Scientific Benefits of Further Lunar Exploration

Benefits to the Scientific Community in Geology, Resources, and Outpost Foundation

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Introduction

There are many benefits of further lunar exploration to the scientific community with regards to geologic research, resources, and the foundation of a lunar outpost. The Apollo Program, which ended in 1972, represents the furthest extent of exploration of the Moon by the United States and the last time a human was on the Moon. Since then, there have been programs of remote exploration, but the last remote vehicle on the Moon since Russia's Lunokhod 2 in 1973, China's Yutu rover, died in 2016 (O'Brien).

Geology

Materials such as ice, which can be found in permanently shadowed craters near the poles on the Moon, that are considered volatile on Earth could be studied on the Moon to determine how a lack of atmosphere affects them (Crawford).

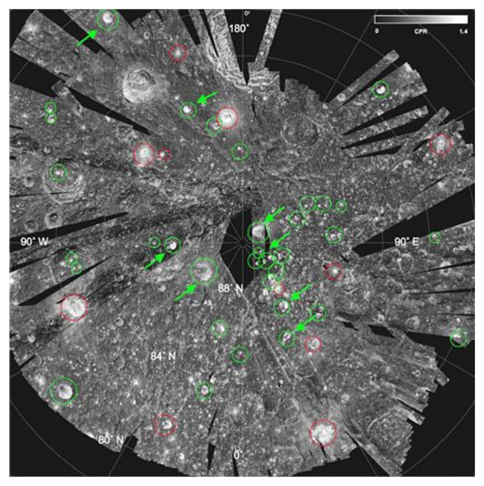

Figure 1: An image of craters likely to contain ice on the north pole, (Dunbar)

Obtaining samples from a more diverse area of the Moon's surface would allow scientists to develop a better understanding of the diversity of lunar geology and the differences between the types of lunar rocks, as well as the ability to authenticate data from remote sensing equipment. This diversity in sample size would also allow for improvement in cratering rate and age calibration points (Crawford).

One of the most important questions in the field of biology is how life arose. The fossil record extends to the end of the Late Heavy Bombardment Period and life likely began during that period. However, the impacts from meteorites, along with millions of years of weathering and tectonic activity, have left Earth's fossil record incomplete. Those same impacts may be the reason that partial fossil records from Earth may exist on the Moon. which has neither weathering nor tectonic activity. It is estimated that as much as 20,000 kg of Earth rocks per every 100 square kilometers exist on the Moon. The eastern part of the near side of the Moon is most likely to have Earth rocks from the Late Heavy Bombardment Period because that is the leading edge in the Moon's orbit around Earth (Earth).

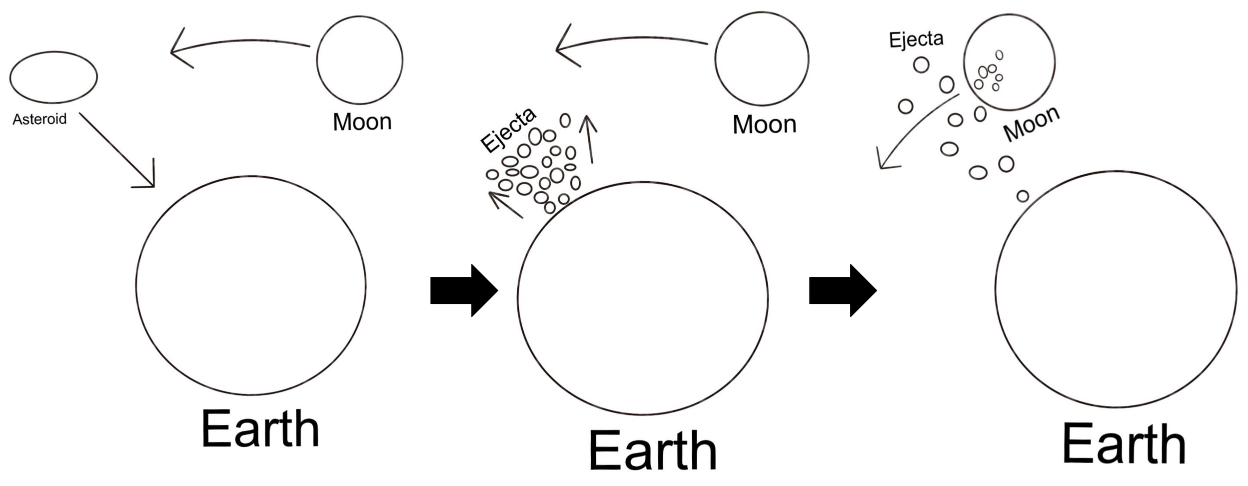

Figure 2: Diagram showing how terrestrial rocks end up on the Moon, photo credit: Rose Murphy

Resources

While there are many elements located on the Moon, Helium-3 could be considered the most productive and useful isotope found in lunar soil (Helium). Helium-3 is a nuclear element that can be used as an alternative energy source in a fusion reactor much like the nuclear energy used on Earth today but both safer and cleaner (Helium). No radioactivity is produced, and no harmful waste is created, making the process much more efficient (Helium). By finding where large deposits of Helium-3 are located, scientists can determine the most ideal location to build a research station with abundant access to the isotope in order to research its energy levels and transport Helium-3 back to Earth or use it to fuel missions further away. Helium-3 is deposited onto the lunar surface in a couple different ways such as solar wind distribution and cosmic-ray induced nuclear fragmentation reactions (Johnson).

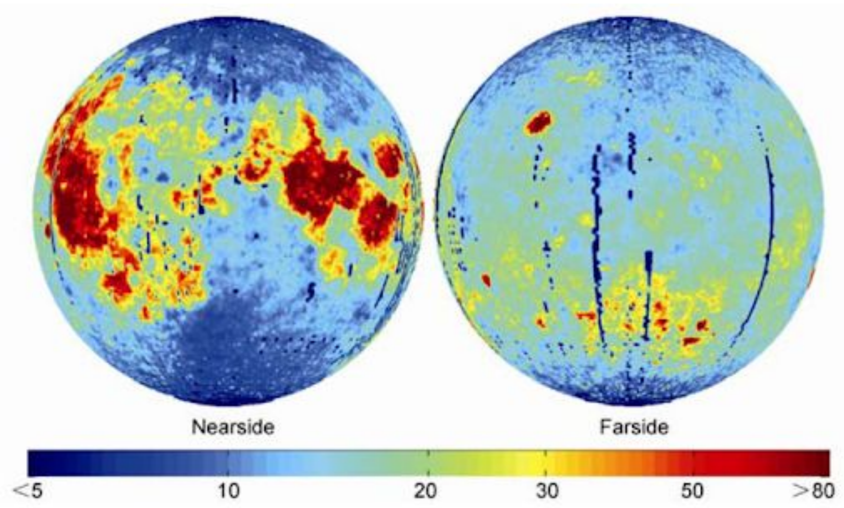

Figure 3: An interpolation of the total amount of Helium-3 per square meter "fixed" in the lunar regolith (ppb/m2) (Fa)

In Figure 3, the estimated distribution of Helium-3 in terms of ppb/m^2 is shown by a multi-channel microwave radiometer (Fa). Based on this, along with other studies on solar wind patterns, the highest density of Helium-3 is likely to be found in the central area on the near side of the Moon (Fa).

Highest Helium-3 Abundances	
Region (Approximate Location)	He-3 Abundance (ppb)
Mare Moscoviense (25° N, 150° E)	8-17
Apollo Basin maria (36° S, 152° W)	8-13
Tsiolkovskiy Crater maria (22° S, 130° E)	7-11
Northern Ocean Procellarum (18° N, 63° W)	9-13
Northeast Mare Fecunditatis (2° N, 56° E)	8-14
Mare Tranquillitatis (11° N, 40° E)	8-16
Mare Orientale (22° S, 93° W)	8-16

Table 1: Approximations of the amounts of Helium-3 in various locations on the Moon in terms of ppb (Johnson).

Table 1 additionally provides more in-depth analysis on the amounts of Helium-3 in specific places on the Moon (Johnson). While a few of the higher condensed amounts are on the far side, more of the smaller amounts are on the near side making it more feasible to mine from these locations (Johnson).

Lunar Outpost

There are two great advantages to constructing a lunar outpost with regards to structural theorization; a lunar launch pad for further space exploration missions and a water borer, both of which will greatly benefit the scientific community and facilitate future exploration of space.

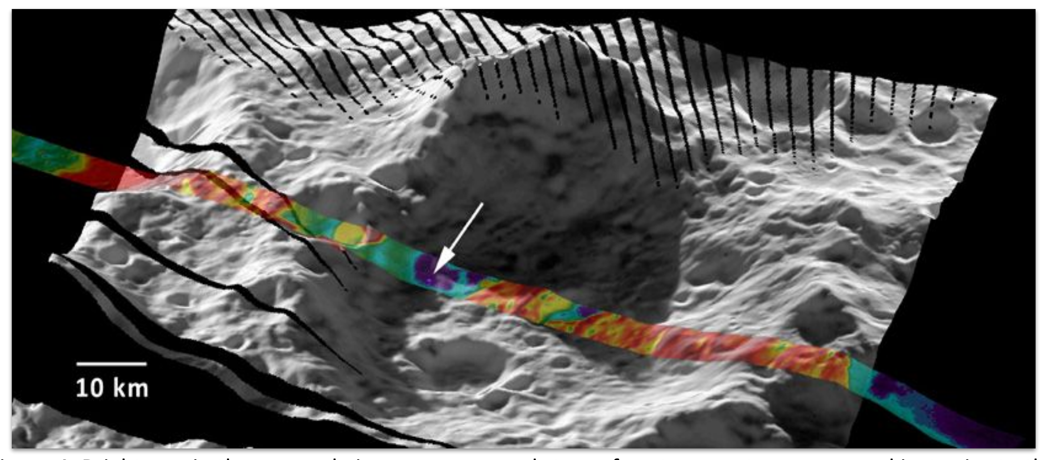

Figure 4: Brightness in the grayscale image corresponds to surface temperature measured just prior to the LCROSS impact at the Cabeus Crater (Choi)

With regards to the location, the lunar south pole is most promising for lunar exploration because it is particularly rich in hydrogen and contains water (Dunbar). Specifically, the Cabeus Crater is the optimal location of a lunar camp because it is the only known location on the Moon that contains water (Elphic). By landing next to water, more research may be conducted in sampling and experimenting with water extraction methods.

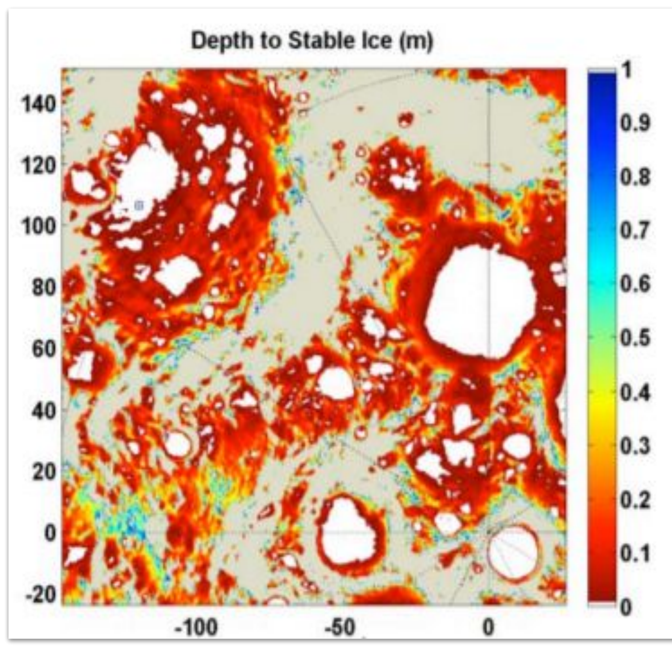

Figure 5: Depth to the 1 kg/m2 per billion year ice loss isotherm, from [5]. White denotes stability within 1 cm of the surface, beige denotes stability at depths greater than 1 meter. (Elphic)

Energy may be provided to the camp about Cabeus Crater by using solar panels (Carnegie). Through observation of solar incidence on the lunar surface, a location best suited for solar panels may be designated. Areas that are on the edge of the crater are ideal for solar panels as they get continuous sunlight throughout the day. The energy will be used to power excavation and scientific equipment.

By building a launch pad, rockets can be launched that are fractions of the size currently required because of the lessened need for large fuel tanks. Arlin Crotts, of Columbia University, said "it takes 25 to 30 times less energy to launch from the Moon than from Earth", which clarifies the benefit of building a lunar launch pad (Guenzel). Soon, it will be cheaper and of less risk to assemble and launch vehicles that have the purpose of going beyond Earth from a pad positioned on the Moon due to the extreme weight of rockets which must be thrusted out of Earth's atmosphere on a regular basis.

Conclusion

Resuming a program of lunar exploration would be advantageous across multiple fronts by providing increased access to resources such as Helium-3, expanding knowledge of Earth's formation and biological history, and facilitating research on other, more distant bodies. Greater information, including maps, images, samples, and spectroscopy data support the study of lunar geography; the field currently representing the greatest amount of information about the Moon. However, there are still many unanswered questions regarding formation and geological processes of the Moon. Returning to the surface of the Moon with either manned or unmanned missions could help to answer those questions. Nearly any location on the surface of the Moon would be a good place to study lunar geography, as much of the Moon's surface has not been studied in-depth and on-site. In order to supply both cleaner resources and increased monetary gain, the rare resource Helium-3 can be mined from the lunar surface. By examining solar wind patterns as well as cosmogenic nuclear reaction sites, scientists can determine the ideal place on the surface of the Moon to do so. In accordance with other research in this project, the near side of the Moon, according to various estimations of Helium-3 abundances, would be the ideal location to establish a lunar outpost. Based on geography and availability of resources, the south pole on the near side of the Moon would be the ideal location for a lunar outpost. The poles of the Moon are the most likely places to have water both underneath the surface and in permanently shadowed craters, and Cabeus Crater is one of the most likely places on the Moon to contain water. Having a lunar outpost, on the polar, near side of the Moon with the capability of performing launches as well as being able to extract water from under the surface would greatly benefit the scientific community by providing the foundation for future exploration of both the Moon and other extraterrestrial bodies.

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