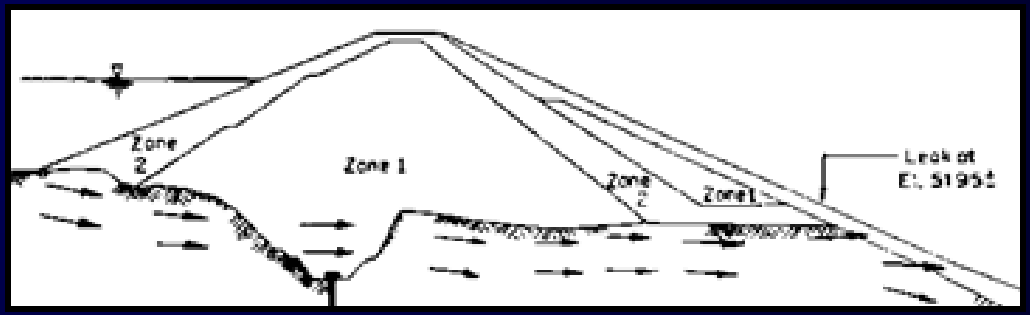
CHARACTERIZATION AND REPAIR OF INTERNAL EROSION IN SANDSTONE FOUNDATION

By J-J FRY & G. JORGE

INTERNAL EROSION IN DAM FOUNDATION

From the 2 hereunder failure paths of internal erosion:

1. 213 piping through the embankment
2. 44 piping through the foundation or of the embankment into the foundation



Internal erosion through foundation is less easy to characterize than through embankment

LESSONS LEARN FROM DAM ACCIDENTS

- BOUZEY (1895)
- TIGRA (1917)
- GLENO (1923)
- FLAGSTAFF (1963)
- FONTENELLE (1965)
- SISGA (1979)
- ITIYURO (1981)

Weathered Sandstone Foundations are most susceptible to internal erosion

CHARACTERIZATION TESTS FOR DAM FOUNDATION

Emphasis is put on two investigation tests to characterize the susceptibility of the sandstone foundation to be eroded

1. The drilling recording
2. The Water tests

1- Drilling Recording

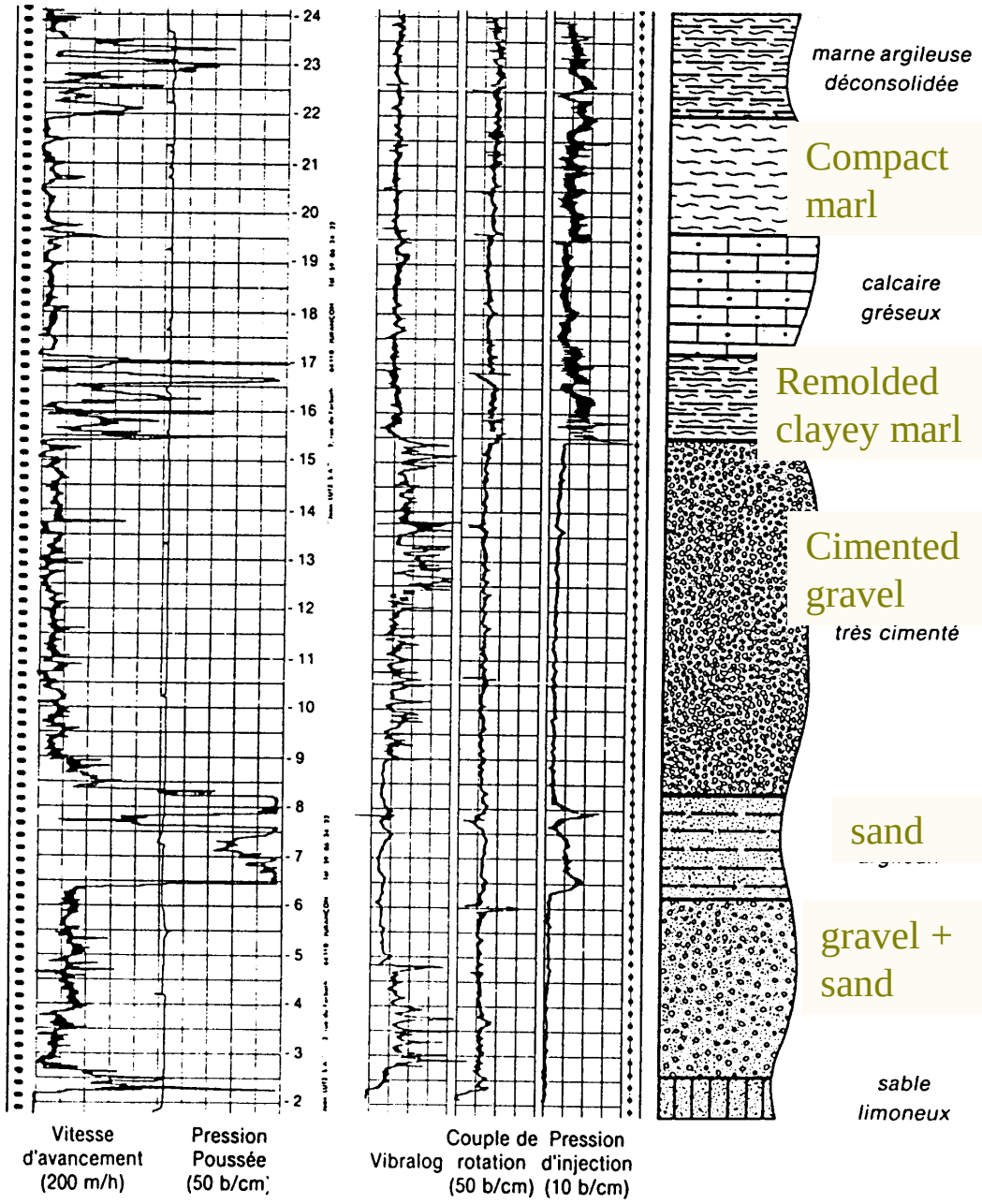
« DUR » =Hardness

Hardness = P*C/V

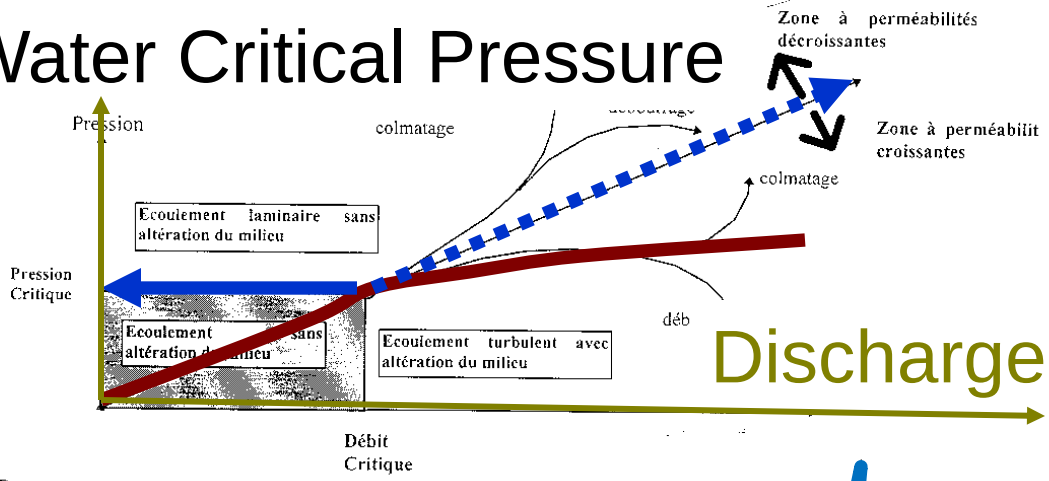
- P : vertical pressure
- C : torque
- V : tool rate

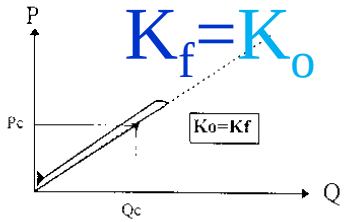
Hardness of the rock is characterized by

Drill machine : F320 with tricone VH1



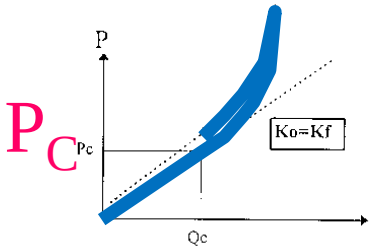
Water Critical Pressure





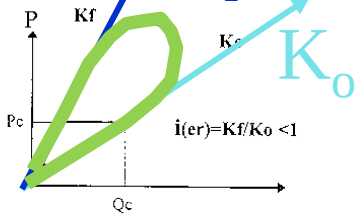
$K_f = K_o$

a1-Ecoulement laminaire en milieu homogène



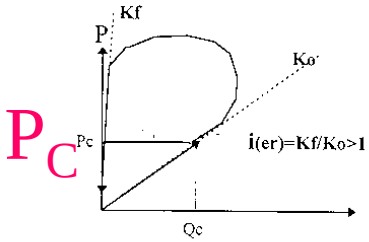
P_C

a4-Ecoulement turbulent en milieu homogène



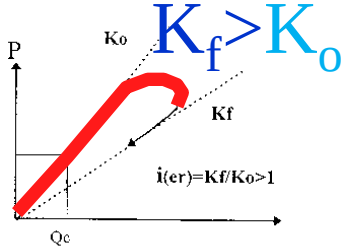
K_f K_o

a2-Ecoulement laminaire, colmatage à haute pression



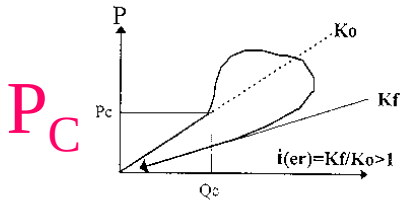
P_C

a5-Ecoulement turbulent, comatage progressif



$K_f > K_o$

a3-Ecoulement laminaire, débourrage à haute pression



P_C

a6-Ecoulement turbulent, débourrage progressif

2 – Water Lugeon tests

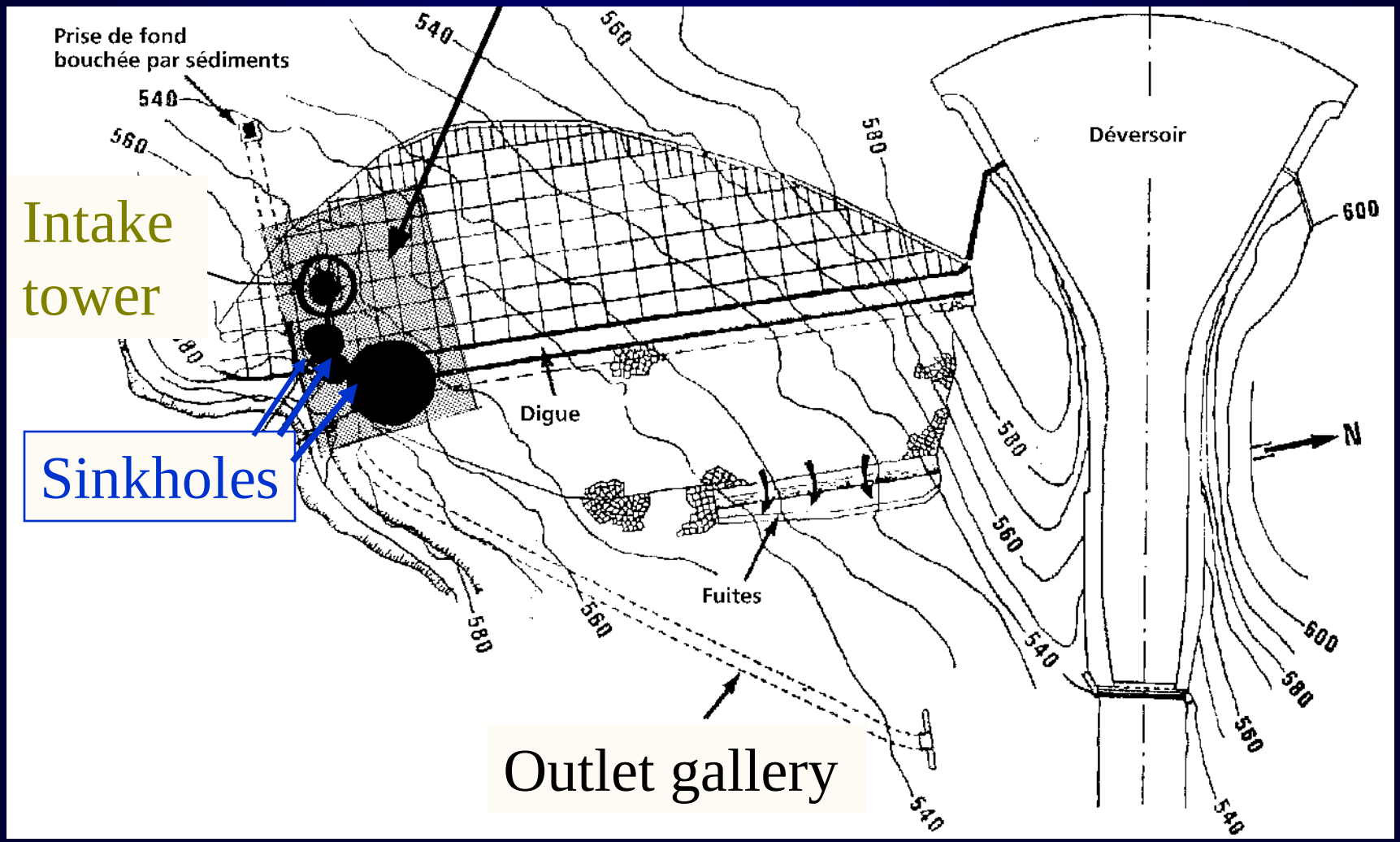
2 new parameters:

Critical pressure P_c limit of linearity between pressure and discharge rate

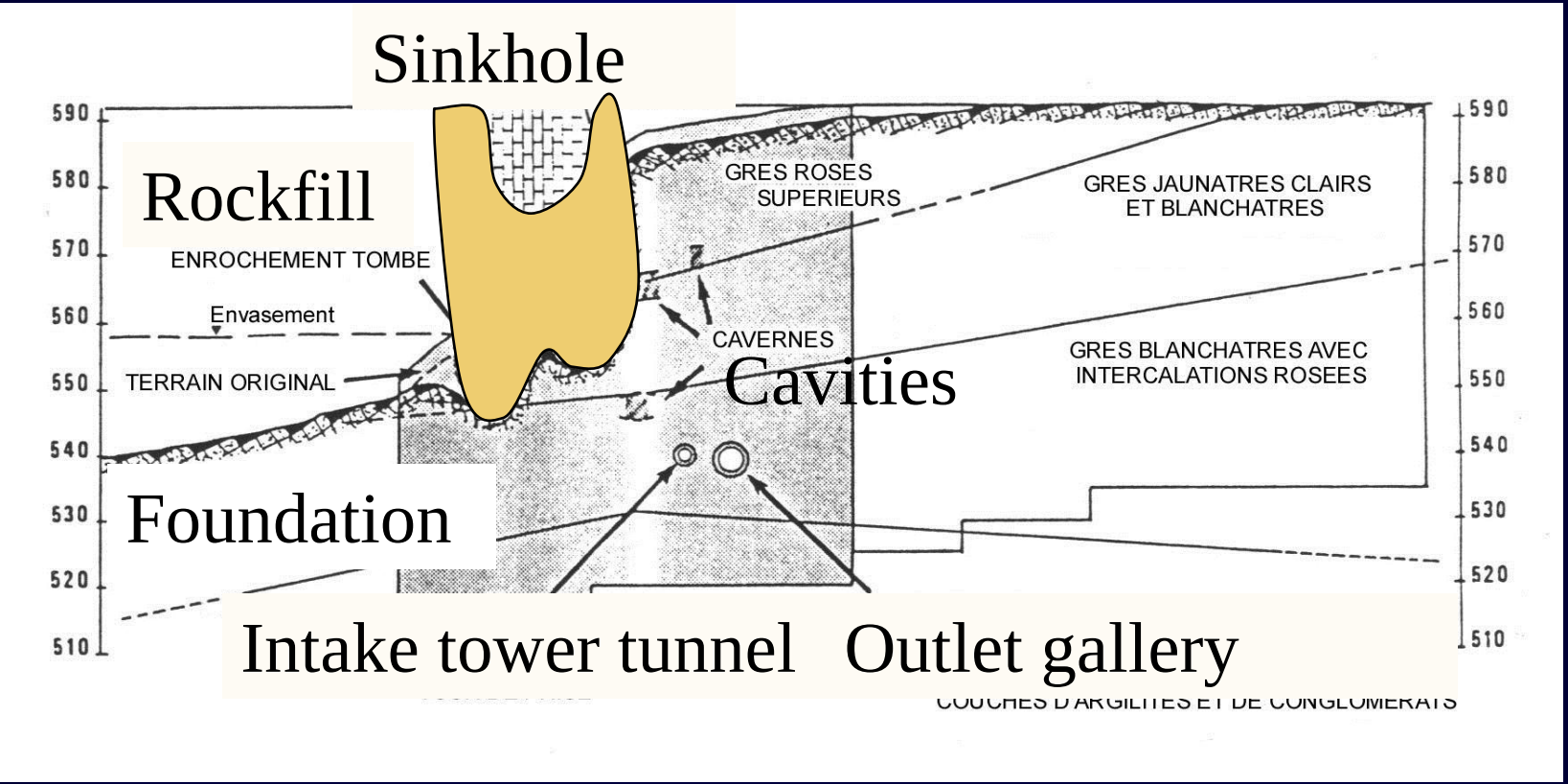
Opening ratio K_f/K_o

- Ko : initial permeability
- Kf : final permeability

Lessons from ITIYURO dam incident

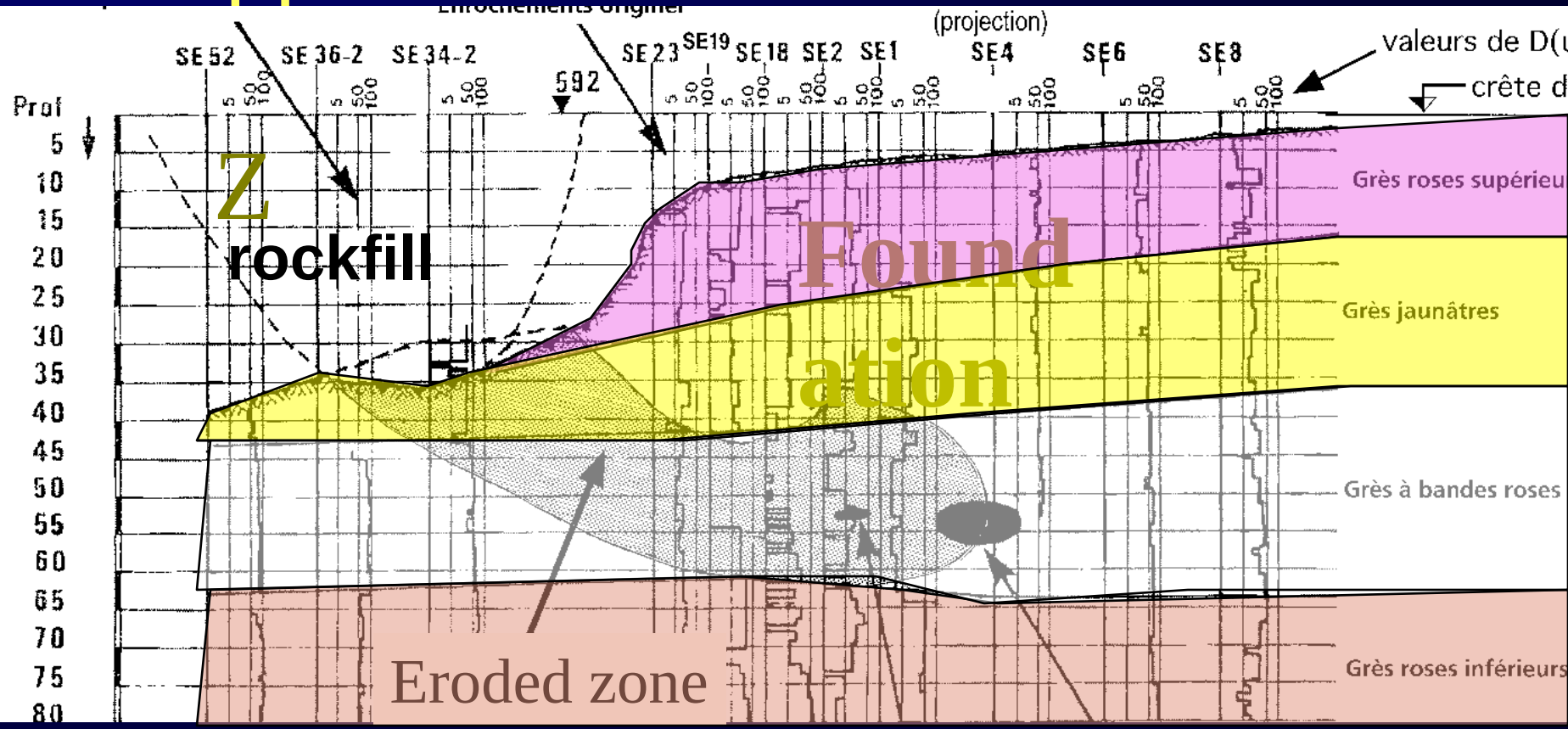


Lessons from ITIYURO dam



Leakages caused internal erosion in the sandstone foundation (>1000m³) Sinkholes occured in the rockfill crest and upstream face

Application to ITIYURO dam



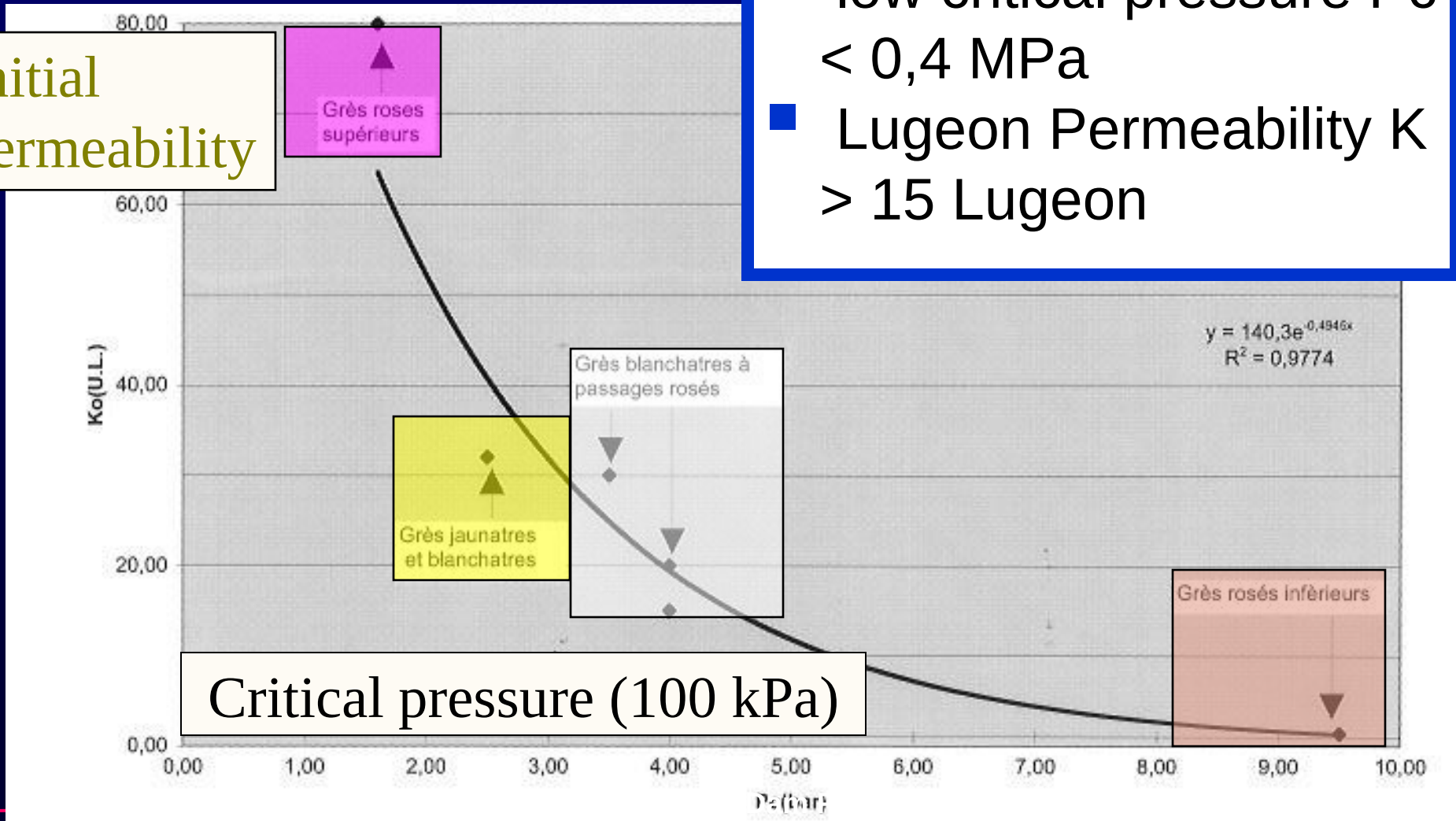
weak sandstones which suffered internal erosion have very low hardness values :

DUR < 20.

Investigations of ITIYURO dam

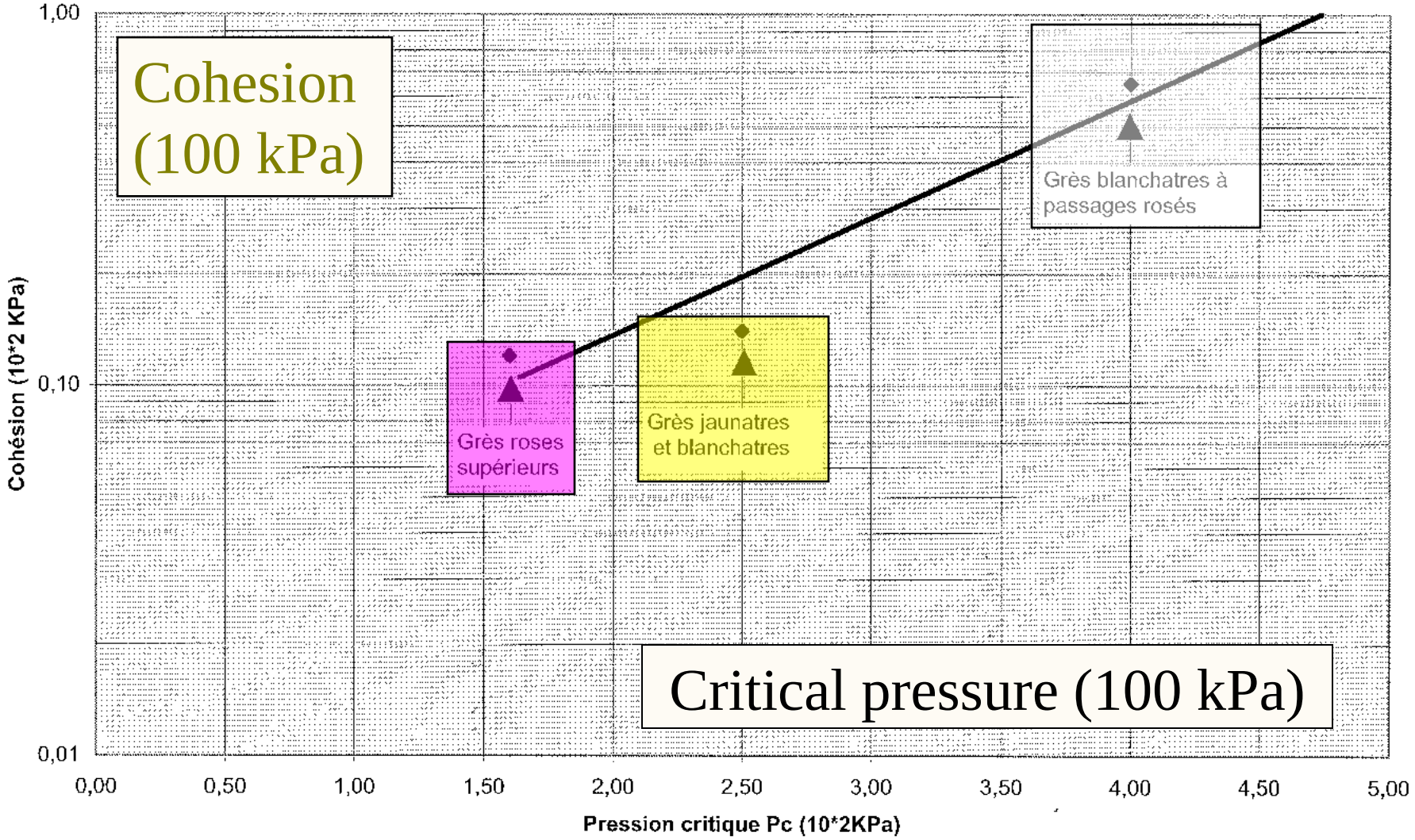
- weak sandstones areas suffering internal erosion have :
- low critical pressure Pc < 0,4 MPa
- Lugeon Permeability K > 15 Lugeon

Initial permeability

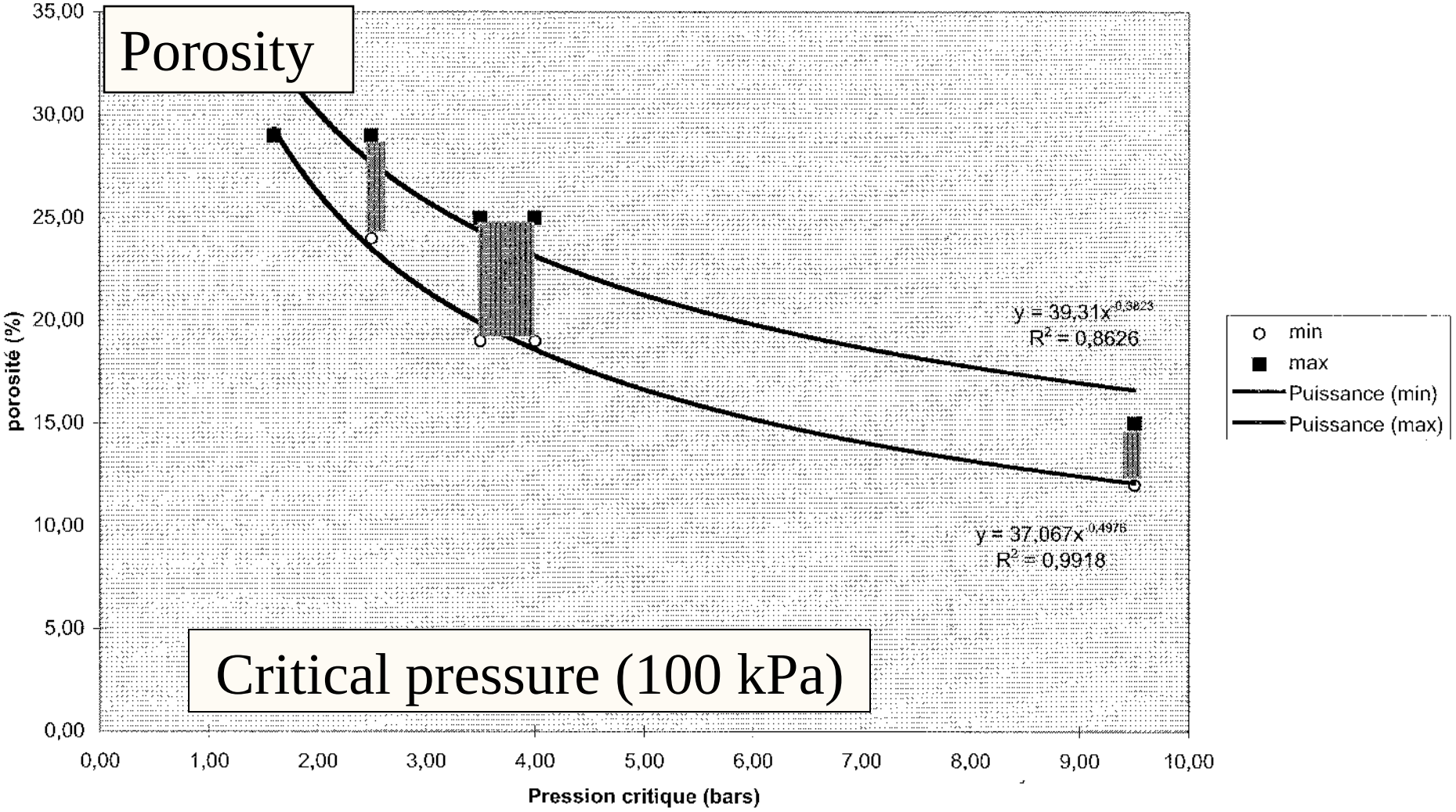


Critical pressure (100 kPa)

Correlation between P_c and Cohesion



Correlation between P_c and porosity



Experience from other dam incidents

Internal erosion in Sandstone Dam Foundations
R263 31/08/12

Criteria from dam incidents

Parameters	Unity	ITIYURO		BORDE SECO		LAS CUEVA		LA HONDA	
Statistics		min	Max	min	Max	min	Max	min	Max
P_c	100 kPa	0	2	0,4	2	0	2	0	1
K_o	LU	35	50	16	57	75	135	15	36
$O_c = K_f/K_o$	-	3	8	3	6	2	4	2	4
Dur	-	0	20	0	10	0	10	0	10

Observed limits between erodable and no-erodable rock

Final assesment of criteria of area susceptible to be eroded

PROPOSED CRITERIA

Critical Pressure :	$P_c < 0{,}2$ MPa
Hardness :	Dur < 10
Opening Criterion :	$O_c > 3$
Initial Permeability:	$K_o > 15$ UL

CONCLUSION : PROPOSED DESIGN CRITERIA

New parameters are proposed from drilling recording and water tests to characterize the resistance to internal erosion of sandstone foundations.

Depth of diaphragm wall : depth where the pore pressure under the full reservoir is lower than the critical pressure and the opening criterion is lower than 2 and Dur > 20-30.