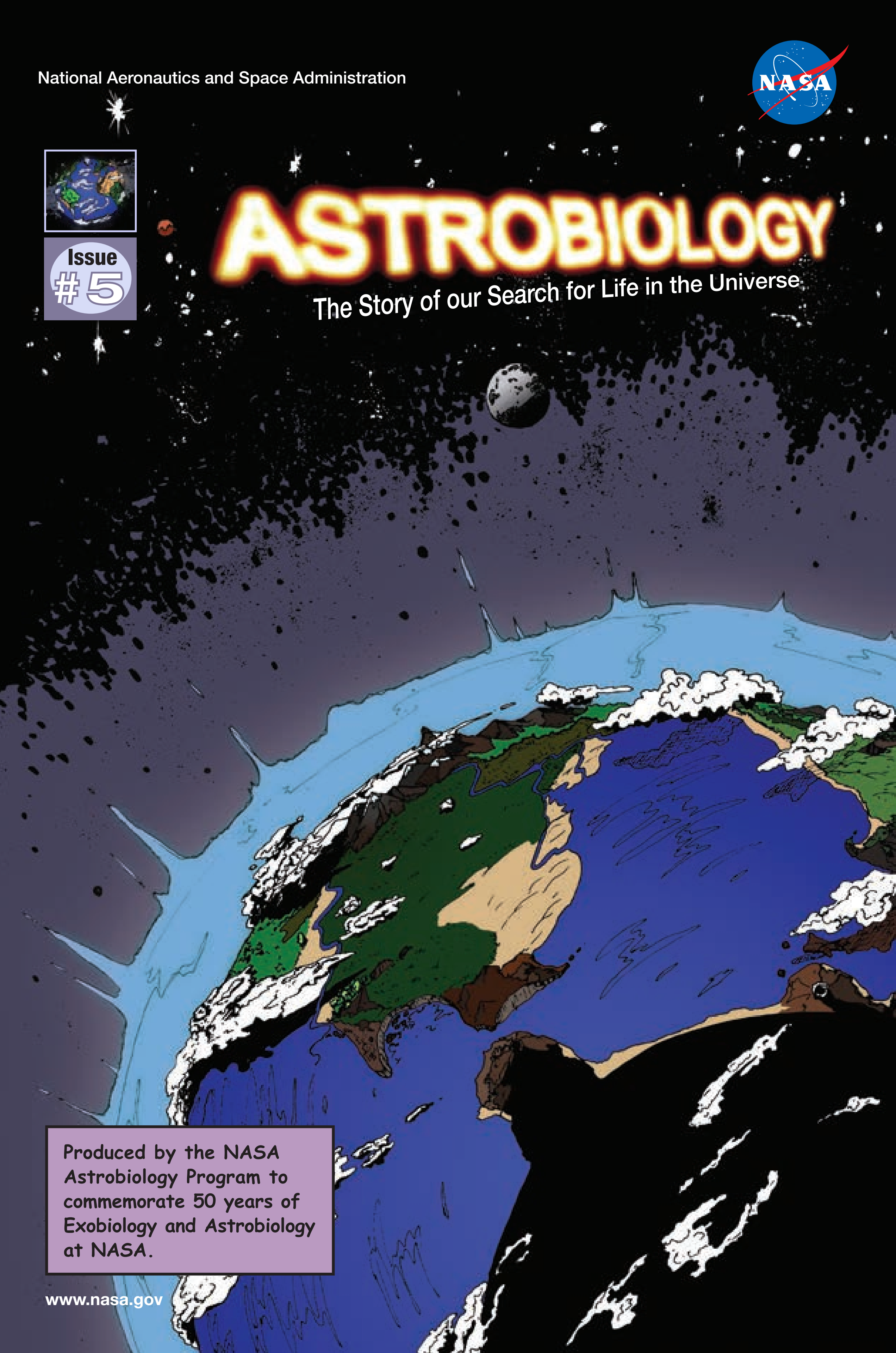
National Aeronautics and Space Administration

NASA

Issue #5

ASTROBIOLOGY

The Story of our Search for Life in the Universe



Produced by the NASA Astrobiology Program to commemorate 50 years of Exobiology and Astrobiology at NASA.

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Astrobiology

A History of Exobiology and Astrobiology at NASA

This is the story of life in the Universe—or at least the story as we know it so far. As scientists, we strive to understand the environment in which we live and how life relates to this environment. As astrobiologists, we study an environment that includes not just the Earth, but the entire Universe in which we live.

The year 2010 marked 50 years of Exobiology and Astrobiology research at the National Aeronautics and Space Administration (NASA). To celebrate, the Astrobiology Program commissioned this graphic history. It tells the story of some of the most important people and events that have shaped the science of Exobiology and Astrobiology. At just over 50 years old, this field is relatively young. However, as you will see, the questions that astrobiologists are trying to answer are as old as humankind.

Concept & Story

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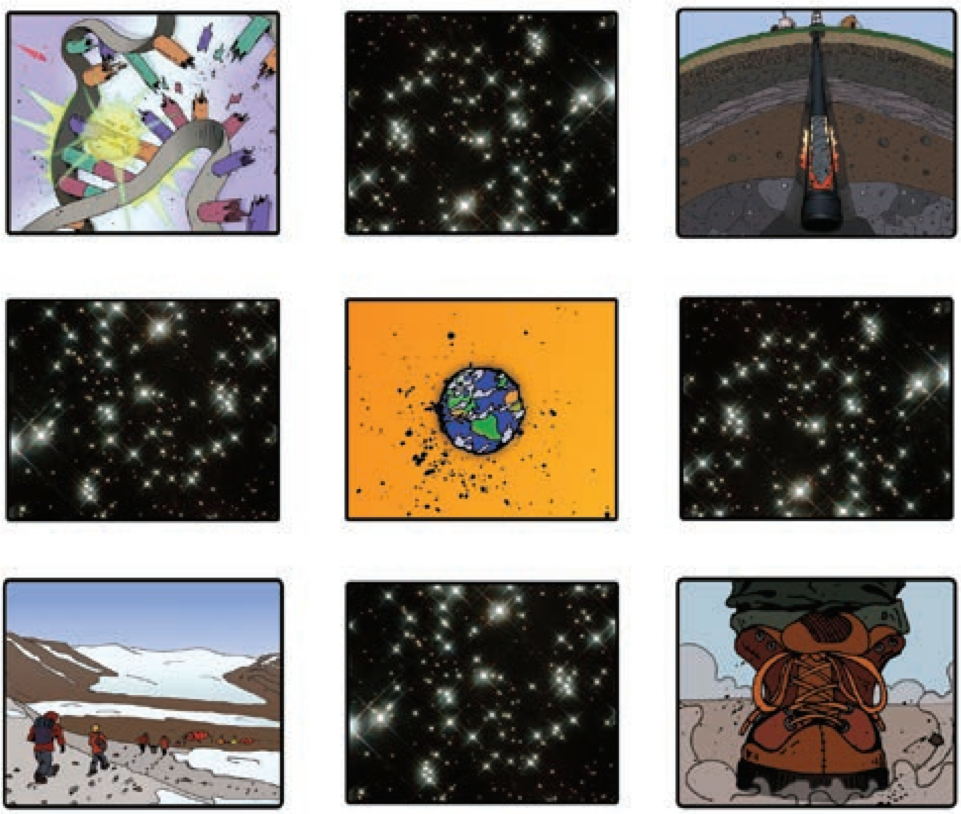
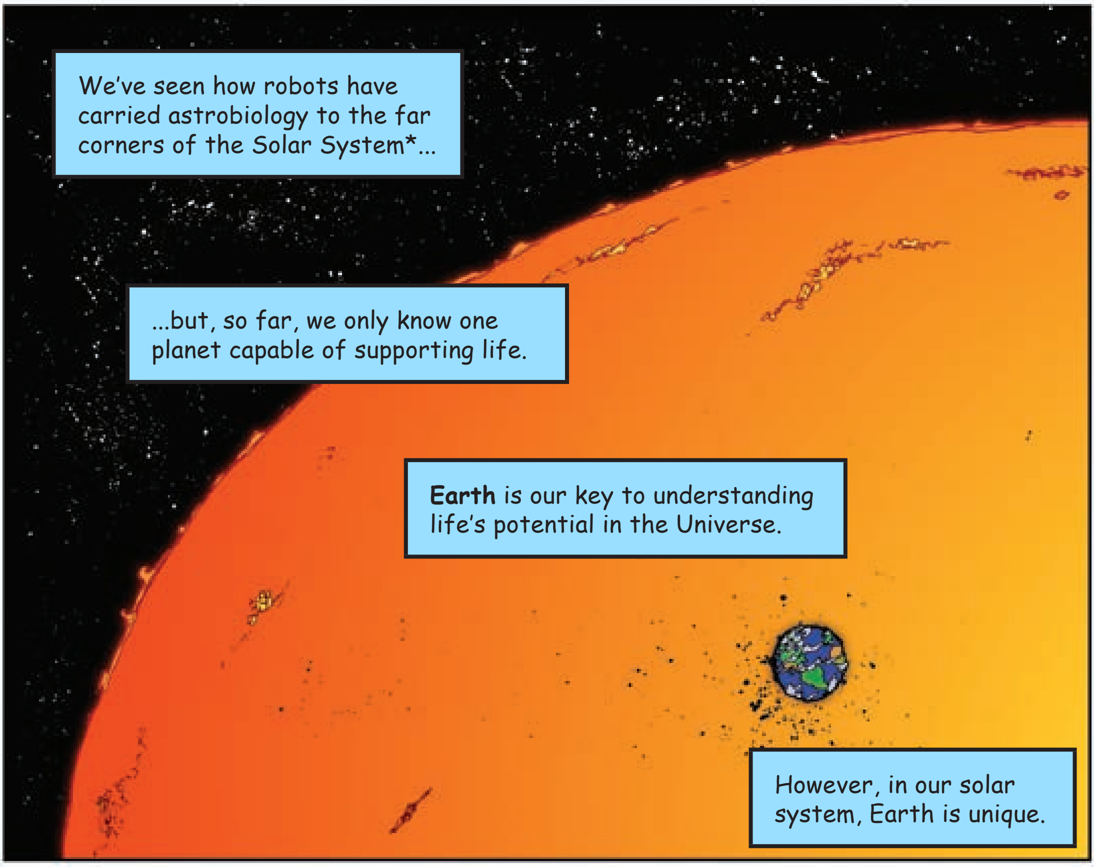
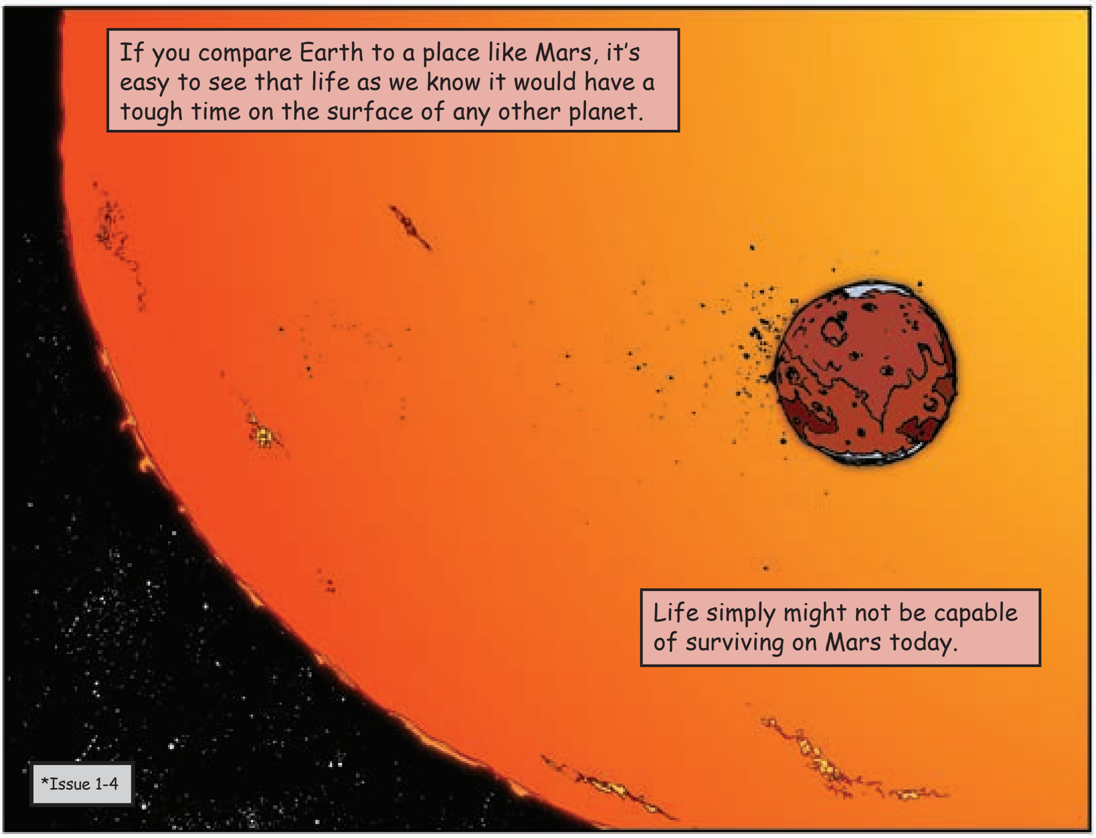
Issue #5—Astrobiology and the Earth

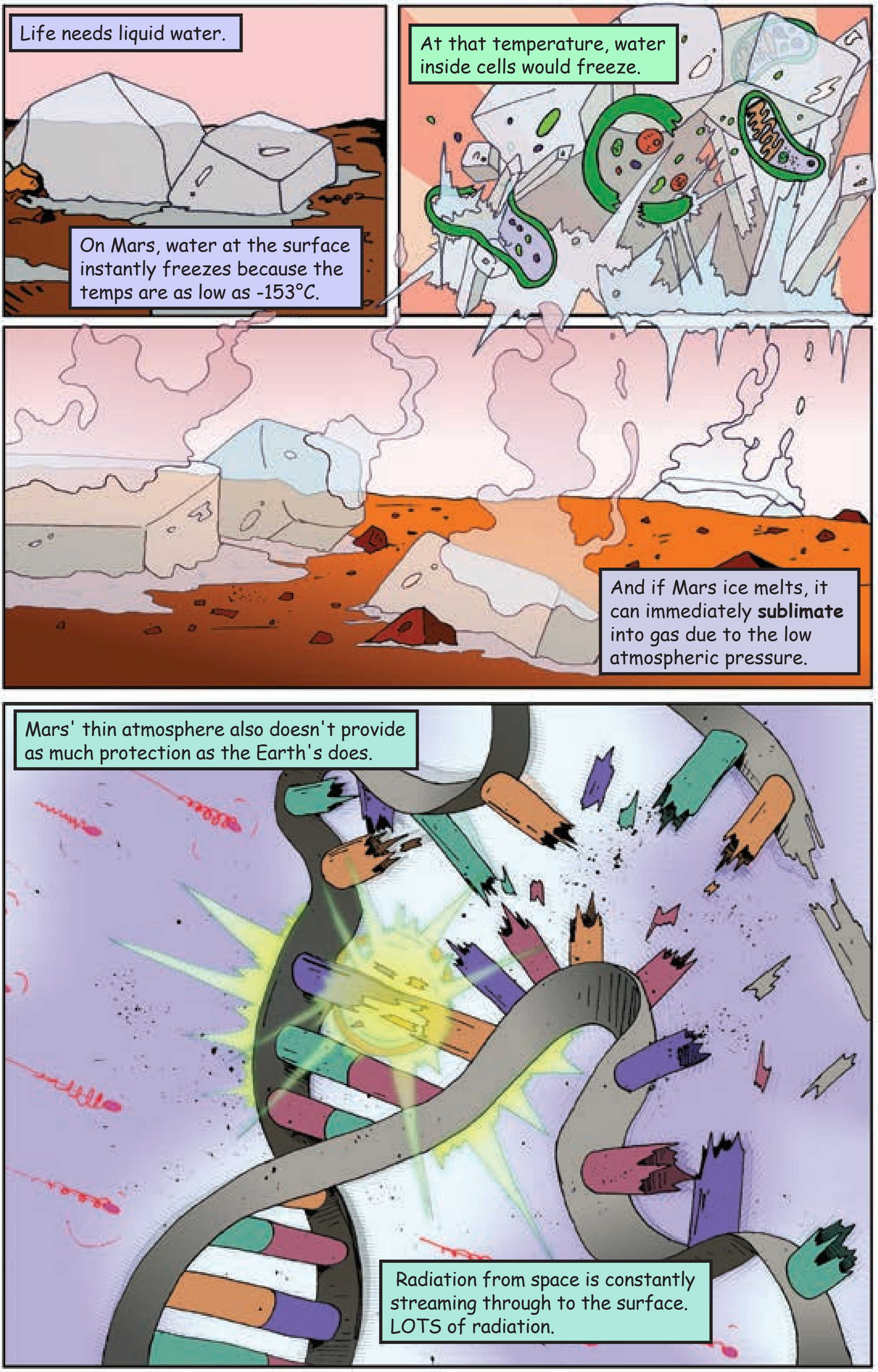


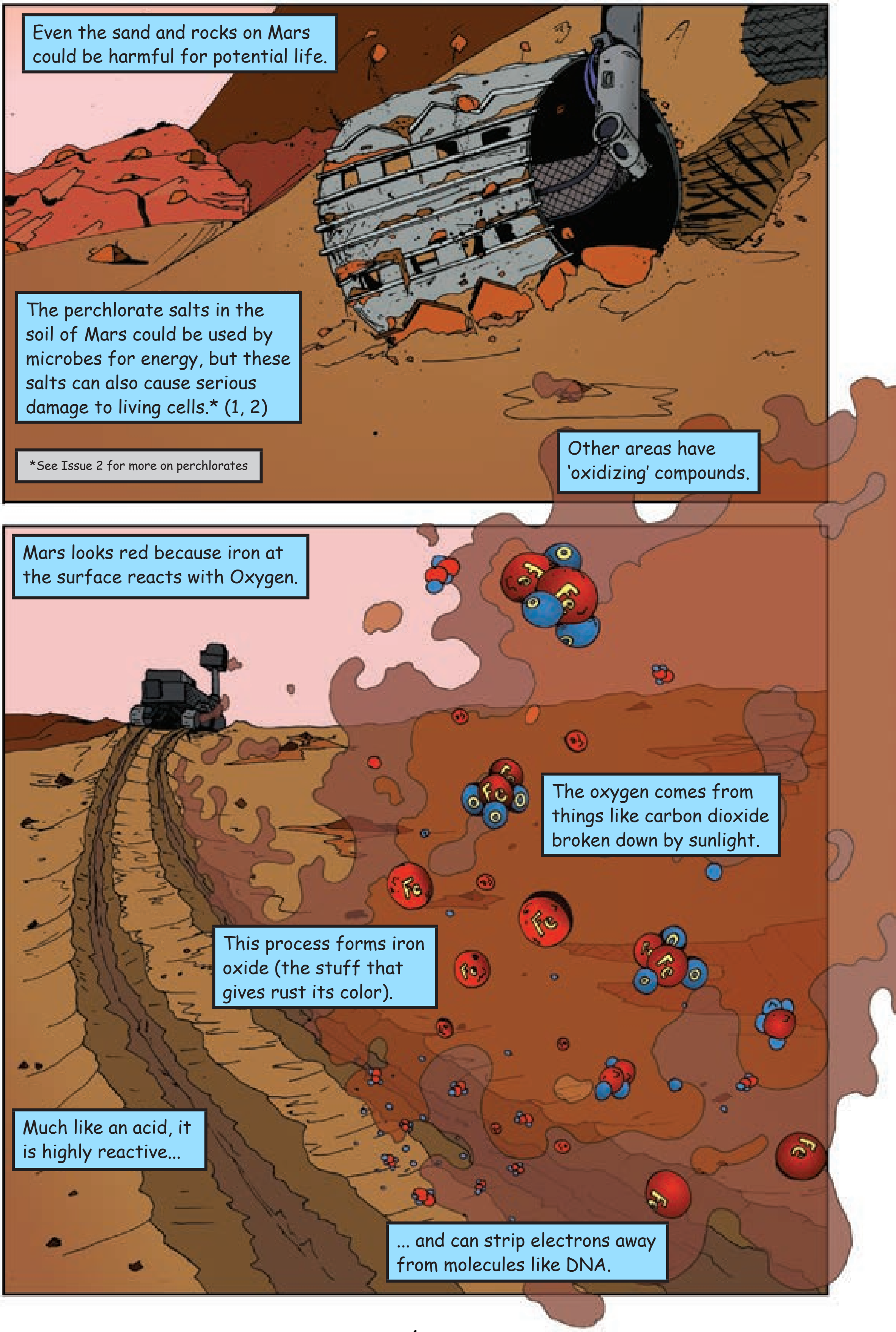
The year 2010 marked the 50th anniversary of NASA's Exobiology Program, established in 1960 and expanded into a broader Astrobiology Program in the 1990s. To commemorate the past half century of research, we are telling the story of how this field developed and how the search for life elsewhere became a key component of NASA's science strategy for exploring space. This issue is the fifth in what we intend to be a series of graphic history books. Though not comprehensive, the series has been conceived to highlight key moments and key people in the field as it explains how Astrobiology came to be.

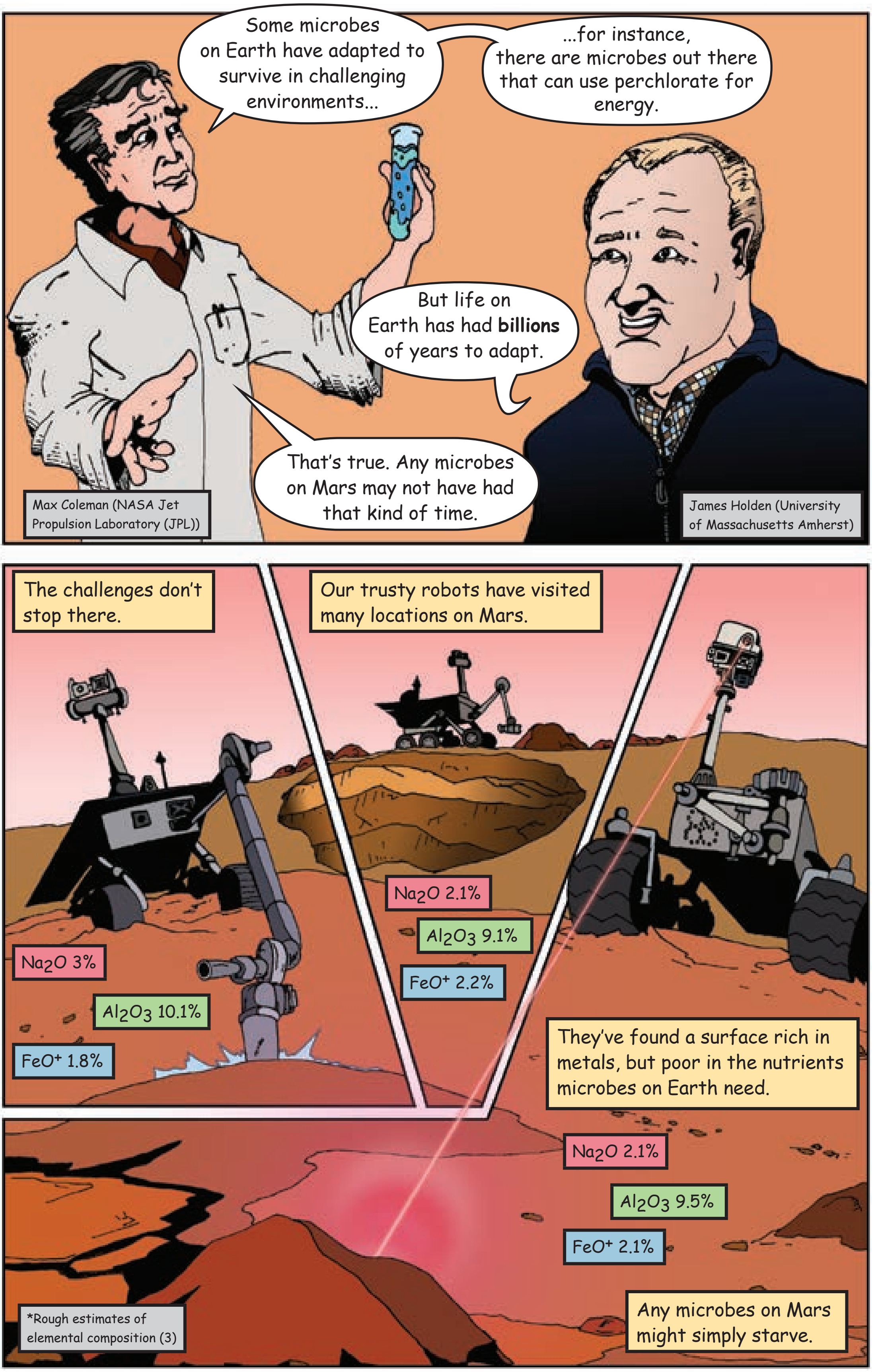
-Linda Billings, Editor


We've seen how robots have carried astrobiology to the far corners of the Solar System*...
...but, so far, we only know one planet capable of supporting life.
Earth is our key to understanding life's potential in the Universe.
However, in our solar system, Earth is unique.

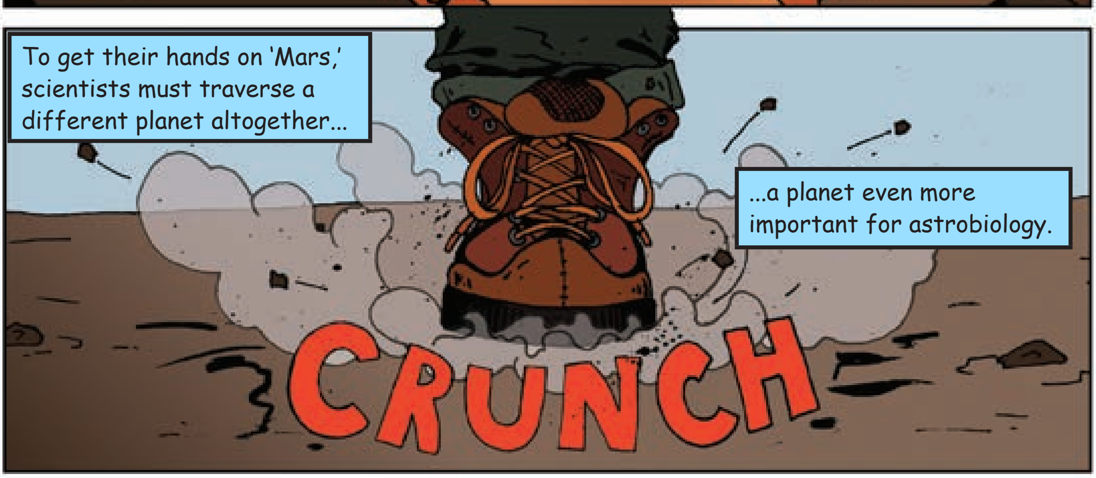

If you compare Earth to a place like Mars, it's easy to see that life as we know it would have a tough time on the surface of any other planet.
Life simply might not be capable of surviving on Mars today.
*Issue 1-4


Life needs liquid water.
On Mars, water at the surface instantly freezes because the temps are as low as -153°C.
At that temperature, water inside cells would freeze.
And if Mars ice melts, it can immediately **sublimate** into gas due to the low atmospheric pressure.
Mars' thin atmosphere also doesn't provide as much protection as the Earth's does.
Radiation from space is constantly streaming through to the surface. LOTS of radiation.

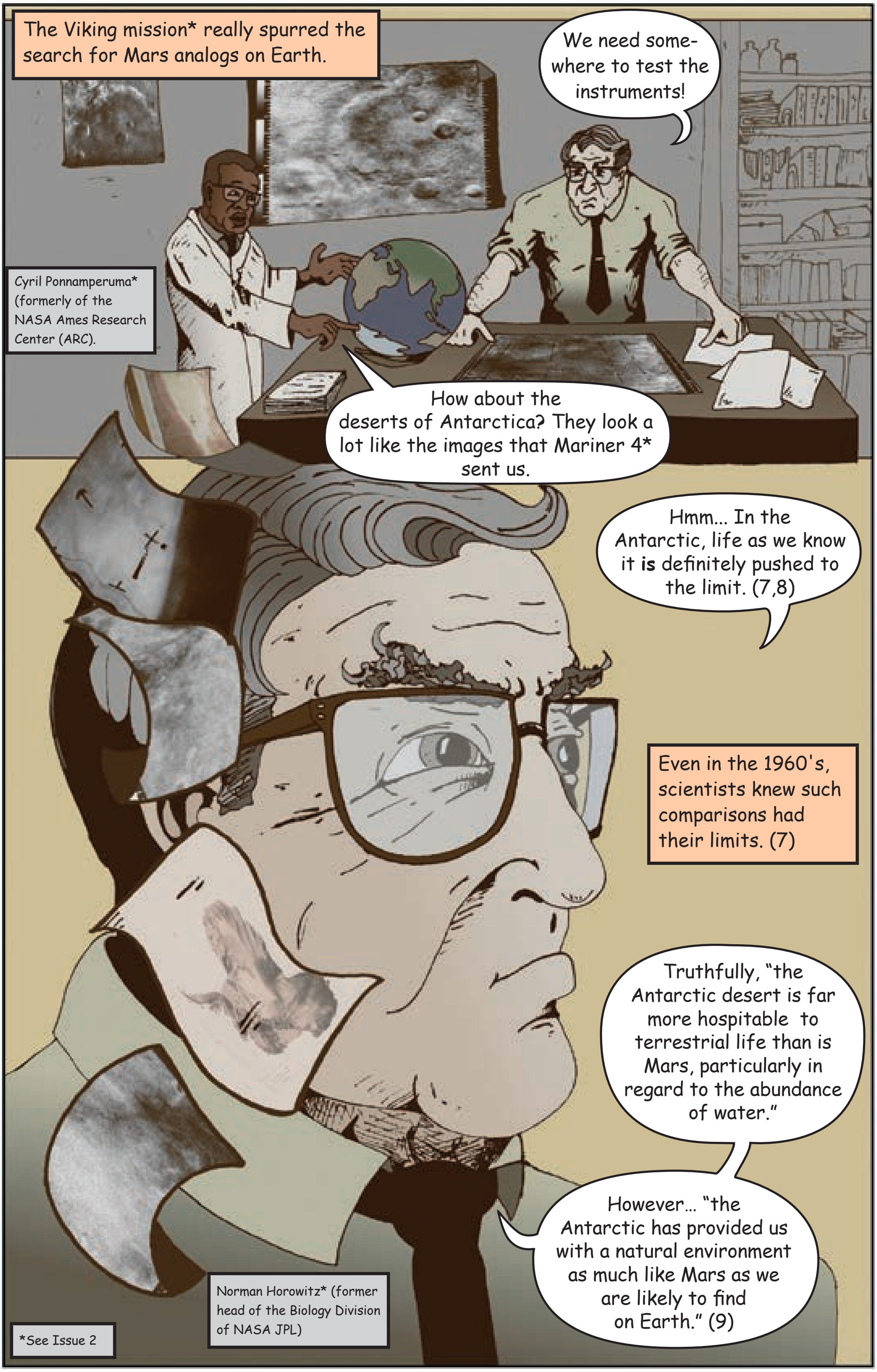

Even the sand and rocks on Mars could be harmful for potential life.
The perchlorate salts in the soil of Mars could be used by microbes for energy, but these salts can also cause serious damage to living cells.* (1, 2)
*See Issue 2 for more on perchlorates
Other areas have 'oxidizing' compounds.
Mars looks red because iron at the surface reacts with Oxygen.
The oxygen comes from things like carbon dioxide broken down by sunlight.
This process forms iron oxide (the stuff that gives rust its color).
Much like an acid, it is highly reactive...
... and can strip electrons away from molecules like DNA.


Some microbes on Earth have adapted to survive in challenging environments...
...for instance, there are microbes out there that can use perchlorate for energy.
But life on Earth has had **billions** of years to adapt.
That's true. Any microbes on Mars may not have had that kind of time.
Max Coleman (NASA Jet Propulsion Laboratory (JPL))
James Holden (University of Massachusetts Amherst)
The challenges don't stop there.
Our trusty robots have visited many locations on Mars.
Na_2O 3%
Al_2O_3 10.1%
FeO^+ 1.8%
Na_2O 2.1%
Al_2O_3 9.1%
FeO^+ 2.2%
They've found a surface rich in metals, but poor in the nutrients microbes on Earth need.
Na_2O 2.1%
Al_2O_3 9.5%
FeO^+ 2.1%
*Rough estimates of elemental composition (3)
Any microbes on Mars might simply starve.


Our robots have discovered so much, but to find life on Mars we may have to go there ourselves.
But humans have not yet set foot on the red planet.

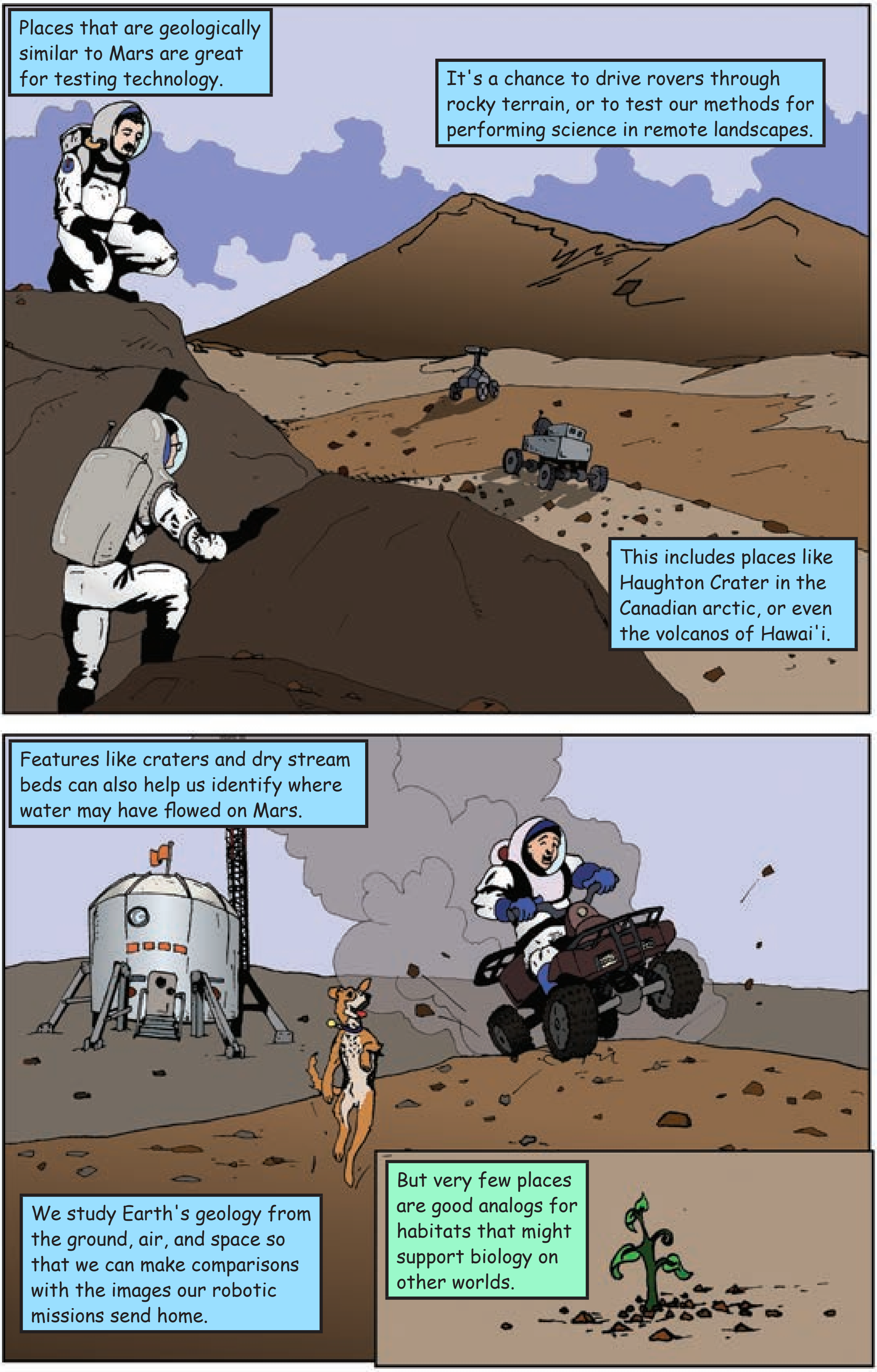

To get their hands on 'Mars,' scientists must traverse a different planet altogether...
...a planet even more important for astrobiology.
CRUNCH


Issue 5...
Analogs on Earth!
Searching for life on Mars starts with searching for habitats.
The trick is to find places on Earth that share some of Mars' life-threatening characteristics!
We call these places **analog environments**. (4-6)
Peter Doran (Louisiana State University)


The Viking mission* really spurred the search for Mars analogs on Earth.
We need somewhere to test the instruments!
Cyril Ponnamperuma* (formerly of the NASA Ames Research Center (ARC).
How about the deserts of Antarctica? They look a lot like the images that Mariner 4* sent us.
Hmm... In the Antarctic, life as we know it **is** definitely pushed to the limit. (7,8)
Even in the 1960's, scientists knew such comparisons had their limits. (7)
Truthfully, "the Antarctic desert is far more hospitable to terrestrial life than is Mars, particularly in regard to the abundance of water."
However... "the Antarctic has provided us with a natural environment as much like Mars as we are likely to find on Earth." (9)
Norman Horowitz* (former head of the Biology Division of NASA JPL)
*See Issue 2


It was physical appearance that first drew us to Antarctica.
The surface here is shaped by the cycling of ice.
Comparing this place to images from Mars helps us understand how similar features could have been made in the red planet's past, and if water might have been involved.
In fact, there are tons of sites on Earth, from North Africa to the California deserts, that are useful for this type of work.
But if you travel deep into Antarctica, you find rarer types of analog environments.


The best analogs we can hope for are places that get very little rain, and the Antarctic Dry Valleys are as cold and dry as it gets on Earth.
Yet, even here, microbial life thrives in soil and ice-covered lakes.
But always remember, no site on Earth is exactly like Mars. Not even close.
Just because Antarctica looks similar to Mars doesn't always mean the landscapes were formed in the same way.
These valleys are remote, but, like anywhere on our planet, they are still part of Earth's immensely productive global biosphere.
Dawn Sumner (University of California, Davis, and Member of the Mars Science Laboratory team)



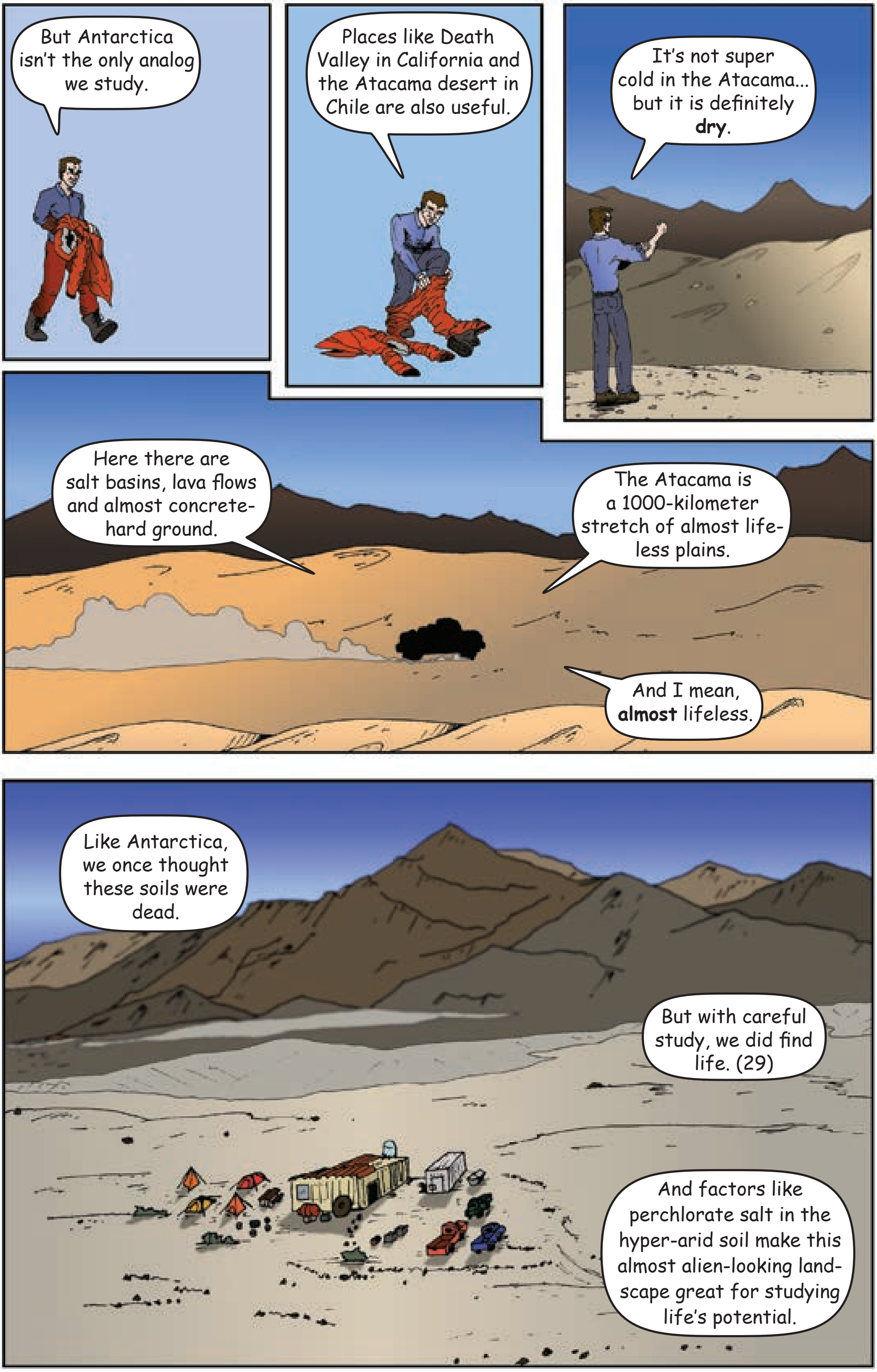
Places that are geologically similar to Mars are great for testing technology.
It's a chance to drive rovers through rocky terrain, or to test our methods for performing science in remote landscapes.
This includes places like Haughton Crater in the Canadian arctic, or even the volcanos of Hawai'i.
Features like craters and dry stream beds can also help us identify where water may have flowed on Mars.
We study Earth's geology from the ground, air, and space so that we can make comparisons with the images our robotic missions send home.
But very few places are good analogs for habitats that might support biology on other worlds.

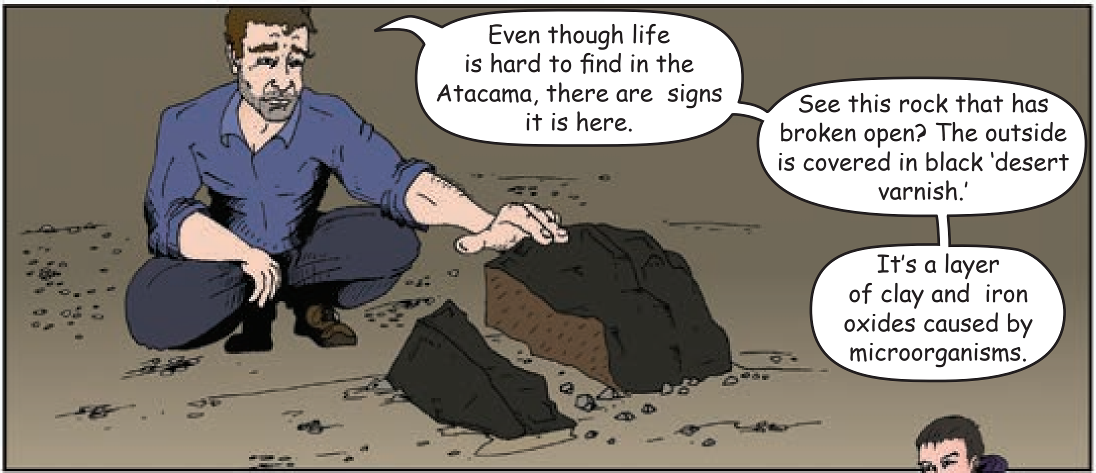
Up close, the Antarctic Valleys do have some Mars-like traits... like salty soil, and elevated UV* levels.
You know the ozone layer is thinner down here, right?
Antarctica isn't exactly like Mars, but it's as close as we can get on this planet.
*Ultraviolet (UV) light
At first we thought the soil here was dead...
...the first naturally sterile habitat on Earth ever found.
SCRRRATCH!
But then we started testing life detection instruments in preparation for Viking.*
WOLF TRAP
*Wolf Vishniac testing the Wolf Trap in the Dry Valleys in the 1970s. (See Issue 2)

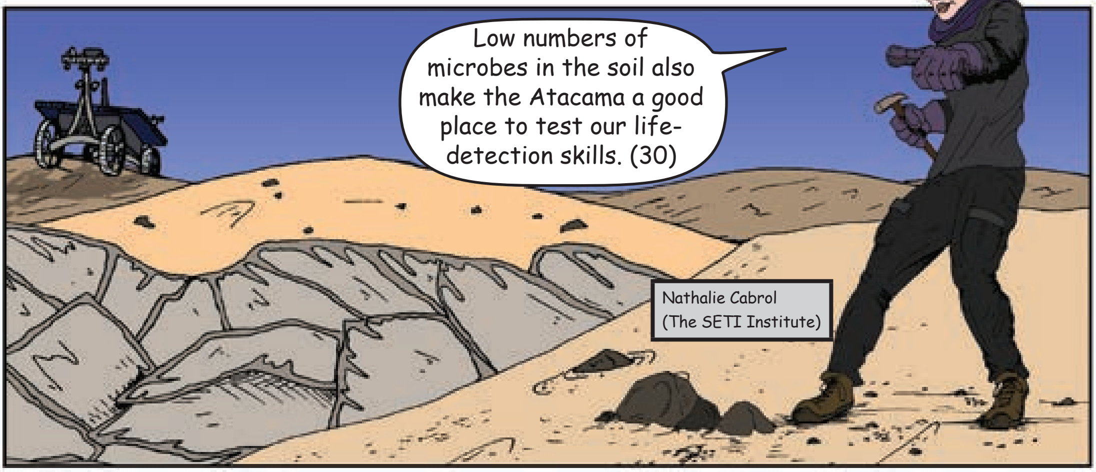

With the Wolf Trap, we found microbes.
And we began to wonder if there **WAS** a chance for life on Mars. (10-12)
After Viking, more and more missions have added their data to the story.
We realized that some Antarctic soils are similar to the martian regolith in terms of their physical and chemical properties. (7, 13, 14)
But no matter what Antarctica has to throw at life, organisms are able to survive.

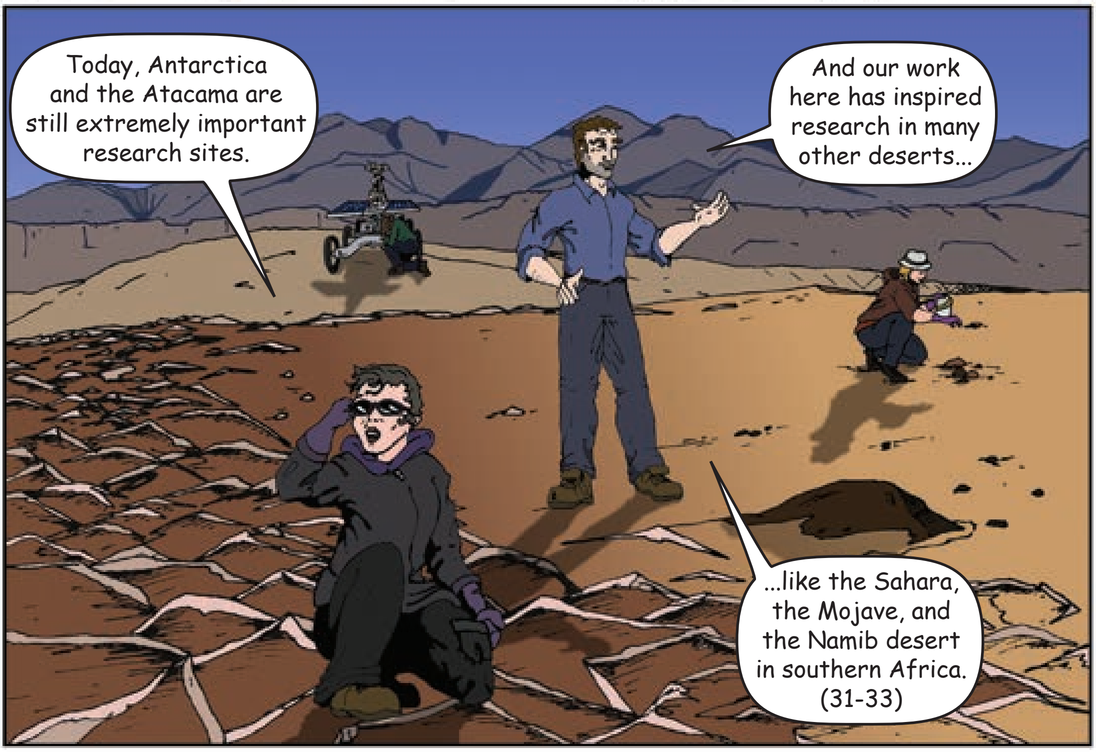

We found microbes in some spectacular hiding places.
Roseli Ocampo-Friedmann (1937-2005) (15)
They were buried under layers of soil...
...and even **inside** rocks!
WHAM!
You can see the green line of photosynthetic microbes just below the rock's surface.
We call these microbes cryptoendoliths. (17-20)
The rock provides a shelter for organisms at the micro- scale.
There's protection from the elements, including insulation from the cold and radiation.
It makes you wonder if life could use similar techniques to survive on a place like Mars.
E. Imre Friedmann (1921-2007) (16)
Even long after the completion of the Viking missions, Antarctica has remained a place of discovery for astrobiology and an important testbed for new technology.


WHRRRR!
The ice-cemented ground is a great place to test drills that could be used at Mars' poles. (21-24)
Chris McKay (NASA ARC)
And we've found lots of other crazy habitats that can teach us about life's potential.
Like isolated ecosystems trapped in ice-covered lakes... (25, 26)
There's also water trapped under glaciers.
High pressures and lots of salt keep it liquid - even below freezing!
And when the water is forced to the surface... (27, 28)
...just guess what we find.
Jill Mikucki (University of Tennessee)


But Antarctica isn't the only analog we study.
Places like Death Valley in California and the Atacama desert in Chile are also useful.
It's not super cold in the Atacama... but it is definitely **dry**.
Here there are salt basins, lava flows and almost concrete-hard ground.
The Atacama is a 1000-kilometer stretch of almost life-less plains.
And I mean, **almost** lifeless.
Like Antarctica, we once thought these soils were dead.
But with careful study, we did find life. (29)
And factors like perchlorate salt in the hyper-arid soil make this almost alien-looking land-scape great for studying life's potential.


Even though life is hard to find in the Atacama, there are signs it is here.
See this rock that has broken open? The outside is covered in black 'desert varnish.'
It's a layer of clay and iron oxides caused by microorganisms.


Low numbers of microbes in the soil also make the Atacama a good place to test our life-detection skills. (30)
Nathalie Cabrol
(The SETI Institute)

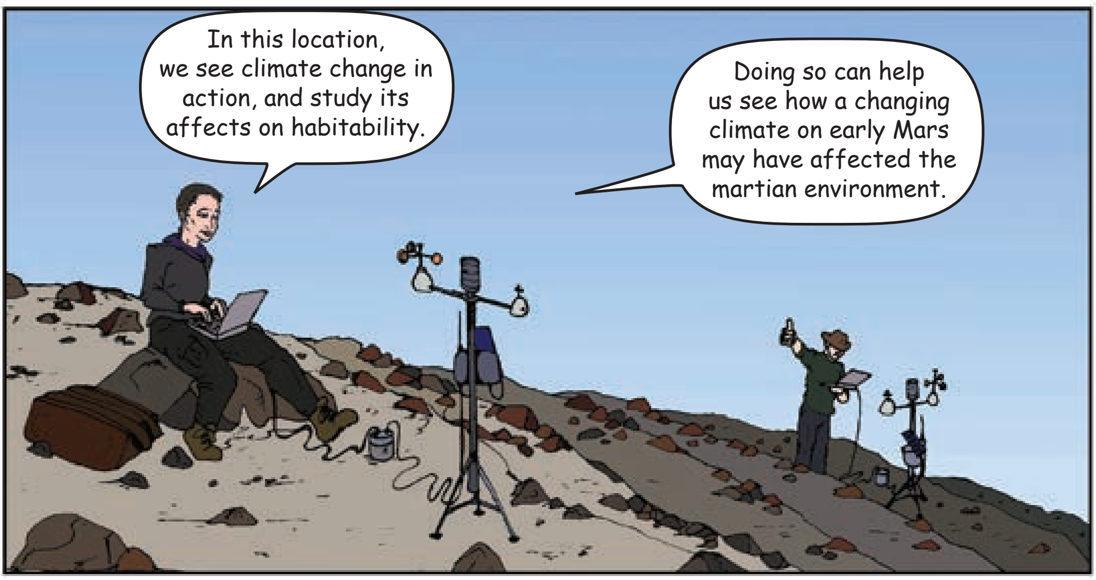

Today, Antarctica and the Atacama are still extremely important research sites.
And our work here has inspired research in many other deserts...
...like the Sahara, the Mojave, and the Namib desert in southern Africa. (31-33)


Astrobiologists travel around the world, from the north pole to the south, searching for analogs.
But one of the least explored analogs can be found anywhere in the world...
...although, it's very hard to visit.
That's because it's basically made of solid rock.
When you dig underground, it might just look like dirt and rocks...
...but under a microscope the view is very different.
Drops of water can be found in tiny cracks and fissures.
And this water is the key to life.
Mary Voytek (NASA)
Drilling programs at the ocean floor and on land provided some of our first views into Earth's **deep biosphere**. (34-36)

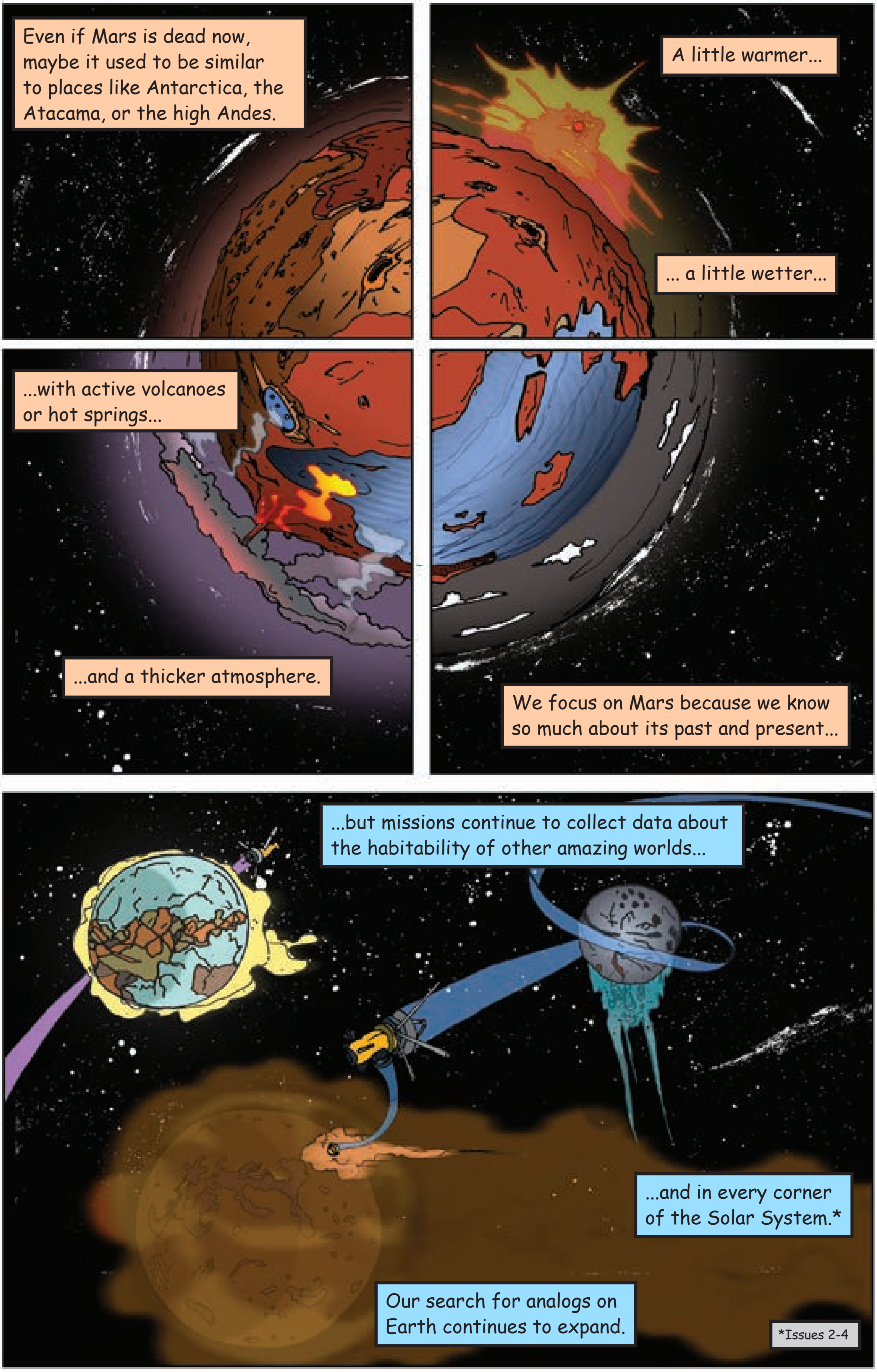

To get to the deep sub-surface, Astrobiologists also explore caves and mines.
Here we can tap into underground water sources and take samples.
We ventured into deep mines in South Africa because drilling from the surface wasn't enough to tell us how life was living down here. (37)
In the mine, we drill sideways into the wall to collect samples that are free from contamination.
In these hidden pockets deep below ground, we find entire ecosystems thriving. (38)
It's true that the surfaces of planets like Mars and Venus are vastly different than the Earth.
But underground, it could be a completely different story.
Penny Boston, Chair of Earth and Environmental Sciences, New Mexico Tech. and Associate Director of the Nat'l Cave and Karst Research Institute
Tullis Onstott (1955-2021) (Princeton University)


The surface of Mars might not be habitable today.
But if life existed on Mars in the past...
...could it still be hiding somewhere underground?
Questions about life in Mars' past bring us to the slopes of Licancabur Volcano in the Andes, and another type of analog.
See those lakes behind us?
Those are Laguna Verde and Laguna Blanca.

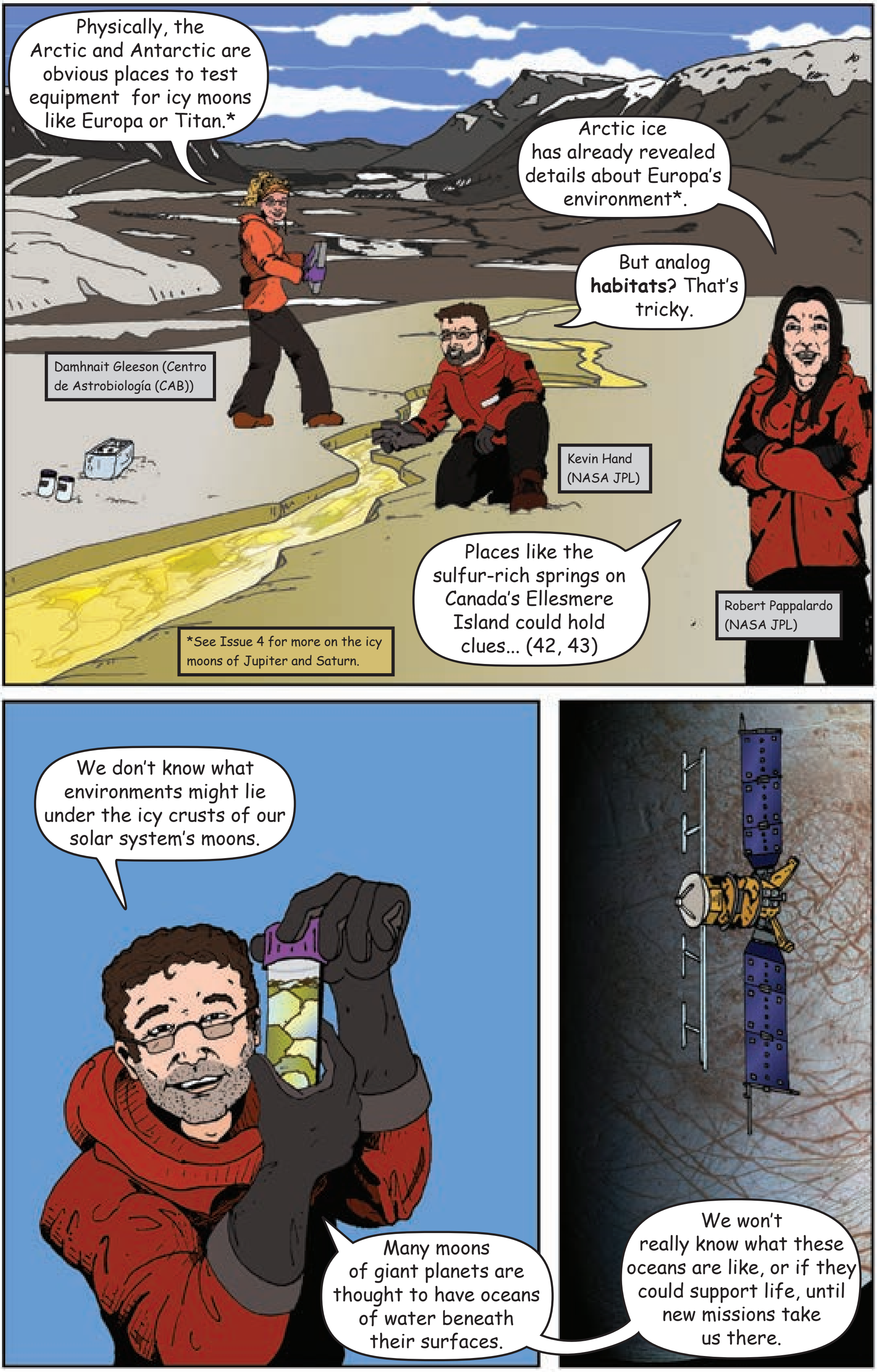

Here we find an analog for a Mars we no longer see.
Aspects like geology, temperature and ultraviolet radiation at this site might be a good analog for an early, **wetter** Mars. (39, 40)
And there's an added bonus.

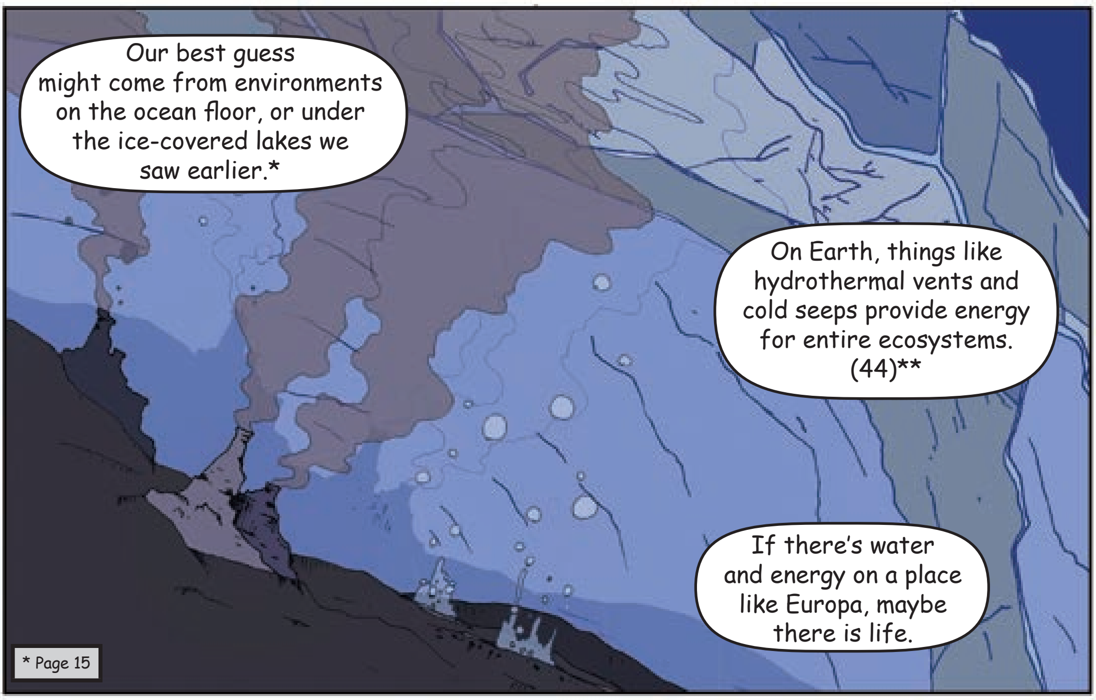

In this location, we see climate change in action, and study its affects on habitability.
Doing so can help us see how a changing climate on early Mars may have affected the martian environment.

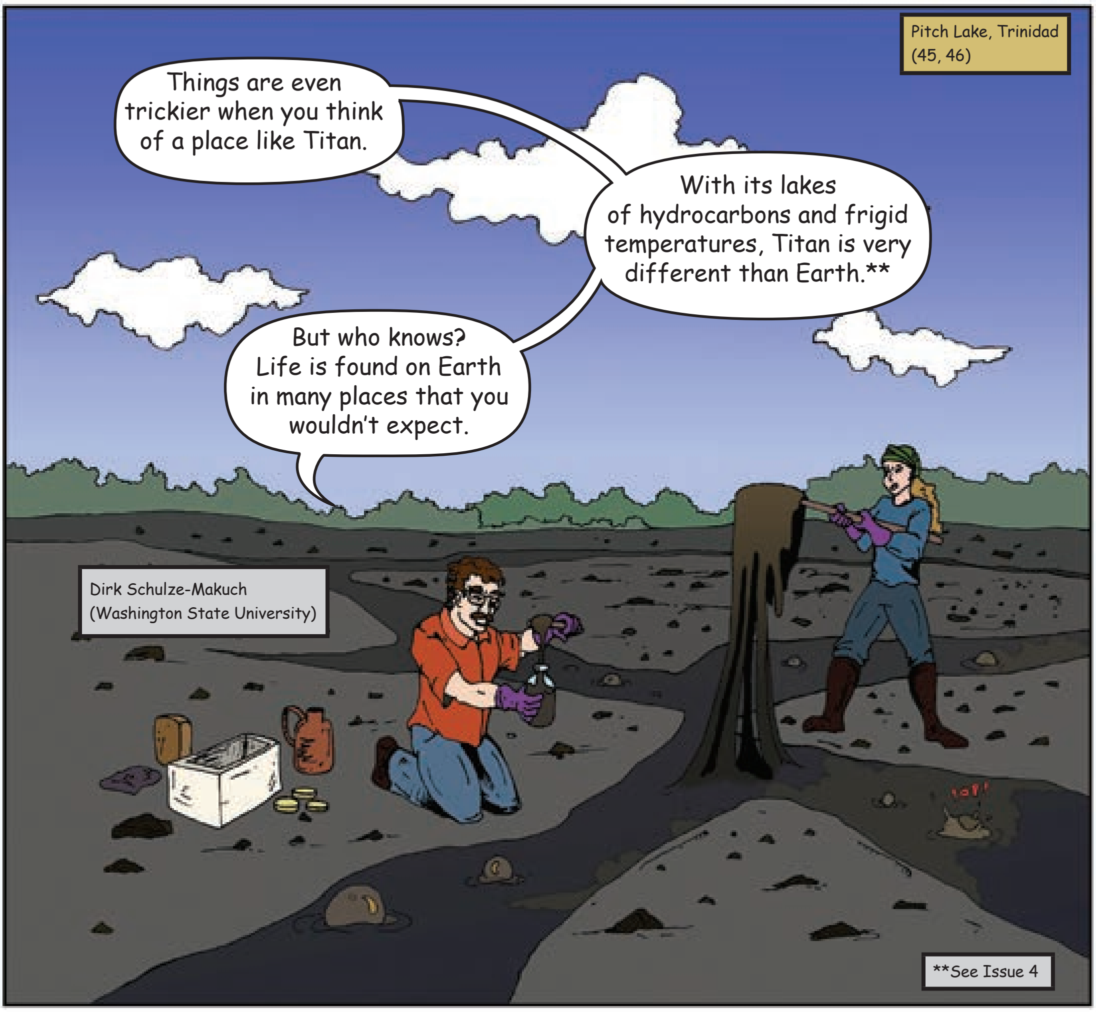

Other analogs for early Mars also exist.
This is Spain's Rio Tinto river, where water runs **red**.
With a pH of 2.3, it's acidic enough to eat metal!
This river is nothing like Mars now...
...but some aspects might be similar to a wet, acidic Mars in the past.
Carol Stoker (NASA ARC)
This water and the ground around the river might hold clues about life's potential on ancient Mars. (41)

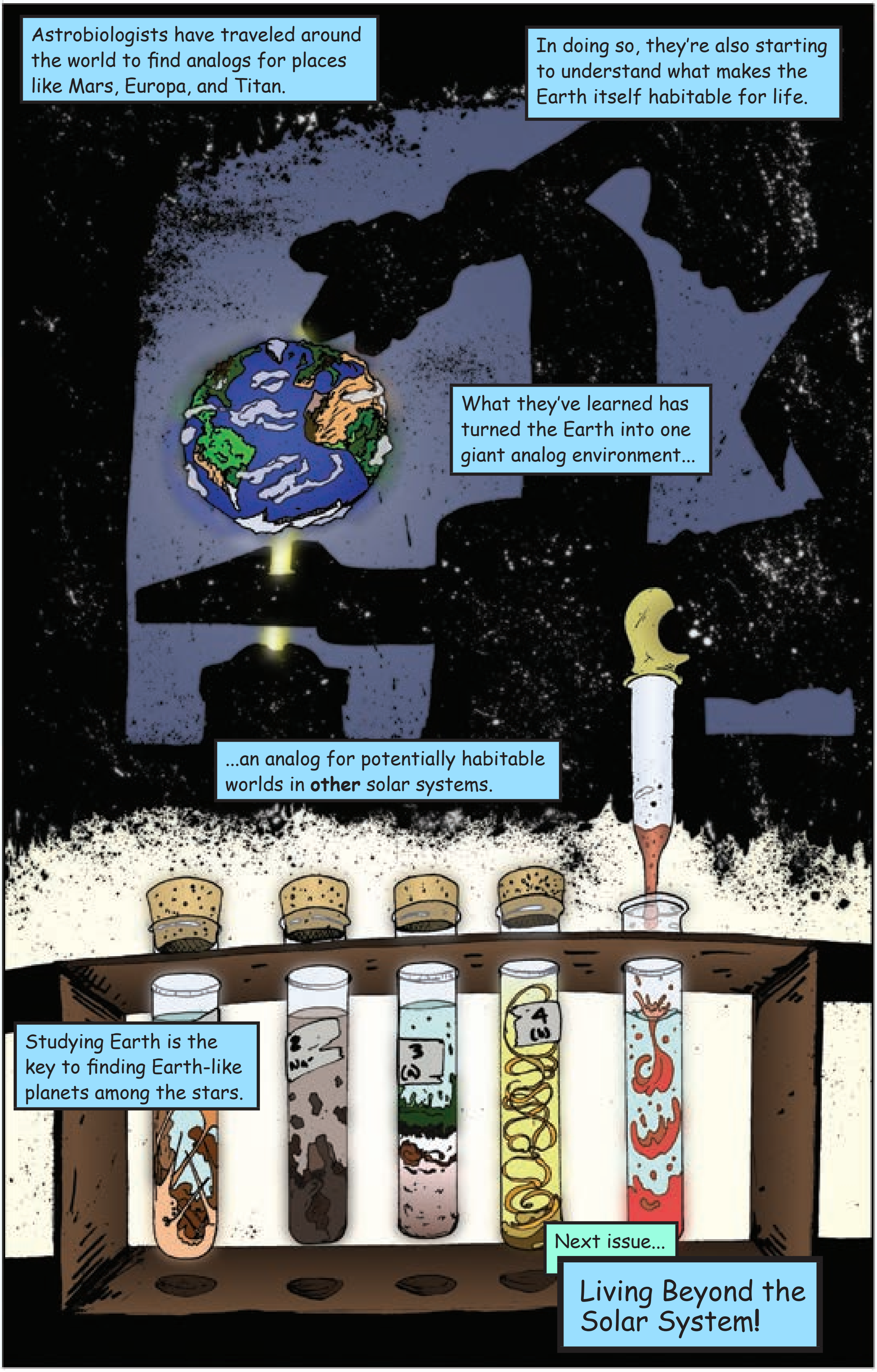


Even if Mars is dead now, maybe it used to be similar to places like Antarctica, the Atacama, or the high Andes.
A little warmer...
... a little wetter...
...with active volcanoes or hot springs...
...and a thicker atmosphere.
We focus on Mars because we know so much about its past and present...
...but missions continue to collect data about the habitability of other amazing worlds...
...and in every corner of the Solar System.*
Our search for analogs on Earth continues to expand.
*Issues 2-4


Physically, the Arctic and Antarctic are obvious places to test equipment for icy moons like Europa or Titan.*
Arctic ice has already revealed details about Europa's environment*.
But analog **habitats**? That's tricky.
Damhnait Gleeson (Centro de Astrobiología (CAB))
Kevin Hand (NASA JPL)
Places like the sulfur-rich springs on Canada's Ellesmere Island could hold clues... (42, 43)
Robert Pappalardo (NASA JPL)
*See Issue 4 for more on the icy moons of Jupiter and Saturn.
We don't know what environments might lie under the icy crusts of our solar system's moons.
Many moons of giant planets are thought to have oceans of water beneath their surfaces.
We won't really know what these oceans are like, or if they could support life, until new missions take us there.


Our best guess might come from environments on the ocean floor, or under the ice-covered lakes we saw earlier.*
On Earth, things like hydrothermal vents and cold seeps provide energy for entire ecosystems. (44)**
If there's water and energy on a place like Europa, maybe there is life.
* Page 15


Pitch Lake, Trinidad (45, 46)
Things are even trickier when you think of a place like Titan.
With its lakes of hydrocarbons and frigid temperatures, Titan is very different than Earth.**
But who knows? Life is found on Earth in many places that you wouldn't expect.
Dirk Schulze-Makuch (Washington State University)
**See Issue 4


Astrobiologists have traveled around the world to find analogs for places like Mars, Europa, and Titan.
In doing so, they're also starting to understand what makes the Earth itself habitable for life.
What they've learned has turned the Earth into one giant analog environment...
...an analog for potentially habitable worlds in **other** solar systems.
Studying Earth is the key to finding Earth-like planets among the stars.
Next issue...
Living Beyond the Solar System!

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