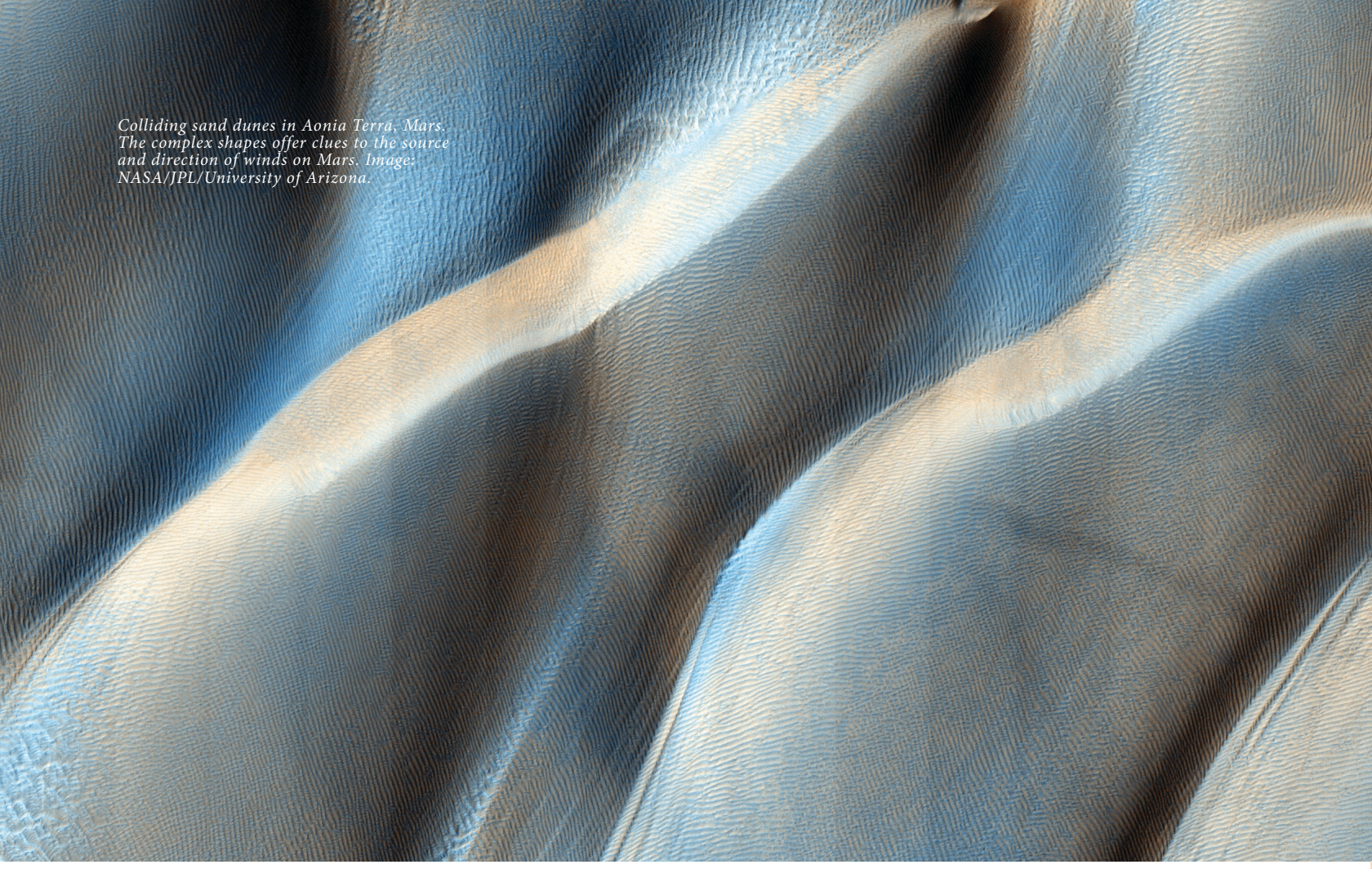


Colliding sand dunes in Aonia Terra, Mars. The complex shapes offer clues to the source and direction of winds on Mars. Image: NASA/JPL/University of Arizona.

Sand Gods

Aeolian Expertise Helps Curiosity Navigate the Shifting Sands of Mars

Mars might be named for the god of war in Roman mythology, but today it's ruled by Aeolus, who in Greek mythology had dominion over wind.

As other geologic processes have faded in impact, wind is the force that has the greatest current bearing on shaping geology on the planet where change has occurred slowly over the past three billion years.

This made Gary Kocurek, the J. Nalle Gregory Chair in Sedimentary Geology in the Jackson School of Geosciences, a likely choice to become a member of NASA's Curiosity rover mission to Mars.

He has studied aeolian processes, the effect of wind on geologic features, for three decades.

"Having aeolian expertise was one reason I was selected to be on the team," he said. "But, equally, they wanted some geologists who were not primarily planetary scientists and who could give the project a wider approach."

Windy Domain

Kocurek said the study of aeolian processes is driven by curiosity into the basics of how wind has shaped the Earth's surfaces—the fundamental research leads to greater understanding of how things work. More specifically, aeolian processes play a big role in land management in arid environments.

"For a geologist working with sub-surface strata, aeolian strata make great reservoirs for water, oil, and gas," he said. "Discover-

ing and producing hydrocarbons from aeolian strata, for example, requires an understanding of aeolian processes and the architecture of the strata they deposit."

The mission's principal purpose is to look for evidence that habitable environments might have existed on Mars.

Though the Curiosity rover's emphasis is not on wind or dunes, "everything on Mars is affected by the wind because the wind is so pervasive," he said. "That's where I come in."

The rover landed in Gale Crater on Mars in August 2012. Since then, it has covered about one-fifth of its five-mile journey to Mount Sharp, which rises 18,000 feet above the crater floor.

Kocurek has studied the Navajo, Entrada, and Page formations of the Jurassic period on the Colorado plateau and the interaction of wind and sand in places like the White Sands area of New Mexico and the Sahara Desert.

Curiosity is not his first experience with Mars. He's studied dune deposits that underlie the planet's north polar ice cap. He is one of about 18 Jackson School researchers who use geologic features on Earth to study Mars and other planets and moons in the solar system with similar features.

Long-Distance Science

As a member of the Curiosity team (about 450 scientists and engineers), Kocurek helps make sure the rover stays on a safe path as it wheels its way across the Martian landscape and studies features that might be interesting from the aeolian perspective.

Curiosity Rover's first picture shows the North Rim of Gale Crater. NASA/JPL.

"It's kind of like looking out the windshield of a car," he said. "You want to avoid craters, big rocks, and you don't want to go up or down slopes that are too steep."

To reach the mountain, the rover must deal with a dune field in its path. That's where the expertise of Kocurek and his aeolian colleagues on the rover team pays off.

"The rover has to get across or around the dune field," Kocurek said. "Because driving on loose sand is tricky, every effort is being

A thick stack of sedimentary debris stands in Gale Crater on Mars, looking southwest toward the crater's central peak, Mount Sharp. Image: NASA/JPL/Arizona State University, R. Luk.

The Ultimate Road Trip

Every road trip needs a destination and the destination of the Curiosity rover mission to Mars is Mount Sharp, a mountain that's five miles from the rover's landing site.

Towering 18,000 feet (five kilometers) above the surface of the Gale Crater, Mount Sharp offers researchers a wide range of Martian geological history to study.

"The reason Mount Sharp was chosen from all the other potential landing site was because it has a nearly 5-kilometer thick stratigraphic record that spans some of the most critical times of Martian history," said Gary Kocurek, the Jackson School sedimentary geologist on the Curiosity team.

He said satellite images show a wide diversity of rock types in the mountain.

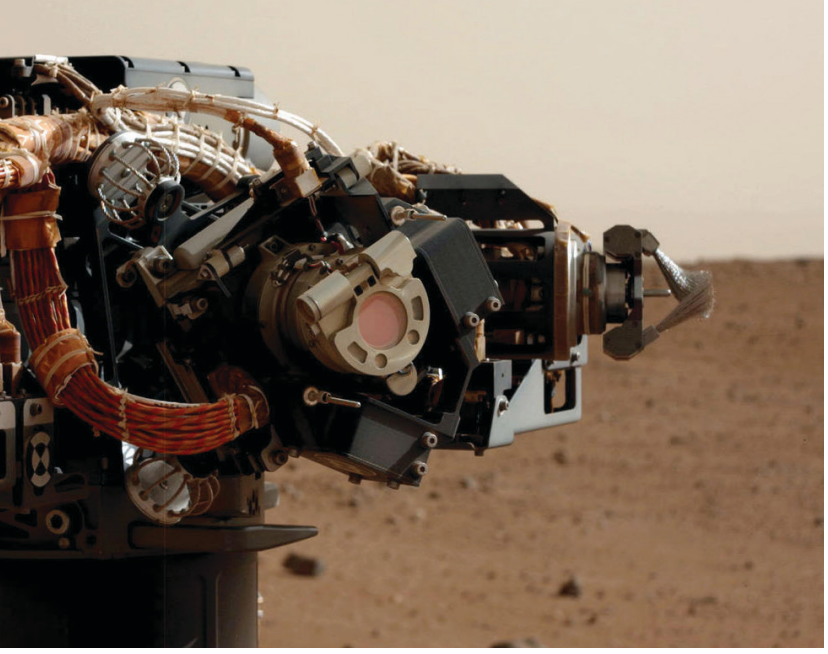
"Of particular note is the basal exposed strata, which almost certainly contain clay which is thought to reflect the presence of water," Kocurek said. "A major part of the MSL (Mars Science Laboratory) mission is to search for a record of past habitable environments, so areas with clay minerals are of particular importance given the connection between habitability and water."

One question of interest to aeolian investigators is how Mount Sharp, Curiosity's destination, was formed by wind or water.

Some scientists, using satellite data, have posited that wind was responsible.

Curiosity has a way to go before it reaches Mount Sharp, so it's still too early to judge. But so far, features observed by the rover seem to have been formed by water, Kocurek said.

"Nearly everything that has been seen thus far was deposited by flowing or standing water, such as rivers and ponds, from the rim into the crater," Kocurek said. "The main aeolian deposits have been surface small dunes and sand drifts. The surface is for sure heavily eroded by the wind, as most of Mars is."



Left: During the Mars mission, the left eye of Curiosity's Mast Camera took this image of the rover's arm, the Mars Hand Lens Imager: NASA. Kocurek with aeolian colleague Nick Lancaster in the Gran Desierto de Altar in the Sonoran desert of Mexico.

made to reduce the area of sand that needs to be crossed,"

Kocurek said that he and other members of the team have spent much time charting the path and gauging how the rover will be behave in loose sand.

"There are several people on the team who have expertise in sand dunes and aeolian processes," he said. "Especially the rover planners, the people who actually drive the rover. They have huge experience from previous missions in driving over all sorts of terrain."

While the sand is an obstacle, it's also an opportunity for geologists like Kocurek who study the interaction of wind and sand to witness wind moving sand across the dunes. That's known as a sand-transporting wind event.

"This would be significant because it has never been done before," he said. "The observations could be used to test a lot of the theory that predicts how sand transport should occur on Mars."

The rover could provide an up-close look at what happens when wind blows sand, an enticing prospect for someone who studies sand-transporting events.

Kocurek manages his Curiosity work from his office on the UT Austin campus. He examines images the rover sends back to Earth and participates in daily scientific meetings in which mission team members decide the rover's next moves.

"Every day I try to see what the rover is doing," he said. "You can look at the images and listen to the scientists' discussion. If there's something coming up in your area, it's up to you to jump in and do it."

Once the next day's activities for the rover are decided, NASA engineers at NASA's Jet Propulsion Laboratory program every single action the rover will take. Then the programming is uploaded across the millions of miles to the rover.

So far, his experience has been a "discovery as you go process," Kocurek said. "It's taking things as you see them and trying to understand them. Knowledge builds."

Martian Field Work

Kocurek is used to working remotely even with his research on Earth, where about three-quarters of his research is conducted through remote sensing. Kocurek and his students examine satellite data, including high-resolution images.

"My greatest research tool is Google Earth Professional," he said. "That's where all the images are. It's incredible."

He also employs other technologies such as LIDAR (Light Detection and Ranging), which provides precise topographic data for his research.

"We have a time series of images with LIDAR of White Sands," he said. "We have measurements of dune volumes, very precise dune migration rates, and changes after single sand storms."

He and his students do field work to see what is actually happening on the ground.

"There is still a big role for getting out and doing real-life measurement on the dunes," he said. "Looking at the rock, measuring the rock. Doing geology like we've done it for a hundred years."

Geology on Mars can be done like it's been done on Earth, but the geologist on Mars is Curiosity itself. The NASA project that built and operates Curiosity is called the Mars Science Laboratory (MSL).

For the big picture, Kocurek uses images from the High Resolution Science Experiment (HiRISE) aboard the Mars Reconnaissance Orbiter satellite.

Panoramic view of Curiosity Rover's surroundings in Gale Crate stitched together by Stuart Atkinson from NASA/JPL images.

"Just like doing geology on Earth, we would use satellite images for the context and then field work to see processes in action or examine the geomorphic forms or outcrops in detail," he said. "MSL is just like a geologist in the field, except that it carries around its own laboratory."

The tool that Kocurek mainly uses is the rover's cameras.

He uses images from the Mastcam, mounted on the rover's mast, for the wide angle and the Mars Hand Lens Imager (MAHLI) for an up-close view that provides sharp detail.

"You can see grains as you would looking at a rock with your hand lens on Earth," he said.

One question of interest to all investigators is how Mount Sharp, Curiosity's destination, was formed by wind or water.

Some scientists, using satellite data, have posited that wind was responsible.

Curiosity has a way to go before it reaches Mount Sharp, so it's still too early to judge. But so far, features observed by the rover seem to have been formed by water, Kocurek said.

"Nearly everything that has been seen thus far was deposited by flowing or standing water, such as rivers and ponds, from the rim into the crater," Kocurek said. "The main aeolian deposits have been surface small dunes and sand drifts. The surface is for sure heavily eroded by the wind, as most of Mars is."

For geologists, Mars offers the opportunity to study geological conditions that don't exist on Earth.

"You get to see early planet history, the first billion or two years," Kocurek said. "We don't see that on Earth anymore because all of those rocks have been destroyed. On Mars, they're still sitting there."

As the rover moves along Mars, Kocurek is interested in studying how the wind shapes dunes and how they are similar to and different from those on Earth.

"Because the boundary conditions are so different, the question is how does this affect the processes?" he said.

Boundary conditions are the environmental factors that affect dunes. They include: How much sand is available? How often does the wind blow? How strong is the wind? Is there water available?

"They're never going to be the same in any two places," Kocurek said. "Whatever you're looking at, they differ from place to place."

While dune fields on Earth have different boundary conditions from each other and from those on Mars, there are still fundamentals with which Aeolus rules.

"The beauty of this is that it's all fundamental physics and processes," Kocurek said. "Wind blows, sand moves, physical laws have to be obeyed. There are basic principles that govern it all." ✷

Field work on Mars? Sign Me Up

Whether you're in Pasadena or Austin doesn't make much difference when the object of your research is millions of miles away. Mackenzie Day is working toward a Ph.D. with Dr. Gary Kocurek in the Jackson School of Geosciences at The University of Texas at Austin and is a participating scientist on the Mars Curiosity rover mission to Mars.

She came to the university from the California Institute of Technology (Caltech), where NASA's Jet Propulsion Laboratory is located. JPL runs the rover mission.

Day's undergraduate advisor at Caltech was John Grotzinger, a sedimentary geologist and the project scientist of the Mars Science Laboratory aboard the Curiosity rover.

"He recommended that I apply to the Jackson School and from there things fell into place," Day said. "Professor Kocurek needed a student to join the MSL team and I was thrilled at the opportunity."

As a participating scientist on the rover mission, Day is not associated with a particular instrument.

"Instead I help with day-to-day operations as a member of the geology theme group," she said. "Each day team members discuss what in the vicinity of the rover is of most scientific interest, and how we should investigate it. When I work shifts in operations, I help develop these plans."

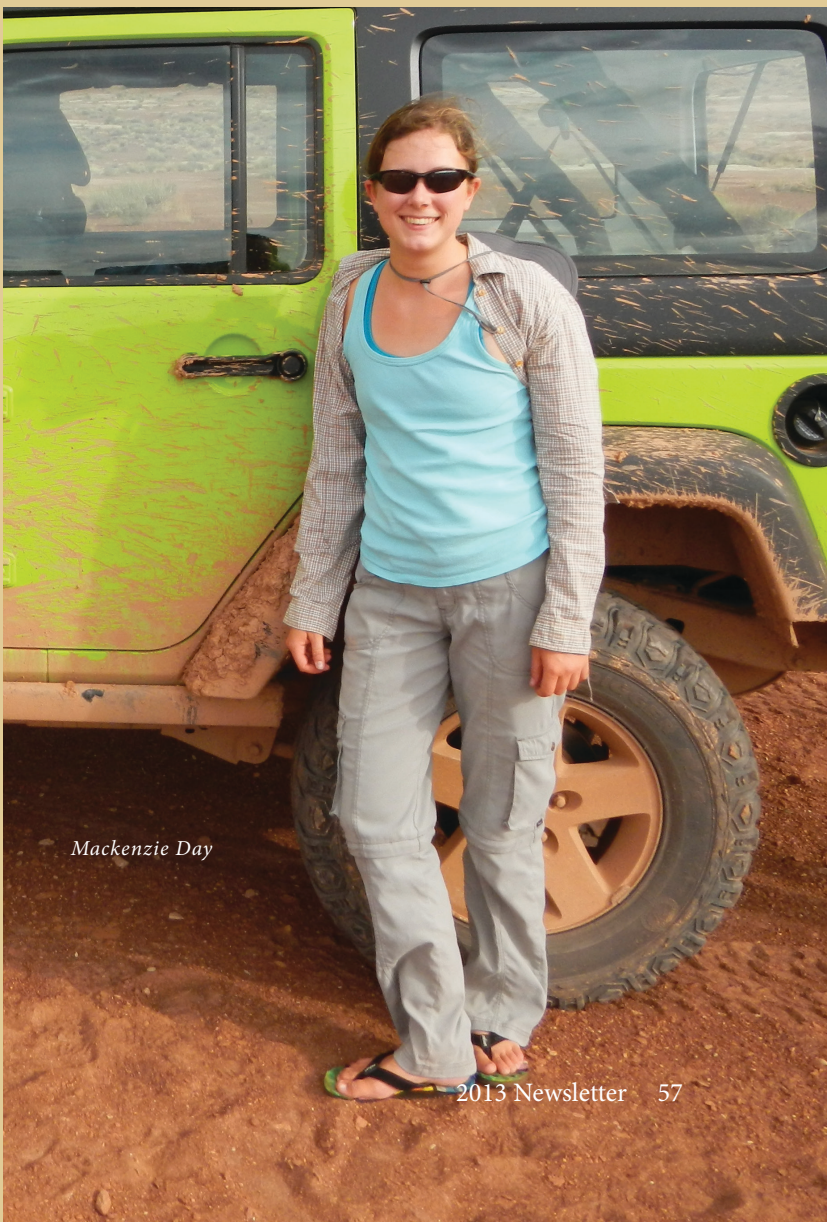
Day's research interests are in the sedimentary budget of Mars. She studies the dynamics between sand and dust on the surface and crater basins across the planet.

"Luckily for me, many members of the team also have similar interests, and an entire group is devoted to sedimentary processes," she said.

When she's not working with the MSL, Day's field work takes her to southern Utah and northern Arizona. She recently was on a field trip to Yellowstone National Park and Kane Cave in association with a course on geomicrobiology.

She would welcome the opportunity to do field work a bit further afield. It is her hope to apply to NASA's astronaut program.

"I would love the opportunity to do field work on Mars," she said.



Mackenzie Day