Pressures in the Los Monos-Huamampampa System and Their Control in Hydrocarbon Fields' Occurrence and Size*

Daniel Starck[1]

Search and Discovery Article #11118 (2018)**
Posted August 27, 2018

*Adapted from oral presentation given at 2018 AAPG Latin America & Caribbean Region, Optimizing Exploration and Development in Thrust Belts and Foreland Basins, Santa Cruz de la Sierra, Bolivia, June 6-8, 2018

[1]Tecpetrol, Buenos Aires, Argentina (daniel.starck@tecpetrol.com)

Abstract

More than 25 TCFE of discovered natural gas in the Southern Subandean are related to the Huamampama (reservoir)-Los Monos (seal, source rock) system. The Huamampampa Formation is a highly diagenized, Lower Devonian sandstone (quartzite) which becomes an efficient reservoir when naturally fractured in anticlinal crests. The Los Monos Formation is an up to 1 km-thick, mainly pelitic package, deposited during the Middle Devonian. Despite its relative lower organic content (< 1% TOC on average), it is thought to have generated almost all the hydrocarbon discovered in the Bolivian-Argentinean Subandean belt. The Los Monos Formation is typically highly overpressured, a fact that has been explained as a result of hydrocarbon generation and retention. Pressures in the Huamampampa Formation vary from normal (in equilibrium with surface conditions) to strong overpressures (in equilibrium with the Los Monos pressure). High overpressures in the Huamampampa Formation impose a physical limit to traps charge: when the buoyancy pressure related to the gas cap is added, the resultant pressure can produce seal failure. This limitation adds a further complication to the exploration of this already complex structural play. In this presentation we discuss the distribution and causes of the different Huamampampa pressures and their exploration consequences.

References Cited

Bradley, J.S., and D.E. Powley, 1995, Pressure Compartments in Sedimentary Basins: A Review, *in* P.J. Ortoleva (ed.), Basin Compartments and Seals: American Association of Petroleum Geologists Memoir 61, p. 3-26.

Starck, D., A. Rodríguez, and L. Constantini, 2002, Las Rocas Reservorio Carbónicas De La Cuenca De Tarija (Cuenca De Tarija "Sensu Stricto"), *in* M. Schiuma, G. Hinterwimmer, and G. Vergani (eds.), Rocas reservorio de las cuencas productivas de la Argentina, Edition: Simposio del V Congreso de Exploración y Desarrollo de Hidrocarburos, Publisher: Instituto Argentino del Petróleo y Gas, Buenos Aires, p. 699-716.

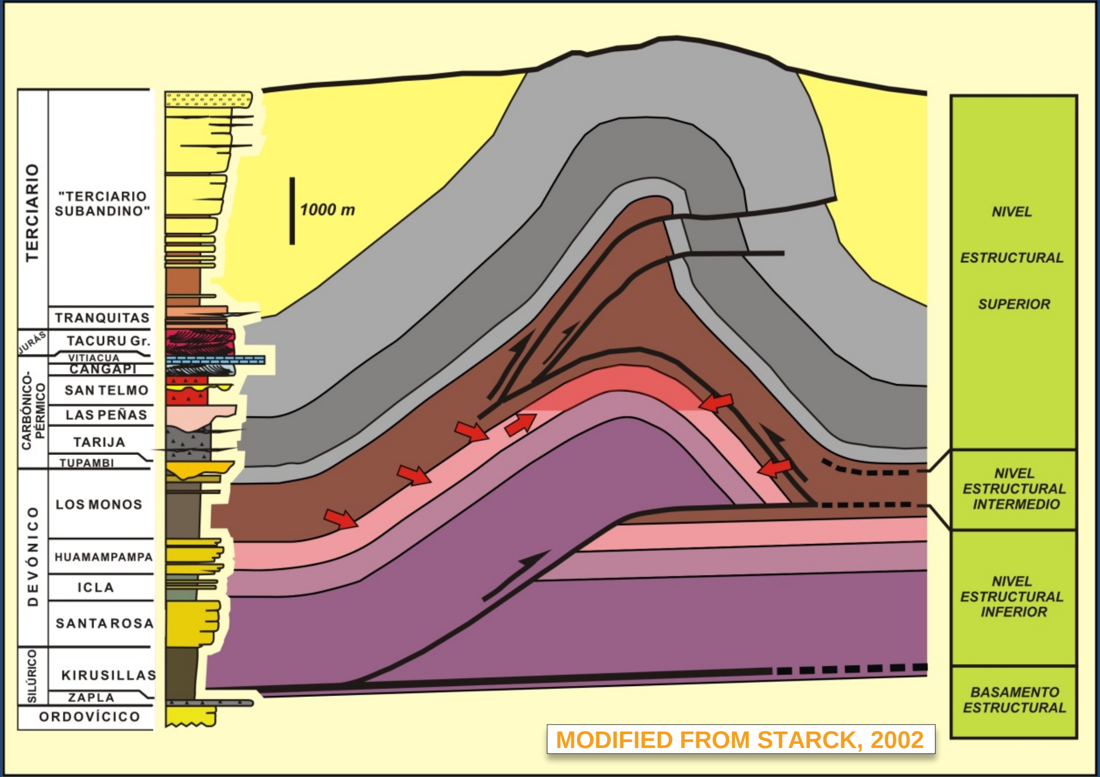
Swarbrick, R.E., and M.J. Osborne, 1998, Mechanisms that Generate Abnormal Pressures: An Overview, *in* B.E. Law, G.F. Ulmishek, and V.I. Slavin (eds.), Abnormal Pressures in Hydrocarbon Environments: American association of Petroleum Geologists Memoir 70, p. 13-34.

AAPG Latin America & Caribbean Region | BOLIVIA 2018 Geosciences Technology Workshop

PRESSURES IN THE LOS MONOS-HUAMAMPAMPA SYSTEM AND THEIR CONTROL IN HYDROCARBON FIELDS' OCCURRENCE AND SIZE

- **Daniel Starck**

  Tecpetrol S.A.

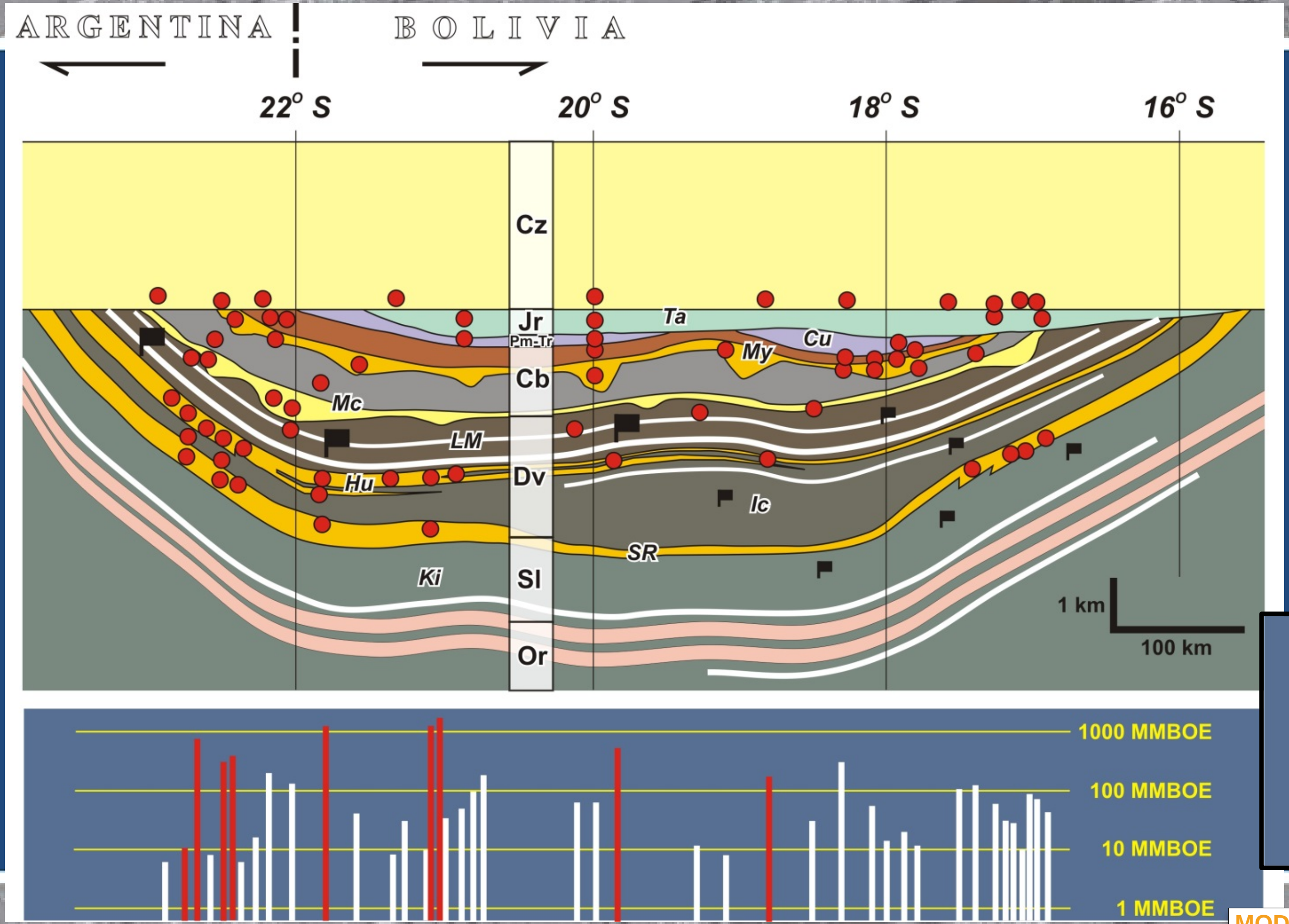


THE HUAMAMPAMPA Fm SUBANDEAN PLAY

FRACTURED QUARTZITES IN LARGE, DEEP ANTICLINES

10's km LENGTH
100's m STRUCTURAL RELIEF
IN GENERAL WITH AN IMPORTANT HYDROCARBON (GAS) FILL

CHARGE (MAINLY GAS) FROM THE LOS MONOS Fm



THE HUAMAMPAMPA Fm SUBANDEAN PLAY

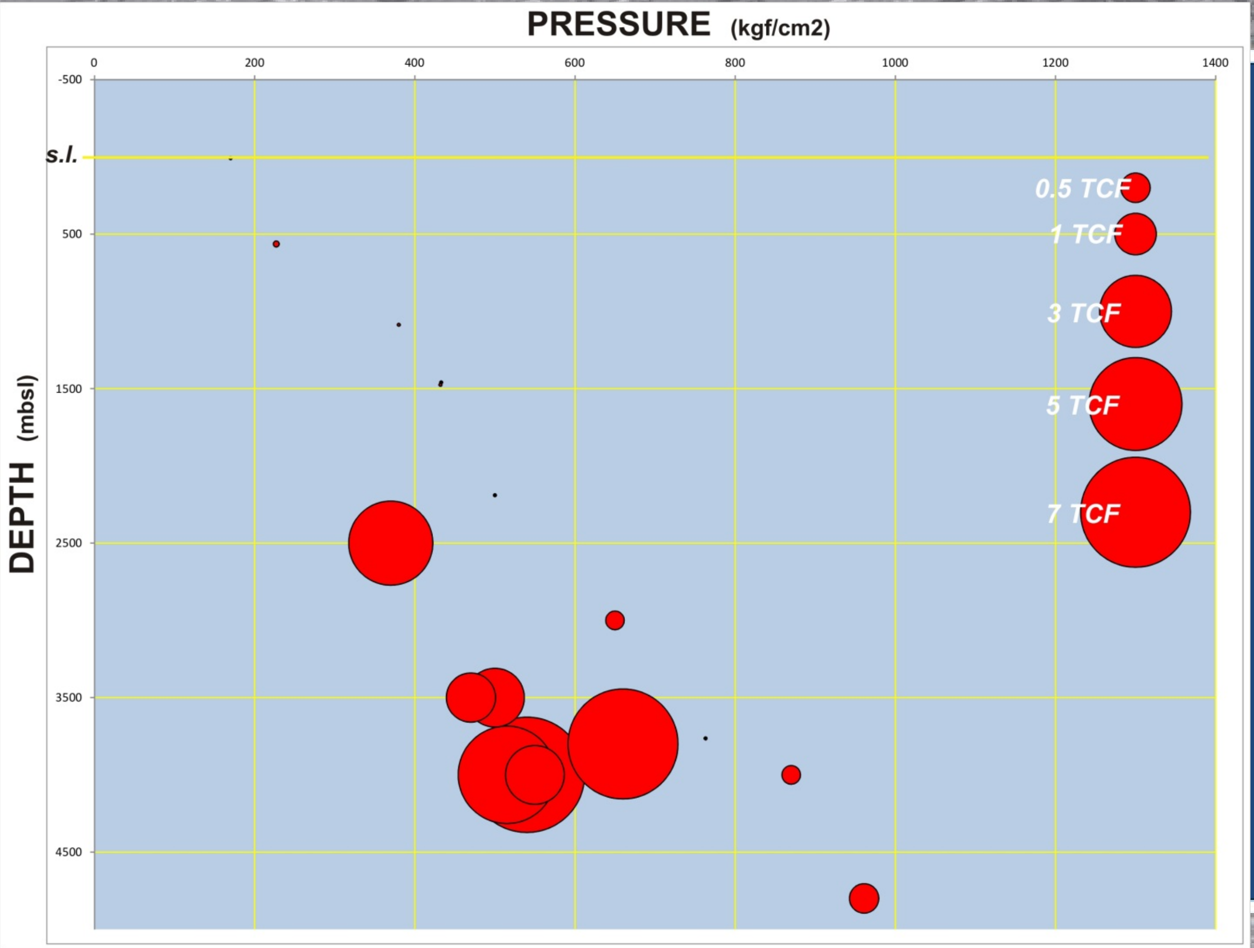
THE HUAMAMPAMPA Fm IS THE MOST PROLIFIC PRODUCING RESERVOIR IN THE SUBANDEAN (PLUS “PIE DE MONTE”)

HUAMAMPAMPA Fm FIELDS (plus S.R. AND ICLA Fms)

YOUNGER RESERVOIRS FIELDS

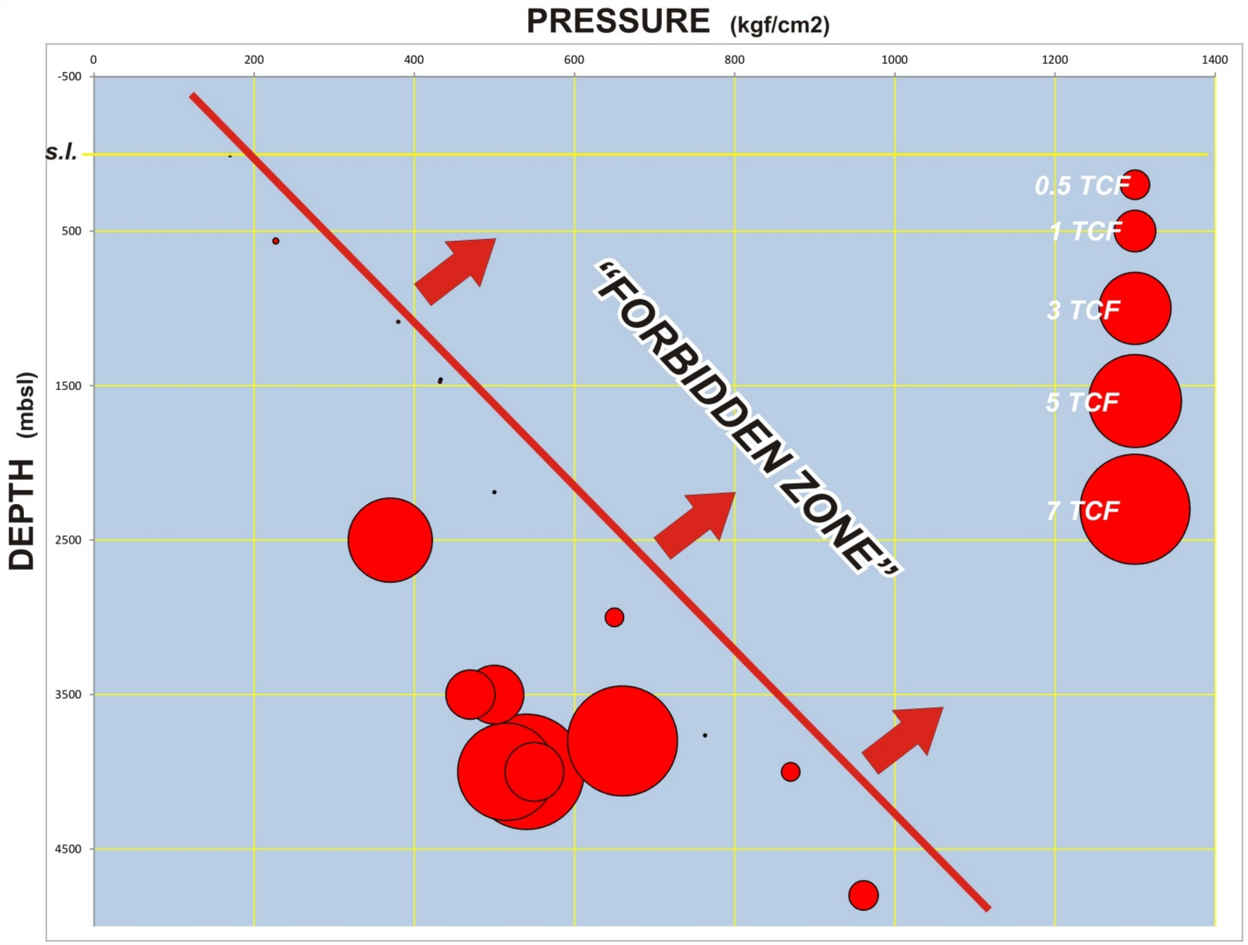
MODIFIED FROM FUENTES *ET AL.*, IN PRESS

PRESSURES IN THE LOS MONOS-HUAMAMPAMPA SYSTEM AND THEIR CONTROL IN HYDROCARBON FIELDS’ OCCURRENCE AND SIZE



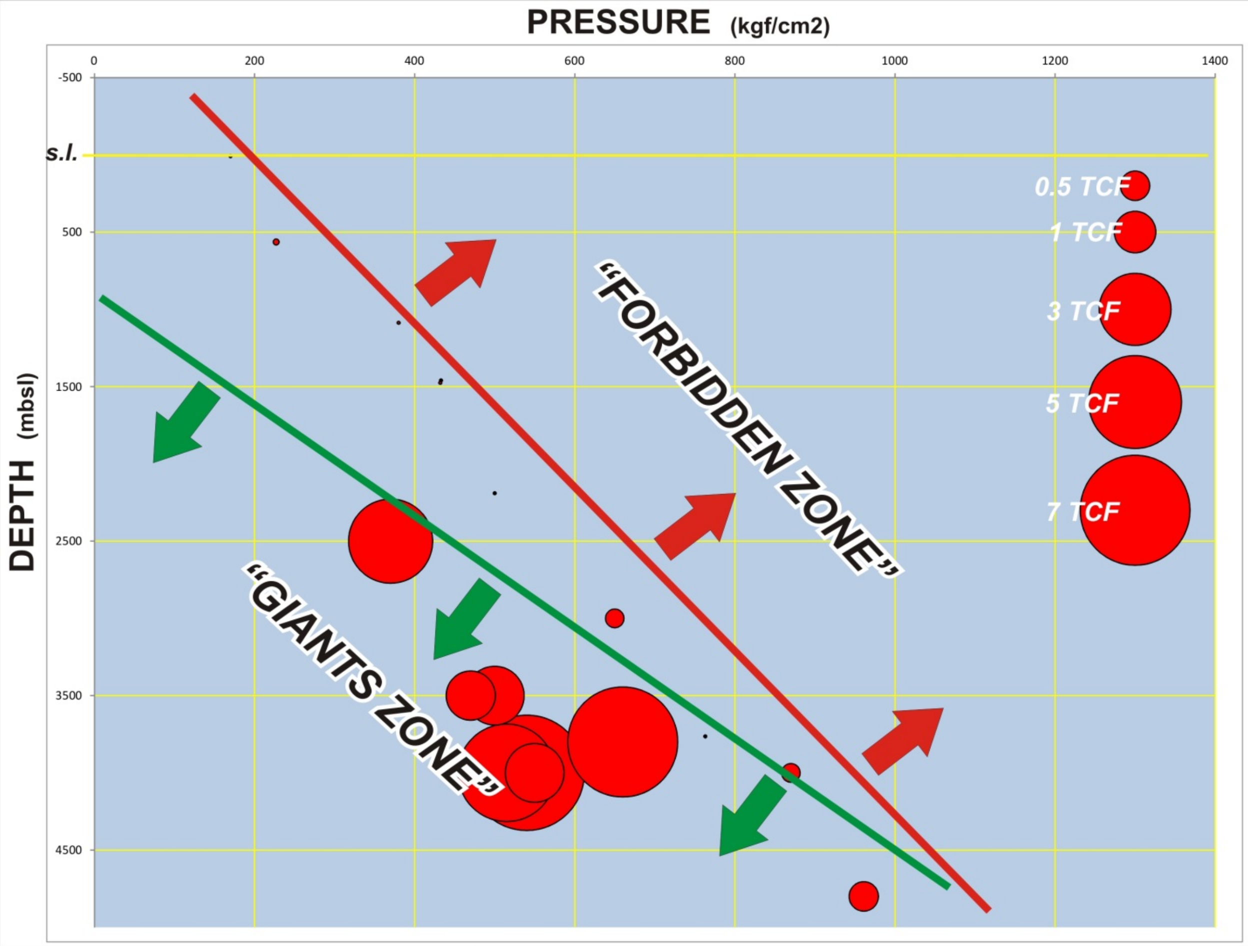
THE HUAMAMPAMPA Fm SUBANDEAN PLAY

FIELD SIZE (OGIP) IN RELATION TO PRESSURE (AND DEPTH)



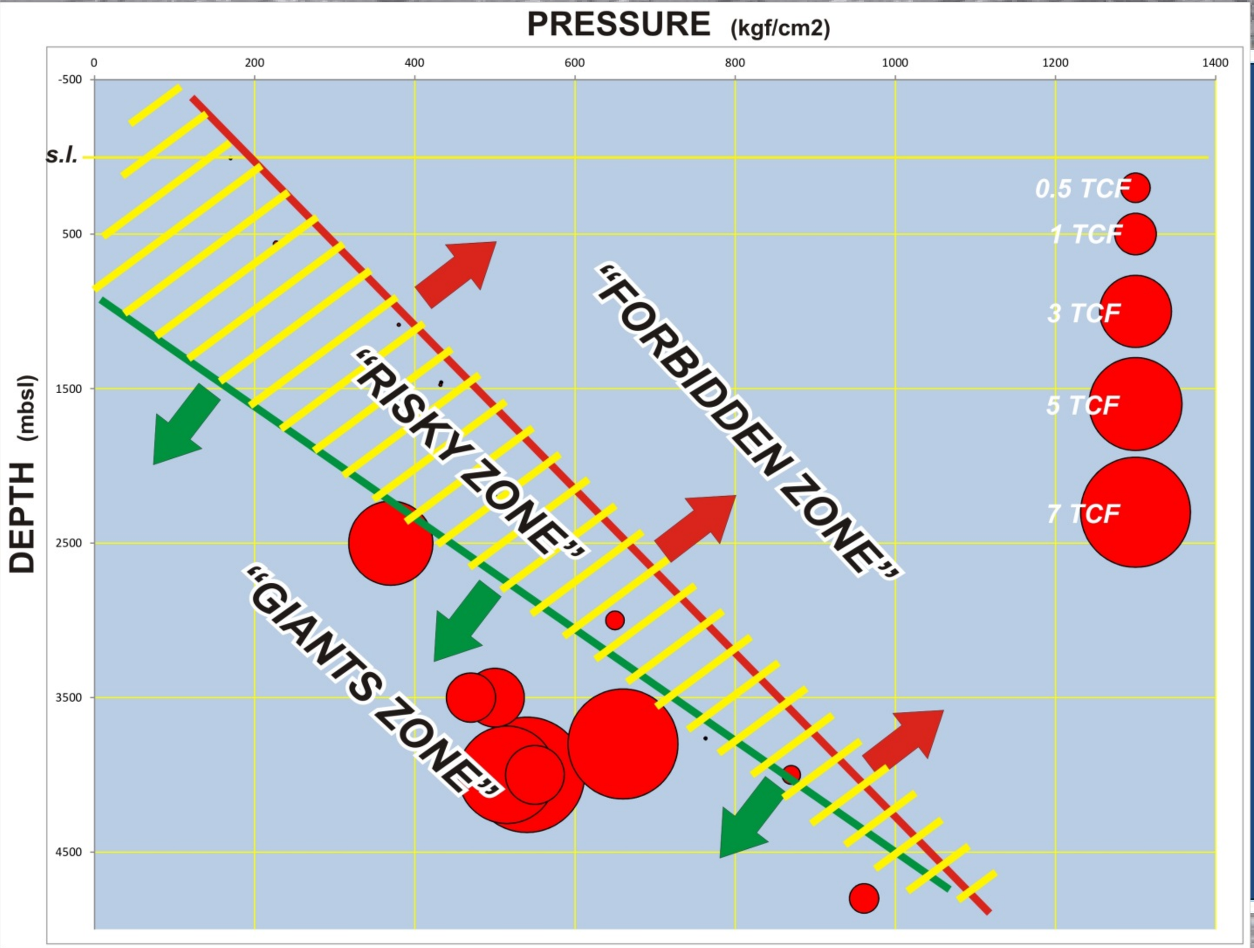
THE HUAMAMPAMPA Fm SUBANDEAN PLAY

FIELD SIZE (OGIP) IN RELATION TO PRESSURE (AND DEPTH)



THE HUAMAMPAMPA Fm SUBANDEAN PLAY

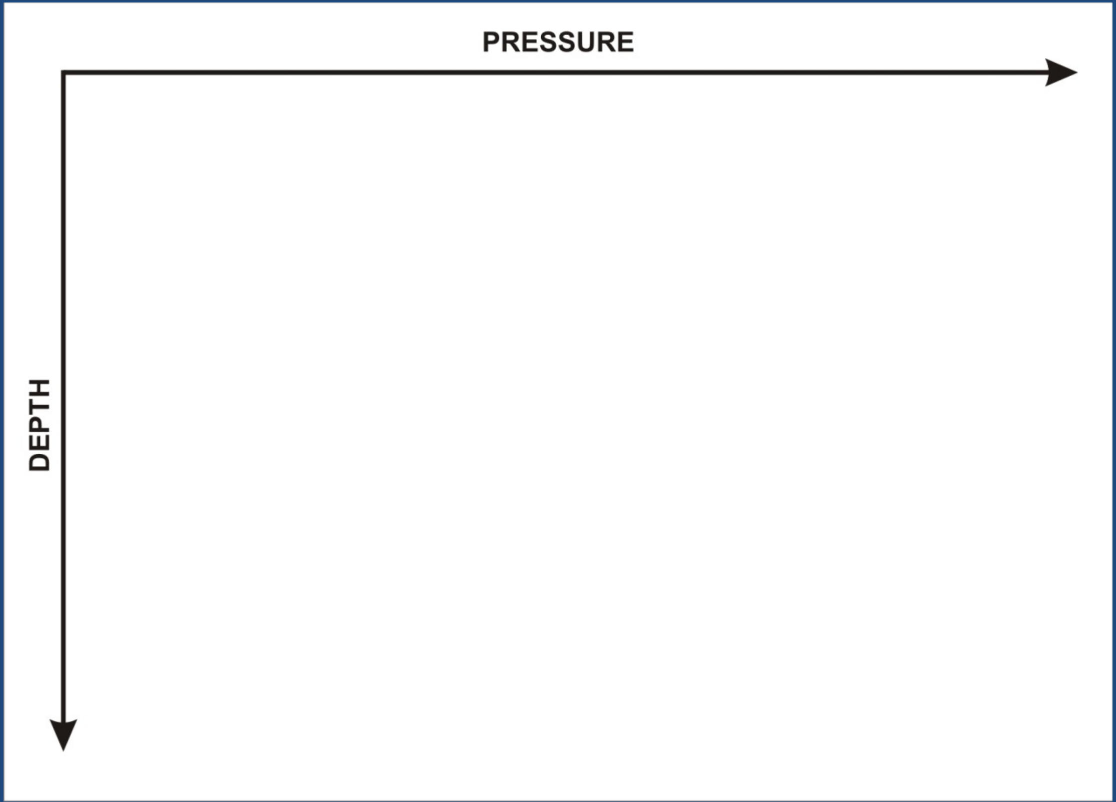
FIELD SIZE (OGIP) IN RELATION TO PRESSURE (AND DEPTH)



THE HUAMAMPAMPA Fm SUBANDEAN PLAY

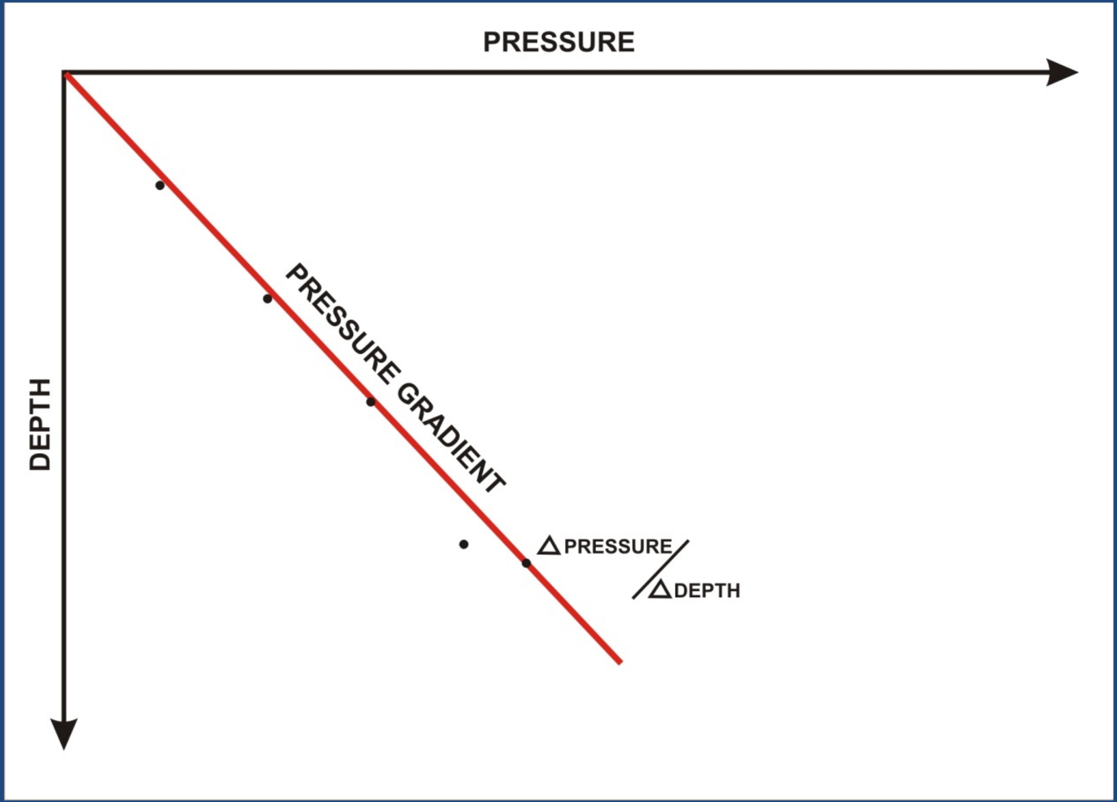
FIELD SIZE (OGIP) IN RELATION TO PRESSURE (AND DEPTH)

PRESSURE SEEMS TO BE AN IMPORTANT CONTROL ...



THE ANALYSIS SCENARIO:

THE DEPTH-PRESSURE PLOT



THE DEPTH-PRESSURE PLOT

PRESSURE GRADIENT

but:

$$p = F/A = F/l^2$$

then:

$$pGrad = \frac{F/l^2}{l} = F/l^3 \Rightarrow$$

specific weight

IN “METRIC” SYSTEM,
THE FRESH WATER GRAD IS:

1kgf/10m

equals to

1 gf/cm3

IN IMPERIAL UNITS SYSTEM,
THE FRESH WATER GRAD IS:

0.433 psi/ft
or
62.43 lbf/ft3
or
8.34 ppg
or
10 API°

HUAMAMPAMPA Fm water has a “regional” salinity of about 30 g/l, which implies a specific weight (“density”) of about 1.03 g/cm3

- Normal pressure
- Hydrostatic pressure
- Abnormal pressure
  - Overpressure
  - Underpressure
- Lithostatic pressure

“Normally pressured reservoirs have pore pressures which are the same as a continuous column of static water from the surface”

SWARBRICK and OSBORNE, 1998

THE LITHOSTATIC PRESSURE IS THE PRESSURE DUE TO THE OVERBURDEN.

ITS GRADIENT IS ABOUT 2.4 g/cm3

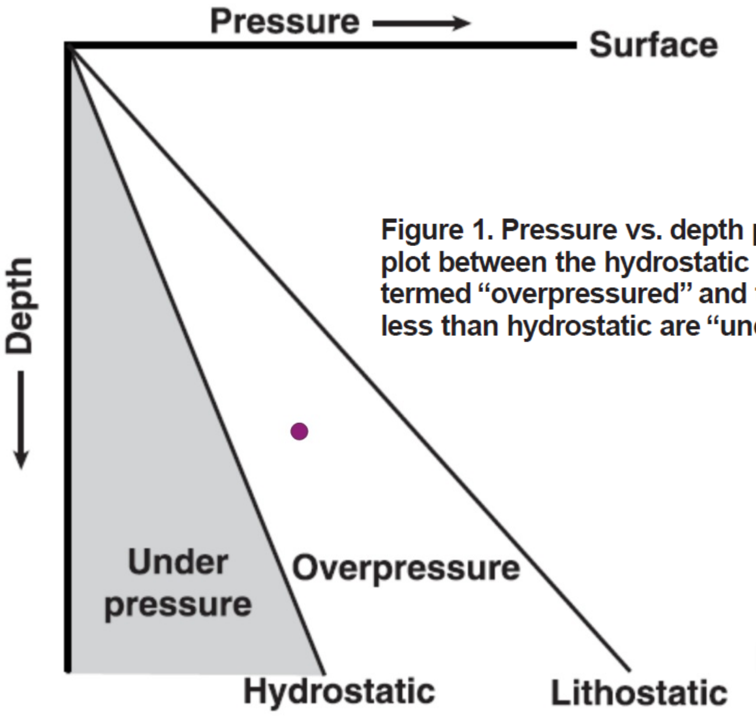
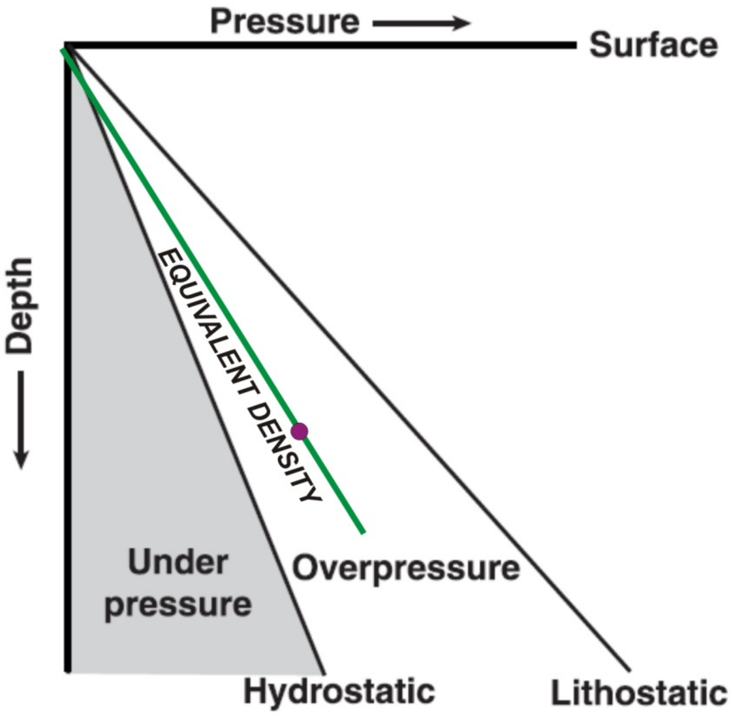


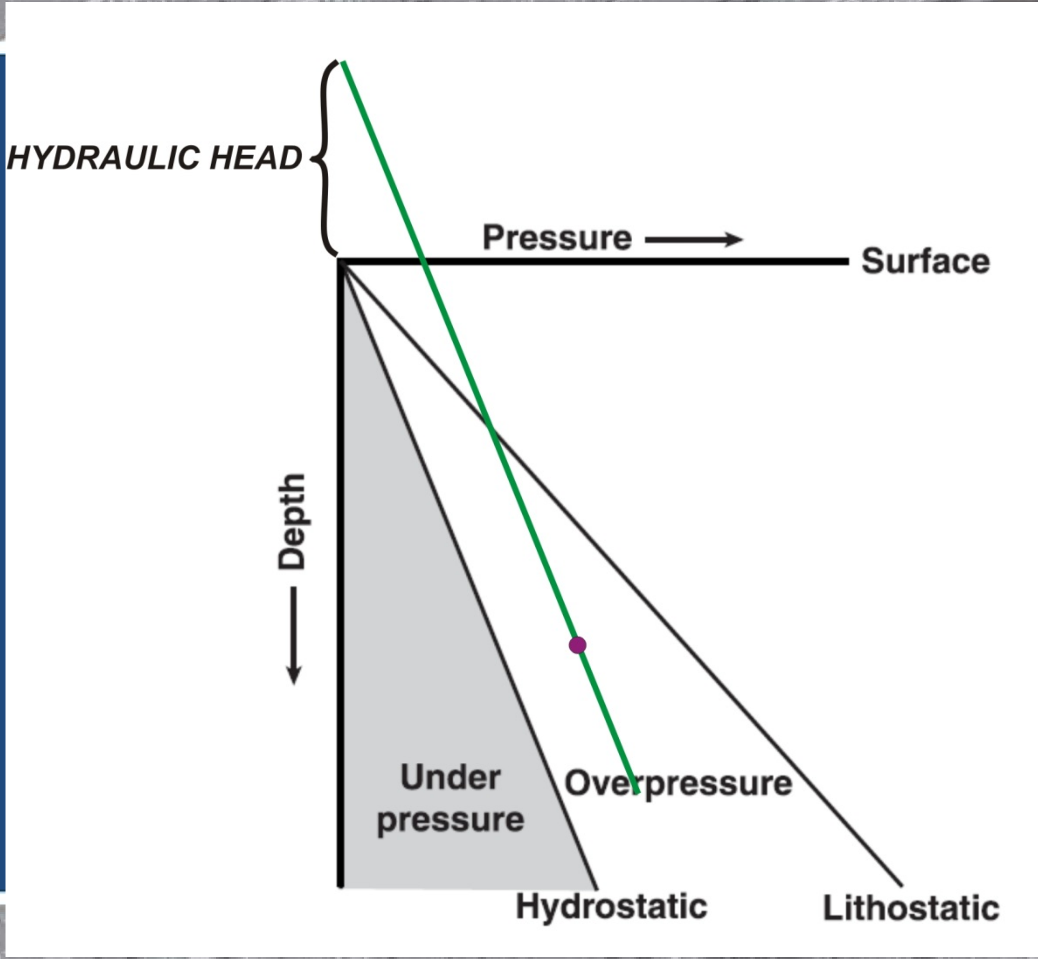
Figure 1. Pressure vs. depth plot. Rocks whose pressures plot between the hydrostatic and lithostatic gradients are termed "overpressured" and those whose pressures are less than hydrostatic are "underpressured".

SWARBRICK and OSBORNE, 1998

THERE ARE TWO WAYS OF EXPRESS THE PORE PRESSURE



AS “EQUIVALENT DENSITY” (or “EQUIVALENT MUD WEIGHT”)



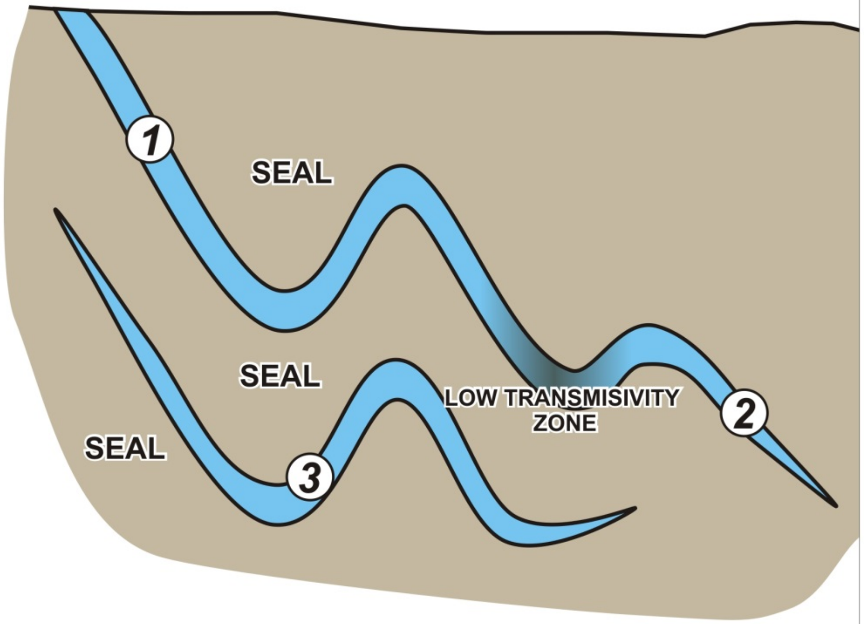
OR AS "HYDRAULIC HEAD" (or "PIEZOMETRIC HEAD", or "POTENTIAL")

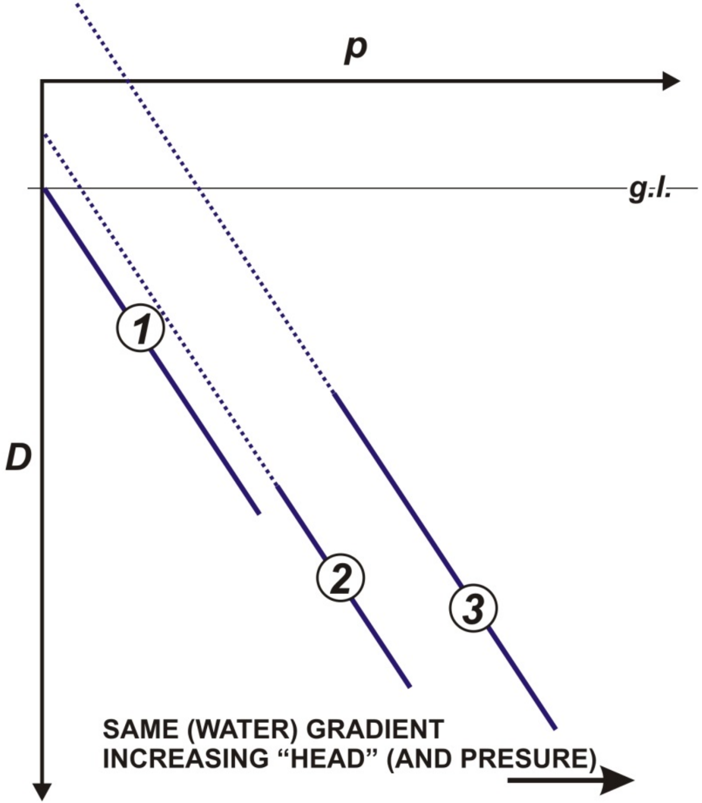
AN OVERPRESSURED AQUIFER HAS AN HYDROSTATIC GRADIENT, BUT ITS HYDRAULIC HEAD IS ABOVE THE TOPOGRAPHIC SURFACE

OPEN HYDRAULIC SYSTEM: WHEN EXISTS FLUID (BRINE, OIL, OR GAS) CONTINUITY THROUGHOUT, RESULTING IN NORMAL HYDROSTATIC PRESSURES

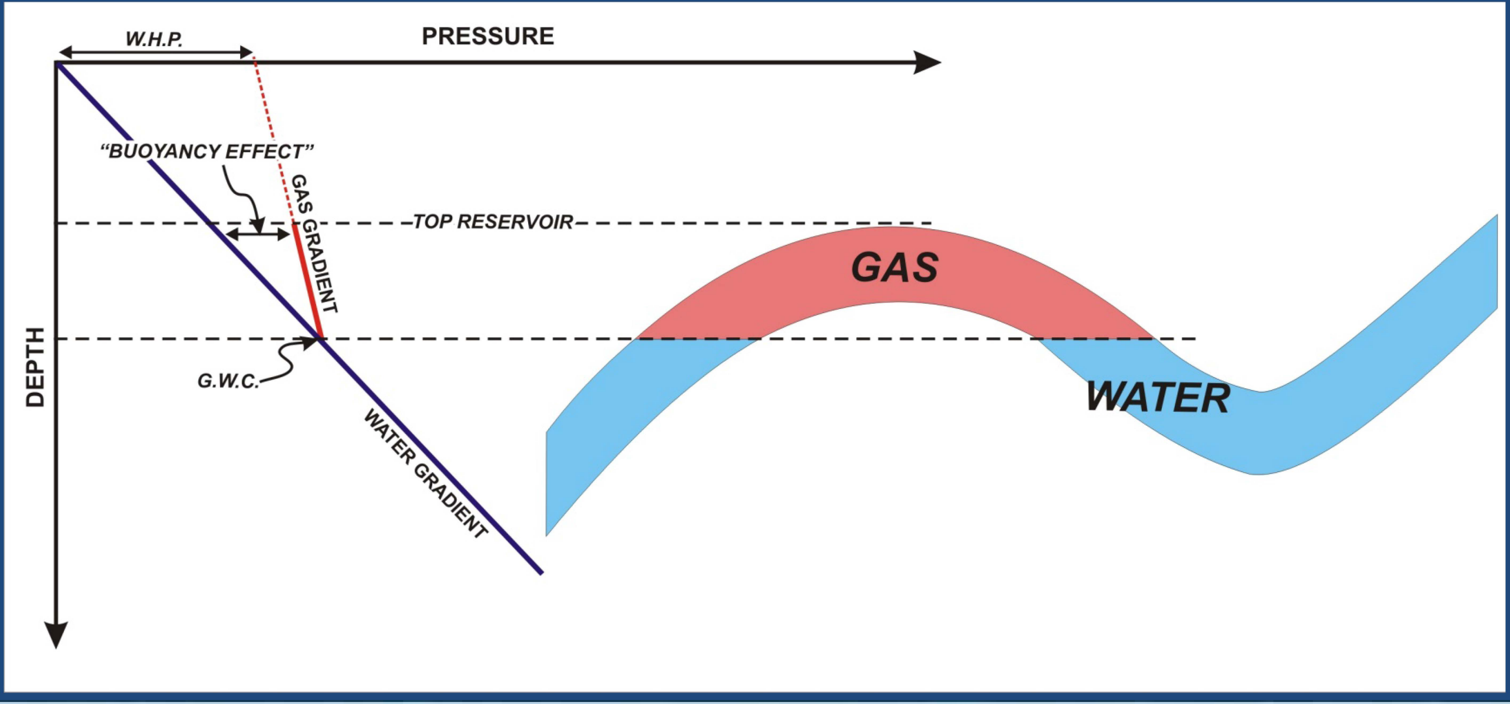
CLOSED HYDRAULIC SYSTEM: HAS NO FLUID CONTINUITY ACROSS THE BOUNDING PRESSURE SEALS, SO THAT THE FLUIDS WITHIN THE SYSTEM MAY BE UNDERPRESSURED, NORMALLY PRESSURED, OR OVERPRESSURED. THERE IS NO FLUID FLOW (BRINE OR HYDROCARBON) ACROSS THE SEAL.

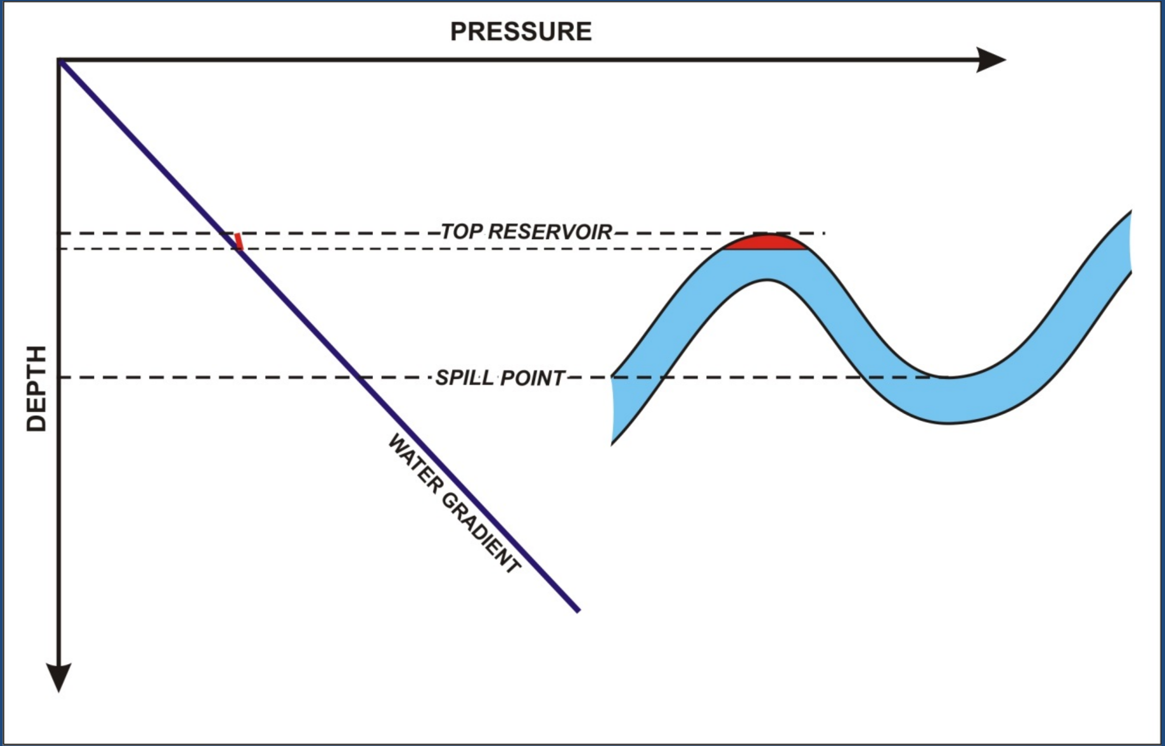
BRADLEY and POWLEY, 1995


SEAL
SEAL
SEAL
LOW TRANSMISIVITY ZONE
1
2
3

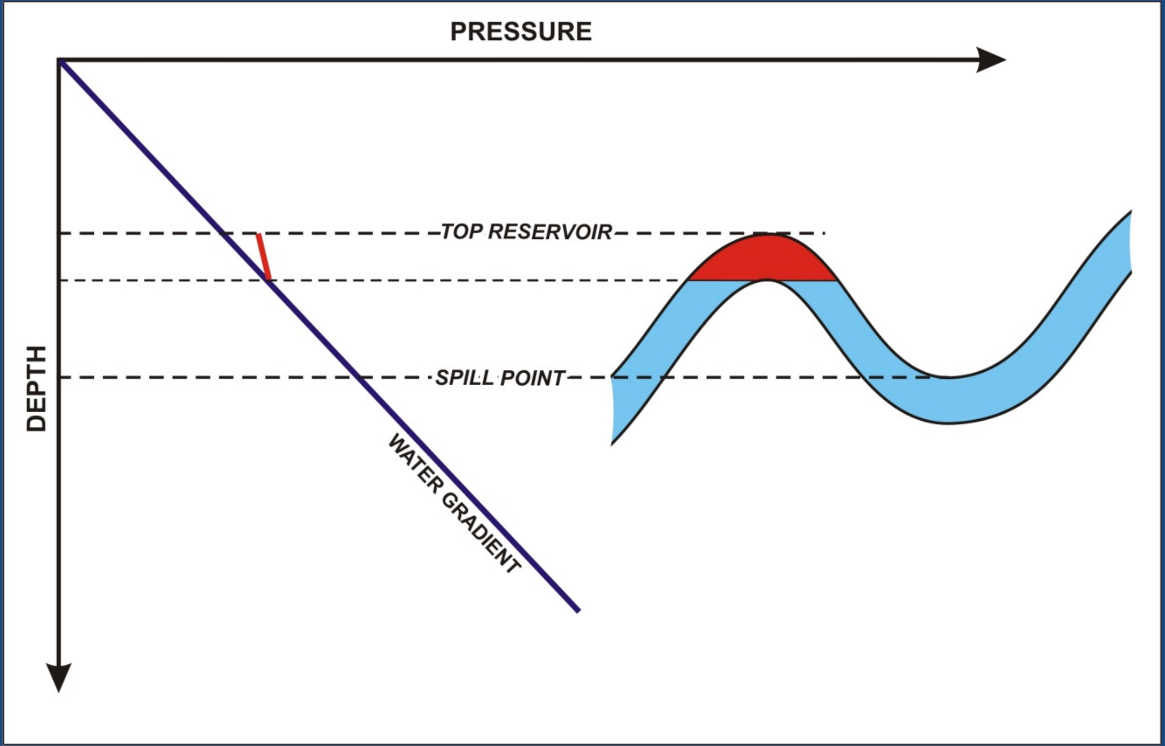

p
D
g.l.
1
2
3
SAME (WATER) GRADIENT
INCREASING "HEAD" (AND PRESURE)

INCREASE OF PRESSURE DUE TO A GAS CAP

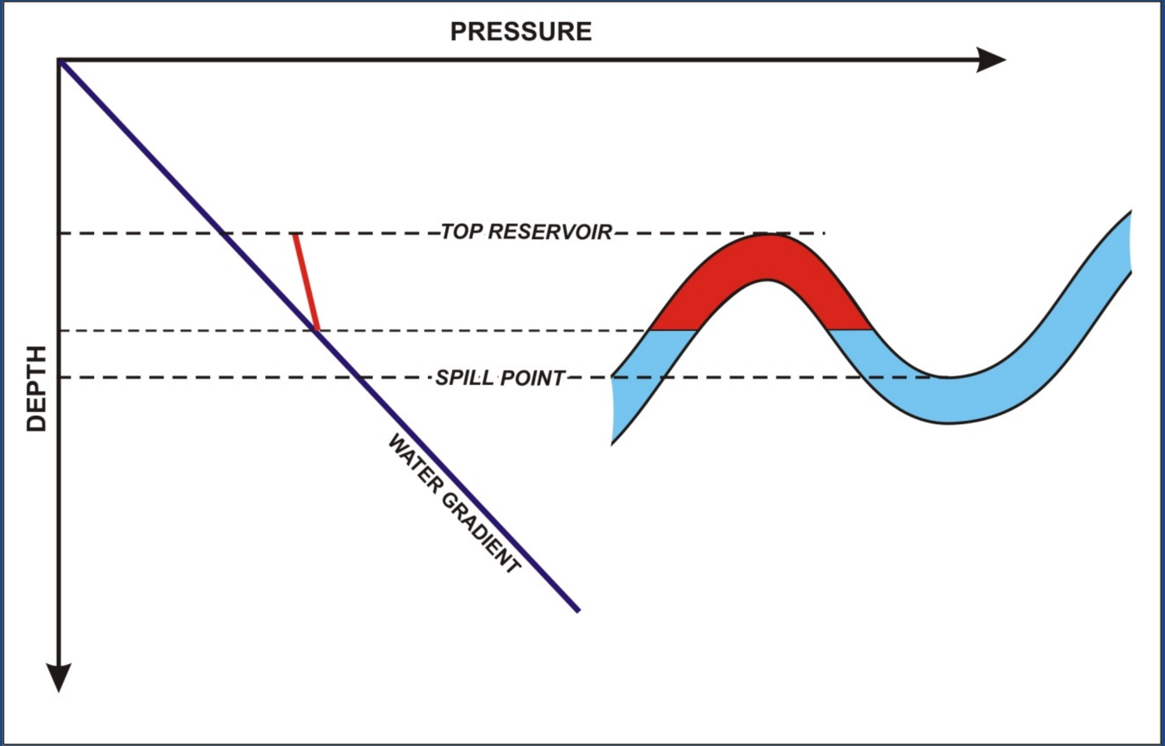




FILLING A TRAP…..

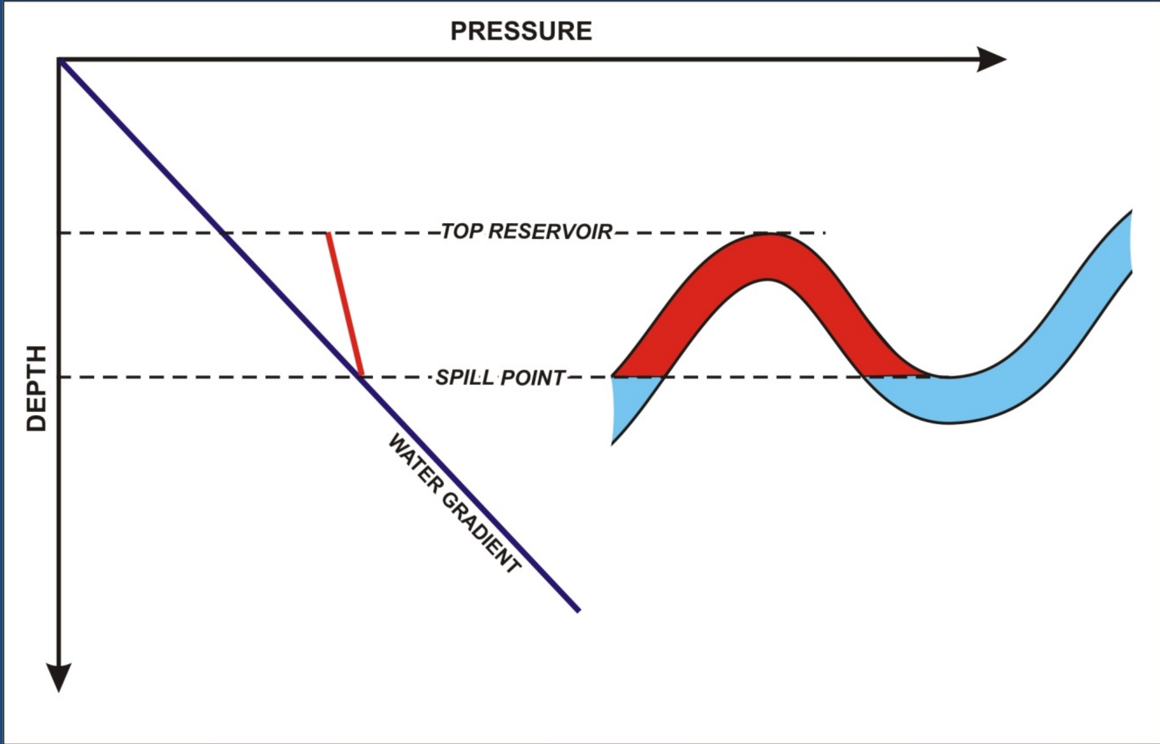


FILLING A TRAP…..



FILLING A TRAP…..

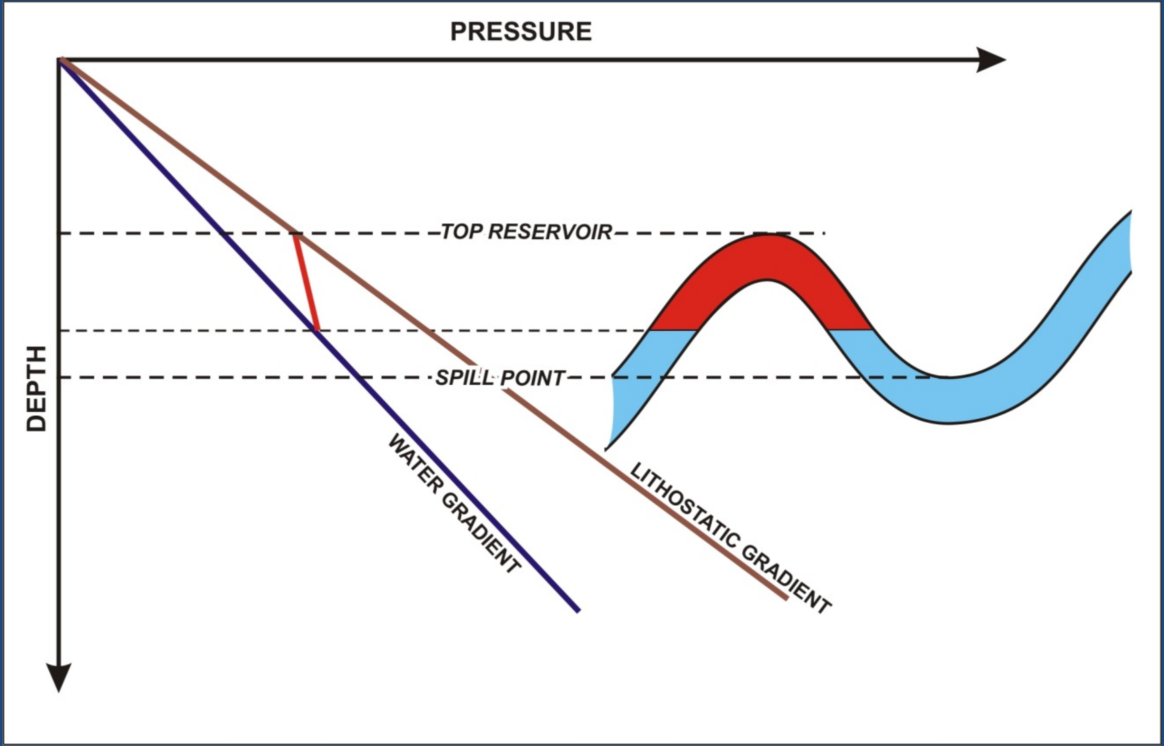
THE BUOYANCY COMPONENT OF PRESSURE INCREASES AS THE GAS CAP GROWS (AND THE G.W.C. MOVES DOWN)



FILLING A TRAP.....

UNTIL THE SPILL POINT
(IF THERE IS NO CHARGE LIMITATION)

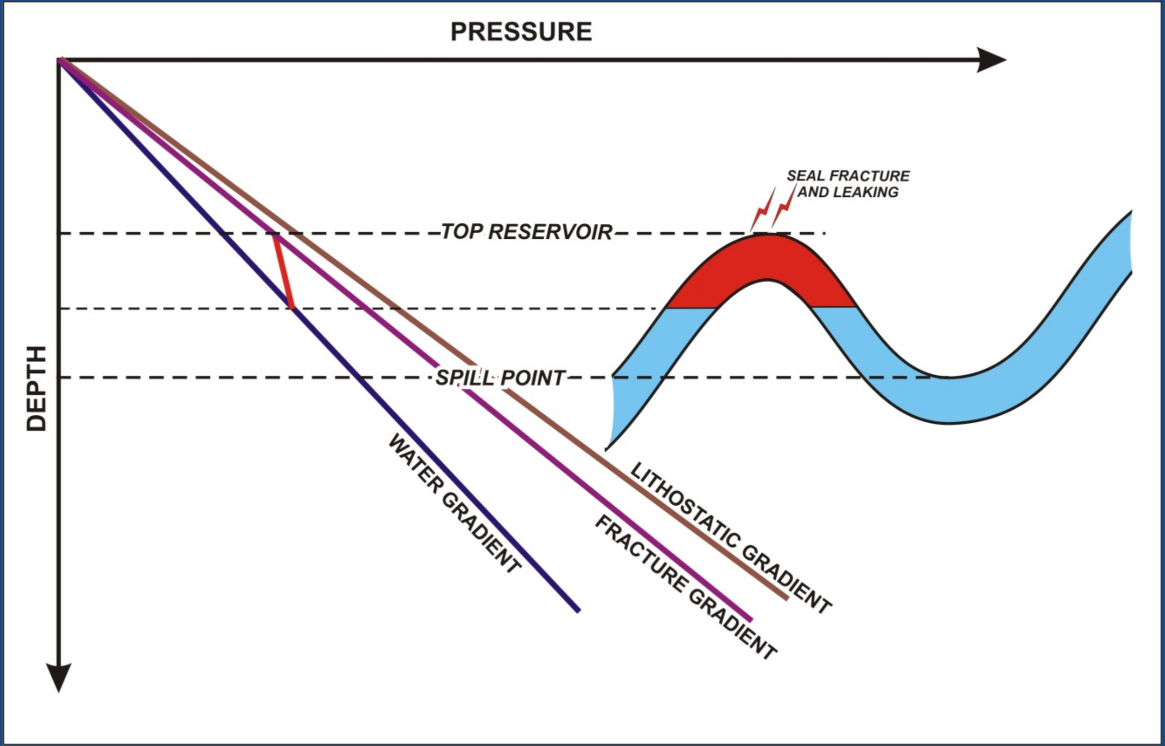
THE FILL IS CONTROLLED BY TRAP GEOMETRY



BUT…..

OTHER LIMITATIONS EXIST:

THE PORE PRESURE CANNOT BE GREATER THAN THE OVERBURDEN

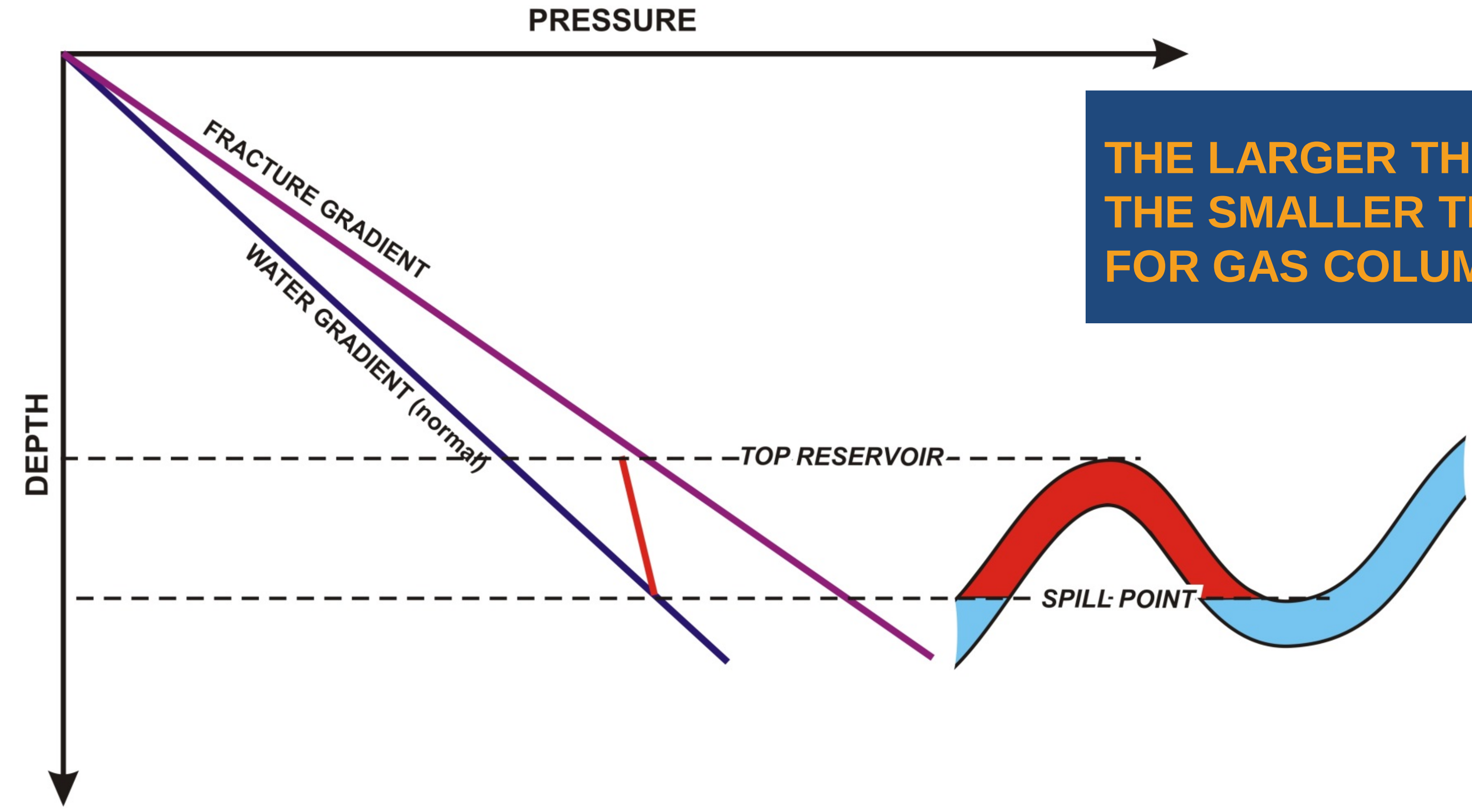


BUT…..

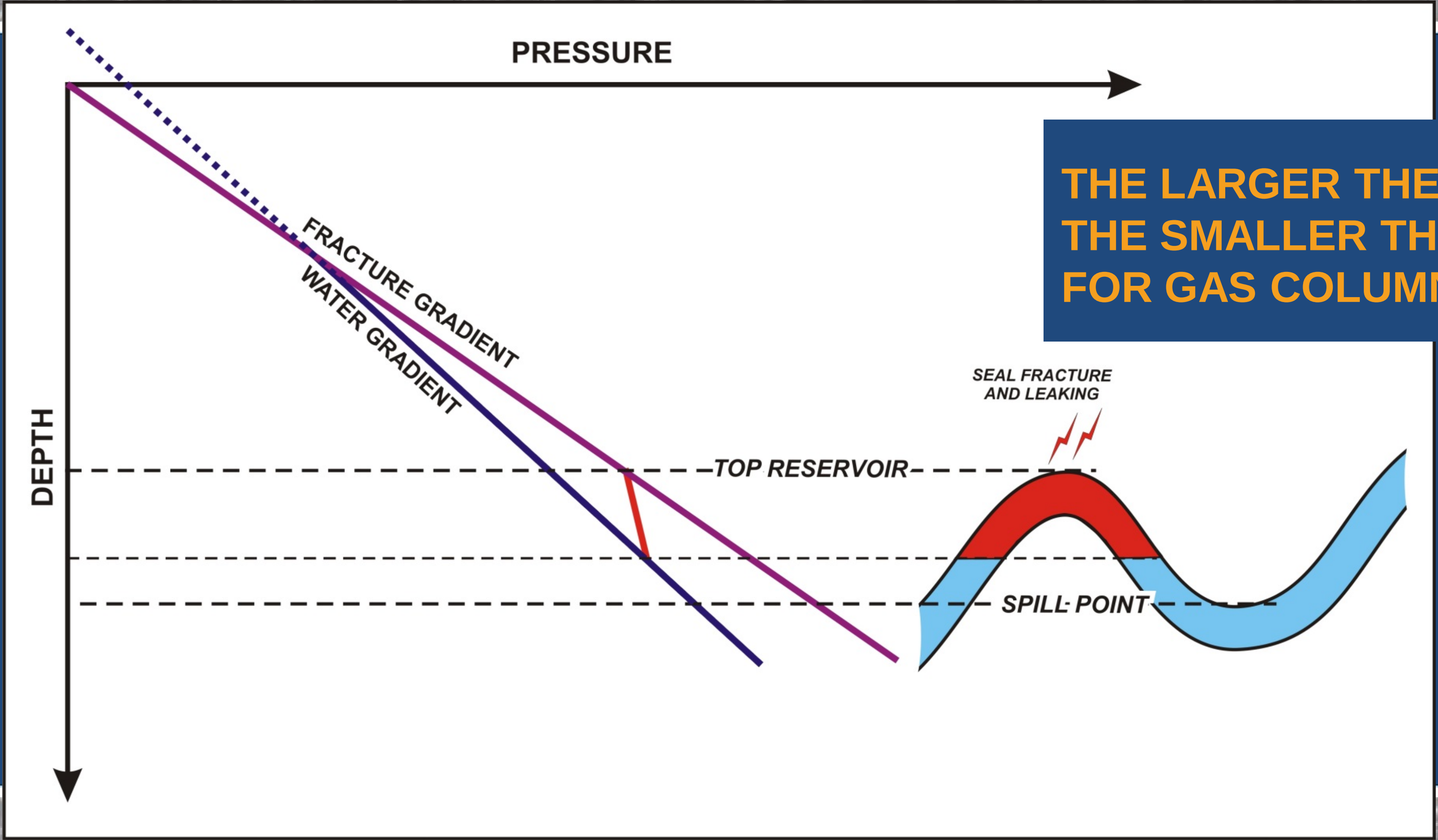
OTHER LIMITATIONS EXIST:

THE PORE PRESURE CANNOT BE GREATER THAN THE FRACTURE PRESSURE

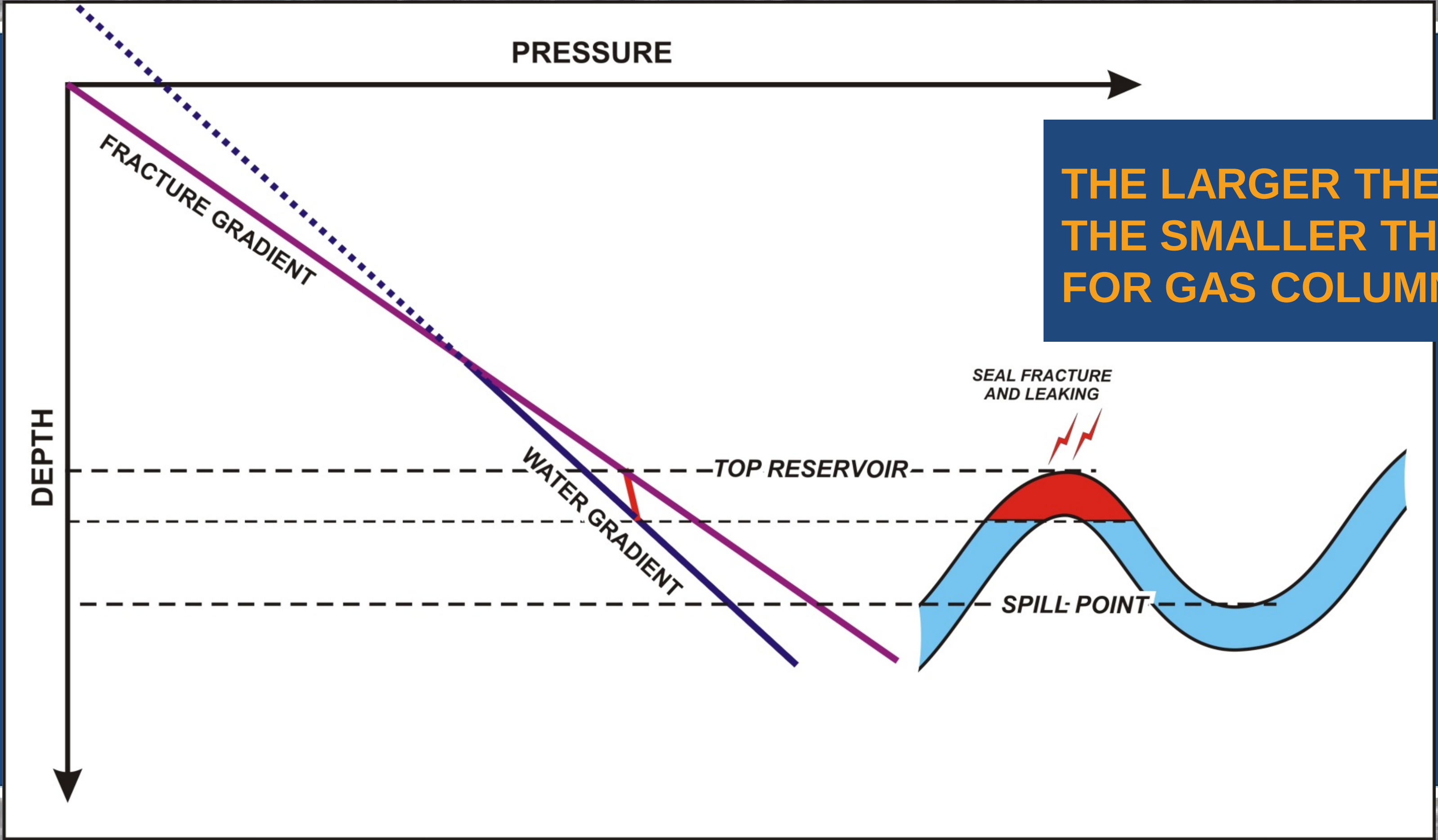
THE FILL IS CONTROLLED BY THE SEAL STRENGTH



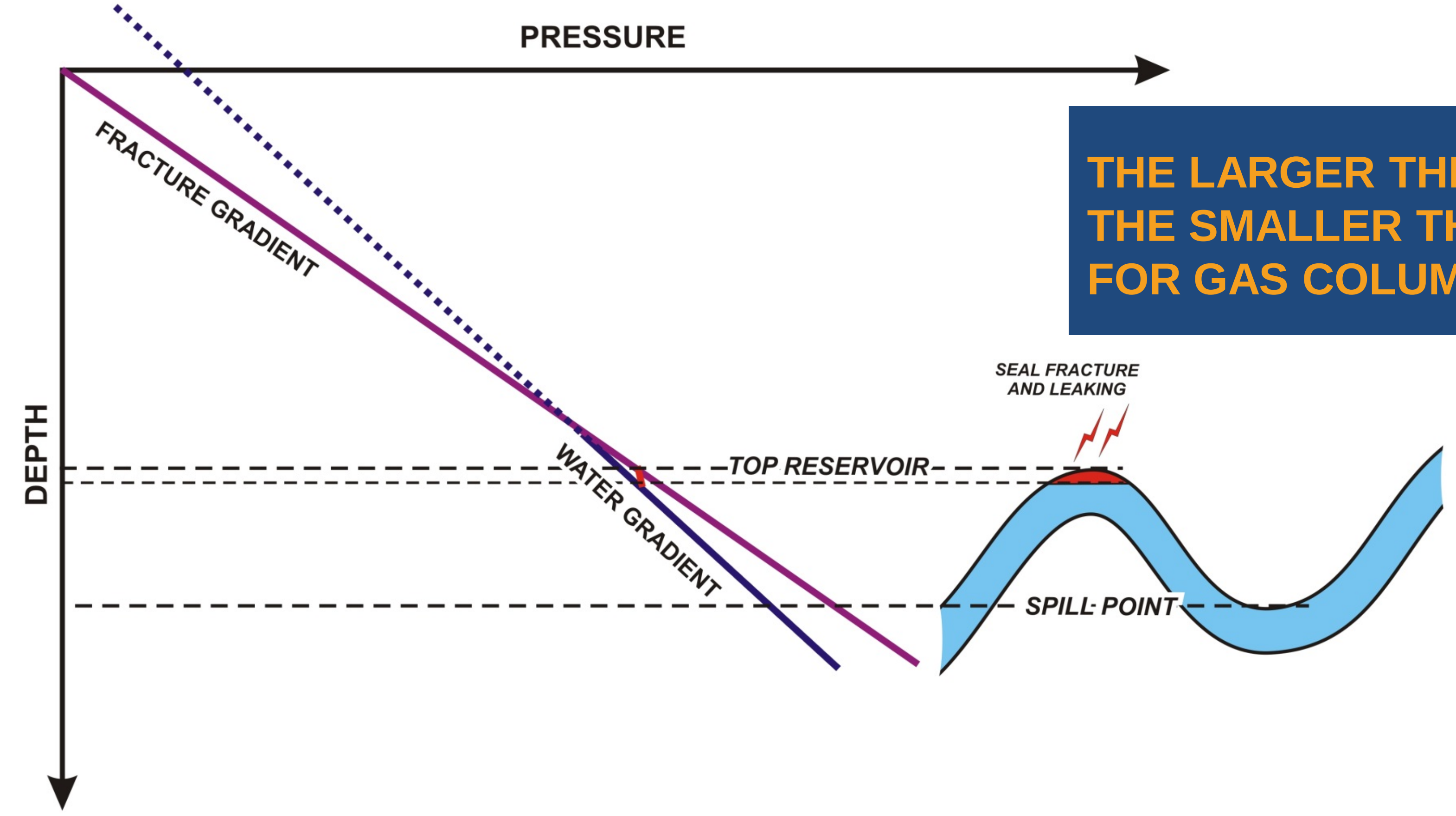
THE LARGER THE HEAD, THE SMALLER THE SPACE FOR GAS COLUMN



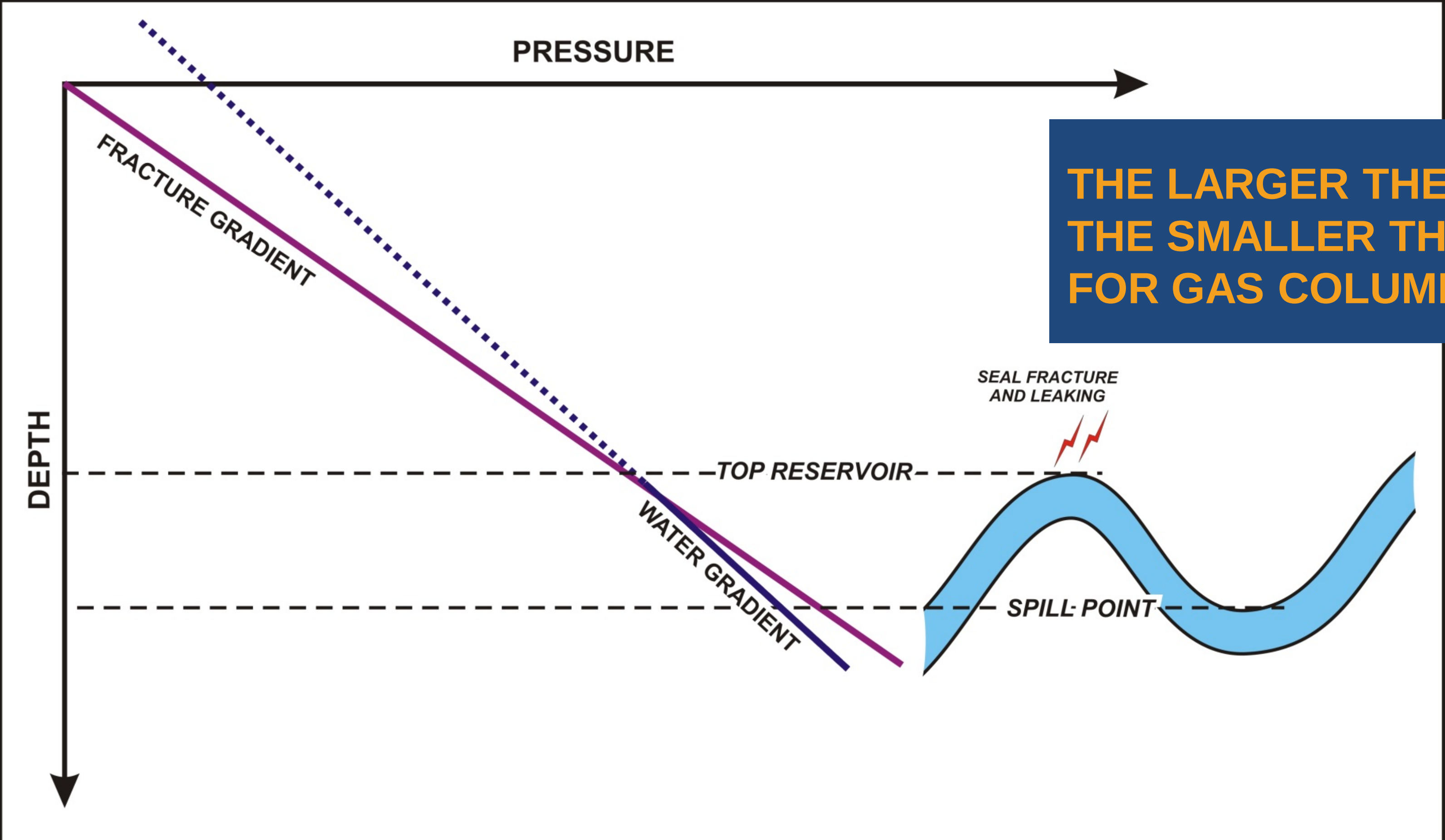
THE LARGER THE HEAD, THE SMALLER THE SPACE FOR GAS COLUMN



THE LARGER THE HEAD, THE SMALLER THE SPACE FOR GAS COLUMN

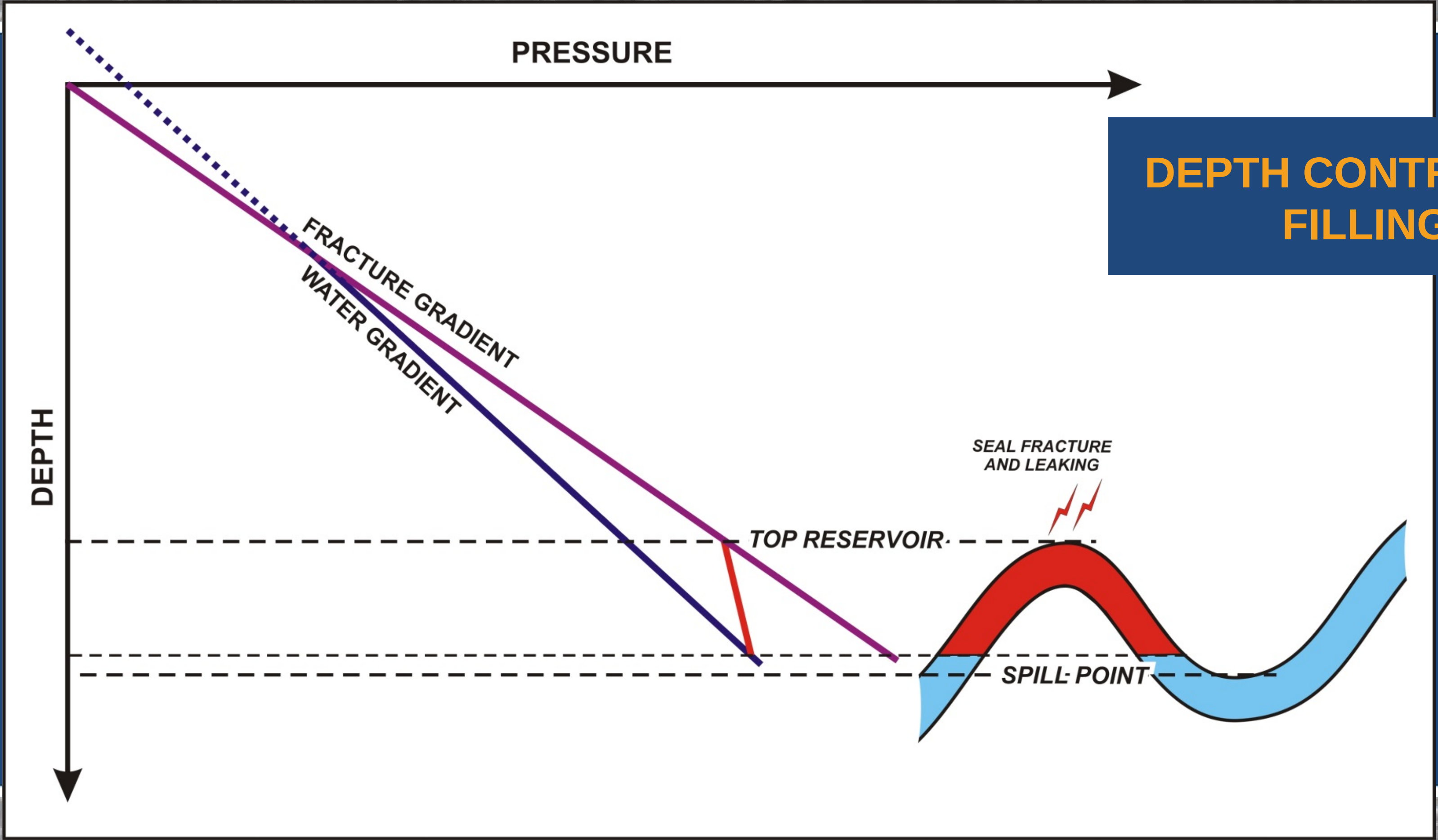


THE LARGER THE HEAD, THE SMALLER THE SPACE FOR GAS COLUMN

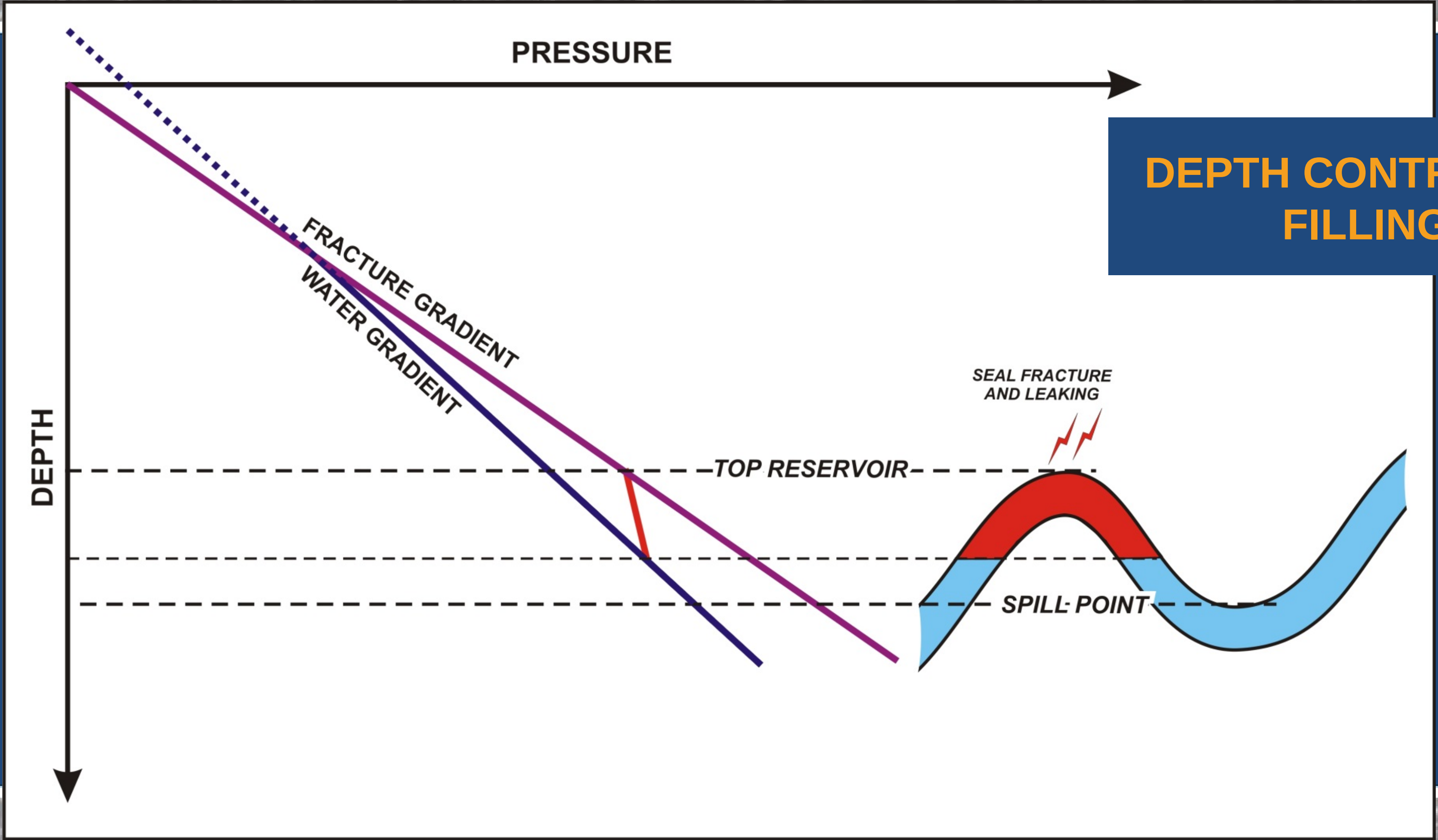


THE LARGER THE HEAD, THE SMALLER THE SPACE FOR GAS COLUMN

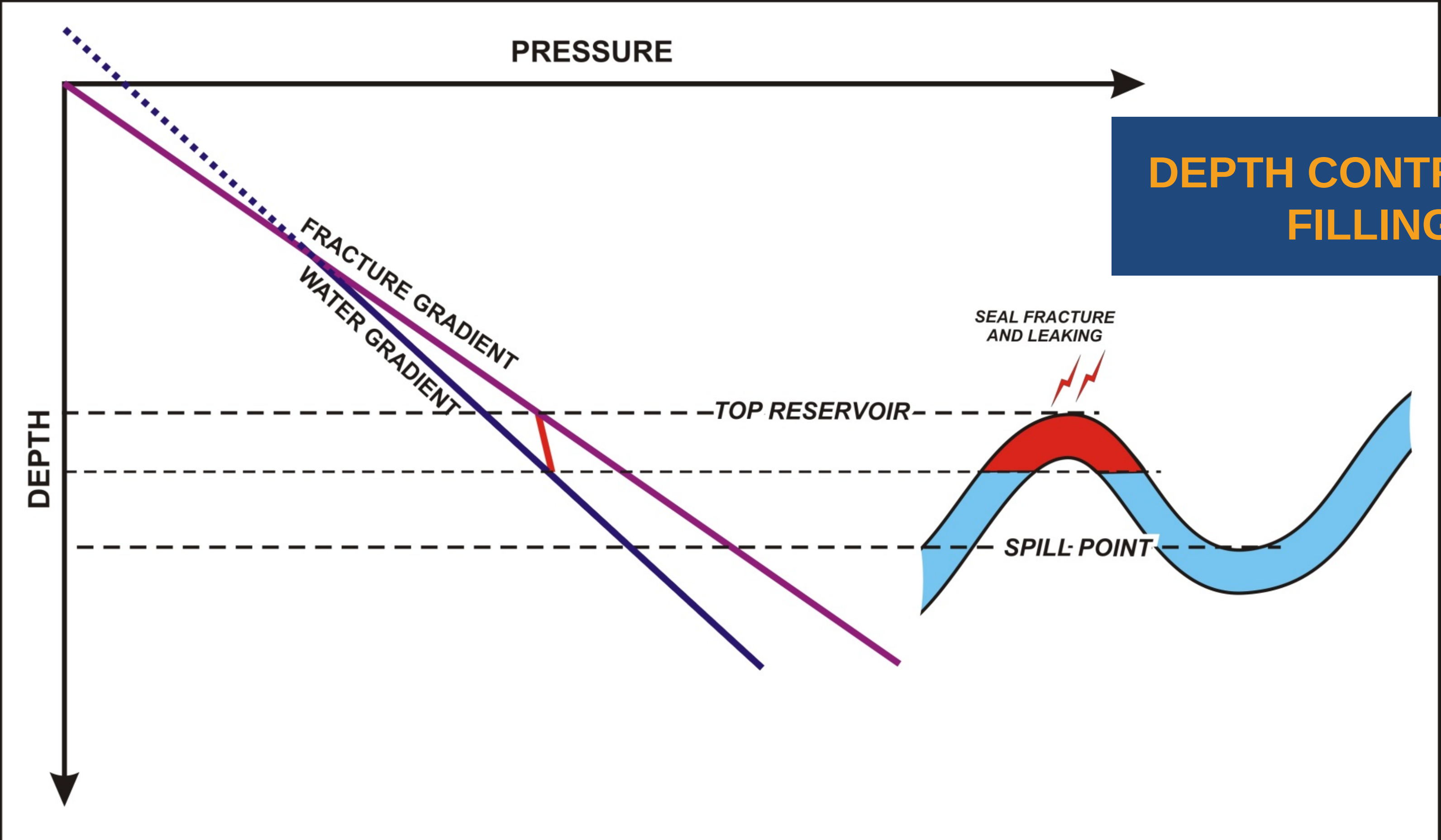
DEPTH CONTROL OF FILLING



DEPTH CONTROL OF FILLING



DEPTH CONTROL OF FILLING



PRESSURES IN THE LOS MONOS – HUAMAMPAMPA SYSTEM

LOS MONOS Fm

500 to 1000 m THICK (MAY INCREASE DUE TO TECTONISM)

LESS THAN 1% TOC average

ALWAYS OVERPRESSURED
(EVEN IN THE FORELAND REGION)

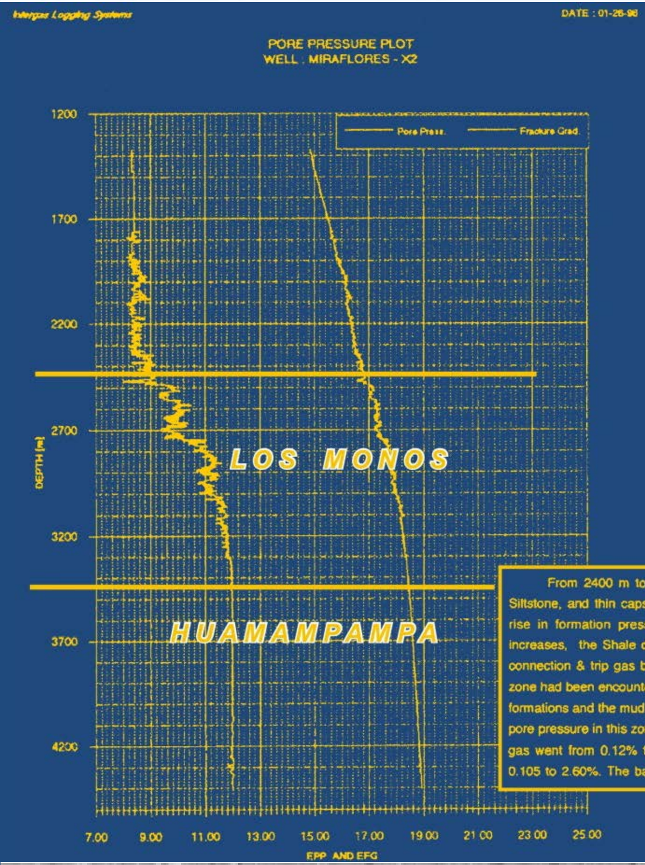
IT BEHAVES AS A “DYNAMIC” SEAL

THE MAIN OVERPRESSURE-CREATING MECHANISM SEEMS TO BE THE HYDROCARBON GENERATION AND RETENTION WITHIN THE PORE SPACE

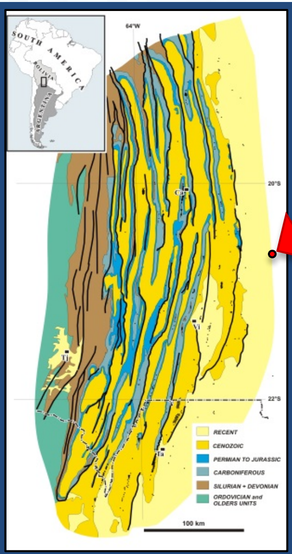
…EVEN IN THE FORELAND AREA

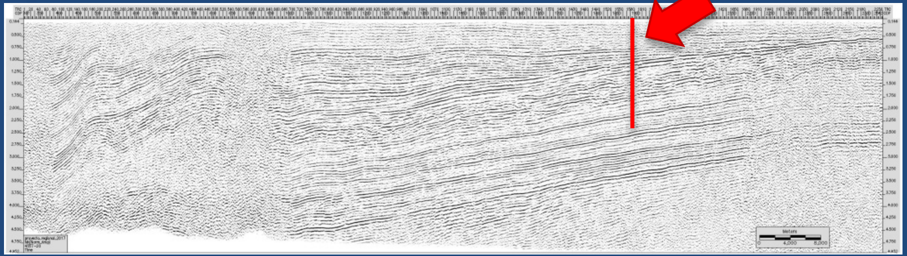
E.G. THE MIRAFLORES X-2 WELL

1.44 g/cm3 EQUIVALENT DENSITY



From 2400 m to 3305 m while drilling a sequence of interbedded Shale, Siltstone, and thin caps of Sandstone, several parameters indicated there was a rise in formation pressure. The dc exponent trend started to show pressure increases, the Shale density began to drop, the background gas began to rise, connection & trip gas began to rise, all of which indicated an abnormal pressure zone had been encountered. This resulted in a gas kick in the Iquiri and Los Monos formations and the mud weight was raised from 9.8 ppg to 12.2 ppg. The estimated pore pressure in this zone went from 9.15 ppg to 11.93 ppg EMW. The background gas went from 0.12% to an average of 14.38%. The connection gas went from 0.105 to 2.60%. The background gas and the trip gas began to drop as the mud





HUAMAMPAMPA Fm

UP TO 400-m THICK

HIGHLY DIAGENIZED QUARTZITIC SANDSTONES WITH POOR PETROPHYSICAL PROPERTIES

EXCELLENT RESERVOIR WHEN FRACTURED IN ANTICLINAL CRESTS

VARIABLE PRESSURE REGIMEN: FROM NORMAL TO HIGHLY OVERPRESSURED

HUAMAMPAMPA Fm

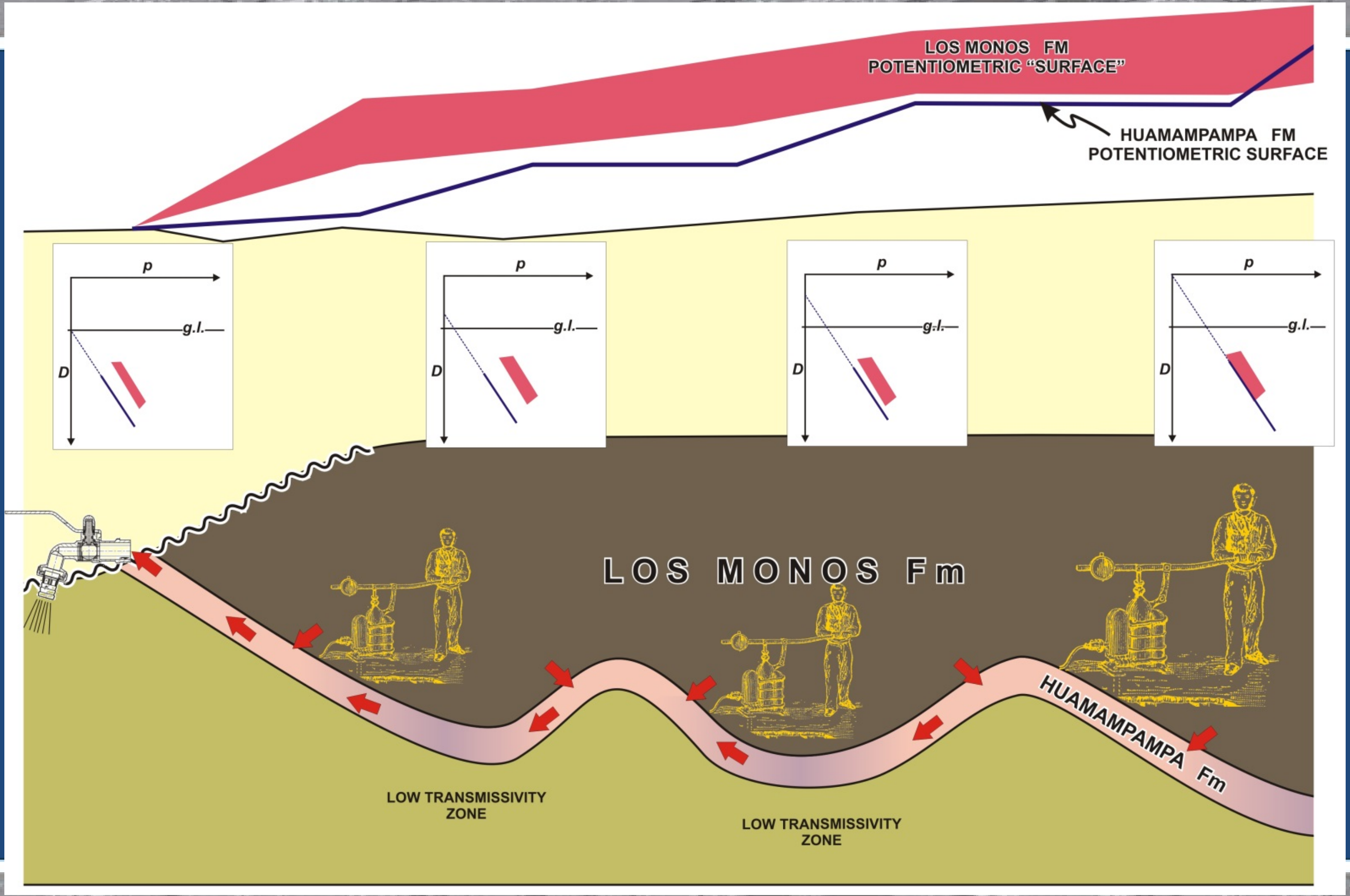
NORMALLY PRESSURED WHEN IT IS RELATIVELY WELL CONNECTED TO THE TOPOGRAPHIC SURFACE

THE PRESSURE INCREASES AS THE CONNECTION BECOMES FAR OR POOR, AND THE HUAMAMPAMPA Fm IS PRESSURIZES BY THE OVERLYING LOS MONOS Fm

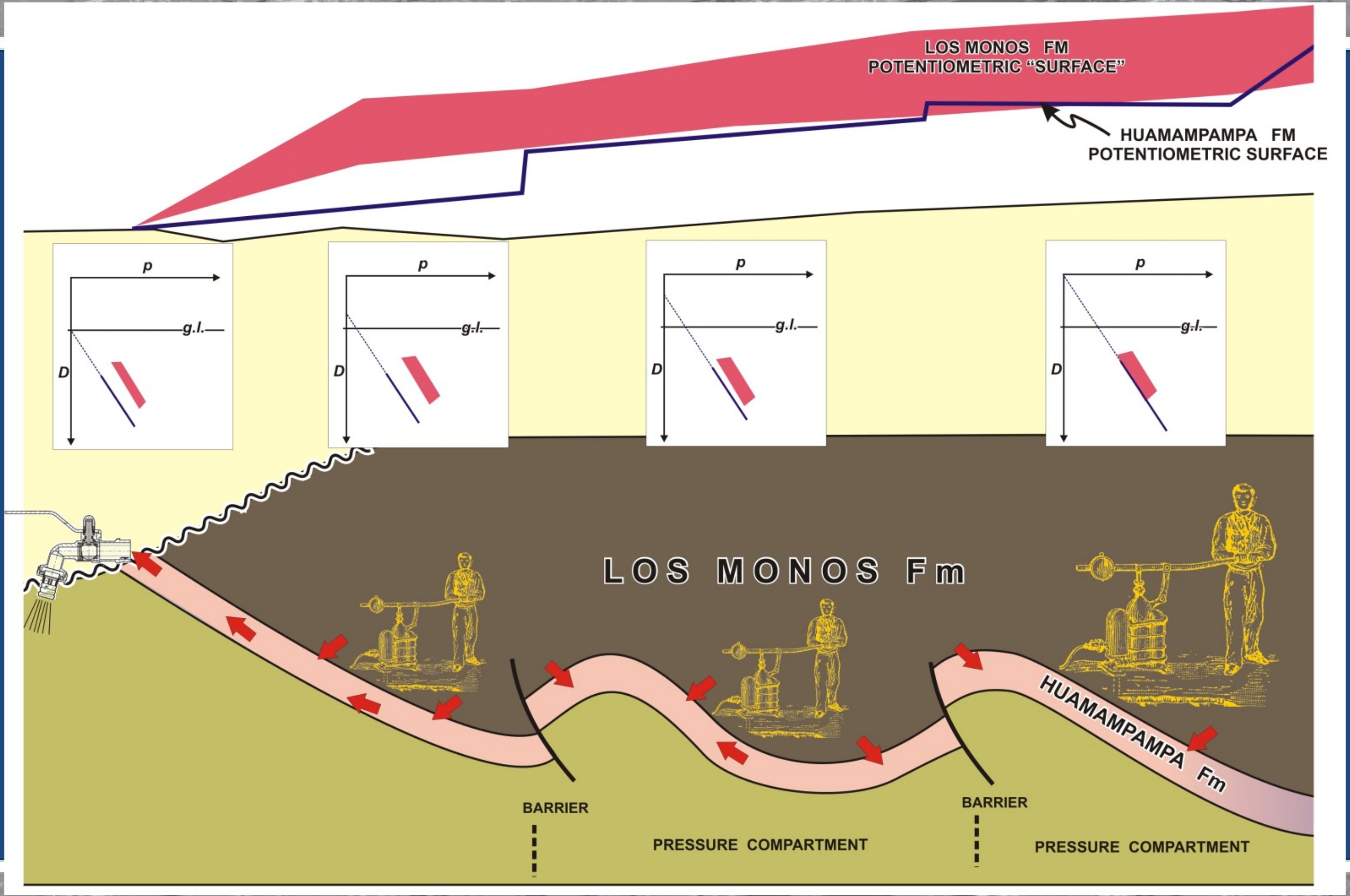
OVEPRESSURE:
“the inability of formation fluids to escape at a rate which allows equilibration with hydrostatic pressure”

SWARBRICK and OSBORNE, 1998

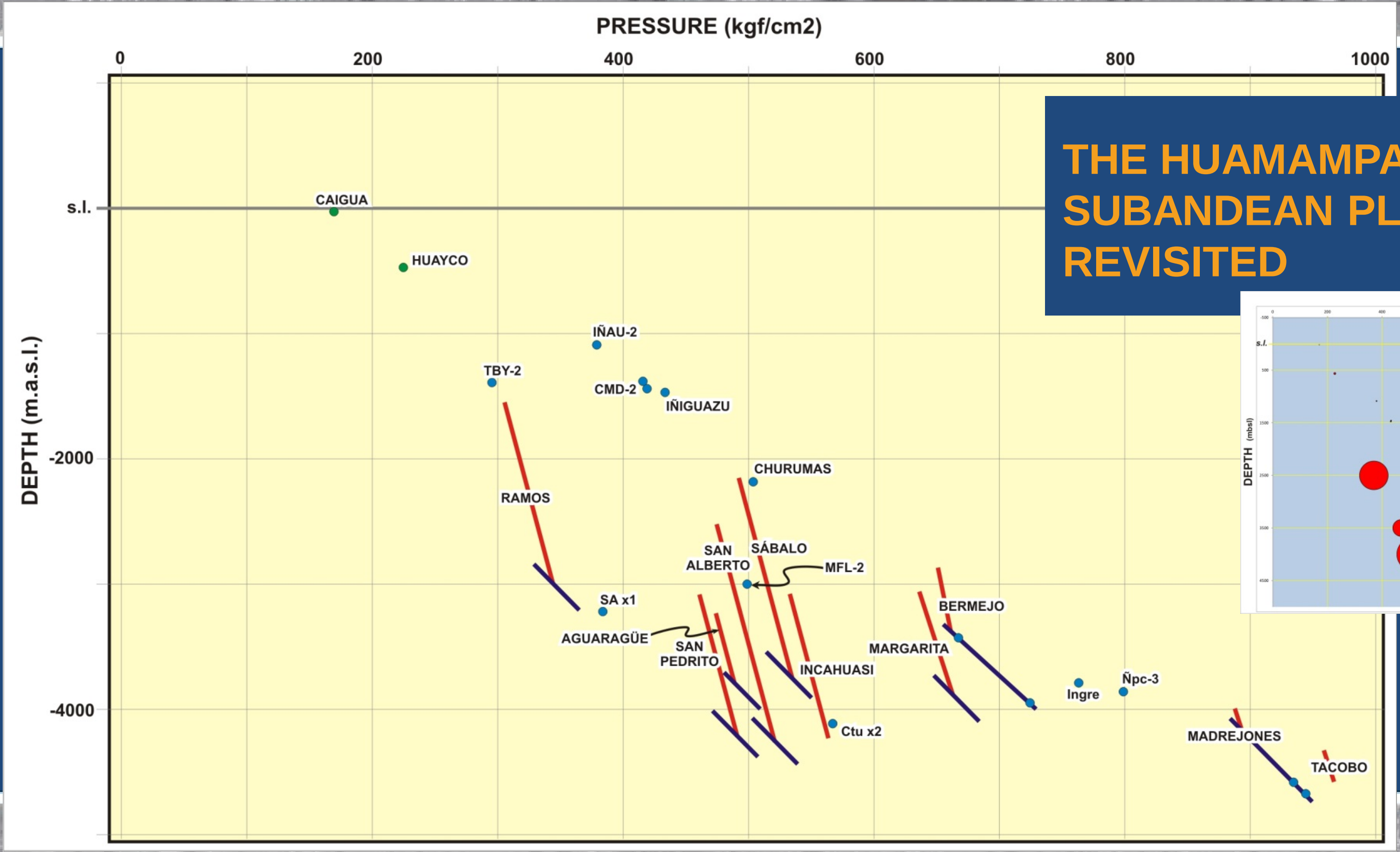
EVEN WHEN WE CAN EXPECT A BAD TRANSMISSIVITY FROM LOS MONOS TO HUAMAMPAMPA, THE FLUID (AND PRESSURE) MOVEMENT ACROSS THE BOUNDING SURFACE (1000’s km2) IS MORE EFFICIENT THAN THE LATERAL DISSIPATION (BLEED OFF) IN THE HUAMAMPAMPA Fm.

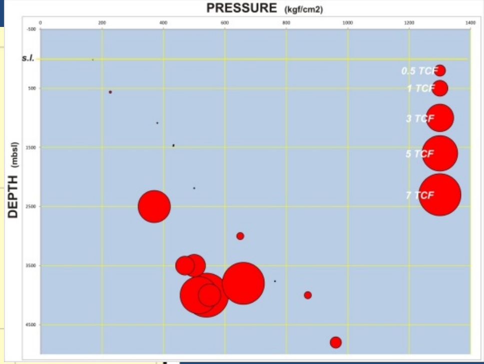


THE FLUIDS MOVE FROM HIGH POTENTIOMETRIC ZONES TO LOW ONES

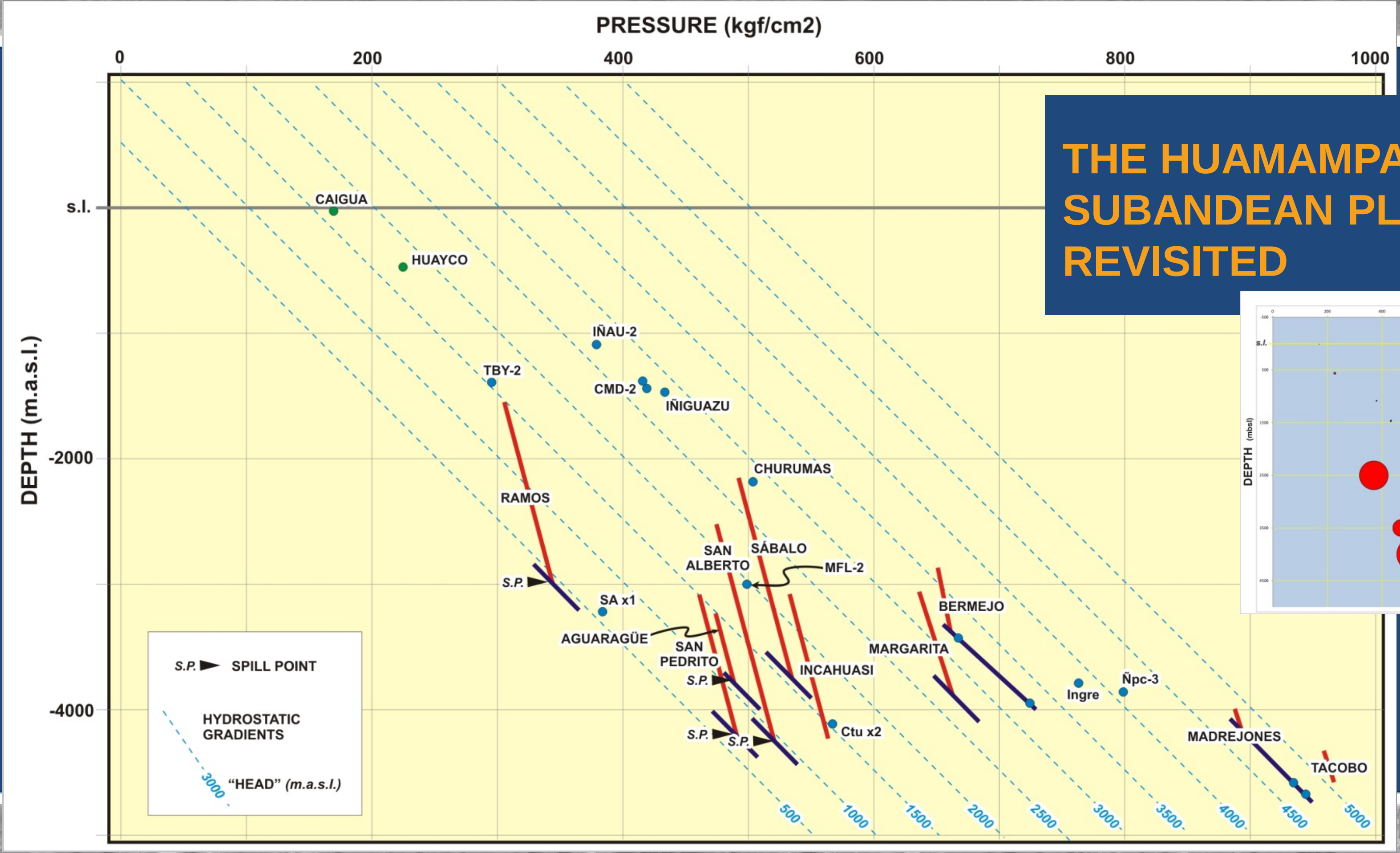

LOS MONOS FM
POTENTIOMETRIC "SURFACE"
HUAMAMPAMPA FM
POTENTIOMETRIC SURFACE
p
g.l.
D
LOS MONOS Fm
HUAMAMPAMPA Fm
BARRIER
BARRIER
PRESSURE COMPARTMENT
PRESSURE COMPARTMENT

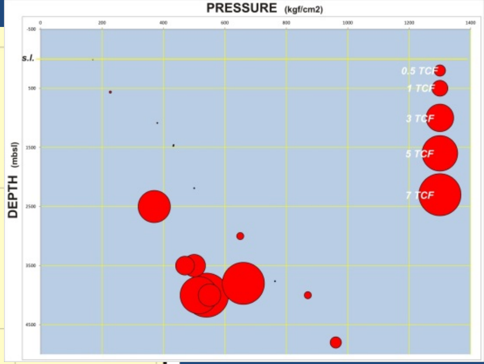
THE HUAMAMPAMPA Fm SUBANDEAN PLAY REVISITED



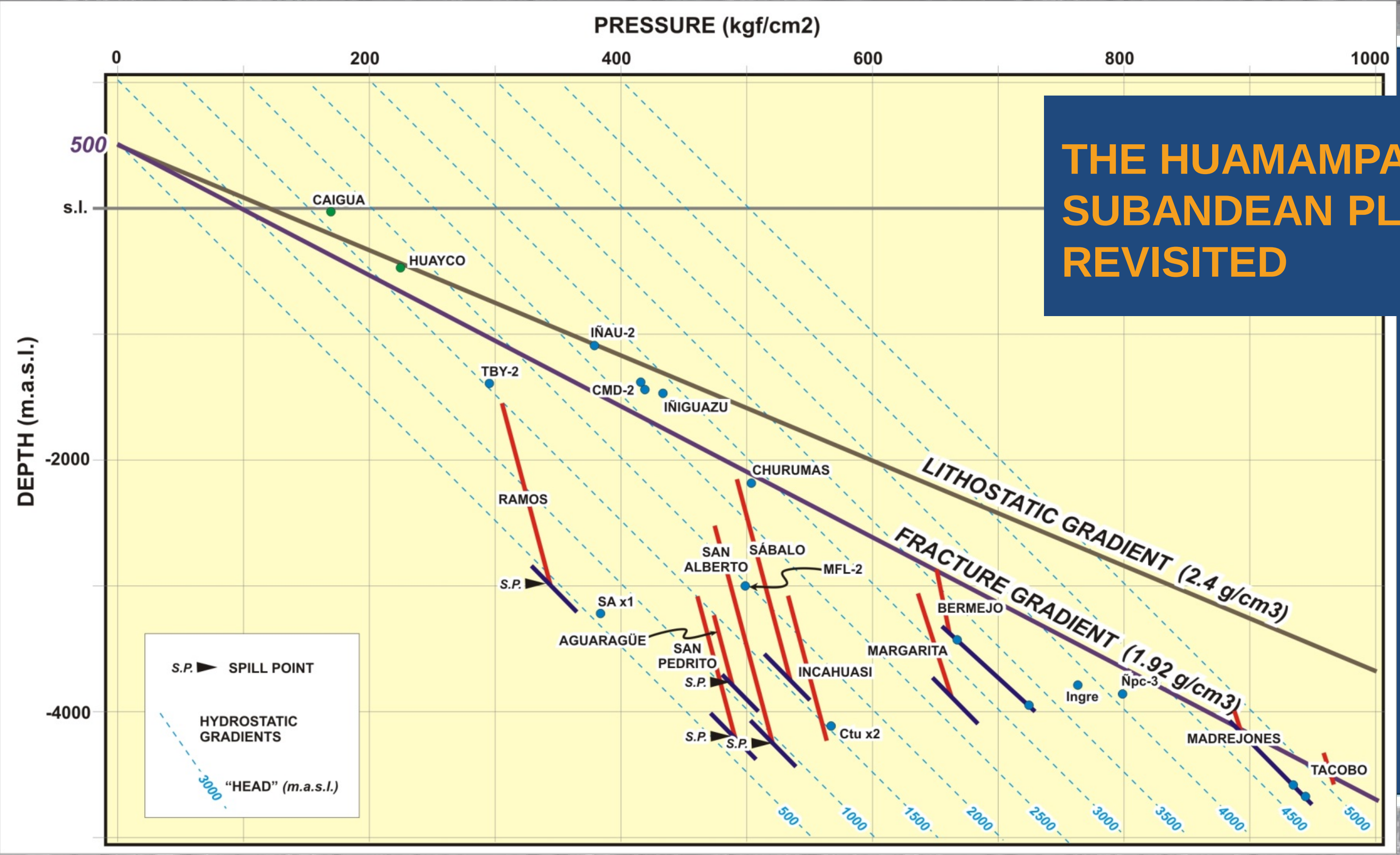


THE HUAMAMPAMPA Fm SUBANDEAN PLAY REVISITED

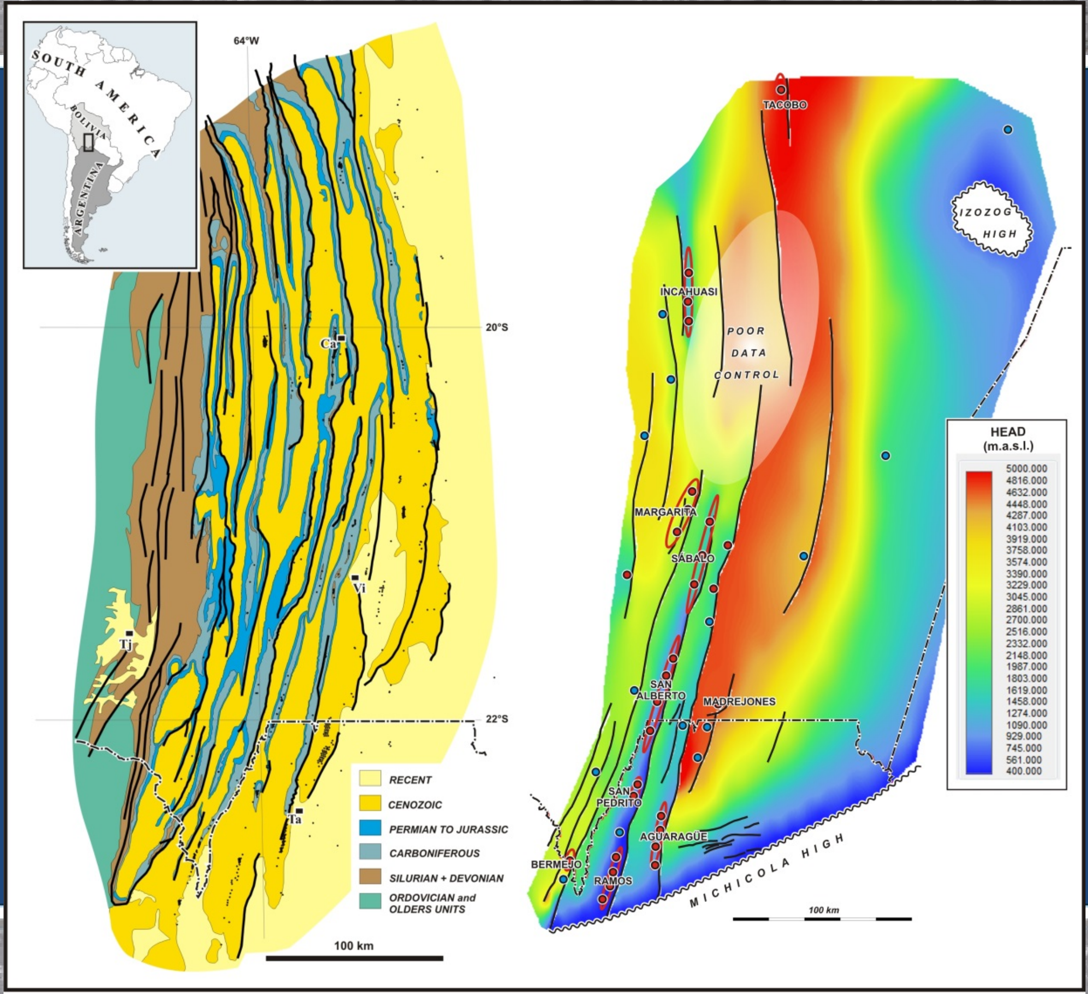




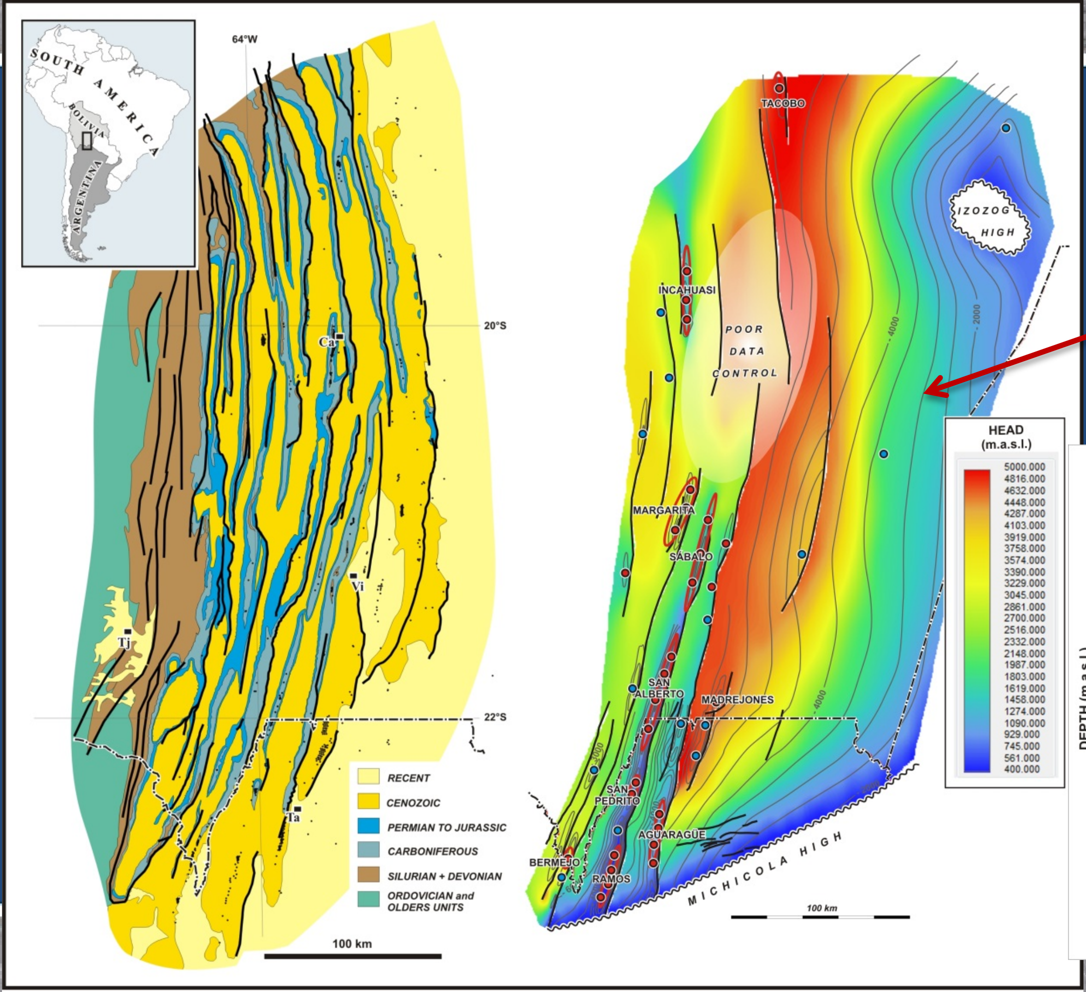
THE HUAMAMPAMPA Fm SUBANDEAN PLAY REVISITED



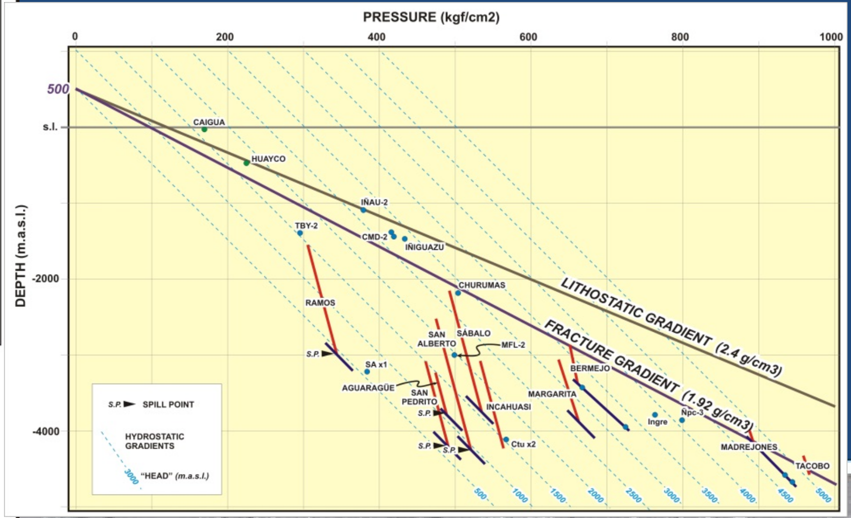
HUAMAMPAMPA Fm POTENTIOMETRIC MAP



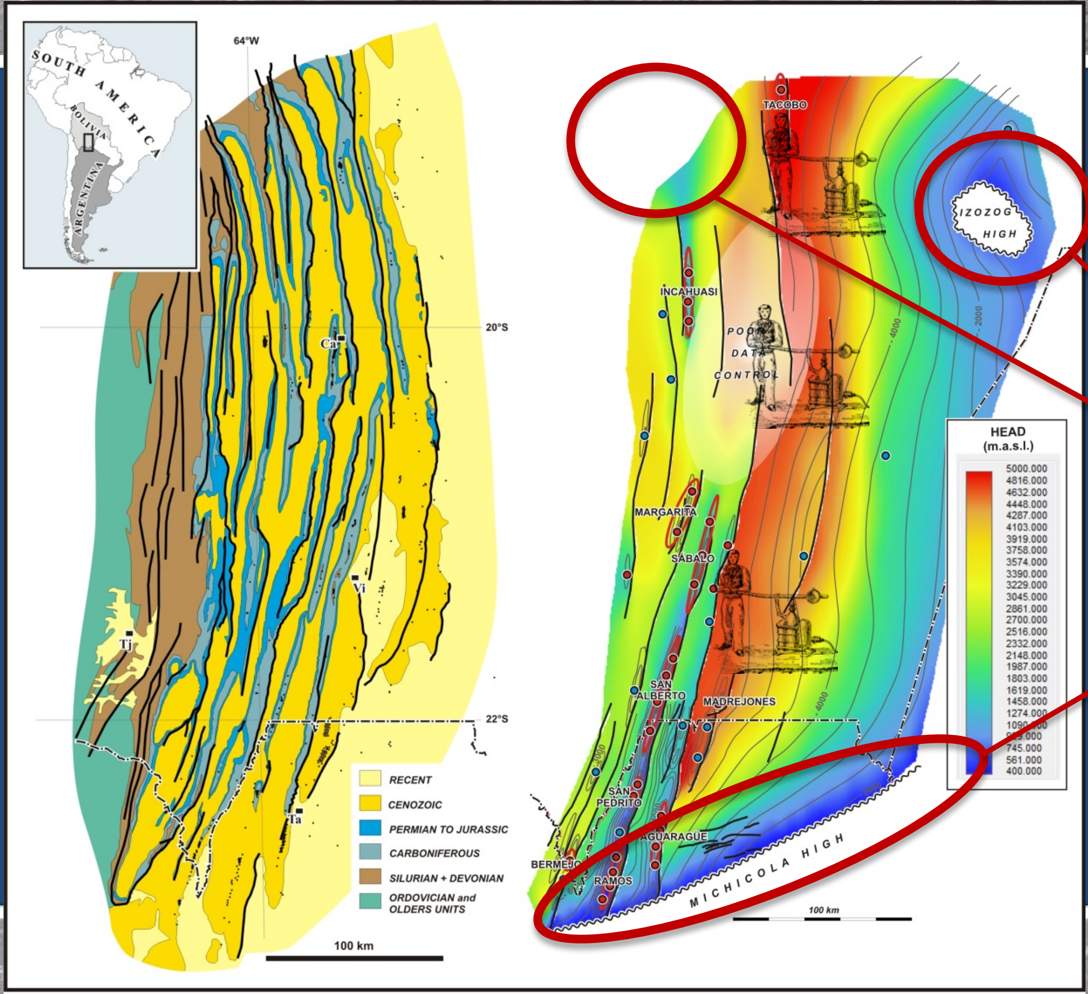
HUAMAMPAMPA Fm POTENTIOMETRIC MAP



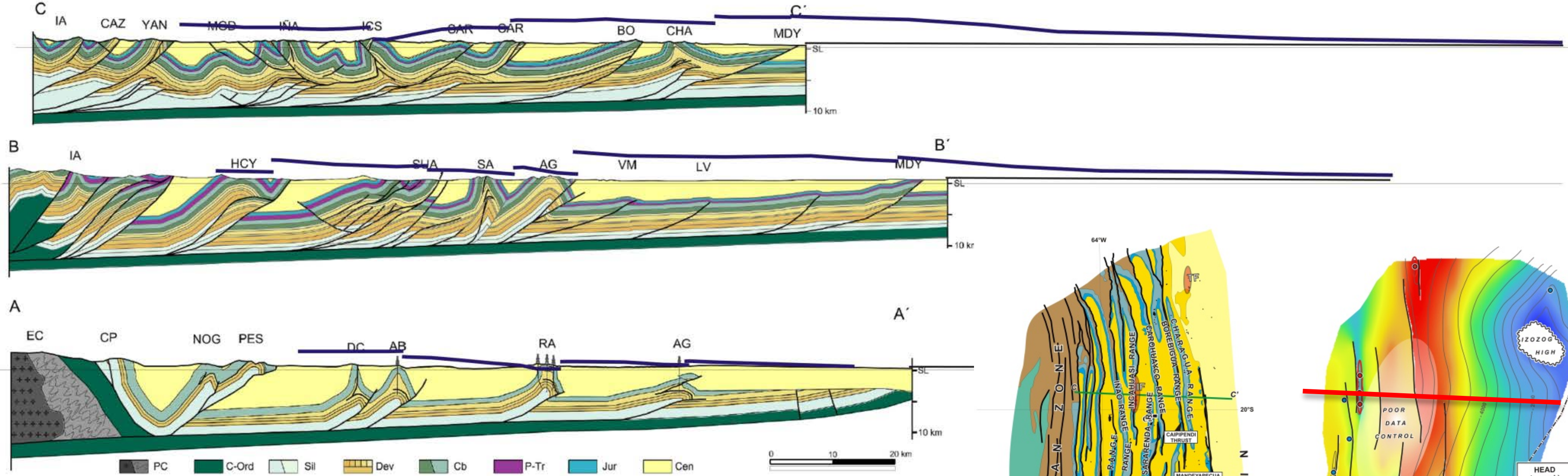
HUAMAMPAMPA Fm STRUCTURAL CONTOURS



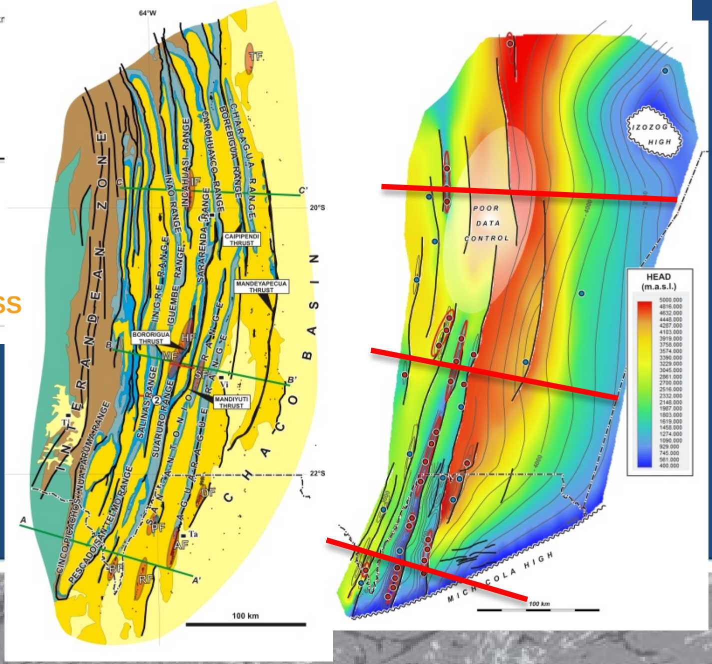
HUAMAMPAMPA Fm POTENTIOMETRIC MAP



MAIN DISCHARGE ZONES

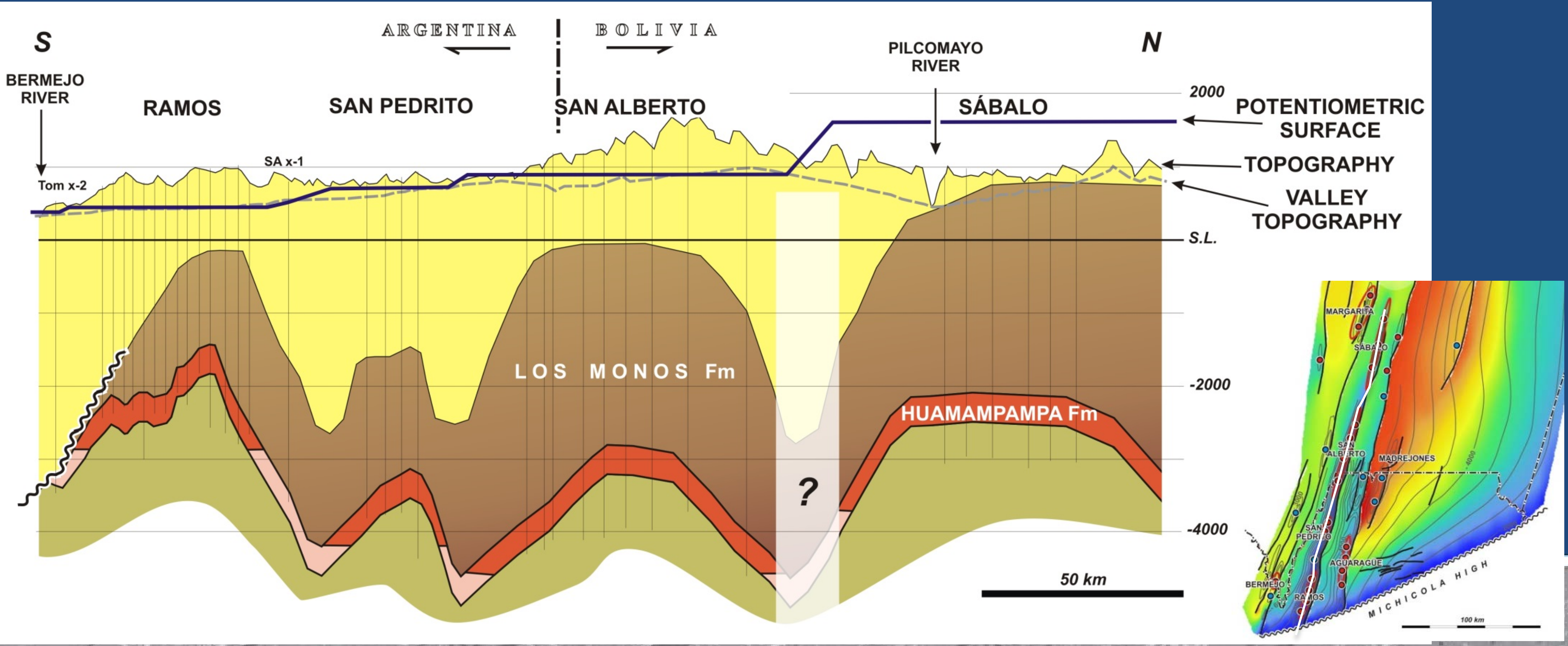


MODIFIED FROM FUENTES *ET AL.*, IN PRESS



REGIONAL POTENTIOMETRIC PROFILES

THE SAN ANTONIO RANGE CASE



CONCLUSIONS

THE PRESSURE REGIME PLAYS A MAJOR CONTROL IN THE OCURRENCE AND SIZE OF GAS FIELDS IN THE HUAMAMPAMA Fm PLAY: THE INCREASE IN THE HEAD COMPONENT OF THE AQUIFER PRESSURE CAN LEAD THE RESERVOIR TO REACH THE FRACTURE PRESSURE; UNDER THAT CONDITION, SEALS CANNOT HOLD LARGE GAS COLUMNS. THE FAILURE OF SEVERAL WELLS IN ANTICLINAL TRAPS IN THE SUBANDEAN (OR THE UNDERFILLING) CAN BE EXPLAINED IN THIS WAY.

IT IS TOO COMPLEX TO PREDICT THE PRESSURE REGIME BEFORE DRILLING (EXCEPT FOR REGIONAL TRENDS), BUT IT IS NOT ADVISABLE TO DRILL UPDIP IN STRUCTURAL TRENDS WITH KNOWN LARGE OVERPRESSURES

CONCLUSIONS

PERHAPS IS TIME TO PAY ATTENTTION TO SITUATIONS WHERE THE OVERPRESSURE “PLAYS IN OUR SIDE”
I.E. LOS MONOS FORMATION

THANKS

AKNOWLEDGMENTS TO F.F., L.C., R.V. AND C.M.