The Value of 3D Models in the Communication and Advancement of Geothermal Projects

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ABSTRACT

The success of a geothermal project relies on the collaboration and agreement of many different domains including investors, local communities, environmental impact, and government bodies. A challenge in moving a project forward is the communication of the subsurface characterization of the resource outside the geoscience community. The ability to visualize interpretations of the subsurface in 3D can facilitate communication across these domains and advise the decision-making of the project as it progresses into the drilling and production phases. The Abaya geothermal project, conducted by Reykjavík Geothermal (RG), an Icelandic geothermal development company has integrated geoscience data collected through numerous and extensive field campaigns into a holistic 3D conceptual model. The presentation of this model in various formats has facilitated understanding of the geothermal potential in a manner that is received easily from audiences regardless of background or previous experience with a geothermal conceptual model. The usefulness of 3D modelling as an effective visualization and communication tool applies not only to the drilling and production phases of a project, but to cascading direct use in the local community once the project is connected to the grid. At all development stages, being able to provide a baseline level of understanding through visualization has potential to increase the receptiveness of a project, and allows conversations and decision-making to be more efficient, purposeful and valuable.

1. Introduction

Geothermal development is a process requiring many different operating parts, from greenfield to production. Like in mining and oil and gas exploration, bringing a geothermal project from greenfield surface exploration to production is an interdisciplinary process with stakeholders ranging from geoscience, engineering, project financing, project management, policy, local communities, the academic community, and environmental and governmental bodies that all play an important role throughout the lifetime of a geothermal energy project. The key to the technical success of the project lies in the collection and understanding of
geoscientific information, while the overall cohesiveness of the different stakeholders is required for the success of the project (Stewart and Lewis 2017). The progressive interaction of this multi-disciplinary team is critical for the project to succeed with the least amount of delays; however, this cohesiveness is sometimes overlooked. Effectively communicating about the project to the different stakeholder domains is the key to smooth collaboration and project advancement. Communicating about geothermal projects may prove to have its challenges as geothermal is often perceived to have a certain intangibility due to its subsurface nature, and its unfamiliarity relative to its energy exploration ‘cousins’, mining and oil and gas (Stewart and Lewis 2017). However, an effective way to facilitate knowledge to the different domains is by communicating with the visual aid of a conceptual model of the project.

Conventionally, a conceptual model is created during the surface exploration phase of a geothermal project and is presented as a single or series of 2D cross-sectional images typically depicting the recharge, reservoir, temperature isotherms, fluid flow and ideal drilling targets. The conceptual model by nature is a collection of the data obtained in the surface exploration phase of the project. The use of a 3D conceptual model provides an extra dimension that is effective in conveying the spatial distance of geo-objects and allows the viewer to get a holistic interpretation of the surface and subsurface from multiple angles and vantage points. The 3D aspect of the model is valuable as it can provide the spatial awareness that can be lacking in a 2D interpretation (Figure 1). 3D conceptual models have recently become an industry standard in geothermal development and have shown to be useful for communication at all stages of a project, from surface exploration, drilling and cascade use.

Figure 1: (Top) A 2D conceptual cross-section taken from the Abaya geothermal project (Guðbrandsson et al. 2019). The cross-section is annotated to depict subsurface heat and fluid flow in the area of
interest, with the faulting resistivity in the area. (Bottom) The same conceptual cross-section from Abaya as shown in the above image, within the 3D model for spatial reference. The conceptual model area is shown with faulting surfaces that have been modelled in 3D, with surfaces representing the top and bottom of the clay cap as interpreted from 1D MT data by RG’s senior geophysicist. The lithological model is present and translucent to show the cross-section, and the Digital Elevation Model of the area can also be seen with an overlain geological map.

It has been found it to be effective to personalize the approach to communicating the project in regard to the audience. Corresponding to this need, while the 3D conceptual model can be regarded as a platform to visualize the interconnectivity of all the data of the project it is also flexible in its presentation to emphasize upon the different needs and interests of various stakeholders. The Abaya Geothermal Project in Ethiopia operated by Reykjavík Geothermal (RG) was chosen as an example for this paper. Throughout this paper, RG also draws experiences from modelling that they have done in the Caribbean, Mexico, and the Ethiopian geothermal projects, Corbetti and Tulu Moye.

2. The Abaya Geothermal Project

The Abaya geothermal project is the third of RG’s geothermal projects in Ethiopia, following Tulu Moye and Corbetti. Residing on the western flank of the Southern Main Ethiopian Rift (SMER), the concession is directly above Lake Abaya, in what is known as the Southern Nations, Nationalities and Peoples’ Region (SNNPR) and is located approximately 280 km southwest from the country’s capital, Addis Ababa (Figure 2).

Through numerous and extensive field campaigns from 2018-2019, RG has been compiling GIS, geological, geochemical and geophysical data of the Abaya geothermal prospect in the
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aim of creating a scientific foundation to characterize the geothermal production potential of the area. Geochemical sampling of thermal manifestations, subsurface fault characterization, structural ground-truthing, rock sampling, soil-gas analysis and an MT/TEM survey provide the data to create a conceptual model (Eysteinsson 2019)(Guðbrandsson et al. 2019). Collected data suggests the Abaya region to be a high-enthalpy geothermal prospect. The collected data was integrated into a holistic 3D model using the software Leapfrog Geothermal, by Seequent (Alcaraz et al. 2011)(Cowan et al. 2002) (Figure 3).

![3D Lithological Model](image)

**Figure 3:** The 3D lithological model of the Reykjavík Geothermal Abaya geothermal project concession, Ethiopia.

The 3D model has proven to be a useful tool in communicating the project from both academic and business perspectives. Data visualization in a 3D movie-format can be created within the Leapfrog program itself and provides a means to clearly visualize key characterizations of a geothermal project, such as clay cap extent and thickness, faulting structure which can indicate areas of possible permeability, and planned wells for exploratory drilling. The Abaya model has been presented at academic and industry conferences, and governmental reports through organizations such as the Ethiopian Energy Authority (EEA) and the Geothermal Risk Mitigation Facility (GRMF). The ability to generate cross sections and other 2D medium also within Leapfrog saves time and allows adaptability in what is desired by the users to be shown in a presentation. As more data is collected and the model refined, and because of the dynamic nature of Leapfrog and the integration of communicating mediums into the same software as the model, the communicating mediums such as the movies are updated automatically with the model.

The presentation of the model will continue to play a role in communicating the Abaya Geothermal Prospect in various settings, such as future conferences, social and environmental matters, and stakeholder meetings, for the purpose of communicating the energy potential of Abaya, while also presenting its impact to local communities and businesses.
3. Using a 3D Conceptual Model as a Communication Tool

The following are examples and observations of how 3D conceptual modelling has aided in the communication of geothermal projects to different disciplinary groups.

3.1 Surface Exploration

A geothermal project typically begins with limited to no data regarding the geothermal potential of the prospect. In the first stages of the project, known as surface exploration, it is the responsibility of the geoscience team to collect data from the license area in order to gain insight of the mechanisms of the subsurface and to determine the best area and subsurface targets for exploratory drilling. The data collected includes but is not limited to the sampling and analysis of water, steam and altered ground, soil-gas and soil-temperature collection and analysis, petrological sampling and analysis, structural surveying of faulting and seismicity, and geophysical subsurface resistivity surveying in the form for MT and TEM. As the data is collected, processed, analyzed and updated, viewing the existing data all together in a 3D model format can provide a useful visualization of where data exists, where data is required for further subsurface characterization, and what changes have occurred in the assessment of the resource when a particular data stream is updated with additional data (Nusantara et al. 2017). In the case of RG, the 3D models of various projects are often referred to and viewed together as a team with the use of a larger display screen, allowing for easy, open viewing and discussion between the geoscience, engineering and technical, and project management teams. A 3D visualization is valuable for the geoscience team to assess the project, make hypotheses, and view different hypotheses side by side for comparison. This capability allows for a holistic evaluation to base decisions and strategy for further data collection and assessment.

3.2 Engineering and Technical

As a geothermal project progresses past the surface exploration phase, more emphasis is placed on technical matters focused on exploratory drilling and fore fronted by engineers and geoscientists. It is the responsibility of the geoscience team to determine from collected surface and subsurface data the optimal subsurface target for exploratory drilling, while it is the engineer’s responsibility to design the borehole to intercept the target. The engineers and geoscientists then collaborate and make decisions on the design and location of exploratory and potential production geothermal wells, injection wells, and the locations of drilling elements such as the drill site area, required roads, well pads, drilling rig, sump pit, piping, etc. A 3D model allows the assessment of any changes in well design or drilling factor to be observed in relation to other subsurface geo-objects, such as faulting or low resistivity. In these situations, it has proven to be extremely useful to provide model images that depict the changes and compare them to one another so that they can be analyzed at the same time in the vicinity of the same surrounding sub-surface elements (Figure 4). It is this side-by-side comparison that allows the team to pinpoint the best solution(s) to technical questions.
3.3 Governmental Entities and Government Financing

Financing geothermal projects can come with their own set of challenges. Many geothermal projects rely partially on financial support from governmental organizations in the form of grants or similar incentives. The Abaya project was financed with the support of the Geothermal Risk Mitigation Facility (GRMF) for Eastern Africa, a program that co-finance surface studies and drilling programs for geothermal energy projects and is a collaboration between the African Union Commission (AUC), the German Federal Ministry for Economic Cooperation and Development (BMZ), and the EU-Africa Infrastructure Trust Fund (EU ITF). Communicating with these kinds of entities are commonly in the form of an extensive written report that goes into detail on each aspect of the surface exploration of a geothermal project. Many maps are collected showcasing various data that is requested. In this scenario, an effective use for the 3D conceptual model has been both as image files of the model and also a presentation in video format, enabling to “tie together” the separate aspects of a geothermal project into a complete visualization that shows how the separate factors interact with one another within the geothermal prospect.
Governmental bodies typically show great interest in their energy projects and thus throughout the life of an energy project, communication to the respective governmental authorities is common. RG regularly communicates with the Ethiopian Energy Authority regarding the status of RG’s geothermal projects in Ethiopia. A full 3D conceptual model movie was designed and produced in Leapfrog Geothermal of the Abaya prospect, showcasing a compilation of the field data collected and resulting interpretations.

3.4 Project Financing

In the realm of project financing, presenting an understanding of the project risks along with a consideration of risk mitigation methods is a topic of great focus and importance. 3D modelling is a risk mitigation tool, allowing a well-rounded assessment of all collected data within one space, in a way that 2D does not provide. In these circumstances, it has been proven valuable to present each aspect of the created model, and to break it down into domains of geology (i.e. how the lithological and structural surfaces are created, from what data), geophysics (i.e. presentation of the magnetotelluric data and what this could tell us about the subsurface), and geochemistry (i.e. where the samples are taken and what this tells us about the regions of the license). At RG, this has been done by creating visualization videos showing how each domain has been constructed in 3D and what data was used. Assessing these geoscientific parameters with the use of a 3D visualization enables the audience to gain perspective and understanding of where and what the risks may be, based on the concentration of data within the project. Project risk is a major attribute in the decision making in a project financing process and therefore presenting a holistic model with better understanding of the risk facilitates the full assessment of the attractiveness of a project from the angles of both risk and reward.
3.5 Local Community

Presenting the project to the local community is of great importance as they are the ones that receive the highest impact in all the phases of the geothermal project, from exploration through production. Many locations that have geothermal potential in developing countries are in rural areas among small towns, villages, and largely agriculturally dominated societies. The Abaya project is located in an area where many close-knit agricultural communities exist, therefore it is important to keep the local community well informed to both the benefits and temporary inconveniences that may be affecting the population as the project develops, to earn their trust, collaboration and cooperation. It is in this regard where the geoscience aspect of a project blends with its environmental and social impact assessment. When communicating with the local community, it is not only important to explain to them about the geothermal prospect, but also how this would affect their overall quality of life such as land, people, flora and fauna and water supply to name a few. The 3D model is useful in presenting the geothermal potential and its subsurface constituents, with the 3D spatial aspect being useful for the audience in assessing how much of their land and community might be affected. Through modelling, images and videos can also be prepared that communicate how the locals may be affected.

3.6 Future Prospects (Cascade Use)

A high-temperature geothermal prospect is typically and rightfully regarded as an opportunity for sustainable and environmentally friendly baseline electricity production. This is especially valued in areas that may rely on imported oil or coal to meet their energy needs. However, any geothermal prospect also presents the opportunity to use the heat for other cascade uses in the industries of agriculture, tourism, or recreation, to further benefit local livelihood (Rubio-Mayá et al. 2015). Examples of this may be greenhouses, recreational spas, or geoparks that locals and visitors can enjoy (Prasetya et al. 2018). The conversations surrounding cascade use opportunities would include and attract a variety audience of stakeholders such as the local community, government, and project financing and investment. Webinars and conferences are a common way to express ideas as such, and in these kinds of presentations the geothermal potential from a geoscientific standpoint is commonly shown as a foundational backdrop. Having an image or short video of the 3D visualization to present the geothermal potential would be the quickest, most efficient way to get a varied audience on the same baseline understanding of the surface and subsurface scientific workings of the geothermal project. This would create the stage for the further discussion of the possibilities of cascade use, and where these opportunities may present themselves within the project.

3.7 Geoscientific Academia

Opportunities such as conferences or webinars occur regularly during the life of a geothermal project and provide a chance to communicate about the project to the scientific community. Presentations in this manner often call for high-detail explanation and discussion of the geological, geochemical and geophysical aspects of the surface and subsurface of the geothermal prospect. With such in-depth presentations, using image snapshots of focal points of the model, and then combining all of the features into a video presentation of the model has proven to be an effective way to present ideas and findings. RG has presented the Abaya project in this manner at the 2018 Rift Volcanism Conference (RiftVolc) and the Geothermal
Resources Council’s (GRC) 42nd Annual Meeting in 2019. This method bridges together various focus areas and their spatial position in the project in relation to other focal points. It is through the presentation of the 3D model where the relationship between the three geoscience domains can most clearly be seen and analyzed.

4. Model Feedback

It has been from our experience that presenting a 3D model to communicate about a project has resulted in positive feedback from respective audiences. The various ways that a 3D model may be presented has enhanced understanding of the geothermal prospect in question, catalyzing valuable questions and insight that move a project forward.

Conclusion

Geothermal projects are complex, however useful tools have been emerging to assist in breaking down their complexity and enhancing understanding. 3D conceptual modelling achieves this objective. The 3D conceptual model of the Abaya geothermal prospect has been a useful communication tool in all the stages of the project thus far, from geoscience focused surface exploration to technical well planning. The model has also proven to be valuable in communicating to involved governmental organizations such as the GRMF and EEA. One of the values of having a 3D visualization is that it can be presented in different ways that customizes and enhances the message to the receiving audience. This is especially valuable in geothermal energy development as these projects require the collaboration of many different domains, which is directly related to the success of the project.
REFERENCES


