Integrated Basin and HC Systems Model, Silurian-Carboniferous, Southern Algeria*

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Abstract

Paleozoic basins of southern Algeria comprise several HC systems: i) infra-Cambrian (?) source rock, Upper Ordovician reservoirs; ii) Silurian source rock, Lower and Middle Devonian reservoirs ; iii) Upper Devonian source rocks, Lower Carboniferous reservoirs. Since 2006, commercially productive gas reservoirs have been proven by several wells in the Reggane and Ahnet Basins. Previous basin evaluation has proposed HC generation predominantly during Mesozoic reburial, with pre-Hercynian generation having been largely ineffective (Purdy & MacGregor 2003, Geol. Soc. Spec. Publ. London, v. 207). Thermochronlogical data (Logan & Duddy 1998, Geol. Soc. Spec. Publ. London, v. 132) have indicated two-phased HC generation: i) simple burial heating to oil window before peak Hercynian orogeny (pre-Early Carboniferous); ii) Late Triassic heating to wet and dry gas window in the Latest Triassic, related to the development of the Central Atlantic Magmatic Province (CAMP) and doleritic dykes/sills (Reggane Basin); and iii) subordinate heating of less mature basin margins until recently.

In order to better assess the basin and HC development including the recently proven gas plays, an integrated study has been performed including: i) seismic and sequence stratigraphy at basin and reservoir resolution; ii) numerical basin modeling (subsidence/uplift, sediment flux); iii) palynostratigraphic (miospores, acritarchs) and organofacies analysis; and iv) paleotemperature analysis including organic maturation, apatite and zircon fission track and (U-Th)/He dating. Focus is on the Reggane Basin, where ample 2D seismic coverage and calibration wells (logs, samples) have been available. Results include: i) trans- and regressive trends within the basin fill; ii) intra- and inter-basin correlation iii) lateral continuation and vertical connectivity of reservoir sandstones; iii) accommodation and sediment flux history; and iv) paleotemperature development related to pre- and post-Hercynian burial and exhumation. The new data show, that the existing models of HC development for the Upper Silurian-Lower/-Middle Devonian and Upper Devonian-Lower Carboniferous systems have to revised.

References

Logan, P. and I. Duddy, 1998, An investigation of the thermal history of the Ahnet and Reggane basins, central Algeria, and the consequences for hydrocarbon generation and accumulation: Geological Society Special Publications, v. 132, p. 131-155.

Purdy, E.G. and D.S. MacGregor, 2003, Map compilations and synthesis of Africa's petroleum basins and systems: Geological Society Special Publications, v. 207, p. 1-8.

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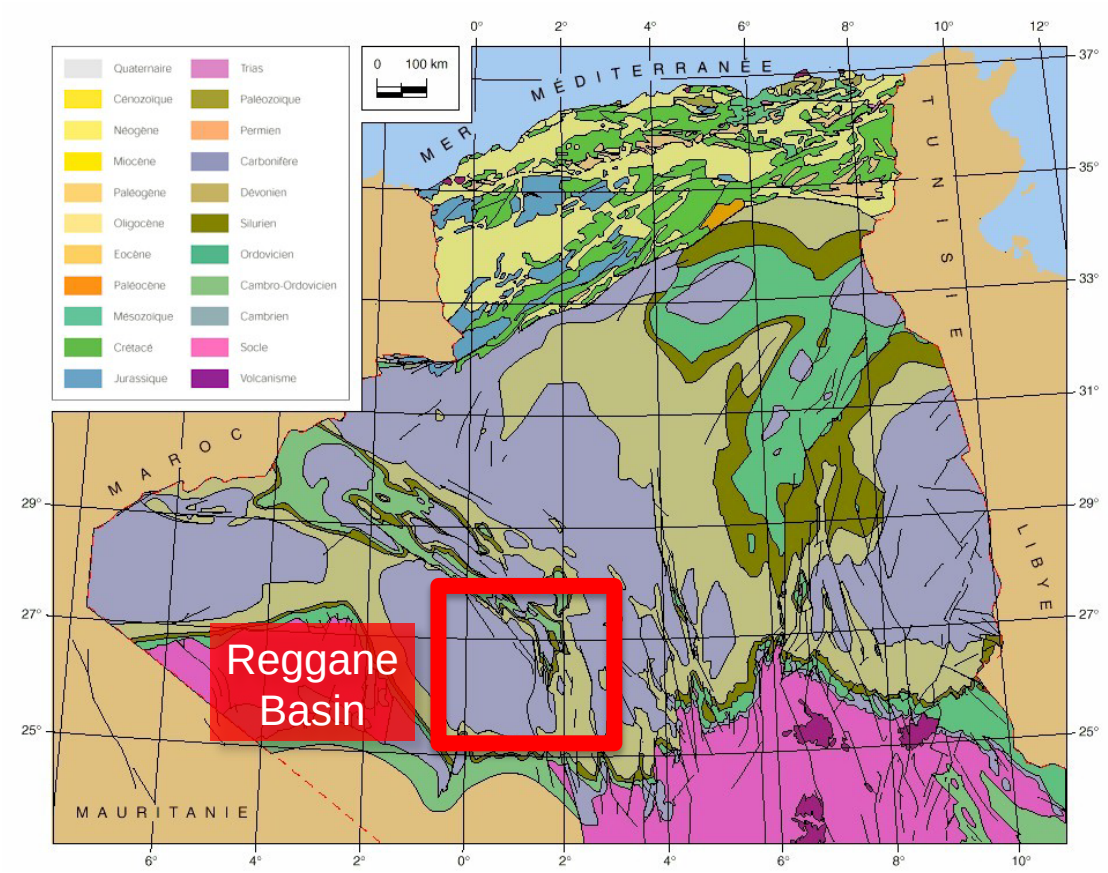
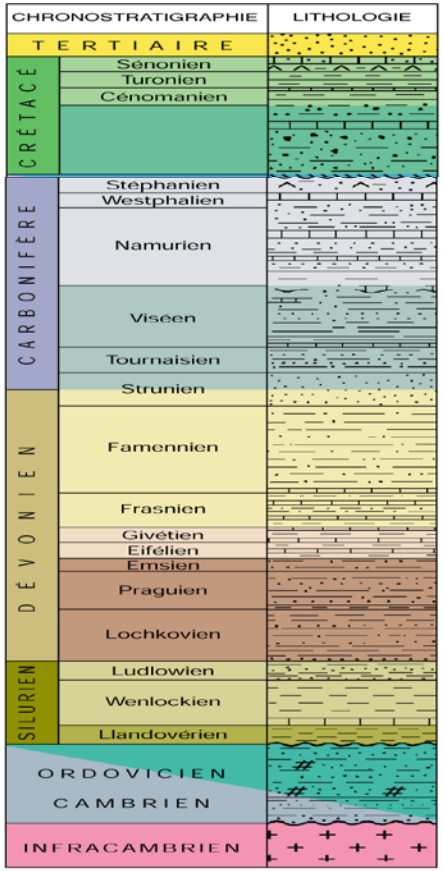
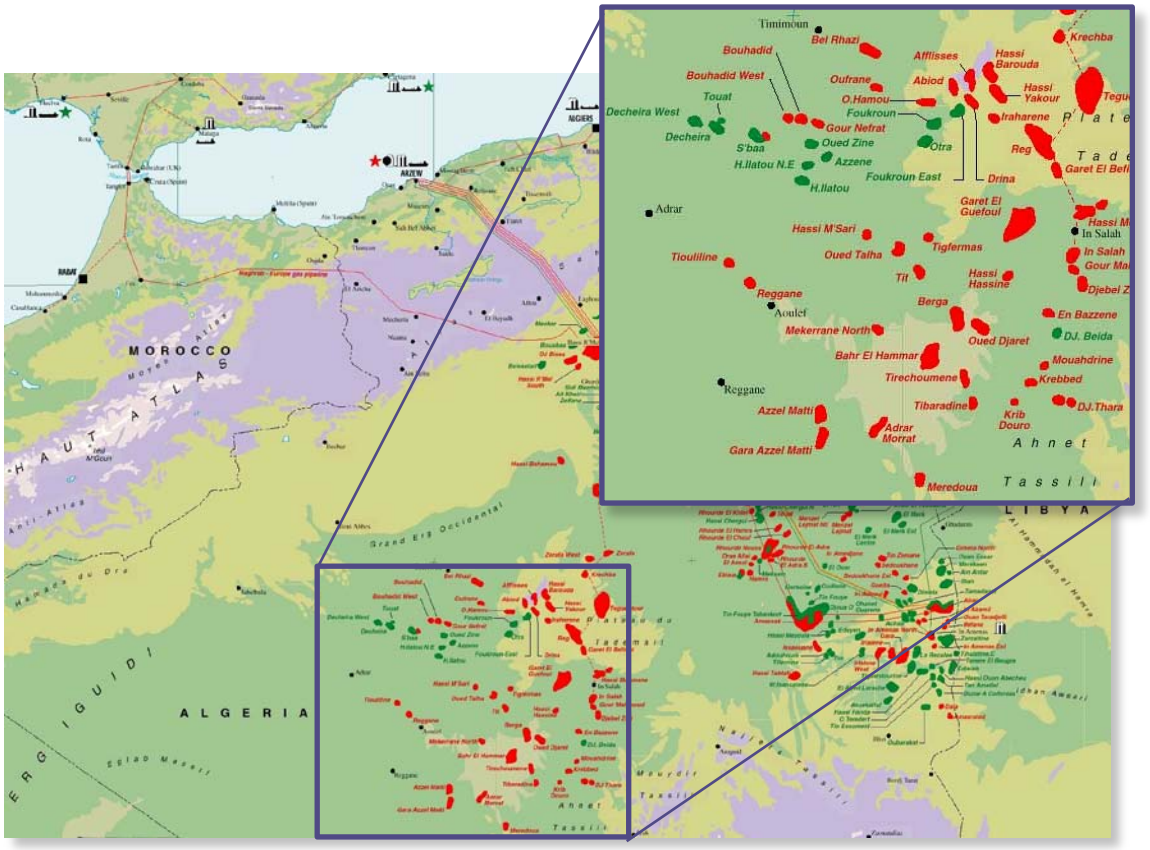
- Framework
  - Regional Geology
  - HC Geology
- Palynology
- Thermal History
- Seismic and Sequence Stratigraphy
- Integrated Basin Model

Regional Geology





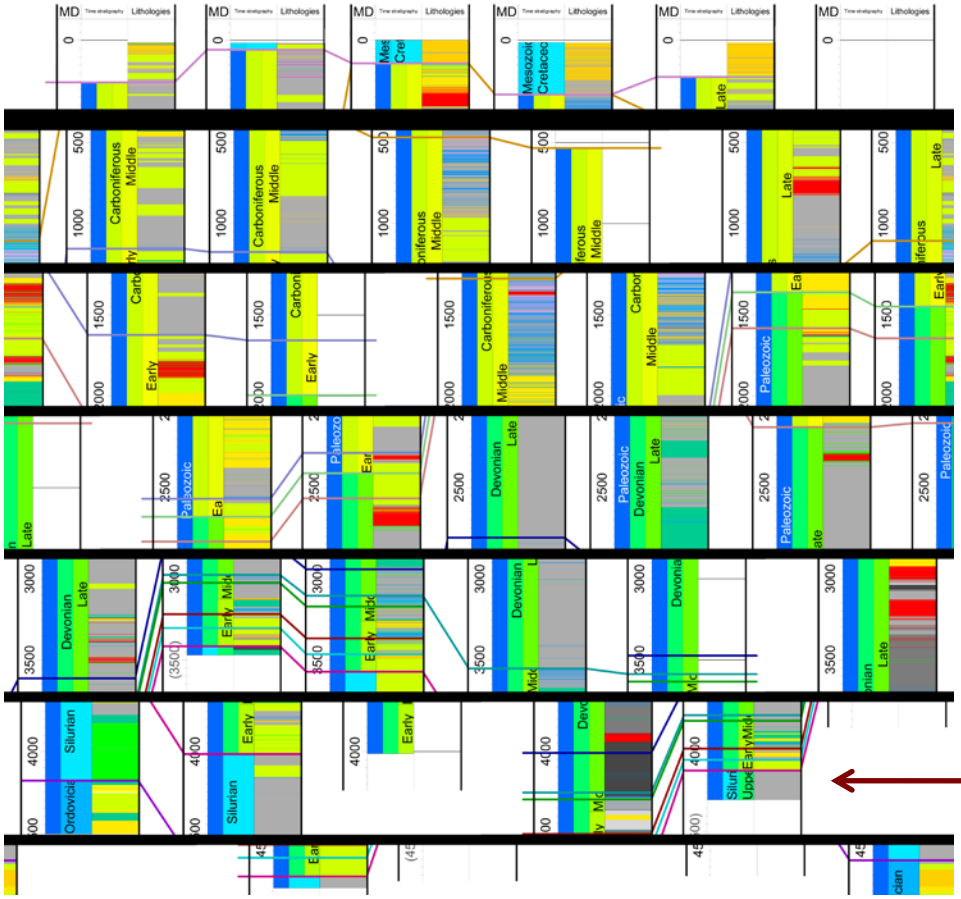
- Paleozoic & Late Cretaceous to Tertiary Basin Fill: 4500-5500 m thickness
- Pan-African plate-tectonic domains: West African Craton, Hoggar Shield
- Northern Gondwana clastic continental shelf



- Two major phases of hydrocarbon generation (Logan & Duddy (1998)
  1. Early, pre-Hercynian phase, in which chiefly liquid hydrocarbons were expelled
  2. Later phase, associated with a “heat spike” at 200 Ma, in which significant quantities of dry gas were generated and expelled

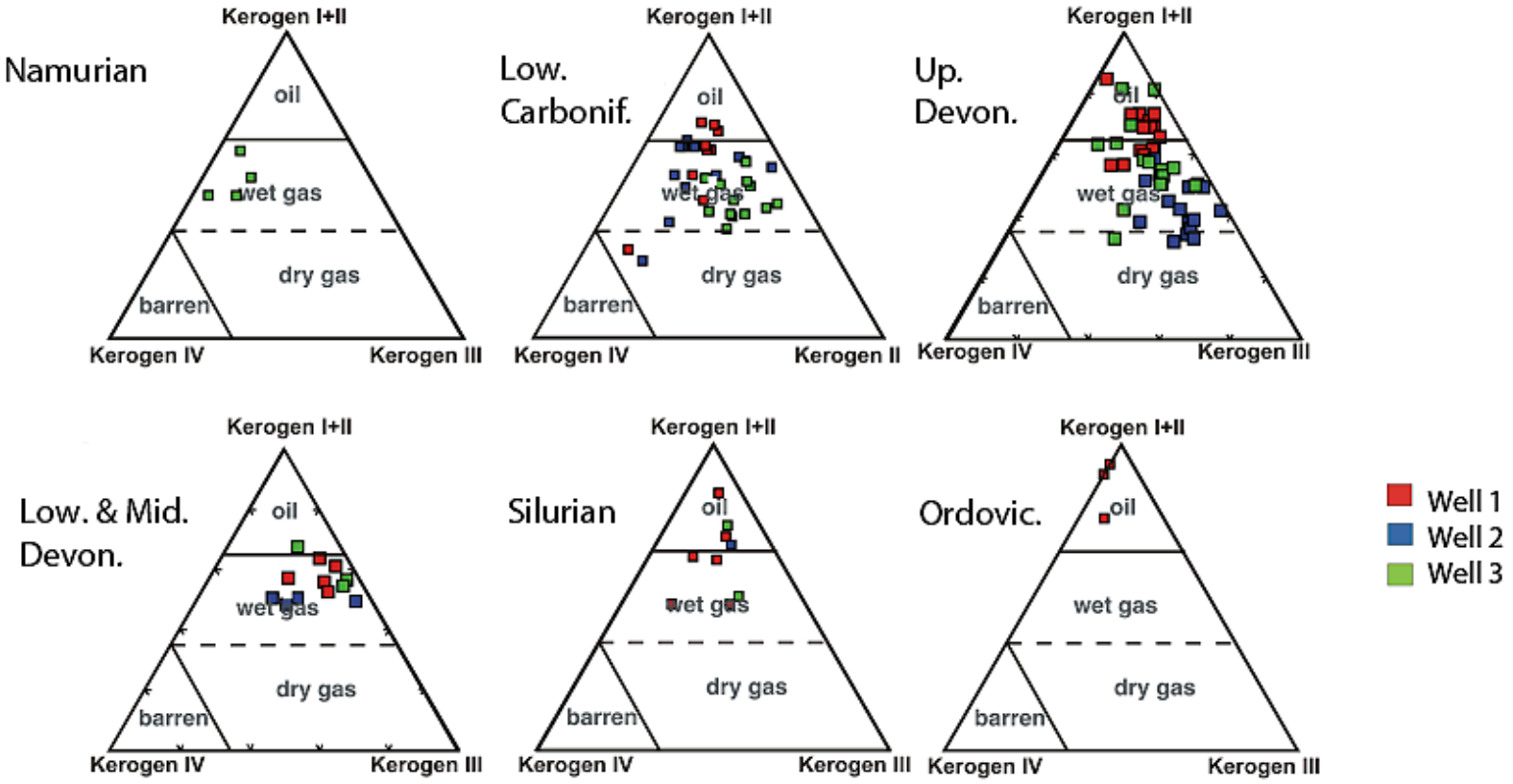
- Framework
- Palynology
  - Palynostratigraphy
  - Organofacies
- Thermal History
- Seismic and Sequence Stratigraphy
- Integrated Basin Model

Palynostratigraphy



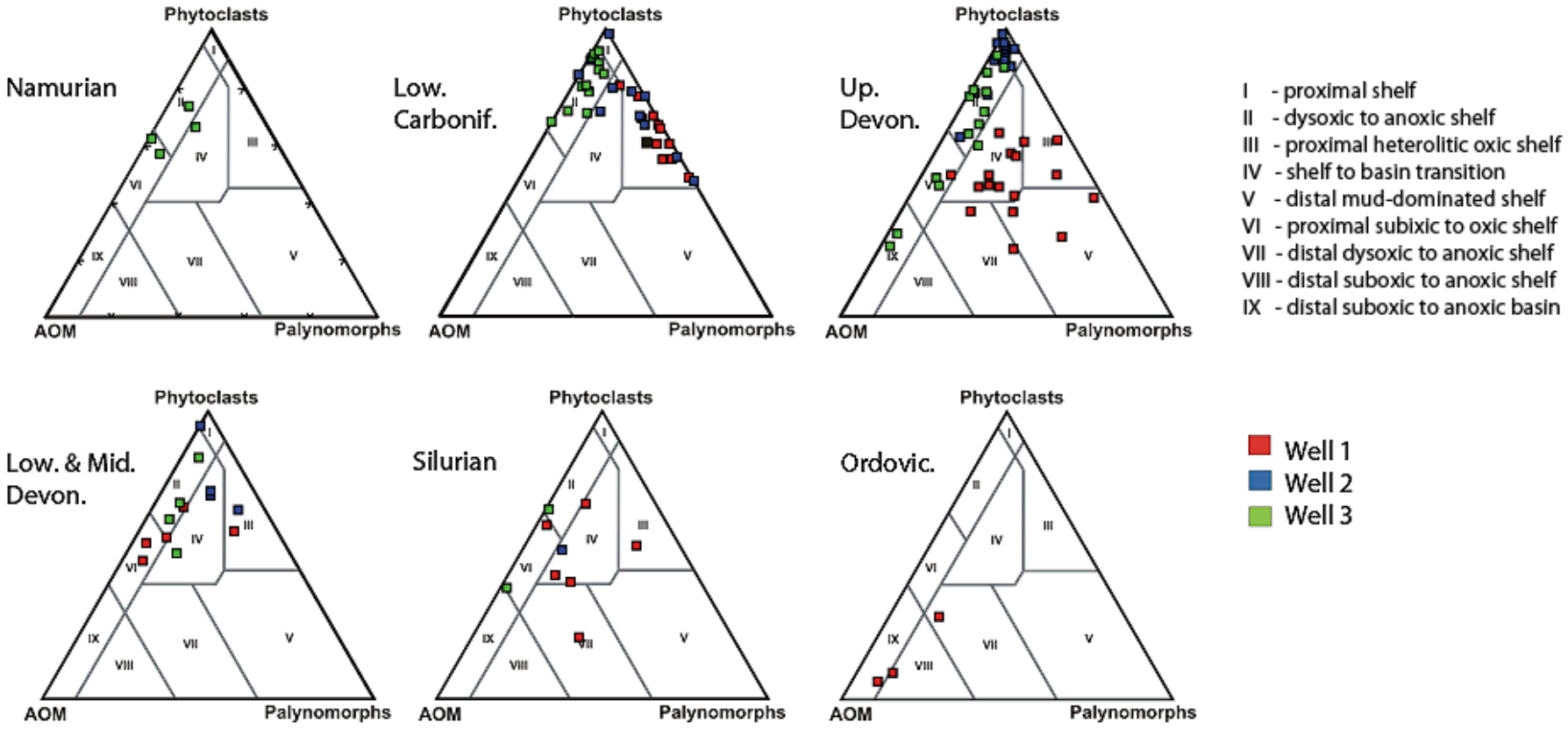
- 12 to 19 stratigraphic levels correlated across basin
- Subzone resolution in Early to Middle Dovinian reservoir intervals
- Zone resolution of Silurian to Carboniferous basin fill

Organofacies



- Kerogene Types II & IV prevail
- High potential for wet gas generation: Devonian to Carboniferous
- Moderate to low potential for oil generation: Ordovician, Silurian, Namurian

Organofacies

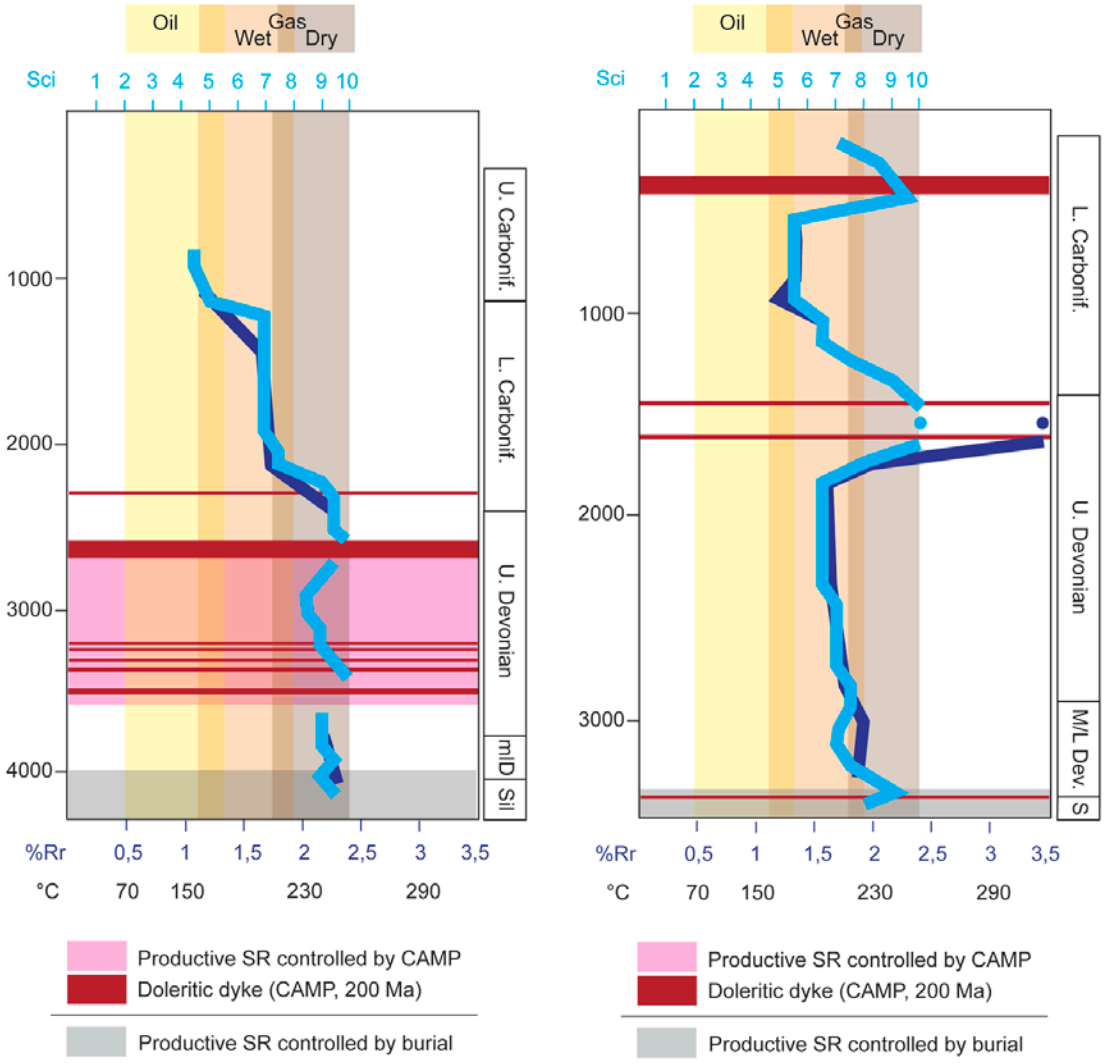


- Mainly proximal shelf settings: Carboniferous, Lower to Middle Devonian
- Mainly distal shelf to basinal settings: Silurian, Upper Devonian
- Proximal to distal transition: SE to NW

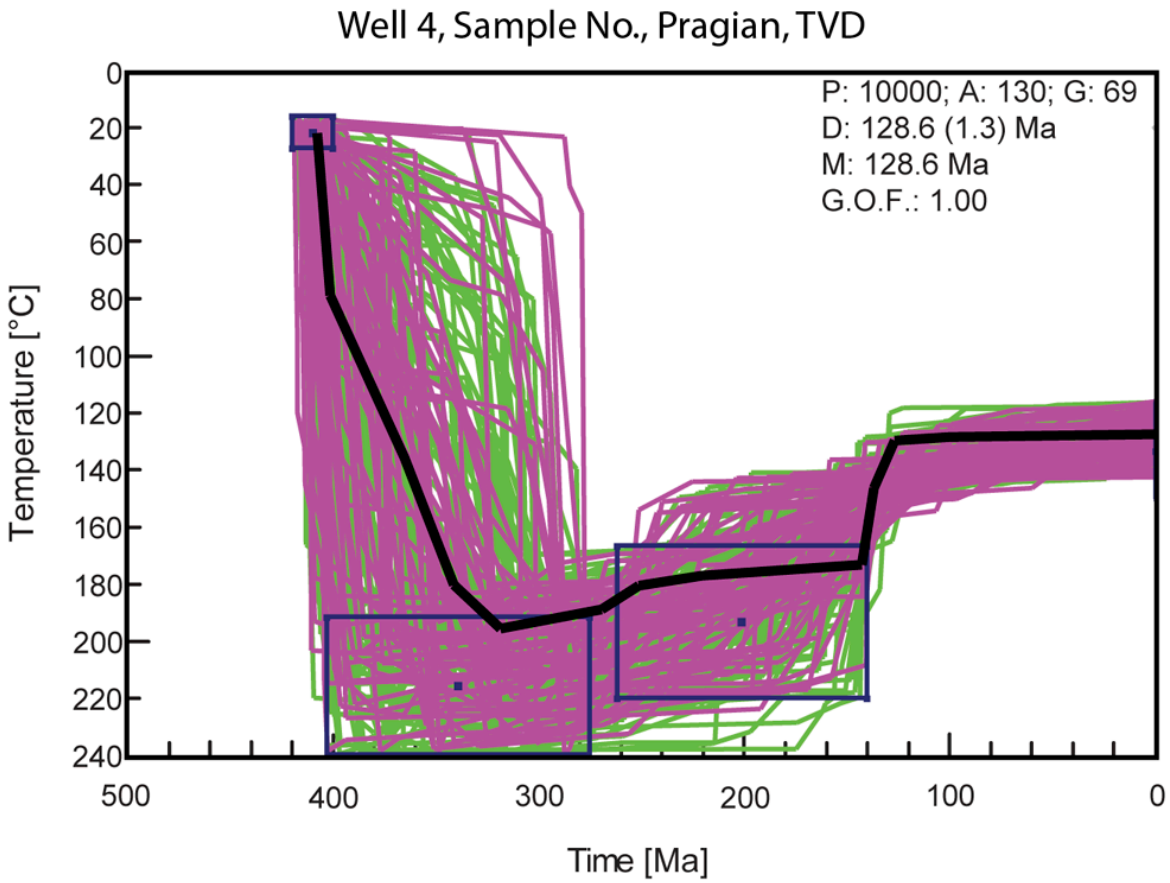
- Framework
- Palynology
- Thermal History
  - Vitrinite reflectance & spore color index
  - Apatite & zircon FT & (U-Th)/He dating
- Seismic and Sequence Stratigraphy
- Integrated Basin Model

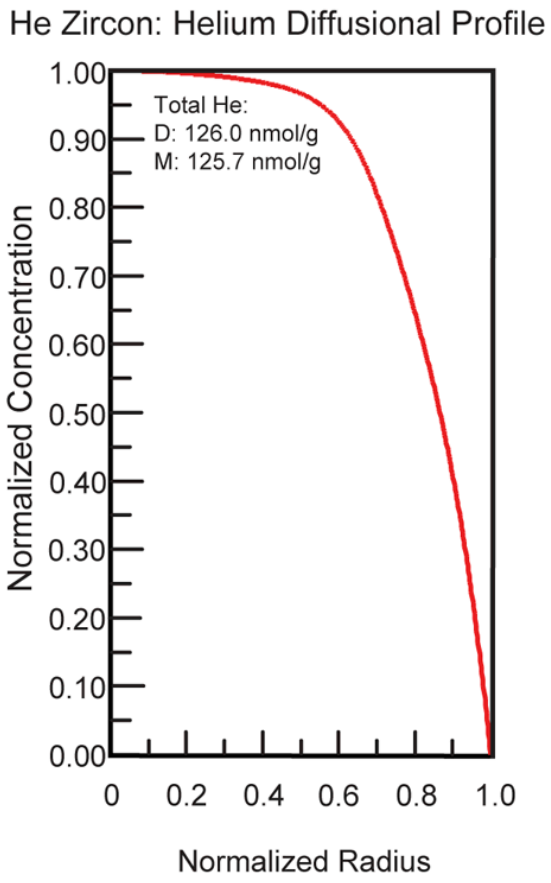
Vitrinite Reflectance & Spore Color Index

- Similar maturation trends in all wells
- Doleritic dykes related to CAMP at 200 Ma
- Silurian & Lower Devonian HC system not affected by dykes – Pre- to Syn-Variscan gas generation by burial
- Upper Devonian & Lower Carboniferous HC system affected by dykes – Post-Hercynian gas generation
- Majority of gas generated and expelled by pre- to syn-Hercynian burial



Apatite & Zircon FT & (U-Th)/He Dating

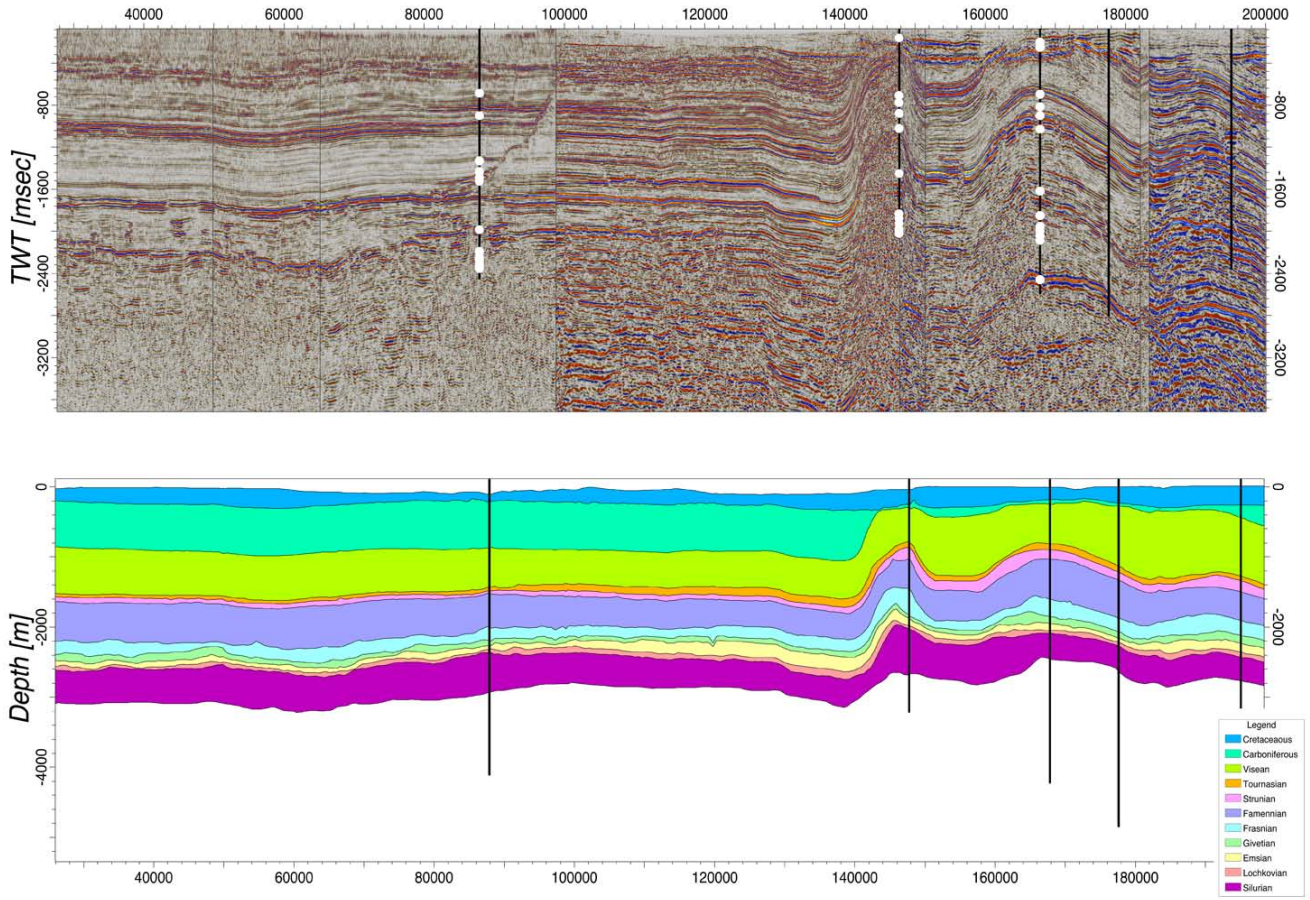




- t-T modeling for 40 samples from 4 wells
- Silurian source rocks reach gas window at 375-330 Ma, Famennian to Visean
- Heat event at 200 Ma (CAMP) not effective

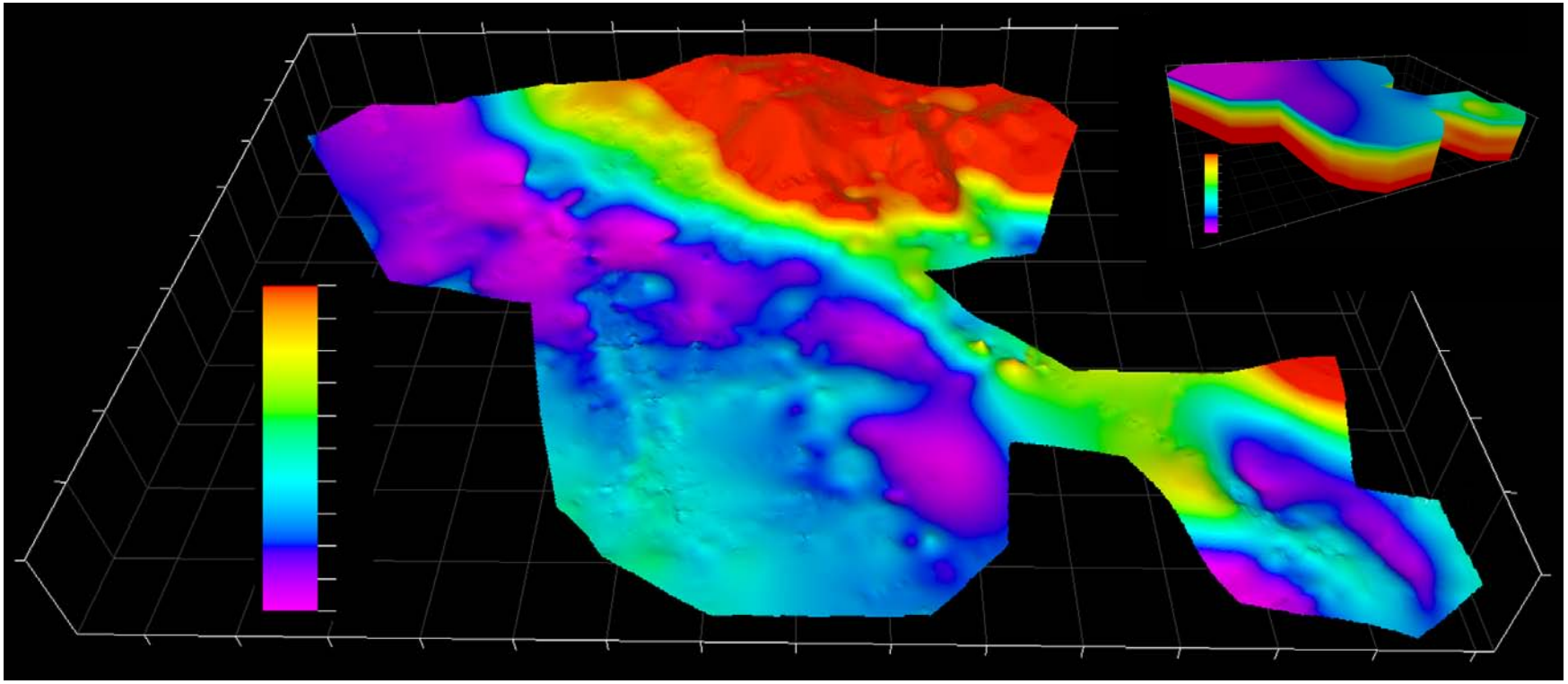
- Framework
- Palynology
- Thermal History
- Seismic and Sequence Stratigraphy
  - 3D Basin Model
  - HR sequence stratigraphy & reservoir model
- Integrated Basin Model

3D Basin Model



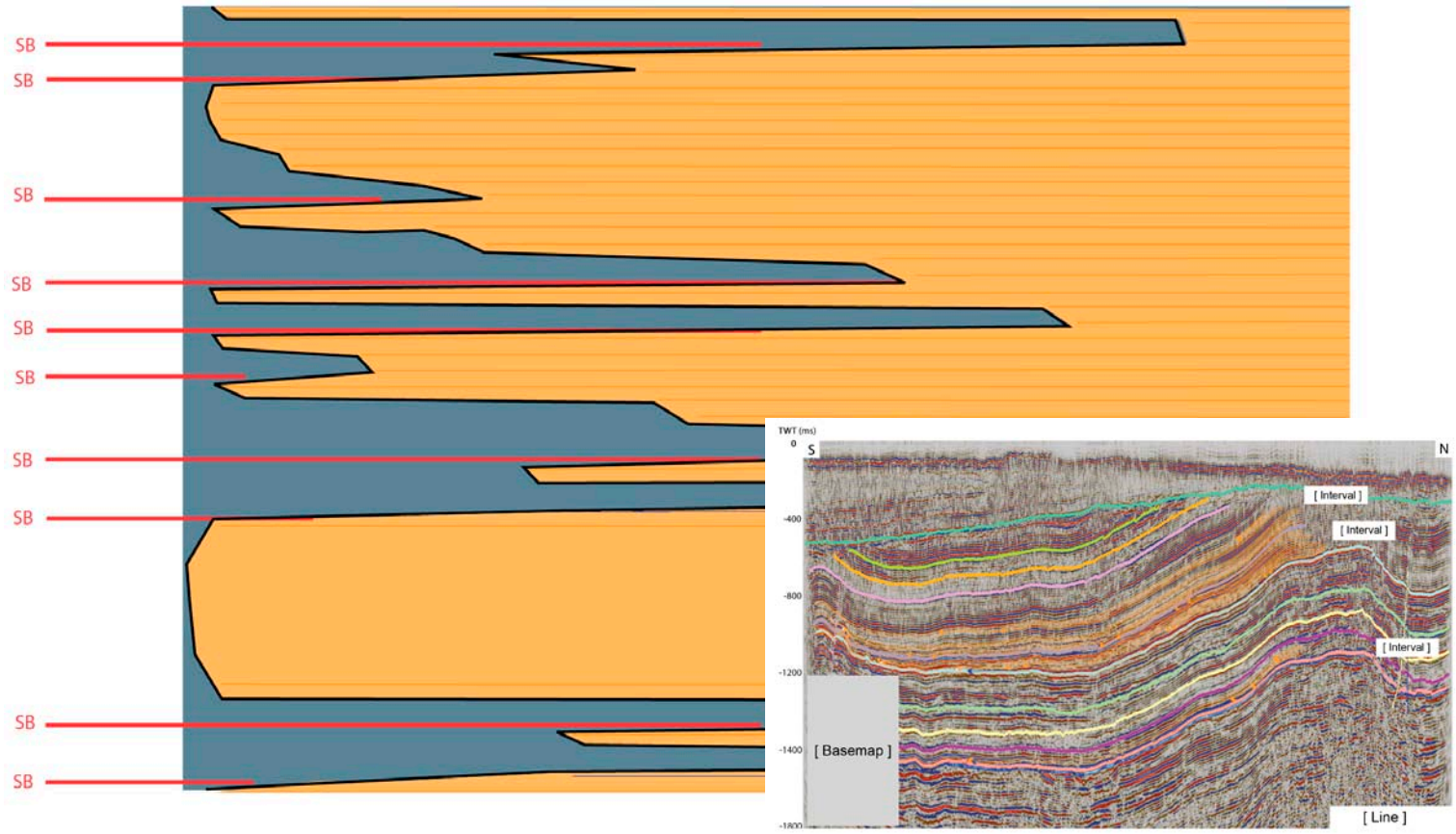
- Database: four 2D seismic surveys, HR palyno- & chronostratigraphic framework
- Late Silurian to Early Carboniferous deposition continuous in NW Reggane Basin
- Eifelian to Early Givetian erosional / depositional gap in SE Reggane Basin

3D Basin Model



- 3D basin model in depth domain with 12 stratigraphic levels
- Reservoir geometries below seismic resolution
- Chronostratigraphic and architectural framework for basin modeling

Seismic & Sequence Stratigraphy

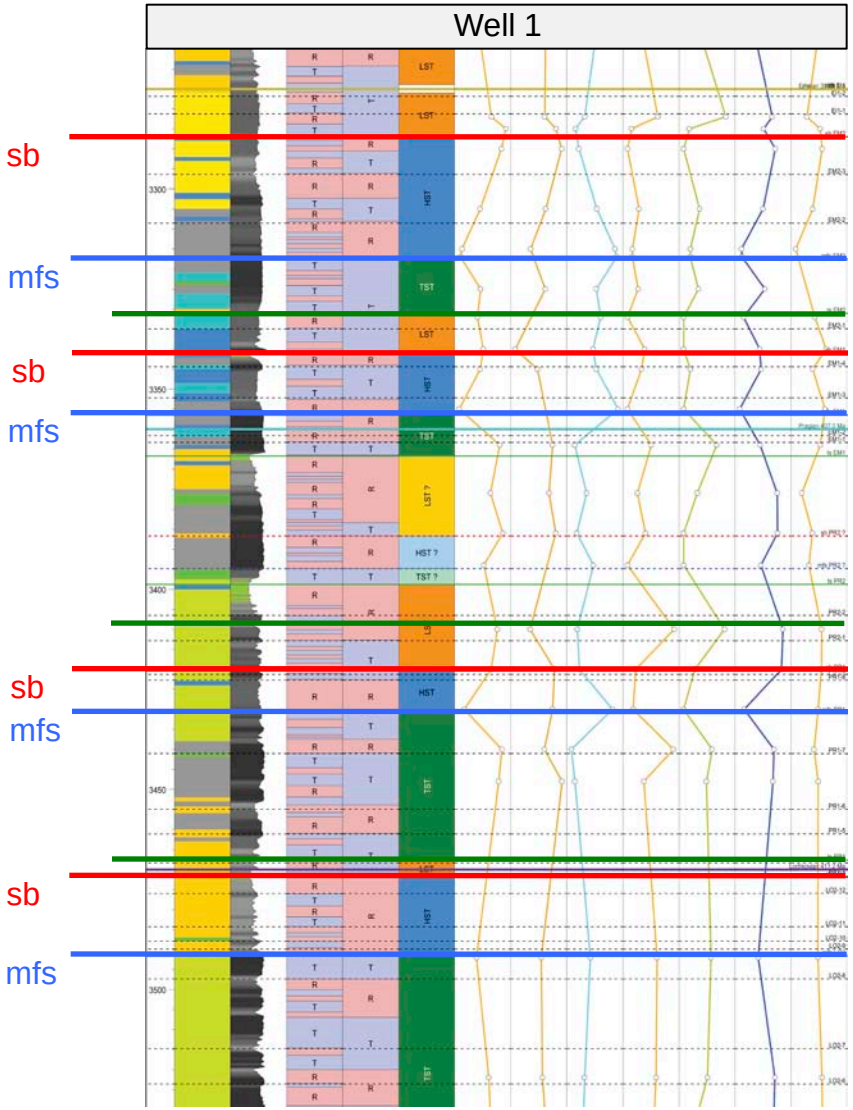


- Coastal onlaps not preserved because of erosion of basin margin
- Low angle clastic ramps without major reflector terminations
- Downlap trajectories indicate basinward limits of shoreface reservoir units

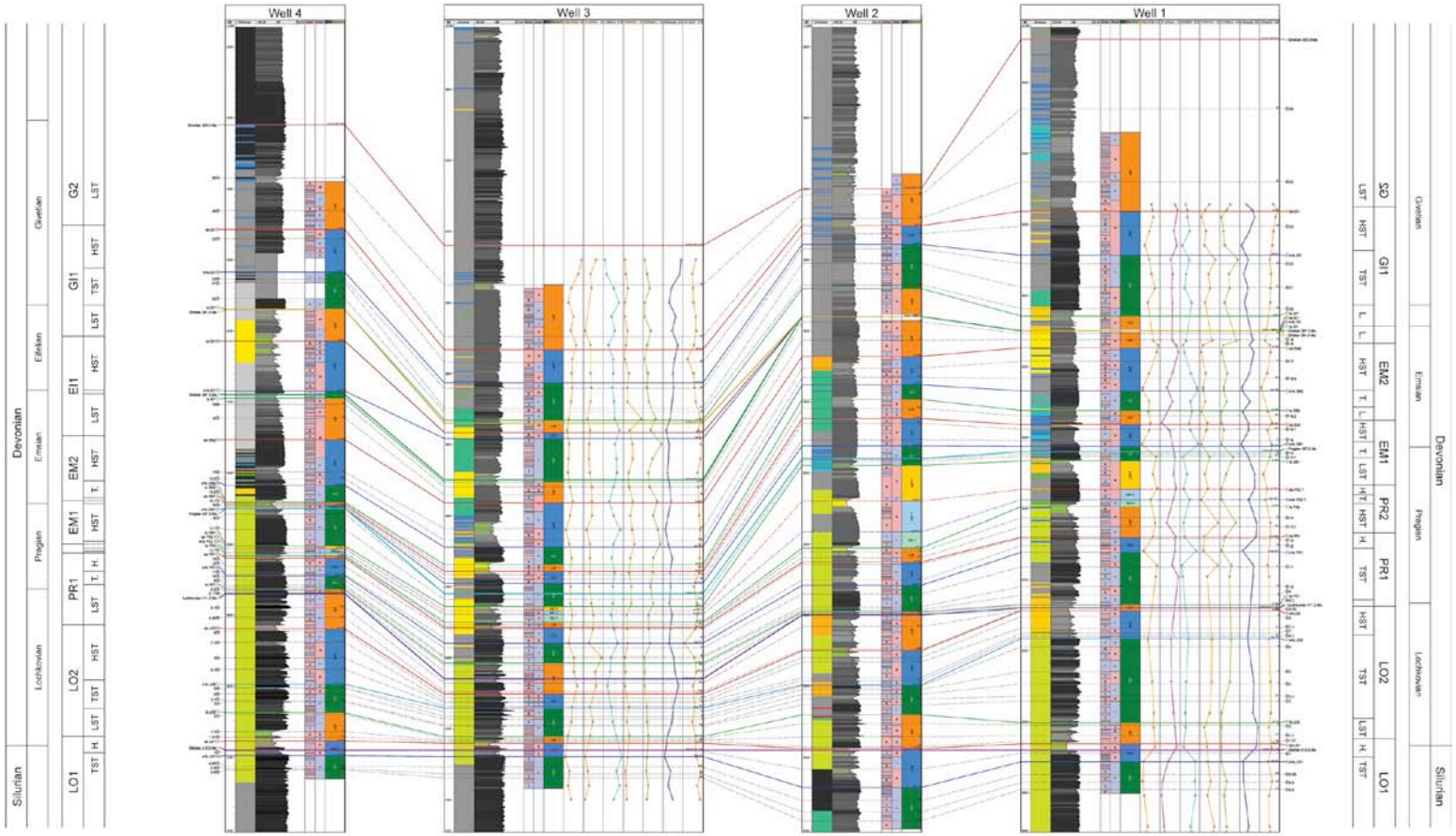
HR Seq Strat & Reservoir Model

- High-resolution sequence stratigraphy
  - Basinal downlaps
  - Well log trends
  - Organofacies proxies

  - Index Terrigene : Marine
    Min: mfs / Max: sb
  - Content amorphous material
    Min: sb/ Max: mfs
  - Content plankton
    Min: sb / Max: mfs
  - Content phytoclasts
    Min: mfs / Max: sb
  - Index Opaque : Translucent
    Min: mfs / Max: sb



HR Seq Strat & Reservoir Model



- HR resolution reservoir model above palynostratigraphic & seismic resolution
- Foreshore to middle shoreface reservoirs on low-angle ramp
- Lower shoreface to proximal offshore reservoirs due to sediment bypass

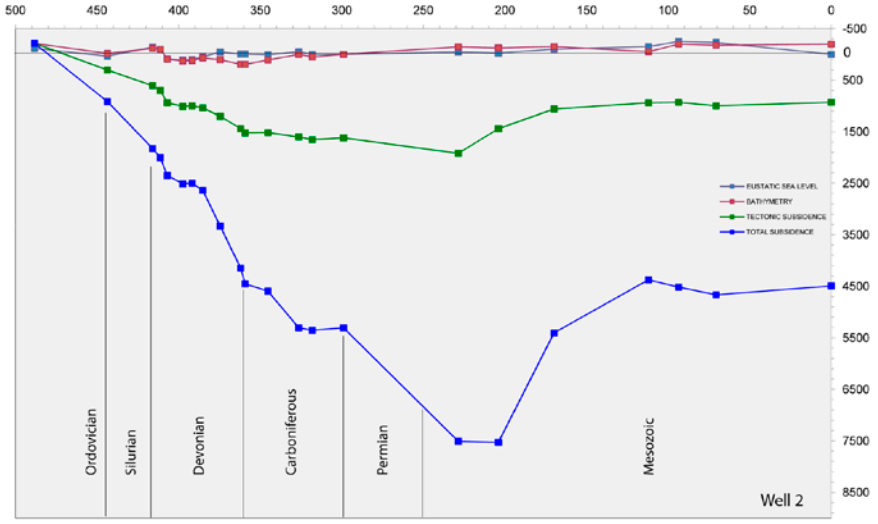
Guideline

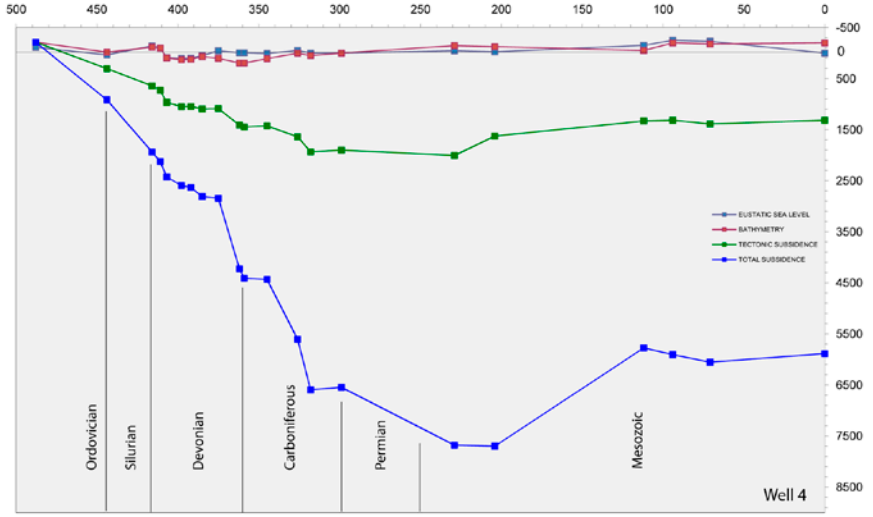
- Framework
- Palynology
- Thermal History
- Seismic and Sequence Stratigraphy
- Integrated Basin Model
  - Flexural basin modeling
  - Paleotemperature model

Flexural Basin Modeling

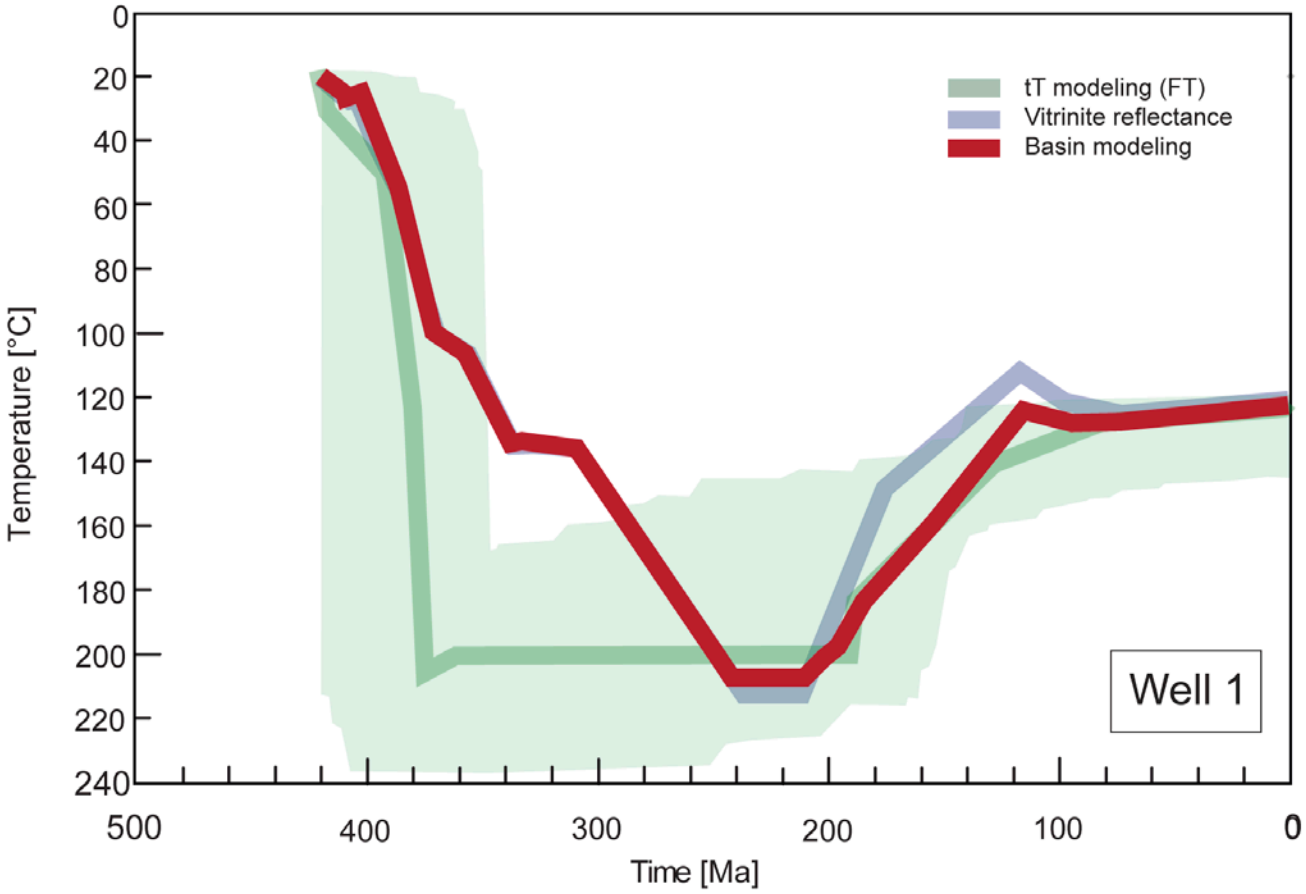
- Eastern Reggane Basin
  Hoggar Shield
  - Increasing subsidence from Ordovician to Tournaisian
  - Reduced subsidence to uplift in Early-Middle Devonian (Eifelian)
  - Additional overburden of approx. 3500 m

- Western Reggane Basin
  West African Craton
  - Increasing subsidence from Ordovician to Late Carboniferous
  - Peak subsidence during Frasnian and Famennian B
  - Additional overburden of approx. 2000 m



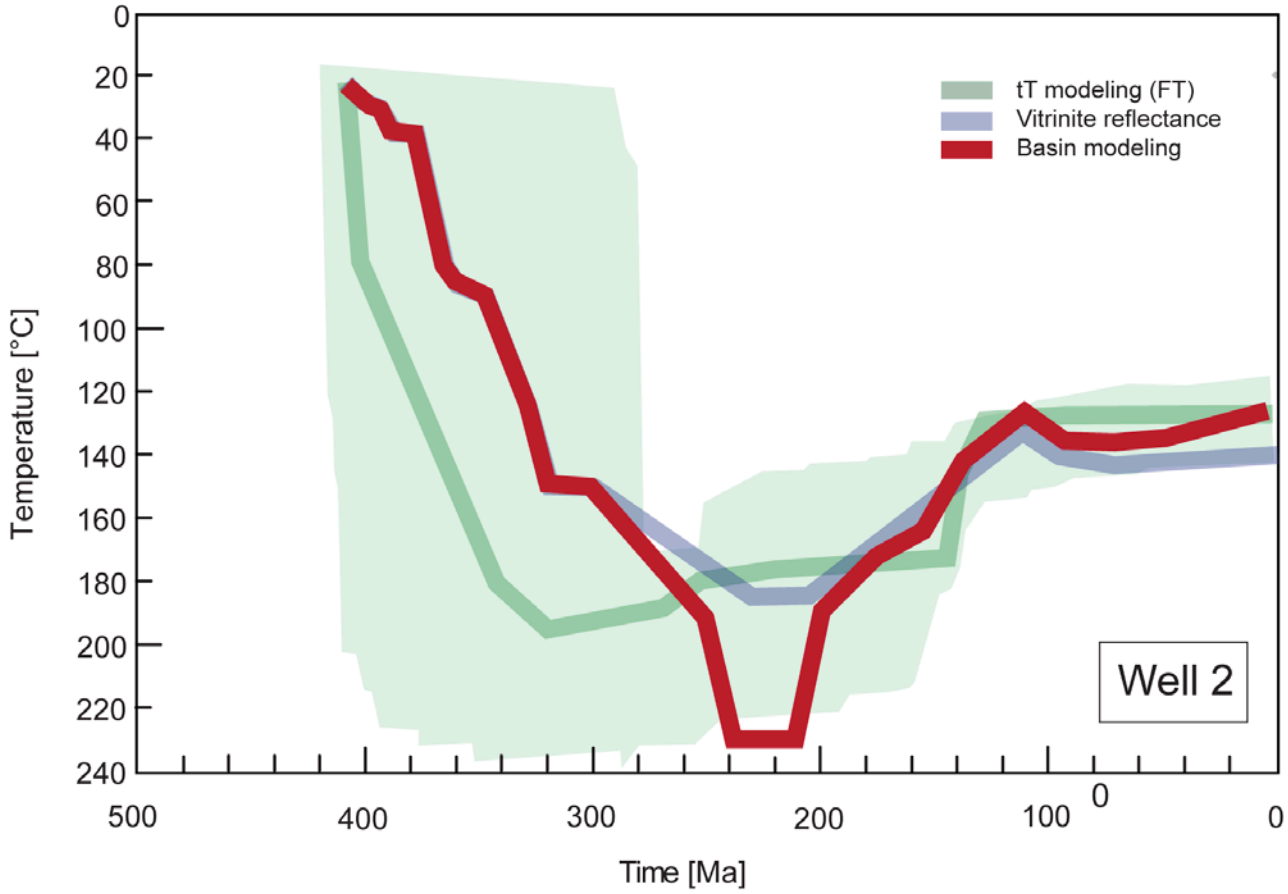


Paleotemperature Model (HS)



- Maximum burial at 320-250 Ma, Late Serpukhovian to Early Induan
- Basin inversion after 250-200 Ma, Early Induan to Rhaetian
- Decreased inversion at approx. 100 Ma

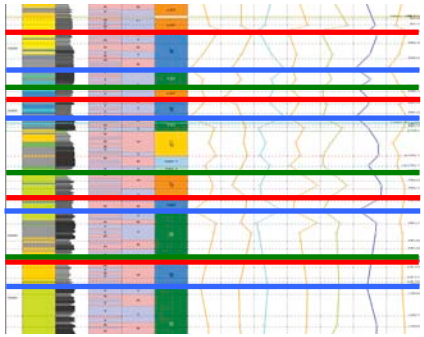
Paleotemperature Model (WAC)



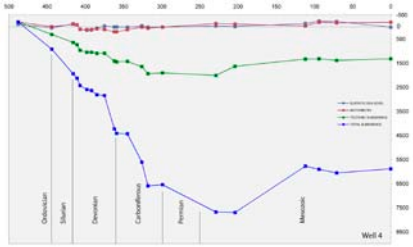
- Intervals of tectonic uplift and erosion during the Hercynian orogeny not resolved
- Complex Carboniferous basin fill with major changes in thickness
- Additional overburden of 2000-3500 m has to be accommodated between 320-200 Ma

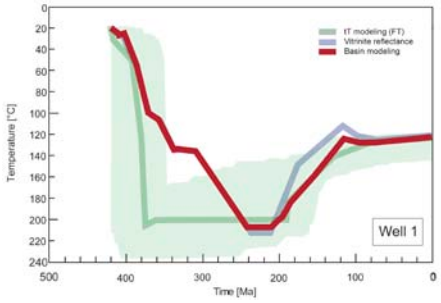
Conclusions I – Approach

- HR reservoir models
  - Downlap trajectories
  - Well log trends
  - Organofacies proxies

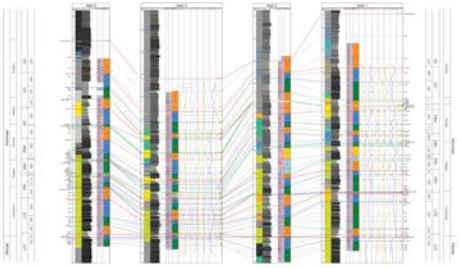


- Integrated paleotemperature histories
  - FT & (U-Th)/He dating
  - vitrinite reflectance
  - spore color index
  - t-T & flexural basin modeling





- Devonian reservoirs
  - Foreshore to middle shoreface
  - Lower shoreface to proximal offshore (bypass)



- Gas generation and expulsion from Silurian source rocks
  - Famennian to Visean
  - Controlled by pre- to syn-Hercynian burial
  - Triassic CAMP-related heat event ineffective for productive Lower Devonian reservoirs
  - Cf. Logan & Duddy (1998)