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A Model for the Exploration and Development of Fractured Basement Oil Pools

Gordon Graham, Consulting Geologist
George Hepler, Consulting Reservoir Engineer

Summary

Data from 142 basement oil fields show that Basement is a conventional reservoir that can be systematically explored for and developed. Drawing on this data and direct experience in several successful basement exploration and development programs, the talk will describe the basement petroleum system and best exploration and development practices.

Results, Observations

Basement reservoirs can be either fractured or weathered or both. The majority (75-80%) of successfully developed oil pools are in fractured reservoirs, the subject of this talk. Weathering can enhance fractured reservoirs or may cause damage by plugging fractures with clay.

Structural closure is not required for a basement oil accumulation although most pools are found on structural highs, the key is to find intensely fractured basement rocks.

Lithology can vary although hard, brittle rock is a better reservoir. The best fracturing is caused by strike slip faulting where the faults and associated fracture zones are vertical to sub-vertical. Fractures can quickly fill with cement, so timing of fracturing relative to oil migration is critically important. The number of open fractures decreases with depth and most of the readily drainable reservoir occurs within 400m of the top of basement. Leaching by hydrothermal fluids often increases fracture zone porosity.

The source rock does not need to overlie the basement although this is the case in the larger basement oil pools. Oil generation and migration must occur at the same time as fracturing. Migration is a dynamic process. Fault related fracturing causes an increase in basement rock volume and the resulting pressure gradient forces oil from the source rock into the basement fractures, this can result in an oil charge several hundred meters below the source rock. Migration occurs in pulses with each movement along the faults in the reservoir.

Seal is usually provided by the source rock but can also be formed by tight sediments or by calcite precipitation at the top of the basement due to the drop in pressure during faulting.

The oil generation and migration concepts are illustrated by the attached cross section through the Santa Maria Valley Field in California. Figure 1 shows the basement oil pool below the Monterey source rock. Figure 2 how oil charges fault related fractures. Figure 3 the oil and gas pools in the field today.

The other aspects of our model will also be illustrated with examples from basement fields that we have worked on.

Conclusions

Exploring for basement oil with a vertical well that tags basement is not effective, an inclined well or a deep basement penetration of several hundred meters is required in order to increase the chances of intersecting a fracture zone.

In development, horizontal or highly inclined wells are required to drain multiple fault damage zones. Pressure maintenance during production is very important as the best reservoir is at the top of the basement and development of a gas cap must be avoided. Fortunately, water injection is highly effective as the water sinks into the deeper, poorer reservoir and recovery factors can easily exceed 30% and in some cases over 50%.

Despite many successful developments basement oil is often seen as unpredictable and too risky to pursue hence much potential remains. Our model shows how this potential can be systematically evaluated.

References

Mc Naughton, D.A., 1953, Dilitancy in Migration and Accumulation of Oil in Metamorphic Rock, AAPG Bull. V.37.2

Figure 1: Santa Maria Valley Field Structural Section

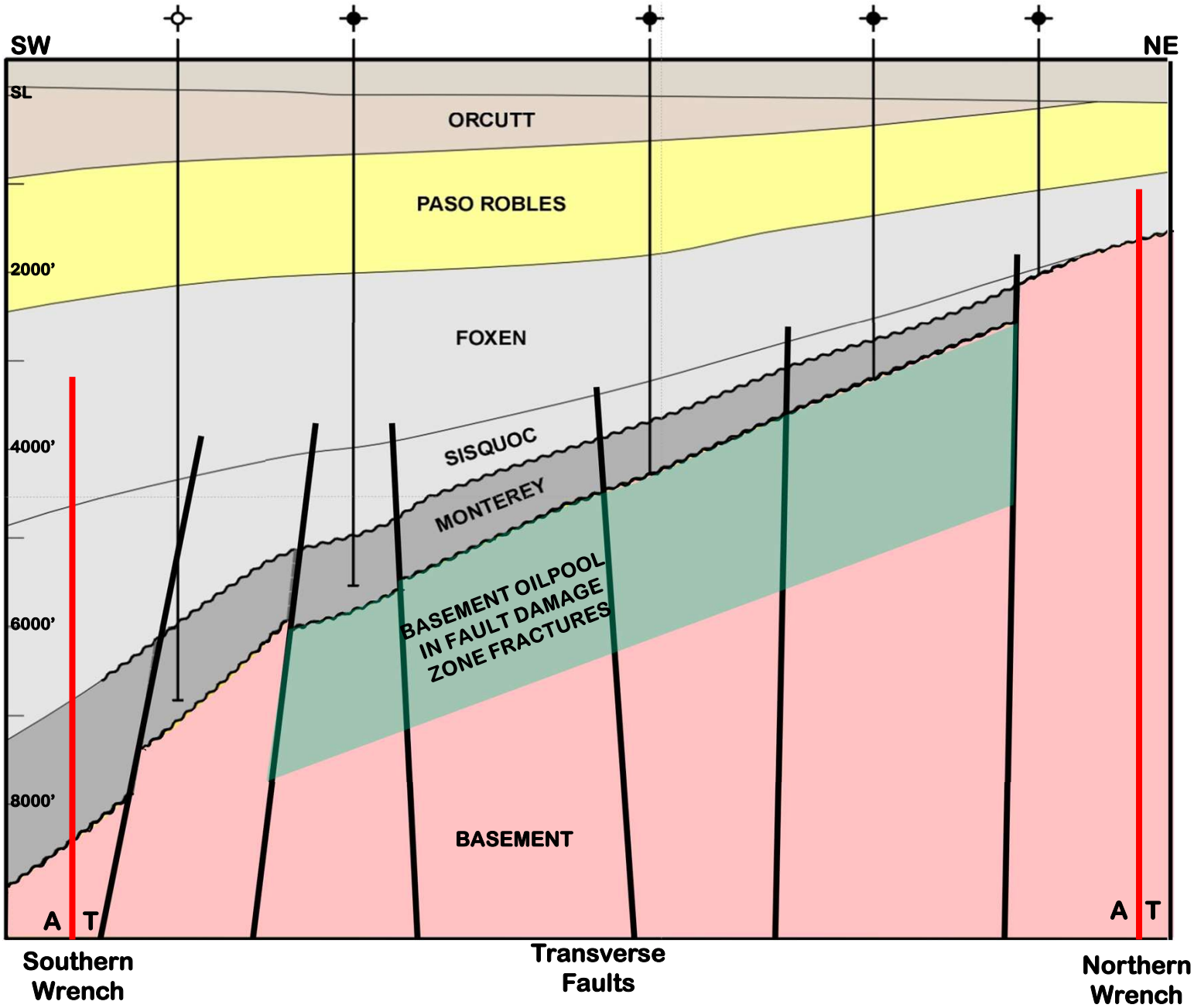
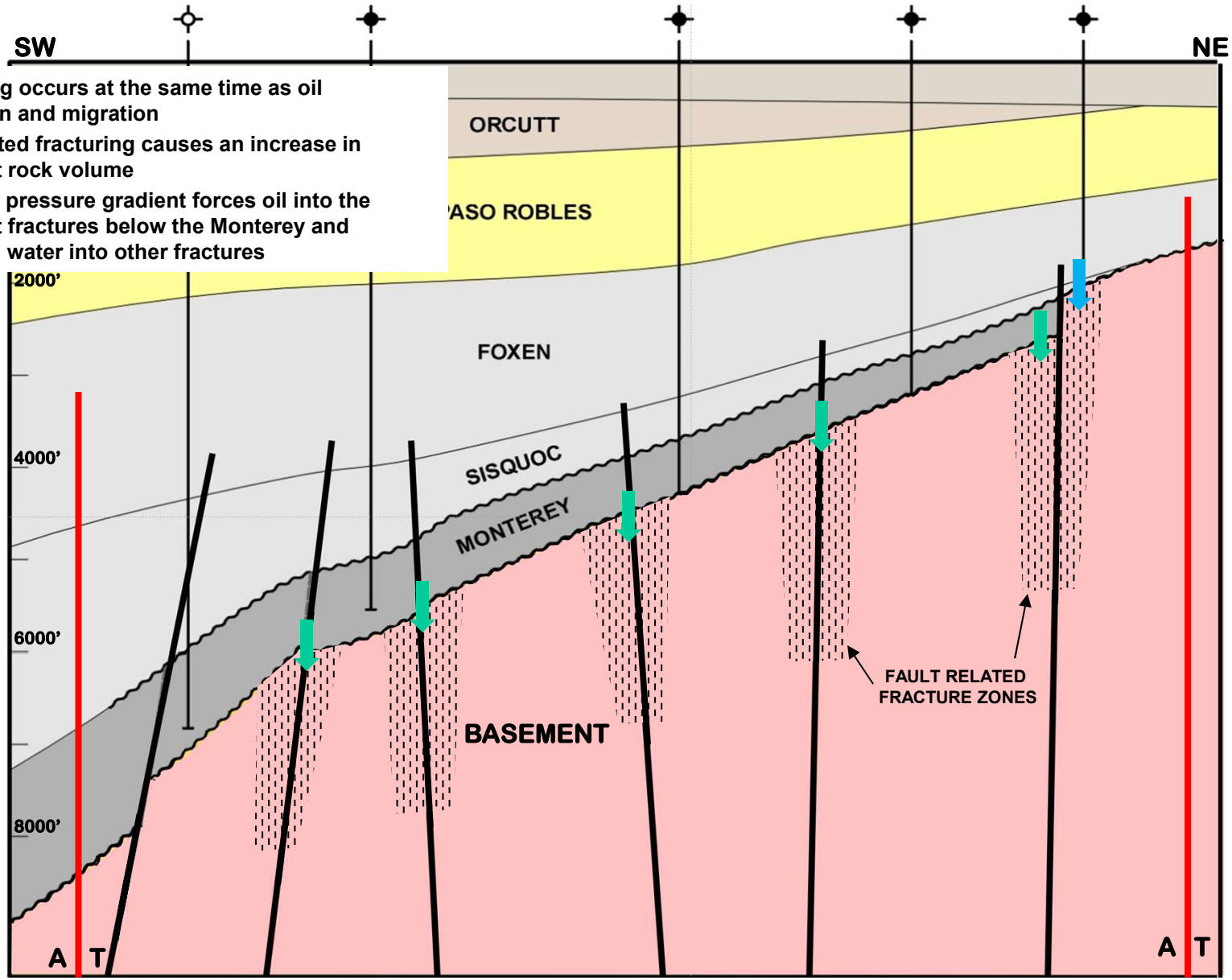


Figure 2: Santa Maria Valley Field: Basement Oil Charge

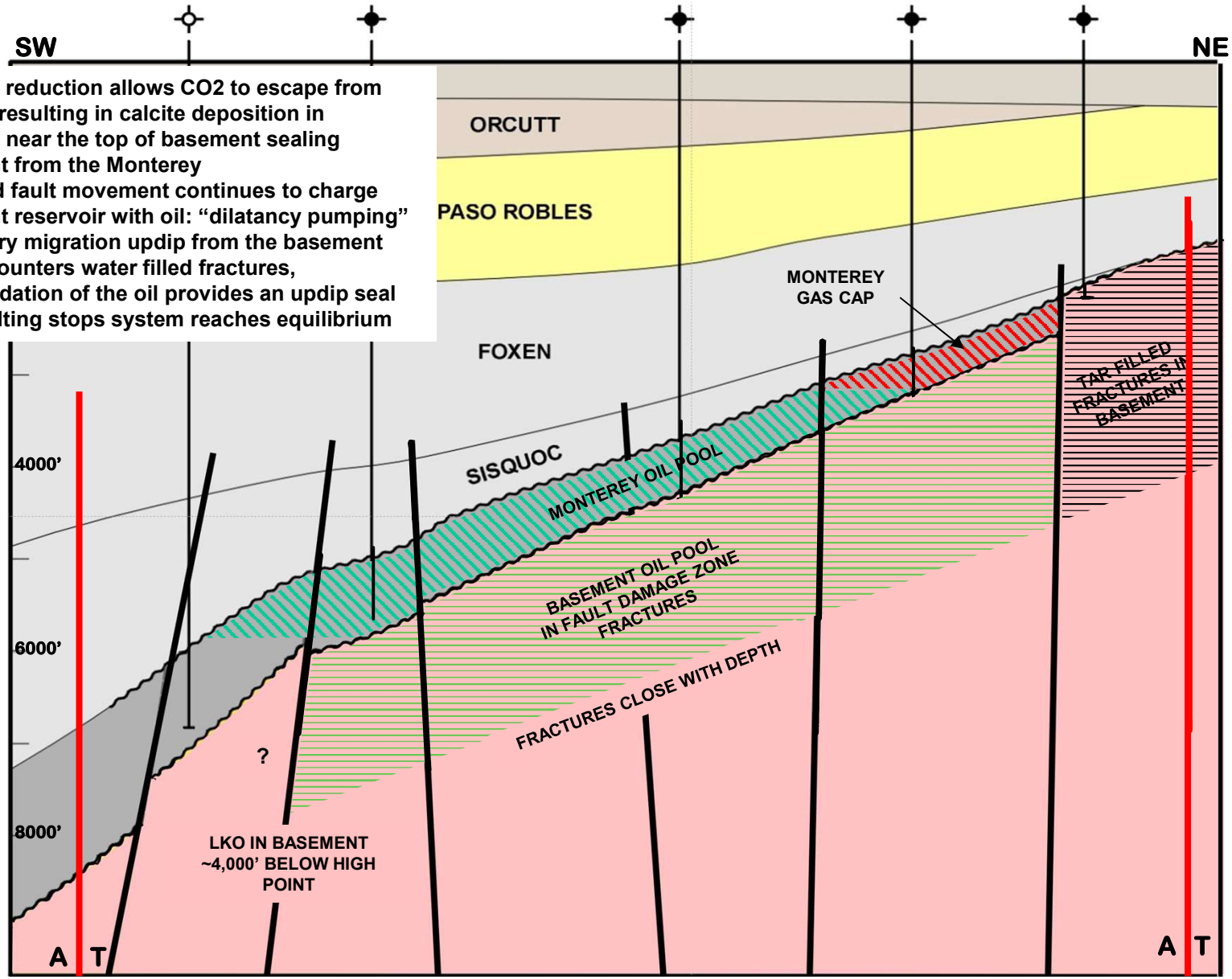
- Wrenching occurs at the same time as oil generation and migration
- Fault related fracturing causes an increase in basement rock volume
- Resulting pressure gradient forces oil into the basement fractures below the Monterey and formation water into other fractures



Original Concept from McNaughton, D.A., Dilitancy in Migration and Accumulation of Oil in Metamorphic Rock, AAPG Bull. V.37.2

Figure 3: Santa Maria Valley Field Oil and Gas Pools

- Pressure reduction allows CO_2 to escape from solution resulting in calcite deposition in fractures near the top of basement sealing basement from the Monterey
- Repeated fault movement continues to charge basement reservoir with oil: "dilatancy pumping"
- Secondary migration updip from the basement pool encounters water filled fractures, biodegradation of the oil provides an updip seal
- After faulting stops system reaches equilibrium



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