GeothermEx
A Schlumberger Company

3260 BLUME DRIVE, SUITE 220
RICHMOND, CALIFORNIA 94806 USA

PHONE: (510) 527-9876
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www.geothermex.com

EDUARDO E. GRANADOS

PRESENT POSITION

Senior Advisor - Drilling and Well Testing

EXPERTISE

Mr. Granados has been active in geothermal exploration, drilling and well testing continuously since 1975. His specialties are:

- drilling engineering
- design of high temperature geothermal wells for flash flow
- design of low temperature geothermal wells for pump flow
- pump specifications
- instrumentation, design and supervision of geothermal well tests
- specification and design of instrumentation for production wells
- analysis of geothermal well-test data for reservoir assessment
- well remediation programs
- blowout prevention and control; relief well operations
- supervision of drilling and workover operations for geothermal wells
- design and supervision of construction for civil works (roads, pipelines, drill pads, sumps)
- preparation of drilling specifications and bid documents
- permitting and coordination with government regulatory agencies

EDUCATION

M.S. in Petroleum Engineering, Stanford University, 1983

Diploma, Geothermal Institute, University of Pisa (Italy), 1975

B.S. in Civil Engineering, University of Costa Rica, 1973

Fluent in Spanish and Italian; reads and speaks French

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EXPERIENCE

GeothermEx, Inc., 1984-present

Mr. Granados has worked in the United States, Portugal, Indonesia, Japan, Iceland, Republic of Georgia, Papua New Guinea, Viet-Nam, Mexico, Guatemala, El Salvador, Nicaragua, Costa Rica, Panama, Chile, and Ecuador, on multiple aspects of geothermal well drilling, testing, data analysis and the construction of surface facilities. Examples of his work include:

- Preparation of report detailing current condition and operational capability of drilling equipment that has been in storage for over 14 years. Preparation of lists of spare and replacement parts, evaluation of economics of refurbishing rig versus contracting services from a private driller. Work conducted on behalf of the Agencie Francaise de Developement (AFD), 2015.
- Design and preparation of Complete Well Design Basis for 5 new wells to be drilled during 2015-2016 at the Wayang Windu geothermal field, Indonesia. Air drilling and inhibited mud use at depths of >2,500 m were an integral part of the calculations, 2013-2014.
- Prepare complete well design and drilling procedure, budget, and safety manual for drilling program at the Blawan Ijen geothermal project, Indonesia, 2013.
- Preparation of bid documents for geothermal drilling and well testing operations for a 300 MW project in Northern Sumatra, Indonesia, 2010-present.
- Well design, preparation of rig specifications and field activities for two multi-well projects in the Republic of Viet Nam, 2010-present.
- Well design, drilling contractor selection, drilling procurement, drilling supervision and management of logistics for drilling and testing of 4 large diameter (12-1/4" open hole) wells through very difficult volcanic terrain in the Azores Islands (Terceira), Portugal, 2009 – 2014.
- Design of deep production wells (15,000+ feet) drilled in volcanic and carboniferous zones, finding temperatures in excess of 220°C at the Naknek, Alalska, geothermal project, daily monitoring of drilling operations, 2009 – 2012.
- Design of deep production wells (10,000+ feet) at the Geysers Field, California (Unit 1) geothermal project, daily monitoring of drilling and testing operations, 2008 - 2009.
- Well design, preparation of bid documents, bid evaluation, drilling contractor selection, drilling procurement, drilling supervision and management of logistics for multi-well drilling programs in the Azores Islands (Sao Miguel), Portugal, 1998 – present.
- Coordination of drilling, well repair and field operations at the Miravalles geothermal field, Costa Rica, 1994 - present.

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- Design and specification of well workover and field-wide well testing operations at the Zugdidi-Tsaishi geothermal field, Republic of Georgia, 1997 - 1998.
- Design of deep (10,000+ feet), high temperature, directional steam wells, some with forked completions, at the Aidlin geothermal project in The Geysers; daily monitoring of drilling operations, 1992 - 1997.
- Drilling engineering services for the design and workover of high-temperature (600°F+) wells in the Puna geothermal field, 2002 - present.
- Development of a Geothermal Master Plan for Nicaragua (10 areas of interest explored and prioritized in order of potential for geothermal energy extraction), 2001 - 2002
- Design of deep injection wells (7,000+ feet) at the Bradys geothermal project, daily monitoring of drilling operations, 1992 - 1994.
- Preparation of technical specifications for bidding drilling services at the Dieng geothermal field, Indonesia, 1994 - 1995.
- Design and specification, daily monitoring of drilling operations for directional wells at the Dieng geothermal field, Indonesia, 1994 - 1995.
- Design and specification for drilling directional wells at the Wayang Windu geothermal field, Indonesia, 1995 - 1997.
- Planning and managing of field operations for repair and control of blow-out situations in uncontrolled wells in a field in northern Japan, 1992.
- Design of deep directional production wells and daily monitoring of drilling operations in the Chipilapa geothermal field, El Salvador, 1991 - 1992.
- Coordination of a scientific group for the preparation a manual for geothermal development ("Guidelines for Geothermal Development in the Latin American Countries"). For the Latin-American Organization for Energy Development (OLADE), Ecuador, 1992 - 1993.
- Design and field supervision of drilling and workover operations for several extremely high-temperature, highly gassy, anomalously pressured geothermal production wells (average depth 8,000 feet), Akita, Japan, 1989 - present.
- Review of drilling results, design and supervision of injection testing of geothermal research wells in the Puna Geothermal District, Hawaii, 1989 - 1995.
- Review of geothermal well drilling programs for Ormat Energy Systems, Inc., private developers in the Puna District, Hawaii, 1989 -1995.
- Design of well tests and assessment of drilling and logging results at Zunil geothermal field, Guatemala, 1988 -1994.

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- Review of exploration and development drilling for high-temperature geothermal resources in El Salvador, 1990 - 1994.
- Design and supervision of well workover operations to upgrade existing wells for pump installation at Empire (San Emidio) and Steamboat, Nevada. 1985-1987.
- Design of large-diameter injection wells, supervision of geothermal drilling and logging and design/supervision of long-term injection testing at an open-pit gold mine located on an active geothermal system at Lihir Island, Papua New Guinea, 1986 - 1988.
- Design and drilling supervision of 25 temperature gradient and exploration holes (20 cored, 5 rotary drilled) for geothermal field assessment at Lihir Island, Papua New Guinea, 1988 - 1990.
- Design of pumped wells, downhole pump installation, and supervision of drilling and testing of geothermal wells at Empire (San Emidio), Steamboat and Soda Lake, Nevada, and East Mesa, California, 1985 - 1988.
- Design and specification of scale and corrosion control field equipment at Asal geothermal field, Djibouti, 1989.
- Assessment of well damage and management of re-logging and testing operations at Uenotai geothermal field, Japan, 1988 - 1989.
- Design and supervision of well testing operations for the Scientific Deep Hole in Salton Sea, Imperial Valley, California, 1987.
- Design of large-diameter geothermal wells, design and supervision of long-term well testing, planning and design of a wellhead maintenance program at the Coso Hot Springs geothermal field, California, 1985 - 1987.
- Design and permitting of deep, directional steam wells in The Geysers geothermal field, California. For Geothermal Energy Partners, Ltd., Northern California Power Agency and California Department of Water Resources, 1984 - 1997.

Mr. Granados has also been extensively involved in the remedial activities in geothermal wells and well control issues, as described by the following examples:

- Blowout Control. Fortunately, most of the projects with which GeothermEx has been involved have not experienced blowouts. However, at a high-gas field in Akita Prefecture (Japan), Mr. Granados has been involved in 3 relevant operations:
  - Designing a procedure to keep a well with shallow casing damage safely flowing during the winter season, and a program to quench and workover the well in the spring. The well was successfully quenched and repaired.
  - Gaining control of a well with a buckled 9-5/8-inch casing just below casing head, caused by excessive horizontal force exerted by the flow, to the point where the

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valve tree had collapsed on the ground. A program utilizing a coiled tubing unit was prepared and successfully implemented.

- Regaining immediate control of a well in which the BOP equipment had failed and damaged the drilling rig, engulfing the rig in steam and endangering the life of the derrick man.

- Well Interventions. Mr. Granados has assisted many clients in designing and conducting well workover operations in wells that had damaged casing or required internal modifications to improve their mechanical integrity, at the following fields:
  - Miravalles, Costa Rica
  - Azores –Portugal
  - Akita, Japan
  - Wayang Windu, Dieng and Cibuni, Indonesia
  - Tibet, China
  - Lihir Island, Papua New Guinea
  - Ahuachapan, El Salvador
  - Zunil, Guatemala
  - Momotombo, Nicaragua
- Relief Well Drilling. Mr. Granados provided a peer review of a relief well plan for mitigating an underground blowout at the Wayang Windu field in Indonesia.
- Forensic Analysis of Drilling Problems: Mr. Granados has served in this capacity in many projects, including
  - Rotokawa, New Zealand – determination of the cause of a casing collapse in a high-temperature well
  - Dieng, Indonesia – identification of the cause for lost well integrity by logging and air compression
  - Puna, Hawaii – identification of slipped casing joint through downhole camera run
  - Lihir Island , Papua New Guinea – determination of the cause for loss of slotted liner (corrosion)
  - Miravalles, Costa Rica – downhole video camera run to confirm reason for casing damage (wrong choice of milling equipment); development and successful execution of a remediation program
  - Tibet, China – identification of the cause for lost well integrity by logging and air injection

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- Terceira, Azores – innovating use of TPS logging to analyze the cause of cyclic production, followed by successful intervention (cementing the lower part of the hole and preserving the upper, more productive zone)
- São Miguel, Azores – well logging and air compression to identify zones of casing damage due to injection of oxygenated fluids; design and successful implementation of a plan to repair the damage and continue using the well for injection at commercial rates.
- Berlín, El Salvador – Rescue of drilling equipment from a well pad that had a blowout situation and stabilization of the shallow steam zone using grouting techniques

Instituto Costarricense de Electricidad (ICE), 1974 - 1984

- Design and supervision of drilling of nine deep geothermal wells (depths 3,600 to 7,500 feet) and 76 temperature-gradient holes (all cored; depths 100 to 1,600 feet)
- Management of well-testing operations
- Design of civil works and camp facilities; construction management
- Design of well-logging and well-test operations
- Preparation of drilling specifications and bid documents; negotiation with drilling contractors; management of drilling budgets

MEMBERSHIPS

Society of Petroleum Engineers

Geothermal Resources Council

International Geothermal Association

SELECTED PUBLICATIONS

Design and Implementation of Steam Supply for the Western GeoPower Unit 1 Project at the Geysers Geothermal Field, California. Transactions, Geothermal Resources Council, 2009 (with Subir K. Sanyal, Roger C. Henneberger, Mike Long and Ken MacLeod).

Well Productivity Enhancement by Drilling Multi-Legged Wells: A Quantitative Assessment. Transactions, Geothermal Resources Council, 2007 (with Subir K. Sanyal, James W. Morrow and Roger C. Henneberger).

An Alternative and Modular Approach to Enhanced Geothermal Systems. Proceedings, World Geothermal Congress, 2005 (with Subir K. Sanyal, Steven J. Butler and Roland N. Horne).

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Mitigation of Cyclic Production Behavior in a Geothermal Well at the Uenotai Geothermal Field, Akita Japan. Transactions, Geothermal Resources Council, 2002.

Updated Numerical Simulation Modeling of the Miravalles Geothermal Field, Costa Rica. Transactions, Geothermal Resources Council, 2002

Development of a Geothermal Master Plan for Nicaragua. Proceedings, World Geothermal Congress, 2000.

Numerical Modeling of the Miravalles Geothermal Field, Costa Rica. Proceedings, World Geothermal Congress, 2000.

Development of Injection Capacity for the Expansion of the Ribeira Grande Geothermal Power Project, São Miguel, Açores, Portugal. Proceedings, World Geothermal Congress, 2000.

Results of a Comprehensive Well Test Program to Assess the Zugdidi-Tsaishi geothermal Field, Republic of Georgia. Proceedings, World Geothermal Congress, 2000.

Analysis of Well Test Data from the High-Temperature Geothermal System of Amatitlán, Guatemala. Transactions, Geothermal Resources Council, Volume 20, 1996.

Injection-related problems encountered in geothermal projects and their mitigation: the U.S. experience. Proceedings, World Geothermal Congress, 1995.

Modeling discharge requirements for deep geothermal wells at Cerro Prieto geothermal field, Mexico. Proceedings of the 19th Workshop on Geothermal Reservoir Engineering, Stanford Geothermal Program, January 1995.

Problems and solutions related to injection of geothermal fluids. Presented at the Workshop on Injection of Geothermal Fluids, Mexicali, Mexico, May 1993.

Numerical modeling of the initial state and matching of well test data from the Zunil geothermal field, Guatemala. Proceedings of the 16th Workshop on Geothermal Reservoir Engineering, Stanford Geothermal Program, January 1991.

An integrated test program for the definition of a high temperature geothermal reservoir. Transactions Geothermal Resources Council, Volume 14, 1990.

Long-term test program at Coso Hot Springs. Proceedings of the 12th Workshop on Geothermal Reservoir Engineering, Stanford Geothermal Program, January 1987.

Long-term testing of geothermal wells at LADWP's leases in the Coso Hot Springs KGRA. Proceedings, Tenth Annual Geothermal Conference Workshop (EPRI AP-5059-SR), February 1987.

Miravalles geothermal field, Costa Rica: technical report. Transactions, Geothermal Resources Council, Volume 9, 1985.

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Scale deposits in geothermal wells at the Miravalles geothermal field, Costa Rica. Geothermics, Volume 14, No. 4, pp. 517-524, 1985.

Two-phase flow and scale deposits in thermal wellbores. Society of Petroleum Engineers, Long Beach, California, 1984.

Calcium carbonate deposition in geothermal wellbores. MSc. Thesis, Stanford University, 1983.

Informe de Factibilidad para el Proyecto Geotermico Miravalles, Area de Perforacion Profunda; Instituto Costarricense de Electricidad, 1980.

Informe de Pre-Factibilidad para el Proyecto Geotermico Miravalles; Instituto Costarricense de Electricidad, 1978.

Heat flow interpretation in the Miravalles geothermal field, Costa Rica. Transactions, Geothermal Resources Council, Volume 1, 1977.

Selection of construction materials for geothermal power plants. Post-graduate thesis for geothermal energy course, Pisa, Italy, 1975.

CITIZENSHIP

USA