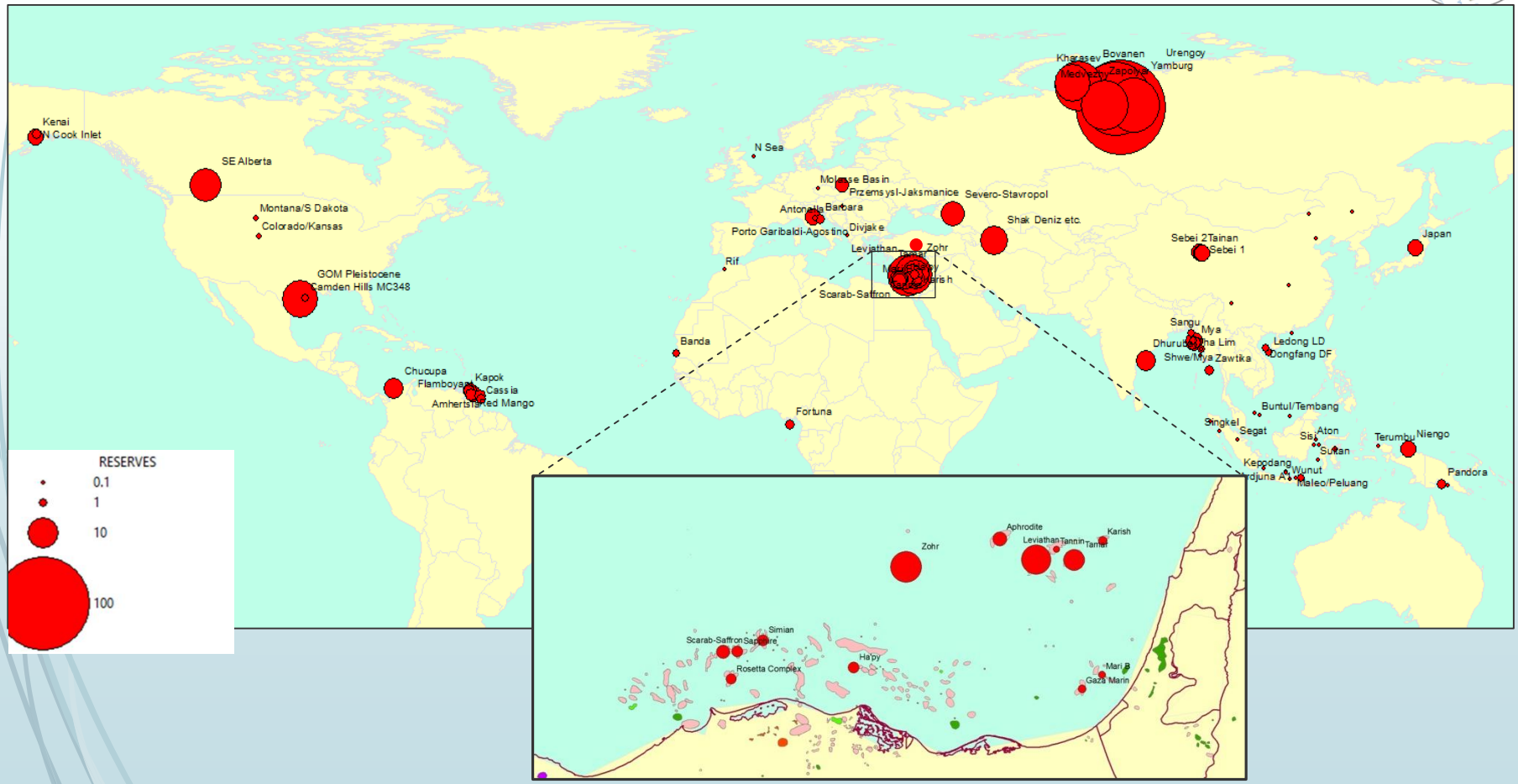
Biogenic Gas Systems of the Eastern Mediterranean

Duncan Macgregor

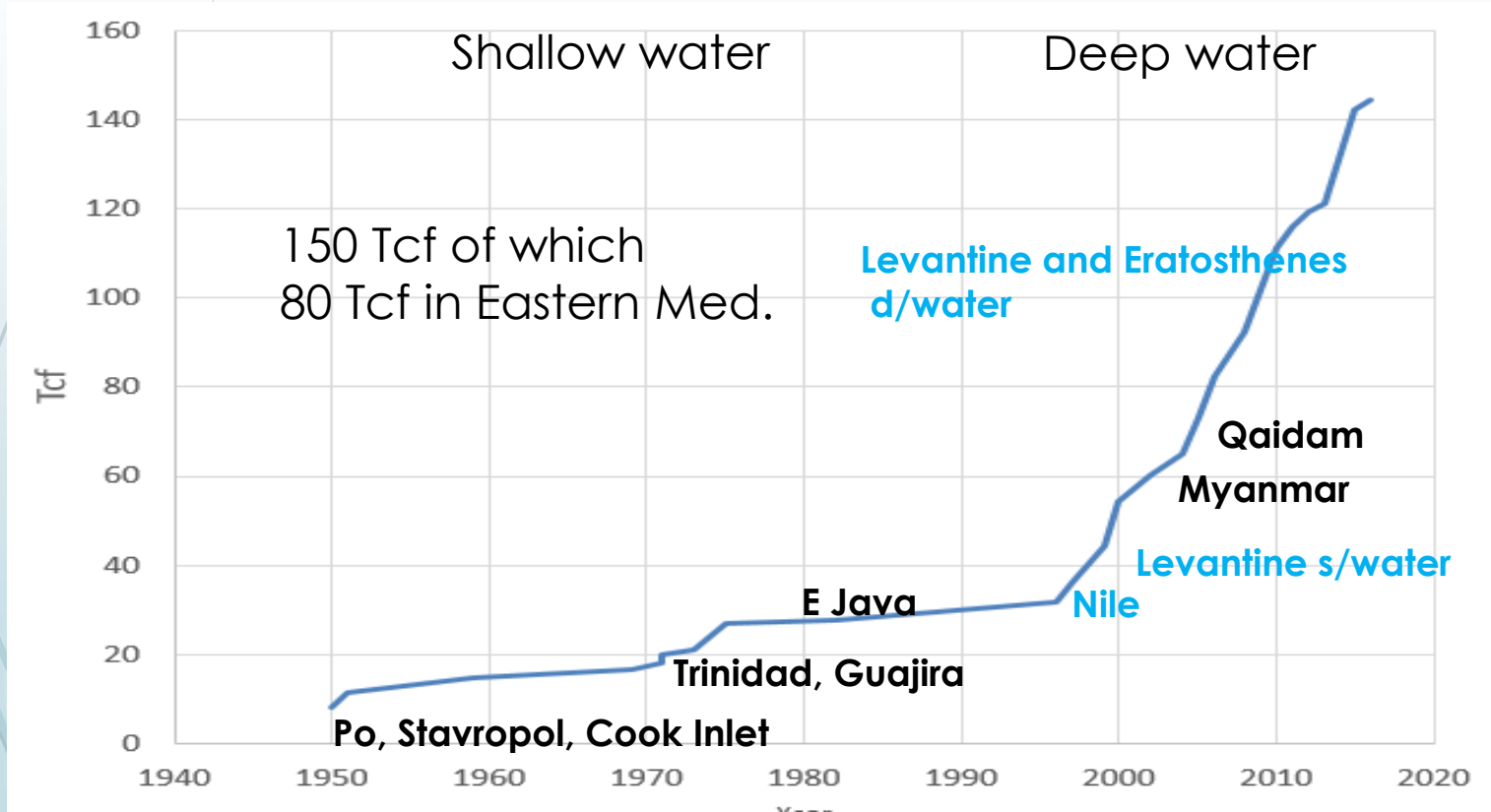
Order of Presentation

- Global Context
- Biogenic Gas Models and Physics
- Eastern Mediterranean Observations and Petroleum System Models
- Screening Applications : Where Next?

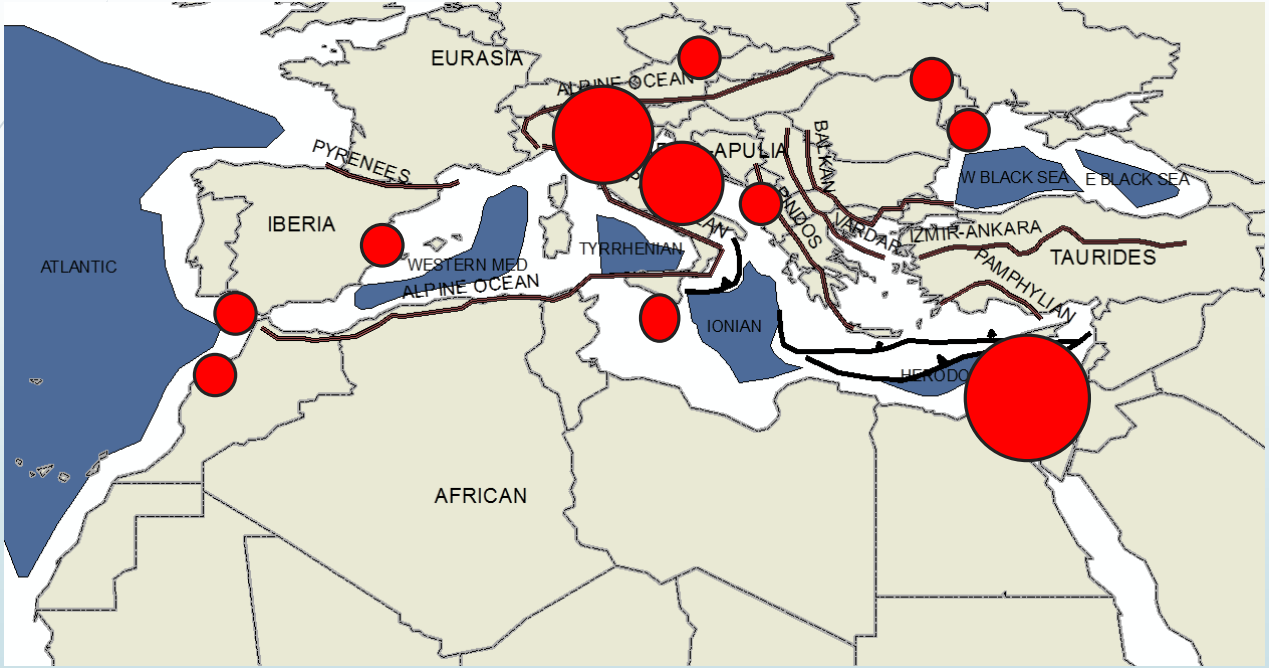
Global Biogenic Gas Reserves



Cumulative Discovery Curve : Global Biogenic Gas Reserves (excluding West Siberia)



Biogenic Gas



Largest 25 Mediterranean Offshore Fields

			Gas TCF	Oil MMbbls	MMBOE	Reservoir	Pet System Type
1	Leviathan	Israel	22		3929	Miocene	Biogenic
2	Zohr	Egypt	21		3929	Miocene	Biogenic
2	Tamar	Israel	10.7		1911	Miocene	Biogenic
3	Bouri	Gabes-Tripoli	2.5	740	1186	Eocene	Thermogenic-Eo and Late Cret
4	Aphrodite	Cyprus	4.5		804	Miocene	Biogenic
5	Temsah	Nile	4.5		804	Miocene	Thermogenic-Oligocene
6	Raven	Nile	4		714	Miocene	Thermogenic-Oligocene
7	Simian	Nile	3.5		625	Pliocene	Biogenic
8	Porto-Garibald	Po	3.5		625	Pliocene	Biogenic
9	Vega	Sicily		625	625	Jurassic	Thermogenic-Trias and Lias
10	Ha'ppy	Nile	3		536	Pliocene	Biogenic
11	Salamat	Nile	3		536	Oligocene	Thermogenic-Oligocene
12	Scarab	Nile	2.8		500	Pliocene	Biogenic
13	Saffron	Nile	2.5		446	Pliocene	Biogenic
14	Rosetta	Nile	2.3		411	Pliocene	Biogenic
15	Abu Qir	Nile	2.1		375	Pliocene	Thermogenic-Oligocene
16	NC 41-C2	Gabes-Tripoli	2.1		375	Eocene	Thermogenic-Eo and Late Cret
17	Wakar	Nile	2		357	Pliocene	Biogenic
18	Sapphire	Nile	2		357	Pliocene	Biogenic
19	Satis	Nile	2		357	Oligocene	Thermogenic-Oligocene
20	D 137 N	Gabes-Tripoli	2		357	Eocene	Thermogenic-Eo and Late Cret
21	Ashtart	Gabes-Tripoli		254	254	Eocene	Thermogenic-Eo and Late Cret
22	Rospo Mare	Adriatic		220	220	Late Cret.	Thermogenic-Trias and Lias
23	B137 N	Gabes-Tripoli		190	190	Eocene	Thermogenic-Eo and Late Cret
24	Miskar	Gabes-Tripoli	1		179	Late Cret.	Thermogenic-Eo and Late Cret
25	Casablanca	Valencia		100	100	Jurassic	Thermogenic-Miocene

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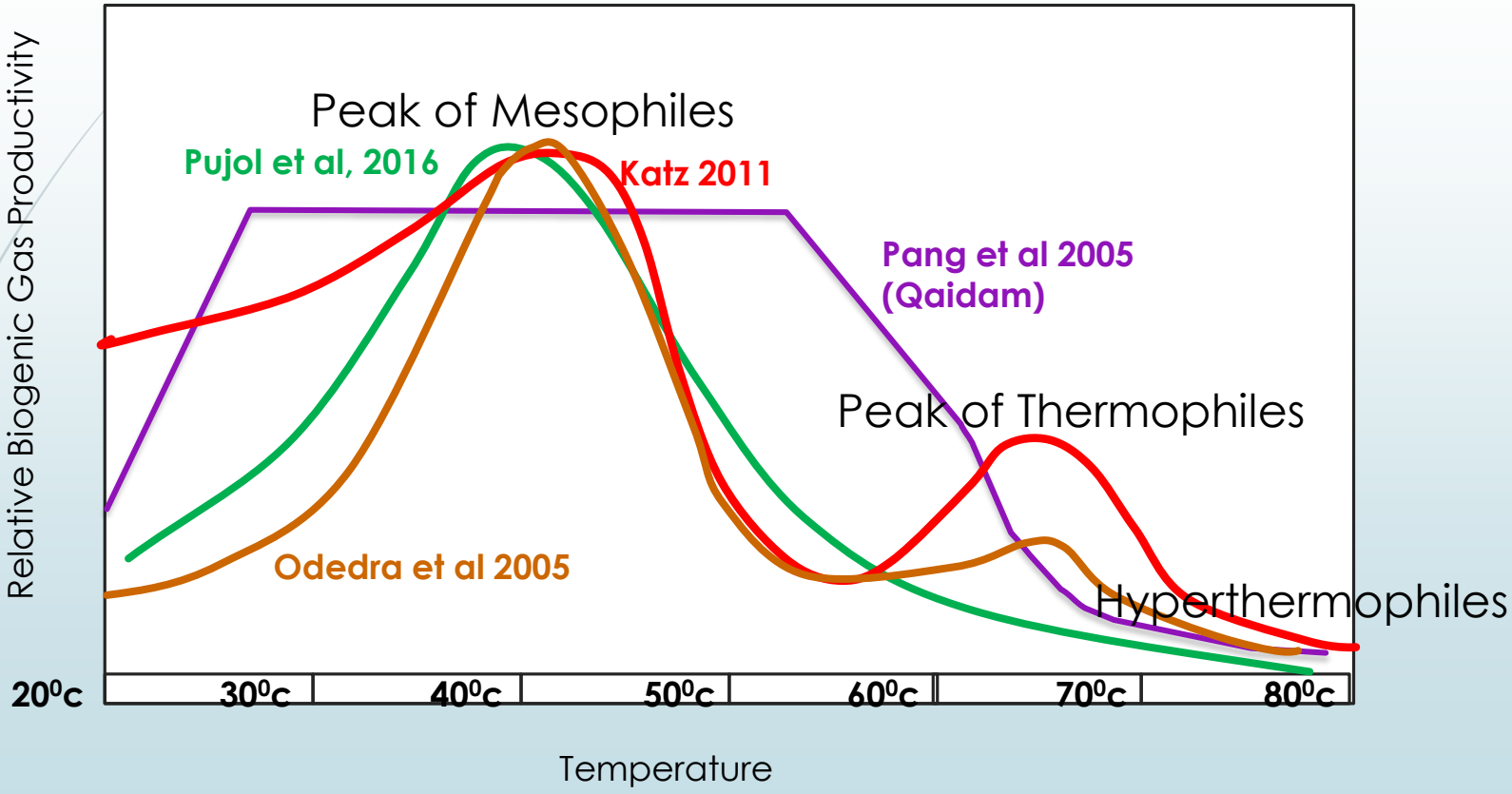
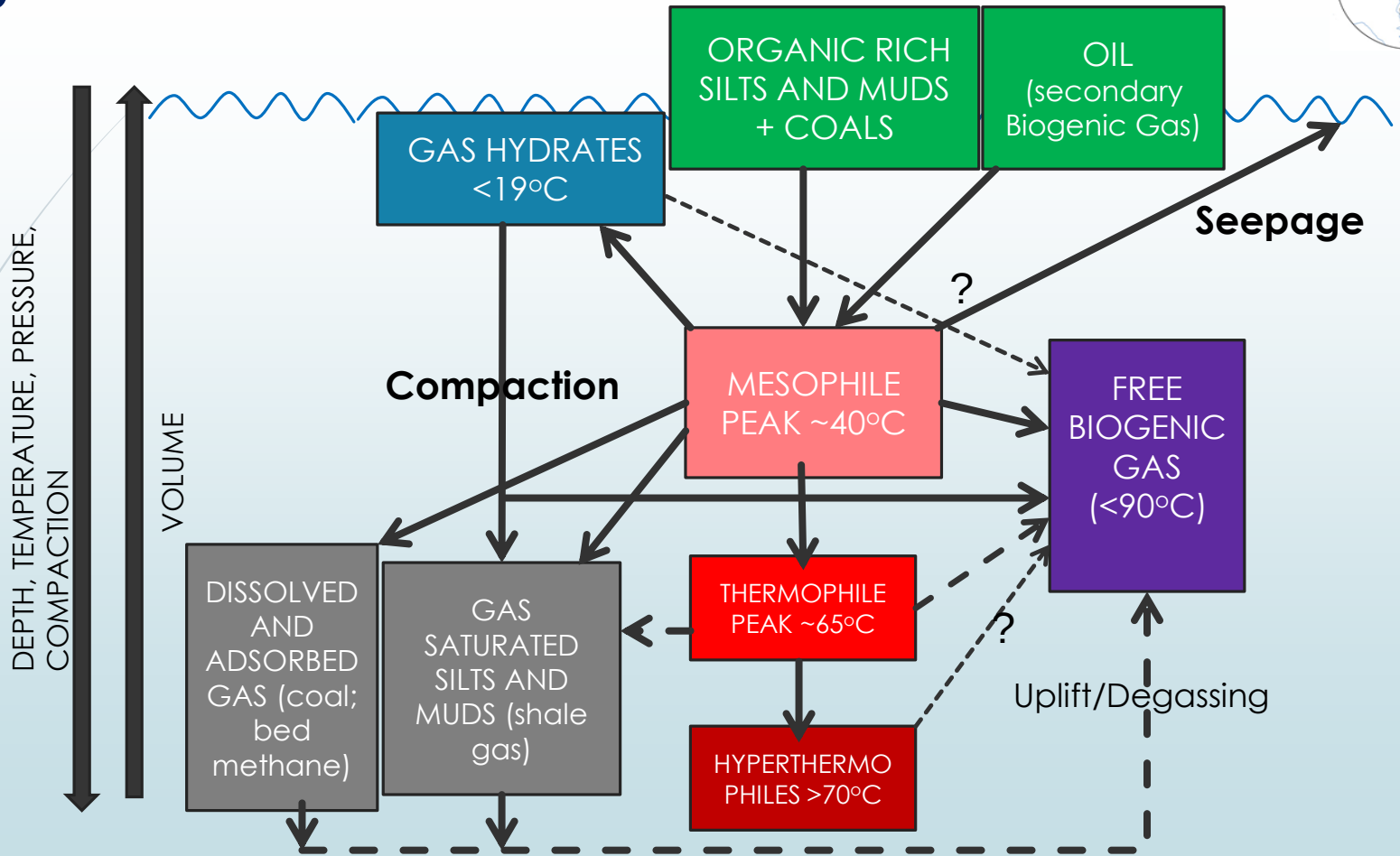
Summary of Methanogen Activity Models



Biogenic Gas Habitats



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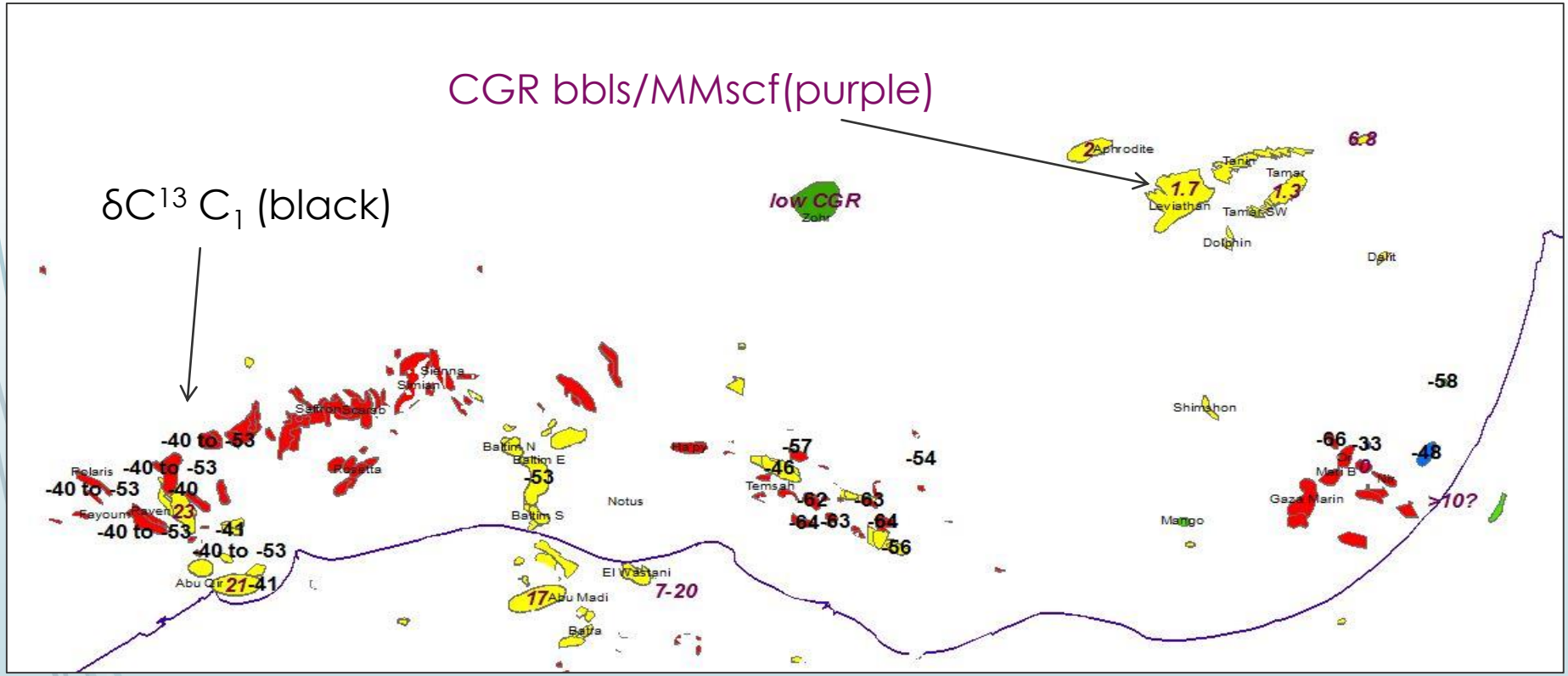
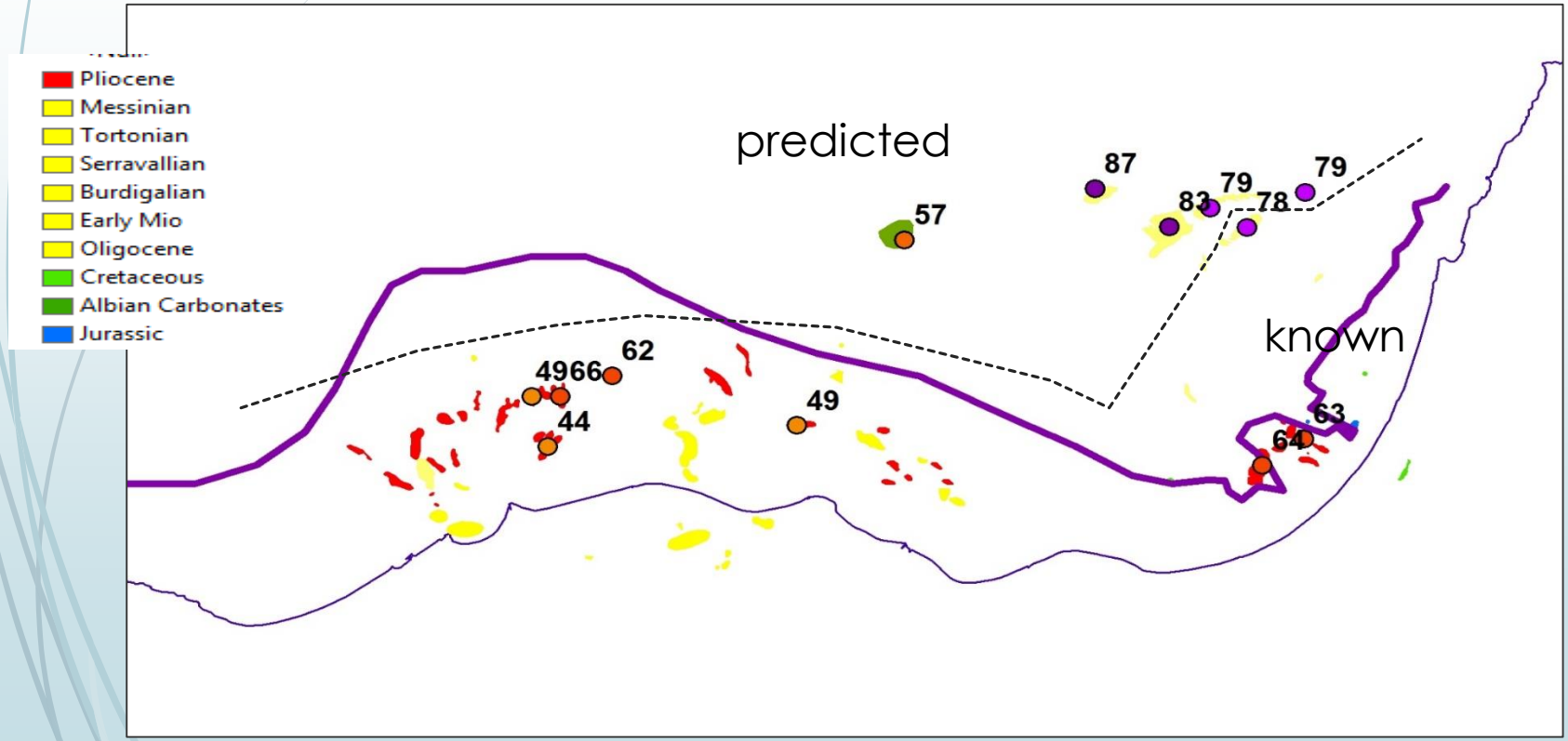
CGRs and Gas Isotopes



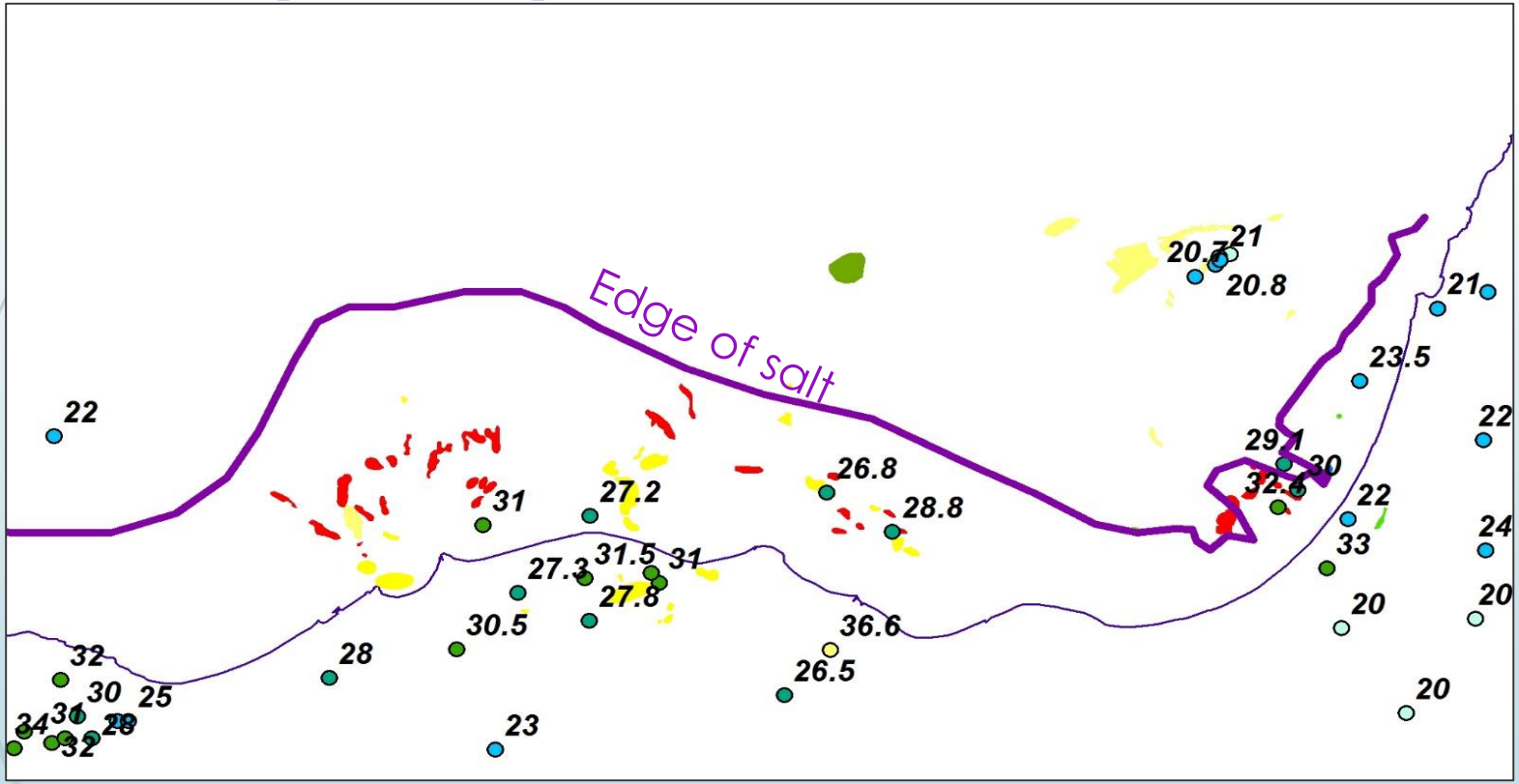
Biogenic Gas δC^{13} C_1<-60$^{0/00}$
CGR ~0

Thermogenic Gas δC^{13} C_1>-50$^{0/00}$
CGR>15bbls/MMscf

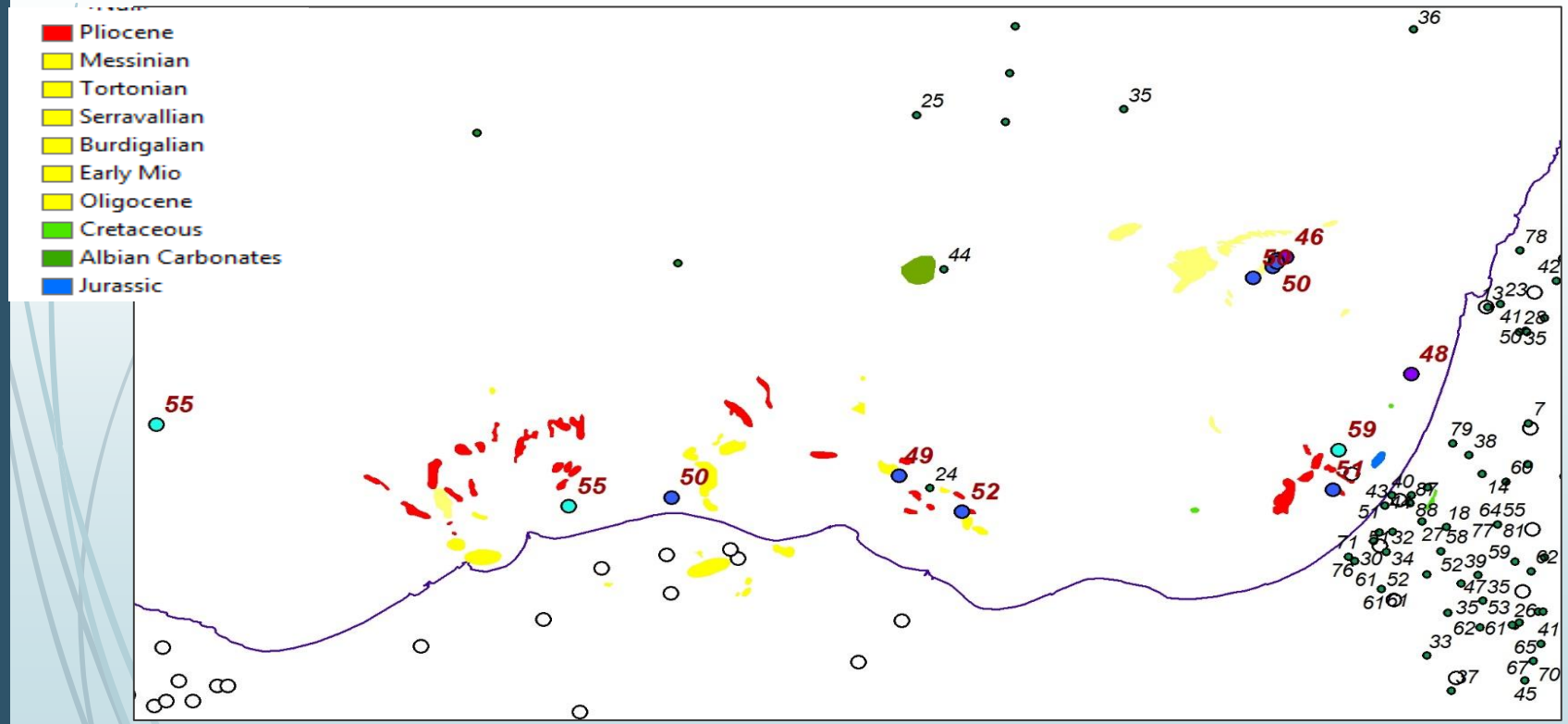
Biogenic Gas Field Reservoir Temperature (°C)



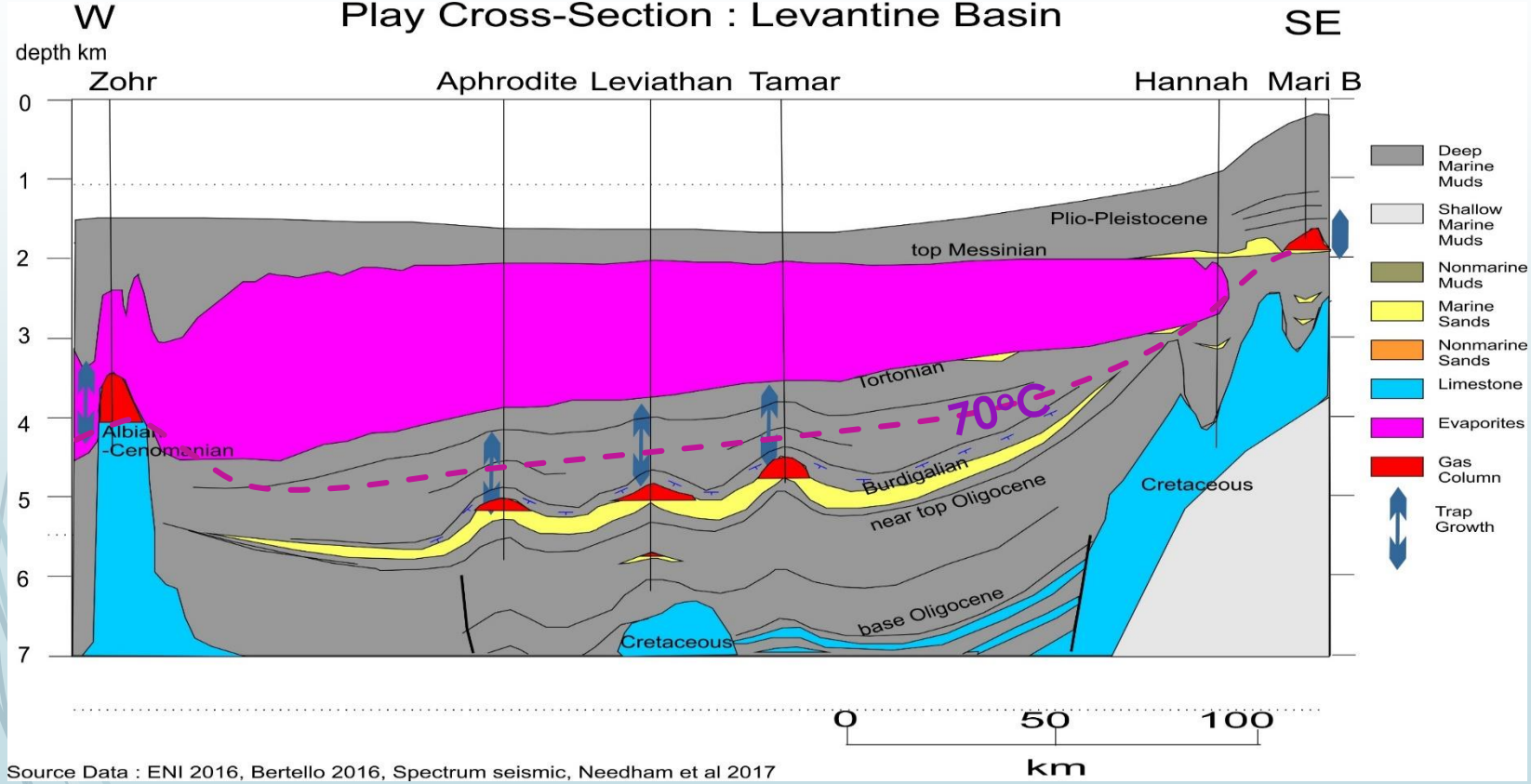
Levantine/Nile Geothermal Gradient (°C/km)



Levantine/Nile Heat Flow (mWm^{-2})

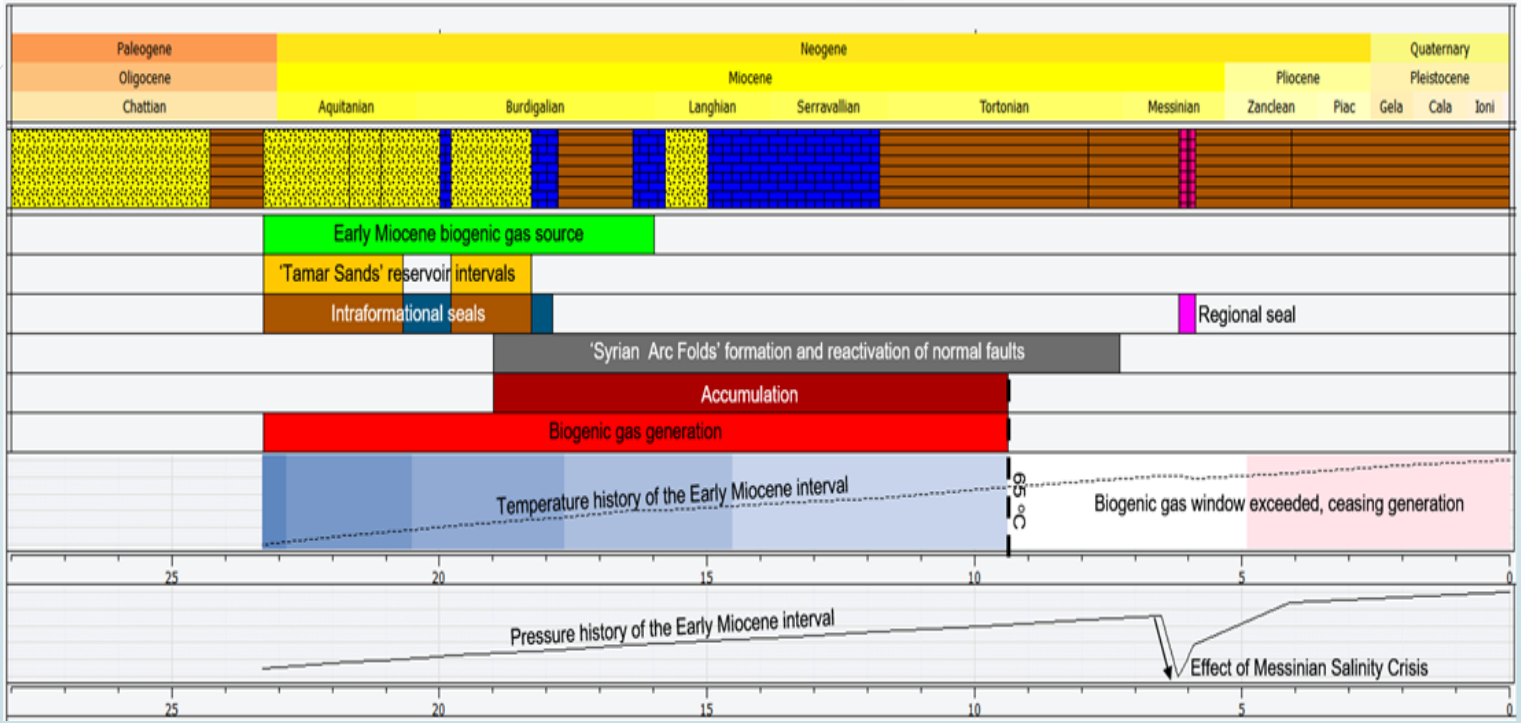


Levantine Biogenic Play Cross-Section



Tamar Petroleum Systems Chart

Gas generated prior to Messinian lowstand
Rapid depressuring and repressuring
Leads to low fill factor



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Fields Not Full to Spill

- Biogenic Model would predict most generation prior to Messinian lowstand
- Reservoir pressure cannot have exceeded 3300 psi at Messinian lowstand
- Reservoir pressure now 8500 psi and gas expansion factor will have doubled
- So would predict fields only 50% full to spill, ?matches observations

Needham et al, 2017

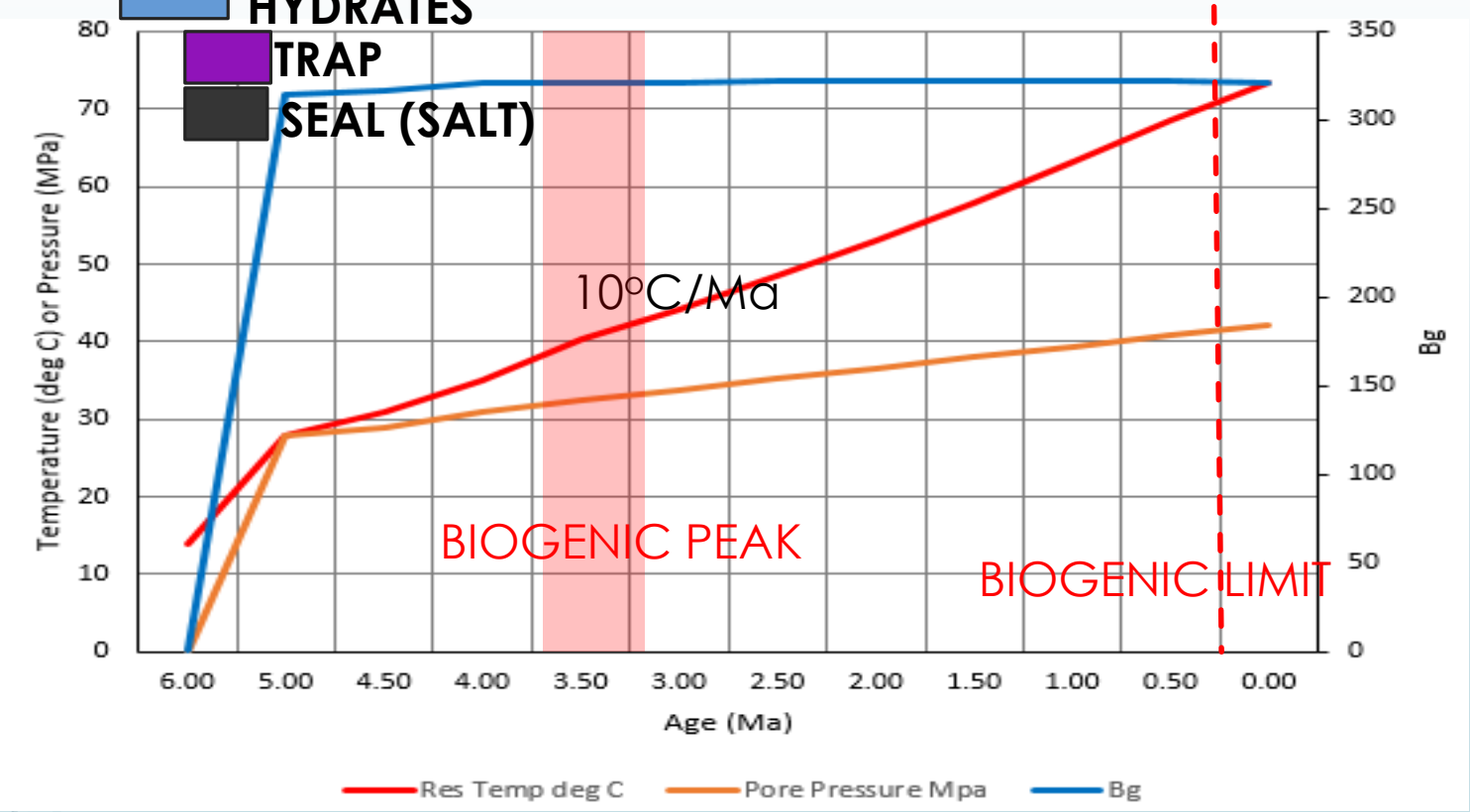
Zohr Onlapping Muds PVT History

RESERVOIR

HYDRATES

TRAP

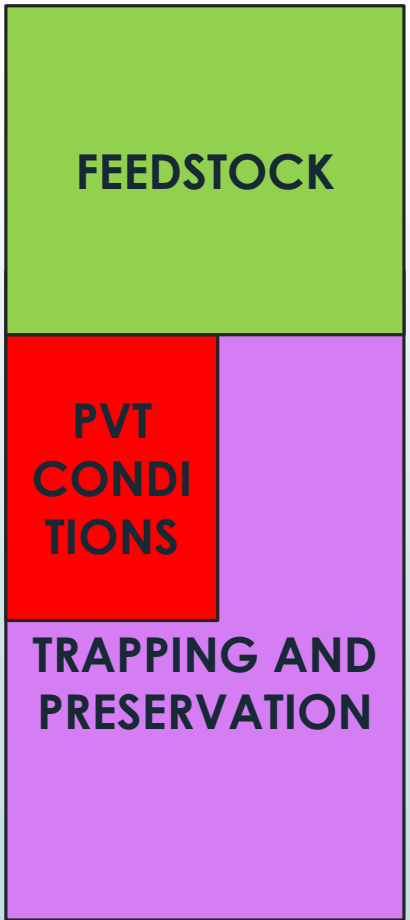
SEAL (SALT)



Key Factors for Biogenic Gas

- Type iii kerogen supply, often a delta/prodelta
  - TOC >0.3% but hundreds/kilometres thick
- Anoxia and/or Rapid Deposition
  - Burial rates between 200-1000m/Ma (5-25 deg C/km)
- Undercompacted Sediments – 2µm pore spaces NOT SHALES
- Extensive Migration Carrier Bed
- Low Temperatures / Geothermal Gradient
  - Ideally low surface temperature (deep water)
  - Typically below 25 degC/km
- Highly pressured deep marine setting during deposition
  - Reduces potential for shrinkage on leaving biogenic window
- Early Trap (and Seal) Formation
  - Trap in place while in main stages of biogenic window
  - Syn-sedimentary structural traps
  - Carbonate Buildups

Rice, 1989



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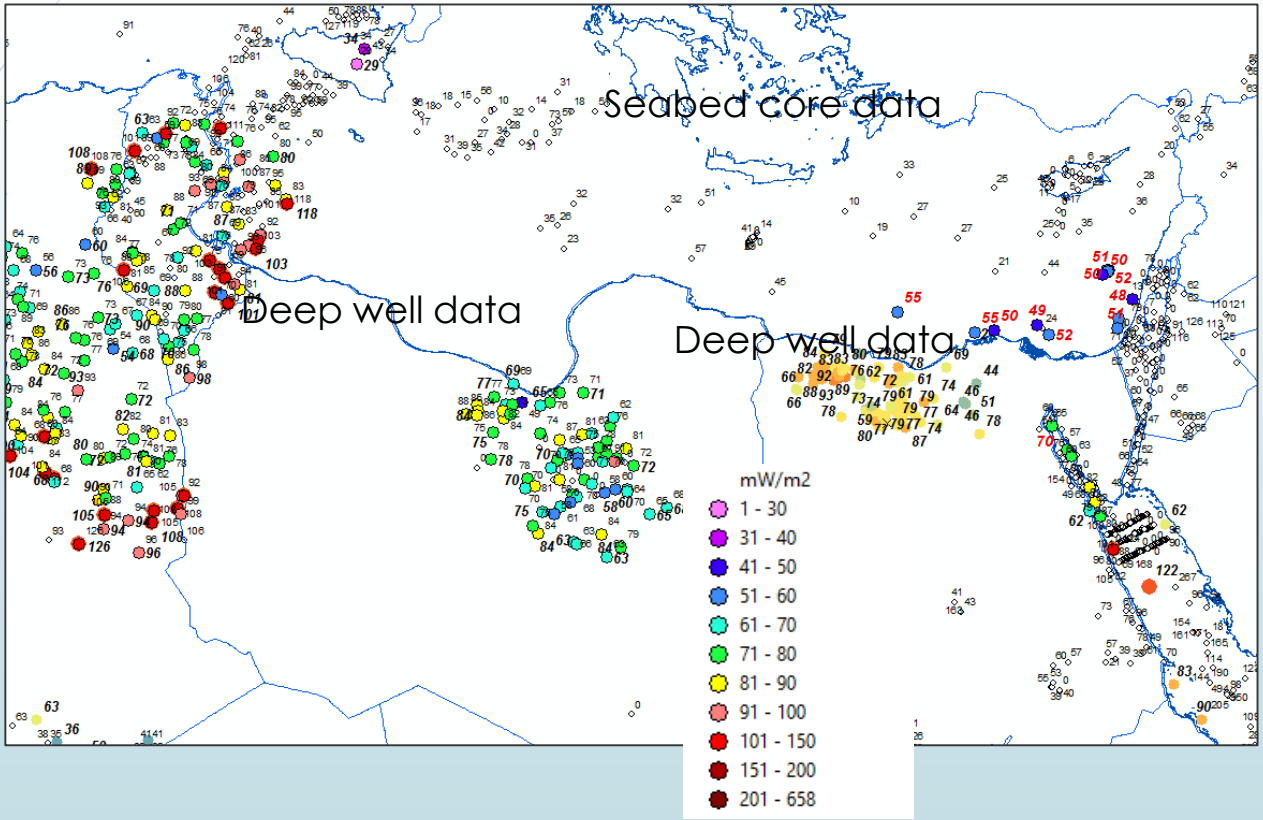
Biogenic Gas Basin Screening Matrix

BIOGENIC GAS SUCCESS FACTORS

	Absent	Possible	Probable	Known
	1	2	3	4
FEEDSTOCK				
Thick (hundreds of m) series of type iii kerogen bearing sediments (e.g. prodelta)				
Anoxia and/or depositional/heating rates of 3-25degC/Ma				
Undercompacted Sediments with >2µm pore spaces				
Extensive migration carrier bed				
Evidence for gas hydrates if/when in deep marine setting				
PVT CONDITIONS				
Low surface temperature and/or geothermal gradient (<25 deg C/km)				
Highly pressured deep marine setting during deposition				
TRAP FORMATION				
Very early trap formation (ideally in place by 40 deg C)				
Reasonably compacted mud seal (circa 500-600m burial) or evaporite				
EFFECTIVE RESERVOIR				

Screening by Heat Flow and Geothermal Gradient



Screening by Timing of Trap Formation

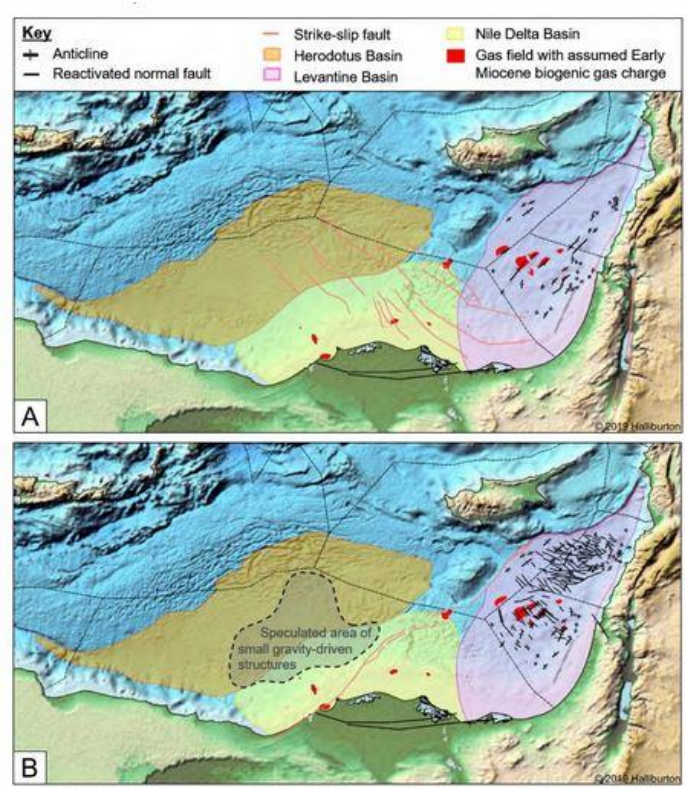


Figure 4 > Tectonic element maps highlighting the key structures that were active across the Eastern Mediterranean during: A) the Early–Middle Miocene, and B) the Late Miocene.

EARLY MIOCENE

LATE MIOCENE

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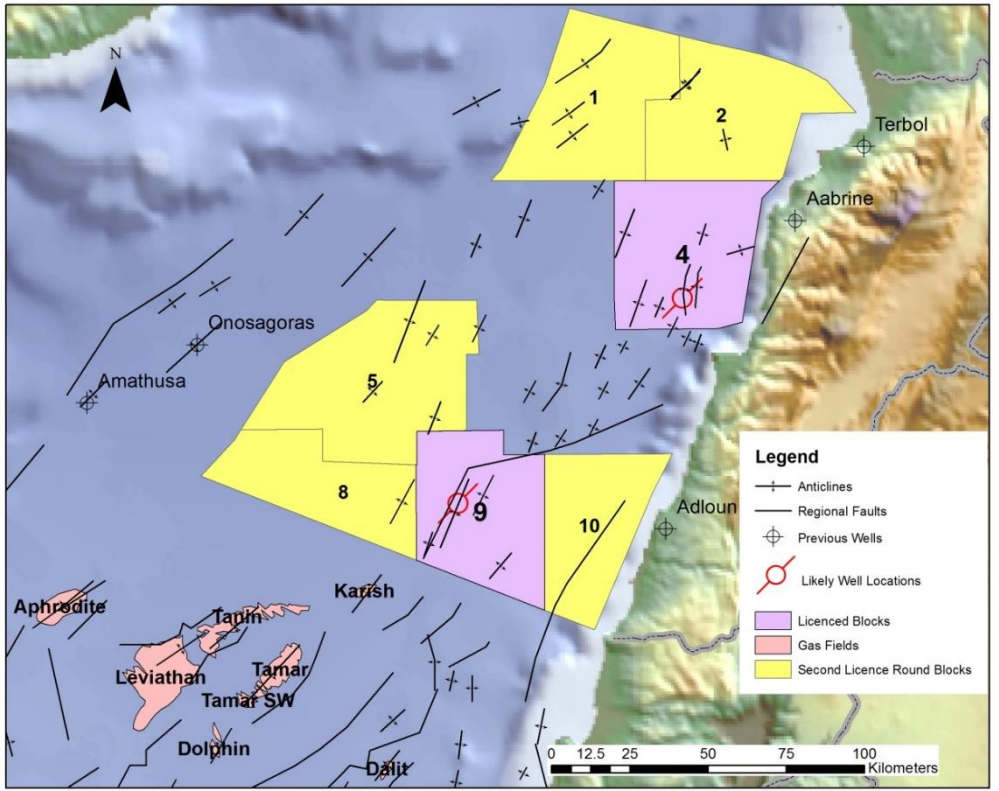
Lebanon Screening Example

- Lebanon is near to unique in the world in having a thick offshore depocentre that is entirely undrilled.
- ENI, Total and Novatek are reported to be planning to drill a well in Q4 2019 in Block 4, followed by a well in Block 9
- A second license round is currently open, largely covering acreage outboard of Block 9 within the Miocene clastic fairway. Deadline 31/1/20
- Many blocks have borders disputed with Israel and Syria



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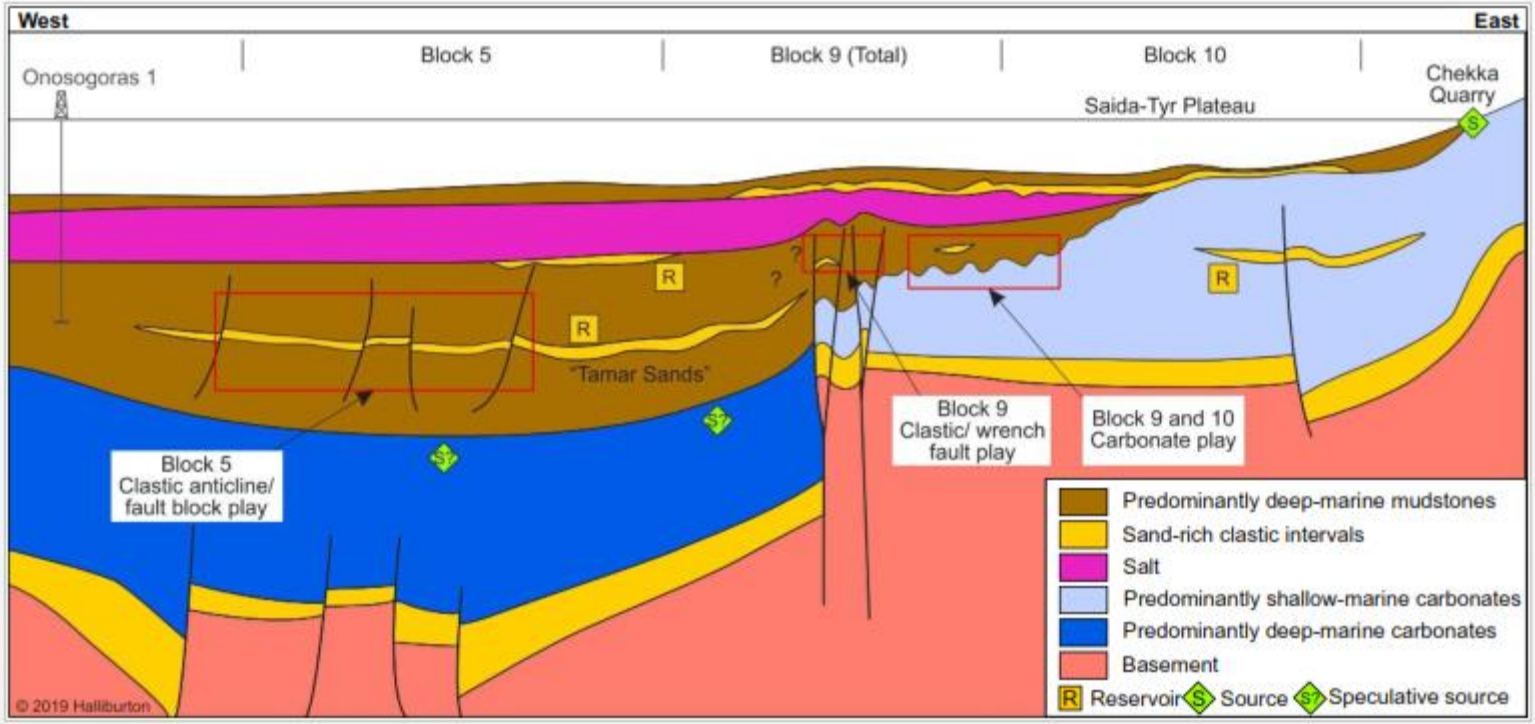
Lebanon Play Cross-Section



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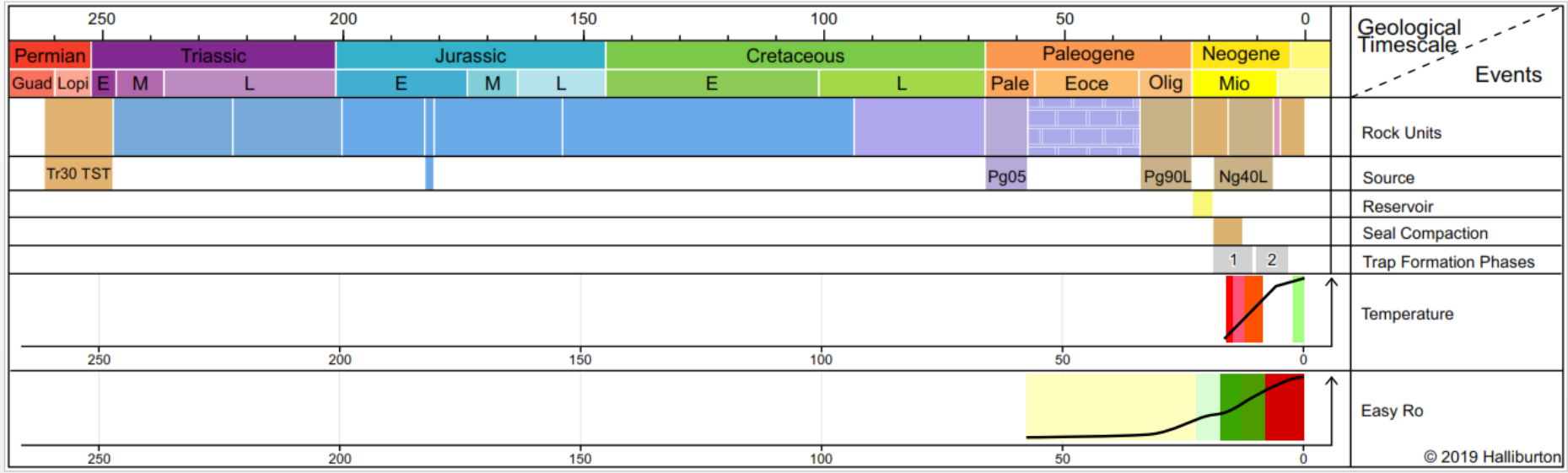
Integration in Petroleum Systems Chart and Modelling, Block 5, Lebanon



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Conclusions

- Biogenic Gas VOLUMES can be large but PRESERVATION is normally low
- Early Trap Formation, Low Geothermal Gradients, High Pressures (deepwater) and Sedimentation Rates are Key
- Detailed Petroleum System Analysis is even more critical than for thermogenic systems
- PARTS of the Eastern Med are special
  - Carbonates rapidly sealed up by salt
  - Clastics structured almost immediately after deposition
- Screening of other Mediterranean regions needs to be based on thorough seismically based and modelling studies
  - This should be done well before licencing and not on 'postage stamps'
  - Or look for flat spots!