



# Formation Evaluation for a Sustainable Future

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# Introduction

Today's energy industry faces the dual challenge of supporting the increasing demand for energy resources from a growing population with rising standards of living, while also addressing sustainability goals (Figure 1). Formation evaluation plays a critical role in the transition from reliance on hydrocarbons to sustainable energy sources.

## What Is Formation Evaluation and Why Is It Important?

Formation evaluation/ petrophysical analysis is performed to assess the volume and types of fluids and minerals present in a formation and to determine the production potential of a reservoir. It analyzes subsurface formation characteristics, such as lithology, porosity, permeability and saturation,

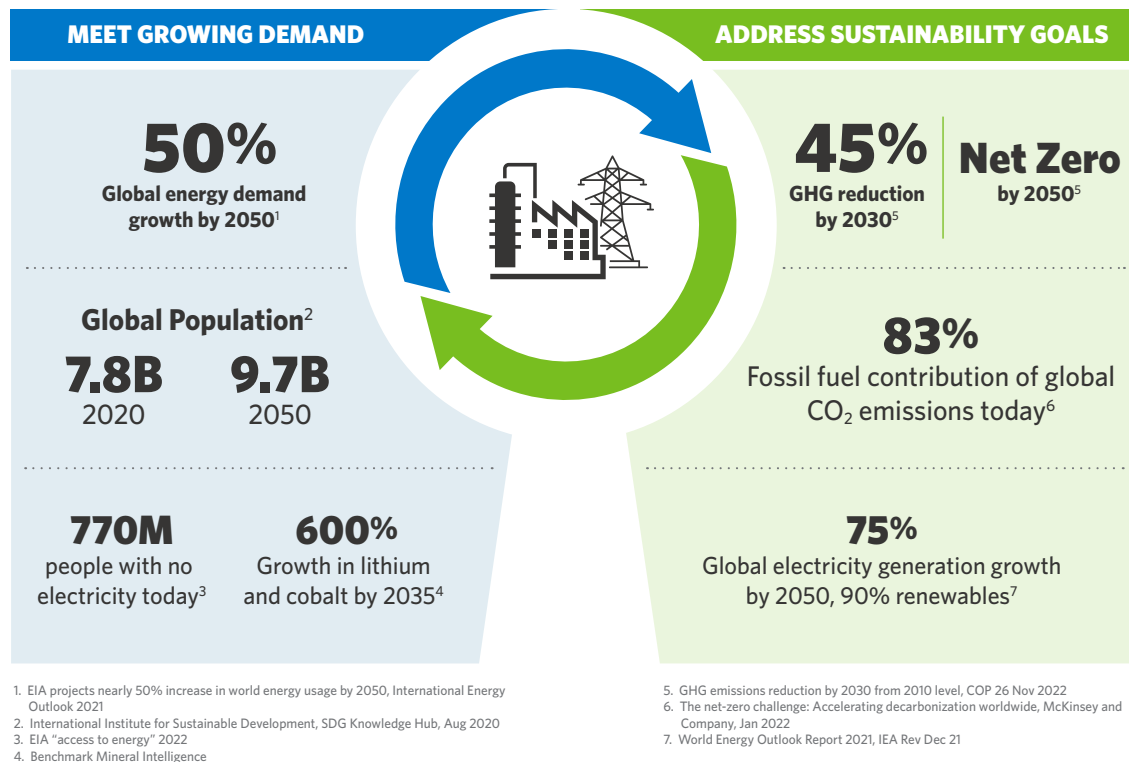


Figure 1. The dual challenge.

“Petrophysical/well-logging technology has played a key role in the oil industry’s success in providing the energy needed for the tremendous economic growth of the 20th century. With an impending transition away from fossil fuels, the application of these techniques in non-petroleum energy systems is of interest. Two areas that have already drawn attention are monitoring CO<sub>2</sub> sequestered in the geology in carbon capture and sequestration (CCS) projects to mitigate climate change and characterization of geological sites for burying high-level radioactive waste from nuclear power plants.”

— SPWLA Journal

and is used to establish the presence of reservoir rock, evaluate reservoirs for potential hydrocarbons or other resources, and estimate the volume of those resources. It is also used to evaluate the mechanical properties of the formations of interest.

Formation evaluation guides wellsite decisions, reservoir development and production planning, and impacts critical financial decisions at every stage of the Exploration and Production (E&P) lifecycle.

### Corporate valuation and stock price are based on accurate reservoir formation evaluation

In order to support corporate valuation and optimize Return on Investment, energy companies are required to report their reserves estimates to their shareholders, the authorities and the public. One of the most important tools for estimating reserves is petrophysical analysis, which provides vital information at the well bore, gives an

idea of the volume of resources in place and helps operators plan a field's development phase. Imprecise estimates are expensive, so there is a pressing need for the most advanced technologies to ensure an accurate estimate of an asset's value.

## History of Formation Evaluation in E&P

Formation evaluation has been a crucial process in the oil and gas industry for over 100 years, supporting informed decision-making during exploration, drilling and production. While the earliest attempts at formation evaluation date back to the late 19<sup>th</sup> century, the development of wireline logging in the 1920s marked a significant advancement. This technology allowed measurements of subsurface properties, such as resistivity, which could be correlated with rock and fluid characteristics. Additional developments are shown in Figure 2 below.

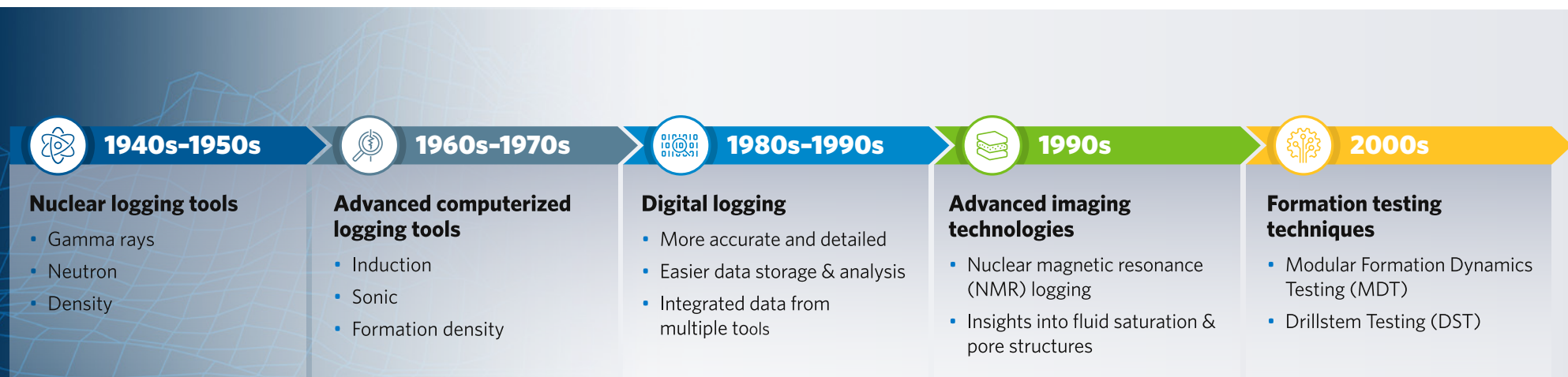


Figure 2. A timeline of developments in Formation Evaluation technologies.

## Environmental Impact Assessment

Before any resource extraction or energy production activity takes place, an environmental impact assessment is often conducted. Formation evaluation contributes to these assessments by providing data on the geological characteristics of the area. This information is crucial for predicting and mitigating potential environmental impacts.

## E&P Formation Evaluation Workflows for Sustainability-Based Projects

In the context of sustainability, formation evaluation generally refers to the assessment of geological formations to determine their potential for sustainable resource utilization. Formation evaluation contributes to informed decision-making, risk mitigation and the overall success of these types of projects. Its principles and techniques can easily be applied to support exploration and production activities in alternative energies, such as geothermal, carbon capture and storage (CCS), lithium brine, hydrogen production or storage, and offshore wind turbine site investigation.

### Carbon Capture and Storage

Today's energy industry faces the unprecedented challenge of balancing energy security, affordability and environmental sustainability. Global pressure to meet aggressive emission reduction targets is mounting on governments and companies. One of the key strategies for achieving these objectives is mitigating carbon dioxide (CO<sub>2</sub>) emissions from industrial processes and power generation, and one of the tools for this is CCS.

According to the UN, over 140 countries have set a net-zero target, covering about 88% of global emissions.<sup>1</sup> This is expected to offer an opportunity for significant growth in the CCS technology industry. Momentum has grown substantially in recent years, with over 500 projects in various stages of development across the CCS value chain. Since January 2022, project developers have announced ambitions for around 50 new facilities to be operating by 2030, capturing around 125 Mt CO<sub>2</sub> per year.

# Carbon Storage Project Challenges

**Costs:** The development of infrastructure, including pipelines for transporting captured CO<sub>2</sub>, is essential for the success of CCS (Figure 3). This can require significant upfront financial investments, which can be a substantial barrier to entry, particularly for smaller-scale applications.

**Environmental and Safety:** The potential for leakage while storing CO<sub>2</sub> underground is a major concern. Determining possible dangers and hazards is directly linked to choosing an acceptable location for CO<sub>2</sub> storage.

**Uncertainty and Risk:** An example is saline aquifers, which are often under-explored and may lack data that can help reduce risk.

**Public Acceptance:** Public awareness and acceptance of CCS projects, as well as regulatory frameworks, are important factors in their successful implementation.

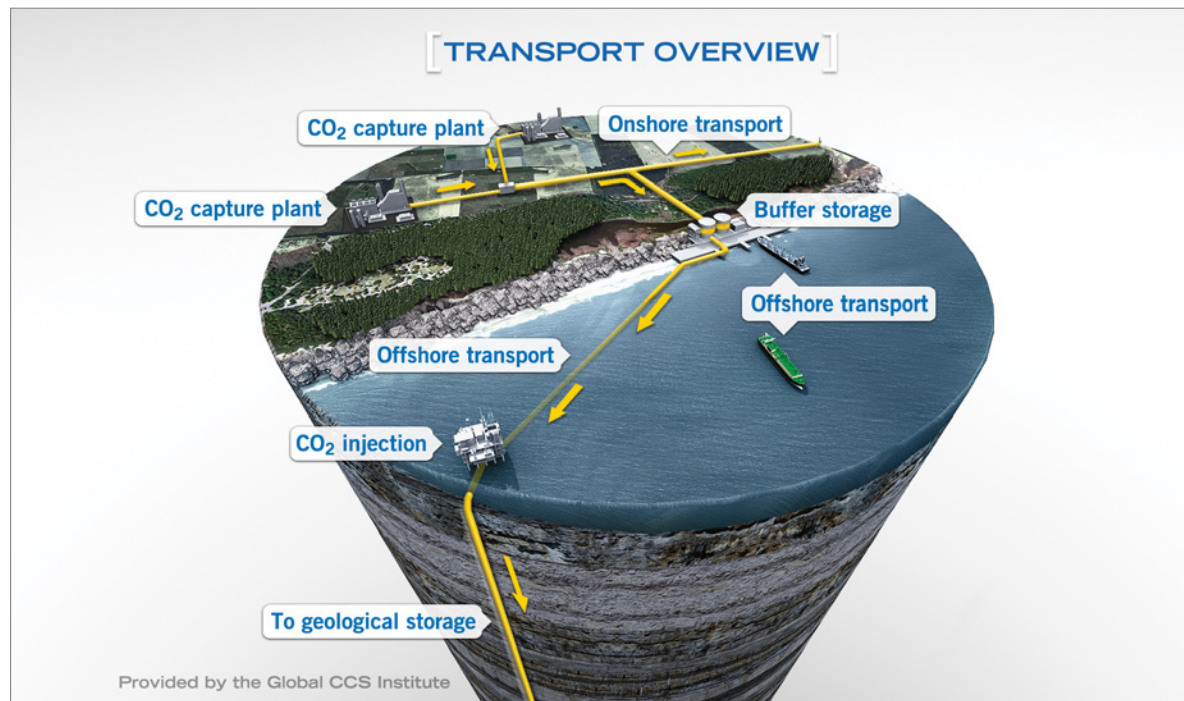


Figure 3. The carbon capture, transport and storage process.



## Digital Solutions Help Ensure Economic Feasibility and Safety Across the CCS Value Chain

- Ensure confidence in low-risk, long-term storage
- Screen storage/sequestration candidates and select storage locations
- Understand impact of future risks and guide investments across dispersed assets and operations
- Improve collaboration and communication
- Optimize injection conditions and track CO<sub>2</sub> movements to show regulatory conformance

## How Can Formation Evaluation Help?

Formation evaluation is used to assess and characterize subsurface formations and help operators understand if the reservoir will provide safe, long-term storage. Identifying suitable geological formations, including their porosity, permeability and sealing capacity, is essential for assessing the feasibility of a site.

Formation evaluation is a multidisciplinary, collaborative process between geologists, geophysicists, geochemists, reservoir engineers and other experts, to ensure the safe and effective storage of CO<sub>2</sub> in the subsurface.

## Formation Evaluation Capabilities for CCS

These formation evaluation workflows provide geoscientists with deeper insight into the geological, geophysical, hydrogeological and geomechanical properties of potential storage sites:

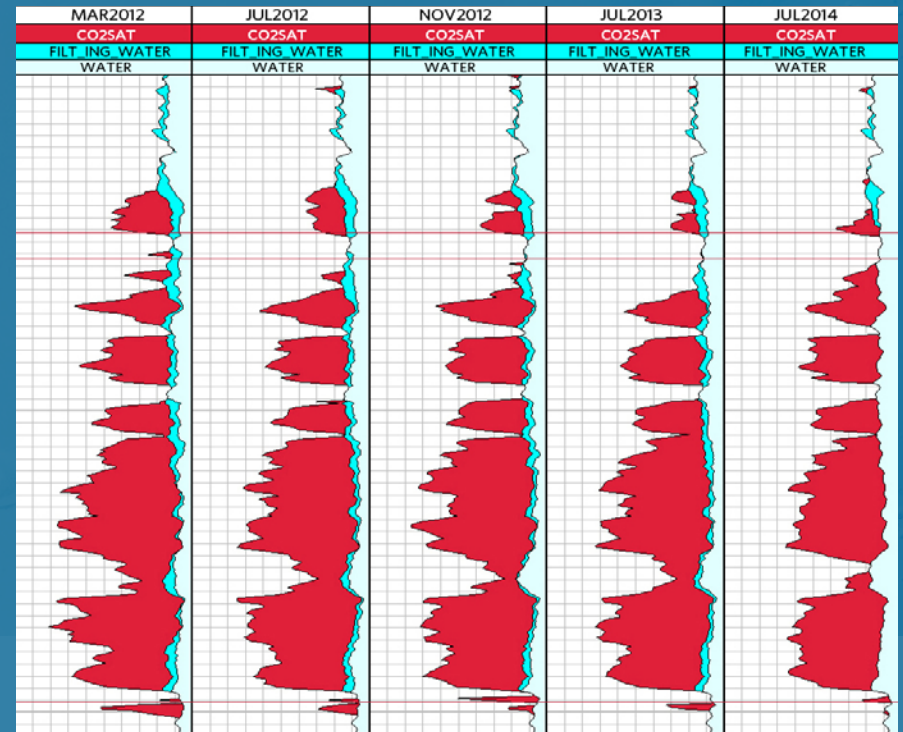


Figure 4. Pulsed Neutron Capture Logging (PNL)—A dedicated time-lapse view showing changes in formation fluids and mechanical integrity over time, due to the migration of injected CO<sub>2</sub>.

## Geological

- Evaluate the geological formations to identify suitable CO<sub>2</sub> storage candidates. Characterize the storage complex and determine the volume of CO<sub>2</sub> which the formations can theoretically hold, through interpreting various well logs and generating porosity and permeability estimates.
- Risk assessment: Quantify uncertainty associated with petrophysical analysis and assess its impact on carbon storage properties.
- Once CO<sub>2</sub> injection begins, use formation evaluation tools for ongoing monitoring and verification of the injected CO<sub>2</sub>. Well log data helps assess the movement and distribution of CO<sub>2</sub> within the storage formation over time (Figure 4).

## Aspen Geolog™ Supports its Customers in their Sustainability Journey

“I previously used Aspen Geolog in the hydrocarbon exploration and production industry, where the system’s ease of use and powerful Python scripting capabilities significantly contributed to the workflow efficiency. I found that Aspen Geolog easily makes the transition to Carbon Storage. We’re currently using it for Carbon Storage exploration; we will soon begin drilling, and plan to continue using the system for monitoring and surveillance.”

— Adam Haeker, Director of Geoscience, Milestone Carbon



### Geochemical and Water Analysis

- Assess the compatibility of the formation fluids with injected CO<sub>2</sub>. This includes analyzing the chemical composition of both the storage formation and the injected CO<sub>2</sub> to avoid reactions that could compromise storage integrity.
- Evaluate the potential for mineral trapping, where CO<sub>2</sub> reacts with minerals in the storage formation over time to form stable carbonates.
- Understand fluid flow dynamics within the storage formation to optimize injection and storage efficiency.

### Geomechanical

- Ensure the presence of a reliable caprock or seal above the storage formation to prevent leakage. Identify fractures and faults stresses and perform formation geomechanical analysis.
- Ensure that boreholes are designed and constructed to high standards to prevent CO<sub>2</sub> leakage along the well pathway. Well integrity is crucial for the long-term containment of injected CO<sub>2</sub>.
- Assess subsurface pressure conditions to ensure boreholes can tolerate the CO<sub>2</sub> injection pressure and that the pressure does not exceed the fracture pressure of the storage formation, which could lead to leakage.

# Geothermal Energy Production

The increasing need for cleaner energy resources globally is propelling the growth of the geothermal energy market. Technological advancements have led to higher volumes of geothermal energy captured.

Geothermal is considered a reliable, cost-effective and environmentally friendly source of energy. It emits 99% less CO<sub>2</sub>, a fact which is anticipated to propel market growth.<sup>2</sup>

Geothermal energy is produced in over 27 countries worldwide. The United States is the the largest producer and hosts the largest commercially developed geothermal field. Known as “The Geysers” in California, the field comprises 22 power plants, with an installed capacity of over 1.5GW. The US is also the world’s largest consumer, followed by Indonesia, the Philippines, Turkey and New Zealand. Describing itself as a ‘pioneer’ of geothermal power, Iceland produces 25% of its energy from five geothermal power plants that tap its 600 hot springs and 200 volcanoes.<sup>3</sup>

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## Geothermal Energy Project Challenges

**Cost:** Drilling geothermal wells often has high upfront capital costs, especially in areas with challenging geological conditions, such as high temperature and high pressure.

**Environmental and Safety:** While geothermal energy is considered a clean and sustainable energy source, the drilling process and fluid reinjection can potentially induce seismic activity, making careful monitoring and mitigation measures essential.

**Uncertainty:** Determining the quality and quantity of a geothermal resource at a specific location can be challenging. Uncertainties can exist regarding the reservoir characteristics, temperature and overall viability of the resource.

**Public Acceptance:** The injection and production of fluids in hydrothermal and enhanced geothermal systems can impact the subsurface and affect local communities. Mitigating those risks is essential in order to increase the number of geothermal projects in a safe and sustainable manner.





## Digital Solutions Help Ensure Economic Feasibility and Safety Across the Geothermal Energy Value Chain

- Reduce drilling risks and costs of geothermal development
- Increase confidence in subsurface predictability
- Better prediction of heat flows
- Improve collaboration and communication
- Understand impact of future risks and guide investments



## How Can Formation Evaluation Help?

Formation evaluation is key to geothermal energy projects in both exploration and production. In exploration, it helps in identifying suitable locations for geothermal wells and targeting the permeable zones.

During production, formation evaluation can provide information that helps quantify geothermal capacity in both current and future targets. Understanding the characteristics and composition of the targeted formation in real time can help improve drilling performance and increase the well success ratio from both stability and cost aspects.

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## Formation Evaluation Capabilities for Geothermal Energy

Formation evaluation workflows involve a series of steps taken to assess the potential of subsurface formations to produce geothermal energy. Some of these include:

### Geological

- Interpret wireline well logs and generate porosity and permeability logs to characterize the geothermal reservoir and assess the reservoir's capacity for heat extraction.
- Analyze cores, images, sonic log, mud, drilling data and production logs to gain a good understanding of natural fractures, faults and permeable entries in the reservoir impacting fluid flow and heat distribution.
- Analyze borehole temperature in order to identify formation intervals suitable for geothermal resource exploitation.
- Assess heat transfer properties of rocks and understand how efficiently heat can be extracted from a geothermal reservoir by evaluating in-situ formation thermal properties (radiogenic heat production, heat capacity, thermal conductivity and thermal diffusivity) using well logs and petrophysical interpretation results.
- Determine the mineral composition of reservoir rock to understand its thermal properties.

## Geochemistry—Water Analysis and Thermal Analysis

- Analyze variations in water chemical composition over time and monitor the response of the geothermal reservoir to exploitation (Figure 5).
- Characterize the geothermal system and help optimize heat extraction processes through water analysis.

## Geomechanical

- Assess mechanical conditions around the borehole for well stability prediction, drilling pressure limits and cement design.

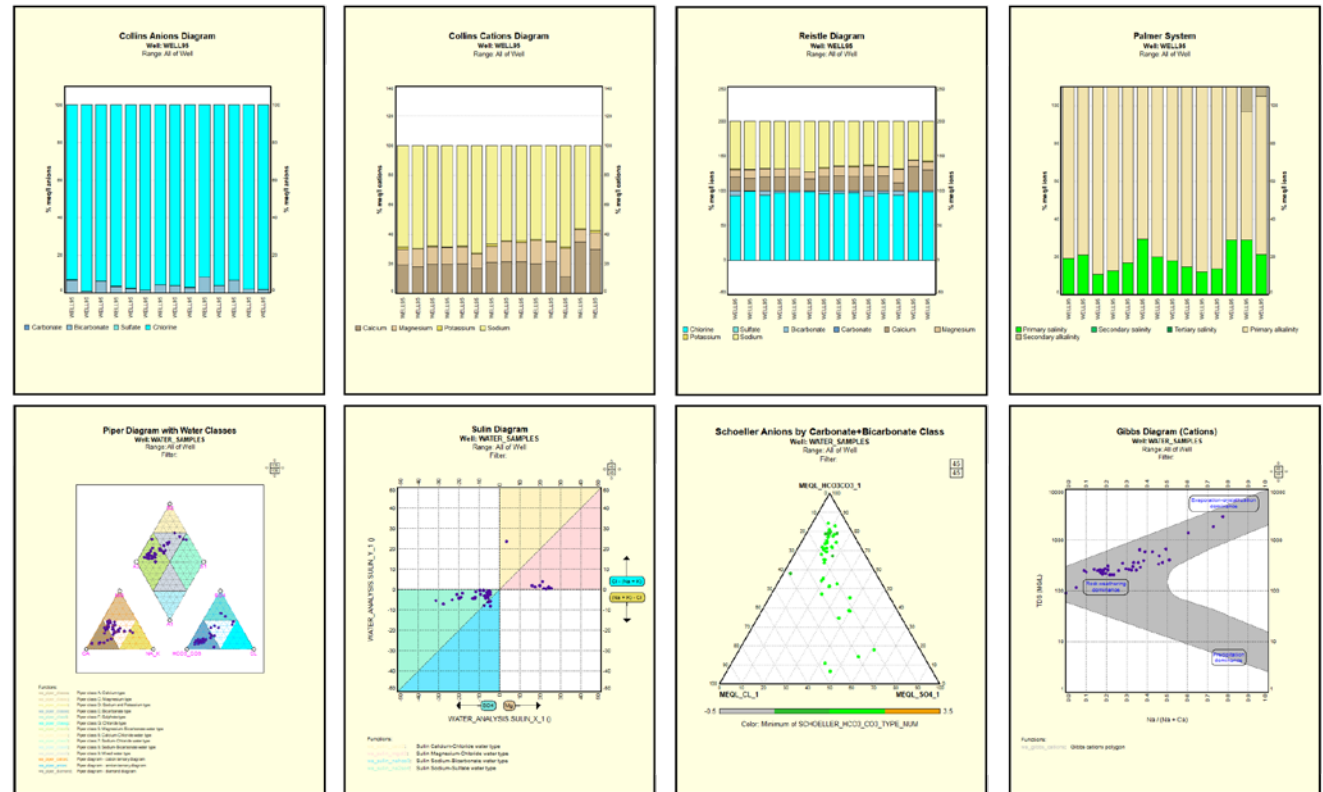


Figure 5. Water analysis graphic plots help define the origin of the water, physical properties and tendency to precipitate.

## Aspen Geolog Supports its Customers in their Sustainability Journey

“Eavor Technologies Inc. is actively applying AspenTech Subsurface Science & Engineering solutions in its geothermal exploration activities, building a compilation of worldwide geothermal assessments that help guide our business investment decisions.”

— Todd Stuebing, Principal Geoscientist, Eavor Technologies



# What to Look for in a Formation Evaluation System

## Database

A robust and reliable borehole data repository is vital for any petrophysical package. Data types acquired at the borehole are many and varied, and as such, a broad data model is needed in order to accurately describe the downhole environment. As borehole data is recorded and indexed against a wide variety of vertical references and storage units, accurate unit conversion and datum handling are essential for correct processing and co-visualization of data. The data repository should also allow the user to search and browse across projects in order to identify and list data by type and geographical area.

## Vendor independence

The ability to process and interpret data from a wide number of service companies is vital for any software package working with borehole data. Although often providing similar measurements of the subsurface, tools from different service companies contain unique acquisition properties and deliver data with mnemonics and formats that are specific to that vendor. Vendor independence ensures unbiased results when performing many different processing and interpretation workflows.

## Scripting

Software applications working with exploration and production data contain many standard processing and interpretation modules. Often, however, geoscientists need to customize the application in order to perform a unique series of steps, or process and interpret the data in a new or proprietary way. Giving users the widest possible range of customization and scripting abilities ensures they can generate the required results. Languages such as Python, Tcl and C++ or dedicated platforms such as MATLAB, coupled with user configurable menus, offer the greatest possible range of customization options.

## Integration

Integration with other solutions enhances efficiency and productivity by providing a seamless connection to other solutions in the E&P workflow.



# Formation Evaluation is a Key Step in Accurate Subsurface Characterization

The outputs derived from formation evaluation workflows offer insights into key parameters, including lithology, porosity, permeability and fluid content, all of which play a pivotal role in accurate reservoir characterization. These outputs are key building blocks in the geological modeling process, where a comprehensive 3D representation of the subsurface is built by integrating data obtained from petrophysical and geophysical analyses. This geological 3D model serves diverse purposes, ranging from estimating hydrocarbon volumes to assessing the potential for CO<sub>2</sub> storage or geothermal development, depending on the nature of the project. Additionally, it allows an understanding of fluid flow behavior through the application of numerical simulations, thereby enhancing decision-making processes and optimizing resource management strategies. 3D geological modeling also plays a crucial role in supporting uncertainty analysis, helping to mitigate the risks associated with reservoir development and management.

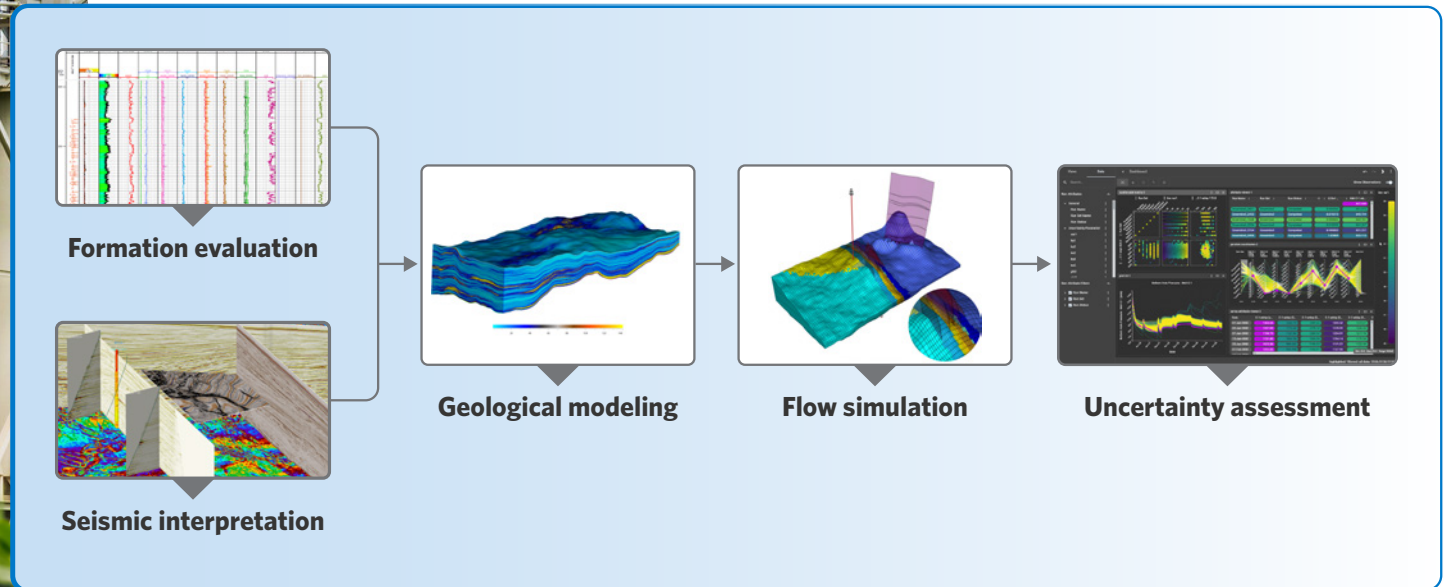


Figure 6. Reservoir characterization workflow supporting:

- Potential assessment for carbon storage or geothermal exploitation
- Well location definition
- Injection or production forecasts

# Conclusion

Formation evaluation plays an essential role in helping decision makers locate the most suitable geological formations for sustainable resource utilization, as well as predict and mitigate potential environmental impacts.

Formation evaluation techniques such as seismic imaging and well logging can be repurposed to assess subsurface conditions for sustainability projects like geothermal energy and CCS. Understanding subsurface geology and fluid dynamics is crucial for the development and operation of these projects, contributing to the expansion of renewable energy sources and the reduction of greenhouse gas emissions.

As the energy transition progresses, there will be growing emphasis on sustainable resource management. By providing accurate data about subsurface conditions, formation evaluation enables informed decision-making regarding resource extraction and development, promoting sustainability and responsible stewardship of natural resources.

## Citations

<sup>1</sup> United Nations - Climate Action: [For a livable climate: Net-zero commitments must be backed by credible action](#)

<sup>2</sup> Fortune Business Insights: [Geothermal Energy Market Size Worth USD 95.82 Billion, Globally, by 2029 at a CAGR of 6.3%](#)

<sup>3</sup> Power Technology: [What is geothermal energy?](#)





## About Aspen Technology

Aspen Technology, Inc. (NASDAQ: AZPN) is a global software leader helping industries at the forefront of the world's dual challenge meet the increasing demand for resources from a rapidly growing population in a profitable and sustainable manner. AspenTech solutions address complex environments where it is critical to optimize the asset design, operation and maintenance lifecycle. Through our unique combination of deep domain expertise and innovation, customers in asset-intensive industries can run their assets safer, greener, longer and faster to improve their operational excellence.

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