

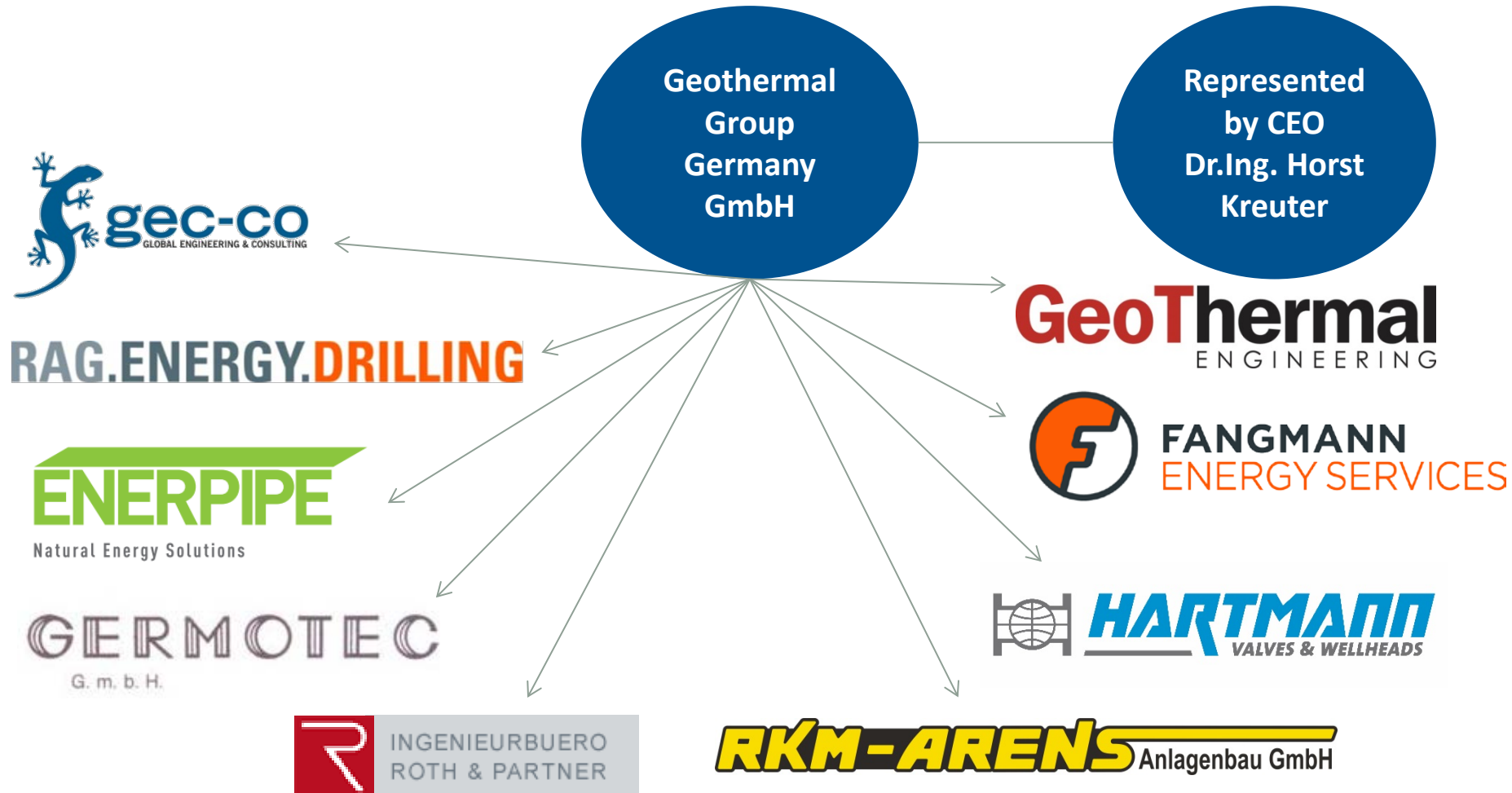


Reservoir Risk in the Development and Use of Geothermal Resources and Risk Mitigation Solutions

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1. Group of Companies



1. Risks

Risks in the Exploration and Exploitation of a Geothermal Reservoir

- Exploration Risk = Finding the expected reservoir quality defined mainly by temperature and flow rate in the development of the reservoir
- Reservoir Risk = Sustainable reservoir performance over an expected time interval defined by a business plan
- Technical Risk = Not able to reach or access the reservoir
- Risk of existing or changing compositions and physicochemical parameters of the produced fluids/gases = Corrosion, scaling, pressure losses,...

2. Play Type

Play Type Concept (Moeck 2014)

- Standardized global approach in the assessment of geothermal resources based on the concept of a geological based play type in the hydrocarbon industry
- The play type is controlled by the geological setting, the heat source and the geological controls on heat transport and thermal energy storage
- The play type catalog covers the whole range of all possible geothermal systems
- The different defined play types require exploration and exploitation concepts fitting the play type which reduces reservoir risk
- The dominant play type in the current geothermal developments in Turkey are graben system play types

3. Risk Mitigation

Risk Mitigation Systems

Exploration Risk

- Grant based (Government or Fund)
 - Grant for surface exploration and/or exploration and production drilling
 - GRMF Africa; State grants Germany, ...
- Loan based (Government or Fund)
 - Non repayable loan, government guarantees
 - Africa , Germany
- Insurance systems (private or government)
 - Pay-out if parameters are not reached
 - Temperature [°C], productivity [l/s], temperature and productivity, energy [MW_{th}]

3. Risk Mitigation

Risk Mitigation Systems

- Technical drilling risk
 - Insurance solutions
- Reservoir risk
 - Performance of reservoir over time
 - Usually not covered except in the Paris basin in France
- Risk of physiochemical parameters
 - Not covered

All reservoir parameters are not covered which involve the operational time of a geothermal project!

Also excluded in the H2020 GeoRisk project!

3. Risk Mitigation

Exploration Risk

Private Insurance Experience

- Structure
 - Cover one production well
 - Cover production and injection well
 - Cover projects with at least six wells
- DD on project development, data, quality of team and suppliers
- Covered cost (drilling, + drill pas, + exploration cost?)
- Productivity [l/s] or produced energy [MW_{th}] threshold to define success / non success.
- Partial success (defined by business plan)
- EGS required before defining non success

4. Sustainability

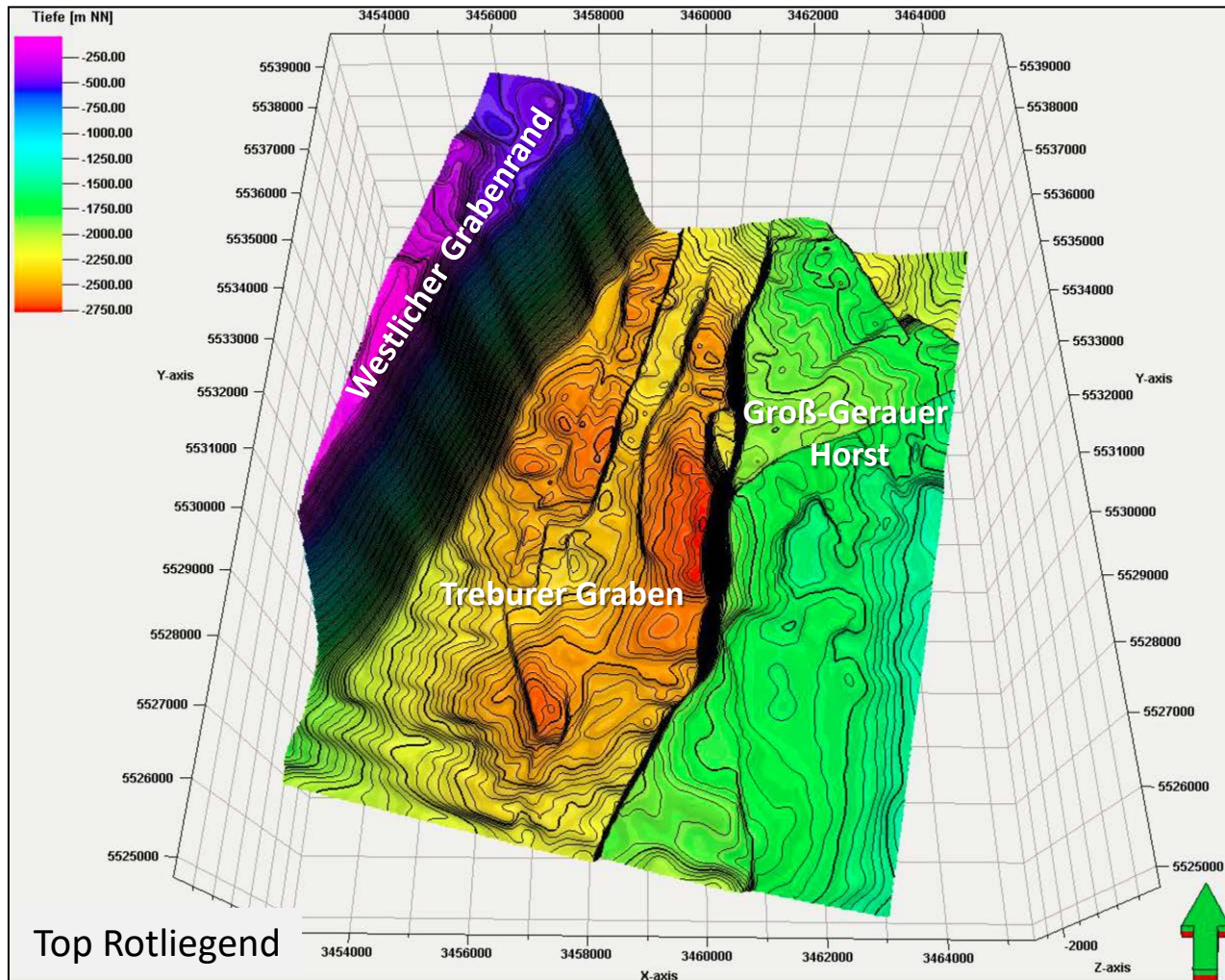
Risk to Sustainability

- Reservoir development
 - Exploration matching play type
 - Exploitation concept has to consider sustainability
- Hydraulic testing
 - single wells versus all wells,
 - short term versus circulation tests
- Decline of pressure and flow rate
 - free flow versus production pumps
- Decline of CO₂
- Interference of neighboring wells (in a license or between licenses)

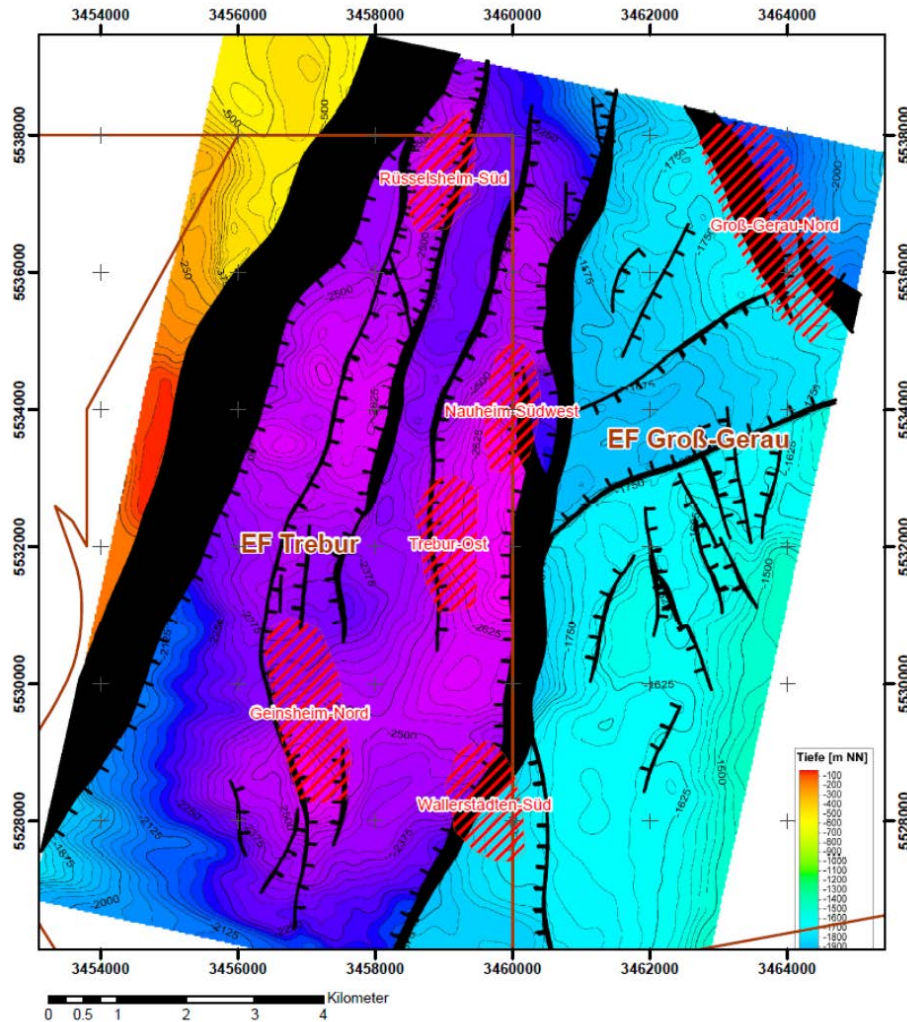
5. Exploration

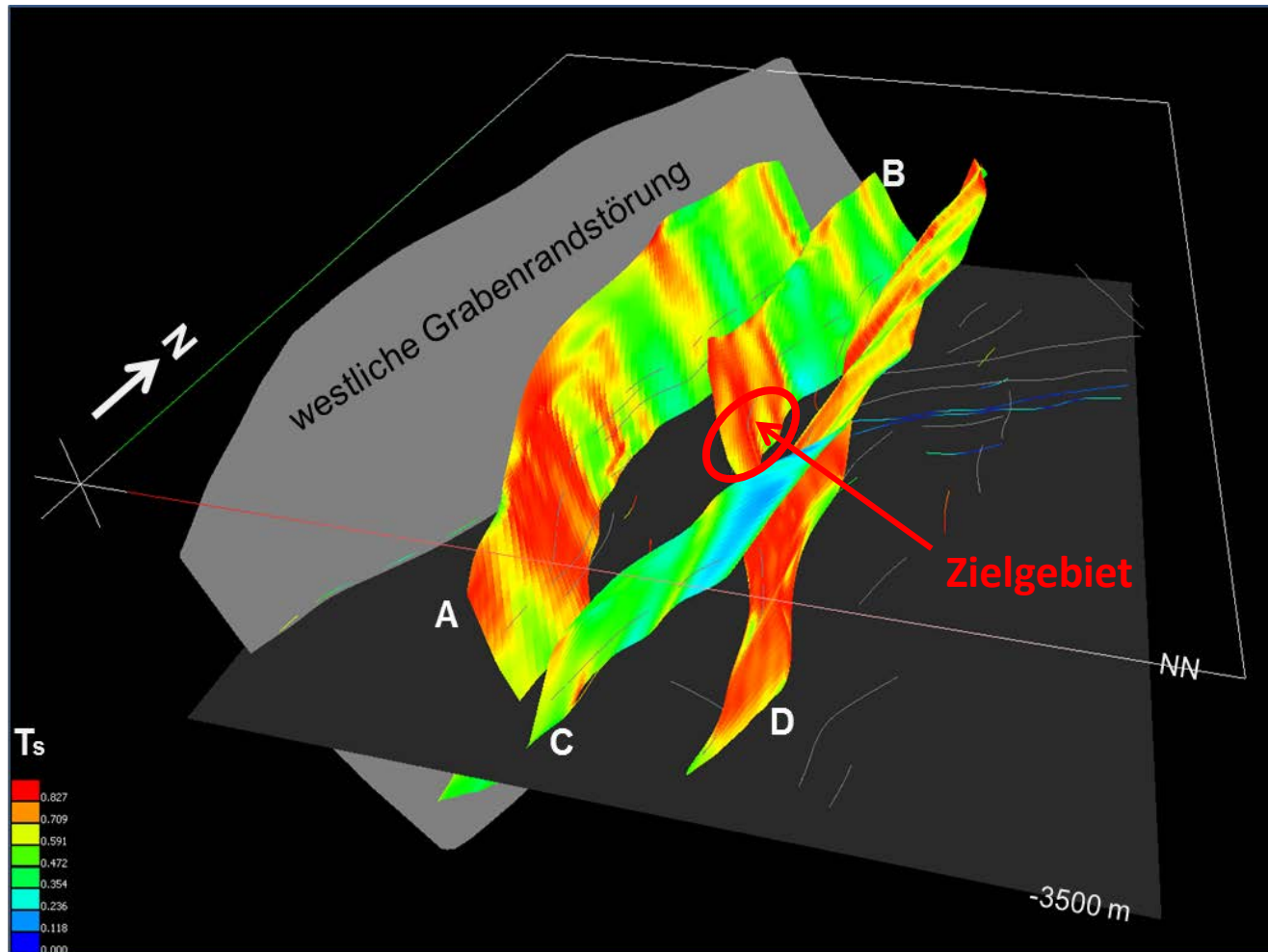
- Best practice
 - Based on experience
 - Local and global
 - Matching play type
- Exploration methods for structural based reservoirs
 - Geophysics: Consider seismic when applicable
 - Seismic: 3D seismic is better than 2D seismic (cost difference)
 - Geomechanical modelling for fault zone permeability and targeting
- Geological model and conceptual model before drilling
- Thermohydraulic modelling over time for layout of production and injection wells

5. Graben in a 3D seismic



5. Graben in a 3D seismic





6. Exploitation

Well Layout and Sustainability

- Critical parameters
 - The distance between production wells / injection wells and their location in respect to geology and structures
 - The distance between production wells and injection wells and their location in respect to geology and structures
- Reservoir modelling
 - Thermohydraulic modelling
 - The model is created based on the geological and conceptual model before drilling
 - The model is used to define the preliminary well layout and run with the expected production rates and temperatures
 - The model is modified based on drilling and testing results and the well layout modifies if necessary

7. Reservoir Management

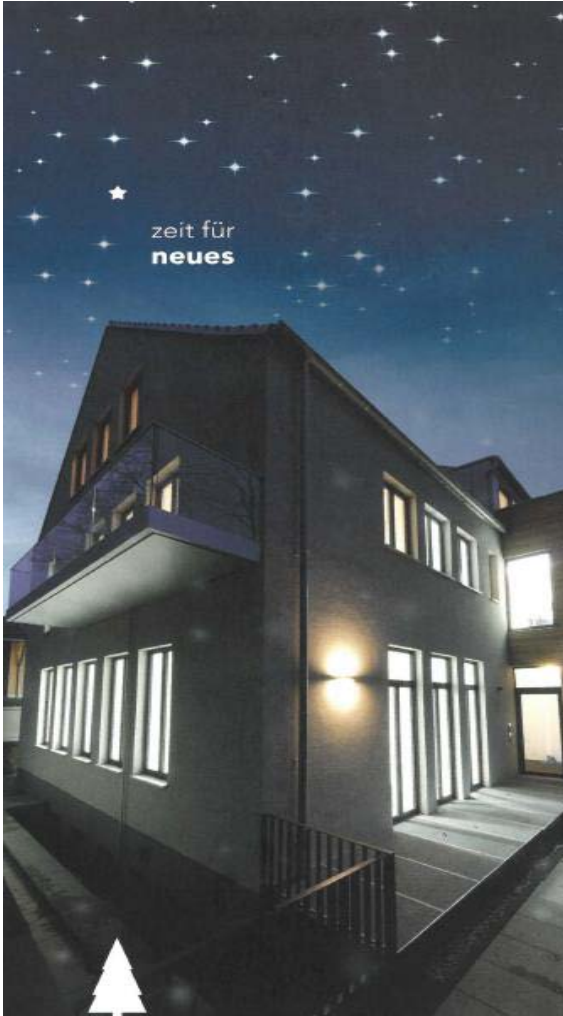
Based on Exploration Results and Exploitation Concept

- Reservoir management can only successfully performed if the exploitation layout considering sustainability
- Monitoring of the exploitation system concerning the parameters of the reservoir like temperature, flow rate, pressure and chemical composition
- These parameters and possible changes will be reflected in the models and may result in changes.
- Make-up wells, if necessary, should be localized based on the reservoir model and their impact on the exploitation layout considered
- Sustainable reservoir management ensures a reliable profit over the lifetime of the project and maybe prolongs the operation over the expected lifetime.

7. Outlook

Risk Mitigation System for Turkey

- Independent of play type
- Grant based with transition to loan based (revolving fund)
 - Depending on experience and maturing geothermal market
- Exploration risk as well as reservoir risk
 - Depending on quality of exploration and exploitation
- Financing of revolving fund
 - Premium
 - Royalties from successful projects
- Future: Coverage of EGS projects with growing experience



Çok Teşekkürler!