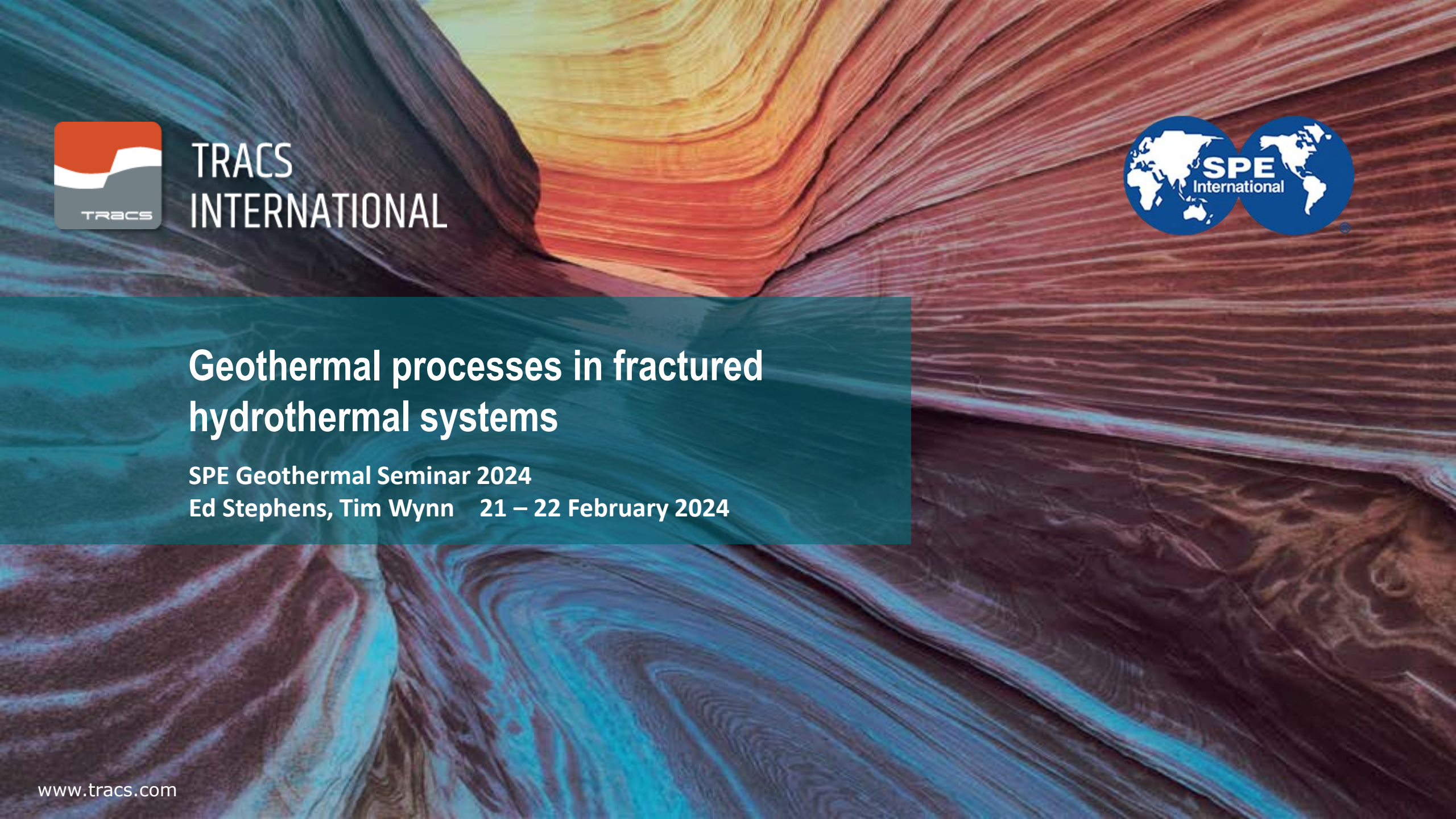

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Geothermal processes in fractured hydrothermal systems

SPE Geothermal Seminar 2024

Ed Stephens, Tim Wynn 21 – 22 February 2024

Agenda

- Quick images: what happens ?
- Fluid and heat transport in fractures
- Impact on heat recovery
- Key messages

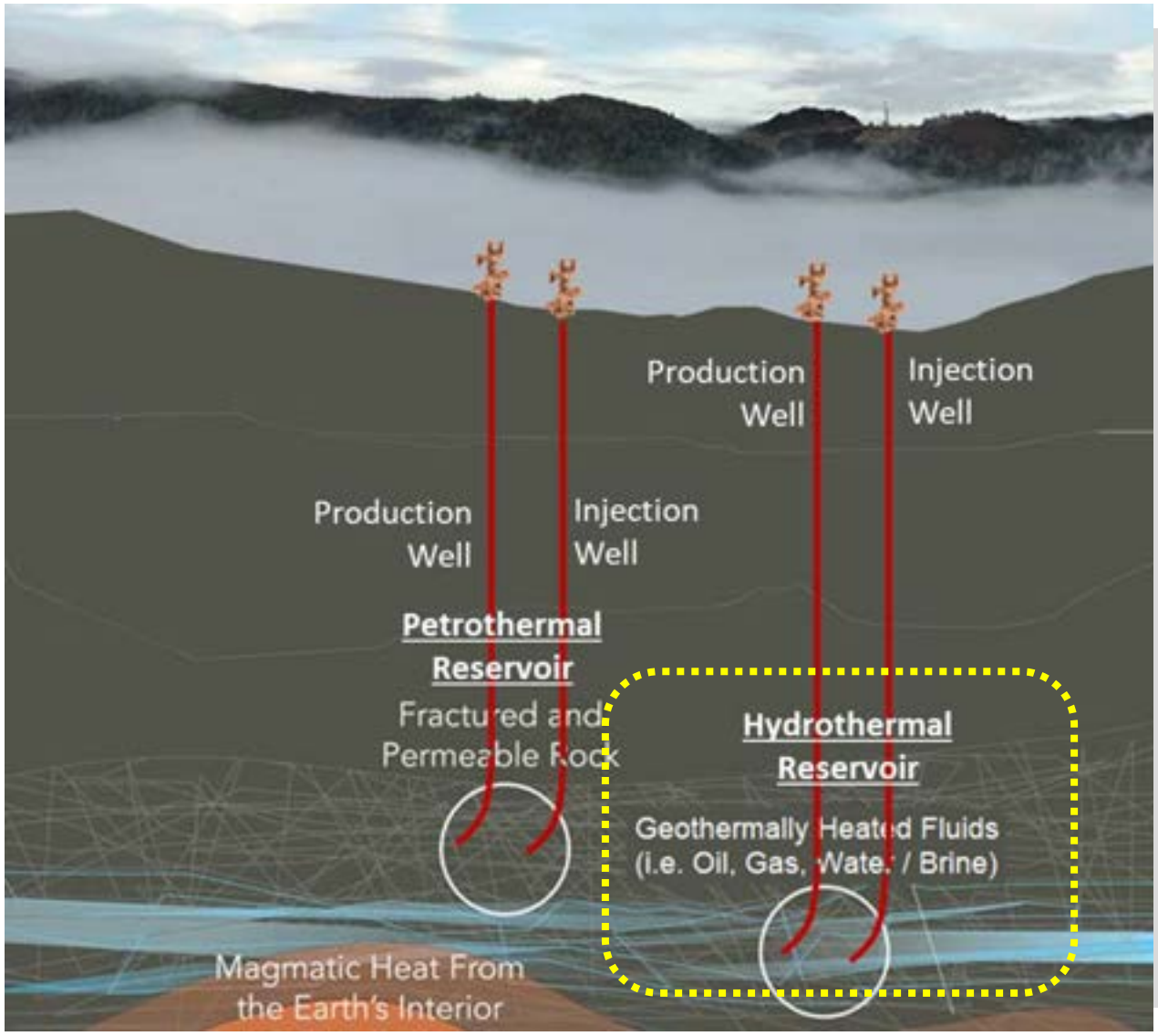
Overview of discussion

Geothermal system type

- Open system hydrothermal reservoir
- Low to Medium enthalpy brines (T_i 100 – 200 ºC)
- Presence of fractures and/or fractured perm zones

Objectives

- Heat recovery: fluids, matrix, degree of bypassing?
- Impact of fractures on fluids and heat recovery



Thermal flood with fractured zones

Schematic sector model

Fractured zones 400 m spacing

- High conductivity
- Low storativity

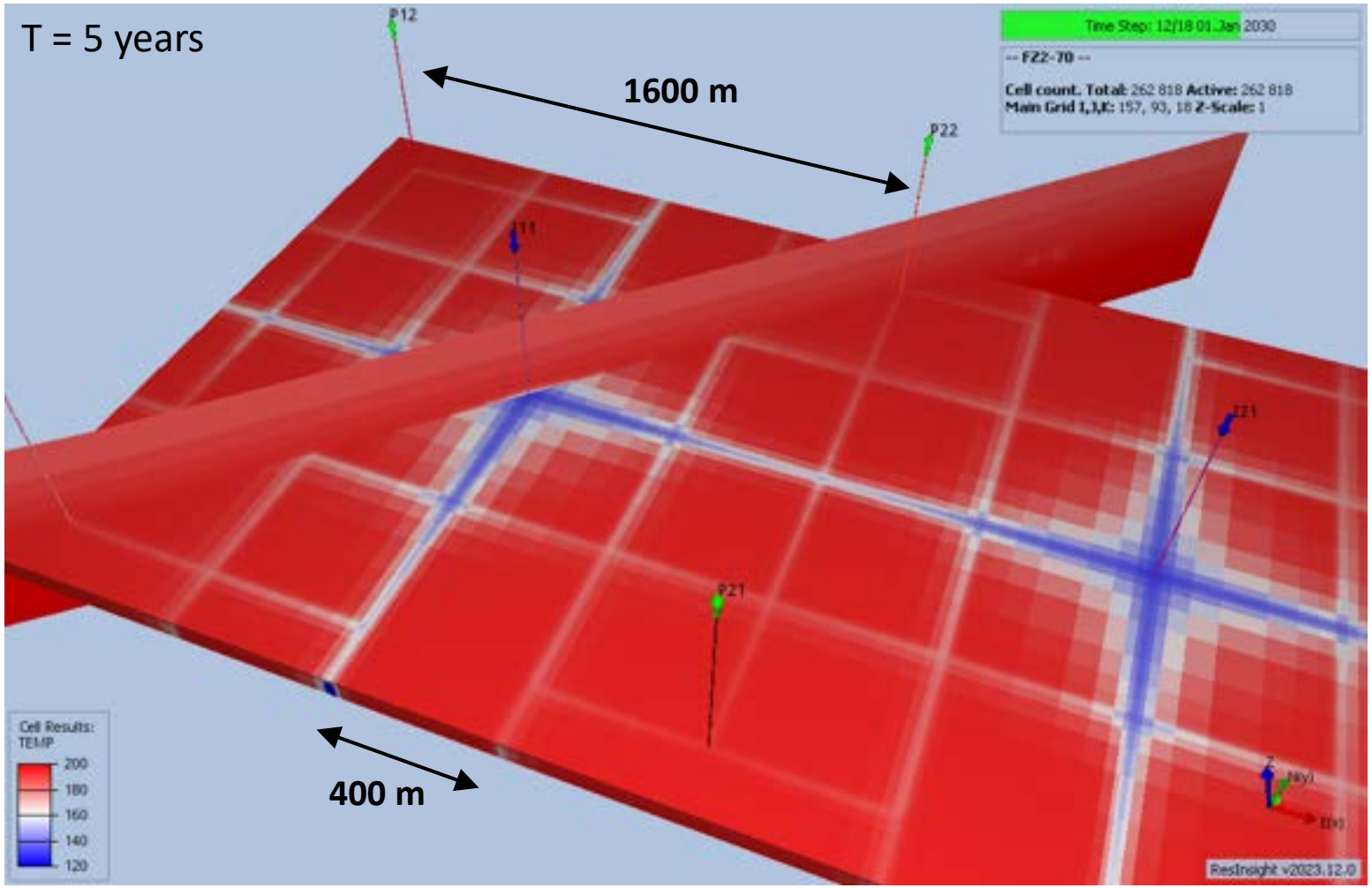
Over and under-burden zones

T_i 200 ºC, reinjection 120 ºC

Scheme: 6 producers, 2 injectors

Pattern: 1600 m (P-I 1150 m)

‘Heat RF’ vs. total rock and fluids heat capacity in pattern



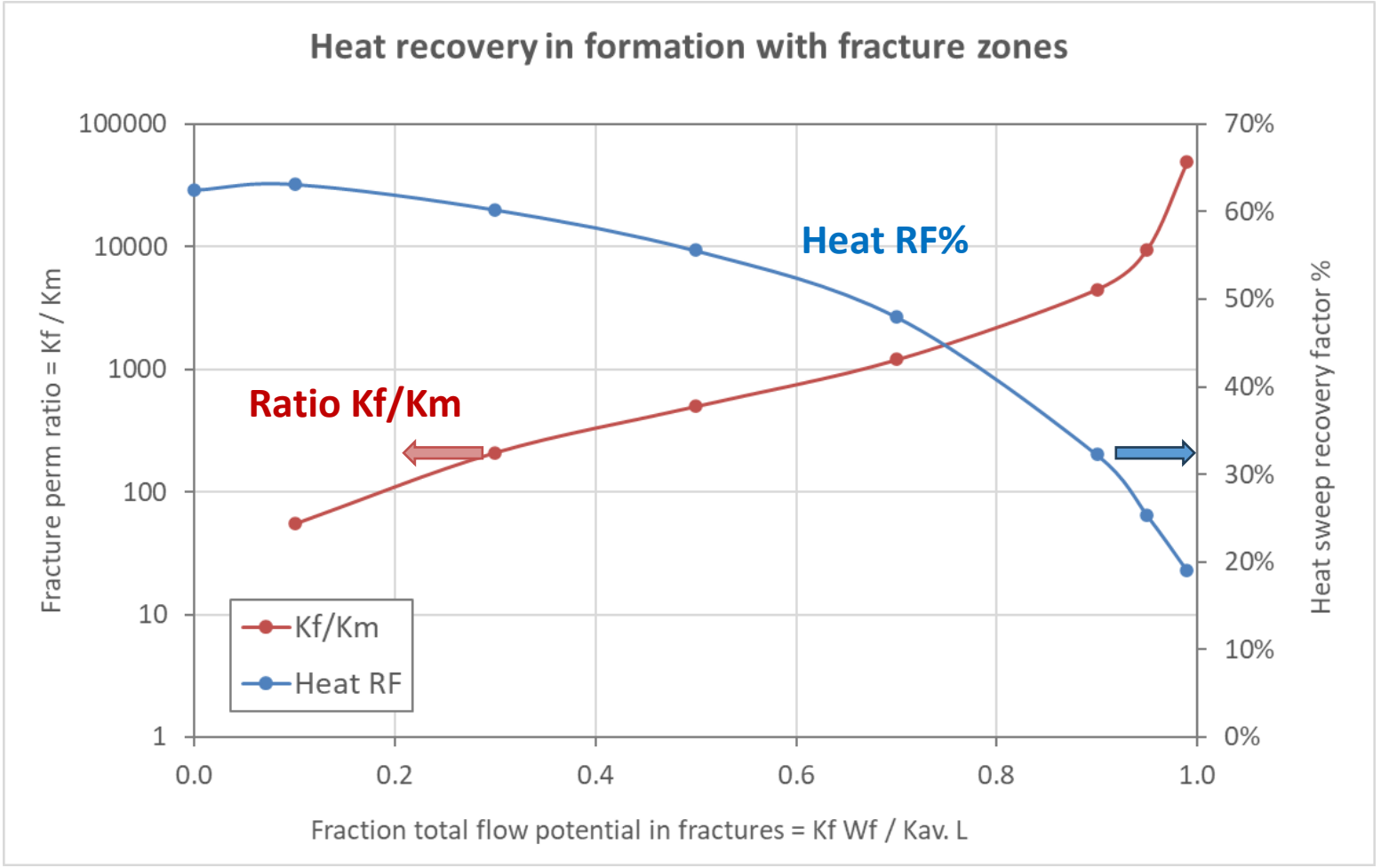
Heat recovery vs. perm contrast

Total matrix + fractures perm = 1 md

Varying fraction of perm in fractured zones: 0% (matrix only) to 99%

Heat recovery drops with increasing perm heterogeneity

… but loss potentially modest even in highly heterogeneous fractured zone flow architecture



Matrix – fracture heat transfer

Sector: 1 km x 250 m, 500 m thickness

$T_{initial}$ 100 ºC, T_{inj} 20 ºC

Gross rock volume 125 M.rm^3

Matrix poro 4% → 5 M.rm^3

Fracture poro 0.1% → 0.125 M.rm^3

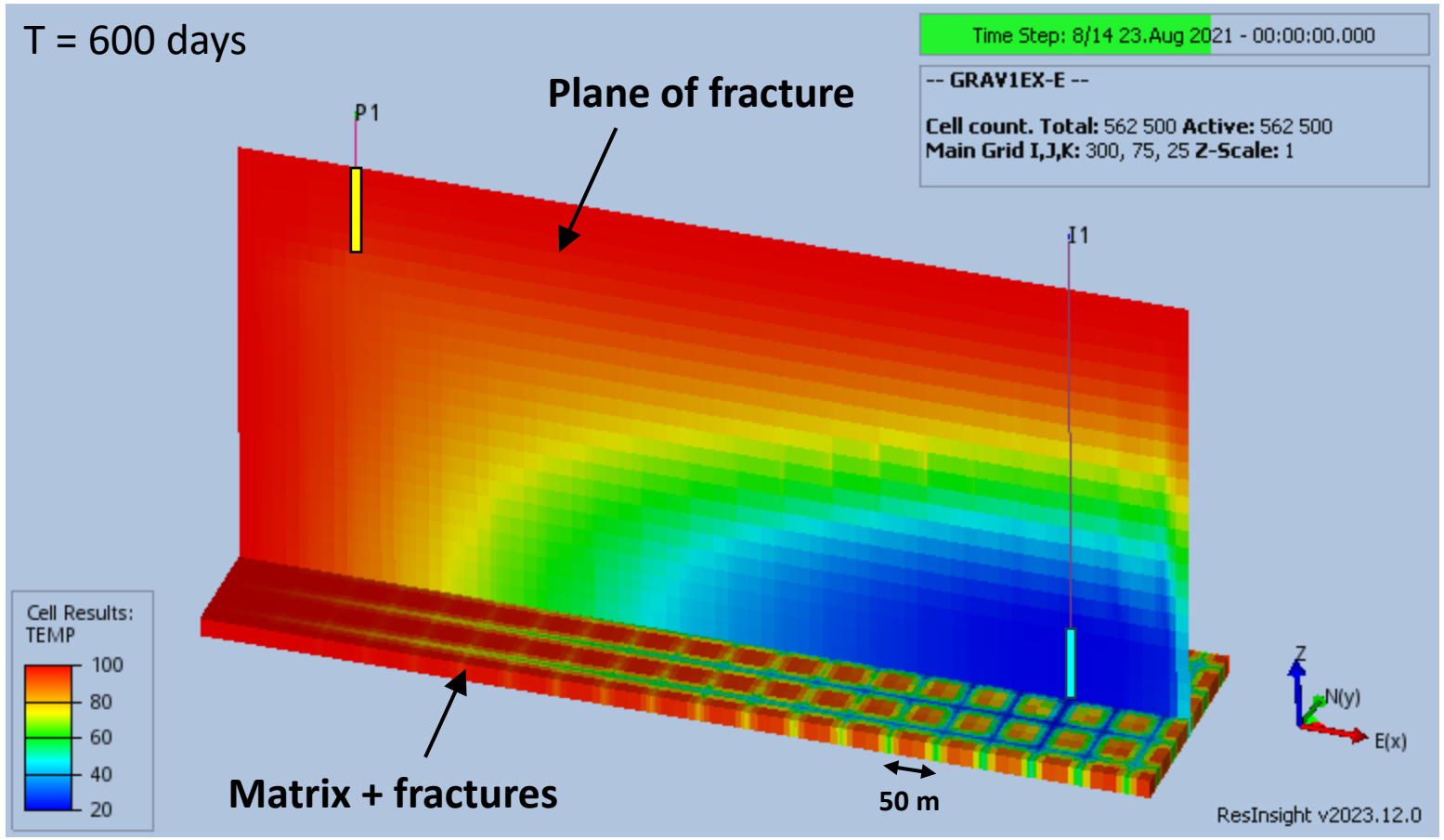
Matrix: k_m 1 md, limestone properties

Fractures: k_{eff} 200 md, 50 m spacing

Fluid: viscosity & density vs. T

Injection rate: 140 litres/s

T = 600 days after start of injection



Dual poro/perm models

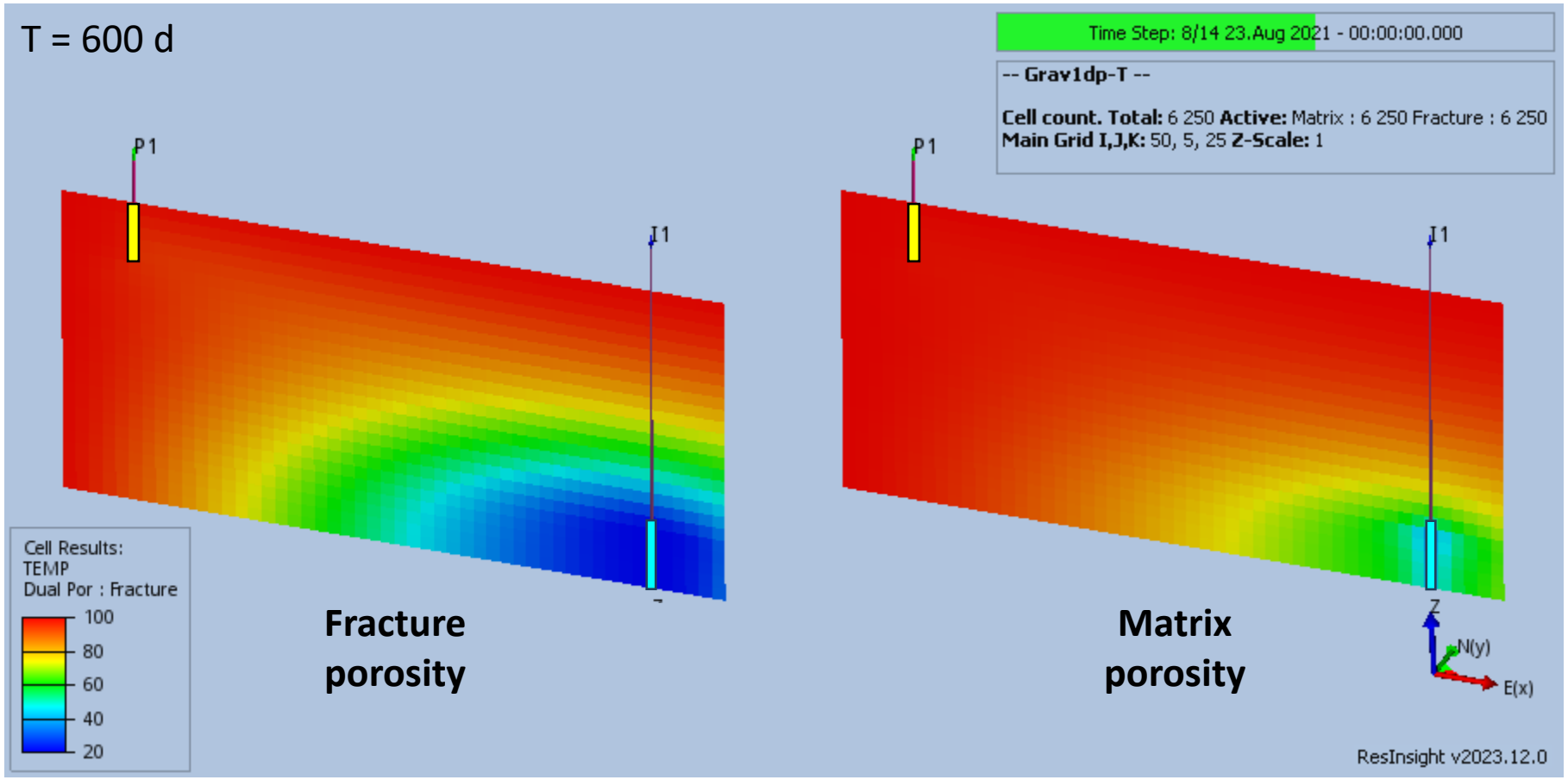
Continuum representation of fractured system

Conventional model process

Fewer grid cells / faster run

Matrix convective fluid flow and conductive heat flow to fracture porosity

Heat transfer scales with conductivity x shape factor



Dual poro/perm: matrix → fracture *heat* transfer (THCONMF, SIGMATH)

Model types compared

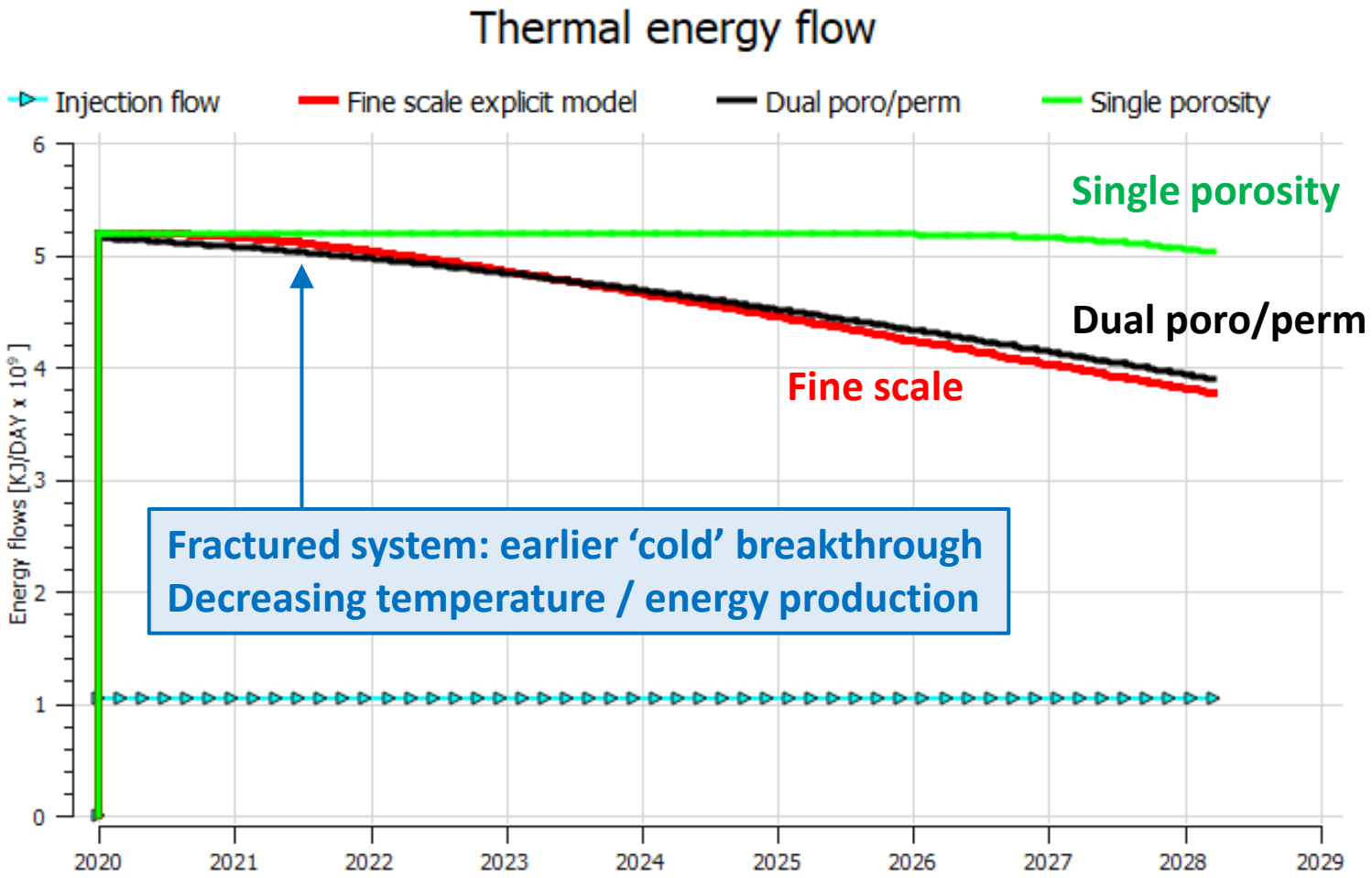
Representations of reservoir

- Explicit grid (562,500 cells)
- Single porosity (6,250 cells)
- Dual poro/perm (12,500 cells)

Single porosity: underpredicts heat breakthrough → optimistic forecast

Dual model: it works! successfully reproduces heat profile / recovery

Fluid cycling: lowering temperature may limit lifetime of efficient heat pump operation



Fracture porosity fluid convection

Fracture pore volume ~ 0.1 M.rm^3

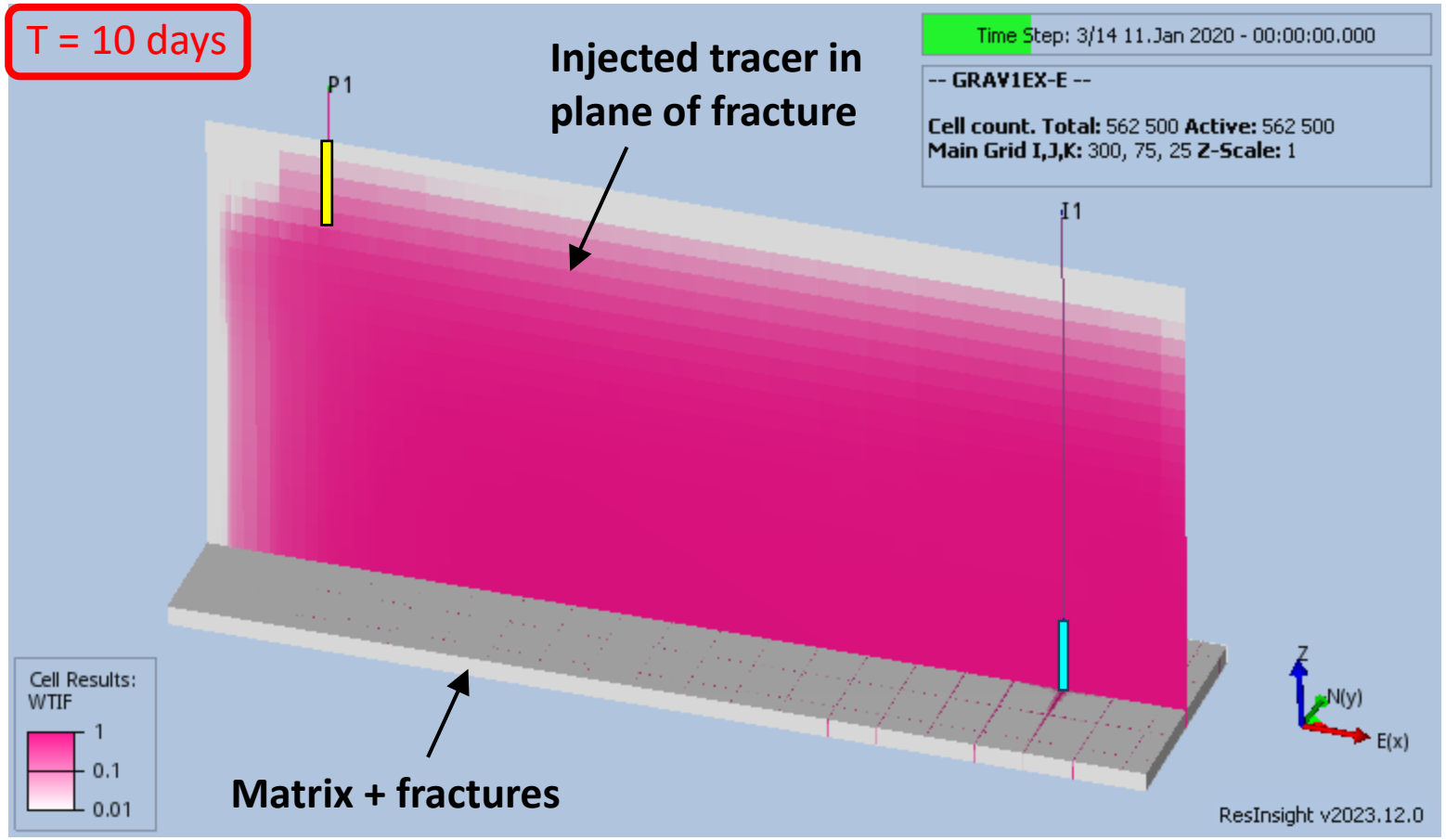
Injection rate: 140 litres/s

Viscous displacement & convection by density contrast … relatively slow

Rapid tracer break through

T ~ 10 days after start of injection

Fluid moves more rapidly than heat

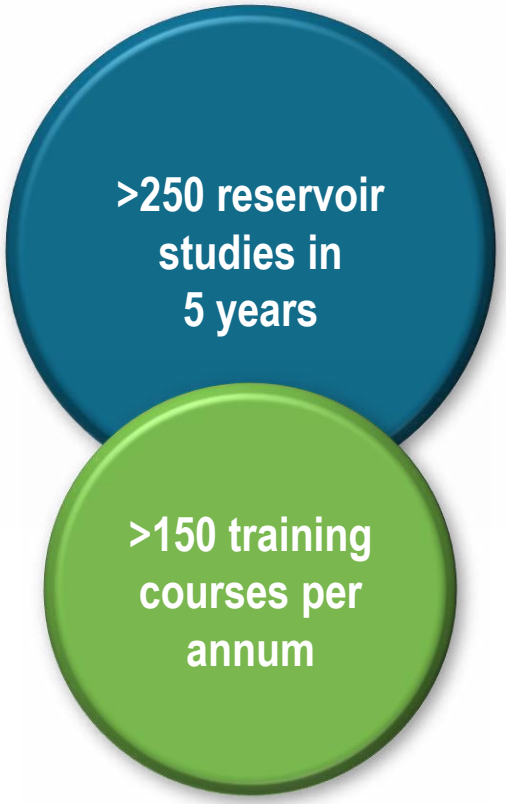


Key messages

- Modelling thermal processes in fractured systems
- Fluids move faster than heat in fractures
- Heat recovery reduces … but potentially modest even in highly heterogeneous fractured zone flow architecture

About Us

Reservoir Consultancy and E&P Training



"We are one of the most experienced and respected providers of integrated reservoir management services and training in the business."

TRACS International is an independent E&P Training and Reservoir Evaluation Consultancy. We have supported a diverse portfolio of international clients for more than 30 years. We are active in conventional Oil & Gas as well as Energy Transition.

30 1992 - 2022

Jill Prabucki

General Manager

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Energy Transition

Supporting Carbon Net Zero

- TRACS continues to harness its skill and experience in reservoir characterisation and resource classification to support the Energy Transition
- TRACS has adapted and expanded its skillset to support the CCUS and geothermal arenas
- TRACS provides training to the next generation scientists picking up the decarbonisation baton

CCUS

Geothermal

TRACS Identity

Powerful combination of experience and technical skill

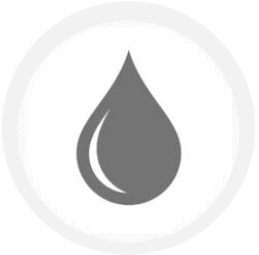
- Experienced staff base and access to a pool of dedicated industry experts
- Integrated project teams
- TRACS rigorous standards
- Evaluations driven by analysis, models and decades of E&P experience
- Results underpinned by quantification of risk and uncertainty
- Technical, economic and commercial expertise

- Worldwide client base and experience in every major producing basin

Our Services

Valuations and Due Diligence

- CPRs
- Valuations and Resource Audits
- Due Diligence
- A&D / M&A support

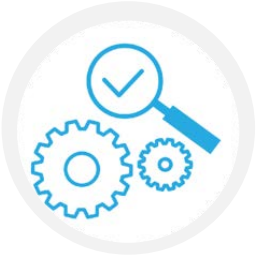


Field Studies

- Field Development
- Exploration & appraisal
- Opportunity ID
- Late life redevelopment
- Geomechanics
- Fractured reservoirs
- Production technology
- EOR
- Unconventional
- Economics and commercial

Energy Transition

- CCUS
- Geothermal



Business Assurance

- Processes & procedures
- Assurance reviews
- Management consultancy

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