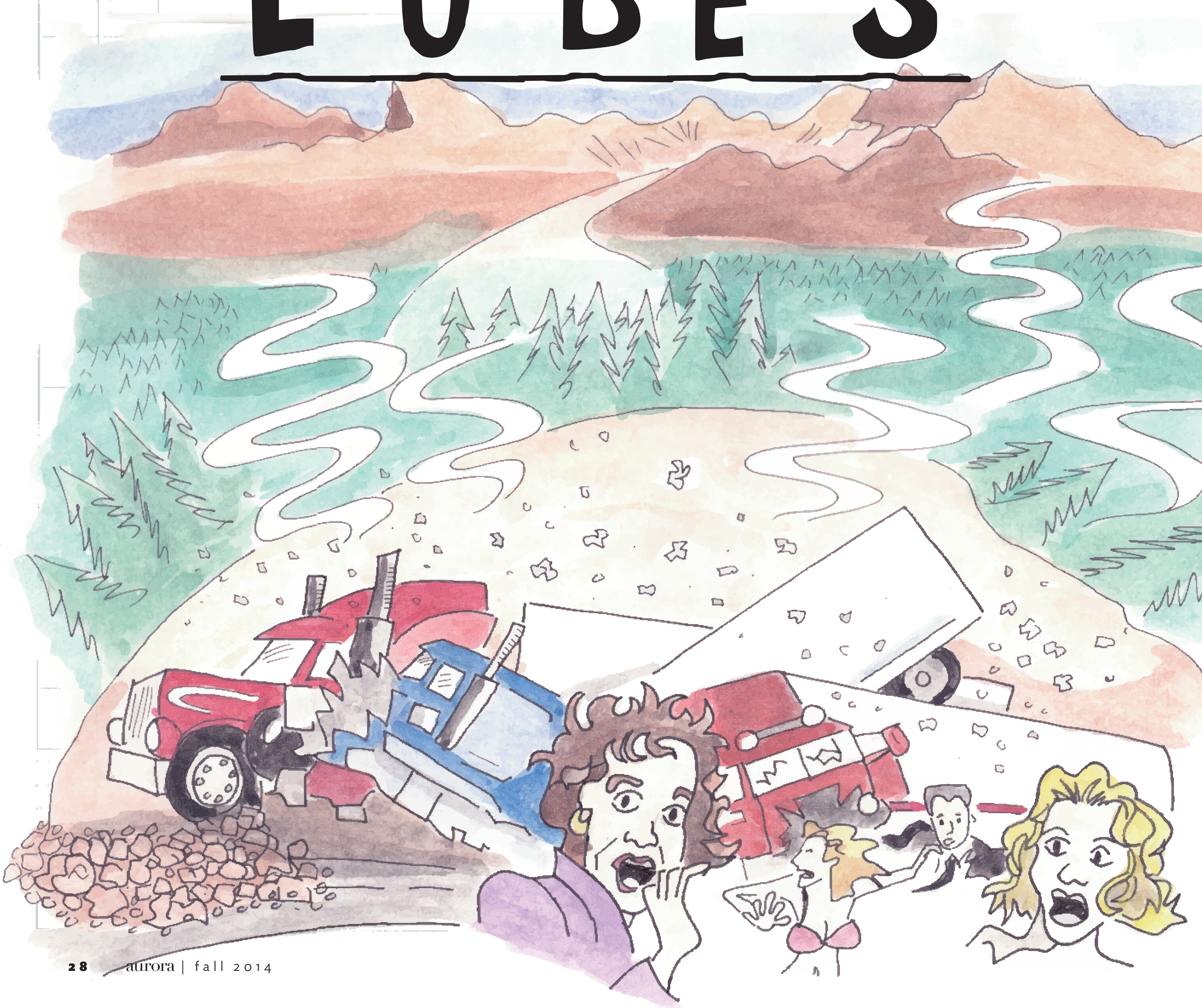
ATTACK OF THE DEBRIS LOBES



Story by Sam Bishop
Illustrations by Daniel Darrow

Margaret Darrow saw the first surprising evidence of pressurized water after a drill bit pierced 50 feet into a massive blob of frozen gravel perched on a mountainside in Alaska's central Brooks Range.

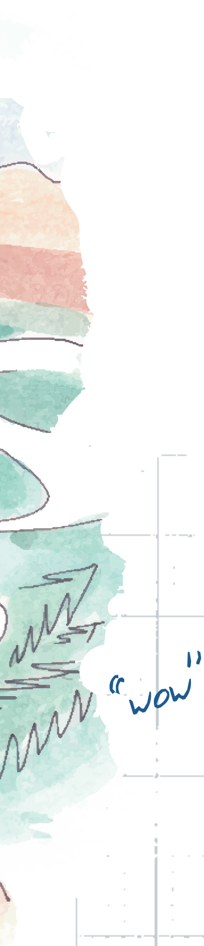
As she and a small band of fellow geologists, engineers and drillers watched, the water percolated from the top of a pipe and into a recycling tub. The gray liquid matched the surface of Frozen Debris Lobe A, itself gone muddy from the light rain on a 35-degree day in late September 2012.

Standing nearby in her rain gear, Darrow had expected some water. The drilling crew, working from a tank-like tracked vehicle, had repeatedly hammered 5-foot sections of casing pipe into the lobe and spun bit-tipped drilling pipe down the casing. Then they'd pumped in water to flush out the resulting ground-up sand and gravel.

However, they got back more water than they put in. When they removed a section of drill pipe during retrieval, the gray liquid would sometimes spurt up several inches from the center of the next pipe emerging from the hole.

"It's not like it shot feet in the air," Darrow said, "but enough that we all went, 'Wow.'"

Later, after sensors lowered into the hole confirmed temperatures well below freezing, Darrow and her fellow researchers said "wow" again.



"Why would there be liquid water that's below freezing? It seems very strange," said Darrow, an associate professor of geological engineering at UAF.

The answer to that question, which team members suspect they have worked out, could help explain the behavior of Frozen Debris Lobe A and other similar blobs that ooze down the mountainsides near the trans-Alaska pipeline where it passes through the Brooks Range. They've counted 23 such lobes less than a mile uphill from the Dalton Highway, which parallels the pipeline and forms the only road connection to Alaska's North Slope oil fields.

With the state's biggest economic engine under a slow-sliding threat, the lobes have drawn the attention of experts from Alyeska Pipeline Service Co. and government agencies, including state and federal transportation departments, the Division of Geological and Geophysical Surveys, and UAF's Alaska University Transportation Center.

By June of this year, Lobe A's leading edge had slid, rolled and crumbled to within 142 feet of the Dalton Highway's embankment at Mile 219. The lobe now moves westward and downhill into the Dietrich River valley at about 15 feet per year. At that rate, less than a decade remains before the lobe hits the road. Its arrival, at current speed, would be like a 50-ton dump truck dropping a full load of rubble on the highway once every 19 hours.

During construction of the highway and pipeline in the mid-1970s, the lobes were noticed but weren't considered a problem. Today, their movement is unmistakable, and their speed is increasing. No one knows if they can be stopped. Lobe A isn't the fastest-moving blob, but it's the closest to the highway. It stretches downhill like an elongated teardrop, flowing about 1,600 feet from its source in a small, round basin set high in a ridge on the eastern side of the Dietrich River valley.

"You can watch it move."

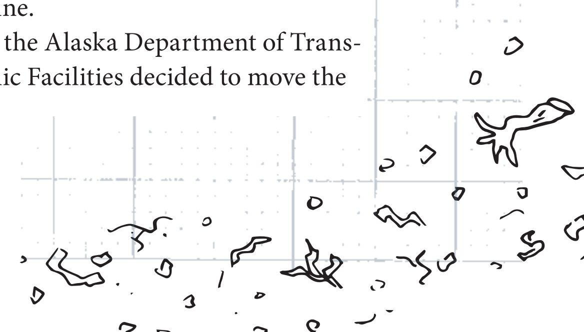
At its most prominent point, the lobe bulges more than 50 feet above the surrounding mountainside. Along its leading edge, or toe, the frozen mass bulldozes trees. In some spots, the toe wrinkles the thick sphagnum moss like a rug kicked on a hardwood floor. Elsewhere, the moss curls in on itself like a cinnamon roll.

On a quiet summer day, Darrow listened as another, more active lobe made small popping sounds. Occasionally, a tree trunk would shift, a little gravel would roll. That lobe's toe has traveled an average of 126 feet per year since 2010, the fastest of several measured to date.

"You can watch it move," Darrow said.

The water her team found within Lobe A could help explain such movement. The water also warns that the movement might soon increase — a change that would mean more costly trouble for the nearby highway and pipeline.

Earlier this year, the Alaska Department of Transportation and Public Facilities decided to move the



highway, shifting it westward and downhill about 400 feet farther from Lobe A.

"The assumption is, that will give us a number of years … to understand it better and come up with a mitigation strategy," said Jeff Currey, a DOT engineer. "It's already giving us some grief with respect to the sediment coming off it."

The sediment has clogged culverts under the highway, built in 1974 to support development of the Prudhoe Bay oil field. The pipeline, which in 2012 carried about 580,000 barrels of oil per day from Prudhoe and other fields, sits another few hundred feet downhill from the planned new road location. So the line has more time.

When the geologists and drilling crew struck water in September 2012, it presented a conundrum. This was, after all, supposed to be a frozen debris lobe. Sensors installed in several drill holes at various depths continued to reinforce the conundrum that fall. Below the summer thaw zone, temperatures sat at 30 degrees Fahrenheit all the way to bedrock at 86 feet.

"We were really wondering, gosh, that's liquid water there, and how is that all possible?" said Ronnie Daanen, a permafrost hydrologist with the Alaska Division of Geological and Geophysical Surveys.

The answer may be pressure, lots of pressure.

"The skate here is actually the debris that moves down the hill."

Think of ice skates, Daanen said. They glide well because they melt a thin layer as they pass across the ice.

"That is a form of pressure melting," Daanen explained.

The pressure creates a layer where most molecules are liquid. That's what he expects happens within the debris lobe.

"The skate here is actually the debris that moves down the hill," Daanen said.

Ronnie Dannen, Trent Hubbard (standing) and Margaret Darrow download data in mid-June from instruments installed two years ago in a hole drilled in Frozen Debris Lobe A.

The researchers measured the highest water pressure at the bottom of Lobe A, a depth of about 85 feet.

About 10 feet above that, the lobe is sliding. The researchers discovered this zone when the movement sheared off the lower end of the 100-foot pipe and strings of sensors in their deepest drill hole. An inclinometer recorded sideways movement of 1 inch per day at the shear zone in the month before it failed.

Before the water pressure sensor at bedrock also broke, it transmitted very high readings — about the equivalent of a column, or head, of water 165 feet tall.

That's intense pressure, but it's not enough to keep water liquid at 30 degrees.

So Daanen started thinking about what else might be happening in the drill hole. When water freezes, the amount of pressure it can exert on the type of instrument they were using drops radically. So he knew that any freezing in the lobe would essentially suck a large chunk of the measurable pressure out of the system. He also saw pressure and temperature measurements indicating that water in the shear zone was in equilibrium — neither melting nor freezing. It was on the cusp between liquid and solid, like the water under a skate blade.

At 30 degrees, that can only happen at a pressure equivalent to 450 feet of head.

When in ice, though, such high pressure isn't detectable — it's there, but it's locked in the frozen molecules. So Daanen added the 450 feet of inferred head to the 165 feet of detected head from the liquid water, arriving at an estimated total pressure head of 615 feet. That's the height of a 60-floor skyscraper.

Yet how could pressure on that scale build within the debris lobe?

A clue appeared on the surface of the debris lobe far up the mountainside from the drill hole. There, the ground is churned, with exposed gravel, sand and rock.

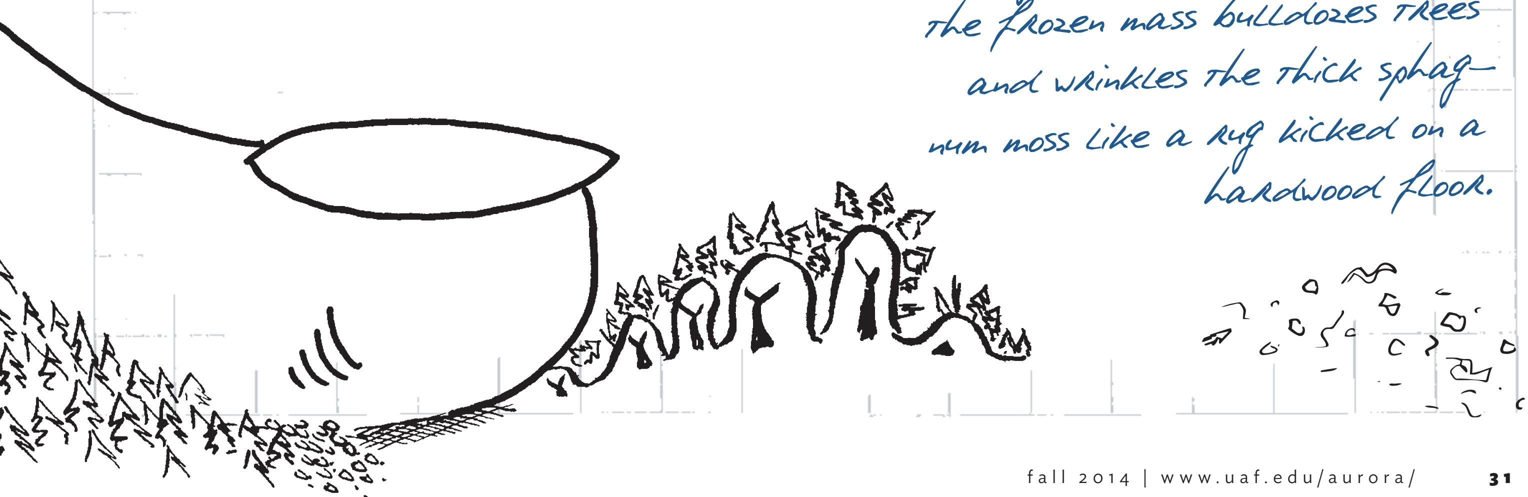
"You can see a little bit of a step, a bit of a nip," Daanen said. It seems that's where the shear zone surfaces at the upper end of the debris lobe. The zone could create a path for water to enter the lobe — in the summer at least.

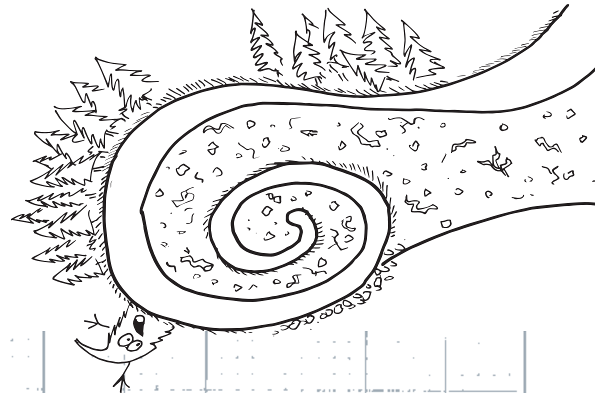
Their theory about the source of the high water pressure got a big boost with one remarkable discovery: The shear zone near the top of the lobe, where the water could enter, is 615 feet above the shear zone near the bottom of the drill hole. In other words, the elevation difference almost perfectly matches the water column that would create the theoretically calculated pressure in the drill hole. It seemed unlikely to be coincidence. The intense pressure appears to be the reason some water remains liquid inside the lobe.

When wet, the lobe's material acts differently than it does when dry. The research team saw that firsthand in the miserable, damp weather they encountered. Daanen, Darrow and graduate student Jocelyn Simpson rented a cabin in Wiseman, a small community 31 highway miles to

Top: Margaret Darrow inspects a tree that has split in several directions while being carried down the surface of Lobe A. Bottom: Darrow views the toe of Lobe 7, a faster-moving mass of gravel, sand and silt on the west side of the Dietrich River valley.

Along its leading edge, or toe, the frozen mass bulldozes trees and wrinkles the thick sphagnum moss like a rug kicked on a hardwood floor.





the south, where they retreated each night to dry out. Days at the drill site, though, were chilly and soggy.

In the rain, the areas of Lobe A with no vegetation quickly turned to a loose, boot-sucking mud. However, after a day with no rain, "you can walk on it and you don't even leave prints," Daanen said. "It dries up and becomes a crust."

In a laboratory at UAF, Simpson has analyzed sand and gravel samples from the drill cores from deep inside Lobe A. The early results mirror their field experience on the lobe's surface.

"When it's saturated, it seems to be really easy to change and it's easy to slide, but, as soon as it gets to a certain dryness, it becomes rock hard and it's really tough to move," Daanen said.

Trent Hubbard inspects a spruce ripped apart by movement on Lobe 7's surface.

This indicates the highly pressurized water in the shear zone within the frozen lobe probably helps the entire mass advance down the slope, Daanen said.

"What happens is that this pressure is going along the shear zone and is lifting up the entire lobe, and when it is doing that it is reducing its friction so it can move faster," he said.

Moving faster has been the trend in recent decades. A question facing the state's highway caretakers and the pipeline owners is whether the rate will continue to increase. More water in the lobe likely would cause such increased movement. Curiously, the long-term rise in central Brooks Range temperatures alone could make that happen. That might seem obvious — wouldn't warmer temperatures mean more rain and greater snowmelt? Not necessarily. The weather could actually become drier in a warmer climate. Rather, Daanen looks at the relationship between temperature, pressure and water. The physics equations that describe the relationship predict that warmer conditions would increase the pressure inside the lobe, even if no additional water enters the shear zone from outside sources.

"The actual measured pressure will go up here if it gets warmer," Daanen said of the shear zone deep inside Lobe A. The higher pressure would allow more water to remain liquid in the shear zone, and that's what would promote movement in the lobe.

"I think that's the risk here in terms of warming events," Daanen said.

Daanen has a chart reflecting the rising long-term temperatures in the central Brooks Range, along with a recent shorter-term drop.

"The only thing we can expect to happen, if you trust everything on this chart, is that this will come back up again," he said, pointing to the recent cooler temperatures. "And, at that point, there's risk of [the lobe] coming down faster."

Darrow, Daanen and Trent Hubbard, a DGGS geologist who's been instrumental in the project, visited the debris lobes in June this year, using money the agency received to investigate geological hazards along the pipeline corridor.

More monitoring and drilling, not only on Lobe A but also on others, would help determine if the discoveries from the recent research are anomalies or widespread realities, Darrow said.

"They all have telltale signs in their catchments. They have cracks in their catchments with water in

Margaret Darrow pulls on sphagnum moss rolled up by Lobe A's toe.

them, and that's a place for water to get down into," Darrow said of the lobes. "If it's going down into the shear zone, if they have a discrete shear zone like A does, that shows that there's signs that they might start moving faster, and it would be good to continue to measure them and see how fast they speed up."

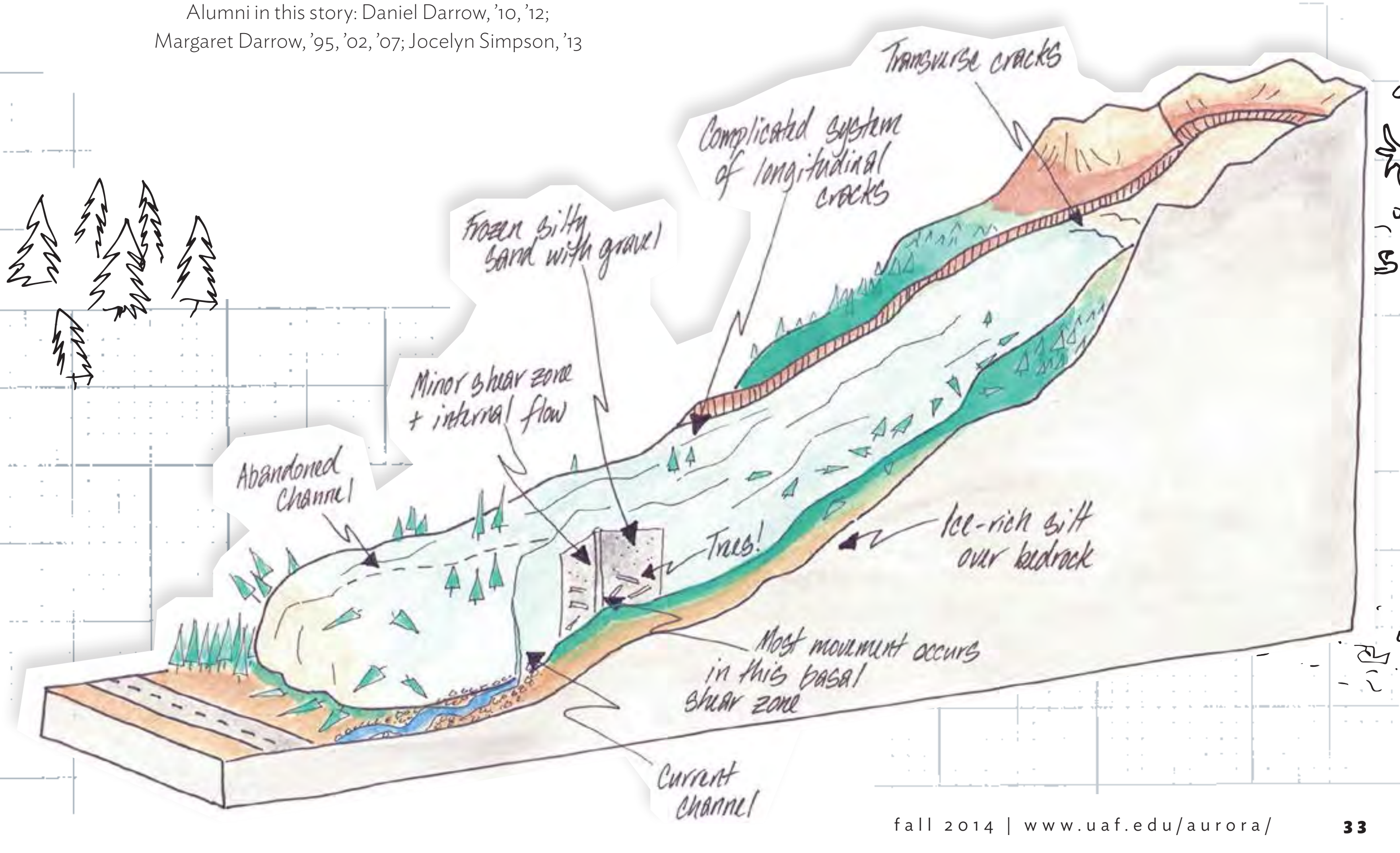
Sam Bishop is an editor and writer at UAF Marketing and Communications. Born in Alaska, he worked previously as a newspaper journalist for 27 years in Fairbanks, Anchorage and Washington, D.C.

Daniel Darrow, mostly known as Margaret's husband, or "oh...you," is a term instructor in the Department of Foreign Languages and Literatures. His last artistic gig was drawing political cartoons for the former bastion of irreverence, the *Ester Republic*.

Web extra: Don't miss a cheesy debris lobes rap video featuring our scientists at **www.uaf.edu/aurora/**.

Alumni in this story: Daniel Darrow, '10, '12; Margaret Darrow, '95, '02, '07; Jocelyn Simpson, '13

Lobe A approaches the Dalton Highway, the main ground transportation route to the Prudhoe Bay oil fields, in this photograph from mid-June. The trans-Alaska oil pipeline is several hundred feet downhill from the highway, buried near the east bank of the Dietrich River.



University of Alaska Fairbanks
PO Box 757505
Fairbanks, AK 99775-7505

The beauty of the Brooks Range hides a perplexing phenomenon — several dozen moving mounds of frozen earth. Some are approaching the Dalton Highway and trans-Alaska oil pipeline in the Dietrich River valley, pictured here looking southward near milepost 219 of the highway. Read more about the frozen debris lobes on page 28 and online at **www.uaf.edu/aurora/**.