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Effects of Steam-Induced Diagenesis on Heavy-Oil Production in Miocene-Pleistocene Sands from Kern River Oil Field, California*

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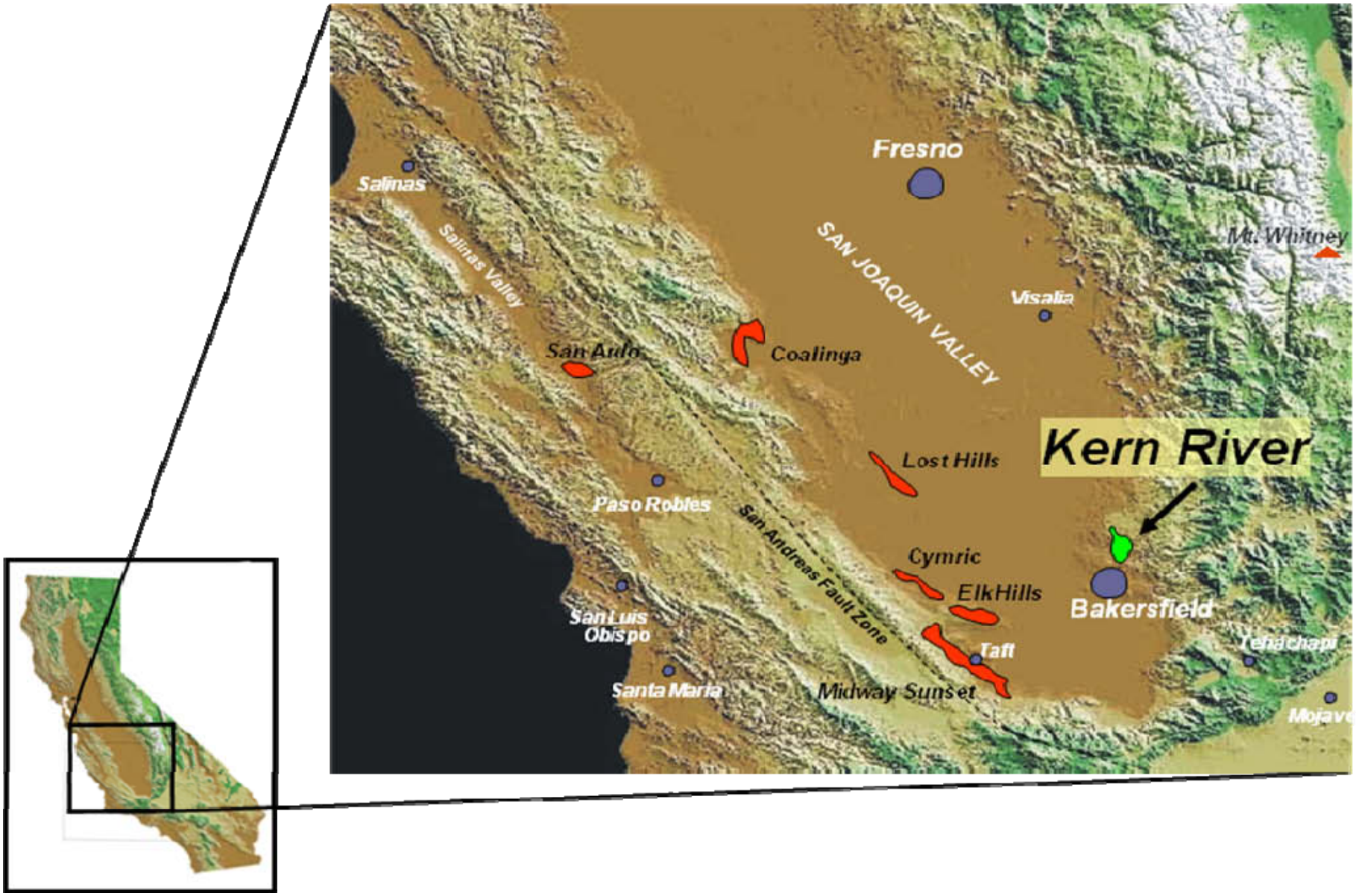
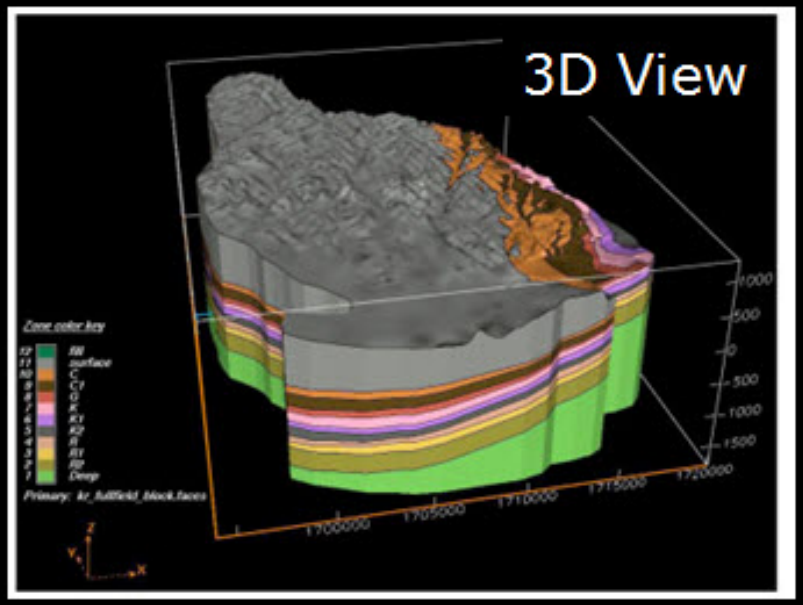
Abstract

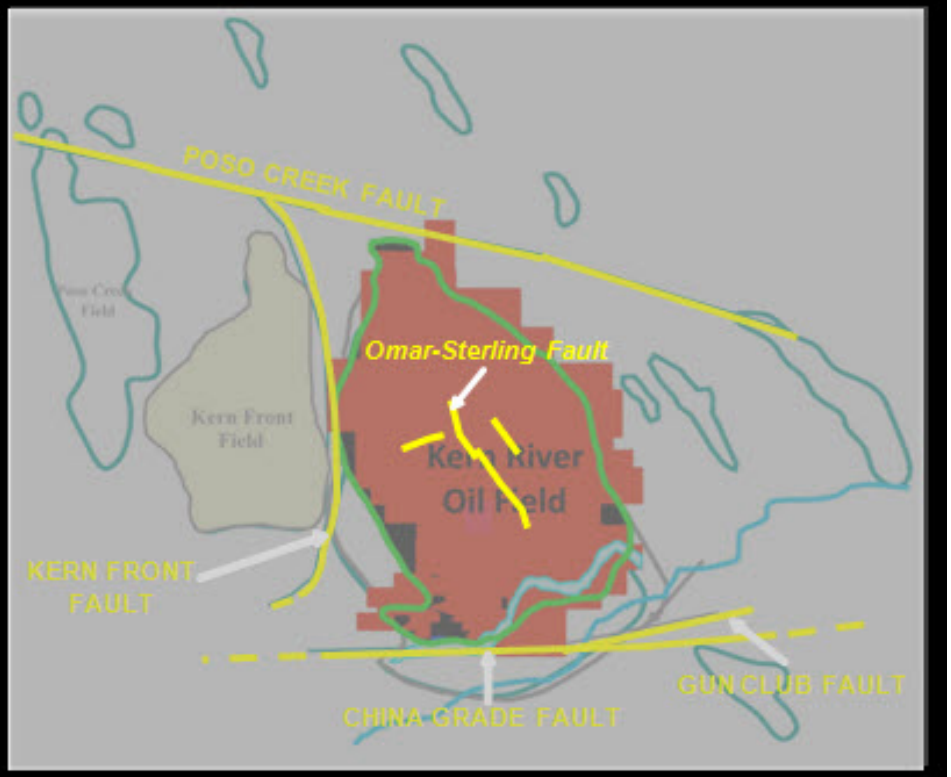
Kern River oil field in Kern County, California was discovered in 1899. Although over two-billion barrels of oil have been produced from this field, substantial reserves remain. The reservoir consists of braided alluvial sands and gravels of the Kern River Formation (Miocene-Pleistocene). Currently heavy oil (12° - 13° API) is produced using steam injection. Steam injection typically results in good production from well sorted medium to very coarse sands, but less well sorted sands and gravels are commonly bypassed and remain unproduced, with residual oil saturations 10-30 saturation units higher than the adjacent rock despite heating to temperatures of 220° F and greater. This study examined mineralogy and pore geometry in sands that had not been heated, sands that had been heated but were not drained, and sands that had been swept of hydrocarbons by steam. The sands of the Kern River Formation are composed predominantly of quartz, K-feldspars (orthoclase and microcline), plagioclase (andesine-oligoclase), microphanerites of granitic composition, and minor biotite (1-3%), reflecting their source from granites in the southern Sierra Nevada. Clays of detrital and authigenic origin typically make up 5-13% of the rocks. The clays are dominated by mixed illite/smectite with 80-90% smectite layers; there is also minor kaolinite. Samples that have been heated but not drained of oil are generally similar to unheated samples. Introduction of steam into the rocks as the sands were drained of oil resulted in the breaking apart of microphanerites, dissolution of feldspars, and a slight increase in the amount of clays; notably there is no significant change in total porosity. Texturally there are significant differences in the distribution of clays and the geometry of the pore networks between unsteamed sands and those that have been swept of hydrocarbons. The disintegration of microphanerites and subsequent rotation of the grain fragments has changed the sorting and reduced pore-throat diameters. Recrystallization and precipitation of mixed illite/smectite has resulted in an increase in the amount of pore-filling clay cements, including as bridges across pore throats that may have restricted fluid flow. The extent to which this may have affected subsequent production is under investigation.



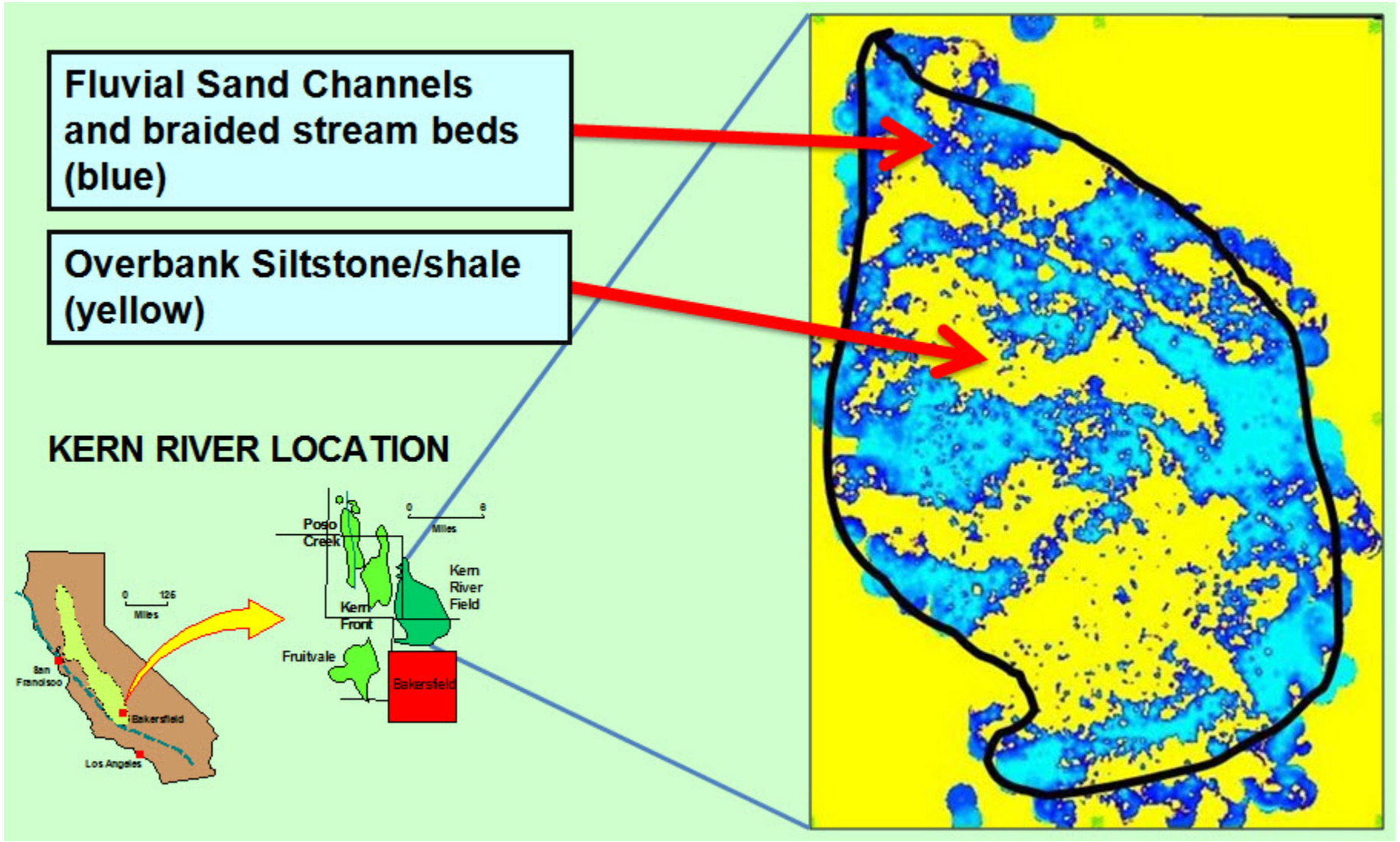
Location map of Kern River oil field.

- Gentle dipping homocline (3.5 degree to the SW)
- Bounding faults: >100' offset
- Several internal faults: 20-50' offset

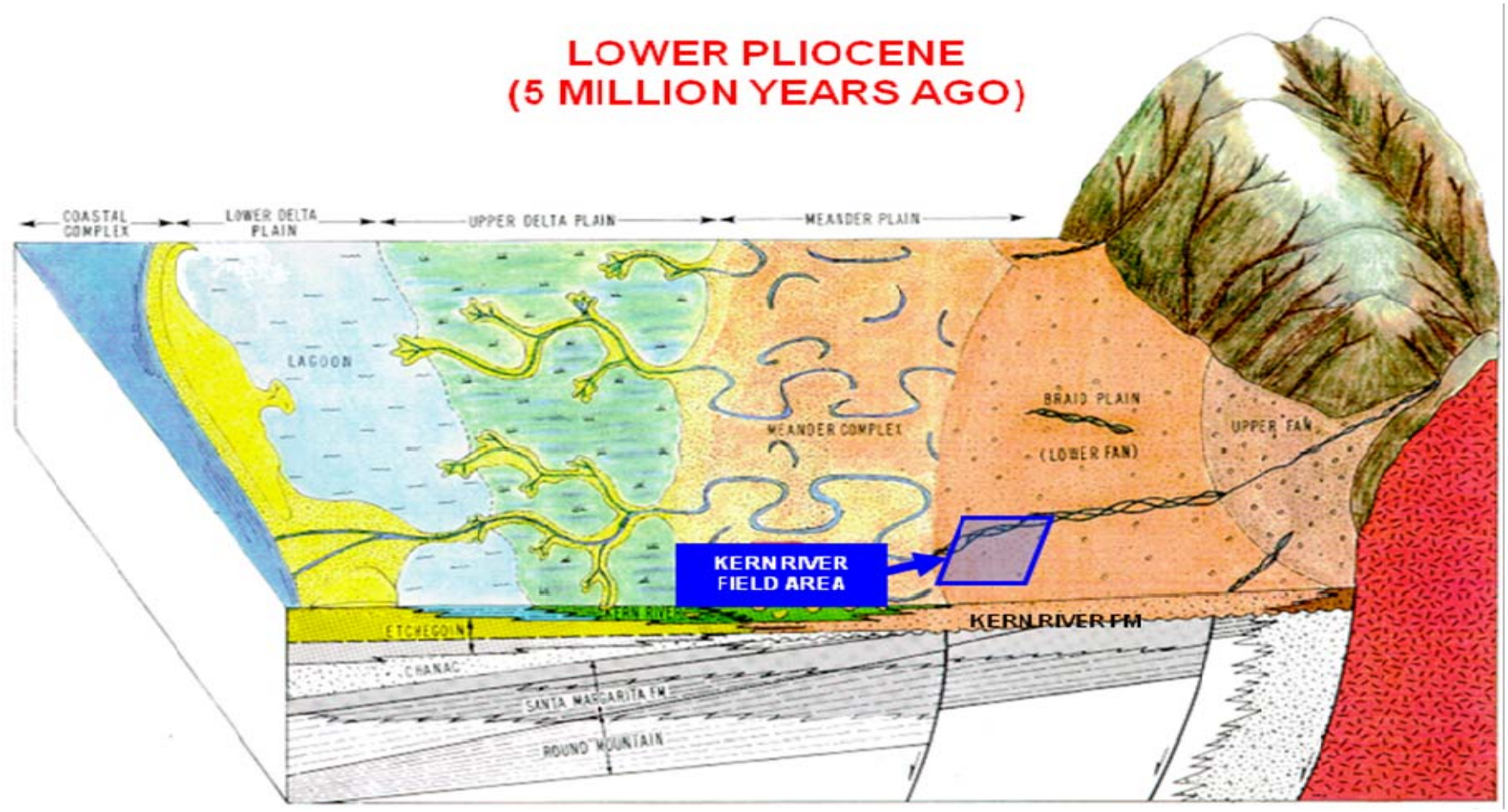




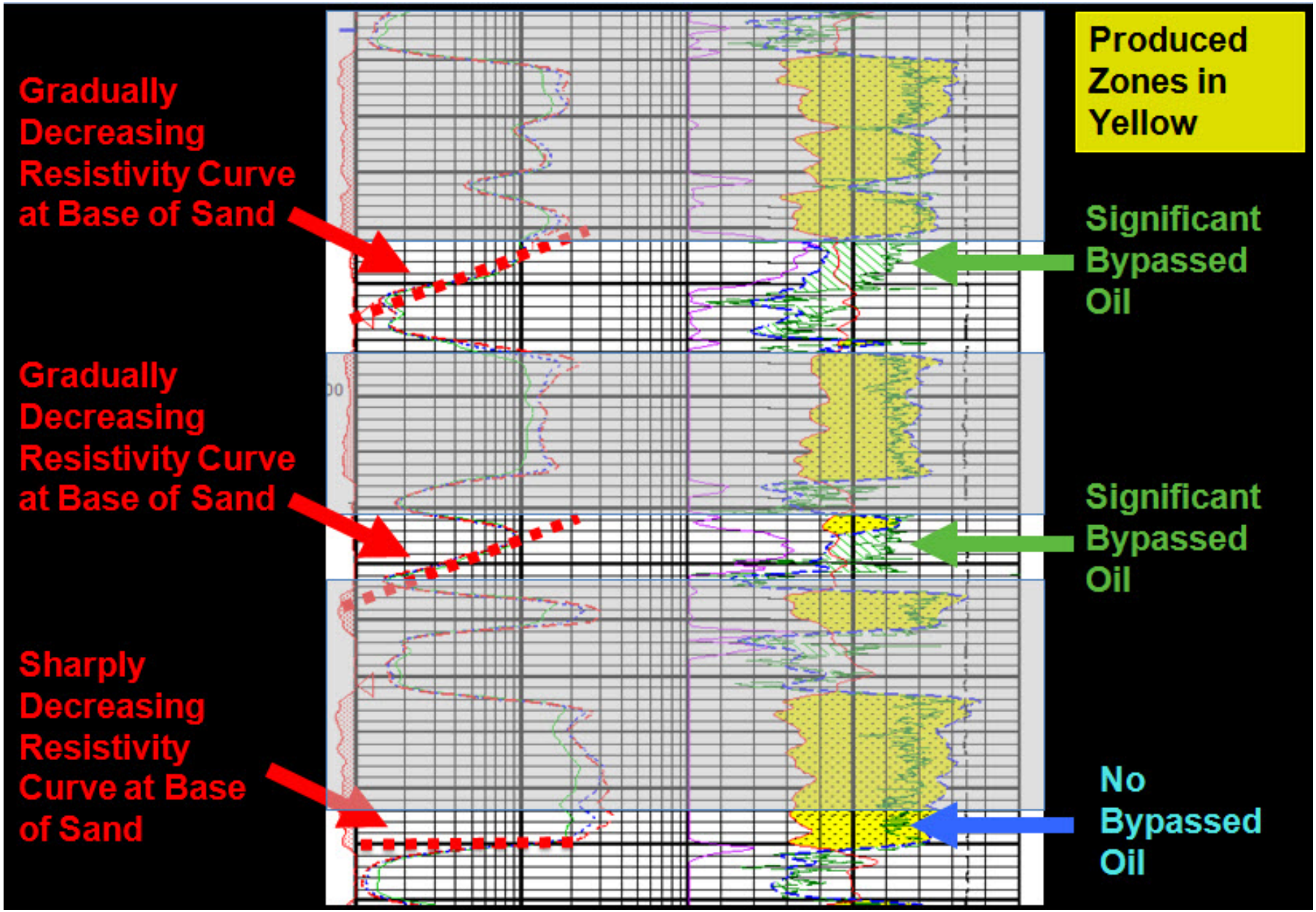
Kern River oil field geologic framework: Structure.



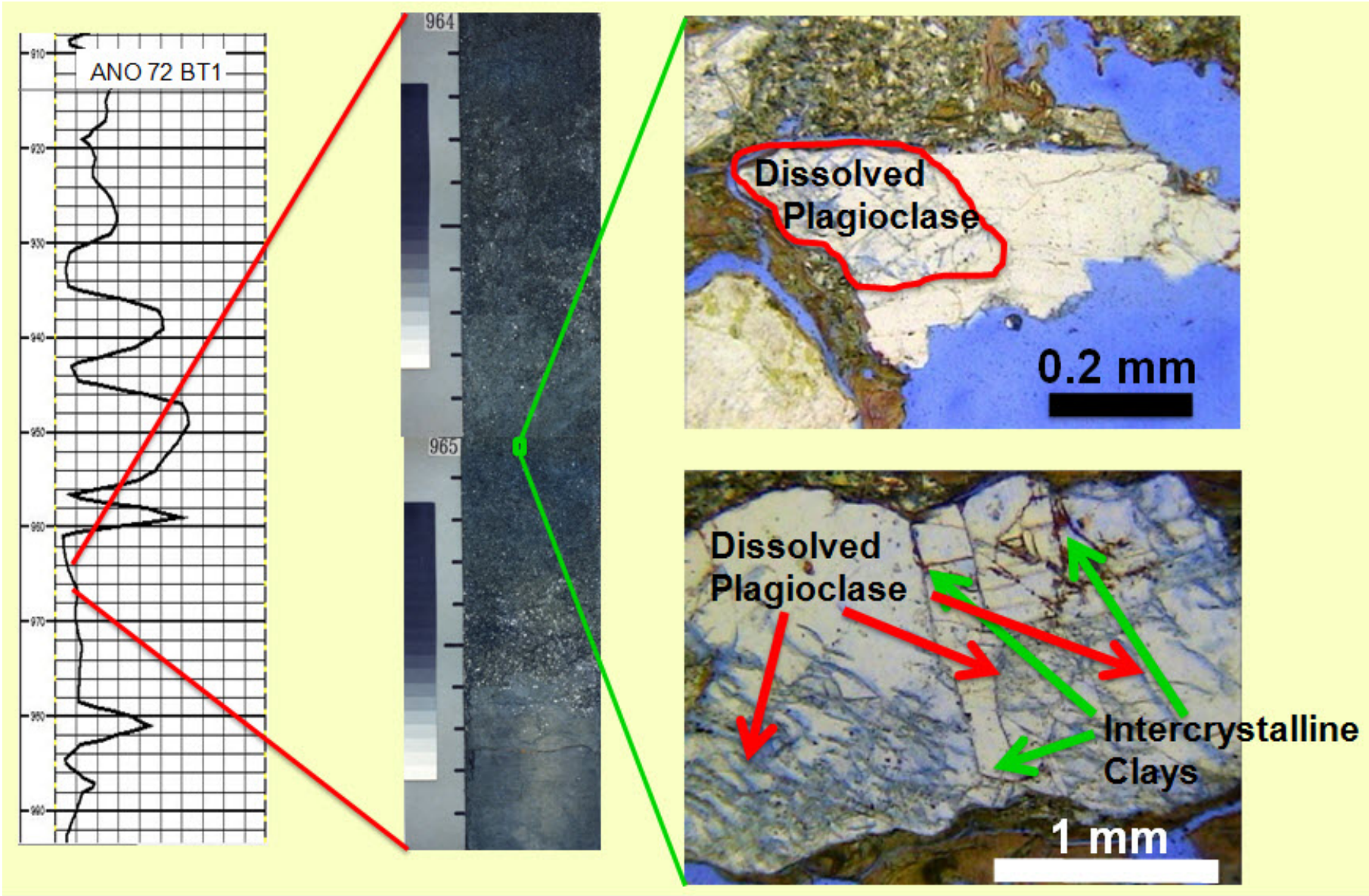
Depositional systems: Horizontal slice through 3D resistivity data cube consisting of 9000+ log traces.



Kern River Formation depositional environment.



Log signatures of bypassed oil zones.



Post-heating dissolved feldspars in granitic rock fragments.

References

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