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

Tongonan Geothermal Reservoir Liquid Saturation Evolution Using Gas Geochemistry

Alvin I. Remoroza
Energy Development Corporation, Pasig City, Metro Manila, Philippines 1610

INTRODUCTION

This comprehensive study leverages an extensive dataset spanning nearly four decades, from 1982 through 2021, to conduct a detailed geochemical investigation. The analysis involved the meticulous processing and evaluation of over 3,600 gas geochemistry sampling data points, collected from a total of 71 distinct production wells.

The primary objective of this research is to definitively assess the presence and extent of superheating phenomena within the geothermal reservoir level itself. This investigation is driven by compelling observations of superheated conditions consistently documented in the surface piping facilities of several key production areas. The persistence of superheating at the surface necessitates a rigorous examination to determine if this condition originates within the deeper reservoir or is a localized effect induced during the fluid ascent or at the surface infrastructure. By analyzing the long-term trends and spatial distribution of the gas geochemistry data, this study seeks to provide the critical evidence needed to understand the thermodynamic state of the reservoir and its direct implications for reservoir management and energy production efficiency.

RESERVOIR GEOTHERMOMETERS

Reservoir temperatures from all available well data were analyzed and compared using water and gas geothermometers. Figure 1 shows the historical temperature distribution calculated by three specific methods: the Quartz (water-based), and the D'Amore & Panichi (DAP) and FT-HSH grid (gas-based) geothermometers. Quartz and DAP geothermometers consistently yielded similar, higher temperatures, reflecting deep, unboiled reservoir fluid conditions. In contrast, FT-HSH (gas ratio) temperatures were systematically lower, likely due to secondary processes like peripheral cold water ingress or mixing with cooler reinjected brine/condensate, which altered gas ratios. However, starting around 2016, all three methods (Quartz, DAP, and FT-HSH) converged, suggesting a change in reservoir dynamics. This convergence implies that the produced fluids are now less affected by secondary cooling/mixing and are increasingly representative of the true, deep-equilibrated reservoir fluid.

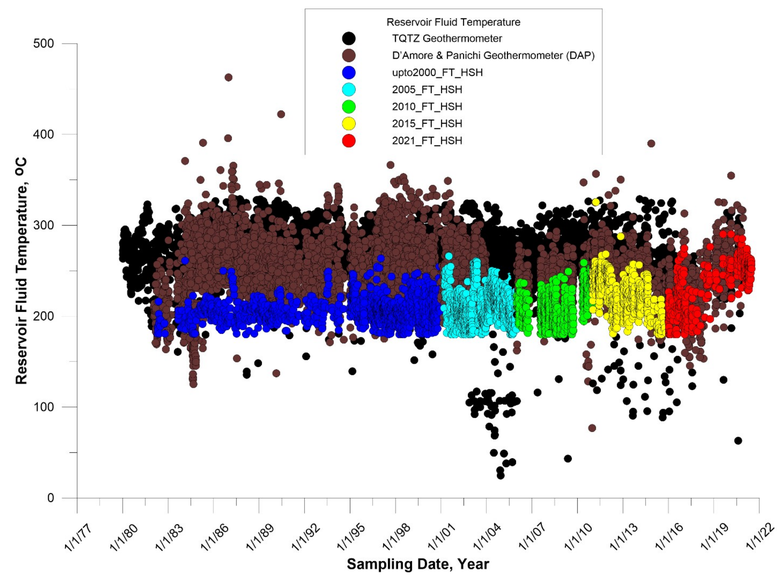


Figure 1. Quartz and FT-HSH grid derived reservoir temperatures of the Tongonan geothermal well fluids.

RESERVOIR STEAM FRACTIONS

The FT-HSH plot (Figure 2), which includes data from Tongonan geothermal wells since gas sampling began in 1981, illustrates a wide range of low to moderate reservoir steam fractions. These findings align with the results of Dacillo and Siega (2005), whose study involved customizing the FT-HSH calculations (Figure 3). Dacillo and Siega specifically classified a group of wells with 1-5% steam fraction as 'dry wells.'

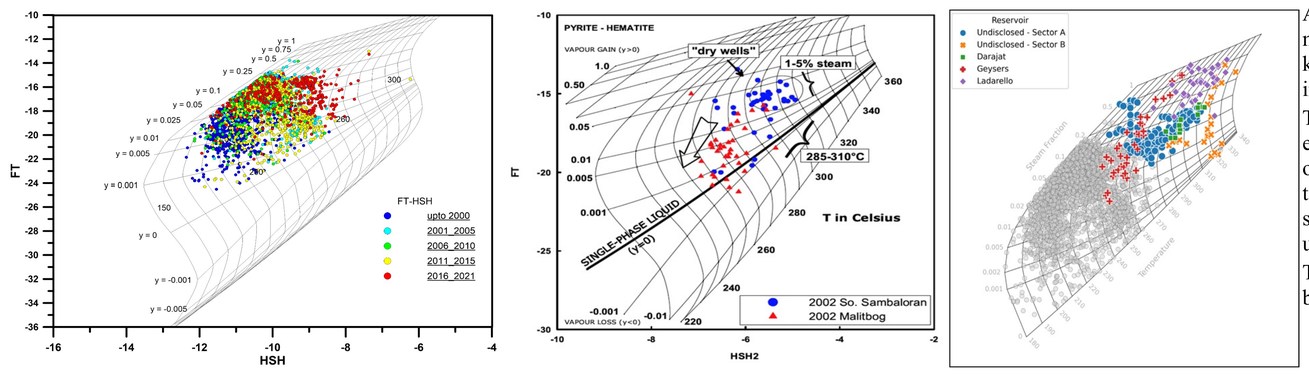


Figure 2. FT-HSH plots of well gas geochemistry samples from Tongonan geothermal reservoir (left). FT-HSH plot of Malitbog and So. Sambaloran during full exploitation after Dacillo and Siega (2005. middle). Comparisons of reservoir steam fractions from published and unpublished case studies (right).

A comparison of Tongonan's results with published and unpublished data from other geothermal reservoirs reveals that Tongonan has lower reservoir temperatures and steam fractions than known vapor-dominated or potentially super-heated reservoirs. The published comparative data include works by Mahagyo et al. (2010) and D'Amore and Truesdell (1995).

The distribution of reservoir steam fractions over time is shown in Figure 5. During the initial exploitation phase, up to the year 2000, the steam fraction displayed a bimodal pattern—a mix of normal and lognormal distributions—suggesting the presence of underlying processes. Prior to 1993, the steam fraction remained below 2.5% before showing a slight increase in 1993. A significant jump in steam fraction occurred in 1996, after which it remained relatively stable until around mid-2010.

The rise in the average reservoir steam fraction between 2001 and 2010 indicates that extensive boiling was occurring as a result of exploitation.

Reservoir conditions in the Tongonan geothermal field, specifically the Upper Mahiao and Malitbog-South Sambaloran sectors, have changed due to operations and natural events.

Pre-2010 Exploitation: Massive fluid extraction in Upper Mahiao and Malitbog-South Sambaloran caused pressure drawdown and reservoir boiling, indicated by increased well discharge enthalpies. From 2006-2010, steam fractions decreased due to reinjection, following an approximate 5 MPaa pressure drawdown.

2010-2012 Changes: Mid-2010 to early 2012 saw a significant decrease in steam fraction and a corresponding temperature increase (Fig 4).

2016-2021 Steam Augmentation & Earthquake: The 2016-2021 steam augmentation drilling campaign led to extensive Tongonan boiling, increasing the reservoir steam fraction. Upper Mahiao and Malitbog-South Sambaloran continue to show boiling (increased enthalpies). The 2017 Leyte earthquake caused the steam fraction to decrease and temperature to rise. High temperatures and lower steam fractions before the earthquake may imply recharge from hotter, liquid-saturated fluids. The higher temperatures and steam fractions after the earthquake could be due to changes in reservoir relative permeability.

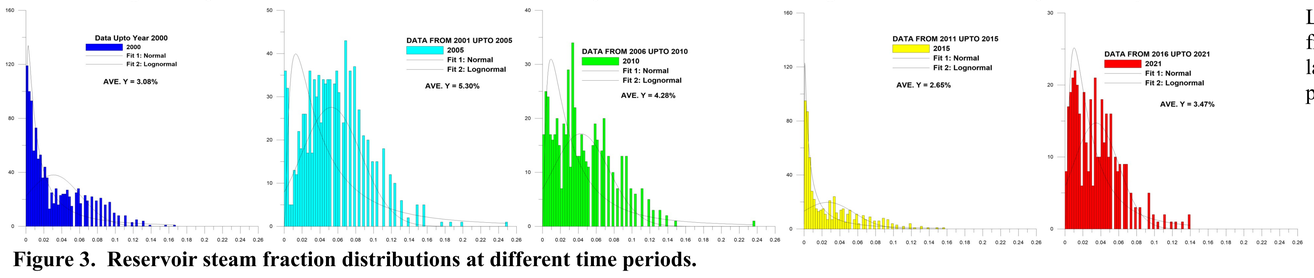


Figure 3. Reservoir steam fraction distributions at different time periods.

Long-Term Trends: A plot of $\log(CO_2/Ar)$-$Log(H_2/Ar)$ (Figure 5) shows the maximum steam fraction population decreasing over time, approaching the liquid equilibrium line. The calculated maximum fluid temperature population also decreases, suggesting reservoir cooling or depletion of hotter parent fluids.

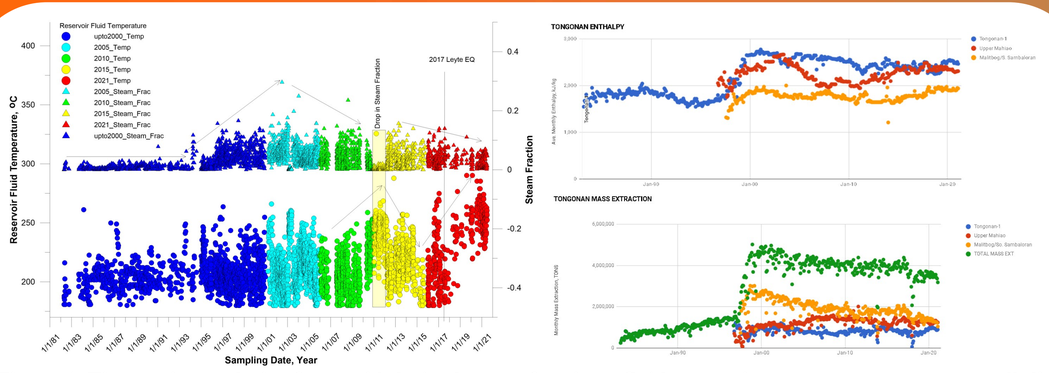


Figure 4. Time series analysis of gas grid derived steam fractions, fluid reservoir temperatures, average well discharge enthalpies, and total mass extractions.

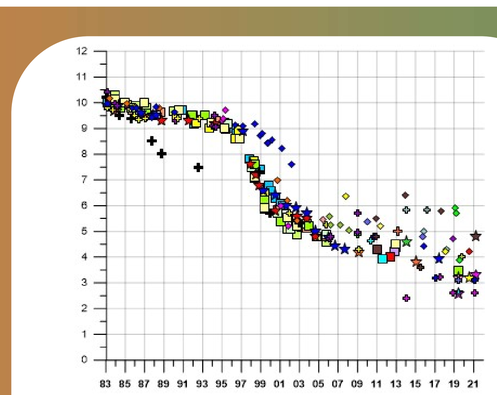


Figure 5. Historical relative measured downhole pressures in Tongonan wells.

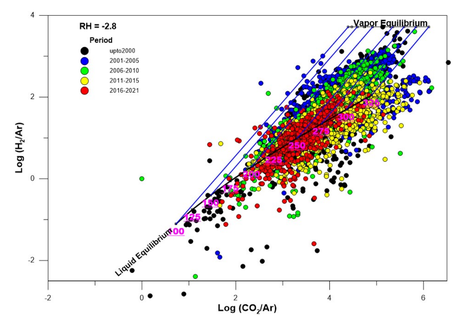


Figure 6. Grid Log (CO2/Ar) – Log (H2/Ar) plot of Tongonan wells at different time periods.

SUMMARY AND CONCLUSIONS

The Tongonan reservoir is primarily characterized by high-enthalpy liquid-saturated conditions, with overall steam fractions being moderate to low, which does not suggest drying-out. The data indicates the occurrence of more extensive boiling at certain times, as well as periods influenced by reinjection returns (separated brine and steam condensate) and/or incursions of colder peripheral water. Reservoir fluid temperature appears to be controlled initially by boiling, with subsequent effects from reservoir pressure drawdown.

Acknowledgements

Grateful to FirstGen—Energy Development Corporation for giving permission to publish and present this study.

REFERENCES

D'Amore, F. and Truesdell, A. 1995. Correlation Between Liquid Saturation and Physical Phenomena in Vapor-dominated Geothermal Reservoirs. In:Proceedings of World Geothermal Congress.Florence,Italy.pp.1927–1931.

Dacillo, D.B and Siega, F.L. 2005. Geochemical Assessment on the Sustainability of the Deep Geothermal Resource of Tongonan Geothermal Field (Leyte, Philippines). In Proceedings World Geothermal Congress 2005 Antalya, Turkey, 24-29 April 2005

Mahagyo, R.P., Molling, P.A. and Hidayaturrobi, A.D. 2010. Review of Baseline Geochemical Model and the Impact of Production at the Darajat Geothermal Field, Indonesia. Proceedings, World Geothermal Congress