Horizontal Hydrothermal Wells: An Idea Whose Time Has Come

Greg Leveille

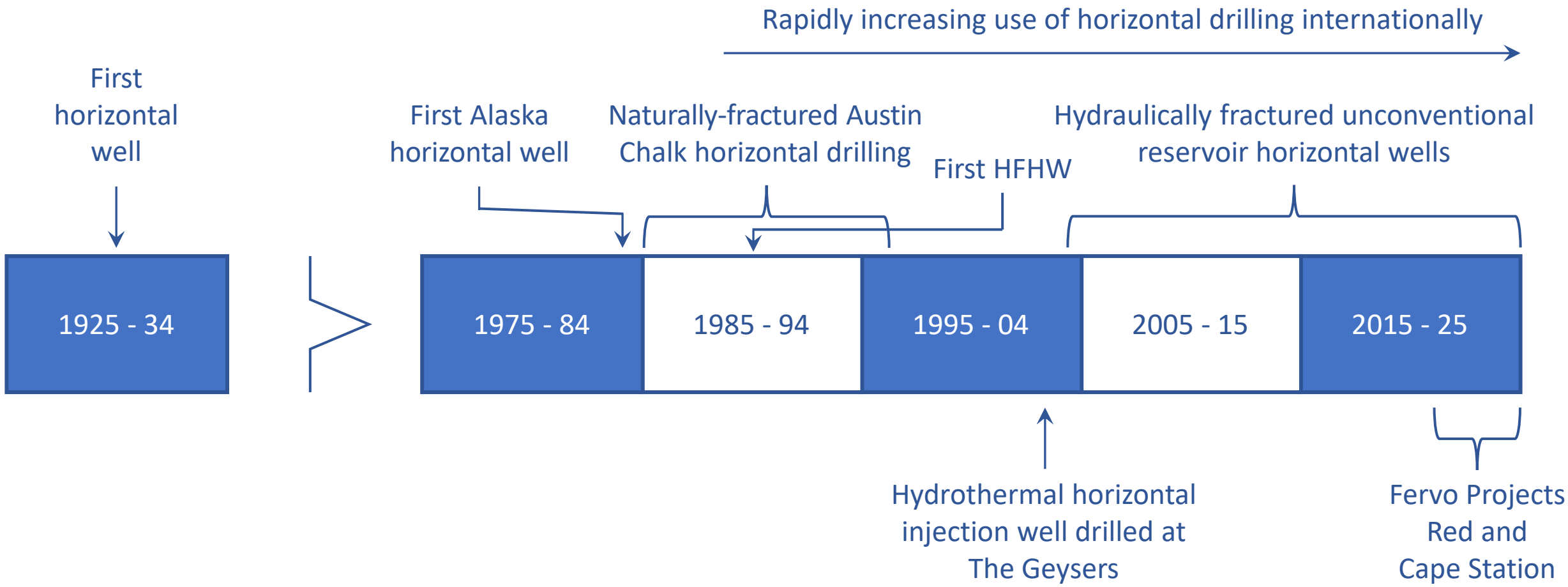
February 10, 2025

Horizontal hydrothermal wells key take-away messages

- Horizontal wells can be cost effectively drilled in the types of basement rocks that host most of our planet's geothermal resources
- Horizontal wells maximize production rates, resource recovery, and economic returns in many types of O&G fields and for EGS; should do the same for fault-hosted hydrothermal reservoirs
- Hydrothermal specific horizontal drilling challenges can be overcome
- Industry is poised to cross the geothermal horizontal well "adoption chasm"; doing so will yield economic, environmental, and energy security benefits

O&G = Oil and gas; EGS = Enhanced geothermal systems

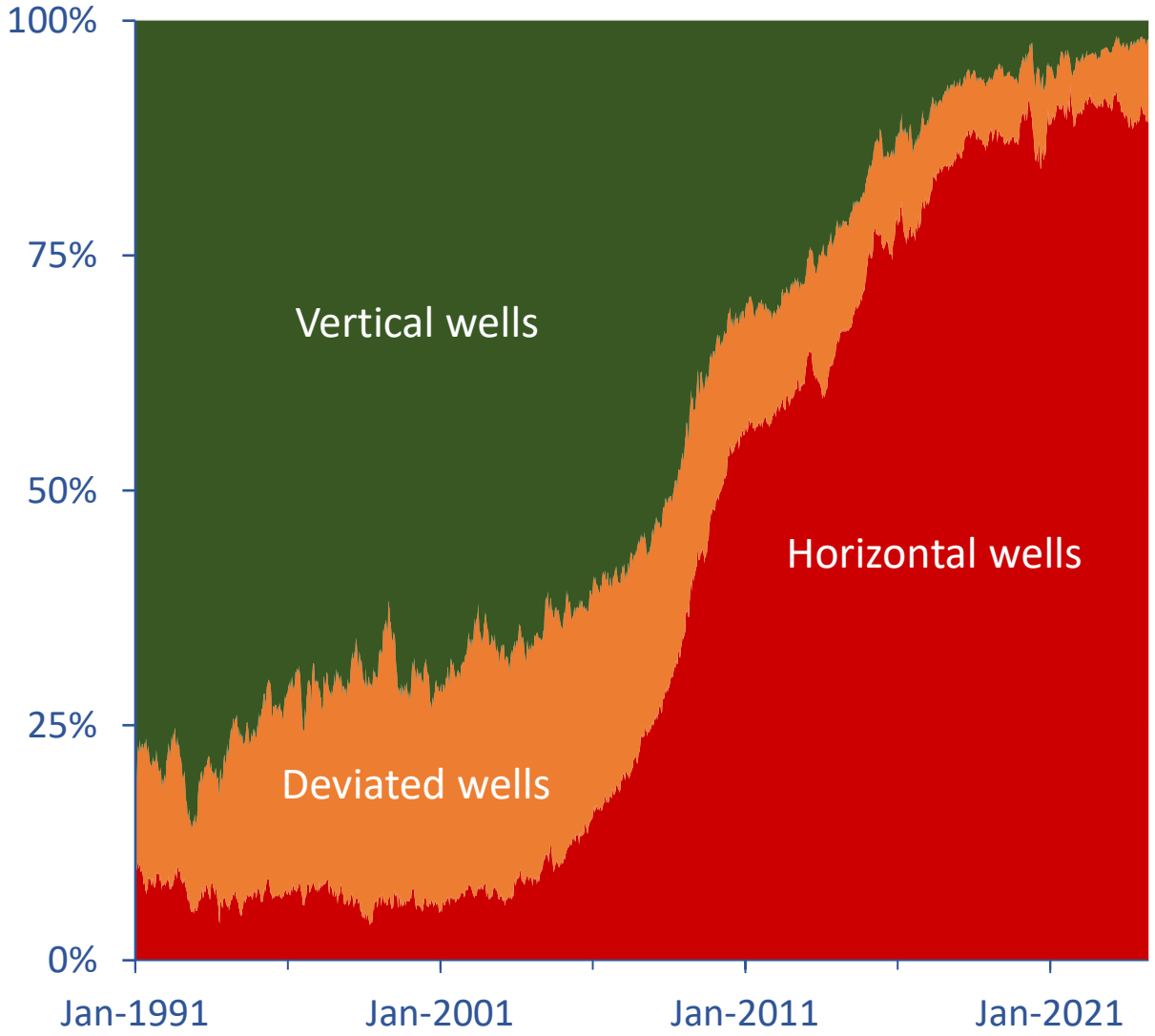
Horizontal drilling – Enormous progress over the past 100 years



Note: For a well to be considered "horizontal", it needs to exceed 80° of deviation from vertical; HFHW = hydraulically fractured horizontal well

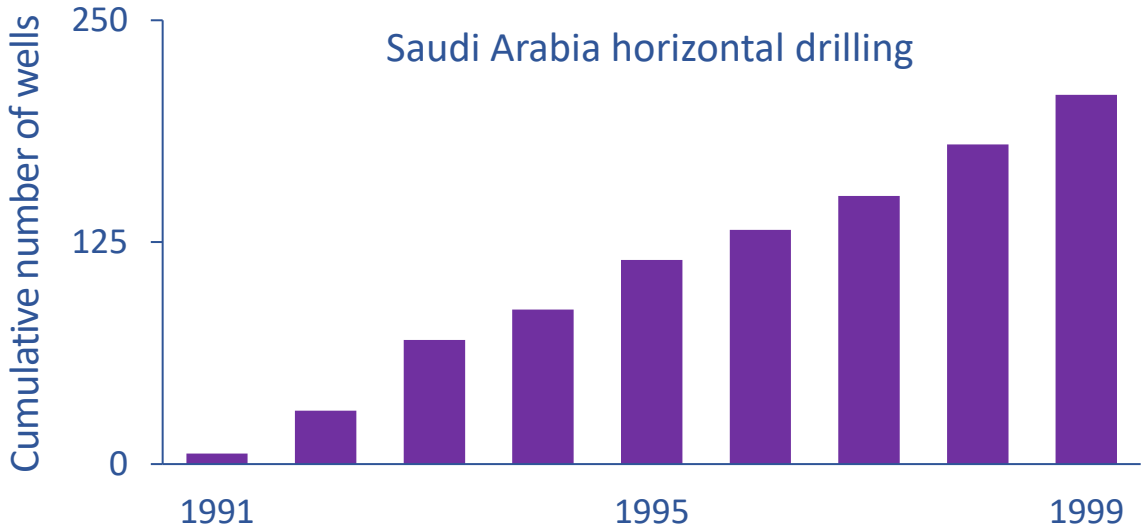
O&G drilling activity – Horizontal wells have become the design of choice

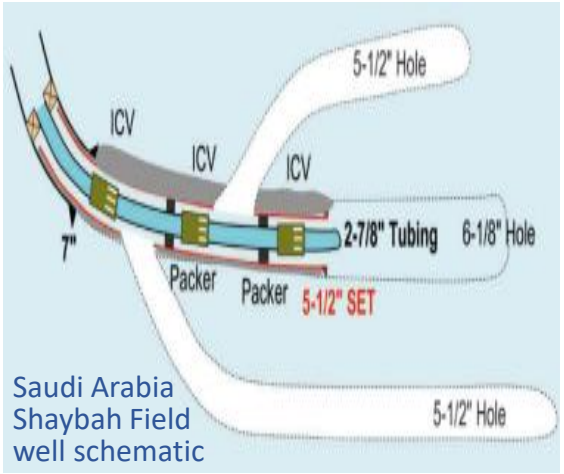
U.S. drilling by well trajectory

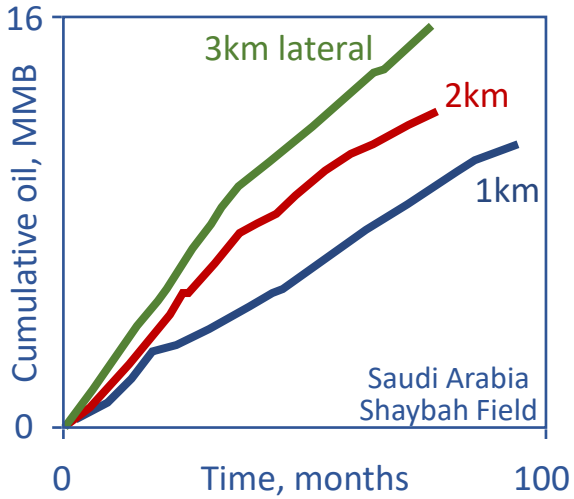


Data from Baker Hughes' online Rig Count spreadsheet

International horizontal well applications







Figures modified after Stenger et al. (2002), Hamada et al. (2001), and Salamy et al. (2008)

Drilling low-cost, long horizontal wells in basement rocks is possible

Utah FORGE (Days, spud to TD)

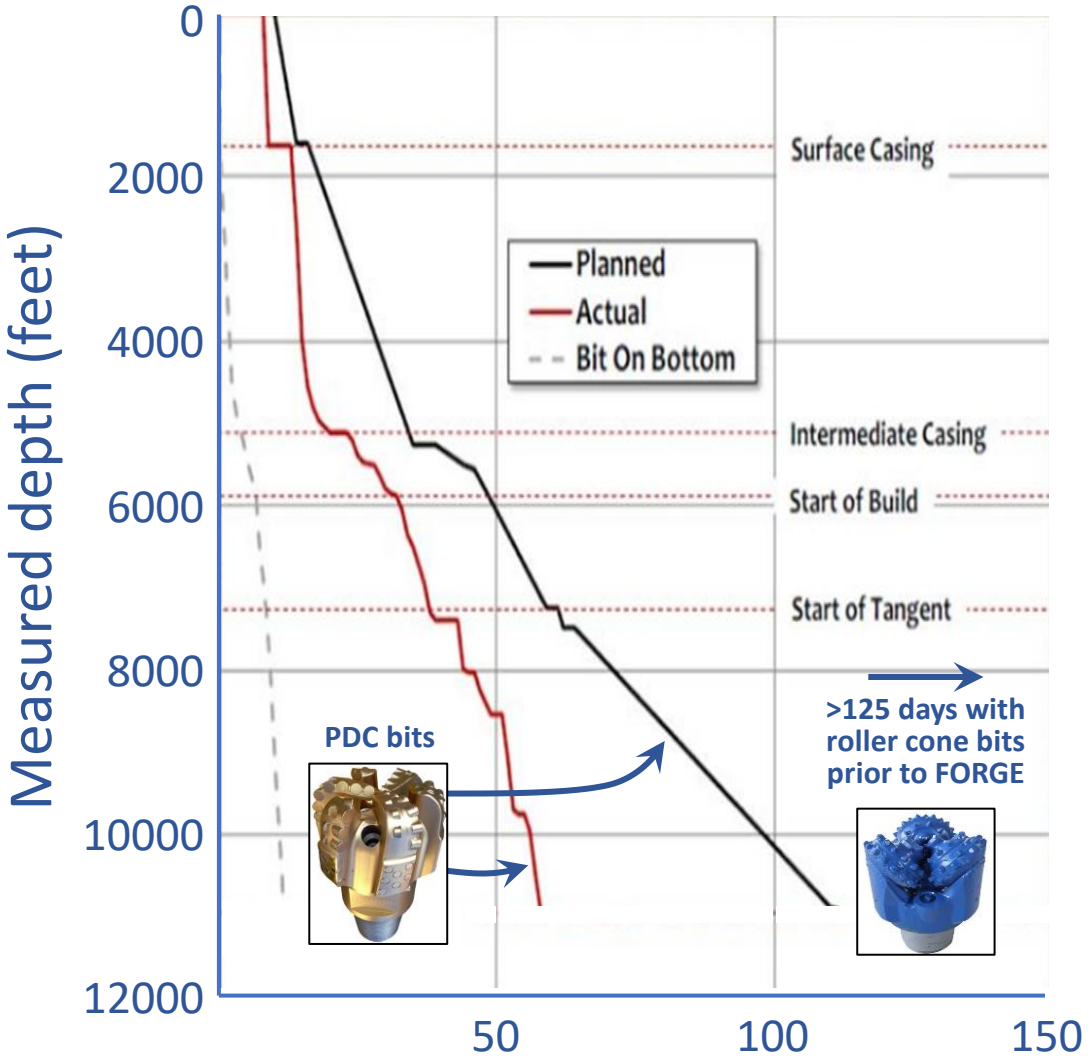


Figure modified after Winkler and Swearingen (2021)

Fervo Energy (Days, spud to TD)

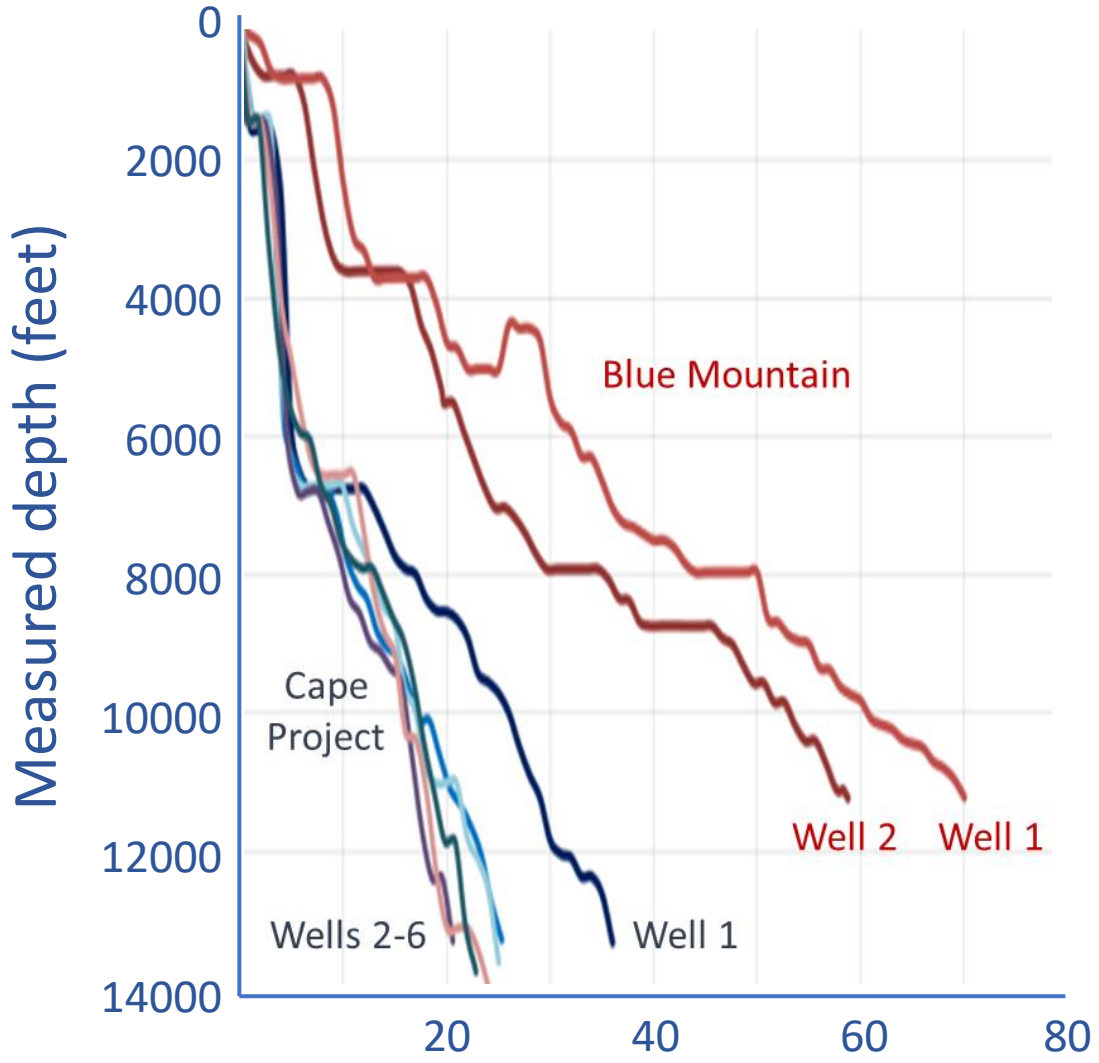
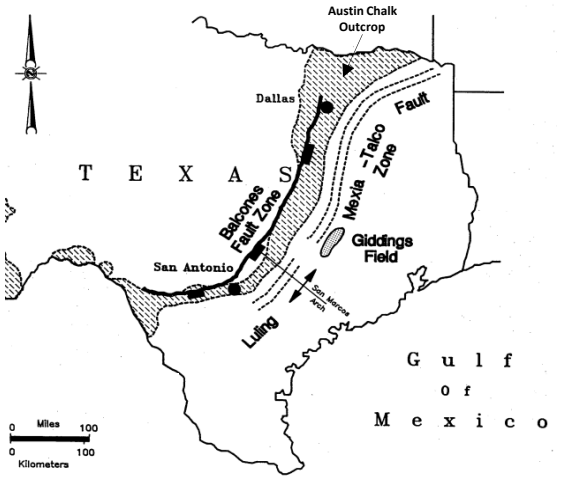
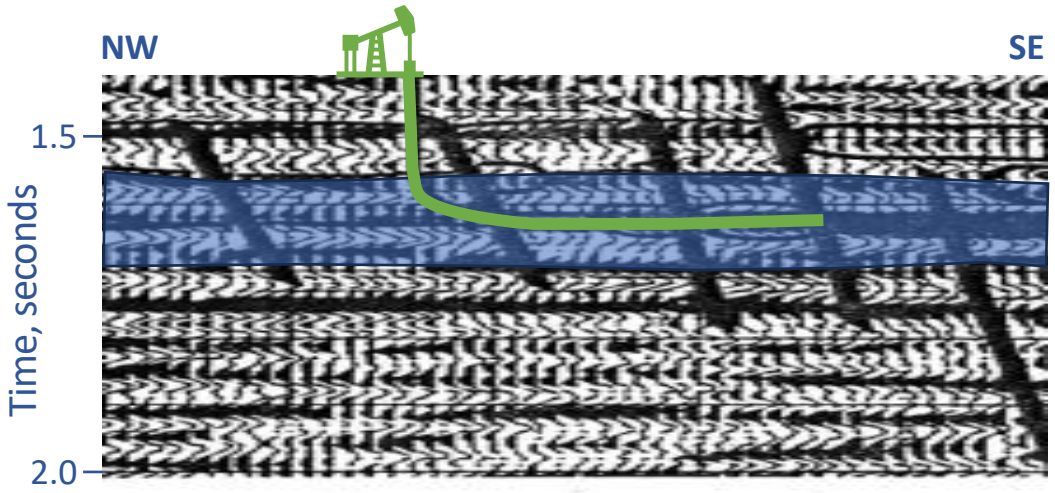
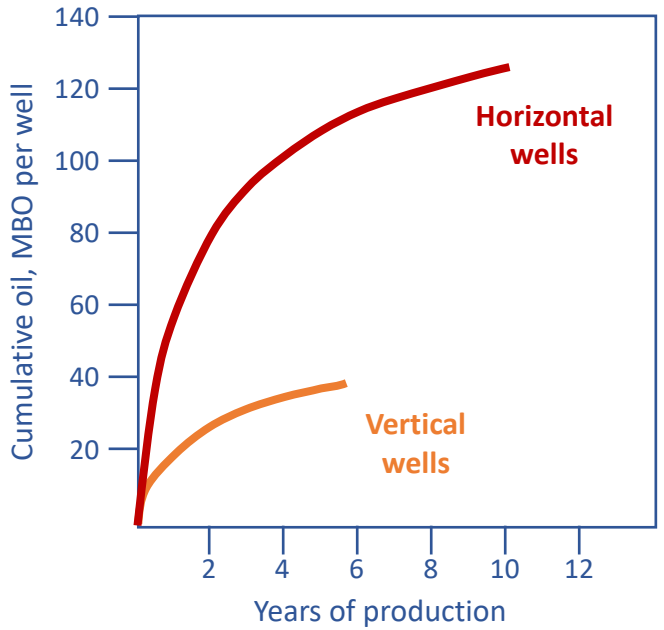


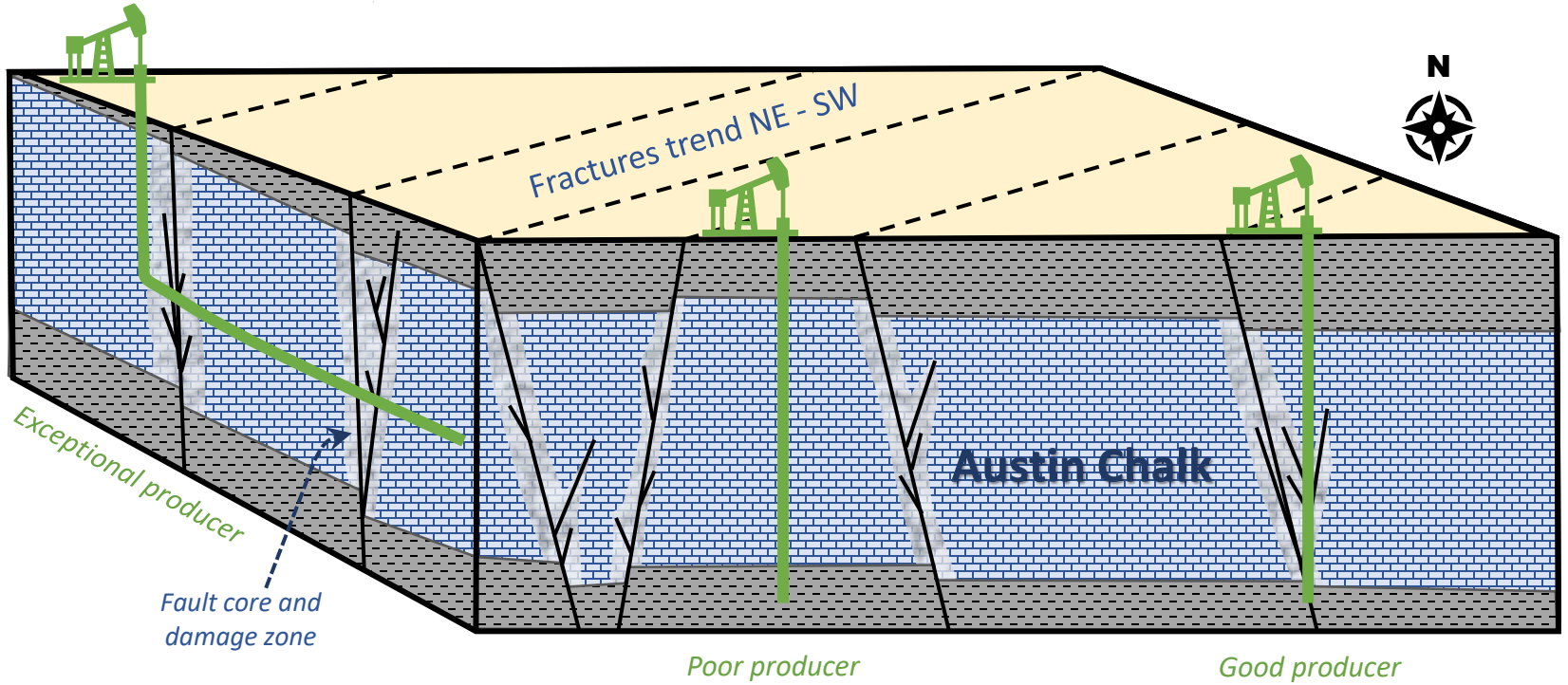
Figure modified after El-Sadi et al. (2024)

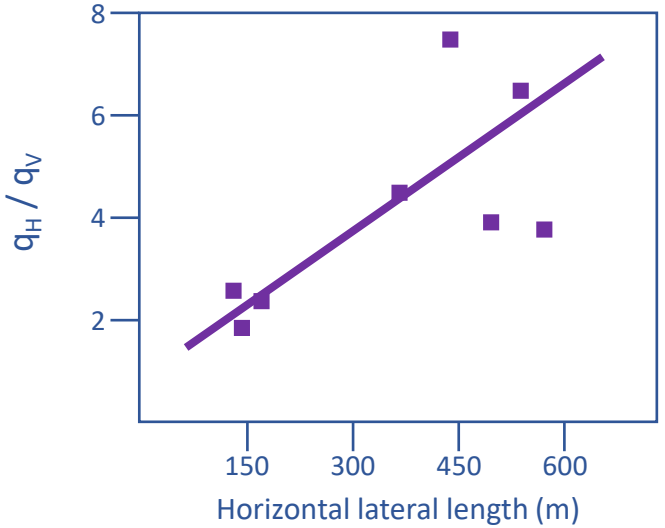
HWs: The optimal design for low-matrix-permeability fractured reservoirs











Figures modified after Kuich (1990); Stell and Brown (1992). HWs = horizontal wells; MBO = thousand barrels of oil

To achieve higher flow rates from basement rocks, intersect more fractures[1]

Hydrocarbon production from basement rocks

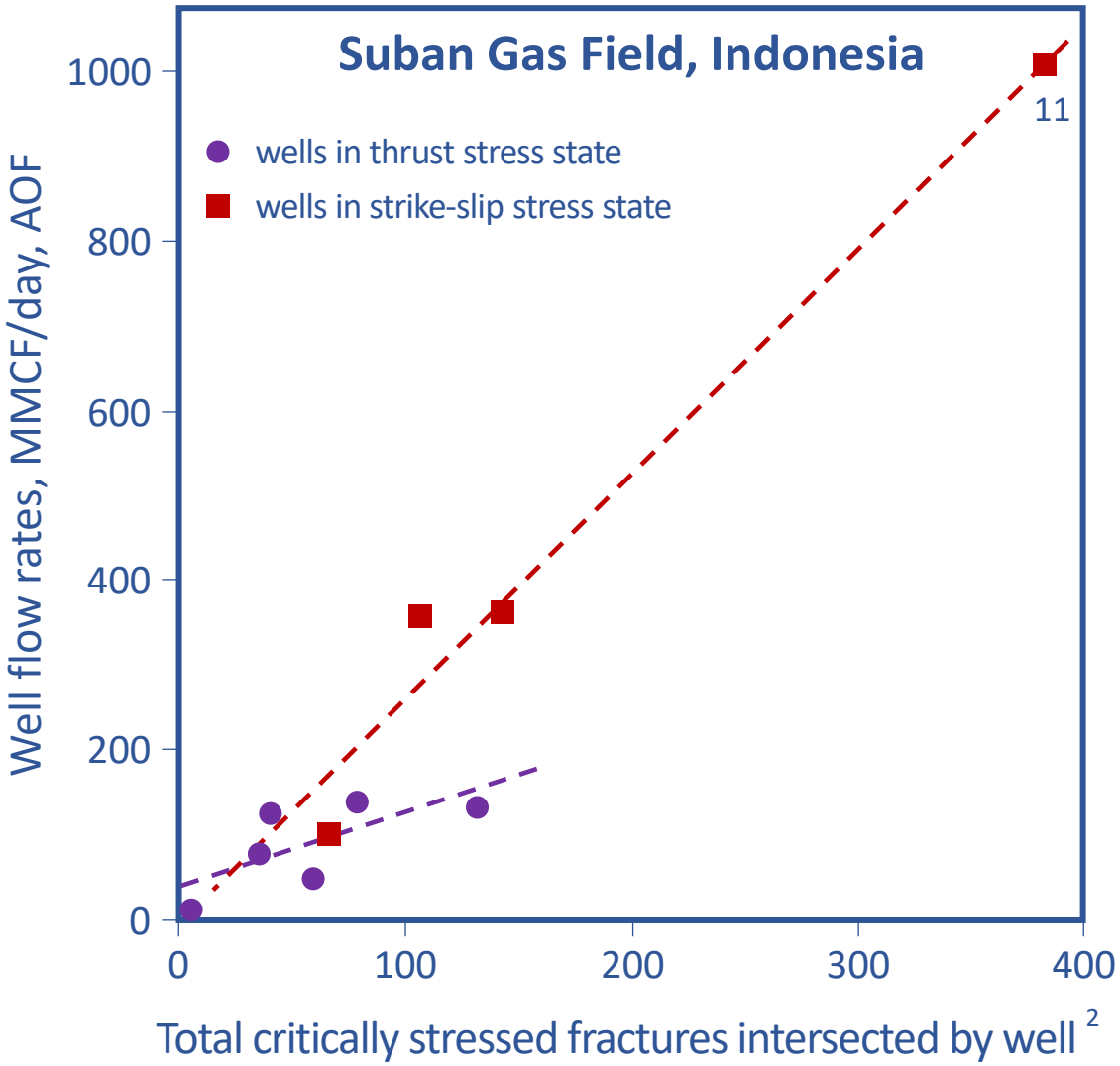


Figure after Hennings et al. (2012). MMCF = million cubic feet; AOF = absolute open flow; [1] critically stressed fractures; [2] from image logs.

Identifying faults in basement rocks is difficult

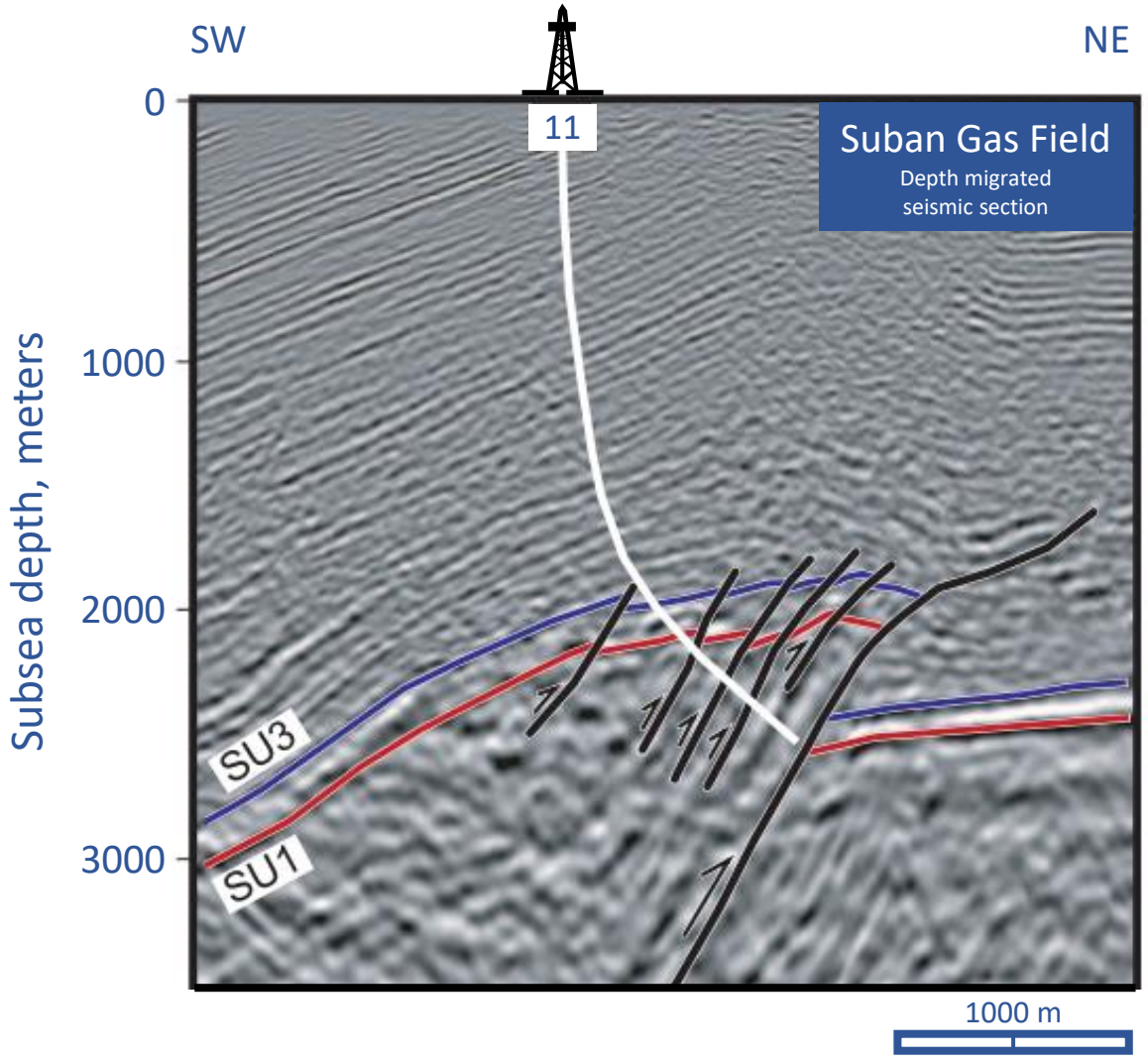
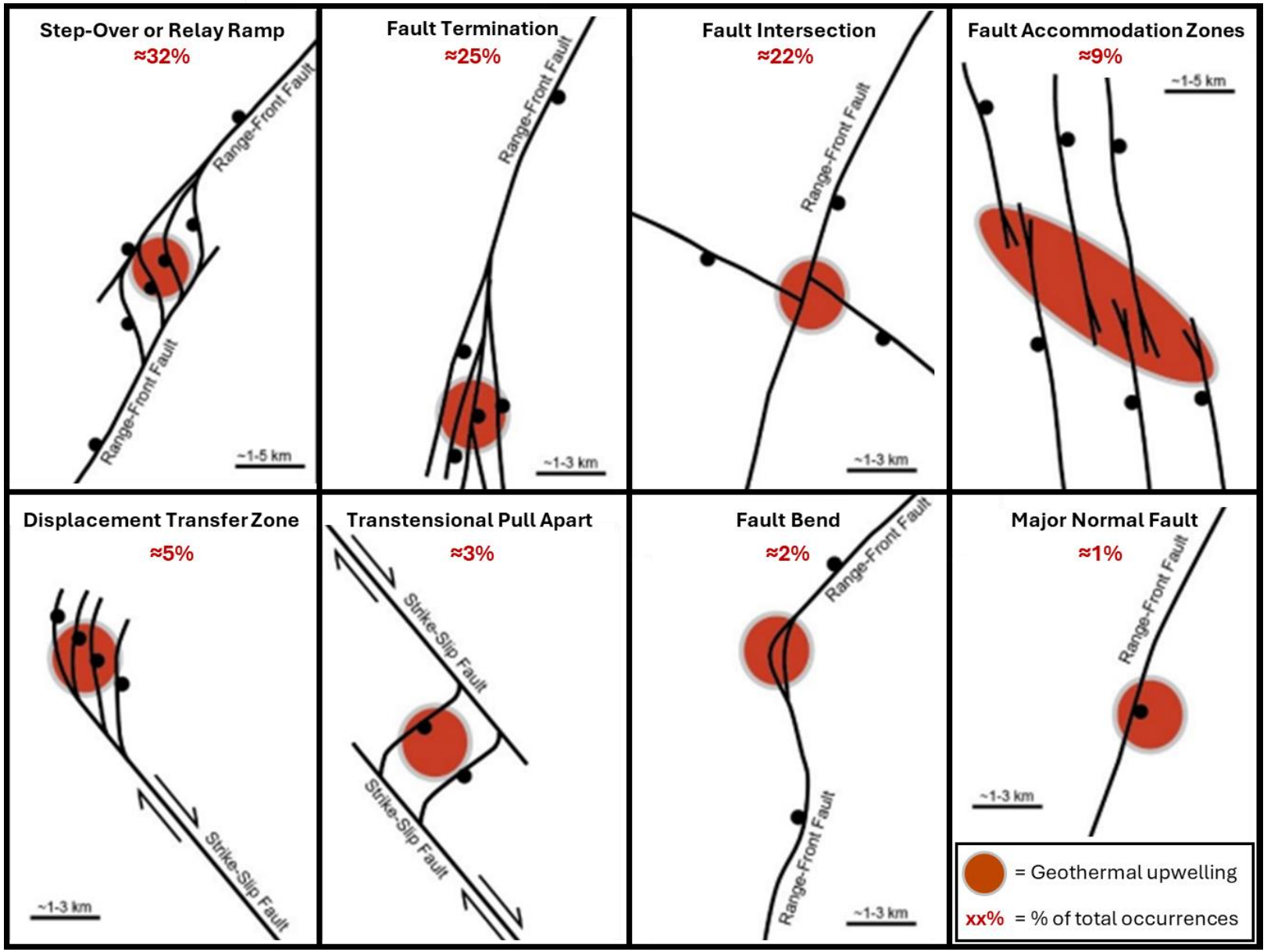
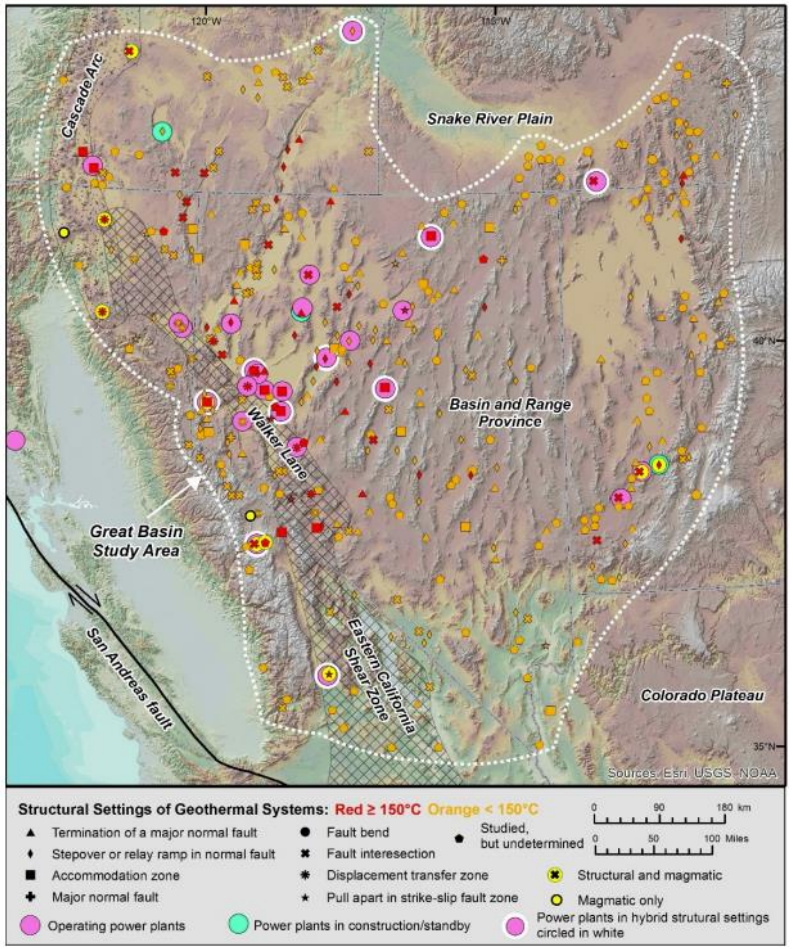


Figure after Hennings et al. (2012). Suban field estimated ultimate recovery = 6 TCFG from fractured basement rocks

Structural characteristics of fault zone hosted hydrothermal systems

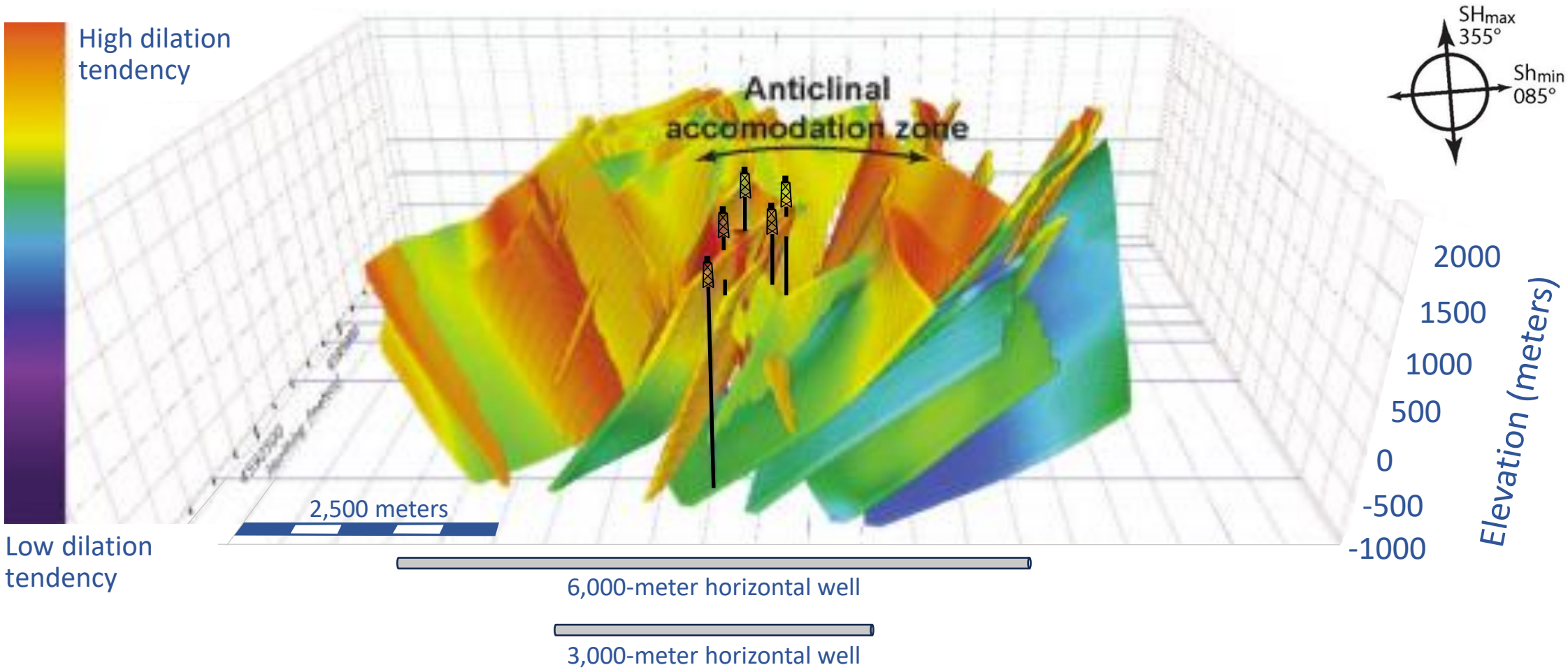




Figures from Faulds and Hinz (2015). Favorable Tectonic and Structural Settings of Geothermal Systems in the Great Basin Region, Western USA: Proxies for Discovering Blind Geothermal Systems. Note – the figure on the left was modified to show the percentages Faulds and Hinz reported for each type of fault related geothermal system.

Application of horizontal wells to fault zone hosted hydrothermal fields

Tuscarora geothermal system



Key uncertainties: Location of faults, dilation tendency, recency of fault movement, degree of mineralization

Figure from Siler et al. (2019)

Special drilling considerations for horizontal hydrothermal wells

Differences compared to oil and gas

- Extremely high formation temperatures (> 200° C)
- Sub-hydrostatically pressured fractured reservoirs
- **LPHT challenges include** (but not limited to):
  - Maintaining circulation, hole cleaning, and wellbore stability
  - Cooling drill string and bottom hole assembly
  - Sustaining communications with MWD and directional steering tools
  - Maintaining acceptable levels of torque and drag

Reasons to be encouraged

- Idea of horizontal hydrothermal wells is not new (e.g., Geysers' horizontal injection well)
- Fervo Energy success with drilling > 1,500 m long horizontal wells in basement rocks at their Cape Station project
- Under-balanced drilling using fluids that are lighter than water
- Innovative engineering solutions and technologies
- There are companies already pursuing HHW!

O&G = Oil and gas; LPHT = Low pressure, high temperature; MWD = Measurements while drilling

HHW = Horizontal hydrothermal wells

Crossing the horizontal well adoption chasm

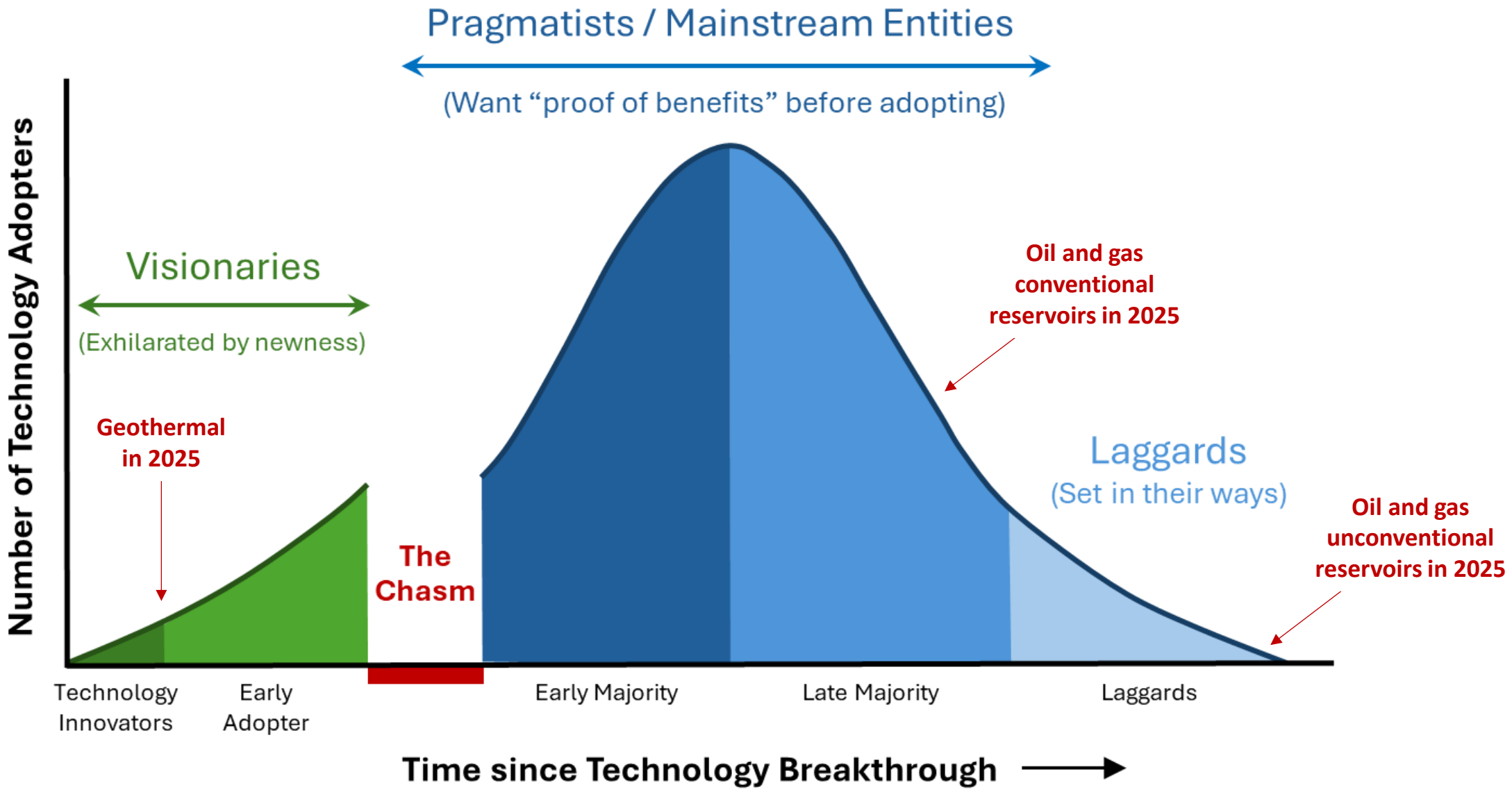


Figure modified after Moore (1991)

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