

SAGE celebrates 25 years of learning geophysics by doing geophysics

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The increasing world demand and record-high costs for energy and mineral resources, along with the attendant environmental and climate concerns, have escalated the need for trained geophysicists to unprecedented levels. This is not only a national need; it's a critical global need. As Earth scientists and educators we must seriously ask if our geophysics pipeline can adequately address this crisis. One program that has helped to answer this question in the affirmative for 25 years is SAGE (Summer of Applied Geophysical Experience). SAGE continues to develop with new faculty, new collaborations, and additional ways to support student participation during and after SAGE.

SAGE program

SAGE is a unique educational program that blends teaching and research as a partnership between universities, industry, and federal agencies. Since 1983, 653 advanced undergraduate students, graduate students, and qualified professionals have attended SAGE. SAGE is a four-week-long program in New Mexico and one-week follow-up for undergraduates at San Diego State University. It teaches the principles and applications of the major land-based geophysical methods (seismic, magnetics, gravity, GPS, electromagnetics) in a field-based, hands-on setting (Figures 1 and 2). SAGE field problems include locating buried hazardous material, mapping archaeological sites, and studying subsurface structure and water resources of the Rio Grande rift near Santa Fe, New Mexico.

The primary goal of SAGE is to actively engage students in all phases of exciting, applied geophysical research using



Figure 1. SAGE 2007. (a) Vibroseis source courtesy of ION Geophysical (formerly Input/Output) and (b) students analyze ground-penetrating radar recording with Peter Annan, president of Sensors and Software.



Figure 2. SAGE 2003 students at the western boundary of the Rio Grande rift near Abiquiu, New Mexico.

modern field equipment and computer processing/modeling. It begins with an introduction to the principles of each geophysical method and how (and why) they are applied to various geologic problems and related societal needs. Students then are closely guided by faculty, teaching assistants, and industry visitors to analyze and interpret geophysical data that they collect. The analysis/interpretation phase is enhanced by

using a two-tier team effort leading to oral and written presentations patterned after the SEG Annual Meeting and *Expanded Abstracts*, respectively. Each student is part of a team focused on a specific geophysical technique and an integration team that synthesizes the combined results. The focus is usually on testable hypotheses that are addressed after processing, modeling, and interpretation. SAGE has placed increasing emphasis on providing the means for students to present their findings after SAGE at professional meetings and forums. For example, a SAGE 2007 undergraduate represented six student co-investigators in an oral presentation of their hydrological results at the American Geophysical Union's 2007 fall meeting. SAGE students are also encouraged to use SAGE data for senior or graduate theses. Upon pre-arrangement with their home campuses, the SAGE program can provide grades for students who need them.

SAGE partnerships

SAGE began as a partnership between Los Alamos National Laboratory (LANL) scientists and six university professors. The partnership quickly grew to include industry, SEG, and federal agencies including the U. S. Geological Survey (USGS), the Department of Energy (DOE), and the National Science Foundation (NSF). Their contributions include visits from professionals (including SEG presidents), evening discussions and short courses, field work assistance, financial donations, and equipment and software loans. These extensions alert students to current job opportunities, inject a high level of technical expertise, and create a stimulating environment at SAGE that is unmatched at most college campuses. SAGE partners and faculty also provide future networking options and help students to select graduate schools and begin careers in today's workforce. Over 75% of SAGE students who have been NSF-supported undergraduates at SAGE go directly on to graduate school. Most former SAGE students are employed in geoscience careers, some have earned PhD degrees and are now university faculty or postdoctoral researchers; others are on technical staffs of major companies, consulting firms, equipment manufacturers, the USGS, and federal laboratories. It is always a special treat when a former SAGE student returns to the program as a company representative. Organizations that provided equipment, software, financial aid, and visitors to SAGE in recent years are listed in Table 1. SAGE is hosted and supported by the LANL Branch of the University of California's Institute of Geophysics and Planetary Physics (IGPP). Institutional support from faculty affiliations includes in-kind contributions of faculty time, equipment, vehicles, and facilities.

SAGE students

The recent three years, 2005–2007, are representative of the student demographics of the SAGE program: there were 87

BH Billiton	National Science Foundation
Chevron	Quantec
Department of Energy	Radford University
Eaglecrest	Schlumberger EMI Technology Center
ExxonMobil	Sensors and Software
Geometrics	Society of Exploration Geophysicists
Geonics	Southern Nevada Water Authority
Geophex	U.S. Geological Survey
Green Engineering	Zonge Engineering and Research Organization
Input/Output (now ION Geophysical)	

Table 1. Organizations recently supporting SAGE.

students representing 48 different campuses and 12 countries. Fourteen local Native American high school and college students from northern New Mexico tribes also attended a portion of SAGE during 2005–2007. Upper division undergraduate students work side-by-side with graduate students, and occasionally college faculty and company professionals attend SAGE as students. SAGE students come from big and small schools alike, from the U.S. and overseas, e.g., recent students have come from colleges and universities as diverse as Augustana College, the University of Texas system, Swarthmore College, University of Miami, Centre College, the University of California system, Stanford University, the SUNY system, College of William and Mary, Dublin Institute for Advanced Studies, National Autonomous University of Mexico, and the University of Copenhagen. SAGE provides unique educational and research opportunities that augment programs at large research schools and that are not available at smaller campuses. Student evaluations of SAGE are very high, averaging 4.8 out of a perfect 5.0, with comments such as:

- “I learned more in this month than I normally do in an entire term of classes.” (Derrick Hasterok, Caltech, SAGE 2000)
- “The faculty and lectures are exceptional. The experience was one I will treasure forever.” (Marie Renwald, University of Arizona, SAGE 2001)
- “Without SAGE, I wasn't sure geophysics was for me. Now I am.” (Colin Cikoski, New Mexico Tech, SAGE 2004)
- “SAGE was one of the best experiences of my life. The friendships will last a lifetime.” (Andrew Steen, Michigan State University, SAGE 2007)

SAGE faculty

Five of the original SAGE faculty from 1983 (Baldrige, Biehler, Ferguson, Gilpin, Jiracek) are still part of the core faculty (Table 2). This represents a commitment to the program, one that was recognized in 1998 by the American Geophysical Union's Excellence in Geophysics Education Award to the SAGE faculty “for significant and lasting contributions to geophysical sciences through innovative training, support, and encouragement of students.” In 2000, SAGE received a Special Commendation Award from the SEG “for exceptional efforts in developing ... the SAGE program.”

Applications to attend SAGE

SAGE seeks to reach a broad and diverse pool of qualified applicants from the greater physical science/mathematics/engineering community. As a result, SAGE students often come from very different backgrounds. Students must have successfully completed at least one year of college physics, including electricity and magnetism, one and one-half years of college calculus through differential equations, and courses in physical and structural geology. A course (or more) in geophysics is desired but not required. Generally a B or better is expected in the physics, mathematics, and geoscience courses. Letters of reference and a letter expressing one's desire to attend SAGE are required. The program usually receives 50 applications or more for 25–30 openings each year. Tuition for the four-week summer program is currently US\$450, which includes room and board in Santa Fe, New Mexico. The living expenses alone are nearly three times this tuition; therefore, tuition covers only a small fraction of the total costs. Most expenses are covered by the organizations listed in Table 1 with NSF and LANL/DOE covering the largest share. Undergraduate students who are U. S. citizens or permanent residents of the U. S. or its possessions are eligible for complete financial support, including transportation to and from SAGE, through the NSF REU (research experiences for undergraduates) program. Two new financial programs are available to SAGE students beginning in 2008:

1) Upon completion of SAGE, students may be eligible for three-year stipends as part of grants with their faculty and LANL staff to support SAGE-related research in graduate school.

2) Graduate students may qualify for an ExxonMobil SAGE Scholars Grant to attend SAGE.

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We are also pleased to announce that a permanent SAGE Endowment Fund has been established in June 2008 through the SEG Foundation with the Founding Donor being Geophysical Pursuit. This is aimed at achieving long-term stability for the SAGE program. A digital geophysics learning Web site called DAGSAW (Digital Analysis of Geophysical Signals and Waves) is under development by SAGE faculty and is accessible at <http://www-rohan.sdsu.edu/~jiracek/DAGSAW/>. More information on all aspects of the SAGE program and how you can apply to or support SAGE are available on the SAGE Web site at <http://www.sage.lanl.gov/>. **TLE**

Acknowledgments: Gary Geernaert, director of the LANL, IGPP

Core Faculty	
W. Scott Baldrige, co-director	Los Alamos National Laboratory
Shawn Biehler	University of California at Riverside
Lawrence W. Braile, co-director	Purdue University
John F. Ferguson	University of Texas at Dallas
Bernard E. Gilpin	Golden West College
George R. Jiracek	San Diego State University
Louise Pellerin	Green Engineering
Adjunct Faculty	
Paul A. Bedrosian	U. S. Geological Survey
Darcy K. McPhee	U. S. Geological Survey
Caherine M. Snelson	New Mexico Institute of Mining and Technology
Aviva J. Sussman	Los Alamos National Laboratory

Table 2. SAGE faculty.

has continued to support SAGE at all levels as did his predecessor Charles (Chick) Keller. The administrative staffs at IGPP and the San Diego State University Research Foundation have diligently attended to countless SAGE organizational and fiscal details; we also thank the support staff at IRIS/PASSCAL. Very special thanks go to each organization listed in Table 1 and to Geophysical Pursuit, Inc., the Founding Donor of the SAGE Endowment Fund with the SEG Foundation. In addition, there are many individuals who have steadfastly supported SAGE and have extended the meaning of partners far beyond any reasonable expectations. Over the recent years they've included: Matt Mikulich, Marty Brandt, Scott Baker, and Paul Vincent (Chevron); Kay Aikin, Terry Carius, Bob Stewart, and Orla McLaughlin (ExxonMobil); Peter Annan and Greg Johnston (Sensors and Software); Jim Hollis and Robert Mardis (ION Geophysical); Hans Rasmussen (Eaglecrest Exploration); Scott Urquhart and Norm Carlson (Zonge); Jeff Johnston and Doug Groom (Geometrics); Bill Doerner (Quantec); Nick Woodward, Mike Kuperberg, and Edith Allison (DOE); I. J. Won (Geophex); Simon Boniwell (Geonics); John Clough (CGGVeritas); Mike Mayhew and Lina Patino (NSF); and Bill Baxter (The Archeological Conservancy). SAGE has graciously been granted permission to conduct recent field operations on lands governed by Cochiti and Santo Domingo Pueblos and occupied by Vulcan Materials. Lee Suina and Vince Rapisarda were especially helpful with these arrangements. A backbone of the SAGE program has been outstanding former SAGE student teaching assistants who, in the last few years, have been Ted Bertrand, Nicole Garcia, Jeremy Gunter, Derrick Hasterok, Emily Hinz, and Matthew Ludwig. Finally, we thank all SAGE students; they have continued to amaze us with their readiness and their capacity to learn geophysics in the accelerated environment of SAGE.

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