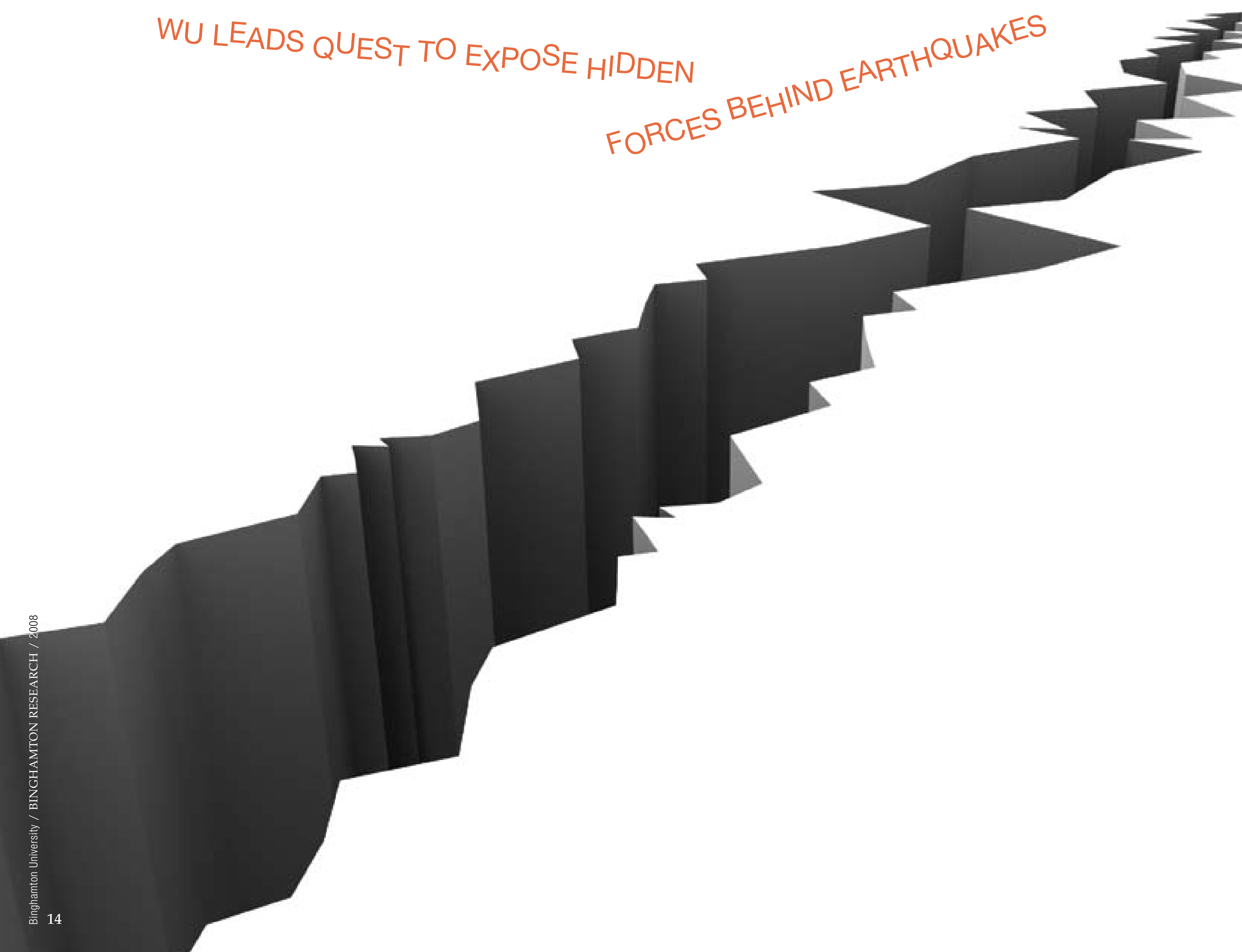
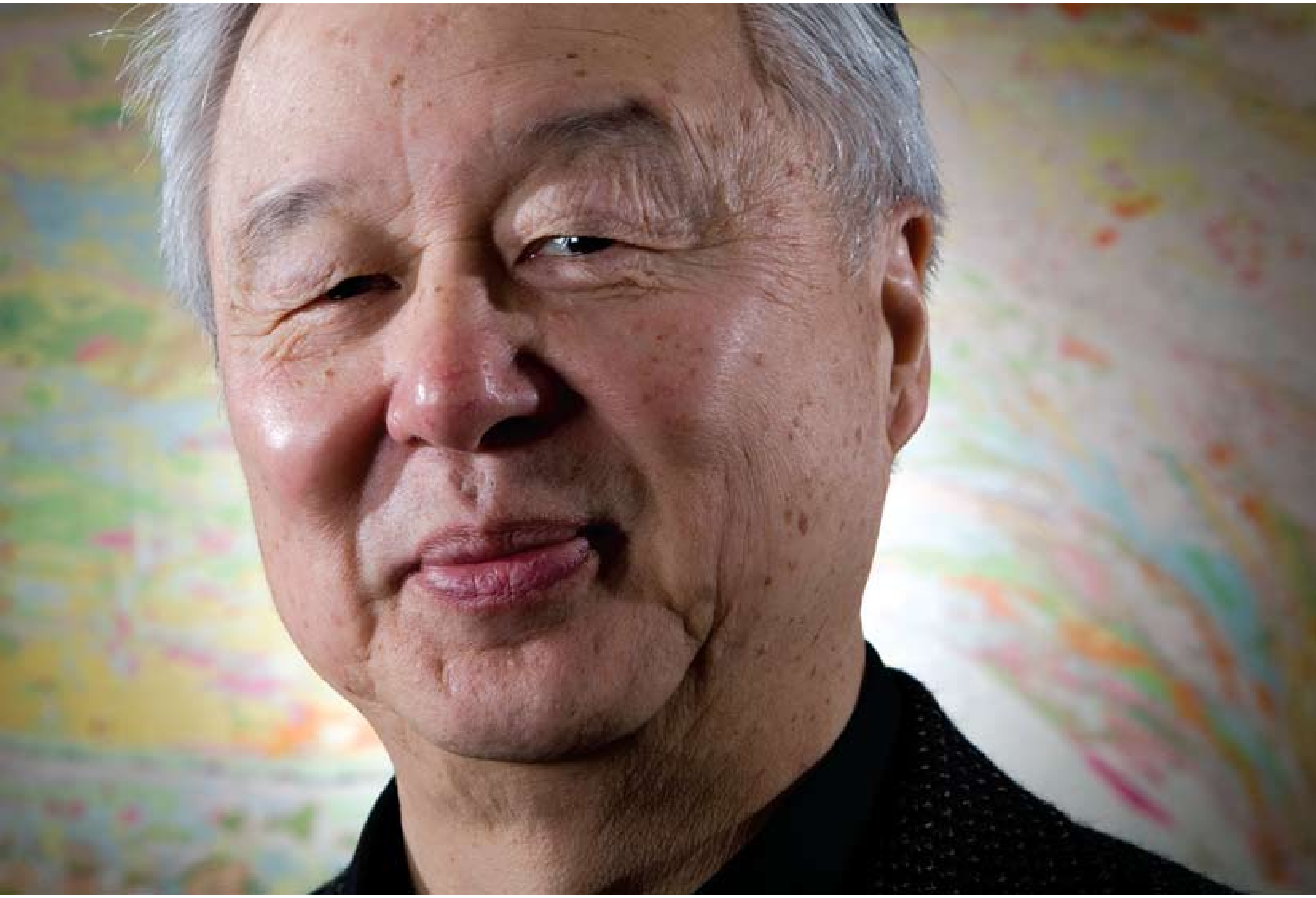
A Fault-Finding Expedition

Wu leads quest to expose hidden forces behind earthquakes





Francis Wu

Francis Wu is using bubbles, explosions, sensors and seismographs to look deep beneath the Earth's crust. The lead investigator on a team of international scientists working on a project of unprecedented scope, Wu intends to capture the first high-def, 3-D image — a virtual MRI — of the abstruse forces at work in the growth of an active, young mountain range.

By using explosive devices to send shock waves through the Earth's crust and upper mantle and by employing emerging technologies to record and "image" the Earth using the wave, the project could help scientists around the globe find subsurface faults and better understand how tectonic forces act to build mountains. This knowledge will ultimately enable scientists to predict earthquakes more reliably.

"I often joke that when we talk about blind faults, we are talking only about faults that we as geologists can't see," Wu said. "But we may be able to image them with seismic waves; and once we can locate small earthquakes at crustal depth precisely, we can determine whether these faults are active."

Seismic waves produced by earthquakes, explosions or controlled vibrating sources are the primary method of underground exploration. They will also be the key in Wu's project to unlock the mysteries of mountain building and tectonic activity that gives rise to earthquakes.

By sending waves through the Earth's crust and upper mantle with a series of controlled explosions, and by sensing, recording and tracking waves from natural seismic events in the crust, the deep mantle and the core of the Earth, Wu's team intends to develop a virtual three-dimensional image of the crust and upper mantle under Taiwan. Wu compares the process to that used by doctors to "see" cancerous tumors deep within the body using magnetic resonance imaging (MRI).

Seismic shock waves bend inside the Earth because of changes in speed as they move through material of different density, composition and temperature. Abrupt changes in direction occur at the boundary between two layers, affording researchers using advanced technologies the opportunity to see what lies deep beneath the surface.

A professor of geophysics at Binghamton, Wu has spent a significant portion of his research career doing fieldwork in the eastern hemisphere, most recently in East Asia. Having worked in Tibet and New Zealand among other regions, he is now concentrating on Taiwan. The small island nation, shaken by about 15,000 detectable earthquakes a year, provides an extraordinary *in vivo* laboratory for Wu's current project known as TAIGER (pronounced "tiger"), Taiwan Integrated Geodynamics Research.

Funded by the National Science Foundation and headed up by Wu, the five-year, $8 million TAIGER project involves nine investigators from six U.S. institutes, one from a Canadian university and scientists from five Taiwanese universities, as well as Taiwan's Institute of Earth Sciences and renowned Academia Sinica, supported by the National Science Council of Taiwan.

The project calls for a comprehensive set of geophysical experiments that will help researchers determine the locations, factor the scale and impact, and obtain multi-scale images of the forces at work within the Earth's crust and upper mantle during manmade and natural seismic events.

Wu's approach to earthquakes is respectful, but far from fearful. It's clear he realizes that when the Earth stops quaking, breaking and belching forth gases and rock, we'll be in more trouble than most of us would care to imagine. That's because for all their unwelcome devastation, earthquakes and volcanoes provide irrefutable planetary "proof of life," not to mention supporting many conditions necessary for it.

"Although a lot of people think of earthquakes and volcanoes as destructive, as long as they are going on, we are assured the Earth is alive," he said. "We know that the Earth has heat inside and the heat is escaping, and that inside the Earth, it is still churning very slowly … convecting." The geothermal heat produced is an important energy source.

Furthermore, scientists have found a liquid outer core composed of iron and nickel. The convective churning generates the magnetic field that shields us from cosmic particles and has guided man's travels through the ages, Wu said.

The churning of the Earth's outer layers results in the shifting of the huge tectonic plates that make up the Earth's crust, giving rise, albeit through disparate processes, to earthquakes and volcanic eruptions. The plate movements led to the mountain building in Taiwan and elsewhere.

But the movement also churns up materials from deep within the Earth, catalyzing complex chemistry that is critical to the formation of the very organic compounds from which life first arose.

So in the grand scheme of things, it seems life itself is caught between a rock and a hot (or cold) place. In spite of our growing concerns that too much environmental CO_2 might soon turn the planet into a hothouse unsuited to most species currently dwelling here, some carbon dioxide is essential.

THIS KNOWLEDGE WILL ULTIMATELY ENABLE SCIENTISTS TO PREDICT EARTHQUAKES MORE RELIABLY

Through the release of CO_2 and other gases, earthquakes and volcanoes do more than simply relieve planetary flatulence. Without such greenhouse gases in our atmosphere to hold in some of the sun's radiant heat, the planet would in short order become frigidly inhospitable to most known forms of life.

But, no matter its importance to life on this planet, what's going on deep within the Earth remains the subject of speculation and cause for intense studies for now.

"Unfortunately, we can't visit the core of the Earth, below the mantle, or the mantle itself," Wu said. To do so would require the ability to "drill down" either by means of a bore hole or penetrating technology to a depth of more than 2,900 kilometers, more than five times deeper than the TAIGER survey will reach.

A major phase of the TAIGER project experiments will take place this spring. It will involve more than 1,000 seismometers to monitor 14 land explosions set off at depths of about 60 meters. A host of sensors and seismometers will also be deployed from the American research ship *R/V Marcus Langseth* for marine experiments off the coast of Taiwan in the spring of 2009. This phase will involve blowing huge bubbles near the ocean surface and monitoring the seismic waves they create.

Far outpacing the omnipresent forces of erosion, the peaks of Taiwan are rising 2 or 3 centimeters a year in places. That's quite the growth spurt in geological terms, and because the mountain-building process is so active there, Taiwan has been the focus of many prior and current international geological studies.

"In Taiwan, land keeps pushing up, and gravity pulls on it, and it comes down. So it is a very lively place in that sense," Wu said. Landslides are commonplace, and residents take them in stride.

"You certainly have to be careful where and how you build roads. I've come across several fresh landslides right after they had closed roads and my Taiwanese colleagues would say, 'Oh don't worry, in another two hours the road will probably be open again,'" Wu said.

The high-resolution images provided by the TAIGER survey are expected to result in the most detailed map ever of Taiwan and its mountains. Imaging is expected to extend from 12,900-foot mountain peaks to the Earth's upper mantle some 370 miles underground.

But Wu and others believe that all the commotion at Taiwan's surface is just an indication of far deeper forces. The TAIGER project will afford a "rare geological test of theory" that ultimately could help architects and engineers build safer structures, Wu said.

"Mountain building is not only in the crust, but also in the upper mantle, probably driven by forces that might be much deeper than previously understood," Wu said. "My view is that one problem that keeps us from predicting earthquakes is that we don't really understand all the processes in question. We know the crust is moving and strain is accumulating and eventually it will break. But when does it start to break and where are the faults? Some are probably too deep to be probed, but some are shallow enough for us to image."

By providing a better understanding of the forces involved in mountain building and the earthquakes to which that process gives rise, Wu also hopes that TAIGER might give scientists a better idea about which major faults to monitor for the purpose of early warning for earthquakes. For some potentially hazardous faults in Taiwan, a warning of 40 seconds or more for a metropolitan area may be possible.

FAR OUTPACING THE OMNIPRESENT FORCES OF EROSION, THE PEAKS OF TAIWAN ARE RISING 2 OR 3 CENTIMETERS A YEAR IN PLACES

“Some people might ask the question, ‘What is the use of this information if we will only know 40 seconds before the earthquake?’

“Maybe this would not be so useful for city dwellers who face a congested highway as they try to evacuate the city,” Wu said. “But on the other hand, even in cities, high-speed transport could be stopped, people could evacuate tall buildings and many businesses, particularly in the semi-conductor industry, which is very big in Taiwan, could have enough time to shut everything off. If you have tens of minutes, you can do all kinds of things. And if we could eventually predict within a few days of an earthquake, then we could effectively prevent loss of life.”■

— Susan E. Barker