IGA NEWS

Newsletter of the International Geothermal Association

Quarterly No. 77

IGA ACTIVITIES

Message from the President

Ladsi Rybach

Dear IGA member

This is the seventh message from your current President.

In my function as IGA President, I am frequently invited to presentations, keynote lectures and the like. Since my last message such an appearance took place in Addis Ababa/Ethiopia at the "Decision Makers' Workshop on Geothermal Energy". The three-day workshop was organized by the ICS-UNIDO with sponsorship of the African Union Commission (AUC), the Ethiopian Government, the IGA, and the BGR of Germany. The workshop was held at the Africa Hall at the United Nations Conference Centre (UNECA) in Addis Ababa from 8 to 10 June. Many high level officials attended; at the end of the workshop the African Energy Ministers issued "The Addis Ababa Declaration on Geothermal Energy in East African Region". For further details see the report of Martin M. Mwangi in this issue of IGA News.

In my last message I mentioned the joint IEA GIA-IGA Workshop "Geothermal Energy - Its Global Development Potential & Contribution to Mitigation of Climate Change", that took place in Madrid/Spain on 5-6 May. The numerous presentations at this successful workshop can now be found on the IEA GIA website www.iea-gia.org under "Activities & Achievements".

In addition to the information contained in my last message I would like to add the following remarks relating to the IGA Committee meetings and the 47th IGA BoD meeting in Madrid:

- The BoD approved the affiliation contracts between IGA and the following organizations: ESGA (El Salvador Geothermal Association), GtV (Geothermische Vereinung e. V., Germany), INAGA (Indonesian Geothermal Association), NGAP (National Geothermal Association of the Philippines), and TGA (Turkish Geothermal Association) ;
- The BoD authorized the Executive Director to establish an IGA Foundation Account for the purposes of allowing both Individual and Corporate membership affiliates and others to make voluntary monetary contributions for the long term benefit of the IGA;

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- The BoD decided that the second next BoD meeting and the 2010 Annual General meeting will be held in Bali/Indonesia, in conjunction with WGC2010. According to the preliminary schedule the committee meetings will be held on Saturday 24 April and the Board meeting on Sunday 25 April 2010. The exact date for the AGM will be decided later.

The new IGA website is now nearing completion. An important link leads to the IGA Conference Data Base; the following additional Conference Proceedings have recently been uploaded: (1) Workshop on Geological Risk Insurance, Karlsruhe/Germany, 11-12 November 2008, (2) Petroleum Engineering Summer School, Dubrovnik/Croatia, 9-13 June 2008 and (3) Stanford Geothermal Workshop 2008 and 2009. The total count of papers in the IGA conference database is now 5569.

Regarding the World Bank - IGA contract, the contract period ended on 30 December 2008. Of the 11 projects in the IGA-GeoFund work program, 8 were completed before that time. Two projects were extended by one year and one project was cancelled. Negotiations for a new contract with the World Bank, especially in the fields of GeoFund and ARGEO, are underway. As a preparatory step, IGA Services Co., Ltd. was established on 18 June in Cologne/Germany.

IGA currently has 24 Corporate and 4 Institutional members. The membership fees are US$ 300 in the case of for-profit Corporate members and US$ 750 for the non-profit Institutional members. Discussions are ongoing within the Membership and Bylaws Committees about whether the fee amounts should be changed.

The preparations for WGC2010 are on track. The Conference website www.wgc2010.org is periodically updated; the booklets for Sponsors and Exhibitors have been printed and are being distributed. Conference registration is now open; "Early Bird" deadline is 30 November. In particular, I would like to invite you all to have a look at the various pre- or post-conference tour options: there are some unique opportunities! Nearly 1000 draft papers have been submitted. They are now in the review process; the authors will be notified by 30 September. Deadline for final papers is 31 October.

The next IGA Committee meetings are scheduled for 28 October, the 48th IGA BoD meeting and the IGA Annual General Meeting 2009 for 28 or 29 October, to take place in the city of Antiguo Cuscatlan, El Salvador. A one-day Geothermal Workshop is scheduled for 30 October in Santa Tecla and a field trip on 31 October to the Berlin geothermal field.

I look forward to continuing to work with all of you in our joint effort to promote geothermal and thank you for your support.

Zurich, 22 July 2009

Ladsi Rybach

UPCOMING EVENTS

International Workshop "Geothermal Energy Development, Opportunities and Challenges", 3-4 September 2009, Pomarance, Tuscany, Italy. Website: www.cegl.it. Contact: Gherardini.s@cegl.it

WPRB, IGA/GCES Joint Geothermal Workshop, Chengdu, Sichuan, China, 19-22 September 2009. Check the IGA website www.geothermal-energy.org

RENEXPO 2009, Augburg, Germany, 24-27 September 2009. Website: www.renexpo.de

GRC 2009 Annual Meeting, Reno, NV, USA, 4-7 October 2009. Website: www.geothermal.org

Renewable Energy World Asia Conference & Exhibition 2009, 7-9 October 2009, Bangkok, Thailand. Website: www.renewableenergyworld-asia.com

Renewable Energy Indonesia 2009 Trade Show, 14-17 October 2009, Jakarta, Indonesia. Website: http://www.allworldexhibitions.com/images/shows/2009 0174_Renewable Energy 2009 Brochure.pdf

2009 GSA Annual Meeting-Session T32 "Survey of International Geothermal Development 2009", 18-21 October 2009, Portland, Oregon, USA. Website: www.geosociety.org/meetings/2009/

GTR-H: International Geothermal Conference, 27-29 October 2009, Dublin, Ireland. Contact: rpasquqli@csa.ie

World Energy Engineering Congress (WEEC), 4-6 November 2009, Washington, DC, USA. Website: www.energycongress.com

2009 Australian Geothermal Energy Conference, 10-13 November 2009, Brisbane, Australia. Website: www.impactenviro.com/au/ausgeothermal/

31st New Zealand Geothermal Workshop, Auckland, New Zealand, 16-17 November 2009. Website: www.science.auckland.ac.nz/uoa7science/about/research/gei/workshop.cfm

Der Geothermiekongress 2009, 17-19 November, Bochum. Germany. Contact: info@geothermie.de

35th Stanford Workshop on Geothermal Reservoir Engineering, 1-3 February 2010, Stanford, California, USA. Website: http://pangea.stanford.edu/ERE/research /geoth/conference/workshop.html

World Geothermal Congress 2010, Bali, Indonesia, 25-29 April 2010. Website: www.wgc2010.org

WORLD GEOTHERMAL CONGRESS 2010

Bali, Indonesia
25-30 April 2010

World Geothermal Congress 2010

WGC2010

Geothermal: The Energy to Change the World

the stage is set for exchange of ideas and sharing of experiences not only on technical and financing aspects but also on policy and global politics of the energy sector

Program at a glance

SUNDAY, 25 APRIL
- Registration
- Welcome Party

MONDAY, 26 APRIL
- Opening session
- Opening of Exhibition
- Lunch
- Keynote Session
- Technical Sessions

TUESDAY, 27 APRIL
- Keynote Session
- Technical Session
- Luncheon Talk
- Indonesian Cultural Night (Optional)

WEDNESDAY, 28 APRIL
- Panel Discussion
- Technical sessions
- Luncheon Talk

THURSDAY, 29 APRIL
- Technical Sessions
- Luncheon Talk
- Farewell Party

FRIDAY, 30 APRIL
- Panel Discussion
- Technical Sessions
- Lunch
- Technical Sessions
- Bali Declaration
- Closing Session

Who should attend the WGC2010

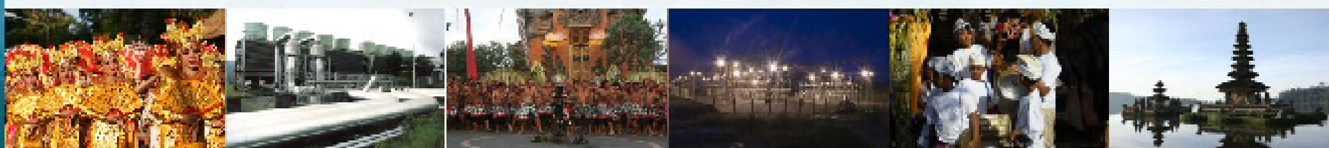
- Leading geothermal industry players
- Experts
- Policy makers
- Academicians

Further Information

Please contact the WGC2010 Secretariat
Grha Bimasena
Jl. Dharmawangsa Raya 39
Jakarta 12160 - Indonesia
Phone : +62-21 7258668
Fax : +62-21 7236193
E-mail : secr@wgc2010.org

To keep up to date with all the latest information on the congress, visit the WGC2010 website at **www.wgc2010.org**

Early bird discounts for the congress available..!! full details can be found at the website.



Convenor:

Co-Convenor:

Endorsed by:

Organized by:

Supported by:

Request for Sponsorship - 2010 World Geothermal Congress Bali

The 2010 World Geothermal Congress (WGC) is now just over a year away. This unique event brings the international geothermal community together once every 5 years to share scientific and technical information, new technology and industry trends, success stories and market opportunities for future developments. The 2010 WGC is being convened by the International Geothermal Association (IGA) and hosted by the Indonesian Geothermal Association (INAGA). It will happen on the 25th to 30th of April 2010 in Bali.

The expected 2000+ participants have the opportunity to visit numerous geothermal fields and cultural sites; attend the trade show and immerse themselves in the technical papers (1,000 abstracts have been received).

The IGA has agreed to solicit funds to support the Technical Program and to provide as many fellowships for geothermalists from developing countries as possible.

Your contribution is at your discretion, however we are seeking donations of approximately US$2500 per person sponsored, but organizations are encouraged to consider more than one person. If you are willing to participate in this sponsorship, further details about the fellowship sponsorship are provided here.

EUROPE

A New European Technology Platform (ETP) Renewable Heating & Cooling - Geothermal Panel

Philippe Dumas, European Geothermal Energy Council - EGEC

A European Technology Platform for Renewable Heating and Cooling (ETP-RHC) was endorsed by the European Commission on 27 October 2008, with the objective of developing a H&C Technology Roadmap. The goal is to involve a wide range of stakeholders: Industry, Academic, Investors, end-users…to define a medium and long term research and technology development vision: 2020/2030.

European actors (large companies, SME's, Universities, Research Centers…) of the geothermal sector decided in early 2009 to create a geothermal panel inside this ETP in order to produce a strategic research agenda for the heating & cooling sector.

EGEC published a first edition of the 'Geothermal Research Agenda -Strategy 2008 to 2030' in January 2009. The objective of the ETP-geothermal panel is to develop a roadmap for geothermal H&C technology.

The kick-off meeting of the ETP-RHC geothermal panel took place in the Renewable Energy House in Brussels on the 26th of June.

<u>Aims of the geothermal panel:</u>

- Strengthen the awareness of the huge potential of geothermal technologies in contributing to a sustainable energy infrastructure
- Increase R&D activities in the geothermal sector
- Accelerate the development of geothermal technology

<u>Objectives of the geothermal panel:</u>

- Develop a vision for geothermal technology in 2030
- Work out a strategic research agenda to achieve this vision
- Support the implementation of the strategic research agenda
- Identify non-technological framework conditions to facilitate a broad market deployment for geothermal technologies

The structure proposed for the geothermal panel at the kick off meeting in Brussels was modified and finally accepted by all participants with 3 Focus Groups:

Focus Group 1: Shallow Geothermal

WG 1.a: Underground systems technologies and installation

WG 1.b: Site investigation, design, sustainability

WG 1.c: exploitation and performance monitoring (inc storage, coupling with others energies)

WG 1.d: Surface systems

Focus Group 2: Deep Geothermal:

WG 2.a: Resource assessment, exploration

WG 2.b: Deep drilling

WG 2.c: Production technologies

WG 2.d: Surface systems: direct uses & cascade uses, district heating & cooling, CHP

WG 2.e: EGS

Focus Group 3: non-technical issues

WG3a : shallow: market and policies (regulations, financing and economics), communication

WG3b : deep: market and policies (regulations, financing and economics), communication

WG3c : training (common for shallow and deep)

The next meeting of the geothermal panel will be held on 03-04/09/2009 in Brussels. More info on www.egec.org

Greenhouses with geothermal energy - Oradea (Romania)

CLUSTHERM project

This project, managed by INNOVA Észak - Alföld Regional Development and Innovation Agency - Hungary, aims at creating a Central European Thermal Water Research Cluster.

The strategic objective of CLUSTHERM is to set up a new research driven cluster in Central Europe on thermal water utilization that will strengthen the research potential of the participating regions.

The direct objectives are to:

- analyse the RTD development and the needs of geothermal energy utilisation
- promote synergies and catalyse links between regional, research and business actors involved in thermal water utilization (vertical clustering)

University of Oradea

Felix Spa - Oradea

- foster transnational and cross-border co-operation between the regional actors of the participating regions in the field of thermal water utilization (horizontal clustering)
- develop and enhance transnational mutual learning through information exchange possibilities of regional stakeholders in creating research driven clusters and to disseminate good policy practices and benchmarking activities
- develop a joint action plan and research strategy among the participating regions to increase the regional economic competitiveness through concentrated use of natural resources.

The 12 partners are public national, regional or local authorities, research entities, enterprises and expert organizations from Hungary, Romania, Austria and Croatia:

INNOVA Észak-Alföld Regional Development and Innovation Agency (Coordinator)

Észak-Alföld Regional Thermal Innovation Public Benefit Organization

"VITUKI" Environmental Protection and Water Management Research Institute Non-profit Company

University of Oradea

North West Regional Development Agency

SC Transgex SA

Vukovar-Srijem County

Energy Institute Hrvoje Pozar

South Great Plain Regional Development Agency

South Great Plain Sustainable Environment Foundation

Central Geo Ltd.

Internationalisierungs Center Steiermark

More information : Márta Völgyiné Nadabán, coordinator - http://www.clustherm.eu/

Iceland

IDDP drills into magma at Krafla

Guðmundur Ómar Friðleifsson, and Wilfred A. Elders , Iceland Deep Drilling Project (IDDP)

After about two months of drilling problems, getting stuck, having twistoffs, and having to sidetrack three times, etc., the source of these problems became clear on Wednesday June 24th, 2009. At 2104 m depth the weight on the drill bit suddenly declined, the rate of penetration shot up and there was an immediate increase in torque. On pulling up a few meters to free the bit and circulate cooling fluid, cuttings of clear glass appeared, followed by darker colored obsidian. This glass is of rhyolitic composition, quenched by the drilling fluid from some 1000°C. Although IDDP must abandon its ambition to drill into an active supercritical zone at this time, the compensation is that the team has the opportunity to study active magma and its interaction with injected water, which is terribly interesting.

If this intrusion occurred at the time of the last eruptions at Krafla (1975-84), a preliminary estimate of its rate of cooling gives a minimum thickness in excess of 30m. MT/TEM surveys suggested that the magma chamber in the vicinity of this well could be deeper than 4

IDDP-1 drillsite at Krafla, showing a fumarolic field at a fault escarpment and the drill rig Tyr . Photo taken by G.O. Fridleifsson, shortly after hitting the magma.

km, so we may possibly have drilled into a sill or a dike-like intrusion. The adjacent rock is granophyre that has intruded the basaltic sequence and has itself been intruded by basalt. There is a 13 3/8" casing cemented to 1958 m and the bottom 127 m of the hole is open, cased by 9 5/8" perforated liner, set about 5 m above the quenched glass which fills the hole between 1985-2104 m. At the moment the IDDP is preparing for a flow test that is likely to occur in September or October this year. The well should

Colorless rhyolitic glass shard (approx. 1 mm across) with spherical vesicles. Photo from the IDDP website, www.iddp.is

produce superheated dry steam for some time from the vicinity of live magma, but since the encounter with the magma the well has been kept cool by coldwater injection - under total loss of circulation (i.e. ~>60 l/s). A tracer injection test is already underway while as yet tracer recovery has not been detected in nearby wells.

After flow testing this autumn, the well might either become a producer of high pressure superheated steam, or be turned into a cold-water injection well. Depending on the result of the IDDP tests, future possibilities might include a project to create the world's highest temperature Engineered Geothermal System (EGS).

IDDP has plans to drill well IDDP-2 in the next few years, presumably at the Hengill Geothermal System, or at Reykjanes, but whether it will happen next year or in 2011 has not been decided.

Switzerland

A new Master in Hydrogeology and Geothermics

Eva Schill, Professor of Geothermics, University of Neuchâtel

After the creation of a new Chair in Geothermics and the establishment of a new Laboratory for Geothermics at the beginning of 2009, the University of Neuchâtel is extending its current teaching program in hydrogeology to a new "Master of Sciences" specialized in Hydrogeology and Geothermics (120 ECTS)[1] from September 2009 on. The objective of the Masters programme is to understand the physical and chemical processes affecting fluid circulation in the shallow and deep subsurface within the frame of sustainable and integrated resource management.

The specialization in geothermics aims to provide a broad training from the understanding of general heat transport processes through geological, geophysical and geochemical reservoir exploration to sustainable reservoir exploitation and resource management. It includes geology, geophysics, petrophysics, hydrogeology and geochemistry.

This Masters programme extends over 2 years. The first teaching period covers the fundamentals of hydrogeology and geothermics in 3 general modules:

1) General hydrogeology, hydrochemistry and tracer tests,
2) General geothermics, geothermics in the shallow subsurface,
3) Reservoir modelling.

The second teaching period is subdivided into the specializations "Hydrogeology" and "Geothermics". In the specialization "Geothermics" the courses concentrate on the topics of deep geothermics. A major focus will be given to hydrothermal and EGS systems:

Module of specialization 4-G in Geothermics
Heat transport
Advanced reservoir modelling
Geophysical exploration (seismic, MT, gravity)
Geochemical exploration
Numerical simulation of geothermal processes
Reservoir stimulation and exploitation
Plant construction

After completion of the module 4-G, the specialization "Geothermics" continues with a seminar, a 2-week field course, field trips and finally a Master thesis (9 months). The total training programme in geothermics is validated with 75 ECTS.

Lectures and courses will be given in cooperation with the Swiss Federal Institute of Technology (EPF-L) and the University of Lausanne. Further information and inscription are available on our webpage http://www1.unine.ch/chyn/php/educ_master_chyn.php?lang=en.

[1]ECTS = credits awarded under the European Credit Transfer and Accumulation System, a mechanism to promote student mobility. See http://ec.europa.eu/education/lifelong-learning-policy/doc48_en.htm

United Kingdom

Revisiting deep geothermal in the United Kingdom

Ryan Law, Tony Batchelor, Peter Ledingham
ryan.law@GeothermalEngineering.co.uk

Abstract

A number of deep geothermal research projects in low permeability formations were started in the mid 1970s, most notably in the United States, the United Kingdom and Japan. The United Kingdom research project ran at Rosemanowes Quarry in SW England for the best part of 15 years and contributed substantially to the technical knowledge of rock mechanics and reservoir development.

Although the research project in the United Kingdom was not designed to produce power, the potential for deep

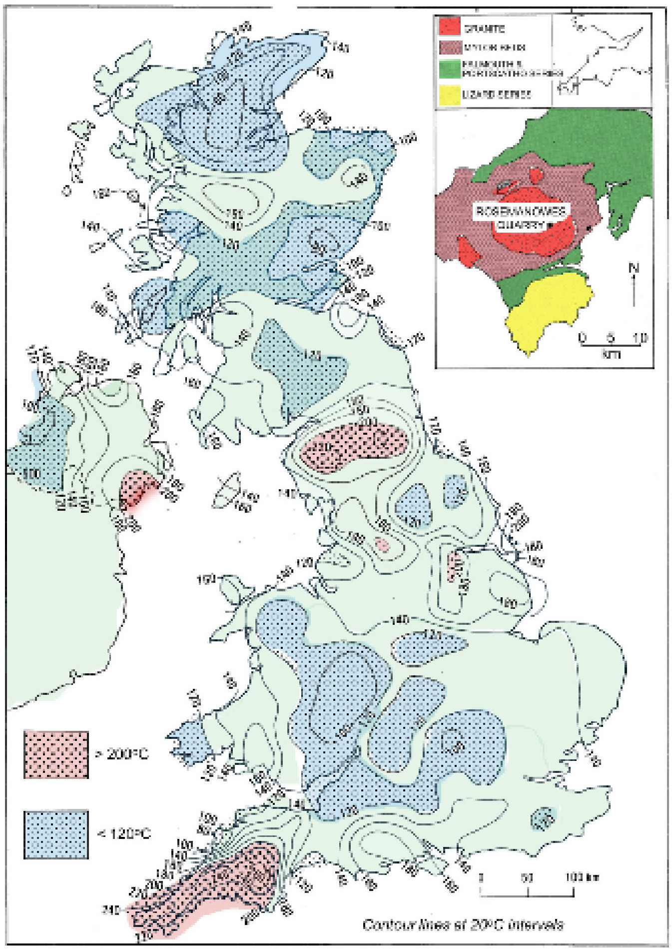


Figure 1. Predicted temperature in °C at 7 km in the UK (after Downing and Gray, 1986) and the research site

geothermal power remains. Data from the original research project and other studies have been re-examined and a potential site selected for a project is being planned around a 10MW power plant. Drilling of a 4.5km exploration borehole is expected to start in 2010.

Introduction

Despite the location of the United Kingdom, on the stable fore-land of Europe, remote from active volcanism and strong tectonism, surface heat flows and geothermal gradients indicated that economically useful temperatures of 60-100°C would be reached at depths of 2 to 3.5 km (Dunham 1974). A calculation was also made of the expected temperatures at significant depth (7 km) and this is shown in Figure 1. Although the calculated temperatures could be regarded as relatively low compared to some of the hottest geothermal resources in the world, it can be seen that, particularly in the far South West of the United Kingdom, the potential does exist for deep geothermal power generation. These prospects warranted further research and an extensive research into the rock mechanics of deep geothermal reservoir creation was undertaken at a site in the Rosemanowes Quarry in Cornwall (Figure 1).

Summary of previous research

The research project started in 1977. It was one of the largest hydrogeological experiments carried out in the United Kingdom, involving staff from a number of institutions.

In Phase 1 (1977-80) of the project, boreholes were drilled to 300 m depth. These were used to demonstrate that is was possible to establish hydraulic connections between boreholes by injecting water at high pressures, thus increasing the permeability of the system by hydraulically developing the natural joints in the granite. Water was then circulated through these joints (Batchelor 1982).

Phase 2 (1980-1988) was designed to be more closely related to the conditions required for commercial exploitation of the technology but with temperatures deliberately kept below 100°C and involved drilling two wells to a depth of 2.1 km. A reservoir was created by hydraulic stimulation but circulation of the system showed that although the stimulated reservoir, as identified by the distribution of the induced microseismicity, occupied a large reservoir rock volume, there was a poor connection between the injection and production wells.

A subsequent well was then drilled to a depth of 2.6 km at which the rock temperature was 100°C. This produced a smaller reservoir, with lower impedance and lower water losses (Parker 1989). The new reservoir was characterised by carrying out a continuous circulation at different flow rates, and measuring the hydraulic and thermal performance. The results showed that the reservoir was smaller than that required for commercial applications, and that at least 15% of the fluid was passing over a small surface area of rock, resulting in premature cooling of the production water (Camborne School of Mines 1989).

Phase 3 began in 1988, with a conceptual design of a 6 km deep prototype of a commercial system for generating electricity in Cornwall. In addition to the conceptual design study, further research and development was also carried out, aimed at manipulating the Rosemanowes reservoir to improve its performance (Camborne School of Mines 1991). An important consequence of this work was a proposal to create large deep geothermal reservoirs by connecting smaller cells in parallel (Green & Parker 1992).

The U.K. Department of Energy decided in 1991 that the next phase of work would concentrate less on research in Cornwall and would involve greater collaboration with a European programme at Soultz-sous-Forets in Alsace, involving France, Germany and the European Commission. The Department's conclusion was that there were still very substantial technical uncertainties concerning the practicability of deep geothermal in the

UK, and it seemed unlikely to be economically competitive in the short to medium term.

Proposed UK project

It is now 18 years since deep geothermal exploration finished in the UK. There is no geothermal licensing structure in place in the UK and, as this will require primary legislation, there will not be for the foreseeable future. This has made development of geothermal projects more complex. However, in spite of this, it was decided in 2008 to revisit the data from the UK experiment and select a new site for a 10MW power plant. Geothermal Engineering Ltd was formed specifically to develop the project following a research programme undertaken by Ove Arup and Partners Ltd. A feasibility study was undertaken in conjunction with Dr Tony Batchelor (project director of the UK research project, now managing director of GeoScience) to find the most promising location for the proposed plant.

The geological study was started in 2008 and is now complete. The study area comprised the portion of west Cornwall from St Agnes on the north coast to Helston in the south and from Truro in the east to Hayle in the west (Figure 2). This area incorporates and surrounds the Carnmenellis granite outcrop (approximate location shown by the grey circle in Figure 2), which was the site of the deep geothermal research programme and, as a result, the subject of significant exploration activity. Of particular relevance to the study were the three deep wells drilled at the test site, extensive characterization of the granite fabric and natural fracture system, temperature and stress measurements, fluid and gas sampling and analysis and extensive hydraulic stimulation experience.

The study area also includes a significant historical mining district that extends across the northeastern, northern and northwestern edge of the granite outcrop. Only one of the mines remains open today but extensive records exist of mining activity from the 19th and 20th centuries, penetrating both the granite and surrounding rocks ('killas') to depths of 1,000m. These records provide valuable insight into the nature of the rock fabric and natural fractures, temperatures, and the occurrence of hot water inflows.

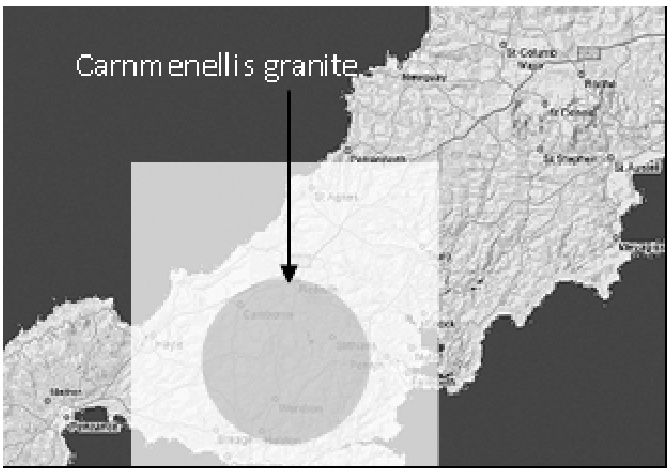


Figure 2: Proposed study area for the new project (square box)

Geology

As a result of the research projects undertaken in the 1970s it is now broadly agreed that some degree of natural permeability needs to be present for the successful development of a deep geothermal system. To assess and compare suitable targets at depth the study defined a number of geological 'domains' which were then evaluated using the following criteria:

Fracture permeability, Domain volume, Temperature

The geology of the study area is highly complex and has been reported in detail in many technical papers (see Parker 1989 Volume 1 for a comprehensive review and reference list).

The key potential lithologies identified for the study are summarised below:

Formation	Description
Background granite	Granite with normal or 'background' fracture intensity, typical blocky fracture network.
Faulted granite	Granite with high fracture intensity due to presence of faults and / or fracture corridors, plus alteration effects.
Background killas	Devonian formations with normal or 'background' fracture intensity.
Faulted killas	Devonian formations with high fracture intensity due to presence of faults and / or fracture corridors, plus alteration effects.
Flank contacts between granite and killas	Steep to moderate dipping contacts due to stoping and / or faulting, with associated intrusives in the killas and alteration effects.
Roof contacts between granite and killas	Flat-lying contacts due to stoping, with associated intrusive complexes in the killas and alteration effects.
Major structural Intersections	Intersections between major faults, fault zones or folds.

Arguments for and against each of the domains were developed based on the assumption that evidence of naturally enhanced permeability is the most desirable attribute of a lithology. The arguments for and above the following formations are summarised below:

Formation	For	Against
Granite	Systematic orthogonal joint sets, master joints, fracture corridors.	Variable and reducing fracture frequency and aperture with depth, limited connectivity.
Faulted granite	High fracture frequency, vuggy fault cores, good connectivity	Narrow damage zones, may be kaolinised with porosity occlusion
Killas	No merit	Non-systematic joint sets, many sealed, low fracture dimension and frequency Possible argillic alteration
Faulted killas	High fracture frequency, vuggy fault cores, wide damage zones, good connectivity, limited alteration effects	on fracture surfaces Many sealed fractures, localisation of faulting at
Flank contacts	Potential for high fracture density in brittle formations and metamorphic aureole	contact very unpredictable Many sealed fractures, unlikely to be faulted
Roof contacts	Potential for high fracture frequency in brittle formations and metamorphic aureole	contact Potentially sealed fractures if structures are
Structural Intersections	High fracture frequency, high flow potential	'fossilized'

The nature of the fracturing in both the killas formation (above) and the granite formation (below) can be most clearly seen in Figure 3. The granite displays a block like fracture network whereas the killas is more intensely fractured. The killas also displays more intense iron staining implying more host rock permeability.

The major controlling factor for the site is that significant faulting is required in order to elevate fracture permeability above background levels, be it granite or killas. Moreover, higher fracture density and the potential for enhanced permeability is likely to exist at structural intersections and in zones of major structural intersection. A further, but more contentious conclusion is that faulted killas may be more suited as a deep geothermal host. This is suggested mainly because fault damage zones may tend to be wider than those in granite (for the same displacement fault), as can be seen in Figure 3, where metric scale fractures and fracture corridors change character when crossing from one formation to the other. A second factor is that fractures in the killas may be less prone to alteration effects.

Significant uncertainty remains about whether these predominantly near-surface observations can be extrapolated to 4,000m depth. Borehole evidence indicates the possibility of this to at least 2,000m in Cornwall, and to greater depths in other locations (eg at the San Andreas Fault California, and the Kola Peninsula deep borehole). However, even if secondary alteration is present and acting to occlude fracture porosity, this may be countered by active stress dilation of fractures, at least for those of susceptible orientation. In the absence of these factors the hydraulic properties of fractures in granite and killas at 4,000m depth may be similar.

Stress regime

Many publications have shown that in-situ stress influences fracture aperture and hence permeability (see Tamagawa and Pollard 2008 for a recent review). The present-day stress field in Cornwall is relatively well understood from downhole measurements made in the Carnmenellis granite (Batchelor and Pine 1986, Parker 1989). The magnitudes and orientations of the principal stress axes were measured from near-surface to 2,500m revealing significant stress anisotropy. The implied strike-slip stress regime is consistent with focal plane solutions from microseismic monitoring carried out during the research project.

The microseismic events which were produced during the injection formed a linear 'cloud' close to the orientation of a major joint set identified in the granite. It was concluded that injection was promoting minor slip on these fractures because they are in a state of critical shear in the current stress field. Similar work carried out in the Troon boreholes (a nearby quarry, Heath 1985) also concluded that fractures oriented approximately NNW-SSE were preferential flow paths, but also noted that flow was taking place in many fractures with strikes orthogonal to σHmax during injection in the wells, which indicated predominantly strike-slip motion on fractures oriented at ~25° to σHmax.

Figure 3: Fault structure showing the difference between granite (below) and killas (above)

These conclusions are in general agreement with the observations of water ingress in mines, which indicate that the NW-SE to N-S striking cross-courses are the main sites of persistent flows, often at intersections with the WSW-ENE striking lode structures (BGS 1989). The cross-course flows were reportedly persistent for many years, and produced water at 40 to 60°C.

Based on the assessment above, it was concluded that fault zones with enhanced and connected fracture permeability at 4,000 to 5,000m depth are the most suitable geological domain for hosting a deep EGS and this formed the basis for the site selection.

Temperatures

The whole study area is underlain by a high heat production granite, the surface expression of which is the Carnmenellis Granite. Heat is generated within the granite by the decay of uranium, thorium and potassium, resulting in elevated heat flow compared to average rocks in the UK. It was assumed at the outset of the study that the whole study area would have higher than average temperature gradients and that the geological criteria were more significant in choosing the target site. However, a reassessment of the relevant heat flow data has been carried out based on heat generation, thermal conductivities, paleoclimate and possible thermal refraction effects caused by proximity to the edge of the granite intrusion in some measurements. Predictions based on this assessment suggest that temperatures at the proposed reservoir depth will be commercially viable.

Uncertainties

There is a moderate to high degree of uncertainty surrounding the prognosis of geological formations and structures at 4,000 to 5,000m depth, and their character. This is true despite the wealth of surface and near-surface data (at least in parts of the study area), and follows from the absence of well control and the coarse resolution and ambiguity of geophysical remote sensing methods. These uncertainties will only be significantly reduced when an exploration borehole is drilled and the host rocks characterised. This drilling is expected to start in 2010.

References

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OCEANIA

Australia

Australian Federal Government's Geothermal Drilling Program Round 2 funding

Jim Driscoll, Hot Dry Rocks Pty Ltd

The Australian geothermal industry continues to expand rapidly since the first geothermal exploration permits were awarded in 2001, and now comprises 48 exploration companies. The area under licence (or application) now totals nearly 358,400 km^2, an area greater than the total landmass of the Federal Republic of Germany.

The Australia Federal Government unveiled Round 2 of its Geothermal Drilling Program (GDP) in June 2009. The GDP is a A$50m competitive merit-based grants program provided as a dollar-for-dollar subsidy, capped at A$7 million per proof-of-concept project.

Round 1 of the GDP closed early in 2009 and resulted in two companies being awarded the full A$7m: Petratherm Limited's Paralana Project and Panax Geothermal Limited's Limestone Coast Project.

The high cost of drilling deep wells was a key barrier identified by the Australian Federal Government during a lengthy consultation process with various stakeholders in the Australian and New Zealand geothermal communities. The GDP funding initiative was implemented to help overcome this short-term hurdle, and thus accelerate the development of the Australian geothermal industry.

The Australian Federal Government is extremely keen to establish Australia as the world leader in EGS (engineered geothermal systems) and HSA (hot sedimentary aquifer) developments. A key component of the GDP is therefore to encourage growth, innovation and technical capability of the Australian geothermal industry. There is a high expectation that these skills will be transferable to the wider international geothermal community.

Four main merit criteria were required to be addressed in the GDP Application: the technical strength of the project, the technical capability and resources available to the applicant, the management capability of the applicant, and the financial capability of the applicant. In addition, the Australian Federal Government was keen for the fund to be used to demonstrate geothermal technology that can be widespread and applied in a variety of geographical and geological settings. A further aim of the GDP was to demonstrate the robustness of the EGS and HSA technology to private sector investors and hence increase confidence in Australia's geothermal industry.

It is anticipated the first small-scale EGS and HSA geothermal power plants will be operating in Australia within the next two years.

A mandatory requirement of the GDP process was the demonstration by each applicant that their nominated project area had a potentially commercially viable geothermal resource. An assessment of each company's resource therefore had to be undertaken, and these inferred resource estimations were to be fully compliant with the Australian Code for Reporting of Exploration Results (launched at the Australian Geothermal Energy Conference in Melbourne in 2008).

Hot Dry Rocks Pty Ltd (HDRPL) has been instrumental in helping companies estimate their Inferred Geothermal Resources; indeed, HDRPL undertook Inferred Resource Reports for both successful applicants of the Round 1 funding.

MNGI Pty Ltd (wholly owned subsidiary of Petratherm Limited)

The Paralana Project (South Australia) is an EGS project which aims to demonstrate a successful, robust and innovative geothermal heat exchanger in the Adelaide Fold Belt metasedimentary rocks at Paralana. It aims to prove EGS technology with the innovative heat exchanger within insulator (HEWI) model that will bring forward geothermal development and investment across Australia by considerably lowering drilling costs and risks.

Panax Geothermal Limited

The Limestone Coast Project (South Australia) is based on the concept that commercially viable geothermal reservoirs can be utilised in deep sedimentary basins where they are buried under a thick layer of sedimentary rocks with low thermal conductivity.

The Australian Federal Government views the typical technical program of a proof-of-concept project being initiated with the drilling of a well between 3 and 5 kilometres. Hydraulic fracture stimulation would usually be necessary to create an effective underground reservoir. Most projects will involve the drilling of a second well to intersect the reservoir. Monitoring and flow testing would finally be undertaken to prove reservoir connectivity and fluid circulation.

The Australian Federal Government has indicated that Round 2 - which closed on 4 August - will be the final opportunity for companies to secure access to the GDP funding arrangement; hence it is anticipated there will be five successful applicants.

Figure 1: An excavator digging on the main street of a county town in Yanqing County, China

ASIA/PACIFIC RIM

China

Geothermal district heating project being implemented in Yanqing county of Beijing

Keyan Zheng, GCES, China

Yanqing County is located in the northwest suburb of Beijing. The prevailing wind in Beijing in winter is from the northwest, so that pollution from existing coal-fired boilers for space heating in Yanqing County is blown towards Beijing urban area. In order to improve the air quality in Beijing as a strategic target, Yanqing County has planned to develop local geothermal resources using 50-71° C geothermal water for district heating in the central town. The Yanqing Geothermal District Heating Project was started formally in the summer of 2009. Four geothermal wells already provide geothermal space heating in institutional buildings. The existing geothermal heating area is 207,000 m^2. Three new geothermal wells will be added to supply an extended 171,000 m^2 of district heating, serving schools, an exhibition center, residential community and resort. The total investment is CNY33,364,000 (about 4.9 million USD).

An excavator is now digging on the main streets of the county town (figure 1), and all the pipelines for district heating will be installed during this year. The geothermal wells will then be drilled year by year (figure 2).

In addition, there are 300,000 m^2 of GSHP heating projects completed in Yanqing. So, a total 678,000 m^2 of geothermal plus GSHP district heating will be run in the coming winter. The remaining 574,000 m2 of buildings have been programmed into the project. They will provide their own infrastructure, but will wait for geothermal well drilling over the following 2 or 3 years. When the project is completed, Yanqing will have over 1.25 million m^2 of geothermal plus GSHP district heating area. It will save 50,700 tons of coal annually, and will be equivalent to 121,000 tons of CO_2 emission reduction.

Figure 2: Drilling for hot water in Yanqing County

Philippines

EDC takes over Mindanao geothermal power plants

Sylvia Ramos, Energy Development Corporation

On June 18, 2009, the Philippines' largest geothermal power producer, Energy Development Corp (EDC) of the Lopez Group of Companies, secured full ownership and control of the 52 MWe Mindanao 1 and 54 MWe Mindanao 2 geothermal power plants located in Mindanao Island, southern Philippines. The signing of the documents that led to transfer of ownership was witnessed by officials from the EDC and the Marubeni Energy Services Corporation (MESC), one of the subsidiary companies of the Marubeni Philippines, in two separate locations: one at the geothermal field in Barangay Ilomavis, Kidapawan City, Province of North Cotabato and the other at the head office of the EDC in Makati City.

EDC took over the two plants from the Mindanao 1 Geothermal Partnership M1GP, a partnership between Oxbow Power Corp and Japan-based Marubeni Corp. The energy conversion agreement (ECA) of the cooperation period also ended on the same day. The plants were constructed from 1994 to 1996 by the M1GP through the build operate transfer (BOT) scheme. The Mindanao 1 and Mindanao 2 geothermal power plants started commercial operations on March 4, 1997, and June 17, 1999, respectively. In October 2006, EDC and MIGP agreed to extend Mindanao 1 power plant's BOT contract period to coincide with Mindanao 2 power plant's turnover. Since commissioning, MIGP and M2GP have operated with average availability factors of 96% and 98% respectively, and average plant capacities of 91.3% and 92.5%. From 2006 to 2007, MIGP and M2GP accounted for an average of 10. 56% of the electricity supply in Mindanao.

Mindanao 1 Power Plant

Mindanao 2 Power Plant

"The turnover of the Mindanao power plants will fully integrate the value chain of the geothermal business from steam production to power generation like our Leyte projects," EDC president and CEO Paul Aquino said. "We will be well positioned to address and benefit from the robust growth in peak electricity demand in the Mindanao grid as we offer cheaper and cleaner sources of energy," he added. The Mindanao plants are the last of the BOT plants turned over to EDC. In 2006 and 2007, EDC assumed operations of the unified Leyte plants from California Energy and Ormat. The unified Leyte plants consist of the 132 MWe Upper Mahiao, 232.5 MWe Malitbog, 180 MWe Mahanagdong and 51 MWe optimization plants. EDC accounts for 62% or 1,199 MW of the country's 1,980 MW total installed capacity.

AFRICA

The Addis Ababa Declaration on Geothermal Energy in East African Region

Martin N. Mwangi - Managing Director, GeoSteam Services Ltd

A three day workshop called "Decision Makers' Workshop on Geothermal Energy" was organised by the ICS-UNIDO with sponsorship of the African Union Commission (AUC), the Ethiopian Government, and IGA in collaboration with BGR of Germany. The workshop was held in the Africa Hall at the United Nations Conference Centre (UNECA), Addis Ababa, Ethiopia from 8th to 10th June 2009. The workshop was opened by the President of the Federal Democratic Republic of Ethiopia, H.E. Girma Wolde-Georgis. Other important high level dignitaries were Ms E.M.A. Ibrahim, Commissioner Infrastructure and Energy, African Union; Ambassador K. Veraeke, EU special Representative to African Union; Mr D. Tommy, Representative of the Director General UNIDO, Ambassador C.D. Knoop, German Ambassador to Ethiopia, Mr Martin Lorenzini, Italian Charge d'Affaires in Ethiopia, Prof L. Rybach, President of IGA; H.E. A Tegenu, Minister of Mines and Energy of Ethiopia; Didace Birrabish, Head of Cabinet of the Ministry of Mines, Burundi; Houmadi Abdallah, Minister for Agriculture, Fishing and Environment, Comoros Islands; Boussa Bouh Odawa, Minister for Energy and Natural Resources, Djibouti; Kiraitu Murungi, Minister for Energy, Kenya; Ambassador Gaspard Nylinkid of Rwanda; Adam Kigoma Malima, Deputy Minister for Energy, Tanzania; D. Vijanga Simon, Deputy Minister for Energy and Mineral Development, Uganda; Alan Mbewe, Deputy Minister for Energy, Zambia; and Mr G. Rosso Cicogna, Managing Director, ICS-UNIDO, among many others. The total number of regular and opening ceremony participants was about 110 and 150, respectively. This is the largest number of high level dignitaries from East Africa to attend a workshop on geothermal development. Unfortunately, Eritrea was not represented.

The workshop was planned to help decision makers of the East African countries that have vast geothermal resources to understand the issues in the implementation of geothermal projects, available technologies, financial and environmental issues. The forum was also aimed at providing an interactive environment between geothermal experts and decision markers with the aim of promoting the development of geothermal energy in the region, which has recently been affected by drought and high prices of fossil fuel for power generation. The workshop covered the following topics:

- Perspective of geothermal development in the East African region from the represented countries
- State-of-the-art of geothermal energy exploration and utilisation
- Success stories and strategic role of geothermal energy from Philippines, Indonesia, Kenya, El Salvador, Guatemala, Mexico, Italy, and Iceland
- Strategic role of legal and regulatory regimes and environmental issues
- Economics, funding and industrial partnerships
- Seminar on electricity production from low enthalpy geothermal steam condensate or brine.

At the end of the workshop, the Energy ministers or their representatives issued a declaration that:

- geothermal energy, as a clean renewable and sustainable resources, is likely to emerge as a mainstream option for future energy challenges for the respective countries; and
- a joint regional effort be urgently activated in order to facilitate the development of geothermal resources through capacity building to enhance exchange of information, data collection, access to short-term and long-term financial resources and industrial cooperation.

The decision makers agreed:

- to recommend to the AUC to establish within the framework of its infrastructure and Energy Programme a new agency to be known as the Geothermal Energy Development Agency with the task of supporting the above activities;
- to recommend to the AUC to convene a permanent Regional Forum with the participation of these

Participants of "Decision Makers' Workshop on Geothermal energy", Addis Ababa 8th-10th June, 2009 countries in order to institutionalize their involvement in the activities of the proposed Agency;

- to mandate the AUC to promote cooperation with ICS-UNIDO in a strategic collective regional project to address these issues, to be submitted to the European Commission and to other potential donors and to be implemented according to the different requirements of each country;
- that such projects should include activities in capacity building, namely advanced training and technical assistance, in order to ensure that highly qualified human resources are locally available as required to sustain a long-term strategy which is aimed at the full exploitation of the geothermal resources; and
- that such projects should also include field activities in order to identify the most promising sites in signatory countries and to start pilot activities for actual drilling as well as public awareness creation activities.

KENYA

Kenya's new Geothermal Development Company to fast-track geothermal resource assessment and development

Dr Peter Omenda and Dr Silas Simiyu - Geothermal Development Company Ltd

The Geothermal Development Company Limited (GDC) which is a special purpose geothermal resource development entity has started its operations in Kenya. The company was conceived by the Government of Kenya to take over from the Kenya Electricity Generating Company (KenGen) the geothermal resources assessment role and to leave KenGen to undertake its core business of power generation. GDC is wholly owned by the Government of Kenya and was incorporated in 2008 and is governed by the State Corporations Act of the laws of Kenya. The main reason for forming GDC was the need to reduce upfront geothermal resource exploration and appraisal risks to investors by the Government taking over these activities. GDC is, therefore, tasked with the responsibility of exploring, assessing, developing and managing geothermal energy resources in the country to reduce upstream (electrical and non-electrical) development risks so as to promote rapid development of power plants and direct use facilities in Kenya.

In order to achieve its mandate, GDC will carry out detailed surface exploration studies, and exploratory and appraisal drilling in the identified geothermal fields with funds from the Government, donors and other low-interest sources. The fields will then be offered for bidding to any interested parties who would proceed with production drilling and power station development. However, if no interested parties are found, GDC will proceed to drill production wells until an interested party is found. It is anticipated that this strategy will assess and develop geothermal steam fields in the numerous potential areas within the Kenya rift valley with the intention of allowing investors to develop power plants and other developments at significantly reduced investment risks and therefore keep the electricity tariff affordable to the people and the economy. As part of its responsibilities, GDC will be in charge of managing all Government resources required for rapid geothermal assessment and development and all grants for this purpose will be channeled through the Company. In order to attract more private developers to participate in geothermal power and direct use applications, the Government, through GDC, has set up a special Risk Mitigation Fund to underwrite unproductive exploration wells for those parties that chose to undertake their own exploration drilling.

As part of its initial activities, GDC has advertised for a tender to drill 10 wells for the planned Olkaria IV (140MW) power plant using two hired rigs. GDC will manage the steam field development while KenGen will develop and operate the power plant.

During the period 2009-2012, GDC with support of the Government and donors plans to acquire 6 new drilling rigs in order to drill on its own more than 100 wells which are expected to prove about 500 MWe (steam equivalent) at a total cost of approximately US$860 million. In order for the above activities to be realized, GDC is planning to undertake detailed surface exploration in all the unexplored high potential geothermal prospects and to drill exploratory and or appraisal wells. The long term goal is to prove steam equivalent to 1,500 MWe by 2019 and 3,000 MWe by the year 2030.

Since 5th August 2009, Kenya is rationing power supply to most customers for up to 37.5 hours a week. This state has been caused by severe drought which has caused the main hydro dam that controls most of the hydro power generation to be closed down for the first time since it was built. It is believed that if the vast geothermal resources in Kenya's rift valley were developed, the current state of power supply would not occur.

TANZANIA

Recent Geothermal Activities in Tanzania

Jacob W. M. Mayalla, Senior Geologist, Ministry of Energy and Minerals, Dar es Salaam, Tanzania

Tanzania is one of the East African countries with all the characteristics of geothermal energy resources. Most of the already identified sites with hot springs are located in areas traversed by the East African Rift System. Such areas include the northern volcanic province of Kilimanjaro, Meru and Ngorongoro and the Rungwe Volcanic province in Southwest Tanzania. In addition, some coastal areas also show surface manifestations of geothermal resources.

The Government of Tanzania intends to diversify the country's energy mix and is looking for alternative sources of energy. Currently, the national power system is heavily dependent on hydropower. Long periods of drought experienced between 2003 and 2006 created serious shortfalls in electricity supply from the hydropower stations. Geothermal power generation is regarded as offering one opportunity to the stabilization of energy supply and energy prices.

In the quest to diversify sources of energy, Tanzania is interested in assessing its geothermal resources for the purpose of exploitation. Although surface geothermal assessments started in 1976 and more than 50 sites along the rift valley were identified, none has been exploited to-date.

Out of the 50 areas identified, the most promising are:

1. Songwe - Mbeya region;
2. Luhoi - lower Rufiji Basin; and
3. Lake Natron - Manyara.

In June 2006, the Ministry of Energy and Minerals in Tanzania (MEM), the Geological Survey of Tanzania (GST) and the Federal Institute for Geosciences and Natural Resources (BGR) of Germany initiated a project called "Geothermal as an alternative source of energy for Tanzania". This project is a part of the GEOTHERM programme which is a technical cooperation programme of the German government. GEOTHERM project has conducted surface surveys in several East African countries in the recent past.

Between June and November 2006, as well as June and July 2007, MEM, GST, TANESCO and BGR carried out a joint field survey in the Songwe-Mbeya region. Geological, geochemical and geophysical results from this work identified an area with potential of about 10MW which has a predicted reservoir temperature exceeding 2000C. The reservoir has fracture permeability with recharge from elevated areas and the heat is fed from a shallow magma chamber.

It has further been recommended that:

1. additional Magnetotellulic (MT) and Transient Electro Magnetic (TEM) resistivity measurements be made;
2. three temperature gradient wells be drilled to 500m to determine the water table; and
3. several deep exploration wells be drilled.

Whereas the government of Tanzania is soliciting funds to carry out the recommendations above, the area is available to any investor who is willing to undertake the development from its currently stage.

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