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TW4-2

Support of Inertial Fluid Flow in Porous Media to CO2 Geological Sequestration Surveillance Program

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OUTLINES

Introduction

Succinct Theory (Inertial Factor, β, Evaluation)

Study Objectives

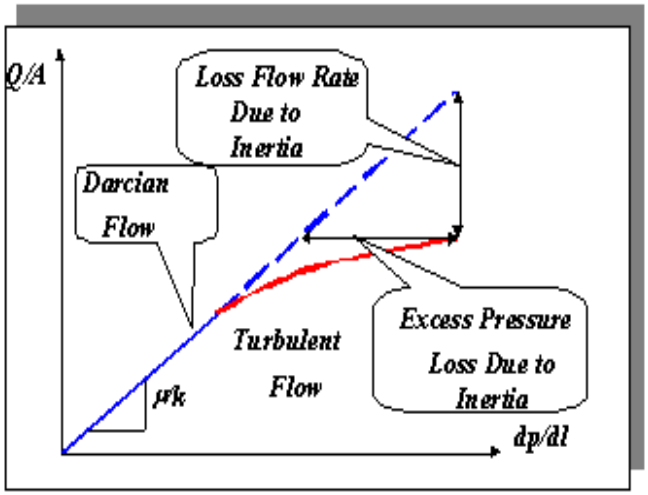
Lab Setup

Application to In Salah CCS project

Conclusions

INTRODUCTION

Gas flow in porous media at high filtration velocity, inertial or turbulent effects affect considerably production flow rate, and the evaluation petrophysical properties of reservoir layers.



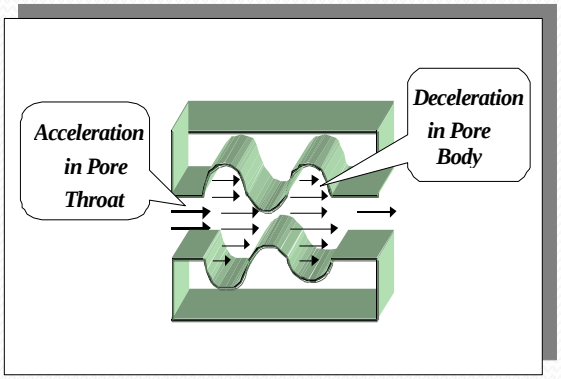
Forchheimer, attributed this deviation to inertial effects

The inertial factor, β,is defined as the deviation of linearity between pressure gradient and flow rate

It describes the excessive pressure loss, which is in strong relation with the internal architecture of the porous media.

Forchheimer. P. H: (1901)., Wasserbewegung durch boden . Zeitscrift des Vereines Deutsher Ingenieur, Vol. 49. pp: 1781-1793.

INTRODUCTION



At very high velocities, the deviation from Darcy's law arises due to inertial effects in pore contractions, expansions and bends followed by turbulent effects.

Jones, presented β, k data from different core samples. He concluded that β can be used as a good reservoir heterogeneity indicator

Wright, E., (1968). Nonlinear flow through granular media. J. Hydraul., Div. Am. SOC. Civ. Engr. Proc., Vol. 94, 851-872.

Geertsma, J., (1974). Estimating the coefficient of inertial resistance in fluid flow through porous media. SPE Journal, Vol.10, 445-450.

Jones S.C. (1987): "Using the Inertial Coefficient, β to Characterize Heterogeneity in Reservoir Rock". SPE 16949,

β EVALUATION

$$P_1^2 - P_2^2 = \frac{2\bar{Z}RTL\beta}{A^2M} q_m^2 + \frac{2\bar{Z}RTL\mu}{kMA} q_m$$

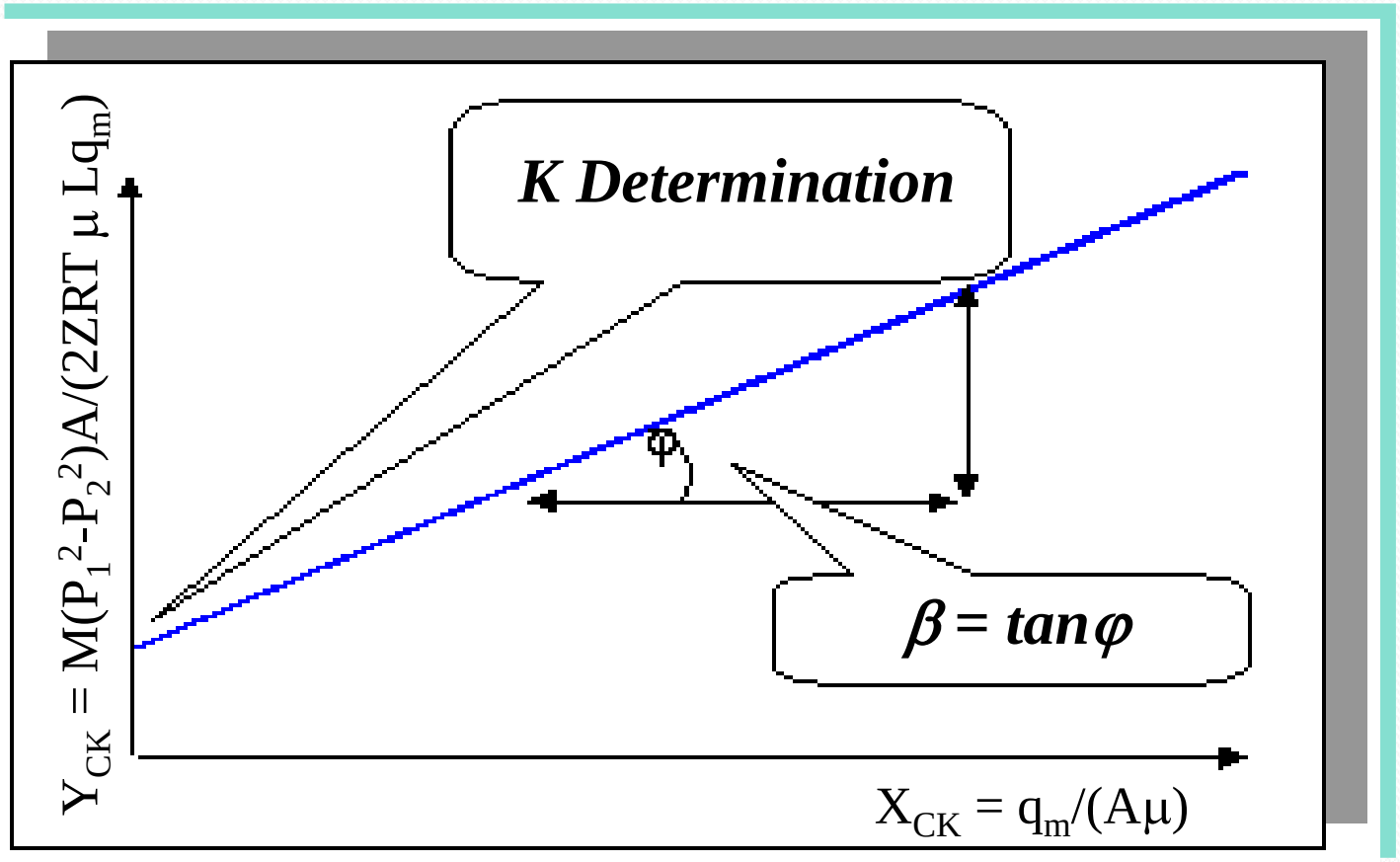
$$\frac{M(P_1^2 - P_2^2)A}{2ZRT\mu L q_m} = \beta\left(\frac{q_m}{A\mu}\right) + \frac{1}{k}$$

$$Y_{CK} = \beta X_{CK} + \frac{1}{k}$$

•[CORNELL. D and KATZ. D.L.: “Flow of Gases Through Consolidated Porous Media” Ind. Eng. Chem., Vol. 45, pp.2145-2152. 1953.]

• [Tiab D. and Donaldson E.C. : Petrophysics : “Theory and Practice of Measuring Reservoir Rock and Fuid Transport Properties”. Gulf Publishing Co, 1st Edition, Houston, Texas, ISBN 0-88415-634-6, 1996]

β EVALUATION



•[CORNELL. D and KATZ. D.L.: "Flow of Gases Through Consolidated Porous Media" Ind. Eng. Chem., Vol. 45, pp.2145-2152. 1953.]

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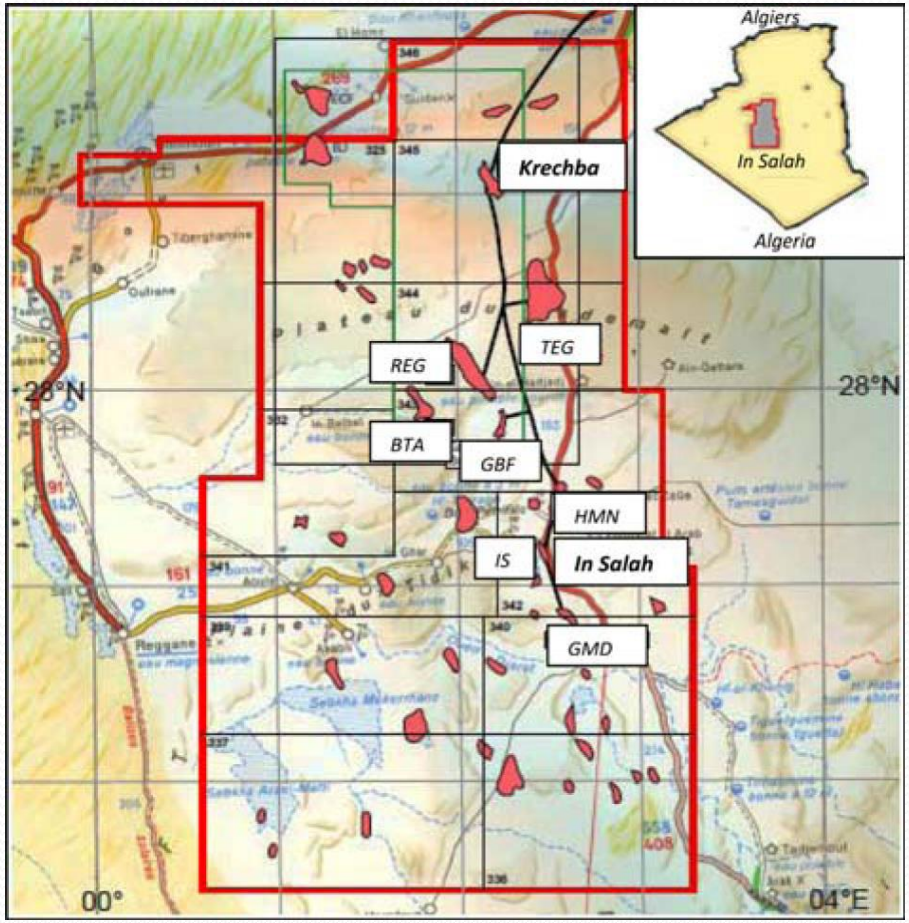
STUDY OBJECTIVES

1. Development of correlations and scales that can yield β from physical properties.
2. Application of these scales in "In Salah" CCS Project for confirming if:

   a: Krechba Carboniferous reservoir is a good candidate for CO2 geological sequestration.

   b: CO2 injectors are drilled in the correct positions in terms of injection performance.

In Salah CCS Project



JIP is a consortium between Sonatrach, BP and Statoil. It is an integrated part of gas production development plan.

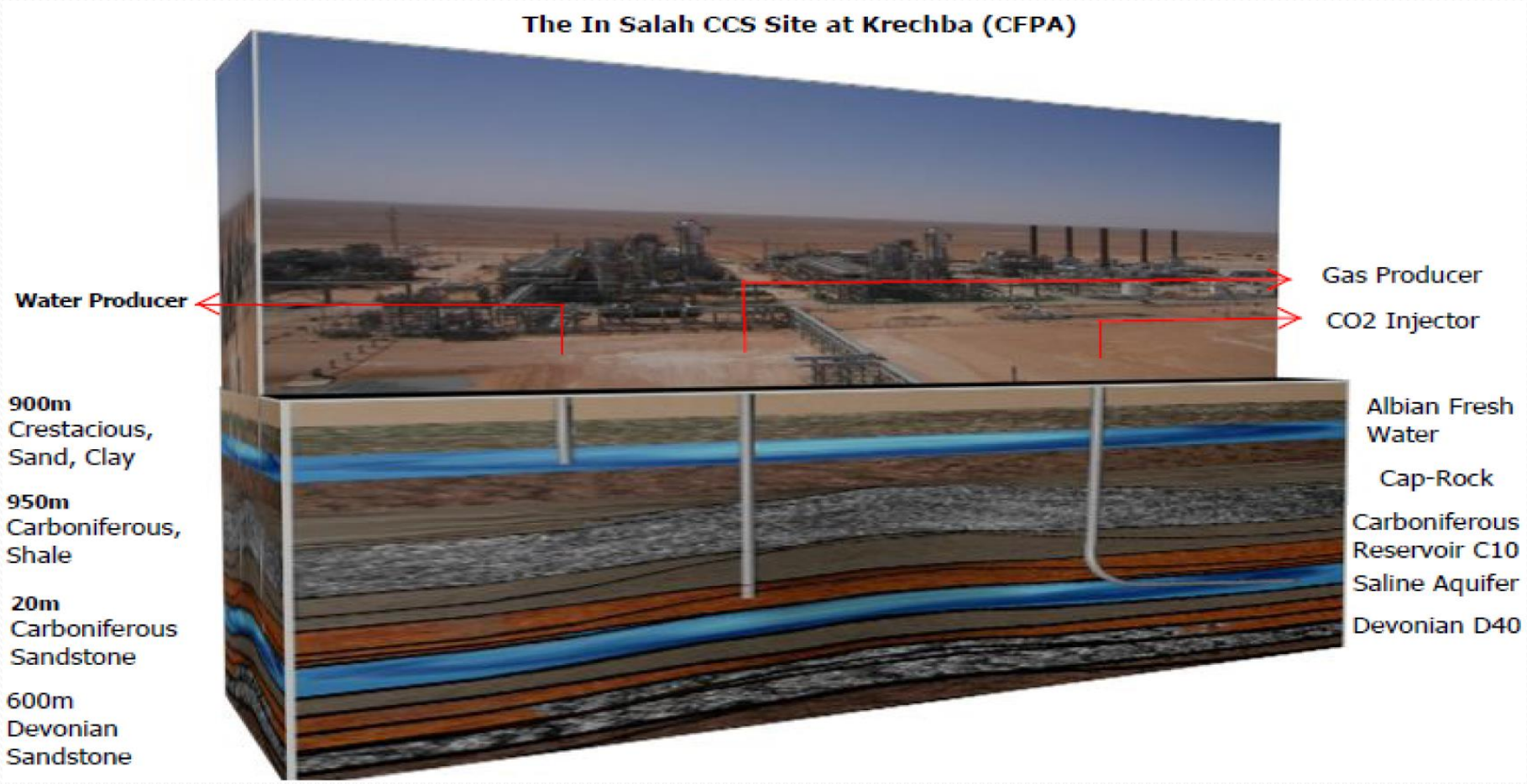
CO_2 comes from the gas production of three fields; **Teg**, **Reg** and **Krechba** with 4 to 10% of CO_2 concentration.

The specification of gas commercialization is 0.3% of CO_2.

CO_2 capture is made by chemical process using amines,

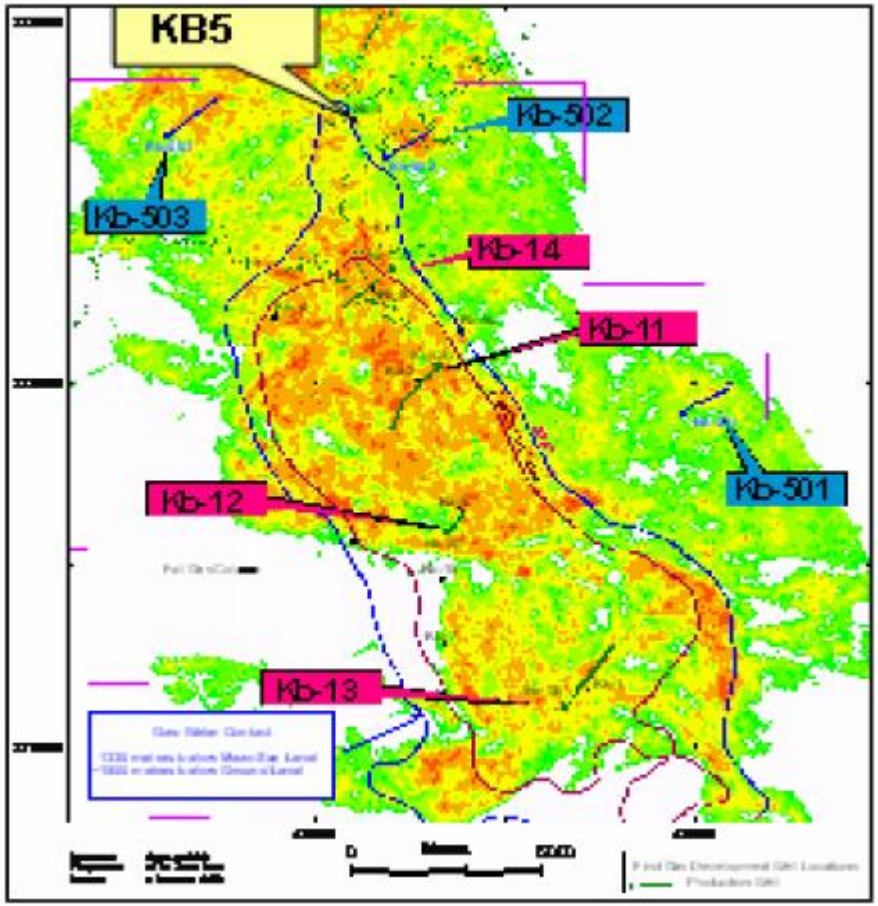
CO_2 drying and compression are made at 185bars, and CO_2 transport is completed via 8-in diameter pipelines

In Salah CCS Project



• [Deghmoum A. H, Badari. K. "A Riveting Review of Worldwide Industrial Geological Carbon Capture and Storage Projects with the Junction of CO2 Emissions in Algeria". Paper SPE N°152755-PP, presented in session 15 HSSE, at the 2012 SPE: “North Africa Technical Conference & Exhibition”, Cairo, Egypt.

In Salah CCS Project



This industrial demonstration project is started in 2004.

The total quantity of CO_2 to be sequestered is 17MMT.

The CO_2 injection rate is 1MMTPA using three horizontal wells.

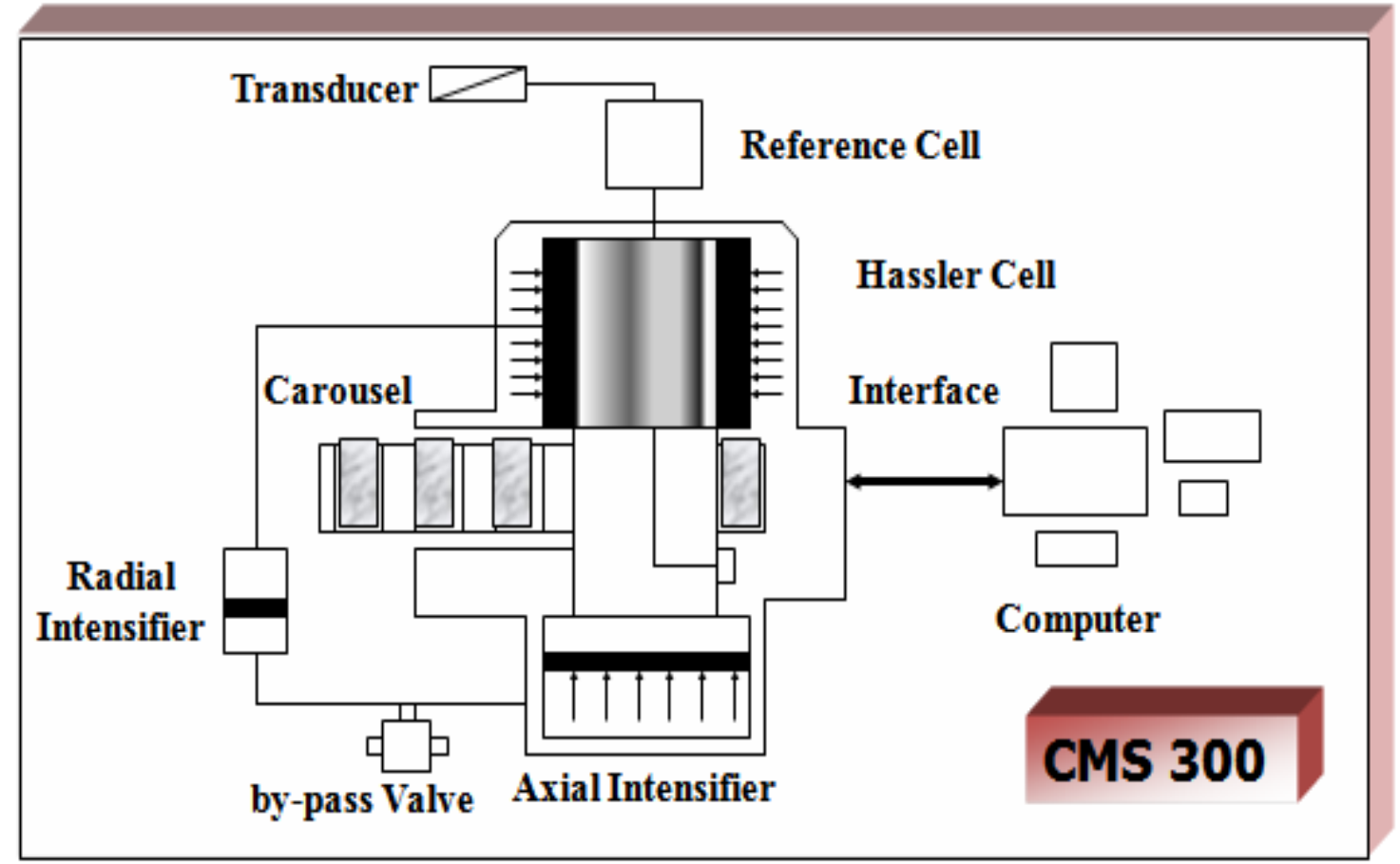
H = 20m.
ϕ = 16%
K = 10md.

Mathieson, A., Wright, I., Roberts, D., Ringrose, P. 2008. "Satellite imaging to monitor CO2 Movement at Krechba, Algeria". GHGT-9, Paper 307, Elsevier Ltd.

LAB SETUP

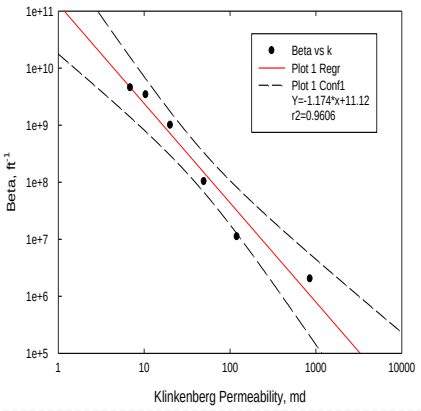
Porous Media							Number of cores
Metallic Number	Metallic 06						06
Krechba Number	KB 10 07						07
Teguentour Number	TEG 15z 03						03
Boutraa Number	BTA 1 05						05
Hassi Moumène Number	HMN 2 07						07
Garet El Befinat Number	GBF 1 07	GB F2 01					8
Gour Mahmoud Number	GMD 2 07	GMD 3 04	GMD 4 03				14
InSalah Number	IS 4 20	ISS 1 03	IS 3Bis 02	IS 2 06	IS 6 01	IS 7 02	34
							Total : 84

LAB SETUP

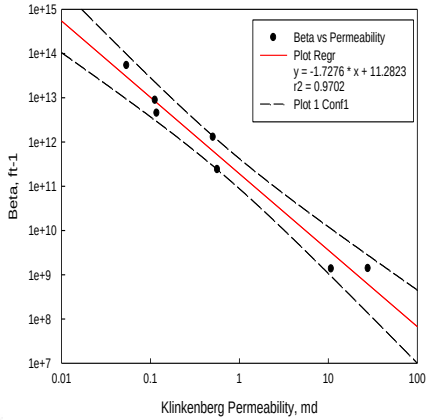


• [CoreLab Instruments, CMS 300 Manual, Vol 1 & 2, Dallas, TX, 1994]

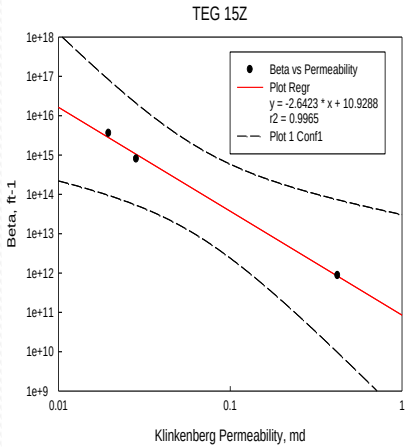
RESULTS



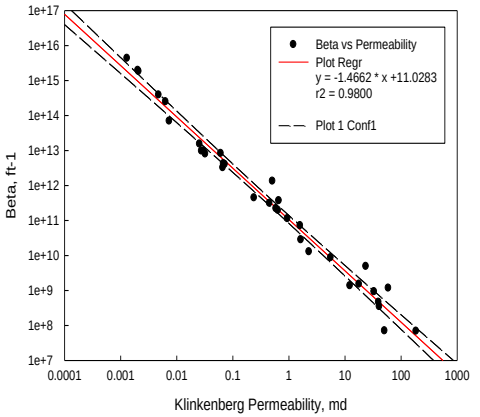
Metallic porous media



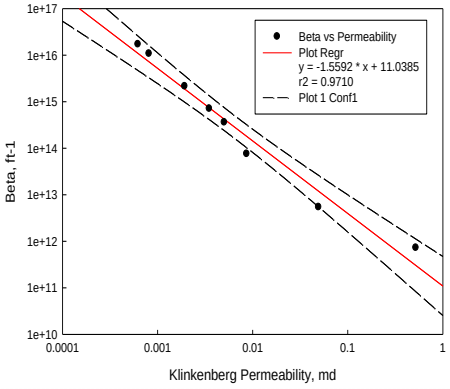
Krechba Core samples



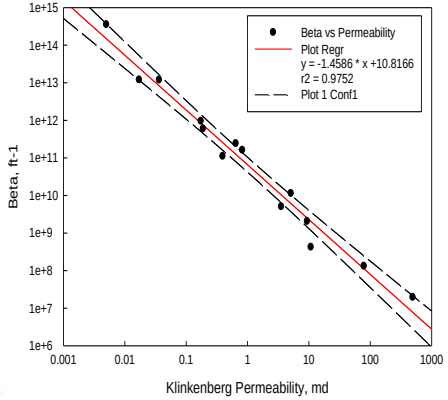
TEG Core samples



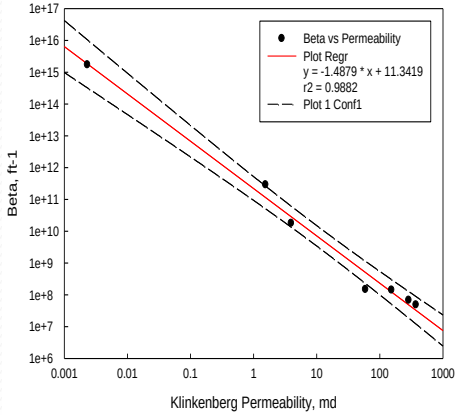
InSalah Core samples



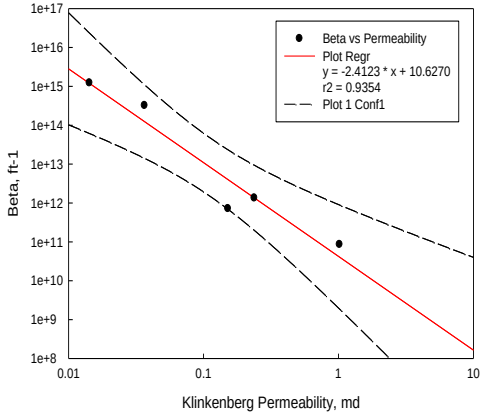
GBF Core samples



GMD Core samples



HMN Core samples

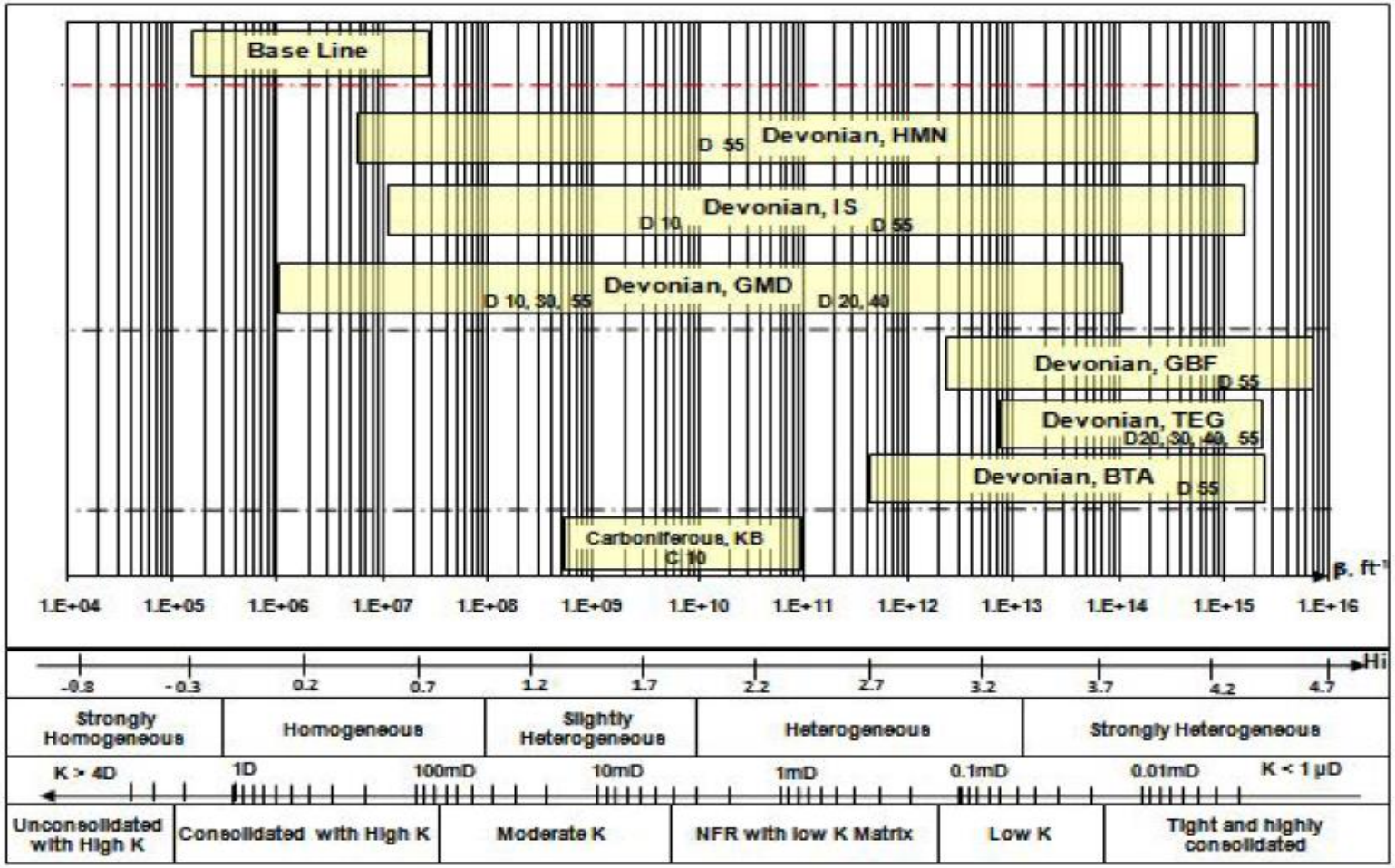


BTA Core samples

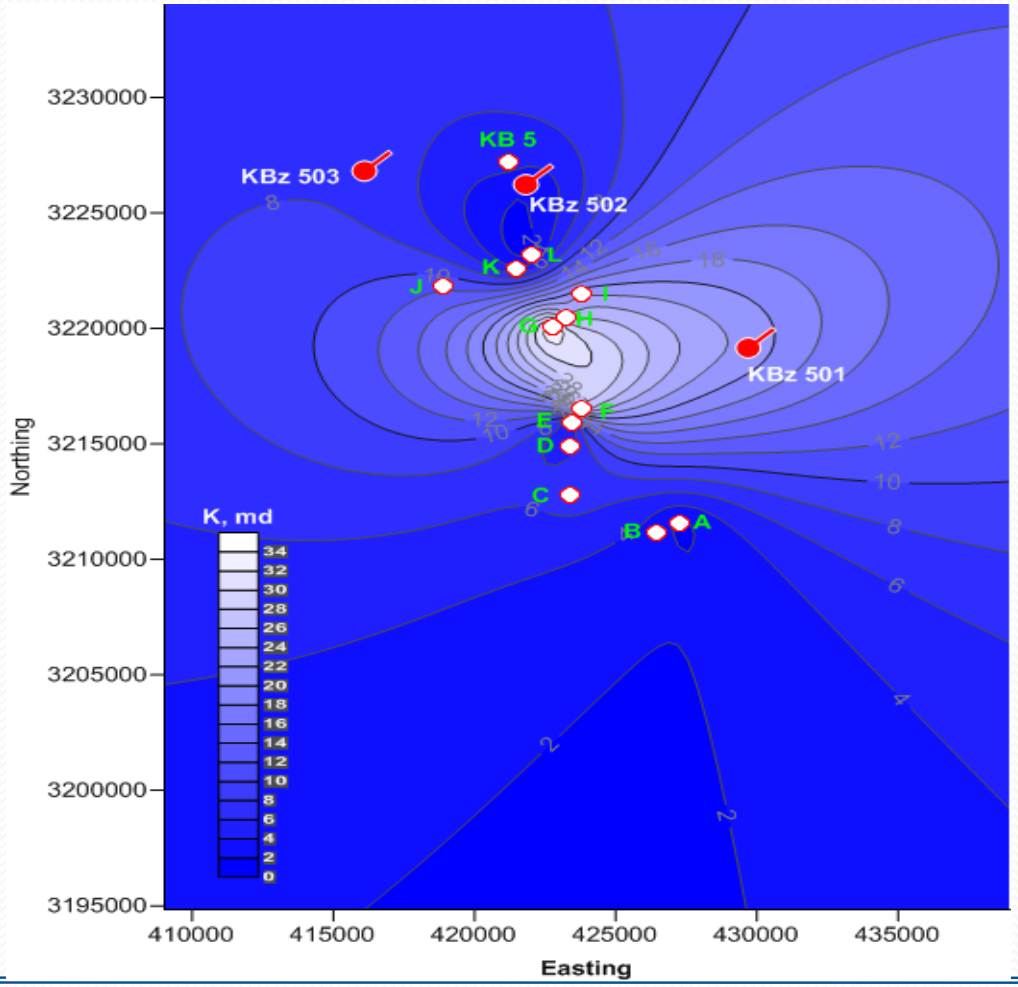
RESULTS

Porous Media	Minimum	Maximum
Metallic	2.46E+06 ft^{-1} 864 mD	1.11 E+08 ft^{-1} 12.00 mD
KB	2.32E+09 ft^{-1} 12.88 mD	1.23E+11 ft^{-1} 1.29 mD
TEG	8.29E+11 ft^{-1} 0.4220mD	2.76E+15 ft^{-1} 0.0196mD
IS	5.02E+07 ft^{-1} 186.025 mD	1.80E+15 ft^{-1} 16.40 mD
GBF	3.02E+11 ft^{-1} 0.52 mD	1.09E+16 ft^{-1} 0.00062 mD
GMD	7.71E+06 ft^{-1} 494.34 mD	1.47E+14 ft^{-1} 0.0053 mD
HMN	3.26E+07 ft^{-1} 374.63 mD	1.81E+15 ft^{-1} 0.0023 mD
BTA	4.04E+10 ft^{-1} 1.02 mD	1.19E+15 ft^{-1} 0.0143 mD

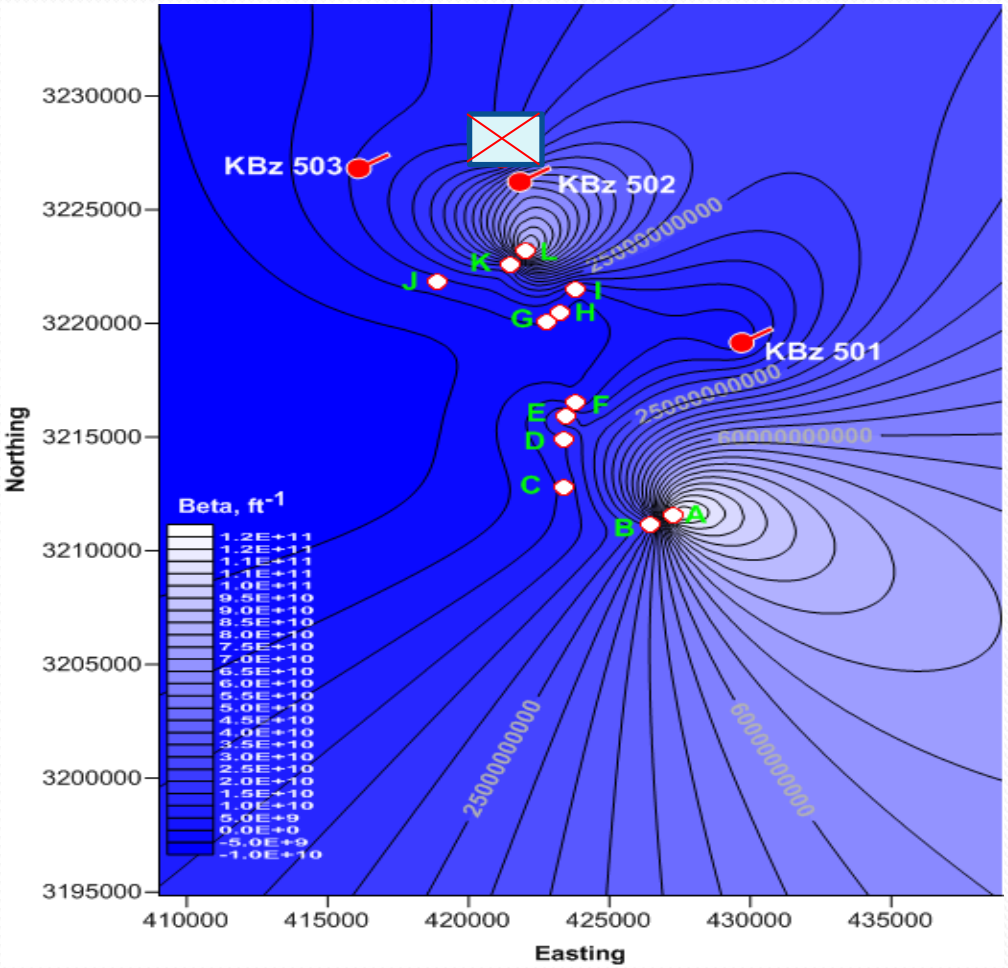
RESULTS


Base Line
D 55
Devonian, HMN
D 10
Devonian, IS
D 55
D 10, 30, 55
Devonian, GMD
D 20, 40
Devonian, GBF
D 55
Devonian, TEG
D 20, 30, 40, 55
Devonian, BTA
D 55
Carboniferous, KB
C 10
β, ft⁻¹
1.E+04
1.E+05
1.E+06
1.E+07
1.E+08
1.E+09
1.E+10
1.E+11
1.E+12
1.E+13
1.E+14
1.E+15
1.E+16
Hi
-0.8
-0.3
0.2
0.7
1.2
1.7
2.2
2.7
3.2
3.7
4.2
4.7
Strongly Homogeneous
Homogeneous
Slightly Heterogeneous
Heterogeneous
Strongly Heterogeneous
K > 4D
1D
100mD
10mD
1mD
0.1mD
0.01mD
K < 1 µD
Unconsolidated with High K
Consolidated with High K
Moderate K
NFR with low K Matrix
Low K
Tight and highly consolidated

RESULTS


KB 5
KBz 503
KBz 502
KBz 501
K
L
J
I
G
H
F
E
D
C
B
A
K, md
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Northing
3230000
3225000
3220000
3215000
3210000
3205000
3200000
3195000
Easting
410000
415000
420000
425000
430000
435000

RESULTS



KB z 501= 2000psi

KB z 502 = 4500psi

KB z 503 =2000psia

CONCLUSIONS

1. According to Beta Scale, Krechba Carboniferous reservoir (Slightly heterogeneous) is a good candidate for CO2 sequestration.
2. The Devonian reservoirs of GBF, TEG and BTA are not recommended for CO2 sequestration because they are strongly heterogeneous.
3. According to Iso-Beta mapping, CO2 injector KBz 502 is drilled in zone of high inertial effects. This well requires high energy for high injectivity performance.

This consequence is possibly the cause of CO2 leakage detected at KB 5, due to induced fractures created by high injection pressure

MANGE TAK

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