PSIntegration of Dynamic Data into Characterization of the Tengiz Reservoir: Tengiz Slope*

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Abstract

The Tengiz reservoir, located on eastern shore of the Caspian Sea in the Republic of Kazakhstan, is an isolated carbonate buildup with a mesa-like geometry containing a flat-topped platform and steep slope. The platform is relatively unfractured, while the slope, largely made up of boundstones, is significantly fractured.

Proper fracture characterization and a good understanding of the fracture-matrix system are critical to properly predict oil recovery from naturally fractured reservoirs.

Wellbore-fracture data is constrained through a combination of both static and dynamic data, such as image logs, Stoneley-reflectivity, photoelectric curve (PEF), caliper logs, and PLT spikes, and lost circulation data respectively. PTT data has allowed us to confirm dual-porosity pressure transient behavior and has been a critical dataset to help constrain estimates of fracture porosity, fracture density, and the matrix-fracture transfer function. Pulse tests provide insights into the connectivity of the fracture system between the wells and between field regions.

Observation of the pulse test data shows different types of heterogeneity in Tengiz with very high connectivity over long distances in slope and poor communication between platform and slope.

Review of the historical static pressure data indicated that there are several distinct pressure regions within the Tengiz Field. The low transmissibility boundaries between these regions are very consistent with the pulse test results indicating very low diffusivity.

Observation of MDT and static pressure data indicates passive depletion of Unit 2/3 platform by connection to Unit1 production through the Unit 2/3 slope fracture network. In addition, pressure monitoring of distal wells also showed passive depletion, which suggests that Tengiz acts as a single reservoir over geologic time with all units in pressure communication.

The topic of this discussion will be the role of the fractures in the reservoir management and on-going reservoir & fracture characterization efforts (through data integration of the previously mentioned data sources) in building of more realistic simulation model. This work will discuss the role of integrating static, dynamic, and engineering data to properly characterize the Tengiz field.

We will illustrate how various static and dynamic data will be incorporated into the P10 P50 P90 model.

Lessons Learned

- The large variety of independent source data and multi-disciplinary teamwork improved the characterization and modeling of the reservoir.

Best Practices

- The Use of different static and dynamic data in combination improved reservoir characterization and helped in building realistic simulation model
- A fit-for-purpose monitoring model with nested grid refinement is developed to properly incorporate scale-dependant dynamic reservoir data.

Challenges

- Limitation of technology and techniques does not allow to directly incorporate dynamic data into the model.
- Due to the large grid size of the geologic model & simulation model (250m x 250m) certain dynamic data (RST, tracer, Pulse test) cannot be input directly into the full-field models because of scale differences between the data and grid system.
- Integration of all data sources improved the teams understanding of the complex nature of the reservoir architecture.

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Lessons Learned

- Multi-disciplinary team work using a large variety of independent sources of well data improved the characterization and development of the reservoir.

Best Practices

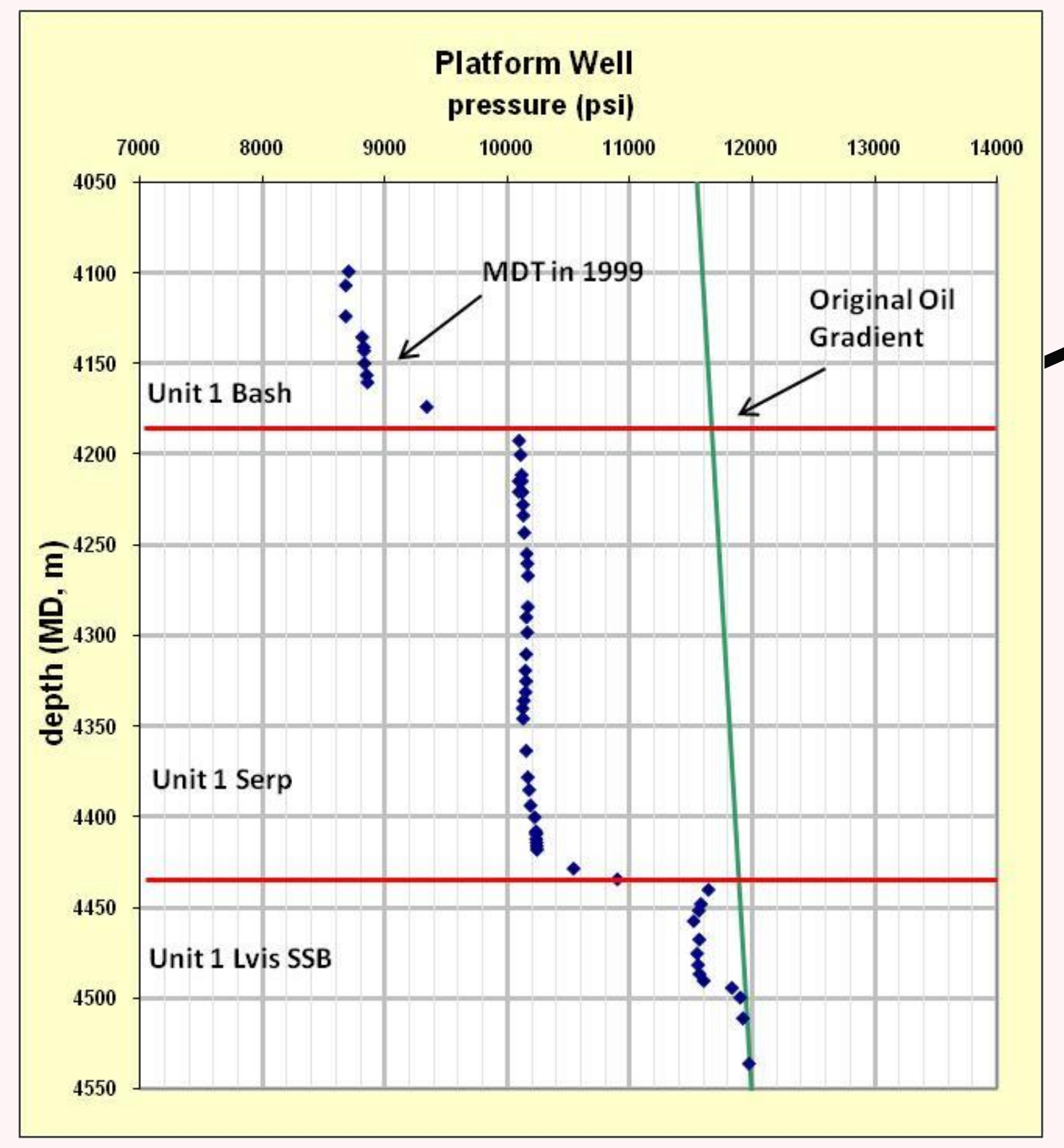
- The use of different static and dynamic data in combination improved reservoir characterization and helped in building realistic simulation model
- A fit-for-purpose monitoring model with nested grid refinement has been developed to properly incorporate scale-dependant dynamic reservoir data.
- Integration of all data sources improved the teams understanding of the complex nature of the reservoir architecture.

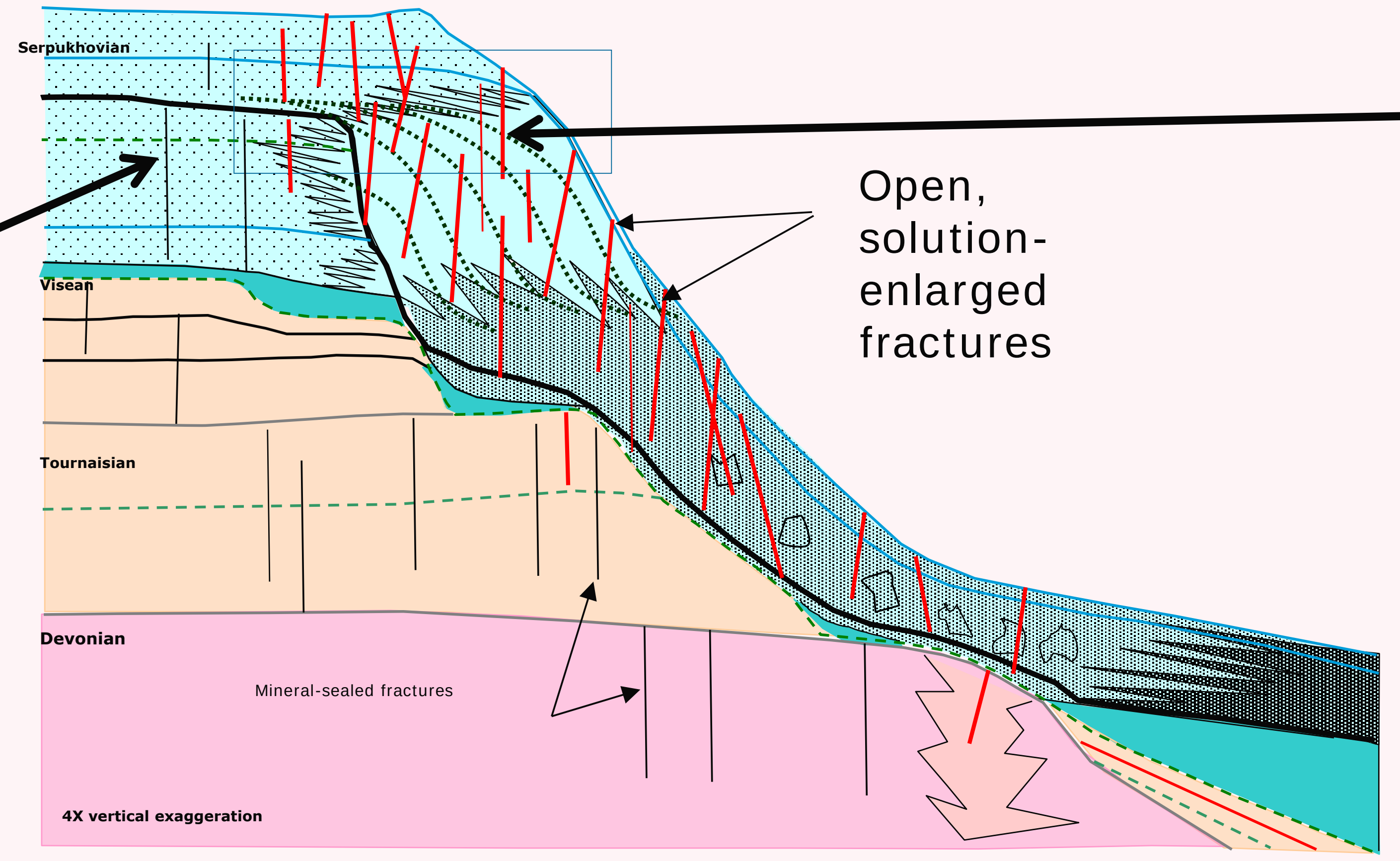
Challenges

- Limitation of technology, techniques and schedule does not currently allow for direct incorporation of all dynamic data into the static model.
- Certain dynamic data (RST, tracer, pulse tests) cannot be input directly into the full-field models because of scale differences between the data and grid system.

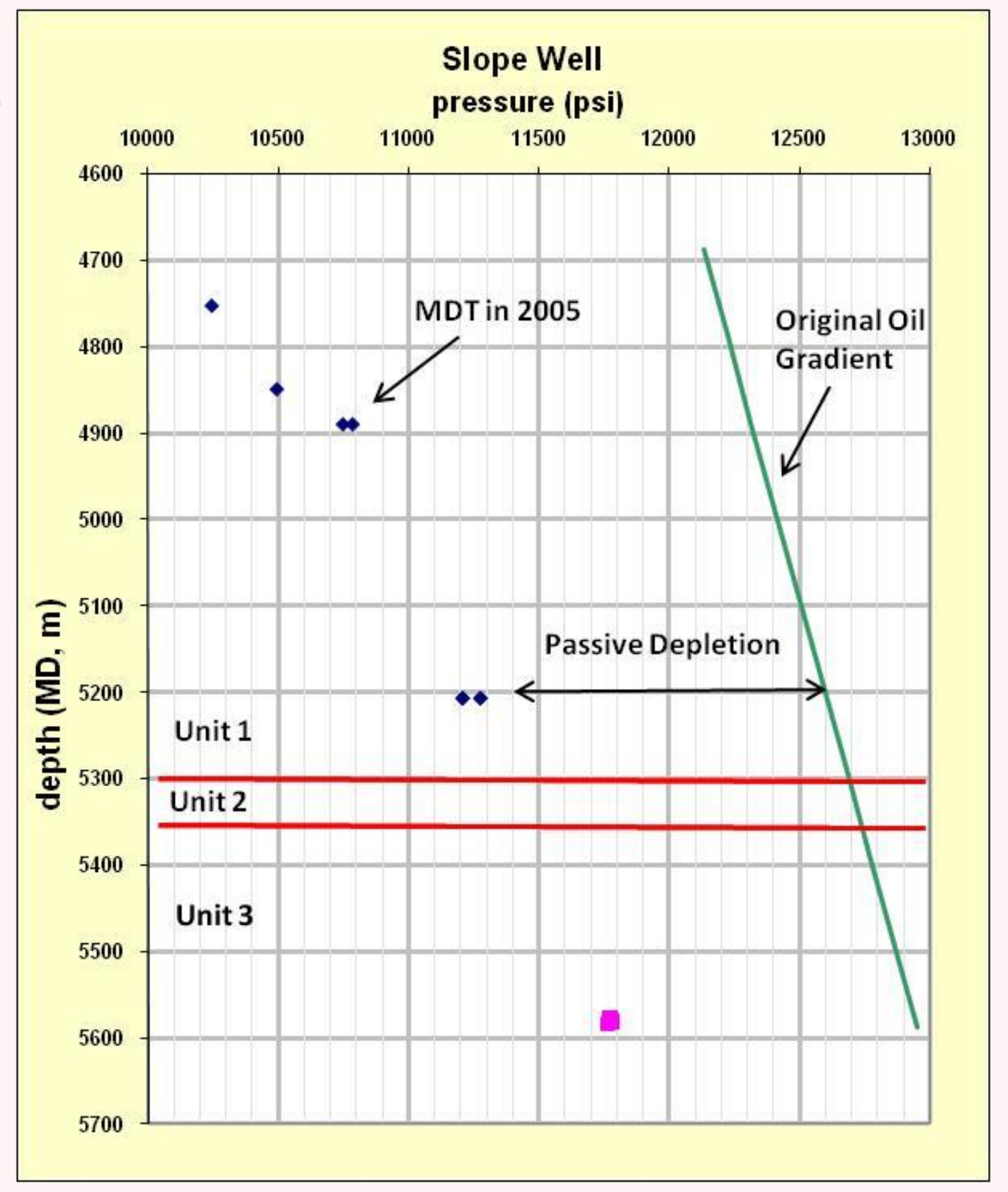
1 Introduction to Tengiz Slope

Significant barriers to vertical flow in Platform





High kv in Slope due to fractures



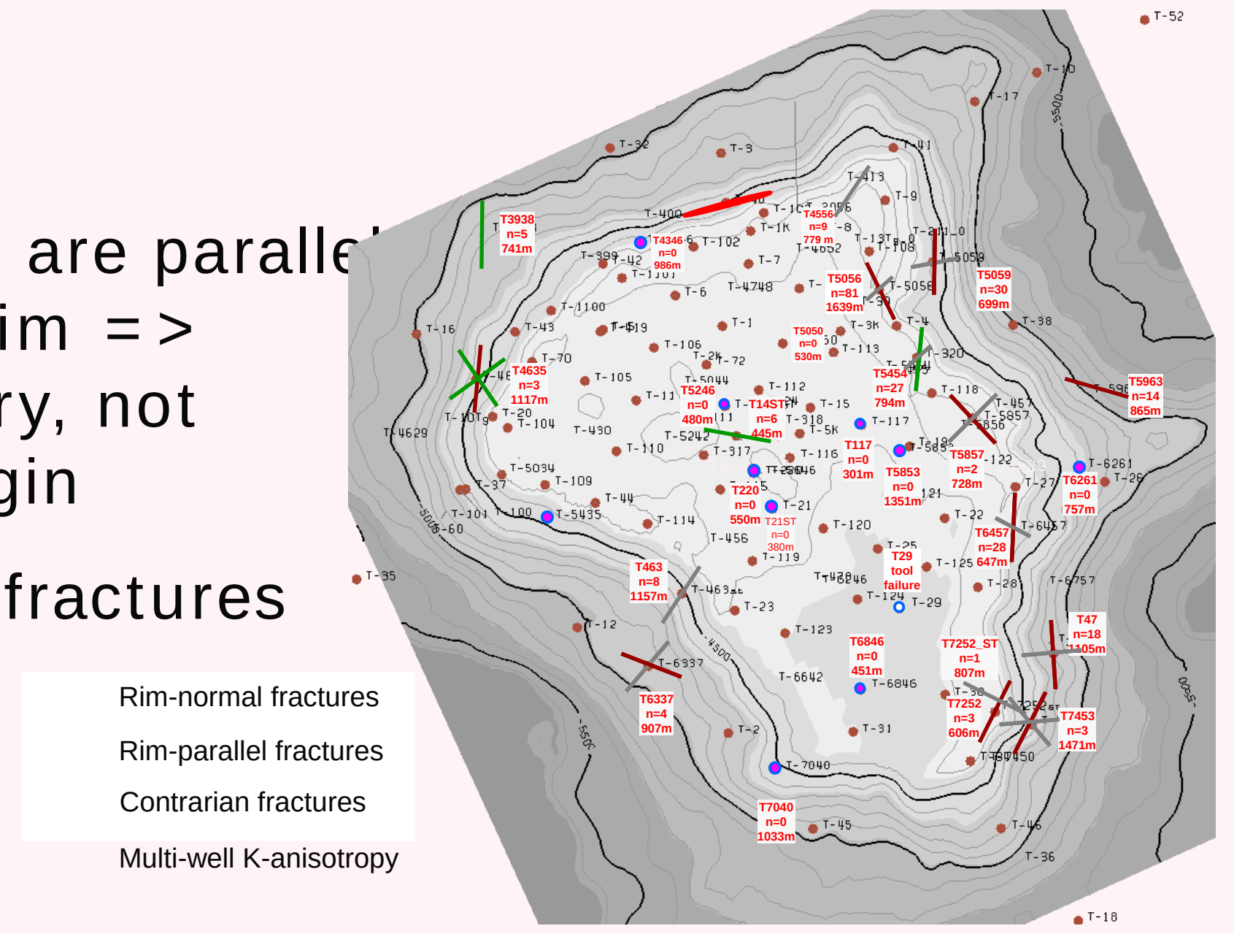
- Tengiz is an isolated Devonian-Carboniferous carbonate platform
- Structure - flat topped (Platform) and steep sided (Margin & Slope)
- Margin and Slope - Low porosity highly fractured
- Platform with good matrix porosity – relatively unfractured
- Most fractures are located in the Serpukhovian and act as a conduits for fluid transport.
- Most wells produce from in Unit 1 and a few wells from Unit2
- Passive Depletion of Units 2 and 3 through Unit 1 Fractures

Fracture Orientation

Fractures control flow in the slope

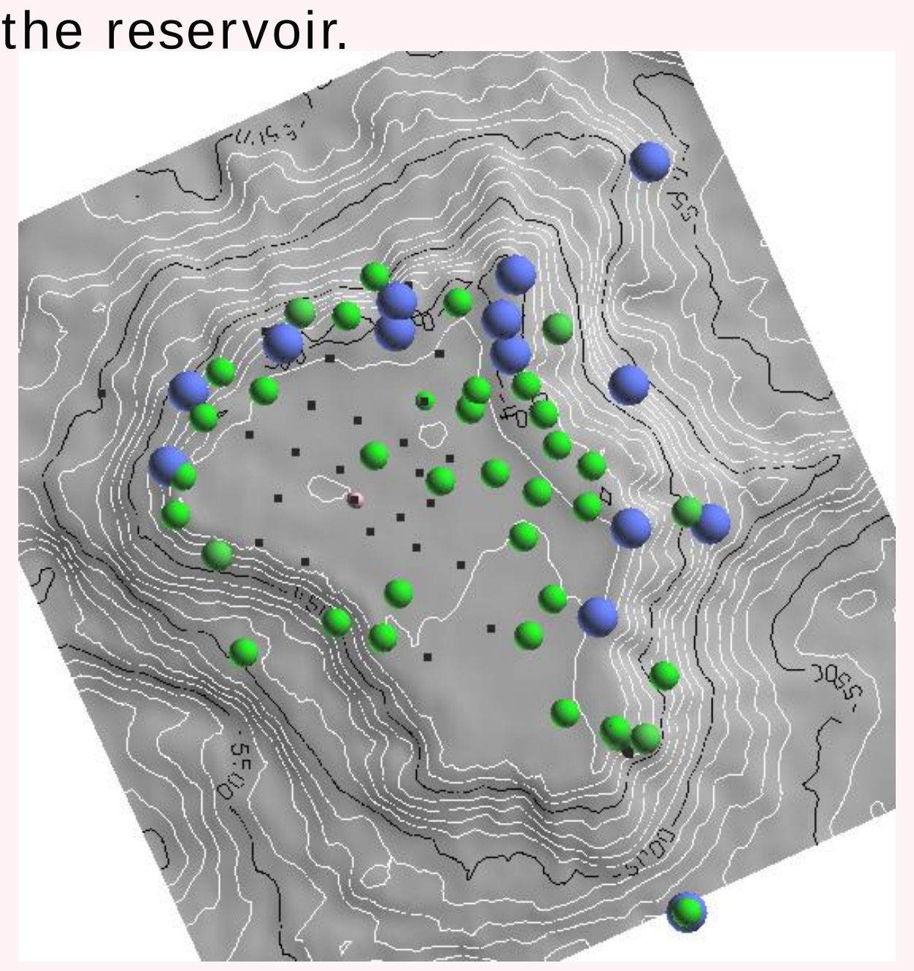
Most fractures are paralle or normal to rim => synsedimentary, not tectonic in origin

Platform: few fractures



Lost Circulation Map

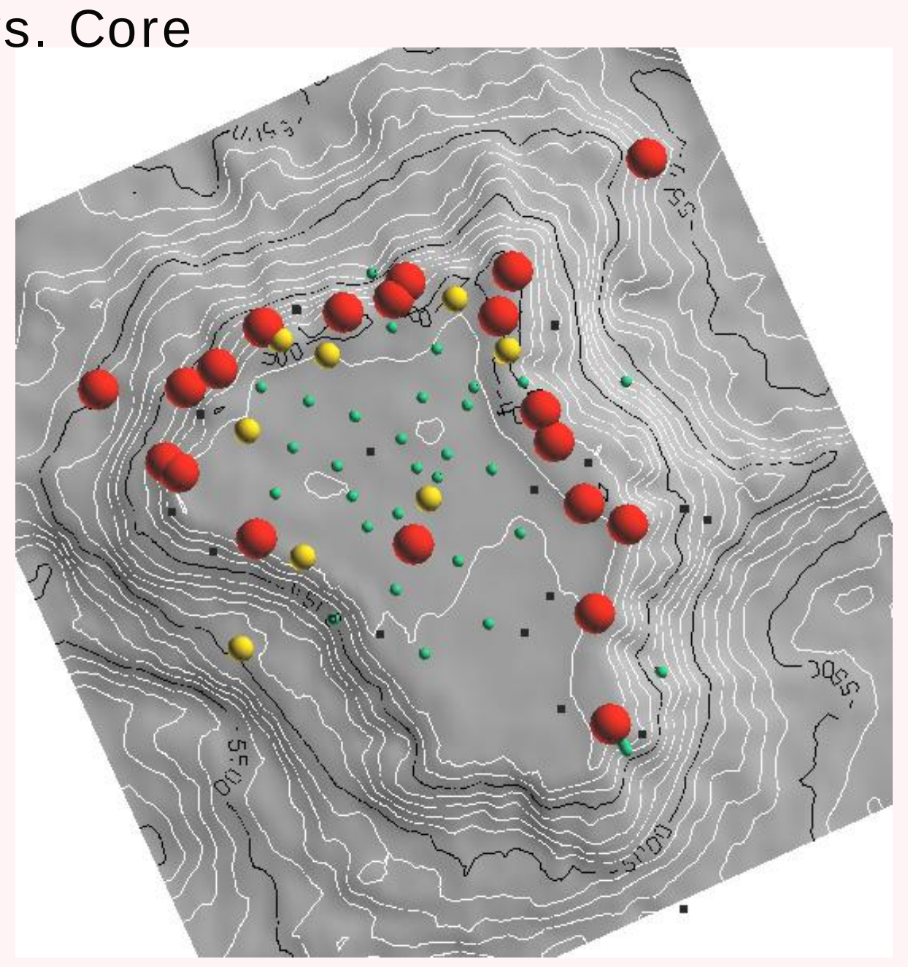
Severe lost circulation occurs in the outer platform and slope of the reservoir.



Lost Circulation
- ● Moderate
- ● Strong

Flow Capacity Index Map

High FCI values in the outer platform and slope: Well test vs. Core

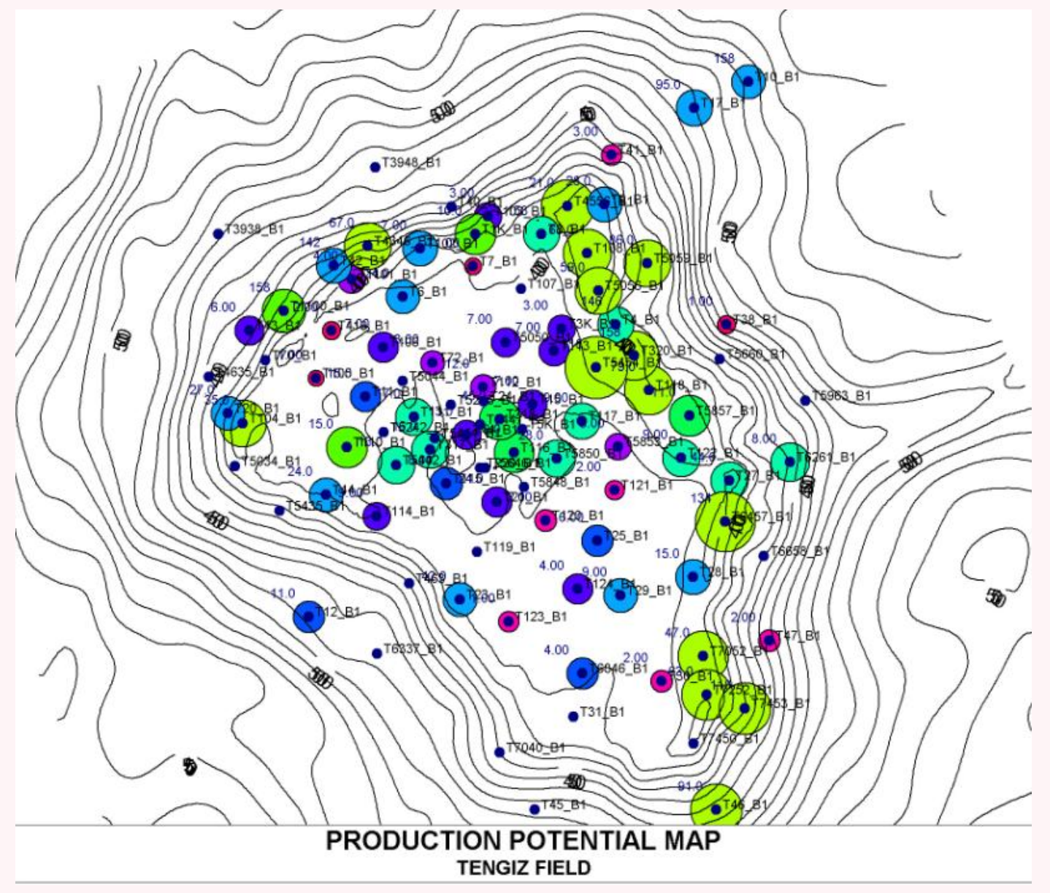


$$FCI = \frac{Kh_{well}}{Kh_{core}}$$

Flow Capacity Index
- ● $0 \le FCI < 3$ Flow ≈ predicted
- ● $3 \le FCI < 10$ Flow > predicted
- ● $10 \le FCI$ Flow >> predicted

Production Potential Map

Most productive wells are located in the rim and slope

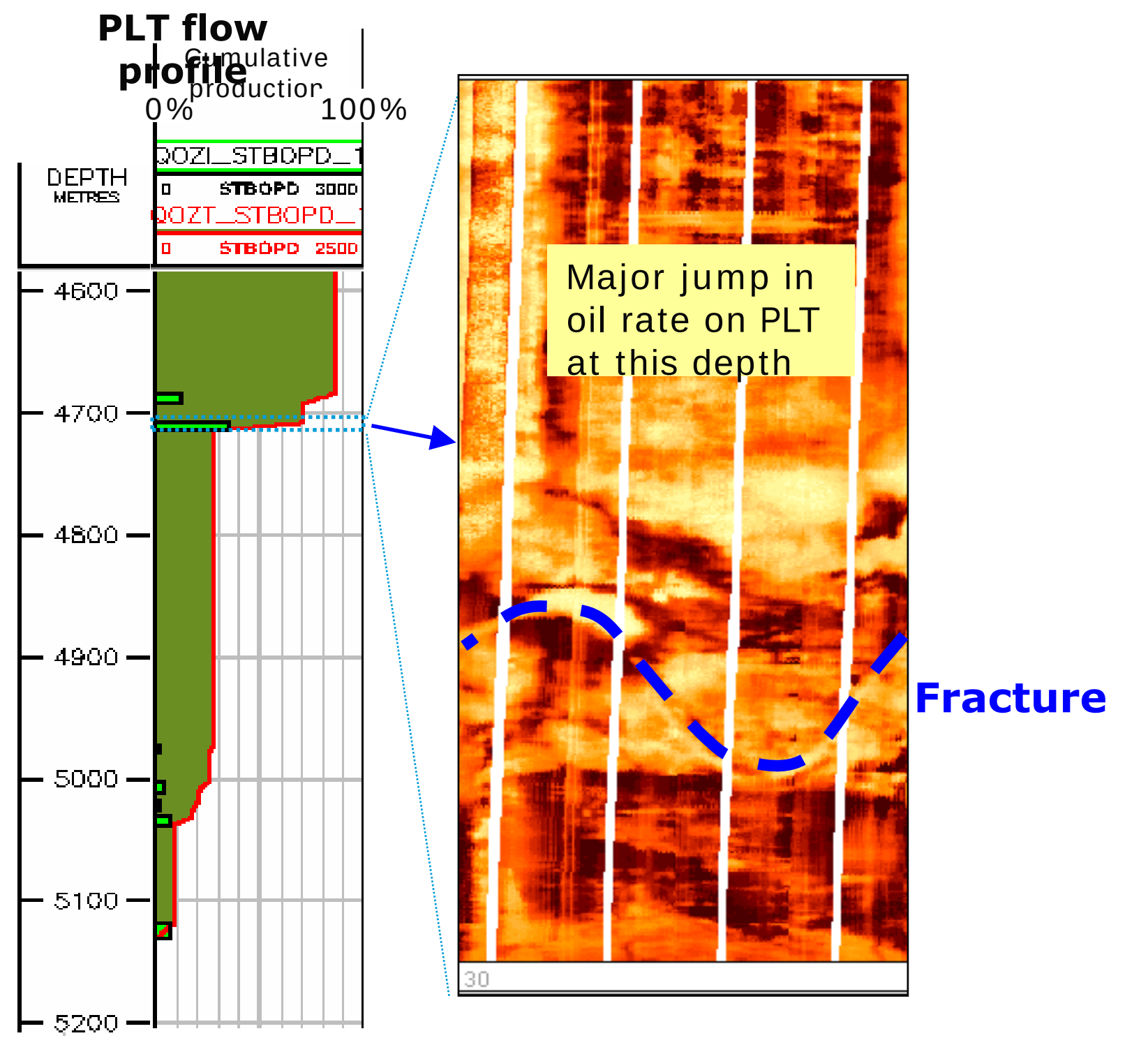


Slope Reservoir and Fracture Characterization: Integration of Static and Dynamic

3 Fracture Density: Static and Dynamic

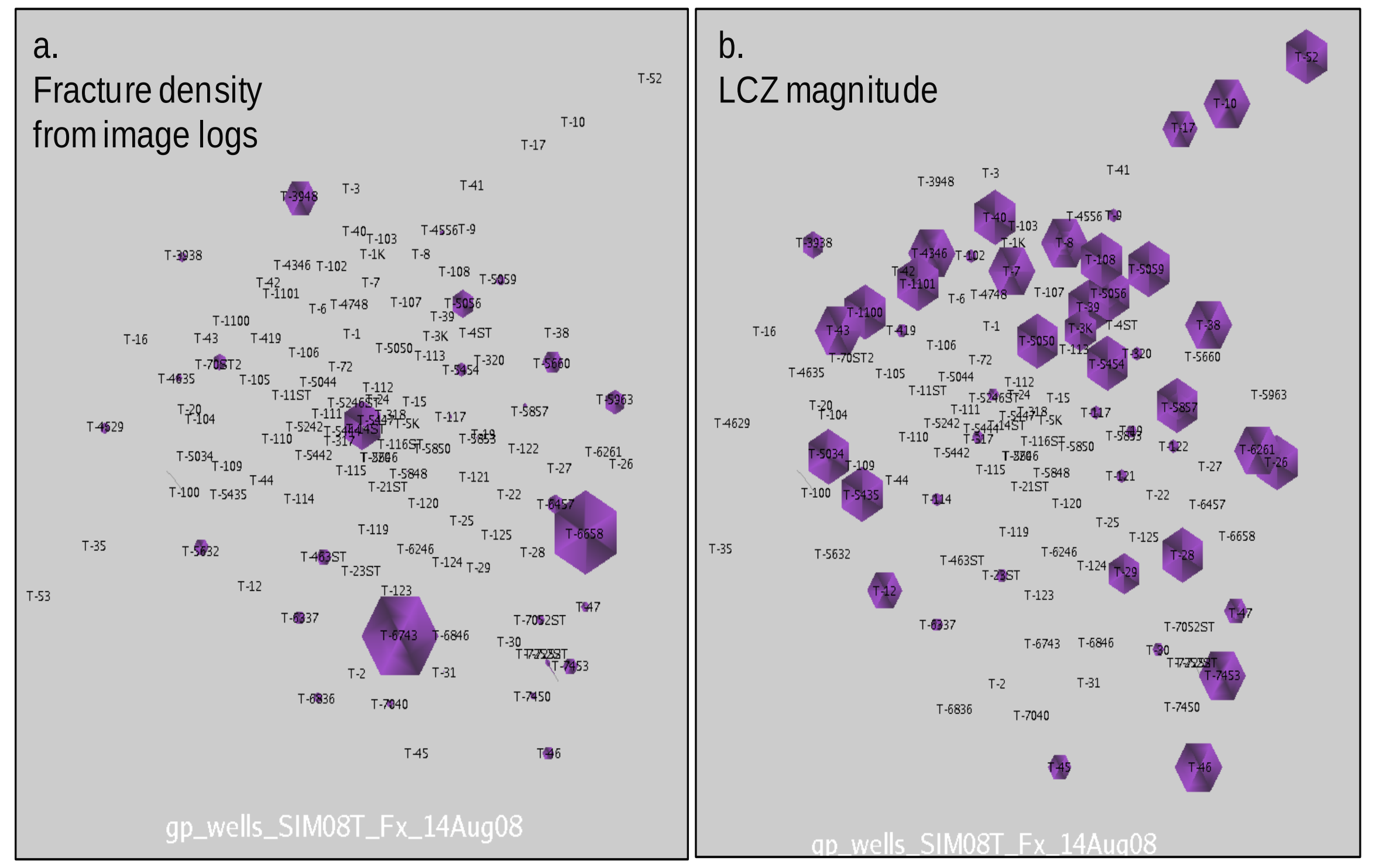
Fracture Characterization

PLT data confirms the presence of effective fractures



Fracture Density from Logs and Dynamic Well Drilling Data

Dynamic drilling data gives much more data than logs alone



Fracture Density from PTT

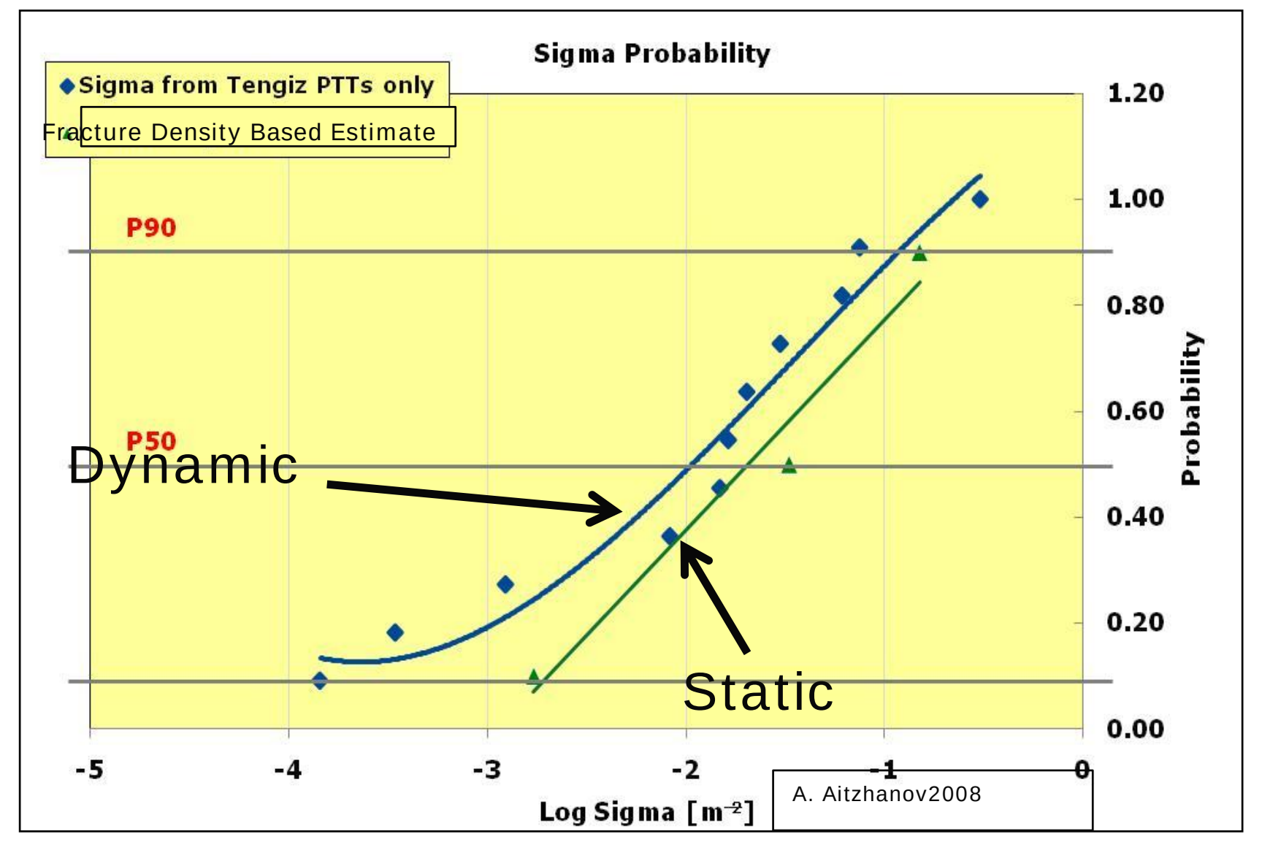
Fracture Density/Shape Factor

$$\lambda = \frac{k_m r_w^{\ 2} \sigma}{\left[\frac{(k_f h)}{h}\right]}$$

$$\sigma = \frac{\lambda \left[\frac{(k_f h)}{h}\right]}{k_m r_w^{\ 2}}$$

FUTURE DIRECTION:
Better modelling of static properties in matrix and fractures of simulation model to match and model PTT response.

Integrating Static and Dynamic Fracture Density

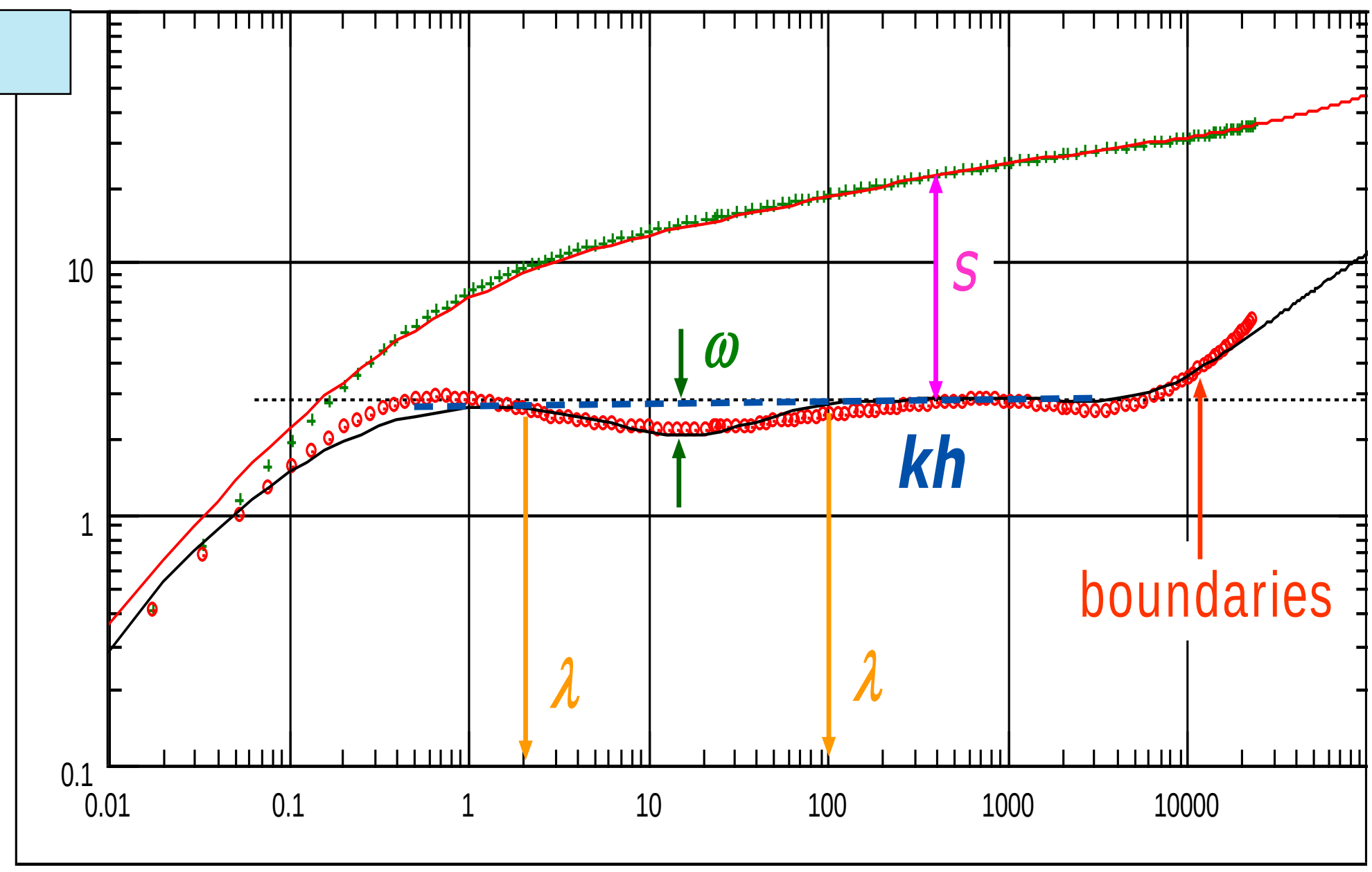


Very different scales of measurement, surprisingly close ranges

	Fracture Density Based Sigma Analysis	Sigma from Tengiz PTTs	Sigma from Mid Static Model	Consolidated Sigma Range Targets
Low	0.00053	0.0035		.0005
Mid	0.0092	0.010	0.0137	.0137
High	0.051	0.03		.1

2 Pressure Transient Tests

PTT constrains estimates of fracture porosity, fracture density, and the matrix-fracture transfer function



log Δp and log tdp/dt (psi) vs. Δt

Log-Log plot: dp and dp' [psi] vs dt [hr]

λ – inter porosity flow parameter, characterizes the ability of the matrix block to flow into the fracture system

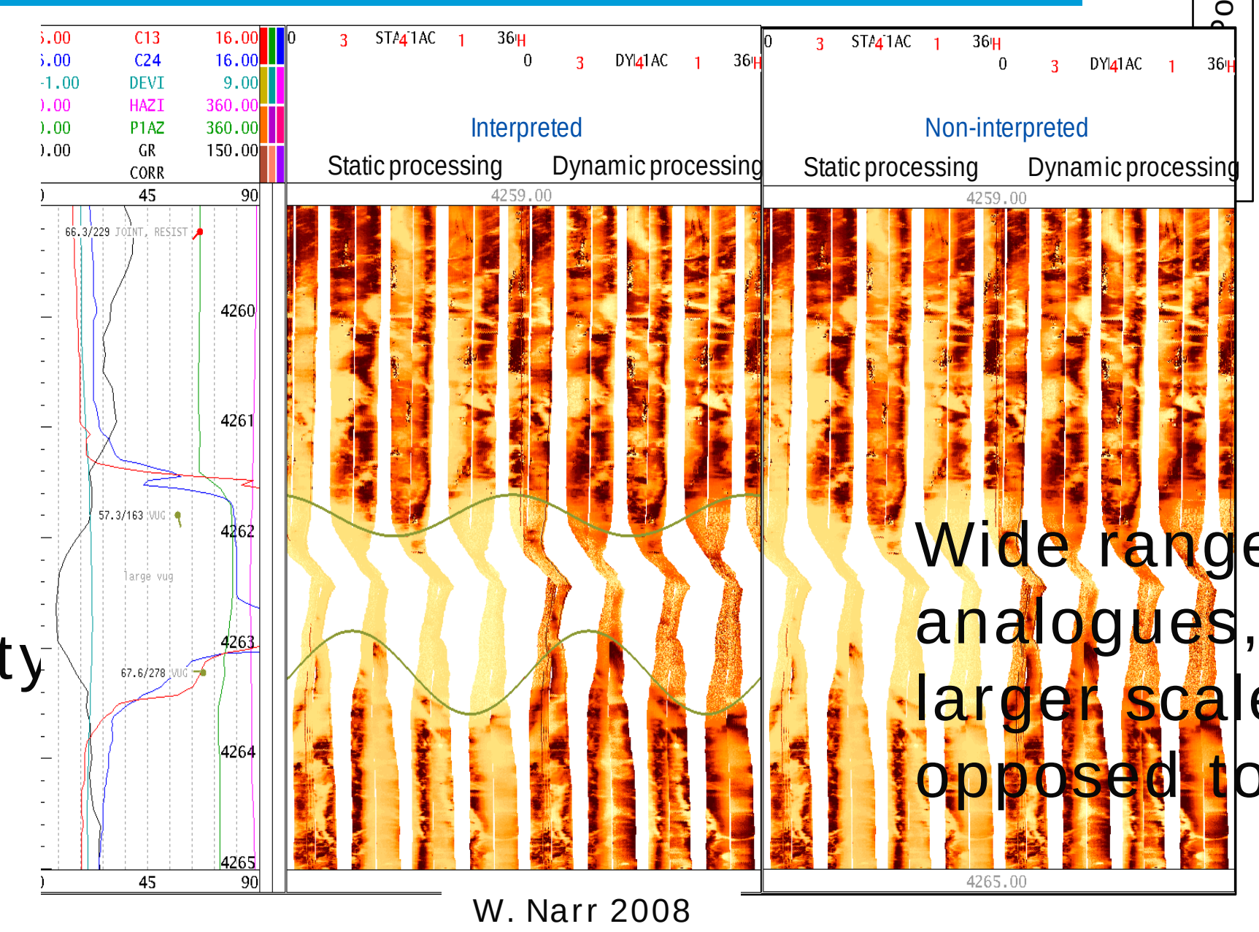
ω - storativity ratio between the matrix and the fracture system

4 Fracture Porosity: Static and Dynamic

Fracture Porosity Estimate from Pressure Transient Test

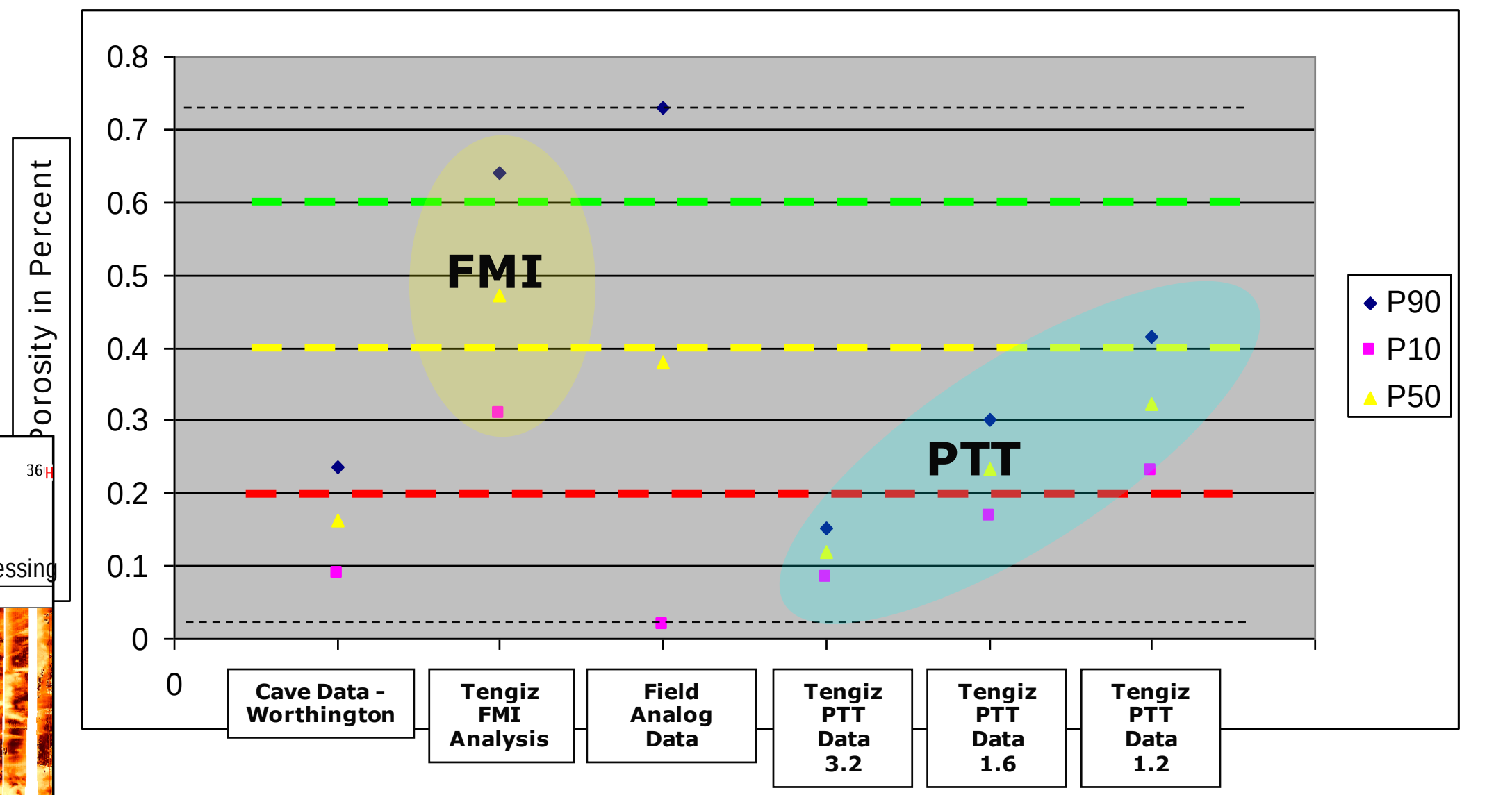
$$\omega = \frac{\phi_f}{\phi_f + \phi_m \cdot \left(\frac{c_{tm}}{c_{tf}}\right)}$$

Fracture Porosity from Logs, LCZ



W. Narr 2008

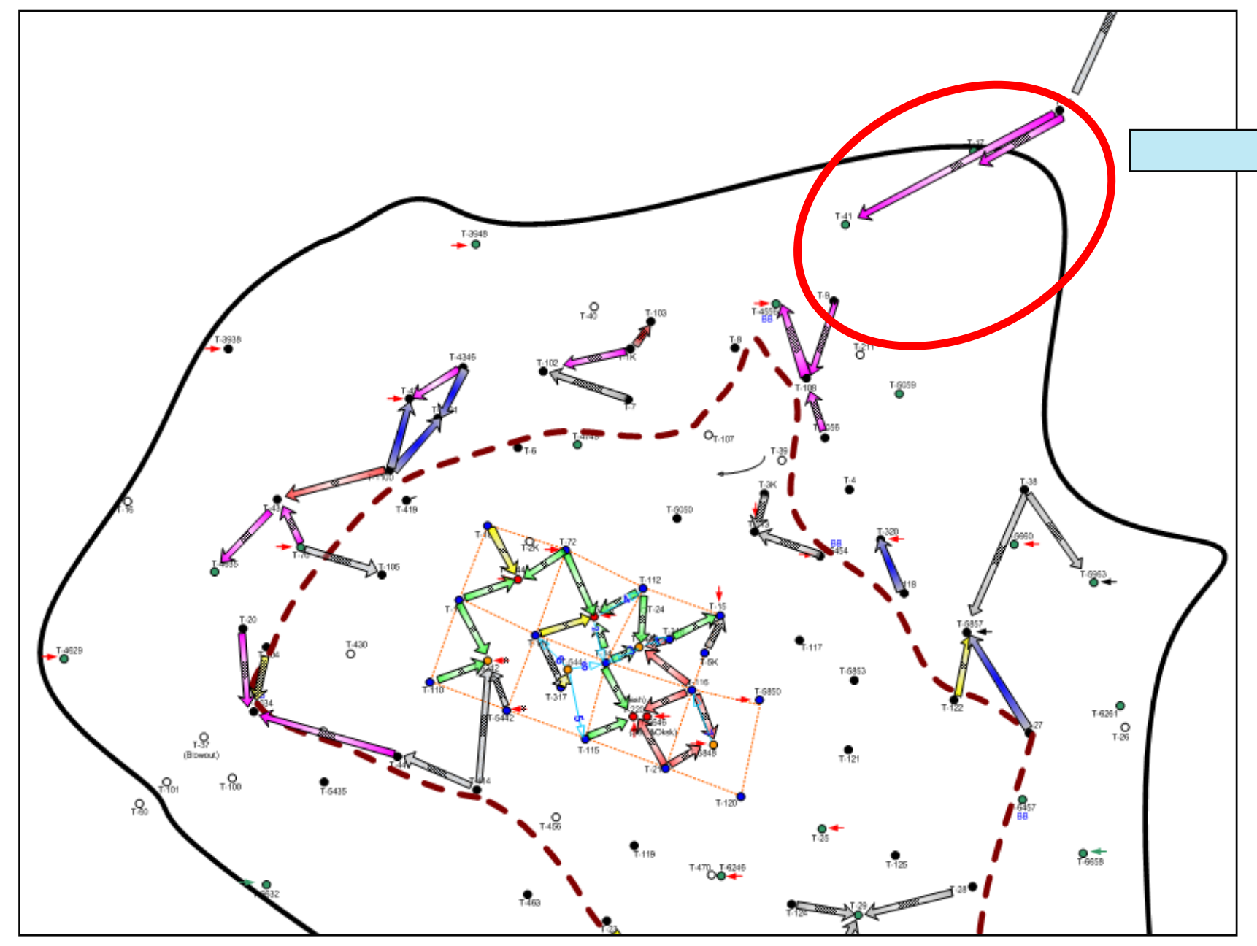
Reconciling Ranges, Scale, and Methods

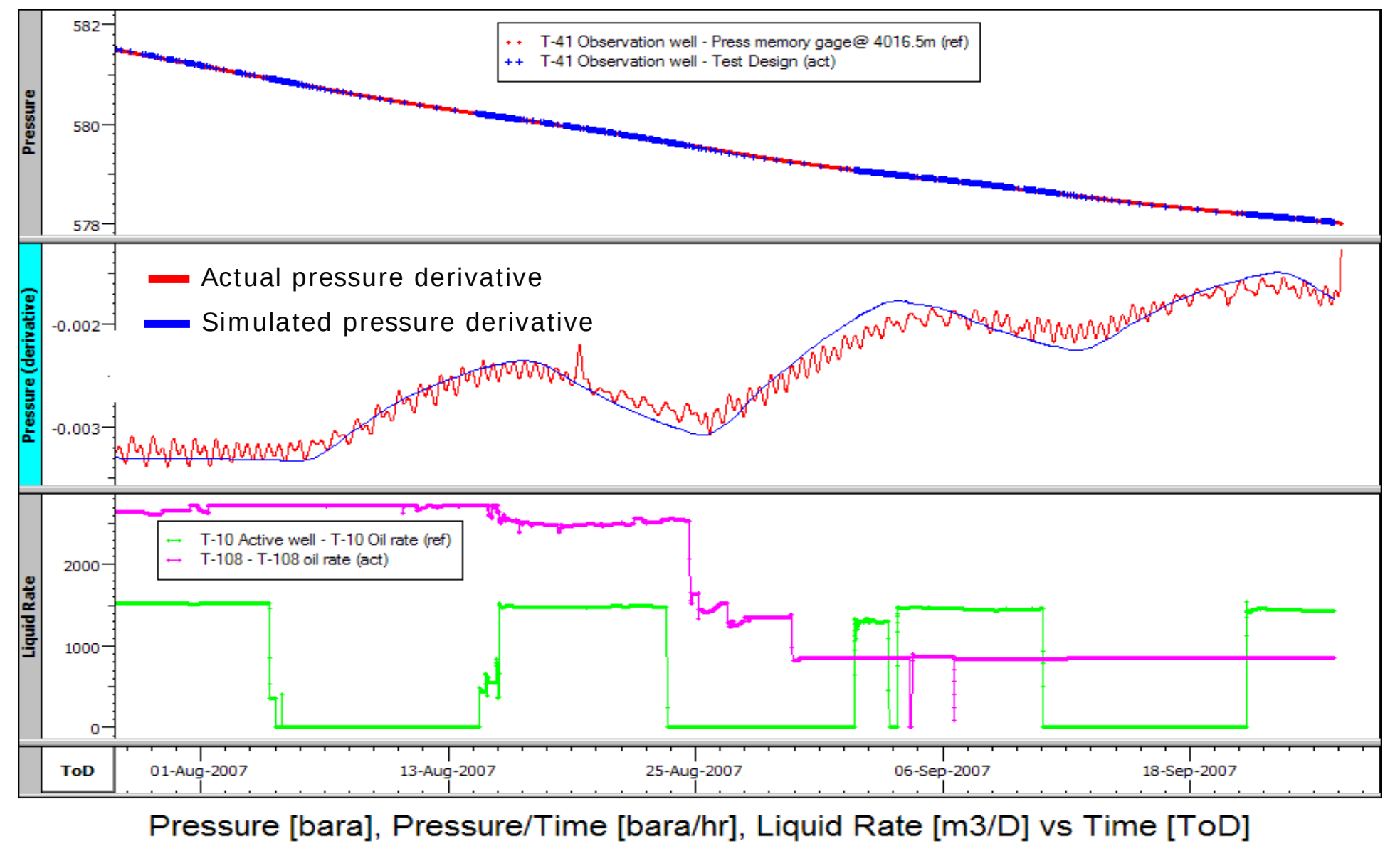


Wide range of estimates of fracture porosity: cave maps, analogues, FMI logs, dual porosity PTT. PTT offers much larger scale than logs, and dynamically sensed volume as opposed to statically measured volume.

5 Fracture Connectivity in the Slope

Pulse test between slope wells

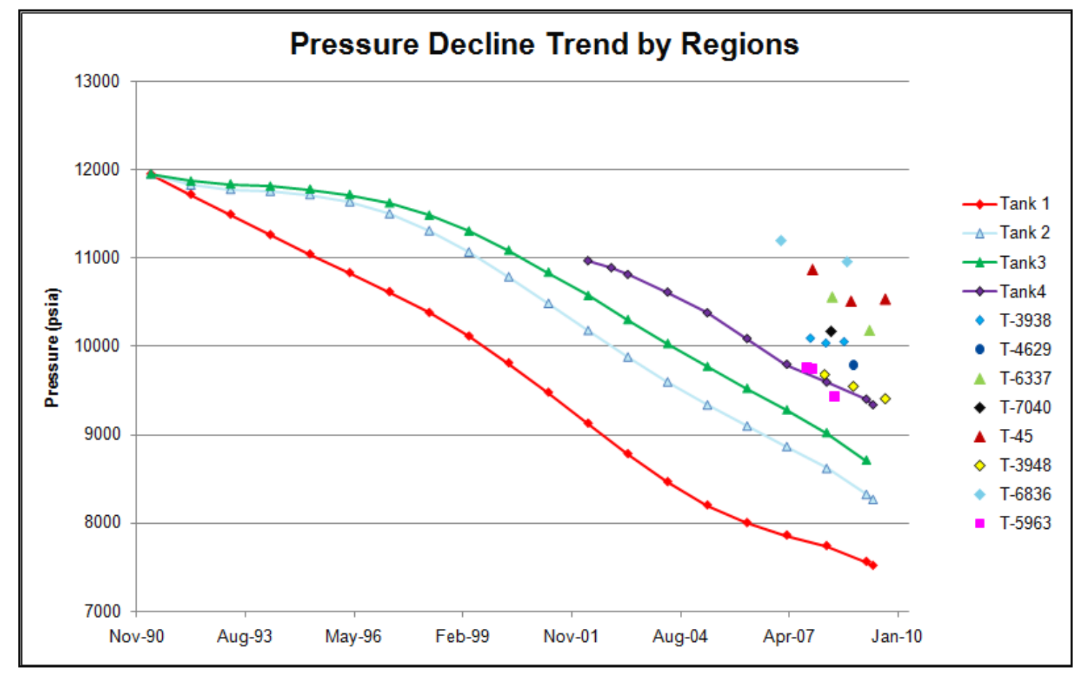




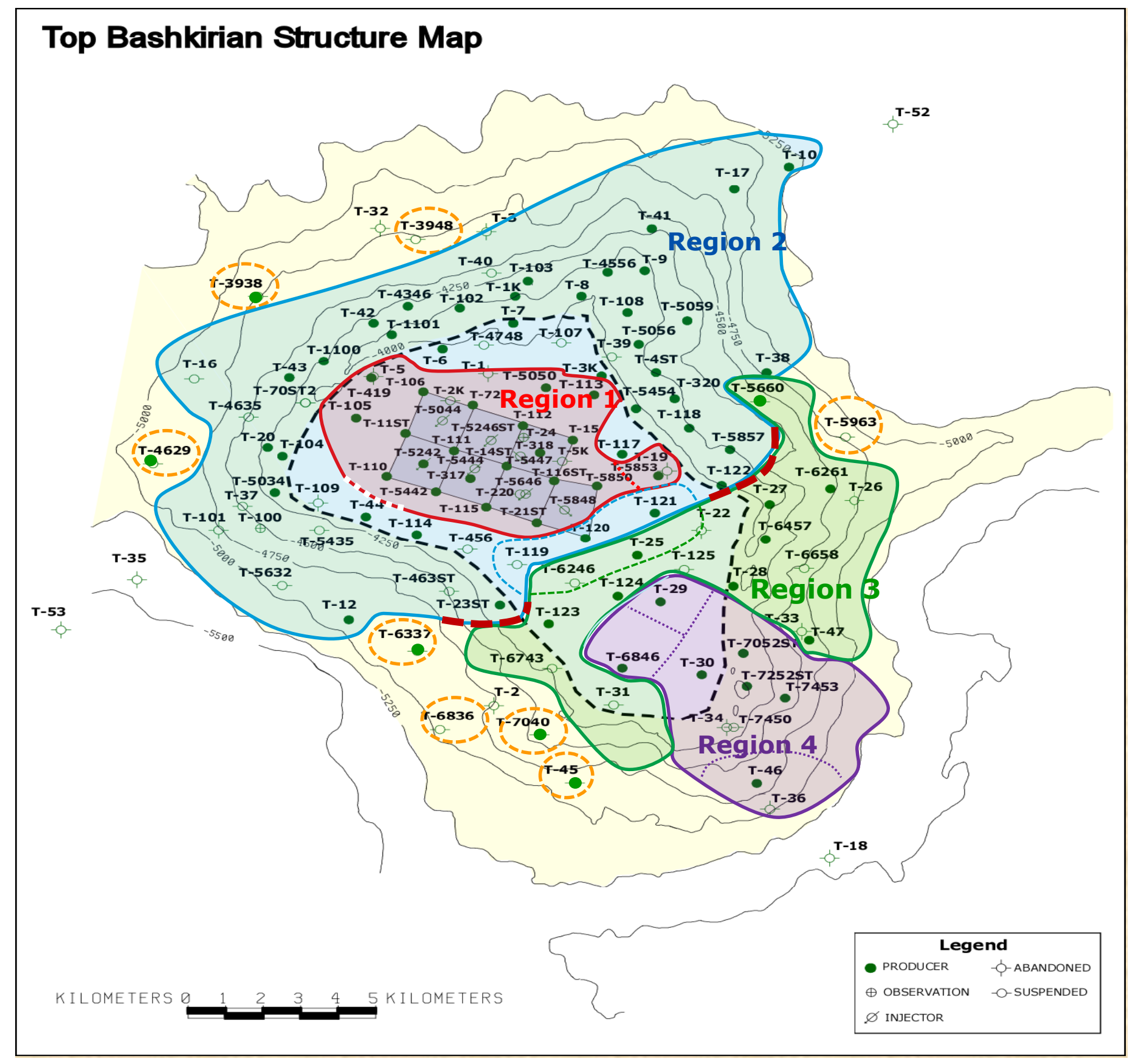
Very good communication between the slope wells located 4 km apart from each other and completed in different stratigraphic intervals. Pulse tests also support fracture directions – higher diffusivity parallel to slope than perpendicular to slope

6 Transmissibility Between Regions

Tengiz Pressure Map by Regions

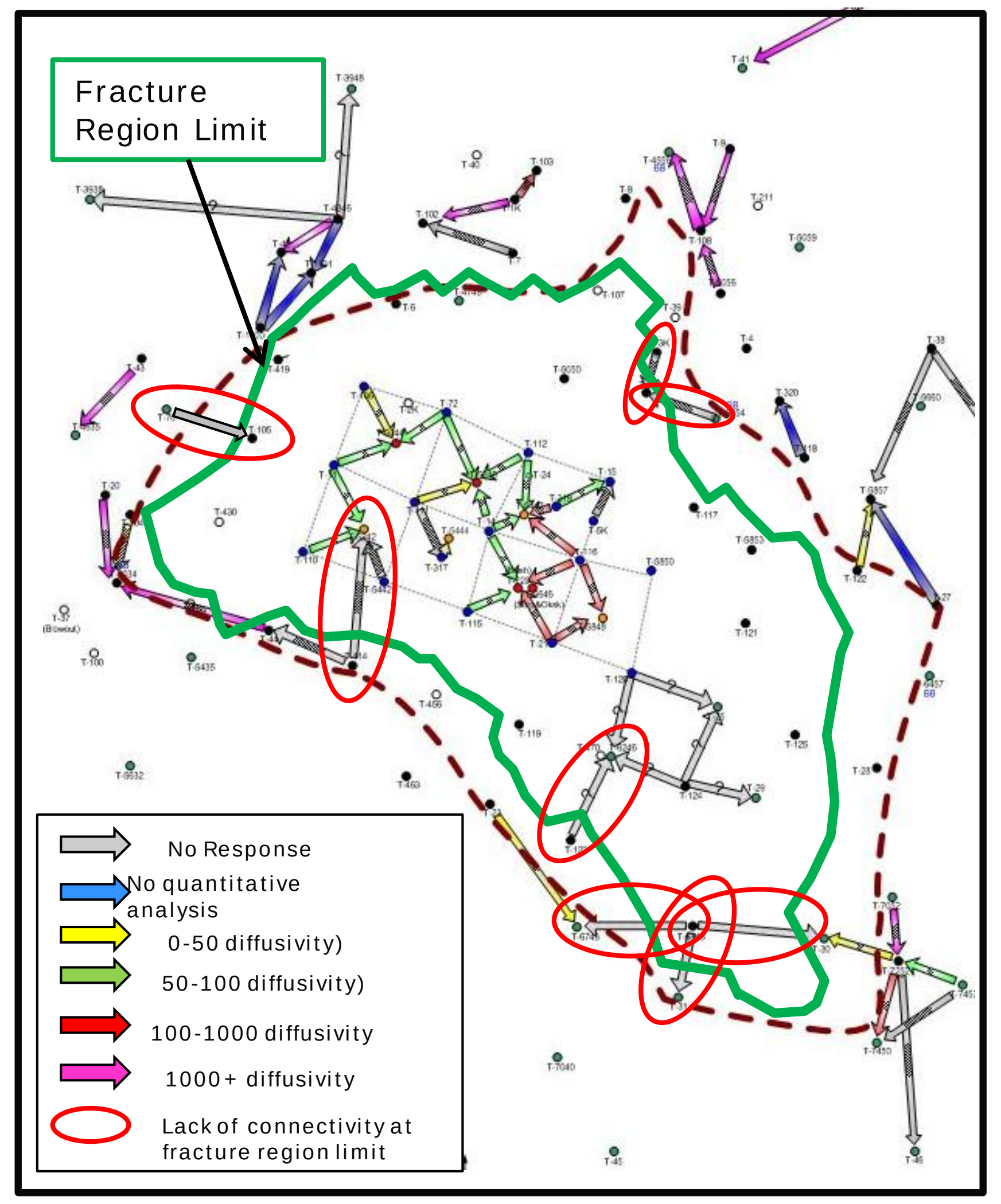


Pressures in different areas of the field fall on distinctly different trends



Non uniform pressure depletion across the field divided field results in several distinct pressure regions

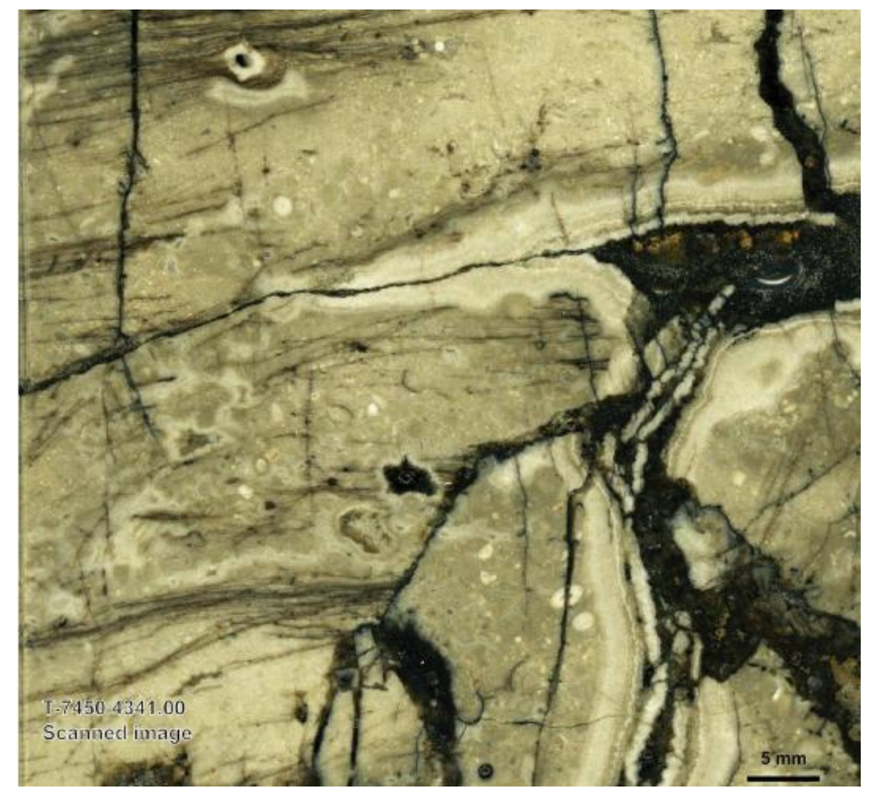
Pulse Tests Across regions



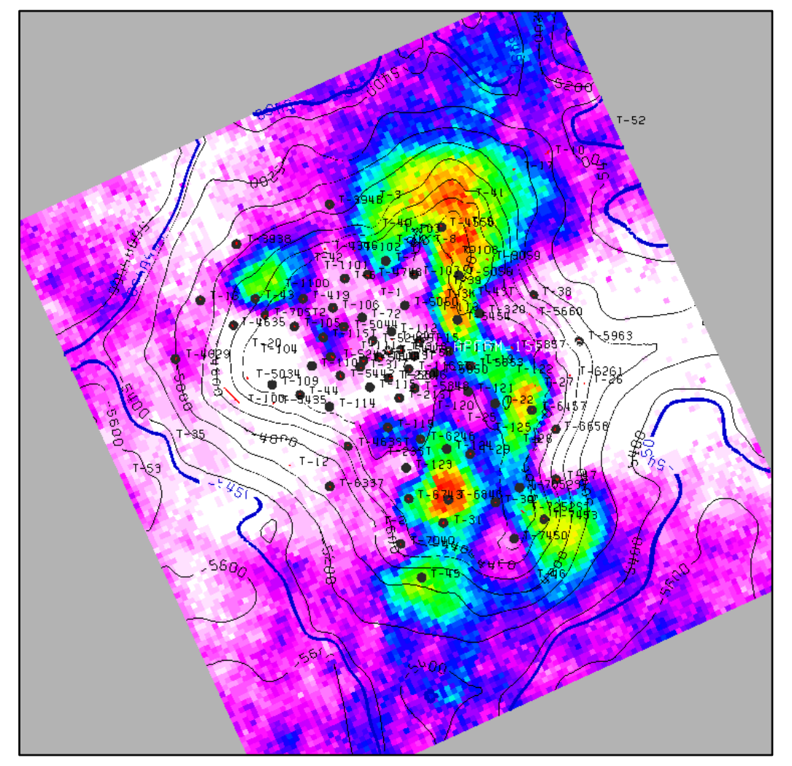
Pulse testing across boundaries defined geologically and by pressure distribution help understand impact of diagenesis on transmissibility

Diagenesis

Fracture Diagenesis



Bitumen Curtain



Effects of diagenesis on pressure distribution and pulse test response. Cementation related to fractured region as well as bitumen deposition can result in transmissibility anisotropy. Modeling transmissibility gives a better history match