ASSESSING GEOTHERMAL POTENTIAL OF THE SAUDI WEST COAST USING THE USA BASIN RANGE AS ANALOG

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OUTLINE

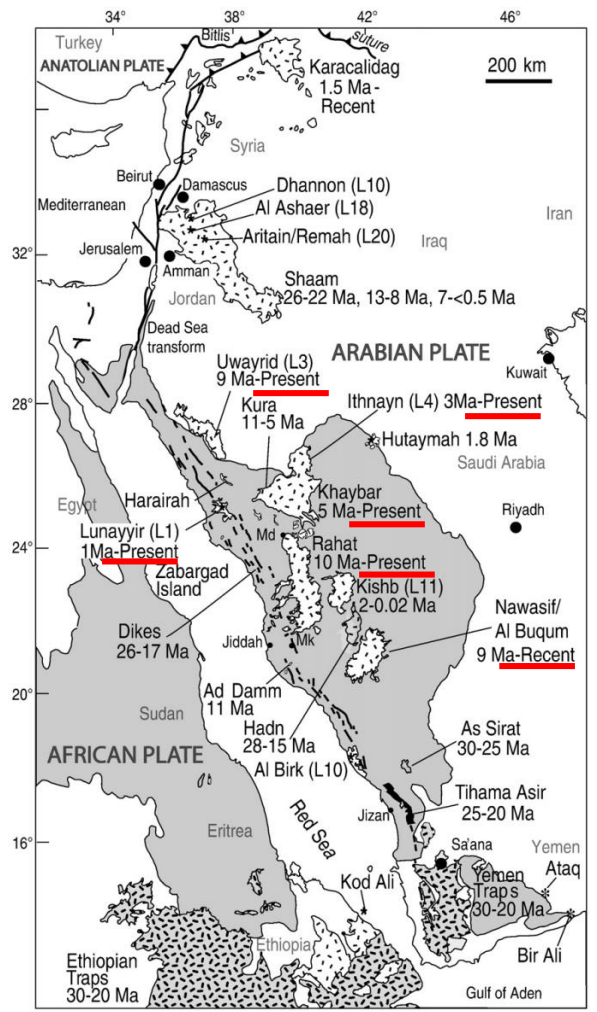
- Why the Basin and Range and Saudi Arabia West coast are suspected analogs
- The hidden resource concept and applicable exploration technologies
- Geothermal data sets
- Useful experience from other locations
- Primary resource properties needed and ideal site selection
- Should the Saudi Red Sea coast be assigned a generating potential in the ~1 GW range and higher if bottoming units like district cooling or thermal desalination are incorporated ?

INTRODUCTION

- The worldwide geothermal industry has been focusing on power production
- Economic in volcanic regions, >240 °C fluids are tapped at 1-3 km depth
- Advancements in pump and heat conversion technologies make other geological settings and cooler resources feasible for geothermal applications
- The USA Basin and Range (B&R) is an example, currently with ~700 MW of installed capacity from 25 power plants in Nevada only
- The arid climate is a major challenge as geothermal reservoirs are unlikely to express themselves with easily visible surface manifestations
- The hidden resource looks as reasonable early exploration concept
- This talk is suggesting how to proceed with geothermal exploration and development, referring to experience in diverse locations such as the UAE, India West Coast and East Coast of Greenland, not forgetting hidden geothermal resource discoveries in Iceland
- Remote sensing with drones

THE ANALOG

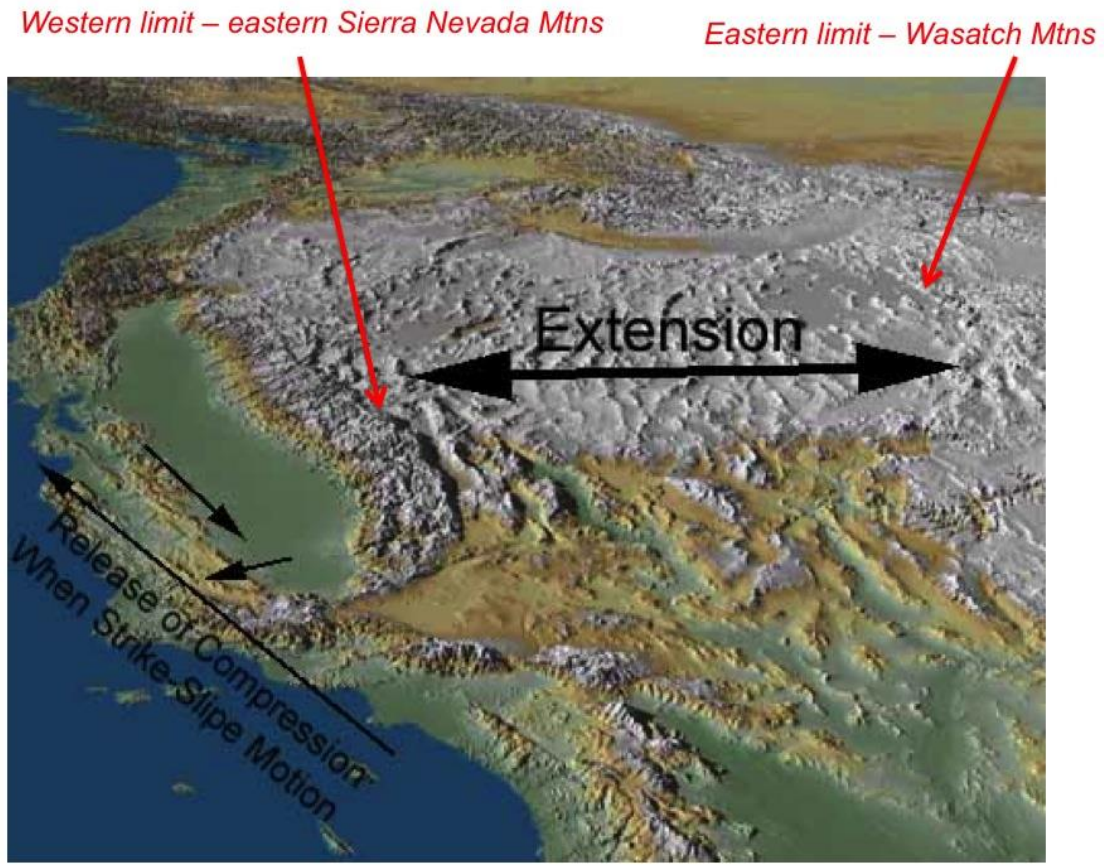
- Extension, crustal thinning, normal faults, volcanic vents, thick alluvium

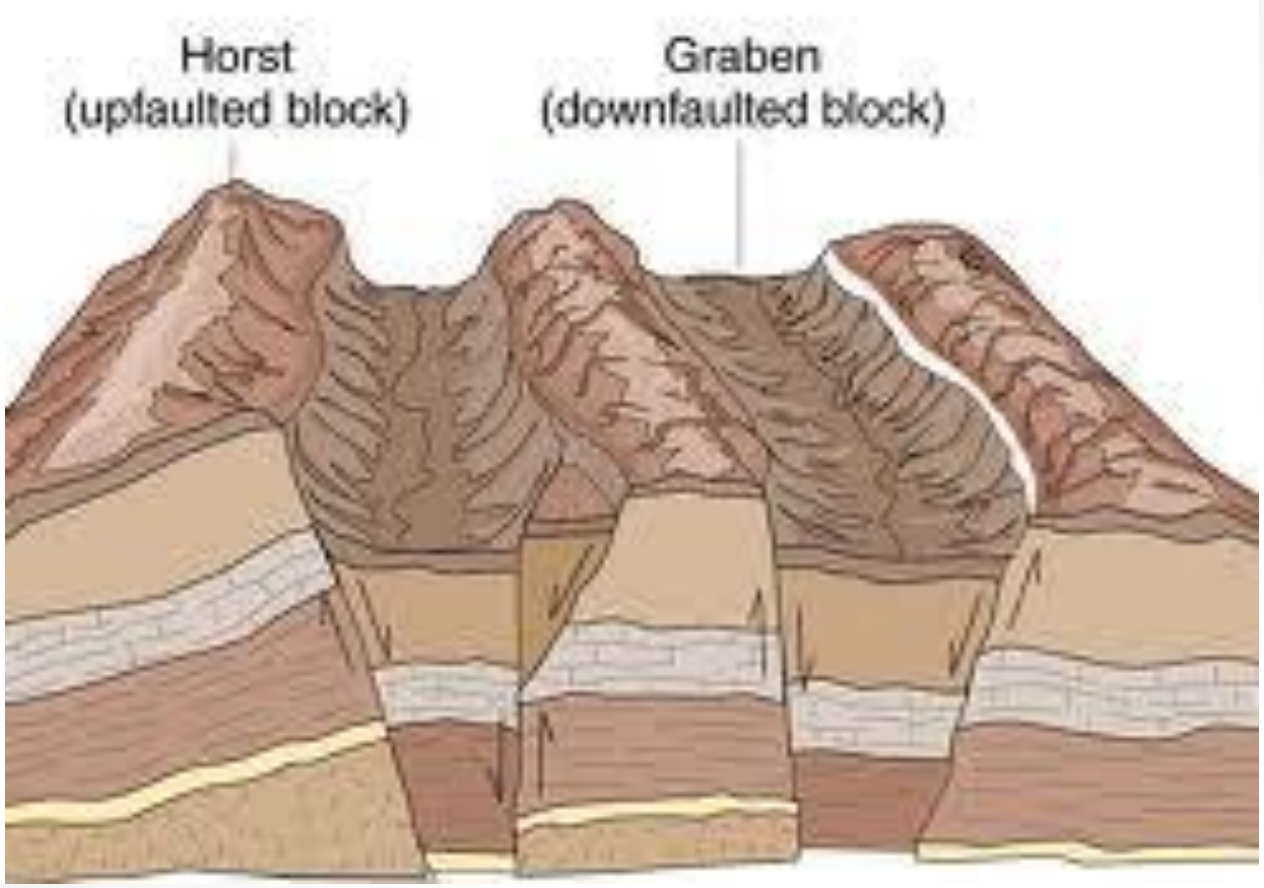


Source: Stern R.J. and P. Johnson, 2010

EXTENSIONAL STRESS FIELD AND CRUSTAL THINNING

- A primary source mechanism for the B&R systems is geothermal convection along normal fault systems





Source: University of Wisconsin, Madison

CONCEPTUAL RESERVOIR MODELS

- Vertical, normal faults channel the heat. Development ranges from targeting the source faults directly up to developing outflow zones that have heated over geological time scales

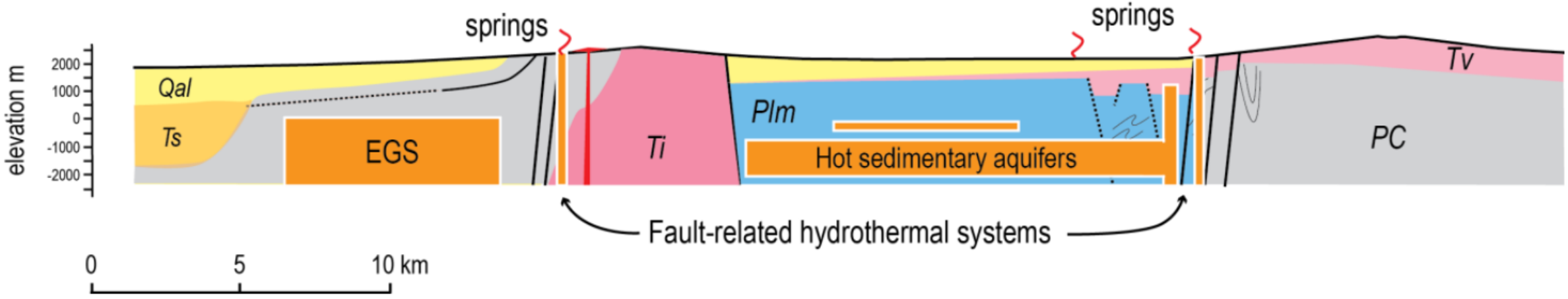


Figure 5: Schematic cross-section showing geothermal resources (orange) in the eastern Great Basin. Fault-related hydrothermal systems are localized along sub-vertical structures. Some have surface expression in the form of hot springs, and some are blind. They are shown to have a potential connection to hot sedimentary aquifers hosted by carbonate rocks. EGS resources occur in hot crystalline rocks that have low porosity. Abbreviations: PC=Precambrian gneiss-schist; Plm=Paleozoic limestone; PS=Paleozoic siliciclastic rock; Qal=Quaternary alluvium; Ti=Tertiary pluton; Tv=Tertiary volcanic rock.

Source: Simmons et al., 2017

SOURCE AND RESERVE CAPACITIES

- Many B&R resources appear to have in common a small heat source
- Over geological time scales the small source can however heat up large reservoir volumes
- When restricting the geothermal development to the heat source only, energy development projects will remain small
- When targeting the stored heat, larger projects are realized
- Under such scenarios, geothermal potential might be that of a large battery with a small charger

CURRENT WORK IN NEVADA GREAT BASIN

- Resource assessment of the Basin and Range is expecting higher generating potential than the current 700 MW installed
- Academic and commercial groups are actively working on locating hidden resources, using a suite of exploration methods
- A grading system, named the Nevada Play Fairway Project, is used to identify potential >130 °C resources from existing data sets
- Follow up work is encouraging for the validity of the site selection strategy
- Please visit the International Geothermal Association web site for access to a geothermal paper database with more details:

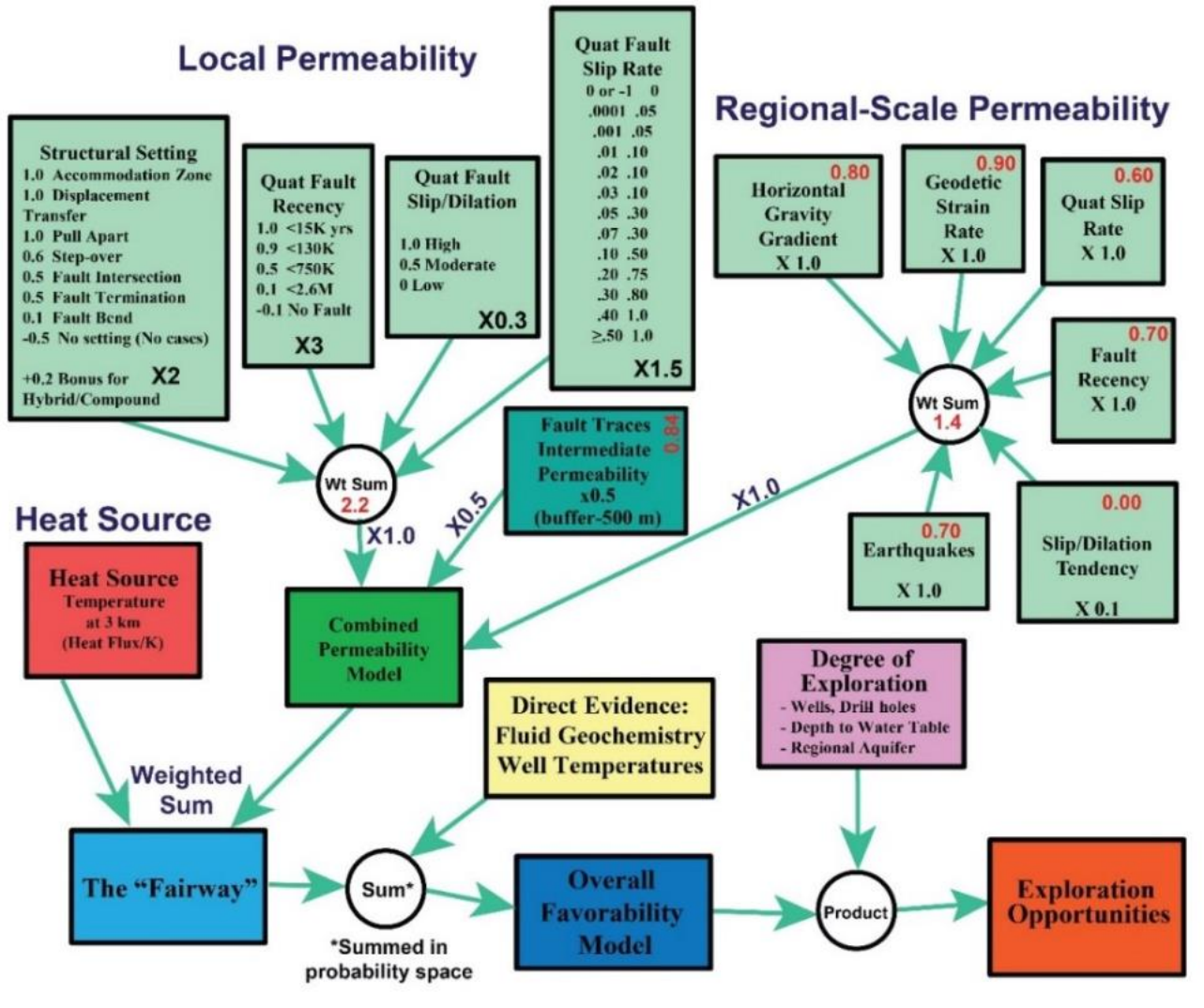
https://www.geothermal-energy.org/explore/our-databases/conference-paper-database/

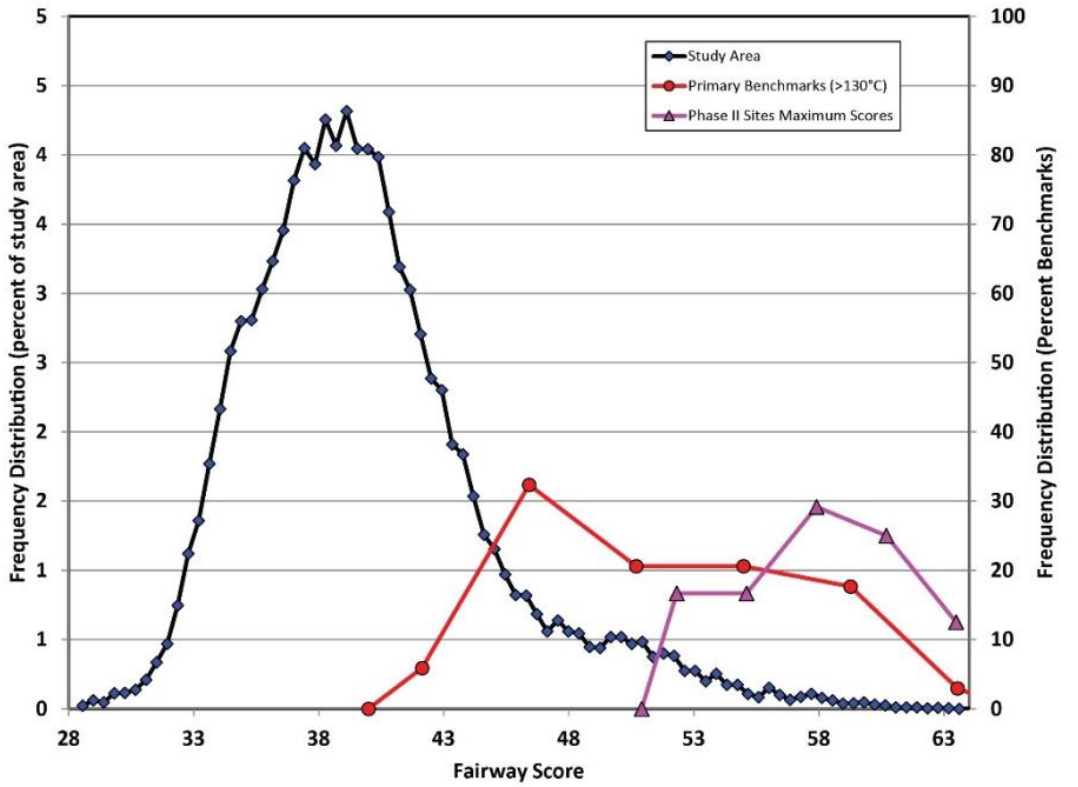
NEVADA PLAY FAIRWAY MODELING WORKFLOW

- A statistically based geothermal potential map for 96,000 km^2 across the Great Basin of Nevada
- The predictive play fairway map included 9 major parameters:
  1) Structural settings
  2) Age of Quaternary faulting
  3) Quaternary fault slip rates
  4) Regional geodetic strain rates
  5) Slip and dilation tendency of Quaternary faults
  6) Earthquake density
  7) Gravity data
  8) Temperature gradient data
  9) Geochemistry from springs
- 2-D and 3-D seismic lines and oil and gas well database appear missing

Source: Faulds et al., 2017

THE FAIRWAY SCORE MECHANISM





Source: Faulds et al., 2017

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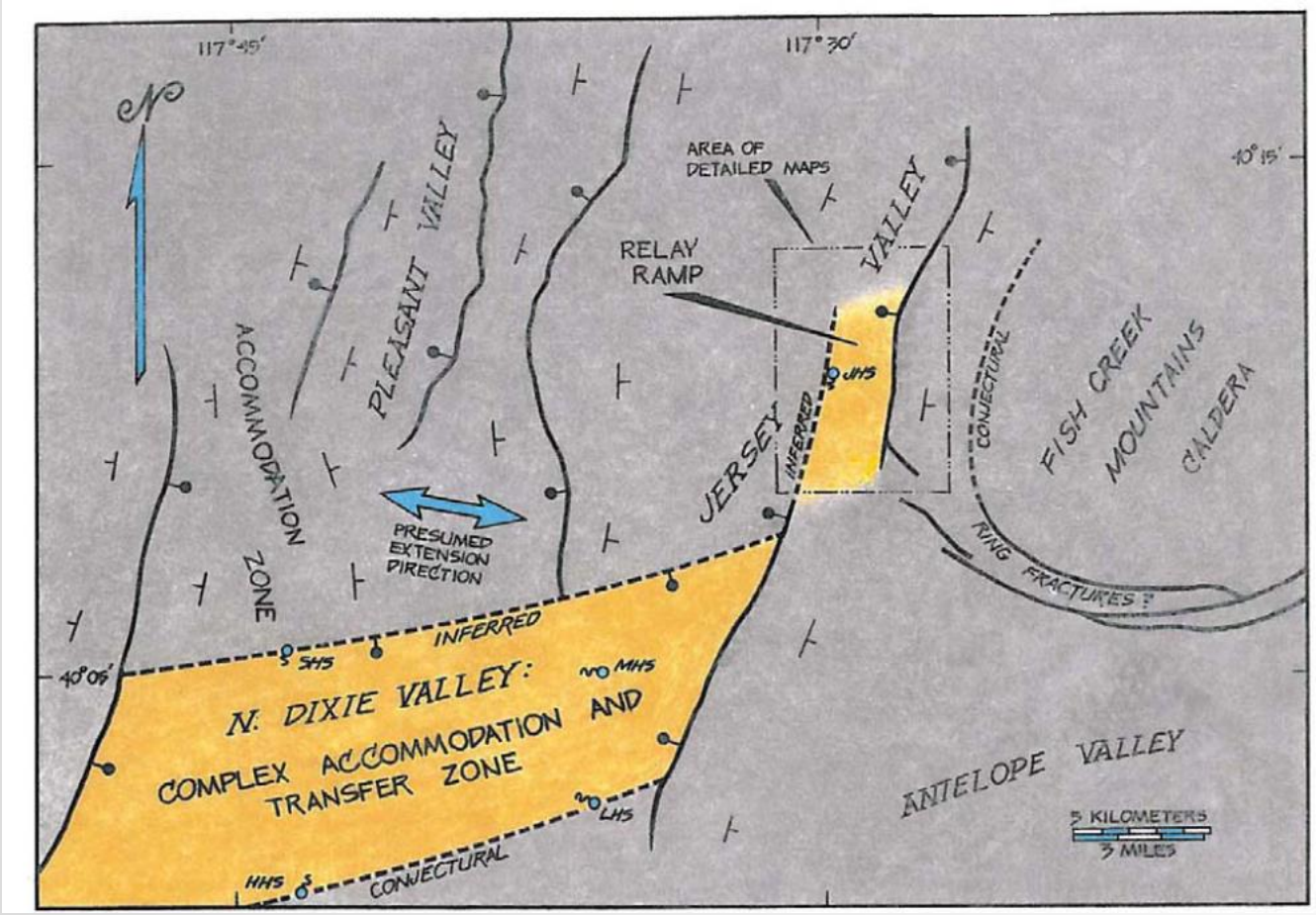
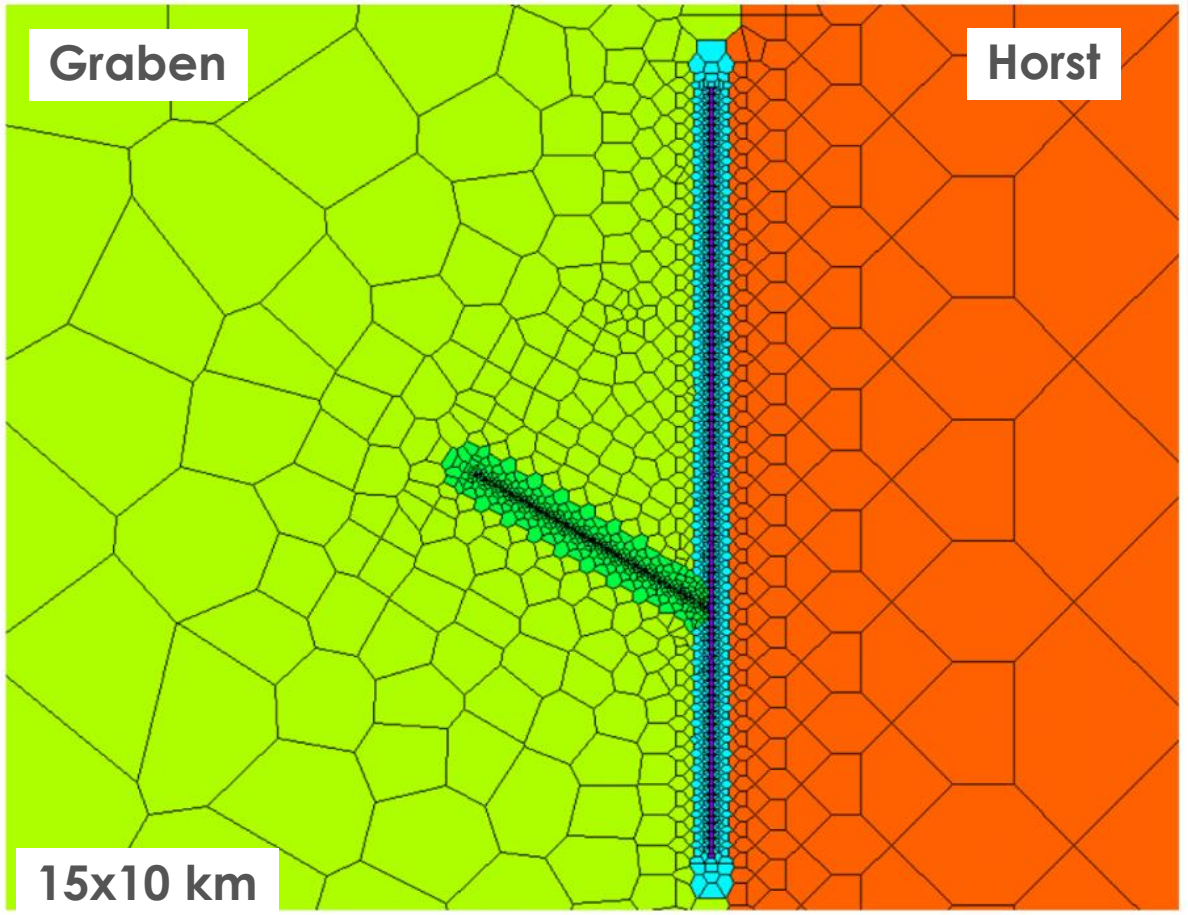
THE JERSEY VALLEY SINGLE FAULT MODEL

- About 15 MW binary power plant tapping 160 °C resource
- Conceptual and numerical models assume two faults only

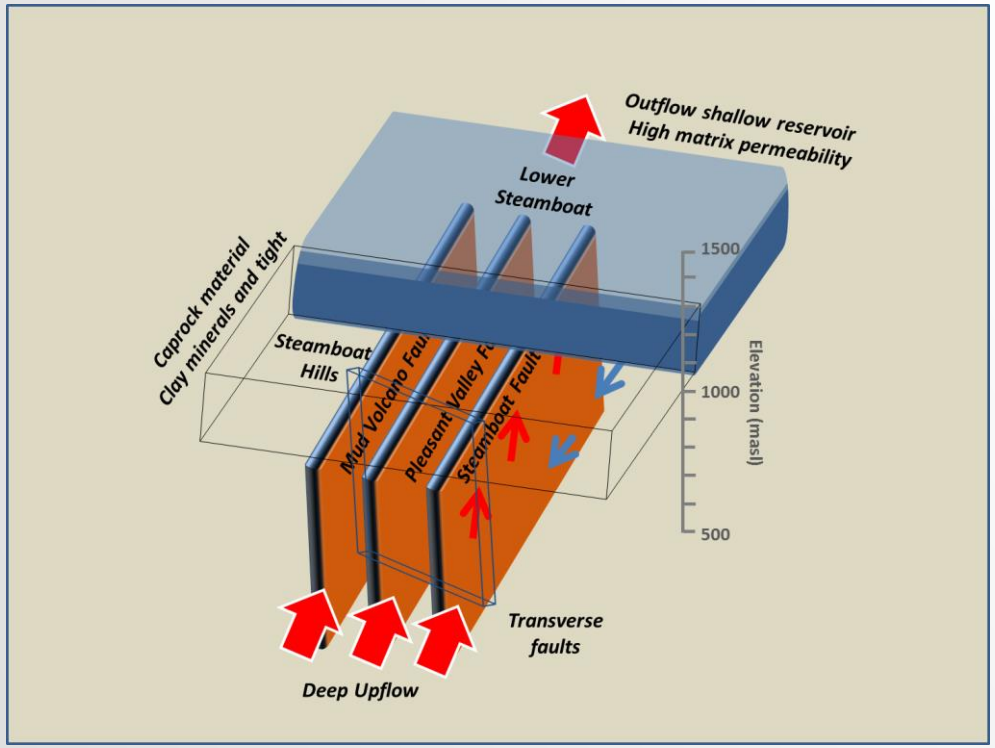


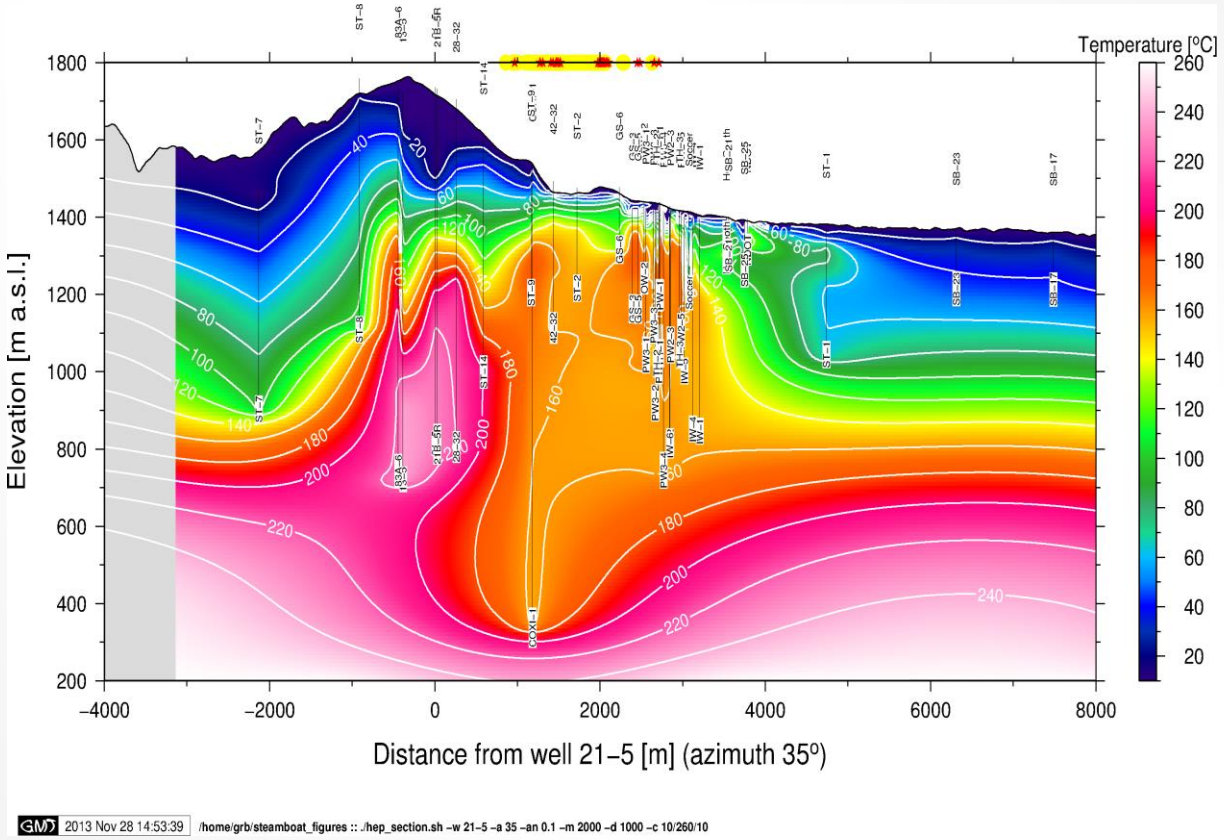


Source: Drakos et al., 2011

THE STEAMBOAT UPFLOW AND OUTFLOW MODEL

- A 3-D numerical reservoir model calibration for 80 MW binary project
- Deep and hot upflow zone and shallow later outflow
- Sizeable part of the power production supported by the large outflow zone





Source: Bjornsson et al., 2014

OTHER CONTINENTAL PLATE LOCATIONS

- The author was part of a team drilling two deep geothermal wells for the Masdar City in Abu Dhabi
- ***Your pay zone is our loss zone*** concept
- Two high flow wells from same pad targeting ~2000 mVD horizontal limestones and dolomites
- The wells are to be picked up by the National Central Cooling Company (Tabreed)
- Author also worked on the Tura, Hungary ~2 MW binary power plant, tapping limestones in the Pannonian Basin
- The India state of Maharashtra hosts about 70 M year old escarpment faults, apparently good for low to medium grade geothermal
- Same age Greenland east coast has active hot springs still to be explored
- The Netherlands house heating by gas turns illegal in 2050

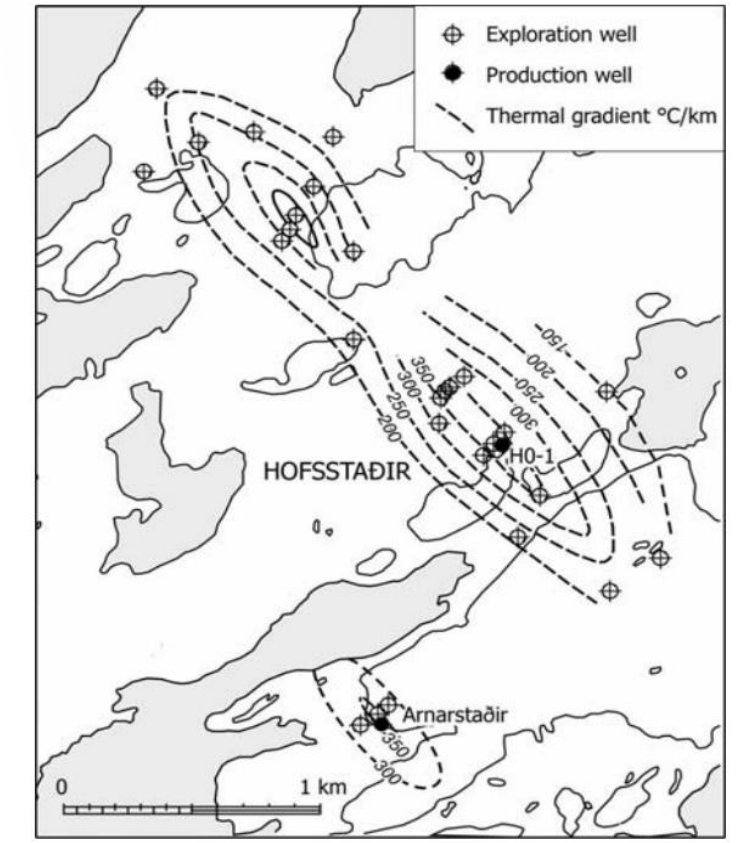
Source: ThinkGeoEnergy, 2020

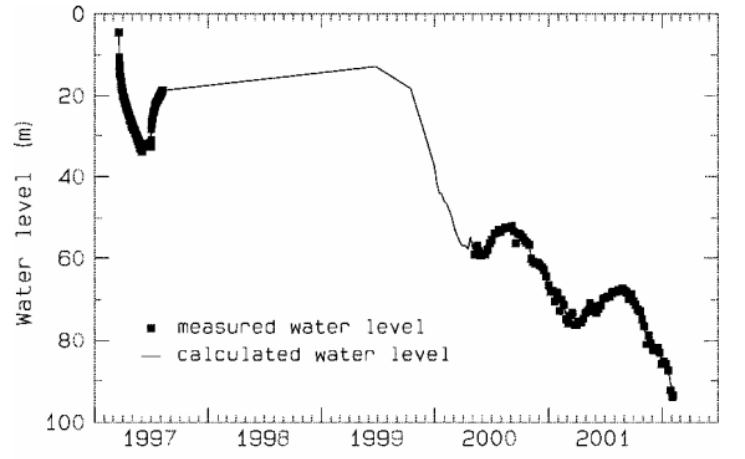
Source: ThinkGeoEnergy, 2017

THE ICELAND STORY

- 95% of the population has access to geothermal district heating
- Both the resource and demand in place
- The first 70-80 % of development were relatively fast, often thanks to hot springs on surface
- Later additions are mostly from hidden resources, discovered by systematic drilling of shallow, thermal gradient wells (50-200 m)
- The exploration in general driven by market demand, and limited to 20-40 km radius
- Established geothermal industry with fairly open data policy, government incentives for geothermal heating and experienced scientists
- Looks like a recipe for success

Source: Axelsson et al. 2005



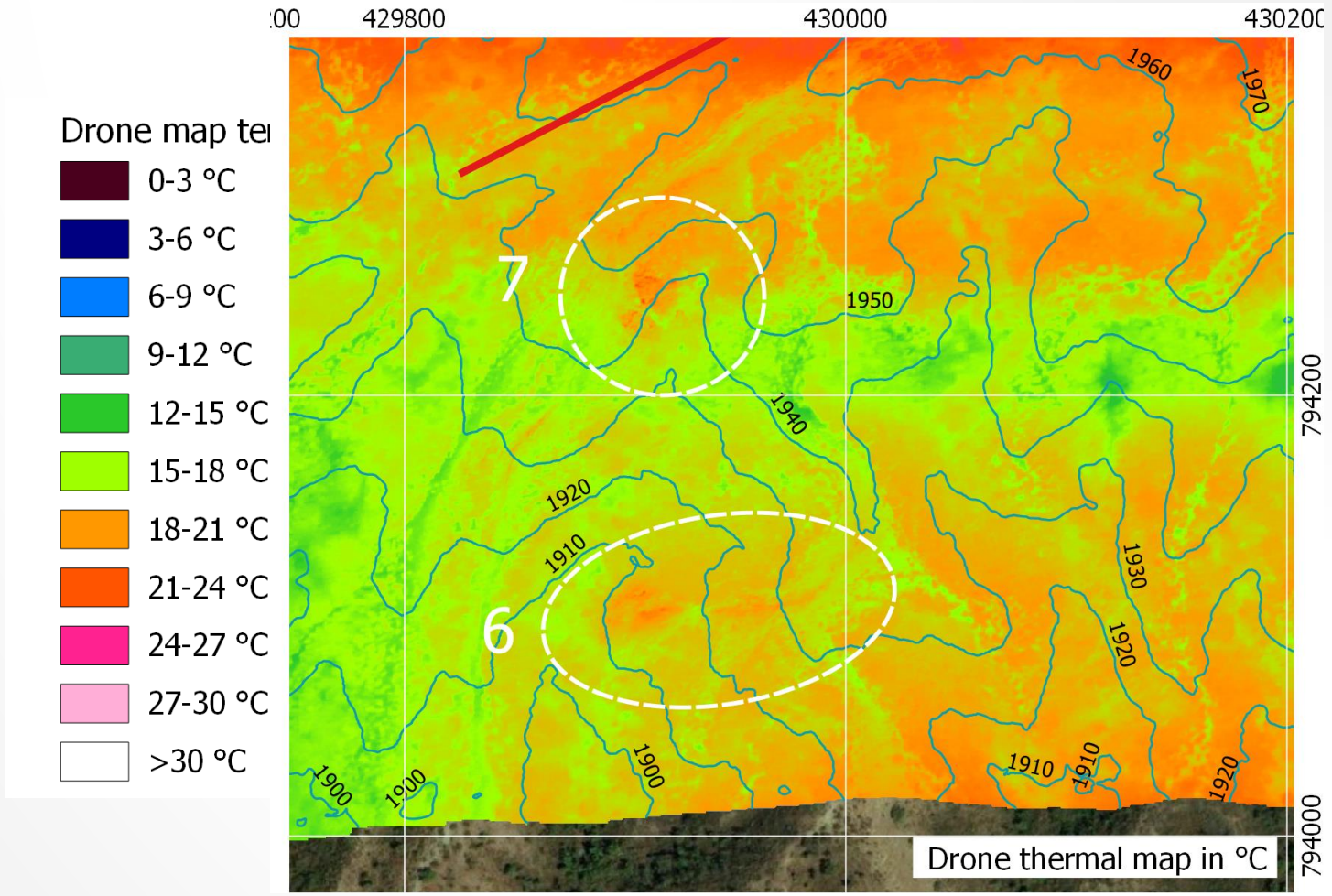


WAY FORWARD IDEAS

- This talk rates the Saudi Arabia possible geothermal power generating capacity on the GW scale - if comparable to the 700 MW installed in Nevada where hidden resources are still to be identified
- Initial work phase appears to be that of a data room, hosting as many as possible of the Play Fairway datasets
- Complement with the local experience and expertise, like oil and gas
- A proposed site selection strategy is T>100 °C and high permeability
- Locations near the coast and populated areas should be preferred for better heat sink, thermal desalination and district cooling become add on options
- With potential sites identified for detailed exploration, consider remote sensing with thermal imaging as priority for low unit area exploration cost
- Aim for high resolution orthomosaics (≤ 25 cm), and fly late nights, before sunrise, to minimize solar impact
- Thermal cameras resolution will determine if fixed wing aircraft or drone is best

DRONE EXAMPLE FROM THE EAST AFRICA RIFT

- Dry-season early morning flights with a drone
- Thick volcanic tuffs on surface
- Figure to left shows two anomalies considered geothermal
- Rest of the map is impacted with all kind of noise, mostly sunrise at the time of flying, but also striping effect of the drone flight direction
- Rapid development in processing thermal images captured by drones
- Artificial intelligence promising for auto picking anomalies



Source: Bjornsson et al., 2019

CONCLUSIONS

- Many reasons to rate the Saudi Arabia West Cost of significant geothermal power generation capacity
- Power production is limited to resources of temperatures >130 °C and high permeability
- At this stage the possible resource is considered largely hidden
- Data room, Play Fairway model and possible local field data sets should assist in selecting potential sites for more detailed exploration
- Coastal locations allow for optional heat processes like district cooling and thermal desalination
- Set the possible early power generating capacity at 1 GW
- Consider thermal mapping by drones or fixed wing aircraft as first stage in the detailed geothermal exploration, followed by other more expensive methods

THANK YOU !

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