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# The U.S. National Geothermal Academy

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**ABSTRACT**

Initiated in 2010 with a grant from the U.S. Department of Energy Geothermal Technologies Office (GTO), the National Geothermal Academy (NGA) serves to train the next generation of scientists, engineers, plant operators, technicians, and policy makers. In spite of the size of the U.S. university enterprise, no single institution has ever had, nor is likely to have, the breadth of faculty expertise to teach all aspects of geothermal energy science and technology. The idea behind the NGA was to create a centrally located, convening organization for developing and conducting instructional programs in all aspects of geothermal science and technology. The goal was to include instructional content that covers the "end-to-end" development of a geothermal system for electrical power generation, from initial exploration to market and political policies that make geothermal power plants cost competitive. The emerging and high-growth areas of direct use and ground source heat pumps were also included. Geothermal experts, faculty from a consortium of U.S. universities, along with professionals from industry, were recruited to serve as instructors to develop and teach relevant curricula. We created eight topical modules or week long short courses offered through University of Nevada, Reno's Extended Studies program for undergraduate or graduate credit in engineering or geology. The course is also offered as professional development for those employed in the geothermal industry. There are currently 15 instructors from various universities and industry working together to further develop the NGA course as a self-funded and self-sustaining enterprise. The course was held during the summers of 2011 through 2014, serving a total of 138 students. The student population included graduates, undergraduates, and professionals. Forty-seven students were international from a total of 23 countries. The first two summers were eight-week long programs offering all individual modules and we have since transitioned to focused shorter programs alternating between geoscience and engineering content.

## 1. INTRODUCTION

The goal of this DOE funded project was to develop and conduct a multidisciplinary higher education geothermal program in geothermal science and technology to educate and train the next generation of the U.S. geothermal energy workforce. We developed instructional curricula, modules and courses to form a National Geothermal Academy (NGA), based in Reno, NV on the Redfield campus of the University of Nevada. The Redfield campus is directly adjacent to Ormat's Steamboat Springs facility and numerous other geothermal sites exist nearby in northern Nevada, eastern California, and southern Oregon, so that the location affords opportunities to visit a wide range of geothermal systems and settings as well as operating power plants as part of the NGA. Curricula included both academic and practical experience in geothermal energy work. The program took advantage of existing education programs within the partnering institutions including Oregon Institute of Technology, Southern Methodist University, Stanford University, University of Utah, and Cornell University as well as utilizing industry consultants and experts.

The summer program was envisioned to encompass the end-to-end development of a geothermal system, from initial assessment, exploration, through establishing an operating power plant. Course content was modular, with each topical area developed as a stand-alone unit which could be combined into a comprehensive 8-week program, (as offered in 2011 and 2012), or subset into shorter combinations focused on geoscience or engineering elements (as offered in 2013 and 2014). One hundred and thirty-eight students participated in the program in the first four summers.

Modules included

1) Introduction to Geothermal Energy Utilization

Exploration and Resource Assessment

2) Geothermal Geology and Geochemistry
3) Geothermal Geophysics

4) Drilling Engineering
5) Reservoir Engineering
6) Power Plant Design and Construction
7) Direct Use
8) Environmental Policy and Business Principles and Development
9) Team or Independent Projects

## 2. BRIEF DESCRIPTION OF THE MODULE CONTENT (2011-2013)

### 2.1 Introduction to Geothermal Energy Utilization

Developed by Jefferson Tester (Cornell University) and Michal Moore (University of Calgary) this introductory course presents the important fundamentals of geothermal resource exploitation. Students gain a general understanding of the basic steps in the economic exploitation of geothermal resources, including financing, exploration, drilling, plant design and construction, plant operation and maintenance, and geothermal field management, as well as the importance of public outreach and acceptance to maximize returns from the resource.

### 2.2 Geothermal Geology and Geochemistry

Joe Moore (EGI, University of Utah) created this module focused on exploration as a topic of primary importance for the economic viability of geothermal energy enterprises, providing critical information on the location, size, and exploitation potential of the resource. This module covers the geologic settings of geothermal systems, geothermometry, fluid geochemistry, and hydrothermal alteration.

### 2.3 Geothermal Geophysics

Developed by Dave Blackwell (Southern Methodist University) this module presents exploration methodologies and tools used to find and characterize geothermal resources, interpretation of their results, and how they are applied to form a synthesis of potential reservoir characteristics. Topics include heat flow, thermal gradients and conductivity, electrical, magnetic, gravity and seismic techniques of exploration, well logging and case histories.

### 2.4 Drilling Engineering

Created by Lou Capuano, Jr., Lou Capuano, III (both of Capuano Engineering Consultants) and Bill Livesay (Consultant) this module took advantage of the strong Capuano history in geothermal drilling. The short course covers the development and planning process that is done for each well, with the intent to expose students to the decisions that are made and how other geothermal resource decisions interact with the drilling design, planning, and operations. The module also covers the drilling aspects of the development of an engineered geothermal system power complex.

### 2.5 Reservoir Engineering

Taking advantage of the degree program at Stanford University, Roland Horne created this module modeled on a semester long course in reservoir engineering and management. Reservoir characterization methods are presented as well as the elements of managing the resource. Individual topics include the fundamentals of reservoir properties and flow mechanisms, the analysis of well measurements and the estimation of well performance characteristics. The course also looks in detail at reservoir modeling, reservoir simulation and the design and management of reinjection.

### 2.6 Power Plant Design and Construction

Created by Ron DiPippo (Consultant) with teaching support from Brian Anderson (West Virginia University) this course covers the fundamentals of geothermal power plant design and construction. Specific topics include power plant designs for dry steam, single- and double-flash, and binary systems. Equipment design and analysis covers major plant components including turbines, separators, flashers, piping systems and heat exchangers. Advanced energy conversion systems are described including several versions of binary plants, combined and hybrid cycles, total-flow systems and enhanced geothermal systems. Environmental impacts and a case study conclude the module.

### 2.7 Direct Use

Developed and taught on the Oregon Institute of Technology campus in Klamath Falls, OR, Tonya "Toni" Boyd, John W. Lund and Andrew Chiasson (Geo-Heat Center, OIT) created this module to cover the basic principles relating to the direct use applications of geothermal energy. The course includes description of equipment, aquaculture facility design, industrial applications, district and space heating, geothermal heat pumps and greenhouse design as well as field trips to sites where direct use has been implemented.

### 2.8 Environmental Policy and Business Principles and Development

This module incorporates two components, “Public Policy, Permitting, and Environmental Issues” created by Mark Demuth (WCRM, Inc.) and “Geothermal Business Principles and Development” developed by John McKinsey (Locke Lord LLP). Many geothermal projects take far longer because of significant environmental, financing, permitting, transmission, or property-acquisition issues that arise and must be resolved. The first component of this module provides an in-depth view of public policy matters that must be mastered in pursuing a geothermal resource, with a focus on the practical steps to be followed for success. In the second component, the economics of a project are examined in detail in order to better predict profitability. Attendees gain an understanding of how to improve a project’s managerial, organizational, and operational effectiveness to facilitate timely project delivery. Project management, environmental and legal issues, government and electric utility interactions are covered.

### 2.9 Team or Independent Projects

A part of the practical training was carried out in connection with research projects, guided by Wendy Calvin (UNR, overall director of the NGA program). Students used data from geothermal projects in their home states and countries, downloaded publically available information, or provided other topics based on suggestions from instructors. Students met weekly to discuss progress and hurdles in developing geothermal projects associated with technology/science issues, case studies, or systems analysis. Students teleconferenced and met with module instructors, academic or industry experts to facilitate project development and design. Final oral and poster presentations were showcased at a reception for geothermal industry representatives at UNR and at the GRC annual meetings.

### 2.10 Course Content

A detailed list of lectures for each week long module and their specific learning goals or outcomes was created as part of our final deliverable for DOE funding. This document is available upon request from the authors.

## 3. COURSE OFFERINGS AND EVOLUTION

The four-year approach taken to develop, implement, and improve the National Geothermal Academy included refinement of content, revision of student scholarship support and program fees, adjustments to program duration and evolution to a short course model. Initially we spent time developing the concept of the National Geothermal Academy and coordinating instructors. With the original plan to offer a comprehensive program on the end-to-end development of a geothermal system, we offered our first Academy, in summer 2011 which ran for eight weeks and provided scholarships for American students to encourage enrollment in this new program. The entire eight-week course was offered for 6 academic credits, or professionals could enroll in single weeks for a professional development certificate. Networking lunches were held to invite representatives from the local geothermal industry to visit with the students and they were also invited to the final poster session where students presented their projects. A total of 54 students participated in summer 2011. Student demographics for all years is provided in section 5. With DOE support contributing to content development and the instruction costs, the student fee for all 8 weeks was $1500 and $500 for an individual week as a professional. Inexpensive room and board was provided in UNR dormitories at cost for the duration of the program (~$55/day). All fees and expenses are cited in USD.

In 2012 we refined our program to reflect changes requested by DOE. The program again ran for eight weeks but students were required to provide partial or total funding for their participation. The student fee for all 8 weeks remained at $1500, and we offered two shorter, 3 week, 3-credit sessions focused on either geoscience or engineering content, with a reduced program fee. Professional registration was again $500/week. The Nevada State Office of Energy provided scholarship support for 10 U.S. students enrolled in the entire program for credit. This summer did not include the Direct Use module, but instead included a week of field trips, described in the next section.

In 2013 as DOE funding was waning, we calculated program expenses based on the first two years and concluded that the full summer program would be prohibitively expensive if students have to pay for the entire program themselves. We revised the format to offer a shorter 4-week program focused on the most popular modules, the reservoir engineering, power plant design and direct use content as full weeks (Modules 5-7). The introduction, geoscience and drilling content was condensed into a one-week overview that started the program. With the need for program fees to pay for the instruction costs, we set the fee for students registered for credit to $1500 and for professionals to $2500, hoping that the higher professional fee would offset those enrolled for credit. However only one person enrolled at the professional rate and program expenses were offset by fees collected in the first two years.

For summer 2014 we evolved to a fully self-supported entity, necessitating an increase in fees and a reduction in scope to a one to two week short course, with limited instructor remuneration. With the goal of offering geoscience and engineering content in alternating summers, 2014 focused on geothermal geoscience in a 10-day program that included a weekend field trip. The course took advantage of four faculty at UNR and their expertise in various aspects of geothermal exploration. Instructors Wendy Calvin, Joe Moore and Dave Blackwell from the original summers returned and we included new expertise from Nic Spycher (geothermometry), Mack Kennedy (isotopes), Jim Faulds (structural geology), Nick Hinz (geologic mapping and cross sections), Drew Siler (3D modeling), Bob Karlin (gravity), Phil Wannamaker (magnetotellurics), Satish Pullammanappallil and John Louie (seismic reflection), and Jeff Witter (geophysical modeling). Gene Suemnicht led the three-day field trip to Long Valley caldera. The program cost was $2500 for all participants. We offered 2 academic credits at either undergraduate- or graduate-level, but the majority of the participants completed the program for professional development instead of credit.

## 4. FIELD TRIPS AND EXCURSIONS

Among the reasons to host the NGA in Reno is the proximity to a wide range of geothermal settings as well as operating power plants. Over the four summers, field trips and excursions have included short outings and longer trips to view the geologic context of both magmatic and structurally controlled systems, and binary and flash power plants. In addition to the educational outings and field trips below we also coordinated picnics, barbecues and sightseeing tours around the Tahoe Basin NV/CA and to Crater Lake, OR in order to make the 8-week sessions a memorable and enjoyable experience.

### 4.1 Steamboat Springs, NV - Ormat Facility (All Years)

We have visited the Ormat Steamboat Springs complex for both the geology of the system as well as to observe plant operations. In 2011 and 2014 we visited specifically to look at the geologic setting and surface expression of the geothermal site. The complex sits near a large sinter terrace and has many areas of hydrothermal alteration. Students use their recently learned geochemistry knowledge to make observations and interpretations about the geothermal history of Steamboat Springs including temperatures involved in erupting fluids rich in silica that lead to the development of the terrace as well as acid alteration resulting in both clay and sulfate precipitation. In 2011, 2012 and 2103 we made an alternate trip to the facility specifically to view both binary and flash plant operations. We toured several power generation facilities with an Ormat engineer who explained the functionality of both mechanical components (cooling towers, turbines) and the high-end computer monitoring and control system employed by Ormat.

### 4.2 Brady's Fault, NV (2011)

We visited Brady's geothermal field in central Nevada where we observed the Brady's fault that is the site of the Gilroy Foods vegetable dehydration plant, a direct use facility that uses geothermal heat to dry onions and garlic. Also along the Brady's fault is an Ormat geothermal plant, and the area is under study for EGS capability. Students explored the small and large scale fractures evident on the surface and the relationship of the structural setting to active fumaroles and mineral precipitation at the site.

### 4.3 Humboldt House, NV (2012)

We took a one-day field trip to the Humboldt House geothermal field in central Nevada, led by Dave Blackwell during the Geophysics module. We viewed the non-functioning geothermal power plant and considered how a company could drill hot wells and ultimately not find an economic resource. We observed geothermal deposits in the valley and discussed the nearby Florida Canyon gold mine, site for the first geo-fluid application of the "Green Machine" developed by ElectraTherm.

### 4.4 Geysers, CA (2012)

This was an optional weekend field trip to the Geysers geothermal field in CA. We toured Calpine's geothermal power plant complex with a company geologist and had the opportunity to visit several of their power plants. The Geyser's setting is unique in being a steam-dominated system and is commonly used as a case study in many of the course modules.

### 4.5 Long Valley Caldera/Inyo-Mono Volcanic Craters, CA (2012, 2014)

This three-day trip encompasses volcanic settings from Mono Basin to Long Valley Caldera in eastern California to learn about the recent eruptive sequence. The trip was developed and led by Gene Suemnicht of EGS, Inc. Stops include Hot Creek, Devil's Postpile, Clay Pit, Earthquake Fault, Inyo Craters, Obsidian Dome, Bishop Tuff, Panum Crater, Mono Lake tufa. We toured Ormat's Casa Diablo geothermal power plant complex and observed many of the volcanic and geothermal features in the area. We stopped at Bodie State Historic Park to consider the ancient geothermal system responsible for the gold deposit.

### 4.6 Lassen Volcanic National Park, CA (2013)

This short trip through Lassen Volcanic National Park followed the guidebook developed by Patrick Muffler and Michael Clynne to examine geochemistry and surface alteration expressed in the Lassen Volcanic Center including visiting geothermal and volcanic features such as Sulphur Works, Diamond Peak overview of the Little Hot Springs Valley, Bumpass Hell, and the Devastated Area. The trip also included a stop near Mt Shasta and views of Medicine Lake and the volcanic complexes at the southern end of the Cascadia volcanic arc.

### 4.7 Direct Use Community Canby, CA (2011, 2013)

This afternoon stop included a tour of the facilities in the community of Canby. This residential community has installed a small (50 kW) plant to serve to generate building heating, laundry facilities, greenhouses and aquaculture. The students were able to examine the powerhouse and observe the mechanical and electrical installation.

### 4.8 Direct Use Facilities Klamath Falls, OR (2011, 2013)

Over the course of several days within the context of the Direct Use module, the students visit numerous sites within the city of Klamath Falls, including the plant that serves domestic hot water and district heating for numerous downtown businesses, several greenhouse and aquaculture developments, the brewery, and the newly installed OIT power plant that delivers both heat and electricity to campus.

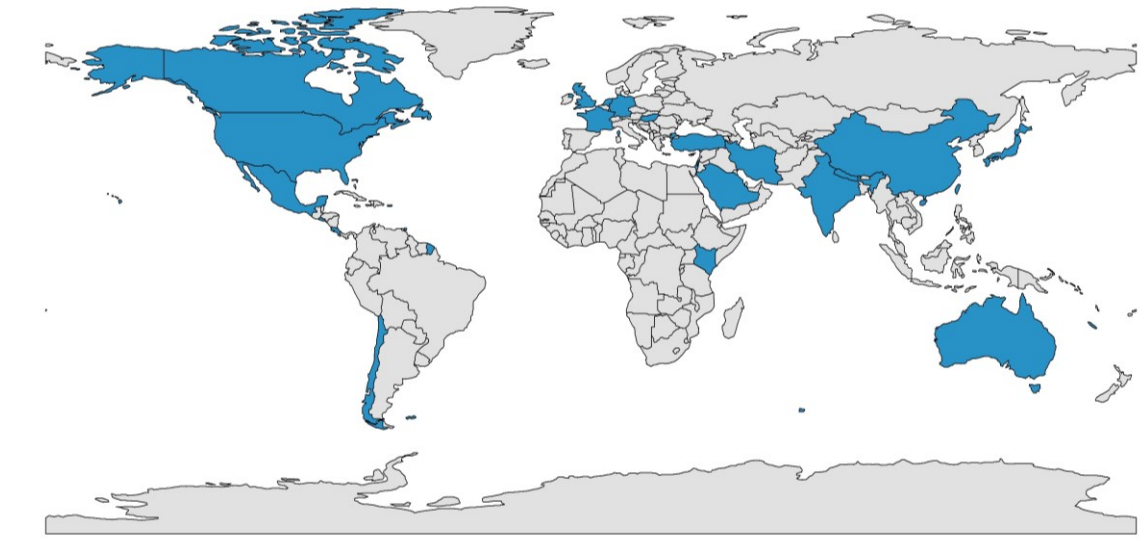
## 5. STUDENT DEMOGRAPHICS AND ENROLLMENTS

Student distribution by enrollment type (undergraduate, graduate, professional), degree or area focus (engineering or geosciences, ENGR or GEOL), nationality and gender is summarized in Table 1 below. In the first year we served a largely U.S. audience equally split between full program attendees (required for fee offsets) and industry participants in individual modules. A similar distribution between the full program or a subset of modules (roughly 50/50) was also observed in the second year. Due to the change in fee structure in the third year, nearly all students enrolled for credit for the entire program. In 2014 only one quarter of the participants were students. In all years, our audience has been largely a graduate or professional one, with undergraduates never more than 15% of the student population. In the first two years interest in engineering content (Modules 4 through 7) was stronger than geoscience content (Modules 2 and 3) which influenced our decision to offer only engineering-related full modules in summer of 2013. We have experienced a steady drop in overall enrollment which is likely linked to several factors, including the current sluggishness of the U.S. geothermal industry, the lack of scholarship support to offset fees, the rising fees required to make the program self-sufficient, and the size of the U.S. geothermal industry which may be to small to sustain large enrollments on an annual basis. We also note a steady rise in the relative proportion of international participants, drawing from all over the globe (Figure 1), but particularly the Americas and Caribbean.

| | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|
| **Undergraduate** | 4 | 6 | 3 | 2 |
| **Graduate** | 21 | 11 | 17 | 3 |
| **Professional – Academic** | 7 | 2 | | 3 |
| **Professional – Government** | 5 | 7 | | 5 |
| **Professional – Industry** | 17 | 16 | 1 | 6 |
| **Professional – Other** | | 1 | | 1 |
| | | | | |
| **ENGR** | 31 | 30 | 21 | N/A |
| **GEOL** | 23 | 13 | N/A | 20 |
| | | | | |
| **Full Program** | 27 | 21 | 20 | 20 |
| **1 week** | 27 | 10 | 1 | |
| **2 or 3 weeks** | | 12 | | |
| | | | | |
| **US** | 45 | 27 | 10 | 9 |
| **International** | 9 | 16 | 11 | 11 |
| | | | | |
| **Male** | 37 | 29 | 11 | 12 |
| **Female** | 17 | 14 | 10 | 8 |
| | | | | |
| **Full Program Duration** | 8 weeks | 8 weeks | 4 weeks | 10 days |
| | | | | |
| **Total Students** | **54** | **43** | **21** | **20** |

**Total all years** **138**

**Table 1: NGA Student Demographics in the first four years.**



Australia, Canada, Chile, China, Costa Rica, Dominica, El Salvador, France, Germany, Hungary, India, Iran, Israel, Japan, Kenya, Mexico, Nepal, The Netherlands, Saudi Arabia, Taiwan, Trinidad and Tobago, Turkey, United Kingdom, United States

**Figure 1: Global distribution of students attending NGA in all four years.**

## 6. IMPACT AND POST-COURSE STUDENT SURVEY

In winter 2013 we distributed a survey to all alumni from 2011 and 2012. Half of all alumni responded. Slightly more (58%) responses were from 2012. This is significant because alumni from 2012 had less time to reap the benefits of the NGA. Most of the responses (72%) were from alumni who attended all 8 weeks. Key point from the survey included the following:

- Of the working professionals,
  - 40% work for a *company*.
  - 33% work for a *government*.
  - 26% work at a *school or research institution*.
  - 7% *own a company*.

- Of the working professionals,
  - 55% said their job is *directly related* to geothermal.
  - 21% said their job is *somewhat related* to geothermal.
  - 14% said their job is *not at all related* to geothermal.

- All of the current students were directly involved with geothermal at school.

- Of all the alumni who responded,
  - 40% said the NGA was *invaluable* to their academic or professional career.
  - 38% said the NGA was *very helpful* to their academic or professional career.
  - 21% said the NGA was *somewhat helpful* to their academic or professional career.
  - Nobody reported *slightly helpful* or *not at all helpful*.

- Of all the alumni,
  - 41% said the NGA helped them to begin *new research*.
  - 28% said the NGA helped them to take on *more responsibility* at work.
  - 12% said the NGA helped them get a *new job*.
  - 9% said the NGA helped them get *accepted to a school*.
  - 5% said the NGA helped them get a *promotion*.

In general we found that the NGA was very helpful to invaluable for the students and professionals who participated in the program. We also offered a survey to participants from the 2014 program, to which half (10) of the class responded. The 2014 respondents rated the value of the NGA course at 90% (excellent) and 90% said they would recommend the program to others. We intend to follow up with alumni from both 2013 and 2014 in the future to collect more information about the larger impact of the NGA on their academic and professional careers.

The National Geothermal Academy was awarded "Special Recognition" by the Geothermal Energy Association in 2012 for leadership in geothermal education programs in the U.S. and attracting national and worldwide attention in its inaugural year.

## 7. FUTURE OFFERINGS

We are considering a future offering of the NGA at Cornell University that provides a 2-week short course on geothermal energy resource assessment and development, utilization (including direct use, heat pumps, electricity and co-generation) and economics. This would include NGA faculty Tester, DiPippo, M. Moore, Horne and Anderson and is tentatively scheduled for summer 2015. A course similar to the summer 2014 offering, focused on geothermal geoscience, will be planned for summer 2016.

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**Full program graduating class of 2011. First row: L. Stowell, N. Arianpoo, S. Tekin, X. Zheng, W. Calvin (Director). Second Row: P. Illig, M. Rivera, C. Reyes, E. Hakanson, A. Sadowski, M. Bereskin, S. Scott, N. Eason, C. Fierro, J. Livermore. Third Row: K. Robinson, N. Pettengill, F. Marzolo, P. Schwering (ambassador), S. Benato, J. Carnell, C. Richard. Back Row: K. Nuzum, S. Arndt, T. Grego, C. Dudley, K. Gray.**


**Most of the 2012 full-program students. First row: J. Hernandez, R. Silverman, J. Timothy, R. Kinslow, B. Hass, P. Maddi, N. Seaman Tyson, E. Littlefield (Asst. Director), S. Erdahl. Second row: M. Arrubarrena, M. Christian, D. Eloi, C. Forson. Back row: T. Alhamoudi, B. Iglesias, C. Lindsey, L. Pelayo, P. Bakane, M. Allen, D. Thelan, G. Allen, R. Koon Koon, T. Boyd (Instructor), A. Sadowski (Class of 2011).**

**Most of the 2013 students. First row: T. Mack, Y. Koizumi, B. Huang, K. Lewis, J. Starnes, J. Andersen, H. Hanson, A. Vazquez-Duarte, J. Lund (Instructor), T. Boyd (Instructor). Second row: D. Naphan (Driver), A. Pollack, J. Frederick, D. Frederick, R. Libbey, M. Jones, K. van Oversteeg, L. Urpi, R. Rodriquez Marian, A. Xu, C. Munoz Saez.**


**Most of the 2014 students. Front row: V. Reyes Orozco, E. McConville, P. Ulibarri, S. Louis, V. Sampson, J. Dublin, N. Lautze, O. Battifarano. Second row: R. Chacko, N. Pearson (Driver), M. Brady, R. Austrie, D. Corriette, J. Noel, D. Toulon, M. Terry, N. Paasche, K. Detouche-Richards, G. Suemnicht (Instructor), F. Khalek-Baillie, E. Davalos Elizondo, W. Calvin (Instructor).**