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The Moon is Earth's only natural satellite and the fifth largest satellite in the Solar System. The average centre-to-centre distance from the Earth to the Moon is 384,403 kilometres (238,857 mi), about thirty times the diameter of the Earth. The common centre of mass of the system (the barycentre) is located at about 1,700 kilometres (1,100 mi)—a quarter the Earth's radius—beneath the surface of the Earth. The Moon makes a complete orbit around the Earth every 27.3 days[nb 3] (the orbital period), and the periodic variations in the geometry of the Earth–Moon–Sun system are responsible for the phases of the Moon, which repeat every 29.5 days[nb 4] (the synodic period).

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The Moon is the only celestial body on which human beings have made a manned landing. While the Soviet Union's Luna programme was the first to reach the Moon with unmanned spacecraft, the NASA Apollo program achieved the only manned missions to date, beginning with the first manned lunar mission by Apollo 8 in 1968, and six manned lunar landings between 1969 and 1972 – the first being Apollo 11 in 1969. Human exploration of the Moon temporarily ceased with the conclusion of the Apollo program, although a few robotic landers and orbiters have been sent to the Moon since that time. The U.S. has committed to return to the Moon by 2018.[5][6][7] On November 13, 2009, NASA announced the discovery of proof that water exists on the Moon, based on data obtained from the LCROSS lunar impact mission.[8]

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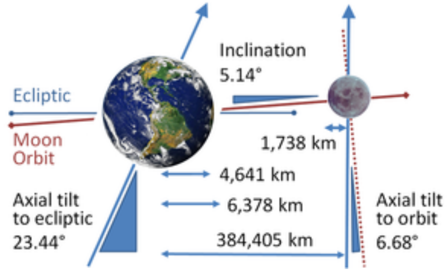

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The Moon is in synchronous rotation, which means it rotates about its axis in about the same time it takes to orbit the Earth. This results in it keeping nearly the same face turned towards the Earth at all times. The Moon used to rotate at a faster rate, but early in its history, its rotation slowed and became locked in this orientation as a result of frictional effects associated with tidal deformations caused by the Earth.[12]

Small variations (libration) in the angle from which the Moon is seen allow about 59% of its surface to be seen from the Earth (but only half at any instant).[4]

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The side of the Moon that faces Earth is called the

near side, and the opposite side the far side. The far side is often inaccurately called the "dark side," but in fact, it is illuminated exactly as often as the near side: once per lunar day, during the new Moon phase we observe on Earth when the near side is dark. The far side of the Moon was first photographed by the Soviet probe Luna 3 in 1959. One distinguishing feature of the far side is its almost complete lack of maria.

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The surface of Earth's Moon is marked by impact craters[20] which form when asteroids and comets collide with the lunar surface. There are about half a million craters with diameters greater than 1 km on the Moon.[citation needed] Since impact craters accumulate at a nearly constant rate, the number of craters per unit area superposed on a geologic unit can be used to estimate the age of the surface (see crater counting). The lack of an atmosphere, weather and recent geological processes ensures that many of these craters have remained relatively well preserved in comparison to those on Earth.

The largest crater on the Moon, which also has the distinction of being one of the largest known craters in the Solar System,[21] is the South Pole-Aitken basin. It is on the far side, between the South Pole and equator, and is some 2,240 km in diameter and 13 km in depth.[22] Prominent impact basins on the near side include Imbrium, Serenitatis, Crisium, and Nectaris.

IMPACT CRATERS

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Blanketed atop the Moon's crust is a highly comminuted (broken into ever smaller particles) and "impact gardened" surface layer called regolith. Since the regolith forms by impact processes, the regolith of older surfaces is generally thicker than for younger surfaces. In particular, it has been estimated that the regolith varies in thickness from about 3–5 m in the maria, and by about 10–20 m in the highlands.[23] Beneath the finely comminuted regolith layer is what is generally referred to as the megaregolith. This layer is much thicker (on the order of tens of kilometres) and comprises highly fractured bedrock.[24]

Astronauts have reported that the dust from the surface felt like snow and smelled like spent gunpowder.[25] The dust is mostly made of silicon dioxide glass (SiO_2), most likely created from the meteors that have crashed into the Moon's surface. It also contains calcium and magnesium.

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The continuous bombardment of the Moon by comets and meteoroids has most likely added small amounts of water to the lunar surface. If so, sunlight would split much of this water into its constituent elements of hydrogen and oxygen, both of which would ordinarily escape into space over time, because of the Moon's weak gravity.

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The Moon is a differentiated body, being composed of a geochemically distinct crust, mantle, and core. This structure is hypothesized to have resulted from the fractional crystallization of a magma ocean shortly after its formation, at about 4.4 billion years ago[34]. The energy required to melt the outer portion of the Moon is commonly attributed to a giant impact event that is postulated to have formed the Earth-Moon system, and the subsequent reaccretion of material in Earth orbit. Crystallization of this magma ocean would have given rise to a mafic mantle and a plagioclase-rich crust (see Origin and geologic evolution below).

Geochemical mapping from orbit implies that the crust of the Moon is largely anorthositic in composition,[35] consistent with the magma ocean hypothesis. In terms of elements, the crust is composed primarily of oxygen (41% to 46% by mass), silicon (21%), magnesium (6%), iron (13%), calcium (8%), and aluminium (7%).[36][37] Based on geophysical techniques, its thickness is estimated to be on average about 50 km.[1]

Partial melting within the mantle of the Moon gave rise to the eruption of mare basalts on the lunar surface. Analyses of these basalts indicate that the mantle is composed predominantly of the minerals olivine, orthopyroxene and clinopyroxene, and that the lunar mantle is more iron rich than that of the Earth. Some lunar basalts contain high abundances of titanium (present in the mineral ilmenite), suggesting that the mantle is highly heterogeneous in composition. Moonquakes have been found to occur deep within the mantle of the Moon about a thousand kilometres below the surface. These occur with monthly periodicities and are related to tidal stresses caused by the eccentric orbit of the Moon about the Earth.[1]

The Moon has a mean density of 3 346.4 kg/m³, making it the second densest moon in the Solar System after Io. Nevertheless, several lines of evidence imply that the core of the Moon is small, with a radius of about 350 km or less.[1] This corresponds to only about 20% the size of the Moon, in contrast to about 50% as is the case for most other terrestrial bodies. The composition of the lunar core is not well constrained, but most believe that it is composed of metallic iron alloyed with a small amount of sulfur and nickel. Analyses of the Moon's time-variable rotation indicate that the core is at least partly molten.[38]

TOPOGRAPHY

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The topography of the Moon has been measured by the methods of laser altimetry and stereo image analysis, most recently from data obtained during the Clementine mission. The most visible topographic feature is the giant far side South Pole-Aitken basin, which possesses the lowest elevations of the Moon. The highest elevations are found just to the north-east of this basin, and it has been suggested that this area might represent thick ejecta deposits that were emplaced during an oblique South Pole-Aitken basin impact event. Other large impact basins, such as Imbrium, Serenitatis, Crisium, Smythii, and Orientale, also possess regionally low elevations and elevated rims. Another distinguishing feature of the Moon's shape is that the elevations are on average about 1.9 km higher on the far side than the near side.[1]

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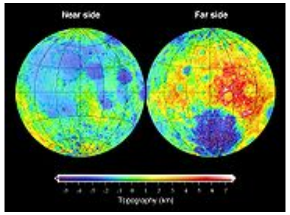

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The gravitational field of the Moon has been determined through tracking of radio signals emitted by orbiting spacecraft. The principle used depends on the Doppler effect, whereby the spacecraft acceleration in the line-of-sight direction can be determined by means of small shifts in frequency of the radio signal, and the distance from the spacecraft to a station on Earth. However, because of the Moon's synchronous rotation it is not possible to track spacecraft much over the limbs of the Moon, and the farside gravity field is thus only poorly characterised.[39]
Radial gravitational anomaly at the surface of the Moon

The major characteristic of the Moon's gravitational field is the presence of mascons, which are large positive gravitational anomalies associated with some of the giant impact basins.[40] These anomalies greatly influence the orbit of spacecraft about the Moon, and an accurate gravitational model is necessary in the planning of both manned and unmanned missions. The mascons are in part due to the presence of dense mare basaltic lava flows that fill some of the impact basins. However, lava flows by themselves can not explain the entirety of the gravitational signature, and uplift of the crust-mantle interface is required as well. Based on Lunar Prospector gravitational models, it has been suggested that some mascons exist that do not show evidence for mare basaltic volcanism.[41] The huge expanse of mare basaltic volcanism associated with Oceanus Procellarum does not possess a positive gravitational anomaly.

MAGNETIC FIELD

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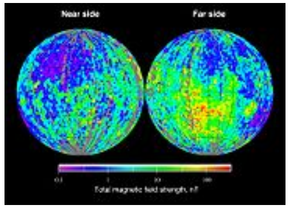

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The Moon has an external magnetic field of the order of one to a hundred nanotesla—less than one hundredth that of the Earth, which is 30–60 microtesla. Other major differences are that the Moon does not currently have a dipolar magnetic field (as would be generated by a geodynamo in its core), and the magnetizations that are present are almost entirely crustal in origin.[42] One hypothesis holds that the crustal magnetizations were acquired early in lunar history when a geodynamo was still operating. The small size of the lunar core, however, is a potential obstacle to this theory. Alternatively, it is possible that on an airless body such as the Moon, transient magnetic fields could be generated during large impact events. In support of this, it has been noted that the largest crustal magnetizations appear to be located near the antipodes of the giant impact basins. It has been proposed that such a phenomenon could result from the free expansion of an impact generated plasma cloud around the Moon in the presence of an ambient magnetic field.[43]

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During the lunar day, the surface temperature averages 107 °C, and during the lunar night, it averages −153 °C.[49]

The Moon has the coldest place in the Solar System measured by a spacecraft.

NASA's Lunar Reconnaissance Orbiter has used its Diviner instrument to probe the insides of permanently shadowed craters on Earth's satellite. It found mid-winter, night-time surface temperatures inside the coldest craters in the northern polar region can dip as low as minus 249C (26 Kelvin). The Diviner instrument observed the lowest summer temperatures in the darkest craters at the southern pole to be about 35K (-238C); but in the north, close to the winter solstice the instrument recorded a temperature of just 26K on the south-western edge of the floor of Hermite Crater.

Calculations suggest one would have to travel to a distance beyond the Kuiper Belt - well beyond the orbit of Neptune - to find objects with surfaces this cold. The discovery adds further weight to the idea that some craters on the Moon could harbour water-ices for extended periods, and also more volatile substances that require even colder storage temperatures.

FORMATION

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Several mechanisms have been suggested for the Moon's formation. The formation of the Moon is hypothesized to have occurred 4.527 ± 0.010 billion years ago, about 30–50 million years after the origin of the Solar System.[50]

Fission hypothesis
Early speculation proposed that the Moon broke off from the Earth's crust because of centrifugal forces, leaving a basin – presumed to be the Pacific Ocean – behind as a scar.[51] This idea, however, would require too great an initial spin of the Earth and also would have resulted in the Moon's orbit following Earth's equatorial plane rather than its current path.[52]

Capture hypothesis
Other speculation has centered on the Moon being formed elsewhere and subsequently being captured by Earth's gravity.[53] However, the conditions conjectured necessary for such a mechanism to work, such as an extended atmosphere of the Earth in order to dissipate the energy of the passing Moon, are improbable.[52]

Co-formation hypothesis
The co-formation hypothesis proposes that the Earth and the Moon formed together at the same time and place from the primordial accretion disk. The Moon would have formed from material surrounding the proto-Earth, similar to the formation of the planets around the Sun. Some suggest that this hypothesis fails to adequately explain the depletion of metallic iron in the Moon.[52]

A major deficiency in all these hypotheses is that they cannot readily account for the high angular momentum of the Earth–Moon system.[54]

GEOLOGIC EVOLUTION

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A large portion of the Moon's post–magma-ocean geologic evolution was dominated by impact cratering. The lunar geologic timescale is largely divided in time on the basis of prominent basin-forming impact events, such as Nectaris, Imbrium, and Orientale. These impact structures are characterised by multiple rings of uplifted material, and are typically hundreds to thousands of kilometres in diameter. Each multi-ring basin is associated with a broad apron of ejecta deposits that forms a regional stratigraphic horizon. While only a few multi-ring basins have been definitively dated, they are useful for assigning relative ages on the basis of stratigraphic grounds. The continuous effects of impact cratering are responsible for forming the regolith.

The other major geologic process that affected the Moon's surface was mare volcanism. The enhancement of heat-producing elements within the Procellarum KREEP Terrane is thought to have caused the underlying mantle to heat up, and eventually, to partially melt. A portion of these magmas rose to the surface and erupted, accounting for the high concentration of mare basalts on the near side of the Moon.[14] Most of the Moon's mare basalts erupted during the Imbrian period in this geologic province 3.0–3.5 billion years ago. Nevertheless, some dated samples are as old as 4.2 billion years,[57] and the youngest eruptions, based on the method of crater counting, are hypothesized to have occurred only 1.2 billion years ago.[58]

There has been controversy over whether features on the Moon's surface undergo changes over time. Some observers have claimed that craters either appeared or disappeared, or that other forms of transient phenomena had occurred. Today, many of these claims are thought to be illusory, resulting from observation under different lighting conditions, poor astronomical seeing, or the inadequacy of earlier drawings. Nevertheless, it is known that the phenomenon of outgassing does occasionally occur, and these events could be responsible for a minor percentage of the reported lunar transient phenomena. Recently, it has been suggested that a roughly 3 km diameter region of the lunar surface was modified by a gas release event about a million years ago.[59][60]

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The current obliquity of the Moon means that the Sun never rises above 1.85° at the poles. The axial tilt of the Moon has remained at its present orientation for the past two billion years, allowing the craters at the poles to remain in permanent shadow for that length of time.[65] Prior to that point, the Moon had much larger values for its obliquity, possibly reaching angles as high as 77° for periods of several hundred thousand years.[66]