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Characterization of variability and uncertainty in *in situ stress* using Bayesian statistics

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Geomechanics of injection-induced seismicity in Illinois Basin

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Partially depleted oil and gas reservoir rock as a possible CO2 storage: experimental study

Abstract

Geological storage of carbon dioxide (CO_2) is a technological practice that emerged as a palliative solution to global warming. When proposing a particular rock formation as a possible CO_2 reservoir, it is necessary to carry out a series of studies to evaluate its feasibility. In this context, two different analysis should be conducted. On the one hand, the evolution of the reservoir rock's properties should be evaluated to verify CO_2-trapping mechanisms. On the other hand, the effects produced by the CO_2 in the discontinuities present in the underground storage, including natural and rock-wellbore cement discontinuities, should be studied to analyze the store's safety. Among the geological formations commonly proposed as CO_2 stores, oil and gas partially or completely depleted reservoirs are a common choice. These rock formations are generally characterized by high porosity and permeability values, which indicate, ease of fluid injection and the availability of large storage volumes. Additionally, there would be geomechanical information available, due to the previously studies carried out for the exploitation of the resources it contained.

The presented research proposes an oil and gas depleted reservoir located in the Argentinian Patagonia as a possible CO_2 underground storage. To study its feasibility, a series of laboratory tests, both routine and novel and even in some cases unique, on specimens in pristine and carbonated state, were developed. The aim of carrying out these tests was to conduct an evaluation as complete as possible of the modifications produced in the behavior of both the reservoir rock proposed as underground storage of CO_2 and the natural and reservoir rock-injection well discontinuities.

Speaker

Cecilia Belén Laskowski Orlandi is a PhD student at both the Universidad Nacional de la Patagonia San Juan Bosco (Argentina) and the Universidad Politécnica de Madrid (Spain). Her PhD thesis is related to the underground storage of CO2. She is currently part of the DISCO2STORE project funded by the European Union's Horizon 2020 research and innovation programme (Marie Skłodowska-Curie). Previous to beginning her postgraduate studies, she participated in research projects related to soil stabilization with eco-friendly additives. She is currently a graduate assistant at the subject "Elasticidad" in the Civil Engineering degree program of the Universidad Nacional de la Patagonia San Juan Bosco (Argentina).

Characterization of variability and uncertainty in *in situ stress* using Bayesian statistics

Abstract

In situ stress in rocks is a key parameter for the design of underground excavations, and the importance of *in situ* stress is heightened for safety-critical projects such as nuclear waste repositories. Extensive campaigns are often launched during design studies to establish the design stress state at a site, but statistically robust and universally agreed techniques for characterization of *in situ* stresses seem to be missing in rock engineering. Stress in rocks is a tensor that contains embedded information on both the principal stress magnitudes and orientations. Therefore, statistical characterization of stress must be performed using stress tensors, and not principal stress magnitudes and orientations. Recent work has shown that a stress tensor which incorporates variability can be characterized using a 6D multivariate normal distribution. However, one significant challenge – due to time and financial constraints – is to obtain sufficiently large numbers of stress measurements at a project to allow stable estimates of the statistical parameters (such as mean and dispersion) to be made. This makes the classical frequentist methods of probability inappropriate.

Bayesian probability allows us to formally augment limited explicit stress data with other knowledge of *in situ* stress at a project site. Here, we present some results from recent studies showing how Bayesian linear regression of the six distinct elements of stress tensor against depth may be used to determine probabilistic estimates of the mean stress state at a given target depth. We show how this technique has the potential to be used for probabilistic, or risk-based, design of underground excavations in rocks.

Speaker

M. Amir Javaid holds an MSc in Engineering Geology from Imperial College London (United Kingdom) and is currently completing his PhD in Civil Engineering (Rock Mechanics) at the University of Toronto. Amir's PhD research focuses on Bayesian statistical methods in characterizing and quantifying the variability and uncertainty exhibited by in situ stress measurements, particularly for the design of nuclear waste repositories. His PhD research is being co-sponsored by the Nuclear Waste Management Organization (NWMO) in Toronto, Canada and the Swedish Nuclear Waste Management Company (SKB) in Sweden. Amir has worked as a geotechnical engineer since 2008 on the design of several civil engineering projects involving rock engineering. He is registered as a professional engineer in Ontario, Canada.

Geomechanics of injection-induced seismicity in Illinois Basin

Abstract

Injection of carbon dioxide (CO_2) into deep underground formations is a promising approach to mitigate accelerating greenhouse gas emissions. However, it affects the state of stress in the subsurface, potentially making it more favorable for fault reactivation and earthquakes. The injection process is associated with complex hydromechanical behavior which cannot be accurately characterized solely based on geophysical data, highlighting the need for precise laboratory testing. Additionally, induced seismic response is usually associated with three-dimensional features, such as architecture of injection site, fractures, faults, and discontinuities rather than failure of intact rock, highlighting the need for advanced interpretation of geophysical surveys. Simplification or neglecting of subsurface features might introduce additional bias in the characterization, while their accurate representation during the assessment is challenging from fundamental and technical standpoints.

The presented research encompasses geophysical field observations, comprehensive laboratory geomechanical testing, and high-performance numerical simulations within self-consistent fully coupled hydro-mechanical framework to improve risk assessment related to the induced seismic response during the subsurface CO_2 injection in Illinois Basin. The analysis revealed presence of critically stressed zones in the crystalline basement which are likely to be associated with the architecture of geologic formations and correlated with the observed microseismic clusters. Finally, the recommendations for assessing future CO_2 injection projects are formulated, drawing insights from the pilot-scale project in the Illinois Basin.

Speaker

Nikita Bondarenko is a PhD candidate at Civil and Environmental Engineering department of the University of Illinois Urbana-Champaign. He is currently part of CarbonSAFE-Illinois initiative aimed to accelerate commercial-scale use of carbon capture and storage technology and led by US DOE. Nikita’s main research interest is integration of geomechanical and geophysical data across spatial and temporal scales to improve the understanding of complex processes occurring in the subsurface.