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A Practical Playbook for Geothermal Exploration in the Great Basin Region, Western USA: Integrating Tools, Fieldwork, and Data Analytics for Resource Assessment

Cary R Lindsey*, Chao Lu, James Faulds , Nicole Hart-Wagoner , and Mark Coolbaugh
Great Basin Center for Geothermal Energy, Nevada Bureau of Mines and Geology, University of Nevada
caryl@unr.edu

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ABSTRACT

Geothermal exploration requires the integration of geological, geochemical, and geophysical data to reduce uncertainty and improve resource targeting. While a broad suite of subsurface characterization tools exists, structured, practical guidance for selecting and applying these methods across diverse exploration contexts remains limited. To address this gap, we are developing the *Geothermal Exploration Playbook for Conventional Hydrothermal Systems in the Great Basin Region, Western USA* (hereafter, the Playbook), a method-focused guide designed to support users at all experience levels, from students and early-career geoscientists to multidisciplinary exploration teams. Each chapter centers on a specific exploration method, combining foundational theory with guidance on field deployment and data analysis workflows. Beyond introducing individual tools, the Playbook is intended to help users construct exploration pathways—such as play fairway analysis, conceptual model development, and preliminary resource assessment—and apply these workflows using their own datasets. Open-source Jupyter Notebooks are being developed alongside the text to enable users to adapt standardized analytical approaches to project-specific needs, promoting both reproducibility and flexibility.

Although the Playbook is framed as an exploration guide for conventional hydrothermal systems in the Great Basin, the methodologies it presents are broadly applicable across different geographic regions, tectonic regimes, and geothermal development approaches. Many of the techniques described are equally relevant to emerging resource types, including enhanced geothermal systems (EGS), where integrated subsurface characterization remains essential for reducing uncertainty. The Playbook is being developed as part of the DOE-funded INGENIOUS project (INnovative Geothermal Exploration through Novel Investigations Of Undiscovered Systems), which seeks to reduce exploration risk and accelerate the discovery of hidden geothermal systems in the Great Basin. Informed by INGENIOUS fieldwork and shaped through collaboration with experts across the geothermal R&D community, the Playbook is envisioned as a living resource that will continue to evolve as new techniques, datasets, and analytical approaches emerge, supporting ongoing innovation and best practices in geothermal exploration.

1 INTRODUCTION

Even with decades of progress in geothermal science and exploration tools, finding viable resources remains uncertain. Exploration teams rely on many types of information including structural geology, geochemistry, geophysics, and thermal indicators to understand the subsurface. Each of these methods is well described on its own. What is often missing is clear guidance on how to bring them together in a way that supports real exploration decisions. In practice, exploration programs are frequently shaped by who is involved and what experience they bring rather than by a shared framework for combining data and interpretations.

This becomes especially challenging when exploring for systems that do not have strong surface expression. In these cases, success depends on recognizing indirect signals of heat and permeability and turning them into a working understanding of the subsurface. The value of any single dataset is therefore tied to how it is interpreted alongside others and incorporated into a conceptual model that can guide targeting.

To help address this need, we are developing the *Geothermal Exploration Playbook for Conventional Hydrothermal Systems in the Great Basin Region, Western USA* (hereafter, the Playbook). The goal is not to introduce new methods, but to organize established ones in a way that supports practical exploration. The Playbook connects fundamental understanding with applied use by grouping techniques into workflows that align with common exploration goals such as play fairway analysis, conceptual model development, and early

stage resource assessment. The intent is to help users move from data collection to interpretation in a more structured and transparent way.

The Playbook is being developed within the DOE funded INGENIOUS project, which is focused on improving the discovery of hidden geothermal systems in the Great Basin. A major objective of this effort is to strengthen how multidisciplinary information is used in areas where traditional surface indicators may be limited. Within that broader context, the Playbook provides a way to translate lessons from field investigations and research into approaches that can be applied in exploration settings.

Although the Playbook is centered on conventional hydrothermal systems in the Great Basin, the approaches it presents are relevant in many other settings. The same methods can be applied in different regions and tectonic environments, and several are also useful for emerging resource types such as enhanced geothermal systems where integrated subsurface understanding remains essential. For this reason, the Playbook is intended to grow over time as new tools and ideas become available.

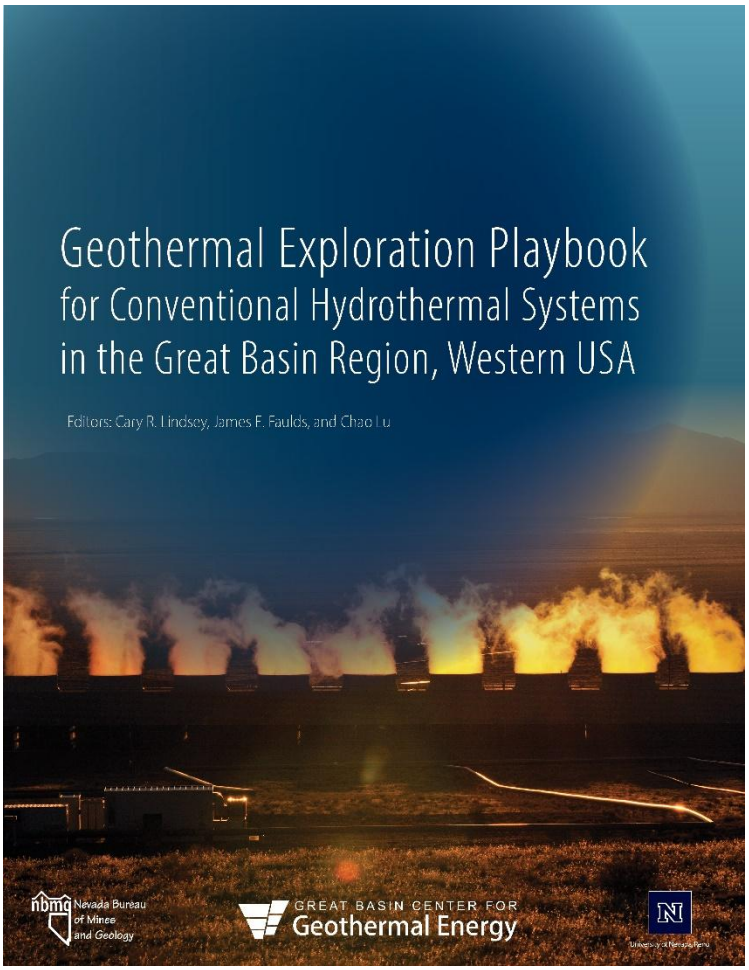


Figure 1. Cover of the Geothermal Exploration Playbook for Conventional Hydrothermal Systems in the Great Basin Region, Western USA.

2 STRUCTURE AND SCOPE

The Playbook is organized around the practical needs of geothermal exploration rather than a fixed sequence of steps. Its structure reflects the reality that exploration programs vary in timing, scale, and available information. Rather than prescribing a single pathway, the Playbook is being developed to support users as they move between regional screening, site scale investigation, and well level decision making.

Several components focus on commonly used approaches to geothermal assessment. For example, sections under development address how play fairway analysis may be applied at different scales, how conceptual models can be constructed and refined as new information becomes available, and how preliminary resource estimates may be supported by multidisciplinary datasets. These elements are paired with guidance on designing exploration workflows around the essential ingredients of a viable hydrothermal system such as heat, permeability, and fluids.

Other material explores how existing data can inform exploration strategy. Illustrative examples include the use of gravity and magnetic datasets to identify structural trends, electrical methods such as magnetotellurics to infer subsurface fluid pathways, and geodetic or seismic observations to evaluate deformation and active processes. Geological inputs such as fault mapping, stratigraphic interpretation, volcanic history, and analysis of paleo geothermal deposits are also considered alongside thermal indicators including surface manifestations, aqueous geochemistry, geothermometry, heat flow measurements, and shallow temperature surveys.

The Playbook also addresses how these different data types may be processed into useful exploration inputs. Examples include geostatistical analysis, distance to fault or feature calculations, and clustering approaches that help transform observations into interpretable patterns. In addition, value of information concepts are introduced as a way to guide decisions about which data may be most beneficial to collect at different stages of exploration, whether during early regional screening or later targeting efforts.

Recognizing that exploration success is influenced by more than technical factors alone, the Playbook also considers practical constraints such as land status, permitting requirements, and proximity to infrastructure. Limited case examples are being incorporated to illustrate how combinations of geological, geophysical, and thermal data may be applied in real exploration settings.

3 EXPLORATION WORKFLOW INTEGRATION

Geothermal exploration rarely progresses through a linear sequence of data collection and interpretation. Instead, teams move iteratively between regional screening, prospect refinement, and site-scale investigation as new information becomes available. The Playbook reflects this reality by organizing commonly used exploration techniques within flexible workflows rather than presenting them as isolated tools.

Each technique discussed in the Playbook is framed in terms of the stage of exploration where it is most effective, the type of uncertainty it helps reduce, and how results may be incorporated into broader interpretation. For example, shallow temperature surveys may be applied early in exploration to identify thermal anomalies that warrant further investigation, while magnetotelluric data are more often used to evaluate subsurface fluid pathways at prospect scale. Geological mapping and structural interpretation may inform both regional favorability assessments and conceptual model development at later stages.

A key component of this approach involves transforming observations into usable analytical inputs through feature engineering. Geological, geophysical, and geochemical datasets are translated into spatial or statistical representations that can be incorporated into favorability modeling or conceptual interpretations. Within this framework, the Playbook supports multiple exploration pathways, allowing users to apply individual techniques independently, integrate datasets within a play fairway analysis workflow at regional or local scale, or use engineered features to inform conceptual model development.

This workflow-oriented approach also helps teams evaluate the relative value of different datasets. By clarifying how specific datasets contribute to interpretation at different stages, the Playbook provides practical support for determining where additional investment may be warranted. Together, these elements are intended to help exploration teams move from multidisciplinary observations to structured interpretations and ultimately toward informed decisions about prospect advancement.

4 CONCLUSION

The Geothermal Exploration Playbook provides a structured framework for applying established exploration techniques within practical workflows. By clarifying how multidisciplinary datasets can be collected, processed, and integrated at different stages of exploration, the Playbook supports more informed decisions regarding data acquisition, prospect refinement, and progression toward drilling. Although developed in the context of the Great Basin, the approaches described are broadly applicable to geothermal exploration in other regions.

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