Palaeo-Stress Directions as a Guide for Fault Conductivity Prediction in 3D Petroleum Systems Modelling*

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Abstract

3D petroleum generation, expulsion, migration and accumulation have been modelled in the Bass Basin, Tasmania, Australia. Model construction and calibrations were performed using all available data (e.g. seismic, lithology character and reservoir and/or sealing properties, temperature, pressure, source rock kinetics, etc.). Fault conductivities within migration and pressure models were given special attention and tested according to fault orientation in relation to palaeo-stress directions. Periods of fault reactivation, accumulation breaching and leakage breakthrough were calibrated against present-day accumulations and empty traps.

Migration models of the Bass Basin support permeable faults in the northeastern region of the basin during Miocene inversion, which resulted in breaches within deeper accumulations and migration to upper reservoir sands and in several cases leakage through the regional seal. N-S and NNE-SSW striking faults were subjected to strike-slip movement and/or compressional reactivation due to their suitable orientation to the direction of the compressional stresses during latest Late Oligocene and Miocene periods. Common NE-SW striking faults in the basin were not affected by the same compressional event.

3D Migration model results suggest, most faults can turn into barriers for petroleum migration soon after deformation periods. Thereafter, rotation in palaeo-stress direction may have a great effect on fault conductivity for migration of hydrocarbons. Pre-existing faults or parts of them may facilitate petroleum migration during periods of suitable stress direction for reactivation despite non-recognition of fault reactivation from seismic. These results may propose a framework for dealing with fault conductivity in future migration modelling studies.

Reference

Mildren, S.D., R.R. Hillis, and J.G. Kaldi, 2002, Calibrating predictions of fault seal reactivation in the Timor Sea: APPEA Journal, v. 42/1, p. 187-202.

Palaeo-stress directions as a guide for fault conductivity prediction in 3D petroleum systems modelling

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Geoffrey O' Brien

Overview

- Importance of faults in petroleum systems modelling
- Fault stability, reactivation and dilation analysis
- Fault orientation in relation to Palaeo-stress directions.
- 3D petroleum systems model of the Bass Basin, an example of good fault permeability prediction
- Conclusion

Importance of faults in 3D Petroleum Systems modelling

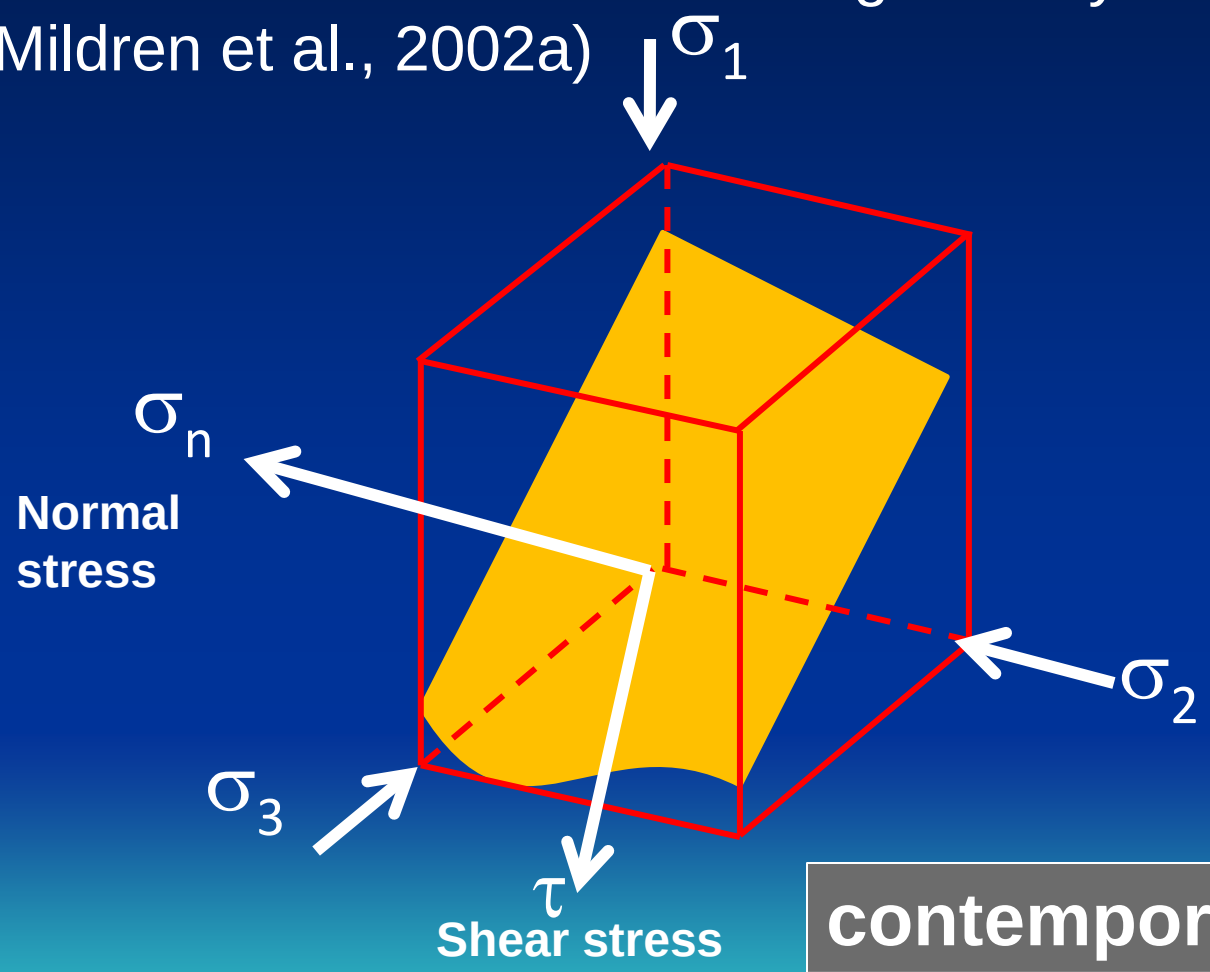
- Faults are principal part of sedimentary basins which make them principal part of modelling structure.
- In sedimentary basins, faults play a significant role for fluid flow and pressure distribution
- Post-charge changes in fault stability may result in accumulation redistribution or change in basins prospectivity.
- Since faults act as conduits (permeable) or barriers (impermeable) for hydrocarbon migration, they can dictate hydrocarbon migration pathways in many cases.
- Good prediction of fault permeability ⟶ good modeling results

Fault stability, reactivation and dilation analysis

- Active faults and fractures can provide high permeability conduits for fluid flow during deformation.

- Non-active faults can seal and inhibit fluid flow due to degradation in permeability by clay smear, grain crush and mineral cementation

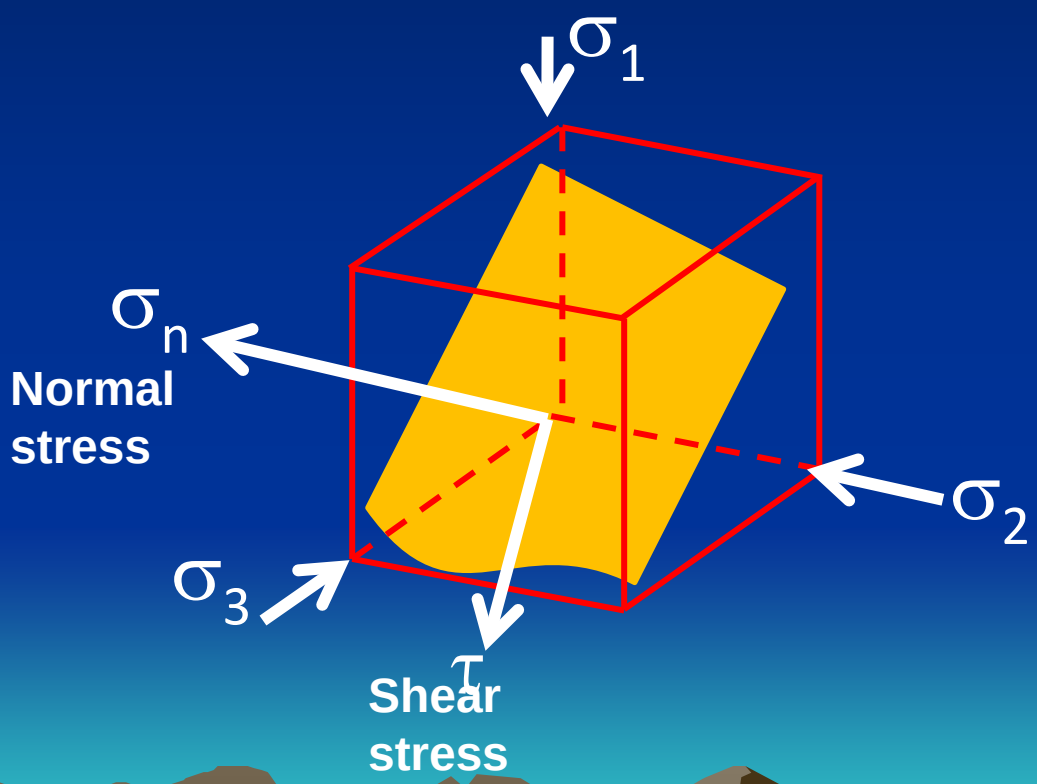
• The risk of reactivation is controlled by the mechanical properties of the fault rock (the contemporary stress environment and the structural geometry of the fault) (Mildren et al., 2002a)



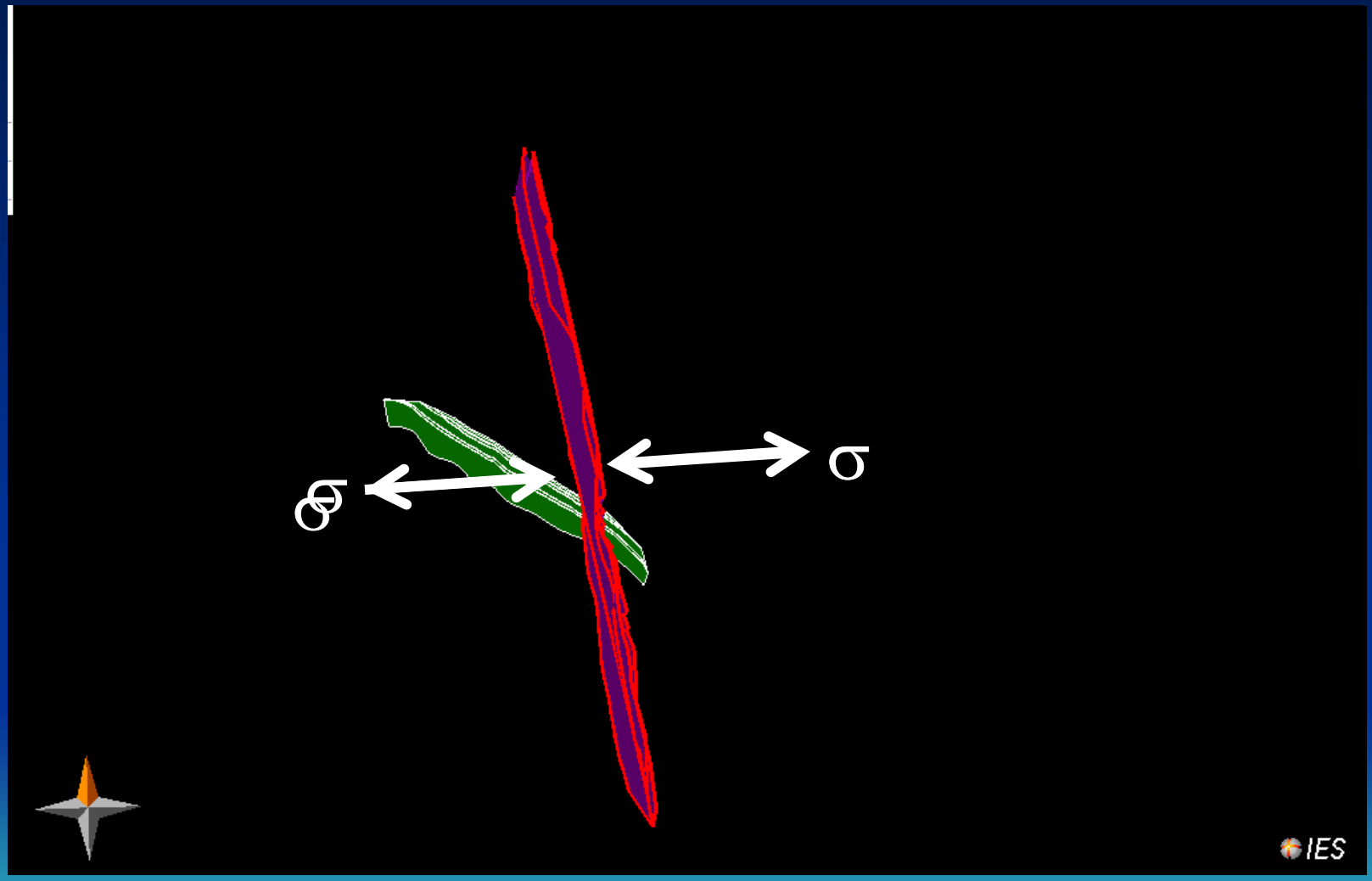
contemporary stresses

Fault orientation in relation to Palaeo-stress directions

The principle of reactivation risk in the past also been defined by the mechanical properties of the fault rock



Palaeo-stresses
(Contemporary stresses of there time)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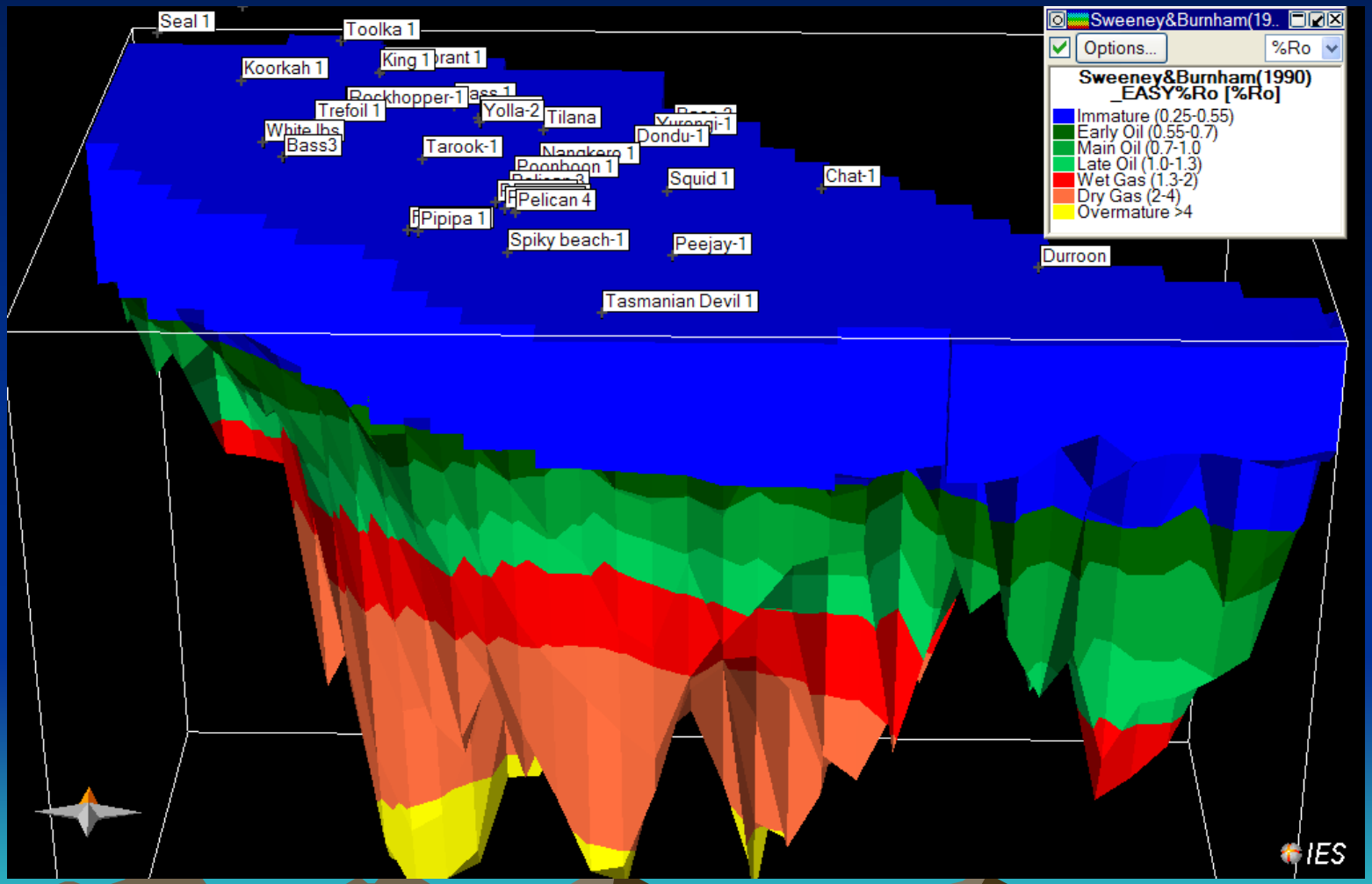
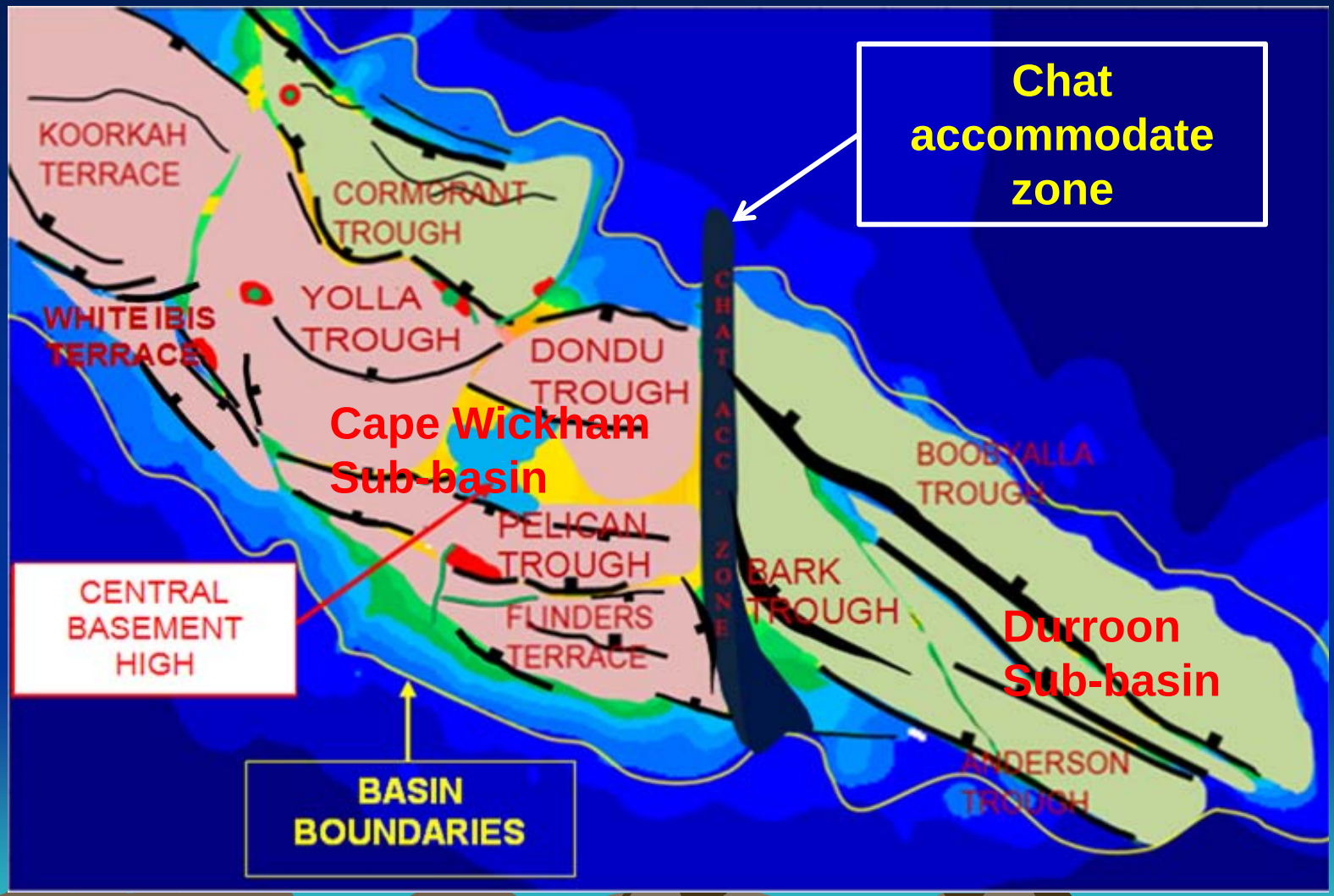
3D petroleum systems modeling of the Bass Basin



Bass Basin Structure:

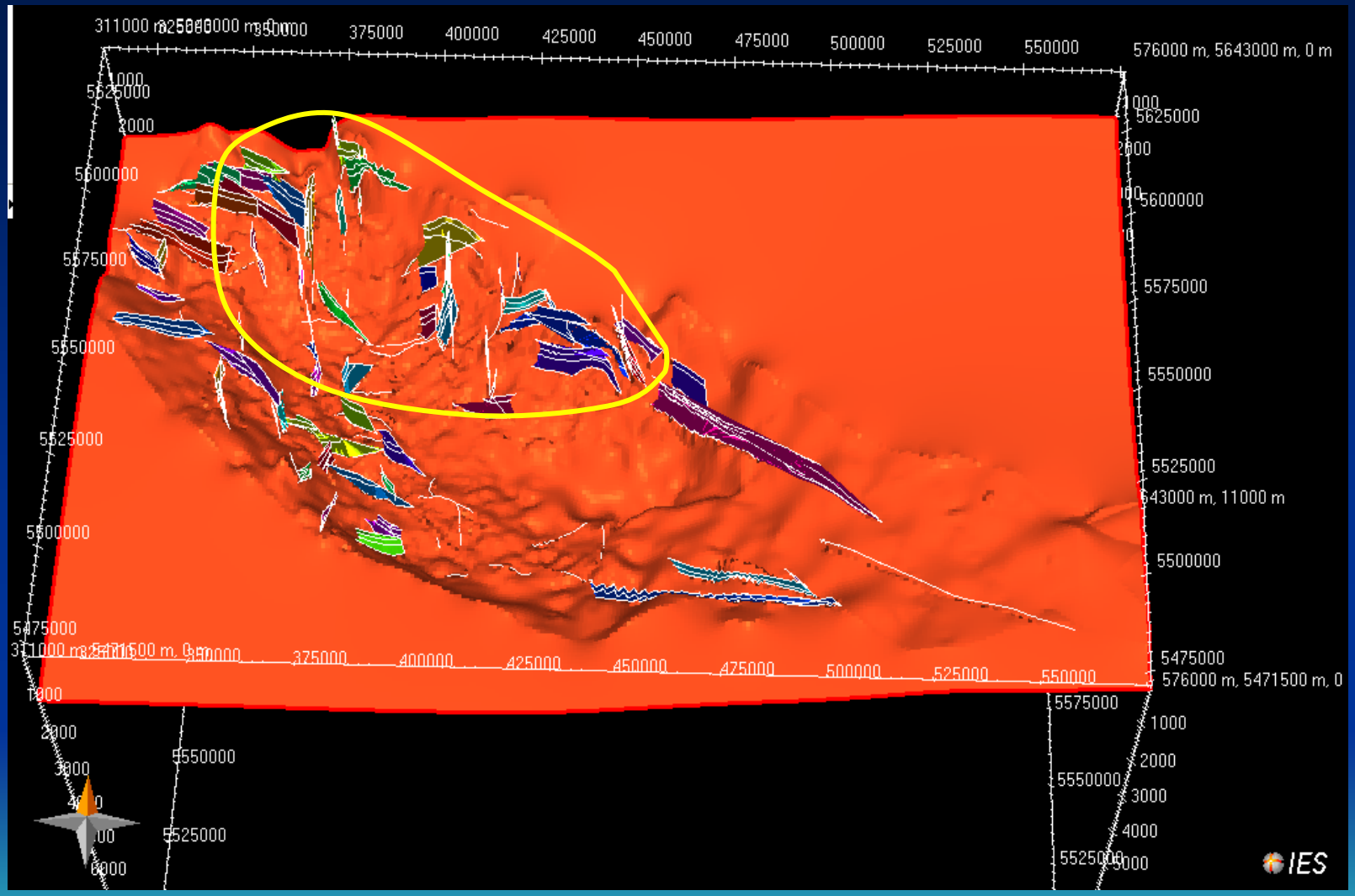


Bass Basin Structure:

- Faults of the Bass Basin are created in response of three different rifting phases (Southern Ocean Rifting, Tasman Rifting and Oblique Bass Rifting).

- NW-SE striking faults (Cretaceous faults)
- NNW-SSE striking faults (Paleocene-Eocene)
- NNE-SSW striking faults (Late Eocene)

- Compressional reactivation during Miocene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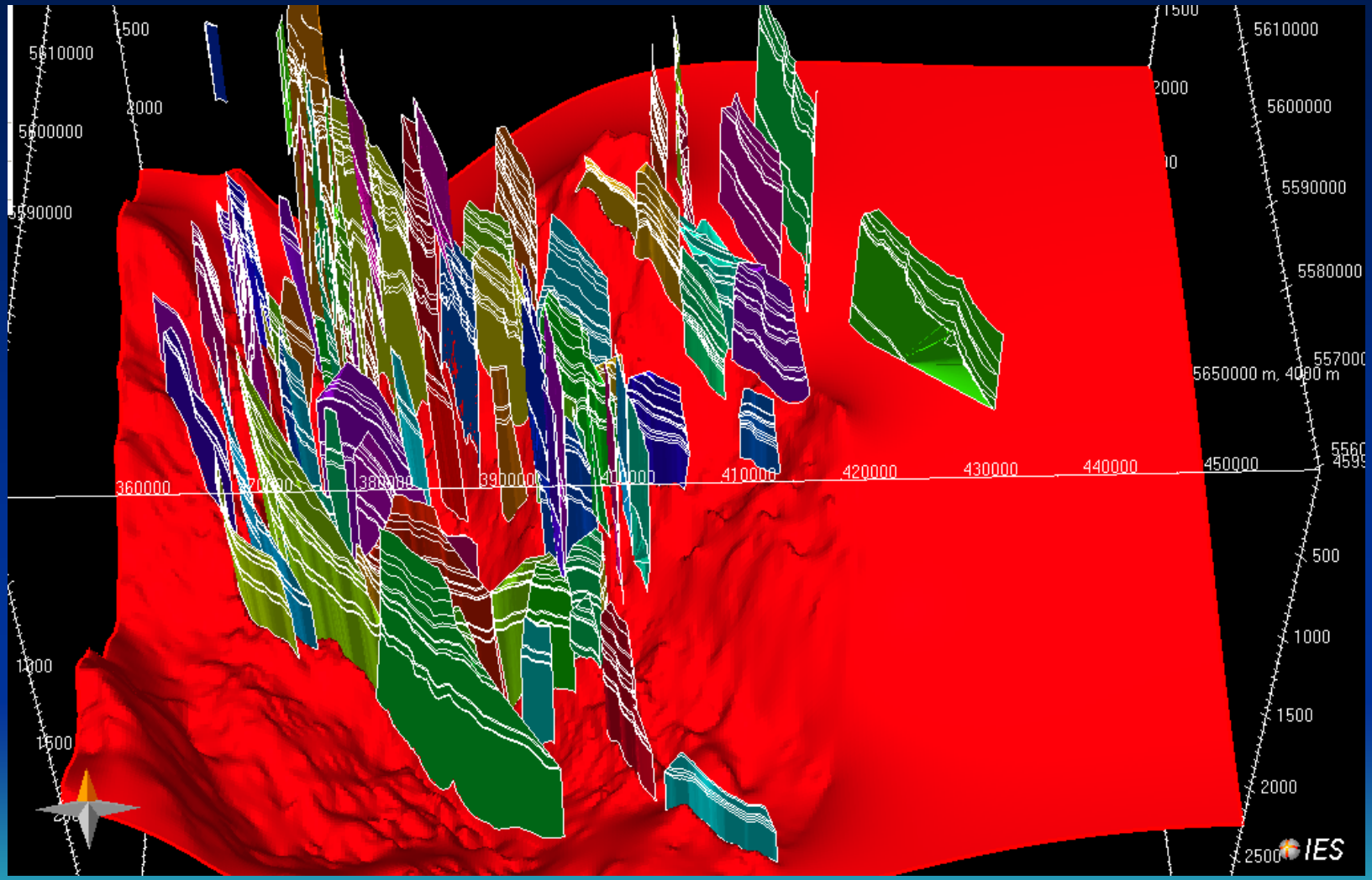
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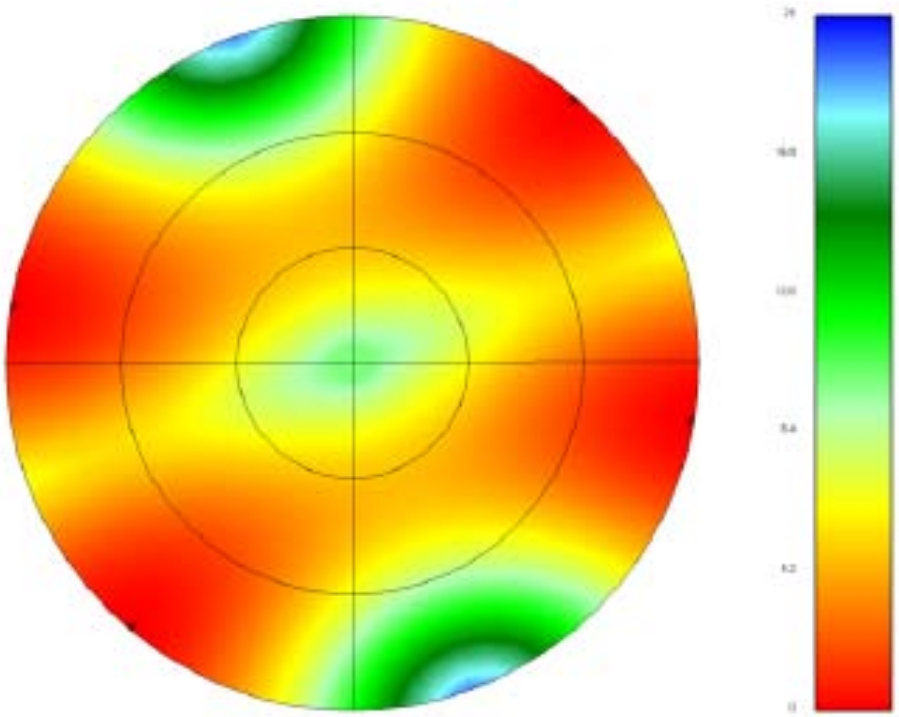
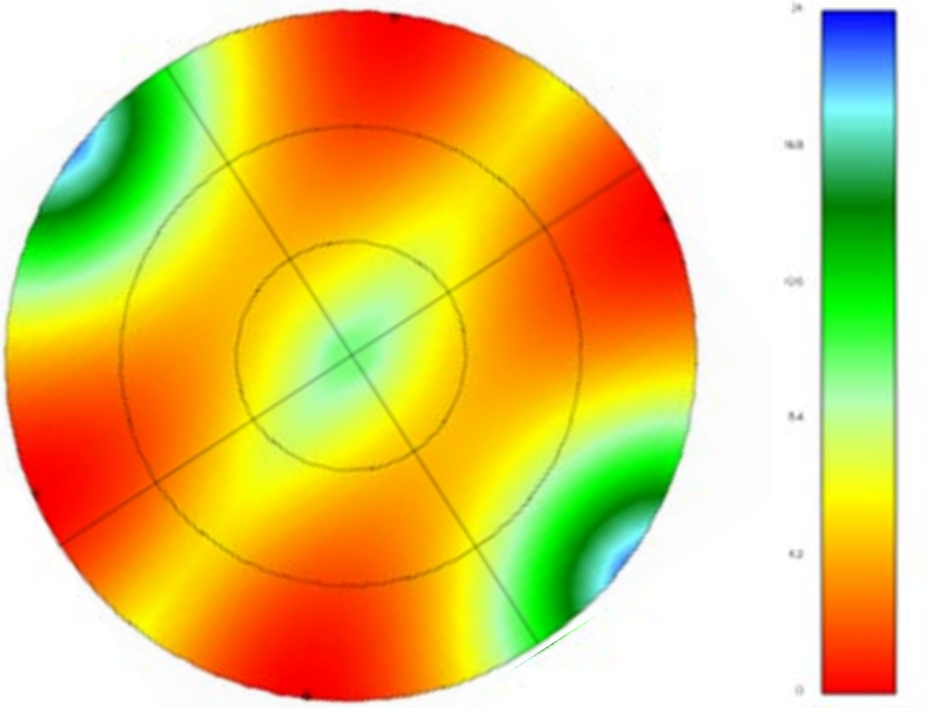
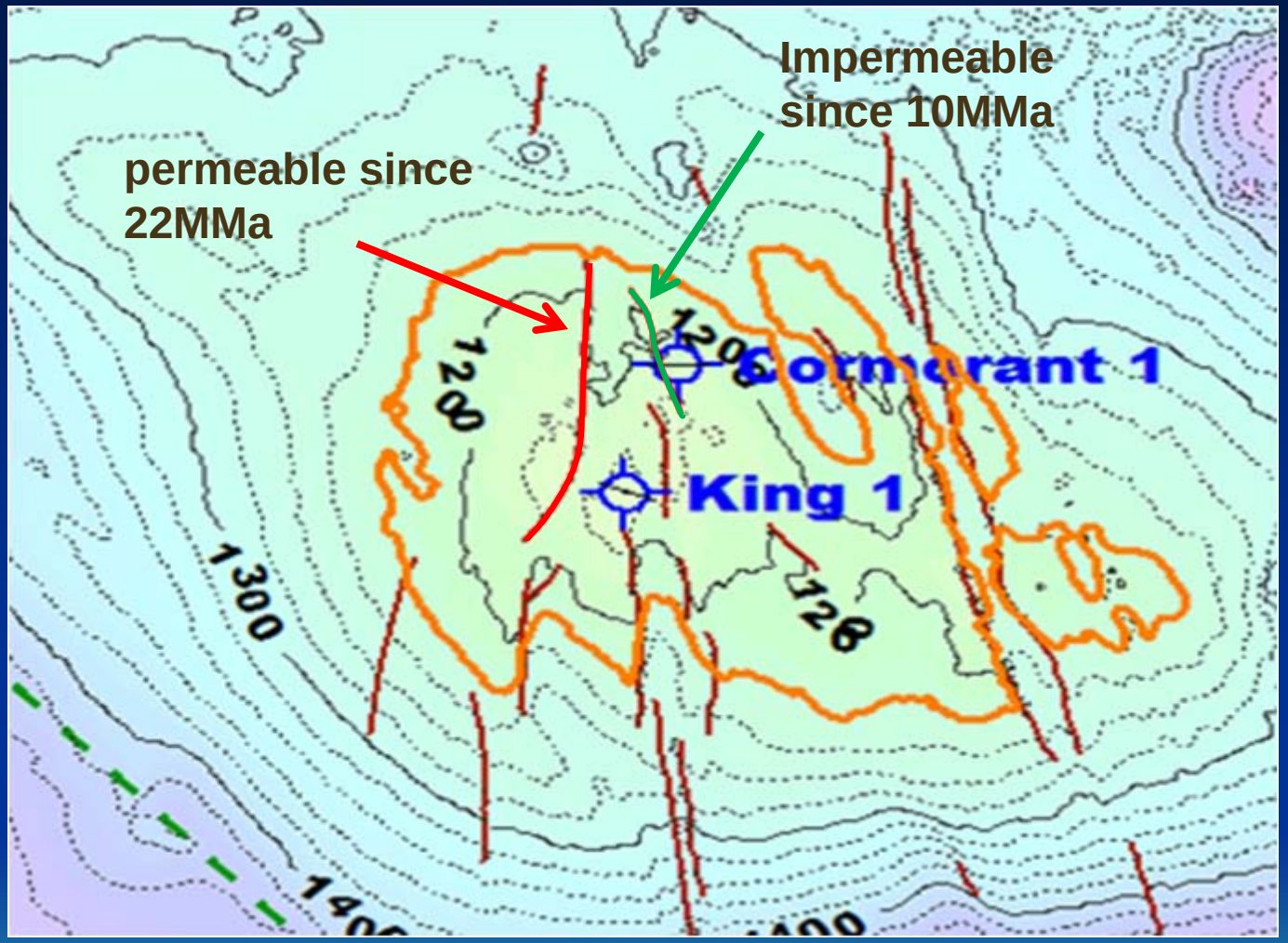


Stereonet illustrating present-day relative risk of reactivation below the regional seal

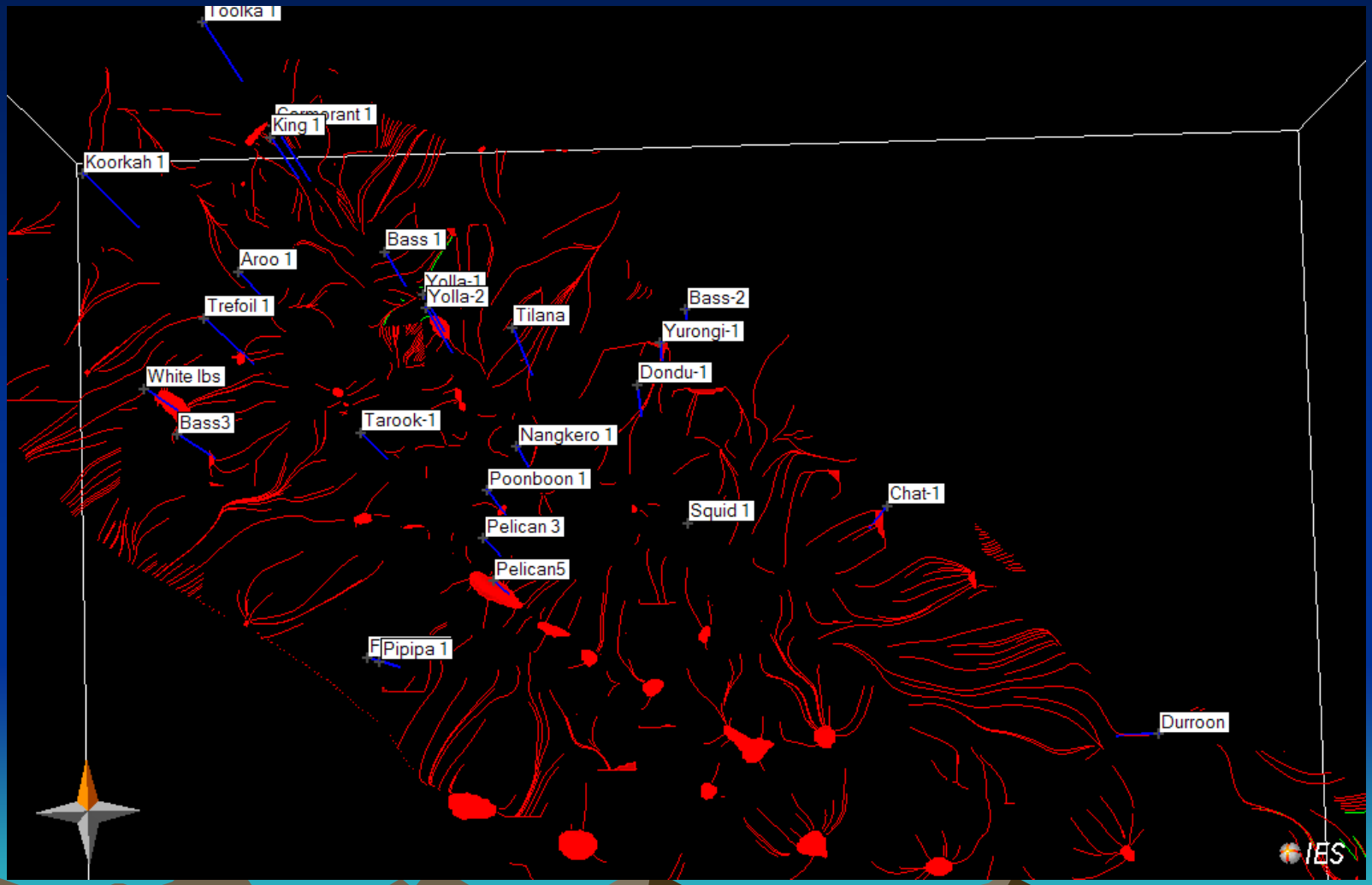


Stereonet illustrating relative risk of reactivation below the regional seal during Miocene



King-Cormorant structure , northeastern part of the Bass Basin

- The Model has predicted all the known accumulations and dry holes correctly.



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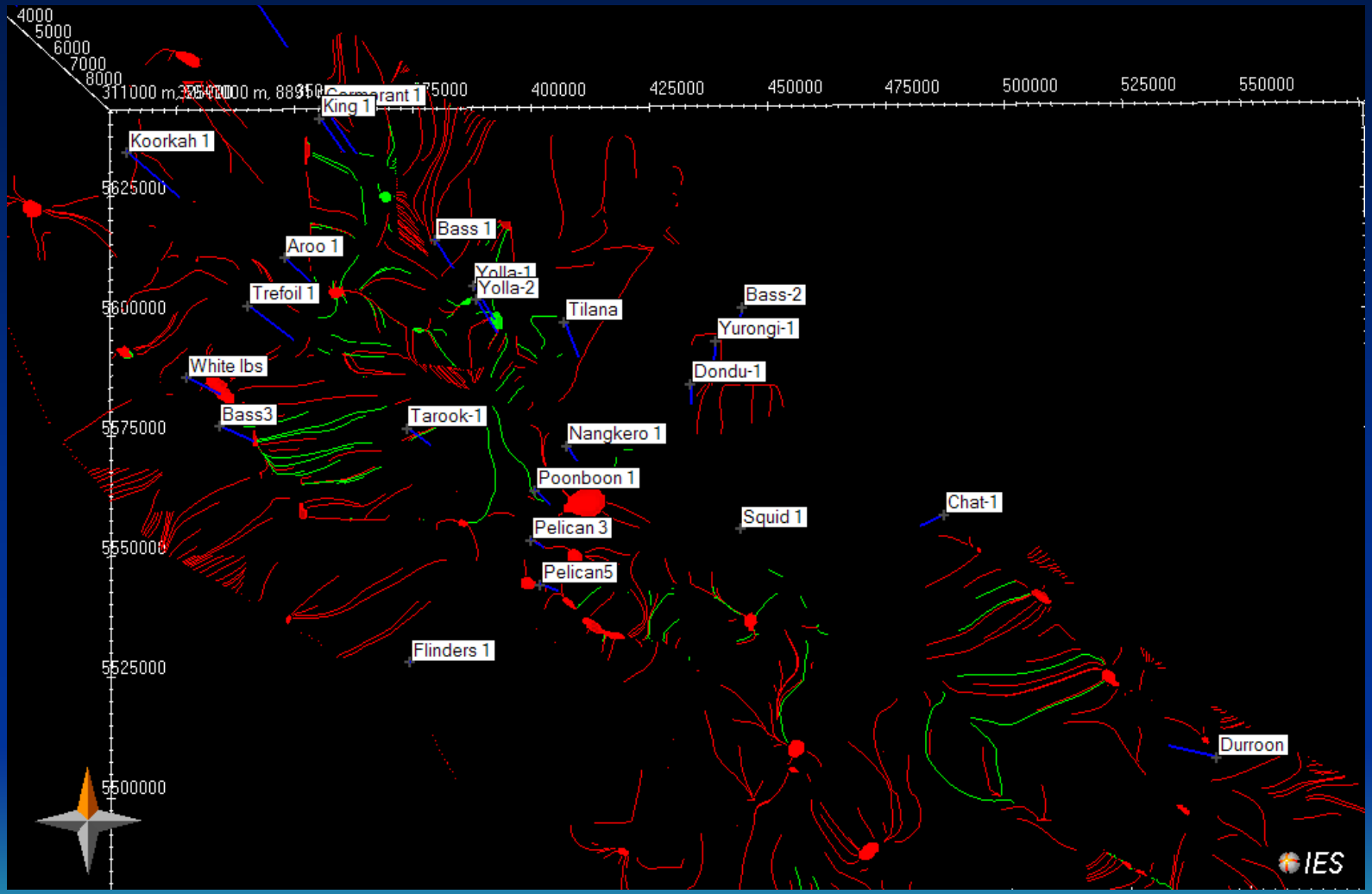
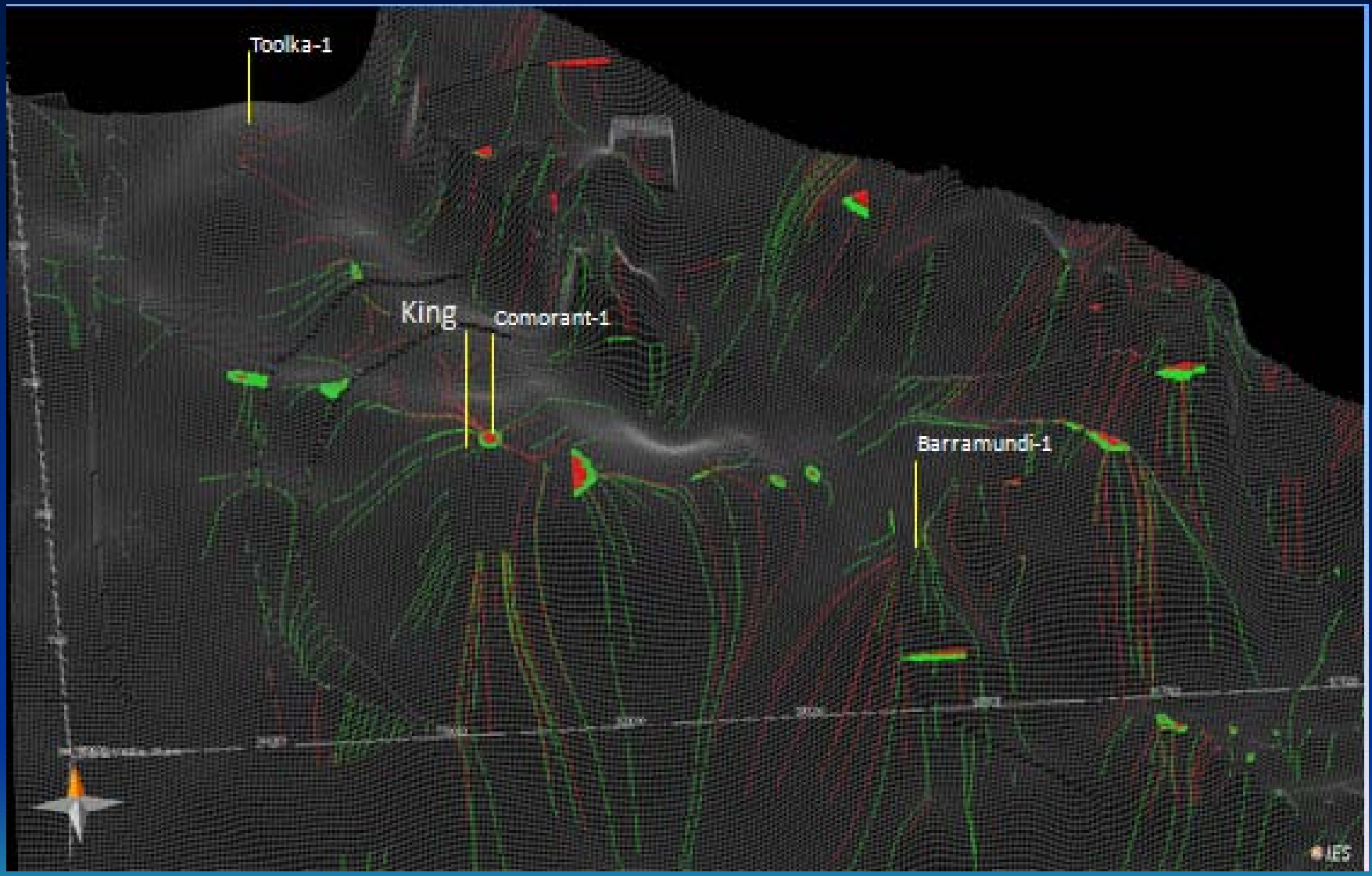
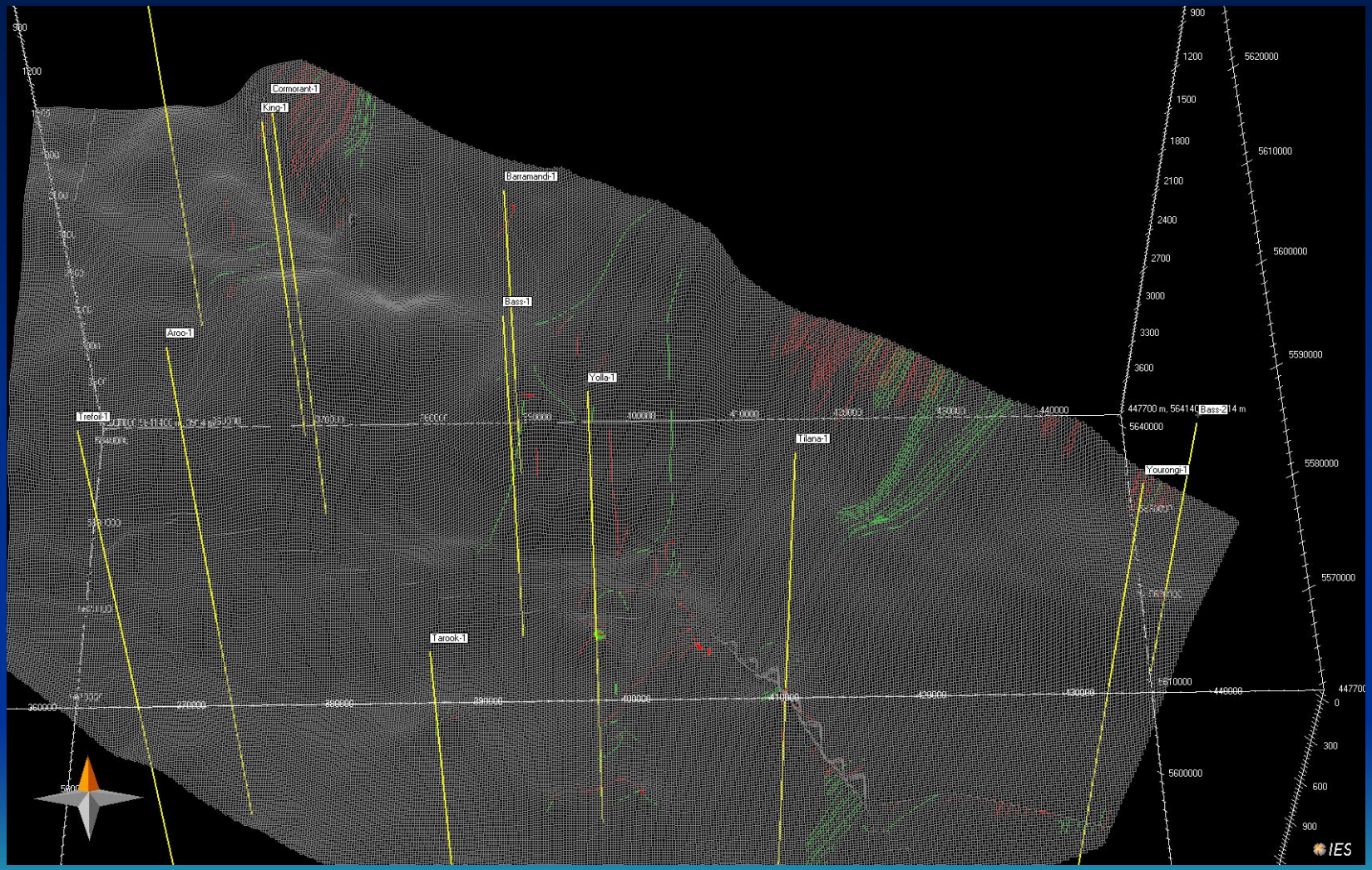


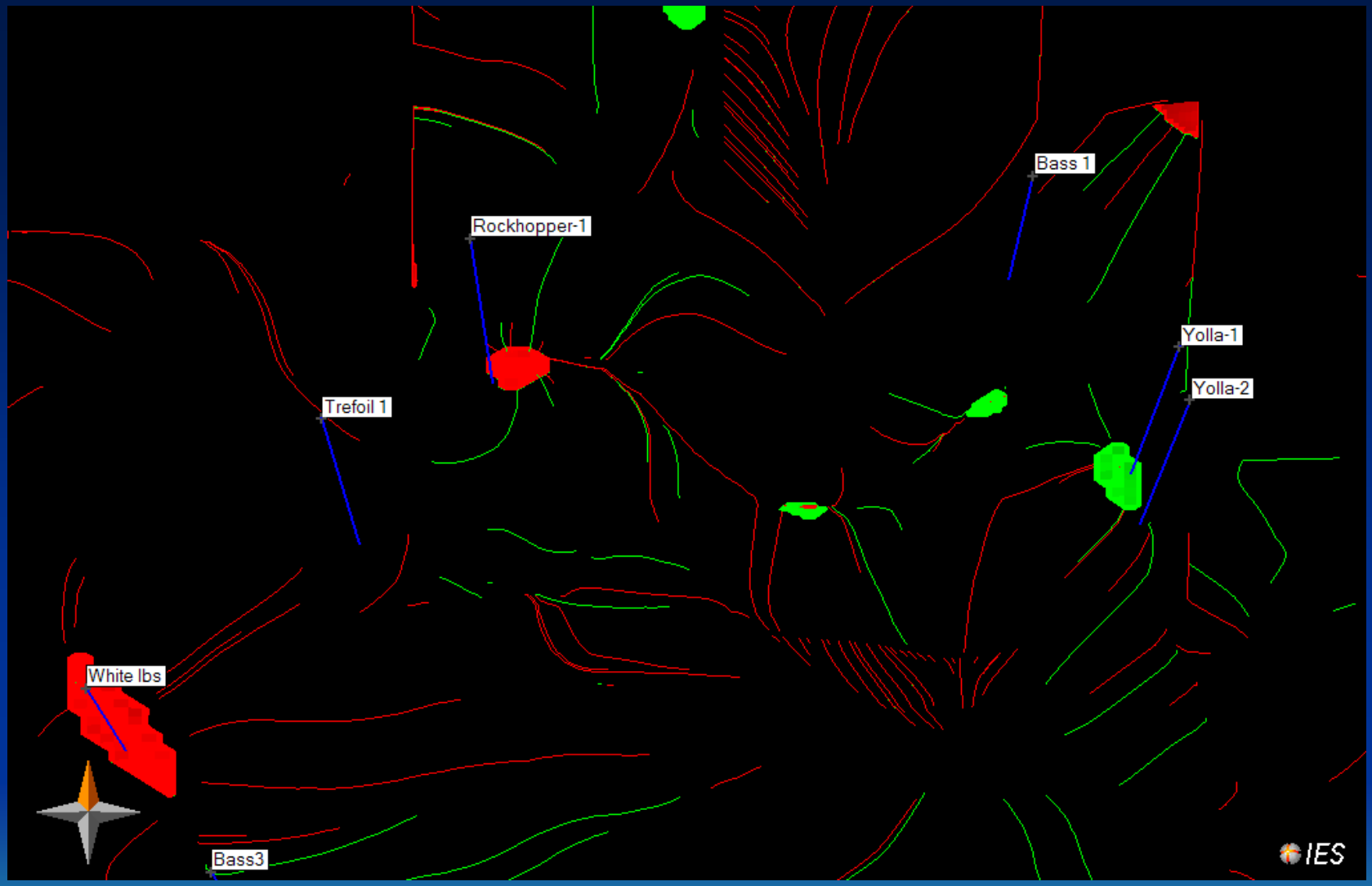
Deeper Reservoirs of the Durroon Sequence



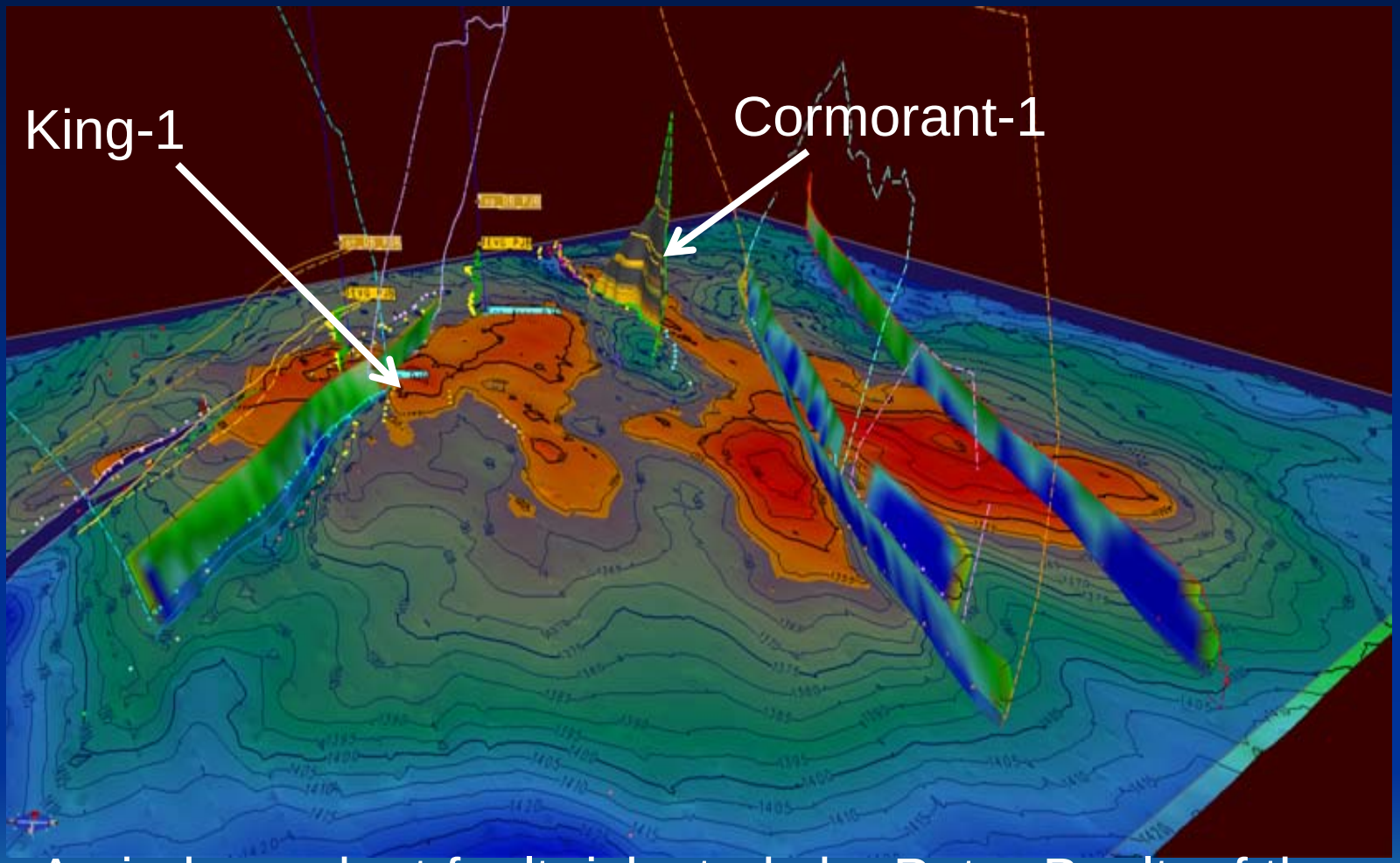
Reservoirs of the lower section of Upper EVG



Reservoirs of the lower section of Upper EVG



2 years after modelling Rockhoper-1 proves a deeper play suggested by this study



An independent fault risk study by Peter Boult, of the King-Cormorant structure, confirmed fault permeability predicted by petroleum systems modelling of the Bass Basin

Conclusions

- Fault permeability is a sensitive issue in petroleum systems practice, particularly hydrocarbon migration modelling and cannot be ignored.

- Non active faults tend to be barriers (impermeable) for hydrocarbon migration unless a greater force overcomes their sealing capacity.

- 3D Petroleum systems modelling of the Bass Basin suggests restored palaeo-stress directions in relation to fault orientation can be used as a guide to predict fault permeability during geological events.

- Modelling results are as good as input data, better modeling practice requires better knowledge and understanding of geological processes.