

A woman wearing a light-colored bucket hat, sunglasses, and a blue t-shirt with a floral pattern is smiling. She is holding a small, light-colored object in her gloved left hand. The background is a vast, flat, reddish-brown desert landscape with mountains in the distance.

LOOKING FOR LIFE IN ANCIENT LAKES

The NASA logo, featuring the word "NASA" in white on a blue circular background with a red swoosh.

NASA

GRAVITY ASSIST



Podcast

1

00:00:02,510 --> 00:00:05,970

The Perseverance rover is on its way to Mars.

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00:00:05,970 --> 00:00:11,800

In February, it will land in a fabulous area called Jezero crater.

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00:00:11,800 --> 00:00:17,670

It's right there on that edge between the land and the ancient ocean.

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00:00:17,670 --> 00:00:19,990

What do we expect to find?

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00:00:19,990 --> 00:00:23,630

There could've been a habitable environment in that watershed area that picked up some

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00:00:23,630 --> 00:00:28,140

potential biosignatures and deposited into the delta and got preserved.

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00:00:28,140 --> 00:00:33,910

Hi, I'm Jim Green, Chief Scientist at NASA and this is Gravity Assist.

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00:00:33,910 --> 00:00:38,199

On this Season of Gravity Assist we're looking for life beyond Earth.

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00:00:38,200 --> 00:00:45,640

I'm here with Dr. Kennda Lynch, and she is an astrobiologist and a geomicrobiologist

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00:00:45,640 --> 00:00:49,019

studying life in extremes.

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00:00:49,020 --> 00:00:52,720

She works at the Lunar and Planetary Institute

in Houston, Texas.

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00:00:52,720 --> 00:00:54,880

Welcome, Kennda, to Gravity Assist.

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00:00:54,880 --> 00:00:55,900

Thank you.

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00:00:55,900 --> 00:00:57,160

It's so great to be here.

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00:00:57,170 --> 00:01:02,359

Well, you know, your current research really focuses on the studying of paleo-lake basins

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00:01:02,359 --> 00:01:08,140

here on Earth, and so that makes you a perfect expert to be involved in the Perseverance

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00:01:08,140 --> 00:01:15,110

rover since it's going to Jezero crater and land on an ancient lake basin, doesn't it?

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00:01:15,110 --> 00:01:20,840

Umm, I, I would say it makes me one of several really good experts that are really excited

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00:01:20,840 --> 00:01:22,400

at the fact that we're going to Jezero.

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00:01:22,400 --> 00:01:28,910

Well, let's first discuss what we know about the Earth's paleo-lake basins.

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00:01:28,910 --> 00:01:30,610

Absolutely.

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00:01:30,610 --> 00:01:35,350

What we know about Earth lake basins is a

lot of our paleo-lake basins, these were ancient

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00:01:35,350 --> 00:01:39,520

lakes that were, in a lot of cases, very, very big, very deep lakes.

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00:01:39,520 --> 00:01:44,050

For example, Lake Bonneville, where my field site is, was an ancient lake of the Pleistocene

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00:01:44,050 --> 00:01:47,230

era, and at one point, it was a thousand foot in depth.

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00:01:47,230 --> 00:01:50,900

It was very big, very deep, actually freshwater lake.

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00:01:50,900 --> 00:01:55,780

But, over time, because it was a closed basin lake and we had climate change, the lake started

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00:01:55,780 --> 00:01:56,780

to dry out.

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00:01:56,780 --> 00:01:59,890

It didn't have any outflow, so everything just evaporated,

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00:01:59,890 --> 00:02:02,979

There's many of these across the world that we study.

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00:02:02,979 --> 00:02:06,880

There's the Great Salt Lake here in Utah. We also have

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00:02:06,880 --> 00:02:09,009

Death Valley also has paleo-lakes in it.

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00:02:09,009 --> 00:02:12,000

The Salar de Uyuni in Bolivia also has one.

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00:02:12,000 --> 00:02:15,380

We have paleo-lakes in China in the Qaidam Basin.

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00:02:15,390 --> 00:02:20,959

So all these big lakes dried into these amazing playa environments where we have all of these

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00:02:20,959 --> 00:02:26,510

lake sediments, we sometimes have occasional very, very shallow lakes that can develop

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00:02:26,510 --> 00:02:32,159

in these environments, but we have amazing microbial diversity that can be found in these

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00:02:32,159 --> 00:02:36,310

lake basin sediments after the lake went away, and that's what I like to study.

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00:02:36,310 --> 00:02:40,450

Well, what exactly are you looking for when you get these sediments?

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00:02:40,450 --> 00:02:43,099

We're looking at a couple of different things.

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00:02:43,099 --> 00:02:47,879

Initially, we wanted to just try to understand what these ecosystems look like.

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00:02:47,879 --> 00:02:51,560

There really hasn't been a lot of research, believe it or not, in these kind of systems

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00:02:51,560 --> 00:02:55,879

because people didn't really understand that

they could be very, very rich in life.

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00:02:55,880 --> 00:02:58,800

So the first thing we do is we do a lot of

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00:02:58,800 --> 00:03:02,500

a lot of heavy biology, so a lot of looking for DNA

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00:03:02,540 --> 00:03:06,859

and trying to understand what we call the
phylogeny.

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00:03:06,859 --> 00:03:11,890

Who's there, how diverse they are, what does
the ecosystem, what do the microbial communities

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00:03:11,890 --> 00:03:13,650

look like? So that's, you know

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00:03:13,650 --> 00:03:16,969

A lot of the first work that I did was understanding
who's there and what they look like.

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00:03:16,969 --> 00:03:21,379

Then the next thing we look for is how are
they interacting with the environment, how

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00:03:21,379 --> 00:03:25,159

are they interacting with the geochemistry,
how are they living there, what are they eating,

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00:03:25,159 --> 00:03:29,530

what are they breathing, how are they getting
their energy, how are they interacting, all

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00:03:29,530 --> 00:03:31,540

of these kinds of things.

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00:03:31,540 --> 00:03:34,599

So we look for that, and we try to understand that.

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00:03:34,599 --> 00:03:39,069
Kennda, can you tell me about a particularly memorable experience you had out in the field?

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00:03:39,069 --> 00:03:42,129
Oh, wow, there's so many. I might,

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00:03:42,129 --> 00:03:44,640
I'm going to give you two quick little ones.

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00:03:44,640 --> 00:03:45,500
Umm, we

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00:03:45,500 --> 00:03:48,140
When we were at the center of the basin we

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00:03:48,140 --> 00:03:50,020
where there's an actual a

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00:03:51,380 --> 00:03:53,540
an actual well that my colleagues

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00:03:53,620 --> 00:03:58,000
had put in permanently, we found a little mouse hanging out in the well, just hanging

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00:03:58,010 --> 00:04:02,739
out in the shade of the well, and he had somehow gotten onto the playa.

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00:04:02,739 --> 00:04:05,299
But he was hanging out there during the heat of the day.

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00:04:05,299 --> 00:04:10,760
Well, the next day, we came back to one of

my boreholes that was about a mile away.

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00:04:10,760 --> 00:04:14,670

That mouse was in my borehole using the borehole as shade.

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00:04:14,670 --> 00:04:21,190

So he had, overnight, had gone that whole mile, mile and a half, and was using our borehole

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00:04:21,190 --> 00:04:23,570

as a refuge for the day heat.

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00:04:23,570 --> 00:04:26,480

It was very cute, and we got pictures of it.

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00:04:26,480 --> 00:04:32,220

Then the second memorable experience was when we got our UTV stuck in some of the playa

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00:04:32,220 --> 00:04:33,220

mud.

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00:04:33,220 --> 00:04:34,320

That was a challenge.

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00:04:35,320 --> 00:04:41,900

You know, the first mission to find perchlorates on Mars was Phoenix, but even Curiosity has

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00:04:41,910 --> 00:04:45,390

confirmed that there are perchlorates but not everywhere.

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00:04:45,390 --> 00:04:52,070

What are perchlorates, and tell us a little bit about how are they important?

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00:04:52,070 --> 00:04:56,380

So perchlorates are what we call chlorine oxyanions.

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00:04:56,380 --> 00:05:03,310
It's a chlorine atom surrounded by four oxygen atoms, and it's a really, really, really big

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00:05:03,310 --> 00:05:07,280
oxidizer very similar to oxygen, so it gives the same

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00:05:07,280 --> 00:05:11,100
kind of energy release that oxygen does.

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00:05:11,100 --> 00:05:17,350
In fact, here on Earth, we use perchlorates as part of solid rocket fuel because when

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00:05:17,350 --> 00:05:21,400
you light it up, it really gives a lot of energy that helps our rockets take off.

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00:05:21,920 --> 00:05:25,060
People experience perchlorates every day in things like firecrackers.

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00:05:25,070 --> 00:05:31,390
But we also know that perchlorate occurs naturally on Earth and, of course, on Mars.

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00:05:31,390 --> 00:05:36,380
And on Mars, we see more perchlorate on Mars than we see anywhere on Earth, and so it's this

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00:05:36,380 --> 00:05:42,980
incredible potential energy resource that life could use to generate energy and sustain

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00:05:42,980 --> 00:05:44,000
an ecosystem.

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00:05:44,000 --> 00:05:50,040
The other reason, which is not as exciting,
but perchlorates on Earth, they can be toxic

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00:05:50,050 --> 00:05:54,440
to humans, so we want to understand perchlorates
so that we can make sure that it doesn't affect

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00:05:54,440 --> 00:05:58,300
our astronauts when we send them to Mars,
so that we can mitigate the perchlorates and

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00:05:58,300 --> 00:06:03,440
make sure that they don't make our astronauts
sick when we send our first human mission

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00:06:03,440 --> 00:06:04,400
to Mars.

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00:06:04,400 --> 00:06:07,500
Ok. We are at our first sampling point.

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00:06:07,500 --> 00:06:12,880
This field site that you went to, the Pilot
field site, where is it at, and why did you

94
00:06:12,880 --> 00:06:14,480
choose that?

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00:06:14,480 --> 00:06:19,720
So Pilot Valley Basin is a part of the Great
Salt Lake Desert, which basically encompasses

96
00:06:19,720 --> 00:06:22,280
pretty much most of northwestern Utah.

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00:06:22,290 --> 00:06:26,560
So basically, once you get past Salt Lake City,

the rest of it is the Great Salt Lake Desert,

98
00:06:26,570 --> 00:06:32,420
and Pilot Valley is a sub-basin of that desert
that actually because of how it's nestled

99
00:06:32,420 --> 00:06:37,370
in between two mountain ranges is kinda off on its
own, it's all Jeep roads to get there, it's

100
00:06:37,370 --> 00:06:38,460
not that easy to get to.

101
00:06:38,460 --> 00:06:45,180
So there hasn't been a lot of anthropogenic
input onto Pilot Valley, whereas other basins

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00:06:45,180 --> 00:06:50,250
in the Great Salt Lake Desert, they do a lot
of salt-mining, a lot of economic geology.

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00:06:50,250 --> 00:06:54,750
Pilot Valley has been off on its own and pretty
much left pristine.

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00:06:54,750 --> 00:06:59,110
And how I found this environment actually very
much relates to the Phoenix mission and our

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00:06:59,110 --> 00:07:00,250
discovery of perchlorate.

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00:07:00,250 --> 00:07:07,030
I was working with Dr. Sam Kounaves, who was
a Co-I on Phoenix at the time and is one of my

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00:07:07,030 --> 00:07:13,880
my long-term mentors and definitely a wonderful,
wonderful scientist.

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00:07:13,880 --> 00:07:20,660

And I was working with him on his sensors, his wet chemistry sensors, and during the Phoenix

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00:07:20,670 --> 00:07:24,680

mission, I was in grad school and he called me.

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00:07:24,690 --> 00:07:28,820

He called me and I think he actually might've called me from JPL and said, "Kennda, do you

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00:07:28,820 --> 00:07:34,040

know anything about perchlorate," and started me down this road about looking at perchlorate

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00:07:34,040 --> 00:07:40,060

and microbes that can use perchlorate.

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00:07:40,060 --> 00:07:48,460

The following summer, I was driving to Ames Research Center to start my Harriet Jenkins

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00:07:48,460 --> 00:07:51,200

Predoctoral Fellowship summer portion.

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00:07:51,200 --> 00:07:54,800

I was driving through Utah and looking at the Great Salt Lake Desert, and I had done

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00:07:54,800 --> 00:07:58,460

all this research about perchlorate and where it lives in the Atacama, and I'm looking at

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00:07:58,460 --> 00:08:02,070

the Great Salt Lake Desert and I'm like, "I wonder if there's perchlorate here.

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00:08:02,070 --> 00:08:03,780

That would be kind of a neat environment to study."

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00:08:03,780 --> 00:08:08,570

So I wrote a little mini-proposal to get the summer internship money the next summer from

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00:08:08,570 --> 00:08:13,810

my school, and I went out and did a field expedition, and literally it changed my whole

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00:08:13,810 --> 00:08:15,440

direction of my dissertation.

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00:08:15,440 --> 00:08:17,060

And you, it just kind of keeps

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00:08:17,060 --> 00:08:21,740

keeps getting more and more interesting and more and more fun every time we go out there.

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00:08:21,740 --> 00:08:25,700

Well you know, there are other places in the solar system, you know, that we were

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00:08:25,700 --> 00:08:28,840

thinking of looking for life, like Europa.

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00:08:28,840 --> 00:08:32,780

Are you doing any research on Earth that relates to Europa?

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00:08:32,780 --> 00:08:35,420

Definitely some of the work that we're doing in my basin.

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00:08:35,420 --> 00:08:40,560

We're looking at perchlorates reducing bacteria in the hypersaline systems of my basin

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00:08:40,760 --> 00:08:46,440

One of my recent research papers that just came out last summer, where we basically documented

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00:08:46,440 --> 00:08:54,550

our first discovery of perchlorate reducing microbes cohabitating in an area there was

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00:08:54,550 --> 00:08:58,440

actually also naturally-occurring perchlorate, something that's never been documented before.

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00:08:58,440 --> 00:09:04,610

So, now, we have a relevant Earth analog ecosystem to learn about how perchlorate reducing microbes

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00:09:04,610 --> 00:09:09,690

can live in what on Earth is an extreme environment but would be more of a normal environment

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00:09:09,690 --> 00:09:15,490

on Mars or Europa, living in a brine or a salty environment in Mars and Europa.

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00:09:15,490 --> 00:09:20,080

I remember that once you did a talk called "All Life Poops."

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00:09:20,080 --> 00:09:24,941

Does that mean that even bacteria has waste, and could we find traces of that in any of

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00:09:24,941 --> 00:09:27,520

the samples that we bring back, whether it's from Mars

138

00:09:27,520 --> 00:09:30,160

or flying through the plume over Europa?

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00:09:30,170 --> 00:09:31,230

Yep, indeed.

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00:09:31,230 --> 00:09:37,050

All life takes in energy and creates waste products or, for lack of a better word, poops,

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00:09:37,050 --> 00:09:41,820

and it is indeed often these waste products that turn into biosignatures

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00:09:41,820 --> 00:09:43,680

or possible biosignatures of life.

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00:09:43,680 --> 00:09:45,800

For example, we're breathing poop right now.

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00:09:45,800 --> 00:09:47,440

We are breathing tree poop.

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00:09:47,440 --> 00:09:49,960

So oxygen is tree poop.

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00:09:49,960 --> 00:09:54,560

So oxygen, molecular oxygen, is a potential biosignature

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00:09:54,560 --> 00:09:56,740

that we look for in extrasolar planets.

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00:09:56,740 --> 00:10:01,160

So, absolutely, poop can be a biosignature.

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00:10:01,160 --> 00:10:02,160

Wow.

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00:10:02,160 --> 00:10:04,410

You're absolutely right.

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00:10:04,410 --> 00:10:06,400

I just never thought of it that way.

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00:10:06,400 --> 00:10:08,600

I know.

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00:10:08,600 --> 00:10:09,600

It's so funny.

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00:10:09,600 --> 00:10:12,690

When I show kids, some of them go ... and try to hold their breath.

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00:10:12,690 --> 00:10:17,020

They're like, "I don't want to breathe poop," and I'm like, "Don't have a choice."

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00:10:17,020 --> 00:10:18,260

You need that, okay?

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00:10:18,260 --> 00:10:19,040

You need that poop.

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00:10:19,040 --> 00:10:24,860

That's what makes different types of life coexist together, and in fact, we need that

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00:10:24,880 --> 00:10:26,980

oxygen production from our plants.

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00:10:26,990 --> 00:10:27,990

Yep, absolutely.

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00:10:27,990 --> 00:10:31,310

Just as they need the CO₂ production that we create.

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00:10:31,310 --> 00:10:31,800

Yep.

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00:10:31,800 --> 00:10:36,380

So that's what creates a biosphere is that important relationship between the different

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00:10:36,380 --> 00:10:38,170

species of life.

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00:10:38,170 --> 00:10:39,170

Exactly.

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00:10:39,170 --> 00:10:44,010

So, Kennda, what about Perseverance is getting you really excited?

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00:10:44,010 --> 00:10:47,950

When that lands in Jezero crater, what do you want it to do?

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00:10:47,950 --> 00:10:53,100

I am so excited about what we call the bottomset deposits.

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00:10:53,100 --> 00:10:57,320

These are these really, really fine deposits, really fine grains.

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00:10:57,320 --> 00:11:02,520

They're usually mostly made up of clays and carbonates on Earth.

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00:11:02,520 --> 00:11:07,320

They're really small particles that deposit in the lake basin and at the front of the

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00:11:07,320 --> 00:11:13,510

delta that can make these great sediments where we can preserve organics and biosignatures.

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00:11:13,510 --> 00:11:19,950

I am so excited for Perseverance to go and start taking a look at those particular deposits

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00:11:19,950 --> 00:11:20,950

in the crater.

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00:11:20,950 --> 00:11:25,690

We're going to have some of the best chances of finding preserved organics in those deposits

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00:11:25,690 --> 00:11:31,390

because that's an environment on Earth where those kind of lake bed deposits or delta deposits,

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00:11:31,390 --> 00:11:36,210

we know we get a lot of concentrated carbon that gets preserved and stabilized very well

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00:11:36,210 --> 00:11:37,440

in those kind of deposits.

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00:11:37,440 --> 00:11:39,950

So I'm really excited about the bottomsets.

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00:11:39,950 --> 00:11:47,420

It's right there on that edge between the land and the ancient ocean, and this river

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00:11:47,420 --> 00:11:54,750

was dumping into that when this impact occurred and created this huge crater we now call Jezero.

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00:11:54,750 --> 00:12:00,000

Would you think we might be able to find some biomolecules if you've got complex carbon,

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00:12:00,000 --> 00:12:01,830

a material that we're also finding?

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00:12:01,830 --> 00:12:03,370

Is there a hope that we could do that?

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00:12:03,370 --> 00:12:10,270

You know, I really do think so because what's really amazing about these bottomset deposits

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00:12:10,270 --> 00:12:14,660

is that because of the lake environment and the fact that we have this delta, it could

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00:12:14,660 --> 00:12:20,580

come from three potentially different habitable environments within the Jezero crater area.

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00:12:20,580 --> 00:12:24,880

It could've come from up in the watershed, and the watershed is that area where all the

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00:12:24,880 --> 00:12:29,440

water kinda flowed together into one big river or stream

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00:12:29,440 --> 00:12:33,560

and deposited the water and the sediments that created the delta.

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00:12:33,560 --> 00:12:37,020

There could've been a habitable environment in that watershed area that picked up some

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00:12:37,020 --> 00:12:43,010

potential biosignatures and deposited into the delta and got preserved.

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00:12:43,010 --> 00:12:45,480

It could've come from the lake itself.

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00:12:45,480 --> 00:12:50,089

Or it could've been preserved from a transitional

habitable zone like I study, this subsurface

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00:12:50,089 --> 00:12:54,399

environment where there's groundwater moving through these sediments after the lake's gone,

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00:12:54,399 --> 00:12:58,830

and there could've been a subsurface ecosystem that could've lived there for a time before

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00:12:58,830 --> 00:13:03,160

water retreated even deeper into Mars, and there could've been life that could've left

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00:13:03,160 --> 00:13:05,000

some potential biosignatures there.

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00:13:05,000 --> 00:13:10,610

So we have three different potential habitable environments that could've left biosignatures

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00:13:10,610 --> 00:13:13,820

in these deposits, so I just

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00:13:13,820 --> 00:13:17,300

I'm so excited to see what we can find out when we get samples from there.

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00:13:17,660 --> 00:13:23,779

You bring up something I hadn't really thought about, but, indeed, with that lake over time

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00:13:23,780 --> 00:13:28,700

being eroded away and then the atmosphere becomes very thin,

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00:13:28,700 --> 00:13:31,740

that's going to draw groundwater out.

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00:13:31,740 --> 00:13:37,580

Yeah, especially since we know now that groundwater was a significant part of the hydrology on

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00:13:37,589 --> 00:13:42,400

Mars, that that's going to be a really important environment for us to start to try to understand. So

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00:13:42,400 --> 00:13:46,820

Again, I'm so excited to see what we're going to be able to find out.

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00:13:46,820 --> 00:13:52,100

Well, you've also been involved in education and diversity efforts in what we call science,

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00:13:52,100 --> 00:13:55,980

technology, engineering, and mathematics or STEM

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00:13:55,980 --> 00:13:57,780

you know, as an acronym.

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00:13:57,780 --> 00:14:01,240

Can you tell us a little bit about what your efforts are and what you've been doing in

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00:14:01,240 --> 00:14:02,240

this area?

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00:14:02,240 --> 00:14:04,900

I am a lifetime member of the Girl Scouts. I started

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00:14:04,900 --> 00:14:08,120

I was my mom's first Girl Scout, and my mom was a professional

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00:14:08,120 --> 00:14:10,120

worked on the professional staff, so I grew

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00:14:10,120 --> 00:14:14,560

up in girl scouting and giving back and reaching

out and educating. And so

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00:14:14,560 --> 00:14:18,850

Yeah, I've just been doing it my whole life,
all through college and undergrad.

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00:14:18,850 --> 00:14:22,700

I have mentored so many students while working
as a full-time engineer.

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00:14:22,700 --> 00:14:25,620

I've done a lot of school presentations.

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00:14:25,620 --> 00:14:27,320

And, right now

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00:14:27,320 --> 00:14:31,940

and in Grad School, you know I've mentored students and taught classes

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00:14:31,940 --> 00:14:37,920

Right now, I've got three students I'm mentoring,
two directly at the LPI, one indirectly with

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00:14:37,920 --> 00:14:42,100

a colleague who's asked me to mentor one of
their students of color, and I'm very excited

224

00:14:42,100 --> 00:14:44,370

to be able to do that.

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00:14:44,370 --> 00:14:50,180

I also do a lot of STEM outreach with our
education and public engagement department

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00:14:50,180 --> 00:14:52,670

here at the Lunar and Planetary Institute.

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00:14:52,670 --> 00:15:00,470

I'm a Ford Fellow, so I interact with that

community quite a lot and try to help with

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00:15:00,470 --> 00:15:06,580

efforts to increase diversity, equity, and inclusion across the space sciences and just

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00:15:06,580 --> 00:15:07,620

STEM in general

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00:15:07,620 --> 00:15:11,200

Well, I personally want to thank you for all that activity.

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00:15:11,200 --> 00:15:17,870

I enjoy talking to the public and talking about the fabulous science that we do.

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00:15:17,870 --> 00:15:21,920

You just can't stop me, and I'm just delighted that you're doing the same.

233

00:15:21,920 --> 00:15:28,390

Well, Kennda, I always like to ask my guests to tell me what was that person, place, or

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00:15:28,390 --> 00:15:34,620

thing that happened that got them so excited, that enabled them to become the scientist

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00:15:34,620 --> 00:15:38,440

they are today, and I call that a gravity assist.

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00:15:38,440 --> 00:15:41,530

So, Kennda, what was your gravity assist?

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00:15:41,530 --> 00:15:45,910

Well, there was so many people along the way, I can't recount them all, but what I will

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00:15:45,910 --> 00:15:51,440

tell you is that my biggest gravity assist,
the one that just makes me well up right now

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00:15:51,440 --> 00:15:58,440

is that my first summer internship at Kennedy
Space Center, I was a space life science training

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00:15:58,440 --> 00:15:59,839

program participant.

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00:15:59,840 --> 00:16:03,850

I won't give you a year, but it was way back
when, when the shuttle was flying.

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00:16:03,850 --> 00:16:08,840

And it was my first, you know, entry into the space world

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00:16:08,840 --> 00:16:10,540

that I'd always wanted to be a part of, and

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00:16:10,540 --> 00:16:12,399

I got accepted into that program.

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00:16:12,400 --> 00:16:16,100

And the biggest gravity assist for me was seeing
my first shuttle launch.

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00:16:17,040 --> 00:16:18,880

They let us go out and watch the shuttle launch

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00:16:18,900 --> 00:16:23,540

at Kennedy, and I got to see one of the shuttle
launches, and that first shuttle launch and

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00:16:23,540 --> 00:16:27,430

watching that spacecraft go into the air and
hearing the noise and watching the alligators

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00:16:27,430 --> 00:16:32,490

jump out of the water because it was so noisy
for them was just so inspiring and just ... I

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00:16:32,490 --> 00:16:36,920

couldn't believe that at 20 years old I was
there and I could be here and that I was a

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00:16:36,920 --> 00:16:38,990

part of the space industry finally.

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00:16:38,990 --> 00:16:42,940

So that was definitely one of my biggest gravity
assists that kept me going.

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00:16:43,480 --> 00:16:44,880

Well, that was wonderful.

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00:16:44,880 --> 00:16:47,520

Well, thanks so much for joining me today.

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00:16:47,520 --> 00:16:49,880

I've really enjoyed our discussion.

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00:16:50,320 --> 00:16:51,320

Me, too.

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00:16:51,320 --> 00:16:53,200

Thank you so much for having me.

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00:16:53,200 --> 00:16:58,529

Well, join me next time as we continue our
journey to look for life beyond Earth.