

Thermal Anomalies Associated with the Newport Inglewood Fault Zone, Long Beach Field, California*

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Abstract

Periodic temperature surveys of shut-in wells in the Long Beach Field show episodic temperature anomalies associated with fault splays of the Newport-Inglewood (NIFZ) fault. These anomalies occur in at least three wells in which the ambient thermal gradient is 0.035 C/m (0.019 F/ft). The reservoir is known to be sub-hydrostatic (as little as 20 % of hydrostatic) overlying a hydrostatically pressured section. Within the identified wells, the temperature anomaly is 11 C (20 F) over the normal geothermal gradient over an interval of about 70 m (224 ft) on average. These elevated gradients occur where the wells cross the North East Flank (NEFF) fault zone, which is within the Newport-Inglewood fault zone. This part of the NIFZ fault has 125 meters (400 ft) of vertical displacement and an unknown amount of strike-slip component. In some cases the thermal anomalies are associated with sandstone intervals adjacent to the underside of the fault. The thermal anomalies appear to be transient over time intervals of two years in specific wells. In SHEU 87 well, the anomaly was not present in temperature surveys in 1979 and in May 1981, but it was present in March 1983.

We interpret these thermal anomalies to represent upward movement of formation fluids, along faults from deeper levels in the basin. The transient nature of the thermal pulse, i.e. a temperature increase of 11 C (20 F) over a time period of less than 2 years, provides firm constraints on the nature of the fluid flux. Our calculations indicate that these fluids could represent movement over a period of 2 years of 169 m³ (1063 bbls) of fluids, at 11 C (20 F) above ambient geothermal gradient, if we assume a fault permeability of 20 to 30 md.

The NEFF fault also shows evidence of fault creep from well casings that are deformed (bent and sheared after local earthquakes). Four wells SHEU 26, SHEU 953, SHEU 960, and SHEU 160 experienced complete casing collapse (which represents a minimum displacement of 17 cm) during the 1994 Northridge earthquake. The above observations indicate the Newport Inglewood fault is an active fluid pathway with some creep displacement in spite of its general aseismic character. We recognize numerous cemented fault zones in new wells drilled within the field, based on image logs, which may represent paleo-fluid flow pathways at a time when the basin may have been overpressured.

Reference

Gardner, J.V., P. Dartnell, L.A. Mayer, and J.E. Hughes Clarke, 1999, Bathymetry and selected perspective views of Lake Tahoe, California and Nevada: USGS Water Resources Investigation Report #99-4043. (2 map sheets).

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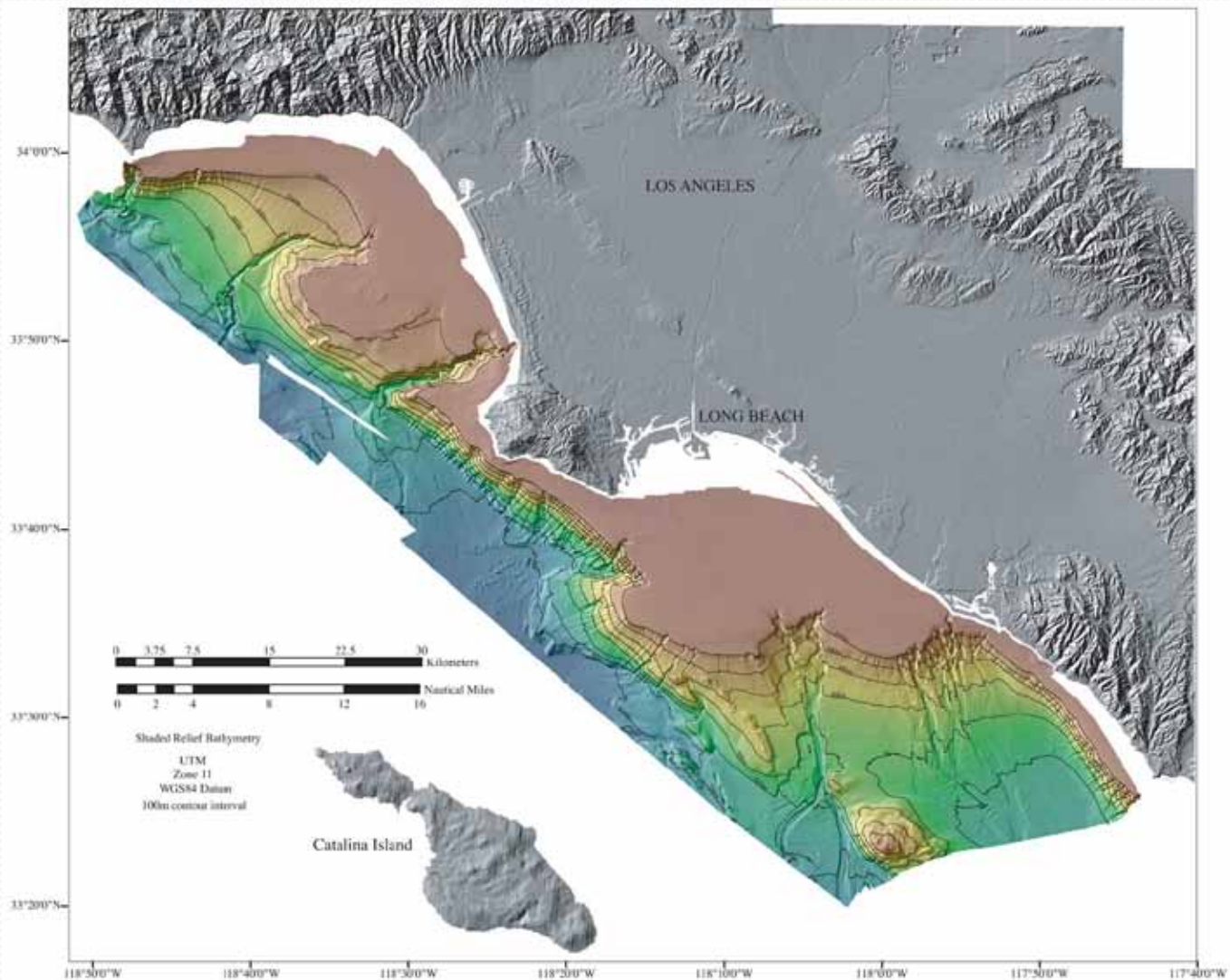
Conclusions

Thermal anomalies, as high as 11°C above normal gradient, are associated with episodic fluid flow along faults in the Long Beach field.

We estimate vertical fluid flow rates in the order of 84 m³/a (180 m) and Horizontal flow rates of 300 m/a. Our model show that heat and mass transfer can occur on a yearly scale.

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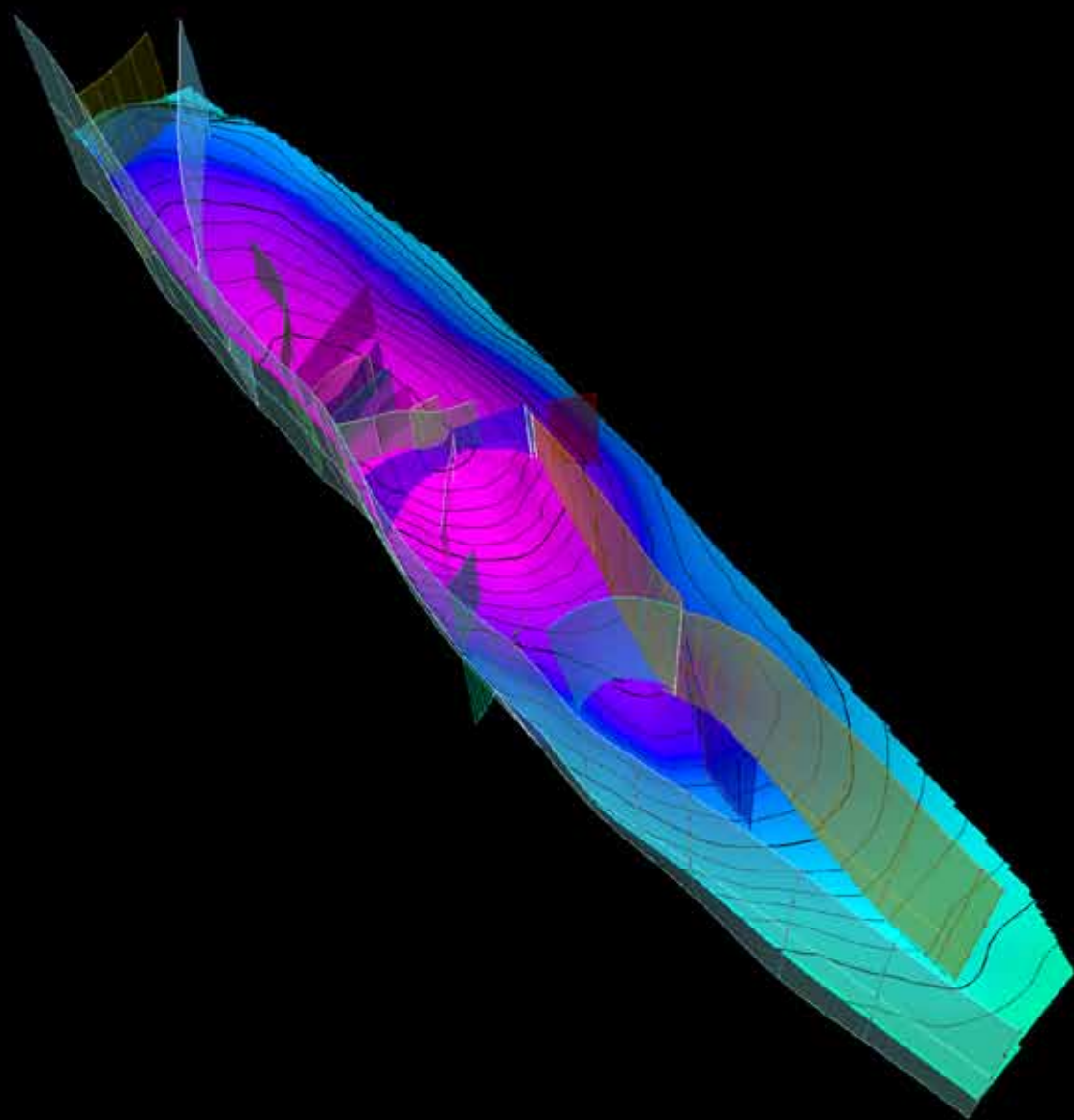
Fault related thermal anomalies can accelerate the onset of hydrocarbon generation by hundreds of thousands of years, as compared to places with normal geothermal gradients as suggested by TTI index modeling.

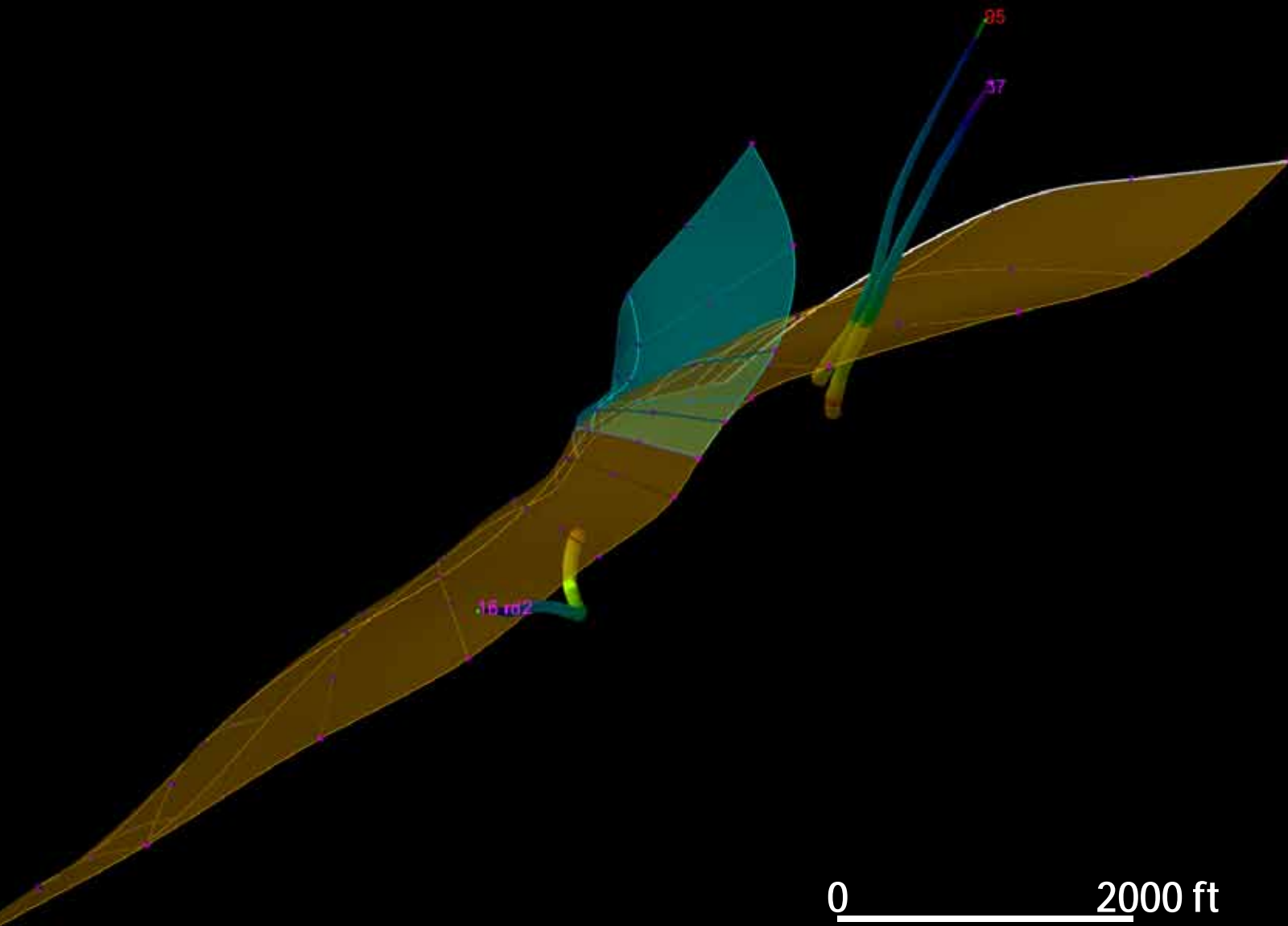


Modified from Gardner and Dartnell, 1999









Well 16 rd2

1981

1983

Well 87

AH ⊕

AH

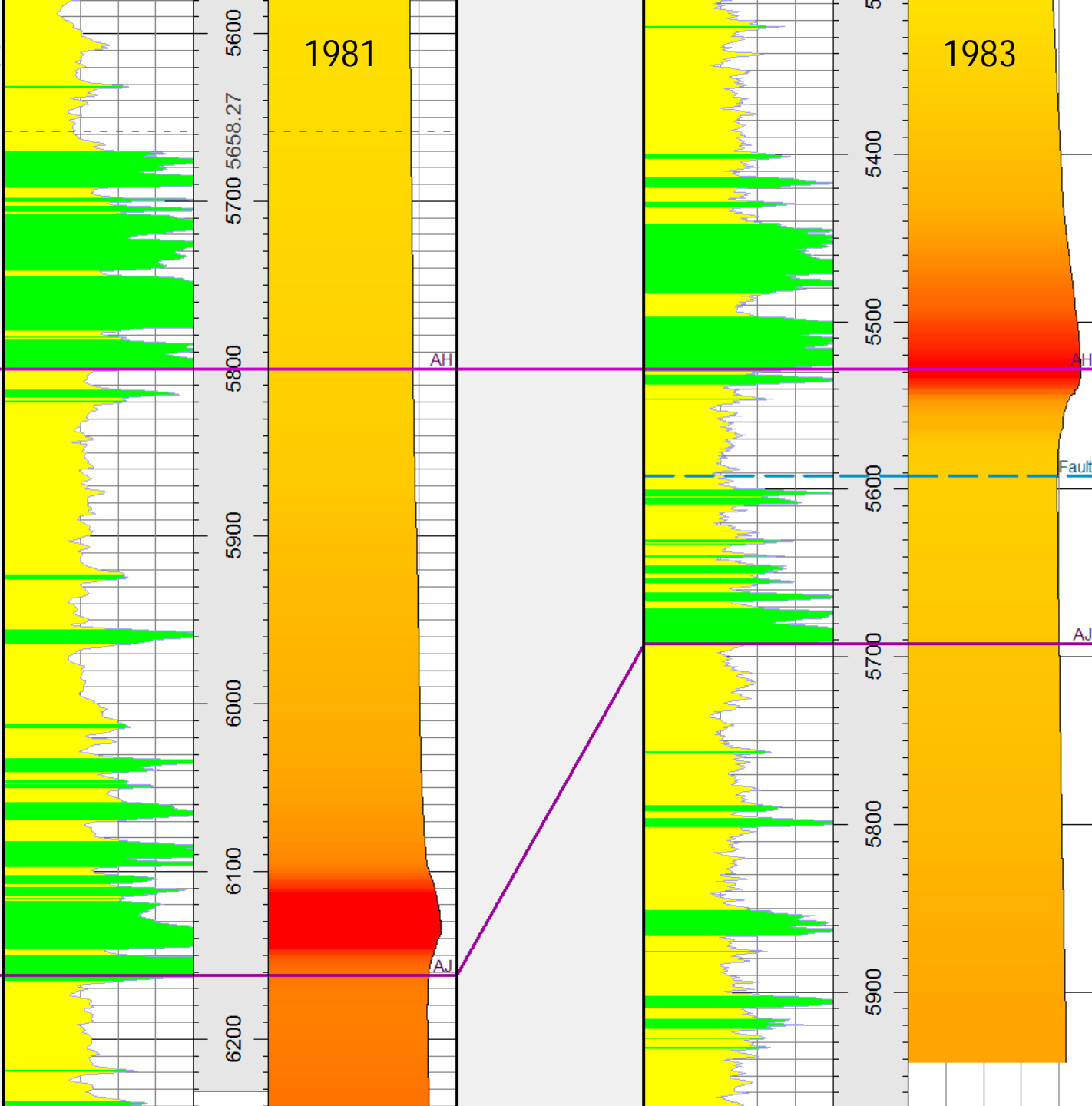
AH ⊕

Fault ⊕

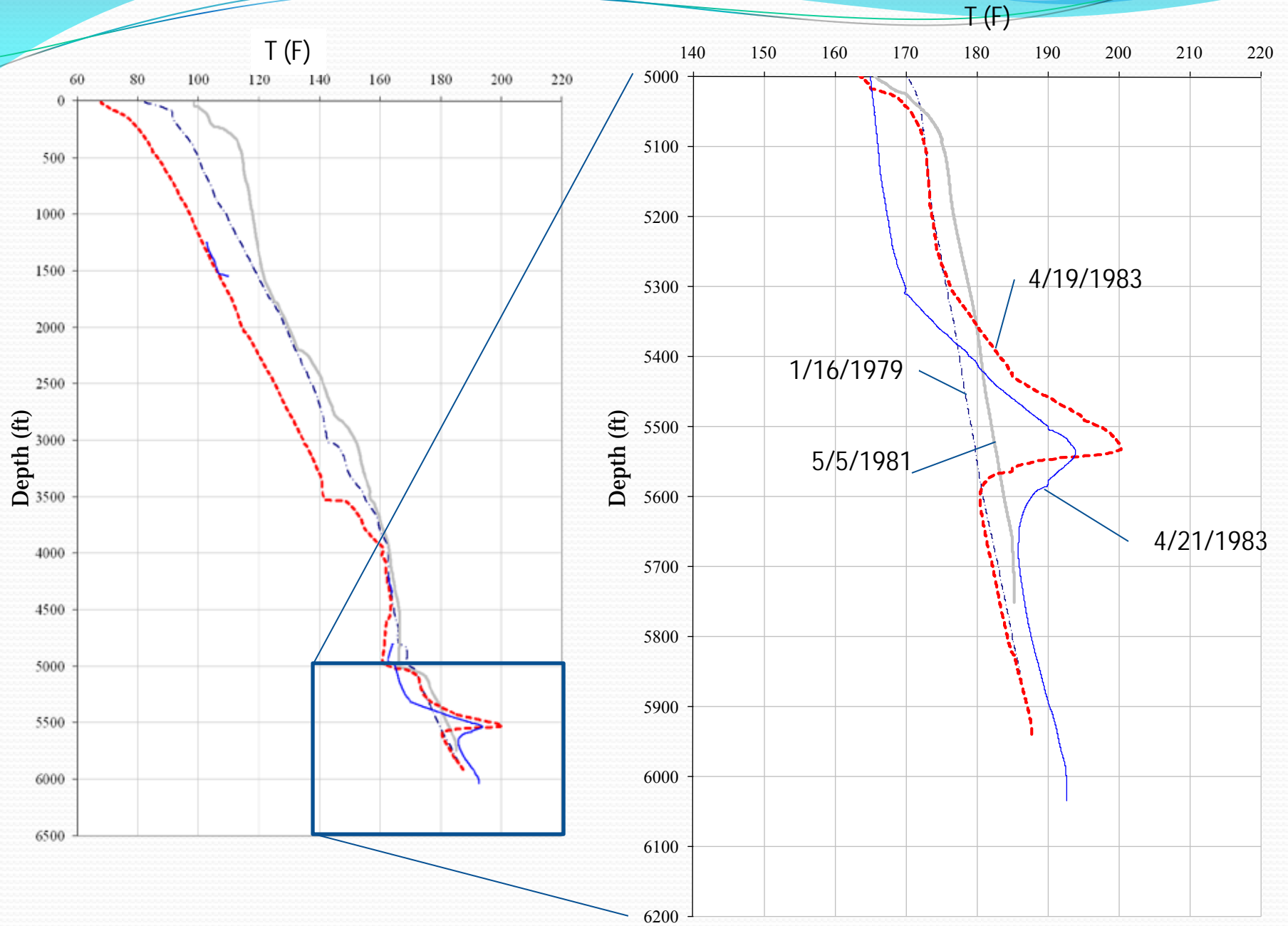
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AJ ⊕

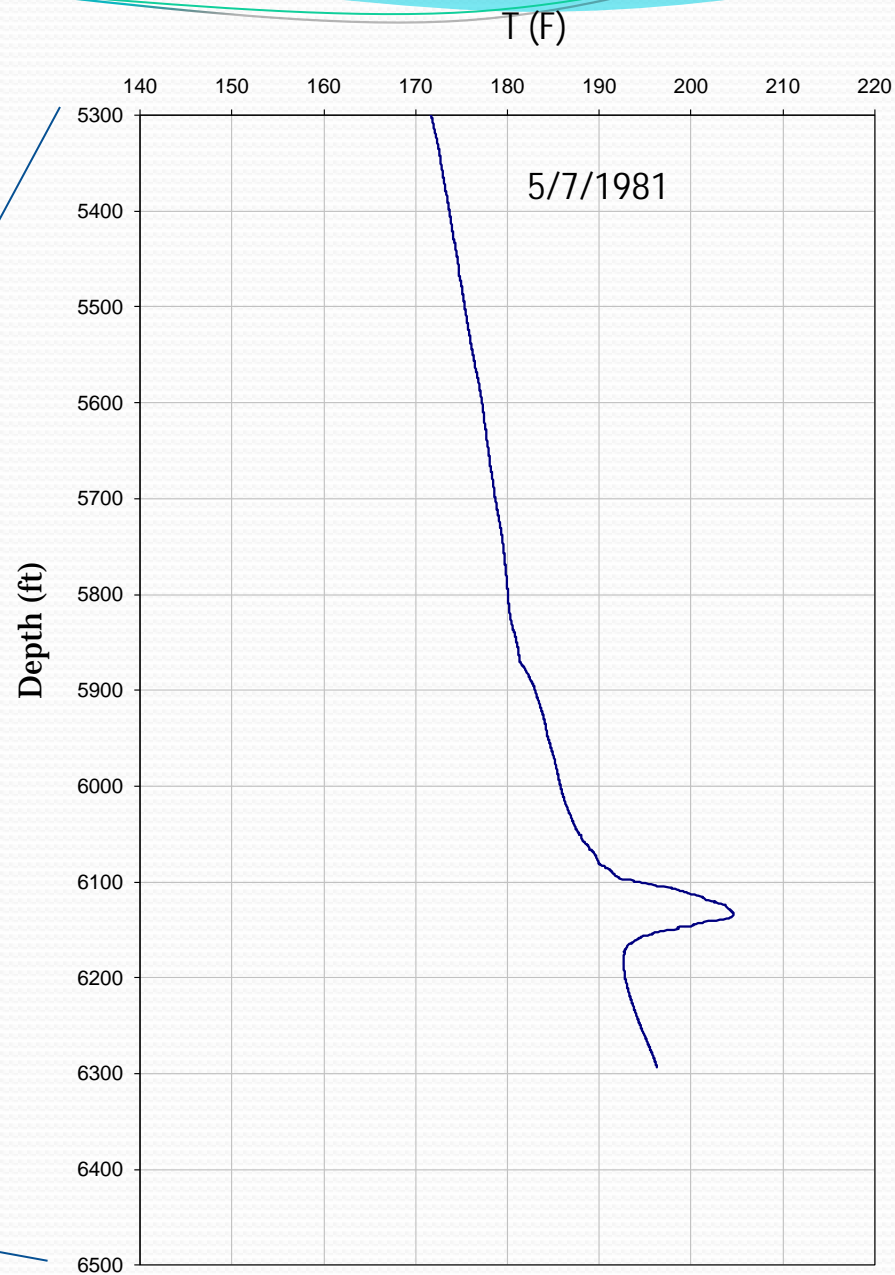
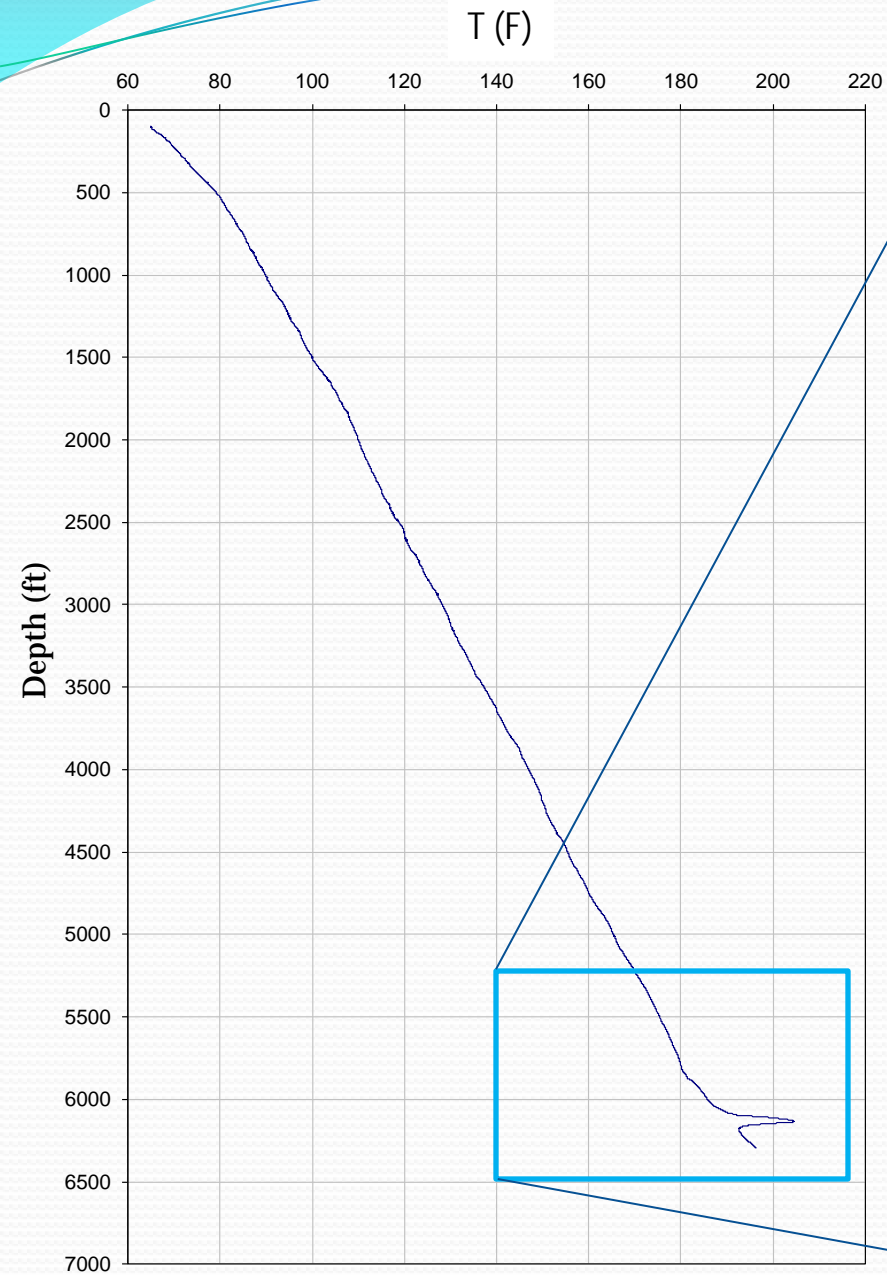
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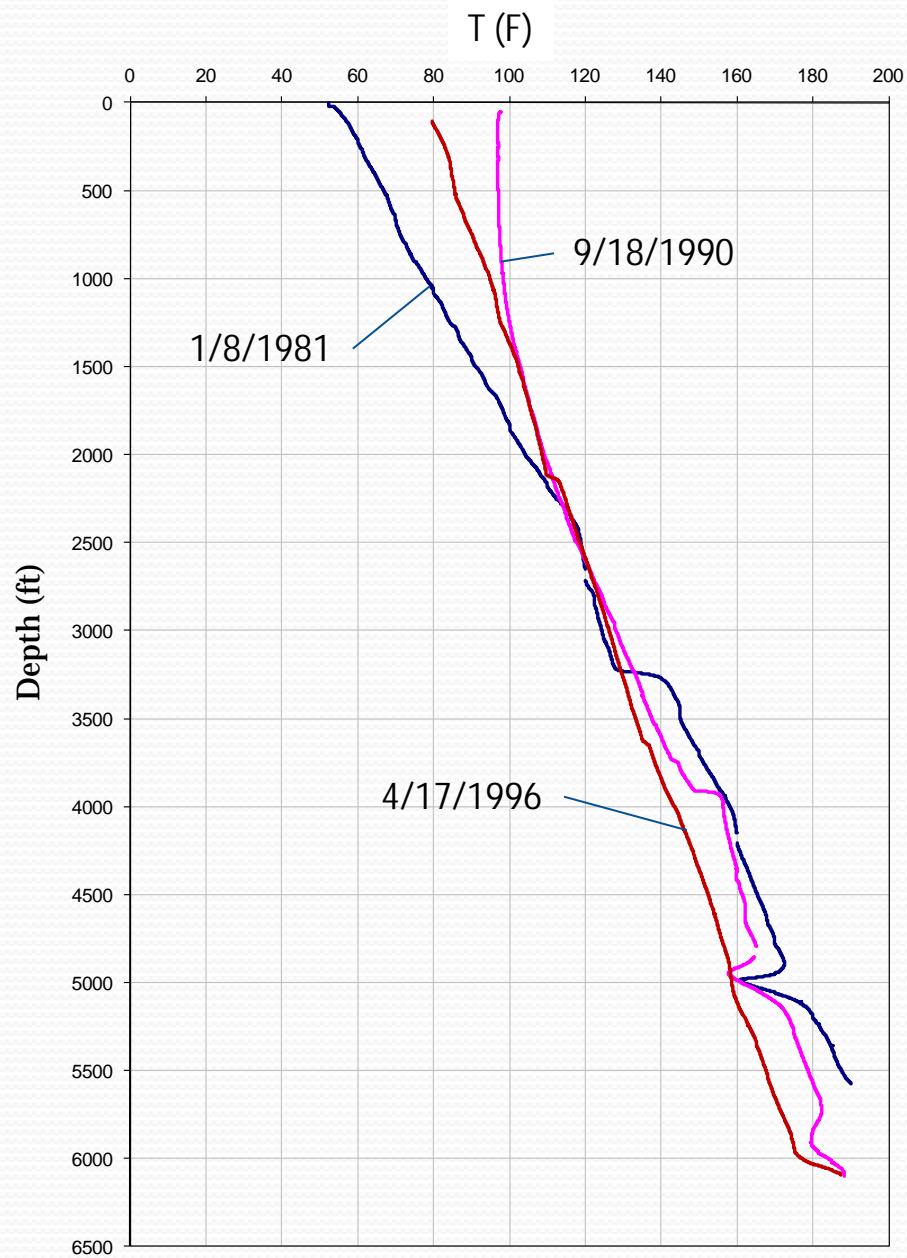
Well 87



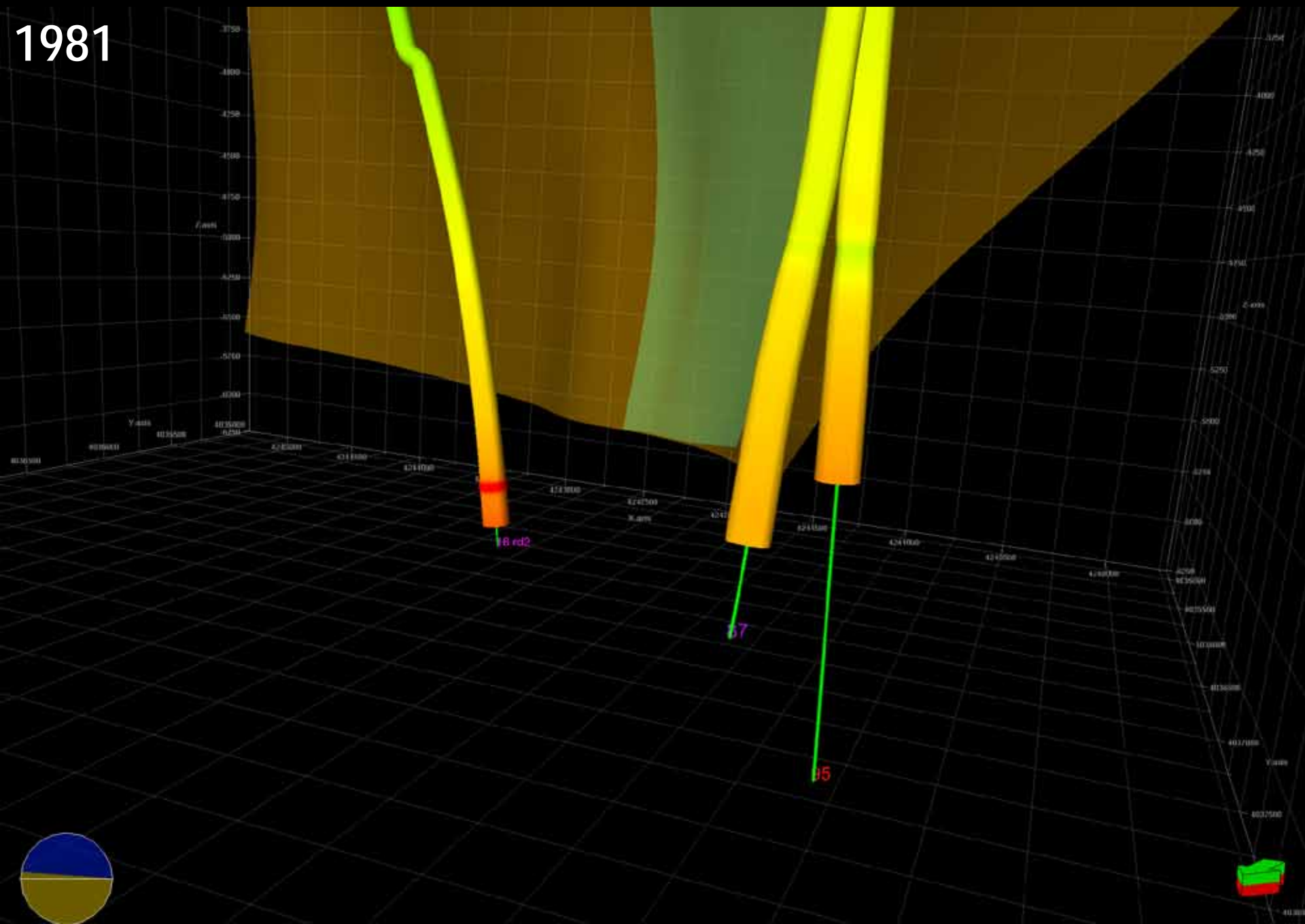
Well 16 Rd 2



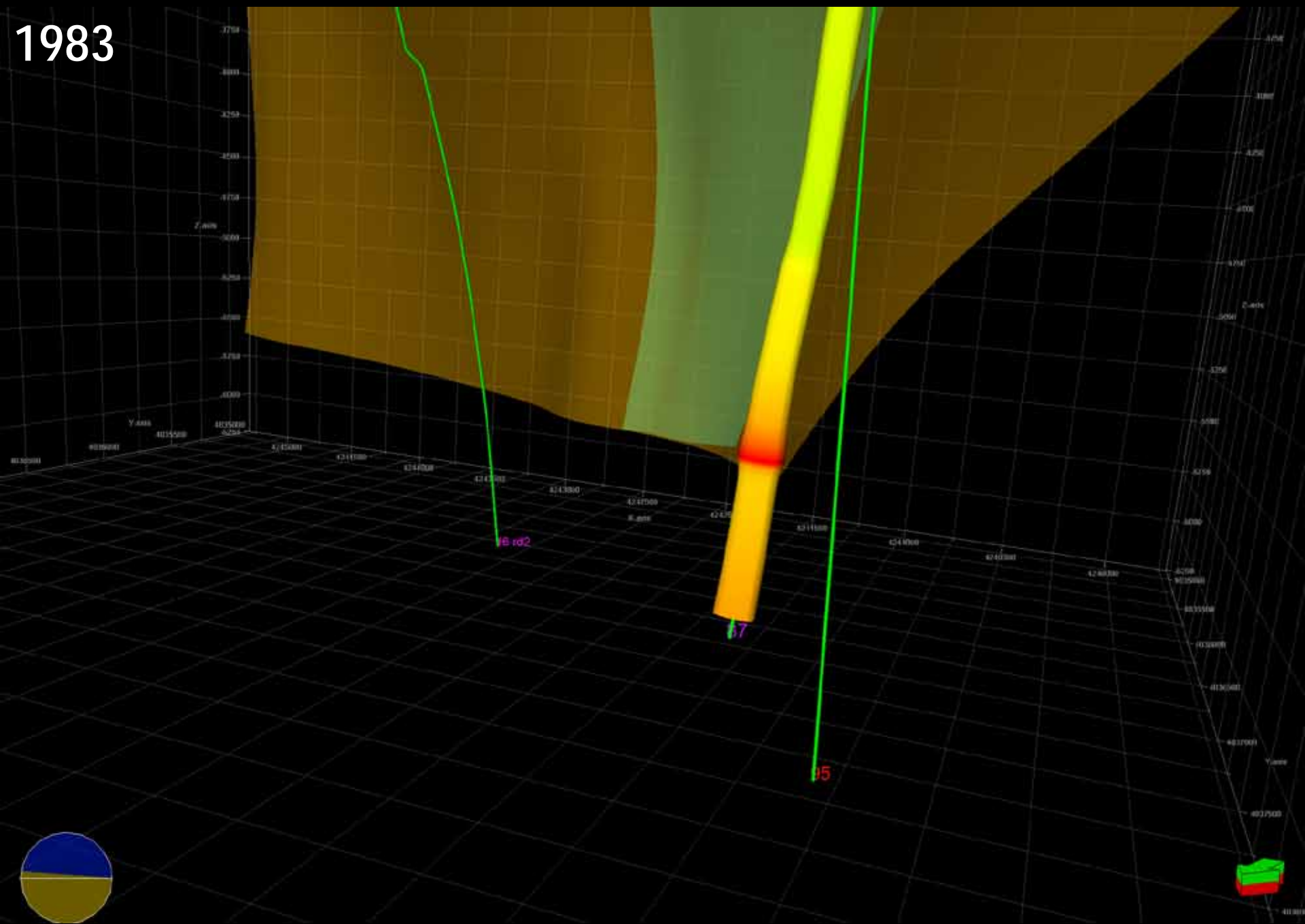
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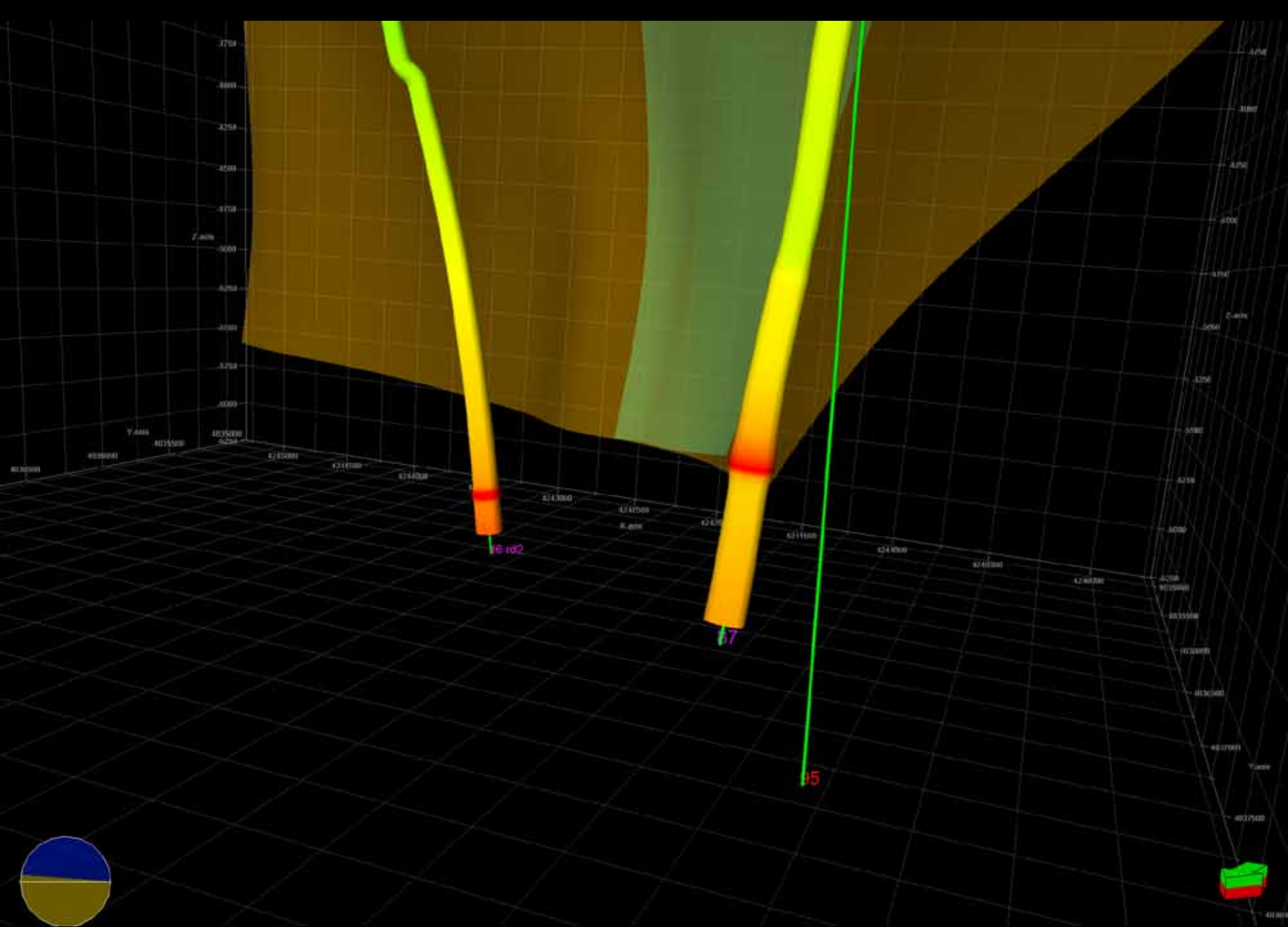


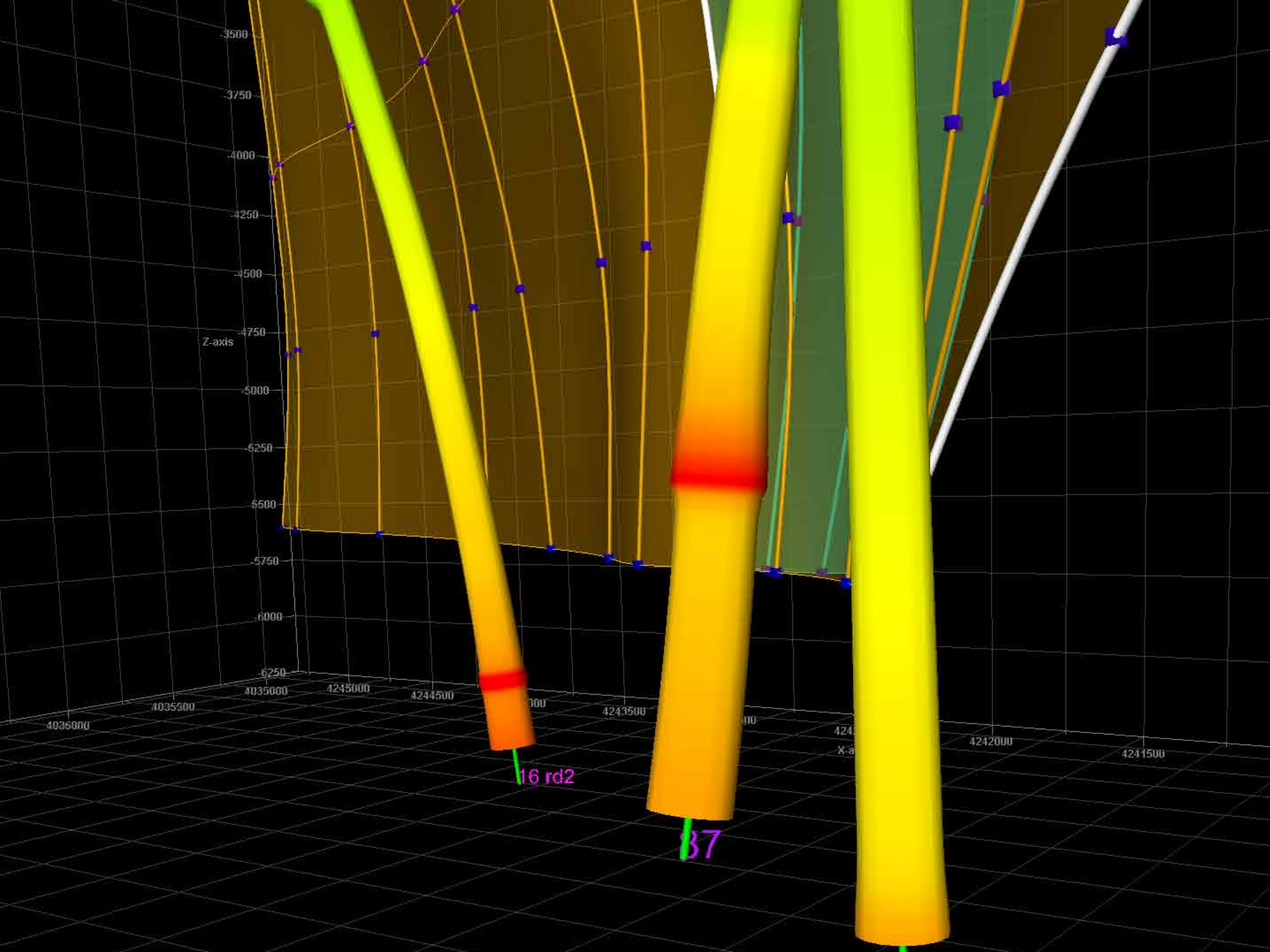
1981



1983







Ignoring transient flow, we construct a thermal balance for 1-D heat flow and 1-D vertical fluid flow in a vertical conduit, then energy conservation would dictate that:

$$(M)(C)(dT/dz) = (K)(dT'/dz)$$

where

M=mass flow rate of the fluid

C=heat capacity of fluid

K=thermal conductivity of fault zone with fluid

dT/dz = ambient cooling rate along the flow path

dT'/dz =geothermal gradient in excess of the ambient/conductive

z=vertical distance

$$dT/dz = 19^{\circ}\text{F} / 1000 \text{ ft} = 35^{\circ}\text{C} / 1000\text{m} = 0.035^{\circ}\text{C}/\text{m}$$

$$dT'/dz = 11^{\circ}\text{C} / 70 \text{ m} = 0.157^{\circ}\text{C}/\text{m}$$

Assuming

$$C \sim 4186 \text{ Joules}/(\text{kg } ^{\circ}\text{C})$$

$$K \sim 2.5 \text{ Watts } /(\text{m } ^{\circ}\text{C}), \text{ where } 1 \text{ W} = \text{J}/\text{s}$$

then

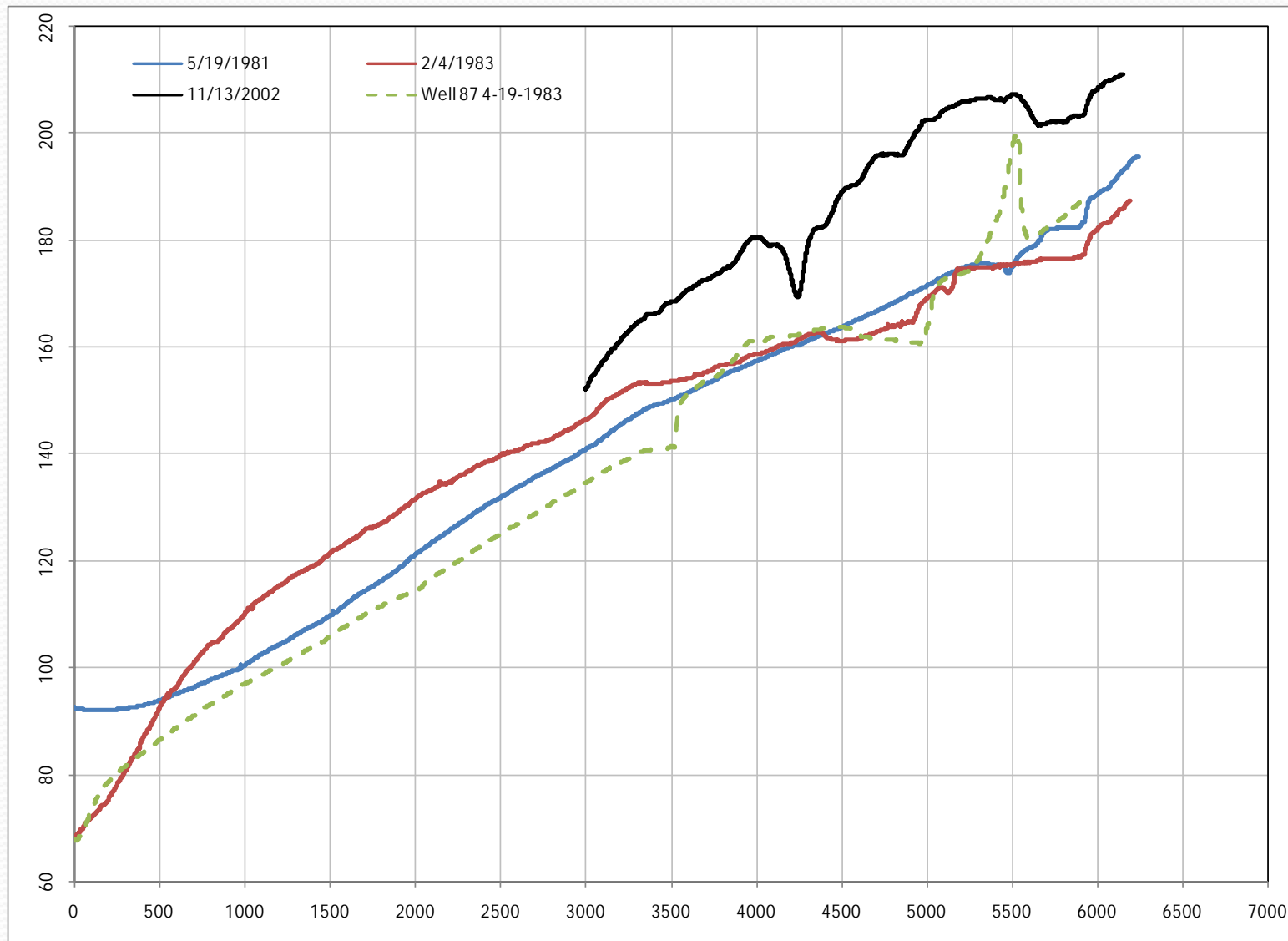
$$M = (K)/(C)\{(dT'/dz)/(dT/dz)\} = 2.681\text{E-}03 \text{ kg}/\text{s}$$

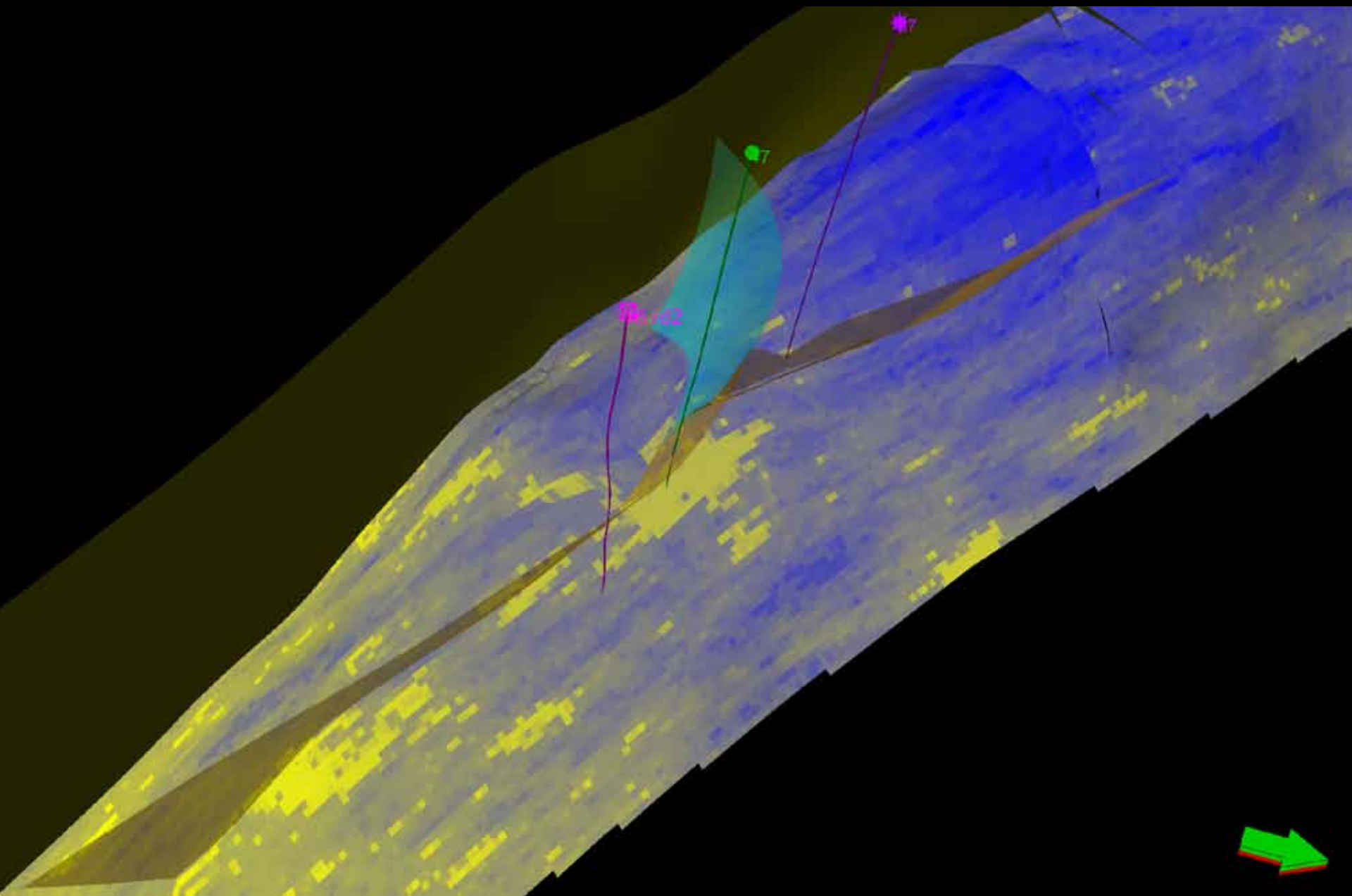
if the fluid density is $\rho \sim 1000 \text{ kg}/\text{m}^3$, the total volumetric discharge rate would be:

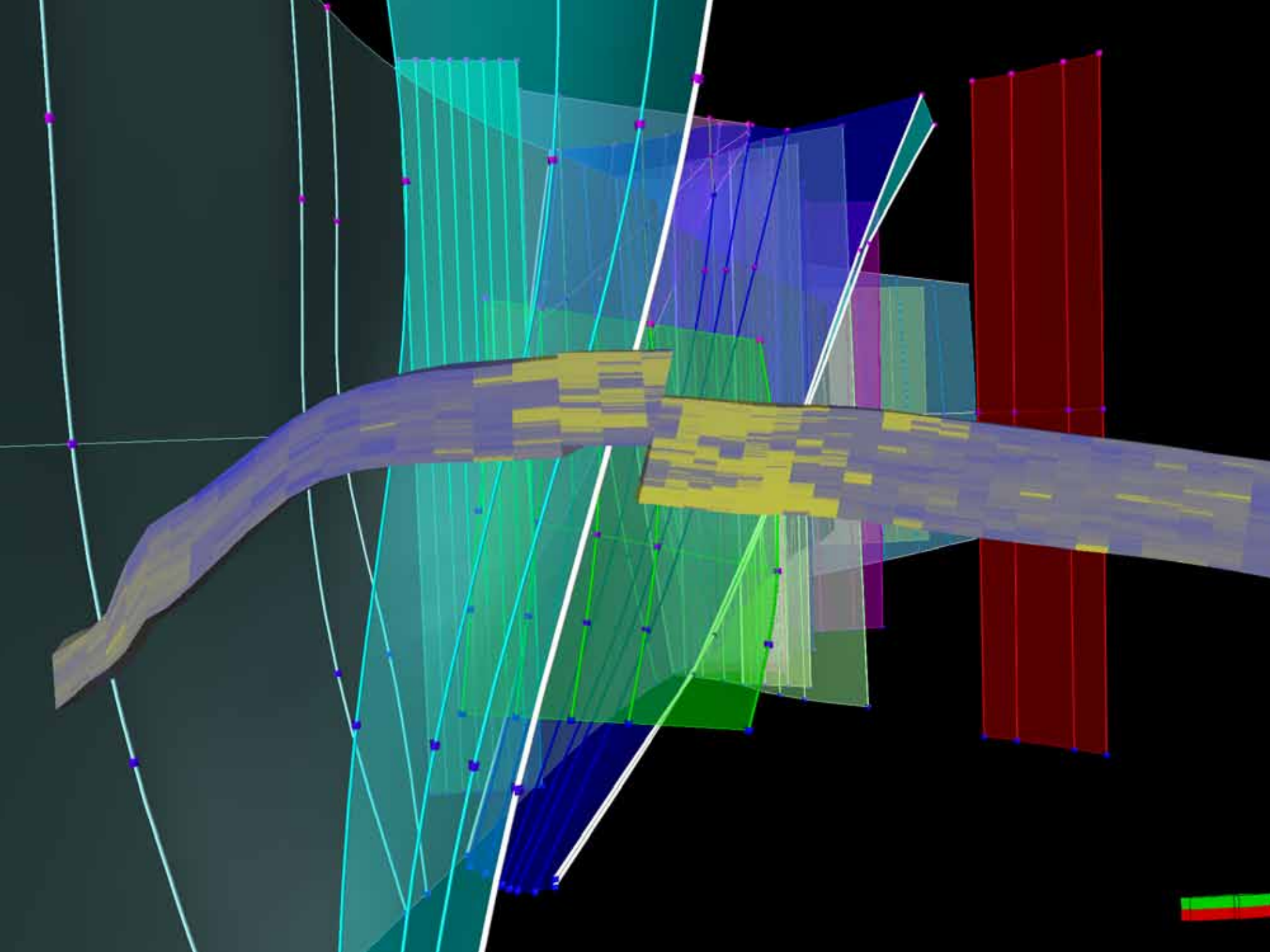
$$Q = (M)/(\rho) = 2.681\text{E-}06 \text{ m}^3/\text{s} = 84.6 \text{ m}^3/\text{year}.$$

Total volume would be about **169** cubic meters over a **2** year period

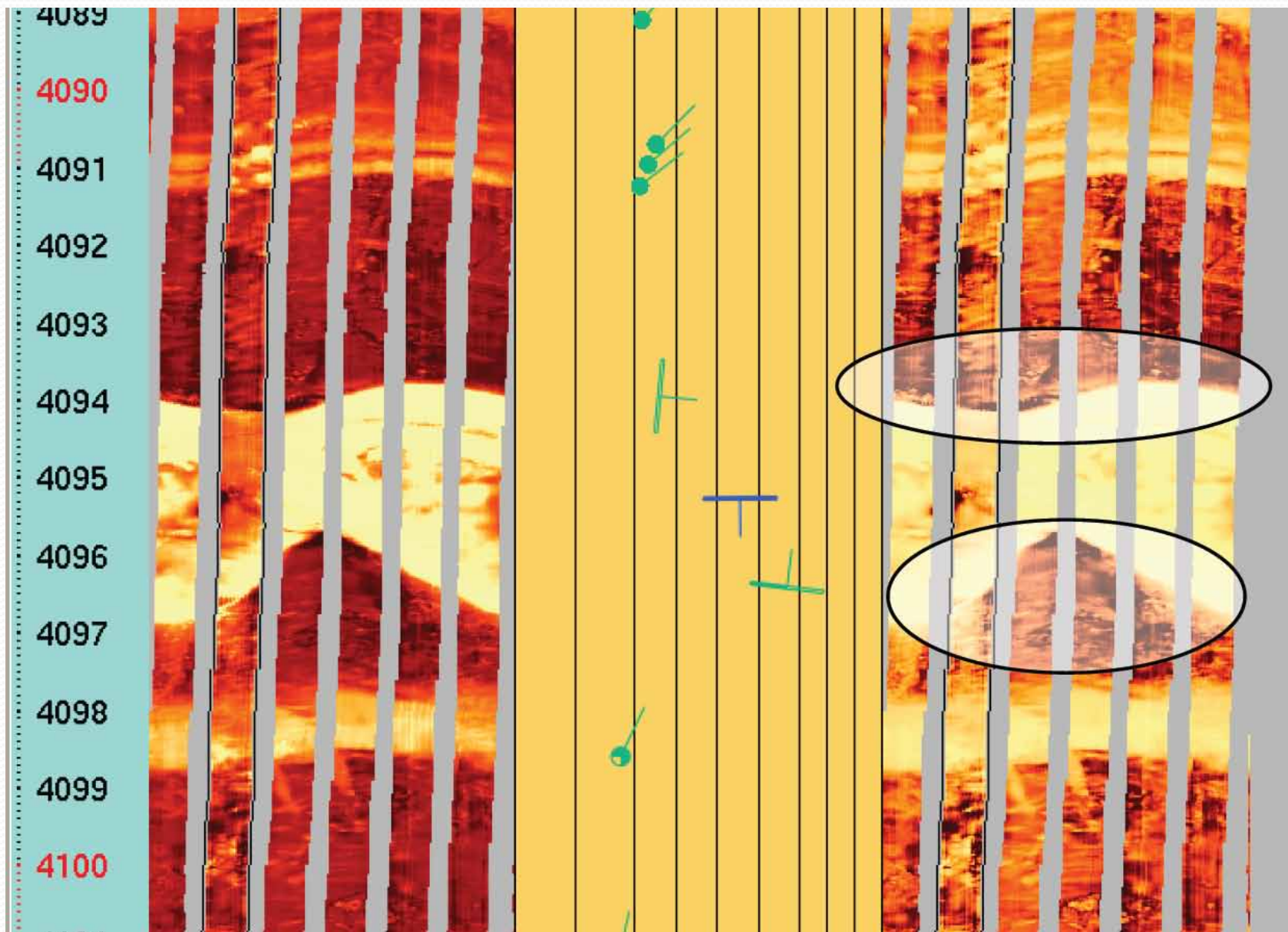
Well 47



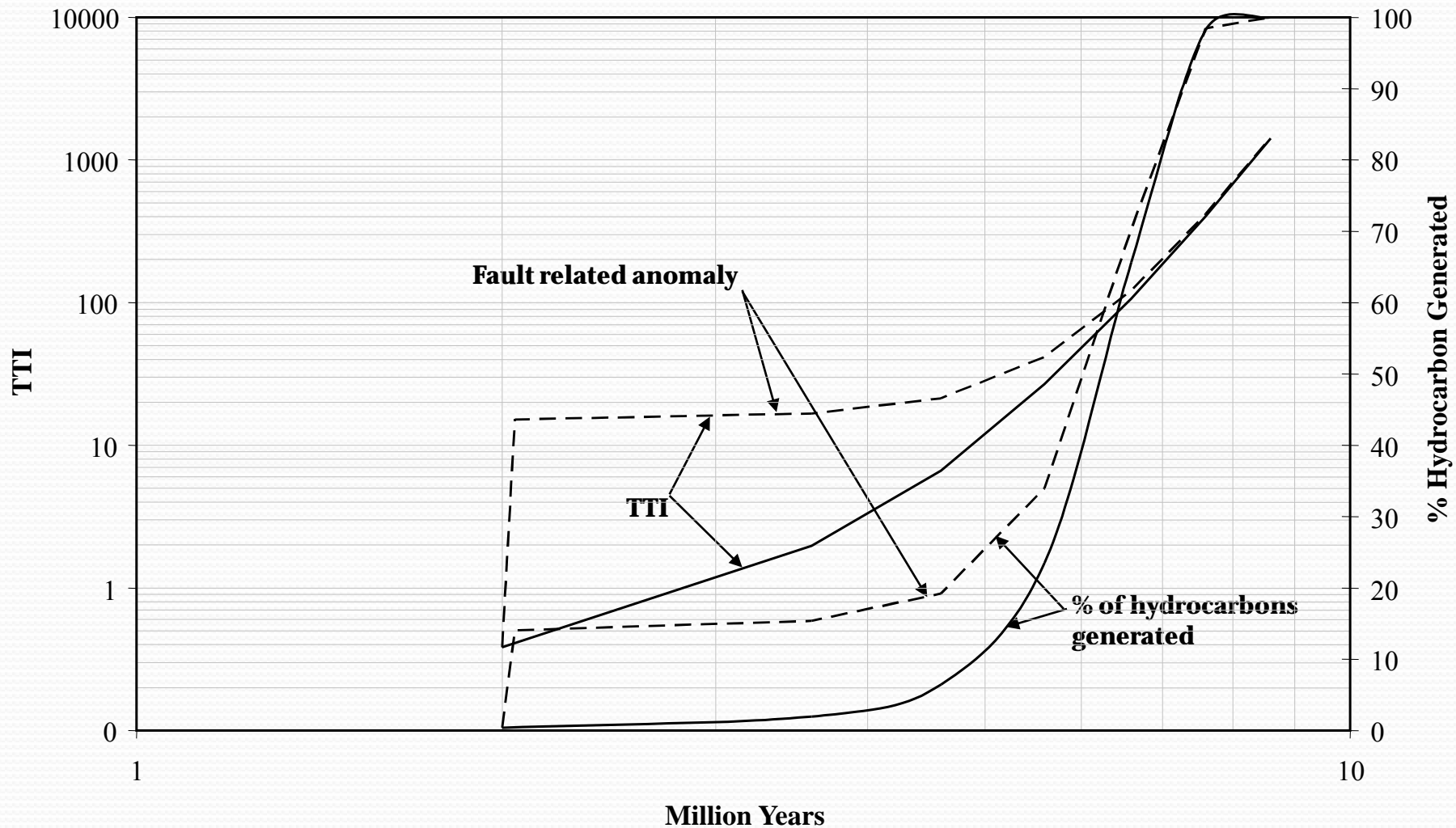




Well 23-6



Temperature-time index for Monterey type kerogen. Solid lines represent TTI at a constant geothermal gradient, Hunt (1996). Dashed lines represents a 0.05 Ma of 50°C fault related anomaly.



Conclusions

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