WINTER 2018

GEOLOGICAL ENGINEERING

UNIVERSITY OF WISCONSIN-MADISON

ADVANCING MEASUREMENTS OF ROCK STRESS

DIRECTOR'S MESSAGE

Bill Likos

Greetings from Geological Engineering at UW-Madison!

The big story for our program this year and the focus of this update is the Geological, Mining, and Geotechnical Engineering 2nd Technical Conference and Alumni Reunion, held in Madison from September 13-15, 2017. What a great crowd and great time! More than 100 alumni, faculty and students attended and enjoyed a stimulating program of technical talks, learned about ongoing and planned activities in GLE, recognized our distinguished alumni and faculty, and got caught up with old friends. One highlight of the event was a banquet to honor former recipients of the College of Engineering Distinguished Achievement Award, including this year's recipient **Dan Piette** (BS Mining, 1980), **Malcolm Theobald** (BS Mining, 1983), **Tom Doe** (PhD Mining, 1980), and **Paul La Pointe** (PhD Mining, 1980). Professors **Herb Wang** and **Craig Benson** were recognized for their significant contributions to the formation and growth of the GLE program. Students **Morgan Sanger** and **Idil Deniz Akin** were presented with the Bezalel Haimson Award and Norman Severson Geotechnical Engineering Award, respectively. Our program is unique and the people involved in its past and present are just outstanding. We are looking forward to our next reunion in 2022. Mark your calendars! Thank you all for your support!

ON, WISCONSIN!

William J. Likos
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Alumni, faculty and students gathered in September for the Geological, Mining, and Geotechnical Engineering Technical Conference and Alumni Reunion.

RESEARCH HELPS PREDICT LANDSLIDES ALONG WISCONSIN COAST

Lake Michigan coastal bluffs near Milwaukee. *Photos by Luke Zoet.*

Luke Zoet

In more than one way, Luke Zoet's research is groundbreaking.

The assistant professor of geoscience studies bluff landslides on the eastern coast of Wisconsin—a longstanding source of concern for the state.

"Because of this historical problem in Wisconsin, people have done all sorts of things to protect the shoreline, like putting up big structures to stop waves from eroding the bluffs," Zoet says. "Sometimes it works, sometimes it doesn't. It's a little more complicated in the Great Lakes because in the winter, ice forms that can move those structures around."

The water level, Zoet says, is the highest it's been since the mid 1990s. It's only by a couple of feet, but that additional water depth could change the position of the water line by 100 feet on a shallow beach.

Zoet's project, which received seed funding from the Sea Grant Institute at UW-Madison, initially focused on Mt. Pleasant in Racine County, Wisconsin. "It's experienced quite high levels of erosion simply because there hasn't traditionally been a lot of protection there," he says. "So some areas undergo a lot of erosion. The people living at the top of the bluffs normally don't realize erosion is a problem in a lot of cases until it's too late when the bluff is really steep. It's really hard to protect it at that point."

Zoet and his team developed a specialized tool they call the BADGER (which is far less of a mouthful than "bluff assessment data generating experiment recorder").

"It's basically like a fishing pole," Zoet says. "It has a line that comes out of it. If you pull on the line, the baler unspools and lets more of the line out. The fishing pole is stuck on the part of the bluff that we think is not going to have a landslide. As a landslide starts to move, it basically pulls the line out. It gives an accurate measure of how those two things are moving relative to each other."

On Dec. 13, 2016, the BADGER captured and recorded its first landslide. "Before this landslide catastrophically broke apart and fell down the bluff, it started moving at a pretty high rate," he says. For two and a half hours before it failed, it moved even faster.

With this data, Zoet used techniques normally applied in materials science to determine what caused the landslide. "The material was somewhere between unfrozen soil and frozen soil and there was an 11-degree Celsius temperature drop from -1 to -12 right before the bluff failed," he says. "What we think happened was when the temperature dropped, groundwater that was in the bluff started to freeze and wedged a crack open. That opening is what caused the landslide."

Zoet set up two more BADGERs: a second one in Mt. Pleasant and one near Port Washington. All three recorders are now showing movement in the landscape, but there haven't been any landslides.

The existing data is encouraging enough to expand his project. Moving forward, he'd like to take measurements of all failing bluffs along the coast of Lake Michigan and estimate what causes them to fail, and what materials will be deposited into the water if they do. It's important because if the failing bluffs have a lot of sand in them, the sand can rebuild the beaches in that area. Meanwhile, a failed bluff with clay will just float into the water and be lost forever.

Furthermore, he intends to learn from the past. "In the 1970s when the water line was high, all bluffs along the coast were exposed and geologists wrote up what they are made of," he says. "So we're going to digitize that data and put it into a model."

The model could enable him to warn counties about when and where bluffs might fail, or which beaches they can expect to be replenished with sand.

"We're trying to accurately measure the properties that are changing leading up to a landslide," he says. "Our goal is not to prevent them. We want to figure out why and how they occur so that we can better estimate when and where they might happen in the future."

Shoreline bluffs near Mt. Pleasant, Wisconsin, have experienced significant erosion in the past.

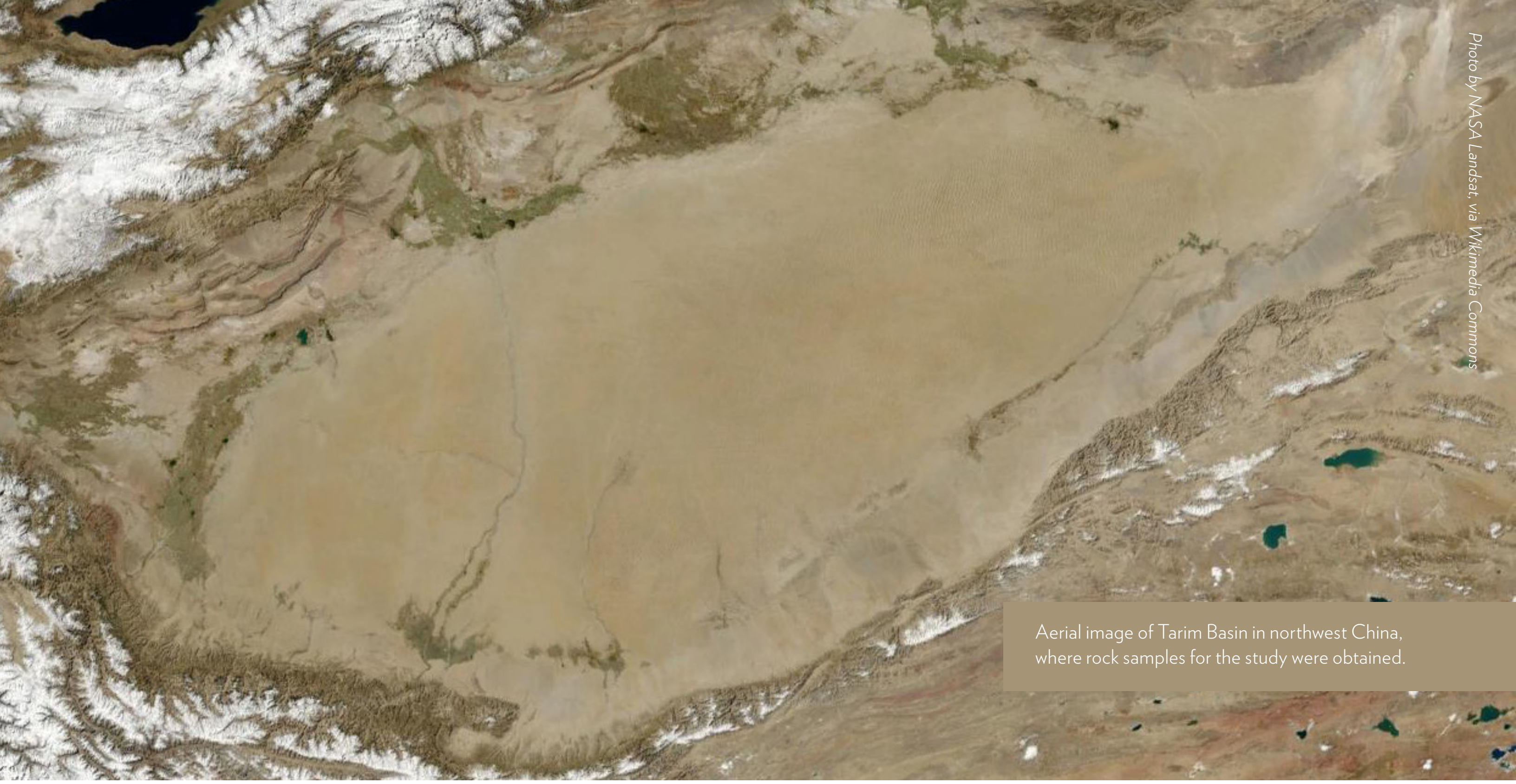


Photo by NASA Landsat, via Wikimedia Commons

Aerial image of Tarim Basin in northwest China, where rock samples for the study were obtained.

FOR UNDER-EARTH EXPLORATION, ENGINEERS DEEPEN UNDERSTANDING OF ROCK STRESS

Measuring unobservable forces of nature is not an easy feat, but it can make the difference between life and death in the context of an earthquake, or the collapse of a coal mine or tunnel.

To manage the risk of such events, researchers often rely on estimating a quantity called rock stress.

"Rock stress—the amount of pressure experienced by underground layers of rock—can only be measured indirectly because you can't see the forces that cause it," explains Hiroki Sone, an assistant professor of civil and environmental engineering and geological engineering. "But instruments for estimating rock stress are difficult to use at great depths, where the temperature and pressure increase tremendously."

Addressing this challenge, Sone and his colleagues in China and Japan have now pushed the limits of rock stress measurements that don't require temperature-sensitive instruments to new depths, from a previous maximum of 4.5 kilometers (2.8 miles) to a whopping 7 kilometers (4.3 miles).

Hiroki Sone prepares a rock sample for deformation measurements under stress conditions in a triaxial rock mechanics apparatus. *Photo by Stephanie Precourt.*

In a study published in July 2017 in *Scientific Reports*, the researchers used rocks sampled from a well bore of that depth to show that stress estimates obtained by the so-called anelastic strain recovery method were consistent with a visual analysis of borehole wall images, a reliable but often infeasible approach that requires a specialized scanner.

The scientists conducted their proof-of-principle study in the Tarim Basin in northwest China, an area almost two-thirds the size of Alaska that is surrounded by K2, the world's second highest mountain after Mount Everest, and several other mountain ranges. The region is well known to historians because of its association with the Silk Road, an ancient trade route between China and the Mediterranean.

Today, in addition to historians and mountain climbers, petroleum companies have taken an interest in Tarim Basin, as it contains some of the largest oil and gas resources in Central Asia. These companies want to understand the region's geology to assess whether drilling may trigger seismic activity, given that many smaller earthquakes have occurred in the surrounding mountains.

For Sone and his colleagues, this presented a unique opportunity to advance the methodology for measuring rock stress.

"We wanted to test the reliability of the anelastic strain recovery method at up to 7

"These new results give us confidence that we can use the anelastic strain recovery method at greater depths than we thought possible."

kilometers depth because its main advantage is that you only need to sample and analyze the rock itself," Sone says. "It estimates stress indirectly by measuring how much the rock sample expands in different directions after it has been recovered."

With that kind of depth, the recovery process—pulling a large enough rock sample out of a borehole—can take a few days, which is why the researchers were excited to prove that the method still worked.

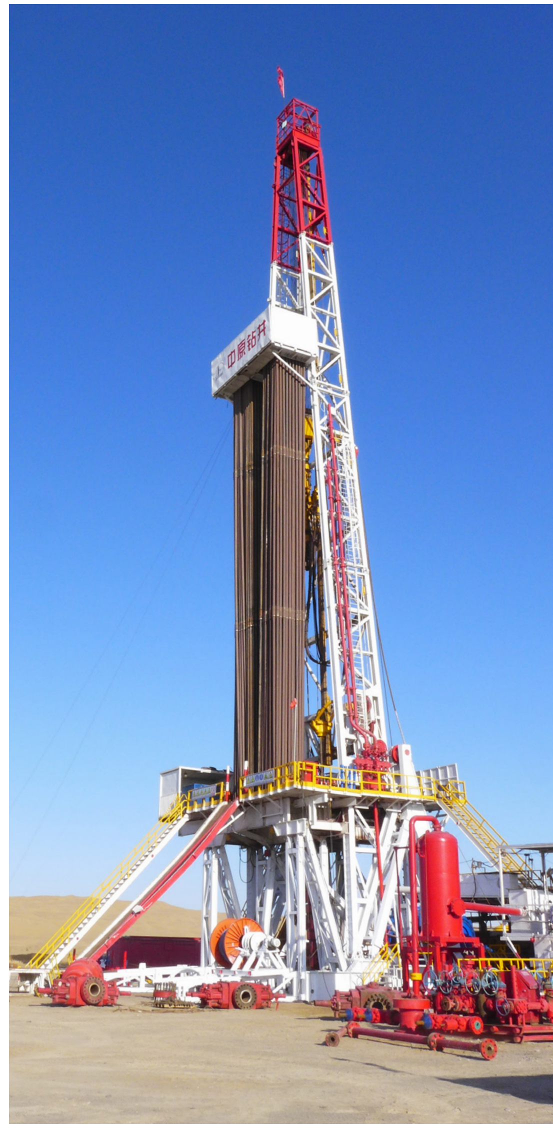
For the first time, they measured rock stress even when sensors weren't attached to the sample until 65 hours after coring and found that the results matched a conventional image analysis of the borehole wall, obtained with a resistivity scanner. While the visual method also worked in this case, it can be infeasible at such great depths because of the scanner's temperature limitations.

In addition to proving the easier method's validity at greatly increased depth, the study resolved a longstanding geological puzzle in the Tarim Basin: The rock stress in Earth's outer shell—which consists of many large pieces of cooler rock (tectonic plates) floating on a very thick layer of hot magma—differs between the basin's periphery and its interior.

Other scientists had found evidence for this difference before, but the current study confirmed it.

In the interior of Tarim Basin, tectonic plates are relatively stable, even though they crash and fold up against each other in the periphery, explaining the observed seismic activity. This translates to a lower risk of earthquakes in the interior and informs a petroleum company's decisions about the depth at which boreholes should be stabilized to minimize the risk of structural collapse.

For earth scientists, the new study is an important validation of a more practical method for estimating rock stress. "These new results give us confidence that we can use the anelastic strain recovery method at greater depths than we thought possible," Sone says. "As long as the rock deforms the same amount in vertical and horizontal directions, this method is much easier to apply when very high temperatures and pressures in the Earth's crust challenge the other options in our toolbox."



A drilling rig in China's Tarim Basin. *Photo courtesy of Hiroki Sone.*

Dongsheng Sun (sitting), the study's first author from the Chinese Academy of Geological Sciences in Beijing, explains the measurement of rock stress after the coring of samples at Tarim Basin. *Photo courtesy of Hiroki Sone.*

MEET DANIEL PIETTE: 2017 DISTINGUISHED ACHIEVEMENT AWARD RECIPIENT

We honored Dan for his career-long leadership in mining engineering and big data, which has helped introduce new technologies to the energy industry.

Daniel Piette
Board member, Petroleum Geo-Services
BSMineE '80

Why did you choose mining engineering?

The art of geology combined with the science of engineering came to a nexus in mining, so it was an interesting field for me. And, the mining department when I was there probably had 30 students. If you wanted to chart your own course, it was really easy to do in a school like mining.

What was a lesson you learned as a student that has benefitted you most in your career?

More than anything, to be flexible. One of the great things about mining is that you apply so many different parts of engineering. You need the chemical engineering for the extractive side. You need civil engineering to design the roads. You need mechanical engineering when you're selecting equipment. You need industrial engineering to say how often the trucks come in. It's the economic side—what's the price of coal going to be, what's the price of copper going to be—because all that stuff feeds into decisions you're making that are affecting your job. Almost everything at Madison teaches you that. Part of the thing you learn in mining is not to be afraid to change. Don't be afraid to change jobs, don't be afraid to try something different—I only worked as a mining engineer for two years and I've probably had three or four careers.

Is there a professional accomplishment you're most proud of?

I joined one company as CEO when it was really small. There were only about eight people, and we grew that company to well over 60 people and ended up selling it to a much larger software company, making money for all of our investors. I'm really proud of that.

What advice would you give to current engineering students?

Cast a broad net. UW has a lot of great classes, and I would encourage people to step outside their major and look beyond what's required. One of my most fun classes was a cultural anthropology class. I took a class on debate; I took a class on music. It's a time in your life where you should be finding out ways to learn things that are outside your exact scope of work. The other thing I would encourage people to do is read as much as possible.

What hobbies or interests do you have outside of your work?

Coffee. I roast my own coffee. I have my own espresso machine—the old-fashioned kind with a spring. Coffee, to me, is fascinating. I read a lot still. I'm very universal in my taste of literature, and so that occupies a lot of my time. My wife and I travel quite a bit. We probably spend at least a month every year out of the country.

Is there anything else that you would like to tell us about yourself?

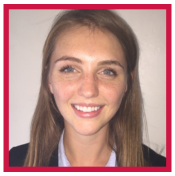
I've enjoyed everything I do. I think I've been very, very lucky. If you look back on how you became successful, it's all about somebody else. I went to high school in Appleton, which had a great high school. If the taxpayers in Appleton hadn't built those high schools, I wouldn't have been able to get to Madison—and the taxpayers in Wisconsin paid for that. I look at all these people who helped me get where I am; I'm a really lucky guy and if one or two things would have gone differently, I would be in a very different place.

GLE PROGRAM NEWS

Professor emeritus **Tuncer Edil** received the Woodland G. Shockley Memorial Award from the committee on soil and rock of the standards organization ASTM International for his exceptional service to the committee's activities. An ASTM International member since 1984, he has also received the committee's awards for special service (2001, 2013), technical editors (2013) and standards development (1992, 1996, 2013, 2017).

Recent PhD graduate **Idil Deniz Akin** won the Norman H. Severson Geotechnical Engineering Award, which recognizes an outstanding graduate student for excellence in scholarship and research in geoengineering. Idil is now an assistant professor at Washington State University in Pullman, WA.

In summer 2017, GLE associate professor **Jim Tinjum** biked almost 1,300 miles in 18 days across Wisconsin, Minnesota, South Dakota and Iowa to promote wind energy. Combining his passions for bicycling, sustainability and energy, he visited nearly 50 wind energy sites. For more information, including a video, search #BiketheWind on Twitter or visit **bikethewind.wordpress.com**.



GLE undergraduates **Renee Olley** and **Morgan Sanger** received a Wisconsin Idea Fellowship and an American Family Insurance Social Entrepreneurship Award from the Morgridge Center for Public Service. Mentored by Angela Pakes, the students will encourage middle school girls to consider STEM-related careers with an interactive classroom exercise that fosters teamwork skills, logical reasoning capacity, and sustainability awareness. Undergraduate **Tyler Klink** is also participating in this project (see research story on page 8).

Morgan won the Bezalel Haimson Award for outstanding academic performance by an undergraduate student.

GLE and geosciences undergraduate **Kyle Powers**, with fellow students Anna Ostermeier (geography, environmental studies) and Brooke Nelson (biology, environmental studies), also received a Wisconsin Idea Fellowship from the Morgridge Center for Public Service. Mentored by Cathy Middlecamp, the students plan to introduce upcycling to rural communities in Costa Rica, promote sustainability leadership opportunities for young people, and support the region's socioeconomic development.

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STUDENTS SUPPLEMENT CLASSROOM LEARNING WITH REAL-WORLD EXPERIENCE

Geological engineering undergraduates Morgan Sanger, Renee Olley and Tyler Klink are trying to make modern construction methods more sustainable and beneficial to the earth.

They conduct research through the Recycled Materials Resource Center and are focusing on the environmental benefits of cold-in-place recycling.

"Cold-in-place recycling is a method of highway resurfacing," Sanger says. "It's an alternative method that's been around for more than a decade and is used for its recognized economic benefits. Conventionally, the asphalt highway is reconstructed with a method called mill-and-overlay, where they mill the existing roadway, haul it to an asphalt plant, bring in new material and then lay that material down. Cold-in-place recycling does the milling, but instead of hauling it away, you mix it with something else at the site and lay it back down."

As a result, road builders use fewer new materials and spend less on transporting materials to a job site. Although the method sounds like a win-win, its environmental benefit has not yet been quantified, says Sanger. The three students compared the cold-in-place technique with the traditional mill-and-overlay process.

"Using cold-in-place recycling saves 20 percent in energy consumption, water consumption and carbon dioxide emissions," says Olley. "We compared the different stages of each method and found that the cold-in-place recycling was much more environmentally friendly, because even though you do use more energy to do the onsite mixing and crushing, this is only a small percentage of the energy you would use in mining and transporting and all this extra virgin aggregate."

Cold-in-place recycling also cuts in half the cost of the mill-and-overlay process.

The student researchers worked with the Wisconsin Department of Transportation to collect data from 68 miles of roadwork. Their advisors, Angela Pakes and Tuncer Edil, presented the results in January 2018 at the annual Transportation Research Board conference in Washington, D.C.

As one of only six groups from UW-Madison, the three students were selected to present their research on Apr. 11, 2018, at the State Capitol during the 15th annual Research in the Rotunda: Showcasing the Work of UW Undergraduates event. Each year, about 120 students representing the 26 schools and colleges in the UW System have the opportunity to share their work with state legislators and officials.

Based on their research, the students also developed a curriculum and, in spring 2017, taught an engineering class called Eva the Engineer to middle school girls. In the program, sixth- through eighth-grade girls learned about engineering concepts like concrete mixtures, waste management, and water treatment.

"It was a chance to develop lesson plans that I never experienced in middle school myself," Klink says. "It was more in-depth, I felt, than a normal science class."