Researchers working on geofluids and pore pressure in deep ocean sediments generally do not wind up at the center of media storms, but in the summer of 2000, that’s where Peter Flemings found himself.

“Tidal Waves Called Threat to East Coast—Study Says Continental Slope off New Jersey Critically Unstable” read a July 14, 2000, New York Times headline. USA Today, Discovery Channel, and other major outlets quickly jumped on the story.

The article was based on research Flemings and his graduate student, Brandon Dugan, published in Science suggesting that portions of the seafloor off the northeastern U.S. coast are more geologically active than once thought and have the potential to spawn underwater landslides and tsunamis.

“Suddenly little old ladies who owned shorefront property in New Jersey were calling me worried about it,” said Flemings. At the time a geoscientist at Pennsylvania State University, he started as a professor and research scientist at the Jackson School this fall.

“If you dig out the article, you’d find it’s actually reasonable,” said Flemings. The writer made it clear the research did not suggest that “strollers on the Atlantic City boardwalk are in imminent danger of being swept away by a tidal wave.” Yet many readers couldn’t get past the headline.

Flemings used the resources of the Ocean Drilling Program (ODP) to drill from the continental slope off the coast of New York, an area where sediment was rapidly deposited hundreds of miles from the present day shoreline. As it turns out, the rocks over the water-logged sediments are squeezing them like a foot stepping on a water balloon. Eventually, the sides of the continental slope could blow out, spawning underwater landslides and tsunamis.

Before Flemings’ work, the continental slope in this region was considered relatively stable. “It changed our view of why you see submarine landslides where you do,” said Flemings. That work led him to more projects with the ODP in the Gulf of Mexico. He is currently a distinguished speaker for the ODP’s successor, the Integrated Ocean Drilling Program (IODP).

He cautioned that the threat to coastal residents in the Northeast is not imminent, yet there is some potential. Rates of sedimentation are much lower now than they were 12,000 years ago when sea level was lower. At that time, according to the geologic record, landslides did occur in this region.

“What we have done is describe a new method to ‘pre-condition’ a slope for failure such that a small event such as a large storm or a small earthquake can cause slope failure,” said Flemings. Recent work suggests that a massive landslide that occurred off the coast of Norway thousands of years ago may have been driven by high pore pressures in the manner that Flemings describes.

The petroleum industry now uses the model he developed to evaluate sea floor stability. Deep see drilling platforms can cost billions of dollars. “So if you don’t understand how stable the sea floor is and you’ve made that big of an investment, you’ve got a big problem,” said Flemings.

Pore Boy
As a postdoctoral researcher at Lamont-Doherty Earth Observatory at Columbia University, Flemings became convinced that studying how fluid moves through pores in rocks and sediments, especially where it goes and why, was important.

“It underlies how oil migrates and where hydrocarbons are and why landslides occur on continental margins,” he said. It also relates to two frontier areas of research actively pursued at the Jackson School: methane hydrates, a possible new energy source, and carbon sequestration, the storing of carbon dioxide underground to help reduce atmospheric greenhouse gas emissions.

Flemings felt that the process of sedimentation plays a key role in porous media fluid flow.

“As sand and mud pile up on the seafloor, they try to squish or compact what’s below them,” he said. “But the only way it can compact is if the fluid gets out of the way.” He created three-dimensional computer models to link sedimentation to fluid flow. He found that fluid moves laterally along confined aquifers, which indeed can drive submarine landslides, hydrocarbon migration, and seafloor venting.

“I used industry data to demonstrate that some of the largest active seafloor vents in the Gulf of Mexico lie above reservoirs that are critically pressured by flow focusing,” he said.

Pore pressures also relate to how much hydrocarbon is trapped in reservoirs. The oil industry uses his models to assess exploration targets.

Later, on an ODP expedition, he documented high pore pressures beneath a zone of large submarine landslides in the Gulf that spans hundreds of square miles. For that work, he used a novel device that he and an engineer at the Massachusetts Institute of Technology designed and built called a pore pressure penetrometer, essentially a large needle for measuring pore pressure at great depths. The device is lowered down a drill pipe on a cable and then pushed down into the sediment. He hopes it will eventually become a standard tool in the field.
These studies may allow us to predict in what locations around the world submarine landslides are more likely, and hence what structures and local populations are at greater risk.

Gone to Texas

When Flemings announced he would leave Penn State to take a joint appointment at the Jackson School of Geosciences—half time in the Department of Geological Sciences, quarter time at the Bureau of Economic Geology, and quarter time at the Institute for Geophysics—some colleagues said he was crazy for taking on triple duty. But the arrangement meshed well with his interests and talents. Part of his research is in marine geophysics, part involves working with the oil industry, and part is fundamental research in the lab. He is also passionate about teaching. The ability to pursue all the things he loves was one of the main attractions of the Jackson School. Another attraction was his wife Ann Flemings’ interest in becoming the school’s first development director, a job she accepted when it became clear the two of them could both find professional homes at the Jackson School.

His new title in the Department is Jackson Chair of Geosystems, which emphasizes the fact that his job will integrate different disciplines to foster understanding of system level processes. He also sees the projected growth of the Jackson School as a great opportunity and a responsibility.

“Geosciences has never been more critical to society,” he said. “We face great challenges in climate, energy, and geo-hazards. If we do our jobs right, the Jackson School will be a leader in tackling all these problems and we will find new and better ways to train the next generation to tackle new problems.”

“To be part of that, to get in on the ground floor of that, I think is fantastic,” he said. “We’re going to hire some extraordinary people and I want to work with them.”

What’s the Problem?

Flemings said in college, too often he was required to memorize too much and was not challenged to understand how things worked. As a teacher he has taken a different approach, emphasizing problem-based learning. “Everything I do involves problem-based learning,” he said. “What I enjoy is not the formal lecture or the presentation, but designing projects where students have to dig in and understand what they’re studying. Even if it’s a simple problem, I try to get them to solve it themselves.”

In a popular undergraduate course, he divided students into teams of four or five to study seismic data. This was real data that petroleum companies used before deciding where to drill. The students would then compete with each other in a “lease sale.” Each team had $100 million to buy leases and had to defend their choices. Representatives from petroleum companies would fly out to evaluate their projects. It became a much anticipated public event.

At the graduate level, he designed and led the GeoSystems Initiative. With the support of Shell and Chevron, he recruited students and formed them into teams each...
Scientists have also worried about their possible dark side. As global warming intensifies, they reasoned, these deposits could begin to break up, releasing the potent greenhouse gas methane into the ocean and eventually into the atmosphere. This could set up a feedback loop that would accelerate the warming. Not only that, but as the methane belches out, it could generate dangerous underwater landslides.

Flemings and his student Xiaoli Liu developed a model that used techniques from the petroleum industry to simulate how hydrates form. It showed how methane gas migrating up through the “hydrate zone”—the region that is cold enough and under high enough pressure to form hydrates—could avoid an icy prison and pass right on through to the ocean.

“The answer is salinity,” said Flemings. For the same reason that people in northern climes put salt on a road to keep snow from turning into ice, the saltier the water, the harder it is to form icy hydrates. Flemings showed that as hydrates form, the surrounding water becomes saltier. If there is enough gas bubbling up, some of it will use these saltier regions as avenues to continue their escape to the seafloor. Flemings’ model was driven by observations made on an ODP leg where these vents of salty water and escaping methane really exist.

“By explaining how they occur, and how gas is expelled through the hydrate stability zone, we have suggested that there may not be nearly as much methane locked up in hydrates as was once thought,” said Flemings. “For all the climate modelers, that’s a big deal because there isn’t as much to warm up the Earth.” Flemings emphasizes that these ideas are currently under great debate in the community.

Although Flemings suggests that there is less total methane hydrate in the world, his model also describes in what locations you can have high concentrations. This could actually turn out to be good news for energy companies.

“We’ve explained a way that you can create very high concentrations of hydrate,” said Flemings. “Instead of a few percent, you could get 50, 60, 70, or 80 percent. And that’s of interest to energy companies.”