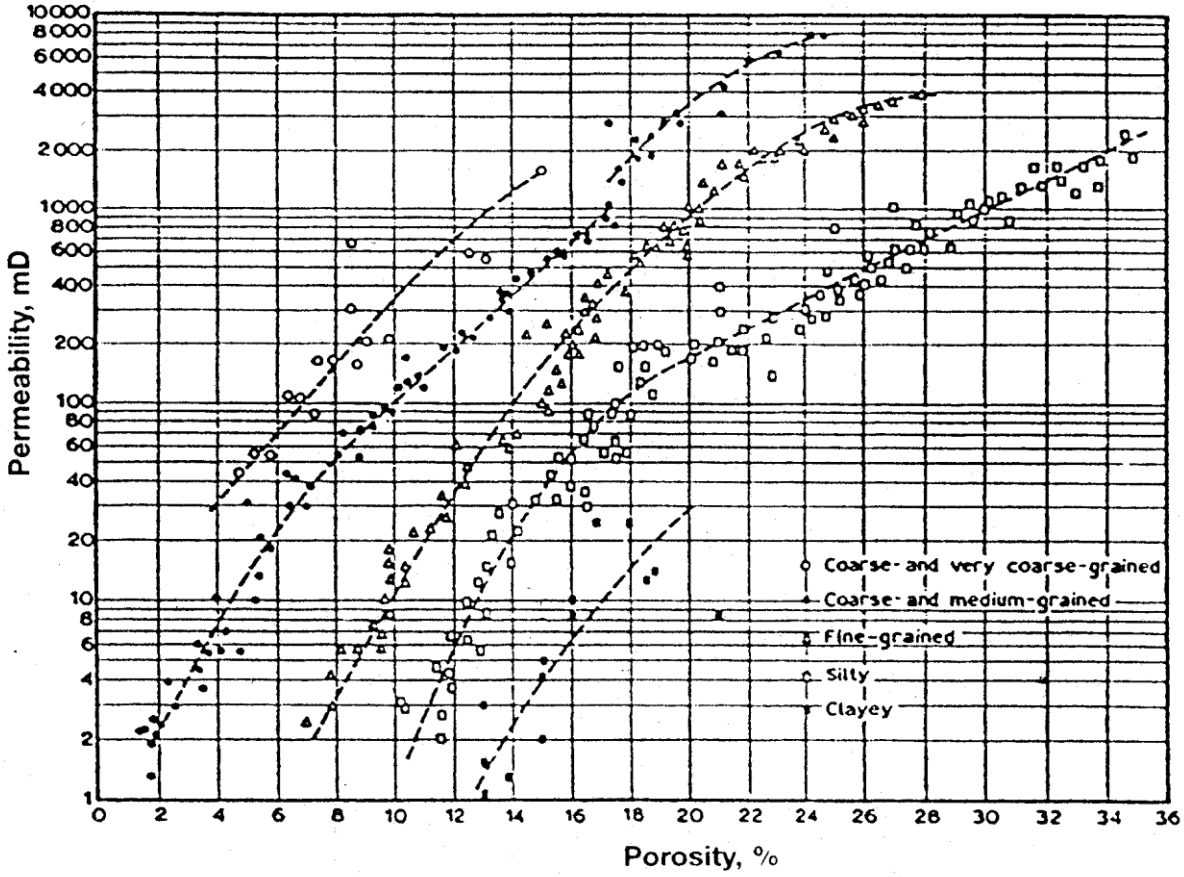
Net Pay Using Core Data

- How do I establish a porosity cutoff to ensure sufficient permeability?
- How do I establish a water saturation cutoff to ensure sufficient relative permeability to flow?
- How do I apply these values to estimate HCIP?

Net Pay Using Core Data

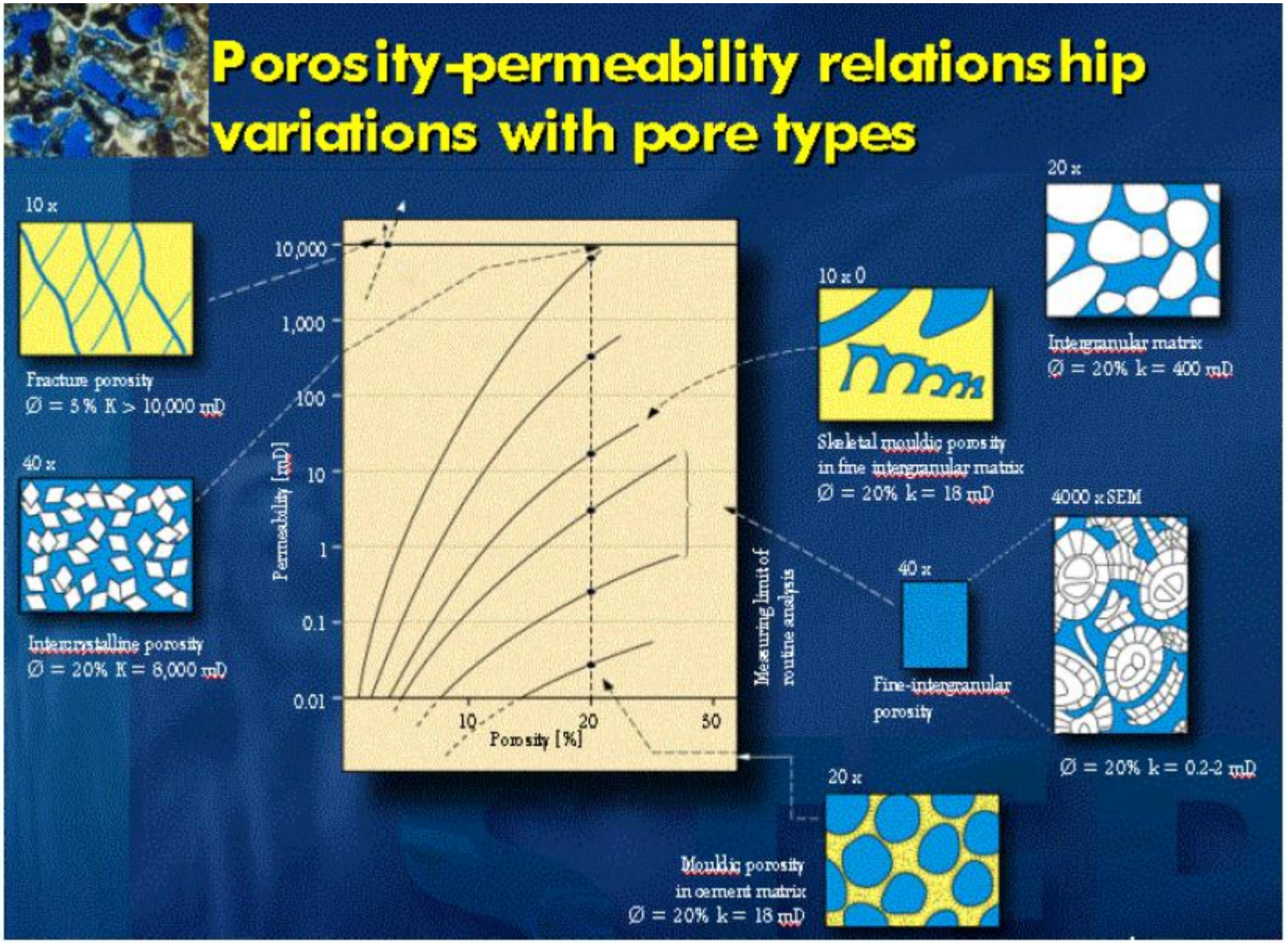
Estimation of Porosity cutoff



Influence of grain size on the porosity-permeability relationship for clastics

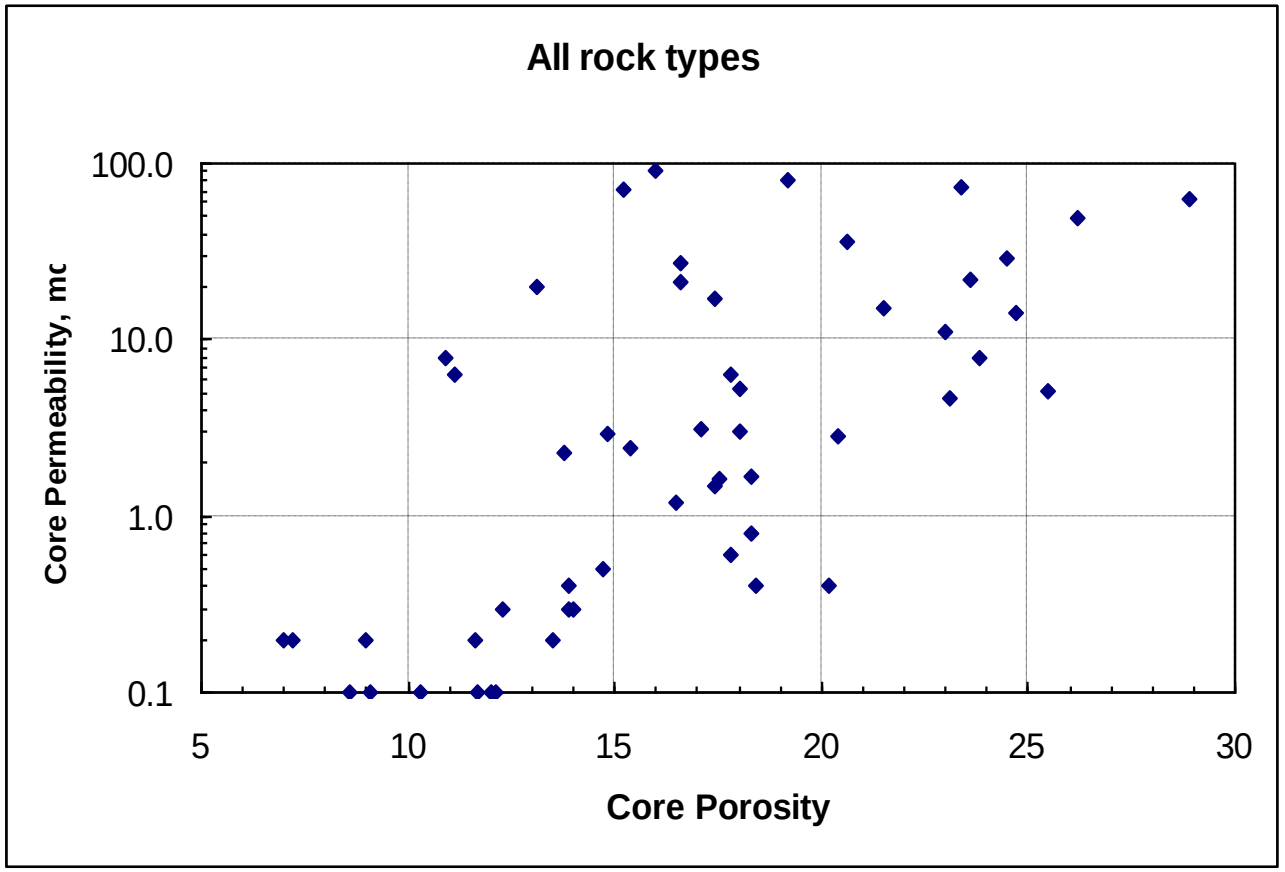
Net Pay Using Core Data

Influence of pore type on porosity-permeability relationship



Net Pay Using Core Data

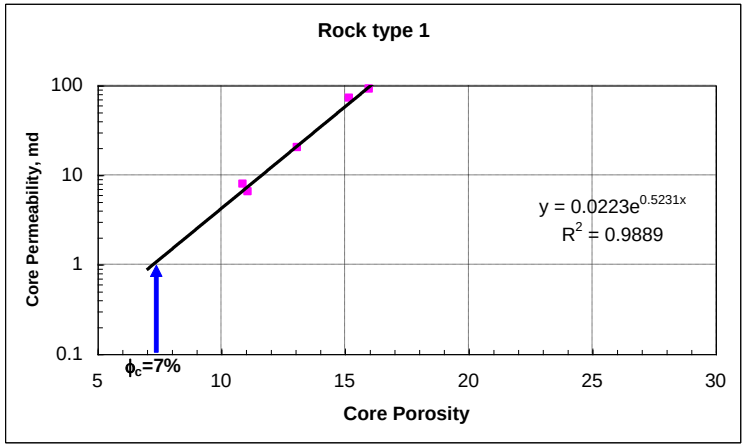
Estimation of Porosity cutoff

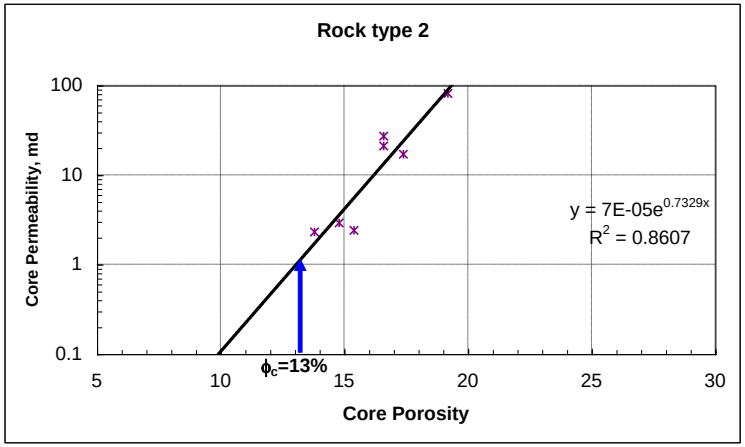


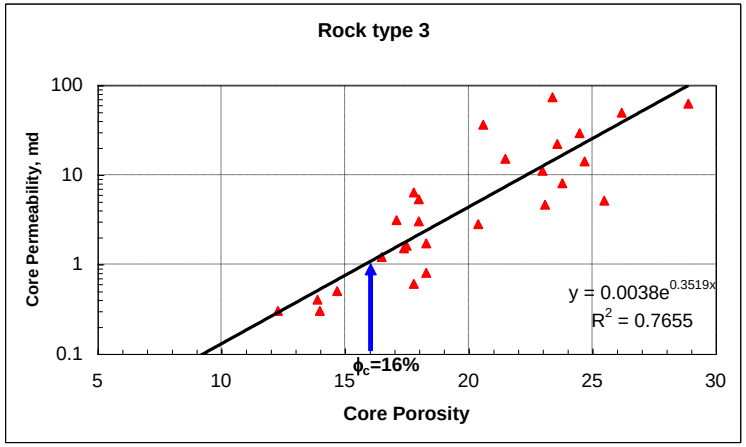
Core permeability – porosity for a San Andres example from West Texas

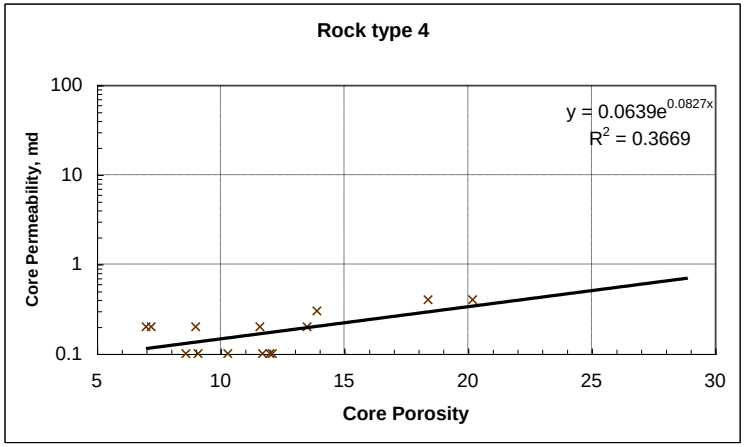
Net Pay Using Core Data

Estimation of Porosity cutoff









Data divided into four rock types

Net Pay Using Core Data

Estimation of Porosity cutoff

Field:	Media	Formation:	Entrada	Company:	Don C. Wiley-Fluid Power P
Core Type:	Dia. Conv. 4"	Report date:	4/6/1969	Well:	Federal-Medio #1
Drilling Fluid:	Low solid, no oil	County:	Sandoval	State:	New Mexico
Elev:	6837 GL	Location:	Sw SW Sec 14 T19N R3W		

Lithological Abbreviations

sand-Ss	Dolomite-Dol	Anhydrite-Anhy	Sandy-Sdy	Fine-Fn	Crystalline-xln	Brown-Brn
Shale-Sh	Chert-Ch	Conglomerate-Con	Shaly-Shly	Medium-med	Grain-grn	Black-blk	Gray-Gry
Lime-Ls	Gypsum-Gyp	Fossiliferous-Foss	Limy-Lmy	Coarse-cse	Granular-grnl		white-wh

Sample Number	Depth,top ft	Depth,bot ft	k md	Porosity %	Residual Saturation, % oil	total water	Sample description
1	5222	5223	0.05	6.9	0	94.1	Ls,red,den-suc,sdy,shly
2	5224	5225	0.19	5.4	0	98.1	Ls,red,den-suc,sdy,shly
3	5226	5227		5.7	0	94.6	Ls,gry,den-suc,sdy,shly
4	5228	5229		7.1	0	95.6	Ls,gry,den-suc,sdy,shly
5	5230	5231	0.41	9.1	0	92.2	Ls,gry,den-suc,sdy,shly
6	5232	5233		1.8	72.2	22.2	Ls,blk,den-suc,shly
7	5234	5235		2.2	68.1	18.2	Ls,blk,den-suc,shly
8	5236	5237		3.3	78.9	12.1	Ls,blk,den-suc,shly
9	5238	5239		2.2	68.1	27.2	Ls,blk,den-suc,shly
10	5240	5241		2.1	61.8	19.1	Ls,blk,den-suc,shly
11	5242	5243	0.01	3.0	43.3	43.3	Ls,blk,den-suc,v/shly
12	5243	5244	6.40	14.7	5.4	72.7	Ss,gry,med-cse,v/calc
13	5244	5245	0.53	7.8	2.6	79.4	Ss,gry,med-cse,v/calc
14	5245	5246	21.00	14.4	20.2	63.9	Ss,gry,med-cse,v/calc
15	5246	5247	72.00	15.5	9.2	74.1	Ss,gry,med-cse,v/calc
16	5247	5248	88.00	19.8	21.7	47.9	Ss,gry,med-cse,sl/calc
17	5248	5249	300.00	21.4	21.5	49.1	Ss,gry,med-cse,sl/calc
18	5249	5250	258.00	21.1	25.1	49.7	Ss,gry,med-cse,sl/calc
19	5250	5251	206.00	20.9	18.2	56.0	Ss,gry,med-cse,sl/calc
20	5251	5252	306.00	20.7	22.6	55.5	Ss,gry,med-cse,sl/calc
21	5252	5253	344.00	20.0	24.0	51.5	Ss,gry,med-cse,sl/calc
22	5253	5254	306.00	22.5	23.6	51.9	Ss,gry,med-cse
23	5254	5255	346.00	25.1	17.9	59.7	Ss,gry,med-cse
24	5255	5256	318.00	22.6	19.9	55.7	Ss,gry,med-cse
25	5256	5257	173.00	24.1	19.1	55.1	Ss,gry,med-cse,sl/calc
26	5257	5258	173.00	22.4	21.8	66.8	Ss,gry,med-cse,sl/calc
27	5258	5259	208.00	24.1	18.3	66.8	Ss,gry,med-cse,sl/calc
28	5259	5260	219.00	27.2	14.0	66.5	Ss,gry,med-cse
29	5260	5261	369.00	29.2	13.0	70.5	Ss,gry,med-cse
30	5261	5262	323.00	27.1	14.4	71.2	Ss,gry,med-cse
31	5262	5263	606.00	27.0	14.1	67.7	Ss,gry,med-cse
32	5263	5264	404.00	27.4	14.6	69.4	Ss,gry,med-cse
33	5264	5265	222.00	25.2	20.6	61.5	Ss,gry,med-cse
34	5265	5266	596.00	28.5	16.5	67.7	Ss,gry,med-cse
35	5266	5267	198.00	23.3	34.7	39.4	Ss,gry,med-cse
36	5267	5268	381.00	25.4	37.4	39.4	Ss,gry,med-cse
37	5268	5269	429.00	25.0	33.2	40.8	Ss,gry,med-cse
38	5269	5270	37.00	25.6	0.0	78.1	Ss,wh,med-cse,v/calc
39	5270	5271	51.00	25.8	0.0	90.0	Ss,wh,med-cse,v/calc

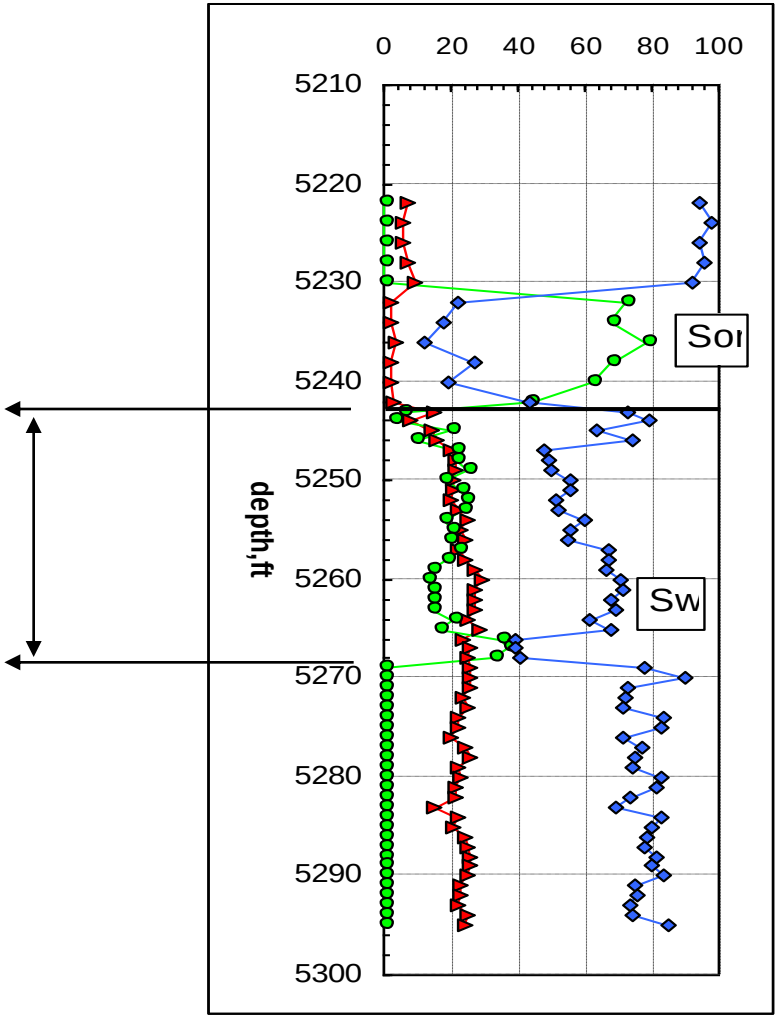
Top of Entrada Ss

Change in saturation

Net Pay Using Core Data

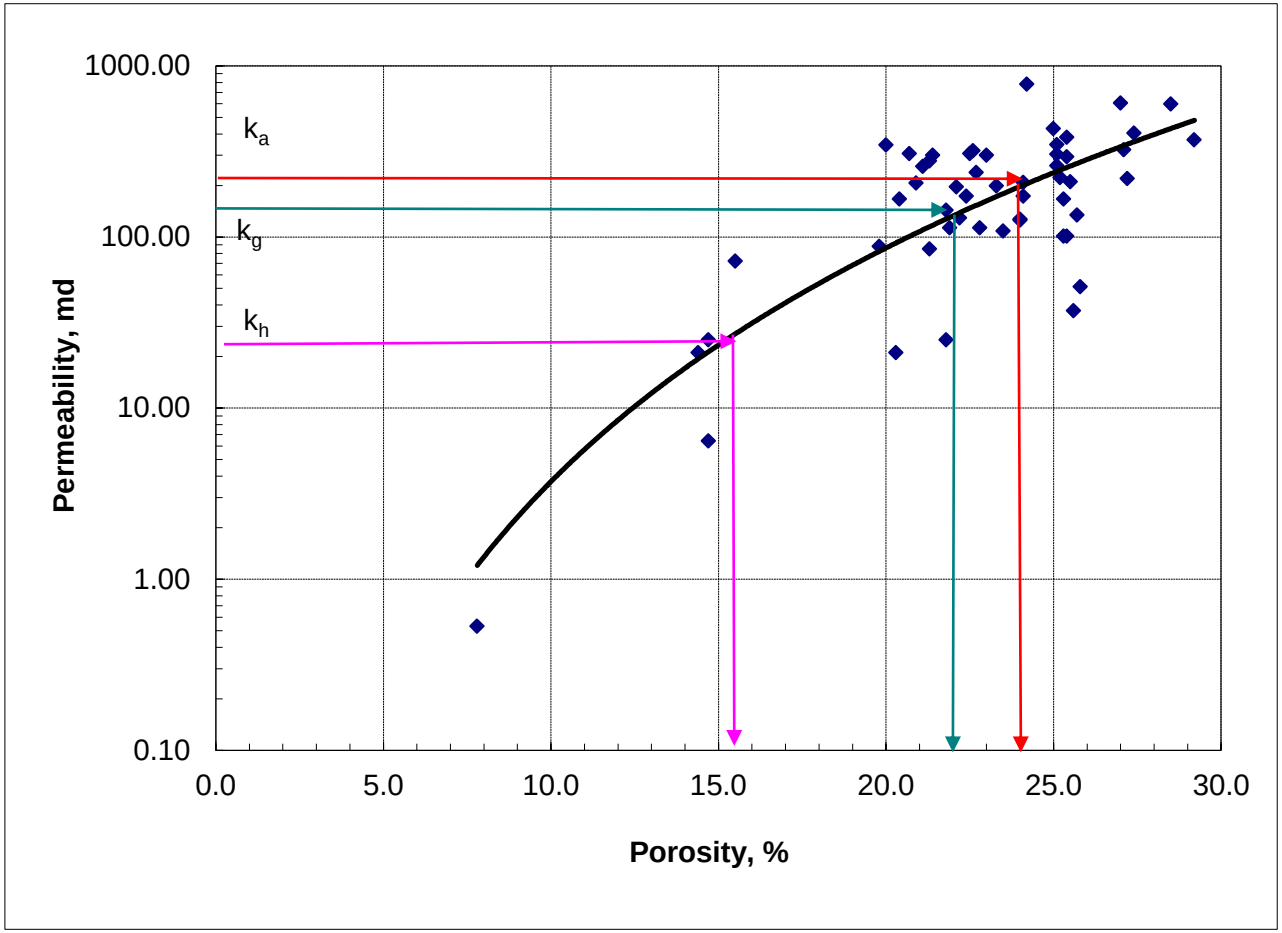
Estimation of Net Pay

Entrada Productive Interval



Net Pay Using Core Data

Estimation of Porosity cutoff

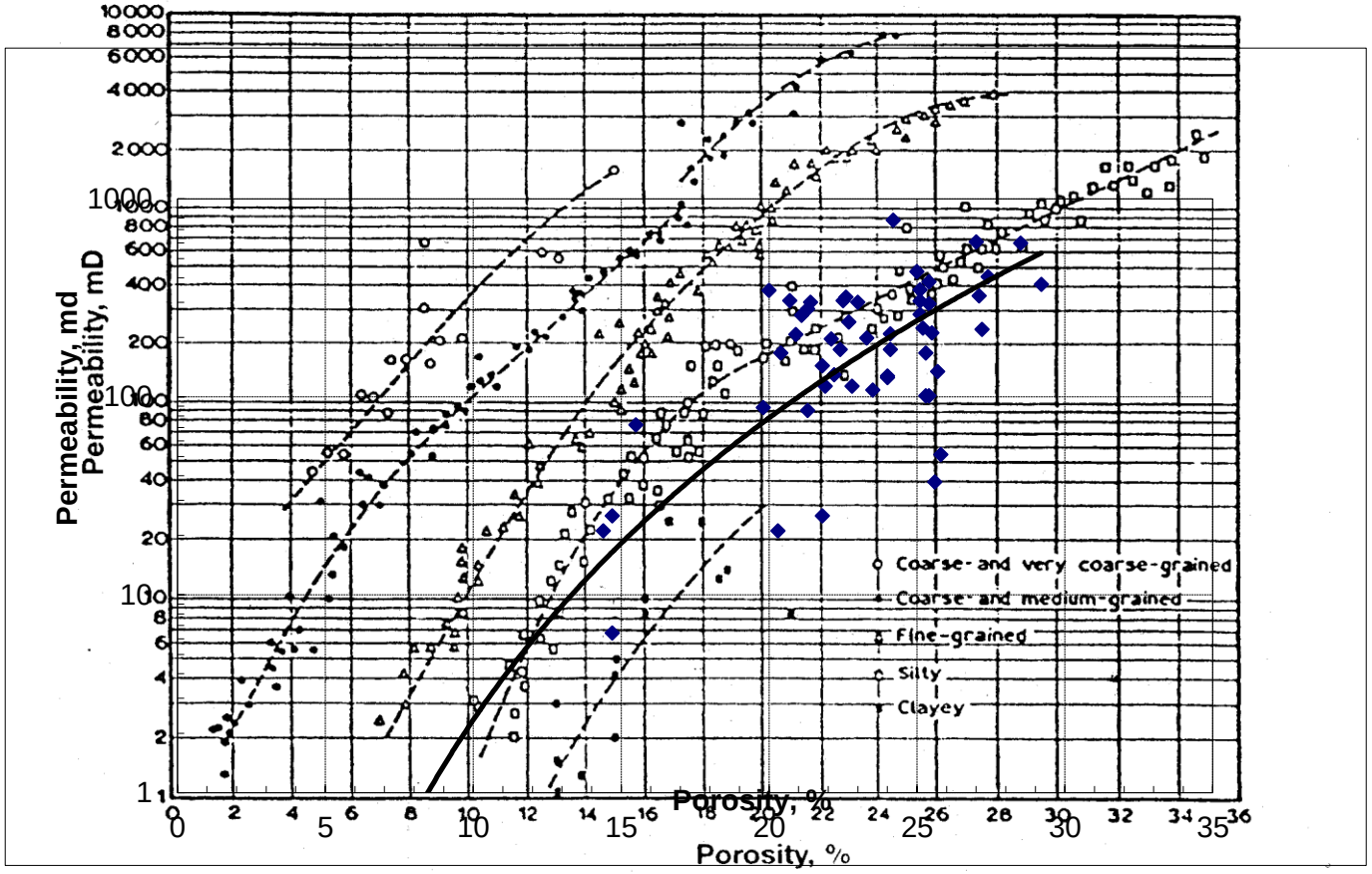


	k,md	ϕ
average =	217	22.8
harmonic=	21	
geometric=	143	

Entrada only
(5243 to 5296 ft)

Net Pay Using Core Data

Estimation of Porosity cutoff



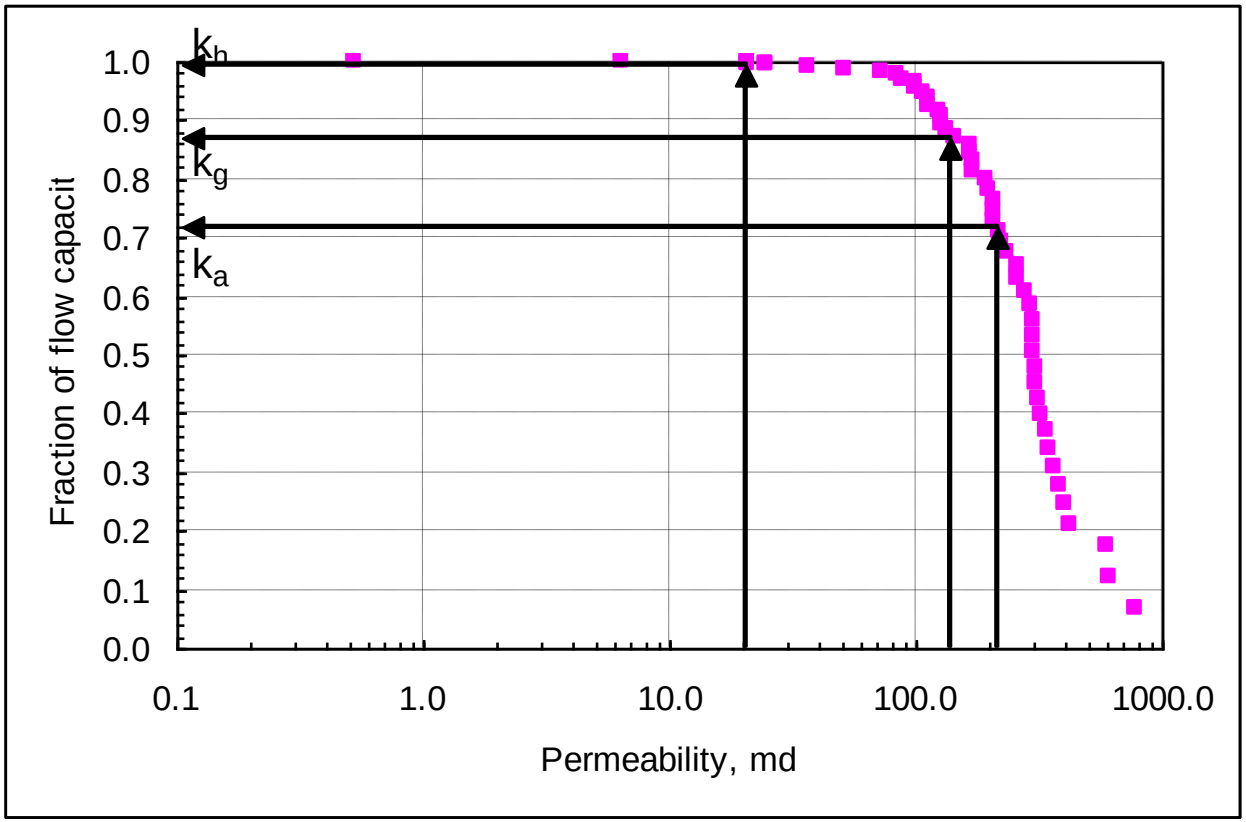
Net Pay Using Core Data

Estimation of Porosity cutoff

Sorted k	h, ft	Σh	kh	Σkh	$\Sigma kh/\Sigma kh_T$
779	1	1	779	779	0.07
606	1	2	606	1385	0.12
596	1	3	596	1981	0.17
429	1	4	429	2410	0.21
⋮	⋮	⋮	⋮	⋮	⋮
0.53	1	53	0.5	11501	1.000

Fraction of total flow capacity as a function of sorted permeability for Entrada Sandstone core

Uncorrelated



Net Pay Using Core Data

Estimation of Porosity cutoff

1. construct table with h, k, ϕ
2. Sort data on permeability
3. Multiply k*h for each entry
4. Σkh
5. Divide by total kh, $\Sigma kh / \Sigma kh_T$
6. Repeat (3) – (5) for porosity, ϕh, $\Sigma \phi h$, $\Sigma \phi h / \Sigma \phi h_T$
7. Apply k and ϕ cutoff values
8. Obtain flow and storage capacity values for given cutoffs.

Net Pay Using Core Data

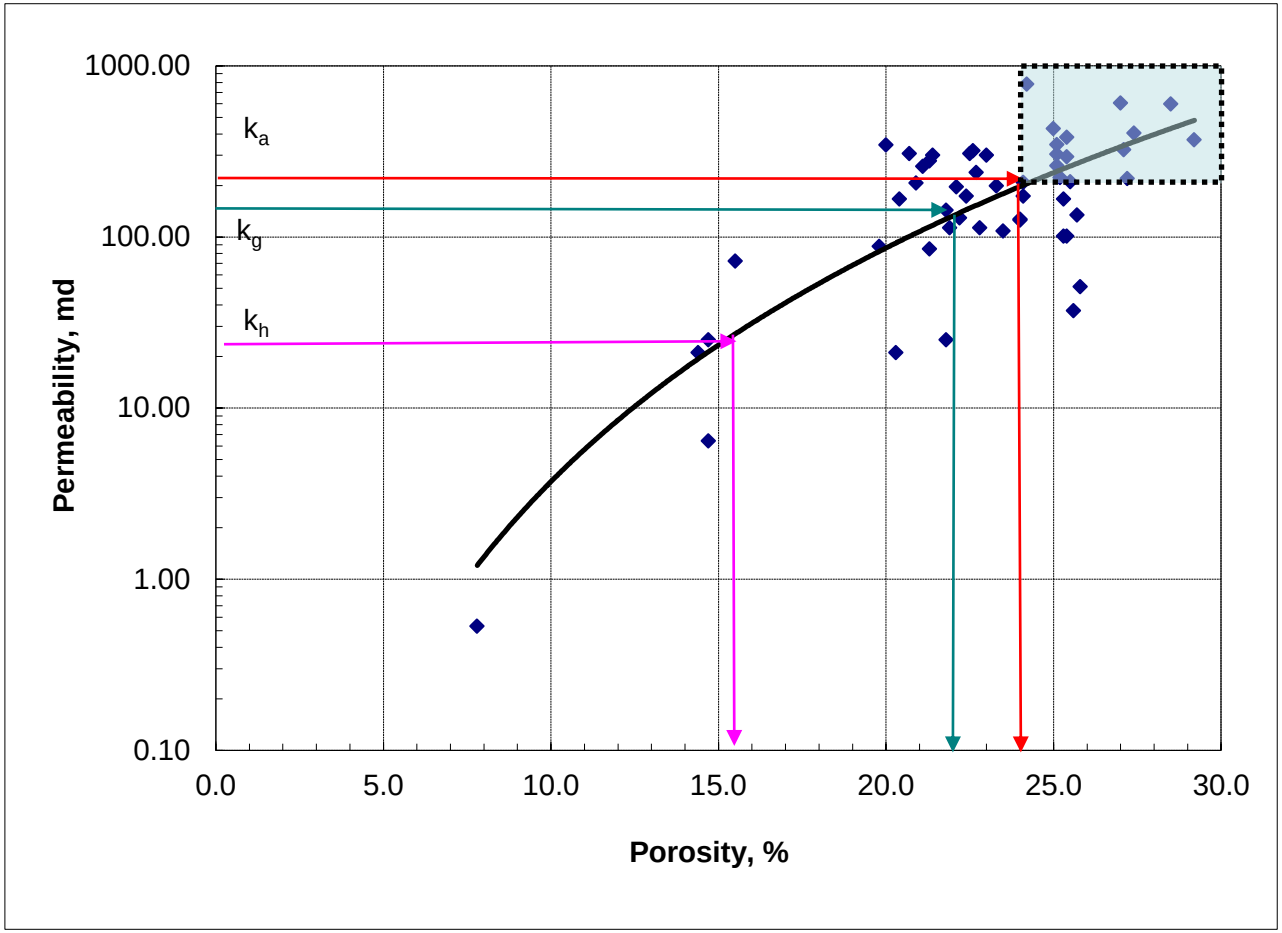
Estimation of Porosity cutoff

arthimetic cutoffs							
Case 1:	k =	217	phi =	24		$\Sigma\phi h_T$ =	**1209**
						Σkh_T =	**11501**

		sorted variable	dependent variable				
No.	h	kh	ϕh	Σkh	$\Sigma kh/\Sigma kh_T$	$\Sigma\phi h$	$\Sigma\phi h/\Sigma\phi h_T$
1	1	779.00	24.2	779	0.068	24.2	0.020
2	1	606.00	27.0	1385	0.120	51.2	0.042
3	1	596.00	28.5	1981	0.172	79.7	0.066
4	1	429.00	25.0	2410	0.210	104.7	0.087
5	1	404.00	27.4	2814	0.245	132.1	0.109
6	1	381.00	25.4	3195	0.278	157.5	0.130
7	1	369.00	29.2	3564	0.310	186.7	0.154
8	1	346.00	25.1	3910	0.340	211.8	0.175
9	1	323.00	27.1	4233	0.368	238.9	0.198
10	1	304.00	25.1	4537	0.394	264.0	0.218
11	1	294.00	25.4	4831	0.420	289.4	0.239
12	1	260.00	25.1	5091	0.443	314.5	0.260
13	1	222.00	25.2	5313	0.462	339.7	0.281
14	1	219.00	27.2	5532	0.481	366.9	0.304

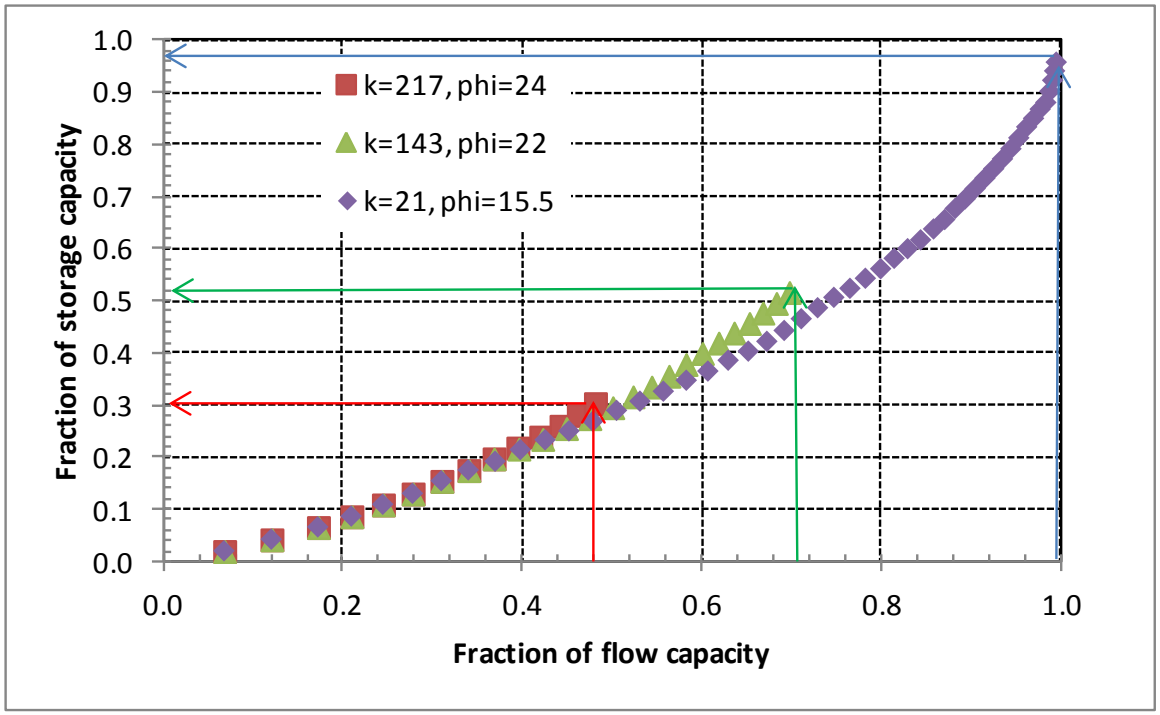
Net Pay Using Core Data

Estimation of Porosity cutoff



Net Pay Using Core Data

Estimation of Porosity cutoff



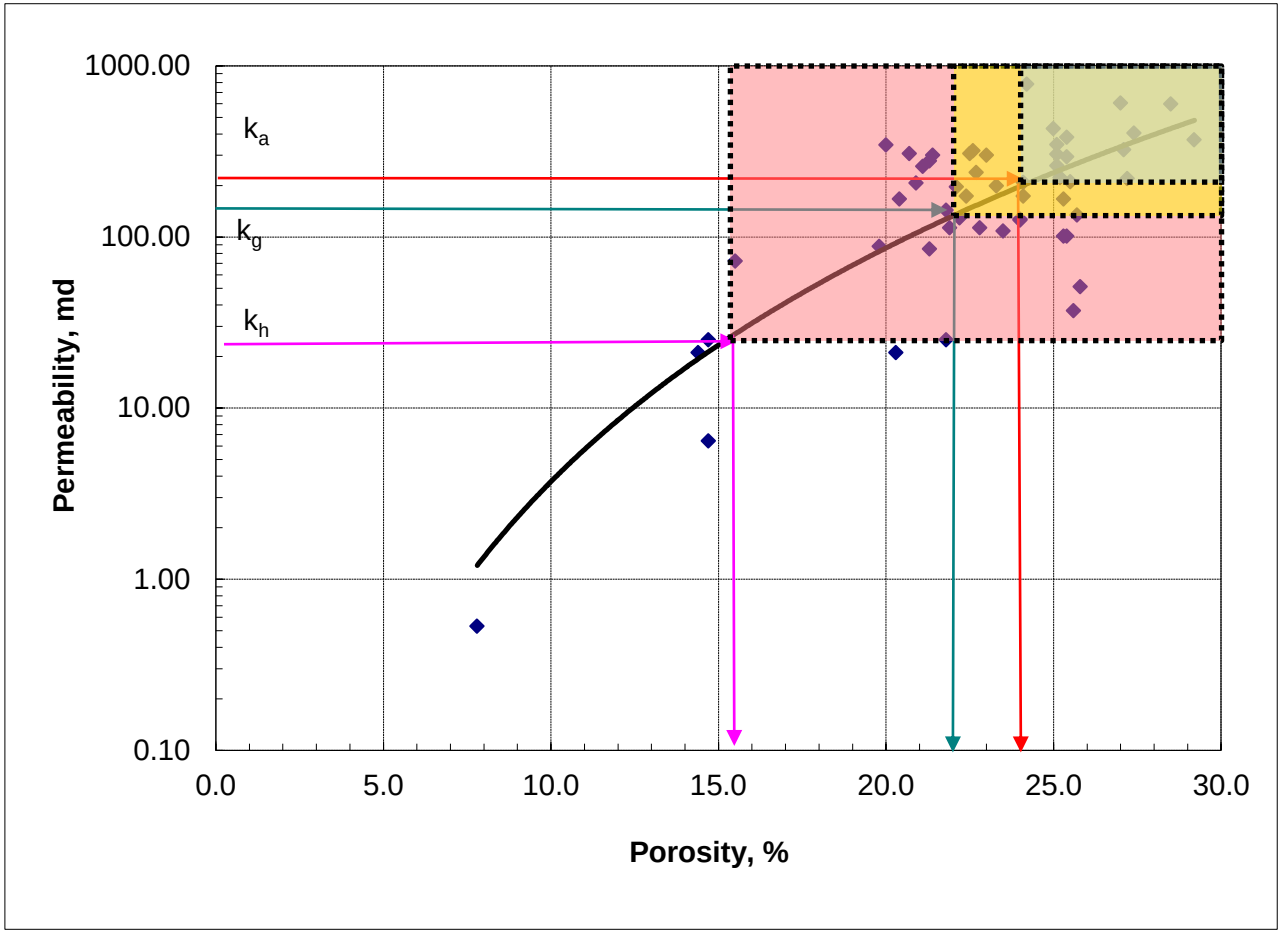
type	k,md	porosity	$\Sigma\phi h/\Sigma\phi h_T$	$\Sigma kh/\Sigma kh_T$
arithmetic	217	24	0.30	0.48
geometric	143	22	0.70	0.52
harmonic	21	15.5	0.99	0.96

$\Sigma\phi h_T =$	**1209**
$\Sigma kh_T =$	**11501**

For all of Entrada

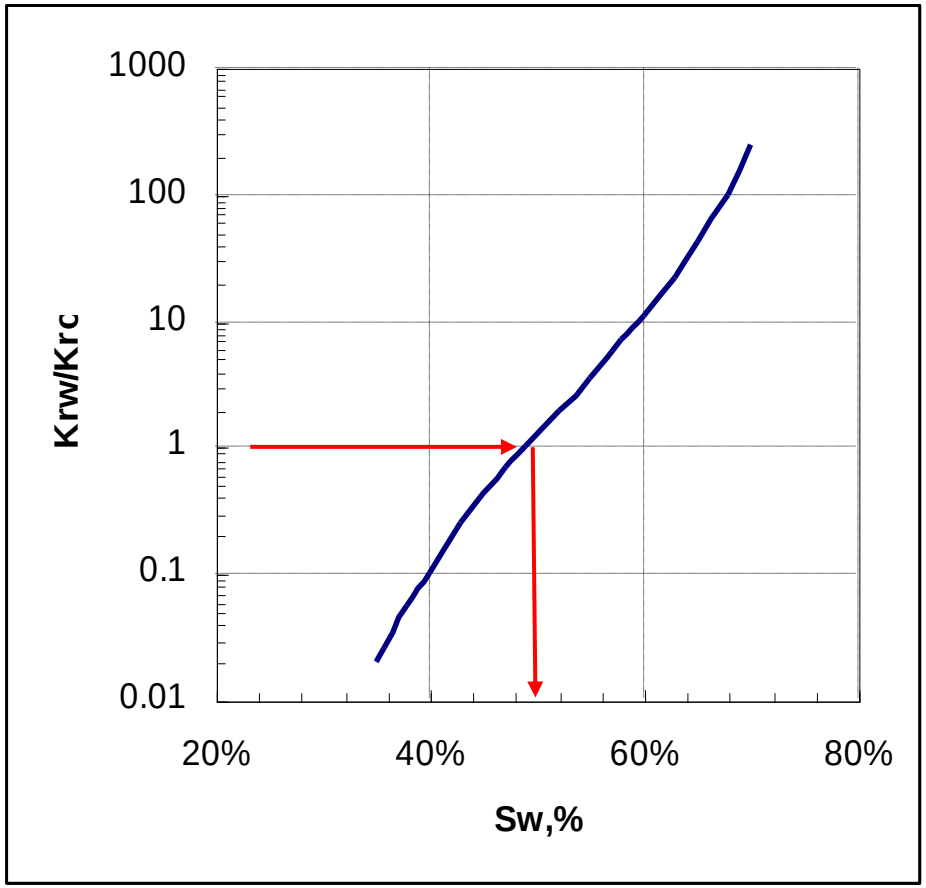
Net Pay Using Core Data

Estimation of Porosity cutoff



Net Pay Using Core Data

Estimation of Water Saturation cutoff

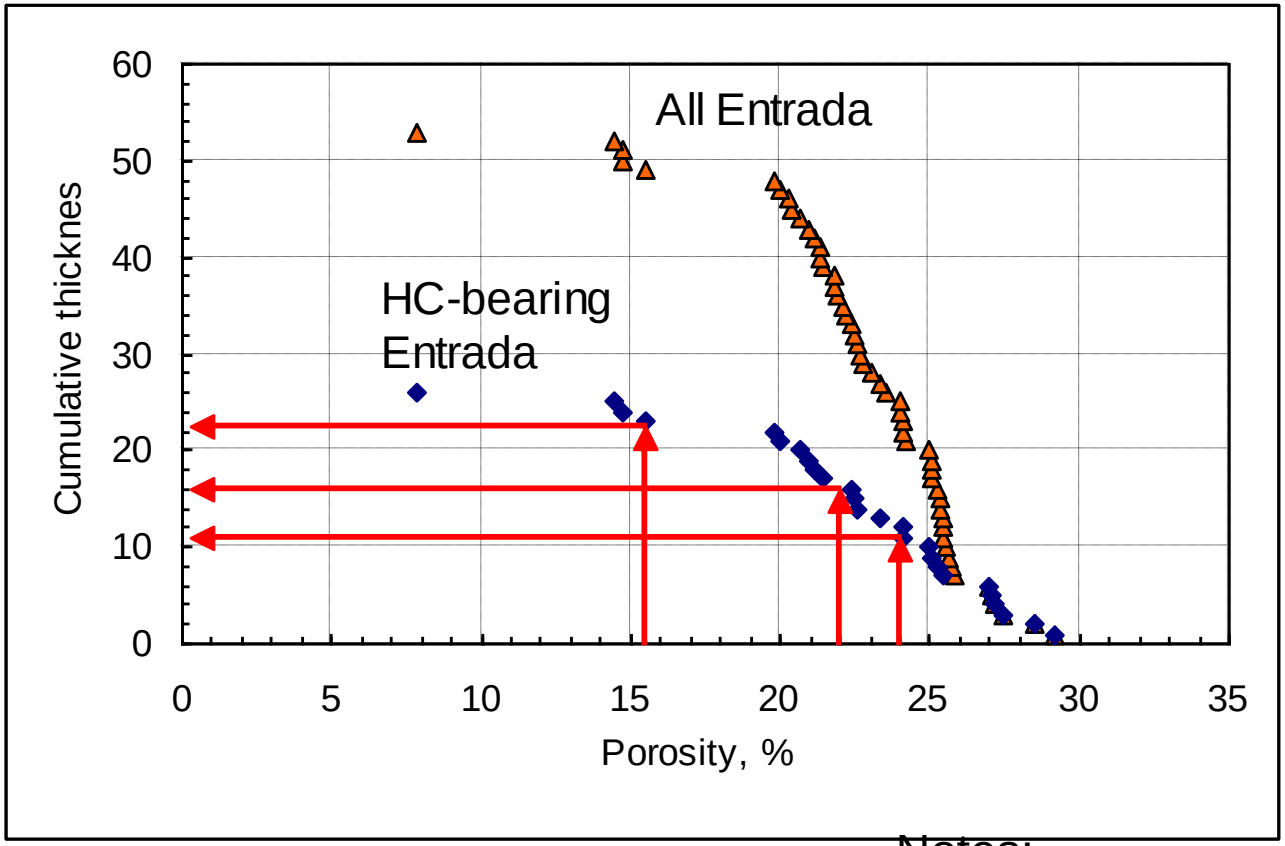


$\log(K_{rw}/K_{ro})$ vs. S_w.

Need Special Core Analysis (SCAL) or Drill with oil-based mud

Net Pay Using Core Data

Estimation of Net Pay



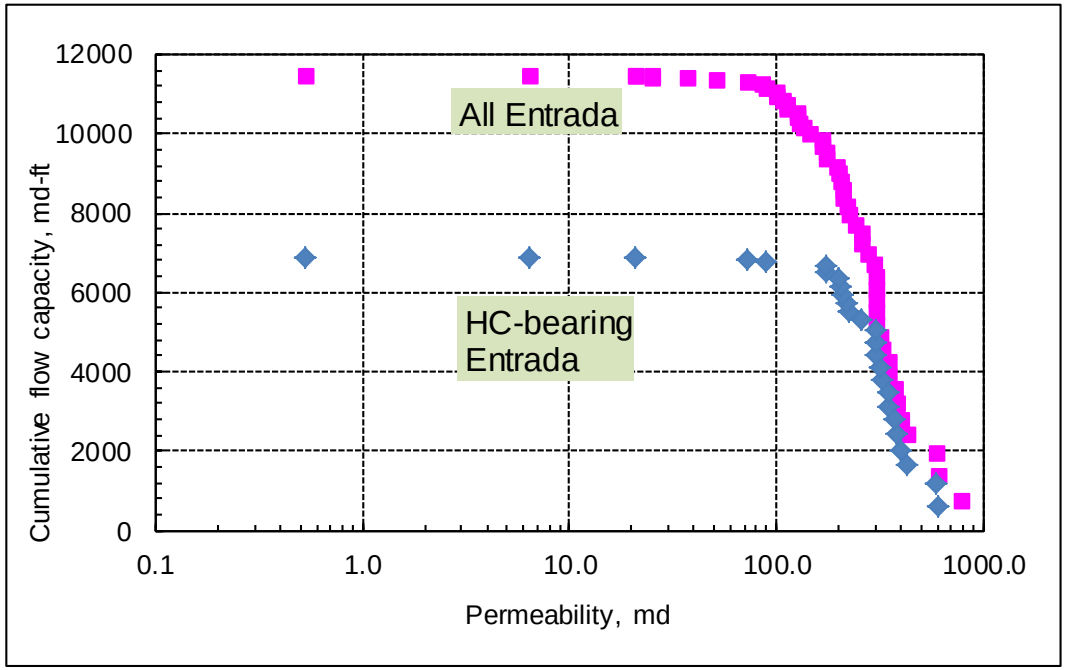
type	k,md	porosity	Σh	Σϕh	Σkh
arithmetic	217	24	10	267	3895
geometric	143	22	16	406	5271
harmonic	21	15.5	23	545	6845
other	90	20	21	510	6685

Notes:

1. Sort only HC-bearing section of Entrada
2. Apply criteria
3. No water saturation cutoff applied

Net Pay Using Core Data

Estimation of Net Pay



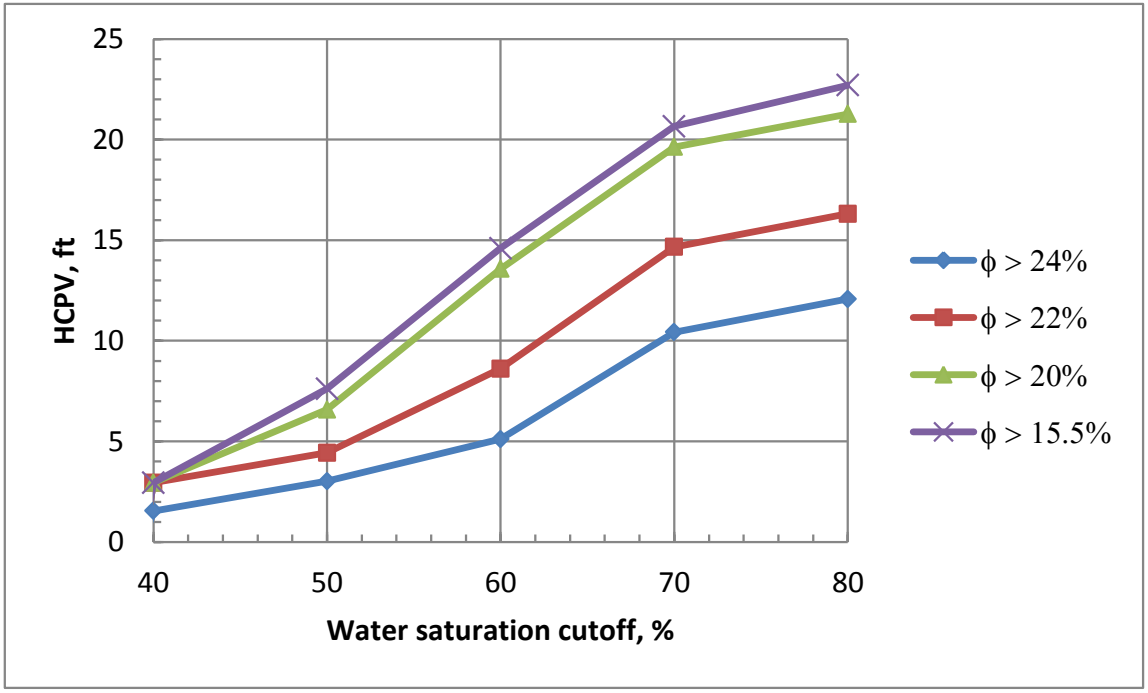
type	k,md	porosity	Σh	Σϕh	Σkh
arithmetic	217	24	10	267	3895
geometric	143	22	16	406	5271
harmonic	21	15.5	23	545	6845
other	90	20	21	510	6685

HC-bearing section only

Net Pay Using Core Data

Estimation of HCIP

- Build a table of core porosity and water saturation, sorted H to L on porosity
- Calculate HCPV = ϕ h (1-Sw) for each entry
- Assume Sw cutoff values
- Sum values that meet both the Sw and porosity cutoff values
- Plot Sw (cutoff) vs HCPV



Net Pay Using Core Data

Estimation of HCIP

Swcutoff	Reserves, MBO			
%	ϕ> 24%	ϕ> 22%	ϕ> 20%	ϕ> 15.5%
39	0.0	0.0	0.0	0.0
40	79.6	152.6	152.6	152.6
50	156.2	229.1	340.3	393.6
60	264.3	445.3	701.8	755.1
70	539.4	758.2	1015.3	1068.5
80	624.3	843.6	1100.1	1174.0
	* Applying R.F. = 40%			

Assume:

- Drainage area = 20 acres
- Boi = 1.2 rbbl/stb

$$N = \frac{7758A}{B_{oi}} \sum_{i=1}^{n} h_i \phi_i (1 - S_{wi})$$

$$N(MBO) = 129.3 \sum_{i=1}^{n} h_i \phi_i (1 - S_{wi})$$

- HCPV = ?___ N = _____MBO

- Recovery Factor = 40%...water drive, sandstone reservoir

R = _____MBO

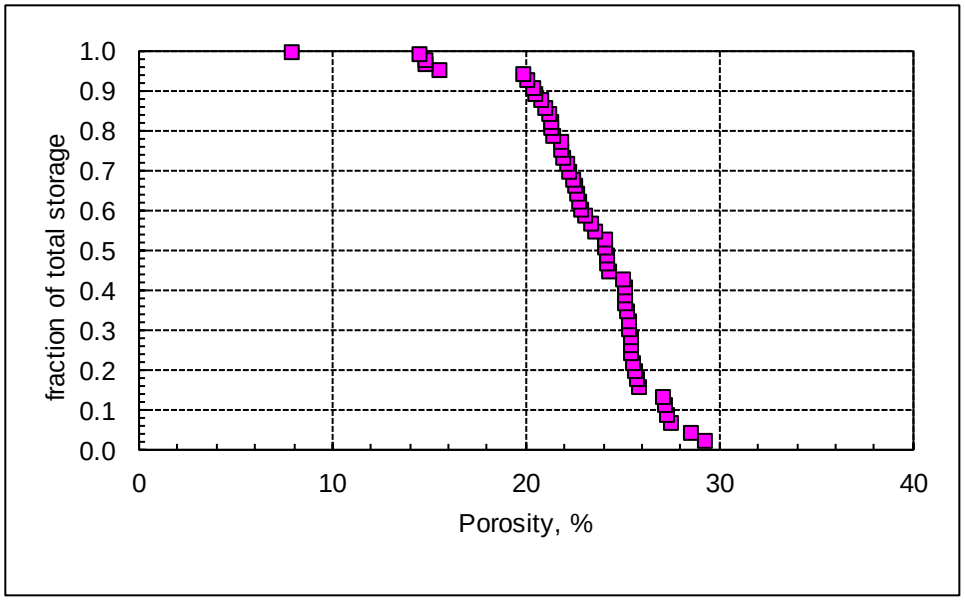
Actual cumulative Production = 364 MBO

Net Pay Using Core Data

Estimation of Porosity cutoff

Sorted ϕ	h, ft	Σh	ϕh	$\Sigma \phi h$	$\Sigma \phi h / \Sigma \phi h_T$
29.2	1	1	29.2	29.2	0.024
28.5	1	2	28.5	57.7	0.048
27.4	1	3	27.4	85.1	0.070
27.2	1	4	27.2	112.3	0.093
⋮	⋮	⋮	⋮	⋮	⋮
7.8	1	53	7.8	1208.6	1.000

Fraction of total storage capacity as a function of sorted porosity for Entrada Sandstone core



Net Pay Using Core Data

Estimation of Porosity cutoff

Sorted ϕ	h, ft	Σh	ϕh	$\Sigma \phi h$	$\Sigma \phi h / \Sigma \phi h_T$
29.2	1	1	29.2	29.2	0.024
28.5	1	2	28.5	57.7	0.048
27.4	1	3	27.4	85.1	0.070
27.2	1	4	27.2	112.3	0.093
⋮	⋮	⋮	⋮	⋮	⋮
7.8	1	53	7.8	1208.6	1.000

Fraction of total storage capacity as a function of sorted porosity for Entrada Sandstone core