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Evaluation of rock masses (pebbles) on planets

Určování hmotnosti kamenů (valounků) na jiných planetách

Bachelor’s thesis

Thesis supervisor: doc. RNDr. Günther Kletetschka, Ph.D.

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Bakalářská práce

Vedoucí práce/školitel: doc. RNDr. Günther Kletetschka, Ph.D.

Praha, 2019

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I, Dayansetsen Boldbaatar, hereby declare that I worked out this bachelor thesis alone and that all the information sources and literature are cited. Entire thesis or any part of it has not been submitted to obtain the same or other academic degree.

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V Praze, 15.8.2019

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SUMMARY

This research is science engineering topic based on compositional and volume information to figure out the mass of a rock pebbles on a planetary surface. For this purpose, 3D computing Photogrammetry method and X-ray Fluorescence methods were used to derive the necessity physical quantities for the mass computing

First section discusses the moon, its characteristics and possibility of terraforming. The second half of this bachelor's thesis is focused on modeling and its techniques. The final part summarizes the results derived from modeling chapter.

ABSTRAKT

Tento výzkum je tématem vědeckého inženýrství založeným na informacích o složení a objemu, aby bylo možné určit hmotnost kamenných valounků na planetárním povrchu. 3D výpočetní technika Fotogrametrie a rentgenové fluorescenční metody byly použity k odvození potřeby fyzikálních veličin pro hromadné zpracování.

První část pojednává o Měsíci, jeho vlastnostech a možnosti terraformingu. Druhá polovina práce je zaměřena na modelování a jeho techniky. Závěrečná část shrnuje výsledky odvozené z kapitoly modelování.

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Contents

1. INTRODUCTION

Humans dream about leaving the Earth and traveling through the galaxy. Unfortunately, is it not possible for now, but we could begin our dream by colonizing and terraforming. Colonizing may incorporate structure bases on the Moon, Mars and different bodies in the nearby planetary group, perhaps leading to terraforming some of them.

In order to create a base, we need to deal with the different kind of gravities and necessity of new technologies. For the construction of bases, we require to mobilize objects, so the main idea was to evaluate masses and to find out how much force will be required. Most of the analysis for investigation of the planets proceeded by remote sensing. If we take an example, the Martian rovers equipped with different type of cameras and spectrometers collect abundant data. With the help of this data it is possible to determine what we mentioned in the previous sentences.

The goal of this bachelor thesis is to develop the methods of analysis suitable for planetary investigations remotely, and to show the techniques how the rovers investigate different planetary surfaces with the help of equipped instruments.

2. MOON

The Moon is a unique satellite in the solar system, the largest relative to its planet. It has a radius of 1738 km, a density of 3.344 g/cm3(Earth density = 5.52 g/cm3), and a mass that is 1/81 that of the Earth. Its orbit is inclined at 5.09° to the plane of the ecliptic. It rotates on its axis once every 27 days. The moment of inertia value is 0.3931, consistent with a small increase of density toward the center. The current consensus is that the Moon formed as a consequence of the collision with the Earth of a Mars-sized body about 4.5 billion years ago (McFadden, L., Weissman, P. R., & Johnson, 2007).

The Moon's center is relatively littler than other earthly bodies' centers. The strong, iron-rich internal center is 149 miles (240 kilometers) in span. It is encompassed by a fluid iron shell 56 miles (90 kilometers) thick. A mostly liquid layer with a thickness of 93 miles (150 kilometers) encompasses the iron center. The mantle extends from the top of the partially molten layer to the bottom of the Moon's crust. It is in all probability made of minerals like olivine and pyroxene, which are comprised of magnesium, iron, silicon and oxygen particles. The outside has a thickness of around 43 miles (70 kilometers) on the Moon's close side of the equator and 93 miles (150 kilometers) on the far-side. It is made of oxygen, silicon, magnesium, iron, calcium and aluminum, with limited quantities of titanium, uranium, thorium, potassium and hydrogen. Long ago the Moon had active volcanoes, but today they are all dormant and have not erupted for millions of years (source: https://solarsystem.nasa.gov/moons/earths-moon/in-depth/ Date retrieved: 15 August 2019 13:31 GMT).

According to the NASA Solar system exploration information with too sparse an atmosphere to impede impacts, a steady rain of asteroids, meteoroids and comets strikes the surface of the Moon, leaving numerous craters behind. Tycho Crater is in excess of 52 miles (85 kilometers) wide. More than billions of years, these effects have ground up the outside of the Moon into sections running from gigantic stones to powder. Nearly the entire Moon is covered by a rubble pile of charcoal-gray, powdery dust and rocky debris called the lunar regolith. Beneath is a region of fractured bedrock referred to as the megaregolith (source: https://solarsystem.nasa.gov/moons/earths-moon/in-depth/ Date retrieved: 15 August 2019 13:31 GMT).

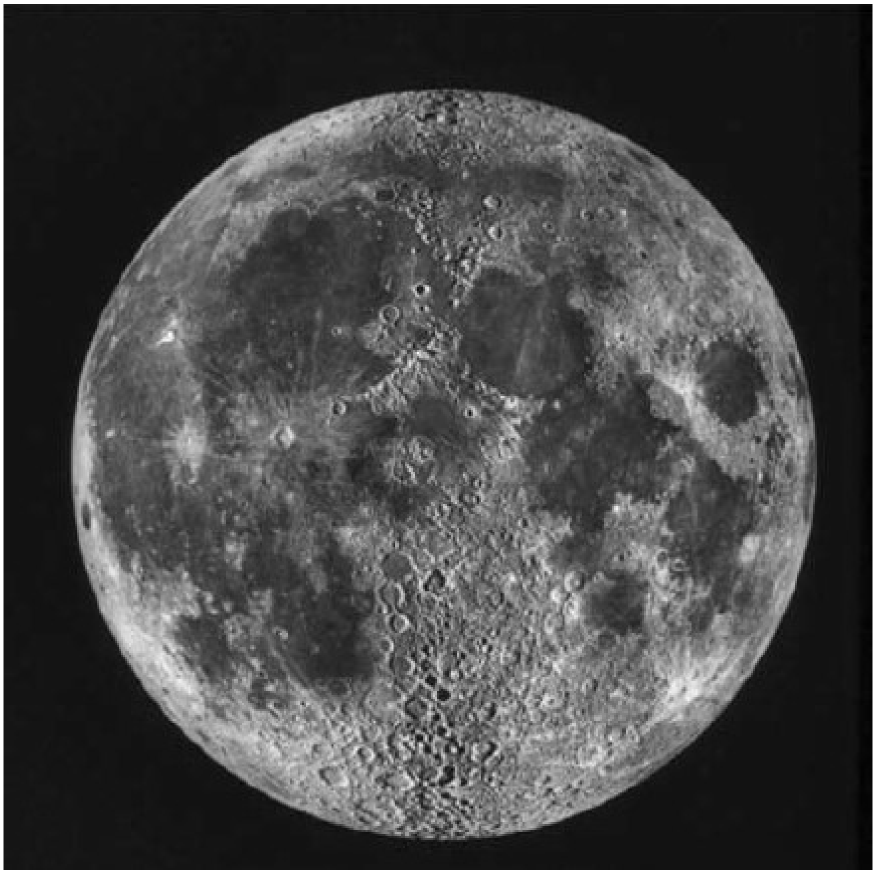

Figure 1. A composite full-Moon photograph that shows the contrast between the heavily cratered highlands and the smooth, dark basaltic plains of the maria (McFadden et al., 2007).

The light areas of the Moon are known as the highlands. The dark features, called maria (Latin for seas), are impact basins that were filled with lava between 4.2 and 1.2 billion years ago. These light and dim zones speak to rocks of various organization and ages, which give proof to how the early outside layer may have crystallized from a lunar magma ocean. The craters themselves, which have been preserved for billions of years, provide an impact history for the moon and other bodies in the inner solar system (source: https://solarsystem.nasa.gov/moons/earths-moon/in-depth/ Date retrieved: 15 August 2019 13:31 GMT).

2.1. An approach to terraforming the moon

2.1.1. Terraforming

Terraforming or terraformation of a planet, moon or other body is the theoretical procedure of purposely adjusting its air, temperature, surface geography or nature to be like the earth of Earth to make it tenable by Earth-like life. The idea of terraforming created from both sci-fi and genuine science. The term was begat by Jack Williamson in a sci-fi short story ("Collision Orbit") distributed during 1942 in Astounding Science (Fiction, 1942), however the idea may pre-date this work. Regardless of whether the earth of a planet could be changed intentionally, the practicality of making an unconstrained planetary condition that mirrors Earth on another planet still can't seem to be checked. The long timescales and practically of terraforming are the subject of debate. Other unanswered inquiries identify with the morals, coordinations, financial aspects, legislative issues, and strategy of changing nature of an extraterrestrial world (source: https://en.wikipedia.org/w/index.php?title=Terraforming&oldid=910880142).

2.1.2. Terraforming the moon

In order to terraform the moon, we would need environmental engineering techniques to alter the moon's temperature, atmosphere, topography or ecology to an extent that it would match to that of Earth. Let's discuss the atmosphere of the moon which is so thin it is just about the one layer of the earth's atmosphere which is exosphere. There is very scant presence of gases on the satellite – sodium and potassium are two unusual gases which are found in the Moon's atmosphere – and it is actually surrounded by vacuum. The Moon's exosphere contains, at any one instance, about 10,000 kg of gas. To create an inflated lunar atmosphere, therefore, the current exosphere mass must be increased by about 10,000 times. Given that the solar wind mass-loss rate peaks at about 100 kg/s, it perhaps makes sense to build up the Moon's atmospheric mass at this same rate. It has been estimated that any gases that might be introduced into the Moon's exosphere will be lost within a matter of a few weeks (Beech, 2009). Well, this problem can be easily addressed by several ways including the industrial heating of lunar regolith material, through subsurface nuclear bomb mining and one of them is iceteroid bombarding (Beech, 2009). In order to perform ice bombarding, we have to capture comets made up of water ices, known as iceteroids and bombard our moon's surface with at least hundreds of those comets. On crashing into the moon's surface, they would accumulate on its surface to form natural bodies of ice. Besides, these comets would disperse carbon-di-oxide, water vapor, and small amounts of ammonia and methane. These gases would provide the required atmosphere to our satellite. The transfer of these comets would also cause the moon to gain momentum, and thus, the Moon would start rotating more rapidly due to the faster rotation, it would no longer be tidally locked to earth. It would gain earth-like rotation. The Earth-like rotation of the moon would make colonization and adaption to life on the Moon easier (source: https://www.scientificmystery.com/terraforming-moon/ Date retrieved: 17 August 2019 16:45 GMT)

Such and atmosphere would be stripped away over short timescales due to the slight gravity, solar wind, and ultraviolet (UV) dissociation according to Oberg, (1981); Goody (1972). Regardless of whether the air could be kept up or ceaselessly renewed, without an attractive field, space radiation could make the surface upsetting, best case scenario and out threatening even from a pessimistic standpoint. If not situated at simply the correct good ways from the star, it would be either solidified strong or would be hot to such an extent that the seas would bubble off (Roy, Kennedy, & Fields, 2009).

Be that as it may, if a round shell of issue could be developed around a planet or huge moon to thoroughly encase the world then the shell could contain the climate, shield the occupants from space radiation, and moot the parameter of distance from the star(s), or even type of star(s). An earth-like environment could be created under the shell with artificial lighting and temperature control. The gravity would depend on the moon or planet selected for enclosure and might be only a fraction of Earth's. Otherwise, all other qualities could be as earthlike as desired. These "shell worlds" would not merely be large habitats, but complete worlds engineered for human habitability and stability across historic timescales. Each would contain fully functioning, self-sustaining ecologies, based on Earth's (Roy et al., 2009).

2.2. Remote sensing of the moon

2.2.1. Definition of Remote sensing of the moon

Remote detecting is the most incredible asset in present day planetary science and over ongoing years, has given the absolute most significant information that we hold of the Moon. Remote sensing data from the Clementine, Lunar Prospector, Chandrayaan and SELENE missions have now provided a global view of the composition of the lunar surface for the first time. In addition, they have given us a more complete view of the shape, mineral composition, gravity and magnetic anomalies associated with the Moon. Measurements of the electromagnetic spectrum are only practical within certain wavelength regions, as they provide specific diagnostic information ranging from atomic/molecular interactions to physical properties of surface materials. Some wavelength regions useful for diagnostic compositional analysis of the surface using remotely sensed data may be obscured by absorption or scatter in the atmosphere of the planetary body being observed (Wrightet al., 2013). Remotely sensed satellite stereo data are useful for extracting elevation through stereo data processing, as well as from active techniques such as radar and laser altimetry. The latter can produce high resolution DTMs that provide 3-dimensional geospatial visualization and characterization of topographic features such as impact and volcanic related structures. Elevation data can also be combined with other datasets to create 3D visualizations that facilitate correlations with spectral units and/or high-resolution morphologic units, and also for interpretation of structural/stratigraphic relationships (Wrightet al., 2013).

2.2.2. Remote sensing techniques

2.2.2.1. Photogeology

Photogeology can be defined simply as the interpretation of geology from photographs. As this interpretation is based mainly on aerial photography, most people would restrict the definition of photogeology to the use of aerial photographs. The earliest attempts at photogeological interpretation in the late 1800's, however, were made land – based photography and even today photographs taken on land may be employed usefully in specialized cases such as the geological interpretation of inaccessible mountain slopes, cliff faces or open pit walls points out (Reedman, 1979). Visible Images are also particularly useful for statistical analyses. For instance, counting the number of impact craters across a surface is the only way of estimating the relative ages of discrete units without direct access to samples, and high-resolution photographic images are the best way of getting this kind of information. Similarly, these data can be used to characterize the morphology and distribution of features such as impact craters, volcanoes, tectonic ridges and fractures (Dunkin & Heather, 2000).

2.2.2.2.Reflectance Spectroscopy

The use of remotely obtained spectra of planetary surfaces for geologic studies has increased dramatically in the last decade. Spectral data have been used to identify minerals on the earth and on all the solid surfaces in the solar system as well as composition of atmospheres when present. The reflectance range of a particulate surface is unpredictable, being influenced by the number and sort of materials present, their weight divisions, the grain size of every material, and the survey geometry. Due to the multifaceted nature, satisfactory speculations for anticipating the light came back from the surface have not been exact enough for all applications and conditions (Clark & Roush, 1984). According to Dunkin & Heather, (2000) the techniques of reflectance spectroscopy were used extensively in the (Dunkin & Heather, 2000), especially when space-based missions to the Moon reduced in number. At this point, telescopes became the only source of new data for the Moon, but these were restricted to observations of the nearside, so no compositional reflectance data could be collected for the far side. The high spectral resolution of the telescopic data enables accurate determination of relative abundances of specific minerals (i.e. pyroxenes vs, olivines), however the poor spatial goals of a couple of kilometers on the ground, best case scenario restricts the utilization of the systems to bigger scale contemplates. Adjustable reflectance information has been utilized in this style to demonstrate compositional varieties crosswise over highlights, for example, the bigger new effect pits and the maria. These gave a portion of the primary signs with regards to the general piece of the lunar outside layer and maria away from the Apollo and Luna testing station. (Dunkin & Heather, 2000).

2.2.2.3.Gamma ray and X-ray spectroscopy

X-ray and gamma-ray remote sensing observations find important applications in the study of the development of the planets out of the primitive solar nebula. Orbital estimations can be completed on nearby planetary group bodies whose airs and caught radiation conditions don't meddle altogether with the discharges. Elemental compositions can be inferred from observations of these line emissions. Gamma-ray emissions can be attributed mainly to natural radioactivity (Th, U and K) and to primary and secondary cosmic ray-induced activity producing identifiable emissions from, for example, H, O, Si, Al, Mg, Fe, Ti and Ca. The major radiation source for remote orbital X-ray spectroscopy is that produced by characteristic X-rays following the interaction of solar X-rays with the surface of the irradiated solar system bodies (Trombka, Evans, Starr, Clark, & Floyd, 1999)

X-ray fluorescence spectroscopy has long been used in the laboratory to determine elemental abundances in rock and oil samples. In this technique, an X-ray source is used to eject electrons from the atoms at the surface of the sample, giving rise to the emission of monoenergetic X-rays with energies characteristic to the elements present. The energies involved range between 0.1 and 100keV, probing only the upper ten of microns of the surface in question. This method was used for remote sensing on a large scale during the Apollo 15 and 16 missions (Dunkin & Heather, 2000)

2.3. GRAVITY OF THE MOON

The gravity field of the moon has been explored since 1966 when the Russian Luna 10 was put in circle around the moon and gave dynamical verification that the oblateness of the moon's gravitational potential Akim, (1966) points out that there was larger than the shape predicted from hydrostatic equilibrium. Before long, Muller and Sjogren Lemoine, (1997) separated the Doppler residuals from Lunar Orbiter (LO)– V to deliver a nearside gravity map that showed sizable positive gravity abnormalities inside the large circular mare basins. These positive anomalies, located in nearside equatorial regions with low topography, showed areas with mass concentrations (or "mascons") in the lunar interior (Konopliv et al., 1998).

The first dedicated gravity mission in planetary science, the Gravity Recovery and Interior Laboratory (GRAIL) (Zuber et al., 2013a), supersedes prior missions in view of revealing a global lunar gravity field. The twin-satellite mission consisting of "Ebb" and "Flow" realized a low-low tracking configuration with a Ka-band inter-satellite link (Wirnsberger, Krauss, & Mayer-Gürr, 2019).

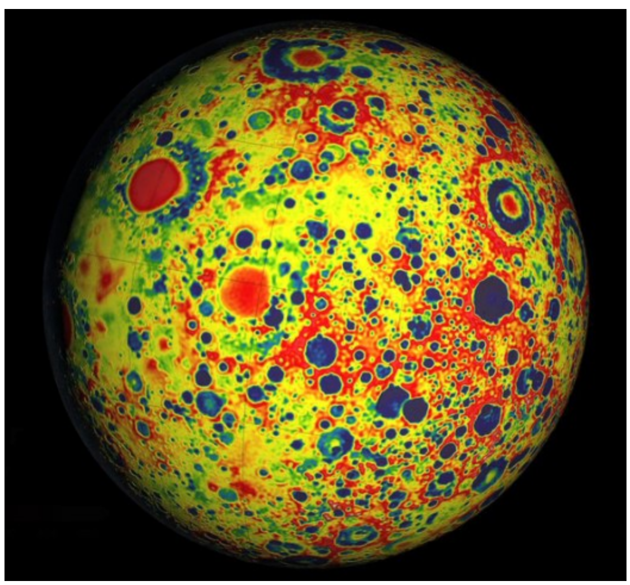

Figure 2. Variations in the lunar gravity field as measured by NASA's Gravity Recovery and Interior Laboratory (GRAIL). The field shown resolves blocks on the surface of about 20 kilometers. Red corresponds to mass excesses and blue corresponds to mass deficiencies (Image credit: NASA/JPL-Caltech/MIT/GSFC).

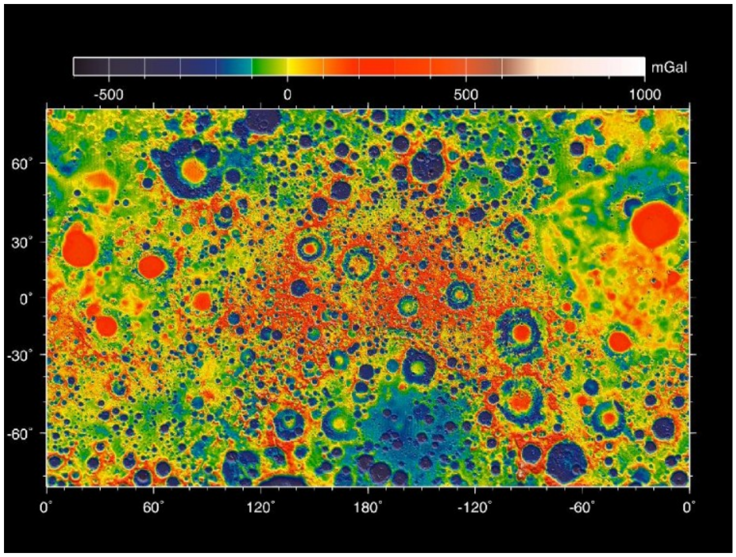

Figure 3. Map of the gravity field of the moon as measured by NASA's GRAIL mission with the viewing perspective of Mercator projection. Reds correspond to mass excesses which create areas of higher local gravity, blues correspond to mass deficits which create areas of lower local gravity (Image credit: NASA/JPL-Caltech/GSFC/MIT).

The lunar highland crust is strong. High mountains such as the Apennines (7 km high), formed during the Imbrium collision 3.85 billion years ago, are uncompensated and are supported by a strong cool interior. The gravity information are steady with an at first molten Moon that cooled rapidly and ended up rigid enough to help loads, for example, the mountainous rings around the enormous, younger, ringed bowls just as the mascons. Regardless of whether some farside lunar bowls don't demonstrate mascons, this may just be an outcome of the greater thickness of the farside crust. The South Pole–Aitken Basin is particularly significant in this respect (McFadden et al., 2007). As the oldest (at least 4.1 billion years) and largest impact basin, the fact that it is uncompensated, with major mantle uplift preserved beneath it, this places considerable restrictions on lunar thermal models It likewise shows that melting in the deep interior to distribute the mare basalts had no impact on the strength of the crust. The volume of mare basalts is only about 0.1% of the whole Moon so that the amount of melting required to produce them involved only a trivial volume of the Moon (McFadden et al., 2007).

3. MODELING

3.1. Volume computing photogrammetry

3.1.1. Definition of Photogrammetry

Photogrammetric systems, estimating objects from photos, have been used since the late 1800s. These strategies are most regularly utilized for mapping enormous zones from aeronautical photos. Computerized short proximity photogrammetry is a system for precisely estimating items legitimately from photos or advanced pictures caught with a camera at short proximity. Numerous, covering pictures taken from alternate points of view, produces estimations that can be utilized to make exact 3D models of articles Tüdeş, (1996) described. Knowing the situation of camera isn't fundamental in light of the fact that the geometry of the item is built up legitimately from the pictures (Yakar & Yilmaz, 2008).

Photogrammetry is the process of obtaining accurate mathematical measurements from multiple 2D images of a 3D scene for the production of concise spatial information (Matthews, 2008; Yilmaz, 2010, p.48). Photogrammetry utilizes overlapping photos recorded with a camera recording common features within overlapping photos enabling software to process the scene in 3D (Yilmaz, 2010). Recently photogrammetry has become very popular among numerous fields, particularly engineering (Raeva et al., 2016).

The photogrammetric 3D coordinate determination is based on the co-linearity equation according to Slama, (1980) which simply states that object point, camera projective center and image point lie on a straight line. The determination of the 3D coordinates from a definite point is achieved through the intersection of two or more straight lines. Therefore, each point of interest should appear in at least two photographs. Later, coordinates are measured from 3D model which is constituted by photogrammetric software (Yakar & Yilmaz, 2008).

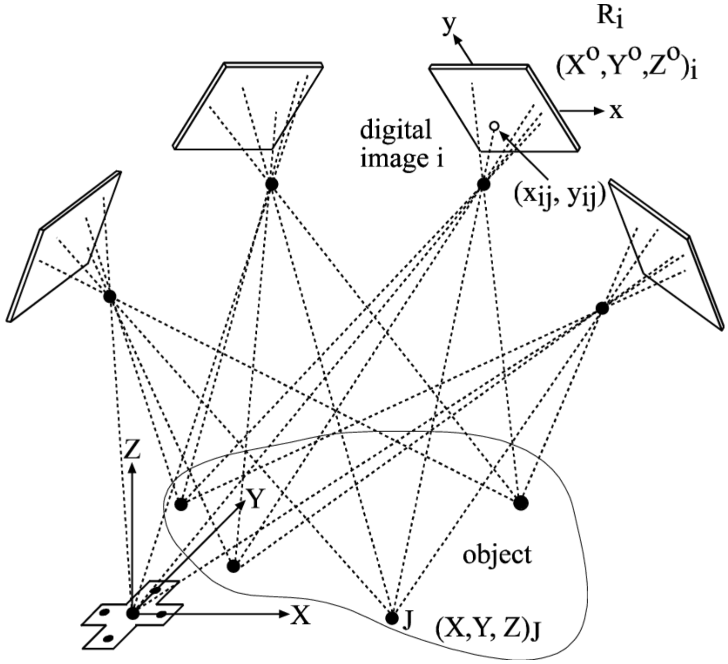

Figure 4. Convergent close-range photogrammetric network comprising four camera stations (G. Ryall, T & Fraser, 2002)

Contrasted with old style strategies, close-range photogrammetry is productive and quick, essentially lessening the time required to gather information in the field. Digital close-range photogrammetric methods have been successfully applied to projects in archaeology, architecture, automotive and aerospace engineering, accident reconstruction and etc. disciplines (Yakar & Yilmaz, 2008).

The same process can be used to obtain dimensional measurements efficiently on inaccessible structures such as tunnels and dams, and large or complex facilities such as refineries or water treatment plants. Computerized short proximity photogrammetric estimations can be incorporated with 3D displaying and figuring out procedures. The acquired data is infinite and the cost savings substantial (Yakar & Yilmaz, 2008)

3.1.2. Software

3.1.2.1. Agisoft PhotoScan

Agisoft PhotoScan version 1.3 was used for all image processing. "PhotoScan is an advanced image-based solution for creating three-dimensional content from still images". PhotoScan is produced by the Russian company Agisoft and is built to operate on windows operating systems, but it also runs on Mac and Linux systems according to Verhoeven, (2011). The major assumption when recreating a scene in 3D is that the object of interest is visible in at least two photographs (Rhodes, 2017)

There are some considerations when determining a system capable of running Photoscan. A 64-bit operating system with a multicore processor and a decent amount of RAM is strongly recommended. As soon as the computer runs out of main memory, it automatically switches to virtual memory slowing down processing time dramatically. When processing large amounts of data, it is advisable to break the data into "chunks" ensuring that each chunk contains at least two images from other chunks for chunk alignment once processing is complete (Rhodes, 2017)

Figure 5. 3D model of sample "SS007E" done by Author of the thesis using Agisoft Photoscan software.

The PhotoScan software takes a three-step processing approach according to Agüera-Vega et a., (2016). The first step in this process is image alignment where photos are aligned resulting in a sparse point could, the camera locations, and calibration parameters. Next, the majority of scene details are built by applying Multiview stereo reconstruction on the previously aligned photos resulting in a dense point cloud. Finally, the mesh is generated and textured using the photographs (Rhodes, 2017))

3.1.2.2.Blender

Blender is a 3D content creation program. It is open source software and free of charge, published under the GNU license by a non-profit organization: The Blender Foundation. That means, you do not need to purchase a license or ask for permission to use it for any kind of private or commercial projects.

Blender is efficient program. It even works on ten and more years old notebooks without greater problems (Köster, 2015). This software is used widely for creating animated films, visual effect, art, 3D printed models, interactive 3D applications and video games. Blender's features include 3D modeling, UV unwrapping, texturing, raster graphics editing, rigging and skinning, fluid and smoke simulation, particle simulation, soft body simulation, sculping, animating, match moving, rendering, motion graphics, video editing and composing (Yakar & Yilmaz, 2008).

3.1.3.Methodology

The first mission has been to take a quality close-range of photos of the samples. Taking photographs has been done with Canon EOS 60-D in Canon EF 50mm f/1.8 STM lens. Camera calibration procedures have been completed with mathematical calculations. I have photographed the samples several times around, tried to make at least 70 percent overlap for each following photo. The methods for catching pictures should be adjusted relying upon the topic and circumstance. The photographs have been done in three type of circles (360°) and angles, from above, the other circle is where the photos had been taken perpendicular and the third circle is from below. Approximately, 60-70 photos had been taken per one sample rock.

Figure 6. Photo of sample SS007D taken with Canon EOS 60-D 50mm f/1.8 STM lens.

The taken photos has been left in RAW format, in order to edit the photos in photoshop to remove glares and shadows. Later photographs have been converted to .JPG format and transferred to Agisoft PhotoScan software. The software will try to match points by doing sparse point cloud based on photo alignment.

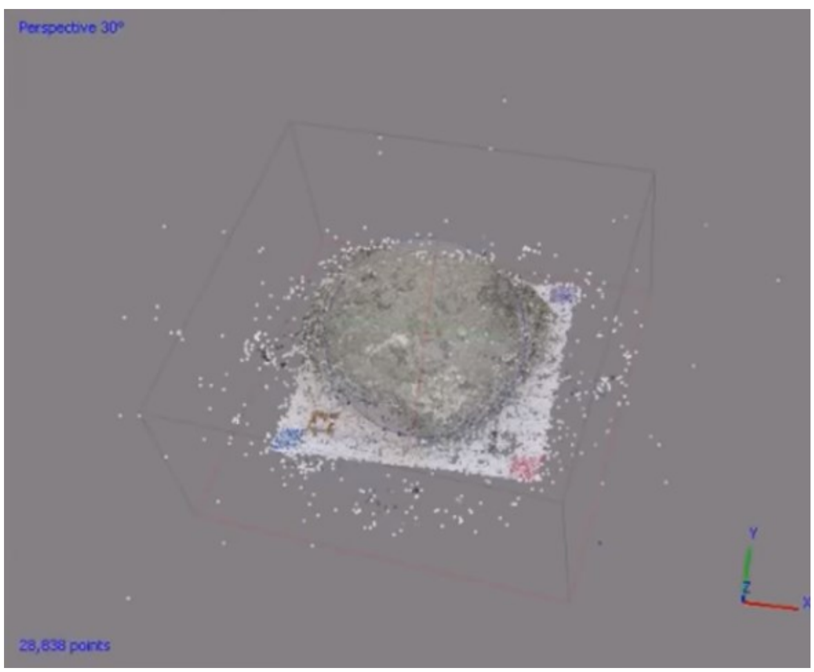

Figure 7. Spare point cloud based on photo alignment by Agisoft PhotoScan software.

The volume of the rocks has been derived from importing .OBJ files which made by Agisoft PhotoScan to Blender software also tested on 3DS MAX software. The volume calculations have been done by Blender software.

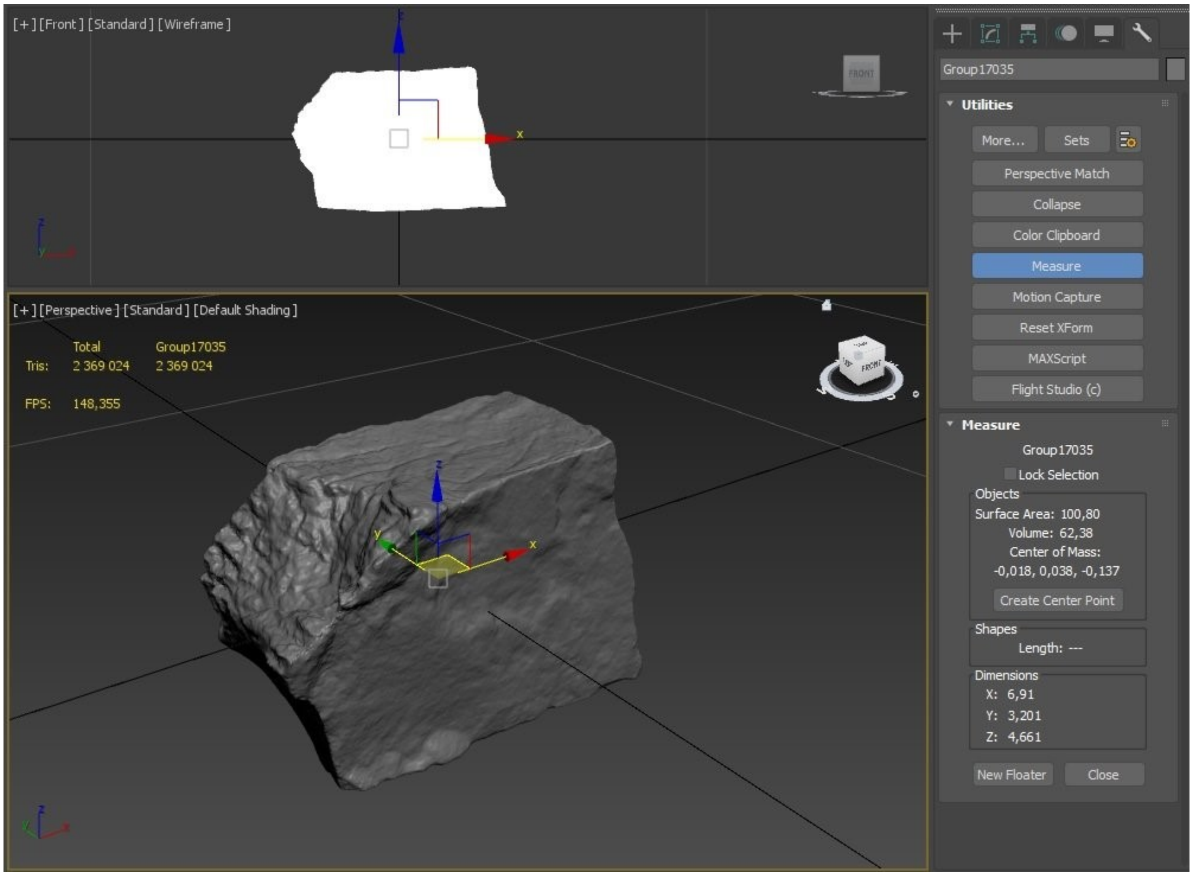

Figure 8. Measured Volume of sample SS007E by 3DS MAX software.

3.1.4.Results

Results from volume estimation provided various level of success. Absolute Error did not exceed 2 cm^3. Table 1 shows the results of the calculated volume. For determining volume for classic method, Archimedes principle is used.

Table 1. Results from volume calculations.

Object	Volume 3D model	Volume Classic Method	Absolute Error
SS007A	6.61 cm^3	6.5 cm^3	0.11 cm^3
SS007D	25.16 cm^3	25.09 cm^3	0.07 cm^3
SS007E	62.45 cm^3	62.51 cm^3	0.06 cm^3
SS007G	11.27 cm^3	11.24 cm^3	0.03 cm^3
SS007H	16.37 cm^3	16.46 cm^3	0.09 cm^3

With the advancement in innovation, computerized clore-range photogrammetry is influencing import degree, with the improvement of equipment and programming items. Some studies can be made more economically, more accurately and faster. Digital close-range photogrammetry also can be applied very different disciplines (Yakar & Yilmaz, 2008). In this study, the situation of digital close-range photogrammetry has been investigated in volume calculation.

3.2. Density determination by x-ray fluorescence

3.2.1. Definition of X-ray Fluorescence

XRF is analytical method to determine the chemical composition of all kinds of materials and the materials can be in solid, liquid, powder filtered or other form. XRF can also sometimes be used to determine the thickness and composition of layers and coatings (Brouwer, 2010). This strategy is quick, precise and non-destructive, and for the most part requires just at least example readiness. Applications are wide and incorporate the metal, bond, oil, polymer, plastic and nourishment enterprises, alongside mining, mineralogy and geology, and natural investigation of water and waste materials (Brouwer, 2010)

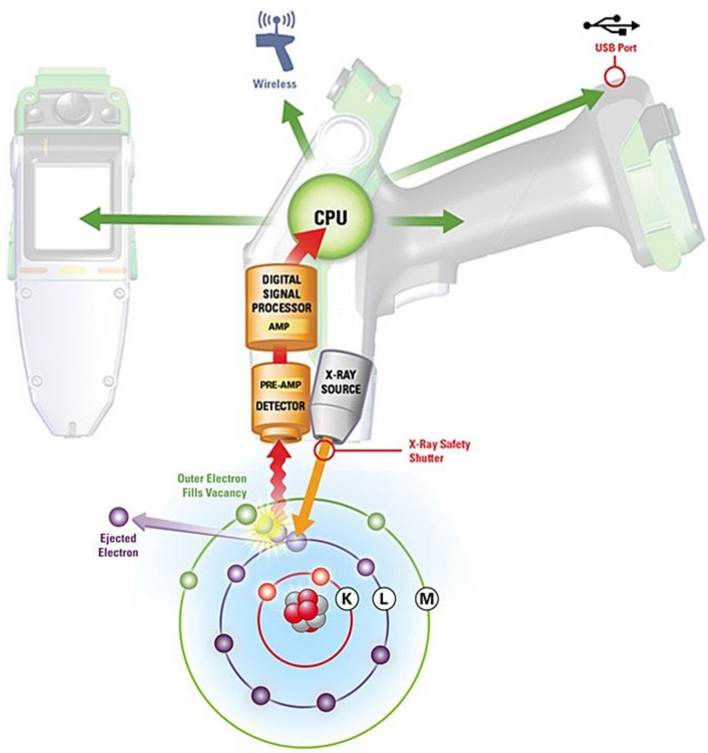

Figure 9. Portable X-ray Fluorescence Instrument.(https://www.thermofisher.com/cz/en/home/industrial/spectroscopy-elemental-isotope-analysis/spectroscopy-elemental-isotope-analysis-learning-center/elemental-analysis-information/xrf-technology.html).

The chemical compositions of rocks are utilized to take care of various geological issues, including crystallization history of molten bodies, for example, stone or basalt, procedures of development of the ocean bottom, nature of compound enduring in different atmospheres, stratigraphic connection of sedimentary and volcanic rocks, procedures of metal age, and numerous others. Most of the rocks are made essentially out of silicate minerals, and over 90% of the structure of most silicate rocks can be described by oxides of Si, Ti, Al, Fe, Mg, Ca, Na and K. Minor and follow components present in rocks incorporate basically every other component, a significant number of which are particularly valuable for geochemical displaying of topographical procedures (Tour, 1989).

In XRF, X-rays produced by a source irradiate the sample. In most cases, the source is an X-ray tube but alternatively it could be a synchrotron or a radioactive material. The elements present in the sample will emit fluorescent X-ray radiation with discrete energies that are characteristic for these elements (Survey & Paper, n.d.). A different energy is equivalent to a different color. By measuring the energies of the radiation emitted by the sample it is possible to determine which elements are present. This step is called qualitative analysis. By measuring the intensities of the emitted energies, it is possible to determine how much of each element is present in the sample. This step is called quantitative analysis (Brouwer, 2003).

3.2.2.Used instrument

For the field measurements there have been used X-Ray Fluorescence Analyzer Vanta Family from company.

3.2.2.1.X-Ray Fluorescence Analyzer

The Vanta XRF analyzer is the most developed handheld X-ray fluorescence gadget and gives fast, exact component investigation and combination recognizable proof to clients who request research facility quality outcomes in the field.

Figure 10. Vanta X-Ray Fluorescence Analyzer instrument (source: http://www.olympus-ims.com/en/vanta)

With intuitive navigation and configurable software, the Vanta series are easy to use with minimal training for high throughput and a fast return on investment. Featuring innovative and proprietary Axon technology, Vanta analyzers give you accurate results and help boost productivity no matter the environment on working conditions. Vanta handhelds feature innovative software features designed to maximize the analyzer's capabilities (source: http://www.olympus-ims.com/en/vanta)

- SmartSort: automatically lengthens or shortens test time based on material to save time; obtain aluminum grade results in as little as 1 second.
- Grade match messaging: real time and/or pop-up messages with familiar trade or grade names or special handling instructions to reduce user training and increase efficiency.
- Nominal value: automatically identifies the likely presence of elements invisible to XRF based on grade specifications.
- Residual library: set a maximum tolerated concentration for residual elements in grade families.
- On-screen grade comparison: compare close grades side-by-side to know which alloy the best match with nominal and residual values.

According to ZH Instruments, (2009) the susceptibility meter is enclosed in a box, which has a front panel with push buttons and a four-digit 10mm character display. In order to get the right value in SI, the user must multiply the reading by a constant 10-3. Behind the front panel there is a buzzer, which monitors by way of acoustics the operation of the meter. On the right-hand side of the cover there is a connector for communication with a computer. A communication cable is delivered as part of the set. On the bottom side of the cover there is a little cubicle holding two Li batteries (ZH Instruments, 2009).

3.2.3. Data interpretation

Vanta X-ray Fluorescence Analyzer instrument was used to measure the chemical compositions of the rock pebbles. Measured data of rocks is shown in Table 2. From the measured chemical compositions, we used iron content to compute the bulk specific gravity (SG_b) of the samples, specific gravity is pore-less density and that is 1/pore-less density.

Table 2. Data from XRF Measurement contents of iron and other elements.

	SS007A	SS007D	SS007E	SS007G	SS007H
Mg (%)	4.829	1.076	1.744	1.828	3.474
Al (%)	4.304	4.064	0.536	3.816	2.491
Si (%)	24.06	25.94	2.2182	10.68	7.829
K (%)	5.807	4.034	0.1129	1.373	0.611
Ca (%)	5.530	0.532	27.7784	20.01	14.92
Ti (%)	0.197	0.302	0.023	0.044	0.148
Mn (%)	0.032	0.108	0.0346	0.082	0.167
Fe (%)	1.305	2.313	0.4427	1.638	1.058
Sr (%)	0.032	0.016	0.1389	0.018	0.0065
Le (%)	53.67	61.43	66.8471	59.61	69.19

With the measured iron content percentage from the XRF, we could determine the specific gravity based on correlation chart (Figure 10.) between iron content in percentage and reciprocal of bulk specific gravity.

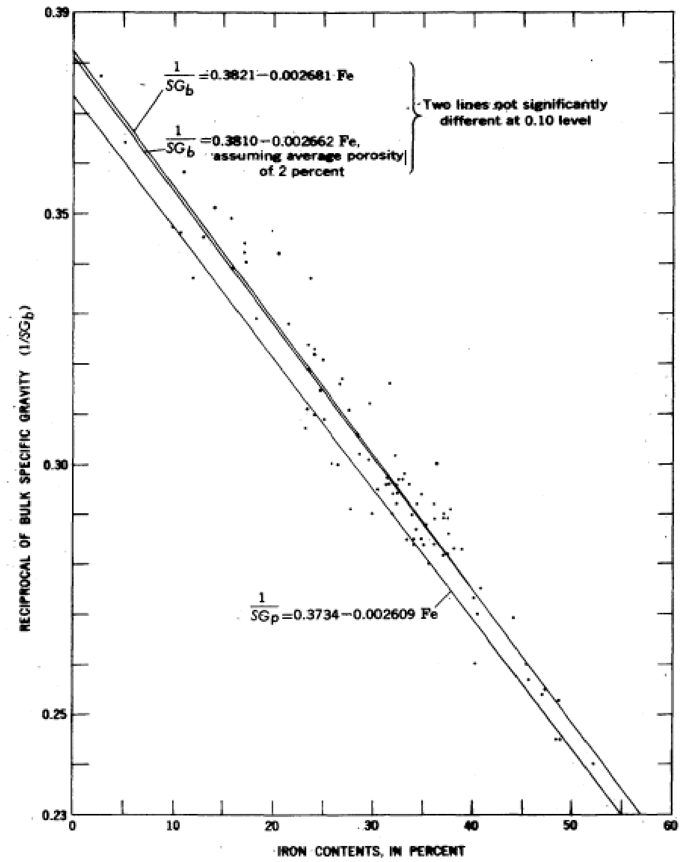

Figure 11. Correlation between the reciprocal of the bulk specific gravity and the iron content. (Sheldon, 1964)

Results from the used chart (Figure 11.) density estimation gave different degree of accomplishment. Absolute Error did not surpass 0.5 g/cm^3. Table 3. demonstrates the consequences of the determined density.

Table 3. Results of density from XRF, absolute density and error calculations

Sample	Absolute density	Density from XRF	Absolute Error
SS007A	2.810	2.70	0.108
SS007D	2.407	2.73	0.332
SS007E	2.889	2.75	0.136
SS007G	2.325	2.71	0.391
SS007H	2.412	2.66	0.253

3.3. Mass determination

Evaluation of rock masses on different kind of planetary surfaces derived from a simple equation.

$$M = V * \rho$$

Where:

V – Volume [m^3]

ρ – Density [g/cm^3]

With the help of new technologies, after finding unknown physical quantities, such as volume determination from 3D modeling and the density determination from X-ray spectrometry, the masses of sample can be found in Table 4. Hence, the weight of the studied samples can be determined from the multiplication of studied mass and gravitational acceleration of the planets which can be seen in the Table 5.

Table 4. Computed mass of the samples.

Samples	Volume from 3D model (m^3)	Density from XRF (g/cm^3)	Computed Mass (g)
SS007A	6.61	2.70	17.86
SS007D	25.16	2.73	68.93
SS007E	62.45	2.75	171.8
SS007G	11.27	2.71	30.62
SS007H	16.37	2.66	43.65

Table 5. Weight distinctions of the samples on the different planetary surfaces in Newtons [N].

	Earth	Moon	Mars	Venus	Mercury	Jupiter	Saturn
SS007A	0.175	0.028	0.067	0.158	0.064	0.463	0.197
SS007D	0.675	0.111	0.259	0.611	0.247	1.788	0.763
SS007E	1.684	0.278	0.648	1.524	0.617	4.460	1.904
SS007G	0.300	0.049	0.115	0.271	0.109	0.794	0.339
SS007H	0.427	0.070	0.164	0.387	0.156	1.132	0.483
acceleration due to gravity (N/kg)	9.8	1.62	3.77	8.87	3.59	25.95	11.08

4. Discussion

The second half of the 20th century started witnessing human kind paying more attention to the outer space since stepping on the moon. Since that moment people started thinking out loud about more creative ideas, one of them being colonizing planets from our outer space. Such kind of ideas motivated people to study deeper by taking the science to the next level. One of the ideas is terraforming, of which problematics can be atmosphere stripping away over short timescales due to the slight gravity, solar wind, and ultraviolet (UV) dissociation after iceteroid bombarding. In order to perform ice bombarding, comets made up of water ices must be captured to accumulate on its surface to form natural bodies of ice, which will lead disperse carbon-dioxide, water vapor and small amounts of ammonia and methane. The required atmosphere to our satellite would be provided by these gases.

To approach such ideas, remote sensing was the key aspect. Remotely sensed satellite stereo data are useful for extracting elevation through stereo data processing, as well as from active techniques. Valuable information and data could be obtained with help of various techniques of remote sensing. Importance of obtaining information about gravities is also one of the significant materials to investigate further. It can be said that the Mars science laboratory missions took the remote sensing to another higher level by investigating Martian land with highly equipped rovers.

Except its main aims, these mars rovers can collect enough data for us to calculate mass of rocks remotely. Mass determination could help for future base constructions. For instance, two key parameters to find mass are density and volume. Density can be calculated using the iron content from XRF and volume can be calculated using 3D model with the help of the method called Photogrammetry.

5. CONCLUSION

While researching science articles related to colonization, terraforming the moon and colonizing outer space bodies would be possible within this 21^{st} century. Using remote sensing before surface landing would be beneficial less with economic expenses and low-cost research.

Methods used in modelling section can be used not only for mass determination but can also be used to study construction materials for terraforming shell, based on measured chemical compositions derived from X-ray spectrometry. Another possibility take advantage of XRF, can be used in the quest of alternative mineral resource. European Space Agency scientists have announced plans to start mining waste-free nuclear energy on the moon by 2025.

During processing 3D model from photo-gravimetry, 60-70 photos were taken from three 3 different angles, above, perpendicular and below, to create the model Agisoft PhotoScan software was used. Later on, software Blender was used to determine the volume of the samples. Calculated masses were found using the volume results from 3D model and from the density which was determined by iron content results from XRF. From the calculated mass, the weight of the rock pebbles was defined for some of the planetary surfaces. To conclude that by using all this methods and research, the purpose of this bachelor’s thesis is achieved.

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