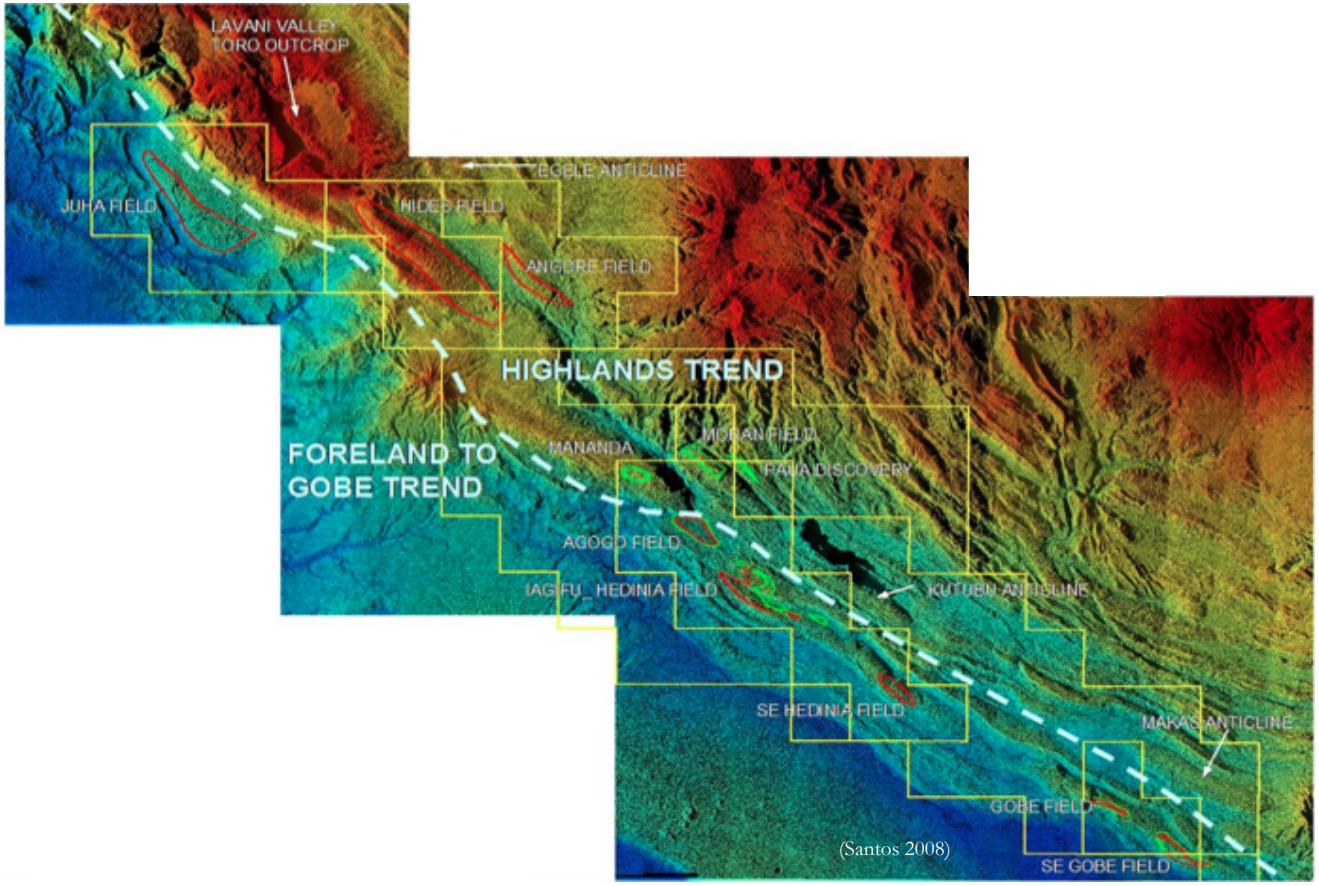
A Regional Study of the Toro and Imburu Formation Aquifers in the Papuan Basin, Papua New Guinea



Santos and ASP Project
Santos - Mike Starcher and Sharon Langston. ASP - Mark Bunch

Project Rationale

- Significant Hydrocarbon reserves in Papuan Basin Fold Belt

- Hydrocarbon distribution likely influenced by hydrodynamic aquifer behaviour in the Toro and Imburu Formation reservoirs.

  [Previous aquifer studies (Eisenberg, 1993; Eisenberg et al., 1994; Kotaka, 1996)].

- Identify hydrodynamically trapped hydrocarbons by generating regional potentiometric surface maps of the Papuan Basin

Project Aims (Outcomes)

- Generate a comprehensive data set of up-to-date well formation fluid pressure, salinity and temperature data, that will allow hydraulic potential (Hw) values to be generated, for the total current set of wells in the Papuan Basin for the Toro and Imburu Formation reservoirs.

- Generate up-to-date potentiometric surface maps within the fold belt and foreland regions of the Papuan Basin for the key reservoir intervals, the Toro Sandstone and the Imburu Formation (Digimu, Hedinia and Iagifu sandstone units), by integrating the Hw data, regional topography, regional outcrop/surface geology and major structural features recognized in the region that may serve as barriers to aquifer connectivity.

- Propose a qualitative Toro aquifer model incorporating key aspects of Toro reservoir hydrodynamic flow patterns identified from the potentiometric surface maps.

Hydrogeology/Hydrodynamics

- Hydraulic potential (Hw) - simple measure of the potential energy of an aquifer at a given point

  $Hw = z + P/\Delta P$

  (where z = depth of the pressure measurement - expressed as an elevation relative to sea level, P is the formation pressure, and ΔP is the pressure gradient in the water leg)

- Potentiometric surface (PS) maps

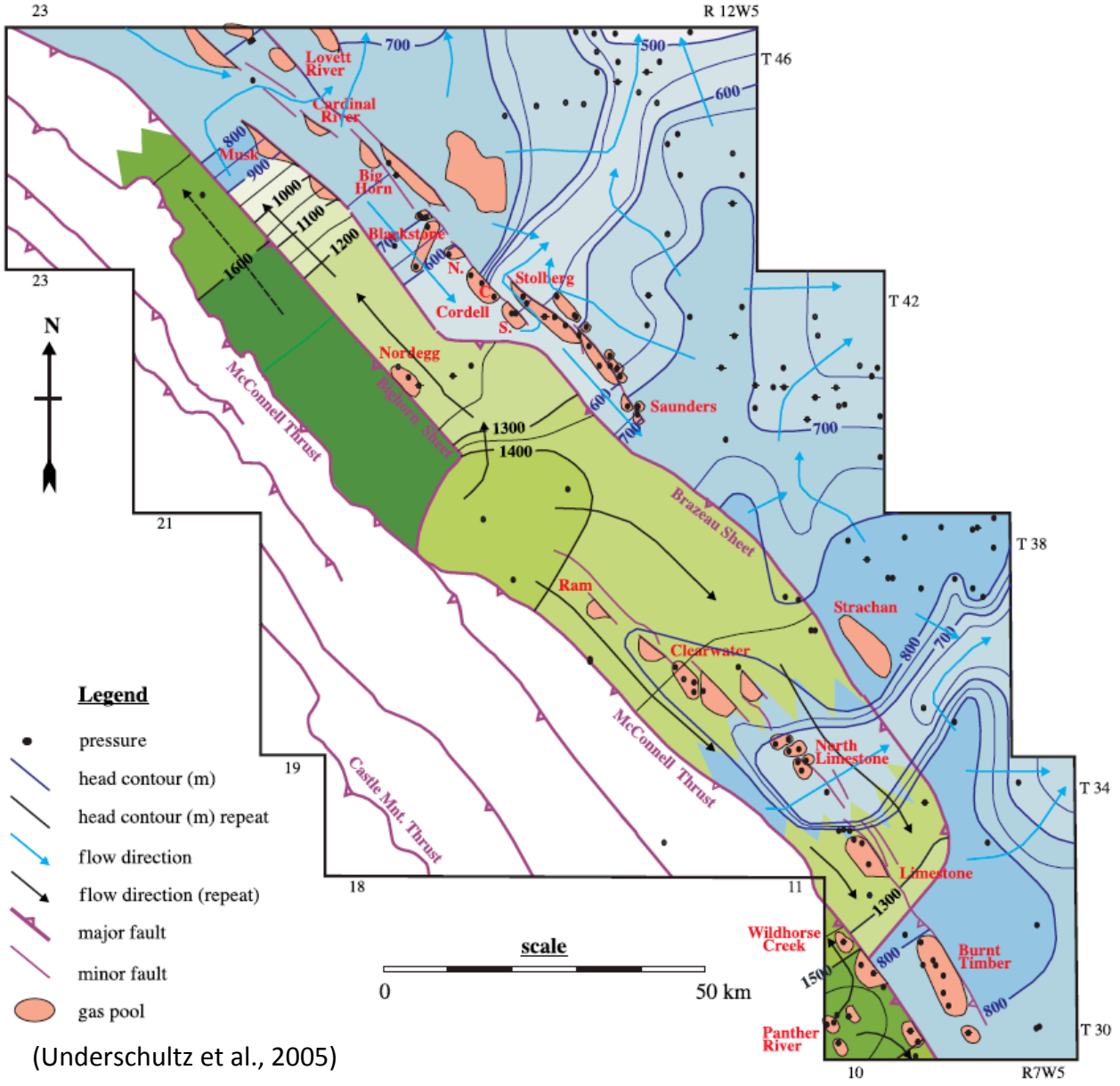
  PS = calculated surface that reflects variation in Hw within an aquifer.

  Elevation of the PS at any point reflects the height that a column of water would rise above sea level if not confined.

- Hydrodynamic vs compartmentalised systems

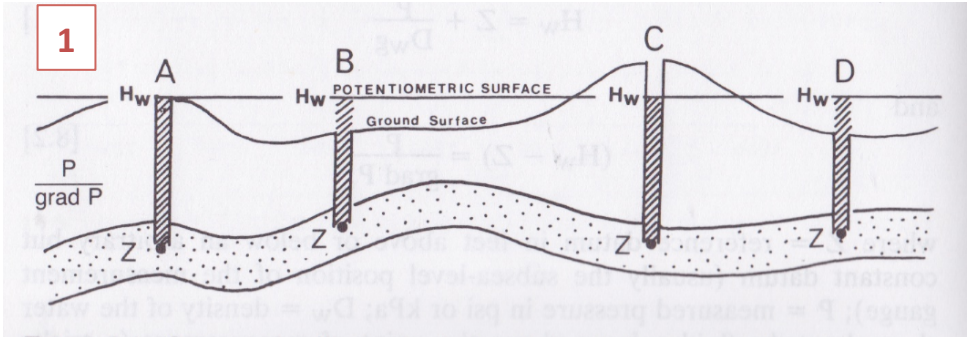
- Hydrodynamic trapping

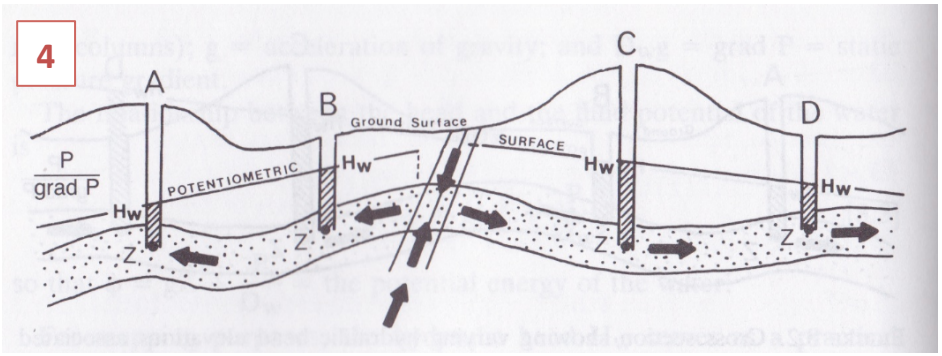
Potentiometric Surface Map: Mississippian Aquifer in West Central Alberta Basin - Western Canadian Fold and Thrust Belt

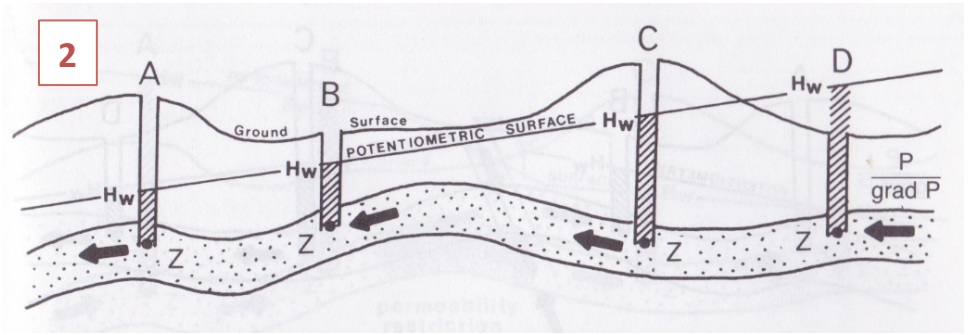


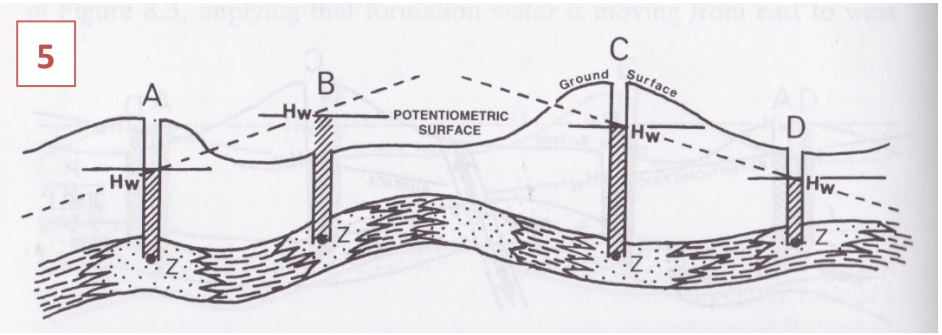
(Underschultz et al., 2005)

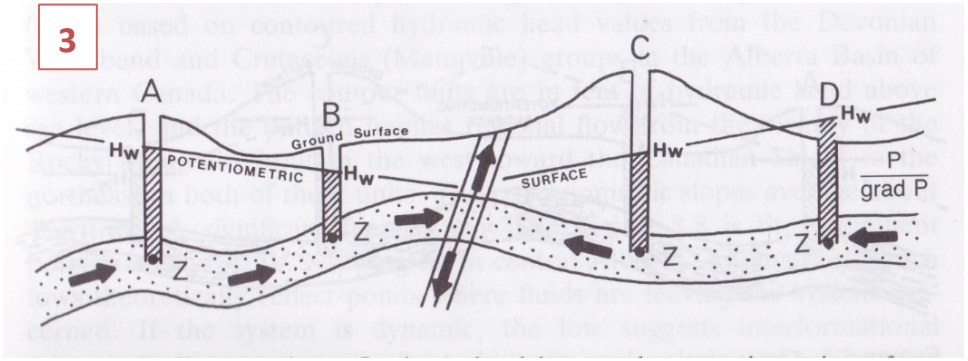
Examples of Subsurface Flow Patterns from Potentiometric Surface Mapping

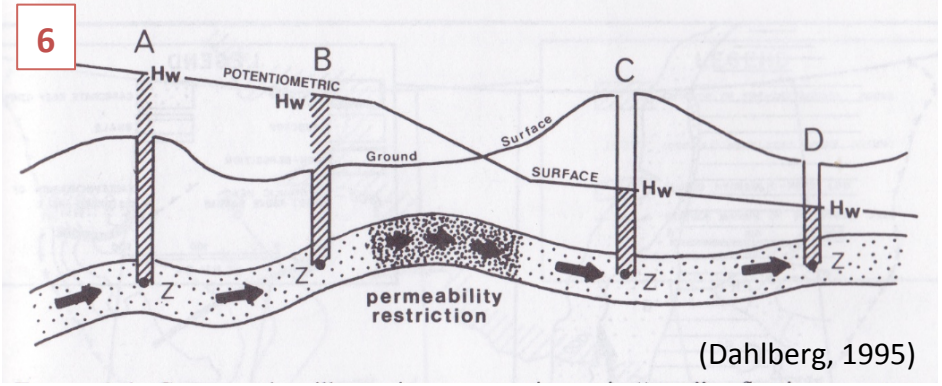






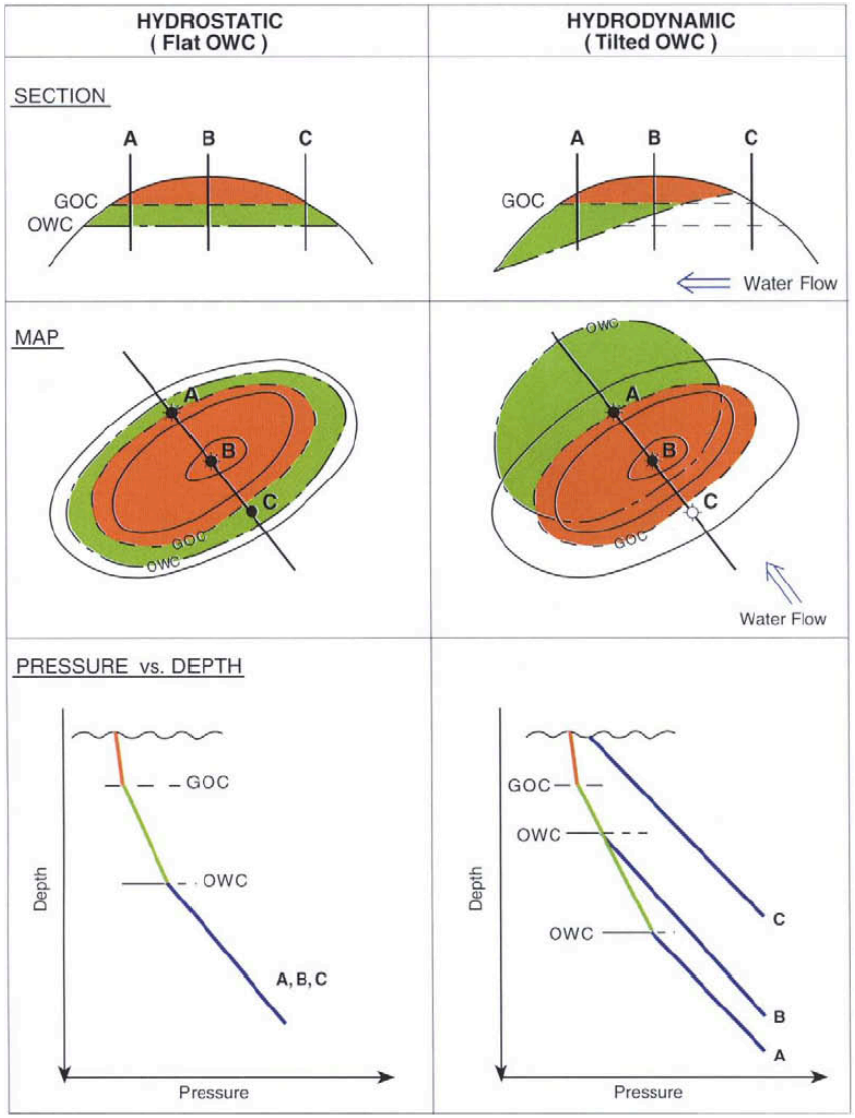






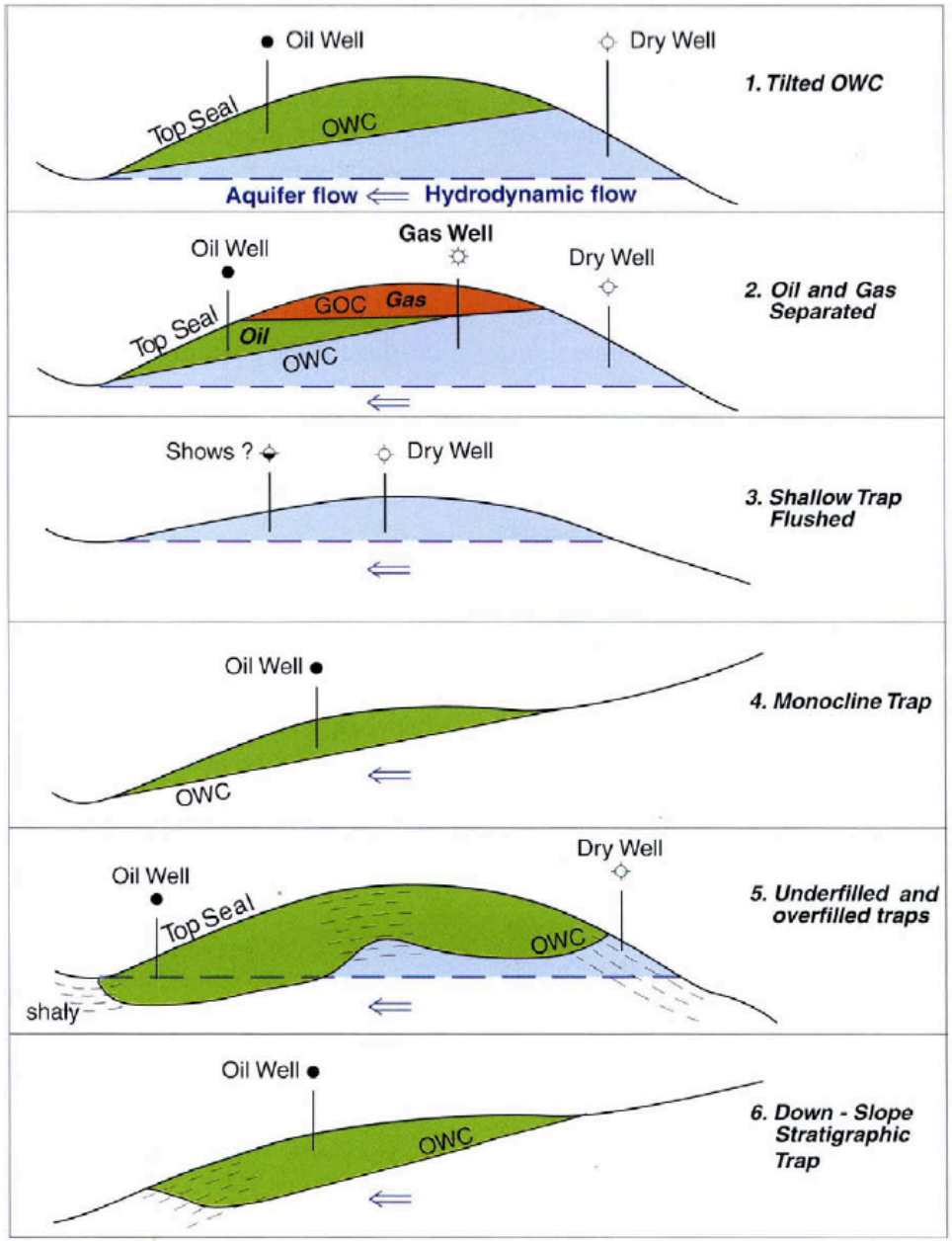
(Dahlberg, 1995)

The Effect of Hydrodynamic Aquifer Behaviour on Oil and Gas Accumulations



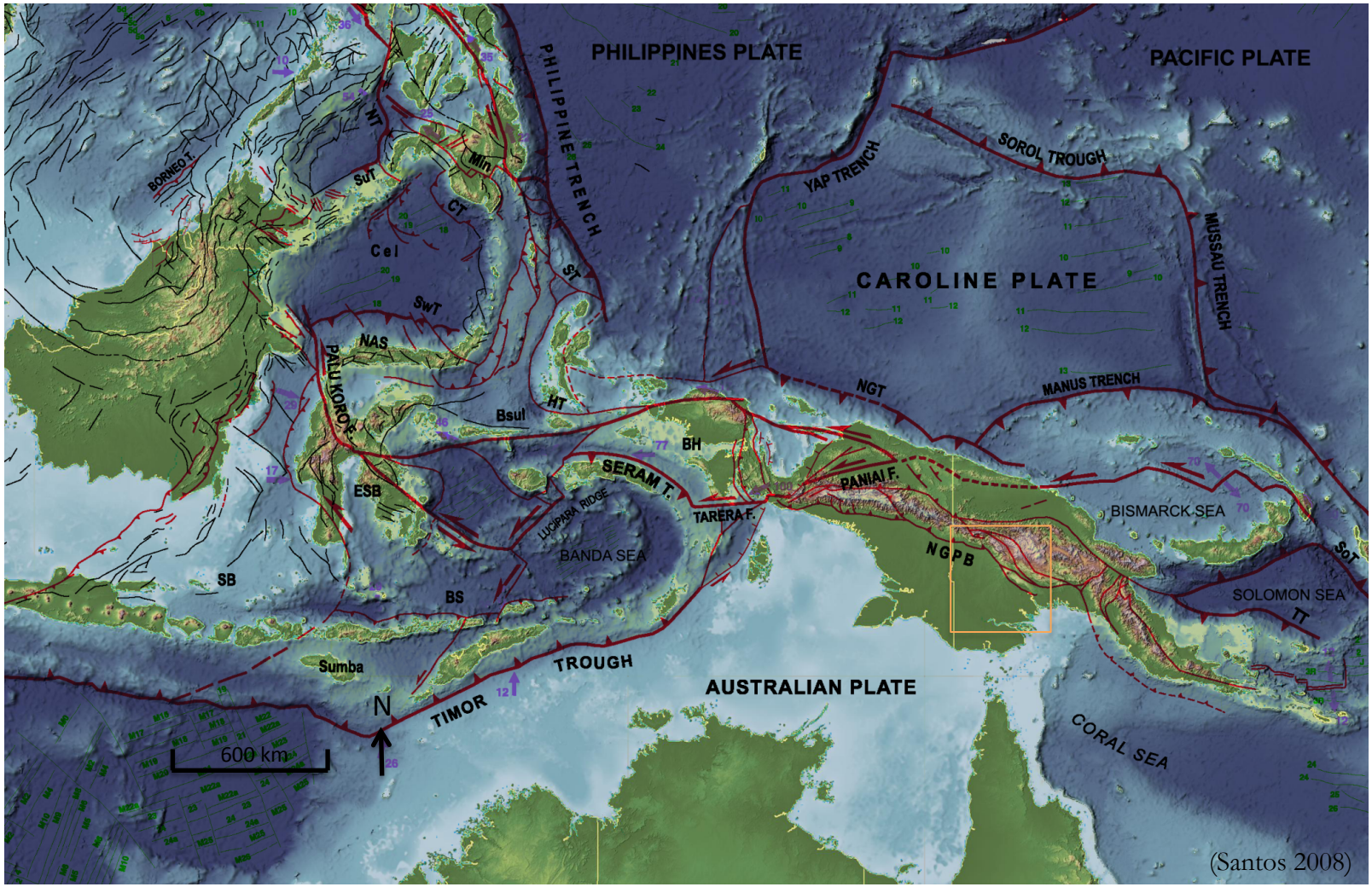
(Dennis et al., 2000)

Examples of Hydrodynamic effects on Trapping Styles

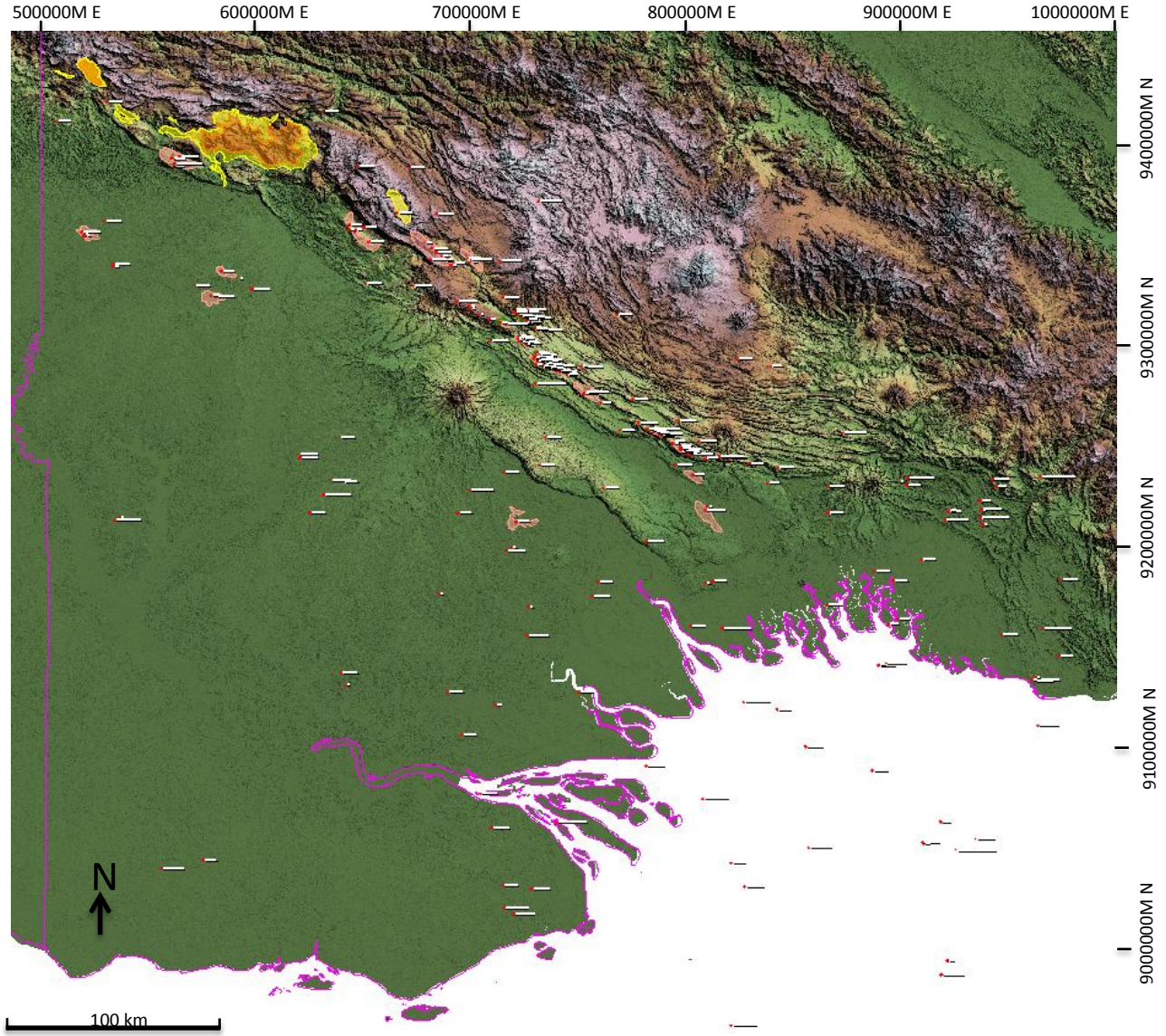


(Dennis et al., 2000)

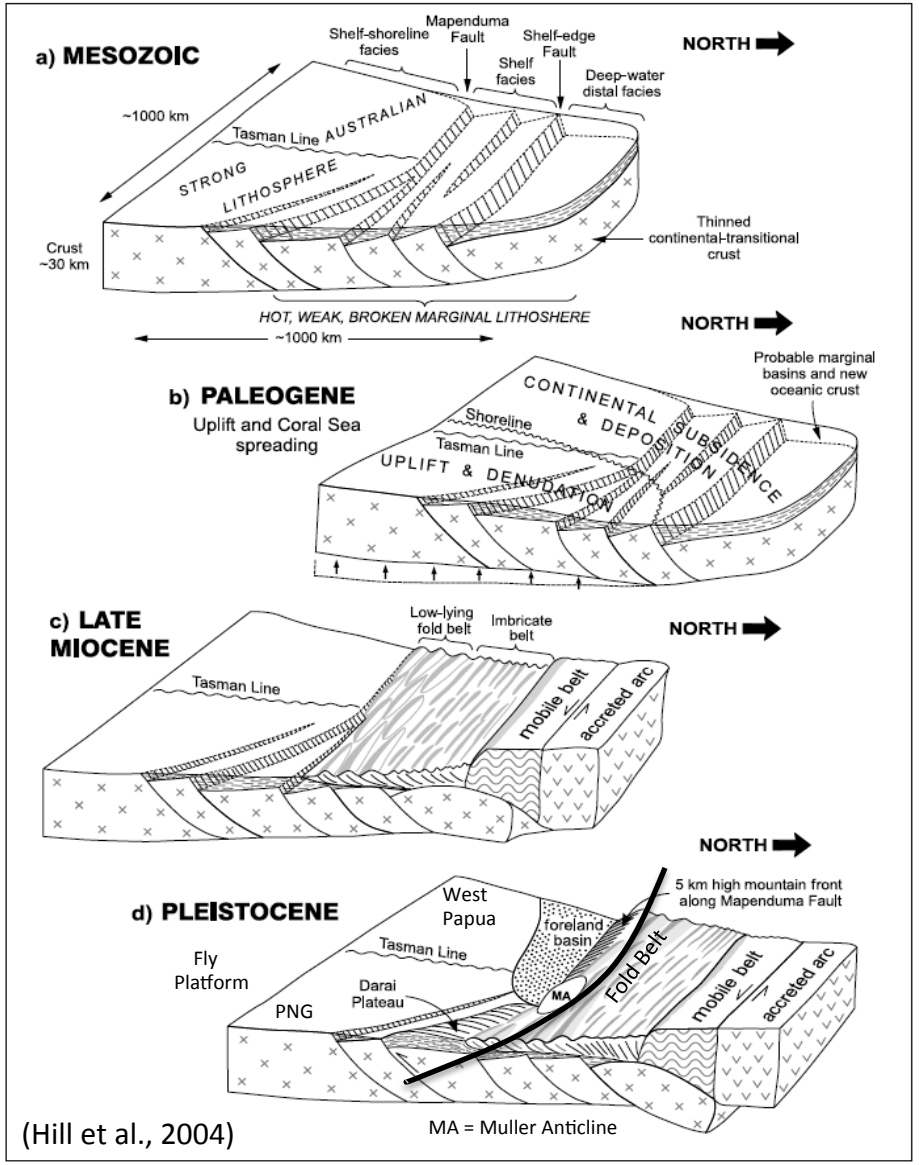
New Guinea - Papuan Basin



Papuan Basin

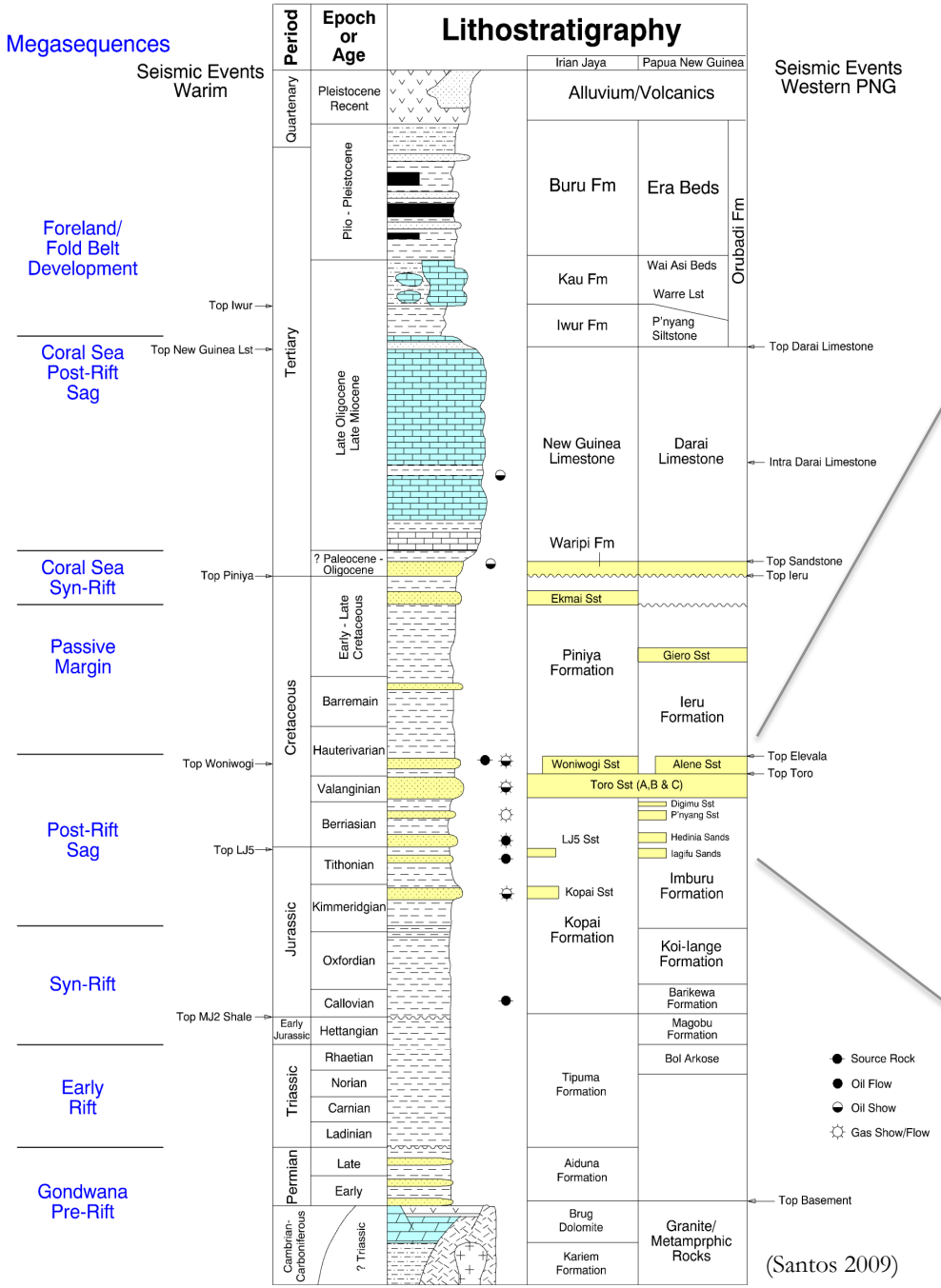


Schematic Tectonic model for the Evolution of the New Guinea Fold Belt

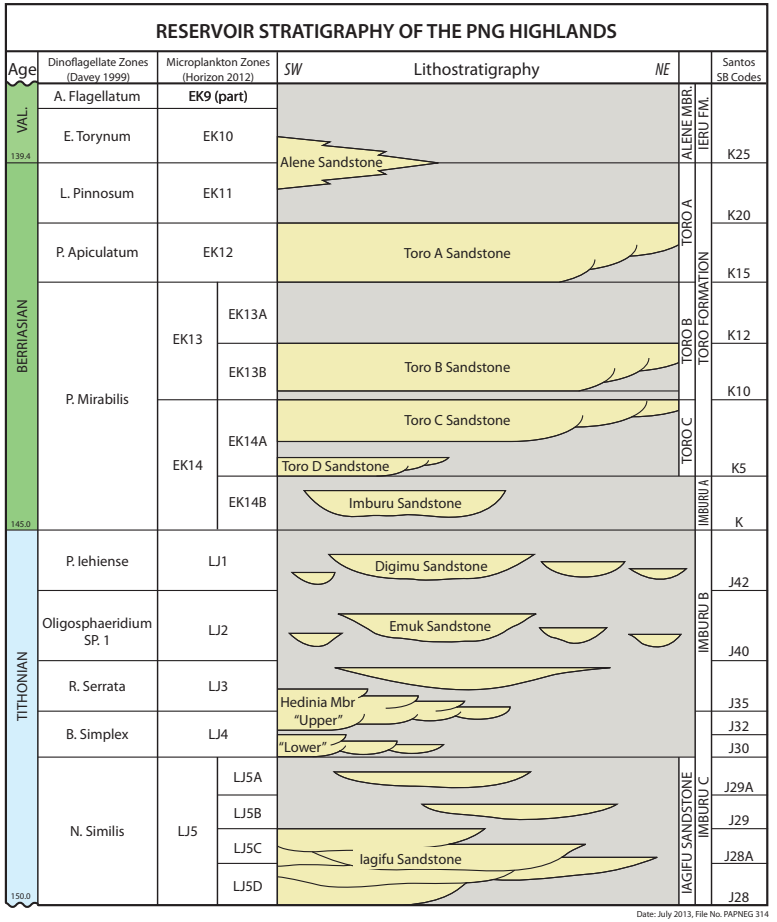


(Hill et al., 2004)

Papuan Basin - Lithostratigraphy

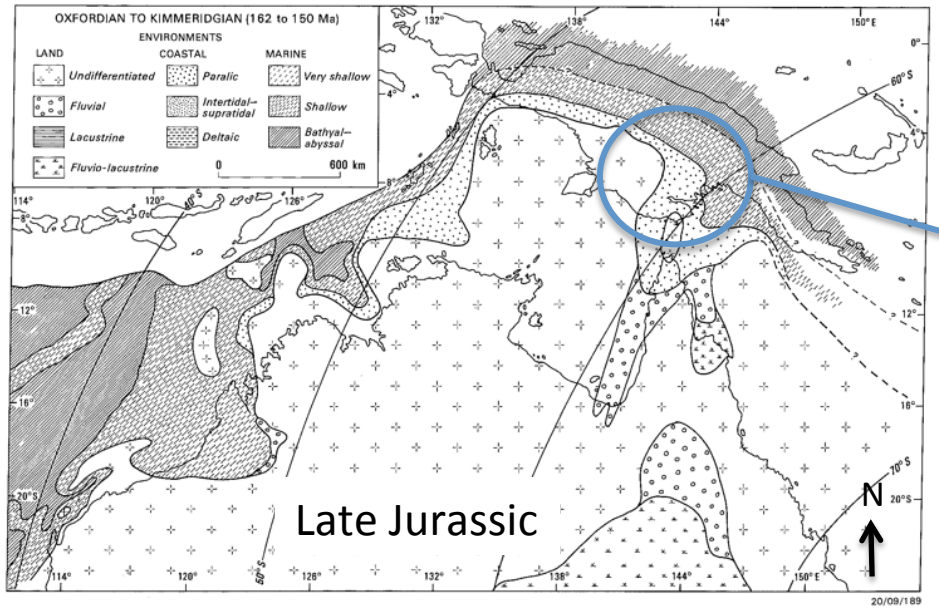


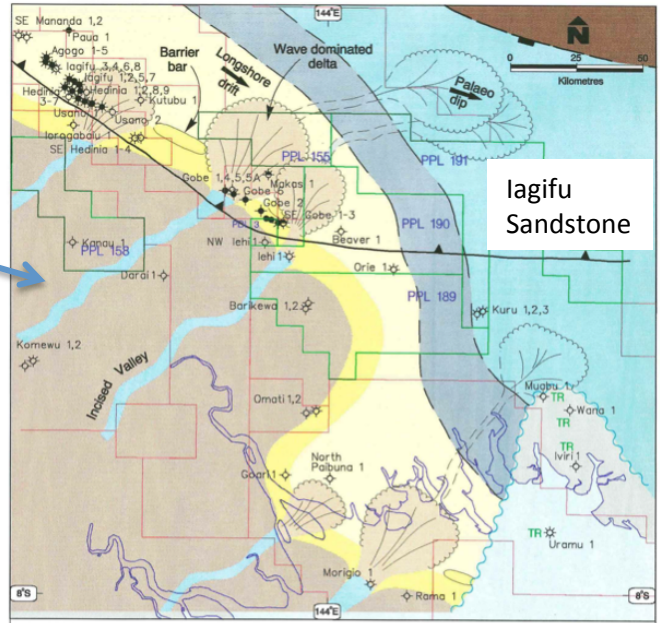
(Santos 2009)

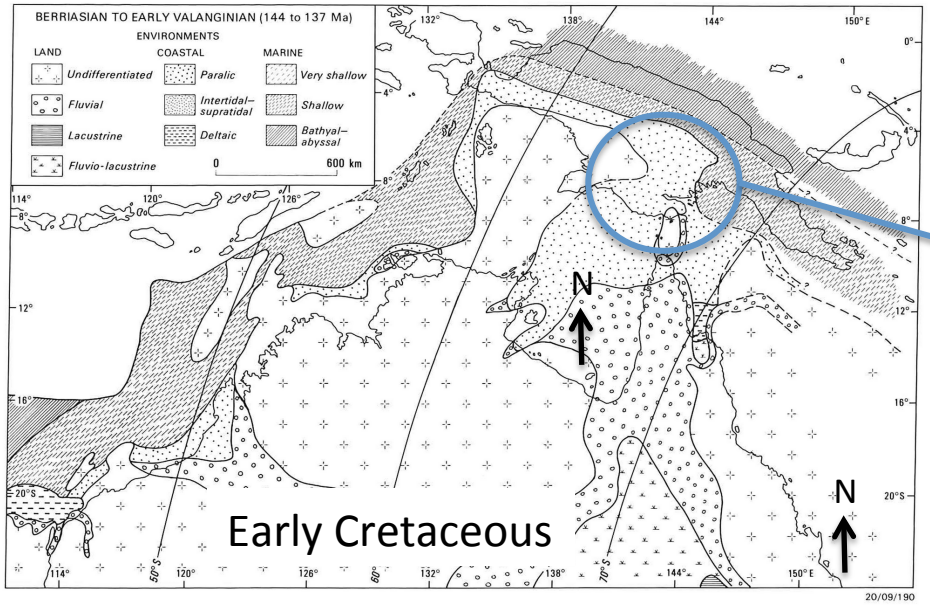


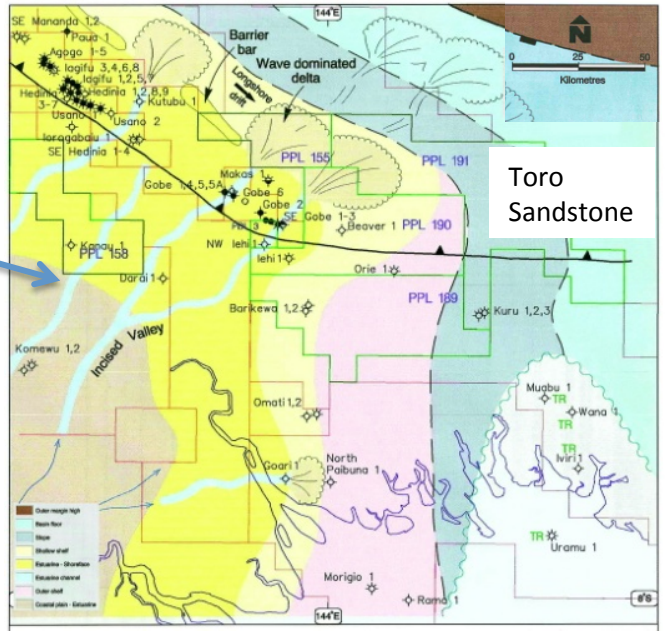
(Santos 2013)

Papuan Basin - Palaeogeography

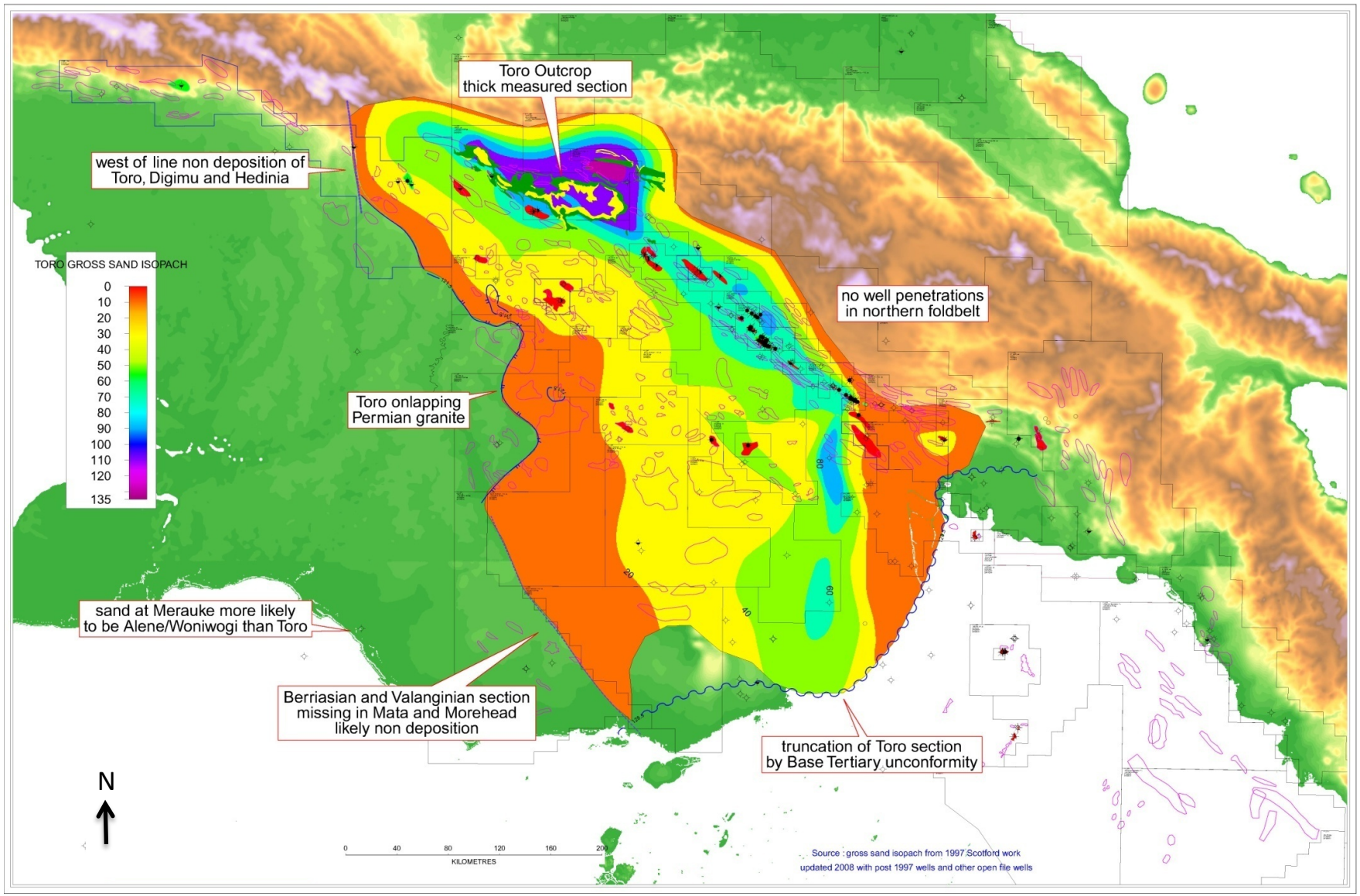




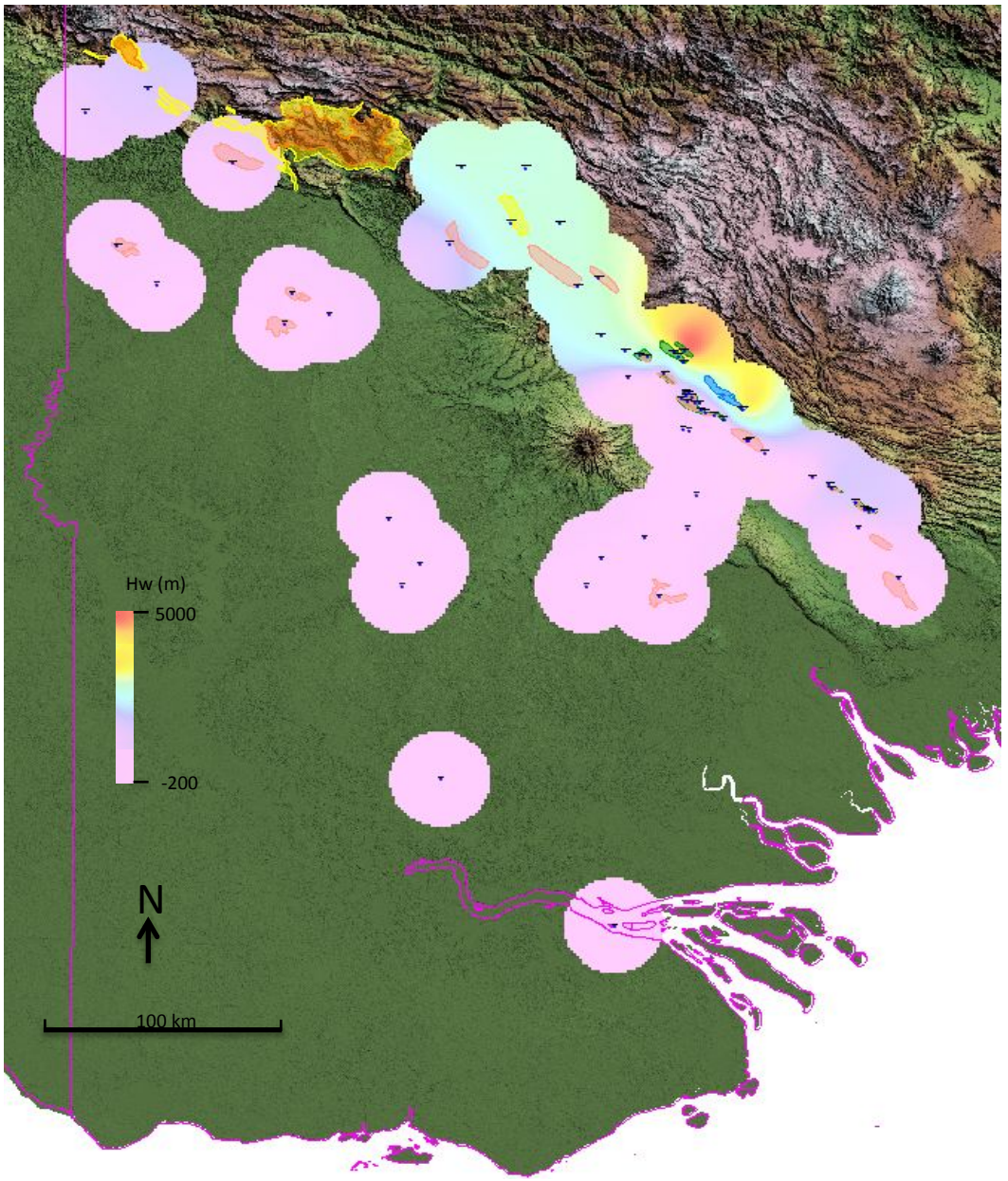




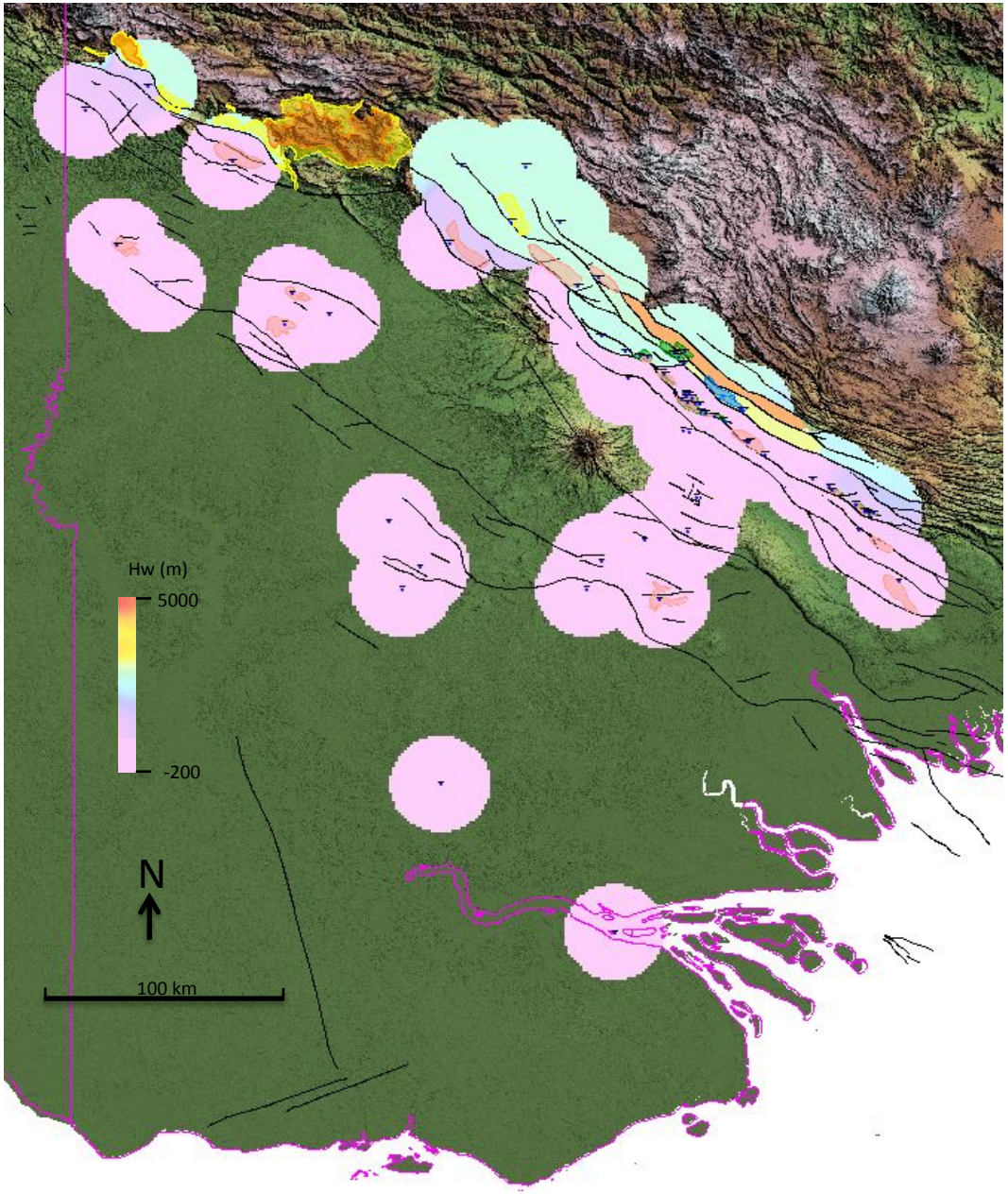
Toro Sandstone Distribution and Thickness



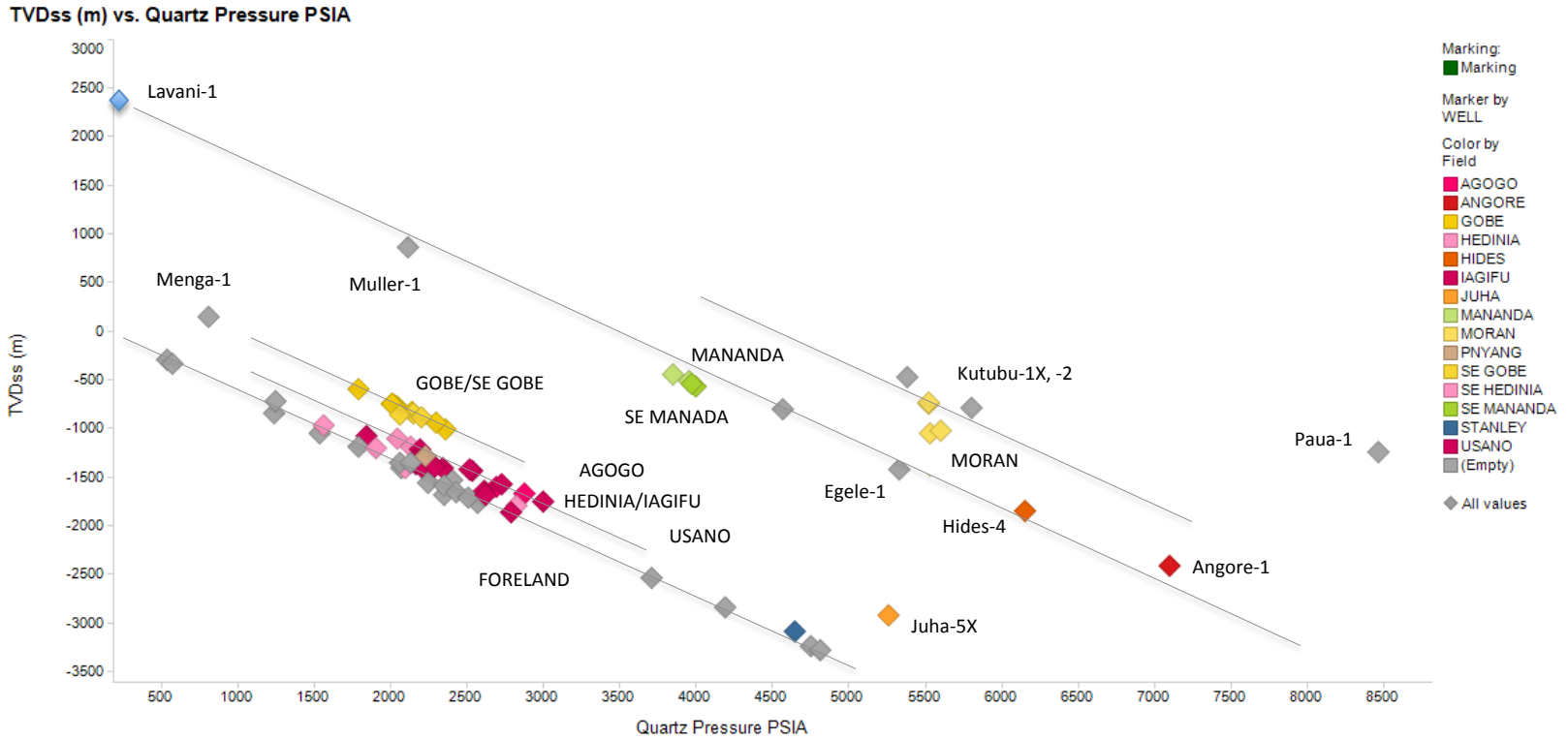
Regional Toro Potentiometric Map 1



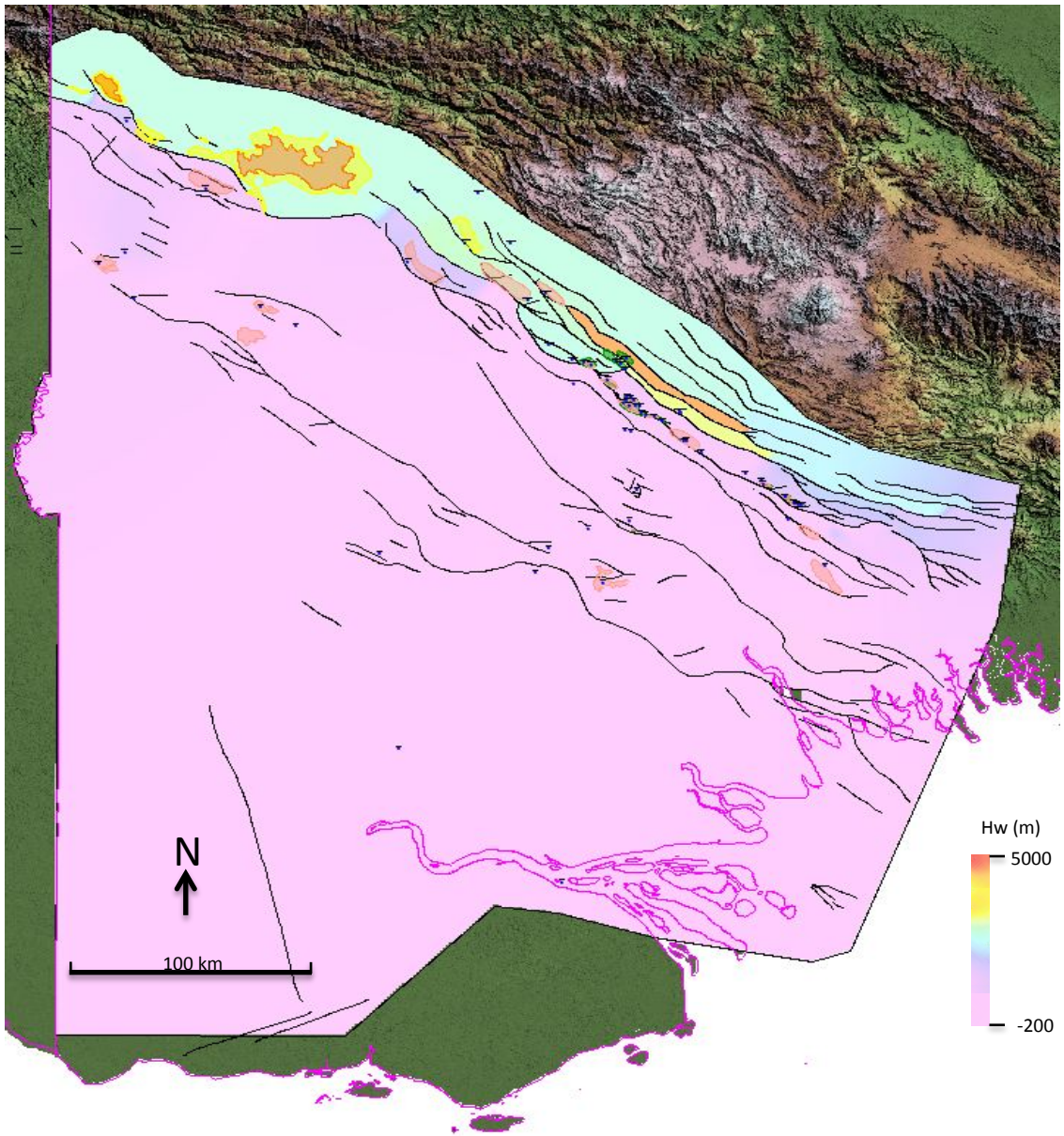
Regional Toro Potentiometric Map 2



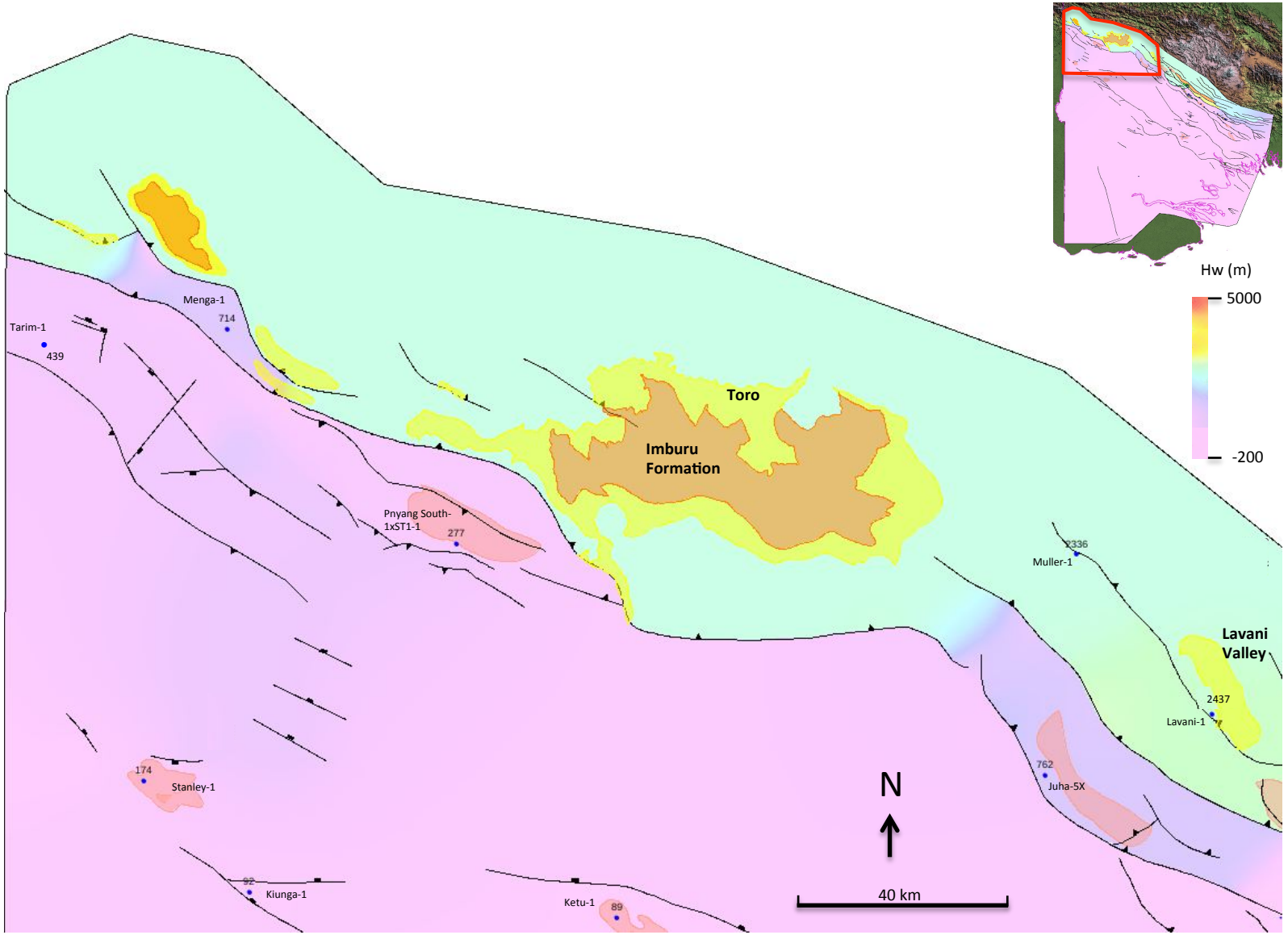
Regional Toro Aquifer Water Pressure Gradient Plot



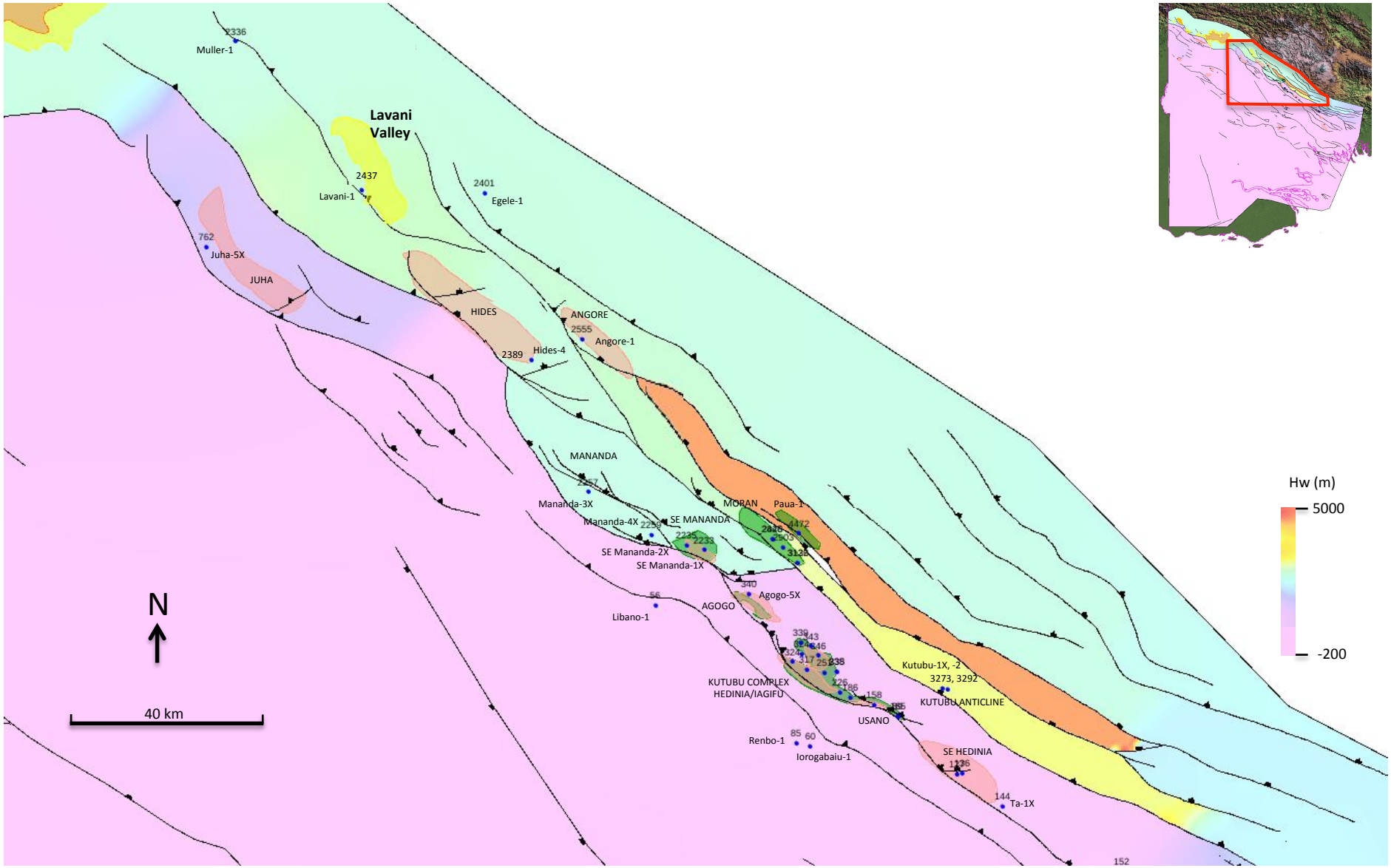
Regional Toro Potentiometric Map 3



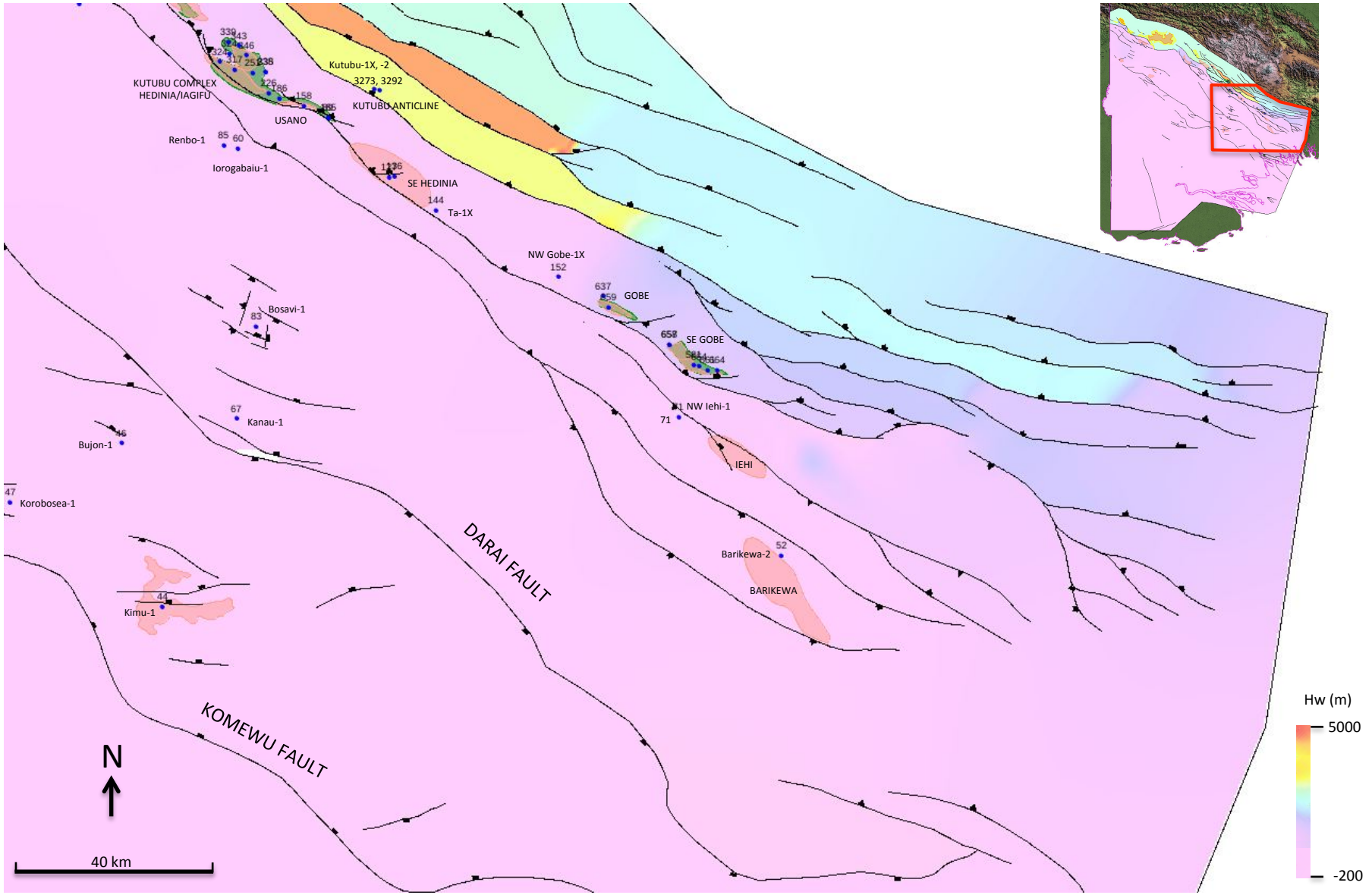
Regional Toro Potentiometric Map 3.1



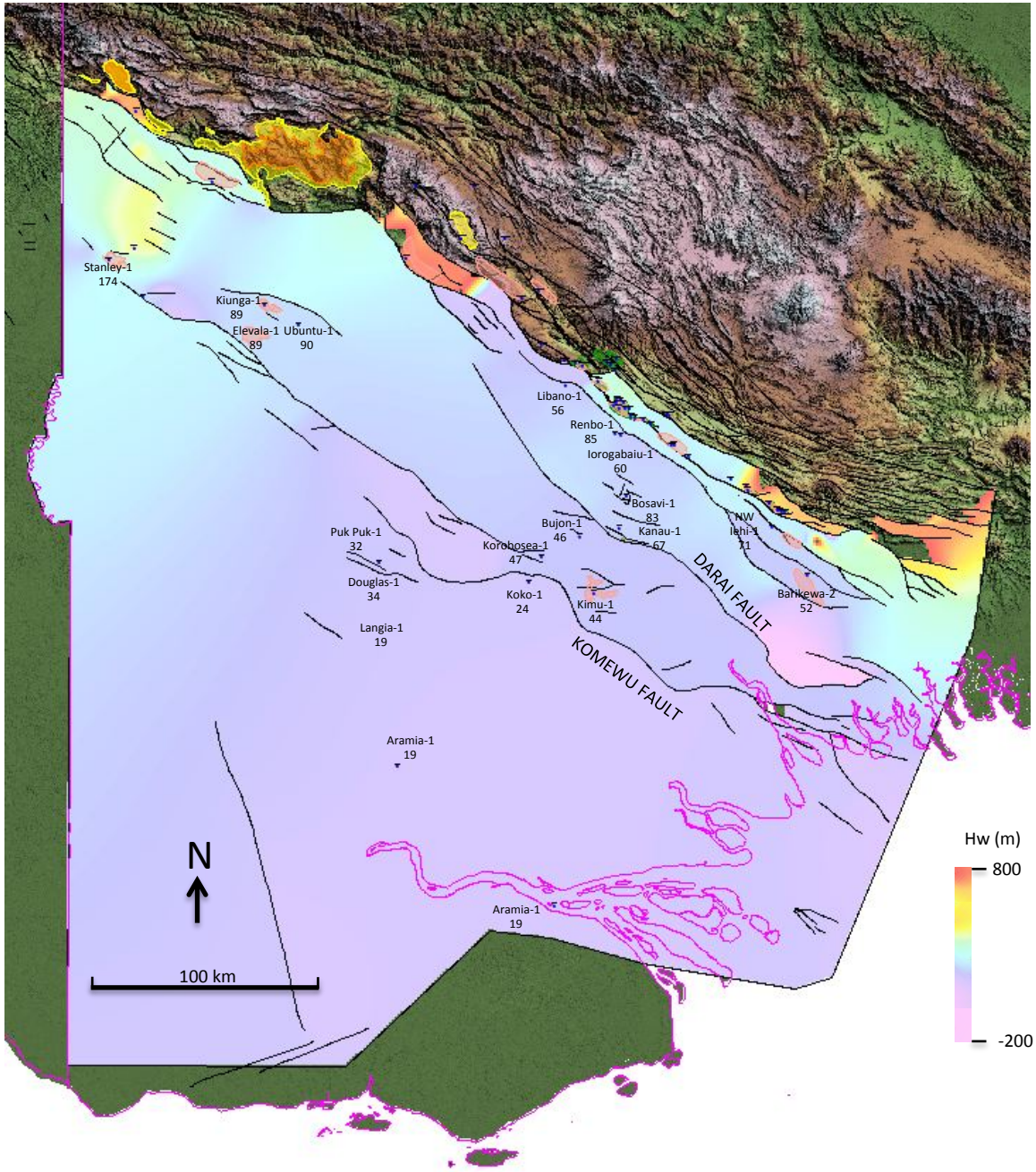
Regional Toro Potentiometric Map 3.2



Regional Toro Potentiometric Map 3.3



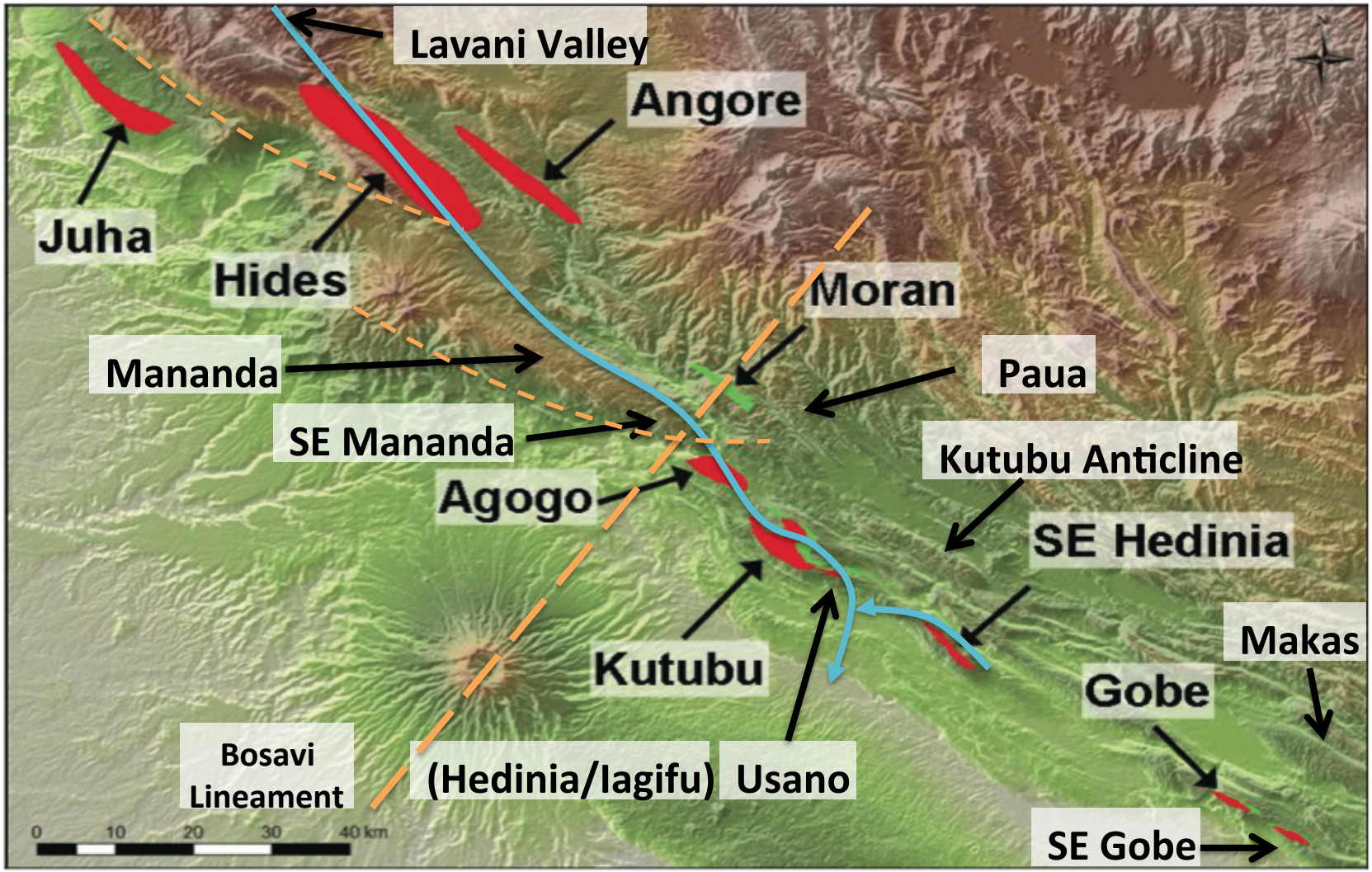
Regional Toro Potentiometric Map 3.4



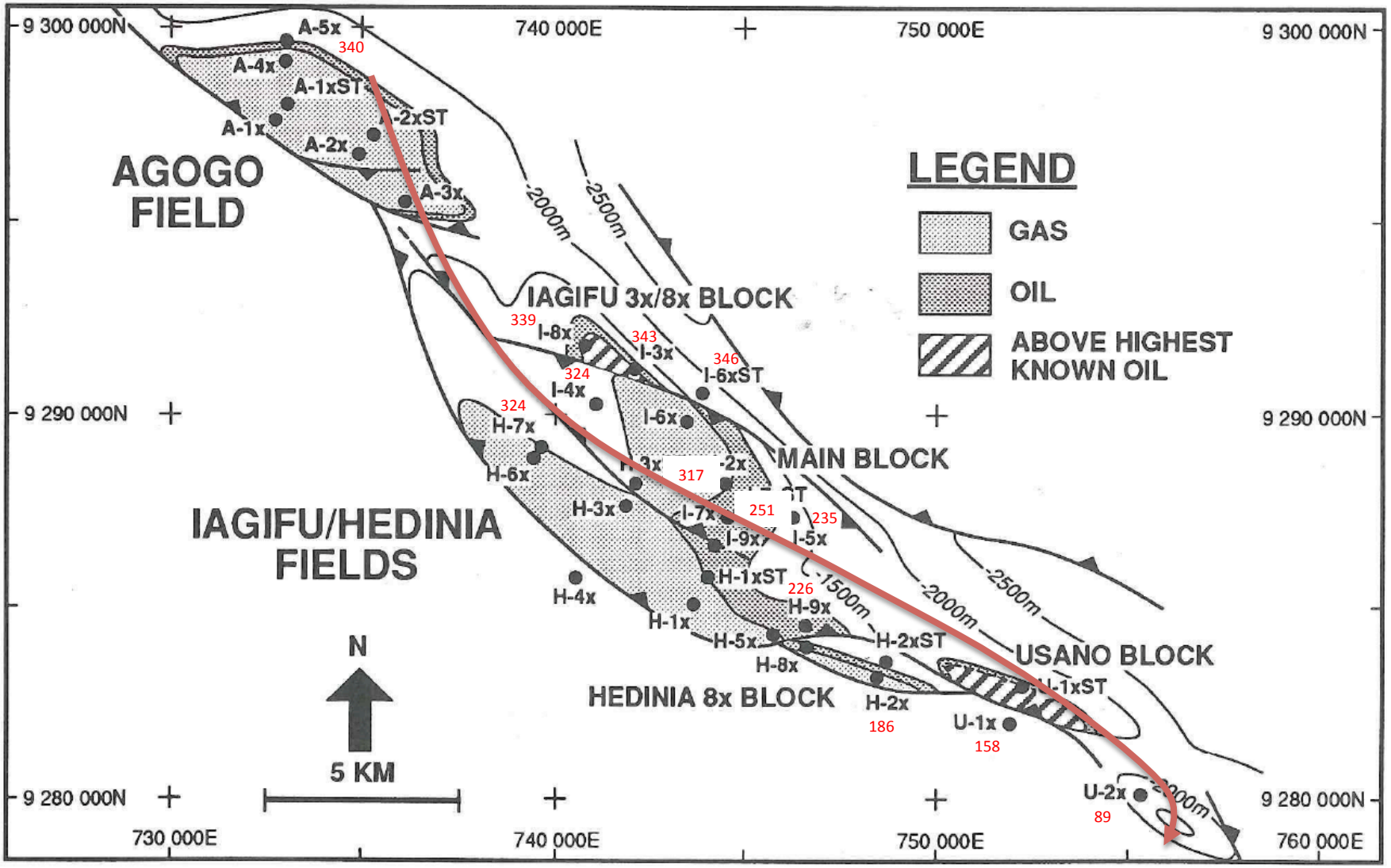
Toro Reservoir Findings

- Likely Toro recharge regions exist in the highlands at Lavani Valley and the Muller Anticline.
- Reasonable possibility of connected Highlands hydrodynamic Toro aquifer from Lavani Valley-Hides-Mananda/South East Mananda.
- Likelihood of significant compartmentalisation of Egele, Angore, Moran, Paua, Kutubu Anticline and Makas Anticline in the hinterland of the fold belt.
- Good evidence for hydrodynamic Toro aquifer in Agogo-Hedinia/Iagifu-Usano Fields (Kutubu Complex) NW-SE flow direction.
- Large hydraulic potential drop in Toro Aquifer between South East Mananda and Agogo: represents baffle in system?
- Evidence for hydrodynamic Toro aquifer in South East Hedinia Field SE-NW flow direction.
- Gobe/South East Gobe Fields likely compartmentalised hydrostatic Toro aquifer
- Likely Toro aquifer flow exit points from fold belt into foreland at southern end of Usano at Iorogabaui-1 and at southern end of South East Mananada Field at Libano-1 involving Bosavi Lineament.
- Likely NW to SE Toro aquifer flow in foreland region of basin from Stanley Field in NW to sea in SE. Komewu and Darai Fault systems providing control/barrier to Toro aquifer flow in NE top SW direction.

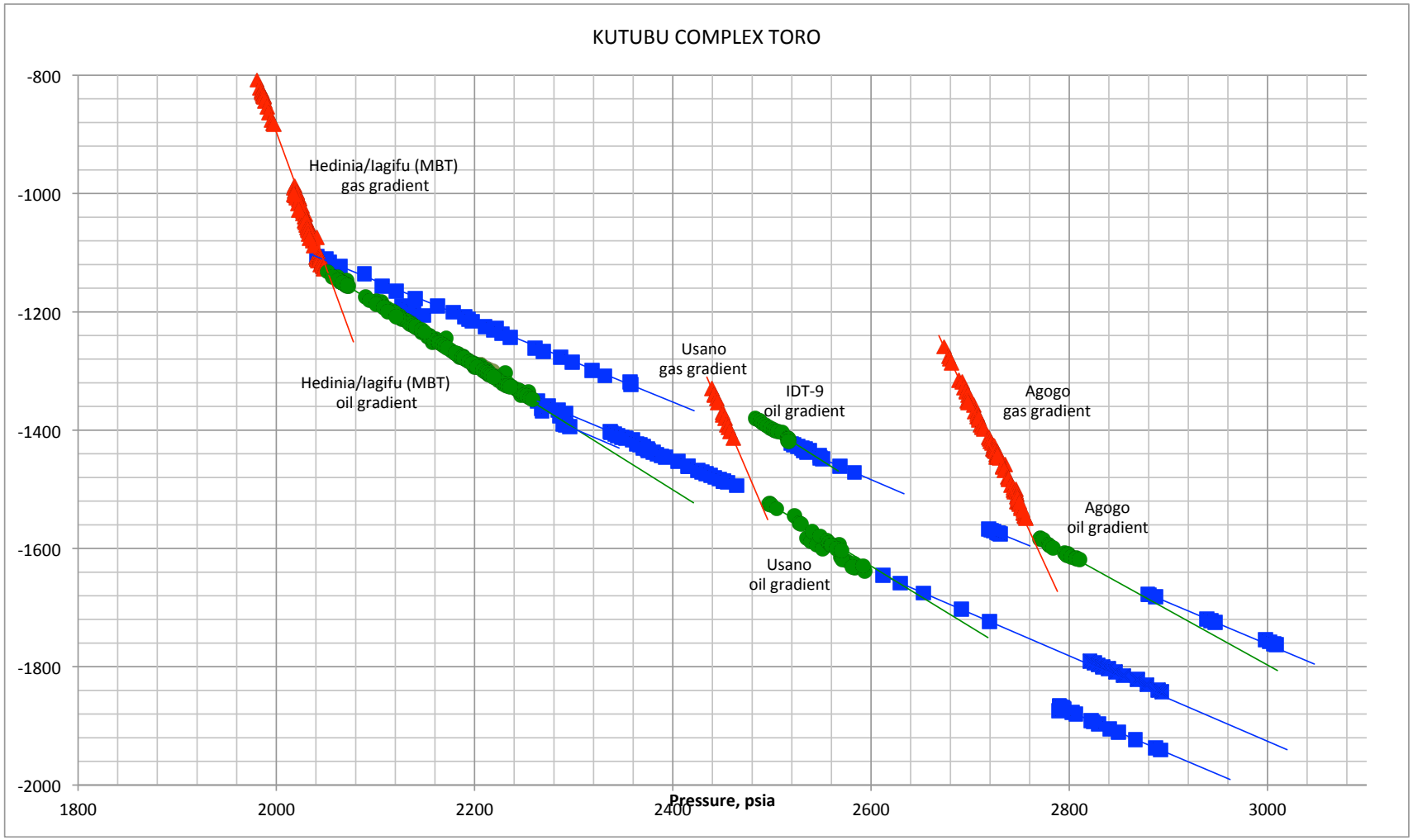
Regional Toro Hydrodynamic Aquifer Model



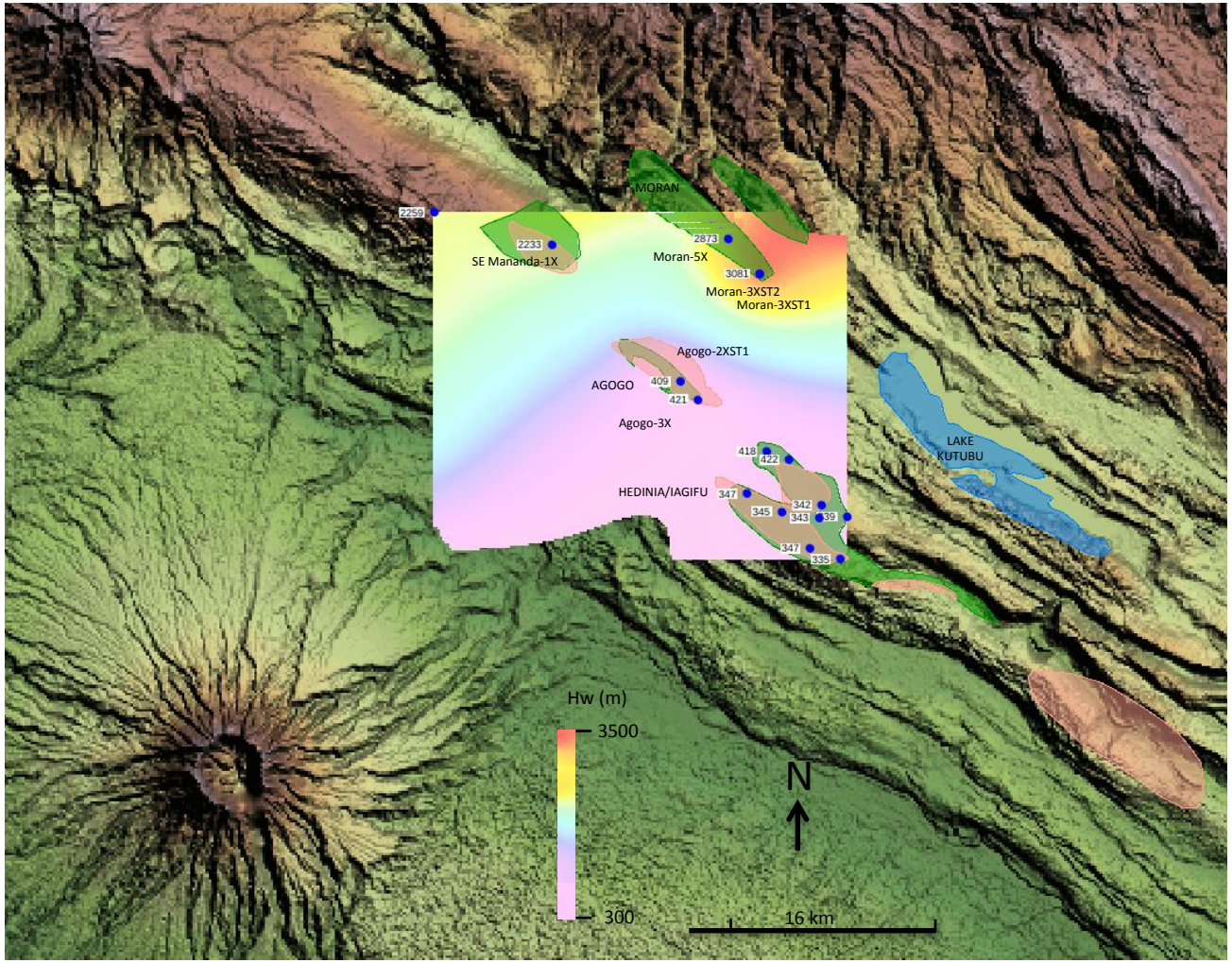
Potentiometric Map for Kutubu Complex - Toro Reservoir



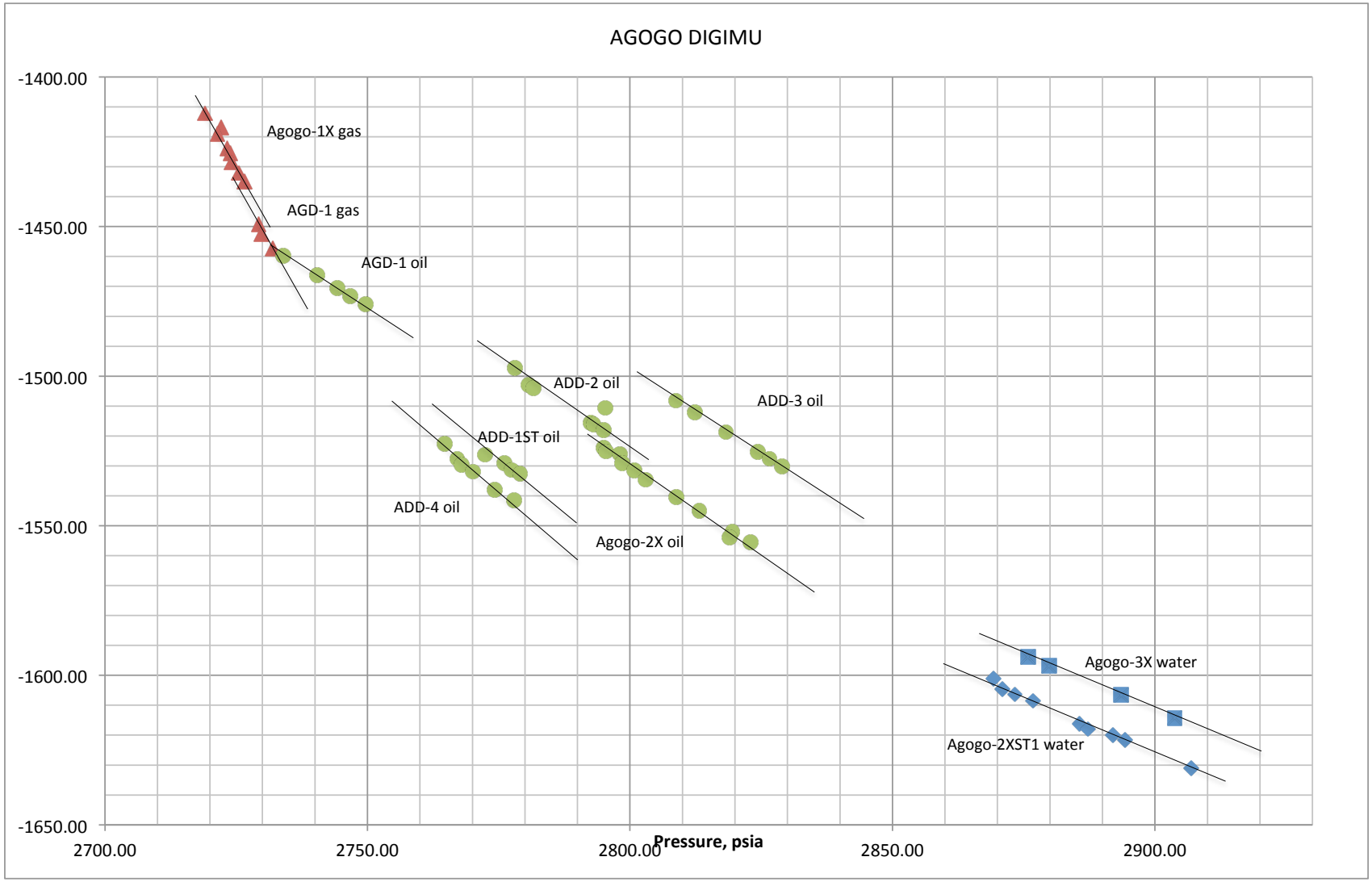
Kutubu Complex Toro Reservoir P-D Plot



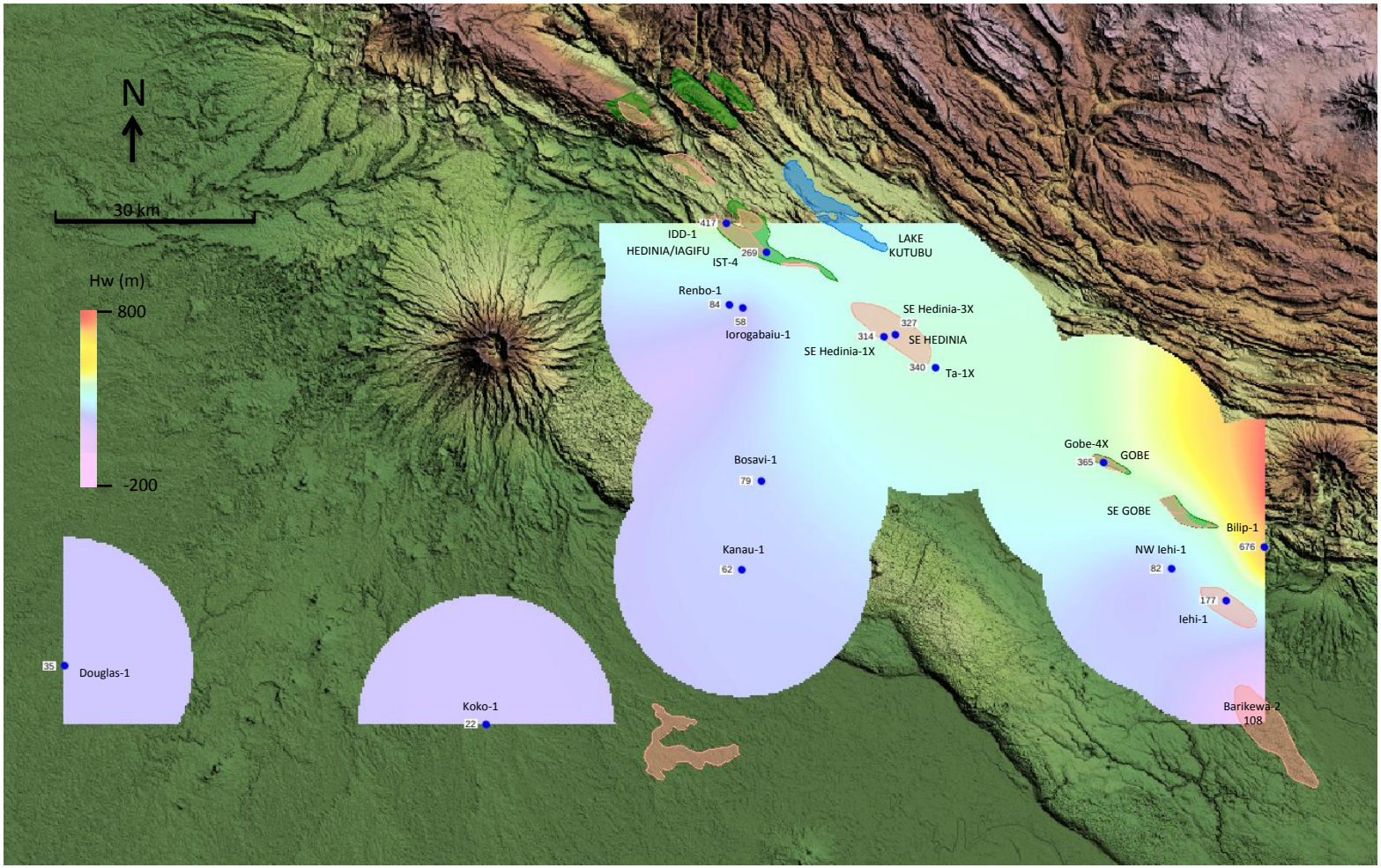
Regional Digimu Potentiometric Map



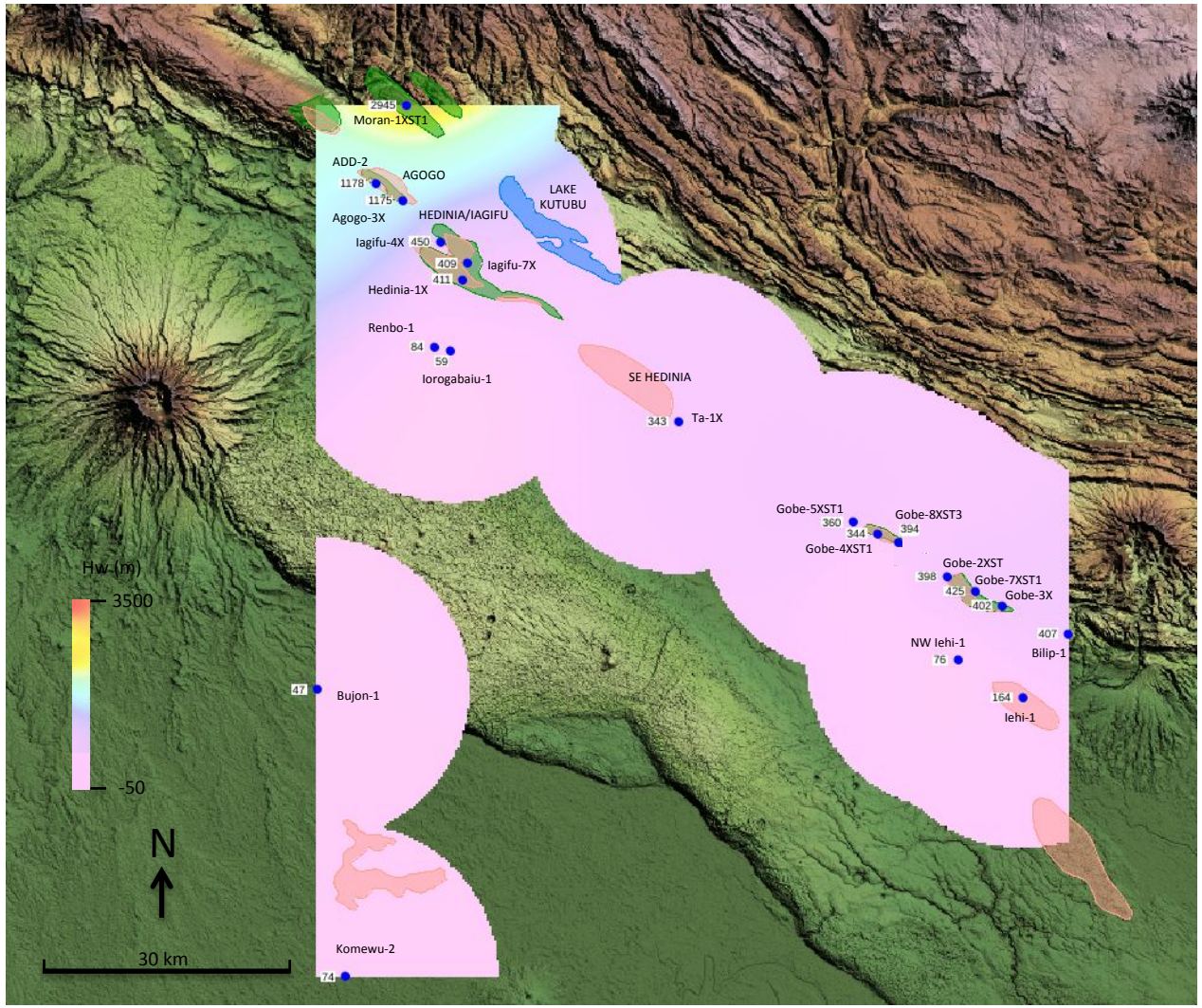
Agogo Field Digimu Reservoir P-D Plot



Regional Hedinia Potentiometric Map



Regional Iagifu Potentiometric Map



Imburu Formation Findings

- Digimu: - No hydrodynamic aquifer in Hedinia/Iagifu Fields?
  - Compartmentalised Agogo Field
  - HC reservoir for Moran Field (compartmentalised aquifer)

- Hedinia: - Limited data, but suggest hydrodynamic aquifer in Hedinia/ Iagifu Fields
  - Hydrodynamic aquifer in SE Hedinia Field?

- Iagifu: - Limited data, but suggest hydrodynamic aquifer in Hedinia/ Iagifu Fields
  - Significant Hw step between Agogo and Hedinia/Iagifu Fields
  - Main HC reservoir for Gobe/SE Gobe Fields (compartmentalised aquifer)

Conclusions

- Extended previous regional studies (Eisenberg, 1993; Eisenberg et al., 1994; Kotaka, 1996). Created up to date comprehensive data set that can now be used for detailed hydrogeology studies.

- Need to generate potentiometric surface elevation maps with top formation maps superimposed, to determine potential hydrodynamic trapping locations

- Limitations on identifying hydrodynamic versus compartmentalised aquifer systems include insufficient well data (outside of Kutubu Complex) and relatively poor delineation of faults and stratigraphic barriers to aquifer flow.

- Formation water chemistry analyses could be used to determine connectivity of reservoirs in fold belt to help identify hydrodynamic versus compartmentalised systems.