Surface Expression Risk Assessment Physiography



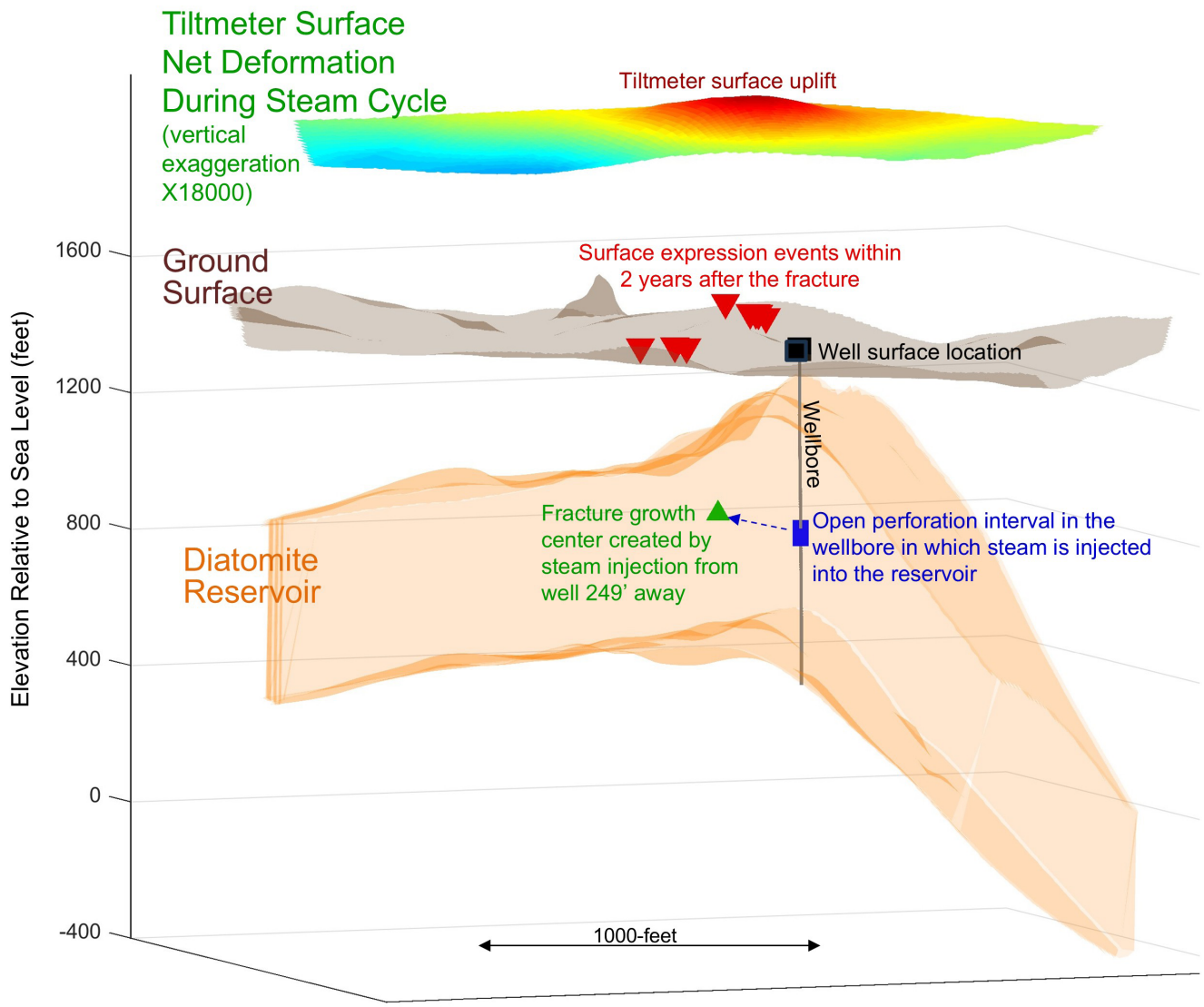
Dangerous subsurface-to-surface flows of hot oil, water, steam, debris, and rock, called surface expressions, have been observed for decades in mature diatomite oil fields in California's San Joaquin Valley. These events are believed to be associated with cyclic steam injection (CSI), a thermal-based enhanced oil recovery method that switches between injection and production through the same wellbore. CSI can cause fracturing in diatomite formations, permanently damaging the reservoir, and likely increasing the risk of surface expressions. In oil fields where surface expressions have occurred, CSI typically began two to three years before the first event. Many oil field operators use tiltmeters, high-precision instruments that measure ground deformation, to monitor tiltmeter surface movement above diatomite reservoirs. Signals recorded by tiltmeters reflect subsurface fracture activity and may offer insights into subsurface diatomite damage. Using tiltmeter data paired with field operations data, we hope to identify specific conditions associated with the development of surface expression risk. The results of this research could assist state regulators and oil field operators by providing insights to help support safe field operations in areas at risk of surface expression events.

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Example of Diatomite Reservoir Damage and Tiltmeter Surface Response During 2 Days of Steam Injection

Subsurface View of 1000' Thick Slice Mid-Reservoir



Cyclic steam injection (CSI), commonly used to extract heavy oil from California's diatomite reservoirs, can induce subsurface fracturing in reservoir rock that may contribute to surface expressions risk. This graphic depicts one example of the spatial geometry, a scenario that has occurred almost daily in diatomite oil fields for decades.

During the injection phase of this CSI well, high-pressure steam entered the reservoir via the open perforation interval. Within a few hours, a fracture was created in the fragile diatomite rock, potentially releasing oil and opening subsurface flow pathways.

As the fracture developed over 2 days, high spatial and temporal resolution tiltmeter data recorded localized surface uplift above the injecting well and fracture growth center. Tiltmeter deformation data may provide insights into the evolution of reservoir damage and the potential for surface expression risk.