Proceedings World Geothermal Congress 2026
Calgary, Canada, June 8 – 11, 2026

Exploring a Novel Geothermal System: A Two-Year Geoscience Study and Conceptual Model of the Cachapoal Prospect, Chile

Joe Elliot[1]*, William Cumming[2] and Carolina Wechsler[3]
Transmark Renewables[1]* Amsterdam (The Netherlands)
Cumming Geoscience[2] Santa Rosa (USA)
Transmark Chile[3] Santiago (Chile)
j.elliot@transmark-renewables.com

Keywords: Geothermal exploration, geochemistry, magnetotelluric, conceptual model, Cachapoal, Chile

ABSTRACT

From 2023 to 2025, Transmark Renewables completed a two-year geothermal exploration program in the Cachapoal concession area of Chile. The project was co-financed by the Federal Republic of Germany through KfW and with funding by the European Union via the Geothermal Development Facility for Latin America. The prospect has been identified from its widespread 32.7°C to 67°C neutral chloride hot springs. Due to the influence of evaporites, the cation chemistry of the springs constrains hydrology but not temperature. Silica geothermometry from 97°C to 176°C suggests the existence of moderate temperature deep-circulation geothermal reservoirs, consistent with elevated heat flow indicated by the recent eruption of a lava flow 8 km to the east. However, most volcanics have been eroded by glaciation in this part of the Andes, exposing Tertiary intrusive and metamorphosed sedimentary rocks that tend to be impermeable except where intersecting structures locally increase stress and fracturing. MT surveys detected <70 ohm-m retrograde hydrothermal clay alteration associated with the hot springs, contrasting with surrounding >300 ohm-m rocks. Based on an integration of geothermometry, hydrology, MT resistivity, and a 3D Leapfrog model of geology and structures from surface mapping and core logs from mining industry wells, a geothermal conceptual model has been developed, and three target zones have been identified. Although the novel characteristics of Cachapoal support an estimate of a 16% probability of success for discovering a geothermal resource using slim hole wells, such a success would demonstrate a new geothermal play type and would create opportunities at analogous prospects.

1 INTRODUCTION

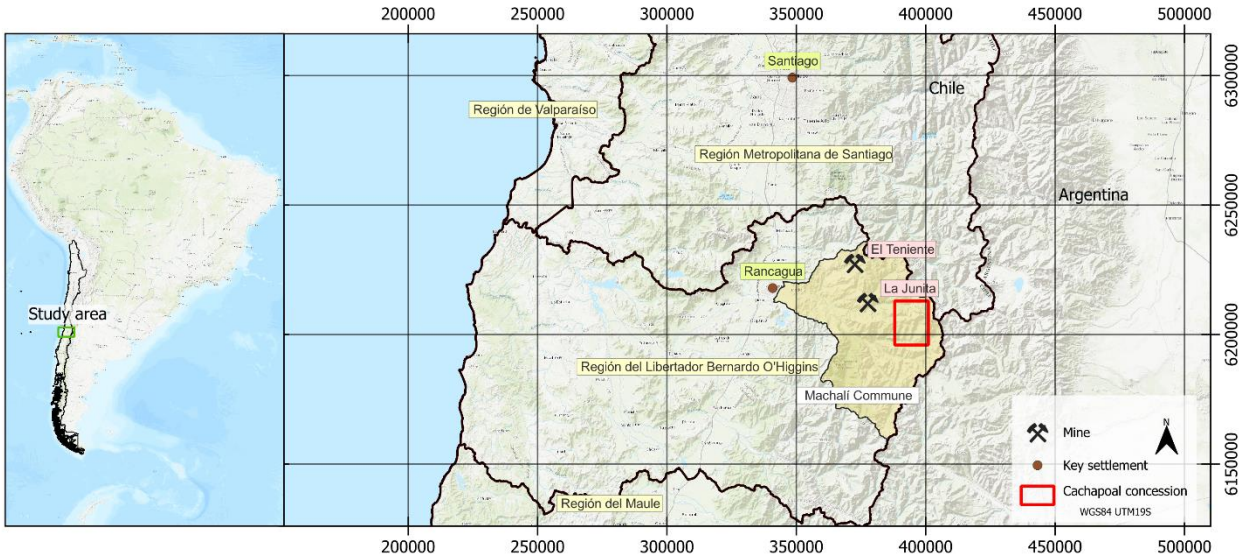


Figure 1 - Cachapoal concession study area.

The Cachapoal exploration concession is in the Machali commune of the Libertador General Bernardo O'Higgins Region, Chile, approximately 20 km east of Rancagua and 100 km south of Santiago (Figure 1). Numerous geological investigations have been conducted in the area, beginning with early mapping by Klöhn (1960), González (1962), and Charrier (1979), which defined the region's complex stratigraphy. Subsequent studies focused on ore mineralisation, particularly in relation to Miocene–Pliocene intrusions, such as those examined

by Kurtz (1997) at the El Teniente copper mine 25km to the northwest of the concession. Direct exploration efforts for copper ore started in the concession by Aurex in 2009, with the drilling of eight core wells to depths of up to 1000m.

Geothermal interest in the concession and surrounding area began shortly after the drilling of these wells, with a geothermal assessment in 2011 (Urzua, 2011) after analysing the extensive hot springs with partial artesian flow, activities included a geochemical survey, an MT campaign and geological field work. These early investigations laid the foundation for further geoscientific study undertaken between 2023 and 2025 by Transmark, which was co-financed by the Federal Republic of Germany through KfW and with funding by the European Union via the Geothermal Development Facility for Latin America, aimed to promote geothermal energy investment within the region.

The aim of the two-year project has been to further develop the concession. As this work progressed, however, it became evident that the prospect does not conform to the conventional geothermal model suggested by Urzua (2011), and so a novel integrated conceptual model has been developed based on geological, geochemical, and geophysical data, synthesised into a 3D Leapfrog model. Although there are no direct geological analogues for this system currently in production, comparisons based on temperature and structure have allowed for preliminary capacity estimates and risk assessments. The results support further investigation through slim well drilling, given the moderate temperature range and structural setting.

2 GEOLOGY

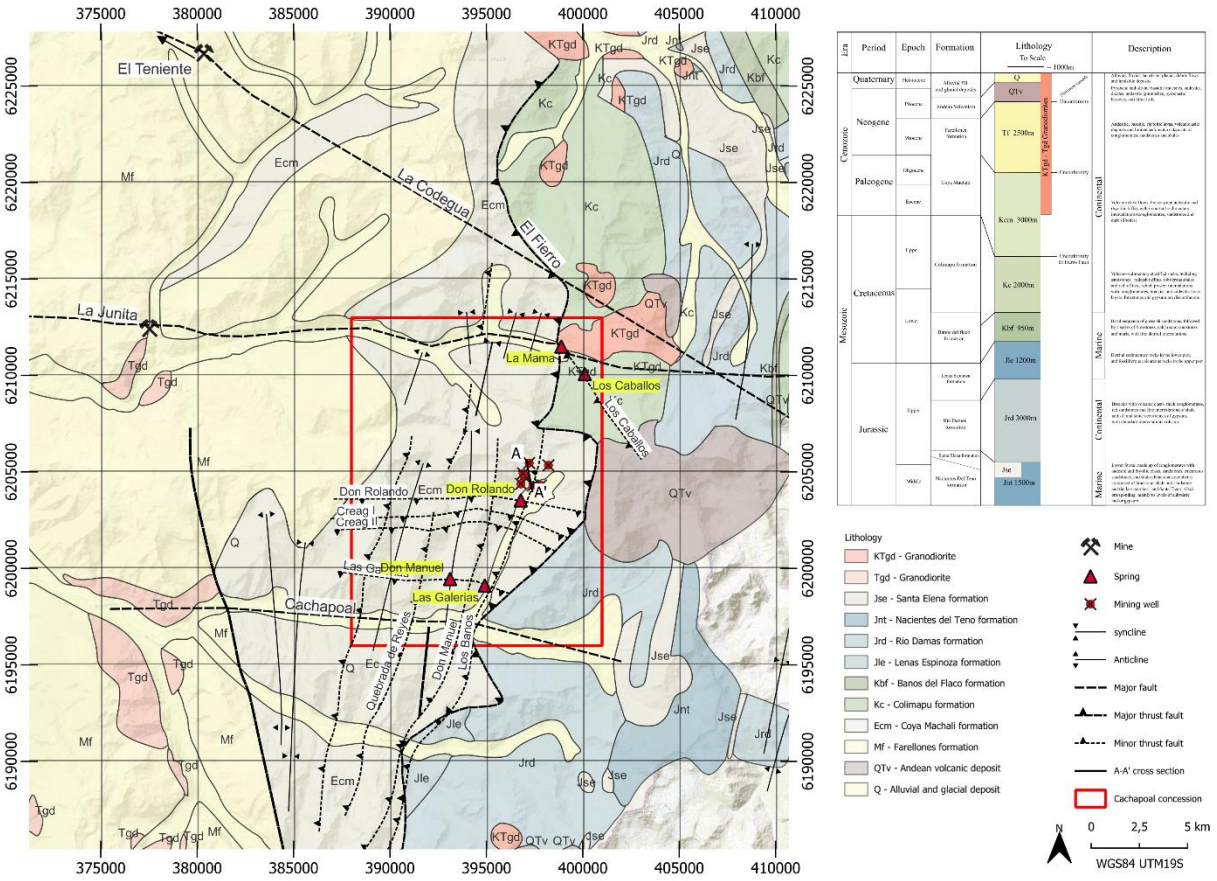


Figure 2 - Geological map and stratigraphic sequence modified from Klöhn (1960) and faults modified from Kurtz (1997).

The Cachapoal concession is in the Southern Volcanic Zone (SVZ) of the Andes, a complex tectonic setting that has resulted from the subduction of the Nazca oceanic plate beneath the South American continental plate. Thick marine sediments were deposited during periods of extension beginning in the Middle Jurassic followed by uplift and associated erosion and continental deposition. Much of the volcanism of the SVZ is more recent, although the rapid erosion associated with glaciation has exposed older formations throughout the Cachapoal concession. Shifts between extension, collision and oblique tectonics have resulted in a complex evolution of faults dominated by regional thrust faults exposed with a NNE strike and local W-E trending growth faults (Figure

2). As a result, the exposed geology in the prospect area is dominated by lightly metamorphosed and impermeable marine and continental sediments, intruded by Tertiary granitic rocks with associated volcanism. Several mineral deposits associated with volcanism have been developed in the region, including the world's largest underground copper mine El Teniente, 25 km northeast and La Junita underground mine 10km west of concession. The geological map in figure 2, illustrates the location of the hot springs that identified the Cachapoal geothermal prospect relative to the simplified regional stratigraphy and structure. The structural details from eight cored mineral exploration wells drilled to over 1000 m depth on the metamorphic halo around an intrusion near the centre of the geothermal prospect area have helped constrain the subsurface model and confirm stratigraphy, with the cross section through these wells displayed on the map.

2.1 Stratigraphy

Formation / Unit	Age	Lithology / Description	Geothermal Relevance
Alluvial Fill & Glacial Deposits	Pleistocene	Unconsolidated alluvium, glacial sediments, moraines. Likely low resistivity when water saturated or altered.	Surface Cover
Andean Volcanism	Holocene–Late Pleistocene	Recent andesite & dacite lavas from Picos del Barroso (<6 km; Sruoga et al., 2005); nearby Maipo had 9 eruptions (1822–1931; González Ferrán, 1995).	Potential Heat Source
Farellones Formation	Miocene	~3,000 m thick; intermediate–acidic flows, breccias, agglomerates, tuffs; minor sediments (Charrier & Munizaga, 1979; Aguirre, 1960).	Cap Rock / Potential Reservoir
Coya-Machali Formation	Oligocene–Eocene	~3,000 m thick; lava flows, breccias, andesitic/rhyolitic tuffs; interbedded conglomerates, sandstones, siltstones (Charrier & Munizaga, 1979).	Cap Rock / Fractured Reservoir
Colimapu Formation	Upper–Lower Cretaceous	Lower: sandstones, micritic limestones (~1,500 m); Upper: tuffs, lapilli, ignimbrites (~1,600 m).	Fractured Reservoir
Baños del Flaco Formation	Upper–Lower Cretaceous	~400 m thick; marine greenish sandstones, limestones, marls, detrital interbeds (Klöhn, 1960; González & Vergara, 1962).	Fractured Reservoir
Leñas Espinoza Formation	Upper Jurassic	~1,200 m; detrital sediments at base, fossiliferous calcareous units at top (Klöhn, 1960; Charrier, 1981).	Fractured Reservoir
Río Damas Formation	Upper Jurassic	Up to 3,000 m; breccias, conglomerates, red sandstones, interbedded shale/siltstone; volcanic layers in upper 1,000 m (Klöhn, 1960).	Fractured Reservoir
Santa Elena Formation	Upper Jurassic	~1,500 m; anhydrite & gypsum (Oxfordian), intensely deformed (Klöhn, 1960).	Geochemical Barrier
Nacientes del Teno Formation	Upper–Middle Jurassic	Conglomerates, sandstones, calcareous sandstones, shales; volcanic-rich (Klöhn, 1960).	Basement / Deep Reservoir

Table 1 - Stratigraphy of the Cachapoal prospect and its potential role in the geothermal system.

2.2 Mineral exploration wells

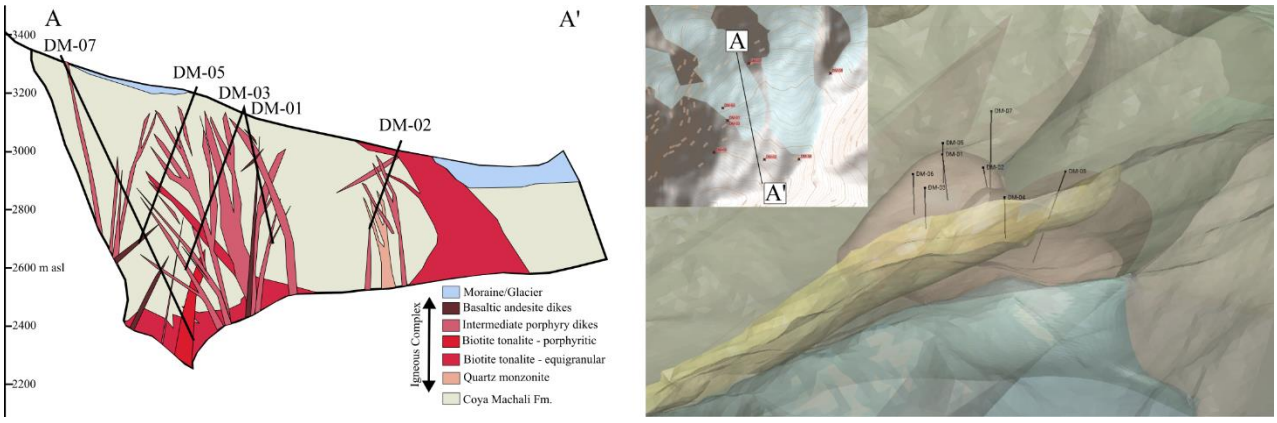


Figure 3 - Cross section through the Don Manuel mineral exploration project (A-A') and cored wells modified from (Gilmer et al., 2021), right shows leapfrog stratigraphy model.

Eight cored slim wells (DM-01 to DM-08) with depths of 373-1001m were drilled in the Don Manuel mineral exploration prospect between 2008 and 2009. These wells have been crucial in confirming lithological units and alteration histories. All eight wells penetrated the Coya Machali formation, which is widely exposed in the area through glacial erosion. The predominant lithology logged is hornfels, formed through the metamorphism of

interbedded mudstones and sandstones by the intrusion of intermediate and tonalite dikes. This is important in highlighting the extent of metamorphism that has occurred, which resulted in the generally impermeable characteristics of this unit. A detailed vein alteration study of the core was reported by Gilmer et al. (2021) in which three stages were identified. The Early Stage saw silicification, biotite, and skarn formation, indicative of fluids interacting with the rocks at over 350°C. The Primary Stage showed the development of quartz and K-feldspar veins with copper sulphides like chalcopyrite, consistent with hydrothermal alteration at over 300°C. Late-stage alteration, characterised by chlorite and sericite veins, point to a cooling geothermal system and fluid migration at about 200°C temperature with additional argillic alteration. Evidence of silicification and argillic alteration was found in the Paredones area (Figure 4) and in the DM wells highlighting structurally controlled alteration, suggesting the presence of shallow geothermal resources, which aligns with 97°C to 176°C temperatures predicted by silica geothermometry. Additionally, the presence of hydrothermal breccias and fault zones indicates active fluid pathways, further supporting the region's geothermal potential.

3 FAULTS

Numerous faults have been identified in the concession area, with fault geometry and formation boundaries exposed in the deeply incised glaciated terrain and in the well cores. The prospect level mapping was based on the regional fault mapping reported by Kurtz (1997). Two surface fault mapping campaigns were carried out for this project where W-E faults and the Los Caballos fault were identified (Figure 2 and 4).



Figure 4 - Field sketches of key faults, from left to right Los Baños and Don Rolando intersecting fault zone and extensive alteration (Paredones area), El Fierro fault in southern section and Los Caballos fault and springs in northern section.

3.1 El Fierro Thrust Fault

The major north-south El Fierro thrust fault, extending ~200 km through the Chilean Andes, is exposed across the prospect, separating Jurassic and Cretaceous formations. While Herman et al. (2023) report steeper dips, the fault dip in the concession matches the 40–45° reported by Gody (1998). It separates the Coya Machali and Río Damas formations in the south and centre area, and the Colimapu and Coya Machali formations in the north.

3.2 Minor NE-SW Faults

Four local faults linked to the El Fierro thrust were mapped by Kurtz (1997) and confirmed during fieldwork. These faults have similar geometry but generally steeper dips. The key NNW-SSE Los Baños fault aligns with major surface alteration, hot springs and the Don Manuel mining project, which is intersected by the newly mapped Don Rolando fault, in the area where the Don Rolando hot spring outcrops.

3.3 La Juanita and Cachapoal Major W-E Faults

The La Juanita and Cachapoal faults strike east-west along prominent valleys at the prospect margins. The La Juanita fault dips steeply north (Cannell, 2004) and hosts copper mineralization at La Juanita mine 12.5 km west. Thick sediment and volcanic accumulations along its northern side suggest it functioned as a growth fault (Falcon & Rivera, 1998). The Cachapoal fault shows similar surface expression and hydrothermal mineralization along its trace.

3.4 Minor W-E Faults

Minor W-E faults, including Don Rolando, Creag I & II, and Las Galerías were identified by field mapping and correlation with hot spring alignments and resistivity data. These faults dip south based on remote sensing and field observations.

4 GEOCHEMISTRY

Geochemical sampling of springs with temperatures of 4.7°C to 67°C was conducted in the area to classify the water types with respect to the elements of the conceptual model and to predict subsurface temperatures. Highlights from chemical analyses reported by Hauser (1997) and Urzua (2011) and from samples collected for this study are compiled in Table 2. Key anion and cation relationships are displayed in figure 5 based on Powell and Cumming (2010) and interpretations of the geochemistry have been further supported by DiPippo et al. (2025), Nicholson (1993) and Marini et al. (2022).

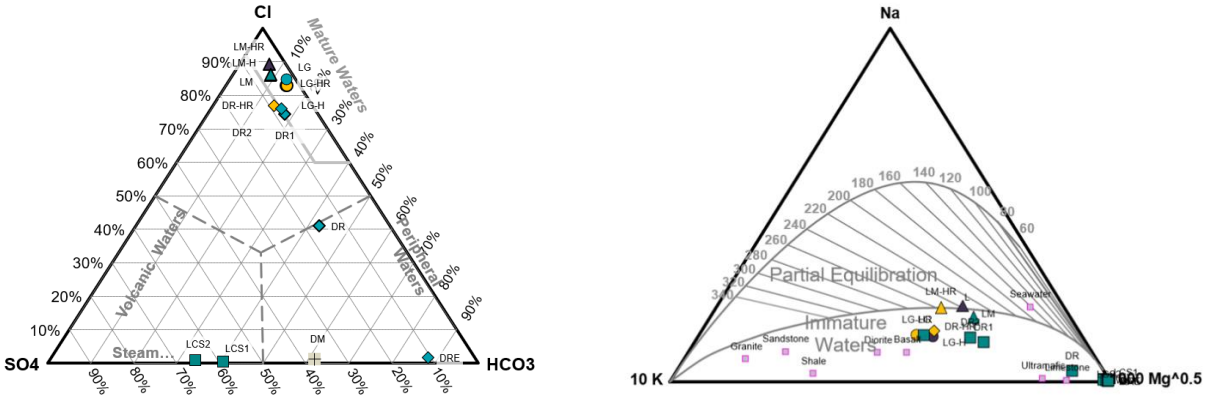


Figure 5 - Cl-HC03-S04 Ternary (left) and Na-K-Mg Ternary (right).

4.1 Cl-HC03-S04 Ternary

In a conventional geothermal classification of water types from neutral hot springs based on the anion ternary plot in Figure 5 (left), the high chloride, low sulphate, and low bicarbonate content of most of the spring water is interpreted as likely originating from a mature equilibrated hydrothermal reservoir with minimal mixing with meteoric water. At Cachapoal, hot springs that fit this neutral chloride classification include those at La Mama (LM, LM-H, LM-HR) with temperatures between 37°C to 47°C, Las Galerías (LG, LG-H, LG-HR) with temperatures between 39.7°C to 67°C, and Don Rolando (DR-1, DR-2, DR-HR) with temperatures between and 32.7°C to 62°C. These neutral chloride hot springs are the main indication that a geothermal reservoir likely exists at the Cachapoal prospect.

The Los Caballos (LCS1, LCS2) cold springs, in contrast, are high sulphate but low chloride content. In a conventional arc volcanic assessment, such a high sulphate, low chloride spring might be interpreted as being derived, not from hot liquid reservoir, but from steam condensed from a deeper boiling chloride reservoir. However, the lack of acid-sulphate thermal manifestations or significant H_2S gas flux in the area makes it likely that the temperature and chemistry of Los Caballos is related to meteoric water traversing evaporite deposits or relict hydrothermal alteration related to mineral deposits found in the area.

The Don Rolando (DR, DRE) and Don Manuel (DM) cold springs have mostly bicarbonate content and plot in the peripheral water classification and so likely consist mainly of meteoric water with minimal liquid from a geothermal reservoir. Although the bicarbonate springs do not constrain reservoir properties, they may indirectly limit the extent of reservoir flow paths.

The use of neutral chloride springs to constrain the elevation of the water table in geothermal conceptual models is complicated at Cachapoal by the large differences in elevation between the neutral chloride hot springs. There is roughly a 560 m difference in elevation over the 4.5 km between the Don Rolando and Las Galerias springs and a 140 m difference in elevation over the 8.5 km between the Don Rolando and La Mama springs (Table 2). The similar chemistry of these springs might be due to a common origin from an aquifer below higher elevation terrain nearby, such as the Picos del Barroso Volcano that exceeds 5000 masl 5 km east of the Don Rolando hot spring at 2790 masl. However, the connection of such an aquifer to most of the springs would likely be low in permeability to avoid artesian pressure in the lower elevation springs. Our preferred model is that each set of hot springs is supplied by hydrologically separate systems where mapped fault intersections create a deep circuit of high permeability fractures embedded in generally low permeability metamorphic and intrusive rocks. The neutral chloride hot springs are not only indicative of reservoir pressure and overall permeability but, because they are more likely to originate from the liquid phase of a geothermal reservoir, they are more likely to provide useful cation or silica geothermometry.

4.2 Cation Interpretation

Because of their relatively high magnesium content, samples fall in the immature water zone of the cation ternary plot in Figure 5, implying that cation geothermometry is likely to be unreliable (Marini et al., 2022). The high magnesium content could be due to re-equilibration, mixing with meteoric water or influence from evaporitic rocks. For those springs that have high chloride and low bicarbonate content, influence on cations from the evaporitic sedimentary rocks is likely, therefore no reliable conclusion and be drawn regarding reservoir temperature based on the cation chemistry.

4.3 Silica Geothermometry

Suite	Sample ID	Elevation	Temp (°C)	pH	AM (°C)	CHAL (°C)	QZ B (°C)	QZ A (°C)
Las Galerias	LG	2197	39.7	6.474	11	103	130	127
	LG-H	2190	45	6.3	6	97	125	122
	LG-HR	2195	67	6.92	10	102	130	126
Don Rolando	DR1	2747	32.7	6.402	8	99	127	124
	DR2	2720	37.7	6.556	19	113	140	135
	DR-HR	2790	62	7.36	52	154	176	164
La Mama	LM	2879	37	6.1	21	116	142	137
	LM-H	2895	37	6.1	30	126	152	145
	LM-HR	2895	47	7.09	32	129	154	147
Bicarbonate Cold Springs	DR	2758	12.9	7.853	N/A			
	DRE	2725	8.5	6.816				
	DM	2367	4.7	7.646				
	LCS1	3402	12.5	6.5				
	LCS2	3299	15.5	6.5				

Table 2 – Hot Spring and cold spring elevations, surface temperature, pH and when applicable silica geothermerty. H = (Hauser, 1997) and HR = (Urzua, 2011).

Silica geothermometry provides the most reliable indication of the temperature of the reservoir(s) supplying hot water to the springs at Cachapoal. Table 2 details the temperatures implied by the silica concentration in each chloride spring using different assumptions for equilibration with chalcedony and quartz phases. Based on the springs with highest chloride concentration and least evidence of dilution with meteoric water, a reasonable expectation for the temperature range of the reservoir(s) supporting the hot springs is from 97°C to 176°C.

5 MT SURVEY

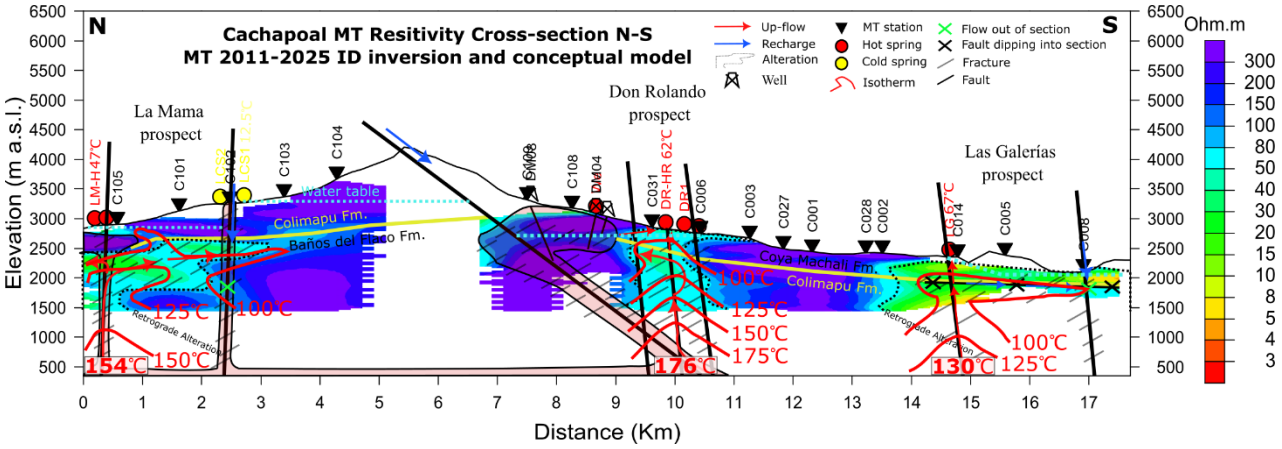


Figure 6 - NE-SW MT Cross section and conceptual model.

Magnetotelluric (MT) surveying is widely regarded as the most decisive geophysical method in conventional geothermal exploration due to its ability to define the geometry of the smectite clay cap typically found above convecting geothermal reservoirs (DiPippo et al., 2025). The non-invasive deployment of its portable equipment also makes it particularly suitable for rugged and remote terrain, such as the Cachapoal Prospect. At Cachapoal, three MT surveys totalling 35 stations and a TDEM survey of 19 stations have been conducted, focusing on areas near active hot springs and zones of hydrothermal alteration. MT dimensional parameters revealed a predominantly 3D resistivity structure on scales of several hundred meters to a kilometre. However, due to

difficult terrain and limited access, survey coverage was concentrated along the trend of the hot springs, restricting full 3D resistivity imaging. As a result, 1D inversion modelling was performed to depths of several hundred meters to over one kilometer. These models were integrated into cross-sections and resistivity maps used to develop the conceptual geothermal model.

In typical volcanic-hosted geothermal systems, MT data are used to delineate low-resistivity zones (usually <10 ohm-m) associated with smectite clay alteration that forms a cap above the reservoir (DiPippo et al., 2025). When combined with geological, geochemical, and hydrological data, the geometry of this clay cap helps constrain upflow and outflow patterns. However, at Cachapoal, glaciation has removed much of the younger volcanic cover, exposing intrusive and previously metamorphosed volcanic and sedimentary rocks that do not readily alter to smectite clay. Instead, shallow resistivity zones below 70 ohm-m are interpreted as retrograde smectite alteration formed in response to fault-controlled hydrothermal upflow within these older rocks. In contrast, some intersecting faults are associated with more resistive zones exceeding 300 ohm-m, which are interpreted as conduits for cooler meteoric downflows that have not undergone smectite alteration. Very shallow zones with resistivity below 10 ohm-m are interpreted as hydrothermally altered clays associated with lower-temperature outflows hosted in glacial clastics.

Integration of the MT resistivity data with geological mapping, spring geochemistry, and structural interpretation has identified three zones of <70 ohm-m resistivity interpreted as potential geothermal up flows. These zones are located at Las Galerías, between MT stations C008 and C002; Don Rolando, between stations C006 and C031; and La Mama, between stations C105 and C103 (Figure 6). Analysis of well core data and regional stratigraphy suggests an unconformity at the base of these resistive zones, indicating that hydrothermal outflow may be occurring along a formation boundary that serves as a regional flow conduit.

6 INTEGRATED 3D LEAPFROG AND CONCEPTUAL MODEL

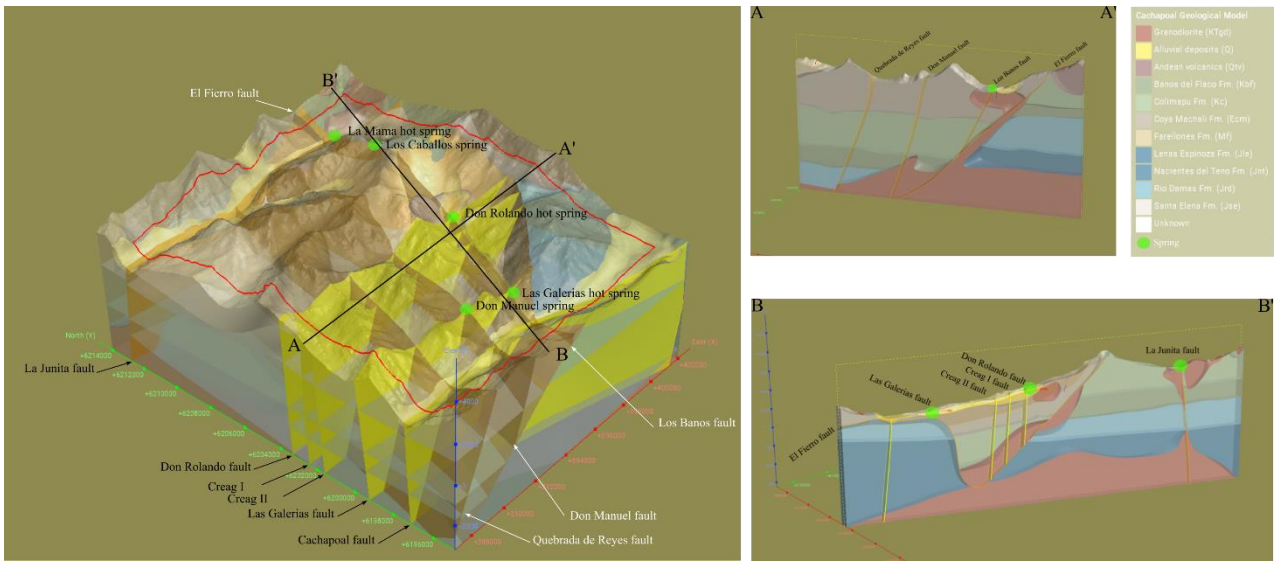


Figure 7 - Integrated 3D model with key faults and hot springs (green circles) interpreted in Leapfrog.

The Leapfrog model was initially constructed from the geological maps and cross-sections, fitting the general stratigraphy expected for the area to the local detail provided by the mineral exploration wells. Both mapped and inferred faults have been incorporated into the model in Figure 7. The geological elements have been adjusted to be consistent with the MT resistivity sections that had been independently correlated with the wells.

The data acquired and compiled during the two-year exploration program, and its integration into the above Leapfrog model has supported the construction of a resource conceptual model used to identify well targets and assess capacity. The conceptual model in Figure 6 differs from those typical of previously suggested models such as Urzua (2011). The proposed geothermal systems are heated by deep circulation in relatively isolated fault systems that host convection in generally low permeability rocks. The systems are mostly capped by < 70 ohm-m moderate resistivity retrograde smectite alteration of metamorphosed sediments rather than by a more extensive < 10 ohm-m low resistivity smectite cap more typical of arc andesite geothermal systems. The evidence for the 97°C to 176°C (Table 2) subsurface temperature is based on silica geothermometry, not on the generally higher temperatures estimated using cation and/or gas geothermometery the drilled geothermal prospects in Chile (Morata et al., 2021).

7 RESOURCE POS AND CAPACITY ESTIMATION

The unconventional geoscience architecture of the Cachapoal prospect complicates the direct application of standard geothermal resource capacity estimation methods. In such cases, the Monte Carlo stored heat method (AGEA, 2010) can yield unrealistically large capacity estimates (Grant, 2015). Given the lack of close analogues for key aspects of the conceptual model, there is significant risk that no developable reservoir exists at Cachapoal. However, if a reservoir is present, fields in the US and Europe provide useful constraints for systems with 97°C to 176°C fluids circulating through fractured metamorphic rocks. To assess resource capacity in this context, the probability of reservoir existence has been estimated separately from the estimate of a resource capacity distribution. The latter is based on power density data from analogous fields (Cumming, 2016).

The approach used to estimate Probability of Success (POS) for resource existence has considered three critical factors: permeability, temperature, and chemistry, consistent with widely followed geothermal industry practice. This evaluation reflects conditions expected from a slim hole exploration program and does not account for economic or development considerations (e.g., Gambini et al., 2025). POS for chemistry is estimated above 90%, given the low likelihood of scaling or corrosion issues. POS for temperature is 60%, reflecting silica geothermometry estimates, the likely need for temperatures above 130°C for power generation, and the risk of cool recharge. POS for permeability is lower, at 30%, due to limited confidence in achieving commercial flow rates in this setting, based on outcomes from less challenging contexts.

While these probabilities are not fully independent, multiplying them yields an overall POS exploration of 16%, which reflects high confidence in chemistry, moderate confidence in temperature, and low confidence in permeability. Applying this POS exploration allows conditional resource capacity to be estimated under the assumption that a reservoir is discovered. For broadly analogous deep circulation systems, installed capacity ranges from under 1 MWe to 160 MWe (e.g., McGinness Hills, Nevada), with a median of 25–30 MW. Wilmarth et al. (2021) show power densities of less than 2 MW/km^2 for systems below 100°C, and a wide range from 1 to over 10 MW/km^2 for those between 130°C and 175°C.Uncertainty in areal extent is based on conceptual models, hot spring distribution, fault zone dimensions, and low-resistivity (<70 ohm) zones. Estimated resource depths range from 600–1400 m at Las Galerías to 1000–2000 m at Don Rolando and La Mama. Mean estimated capacities are 21 MW at Las Galerías, 12 MW at La Mama, and 10 MW at Don Rolando, though uncertainty is high. The 16% POSexploration for Cachapoal is more promising if considered with respect to the implications of a discovery at Cachapoal, which would improve confidence in similar undrilled prospects across the region.

8 CONCLUSION

The Cachapoal geothermal system in the Chilean Andes is an unusual but potentially promising exploration target. Three geothermal areas, Las Galerías, Don Rolando, and La Mama, have been identified with neutral chloride hot springs with temperatures ranging from 32.7°C to 67 °C. Silica geothermometry indicates subsurface temperatures between 97°C and 176°C, consistent with a moderate temperature resource. Although the springs share similar fluid geochemistry, their elevation differences suggest hydrologically separate up flow zones. If they access a common deep reservoir, it must be through relatively low permeability discrete structural pathways rather than a shared shallow system.

Geological, geophysical, and geochemical evidence collectively points to separate fracture-controlled systems hosted within metamorphosed sedimentary rocks and intrusive units that are otherwise low permeability. Permeability is inferred to be strongly controlled by the Los Baños and El Fierro faults together with intersecting west to east trending structures, that create conduits for deep fluid ascent. This architecture is consistent with geothermal systems where flow is concentrated at major fault intersections rather than within distributed fracture systems and/or permeable stratigraphic units.

Magnetotelluric data reveal low resistivity (<70-ohm-m) zones interpreted as localized smectite alteration produced by retrograde hydrothermal processes. These may act as partial caps in the absence of a continuous clay rich layer typical of volcanic geothermal systems that often exhibit resistivity values below 10 ohm-m. Cation geothermometry is unreliable due to ionic contributions from the Santa Elena evaporitic formation, resulting in the use of silica geothermometry as the primary temperature indicator, although with elevated uncertainty due to the scarcity of analogues.

Integrating the datasets yields a conceptual model of a structurally focused geothermal systems with potentially commercial temperatures but with significant targeting uncertainty. A probability of success of 16% has therefore been assigned, reflecting both the generally limited permeability and the challenge of intercepting fault hosted up flows. Despite this, the overall resource assessment supports a mean generation capacity of

approximately 21MW for Las Galerías, 12MW for La Mama, and 10MW for Don Rolando, assuming successful well development.

Given the combined evidence, drilling of a slim exploratory well is recommended as the next step. This low-cost approach is well suited to high uncertainty environments and would allow direct testing of the conceptual model. Las Galerías is the preferred initial target, which offers the best access, highest POS, largest estimated production zone based on MT and moderate reservoir temperature. If successful, this would validate the conceptual model, increase confidence in the Don Rolando and La Mama prospects, both of which remain viable with Don Rolando potentially hotter but smaller, and support broader exploration of structurally analogous, retrograde altered systems in Chile and further afield.

Acknowledgements

We sincerely thank Gerard Krans and his family for their unwavering belief in the geothermal mission and to Frederik Kam for his crucial support in developing conceptual models. Thanks to the Geothermal Development Facility for Latin America for co-funding the two-year campaign. Thanks to Centro de Excelencia en Geotermia Los Andes (CEGA) for their support during the field work and sampling analysis. Thanks to Macarena López for logistical support and to Borja Farah for field surveying support. Special thanks to Claudio Roberto Cádiz and his family for providing horses and guidance essential to accessing the study sites.

Some of the data supporting the findings of the study are available via the author [J.E.] upon reasonable request.

REFERENCES

AGEA.: The Geothermal Reporting Code, Second Edition. Australian Geothermal Energy Association (2010).

Aguirre, L.: Geología de los Andes de Chile Central. Escala 1:100.000, Instituto de Investigaciones Geológicas (SERNAGEOMIN), Santiago, Chile (1960).

Cannell, J.B.: El Teniente Porphyry Copper-Molybdenum Deposit, Central Chile, Ph.D. Thesis, University of Tasmania, Australia (2004).

Charrier, R.: Mesozoic and Cenozoic stratigraphy of the central Argentinean-Chilean Andes (32°–35°S) and chronology of their tectonic evolution, Zentralblatt für Mineralogie, Geologie und Paläontologie, 1(3–4) (1981).

Charrier, R., and Munizaga, F.V.: Edades K-Ar de volcanitas cenozoicas del sector cordillerano del río Cachapoal, Chile, 34°15' de latitud sur, Revista Geológica de Chile (1979).

Cumming, W.: Resource capacity estimation using lognormal power density from producing fields and area from resource conceptual models; advantages, pitfalls and remedies, Proceedings, 41st Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California (2016).

DiPippo, R., Gutiérrez-Negrin, L.C., and Chiasson, A.: Geothermal Power Generation Developments and Innovation, 2nd Edition, Elsevier (2025).

Falcon, M.F., and Rivera, O.: Estudio geológico distrital de la División El Teniente de Codelco-Chile, Corporación Nacional del Cobre (Codelco-Chile), Santiago, Chile (1998).

Gambini, R., Waters, D., Sansone, F., and Memmo, V.: Risk and Uncertainty in Geothermal Projects: Characteristics, Challenges and Application of the Novel Reverse Enthalpy Methodology, Energies, 18(15) (2025).

Giggenbach, W.F.: Geothermal solute equilibria. Derivation of Na-K-Mg-Ca geoindicators, Geochimica et Cosmochimica Acta, 52 (1988).

Gilmer, A.K., Sparks, R.S.J., Barfod, D.N., Brugge, E.R., and Parkinson, I.J.: Duration of Hydrothermal Alteration and Mineralization of the Don Manuel Porphyry Copper System, Central Chile, Minerals, 11(2) (2021).

Godoy, E.: Intrusivos sintectónicos entre los ríos Aconcagua y Cachapoal, Andes de Chile Central, Proceedings, 10th Congreso Latinoamericano de Geología, Concepción, Chile (1998).

González Ferrán, O.: Volcanes de Chile, Instituto Geográfico Militar, Santiago, Chile (1995).

González Ferrán, O., and Vargara, M.: Reconocimiento geológico de la Cordillera de los Andes entre los paralelos 35° y 38° latitud S, Instituto de Geología, Universidad de Chile, Publicación No. 24 (1962).

Grant, M.: Resource assessment, a review, with reference to the Australian Code, Proceedings, World Geothermal Congress, Melbourne, Australia (2015).

Hauser, Y.A.: Catastro y caracterización de las fuentes de aguas minerales y termales de Chile, Boletín Nº050, SERNAGEOMIN, Santiago, Chile (1997).

Herman, P., Jara, P., and Charrier, R.: Tectonic inversion of the Abanico basin eastern border and the structuring of the Aconcagua thrust-fold belt, southern Central Andes at 32°–33°S, Journal of South American Earth Sciences (2023).

Klöhn, C.: Geología de la Cordillera de los Andes de Chile Central: provincias de Santiago, O'Higgins, Colchagua y Curicó, Instituto de Investigaciones Geológicas, Boletín 8, Santiago, Chile (1960).

Kurtz, A.C., Kay, S.M., Charrier, R., and Farrar, E.: Geochronology of Miocene plutons and exhumation history of the El Teniente region, Central Chile (34°–35°S), Revista Geológica de Chile, 24 (1997).

Marini, L., Procesi, M., and Apollaro, C.: Through a glass, darkly: Trying to understand geothermal systems by means of geothermometers and fCO_2-indicators, Journal of Geochemical Exploration (2022).

Morata, D., Aravena, D., Lahsen, A., Muñoz, M., and Valdenegro, P.: Chile Up-Date: The First South American Geothermal Power Plant After One Century of Exploration, Proceedings, World Geothermal Congress, 2020+1, Reykjavik, Iceland (2021).

Nicholson, K.N.: Geothermal fluids: Chemistry and exploration techniques. Springer-Verlag (1993).

Powell, T., and Cumming, W.: Spreadsheets for geothermal water and gas geochemistry, Proceedings, 35th Workshop on Geothermal Reservoir Engineering, California, USA (2010).

Simmons, S.F., Allis, R.G., Moore, J., Gwynn, M., Hardwick, C., Kirby, S., and Wannamaker, P.: Conceptual Models of Geothermal Resources in the Eastern Great Basin, Proceedings, 42nd Workshop on Geothermal Reservoir Engineering, Stanford University, California (2017).

Sruoga, P., Llambías, E.J., Fauqué, L., Schonwandt, D., and Repol, D.G.: Volcanological and geochemical evolution of the Diamante Caldera–Maipo volcano complex in the southern Andes of Argentina (34°10'S), Journal of South American Earth Sciences, 19(4) (2005).

Urzua, L.: Experiencia en Exploración Nacional, Proceedings, I Congreso Geotermal Chileno (ACHEGO), Hot Rock Limited, Santiago, Chile (2011).

Wilmarth, M., Stimac, J., and Ganefianto, G.: Power Density in Geothermal Fields, 2020 Update, Proceedings, World Geothermal Congress, 2020+1, Reykjavik, Iceland (2020).