A Method for Estimating the Permeability of Reservoirs during Hydro-fracturing Stimulation.

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Reservoir 5000m

Estimating Permeability from Micro Seismicity

\[ \int \frac{ds}{D(x, t)} = 4 \pi \int \frac{d\tau}{D(r, \tau)} \]

Temporal average

r is the distance between the source and a microseism recorded at time 1

# D remains constant in space and time :

\[ r = \sqrt{4 \pi D t} \]

(Shapins, 1997)

Diffusivity at 5000m

Estimating hydraulic diffusivity and permeability

<table>
<thead>
<tr>
<th>D</th>
<th>13 0 0</th>
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<tbody>
<tr>
<td>K</td>
<td>16 0 0</td>
</tr>
<tr>
<td>0 10 10 x10^{-2} m/s</td>
<td></td>
</tr>
<tr>
<td>0 0 3</td>
<td></td>
</tr>
<tr>
<td>12 0 10^{-1} m^2</td>
<td></td>
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<tr>
<td>0 0 3.6</td>
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</tbody>
</table>

Discussion

• D & K in reservoir 5000m have same order of magnitudes than at 3800m
• Slight Rotation of Principal Axis (Anisotropy)
• Higher permeability between GPK2 and GPK3
• Smaller permeability between GPK4 and GPK2 along a plane, but similar values around GPK4

HDR Project At Soultz-s-Forêts

Heat Surface Flow Map in Europe

Fracture Opening during Hydrofracturation

UBI images

Methodology

Main active fractures zones were identified on three available wells by interpreting and processing the boreholes UBI images. Orientation and opening of each fracture were evaluated using the GMI software, and integrated into a comprehensive 3D model using the Gocad geomodeler.

The 3D fracture network seems to be coherent with a strike slip model related to the formation of the Soultz horst. The relationship between the induced micro-seismicity and the identified fracture zones are then discussed in terms of hydraulic potentials.

Shearing Model

Wells Connection

Displacements are compatible with a shearing link to the uplift of the horst. Fractures at depth (5000m) result from this regional deformation model.

Fault Identification

Major fractures are connected to wells GPK1, GPK2 and GPK3, not to GPK4 explaining the good connectivity between GPK2 and GPK3 at depth and the bad connectivity of GPK4.

Conclusions

Careful study of the fracture network shows:
• good connection between wells GPK1, GPK2 and GPK3.
• bad connection of wells GPK4 to the surrounding fracture network.

Two groups of sub-vertical fractures can be identified based on opening and orientation criteria: large open N170 fractures in agreement with the regional stress field and conjugates. This pattern corresponds to the uplift of the Soultz-s-Forêts horst and indicates a shearing with about 100m in displacement.

Future Works

• Need experiments for calibrating the new micro-seismic methodology (Pumping tests)
• Further work for interpreting microseismicity induced by several injection sources
• Accounting for uncertainties
• Continue to calibrate this approach onto real case tests such as reservoirs and natural analogues
• Better integration of fractures in reservoir modeling

References