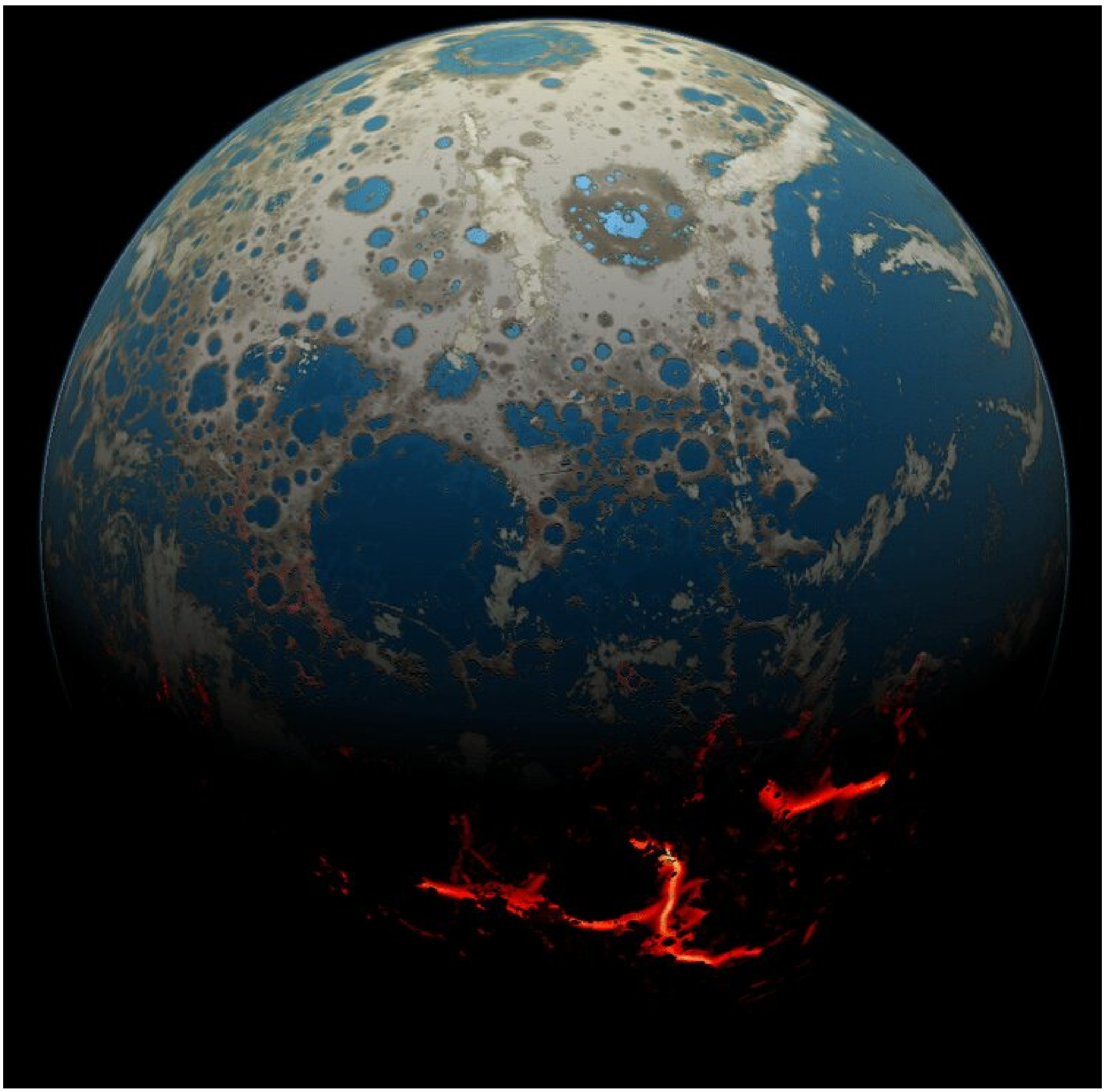
If a planet has a lot of methane in its atmosphere, life is the most likely cause

December 24 2020, by Evan Gough



Artist’s conception of early Earth after several large asteroid impacts, moving magma on to the surface. Credit: Simone Marchi/SwRI

The ultra-powerful James Webb Space Telescope will launch soon. Once it's deployed and in position at the Earth-Sun Lagrange Point 2, it'll begin work. One of its jobs is to examine the atmospheres of exoplanets and look for biosignatures. It should be simple, right? Just scan the atmosphere until you find oxygen, then close your laptop and head to the pub: Fanfare, confetti, Nobel prize.

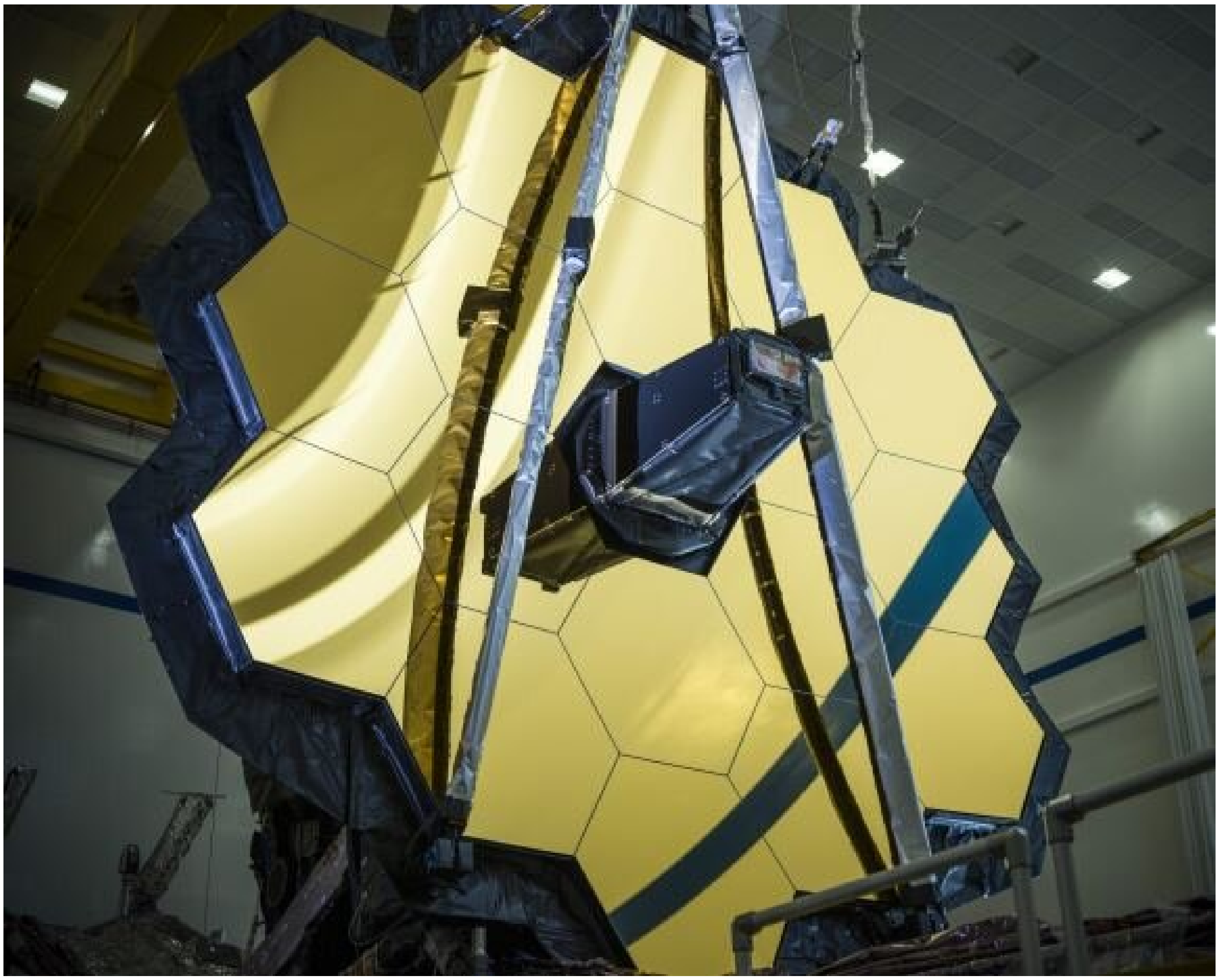
Of course, Universe Today readers know it's more complicated than that. Much more complicated.

In fact, the presence of oxygen is not necessarily reliable. It's methane that can send a stronger signal indicating the presence of life.

Oxygen might seem like the obvious thing to look for in a planet's atmosphere when searching for signs of life, but that's not the case. Its presence or lack thereof is not a reliable indicator. Earth's history makes that clear.

Modern Earth's atmosphere contains about 21% oxygen, and we know that most of it comes from organisms in the planet's oceans. But there's a hitch: Once cyanobacteria on ancient Earth started producing oxygen as a byproduct of photosynthesis, it still took an awfully long time before the atmosphere became oxygenated, possibly a billion years.

What if we examined an exoplanet, found no oxygen, then moved on, not realizing that there was life down there, at the beginning of oxygenating that world? What if we were a billion years too early, and life hasn't oxygenated the exoplanet's atmosphere yet? Rocky planets have many oxygen sinks, and biologically produced oxygen wouldn't be found free in the atmosphere until those sinks were becoming saturated.

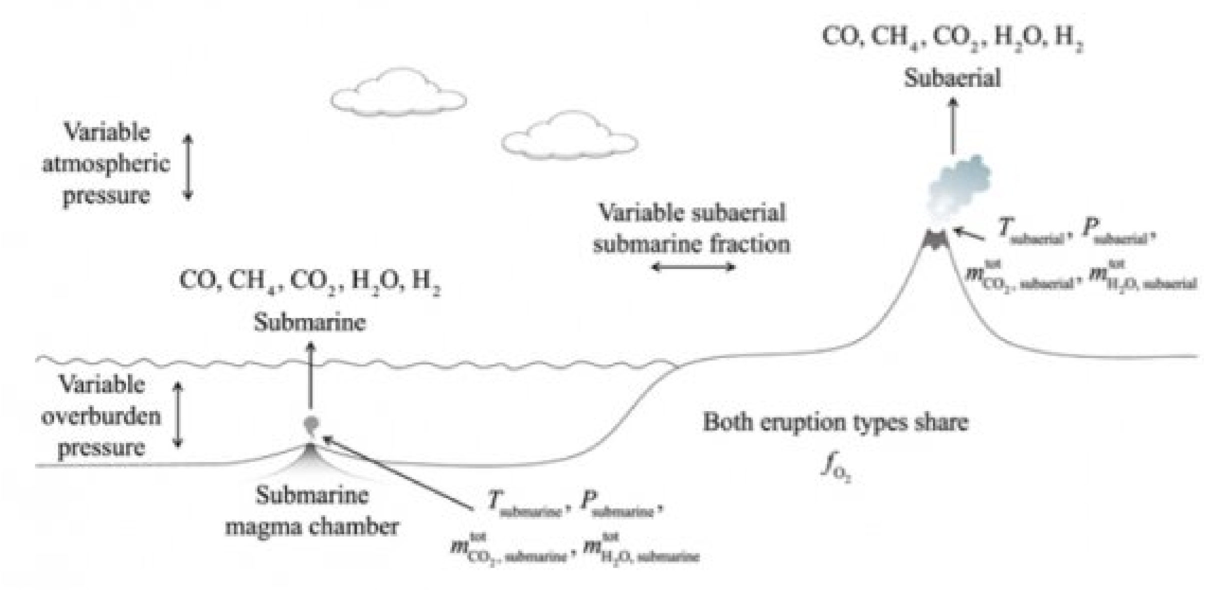


Shown with its primary mirror fully deployed, NASA’s James Webb Space Telescope is the largest and most technically complex space science telescope NASA has ever built. One day, hopefully soon, it’ll finally launch. Credit: NASA/Chris Gunn

That's what happened on Earth, and that's what we expect might happen on other rocky worlds. On Earth, geological activity churns magma up from the mantle onto the crust. Much of the mantle material, like iron, for example, bonds with atmospheric oxygen, pulling it out of the atmosphere.

This is one reason that planetary scientists focus on other things, like methane (CH_4). In a new paper, researchers examined the potential for methane to signal biological activity. They say that abundant methane in a planet's atmosphere is unlikely to come from volcanoes and most likely has a biological origin.

The paper's title is "Abundant Atmospheric Methane from Volcanism on Terrestrial Planets Is Unlikely and Strengthens the Case for Methane as a Biosignature." The lead author is Nicholas Wogan from the Dept. of Earth and Space Sciences, University of Washington, and from the Virtual Planetary Laboratory at the U of W. The paper is published in *The Planetary Science Journal*.



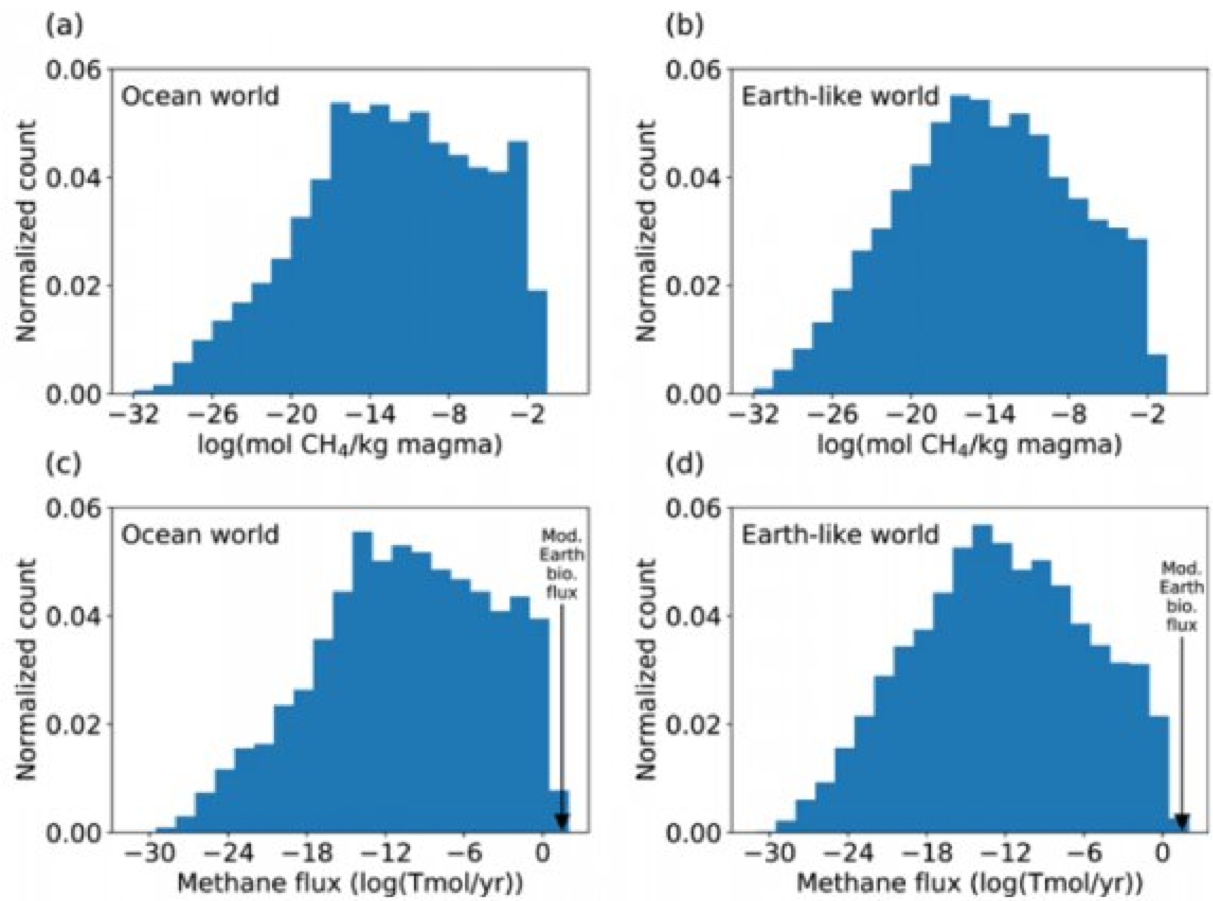
The trio of researchers investigated volcanic false positives to the

CH4+CO2 biosignature on two types of planets: one with only submarine volcanic outgassing, a water world, and one more like Earth, with both submarine outgassing and subaerial outgassing. This figure from the study shows some of the parameters used in the models. Credit: Wogan et al, 2020

Detecting potential biosignatures like methane in the atmospheres of distant exoplanets is tricky. But once something like methane is detected, harder work awaits. Its presence must be investigated in the context of the planet itself.

Biosignature researchers haven't been waiting idly for the James Webb Space Telescope to launch. They've put a lot of thought into detecting biosignatures with the telescope. Scientists have proposed that planetary atmospheres with abundant methane and carbon dioxide in disequilibrium could be a strong biosignature. In their paper, the authors point out that "…few studies have explored the possibility of nonbiological CH_4 and CO_2 and related contextual clues." In this case, nonbiological means volcanoes.

The authors wanted to use a thermodynamic model to investigate whether or not outgassing from volcanic magma on Earth-like planets could put CH_4 and CO_2 into the atmosphere. In essence, they found that volcanoes are unlikely to produce the same methane quantities that biological sources could. It's not impossible, just improbable.



A figure from the study. (a) and (b) show normalized methane production for an ocean world and an Earth-like world. (c) and (c) show methane production multiplied by Earth's magma production rate. For modern Earth's magma production rate, volcanoes are likely to produce negligible CH4, which strengthens the case for methane as a biosignature. Credit: Wogan et al, 2020

That's largely because hydrogen likes to stay in magma. H_2O is highly soluble in magma, limiting the amount of H that's outgassed and consequently restricts how much CH_4 is present in a planet's atmosphere. Another reason is that CH_4 itself requires low-temperature magma to outgas, whereas the majority of Earth's magma is higher temperature.

In those improbable cases where volcanism could produce large amounts of methane, the authors found, they would also produce carbon dioxide. Ancient Archaean Earth was much more volcanically active than modern Earth. During the Archaean Eon, Earth's heat flow was up to three times more than it is currently. According to the study, it could've produced 25 times more magma than modern Earth and much more methane. But the same activity that produced all that methane would also produce far more carbon dioxide. That, the authors point out, is a detectable false-positive. But if abundant methane is detected without accompanying amounts of CO_2, then that is a more reliable biosignature.

An artist’s illustration of early Archaean Earth, when the planet was much more volcanically active. Credit: Tim Bertelink – Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=57273984

The authors say that it would be difficult to explain methane and carbon dioxide detection without invoking biological sources, at least for any similar planets to Earth. They also concluded that a small or negligible amount of carbon monoxide detected in an atmosphere strengthens the CH_4+CO_2 biosignature because "…life readily consumes atmospheric CO, while reducing volcanic gases likely cause CO to build up in a planet's atmosphere."

The researchers conclude with a cautionary note, pointing out that this work is all based on what we know about Earth and other planets in our own solar system. How far that knowledge can be extended to thousands of different exoplanets is unclear.

"These conclusions should be taken with caution because they are based on what is understood about processes occurring on the Earth and our solar system, which may be a very sparse sampling of what is possible," they write.

More information: Nicholas Wogan et al. Abundant Atmospheric Methane from Volcanism on Terrestrial Planets Is Unlikely and Strengthens the Case for Methane as a Biosignature, *The Planetary Science Journal* (2020). DOI: 10.3847/PSJ/abb99e

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