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Introduction to the 2023 Stanford Geothermal Workshop

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ABSTRACT

The 2023 Stanford Geothermal Workshop is the 48th time that the workshop has been held, and the first return to in-person running of the event following two virtual years due to to the Covid-19 pandemic. This short overview will describe the background and the recent history of the workshop.

A BRIEF HISTORY

The first Stanford Geothermal Workshop was held in December 1975, as the brainchild of Prof. Paul Kruger. Paul Kruger was one of the three founders of the Stanford Geothermal Program, the other two being Prof. Henry J. Ramey, Jr., and Prof. Lou London (Figure 1). In 1975, geothermal energy development was in its infancy in the US, but expanding rapidly as a response to the 1973 Energy Crisis. The Department of Energy was just being formed, out of the ashes of ERDA, the Energy Research and Development Agency.

Given the large number of new projects and new researchers turning their expertise to the new field of geothermal energy, Paul Kruger's concept was for a meeting at which researchers and developers could share their nascent ideas and learn from discussions with others while the projects were still in progress. Stanford Workshop papers were intended to be "work in progress" discussions, rather than completed scientific papers. The Stanford Geothermal Workshop was intended to be a proving ground for testing new ideas. It is called a workshop and not a conference for that reason.

The informal style and organization of the Workshop follows this pattern to the present day. The focus on fostering innovative ideas and fruitful discussion is reflected in the "just in time" paper submission and collation process that is used.

The Stanford Geothermal Workshop has served as a prototype for several other annual geothermal meetings around the world.

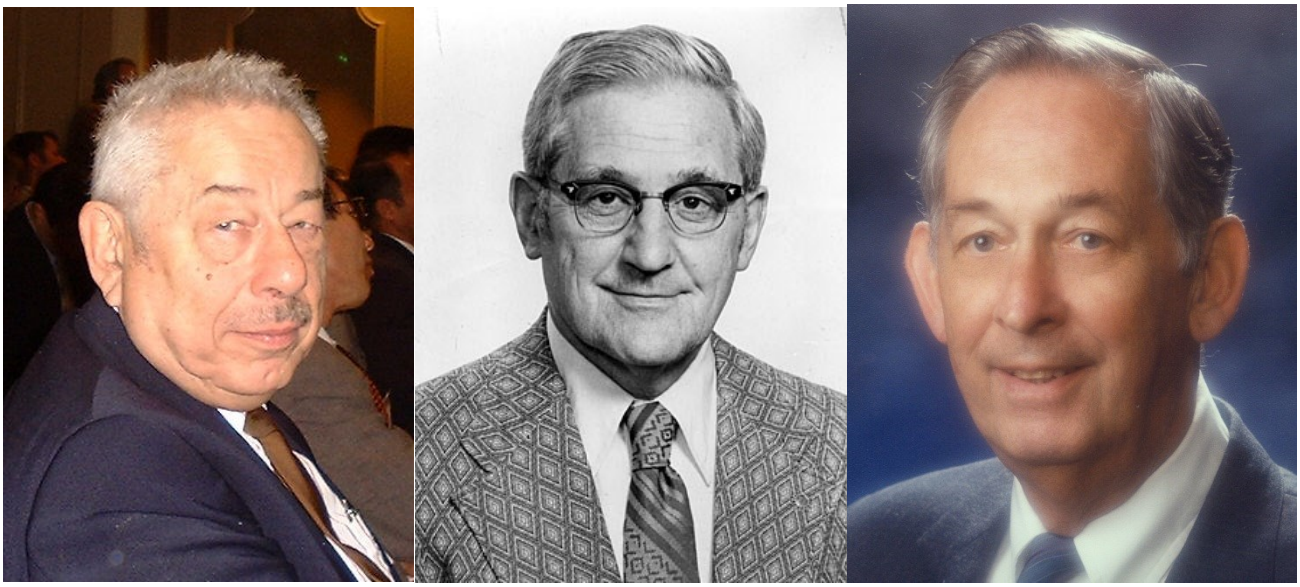


Figure 1: Founders of the Stanford Geothermal Program, Prof. Paul Kruger, Civil Engineering (left), Prof. A. Louis London, Mechanical Engineering (center), Prof. Henry J. Ramey, Jr., Petroleum Engineering, (right).

WORKSHOP STATISTICS

Over 47 years the Workshop has evolved. From 1975 until 1995 the meeting had only a single session sequence, and all participants attended every presentation. A lot was learned about topics not usually the daily routine of the audience members. About 40-50 papers were presented each year.

In 1995 the number of papers increased to 70-80, which necessitated the shift to two parallel sessions, often one focusing on engineering and the other on geosciences. In 2011 the number of papers increased dramatically to 147, and the number of parallel sessions increased to three. In 2012 the number of abstracts submitted climbed to 253, and for the first time the Workshop organizers were obliged to reject some abstracts, despite moving to four parallel sessions. The most recent years' numbers are illustrated in Table 1 and Figure 2. A striking feature is that prior to 2010, it was uncommon for authors to submit abstracts without completing the final papers and attending the Workshop to present them. After 2010, there was a greater number of nonauthor attendees and a greater percentage of "shrinkage" (abstracts submitted that did not ultimately become papers and presentations).

Table 1: Statistics of abstracts, papers and registrations over the years 2002-2023.

Year	Countries	Abstracts	Papers	Registrants	shrinkage
2002	13	65	65		0
2003	13	51	51		0
2004	13	48	48		0
2005	13	70	70		0
2006	13	74	74		0
2007	13	64	60		0.06
2008	13	61	61		0.00
2009	13	63	57		0.10
2010	15	75	70		0.07
2011	19	163	141		0.13
2012	24	253	215	327	0.15
2013	25	236	206	332	0.13
2014	30	188	178	274	0.05
2015	24	166	132	230	0.20
2016	27	268	207	296	0.23

2017	29	261	177	276	0.32
2018	29	283	196	280	0.31
2019	31	263	153	239	0.42
2020	20	179	143	200	0.20
2021	15	161	98	148	0.39
2022	16	187	110	150	0.41
2023	20	260	185	312	0.29

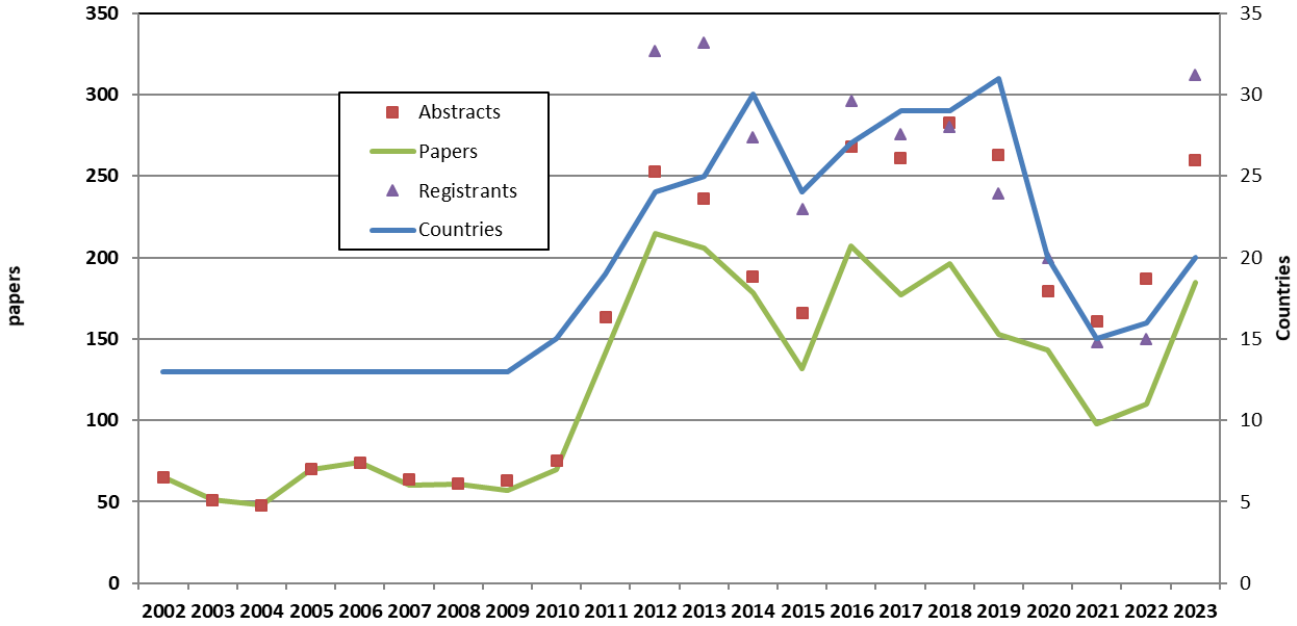


Figure 2: Number of abstracts, final papers, and countries represented over the past 20 years.

PUBLISHING FOR ACCESS

Based on the philosophy of making results and ideas available widely to the geothermal community, the Proceedings of the Workshop have been distributed internationally since the beginning of the event. Until 1999 the proceedings were published first as a preprint volume for use at the Workshop itself, followed by a hard cover volume created over the following two or three months. The hard cover volumes were sent to all participants who had attended the Workshop, as well as to libraries, universities and companies worldwide.

Starting in 1999, the Workshop began to use CD-ROMs to distribute the papers, and discontinued the paper volumes the following year. In 2000, the Stanford Geothermal Program initiated one of the first online collections of geothermal papers, based on the 25 years of Stanford Workshops up to that date. The collection was shared with the international community in collaboration with the International Geothermal Association (which also contributes papers to the collection). In 2012, the online collection was integrated with the National Geothermal Data System (NGDS), and at the same time collaborated with the Geothermal Resources Council (GRC) to cross-list papers from the Stanford Geothermal Workshop and the Geothermal Resources Council Annual Meeting. In 2023, the total number of papers in the searchable collection exceeds 22,000. The online collection is accessed on average about 6000 hits/month.

PAPER AND PEOPLE MANAGEMENT

With a target of encouraging papers that include the most recent results and ideas, the Workshop is organized to minimize the time between submission of papers and their presentation at the Workshop. By use of online submission and a high degree of automation, the paper submission deadline is only 9 days in advance of the workshop. The proceedings volume is collated and indexed, prepared on a USB stick master and manufactured in time for distribution at the workshop. The full schedule of the technical program is also created automatically, which allows for it to be modified as necessary and shown online immediately.

The automation process depends on reducing the handling of information such as author names, addresses, key words etc. The model is that authors submit their own information, which then migrates throughout the Workshop administration and paper management. This is not only faster, but also more accurate as transcription errors are avoided. But a participant who misspells their own name in their submission will have a misspelled name badge at the Workshop!

In 2012 we wrote a new database/web interface for paper and registration management. The program is based on PHP and MySQL. Instead of the flat database we used previously, the 2012 system separates people from papers, so that (for example) one person can submit multiple papers and associate them all with a single username. This differs from the system used until 2011, in which each record defining a paper also required the full information about the submitting author.

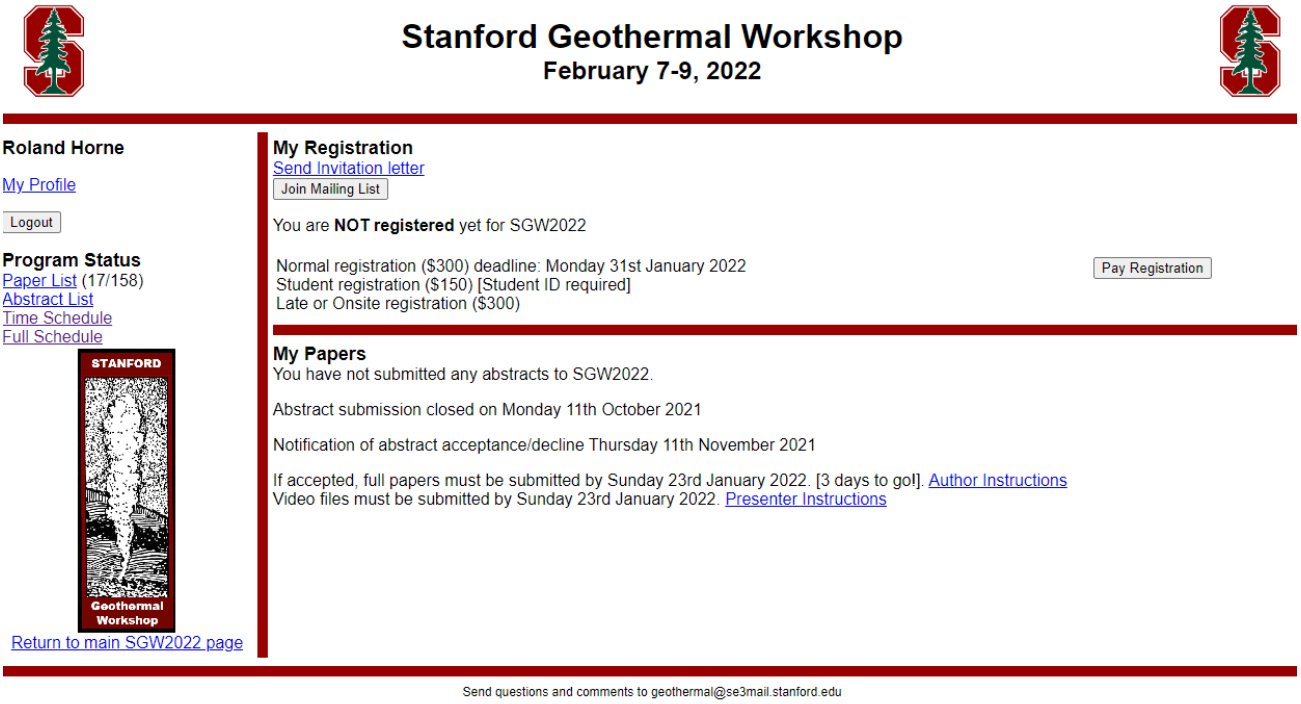


Figure 2: The web-based paper handling and registration, used since 2012.

The system also allows the username to be used in subsequent years, so authors will not have to enter their address and contact information year after year.

New since 2015 has been a smartphone/tablet version of the program that allows real-time access to the program, with downloadable files.

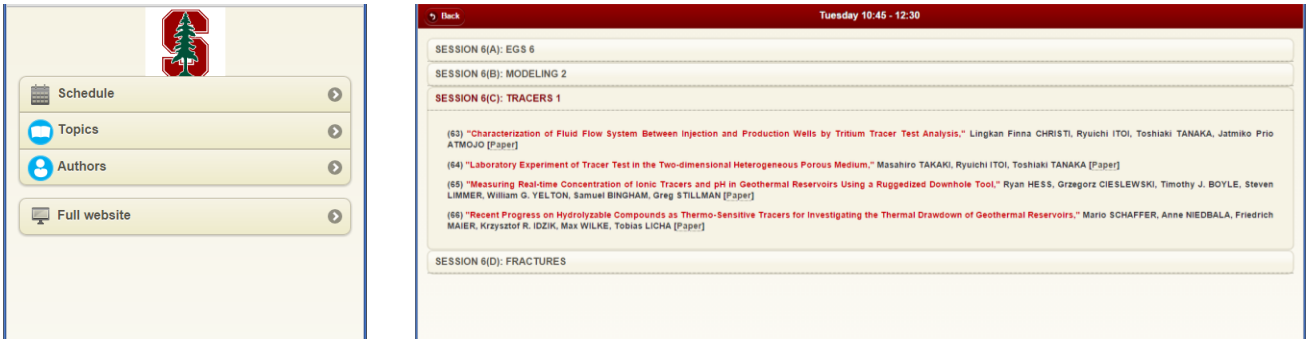


Figure 3: The smartphone/tablet access system developed in 2015.

And finally in 2021, an extraordinary year due to the Covid-19 pandemic forced the Workshop to be an entirely online event. The 2021 virtual workshop was a success, but was not expected to be other than a one-time event – unfortunately the emergence of the omicron variant in late 2021 forced the 2022 workshop into a virtual format once again. But, in 2023 the Workshop is back in a fully in-person format!

STANFORD GEOTHERMAL PROGRAM STATISTICS

In addition to 48 Workshops, the Stanford Geothermal Program has produced a large number of research publications, in the form of technical papers in peer-reviewed journals, reports to the US Department of Energy, and many student theses and reports. In its 50 years of activity, the Stanford Geothermal Program has produced 133 graduates: 38 PhD, 4 Engineer, and 92 MS. Many of these have gone to leading roles in the geothermal community worldwide. A list of the graduates, and the subjects of their research, is shown in Table 2.

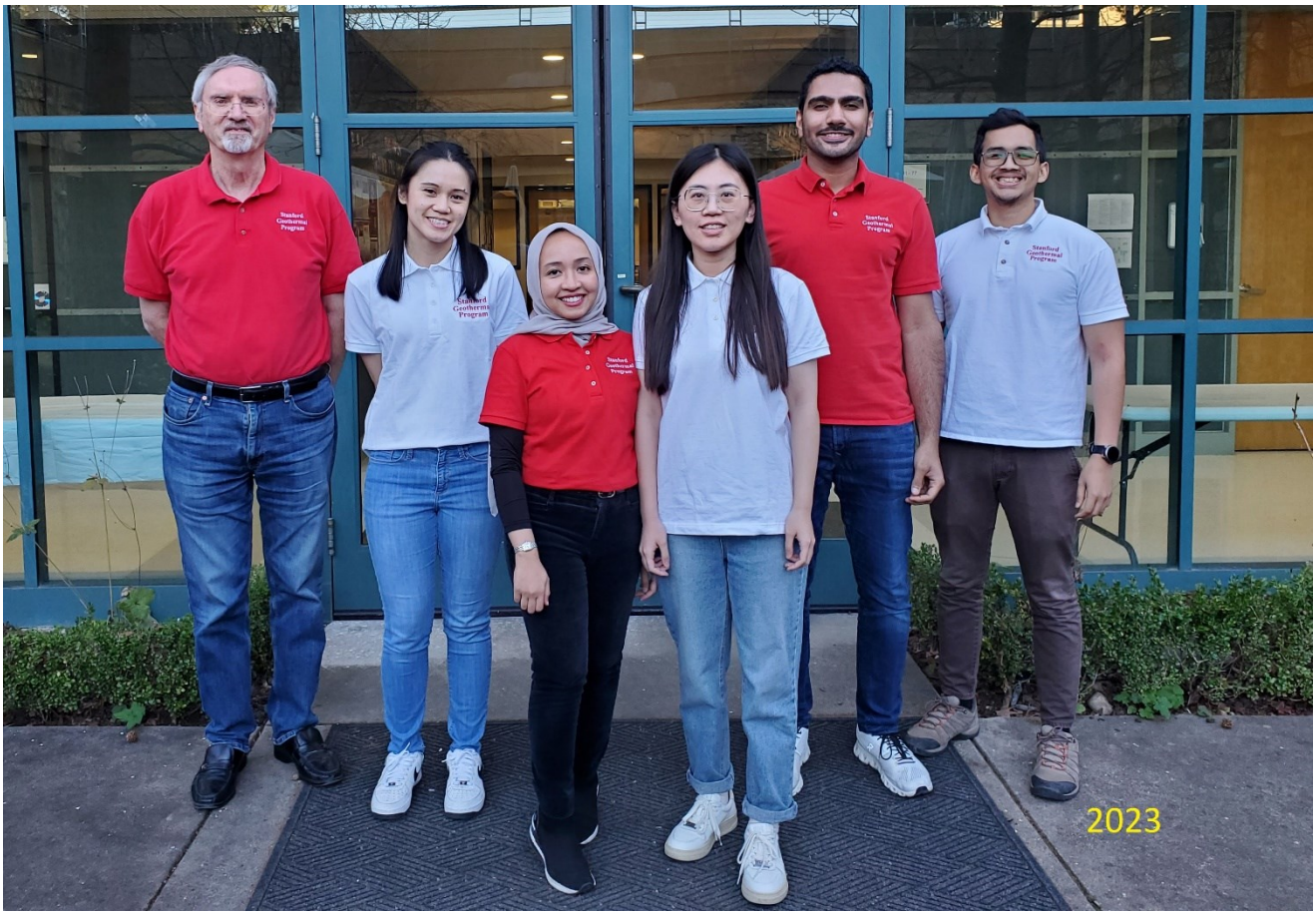
Table 2: Graduates of the Stanford Geothermal Program, 1974-2022. 38 PhD, 4 Engineer, 91 MS, 133 TOTAL.

Norio Arihara, "A Study of Non-isothermal and Two-phase Flow Through Consolidated Sandstones," PhD 1974.
Francis J. Casse, "The Effect of Temperature and Confining Pressure on Fluid Flow Properties of Consolidated Rocks," MS 1974.
Alan K. Stoker, "Radon Measurements in Geothermal Systems," Eng. 1975.
Anstein Hunsbedt, "A Laboratory Model of Stimulated Geothermal Reservoirs," PhD 1975.
Ming-Ching Tom Kuo, "Heat and Mass Transfer in Porous Rock Fragments," PhD 1975.
Muhammadu Aruna, "The Effects of Temperature and Pressure on Absolute Permeability of Sandstones," PhD 1976.
Paul G. Atkinson,"Mathematical Modelling of Single-Phase Nonisothermal Fluid Flow through Porous Media," PhD 1976.
Hsiu-Kuo Chen, "Measurement of Water Content of Porous Media Under Geothermal System Conditions," PhD 1976.
Stephen D. Chicoine, "A Physical Model of a Geothermal System-Its Design and Construction and Its Application to Reservoir Engineering," MS 1975.
Roger P. Denlinger, "An Evaluation of the Capacitance Probe As a Technique for Determining Liquid Saturations In Laboratory Flow Experiments," MS, 1975.
Gary Warren, "Radon in Vapor-Dominated Geothermal Reservoirs," MS 1978.
Syed M. Tariq, "A Study of the Behavior of Layered Reservoir with Wellbore Storage and Skin Effect," MS 1977.
Leslie S. Mannon, "The Real Gas Pseudo-Pressure for Geothermal Steam," MS 1977.
Kiyoshi Shinohara, "Calculation and Use of Steam/Water Relative Permeabilities in Geothermal Reservoirs," MS 1978.
Roberto Iregui, "Analysis of the Heat Transfer Limitations on the Energy Recovery from Geothermal Reservoirs," MS 1978.
Patricia Arditty, "The Earth Tide Effects on Petroleum Reservoirs; Preliminary Study," MS 1978.
Christine A. Ehlig-Economides, "Well Test Analysis for Wells Produced at a Constant Pressure," PhD 1979.
John R. Counsil, "Steam-Water Relative Permeability," PhD 1979.
Chih-Hang Hsieh, "Vapor Pressure Lowering in Porous Media," PhD 1980.
Kiyoshi Shinohara, "A Study of Inertial Effect in the Wellbore in Pressure Transient Well Testing," PhD 1980.
Kern H. Guppy, "Non-Darcy Flow in Wells with a Finite Conductivity Vertical Fracture," PhD 1980.
Abraham Sageev, "The Design and Construction of an Absolute Permeameter to Measure the Effect of Elevated Temperature on the Absolute Permeability to Distilled Water of Unconsolidated Sand Cores," MS 1980.
Hasan Y. Al-Yousef "Limitations of the p/q Approximation in the Analysis of Pressure Drawdown Interference with Variable Flow Rate," MS 1979.
Mario Castaneda, "Feed Zones in Geothermal Wellbores," MS 1981.
John D. Westwood, "The Application of Lumped Parameter Modeling to Cerro Prieto Geothermal Field," MS 1981.
Giovanni Da Prat, "Well Test Analysis for Naturally-Fractured Reservoirs," PhD 1981.
David Spivak, "Unsteady-State Pressure Response in a Slotted Liner," MS 1981.
Kenneth A. Breitenbach, "Chemical Tracer Retention in Porous Media," MS 1982.
Rajiv Rana, "Exploratory Study of the Effect of Thermal Stressing on Granite Strength and Porosity," Eng. 1984.
Martin P. Fossum, "Tracer Analysis in a Fractured Geothermal Reservoir: Field Results from Wairakei, New Zealand," MS 1982.
Anthony J. Menzies, "Flow Characteristics and Relative Permeability Functions for Two Phase Geothermal Reservoirs from a One Dimensional Thermodynamic Model," MS 1982.
John D. G. Moody, "Heat Transfer in a Naturally-Fractured Geothermal Reservoir Undergoing Reinjection," MS 1982.
Kazuichi Satomi, "Radon Emanation Mechanism from Finely Ground Rocks," MS 1982.
Mark A. Miller, "Effect of Temperature on Oil-Water Relative Permeabilities of Unconsolidated and Consolidated Sands," PhD 1983.
Avrami Sageev, "Pressure Transient Analysis of Reservoirs with Linear or Internal Circular Boundaries," PhD 1983.
Jaime Ortiz-Ramirez, "Two-Phase Flow in Geothermal Wells: Development and Uses of a Computer Code," MS 1983.
Eduardo Granados, "Calcium Carbonate Deposition in Geothermal Wellbores: Miravalles Geothermal Field, Costa Rica," MS 1983.
Michael Economides, "Geothermal Reservoir Evaluation Considering Fluid Adsorption and Composition," PhD 1983.
Miguel-Angel Saldana-Cortez, "Drillstem Test Data Analysis Considering Inertial and Frictional Wellbore Effects," PhD 1983.

Khalid Mateen, "Slug Test Data Analysis in Reservoirs with Double Porosity Behaviour," MS 1983.
Clair Lynn Jensen, "Matrix Diffusion and Its Effect on the Modelin of Tracer Returns from the Fractured Geothermal Reservoir at Wairakei, New Zealand," MS 1983.
John Dee, "A Reservoir Engineering Analysis of a Vapor-Dominated Geothermal Field," MS 1983.
Olivier P. Houze, "Infinite Conductivity Fracture in a Naturally Fractured Reservoir," MS 1983.
Gardner Walkup, Jr., "Characterization of Retention Processes and Their Effect on the Analysis of Tracer Tests in Fractured Reservoirs," MS 1984.
John R. Gilardi, "Experimental Determination of the Effective Taylor Dispersivity in a Fracture," MS 1984.
Richard B. Cindrich, "Application of Stable Isotope and Geochemical Techniques to Problems in Tracing Geothermal Recharge: The Reykjanes Peninsula," MS 1984.
Gudmund Olsen, "Depletion Modeling of Liquid Dominated Geothermal Reservoirs," MS 1984.
Stephen E. Johnson, "Tracer Test Analysis of the Klamath Falls Geothermal Resource: A Comparison of Models," MS 1984.
Barry A. Beal and Craig S. Nunes, "Velocity and Gravity Effects in Relative Permeability Measurements," MS 1984.
Glenn Fox, "Linear Boundary Detection Using Pressure Buildup Tests," MS 1984.
Mary E. Eipper, "Computer Generation of Type Curves," MS 1985.
Jeffrey F. Simmons, "Closed Chamber Well Test Analysis by Superposition of the Constant Pressure Cumulative Influx Solution to the Radial Diffusivity Equation," MS 1985.
Luis Macias-Chapa, "Multiphase, Multicomponent Compressibility in Petroleum Reservoir Engineering," PhD 1985.
John Andrew Marcou, "Optimizing Development Strategy for Liquid Dominated Geothermal Reservoirs," Eng. 1985.
J. Flint Pulskamp, "The Generation of Response Curves from Laboratory Tracer Flow Experiments," MS 1985.
Jonathan D. Leaver, "A Technical Review of Interference Testing with Application in the Ohaaki Geothermal Field"' MS 1986.
Ibrahim Kocabas, "Analysis of Injection-Backflow Tracer Tests," MS 1986.
Priscilla, G. McLeroy, "Transient Pressure Analysis in Strip Reservoirs with Linear Skin Discontinuities," MS 1986.
Joseph R. Sinner, "The Determination of a Volumetric Mixing Law for Use with the Neutron Porosity Logging Tool," MS 1986.
Constantinos V. Chrysikopoulos, "Chelated Indium Activable Tracers for Geothermal Reservoirs," MS 1986.
Anil K. Ambastha, "Collection and Evaluation of Flowing Pressure and Temperature Data from Geothermal Wells," MS 1986.
Carlos Tavares, "Discharge Analysis of Two-Phase Geothermal Wells in Liquid-Dominated Reservoirs." MS 1986.
David C. Brock, "Compressibility Effects in Modeling Two-Phase Liquid Dominated Geothermal Reservoirs," MS 1986.
Lawrence W. Bouett, "The Effect of Transverse Mixing on Tracer Dispersion in a Fracture," MS 1986.
Beatriz del Socorro Salas, "Closed Chamber Well Test Including Frictional Effects," MS 1986.
Brenna L. Surritt, "Computer Generation of Type Curves," MS 1986.
Yathrib M. Al-Riyami, "Thermal Stability of Fluorescent Dyes as Geothermal Tracers," MS 1986.
Robert Anthony Johns, "Injection Through Fractures," MS 1987.
Jay A. Demski, "Decline Curve Derivative Analysis for Homogeneous and Composite Reservoirs," MS 1987.
James Lovekin, "Optimization of Injection Scheduling in Geothermal Fields," Eng. 1987.
Jeralyn Luetkehans, "A Laboratory Investigation of Steam Adsorption in Geothermal Reservoir Rocks," MS 1988.
Knut Aarstad, "Criteria for Determining Times for End of Transient Flow and Start of Pseudosteady State Flow," MS 1987.
Anil Kumar Ambastha, "Pressure Transient Analysis for Composite Systems," PhD 1988
Antonio Claudio de Franca Correa, "Application of the Unit Step Function to Transient Flow Problems with Time-Dependent Boundary Conditions," PhD 1988.
Charles E. Fox, "Determination of Fracture Aperture: A Multi-Tracer Approach," MS 1988.
Kwaku Ofori Temeng, "Effects of High Pressure Gradients on the Flow of Real Gases Through Porous Media," PhD 1988.
Russell T. Johns, "Comparison of Pressure Transient Response in Intensely and Sparcely Fractured Reservoirs," MS 1989.
Ashok Kumar Belani, "Estimation of Matrix Block Size Distribution in Naturally Fractured Reservoirs," MS 1988.
Jitendra Kikani, "Application of Boundary Element Method to Streamline Generation and Pressure Transient Testing," PhD 1989.
Ibrahim Kocabas, "Analysis of Tracer and Thermal Transients During Reinjection," PhD 1989.

Katsunori Fujiwara, "Rate Decline Analysis for Naturally Fractured Reservoirs," MS 1989.
Sanjay Bhatnagar, "Pressure Oscillations Caused by Momentum on Shut In of a High Rate Well in a Fractured Formation," MS 1989.
Stephen Tang-Fei Lam, "Heat Extraction Modeling of Single-Phase Sweep Flows in Fractured Geothermal Reservoirs," PhD 1990.
Michael Francis Riley, "Finite Conductivity Fractures in Elliptical Coordinates,"
Maria Elena G. Macario, "Optimizing Reinjection Strategy in Palinpinon, Philippines Based on Chloride Data," MS 1991.
Michael S. Harr -"Laboratory Measurement of Sorption in Porous Media," MS 1991.
Xianfa Deng, "Analyzing Multiwell Pressure Data of the Reservoir with Variable Properties," MS 1991.
Francois Joseph Groff, "Microcomputer Simulation of the Transient Flow of Real Gas through Porous Media," MS 1992.
Francisco Roberto Couri, "A Finite Difference Model for Free Surface Gravity Damage," PhD 1993.
Ming Qi, "Estimation of Adsorption Parameters from Experimental Data," MS 1993.
John W. Hornbrook, "The Effects of Adsorption on Injection into and Production from Vapor Dominated Geothermal Reservoirs," PhD 1994.
Steve Palar, "The Effects of Non-Condensible Gas and Salinity on Steam Adsorption," MS 1994.
Xianfa Deng, "Description of Heterogeneous Reservoirs Using Pressure and Tracer Data," PhD 1996.
Roman Sta. Maria, "Optimization of Injection into Vapor-Dominated Geothermal Reservoirs Considering Adsorption," MS 1996.
Willis Ambusso, "Experimental Determination of Steam Water Relative Permeability Relations," MS 1996.
Raul A. Tovar, "Measurements of Relative Permeability for Steam-Water Flow in Porous Media," MS 1997.
Nemesto Noel A. Urmeneta, "The Role of Capillary Forces in the Natural State of Fractured Geothermal Reservoirs," MS 1997.
Ma. Michelle Sullera, "Inferring Injection Returns from Chloride Monitoring Data," MS 1998.
Meiqing He, "Application of X-Ray Tomography to Measurement of Fractures in Rocks," MS 1998.
Marilou Tanchuling Guerrero, "Estimation of Relative Permeability from a Dynamic Boiling Experiment," MS 1998.
Robert J. DuTeaux, "Experimental Investigation of Boiling Heat Convection in a Fracture," MS 1998.
Glenn F. Mahiya, "Experimental Measurement of Steam-Water Relative Permeability", MS 1999.
Robb Allen Barnitt, "Boiling Radial Flow in Fractures of Varying Wall Porosity", MS 2000.
Rodolfo P. Belen, Jr., "Inferring Immobile and In-situ Water Saturation from Laboratory and Field Measurements", MS 2000.
Peter A. O'Connor, "Constant-Pressure Measurement of Steam-Water Relative Permeability", MS 2001.
Gracel P. Diomampo, "Relative Permeability through Fractures", MS 2001.
Mark D. Habana, "Relative Permeability of Fractured Rock", MS 2002.
Jericho Reyes "Estimating Water Saturation at the Geysers Based on Historical Pressure and Temperature Production Data," MS, 2003.
Chih-Ying Chen, "Liquid-Gas Relative Pemeabilities in Fractures: Effects of Flow Structures, Phase Transformation and Surface Roughness." PhD 2005.
Anson Villaluz, "Relative Permeability of Fractured Rock." MS 2005.
Aysegul Dastan, "Direct Measurement of In-Situ Water Saturation in Geothermal Rocks," MS 2006.
Egill Juliusson, "An Investigation of Void Fraction and Dispersed-Phase Velocity Measurement Techniques," MS 2006.
Robert W. Stacey, "Electrical Impedance Tomography," MS 2006.
Nicholas Speyer, "Experimental Measurement of Two-Phase Relative Permeabilities in Synthetic Vertical Fractures," MS 2007.
Nilufer Atalay, "Downhole Enthalpy Measurement in Geothermal Wells with Fiber Optics," MS 2008.
Mark W. McClure, "Fracture Stimulation in Enhanced Geothermal Systems," MS 2009
Zhe Wang, "Modeling Study of a Single-Well Enhanced Geothermal System (EGS)," MS 2009
Morgan Ames, "Nanosensors as Reservoir Engineering Tools to Map Insitu Temperature Distributions in Geothermal Reservoirs," MS 2011
Sarah Pistone, "The Significance of CO2 Solubility in Deep Subsurface Environments," MS 2012.
Egill Juliusson, "Characterization of Fractured Geothermal Reservoirs Based on Production Data," PhD 2012.
Kara Bennett, "Power Generation Potential from Coproduced Fluids in the Los Angeles Basin," MS 2012.

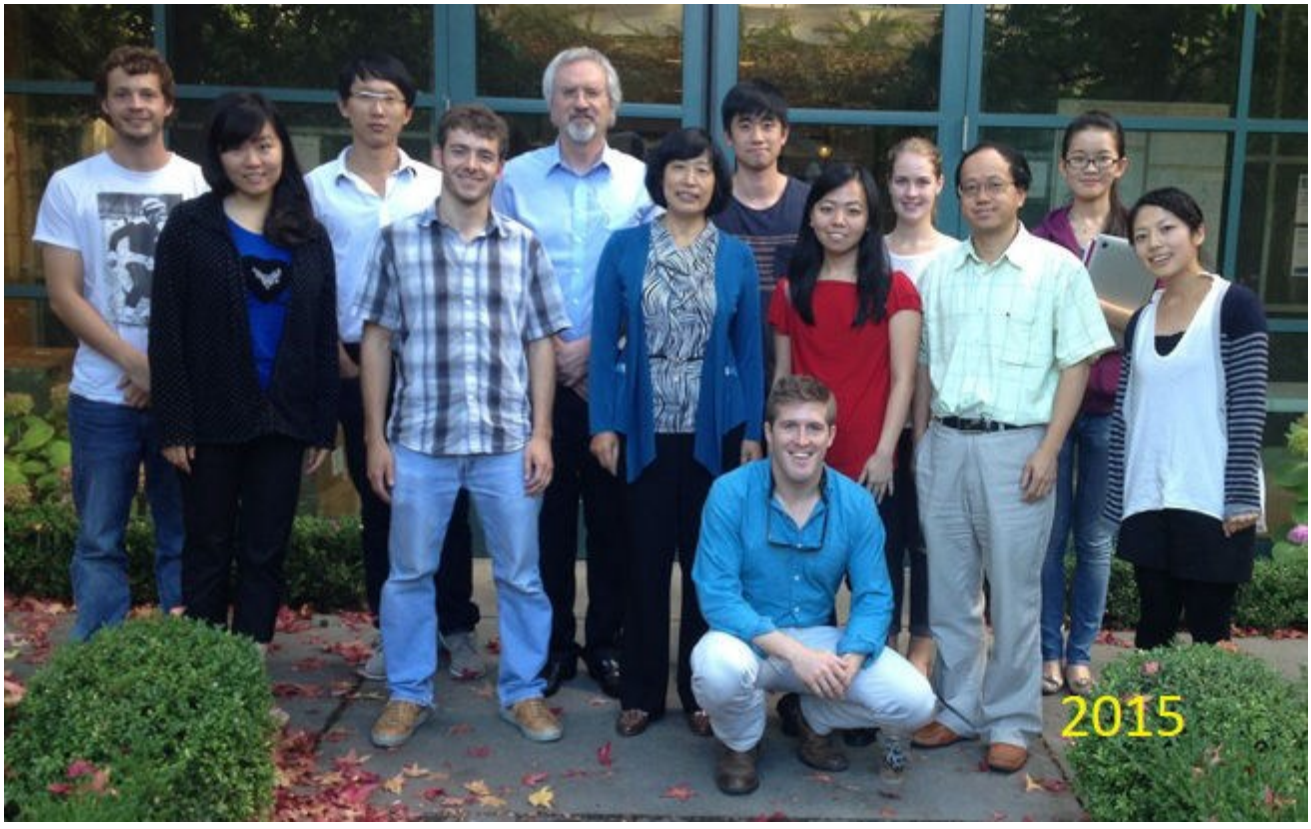
Carla Co, "Characterization of Geothermal Feedzones and Interwell Connectivity," MS 2012.
Mark McClure, "Modeling and Characterization of Hydraulic Stimulation and Induced Seismicity in Geothermal and Shale Gas Reservoirs," PhD 2012.
Lawrence Valverde, "Fracture Characterization via Electrical Impedance and Resistance," MS 2013.
Lilja Magnusdottir, "Characterizing Fracture Properties in Geothermal Reservoirs using Electrical Resistivity Measurements with Conductive Fluid Injection," PhD 2013.
Mohammed Alaskar, "In-Situ Multifunctional Nanosensors for Fractured Reservoir Characterization," PhD 2013.
Yuran Zhang, "DNA-Encapsulated Silica Nanoparticle Tracers for Fractured Reservoir Characterization" MS 2015
Zhi Yang Wong, "A Geothermal Reservoir Simulator in AD-GPRS," MS 2015
Morgan Ames, "Temperature-Sensitive Tracers for Fractured Geothermal Reservoir Characterization," PhD 2016
Xuhua Gao, "Development of a Downhole Technique for Measuring Enthalpy in Geothermal Wells," MS 2017
Carla Co, "Modeling and Characterization of Fracture Roughness and Its Impact on Mass Transport Processes," PhD 2017
Zhi Yang Wong, "Sequential-Implicit Newton`s Method for Geothermal Reservoir Simulation," PhD 2018
Yuran Zhang, "DNA-based tracers for fractured reservoir characterization," PhD 2020
Ahinoam Pollack, "Quantifying Geological Uncertainty And Optimizing Technoeconomic Decisions for Geothermal Reservoirs," PhD 2020
Rita Okoroafor, "Comparison of EGS Thermal Performance with CO2 and Water as Working Fluids," PhD 2021
Ayaka Abe, "Investigating Fracture Network Creation during Hydraulic Stimulation in Enhanced Geothermal Reservoirs," PhD 2021
Dang Ton, "Interpreting Drilling Records To Predict Well Success," MS 2021
Rita Okoroafor, "Heat Transfer Investigations For Optimal Harnessing Of Enhanced Geothermal Systems," PhD 2021




JABS Aljubran
Sarah Sausan
2022


2020


Stanford Geothermal Program
2016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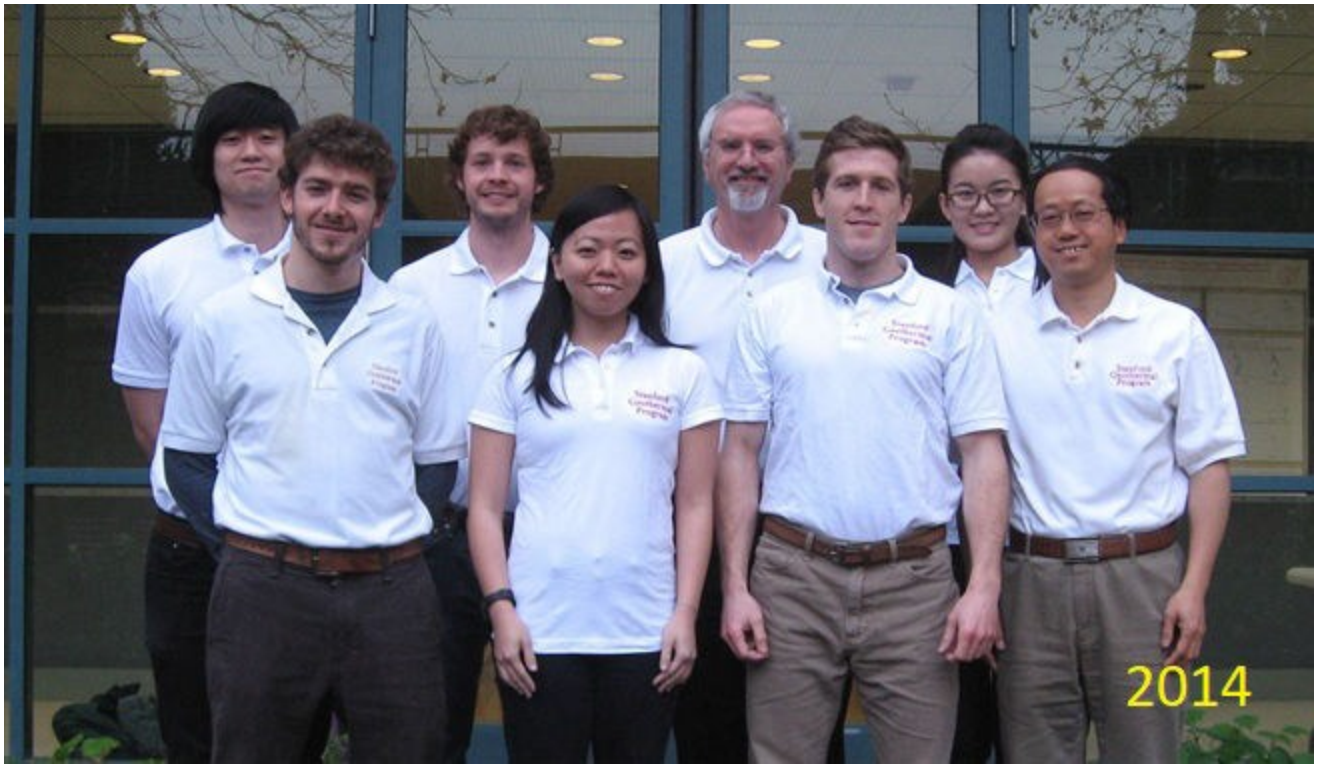
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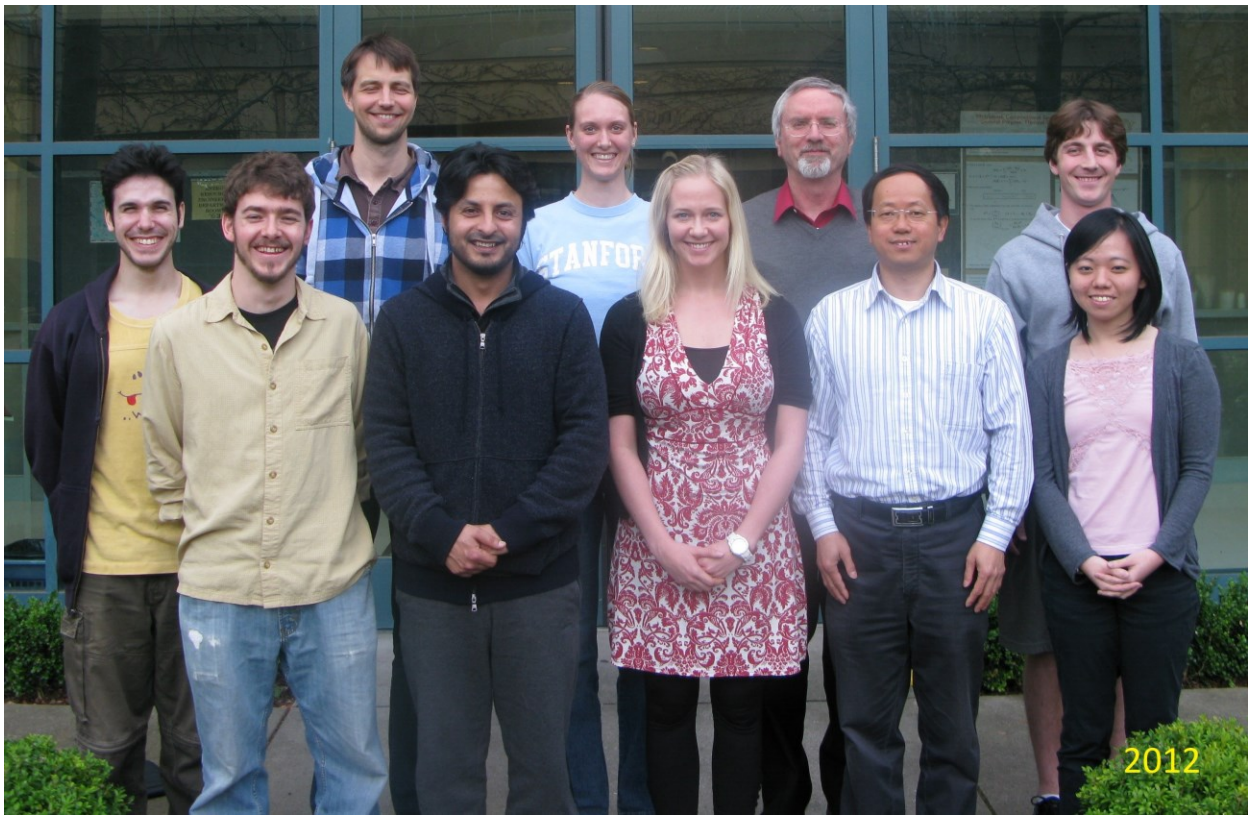
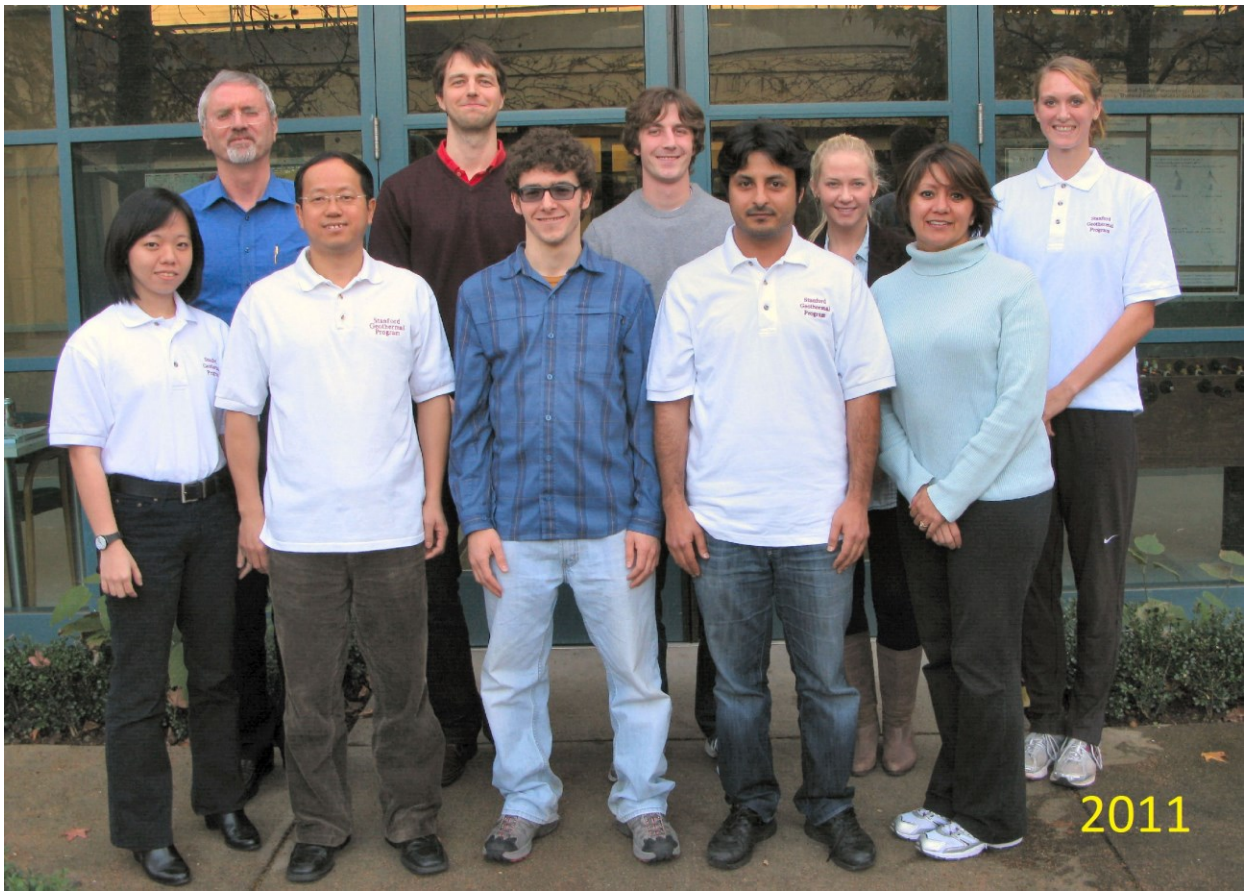

2012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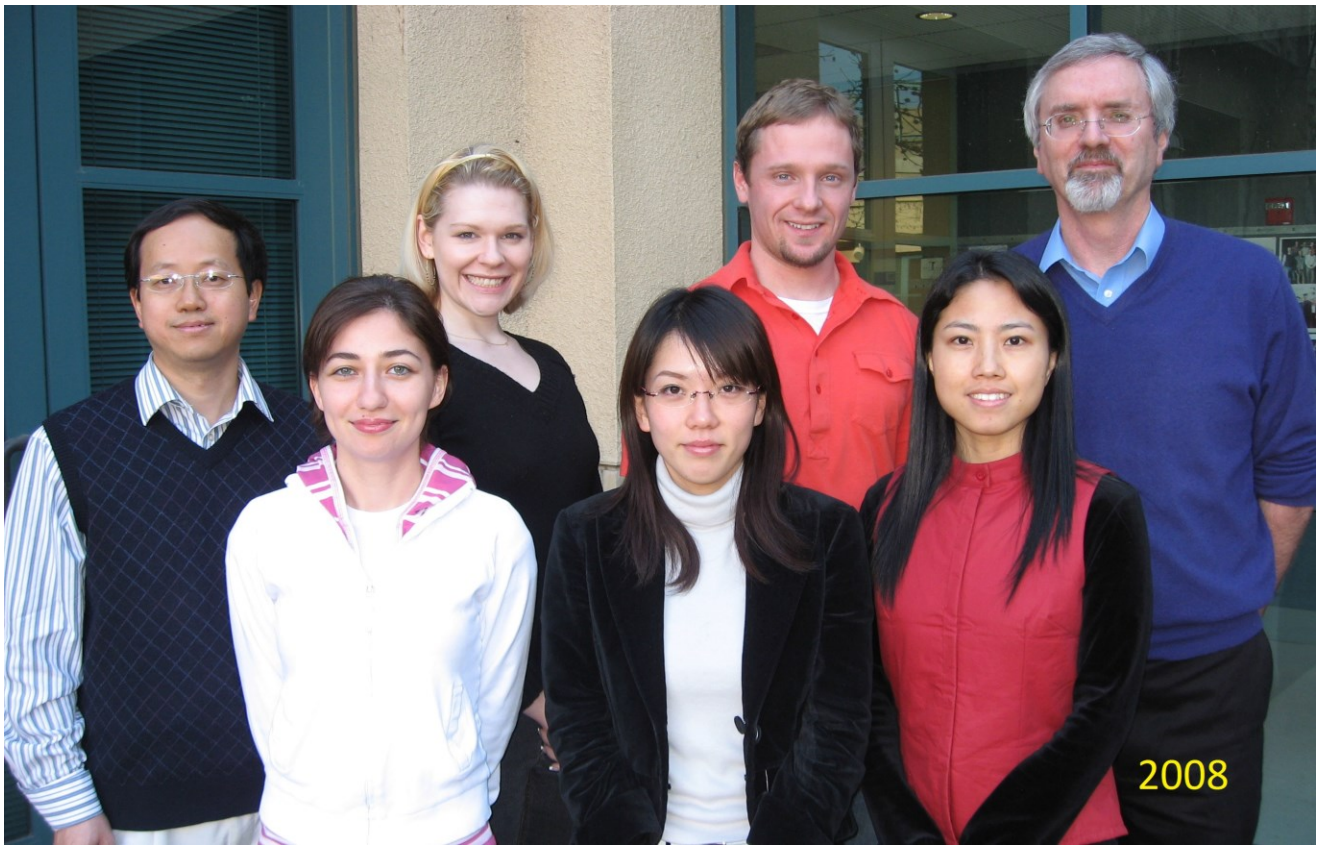
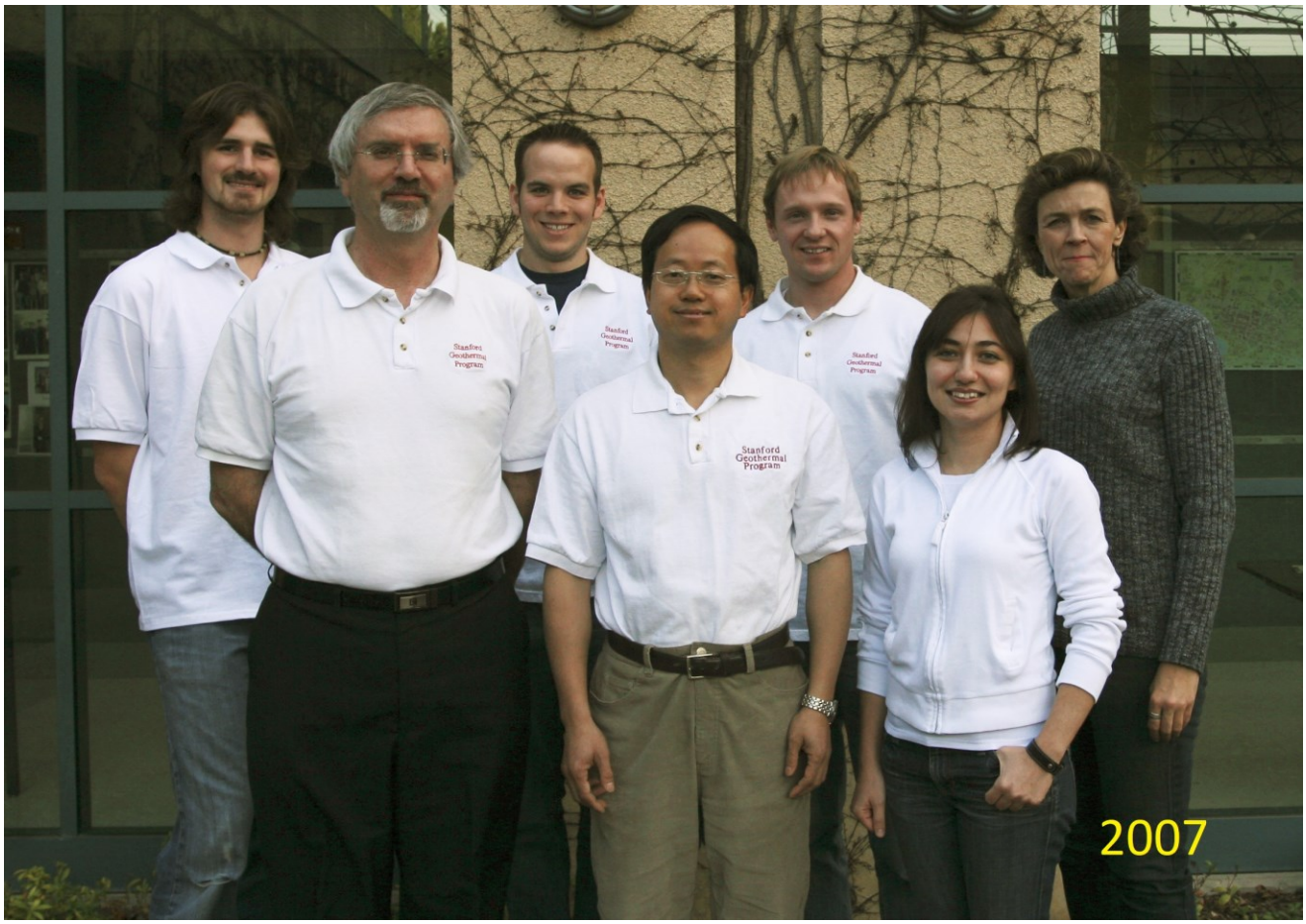

2008


Stanford Geothermal Program
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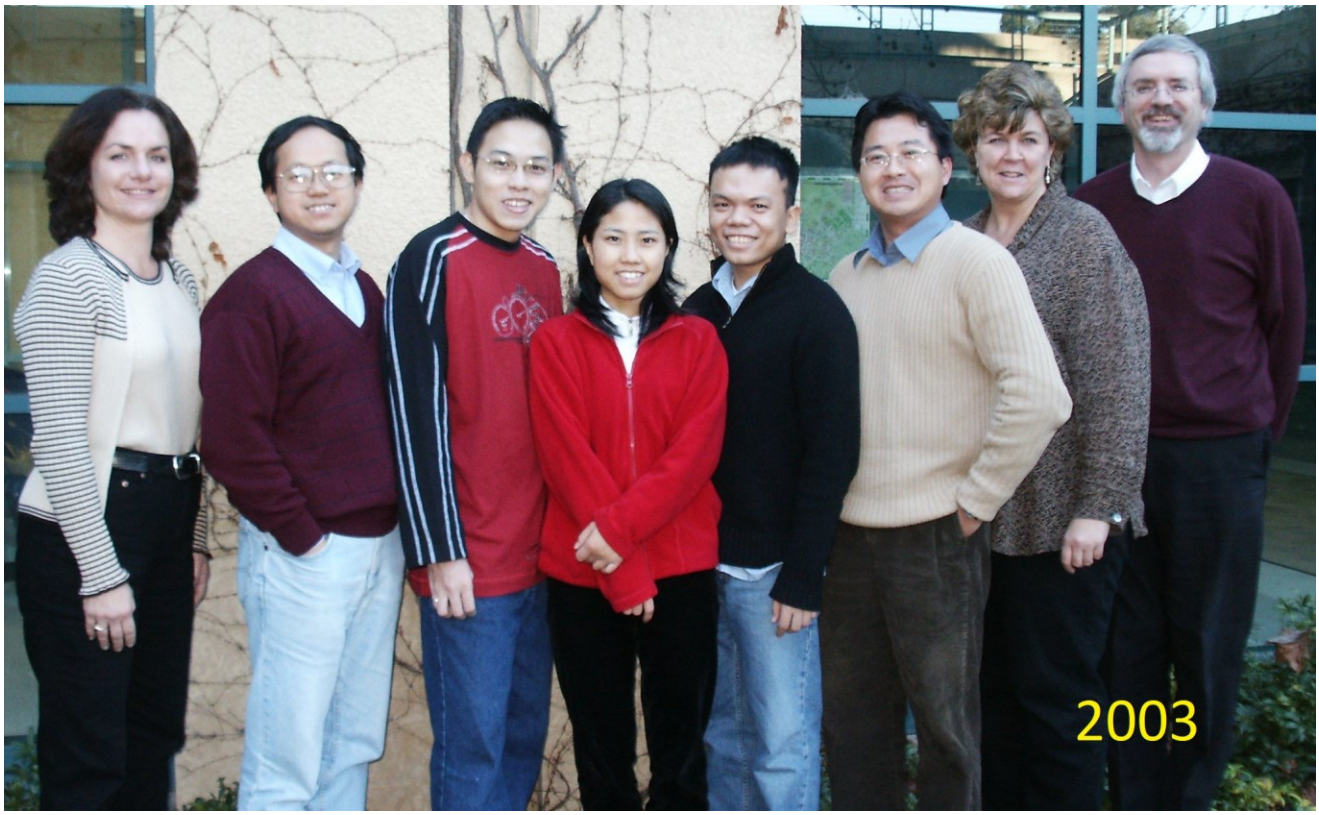
2006


2004


2003


2002

INFORMATION

If you have any questions concerning the Workshop, or the research of the Stanford Geothermal Program, please email us: (geothermal@se3mail.stanford.edu).