F-O Gas Field, Offshore South Africa — From Integrated Approach to Field Development*

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Abstract

The F-O tract is located in the eastern part of Block 9 on the northeastern flank of the Bredasdorp Basin, a sub-basin of the Outeniqua Basin on the southern continental shelf, offshore South Africa. The F-O field is situated 110km from the nearest landfall and 40km SE of the F-A platform, which supplies gas and condensate to the PetroSA GTL plant located in Mossel Bay.

The principal reservoirs are tight, overpressured, highly faulted Valanginian shallow-marine sandstones beneath the drift-onset unconformity, 1At1. These were deposited as an extensive sandstone "sheet" within a tidal dunefield setting. The top and base of the reservoir are defined by the TUSM (Top Upper Shallow Marine) and BUSM (Base Upper Shallow Marine) seismic events, respectively. Four wells have been drilled in the F-O field, two of which are classified as gas discoveries with potentially commercial production rates. This heterogenous reservoir has low porosity (2-18%) and low permeability (<0.1 to 10 mD). The field has some good permeability streaks that reach values of 250 md. The field is on a well defined structural high at the level of the regional drift-onset unconformity, 1At1.

The proposed development of this field followed an integrated approach, incorporating geology, geophysics, sedimentology, reservoir engineering, petrophysics, and rock mechanics. The aim was to understand reservoir distribution and quality to optimally locate the proposed three development wells. One of the considered options that can increase production is fracturing the reservoir. The study with Schlumberger integrates geomechanical analysis (single well geomechanical analysis, lab core analysis and hydraulic fracture designs), 3D static geological modelling, dynamic modeling, and 3D mechanical earth modelling.

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F-O Gas Field, Offshore South Africa – an Integrated Approach to Field Development

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1 PetroSA

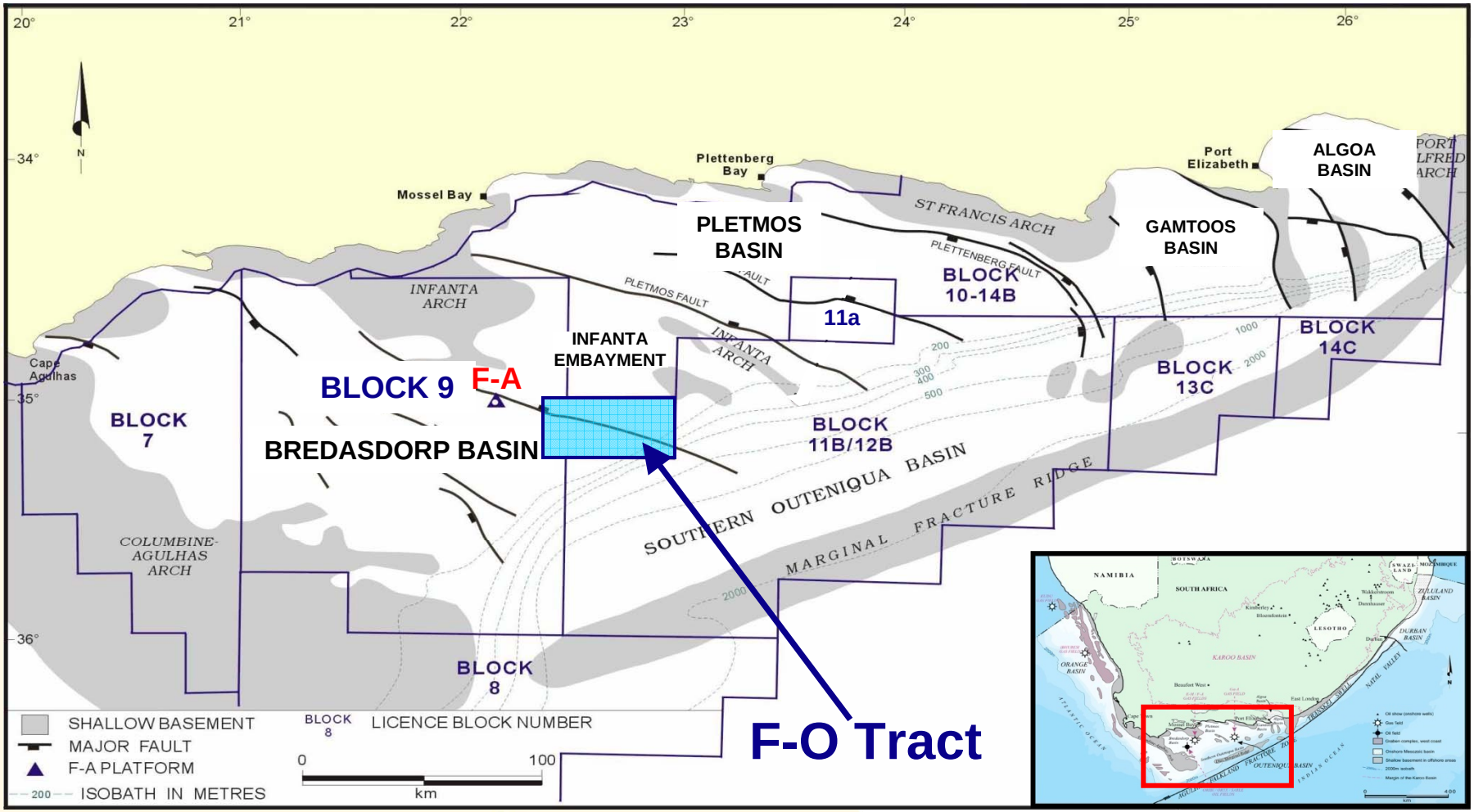
2 Consultant

FO Field Summary

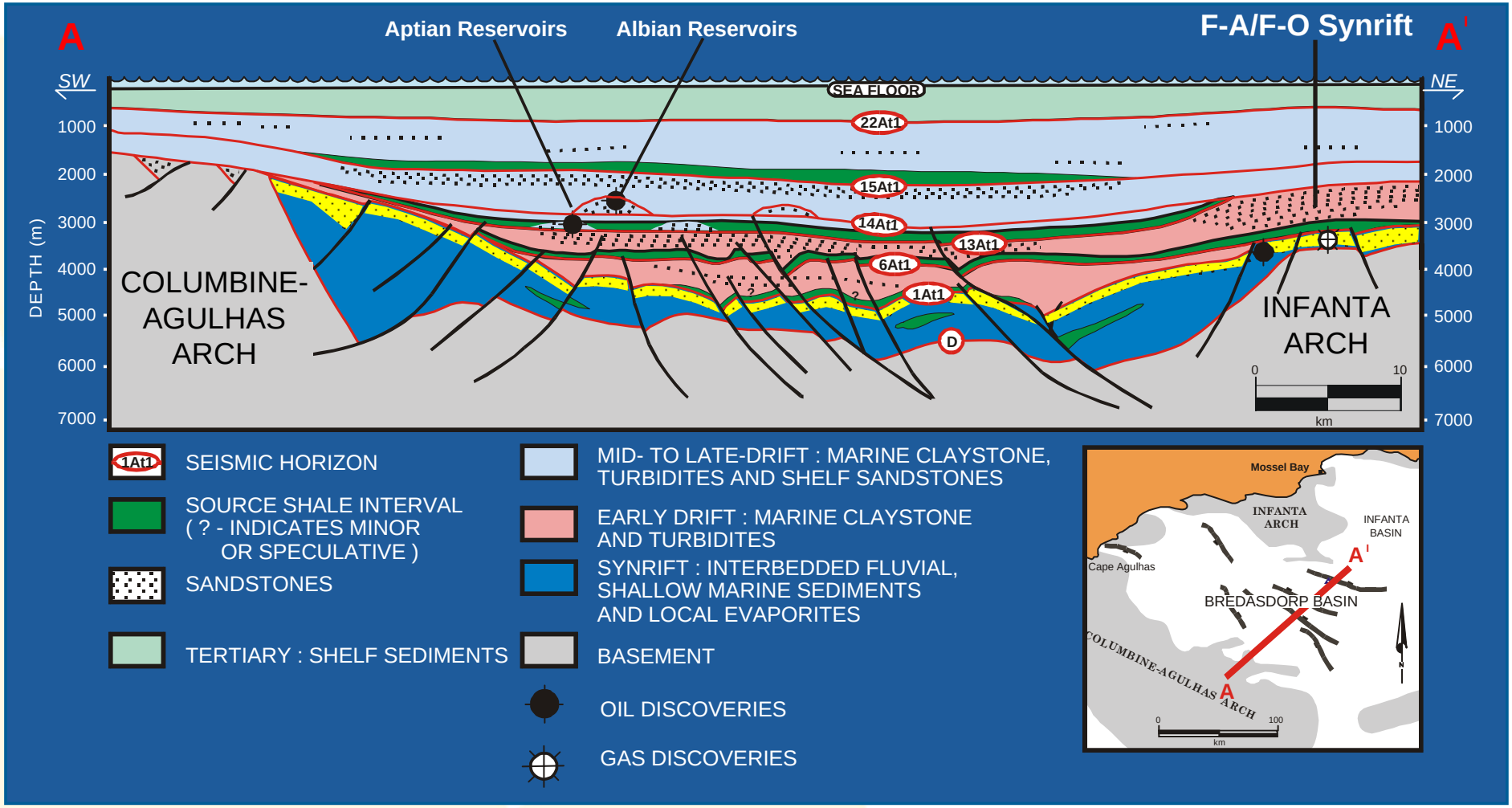
- Tight shallow marine gas field offshore South Africa
- Large domal / fault closure
- ~1.3Tcf gas in place – how to develop? Fraccing?
- Applied an integrated approach to problem:
  - G & G
  - Reservoir Engineering
  - Petrophysics
  - Rock Mechanics (Schlumberger)
- Rock mechanics study incorporates:

  geomechanical analyses, 3D static modelling (Petrel), Dynamic modelling (Eclipse) and 3D mechanical earth modelling (Fracade)

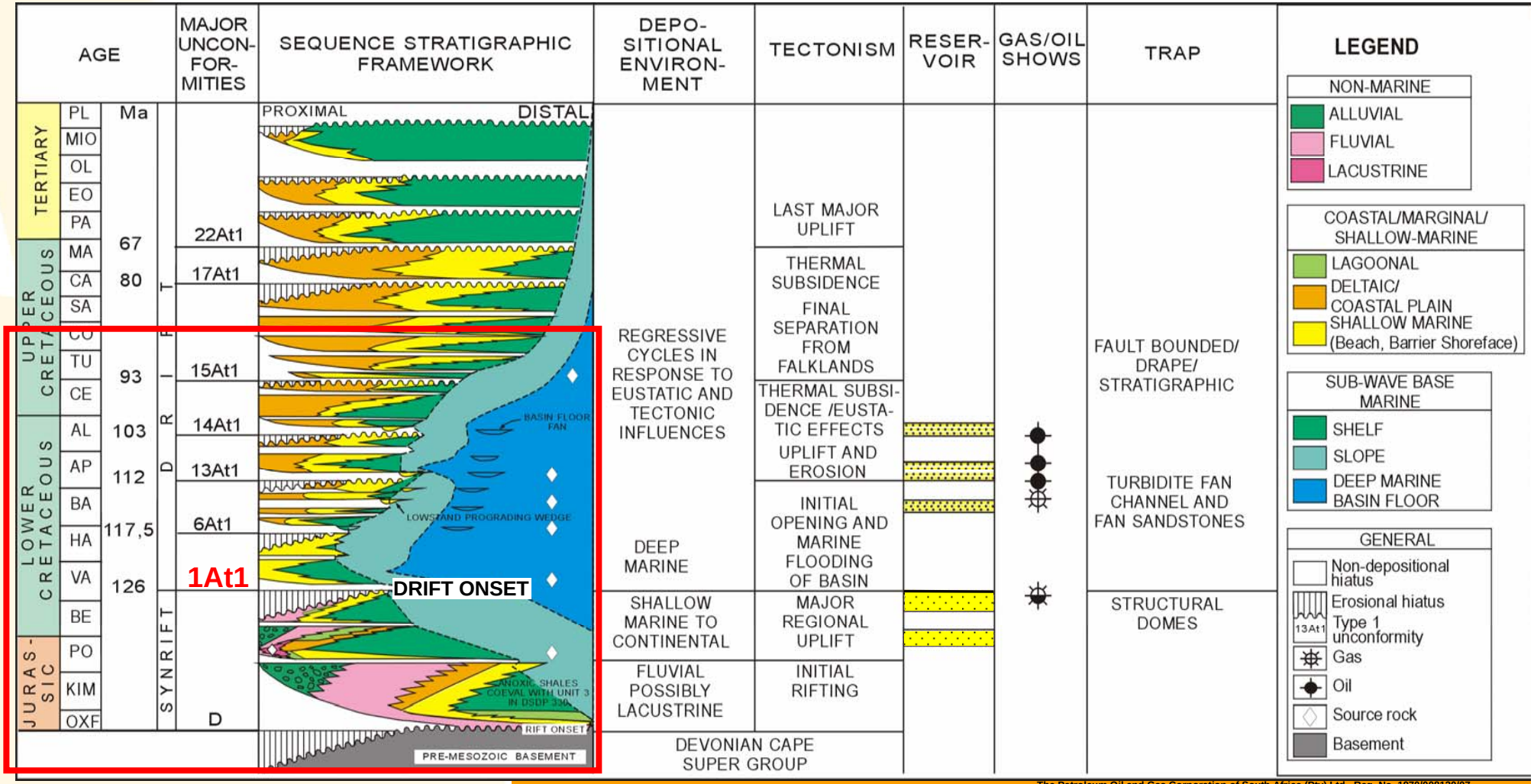
Major Tectonic Elements in the Outeniqua Basin and F-O Tract Location



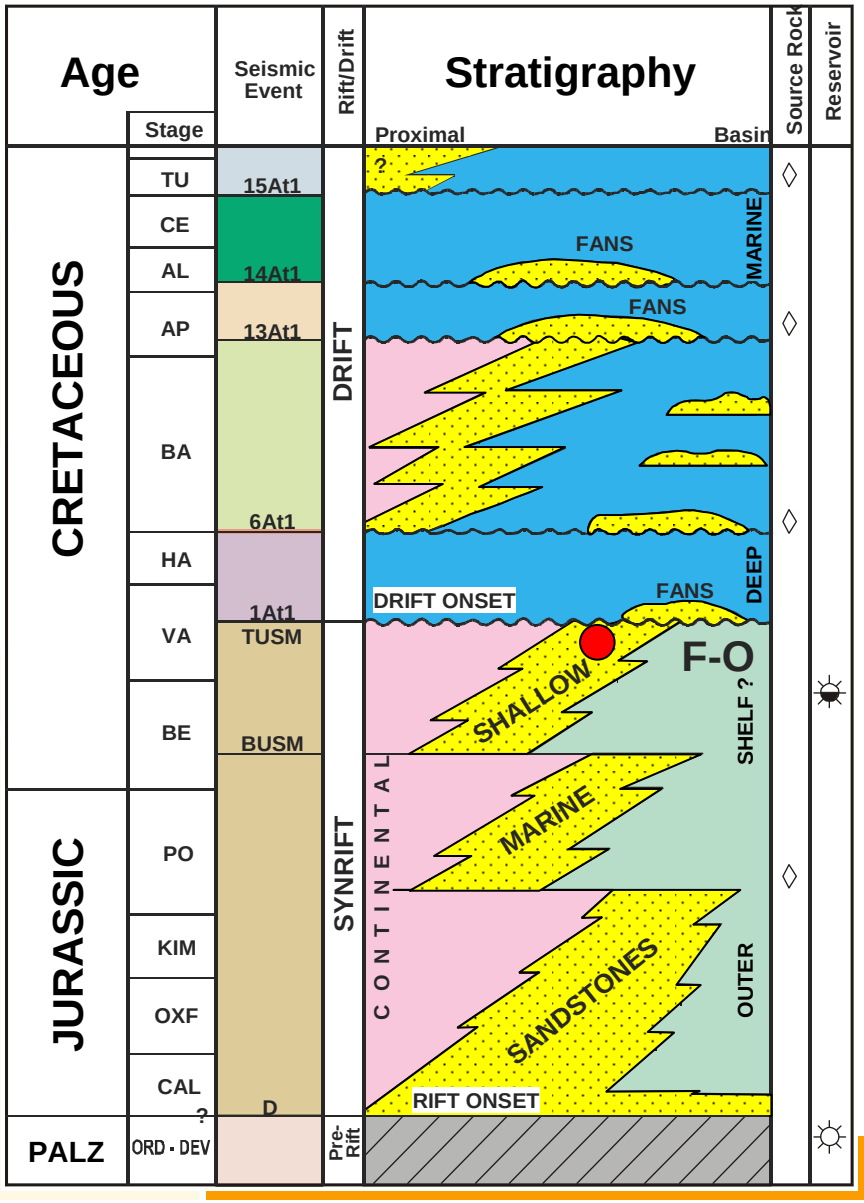
Schematic Section Across the Bredasdorp Basin



Generalised Chronostratigraphy of the Bredasdorp Basin

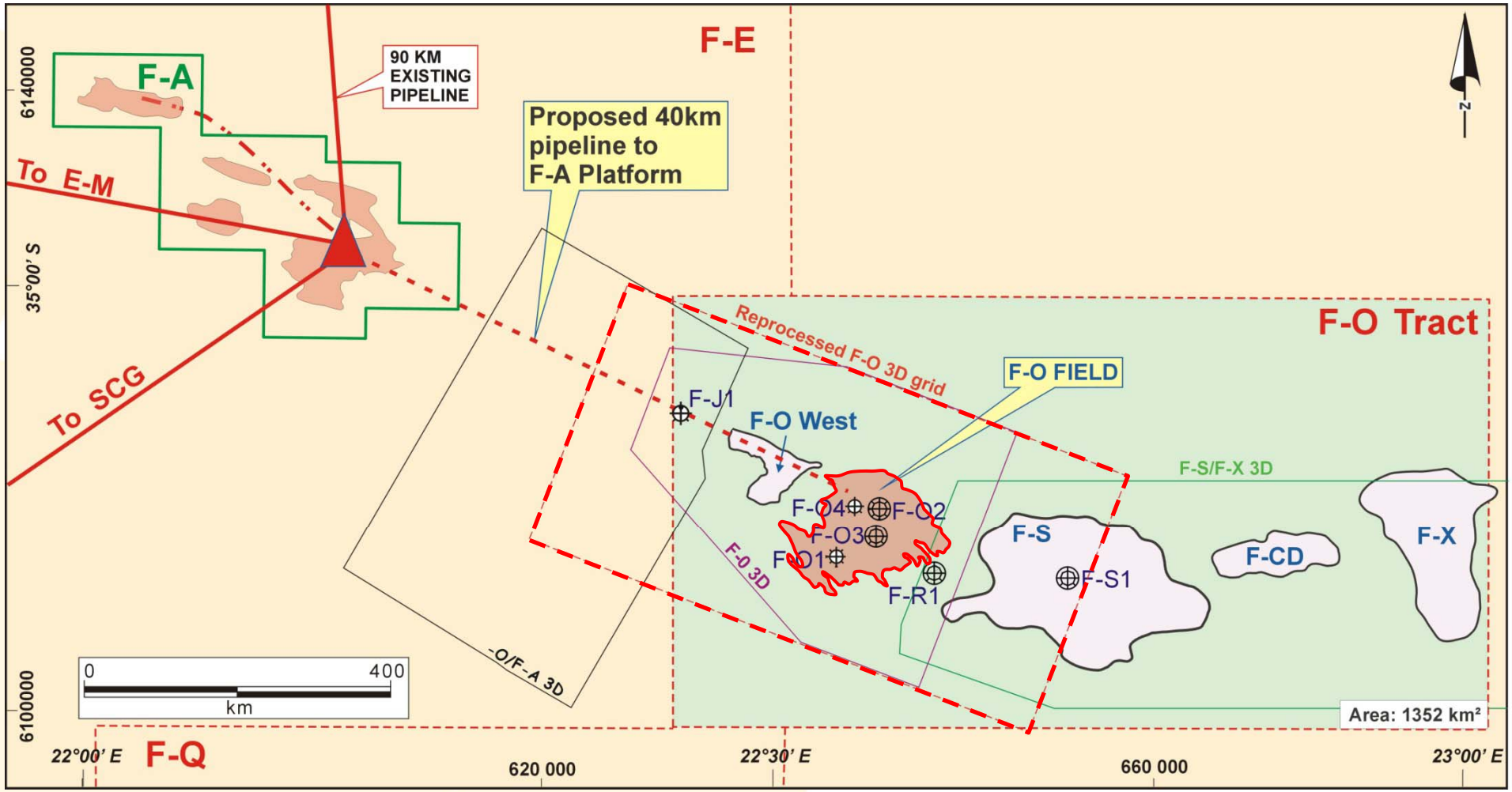


Simplified Chronostratigraphy



F-O USM reservoir

FO Tract: fields and infrastructure

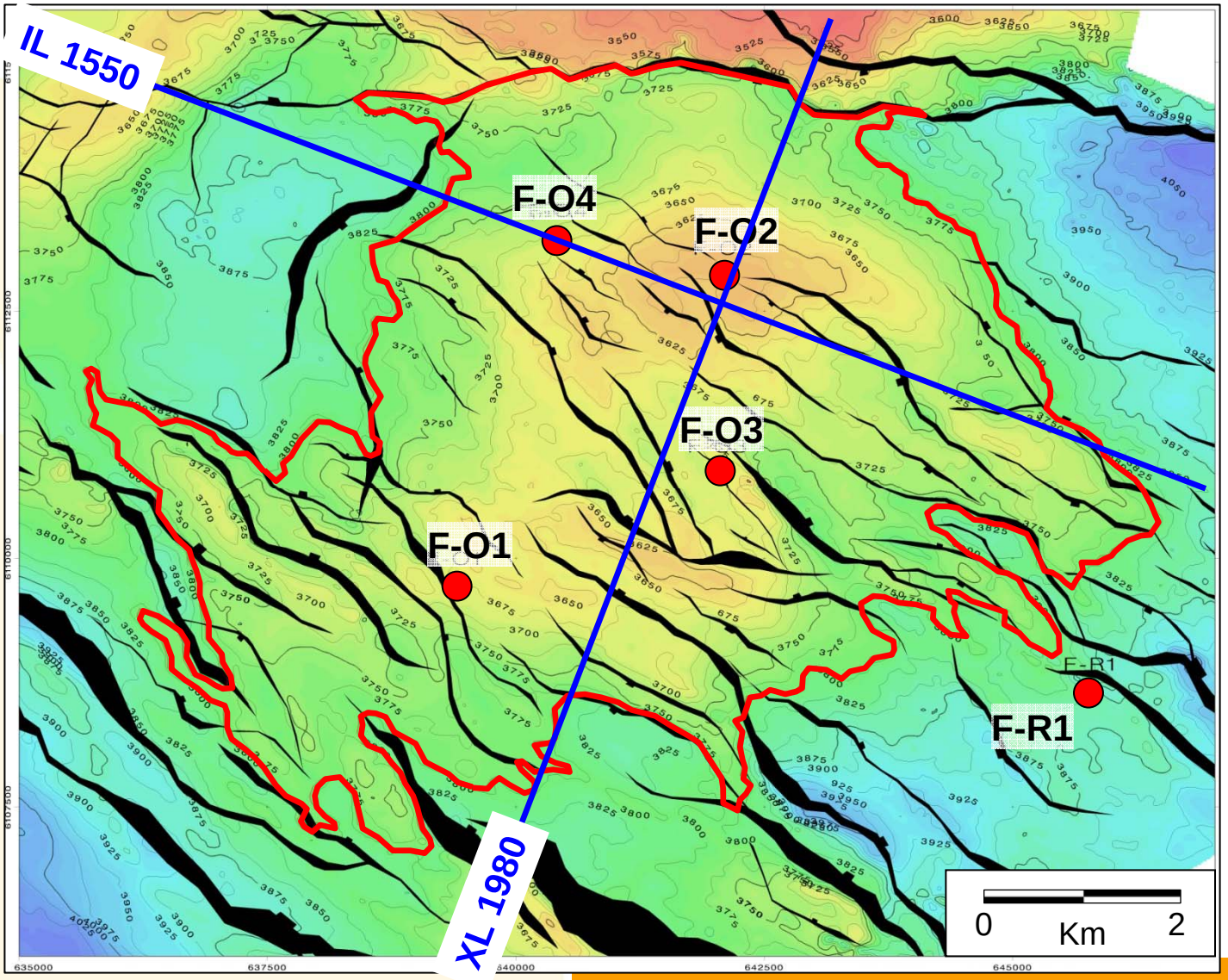


3D reprocessed 2000

F-O Well Summary

	Location	Gross thickness (m)	Cores	Average Porosity %	Permeability mD	DST
F-O1	Downdip SW of F-O structure	101	2	11	5 – 40 (max 250)	No test—due to mechanical problems; poss >60 MMscf/d
F-O2	Crest of structure	69.5	4	12	4 (max 75)	31.5 MMscf/d CGR 2 bbl/MMscf
F-O3	Downdip S of F-O2	69.5	5	8	0.1	No flow
F-O4	West of F-O2	152	3	10.4	0.1 - 1	3.5 MMscf/d
F-R1	Downdip SE of F-O structure	134	2	10	1	0.3 MMscf/d

Depth Structure Map to Top Reservoir (TUSM)



FO GWC = 3794m SS

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Crossline 1980

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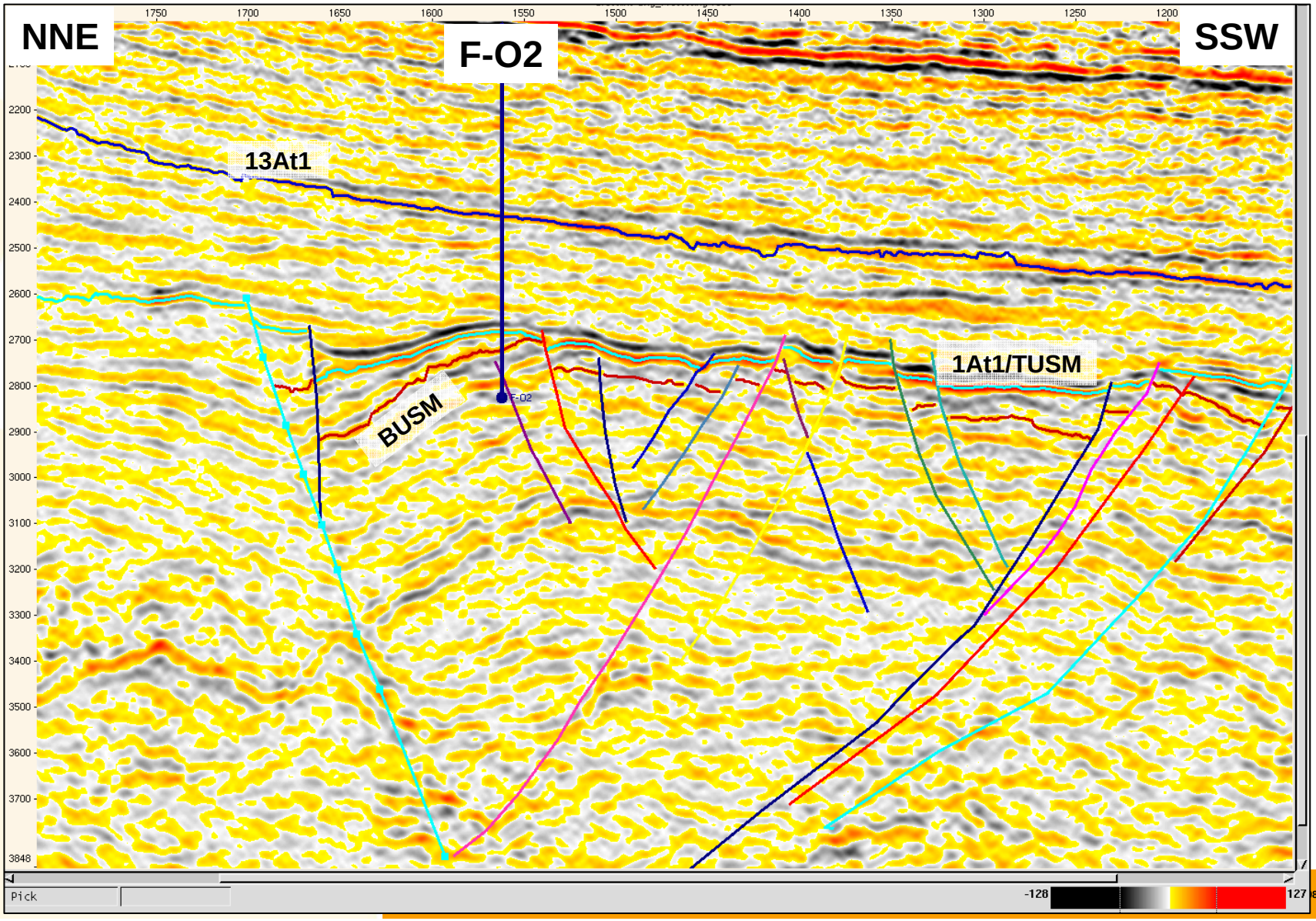

Inline 1550

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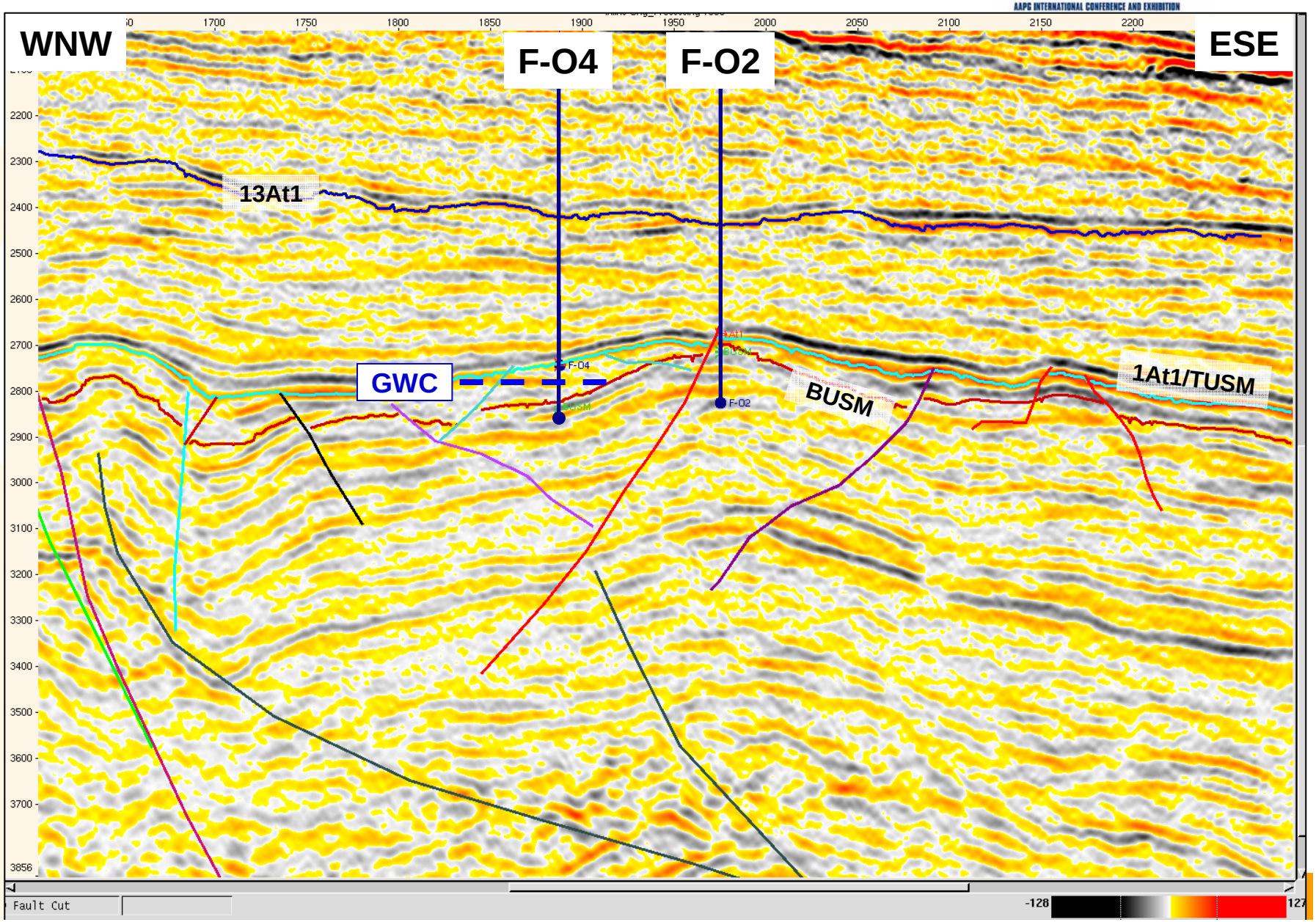

Petroleum System

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Reservoir Parameters	
Source	All wells intersected gas-bearing synrift sediments
Timing / Migration	All wells intersected gas-bearing synrift sediments
Reservoir	Sand intersected by all wells
	Gas indication on all Well Logs
	2 Wells flowed gas to surface
	Lateral reservoir thinning by erosion
	Lateral reservoir shaleout
	Lateral reservoir deterioration by over-cementation
Closure	2D & 3D coverage – good quality. Complex fault system
Containment	Regional top seal

Multi-disciplinary Studies

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Inversion Study → Completed → PetroSA
- Inversion Algorithms
- Impedance maps

→ Input into static model

Schlumberger Study → Completed →
- Petrophysics
- 1D Mechanical Earth Model (MEM)
- Rock Mechanical Lab anal: Terratek
- Fracture Designs
- Static Model
- 3D Mechanical Earth Model (MEM)
- Dynamic modelling & forecast
- Coupled geomechanical modelling

→ **Optimal Placement and Fracture Design for new well & Optimal Development of F-O Field**

Sedimentological Study → Completed →
- Study by Dr Higgs
- Petrophysics – PetroSA
- Isochore maps - PetroSA

→ Input into static model

Sedimentology Study (Higgs)

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Depositional Environment

1. Shallow marine tidal dunefield
2. Sst reach substantial thicknesses through subsidence
3. Sandsheet coarsens NW and fines both distally and laterally by gradation into heterolithics

Facies

Six main facies recognized (Cores).

F1	pure shale
F2, F3, F4	progressively coarsening interbedded sand – shale "heterolithic" facies
F5, F6	cross-bedded and massive Sst

Reservoir Zonation

Seven zones recognized:

Wireline correlations (coarsening and fining-upward successions, interpretable as parasequences/sets), give a proposed reservoir zonation (Zones A-H in upward order). **Best quality reservoir in Zones C, D, E**

Reservoir Quality

1. Enhanced poro-perm (EPP) present in clean Sst of F5 & F6
2. Enhanced porosity secondary in nature
3. Confinement of EPP to upper USM related to telodiagenesis – meteoric water percolated to subsurface dissolving carbonate cement and feldspar replacive-carbonate

Synrift Sst Distribution within Block 9

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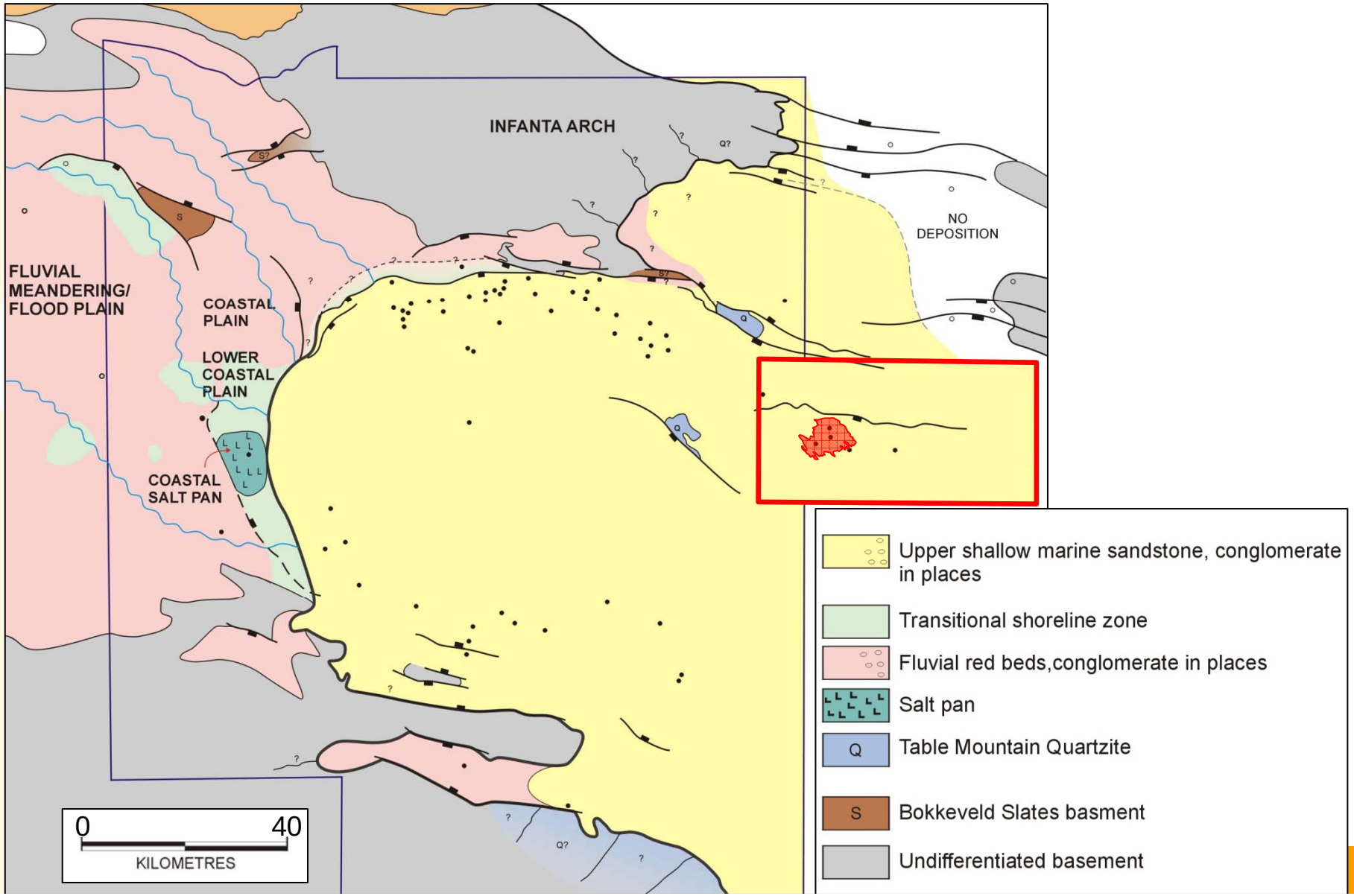
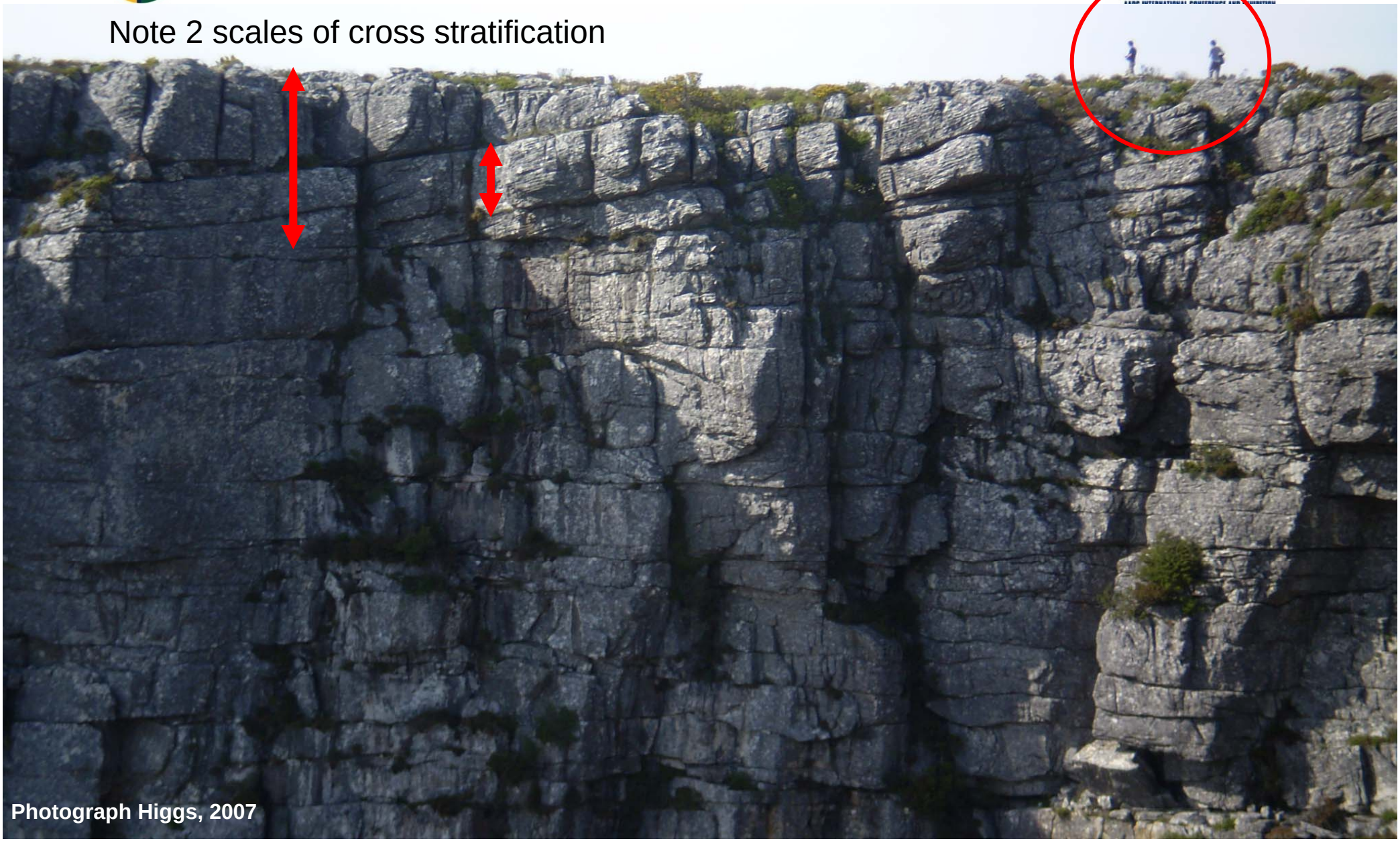


F-O Field Analogue: Table Mountain

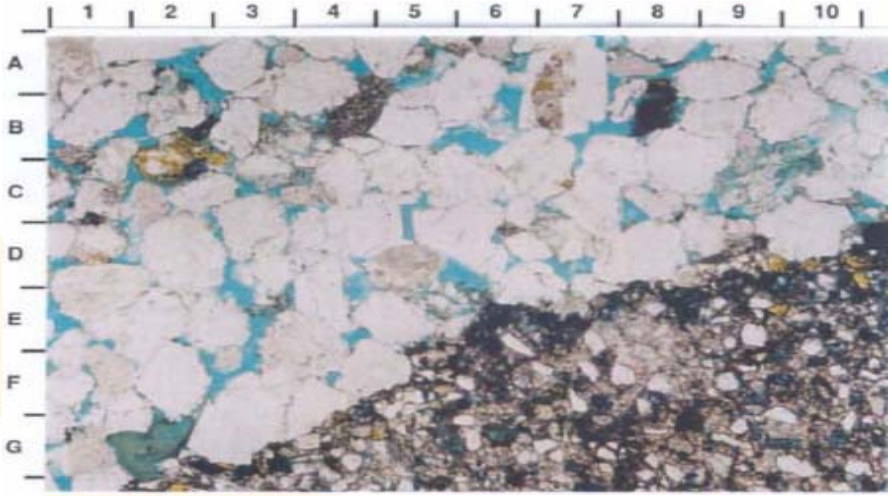
Note 2 scales of cross stratification



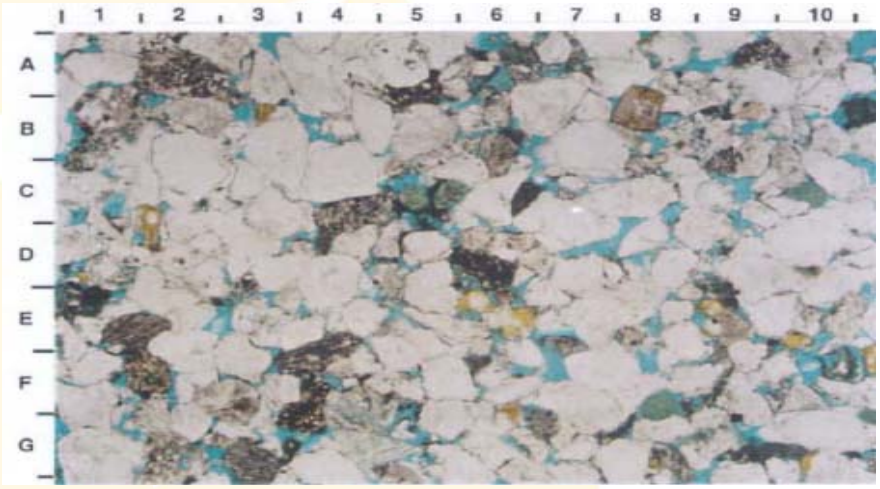
Photograph Higgs, 2007

Thin Sections and Cores

F-03 : Facies 5

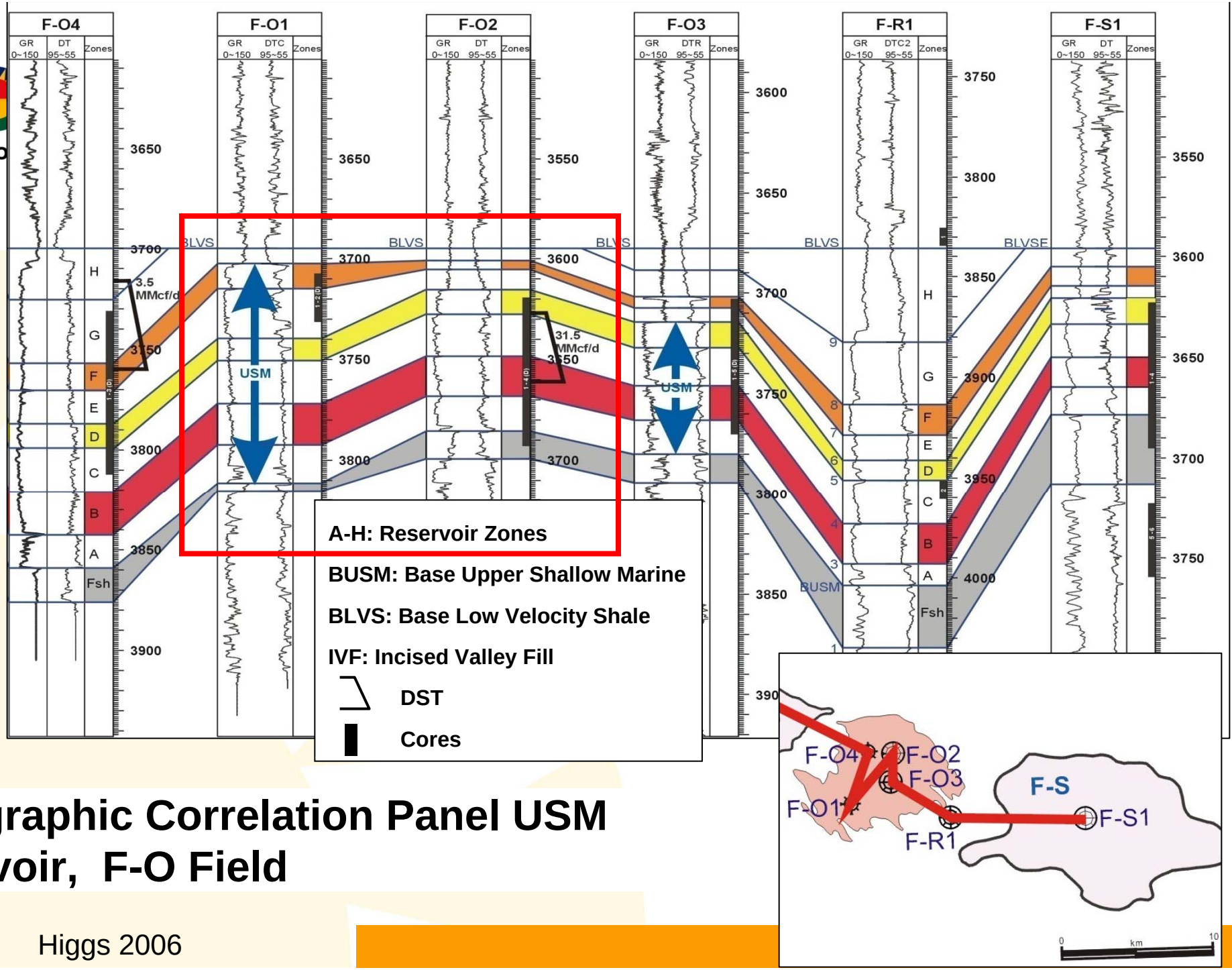


F-O1 : 3714.89m Facies 5



F-O2 : 3630.29m Facies 6

F-04 : Facies 6



Stratigraphic Correlation Panel USM Reservoir, F-O Field

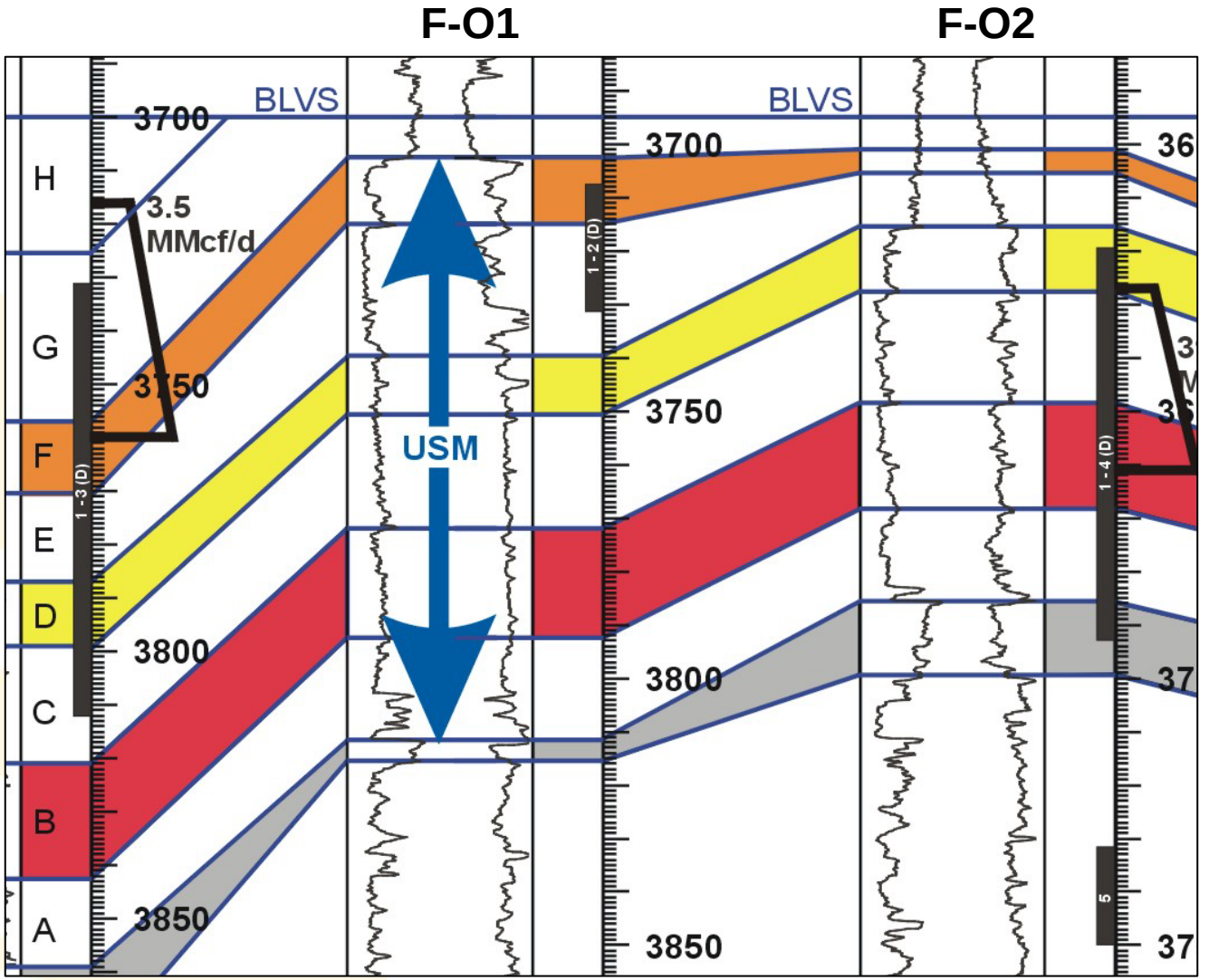
Higgs 2006

Reservoir Zonation

Seven Zones recognised, A to H:

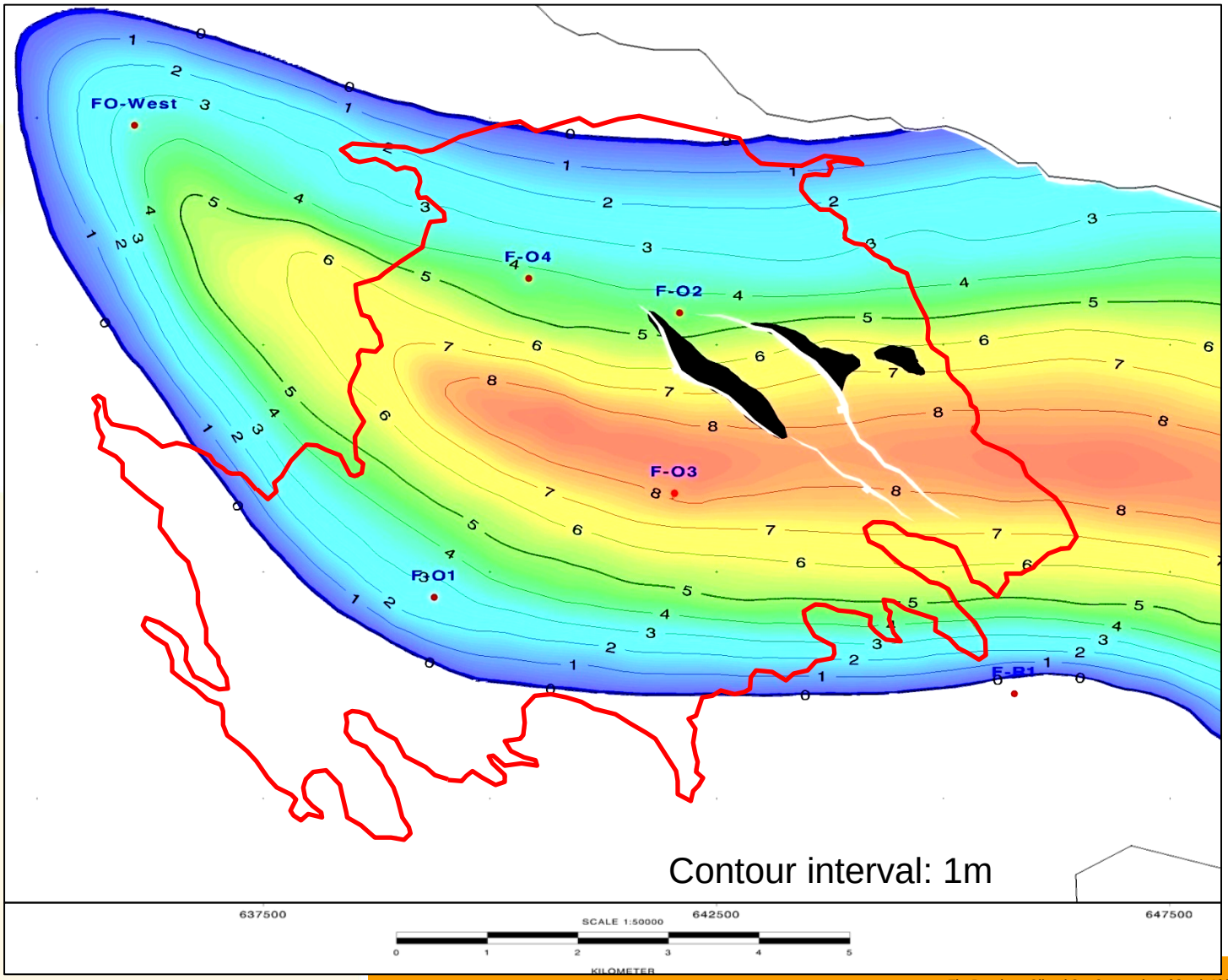
Reservoir zonation based on wireline correlations (interpretable as para-sequences/sets).

Best quality reservoir in Zones C, D, E



Higgs 2006

Net sand isochore, USM Zone D, F-O Field



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F-O2 Petrophysical Evaluation

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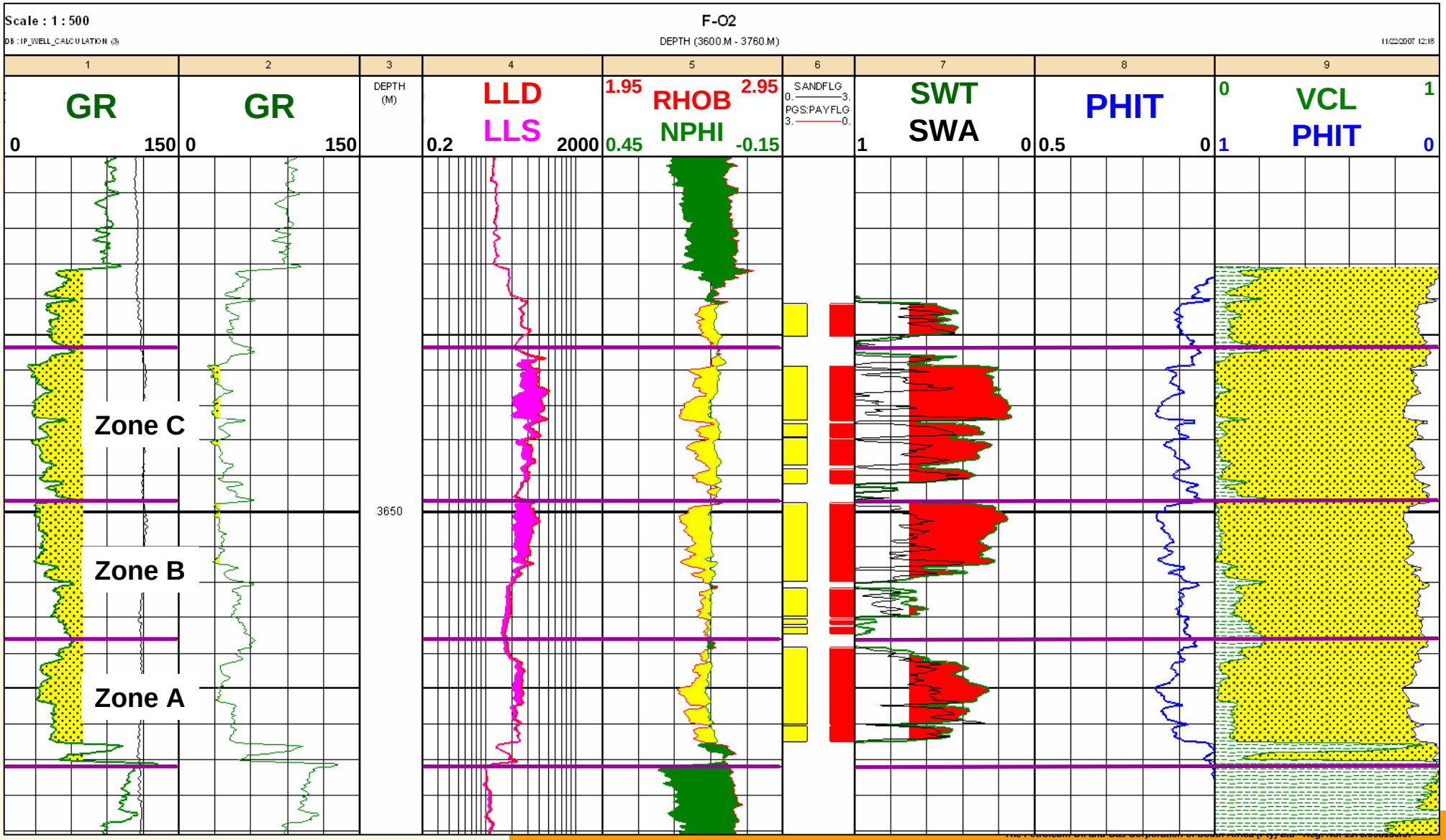
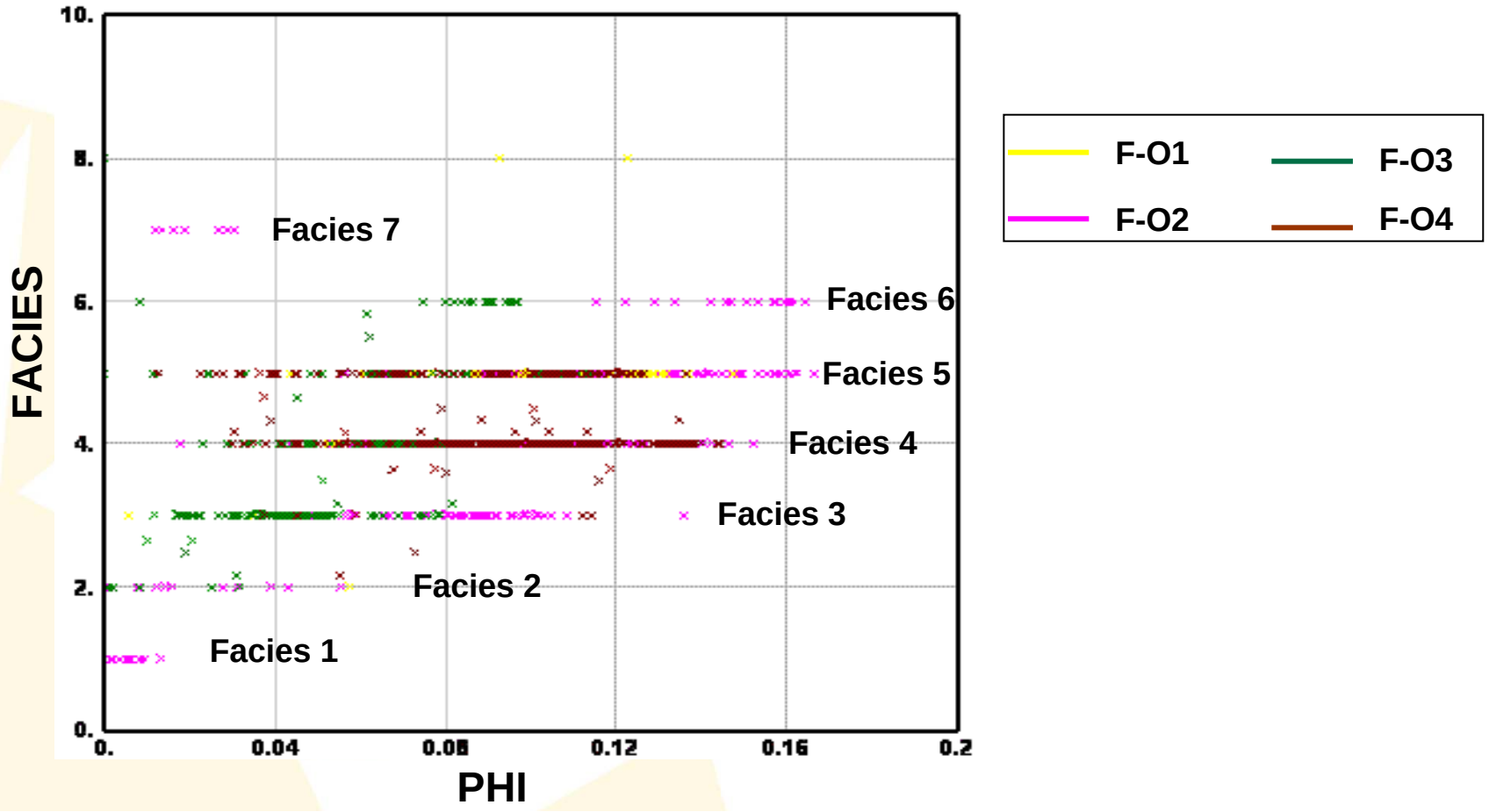


PHI VS FACIES
MultiWells (F-O1, F-O2, F-O3, F-O4)



A wide range of porosity by Facies for each well → **However it is not possible to identify Facies from a porosity curve**.

Best porosity of Facies 4,5,6 is identified in F-O2 well, followed by F-O1.

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PHI VS DEPTH

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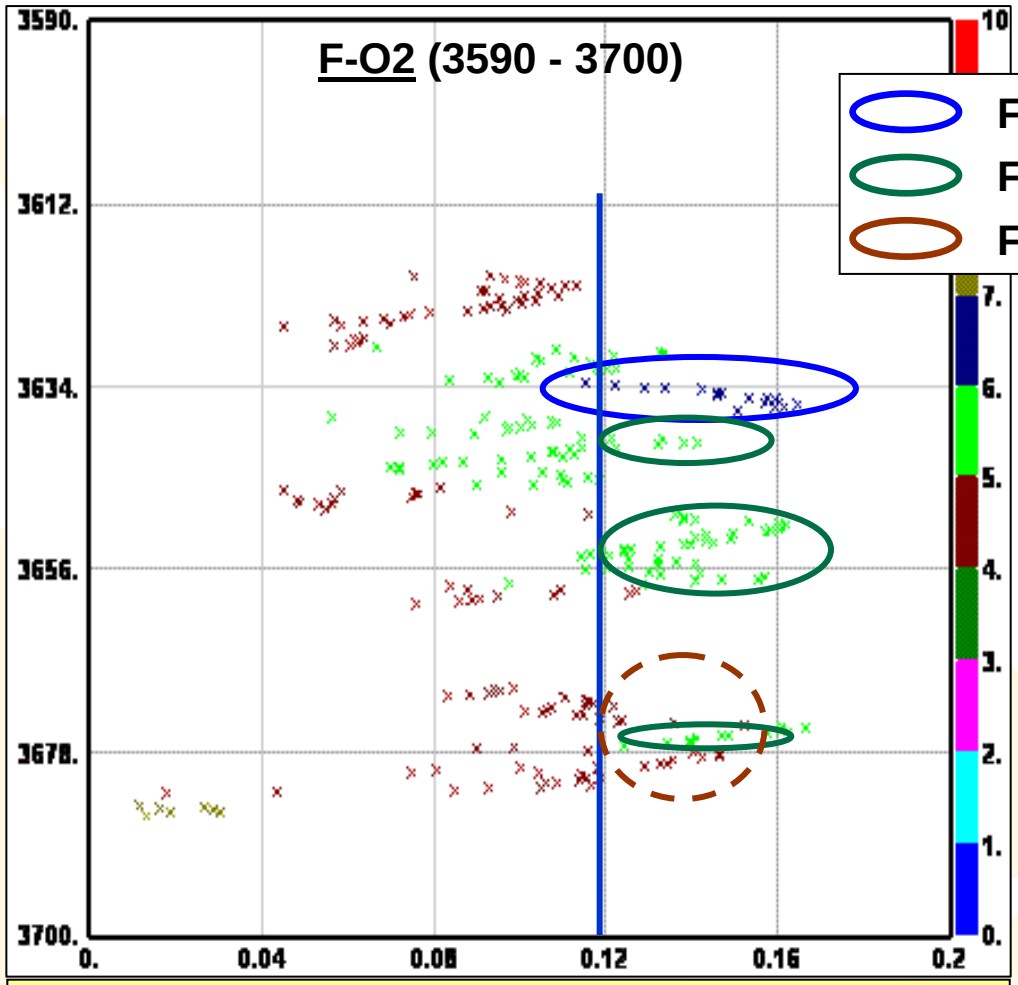
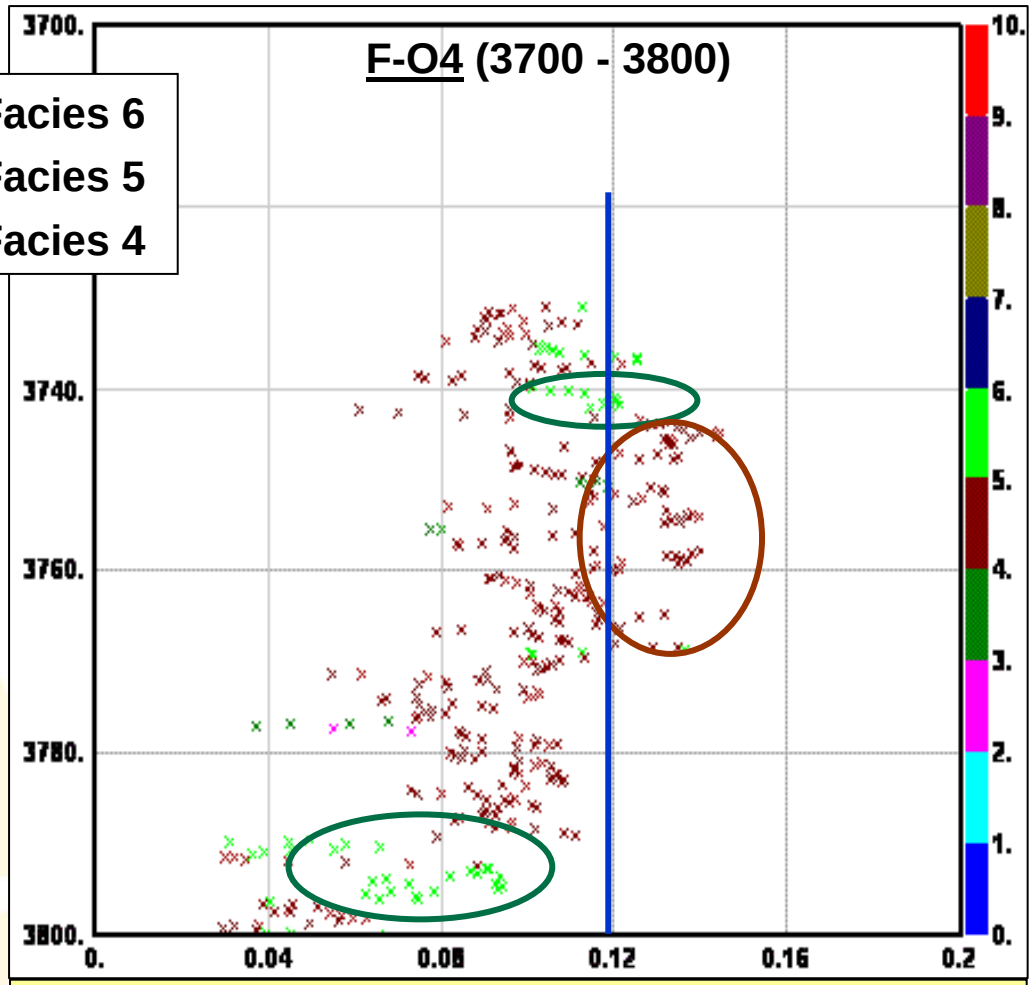


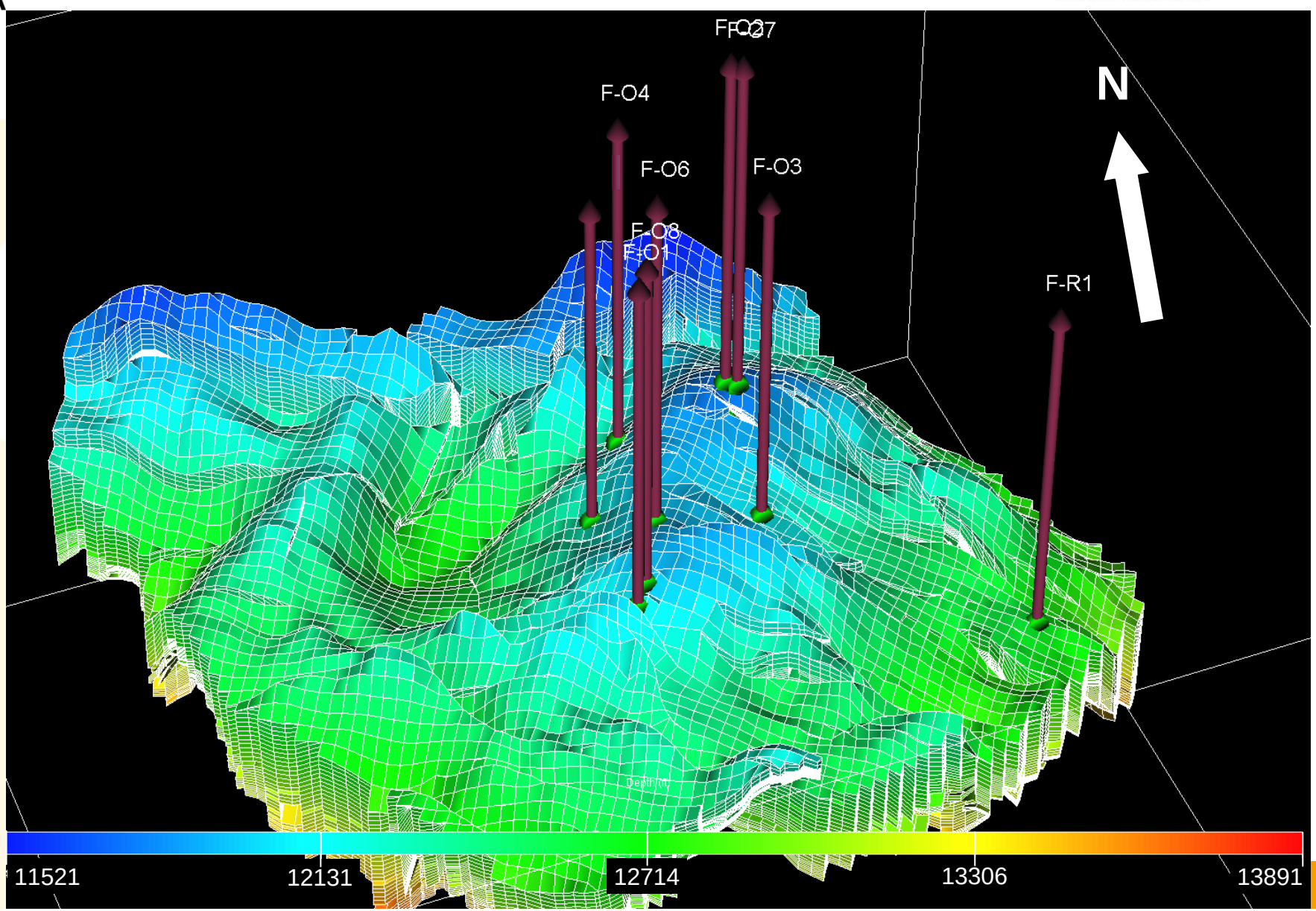


Facies 4,5 & 6 show EP by telodiagenesis

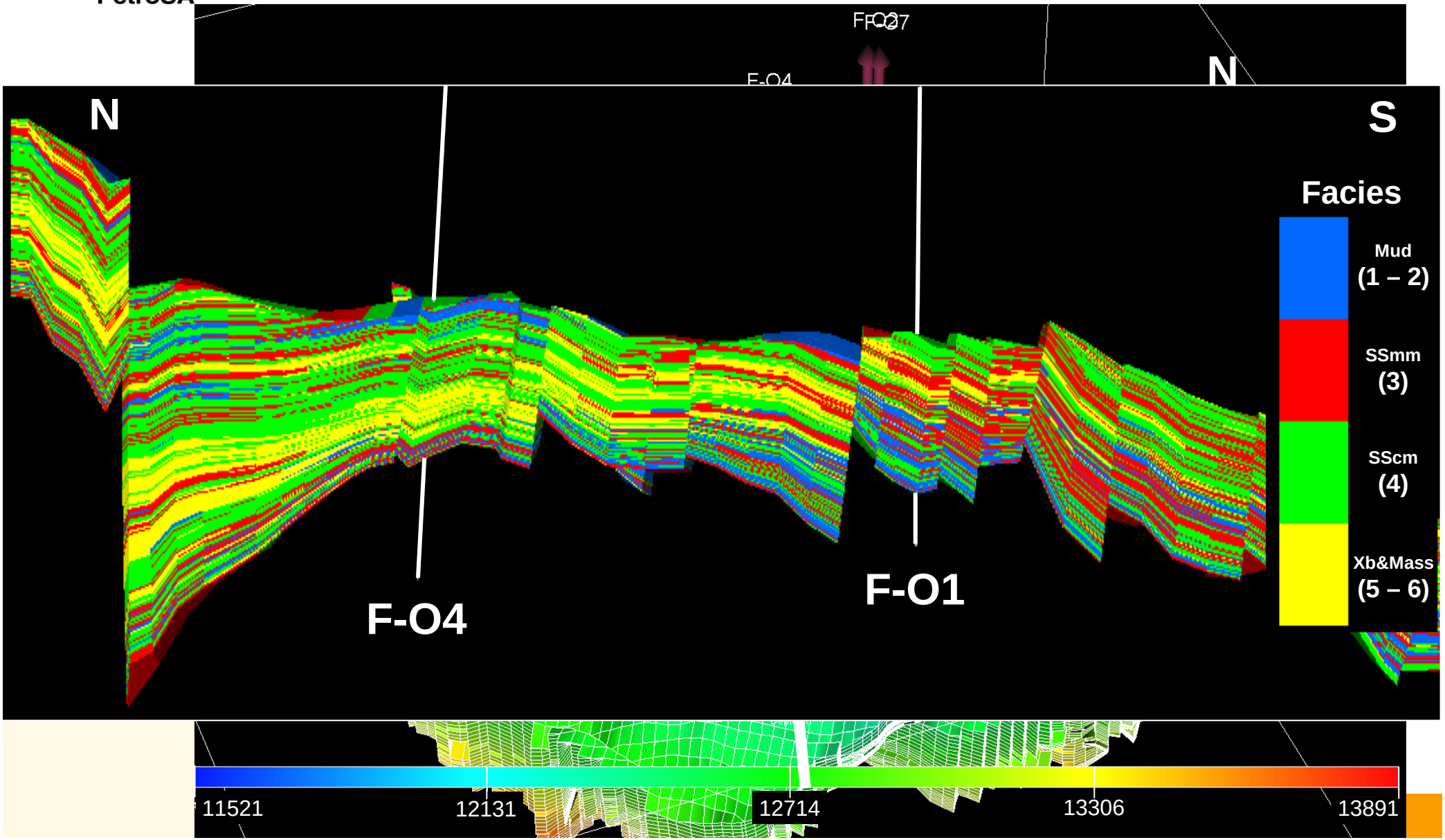
Porosity decreases with depth. Facies 4 with EP, Facies 5 more primary porosity

Enhanced Porosity (EP) > 12%

ECLIPSE Model Depth Grid



Cross-section with Extrapolated Facies (Petrel)



VISAGE Stress Initialisation Model

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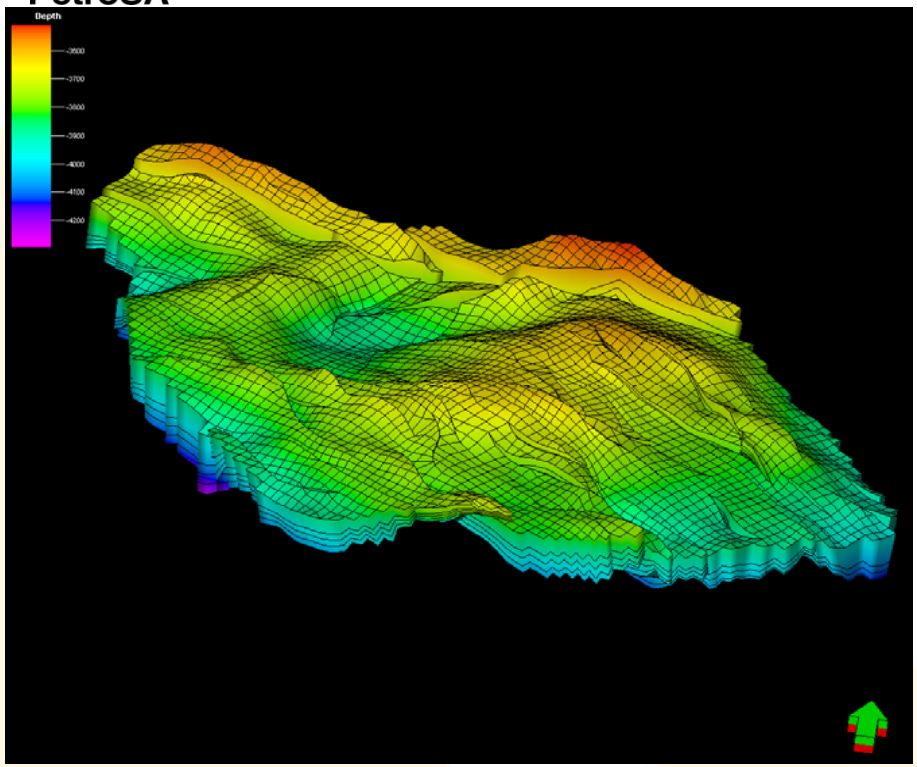
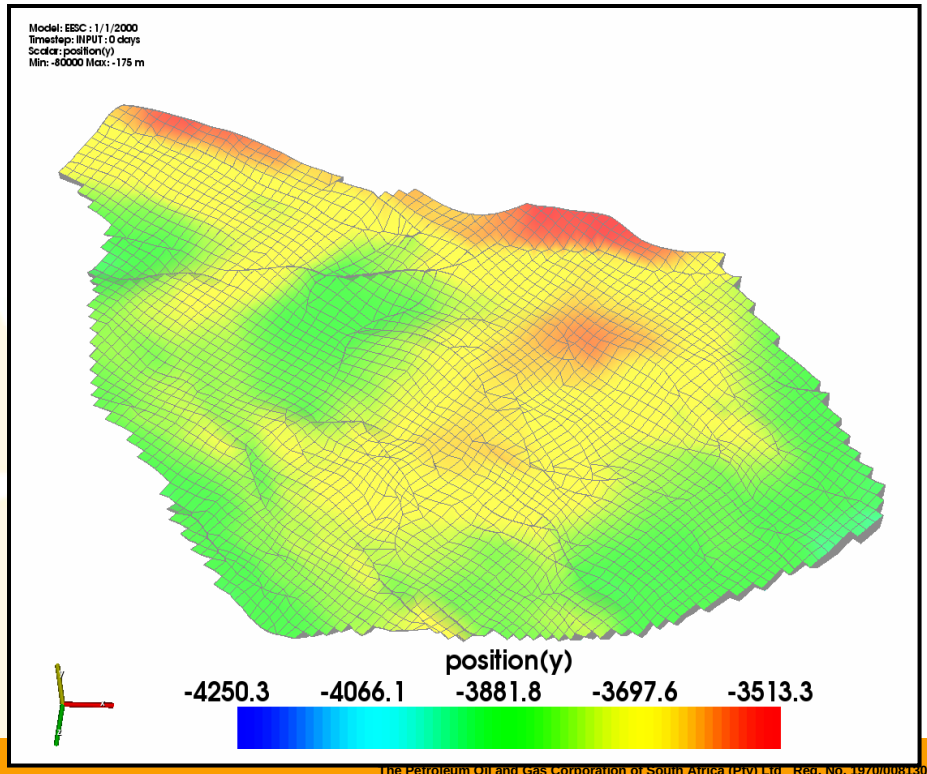


Upscaled Model

Upscaled Petrel GRID exported to VISAGE, smoothed and negative volume cells adjusted to comply with VISAGE parameters.



Visage: Geomechanical Properties

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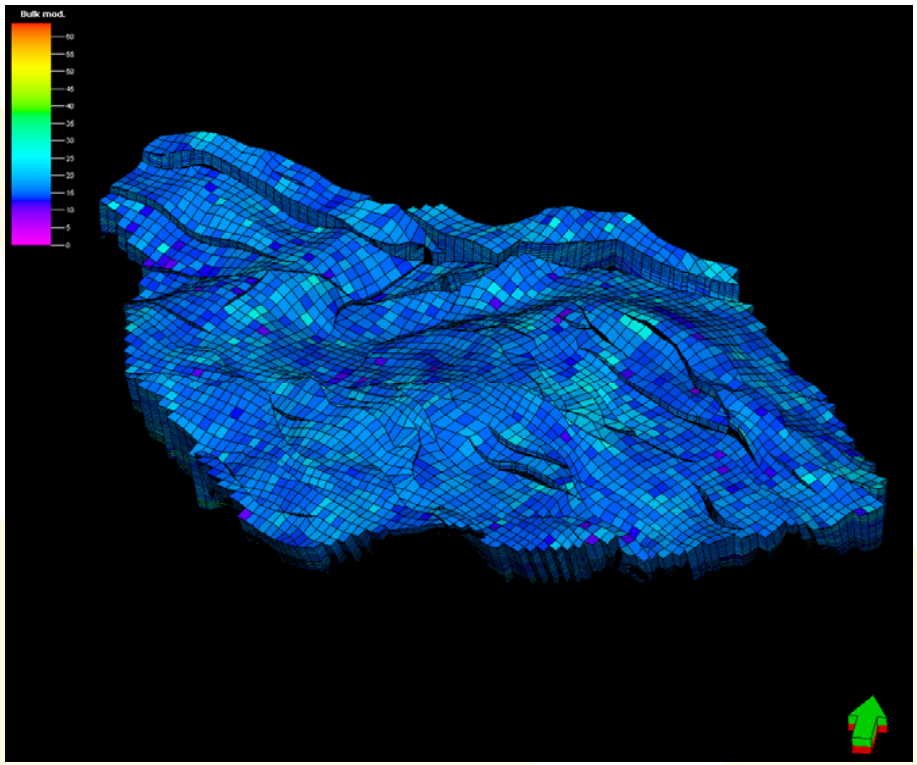
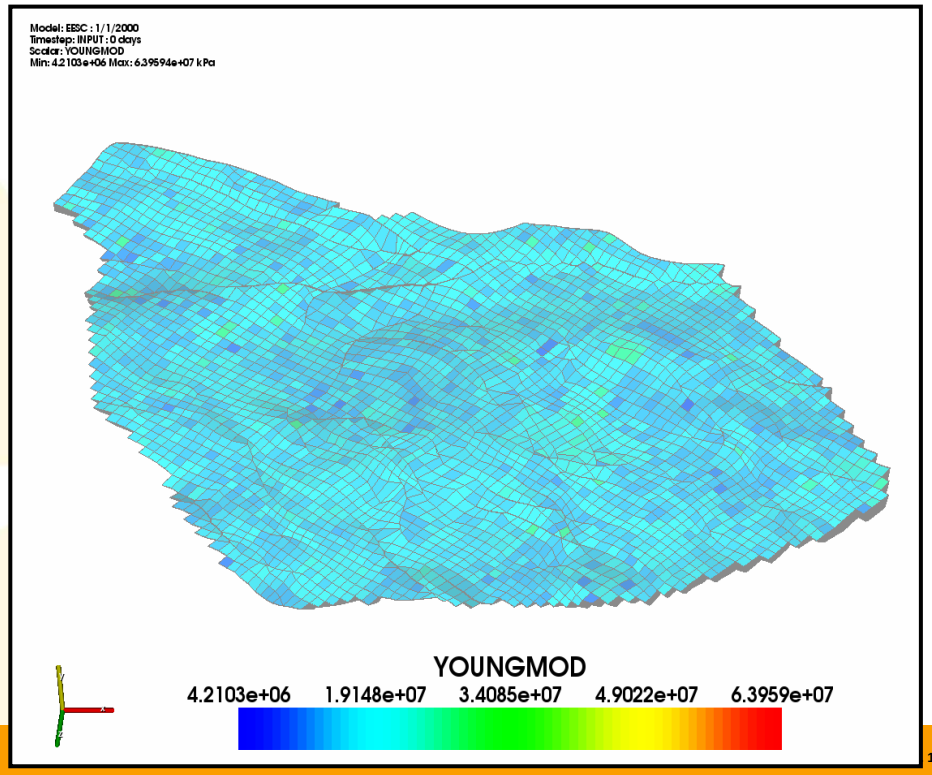


Stochastic geomechanical properties were upscaled and imported into VISAGE.

Upscaled Model: Young's Modulus



Visage: Faults

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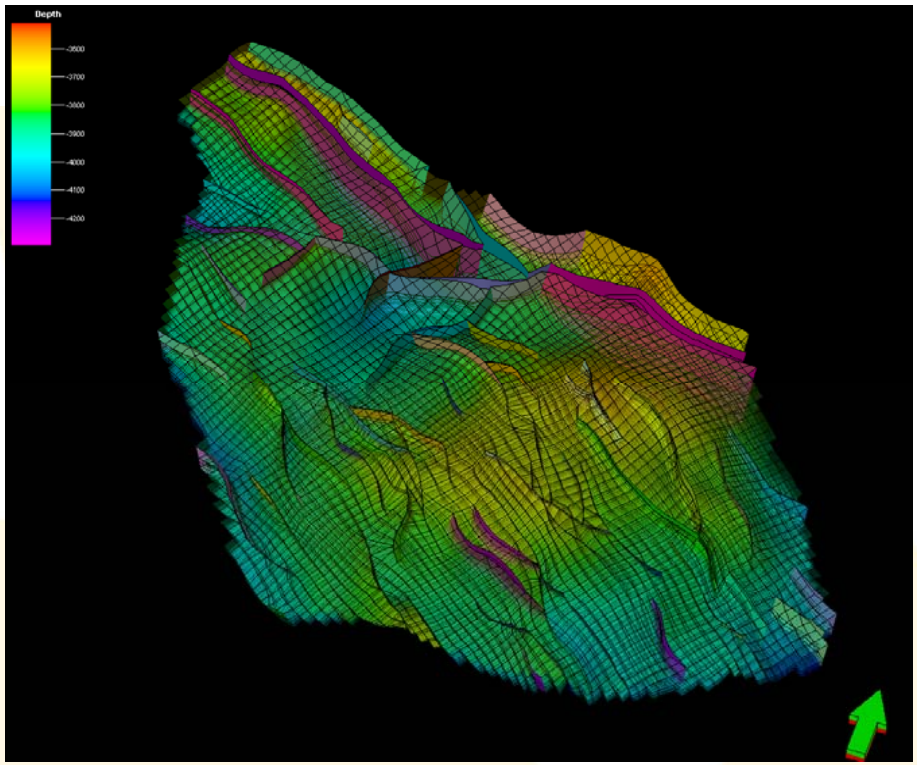
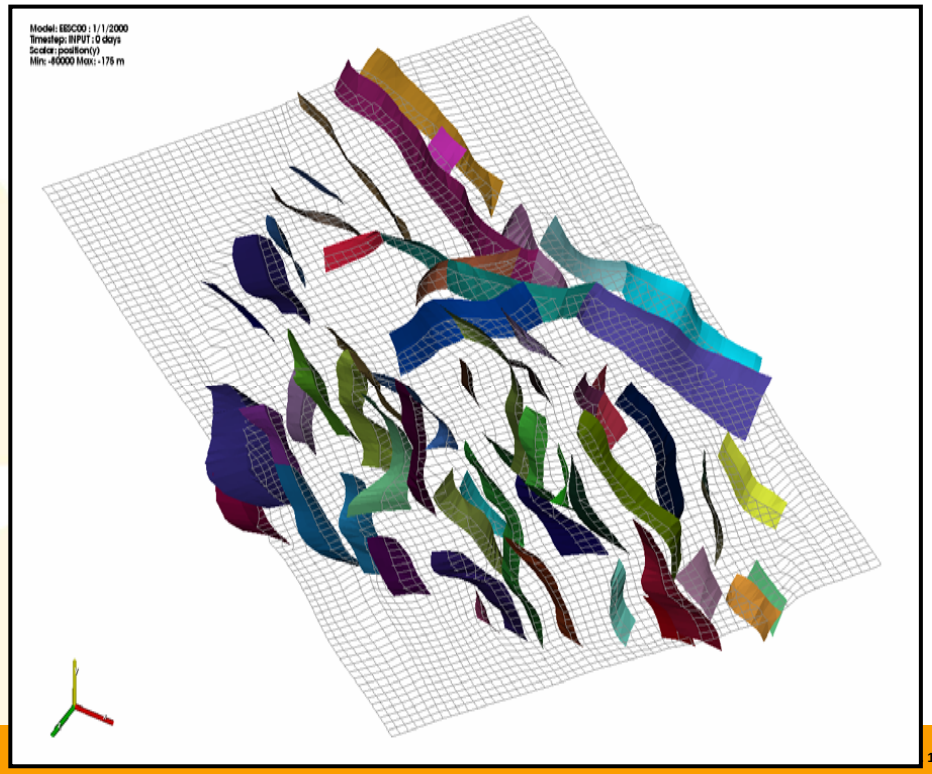
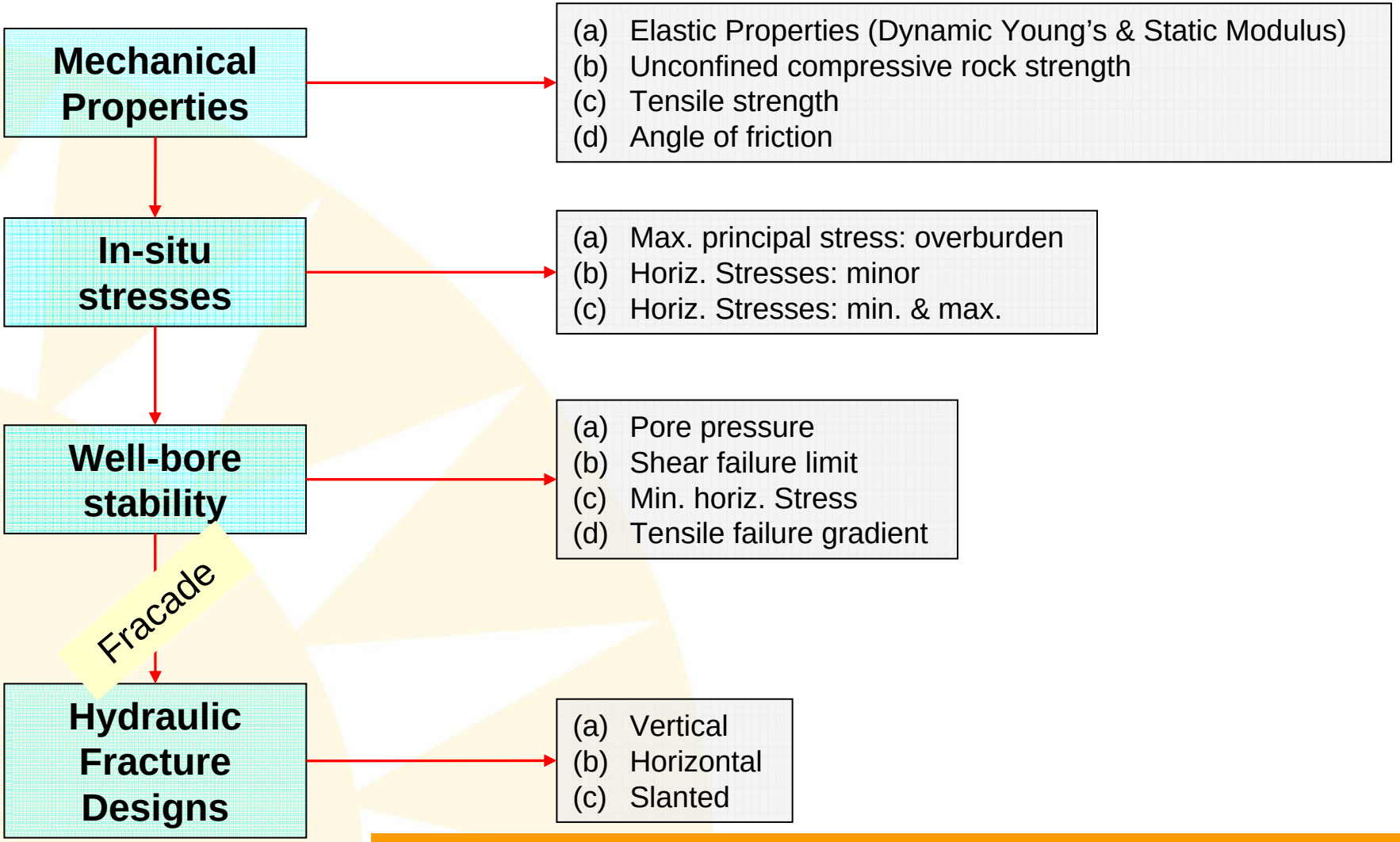


Faults imported into the VISAGE Geomechanical model.



Geomechanical Study of the F-O Field by Schlumberger

1-D Mechanical Earth Model using log data for F-O4



Proposed Field Development Plan

Three well development (provisional plan):

- 1st well, vertical ~100m North-East from F-O1.
- 2nd well, ~100m from F-O2, probably north,
- 3rd well, towards the middle of the F-O reservoir, between F-O1 and 2.

The optimal development plan will be determined from the ongoing studies:

- pipeline will be routed from the F-A Platform to the 3rd well location.
- spur lines from the 1st and 2nd well locations will be tied back to a pipeline end manifold (PLEM) at the 3rd well location. This “hub and spoke” field development plan optimises the drainage area in the reservoir.

Acknowledgements…

- Schlumberger for the static, dynamic and 3D mechanical earth modelling, geomechanical analysis, lab core analysis and hydraulic fracture designs

- Management and colleagues within the New Ventures Division of PetroSA

- Dr Higgs for the sedimentology study