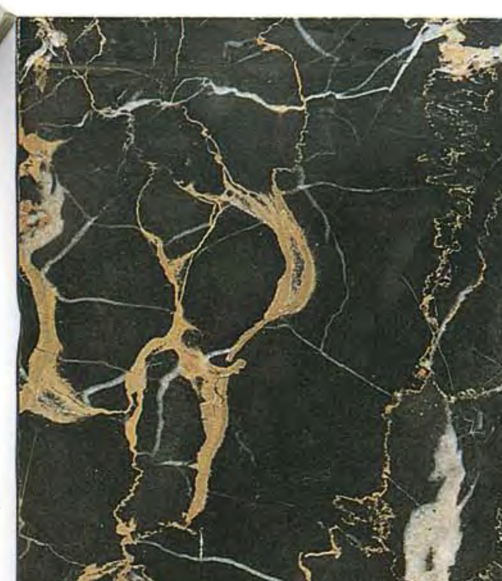
MEDICI MADONNA
Michelangelo sculpted this statue from Carrara marble, c. 1530.

CARRARA QUARRY
The world's most famous marble comes from the Carrara quarry in Tuscany, Italy. Michelangelo used it, since it was the local stone.

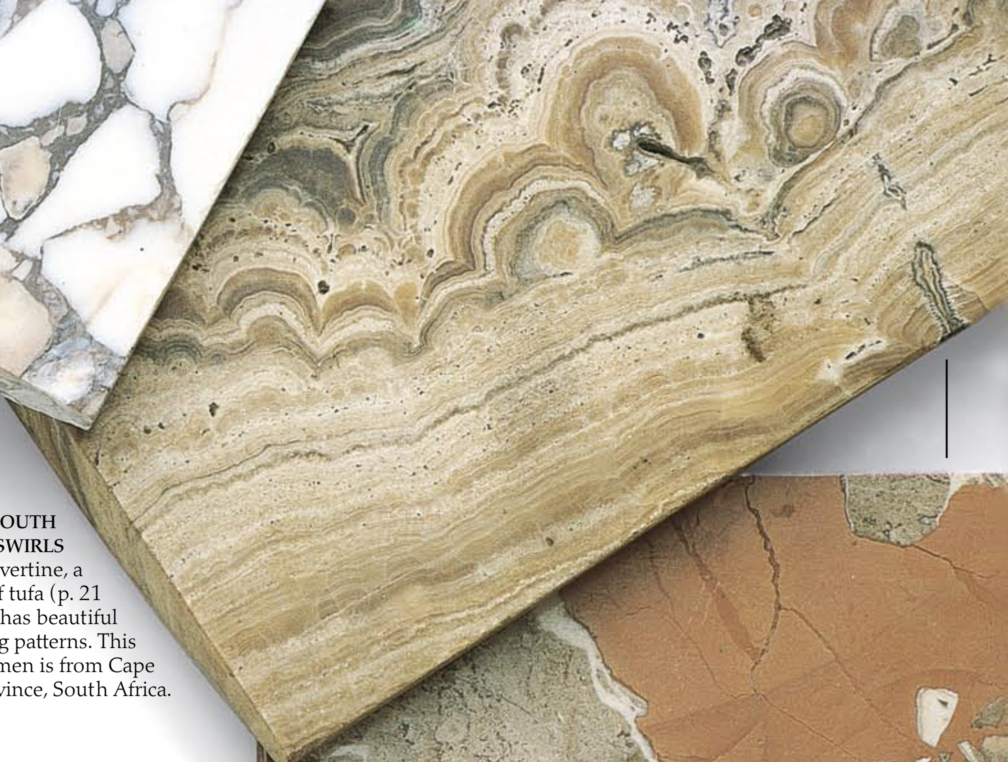
ITALIAN SPECIALITY *left*
Gray Bardilla marble comes from Carrara, Italy, an area famous for its marble production.

GREEK CONNECTION
Originally from the Greek island of Euboea, streaked Cipollino marble is now quarried in Switzerland, the island of Elba, and Vermont. It was used in the Byzantine church of Saint Sophia in Istanbul, Turkey.

ITALIAN ELEGANCE *right*
Another striking Italian marble is the black and gold variety from Liguria.



TUSCAN STONES
The distinctive texture of the Italian decorative stone breccia violetto was the reason for its use in the Paris Opera House in 1875.

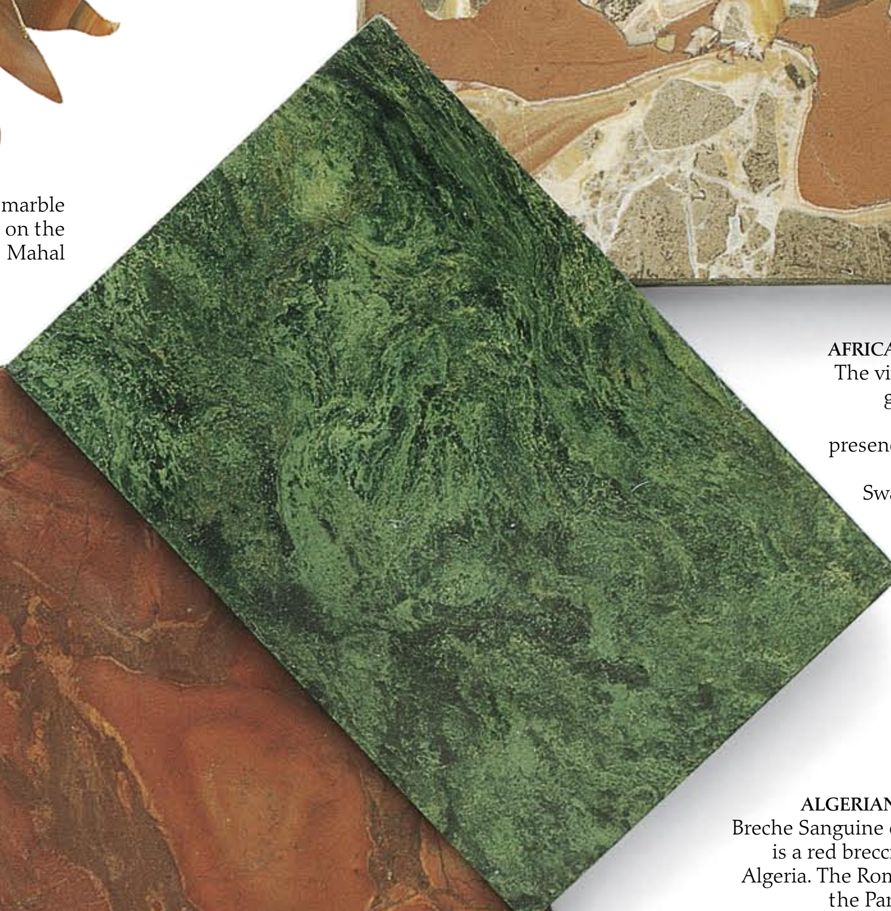


SOUTH AFRICAN SWIRLS
Polished travertine, a variety of tufa (p. 21 and p. 23), has beautiful swirling patterns. This specimen is from Cape Province, South Africa.

TAJ MAHAL
India's most famous monument is made of assorted marbles.

SWISS ORIGINS
The limestone breccia known as macchiavecchia is quarried in Mendrisio, Switzerland.

Detail of marble inlaywork on the Taj Mahal



AFRICAN COPPER *left*
The vivid coloring of green verdite is caused by the presence of copper. It comes from Swaziland, Africa.

ALGERIAN ROCK *bottom*
Breche Sanguine or Red African is a red breccia (p. 21) from Algeria. The Romans used it in the Pantheon, Rome.

The first flint tools

BECAUSE FLINT SPLITS in any direction, fractures to a sharp edge, and is fairly widespread, it was adopted by prehistoric people to fashion sharp tools. In the beginning these were crude choppers, but gradually more complex weaponry and tools such as scrapers and knives were developed.

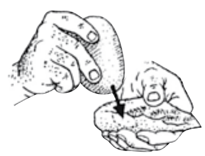
Rough flint chunk found in Chalk areas

Leather thong securing flint and antler sleeve to handle

Flint flakes and chippings

TOOLS FROM FLINT

Flint was shaped by chipping flakes from a chunk to leave a core that gradually became more refined.



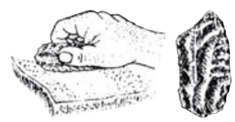
STONE ON STONE

The earliest tools were made by striking a stone against the flint, to remove chips and leave sharp jagged edges.

PRESSURE-FLAKING

Better cutting edges and finer chips were made with sharp, pointed objects, such as antler bone.

Sharp edged tool used for skinning and cutting



Scrapers were used to dress animal hides during the Neolithic period (4000-2300 B.C.)

Crude early chopper

Rough cutting edge

Large sharpened hand axe

Sharp cutting edge

Cutting edge

Light-colored hand axe

Small sharpened hand axe

Early men using hand axes

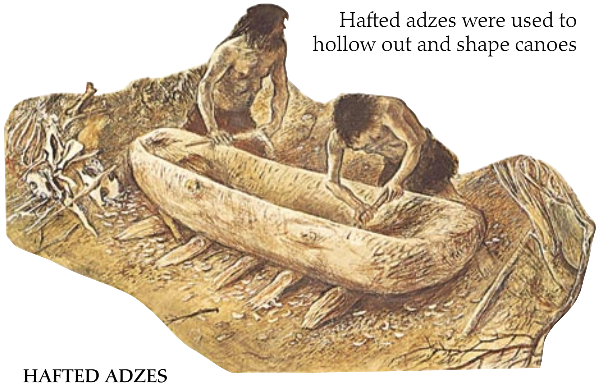
HAND AXES

Stone Age hand axes were used for smashing animal bones, skinning hunted animals, cutting wood, and sometimes even for cutting plants. The well-developed, dark axes are 300,000-70,000 years old. The smaller of the two may once have been larger and been reduced by sharpening. The lighter-colored axe dates from around 70,000-35,000 B.C.

Mesolithic adze

Antler sleeve

Reproduction wooden handle



Hafted adzes were used to hollow out and shape canoes

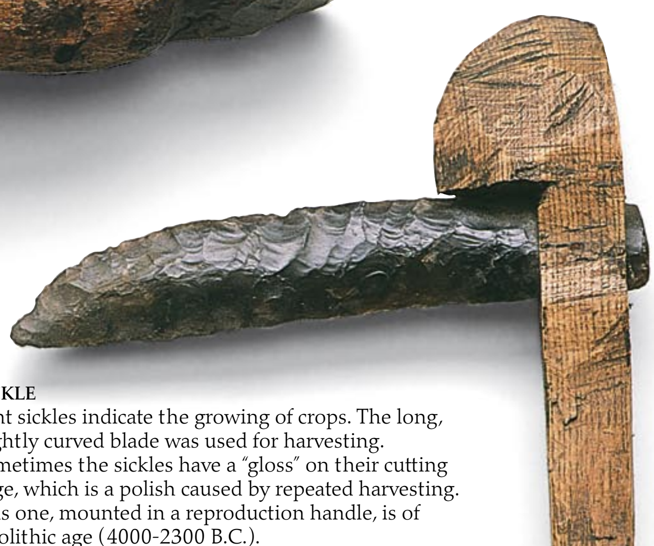
HAFTED ADZES

Adzes had uneven (asymmetrical) cutting edges, and the blade was at a right angle to the handle, or haft. They were used for shaping wood, and were swung from above rather than the side. These specimens date from the Mesolithic period (10,000-4000 B.C.).

Adze mounted directly onto handle

Asymmetrical cutting edge of flint

Reproduction wooden handle



SICKLE

Flint sickles indicate the growing of crops. The long, slightly curved blade was used for harvesting. Sometimes the sickles have a "gloss" on their cutting edge, which is a polish caused by repeated harvesting. This one, mounted in a reproduction handle, is of Neolithic age (4000-2300 B.C.).

9th-century obsidian axe from Mexico

Spearhead with obsidian blade from the Admiralty Islands, off Papua New Guinea

OBSIDIAN

Like flint, obsidian was fashioned into early tools because it fractures with sharp edges. It was also used as a primitive mirror.

DANISH AXE AND DAGGER

This Early Bronze Age axe, found in the river Thames in England, is known to be an imported piece because of its shape. This fact and the careful polish applied to it suggest it would have been a valuable object. This is also true of the Early Bronze Age flint dagger (2300-1200 B.C.). Its shape imitates the earliest copper daggers, which would have been very rare, highly valued items at first.

Axe

Flint dagger

ARROWHEADS

Although the bow and arrow was first invented in the preceding Mesolithic period, it continued to be used for hunting in the Early Neolithic period, when leaf-shaped arrowheads were common. Later, in the Beaker period (2750-1800 B.C.), barbed arrowheads became characteristic. It was a time of change with the introduction of metalworking.

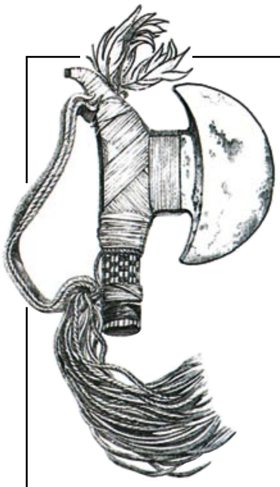
Neolithic leaf-shaped arrowheads

Beaker-period arrowheads

FLINT DAGGERS

These two daggers are also from the Beaker period. Their rarity, and the care with which they were made, suggest they may have served as both status symbols and weapons.

Rocks as tools



Brazilian stone axe

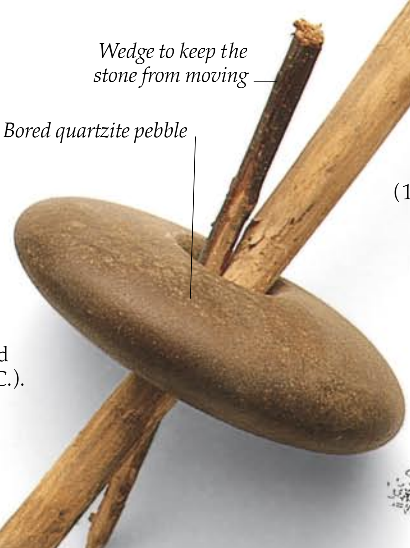
FLINT WAS NOT THE ONLY ROCK used by early people. Archaeologists have found numerous examples of stone implements from many different cultures around the world. Some were used as weapons, others as agricultural or domestic tools, ranging from mortars (for grinding) to storage vessels and make up palettes. Many weapons appear never to have been used, and may have been purely status symbols.

Neolithic axe showing a highly polished surface

Neolithic axe made of diorite, an igneous rock

Neolithic axe made of rhyolitic tuff, a volcanic rock

STONE AXES
All these stone axes date from the Neolithic period in Britain (4000-2300 B.C.). They are highly polished and tougher than flaked flint axes. They must have been traded over long distances, as the source rocks were hundreds of miles from the places where the axes were found.



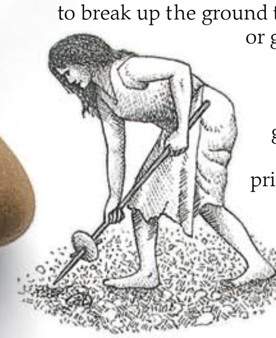
Wedge to keep the stone from moving

Bored quartzite pebble

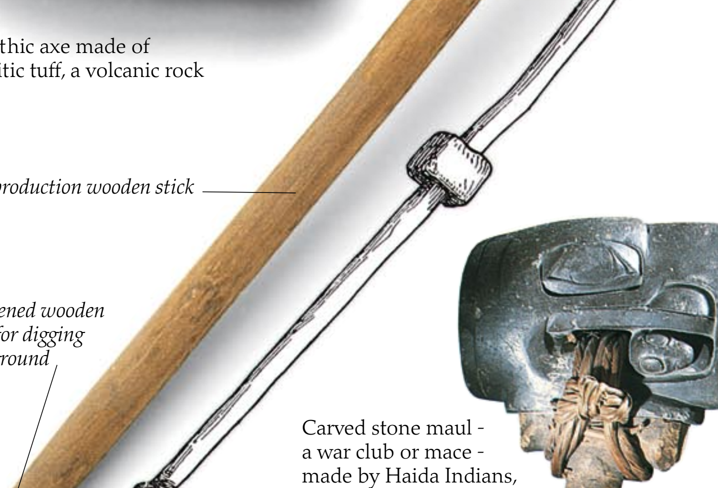
Reproduction wooden stick

Sharpened wooden point for digging hard ground

WEIGHTED DIGGING STICK
Pebbles, like this quartzite example, were sometimes pierced and used to weight the end of pointed wooden sticks. During the Mesolithic and Neolithic periods (10,000-2300 B.C.) such sticks were used to break up the ground to plant crops or grub up roots.



Breaking up ground with a digging stick prior to planting

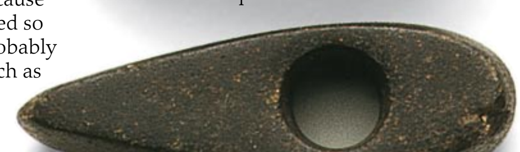


South African digging stick with horn point and stone weight

BATTLE-AXES
These perforated axes (pierced with holes) belong to the Early Bronze Age (2300-1200 B.C.). The top two could have served as weapons but the bottom one is usually described as an axe-hammer because one end could have been used as an axe, the other as a hammer. Because they are preserved so well they were probably for display as much as for use.

Side view of battle-axe made of diorite

Top view of battle-axe



Carved stone maul - a war club or mace - made by Haida Indians, a North American tribe who live on islands off British Colun bia, Canada

Dual-purpose granite axe-hammer

Hammer end

Axe end

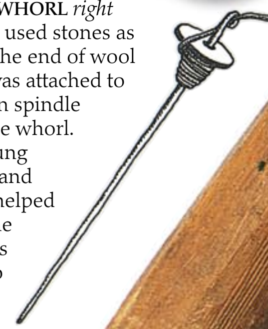
WHETSTONES
Bronze implements were sharpened by rubbing the blunt edge against a long whetstone. Often the stones were perforated so that they could be hung on a loop around the neck or belt. These whetstones are from the Bronze Age (2300-700 B.C.).

Engraved Viking forge stone made of soapstone, used in making metal weapons and tools

A bird-shaped mortar carved by Haida Indians (opposite)

MARBLE MAKE UP PALETTE
Roman cosmetics included chalk and powdered lead to whiten the face and arms, red ochre to tint the lips and cheeks, and soot to darken the eyebrows. Using fine bronze or bone spoonlike objects, small amounts were placed on stone palettes and mixed with water or a water-soluble gum. They could then be applied as a paint or paste.

STONE SPINDLE WHORL *right*
The Romans also used stones as spindle whorls. The end of wool or cotton fibers was attached to a bone or wooden spindle weighted with the whorl. As the spindle hung down, its weight and rotating motion helped the twisting of the thread, which was then wound onto the spindle.



ROMAN ROTARY QUERN
During Roman times a portable quern (mill) was used for grinding corn in the home. It consisted of two stones: the lower one was bedded in earth or fixed to a bench, and the upper stone, held in position by a spindle, was rotated above it by means of the handle. The grain was fed through the hole in the upper stone; the rotary motion forced it between the grinding surfaces.

Using a stone quern to grind corn during the Iron Age

Grain ready for grinding

Pigments

When early people started to paint their homes and bodies, they did not have to look far for pigments to color paints and dyes. By crushing local colored rocks and mixing the powders with animal fats, they produced a range of colors. As trading routes expanded over the centuries, new colors were introduced. Many of the pigments were toxic (poisonous), so their colors are now produced in the laboratory.

Brown clay

Powdered brown clay

Green clay

Powdered green clay

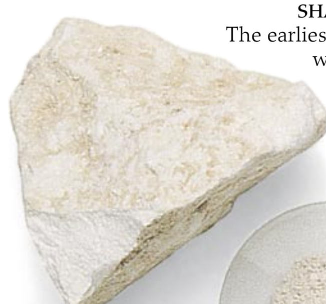
EARTHY HUES
Clays were used a lot by early artists because they were widely available and, being fine-grained, were easy to grind up. They produced mostly drab green and brown colors.

Ocher paint

Umber paint

CAVE PAINTING
The earliest known artworks were done by cavemen using a mixture of clays, chalk, earths, and burnt wood and bones.

COLOR VARIATION IN A MINERAL
Many minerals are always the same color. This is useful for identifying them. Some, however, exhibit a range of colors. For example, tourmaline (p. 55) may occur as black, brown, pink, green, and blue crystals or show a variety of colors in a single crystal.



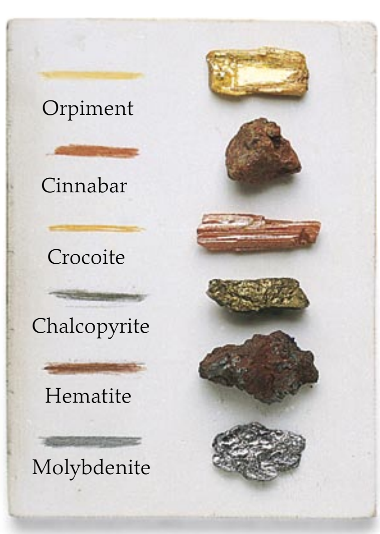
SHADES OF WHITE
The earliest white pigment was chalk (p. 20), although in some areas kaolin (china clay) was used instead.

Powdered chalk

Chalk white paint

Bison from Grotte de Niaux, France, c. 20,000 B.C.

COLOR CLUES
A useful aid in identification is the color produced when a mineral is finely crushed. The simplest way to do this is to scrape the sample gently across an unglazed white tile. Many minerals leave a distinct colored streak that may or may not be the same color as the mineral; others crush to a white powder and leave no visible mark.



BLACK AS COAL
Still popular with artists today, charcoal was well known to cave painters. They found plentiful supplies in the embers of their fires.

Powdered charcoal

Lamp black paint


Powdered hematite

Red paint

SKIN COLORING
The earthy variety of hematite produces a rich reddish-brown pigment. Very finely powdered material was also used as a skin make up and has been employed as a fine polishing medium (jewelers' rouge).


Powdered realgar

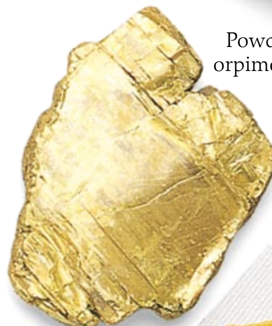
Arsenic orange paint

EGYPTIAN ORANGE
About 1,500 B.C. Egyptians first crushed realgar, an arsenic compound found in hot-spring deposits, to form an orange pigment. Medieval artists preferred to use the mineral cinnabar.


Powdered malachite

Malachite green paint

BRILLIANT GREEN
Malachite, a copper compound, produces a rich bright green. It was first used during the Bronze Age in Egypt.




Powdered orpiment

King's yellow paint

FOOL'S GOLD
Medieval artists used orpiment, an arsenic compound, to make many colors and to imitate gold. Its resemblance to gold made some chemists of the time try to extract the noble metal from it!


Powdered lapis lazuli

Ultramarine paint

PRECIOUS BLUE
The refinement of lapis lazuli (p. 52) powder into rich ultramarine blue was first achieved in Persia. Because it was expensive, it was used less often than azurite.


Powdered azurite

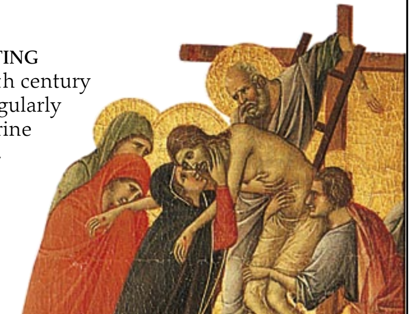
Azurite blue paint

CLASSICAL BLUE
Azurite, a copper compound, was one of the great blue pigments of early peoples. This sample is particularly earthy and would have produced a fine, highly prized pigment.


Powdered cinnabar

Vermilion paint

NATURAL VERMILION
The bright vermilion red of cinnabar (mercuric sulfide) was used in China in prehistoric times, but only came into widespread use in the Middle Ages (5th-15th centuries). Vermilion was later made from mercury and sulfur.



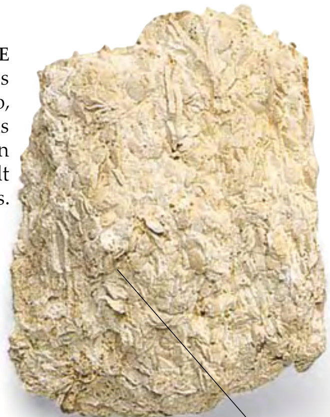
BRIGHT PAINTING
By the late 13th century artists were regularly using ultramarine and vermilion, as in this painting by Duccio.

Quarrying in the early 19th century was still done almost entirely by manual labour

Building stones

Most of the great monuments of the past - the temples and palaces - have survived because they were made from tough, natural stone. Good building stones are relatively easy to work yet must be neither too friable nor prone to splitting and weathering. Today, natural building stones, such as marbles (p. 26), are used mainly as decorative stones, and man-made materials are used for construction.

NUMMULITIC LIMESTONE
This, one of the most famous limestones, is quarried near Cairo, Egypt. It contains many small fossils and was formed about 40 million years ago. The Pyramids were built with stone from the same quarries.



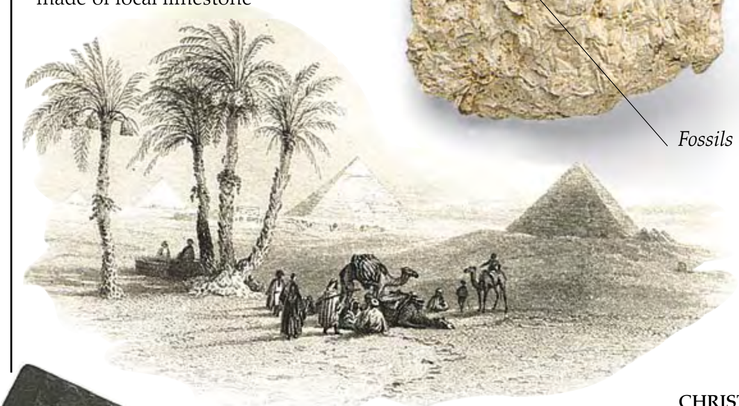
Fossils

Tooling

PORTLAND STONE
The surface marks on this English limestone are produced by "tooling", a decorative technique which was popular in the last century. After the Great Fire of London in 1666, Portland Stone was used to rebuild St Paul's Cathedral.

OOLITIC LIMESTONE
Formed some 160 million years ago, this limestone is used as a building stone and sometimes in the manufacture of cement.

The Pyramids, Egypt, made of local limestone



CHRISTIAN MOSAIC
Small fragments of local stones were often used to make intricate mosaic floors.

Welsh slate

160-million-year-old limestone used for roofing

SLATE
Unlike most building materials, roofing stones must split easily into thin sheets. Slate (p. 25) is ideal. However, where it was not available, builders used local, often inferior, stone for roofing.

NOTRE DAME, PARIS
The famous Parisian cathedral was built from local limestone from the St Jacques region of Paris between 1163 and 1250. Interestingly, the catacombs in Paris are old quarries.

Interlocking roof tile

Pantile

SANDSTONES
Various coloured sandstones make excellent building stones. The French town of Carcassonne is mostly built of sandstone, as are many fine Mogul monuments in India.

230-million-year-old sandstone

Red sandstone from Scotland used as a cladding building stone

GRANITE
Frequently used to face large buildings, polished granite is also used for headstones. Much of Leningrad, U.S.S.R., including the imperial palaces, is made of imported Finnish granite.

Man-made stones

Man is now able to manufacture building stone substitutes such as brick and tiles, cement, concrete and glass. However, all these products originate from rocks of some kind.

EMPIRE STATE BUILDING, NEW YORK
Although mostly made of granite and sandstone, some man-made materials were used in the construction.

ROOFING TILES
In many parts of the world, man-made roofing tiles are moulded and fired from clay.

Textured buff brick

Smooth red brick

GREAT WALL OF CHINA
The 2400 km- (1500 mile-) long Great Wall, the largest single building work on Earth, is built of various materials depending on the terrain it passes through. Sections include brick, granite and various local rocks.

BRICKS
Easily moulded clays are fired to make bricks. Impurities in clays produce bricks of different colours and strengths, making them suitable for a variety of uses.

CEMENT
This is made by grinding and heating a suitable limestone. When mixed with sand, gravel and water, it produces concrete, perhaps the most common building medium today.

The story of coal

The coal we burn today is millions of years old. It started off as vegetation in the swampy forests that covered parts of Europe, Asia, and North America. As leaves, seeds, and dead branches fell to the wet forest floor, they began to rot. This soft, rotting material later became buried. The weight of the layers above gradually squeezed the water out and compressed the plant material into a solid mass of peat and eventually coal. As pressure and heat increased, five different types of coal were formed, one after the other.

FOSSILIZED WOOD
Jet is a hard black material obtained from driftwood fragments laid down in the sea. It is very light. Often polished, carved, and made into jewelry or decorative objects, jet has been used since the Bronze Age.

"COAL" AS JEWELRY
A major source of jet is found in Yorkshire, northern England. These Roman pendants were found in York and so were almost certainly made of local material.

OIL SHALE
This sedimentary rock is called oil shale because oil can be removed from it. It contains an organic substance of plant and animal origin called kerogen. When heated, this gives off a vapor that contains oil.

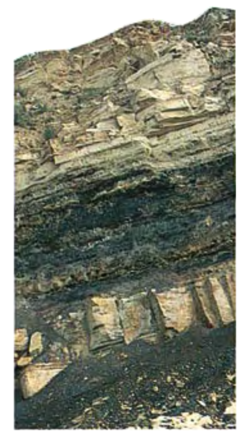
THE ORIGINS OF COAL
Carboniferous (coal-forming) swamps of 270-350 million years ago may have looked like this stylized engraving.

THE RAW INGREDIENTS OF COAL
For coal to form, there must be thick layers of vegetation in areas with poor drainage, such as swamps or bogs. The dead plants become waterlogged, and although they start to rot, they cannot decay completely.

THE PEAT LAYER
Peat is a more compact form of the surface layer of rotting vegetation. Some plant roots and seed cases are still visible. In certain parts of the world, where new peat is forming today, it is cut and dried, then burned as a fuel.

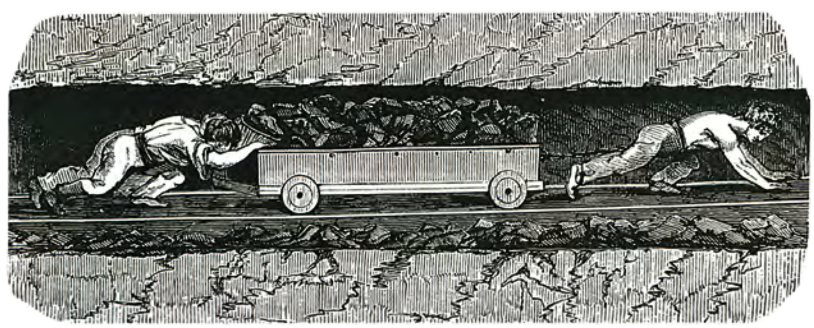
CUTTING PEAT
Like their ancestors, many Irish farmers still collect peat using traditional methods.

BROWN COAL
When peat is compressed, it forms a crumbly brown substance called lignite which still contains recognizable plant remains. Ninety percent of undried peat is water; lignite contains only 50 percent water.



COAL SEAMS
Layers of coal are called seams. They are sandwiched between layers of other material, such as sandstones and mudstones, which were formed by deposits from rivers. These lignite seams are in a French quarry.

"BLACK GOLD"
Under pressure, lignite is changed into bituminous or household coal. It is hard and brittle and has a very high carbon content. It is dirty to handle because it contains a charcoal-like, powdery substance. A lump of coal may have alternating shiny and dull layers and recognizable plant material, such as spores.

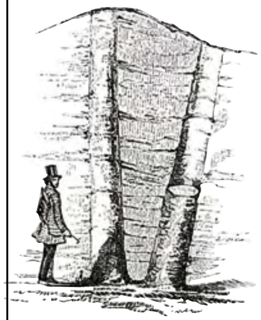


CONDITIONS IN THE MINES
During the Industrial Revolution in England, many children were forced to work extremely long hours in horrible conditions in underground mines, as this 1842 engraving shows.

MINING FOR COAL
People have been mining coal since the Middle Ages. At "strip" mines, all the coal is removed from the surface. Most other mines are several hundred yards beneath the land or sea, and a lot of mechanized equipment is used.

THE HARDEST COAL
The highest-quality coal is called anthracite. This shiny substance is harder than other coal and clean to touch. It is the most valuable of all the coals because it contains the most carbon and produces the most heat and the least smoke.

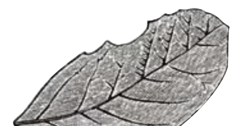
Fossils



Fossils are the evidence of past life preserved in the rocks of the Earth's crust. Fossils are formed when an animal or plant is buried in sediment. Usually the soft parts rot away, but the hardest parts remain. This is why most fossils consist of the bones or shells of animals, or the leaves or woody parts of plants. In some marine fossils, shells may be replaced by other minerals or an impression of the insides or outsides may be preserved. Fossils are found in sedimentary rocks, especially limestones and shales. Many fossils are of plants and animals now extinct, such as dinosaurs. They reveal details about the animals and plants that existed millions of years ago, and enable palaeontologists to date the rocks in which they appear. Fossils showing footprints or burrows, rather than remains are called "trace fossils".

Beech leaf

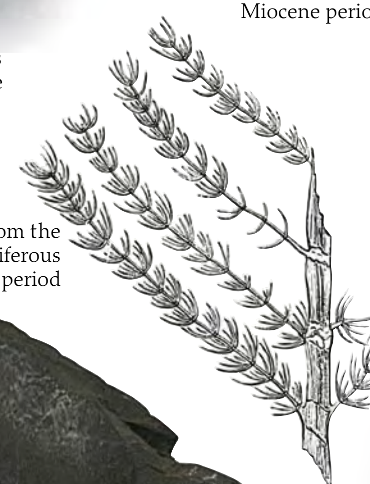
LEAF IMPRINT
This preserved leaf is similar to the modern beech leaf. Even though it is about 40 million years old, much of the original detail and texture can still be seen.



Magnolia leaf from Miocene period

Neuropteris - a seed-fern - fossilized in ironstone

PLANT FOSSILS
Many fern-like fossils are found in coal-bearing rocks (p. 36). Formed in the Carboniferous period, they are called "Coal Measures fossils". Although they are not exactly the same botanical species as the ferns that grow today, many are extraordinarily similar.



Fern from the Carboniferous period

Fronds of a fern called *Asterotheca* preserved in stone

Present-day fern

Section of a Nautilus shell

NAUTILUS
Like the ammonite's, the shell is divided into chambers. By regulating the gas in these chambers, the animal moves up or down in the water. It swims backwards with its head pointing downwards.

Ammonite remains

ANCIENT ANCESTORS
This limestone is about 200 million years old. It is packed with the remains of hundreds of ammonites. These sea creatures had hard, coiled shells, and are now extinct. Because the species changed rapidly and lived in many areas of the world, they can be used to determine the relative ages of the rocks in which they occur. The nearest modern equivalent to the ammonite is Nautilus, which lives in the Pacific Ocean.

Impression of interior of shell

Gastropod shell

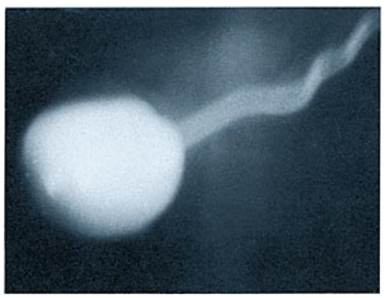
A GRAVEYARD FOR SNAILS
This piece of limestone contains the hard spiral shells of marine gastropods (snails) from about 120 million years ago. In places, the white shell has dissolved, leaving an impression of the inside.

FOSSIL HUNTING
The abundance of fossils at the seashore made collecting a popular pastime during the 19th century.

Garden snails

Rocks from space

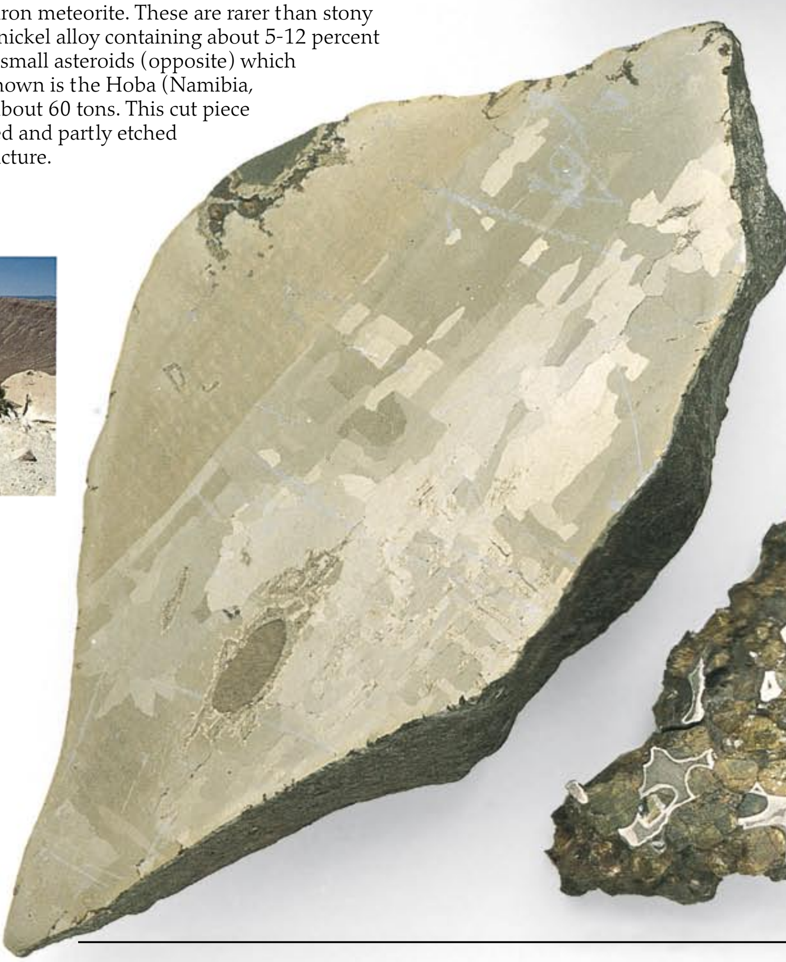
Every year about 19,000 meteorites, each weighing over 4 oz (100 g), fall to the Earth. Most fall into the sea or on deserts, and only about five are recovered annually. Meteorites are natural objects that survive their fall from space. When they enter the Earth's atmosphere their surfaces melt and are swept away, but the interiors stay cold. As meteorites are slowed down by the atmosphere, the molten surface hardens to form a dark, thin "fusion" crust.



PASAMONTE FIREBALL
Photographed by a ranch foreman in New Mexico at 5 A.M., this fireball fell to Earth in March 1933. Meteorites are named after the places where they fall, this one being Pasamonte. The fireball had a low angled path about 500 miles (800 km) long. It broke up in the atmosphere and landed as dozens of meteoritic stones.

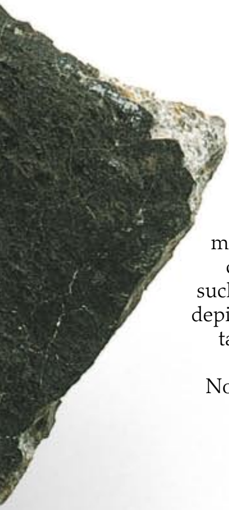
EARTH'S CONTEMPORARY *above*
The Barwell meteorite fell at Barwell, Leicestershire, England, on Christmas Eve, 1965. The meteorite is 4.6 billion years old and formed at the same time as the Earth but in a different part of the solar system. Of every ten meteorites seen to fall, eight are stones like Barwell.

METALLIC METEORITE
The Cañon Diablo (Arizona) meteorite collided with the Earth about 20,000 years ago. Unlike Barwell, it is an iron meteorite. These are rarer than stony meteorites and consist of an iron-nickel alloy containing about 5-12 percent nickel. They once formed parts of small asteroids (opposite) which broke up. The largest meteorite known is the Hoba (Namibia, Africa) which is iron and weighs about 60 tons. This cut piece of Cañon Diablo has been polished and partly etched with acid to reveal its internal structure.

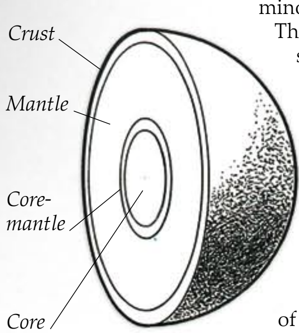


EXPLOSION CRATER
When the Cañon Diablo meteorite hit Arizona, about 15,000 tons of meteorite exploded. It created an enormous hole, Meteor Crater, about 0.75 mile (1.2 km) across and nearly 600 ft (180 m) deep. Only 30 tons of meteorite remained, scattered as small fragments across the surrounding countryside.

METAL AND STONE *below*
"Stony-irons" form a separate group of meteorites. The surface of this slice of the Thiel Mountains meteorite has been cut and polished to show bright metal enclosing stony material, the mineral olivine. It was found in Antarctica where meteorites have been on Earth for about 300,000 years and for much of this time have been encased in ice.



HALLEY'S COMET
Water-bearing meteorites may have come from comets, such as Halley's - here depicted in the Bayeux tapestry, which tells the story of the Norman Conquest of England in 1066.



ASTEROID STRUCTURE
Many meteorites come from minor planets, or asteroids. They were never part of a single planet, but circle around the sun between the orbits of Mars and Jupiter. The largest asteroid, Ceres, is 632 miles (1,020 km) across. Most asteroids are less than 62 miles (100 km) in diameter. Their interiors consist of a central core of metal, which is the source for some iron meteorites like Cañon Diablo; a core-mantle region which provides stony-iron meteorites like Thiel Mountains; and a crust which provides stony meteorites like Barwell.

WATER BEARERS
The Murchison meteorite fell in Australia in 1969. It contains carbon compounds and water from space. Material similar to this is believed to form the nucleus of a comet. The carbon compounds were formed by chemical reactions and not by a living organism. Such meteorites are rare - only about three falls in 100 are of this type.

Rocks from the Moon and Mars

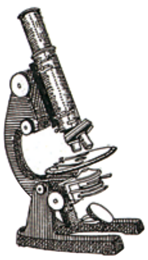
Five meteorites found in Antarctica are known to have come from the Moon because they are like lunar highlands rocks collected by the Apollo missions. Eight other meteorites are thought to have come from Mars.

MARTIAN ORIGIN
The Nakhla stone fell in Egypt in 1911 and is reported to have killed a dog. This stone formed 1,300 million years ago, much more recently than most meteorites, and probably came from Mars.

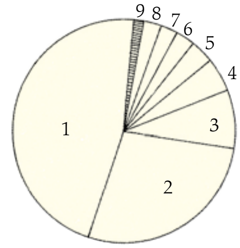
LUNAR DISCOVERIES
The lunar meteorites are made of the same material as the lunar highlands boulder next to Apollo 17 astronaut Jack Schmitt.

MOON ROCK
The Moon's surface is covered with soil made of tiny rock and mineral fragments. It was formed by repeated bombardment of the surface by meteorites. Material like this on the surface of an asteroid was compressed to form many stony meteorites. Here, the light-colored mineral is feldspar, and the darker mineral is pyroxene.

Rock-forming minerals



Petrological microscope



COMPOSITION OF THE EARTH'S CRUST
In weight per cent order, the elements are: oxygen (1), silicon (2), aluminium (3), iron (4), calcium (5) sodium (6), potassium (7), magnesium (8), and all other elements (9).

EIGHT ELEMENTS make up nearly 99 per cent of the Earth's crust. These elements combine to form naturally occurring minerals. Silicate minerals and silica predominate in most common rocks except limestones. Igneous rocks form the greatest part of the rocky interior of the earth, and specific rock-forming mineral groups are characteristic of certain types of igneous rocks.

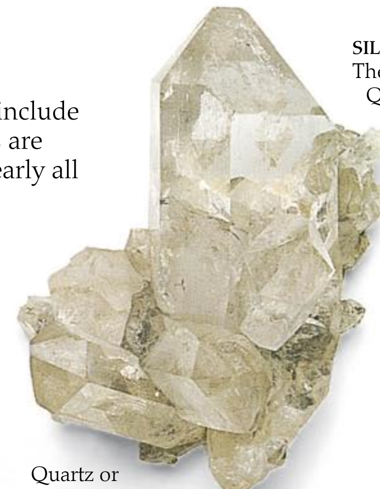
Minerals in granitic rocks

The minerals that form granitic and dioritic rocks include feldspars, quartz, micas and amphiboles. Feldspars are the most abundant of all minerals, and occur in nearly all types of rock.

Group of black prismatic crystals with calcite

Single hornblende crystal

Hornblende, an amphibole, common in igneous rocks and in metamorphic rocks such as hornblende schists



Quartz or rock crystal

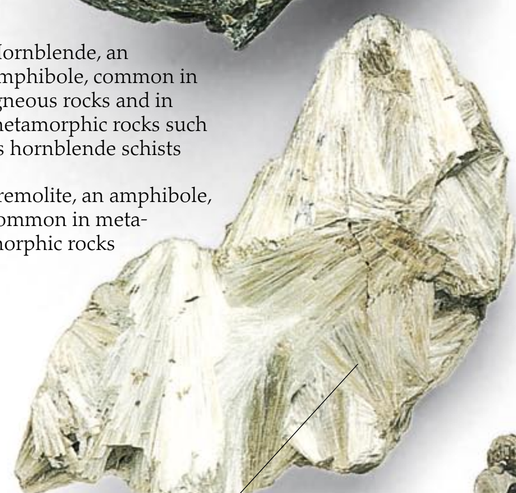
SILICA MINERALS
These include quartz, chalcedony (p. 52) and opal (p. 51). Quartz is one of the most widely distributed minerals, occuring in igneous, sedimentary and metamorphic rocks. It is characteristic of granites, gneisses and quartzites.

POTASSIC FELDSPARS
Orthoclase is found in many igneous and metamorphic rocks, while microcline (the lower temperature form of orthoclase) is found in granite pegmatites.

Green microcline (or amazonstone) crystal

Twinned crystals of pink orthoclase

THIN SECTION OF A GRANITIC ROCK
When a slice of diorite about 0.03 mm thick is viewed under a petrological microscope (above), it reveals coloured amphiboles, plain grey to colourless quartz, and lined grey plagioclase feldspar.



Tremolite, an amphibole, common in metamorphic rocks

Silvery, radiating, needle-like crystals

AMPHIBOLES
This group of minerals is widely found in igneous and metamorphic rocks. Amphiboles can be distinguished from pyroxenes (opposite) by the characteristic angles between their cleavage planes (p. 48).

Muscovite, an aluminium-rich mica, is abundant in schists and gneisses

Silvery brown tabular crystals

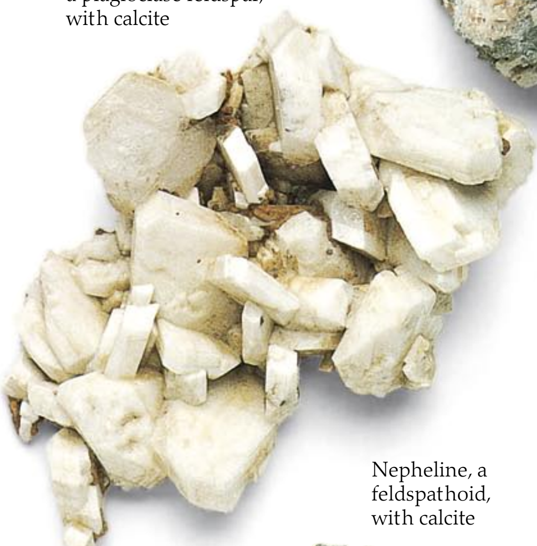
Biotite, a dark, iron-rich mica usually found in igneous rocks, is also a common constituent of schists and gneisses

MICAS
There are two main types of mica: dark iron- and magnesium-rich mica, and white aluminium-rich mica. All have perfect cleavage (p. 48), splitting into thin flakes.

Minerals in basic rocks

The seven minerals shown a here are all commonly found in basic rocks like basalts and gabbros.

Pink anorthite crystals, a plagioclase feldspar, with augite



Twinned albite crystals, a plagioclase feldspar, with calcite

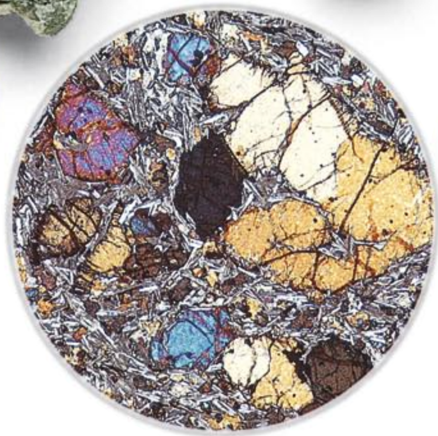
OLIVINE
This silicate of iron and magnesium is typically found in silica-poor rocks such as basalts, gabbros and peridotites. It often forms as small grains or large, granular masses. Clear crystals are cut as gem peridots (p. 54).

Green olivine crystals

Volcanic bomb containing olivine, from Vesuvius (p. 18)

Single crystal of augite

Greenish-black prismatic crystals of augite, a pyroxene



THIN SECTION OF A BASIC ROCK
A section of olivine basalt in polarized light reveals brightly coloured olivine, brown-yellow pyroxene, and minute lined, grey plagioclase feldspars.

Nepheline, a feldspathoid, with calcite

PLAGIOCLASE FELDSPARS *above*
This series of minerals contains varying proportions of sodium and calcium. Plagioclase feldspars are common constituents of igneous rocks.

Leucite crystal, a feldspathoid, on volcanic rock

FELDSPATHOIDS
As their name suggests, these minerals are related to feldspars, but they contain less silica and are typically formed in silica-poor volcanic lavas.

Prismatic crystal of enstatite with biotite

PYROXENES
The most common pyroxenes are calcium, magnesium and iron silicates. Augite is a widely distributed pyroxene, and is found abundantly in igneous rocks such as gabbros and basalts. Less common is enstatite, which is found in gabbros, pyroxenites and some peridotites.

Other rock-forming minerals

There are two other important groups of rock-forming minerals - carbonates and clays.

CARBONATES
These are important constituents of sedimentary (limestones) or metamorphic (marble) rocks, also in ore-vein deposits. The most common is calcite, the main constituent of limestones.

Dolomite, a carbonate, found in some sedimentary deposits usually interbedded with limestones

Kaolinite (china clay) formed from partly decomposed orthoclase

Montmorillonite

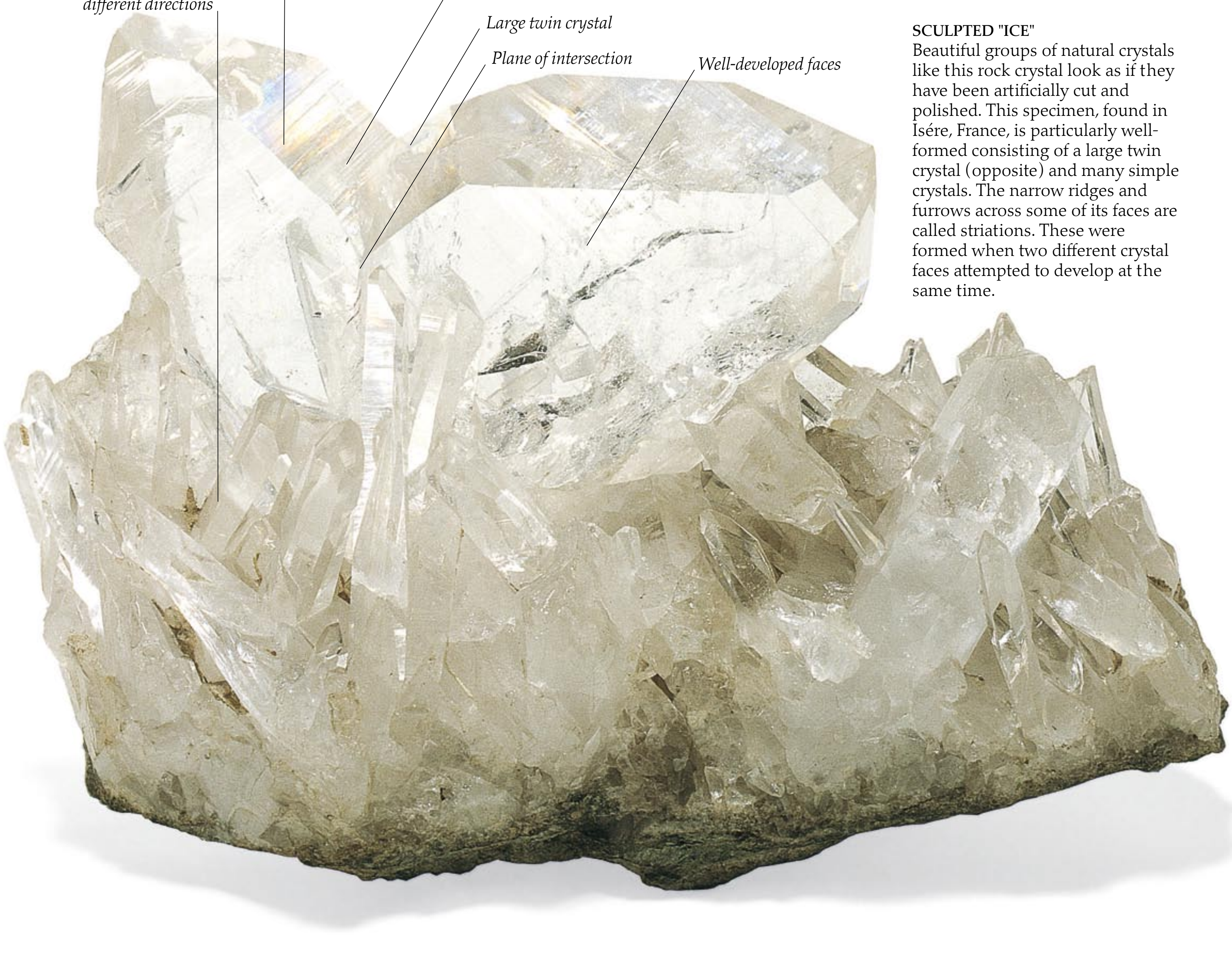
Illite

CLAYS
An important part of the sedimentary rock sequence, clays form from the weathering and alteration of aluminous silicates. Clays include kaolinite, montmorillonite and illite.

Crystals

THROUGH THE AGES people have been fascinated by the incredible beauty of crystals. For centuries it was thought that rock crystal, a variety of quartz, was ice that had frozen so hard it would never thaw. The word "crystal" is derived from the Greek word *kryos*, meaning "icy cold." In fact, a crystal is a solid with a regular internal structure. Because of the arrangement of its atoms, a crystal may form smooth external surfaces called faces. Different crystals of the same mineral may develop the same faces but they may not necessarily be the same size or shape. Many crystals have important commercial uses, and some are cut as gemstones (p. 50).

Crystal collecting in the Alps, c. 1870

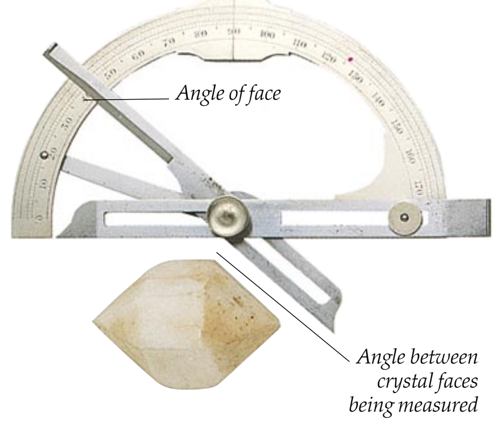


SCULPTED "ICE"
Beautiful groups of natural crystals like this rock crystal look as if they have been artificially cut and polished. This specimen, found in Isére, France, is particularly well-formed consisting of a large twin crystal (opposite) and many simple crystals. The narrow ridges and furrows across some of its faces are called striations. These were formed when two different crystal faces attempted to develop at the same time.

Crystal symmetry

Crystals can be grouped into the seven systems shown below according to their symmetry. This is reflected in certain regular features of the crystal. For example, for every face there may be another on the opposite side of the crystal that is parallel to it and similar in shape and size. However, it may be hard to see the symmetry in many mineral specimens because crystals occur in groups and do not have well-developed faces.

SCIENTIFIC MEASUREMENT
A useful feature in identifying crystals is that the angle between corresponding faces of a particular mineral is always the same. Scientists measure this accurately using a contact goniometer.



TRICLINIC
Crystals in this system have the least symmetry - as shown by this wedge-shaped axinite crystal from Brazil. Plagioclase feldspars (p. 43) are also triclinic minerals.

CUBIC
Metallic pyrite (p. 59) forms cube-shaped crystals but other cubic mineral forms include octahedra (with eight faces) and tetrahedra (four faces). Garnet (p. 55) is also classified in this system. Crystals in this system have the highest symmetry.

TETRAGONAL
Dark green idocrase crystals, like this Siberian specimen, are grouped with zircon (p. 54) and wulfenite (p. 9) in the tetragonal system.

ORTHORHOMBIC
Common orthorhombic minerals include baryte (from which we get barium for medicinal uses), olivine (p. 43), and topaz (p. 54).

MONOCLINIC
The most common crystal system includes gypsum (from which we make plaster of Paris; p. 21), azurite (p. 33), and orthoclase (p. 49).

RHOMBOHEDRAL (TRIGONAL) *below*
Smaller secondary crystals have grown on this siderite crystal. Quartz (opposite), corrundum (p. 51), tourmaline (p. 55), and calcite (pp. 22 and 48) belong to the same system.

HEXAGONAL *above*
Beryl (p. 50), including this Colombian emerald variety, crystallizes in the hexagonal system as does apatite (p. 49) and ice. (But each snowflake is different from every other.)

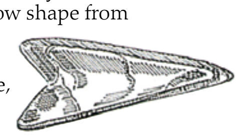
Snowflakes

Twinning

Crystals may grow in groups in cavities in mineral veins. Occasionally they develop in such a way that two (or sometimes more) individual crystals appear to intersect in a symmetrical manner. Related crystals like this are known as twin crystals.

CONTACT TWINS
The crystal form of the mineral cerussite is orthorhombic. This group of twin crystals is from Southwest Africa.

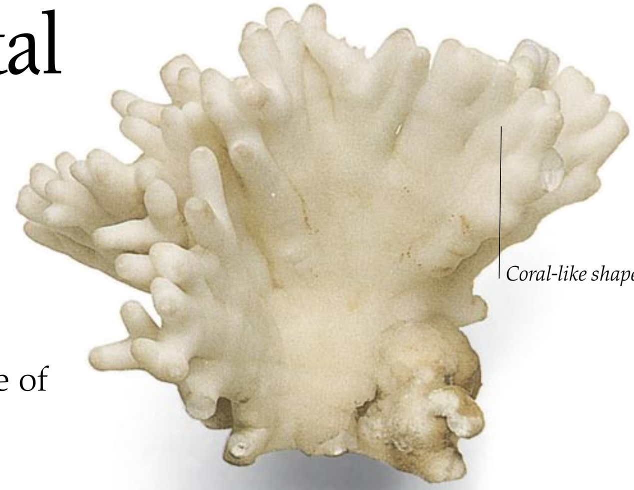
PENETRATION TWINS
Staurolite is also an orthorhombic mineral. In this cross-shaped Brazilian specimen one twin appears to penetrate into the other.



Twinned gypsum crystals form a distinctive arrow shape from which they get their common name, "swallow-tail"

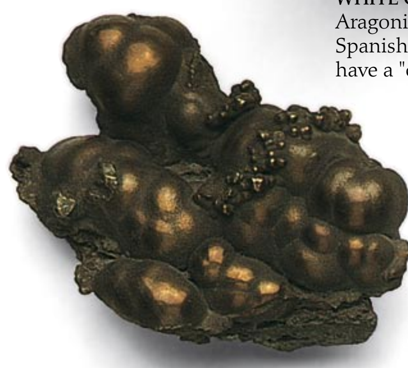
The growing crystal

NO TWO CRYSTALS are exactly alike because the conditions in which they develop vary. They can only grow where there is sufficient space, and if this is restricted, distortions or unusual features may develop. Crystals range in size from microscopic to several metres long. The shape and size of a crystal or aggregate of crystals constitute its "habit".



WHITE CORAL
Aragonite, which was named after the Spanish province of Aragon, can sometimes have a "coralloid" habit. This term is used to describe minerals whose shape resembles corals.

RADIATING NEEDLES
Very slender, elongated crystals with a needle-like appearance are described as having an "acicular" habit. In this scolecite specimen, grey acicular crystals radiate from the centre.

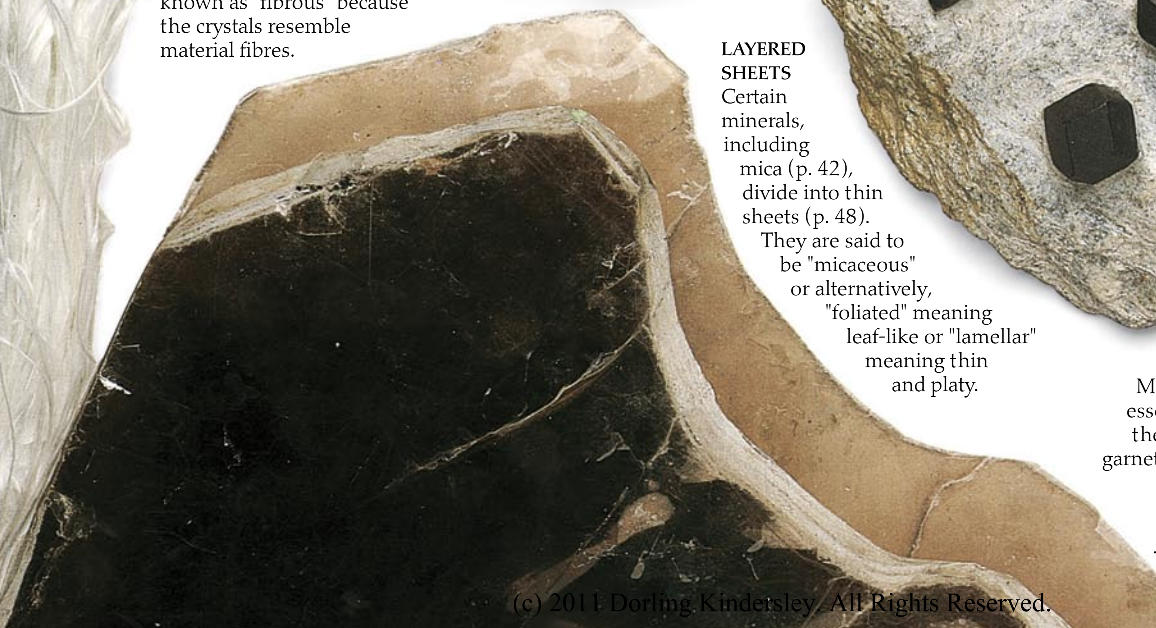


METALLIC "GRAPES"
Some chalcopyrite (p. 59) crystals grow outwards from a centre and such aggregates appear as rounded nodules. The habit is "botryoidal", a term strictly meaning like a bunch of grapes.

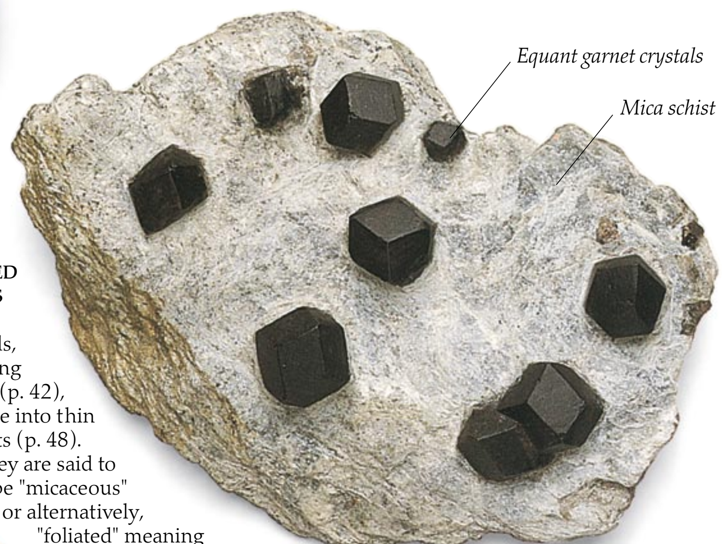
SPARKLING AGGREGATE *below right*
Hematite (p. 33) occurs in a number of different habits. When it forms lustrous, sparkling crystals it is said to have a "specular" habit, named from the Latin *speculum* meaning to reflect. The specimen shown consists of an aggregate of specular crystals.

CRYSTAL COLUMNS
"Prismatic" crystals are much longer in one direction than in the other two. This beryl crystal (p. 50) has six large rectangular prism faces and a flat hexagonal terminal face at each end.

SOFT STRANDS *left*
Crystals of tremolite, one of several minerals commonly known as asbestos, are soft and extremely pliable. Their habit is known as "fibrous" because the crystals resemble material fibres.



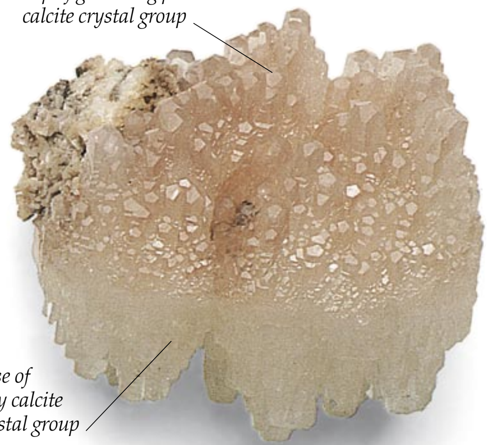
LAYERED SHEETS
Certain minerals, including mica (p. 42), divide into thin sheets (p. 48). They are said to be "micaceous" or alternatively, "foliated" meaning leaf-like or "lamellar" meaning thin and platy.



EQUAL SIDES
Many minerals develop crystals which are essentially equal in all dimensions, and are then said to be "equant". This specimen of garnet (p. 55) in mica schist is a fine example.

DUAL FORM

Pyrite (p. 59) may crystallize as simple cubes and also as 12-faced solids called pentagonal dodecahedra. If the conditions change during growth, both forms may co-develop, resulting in a series of striations (p. 44) on the crystal faces.



PARALLEL LINES

During crystal growth a series of crystals of the same type may develop growing in the same direction. This calcite aggregate shows a number of tapering pale pink and grey crystals in perfect parallel orientation.

SALT LAKE, CYPRUS

When salt lakes dry up, a thick crust of soluble salts is left.

HOPPER GROWTH

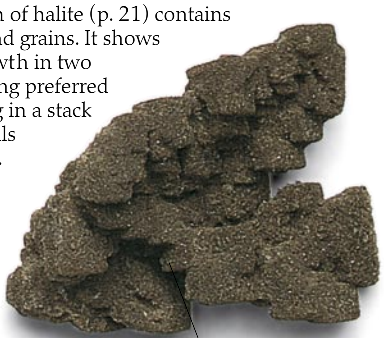
The mineral halite (salt, p. 21) is cubic but crystals sometimes grow from solution faster along the cube edge than in the centre of the faces, resulting in the formation of "hopper crystals" that have stepped cavities in each face.

DOUBLE DECKER

Chalcopyrite (p. 59) and sphalerite (p. 57) crystals have similar structures. Here, tarnished, brassymetallic chalcopyrite crystals have grown in parallel orientation on brownish-black sphalerite crystals.

STEPPED CRYSTALS

This specimen of halite (p. 21) contains numerous sand grains. It shows excessive growth in two directions along preferred axes, resulting in a stack of cubic crystals forming steps.



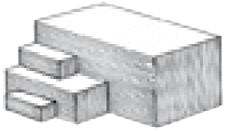
BRANCHING METAL

Where space is restricted, such as in confined spaces between two beds of rock, native copper (p. 56) and other minerals may grow in thin sheets. Its characteristic branch-like form is described as "dendritic".

PHANTOM GROWTH

The dark areas within this quartz crystal formed when a thin layer of chlorite coated the crystal at an earlier stage of its growth. As the crystal continued to grow, the chlorite became a ghost-like outline.

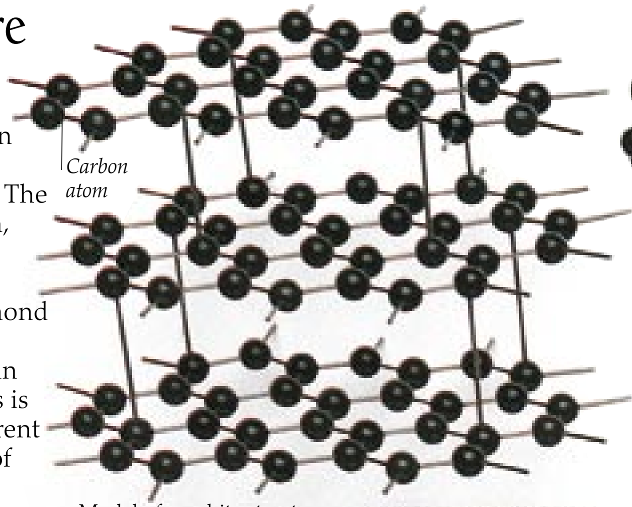
The properties of minerals



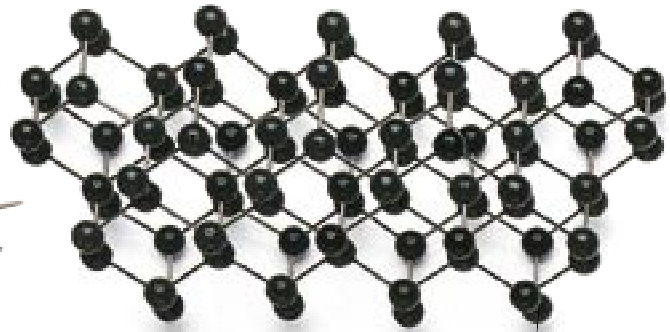
THE MAJORITY OF MINERALS have a regular crystal structure and a definite chemical composition. These determine the physical and chemical properties that are characteristic for each mineral, some having a great deal of scientific and industrial value. By studying mineral properties such as cleavage, hardness, and specific gravity, geologists can discover how the mineral was formed and use them, along with color and habit (p. 46), to identify minerals.

Structure

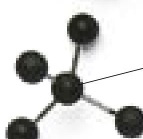
Some chemically identical minerals exist in more than one structural state. The element carbon, for example, forms two minerals - diamond and graphite. The difference in their properties is caused by different arrangements of carbon atoms.



Model of graphite structure

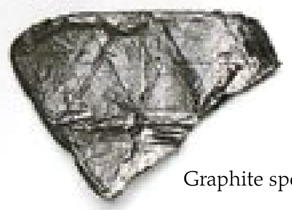


Model of diamond structure



Model showing how one atom is bonded to four others

GRAPHITE
In graphite, a hexagonal mineral formed under high temperature, each carbon atom is closely linked to three others in the same plane. The structure is made of widely spaced layers that are only weakly bonded together. Graphite is one of the softest minerals (Mohs' scale 1-2), and its loose bonding enables it to leave marks on paper, which is why it is used in pencils.



Graphite specimen

Diamonds

DIAMOND
In diamond (p. 50), a cubic mineral formed under high pressure, each carbon atom is strongly bonded to four others to form a tight, rigid structure. This makes diamond extremely hard (Mohs' scale 10). Because of this, it is used as a cutting tool in industry.

Cleavage

When crystals break, some tend to split along well-defined cleavage planes. These are caused by the orderly arrangement of the atoms in the crystal.

THIN SHEETS
Stibnite, an ore of antimony, shows a perfect sheet-like cleavage because of weak bonds between antimony and sulfur atoms.

LEAD STEPS
Galena, the main ore of lead (p. 57), has a perfect cubic cleavage, because of the internal arrangement of lead and sulfur atoms. A broken crystal face consists of many small cubic cleavage steps.

PERFECT BREAK
Baryte crystals (p. 45) show an intersecting, perfect cleavage. If this crystal was broken, it would split along these planes of cleavage.

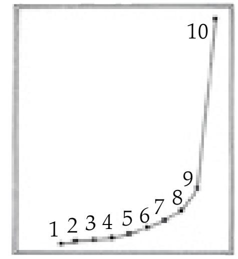
PERFECT RHOMB
Any piece of calcite has such a well-developed rhombohedral cleavage that a break in any other direction is virtually impossible.

FRACTURE
Quartz crystals break with a glassy, conchoidal (shell-like) fracture rather than cleaving along any particular plane.

Hardness

The bonds holding atoms together determine a mineral's hardness. In 1812, the Austrian mineralogist Friedrich Mohs devised a scale of hardness that is still in use today. He selected ten minerals as standards and arranged them so that any mineral on the scale would scratch only those below it. Everyday objects can be used to test where a mineral fits into the scale. A fingernail has a hardness of 2.5, and a penknife is 5.5. Minerals of six and above will scratch glass; glass will scratch apatite and other minerals below it.

GRAPH SHOWING RELATIVE HARDNESS
The intervals between the minerals in Mohs' scale are irregular. Diamond is about 40 times harder than talc, and corundum is only nine times as hard.



1	2	3	4	5	6	7	8	9	10
Talc	Gypsum	Calcite	Fluorite	Apatite	Orthoclase	Quartz	Topaz	Corundum	Diamond

Magnetism

Only two common minerals, magnetite and pyrrhotite (both iron compounds), are strongly magnetic. Some specimens of magnetite called "lodestones" were used as an early form of compass.

NATURAL MAGNET
Magnetite is permanently magnetized and will attract iron filings and other metallic objects such as paper clips.

Optical properties

As light passes through minerals, many optical effects are produced due to the way light reacts with atoms in the structure.

DOUBLE IMAGE
Light traveling through a calcite rhomb is split into two rays, making a single daisy stalk appear to the eye as two.

FLUORESCING AUTUNITE
When viewed under ultraviolet light, certain minerals fluoresce (give off light).

Specific gravity

This property relates a mineral's chemical composition to its crystal structure. It is defined as the ratio of the weight of a substance to that of an equal volume of water. Determining the specific gravity may aid identification.

SIZE vs. WEIGHT
The nature of the atoms and the way they are arranged in a mineral determines its specific gravity. These three mineral specimens all weigh the same, but because the atoms in quartz and galena are heavier or more closely packed together than those in mica, the quartz and galena specimens are much smaller.

Mica

Quartz

Galena

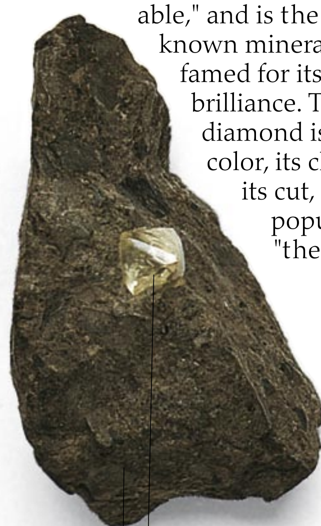
Gemstones

GEMSTONES are minerals that occur in nature and are valued for their beauty and rarity, and because they are hardy enough to survive everyday wear on jewelry and other objects. Diamond, emerald, ruby, sapphire, and opal all fit this description. Light reflects and refracts (changes direction) with the minerals to produce the intense colors of ruby and emerald and the "fire" of diamond. Color, fire, and luster (shine) are usually revealed only by skilled cutting and polishing (p. 60). Gems are commonly weighed by the carat, equal to one fifth of a gram, and not to be confused with the carat used to describe the quality of gold (p. 59).

Diamond

Diamond is named from the Greek word *adamas*, meaning "unconquerable," and is the hardest of all known minerals (p. 49). It is famed for its lasting fiery brilliance. The quality of a gem diamond is measured by its color, its clarity, the quality of its cut, and its carat weight popularly known as "the four C's."

Kimberley mine, South Africa

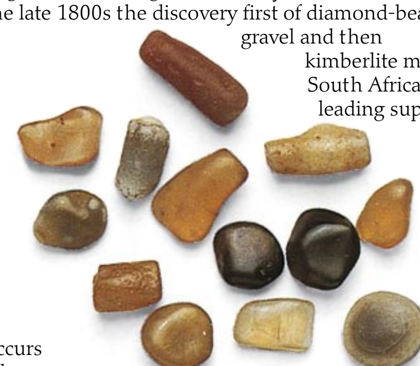


Diamond crystal

Kimberlite

DIAMONDS IN ROCK
Kimberlite is the source rock for most diamonds. It is named after Kimberley in South Africa, where it occurs in a volcanic pipe that has its roots between 100 and 200 miles deep in the Earth's crust.

TREASURES IN GRAVEL
Before 1870 diamonds were found only as crystals or fragments in river gravels, mainly in India or Brazil. In the late 1800s the discovery first of diamond-bearing gravel and then kimberlite made South Africa the leading supplier.



MULTI-COLORED DIAMONDS
Diamond ranges from colorless through yellow and brown to pink, green, and blue. Red diamond is very rare. To show off the stones to their best advantage, for centuries diamond cutters have fashioned table and rose-cut stones (p. 60) and, more recently, "brilliant" cuts which display the gem's fire and luster.

KOHINOOR DIAMOND
This famous Indian diamond, here worn by Queen Mary of England, was presented to Queen Victoria in 1850.

Beryl

The most important gem varieties - emerald and aquamarine - have been used for centuries: Egyptian emerald mines date back to 1650 B.C. Beautifully formed hexagonal beryl crystals may be found in pegmatites and schists in Brazil, Russia, and many other countries.

Cut emerald

EMERALDS
The finest emeralds, such as those in the British Crown Jewels, come from Colombia, South America, where they occur in veins with calcite and pyrite. Flawless emeralds are very rare; most crystals are fractured or contain other minerals. These may seem to detract from a stone, but in fact they may be crucial in proving its natural origin.

ROMAN BERYL JEWELRY
The earrings and necklaces contain cut emeralds.

Aquamarine

Yellow heliodor

Greenish heliodor

Pink morganite

THE ASSORTED COLORS OF BERYL
Pure beryl is colorless. The gems' colors are due to impurities such as manganese which produces the pink of morganites. Greenish-blue aquamarine crystals are often heat-treated to produce a more intense blue color.

Corundum

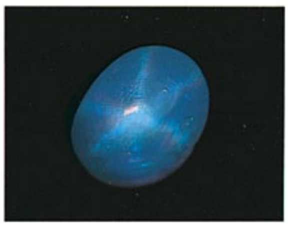
The beauty of ruby and sapphire lies in the richness and intensity of their colors. Both are varieties of the mineral corundum, which is colorless when pure. Tiny quantities of chromium give rise to the red of ruby, and iron and titanium are responsible for the blues, yellows, and greens of sapphire.

SAPPHIRE CRYSTAL
While ruby tends to form in flat crystals, sapphires are generally shaped like barrels or pyramids. They often feature zones of blue to yellow color that are important in choosing which crystals to cut.

RIVER JEWELS
Most sapphires and rubies are taken from gem-rich gravel. The gem minerals are usually harder and more resistant to chemical weathering than their parent rocks and become concentrated in river beds.

GEMSTONES IN JEWELRY
The oldest jewelry comes from ceremonial burials 20,000 years ago. Here, rubies, emeralds, and diamonds decorate a late 16th-century enameled gold pendant.

STAR SAPPHIRE
Some stones contain very fine needle-like crystals orientated in three directions. Proper cutting will give star rubies or star sapphires.



RUBY CRYSTAL
Known as the Edwardes Ruby, this crystal is of exceptional quality, weighing 162 carats. It is almost certainly from the famous gem deposits of Mogok, Burma.

Cut ruby

Blue sapphire

Colorless sapphire

Pink sapphire

Yellow sapphire

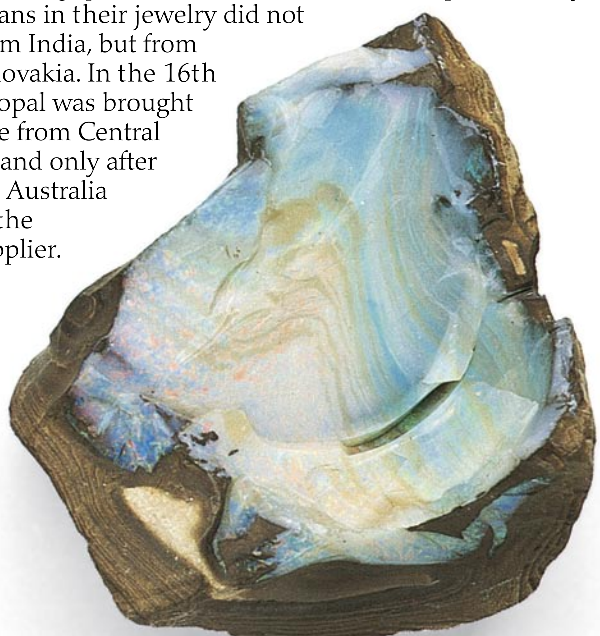
Clear sapphire

Mauve sapphire

GEM SOURCES
Australia is the most abundant source of blue and yellow sapphires; rubies are mined in Burma, Thailand, and central Africa. The rich gem gravel of Sri Lanka has for at least 2,000 years supplied exceptional blue and pink sapphires.

Opal

The name opal probably derives from the Sanskrit word *upala*, meaning "precious stone". However, the opals used by the Romans in their jewelry did not come from India, but from Czechoslovakia. In the 16th century, opal was brought to Europe from Central America and only after 1870 did Australia become the main supplier.



OPAL'S ROCKY ORIGINS
Most opal forms over long periods of time in sedimentary rocks, as in this sample from Australia. However, in Mexico and Czechoslovakia opal forms in gas cavities in volcanic rocks. It is often cut as cabochons (p. 60). The opal veins in sedimentary rocks are usually thin, and slices of these may be glued onto onyx or glass to form "doublets." These stones are sometimes made even more valuable by adding a cap of clear quartz to form a "triplet."

OPAL MINING IN AUSTRALIA
Aside from its use in jewelry, opal mined today is also used in the manufacture of abrasives and insulation products.

COLOR VARIATIONS IN OPAL
The beautiful blue, green, yellow, and red rainbow in precious opal is caused by the reflection and scattering of light from tiny silica spheres inside the mineral. This is different from the background or "body" color, which may be clear as in water opal, milky as in white opal, or gray, or black as in the most precious form, black opal.

Black opals

White opal

Milky opal

FIRE OPAL
The finest fire opal comes from Mexico and Turkey and is generally cut as faceted stones. It is valued for the intensity and rainbow quality of its colors.

Decorative stones

TURQUOISE, agate, lapis lazuli, and jade are all gems made up of many crystals. They are valued mainly for their color, either evenly distributed as in fine turquoise, or patterned as in an agate cameo. The toughness of jade and agate makes them ideal for delicate carving, and the softer turquoise is used for "protected" settings, such as pendants or inlay. Lapis lazuli is variable in quality and fine carving is only possible in high-quality material.

Chalcedony

Carnelian, onyx, agate and chrysoprase are all forms of chalcedony. Pure chalcedony is translucent (frosty) gray or white and consists of thin layers of tiny quartz fibers. Obviously banded chalcedony is called agate. Impurities cause the different colors and patterns.

Chrysoprase cabochon

ANCIENT FAVORITE
Apple-green chrysoprase has been used in jewelry since pre-Roman times, often as cameos or intaglios (p. 61) in rings and pendants.

Turquoise

Found in the earliest jewelry, turquoise is so universally recognized that "turquoise blue" is an accepted term for a pale greenish blue. Its color is largely due to copper and traces of iron. The more iron that is present, the greener (and less valuable) the turquoise.

CUT TURQUOISE
The finest sky-blue turquoise occurs in Nishapur, Iran, where it has been mined for about 3,000 years. Another ancient source, known to the Aztecs, is the southwestern United States. Today this area supplies most of the world's turquoise.

TURQUOISE ORNAMENTS
This object may be from ancient Iran (Persia). The double-headed serpent (top) is an Aztec necklace. It was sent to Cortez by Montezuma during the early 16th century.

Lapis lazuli

Blue lapis lazuli is composed mainly of the minerals lazurite and sodalite with smaller amounts of white calcite and specks of brassy colored pyrite.

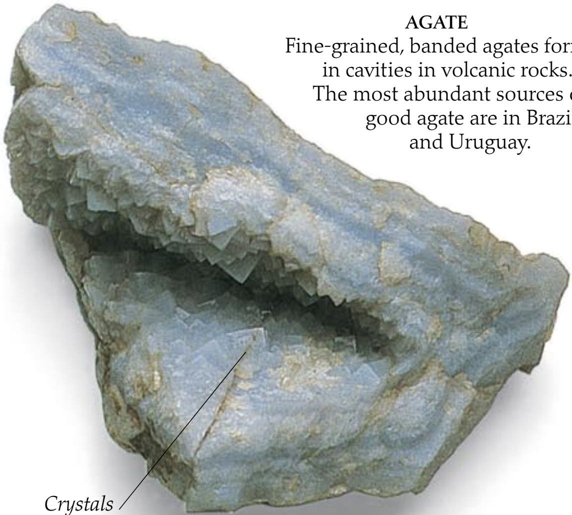
PUREST SAMPLES
The best lapis lazuli is mined in Badakhshan, Afghanistan, where it occurs in veins in white marble.

ANCIENT LAPIS JEWELRY
For centuries lapis has been fashioned into beads and carvings. It has been known for over 6,000 years and is named from the Persian word *lazhward*, meaning "blue."

ANCIENT ARABIC MOSAIC
Lapis was used to decorate the wooden box known as the Standard of Ur, c. 2500 B.C.

EGYPTIAN AMULET
Many fine pieces of early Egyptian craftsmanship have been recovered from the tombs of the kings.

TRUE BLUE *left*
The vivid blue of this lapis slice is caused by small amounts of sulfur, and has been imitated in glass and synthetic lapis.



AGATE
Fine-grained, banded agates form in cavities in volcanic rocks. The most abundant sources of good agate are in Brazil and Uruguay.

Crystals

POLISHED AGATE
The beautiful patterns shown in polished agate slices were caused by hot, silica-rich solutions filtered through rocks. The crystals then formed in bands and colored deposits.

Deep-colored band

CARVED PORTRAIT
Bloodstone cameos were popular in Roman times.

STONE LANDSCAPE
The pattern in moss agate or mocha stone is well shown in this delicate cabochon.

ORNAMENTAL KNIFE
Carnelian is red chalcedony and has been used widely in decorative jewelry and inlay work throughout history. Here it has been fashioned into a knife.

Jade

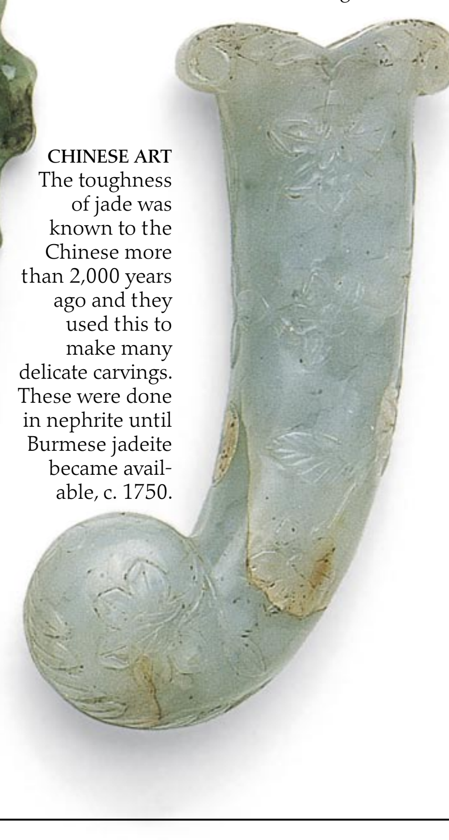
Originally named from the Spanish *piedra de hijada*, used to describe the green stone carved by the Indians in Central America, jade actually refers to two different substances - jadeite and nephrite.

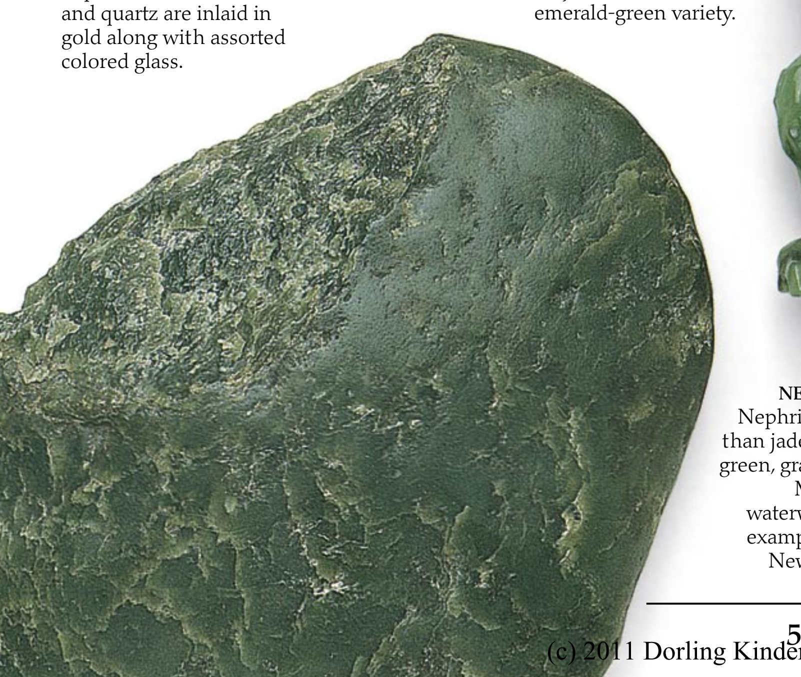
TUTANKHAMUN'S MASK
Lapis, carnelian, obsidian, and quartz are inlaid in gold along with assorted colored glass.

RARE JADE
Jadeite may be white, orange, brown, or, rarely, lilac, but the most prized is "imperial jade," a translucent emerald-green variety.

CHINESE ART
The toughness of jade was known to the Chinese more than 2,000 years ago and they used this to make many delicate carvings. These were done in nephrite until Burmese jadeite became available, c. 1750.

MOGUL DAGGER
Pale green and gray nephrite was a favorite material of the Mogul (Indian) craftsmen, who fashioned dagger handles, bowls, and jewelry, often inlaid with rubies and other gems.





NEPHRITE BOULDERS
Nephrite is more common than jadeite and is generally green, gray, or creamy white. Much jade occurs as waterworn boulders. This example of nephrite from New Zealand is typical.

Lesser-known gems

In addition to the well-known gemstones such as diamond, ruby, sapphire, emerald, and opal, many other minerals have been used for human adornment. Beautiful features like the luster and fire of zircon and demantoid garnet, and the multicolored hues of the tourmaline family, have attracted attention. There is space here only to glimpse some examples of the stones more frequently seen in jewelry, but the range of color even in these species is extensive.

Multicoloured topaz

Blue topaz

Yellow topaz

TOPAZ
Occuring chiefly in granites and pegmatites, some gem-quality topaz crystals are very large, weighing many pounds. The largest stones are colorless or pale blue. The most valuable in terms of price per carat are golden yellow - "imperial topaz" - or pink, both of which are found in Brazil. Pakistan is the only other source of pink topaz. Yellow topaz is slightly more common, and colorless topaz is found worldwide.

Blue spinel

Pink spinel

Mauve spinel

SPINEL
Red spinels are very similar to rubies. They were once called balas rubies, probably after Balascia, now Badakhshan in Afghanistan, their supposed source. Fine red spinels also come from Burma, and from Sri Lanka, where there is also a range of pink, lilac, blue, and bluish-green stones

TOPAZ BROOCH
Brown topaz was commonly used in 18th- and 19th-century jewelry. The rarer pink stones were man-made by heating yellow topaz.

Cut spinel

BLACK PRINCE'S RUBY
This famous spinel is the central stone in the British Imperial State Crown.

PERIDOT
This is the transparent gem variety of olivine (p. 43), a mineral common in basaltic lavas and some deep-seated igneous rocks. The amount of iron in the mineral determines the shade of color - the more valuable golden-green and deep-green stones contain less iron than those with a brownish tinge. Peridot is softer than quartz and has a distinctive oily luster, and has beeen used in jewelry since Roman times. The original source was the island of Zebirget in the Red Sea, but fine material has since come from Burma, Norway, and Arizona.

Cut peridots

Vermilion zircon

Pink zircon

Green zircon

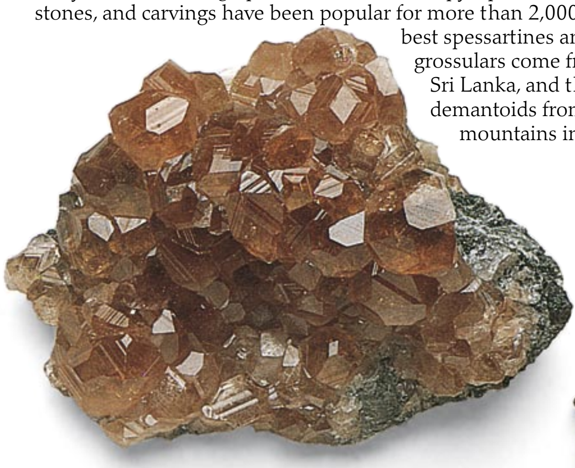
Yellow zircon

Blue zircon

ZIRCON
Named from the Arabic word *zargoon*, meaning "vermilion" or "golden colored," stones of these colors, in addition to green and brown varieties, have been used in jewelry in India for centuries. When transparent stones are cut and polished they display a luster and fire similar to diamond, but they are softer and chip more easily.

GARNET

Garnet is a group name for a set of gems that includes almandine and pyrope (red and purplish red), spessartine (orange red), grossular (orange, green, or colorless) and demantoid (green). Fine demantoid has a color like that of emerald and a fire exceeding that of diamond. Its beauty and rarity command a high price. Almandine and pyrope cabochons, faceted stones, and carvings have been popular for more than 2,000 years. The best spessartines and orange grossulars come from Brazil and Sri Lanka, and the best demantoids from the Ural mountains in Russia.



Grossular garnets

GARNET EARRINGS

Rose-cut stones (p. 60) make attractive jewelry when set in gold, as shown by these 18th-century earrings.

Rose-cut stone

Gold

Almandine

Hessonite

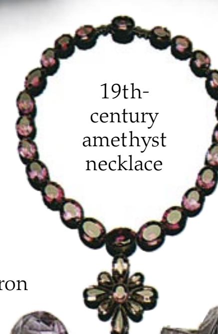
Pyrope

Demantoid

Demantoid garnets

GREEK DIADEM (HEADBAND)

This section of an enameled Greek diadem, dating from the 2nd century A.D., is inlaid with garnets. Its design is common to many Greek objects of the time.



19th-century amethyst necklace

AMETHYST

Purple amethyst is a variety of quartz (p. 44). Colorless, transparent rock crystal is the purest form of quartz, and the colors of amethyst, citrine (yellow quartz), and rose quartz are caused by iron or titanium impurities. The finest crystalline amethyst occurs in gas cavities (geodes) in volcanic rocks in India, Uruguay, and Brazil.

Cut amethyst

TOURMALINE

Tourmaline has the greatest color range of any gemstone, and some single crystals are multicolored. The crystal forms and the electrical properties are different at each end of a crystal. This polarity is sometimes reflected in color differences, especially pink and green. Carvings and cut stones may show this variation to advantage. The best gem-quality tourmaline crystals come from pegmatites. The Pala and Himalaya mines in California are famed for pink and green crystals, and other fine material is found in the Ural mountains (Russia), Brazil, and Madagascar.

Yellowish-green tourmaline

Green tourmaline

Blue tourmaline

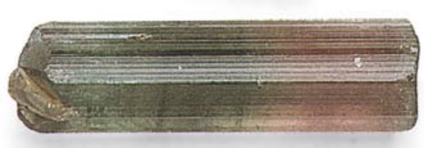
Pink tourmaline

Brown tourmaline

Mauve-grey tourmaline

"Watermelon" tourmaline

Graduating color tourmaline



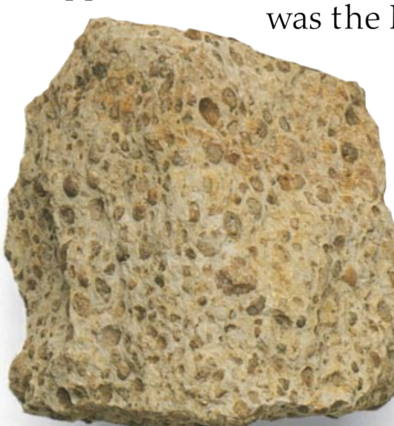
BYZANTINE RELIC, C. 955

Many Byzantine objects were made of gold and decorated with precious stones.

Ore minerals and metals

Bronze ritual food vessel from China, c.10th century BC

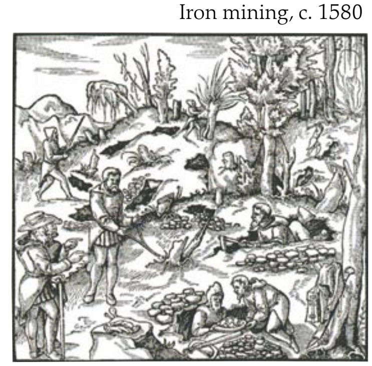
ORE MINERALS are the source of most useful metals. After the ores are mined, quarried, or dredged (from lakes and rivers), they are crushed and separated, then refined and smelted (fused and melted) to produce metal. Even before 5000 B.C., copper was used to make beads and pins. However, it was the Mesopotamians (ancient Arabs) who first began large-scale smelting and casting. Then, around 3000 B.C., tin was added to copper to produce bronze, a harder metal. Still more important was the production of iron, fairly widespread by 500 B.C. Iron was harder than bronze, and iron ores were much more common.



Bauxite – aluminium ore (p. 13)

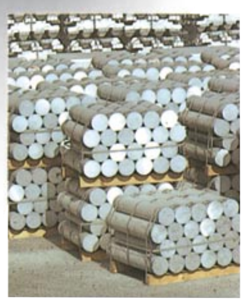
Hematite – iron ore

Iron mining, c. 1580



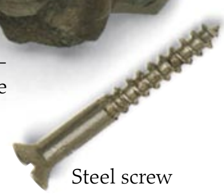
LIGHTWEIGHT ALUMINUM
Aluminum is a good conductor of electricity, lightweight, and not easily corroded. It is used in power lines, building and construction, cars and washing machines, pots and pans.

Aluminium foil



Stacks of aluminium ingots

TOUGH IRON
Hematite, the most important iron ore, commonly occurs as "kidney ore" – so-called because of its shape. Iron is tough and hard, yet easy to work. It can be cast, forged, machined, rolled, and alloyed with other metals. It is used extensively in the construction industries. Steel and many household items are made from iron.



Steel screw

Rutile – titanium ore

COLORFUL COPPER
Brassy, yellow chalcopyrite and bluish-purple bornite are common copper ores. Massive ores are generally found in isolated deposits that are too expensive to mine, and most copper now comes from large, low-grade deposits. Because it is a good conductor, copper is used in the electricity industry', and because it is easy to shape and roll, it is good for household water pipes. It is also used in alloys with zinc (brass) and with tin (bronze).

Chalcopyrite – copper ore

Bornite – copper ore

STRONG TITANIUM
Rutile and ilmenite are the principle ores of titanium. Usually found in igneous or metamorphic rocks, these two minerals are concentrated in the weathering process and form deposits with other minerals, many of which are extracted as by-products. Because of its light weight and great strength, titanium is widely used in aircraft frames and engines.

Airliner partially constructed from titanium

Copper plumbing joint

Galvanized nail

Sphalerite - zinc ore

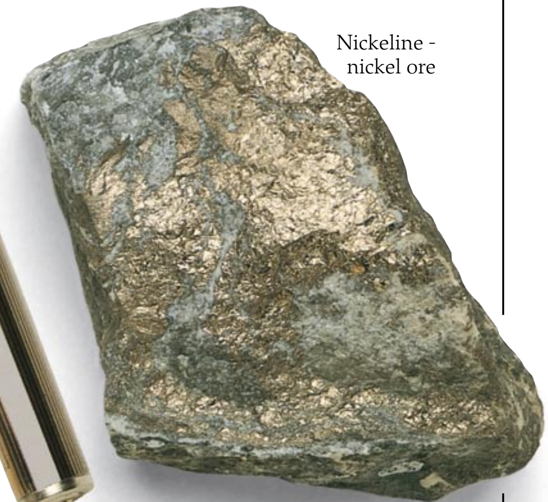
BLACKJACK ZINC

Sphalerite or "blackjack," as it was commonly known by miners, is the most important zinc ore and is found in deposits in sedimentary

Zinc processing in Belgium, c.1873

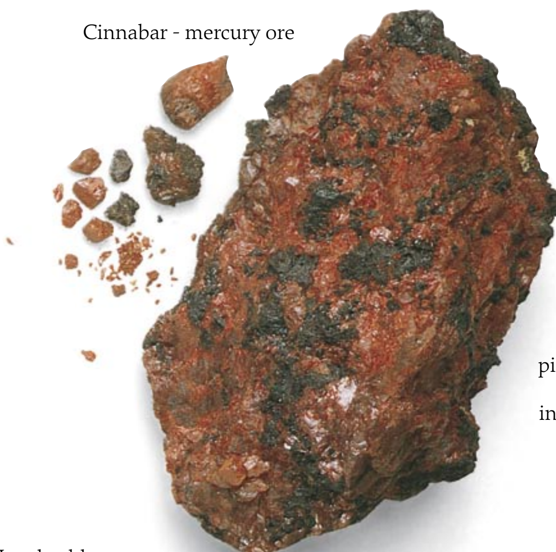
DURABLE NICKEL

Nickel comes from deposits in large layered gabbroic intrusions (p. 17) and from deposits formed by the weathering of basaltic igneous rocks. Small amounts of nickeline occur in silver and uranium deposits where nickel is a byproduct. Nickel is used in alloys like stainless steel to help it resist corrosion. High-strength, high-temperature alloys are suitable for aircraft and jet engines.



Nickeline - nickel ore

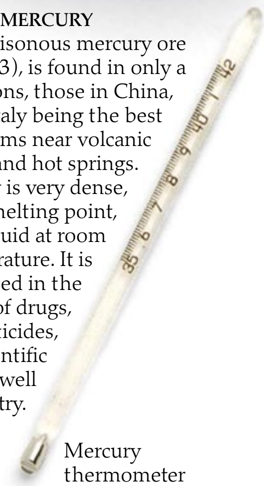
Nickel alloy battery



Cinnabar - mercury ore

RED MERCURY

The poisonous mercury ore cinnabar (p. 33), is found in only a few locations, those in China, Spain, and Italy being the best known. It forms near volcanic rocks and hot springs. Mercury is very dense, has a low melting point, and is liquid at room temperature. It is widely used in the manufacture of drugs, pigments, insecticides, and scientific instruments, as well as in dentistry.



Mercury thermometer

SOFT AND SHINY LEAD

Galena, the main lead ore, is worked chiefly from deposits in limestones, such as those in the southern U.S. Some lead deposits are mined only because of their high silver content. Lead is the densest and softest common metal and is very resistant to corrosion, but it is not very strong. It is used in storage batteries, gasoline, engineering, and plumbing, and with tin in solder.

Lead solder

Galena - lead ore

19th-century Cornish tin mine, England

Crystalline cassiterite - tin ore

WORKABLE TIN

The tin ore cassiterite is hard, heavy, and difficult to scratch. Crystalline forms, like this Bolivian specimen, are relatively rare. Tin has a low melting point and does not corrode easily. It is nonpoisonous, easy to shape, and a good conductor of electricity. It is used in solder and tinplate (although aluminum is now more widely used for canning). Pewter is an alloy with roughly 75 percent tin and 25 percent lead.

Tin can

Precious metals

GOLD AND SILVER were among the earliest metals discovered and were valued for their beauty and rarity. Both were used in coins and bars which were visible items of wealth, and were used to buy things. Gold and silver were used on jewelry and other objects. Platinum was first reported from Colombia, South America, in the mid-18th century but was not widely used in jewelry and coins until this century.

Platinum

Currently more valuable even than gold, platinum is used in oil refining and in reducing pollution from car exhausts.

SPERRYLITE CRYSTAL
Platinum is found in a variety of minerals, one of which is sperrylite. This well-formed crystal was found in the Transvaal, South Africa, around 1924. It is the world's largest known crystal of this species.

PLATINUM GRAINS
Most platinum minerals occur as very small grains in nickel deposits. However, platinum-bearing grains are also commonly found in gold workings. These grains are from Rio Pinto, Colombia.

PLATINUM NUGGET
Very rarely, large nuggets of platinum are found. This one, from Nijni-Tagilsk in the Ural mountains of Russia, weighs 2.4 lb (1.1 kg). The largest ever recorded weighed 21.4 lb (9.7 kg).

RUSSIAN COINS
Platinum has been used for coins in several countries. During the reign of Nicholas I, the Russians minted platinum coins worth three roubles.

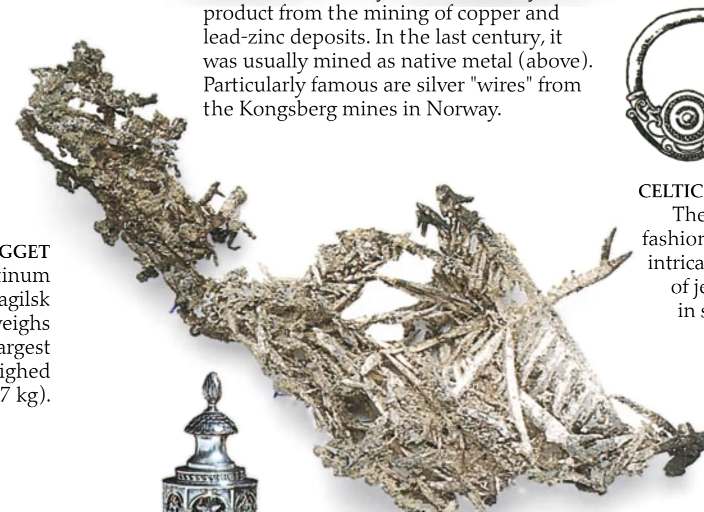
Silver

Silver tarnishes (discolors) easily and is less valuable than either gold or platinum. Both sterling and plated silver are made into jewelry and ornaments, and silver is also used in the photographic industry.

MEXICAN ORE-CRUSHER
Early methods of crushing silver ores were primitive but effective.

DELICATE SILVER WIRES
Silver is now mostly removed as a by-product from the mining of copper and lead-zinc deposits. In the last century, it was usually mined as native metal (above). Particularly famous are silver "wires" from the Kongsberg mines in Norway.

CELTIC BROOCH
The Celts fashioned many intricate pieces of jewelry in silver.



SILVER BRANCHES
Occasionally, as in this specimen from Copiapo, Chile, silver occurs in delicate, branchlike "dendritic" forms (p. 47).

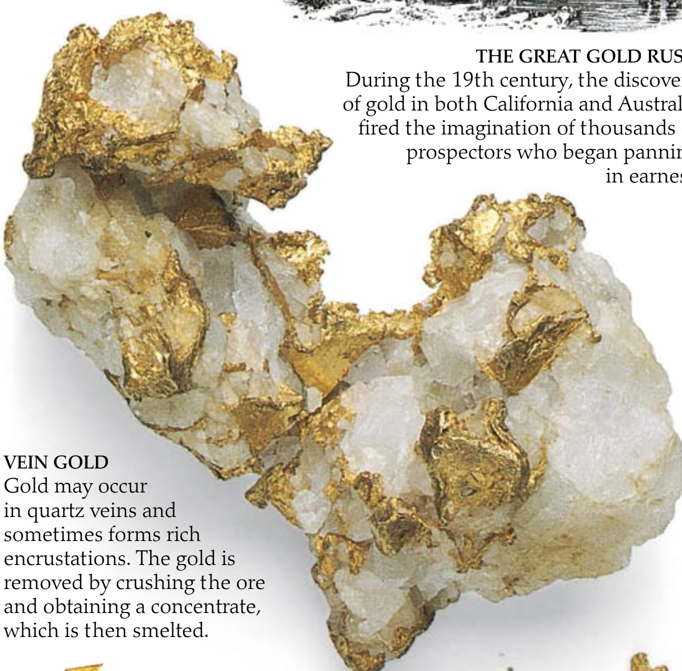
RELIGIOUS BELL
One of a pair, this silver Torah bell was made in Italy in the early 18th century and was used in Jewish ceremonies.

Gold

Today this familiar yellow metal is important in jewelry, dentistry, and electronics, yet more than half the gold, mined with so much labor, returns to the earth - buried in bank vaults for investment purposes!

SOUTH AFRICAN MINE
Traditional gold mining methods required much labor, c. 1900.

THE GREAT GOLD RUSH
During the 19th century, the discovery of gold in both California and Australia fired the imagination of thousands of prospectors who began panning in earnest.



VEIN GOLD
Gold may occur in quartz veins and sometimes forms rich encrustations. The gold is removed by crushing the ore and obtaining a concentrate, which is then smelted.

Crystalline chalcopyrite

FOOL'S GOLD
Amateurs sometimes mistake either chalcopyrite or pyrite for gold because of its brassy color, hence the term "fool's gold." Chalcopyrite, the main ore of copper, is greenish yellow compared to gold, and is more brittle and harder, although not as hard as pyrite.

Massive chalcopyrite

PYRITE
Pyrite generally forms cubic crystals and, on a fresh surface, is closer in color to "white gold" or electrum, an alloy of gold and silver, than to pure gold. However, pyrite is much harder than gold.

Tutankhamen's collar

GOLD GRAINS
Gold is also produced from the rounded grains that occur in some gravel and sand deposits. These deposits are worked either by panning or larger-scale dredging. The gold particles are removed before smelting.

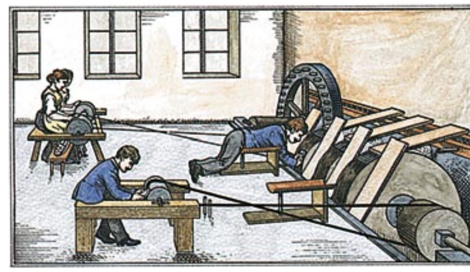
Crystalline pyrite

EGYPTIAN CRAFT
The ancient Egyptians were one of the earliest civilizations to master the art of goldsmithing. They used solid, beaten gold: Nowadays, copper and silver are often added to make the gold harder. The gold content is then measured in carats.

Massive pyrite

Cutting and polishing stones

THE EARLIEST METHOD of fashioning stones was to rub one against another to produce a smooth surface that could then be engraved. Much later, professional craftsmen (lapidaries) became skilled at cutting precious stones to obtain the best optical effect and to maximize the size of the cut stone. In recent years, amateur lapidaries have shaped rounded "pebbles" of various minerals by going back to the process of rubbing stones together, using a rotating drum.



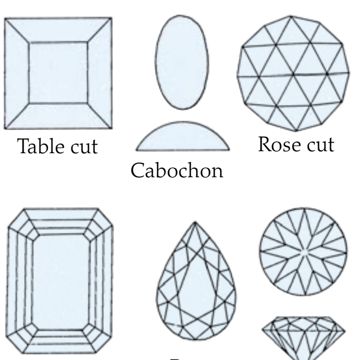
Grinding and polishing agates in a German workshop, c. 1800

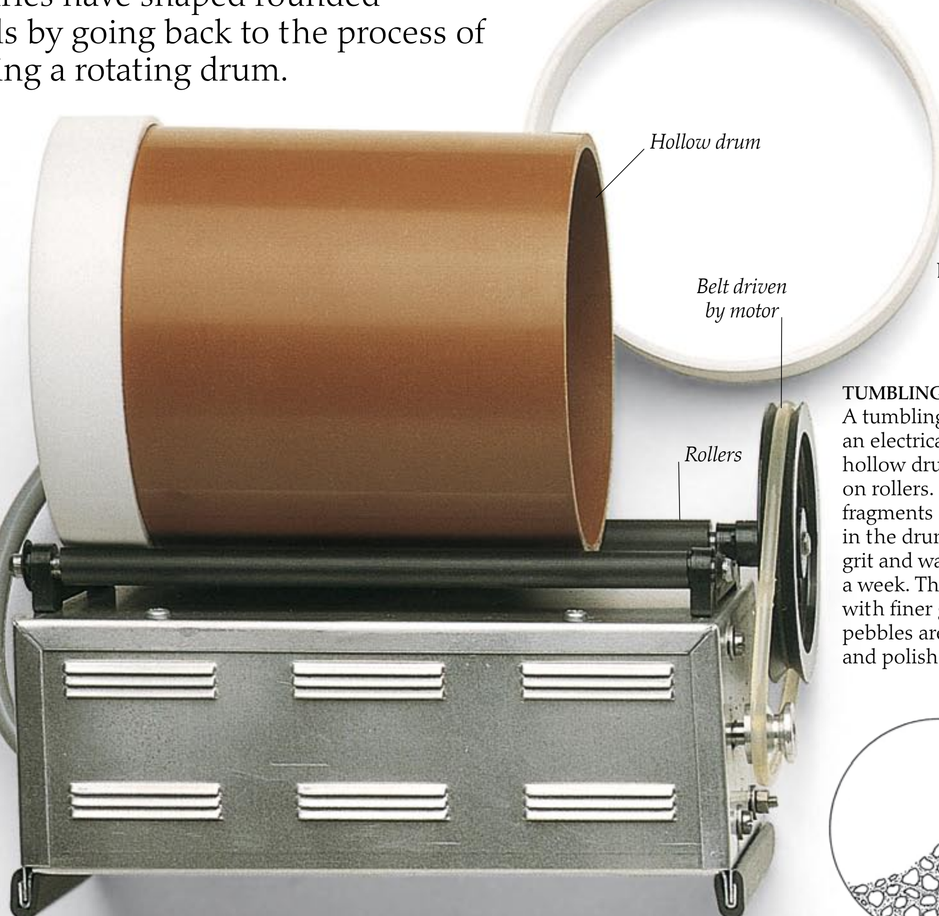
Cutting gems

When mined, many gemstones look dull (p. 50). To produce a sparkling gem, the lapidary must cut and polish the stone to bring out its natural beauty, bearing in mind the position of any flaws.

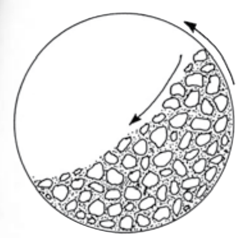
THE HARDEST CUT
Rough diamonds are marked with India ink before cutting.

POPULAR CUTS
The first gemstones were cut into relatively simple shapes, such as the table cut, and cabochon cut. Later lapidaries experimented with more complex faceted cuts, such as the step cut for colored stones, and the brilliant for diamond and other colorless stones.





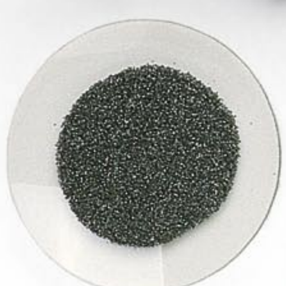
TUMBLING
A tumbling machine is an electrically driven hollow drum mounted on rollers. Mineral fragments are tumbled in the drum with coarse grit and water for about a week. This is repeated with finer grits until the pebbles are rounded and polished.



TUMBLING ACTION
As the drum rotates, pebbles are smoothed and rounded by the grit and by each other.

Rough mineral pieces ready for tumbling

GRITS AND POLISHES
Various grinding grits are used in sequence from the coarsest to the finest, followed by a polishing powder.



Coarse grinding grit used in first tumbling

Fine grinding grit used for second tumbling

Water added with grits

Cerium oxide, very fine polishing powder, used finally to make pebbles smooth and sparkling

UNAKITE *below*
Another material widely used by amateur lapidaries is a rock consisting of pink feldspar and green epidote, popularly known as unakite. The stones are mottled.

Massive rock crystal (quartz)

Polished rock crystal (quartz)

QUARTZ *left*
Because of its abundance and hardness (and hence its ability to take a good polish), the silica group of minerals including quartz (pp. 42 and 44) is the most commonly used for the production of tumbled stones.

Fragments of unakite

Polished unakite

Portrait intaglio

Classic portrait cameo

Polished rose quartz

Fragments of rose quartz

CARVED STONES
Cameos are stones that are carved in relief; intaglios have the design hollowed out.

NECKLACE
Tumbled agates are drilled and strung with spacers.

ROSE QUARTZ
This pinkish variety of quartz is considerably rarer than either milky quartz or amethyst. Most rose quartz comes from Brazil, but the U.S. is also an important producer.

AMETHYST *below*
Because the color in this violet variety of quartz (p. 55) is rarely distributed evenly, tumbled stones generally have an attractive mottled appearance.

Fragments of amethyst

Polished amethyst

Cameo cut in cornelian-onyx

Intaglio of a biblical scene

Polished thomsonite

Massive thomsonite

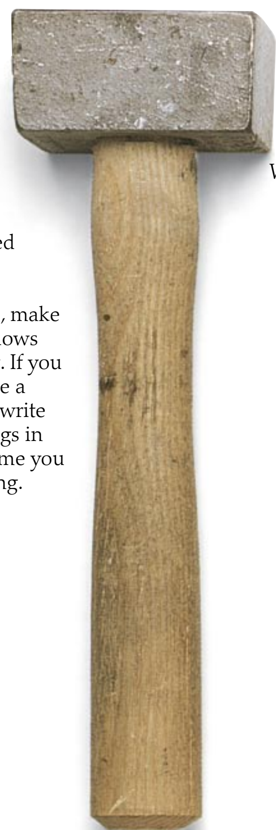
THOMSONITE
Color-banded thomsonite fragments produce unusual patterns and "eyeballs" when tumbled. The best material is found in Minnesota. Thomsonite is a fairly widespread silicate mineral (p. 42) and occurs in basalt lava flows (p. 19).

ASSORTED STONES
Various mineral and rock species are suitable for rumbling. Some of the most attractive include: tiger-eye (1), blue aventurine (2), amazonite (3), snow-flake obsidian (4), apache tears (5), moss agate (6), red-banded agate (7), sodalite (8), crazy lace agate (9), and snakeskin agate (10).

Collecting rocks and minerals

THE COLLECTING OF MINERAL and rock specimens and the recording of finds is a rewarding and popular pastime. As a hobby, it is in a tradition that dates back to the amateur geologists of the 19th century, many of whom had impressive collections.

COLLECTING TOOLS
The basic equipment required is a geological hammer, weighing between 1 and 2 lb (0.5 and 1 kg), and a range of chisels. Geological hammers usually have a square head and a chisel edge used for splitting rocks. They are specially made for the job; other types of hammer should not be used because they are more likely to splinter.



Club hammer for use with chisels

Wide-ended chisel

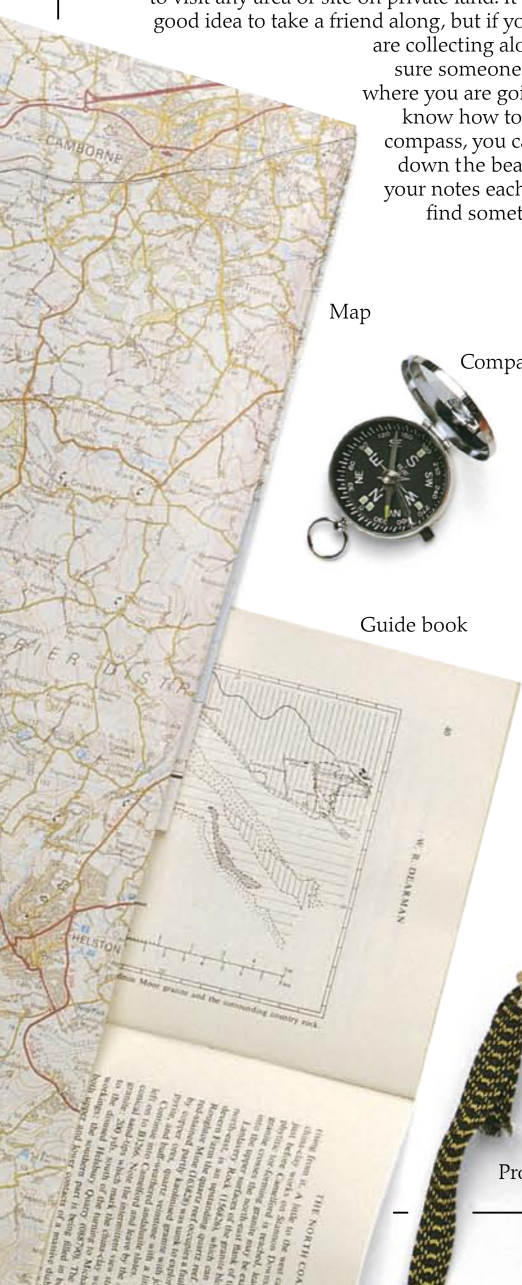
Sharp, pointed chisel

Geologist's hammer (0.5 kg/1 lb)

Geologist's trimming hammer

CAREFUL PLANNING
All field work and collecting trips should be planned in advance using geological guide books and maps. Permission must be obtained to visit any area or site on private land. It's a good idea to take a friend along, but if you are collecting alone, make sure someone knows where you are going. If you know how to use a compass, you can write down the bearings in your notes each time you find something.

FIELD WORK
During the 19th century, geologists working in the field developed the techniques of collecting and mapping rocks.



Map

Compass

Guide book

PROTECTIVE CLOTHING
Great care must be taken when hammering rocks to prevent injury from flying rock and metal splinters. Wear protective goggles, a safety helmet, gloves, sturdy shoes or boots, and strong, waterproof clothing.

Safety helmet

Strong gloves

Protective goggles

RECORDING A FIND
The exact location and details of a find should be recorded in a notebook, and the specimen carefully numbered using a pen or sticky tape. A photograph or sketch of the specimen before collection will provide a permanent field record.

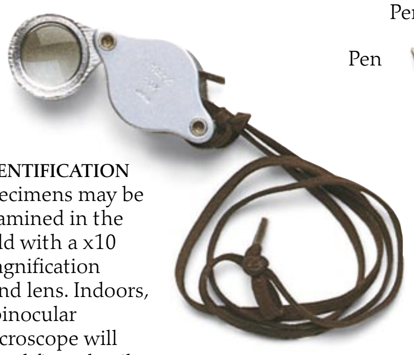
Camera to record site or location of find; when taking photographs try to give some indication of scale

WARNING
When rock collecting, there are certain rules you should follow at all times: ask permission before entering private land, avoid disturbing wildlife, wear suitable clothing, use proper equipment, and avoid creating hazards for others.

Notebook

Pencil

Pen



IDENTIFICATION
Specimens may be examined in the field with a x10 magnification hand lens. Indoors, a binocular microscope will reveal finer details.

Spatulas for fine work, such as cutting around fossils

Surgical knife for fine preparatory work on fossils

Palette knife for excavating small crystals from soft fossils or minerals

TOOLS FOR FINE WORK
Surplus rock can be removed from a specimen by washing in water and scrubbing lightly with a soft brush. Soft rock such as clay may be dug with a trowel, then sifted for small crystals or rock fragments.

Muslin bag

Newspaper

TRANSPORTING SPECIMENS
Each specimen should be individually wrapped in newspaper or other protective material to prevent chipping or scratching. Crystal groups are usually very fragile and should be packed in tubes or boxes with suitable wrapping and carried in special collecting bags.

Plastic tube

Bubble wrap

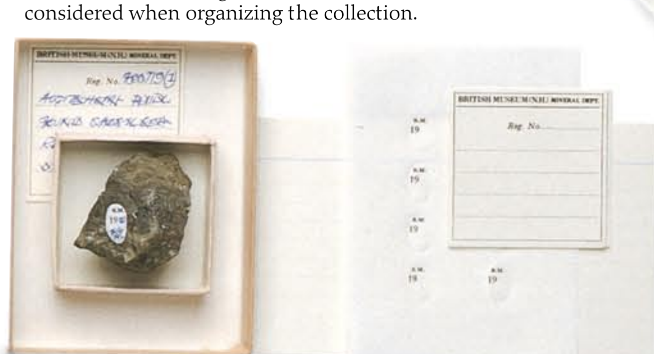
Sealable plastic bag

KEEPING THE COLLECTION
To avoid damage to specimens, they should be stored in individual trays or boxes within a cabinet of shallow drawers. Some minerals fall apart rapidly in damp conditions, at high temperatures, or under the effects of light, so the needs of each one must be considered when organizing the collection.

Trowel for digging soft rocks

Sieve for sorting material

Paint brushes for cleaning specimens



Cardboard boxes for storing specimens

Labels for documenting specimens

Did you know?

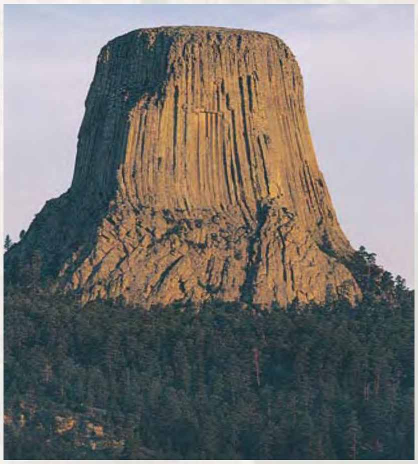
AMAZING FACTS

After astronauts returned from the Moon, scientists discovered that the most common type of rock on the Moon is a type of basalt that is also found on Earth.

Spider preserved in amber

The amber we find today formed when resin dripped from trees millions of years ago and then hardened. Sometimes, insects were trapped in the sticky resin before it set and have been preserved to this day.

The deeper down inside the Earth a tunnel goes, the hotter it becomes. The deepest gold mines in South Africa have to be cooled down artificially so that people are able to work in them.



Devil's Tower, Wyoming

Devil's Tower, in Wyoming, is a huge rock pillar made from lava that crystallized inside the vent of a volcano. Over thousands of years, the softer rock of the volcano itself has worn away.

More than 75% of the Earth's crust is made of silicates, minerals composed of silicon, oxygen, and some metals.

Meteorites found on Antarctica may have come from Mars, and some appear to contain fossilized bacteria.

On some coastlines made up of soft rocks, the sea carves away yards of land every year. Some villages, such as Dunwich in Suffolk, England, have partly vanished into the sea as cliffs collapsed beneath them due to erosion.

Ice has the power to shatter rock. Granite, one of the hardest rocks, can be split by water in cracks expanding as it freezes. The combined weight and movement of a glacier (a river of ice) can hollow out a whole mountainside.

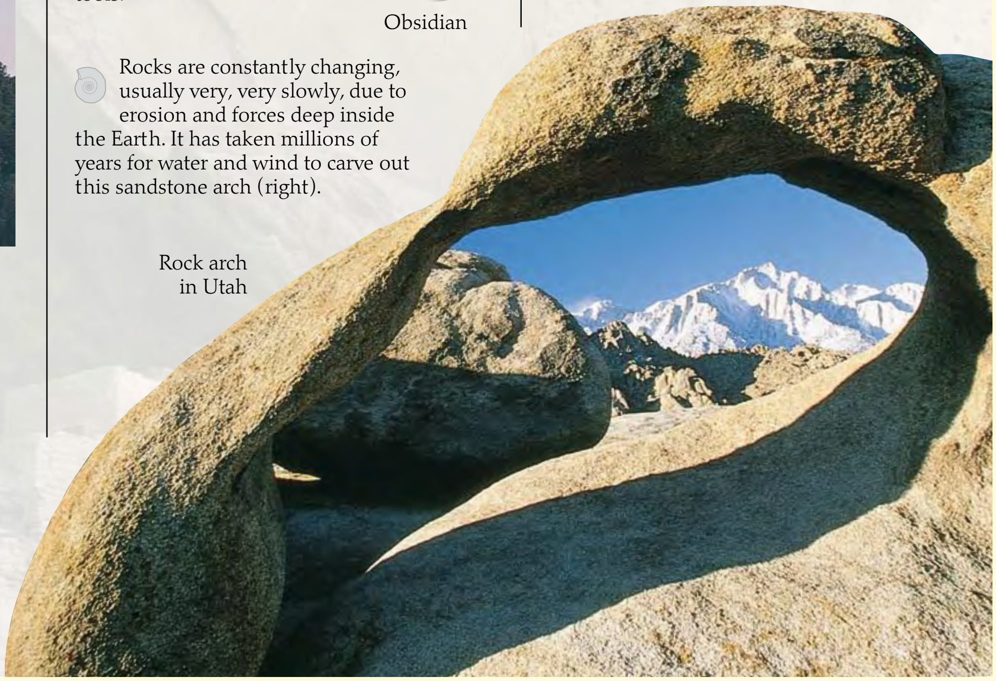
Unaware that it was poisonous, women in ancient Rome used the mineral arsenic as a cosmetic to whiten their skin.

Graphite, the soft mineral used in pencil leads, is also used in nuclear power stations. Huge graphite rods help to control the speed of nuclear reactions in the reactor core.

Obsidian is a black, volcanic rock that is so shiny that people in ancient times used to use it as a mirror. The rock also forms such sharp edges when it is broken that it was also used to make cutting tools.

Obsidian

Rocks are constantly changing, usually very, very slowly, due to erosion and forces deep inside the Earth. It has taken millions of years for water and wind to carve out this sandstone arch (right).



Rock arch in Utah

Fossil of *Archaeopteryx*

In 1861, a quarryman split open a block of limestone and discovered the fossil of a bird-like creature with feathers that lived 150 million years ago. This creature, which scientists called *Archaeopteryx*, may be the link between prehistoric reptiles and the birds of today.

Minerals don't just exist in rocks. Your bones are made of minerals, too!

Questions and answers

Q What are the most common rocks in the Earth's crust?

A Volcanic rocks, such as basalt, are the most common rocks in the Earth's crust. Basalt forms from the more fluid type of lava as it cools and hardens. It makes up the ocean floors, which cover 68% of the Earth's surface.

Q How do we know that dinosaurs existed?

A Dinosaur bones and teeth have been found as fossils in rocks all around the world. In some places, even their footprints and dung have been preserved in rock. It is mainly from fossils that we know about plants and animals that lived on Earth in the past.

Chinese nephrite dragon.

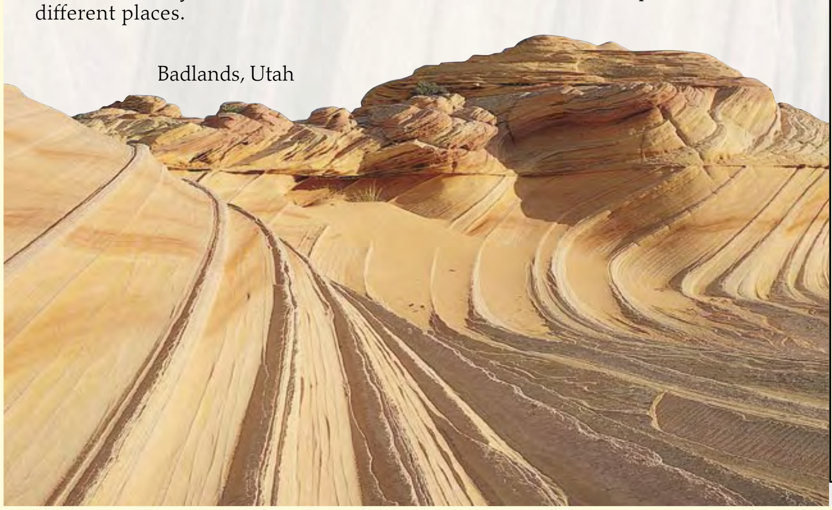
Q What is jade, and why does it have more than one name?

A People once thought there was a single green stone called jade. But, in 1863, this rock was found to be two different minerals, now called jadeite and nephrite.

Q Why are the pebbles on a beach so many different colors?

A Pebbles are made up of many different types of rock. Their colors show what kinds of minerals they contain. The pebbles on one beach may have been washed there by the sea from several different places.

Badlands, Utah



Fossilized footprint of a dinosaur

Q Why is the sand black on some beaches around the world?

A Sand is made from rocks and pebbles that have been worn down into fine grains. In some places, such as the Canary Islands, Spain, the sand is black because it is made of volcanic ash rich in dark minerals.

Q If pumice is a rock how come it can float on water?

A Pumice is hardened lava froth. It is full of tiny air bubbles; the air trapped inside these bubbles makes the pumice light enough to float on water.

Q What made the stripes on the rocks in Utah?

A The desert rocks are made of layers of sandstone. Hot days, cold nights, floods, and storms have worn away the softer layers of rock the fastest, creating stripes in the landscape.

Q What are the oldest rocks on Earth?

A The oldest known rocks came from outer space as meteorites. This piece of chondrite (right) is a meteorite that is about 4.6 billion years old. The first rocks to form on Earth didn't develop until later on, about 4.2 billion years ago.

Chondrite

Q Where do new rocks come from?

A New rocks are forming all the time, on the surface of the Earth and deep in its crust. Some rocks are made from layers of sediment. Others are the result of volcanic activity, both on the ocean floors and above ground. The Earth constantly recycles rocks by means of heat, pressure, and erosion.

Q What is a desert rose made from and how did it form?

A A desert rose is made of a mineral called gypsum. It formed in a desert when water evaporated quickly. Impurities from the water were left behind and formed crystals shaped like petals.

Desert rose

Record Breakers

Most valuable metal
Platinum is currently the most valuable metal, more valuable than gold.

Biggest gold nugget
The largest gold nugget ever found weighed 156.3 lb (70.9 kg)–that's as heavy as a man.

Most valuable religious item
The Golden Buddha of Bangkok is the most valuable religious item in the world. It is made of 6.1 tons (5.5 metric tons) of solid gold.

Hardest mineral
Diamond is the hardest known mineral and cannot be scratched by any other mineral.

Biggest stalagmite
The biggest stalagmite is in Krasnohorska, Slovakia. It is 105 ft (31.5 m) tall.

Biggest rock
Uluru (Ayer's Rock) in Australia is the biggest freestanding rock in the world. It is over 2 miles (3.6 km) long.

Geologist's tools

Rock or mineral?

GEOLOGISTS CLASSIFY ROCKS according to the way in which they were formed. There are three main types of rock: igneous, metamorphic, and sedimentary rocks. Below you can find out about the main characteristics of each type.

IDENTIFYING ROCKS

IGNEOUS ROCKS

Igneous rocks are made from hot, molten rock from deep within the Earth that has solidified as it has cooled. Like metamorphic rocks, they are made of interlocking crystals of different minerals. The more slowly a rock has cooled and solidified, the larger the crystals that have formed within it.

Large crystals of quartz, feldspar, and mica formed as the rock cooled slowly

Granite

Large crystals that formed as the rock cooled slowly

Gabbro

Dark, finegrained volcanic rock that formed from lava

Basalt

Glassy volcanic rock that cooled too quickly to form crystals

Obsidian

METAMORPHIC ROCKS

Entirely new metamorphic rocks are formed when sedimentary, igneous, or existing metamorphic rocks undergo a complete transformation as a result of heat and pressure within the Earth's crust. The minerals in a metamorphic rock usually form crystals of a size that reflects the degree of heat they underwent.

Crinkled layers

Folded schist

Fine grain size

Slate

Dark and light bands of colour

Gneiss

SEDIMENTARY ROCKS

Sedimentary rocks are usually made from particles that have been weathered and eroded from other rocks. These particles, which range from the size of sand grains to that of boulders, are deposited in layers (strata) and, over time, become rocks. Sedimentary rocks contain fossils.

Large, coarse pebbles cemented together

Conglomerate

Iron oxide gives orange color

Sandstone

Angular fragments of rock held together by a fine, sandy material

Breccia

Formed from the skeletons of microorganisms, chalk has a soft, powdery texture

Chalk

IDENTIFYING MINERALS

NO TWO MINERALS ARE the same, and many have a particular color or shape that will help in identifying them. Some form large crystals; others form bubbly masses or grow as crusts on rocks. Below is a sample of minerals and their distinguishing features.

QUARTZ
One of the most common minerals, quartz occurs in many rocks and is often found in mineral veins with metal ores. Quartz crystals usually have six sides with a top shaped like a pyramid. Clear, transparent quartz is often called rock crystal and is sometimes mistaken for diamond.

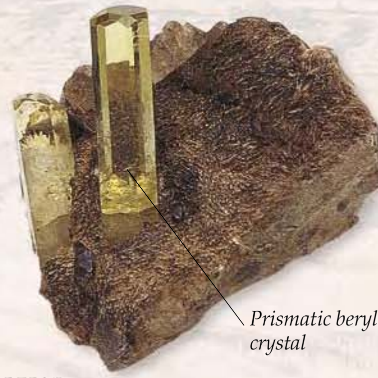
ALBITE
Albite is an important variety of feldspar, a rock-forming mineral, and is often found in granites, schists, and sandstones. It is usually white or colorless and can also form blocky, platelike, or tabular crystals.

CALCITE
Calcite is the main mineral in limestone, which is usually formed in a marine environment. It is also found in bone and shell, and also forms stalactites and stalagmites.

GOLD
Gold is a metal and a rare native element. It is usually found as yellow specks in rocks and often grows with quartz in mineral veins when hot, watery liquids cool. Gold occasionally forms large crystalline nuggets with rounded edges

COCKSCOMB BARITE
Barite forms in many environments, from hot volcanic springs to mineral veins. Cockscomb barite is made up of rounded masses of soft, platelike crystals.

SULFUR
A native element, sulfur crystallizes around hot springs and volcanic craters. It sometimes forms a powdery crust of small crystals, but large crystals are also common. Pure crystals are always yellow and are soft enough to be cut with a knife.



BERYL
Beryl forms deep within the Earth's crust and is found mainly in granites and pegmatites. Transparent beryl is hard and rare, making it a valuable gemstone. It has different names, depending on its color. Green emerald and blue-green aquamarine are the best-known varieties.

CORUNDUM
Although the pure form of corundum is colorless, it comes in many colors. Rubies and sapphires are both rare forms and are most commonly found in river gravels. Corundum is extremely hard.

HALITE
Halite belongs to a range of minerals called evaporites, which form when salty water evaporates. It occurs around seas and lakes in dry climates and is best known as rock salt. It is usually found in masses but also forms cube-shaped crystals.

Find out more

You can go rock and mineral collecting almost anywhere. Rocks are all around you, not just on the ground, but in walls, buildings, and sculptures. The best way to find out more about them is to collect them. There are suggestions on the left for where to start looking. Many museums have extensive rock collections and are a good source of information. Going on a trip can also provide valuable opportunities to find different rocks and discover new types of landscape. Here you will find suggestions for good places to visit, as well as a list of useful Web sites that can provide plenty of additional information.

COLLECTING ROCKS AND MINERALS
Pebble beaches are good places to search for specimens. To start with, look for pebbles in different colors, and see how many types you can find. Other interesting places to look are lakesides and river banks.

GATHERING INFORMATION
Visit your nearest natural history or geological museum to see collections of rocks and minerals both rare and common and to find out how the rocks were formed. Many museums have interactive displays and lots of information on volcanoes, earthquakes, and rocks from space.

Places to visit

Natural-history museums feature rocks and minerals from around the world, and the experts there can provide information on the origin and composition of the rocks in their collection—or yours. Here are some of the best in the United States:

AMERICAN MUSEUM OF NATURAL HISTORY
New York, New York
NATIONAL MUSEUM OF NATURAL HISTORY
Smithsonian Institution, Washington, D.C.
CALIFORNIA MINING AND MINERAL MUSEUM
Mariposa, California
THE FIELD MUSEUM
Chicago, Illinois

Earth Lab

IDENTIFYING SPECIMENS
You can take your rock samples to some museums for help in identifying them. At the Earth Lab in the Earth Galleries at the Natural History Museum in London, there are more than 2,000 specimens of rocks, minerals, and fossils. You can identify your own specimens, examine materials with the Lab microscopes, and consult qualified staff members about your findings.

DISPLAYING YOUR COLLECTION
Gently clean your rock samples with water and let them dry, then arrange them in empty matchboxes or small cardboard trays. For delicate items, line the trays with tissue paper. Put a small data card in the base of each tray, with the specimen's name, where you found it, and the date you found it. Group the specimens in a tray or drawer, arranging them by color or by the places where you found them, for example.

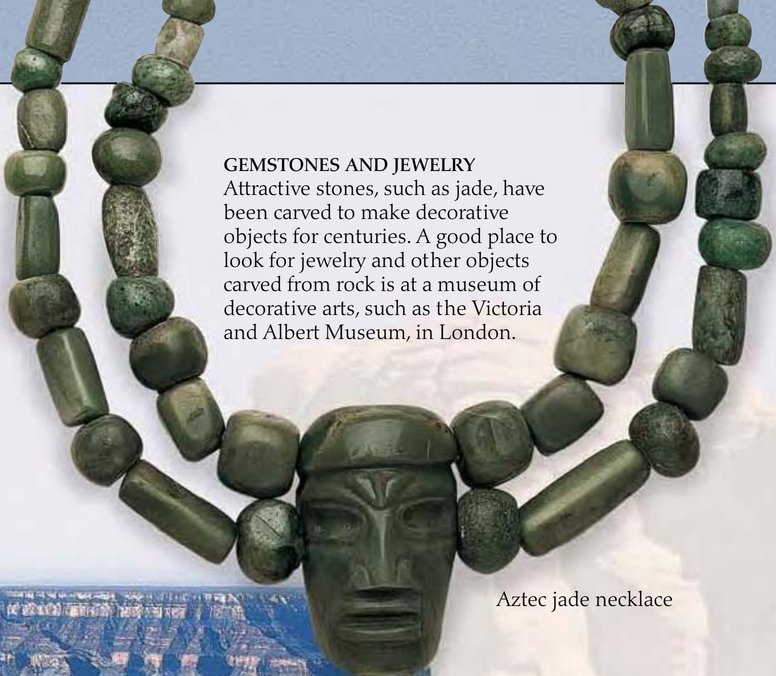
Cardboard trays lined with tissue

Specimen labels

USEFUL WEB SITES

- This searchable guide to gemstones and minerals also offers a photo gallery, glossary, and resource page.
www.minerals.net
- Get tips on starting your own rock collection:
www.fi.edu/fellows/fellowl/oct98/index2.html
- Find information on how rocks and minerals form, as well as how to collect and identify rocks and minerals.
www.rocksforkids.com
- Detailed information about a long list of minerals is available on this Web site, which can be searched by mineral name or class.
mineral.galleries.com

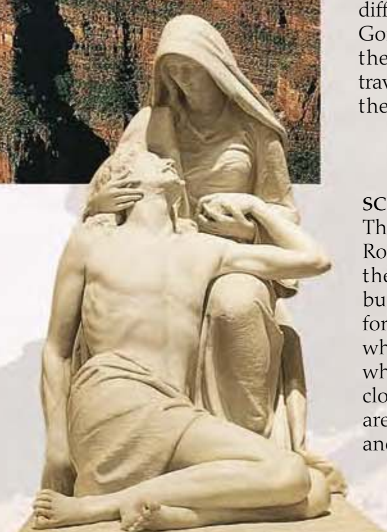
GEMSTONES AND JEWELRY
Attractive stones, such as jade, have been carved to make decorative objects for centuries. A good place to look for jewelry and other objects carved from rock is at a museum of decorative arts, such as the Victoria and Albert Museum, in London.



Aztec jade necklace

The Grand Canyon

HISTORY IN THE ROCKS
Visitors to the Grand Canyon in Arizona have a spectacular view of different layers of the Earth's rocks. The canyon was carved out by the Colorado River and took several million years to form. As the river cut its way downward, it exposed different layers of rock that had been hidden beneath the ground. The rocks are mostly sandstone and limestone and contain bands of fossils from different geological periods. Going down the steep trails to the bottom of the gorge is like traveling back in time through the history of the rocks.



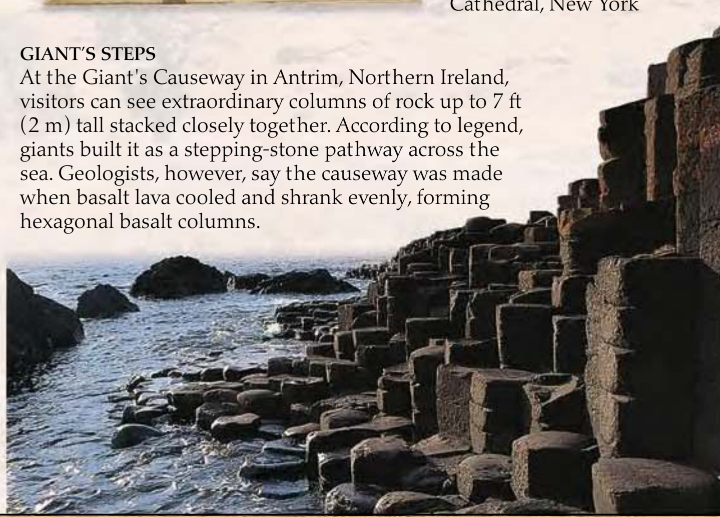
SCULPTURES
The Ancient Greeks and Romans used marble to create their finest statues and buildings because it was ideal for carving. Pure marble is white and is smooth and shiny when polished. Look at statues closely to find out whether they are made from marble or another type of stone.

Marble statue of Pieta, St. Patrick's Cathedral, New York

Cave at Melissani, Greece

LIMESTONE CAVES AND GROTTOS
Limestone caves are good places to see brilliant turquoise waters and stalactites that look like giant icicles. There are blue grottos at several islands in the Mediterranean, such as Cephalonia in Greece. Famous limestone caves include the Lascaux Caves in France, where you can also see prehistoric cave paintings.

GIANT'S STEPS
At the Giant's Causeway in Antrim, Northern Ireland, visitors can see extraordinary columns of rock up to 7 ft (2 m) tall stacked closely together. According to legend, giants built it as a stepping-stone pathway across the sea. Geologists, however, say the causeway was made when basalt lava cooled and shrank evenly, forming hexagonal basalt columns.



Glossary

ABRASION Erosion caused by water, wind, or ice laden with sediments, and scraping or rubbing against the surface of rocks.

ACICULAR A term used to describe the needlelike form of crystals.

ALLOY A metallic material, such as brass, bronze, or steel, that is a mixture of two different types of metal.

CABOCHON A gemstone cut in which the stone has a smooth domed upper surface without any facets.

CARAT The standard measure of weight for precious stones. One metric carat equals 0.2 g. The term is also used to describe the purity of gold; pure gold is 24 carat.

CLEAVAGE The way in which a crystal splits apart along certain well-defined planes according to its internal structure.

CORE The area of iron and nickel that makes up the centre of the Earth. It is about 850 miles (1,370 km) in diameter.

CRUST The thin outer layer of the Earth. It varies in thickness between 4 and 43 miles (7 and 70 km).

CRYSTAL A naturally occurring solid with a regular internal structure and smooth external faces.

Group of natural crystals

CRYSTALLIZE To form crystals.

DEBRIS Scattered broken fragments of material formed by weathering and erosion.

DENDRITIC Having a branchlike form.

DEPOSIT A buildup of sediments.

ELEMENT One of the basic substances from which all matter is made. An element cannot be broken down into a simpler substance.

EROSION The wearing away of rocks on the Earth's surface by gravity, wind, water, and ice.

Ground worn away by erosion

EVAPORITE Mineral or rock formed as a result of salt or spring water evaporating.

EXTRUSIVE ROCK Rock that is formed when magma erupts from the Earth as lava and cools on reaching the surface.

FACE A surface of a crystal.

FACET One side of a cut gemstone.

FIRE A term used for dispersed light. A gem with strong fire, such as a diamond, is unusually bright.

FOLIATION Sheetlike layers of aligned crystals in metamorphic rocks.

FOSSIL The remains or traces of plants or animals that have been preserved in the Earth's crust. They may be in rock, amber, permafrost, or tar pits. Even the impressions of delicate leaves, feathers, or skin as well as traces such as footprints are considered to be fossils.

Ammonite fossil

GALVANIZATION A process by which zinc is added to other metals or alloys to prevent them from rusting.

GEMSTONE Naturally occurring minerals, usually in crystal form, that are valued for their beauty, rarity, and hardness.

Diamond

Sapphire

GEOLOGIST A person who studies rocks and minerals to find out about the structure of the Earth's crust and how it formed.

HABIT The shape and general appearance of a crystal or group of crystals.

HOPPER CRYSTALS Crystals that have regular, stepped cavities in each face.

INTRUSIVE ROCKS Igneous rocks that solidify within the Earth's crust and only appear at the surface once the rocks lying on top of them have eroded away.

IRIDESCENCE A rainbowlike play of colours on the surface of a mineral, similar to that of a film of oil on water.

KARST SCENERY The characteristic broken rock formations of some limestone plateaus.

LAPIDARY A professional craftsman skilled at cutting gemstones to obtain the best optical effect.

LAVA Red-hot, molten rock (magma) from deep within the Earth that erupts on to the surface from volcanoes and other vents.

LUSTER The way in which a mineral shines. It is affected by the way that light is reflected from the surface of the mineral.

MAGMA Molten rock below the surface of the Earth.

MANTLE The layer of the Earth between the core and the crust. It is about 1,800 miles (2,900 km) thick.

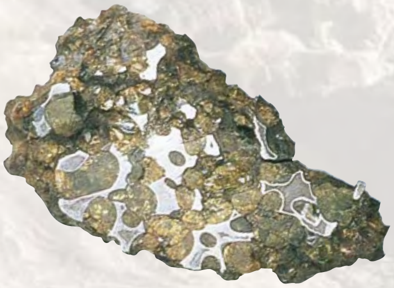
MASSIVE A term used to describe a mineral that has no definite shape.

MATRIX A mass of small grains surrounding large grains in a sedimentary rock.

METAMORPHOSE To undergo a change of structure. In rocks, this is usually caused by the action of heat or pressure.

METEORITE An object from outer space, such as a rock, that survives the passage through the atmosphere to reach Earth.

MINERAL A naturally occurring, inorganic solid with certain definite characteristics, such as crystal structure and chemical composition.



Meteorite

MINERAL VEIN A crack in rock filled with minerals deposited from hot fluids.

MOHS' SCALE A scale of hardness from 1 to 10 based on 10 minerals. Minerals of a higher number are able to scratch those of a lower number.

MOLTEN Melted, made into a liquid by great heat, especially with reference to rocks.

NATIVE ELEMENT An element that occurs naturally in a free state and does not form part of a compound.

NODULE A rounded lump of mineral found in sedimentary rock.

OOLITH Small rounded grains in limestones.

OPAQUE Material that does not let light pass through it.

OPTICAL PROPERTIES The various optical effects produced as light passes through minerals. This is one of the properties used to help identify minerals.

ORE A rock or mineral deposit that is rich enough in metal or gemstone for it to be worth extracting.

OUTCROP The whole area that one type of rock covers on a geological map, including the parts covered by soil or buildings.

PALEONTOLOGIST A scientist who studies fossils.

PIGMENT A natural coloring material often used in paints and dyes. Many pigments were originally made by crushing colored rocks and mixing the powders with animal fats.

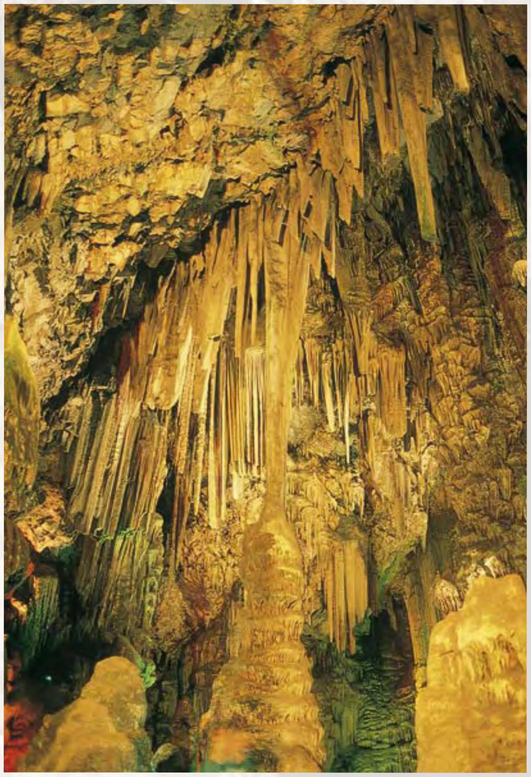
Azurite, once ground into a prized blue pigment

POROUS Able to absorb water, air, or other fluids.

PORPHYRY An igneous rock containing fairly large crystals set into a finer matrix.

PRECIPITATION A chemical process during which a solid substance, such as lime, is deposited from a solution, such as lime-rich water.

PYROCLASTIC ROCK Pyroclastic means "fire-broken" and describes all the fragments of rock, pumice and solid lava that may be exploded out of a volcano.



Stalactites hanging from the roof of a cave

RESIN A sticky substance that comes from some plants.

ROCK An aggregate of mineral particles.

SEDIMENT Rock material of various sizes, ranging from boulders to silt, which is the product of weathering and erosion, as well as shell fragments and other organic material.

SMELTING The process by which ore is melted to extract the metal that it contains.

SPECIFIC GRAVITY A property defined by comparing the weight of a mineral with the weight of an equal volume of water.

STALACTITE An irregular, hanging spike made of calcium carbonate (lime) formed as dripping water precipitates lime from the roof of a cave. Over a long period of time, stony stalactites build up in size and may hang many yards from a cave roof.

STALAGMITE A stony spike standing like a tapering post on the base of a limestone cave. Stalagmites form where water has dripped from the roof of the cave or a stalactite above, slowly building up lime deposits.

STREAK The color produced when a mineral is crushed into a fine powder. The color of a streak is used to help identify minerals. It is often a better means of identification than the color of the mineral itself, as it is less variable.

STRIATIONS Parallel scratches, grooves or lines on a crystal face that develop as the crystal grows.

SWALLOW HOLE A hollow in the ground, especially in limestone, where a surface stream disappears from sight and flows underground.

TRANSLUCENT Material that allows some light to pass through it, but is not clear.

TRANSPARENT Material that allows light to pass through it. It can be seen through.

TUMBLING The process of rolling rough mineral pieces in a tumbling machine with grit and water until the pebbles are rounded and polished.

VEIN A deposit of foreign minerals within a rock fracture or a joint.

Veins of calcite

VESICLE A gas bubble or cavity in lava that is left as a hole after the lava has cooled down and solidified.

VOLCANIC BOMB A blob of lava that is thrown out of a volcano and solidifies before hitting the ground.

VOLCANIC VENT The central passage in a volcano through which magma flows and erupts as lava.

WEATHERING The breaking down of rocks on the Earth's surface. This is mainly a chemical reaction, aided by the presence of water, but it may also be due to processes such as alternate freezing and thawing.

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