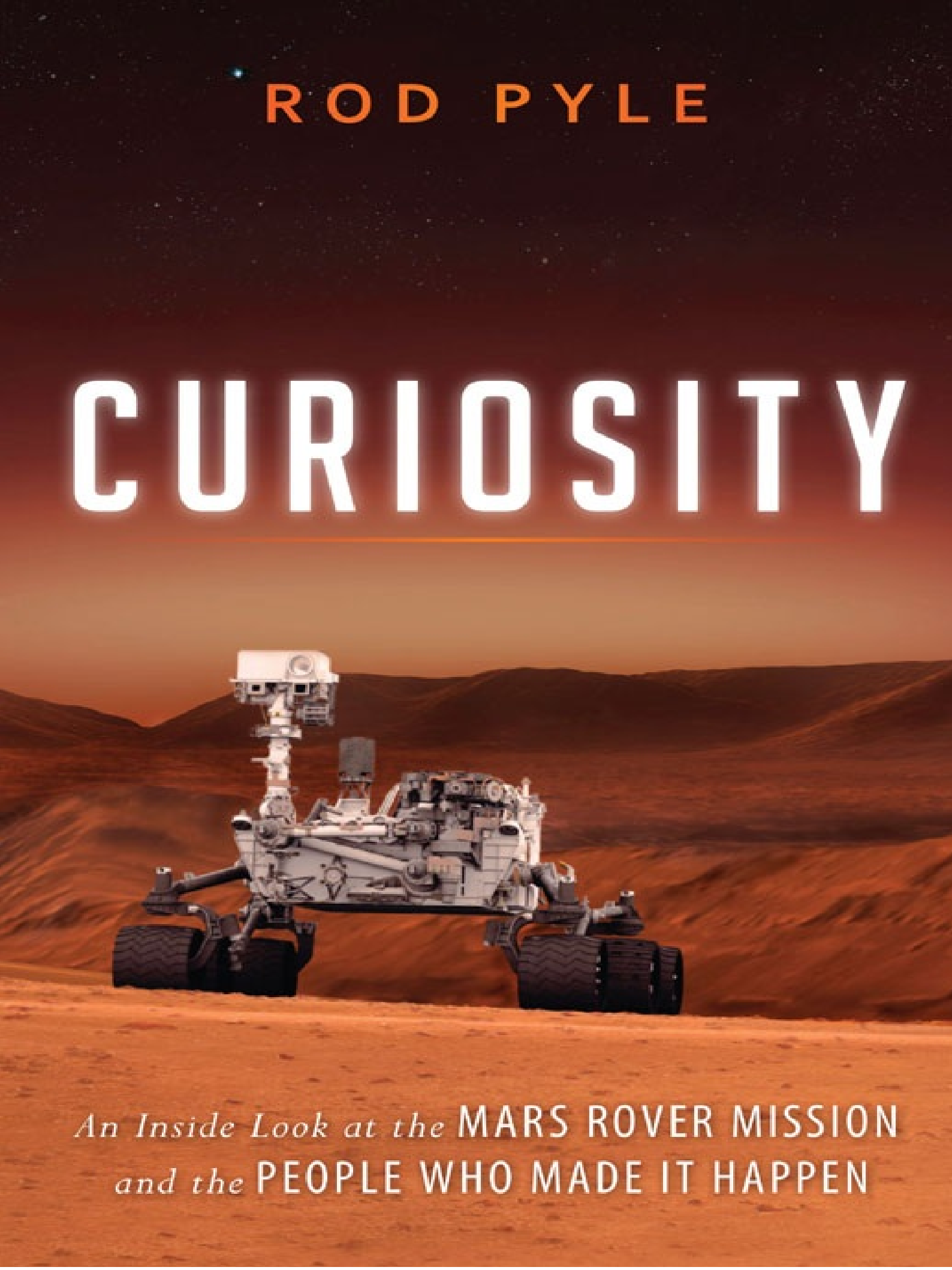
ROD PYLE

CURIOSITY



An Inside Look at the MARS ROVER MISSION *and the* PEOPLE WHO MADE IT HAPPEN

ALSO BY ROD PYLE

Destination Mars: New Explorations of the Red Planet

CURIOSITY

An Inside Look at the MARS ROVER MISSION
and the PEOPLE WHO MADE IT HAPPEN

ROD PYLE

Prometheus Books
59 John Glenn Drive
Amherst, New York 14228

Published 2014 by Prometheus Books

Cover images © Media Bakery
Cover design by Nicole Sommer-Lecht

Inquiries should be addressed to
Prometheus Books
59 John Glenn Drive
Amherst, New York 14228
VOICE: 716–691–0133
FAX: 716–691–0137
WWW.PROMETHEUSBOOKS.COM

18 17 16 15 14 5 4 3 2 1

The Library of Congress has cataloged the printed edition as follows:

Pyle, Rod, author.
Curiosity : an inside look at the Mars rover mission and the people who made it happen / by Rod Pyle.
pages cm
Includes bibliographical references and index.
ISBN 978-1-61614-933-8 (paperback) — ISBN 978-1-61614-934-5 (ebook)
1. Roving vehicles (Astronautics) 2. Curiosity (Spacecraft) 3. Mars (Planet)—Exploration. 4. United States. National Aeronauti and Space Administration. I. Title.

TL799.M3P95 2014
559.9'23—dc23

20140075

Printed in the United States of America

To my son, Connor:
The future is yours,
use it wisely.

CONTENTS

ACKNOWLEDGMENTS

Thanks are due to countless people who generously gave of their time and energies to assist in th completion of this book. The bulk of these people work at JPL, either on staff or as contractors, an rarely get the thanks or recognition they deserve.

First and foremost: my deepest thanks to the selfless Guy Webster, as fine a person as you are like to meet during your brief time on our planet. He is the media's point man for JPL's Mars program, an gives and gives without complaint or hesitation, which is rare in his area of endeavor. And—he know his stuff; Mars is no stranger. I simply cannot thank you enough.

John Grotzinger, who was kind enough to survive my many questions, most of which are well belo his pay grade. John made time for me on numerous occasions when I'm sure he had better things to d (like exploring Mars, for example). John, I am in your debt for the many hours you spent educatin me on things I did not know I needed to know, and making it fun.

Rob Manning, a fantastic guy, gave me more time than I could have asked for and did so wi copious good grace. He is a font of information presented in a way that is as enjoyable as it informative, and the fact that he enjoys it so much means that all of us do too.

Very special thanks to: Ashwin Vasavada, Dan Limonadi, Joy Crisp, Justin Maki, Mike Malin, Ke Edgett, Scott McLennon, Lauren DeFlores, Vandi Tompkins, Doug Ming, Brian Cooper, Rebecc Williams, Al Chen, Steve Squyres, Chris McKay and Jakob van Zyl. You all provided time fo interviews in schedules that were already jammed to the hilt. My thanks.

To Buzz Aldrin, who made time for questions about this story as well as others; you are a founde of the Space Age, and one of the few key players who continuously strives to push open the frontier Mars owes you much.

Robert Zubrin, whose work underlies so much of manned Mars planning now it's hard to find th borders of his involvement. Thanks for being a selfless champion of the red planet. Alexandra Hall o the Google Lunar XPrize: you will first win the moon, then Mars. Carry on.

Steven Dick, former NASA chief historian and now astrobiology chair for the Library of Congres and Roger Launius of the Smithsonian NASM, thanks as always. Leonard David, space journalist an fellow niche author: thanks for being there.

Steven L. Mitchell of Prometheus Books: your continued support of planetary exploration and th sciences at large are a testament to the integrity and high standards of Prometheus. We are all bett for your efforts. And to the rest of the Prometheus Books staff: Catherine Roberts-Abel, Melissa Ra Shofner, Bruce Carle, Nicole Sommer-Lecht, Jade Zora Scibilia, Mariel Bard, Meghan Quinn, an those who worked behind the scenes—thank you.

John Willig, ever-present agent and supportive friend, who wrangled the details and made it loo easy as he always does. Deepest thanks once again.

Blaine Baggett runs a tight ship at JPL and it shows. The communication division works wonde with limited resources. Veronica McGregor, Jane Platt, Jia-Rui Cook and D. C. Agle make this sort o thing possible.

To the rest of JPL's able PR staff: Elena Mejia, Mark Petrovich, Daniel Goods, Erik Conway, Sco Hulme, and John Beck-Hoffman—thanks for responding to my continuous (and probably irritatin requests for media materials. There is simply no way for an author to approach such as task witho

your talents and support.

Lawren Markle and Brian Bell of Caltech's media relations: thanks for your accommodatio
Lawren has since moved on, but may well have saved me from becoming a permanent part of Dea
Valley.

Janice Alvarez provided tireless transcriptions on time and with remarkably few errors or omissio
considering the complexity of the work—and while delivering a new baby, no less. I have no idea ho
you did it.

Thanks to my pals from the Griffith Observatory days who generously donated their time to JP
during the Curiosity landing: Jim Somers and John Sepikas. You made the landing a whole lot easi
for the press; they will never know what you did for them. Glenn Miller helps you stay the cours
And Bob Brooks, who is at JPL every day—Mars would not be the same without you.

Thanks to Ken Kramer, Sherry Clark, and Scott Forbes, for being there. To my son, Connor, wh
endured countless hours of silence and separation (do teenagers even notice?) while I operated
missile-silo mode to write: thanks for being understanding.

Sherry Clark, you are a pillar of strength and support. Gloria Lum, your contribution to this proce
is too much to write. Thanks.

To mom and dad: thanks for being understanding of a sometimes-puzzling son.

To the readers: thanks for being understanding of a sometimes-puzzling adult. I love writing book
and your support is the greatest treasure any author can ask for.

AUTHOR'S NOTE

Any book such as this requires a vast amount of research and cooperation with the Nation Aeronautics and Space Administration (NASA), the Jet Propulsion Laboratory (JPL), Caltech, ar other appendages of the government/academic space-exploration enterprise. Of course, the riche resources are the people within, and the larger NASA entity is filled with wonderful and helpful on who have vast experience and long memories. In particular, the exploration of Mars is an undertakir that inspires great passion in the participants, fostering deeply moving and fascinating conversations

I interviewed dozens of participants in the Mars Science Laboratory (MSL) mission for this boo and it draws upon their statements and memories liberally. In all cases they demonstrated an acu memory of entry, descent, and landing akin to people's memories of where they were when Apollo 1 landed on the moon, or for the younger generation, that awful day when the space shuttle *Columb* disintegrated during reentry. Other memories and recollections of duties and actions taken sinc landing, during the primary mission, were also fresh. For the scientists, their summaries of the particular areas of interest were detailed and exact. Likewise for the engineers; their recall of the portions of the mission and the technologies within were acute and complete. These record interviews were later transcribed into about three hundred pages of text for reference.

For the recounting of specific statements and events not covered within interviews (or requirir backup), I relied on two primary sources. The first, where applicable, were the vast amounts archival video footage of various phases of the MSL mission which are available online both throug publicly accessible NASA websites and by request via JPL's servers. One may also order footage fro JPL's vendor if desired. Thousands of still photos back up this visual data, too. The second source w the statements of other participants in the mission themselves, and in cases where there was ar mismatch or doubt, I attempted to find a third source to support individual claims.

In absence of other recorded data, Guy Webster, JPL's point man for Mars, has a vast institutiona memory and was helpful when other methods failed. He is a rich resource.

For older missions and histories, NASA has massive archives spread across the web and in variou physical locations—specific to planetary exploration, JPL, Caltech, and Nils Bohr Institute archiv can be particularly helpful.

All this said, one occasionally finds an error or misquote that has been propagated across time ar space—something printed twenty-five or thirty years ago, then erroneously quoted in another book article, *then* archived among a half dozen or more web portals, can become very thorny to unrave especially when (as sometimes occurs) the primary reference may have gone missing. Fortunatel MSL is a young-enough mission that this is not yet a concern. In fact, part of NASA/JPL-Caltech challenge with this mission is to preserve and archive events and documents as they happen, with ve little budget to do so.

The vast bulk of the imagery in the book comes courtesy of NASA/JPL-Caltech. Their online imag archives are superlative, and in most cases the accompanying captions make clear the phase of th mission related to the photo at hand. A few other images were sourced from stock agencies or Creativ Commons sources. Still others come from my personal collection.

Review and some fact-checking was performed by JPL and in some cases specific missio participants. Any remaining mistakes are my own.

CHAPTER 1

DEATH VALLEY DAYS

Vultures cut lazy circles in the sky above me, patiently awaiting my certain demise. Dropping m gaze, I could see the heat shimmering off the mountainside. It was well over one hundred degrees ar the last of the water was long gone. I was close to forty miles from the nearest road and the situatio looked bleaker than the late dinner seating on the *Titanic*.

What did this potentially life-threatening situation have to do with Curiosity on Mars?

Then the image of Lawren Markle, the dapper (and sweatless, in stark contrast to my drenche shirt) PR rep from Caltech, swam into focus before my parched and crispy eyes.

"You doing OK?" he said with a look of genuine and entirely reasonable concern, given m condition. "Sure," I croaked. "I'm…good…." It was then that the death fantasy evaporated and I wa back in an equally grim state—atop a barren, rocky peak in Death Valley with a group of scienc journalists and our Edmund Hillary–esque geological guide, Caltech's Dr. John Grotzinger.

I looked from Grotzinger, who was holding forth on a geological premise that was not quite soakin in, to Lawren, who had refocused his attention to Grotzinger, where it belonged. Having Grotzinger a our tour guide in this garden spot of Death Valley was a true privilege. If I survived it, I would be ver grateful in a week or so, once I was able to rehydrate.

Reality hit: we were probably a mile from the road, it was about eighty-four degrees, and we ha been hiking for about twenty minutes. I was wiped out. This was not promising to be my best day.

The invitation I received in my e-mail a week before had sounded exciting and bore the retu address of Caltech. I was invited to join Dr. John Grotzinger, mission scientist (a.k.a. Big Kahuna) fo the Mars Science Laboratory, as he hosted a two-day press junket into Death Valley to discuss some the formations that informed earthbound geologists about what they might find on parts of Mars. It a looked like good fun, and there would be only a handful of us, maybe twelve science writers. I wou be the sole outside video guy; JPL's John Beck-Hoffman would shoot for their media operation.

At the end of the note was added, "Wear sturdy shoes, as we will do a bit of walking." Oddly, missed the hidden meaning even though I had taken a string of geology classes in college. I shou have remembered that this was geologist's code for "wear steel-toed boots, as we are likely to run in rattlers and possibly even desert snarks as we hike over hill and dale looking for the perfe Precambrian outcrop"…or in this case, as we hike about twelve miles, mostly vertical, in the hotte and driest place in the continental United States.

What may have thrown me off was that Grotzinger is not the old-breed of geologist I knew from m increasingly distant college days. He wore no suspenders, no plaid flannel shirt, and did not smoke pipe. He had no gold-miner's belly hanging over a turquoise-buckled beltline. He is, in fact, tall, slim irritatingly fit, and tan. His weathered good looks would be welcomed into the Explorer's Club. Whi his explanations can be challenging to follow, he is patient and graceful with the laypeople. He can b folksy and technical in the same sentence, so clearly the geologist's pedigree was there.

We traversed many roads and junctions on our way into the high desert, and the map showed man nearby avenues with such charming (and informative) names like Talc Road, Sulfate Road, and Cactu Flats Road. A few hours out of LA, we reached our destination: Shoshone, California, with

population of thirty-one. Our group almost doubled it.

As we checked in at the cinder-block penitentiary that was to serve as our motel for the night, a optimistically named "inn," Grotzinger wandered over to one of the hulking, chalk-white Calte SUVs that had transported us there. By the time I got my camera equipment and other packin stowed in the room, he was completing elaborate dry-marker murals on the rear passenger-side do of one of these overwrought grocery haulers. Big murals. Murals of complicated rock bedding, upli and other geological delights. And on the front door, he had drawn surprisingly artistic renderings very steep Alpine-looking mountains, which I hoped were metaphorical. As I watched, and thoug back to my own college geology field trips, I wondered if any of his compatriots had ever swapped o a permanent marker in the SUV drawing kit just for laughs. I know I would have. "Ha ha, that w funny. Here's the turpentine…oh, that takes off the car's paint too, now doesn't it…"

As we waited for the formal talk to begin, a three-foot-long and very red snake worked its wa across the roadway and for some reason (probably seeking the same relieving shade that I would soo pine for) decided to work its way through the spokes of the truck's wheel. Our group titter nervously. Most of us were now regretting the light athletic shoes we had chosen to wear.

We moved to a fire ring nearby (why a fire ring in Death Valley, you might ask? To keep th sidewinders and rabid coyotes away at night, of course), and Grotzinger began discussing the da ahead. I missed most of it because I don't shoot video out on location all that often and was fiddli with my camera gear and cleaning the sand off the parts I had already dropped twice. But I had running by the time he got to the most immediately relevant part of the talk, moving back to the mur on the Suburban. "Then we'll end up at this formation, here in the foothills. It's the Glimmensho Finkleheimer formation of preglandular hermphratite…"(this was not exactly what was said, but i how it registered in my overheated brain).

I was still rolling video, so I meekly asked, "John, for *my* audience would you mind giving me th eighth-grade, *Weekly Reader* version of the story?" He paused for a moment, looking at the ground thought perhaps I had committed some kind of faux pas, but I think he was merely gathering h thoughts. At least I hope so.

"Um, OK. So what these structures represent is a feature called stromatolites, that we interpret Earth to represent the interplay between microbial mats that are living on the seafloor and sedime that comes in and interacts with the mat. The sediment is ultimately why it becomes a rock. If it's ju left as a microbial mat, the organics will decay and there will be no record of that, but by having th sediment come in, it can get cemented and turn into a rock. Then we see these features in the roc record and infer that there were once microbes living on the seafloor that were forming the structures."

He paused for a moment to make sure I was getting it. At least the camera was. He continue "What it has to do with the MSL [Mars Science Laboratory] mission is that it represents an en member of a feature that, if we saw it on Mars, we would stop and definitely study the outcro Immediately there would be a lot of discussion, because even on Earth we cannot take this rock an bring it back to the lab and prove to you unequivocally that this feature represents evidence of life the early Earth." As we will learn later, and I promise it will be simpler, on Earth these stromatolit like features *can* be caused by living things, or they can mimicked by processes having nothing to with life. On Mars it would be (a) a wonderful shock and (b) a guaranteed conundrum. "[On Earth] you put in the context of other features that occur along with it, it's a perfectly reasonable suggestio that these were microbial mats on a seafloor. But independent of that, in rocks of this age, we ofte see microfossils. I would say that if we ever found something like this with MSL, we would stop an study it, and it might be a really good place to come back to someday in the future and do a samp return to Earth." Not to mention a press sensation and a tenfold increase in planetary-explorati

budgets. But I digress.

He stopped, flashed what felt like a sympathetic smile, and it was time to move on with the adu portion of our program. I envied the grad-student assistants present that they could understand th version that was to come.

Soon we headed out to the first stop on the side of the scenic Western Talc Mine Road. Onc disembarked, Grotzinger began with a sweeping gesture toward some distant hills. “See those whi areas over there? They are due to this rock,” He gestured to a chart he had prepared, “which is shov to have a cross-cutting relationship where it comes up and goes into the Crystal Springs formatio there…” Pointing to a specific spot (that looked to this layman like more gray hillside), “It's a basalt composition rock, and that's a Mars kind of rock. It's not a granite; it's got olivine and pyroxene in i or once had it, and it intruded into the Crystal Spring adjacent to some carbonate rocks…and it ha altered the rock. You'll hear that from the Mars guys, especially the mineralogists, talking abou alteration. Well, that white rock is a result of alteration, it's a mineral called talc.”

I felt a moment of pride, for I knew what talc was. It comes as a powder in bottles and lives bathrooms.

“We're going to go right up there to see the talc and the carbonates that it's intruding into, so yo will see the source of the heat which is the basaltic rock. It intruded in, and then it heated up th sediments which were wet, and it made talc, which is a hydrated magnesium silicate mineral, kind like a clay.”

Aha! Understanding crept into my brain. If Curiosity found clays on Mars, that would be evidenc of water, and there were many complex processes under which this alteration into clays might tak place. This one had involved intense heating.

Fig. 1.1. STROMATOLITES: This is one form (of many) that stromatolites can take. They can be caused by either biological or nonliving activities, and it can be difficult to discern one from the other. Still, were something like this found on Mars, it would grab the attention of the geologists. *Image from Mark A. Wilson (Wilson44691).*

Overall, this was a dense subject, somewhat above my pay grade, but clearly Grotzinger loved th topic and while it may have been a challenge to talk at our level, his enthusiasm was highly infectiou

We loaded up the trucks and headed out to some barren, rocky mountains in the lowest, hotte

place of America.

Less than an hour later, we were in the foothills heading to the first hike of the day. Leading up t this, the sights had been within a few dozen yards of the highway. This had suited me fine, what wi my twelve-pound camera and eighteen-pound aluminum tripod (the lighter, carbon-fiber ones a expensive…I pride myself on equipment frugality and never understood those guys who spe thousands on carbon-fiber tripods—I soon would). It was early and I had already sweated out a fe quarts into my designer tropical shirt, vented at the back as a fashion statement.

As we unpacked for the hike, I took stock of my companions. There were about a dozen of u including Mike Wall, my compatriot from Space.com. He was writing a story and I was shooting on I would soon admire his choice of a pen as an instrument of communication over my camera. Othe were from the *Wall Street Journal*, *Reuters*, *New York Times*, *Washington Post*, *New Scientist*, and t *LA Times*. And then there was Beck-Hoffman, the JPL camera guy who was annoyingly fit and nimb (and who would soon be known as the *auteur* behind the "7 Minutes of Terror" video that w downloaded millions of times). He was carrying a large, shoulder-mounted camcorder. It would slo him down far less than my smaller rig would me.

We parked on a mesa and headed off, following Grotzinger toward a series of hills. They didn't loo like much from the starting point. But by the time we got to the bottom of them, they were impressiv indeed. Funny how these things magnify in intimidation when you get closer—the desert compress everything from a distance. The group made its way up, each at his or her own pace but in little clo of people—and then there was me. To be fair, I was carrying the camera in one hand and the tripo over the opposite shoulder, trying to balance myself as we climbed the rough, bouldery hillside. A least that's the excuse I was using. Within moments, I was out of breath, panting like a dyi asthmatic, and falling behind. I looked from side to side—there were mounds here, surely shallo graves of journalists who had gone before me. But I stuck with the program.

When I reached the top, the lecture had begun and the other journalists were taking copious notes set up my camera with slippery, sweaty hands, and once the ringing in my ears abated, which for moment I thought might be the signs of a mild stroke, I listened to Grotzinger speak on the formatio at hand.

No sooner had I caught my breath than we were on our way farther up the hill. To the top. Whic looked very far away. I shouldered the camera rig and followed at an ever-increasing distance, Lawre shooting worried (and deservedly so) glances my way from time to time. It's nice to be cared abo when you're in extremis. On the other hand, I guess it would have been bad publicity for Caltech host the death of overweight, out-of-shape, late-middle-aged journalist.

For the rest of the day we climbed, descended, and climbed again. The rocks were sharp and nast Grotzinger literally scampered hither and yon and most of the journalists were keeping pace, albe with an increasing gap between themselves and Grotzinger. And then there was the gap between the and me. Leave me, save yourselves.

Fig. 1.2. WHY THEY CALL IT DEATH VALLEY: This was not the region we visited, but it's close enough to give you an idea of how the place got its name. Fascinating, lovely…and on the wrong day, deadly. Summer temperatures can top 130°F. *Image from iofoto.*

We came to another mountaintop (OK, it was a hilltop but give me some dignity), and Grotzinge waited for the group to settle. I approached as he began his talk. He was not even sweating. “If yo look carefully enough, you will see that these things all go in the same direction. So if you walk up bit you'll see more of them, then we'll go around the corner where you can see a really big one, about meter in diameter. Have a look, then we can talk some more about it.” He walked off to chat wi another husky, bearded fellow (he could pass as a younger version of me, without the cardiac issues Ken Edgett. Ken is a geologist who works for Malin Space Science Systems (MSSS), makers of th main imaging cameras on Curiosity (and imaging systems of other spacecraft that have orbited Mars He wasn't sweating either.

The landscape was pretty in a bleak way, but I had missed the actual subject of the stop. I resolve to be more prompt to the next one, even if it meant an early demise.

The remainder of that day and the next followed in a similar pattern, and a night of deep sleep d little to lessen the impact of the second day's calisthenics. It was informative but challenging. At th end of the second afternoon, I pigeonholed Mike Wall and asked him to summarize the trip. He has doctorate after all (though in an unrelated field) and is the senior writer for Space.com.

He summarized the excursion succinctly: “John walked us through what field geologists do, ho you can make sense of all the different rock layers, what they mean, how they were deposited, and s forth. It was a great exercise. Couched in this is what Curiosity will be doing on Mars and how we ca try to make sense of the sort of rocks and formations that we may find in Gale Crater.”

He thought for a moment and continued: “It's a process, it's all context and getting to know th environment. We learned that it's harder than you think it is, that you really need to know the rock

It's going to be hard for a robot to do that on a different planet, but MSL has a great support team, ov
four hundred scientists who are working on the project. They will interpret all this incredible data th
the rover will gather. They are very smart people and will figure it out."

Looking at my sweat-soaked shirt, he smirked and added, "It's windy, but not even one hundred ye
maybe ninety-five degrees. Easy."

I thanked him and returned to the air-conditioned Suburban. We headed back to civilization t
witness the beginning of the most ambitious and incredible mission to the surface of another wor
ever attempted.

CHAPTER 2

TANGO DELTA: TOUCHDOWN

As you have probably surmised, John Grotzinger is not normally a nervous man. A career geologi and professor at the California Institute of Technology (Caltech), he seems equally at home running huge spaceflight project as he is in front of a class of anxious undergraduates. He jokes easily, and h explanations can be disarmingly folksy but can also turn deadly serious when explaining the relevan of contact metamorphism in a rock. Both are useful traits in his area of endeavor.

But tonight is different. Tonight the stakes are high indeed. Tonight, $2.5 billion of Mars rover, th aptly named Curiosity, will either land in Gale Crater to begin its twenty-four-month (one Martia year) primary mission, or pinwheel into costly wreckage across a couple hundred acres of Martia desert. Tonight will be either a validation of a decade of planning, designing, building, and launchin of a wonderful era of exploration, or the likely end of America's Mars exploration program.

So tonight, Grotzinger seems as nervous as a cat on the freeway.

You would never guess it just by looking, of course; geologists don't roll like that. It can be easi to gauge the feelings of his associates in mission control at the Jet Propulsion Laboratory. Dozens engineers, controllers, scientists, and other highly proficient people surround him in the fin moments of the flying phase of Curiosity's mission, and some display their feelings a bit mo directly. Perhaps it is because each of them has been intensely focused on a smaller part of th mission—parachute deployment, entry and guidance, pyrotechnics, software design, or one of a doz other specialized areas. Grotzinger, as the principal scientist of the mission, must be conversant each specialization of MSL yet also possess a more global perspective, that is, to oversee the missio once on the ground. Tonight there is not much that he can do except wait and hope.

A few consoles forward sits a man whose face is known to Mars enthusiasts worldwide but whos name may not be. Middle-aged and graying, he is nonetheless clearly still the smiling, ever-cheerf man we saw flashed so memorably across the Internet, fist-pumping the air when Mars Pathfind landed successfully in 1997. He was thinner and darker-haired then, but the effervescent energy is sti there. Rob Manning may have matured, but he is once again the chief engineer in charge of a Ma machine, and there is nowhere he would rather be. It shows.

Rob is not a professor, nor does he hold any official positions outside JPL. He has been the ma machine guy for every Mars rover to date—that is his raison d'être. He is also father to tw precocious daughters and plays jazz trumpet gigs in his scant spare time. Back at work, after sweatin out the pioneering Pathfinder mission in 1997 and the design and landings of both Mars Explorati Rovers, Spirit and Opportunity, in 2004, he is at the crescendo of his career with Curiosity. It's been long haul, though, and the endless hours of meetings and checkouts and visits to the cape have taken toll. He will rest when the rover is on the ground—in one piece or in hundreds. For now his normal cheerful face shows intense concentration as he follows the data coming back from Mars. So fa Curiosity, as much a third child to him as any machine could be, is doing fine.

Down near the front sits a man whose face—or, to be more precise, whose hair—will soon b iconic. Bobak Ferdowsi sports a wild, multicolored Mohawk hairstyle, a personal statement celebration for this momentous mission. It's like nothing we have ever seen in mission control, ar

within hours the Internet is alive with tweets and posts about this new phenomenon. Bobak, in his la
thirties, is a handsome young man who has worked for almost a decade on MSL's launch, cruise, a
approach phases. His role in these final moments of landing is largely one of quiet observatio
watching data he knows are already fourteen minutes old, delayed by the huge distance between Ear
and Mars. He summarized it well: “It's like taking the SAT [college entrance exam]—you've taken th
test, you are done. Nobody will tell you the score right then, so you have to wait. You're nervous.
something happening now could change the outcome of your life.” And he couldn't be more correc
except that his life will change in ways far different than he expects, including a couple of hundr
marriage proposals via Twitter and a future visit to the White House to meet the president and Fir
Lady. But that is some time off, and at the moment he is fixated on the screen in front of him.

But not everyone involved with the mission can fit in mission control. A building away, Ashwi
Vasavada sits, also intently eyeing a computer screen. He is, along with Joy Crisp, a deputy proje
scientist on MSL. He is also a spectator at this point. Curiosity carries experiments that he and Jo
have helped to shepherd through the process of construction, testing, installation, and launch, as the
oversee the larger science team behind the MSL mission. “I feel like I'm enabling almost 48
scientists and a spectacularly good mission with a lot of scientific integrity,” he comments. “I like
put my heart and soul into making sure we do good science.” Now, like Grotzinger, all he can do
watch, a helpless captive to events far away, above another world, as the much-anticipated entr
descent, and landing (or EDL) sequence begins.

Vandi Tompkins, slated to be one of a small group of rover drivers and programmers for Curiosity
is also waiting out the landing as an observer. As an engineer, she has ultimate faith in the machin
and her comrades who designed it. As a PhD in advanced robotics, she also has a deep attachment
the machine in a way that few would understand. And as a woman who came to the United States fro
India to make her way into the stratified world of planetary exploration, she can sometimes scarce
believe her good fortune to be here, on this program, at this moment. The next few minutes may we
determine her fate for the next decade.

And this is it—the by now well-known seven minutes of terror, made famous by the video of th
same name that went viral a couple of months earlier. On cue, MSL spacecraft plunges into the thi
Martian atmosphere after a largely uneventful journey lasting nine months. Much like war, robot
spaceflight is often characterized as long stretches of boredom followed by moments of intense terro
The spacecraft will automatically go through the intricate ballet of landing in a small target area on
planet far, far away. When it is over, the signals describing success or failure will still be making the
way back to Earth at the speed of light; during landing, MSL (and the Curiosity rover ensconce
within) is completely on its own. Grotzinger, Manning, Ferdowsi, Vasavada, Tompkins, and thousand
of others will still be staring at computer screens, continuing to count the seconds and ticking off th
milestones as if events were still unfolding. In short, regardless of Curiosity's fate, people in Pasader
and all over the world will continue watching and waiting for the signal that will free them to breath
again.

High in the skies of Mars, following a roughly equatorial trajectory, MSL hurtles toward th
Martian surface. The onboard computer, a radiation-hardened version of an early-2000s Macintos
PowerPC chip, is processing incoming data like mad and adjusting flight parameters to match.
firing of a thruster here, a guidance adjustment there. There's not much time left to correct anythin
though, for the guided portion of entry—where MSL glides across the skies on its heat shiel
adjusting course continuously—is just about over.

On cue, the huge parachute deploys, unfurling spectacularly above the spacecraft while it is sti
traveling at supersonic speed. The craft begins to slow and angle toward the ground. High above,
Martian orbit, one of JPL's other robotic explorers, the Mars Reconnaissance Orbiter, snaps a photo

a tiny spacecraft dangling from a parachute. That it captures the lander at all is a near miracle, for was being aimed in advance purely by sophisticated calculations performed by JPL flight engineer The resulting image was a remarkable bit of space-age orchestration.

Down, down Curiosity drops, until—while still high in the air and in an apparent contravention logic—it separates from the parachute. But seconds later, powerful onboard rockets fire, furth slowing the spacecraft.

At JPL, a room full of men and women, mostly in their twenties and thirties, monitor the hundre of systems and subsystems critical to a successful landing. The old folks—the ones over fifty—a mostly in the back row. This is a young person's mission.

Adam Steltzner, the forty-nine-year old rock 'n' roller primarily responsible for getting Curiosit onto the surface of Mars safely, paces like a lion on the hunt behind a row of intent controllers. He been likened to Elvis with a doctorate in engineering, and now he monitors the consoles and the b picture. His pace quickens as the displays show MSL getting closer to Mars.

Events are occurring rapidly. Data from multiple onboard radars are guiding the machine to landing inside Gale Crater, and within that into a landing zone called a "landing ellipse" due to th shape. It is just over five miles in width, and its long axis is twelve miles. It is the most ambitious accurate landing attempt yet, and from what the folks back home can see, as smooth as any to dat The rocket pack/descent stage and its associated winching mechanism, collectively dubbed "sk crane," is working perfectly. In the final phase of what looks like a landing cycle designed by Rub Goldberg, or possibly Wile E. Coyote, the descent stage slows to a walking pace and sky crane begi to winch the Curiosity rover down via four cords, each about sixty feet long. It is by far the mo complex interplanetary robotic undertaking in history.

Manning is at one of the rearward consoles, not quite with the old guys in the back but not with th youngsters at the front either. He's watching the system he led his team to create—not just sky cra but the whole landing system—and probably also thinking about the last-minute fixes he applied Curiosity while it was already bolted atop the rocket, ready to launch. It was a close thing.

Al Chen is on the console as the operations lead for this critical phase of the mission and also th voice of MSL tonight. He is in his thirties, is married with three kids, and is normally a pret unassuming guy. MSL has thrust him into the limelight, and his announcements come over th speakers in hushed, almost-unbelieving tones: "Sky crane deploying." It's JPL shorthand for "Holy —! This damn thing works!" A collectively held breath releases and some scattered cheering issue forth, followed by applause. Then, a few moments later: "Touchdown confirmed—we're safe o Mars!"

The room goes nuts as controllers, scientists, engineers, and other associated JPL'ers erupt i heartfelt cheers. In a nearby building, inside the press room, normally stoic and hardened reporte from the major TV networks, newspapers, and periodicals just lose it. It is true pandemoniu Curiosity has arrived…and done so to perfection.

On Mars, MSL's rocket pack, comprising the engines and the navigational unit that brought th rover to the surface, has long since detached and flown off to crash a few miles distant. After muffled thump, silence returned to Mars.

It will later be concluded that the rover alighted about 1.5 miles from point zero, well within th landing ellipse. It's a true pinpoint landing, as close to Mount Sharp, their primary objective, anyone dared to hope.

Fig. 2.1. THE VOICE OF EDL: Al Chen on the console shortly before touchdown, narrating the entry, descent, and landing phases like a play-by-play. *Image from NASA/JPL-Caltech.*

Once the machine is secured, a jubilant EDL team bursts forth from mission control, heading to th press room (in more normal times, JPL's auditorium), wearing matching powder-blue polo shirts an chanting “Eee-Dee-El! Eee-Dee-El!” in triumph. It is a rare moment of collective joy and outrigh raw emotion for these normally reserved people as they literally dance across the university-like qua And it is well deserved.

Grotzinger smiles broadly, hugs a few people, pumps even more hands, and prepares for the pre conference soon to follow. Rob Manning is mobbed by well-wishers, smiles like the punch-drun engineer he is (he has been at this for eight intense years and has not slept much for almost thirty-fiv hours), and heads off to a series of interviews. Joy and Vandi hug coworkers and then begin to thin ahead. Unlike Grotzinger, they do not have the camera lights and questions of a press conference t distract their attention from the challenges that lie before them. Both return to thinking about th larger mission—the upcoming milestones needed to ensure that the rover can accomplish its prima objectives.

Bobak Ferdowsi takes a moment to check his smartphone and discovers that in the past few hour he has become an Internet meme and instant sensation. But there is not time for that now; he ha people to congratulate and a rendezvous with a pillow. Ashwin feels the glow begin to fade a bit. He responsible for coordinating the moment-to-moment science activities of the mission, a massive jo and tomorrow things will get very busy regardless of how much—or how little—sleep he manages get. Nonetheless, he will remember the landing as one of the high points of his life.

Hundreds of others on-lab, and hundreds more offsite, pop champagne corks and toast succe tonight. They enjoy the moment, as well they should, for tomorrow engineers, scientists, an managers begin a multimonth grind known as Mars Time—their days will match Martian days, know as “sols,” which add forty minutes to each twenty-four-hour Earth day. The world will soon become surreal, time-shifted place to the bleary-eyed participants in Curiosity's mission. But tonight is f celebration.

On Mars, the dust has settled around the unmoving rover. A few clicks and whirs can be heard fro the inside as the Hazcams pop open lens coverings and begin imaging the immediate surrounding Other mechanisms restrained for landing free themselves, and heating systems power on for the co Martian night ahead.

Curiosity has arrived, and the greatest adventure Mars has known is about to begin.

CHAPTER 3

A LONG ROAD TO A RED PLANET

Exploring Mars has been a passion of earthbound scientists for centuries. Few thought of actual *going* there until the mid-1800s, but notions of Mars as a planet where beings might exist date bac nearly two hundred years earlier. Christiaan Huygens, a Dutch astronomer and cosmologist, publishe a book in 1698 that speculated about life on the red planet. This idea bloomed in the 1800s, but would be much later that the idea of exploration of the planet with humans was taken seriously. Th idea of using machines to do so came later still. Many early visions harkened back to the golden ag of earthly exploration, which was not conducted by robotic machines—there weren't any to do so ye These voyages were accomplished by *men* in square-rigged ships that traveled to distant ar forbidding places to plant the flag of their nations in faraway lands (and often cause disease ar destruction to rampage through the native inhabitants). Surely, the thought went, the exploration Mars would be accomplished in a similar fashion—by men (probably military) in rocket ships.

While many over the centuries thought of traveling to other worlds, it was not until Mars wa understood as a planet—that is, a *place*—that these notions gained any sophistication. But even ve early observers with scientific grounding began to notice things about Mars that were telling. In th fourth century BCE, Aristotle noted that Mars was occulted by the moon—Mars clearly passed behin it. This led him to the conclusion that Mars was farther away from Earth than the moon was. Whi this may seem painfully obvious to us today, at the time little was known about *anything* in the nig sky; certainly Mars had not yet been identified as a world.

The earliest observations of Mars centered on its color. Few objects in the night sky exhibited ar hues other than white, and none were as ruddy as Mars. So it is not surprising that the planet becam intimately identified with all things violent—war, famine, and death. The various mythic figures th Mars became associated with were murderous at worst and portended a bad day at best. It was th Hannibal Lecter of celestial bodies.

Ancient Babylon, Egypt, and China all had deities associated with Mars. To the Babylonians, Ma was associated with Nergal, a deity of fire and destruction. To the Egyptians, Mars was Horus the Re associated at first with the harvest, but later with violence. China and other Asian cultures saw th planet as representing fire and all its unpleasant associations, and eventually with mayhem. You didn want Mars (or Nergal, Horus, or even the combustible Asian version) dating your daughter.

The Greeks also worshipped Mars as a god, named Ares, who carried with him the usual unfortuna associations. Though he was the son of Zeus, king of the gods, and his wife Hera, who was beautif and wise, Ares was a wayward scoundrel and simply could not live up to his parent's accomplishmen without getting into trouble. Perhaps the fact that Hera was also Zeus's sister may have been a factor- a troubled gene pool indeed.

The Romans had a similar interpretation of the god they renamed Mars. While they imported h virtues—or lack of them—from the Greeks, in Rome the red planet's penchant for violence wa considered a big plus. Since the empire would conquer and rule by force, paying homage to Mars psychotic tendencies made a certain amount of sense. The one thing the Roman Mars did have over h predecessors was a measure of intelligence—in many previous iterations, he was downright doltish.

the Romans made him a violent and warlike being, they also made him a smarter one. He went fro
being Steinbeck's Lennie to TV's Dexter in one sweeping cultural iteration.

Then Ptolemy, a Greek living in ancient Alexandria, came along in the second century CE ar
(surely with the best of intentions) created a model for the solar system that brought some appare
order to the chaos seen overhead, but also gummed up Western astronomy for well over a millenniu
In his universe, Earth was at the center of all things, and the lights observed in the sky moved arou
it. These other bodies were affixed to spheres—unimaginably huge, crystalline, transparent ones—th
rotated, imparting the motions observed. The obvious planets, those observable by the naked e
(Mercury, Venus, Mars, Jupiter, and Saturn), each had a crystal sphere of their own in logical orde
The moon's was closest to Earth, the sun fell between Venus and Mars, and the final sphere was th
upon which the stars were mounted. This system, logical from a contemporary observer's viewpoi
was to remain fixed in place (just as Earth was, at dead center) for about 1,200 years. It was one
science's longest-held misconceptions, but at least it was an attempt at science. Despite this valia
effort at understanding the solar system, the broader culture that surrounded Ptolemy continued to s
gods in the heavens.

Mars continued to be the scourge of the cosmic playground through medieval times, and not un
1543 did the red planet really become a *what* rather than a *whom*. Nicolaus Copernicus, a brillia
Polish astronomer, was finally able to build a mathematical model that supported a heliocentr
system, that is, one with the sun at the center of the solar system (in fact, the sun was the center of t
entire universe so far as he was concerned, but that inconvenience was cleared up much later). The
almost a half century later, Johannes Kepler, a German scientist who worked out the laws of planeta
motion, further developed the mathematical certainty of a sun-centered system.

About the same time, Galileo Galilei began looking the planets through his telescope, observin
among other things, the distinct phases of Venus. He was also able to see the planets as objects, n
just as points of light, and their massiveness and motions under a heliocentric model made even mo
sense. He couched his opinions somewhat, though, as he had already endured enough torment at t
hands of the Renaissance church to make him gun-shy. Speaking openly of his ideas turned out to be
recipe for papal investigation and, ultimately, a lifetime of house arrest. Sometimes it sucks to be t
far ahead of your time.

It was not until the 1800s that Mars truly came into its own as a planet, apparently similar to Eart
in the minds of astronomers. While many were using telescopes at this time to observe the planet
notable among them was Giovanni Schiaparelli. During Mars's closest approach to Earth in 187
(when the two planets' orbits bring them closest together, an event called "opposition"), he began
series of extensive observations that resulted in one of the first true maps of Mars. Schiapare
invented a vast network of continents and seas for the red planet, further adding to its Earth-li
mystique. Mars was continuing on its long journey to being a world, a place, that could be explor
and—possibly—inhabited.

Among Schiaparelli's unintended "gifts" to Western science was the misinterpretation of h
observation of linear features on Mars that he called *canali*. While in his native Italian this mere
describes a channel (natural or not), to the English-speaking ear this sounds like "canal," and in
profound case of mistaken identity, a great controversy began.

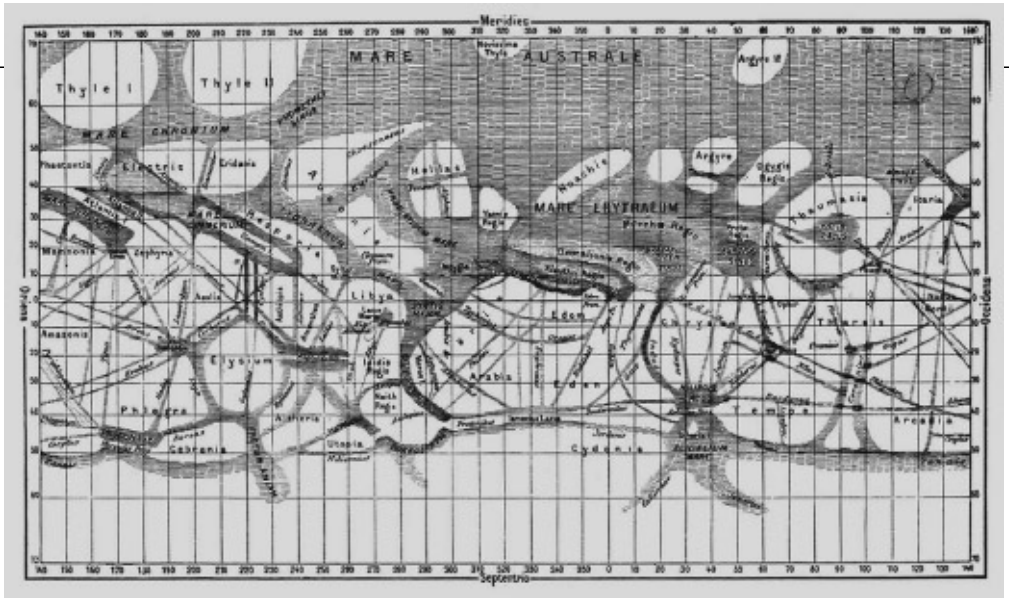


Fig. 3.1. *PLANETA MARTIS*: Schiaparelli's Mars map of 1877 demonstrated far more detail than he was able to see through the telescope. Many of the lines seen here did not exist, and were either figments of his imagination or the possible result of eyestrain. Regardless, these charts had a profound impact on popular thinking about Mars and strengthened the tradition of naming features in Latin. *Image from NASA.*

This misinterpretation was picked up and vastly amplified by an American amateur astronom named Percival Lowell. Born of a wealthy Boston family with a fortune made in the textile busines Lowell spent years in Asia making a mark as a chronicler of Japanese culture before taking u astronomy seriously (he already had a degree in mathematics from Harvard). Once bitten by th celestial bug, however, he was unstoppable. He moved to the Arizona territory in 1894 and built a observatory in Flagstaff with the stated aim of observing Mars. Lowell commissioned one of th larger refracting telescopes of the time, an instrument twenty-four inches in diameter, to facilitate h Martian observations.

It's interesting to note that Schiaparelli and Lowell were somewhat contemporary to one anothe with their respective peak activities being offset by about twenty years. When confronted wi Lowell's interpretations of his work, initially Schiaparelli was somewhat miffed, but over time h softened and moved from denial to ambivalence, then even to a certain level of enthusiasm, about th idea of artificially created canals on Mars. Even then, people seemed to know the value of good P Lowell was the P. T. Barnum of Mars, and if you can't beat 'em…

Lowell took to his new life's purpose with relish. Over the next fifteen years, he spent countle nights in his cold observatory, observing and sketching Mars. Lowell also saw the elusive canals b perceived of them differently than did Schiaparelli. He charted these illusory features in much great detail, numbering them and striving to discern some logical order to their design and placement. Fro these extensive and painstaking (and largely imaginary) observations, he began to develop his ov theories about Mars and what—or *whom*—might exist there. Perhaps most profoundly, rather tha limiting his ideas to scientific circles (where he met with opposition to his unique notions), h published a series of popular books between 1895 and 1908 that struck a chord with the general publi

These widely read books built a public case for intelligent life on Mars. Going far beyond me observation and charting of the planet, Lowell imagined a vast civilization with a form of planeta government (after all, the rulers would need to have global reach to build such a vast network canals). This technologically brilliant Martian empire was working against the clock to save the dying world as the water vanished. Mars was much older than Earth, he reasoned, and was thus farth along in its planetary evolution. It was cooling and was water-starved, and the Martians had built th vast network of canals, complete with pumping stations, locks, and other manipulations, to brin

water from the poles of the planet to its parched temperate regions. It was an elaborate ment
invention, and the romance of these ideas was to last for a half century in the public mind. Lowell
ideas about how Mars lost water were not really wrong, they were just off by about 3.5 billion year
The rest, engaging though it might be, was just so much mental popcorn.

While it is easy to dismiss Lowell's fanciful ideas today, reading his books (not a trivi
undertaking) does impress one with the (admittedly misplaced) rigor of his thinking. If one starts o
by accepting the idea that his Martians might actually exist, he builds a convincing case, usi
whatever scientific ideas were supportive to his arguments. While this is not a true implementation
the "scientific method," it was an attempt at building a logical view of another culture that held son
allure.

Although few discuss it today, while Mars was wiling away the early twentieth century as a plan
inhabited by parched, clever engineers, Venus was thought to be a sunny, humid jungle world. Litt
was known about the planet, and virtually nothing could be observed beneath its opaque cloud cove
Well into the 1950s, popular culture (aided by the likes of Edgar Rice Burroughs, who had his wa
with both Mars and Venus), Venus was the jungle world, with riotous plant growth and steamin
swamps. The truth was even more shocking than it would be with Mars, as Venus was ultimatel
unveiled as a hellishly hot, sterile, acidic nightmare.

During the first half of the twentieth century, other scientists spent years observing Mars via th
telescope, often striving to disprove Lowell's assertions. Using spectroscopes as their primary weapo
various observers were able to discern that there was far less water in the atmosphere than Lowell ha
theorized, and that the air was much thinner than appropriate for his Martian civilization. Lowell
romantic world was beginning to slip away.

This work was, however, restricted to the evidence of the telescopic eyepiece and other earthbou
methodologies of observing Mars. Under optimal conditions, with a large, well-placed telescope, ar
even during its closest approach, the best image of the red planet is still subject to the vagaries of wh
astronomers call "seeing." Earth is covered in a blanket of air, turbulent and fickle, and air is dens
enough to distort light. So even on the best of nights, the small, dim, red image of Mars swims in ar
out of focus, bending and flexing at the whims of the atmosphere. Profound or accurate observatio
of the Martian surface are difficult at best. The use of the spectroscope, a prismatic device that spli
the light from a planet or star into its constituent gasses and elements, strove to overcome th
limitation but was able to supply only a limited range of answers. Later, radio telescopes, unaffecte
by the optical properties of the atmosphere, were utilized to explore Mars but were also limited
what they could "see" on a planet and had other issues with Earth-based interference and backgrou
noise from space. In short, to really understand Mars, we would have to *go there*.

This idea of traversing the great blackness between Earth and Mars had appealed to many over th
years. Fiction treated it in various ways: In the worlds of Edgar Rice Burroughs, writer of the Joh
Carter books, all you needed to do was fall asleep in the back of an enchanted cave in the Wild We
and * poof * you awoke on Mars. Later on, the brilliant Russian Konstantin Tsiolkovsky and Germa
like Hermann Oberth speculated on the use of rockets to carry people into space and perhaps even on
other planets. They were widely dismissed as cloudy-minded visionaries at best, crackpots at worst.

With the advent of modern rocketry in the twentieth century, these simple ideas became elabora
plans. No less a personage than Wernher von Braun, alleged Nazi and father of the Saturn V rock
that took America to the moon, labored on the problem. In his 1953 book *Das Marsprojekt* (*The Ma
Project*), von Braun envisioned an armada of ten enormous spacecraft assembled in Earth orbit b
reusable space shuttles. This fleet would embark sometime around 1965 for a three-year round-tri
including a yearlong stay on the surface of the planet.

The elaborate scheme was presented in a simplified form in *Collier's* magazine and generated

sample content of Curiosity: An Inside Look at the Mars Rover Mission and the People Who Made It Happen

- *Schrecken der Hohlwelt (Perry Rhodan SilberbÃ¤nde, Band 22; Die Meister der Insel, Band 2) here*
- download Modigliani pdf, azw (kindle), epub, doc, mobi
- download online The Picnic and Suchlike Pandemonium for free
- *On the Beach pdf*
- The Heart: A Novel here

- http://www.gateaerospaceforum.com/?library/Schrecken-der-Hohlwelt--Perry-Rhodan-Silberb--nde--Band-22--Die-Meister-der-Insel--Band-2-.pdf
- http://tuscalaural.com/library/Exemplary-Women-of-Early-China--The-Lien---zhuan-of-Liu-Xiang.pdf
- http://deltaphenomics.nl/?library/Grave-Surprise--Harper-Connelly-Mysteries--Book-2-.pdf
- http://www.gateaerospaceforum.com/?library/The-Universe-Wide-Web-1--Getting-Started.pdf
- http://www.gateaerospaceforum.com/?library/The-Heart--A-Novel.pdf