SPWLA FRANCE CHAPTER

Geothermal Energy Seminar

Friday 28th June 2024

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Title: New insights in geothermal reservoir using 3D far field sonic imaging

Leon Dahlhaus - SLB

Abstract:
Dipole sonic array measurements were used to help improve the understanding of the geometry of a geothermal aquifer by mapping the porous-permeable layers below and above a sub horizontal drain (named GGR5-ST1) in the Paris basin. Reflected shear wave events, recorded on azimuthal sonic sensors looking all around the wellbore, were extracted and a novel 3D far field sonic imaging technique was used to provide both migrated acoustic images as far as 35 meters away from the well bore, as well as bedding dip and orientation information. While confirming the overall aquifer geometry along the drain, this methodology also identified a series of unexpected steeper dipping events, likely attributed to the flanks of an ancient dune system.

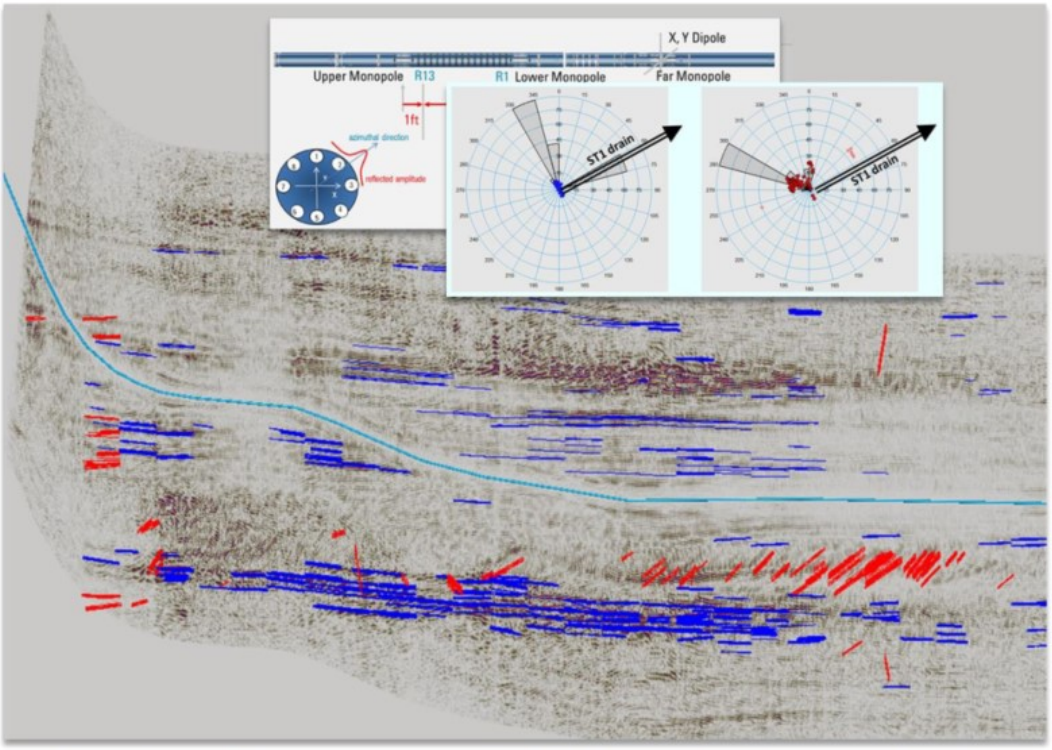


Figure 1 Vertical plane migration image with individually identified reflectors superimposed.

Presenter Bio:

Leon Dahlhaus is a petro-technical expert with more than 25 years' industry experience with SLB on a wide variety of borehole seismic and acoustics projects in various parts of the world. Currently based in the UK, he heads a geophysics processing and interpretation team, providing technical support, software development and training. Leon is a member of EAGE and SEG, and he loves the challenge of a good geoscience puzzle, always on the lookout for New Technology applications.

Title: Oblique reflections in Dogger aquifer below GGR5 well.

Benoit Vincent* (Cambridge carbonates), Nobuyasu Hirabayashi (SLB), Jeroen Jocker (SLB), Youri Hamon (IFPEN), Arnaud Loirat (Elyteq), Erik Wielemaker (SLB), Leon Dahlhaus (SLB), Rajeev Kumar (SLB) and Charles Naville (IFPEN).

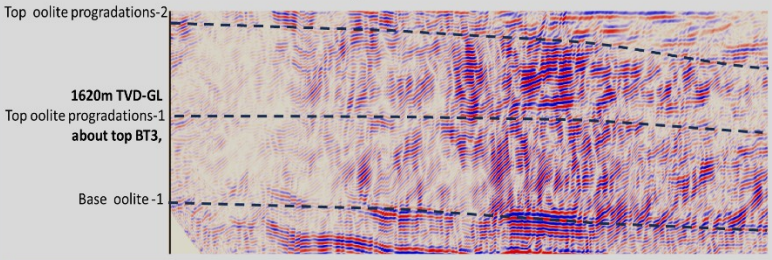
Abstract.

The dipole sonic scanner tool run in the subhorizontal geothermal (SH) well of Grigny GGR5 in April 2023 provided interesting images of a reflector population oblique to the main bedding and attributed to oolite progradation located in a depth interval from 4 to 7m below the SH drain, without intersecting the borehole. The prograding oblique reflections have been detected with a 7-15° Dip, towards an azimuth outside the near vertical plane containing the SH drain and orthogonal to the subhorizontal bedding of the carbonate Dogger aquifer, thanks to the automated sonic imaging (ASI) processing of the 8 azimuthal sensors located on each of the 13 receiver levels of the oriented array dipole sonic tool.

In February 2024, Schlumberger successfully improved the image of all dipole sonic reflectors in the SH well vicinity, up to a radial distance of 30-35m to the SH drain, with sharper reflector definition, reduced artefacts and more accurate coherency of all reflectors, either bedding reflectors subparallel to the SH drain, or oblique reflectors. What might have previously appeared as reflection "noise" to the interpreter is now attributed to a continuous succession of oblique reflectors located all along and below the 800m long horizontal extension of the SH drain.

The main bedding reflections, such as the top of Dogger carbonates, show an improved lateral coherency on the new S-S dipole sonic cross-sections. Moreover, the improved oblique reflection images exhibit various dip of the oblique reflectors, and two superposed layers of oblique reflections with different dips, located slightly above the bottom of the pilot hole (Fig.1). The proposed presentation includes a tentative description of the expected geological bodies observed, as the processing engineers of the array sonic data confirm the reliable capabilities of their imaging routines to reach detailed structural features (dip, azimuth, lateral image coherency, etc..) useful to geological description. Refined local study of the detailed local stratigraphy the geological bodies observed in the Grigny GGR5 vicinity might be potentially motivated, through a collaboration of industrial engineers with academic researchers. Curiously, the detailed sonic sections do not show any fault with metric throw similar to the ones present on the VSP image right below the deviated section of the GGR5 well, 150m laterally to the SW of the GGR5 pilot hole.

Figure 1



TWO episodes of prograding deposits CLEARLY appear with different obliquity.
Permeability occurs mainly in the lower oblique reflection layer (oolite-1, below Bt3),
Although the sonic, density, resistivity logs do not show significant decrease locally.

Presenter bio:

Benoit works as a Consultant Geologist with Cambridge Carbonates since 2009. He obtained his MSc and PhD at the University of Burgundy in Dijon (France) in the field of Sedimentary Geology. After a Post-Doctoral position, he joined the Institut Français du Pétrole (IFP) between 2002 and 2008 where he worked on sedimentology, stratigraphy, and diagenesis of carbonates, as well as on the impact of diagenesis on reservoir properties, mainly in the Middle East for O&G but also in Europe for CCS purposes. Benoit was lately employed as an expert Geologist in the Andra (French National Agency for Radioactive Waste Management).

Title: Development of geothermal energy in areas with low transmissivity and/or in areas with a high density of operations. Well architectures to maximise heat extraction.

Pierre Ungemach, Miklos Antics, Gillian Bethune, Maxence Gaillard- GPC IP/GEOFLUID

Abstract:

Energy transition policies implemented recently in France acted as a strong stimulus by targeting a quasi two fold increase in heat production from deep seated geothermal reservoirs.
Clearly the message means that the Dogger (Mid Jurassic) carbonate rocks, a dependable hot water resource of regional extent supplying, via 50 doublets and grids, ca 1,500 GWhth/year to the Paris suburban areas, the world's largest Geothermal District Heating operated to date, will have its capacity doubled by the scheduled 30 new doublets, each rated 50,000 MWhth/year.
The ambitioned goals required appropriate well designs taking advantage of the multilayered reservoir structure, a distinctive attribute of a number of sedimentary settings securing both thermal longevity along well to reservoir exposure. Another concern addressed the reclamation of moderately to poorly productive areas, which otherwise would have remained unchallenged.
The so-called subhorizontal (SH) well concept was initiated on the Cachan, moderately performant (15 Dm transmissivity) site, South of Paris, with a view to replace two, 33 year old doublets, cumulating 350 m3/h nominal production. The philosophy behind the concept aimed at intersecting via a step wise, en echelon type, trajectory, the layering sequence inferred from either temperature/flowmeter (PLT) logs on offset wells or straightforwardly from direct drilling assessment.
Trajectories both landed at top reservoir at 85 to 88° angles easing the geosteering process securing low DLS's by avoiding sharp angles. RSS(Rotary Steerable System), MWD, LWD, PDC bits equipped the BHA (Bottom Hole Assembly) complemented by XRF/XRD analysis performed on cuttings, allowing to anticipate the bit position ahead from LWD information. The first geothermal SHW doublet awarded as a world premiere achieved 450 m3/h production and operates safely 4 years after completion of two 1 km long drains.
The concept replicated in 2022 on a poorly productive (10 Dm transmissivity) site achieved similar performances thanks to a modified Ecoscope/Periscope HD (SLBä) geosteering BHA, confirming the pilot hole strategy as non essential.
Typical programmes and workflows along architecture modelling are documented. Technological and economic issues are also discussed.

Title: Celsius - Shallow Geothermal Integrated Systems

Ombline Le Maréchal & Hugo Mantel

Abstract:

Celsius Energy (an SLB-company) provides heating and cooling to buildings by designing, constructing and delivering shallow geothermal integrated systems.
Our systems must comply with the site and environmental/industrial constraints to preserve resources and minimize the risk of geotechnical problems and subsoil pollution.
Two main types of shallow geothermal (geoenergy) installations exist:

- Closed-loops systems- with the circulation of a coolant-fluid within the HDPE U-pipes,
- Open-loops systems with the aquifer groundwater production between injection and production wells.

Celsius Energy conducts pre-feasibility, feasibility, and executive studies by estimating the building needs (heating, cooling, hot water) and the thermal properties of the soil, and then refining the installation according to the BHE-drilled geometry and the measured thermal properties (average temperature of the soils, thermal conductivity, ...).
Celsius Energy designs and builds the Borehole Heat Exchangers (BHE) installation and the related Technical Building Room (TRB) which responds to the site/client constraints (ROI, CO2, final energy). Celsius Energy also provides a digital energy management system managed by an embedded computing system.
The BHE team designs the geometry of the exchanger, propose the bottom hole assembly according to the estimated lithological column to the driller, prepare the executive plans, determine the geotechnical conditions to implement the drilling platform, validate the well-testing (circulation and pressure testing, direction and inclination measurements, fiber optic heating to assess the cementing phase, thermal response test to determine the thermal properties of the soil, lithological assessment of the drilling cuttings, ...)
More than 95% of France's metropolitan area is subject to geothermal energy. Celsius Energy's mission is to connect buildings to the earth to develop low-carbon constructions on a large scale and minimize climate change. The shallow geothermal activities allow to reduce the CO2 emissions from heating and cooling demands up to 90% and to cut the energy bill by 60%.

Presenter Bio:
Ombline Le Maréchal is the Geologist Team Lead, within the Operation Team in Celsius Energy.
She is involved in underground operations with a team of geological and hydrogeological engineers who are responsible for designing the borehole heat exchanger and monitoring the construction right through to commissioning.
Ombline is a senior hydrogeological engineer with a degree from the Ecole Nationale Supérieure de Géologie, and specialized in water and environmental management at the École Polytechnique de Montréal.

Title: Integrated modelling of an EGS site, from concept to production: the case of Utah FORGE

Giovanni Sosio*, Sri Mulyani, Lesly Gutierrez-Sosa, Abdul Muqtadir Khan

Abstract:
Enhanced Geothermal Systems (EGS) have the potential to accelerate geothermal energy development beyond the traditional hydrothermal regions. The importance of appropriate geoengineering to achieve sustainable development of EGS demands, more than ever, accurate predictions to ensure successful technical, operational and economic feasibility. Understanding, characterisation, and modelling of EGS are challenging because of geological, structural, and mechanical complexity, before and after injection, production and stimulation operations. To forecast energy production and injection operations requires robust characterisation and modelling approaches within the different geosciences and engineering disciplines. The integrated multi-disciplinary approach accounts for key aspects of the geoscience and engineering domains while preserving consistency across multiple modelling stages.

The Utah Frontier Observatory for Research in Geothermal Energy (FORGE) is an underground field laboratory for developing, testing, and accelerating breakthroughs in EGS technologies. The FORGE project provides public access to geothermal data resources that can be used in characterisation and modelling studies, to promote the understanding of EGS worldwide.
We will present an integrated modelling approach for field scale studies carried out on our FORGE synthetic model. The proposed end-to-end approach consists of a multi-stage workflow:
(1) Characterisation of natural fracture networks through wireline, borehole and core data interpretation.
(2) Geological modelling, integrating a diverse dataset (including surface lineaments, non-seismic geophysical surveys, well data and conceptual models) to describe the site's structure, lithology, rock properties, fracture distribution and temperature.
(3) Hydrodynamic modelling (natural state modelling): implementation of thermal boundary conditions together with the hypothesised conceptual temperature, pressure and saturation model, to obtain the initial state of the system as a starting point for diverse forecast scenarios under different operating conditions.
(4) Modelling engineered EGS operations (post-initial state): stimulation design integrating geomechanical models, natural and induced fracture interaction models, and stimulation engineering constraints (such as pumping strategy and fluid and proppant properties) to forecast fracture propagation geometry and its effect on injection-production operations. Fracture modelling involves a detailed calibration loop (stress and leak-off model) based on downhole measurements such as microseismic.

The proposed end-to-end workflow allows building sound geological and engineering models that can provide representative predictions of the performance of the EGS development plans, and thus identify and assess the associated risks to support reservoir management decisions.

Presenter Bio:
*Giovanni Sosio is a senior geoscientist at SLB. After graduating in environmental engineering and applied geophysics in Milan, he joined Schlumberger as a wireline engineer in 2005. He has held positions as software support engineer, CO2 storage geomodeler, technical sales engineer, team leader, consulting project manager, as well as business development lead for Celsius Energy and subsurface technology lead for deep geothermal energy. Living in France since 2009, he is based at the Schlumberger-Riboud center in Clamart. He presents this work on behalf of several colleagues from SLB across three continents.

Title: HF-HR VSP results in geothermal GGR5 well

Charles Naville*(IFPEN), James Bailey (VSPROWESS), Mary Humphries (VSPROWESS), Joséphine Vicelli (CDPconsulting), Frank Hanot (CDPconsulting), Sebastien Soulas (ASL).

Abstract

Defining 5m thin, or even thinner, porous reservoir beds was the feasibility objective assigned to the High Frequency/High Resolution (HF/HR) look ahead VSP survey to be recorded in the deviated section of a geothermal production well drilled down to the top of the carbonate Dogger aquifer in the Paris basin, around 1500m in vertical depth, with a landing angle of 65°. The idea was to predict the depth of the first porous bed to be drilled at high angle, to avoid directional drilling with sharp angles after setting a production casing at the top Dogger level. A 50-100m vertical depth range was targeted for the acoustic impedance to be predicted below the top Dogger carbonate aquifer. Despite the high frequencies emitted, the vertical resolution of intra-Dogger thin beds obtained by the VSP barely reached 10m, due to geological heterogeneities present in the propagation pathway. Besides, a Pilot Hole (PH) was drilled prior to the high angle leg to assess with full reliability the depth of productive thin beds to be subsequently drilled at high angle.

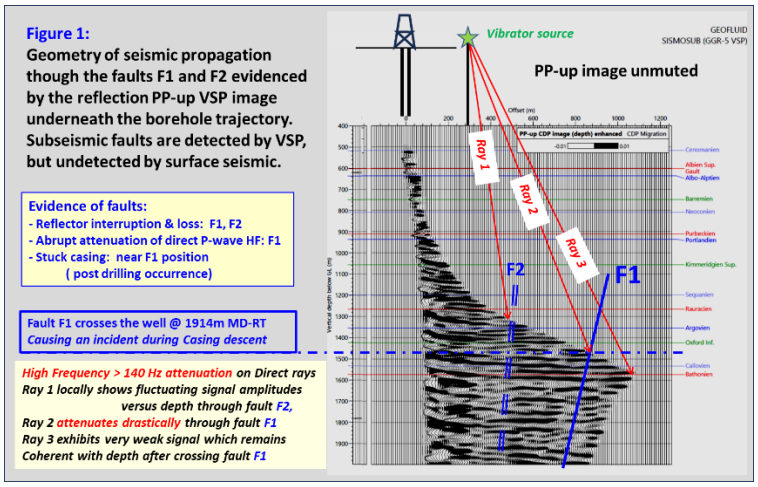
High Frequency (HF) VSP still represents a frontier seismic domain for which technical difficulties are piling up:

First, the surface fix source should be extremely repeatable and preferably delivers an increased amount of HF energy to compensate somehow for the high loss of seismic amplitudes at high frequency.

Second, downhole receiver tool or toolstring may not present a consistent fidelity of 3 component reception over the whole recording frequency range, due to mechanical coupling characteristics of the VSP tool hardware and the open borehole ruggedness; in cased hole, the mechanical coupling of the VSP tool to the formation is insured by a good cementing quality between casing and borehole wall.

Third, the physics of the seismic attenuation depends on several factors, including viscoelasticity and heterogeneity, potentially variable in depth and laterally to the wellbore. Additionally, the geometrical spreading represents the main factor of amplitude decay, independent from frequency, and can be estimated at VSP processing stage.

Unexpectedly, the VSP image produced underneath the deviated hole section evidenced a faulted structure. Abrupt amplitude losses of high frequencies above 120Hz occur where the direct P-wave ray crosses one of the confirmed minor faults: it demonstrates that deeply buried formation rocks reworked by tectonic action drastically and preferably attenuate high seismic frequencies (Fig.1).



Presenter Bio:

Charles Naville: Polytechnique-Paris 1973, ENSPM Engineer 1980, Geophysicist in CGG 1977-1989, field assignments in Gabon, USSR, USA, France. Geophysicist in IFPEN, 1990 to present. Experience in Surface seismic, reflection and long-range refraction. Borehole seismic / VSP & Full wave form sonic; VSP tool orientation; Drillbit SWD/RVSP; seismic integration.

Title: Full-wave inversion results for offset VSP data in geothermal GGR5 well

Christophe Barnes* (CYU), Charles Naville (IFPEN).

Abstract:

Borehole seismic is supposed to provide better image of the subsurface near the well, with better resolution, and more precise location of structures than surface seismic. However, the wavefield is often complex and difficult to exploit when using standard imaging techniques. The full-wave inversion (FWI) method applied to such well seismic data can extract a lot of information from the data, allowing both a thin image of structures and an estimate of physical parameters like the P- and S-wave velocities or the density of the rocks. The goal of the present study is to verify that the FWI can detect very thin porous reservoir beds below the geophone antenna from an offset VSP dataset with an expected thickness of 5-10 m. The data are from the HF/HR look ahead VSP survey recorded in the deviated section of a geothermal production well GGR5 drilled down to the top of the carbonate Dogger aquifer in the Paris basin.

The FWI approach is based on the seismic modeling of the wave equation through numerical methods. In the present study, the seismic modeling is achieved for a viscoelastic rheology, and we invert for the P- and S-wave velocities and density. Full-wave seismic modeling allows to reproduce the data with the correct geometrical spreading, the correct decay of seismic amplitude due to attenuation and all elastic effects. The results show that we can detect the thin porous reservoir in the upper part of the Dogger (see figure 1). These results are reproducible when modifying the FWI algorithm parameters, reinforcing their reliability.

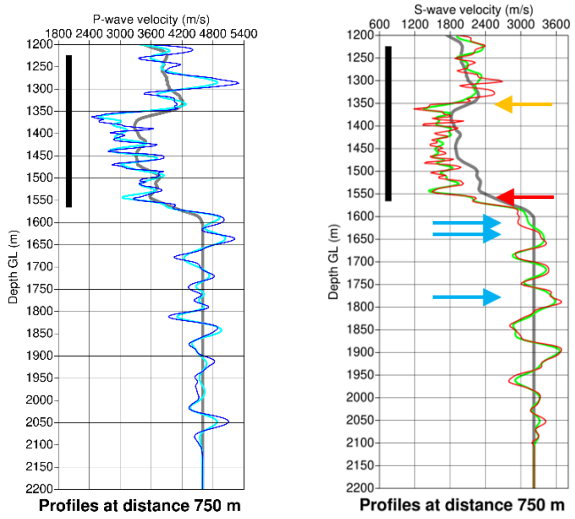


Figure 1: P- and S-wave velocity profiles at 750 m from the source. The blue/cyan and green/red lines are the results for 10-80 Hz and 10-120 Hz frequency bands respectively, the gray line is the initial profile and the thick black line the antenna. The Argovian and Bathonian tops, clearly marked, are indicated respectively by the orange and the red arrows. The thin layer with a lower velocity indicated by the blue arrow at 1615 m vertical depth coincides with the targeted porous thin bed.

Presenter Bio:

Christophe Barnes: Mines de Paris 1989; PhD in geophysics, IPGP, 1997. Associate professor at CYU and GIMlabs company CEO. Borehole seismic, traveltime/full-wave modeling and inversion, numerical methods, inverse problems.

Title: Integrated Workflow Over the Entire Geothermal Value Chain

Stavros ARSENIKOS-Beicip-Franlab, Ghislain de JOUSSINEAU-Compagnie Française de Géothermie (CFG) & Eric LASNE2- Orleans

ABSTRACT:

As part of the governmental plan, France aims to double the amount of energy provided from geothermal resources from now until 2030. This ambition will be based on the scaling up of the exploration studies, operations, and maintenance.

Beicip-Franlab and Compagnie Française de Géothermie (CFG) have joined their forces to provide an integrated workflow that covers the entire geothermal value chain from exploration on unknown areas or uncertain stratigraphic levels, all the way to operations,maintenance, and monitoring.

During this presentation we discuss the integrated workflows and differentiating points that have been tested in recent projects. We discuss how the knowledge acquired from the O&G workflows can be invaluable and adapted to geothermal. Specifically, we will present our key observations in terms of subsurface modeling, advanced simulations, and resource derisking.

Furthermore, we present how resources estimation, and a good grasp of the uncertainty analysis can help the geothermal business, especially when it comes to the French legislation and compliance with the subsidies provided by the government for geothermal operations.

Finally, we discuss the economics of geothermal studies compared to the O&G, how the business is set up and our vision of how it could evolve in the years to come to comply with the 2030 ambition.

Presenter Bio:

Stavros Arsenikos is the Head of the Energy Transition and Carbon Management Unit at Beicip-Franlab, covering the Geothermal, Lithium, CCUS and Natural Hydrogen Business. His role is to oversee new business, develop collaborations, project follow-up and development of the teams' skills on the Energy Transition domain. In parallel, he manages projects related to both O&G resources and New Energies as a senior project manager.
He is a Senior Geoscientist with a PhD in Geodynamics and Geophysics. His main expertise is in Resource Prospectivity Assessment and Exploration studies.