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New Gas Geothermometers for the Prediction of Subsurface Geothermal Temperatures: An Optimized Application of Artificial Neural Networks and Geochemometric Analysis

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Abstract : Four new gas geothermometers have been derived from a multivariate geo chemometric analysis of a geothermal fluid chemistry database, two of which use the natural logarithm of CO_2 and H2S concentrations (mmol/mol), respectively, and the other two use the natural logarithm of the H_2S/H_2 and CO_2/H_2 ratios. As a strict compilation criterion, the database was created with gas-phase composition of fluids and bottomhole temperatures (BHTM) measured in producing wells. The calibration of the geothermometers was based on the geochemical relationship existing between the gas-phase composition of well discharges and the equilibrium temperatures measured at bottomhole conditions. Multivariate statistical analysis together with the use of artificial neural networks (ANN) was successfully applied for correlating the gas-phase compositions and the BHTM. The predicted or simulated bottomhole temperatures (BHTANN), defined as output neurons or simulation targets, were statistically compared with measured temperatures (BHTM). The coefficients of the new geothermometers were obtained from an optimized self-adjusting training algorithm applied to approximately 2,080 ANN architectures with 15,000 simulation iterations each one. The self-adjusting training algorithm used the well-known Levenberg-Marquardt model, which was used to calculate: (i) the number of neurons of the hidden layer; (ii) the training factor and the training patterns of the ANN; (iii) the linear correlation coefficient, R; (iv) the synaptic weighting coefficients; and (v) the statistical parameter, Root Mean Squared Error (RMSE) to evaluate the prediction performance between the BHTM and the simulated BHTANN. The prediction performance of the new gas geothermometers together with those predictions inferred from sixteen well-known gas geothermometers (previously developed) was statistically evaluated by using an external database for avoiding a bias problem. Statistical evaluation was performed through the analysis of the lowest RMSE values computed among the predictions of all the gas geothermometers. The new gas geothermometers developed in this work have been successfully used for predicting subsurface temperatures in high-temperature geothermal systems of Mexico (e.g., Los Azufres, Mich., Los Humeros, Pue., and Cerro Prieto, B.C.) as well as in a blind geothermal system (known as Acoculco, Puebla). The last results of the gas geothermometers (inferred from gas-phase compositions of soil-gas bubble emissions) compare well with the temperature measured in two wells of the blind geothermal system of Acoculco, Puebla (México). Details of this new development are outlined in the present research work. Acknowledgements: The authors acknowledge the funding received from CeMIE-Geo P09 project (SENER-CONACyT).

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