The Synthesis and Characterization of Artificial Mars Regolith for Astrobiological and Geotechnical Applications.

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MARS LAB | ECO ASTRONOMY Inc | MADE IN SRI LANKA

ARTIFICIAL REGOLITH OF MARS | J – COLLECTION

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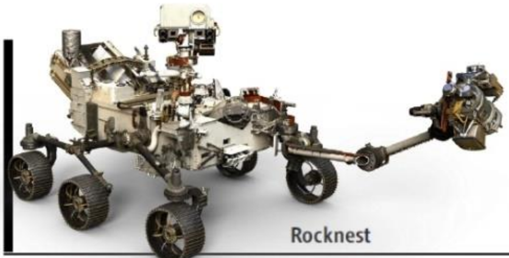
The Mars laboratory of Eco Astronomy Inc. is pioneering the development of a standard Mars Regolith Simulant for students, researchers, hobbyists, and educators globally. This initiative is rooted in petrological data obtained from NASA's Mars Curiosity Rover, combined with the precision engineering of Eco Astronomy's Artificial Regolith of Mars J–Collection Simulant. Designed to closely mimic the composition and properties of Martian soil, these simulants provide an unparalleled opportunity to study and experiment with Martian-like materials without leaving Earth. Aimed at advancing STEAM (Science, Technology, Engineering, Arts, and Mathematics) education, these simulants empower educators to inspire curiosity and scientific literacy in their classrooms. By fostering a well-informed and enthusiastic public, Eco Astronomy Inc. contributes to building a strong foundation of support for humanity's ambitious journey to Mars.

CHEMICAL PROPERTIES



MARS

	Rocknest	Gusev	Meridiani
Number	1*	48†	29†
SiO_2 (wt %)	42.88 ± 0.47	46.1 ± 0.9	45.7 ± 1.3
TiO_2	1.19 ± 0.03	0.88 ± 0.19	1.03 ± 0.12
Al_2O_3	9.43 ± 0.14	10.19 ± 0.69	9.25 ± 0.50
Cr_2O_3	0.49 ± 0.02	0.33 ± 0.07	0.41 ± 0.06
Fe_2O_3 + FeO	19.19 ± 0.12	16.3 ± 1.1	18.8 ± 1.2
MnO	0.41 ± 0.01	0.32 ± 0.03	0.37 ± 0.02
MgO	8.69 ± 0.14	8.67 ± 0.60	7.38 ± 0.29
CaO	7.28 ± 0.07	6.30 ± 0.29	6.93 ± 0.32
Na_2O	2.72 ± 0.10	3.01 ± 0.30	2.21 ± 0.18
K_2O	0.49 ± 0.01	0.44 ± 0.07	0.48 ± 0.05
P_2O_5	0.94 ± 0.03	0.91 ± 0.31	0.84 ± 0.06
SO_3	5.45 ± 0.10	5.78 ± 1.25	5.83 ± 1.04
Cl	0.69 ± 0.02	0.70 ± 0.16	0.65 ± 0.09
Sum (wt %)	99.85	99.88	99.88

ARTIFICIAL REGOLITH OF MARS

J– COLLECTION SIMULANT BY ECO ASTRONOMY

	Artificial Soil Simulant | Calibration to Rocknest 1*
SiO_2 (wt %)	42.88 ± 1.5
TiO_2	1.19 ± 0.5
Al_2O_3	9.43 ± 1.5
Cr_2O_3	1.19 ± 0.5
Fe_2O_3 + Feo	19.19 ± 1.5
MnO	0.41 ± 0.4
MgO	8.69 ± 1.5
CaO	7.28 ± 1.5
Na_2O	2.72 ± 1.5
K_2O	0.49 ± 0.2
P_2O_5	0.94 ± 0.5
SO_3	5.45 ± 1.5
Cl	0.69 ± 0.5
	99.85

Basaltic soil compositions from APXS analyses for Rocknest Portage, Gusev Crater, and Meridiani Planum on MARS | XRF data - Artificial Regolith of Mars | J– Collection Simulant- Eco Astronomy | Sri Lanka

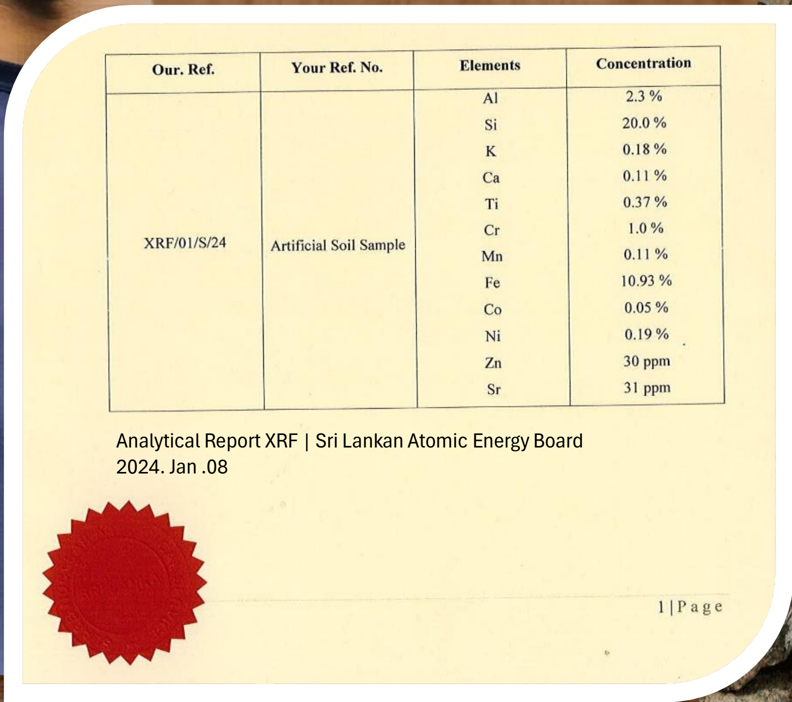
ANALOGIES LOCATIONS OF MARS - Gusev Crater, Meridiani Planum, Noachian terrains, Juventae Chasma.

GRAIN DIAMETER - 0.002- 1mm **ADDITIONAL ELEMENTS -**Ni, Zn, Sr, Co

SOIL MOOD: Ultra Superfine **RADIOACTIVE:** Nil

Artificial RM 01 | Artificial RM 02

Artificial Regolith of Mars | J– Collection



Our. Ref.	Your Ref. No.	Elements	Concentration
XRF/01/S/24	Artificial Soil Sample	Al	2.3 %
		Si	20.0 %
		K	0.18 %
		Ca	0.11 %
		Ti	0.37 %
		Cr	1.0 %
		Mn	0.11 %
		Fe	10.93 %
		Co	0.05 %
		Ni	0.19 %
		Zn	30 ppm
		Sr	31 ppm

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Analytical Report XRF | Sri Lankan Atomic Energy Board
2024. Jan .08

ECO ASTRONOMY
INTERNATIONAL RESEARCH INSTITUTE

*__Notice:__ We are pleased to inform you that the Mars Lab at Eco Astronomy Inc. has successfully completed the calibration of mineral composition based on the latest analytical report from SLAEB. This calibration process was conducted exclusively on heated samples only, ensuring precise and accurate data for further research and analysis. The findings from this calibration will significantly contribute to our ongoing efforts to understand the mineralogical properties of Martian materials. We remain committed to advancing our knowledge and supporting innovative discoveries in the field of planetary science. Should you require further details or have any questions regarding the calibration process or results, please do not hesitate to reach out.

Research DATA

It is important to understand Martian samples and their exact habitats, including extreme conditions, to improve future exploration of Mars. The Mars laboratory of Eco Astronomy Inc., represented by the Department of Research and Innovation's Advances in Multidisciplinary Studies Unit, has developed a standard Mars Regolith Simulant called "HAYA"—Eco Astronomy Artificial Regolith of Mars | J-Collection. This experiment is based on APXS data from Meridiani Planum, which was pre-analyzed via CheMin on NASA's Mars Curiosity Rover. To develop the Martian soil simulant, serpentine soil from Ussangoda and Indikollapelessa in Sri Lanka was selected as the initial material for this simulation, which was ground and sorted to a predetermined particle size ratio [grain diameter: 0.002- 1 mm]. The simulant initial materials were treated with a specific heat of algorithm using an HT 1800 high-temperature chamber furnace. To calibrate the exact chemical properties, small amounts of hematite, aluminum oxide (from sapphire), titanium oxide, manganese oxide, and calcium oxide were added. The upgraded materials were then kept under saturation in a radioactive chamber for 7–30 days. The final sample of Mars Regolith Simulant was analyzed via X-ray fluorescence (XRF), yielding the following results: SiO_2 (wt%) 42.88 ± 1.5, TiO_2 1.19 ± 0.5, Al_2O_3 9.43 ± 1.5, Cr_2O_3 1.19 ± 0.5, Fe_2O_3 + Feo 19.19 ± 1.5, MnO 0.41 ± 0.4, MgO 8.69 ± 1.5, CaO 7.28 ± 1.5, Na_2O 2.72 ± 1.5, K_2O 0.49 ± 0.2, P2O5 0.94 ± 0.5, SO3 5.45 ± 1.5, Cl 0.69 ± 0.5. These results show that the simulant is 90% similar to basaltic soil compositions from APXS analyses of Rocknest Portage. These measurements demonstrate the ability of the simulant to accurately represent the mechanical properties of in situ Mars soils for comparative studies. The Eco Astronomy-HHAYA Martian Simulants are designed to promote Earth-Mars analog activities, Mars terraformation activities, and STEAM education in classrooms. A well-informed and enthusiastic public base of support is crucial for the journey to Mars.

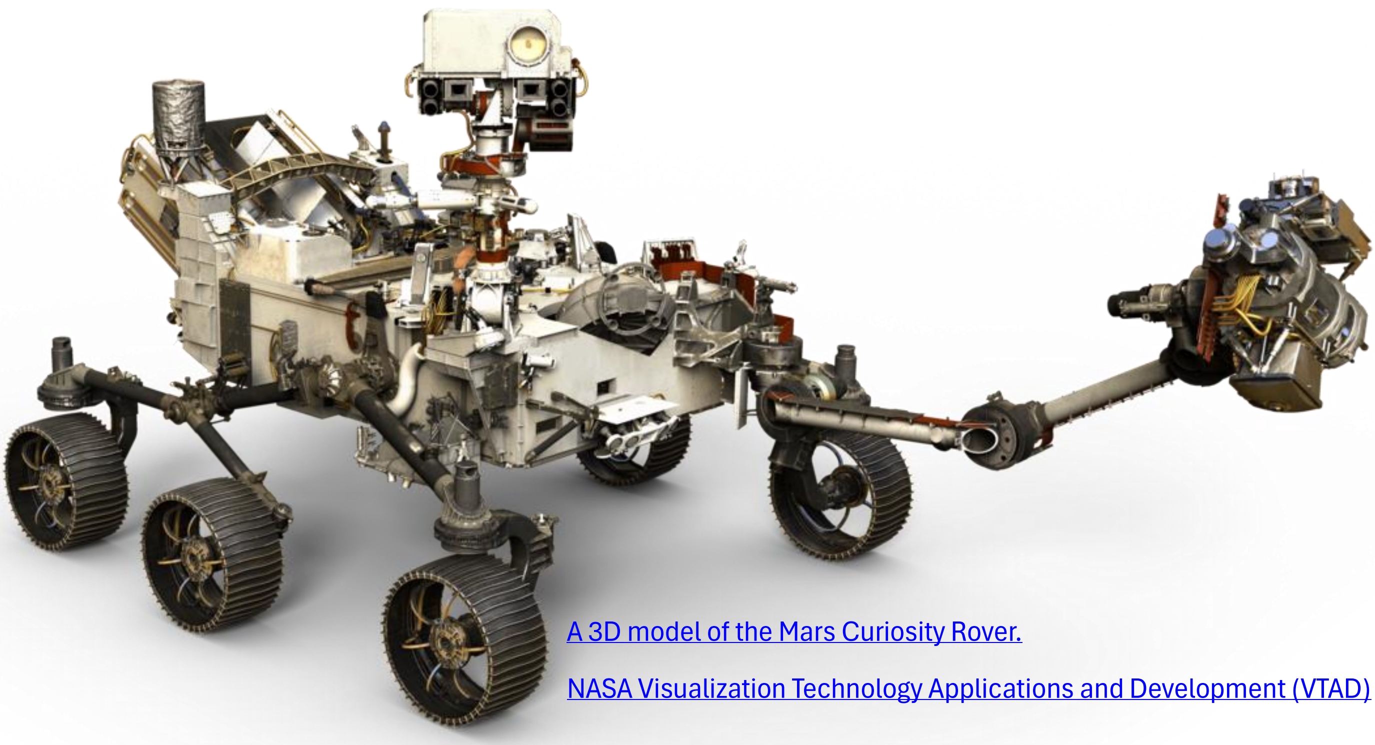
The Importance of Mars Regolith Simulants in Advancing Space Exploration

Mars regolith simulants play a crucial role in preparing for future Mars exploration by providing a terrestrial substitute for Martian soil. These simulants enable engineers to test the performance and durability of technologies such as rovers, landers, and excavation tools under conditions similar to those on Mars. Additionally, they facilitate the development of construction techniques, including using regolith as a building material for habitats and radiation shielding.

Simulants are also indispensable for advancing *in situ* resource utilization (ISRU), a strategy critical for reducing dependence on Earth-based supplies. By simulating Martian regolith, researchers can refine methods for extracting oxygen through electrolysis, producing building materials like bricks or concrete, and testing water extraction techniques.

Agricultural and sustainability research also benefits from regolith simulants, as scientists explore the feasibility of growing plants in Martian soil. These studies address key challenges such as soil toxicity, lack of organic matter, and nutrient deficiencies. Moreover, simulants aid in safety assessments, allowing researchers to evaluate the potential hazards of Martian dust, including its abrasiveness and chemical reactivity, which could impact machinery, human health, and filtration systems.

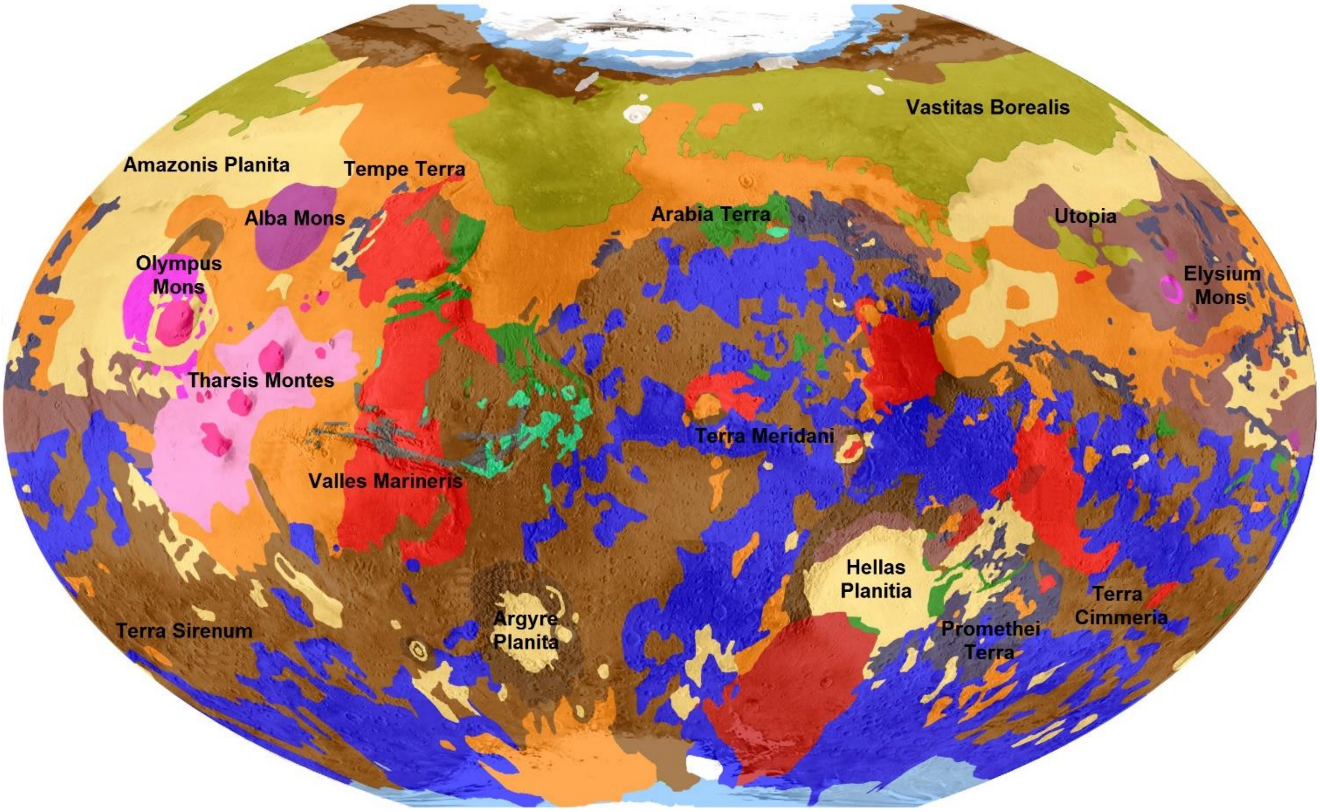
Prominent organizations, such as the Exolith Lab at the University of Central Florida and NASA's Swamp Works, have developed high-fidelity simulants like MGS-1 to mimic Martian regolith's mineralogical and geotechnical properties. These materials support mission preparation by enabling space agencies to train astronauts, test sample collection techniques, and refine geophysical and geochemical analysis methods. By addressing these challenges on Earth, Mars regolith simulants save time, reduce costs, and ensure the success of future exploration missions.



A 3D model of the Mars Curiosity Rover.

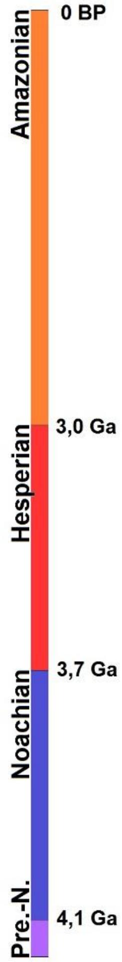
NASA Visualization Technology Applications and Development (VTAD)

Generalised Geological Map of Mars



Based on Scott & Carr (1978) and MOLA-data from NASA

- Polar ice
- Volcanic plains
- Smooth plains made of eolian deposits
- Volcanic material with a moderated relief, made of basalt and pyroclastic material
- Crater plains made of lava, coated by loess
- Fissured lava plains
- Marginal lifted volcanic material, potentially made of ancient volcanic shields
- Plains with lava-channels
- Lavaplateaus covered by breccia-like ejecta
- Eroded edges and pyroclastic basin rim material with a knobby texture
- Bedded plain material of eolian deposits
- Canyon floor material of the Valles Marineris: made of fluvial and eolian sediments, as well as of landslide material (possibly with partial exposed bedrock)
- Basalt (200-800 Ma)
- Fluvial and eolian deposits
- Breccia material, due to subsurface collapse of ground ice melting
- Aureole material: lava flows from fissures
- Belted plains with lava channels
- Mottled lava plains
- Knobs: orogen relics, relief inversion and subsurface collapse (contains ejecta)
- Hilly lava plains



Mars, the fourth planet from the Sun, presents a geologically diverse and mineralogically rich landscape. Its surface is a mosaic of volcanic plains, sedimentary basins, and ancient impact craters, shaped by processes including volcanism, tectonics, erosion, and the activity of liquid water. This article explores the geological history of Mars and its mineral composition, highlighting findings from rover missions, orbiters, and meteorite studies. These insights provide critical information about the planet's past environmental conditions and its potential for supporting life.

Mars has captivated scientists and astronomers for centuries due to its similarities and contrasts with Earth. Geology and mineralogy studies of Mars are essential for understanding its formation, evolution, and habitability. The data gathered from missions such as Viking, Mars Odyssey, Mars Reconnaissance Orbiter, and the rovers Spirit, Opportunity, Curiosity, and Perseverance offer unprecedented views into the planet's subsurface and surface composition.

Geological Features

Volcanism Mars hosts some of the largest volcanoes in the Solar System, including Olympus Mons, which rises approximately 21.9 kilometers above the surrounding plains. The Tharsis volcanic region and Elysium Planitia are prominent centers of volcanic activity. Evidence of basaltic lava flows suggests prolonged volcanic activity during the Noachian and Hesperian periods.

Impact Cratering Impact craters such as Hellas Planitia and Gale Crater provide windows into Mars's geological past. These craters reveal layered sediments that hint at past environmental conditions, including fluvial activity.

Tectonics Unlike Earth, Mars lacks plate tectonics. However, the planet shows significant tectonic features, such as rift valleys and fault lines. The Valles Marineris, a canyon system over 4,000 km long, is a prime example of extensional tectonic activity.

Erosional and Sedimentary Processes Wind and water erosion have shaped Mars's landscape, creating dune fields, river valleys, and deltas. Sedimentary rock layers in locations such as Gale Crater and Jezero Crater suggest the presence of ancient lakes.

Mineralogical Composition

Silicates Basaltic rocks dominate the Martian surface, consisting primarily of pyroxenes, olivine, and plagioclase feldspar. The presence of these minerals points to a history of volcanic activity and cooling processes.

Hydrated Minerals Phyllosilicates (clays) and sulfates provide evidence of past interactions between water and rock. These minerals have been detected in various regions, including the ancient terrains of Arabia Terra and Mawrth Vallis.

Iron Oxides Hematite and magnetite are abundant, contributing to Mars's characteristic red hue. Hematite-rich regions, such as Meridiani Planum, suggest the past presence of liquid water.

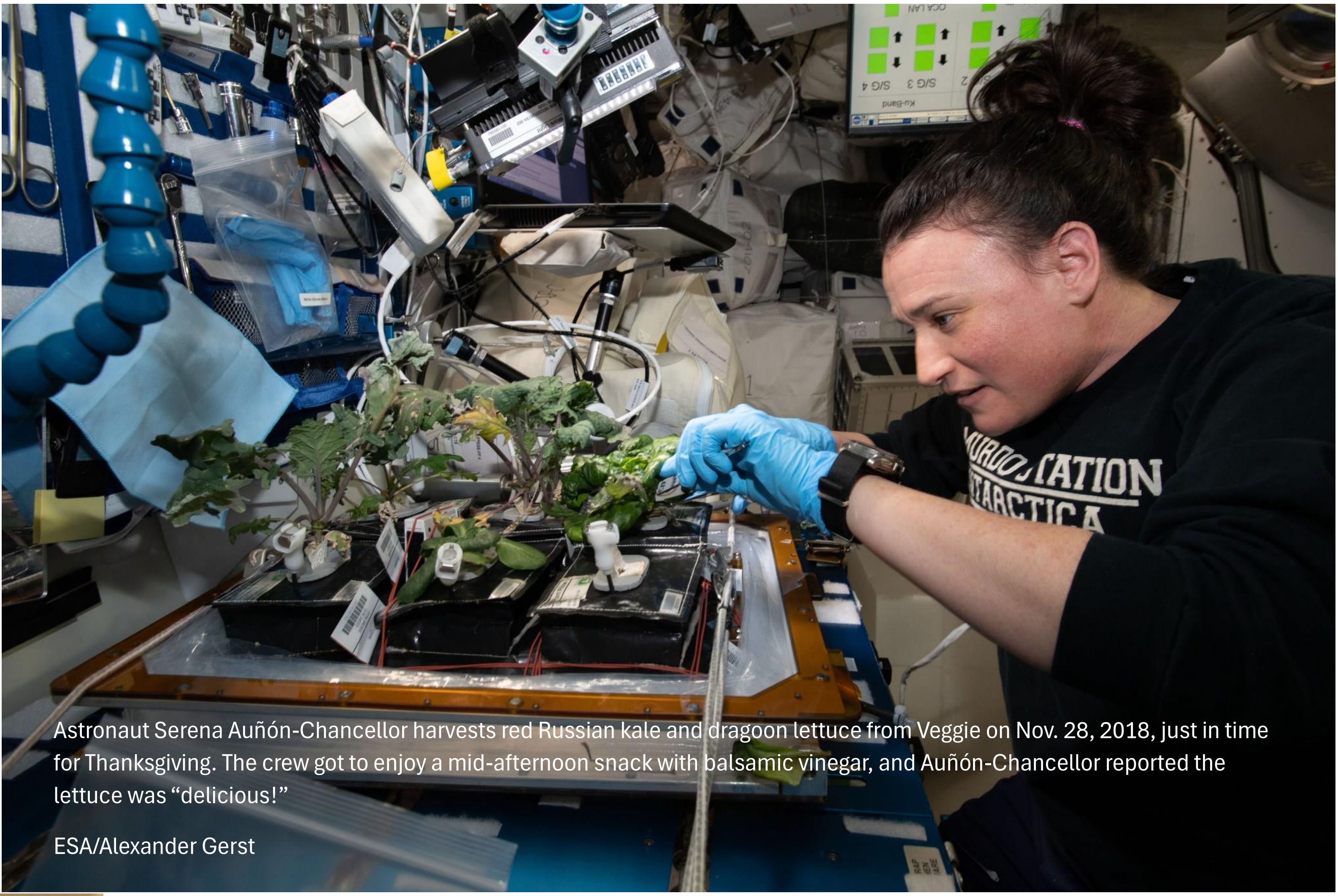
Carbonates While less common, carbonates have been identified in regions such as Nili Fossae, hinting at episodic CO2-rich aqueous environments.

Perchlorates Perchlorates, discovered in Martian regolith, are of particular interest for astrobiology and in-situ resource utilization. They indicate a chemically active environment.

Geochronology and Evolution Mars's geological history is divided into three main eras: the Noachian, Hesperian, and Amazonian. The Noachian era (4.1 to 3.7 billion years ago) was marked by intense bombardment and fluvial activity. The Hesperian era (3.7 to 3.0 billion years ago) saw widespread volcanic activity and the formation of extensive lava plains. The Amazonian era (3.0 billion years ago to present) is characterized by reduced volcanic activity and ongoing aeolian processes.

Astrobiological Implications The identification of hydrated minerals, ancient riverbeds, and lake deposits supports the hypothesis that Mars once harbored conditions suitable for life. Organic molecules detected by the Curiosity rover and the presence of subsurface brines detected by orbiters strengthen this possibility.

Conclusions The geology and mineralogy of Mars offer invaluable clues about the planet's history and potential for life. Future missions, such as the European Space Agency's ExoMars and NASA's Mars Sample Return campaign, will deepen our understanding of the Red Planet. By studying Mars, we not only uncover its secrets but also gain insights into planetary processes that shape terrestrial worlds across the Solar System.



Astronaut Serena Auñón-Chancellor harvests red Russian kale and dragoon lettuce from Veggie on Nov. 28, 2018, just in time for Thanksgiving. The crew got to enjoy a mid-afternoon snack with balsamic vinegar, and Auñón-Chancellor reported the lettuce was “delicious!”

ESA/Alexander Gerst

Mars colonization represents a significant milestone in the quest for human exploration and expansion beyond Earth. As the fourth planet from the Sun, Mars offers a unique environment with challenges and opportunities for establishing a sustainable human presence. Its thin atmosphere, composed primarily of carbon dioxide, along with its freezing temperatures and lack of liquid water on the surface, demands innovative technologies for survival. Advancements in areas such as habitat construction, life support systems, and resource utilization—like extracting water from Martian soil or generating oxygen—are critical to making colonization feasible. Furthermore, Mars's lower gravity, compared to Earth's, may impact human health over long durations, necessitating rigorous studies on its physiological effects. Beyond the scientific challenges, Mars colonization could serve as a stepping stone for interplanetary travel and ensure humanity's survival in the event of global catastrophes on Earth.

About Eco Astronomy Inc

Eco Astronomy Inc., established in 2018 in Sri Lanka, is a leading multidisciplinary astronomical research institute in South Asia, dedicated to advancing the frontiers of science and education.

The organization primarily focuses on investigating extreme environmental conditions and their implications for the "Harbor Life" concept and astrobiology, contributing to our understanding of life beyond Earth. As a distance-learning institution, Eco Astronomy Inc. integrates astronomy, astrobiology, and paleontology into its innovative online courses, fostering a multidisciplinary approach that enhances students' academic and analytical abilities. These programs emphasize critical communication skills, enabling meaningful engagement with international experts. Additionally, the institute actively supports major space exploration initiatives, including lunar and Martian programs, while innovating extraterrestrial simulation materials for advanced research. It also adds value to terrestrial minerals and gems through cutting-edge technologies. Through its research, education, and advocacy efforts, Eco Astronomy Inc. promotes sustainable innovation in global education and the astronomical research industry, driving impactful development and fostering a future-oriented scientific community.

Product Information

Citation

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