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Rebound Affected Traps – Part 1: Basin Centered Accumulations

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Summary

In a 2022 paper, the lead author proposed understanding the role of electrostatic forces within pores systems combined with natural expansion of pore systems in response to lithostatic unloading from erosion could be the cause of the apparent downward flow of water in the Deep Basin of western Canada (Lee et al., 2022). While the idea that pore system apertures dilate during uplift has been stated by several authors (Matava & Barclay, 2025; Putnam & Ward, 2001), the effect of electrostatic forces on the resulting fluid saturations and mobility has not. Capillary Forces Theory describes the role and some of the effects of electrostatic forces within reservoirs and provides the theoretical foundation for this presentation (Lee et al., 2022).

Theory

The purpose of this presentation is to present a model which integrates the role of electrostatic forces into existing understandings of regional scale, rebound affected traps. Specifically, we will discuss how pore aperture dilation due to lithostatic unloading plus electrostatic driven imbibition would result in predictable changes in pressures and fluid saturations near and at the updip limits of a regional hydrocarbon phase.

Observations

Burial history modelling of Alberta indicates erosion from uplift after the Paleocene maximum burial ranges from ~3000m over the Deep Basin to 650m in eastern Alberta (Connolly, 1989; Higley et al., 2009; Matava & Barclay, 2025). A long history of engineering studies, focused primarily on the effects of pressure drainage or support in producing oil pools, have looked at pore aperture compression and dilation in core samples (Fatt, 1958; Ganat et al., 2024). Since emplacing hydrocarbons into a wet pore system ALWAYS requires force (capillary entry pressure), it is reasonable to assume the whole gas saturated region was overpressured at the time of maximum burial and emplacement when pore apertures were at a minimum. Thermodynamic calculations indicate nearly 40 moles of gas are produced per mole of Type I kerogen at peak generation so volumetric expansion plays a primary role in overpressuring (Helgeson et al., 2009). Since porosity increases updip, capillary entry pressure would have decreased updip. Therefore, these systems were always upside down relative to conventional migrated saturation height profiles. Pore aperture dilation affected the entire rebounded system which means the system pressure would be lower now than at time of emplacement. The pore aperture dilation would facilitate imbibition of previously expelled water with counter current leakage at the updip edge (Lee et al., 2022). Essentially, the updip edge of a rebounded continuous hydrocarbon phase acts as a giant electrostatic sponge pulling water into the capillary film. This means imbibition would be the primary drive of the apparent downdip flow.

The updip underpressured region is a complex problem. Imbibition lab experiments typically used oil with similar viscosity to water. Oil displacement stops when the imbibition front reaches the end of the core sample so buoyancy doesn't factor into recovery. The much higher mobility and buoyancy of gas means leakage from beyond the region directly affected by imbibition is likely. The hydrodynamic gradients associated with rebound affected traps indicate there is very low

water mobility within the underpressured region. This could be due to relative permeability phase blocking. Water influx may also be limited by countercurrent gas leakage.

Conclusions

The accumulations we see today are the decaying remnants of the initial resources. We wonder how big the gas saturated area was at time of emplacement?

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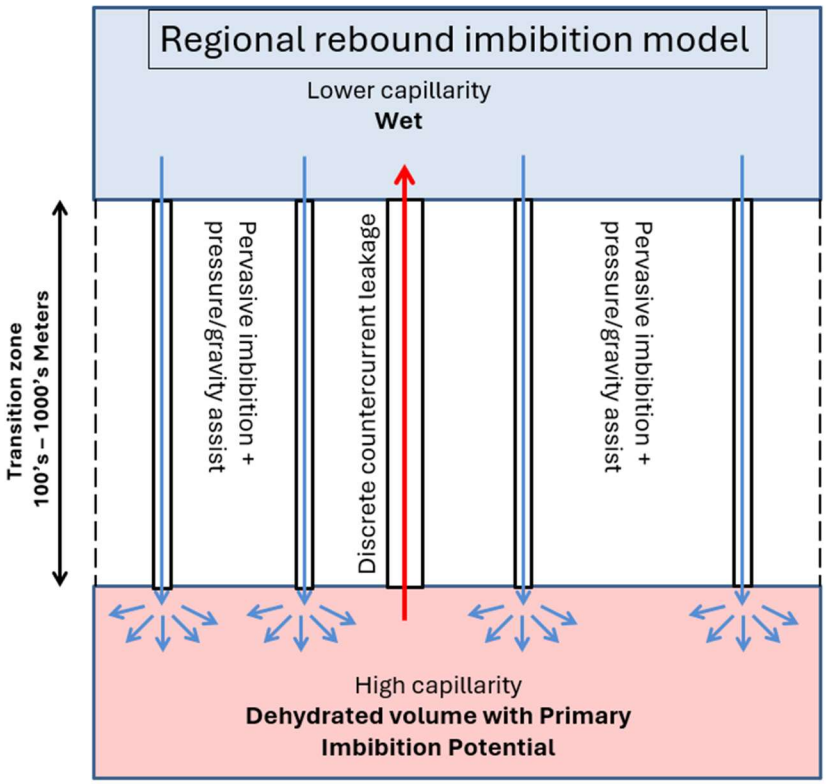


Fig. 1 Pore aperture dilation from rebound reduces capillarity which increases pore volume and fluid mobilities. Basin scale imbibition of previously expelled water in response to Primary Imbibition Potential and excess countercurrent leakage due to high gas mobility results in a broad transition saturation region above a subnormally pressured region.

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