Science AMA Series: We're researchers at the University of Texas Institute for Geophysics, who just published a pair of papers on buried ice deposits and potential volcano/ice and impact/ice interactions on Mars: ask us anything!

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April 17, 2023

Abstract

Hi! We're Dr. Joe Levy and Cassie Stuurman—we study geological systems in cold regions on Earth to try to understand the evolution of the surface of Mars and how cold landscapes on Earth record evidence of climate change. Ice is one of the most important, but least appreciated geological materials. It flows and melts when local climate conditions are warm, and piles up when conditions are cold. You can drink it, measure the chemical fingerprint of past ice ages locked away in it, and even look for modern and ancient microbial life in it. So how do we use planetary analogs on Earth to understand surface processes on Mars? Where is the ice on Mars? How similar is it to glacial and permafrost landforms on Earth? What kind of changes to the surface of Mars and Earth have been wrought by changing climate over the last few million years? How are we going to use ice on Mars when humans begin to settle on that planet? This is the paper Joe published - Candidate volcanic and impact-induced ice depressions on Mars and this is the paper Cassie published - SHARAD Detection and Characterization of Subsurface Water Ice Deposits in Utopia Planitia, Mars And here's the original Reddit post that made it to the front page - A strangely shaped depression on Mars could be a new place to look for signs of life on the Red Planet, according to a study. The depression was probably formed by a volcano beneath a glacier and could have been a warm, chemical-rich environment well suited for microbial life. I will be back at 1 pm EDT to answer your questions, ask me anything!

REDDIT

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LEVY_LAB R/SCIENCE

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READ REVIEWS

WRITE A REVIEW

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Is there a scientific consensus on how the outflow channels on Mars were formed? I have read that the Kasei Valles was formed when volcanic/tectonic activity melted subsurface ice above pressurized groundwater. It's just so hard to imagine a "spring" creating such a massive land form feature. I did a video about this flood on my YouTube channel, but I would love to hear from some actual scientists about what an event like that may have been like.

gradyh

The preferred model at the moment is that the outflow channels likely formed from volcanic and/or impact cracking of the martian cryosphere (the frozen part of the crust near the surface), which released large volumes of water and lava (although the exact order of which erupted first and in what order seems to vary from outflow channel to outflow channel).

There is a minority view that outflow channels may only represent evidence of the eruption of lava, and

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that water may not have been involved (http://www.webpages.ttu.edu/dleverin/leverington_mars_outflow_channels_geomorphology_2011.pdf)

That would mean the lava was either very hot (to make it runny) or very low silica (which also makes it runny--like in Hawaii).

Outflow channels are definitely one of the most mysterious landforms on Mars, which are still being actively investigated with radar, imagers, etc.

What are the viable applications of martian ice? Would it primarily be used for food production and consumption or would it also be used for production of energy?

IPlayAtThis

Spot on, SkunkyFatBowl--water ice is useful for lots of reasons. It can be electrolytically "cracked" in to hydrogen and oxygen to make air to breathe and rocket fuel to burn (or fuel for hydrogen fuel cells). It can be melted to drink or sustain crops. Water ice is an excellent shield against cosmic rays, which will help keep astronauts cancer risk down. So in addition to its scientific uses (martian climate records, preservation of organics) it also has many uses for supporting human exploration.

Is your expertise useful in any way in understanding CO2(dry ice) formations on mars? Does it complicate your research studying environments where types of ice other than water ice can form?

salton

Great question--CO2 ice and water ice are both seasonally stable at the martian middle latitudes and poles. The evidence that the ice deposits in Utopia, Galaxias, and North Hellas (among other places on Mars) is water ice, not CO2 ice comes from a few lines of evidence:

1) Water ice is more stable than CO2 ice (which sublimates at 150 K). The near-subsurface in these mid-latitude locations is usually warmer than the frost point of CO2, so any CO2 ice at these locations would have sublimated away.

2) The speed of radar waves through water ice and CO2 are are different--radar waves move faster through CO2 ice than through water ice. In Cassie's study (as well as other studies of ice cored glacial deposits), by measuring the thickness of the deposits and the time it takes the radar to travel through them, we can determine the speed at which the radar waves moved (distance / time = velocity). That radar velocity is most diagnostic of ice + sediment + air for these deposits, and is too slow to be CO2 ice.

Amazingly, at really high latitudes, where it's cold enough for CO2 to condense out, some dry-ice glaciers may have formed in the past: http://www.planetary.brown.edu/pdfs/3803.pdf

Hey there, I work right across the street in the CRC! Great to see some UTIG people on here.

Hmm, my question...is it possible to use remote capabilities to extract ice core on Mars the way people do in Antarctica? And if so, how long away are we from that technology? Is there anything particular in Martian ice core you'd really hope to find?

NotTheHartfordWhale

Small world! Come over and visit some time!

Ice core handling on Earth is a very human-intensive activity. In addition to building and operating the ice coring rigs (which include large shelters the size of circus tents and complex hydraulic/electric coring systems -- http://www.andrill.org/static/index.html), the handling of core is also very human intensive. Even in coring rigs that automatically eject cores, there is a lot of human input in tempering and caring for the ice cores to keep them at the right temperature and pressure to keep from cracking (which can be a big deal for a core pulled up from a km or two's depth).

Even for shallow cores (<20 m), which I've extracted from glacial environments in Antarctica, there's the challenges of drilling in rocky/sandy/dusty ice. Ice corers typically use carbide blades that are great for shaving ice, but which are very brittle and break even on small pebbles. Swapping core barrels, bearing down to blast through obstacles, and then really hauling to free stuck cores is all very human intensive.

One way around this problem is to use "cryo-bots" that are basically hotplates with a really long extension cord. They melt through ice, sample the melt for chemistry/isotopic composition/cells/etc. and then either refreeze the ice above the 'bot (sealing the cavity as it descends), or pass the melt up to a pump on the surface, which strains it, analyzes it, and heats it up more to help melt deeper down the hole. Cryobots have been used in Antarctica before (https://en.wikipedia.org/wiki/IceMole) and have been proposed for making ice-core equivalent measurement on the polar caps of Mars.

Would we use Mars ice in much the same way early humans used ice here or would there be far more advanced applications

SubNoize

After they look in the ice for biomarkers or climate-diagnostic chemical signatures, I hope human explorers use at least some of the ice on Mars to cool their whisky, the same way we use shattered ice cores to do that on Earth (if your core shatters, all the gas escapes and there's no way to tell what came from where, so you might as well at least enjoy it).

What do you think would be a realistic timeframe on forming an atmosphere suitible for humans to live in, based off of what you have learned so far?

RealOxygen

It depends how many nukes Elon Musk takes to Mars: http://www.theverge.com/2015/10/2/9441029/elon-musk-mars-nuclear-bomb-colbert-interview-explained

Right now, there's enough CO_2 locked away in the south polar cap of Mars to double the atmospheric pressure on Mars from about 6 mb to about 12 mb (atmospheric pressure on Earth is ~1 bar): http://science.sciencemag.org/content/332/6031/838

That means Mars' atmosphere may have been thicker as recently as a few million years ago. But getting Mars' atmosphere to a breathable, non-poppable, non-toxic state would mean adding large amounts of O_2 (which photosynthetic organisms on Earth give us for free) as well as inert gases like N_2. Keeping a thick atmosphere on Mars would require constant maintenance and addition of gases (e.g., from comets, asteroids), because low gravity plus a lack of a protective magnetic field cause Mars' atmosphere to be stripped off aggressively by solar radiation: http://lasp.colorado.edu/home/maven/2015/11/05/maven-reveals-speed-of-solar-wind-stripping-martian-atmosphere/

So for now, visitors to Mars should plan to bring warm socks, plenty of sun block, oxygen, and at least a pressure suit, if not a full space suit. There will be no "300 degree club" on Mars any time soon (https://en.wikipedia.org/wiki/300_Club).

When you propose volcanic/impact-melted ice as potentially harboring microbial life, do you mean that these conditions might last long enough for life to develop, or only that it could allow preexisting life from before the Amazonian to emerge from dormancy?

Also, do subsurface ice conditions vary significantly between the northern and southern hemispheres?

loki130

One of the big problems with thinking about the search for life on Mars is that we don't have a good handle on how/where/exactly-when life arose on Earth. As a result, we search for "habitability"--places that are warm enough and wet enough, to meet the threshold conditions for life as we know it on Earth.

The most fair assessment of the volcano/ice depressions on Mars is that **if** melting occurred in them (which appears likely, though sublimation could also have removed ice), then for their duration, there would have been a combination of water, solutes/nutrients, and temperatures above -20˚C, which is what is needed on Earth for microbial life to replicate.

So the conjecture here would be that any microbial life present at these sites could have emerged from dormancy during the active formation of the depressions.

How possible is to extract and process it by an eventual manned mission to the zone?

How likely would be to found a liquid lake under the ice, like vostok lake on antartica?

Could the ice shield anything bellow it from solar radiation?

leojg

Getting ground ice out of the ground on Mars is as easy as exposing it to the cold dry atmosphere, and allowing it to sublimate away: https://www.nasa.gov/mission_pages/MRO/news/mro20090924.html

So while there are proposals to try to scoop up icy dirt mixtures on Mars (like of like a lawnmower of doom), my preferred solution for future martian explorers is to just blow up a small pit in the ground and put a tarp over it. Sunlight will destabilize the ice, allowing it to be collected by a dehumidifier.

Actual liquid lakes under ground ice on Mars (either under permafrost regions or glaciers) are thought to be unlikely. Ice sheets on Earth are mostly "wet based"--because they are thick, they reach the point at their bases where pressure is high enough that melting occurs. This pressure-melting helps generate the kind of subglaical lakes that dot Antarctica: http://www.antarcticglaciers.org/modern-glaciers/subglacial-lakes/

Some thin Antarctic glaciers, as well as all the glaciers we observe on Mars, appear to be "cold-based." They are thin and cold enough that they are frozen to their beds. So they don't slide or produce meltwater to make subglacial lakes.

The role of brines (which can be stable to -50˚C or even colder!) is not well understood on Earth or Mars, and is an area of active exploration and research. Briny water droplets can be a whole "universe" to microbes, making them potentially habitable oases, even in these otherwise very cold, very dry glacier and permafrost deposits.

Ice is a good absorber of cosmic rays, so it holds a lot of promise for preserving biomarkers, if present. The big problem is that ice on Mars is generally thought to be "young." Most of what we can see on the surface has been dated to less than 1 billion years, which is still amazingly ancient, but is younger than when Mars was thought to be warmer and wetter than it is today (and therefore, a better candidate for producing widespread habitable conditions). I think future life detection missions that go to Mars but that don't look in martian glacial or permafrost deposits are going to be missing an important potential reservoir of biomarkers.

Student of engineering for mines here! Any info regarding the potential of space mining?

AndForWar

Ice is a very minable resource on Mars, but unfortunately, it's only really useful to martians. One reason the pace of space exploration has been so slow is that there do not appear to be any resources that are so valuable on Earth today that the costs associated with getting them from space have made it economically feasible to go out and get them. Gold and silver during the age of exploration were such dense stores of value that they helped drive incredible national efforts to seek them out. Until we find something that we hold in such high esteem (sadly, knowledge doesn't seem to fit that bill), we'll be slowly creeping away from our home world instead of racing.

How energy intensive would it be to be able to actually mine and purify that ice for a human habitat, say six Mark Watneys? Are we talking about a few tens of square meters of solar panels, or a small fission reactor?

the-player-of-games

For midlatitude ice, my preferred extraction approach is to let nature do the hard work. Because the ice is only stable below a few meters of sediment (where it's shielded from the warmest summer temperatures that would cause it to sublimate away), you can get it into a vapor form just by uncovering it. Bulldoze, blast, or hand-dig a pit and put a clear tarp over it. Sunlight an ambient pressure will cause the ice to sublimation, and then the water frost will cold-trap out on the tarp, like frost on a windshield. Taking the tarp into a hab will let it melt. Scrape and repeat!

Adding power to the mix would accelerate the process, but is power that could be used for other purposes (like comms, life support, etc.).

Since the ice in the mid-latitudes appears to be high purity (Cassie's results point to up to 85% ice by volume), it's already been concentrated by nature and is ready to harvest!

I always wonder what people in your positions think the future will be like. Where do you guys think we will be when your kids are your age? Will we be colonizing Mars and figuring out immortality or being sunk by rising oceans and tides of zombies? Maybe you guys think things wont change all that much?

snorkleboy

Great question! I'd like to be optimistic and think that by the 2030s (when my son will be in his 20s), that there's a good chance he'd be thinking about going to grad school to train to join the budding human Mars settlement. It just takes will to explore and settle--I think all the engineering challenges to getting humans to Mars are surmountable.

But I'm not too optimistic that there is political will sufficient to get humans to Mars these days. It will take organization, cooperation, but most importantly, sustained vision and patience. These virtues are always in short supply.

Fellow geologist here, can help but ask : how similar is permafrost on mars to that on earth? Do they also have the same oxygen isotopes (O18 and O16) that are here on earth? What about deuterium on mars?

bonanzax

Mars permafrost appears to be most like permafrost in the high, dry parts of Antarctica. That is to say, it's not like Arctic permafrost, which makes excess ice through melting and formation of giant ice lenses, and which has abundant peat and organic matter in it. Rather, it seems to be mostly buried ice and/or vapor emplaced pore ice, in sandy, dusty mineral soils: http://www.planetary.brown.edu/pdfs/3790.pdf

I think the NASA Phoenix mission was hoping to measure O and H isotopic ratios in the ice, but I can't find any citations at the moment that mention the results. Knowing these values, and the values of O and H isotopes for the polar reservoirs, would tell us a lot about how water moves around the martian climate system. Next mission?

Great work guys - this is really interesting.

Just a quick question I'm confused about (from Joe's paper) - what material are these ice depressions in? It's not ice (I assume??) so is this rock or sediment which is thought to have fractured below the former glacier or ice sheet?

Glaciologytim

The North Hellas depression appears to be in a remnant concentric crater fill deposit, which we infer has ice underneath its surface sediments. The Galaxias depression is in some kind of ice-rich permafrost unit--either part of the larger latitude dependent mantle--or as part of a greater Elysium icy deposit.

How far down is it? Could we slam something into the spot to have a look at it and collect samples?

fishinbuttersauce

The ice in Utopia Planitia appears to be ~1-10 m down (this is constrained by 2 geophysical instruments). So, yes, a fast enough chunk of anything hurtling into the area would expose and extract it. Deep Impact 2, Mars Bugalloo?

What are your thoughts on their being ice in other galaxies or solar systems? Is it unique to ours or will it exist in large amounts elsewhere?

NINETYLIVES

The same chemistry and physics seem to be at work all across the visible universe. Water ice is probably one of the most common solids in solar systems beyond our own.

How did the volcano form? Subduction? Hotspot? Is there any way Mars can still have active volcanoes?

tkdfoster

Great question! There's no evidence for plate tectonics on Mars, so all the volcanism seems to be isolated hotspots/plumes. The North Hellas depression is near one such isolated volcanic center.

How does mars has ice below it's rocky surface, and we don't see similar ice below earth's surface.

uberpoisedmortal

There are tons of debris-covered glaciers on Earth, and lots of ground ice in permafrost regions that can't be seen from the surface. All it takes is a shovel and patience to find it!