Parlez-vous geophysics?

Summer of Applied Geophysical Experience: the equivalent of an immersion course in a foreign language

Story and photos by John R. Gustafson

In a small motel room in the Jemez Mountains of New Mexico, a sleepy-eyed scientist works on newly gathered data. He had stayed overnight in the field to make sure neither elk nor coyotes dug up the spear-like instruments buried to receive electrical signals in Earth or disturbed cables connecting the instruments to a portable computer.

The scientist announces that the data — measures of Earth's electrical properties at different depths offering clues to the underlying geology and fluids — are ready for display. Five college students in the Summer of Applied Geophysical Experience (SAGE) field course crowd around the laptop computer with SAGE co-director George Jiracek.

"You dream about data plots with this much character," says Jiracek, professor of geophysics at San Diego State University, as he points to the screen. "I'm enthused about that dip there — that's a sign of something conductive and fairly shallow. This ascending branch shows something resistive at depth. It could be crystalline rock in the caldera."

In explaining the data, Jiracek draws the students into the field of magnetotellurics, one of the various techniques taught at SAGE for exploring the physics of Earth's interior.

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The three-week SAGE program, described as the geophysical equivalent of an immersion course in a foreign language, has taught nearly 200 students in its nine-year existence. "They get a one-of-a-kind experience in geophysics, with instructors drawn from industry, academic institutions and a research laboratory," says Scott Baldridge, SAGE co-director and staff member in Geology and Geochemistry (EES-1).

SAGE involves faculty from the University of California-Riverside, Purdue University, the University of Texas-Dallas and Golden West College in Huntington Beach, Calif., in addition to Los Alamos and San Diego State.

Sponsored by the Los Alamos branch of the Institute of Geophysics and Planetary Physics (IGPP), a research unit of the University of California, SAGE this year received support from the National Science Foundation, ARCO, Chevron, Mobil, Conoco and Electromagnetics Instruments Inc. to meet its $180,000 budget.

"Everyone in academia and in industry is very concerned about the number of students in geophysics," says Larry Braile, earth and atmospheric sciences professor at Purdue University. "With the recent downturn in the oil industry, many have left the field."

"The reason for SAGE is to better train students in the field of geophysics and to capture other students into the field," says Baldridge.

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LEFT: ARCO technician George Clark (seated at computer keyboard) watches a monitor showing the readiness of the seismic recording stations as he prepares to begin an experiment. Students from SAGE crowd into the control trailer, known as the "doghouse," to watch the operations.

Jiracek realizes the data are first-rate. He and the students recover the recording gear and move it to a new site in the Jemez Mountains, at the western edge of the Rio Grande Valley.

The previous week, at a site 30 miles away near Abiquiu, the full class of 18 SAGE students helped a field crew from ARCO Oil and Gas Co. set out $2 million in state-of-the-art equipment to conduct seismic measurements in the Chama Valley. They worked hand-in-hand with a professional geophysical exploration crew.

Operating from the "doghouse" — a trailer loaded with computers and other electronic equipment — ARCO technician George Clark began each experiment by radioing to a pair of seismic vibrators. The huge tractorlike vibrators planted 4-foot-square steel plates on the ground and shook it so hard that the vibrations came through your feet if you stood nearby.

The vibrations traveled underground, bounced off different geologic features and emerged again at the surface, where 268 instrument stations arrayed along a five-mile stretch of dirt road registered them. The signals raced along cables back to the doghouse, where they were recorded on magnetic tapes and plotted on paper charts.

ARCO geophysicist Mike Verhoeks gave the students a quick lesson on how the plots revealed geologic formations and the natural noises — rivers and roadways, for example — that must be removed in processing. Later, at the nearby El Rito campus of Northern New Mexico Community College, the students and Verhoeks analyzed the data more fully.

"I had seen seismic data like this before, but I never went through how they collect and process it," said Robert Anders, undergraduate in geochemistry at SDSU. "You appreciate the final result more when you see how much actually goes into collecting the data."

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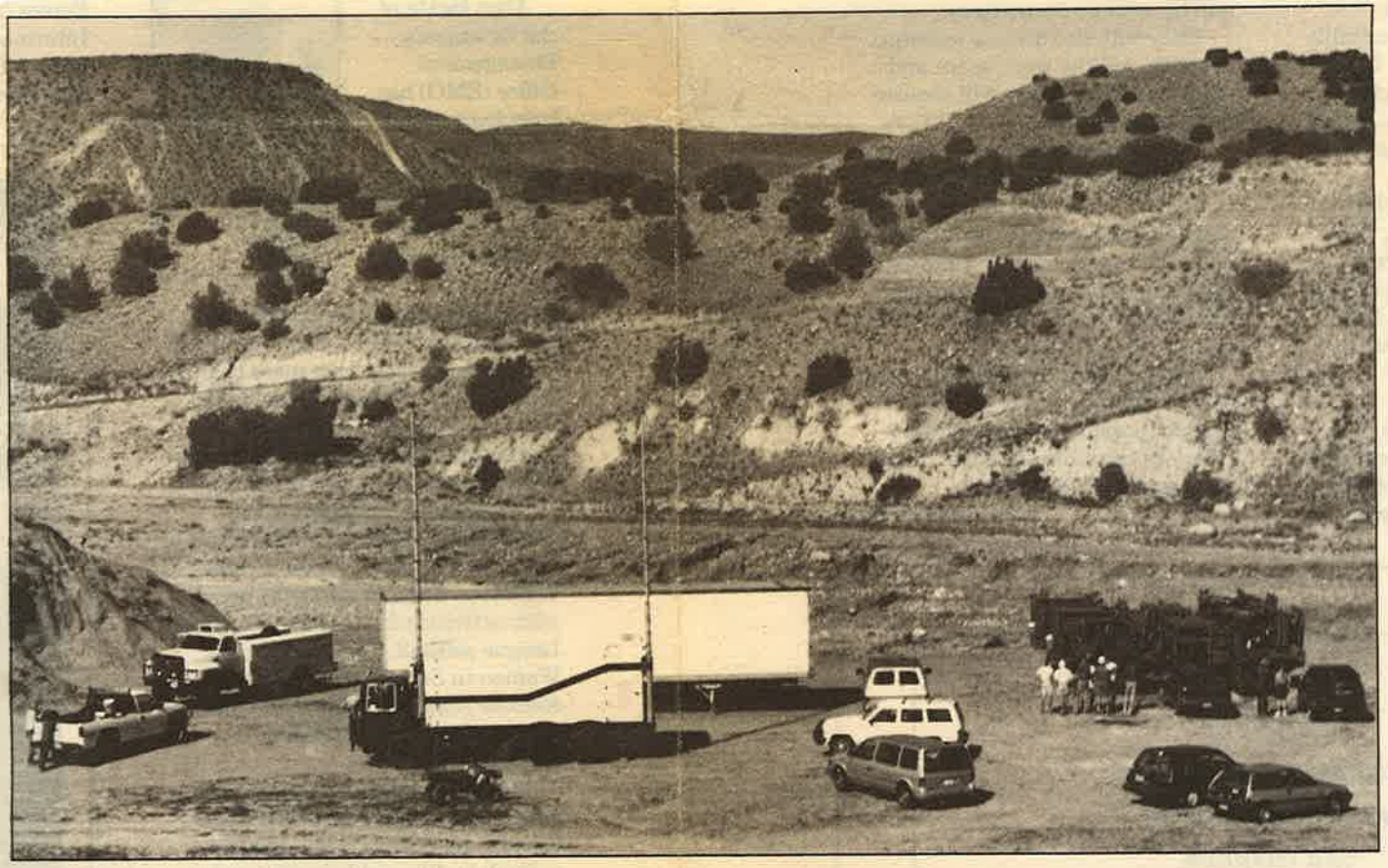
"My reasons for coming to SAGE were simple: to see geophysics on a scale I hadn't seen before," says David Masters, graduate student from Macquarie University. "In Australia, things like the seismic ground crew, on this scale, are not around because most companies can't afford them."

ARCO has sent its seismic crew — the company's only one still active — to SAGE three years running to help train budding geophysicists. Geophysical expertise is essential for the task of finding new oil and gas reservoirs.

"The better trained the students are, the better off ARCO is," says Lynn Forgey, director of ARCO's field support group. "My job is to look for oil and gas and to make a profit doing it. At SAGE I get to meet people from different disciplines, from different parts of the country and with different



ABOVE: In the Chama Valley near Abiquiu, an ARCO exploration crew met with the students and faculty of SAGE. In the background, right, are the two seismic vibrators. At the center, marked by two antennae, is the "doghouse," the computer-filled trailer from which seismic experiments are controlled. The SAGE field course ran from June 17 through July 5 this year and had 18 students.

ideas about what we do as a business."

"This has been our best year for interactions between the students and the ARCO personnel," Baldridge says. "Mike Verhoeks lectured to the students on the seismic reflection techniques and Robert Withers, ARCO's director of reservoir geophysics, described how the techniques were applied to problems in a prospective Oregon oil field."

Although essential for the oil business, geophysical techniques also are applied in other fields. This year's students included geochemists, hydrogeologists and engineering geologists. They saw how geophysics can be used to map out aquifers, trace underground contamination or address problems associated with underground waste storage.

The students, an international mixture of undergraduates and graduates, also learned how to think independently, how to work together as a team and how scientists go through different processes in seeking answers.

"By teaching students through hands-on experience we communicate the excitement of the work — even the faculty doesn't know what the answers are," says Baldridge. "The students learn how a scientist makes multiple hypotheses, learns to focus questions and deals with the frustrations of bad data."

"The best thing about SAGE and what made me come back as a teaching assistant was the idea of working with other people," says Craig Schultz, a graduate student at the Massachusetts Institute of Technology and former SAGE student. "In an academic atmosphere, people typically battle each other. SAGE taught me that by working with other people you can go a lot further a lot faster."

"In SAGE, you're with people who all share the same curiosity, so everyone feeds on each other's thoughts and ideas," says Anders. "Everybody wants to be here and wants to do exactly what we are doing. That is one major reason why this program works so well."

"The final kicker for me was that I could come here and just learn," says Todd Manes, SDSU undergraduate in engineering geology. "I'm not getting credit for this, I'm not being graded. I just want to find out what geophysics is all about."

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By being immersed in field work — magnetotelluric and seismic studies, standard geographic surveys, gravity and magnetic measurements, and others — and the analysis of the data they collect, the students experience a brand of learning that goes deeper than classroom lectures.

"This three-week experience is really going to tell us whether we want to do geophysics for the rest of our lives or not," says Pierre Maregiano, an exchange student from France studying physics at SDSU.

"You read about all these different measurements in books, but here they are all in front of you and you get to try them," says Vikas Mathur, graduate student at Cal State Long Beach. "I get to find out what I like best and I can do my graduate work in that field."

"No other program that I know of offers this wide a variety of geophysical techniques," Jiracek says.

But those techniques are elaborate and expensive. "Only by pooling resources among several campuses and Los Alamos, together with industry support, can we put on this program," says John Ferguson, professor of geophysics at the University of Texas-Dallas.

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SAGE students engage in an ongoing study of the Rio Grande Valley, a continental rift formed as Earth's outer crust stretches apart. Rifts offer potential oil and mineral deposits and geothermal resources, and windows into plate tectonics and crustal evolution.

"SAGE is unique in that we are doing this field camp in truly a research environment," says Jiracek. "We're doing first-class geophysical studies, not some little demonstration."

Although each SAGE class adds only a small amount of additional data to the study of the rift, "incrementally we've built up a considerable data base," says Ferguson.

The SAGE students spend two weeks in the field collecting data, and a third week processing and analyzing what they have collected. Each student chooses a topic on which he or she must present a final report based on what the analysis reveals.

"It's our own research, to a certain extent," says Kris Eckhardt, recent Southern Methodist University graduate. "We have to design our own projects, ask our own questions and see if the data

SAGE co-director and Los Alamos staff member Scott Baldridge stands beside one of two vibrators from ARCO used to conduct seismic studies at SAGE. Between the vibrator's wheels is the steel plate that is planted on the ground and shaken to generate the seismic signals.

SAGE co-director George Jiracek (right) and Carlos Moraila Valenzuela, graduate student from Ensenada, Mexico, dig up one of the magnetotelluric recorders. Inside the spear-shaped device, wire coiled around a magnet responds to Earth's electrical currents and probes the underground electrical properties. The measurements point to fluids, such as magma or water, and different rock formations.

fit what we have hypothesized is the answer."

"SAGE has all the uncertainties of actual research," says Ferguson. "We don't know in advance what kind of data we are going to get — and we've had some spectacular failures. But that's the way research is. Particularly for the undergraduates, it's probably their first exposure to that type of activity."

The instructors also challenge the students. "The faculty want to see what you have," says Schultz. "They're always posing questions and coming to you for answers."

"We make every effort to provide guidance and direction, but we want the students to draw their own conclusions as much as possible," says Ferguson.

National Science Foundation support this year allowed undergraduates to stay four days for extra training and to continue data analysis at their home campuses. "The NSF support is one of the main reasons I'm here," says Manes. "Up until SAGE rolled around I did not have a clue what to do for my senior thesis. Now I can collect good data, process it and learn something about it, rather than picking a topic just to fulfill a requirement."

Baldridge, in addition to lauding ARCO's increasing involvement, praises Chevron's chief geophysicist Matt Mikulich for his long-running support of SAGE. But he also hopes to increase industry participation in SAGE through an affiliates program. He and Jiracek will present the idea to industry representatives at a meeting of the Society of Exploration Geophysicists in Houston this November.

Baldridge also believes SAGE could become a flagship program for the Department of Energy, which is expanding its efforts in support of education.

"We can orient students toward fields of national importance, such as environmental restoration, energy resources, waste storage and groundwater management. SAGE cuts across program lines and embodies what I think DOE is striving for," Baldridge says.

RIGHT: ARCO geophysicist Mike Verhoeks (second from right) discusses a printout of seismic vibration data with SAGE co-director Scott Baldridge (right) and three SAGE students.

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At the end of SAGE, the participants go their separate ways, ready to decompress after an intense, three-week association. Kris Eckhardt heads off to a student internship with ARCO, continuing her hands-on education before deciding on a graduate program to enter.

Even though the SAGE program has ended, the personal interactions it engendered will likely continue. Eckhardt, for example, expects she will see her fellow SAGE students again.

"There aren't many geophysicists out there," Eckhardt says. "Through SAGE I've made a lot of friends in the field, which is going to be a unique networking tool as we go on."

It also helps that the members of the program all speak a common language — the language of geophysics.