

An Integrated 3D Geological and Isothermal Modelling to Better Understand Geothermal Reservoir

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ABSTRACT

Conceptual models are usually made in 2D during the Exploration stage. The 2D model is generally limited to providing subsurface images, overcoming these limitations it is very important to use a 3D approach to improve understanding of subsurface conditions. This study presents some techniques to construct an integrated 3D model of a geothermal field. The geological setting of the field is defined from surface geological data. Identification of the reservoir area using the first appearance of the epidote and integrated with the static temperature of the well. Visualization of the 3D model in this study was made using Leapfrog Geothermal software. This 3D model can be used to help better understand the evolution of geothermal system, support drilling strategies and management of the resource.

1. INTRODUCTION

The key to the success of exploration is there is a clear perspective on the description of surface and subsurface conditions and understanding the characteristics of Geothermal systems in the area. The conceptual model of Geothermal systems is used to describe and illustrate the geological conditions and delineation of important processes that occur in a geothermal field. There is never one answer and conceptual models are used to explore different thoughts or options. The process is an iterative process to create a model, evaluate and update if required. Basically, a conceptual model is dynamic and is based on geoscientists and engineer's interpretation and the data to hand. The construction of a conceptual model must be updated as information increases.

The modelling software is needed to process and integrate geoscience data to simplify modelling. Leapfrog Geothermal software has been developed to model and visualize geothermal systems in 3D. The technology was originally developed for the mining industry (Cowan and Beatson, 2002) but recently the technology has been adapted for the geothermal industry (Milicich et al., 2010).

There are two basic forms of models. Firstly, there are discrete models which describe quantities that occur in discontinuous units such as geology and alteration. Secondly there are continuous models that describe numeric quantities such as temperature, pressure, contaminant levels etc. (Newson et al., 2012).

2. METHOD

Leapfrog Geothermal uses fast 3D interpolation to derive a continuous function from the data which is evaluated at any point in the model (Alcaraz et al., 2015). The model is created by combining geological maps and cross sections that are digitized using polyline. The 3D conceptual model built on this paper uses data from a published paper PGE by Prasetyo et al., 2015. The data used to create the 3D isothermal model is data PGE from Gunawan, 2016.

3. RESULT AND DISCUSSION

3.1. 3D Geological Model

The study area in this research is around Soputan Mountain, North Sulawesi Province. The 3D geological model is created by combining geological map and cross sections that are digitized using polyline. Figure 1 shows the workflow to build 3D geological model.

3.1.1. Topography

The first step to create the topography is importing the topography point from DTM/DEM data. The result of importing topography data shows in Figure 2. Next step is creating the topography from point. The Topography surface in Leapfrog is unique relative to other surfaces in Leapfrog in 2 ways (Leapfrog Geothermal Fundamentals):

- The Topography surface will automatically act as the upper boundary of 3D model
- All GIS data in the model is automatically draped onto the Topography surface providing it with reliable elevation data

3.1.2. Geological Map

Figure 3 and Figure 4 is a geological map and cross section that was made by Ganda and Sunaryo (as cited in Prasetyo, 2015) and further detailed study of the structure was added by Siahaan (as cited in Prasetyo, 2015). The geological studies divided the lithology into 7 different formations (Prasetyo 2015):

- Tondano Formation (Tt): Interlayers of pyroclastic breccias, andesite lava, and tuff. These rocks carved the morphology on the south eastern part of the field. This lithology is the oldest unit in the field.
- Tondano Tuff (Tf): This unit comprise mainly tuff and pumice formed during the formation of the Tondano caldera. It can be compared to ignimbrite that formed during the erratic explosion of Tondano volcano.
- Lengkoan Lava (Qlk): Lengkoan mountain range is located on the northern side and consist mainly of andesite lava.
- Rindengan 1 (Qrd1): A series of interbedded layers of pyroclastic breccia, lapilli, tuff. This unit forms the flat morphology and covers the most part of the prospect area.
- Rindengan 2 (Qrd2): Interlayers of andesite lava and breccia; volcanic bomb and lapilli from proximals to the Rindengan mountain.
- Sempu (Qsp): Interbedded layers of pyroclastic breccias and andesite lava from Sempu volcanic centre located in the south part of the map.
- Tondano Lake deposit (Qal): Alluvium and lake deposit that consists of fine grain sandstone with thin layer of tuff. These sediments occur in the vicinity of Lake Tondano on the eastern side of the map.

The surface of model is digitized from the geological map using polyline tools, the results shown in Figure 5.

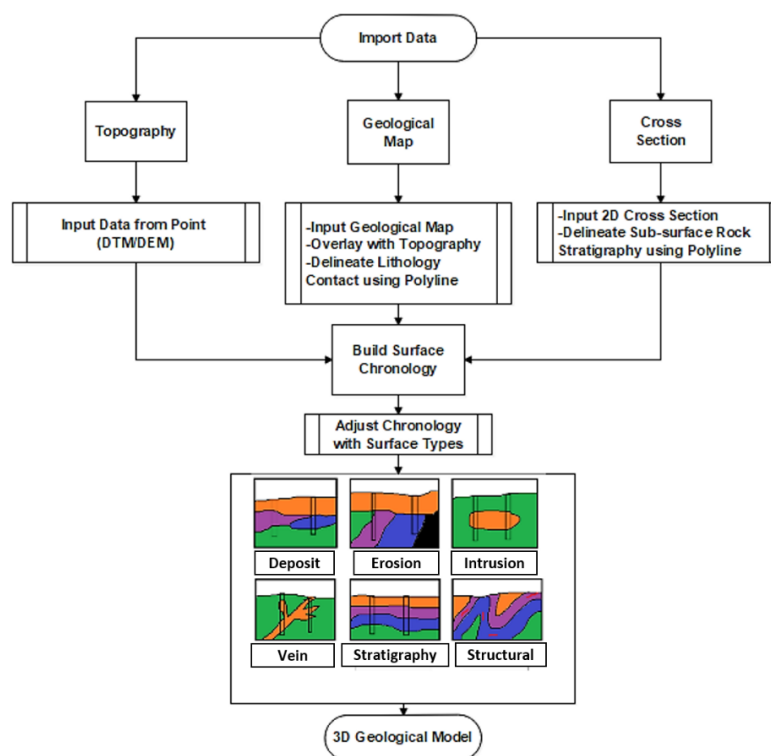


Figure 1: Workflow to Build 3D Geological Model (Ponggohong, 2019)

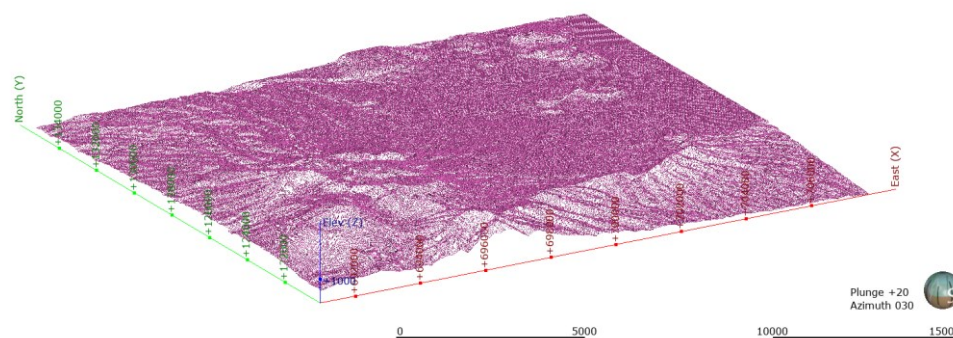


Figure 2: Topography Point from DEM Data

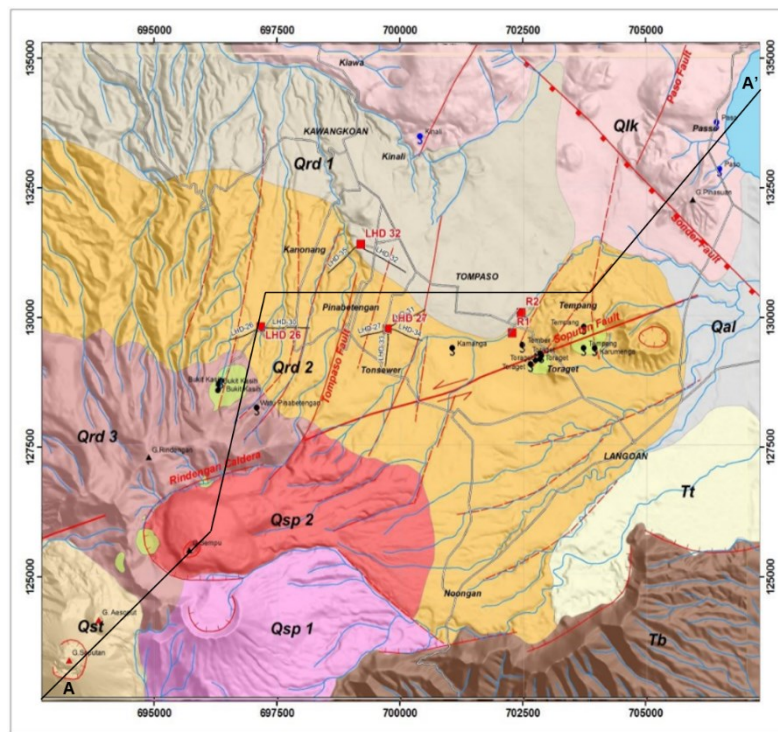


Figure 3: Geological Map of Study Area (modified from Prasetyo, 2015)

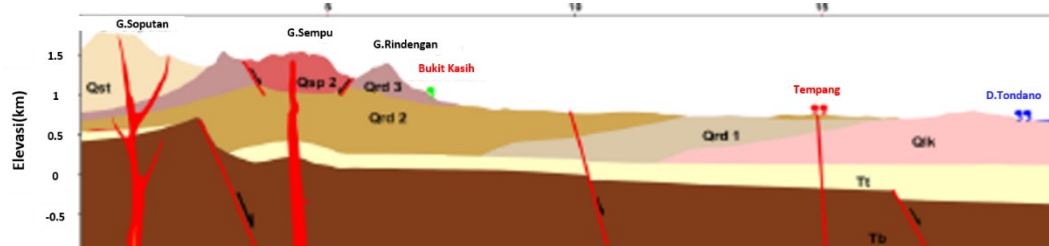


Figure 4: Cross Section of Study Area (modified from Prasetyo, 2015)

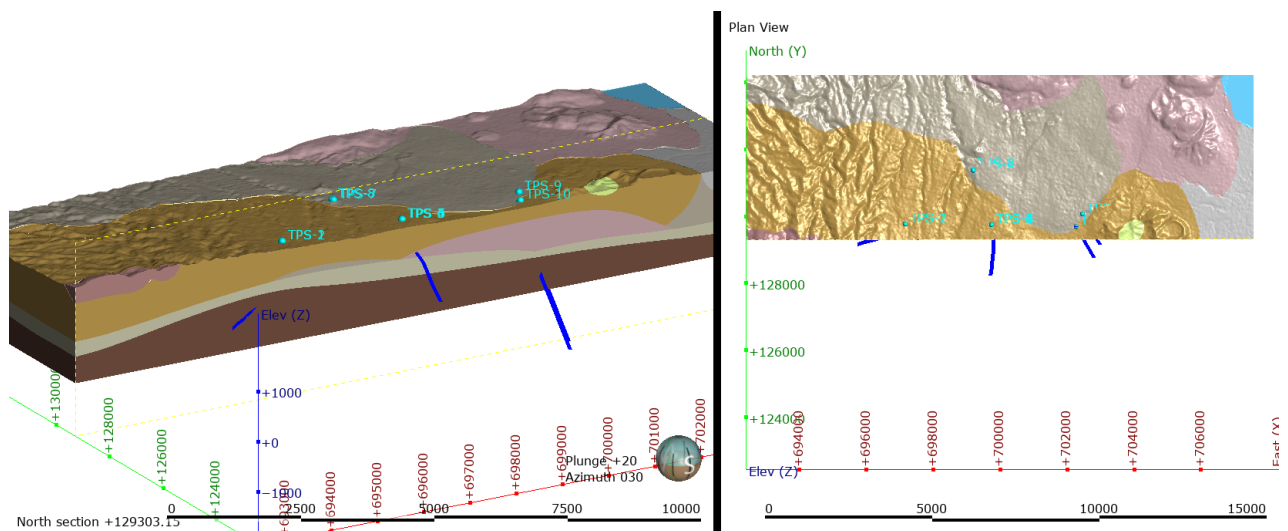


Figure 5: Volume of the 3D Geological Model

3.2. 3D Isothermal Model

The 3D isothermal modeled based on temperature data PGE from Gunawan, 2016 (Figure 6). The temperature value of the digitization can be different from the temperature value of the actual measurement, but this digitizing follows the temperature slope pattern so that even though the measurement value is different, the result of the isothermal pattern will remain the same. This isothermal model boundary is only adjusted to the area around the well. The isothermal model in Figure 7 will automatically adjust to the well trajectory.

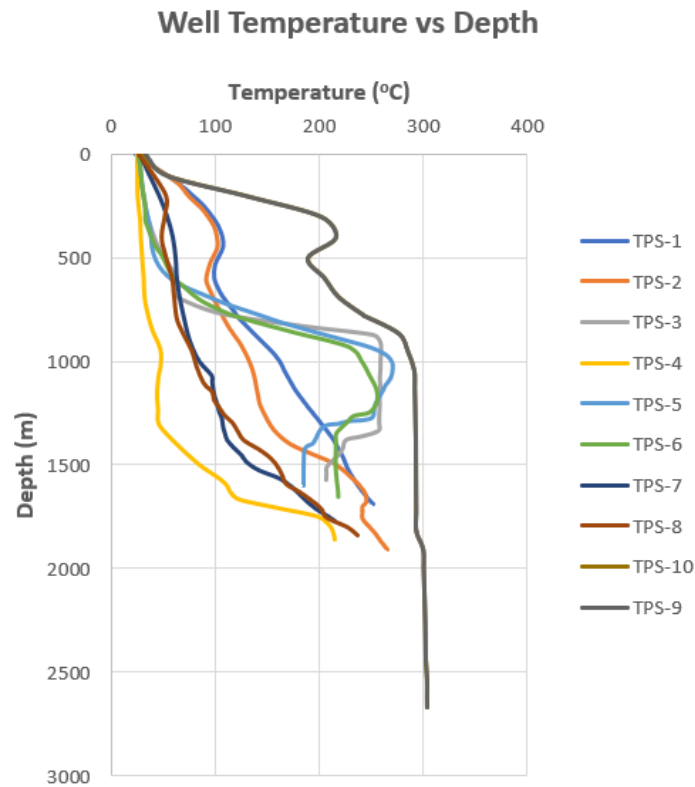


Figure 6: Well Temperature vs Depth in Study Area (modified from Gunawan, 2016)

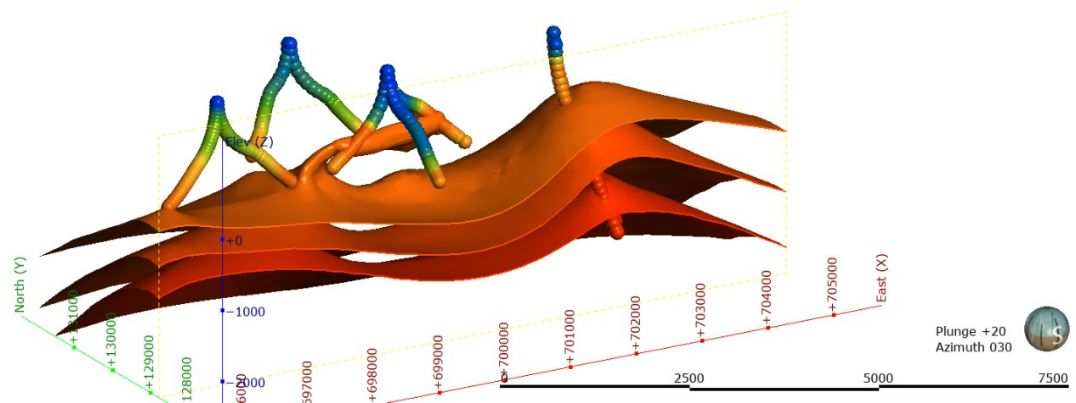


Figure 7: 3D Isothermal Model shows temperature 250°C, 280°C, and 300°C

3.3 Geothermal Caprock

Generally, the upper boundary of the geothermal reservoir in the study area varies from elevation 500 – 1000 masl. Reservoir thickness based on vertical and lateral cross section resistivity of 2D inversion results vary from about 750 – 1250 m (Gunawan, 2016). The dimension of the caprock in study area area ensured by the MT method (unpublished data). Indication of caprock is estimated to be at $<10 \Omega\text{m}$ resistivity. The presence of caprock is under Clusters TPS-1 and TPS-3 then thinned between Clusters TPS-3 and TPS-9 (Figure 8). This thinning hood is correlated with the identification of the structure that separates Bukit Kasih system (western area) and Toraget system (eastern area). This suggests that there are 2 different reservoirs in the study area.

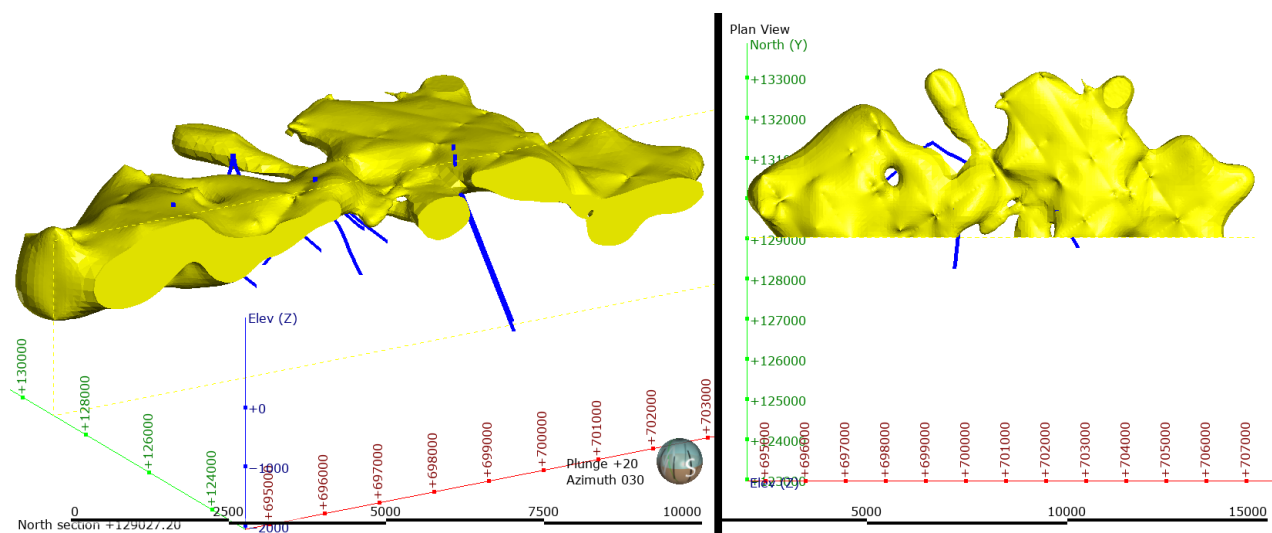


Figure 8: Low Resistivity Zone Identified as A Caprock

3.4 Geothermal Reservoir

Estimated reservoir area integrates temperature data, caprock, and first epidote appearance. Epidote is a hydrothermal alteration mineral that characterizes high temperature zones (Reyes et al., 1993). First epidote found on varying depth 100 mbsl – 900 mbsl. First epidote appearance shown in Figure 9 (red colour).

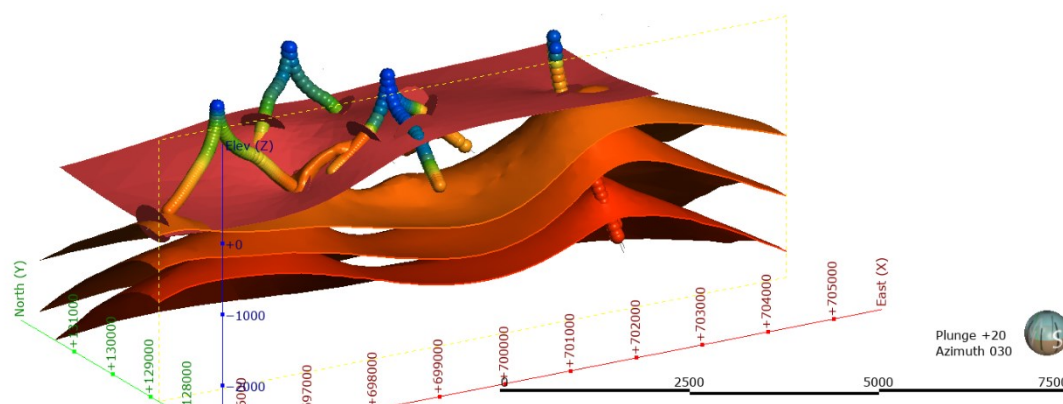


Figure 9: First Epidote Appearance

Based on first epidote appearance and static temperature (250°C), it is estimated that top of reservoir is at depth 0 – 500 mbsl. In this study the reservoir thickness was modeled to the depth of the well. Geometry of reservoir show in Figure 10.

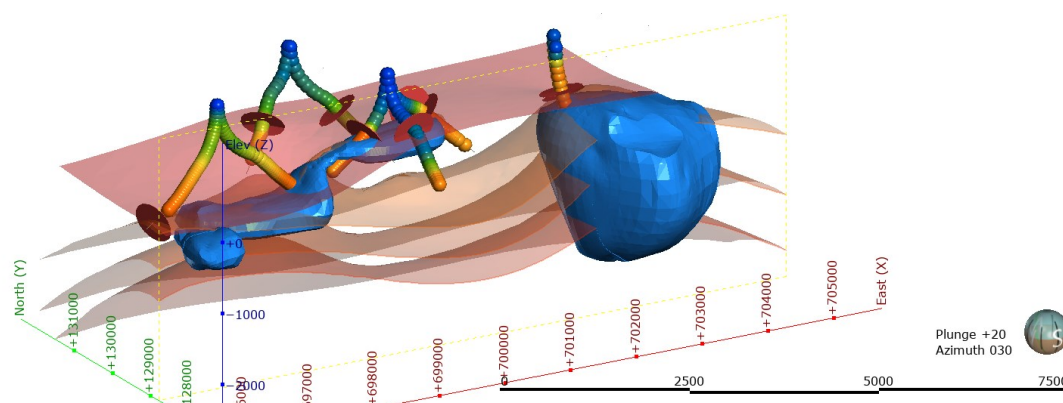


Figure 10: Estimated Reservoir Area

4. CONCLUSION

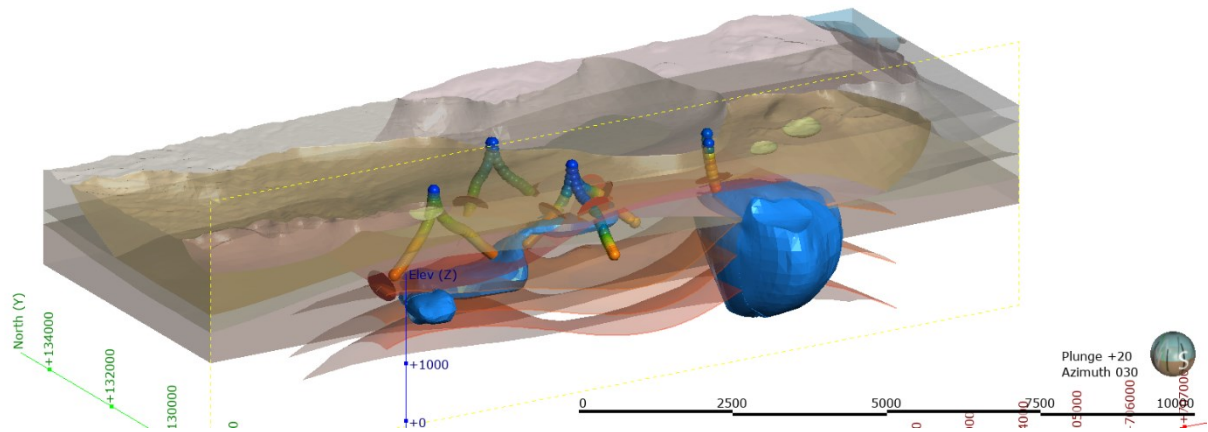


Figure 11: Integration 3D Model

Figure 5, 6, and 7 shows static temperature has a relationship with the first epidote appearance, this indicates that the geothermal system in this area is categorized as recent geothermal system and has not undergone a cooling process. Based on isothermal pattern and low resistivity zone it can be concluded that not all areas with high temperature have good permeability as a reservoir. This 3D model can be updated as data increases. More data is obtained, better models can be made.

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REFERENCES

- Alcaraz, S. A., Chambefort, I., Pearson, R., & Cantwell, A.: An Integrated Approach to 3-D Modelling to Better Understand Geothermal Reservoirs, *Proceedings*, World Geothermal Congress 2015, Melbourne, Australia, (2015).
- Cowan, J., and Beatson, R.: Rapid geological modelling, *Extended Abstract*, Applied Structural Geology for Mineral Exploration and Mining, International Symposium, (2002).
- Gunawan, F.: Rencana Pengembangan Panas Bumi Lapangan Tompaso Sulawesi Utara dengan Simulasi Reservoir, (*Unpublished Thesis*) Institut Teknologi Bandung, (2016).
- Milicich, S. D., Dam, M. A. Van, Rosenberg, M. D., Rae, A. J., and Bignall, G.: "Earth Research" 3-Dimensional Geological Modelling of Geothermal Systems in New Zealand – a New Visualisation Tool, *Proceedings* World Geothermal Congress 2010, Bali, Indonesia, (2010).
- Newson, J., Mannington, W., Sepulveda, F., Lane, R., Pascoe, R., Clearwater, E., and Sullivan, M. J. O.: Application of 3D Modelling and Visualization Software to Reservoir Simulation: Leapfrog Geothermal and TOUGH2, *Proceeding* 37th Workshop on Geothermal Reservoir Engineering, Stanford, California, USA. (2012).
- Ponggohong, C. R. I., Suryantini, Pratama, A. B.: 3D Geological Modelling Workflow using Leapfrog Geothermal: Preliminary Stage, *Proceedings* 7th Indonesia International Geothermal Convention & Exhibition (IIGCE) 2019, Jakarta, Indonesia, (2019).
- Prasetyo, I. M., Koestono, H., and Thamrin, M. H.: Clay Alteration Study from Wells of Tompaso Geothermal Field, North Sulawesi, Indonesia, *Proceedings* World Geothermal Congress 2015, Melbourne, Australia, (2015).
- Seequent : Leapfrog Geothermal Fundamentals.