

# NET PAY DETERMINATION FOR PRIMARY AND WATERFLOOD DEPLETION MECHANISMS

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BY  
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## INTRODUCTION

The goal of SPE and AAPG's definition of reserves is to identify those **quantities** of oil and gas which, by analysis of geological and engineering data, are anticipated to be **economically recovered** from known reservoirs from a given date forward.

## THEREFORE:

It would seem logical that, at a minimum, *net pay* should represent that portion of the reservoir containing oil and gas reserves which are anticipated to be economically recoverable.

## WHY SUCH A BASIC PRESENTATION?

- Industry guidelines and procedures for computing net pay are very limited or do not exist!
- Net pay is easy to discuss but difficult to quantify!
- Nobody seems to know how to compute it!

## NET PAY DETERMINATION

- No procedures for computing producible net pay in reservoir texts.
- No procedures in formation evaluation texts.
- No procedures in geological texts.
- No procedures from colleges and universities.
- No procedures in industry short courses.

## PURPOSE

To encourage technical publications, closely reevaluate field data in light of unusually low or high recovery factors, and create debate on procedures for selecting net pay cutoffs.

# PRODUCIBLE NET PAY CONSIDERATIONS

- Recognize that producing OOIP may be very different from total OOIP.
- Producing net pay is dependent on the reservoir drive mechanism (primary, secondary, tertiary, etc.)
- Producing OOIP and producing net pay are governed by Darcy's law and must consider rock and fluid properties such as permeability, viscosity, pressure gradient, and skin factor.

Why not incorporate the total OOIP (h) into a numerical simulator and allow it to predict producible oil, thus defining net pay?

- OK, but results would require a finely-gridded, multi-layered model.
- Most reservoirs have not or will not be simulated.

## PRODUCIBLE NET PAY CUTOFFS

- Permeability should be the primary factor used to differentiate between producible net pay and non-pay for a particular reservoir.
- Permeability cutoffs should be calculated after giving consideration to the reservoir drive mechanisms, specific reservoir rock and fluid properties, and reservoir pressure.

## DARCY'S LAW

$$q = \frac{kh(\bar{P} - P_{wf})}{\beta\mu[\ln(\frac{r_e}{r_w}) - 0.75 + S]}$$

Would you use the same permeability  
(or porosity) cutoff for the following  
fluids?

<u>Fluid</u>	<u>Viscosity, cp</u>
Gas	0.02
Oil	2.00
Oil	20.00
Oil	200.00

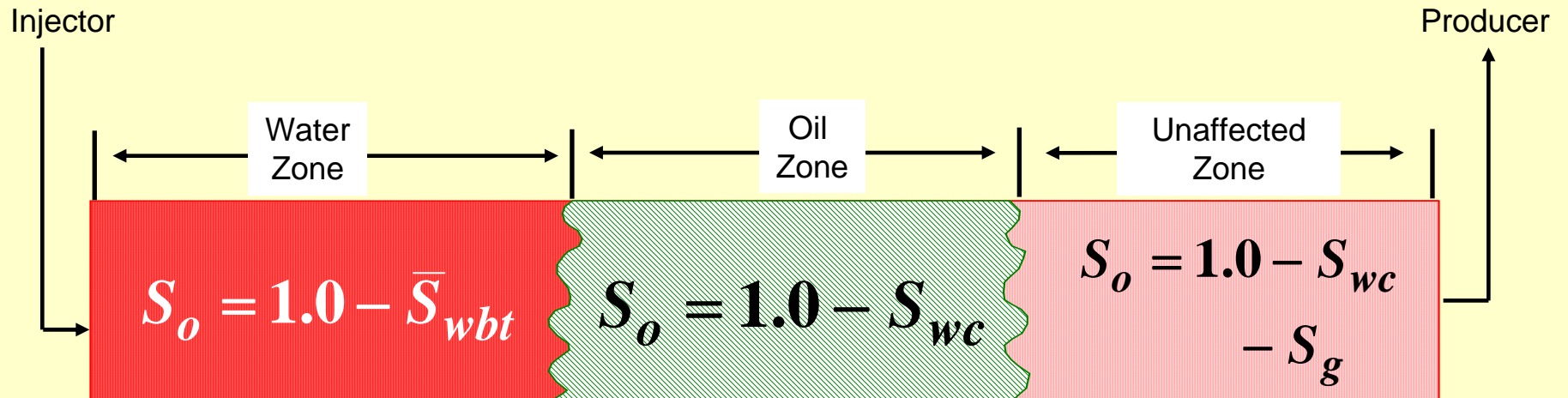
## NET PAY DETERMINATION

- Net pay determination (cutoffs) is a fluid flow issue.
- Reservoir engineers should take the lead role in the selection of net pay cutoff criteria.
- Geologists and/or log analysts will usually take the lead role in the application of cutoffs to log and core data.

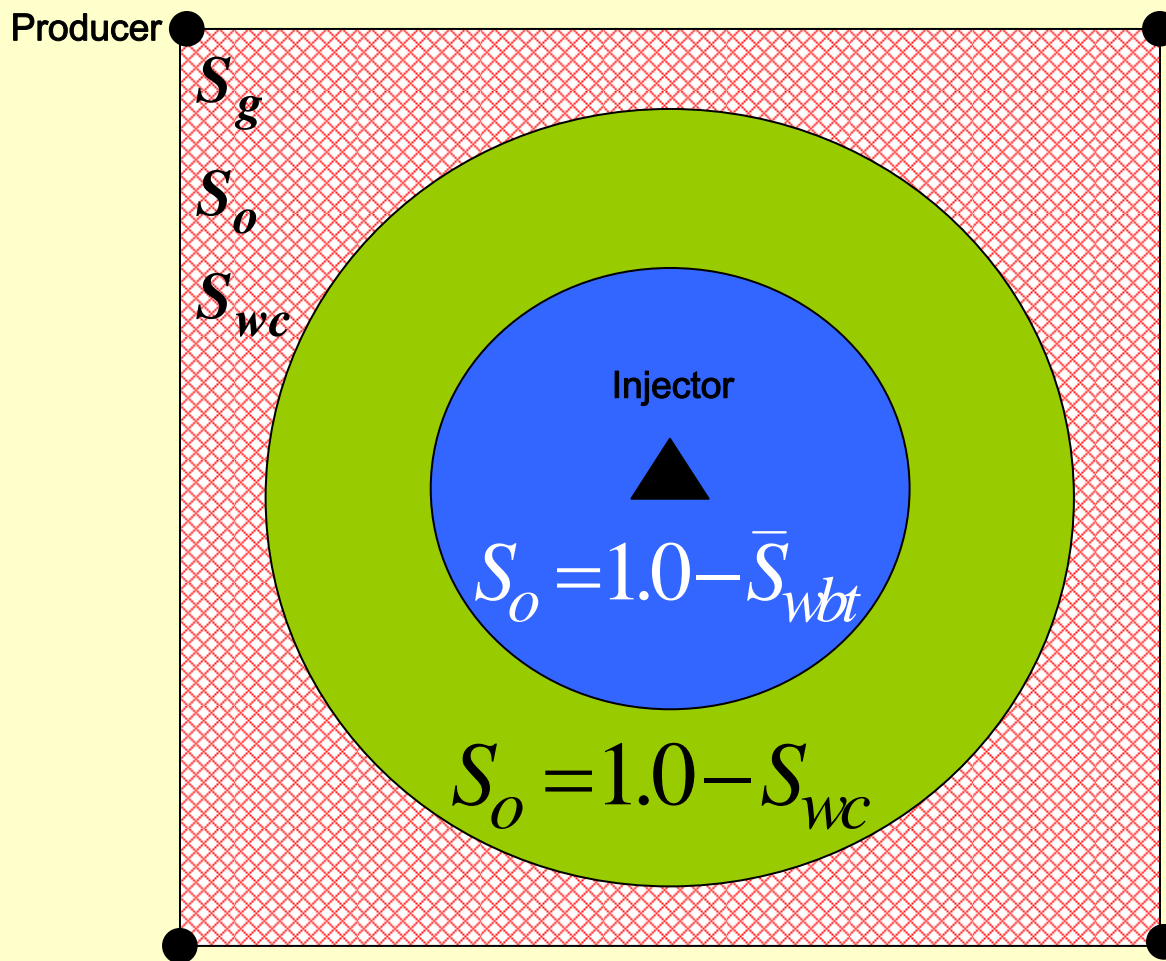
# WATERFLOOD PERMEABILITY CUTOFF DETERMINATION

- SWAG – no technical basis
- Water Cut – more rigorous method

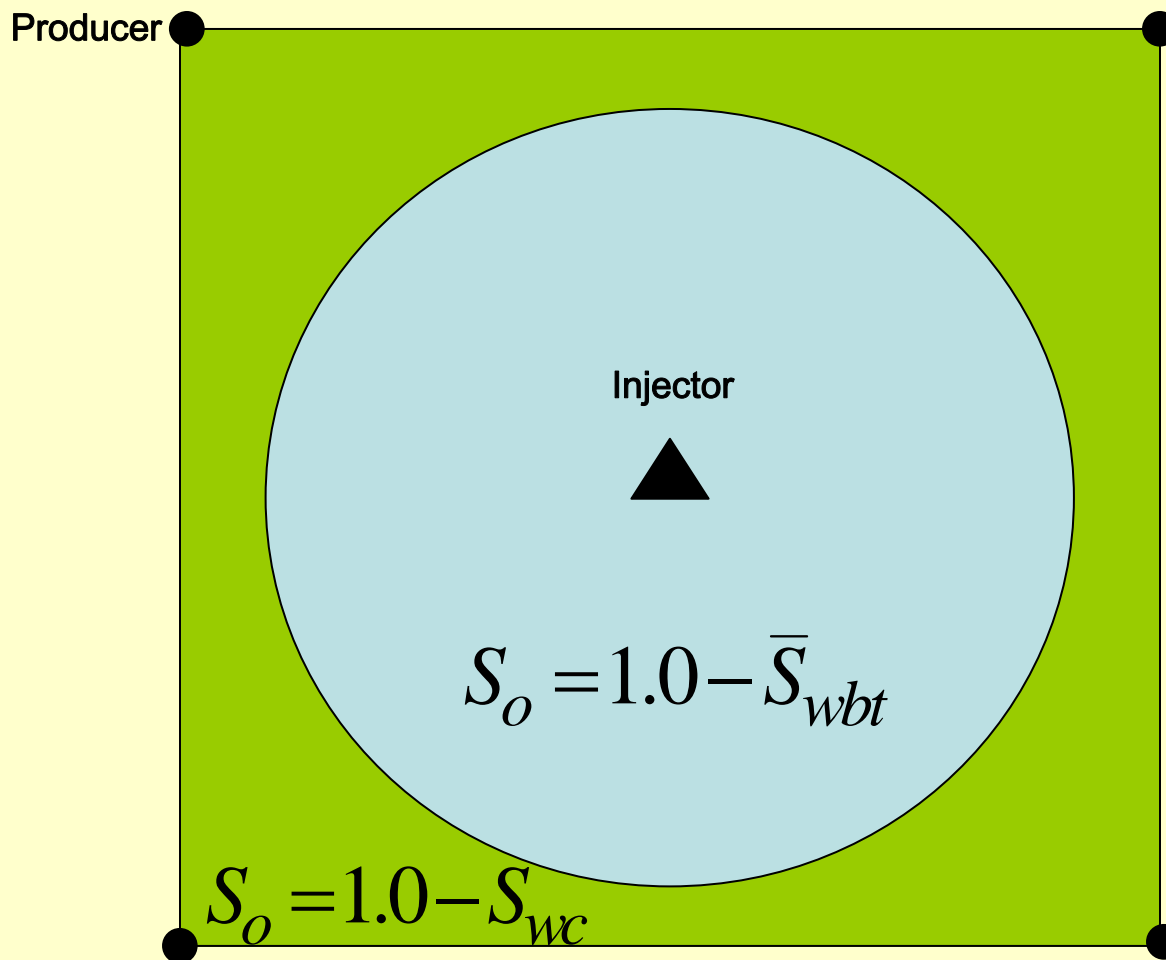
# CROSS-SECTION VIEW OF A SINGLE LAYER DEPICTING FLUID SATURATION DISTRIBUTIONS PRIOR TO GASS FILLUP



# AREAL VIEW OF FLUID SATURATIONS FOR A SINGLE LAYER WITHIN A 5-SPOT PATTERN PRIOR TO GAS FILLUP

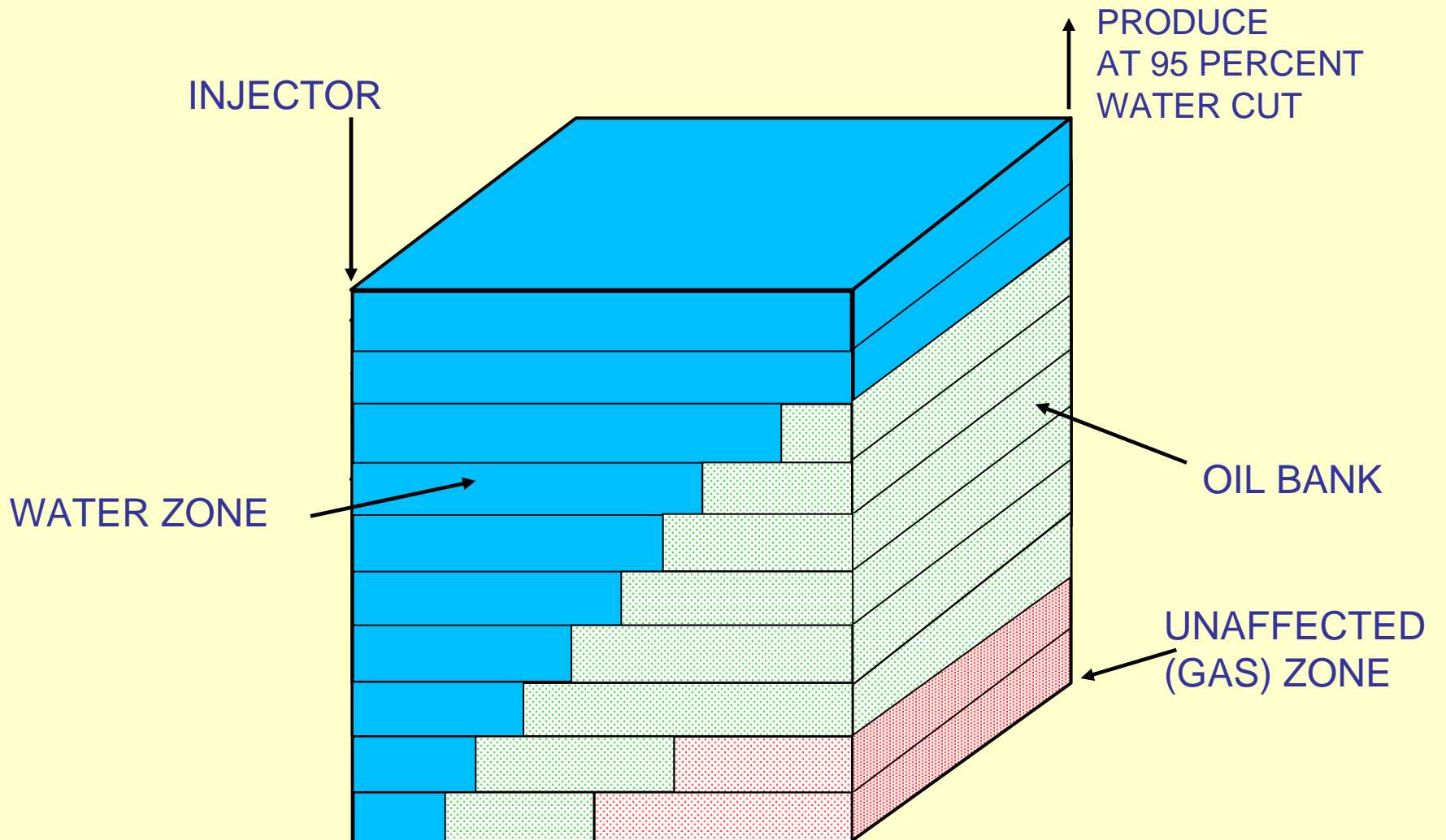


# AREAL VIEW OF FLUID SATURATIONS FOR A SINGLE LAYER WITHIN A 5-SPOT PATTERN AT GAS FILLUP



WATER CUT METHOD  
FOR  
COMPUTING PERMEABILITY  
CUTOFF

THREE-DIMENSIONAL VIEW  
OF A NON-COMMUNICATING MULTI-LAYER 5-SPOT PATTERN  
WITH A PRODUCING WATER CUT OF 95 PERCENT



# HYPOTHETICAL FIVE-SPOT PATTERN USED TO ESTIMATE PERMEABILITY CUTOFFS

## Pattern Area

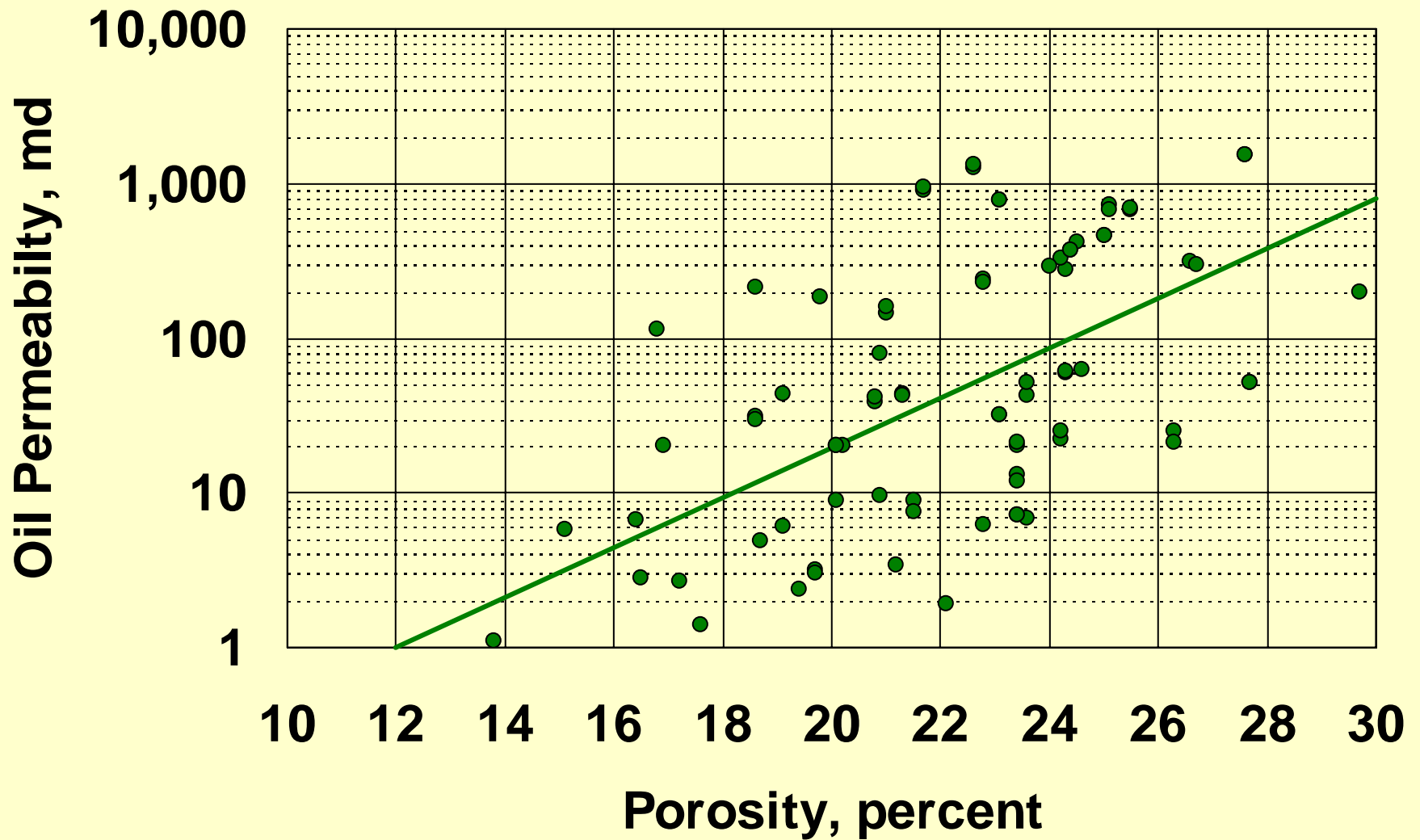
## 80 Acres (40 Acre Well Spacing)

$\bar{p}$	1000 psi at start of water injection
$p_{wi}$	3600 psi
$p_{wf}$	400 psi
$S_i$	0.0
$S_p$	0.0
$\phi$	15 percent
$\mu_w$	0.6 cp
$\mu_o$	3.0 cp
$S_{wc}$	32 %
$S_{or}$	28 %
Relative Permeability	Oil Wet

**PERMEABILITY CUTOFF**  
**USING THE WATER CUT METHOD**  
**AT A 95 PERCENT WATER CUT ECONOMIC LIMIT**

<u>Dykstra-Parsons, V</u>	80 Acre Pattern $k_{50} = 20 \text{ md}, S_i = 0$	
	$S_g = 0\%$	$S_g = 10\%$
	0.6	0.24
0.7	0.71	3.30
0.8	1.20	3.60

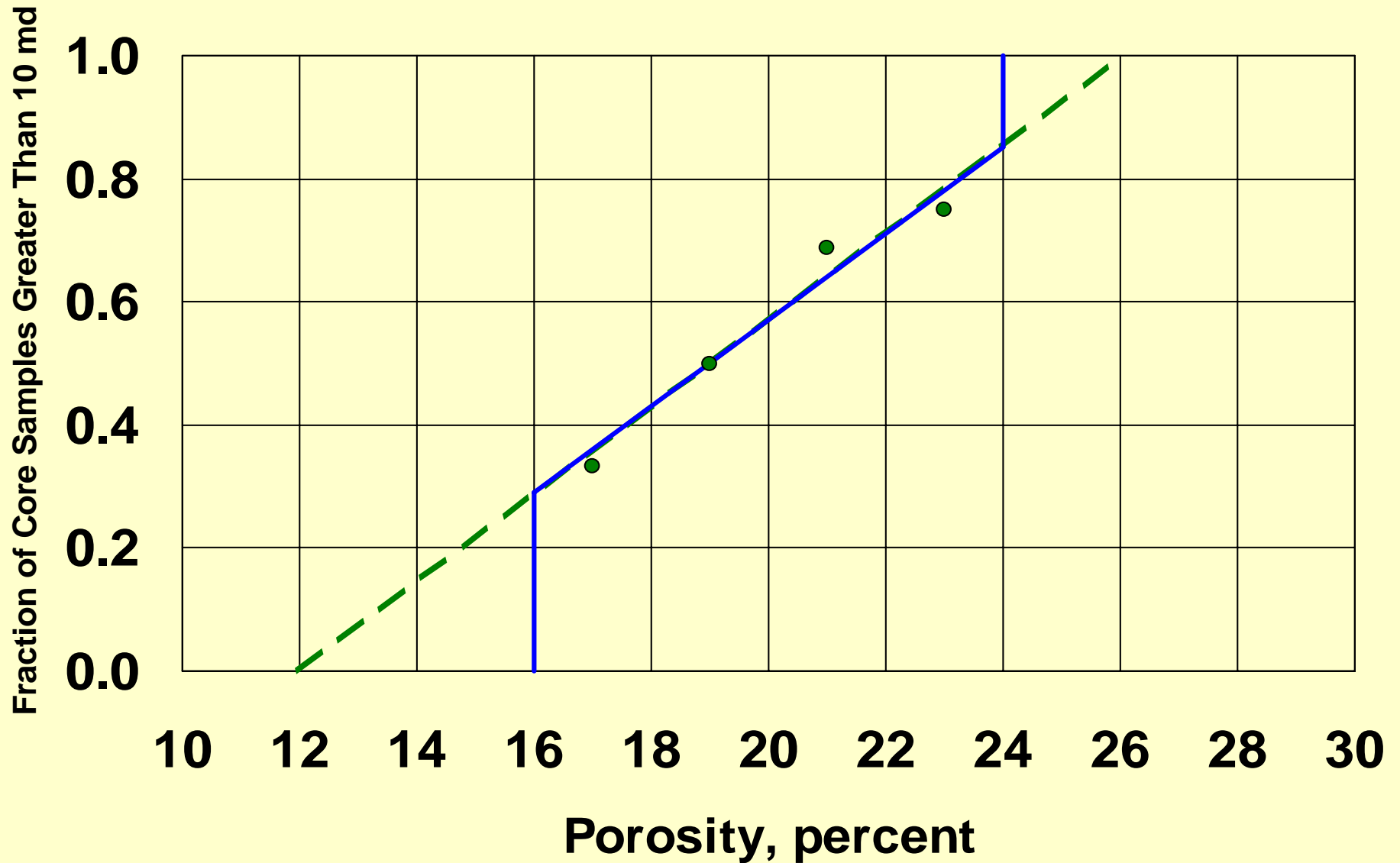
# OIL PERMEABILITY AT IRREDUCIBLE WATER SATURATION VERSUS POROSITY FOR RESERVOIR C



# FRACTION OF CORE SAMPLES WITH PERMEABILITY GREATER THAN THE PERMEABILITY CUTOFF FOR DIFFERENT POROSITY RANGES

Porosity Range <u>percent</u>	Fraction of Core Samples with Permeability Greater Than 10 md <u>(Weighting Factor)</u>
Less than 16	0.00
16 to 18	$2/6 = 0.333$
18 to 20	$5/10 = 0.500$
20 to 22	$11/16 = 0.688$
22 to 24	$12/16 = 0.750$
Greater than 24	1.00

**FRACTION OF CORE SAMPLES WITHIN A POROSITY RANGE  
(WEIGHTING FACTOR) WITH PERMEABILITY  
GREATER THAN CUTOFF VALUE OF 10 MD FOR RESERVOIR C**



# CONCLUSIONS

- Technical literature provides little information regarding guidelines for selecting net pay criteria.
- Fluid mobility is a major consideration in developing net pay cutoffs.
- Permeability should be the principle basis for differentiating between pay and non-pay.

# CONCLUSIONS

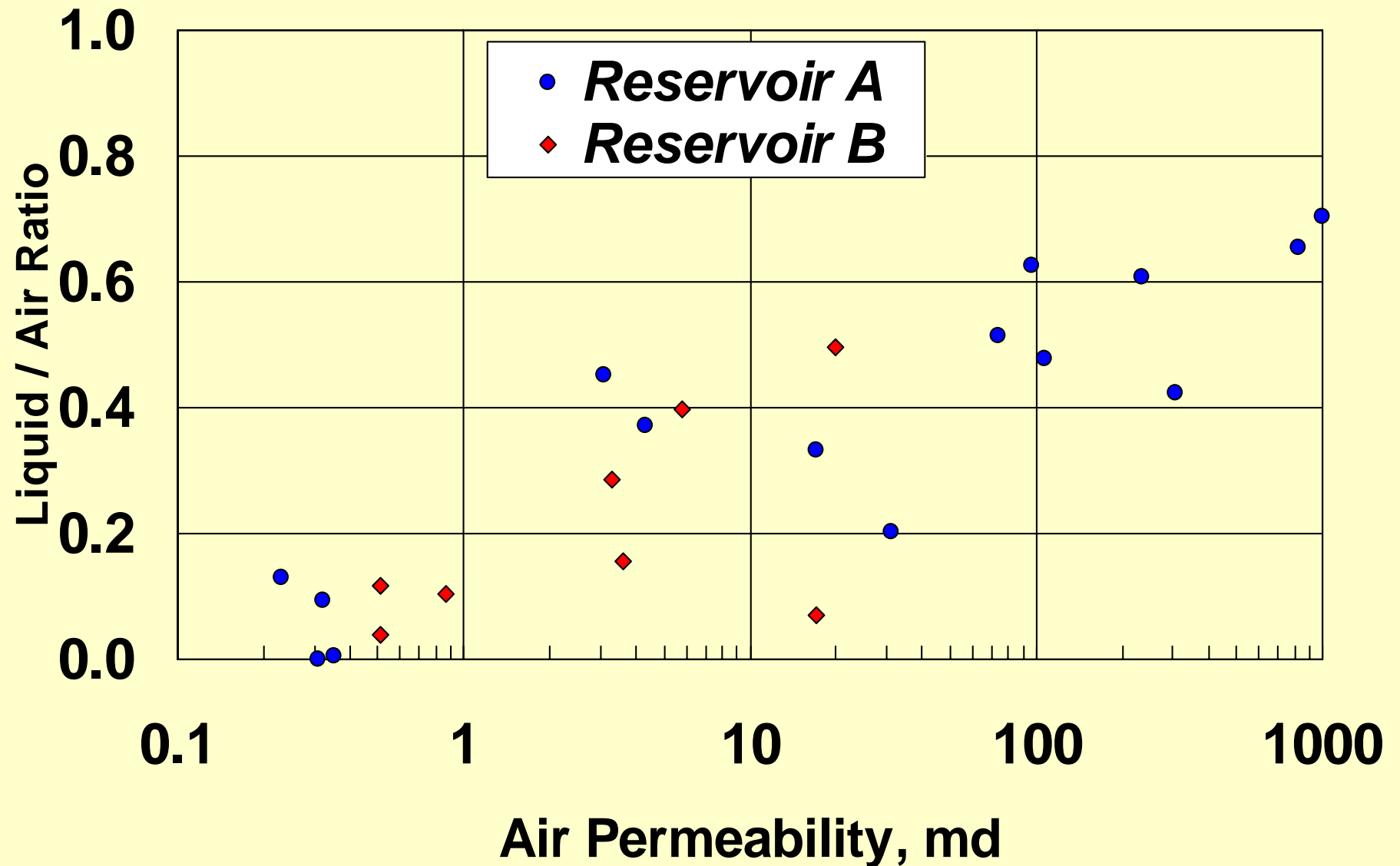
- Net pay cutoffs will depend on the drive mechanism (primary vs waterflooding) and will result in lower values for primary depletion.
- Secondary net pay cutoff should give consideration to a number of factors including:
  - ✓ Mobility Ratio
  - ✓ Relative Permeability
  - ✓ Gas Saturation
  - ✓ Pressure Drop
  - ✓ Skin Factors
  - ✓ Well Spacing
  - ✓ Lateral Continuity
  - ✓ Water Cut Economic Limit

## CONCLUSIONS

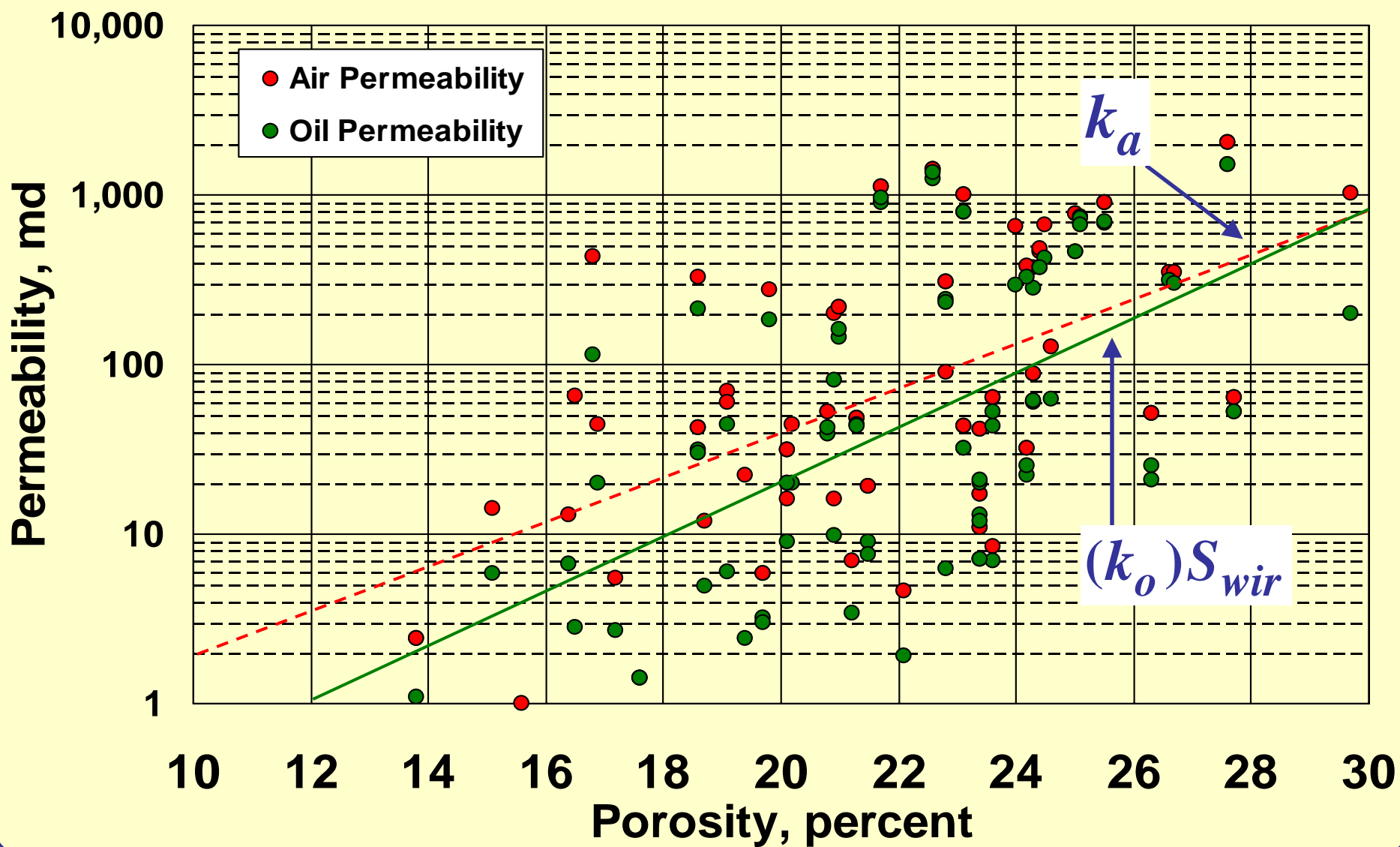
- A procedure, the water cut method, is presented which provides insight into the determination of producible net pay permeability cutoff for use in waterflood screening, feasibility, and surveillance calculations.
- For a more detailed description of this method see SPE Paper No. 48952 entitled “Net Pay Determination for Primary and Waterflood Depletion Mechanisms” by Cobb and Marek.

## Two Significant Comments Related to Permeability

# RATIO OF LIQUID/AIR PERMEABILITY VERSUS AIR PERMEABILITY FOR TWO SANDSTONE RESERVOIRS



# COMPARISON OF AIR AND OIL PERMEABILITY VERSUS POROSITY FOR RESERVOIR C



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