Proceedings World Geothermal Congress 2000
Kyushu - Tohoku, Japan, May 28 - June 10, 2000

HYDROGEOLOGIC MODEL OF THE GEOTHERMAL RESERVOIRS FROM LOS HUMEROS, PUEBLA, MEXICO

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Key Words: ground water systems, reservoir, flow direction, geothermal

ABSTRACT

Petrological and geochemical studies of water and gases and reservoir engineering from geothermal wells, show two geothermal reservoirs. This is confirmed by petrographic and structural correlations and the conditions of the casing in the productions intervals in the geothermal wells. The upper reservoir in andesites with augite has neutral pH and is non-corrosive. The lower reservoir in basalts and andesites with hornblende has very high temperatures and an acid pH. They are separated by a layer of vitric tuffs (the Toba Humeros). Differences in elevations between potentiometrics levels in the wells do not allow the direction of the flow of the deep geothermal fluids to be inferred.

Lithological, hydrogeochemical and piezometric results from the gradient wells drilled inside the Caldera of Los Humeros, also show two superficial zones of ground water one relatively cold and the other hotter. Due to the distance between these wells and their geologic environment, neither zone (cold on warm) can be used to infer the direction of the fluid flow.

Regional studies of hydrology, geophysics, hydrogeochemistry and structural geology, confirm that the shallow ground waters (cold and warm) do not have hydraulic connection with the deep wells, water wells or springs around Los Humeros. Therefore, the recharge of the shallow waters (cold and warm), occurs inside the closed basin of the caldera of Los Humeros, delimited by topography. Those ground waters recharge the geothermal fluids through faults and fractures inside the limits of collapse of Los Humeros.

The regional geological-structural sections supported by evidence of the lithology from geothermal wells, show that the outcrops of granitic rocks and clay limestones appear at the level of geothermal reservoirs, obstructing the regional lateral recharge. The annular faults of the collapse Los Humeros and Los Potreros form impermeable barriers to the lateral fluids. The supply to the geothermal reservoirs is produced only inside the limits of the Los Humeros, Caldera.

1. INTRODUCTION

The Los Humeros geothermal field, is located in the eastern portion of the state of Puebla and west of the state of Veracruz. It is located at 19° 35´- 19° 45´ W longitude and 97° 24´- 97° 30´ N latitude. The surface now in exploitation is 16 km^2 and has an elevation about 2800 m (figure 1). The geologic indications from The Caldera of Los Humeros, its anular faults, echelon fault system and the arrangement of the geological events, demonstrate that in its interior there exist two shallow ground water systems and two geothermal reservoir zones. The latter two are separated by a layer of vitric tuff called Toba Humeros. The Xaltipan Ignimbrite separates the shallow ground water system from the geothermal reservoirs. Limited hydraulic interconnection between the ground waters and the geothermal reservoirs takes place through faults systems and fractures. The interconnections of the magmatic fluids with geothermal fluid zones is facilitated by the faults and fractures too.

2. GROUND WATER SYSTEM

The results for gradient wells of 200 to 400 m depth situated inside and outside of The Caldera of Los Humeros show two ground water systems. One cold the other warmer, both delimited by fault systems. This ground water is found in basalts, tuffs and andesites. Their lower limit is the Xaltipan Ignimbrite, and their lateral limits are the Collapse of Los Potreros and the main collapse caldera (Colapso de Los Humeros), which act as barriers to flow. The recharge to these systems is supplied by the local rainfall. Effectively an almost closed basin with an area of 100 km^2. The discharge is mainly through the faults and fractures to deeper levels where geothermal reservoirs are located (figure 2).

The reinterpretation of the resistivity studies, allows the detection of two ground water systems. Figure 3, shows the resitivity evidence, the value minor of 50 ohm-m even depths of 400 m, which correspond to an ground water. Resistivity between 100 and 200 ohm-m delineates the cold ground water zone.

2.1 FLOW DIRECTION OF THE GROUND WATER SYSTEMS

It is difficult to identify directions of water flow in any of the shallow aquifers or geothermal reservoirs. In the case of the shallow aquifers this is hindered by the considerable distances between the small number of wells, but even in the thermal reservoirs, where there is a greater density of wells, inference of flow directions is not simple.

3. GEOTHERMAL RESERVOIRS

The interpretation of pressure and temperature records (Torres, 1993), fluid geochemistry from the testing of wells (Tovar, 1998), petrographic analysis (Viggiano and Robles, 1988), recovery of the casing liner of well H-16, fluid geochemistry on repaired wells, and the construction of new geothermal wells, all confirmed two zones of geothermal fluids, an upper zone with temperature of 282 °C and neutral pH, and a lower with a temperature of about 330 °C and much lower pH (Hydrogeological sections, figures 4, and 5).

The hydrogeological sections WNW-ESE, N-S, (figures 4, and 5) show the structure of these geothermal reservoirs. The upper reservoir is in andesites with augite (Tsan) and the lower is in basalts and andesites of hornblende (Tvan) (Viggiano, 1988), both
are separated by a layer of vitreous tuff (Tvs), the Toba Humeros (Cedillo, 1997).

The geochemical observations, concluded that "When the geothermal wells produce fluids from both reservoirs, the mixing brings about incrustation and corrosion casing (Truesdell, 1997, Tello, Pal Verna and Tovar 1999). Viggiano, (1988) suggests that drilling should be terminated when potassic mica and biotite apper in the drill cutings, because these secondary minerals indicate zones of high temperature and acid envirومments. To avoid corrosion and production from the upper reservoir, some wells were reconditioned. Sealing the acid zone, those wells were rebuilt in order to give a production greater than 20 ton/ h of steam and were located in zones with permeability that has a relation with faults and has as a lower limit a layer of vitric tuff or potassic mica and biotita. Particular examples are the wells H-6, H-7 and H-12 that only produced in the lower reservoir (figure 5).

3.1 RECHARGE TO THE GEOTHERMAL RESERVOIRS

To understand the recharge of geothermal reservoirs at Los Humeros, we have conducted regional studies of superficial hydrology. We explain gravimetrics and geoelectrical results. Also we review regional geology, lithology, piezometric data and the geochemistry of the geothermal wells, with additional information from temperature and pressure records of the geothermal wells.

The recharge of the ground water systems and geothermal reservoirs is initially vertical, beginning with rainfall infiltration and is transmited through faults and fractures. After this vertical recharge, lateral movement occurs into the geothermal reservoirs. This vertical-lateral supply occurs only within limits of The Humeros Collapse (figure 2).

Another vertical recharge route is upward for magmatics fluids that travel through faults and fractures to the lower reservoir and eventually the upper reservoir. If the faults are connected with the upper reservoir of normally neutral pH, part of this becomes acidic. This situation is show by well H-4, because which was extremely acidic, and close to a fault zone (pH Fault).

If the fault systems (Falla Humeros) are recent and deep, the magnatic fluids will rise to upper levels, contaminating and transforming the shallower waters from colder to warmer, causing contamination with boro and other sulfates.

4. CONCLUSIONS AND RECOMMENDATIONS

The distribution of low-permeability geologic units (granites and clay limestones) around La Caldera Los Humeros, combined with the annular faults isolate the geothermal reservoirs from regional recharge therefore, the main supply is produced from rainfall infiltration inside the limits of the Los Humeros Caldera Collapse.

The lithological, geochemical and piezometric information of the geothermal wells, artesian wells and springs indicate that hydraulic interconnection does not exist between the colder ground water from Los Humeros with the wells, artesian wells and springs around Los Humeros.

The interpretation of pressure and temperature records, petrographic analysis and the results of chemical analysis of gases and water from new and repaired geothermal wells, confirm two geothermal reservoirs, an upper zone with neutral pH in andesites, a lower zone with high temperature and acid pH in basalts and andesites, these are separated by a layer of vitric tuff. The wells H-6, H-7, and H-12 produced 33, 47 and 49 ton/h of steam from the lower reservoir without problems of corrosion.

Pressure and temperatures records in each well should be examined in order to determine the static levels and to draw the flow net to identify the directions of geothermal fluids, and the supply zone, and lateral discharge and recharge zones.

The geological and the thermodynamic conditions of the wells H-6, H-7 and H-12 should be considered, these wells are producing exclusively from lower reservoir and it is recommended that production should take place in this reservoir along La Falla Antigua and Xalapasco from Maxztaloya (figure 6) with wells from

2500 to 3000 m of depth, drilling 400 m of lower reservoir and setting slotted casing under the layer of vitric tuff (Toba Humeros).

ACKNOWLEDGEMENTS

The author is a geologist, who has contributed during 11 years in siting of wells in the geothermal field Los Humeros, Puebla. The author would like to thank; Dr. Gerardo Hiriart Lebert manager of Gerencia de proyectos geotermoeléctricos, C.F.E. and Mr. Jose Luis Quijano León, sub manager of Studies; the people of Residencia Los Humeros, Pue; Mr. Raúl Estrada Serrano, manager from Los Humeros, Mr. Manuel Machorro Jiménez and Mr. Gerardo García Estrada for review of the manuscript, Mr. Ignacio Martínez Estrella for their help in preparing the drawings and maps of this paper and W. George Darling, Ph. D from British Geological Survey and Ken Wisian, Ph. D. from Souther Methodist University, Dallas, Texas for their comments on this paper .

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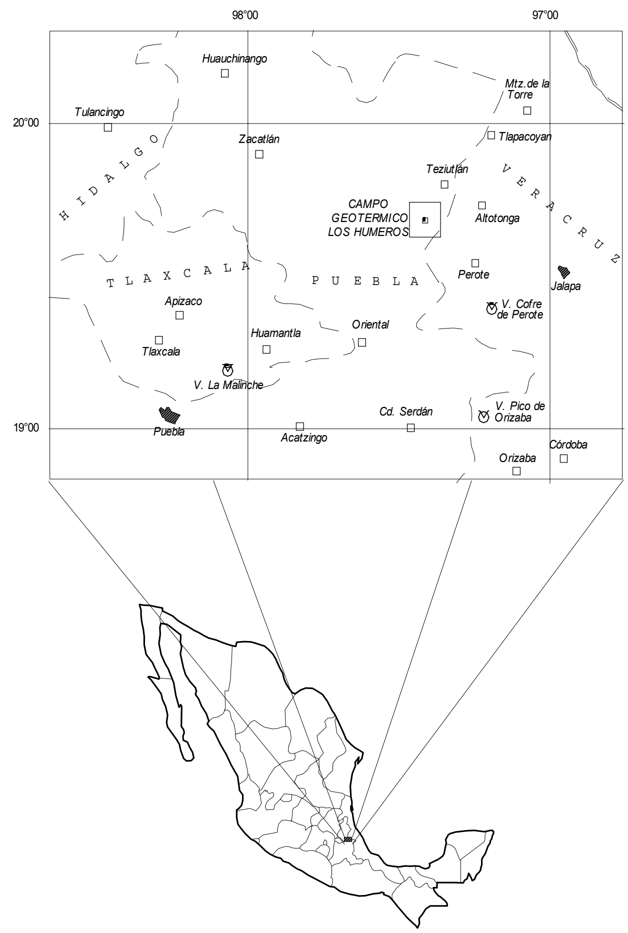

Figure 1 Location map

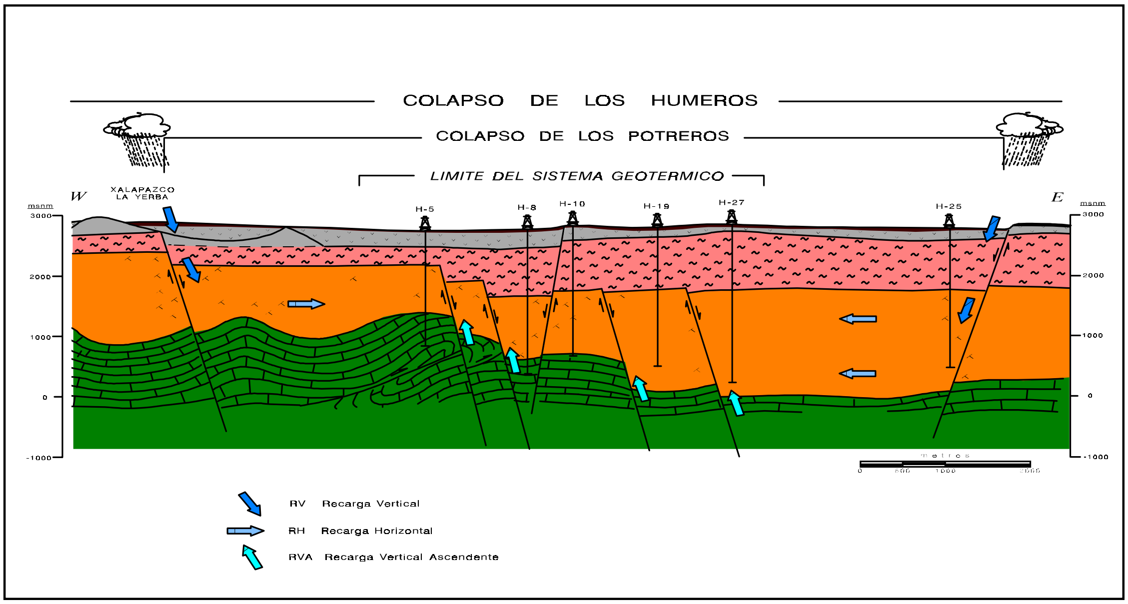

Figure 2 Recharge and discharge from ground water system and geothermal reservoir

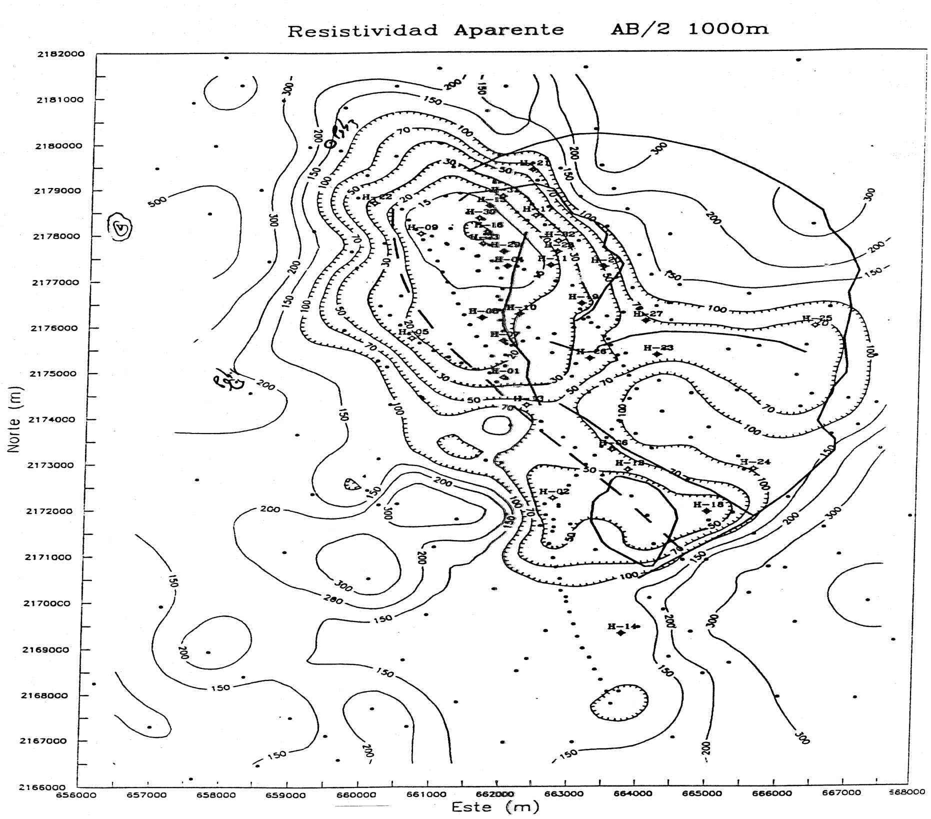

Figure 3 Apparent resistivity AB/2=1000 m (Contour in ohm-m)

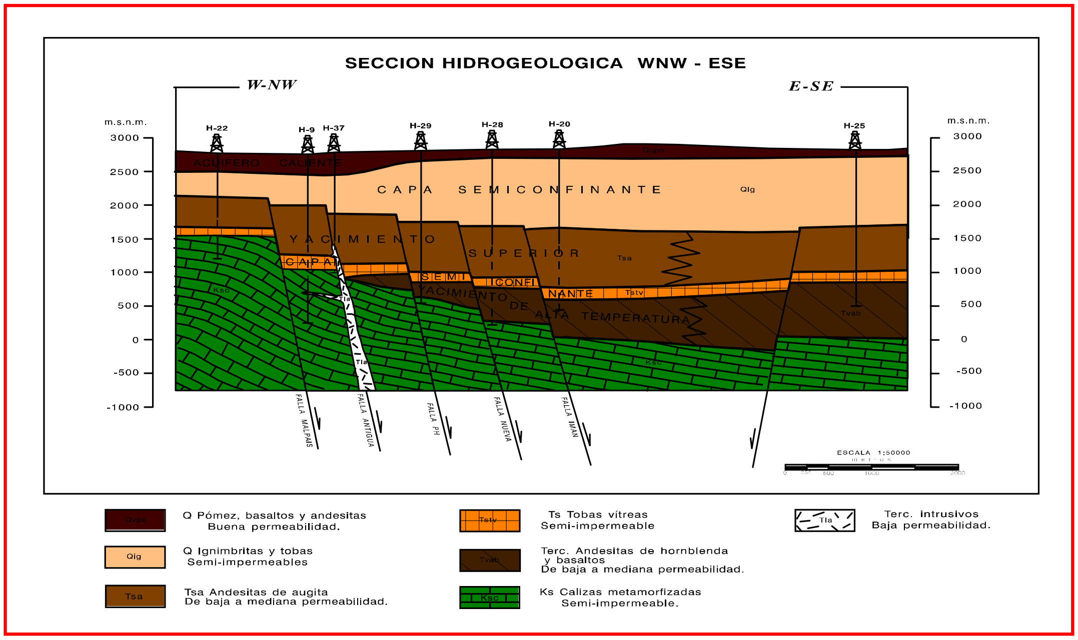

Figure 4 Hydrogeological section WNW-ESE

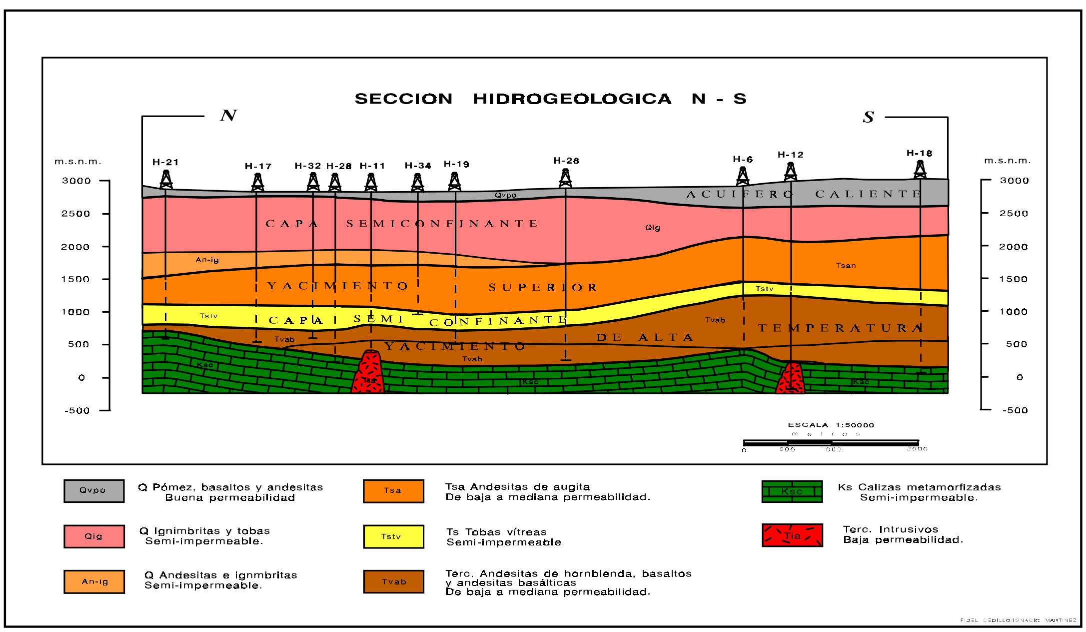

Figure 5 Hydrogeological section N-S

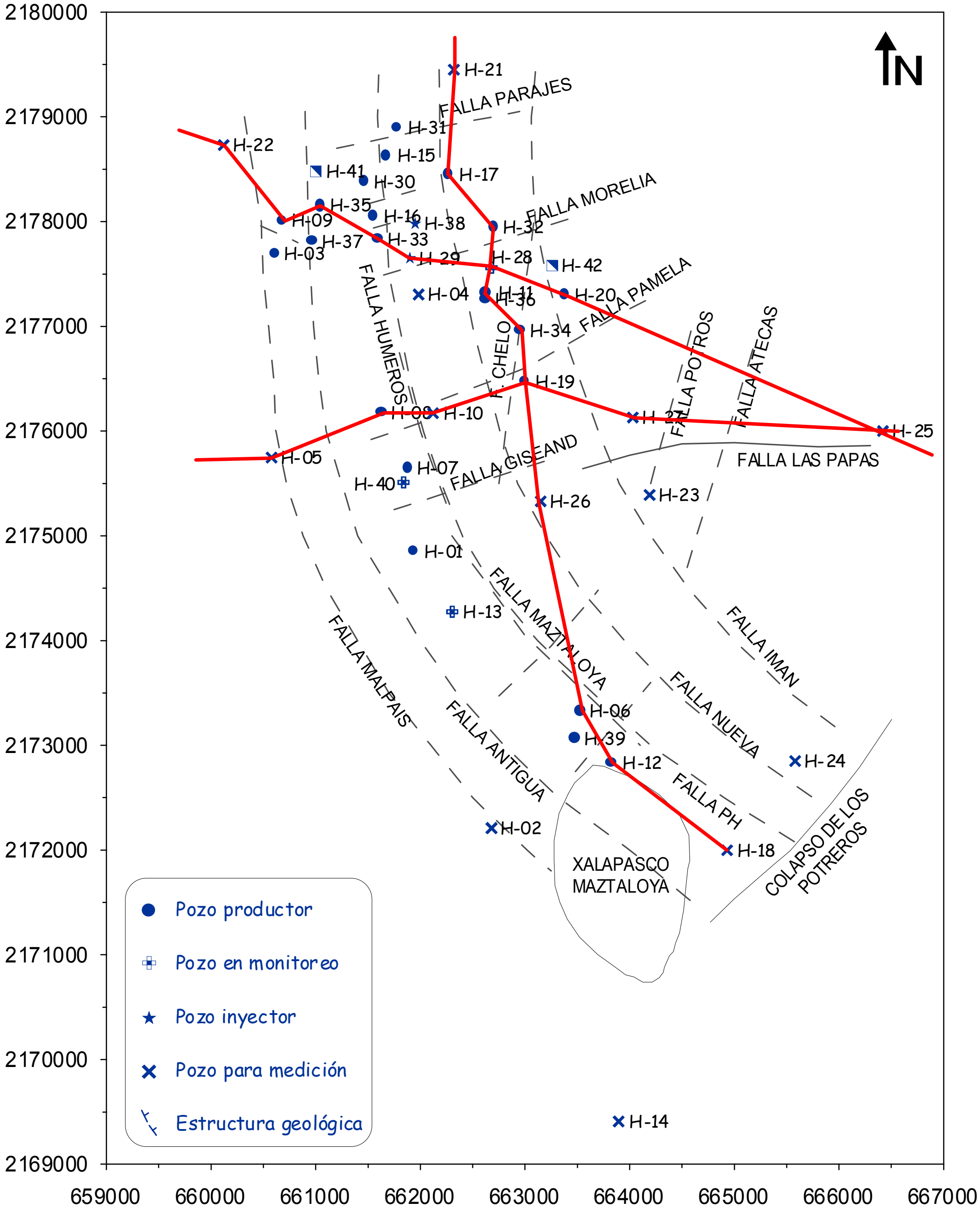

Figure 6 Location of wells and hidrological sections