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Workflows and Technical Challenges of Regional Multi-Resource Assessments in the U.S. Geological Survey

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Abstract

The U.S. Geological Survey (USGS) conducts regional assessments of the nation's energy resources. Expansion of these assessments to evaluate multiple energy resources within a single basin, commonly referred to as multi-resource assessments (MRA), could utilize similar workflows and subsurface properties applicable to hydrocarbon, carbon dioxide (CO2), and more. Technical challenges arise in managing data quantity and quality to develop and calibrate scalable subsurface characterization models. Subsurface geologic characterization, particularly porosity, is key to estimating existing resources, and the methodologies to determine pore space are essentially the same regardless of the rock type or fluid within the pores. Development of a framework applicable for multiple subject matter experts at the USGS requires a flexible and scientifically rigorous workflow.

Introduction

Building framework geology models for CO_2 evaluations requires significant amounts of data; the USGS primarily relies on commercial wireline and well data, as well as internal core laboratories, and data from the literature to generate our models. Selecting a basin for study requires the alignment of overlapping data elements, including log and core data quantity and quality, and geographic and stratigraphic coverage.

Development of a CO_2 assessment workflow includes a recognition of the limits of the available data while also setting challenging goals for analysis. Porosity is a key parameter for characterization of CO_2 storage targets and includes data quality control, core calibration, multi-mineral analysis, and mapping over hundreds or thousands of wells. Generating three-dimensional, spatially distinct data distributions to understand subsurface heterogeneity, and ultimately, build geologic frameworks for modeling fluid and gaseous resource properties are the primary objectives for USGS MRA analyses.

Methods

To develop robust framework geology in which to conduct MRA first requires the selection of a target basin which contains the necessary high-quality core and wireline data over the appropriate stratigraphic intervals and geographic area. Once a basin is identified, a data collection and integration, subsurface characterization, and model optimization workflow is implemented to ensure that quality controlled, spatially distinct, and optimized interpretations are generated.

i. Data Collection and Integration

The primary data sources available to the USGS include commercial wireline logs, internal core and laboratory samples, and relevant published literature. These data are compiled for each basin and stratigraphic unit of interest. For hydrocarbon and carbon dioxide reservoir and seal evaluations, particular emphasis is placed on identifying, collecting, and integrating high-quality porosity and permeability data from core and wireline data which can be used to calibrate porosity and mineralogical models. A robust protocol to QC data identifies inconsistencies and errors which are eliminated or mitigated prior to subsurface characterization.

ii. Subsurface Characterization and Model Development

Subsurface characterization requires the assessment of key parameters to evaluate reservoir and seal properties in three-dimensional data distributions. Subsurface storage and connectivity, porosity and permeability are critical parameters to identify potential resource targets. Quality controlled and integrated wireline and core data are added to geologic mapping and petrophysical modeling software for petrophysical analysis, model building, and mapping of stratigraphic units. Data-dense wells with core and/or high-end wireline data serve as key calibration points for the model upon which less data-dense wells and areas rely.

Using geostatistical techniques, 3D spatial distribution of subsurface properties (e.g., porosity, permeability, mineralogy) are created to visualize variations in subsurface conditions across large geographic areas. The spatial modeling incorporates both the horizontal and vertical heterogeneity observed in the data and allow for detailed mapping of potential storage targets and sealing layers. Dynamic framework modeling integrates subsurface data, including stratigraphic and geospatial information. Using geostatistical interpolation, kriging, and inverse distance weighting methods, continuous models are generated which accurately represent subsurface heterogeneity.

iii. Model Optimization

Model refining and workflow optimization ensures scalability, flexibility, and consistency of subsurface interpretations across the selected basin, as well as fit-for-purpose value between scientists and work groups. This includes generating standardized data formats, geospatial reference systems, and alignment of analytical methods for consistent interpretations. Workflow scalability allows for the expansion of regional assessments as new data comes available, without disrupting the overall analysis. Collaboration between subject matter experts is facilitated by data sharing, resulting in a unified MRA workflow.

Results

The development of a robust MRA workflows relies on recognizing the limitations of available data while striving to meet challenging goals for comprehensive subsurface analysis. Through this workflow, a significant step towards building MRA framework geology can be achieved. The interpretations generated can be applied to different resource evaluations including oil and gas, carbon dioxide, and more. MRA evaluations, when integrated with these other energy resources allow for comprehensive assessments. These models offer new insights into the potential of our nation's resources.

Discussion

The development of a MRA evaluation workflow presented several key technical and methodological challenges. One of the primary challenges is managing the sparsity and variability of the data, especially when working with porosity as the main parameter for evaluating subsurface storage potential. Data resolution and spatial distribution may result in uncertainty in assessments, particularly in under-sampled regions. The data QC process is crucial to ensure that the core data, wireline logs, and other input datasets are accurate and consistent across different regions and well types.

Core calibration and petrophysical analysis will provide an essential foundation for accurate porosity and mineralogy estimates, but these methods require substantial refinement to account for the complexity encountered in the subsurface across stratigraphic units and resource types. The heterogeneity of subsurface conditions in different basins will require that models need flexible methods to determine porosity and permeability, making the creation of robust geologic frameworks a highly dynamic process.

The ability to generate 3D spatial data distributions is a transformative aspect of this workflow. These data distributions not only help visualize subsurface heterogeneity but also provide essential inputs for building detailed geologic models that can be used to evaluate multiple resource types. Dynamic 3D models will be a significant advancement to our current assessments but is expected to also expose limitations in the consistency and resolution of available data.

Ultimately, the implementation of MRA analyses is expected to demonstrate the potential for a unified approach to resource assessment. This method aids in understanding subsurface storage capacity and also informs the broader context of resource management, such as identifying optimal locations for energy extraction and storage.

Conclusions

Understanding subsurface storage availability and accessibility relies on modifying established USGS energy assessment methodologies for hydrocarbons and water. The USGS is uniquely positioned to perform this task as it has the expertise and an understanding of resource distribution.
Moving forward, the framework developed in this study can be applied to future regional assessments, supporting not only the evaluation of carbon dioxide sequestration potential but also informing broader resource management strategies of other gaseous and fluid resources. As data availability and quality continue to improve, the workflow can be expanded and refined to address emerging challenges in energy resource evaluation, ultimately contributing to comprehensive resource assessments.