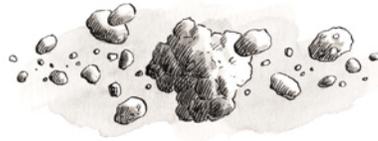


Origins: Earth Is Born

PROGRAM OVERVIEW

NOVA traces Earth's geologic evolution.



The program:

- chronicles the formation of Earth from solar system dust particles that coalesced and became one of the four rocky planets closest to the sun.
- shows how scientists examine meteorites to determine the chemical composition of the dust grains that helped build Earth.
- explains that scientists estimate Earth to be about 4.6 billion years old, the average age of most meteorites discovered.
- describes the theory of the Iron Catastrophe, thought to have occurred almost 50 million years after Earth's formation, when internal heat from trapped radioactive elements and external heat from surface collisions caused the planet's iron to melt, sink, and form Earth's core.
- tells how convection currents in Earth's core generate the planet's magnetic field and relates the migration of Earth's magnetic north pole.
- looks at one theory of how the moon formed—a massive collision of Earth with a Mars-sized planetesimal produced debris that combined to form the moon some 50,000 years after Earth formed.
- reveals the finding that water may have been present about 200,000 years after Earth formed and details one theory that Earth's water came from comets.
- shows how scientists have tried to verify this theory through spectroscopy by examining and comparing the water in passing comets with that of Earth's water.

Taping Rights: Can be used up to one year after the program is taped off the air.

BEFORE WATCHING

- 1 The universe is about 14 billion years old, while Earth is estimated to be about 4.6 billion years old. Homo sapiens evolved about 600,000 years ago. Have students calculate the length of a time line that would show all these events if 500,000 years were represented by one centimeter (About 280 meters). Where would Earth's formation fall on the time line? (About 92 meters.) The appearance of Homo sapiens? (About 1.2 centimeters.)
- 2 Organize students into three groups. Assign each group to take notes on one of the following concepts as they watch: Earth's formation, the moon's formation, and how Earth came to have water.

AFTER WATCHING

- 1 Explain what differentiates a fact (an observation that has been repeatedly confirmed), a hypothesis (a testable statement about an aspect of the natural world), and a theory (a well-confirmed explanation of an aspect of the natural world—a theory can incorporate both facts and tested hypotheses). Discuss these three concepts considering the notes students took regarding how Earth and the moon formed and how Earth became a watery planet. What were facts? What were hypotheses? Theories? Have students support their reasoning.
- 2 By applying radiometric dating to meteorites, scientists have estimated Earth's age to be about 4.6 billion years. Have students research the process of radiometric dating. How many different isotopes can be used for radiometric dating? Why are some isotopes used instead of others? Find more information at pubs.usgs.gov/gip/geotime/radiometric.html

CLASSROOM ACTIVITY

Objective

To collect and identify micrometeorites from space.

Materials for teacher

- razor blade or modeling knife
- small plastic bags to store prepared slides
- 4 single-ply cereal boxes
- 4 plastic sandwich bags
- various-sized rocks (for weighting down collector)

Materials for students

- 1 light-colored shower liner
- 1 rigid plastic wading pool, about 1.5 meters in diameter (optional)
- duct tape (optional)
- 4 coffee cans (10 cm diameter; 11.5 oz.) with bottom end cut out and plastic lids modified per instructions
- 4 junior size basket-style coffee filters (round base should be about 7 cm)
- 4 cereal box halves
- 16 microscope slides (2.5 cm x 7.5 cm)
- masking tape

Materials for each team

- copy of the “The Hunt for Micrometeorites” student handout
- copy of the “Identifying Sky Dust” student handout
- spray bottle with trigger
- 1 cereal box half
- 4 microscope slides taped to cereal box half
- white glue, thinned 50 percent with water
- large plastic bag for storage
- microscope, with low (100x) and high (400x) power lenses, or stereomicroscope
- table lamp
- scissors

Procedure

- 1 Some scientists estimate that about 30,000 to 90,000 metric tons of space dust and micrometeorites strike Earth yearly, mostly in the form of particles less than a millimeter in size. These are remnants of the time when the solar system formed about 4.6 billion years ago. In this activity, four student teams will collect and identify sky dust over an eight-day period. (To shorten the activity time period, you can increase the number of collectors or decrease the number of times a single collector is deployed. Note, however, that the more samples that are collected, the higher the probability of students finding a micrometeorite.)

STANDARDS CONNECTIONS

The “The Hunt for Micrometeorites” activity aligns with the following National Science Education Standards.

GRADES 5–8

Science Standard D:

Earth and Space Science

Earth in the solar system

- The Earth is the third planet from the sun in a system that includes the moon, the sun, eight other planets and their moons, and smaller objects, such as asteroids, and comets. The sun, an average star, is the central and largest body in the solar system.

GRADES 9–12

Science Standard D:

Earth and Space Science

The origin and evolution of the Earth system

- The sun, the Earth, and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. The early Earth was very different from the planet we live on today.

*Video is not required
for this activity.*

Classroom Activity Author

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CLASSROOM ACTIVITY (CONT.)

2 Prior to class:

- rinse the shower liner (to wash away any contamination)
- hang it to dry vertically (to minimize dust contamination)
- store it in a plastic bag (to protect it from contamination)
- cut each of the four empty cereal boxes in half lengthwise (four halves will be used for slide mounts, four halves will be used as the base on which students will cut the wet coffee filter)
- cut the bottom end from the four coffee cans and then cut the center from the plastic can covers, leaving the lip and a half-centimeter rim
- fill the plastic bags with rocks and seal them (these will hold down the collector)

3 Assign students to make the filter assemblies and slide mounts (see illustrations below). Alternately, you can construct these for students.

Filter: Filter devices can be made by carefully folding a coffee filter evenly over the top of the can and securing it with the modified plastic cover. Four filter devices should be made.

Slides: Place four microscope slides side-by-side on a piece of thin cardboard and secure them with masking tape placed perpendicularly across both ends of the slides. There should be no space between the slides. Four sets of mounts should be made.

4 Review the instructions on the “The Hunt for Micrometeorites” student handout. Organize students into four teams. Provide each team with a copy of the handout and review the instructions with students. Tell students that each team will take turns using the collector (light-colored shower liner) with their filter device for a 48-hour period.

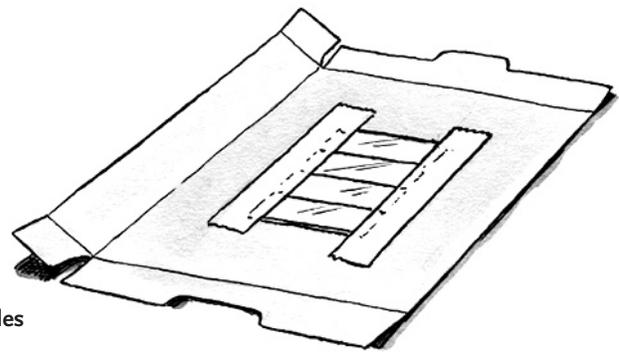
USING A PLASTIC WADING POOL

Although not required for this activity, a plastic wading pool is recommended. The pool will prevent the shower liner from flapping in the wind and help keep students from accidentally stepping on the liner. A pool will also allow the collector to remain relatively undisturbed (flapped or shaken) if it needs to be moved indoors because of high winds or a rain storm.

Finished Filter



Taped Slides



For additional setup photographs, see www.pbs.org/nova/teachers/activities/3111_origins_o3.html

CLASSROOM ACTIVITY (CONT.)

- 5 For the first round of collecting, have one of the teams place the collector outside in an open location such as the middle of a lawn or open field (if putting the collector in a plastic pool, use duct tape to secure the four corners). Avoid areas that are exposed to gusty winds, (such as building corners) and contamination from sources (such as falling tree leaves and road spatter). Avoid rainy days. Time of day is unimportant.
- 6 Leave the collector out for 48 hours. If high winds or rain are forecast, temporarily move the collector inside. Store the collector by folding it in half (if using pool) or placing it in the plastic bag so that no dust settles on it. Have students look at the collector after 24 hours; if detritus is visible, students can collect the particulate matter at that time.
- 7 Provide the first team with a set of collection materials and have team members use the retrieval method outlined in their handouts to collect any particulate matter that has fallen into the collector. If the shower liner is taped to a plastic wading pool, make sure that students do not shake the sheet as they carefully cut the duct tape securing the shower liner to the pool.
- 8 Have the first team prepare its slides, making sure that team members only very thinly coat their slides with the watered-down glue. If too much glue is used, it will impart a gloss that makes micrometeorite identification more difficult.
- 9 After the slides have dried, use a razor blade or modeling knife to separate them by cutting through the filter material. Choose and store in a plastic bag the slides that have the most particulate matter (not all the slides will have particulate matter on them; four slides are used to allow for a margin of error for students placing the filter on top of them). Repeat the collection procedure with all of the teams.
- 10 Once all the teams have retrieved particles from the collector, have students view their findings. If using a compound microscope, have students position a table lamp slightly above the microscope stage. What do students see on their slides? How many different kinds of particles do they see? Have students record the particles they see on their “Identifying Sky Dust” student handout. Work with students to identify as much as possible on their slides. (See Activity Answer on page 5 for a list of Web sites that contain photos of micrometeorites and other particulate matter that may be found.) Where do students think each of the identifiable particles came from?
- 11 As an extension, have students research the origins of the solar system’s asteroids and meteorites and write a one-page summary describing the differences between them, where they come from, how they are studied, and what information they can reveal about the universe.

RELATED ACTIVITIES

Mineral Identification

www.pacsci.org/origins/

Identify minerals and consider what information they can reveal about the planet from which they came.

Origins

www.amnh.org/education/resources/programs/origins/earth.php

Learn how Earth was born and how meteorites are found in this American Museum of Natural History site that offers articles and student materials related to NOVA’s “Earth Is Born” program.

ACTIVITY ANSWER

While most of the material students collect likely will be terrestrial sky dust, it is possible that students may find one micrometeorite in the collector each night. If students do not find any micrometeorites, you may want to lengthen the collection period or try a different venue.

See the following Web sites for photos of micrometeorites and other sky dust:

www.skydust.org/

physicsweb.org/article/news/2/5/12#news-2-17-4-1

www.crrel.usace.army.mil/research/projects/Antarctic/epww.htm

Here are some items that have been found by U.S. teams participating in the National Aeolian Detritus Project, a pilot National Science Foundation project to collect and identify sky dust:

Micrometeorites.

These can be composed of rock, metal (nickel and iron), or both. The majority of the micrometeorites are made of rock, although these are more difficult to identify than metal micrometeorites, which look small, shiny, etched, black, and more or less round. Metal micrometeorites will respond to magnets. Although micrometeorites come in a range of sizes (from about 10 microns to 500 microns), the smaller sizes are more common.

Carbon balls.

Similar to micrometeorites except that they are dull black and lumpy. Formed when a commercial boiler uses steam to dislodge carbon buildup.

Pollen.

Almost always present in various shapes and sizes. Find U.S. regional pollen season information at www.aaaai.org/nab/index.cfm?p=uspollen_seasons

Insect parts.

Sometimes parts of insects will show up in collectors. For example, ant wings left from spring mating flights.

Whole insects.

Gypsy moth instars (young form) show up in the collectors before their presence is detected by other means.

Mineral fractions.

Unusual amounts of illite, a kind of clay particle, were detected in New England collectors two weeks after a large dust storm in Mongolia. The actual arrival time matched the arrival time predicted by computer models.

Local oddities.

A team in Massachusetts found “Christmas trees”—clumps of small splinters with little balls at their tips. The team thought they might be a new form of micrometeorite when they discovered that a magnet attracted them. Careful checking revealed that the collector was near a body shop and that the “Christmas trees” were partially oxidized steel grindings.

Another team found long tubes running all over a filter. They turned out to be hyphae, the vegetative body of a fungus that grew on the filter after it had been processed and left damp for too long.

LINKS AND BOOKS

Links

NOVA Web Site—Origins

www.pbs.org/nova/origins/

In this companion Web site to the program, find out how life could have started and why water is needed for life; read about the latest discoveries in origins research; use raw data to assemble the famous Eagle Nebula image; insert your own values into the Drake Equation; decode cosmic spectra; and more.

Age of the Earth

pubs.usgs.gov/gip/geotime/age.html

Explains radiometric dating methods used by scientists to estimate the age of Earth.

Exploring Meteorite Mysteries

spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Exploring.Meteorite.Mysteries/

Provides information and activities related to meteorites and their origins from such places as Mars, asteroids, and the moon.

Magnetic Field of the Earth

hyperphysics.phy-astr.gsu.edu/hbase/magnetic/magearth.html

Examines the Dynamo Effect and its relevance to the formation of Earth's magnetic field.

National Aeolian Detritus Project

www.skydust.org/

Details a project in which students discover micrometeorites and other materials by collecting and identifying sky dust.

The Origin of the Moon

www.psi.edu/projects/moon/moon.html

Explores in detail the leading theory of how the moon formed, including factors supporting the theory and its development.

Books

Ball, Phillip.

Life's Matrix: A Biography of Water.

New York: Farrar, Straus and Giroux, 1999.

Tells of the possible origins of water—its history, pervasiveness and potential presence on other planets.

Marsh, Carole.

Asteroids, Comets, and Meteors.

New York: Twenty-First Century Books, 1996.

Compares asteroids, comets, and meteors and provides a range of general information on the solar system, the galaxy, and the universe.

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The Hunt for Micrometeorites

It is difficult to imagine that Earth grew from many small bits of dust and debris that were formed long ago in stars. Although most of the solar system debris has settled, meteorites do still enter Earth's atmosphere. While most of the rock and metal objects entering Earth's atmosphere burn up due to friction between the debris and atmospheric gases, some surviving fragments fall to Earth. In this activity you will hunt for remnants of the early solar system—micrometeorites that are about 4.6 billion years old!

Procedure

- 1 To gather material from your collector, first carefully lift the collector by the corners so that it hangs in a "U" shape, keeping one end of the "U" slightly higher than the other.
- 2 Hold the filter at the low end of the collector so that the water sprayed on the sheet will flow down into the filter.
- 3 Carefully wash all particulate matter from the collector into the filter assembly. Squirt the sheet with the water from the sprayer, starting at the top of one side of the "U," and wash back and forth to the bottom. Then switch and wash the other side. Finally, squirt the bottom of the "U" from the high to the low end.
- 4 Carefully remove the filter from the coffee can and spread it out on the square piece of cardboard. Cut out and remove a 5 cm wide band from the center of the filter (cutting the wet filter on a piece of cardboard helps prevent the sheer paper from bunching up).
- 5 After the water has drained from the filter, spread a *very thin* film of diluted white glue in the middle of the four cardboard-mounted microscope slides. The glue will anchor any particulate that has collected on the filter. Each slide must be coated from side-to-side and to within a half inch of both ends.



- 6 Lift the wet filter band away from the cardboard and center it across the microscope slides, with the particulate matter facing up. Keeping the particulate matter face up, lay the filter over all the slides. Set the microscope slides and filter aside to dry.
- 7 After the glue dries, have your teacher cut the four slides apart. Peel the masking tape away from the slide ends to free them and store in a plastic bag the slides that contain the most particulate matter.
- 8 Once all teams have collected samples, you will be given your slides to examine under a microscope. Use a table lamp to light your slide from above. Draw a picture on your "Identifying Sky Dust" handout of what is on your slide, and describe each object. Then conduct research to identify as many of the particles as you can.



