Updated Resource Assessment and 3-D Geological Model of the Mita Geothermal System, Guatemala

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Mita, Cerro Blanco, gold deposit, geothermal exploration, resource assessment, Guatemala, geological model, Leapfrog Geothermal

ABSTRACT

Mita is a moderate temperature geothermal system that was discovered in 1997 during gold exploration in south-eastern Guatemala. This system is associated with bimodal basalt-rhyolite volcanism, and occurs alongside (and overlapping with) the Cerro Blanco 2 million ounce epithermal gold deposit. Four 1000-1500m deep slim holes were drilled in 2008-09 to confirm the nature of the deep reservoir.

This drilling program outlined an intermediate depth reservoir with temperatures in the region of 200°C, with a deeper inferred reservoir with temperatures of around 240°C. The intermediate geothermal system has been interpreted to be an outflow of a deeper system which migrates up along a horst fault.

Following the latest exploration drilling phase, an updated conceptual model and 3D geological model have been created. This reservoir is liquid-dominated with a sodium-chloride-bicarbonate composition, TDS of about 1,900 mg/kg and gas content of 0.4 wt%. The shallow outflow from this system appears to be linked to the thick Salinas rhyolite encountered at shallow depths. Commercial electricity generation is feasible from wells targeted along the Eastern Horst Fault (EHF). The extraction from these wells will also assist in the dewatering and cooling of the Cerro Blanco gold deposit.

1. Introduction

The Mita geothermal system is located approximately 80km east of Guatemala City, less than 10km from the El Salvador border. The nearest town, Asuncion Mita, lies 5km to the west. Cerro Blanco is a small hill that rises from about 500m above sea level, in the south, to about 600m in the north.

The Cerro Blanco gold deposit was initially found in the late 1990s to be immediately adjacent to active thermal springs. There is no evidence of historical mining activity in the Cerro Blanco area.

A mineral resource of approximately 2 million ounces of gold and 8 million ounces of silver has been delineated at Cerro Blanco.

The hot water at depth was identified to be a major factor in determining when or whether the mineral resource could be extracted commercially, as well as potentially providing a relatively cheap local source of electrical power for the mine operation.

Goldcorp has been the owner of the deposit since 2007 after acquiring Glamis Gold Ltd which had owned the property since 1998. Goldcorp then formed a subsidiary geothermal company (Geotermia Oriental de Guatemala S.V.), which obtained a license to explore and develop the Mita geothermal system. Exploration activities focusing specifically on the geothermal system began in 2007.

White et al. published a paper in 2010 establishing the geothermal system and the exploration activities to date. This paper presents the results of the geological, geochemical, geophysical assessments along with the results of the drilling and testing of three additional slimholes (MG-01, MG-02 and MG-03) in the area.

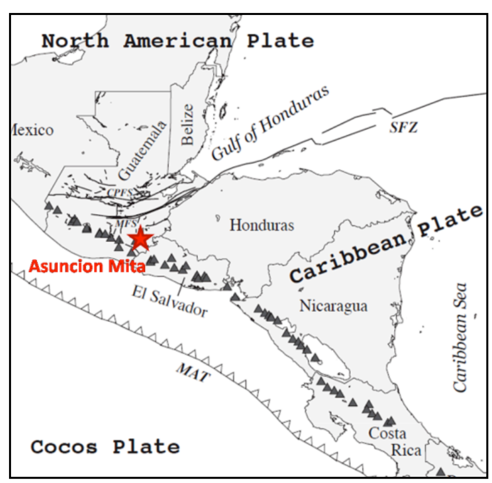


Figure 1. Tectonic setting of Central America (from Monteroso and Kulhanek, 2003).

The conceptual model of Mita geothermal system has been updated from the results of geoscientific and drilling activities and a three dimensional (3D) geological model was developed.

2. Geological Setting

2.1 Tectonic Setting

The Mita area in southern Guatemala is located near the intersection of the North American, Cocos and Caribbean plates (Figure 1). To the southwest, the Cocos plate is being subducted beneath Central America along the Middle America Trench (MAT), giving rise to a chain of active volcanoes.

The boundary between the North American and Caribbean plates is marked by a zone of active sinistral strike-slip faults in central Guatemala. These faults continue off shore of Honduras as the Swan fracture zone (SFZ). In southern Guatemala, the major structures strike N-S, E-W, NNE and NW to NNW, and a zone of east-west extension has produced north-south trending grabens (White et al., 2010).

2.2 Local Geology

While andesite stratovolcanoes are the most obvious expression of arc volcanism, the local geology is dominated by bimodal basalt-rhyolite volcanism associated with backarc rifting. Near surface units are mainly andesitic and rhyolitic tuffs, lithic tuffs and epiclastic deposits, with some basaltic and dacitic flows. These comprise a Pliocene(?) Salinas tuff/volcaniclastic sequence overlying a Paleocene-Eocene(?) Mita Group volcano-sedimentary sequence (Edwards 2006). The Mita Group includes terrestrial red-bed sandstone and conglomerate of the Subinal Formation, and older volcaniclastic deposits. These overlie a Cretaceous(?) sequence that includes altered andesites, dacites and limestones of the Tempisque Complex, which is intruded by andesite dykes and granitic intrusives. Older rocks exposed nearby include Cretaceous calcareous clastic sediments (Matapán Formation) and Paleozoic(?) schists (White et al., 2010).

The nearest large andesite stratovolcano is Volcán Suchitán, some 12 km to the northwest of Cerro Blanco. This volcano appears relatively old and eroded, with no known historic volcanic or thermal activity. Like many Central American gold deposits, Cerro Blanco is closely associated with the bimodal basalt-rhyolite volcanic association.

There are a number of small basalt scoria cones and flows, and dacite and rhyolite flows and domes nearby. These include two well-preserved basalt scoria cones and lava flows about 5 and 8 km to the east of Cerro Blanco, dacite flows to the northeast and southeast, and the Ixtepeque obsidian flow-dome complex approximately 9 km north of Cerro Blanco.

Epithermal mineralization is found in and adjacent to Cerro Blanco. It is hosted by subhorizontal silicified zones up to 40 m thick that appear to be interbedded with the upper part of the Salinas Sequence. Mineralization largely occurs within quartz-adularia-calcite veins, which consist of colloform and crustiform banded quartz, adularia and calcite, including platy calcite, with dark sulfide-rich bands containing pyrite, marcasite, acanthite and native gold (Economic Geology Consultants 2006). The mineralogy and textures are typical of low sulfidation epithermal mineralization.

2.2 Local Structure

Major structures that have been mapped at Cerro Blanco strike north-south, east-west, NNE and NW to NNW. The geological map of Cerro Blanco (Figure 2) indicates that the east-west faults are the youngest, since these offset all other faults. The combination of these faults has led to significant compartmentalization of the shallow hydrogeological system.

3. Exploration Phase 1

Exploration activities between 2005 and 2009 have included spring sampling, geophysical surveys and the drilling and testing of three slimholes. The results of these exploration activities helped build an initial picture of the geothermal reservoir setting.

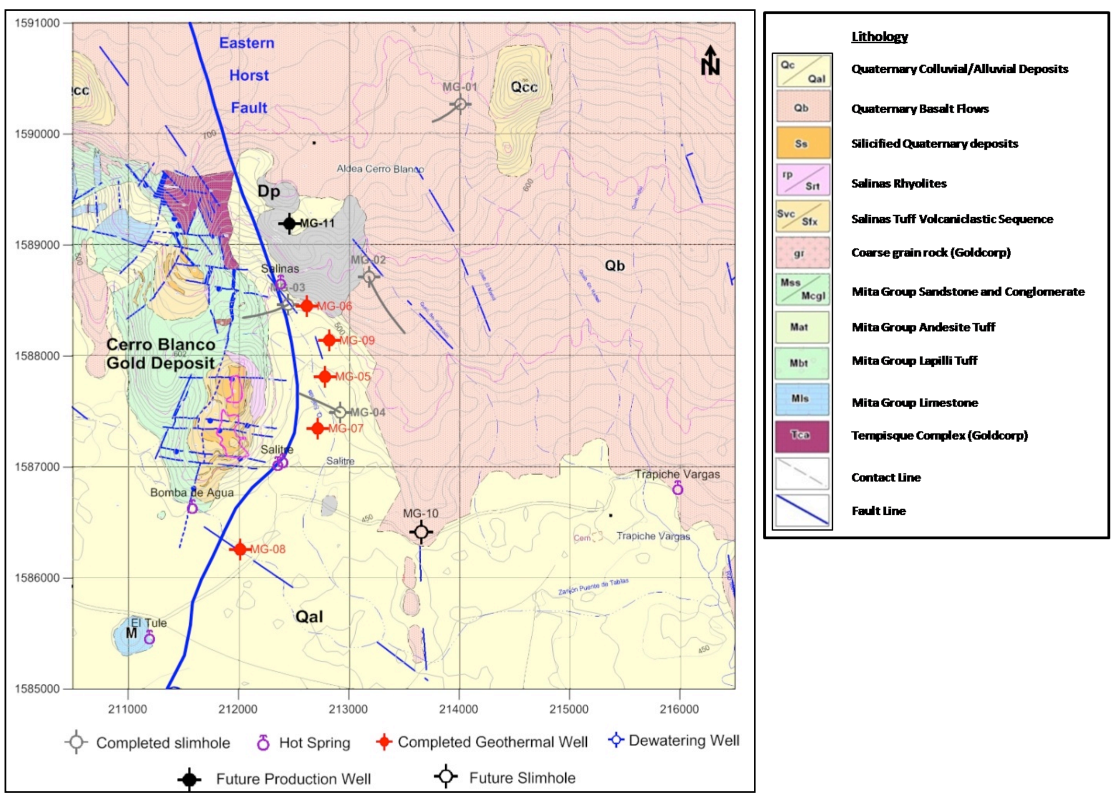


Figure 2. Cerro Blanco Geological Map (after Entremares 2005).

3.1 Surface Features

Surface thermal activity comprises hot springs at Salitre, Bomba de Agua, Salinas, El Tule and Trapiche Vargas (Figure 2). There are no natural fumaroles or areas of steaming ground associated with the Mita geothermal system.

The hot springs at Salitre are surrounded by a large area of silica sinter, which is probably relict or evaporative in nature because the spring waters are not over-saturated with respect to amorphous silica. The other springs are all surrounded by calcium carbonate deposits. The water temperatures range from 50-89°C, Salitre having the hottest discharge (Figure 2). There is some structural control on individual thermal features with both north-south and east-west alignments mapped.

The spring waters are dilute, near neutral pH, sodium-chloride-bicarbonate waters with TDS of up to 2,200 mg/kg. The springs in the Cerro Blanco area have very similar chemistry to the shallow reservoir, indicating that they are fed directly from the reservoir with little modification apart from conductive cooling.

The Trapiche Vargas spring, located 3-4 km east of the main thermal area (Figure 2), is significant. Although only 70°C, the chloride concentration of 640 mg/kg is higher than seen in the other springs and deep exploration wells. The cation geothermometer indicates source water temperatures of 240-260°C. The high chloride suggests a deep magmatic origin.

3.2 Geophysics

Between 1998 and 2008 a number of MT and gravity surveys have been undertaken covering an area of up to 75km^2, mostly to the east of the mine.

The MT surveys revealed a shallow layer of very low resistivity, of variable depth and thickness, but spanning most of the eastern part of the area surveyed. This layer has minimum resistivity values in the range of 1-3 Ωm, which is typical of the conductive clay caps found above and surrounding most high temperature geothermal systems.

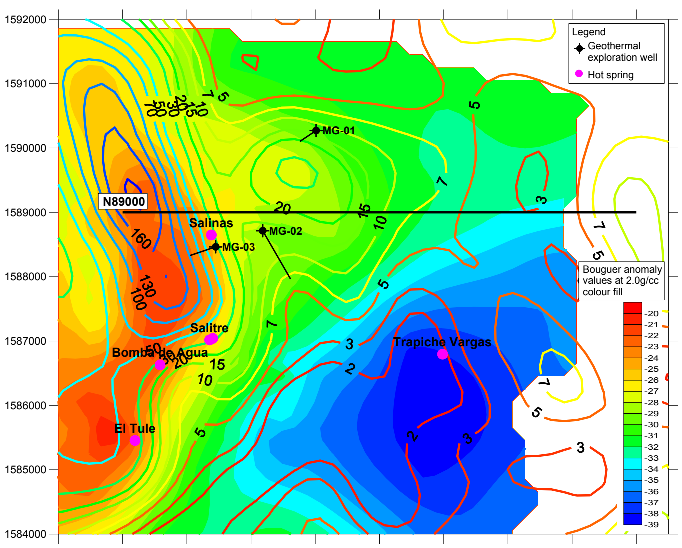


Figure 3. Bouguer anomaly map at 2.0g/cc (colour fill) and slice through the MT 3D resistivity model at sea level (contours, values in Ω.m).

The base of the conductor forms a dome-shaped anomaly centered to the NE of the mining lease (Figure 3).

The dome in the conductive layer is underlain by a zone of higher resistivity that tapers off in the east. There is another high resistivity body in the west that appears to be separate from the one in the east and closely coincides with a gravity high (Figure 4). This resistivity-gravity high appears to comprise a horst structure. The high resistivity implies that it has both low porosity and permeability, in which case it will act as a barrier to effectively prevent the circulation of geothermal fluids west of the Cerro Blanco ridge at depth.

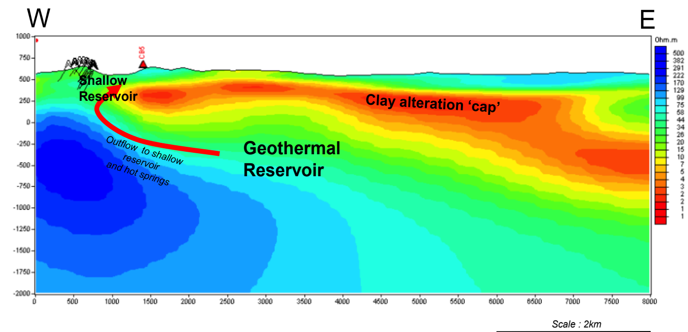


Figure 4. 3D modeled east-west resistivity section along profile N1589000 (see Figure 3) showing the dome shaped conductive body thickening towards the east.

On the basis of the MT results and what was known of the geology, geochemistry and location of thermal features, four slimholes were targeted to the east and northeast of the Cerro Blanco mining lease. The first of these was sited near the centre of the dome in the low resistivity layer, with the others to the south and southwest.

3.3 Drilling Results

MG-01

MG-01 was drilled near the centre of the main geophysical target to a depth of 1,528 mMD (1,497 mVD). MG-01 was impermeable throughout, apart from the unaltered lava flows close to the surface. This indicated that the deep formations have low intrinsic permeability, except where they are fractured. MG-01 exhibited a near-linear conductive profile and a maximum temperature of 176ºC. No fluid sampling was undertaken at MG-01.

MG-02

MG-02 was located 1.75 km to the south-southwest of MG-01, and drilled to 1,500 mMD (1,363 mVD). MG-02 encountered similar lithology and alteration mineralogy to that of MG-01. The Tempisque Complex was intercepted at 1,495-1,500mMD.

Permeability was encountered in MG-02 at a depth of ~1,420 mMD, where the core is cut by numerous quartz veins and quartz-lined open fractures at a variety of orientations. MG-02 encountered the highest temperature of 217ºC at -800 masl and showed evidence of a convective profile. The well was not discharged long enough to clear drilling fluids and as a result the reservoir chemistry has not yet been established. .

MG-03

MG-03 was drilled near the Salinas warm spring, 2.5 km southwest of MG-01, to 1,350 mMD (1,271 mVD). MG-03 drilled into a thinner sequence of tuff, sandstone and conglomerate, and volcaniclastics before encountering veined and altered volcaniclastics and skarns (Tempisque Complex), intruded by andesite dykes and granitic intrusives.

Formations occurred several hundred meters higher in MG-03 than in the other two wells, which along with the presence of granitic intrusives near the bottom of this well is entirely consistent with the geophysical interpretation of a horst structure beneath Cerro Blanco. Minor permeability was encountered in MG-03 at 1,000-1,020 mMD.

MG-03 reached a maximum temperature of 195ºC near -200 masl, with a temperature inversion below this depth.

The chloride concentration for MG-03 (540 ppm in total discharge) is lower than the concentration for Trapiche Vargas spring (640 ppm) which suggested that this well has not located the hottest part of the Cerro Blanco resource.

MG-04

MG-04 was drilled at an inclination of 20° (from vertical) to the northwest. The aim of this slimhole was to intercept the horst structure interpreted to exist based on the results of MG-03 and the MT and gravity geophysical surveys.

A thick rhyolite unit was encountered in MG-04 (>400m) which was not found in the earlier wells. This has been called the Salinas rhyolite. MG-04 encountered a fault zone at 600m which corresponded with a change in lithology from the Mita Group Volcaniclastics to the Tempisque Complex. This was close to the predicted depth of the eastern horst fault predicted by geophysics with an assumed 70-80° fault angle. A deeper fault at 880m was interpreted to be a west-east trending fault. Fossil alteration at temperatures higher than 300°C were recorded below 600m including epidote. Overprinting with lower temperature mineral suites indicate that the high temperature alteration is not current.

A high injectivity index (II) was determined following the completion testing with the majority of the permeability attributed to the 600m feed zone. The well was slightly over-pressured with a wellhead pressure of 2 barg. Discharge testing of MG-04 confirmed the high permeability with an estimated 45t/hr mass flow and a discharge temperature of approximately 198°C (~845 kJ/kg). The fluid chemistry had a near-neutral pH, sodium-chloride-bicarbonate composition and a gas content of 0.35 wt%, comprising 99% by volume CO_2.

The results of the testing at MG-04 indicated that the EHF had significant permeability and represented a commercial target for production well drilling.

3.4 Summary

The first four completed geothermal slimholes confirmed the existence of a moderate-temperature, liquid reservoir to the east of the EHF. They also tested the resistivity structure and showed that this is complicated by several factors; the permeability at depth varied considerably and that alteration assemblages are affected by overprinting. The final slimhole, MG04, indicated the presence of an intermediate level geothermal system and confirmed the presence of the Eastern Horst Fault.

4. Exploration Phase 2

4.1 Introduction

Following on from the first four slimholes, five large diameter vertical wells have been drilled at the Mita geothermal system. Two slimholes have been targeted to find injection capacity, with one completed and one yet to be spudded at the time of writing (MG-08A and MG-10). A sixth production well, MG-11, was being drilled at the time of writing. The main focus of this phase of the exploration was to target the predicted Eastern Horst Fault (EHF) in order to intercept hot fluids and permeability with two main objectives; enable commercial electricity generation from the geothermal system and intercept the mass upflow entering the gold deposit, thus assisting the mine dewatering program and increasing gold mining potential. The locations of the wells are shown in Figure 2.

4.2 MG-05

Drilling

Following the success of MG-04, well MG-05 was drilled vertically to 837mVD to intercept the Eastern Horst Fault 400m northwest of MG-04. MG-05 was completed with a 9"5/8 production casing and 7" liner.

Geology

The geology encountered in MG-05 was similar to that of MG-04 including the presence of the Salinas rhyolite unit (~450m) and the EHF at approximately 615mMD. Deeper permeable zones were attributed to either splays of the EHF or west-east trending faults.

Temperature

A maximum temperature of 197°C was measured directly prior to discharge testing. The temperature profile indicated shallow hot aquifers and a convective system below approximately 450mMD (Figure 5).

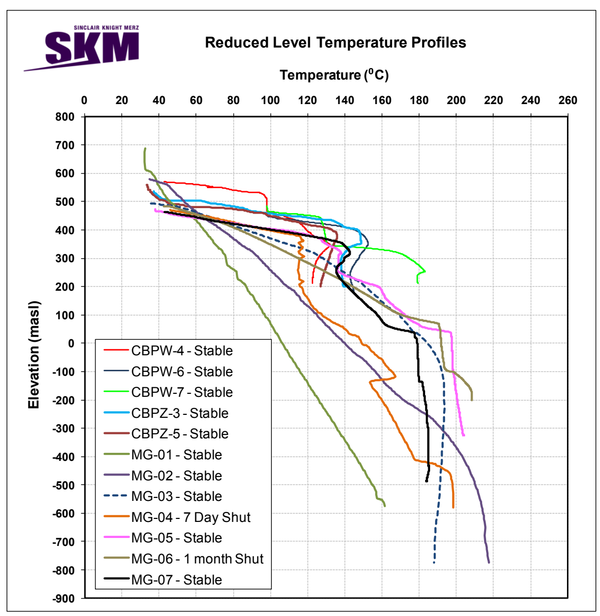


Figure 5. Static Temperature Profiles.

Testing

Completion testing performed on MG-05 indicated a moderate injectivity index of 30t/hr/bar with the main zone of permeability associated with the EHF between 550-620m. MG-05 was over pressured with 3 barg at the wellhead. During the discharge test the well produced approximately 180t/hr total mass flow at an enthalpy of 860kJ/kg corresponding to a fluid temperature of 202°C. Flowing surveys confirmed this discharge temperature and indicated that the main feed for this fluid was associated with the horst fault zone.

4.3 MG-06

Drilling

Exploration was subsequently shifted further to the north along the horst fault. MG-06 was drilled vertically ~600m north of MG-05 to 706mMD with 9"5/8 production casing to 456m and a 7" slotted liner to bottom hole.

Geology

MG-06 encountered a slightly different geological profile to that of the previous production wells. The Salinas Sequence was considerably thinner (~70m) and did not contain the rhyolites seen in the other wells. The EHF was intercepted roughly as predicted at 600m.

Temperature

MG-06 has a maximum shut-in temperature of 208°C. The hot shallow aquifers are not seen in the MG-06 profile. A convective profile is observed below the casing shoe (Figure 5).

Testing

Due to significant over-pressure observed at the wellhead (~18barg) completion testing was not performed and testing was progressed straight to discharge testing. At the time of writing, the discharge test had yet to commence.

4.4 MG-07

Drilling

MG-07 was located on the success of the results from MG-04. It targeted the eastern horst fault to the south of MG-04 and MG-05, directly east of the Cerro Blanco gold deposit. MG-07 was drilled to a depth of 1,020mMD with a 9"5/8 production casing and 7" slotted liner.

Geology

The geology encountered in MG-07 was similar to that of MG-04 and MG-05, although the Salinas rhyolite was slightly thinner (~300m). The boundary between the Salinas Volcanic Sequence and the Mita Group was 100m shallower, while the horst fault was intercepted deeper at approximately 690m.

Temperature

The heat-up surveys indicated cooler temperatures overall for MG-07 while still indicating hot shallow aquifers and a convective zone below 450m. The maximum temperature measured prior to testing was 185°C (Figure 5).

Testing

Completion and discharge testing indicated that the permeability in MG-07 was low and production capacity was limited. The wellhead pressure prior to discharge indicated a slight over pressure (1 barg). The total mass flow from the well was approximately 54t/hr with a discharge enthalpy of 675kJ/kg. The low discharge enthalpy was attributed to a cool inflow into the well at the main zone of permeability. This 160°C inflow dominated the flow from the well.

4.5 MG-08

Drilling

MG-08 targeted the EHF south of the identified geothermal reservoir. The purpose of this well was to provide injection capacity. MG-08 was drilled vertically to 1,119mMD. The well encountered the EHF at 567m, but no significant permeability and as such was not completed with slotted liner. The production casing was installed to 453mMD.

Geology

The stratigraphy of MG-08 was similar to that of MG-06. Although the Eastern Horst Fault was intercepted at 567m, no permeability was found, with considerable sealing by quartz and calcite. The Tempisque Complex was encountered beyond the fault zone.

Temperature

There are no downhole temperature records for MG-08 as significant collapse occurred below the casing shoe and no liner was installed. The well was expected to be cold, and the observed alteration mineralogy was consistent with this.

4.6 MG-09

Drilling

Following the success of MG-05 and promising outlook for MG-06, further production was targeted in the area between them. MG-09 was still being drilled to a proposed depth of 800mMD at the time of writing, and has encountered over-pressured formations associated with the Eastern Horst Fault.

4.7 Reservoir Pressures

Reservoir pressures have been correlated for all wells drilled to date, including a selection of the shallow dewatering wells drilled at the gold mine (Figure 6). A distinct trend has been observed, with wells on the eastern side of the EHF and to the north of MG-05 showing higher reservoir pressures, while MG-04, MG-05, and MG-07 exhibit lower pressure profiles and match well with the pressure profiles of the shallow dewatering wells at the mine on the western side of the main horst.

Overall, wellhead pressures are seen to increase from south to north.

4.8 Discharge Chemistry

The discharge chemistry from MG-04, MG-05 and MG-07 all show similar characteristics. Although the temperature of the fluids varied from 160°C to 202°C the reservoir fluids encountered are near-neutral pH, sodium-chloride-bicarbonate waters, with gas content ranging from 0.35 to 0.5 wt%, comprising 98% by volume CO_2. The potential for calcite scaling is high in the production wells. Because of the moderate feed-zone temperatures, the discharge water only becomes supersaturated with respect to amorphous silica at pressures less than 2 bar abs, approximately. .

The cation geothermometry for MG-04 and MG-05 indicates a deep reservoir with 240°C fluid, while MG-07 indicated a cooler (200°C) part of the reservoir.

The discharge chemistry, with low chloride and low H_2S, continues to suggest that the geothermal system is in mature stage with diminishing input of magmatic volatiles.

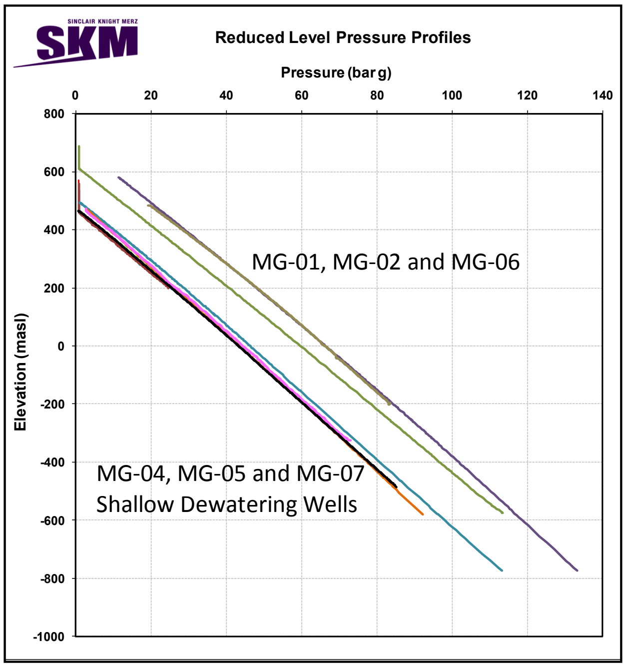


Figure 6. Pressure Profiles.

4.9 Drilling Summary

The successful drilling of the EHF has intercepted significant permeability and geothermal fluids of 200-210°C. Testing and drilling of additional production is ongoing. Two production wells, MG-05 and MG-07, are likely to allow commercial exploitation of the intermediate level geothermal reservoir. Injection targets remain an important part of the Mita geothermal development strategy. The combined extraction from MG-05 and MG-07 along with additional production wells will intercept geothermal fluid prior to entering the gold deposit, and, as such, will assist in the dewatering/cooling of the deposit for mineral extraction.

4.10 Future Exploration Strategy

Continued drilling for injection capacity will be the immediate focus of future exploration activities. The exploration along the Eastern Horst Fault has had success to date and represents the first phase of development of the Mita resource. The deep resource at Mita has yet to be explored sufficiently. In the future, exploration is likely to step out to the east away from the EHF.

The higher temperature deeper reservoir has not been targeted to date based on the current strategy of combining dewatering of the gold deposit with geothermal electricity production.

It is envisaged that, as for the initial stages of exploration, slimholes will be used to obtain information regarding permeability and temperatures at greater depths, both for deep production and injection drilling.

5. Updated Conceptual Model

With the latest phase of exploration almost complete, an updated conceptual model has been prepared. The understanding of the shallow and intermediate aquifers in the Mita geothermal system has advanced considerably. The downhole temperatures, fluid chemistry, reservoir pressures and discharge testing have enabled a more accurate delineation of the intermediate resource and its links to the shallow system supplying hot fluids to the mine area. A 3-D representation of the conceptual model is shown in Figure 7.

A deep reservoir (below 1,500m) with temperatures approaching 240°C is considered to exist to the east and northeest of the Cerro Blanco gold deposit. The intersection of the Eastern Horst Fault and younger east west trending faults with the deep reservoir allows the migration of fluids along fault planes to shallower depths. This has led to the formation of an intermediate level geothermal system with temperatures ranging from 185-210°C. The extent of this resource to the north is, as yet, not clear. To the south, MG-07 is considered to be close to the southern limit.

The shallow geothermal aquifers are seen in the well profiles of the dewatering wells on the eastern side of the Cerro Blanco

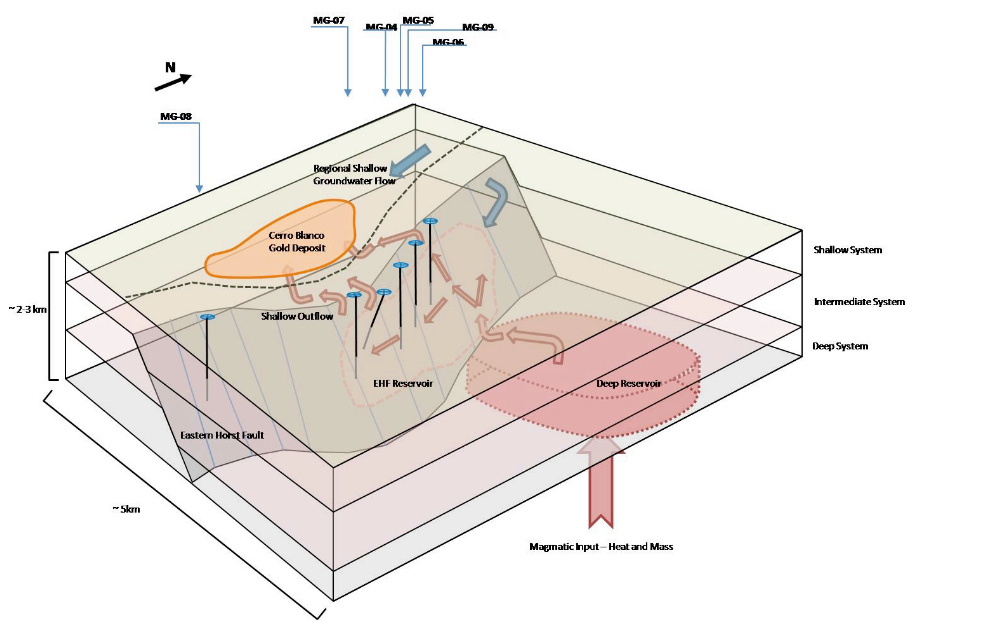


Figure 7. Mita 3D Conceptual Model.

gold deposit as well as in the geothermal wells, MG-04, MG-05 and MG-07. Temperature and pressure trends between 0-400m are similar. There are also considerable similarities in the fluid chemistry between these wells as well as indications of significant connections; discharge testing of MG-07 indicated an under-pressured 160°C feed, which pointed towards a downflow from a shallow aquifer.

The link between the two systems is not clear, however, the presence of significant thicknesses of the Salinas Volcaniclastic Sequence and in particular large rhyolitic units in MG-04, MG-05 and MG-07 suggests that it is the rhyolite units which provide this connection. This has been seen in many NZ reservoirs including Ngatamariki and Wairakei, where rhyolites act as conduits for fluid movement, particularly along brecciated margins.

This unit is noticeably absent in MG-06 which does not show any evidence of the shallow hot aquifers and has a much higher pressure profile. MG-03, located close to MG-06, but on the western side of the fault zone, also shows no indication of these shallow aquifers while retaining similar pressures to the dewatering wells.

It is hypothesized that, as fluid migrates up along the main fault zone, the rhyolitic units channel the fluid into the shallower aquifers. The northern limit of this flow is considered to be between MG-06 and MG-05. The regional groundwater flow from north to south will tend to deflect the geothermal outflow at shallower depths to the southwest. This is seen in the temperature profiles of the mine dewatering wells where CBPW-7 (at the northern extent of the gold deposit) has the highest temperatures while CBPZ-5 has a much cooler profile (Figure 2).

It is possible that these rhyolite units will also act as 'cold towers/tanks' allowing the migration of cooler fluids into the intermediate reservoir as extraction progresses and pressures drop in the reservoir.

The updated conceptual model then formed a basis for the development of the three dimensional (3D) geological and proposed numerical reservoir model of Mita geothermal system.

6. Leapfrog 3d Geological Model

6.1 Introduction

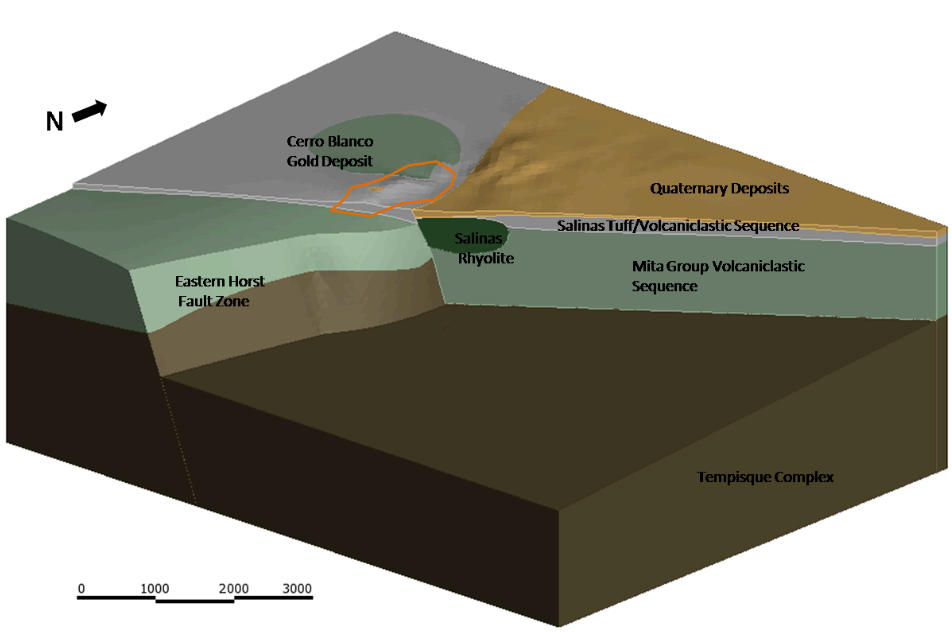
Leapfrog Geothermal is a 3D implicit geological modeling package based on implicit modeling methods that represent geology, structure, geophysical and reservoir data with fitted mathematical functions (Alcaraz et al., 2011). This approach is highly flexible and allows such tasks as the changing of model resolution, the consideration of alternative scenarios and the comparison of numeric and geological models to be performed quickly and easily.

The data processing is underpinned by a fast Kriging engine implemented using radial basis functions. This allows the software to deal with datasets containing millions of points using standard desktop computing. This is combined with the ability to track dependencies in the modelling process to ensure that the models are automatically updated when the data is modified.

Geological models built in Leapfrog can be exported to populate input files for the TOUGH2 numerical simulator used in geothermal reservoir modelling. This enables the quick updating of reservoir models when new data is available and enables confidence in the control of the geological structure of reservoir models. Future developments in the software will include the ability to review TOUGH2 simulator results within the software and allow parameter alterations to the geological units.

6.2 Mita Geological Model

A 3D geological model has been created for the Mita system using a combination of datasets including digital terrain models, geological maps, geological cross sections, geophysical data and well data. The model included in this paper represents the first stage of the geological modeling of the system (Figure 8). Surface geology mapping has not been incorporated at this stage, but will be included in a later revision of the model.



Leapfrog Lithological Group	***Geological Units***
Quaternary Deposits	Basalt Lavas, Soils, Clays, Sediments, Alluvial deposits, Conglomerates
Salinas Tuff/Volcaniclastic Sequence	Salinas Rhyolite, Tuffs, Volcaniclastics, Phreatic Breccia
Mita Group Volcaniclastic Sequence	Quartz latite crystal lithic tuff, Shale, Sandstone, Conglomerate
Tempisque Complex	Andesitic and dacitic lava flows, Brecciated andesites
Granite	Granite Intrusion

Figure 8. Leapfrog Geothermal 3D Geological Model.

The extent of the geological model has been designed such that it will match with a sufficiently large numerical grid to be used in the TOUGH2 numerical simulator. As such, there are large areas outside of the explored section of the reservoir where the geology has been interpreted. In order to construct the first stage model, a simplified lithological structure has been used.

As exploration progresses, the structure can be refined. The lithological units are shown in the table alongside Figure 8. The main structural feature included in the model at this stage of the modeling process is the Eastern Horst Fault which has been constructed based on the geophysical data and the contact points from MG-04, MG-05, MG-06, MG-07 and MG-08; all of which have intercepted the fault zone. The approximate dip of the fault is 70°. While splays and associated faults are likely to exist, the limited area covered by exploration to date has not warranted the inclusion of additional parallel horst structures stepping down to the east. Although the Tempisque Complex has been intercepted only once on the eastern side of the horst fault (MG-02) a vertical offset of between 400-700m is indicated.

EW faults have been interpreted from the gold exploration core holes drilled at Cerro Blanco. These structures have not been incorporated in the current model as they have not been encountered on the eastern side of the horst fault. A separate rhyolite unit (Salinas rhyolite) has been included to allow for the rhyolite and significant change in thickness observed in the Salinas Tuff Sequence at MG-04, MG-05 and MG-07. This rhyolite is considered to represent an important link between the EHF reservoir and shallow aquifer systems.

Stable temperatures for the MG and dewatering wells have been imported into the Leapfrog model to generate temperature isosurfaces. The interpolation performed by Kriging. The contours generated initially are isotropic with no bias incorporated.

Combining the temperature isosurfaces with the geological model allows for quick interpretation of the structural controls affecting the fluid movement from depth. Figure 9 shows a SW-NE cross section through the model to indicate the link between the EHF and fluid movement. The 230°C and 240°C contours have been estimated.

7. Numerical Model

Within Leapfrog Geothermal a function exists to convert the geological model to a block model structure. The grid can be defined by the user and used to generate the geological input required to perform a numerical simulation.

Numerical simulation of heat and mass transfer through the Mita system has yet to start. Once the latest exploration phase is complete, the geological model will be updated accordingly. The TOUGH2 finite difference numerical simulator will be used to generate a natural state model for the Mita geothermal system. At this stage it is envisaged that a single porosity air/water model will be used, although the possibility of using a dual porosity model at a later date will also be considered.

A rectangular Cartesian grid with areas of refinement has been prepared for the Mita model to allow for more accurate calibration of the upflow zone and areas where geological data is better constrained (Figure 10). This has been populated with the current geological structure. The topography has also been fitted onto the grid. The grid covers an area of 63km^2 (7000m x 9000m) using approximately 8000 blocks with a refined area close to the EHF upflow and mine using 200x200m blocks. This will allow for more accurate matching of the upflow and downhole temperatures. The model is aligned in a north-south orientation and extends from approximately 800masl to -2500masl. The model comprises 18 layers with thicknesses varying from 500m at the base to 50m at the top.

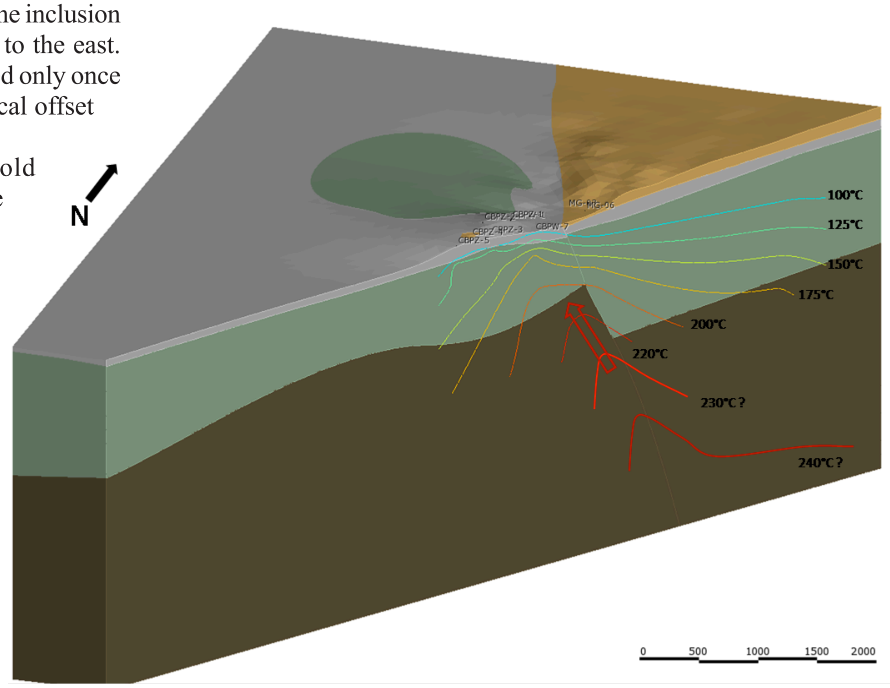


Figure 9. Combined Geology and Temperature 3D Models.

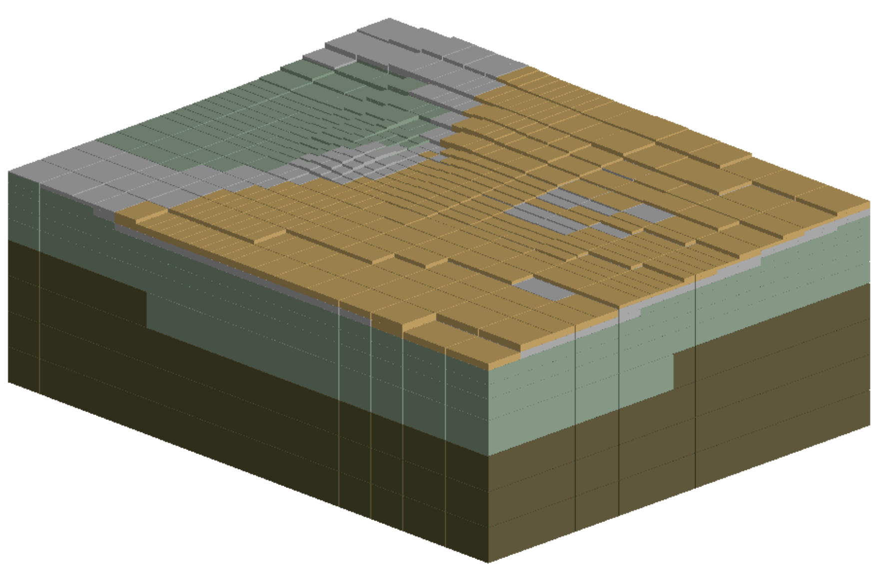


Figure 10. TOUGH2 Grid Geological Model.

8. Conclusions

Exploration of the Mita geothermal system has advanced considerably over the past 18 months. Wells targeting the EHF have encountered an intermediate level geothermal system with temperatures between 185-210°C. This has confirmed the geophysical interpretation made during the early stages of exploration. The horst fault has displaced geological units by 400-700m down to the west. A thick rhyolite unit thought to be associated with the Salinas Tuff is considered to represent an important unit in terms of the shallow hot aquifer systems which are encountered in the shallow mine wells and MG-04, MG-05 and MG-07.

The conceptual model of the system has developed accordingly with the new data. The EHF system is considered to be a relatively narrow upflow from a deeper reservoir of ~240°C fluid. The shallow outflow from this system appears to be linked to the thick Salinas rhyolite encountered at shallow depths.

Using the well lithologies, geophysical and topography data, a 3D geological model has been constructed in Leapfrog Geothermal. The software, specifically designed for the geothermal industry, has allowed further interpretation of the system dynamics. This model will continue to be refined with new data. When ready it will be converted into a block model for export in order to create a reservoir model for numerical simulation of the heat and mass transfer in the system.

Commercial electricity generation from wells targeting the EHF is projected. Not only can these wells provide a valuable source of power for the mining operation, but the extraction of fluid will also assist in the dewatering and cooling of the Cerro Blanco gold deposit and therefore allow more rapid extraction of the mineral resources. Further exploration of the deep reservoir is predicted following the completion and review of the latest exploration drilling phase.

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