LUNAR GEOLOGY: AN OVERVIEW

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Abstract- I would like to begin with elaborated version of SPACE w.r.t Remote Sensing as-

S`atellites are there to orbit our planet

P`lacing igneous, metamorphic and igneous structures and that too with worth.

A`steroids are having comets covering spatial space trail, planet Mars is fourth to Earth.

C`elestial with extra-terrestrial satellite data so equidistant with Lunar Geology, being distant yet near, its' kind of natural rebirth of mother of all man-made satellites.

E`cology related issues are there in Selene too, dealing with the same, resolving and improving as the mother of our geographical setup 'Pangaea' will soon be replaced by 'Amasia'.

Keywords-

Selenology[1], Geology[2], Space[3], Craters[4,] Moon Minerals[5], Rocks[6]

INTRODUCTION-

Describing space geology as like from space, we are having a proof by imageries. Via satellite data that our earth is oblate spheroid with remote/urban/rural setup with their Land Use Land Cover, Land Surface temperature, Sea Surface temperature, Chlorophyll account, Normalized difference Vegetation index and so on. Its' actually not distant but nearby only. Just by clicking few buttons on SOFTWARES like GEOFACET, ARCGIS, MATLAB, GRADS and so on, too with the help from space agencies like NASA, NOAA, INCOIS, GSI, SAC IIRS NRSC of ISRO etc., we can see what all is happening on our planet, not confined to earth only, but too to Moon, Mars, outer space etc.

Geology from space is near only if we compare it with ground field view. Just few clicks and your job done.

MOON is known as CHANDRA in SANSKRIT & ROCK as SHILA!

Estimated AGE of EARTH is about 4.543 billion years and of MOON, it is about 4.530 billion years. The first important event in the geologic evolution of the Moon was the crystallization of the near GLOBAL MAGMA ocean. It is not known with certainty what its depth was, but several studies imply a depth of about 500 km or greater. The first minerals to form in this ocean were the iron and magnesium silicates of olivine and pyroxene. Because these minerals were denser than the molten material around them, they sank. After crystallization was about 75 percent complete, less dense Anorthosite plagioclase feldspar crystallized and floated, forming an anorthosite crust about 50 km in thickness. The majority of the magma ocean crystallized quickly (within 100 million years or less), though the final remaining KREEP- rich magma's where-

KREEP stands for: K- Potassium, REE- Rare Earth Elements and P- Phosphorus, which are highly enriched incompatible and heat producing elements, could have remained partially molten for several hundred (or perhaps one billion) years. It appears that the final KREEP- rich magmas of the magma ocean eventually became concentrated within the region of

OCEANUS PROCELLARUM and the IMBRIUM BASIN, a unique geologic province that is now known as the PROCELLARUM KREEP Terrane. Quickly after the lunar crust formed, or even as it was forming, different types of magmas that would give rise to the Mg-suite norites and troctolites began to form, although the exact depths at which this occurred are not known precisely. Recent theories suggest that Mg-suite plutonism was largely confined to the region of the PROCELLARUM KREEP Terrane, and that these magmas are genetically related to KREEP in some manner, though their origin is still highly debated in the scientific community. The oldest of the Mg-suite rocks have crystallization ages of about 3.85 Ga (Giga Annum). However, the last large impact that could have excavated deep into the crust (THE IMBRIUM BASIN) also occurred at 3.85 Ga before present. Thus, it seems probable that Mg-suite plutonic activity continued for a much longer time and that younger plutonic rocks exist deep below the surface. Analysis of the lunar samples seems to imply that a significant percentage of the lunar impact basins formed within a very short period of time between 4 and 3.85 Ga ago. This hypothesis is referred to as THE LUNAR CATACLYSM OR LATE HEAVY BOMBARDMENT. However, it is now recognized that ejecta from the IMBRIUM IMPACT BASIN (one of the youngest large impact basins on the Moon) should be found at all of the Apollo landing sites. It is thus possible that ages for some impact basins (in particular MARE NECTARIS) could have been mistakably assigned the same age as IMBRIUM. The LUNAR MARIA represent ancient flood basaltic eruptions. In comparison to terrestrial lavas, these contain higher iron abundances, have low viscosities, and some contain highly elevated abundances of the titanium rich mineral ILMENITE. The majority of basaltic eruptions occurred between 3 and 3.5 Ga ago, though some mare samples have ages as old as 4.2 Ga, and the youngest (based on the method of crater counting) are believed to have erupted only one billion years ago. Along with mare volcanism came pyroclastic eruptions, which launched molten basaltic materials hundreds of kilometres away from the volcano. A large portion of the mare formed, or flowed into the low elevations associated with the nearside impact basins. However, OCEANUS PROCELLARUM does not correspond to any known impact structure, and the lowest elevations of the MOON within the far side South Pole- AITKEN BASIN are only mostly covered by MARE. The word CRATER was adopted by GALILEO GALILEI first from the Greek word for VESSEL. Galileo built his first telescope in late 1609, and turned it to the Moon for the first time on November 30, 1609. He discovered that, contrary to general opinion at that time, the Moon was not a perfect sphere, but had both mountains and cup like depressions, the latter of which he gave the name CRATERS. Scientific opinion as to the origin of craters swung back and forth over the ensuing centuries.

The competing theories were-

1. VOLCANIC ERUPTIONS BLASTING HOLES IN THE MOON
2. METEORIC IMPACT
3. A THEORY KNOWN AS THE WELTEISLEHRE DEVELOPED IN GERMANY BETWEEN THE TWO WORLD WARSWHICH SUGGESTED GLACIAL ACTION CREATING THE CRATERS.
   Evidence collected during the Apollo Project and from unmanned spacecraft of the same period proved conclusively that meteoric impact, or impact by asteroids for larger craters, was the origin of almost all lunar craters, and by implication, most craters on other bodies as well. The formation of new craters is studied in the lunar impact monitoring program at NASA. The biggest recorded creation was caused by an impact recorded on March 17, 2013. The explosion, which was visible with the naked eye is believed to be from an approximately 40kg meteoroid hitting the Moon with a speed of 90000 km/h.

LUNAR TIME SCALE:

SYSTEM	EVENTS
COPERNICAN	YOUNG RAY CRATERS (younger than about one billion years)
ERATOSTHENIAN	OLDER POST-MARE-CRATERS (about 1-3 billion years)
IMBRIAN	MAIN MARE BASALT FLOODING, PRECEDED BY FORMATION OF THE IMBRIUM & ORENTALE BASINS (3-3.85 billion years)
PRE –IMBRIAN: NECTARIAN	FORMATION OF 11 MAJOR IMPACT BASINS PRECEDED BY THE NECTARIS BASIN (3.85-3.92 billion years)
PRE-NECTARIAN	FORMATION OF ABOUT 30 IMPACT BASINS PRECEDED BY THE PROCELLARUM BASIN (before 3.92-4.2? billion years)

LUNAR SOIL- It is the fine fraction of the regolith found on the surface of the Moon. Its properties can differ significantly from those of terrestrial soil. The physical properties of lunar soil are primarily the result of mechanical disintegration of BASALTIC and ANORTHOSITIC ROCK, caused by continuous meteoric impact and bombardment by interstellar charged atomic particles over billions of years. The process is largely one of the mechanical weathering in which the particles are ground to finer and finer size over time. This situation contrasts fundamentally to terrestrial soil formation, mediated by the presence of molecular oxygen (O_2), humidity, atmospheric wind, and a robust array of contributing biological processes. Some have argued that the term "SOIL" is not correct in reference to the Moon because on the Earth, soil is defined as having organic content, whereas the moon has none. However, standard usage among lunar scientists like Dr MAMTA CHAUHAN from IIRS, ISRO and others is to ignore that distinction. The term LUNAR SOIL is often used interchangeably with "LUNAR REGOLITH" but typically refers to only the finer fraction of regolith, that is composed of grains of one centimeter in diameter or less. Lunar dust generally connotes even finer materials than lunar soil. There is no official definition of what size fraction constitutes "dust", some place the cut off at less than 50 micrometers in diameter, others at less than 10.

SOIL FORMATION PROCESSES-

The major processes involved in the formation of lunar soil are- COMMINUTION: Mechanical breaking of rocks and minerals into smaller particles by meteorite and micrometeorite impact;

AGGLUTINATION: Welding of mineral and rock fragments together by micrometeorite-impact-produced-glass.

SOLAR WIND SPALLATION AND IMPLANTATION: Sputtering caused by impacts of ions and high energy particles. These processes not only form lunar soil, they also continue to change the physical and optical properties of the soil over time, this process is known as SPACE WEATHERING. In addition, fire fountaining, whereby volcanic lava is lofted and cools into small glass beads before falling back to the surface, can create small but important deposits in some locations, such as the ORANGE SOIL found at SHORTY CRATER in the TAURUS_LITTROW VALLEY by APOLLO 17, and the GREEN GLASS found at HADLEY_APENNINE by APOLLO 15. Deposits of volcanic beads are also thought to be the origin of DARK MANTLE DEPOSITS (DMD) in other locations around the MOON.

MINERALOGY and COMPOSITION-

Lunar soil is composed of various types of particles including rock fragments, MONO-MINERALIC FRAGMENTS, and various kind of glasses including agglutinate particles and volcanic and impact spherules. The agglutinates form at the lunar surface by micrometeorite impacts that cause small- scale melting which fuses adjacent materials together with tiny specks of metallic iron (Fe0) embedded in each dust particle's glassy shell. Over time, material is mixed with both vertically and horizontally (a process known as "gardening") by impact processes. However, the contribution of material from great distances is relatively minor, such that the soil composition at any given location largely reflects the local bedrock composition. There are two profound differences in the chemistry of LUNAR REGOLITH and SOIL from terrestrial materials. The first is that the Moon is very dry. As a result, those minerals with water as part of their structure such as CLAY, MICA, and AMPHIBOLES are totally absent from the Moon. The second difference is that LUNAR REGOLITH and CRUST are chemically reduced, rather than being significantly oxidized like the Earth's crust. In the case of REGOLITH, this is due in part to the constant bombardment of the lunar surface with protons (i.e., Hydrogen (H) nuclei) from the solar wind. One consequence is that Iron on the Moon is found in the metallic 0 and +2 oxidation state, whereas on Earth iron is found primarily in the +2 and +3 oxidation state.

PROPERTIES-

The significance of acquiring knowledge of lunar soil properties is amazing in its own. The potential for construction of structures, ground transportation networks, and waste disposal systems, to name a few examples, will depend on real-world experimental data obtained from testing lunar soil samples. The load carrying capability of the soil is an important parameter in the design of such structures on Earth. Due to myriad meteorite impacts (with velocities in the range of 20 km/s), the lunar surface is covered with a thin layer of dust. The dust is electrically charged and sticks to any surface it

comes in contact with. The soil becomes very dense beneath the top layer of REGOLITH. Other factors which may affect the properties of lunar soil include large temperature differentials, the presence of a hard vacuum, and the absence of a significant lunar magnetic field (thereby allowing charged solar wind particles to continuously hit the surface of the moon).

MOON DUST FOUNTAINS AND ELECTROSTATIC LEVITATION-

There is little evidence that the Moon may have a tenuous atmosphere of moving dust particles constantly leaping up from and falling back to the Moon's surface, giving rise to a "dust atmosphere" that looks static but is composed of dust particles in constant motion. The term "Moon Fountain" has been used to describe this effect by analogy with the stream of molecules of water in a fountain following a ballistic trajectory while appearing static due to the constancy of the stream. According to a model proposed in 2005 by the Laboratory for Extra-terrestrial Physics at NASA's Goddard Space Flight Centre, this is caused by electrostatic levitation. On the daylit side of the Moon, solar ultraviolet and X-ray radiation is energetic enough to knock electrons out of atoms and molecules in the lunar soil. Positive charges build up until the tiniest particles of lunar dust (measuring one micrometre and smaller) are repelled from the surface and lofted anywhere from metres to kilometres high, with the smallest particles reaching the highest altitudes. Eventually they fall back towards the surface where the process is repeated. On the night side, the dust is negatively charged by electrons in the solar wind. Indeed, the fountain model suggests that the night side would charge up to higher voltages than the day side, possibly launching dust particles to higher velocities and altitudes. This effect could be further enhanced during the portion of the Moon's orbit where it passes through Earth's magnetotail "Magnetic field of the Moon". On the terminator, there could be significant horizontal electric fields forming between the day and night areas, resulting in horizontal dust transport- a form of "MOON STORM". This effect was anticipated in 1956 by SCIENCE FICTION author HAL CLEMENT in his short story "DUST RAG", published in Astounding Science Fiction.

MOON ROCK FEATURES- MINERAL COMPOSITION OF HIGHLAND ROCKS:

	PLAGIOCLASE	PYROXENE	OLIVINE	ILMENITE
ANORTHOSITE	90%	5%	5%	0%
NORITE	60%	35%	5%	0%
TROCTOLITE	60%	5%	35%	0%

MINERAL COMPOSITION OF MARE BASALTS-

	PLAGIOCLASE	PYROXENE	OLIVINE	ILMENITE
HIGH TITANIUM CONTENT	30%	54%	3%	18%
LOW TITANIUM CONTENT	30%	60%	5%	5%
VERY LOW TITANIUM CONTENT	35%	55%	8%	2%

COMMOM LUNAR MINERALS-

MINERAL	ELEMENTS	LUNAR-ROCK APPEARANCE
PLAGIOCLASE FELDSPAR	CALCIUM(Ca)	LUNAR-ROCK-APPEARANCE, WHITE TO TRANSPARENT GRAY, USUALLY AS ELONGATED -GRAINS
	ALUMINIUM(Al)	
	SILICON(Si)	
	OXYGEN(O)	
PYROXENE	IRON(Fe)	MARRON TO BLACK, THE GRAINS APPEAR MORE ELONGATED IN THE MARIA & MORE-SQUARE IN THE HIGHLANDS
	MAGNESIUM(Mg)	
	CALCIUM(Ca)	
	SILICON(Si)	
	OXYGEN(O)	
OLIVINE	IRON(Fe)	GREENISH-COLOR, GENERALLY, IT APPEARS IN A ROUNDED SHAPE
	MAGNESIUM(Mg)	
	SILICON(Si)	
	OXYGEN(O)	
ILMENITE	IRON(Fe)	BLACK-ELONGATED SQUARE CRYSTALS
	TITANIUM (Ti)	
	OXYGEN(O)	

PRESENT AVAILABILITY-

The Apollo astronauts brought back some 360 kilograms (800 pounds) of lunar rocks from six landing sites. Although this material has been isolated in vacuum packed bottles, it is now unusable for detailed chemical or mechanical analysis- the gritty particles deteriorated the knife-edge indium seals of the vacuum bottles; air has slowly leaked in. Every sample brought back from the moon has been contaminated by Earth's air and humidity. The dust has acquired a patina of rust, and, as a result of bonding with terrestrial water and oxygen molecules, its chemical reactivity is long gone. The chemical and electrostatic properties of the soil no longer match what future astronauts will encounter on the moon. Moon dust contaminated items finally became available to the public in 2014, when the US government approved the sale of private material owned, and collected by astronauts. Since than only one item has been produced for sale with genuine moon dust collected after the item spent over 32 hours on the moon. A luggage strap, exposed to the elements of the moon for 32 hours, a piece of Charles Pete Conrad's Spacesuit on the Apollo 12 mission was sold by his estate to a private purchaser at auction. While many jewelry and watch makers claim their product contains "MOON DUST", the products only contain pieces of, or dust from meteorites believed to have originated from the Moon.

Nowadays, distributors and gemstone consumers claim that they have MOONSTONE or SUNSTONE or AMAZONITE necklaces/ rings / ear rings etc.

Too, i was able to purchase an acre of land on Moon for my husband on the region called THE SEA OF CLOUDS on July 17, 2021 from THE LUNAR REGISTRY that proclaims the deed property agreement and other such documents. Yes, its real. As because i am MOON lover since childhood, attended PLANETARY DEFENCE CONFERENCE from UNITED NATIONS and other such webinars, used to research about MOON a lot, even used to make MOON shaped cakes, deserts, snacks in eatables, therefore was able to make the effort.

Proof of my passion-

LIST OF TALLEST MOUNTAINS OF EARTH & MOON-

EARTH:

TALLEST PEAK/s	HEIGHT	RADIUS	ORIGIN	REMARK/s
MAUNA KEA & MAUNA LOA	10.2km	O.16	VOLCANIC	JUST 4.2km OF THIS IS ABOVE SEA LEVEL
PICODEL TEIDE	7.5km	0.12	VOLCANIC	RISES 3.7km ABOVE SEA LEVEL
DENALI	5.3 to 5.9km	0.093	TECTONIC	TALLEST MOUNTAIN BASE TO PEAK ON LAND
MOUNT EVEREST	3.6 to 4.6km	0.072	TECTONIC	4.6km ON NORTH FACE, 3.6km ON SOUTH FACE

MOON:

TALLEST PEAK/s	HEIGHT	RADIUS	ORIGIN	REMARK/s
MONS HUYGENS	5.5km	0.32	IMPACT	FORMED BY THE IMBRIUM IMPACT
MONS HADLEY	4.5km	0.26	IMPACT	FORMED BY THE IMBRIUM IMPACT
MONS RUMKER	1.1km	0.063	VOLCANIC	LARGEST VOLCANIC CONSTRUCT ON THE MOON

FAR SIDE OF THE MOON-

The far side of the moon is the hemisphere of the moon that always faces away from the Earth. The far side's terrain is rugged, with a multitude of impact craters and relatively few flat lunar maria. It has one of the largest craters in the Solar System, the South Pole Aitken Basin. Although both sides of the moon experience two weeks of sunlight followed by two weeks of night, the far side is also referred to as the dark side of the Moon, originally in the sense of "unknown" rather than lack of light. About eighteen percent of the far side is occasionally visible from Earth due to LIBRATION. The remaining eighty two percent remained unobserved until 1959, when the Soviet Union's Luna 3 space probe photographed it. The Soviet Academy of Sciences published the first atlas of the far side in 1960. In 1968, the Apollo 8 mission's astronauts were the first humans to view this region directly when they orbited the Moon. To date, no human being has ever stood on the surface of the far side of the moon. Astronomers have suggested installing a large radio telescope on the far side, where the moon would shield it from possible radio interference from Earth. Tidal forces from earth have slowed down the Moon's rotation so that the same side is always facing the earth, a phenomenon called tidal locking. The other face, most of which is never visible from the earth, is therefore called the far side of the moon. Over time, some parts of the far side can be seen due to LIBRATION. In total, fifty nine percent of the Moon's surface is visible from Earth at one time or another. Useful observation of the parts of the far side of the moon occasionally visible from earth is difficult because of the low viewing angle from earth (they cannot be observed "full on"). The idiomatic phrase "dark side of the moon" does not refer to dark as in the absence of light, but rather as the unknown (as with Africa called the dark continent), as until humans were able to send spacecraft around the moon, this area had never been seen. While many misconstrue this to think that the dark side receives little to no sunlight, in reality, both the near and far sides receive (on average) almost equal amounts of light directly from the Sun. However, the near side also receives sunlight reflected from the Earth, known as EARTHSHINE. Earthshine does not reach the area of the far side which cannot be seen from earth. Only during a full moon (as viewed from Earth) is the whole far side of the Moon dark. The word "dark" has expanded to also refer to the fact that communication with spacecraft can be blocked while on the far side of the moon, during Apollo mission for example.

MOON & EARTH FACT SHEET-

PROPERTY	EARTH	MOON	BRAIN BUSTERS
EQUATORIAL DIAMETER	12,756km	3,476km	How long would it take to drive around the Moon's equator at 80Km per hour?
SURFACE AREA	510 million square km	37.8 million square km	The Moon's surface area is similar to that of one of Earth's continents. Which one?
MASS	5.98*10^24kg	7.35*10^22kg	What percentage of Earth's mass is the Moon's mass?
VOLUME	-	-	Can you calculate the volume of Earth & the Moon?
DENSITY	5.52 grams per cubic cm	3.34 grams per cubic cm	Check this by calculating the density from the mass & volume.
SURFACE GRAVITY	9.8m/sec	1.63m/sec	What fraction of Earth's gravity is the Moon's gravity?
CRUST	Silicate rocks, continents dominated by granites, ocean crust dominated by	Silicate rocks, highlands dominated by feldspar-rich rocks & maria basalt	What portion of each body is crust?

	basalt		
MANTLE	Silicate rocks dominated by minerals containing iron & magnesium	Similar to Earth	Collect some silicate rocks & determine the density. Is the density greater or lesser than the Earth's /Moon's density? Why?
CORE	Iron, Nickel metal	Same, but core is much smaller	What portion of each body is Core?
SEDIMENT or REGOLITH	Silicon and Oxygen bound in minerals that contain water, plus organic materials	Silicon and oxygen bound in minerals, glass produced by meteorite impacts, small-amount of gases (example-hydrogen) implanted by the solar wind. No water or organic materials.	Do you think life ever existed on the Moon? Why or Why not?
ATMOSPHERE (main constituents)	78% Nitrogen 21% Oxygen	Basically none. Some carbon gases (CO_2, CO and Methane), but very little of them. Pressure is about one-trillionth of Earth's atmospheric pressure.	Could you breathe the lunar atmosphere?
LENGTH OF THE DAY (Sidereal rotation period)	23.93 hours	27.3 Earth days	How long does daylight last on the Moon?
SURFACE TEMPERATURE	Air temperature ranges from -88'C(Winter in polar regions) to 58'C(summer in tropical regions)	Surface temperature ranges from -193'C (night in polar regions) to 111'C (day in equatorial regions)	Why are the temperatures of EARTH & the MOON so different?
SURFACE FEATURES	25%-land (7 continents) with varied terrain of mountains, plains, river valleys. Ocean floor characterized by mountains & plains	84% heavily- cratered highlands. 16% basalt-covered maria. Impact craters – some with bright rays, crater chains and rilles	Compare maps of EARTH and MOON. Is there any evidence that plate tectonics operated on the Moon?

CONCLUSION-

Selene has around 30,000 craters like Copernicus, Tycho, Wood, Shackleton and so on out of which some are visible from naked eyes while some are in its farthest side. Mons Huygens is its tallest peak (5.5km) which was formed by IMBRIUM IMPACTION containing maximum concentration of ANORTHOSITE ROCKS along with NORITES and TROCTOLITES.

High TITANIUM content is found in PYROXENE and PLAGIOCLASE. LUNAR minerals namely PLAGIOCLASE FELDSPAR, PYROXENE, OLIVINE and ILEMENITE are having CALCIUM, ALUMINIUM, SILICON, OXYGEN, MAGNESIUM, TITANIUM and IRON content like ROCKS/ GEOLOGY of our PLANET "EARTH".

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