THE MOON:

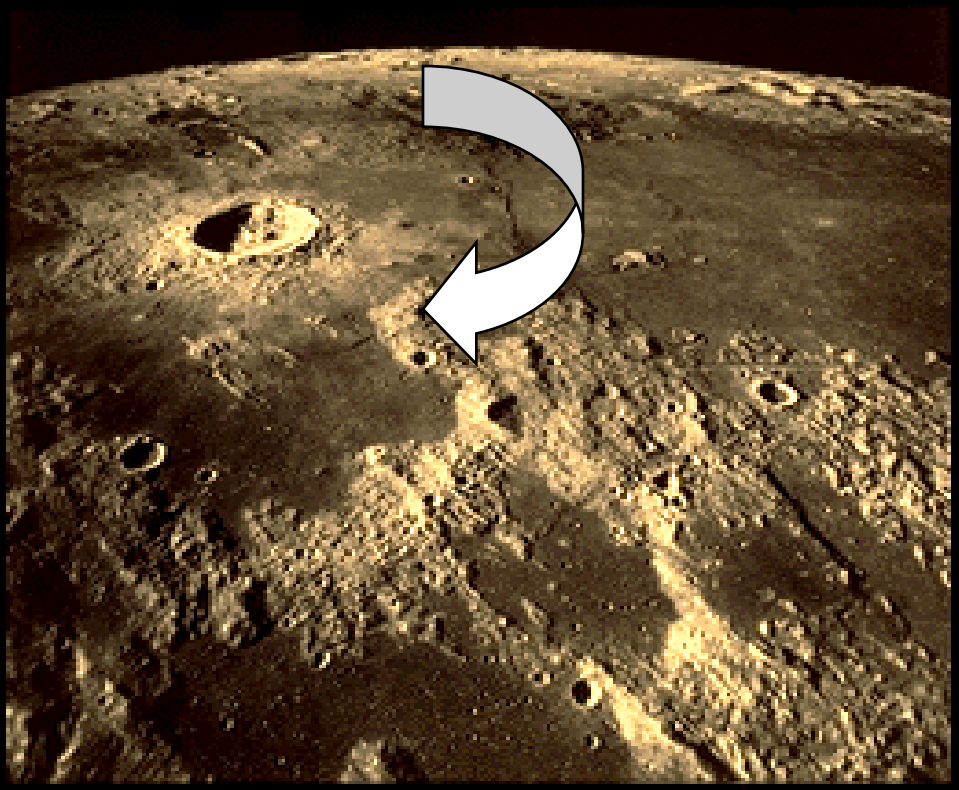
Geologic History and Future Exploration

What did we know about the Moon before Apollo?

- Two types of Terrain
  - Highlands
  - Maria
- This picture of the moon was taken with a telescope at Lick Observatory, CA

WHAT A VIEW!

- A view seen by Apollo 17 astronauts as they orbited the Moon
- The Maria are smoother, lower, and darker than the highlands
- The crater in the upper left is 20 kilometers across!



Apollo Missions

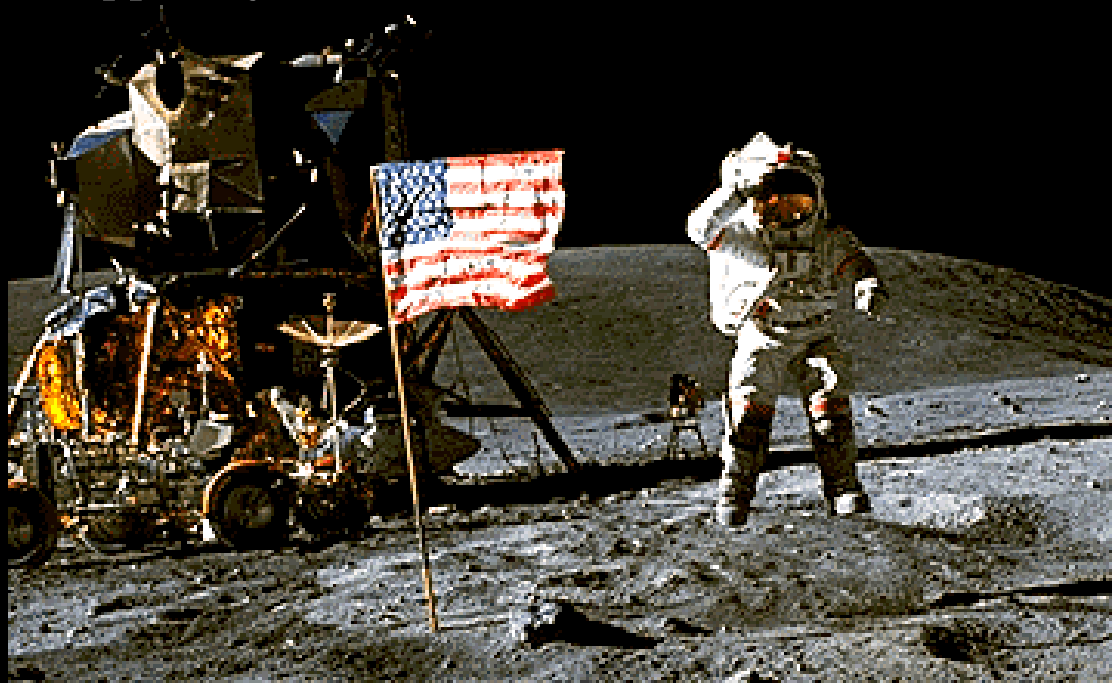
The launch in 1972 of the Apollo 16 mission to landing site in the highlands of the Moon.

6 Apollo Landings on the Moon:

- In each case 2 astronauts descended to the Moon's surface
- A third remained in orbit around the Moon in the main spacecraft called the Command and Service Module

Commander John Young of Apollo 16 Mission

- Behind Young is the Lunar Module with the Lunar Roving Vehicle parked beside it
- Notice Commander Young is wearing a space suit. There is no air on the Moon, so, astronauts must bring their life support systems with them
- He has jumped about a meter off the ground. Commander Young's extraterrestrial space suit weighed 150 kilograms on Earth. If gravity was the same on the Moon, nobody could jump this high



LUNAR ROVING VEHICLE

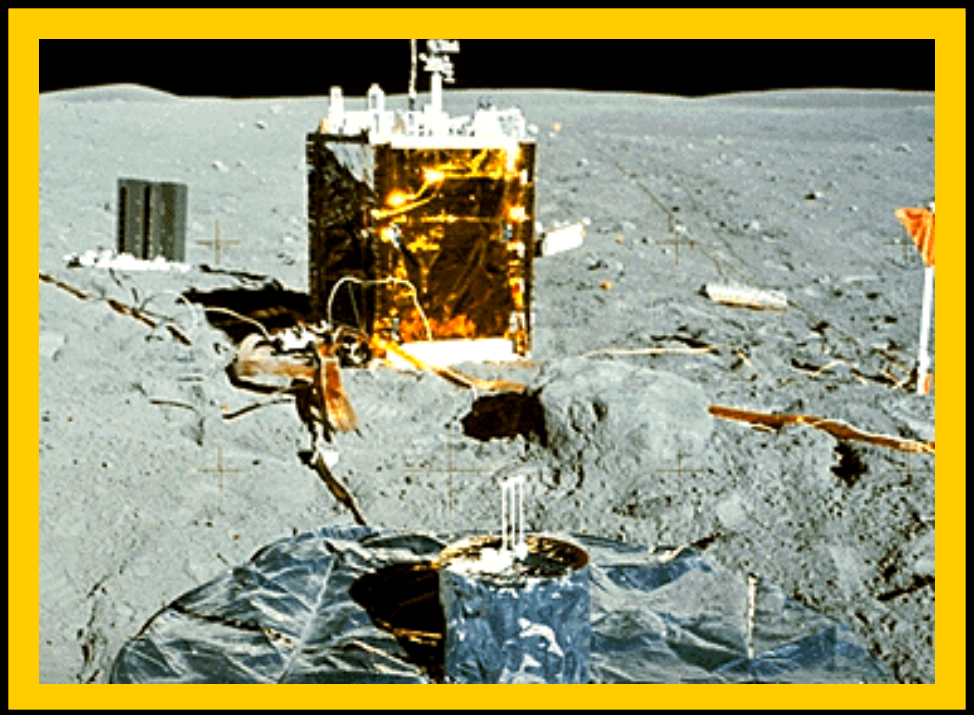
- Driving the Lunar Roving Vehicle, Astronaut Harrison Schmitt
- The Rover greatly enhanced lunar exploration on the last three Apollo missions by allowing much longer traverses around the landing sites

ROVER

- Apollo 17 astronauts repaired this broken fender on their Rover by using a map and duct tape
- Without a fender, dust was being thrown both forwards and backwards, interfering with driving

Astronaut Activities on the Lunar Surface

- The larger object in the center of the picture is the Central Station, which sent data back to Earth.



- The smaller, dark object to the left of the Central Station is the power supply needed to run the experiments.

- The shiny object in the foreground is a seismometer, which detected moonquakes.

Apollo 17 Landing Site

- Harrison Schmitt examining boulder
- Geologists want to know how different rock types relate to each other
- Schmitt and other astronauts examined large boulders carefully, sampling rocks from discernible layers
- They also tried to see where the boulders came from; in this case, the large rock rolled down from the top of a nearby hill.

RAKE SAMPLES

- Astronaut Collecting walnut-sized rocks with a rake
- These samples proved to be extremely valuable because they provided a broad sampling of the rock types present at a landing site

Lunar Curatorial Facility

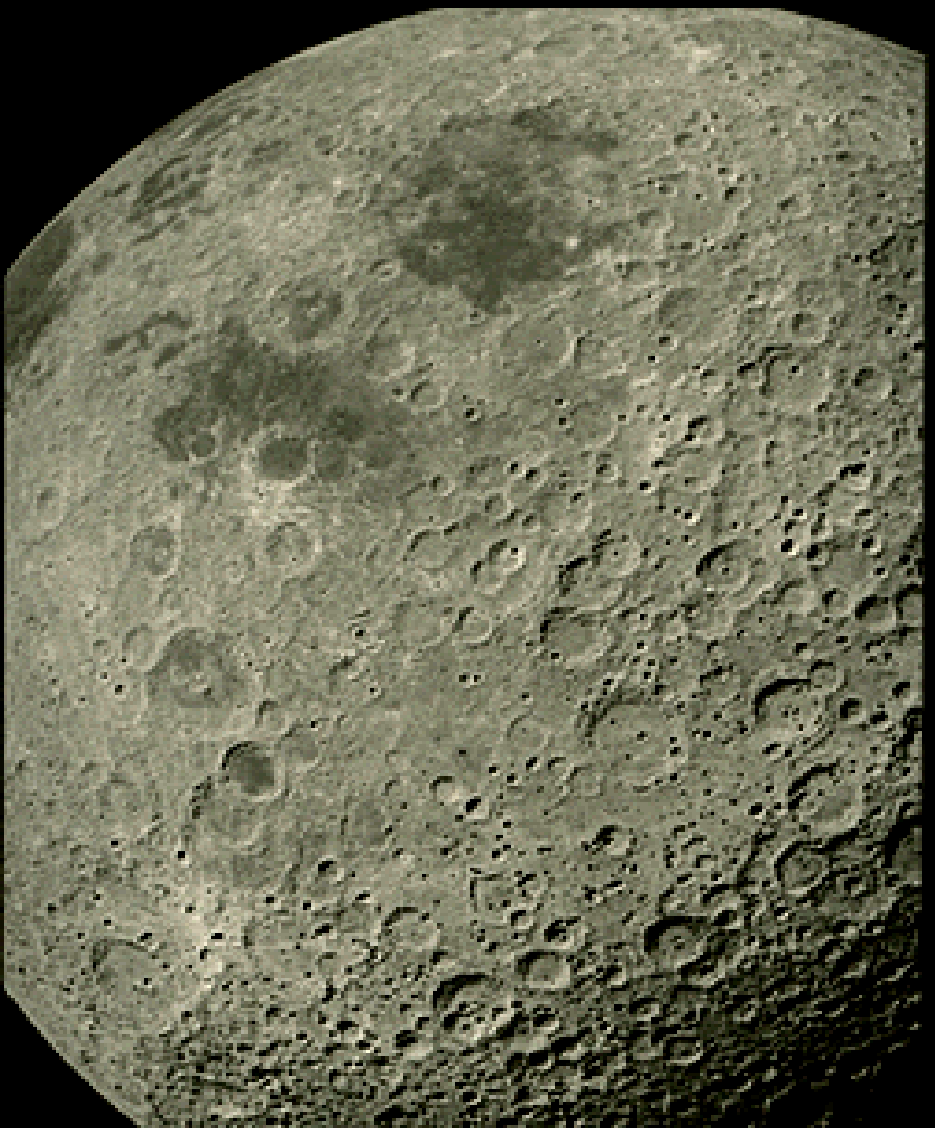
Samples remain in the glass and steel cabinets, bathed in an atmosphere of pure nitrogen, to keep the samples from altering by reaction with air.

NASA JOHNSON SPACE CENTER

HOUSTON, TEXAS

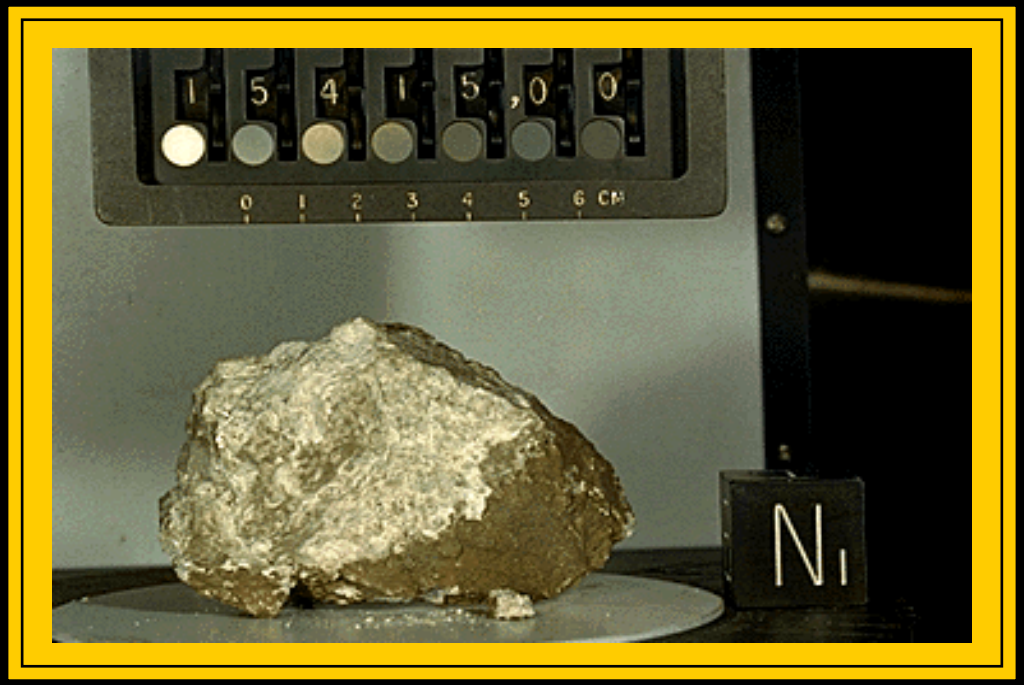
- These skilled technicians who curate the lunar samples wear lint-free suits for cleanliness, but actually never handle the samples directly
- They pick them up and chip samples off by using Teflon-covered gloves that protrude from the cabinets

THE FARSIDE OF THE MOON



- The dark Maria on the left are barely visible from Earth
- All the terrain to the right is on the farside and was completely unexplored until the space age
- The highlands are lighter in color than the maria, higher by a few kilometers on average, and intensely cratered.

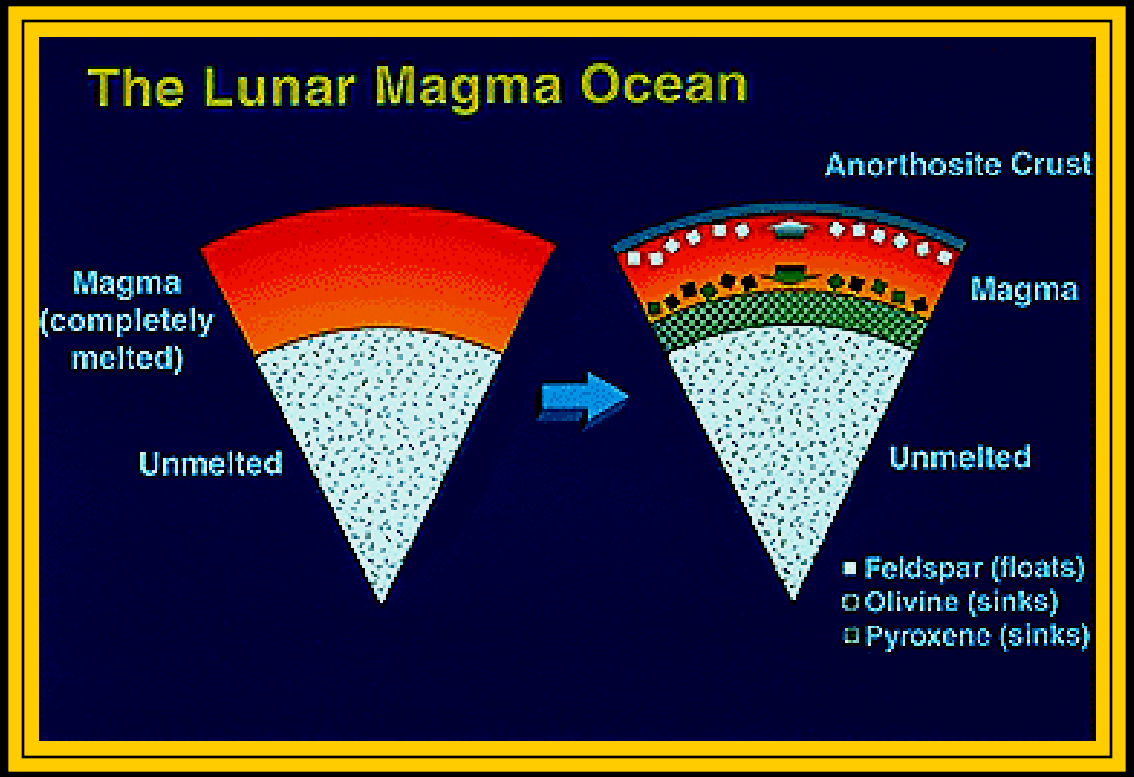
ANORTHOSITE



- Returned by the Apollo 15 mission
- Anorthosites are composed almost entirely (98%) of one mineral, Plagioclase Feldspar
- One way single-mineral rock forms is by accumulation by either floating or sinking in a magma

LUNAR MAGMA OCEAN

When the Moon formed it was enveloped by a layer of magma hundreds of kilometers thick!

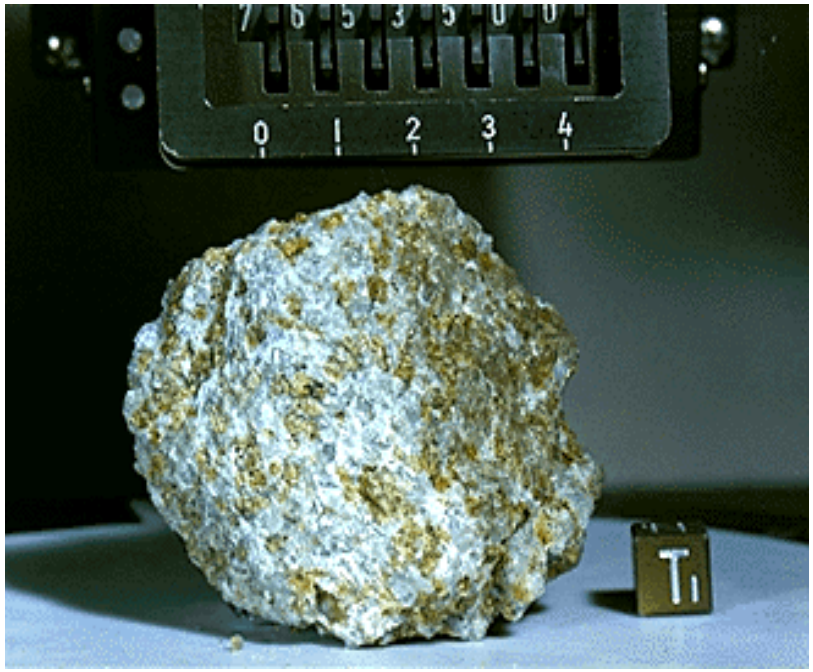


The dense minerals later remelted to produce the basalts that compose the maria

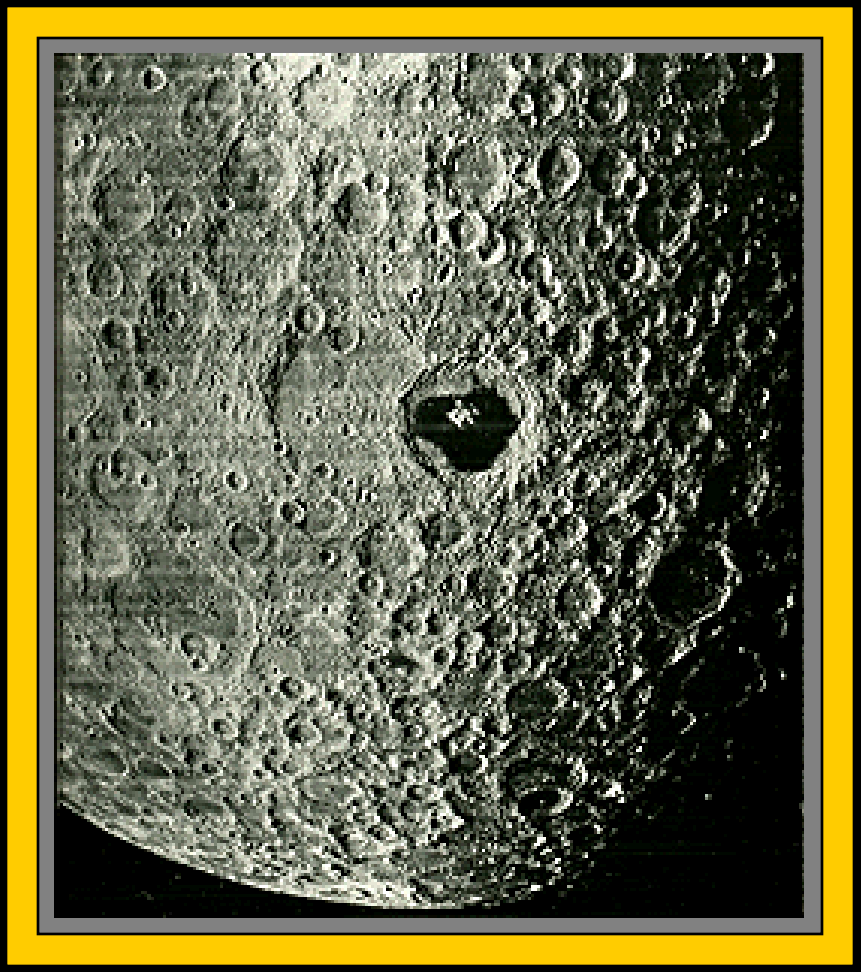
As the magma crystallized, the minerals more dense than the magma sank, while those less dense floated, forming the anorthosite crust

TROCTOLITE

- After the first crust formed in the highlands, it was modified under the intrusion of other rock types
- The Troctolite is composed of olivine and plagioclase feldspar
- A large variety of rock types formed during this period



TSIOLKOVSKY



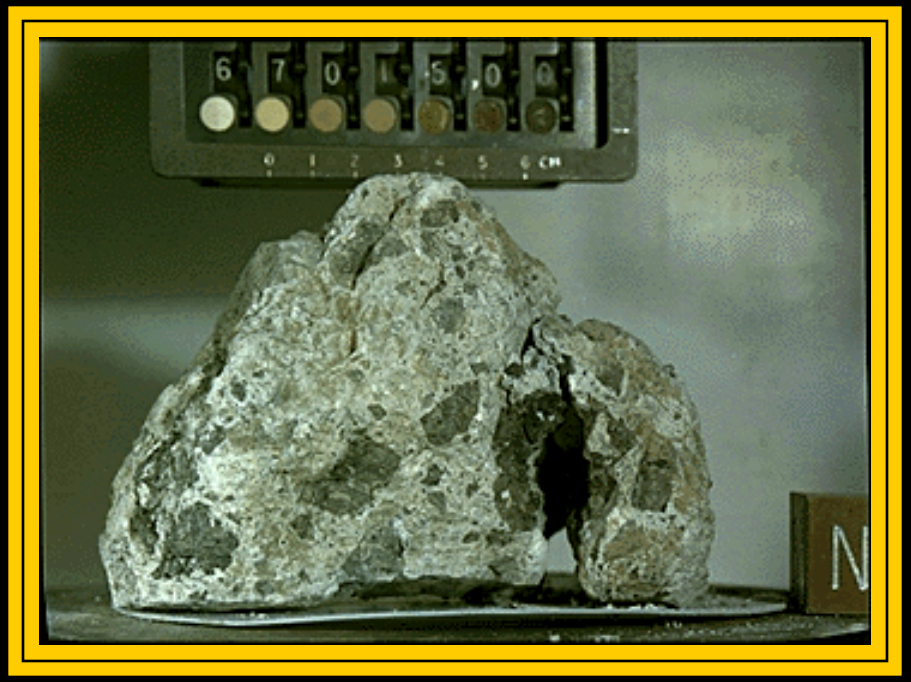
- The dark splotch in the center is one of the rare maria on the farside
- It sits in a large crater called Tsiolkovsky
- Every crater visible in this photograph formed by the impact of objects into the Moon

ORIENTALE BASIN

- On the western limb of the Moon
- 1 of 40 such structures on the Moon
- Formed by a large impact
- About ½ of this structure is seen from Earth
- The diameter of the 3rd ring is 930 kilometers

BRECCIAS

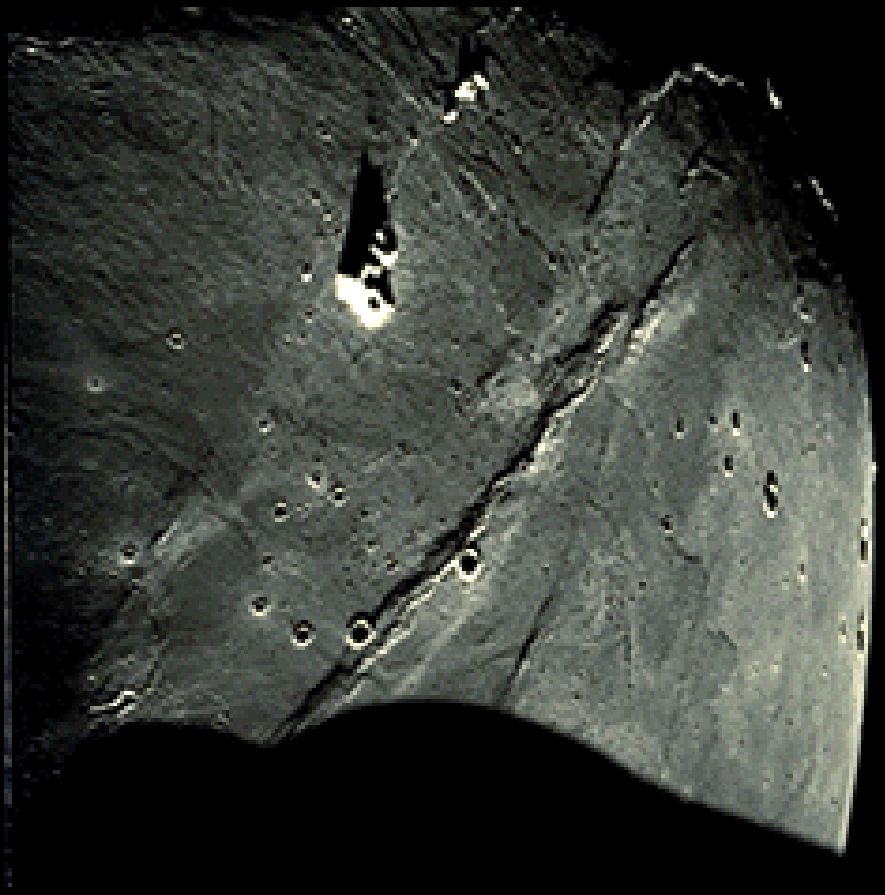
A collection of rock fragments all mixed together Geologists call such rocks “Breccias”



This sample was collected in the Highlands by the Apollo 16 mission

With so many craters of all sizes in the lunar highlands, it is no wonder that the rocks have been modified by meteorite impact

MARE IMBRIUM



- This picture taken during the Apollo 15 mission shows lava flows in Mare Imbrium
- The prominent lava flows that extend from lower left to upper right of this slide are among the youngest on the Moon, a mere 2.5 billion years old!
- These flows are several hundred kilometers long

MARIUS HILLS

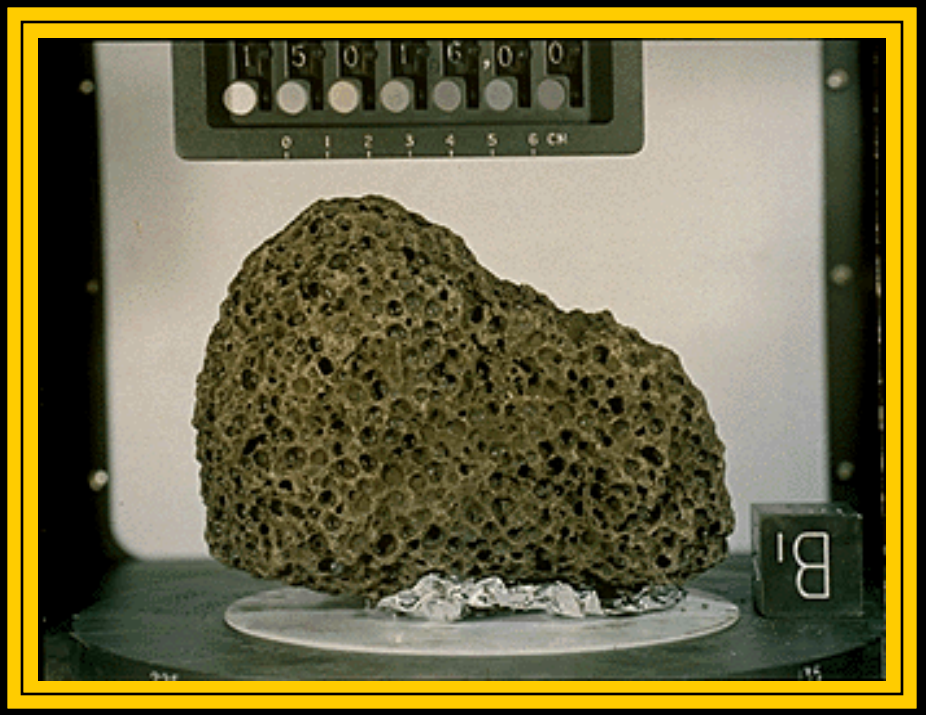
This shows the Marius Hills, a collection of relatively low domes.

Rilles (sinuous lava channels) are also visible, one of which cuts across a mare ridge

Although eruption of most mare basalts did not produce volcanic mountains, there are small volcanic domes in a few places

BASALT SAMPLE

Returned from the Apollo 15 Mission

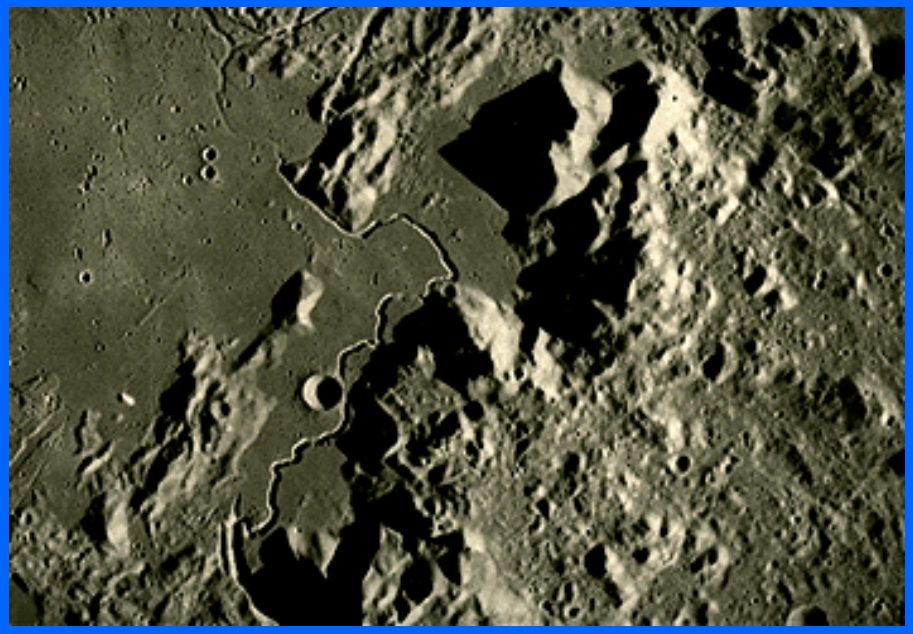


The brownish color is caused by the presence of the mineral pyroxene

The holes are frozen gas bubbles called “vesicles”, a common feature of terrestrial volcanic rocks

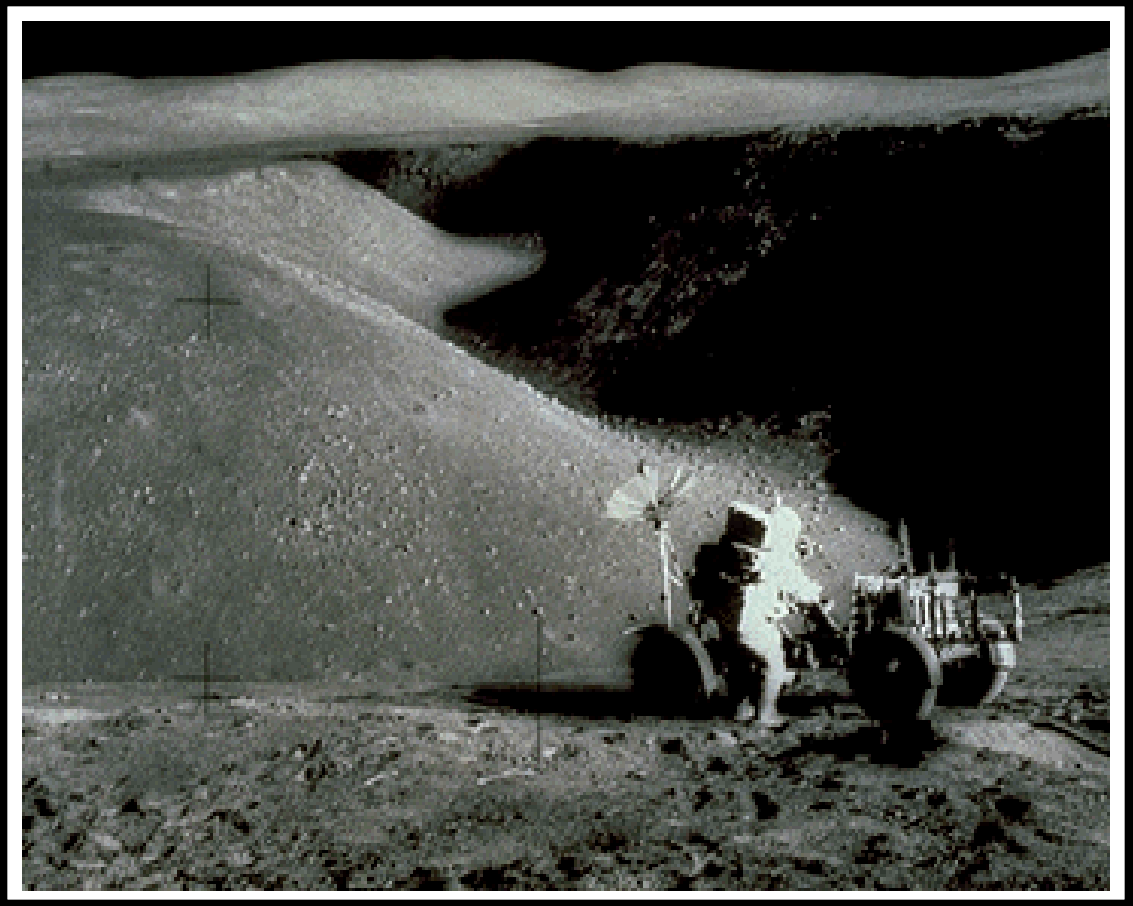
HADLEY RILLE

The river-like feature in this photograph is called a “rille.”



- Apollo 15 landed near the rim of this rille between the two largest mountains
- Hadley Rille is 1.5 kilometers wide and 300 meters deep
- Rilles are channels in which lava flowed during the eruption of mare basalts
- All samples collected from its rim are basalts, proving that flowing water did not form these river-like features

APOLLO 15 LANDING SITE



- Looking down into the rille

- The crew could have walked down into the rille and sampled rocks from its walls, but time and concern about their safety did not permit it

Kilauea Volcano

We see here a lava channel about 4 meters across on Kilauea Volcano, Hawaii in 1986

The lava cools on top, forming a darker skin

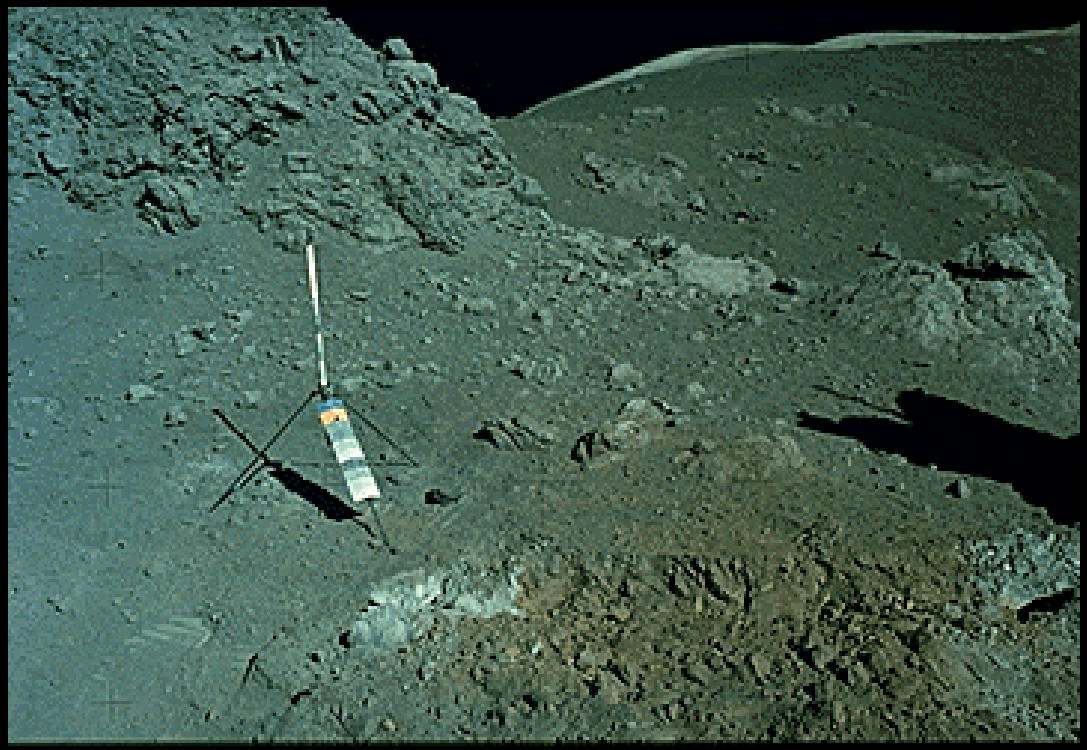
The cone in the distance is Pu'u 'O'o, the source of the lava

When it was active, Hadley Rille probably resembled this channel, although it was much larger.

FIRE FOUNTAINING

- Fire fountaining is another form of volcanic eruption
- This one took place in 1959 at Kilauea Volcano and sent lava up to 550 meters into the air
- Such eruptions, called “pyroclastic” eruptions, produce loose fragments of hardened lava rather than lava flows
- Fire fountaining takes place when the magma contains a high concentration of gases

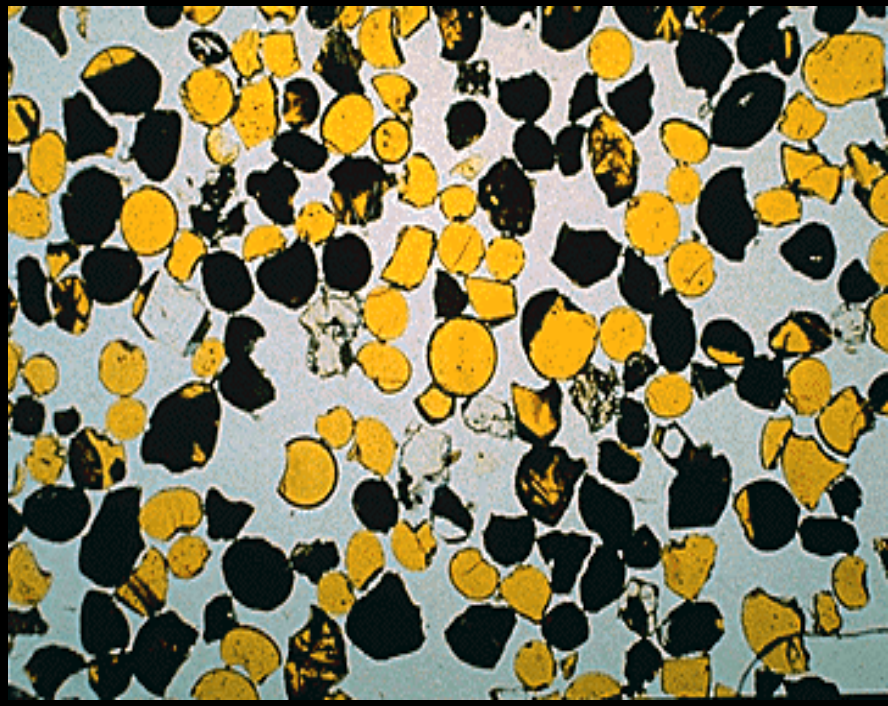
PYROCLASTIC DEPOSIT



Astronauts found a pyroclastic deposit on the Moon at the Apollo 17 landing site. The orange soil is composed of numerous droplets of orange glass that formed by fire fountaining

ORANGE SOIL

- Thin slice of Apollo 17 orange soil
- This view Is 2.5 millimeters across
- The small drops of lava did not have time to form minerals in it before it cooled, so most of the droplets are composed of glass
- The darker ones did have time to crystallize partially, and formed the mineral ilmenite, which is opaque, and so appears black in this photograph



ALPHONSIS

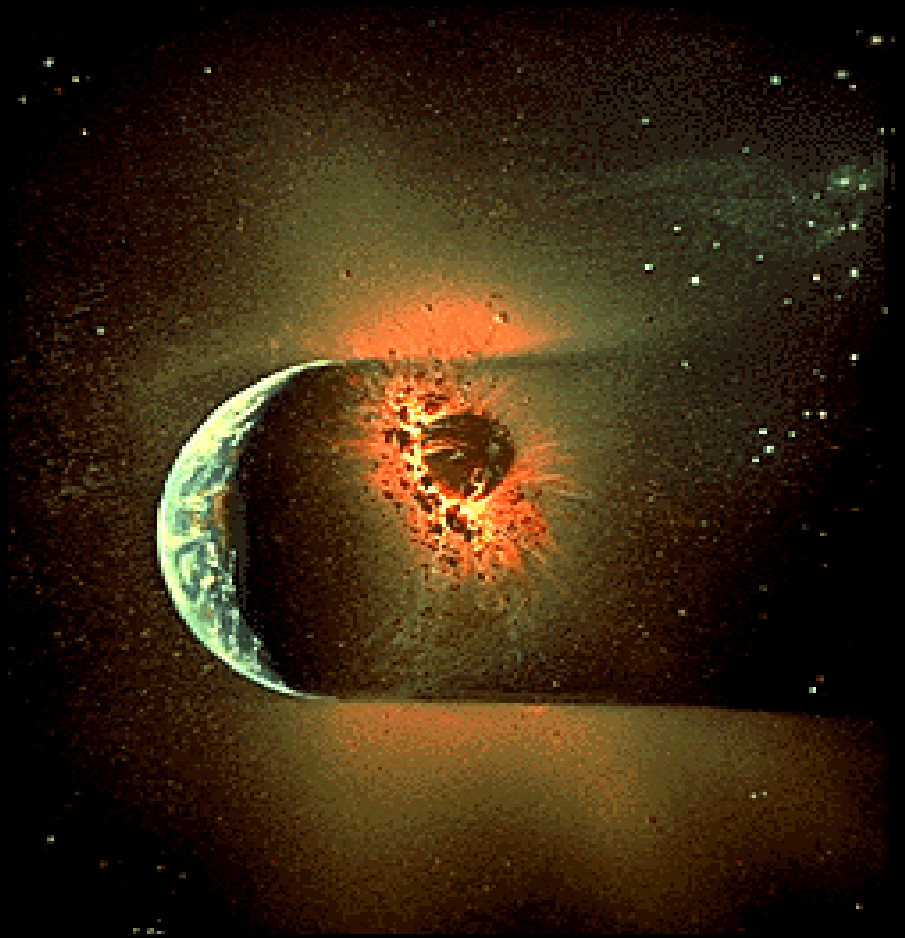
This is the crater Alphonsis on the moon

The large impact crater is 120 kilometers across

The dark circular features on the floor of Alphonsis are cinder cones produced by pyroclastic eruptions

They are lower and wider than cinder cones on Earth because the Moon’s lower gravity and lack of air allow the particles to travel further

HOW DID THE MOON FORM?

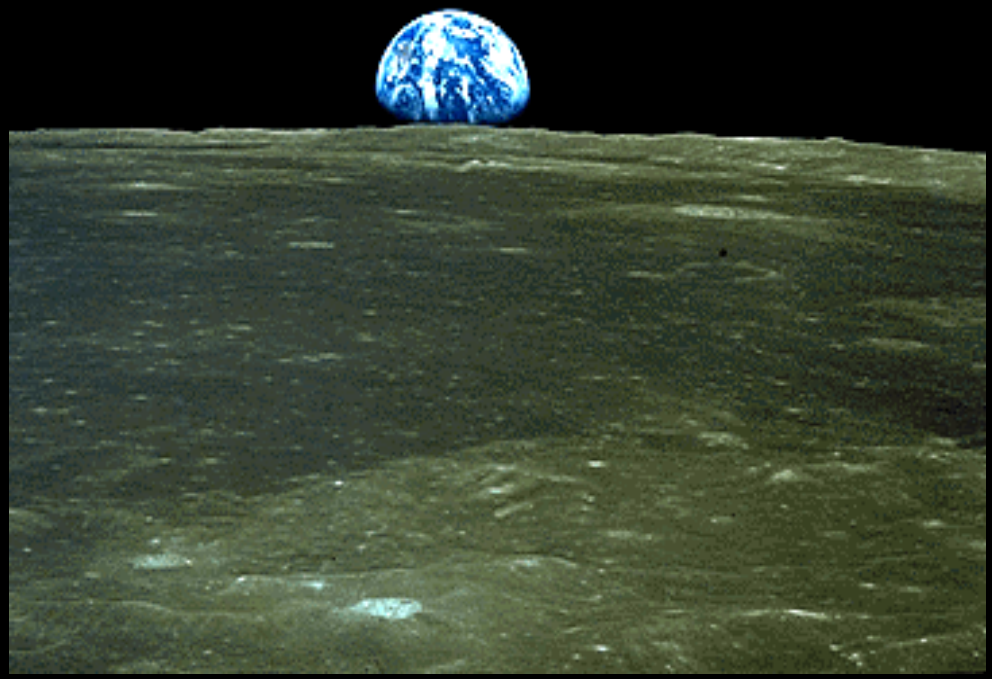


This is a painting by William Hartmann depicting the way most scientist believe the Moon formed

- Because all the traditional ideas for lunar origin had fatal flaws, Hartmann and other scientists devised the idea that the Moon formed as a result of impact of a projectile the size of the planet Mars with the almost completely constructed Earth
- The material that ended up in orbit around the Earth then accreted to form the Moon

FUTURE LUNAR SCIENCE AND EXPLORATION

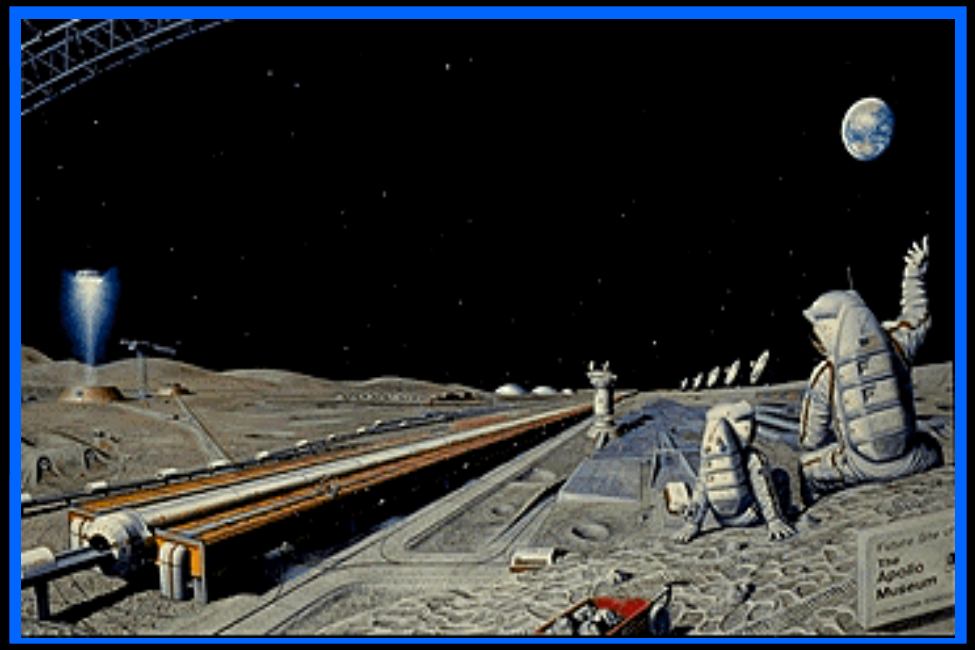
- One of the reasons for studying the Moon is to understand more about the origin and geologic history of the Earth
- The Moon provides information about how Earth formed, about its initial state, and about its bombardment history
- This information has been erased from Earth by billions of years of mountain building, plate motions, volcanism, weathering, and erosion



This is what Earthrise looked like from lunar orbit during the Apollo 11 mission

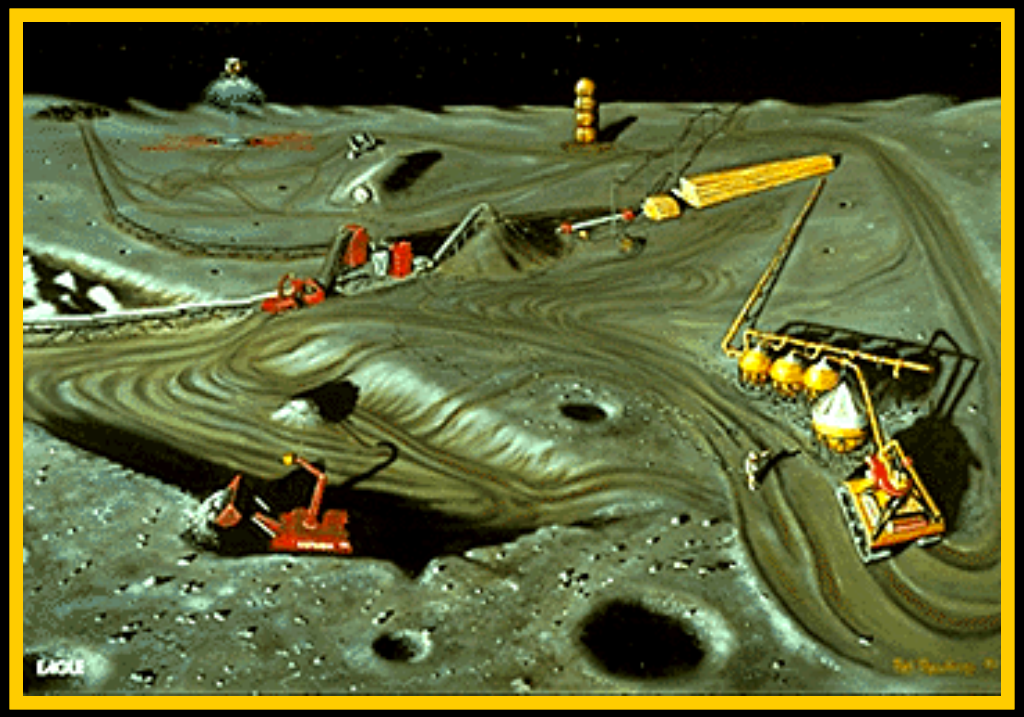
IMAGINE THIS

People with imaginations envision large bases on the Moon



This picture shows a complex installation with radio telescopes, launch site, mass driver, and a parent talking with a child, perhaps explaining where their ancestors came from

SOIL



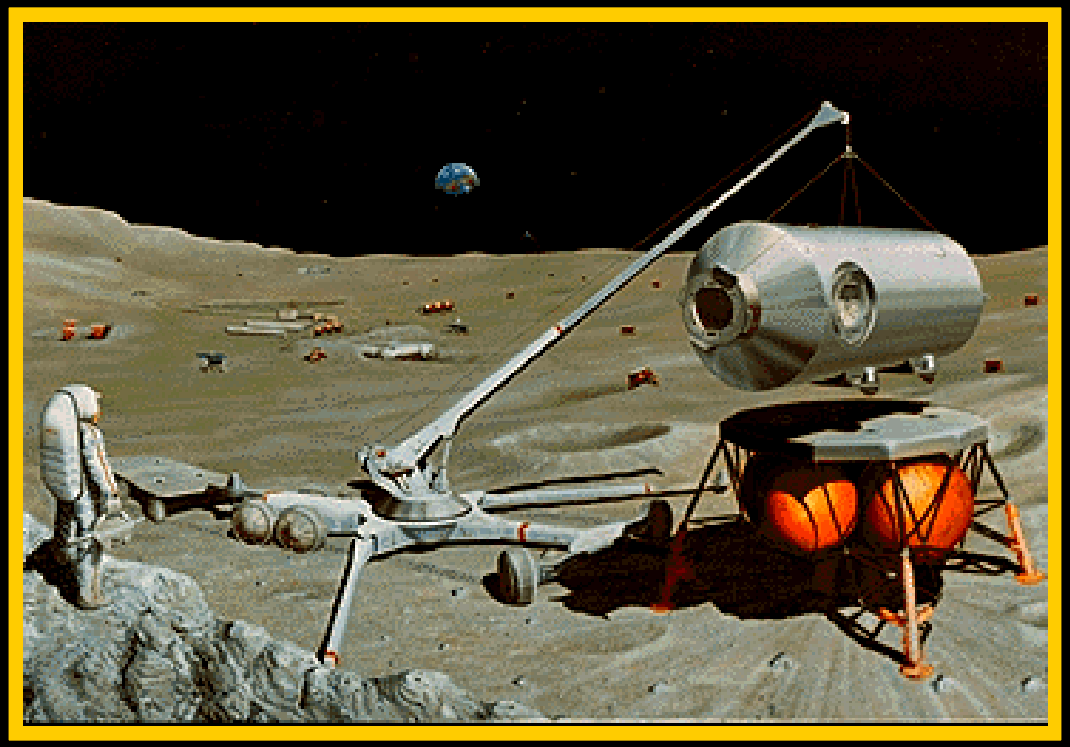
Although the Moon has no running water or air to breathe, its soil contains enormous amounts of oxygen

This key element for life support and rocket propellants can be extracted from the surface materials by reaction with hydrogen

It might be exported for use in earth orbit or to fuel spacecraft on trips to Mars and elsewhere in the Solar System

HABITAT MODULE

A lunar base could be built up gradually

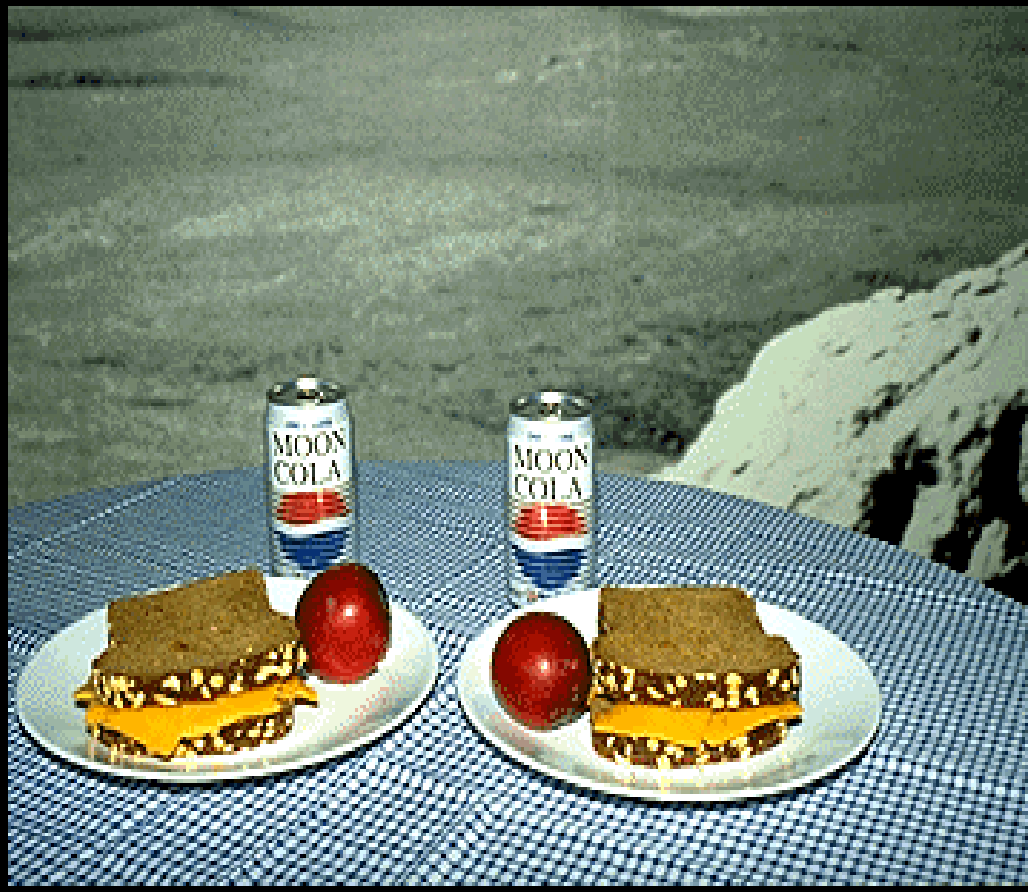


The spherical objects are fuel tanks, which might use fuel produced on the Moon

This artist’s conception shows a habitat module being uploaded form an automated spacecraft

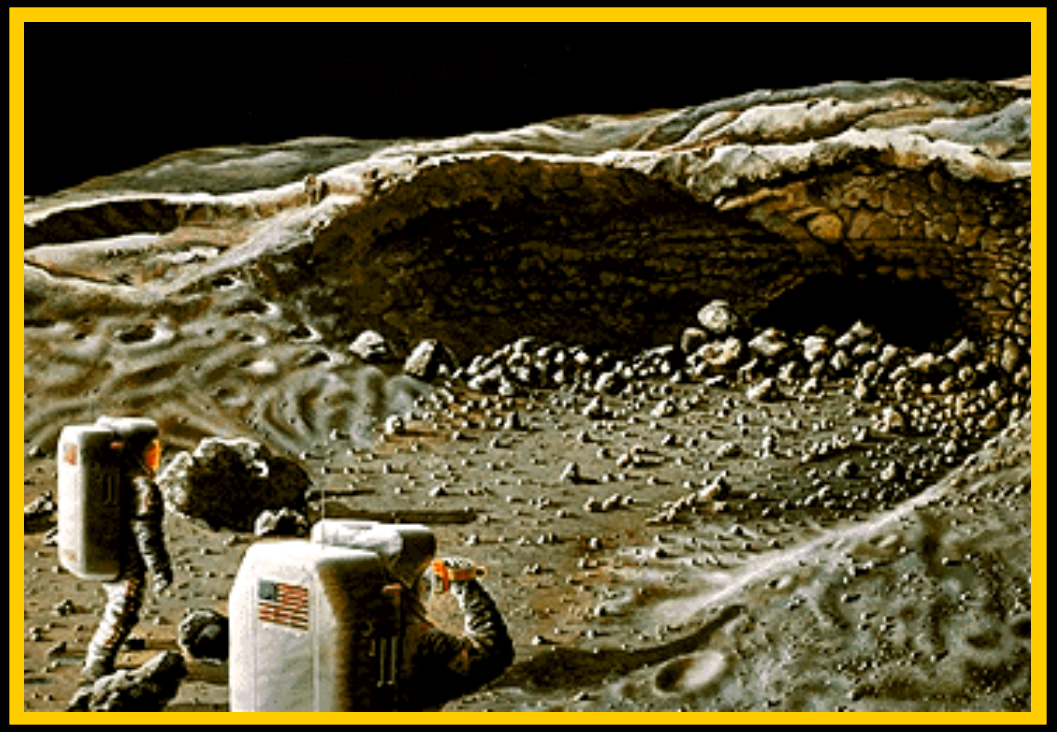
FOOD

Professor Larry Haskin of Washington University in St. Louis has pointed out that besides the abundant oxygen present in every rock, the Sun has implanted enough hydrogen, carbon, and nitrogen into the lunar soil to produce plenty of food



Although the lunar surface is dry and lifeless, each cubic meter of moon dirt contains the ingredients to make lunch for two

FIELD GEOLOGY

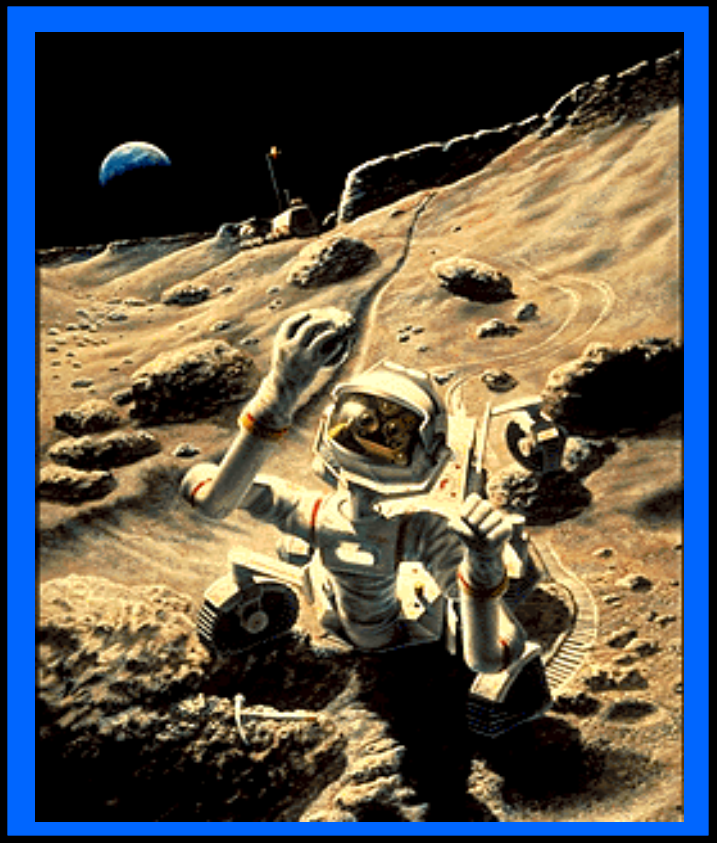


- A key scientific task when people live and work at a lunar base will be field geology
- The real work of geology is done in the field, where geologists map rock distributions and observe both large- and small-scale features
- In the scene depicted here, astronauts are examining a lava tube, a common feature in basaltic lava flows on Earth and almost certainly present in flows on the Moon

TELEROBOTICS

One problem with exploration of either the Moon or Mars is that there is no breathable atmosphere

Astronauts are also exposed to dangerous radiation



Such devices are a combination of autonomous robots and human operators so a human brain can be present in the robot even if located a thousand kilometers away

To get around these risks, but still make use of human intelligence, future space exploration will probably make use of telerobotics

THE

END