Stanford

Earth

Stanford | SCHOOL OF EARTH SCIENCES

Advisory Board Meeting
April 10-11, 2014
Hartley Conference Room
Mitchell Building

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Advisory Board
2014 Annual Meeting

Thursday and Friday, April 10 & 11
Hartley Conference Room, Mitchell Building

AGENDA

Wednesday, April 9

6:00 – 8:00 pm	Informal reception at the home of Dean Pamela Matson, 950 Mears Court, Stanford, CA 94305 (map at http://bit.ly/1i9Fl5h)

Thursday, April 10

8:00 – 8:30	Breakfast in Hartley Commons
8:30 – 9:00	Welcome and Introductions
9:00 – 9:45	Stanford Earth Sciences State of the School (Pam Matson)
9:45 – 10:15	Stanford Earth Sciences: Re-envisioning the Development Office (Becky Vogel)
10:15 – 10:30	Break
10:30 – 11:45	Task Force Status and Issues (Pam Matson, Becky Vogel, John Moragne, Terry Huffington)
12:00 – 1:30	Lunch with Graduate Student Advisory Committee, Stanford Faculty Club
1:30 – 2:30	Task Force Discussion (continued) (Pam Matson)
2:30 – 4:00	Facility Tours
4:00 – 5:00	Panel: Mitchell Building (Pam Matson and panelists)
6:30 pm	Cocktail Hour and Dinner at the home of board member John Moragne and his wife, Kim Young 71 Santiago Avenue, Atherton, CA 94027 (map at http://bit.ly/1gjCWAA)

Friday, April 11

8:00 - 8:30	Breakfast in Hartley Commons
8:30 – 9:00	Debrief from Thursday: Building and Other Task Force Issues (Pam Matson)
9:00 – 10:30	Faculty Panel: Natural Gas Initiative (Sally Benson, Adam Brandt, Rob Jackson, Mark Zoback)
10:30 – 11:30	Executive Session
11:30 – 12:00	Report to Dean and Wrap-up
12:00 – 1:30	Lunch in Hartley Conference Center (optional)

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March 2014

Dear Earth Sciences Advisory Board Members:

I am looking forward to welcoming you back to campus next month! It's an exciting time for the School of Earth Sciences, and we are in building mode in more ways than one. The strategic conversations in which we've been engaged within our own faculty, with you, and across the university are shaping a plan for the school's future. When the board last met, we were working hard to define the role the school would play in addressing the great resource and environmental challenges of the coming decades. With that plan more or less in place, I am necessarily focused on the next steps needed to implement our vision for greater impact.

Our goals are ambitious, including these key elements of the school's evolution:

- Additional faculty with the expertise needed to address today's complex research questions.
- A facility that meets our 21st century needs, including for state-of-the-art laboratory space, computational facilities, and "smart" classrooms.
- New programs that meet curriculum demand from on- and off-campus students, including professional master's students and executives.

Achieving these goals carries an estimated $100-125 million price tag, demanding that we continue to bolster our development and communications operations and create a clear, compelling narrative with which to attract financial support.

I look forward to discussing all of this in more detail when we meet, but the following offers a glimpse of where we are.

Building our Development and Communications Capacity

There is no question that our objectives represent a formidable fundraising agenda, especially for a school with a small alumni base. We will need to communicate our vision and development priorities effectively and engage volunteers and prospective donors. To ensure we are prepared to make our case within these key constituencies, we have established a volunteer task force to help us shape our strategy and messaging and identify potential donors.

Assembled for the period of a year, the 16-member School of Earth Sciences Task Force will advise us on fundraising strategies for our key priorities: the building, faculty growth, and new

programs, as well as on messaging about the important role the School of Earth Sciences plays at Stanford, particularly vis-à-vis the Woods and Precourt Institutes.

A list of task force members is enclosed. Two of its three chairs, Terry Huffington, ’77, and John Moragne, MS ’83, MBA ’86, are also members of the advisory board. We purposely recruited many of the remaining members from beyond the ranks of the SES community with the knowledge that we will need to reach out very broadly in order to meet our fundraising objectives.

The task force first met on February 3 with a great deal of enthusiasm about the direction in which the school is heading. The group also highlighted some areas where we still have work to do, and about which I will share more at our meeting.

On the staffing side, we are in the process of ramping up our development team by adding field staff as well as targeted communications and administrative support. At this time last year, we had already begun investing in a more robust communications team by hiring a chief communications officer. We have since added a science writer. With this staff of two crafting and telling our story, the school has a great deal more visibility with audiences ranging from the science media to prospective donors. We will continue to build this team by adding digital media capabilities.

Building the Faculty

As you know, we have been engaging the faculty in a long-term dialogue, beginning with our strategic planning process in 2010-11, to identify gaps in our Earth-related expertise at Stanford. We have made progress with some exceptional hires in the past decade, including recent MacArthur Fellows David Lobell and Kevin Boyce, both of whom transcend disciplinary boundaries to conduct rigorous science with broad implications.

However, we still have relatively few faculty who focus on the intersection of human decision making, resources, and the environment. This expertise is critical to leveraging our traditional science and engineering research and making it not just useful but *used* by decision makers. It is also an area in which students are eager to be advised and mentored in far greater numbers than we can currently accommodate.

The provost’s allocation of five incremental faculty billets is a green light to take this process to the next level. I held two brainstorming meetings with the faculty this winter to zero in on the skills and expertise that would add the most value within the broad areas of energy resources, hazards, water resources, and climate. As we ramp up on the funding side, we will be working hard to clarify these ideas and priorities into gift opportunities and, ultimately, into positions held by real people.

In the meantime, we have several immediate vacancies to fill, including two of three positions that will complete the geobiology initiative. We also have an opening in energy resources due to

Lynn Orr's pending appointment as undersecretary for science at the U.S. Department of Energy. In addition, we will be searching in the coming year for an expert on land or water resources management, and are in discussions with the Woods Institute about shared positions in social-environmental systems.

Building a Facility Worthy of our Aspirations

As you know, our physical infrastructure cannot meet our current research and teaching needs, let alone accommodate an expanded faculty and educational program. Y2E2 and the Green Earth Sciences building are excellent facilities, but those spaces are maximized already. The 1960s era Mitchell building is likewise fully occupied, but its most critical problem is that it cannot accommodate the modern technology our laboratories and classrooms need.

We are still early in the concept phase for a new building. We have approval to seek funding for a facility of 116,000 gross square feet, with a $40 million commitment from the provost and a mandate to fundraise for the rest. The building's location is still in play. One possibility is the site formerly occupied by Terman Engineering Center. There is another potential site adjacent to Y2E2. Each site has its pros and cons.

Our challenge is to ensure that our vision for the building is compelling enough to attract the sizable gifts the project will require. What exactly will happen in the building? How will it move Stanford forward with respect to teaching and research on energy, environment, and resources? The task force is advising us closely on this matter as we develop a strategy and seek to identify potential donors. I am eager for your input as well; this will be an important agenda item at our meeting.

Building out the Program: Teaching and Learning

Professional MS Program

Near- and long-term resource challenges call for the development of a new breed of leader. These future decision makers will need to leverage theoretical and analytical tools from a broad range of disciplines, and have both practical experience and leadership training. Their skill set must include the capacity to:

- work in complex social-environmental systems
- think intergenerationally
- work across varied contexts
- cultivate empathy for diverse people
- forge alliances that yield enduring and resilient solutions
- adapt as circumstances change

Global assessments by the National Academy of Sciences and the International Commission on Education for Sustainable Development Practice identify a critical shortage of leaders prepared

with these competencies. At the same time, we have identified a growing demand by Stanford students for curricular programs focused on sustainability challenges and solutions.

In the coming months, we will seek further input from faculty and students around the university and from corporate, NGO, and government policy makers about what is needed in the next generation of decision makers. We will also examine and evaluate offerings at other universities, and identify potential unique roles and opportunities for Stanford leadership in this area. We expect this initiative to yield a very special and high profile professional master's degree, new courses at the graduate and undergraduate level, and potentially a co-terminal master's degree in Earth Systems.

At the same time, we are gathering input on options for executive education, especially in our strong areas of energy resources science and engineering.

Science Communication Master's Degree

Over the past several years Earth Sciences has developed a handful of very popular courses centered around environmental science and policy communications. Five years ago, we hired an environmental journalist as a full-time lecturer who has also become a core instructor in the university's journalism program. Student demand for education and training in this area has grown substantially and many students would like to pursue some graduate study in environmental communication. In response to this, the Earth Systems Program is seeking university approval to offer a co-terminal master's in environmental science communication.

Leveraging Online Education

SES would also like to more fully engage in online teaching and learning. We have asked the provost for funding to support an academic technology specialist who can serve as an expert bridge between SES and Stanford's considerable expertise in this area, including in the Office of the Vice Provost for Online Learning, the Center for Teaching and Learning, and Stanford University Libraries and Academic Information Resources.

In addition to online learning's potential to transform the classroom experience for undergraduate and graduate students here at Stanford, SES hopes to leverage these new methods to reach students beyond campus—including executive and professional audiences—and increase Stanford's global visibility in Earth-related fields.

Building Diversity

SES is proud to say that our efforts over the last several years to increase our diversity have yielded important results. For example, we have successfully recruited three women and two underrepresented minority (URM) faculty members in the last two years. Our graduate student diversity applications and enrollment also show an overall upward trend despite some ups and downs year-to-year.

Programs offered through our Office of Multicultural Affairs are well-received and effective, including the summer undergraduate research program, which has resulted in seven applications to SES graduate programs for next fall.

The California Alliance for Advancing Graduate Education and the Professoriate

As you may have read in the news, Stanford has partnered with Caltech, UCLA, and UC Berkeley to create a professional development and mentoring network for URM graduate students and postdoctoral fellows in math, computer science, engineering, and Earth sciences. SES faculty are playing a leading role in this initiative, with Page Chamberlain serving as a principal investigator (PI) on the four-university National Science Foundation grant, and Jerry Harris serving as co-PI for Stanford. Stanford is also hosting the alliance's first annual retreat in early April.

InTeGrate: Interdisciplinary Teaching about the Earth for a Sustainable Future

We are also playing a critical role with InTeGrate, another NSF-funded program that supports the nationwide teaching of geoscience in the context of societal issues across the undergraduate curriculum. In a mutually beneficial exchange, Stanford graduate students and postdoctoral fellows will teach geoscience modules at local two- and four-year colleges with significant URM enrollment. Academic content and teaching methods Stanford students enjoy will be made available to a much larger undergraduate population, and our graduate students and postdocs will develop experience with more diverse students and teaching environments than they are accustomed to at Stanford.

Diversity and Inclusion Study

One key success metric for our diversity efforts is the number of people representing different racial, ethnic, and cultural backgrounds who successfully enter our graduate programs. We are preparing a study that will identify key factors influencing the number of SES graduate admits from underrepresented racial/ethnic minority groups and provide practical recommendations to support the School of Earth Sciences' diversity and inclusion objectives.

Building a "Farm on the Farm"

I am pleased to report that the O'Donohue Family Stanford Educational Farm will be ready to begin operations in September. Following the construction of basic structures over the summer, planting will begin in the fall with cover crops, winter vegetables, perennial herbs, and preparation for winter orchard planting. Filling a need that has been strenuously articulated by students for many years, this multifaceted learning environment and living laboratory will serve the entire campus and the public. In particular, Stanford students will have the opportunity to integrate and extend their classroom learning while gaining practical experience addressing critical sustainability issues in farming and food systems.

In summer 2013, an anonymous gift supported our Summer Agricultural Internship pilot program, which provided stipends for three teenagers to work in our outdoor classroom garden. These low-income teens from San Jose, Redwood City, and San Francisco were participants in the School of Earth Sciences Summer Internship Program, which places high school interns in SES labs and programs. They received wide exposure to Stanford research and education programs while learning the science and practice of ecological food production. Based on the success of this pilot, we expect to grow the program along with the farm.

While the O'Donohue Family Stanford Educational Farm will provide many such opportunities for education and outreach to our broader community, its ability to do so will depend on additional fundraising—for graduate fellowships, outreach programs and staff, and infrastructure like the planned sustainable agriculture learning center.

Summary

The 21st century holds a range of challenges related to meeting the needs of people for food, energy, water, and other resources. Doing so in a way that maintains the life support systems of the planet is essential so that future generations can have their needs met as well. These are complex problems that present huge opportunities.

SES is a recognized leader in the analysis of geohazards and the exploration for oil, gas, water, and mineral resources. Building on this strong foundation, we have spent more than a decade growing into new aspects of our traditional focus areas (e.g. renewable energy resources) as well as areas related to Earth system science, global environmental change, and sustainable development.

We can further leverage our expertise by strategically expanding the faculty, extending our reach with professional master's and executive training programs, and building a facility that will inspire and enable innovation. Stanford's leadership in areas related to Earth, energy, and environment will depend on our ability to build on our traditional excellence to meet the planet's growing challenges head on.

I look forward to sharing more details and inviting your input at our meeting on April 10-11.

Pamela A. Matson
Chester Naramore Dean
Richard and Rhoda Goldman Professor of Environmental Studies

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Our Mission

- We are a **world leader** in Earth, energy, and environmental sciences and engineering.
- We **create, integrate, transform, and teach** fundamental understanding of Earth, resource, and environmental processes and problems.
- We **use our knowledge** to help provide energy, water, and a safe and sustainable planet.

School of Earth Sciences Milestones

1891 **John Casper Branner,** a geologist, is hired as Stanford's first professor. He brings his personal 5,000-volume geological library, which becomes the basis for the Branner Earth Sciences Library (housed in Mitchell). It currently holds about 125,000 volumes and 270,000 sheet maps.

1898 **The Department of Geology (one of Stanford's first departments) becomes the Department of Geology and Mining,** reflecting a focus on the search for and extraction of natural resources during the period of Western development. The department is housed in the southwest corner of the Main Quad, which becomes known as Geology Corner.

1913 **Branner** becomes Stanford's second president.

1914 **Petroleum Studies** is added.

1947 The **School of Mineral Sciences** is created. **A.I. Levorsen**, a petroleum geologist, is the inaugural dean. The new school has no departments, and covers fields including geology; geophysics; geochemistry; and mining, metallurgical, and petroleum engineering.

1950 **Charles Park**, a mining engineer, becomes the school's second dean.

1962 The school is renamed the **School of Earth Sciences** to more fully reflect the scope of the work being done by its faculty and students. The school is also organized into four departments: Geology, Geophysics, Mineral Engineering, and Petroleum Engineering.

1965 **Richard Jahns**, a geologist, becomes the school's third dean. He creates the Department of Applied Earth Sciences, which includes the fields of ore deposits, hydrogeology, engineering geology, and remote sensing. Mineral engineering faculty join the new department.

1970 The **Ruth Wattis Mitchell Earth Sciences Building** is dedicated. The building accommodates new analytical and experimental equipment.

1979 **Allan Cox**, a geophysicist, becomes the school's fourth dean.

1987 **George Thompson**, a geophysicist, becomes the school's fifth dean.

1989 **Gary Ernst**, a geologist, becomes the school's sixth dean. The Loma Prieta earthquake strikes one month after he takes the deanship, and Geology Corner is closed for the duration of his tenure. The infamous modulars, Bambi and Godzilla, serve as a temporary home while Geology Corner is rebuilt. (Geology Corner is renamed Braun Hall in 1996 to recognize gifts from the Carl F. Braun family for restoration.)

1992 **The Earth Systems Program** is created under the leadership of Dean Gary Ernst.

1993 The Departments of Geology and Applied Earth Sciences combine to become the **Department of Geological and Environmental Sciences**.

The **Cecil H. and Ida M. Green Earth Sciences Building** is dedicated. Today, the building is home to the analytical facilities serving the entire school, and faculty from three of the four departments.

1994 **Lynn Orr**, a petroleum engineer, becomes the school's seventh dean.

1996 The school expands into **ocean and land science** areas, hiring three marine scientists, a soil scientist, and a biogeochemist before the turn of the century.

2001 The **Interdisciplinary Graduate Program in Environment and Resources (IPER)** is created under the leadership of Pamela Matson and Lynn Orr. The program is renamed the **Emmett Interdisciplinary Program in Environment and Resources (E-IPER)** in 2009 in recognition of a generous gift from Rae and Dan Emmett, '61.

2002 **Pamela Matson**, an interdisciplinary Earth systems scientist, becomes the school's eighth dean.

2003 Matson leads the school through a **year-long strategic planning process** that culminates in a vision of the school as a collegial, collaborative, and inspiring home for discovery about the Earth, its resources, and the environment, and for the transformation, integration, and application of knowledge for resource and environment problem solving. Many of the changes in the following six years are direct outcomes of this plan.

With the help of Matson's leadership (as a member of the provost's Committee on the Environment and then as dean), the **Institute for the Environment** (later to become the **Ward W. and Priscilla B. Woods Institute)** is created as a hub for Stanford's environmental researchers, bringing together experts from across the university's seven schools to pursue interdisciplinary, solutions-oriented research addressing the planet's most complex environmental challenges. Today, many SES faculty (including Matson) have joint positions or are otherwise affiliated with the Woods Institute.

2005 The school launches the **Center for Computational Earth and Environmental Science** to provide support and collaborative space for faculty working on computational and large database issues.

2006 **The Stanford Challenge**, a five-year university fundraising campaign with a $4.3 billion goal, launches. Along with Jeff Koseff (civil and environmental engineering) and Buzz Thompson (law), Matson leads the **Initiative on the Environment and Sustainability**, one of the campaign's anchor initiatives.

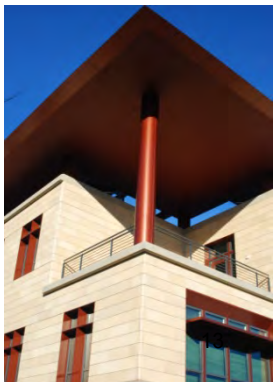
The Department of Petroleum Engineering becomes the **Department of Energy Resources Engineering (ERE)**. While still offering master's and doctoral degrees in petroleum engineering, ERE provides training for students pursuing broader careers in geothermal energy, carbon capture and storage, and other energy resource areas.

The school launches the first of now seven shared analytical facilities, providing faculty and students access to cutting-edge and continuously improving research facilities.

2007 The school adds a new interdisciplinary department, **Environmental Earth System Science (EESS**), and hires four new faculty. EESS faculty and students are engaged in biogeochemical, geophysical, geographical, and social dynamics of land and agricultural, atmospheric and climatic, freshwater, and oceanic components of the global system.

The **Emmett Interdisciplinary Program in Environment and Resources adds a joint master's degree program** for students in the Graduate Schools of Business and Education, the Law School, and the School of Medicine.

2008 The **Jerry Yang and Akiko Yamazaki Environment and Energy Building (Y2E2)** is dedicated. (Matson was lead dean and a member of the planning committee for the effort.) Among the occupants are the Earth Systems Program, the Emmett Interdisciplinary Program in Environment and Resources, and the Department of Environmental Earth System Science.



2009 **The Precourt Institute for Energy (PIE)** and the **TomKat Center for Sustainable Energy** are created with gifts from Jay Precourt,'59, MS '60 (petroleum engineering), and Tom Steyer, MBA '83, and Kat Taylor, JD/MBA '86, respectively. Like the Woods Institute, PIE and TomKat involve faculty from across the university, including many from SES. PIE's first director is former SES Dean Lynn Orr. The Global Climate and Energy Project, a partnership between Stanford and a range of corporations that was created in 2003, sits within the Precourt Institute and is led by SES Professor Sally Benson.

2011 The school launches a series of faculty searches in the new area of geobiology. **Kevin Boyce** (pictured far left), one of the first geobiology faculty hires, arrives in 2013 and is simultaneously awarded a **MacArthur Fellowship** along with **David Lobell** (also pictured), an associate professor in Environmental Earth System Science.

The new **Computational Geosciences (CompGeo) master's degree program** within the Institute for Computational and Mathematical Engineering welcomes its first cohort of students. CompGeo trains students to develop efficient and robust numerical solutions to Earth science problems using high-performance computing.

Quick Facts

- 61 faculty members (22 hired in the past 8 years)
  - 9 members of the National Academies of Sciences or Engineering
  - 6 members of the American Association for the Advancement of Science
  - 3 MacArthur Fellows
  - 7 current NSF Career Award recipients
- ~400 graduate students
- ~150 undergraduate students
- 4 departments: Energy Resources Engineering, Geological and Environmental Sciences, Environmental Earth System Science, Geophysics
- 2 interdepartmental programs: Earth Systems undergraduate interdisciplinary program, and the graduate Emmett Interdisciplinary Program in Environment and Resources
- 1 master's degree track program (in the Institute for Computational and Mathematical Engineering): Computational Geosciences (CompGeo)
- 8 school-wide centers and facilities: Center for Computational Earth and Environmental Science, Stable Isotope Biogeochemistry Facility, Geochronology/Thermochronology Facility, Rock Preparation/Mineral Separation Lab, Environmental Measurements Analytical Facility, Environmental Isotopic Geochemistry Lab, Spatial Analysis Center, and Branner Earth Sciences Library
- 2 research stations (administered by H&S): Jasper Ridge Biological Preserve and Hopkins Marine Station
- 2 standing volunteer advisory boards: SES Advisory Board, Petroleum Investments Committee

Current Facilities

Geology Corner (Braun Hall) (26,000 nsf)
Geology Corner has the unique distinction of being the only Quad building still being used for its original purpose. It houses the main offices for the Department of Geological and Environmental Sciences (GES). In addition, 11 faculty from GES and the Department of Environmental Earth System Science (EESS) call it home for both their offices and dry labs. Between 40 and 50 graduate students from GES and EESS are housed in the building, along with the school's undergraduate program manager and undergraduate lounge. Geology Corner also has a number of classrooms and instructional spaces—some controlled by the registrar and some by the school.

Cecil H. and Ida M. Green Earth Sciences Building (43,000 nsf)
Energy Resources Engineering (ERE) is fortunate to have all of its faculty, research, administrative staff, laboratories, and most of its students and post docs housed in Green Earth Sciences. In addition, seven GES faculty and three EESS faculty reside in Green, along with research and technical staff, post docs, and approximately 50 graduate students. Green is also home to several high-end analytical laboratories, and it is the only SES building with the infrastructure needed for modern scientific research.

Ruth Wattis Mitchell Earth Sciences (66,000 nsf)
Mitchell Earth Sciences is home to the dean's office and various central offices (approximately 20 staff). The Department of Geophysics (GP) is primarily located on the 3rd and (windowless) 4th floors of Mitchell, with 12 faculty, 70 graduate students, and 10+ post docs. Many graduate students, visitors, emeriti faculty, and post docs from all departments are located on the basement level. Since the sub-basement is not optimal space, it has become the back-up plan for space assignments.

The Mitchell basement and sub-basement contain a number of wet chemistry labs (for GP, GES, and EESS), a shared computer instructional space, a plotter room for printing large maps/documents, and storage, including the school's gem and mineral collection and its teaching collection. Technical staff for these labs are also housed in Mitchell.

Branner Library, which is part of Stanford University Libraries and Academic Information Resources, occupies the second floor and mezzanine as well as some compact-shelving storage in the sub-basement. The Hartley Conference Center is also located in Mitchell, with several small conference rooms, one registrar-controlled classroom (basement), and two other classrooms on the 3rd floor.

The Jerry Yang and Akiko Yamazaki Environment and Energy Building (Y2E2) (7,000 nsf)
The School of Earth Sciences has several programs in Y2E2, which is shared with other Stanford departments and programs related to environment and energy research. E-IPER (four staff and 25 PhD students) and Earth Systems (three staff and a large undergraduate community) are housed there along with departmental offices, nine faculty, a small number of graduate students, post docs, and staff for EESS.

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Advisory Board
Member Roster, 2013-14

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Lawrence Livermore National Laboratory

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Lilian Fandriana (MS ’79 PE)
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Stefan Heck (BS ’92 Symbolic Systems)

George M. Hornberger (PhD ’70 Hydro)
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Terry Huffington (BS ’77 Geo)
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Craig Jarchow (MS ’87, PhD ’91 Geo)
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Trident Capital

Kwaku Temeng (MS ’80, ENG ’82, PhD ’88 PE)
Director of Upstream
Aramco Services Company

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FACULTY				
Name	Start	Department	Title	Additional Information
Arrigo, Kevin R.	1999	EESS	Donald and Donald M. Steel Professor	Victoria and Roger Sant Co-Director, Earth Systems Program; Gerhard Casper University Fellow in Undergraduate Education
Aydin, Atilla	1991	GES	Professor (Research)	
Benson, Sally M.	2007	ERE	Professor (Research)	Director, Global Climate and Energy Project (GCEP); Senior Fellow, Woods Institute; Senior Fellow, Precourt Institute
Beroza, Gregory C.	1990	GP	Wayne Loel Professor	
Biondi, Biondo L.	1999	GP	Professor	Co-Director, Center for Computational Earth & Environmental Sciences (CEES)
Bird, Dennis K.	1982	GES	Professor	
Boyce, C. Kevin	2013	GES	Associate Professor	
Brandt, Adam	2012	ERE	Assistant Professor	
Brown, Gordon E., Jr.	1973	GES	Dorrell William Kirby Professor	Chair, Geological and Environmental Sciences; Professor, Department of Photon Science, SLAC
Caers, Jef K.	1999	ERE	Professor	
Casciotti, Karen	2011	EESS	Assistant Professor	
Chamberlain, Page	2001	EESS	Professor	
Diffenbaugh, Noah	2009	EESS/Woods	Associate Professor/Center Fellow	
Dunbar, Robert B.	1997	EESS	W.M. Keck Professor	Weintz University Fellow in Undergraduate Education; Senior Fellow, Woods Institute
Dunham, Eric	2009	GP	Assistant Professor	
Durlofsky, Louis J.	1998	ERE	Otto N. Miller Professor	
Ewing, Rod	2014	GES/CISAC	Frank Stanton Professor in Nuclear Security, FSI	Senior Fellow, Freeman Spogli Institute
Fendorf, Scott E.	1999	EESS	Terry Huffington Professor	Chair, Environmental Earth System Science; Senior Fellow, Woods Institute
Field, Chris	2008	EESS/BIO	Professor	Melvin and Joan Lane Professor for Interdisciplinary Environmental Studies; Director, Department of Global Ecology, Carnegie Institution; Senior Fellow, Woods Institute; Fellow, Precourt Institute
Francis, Chris	2003	EESS	Associate Professor	
Gerritsen, Margot G.	2001	ERE	Associate Professor	Director, Institute for Computational and Mathematical Engineering (ICME)
Gorelick, Steven M.	1988	EESS	Cyrus Fisher Tolman Professor	Senior Fellow, Woods Institute
Graham, Stephan A.	1980	GES	Welton & Maud L'Anphere Crook Professor	Associate Dean, Academic Affairs
Grove, Martin J.	2008	GES	Professor (Research)	

Harris, Jerry M.	1988	GP	Cecil and Ida Green Professor	Associate Dean, Multicultural Affairs
Hilley, George E.	2005	GES	Associate Professor	
Horne, Roland N.	1981	ERE	Thomas Davies Barrow Professor	Fellow, Precourt Institute
Jackson, Rob	2013	EESS	Michelle and Kevin Douglas Provostial Professor	Senior Fellow, Woods Institute and Precourt Institute
Kennedy, Julie	2011	EESS	Professor (Teaching)	Victoria and Roger Sant Co-Director, Earth Systems Program; Faculty Director, Haas Center; Landreth Family University Fellow in Undergraduate Educ
Klemperer, Simon L.	1990	GP	Professor	
Knight, Rosemary J.	2000	GP	George L. Harrington Professor	
Kovscek, Anthony R.	1996	ERE	Professor	Chair, Energy Resources Engineering
Lambin, Eric	2010	EESS	George and Setsuko Ishiyama Provostial Professor	Co-Chair, Environmental Earth System Science; Senior Fellow, Woods Institute
Lawrence, Jesse F.	2007	GP	Assistant Professor	
Loague, Keith	1994	GES	Professor	
Lobell, David	2009	EESS/FSI/Woods	Associate Professor/Senior Fellow	
Lowe, Donald R.	1987	GES	Max Steineke Professor	
Maher, Katharine	2007	GES	Assistant Professor	
Mahood, Gail A.	1979	GES	Professor	
Mao, Wendy Li-Wen	2007	GES/SLAC	Assistant Professor	
Matson, Pamela A.	1997	EESS	Chester Naramore Dean	Richard and Rhoda Goldman Professor of Environmental Studies; Bass University Fellow in Undergraduate Education; Senior Fellow, Woods Institute
Mavko, Gerald M.	1993	GP	Professor (Research)	
Miller, Elizabeth	1978	GES	Professor	
Mukerji, Tapan	2008	ERE	Associate Professor (Research)	
Naylor, Rosamond L.	2009	EESS/FSI/Woods	Professor	William Wrigley Senior Fellow, Freeman Spogli and Woods Institutes
Orr, Franklin M., Jr.	1984	ERE	Keleen & Carlton Beal Professor	Director, Precourt Institute for Energy; Senior Fellow, Woods Institute; Fellow, Precourt Institute
Payne, Jonathan	2005	GES	Associate Professor	
Pollard, David D.	1983	GES	Barney & Estelle Morris Professor	
Rajaratnam, Bala	2010	EESS/Statistics	Assistant Professor	
Segall, Paul	1989	GP	Professor	

Sleep, Norman H.	1979	GP	Professor	
Stebbins, Jonathan F.	1985	GES	Professor	Bass University Fellow in Undergraduate Education
Suckale, Jennifer	2014	GP	Assistant Professor	
Tchelepi, Hamdi	2003	ERE	Professor	Co-Director, Center for Computational Earth & Env Sciences (CEES)
Thomas, Leif N.	2008	EESS	Assistant Professor	
Vanorio, Tiziana	2013	GP	Assistant Professor	
Warren, Jessica	2010	GES	Assistant Professor	
Welander, Paula	2012	EESS	Assistant Professor	
Wilcox, Jennifer	2008	ERE	Assistant Professor	
Zebker, Howard A.	1995	GP/ELEC ENG	Professor	Chair, Geophysics
Zoback, Mark D.	1984	GP	Benjamin M. Page Professor	Fellow, Precourt Institute
February 2014. Emeritus (including those recalled to active duty), acting assistant, and consulting professors not listed.				

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Earth Sciences Council

Stephan Graham* (chair)
Associate Dean, Academic Affairs;
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Kevin Arrigo*
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Donald and Donald M. Steel Professor, Department of Environmental Earth System Science

Adam Brandt
Assistant Professor, Department of Energy Resources Engineering

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Cecil and Ida Green Professor, Department of Geophysics

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George and Setsuko Ishiyama Provostial Professor, Department of Environmental Earth System Science

Jonathan Payne
Associate Professor, Department of Geological and Environmental Sciences

Paul Segall*
Professor, Department of Geophysics

Jonathan Stebbins*
Professor, Department of Geological and Environmental Sciences

Peter Vitousek
Director, Emmett Interdisciplinary Program in Environment and Resources
Clifford G. Morrison Professor in Population and Resource Studies, Department of Biology

Howard Zebker*
Professor, Department of Geophysics

*core council member (core council members are responsible for appointment and promotion decisions; full council provides advice on hiring priorities and sets school strategic directions)

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Graduate Student Advisory Committee

Bryce Anzelmo (Energy Resources Engineering)
briz@stanford.edu

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Andy Stock (Emmett Interdisciplinary Program in Environment and Resources)
astock@stanford.edu

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Petroleum Investments Committee

The Petroleum Investments Committee (PIC) is a group of alumni volunteers who use their academic training and broad industry experience and expertise to manage the Petroleum Investments Funds (PIF). Established in 1953, the PIF is an endowment that invests in producing oil and gas royalties and other mineral and energy interests to provide discretionary income for use by the dean to support the teaching and research of the School of Earth Sciences—$1.628 million for the 2013 fiscal year. The principal value of the PIF has grown from about $4 million in 1996 to its current $48 million.

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Breitenbach Petroleum Corporation
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School of Earth Sciences
Stanford University

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BreitBurn Energy Company, LLC
Los Angeles, CA

John G. Leede
Leede Operating Company, LLC
Englewood, CO

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Consultant to the Stanford Management Company
Menlo Park, CA

Pamela A. Matson (*ex officio*)
Dean, School of Earth Sciences
Stanford University

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Denver, CO

Richard R. Mrlik
Intertie LLC
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Stephen C. Rose
Compass Rose Consulting
Vashon, WA

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Mike Dorsey, ’77

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Terry Huffington, ’77 (co-chair)

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Craig McCaw, ’72

Dirk McDermott, MS ’81, MBA ’91

John Moragne, MS ’83, MBA ’86 (co-chair)

Margaret Raffin, ’68

David Rogers, ’80, JD ’83

Gene Sykes, MBA ’84 (co-chair)

Heidi Welch, MBA ’90

Jane Woodward, MS ’83, MBA ’87

Julie Wrigley, ’71

Jerry Yang, ’90, MS ’90 (ex officio)

Gideon Yu, ’93

(as of 2/3/14)

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Office of the Dean
Pamela Matson, Dean
Associate Deans: Amy Balsom, Sue Crutcher, Stephan Graham, Jerry Harris and Rebecca Vogel

Departments

- Energy Resources Engineering (ERE) — *Tony Kovscek, chair*; *Sandy Costa, DM*
- Environmental Earth System Science (EESS) — *Scott Fendorf, chair*; *Robin Maslin, DM*
- Geological and Environmental Sciences (GES) — *Gordon Brown, chair*; *Lauren Nelson, DM*
- Geophyics (GP) — *Howard Zebker, chair*; *Csilla Csaplar, DM*

Interdisciplinary Degree Programs

- Earth Systems — *Kevin Arrigo, co-director*; *Julie Kennedy, co-director*; *Deana Fabbro-Johnston, prog. mgr.*
- Emmett Interdisciplinary Program in Environment & Resources (E-IPER) — *Peter Vitousek, director*; *Deborah Wojcik, assoc. director*

School-wide Centers & Facilities

- Center for Computational Earth & Envir Sciences (CEES) — *(Biondo Biondi & Hamdi Tchelepi)*
- Stable Isotope Biogeochemistry Facility (EMF 2) — *(Rob Dunbar & Page Chamberlain)*
- Geochronolgy/ Thermochronology Facility — *(Marty Grove)*
- Rock Preparation/ Mineral Separation Lab — *(Steve Graham)*
- Environmental Measurements Analytical Facility (EMF 1) — *(Scott Fendorf)*
- Isotopic and Geochemical Measurements & Analysis (SIGMA) — *(Kate Maher)*
- Spatial Analysis Center — *(Eric Lambin)*

School-wide Offices & Resources

- *Communications & Web (Nancy Peterson, Aaron Cole & Ker Than)*
- *Development & Alumni Relations (Rebecca Vogel, Cynthia Gori & Astrid Thompson)*
- *Educational Outreach (Jenny Saltzman)*
- *Human Resources and Faculty Affairs (Sue Crutcher)*
- *Finance (Jane Chen)*
- *Graduate Student Services (Roni Holeton)*
- *Health & Safety and Facilities Management (Felicia Morales & Tom Koos)*
- *Office of Multicultural Affairs (Jerry Harris & Tenea Nelson)*
- *Information Technology (Phil Farrell)*
- *Undergraduate & Field Education (Richard Nevle & Sara Cina)*

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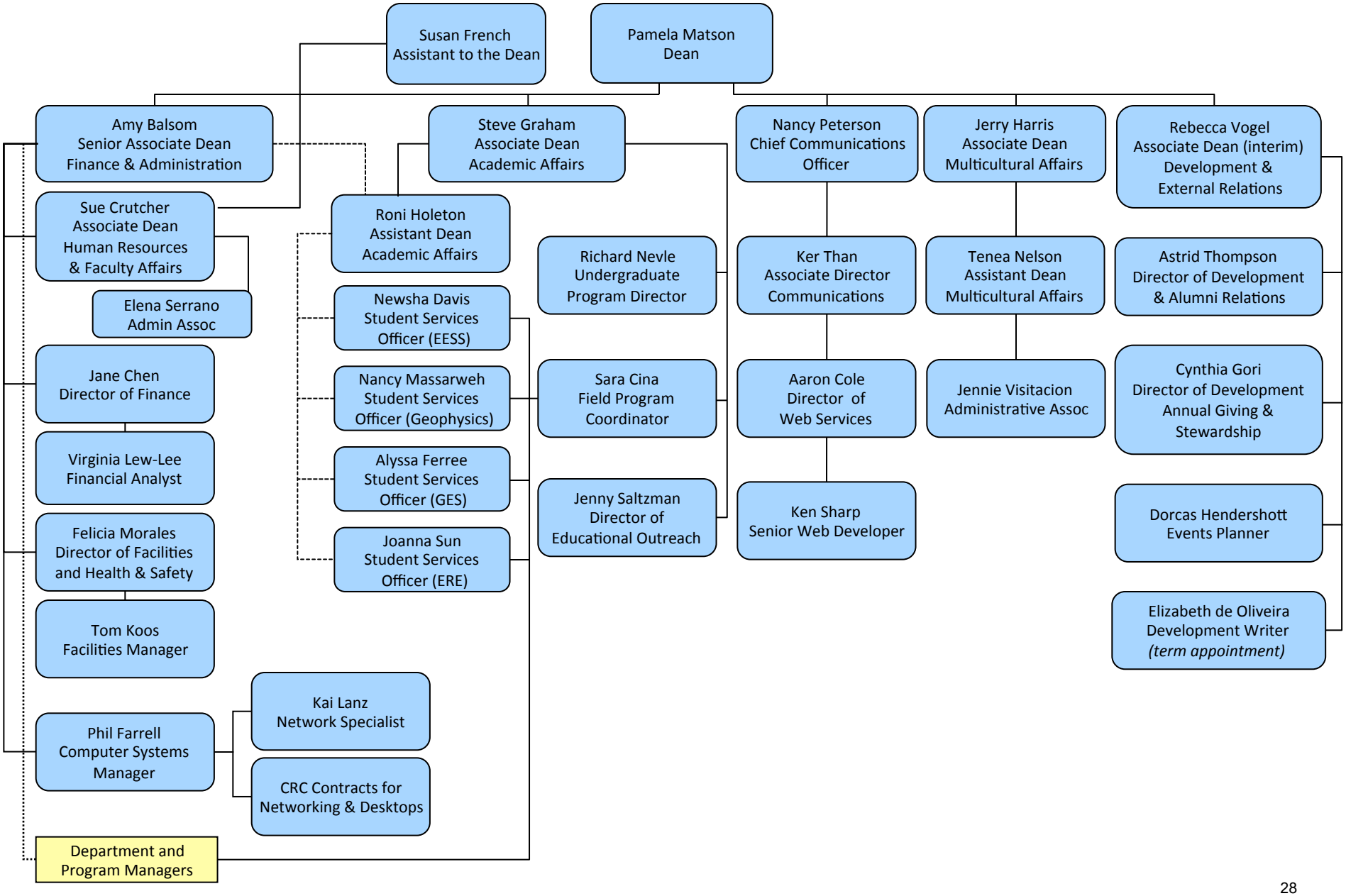
Office of the Dean and Central Services



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- Vaughn C. Williams, Of Counsel, Skadden Arps Slate Meagher & Flom, New York, NY
- Jerry Yang, AME Cloud Ventures, Palo Alto, CA

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MS and PhD Admissions

MS Admissions

	Applications					Admissions					% Admitted					Number Enrolled					% Admitted Who Enrolled				
	2009	2010	2011	2012	2013	2009	2010	2011	2012	2013	2009	2010	2011	2012	2013	2009	2010	2011	2012	2013	2009	2010	2011	2012	2013
GES	16	22	24	37	36	3	7	3	3	3	18.8%	31.8%	12.5%	8.1%	8.3%	2	3	2	2	3	66.7%	42.9%	66.7%	66.7%	100.0%
GP	8	14	14	20	32	2	3	1	4	4	25.0%	21.4%	7.1%	20.0%	12.5%	2	3	-	4	4	100.0%	100.0%	0.0%	100.0%	100.0%
ERE	98	115	140	172	184	19	9	10	22	17	19.4%	7.8%	7.1%	12.8%	9.2%	16	8	7	19	13	84.2%	88.9%	70.0%	86.4%	76.5%
E-IPER	25	39	34	38	N/A	24	35	33	35	N/A	96.0%	89.7%	97.1%	92.1%	N/A	24	28	18	33	N/A	100.0%	80.0%	54.5%	94.3%	N/A
EESS	10	23	19	35	36	-	1	-	4	1	-	4.3%	0.0%	11.4%	2.8%	-	1	-	4	1	-	100.0%	-	100.0%	100.0%
TOTAL	157	213	231	302	288	48	55	47	68	25	30.6%	25.8%	20.3%	22.5%	8.7%	44	43	27	62	21	91.7%	78.2%	57.4%	91.2%	84.0%

PhD Admissions

	Applications					Admissions					% Admitted					Number Enrolled					% Admitted Who Enrolled				
	2009	2010	2011	2012	2013	2009	2010	2011	2012	2013	2009	2010	2011	2012	2013	2009	2010	2011	2012	2013	2009	2010	2011	2012	2013
GES	74	54	75	68	73	15	13	24	11	12	20.3%	24.1%	32.0%	16.2%	16.4%	9	7	19	7	8	60.0%	53.8%	79.2%	63.6%	66.7%
GP	64	61	85	72	69	17	22	23	13	17	26.6%	36.1%	27.1%	18.1%	24.6%	8	11	16	8	10	47.1%	50.0%	69.6%	61.5%	58.8%
ERE	75	86	77	74	81	6	13	11	9	5	8.0%	15.1%	14.3%	12.2%	6.2%	6	10	11	8	5	100.0%	76.9%	100.0%	88.9%	100.0%
E-IPER	110	118	129	156	124	4	7	6	8	8	3.6%	5.9%	4.7%	5.1%	6.5%	3	6	5	6	6	75.0%	85.7%	83.3%	75.0%	75.0%
EESS	38	77	108	97	90	5	11	21	8	9	13.2%	14.3%	19.4%	8.2%	10.0%	2	7	16	2	8	40.0%	63.6%	76.2%	25.0%	88.9%
TOTAL	361	396	474	467	437	47	66	85	49	51	13.0%	16.7%	17.9%	10.5%	11.7%	28	41	67	31	37	59.6%	62.1%	78.8%	63.3%	72.5%

Notes: *The MS degree is required in Energy Resources Engineering before entering Ph.D. program.*
E-IPER joint master's program admissions is in progress until February
GES = Dept of Geological and Environmental Sciences; GP = Dept of Geophysics; ERE = Dept of Energy Resources Engineering (formerly Petroleum Enginering);
E-IPER = Emmett Interdisciplinary Program in Environment and Resources; and EESS = Dept of Environmental Earth System Science

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Undergraduate and Graduate Enrollment

Undergraduate Enrollment, Fall Quarter, 2013-14

	Total Students	# Women	% Women	# URG	% URG	# INTL	% INTL
Earth Systems	96	59	61.46%	20	20.83%	4	4.17%
Energy Resources Engineering	10	5	50.00%	2	20.00%	2	20.00%
Geological & Environmental Sciences	13	7	53.85%	5	38.46%	1	7.69%
Geophysics	3	1	33.33%	0	0.00%	0	0.00%
TOTALS	122	72	59.02%	27	22.13%	7	5.74%

Graduate Enrollment, Fall Quarter, 2013-14

	Total Students	# Women	% Women	# URG	% URG	# INTL	% INTL
Earth Systems	23	18	78.26%	4	17.39%	1	4.35%
Earth, Energy & Environmental Sciences	1	0	0.00%	0	0.00%	1	100.00%
Environmental Earth System Science	53	27	50.94%	4	7.55%	6	11.32%
Energy Resources Engineering	96	20	20.83%	5	5.21%	71	73.96%
Geological & Environmental Sciences	67	35	52.24%	5	7.46%	14	20.90%
Geophysics	78	32	41.03%	2	2.56%	43	55.13%
E-IPER	79	39	49.37%	2	2.53%	5	6.33%
TOTALS	397	171	43.07%	22	5.54%	141	35.52%

URG=African American;Hispanic American; American Indian/Native American (US citizens & permanent residents)
INTL= International (non-US citizens)

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Degrees Awarded

	GES			GP			ERE			ESYS		E-IPER		EEES		EESS	
	BS	MS	PhD	BS	MS	PhD	BS	MS/ENG	PhD	BS	MS	MS	PhD	MS	PhD	MS	PhD
1999-00	5	5	7		19	6		16	5	30	12						
2000-01	6	5	13		9	11		15	2	25	15						
2001-02	4	9	9		10	10		17	9	25	13						
2002-03	2	4	16	1	7	5		21	6	14	8						
2003-04	6	6	16	1	13	8		19	1	30	15		1				
2004-05	16	11	18		4	12		14	9	36	20						
2005-06	11	3	19		9	6		15	4	20	12						
2006-07	8	8	16		7	12		13	8	22	15	1	3		1		
2007-08	7	6	12		6	11	1	10	5	26	10	3	2		1		
2008-09	4	1	17		8	4		18	6	24	14	6	6		2		
2009-10	9	12	10	2	5	3	3	14	7	34	15	9	4		3	2	3
2010-11	4	2	5		6	9	5	27	3	40	30	17	3		1	1	3
2011-12	5	2	14		4	4	2	24	5	28	26	9	3				2
2012-13	3	4	10	1	5	6	1	12	15	33	21	12	6		2		1

TOTALS

	BS	MS/ENG	PhD
1999-00	35	52	18
2000-01	31	44	26
2001-02	29	49	28
2002-03	17	40	27
2003-04	37	53	26
2004-05	52	49	39
2005-06	31	39	29
2006-07	30	44	40
2007-08	34	35	31
2008-09	28	47	35
2009-10	48	57	30
2010-11	49	83	24
2011-12	35	65	28
2012-13	38	54	40

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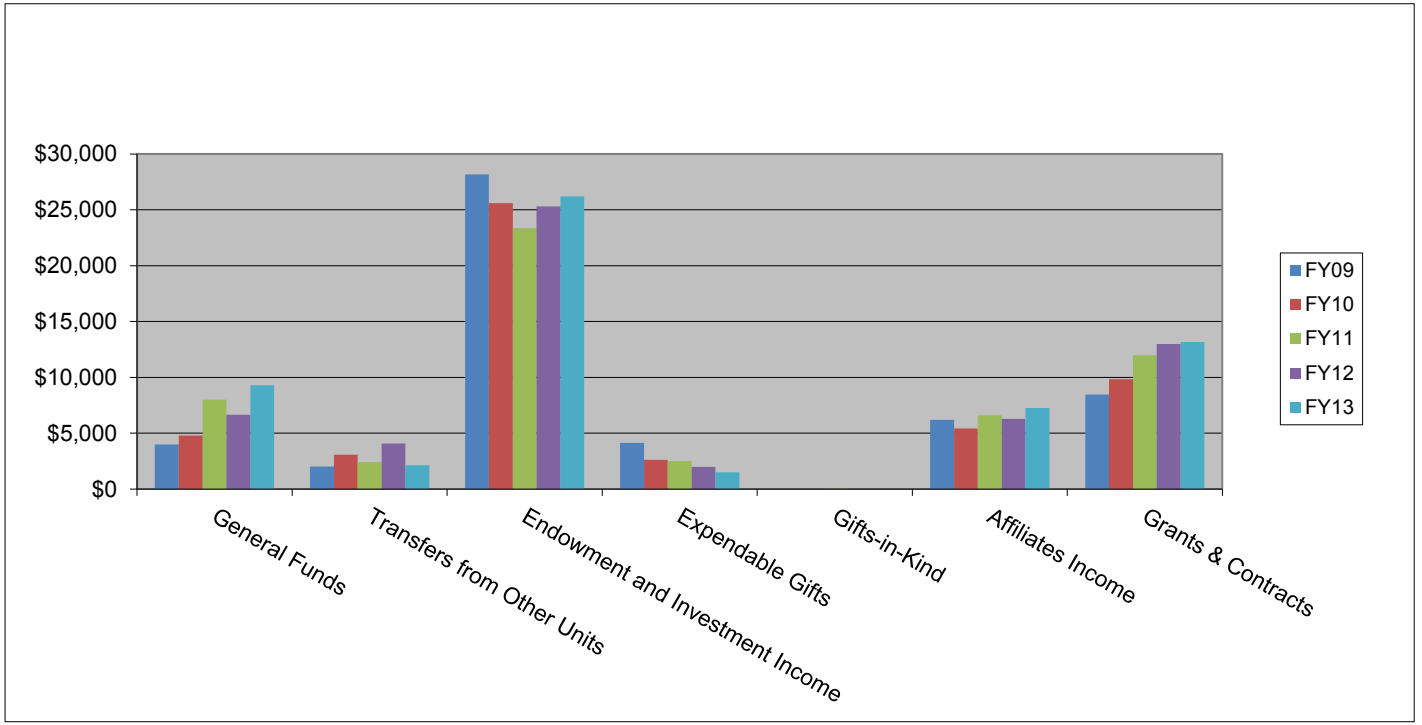
5 Year Revenue, FY09 - FY13
($ in 000's)

	FY09	FY10	FY11	FY12	FY13
General Funds	$4,003	$4,784	$8,005	$6,662	$9,284
Transfers from Other Units	$2,017	$3,081	$2,424	$4,066	$2,127
Endowment and Investment Income	$28,165	$25,602	$23,366	$25,297	$26,204
Expendable Gifts	$4,145	$2,604	$2,511	$1,995	$1,490
Gifts-in-Kind			$25		
Affiliates Income	$6,183	$5,411	$6,596	$6,273	$7,258
Grants & Contracts	$8,456	$9,822	$11,981	$12,975	$13,155
Total	**$52,969**	**$51,303**	**$54,908**	**$57,269**	**$59,518**



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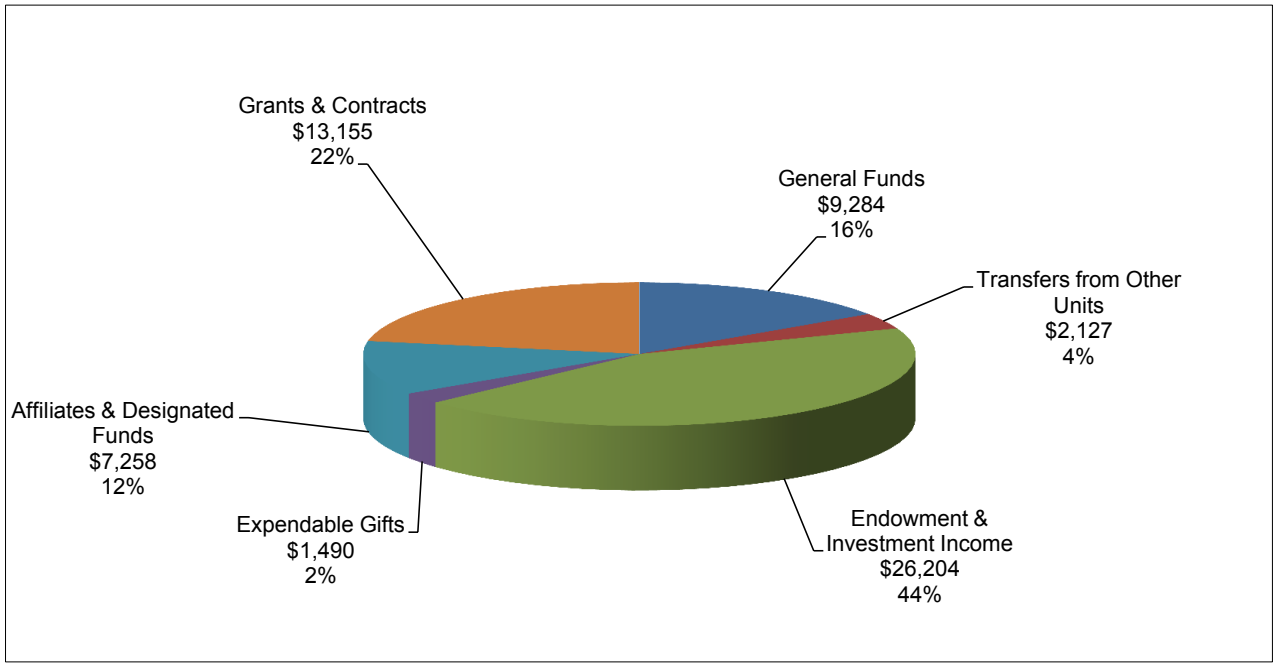
FY13 Revenue
($ in 000's)

General Funds	$9,284
Transfers from Other Units	$2,127
Endowment & Investment Income	$26,204
Expendable Gifts	$1,490
Affiliates & Designated Funds	$7,258
Grants & Contracts	$13,155
Total	**$59,518**



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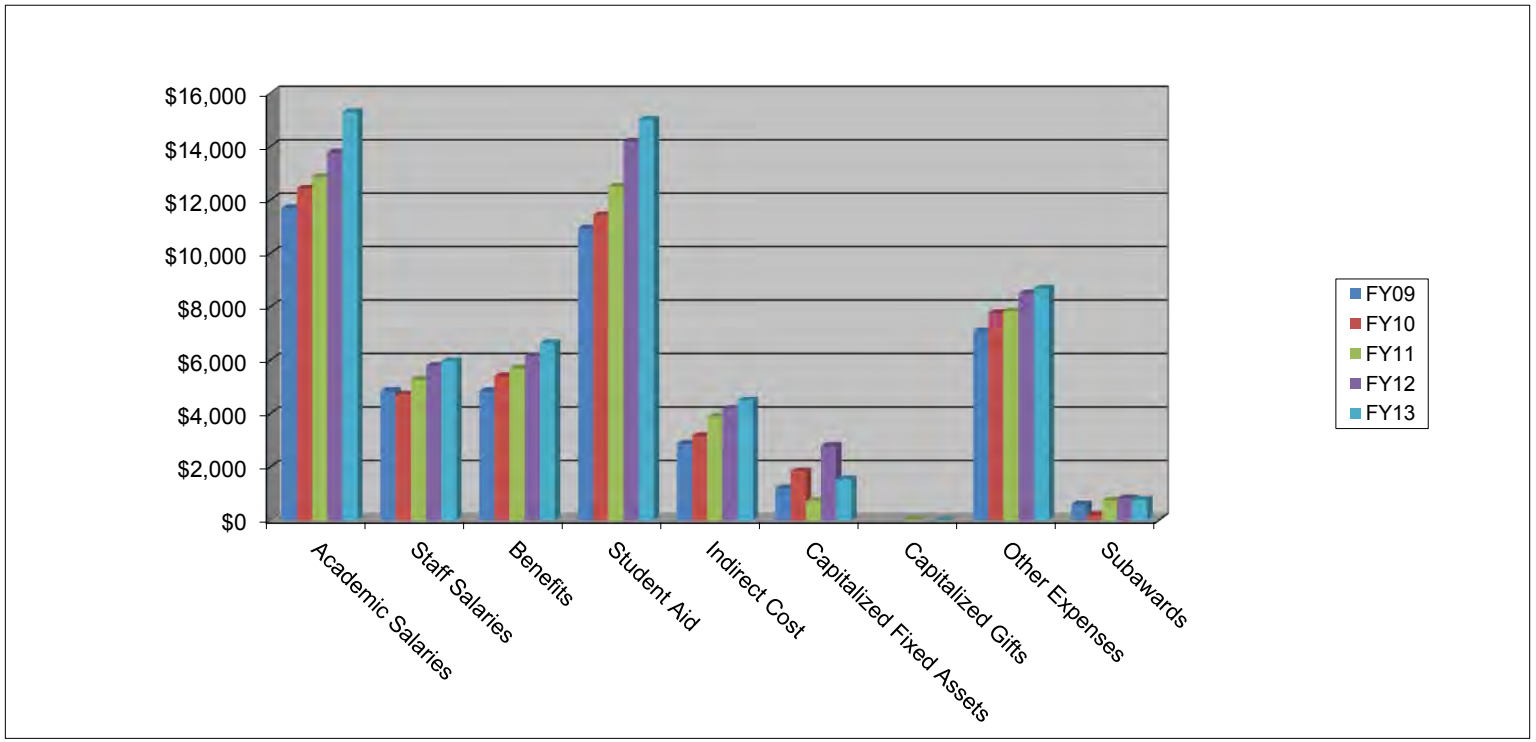
5 Year Expenses, FY09 - FY13
($ in 000's)

	FY09	FY10	FY11	FY12	FY13
Academic Salaries	$11,692	$12,423	$12,858	$13,777	$15,281
Staff Salaries	$4,836	$4,712	$5,277	$5,782	$5,960
Benefits	$4,842	$5,398	$5,692	$6,143	$6,632
Student Aid	$10,928	$11,430	$12,504	$14,179	$15,001
Indirect Cost	$2,869	$3,152	$3,882	$4,177	$4,489
Capitalized Fixed Assets	$1,201	$1,834	$725	$2,787	$1,530
Capitalized Gifts			$25		$7
Other Expenses	$7,074	$7,765	$7,831	$8,499	$8,686
Subawards	$589	$198	$730	$818	$778
Total	**$44,031**	**$46,912**	**$49,524**	**$56,160**	**$58,363**



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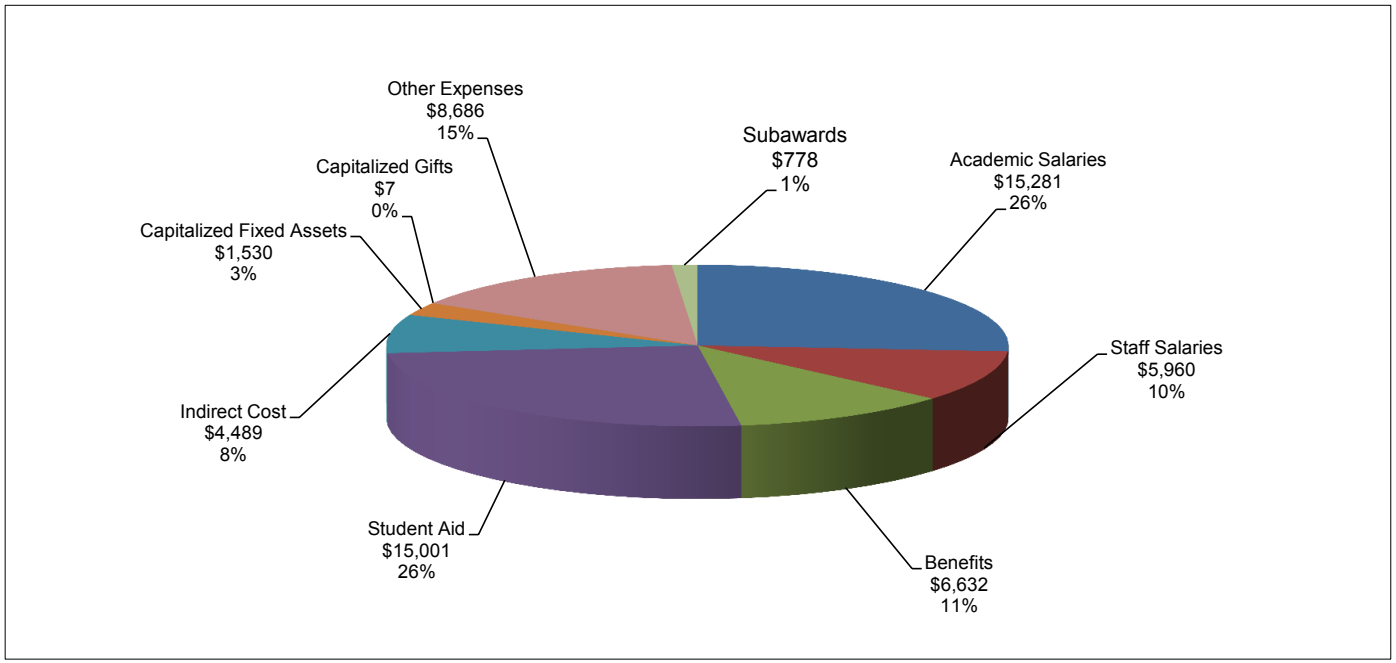
FY13 Expenses

($ in 000's)

Academic Salaries	$15,281
Staff Salaries	$5,960
Benefits	$6,632
Student Aid	$15,001
Indirect Cost	$4,489
Capitalized Fixed Assets	$1,530
Capitalized Gifts	$7
Other Expenses	$8,686
Subawards	$778
Total	**$58,363**



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Alumni Relations

Receptions in association with professional conferences

Each year, the School of Earth Sciences (SES) hosts alumni receptions in association with professional conferences. SES provides light refreshments, and the dean (or another faculty member) provides school highlights and participates in Q&As. As conference attendance is not required, all SES alumni in the area are invited to participate. Dates below are tentative, based upon conference schedules for FY15 (September 1, 2014 – August 31, 2015).

- Geological Society of America (GSA)
  Conference runs Oct. 19-22, 2014 – Vancouver, BC, Canada (reception TBD)
- Society of Exploration Geophysicists (SEG)
  Monday, October 27, 2014 – Denver, CO
- Society of Petroleum Engineers (SPE)
  Conference runs Oct. 27-29, 2014 – Amsterdam, The Netherlands (reception TBD)
- American Geophysical Union (AGU)
  Monday, December 15, 2014 – San Francisco, CA
- North American Prospect Expo (NAPE)
  Thursday, Feb. 12, 2015 – Houston, TX
  (hosted by SES in conjunction with Petroleum Investments Committee)
- American Association of Petroleum Geologists (AAPG)
  Monday, June 1, 2015 – Denver, CO

Dean Matson at Stanford+Connects Minnesota

Professor Rob Dunbar at Stanford+Connects LA

Stanford+Connects events

Stanford+Connects is a 16-city world tour that brings President Hennessy, faculty, and students to our alumni community—both in person and online. This event series is produced by the Stanford Alumni Association. For more information, please visit http://stanfordconnects.stanford.edu/.

*Note: in certain cities SES will hold small alumni donor dinners, as appropriate.

Published dates and locations to date include:

- New York, NY on Saturday, September 27, 2014
- Seattle, WA on Saturday, November 1, 2014
- San Diego, CA on Saturday, November 8, 2014

University-wide events

- TEDx Stanford (https://tedx.stanford.edu/) – Saturday, May 10, 2014
  Includes presentations by SES faculty members Margot Gerritsen and Noah Diffenbaugh

- Reunion Homecoming – Friday, October 24, 2014
  SES hosts an alumni reception on Friday. Our faculty also participate in 'Classes without Quizzes' and lead campus tours.

- Parents' Weekend – February 27-28, 2015
  SES traditionally leads the 1906 Earthquake Tours.

- Commencement – Sunday, June 14, 2015
  SES holds a diploma granting ceremony.

Stanford Earth Sciences on-campus events

Alumni Relations is making an effort to inform and extend personal invitations to local alumni, donors, and friends to the following campus events.

- Earth Matters Lectures –a quarterly series co-sponsored by the School of Earth Sciences and Stanford Continuing Studies

    - Mark Zoback - Is fracking the blue bridge to a green future?
      http://www.youtube.com/watch?v=Kypbngpeqwg&list=PLk090owzLY7eIj9YNMf8dkVOcJuKzKaCa

    - Rob Dunbar - Antarctic Mysteries: Icy Clues to Earth's Past, Present and Future
      http://www.youtube.com/watch?v=nndQaY_ZrVk&list=PLk090owzLY7eIj9YNMf8dkVOcJuKzKaCa

    - Upcoming on April 22, 2014: Roz Naylor - Feeding the World in the 21st Century

- SES Distinguished Lectures

    - George Hilley - A Beautiful, Hazardous Haven: The Shaping of the Santa Cruz Mountains
      http://www.youtube.com/watch?v=md7XBZRV61g&list=PLk090owzLY7cQfxQq1oOj8qXj9EO7wAge

    - Ross Stein - Earthquake Interaction on the Scale of a Fault to the Planet
      http://www.youtube.com/watch?v=aiVWzDwiXlI&list=PLk090owzLY7cQfxQq1oOj8qXj9EO7wAge

Stanford Earth Sciences Faculty off-campus events

Alumni Relations is planning for a new alumni event series that will bring SES faculty to alumni communities. We plan to pilot the first event in Houston in FY15.

Alumni communications

Alumni Relations worked initially with Communications in the planning phases to launch the school's new electronic alumni newsletter, *Earth Matters* (which is the revamp/combination of the *Earth Scientist* and our monthly email updates). Our objective is to reach, inform, and engage priority audiences at a new level with vivid, high quality content. Our audience includes alumni, faculty, students, staff, prospective students, the broader campus community, and current and prospective donors. The first electronic issue launched Fall 2013 and can be viewed at http://pgnet.stanford.edu/SmartMail/htmlPreview?mode=html&rtacode=315404.

Stanford
SCHOOL OF
EARTH SCIENCES

Energy Resources
Engineering

Full-time faculty: 11
Chair: Anthony Kovscek
Degrees: MS & PhD, Energy Resources Engineering or Petroleum Engineering
BS, Energy Resources Engineering
Home: Green

Energy Resources Engineering at Stanford focuses on the design of processes for energy production and energy transformations, and the long-term storage of energy byproducts such as carbon dioxide.

ERE research on the design of subsurface processes covers:

- Characterization of the spatial distribution of formation properties
- Experimental investigations of flow behavior
- Computational and analytical modeling of flow
- Selection and implementation of methods for enhancing fluid recovery or long-term storage
- Understanding the environmental aspects of resource production
- Optimization of process performance

Other areas of focus include:

- Clean energy conversions (e.g., clean coal)
- Geothermal engineering
- Energy systems modeling and optimization
- Marine energy systems, large-scale solar, and other renewable energy resources

The department operates experimental facilities for research on:

- Carbon dioxide capture and storage
- Clean energy conversions
- Enhanced oil recovery processes
- Geothermal reservoir engineering

ere.stanford.edu

Chair's Report

The past year has been an active and eventful one in the Department of Energy Resources Engineering. Admission into our graduate program remains highly sought after for both energy resources engineering and petroleum engineering degrees. We began the school year with 118 students in total; there are currently 92 graduate and 13 undergraduate students because graduations have reduced our numbers somewhat. On the undergraduate side, we have a cohort of 5 seniors graduating in June—our largest graduating class since the BS in ERE has been offered. We continue to try to grow our undergraduate program to about 20 students, but feel that we reached critical mass several years ago.

Our students continue to be a well-recognized and celebrated group. After finishing first at the Society of Petroleum Engineers (SPE) Western Region Student Paper Contest, Hamza Aljamaan and Obi Isebor went on to compete in the respective MS and PhD international contests. Obi garnered a first place finish and Hamza a second place finish. Additionally, Kyoungjin Lee won a student poster award at the School of Earth Sciences Research Review. Abdulrahman Manea and Sumeet Trehan both won Centennial Teaching Assistant Awards in recognition of their work in *Energy 223: Reservoir Simulation*.

This past year saw the establishment of the Stanford–Chevron Reservoir Imaging, Characterization and Simulation Center of Research Excellence (CoRE). The center involves departments from across the school and ERE expects to play a large role. We plan to develop cooperative research projects and the CoRE is expected to provide funding for graduate students, postdoctoral researchers, and research associates. The initial period is four years, with the possibility of extension beyond that time frame.

Turning to faculty news, I am pleased to report that Jef Caers was recently promoted from associate professor to professor. Promotion to full professor is a significant step signifying that the recipient is among the very best individuals in their field in both scholarship and scholarly contributions. Jef's recent book, *Modeling Uncertainty in the Earth Sciences,* continues to receive critical acclaim. Congratulations to Jef on both counts.

In November the White House announced that Lynn Orr was nominated by President Obama to serve as Under Secretary for Science at the U.S. Department of Energy. Lynn would be responsible for overseeing all of the energy and science research programs in the Department of Energy, including the majority of the national laboratories. Lynn is currently waiting to be confirmed by the U.S. Senate. If confirmed, Lynn will step down from his post as the director of the Precourt Institute for Energy, which he has led since the institute was created in 2009, and he will retire from Stanford. You will recall that Lynn served as dean of the School of Earth Sciences from 1994-2002.

In February, Roland Horne convened the 39th annual Stanford Geothermal Workshop. Interest in geothermal energy remains strong, not only in the U.S., but also worldwide. This year the workshop attracted 278 attendees from 25 countries and 152 papers were presented. Until the last few years, the workshop had attracted only 120-150 people from roughly 13 countries.

Margot Gerritsen, director of the Institute for Computational & Mathematical Engineering (ICME), is organizing the Society for Industrial and Applied Mathematics Conference on Geosciences to be held on campus in 2015. Five hundred attendees are expected. In collaboration with ICME, we now have the "HIVE," a new visualization center built in partnership with the Army High Performance Computing Research Center and software and services provider SAP. The HIVE allows collaborative visualization in teaching and research across the sciences, social sciences, and engineering. The official opening is coming soon.

In 2013, Sally Benson coauthored a paper in *Energy and Environmental Sciences* with postdoctoral fellow Charlie Barnhart. The paper, which explored how much energy is required to build storage on future power grids that are heavily supplied by renewable resources, earned the distinction of being that journal's most-downloaded article for two quarters. Lou Durlofsky received a 2013 IBM Faculty Award. Jen Wilcox reports that her book, *Carbon Capture*, is doing well with over 4500 e-book downloads, 2000 hard copy sales, and a Mandarin translation through the Chinese Electricity Press.

Anthony R. Kovscek
Professor and Chair

Stanford
SCHOOL OF
EARTH SCIENCES

Environmental Earth
System Science

Full-time faculty:	18
Chairs:	Scott Fendorf, Terry Huffington Professor
	Eric Lambin, George and Setsuko Ishiyama Provostial Professor
Degrees:	MS & PhD
Home:	Y2E2 (EESS faculty are also located in Geology Corner and Green)

Faculty and students in the Department of Environmental Earth System Science work to understand, predict, and respond to human-caused environmental change at local to global scales. They investigate the complexity of the global system, including the interactions, synergies, and feedbacks that link the oceans, atmosphere, land surfaces, and freshwater systems.

A global perspective has emerged that challenges the research community to view and study the planet as a singular, highly-interactive system, moving past disciplinary approaches to evaluate the interactions among chemical, biological, and physical processes across the Earth's surface. Through graduate and undergraduate programs, EESS trains a new generation of scientists who comprehend the multiple facets of environmental processes, and who are able to think synthetically, evaluating change in our oceans, water, air, and land processes as part of an integrated and connected system.

Research areas include:

- Hydrogeology
- Ocean circulation
- Land use change
- Sustainable food and water practices
- Climate, tectonics, and landscape evolution
- Climate and Earth system dynamics
- Ocean and land system biogeochemistry
- Microbial ecology
- Geostatistics

eess.stanford.edu

Chairs' Report

This year, two of us are writing the annual chairs' report. Our department innovates by having two co-chairs, Scott Fendorf and Eric Lambin. While Scott keeps a lead role during the summer and fall quarters, Eric takes the lead during the winter and spring quarters. However, given a very busy period at the start of 2014, having two co-chairs has proven to be a very useful arrangement. Our department is currently involved in two faculty searches—one joint with GES for (up to) two new positions in geobiology, and one joint with the Center for Ocean Solutions of the Woods Institute for the Environment on human-environment interactions in coastal zones. During fall and winter quarters, we hosted applicants on campus to interview and give one or two talks each, and we hope to conclude our deliberations in spring quarter.

We are also actively preparing for the external review of our department. Four selected experts will visit the department in mid-April, and we are now assembling a detailed "self-study" file that includes our most current vision of our mission and vision statements, achievements, challenges, and questions. It also includes results from a survey of all our past PhD students and postdoctoral fellows. Finally, our department is responding to opportunities to include more expertise and diversity in both the professorial and graduate student ranks.

EESS continues to grow. Rob Jackson joined the department this winter, coming from Duke University. Rob is the Michelle and Kevin Douglas Provostial Professor, appointed jointly between our department, the Woods Institute for the Environment, and the Precourt Institute for Energy. Rob's team does basic and applied research on carbon, water, and nutrient cycling; plant and microbial ecology; and global change. Recently he has led efforts to define the hazards invoked by hydraulic fracturing on groundwater quality and methane emissions. The goal of Rob's research is to build predictive scientific frameworks that help guide policy solutions for global warming and other environmental problems. He uses the tools of molecular biology, biogeochemistry, and environmental sciences. Rob is a true interdisciplinary Earth system science scholar and we all look forward to interacting with him.

We are excited to note that, in spring 2013, Noah Diffenbaugh and David Lobell were promoted to the rank of associate professor with tenure. Continuing to mentor and review the progress of our junior faculty as they move towards tenure remains one of our primary priorities.

In the coming year, we will be initiating a new faculty search on processes shaping land-water resources. These new positions add important strength to our department, and are often a response to new opportunities. It is equally important for the future of EESS to expand in directions that our department has identified as being crucial for Earth system science, such as the study of the cryosphere, atmosphere, and human-environment interactions. We are also continuing a strategy initiated last year to increase the diversity of our department at all levels, whereby we seek to establish a diverse and vibrant community through new hires, student recruitment, and both short- and long-term visitors.

Although we are growing and evolving, our mission remains to discover and disseminate knowledge about the Earth system, with a vision of understanding, predicting, and responding to human-caused and natural environmental change at local to global scales. It becomes increasingly clear that the combination of expertise we have assembled in our department invents a new way to conduct Earth system science. While none of us develops global-scale, integrated models, we all conduct detailed research on regional scale processes that influence the functioning of the Earth system. While some of us study one Earth system component by integrating multiple disciplinary perspectives and methods (e.g., field experiments, remote sensing, and regional modeling), others focus on the interactions between multiple Earth system components (e.g., through biogeochemical cycles). We maintain a portfolio of research themes that reaches beyond fundamental research on biophysical processes to larger issues related to global environmental change that have a high societal relevance and integrate the human dimension. These include food security, vulnerability of freshwater systems, adaptation to climate change, and the impact of globalization on land use changes.

Graduate and Undergraduate Education

We continue to dedicate a lot of energy to the selection and recruitment of the best applicants to our graduate program. The pool of applicants is steadily growing, with more than 125 applications received this year, many of them from outstanding young scientists. Analyzing each of these files, inviting the best candidates to campus for a two-day interview, and making attractive offers to selected applicants is a demanding process, and yet crucial for achieving our education and research missions.

We also continue to evolve our curriculum, with the direct involvement of a number of our faculty, as well as with the input of interested students. And we are ever striving to evolve and improve our three introductory classes for the core graduate program. They are designed to equip our PhD students with common tools and concepts, and help them to develop an Earth system science approach. While each individual PhD project is likely to focus in great depth on a small piece of the Earth system puzzle, it is essential that our students develop a clear understanding of how their research fits in the bigger picture, as well as develop a strong rapport with their fellow students. After a couple of years of trial-and-error, we have achieved a good balance of useful content (without overburdening the students who are keen to embark on their research projects) coupled with excellent delivery (as noted by both the opinion of the instructors and the student evaluations). The courses required for first-year students include *Environmental Modeling*, *Measurements in Earth Systems*, and *Earth System Dynamics*. The first-year requirements are followed by a flexible graduate program that is tailored by the graduate committee to a student's research focus. Consultation with the student's advisor, in concert with oversight by the departmental graduate reporting structure ensures the rigor and continuity of students' curriculum.

EESS is strongly associated with the Earth Systems Program, a recognized model for interdisciplinary education. Earth Systems engages faculty throughout the university in the teaching of global environmental challenges, integrated Earth systems processes, sustainable practices, and solutions to environmental problems. The faculty in EESS also play an important role in the program, by teaching several of the undergraduate courses in the program, serving as

advisors of Earth Systems students, and working closely with the program directors, Julie Kennedy and Kevin Arrigo, to ensure a seamless integration of the program with the department.

In addition to thinking of the Earth Systems undergraduate and coterminal master's program as an extension of our EESS identity, faculty in EESS also reach out and contribute to undergraduate education across campus. Several of our faculty offer Freshman Seminars and Sophomore College trips, and they are also branching out into overseas experiential learning through the Bing Overseas Studies Program. This opportunity to reach the undergraduate population is important to our mission, and also serves to increase our visibility across campus. Further, our graduate students are heavily involved in program development, which provides them with an invaluable educational experience.

Another important component of our department community is our postdoctoral scholar cohort, which has shown considerable growth over the past few years. Currently, 75 percent of our faculty have at least one postdoc in the group and EESS now benefits from the efforts of 20-25 postdocs at any given time. In order to incorporate their presence into the department, we support a student-organized weekly seminar, at which graduate students and postdocs present their work, with each group benefitting from the ideas and experience of the others. These seminars have proven to be very effective as a community-building mechanism within EESS.

Faculty Composition and Endeavors

The department is composed of 18 regular faculty and 4 highly engaged courtesy faculty: Kevin Arrigo, Karen Casciotti, Page Chamberlain, Noah Diffenbaugh (joint with the Woods Institute), Rob Dunbar, Scott Fendorf, Chris Field (joint with biology), Chris Francis, Steve Gorelick, Robert Jackson (joint with the Woods Institute and the Precourt Institute), Julie Kennedy (Teaching), Eric Lambin (joint with the Woods Institute), David Lobell (joint with the Woods Institute and FSI), Pam Matson, Roz Naylor (joint with the Woods Institute and FSI), Bala Rajaratnam (joint with statistics), Leif Thomas, and Paula Welander. Our courtesy faculty appointments are: Ken Caldeira. Greg Asner, and Anna Michalak (all from the Carnegie Institution, Global Ecology Department), and Peter Vitousek (Biology Department).

Faculty in EESS have made remarkable advances in teaching and research, and their efforts have been recognized in numerous ways. Here are a few brief updates.

Kevin Arrigo continues his research looking at the impact of climate variability and climate change on rates of marine primary productivity in both the Arctic and Antarctic. While last year's exploration took him north to the Bering Sea, this year his research group participated in a 66-day Antarctic research cruise (Phantastic) to study Antarctic phytoplankton. In the coming year he plans to expand his work in new directions, as influenced by EESS colleagues working on the marine nitrogen cycle and small scale ocean physics. This past year Kevin was named the Donald and Donald M. Steel Professor in Earth Sciences, in recognition of his contributions in ocean science, education, leadership, and service to the university.

Karen Casciotti continued her investigations using stable isotope technology to examine nitrogen cycle biogeochemistry in oceans, tracking the rise in anthropogenic nitrogen deposition to terrestrial and marine ecosystems. She is developing unique approaches to studying

biogeochemical processes at different ocean depths, in diverse locations ranging from the eastern tropical South Pacific to our local Monterey Bay. Karen serves on the AGU/Ocean Sciences Section Executive Committee and the U.S. GEOTRACES Steering Committee, which provides opportunities for Stanford visibility within these organizations.

Page Chamberlain was elected an American Geophysical Union Fellow in 2013. He was lauded for "his pioneering application of stable isotopes across the geophysical sciences." With co-author Kate Maher (GES), Page has a paper in press in the journal *Science* titled "The Hydrologic Regulation of Chemical Weathering and the Geologic Carbon Cycle," which provides the first model that illustrates the limits of chemical weathering feedback to the global carbon cycle. Page also established a formal agreement between the School of Earth Sciences and the Senckenberg Biodiversity and Climate Change Research Institute in Germany. This agreement will facilitate collaborations between the school and institute in climate change and biodiversity and encourage the exchange of students, post-doctoral fellows, and faculty.

Noah Diffenbaugh served as a lead author of the forthcoming Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), and on a National Academy of Sciences committee evaluating the impact of the U.S. tax code on greenhouse gas emissions. Among other contributions, he led papers showing that: 1) continued global warming is likely to drive robust increases in the number of days that support severe thunderstorms in the U.S. (published in the *Proceedings of the National Academy of Sciences*); and 2) the global warming that has already occurred has quadrupled the likelihood of record heat like that experienced by the Midwest and Northeast in summer 2012. Additionally, he collaborated with Chris Field on a review of ecologically critical terrestrial climate change, which was published as the lead article in a special issue of *Science*. He also began service as director of the Goldman Honors Program in Environmental Science, Technology and Policy, an interdisciplinary honors program for seniors from majors across campus. In September 2013 he provided testimony to the Safe Climate Caucus of the U.S. House of Representatives.

Rob Dunbar's work is far ranging. Some highlights this past year include analysis of the speed at which the Antarctic ice sheet can retreat and melt during rapid climate transitions, estimated rates of calcification and primary production for coral reefs based on ocean physics and chemical methods developed at Stanford, and several pieces highlighting conservation opportunities and efforts in the tropical Pacific. He also continues to supervise the Stanford Isotopic Biogeochemistry Lab (SIBL) with Page Chamberlain, and he maintains a large stock of oceanographic equipment, including a 12.5-meter research vessel currently based in southern Chile. Rob has also developed and led off-campus seminars geared towards the undergraduate experience, including this past year a Sophomore College offering in Sitka, Alaska, and a Bing Overseas Seminar in Palau. He was also elected board chair for the Consortium for Ocean Leadership, which represents the broader U.S. ocean sciences community.

Scott Fendorf now serves as co-chair of the department with Eric Lambin. He also is the faculty director of the school's Environmental Measurements I facility. He served as chair of the Soil Chemistry Division of the Soil Science Society of America this past year and is completing a three-year rotation in that position. He continues a collaborative agreement between the school and the China University of Geosciences–Wuhan (host of the International University Consortium in Earth Science, of which Stanford is a founding member.) He hosted a delegation

from China in February. Scott also received the Soil Science Society of America Research Award and an outstanding postdoctoral mentoring award from Stanford.

Chris Field continues investing time at Stanford as a member of our faculty, as the director of the Carnegie Institution's Department of Global Ecology, and as faculty director of the Jasper Ridge Biological Preserve. In addition to his campus teaching and research activities, Chris is involved nationally as a lead player in Working Group II of the Intergovernmental Panel on Climate Change. His accolades of the past year include the Max Planck Research Award 2013 for research that builds bridges between field trials, lab studies, and global analysis. He was also awarded the 2014 BBVA Foundation Frontiers of Knowledge Award, in the climate change category, for his fundamental contributions to understanding interactions between the dynamics of plants and land ecosystems and carbon dioxide released through human activities.

Chris Francis is currently co-chairing the second leg of the geobiology initiative faculty search, jointly run between EESS and GES. Two new faculty members (Welander, Boyce) were hired through the first leg of the search, and a total of 10 candidates will be interviewed during the second phase, ongoing this winter quarter (2014). This past year he also served on the coastal–human environment systems faculty search committee, which is nearing the conclusion of the interview and evaluation phase. He also continues to co-direct/teach the prestigious Hopkins microbiology course—an intensive, 4-week summer course held at Hopkins Marine Station. The course has now been taught for eight consecutive years. Among Chris's honors in 2013–14 was the invitation to give the annual C.B. Van Niel Memorial Lecture at Hopkins Marine Station. He also co-organized the "Populations and Activity of Ammonia-Oxidizing and Denitrifying Organisms in Coastal Waters" session at the Association for the Sciences of Limnology and Oceanography 2013 Aquatic Sciences Meeting in New Orleans.

Steve Gorelick launched a large, international, and multi-institution program, Integrated Analysis of Freshwater Resources Sustainability, in Jordan. Funded by an international consortium of science-funding agencies, this effort is programmed to continue for three years. It focuses on development of an integrated framework to evaluate water policy interventions in water-stressed countries using Jordan as a model system. Steve also continues to serve as director of the Woods Institute Global Freshwater Initiative. This effort strives to develop strategies that promote the long-term viability of freshwater supplies for people and ecosystems threatened by climate change, shifts in land use, increasing population, and decaying infrastructure. He was also awarded the 2013 American Geophysical Union Editor's Choice Award for Water Resources Research for the 2012 paper, "The Nature and Causes of the Global Water Crisis: Syndromes from a Meta Analysis of Coupled Human-Water Studies," co-authored with EESS and Woods Institute faculty and researchers.

Rob Jackson, EESS's most recent faculty arrival, is the Michelle and Kevin Douglas Provostial Professor, jointly appointed as a professor in EESS and as a senior fellow in the Woods Institute for the Environment and the Precourt Institute for Energy. Rob's team does basic and applied research on carbon, water, and nutrient cycling; plant and microbial ecology; and global change. The goal of Rob's research is to build predictive, scientific frameworks that help guide policy solutions for global warming and other environmental problems. During the past year he published extensively, including the first map of natural gas leaks for any city (3,400 leaks across Boston's 800 road miles!), and presented work at the Environmental

Protection Agency, the National Academy of Sciences, and the National Research Council in Washington D.C. He also co-authored a new edition of *Biology*, the best-selling college science text in the U.S.

Julie Kennedy has now reached the 20-year mark with Earth Systems, and is currently serving as the program co-director. In this role she works with the associated faculty to expand and grow the curriculum in response to increased and changing student interest. A recent addition to the program is a new study track on sustainable food and agriculture systems, and there are two new master's level tracks in development that encompass areas of environmental communications and sustainability. In addition to her involvement in EESS, Julie also continues as a co-director of the Haas Center for Public Service, which provides an effective mechanism to bring the action of public service into the arena of environmental concerns that are a focus of the Earth Systems Program and EESS.

Eric Lambin became co-chair of the department this year. With his research group he examines the impact of globalization on land use changes. Lately his research has focused on land use governance through commodity supply chains, and on interactions between public and private regulations of land. His research team recently produced among the first rigorous, ecosystem-level evaluations of the effectiveness of eco-certification programs of agricultural commodities, integrating both remote sensing analyses and detailed farm-level surveys. Eric also serves as co-director of the school's Spatial Analysis Center, which is an SES shared facility, serving students and research programs across campus.

David Lobell is jointly appointed as associate professor in EESS and senior fellow at the Woods Institute for the Environment and the Freeman Spogli Institute for International Studies. He also serves as associate director of the Center on Food Security and the Environment. He and his group focus on understanding the interactions between food production, food security, and the environment, using a range of modern tools. Nationally he serves as a lead author for the Intergovernmental Panel on Climate Change, and participated in plenary approval meetings of Working Group II. David was selected as a 2013 MacArthur Fellow and was also named a Google Science Communication Fellow, selected for his visibility and leadership in climate change research.

Roz Naylor is jointly appointed as professor in EESS and senior fellow at the Freeman Spogli Institute for International Studies and the Woods Institute for the Environment. She is also director of the Center on Food Security and the Environment. Bringing these focus areas together, her work is increasingly situated at the intersection of agriculture, climate dynamics, water resources, and nutrient cycling. She has recently completed an edited volume, *The Evolving Sphere of Food Security,* which includes chapters by authors currently at or affiliated with Stanford, a number of whom are faculty colleagues in EESS. A main theme of this volume is that food security in its broadest form is linked to security of many other kinds: energy security, water security, health, climate, the environment, and national security. Roz currently serves as a science advisor for a United Nations initiative on sustainable development and as a trustee of the Nature Conservancy California Chapter.

Bala Rajaratnam, in collaboration with colleagues at Stanford, was instrumental in developing a statistical framework for analyzing the climate hiatus. Bala received the school's 2013 Award for

Excellence in Teaching, and also received a grant award from the UPS Foundation for his work on paleoclimate reconstructions.

Leif Thomas and his group, in work conducted this last year as part of a newly-funded NSF project, have made fundamental discoveries on how wind-driven internal waves, some of the most energetic motions in the sea, break and drive mixing at strong ocean currents like the Gulf Stream. The results have implications for the dispersal of tracers (e.g. heat, salt, nutrients, pollutants, etc.) and the energy balance of the ocean. The group is also studying turbulent motions in the equatorial Pacific and how they modulate the sea-surface temperature in the tropics, which is known to control global-scale climate variations such as El Niño. These studies involve high-resolution numerical simulations run on the SES Center for Computational Earth and Environmental Science cluster, and the findings have been published in the leading journals in physical oceanography.

Paula Welander studies the biosynthesis and physiological function of "molecular fossils" or biomarkers in extant bacteria. Her work continues to impact our understanding of microbial life in modern and ancient ecosystems and continues to inform our interpretation of the co-evolution of life and Earth. This past year Paula gave the keynote address in a session titled "Phototrophic Life and Earth's Redox Evolution" at the Goldschmidt Conference in Florence, Italy. In addition, she was invited to particpate in the NASA Astrobiology Road Map Meeting of Experts in Wallops Island, Virginia. The meeting purpose was to discuss and draft the next Astrobiolgy Road Map, which will guide the research focus for the institute's next ten years. Paula was also invited to and participated in the NSF Geomicrobiology and Microbial Geochemistry Workshop in Chicago, Illinois. This workshop was funded by the NSF Division of Earth Sciences to gather experts in geomicrobiology and determine future areas of importance in this field. Finally, Paula has been invited to give a "Young Investigator Oral Presentation" at the American Society for Microbiology General Meeting in May 2014.

Life in EESS is charging ahead in an exciting and invigorating way. We have recently welcomed one new faculty member and have the opportunity for additional hires in the coming year(s). Of course, each new hire brings growth in our numbers overall, with the addition of accompanying students, staff, and postdocs, and the resulting need for more work and laboratory space. Along with that comes the challenge to build an intellectual community that interacts across areas of scholarship and continues to redefine the field of Earth system science. As a department, we continue to be engaged in active discussion about our future, including plans to bring in expertise in human-environmental science, and are excited to move forward in novel and productive directions.

Eric Lambin
George and Setsuko Ishiyama Provostial Professor and Co-Chair

Scott Fendorf
Terry Huffington Professor and Co-Chair

Stanford
SCHOOL OF
EARTH SCIENCES | Geological and
Environmental Sciences

Full-time faculty: 18
Chair: Gordon Brown, Dorrell William Kirby Professor in Geology
Degrees: BS, MS, ENG, PhD
Home: Geology Corner (GES faculty are also located in Mitchell and Green)

The geological and environmental sciences are naturally interdisciplinary, and include the study of earth materials and earth processes, and how they have changed over Earth's 4.56 billion year history.

GES research is critically important to the following areas:

- The study of natural hazards (earthquakes, volcanic eruptions, landslides, and floods)
- Environmental and geological engineering
- Surface and groundwater management
- The assessment, exploration, and extraction of energy, mineral, and water resources
- Remediation of contaminated water and soil
- Geological mapping and land use planning
- Human health and the environment

Topics addressed in GES courses and research include:

- The chemical and physical makeup and properties of minerals and rocks (at pressures from the surface to the core), as well as of soils, sediments, and water
- The formation and evolution of Earth and other planets
- Processes that deform Earth's crust and mantle and that shape Earth's surface
- Stratigraphic, paleobiological, and geochemical records of Earth history, including changes in climate, oceans, and atmosphere
- Present-day, historical, and long-term feedbacks between the geosphere and biosphere, and the origin and occurrence of our natural resources

GES has access to a broad range of instrumentation for elemental, structural, and radiogenic/stable isotope analysis, including ion microprobe, electron microprobe, thermal and gas source mass spectrometry, inductively coupled plasma mass spectrometry, nuclear magnetic resonance, X-ray diffraction, and scanning electron microscopy. The Stanford Nanocharacterization Laboratory and facilities at the Stanford Synchrotron Radiation Lightsource (SSRL) and the U.S. Geological Survey in nearby Menlo Park are also available. Branner Library, devoted exclusively to the Earth sciences, represents one of the department's most important resources. The department also maintains rock sample preparation (crushing, cutting, polishing), mineral separation, and microscopy facilities.

ges.stanford.edu

Chair's Report

GES Faculty and Students

In the 2013–14 academic year to date, GES has added a new senior faculty member (Rod Ewing) and made a successful case for Wendy Mao's promotion to tenure (effective September 2013). We have two reappointment cases under way, including Professor (Research) Marty Grove and Assistant Professor Jessica Warren. We currently have 18 faculty members, including 10 full professors (Dennis Bird, Gordon Brown, Rod Ewing, Steve Graham, Keith Loague, Don Lowe, Gail Mahood, Elizabeth Miller, David Pollard, Jonathan Stebbins); three associate professors (Kevin Boyce, George Hilley, Jonathan Payne); three tenure-track assistant professors (Kate Maher, Wendy Mao, Jessica Warren); and two professors (research): Atilla Aydin and Marty Grove. GES is likely to add at least one new faculty member in 2014 in the area of geobiology as the result of a current faculty search in collaboration with the Department of Environmental Earth System Science (EESS).

GES faculty research interests span a range of spatial scales from the global to the atomic and temporal scales from billions of years of Earth's history to femtoseconds, the time required for the breaking and making of chemical bonds during chemical weathering. Our interests range from fundamental studies of Earth processes—such as water-mineral interfacial reactions, chemical weathering, reactive transport of contaminants, stable and radiogenic isotope fractionation, landscape evolution and active tectonics, rock fracturing and faulting, formation of sedimentary basins and Archean depositional systems, evolution of Earth's crust, continental accretion, evolution of plant physiology, extinction events, volcanic eruptions, mantle flow, and planetary core formation—to more applied studies, including transport of environmental contaminants in groundwater; transformations of natural, incidental, and engineered nanoparticles in different Earth-surface environments and their impact on nanoparticle toxicity; petroleum geology; sequestration of carbon dioxide (CO_2) through mineral carbonation reactions and catalytic reduction of CO_2 to simple organic acids; sorption of CO_2 and heavy metal contaminants in mesopores in minerals; storage of hydrogen in clathrate structures for use as automobile fuel; and silicate glass/melt structure-property relationships.

We use a variety of state-of-the-art tools in our studies including mass spectrometers and ion microprobes, synchrotron light sources, nuclear magnetic resonance spectroscopy, transmission electron microscopes, electron microprobes, and geographic information systems. We also use a variety of quantitative modeling approaches, and we continue the Stanford Earth Sciences tradition of detailed fieldwork in many parts of the world.

Some of our recent research has attracted media attention, including 1) Wendy Mao's work on the mechanism of planetary core formation and the discovery that Earth's inner iron core is relatively weak, both of which were published in *Nature Geosciences* (http://news.stanford.edu/news/2013/may/earth-iron-core-051613.html, 2) the work of Kate Maher, Dennis Bird, Gordon Brown, and their students on the clues that old mines hold about

mineral carbonation, the ultimate solution to the CO_2 sequestration problem (http://news.stanford.edu/pr/2013/pr-permanent-co2-sequestration-120613.html), and 3) the discovery by Dennis Bird and collaborators of new rare earth element deposits in West Greenland, where continental plates collided (https://pangea.stanford.edu/news/precious-rare-earth-metals-discovered-where-continental-plates-collided).

GES currently has 64 graduate students, 16 postdoctoral students, and 15 undergraduate majors. Sixteen of our current graduate students are scheduled to graduate this spring/summer, with 13 to receive PhD degrees and 3 to receive MS degrees. We continue to attract a relatively small number of bright and dedicated undergraduate majors in GES. In December we received 116 applications for graduate study beginning in September 2014. Following a careful selection process by our graduate admissions committee (Mao, Miller, Boyce), the GES faculty chose 24 of the applicants for visits to the department. For the first time in the long history of the department, we decided to have all of them visit us as a group. Seventeen of the 24 prospective students visited Stanford on February 11-12 in order to meet with potential faculty advisors, our graduate students, and each other, as well as to see Stanford and its facilities. The other seven prospective students made individual visits. Following these visits, individual GES faculty members decided which students in their specialty area to admit, and offers have been sent to 15 students, including one who was selected to receive a four-year Stanford Graduate Fellowship, the most prestigious graduate fellowship awarded by Stanford. Alyssa Feree, GES student services manager, did an excellent job of coordinating these visits and keeping track of the visiting students and the final offers of admission. Although some of the prospective students felt the group visit worked well, others were not as comfortable, so some additional tuning of this selection process will occur before the next graduate application season, which begins in December 2014.

Faculty Additions, Honors, Promotions, and Selected Activities

In last year's GES chair's report I revealed that we were in the final stages of a senior faculty appointment that would for the first time couple the School of Earth Sciences with the Stanford Center for International Security and Cooperation (CISAC), which is part of the Freeman Spogli Institute for International Studies. I am very pleased to report that this appointment is now completed and that Rod Ewing joined the GES Faculty as a full professor (50 percent) and CISAC as a senior fellow (50 percent) in January 2014. Rod's specialties include the nuclear fuel cycle, high-level nuclear waste disposal, and radiation damage in Earth materials. Previously the Edward H. Kraus Distinguished University Professor at the University of Michigan, Rod was appointed by President Obama as chair of the U.S. Nuclear Waste Technical Review Board in 2012. At Stanford, Rod is the inaugural Frank Stanton Professor of Nuclear Security at CISAC. This is quite an honor for Rod and quite a coup for GES and CISAC.

As mentioned above, Wendy Mao was approved for promotion to tenured associate professor after a rigorous review of her scholarly record, teaching, and advising/mentoring. Wendy is also a faculty member in the Department of Photon Science at the SLAC National Accelerator Laboratory and holds a courtesy faculty appointment in the Department of Geophysics. Wendy's specialty is mineral physics, and she has made major contributions to our understanding of the core-mantle boundary region, the formation mechanism of planetary cores, the storage of hydrogen in clathrate compounds, the formation of ultra-hard diamonds, and the use of synchrotron radiation-based microtomography to study phase separation in mantle silicates at

high pressure and temperature. Wendy's promotion will take effect September 2014. Wendy was awarded the 2013 Mineralogical Society of America Award in October 2013 and was elected co-chair of the Extreme Physics and Chemistry Directorate, Deep Carbon Observatory, Carnegie Institution of Science.

A major GES faculty honor was the selection of Associate Professor Kevin Boyce as a MacArthur Fellow in 2013. Kevin was one of two MacArthur fellows from Stanford, the other being Associate Professor David Lobell of the EESS Department.

Dennis Bird and collaborators discovered a new rare earth element deposit in East Greenland. Dennis also led a contingent of GES graduate students to the Prospectors and Developers Association of Canada meeting in Toronto in March 2014.

I (Gordon Brown) was elected as a foreign member of Academia Europaea (Earth and Cosmic Sciences Section) in 2013 and am continuing my studies of the structure and properties of engineered and natural nanoparticles as part of the Center for Environmental Implications of Nanotechnology, which is a multi-institutional NSF-funded national research/training center. I am also collaborating with Kate Maher, Dennis Bird, and a group of very bright Stanford graduate students and post-docs on CO_2 sequestration, work that is funded by the Stanford Global Climate and Energy Project. I am further collaborating with ERE professor Jennifer Wilcox on an NSF-funded project on the speciation of arsenic, mercury, and selenium associated with fly ash from coal-fired electric power plants. In addition to these research activities, I began my tenure as principal editor of *Elements* in January 2014. With the help of graduate student Cynthia McClain and post-doc Jennifer Druhan, I organized a special symposium held at Stanford on February 6 with presentations by 15 faculty, graduate students, and post-docs who gave keynote, invited, and contributed talks at the Goldschmidt Conference held in Florence, Italy, in August 2013. The Goldschmidt at Stanford symposium was intended for SES faculty and students who could not attend this international geochemistry conference.

Professors Don Lowe and Steve Graham continue to attract significant support from industrial affiliates for their sedimentary basins project and their deep water sedimentation project. Don recently initiated a research program with King Fahd University of Petroleum and Minerals, funded by Saudi Aramco, on syn-rift Miocene turbidites along the northern Saudi margin of the Red Sea. Three weeks were spent in the field with a group of four scientists, two graduate students (including student Cody Trigg), and support personnel. Another NASA-funded project continued with investigation of sedimentary layers exposed in the wall of a moderate-sized crater in the Mawrth Vallis region of Mars. Don and longtime collaborator Gary Byerly (LSU) also published a geologic map of the Barberton greenstone belt in South Africa, which represents the culmination of over 30 years of personal mapping and research in the Barberton Belt. They also continued research on Archean impact layers, which has led to a fundamental change across the scientific community in the interpretation of the Late Heavy Bombardment (LHB) and recognition that large (20-50 km) meteorite impacts continued on Earth until at least 3.0 billion years ago (Ga.) and that LHB did not end at 3.8 Ga. Don was awarded honorary membership in the Pacific Section of the Society for Sedimentary Geology in March 2013, and he will receive the Grover E. Murray Memorial Distinguished Educator Award from the American Association of Petroleum Geologists in April 2014.

Kate Maher just had a manuscript accepted by *Science* on a new non-empirical model for global silicate weathering that links climatic and tectonic forcing through the operation of a hydrologic

"thermostat" (https://pangea.stanford.edu/news/understanding-how-mountains-and-rivers-make-life-possible). In addition, two of Kate's postdocs, Jenny Druhan and Laura Nielsen, just accepted faculty positions at the University of Illinois Urbana-Champaign and UC Berkeley, respectively. Jenny Druhan was also honored for the best talk at the 2013 EnviroMetal Isotope Conference in Ascona, Switzerland. In addition, Kate's PhD student Cynthia McClain and MS student Daniel Ibarra were awarded the number one and number two best poster presentations at the SES annual research review. Kate co-taught a reactive transport modeling short course before the Goldschmidt 2013 Conference, and she is preparing to teach a yearly summer school in reactive transport at Stanford starting this June as part of an NSF-sponsored program to increase access to education in reactive transport principles and modeling. Kate recently was elected to the Stanford Faculty Senate for a two-year term as one of two representatives from the School of Earth Sciences.

Gail Mahood recently spent three weeks in western Saudi Arabia as part of a joint USGS–Saudi geologic survey team studying Harrat Rahat, a volcanic field that last erupted in AD 1256. This fieldwork was the initiation of a three-year geologic, geochronologic, petrologic, and seismologic study to assess the volcanic and seismic hazards in the vicinity of the holy city of Al Madinah.

Associate GES chair Elizabeth Miller just received an NSF grant to continue her studies of the use of zircon to reveal the history of the deep continental crust. Elizabeth and her graduate students are continuing their Arctic field research, which has revealed that northern Alaska likely rifted from northern Europe, bringing with it a part of the ancient Caledonian mountain belt of England, Norway and Greenland. This discovery helps explain why we find parts of the Caledonides as far south as the Klamath Mountains and Sierra Nevada of California.

Jon Payne launched a new high school internship program (History of Life Internship Program) in collaboration with Jennifer Saltzman, Director of Outreach Education, and under the direct supervision of Noel Heim, a research associate. This team hosted 19 Bay Area high school students for eight weeks; 17 of the students went on to present posters at the American Geophysical Union (AGU) meeting in December. Jon also co-organized the Paleontological Society Short Course (on the topic of ecosystem paleobiology and geobiology) at the 2013 Geological Society of America fall meeting in Denver and co-edited the proceedings volume, which has been published. In addition Jon was nominated to serve in the Office of the Vice Provost for Undergraduate Education's first group of faculty scholars. This yearlong pilot program gives newly tenured faculty the opportunity to explore, experiment, and take new creative risks in research and teaching. He was recently invited to spend a quarter teaching in the Stanford overseas program in Florence, Italy, as well. Jon's post-doctoral fellow, Katja Meyer, accepted a faculty position at Willamette University in Salem, Oregon. Another post-doctoral fellow, Matthew Knope, accepted a position as a lecturer in biology at Stanford; graduate student Brian Kelley accepted a research scientist position at Exxon; and undergraduate student Franklin Caval-Holme first-authored an article published in *Evolution* and received the 2013 Dean's Award at graduation.

David Pollard has completed about half of a new undergraduate textbook on structural geology. The book is being prepared under a contract from Cambridge University Press. It is the first undergraduate textbook that integrates calculus, linear algebra, and continuum mechanics with the classic topics of structural geology. If successful, this book will change the way structural geology is introduced to students and transform the practice of structural geology over the next

few decades.

Having stepped down from his second tenure as GES department chair, Jonathan Stebbins continues with his research and teaching at the interface between geochemistry and materials science. His group of students and postdocs, with diverse backgrounds in geosciences, chemistry, and physics, has made important progress on questions concerning the structure of silicate glasses and melts, which are of major relevance to natural igneous processes (e.g., what controls the fluidity of erupting magmas) as well as to advanced technological materials (e.g., how to optimize the properties of glasses for computer and smart phone displays). Their primary research tool is solid-state nuclear magnetic resonance (NMR). They continue to work on both minerals and glasses made at upper- to lower-mantle pressures in collaborations with colleagues at the USGS in Menlo Park and at the Geophysical Laboratory in Washington D.C. Another ongoing project, with colleagues in applied physics (Ginzton Lab), involves the poorly known structures of amorphous heavy metal oxides critical in high-performance optical mirrors in the Laser Interferometric Gravitational Wave Observatory (LIGO), a decades-old "big-physics" project that could someday contribute to solving major questions in cosmology. Their NMR studies have also recently contributed to important new understanding of the properties of thin-film dielectric coatings for microelectronics, in work with colleagues in materials science and engineering.

Jessica Warren gave a keynote presentation at the Goldschmidt Conference in August 2013, where she discussed global constraints on the composition of Earth's mantle. She recently had a manuscript accepted by the *Journal of Geophysical Research* on the use of pyroxenes to constrain the amount of water in the mantle. Jessica has also been awarded a new NSF Tectonics grant to examine the role of fluids during ductile deformation beneath strike-slip faults. Lars Hansen recently completed a postdoc in Jessica's lab and will begin a faculty position at Oxford University. Finally, Suzanne Birner, one of Jessica's graduate students, received an AGU Outstanding Student Paper Award and an honorable mention in the GeoPRISMS student competition for her presentation at the AGU fall meeting.

Future Faculty Growth, Potential Losses, and New Additions to the GES Family

The GES faculty continues to be interested in new faculty hires in the areas of strategic mineral resources and natural hazards and submitted white papers on these two potential growth areas to Dean Matson last year. The area of strategic mineral resources has also attracted the attention of a group of about 15 GES graduate students who meet monthly to discuss research in this area and host occasional speakers from other universities. Five of these students attended the Prospectors and Developers Association of Canada meeting in Toronto in March 2014.

Two GES faculty members, Atilla Aydin and David Pollard, have announced their intention to retire in June 2014 and June 2015, respectively. These two retirements will substantially weaken our quantitative structural geology and rock mechanics programs in GES. It is likely that GES will have several other faculty retirements over the next three to five years, which will result in a major change in expertise in the GES Department. We will have a GES faculty retreat during fall quarter 2014 to continue our discussion and planning for new faculty hires in areas critical to the functioning and future of our department.

Finally, I would like to welcome two new additions to the Stanford GES family. Wendy Mao gave birth to a son (Jackson) in the summer of 2013, and Jessica Warren gave birth to a daughter (Amaya) in January 2014.

Gordon Brown
Dorrell William Kirby Professor and Chair

Stanford
SCHOOL OF
EARTH SCIENCES | Geophysics
Department

Full-time faculty: 14
Chair: Howard Zebker
Degrees: BS, MS, PhD
Home: Mitchell

Geophysics integrates geology, mathematics, and physics in order to understand how the Earth works. Geophysicists study Earth processes through a combination of laboratory experiments, computational and theoretical modeling, remote imaging, and direct observation.

Research in the Department of Geophysics has both fundamental and strategic elements. Thanks in part to this breadth of exposure, its students are highly sought after for positions in academia, industry, and government. Much, though not all, of the department's research can be grouped into three broad themes: energy, environment, and hazards.

Topics pursued by geophysics faculty and graduate students include:

- Measurement of crustal deformation using precision geodesy
- High resolution imaging of the shallow crust using active source seismology
- Studies on the feasibility of carbon sequestration
- Earthquake source studies and hazard analysis
- Radar remote sensing of the Earth and other bodies in the solar system
- Rock physics of petroleum reservoirs and for environmental remediation
- State of stress and mechanical behavior of the crust
- Passive imaging of the crust and upper mantle
- Regional tectonics and continental evolution

Faculty, staff, and students benefit from research interactions with other groups on campus and the nearby U.S. Geological Survey, Lawrence Livermore National Laboratory, and Lawrence Berkeley National Laboratory, as well as with industry and other universities around the world.

geophysics.stanford.edu

Chair's Report

This has been another very busy year for the Department of Geophysics, with growth statistically and in several promising research areas. We are completing a strategic planning exercise prompted by the 2012 Visiting Committee. This report can be summarized as noting that while we continue to excel at our individual research program level, we have been less successful in addressing broader problems that require coordination among multiple groups within and outside our department. We enthusiastically took up this challenge and developed a decade-outlook strategic plan reprioritizing our teaching and research missions, with appropriate changes to our internal organization. The final stages of completing the plan are ongoing, but we have already implemented several of our responses to these challenges.

Looking at the numbers, we have increased our faculty by two, expanded to 16 postdocs (up from 11) and 83 graduate students (up from 72), and now we can boast of 5 undergraduate students. This growth taxes our physical space, but we are committed to growing our department intellectually and addressing some very exciting new areas of research.

We have identified several new research initiatives that form the core of our strategic planning. The highest priorities are study of the Earth's cryosphere, the physics and management of groundwater systems, and the interface between hazards and energy development. All address ongoing changes on Earth and how we can live sustainably within its means. For example, Mark Zoback, along with other faculty within geophysics, ERE, EESS, and civil and environmental engineering, has developed a new consortium, the Stanford Center for Induced and Triggered Seismicity. The consortium coordinates and sponsors research on hazards triggered by the new technologies of horizontal drilling and hydraulic fracturing for shale gas production. For all these initiatives we are in the process of developing strategies to enable exciting new science through faculty hiring not only in geophysics, but also as catalysts for related hiring across the entire school.

We are fortunate to have had two new faculty members join us this year. Tiziana Vanorio's research program on the geophysics of rock-fluid interaction continues Stanford's long tradition of excellence in our rock physics program. Her group addresses the challenges we face when modeling and interpreting geophysical observations in chemo-mechanically altered systems. Her group uses a multi-scale and multi-physics experimental approach to 1) study the microstructural changes that a rock experiences as a result of coupled thermo-chemo-mechanical processes, and 2) understand the effects on the observed geophysical parameters. Tiziana's long-term goal is to enhance our current ability to geophysically characterize the effects of chemical and physical changes undergone by a rock formation upon the injection of fluids for the purpose of storage (i.e., carbon dioxide), enhancement of the production of fossil energy (i.e., unconventional reservoirs and formation damage), or monitoring geothermal and volcanic areas.

Jenny Suckale joins us from Harvard, where she most recently served as a lecturer in applied math. Her research aims to advance our basic understanding and predictive capabilities vis-à-vis the complex multi-phase flows that are fundamental to Earth science. She pursues this goal by

developing original computational methods customized for the problem at hand. The phenomena she explores range from the microscopic to the planetary scale and span a wide variety of geophysical systems such as volcanoes, glaciers, and magma oceans. Her main focus in winter 2014 was to finalize the publication of a new approach to understanding the dynamics of the West Antarctic ice streams, which are responsible for the majority of ice loss from the Antarctic ice sheet. Her study suggests that melt percolation at the microscopic scale might play a crucial role in the dynamics of ice streams and thus affect the stability of the Antarctic continent as a whole.

Greg Beroza and his research group are working to understand earthquakes and the hazards they pose. Research highlights for the past year include: a technique for developing large virtual earthquakes using the ambient seismic field; the first use of tectonic tremor for ground motion prediction; evidence for high energy dissipation, and hence possible partial melting, during intermediate-depth earthquakes; and several new methods for detecting earthquakes using continuous ground motion data. In addition to ongoing research in these areas, his research group is developing new techniques for data-intensive waveform similarity search. Our collaborations with colleagues in Japan remain vibrant, and we have initiated a new collaboration focused on ambient-field seismology with scientists at ISTerre, Grenoble. Greg was appointed by California Governor Jerry Brown to serve on the State Seismic Safety Commission. He was also honored with the 2014 Gutenberg Medal of the European Geosciences Union for outstanding contributions to seismology.

Biondo Biondi and his students continue to devise new methods to image active and passive seismic data collected at the Earth's surface. Last year they started an exciting new project to develop a novel approach to seismic full waveform inversion. The method converges to accurate models even when conventional methods fail. Sjoerd de Ridder applied a concept proposed by Jon Claerbout in the 1960s to synthesize active data from passive seismic noise using cross-correlation. Using this synthesized data he created a high-resolution image of the subsurface, and demonstrated that useful information can be extracted without the deployment of expensive man-made sources.

Biondo's other main interest is in computational geosciences. As co-director of the Stanford Center for Computational Earth and Environmental Science (CEES) he helps other investigators in the school leverage modern computer technology for modeling complex Earth phenomena and extract information from the huge datasets collected by modern sensor arrays. He is also the program director of the new computational geoscience degree program designed to educate the computational geoscientists of the future.

Eric Dunham and his group have been studying earthquakes, volcanoes, and tsunamis. Through computer simulations of the 2011 Tohoku earthquake, they discovered that these great subduction zone events generate large amplitude sound waves in the ocean. These sound waves turn out to have amplitudes that correlate well with tsunami wave heights, suggesting their possible use as part of local tsunami early warning systems employing ocean bottom sensor networks. In another project, the group studied swarms of small earthquakes that preceded the eruption of Redoubt Volcano, Alaska. These earthquakes occurred at an incredible rate, approaching more than twenty per second just before the eruption, likely as a result of pressurization within the magma that ultimately culminated in an explosion. Eric and his students have used properties of those earthquakes to piece together how magma flows beneath volcanoes before explosive eruptions.

Jerry Harris and his graduate students, collectively the Stanford Wave Physics Laboratory, work on acquisition technology and data processing methods for continuous slow-time reservoir monitoring. The primary focus of this work is the development of reduced-order models and dynamic-imaging methods for carbon dioxide storage and improved oil recovery. The group is an active participant in the Stanford Center for Carbon Storage (SCCS) and the Carbon Capture Project (CCP). Jerry is also the school's associate dean for multicultural affairs. The Office of Multicultural Affairs facilitates diversity activities within the School of Earth Sciences, organizes a summer pipeline program for undergraduates, and assists with the implementation of a school partners program with participation from domestic and international universities.

Simon Klemperer and his crustal research group continued their efforts to understand extension and magmatism in the western U.S., and convergence and magmatism in Tibet. Two theses are in progress on the Ruby Mountains core complex and on the Salton Trough, to explore different manifestations of crustal stretching in the Basin and Range Province using seismic data we have collected. Two incoming students began work on new collaborative ventures with Chinese scientists, using data acquired by Chinese scientists. A new initiative will venture into active tectonics off the shore of California, and seismically study buried paleo-shorelines to help understand patterns of subsidence and uplift around strands of the San Andreas fault system.

Rosemary Knight and her research group continue to work on geophysical methods for groundwater applications. The highlight of the past year was a 7 km-long electrical resistivity survey along the coast of Monterey Bay, imaging saltwater intrusion to a depth of 150 km. Saltwater intrusion is a huge threat to agriculture, which obtains more than 85 percent of its water in the Monterey area from groundwater. With the success of this work, she was invited to testify before a select committee of the state legislature on sea level rise and the California economy. The plan for the fall is to return to Monterey Bay and acquire data along a 50 km stretch, imaging saltwater intrusion to a depth of 300 m from Monterey to Santa Cruz.

One focus of their research is nuclear magnetic resonance (NMR). Logging NMR is widely used in the petroleum industry for estimating permeability in consolidated reservoirs. Now Knight's group has shown that NMR logging can be used to obtain reliable estimates of water content and hydraulic conductivity in unconsolidated groundwater aquifers. Her group is also very active in studying a surface-based NMR system that uses Earth's magnetic field to non-invasively obtain the same information to depths of ~100 m. Through partnerships with groundwater districts in California, they are hoping to bring state-of-the-science in geophysics to state-of-the-practice.

Jesse Lawrence's deep Earth seismology group is continuing to monitor Yellowstone, and have measured clear time-dependent changes in the seismic properties of the crust within the caldera. In addition to studying deep Earth dynamics, Cyndi Kelly, a second-year graduate student, is investigating the seismic signature of geyser eruptions. Cyndi led a team down to El Tatio, Chile, which is the third largest geyser field in the world. By studying the seismic source of geysers they hope to determine if geysers are driven by top-down or bottom-up dynamics. The Quake-Catcher Network, a low-cost volunteer seismic network, continues to grow, with increased capabilities of rapid earthquake detection.

Gary Mavko and his rock physics group continue to investigate the physical interactions of rocks and fluids in the subsurface of the Earth. Some members of the team are using computational methods to simulate the elastic and mechanical behavior of rocks under both seismic wave excitation and static loading. Others are developing theoretical models that can explain how the

elastic and viscoelastic behavior of rocks is affected by composition, micro geometry, and conditions of temperature and stress. Current applications include modeling the elastic and electrical signatures of carbon dioxide that has been injected into the subsurface; predicting the viscoelastic behaviors of rocks with extremely viscous components, such as partial melt and very heavy oil; integrating geologic and compositional information to improve estimates of rock anisotropic parameters from sparse elastic information; and understanding how heterogeneity at many scales impacts mechanical and transport properties in rocks.

Tapan Mukerji and his students continue to work on aspects of theoretical and computational rock physics at the pore scale, as well as applications of geostatistics and rock physics for reservoir characterization, basin modeling, and value of information analysis. Recently one of his co-advisees, Dario Grana, now a faculty member at the University of Wyoming, won the Gustavo Sclocchi Award from the European Association of Geoscientists & Engineers for his thesis on Bayesian inversion methods for seismic reservoir characterization and time-lapse studies.

Paul Segall's group continues to study earthquake and volcanic processes, through a combination of monitoring active crustal deformation and physics-based modeling. They are working to develop methods for bounding the potential size of future earthquakes based on geodetic measurements of strain accumulation. The group is analyzing an unprecedented long duration transient recorded by GPS measurements prior to the magnitude 9 earthquake in Japan. They continue to develop physics-based models of newly discovered slow-slip and tremor in subduction zones, as well as induced seismicity generated by fluid injection. On the volcano side, Paul's group continues development of physics-based methods that employ GPS, effusion rate, and gas emission data to bound aspects of subsurface magmatic systems. They hope that such models may someday allow improved eruption forecasts.

Norman Sleep continues to work on rock damage from strong seismic waves. He is quantifying how damage both reduces the shear wave velocity and nonlinearly attenuates the seismic wave. This work shows how ground subjected to numerous seismic waves self-organizes so that the shear modulus increases with depth (allowing calculation of past PGV) and the material barely becomes nonlinear over the depth range of damage (low-cycle fatigue). For example, wakes impinging on the Los Angeles basin from the San Andreas fault funnel through Whittier Narrows. Pumping down of the water table in the region from its present shallow level would double the amplitude of the wave that could pass through the funnel. Additionally, with Don Lowe, Norman has investigated ancient seafloor damaged by extreme seismic waves from a 50 km diameter asteroid impact. Norman has also continued his work on the effect of biological processes on geodynamics and the distribution of elements in the mantle.

Mark Zoback and his students continue work on a range of research topics in reservoir geomechanics with an emphasis on shale gas production. Over the past year Mark served on a Secretary of Energy committee tasked with evaluating how to develop shale gas resources while protecting public health and the environment. The committee published two reports: one making recommendations for improved practice, the other assessing implementation of the recommendations. Mark spent a considerable amount of time giving talks and writing about environmentally responsible shale gas production. He is a founder of the Stanford Center for Induced and Triggered Seismicity, which addresses hazards caused primarily by the development of natural gas from shale. Small earthquakes arising from horizontal drilling and hydraulic fracturing technologies are the best known of these, but associated groundwater contamination

may pose the larger potential threat and has been in the news over the past year. Mark serves as president of the American Rock Mechanics Association and is on the board of the Research Partnership to Secure Energy for America.

My own radar remote sensing group continues to improve interferometric radar technology. We have used InSAR observations to estimate, for example, the locking depth of the San Andreas Fault and how slip varies with time. We are now applying this method to slow earthquakes in Hawaii, where the temporal and spatial resolution allows us to resolve episodic events in time and to associate slip with specific geologic structures. We continue to collaborate with Rosemary Knight's group to measure vertical motions for monitoring aquifers critical to food production. We are also working with Steve Gorelick's group to monitor subsidence from overpumping aquifers that releases arsenic into the water supply. I also continue a long-term interest in planetary science and exploration of the solar system by analyzing radar backscatter data acquired by NASA spacecraft to understand the evolution of our planetary environment.

Howard A. Zebker
Professor and Chair

Stanford
SCHOOL OF
EARTH SCIENCES | Earth Systems
Program

Affiliated faculty:	65-70 from 16 departments and all 7 schools
Directors:	Kevin Arrigo (Donald and Donald M. Steel Professor) and Julie Kennedy, Victoria and Roger Sant Co-Directors
Degrees:	BS & MS
Home:	Y2E2

The Earth Systems Program is an interdisciplinary environmental science major in which students learn about and independently investigate complex environmental problems caused by human activities in interaction with natural changes in the Earth system.

Earth Systems majors become skilled in those areas of science, economics, and policy needed to tackle the globe's most pressing environmental problems, becoming part of a generation of scientists, professionals, and citizens who approach and solve problems in a systematic, interdisciplinary way. For students to be effective contributors to solutions for such problems, their training and understanding must be both broad and deep. To this end, Earth Systems students take courses in the fundamentals of biology, calculus, chemistry, geology, and physics, as well as economics, policy, and statistics.

After completing breadth training, students concentrate on advanced work in one of five academic tracks:

- Anthrosphere
- Biosphere
- Energy, Science and Technology
- Oceans
- Land Systems and Land Use

The academic tracks are designed to support focus and rigor but include flexibility for specialization. Examples of specialized focus include:

- Environment and human health
- Sustainable agriculture
- Energy economics
- Sustainable development
- Business and the environment
- Marine policy

Along with formal course requirements, Earth Systems students complete a 9-unit (270-hour) internship. The internship provides a hands-on academic experience working on a supervised field, laboratory, government, or private sector project. The Earth Systems Program provides an advising network that includes faculty, staff, and student peer advisers.

earthsystems.stanford.edu

Directors' Report

The Earth Systems Program was founded 23 years ago on the premise that students who expect to analyze and solve complex problems at the interface of human and natural systems must become skilled at integrating knowledge and methods from a cross section of disciplines. Our students earn a bachelor's or master's of science degree, but along with science they also learn and integrate knowledge and techniques from the social sciences and, in some cases, engineering, law, or medicine. At a university rich in choices for students seeking an interdisciplinary major, Earth Systems remains an attractive option. We currently have 155 declared Earth Systems students, including about 37 coterminal master's students. As has always been the case, Earth Systems benefits from teaching and advising contributed by more than 50 faculty members from across the university.

Throughout the program's history we have recognized the critical importance of attentive advising. Helping students develop and excel as interdisciplinary thinkers, analysts, and problem solvers requires the support of an extensive advising team. Earth Systems offers a multi-tiered advising structure tailored to meet the individual needs of our students.

At the gateway level, we hire and train an annual cohort of six peer advisors who are seniors or coterminal MS students in the program. The student advisors introduce younger colleagues to the major and help us provide an academic "home" for any student interested in interdisciplinary study of the environment. Our talented administrative and teaching staff includes associate director, Deana Fabbro-Johnston, who has been with the program since its inception; Kristin Tewksbury, student services manager; Melissa Vallejo, administrative assistant; and Dr. Katie Phillips, program lecturer. Together our administrative and teaching staff has over 60 years of student engagement experience at Stanford.

As faculty co-directors, we also actively advise Earth Systems students, giving particular attention to those undertaking honors research or considering graduate study. Finally, we have an extensive community of faculty volunteers who advise students within each of the academic tracks. Our goals are straightforward: we want all Earth Systems students to feel supported, and we intend for every student to have an advising relationship with a faculty mentor. Whether we are offering tips to students on how to navigate their way at Stanford or helping them find a first job or choose an advanced degree program, our students know that they can come to the Earth Systems advising team for guidance.

Prior directors' reports have discussed at length our curricular tracks and the regular process of revision for each. This year we asked ourselves, what's trending in Earth Systems? What content or skills are students seeking that no existing track fully covers? Two focus areas surfaced in conversations with students: sustainability and environmental communication.

Recently, one of us heard a comment that resonated with our discussions about future directions for the program. In a nutshell, that comment was "*all systems are perfectly designed for the product they produce. If you want to change the product, change the system."* In a world increasingly focused on triple bottom line outcomes—improvements that benefit people, the

planet, and profits—it is important to train students who can both measure the performance of existing systems and redesign those systems for better outcomes. Increasingly Earth Systems graduates are joining corporations that need sustainability performance analysts. Our goal is to formally marry existing interdisciplinary training in the Earth Systems undergraduate tracks with sustainability analysis and creative design skills in a structured coterminal master's degree in sustainability management. By this summer we will have in place a skills-based curriculum that will launch ever more students into industry or local government positions as sustainability leaders. We want to help them change the system.

Similarly, sustainability transformations require changes in individual behavior and group cultures. Driving such change demands more than the ability to transfer knowledge. Lasting impacts result when knowledge and inspiration effectively combine. For decades in Earth Systems we have worked with our students to help them build solid science writing skills. At the same time, we have had a consistent focus on translating technical research results for non-expert audiences. In the coming year we hope to expand on that latter theme by designing a new curriculum that, if approved, will lead to a coterminal master of *arts* in environmental science communication. We expect to enroll Earth Systems students who want to combine deep content knowledge with effective communication through writing, photography, film, museum exhibits, and more. We know there is a need to train students who can simultaneously inform and inspire others. Our goal is to fill that niche and provide a path for scientific and creative engagement with human–environment problems and challenges.

As you can see, Earth Systems is alive, well, and remaining adaptive. We are easy to find on the first floor of Y2E2, so please come for a visit when you are in town.

Julie Kennedy and Kevin Arrigo
Victoria and Roger Sant Co-Directors

Stanford
SCHOOL OF
EARTH SCIENCES

Emmett Interdisciplinary Program
in Environment and Resources

Affiliated faculty:	109 from all 7 schools
Director:	Peter Vitousek, Sykes Family E-IPER Director and Morrison Professor in Population and Resource Studies
Degrees:	MS (jointly with MBA, JD, or MD degrees) & PhD
Home:	Y2E2

Stanford's Emmett Interdisciplinary Program in Environment and Resources (E-IPER) is designed to create interdisciplinary scholars and leaders to address the world's most challenging environmental and sustainability problems.

E-IPER students combine academic disciplines, including:

- Natural and Earth sciences
- Engineering
- Economics
- Humanities
- Social sciences
- Law
- Health
- Policy
- Business

They seek new insights and novel solutions to urgent global problems, such as:

- Energy use
- Climate change
- Food security
- Freshwater availability
- Depletion of ocean resources
- Land degradation
- Biodiversity loss

E-IPER offers a PhD in Environment and Resources. For students in Stanford's Graduate School of Business, Stanford Law School, and School of Medicine, the program offers a joint MS in Environment and Resources in conjunction with their professional degree (MBA, JD, or MD).

eiper.stanford.edu

Director's Report

The Emmett Interdisciplinary Program in Environment and Resources (E-IPER) has had an exciting and successful year. We have been working to complete several key initiatives identified in our strategic plan, which we began to implement in April 2013 when Deb Wojcik joined E-IPER as our new associate director. Specifically, we have been working to create more meaningful opportunities for engagement across the PhD and Joint MS programs. To this end, we plan to offer the opportunity for integrated groups of PhD and Joint MS students to propose research projects in a competitive process; successful projects will receive funding from the program. Thanks to financial support from Anne and Reid Buckley, we can fund a couple of projects in the energy and climate area; we will be seeking support for projects in other areas of study.

Our autumn 2013 annual retreat, which included an overnight component for the first time, was another opportunity for engagement across the program. Nearly 50 students, including 15 Joint MS students, participated in the retreat, more than triple past retreat participation among this group. We have also initiated "Interdisciplinary Dialogues," a program to engage our E-IPER affiliated faculty on a regular basis. Our first session, in October 2013, featured Neil Hannahs, a leader from the First Nations' Futures Program, who engaged seven affiliated faculty members in a meaningful dialogue around interdisciplinary, applied research.

As our endowments grow, we are becoming more self-sufficient (though we will continue to draw upon school funds for several key functions). In addition, our students continue to bring in competitive fellowships: in recent years, including this one, roughly half of our PhD students have been supported with E-IPER fellowships and half have secured Stanford Graduate Fellowships, Stanford Interdisciplinary Graduate Fellowships, or National Science Foundation graduate fellowships.

At present, we have 34 PhD students and nearly 50 Joint MS students from the Graduate School of Business (GSB) and Stanford Law School (SLS). In accordance with our 2012 strategic plan, we are increasing the number of students admitted into the PhD program to eight per cohort (up from six). Admission continues to be highly competitive. We received 136 PhD applications for fall 2014 and accepted eight; we will have final decisions from admitted students by mid-April.

Applications for the Joint MS degree have also been robust. MBA students are taking advantage of the opportunity to apply to E-IPER at the same time they apply to the GSB; we review three rounds of applications through this process. Having completed one of three rounds and our open application process, we have accepted 22 GSB students, three law students, and two medical students. The inclusion of medical students is exciting for the program and reflects a stronger emphasis on outreach in this direction. Most of these students will start their program with us in Spring 2014 with our new core Joint MS course, *Introduction to Environmental Science*, which was taught for the first time in autumn 2013 and will be taught annually in the spring hereafter.

We now have more than 100 affiliated faculty. Faculty from all seven schools are not only part of our program but also serving as lead PhD advisers. We welcomed five new affiliated faculty members this year and are working with newly affiliated faculty member Charlie Kolstad of the Stanford Institute for Economic Policy Research (SIEPR) to develop a new core economics and policy course for our incoming PhD students. It will be offered for the first time in autumn 2014.

As summarized in the table below, just over half of our doctoral graduates are pursuing academic careers. Several are pursuing prestigious postdoctoral fellowships and others have secured professorial positions at the University of Rhode Island, Oregon State University, UC Santa Cruz, Harvard, University of Hawaii, University of Santiago, University of New Mexico, Lund University, and Sichuan University. Several PhDs are working in governmental or non-profit organizations, including the Department of Energy, Office of Management and Budget, World Bank, Nature Conservancy, and Environmental Defense Fund.

As expected, a majority of our Joint MS students go into the for-profit sector. About 75 percent of our Joint MS graduates also completed the MBA program and are now working in venture capital firms, start-ups, or established companies. The Capstone Seminar, required of all Joint MS students, allowed many students to develop the science and technology aspects of their start-up ideas. A majority of students who concurrently completed the JD are now serving as law clerks or practicing law in non-governmental organizations like the Natural Resources Defense Council and Sierra Club.

	PhD		MS		Total	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Academia	19	56%	5	6%	24	20%
For-profit	4	12%	59	68%	63	52%
Government	5	15%	5	6%	10	8%
Non-profit	5	15%	7	8%	12	10%
In transition	1	3%	11	13%	12	10%
Total	34	100%	87	100%	121	100%

We currently engage our 121 graduates in a variety of ways, and we are in the process of gathering information about how to facilitate more meaningful and sustained engagement in the future. In autumn 2013, we conducted a brief survey of alumni to ascertain their interests. We will be working with current students and drawing on these results to think strategically about how to build bridges that will benefit both present and past students. We invited several alumni to our annual retreat and held alumni dinners in Washington, DC in October and San Francisco in November, the latter hosted at the business offices of one of our Joint MS graduates. We held our annual alumni career panel in January, which allowed current and prospective Joint MS students to learn from the experiences of recent graduates.

Our June and December 2013 symposia of Joint MS students' capstone projects again impressed attendees, including donors, faculty, and fellow students. Students combined the skills developed through their professional degree programs with science, engineering, and technology to develop creative solutions to current and future sustainability challenges. Projects have covered topics

ranging from renewable energy ideas to agricultural efficiency. The titles of all spring and fall 2013 projects are listed below:

- A Framework for Assessing the Science and Policy of Citizen Protests to BLM Grazing Permits
- Advancing Efficiency and Renewable Power Through State Level Energy Policy: A Survey of What Works
- AgoraSol: Powering Brazil's Future Through Distributed Solar
- Big Data Analytics for Building Energy Efficiency; Statistical Anomaly Detection in Building Data
- Bringing Sustainable Produce Offerings to Walmart's Same-day Delivery Service
- Carbon Finance for Small-scale Renewables
- Ceres Imaging: Making Farming Data-Driven—Visualizing Water Stress Through Multispectral Imaging
- Developing a Model for Better Targeting of Residential Solar PV Sites
- Energy Efficiency in the Hospitality Industry: Retrofitting a Bay Area Hotel
- Evaluating the Sustainability of Direct-Delivery Food Service Relative to Traditional Brick and Mortar Restaurants
- Measuring Sustainable Development in the Global Engineering, Procurement, and Construction (EPC) Industry
- Residential Grid Parity–Affordable Solar Electricity in Palo Alto, California, and Beyond
- Smart Meter Deployment in Missouri: Policy and Strategy
- Unlocking the Potential of Energy Efficiency in Russia

As we continue to implement the strategic plan finalized in 2012, we look ahead to our next strategic planning process, which we plan to initiate in summer 2014. This will be an important team effort, rallying our students, faculty, alumni, and staff around new ideas and goals to increase the program's effectiveness and impact.

Peter Vitousek
Sykes Family E-IPER Director
Clifford G. Morrison Professor in Population and Resources Studies