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## Stanford BPSM Industrial Affiliates Meeting

**5 November 2010**

### Schedule

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<td>Meng He</td>
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**Stanford Faculty Affiliated with the Basin and Petroleum Systems Curriculum**

**STEPHAN GRAHAM ~ Stanford University, Department of Earth and Environmental Sciences, School of Earth Sciences, Stanford 94305; 650-723-0507; sagraham@stanford.edu**

Stephan Graham is W.J. and M.L. Crook Professor in Stanford University’s School of Earth Sciences, where he also serves as GES Department Chair. Dr. Graham’s research deals with the tectonics and fill patterns of sedimentary basins and their petroleum resources, especially basins associated with convergent continental margins and collisional orogens; as well as the characteristics and evolution of deep-water clastic depositional systems.

**J. MICHAEL MOLDOWAN ~ Stanford University, Department of Earth and Environmental Sciences, School of Earth Sciences, Stanford 94305; 650-725-0913, moldowan@stanford.edu**

J. Michael Moldovan is a Professor (Research) in Stanford University’s School of Earth Sciences, Department of Geological and Environmental Sciences. Dr. Moldovan’s research focuses on organic geochemical methods for characterization of fossil fuels and ancient sediments. Applications are at the foundations of petroleum systems analysis and basin modeling, environmental issues of petroleum production and usage, as well as biogeochemical, paleoenvironmental and evolutionary aspects of life.

**TAPAN MUKERJI ~ Stanford University, Department of Energy Resources Engineering, School of Earth Sciences, Stanford 94305; 650-723-0507; mukerji@stanford.edu**

Tapan Mukerji is Associate Professor in Stanford University’s School of Earth Sciences, Department of Energy Resources Engineering. Dr. Mukerji was a Research Scientist in the Department of Geophysics prior to assuming his present faculty position in the ERE Department in 2007. He specializes in rock physics, geostatistics, and wave propagation.
Stanford Faculty Affiliated with the Basin and Petroleum Systems Curriculum

KENNETH E. PETERS ~ Business Development Manager, IES Schlumberger, kpeters2@houston.westerngeoco.slb.com; kpeters@stanford.edu

Ken Peters is currently Consulting Professor in the Department of Geological and Environmental Sciences, Stanford University, as well as a scientist/manager with IES Schlumberger. He has used geochemistry and numerical modeling to study petroleum systems at the USGS since 2002. He spent 15 years with Chevron and 9 years with Mobil and ExxonMobil and taught courses in petroleum geochemistry and thermal modeling at Chevron, Mobil, ExxonMobil, Oil and Gas Consultants International, the University of California at Berkeley, and Stanford University. Ken is principal author of *The Biomarker Guide* (2005, Cambridge University Press).

LESLIE B. MAGOON ~ Department of Geological and Environmental Sciences, Stanford University, Stanford, CA 94305; Imagoon@stanford.edu

Les Magoon is currently Consulting Professor in the Department of Geological and Environmental Sciences, Stanford University, as well as Emeritus Research Geologist with the U.S. Geological Survey. He worked 8 years for Shell Oil Company in exploration and 32 years with the USGS. From 1981, he has investigated and popularized the petroleum system through talks, courses, and AAPG Memoir 60, *The Petroleum System—From Source to Trap*, which received the R.H. Dott. Sr. Award in 1996.
Scientists Associated with BPSM Teaching/Research at Stanford

ALLEGRA HOSFORD SCHEIRER ~ Research Scientist, Department of Geological and Environmental Sciences, Stanford University, allegras@stanford.edu

For 5 years Dr. Hosford Scheirer specialized in oil and gas resource assessment at the U.S. Geological Survey. Her research expertise includes constructing three-dimensional geologic models of sedimentary basins, potential fields analyses, and seismic refraction studies. She has participated in numerous field studies, both at sea and on land.

CAROLYN LAMPE ~ ucon Geoconsulting, Cologne, Germany

Dr. Lampe worked at BEB (German branch of Royal Dutch Shell and Exxon Mobil), and subsequently spent seven years as chief geologist at Integrated Exploration Systems GmbH (IES) where she was involved in worldwide training of industry clients, agents and consultants for 2D and 3D petroleum systems modeling. She is currently Director of ucon Geoconsulting, providing support of oil and gas exploration and development projects with internationally operating E&P companies in the areas of petroleum systems analysis, migration modeling, charge risk and resource assessment.

BJORN WYGRALA ~ The Petromod Group, IES Schlumberger, Aachen, Germany

Dr. Bjorn Wygrala has had more than 20 years of experience in basin analysis and the application of simulation technologies for exploration risk and resource assessments of petroleum E&P companies in more than 40 countries. His interests lie in the areas of applied petroleum systems modeling, and quantification and sensitivity analysis of geologic parameters and processes in petroleum exploration. He is currently Managing Director, Technology Transfer at IES, which provides software and services for Petroleum Systems Modeling.
Proposal and Science Plan for
Basin and Petroleum Systems Modeling
at Stanford University

Objectives

A team of researchers has developed a science plan to facilitate training of
students and non-proprietary research in quantitative numerical modeling of
petroleum systems, through an industrial affiliates program at Stanford
University.

Our goal is to become a recognized center of excellence for training and
research in visualization and quantification of the geohistory of basins and
petroleum systems.

Objectives:

1. Train the next generation of petroleum systems modelers
2. Devise quantitative tools that, in combination with assessment methodology,
can be used to evaluate geologic risk in various exploration settings
3. Conduct basin and applied energy-focused research
Impetus to Form the BPSM Graduate Curriculum

• Rare among American university programs
• Exceptional student talent pool
• Comprehensive set of courses already available
• Good pre-existent university-industry relations
• Draw together multiple relevant/interested faculty and local experts
• Computational resources (CEES)
• Perceived industry need
Mission

The basin and petroleum systems modeling group at Stanford consists of students and geoscientists engaged in domestic and international energy-focused studies of sedimentary basins.

A fundamental goal is to train students to be the basin modelers of the future, which includes teaching the principles of petroleum systems methodology and basin modeling with hands-on experience using the latest basin modeling software.

An additional goal is to develop new modeling technology in close association with manufacturers of numerical modeling software, so that each new exploration study by the group is state-of-the-art and is driven by science and not just data.
Science Strategy

Concepts, data, expertise, and software/hardware related to 4-D petroleum systems modeling already exist. Growth in 4-D petroleum systems modeling is similar to developments in hydrogeology and reservoir engineering. These parallel developments suggest the need for coordination of GIS, EarthVision®, and computing efforts between groups with attendant time/cost savings for all.

Some key objectives of our proposed science strategy include:

- Improve links between input structural grids (i.e., seismic, wellbore data) and software (e.g., EarthVision®) to facilitate rapid and effective 4-D modeling.
- Develop quantitative, reproducible techniques for seamless transfer of subsurface geologic information to modeling software.
- Develop statistical versus deterministic representations of subsurface geology and properties (risk analysis!).
- Develop techniques to determine and represent uncertainties in geologic surfaces, volumes, and properties, including consistent incorporation of competing, mutually exclusive interpretations.
- Develop more sophisticated models that include episodes of deformation, faults, mineral phase transitions (e.g. opal A-opal CT-quartz), biodegradation, secondary cracking, and prediction of phases and migration fractionation (e.g., PVT studies).
- Identify calibration case studies for 4-D modeling assessment of petroleum volumes and detailed hydrocarbon compositions of reservoirs.
- Develop sequence stratigraphic frameworks linked to basic elements of the petroleum system that will facilitate evaluation of the potential for reserve growth and undiscovered oil and gas in major worldwide basins.
Scientific Benefits for Industry and Stanford

A center of excellence for 4-D petroleum systems modeling could benefit both industry and Stanford in many ways, some of which are listed below:

• A critical mass of 4-D modeling experts and students at Stanford will improve cooperation and our ability to undertake advanced research and large-scale modeling projects.

• Parallel processing environment offered by distributed and shared memory clusters at Stanford might be shared by other petroleum systems modeling groups, thus maximizing efficiency while minimizing computing time, duplication of support staff, and software/hardware costs.

• 4-D petroleum systems modeling allows extraction of 1-D models, maps of the pod of active source rock and regional source-rock thermal maturity, fluid-flow maps, and detailed petroleum generation timing (i.e., compared to timing of trap development)…..critical information in exploration efforts.

• Regional 4-D models are typically conducted at a larger scale (~1-10 km spacing between nodes) than that used by industry petroleum engineers or reservoir geologists concerned with specific reservoirs and fields. Our Stanford models will fill a gap in regional 4-D interpretations because most petroleum companies do not conduct studies at this scale. For this reason, we anticipate that companies will volunteer to provide regional seismic and well-log data in exchange for cooperative discussions of our results.

• As a research organization, Stanford University is well positioned to be an important contributor to progress in these areas because of its outstanding geology department, the school’s Center for Computational and Environmental Science, and its proximity to Silicon Valley.
Resources

The proposed research group uses the following assets, among others:

1. A parallel processing environment. Hardware time provided at no cost from the Center for Computational Earth and Environmental Sciences at Stanford (CEES).

2. All necessary Petromod® licenses (latest version) for research and teaching purposes to allow parallel processing of large models. Provided by Schlumberger IES, Aachen Germany.

3. All necessary PC-based Petromod® licenses (latest version) for research and teaching purposes to allow students to run simple 1-D or 2-D models and prepare input for larger 4-D models using their own PCs. Provided by Schlumberger IES, Aachen Germany.
CEES, Prof. Jerry Harris, Director

The CEES Grid hardware is organized into three resource clusters:

The Opteron Cluster is composed of 64 Sun v20z dual cpu nodes running Linux. Half of the nodes have 2GB of memory, and the other half have 8GB of memory. The head node is a Sun v40z with 4 dual core Opteron cpus and 16GB of memory. This cluster is designed for distributed programming and runs MPICH. The cluster software is Sun Grid Engine, and the network is Infiniband.

The Sparc Cluster is composed of 2 Sun servers running Solaris 10. The head node is a Sun 490 with 4 dual core Sparc cpus and 16 GB of memory, and the compute node is a Sun 6900 with 24 dual core Sparc cpus and 192 GB of memory. This cluster is designed for SMP programs and runs OpenMP. The cluster software is Sun Grid Engine, and the network is 10Gb ethernet.

The Tool Cluster is composed of 2 Sun v40z machines running Linux, each with 4 dual core Opteron cpus and 32 GB of memory. This cluster runs standalone programs and applications such as Matlab.
CEES Grid

Grid Software: Sun N1 Grid Engine

OPTERON CLUSTER

Opteron Cluster Nodes
Sun V20z
64 dual Opteron

InfiniBand Network

32 8GB Memory

TOOL CLUSTER

Tool-A
Sun V40Z
4 dual-core Opteron
32GB Memory

Tool-B
Sun V40Z
4 dual-core Opteron
32GB Memory

1 GbE Network

32 2GB Memory

SPARC CLUSTER

Sparc Cluster Node
Sun-Fire 6900
24 dual-core Sparc IV
192GB Memory

Opteron Head Node
Sun V40Z
4 dual-core Opteron
16GB Memory

10 GbE Network

Sparc Head Node
Sun 490
4 dual-core Sparc IV
16GB Memory

Fiber Channel

NFS Server
Sun V40Z

NFS Server
Sun V40Z

Stanford Network

Sun 3500FC
10TB Disk
BASIN AND PETROLEUM SYSTEMS MODELING PROGRAM (BPSM), DEPARTMENT OF GEOLOGICAL AND ENVIRONMENTAL SCIENCES

GRADUATE PROGRAMS

Admission—For admission to graduate work in the department, the applicant must have taken the Aptitude Test (verbal, quantitative, and analytical writing assessment) of the Graduate Record Examination. In keeping with University policy, applicants whose first language is not English must submit TOEFL (Test of English as a Foreign Language) scores from a test taken within the last 18 months. Individuals who have completed a B.S. or two-year M.S. program in the U.S. or other English-speaking country are not required to submit TOEFL scores. Previously admitted students who wish to change their degree objective from M.S. to Ph.D. must petition the GES Admissions Committee.

MASTER OF SCIENCE

Procedures—The graduate coordinator of the department appoints an academic adviser during registration with appropriate consideration of the student’s background, interests, and professional goals. In consultation with the adviser, the student plans a program of course work for the first year. The student should select a thesis adviser within the first year of residence and submit to the thesis adviser a proposal for thesis research as soon as possible. The academic adviser supervises completion of the department requirements for the M.S. program (as outlined below) until the research proposal has been accepted; responsibility then passes to the thesis adviser. The student may change either thesis or academic advisers by mutual agreement and after approval of the graduate coordinator.

Requirements—The University’s requirements for M.S. degrees are outlined in the “Graduate Degrees” section of this bulletin. Practical training (GES 385) may be required by some programs, with adviser approval, depending on the background of the student. Additional department requirements include the following:

1. A minimum of 45 units of course work at the 100 level or above.
   a. Half of the courses used to satisfy the 45-unit requirement must be intended as being primarily for graduate students, usually at the 200 level or above.
   b. No more than 15 units of thesis research may be used to satisfy the 45-unit requirement.
   c. Some students may be required to make up background deficiencies in addition to these basic requirements.
2. By the end of Winter Quarter of their first year in residence, students must complete at least three courses taught by a minimum of two different GES faculty members.
3. Each student must have a research adviser who is a faculty member in the department and is within the student’s thesis topic area or specialized area of study.
4. Each student must complete a thesis describing his or her research. Thesis research should begin during the first year of study at Stanford and should be completed before the end of the second year of residence.
5. Early during the thesis research period, and after consultation with the student, the thesis adviser appoints a second reader for the thesis, who must be approved by the graduate coordinator; the thesis adviser is the first reader. The two readers jointly determine whether the thesis is acceptable for the M.S. degree in the department.
DOCTOR OF PHILOSOPHY

Requirements—The University’s requirements for the Ph.D. degree are outlined in the “Graduate Degrees” section of this bulletin. Practical training (GES 385) may be required by some programs, with adviser approval, depending on the background of the student. A summary of additional department requirements is presented below:

1. Ph.D. students must complete the required courses in their individual program or in their specialized area of study with a grade point average (GPA) of 3.0 (B) or higher, or demonstrate that they have completed the equivalents elsewhere. Ph.D. students must complete a minimum of four letter-grade courses of at least 3 units each from four different faculty members on the Academic Council in the University. By the end of Winter Quarter of their first year in residence, students must complete at least three courses taught by a minimum of two different GES faculty members.

2. Each student must qualify for candidacy for the Ph.D. by the end of the sixth quarter in residence, excluding summers. Department procedures require selection of a faculty thesis adviser, preparation of a written research proposal, approval of this proposal by the thesis adviser, selection of a committee for the Ph.D. qualifying examination, and approval of the membership by the graduate coordinator and chair of the department. The research examination consists of three parts: oral presentation of a research proposal, examination on the research proposal, and examination on subject matter relevant to the proposed research. The exam should be scheduled prior to May 1, so that the outcome of the exam is known at the time of the annual spring evaluation of graduate students.

3. Upon qualifying for Ph.D. candidacy, the student and thesis adviser, who must be a department faculty member, choose a research committee that includes a minimum of two faculty members in the University in addition to the adviser. Annually, in the month of March or April, the candidate must organize a meeting of the research committee to present a brief progress report covering the past year.

4. Under the supervision of the research advisory committee, the candidate must prepare a doctoral dissertation that is a contribution to knowledge and is the result of independent research. The format of the dissertation must meet University guidelines. The student is strongly urged to prepare dissertation chapters that, in scientific content and format, are readily publishable.

5. The doctoral dissertation is defended in the University oral examination. The research adviser and two other members of the research committee are determined to be readers of the draft dissertation. The readers are charged to read the draft and to certify in writing to the department that it is adequate to serve as a basis for the University oral examination. Upon obtaining this written certification, the student is permitted to schedule the University oral examination.
BPSM COURSES

The BPSM curriculum consists of 8 core courses, selected to provide a broad cross-sectional view of the elements of basin modeling. Students will complete the balance of required total units from the list of elective courses. Other courses may be substituted in consultation with faculty advisor. Some prerequisite undergraduate courses, such as those listed below, may be necessary for some students.
GRADUATE COURSES

CORE BPSM COURSES

GES 240. Geostatistics for Spatial Phenomena—(Same as ENERGY 240.) Probabilistic modeling of spatial and/or time dependent phenomena. Kriging and co-kriging for gridding and spatial interpolation. Integration of heterogeneous sources of information. Multiple-point geostatistics and training image-based stochastic imaging of reservoir/field heterogeneities. Introduction to GSLIB and S.GEMS software. Case studies from the oil and mining industry and environmental sciences. Prerequisites: introductory calculus and linear algebra, STATS 116, GES 161, or equivalent. 3-4 units, Win (Journal, A)

GES 249. Petroleum Geochemistry in Environmental and Earth Science—How molecular fossils in crude oils, oil spills, refinery products, and human artifacts identify their age, origin, and environment of formation. The origin and habit of petroleum, technology for its analysis, and parameters for interpretation, including: origins of molecular fossils; function, biosynthesis, and precursors; tectonic history related to the evolution of life, mass extinctions, and molecular fossils; petroleum refinery processes and the kinds of molecular fossils that survive; environmental pollution from natural and anthropogenic sources including how to identify genetic relationships among crude oil or oil spill samples; applications of molecular fossils to archaeology; worldwide petroleum systems through geologic time. 3 units, Win (Moldovan, J)

GES 251. Sedimentary Basins—Analysis of the depositional framework and tectonic evolution of sedimentary basins. Topics: tectonic and environmental controls on facies relations, synthesis of basin development through time in terms of depositional systems and tectonic settings. Weekend field trip required. Prerequisites: 110, 151. 3 units, Aut (Graham, S)

GES 253. Petroleum Geology and Exploration—The origin and occurrence of hydrocarbons. Topics: thermal maturation history in hydrocarbon generation, significance of sedimentary and tectonic structural setting, principles of accumulation, and exploration techniques. Prerequisites: 110, 151. Recommended: GEOPHYS 184. 3 units, Spr alternate years, (Graham, S)

GES 255. Basin and Petroleum System Modeling—For advanced undergraduates or graduate students. Students use stratigraphy, subsurface maps, and basic well log, lithologic, paleontologic, and geochemical data to construct 1-D, 2-D, and 3-D models of petroleum systems that predict the extent of source-rock thermal maturity, petroleum migration paths, and the volumes and compositions of accumulations through time (4-D). Recent software such as PetroMod designed to reconstruct basin geohistory. Recommended: 251 or 253. 3 units, Win (Peters, K)

GES 257. Clastic Sequence Stratigraphy—Sequence stratigraphy facilitates integration of all sources of geologic data, including seismic, log, core, and paleontological, into a time-stratigraphic model of sediment architecture. Tools applicable to regional and field scales. Emphasis is on practical applications and integration of seismic and well data to exploration and field reservoir problems. Examples from industry data; hands-on exercises. 3 units, Spr alternate years (McHargue, T)

GEOPHYS 183. Reflection Seismology Interpretation—The structural and stratigraphic interpretation of seismic reflection data, emphasizing hydrocarbon traps in two and three dimensions on industry data, including workstation-based interpretation. Lectures only, 1 unit. Prerequisite: 182, or consent of instructor. 1-4 units, Spr (Klemperer, S; Graham, S)

GEOPHYS 200. Fluids and Flow in the Earth: Computational Methods—Interdisciplinary problems involving the state and movement of fluids in crustal systems, and computational methods to model these processes. Examples of processes include: nonlinear, time-dependent flow in porous rocks; coupling in porous rocks between fluid flow, stress, deformation, and heat and chemical transport; percolation of partial melt; diagenetic processes; pressure solution and the formation of stylolites; and transient pore pressure in fault zones. MATLAB, Lattice-Boltzmann, and COMSOL Multiphysics. Term project. No experience with COMSOL Multiphysics required. 3 units, Win (Mukerji, T)
What?  
Why?  
Where?  
When?  
Who?  
How?  

Liquid, Vapor
SUGGESTED ELECTIVE COURSES

Structural Geology

GES 215A. Structural Geology and Rock Mechanics—(Same as CEE 297G.) Quantitative field and laboratory data integrated with solutions to initial and boundary-value problems of continuum mechanics introduce tectonic processes in Earth’s crust that lead to the development of geological structures including folds, faults, fractures and fabrics. Topics include: techniques and tools for structural mapping; using differential geometry to characterize structures; dimensional analysis and scaling relations; kinematics of deformation and flow; traction and stress analysis. Data sets analyzed using MATLAB. Prerequisites: GES 1, MATH 53, MATLAB or equivalent.

  3-5 units, Aut (Pollard, D)

GES 215B. Structural Geology and Rock Mechanics—(Same as CEE 297H.) Field equations for elastic solids and viscous fluids derived from conservation laws to develop mechanical models for tectonic processes and their structural products. Topics include: conservation of mass and momentum in a deformable continuum; linear elastic deformation and elastic properties of rock; brittle deformation including fracture and faulting; linear viscous flow including folding, model development, and methodology. Models constructed and solutions visualized using MATLAB. Prerequisite: GES 215A.

  3-5 units, Win (Pollard, D)

GES 216. Rock Fracture Mechanics—Principles and tools of elasticity theory and fracture mechanics are applied to the origins and physical behaviors of faults, dikes, joints, veins, solution surfaces, and other natural structures in rock. Field observations, engineering rock fracture mechanics, and the elastic theory of cracks. The role of natural fractures in brittle rock deformation, and fluid flow in the earth’s crust with applications to crustal deformation, structural geology, petroleum geology, engineering, and hydrogeology. Prerequisite: GES 215 or equivalent.

  3-5 units, Aut (Pollard, D)

GES 217. Faults, Fractures, and Fluid Flow—Process-based approach to rock failure; the microstructures and overall architectures of the failure products including faults, joints, solution seams, and types of deformation bands. Fluid flow properties of these structures emphasizing sealing and transmitting of faults and their role in hydrocarbon flow, migration, and entrapment. Case studies of fracture characterization experiments in aquifers, oil and gas reservoirs, and waste repository sites. Guest speakers; weekend field trip. Prerequisite: first-year graduate student in Earth Sciences.

  3 units, alternate years, (Aydin, A)


  3 units, alternate years, (Zoback, M)
Sedimentary Geology and Geochemistry

GES 246. Reservoir Characterization and Flow Modeling with Outcrop Data—(Same as ENERGY 246.) Project addressing a reservoir management problem by studying an outcrop analog, constructing geostatistical reservoir models, and performing flow simulation. How to use outcrop observations in quantitative geological modeling and flow simulation. Relationships between disciplines. Weekend field trip.

3 units, Aut (Graham, S; Tchelepi, H; Boucher, A)

GES 250. Sedimentation Mechanics—The mechanics of sediment transport and deposition and the origins of sedimentary structures and textures as applied to interpreting ancient rock sequences. Dimensional analysis, fluid flow, drag, boundary layers, open channel flow, particle settling, erosion, sediment transport, sediment gravity flows, soft sediment deformation, and fluid escape. Field trip required.

4 units, Aut (Lowe, D)

GES 252. Sedimentary Petrography—Siliciclastic sediments and sedimentary rocks. Research in modern sedimentary mineralogy and petrography and the relationship between the composition and texture of sediments and their provenance, tectonic settings, and diagenetic histories. Topics vary yearly. Prerequisite: 151 or equivalent.

4 units, alternate years, not given this year (Lowe, D)

GES 254. Carbonate Sedimentology—Processes of precipitation and sedimentation of carbonate minerals with emphasis on marine systems. Topics include: geographic and bathymetric distribution of carbonates in modern and ancient oceans; genesis and environmental significance of carbonate grains and sedimentary textures; carbonate rocks and sediments as sources of geochemical proxy data; carbonate diagenesis; changes in styles of carbonate deposition through Earth history; carbonate depositional patterns and the global carbon cycle. Lab exercises emphasize petrographic and geochemical analysis of carbonate rocks including map and outcrop scale, hand samples, polished slabs, and thin sections.

3-4 units, Spr (Payne, J)

GES 258. Introduction to Depositional Systems—The characteristics of the major sedimentary environments and their deposits in the geologic record, including alluvial fans, braided and meandering rivers, aeolian systems, deltas, open coasts, barred coasts, marine shelves, and deep-water systems. Emphasis is on subdivisions; morphology; the dynamics of modern systems; and the architectural organization and sedimentary structures, textures, and biological components of ancient deposits.

3 units, offered occasionally (Lowe, D)

GES 260. Laboratory Methods in Organic Geochemistry—Knowledge of components in geochemical mixtures to understand geological and environmental samples. The presence and relative abundance of these compounds provides information on the biological source, depositional environment, burial history, biodegradation, and toxicity of organic materials. Laboratory methods to detect and quantify components of these mixtures. Methods for separation and analysis of organic compounds in geologic samples: extraction, liquid chromatography, absorption by zeolites, gas chromatography and gas chromatography-mass spectrometry. Student samples considered as material for analysis. Recommended: 249.

2-3 units, Spr (Moldovan, J)
Geophysics

ERE 130. Well Log Analysis For earth scientists and engineers. Interdisciplinary, providing a practical understanding of the interpretation of well logs. Lectures, problem sets using real field examples: methods for evaluating the presence of hydrocarbons in rock formations penetrated by exploratory and development drilling. The fundamentals of all types of logs, including electric and non-electric logs. 3 units, Aut (Staff)

GEOPHYS 230. Advanced Topics in Well Logging — (Same as ENERGY230.) State of the art tools and analyses; the technology, rock physical basis, and applications of each measurement. Hands-on computer-based analyses illustrate instructional material. Guest speakers on formation evaluation topics. Prerequisites: 130 or equivalent; basic well logging; and standard practice and application of electric well logs. 3 units, Spr (Lindblom, R)

GEOPHYS 241A. Practice of Geostatistics and Seismic Data Integration — Students build a synthetic 3D fluvial channel reservoir model with layer depths, channel geometry, and facies-specific petrophysic and seismic properties, stressing the physical significance of geophysical data. Reference data set is sparsely sampled, providing the sample data typically available for an actual reservoir assessment. Geostatistical reservoir modeling uses well and seismic data, with results checked against the reference database. Software provided (GSLIB and SRB tools). Prerequisite: ENERGY 240. Recommended: experience with Unix, MATLAB/C++/Fortran programming. 3-4 units, Spr (Mukerji, T; Caers, J)

GEOPHYS 260. Rock Physics for Reservoir Characterization — How to integrate well log and laboratory data to determine and theoretically generalize rock physics transforms between sediment wave properties (acoustic and elastic impedance), bulk properties (porosity, lithology, texture, permeability), and pore fluid conditions (pore fluid and pore pressure). These transforms are used in seismic interpretation for reservoir properties, and seismic forward modeling in what-if scenarios. 3 units, Win (Dvorkin, J)

GEOPHYS 262. Rock Physics — Properties of and processes in rocks as related to geophysical exploration, crustal studies, and tectonic processes. Emphasis is on wave velocities and attenuation, hydraulic permeability, and electrical resistivity in rocks. Application to in situ problems, using lab data and theoretical results. 3 units, Aut (Mavko, G)

GP 262
UNDERGRADUATE BACKGROUND COURSES

GES 110. Structural Geology and Tectonics—Techniques, principles, and theory to describe, measure, analyze, and interpret deformation-related structures in rocks and minerals. Techniques of structural data collection in the field; lab and computer analysis of structural data; theory and principles of brittle deformation, faulting, and folding; interpretation of geologic maps and principles of cross-section construction; strain measurement and the structural analysis of metamorphic rocks; evolution of fold and thrust belts, rift-related sedimentary basins, and strike-slip fault systems. Prerequisites: 1, calculus. Recommended: 102. GER:DB-NatSci
5 units, Spr (Miller, E)

GES 111A. Fundamentals of Structural Geology—(Same as CEE 195A.) Techniques for structural mapping; using differential geometry to characterize structures; dimensional analysis and scaling relations; kinematics of deformation and flow; measurement and analysis of stress. Sources include field and laboratory data integrated with conceptual and mechanical models. Models of tectonic processes are constructed and solutions visualized using MATLAB. Prerequisites: GES 1, MATH 51, 52. GER:DB-NatSci
3 units, Aut (Pollard, D)

GES 111B. Fundamentals of Structural Geology—(Same as CEE 195B.) Continuation of GES 111A/CEE 195A. Conservation of mass and momentum in a deformable continuum; linear elastic deformation and elastic properties of rock; brittle deformation including fracture and faulting; linear viscous flow including folding and magma dynamics; model development and methodology. Sources include field and laboratory data integrated with conceptual and mechanical models. Models of tectonic processes are constructed and solutions visualized using MATLAB. Prerequisite: GES 111A/CEE 195B.
3 units, Win (Pollard, D)

GES 151. Sedimentary Geology and Petrography: Depositional Systems—Topics: weathering, erosion and transportation, deposition, origins of sedimentary structures and textures, sediment composition, diagenesis, sedimentary facies, tectonics and sedimentation, and the characteristics of the major siliciclastic and carbonate depositional environments. Lab: methods of analysis of sediments in hand specimen and thin section. Field trips. Prerequisites: 1, 102, 103. GER:DB-NatSci
4 units, Win (Graham, S; Lowe, D)

GES 161. Statistical Methods for the Earth and Environmental Sciences: Geostatistics—(Same as ENERGY 161.) Statistical analysis and graphical display of data, common distribution models, sampling, and regression. The variogram as a tool for modeling spatial correlation; variogram estimation and modeling; introduction to spatial mapping and prediction with kriging; integration of remote sensing and other ancillary information using co-kriging models; spatial uncertainty: introduction to geostatistical software applied to large environmental, climatological, and reservoir engineering databases; emphasis is on practical use of geostatistical tools.
3-4 units, Win (Boucher, A)
**Example of Typical BPSM Course Flow (MS or PhD)**

<table>
<thead>
<tr>
<th>Year One</th>
<th>Year Two</th>
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</thead>
<tbody>
<tr>
<td><strong>Autumn Quarter</strong></td>
<td><strong>Autumn Quarter</strong></td>
</tr>
<tr>
<td>GES 251 Sedimentary basins</td>
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<tr>
<td>Elective course</td>
<td>Elective course</td>
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<tr>
<td>Elective course</td>
<td>Research</td>
</tr>
<tr>
<td><strong>Winter Quarter</strong></td>
<td><strong>Winter Quarter</strong></td>
</tr>
<tr>
<td>GES 255 Basin &amp; pet sys modeling</td>
<td>GES 240 Spatial geostatistics</td>
</tr>
<tr>
<td>GP 200 Fluids &amp; flow in the earth</td>
<td>Elective course</td>
</tr>
<tr>
<td>GES 249 Petroleum Geochemistry</td>
<td>Research</td>
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<tr>
<td><strong>Spring Quarter</strong></td>
<td><strong>Spring</strong></td>
</tr>
<tr>
<td>GES 257 Sequence stratigraphy</td>
<td>Research</td>
</tr>
<tr>
<td>GP 183 Seismic interpretation</td>
<td>For PhD students: Qualifying exam</td>
</tr>
<tr>
<td>GES 253 Petroleum geology</td>
<td>For MS students: Graduation at end of quarter</td>
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<tr>
<td><strong>Summer Quarter</strong></td>
<td></td>
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<tr>
<td>Internship or Dissertation research</td>
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</tbody>
</table>
Graduate Students Affiliated with BPSM

**Current**

<table>
<thead>
<tr>
<th>Name</th>
<th>Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bin Jia</td>
<td>ERE Dept</td>
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<tr>
<td>Meng He</td>
<td>GES Dept</td>
</tr>
<tr>
<td>Danica Dralus</td>
<td>GP Dept</td>
</tr>
<tr>
<td>Blair Burgreen</td>
<td>GES Dept</td>
</tr>
<tr>
<td>Keisha Durant</td>
<td>GES Dept</td>
</tr>
<tr>
<td>Tess Menotti</td>
<td>GES Dept</td>
</tr>
</tbody>
</table>
Overriding Principles Applicable to Stanford Industrial Affiliates Programs

- Promotion of openness in research results
- Enrichment of educational experiences for students and postdocs
- Maintenance of the University’s role as a credible and impartial resource
- Protection of faculty members’ right to pursue research topics and methodology of their choice
- Conformance to the University’s primary mission of teaching and research

While member companies may offer suggestions for research activities, the involved faculty must be free to select research topics, adopt research methodology, select participants, and direct research funded by the programs.

Consistent with Stanford’s openness in research and dissemination of research policy, research activities generated under the program will be made to members and non-members.

Research must have broad application and may not be geared toward any member or company.
Industrial Affiliate Programs in the School of Earth Science

Basins and Petroleum Systems Modeling Group

Center for Aquifer Simulation

Geothermal Program Affiliates

Molecular Organic Geochemistry Industrial Affiliates

Smart Fields

Stanford Center for Reservoir Forecasting

Stanford Exploration Project

Stanford Project on Deep-water Depositional Systems

Stanford Project on Productivity & Injectivity of Horizontal Wells

Stanford Rock Fracture Project

Stanford Rockphysics & Borehole Geophysics Project

SUPRI-A (Stanford University Petroleum Research Institute): Thermal Oil Recovery Program

SUPRI-B (Stanford University Petroleum Research Institute): Reservoir Simulation Affiliates

SUPRI-C (Stanford University Petroleum Research Institute): Gas Injection Affiliates

SUPRI-D (Stanford University Petroleum Research Institute): Well Test Interpretation Affiliates
Impetus to Form the BPSM Industrial Affiliates Program

- Greater access to research problems & data
- Platform for expanded BPSM research at Stanford
- Closer relations between faculty, students & industry
- Financial support for students & research projects
Benefits of Industrial Affiliates Membership

Industrial Affiliates and related Stanford programs supported by corporate membership fees:

- facilitate the transfer of knowledge into society and dialogue between academia and industry
- provide an effective way for industry to contribute to and sustain the research and teaching of the departments and programs in which they have long-term interests.

Access to membership will be available equally to all companies prepared to meet the requirements of membership.

Facilitated access to research programs and relevant faculty and students is provided to members.
Specific Benefits of Membership in the BPSM Industrial Affiliates Program

• Invitations to annual meetings and workshops
• Faculty liaison
• Student recruitment opportunities
• Copies of reports and publications
• Opportunities to interact with students in research projects
• Campus visits
Basin and Petroleum Systems Modeling (BPSM)
Industrial Affiliates 2010

BP
Chevron
IES-Schlumberger
JOGMEC
Petrobras
Stanford University
Basin and Petroleum Systems Modeling (BPSM)
Industrial Affiliates Summer Meeting