Effects of Stratigraphy on Geothermal Reservoir Performance*

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Abstract

Geothermal reservoir performance is critical to successful production of energy from geothermal resources. It is highly dependent upon a variety of factors, including reservoir types, fluid properties, rock properties, temperature, structural geology, stratigraphy, and others. Drilling of the well field and construction of the associated fluid collection and processing system is one of the largest costs of developing a geothermal resource. Proper conceptual modeling of the geothermal resource is necessary to optimize the design of the subsurface and surface geothermal energy production system. When done correctly, we can maximize the return on investment of our development dollars. Furthermore, we can use this information to better maintain the ‘health’ of our reservoirs and wells. We can also improve and optimize well and reservoir productivity, providing additional return on our geothermal investments. This paper outlines some of the interactions between geothermal reservoirs and their associated stratigraphies. The resultant effects upon reservoir performance as seen at the wellhead are discussed in detail.
References


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Factors

Many factors influence geothermal reservoir performance:

• Reservoir type
• Fluid properties
• Rock properties
• Temperature
• Structural geology
• Stratigraphy
• Others

This paper focuses on stratigraphy, specifically cap rock.
An Idealized Geothermal System

For the investigations described in this paper, a model comprising a 4-layer stratigraphic column was used:

- Atmosphere (cool, partially-saturated, heat sink)
- Cap rock (warm, porous, saturated, insulator)
- Reservoir rock (hot, porous, saturated fluid source)
- Basement rock (hot, porous, saturated heat source)
Pressure Gradients of Cold Water Systems

Pressure (bara)

Depth (m)

- Pressure (PHYDROSTATIC: SG=1.0) bara
- Pressure (PLITHOSTATIC: SG=2.0) bara
- Pressure (PLITHOSTATIC: SG=3.0) bara
Pressure Gradients of Geothermal Systems

- Pressure (PHYDROSTATIC: SG=1.0) bara
- Pressure (PLITHOSTATIC: SG=2.0) bara
- Pressure (PLITHOSTATIC: SG=3.0) bara
- Pressure (PVAPORSTATIC) bara
- Pressure (PSATURATION) bara

Geopressurized
Vapor-Dominated
Natural
Two-Phase
Liquid-Dominated

Depth (m)

Pressure (bara)
Temperature Gradients of Geothermal Systems

Temperature (°C)

Depth (m)

Temperature (Hydrostatic) °C
Temperature (Average Conductive) °C
Temperature (Highly Conductive) °C
Temperature (Saturation) °C

Conductive
Convective
Vapor-Dominated
Liquid-Dominated
Natural Two-Phase
Natural State Modeling
Temperature Profiles vs. Cap Rock Thickness

T (°C)

z (m)

Saturation (°C)

T (°C), No Cap Rock

T (°C), 2m

T (°C), 20m

T (°C), 40m

T (°C), 60m

T (°C), 80m

T (°C), 100m

T (°C), 200m

T (°C), 300m

T (°C), 400m

T (°C), 800m

T (°C), 1600m
Temperature Profiles vs. Cap Rock Thickness

T (°C)

z (m)

Saturation (°C)

T (°C), No Cap Rock

T (°C), 2m

T (°C), 40m

T (°C), 60m

T (°C), 80m

T (°C), 100m

T (°C), 200m

T (°C), 300m

T (°C), 400m

T (°C), 800m

T (°C), 100m
Pressure Profiles vs. Cap Rock Thickness

P (bara)

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160

Pressure (PLITHOSTATIC: SG=2.0) bara
Pressure (PHYDROSTATIC: SG=1.0) bara
Pressure (PSAT) bara

- P (bara), No Cap Rock
- P (bara), 2m
- P (bara), 20m
- P (bara), 40m
- P (bara), 60m
- P (bara), 80m
- P (bara), 100m
- P (bara), 200m
- P (bara), 300m
- P (bara), 400m
- P (bara), 800m

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Pressure Profiles vs. Cap Rock Thickness

P (bara)

Pressure (PLITHOSTATIC: SG=2.0) bara
Pressure (PHYDROSTATIC: SG=1.0) bara
Pressure (PSAT) bara

P (bara), No Cap Rock
P (bara), 2m
P (bara), 20m
P (bara), 40m
P (bara), 60m
P (bara), 80m
P (bara), 100m
P (bara), 200m
P (bara), 300m
P (bara), 400m
P (bara), 800m

z (m)
Vapor Saturation Profiles vs. Cap Rock Thickness

Vapor Saturation vs. Depth (0 to 200 m)

- SG, No Cap Rock
- SG, 2m
- SG, 60m
- SG, 20m
- SG, 40m
- SG, 40m
- SG, 80m
- SG, 300m
- SG, 400m
- SG, 800m

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Conclusions

Cap rock thickness is a key factor in the formation and performance of geothermal reservoirs. While geothermal reservoirs can form without the presence of a cap rock layer, these will tend to be cool, small, and unstable. Geothermal reservoirs with thin cap rock layers will tend to be hotter, larger, and less stable than those without any cap rock. There seems to be a ‘critical thickness’ above which the reservoir becomes progressively more stable.

With cap rock layers of sufficient thickness and integrity, we will probably see little or no surface temperature elevation and few or no surface expressions; theoretically, this proves the probable existence of many ‘hidden reservoirs’.
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References


