# [AV]Development of Abnormally High Pore Pressures in a Geologically Young, Basin-Centered Oil and Gas Accumulation, Mako Trough, Hungary*

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Search and Discovery Article #110104 (2009)
Posted July 30, 2009

*Adapted from oral presentation at AAPG Annual Convention, Denver, Colorado, June 7-10, 2009

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## Abstract

The processes involved in the development of abnormally high-pressured, basin-centered gas and oil accumulations (BCGA's/BCOA's) have been formulated on observations of Paleocene and older accumulations from North America that have experienced temperatures and depths of burial greater than presently observed. As a consequence, the development of abnormal pore pressures has been the subject of controversy. One model maintains that overpressures are a consequence of hydrocarbon generation during maximum burial and temperature. Alternatively, another model proposes the development of overpressuring as a consequence of structural uplift. The opportunity to test these hypotheses is provided by an upper Miocene and Pliocene BCGA/BCOA in the Mako Trough, southeastern Hungary.

Structurally, the Mako Trough is a sub-basin within the larger Pannonian Basin of central Europe that has not experienced significant vertical uplift. The thickness of the BCGA/BCOA is approximately 2500 m. Fluvial, deltaic, and lacustrine environments of deposition are represented. Source rocks occur primarily within Pannonian and younger Miocene rocks and the organic matter ranges from types I to III kerogen; thus, both oil and gas have been generated. Reservoirs typically are sandstone with low-permeability (<0.1md) and porosity (< 14%). Heat flow values are as high as 100 $mW/m^2$. As a consequence of the high heat flow, temperature at depths greater than 5500 m (18,040 ft) are high ($460^oF$) and levels of thermal maturity are also high, attaining vitrinite reflectance values of 2.0%. Pressure gradients at these depths are as high as 1.0 psi/ft. As a consequence of the high temperatures in the Mako Trough the petroleum system is dynamic and source rocks are actively generating and charging reservoirs, unlike current conditions in most North American BCGA's/BCOA's.

The dynamic nature of the hydrocarbon system in the Mako Trough has resulted in the development of pore pressures in excess of hydrostatic pressure. The original mechanism of overpressure may have been compaction disequilibrium that was subsequently replaced by a hydrocarbon generation mechanism during maximum burial; structural uplift is not required for the development of overpressure. The development of overpressures through a hydrocarbon generation mechanism in this geologically young sequence provides a good analog for the incipient development of abnormally high pressures in BCGA's/BCOA's.

## References

Meissner, 1987, F.F., 1987, Mechanisms and patterns of gas generation, storage, expulsion-migration and accumulation associated with coal measures in the Green River and San Juan basins, Rocky Mountain region, U.S.A., *in* B. Doligez, ed., Migration of hydrocarbons in sedimentary basins: 2nd Institut Francais du Petrole Exploration Research Conference, Carcais, France, June 15−19, 1987, Paris, p. 79−112.

Surdam, R. C., Z. S. Jiano, Y. Ganshin, 2003, Rock-fluid systems characteristics of the Rocky Mountain Laramide basins: Wind River Basin, Wyoming: paper presented at the RMAG Petroleum Systems and Reservoir of Southwest Wyoming Symposium, Denver, CO, (September 19, 2003).

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# DEVELOPMENT OF ABNORMALLY HIGH PORE PRESSURES IN A GEOLOGICALLY YOUNG BASIN-CENTERED OIL AND GAS ACCUMULATION, MAKO TROUGH, HUNGARY

B. Law[1], J. Edwards[1], R.Wallis[1], M. Sumpter[1], D. Hoyer[1], G. Bada[2], and A. Horvath[2]

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# OBJECTIVES

- **Discuss the early development of a BCGA/BCOA through a case study in the Mako Trough, Hungary**
- **Discuss alternative interpretations for the development of abnormally high pore pressures in a BCGA/BCOA**

# HYPOTHESES

- I--BCGA’s develop abnormally high pressures due to hydrocarbon generation during maximum burial and temperature
- II--BCGA’s require structural uplift to become abnormally high pressured
- III—High pressures are caused by compaction disequilibrium

# Defining Characteristics of Basin-Centered Gas Systems

- Thermogenic gas
- Gas saturated (bearing)
- Low permeability
- Abnormally pressured
- No down-dip water leg

# EVIDENCE FOR EXISTENCE OF A BCGA/BCOA IN THE MAKO TROUGH ?

Thermally Mature (0.55-2.0 % Ro)

Regionally Pervasive Accumulation  Independent of Structure (Gas Present  In 2,500 m Interval, Through Most Of Basin.  Oil present in non-structural position )

Abnormally Pressured (Overpressured)

Low-Porosity and Permeability (< 14% - 0.1 md)

Gas Saturated ?

Absence of Down-dip Water leg ?

# Hypothesis I– Hydrocarbon Generation Mechanism

- **Moderate to low levels of organic richness are sufficient to develop abnormal pressure**
- **Empirical observations provide compelling evidence for development of abnormal pressure during maximum burial and temperature**

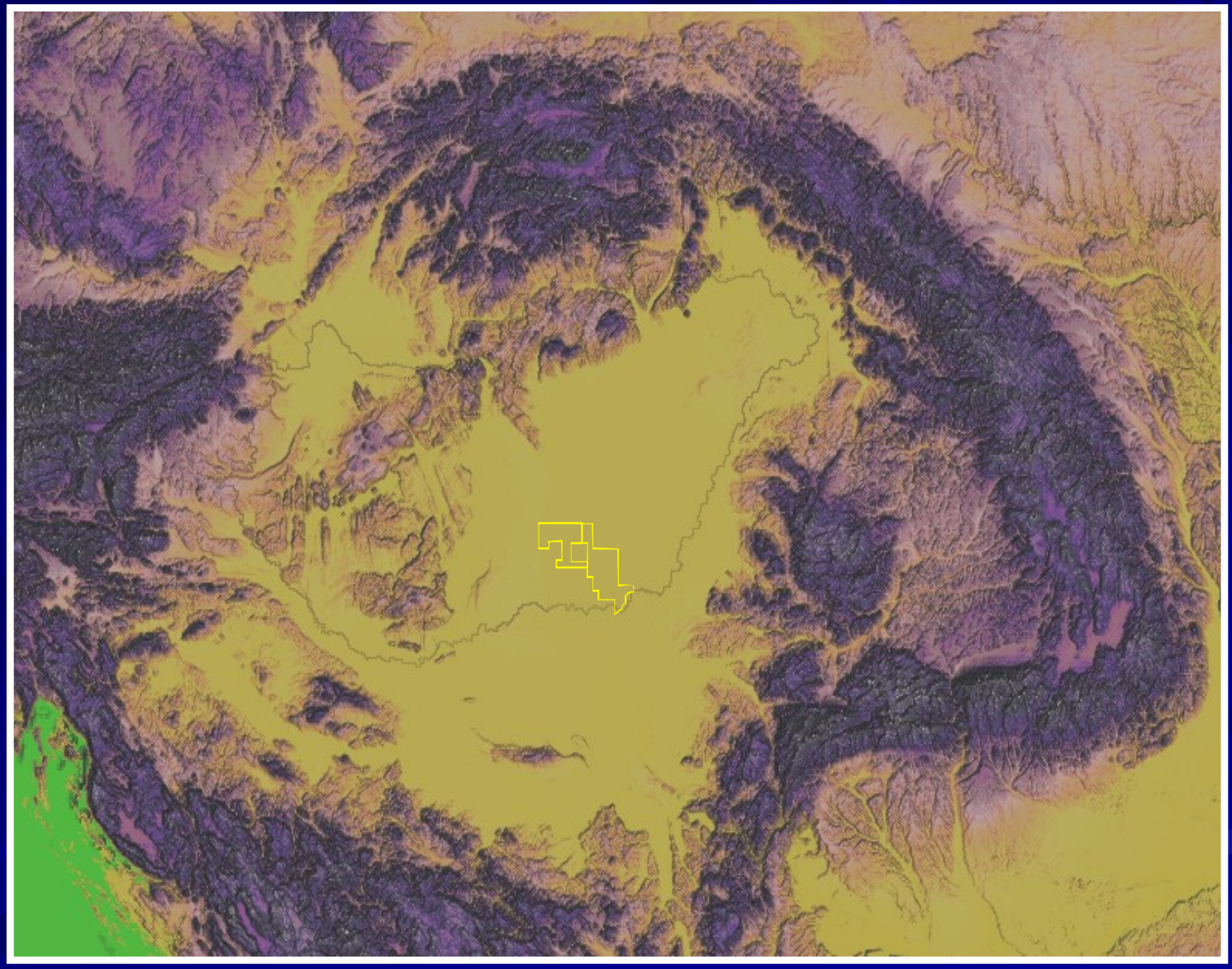
# Hypothesis II –Exhumation and Exsolution

- Most source rocks associated with tight gas systems have insufficient TOC, it is unlikely that reservoirs could be abnormally pressured from hydrocarbon generation mechanism alone.
- Gas saturation may increase because of exhumation and increasing gas volume.
- Exsolution of gas from formation water will increase gas saturation.
- **Hypothesis is dependent on a perfectly closed system.**

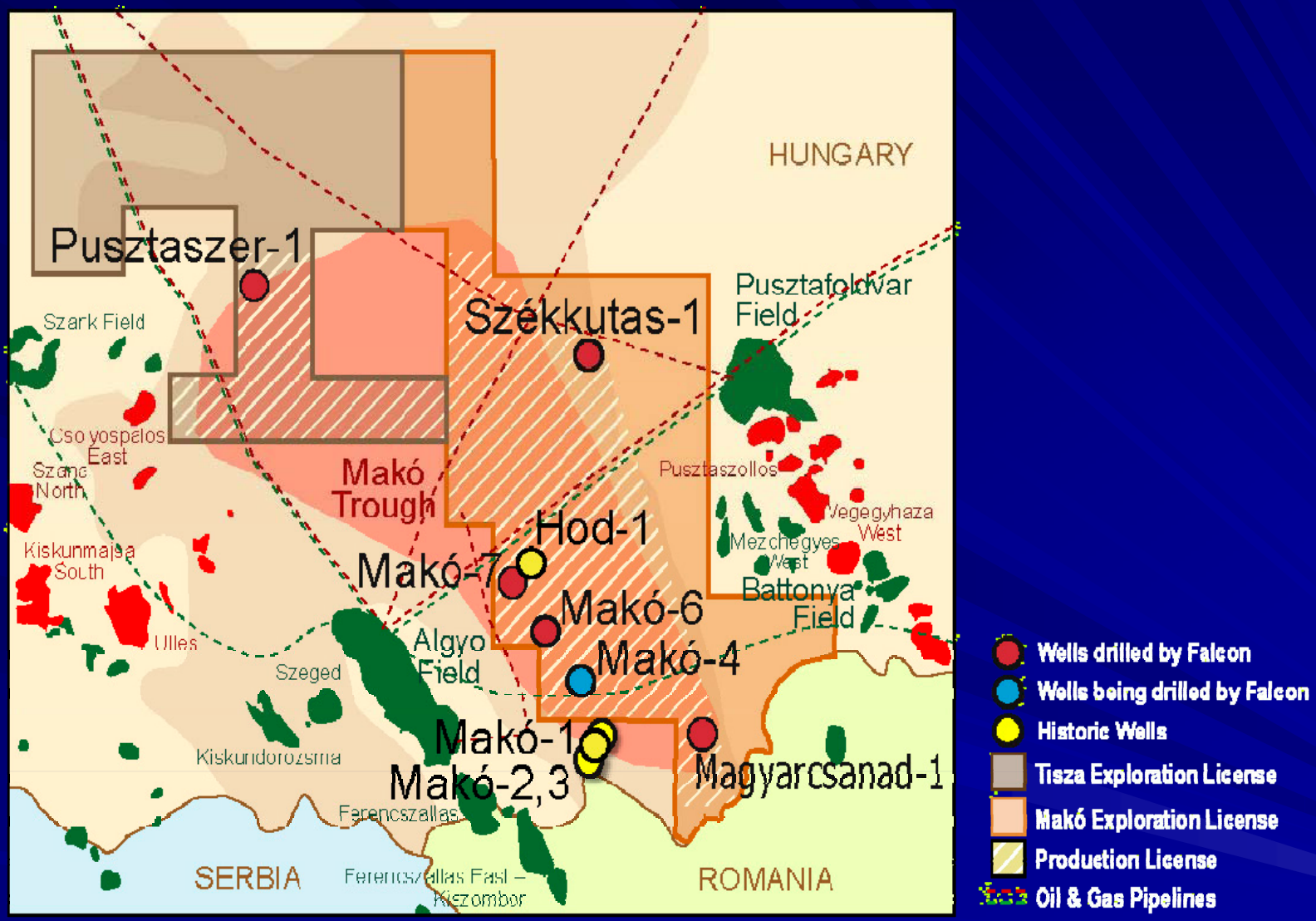
# Hypothesis III—Compaction Disequilibrium

1.Rapidly Subsiding Basins

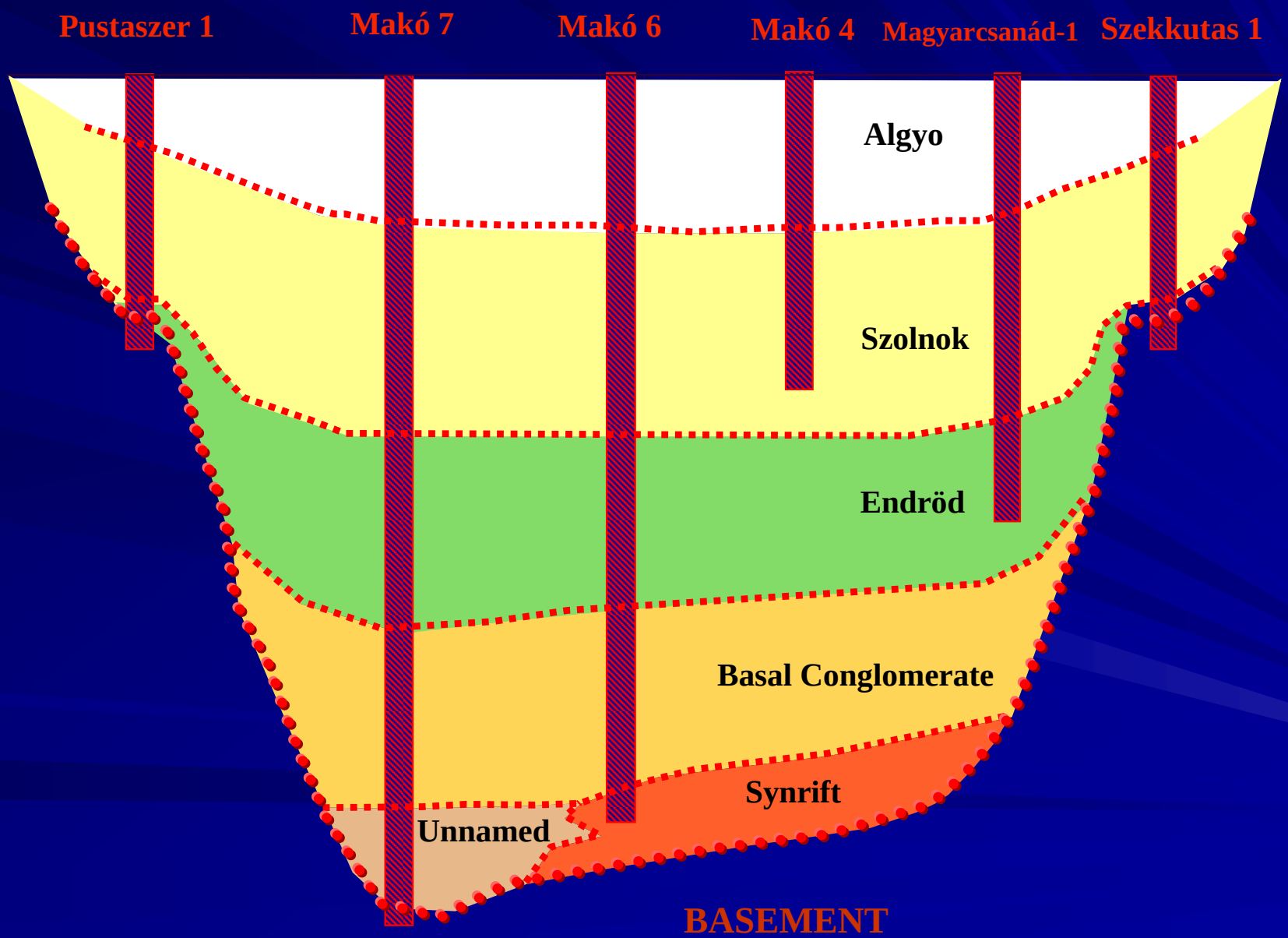
2.Due to rapid sedimentation rates, water is retained in the pore system. Consequently, the lithologic load is buoyed by water. Therefore, water is the pressure fluid phase -- not gas.



# PANNONIAN BASIN


HUNGARY
Pusztaszer-1
Székkutas-1
Pusztafoldvar Field
Szark Field
Csongrad East
Szank North
Makó Trough
Hod-1
Pusztaszollos
Vegegyhaza West
Mezohegyes West
Kiskunmajsa South
Makó-7
Makó-6
Battonya Field
Algyo Field
Makó-4
Ulles
Szeged
Makó-1
Kiskundorozsma
Makó-2,3
Magyarcsanad-1
Ferencszallas
SERBIA
Ferencszallas East – Kiszombor
ROMANIA
Wells drilled by Falcon
Wells being drilled by Falcon
Historic Wells
Tisza Exploration License
Makó Exploration License
Production License
Oil & Gas Pipelines

# Falcon Wells



# Updated Scotia Resource Estimate (May 2008)

## RPS Scotia Resource Estimates, 2006 vs 2008

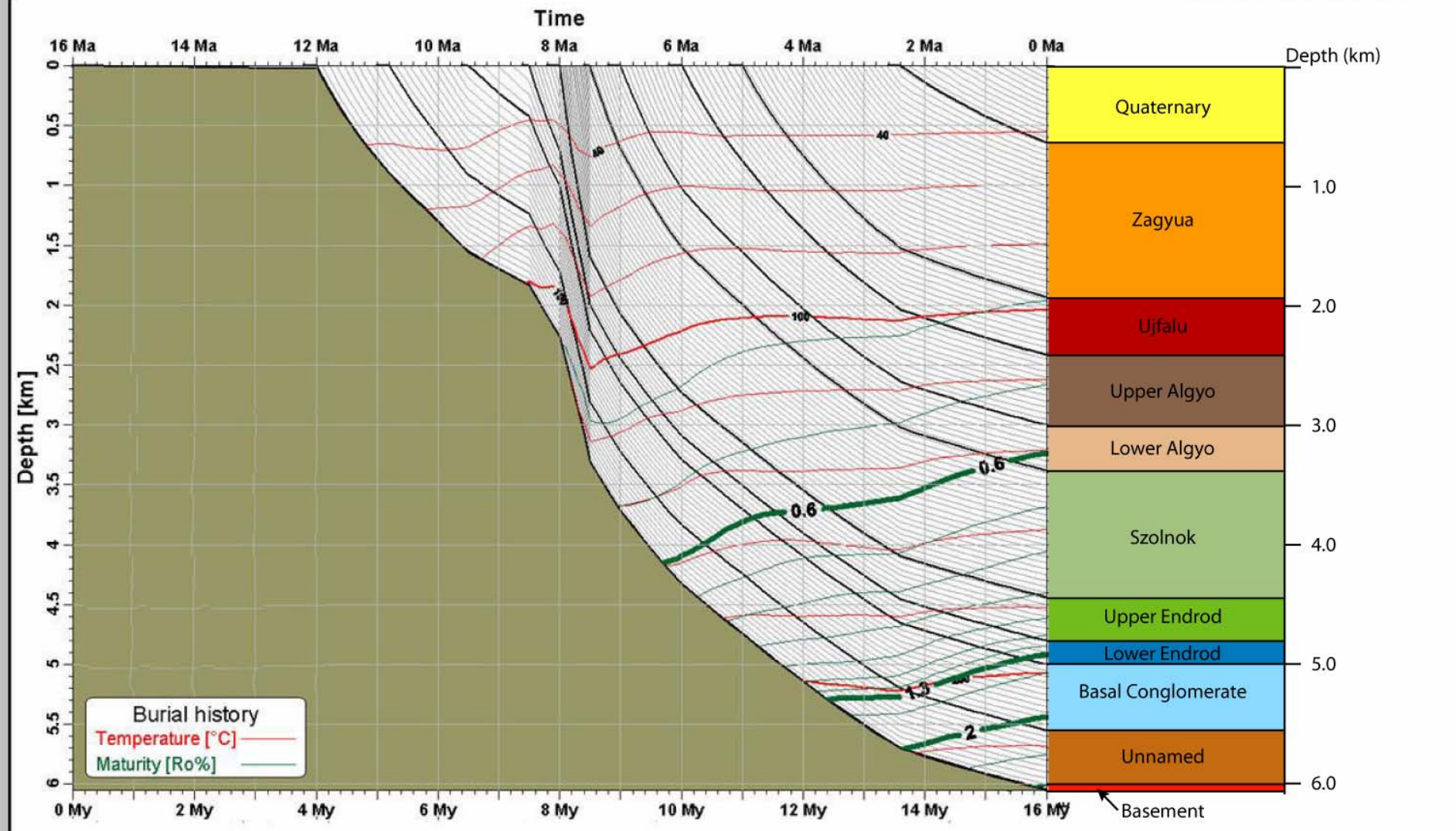
The Scotia Group was commissioned by Falcon to independently describe and quantify the resource of the Makó Trough and has assigned the following probabilistic estimation of the recoverable portion of contingent resources:

| | | 2006 | | | 2008 | |
|---|---|---|---|---|---|---|
| **Potential Zone** | **P90** | **P50** | **P10** | **P90** | **P50** | **P10** |
| **Szolnok, Tcf** | **16** | **42.2** | **92.1** | **15.7** | **38** | **74.4** |
| **Endrod, Tcf** | **1.3** | **3.1** | **6.2** | **0.44** | **0.82** | **1.4** |
| **Basal Conglomerate, Tcf** | **2.9** | **6.9** | **13.4** | **1.1** | **2.3** | **4.2** |
| **Synrift, Tcf** | **1.6** | **2.7** | **4.4** | **0.07** | **0.15** | **0.33** |
| **Arithmetic Summation** | **21.8** | **54.9** | **116.1** | **17.3** | **41.3** | **80.3** |
| **Probabilistic Summation** | | | | **25.8** | **43.9** | **68** |
| **Upper Endrod Oil, Mmbo** | **0** | **0** | **0** | **42.6** | **97.8** | **202.7** |

(1) The recoverable portion of contingent resources estimate has been conducted using the definitions specified by the Canadian Oil and Gas Evaluation Handbook and is compliant with National Instrument 51-101.

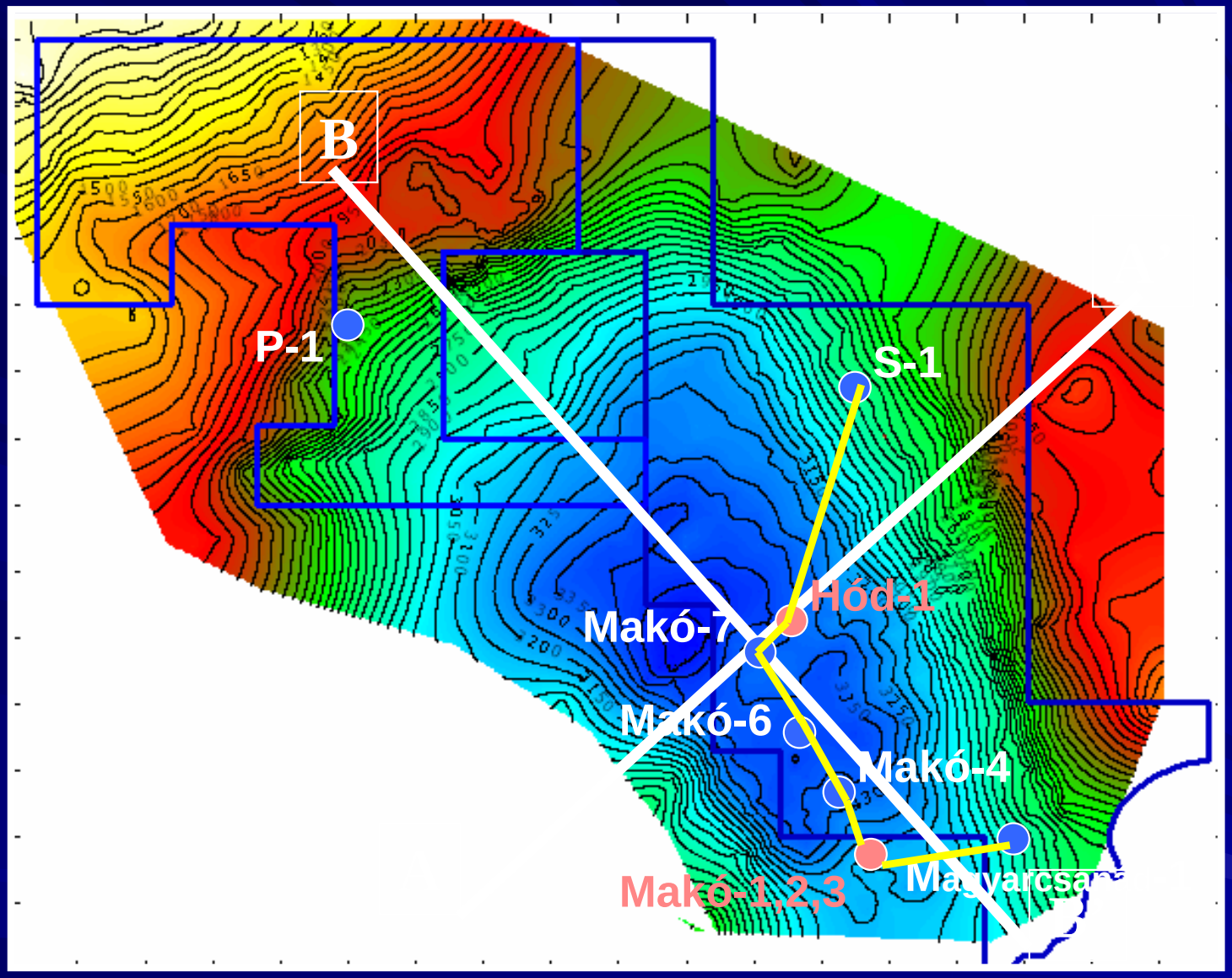
(2) Estimates are as at August 15, 2006, and March 31st 2008 the effective date of the initial Scotia Reports (under their previous name) and the updated RPS Scotia report.

(3) Falcon's discovered resources are not reserves. Only those quantities of oil and gas recoverable from discovered resources are classified as reserves. Discovered resources are proven to be reserves, there is a risk that Falcon may not produce any portion of its revenue.

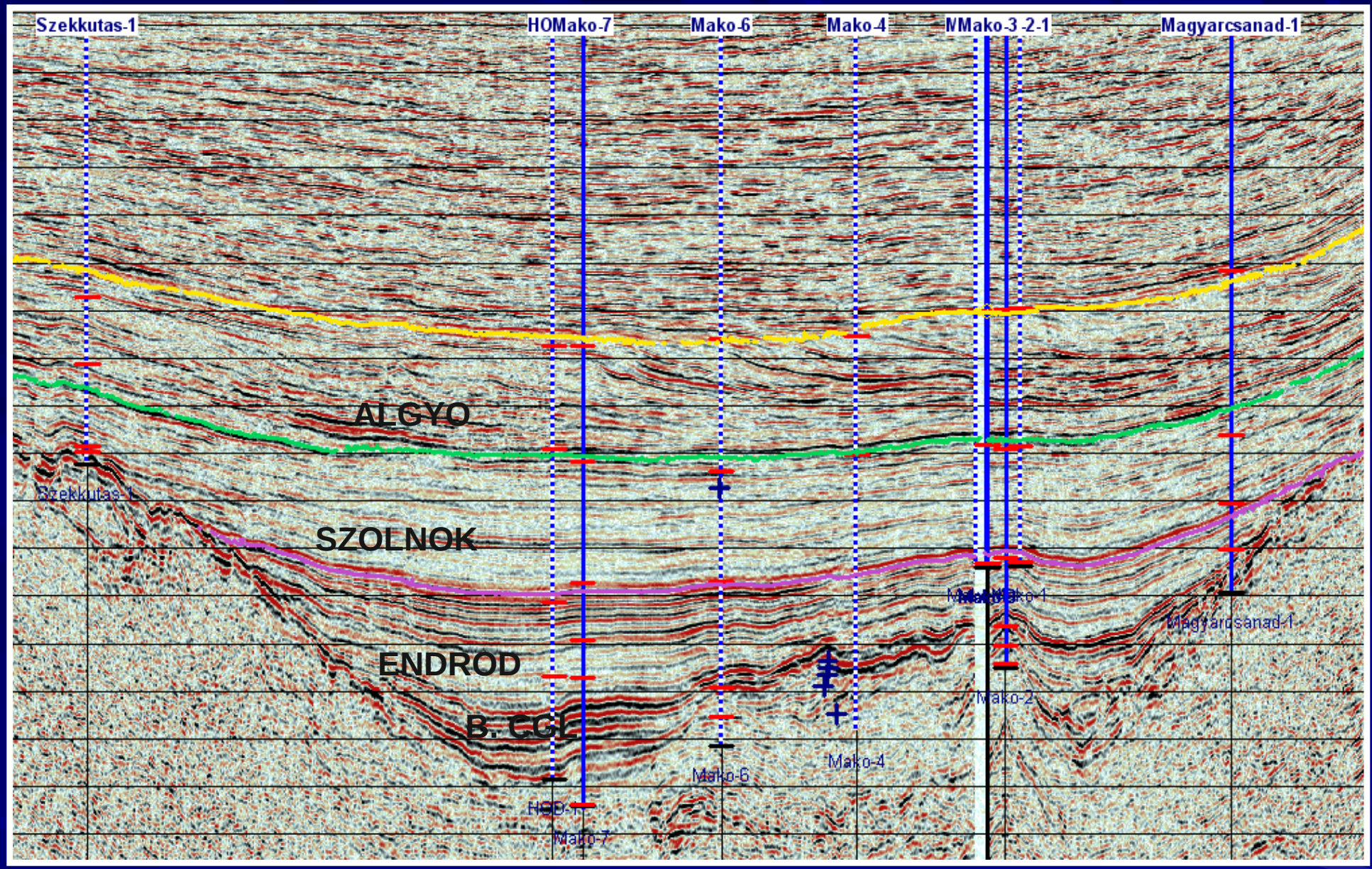



modified from Bada and Dävényi (2008)

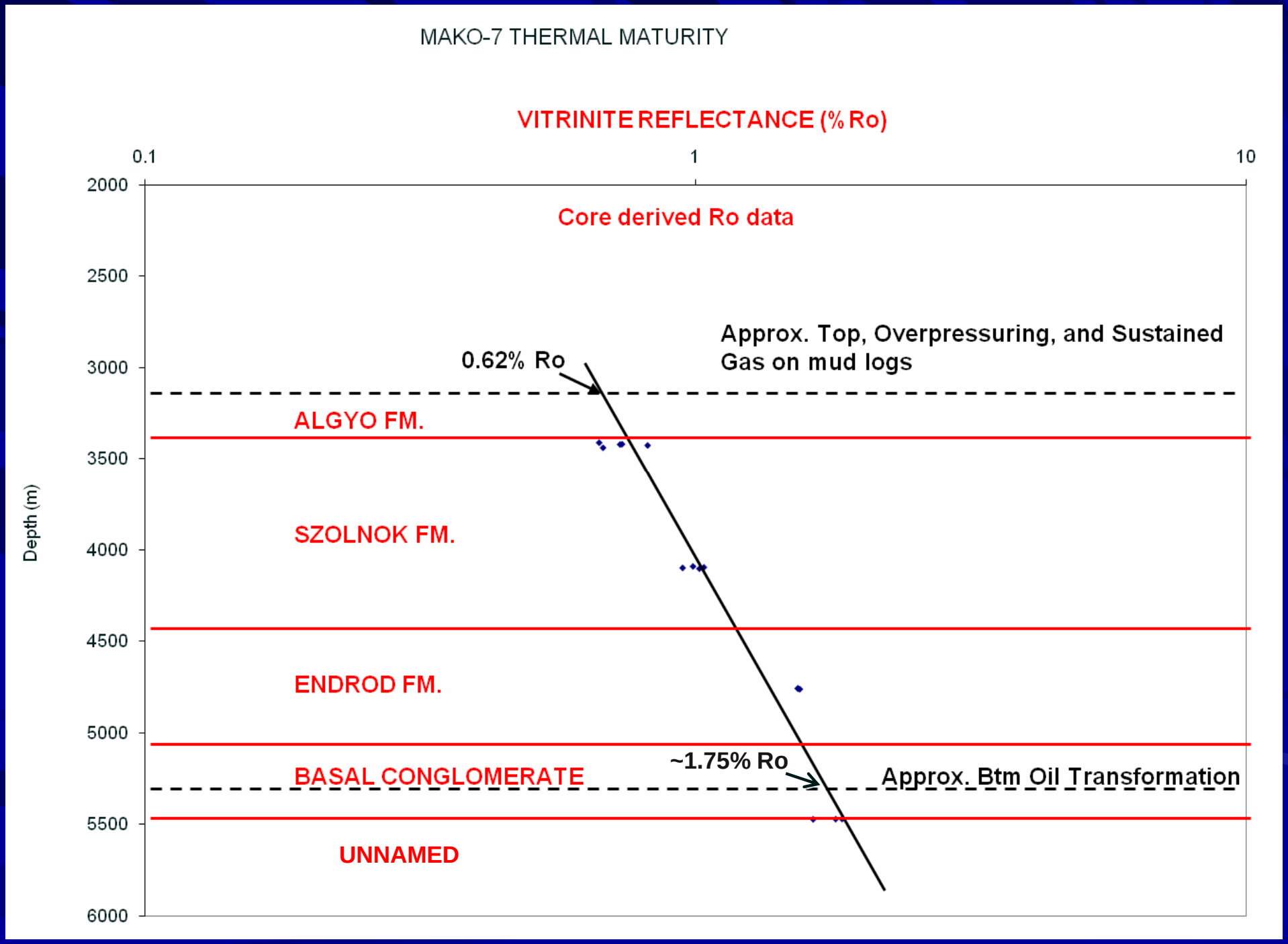
# Mako 7 Burial History



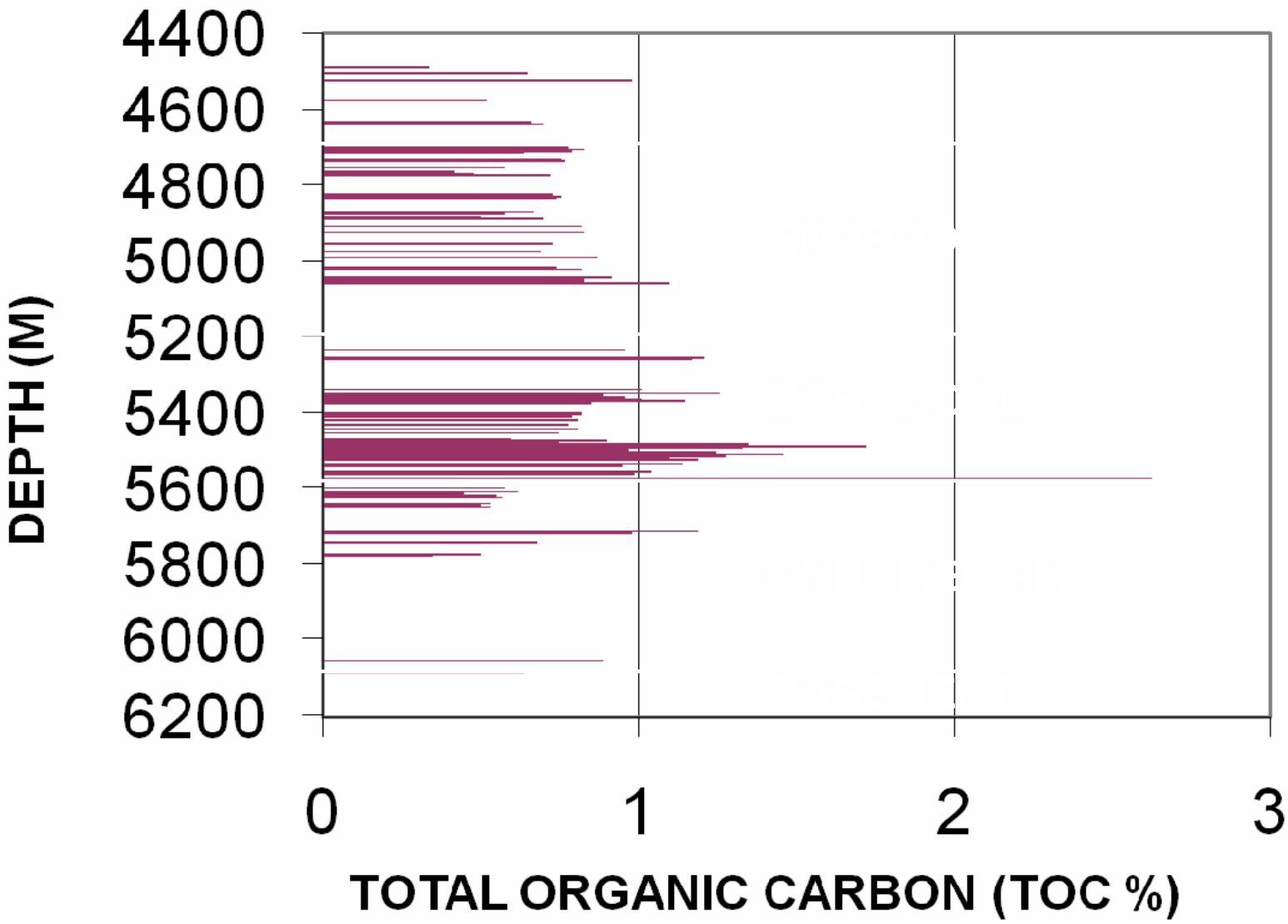

# STRUCTURE- TOP ENDROD



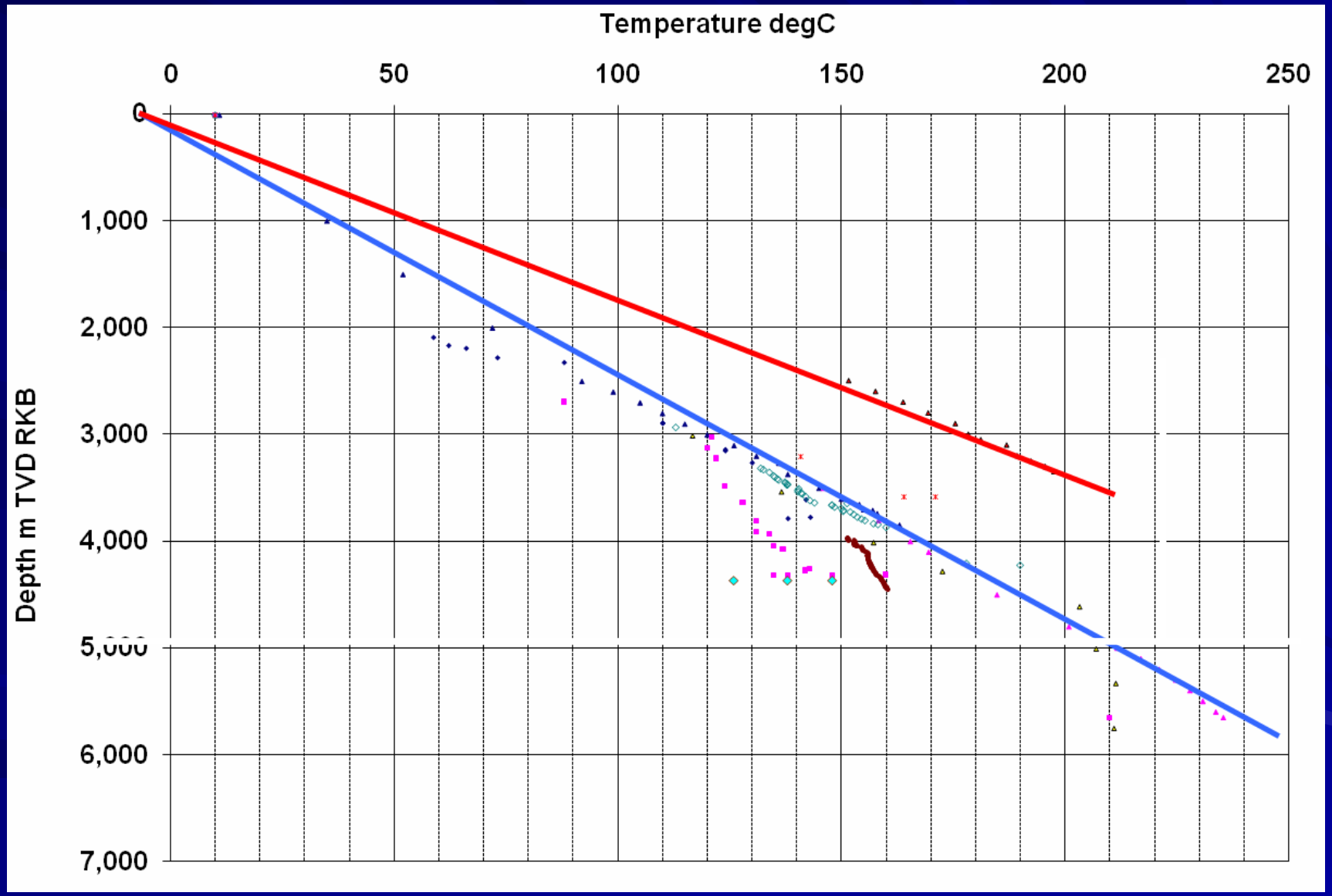

# SEISMIC LINE CONNECTING ALL WELLS

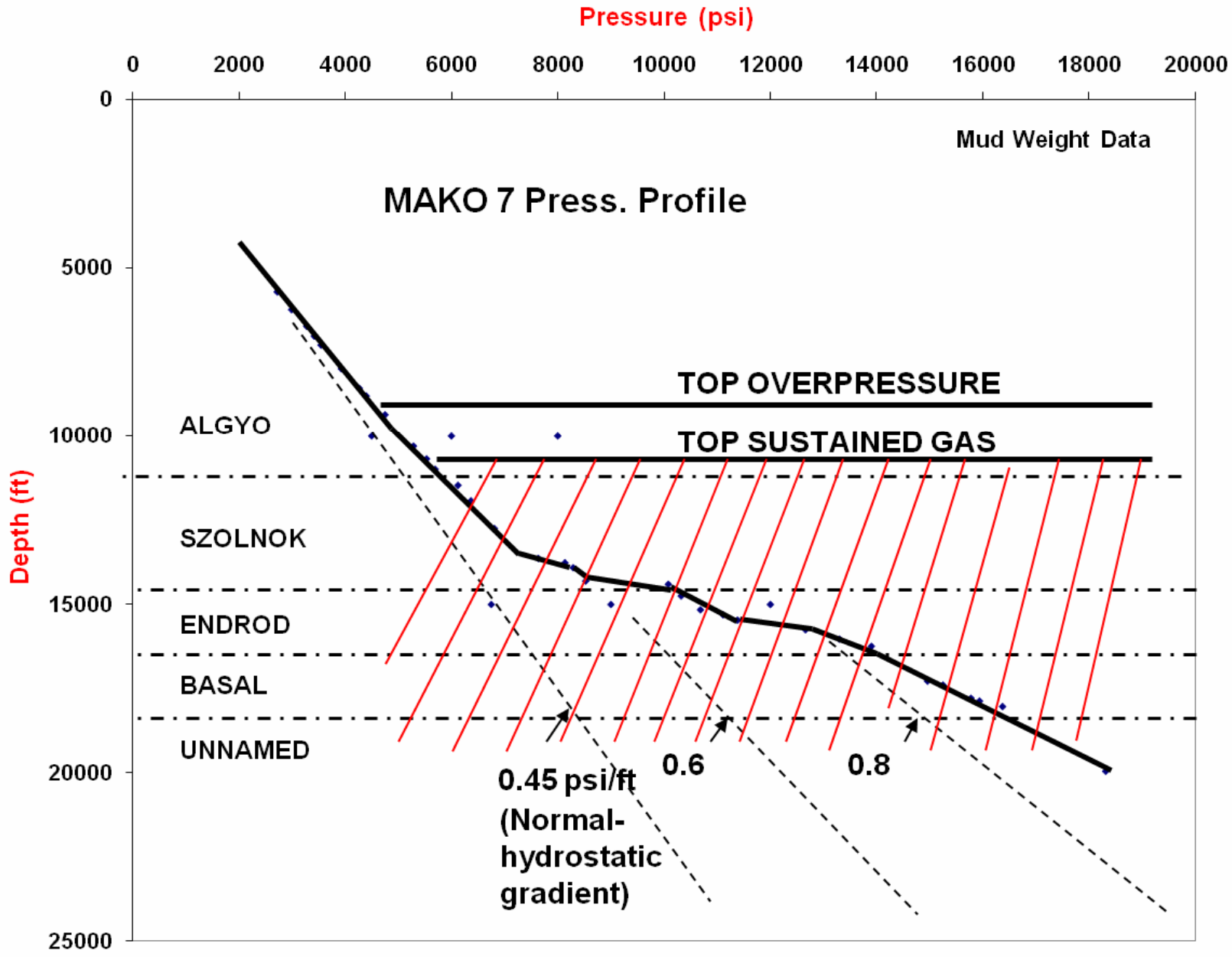

MAKO-7 THERMAL MATURITY
VITRINITE REFLECTANCE (% Ro)
0.1
1
10
2000
2500
3000
3500
4000
4500
5000
5500
6000
Depth (m)
Core derived Ro data
Approx. Top, Overpressuring, and Sustained Gas on mud logs
0.62% Ro
ALGYO FM.
SZOLNOK FM.
ENDROD FM.
BASAL CONGLOMERATE
~1.75% Ro
Approx. Btm Oil Transformation
UNNAMED

# MAKO-7 TOC PROFILE

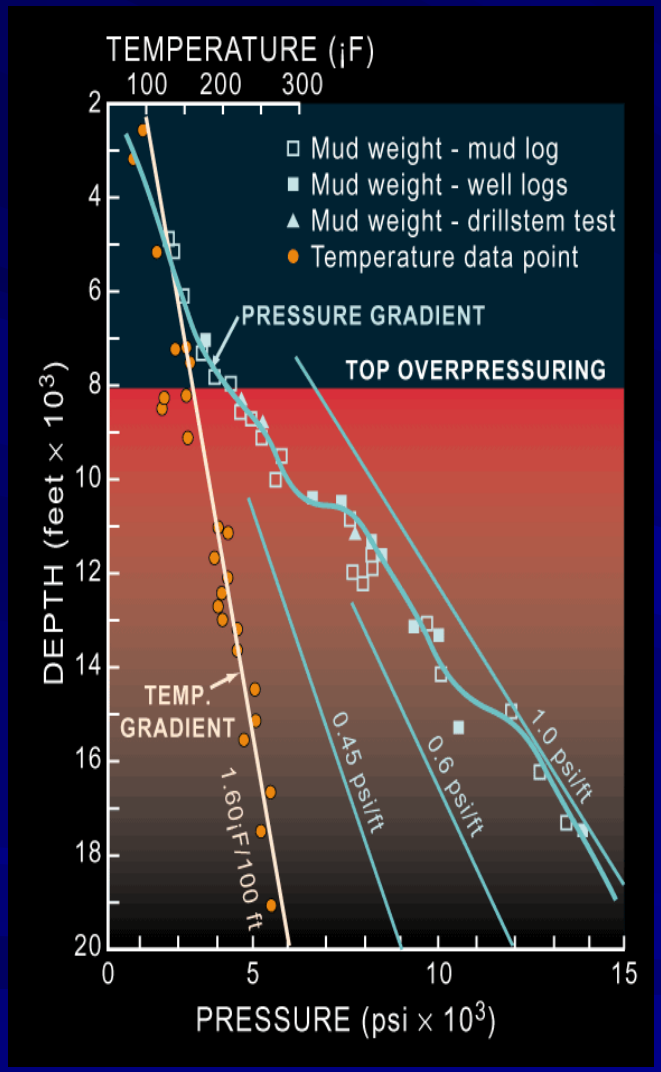


# Mako Trough : Temperature vs Depth

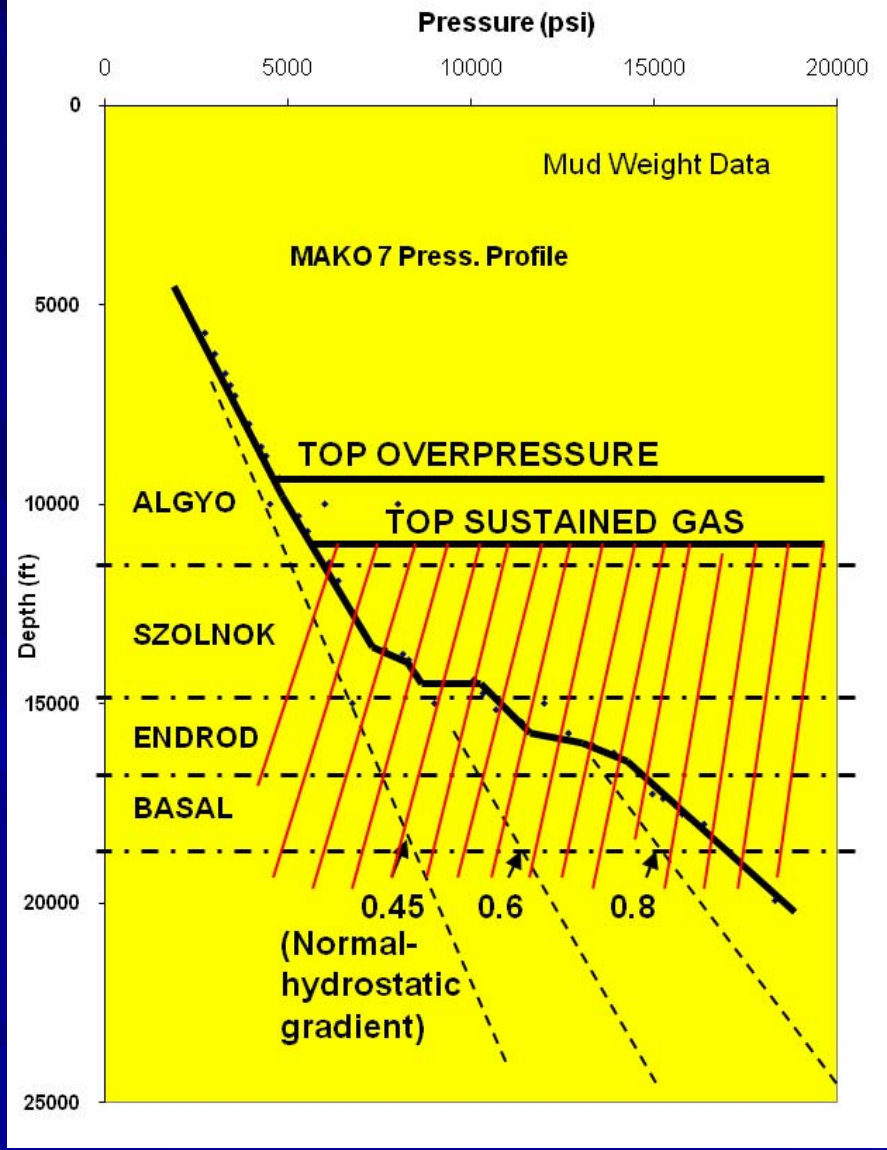



Pressure (psi)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Depth (ft)
0
5000
10000
15000
20000
25000
Mud Weight Data
MAKO 7 Press. Profile
TOP OVERPRESSURE
TOP SUSTAINED GAS
ALGYO
SZOLNOK
ENDROD
BASAL
UNNAMED
0.45 psi/ft
(Normal-
hydrostatic
gradient)
0.6
0.8

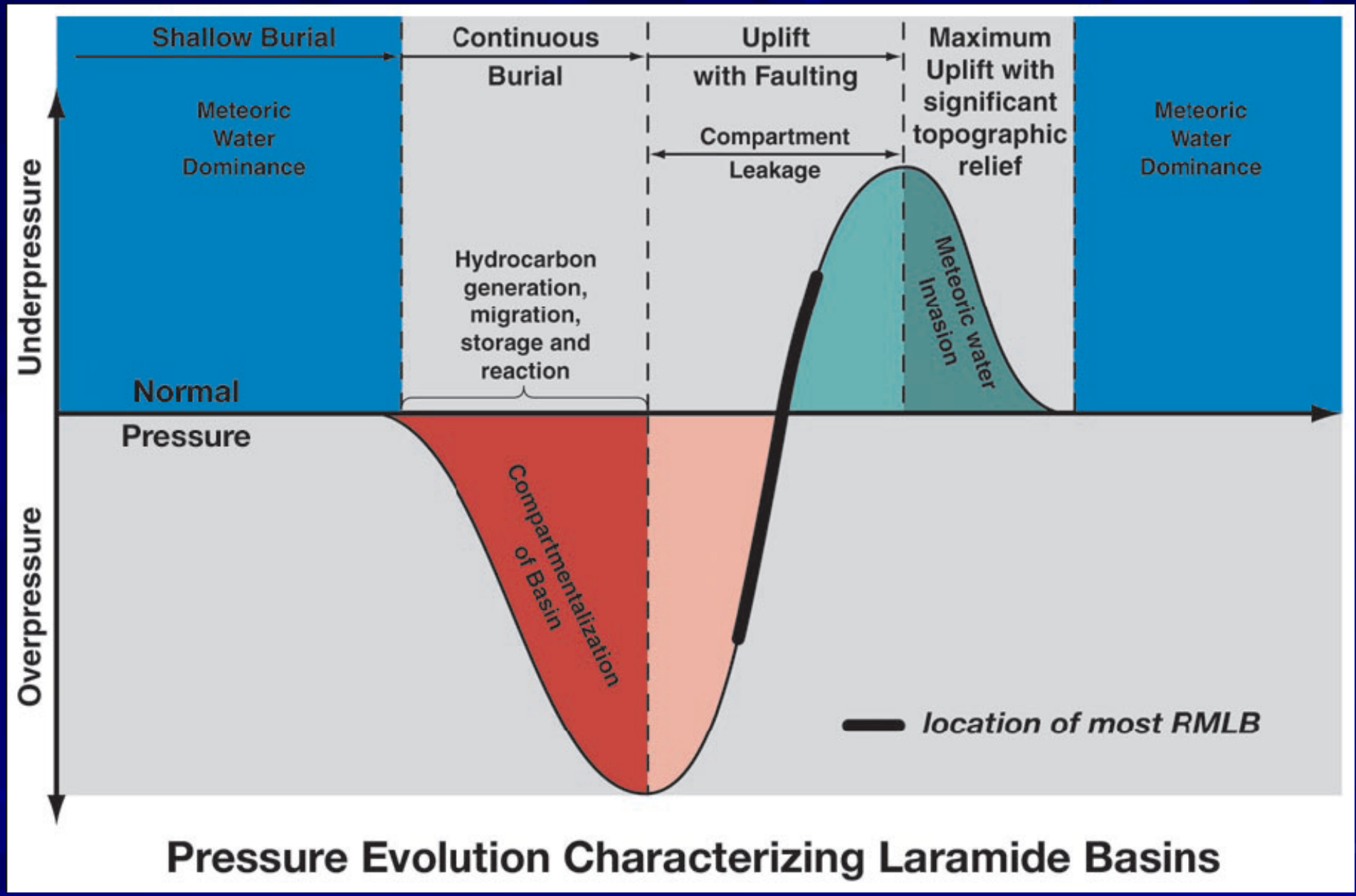
# ABNORMALLY HIGH PRESSURES



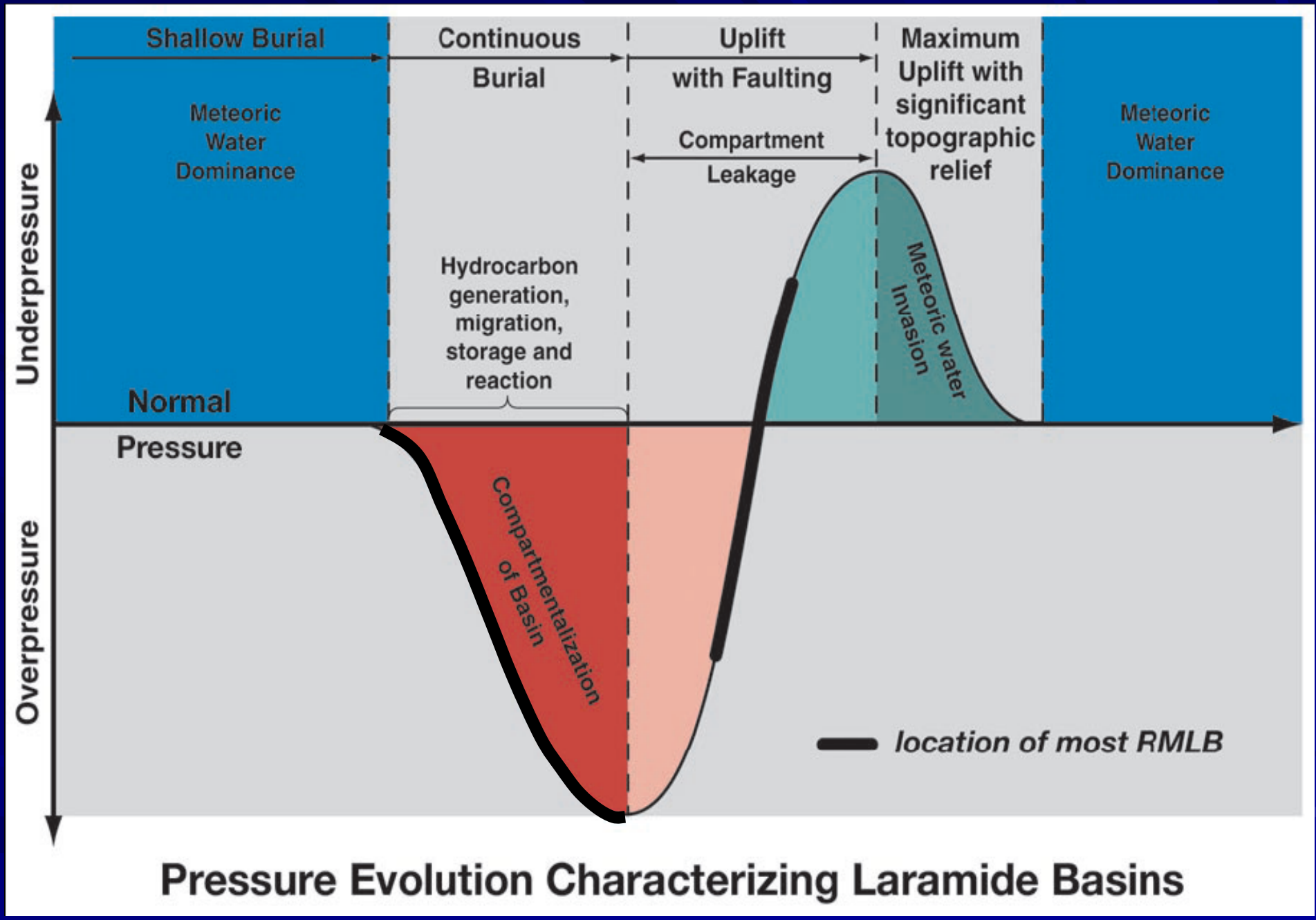

Wagon Wheel, Green River Basin




Mako-7, Mako Trough

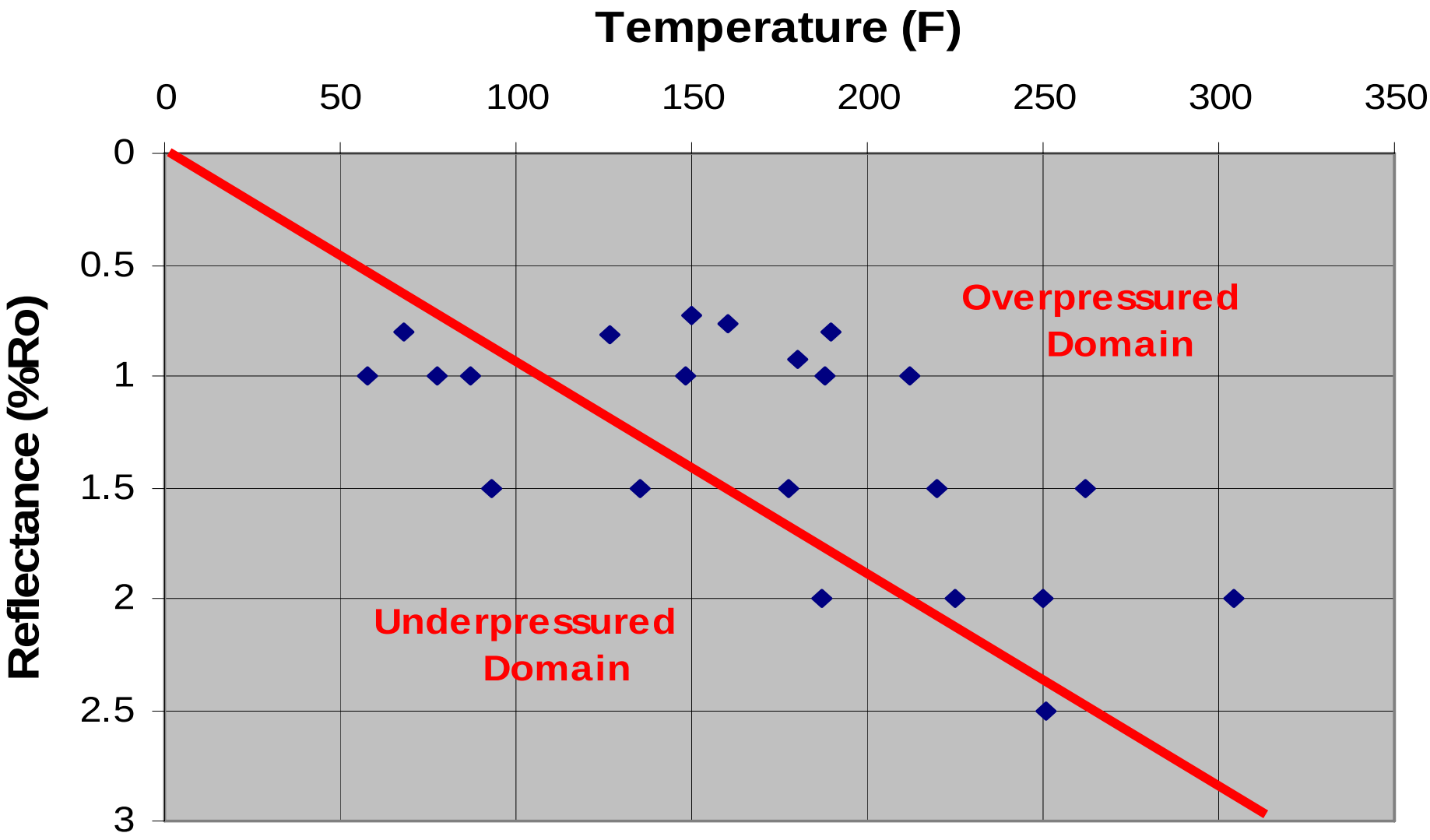



**Modified after Meissner (1987) and Surdam et al. (2003)**

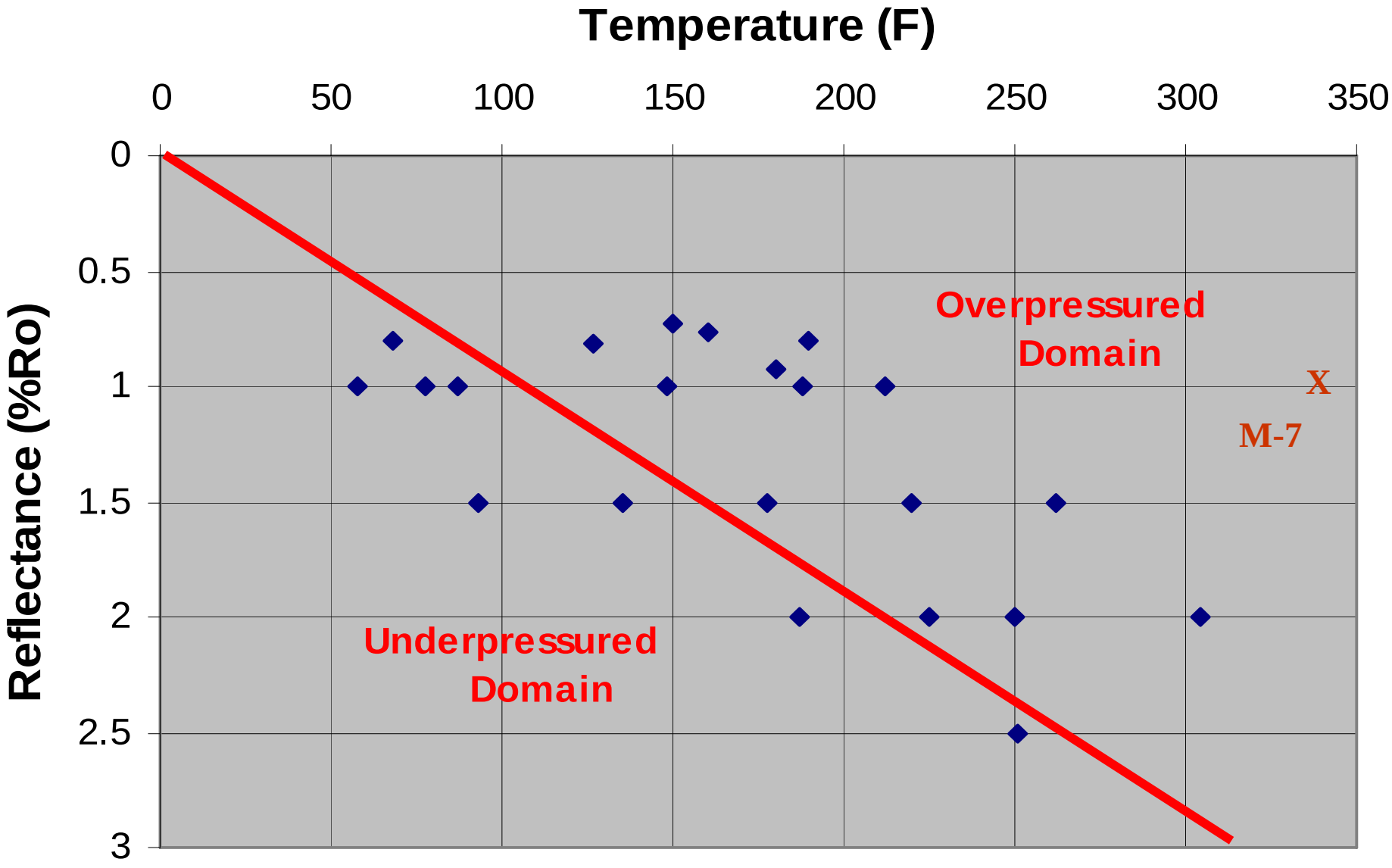



Modified after Meissner (1987) and Surdam, (2003)

# PRESSURE DOMAINS



# PRESSURE DOMAINS



# CONCLUSIONS

- **The Mako Trough exhibits the early development stages of a geologically young BCGA/BCOA**

- **The origin of abnormally high pressures in BCGA/BCOA's is a consequence of hydrocarbon generation---not structural uplift and exhumation. However, we cannot dismiss the possibility of compaction disequilibrium subsequently supplanted by hydrocarbon generation**