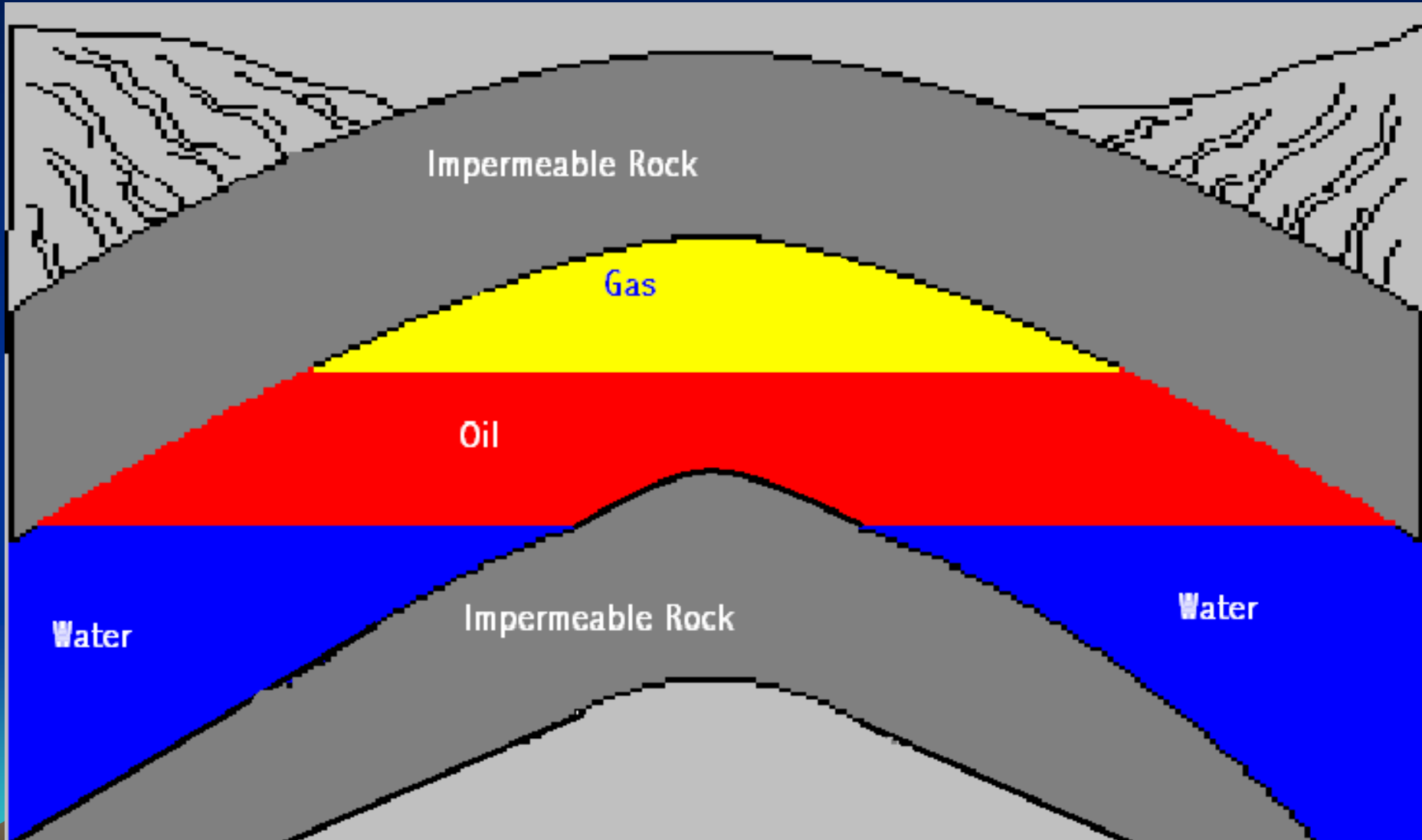


RESERVES

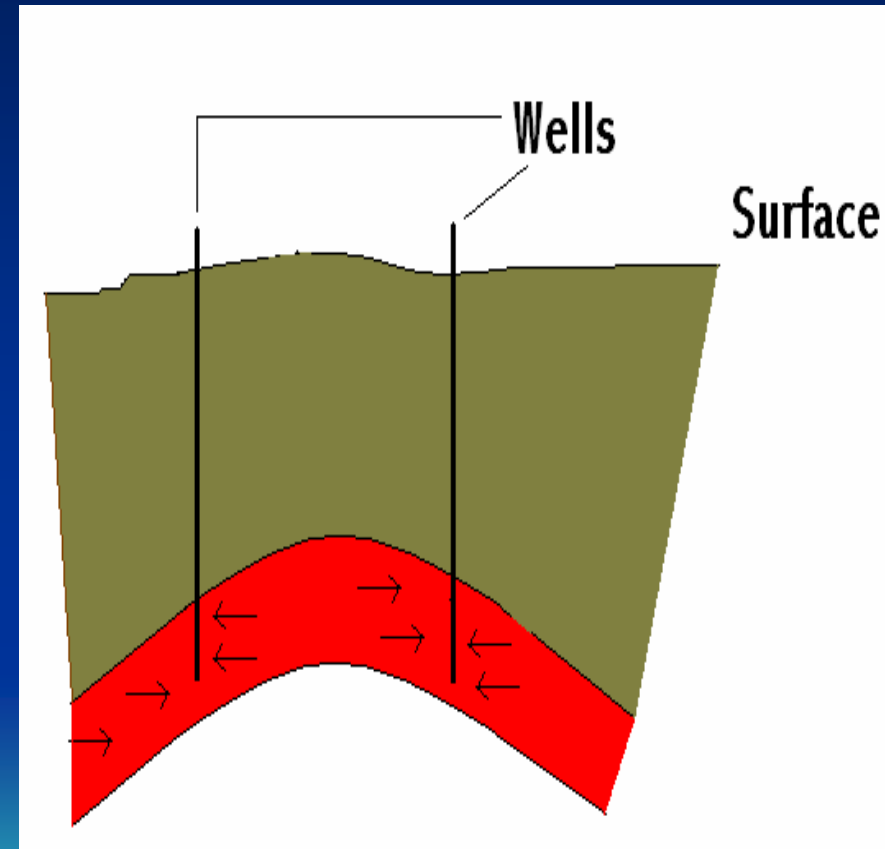
***What They Mean
and
How They Are Calculated***

Cross-section of Typical Oil Field

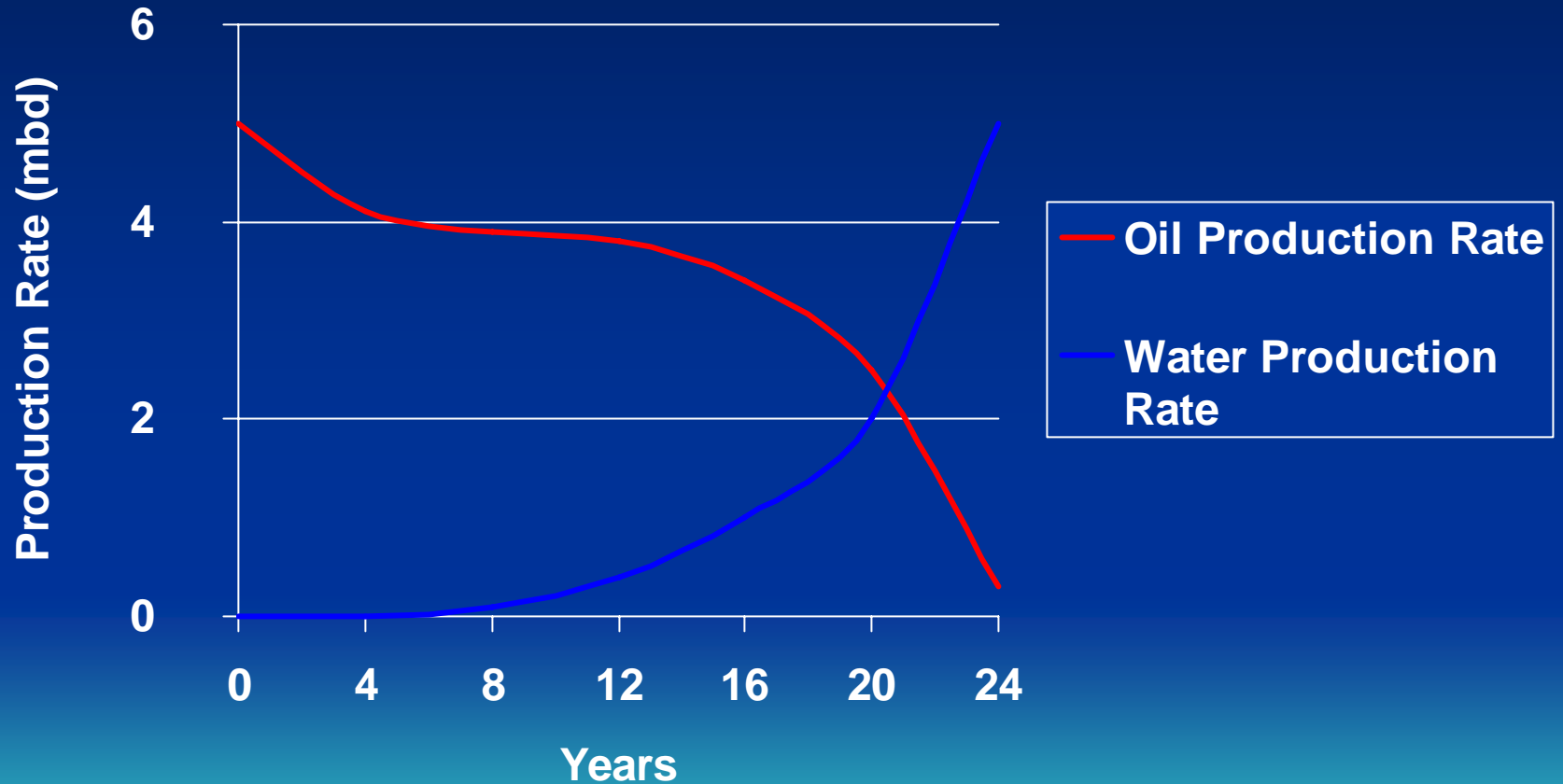


Typical Producing Oil Field

- Pressure in rock's pore system forces oil into wells and towards the surface
- Water beneath the oil moves upwards, supporting oil flow; ultimately it reaches wells
- Gas does the same - but from above



Typical Well Production Profile



Resources & Reserves (1)

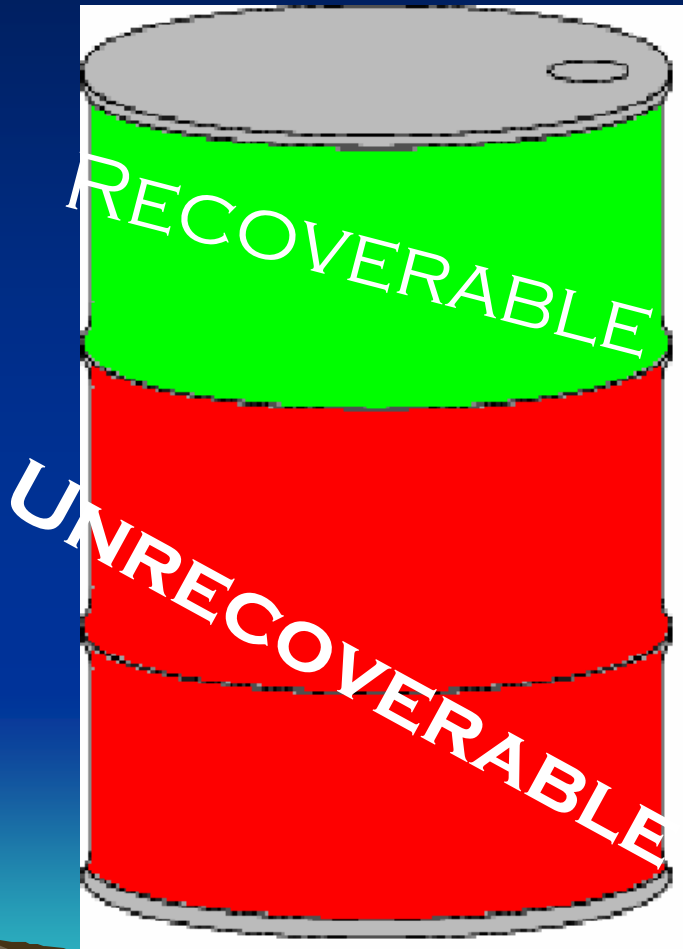
Resources

- Total volume of oil/gas in the reservoir
- Often called 'oil-in-place' or 'gas-in-place'.

Reserves

- Volume of oil / gas in the reservoir which we can produce

Resources & Reserves (2)



- One barrel of **RESOURCE**
- yields a much smaller volume of **RESERVES**
- On average we now recover only about 35% of oil-in-place

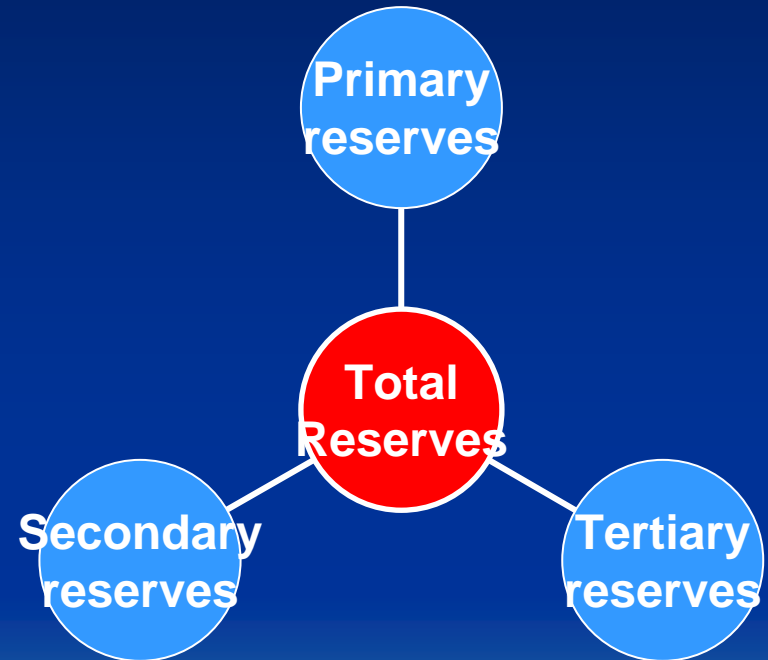
Recovery Efficiency

- Recovery Efficiency =
$$\frac{\text{Reserve volume}}{\text{Resource volume}}$$

Recovery Efficiency depends on both technical and economic factors, **NOT just geology**

Total Reserves

- Reserves are often sub-divided:



Primary Reserves

- Depend only on natural reservoir energy for production
- Recovery Efficiency depends on:
 - Compressibility of oil
 - Gas dissolved in oil
 - Gas-cap
 - Strength of associated aquifer

6 – 40 % of oil-in-place recovered

Secondary Reserves

- **Augment natural reservoir energy by injecting water or gas to help maintain pressure**

Additional 0 – 40 % of oil-in-place recovered

Tertiary Reserves

- **Modify physical properties of reservoir fluids by chemical or thermal means**

Additional 0 – 10% of oil-in-place recovered

Porosity of a Rock

Reservoir rock composed of tiny irregular grains cemented together

Voids between grains provide space for fluids to move

Porosity (fraction) = $\frac{\text{Void vol.}}{\text{Rock vol.}}$



Porosity depends mainly on sand grain shape and sorting

Estimating Oil-in-Place

Volume of oil-in-place:

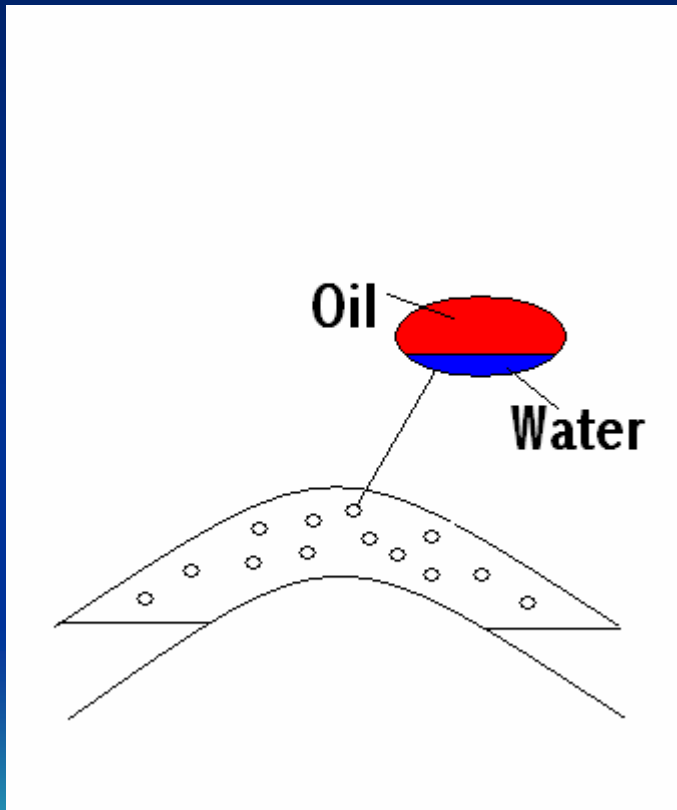
Rock Volume

x

Porosity Fraction

x

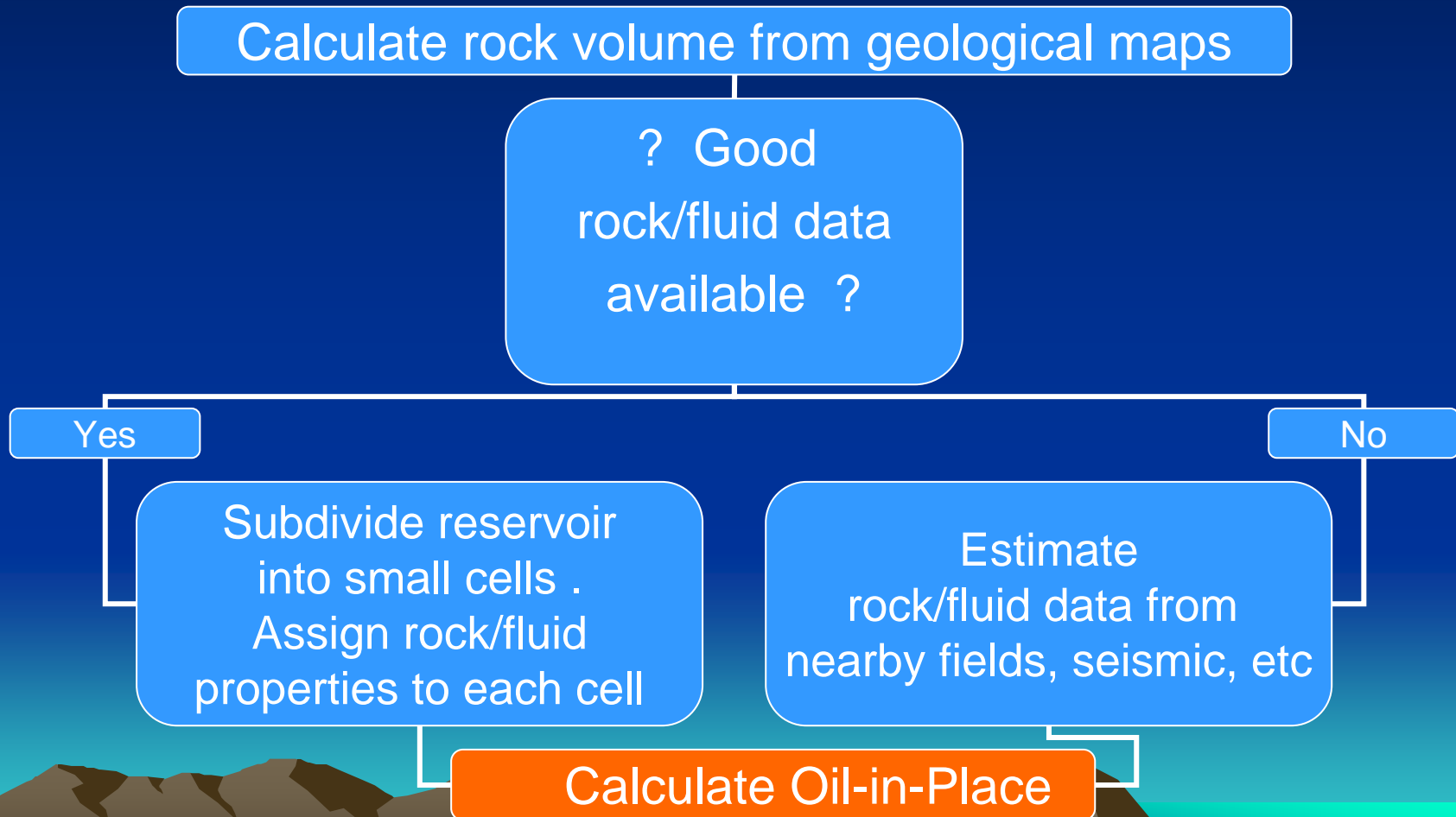
Oil saturation in pores



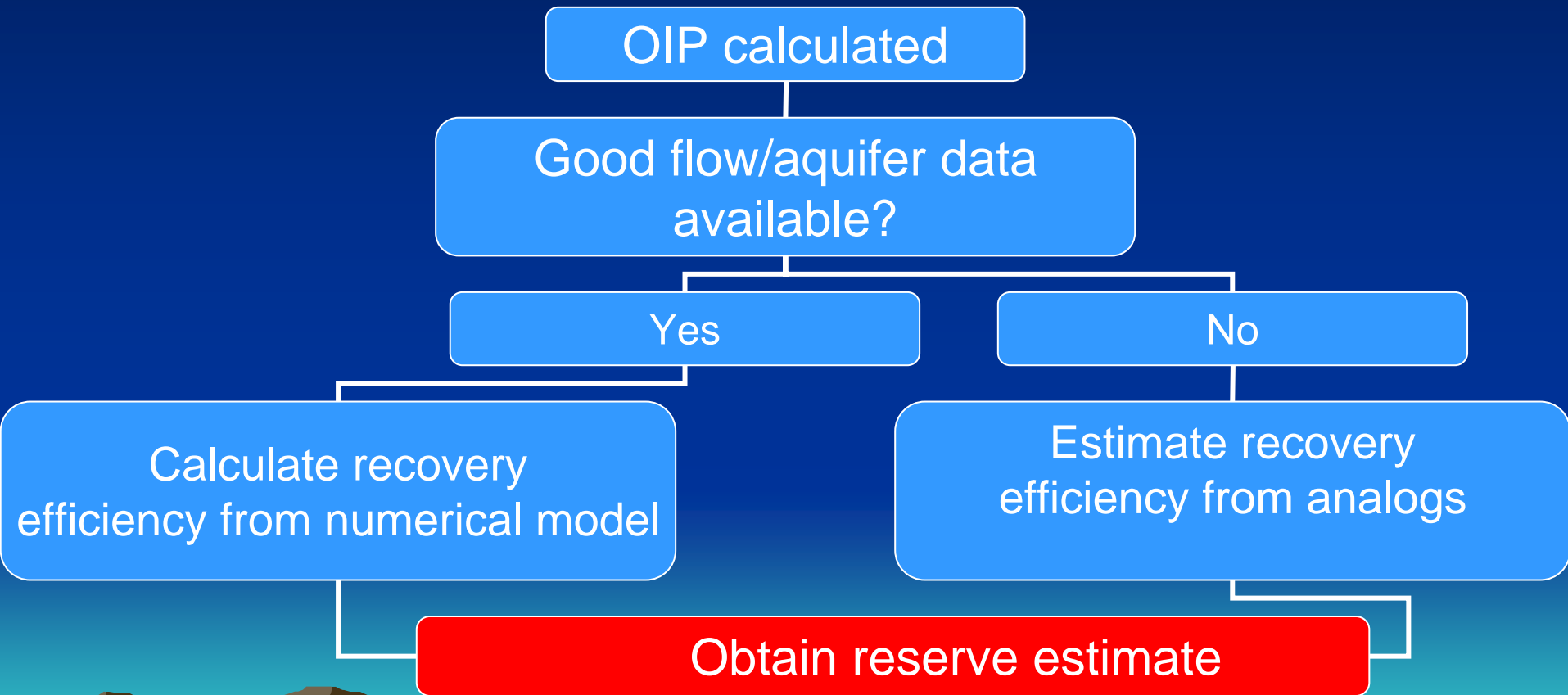
Estimating Oil-in-Place and Reserves

- Data always scarce - particularly at exploration / appraisal stage
- More data means *more accurate estimate*
- Initial estimates made by **geologists** on basis of analogs
- Later estimates made by **engineers** using numerical models

Estimating Oil-in-Place and Reserves



Estimating Oil-in-Place and Reserves



Principal Sources of Volumetric Data

DATA	SOURCE
Porosity	Wireline logs Rock samples
Oil saturation in rock pores	Wireline logs
Rock and fluid compressibilities	Rock and fluid samples

Problems in calculating OIP/Reserves

Analog Method

Reservoirs thought to be good analogs may in fact be different

Engineering Method

Even in best situations, data available from only tiny fraction of reservoir volume

Much interpolation/
extrapolation needed

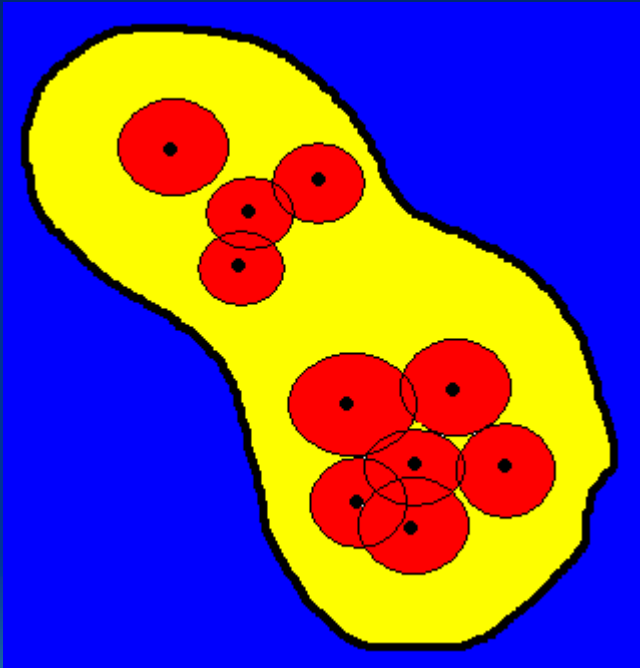
SEC Reserves Calculation

- US SEC sets rules for amount of extrapolation/interpolation allowed in calculating volumes of proved oil
- Rules result in very conservative reserves reporting
- Volumes almost always increase as additional data is gathered from infill / deeper wells
- Rules are out-of-date and incompatible with modern approach to reservoir appraisal

Application of SEC Rules

- Used by virtually all US and major international companies
- Alternative – but still strict – rules used by some non-US companies and some national companies
- Standards used by some foreign companies and many national companies not known

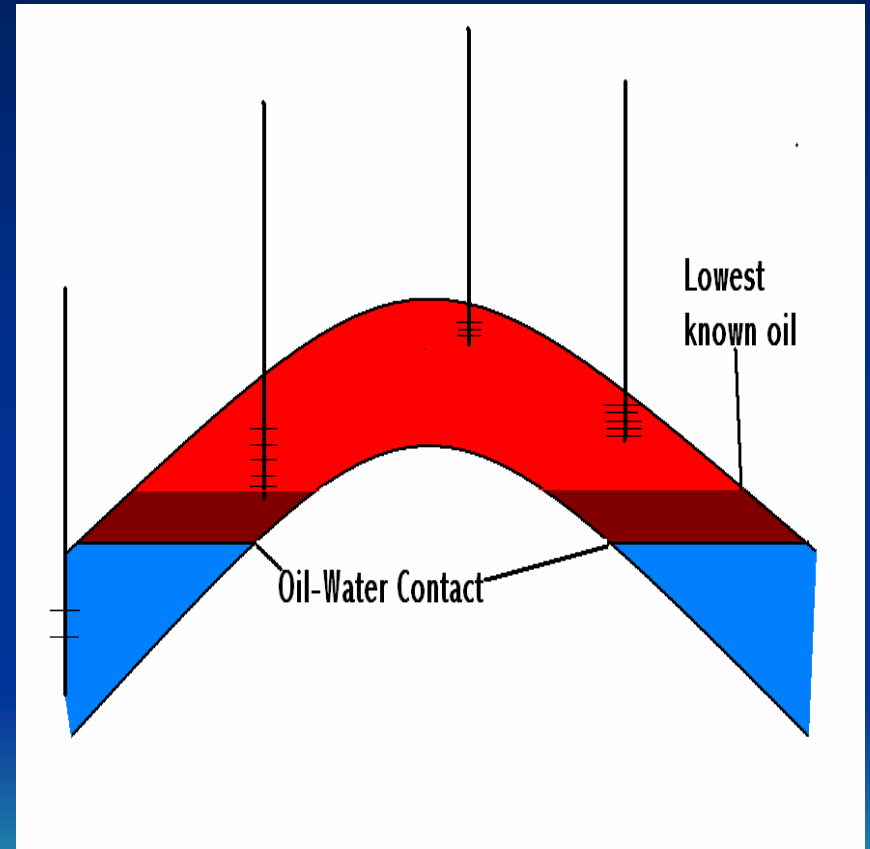
SEC Definitions: Problems (1)



- Need to be able to confirm properties in yellow areas, else must ignore oil which we can confidently predict to be there.

SEC Definitions: Problems (2)

- Need to prove position of oil-water contact, else must ignore volume which we can confidently predict to be there below '*lowest known oil*'



SEC Definitions: Problems (3)

- SEC definitions only recognize oil which can be recovered under existing economic and technical conditions
- Technology improves!
- Oil prices change –higher prices usually mean higher reserves (but NOT always for developer)

Hindsight v. Foresight (1)

	<i>OIP</i>	<i>Initial Reserves</i>	<i>Current OIP</i>	<i>Current Reserves</i>
<i>Forties</i>	4.6	n.a. / 1.8	5.0	2.7 – 3.0
<i>Prudhoe Bay</i>	24	13.5 / 9.0	25	12 - 15

All data in billion barrels

Hindsight v. Foresight (2)

Estimated Recovery Efficiency (%)

	At Start Up	Now
Forties	39	~ 60
Prudhoe Bay	38	~ 54

??How much of increase due to:

SEC 'reserves growth'

New technology

Increased oil price

Changed reservoir description

OPEC Reserves

- Basis for calculation unknown
- Reasons for huge growth unclear – and unlikely to be technically sound
- Some increase justified on basis of technology advances and higher prices

	A. Dhabi	Iran	Iraq	Kuwait	N. Zone	S. Arabia	Venezuela
1980	28	58	31	65	6.1	163	18
1981	29	58	30	66	6.0	165	18
1982	31	57	30	65	5.9	164	20
1983	31	55	41	64	5.7	162	22
1984	30	51	43	64	5.6	166	25
1985	31	49	45	90	5.4	169	26
1986	30	48	44	90	5.4	169	26
1987	31	49	47	92	5.3	167	25
1988	92	93	100	92	5.2	167	56
1989	92	93	100	92	5.2	170	58
1990	92	93	100	92	5.0	258	59
1991	92	93	100	95	5.0	259	59
1992	92	93	100	94	5.0	259	63
1993	92	93	100	94	5.0	259	63
1994	92	89	100	94	5.0	259	65
1995	92	88	100	94	5.0	259	65
1996	92	93	112	94	5.0	259	65
1997	92	93	113	94	5.0	259	72
1998	92	90	113	94	5.0	259	73
1999	92	90	113	94	5.0	261	73
2000	92	90	113	94	5.0	261	77
2001	92	90	113	94	5.0	261	78
2002	92	90	113	94	5.0	250	78

OPEC's Reported Reserves

Kuwait 1984

Produced: 22 Gb
 Remaining: 64 Gb
 Total Found: 86 Gb

ASPO Reserve Estimates

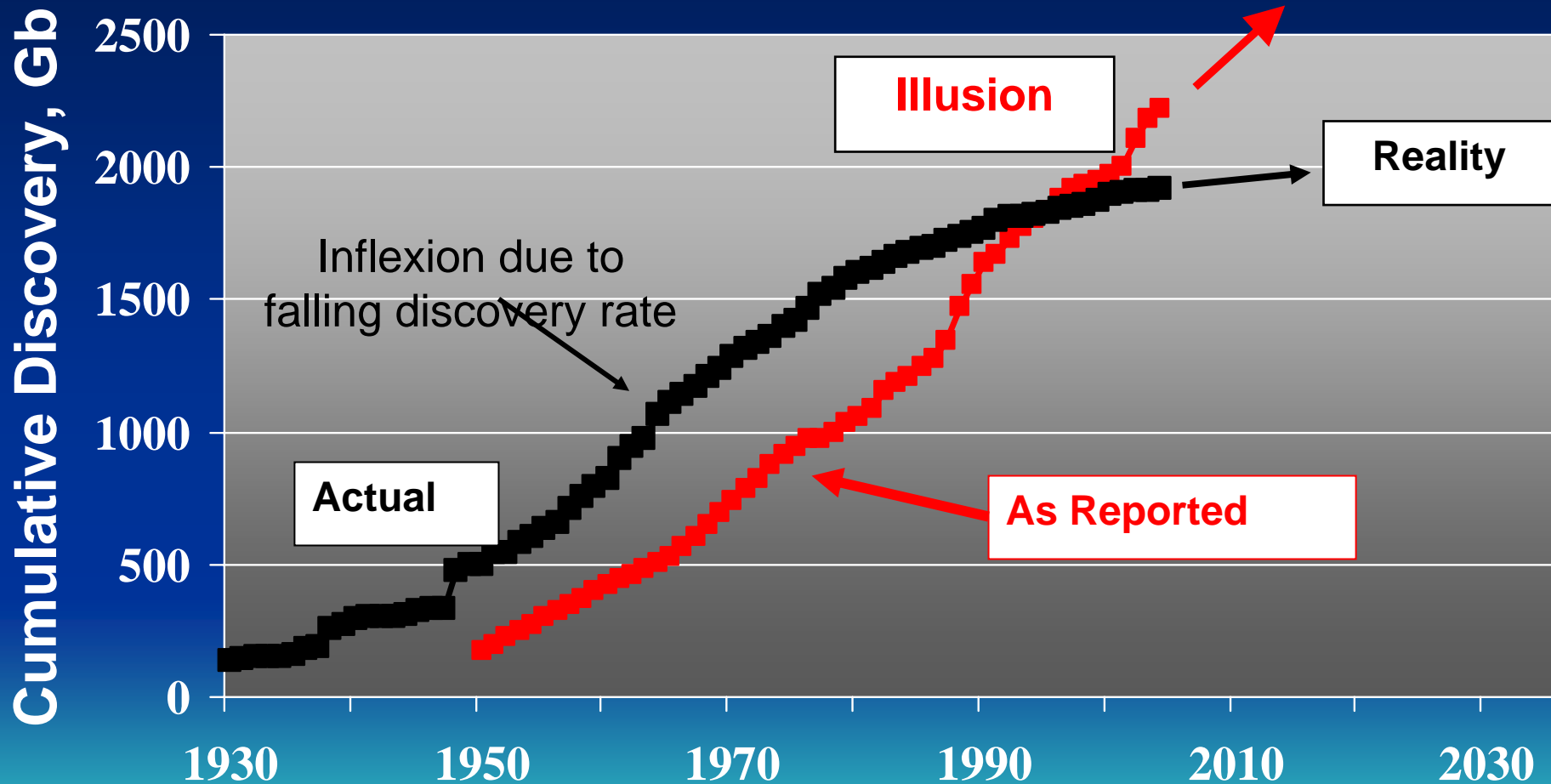
Base data from world's best data bases and reviewed/edited by impartial experts

BUT

Many countries have sparse / uncertain data

**Estimates are for oil prices ~ 50% of current;
impact of additional drilling / facilities
enabled by higher prices not yet considered**

Reality and Illusion



Draining the Tanks - Regular Oil

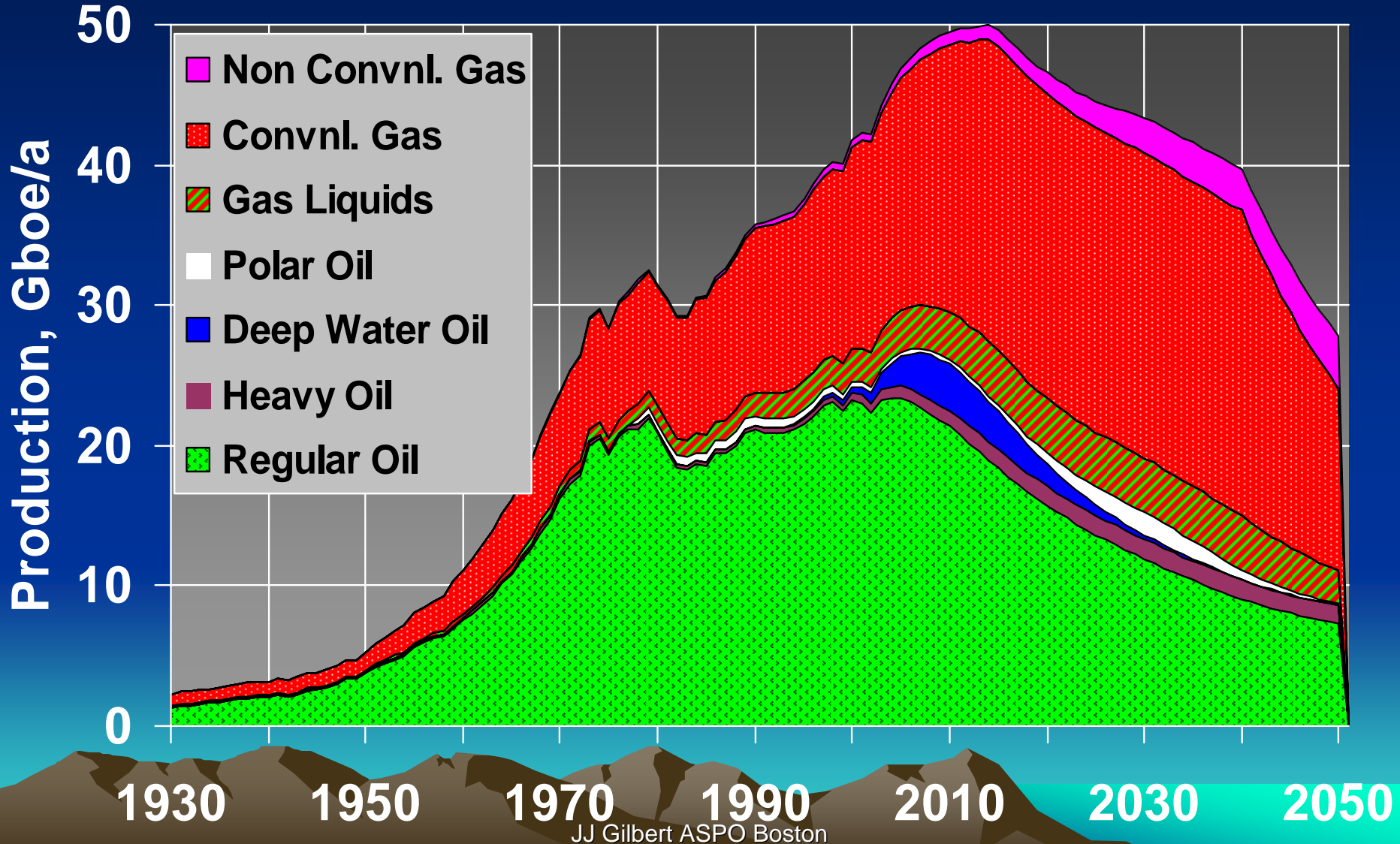


..... to be continued!

For the ASPO 'Blueprint' :

- **Build relationship with upstream industry which allows discussion, data transfer and mutual respect**
- **Attract people with knowledge of upstream industry into ASPO; use their expertise and contacts to improve understanding of future supply**
- **Improve ASPO's capability of analyzing reserves data to obtain estimates of future oil availability**

All Oil & Gas



Reality and Illusion

