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SCIENCE NEWS BY AGU

Gardening in Moon Soil

Utah Rocks

Hot Springs Clues in Tibet

FIELD TRIP

Some researchers trek along active fault lines, others launch drones into Category 4 hurricanes. Either way, it's time for an adventure.

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Lunar Soil Can Grow Plants

Lunar regolith is capable of growing greenery, but plants grown in younger lunar soil were less stressed than plants grown in more mature soil. These experiments were the first attempts to grow plants in actual lunar regolith rather than soil simulant. The results, which were published in *Communications Biology*, are a critical step in understanding how future long-term residents of the Moon may be able to produce their own food and oxygen through lunar agriculture (bit.ly/lunar-soil-plants).

"It's really good news that plants can grow in the lunar soils," said coauthor Robert Ferl, a space biologist at the University of Florida (UF) in Gainesville, during a press briefing. The challenges that the plants experienced showed that "there is some very interesting biology, lunar biology, lunar biological chemistry, that's yet to be learned. But the bottom line is that until it was actually done, nobody knew whether plants, especially plant roots, would be able to interact with very sharp, very antagonistic soils that the lunar regolith presents."

This Arabidopsis *plant was grown in lunar soil for about 2 weeks. Credit: Tyler Jones, UF/IFAS*

"It's really good news that plants can grow in the lunar soils."

The Moon Is Stressful

The researchers sowed *Arabidopsis thaliana* (thale cress) seeds in small quantities of regolith preserved from the Apollo 11, Apollo 12, and Apollo 17 landing sites, as well as in lunar soil simulant. *Arabidopsis* plants, which are related to mustards, cauliflower, broccoli, kale, and turnips, have been grown in a wide variety of soils and environments, including in space.

"It is edible, but it's not especially tasty," said lead author and plant biologist Anna-Lisa Paul of UF. "We learn a lot that can be translated into crop plants from looking at *Arabidopsis*." Moreover, *Arabidopsis* plants are small and have a growth cycle of about a month, which is ideal when trying to grow them in about a teaspoon's worth of lunar regolith.

The researchers found that all three lunar soils were capable of growing plants, but with some difficulty. Compared with the control samples grown in lunar simulant soil, plants grown in actual lunar regolith had more stunted root systems, slower growth, and less extensive leaf canopies. They also exhibited stress responses like deeper green or purple leaf pigmentation. Although all of the plants grown in lunar soil were stressed, some were more stressed than others. Those grown in Apollo 11 regolith were the most stressed, and those in the Apollo 17 regolith were the least stressed.

Although Apollo 11, 12, and 17 all landed in basaltic mare regions of the Moon, the sites exhibited some key differences. Regolith at the Apollo 11 site is considered to be the most mature soil of the three. The site has been exposed to the lunar surface the longest, which has led to the soil being weathered by the solar wind, cosmic rays, and micrometeorite impacts. These maturation processes can alter the chemistry, granularity, and glass content of the regolith. The other two sites have also been "matured" by these processes but to lesser extents, Apollo 17 least of all.

The team performed gene analysis on the plants after 20 days of growth and found that the regolith-grown plants showed stress responses related to salt, metals, and reactive oxygen species. Those results suggested that much of the plants' difficulty was related to the chemical differences between lunar regolith and lunar soil simulant, such as the oxidation state of iron—lunar iron tends to be in an ionized metallic state, whereas simulant and Earth soils tend to contain iron oxides that are easier for plants to access. Ionized iron results from interactions with the solar wind, which explains why the most mature soil, that from Apollo 11, grew the most stressed plants.

"The simulants are incredibly useful for, say, engineering purposes.... They're wonderful for determining whether or not your rover is going to get stopped in the soil," said coauthor Stephen Elardo, a planetary geochemist at UF. "But when you get down to the chemistry that's accessed by plants, they're not really one to one. The devil is in the details, and in the end the plants are concerned about the details."

"The devil is in the details, and in the end the plants are concerned about the details."

Choose Your Resources Wisely

These results show that lunar regolith is capable of supporting the growth of plants, which will be an integral component of any long-term lunar habitat. Plants will be able

Anna-Lisa Paul harvests plants for genetic analysis. Credit: Tyler Jones, UF/IFAS

to support key functions like water recycling; carbon dioxide removal; and oxygen, food, and nutrient production.

"It's a well-organized and thought-out experiment to test growing plants in actual lunar regolith returned from the Apollo 11, 12, and 17 missions," said Edward Guinan, an astronomer at Villanova University in Pennsylvania who has conducted plant experiments in Moon and Mars soil simulants. "As the authors point out, the test plants are stressed and don't grow well. The plants have characteristics of plants grown in salty or metal-rich soils. Maybe trying different terrestrial plants that do well in poor or salty soils might be an interesting follow-up." Guinan was not involved in this research.

This study also shows that although plants can be grown using in situ lunar resources, where those resources come from will be important for the plants' growth success.

Regardless of where future lunar explorers build a habitat, "we can choose where we mine materials to use as a substrate for growth habitats," Paul said. "It's where the materials are mined from that makes a difference, not where the habitat exists."

By **Kimberly M. S. Cartier** (@AstroKimCartier), Staff Writer

Million or Billion? Narrowing Down the Age of Mantle Processes

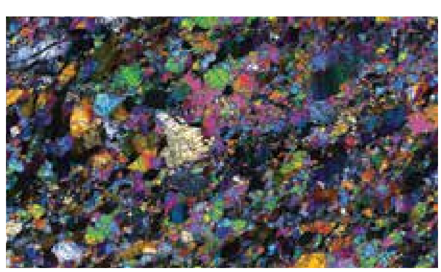
As tectonic plates jostle one another, collisions can cause the bottom of the ocean to end up on land. Formerly underwater sequences of oceanic crust and mantle, called ophiolites, help geologists not only to disentangle the history of how these rocks went skyward but also to discern past exploits of Earth's mantle.

In a recent study published in the *Journal of Petrology* led by Natasha Barrett while she was a doctoral student at the University of Alberta, Barrett and her team examined samples from jungle-encased ophiolites collected more than 40 years ago from Papua New Guinea, an island nation just north of Australia (bit.ly/ophiolites-guinea).

The spreading center that produced these ophiolites was likely erupting basalt seafloor about 70–55 million years ago—around the time the dinosaurs died. However, scientists suspected that the ophiolites's lowermost mantle rocks, which have strange geochemical signatures, must have come from mantle that melted eons before, likely during the Archean, between 4 billion and 2.5 billion years ago (when life was restricted to single-celled organisms). Barrett and her team demonstrated that the ophiolites' lowermost mantle is instead much younger and proposed that it melted in a modern subduction zone setting, forcing petrologists to rethink how these geochemical signatures developed.

Leftovers

Some scientists think that before the dinosaurs' demise, oceanic lithosphere hanging off the northern edge of Australia plunged into the mantle, producing a trench and spreading center on the seafloor where new oceanic crust erupted. Past the proposed spreading center may have been yet another subduction zone accommodating the disappearance of the Pacific plate into the mantle, with a string of volcanoes poking above the water. Eventually, these disparate pieces of Earth's surface—northern Australian fragment, spreading center, and volcanic island arc—collided, with the remnants of these events preserved in parts of New Guinea.



Scientists analyzed peridotites like this, from ophiolite in Papua New Guinea, to better understand the complex geology of the region. Credit: Natasha Barrett

"In the Archean, the mantle was hotter, so you expect to have more melting."

Today, New Guinea—an island split between the countries of Indonesia and Papua New Guinea—peers above various Pacific seas. This scrap of mostly continental crust, which connects to Australia when sea level decreases, hides those ophiolites below its lush vegetation.

Unique Ophiolites

If intrepid geologists came upon a complete ophiolite, they would walk through seafloor sediments, lavas and intrusive igneous rocks of the crust, and mantle rocks called peridotites that are rich in the greenish mineral olivine. Barrett compared the lowest layer of mantle peridotite, which is what was left over after the mantle melted, to a squeezed sponge, bereft of its water (the melt, in this analogy). It is these rocks—equivalent to the wrung-out sponge—that scientists expected to be billions of years old.

In New Guinea's ophiolites, the leftover, lowermost peridotites are unique in two ways. First, they're especially refractory, which means they're filled with elements, particularly magnesium, that don't like to be in melts, said Marguerite Godard, a mantle petrologist at the French National Centre for Scientific Research who is hosted at the Université de Montpellier. Godard was not involved with this study.

Second, these rocks lack many elements already in low abundances in the mantle; these trace elements strongly prefer the melt, depleting the residue. "Highly refractory [and depleted] mantle means a lot of melting,"