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# A RADIATOR – EGS SYSTEM: A NOVEL CONCEPT FOR GEOTHERMAL ENERGY EXTRACTION

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Johns Hopkins University & Global Geophysical Services

SMU Geothermal Conference

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# Enhanced Geothermal Systems -- EGS

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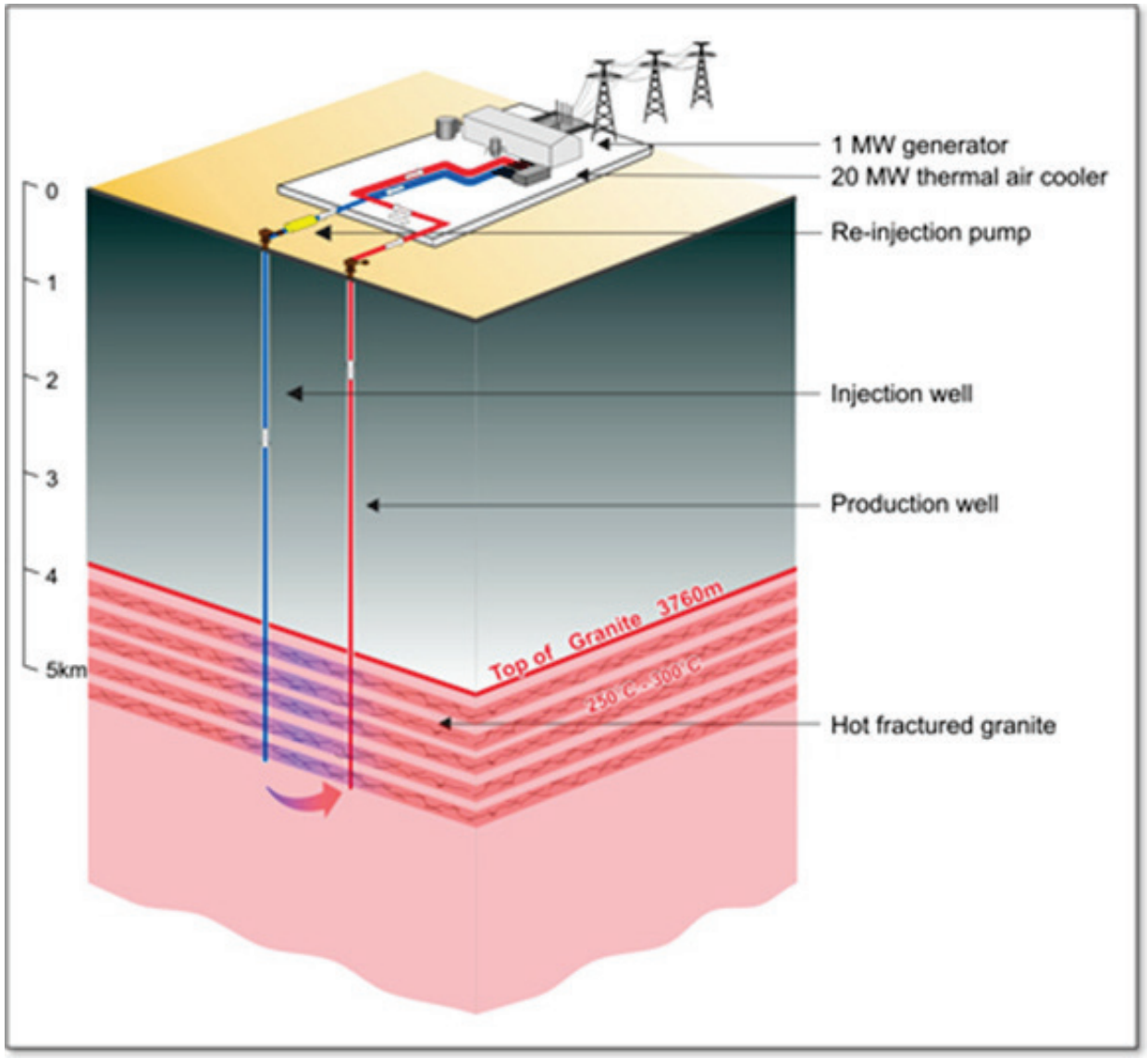


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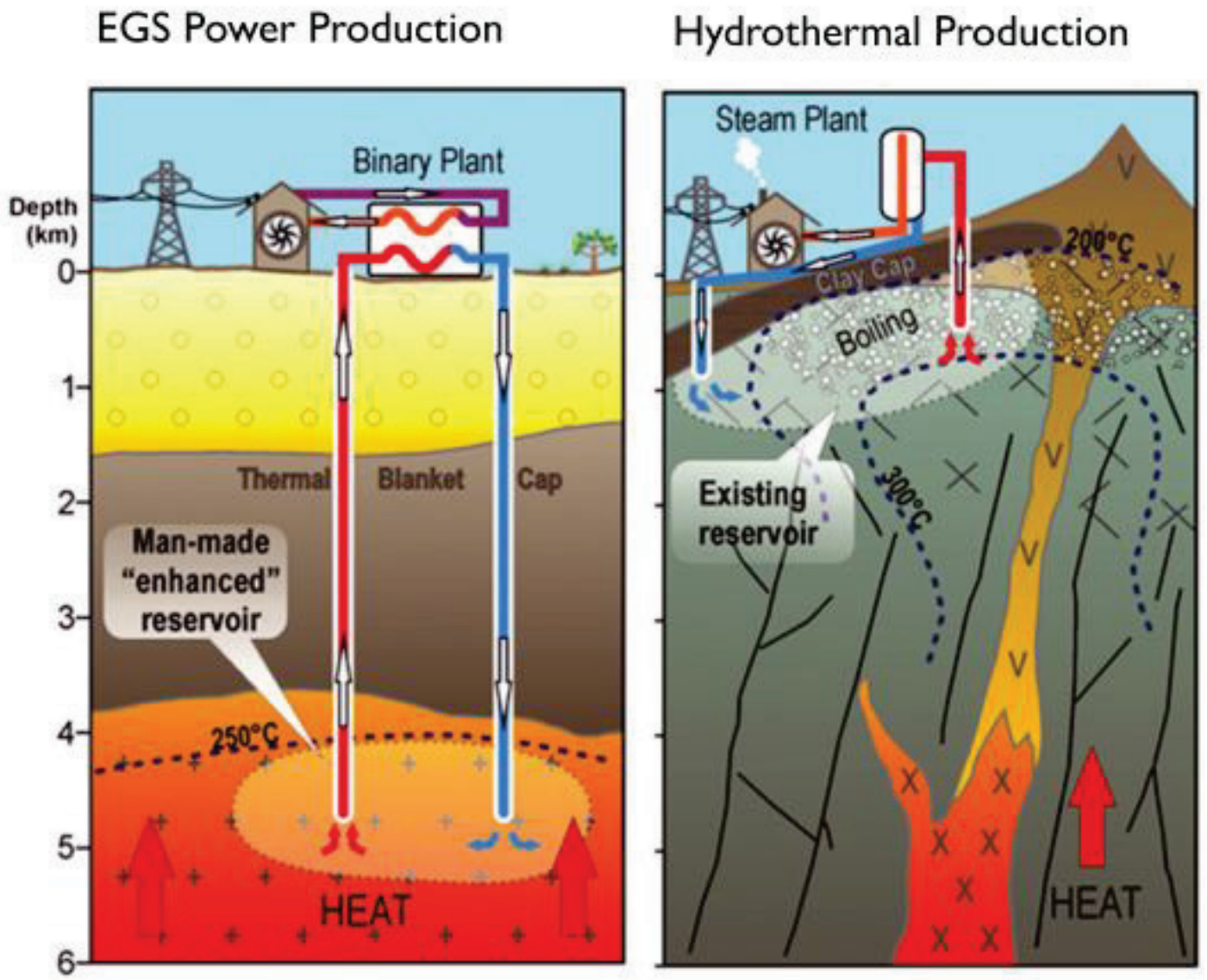
EGS Power Production
Hydrothermal Production
Depth (km)
0
1
2
3
4
5
6
Binary Plant
Thermal
Blanket
Cap
Man-made "enhanced" reservoir
250°C
HEAT
Steam Plant
Clay Cap
Boiling
200°C
300°C
Existing reservoir
HEAT

# The Geysers, Northern Californian

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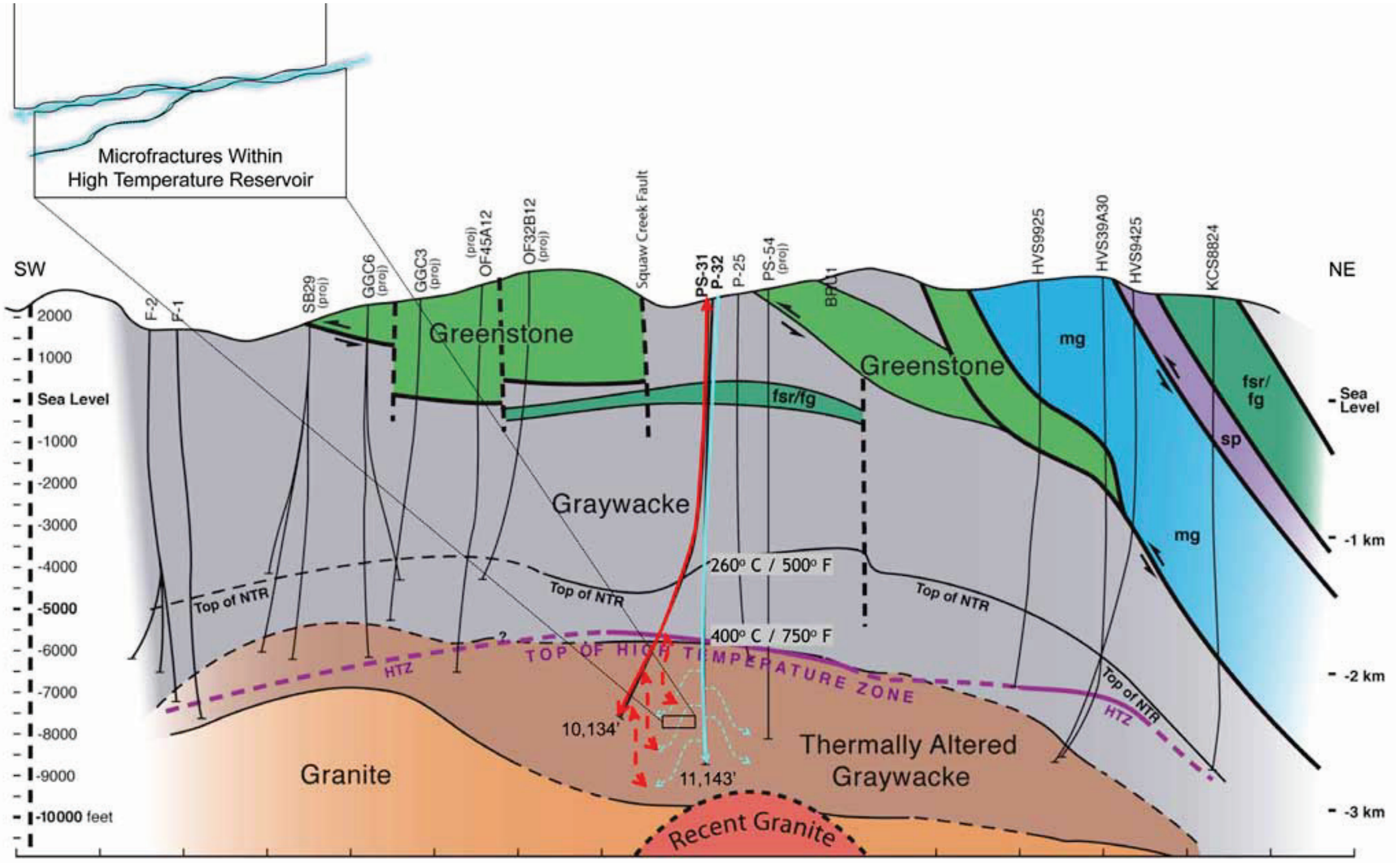


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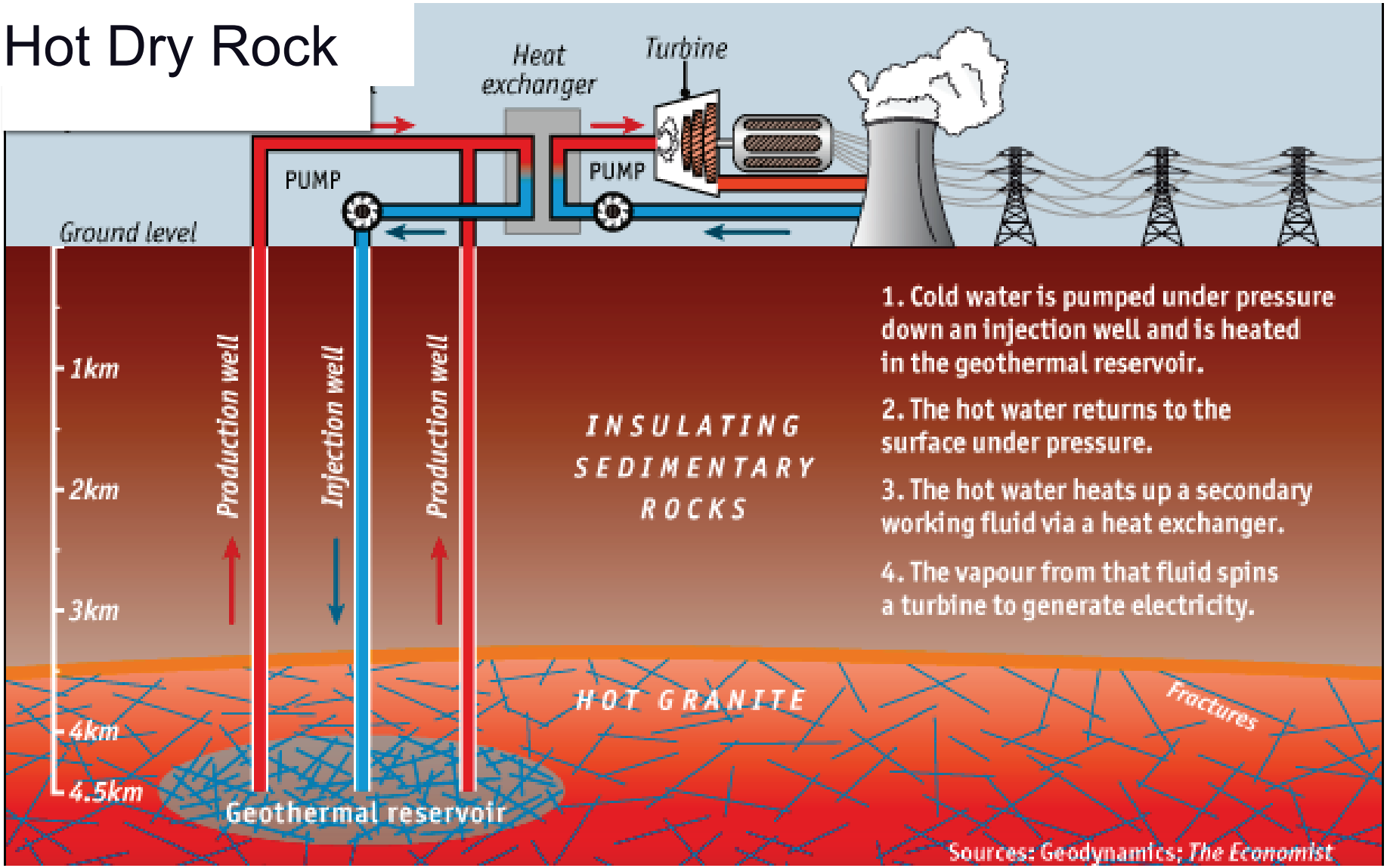
## Hot Dry Rock

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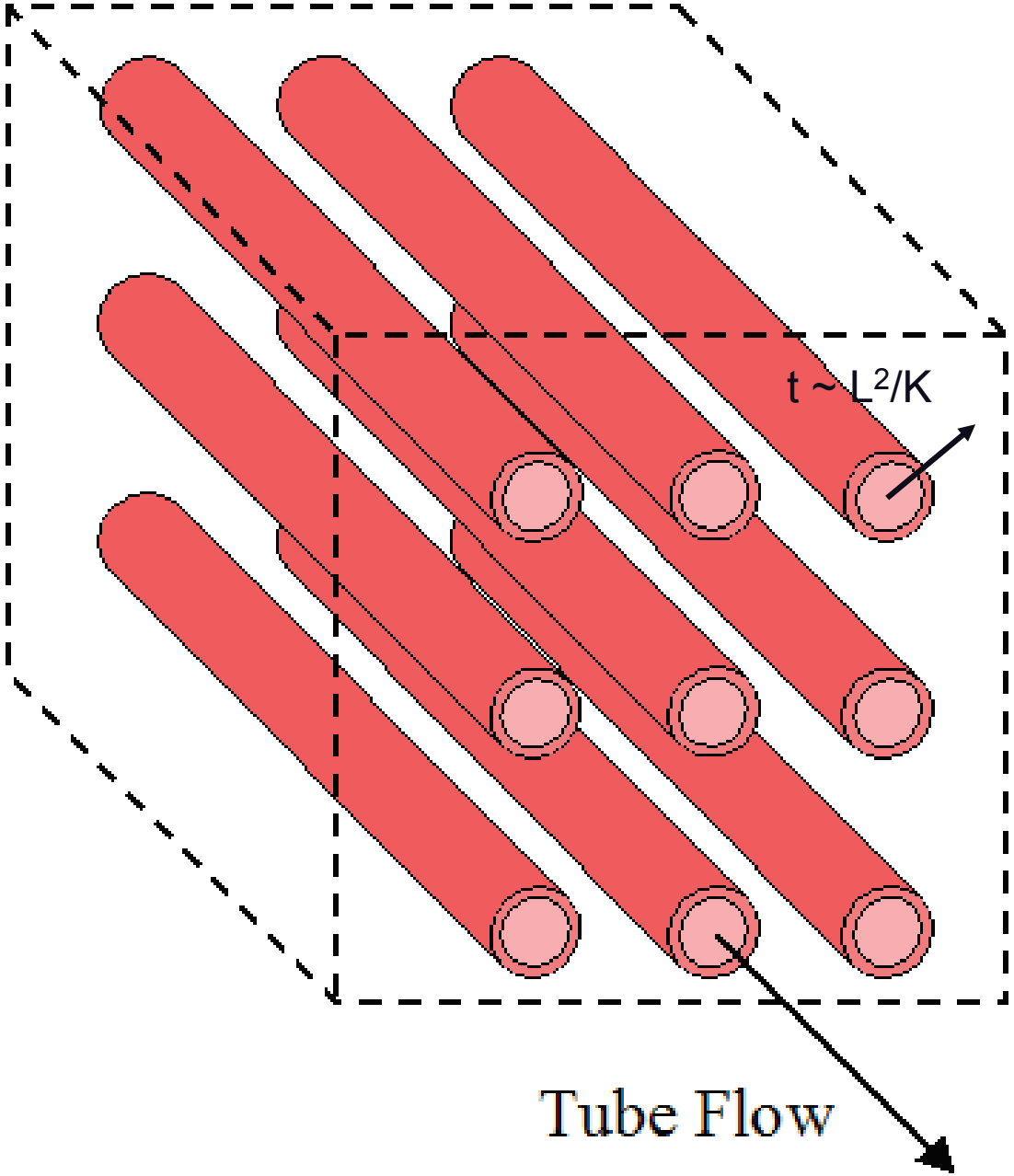
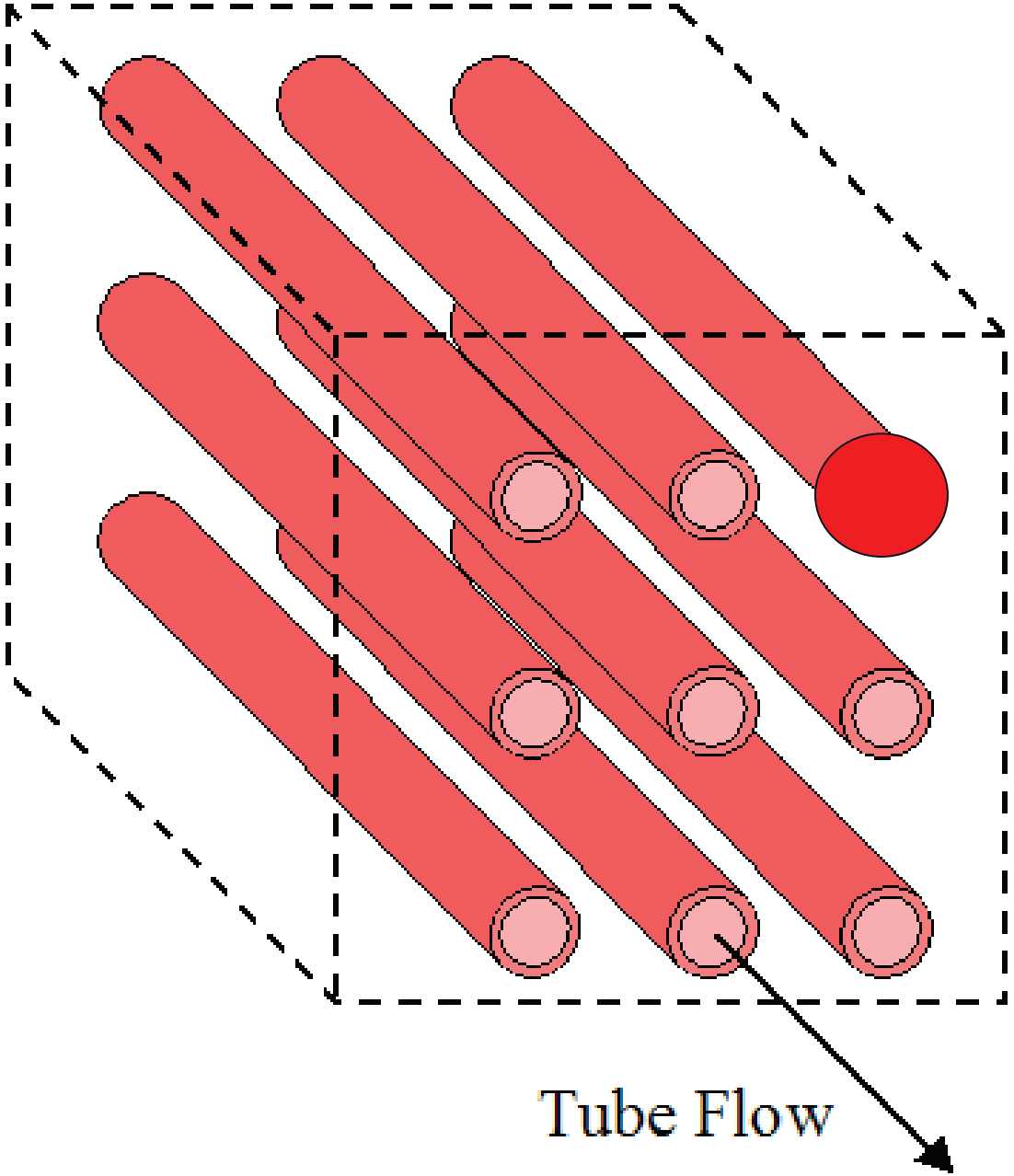
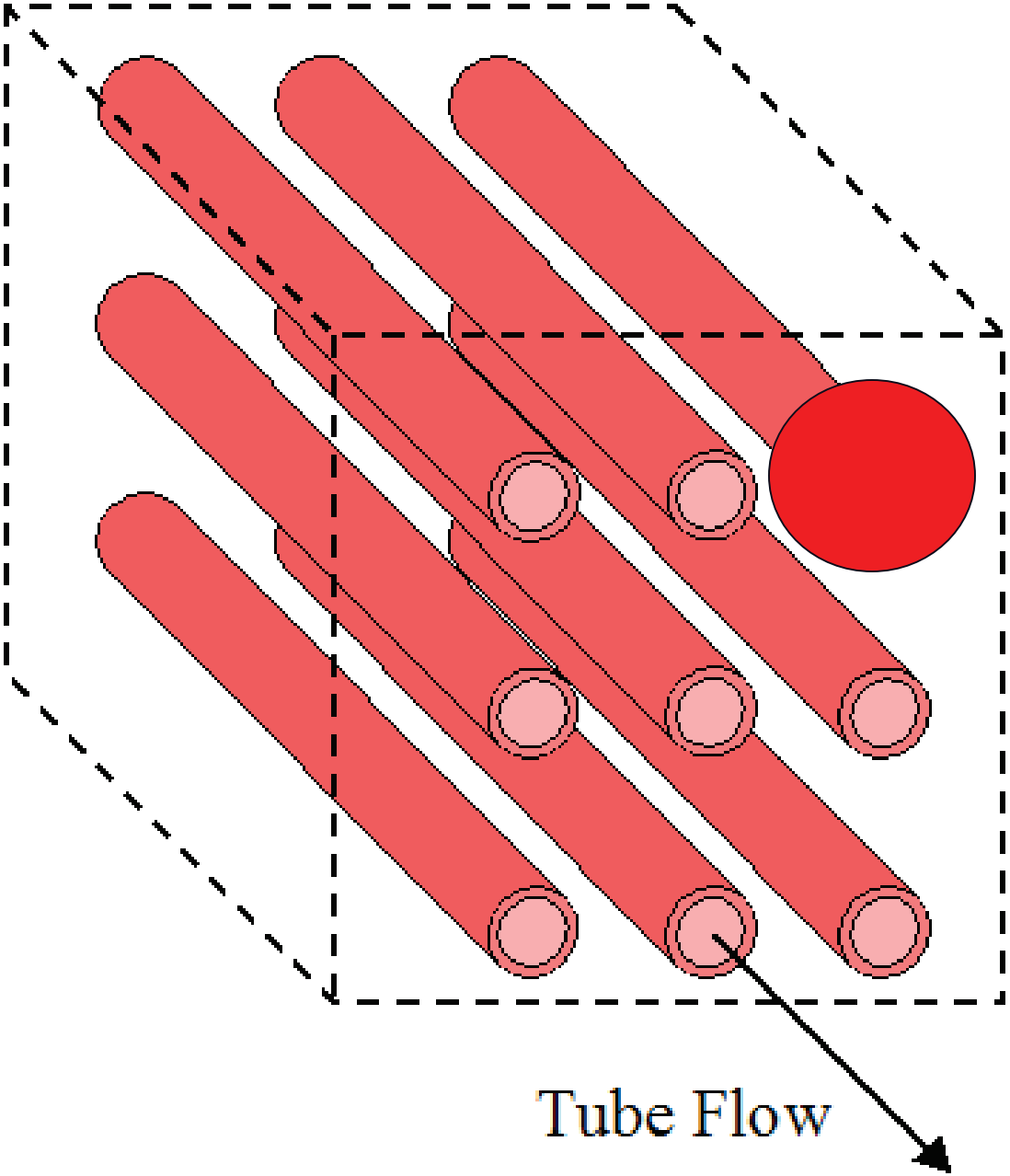
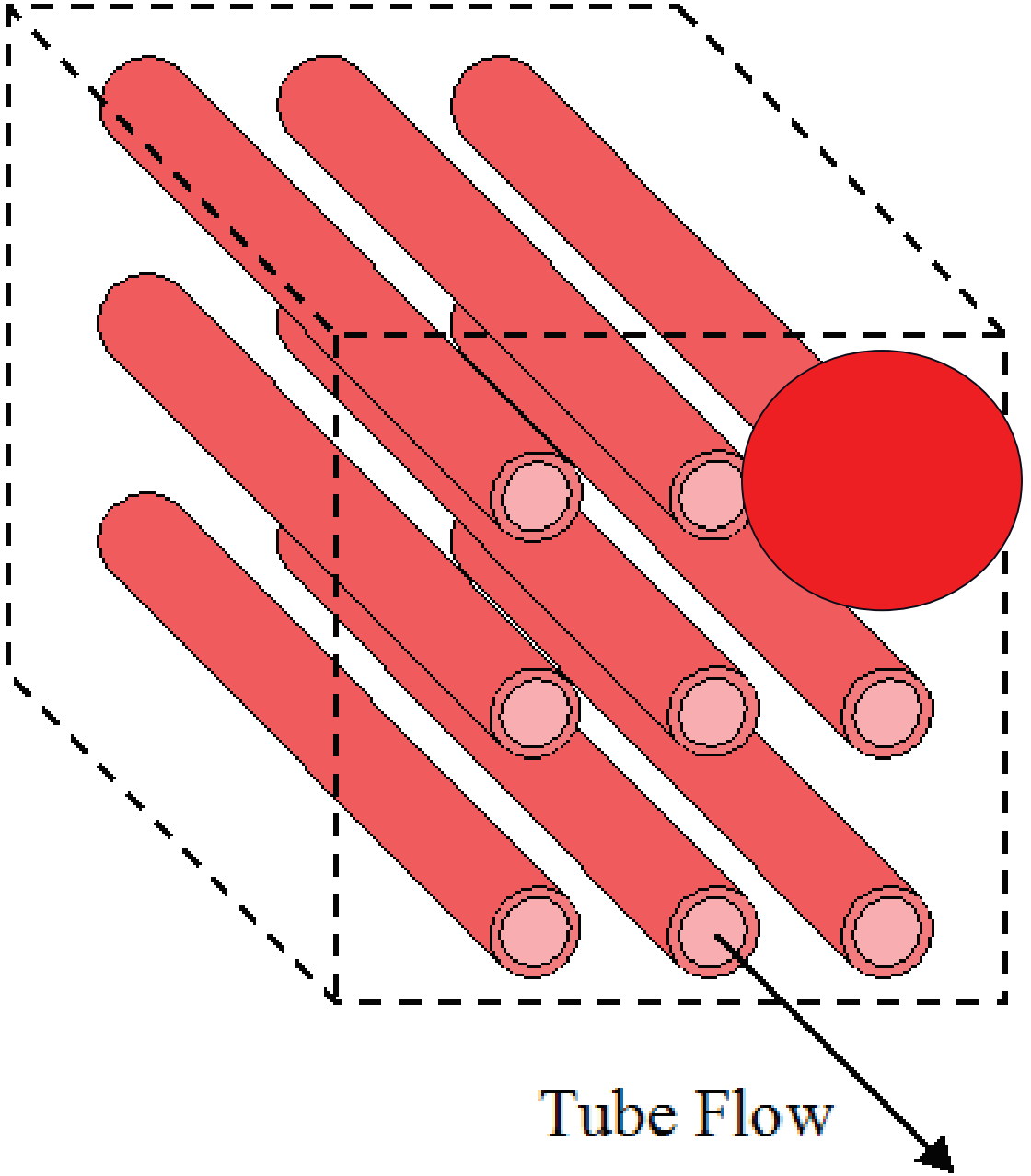
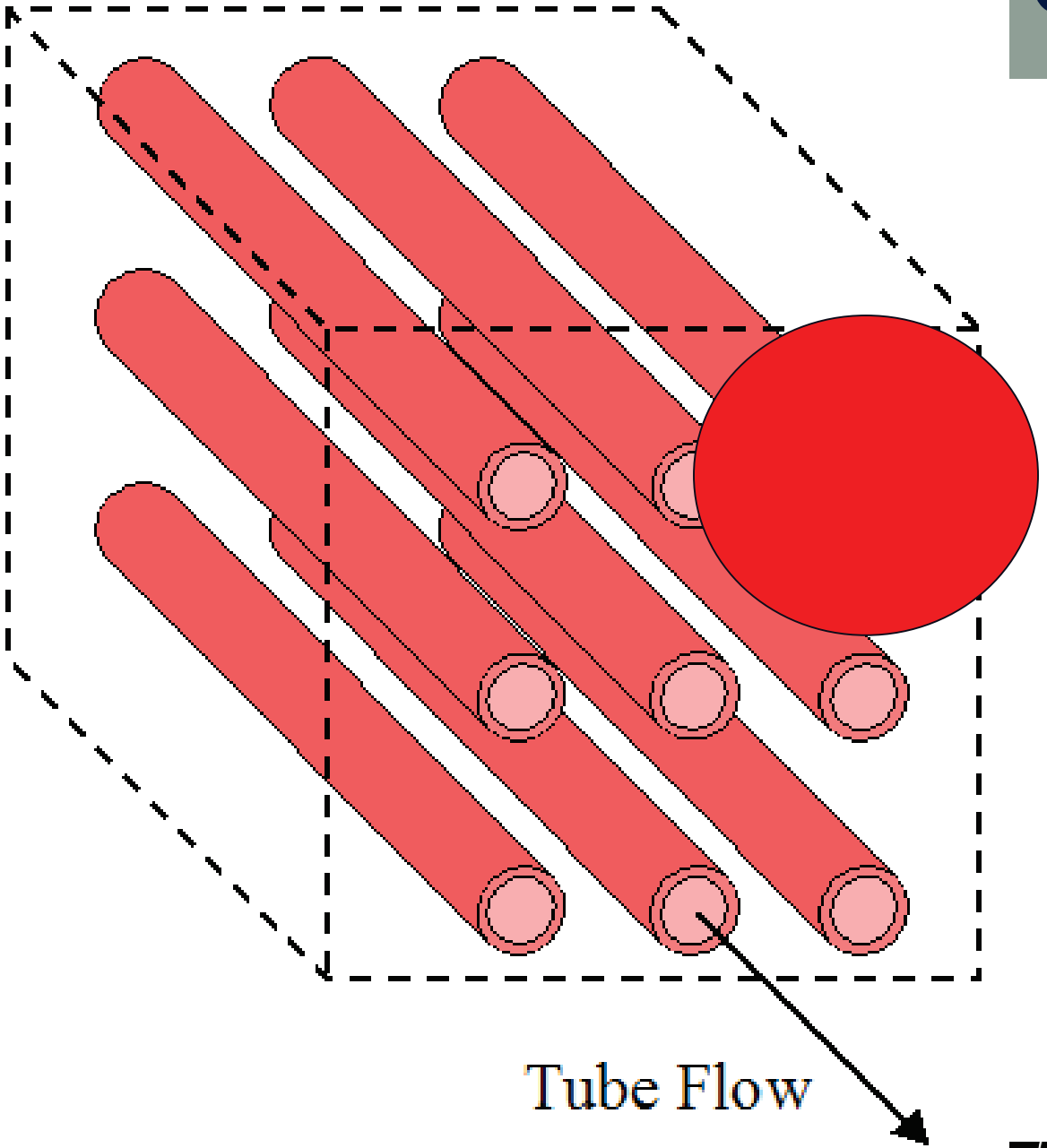
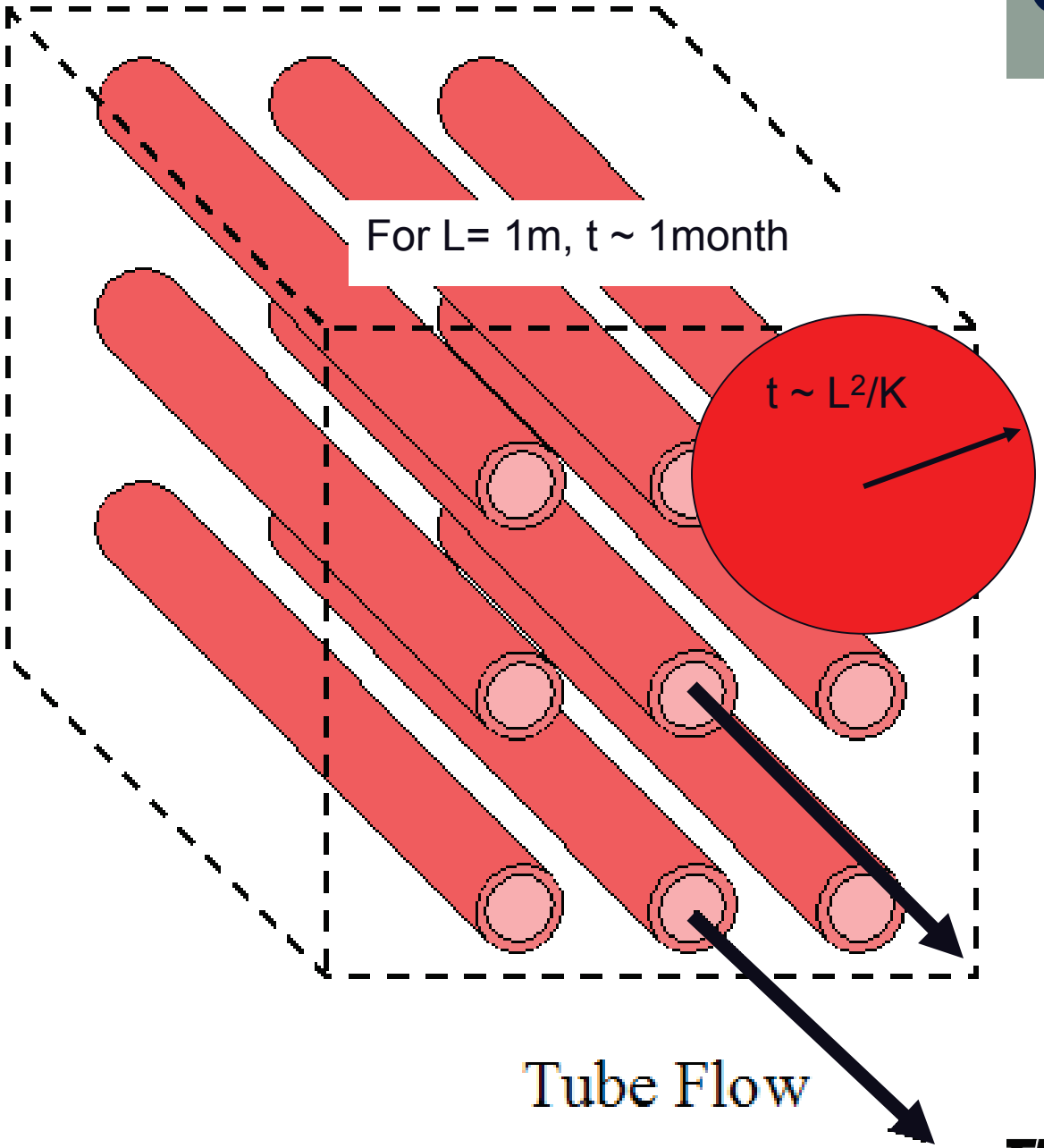

t ~ L²/K
Tube Flow


Tube Flow


Tube Flow


Tube Flow


Tube Flow


For L= 1m, t ~ 1month
t ~ L²/K
Tube Flow

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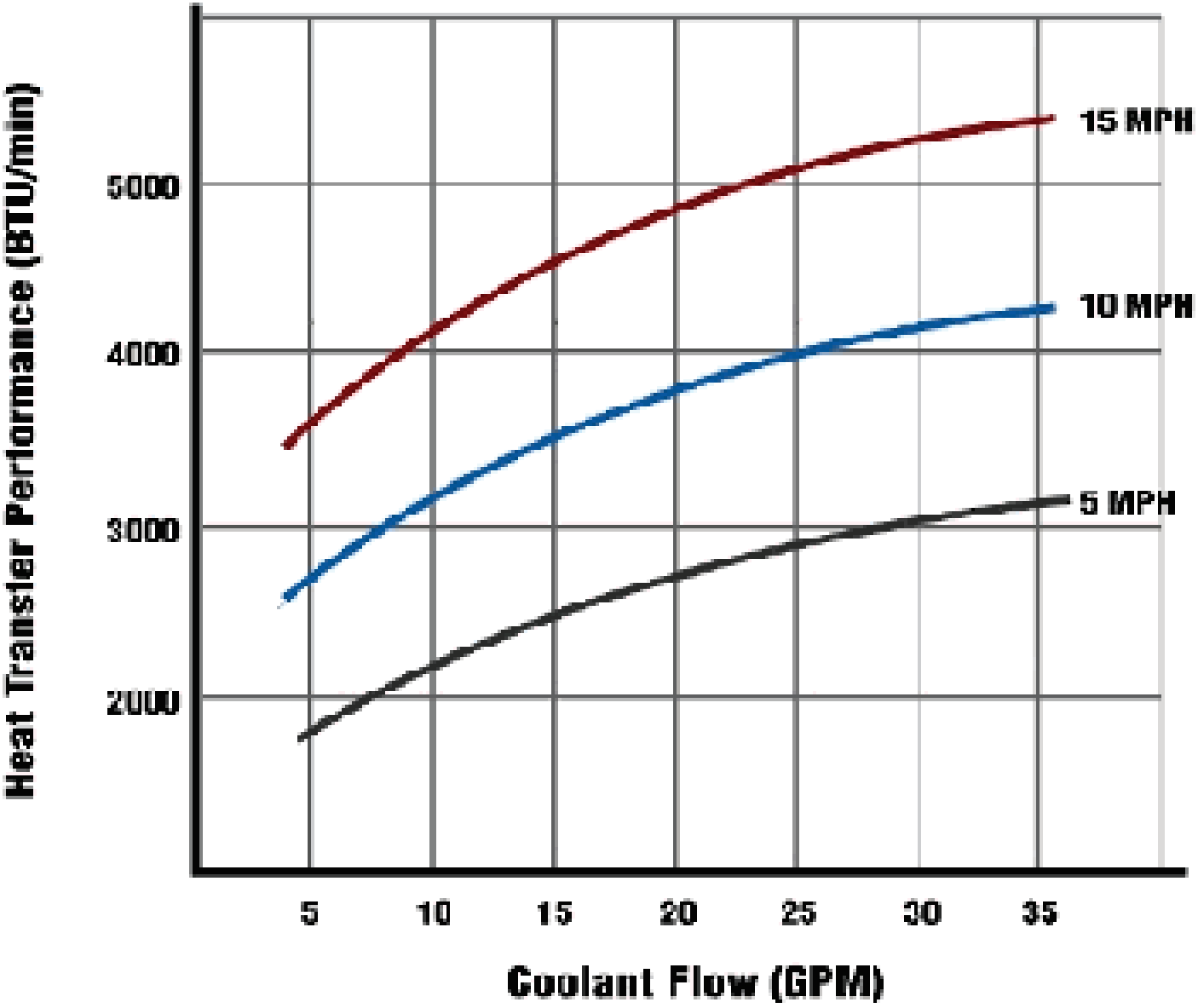
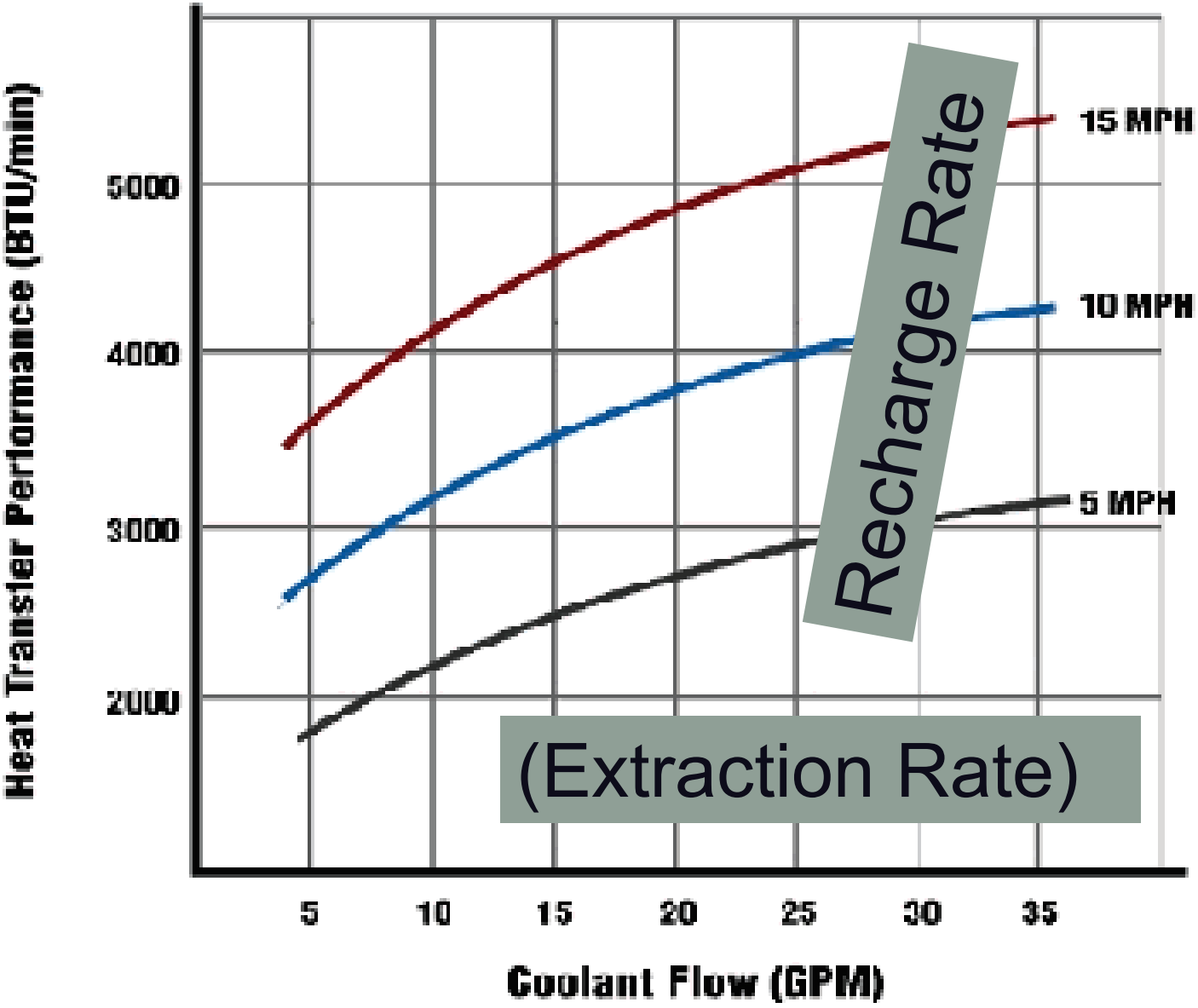
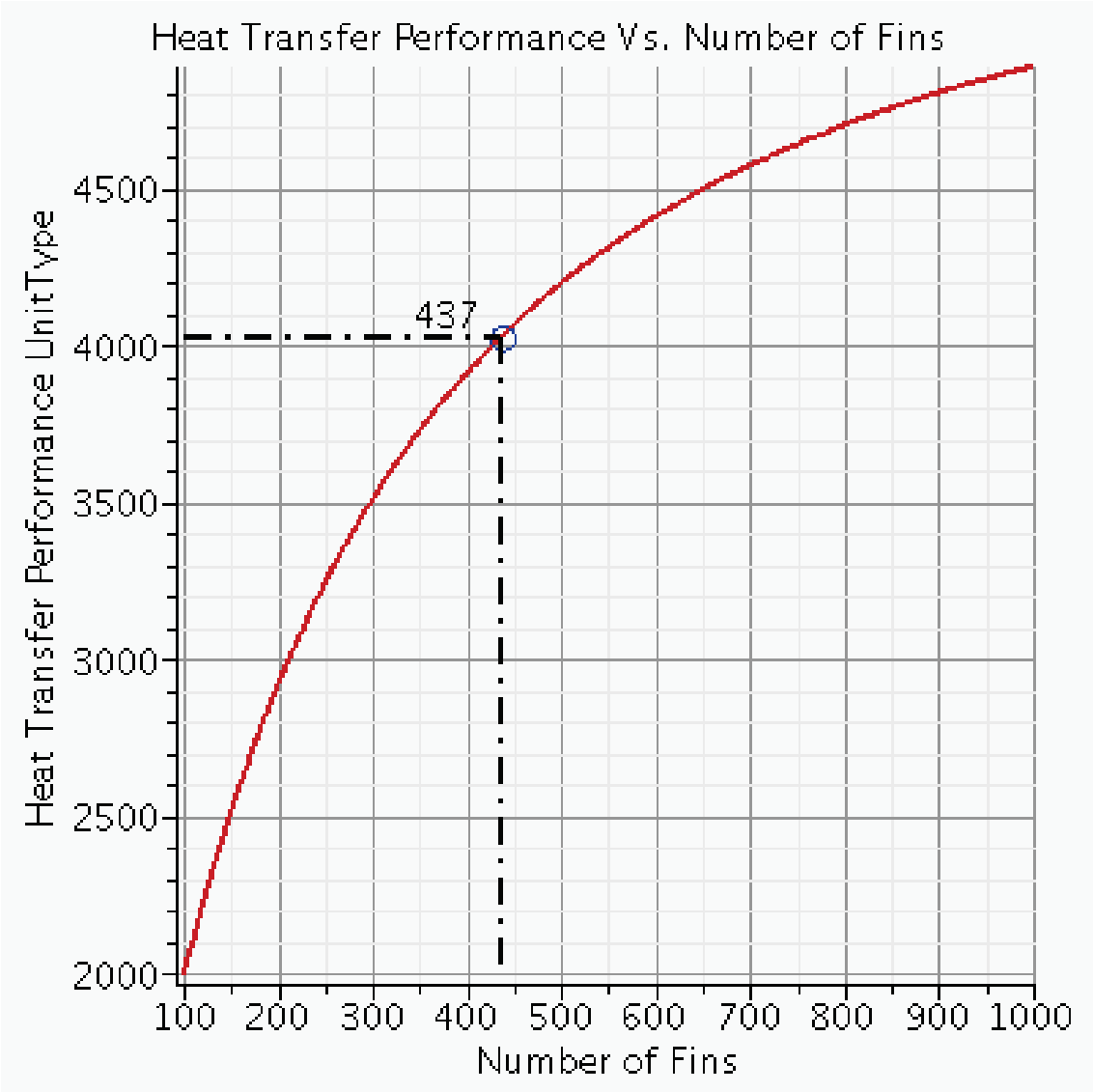
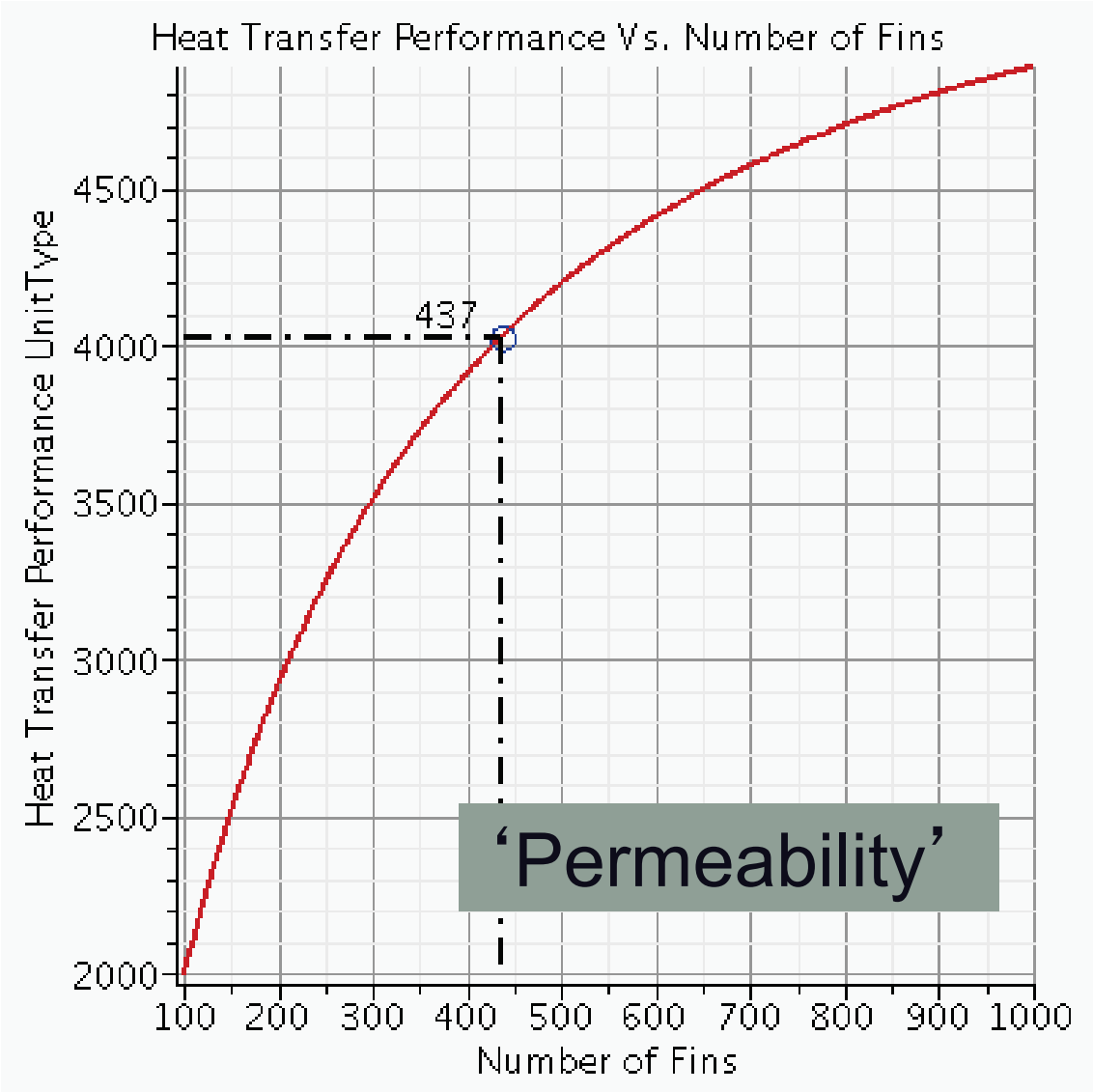
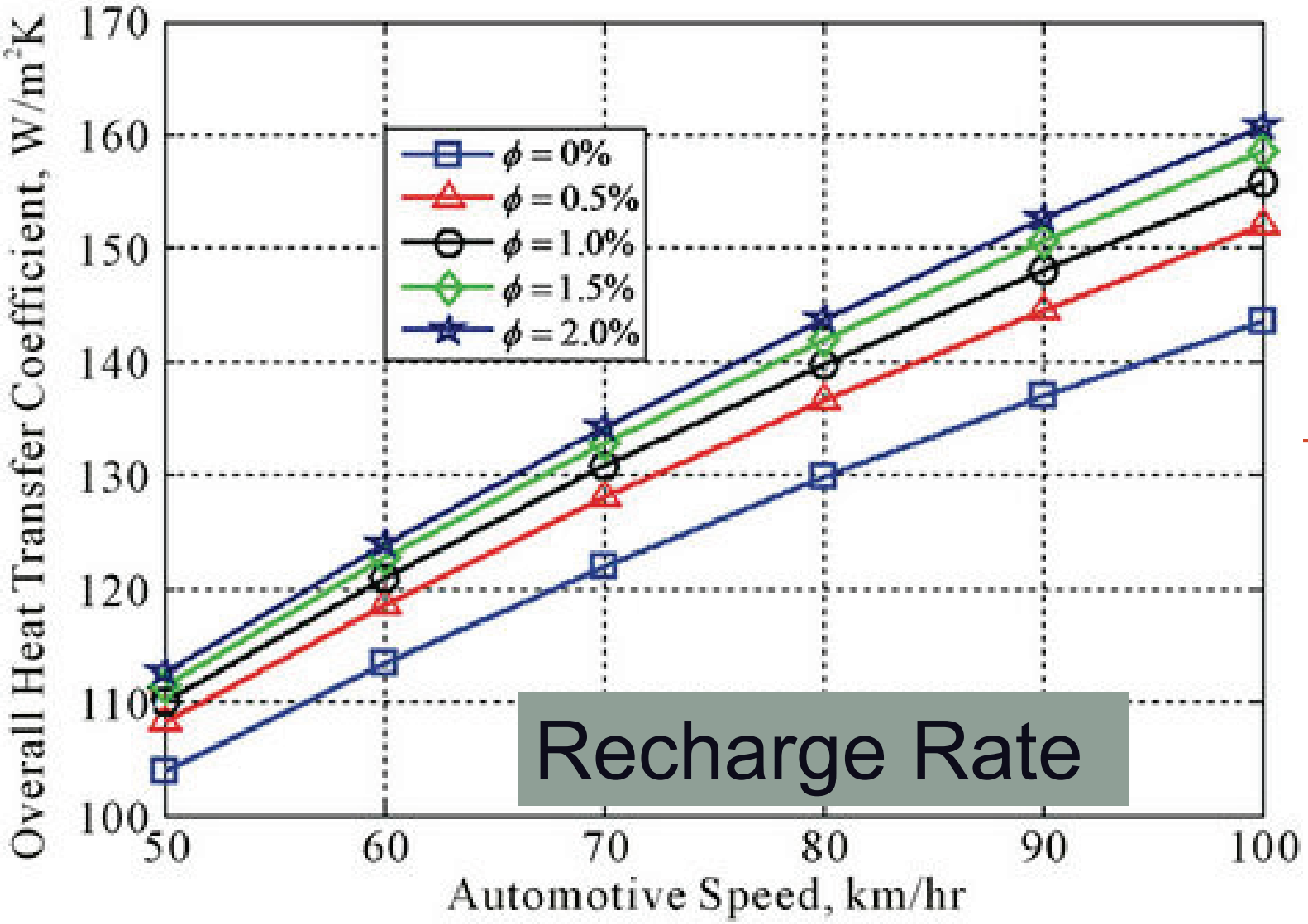

Heat Transfer Performance (BTU/min)
5000
4000
3000
2000
15 MPH
10 MPH
5 MPH
5
10
15
20
25
30
35
Coolant Flow (GPM)


Heat Transfer Performance (BTU/min)
5000
4000
3000
2000
15 MPH
10 MPH
5 MPH
Recharge Rate
(Extraction Rate)
5
10
15
20
25
30
35
Coolant Flow (GPM)


Heat Transfer Performance Vs. Number of Fins
Heat Transfer Performance UnitType
4500
4000
3500
3000
2500
2000
437
100
200
300
400
500
600
700
800
900
1000
Number of Fins


Heat Transfer Performance Vs. Number of Fins
Heat Transfer Performance UnitType
4500
4000
3500
3000
2500
2000
437
100
200
300
400
500
600
700
800
900
1000
Number of Fins
‘Permeability’


Overall Heat Transfer Coefficient, W/m²K
170
160
150
140
130
120
110
100
50
60
70
80
90
100
Automotive Speed, km/hr
$\phi = 0\%$
$\phi = 0.5\%$
$\phi = 1.0\%$
$\phi = 1.5\%$
$\phi = 2.0\%$
Recharge Rate

# Geothermal Systems

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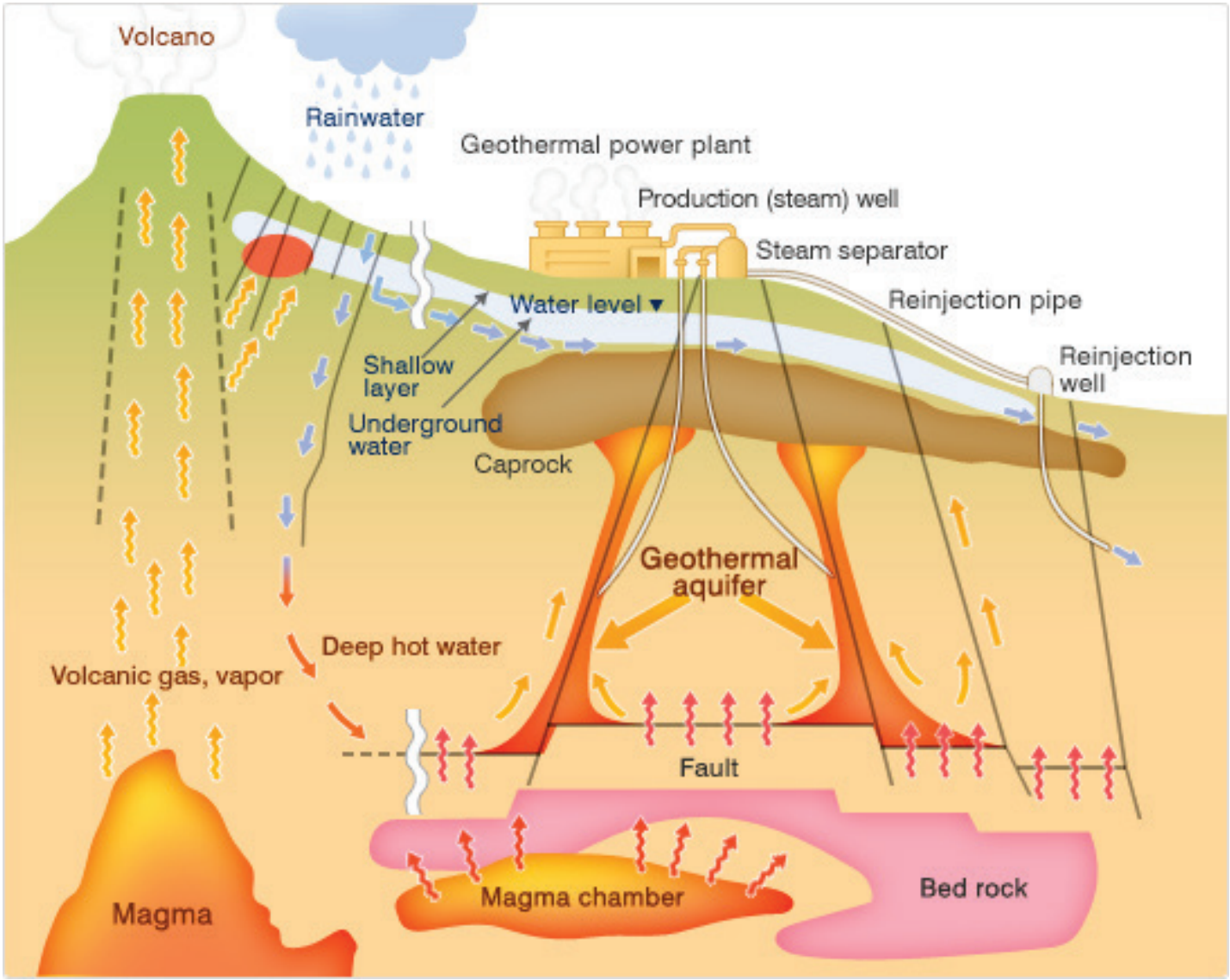


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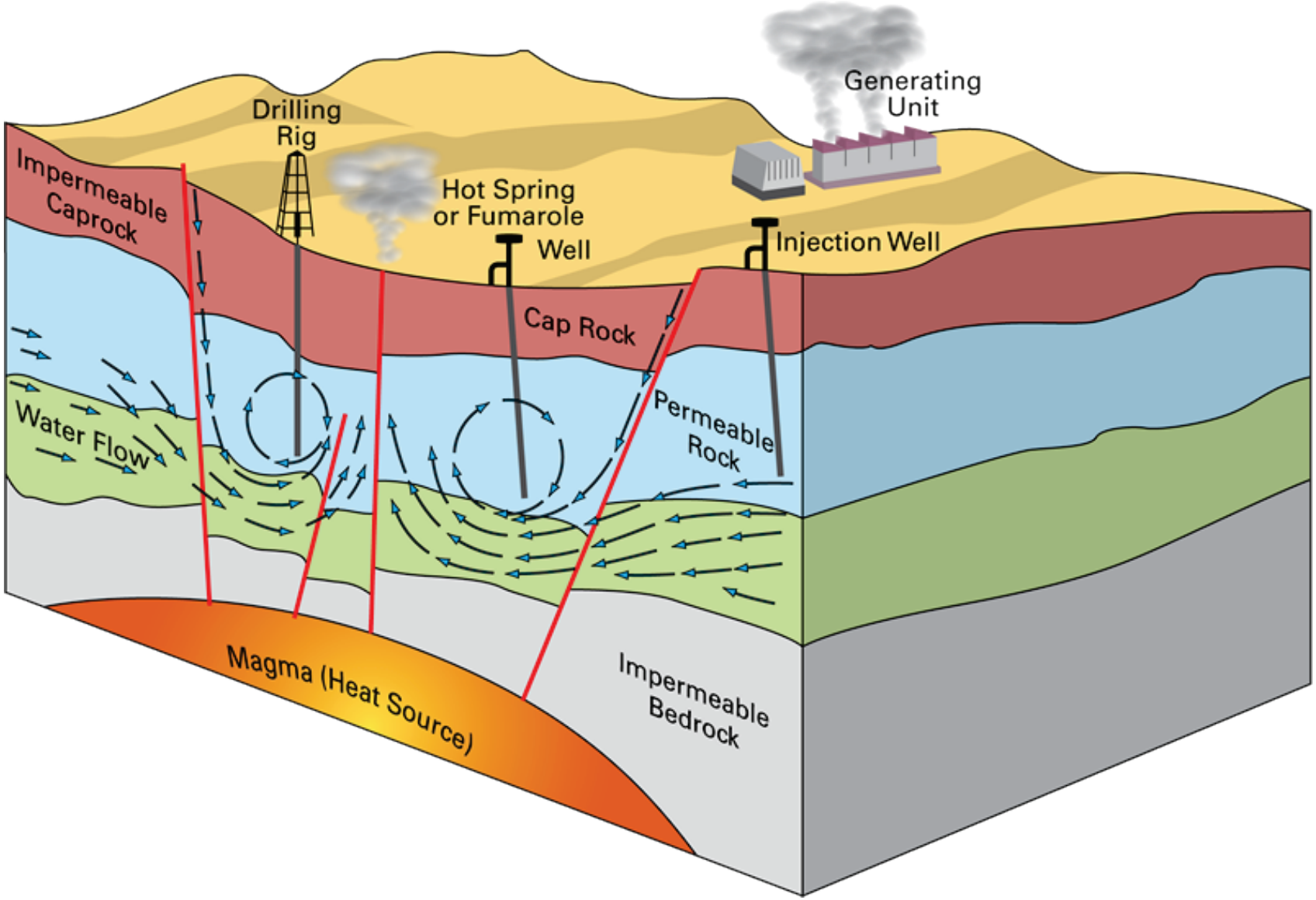
Generating Unit
Drilling Rig
Impermeable Caprock
Hot Spring or Fumarole
Well
Injection Well
Cap Rock
Permeable Rock
Water Flow
Magma (Heat Source)
Impermeable Bedrock

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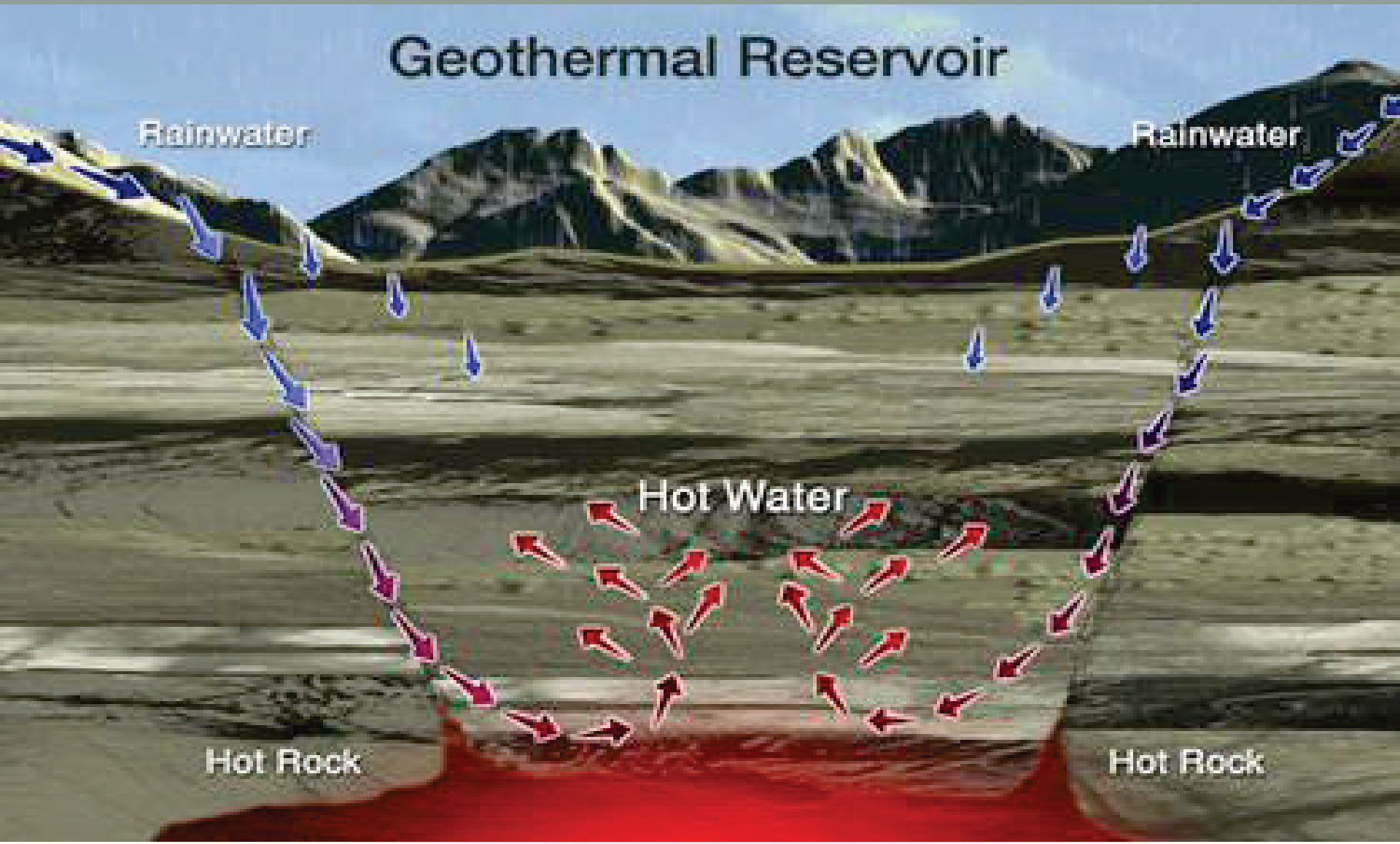


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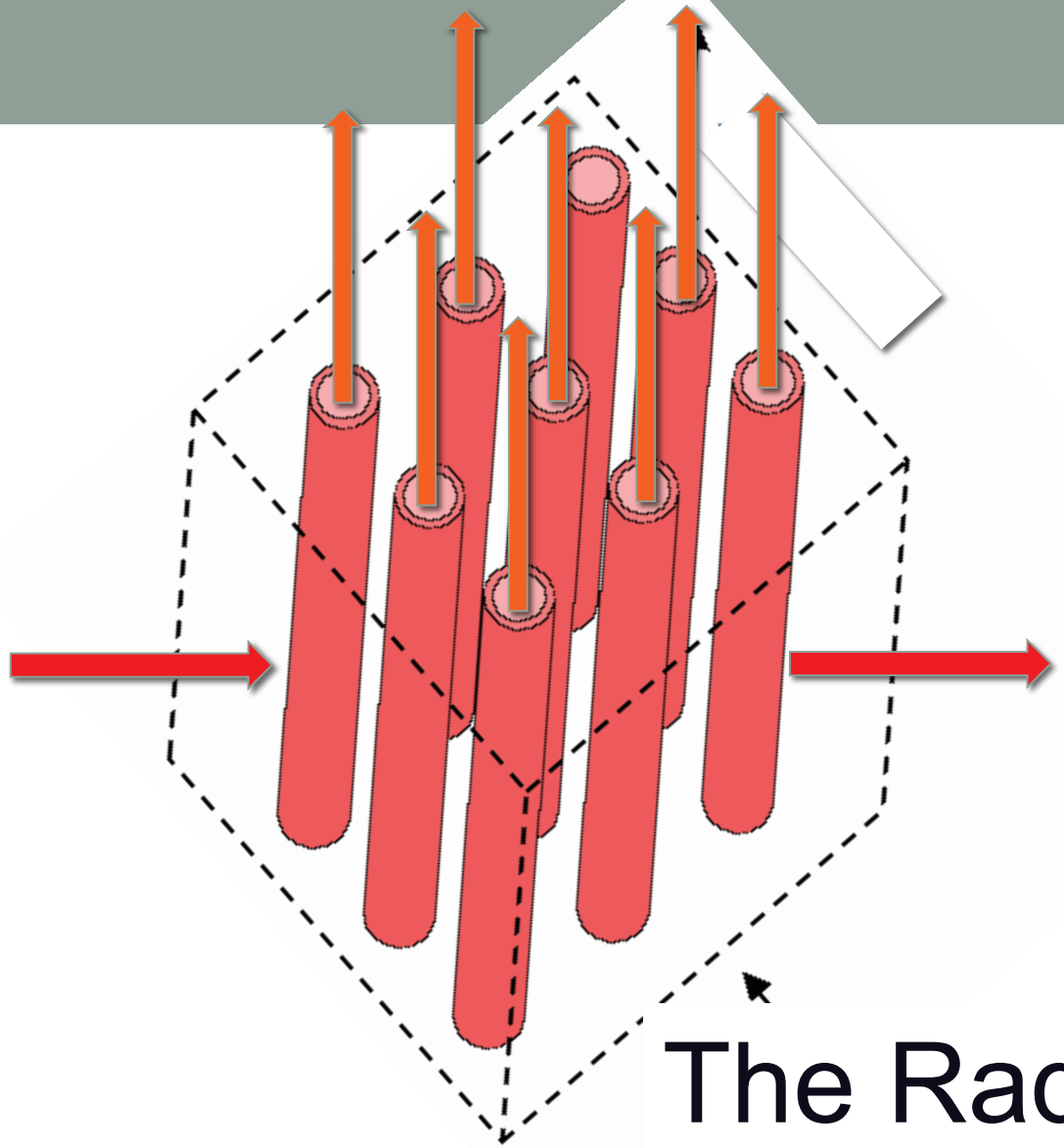


# The Radiator Model

# Creating a Successful EGS: Proposed Solutions

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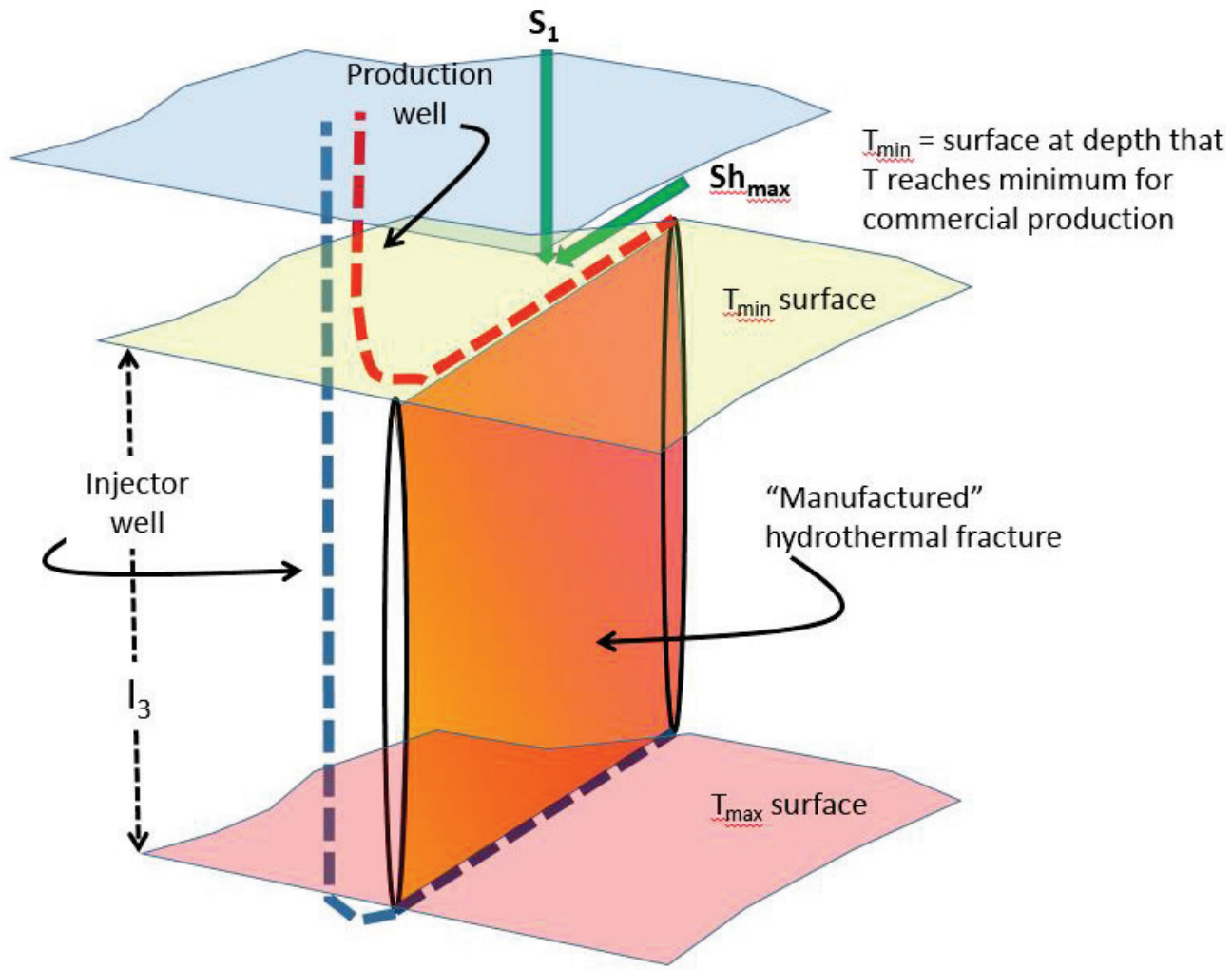
## The RAD-EGS

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# Creating a Successful EGS: Proposed Solutions

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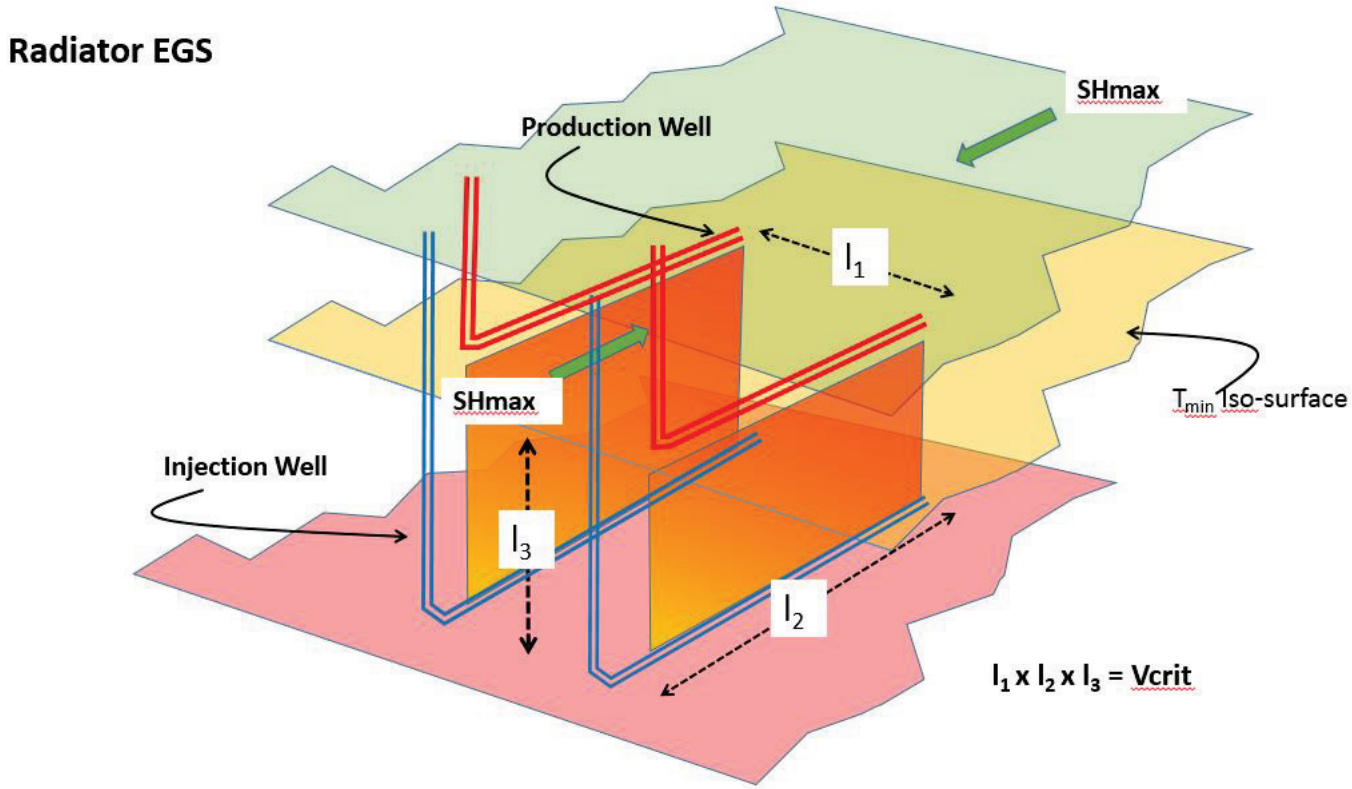
## The RAD-EGS

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# Creating a Successful EGS: Proposed Solutions

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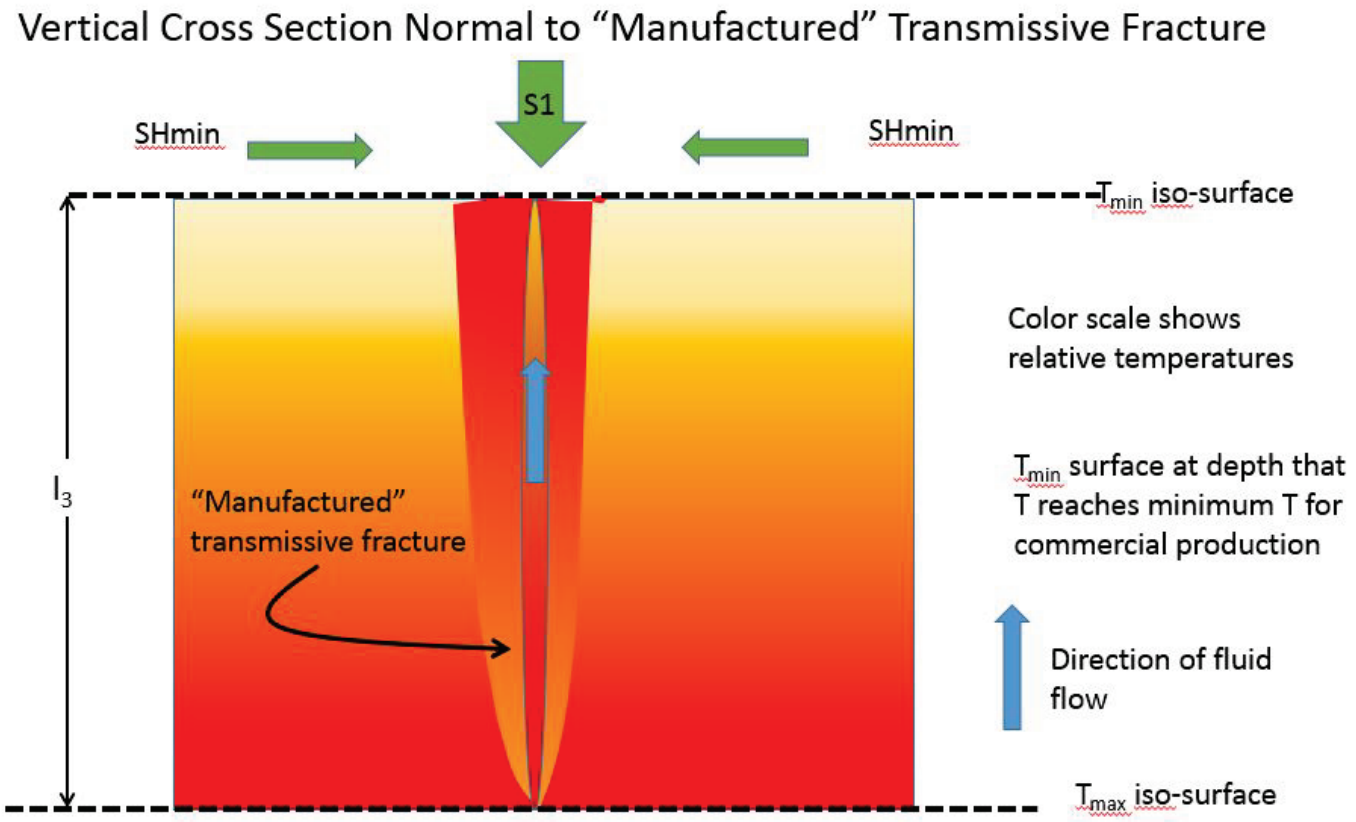
## The RAD-EGS

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# Creating a Successful EGS: Proposed Solutions

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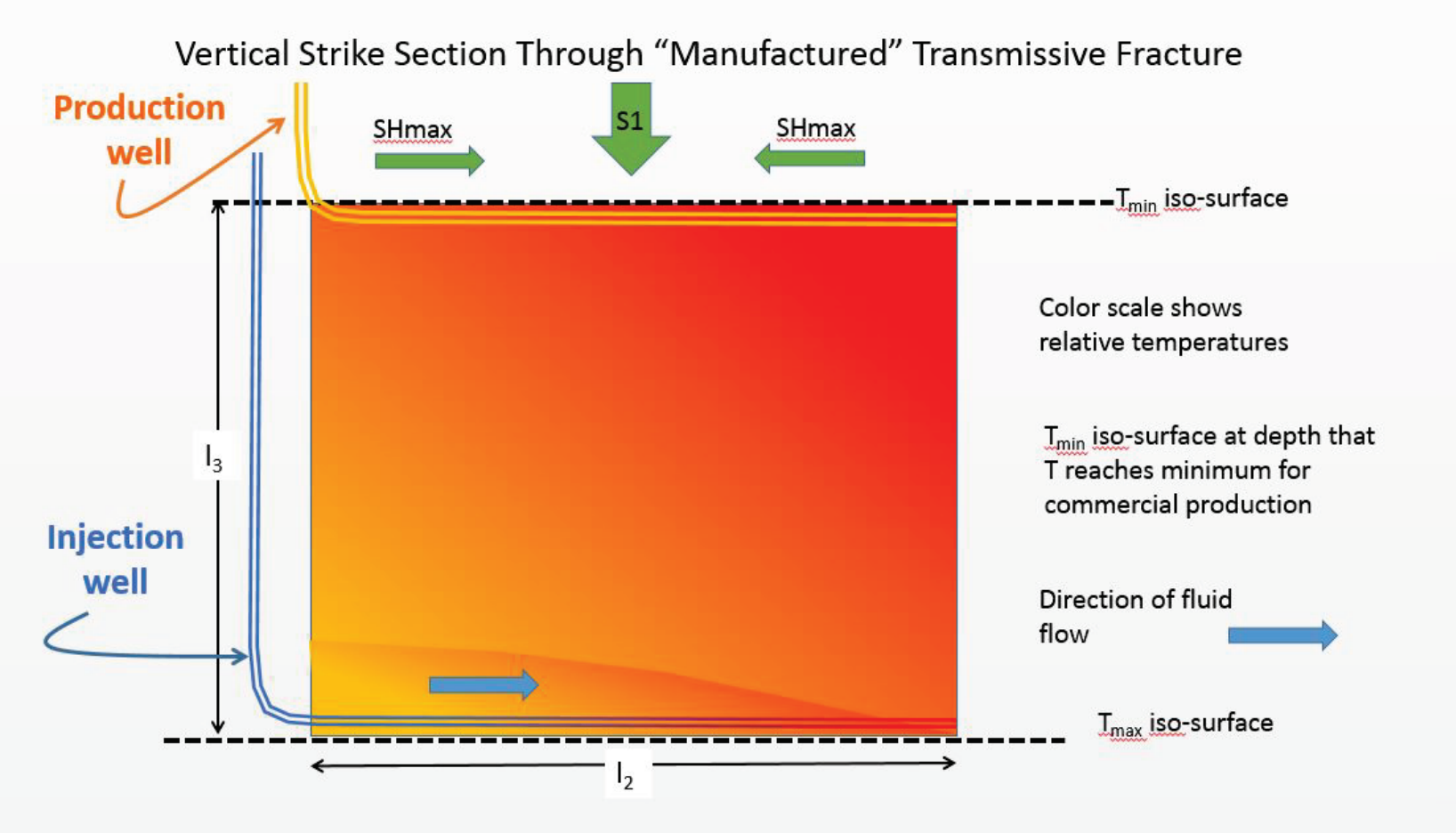
## The RAD-EGS

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# Fluid Transfer in Cracks and Slots

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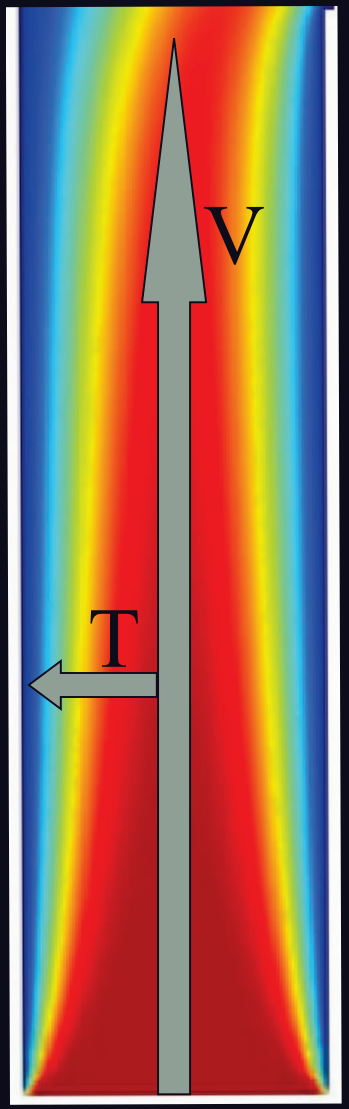
## For Laminar Flow with Thermal Entry Effects

Cool Thermal Boundary Layers From the Full Energy Equation

$$V \cdot \text{grad } T = 0$$

Fluid Progressively Cools with Ascent Distance where the amount of cooling depends on the rate of ascent or withdrawal.



- The ratio of heat transfer by fluid flow relative to
- Conduction is measured by the Peclet Number

- $Pe = VL / K$
- Where:
- V = fluid velocity, L = length scale, K = thermal diffusivity

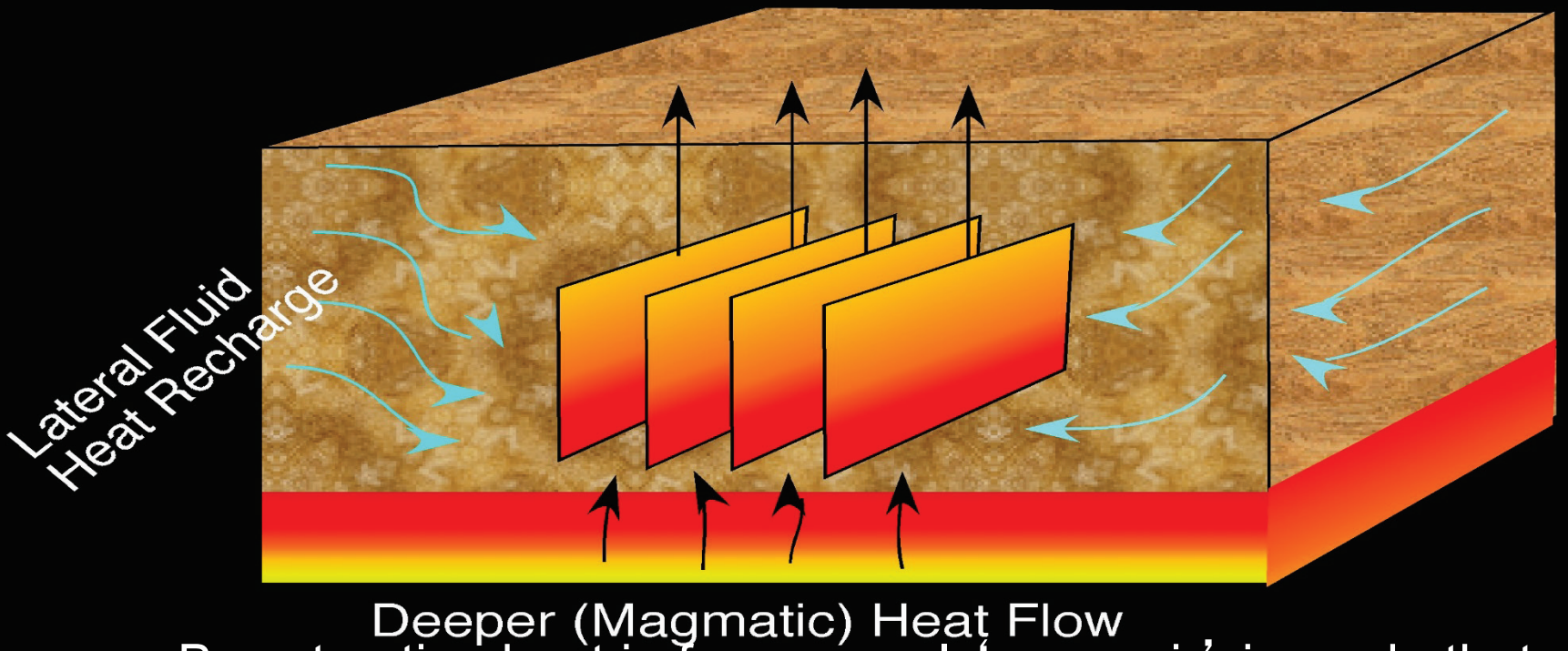
- For V~1km/year, L~1 km, and K = $10^{-2}$ $cm^2/sec$

- $Pe \sim 100$

- So, inflowing crustal fluids (laterally) from all directions, even at a slow rate, can possibly offset the losses due
- to conduction at the walls of the fracs.

# Creating a Massive Heat Sink

## Heat Extraction




By extracting heat in fracs a cool ‘reservoir’ is made that will be recharged through natural lateral inflow of adjacent crustal fluids thereby offsetting thermal ‘death’ to conduction.

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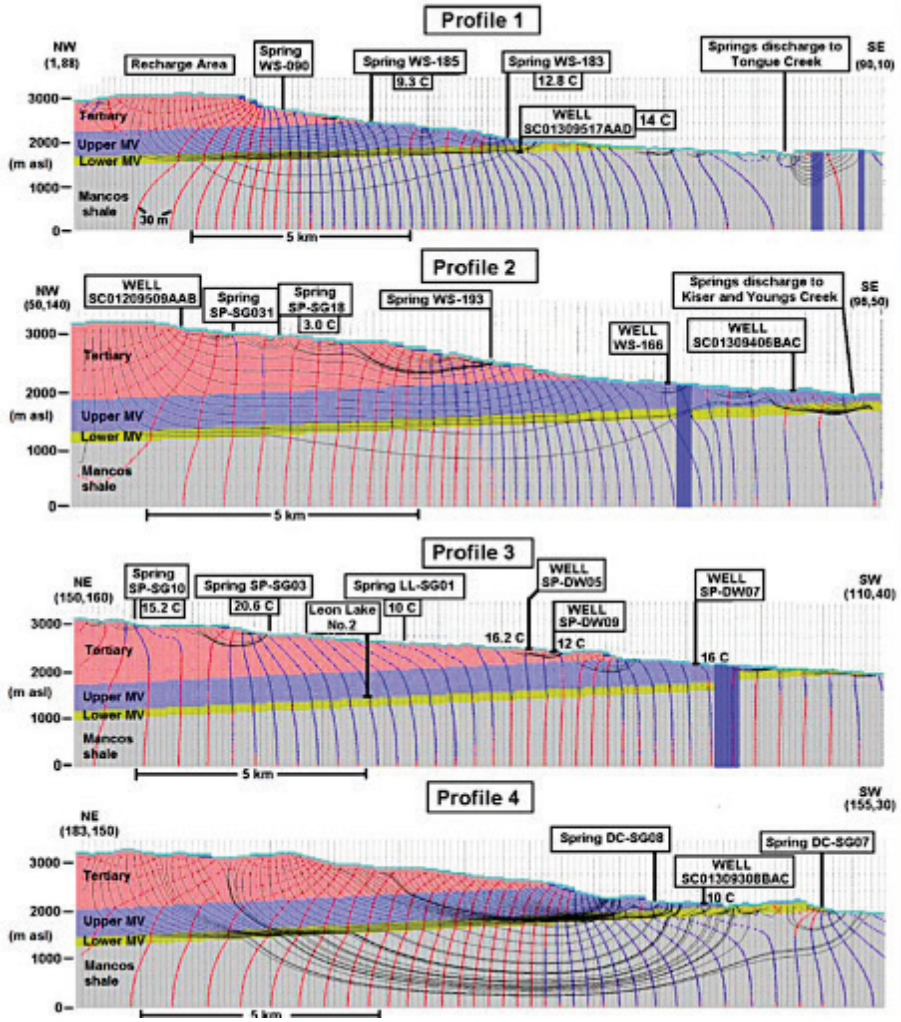
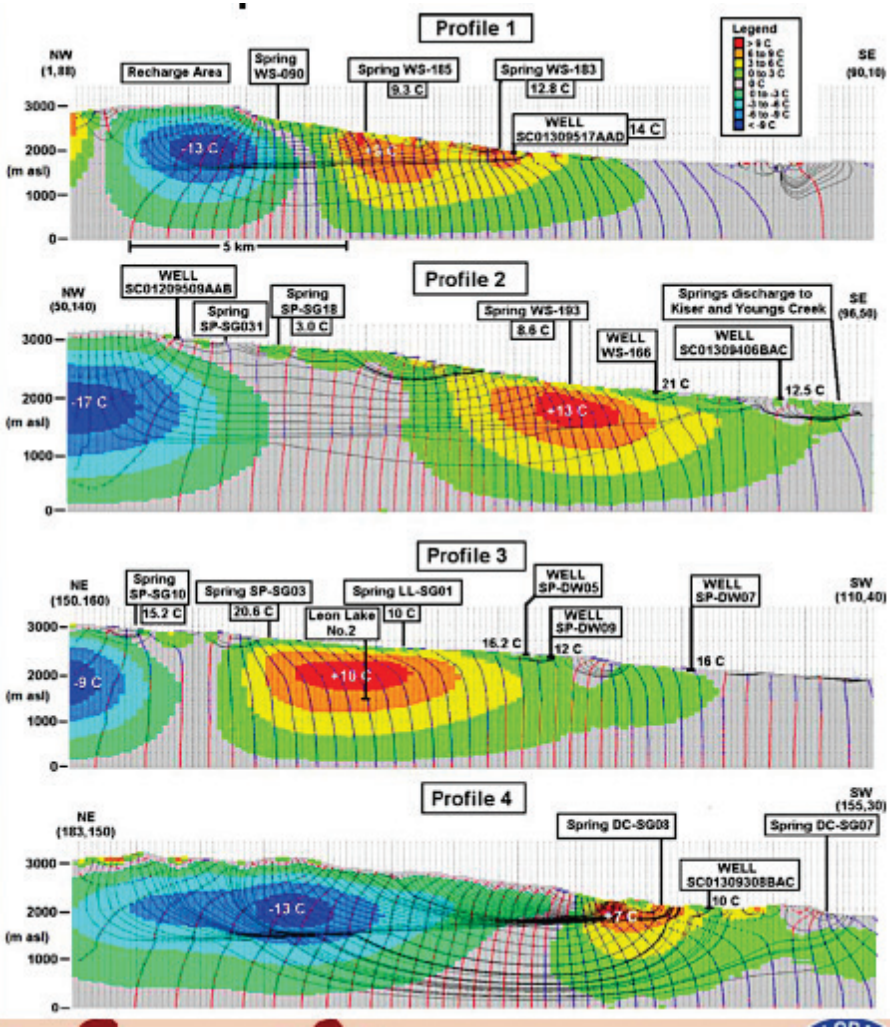
# Flow

# Temperatures

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# Radiator Enhanced Geothermal System

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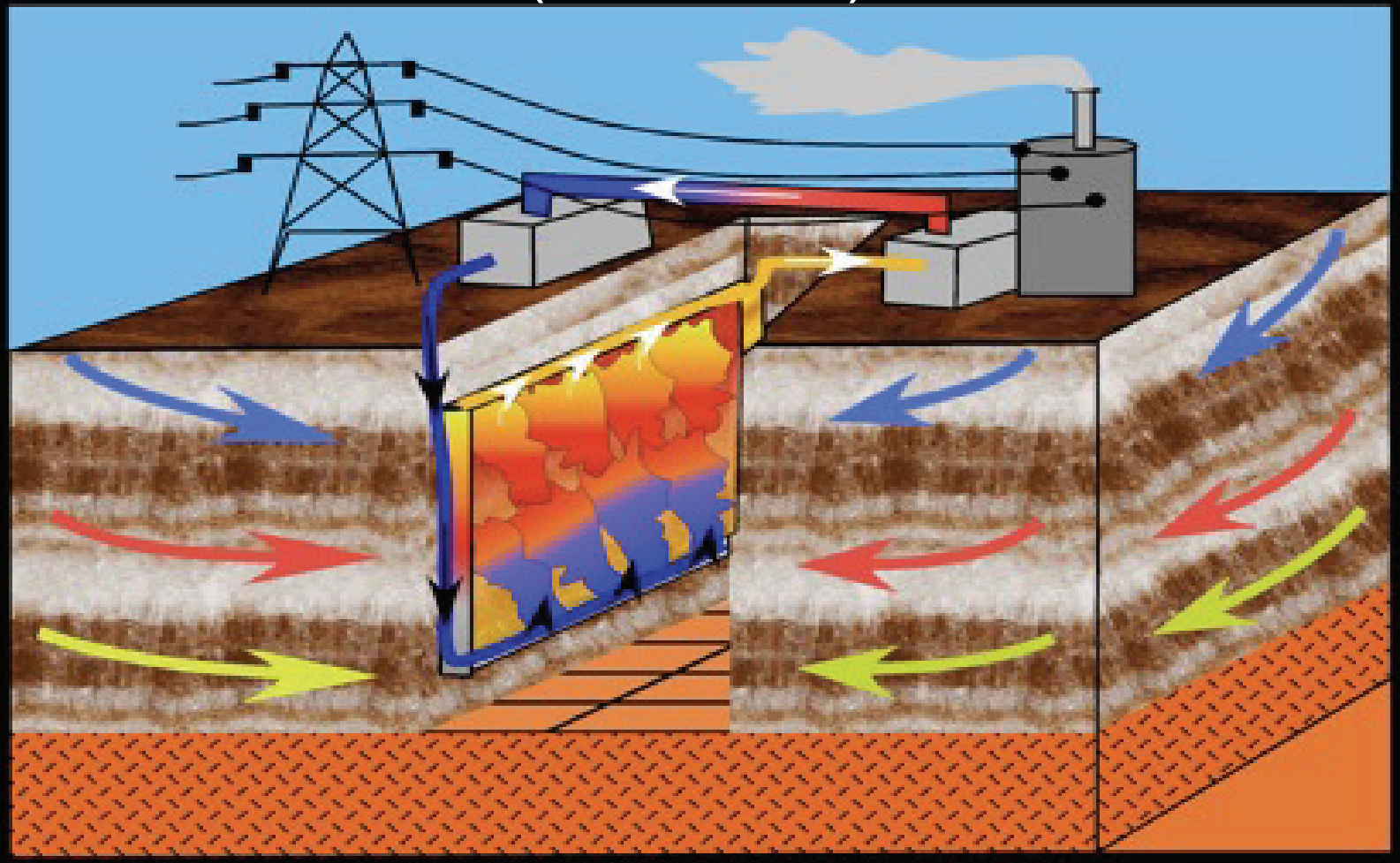
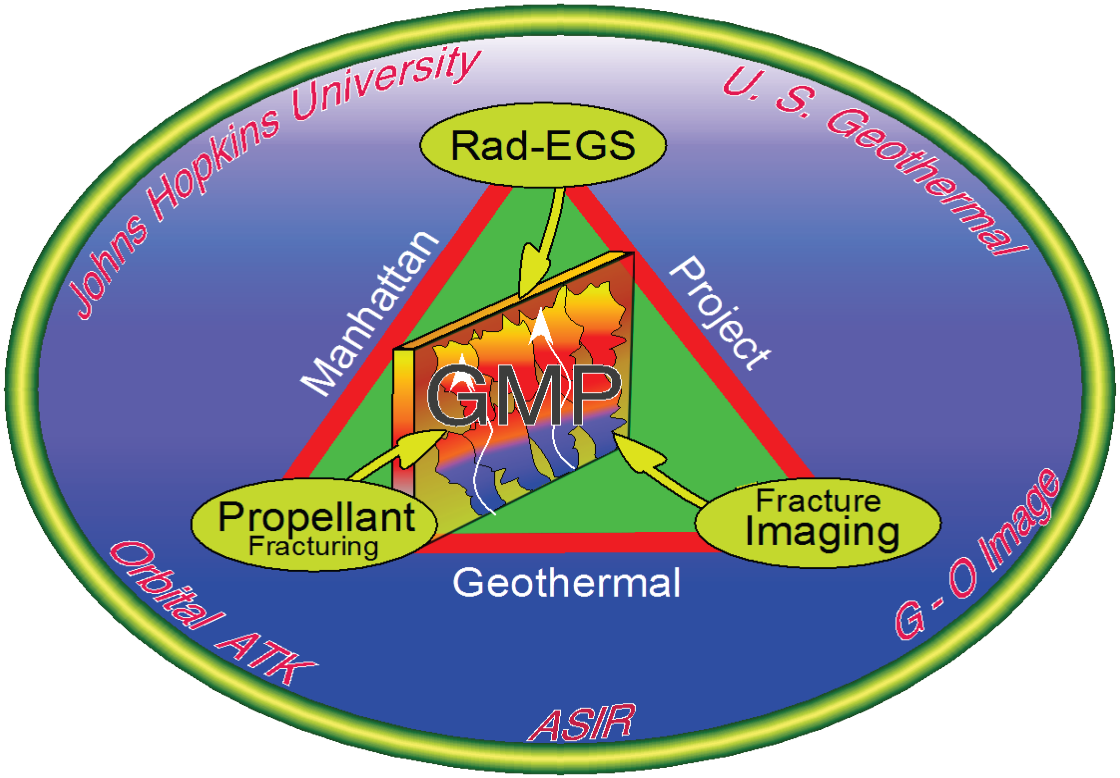
(RAD-EGS)



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