Pressure and Basin Modeling in Foothills: A Study of the Kutubu Area, Papua New Guinea Fold and Thrust Belt*

Jean-Paul Callot[1], Kevin C. Hill[2], Renaud Divies[3], Steven Wood[2], Francois Roure[4], and William Sassi[4]

Search and Discovery Article #30431 (2015)
Posted November 30, 2015

*Adapted from oral presentation given at AAPG/SEG International Conference & Exhibition, Melbourne, Australia, September 13-16, 2015

[1]Geosciences, University of Pau, Pau, France (jean-paul.callot@univ-pau.fr)
[2]Oil Search Ldt, Sydney, France
[3]Beicip-Franlab, Rueil-Malmaison, France
[4]Geology, IFP-Energies Nouvelles, Rueil Malmaison, France

Abstract

During the last decade, the Papua New Guinea fold and thrust belt has been the locus of renewed exploration. In that frame, a study of the PNG petroleum system has been undertaken along a 200 km long transect in the frontal fold and thrust belt, based on a regional balanced cross section. The scenario integrates the Jurassic rifting and passive margin stage, the uplift related to Coral Sea rifting and the Plio-Pleistocene shortening, together with a moderate amount of erosion during the Upper Cretaceous (600 to 1300 m), and an early growth of the Hedinia Anticline. Calibration of the section boundary conditions and properties was done by comparison with data from 7 wells and field data. Apart from the high pressure trend in the Kutubu structures, all data are accounted for with a good to very good fit, and the modeled section appears quantitatively predictive. Water flow away from the topographic highs in the pervious Darai carbonates is decoupled from the underlying low velocity fluid in the Ieru Shale creating a delay in the pressure equilibrium between the deep escape of the fluids from the highs and the slow recharge from above.

There are three major pathways for water: (1) topographically driven flow, from the onset of mountain building until present, (2) deep basinal flux, flowing along the flexed reservoirs at the onset of thrusting, and (3) across fault escape from connected reservoir bodies during late stage of basement fault inversion. The petroleum system evolution shows that the deep type III source rock explains the small extent of its maturation. Type II or mixed type II/III are used to model the Cretaceous source rock shales. Maturation starts in the Middle Cretaceous, increases regularly during burial, with a strong increase during the late tectonic burial (50% increase during the last 7 Ma). The saturation shows three main accumulations: (1) the deep part of the Mubi zone, with vertical migration along faults, (2) the Hedinia Anticline charged

during Orubadi deposition and the Kutubu Anticline charged during Era deposition, and (3) less important, the Darai Plateau, cutoff from lateral charge by the early growth of the Hedinia Anticline.

Selected References

Hill, Kevin C., and Robert Hall, 2002, Mesozoic-Cainozoic evolution of Australia's New Guinea margin in a West Pacific context: GSA Special Paper 372, p. 265-290.

Schneider, F., 2003, Basin modeling in complex area: examples from eastern Venezuelan and Canadian foothills: Oil & Gas Science and Technology, v. 58/2, p. 313-324.

Thibaut, M., I. Faille, F. Willien, P. Have, S. Pegaz-Fiornet, and G. Rodet, 2012, Building Better Integration between Structural Complexity and Basin Modelling: AAPG International Conference and Exhibition, Milan, Italy, October 23-26, 2011. Search and Discovery Article #40891 (2012).
http://www.searchanddiscovery.com/documents/2012/40891thibaut/ndx_thibaut.pdf

Wendebourg, J., and J.W. Harbaugh, 1997, Simulating oil migration in clastic sequences: Pergamon Press, Oxford, 199 p.

Pressure and Basin modelling in foothills: A study of the Kutubu area, Papua New Guinea fold and thrust belt

J.-P.Callot, K. Hill, R. Diviès, S. Wood, F. Roure, and W. Sassi

Why Basin modelling? For…

….Oil Exploration:

- …to Limit risks
  - Maturity window
  - Pressure estimates
  - Accumulation localization
- …to predict products properties
  - Composition density, viscosity, gas/oil ratio…
- …to perform volumetric estimates
  - Resources/reserves assessments, …

Lorant, 2010

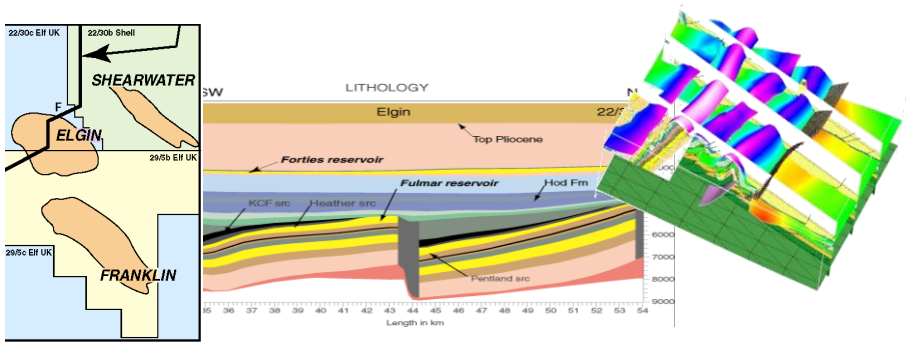
How? Basin modelling…

- … Simulate geologic phenomena, physical and chemical reactions responsible for basin evolution
  - Deposition and compaction
  - Burial and thermal maturation
  - Genesis and expulsion of hydrocarbon
  - Fluid migration (water, oil, gas)
  - Near surface oil alteration
  - and now diagenesis
- … Global modelling of petroleum system evolution
- … Basin scale

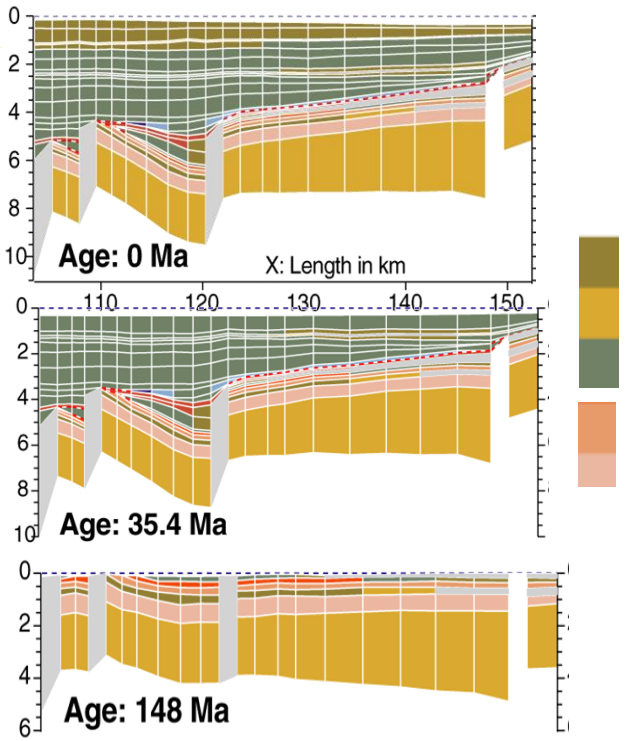
Lorant, 2010

How to proceed?: Present day workflow

Present day interpretation

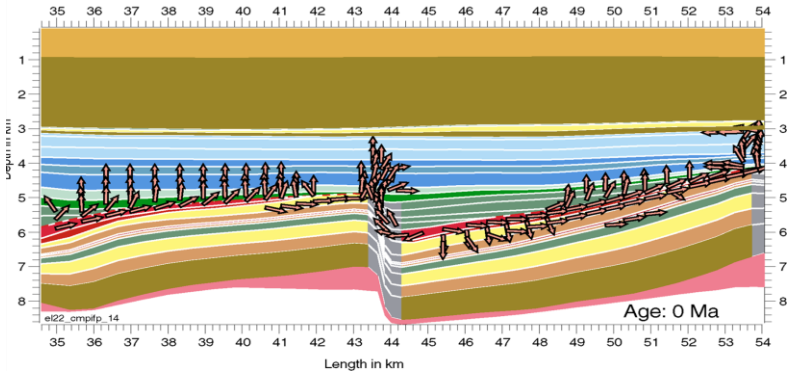


Backstripping: peeling the onion



Forward simulation

Thermal calibration, maturity, fluid flow circulation

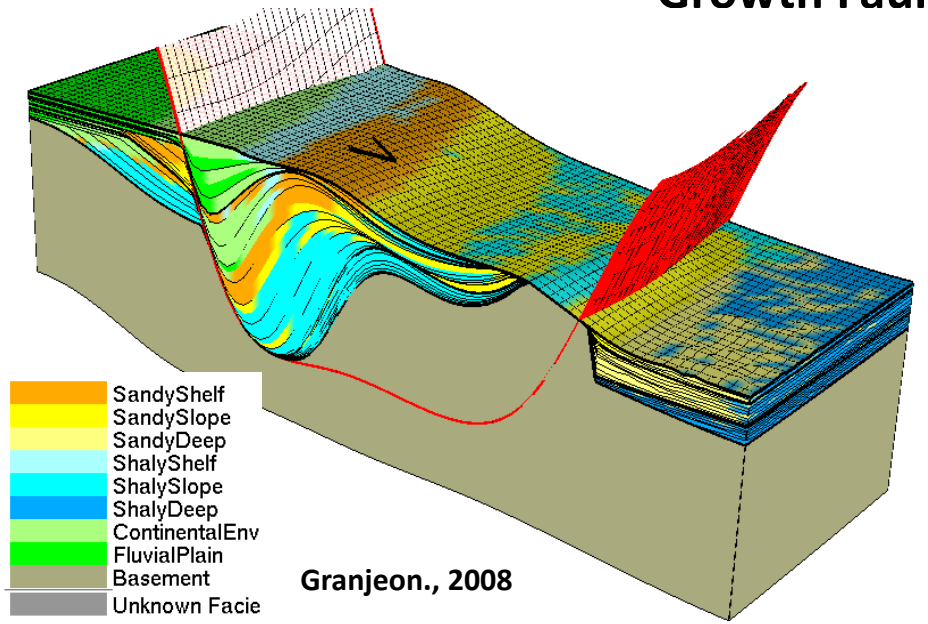


Wendebourg et al. 1998

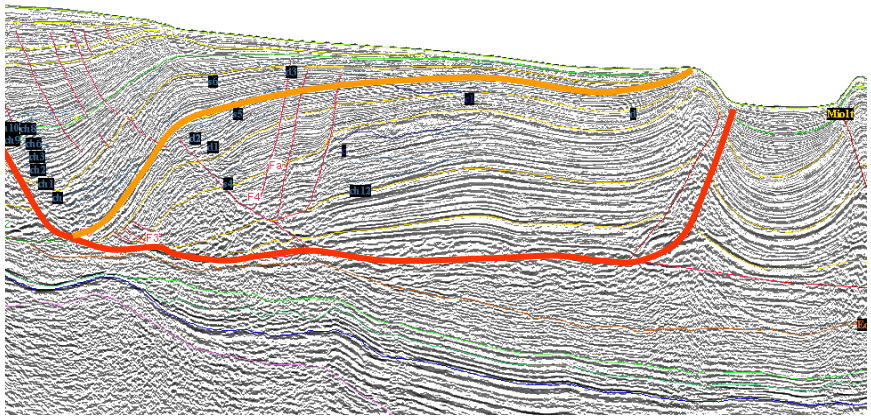
Thibaut et al., 2010

Structural complexity, still a challenge

Growth Faults

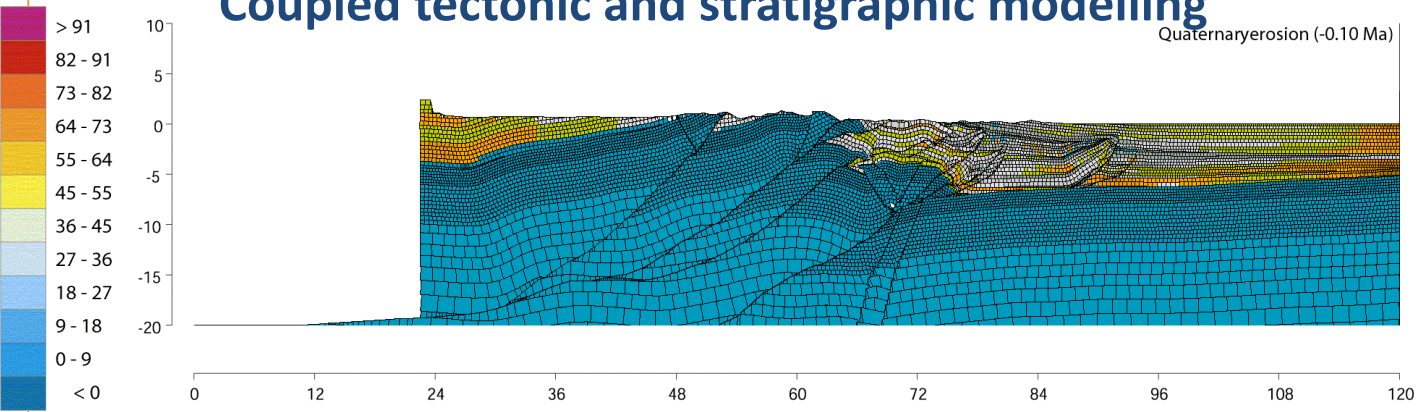


Granjeon., 2008



Alzaga et al., 2008

Coupled tectonic and stratigraphic modelling

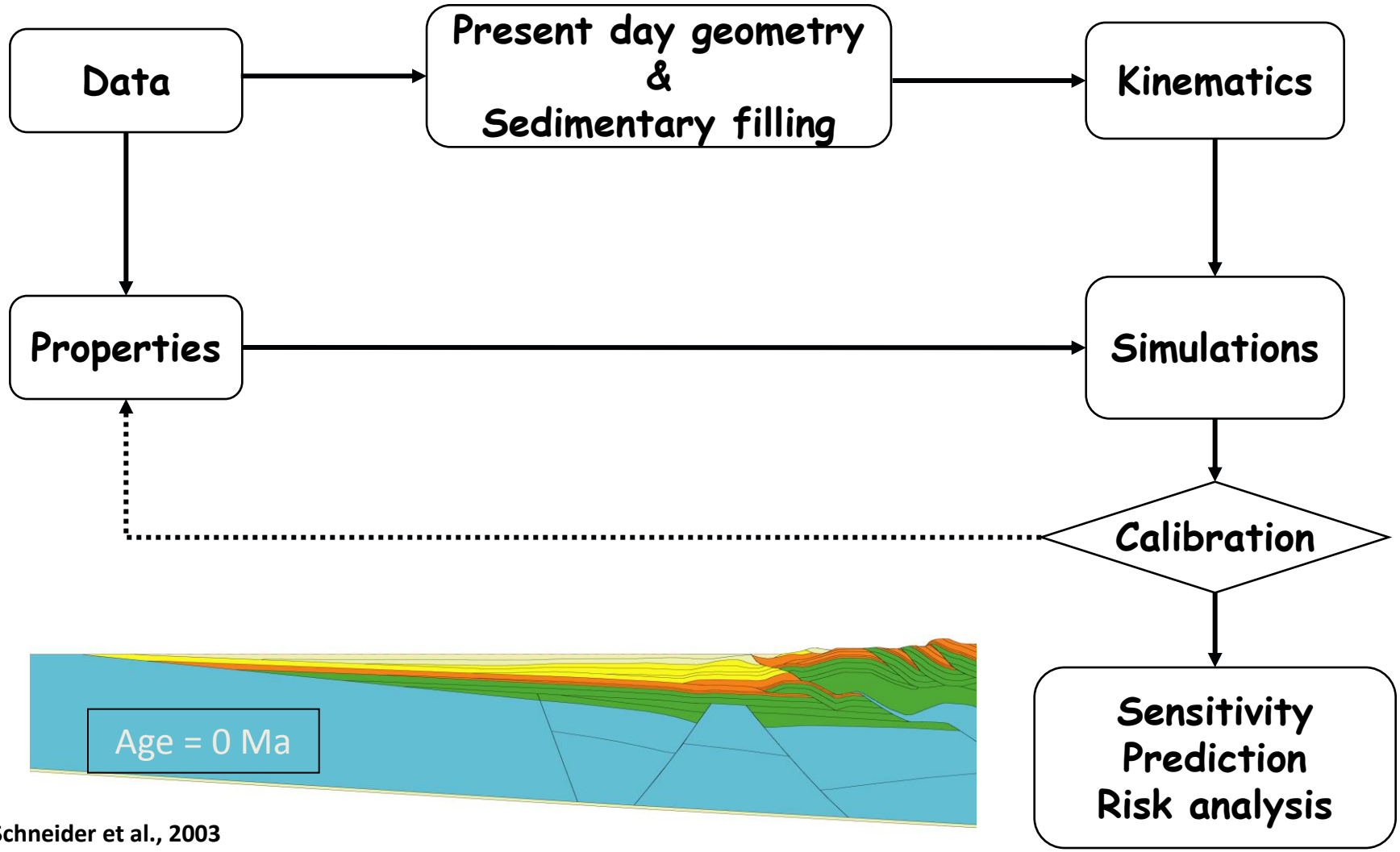


Need to account for

- **Block kinematic, folding, offsets;**
- **Erosion, Sedimentation;**
- **Fault as barrier or conduits…**

Albouy et al., 2006

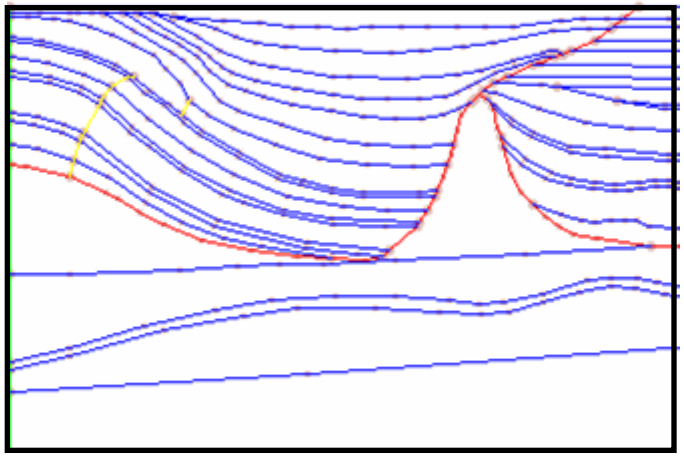
Workflow



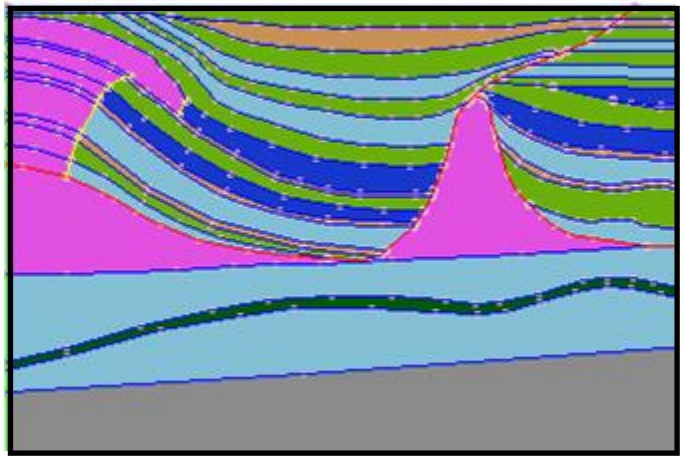
Schneider et al., 2003

Initial section building: domain decomposition

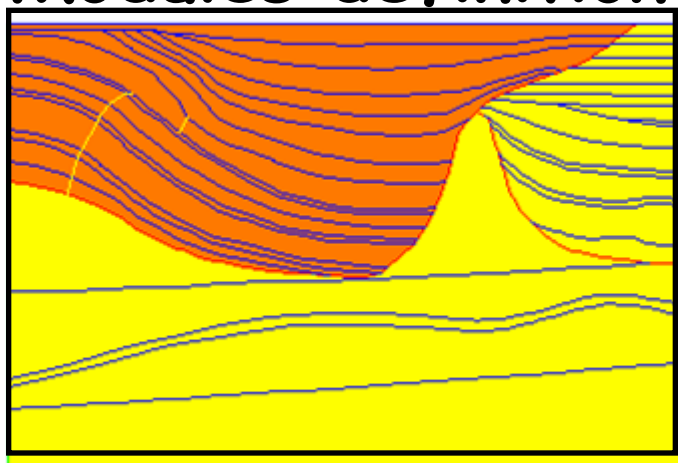
Geometry



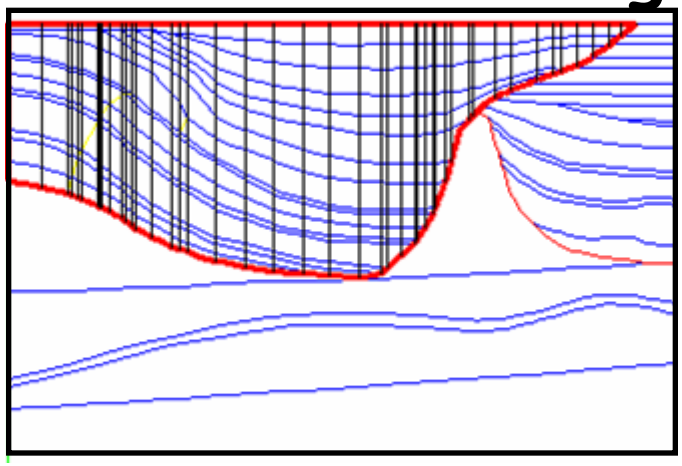
Geology



Modules definition



Module meshing



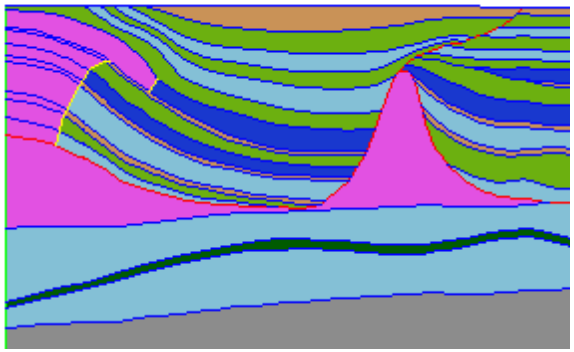
Defines the fundamental kinematic units for calculation

No meshing constraints from adjacent blocks

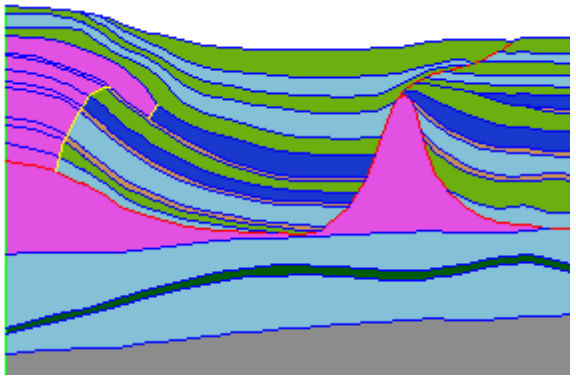
Schneider et al., 2003

Backward reconstruction of past stages

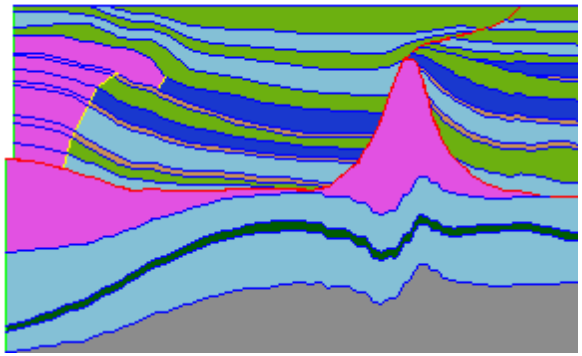
1: Initial Section



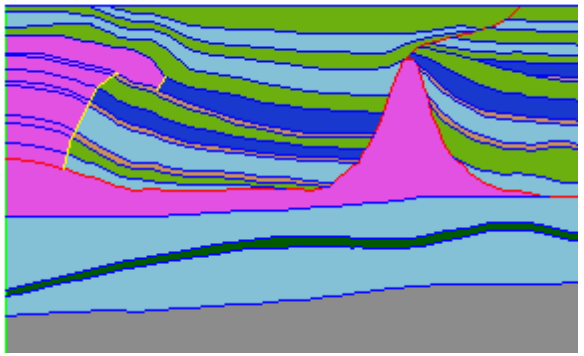
2: Sedimentation/Erosion/ Backstripping



3: Kinematic restoration

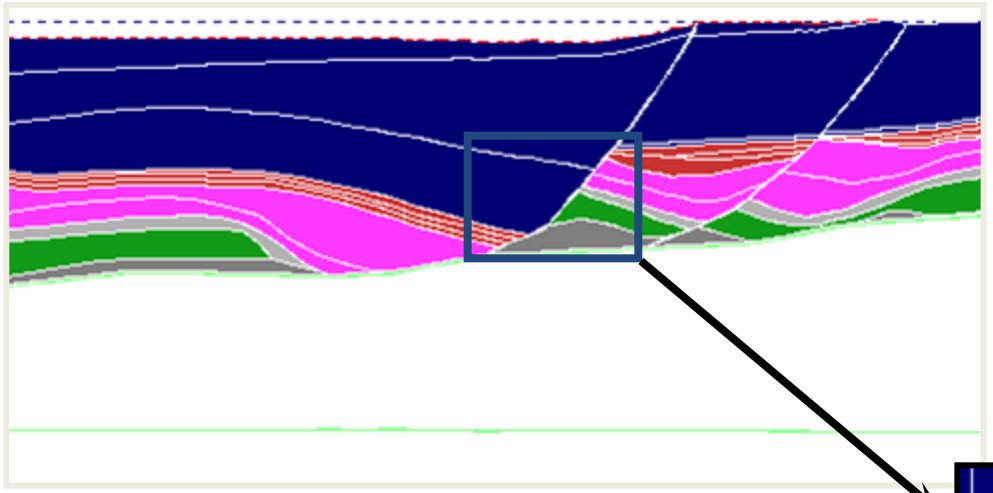


4: Thickness management

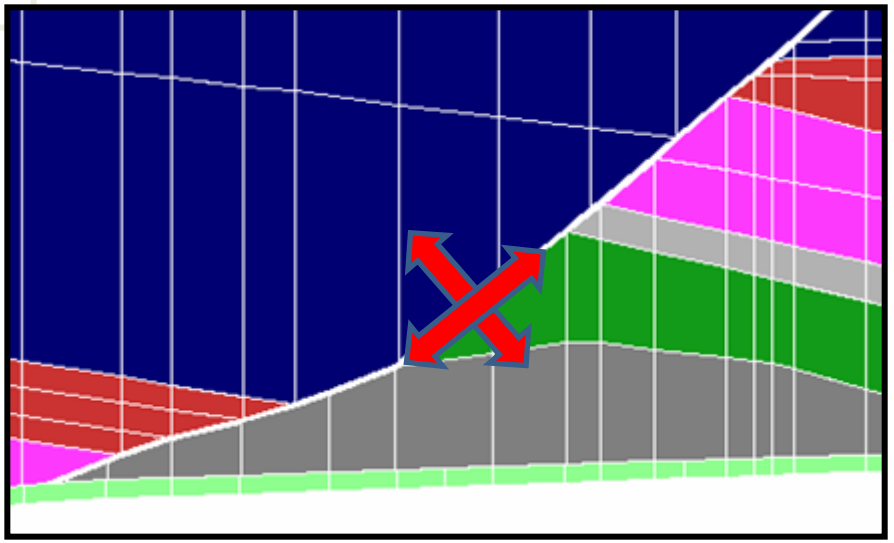


Schneider et al., 2003

Fault permeability management



2D forward simulator able to handle evolving and non conforming mesh with different physics in the faults

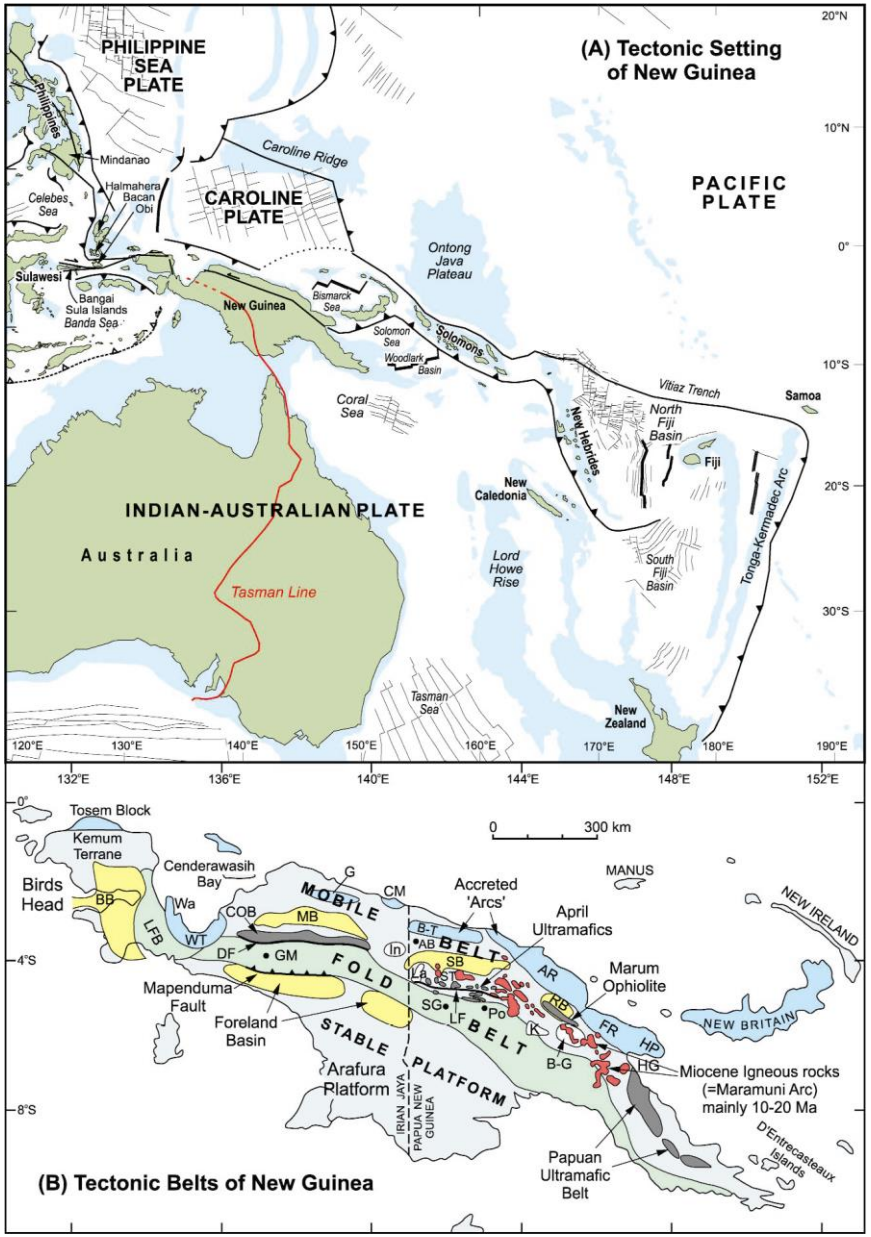


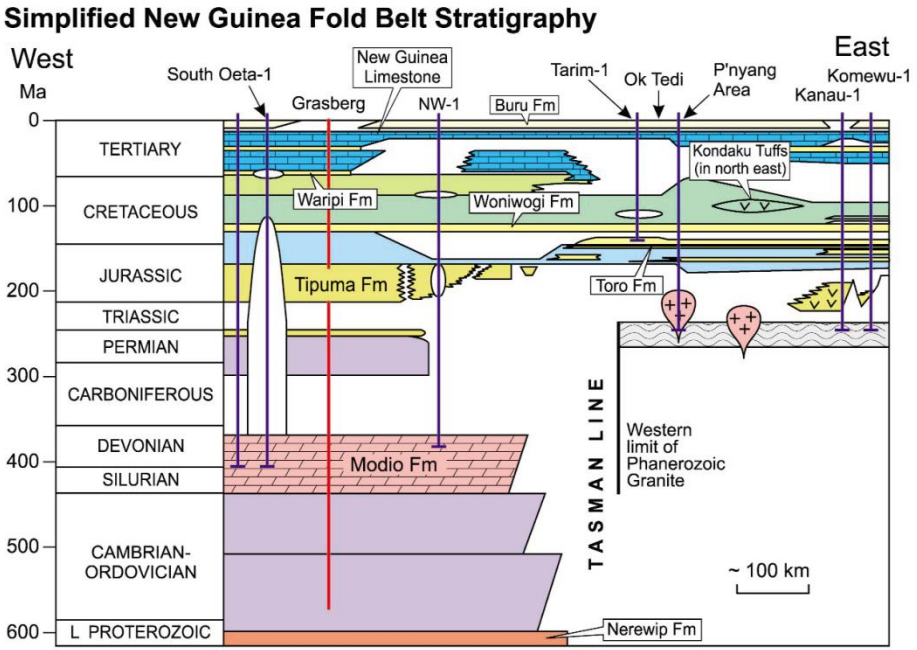
4 Fault Models:

1. Impervious
2. Pervious
3. K (ε)
4. K (closest neighbors)

Schneider et al., 2003

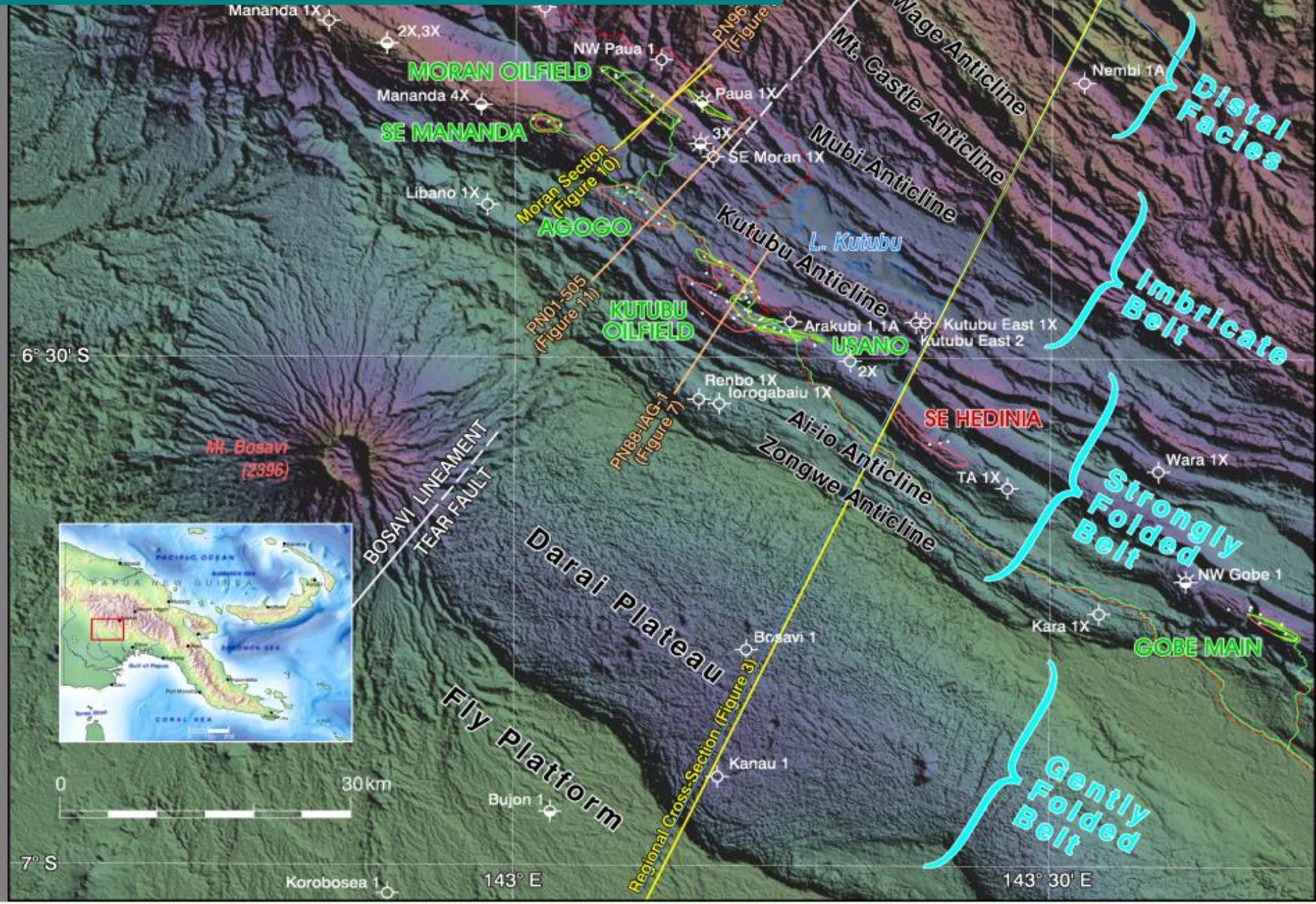
Geologic setting



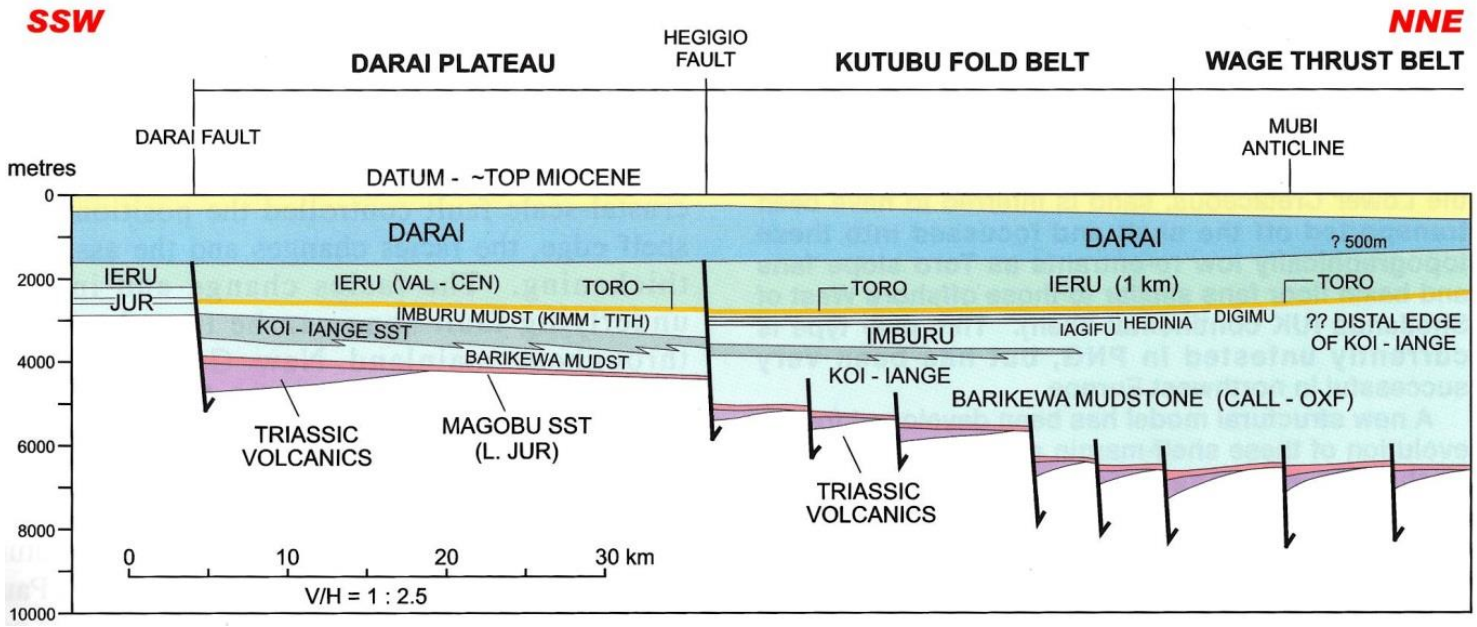


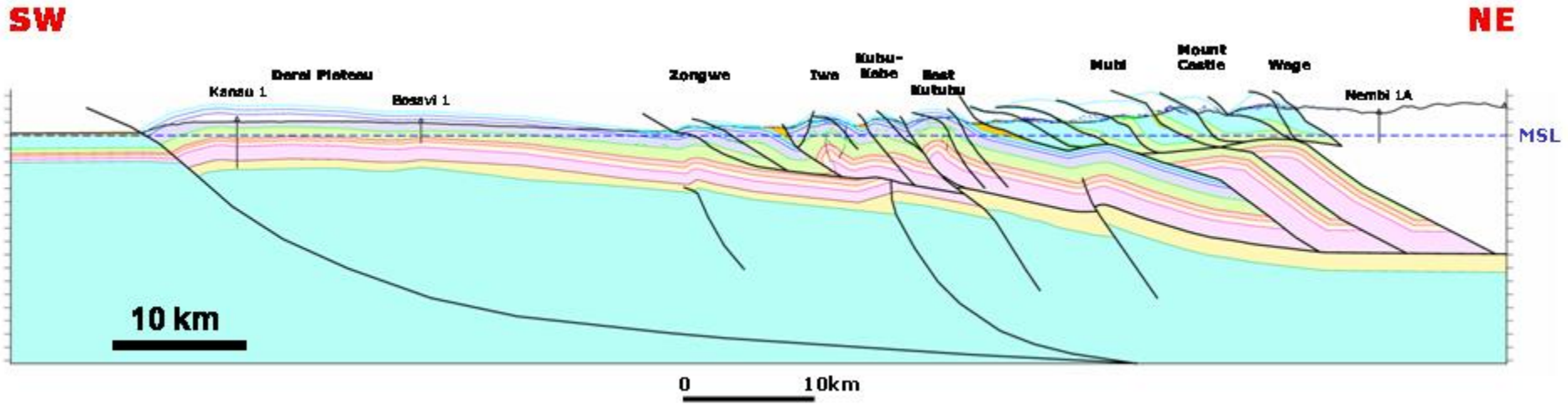
Hill and Hall, 2002

Structural zones & section



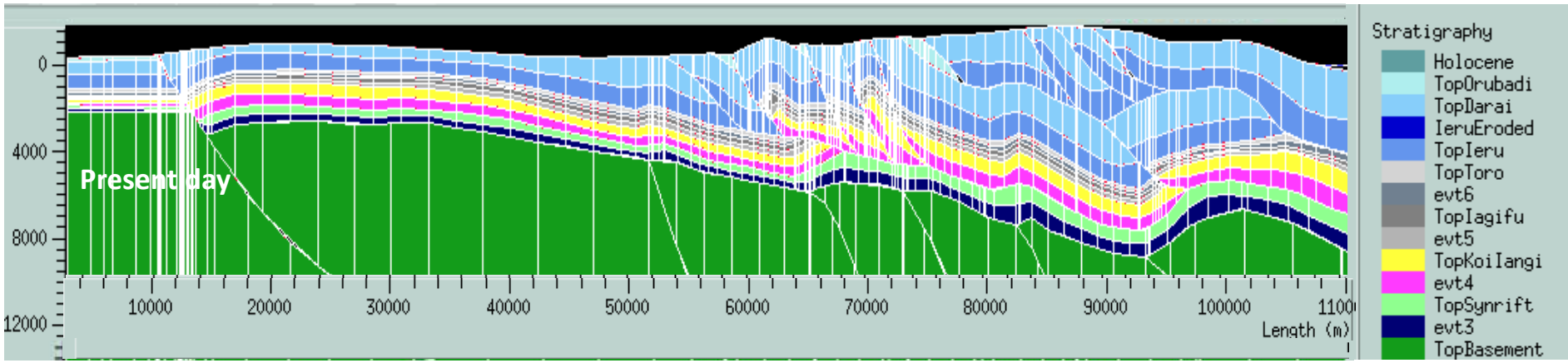
Present day section and petroleum systems





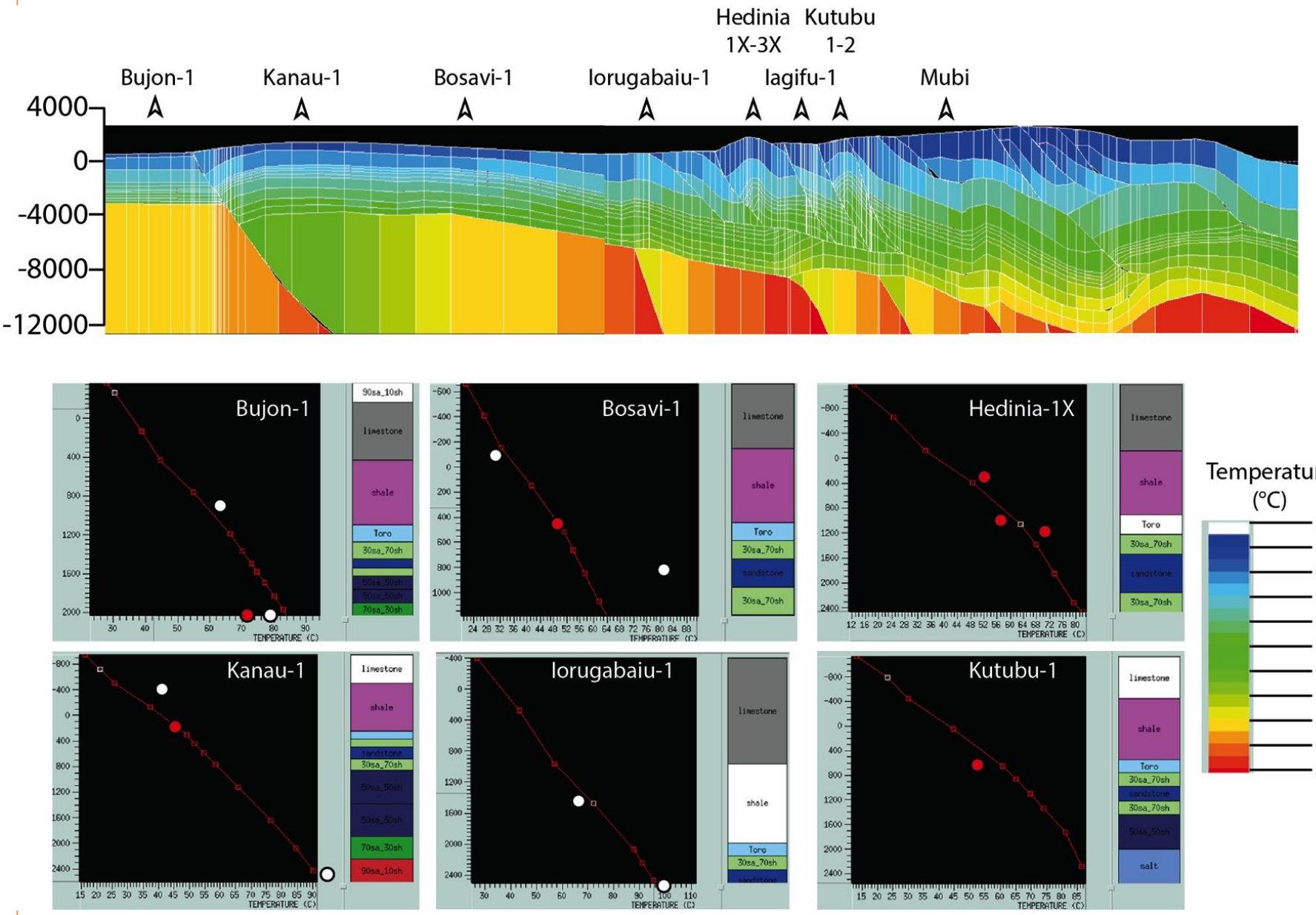
Hill et al., 2010

The basin model scenario



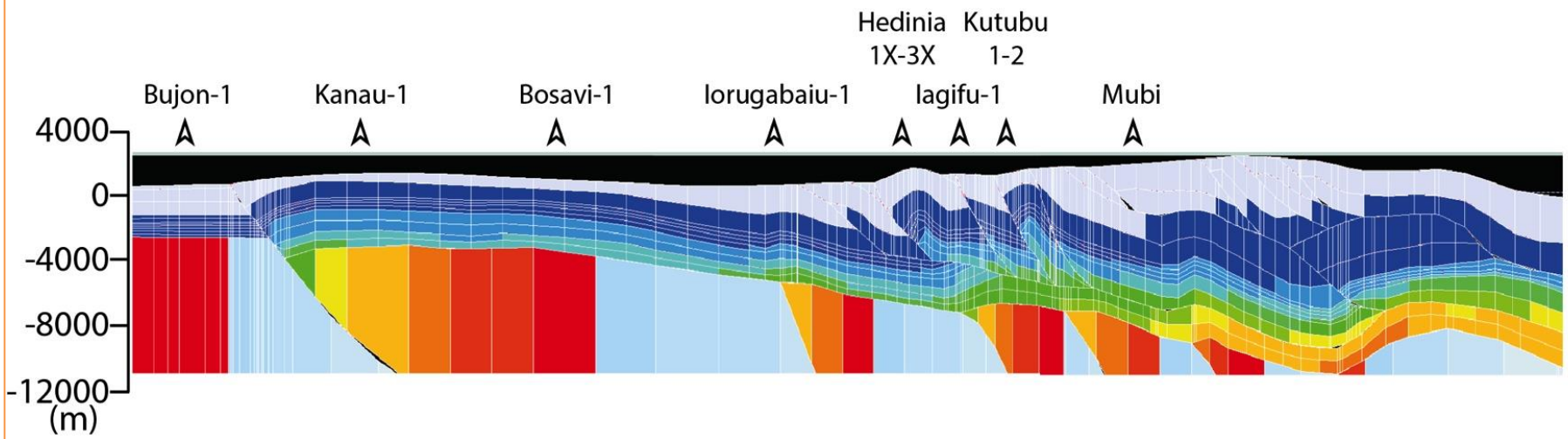
Callot et al., accepted

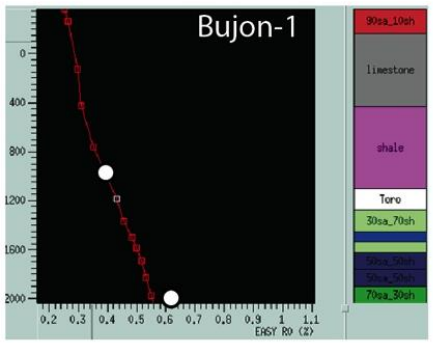
Temperature field versus well data

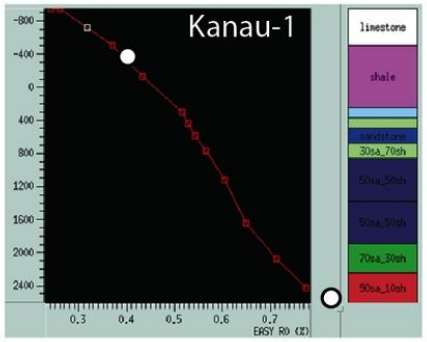


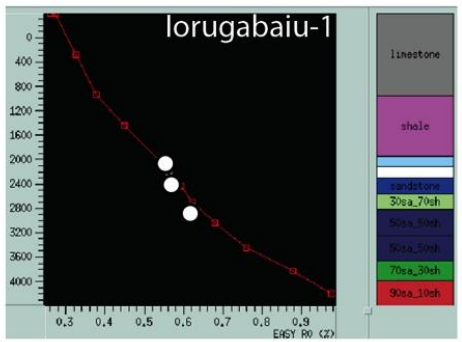
Callot et al., accepted

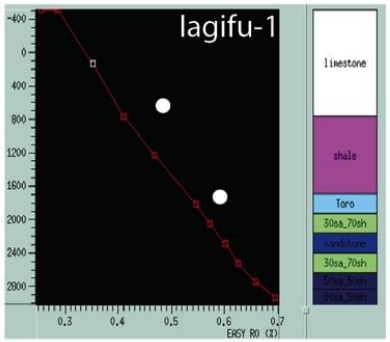
Vitrinite field versus well data

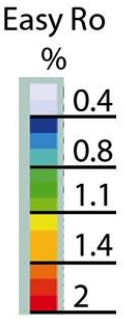










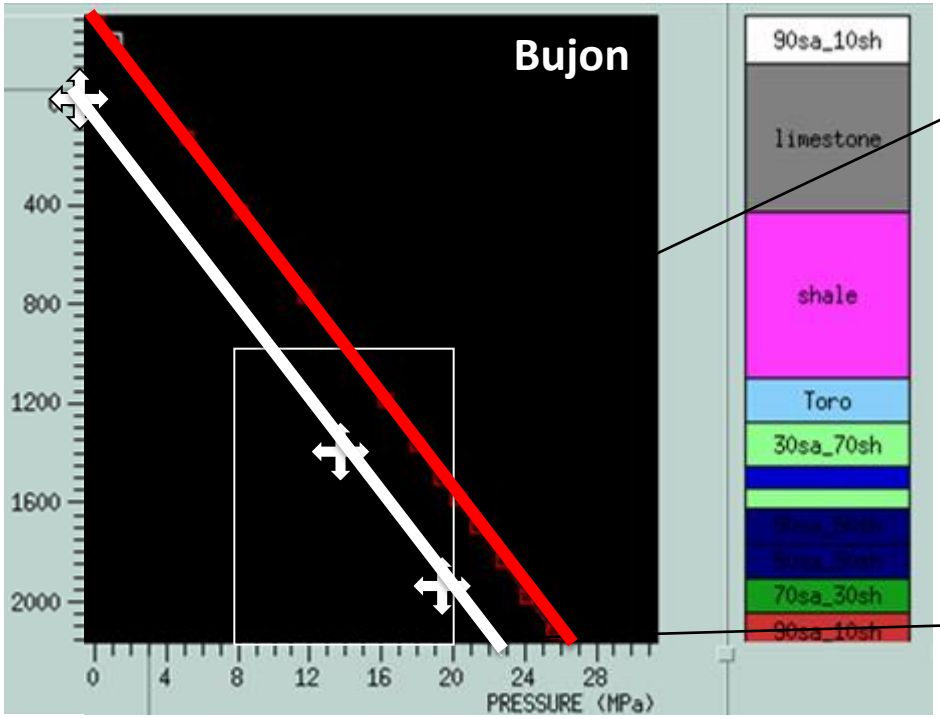


Callot et al., accepted

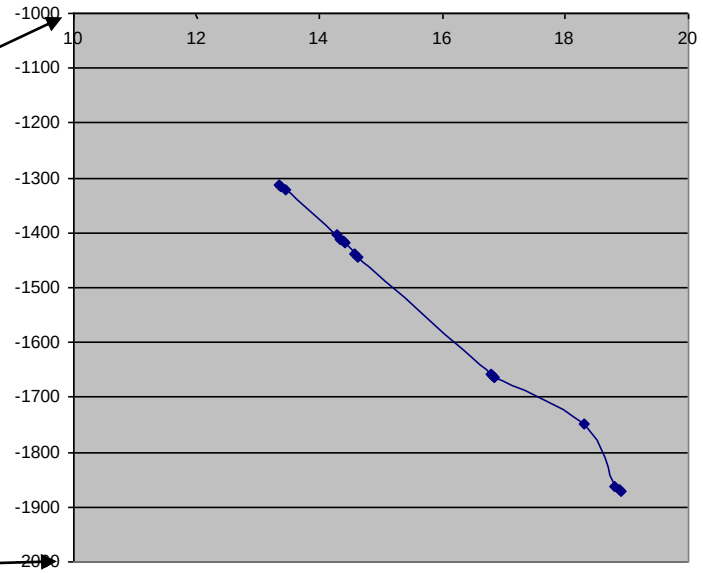
Pressure calibration: Bujon

Water table level

Pressure trends



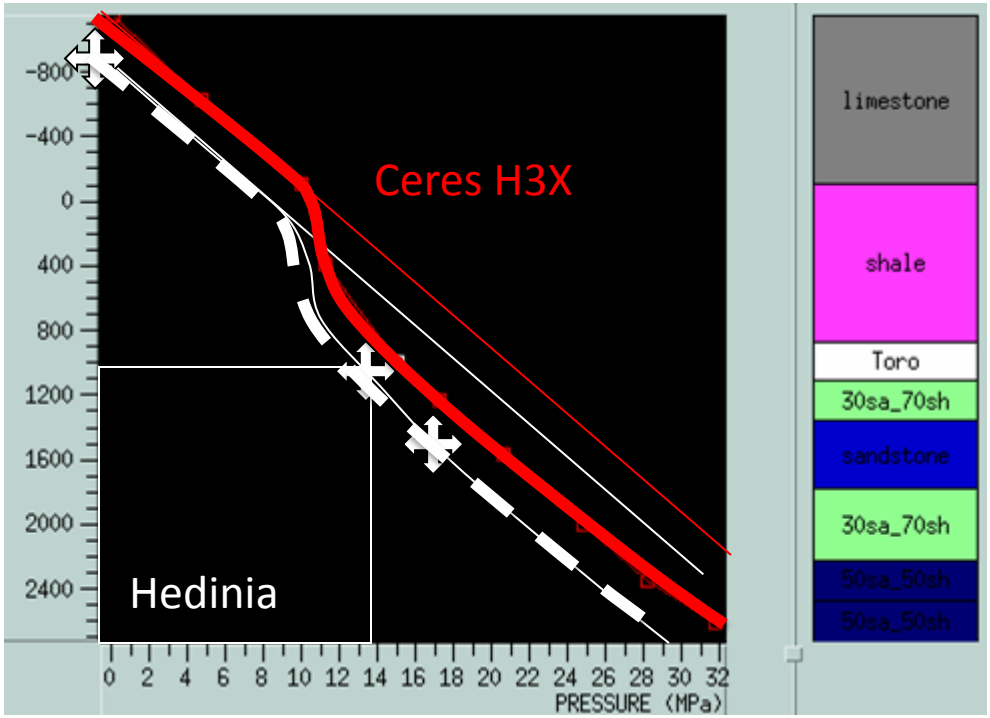
Well data



Taking into account the water table depth, less than 5% misfit

Callot et al., accepted

Pressure calibration: Hedinia3X

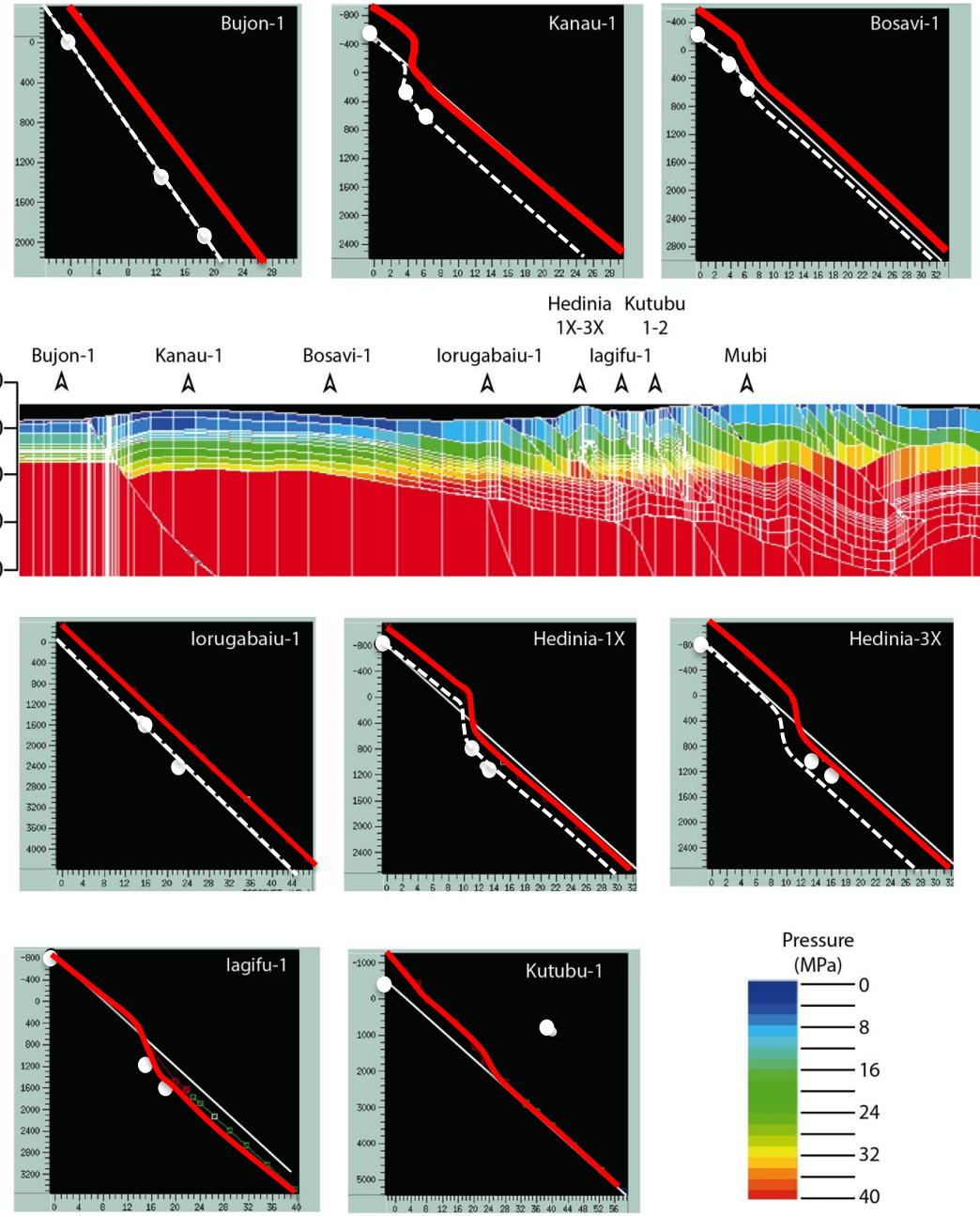


Less than 1MPa of misfit.

The modelling predicts an 'under-pressurization' below the hydrostatic trend, which can fit the observed data and aquifer depth.

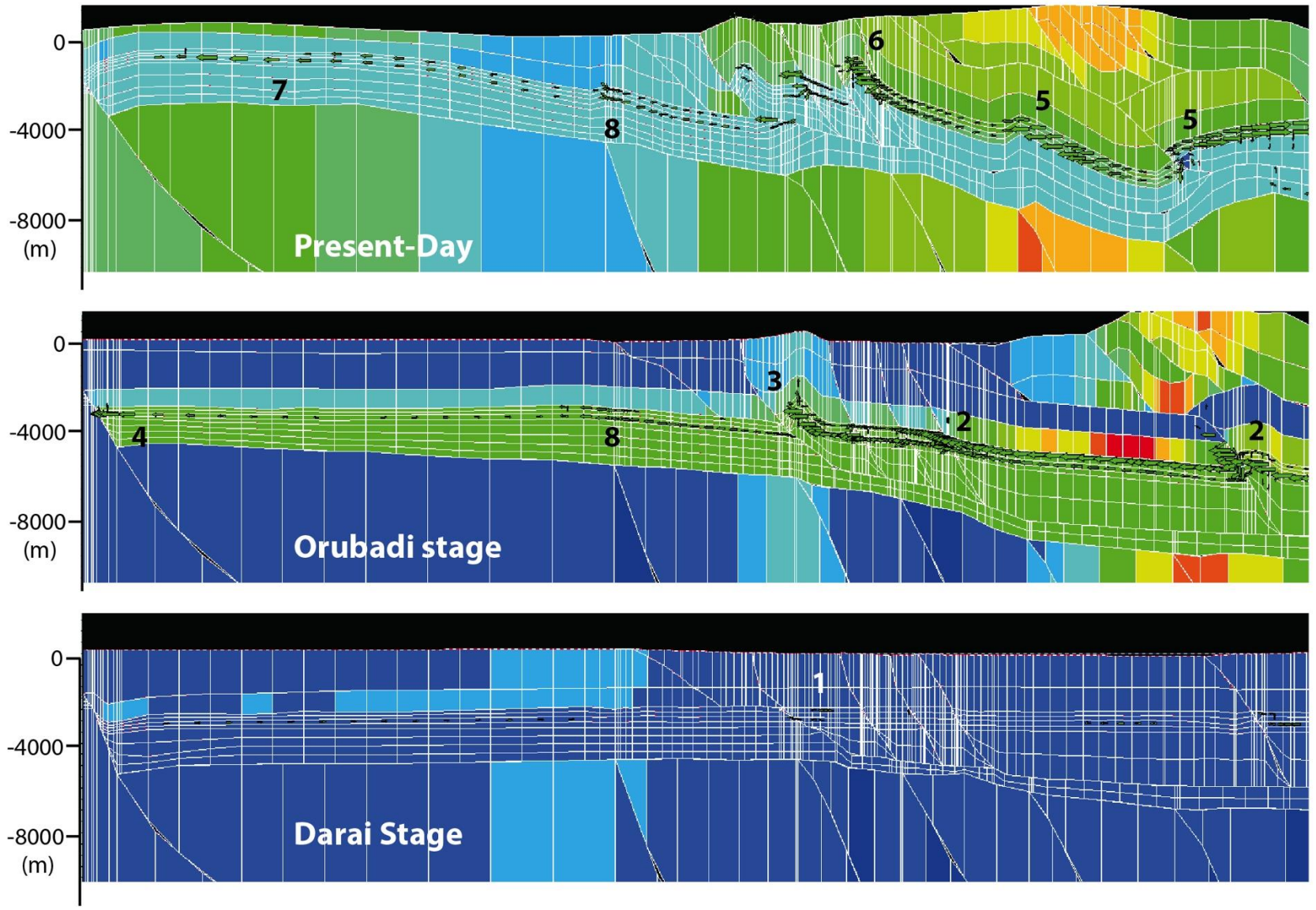
Callot et al., accepted

Pressures along the sections



Callot et al., accepted

Oil charge and migration

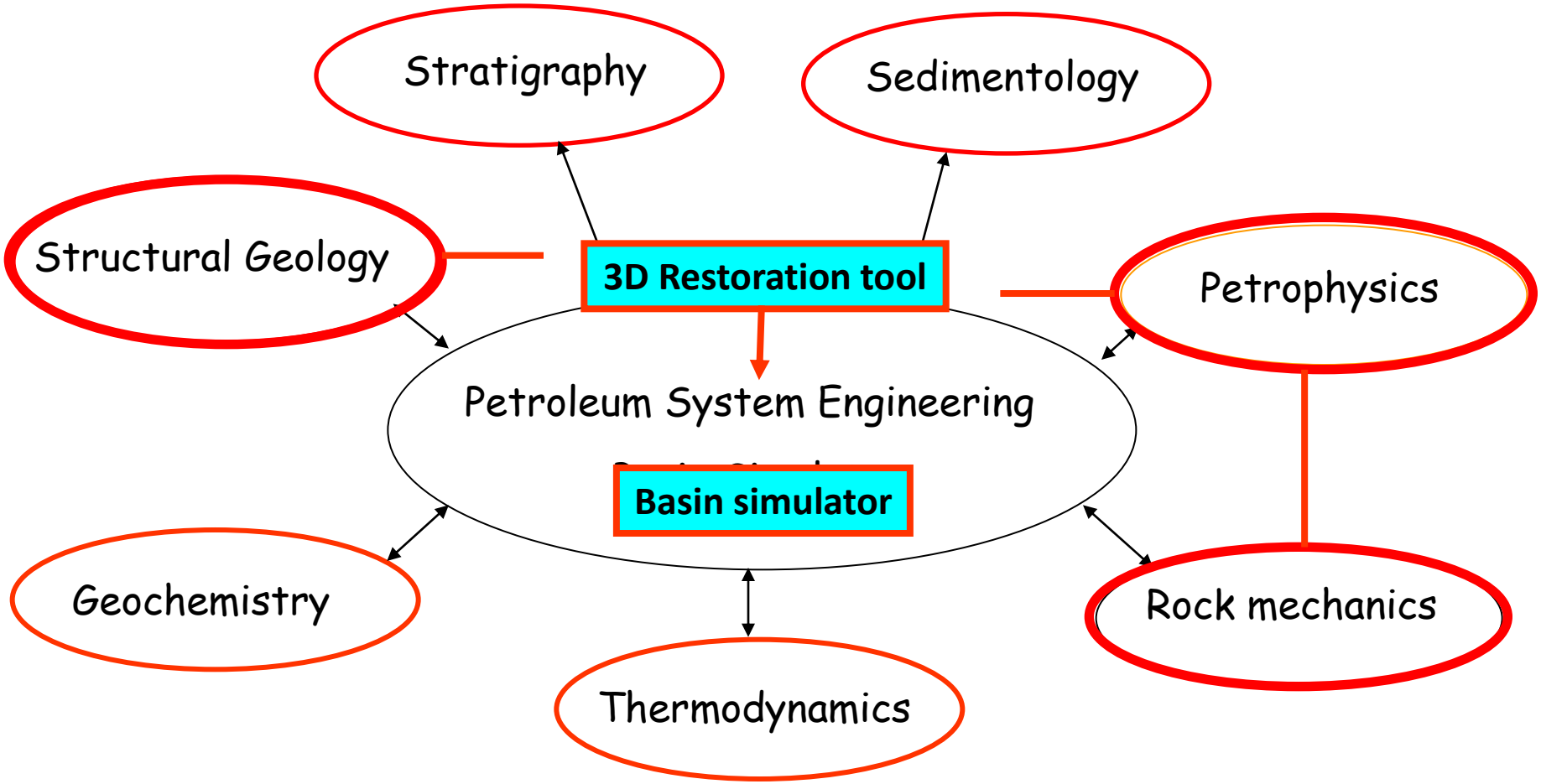


Callot et al., accepted

Interpretation of pressure data

- **Hydrostatic trend: Foreland, Darai, Iorugabai, Hedinia and Iagifu**
- **Shift of 200m to 500m of the vadose zone**
  - **Ceres is water saturated everywhere whereas,**
  - **Karstified carbonate may conduct easily and rapidly water at depth**
- **Underpressurization below the Ieru shales**
  - **Topographically driven flux in the carbonates**
  - **Need for a facies (silt/shale) map for**
- **Still No overpressurization in Kutubu**

Conclusions:



Basin modeling tools coupled to structural scenarios allow coupling of the physical and the chemical processes at geological time and at basin scale, within a realistic structural framework