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Selenographic Description of The Moon Rocks and Minerals – Lunarites and Lunabazites.

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Abstract: The Apollo Lunar landings yielded an abundance of new scientific data on the Moon.
The various experiments placed on the surface provided information on seismic, geophysics, resp. selenophysics, gravitational and other characteristics of lunar rocks and minerals.
But perhaps the most dramatic result of the missions was returning a total of more than 800 pounds (381,7 kg) of a lunar rock and soil (regolith) for analysis on Earth.
These samples of the evolution of Moon regolith offered a deeper appreciation of the genesis of our nearest planetary neighbor.
Sometimes the experts say about Earth and Moon like about a TWINPLANET EARTH–MOON.
The Lunar surface we can divided into two topological and selenographical units
a) Moon’s Continents (Highlands)
b) Moon's Mares, Sinuses, Oceans, Basins
c) Craters (impact objects).
The Moon continents are connected with Mountains like The highest point, located on the far side of the Moon, above 10 000 m is 8 700 m NORTH–EAST OF CRATER CURTIUS, approximately 6 500 meters higher than Mons Huygens (usually listed as the tallest Mountain). The surface Temperature reached +110 °C or -160 °C.
Mons Agures, Mons Ampére, Mons Andre, Mons Blanc, Mons Hadley,
Moon Mountains – Ranges: Montes Agricoly, Montes Alpes, Montes Apenninnes, Montes Carpatus, Montes Caucasus, Montes Cordillera, Montes Jura, Montes Pyrenaeus, Montes Rook,
Geology (Selenology) of the Moon is very different of the Earth.
Moon doesn’t have any atmosphere and doesn’t have the significant volumes of water, which is connected with no erosion by the weather, and doesn’t have plate tectonics.

Keywords: Moon, Mantle, Crust, Core, Selenography, Moon’s highlands, mares craters, bazalts, anorthosite, regolith, soil, Apollo, Luna.

Content

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1. Highlights Pictures of Author

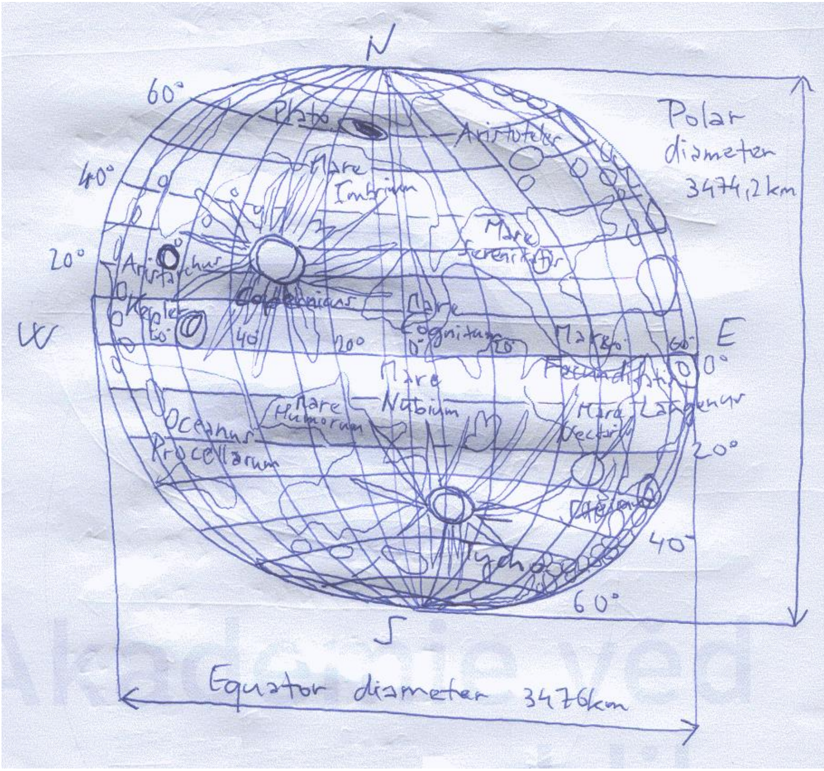

Fig. 1. Selenographic coordinates Near Side of the Moon.

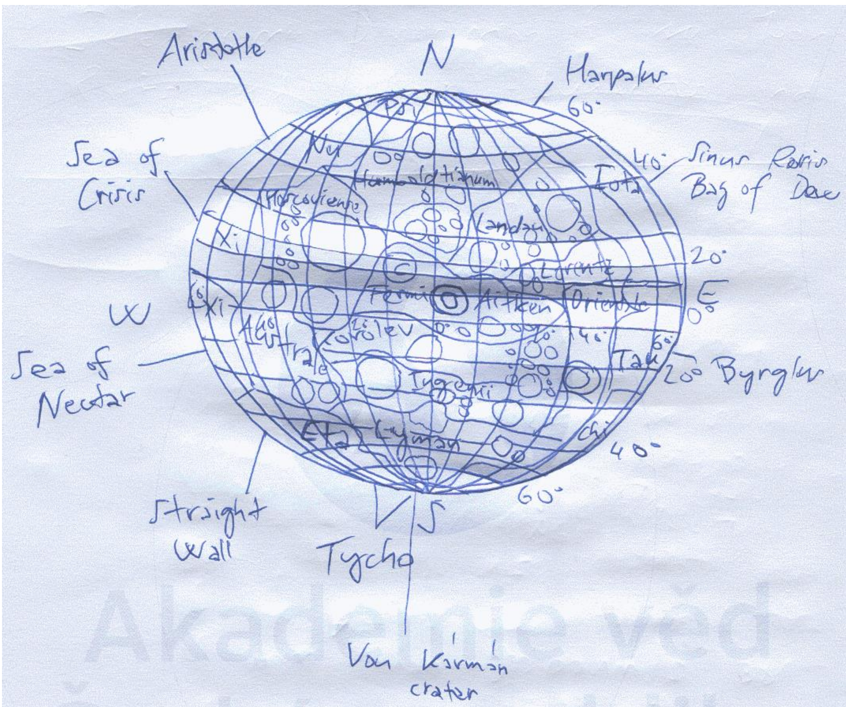

Fig. 2. Concise Map of Dark(far) Side of The Moon.

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Fig. 3. "Footprint" on Moon (Aldrin Boot Print on Moon) in the lunar soil at Tranquility Base (1 inch = 2,5 cm deep)
"ONE SMALL STEP FOR MAN AND ONE GIANT LEAP FOR MANKIND".
Apollo 11 astronaut Neil A. Armstrong left this bootprint in the lunar soil at Tranquility Base, July 20, 1969.

The impression, about 2.5 centimeters (1 inch) deep, demonstrate the finesses and cohesiveness of the lunar soil.

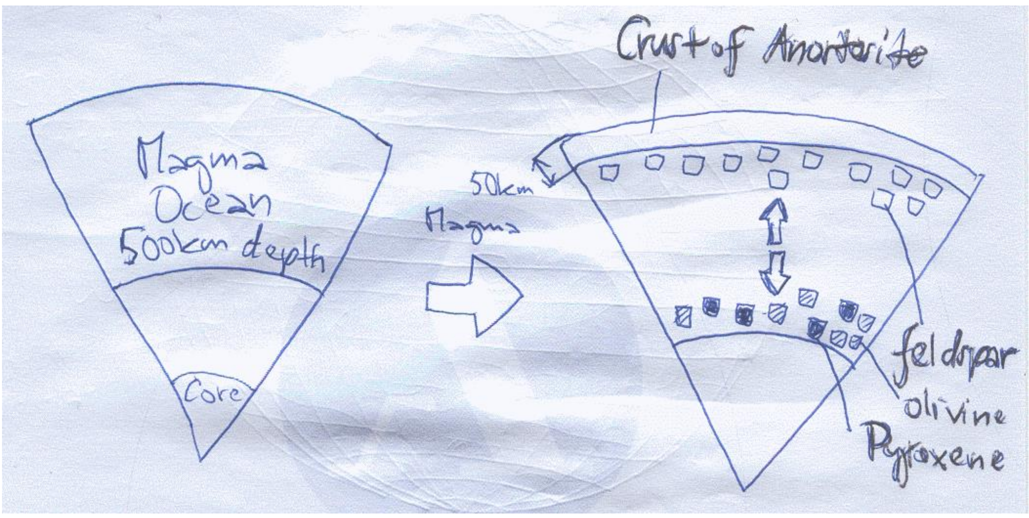

Fig. 4. Forming of Moon Crust.

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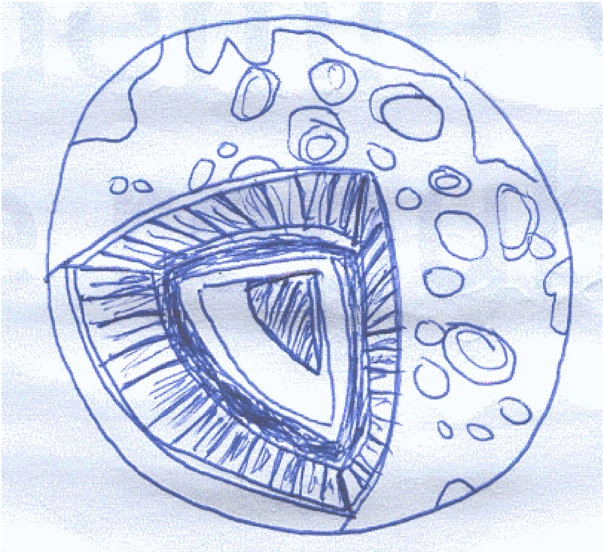

Fig. 5. Lunar Anorthosite Origin.

One explanation for the presence of anorthosite in the lunar crust is based on the assumption thar the Moon was once molten. As the Moon cooled, the lighter mineral floated toward the surface and formed anorthosite. The similar are the Rudice geodes in Moravian Karst.

2. Moon Mantle

Contemporary model's shows, that great part of Moon was dissolved. Models show, that to dissolution must going shortly after creation of Moon and maded magmatic ocean reached of depth approximately 500 km. How to magmatic ocean cold goes to crystallization. First minerals, which were created in this ocean were iron (ferric) and magnesium silicates olivine and pyroxene. Because these minerals had bigger density than dissolved material around them, falling to bottom and created Moon's Mantle.

After 75% crystallization was ending, begin creation less density anorthositic feldspar plagioklas. These on the surface floating and created anorthositic crust about thickness probably 50 km This crust was strongly in this time impacted by asteroids. Processing crystallization of magmatic ocean lead to difference of Moon's Mantle and Moon's Crust.

Major part of magmatic ocean crystallized fast (during approximately 100 million years or minor). Magma rich of KREEP was concentrated in Region Oceanus Procellarum and Imbrium Basin (Region, which created in Big part Mare Imbrium), these regions are nowdays completely called Procellarum KREEP Terrare.

3. Moon Crust

Moon's Crust is average thick approximately 50 km (± 15 km). On the far side of the Moon is probably stronger. Density of crust isn't everywhere identicaly, Basalts or LUNABAZES creating Moon's Mares have bigger denity than rocks building Moon's Mountains (Ranges). Above the places with increased density called "mascons" is stronger gravitational field than above the Mountains (Ranges).

The most occurated elements in Moon's Crust are Uranium, Thorium, Kalium, Silicium, Magnesium, Ferrum, Titanium, Calcium and Aluminium.

The Moon has inner differentialy structure, is possibly to resolve crust, Moon's Mantle and core. On the Earth was transported 381,7 kg of Moon Rocks and Minerals.

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The Moon has probalby the iron core with radius about 350 km. With creation of the Moon's connecetd Magmatic Ocean of the deep about 500 km.

How the magmatic ocean going colder crystalization. The First minerals, which were created in this ocean were iron (ferric) and magnesium silicates like olivine and pyroxene – these minerals have big density – going down and created Moon's mantle. Later created low densitz anorthoyoic feldspar plagioklases – made a anorthozoitic crust of thickness about 50 km.

4. Moon Core

Moon has probably iron (ferric) core, which has radius smaller than 350 km. No existence of own magnetic field around the Moon shows, that core will be whole solid.

Studies of vibration of Moon (small deviations from his rotation) by contrast shows, that Moon's Core is still yet liquid. Small Moon's core explained theory of Big Impact, which described, how was Moon created.

5. Sampling The Moon

Apollo astronauts had many tasks to perform during brief moonwalks. They erected scientific equipment, made precise observations of conditions on the lunar surface, and collected samples of the Moon's soil and rocks.

Specialized tools for collecting lunar samples were carried to the Moon in the descent stage of the Lunar Module. The tools are made of stainless steel and aluminium.

Selenographic Units made by Lunar Rocks

i) Moon Mare Rock BASALTS (LUNABAS) – MAFIC ROCKS, DARK ROCKS
Distribution of Basalt – Basalt is not distributed uniformly over the Moon. Nearly 26% of the near side of the Moon is basalt and only 2% of the far side is basalt. Most basalt in other hemisphere is found in the very large impact basins.
Basalt Flows
Distinct basalt flows overlap each other near a wrinkle ridge in Mare Imbrium. These lava flows are about 35 meters (115 feet) thick near their margins.
Apollo 15 Basalt
The dark, flat often circular regions called lunar maria (singular form: mare) are composed of the rock basalt (lunabas). This basalt sample was collected near the rim of Hadley Rille.
The fine–grained crystallicity and large holes indicate that this rock crystallized near the to of a molten lava flow. The grey color of this rock is due to the presence of dark–colored mineral.

ii) Moon Highland (Continent) Rocks Anorthosite – LUNARITE
The Lunar Highlands (Continets)
Regions of both the near side and the far side of the Moon not covered by mare basalt are called highlands.
The highlands consist of the ancient lunar surface rock, anorthosite, and materials thrown out during the creation of the impact basins.

iii) The Lunar Highlands (Continents) LIGHT ROCKS LUNARITES
Relatively young basins are shown in light colors, the oldest basins are in dark (mafic) colors.
ORIGIN OF ANORTHOSITE (LUNARIT)
The ancient crust of the Moon is believed to have been composed of the rocks, anorthosite, a calcium–rich and titan and argentum–rich white rock. This ancient crust has been smashed and redistributed by countless meteoric impacts.
One explanation for the presence of anorthosite in the lunar crust is based on the assumption that the moon was once molten.

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Plagioclase, a relatively light mineral, crystallized as the Moon cooled and solidified.
This mineral floated toward the surface and formed anorthosite. Heavier minerals sank and produced the denser interior of the Moon.
Anorthosite – igneous rocks, is one of species of gabro. Consist of baziofeldspar (anortit, bytovnit and labradorit) which made 90% – 100% of his volume. Rest part is 0% – 10% are mafic minerals (pyroxene, ilmenite, magnetite or olivine).
This rock is not only on the Earth, but also in other bodies of solar System for example on the Moon, where created light moon plains – moons highlands and ranges.
Apollo 16 Anorthosite
Anorthosite is an important rock type of the lunar highlands and probably formed the primitive lunar crust. This sample has been determined to be 4.19 billion years old by the Argon method of dating. This date corresponds to the formations of a large lunar impact basin.
Crater Lambert
This crater in Mare Imbrium, 32 kilometres (20 miles) in diameter, is surrounded by a blanket of material blasted out by the impact that produced the crater. Near the crater's rim the ejected material is thick and hilly. Farther away, the material is thinner and has a radial pattern.
Secondary Craters
Rocks thrown out during the formation of large impact craters often produce smaller, secondary craters when they fall back to the lunar surface.
The 1 – 3 meter (3 – 10 feet) secondary craters in the foreground of this picture have numerous rocks on their rims. These rocks were excavated from beneath the surface by the impacts from which the rock was thrown. Other studies indicate that the rock lay exposed on the lunar surface for 8.3 million years after it was moved again by the formation of Spook Crater).

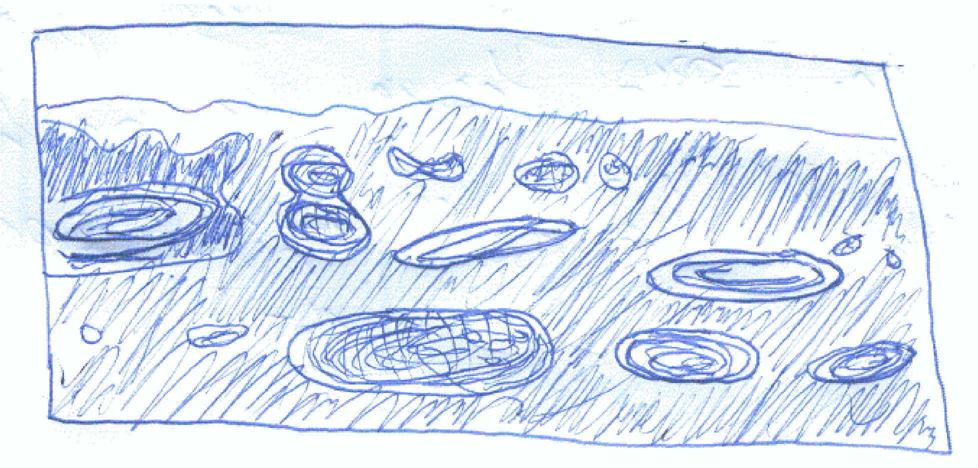

Fig. 6. Secondary Craters on Moon.

iv) Breccia: Shocked Metamorphosed Rocks

Lunar breccias are rocks produced by the smashing, melting, and mixing of the lunar surface materials by large and small meteoric impacts. Evidence of this process can be seen in the countless crates of various sizes which cover the Moon.

Crisium Basin

The Crisium basin, about 700 kilometers (430 miles) in diameter is one of many large circular lunar depressions. These basins or craters formed by the collisions of very large meteoroids with the Moon. After the impacts, basalts from the interior of the Moon welled up and partially filled the basins. Material thrown out by the impacts that produced the basins is spread widely over the Moon.

Zap Pit

Tiny impact craters, called "zap pits" are produced by small, high velocity particles and are common on the exposed faces of lunar rocks. This zap pit is 50 microns (2/1 000 inch) in diameter and has a raised rim of glassy material caused by the impact.

Breccia in Breccia

Some rock fragments found in breccias are pieces of more ancient breccias. Repeated impacts have smashed the older rock and refused it with more recently formed breccia. As many as four generations of breccia have been found in a single lunar rock.

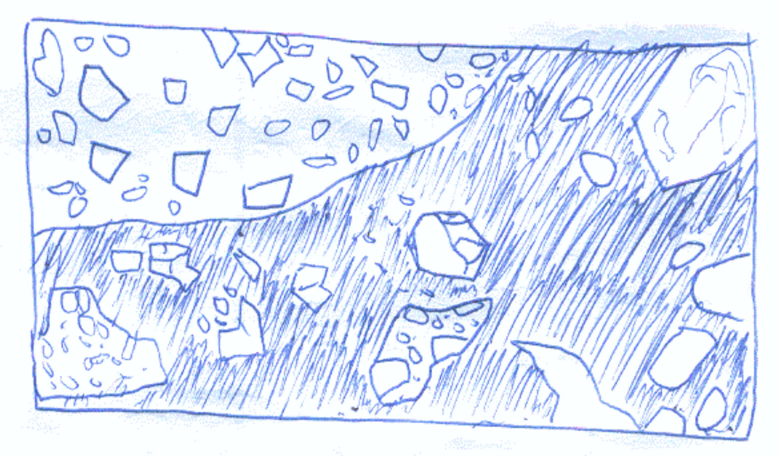

Fig. 7. Breccia in Breccia (Lunar Rocks).

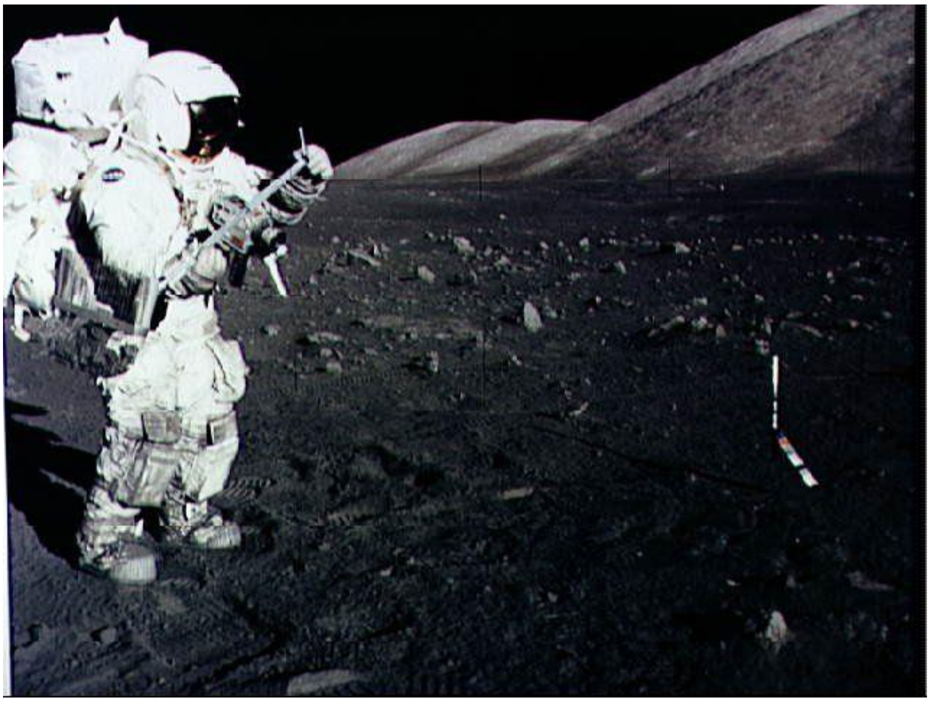

Fig. 8. The Scientist on The Moon, Harrison Schmitt (Apollo 17) near the rock in the valley Taurus–Littrow (1972). (The first geologist on The Moon).

Granulation

A common feature of many lunar crystalline rocks is the grinding and crushing, or granulation, of their minerals caused by repeated meteoric bombardment. This makes the original textures difficult to recognize.

Shock Melting

A glassy material produced by the shock of a meteoric impact coats this rock fragment from an Apollo 11 breccia sample. Since, the glass is not uniform in composition, it strongly indicates that the glass was formed by shock.

The ellipsoidal lunar glass particle contains numerous tiny spheres of nickel – iron. These metallic spheres are meteoric in origin and indicate that the glassy particle was produced by shock melting during a meteoric impact.

Apollo 17 Breccia
Lunar Breccias are fragmental rocks which are the products of meteoroid impacts. This ample is a type called lithified mature soil. The sample consist of fragments of glass, minerals, and rock cemented together in a glassy matrix.
The materials which compose this sample have been determined to be 4.53 billion years old by the Rubidium – Strontium method of dating.

Soil: The Surface Layer
The Surveyor probe landed on the Moon before any humans had. It bounced upon landing, leaving the footprint. Television images of the footprint were transmitted to Earth, showing us that men would be able to move without sinking deep into the soil.

Lunar Roving Vehicle Tracks
The lunar roving vehicle, driven by astronauts on the Moon left these tracks. Studies of the wheels' performance and the tracks they left have improved understanding of the mechanical properties of lunar soil.VV

v) LUNAR SOIL (REGOLITH, SURFACE LAYER)

ORANGE SOIL
Apollo 17 astronauts discovered an area of orange soil on the rim of Shorty Crater, in the Valley of Taurus – Littrow. A trench was dug to obtain samples of the material. Subsequent study of the orange soil indicates that it was formed during volcanic eruptions 3.7 billion years ago.

SOIL PARTICLES
Lunar soil contains fragments of the major lunar rock types: basalt (lunabaz) (A), anorthosite (lunarit) (B), and breccia (C). In addition round glass particles (D) are common.
The fragments that make up lunar soil are the products of the ceaseless bombardment of the Moon by meteoroids which smash and grind rocks into soil and weld soil into new rocks.

SOIL TEXTURE
The texture of undisturbed lunar soil can be seen in this close–up photograph, which shows the soil enlarged about 35 times. This soil is composed of aggregates, clumps of small particles 0.1 – 0.6 millimeters (4/1 000 – 24/1 000 inch) in diameter.

GREEN GLASS
MOST LUNAR GLASSY MATERIALS WERE CREATED BY THE SHOCK OF METEOROID IMPACTS. HOWEVER, THE GREEN GLASS PARTICLES SHOWN HERE PROBABLY HAD A DIFFERENT ORIGIN. THE UNIFORMITY OF THEIR SIZE AND COMPOSITION SUGGESTS THAT THEY WERE FORMED IN LAVA FOUNTAIN ERUPTIONS.

ORANGE GLASS
ORANGE GLASS SPHERES, LIKE THE GREEN GLASS SPHERES, ORIGINATED IN LAVA FOUNTAINS. THE GLASS IN THE SPHERES SHOWN HERE HAS BEGUN TO CRYSTALLIZE INTO DARK, NEEDLELIKE CRYSTALS.

APOLLO 17 SOIL
LUNAR SOIL CONSISTS OF PARTICLES OF MANY SIZES. HERE INDIVIDUAL PARTICLES LESS THAN 1 MILLIMETER (4/100 inch) have been picked from the bulk soil and segregated by type.

COMMON CHONDRITIC ORIGIN OF THE MOON AND THE EARTH
TITANIUM ISOTOPES ARE POTENTIAL TRACERS OF PROCESSES OF EVAPORATION/CONDENSATION IN SOLAR NEBULA AND MAGMATIC DIFFERENTIATION IN PLANETARY BODIES.
TO GAIN NEW INSIGHTS INTO THE PROCESSES THAT CONTROL Ti (Titanium) isotopic variation in PLANETARY MATERIALS, 25 KOMATIITES, 15 CHONDRITES, 11 HED-clan meteorites, 5 angrites,

6 aubrites, a martian shergottite, and a KREEP–rich impact melt breccia have been analyzed for their mass–dependent Ti isotopis compositions.
Presented using the δ^{49}Ti notation (deviation in permil of the ^{49}Ti / ^{47}Ti ratio relative to the OL–Ti standard). No significant variation in δ^{49}Ti is found among ordinary, enstatite, and carbonaceous chondrites, and the average chondritic δ^{49}Ti value of +0.004±0.010‰ is excellent agreement with the published estimate for the bulk silicate Earth, the Moon, Mars and the HED and angrite parent – bodies. The average δ^{49}Ti value of komatiites of -0.001±0.019‰ is also identical to that of the bulk silicate Earth and chondrites.
OL–Ti has a Ti isotopic composition that is indistinguishable from chondrites and is therefore a suitable material for reporting δ^{49}Ti values. Previously published isotope data on another highly refractory element, Ca (Calcium), show measurable variations among chondrites. The decoupling between Ca and Ti isotope systematics most likely occurred during condensation in the solar nebula.
Aubrites exhibit significant variations in δ^{49}Ti, from -0.07 to +0.24‰. This is likely due to the uniquely reducing conditions under which the aubrite parent–body differentiated, allowing chalcophile Ti^{3+} and lithopile Ti^{4+} to co–exist.
Consequently, the observed negative correlation between δ^{49}Ti values and MgO concentrations among aubrites is interpreted to be the result of isotope fractionation driven by the different oxidation states of Ti in this environment, such that isotopically heavy Ti^{4+} was concentrated in the residual liquid during magmatic differentiation.
Finally, KREEPy impact melt breccia SaU 169 exhibits a heavy δ^{49}Ti value of +0.33±0.034‰ which is interpreted to result from Ti isotopic fractionation during ilmenite precipitation in the late stages of lunar magma ocean crystallization. A Rayleigh distillation calculation predicts that a δ^{49}Ti value of +0.330‰ is achieved after removal of 94% of Ti in ilmenite

6. Main Rockforming Minerals of Moon

LUNAR ROCKS
OLIVINE, PYROXENE, PLAGIOCLASE FELDSPAR

SILICATES: ZIRKON (URANOTHORIT), ANORTHOSITE, Uh, Th, $ZrSiO_4$ – URANOTHORIT, PYROXFERROITE,GARNETS, TRANQUILLITYITE
Plagioclase feldspar is mostly found in the lunar crust, whereas pyroxene and olivine are typically seen in the lunar mantle. New minerals like tranquillityite or armalcolite were found initially in moon rocks.

OXIDES: ILMENITE, SPINELS, ARMALCOLITE, CHROMITE

SULPHIDES: TROILITE

NATIVE METALS: NATIVE IRON

OTHER SILICATES: QUARTZ, TRIDYMITE, CRISTOBALITE

Phosphates: Apatite, Whitlockite

Meteoric minerals of origin: Cohenite, Mningérite, Lawrencite

OLIVINES (INSIDE BASALTS): FORSTERITE+FAYALITE

Clinopyroxene: Augit, pigeonite

Plagioclase – enriched in potassium (K), in rare earth (= RARE EARTH ELEMENT OR REE) and in phosphore (P) for which the name KREEP!

High pressure silica polymorph: coesite, stishovite.

Quartz was found in felsitic clast in crystals having a needle shape (tridymite crystals). Quartz was also found in few rare lunar granite samples.

Pyroxferroite – equivalent of terrestrial pyroxmangite $(Mn,Fe)SiO_3$

Oxides – the pseudobrookite group or "armalcolite group", PSEUDOBROOKITE (Fe_2TiO_5) FERROPSEUDOBROOKITE ($FeTiO_5$), ARMALCOLITE ($Mg0,5\ Fe0,5\ TiO_5$), CHROMITE, SPINELS.

Comment: KOMATIITES – ultramafic effusive rock, characteristic MgO high of Magnesium (Mg), characteristic for pillow lavas → MgO, Olivine, Pyroxene named according typic locality near the river Komati in South Africa, Ontario, Canada.
Main minerals: olivine, pyroxene, anortite, axcesories chromit.
Typically sign is – similar Australia grass spinifex.

7. Study of The Moon

Lunochod (1969 – 1977)

Apollo (1969 – 1972) which returned 380,96 kg (839,9 lb) of lunar rock and lunar soil to Earth.

Soviet Luna spacecraft returned another 326 grams (11,5 oz) from 1970 – 1976.

Elemental composition of Moon body
oxygen (O), silicon (Si), iron (Fe), magnesium (Mg), calcium (Ca), aluminium (Al), manganese (Mn) ant Titanium (Ti), Carbon (C), and nitrogen (N).

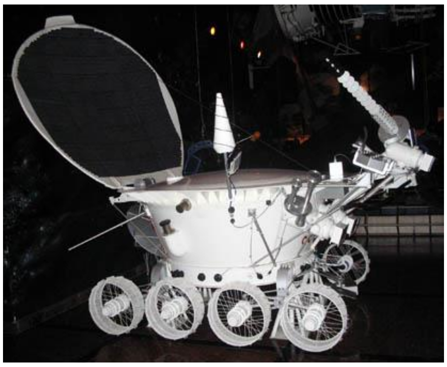

Fig. 9. Lunochod 2 (Source:Wikipedie)

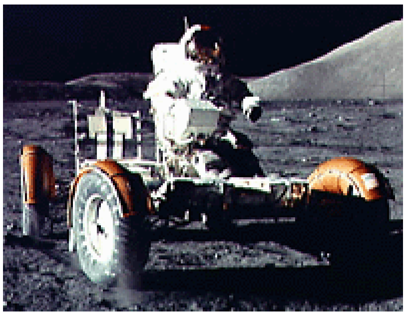

Fig. 10. The Apollo Lunar Rover (from nssdc.gsfc.nasa.gov)

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8. Retroreflectors on Moon

Are devices which reflect light back to it's source. Five were left at five sites on the Moon by three crews of the Apollo program and two remote landers of the Lunokhod program. Lunar reflectors have enabled precise measurement of the Earth–Moon distance since 1969.

LUNAR LASER RANGING EXPERIMENT OR APOLLO LANDING MIRROR

Principle: Laser light pulses are transmitted and reflected back to Earth, and the round–trip duration is measured.

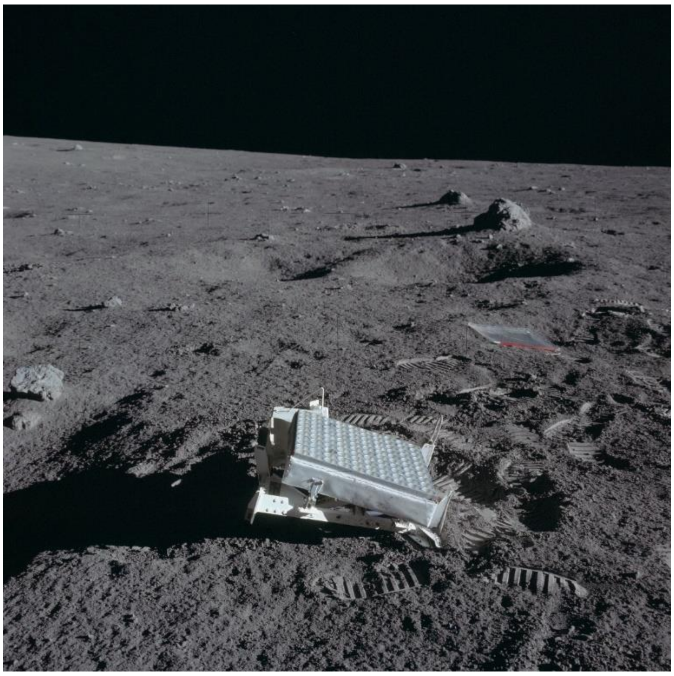

Fig. 11. Apollo 14 Lunar Ranging Retro Reflector (LRRR).

Artemis Project – program for Terraforming The Moon

ISS
with speed 7,66 km/s,
408 km above Earth,
max. speed: 27 600 km/h.

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