**A Review of the Geodynamics Constraints on Central Andean Volcanic Zone (18º-28ºLat.S): Implications for the Development and Evolution of High-Enthalpy Geothermal Systems**

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**Supplementary Material**

Main characteristics of known/identified geothermal systems in the CAVZ

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| --- | --- | --- | --- | --- |
| Host-rock | Associated Volcano (quaternary activity unless stated) | Local Structures and Tectonics | Geothermal Manifestations, Water and Reservoir Temperatures and associated structures | References |
| Tacora (-17.698; -69.282) | | | | |
| Conglomerates, sandstones, shales and ignimbrites | Tacora | NW-trending left-lateral strike-slip faults, and minor compressional components (perhaps anachronic) | Outflow gas with temperatures between 82-93ºC; fumarolic field at the flank of the volcano; reservoir temperature calculated to be 270-310ºC. Other hot water manifestations (superficial) have temperatures of about 40ºC as acid-sulfate waters | Salas et al., 1966; David, 2007; Capaccioni et al., 2011; Contreras, 2013. |
| Colpitas (-17.954; -69.440) | | | | |
| Rhyolitic ash flows, andesitic lavas and epiclastic sandstones interbedded with ash layers | Tacora and Lexone, plus several NW- and NNE-trending aligned volcanic centers | NW-trending left-lateral strike-slip and normal and thrust faults, NNE-to-NE trending normal faults, sharing the same orientation of folds and faults affecting (regionally) Miocene rocks | Water surface manifestations between 20ºC and (bubbling at) 55ºC, located along NW-trending structures (N20º-40ºW), and associated with the Tacora volcanic edifice; Chloride waters on northern and southern springs; Reservoir equilibrium temperatures about 200º-235ºC. Compositional trends indicate mixing of water brines. Heat source located most probably near the south flank of Lexone volcano | Garcia et al., 2004; Aguirre et al., 2011; Navarrete, 2012. |
| Jurase (-18.201; -69.530) | | | | |
| ¿? | Taapaca (?) | Thrust faults of the WVS located west of the geothermal field, and NW-trending lineaments and small faults | Hot springs of 65ºC, hydrothermal alteration and silica sinters. Thermal waters with pH of 7.04; SO4-Na waters and high Boron concentrations (up to 1350 mg/L) in thermal springs | Dias, 1983; Hauser, 1997; Chong et al., 2000; Farías et al., 2005; Tassi et al., 2008; Risacher et al., 2011; |
| Surire (-18.917; -68.983) | | | | |
| ¿? | Polloquere | Mostly covered yet associated with NNW trending anticlinal hinges of the WVS. NW-tending faults show left-lateral strike-slip displacements | Thermal discharges not clearly associated with N-to-NW-trending anticlinal hinges and thrust faults in the area (WVS), as well as NW-trending lineaments; Reservoir temperatures about 230ºC | Cusicanqui, 1979; Farías et al., 2005; Tassi et al., 2010 |
| Licancura (-19.141; -69.169) | | | | |
| Ignimbrites and andesitic volcani-clastic deposits | Isluga (?) | NW-trending left-lateral faults, N-to-NNW trending thrust faults (WVS?) and minor NE-trending faults | Hot and cold water discharges spatially associated with river and gullies that follow the direction of the main structures in the area, mostly along NW-trending faults and at the crossing of NW- and N-trending lineaments | Veloso et al., 2016; Maureira, 2013 |
| Berenguela (-19.247; -69.177) | | | | |
| Ignimbrites (?) | Isluga (?) | Mainly NNW-to-NW trending thrust faults (?) as well as right-lateral (?) NE-trending faults | Water discharges about 59ºC with pH 6.6, probably mixing between hydrothermal fluids and meteoric waters | Maureira, 2013 |
| Puchuldiza (-69.015; -19.382) | | | | |
| ¿? | Isluga | NW-trending left-lateral strike-slip, NE-trending (right-lateral?) and NS-to-NNW-trending normal (?) faults | Constant fumarolic activity with associated bubbling and mud pools, thermal springs and geysers. Water discharges probably controlled by N-, NW- and NE-trending faults, on where thermal manifestations are spatially associated mostly with the intersection of N- and NW-trending faults; Deep temperatures (ca. 900m depth) of about 166ºC, and estimated reservoir temperatures of 210º-220ºC | Letelier, 1981; JICA, 1981; Céspedes et al., 2004; Tassi et al., 2010; Mahon and Cusicanqui, 1980. |
| Pampa Lirima (-19.851; -68.934) | | | | |
| Volcanic and sedimentary rocks covered by volcanic products and edifices | None (?) | NS-, NW-, and NE-trending faults | Water pools with temperatures between 38º-80ºC (pH 7.4); geothermal manifestations located on top of NW-trending lineaments; N-, NW- and NE-trending faults recognized on ZTEM surveys. There is a recognized conductive layer at >500-1000 m depth representing a clay-cap horizon. Reservoir temperatures estimated at 200ºC | Arcos et al., 2011; Legault et al., 2012; Procesi, 2014; Nicolau et al., 2015. |
| Salar de Empexa (-20.361; -68.612) | | | | |
| Volcanic and sedimentary rocks covered by volcanic products and edifices | None (?) | NW-to-NNW trending normal faults, with small strike-slip displacements | Water thermal manifestations of about 88ºC, as well as a sulfur mine pit. Depth temperatures of 125ºC (60-165m); presence of sulfated water; Geothermal manifestations along NE-trending lineaments, commonly close or in the intersection of NE- and NW-trending lineaments. Reservoir temperature of 230º-240ºC, however, based on water chemistry is of 180ºC | Scandiffio and Cassis, 1992; Risacher and Fritz, 2009; JOGMEC et al., 2011; Ramos, 2015; Bona and Coviello, 2016. |
| Irruputuncu (-20.728; -68.581) | | | | |
| Ignimbrites | Irruputuncu | NW-trending lineaments probably associated with left-lateral/normal displacements | Permanent deposition of sulfur and gas emissions with SO2 as the main phase; outlet temperatures between 83º and 240º with highly concentrated SO2, H2S and abundant HCl, N2, HF, O2 y CH4; Volcanic craters at the summit are NW-SE aligned as well as hot springs and fumaroles; Reservoir temperature of >220ºC | Vergara and Thomas, 1984; Naranjo, 1985; Clavero et al., 2006; Reyes et al., 2011; Tassi et al., 2011; Rodriguez et al., 2015. |
| Olca (-20.940; -68.485) | | | | |
| Andesitic lava flows | Olca | Olca volcano lies on the westernmost end of an E-trending chain of Holocene volcanoes. Regional pattern dominated by N-to-NW-trending structures as well as local E-trending structures | Fumaroles at the crater and at a single warmspring at the base of the Olca volcano. Few geothermal manifestations aligned NW-SE. Estimated reservoir temperature of 230º-300ºC. Small native sulfur mining pits | Reyes et al., 2011; Gardeweg and Salas, 2011; Reyes et al., 2011. |
| Cerro Pabellón (-21.883; 68.119) | | | | |
| Eroded andesitic to dacitic stratovolcanoes and a series of younger porphyritic dacite domes and flows | San Pedro-San Pablo | NNW-trending normal faults hosting a series of eroded volcanoes and young lava domes | Fumaroles with high steam-discharge in summit of Cerro Apacheta with 109º and 118ºC (superheated). Some water wells have bubble gas. Structures form a geomorphological graben ca. 3-5km wide (Pabelloncito graben), part of the NW-trending Paniri-Inacaliri-Azufre lineament. Reservoir temperature calculated at >320ºC with significant amounts of gas derived from a geothermal reservoir. Superficial alterations are clay and native sulfur around fumaroles and silica veins. | Francis and Rundle, 1976; Urzúa et al., 2002; Godoy et al., 2017. |
| El Tatio (-22.383; -67.994) | | | | |
| Ignimbrites, tuffs and lavas, covered by Holocene deposits | Putana (?) (Uturuncu?) | NW-trending lineaments and N-trending normal/thrust (?) faults forming a geomorphological half-graben structure | Thermal manifestations developed in the hanging wall of N-trending half-graben. Surface thermal activity is mostly restricted to geysers, hot pools, fumaroles, mudpots, sinter aprons, salt incrustations and growth of microbes. Temperature at 600m depth is 253ºC. Most vents and thermal manifestations occur along N-to-NNE- and NW-trending lineaments. Discharged thermal waters at geysers have high Cl, Na, SiO2 and As and low SO4 concentrations. Water chemistry indicates complex mixing process between magmatic, meteoric and hydrothermal sources. Gas chemistry is dominant in CO2, N2, H2S and CH4. Increased fracturing on ignimbrite layers. MT surveys suggest a magmatic intrusion at 5-7 km depth | Ellis, 1969; Lahsen and Trujillo, 1975; Cusicanqui et al., 1976; Schwartz et al., 1984; Muñoz and Hamza, 1993; Cortecci et al., 2005; Tassi et al., 2005; Lucchi et al., 2009; Nicolau et al., 2014; Muñoz-Saez et al., 2015; Muñoz-Saez et al., 2018. |
| Sol de Mañana (-22.427; -67.819) | | | | |
| Ignimbrites, andesitic-dacitic lava sequences | Putana (?) Uturuncu (?) | NNW-trending faults forming small grabens and horsts, with measured seismic activity, and a second system with NNE- trending orientation | Fluids transported upwards through NNW- and NNE-trending fracture mesh. Surface manifestations along NNE-trending (?) faults and lineaments. Mature waters with neutral pH and high chloride concentration. Reservoir temperature between 280º-250ºC, located at a depth of ca. 800-900m. Springs in the area indicate mixture with cold groundwater. MT data indicates low resistivity areas related to the occurrence of a cap rock. Gravity and resistivity data indicate reservoir should be located within the fracture mesh | ENEL, 1991; Delgadillo and Puente, 1998; Cortecci et al., 2005; Villarroel, 2014; Ramos, 2015; Ramos, 2015; Bona and Coviello, 2016. |
| Tilocalar (-23.958; -68.117) | | | | |
| Ignimbrites | Possibly associated with Lascar, Miscanti or Aguas Calientes volcanoes | N-trending thrust faults and folds and scarce NW-trending lineaments | Scarce hot water manifestations commonly located at the hinges of N-trending folds (axes) or at the foot of N-trending thrust faults. Discrete water manifestations along N-trending thrust faults and at the intersection of these with NW-trending faults | Kuhn, 2002; Gonzalez et al., 2009. |
| Lazufre (-25.187; 68.533) | | | | |
| Andesitic-to-dacitic lava flows and domes, and dacitic ignimbrites | Lastarria | Mostly NW-trending lineaments and faults. Some minor occurrences of NE-trending and N-trending lineaments and faults, mostly bounded by NW-trending faults and lineaments | Geothermal manifestations on the flanks and summit of Lastarria volcano aligned NW-ward. Fumarolic fields with temperatures ranging between 80º-408ºC. Isotopic ratios on fumarolic gases are diagnostic of magmatic gas source. MT surveys indicate a conductive zone at 6km depth south of Lastarria volcano and interpreted as a magmatic heat source connected to a shallow conductor beneath the volcano | Naranjo and Cornejo, 1992; Aguilera et al., 2012; Diaz et al., 2015. |
| Juncalito (-26.534; -68791) | | | | |
| ¿? | Los Cuyanos-Sierra Nevada Volcanic Complex | NW-trending lineaments as well as N-trending thrust faults. Southward of the area, a series of subparallel ENE-trending lineaments are present | Five different thermal manifestations, with temperatures between 18-25º and 32-42ºC. Estimated reservoir equilibrium temperature of 160ºC. Thermal anomalies spatially associated with NNE- and N-trending faults and lineaments | Clavero et al., 1998; Mayorga, 2011; Lira et al., 2011. |
| Ojos del Salado (-27.081; -68.967) | | | | |
| Basaltic andesites, dacites and rhyolites | Spatially associated with the El Solo-Ojos del Salado-Tipas volcanic complex as well as with the Whellwright Caldera | N-to-NNE-trending thrust faults cut and displaced by NW-trending normal-left-lateral faults and lineaments, as well as a series of ENE-trending faults (left-lateral?) | Manifestations occur between two NW-trending, west-dipping normal-left-lateral faults | Baker et al., 1987; SERNAGEOMIN, 2003. |
| Uturuncu (-22.207; -67.233) | | | | |
| Ignimbrites | Uturuncu volcanic center, plus several calderas in the area (e.g. Panizos, Vilama and Coruto) | NW-trending normal-left-lateral faults of the Olacapato-El Toro-Calama lineament | Two active sulfur fumarole fields located near the summit of Uturuncu volcano, with temperatures slightly below 80ºC, spatially associated with the NW-trending normal (left-lateral) faults that of the Lipiz-Coranzuli (or Pastos Grandes-Cojina) lineament. Volcanic-tremors are aligned NW-ward. Five large domes outside the current dual-summit of Uturuncu volcano are approximately NE-SW aligned. Calculations suggests that heat flow at Uturuncu is larger than 200 mW/m2 | Sparks et al., 2008; Salisbury et al., 2011; Jay et al., 2012; Muir et al., 2015. |
| Tuzgle (-24.017; -66.543) | | | | |
| Ignimbrites | Tuzgle | N-to-NNE-trending thrust faults belonging to the Andean Foreland and NW-normal-left-lateral faults. NW-trending faults displace and deform (drag-folds) N-to-NNE-trending thrust faults | Fumaroles, water and water plus gases discharges. Fumaroles and other thermal manifestations are slightly NW-ward aligned. Field survey indicates that EW-to-NW trending structures favor upward fluid flow. Alkaline-chlorine type waters, with water temperatures between 21º-56ºC. Geothermal manifestations are rich in SiO2, SO4 and CO3 with a magmatic signature. Geoelectrical and MT surveys suggest the presence of a geothermal reservoir between 50-300m depth and with a variable thickness between 100-600m. A possible second, deeper, reservoir would be located at ca. 2km depth. Reservoir temperatures estimated between 134º and 143ºC | Aquater, 1980; Coira, 1995; Sainato and Pomposiello, 1997; Ferreti, 1998; Bonali et al., 2012; Giordano et al., 2013; Norini et al., 2013. |
| Tocomar (-24.233; -66.468) | | | | |
| Ignimbrites | Tuzgle Volcano ? | NNW-trending normal and left-lateral faults of the Calama-Olacapato-El Toro lineament | Hot and cold springs along the NW-trending faults | Giordano et al., 2013 |
| Antofalla (-26.104; -67.493) | | | | |
| Volcani-clastic deposits (?) | Antofalla Volcanic field as well as with the Cerro Blanco Caldera | N/A | N/A | Matteini et al., 2002; Gamonal, 2007; Richards et al., 2006; Tibaldi et al., 2009 |

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