Structural Controls on Hydraulic Properties of Karstified Faults in Dinantian Limestones of the Nord-Pas-de-Calais Basin

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Résumé

This study investigates the complex structural and hydraulic architecture of geothermal reservoirs developed in fractured and karstified Dinantian limestones within the Nord-Pas-de-Calais foreland basin, located at the northern margin of the Variscan orogenic front. The region is characterised by a dense network of thrust faults, shear zones, and background fracture systems affecting both autochthonous and allochthonous carbonate units. These structures exhibit strong segmentation and diverse connectivity patterns that critically influence fluid circulation, permeability anisotropy, and thermal transport-key parameters for geothermal exploitation.
The work focuses on structurally significant subregions such as the Boulonnais and Tournaisis, where tectonic deformation and karst processes are superimposed. Geological structures are characterised using an integrated workflow combining high-resolution field mapping, Digital Terrain Model (DTM) analysis, and advanced QGIS spatial processing. This multi-scale approach enables detailed 3D reconstruction of fault cores and damage zones, and provides insight into how karstification preferentially localises along zones of increased fracture density.

Results reveal a complex, heterogeneous fault zone architecture with significant subseismic-scale variability. Damage zones show a mixture of dilatant and shear features, locally enhanced by dissolution processes. These features generate highly variable and compartmentalised permeability fields. Conceptual thermo-hydro-mechanical (THM) models can then integrate these data to assess how fault-related heterogeneity affects fluid flow patterns and heat transfer efficiency, impacting reservoir productivity and sustainable exploitation strategies.
Comparative analysis with subsurface data from the Lille Metropole area confirms the importance of structural inheritance and fault reactivation in enhancing or restricting reservoir connectivity. This contribution underscores the need for detailed structural and petrophysical characterisation of fault zones in carbonate settings, particularly in the context of developing reliable and safe geothermal systems. It also supports broader efforts to reduce uncertainty in predicting the mechanical and hydraulic behaviour of faulted reservoirs.

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Mots-Clés: Fault zone architecture, Karstified limestones, Hydraulic heterogeneity, Geothermal reservoir