National Aeronautics and
Space Administration

Educational Product
Teachers Grades 5-12

Exploring Meteorite Mysteries

Slide Set with Script

NOBLESVILLE FALL

Just after riding bikes Brian and Brodie were standing talking on Brodie's lawn. Suddenly they heard a low-pitched whistling sound and Brian saw an object spinning through the air past Brodie.

The object, which looked like a rock, landed with a thud on the ground near them. The boys picked up the rock and found it slightly warm. They looked around, but couldn't find anyone who might have thrown it.

A scientist from Purdue University confirmed that the rock really was a meteorite.

13 year old Brodie Spaulding and
9 year old Brian Kinzie
August 31, 1991
Noblesville, Indiana

NOBLESVILLE METEORITE

BRIAN AND BRODIE'S ROCK

Now known as the Noblesville Meteorite

- It is a typical stony meteorite, gray inside and covered with a dark crust
- About 30,000 small meteorites like Noblesville fall on Earth each year, but only a few are found

PAINTING OF THE SIKHOTE-ALIN FIREBALL

- Large meteorite falls are rare, about one every ten or twenty years over the whole Earth
- One of the most spectacular occurred in 1947, in the Sikhote-Alin mountains of eastern Russia
- February 12, the calm was shattered by a bright meteor, visible for more than 300 kilometers
- After it streaked over the horizon, great explosions roared and echoed from the hills, so loud they were heard 100 kilometers away

SIKHOTE-ALIN FOREST

- Some of the meteorites were embedded in trees!
- The Sikhote-Alin meteorite was probably a piece broken off an asteroid
- Clearings in the thick forest were blasted open by the impact
- It must have been larger before it hit the Earth, because some of it vaporized in the atmosphere and on impact
- There were 106 craters and holes in the forest where the meteorites had landed

SIKHOTE-ALIN METEORITE

- This is one fragment of the Sikhote-Alin meteorite
- It is about 15 cm across
- The photograph shows the original meteorite surface, melted into thumb-print shapes during its flight through our atmosphere

METEOR CRATER IN ARIZONA

- Larger meteorites are extremely rare, but make enormous craters when they hit the Earth

- It was formed about 50,000 years ago when a large iron meteorite hit the Earth

- Scientists estimate that the meteorite weighed one million tons

- Meteor Crater in Arizona is over one kilometer across and 150 meters deep

DESERT COLLECTION

- Many meteorites have been found in deserts, where the heat and dryness have kept them from rusting away
- When meteorites are discovered, they are called finds
- Over 2,000 meteorite finds have been made around the world
- Some of these meteorites were on Earth for hundreds of thousands of years before being found

METEORITE IN ANTARCTICA

- The best collecting place in the world is Antarctica, where meteorites fell on the ice and were preserved in it

- Here scientists have found a meteorite, and have taken pictures to document their find

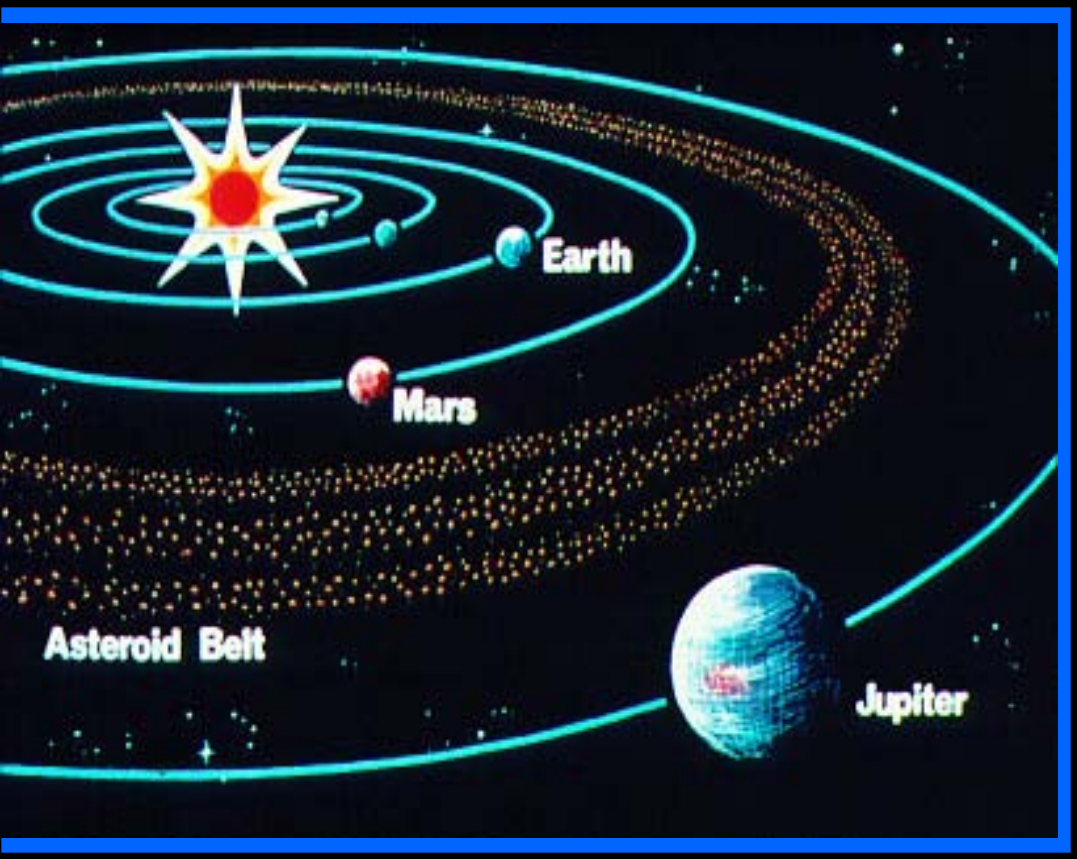
- Each sample is photographed, given a number, and carefully packaged.

METEORITE CURATION

- Meteorites collected by U.S. expeditions in Antarctica are sent to this clean lab at NASA's Johnson Space Center in Houston, Texas

- There they are described, classified, and distributed to researchers around the world for study

THE SOLAR SYSTEM



- Although people have seen meteorites fall since the earliest times, it was only about 1800 when scientists finally became convinced that rocks really did fall from the sky

- Since then, we've discovered that most meteorites come from the asteroid belt, the area of the solar system between the orbits of Mars and Jupiter where many asteroids orbit the sun

ASTEROID IDA

- Asteroids are small planets, fragments of rock and iron left over from the formation of the solar system or the breakup of larger fragments
- Many asteroids probably look like Ida, the asteroid in this picture taken by the Galileo spacecraft in 1993
- Ida is about 30 kilometers long, is made of rock, and has many craters

COMET GIACOBINI-ZINNER

- Comets are small bodies made of rock, dust and ice, formed in the distant reaches of the solar system

- Then solar radiation heats the comet's surface, causing part of the ice to boil off into space and carry some of the dust with it

- When this happens the comet can develop a "tail" millions of kilometers long, and leave a dust trail behind in solar orbit

ASTEROID IN SPACE

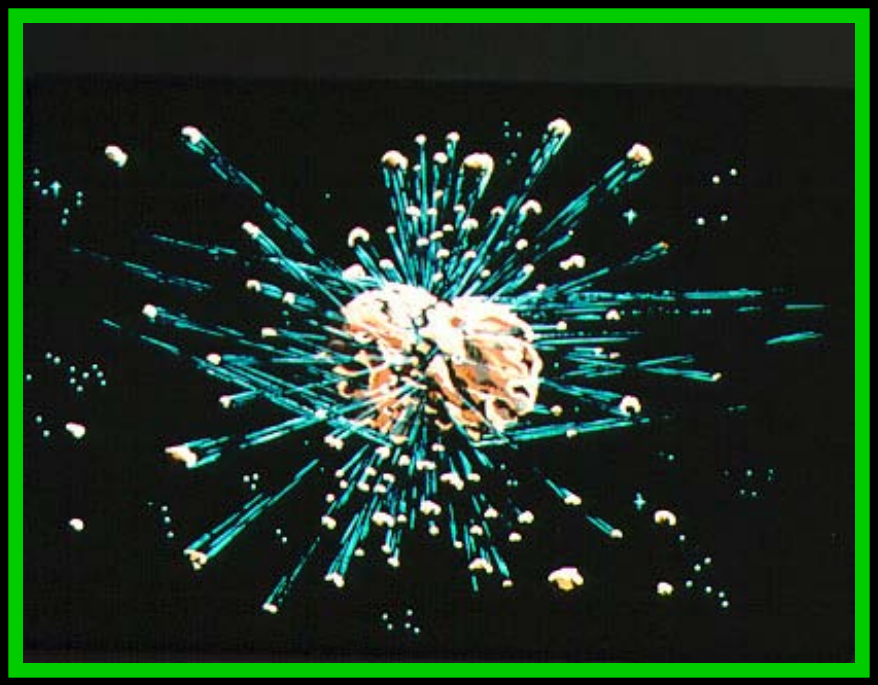
Larger meteorites don't come from comets but from asteroids

It's a long way from the asteroid belt to the Earth

- Very few asteroid pieces get the chance to travel that far

- Most asteroids never do, and spend eternity in space, quietly orbiting the Sun

ASTEROID COLLISION



- Every now and again the orbits of asteroids cross and their quiet times end
- Then the asteroids collide and shatter, and the pieces fly into different orbits around the sun
- Some of these pieces orbit closer and closer to the sun
- Eventually some of their orbits cross the Earth's orbit, and the piece of asteroid can hit the Earth

METEOR

- We see this moving flame as a meteor crossing the sky
- If the asteroid fragment is big enough, fist-sized or so, it won't burn up completely and will fall to the Earth as a meteorite
- These small meteorites do not explode or make craters when they hit
- They just hit like an extra large hailstone or a rock thrown from across the street

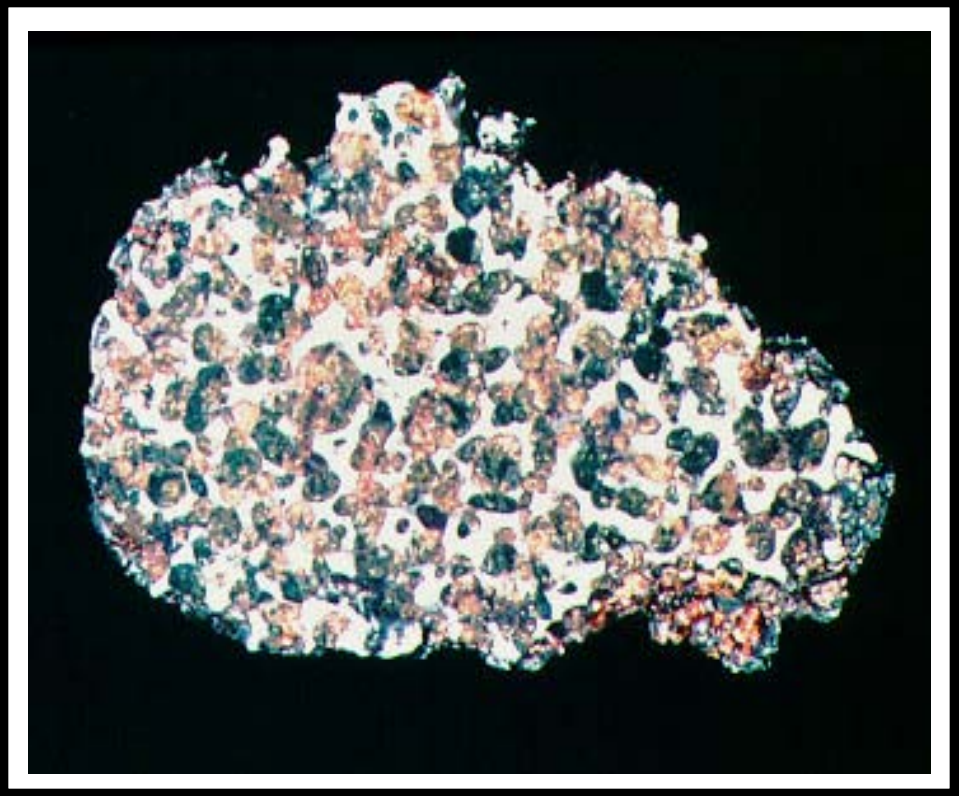
STONY METEORITE

- Stony meteorites are commonly made of familiar minerals like plagioclase, pyroxene, and olivine
- Scientists believe that they were formed in the outer parts of asteroids
- The two main types of stony meteorites are chondrites and achondrites
- Stony meteorites look a lot like Earth rocks, and are often not recognized as meteorites

IRON METEORITE

- Iron meteorites probably formed in the cores of asteroids
- Inside, many iron meteorites are made of criss-crossing intergrown crystals of two iron-nickel minerals
- The sizes and shapes of the crystals suggest that they cooled down so slowly, a few degrees each million years, that they must have been inside large asteroids
- The two types of crystals in this sample are several centimeters wide

STONY-IRON METEORITE



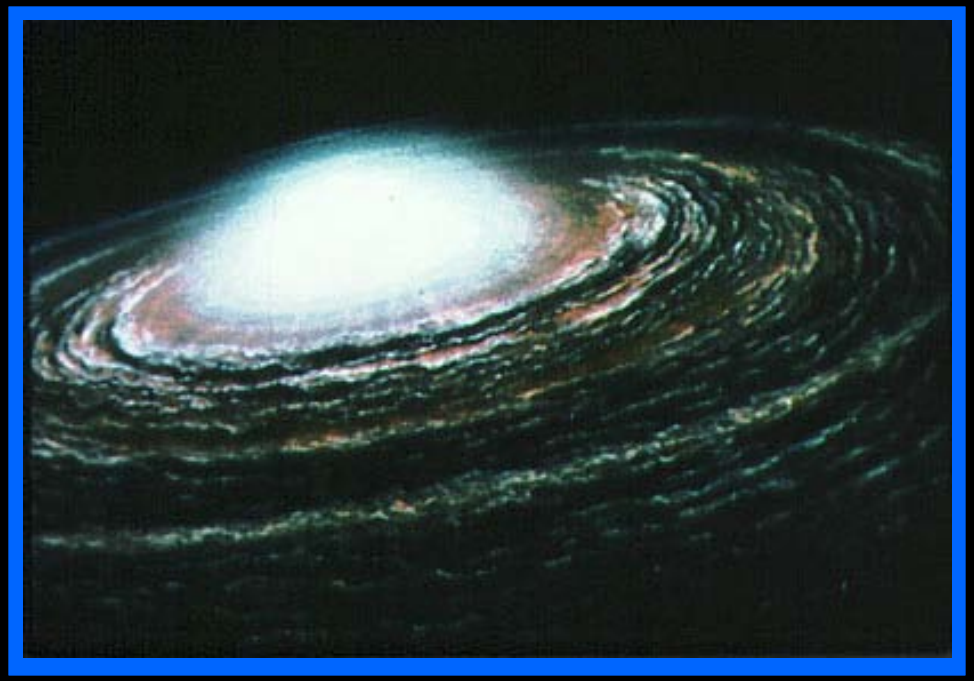
- Some meteorites are mixtures of iron and fragments of rock
- They are called stony-iron meteorites
- This sample, like the one in the Meteorite Sample Disk, formed at the boundary between the metal core and the rocky mantle of an asteroid

SOLAR NEBULA

- The story of meteorites begins 4.6 billion years ago

- The solar system began as a spinning cloud of gas and dust, called the solar nebula, which collapsed under its own weight to form a new star, our Sun

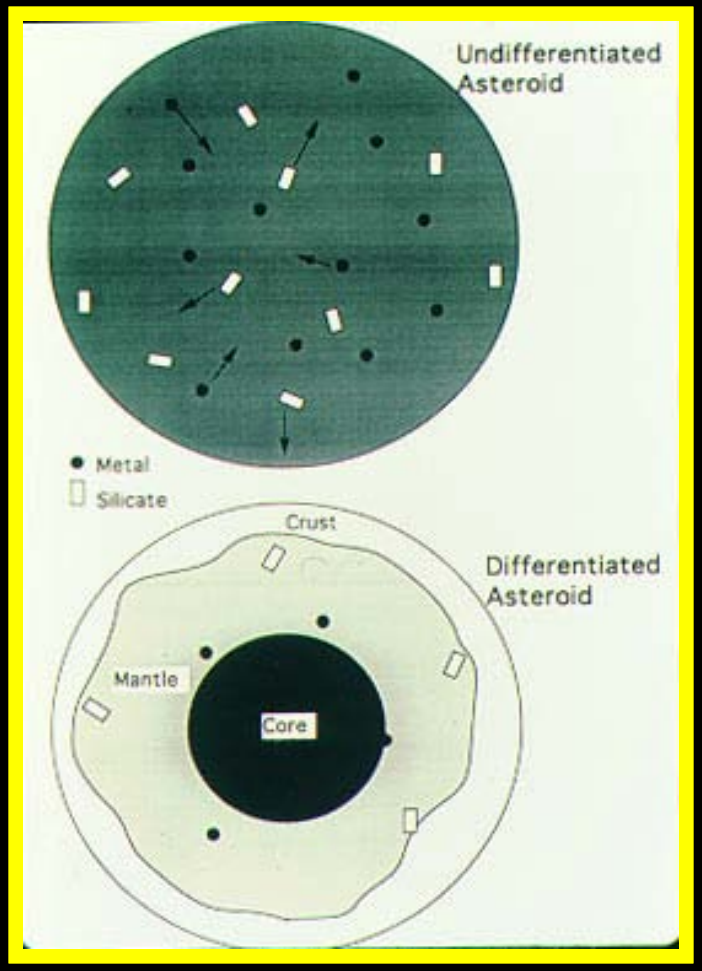
- As the solar nebula spun and churned, dust grains stuck together to form dustballs, and huge bolts of lightning melted them into small spheres



- These solidified into rocky balls called chondrules

DIFFERENTIATION

- This diagram shows an undifferentiated stony asteroid which was heated enough for the inside to melt
- In an asteroid the densest material is iron metal, shown as black dots, which sinks toward the center
- The lightest minerals, silicates called feldspar, float toward the surface
- The remaining material solidifies to form the minerals olivine and pyroxene, which stay in the middle
- The Earth and Moon differentiated just this way



THE EARLY EARTH

- Early in the solar system's history, about 4.4 billion years ago, the Earth's surface was a violent, lifeless place

- Primitive meteorites, called carbonaceous chondrites, may have brought water and carbon into this inhospitable world, and so helped set the stage for life

- It was covered with active volcanoes and hot lava flows, as in this photo

DEATH OF DINOSAURS

Meteorites have also had devastating effects on life...

The dinosaurs were killed 65 million years ago after a huge meteorite hit the Earth

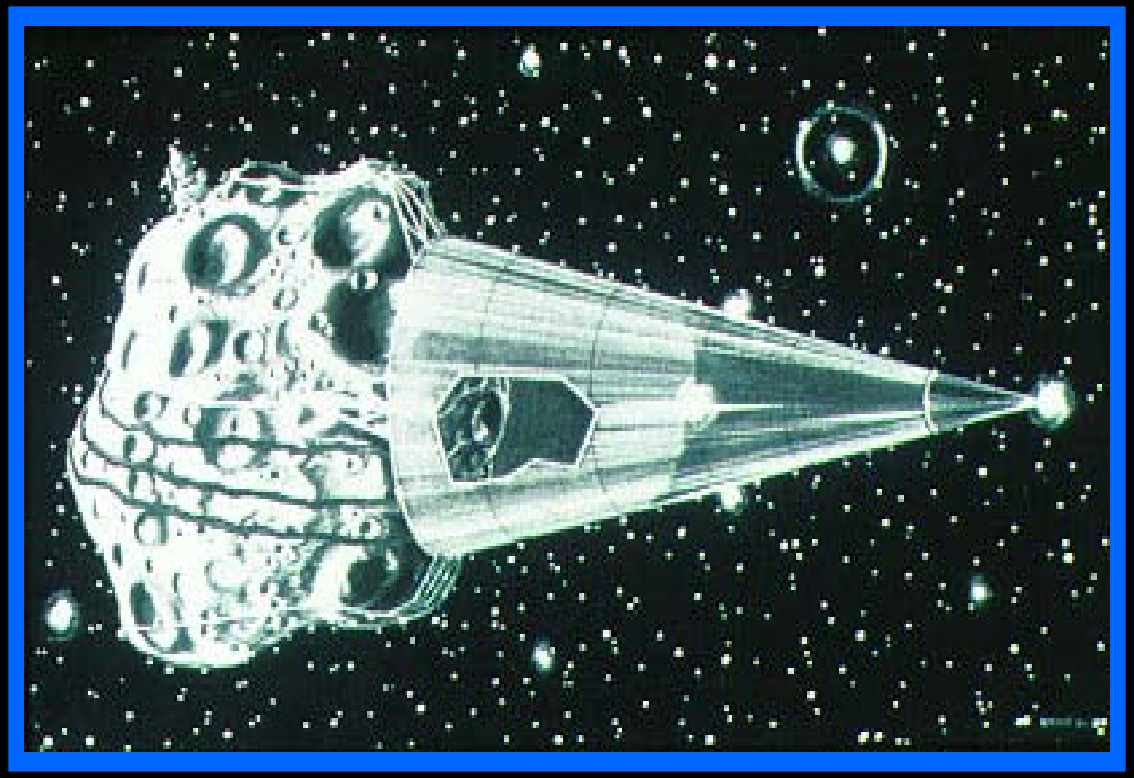
The explosion caused great storms and waves, and the sky was dark for months with dust and ash

The dinosaurs, along with many other animals and plants, were probably killed by the climate changes that followed the explosion

COMET SHOEMAKER-LEVY 9

- In 1993 a comet was discovered heading for Jupiter
- That planet's immense gravity had torn the comet into more than 20 fragments, which were lined up and heading for Jupiter at over 60 km/second
- We saw, from a safe distance, the kind of massive impacts that have scarred all of the planets, including Earth
- In the summer of 1994 one fragment after another smashed into the planet, producing huge explosions

VISITING AN ASTEROID



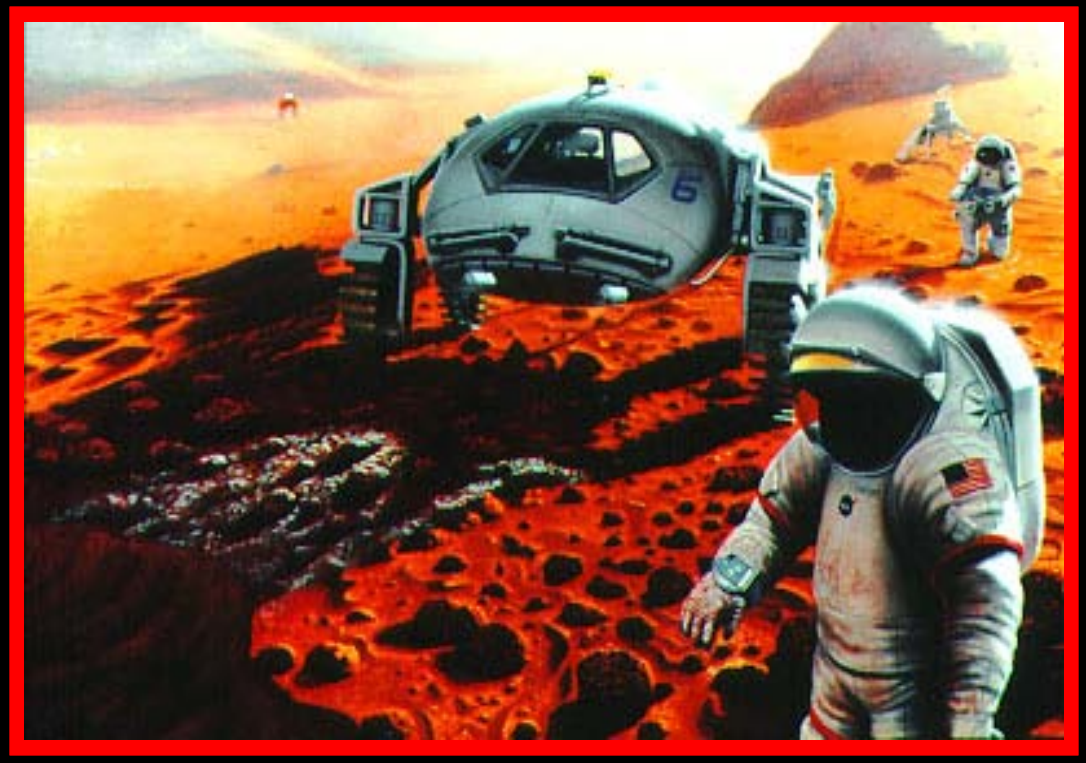
- Today, we look to the future, toward space missions to the asteroids, and eventually to human travel to other planets

- Guided by the meteorites that fall to Earth, we might mine the asteroids for oxygen, water or metal

- We might also search them for more clues to our origins, as we continue to explore the solar system

EXPLORING MARS

- One day humans will explore the surface of Mars and other worlds farther still from Earth
- In order to stay for long periods, we will have to learn to "live off the land," just like the pioneers of old
- Resources from the planets and asteroids may provide the key to humanity's exploration across the solar system



THE MOON

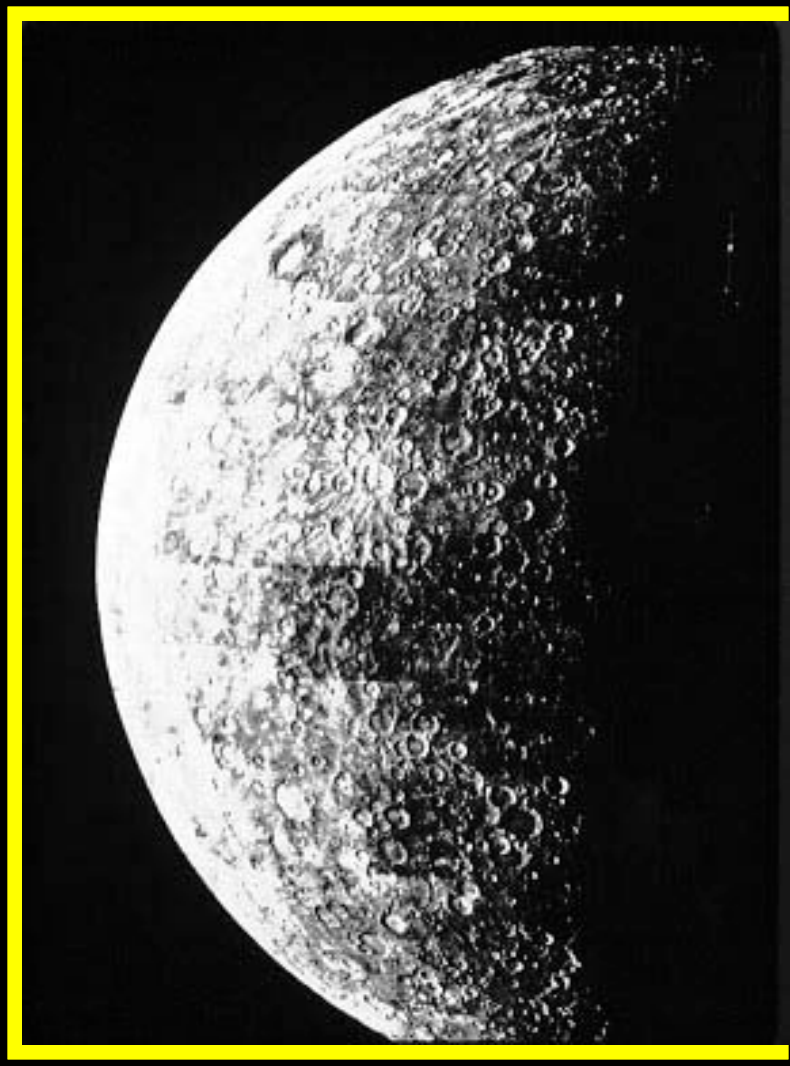
- The Moon is covered with craters in a wide range of sizes

- You can see a few of the largest with your naked eyes, and many more with binoculars

MERCURY

- The planet Mercury, as seen by the Mariner 10 spacecraft, is also covered with craters

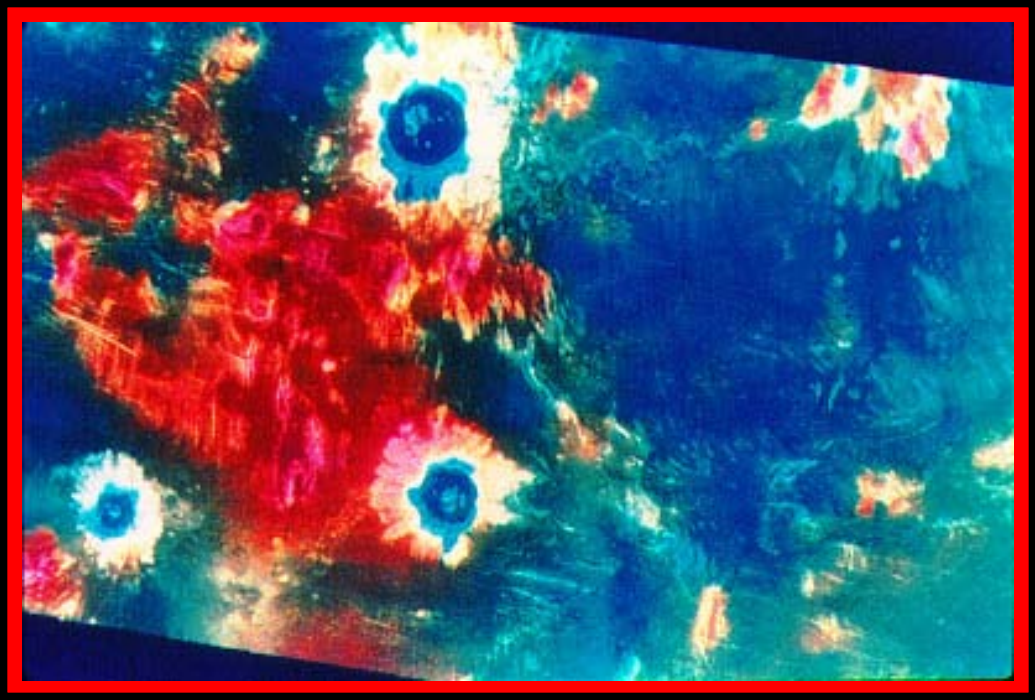
- Mercury has essentially no atmosphere, and its cratered surface looks much like that of the Moon



VENUS

- The surface of Venus has craters too

- Venus has a thick atmosphere which destroys many impacting bodies before they reach the surface



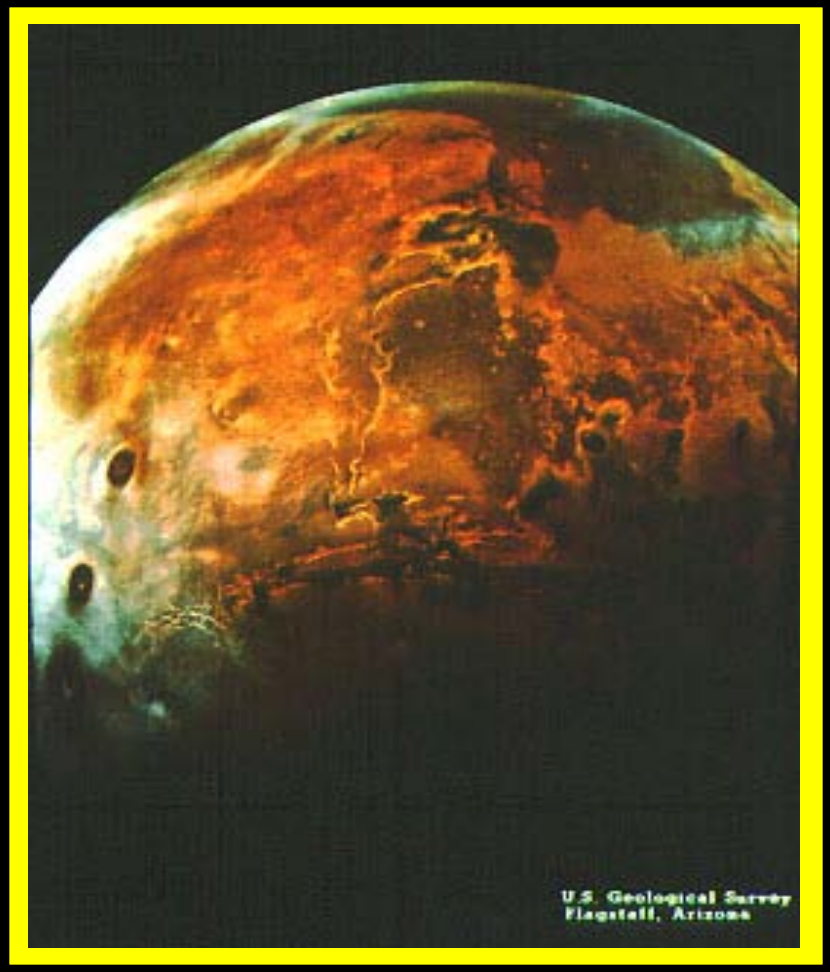
- We cannot see the surface of Venus directly, since the atmosphere is filled with thick clouds

- The colors in this picture were made by a computer, to make it easier to pick out the craters and other features

MARS

- Impact craters are also visible on the planet Mars

- The thin martian atmosphere does not do much to slow an impacting body from space



MARS CRATER

- This photo, taken by the Viking spacecraft, shows a relatively fresh crater on the martian northern plains

- If craters are so common in the solar system, why are they so rare on Earth?

EARTH

- The Earth's surface is constantly being changed by erosion

- Water, ice, wind, and plate tectonics have destroyed most of the craters that Earth once had

- Only relatively young or quite large craters exist on Earth today

CLEARWATER LAKES, CANADA

- The craters of some impacts can still be seen, often as round lakes like the twin Clearwater Lakes in Canada

- These two craters, 32 and 22 km across, are both 290 million years old

MANICOUAGAN, CANADA

- Manicouagan crater in Canada is a ring-shaped lake nearly 70 km across

- In the 212 million years since it was formed, the crater has been deeply eroded

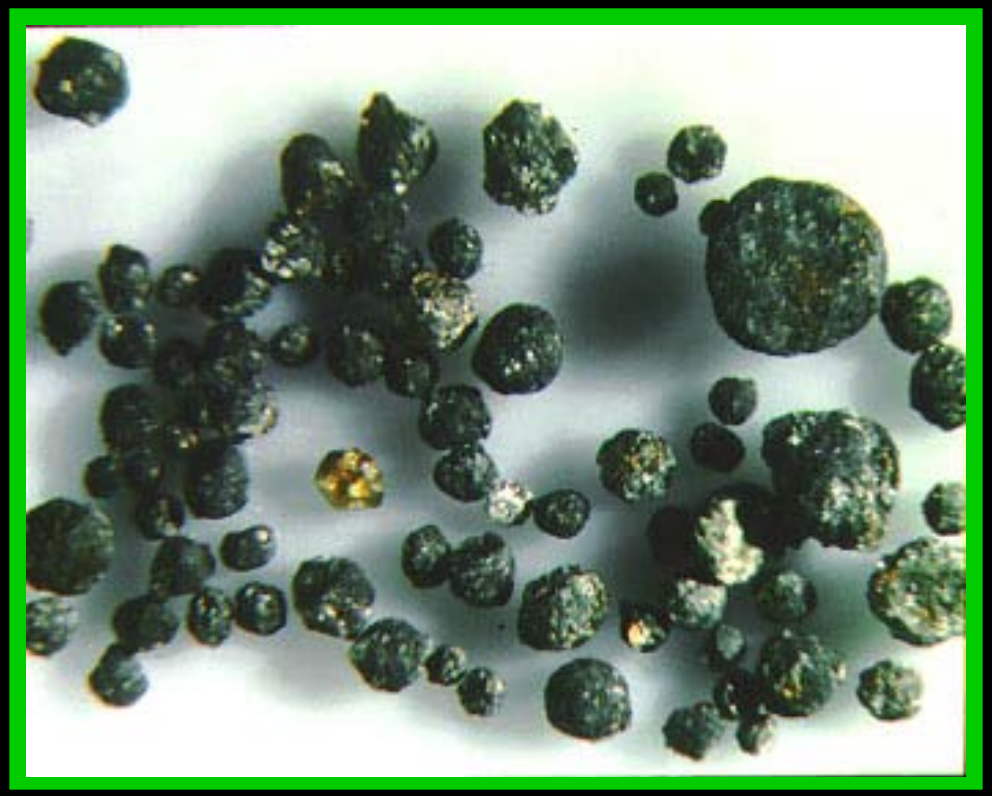
SPIDER CRATER, AUSTRALIA

- Some craters have been almost completely eroded away

- Spider Crater in Australia, 13 km across, is over 600 million years old

- It is barely recognizable as an impact structure

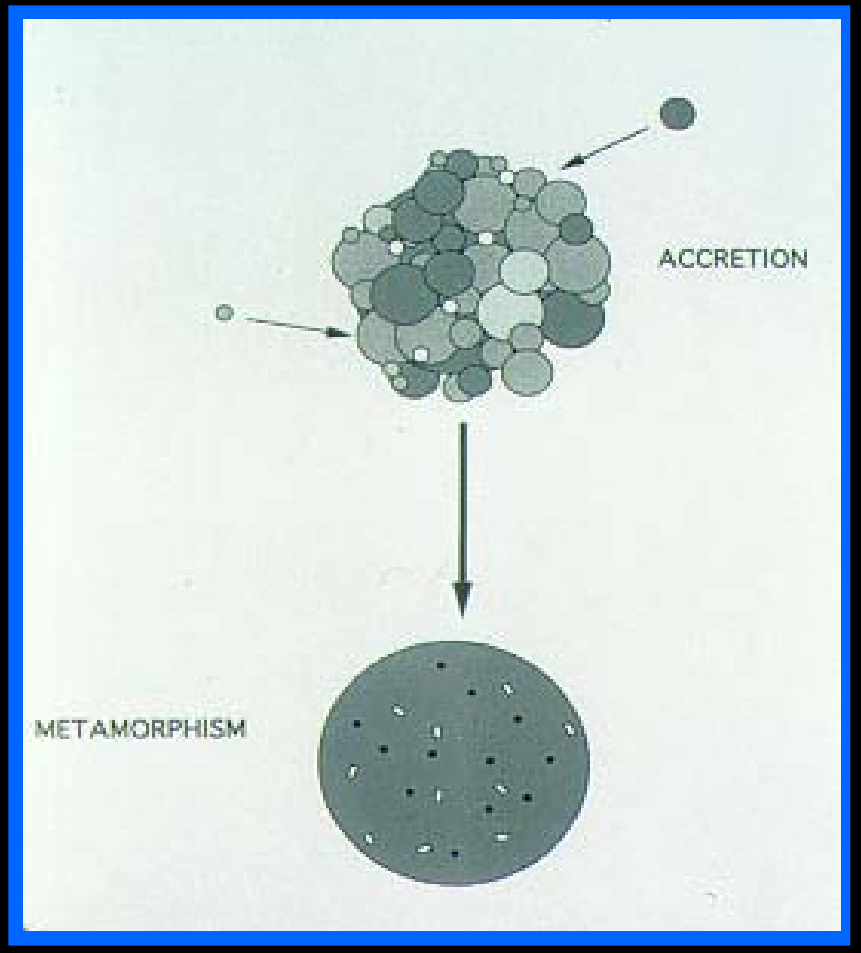
CHRONDULES



- Chondrules are the primitive building blocks of the solar system
- The largest chondrule in this picture is less than 1 cm across
- Most chondrules are so small that it is difficult to learn much about them without a microscope

ACCRETION & METAMORPHISM

- In the early solar nebula chondrules came together to form larger and larger masses, this process is called accretion
- In most meteorites, though, the chondrules have been partially or totally destroyed by metamorphism
- To destroy chondrules takes a lot of pressure and cooking time, so much that these meteorites could not have been formed as small rocks floating in the solar nebula



CHONDRITE

- In some chondrites the chondrules are separated by patches of iron metal
- Different types of chondrite meteorites have different amounts of metal and have been heated to varying degrees
- Chondrites are called primitive because they formed early in solar system history and haven't changed since then

CARBONACEOUS CHONDRITE

- Carbonaceous chondrite meteorites are black because they contain carbon, like soot or pencil lead

- They also contain water, complex carbon compounds and mineral grains even older than the solar system – pieces of dust that formed long ago around far distant stars

VOLCANISM

- Some asteroids got so hot that they melted inside and spewed lava onto their surfaces, just like this lava flow on Earth

- Action on an asteroid may not end with differentiation
- The lava hardens to a rock called basalt
- Some basalts from asteroids fall to Earth as meteorites

ACHONDRITE

- Achondrites are a class of stony meteorites, so named because they do not contain chondrules
- They look like igneous (lava) rocks on Earth
- These achondrites formed during volcanic eruptions on planets or asteroids

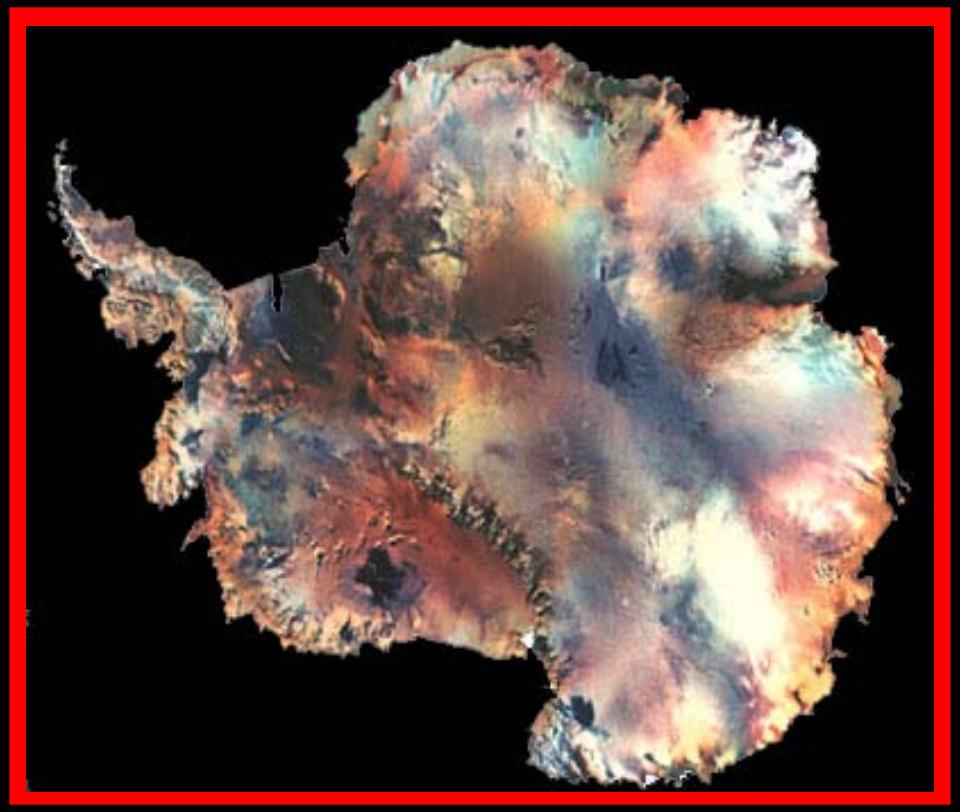
METEORITE FROM THE MOON

- This is a meteorite which was found a few years ago in Antarctica
- Scientific studies have proven that this meteorite and a few others like it are from the Moon, not from asteroids
- They were blasted off the Moon by other meteorite impacts there, and quickly traveled the short distance from the Moon to the Earth

METEORITE FROM MARS

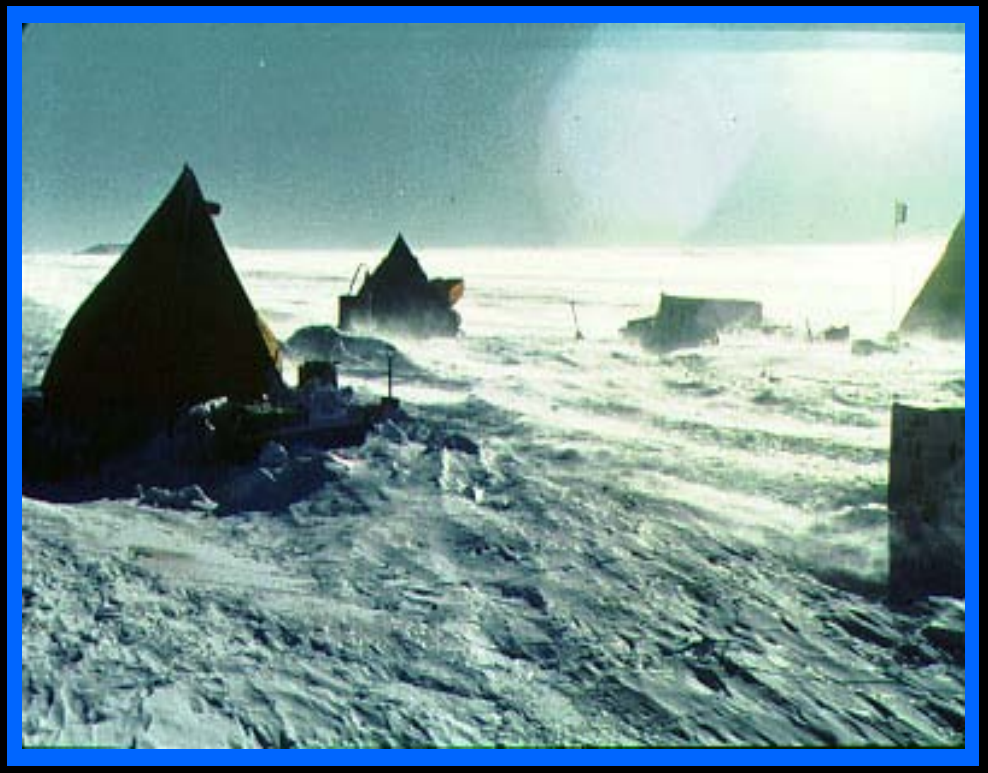
- This meteorite, found in Antarctica, contains traces of Martian atmosphere
- The Martian atmosphere gas is in black veins and pockets of glass, which you can see on this cut surface
- The glass probably formed when another meteorite hit Mars and partly melted these rocks

ANTARCTICA



- The frozen continent of Antarctica has proven to be the best place on Earth to find meteorites
- The meteorites fall onto glacial ice and are carried along until the glacier encounters a mountain range or other barrier
- The ice then stops and eventually evaporates, leaving the meteorites behind

TENTS



- Meteorite collecting trips to Antarctica are not easy
- Teams live in polar tents far from their permanent bases for months at a time
- In bad weather team members may be confined to their tents for days, but on good days they are out finding meteorites
- They travel by helicopter and snowmobile

GLOVE BOX

- Meteorites collected in Antarctica by U.S. expeditions are brought to this special clean lab at the NASA Johnson Space Center in Houston, Texas for initial study

- Experienced curators describe and classify them

- The meteorites are kept in glove boxes filled with nitrogen gas to keep them from rusting or otherwise changing

CHIPPING

- The curators are responsible for distributing meteorite samples to scientists around the world

- Here a piece of a small meteorite is being chipped off for scientific study

SCANNING ELECTRON MICROSCOPE

- The meteorites are examined with many sophisticated tools
- One of them is the scanning electron microscope
- This microscope can take pictures with magnifications of over 100,000 times and determine the chemical compositions of bits of material too small to be seen with the naked eye

COMPUTER

- Computers are used everywhere in scientific laboratories
- Some are used to control instruments and some to collect data
- Scientists also use computers to create the diagrams and write the reports that tell others of their results