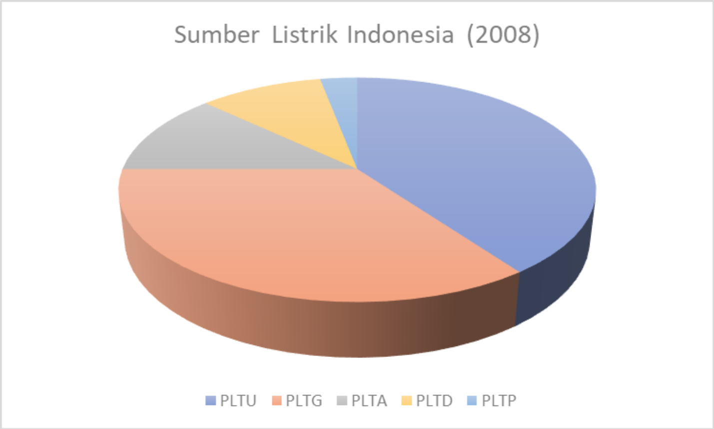
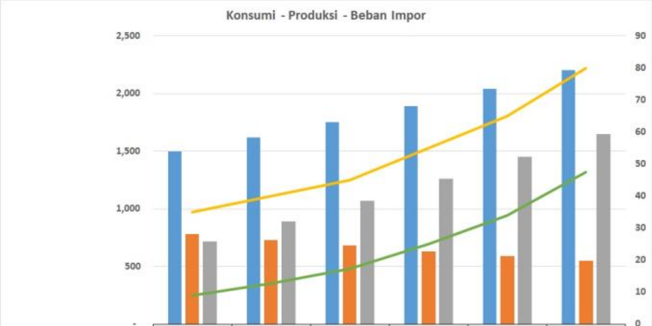
Minyak & Gas Sebagai Sumber Daya Energi
Understanding Petroleum Sytem
Case Study: East Java

Budi R Permana

9th April 2022

TecrÜbe
Energi Negeri





	2015	2016	2017	2018	2019	2020
Konsumsi BBM	1,500	1,620	1,750	1,890	2,040	2,200
Produksi Minyak	780	730	680	630	590	550
Defisit	720	890	1,070	1,260	1,450	1,650
Rerata CP (USD - Barrel)	35	40	45	55	65	80
Est. Tahunan (USD Miliar)	9	13	17	25	34	48

Hydrocarbon

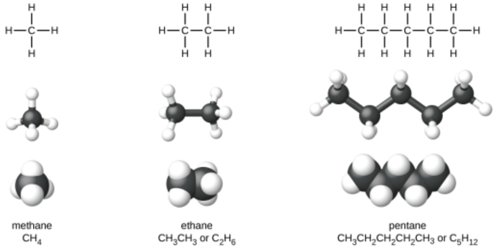
Crude Oil

Gas

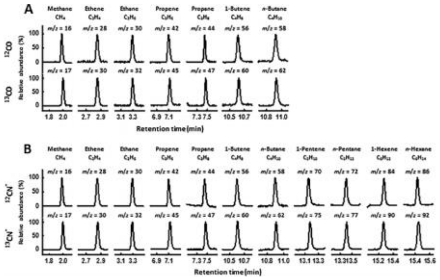
Crude Oil : A mixture of liquid hydrocarbon, occasionally contains some nitrogen, sulfur, and oxygen

https://kimray.com/

Petroleum



Natural Gas: colorless highly flammable gaseous hydrocarbon consisting primarily of methane and ethane, occasionally contains CO_2, H_2S, N_2



Early History

Modern History

Indonesia before Independent

- Babel Tower
- Oil well in China in 347 using bamboo 800 ft
- In 7th Century Srivijaya used black oil for lamp
- In 9th century first street in Bagdad using tar
- In 9th oil mine in Baku

Baku (Azerbaijan)
1840-1848 (20+ meter)

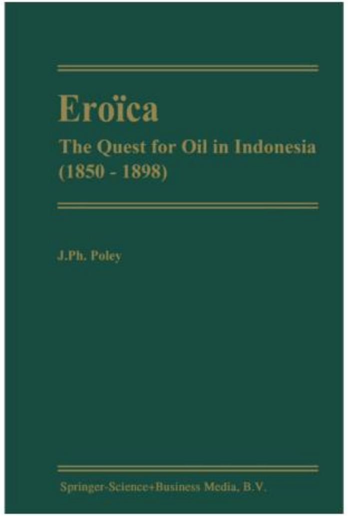
Pennsylvania - Edwin Drake
1859 (69.5 feet)

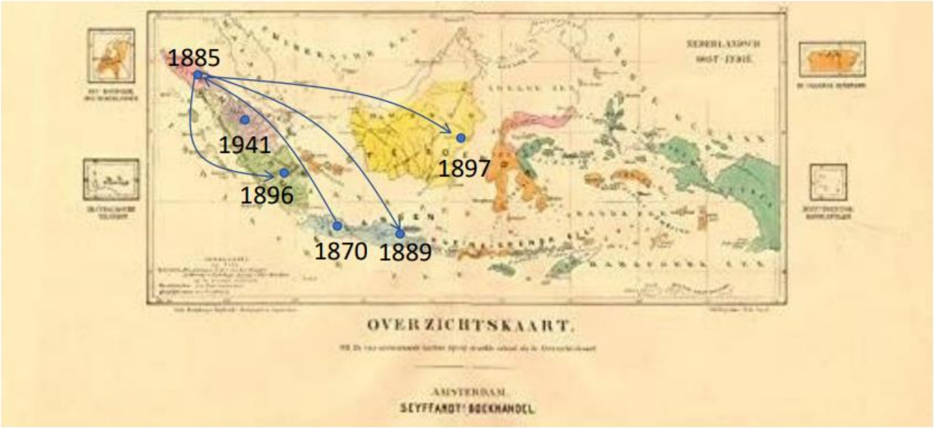
Jan Reerink

Majalengka 1870-1874 (~125 ft)

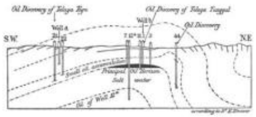
Aeilko Jans Zijklert

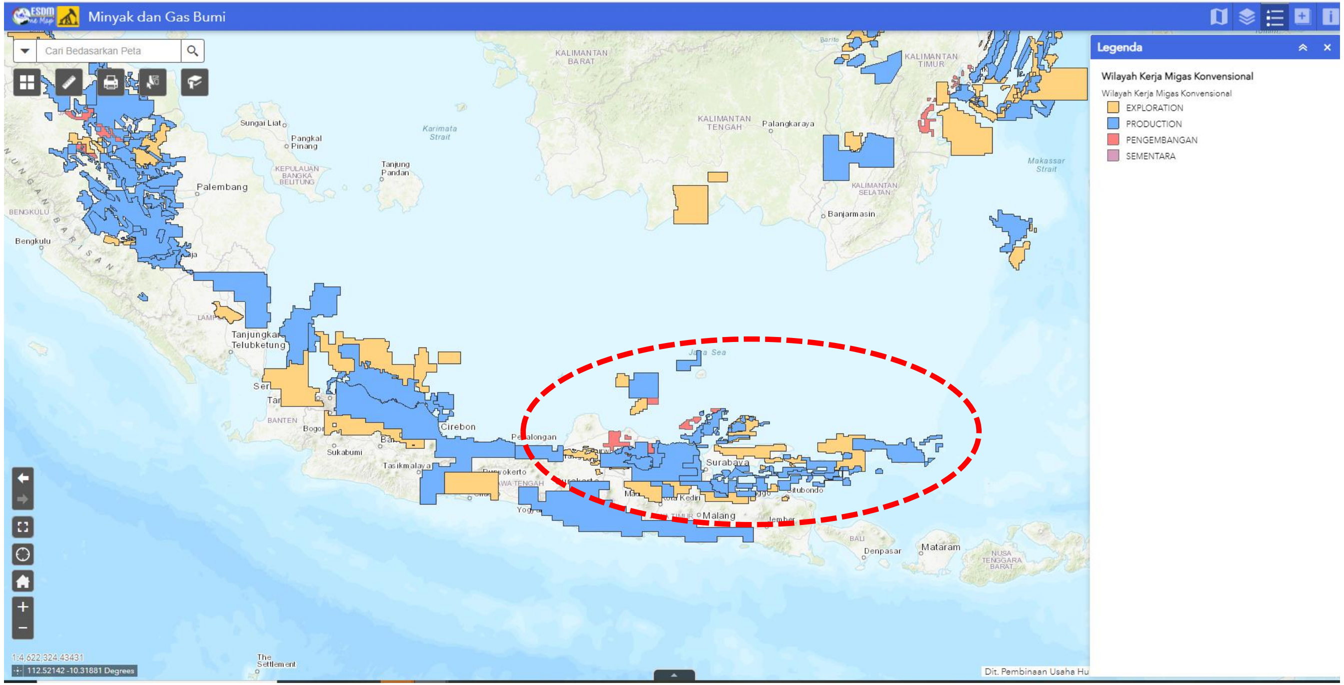
Telaga Tunggal-1 (Langkat, 1885)
~121 m





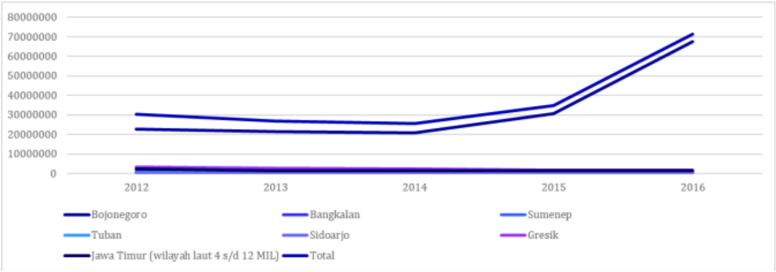
Kruka is the first oil field that was discovered in east Java





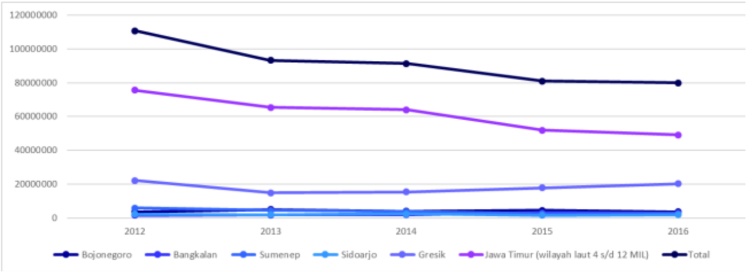
- Cadangan minyak dan gas bumi terbesar ketiga setelah Kalimantan Timur dan Riau
- Terdapat sekitar kurang lebih 40 wilayah kerja MIGAS

Tren Produksi Minyak Mentah (Barel) Beberapa Kabupaten di Jawa Timur (2012 – 2016)

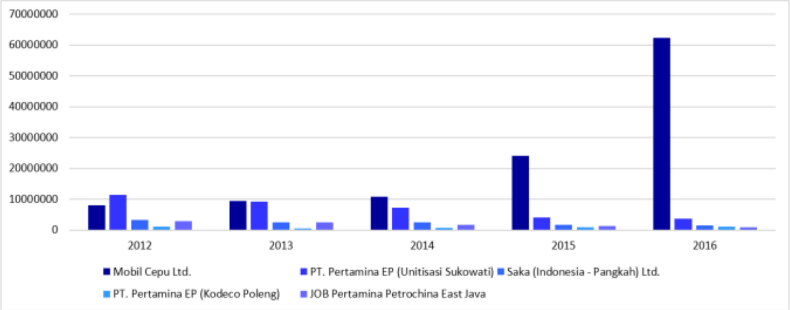


Sumber: Kementerian ESDM, www.lifting.migas.esdm.go.id (Diolah, PWYP, 2017)

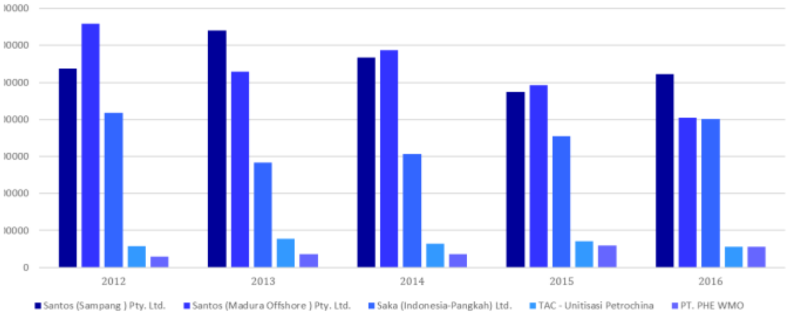
Tren Produksi Gas (MMBTU) Beberapa Kabupaten di Jawa Timur (2012 – 2016)



Sumber: Kementerian ESDM, www.lifting.migas.esdm.go.id (Diolah, PWYP, 2017)



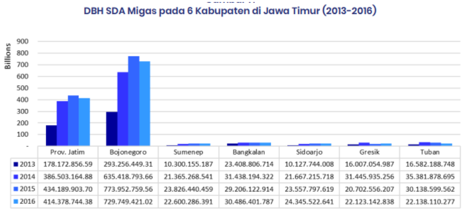
Sumber: Kementerian ESDM, www.lifting.migas.esdm.go.id



Sumber: Kementerian ESDM, www.lifting.migas.esdm.go.id (Diolah, PWYP, 2017)

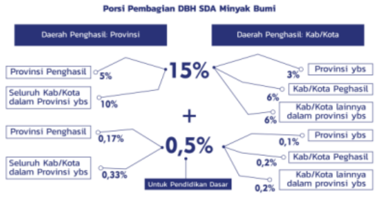
Dahkelan, et al., 2017

- Total pendapatan negara 2020 → Rp 1.633,6 Triliun
- Pendapatan negara Oil & Gas → Rp 110 Triliun



	Prov. Jatim	Bojonegoro	Sumenep	Bangkalan	Sidoarjo	Gresik	Tuban
2013	178.172.856.59	293.256.449.31	10.300.155.187	23.408.806.714	10.127.744.008	16.007.054.987	16.582.188.748
2014	386.503.164.88	635.418.793.66	21.365.268.541	31.438.194.322	21.667.215.718	31.445.935.256	35.381.878.695
2015	434.189.903.70	773.952.759.56	23.826.440.459	29.206.122.914	23.557.797.619	20.702.556.207	30.138.599.562
2016	414.378.744.38	729.749.421.02	22.600.286.391	30.486.401.787	24.345.522.641	22.123.142.838	22.138.110.277

Sumber: Laporan Keuangan Pemerintah Pusat (LKPP) Tahun 2013-2016 (Diolah, FITRA Jatim, 2017)



Sumber: Maryati, Ambarsari (Pattiro, 2010)

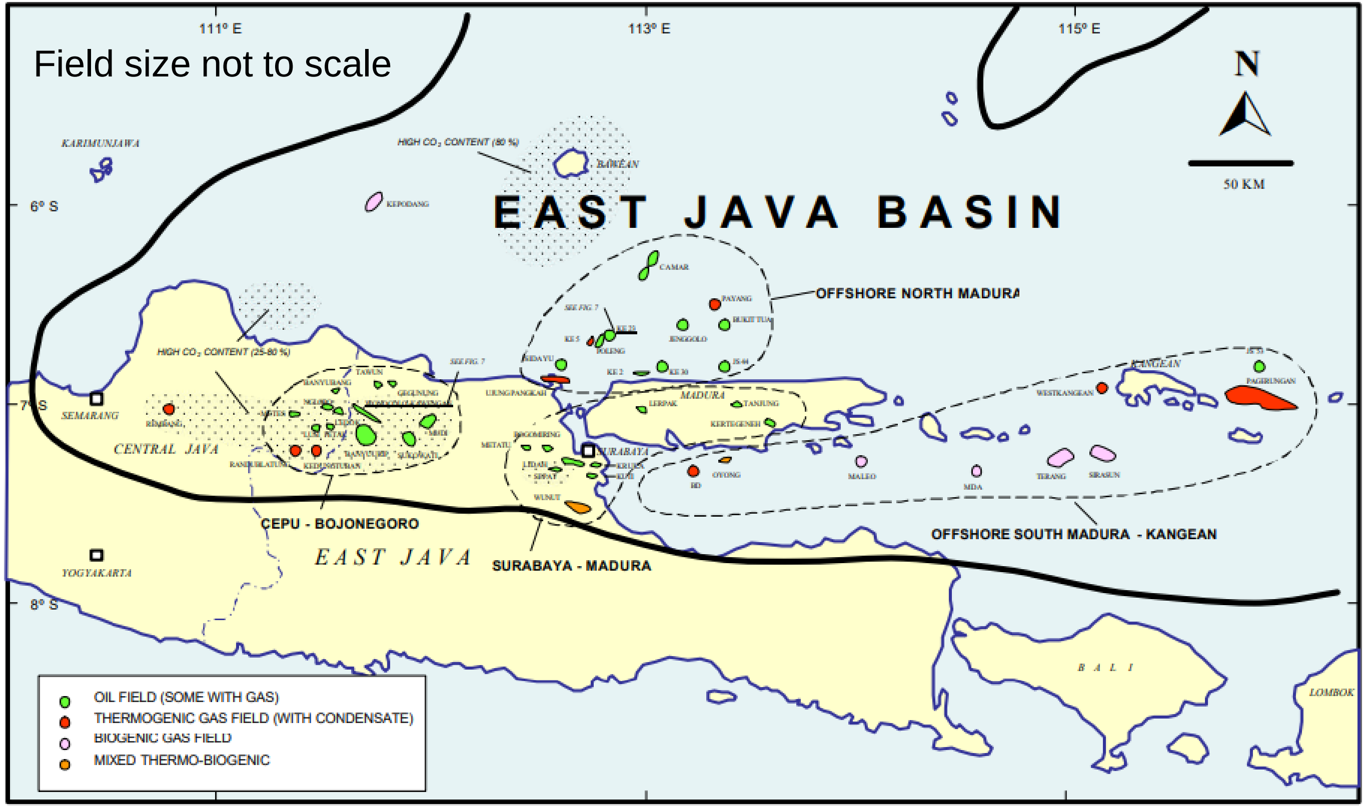
Sumber: Maryati, Ambarsari (Pattiro, 2010)

Hunter Philosophy

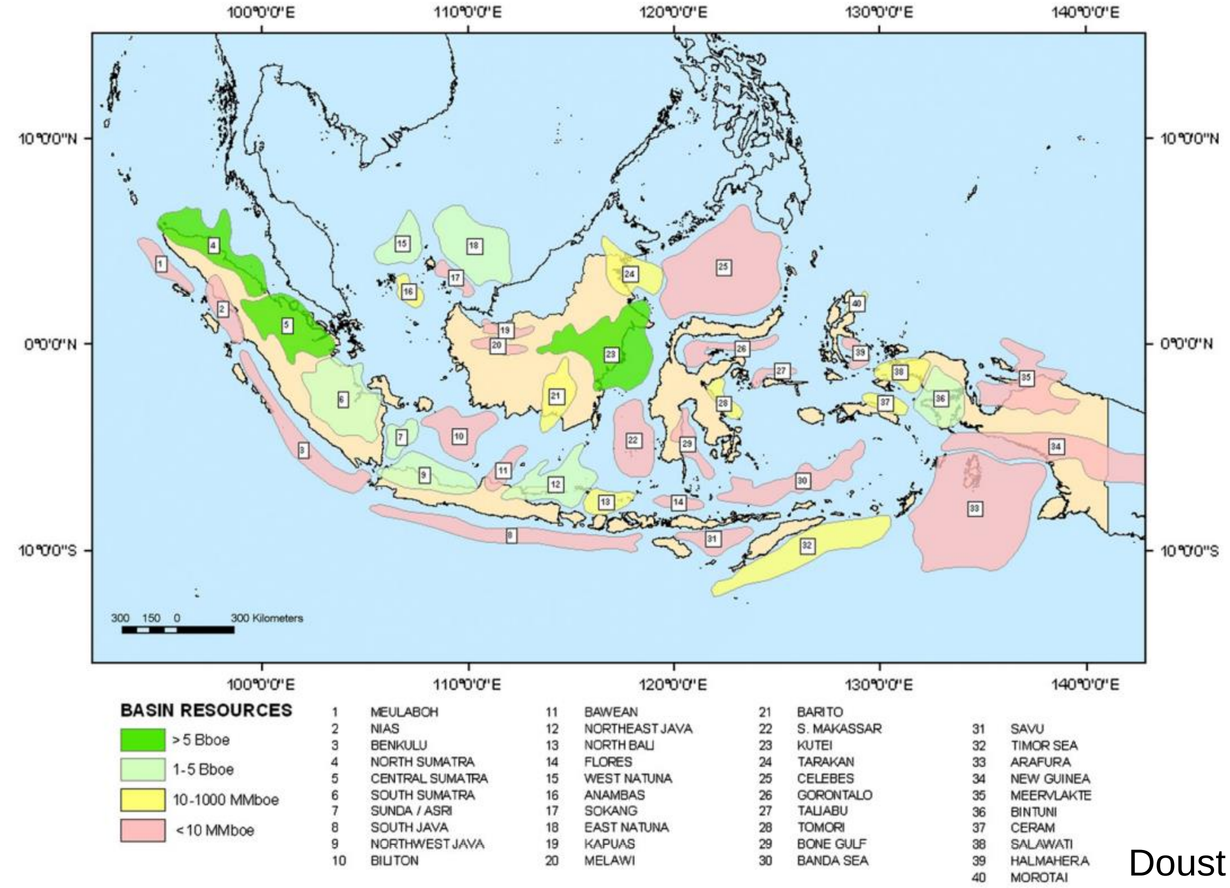
Good knowledge regarding:

- The animal characteristic
- The habitat
- The way of life
- Trap & The weapon

Adopted from Koesoemadinata's lecture in 2002 (Perencanaan Eksplorasi)



Satyana & Purwaningsih, 2003



Doust & Noble, 2006

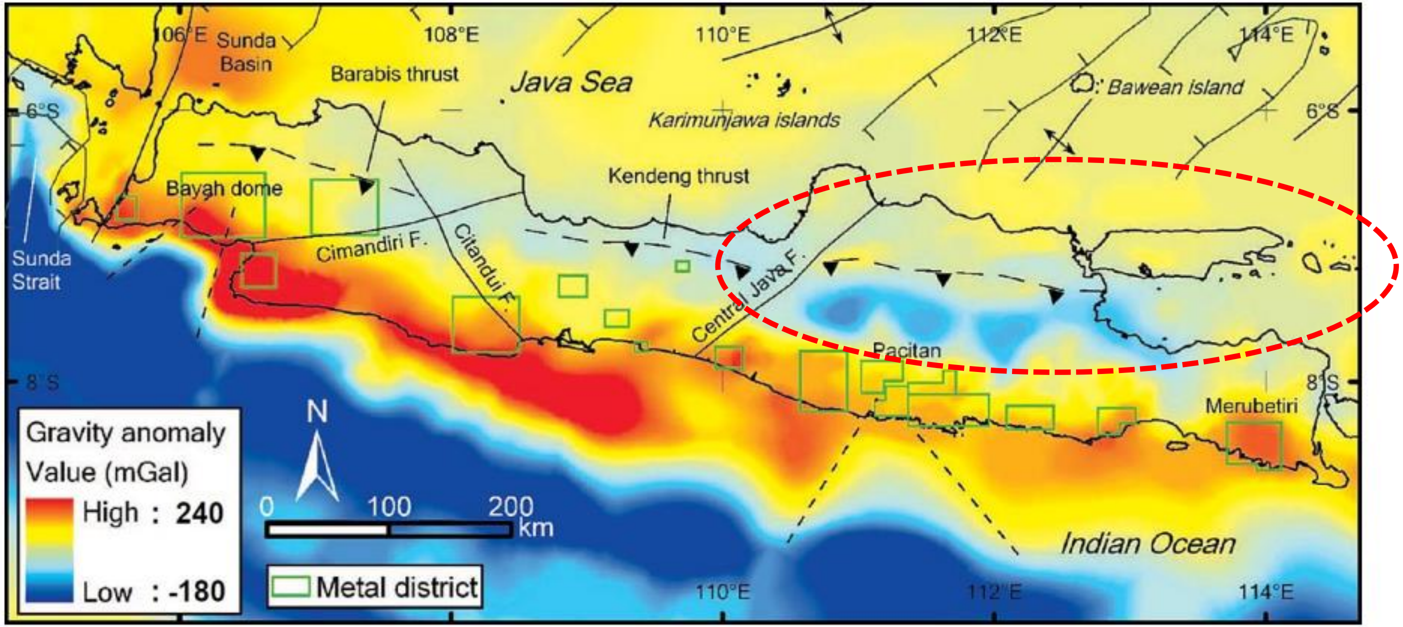


Figure III.1.4. Java Regional gravity map, main faults and important mineral districts (green) (Setijadji et al. 2006). Gravity highs in red along the south coast, reflect the Oligocene- Early Miocene 'Old Andesites' volcanic arc of the Southern Mountains, which is located South of the modern arc. Blue low gravity zones of northern Java are the Neogene lows of the Bogor Trough- Kendeng zone.

Van Gorsel, 2018

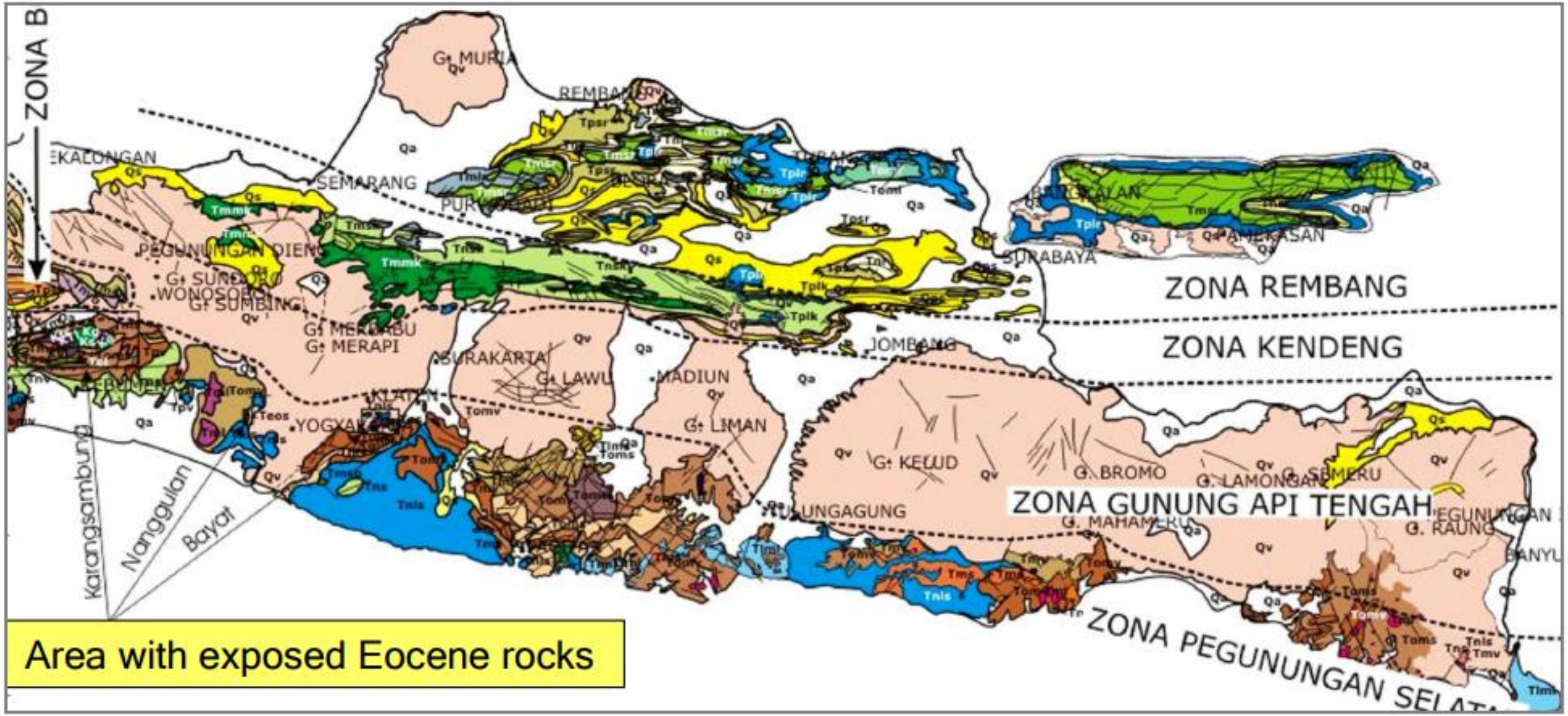


Figure III.1.5. East Java main structural domains, from South to North: Southern Mountains, Volcanic arc, Kendeng zone and Rembang zone (Prasetyadi et al., 2005, after Van Bemmelen, 1949) .

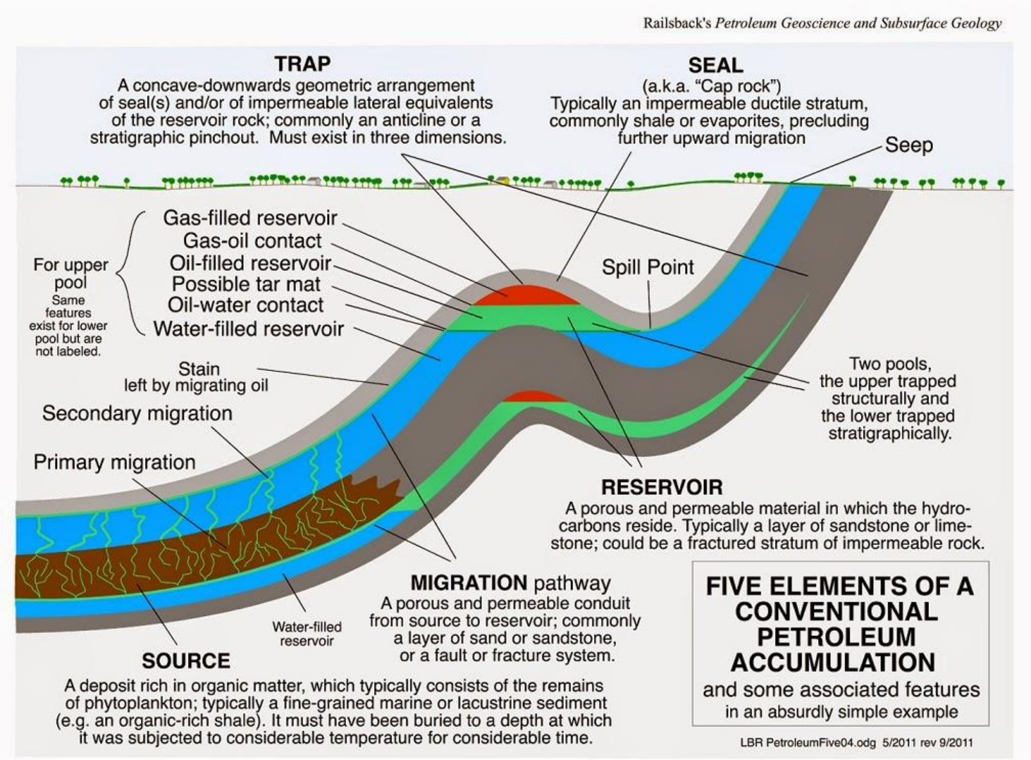
Van Gorsel, 2018

Analogi

Oil product

Source Rock

Petroleum System



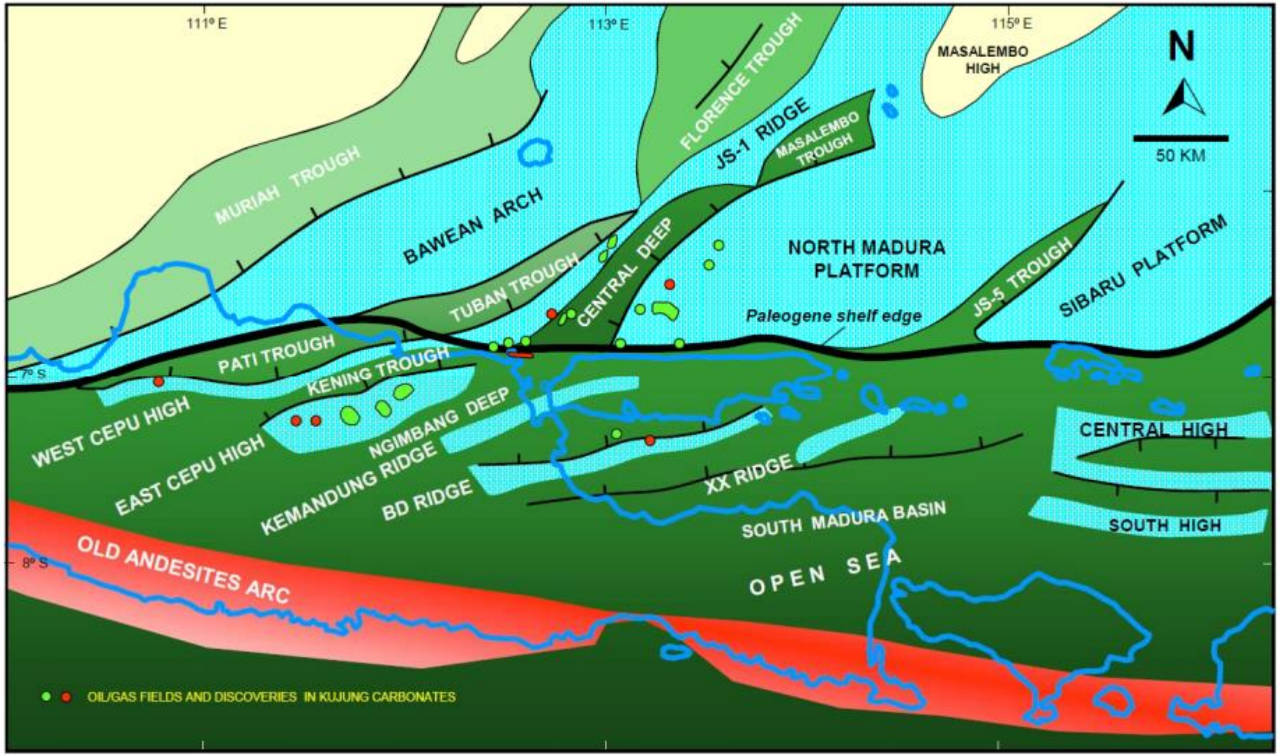
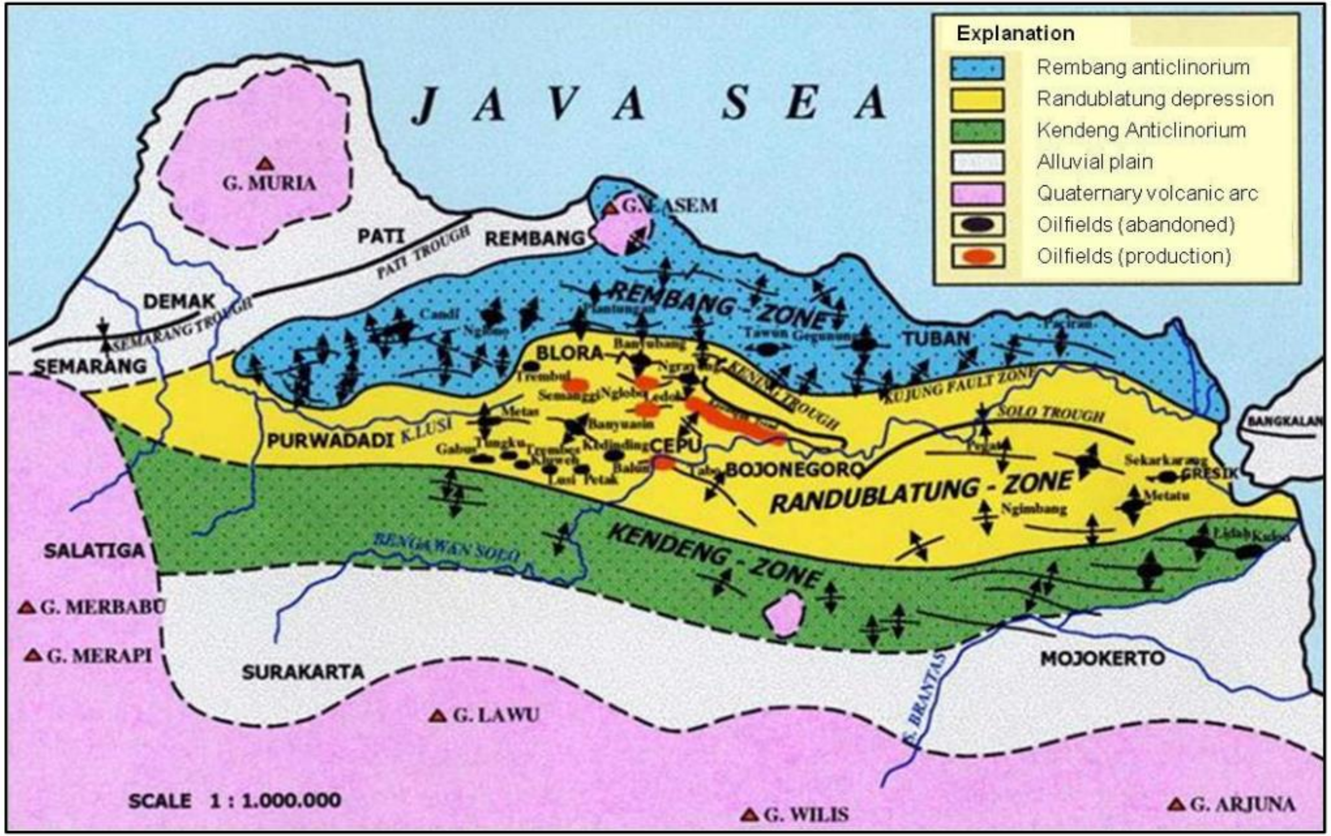
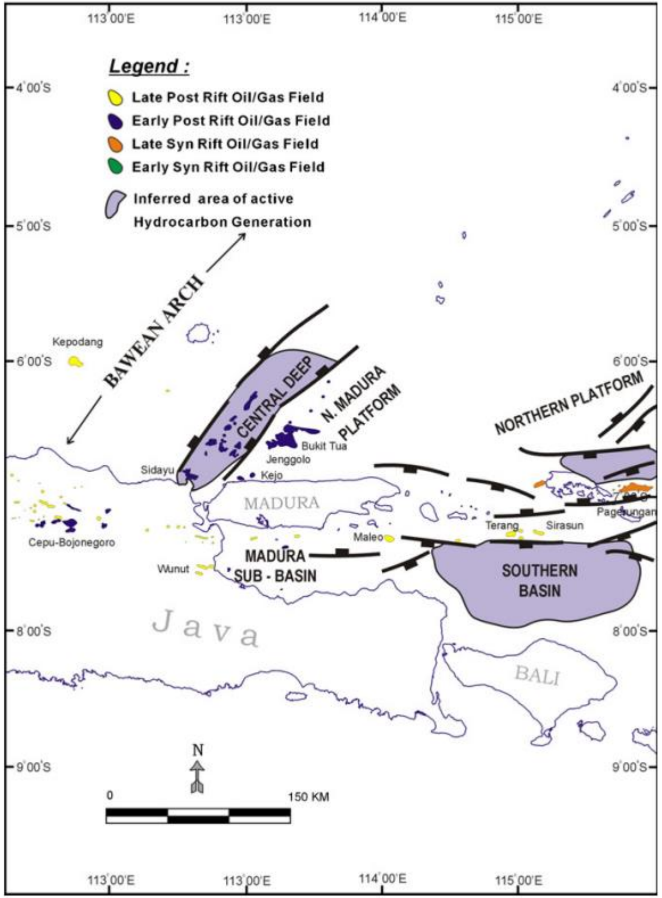


Figure III.1.13. The onshore NE Java basin and adjacent Java Sea are underlain by a Paleogene ENE-WSW and NE-SW horst and graben pattern. Oligocene- Early Miocene carbonate buildups formed on the highs and some of these are oil (green) and gas (red) fields (Satyana 2005)

Van Gorsel, 2018



(Nachrowi & Koesoemo, 2003)



Early Synrift (Late Eocene to Early Oligocene): This is represented by the Ngimbang Formation, in which a basal la*custr*ine to paralic sequence with source rocks is rapidly succeeded by open marine shales with sands and carbonates.

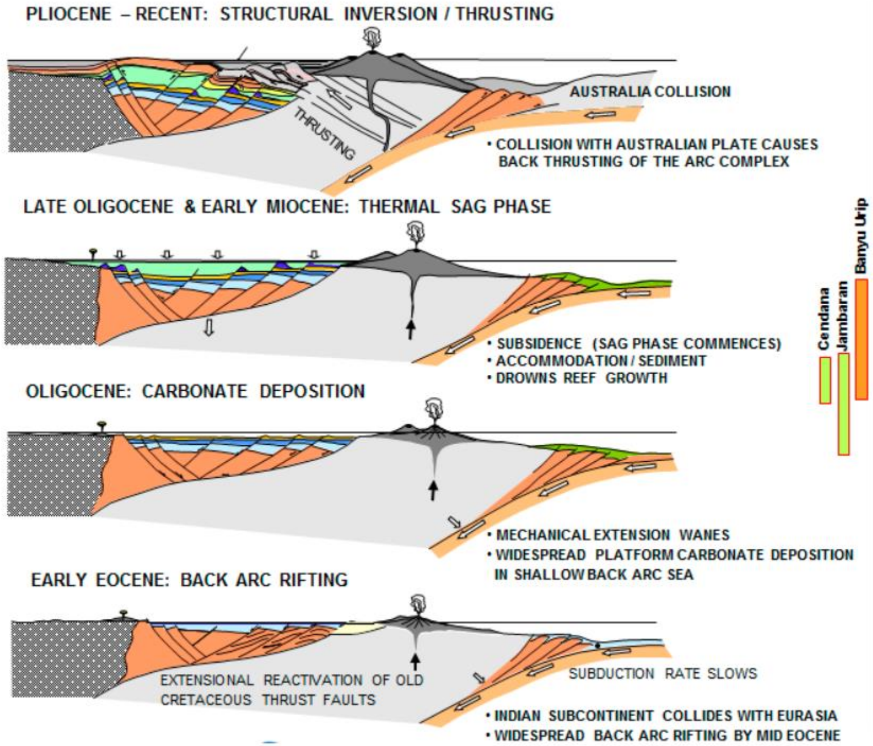
Late Synrift (Late Oligocene to Early Miocene): This is dominated by carbonates of the Kujung and Prupuh formations with, at the base, marine shales (with thin sands).

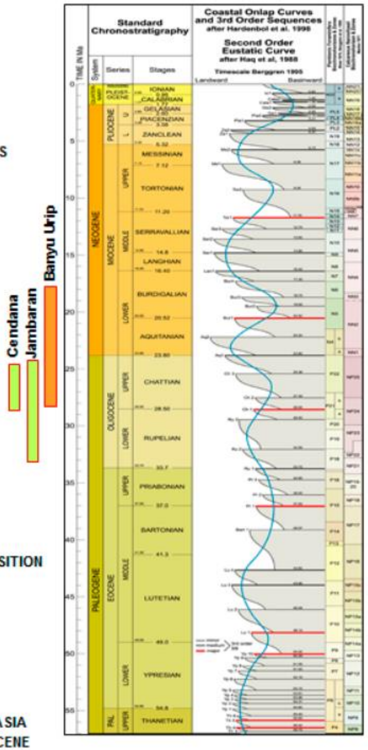
Early Postrift (Early to Late Miocene): At the beginning of this period, the carbonate platforms were drowned and extensive deeper marine clastics (Tuban and Woncolo Formation shales and Ngrayong Formation sands) were deposited.

Late Postrift (Late Miocene to Quaternary): Local tectonics and widespread active volcanism dominated this period, so that a variety of sequences is developed, including marine clays, volcaniclastics, carbonates and sands, deposited in a variety of shallow to deeper water environments.

Doust & Noble, 2006

East Java Basin Evolution





Simo, et al., 2012

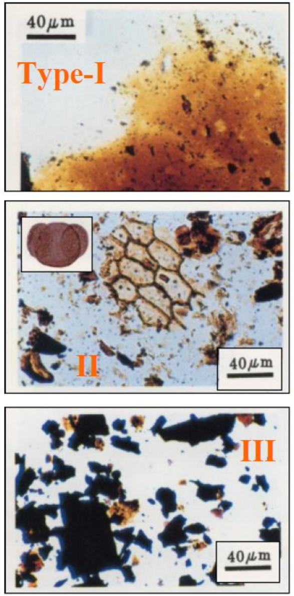
Source Rock

https://ife.no/en/project/monitoring-of-petroleum-generation-and-expulsion-from-shale-source-rocks/

A source rock is a rock that containing organic matter and can generate movable quantities of hydrocarbons:

- Shale
- Carbonate
- Coal

Source Rock



Shimazaki (1986)

Kerogen Type
Kerogen: Insoluble; preserved in sedimentary rocks

Type I (very oil prone): amorphous
hydrogen-rich; algal in anaerobic; especially lacustrine.

Type II (oil prone): herbaceous
comparatively hydrogen-rich; phytoplankton in suboxic; especially marine.

Type III (gas prone):Woody&coaly
hydrogen-poor & poly-aromatic; higher plants

Type IV (inertinite) : Woody&coaly
oxidized and hydrogen-very-poor
Type II-S : amorphous
unusually high organic sulfur about 8-14% (atomic S/C>0.04) and appear to begin to generate oil at lower thermal exposure

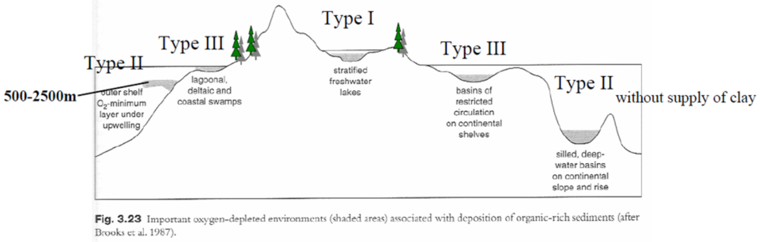
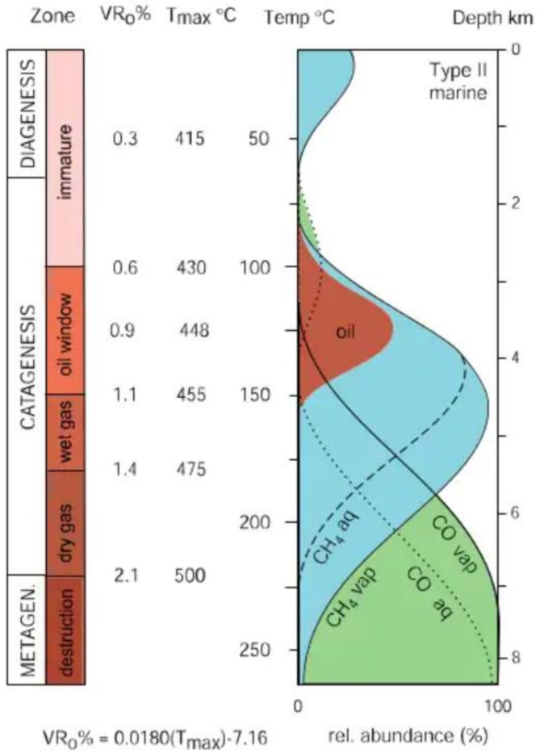


Fig. 3.23 Important oxygen-depleted environments (shaded areas) associated with deposition of organic-rich sediments (after Brooks et al. 1987).

Peters and Moldowan (1993)

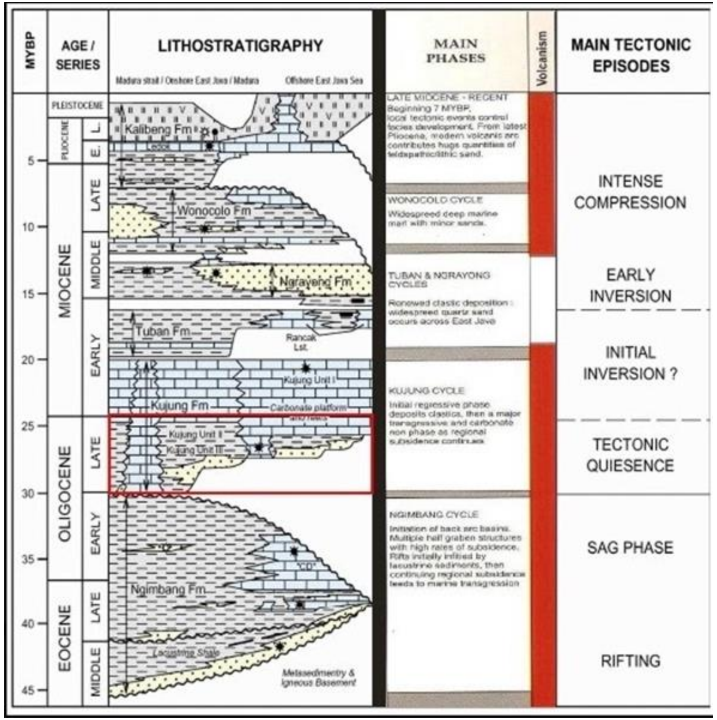
Satyana, 2011

Hydrocarbon Generation

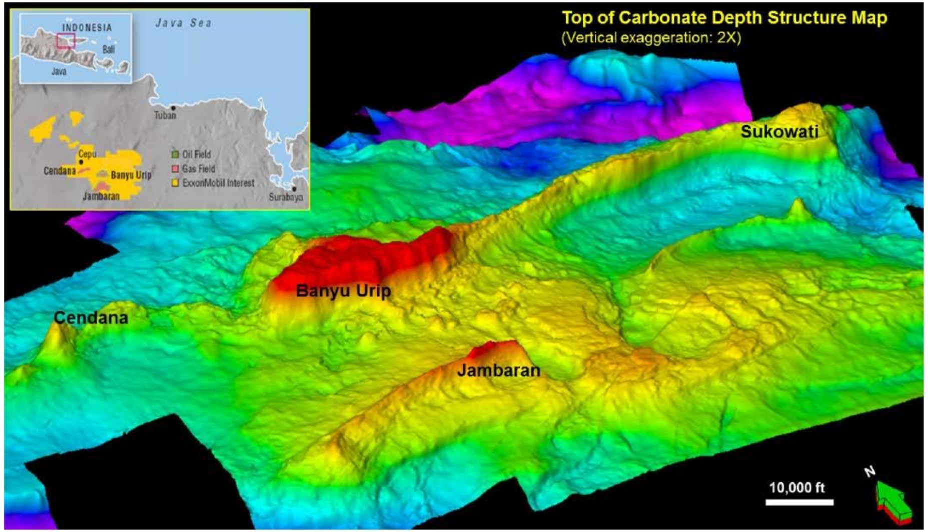


- As Black Shale is buried, it is heated (usually at 30°C km^{-1}).
- Organic matter is first changed by the increase in temperature into kerogen, which is a solid form of hydrocarbons.
- The oil window is an interval in the subsurface where liquid is generated and expelled from the source rocks.
- The oil window is often found in the 75-150°C interval (approx. 2-4 km depth).
- The gas window is found in the 100-220°C interval (4-6 km depth).
- Above 220°C the gas is destroyed

Septhon & Spathopoulos, 2012



Mudjiono and Pireno, 2001



Romadhona, et al., 2016

Banyu Urip Carbonate of Kujung Formation

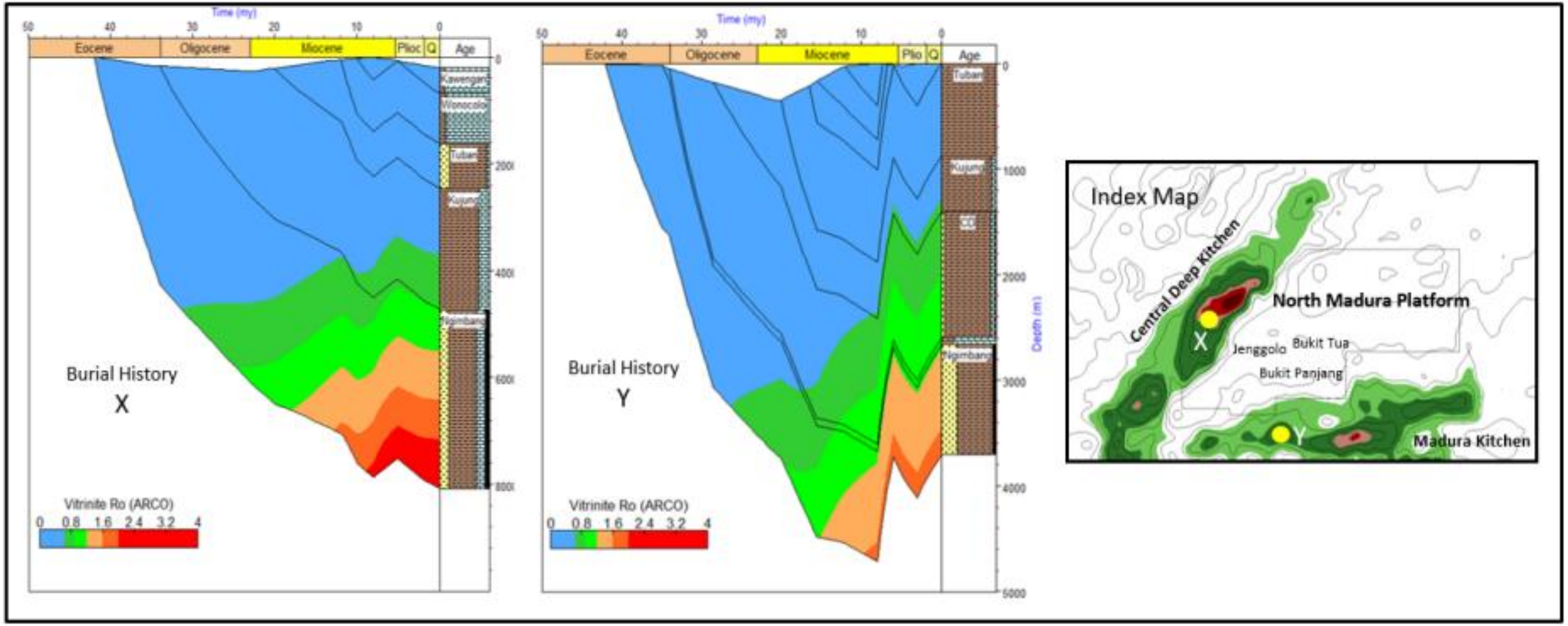
EAST JAVA ROCK/EXTRACT SAMPLE-ONSHORE

well/seep	sample origin	TOC(%)	HI	13Csat($^0/_{00}$)	13Caro($^0/_{00}$)	pr/ph	ol/hop	hop/ster	C27(%)	C28(%)	C29(%)
Arosbaya-1	Cepu			-27.67	-26.92	2.61					
	Kujung			-27.42	-26.58	2.25					
	Kujung			-26.30	-25.20						
	Ngimbang	3.17	299	-26.67	-26.24						
Batakan-1	Ngimbang	5.67	133	-28.7	-27.5	0.85					
Bawean-1	Kujung	17.27	157	-27.58	-26.54						
Blimbing-1	Tuban	1.30	235	-27.6	-26.60	4.7					
Gigir-1	Cepu	5.97	426	-28.08	-26.61	2.19					
Gondang-1	Ngrayong			-26.55	-27.48	4.56					
	Tuban			-27.71	-27.38	4.84					
Grigis Barat-1	Ngrayong			-27.23	-27.3	2.78					
	Tuban			-27.46	-27.54	3.14					
Kembang Baru-1	Kujung-1			-18.64	-17.56	1.2					
Kembang Baru-2	Kujung-1			-27.53	-24.97	5.5					
Kradenan-1A	Tuban	1.37	158	-26.79	-27.29	3.8					
Kujung-1	Ngimbang			-27.1	-25.3						
Ngasin-1	Wonocolo			-27.67	-27.72	3.11					
	Ngrayong			-27.68	-27.02	4.4					
Kedung Tuban	Tuban	0.81	87	-25.54	-24.75	5.4	0.64		5	39	56
	Kujung	0.14	29	-25.68	-24.75	2.9	0.51		25	29	46
Banyubang-1	Rancak			-26.09	-25.66	1.91		5.07	32	33	35
Suci-1	Rancak			-27.25	-26.93	1.2		2.27	27	27	46
Jatirogo-1	Rancak			-26.57	-26.03	1.95		4.2	33	29	38
Ngimbang-1	Rancak			-26.77	-26.35	0.97		2.05	34	21	45
Dander-1	Prupuh	2.57	97			3.22					
	Kujung	0.95	122			3.45					
Purwodadi-1	Ngimbang	2.25				3.78			35	18	47
Kayen-1	Kujung Lst					1.68					
Rembang-1	Kujung Lst	0.78	32.8			11.47		2.88	19	30	51
	CD Shales	12.17	396	-27.33	-26.99	10.44	0.19	4.27	38	29	33
	CD Shales	56.86	343	-26.75	-26.95	9.81	0.11	3.27	28	25	47
	Eocene clastics	0.69	49			4.66		3.14	31	23	46

EAST JAVA ROCK/EXTRACT SAMPLE-OFFSHORE

well/seep	sample origin	TOC(%)	HI	13Csat($^0/_{00}$)	13Caro($^0/_{00}$)	pr/ph	ol/hop	hop/ster	C27(%)	C28(%)	C29(%)
Cassiopeia-1	Kujung II			-28.99	-27.7	7.45					
JS 4-1	Cepu			-26.82	-6.8	0.54					
JS 8-1	Cepu			-27.86	-26.79	2.18					
JS 13A-1	Kujung			-27.83	-26.6	1.92					
JS 14A-1	Kujung	2.67	443	-26.28	-25.36	1.76					
JS 17-1	Kujung	0.52	286	-26.5	-26.3	1.85					
JS 20-3	Kujung	1.15	93	-26.19	-25.53	4.96					
JS 28-1	Kujung	3.93	253	-26.95	-25.53	4.96					
JS 3-1	Ngimbang	1.64	233	-28.44	-27.17						
JS 53A-1	Ngimbang	62.3	245	-27.8	-26.41	8.31					
	Ngimbang	1.93	110	-27.9	-26.71	2					
MDA-2	Mundu			-27.58	-27.21	0.94					
MS 2-1/1A	Cepu			-27.3	-26.03	2.47					
JS 3-1	Ngimbang	1.64		-28.44	-27.17	2.28					
Nuri-1	Ngrayong					2.43					
	Tuban					5.1					
	Kujung					3.73					
Poleng	Cepu			-27.67	-26.61	2.04					
	Kujung			-27.69	-27.2	1.04					
Rajawali-1	Kujung	5.7	154	-27.57	-26.82	4.93					
Sakala-1	Pre-Eosen			-27.67	-26.75	1.94					
Terang-1	Cepu	0.81	235	-27.12	-25.71	2.95					
Pagerungan	Ngimbang	67.04	448	-28.2	-26.1						
	Ngimbang	2.41	231	-29.1	-26.6						
South Sepanjang	Pre-Ngimbang	8.03	42								
	Pre-Ngimbang	0.96	24	-25	-24						

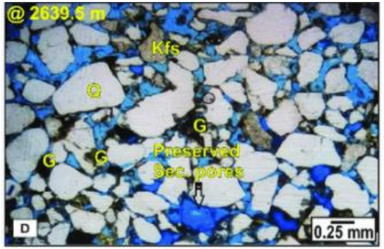
Burial History



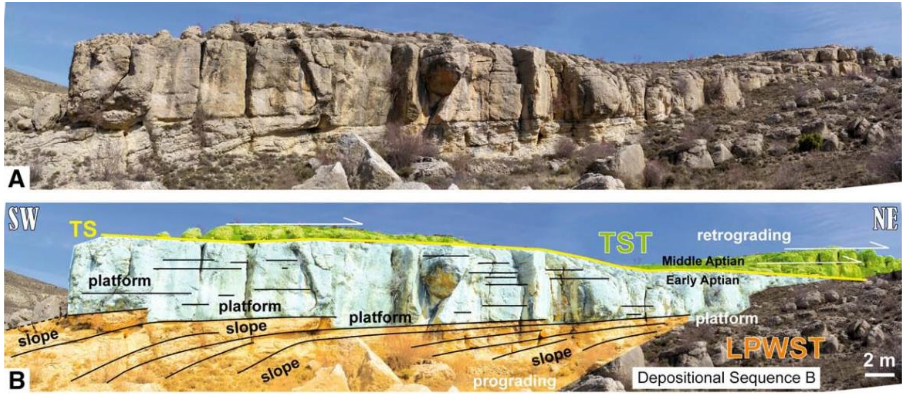
Darmawan, et al., 2018

Reservoir – Sedimentary Rock

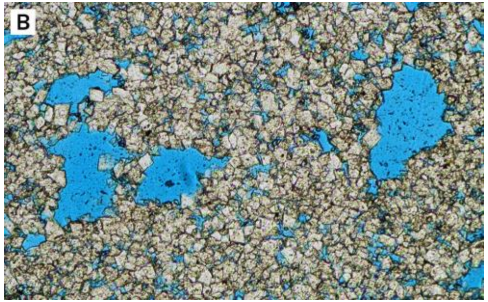
Maslinda, et al.,2017



Leila, et al., 2020

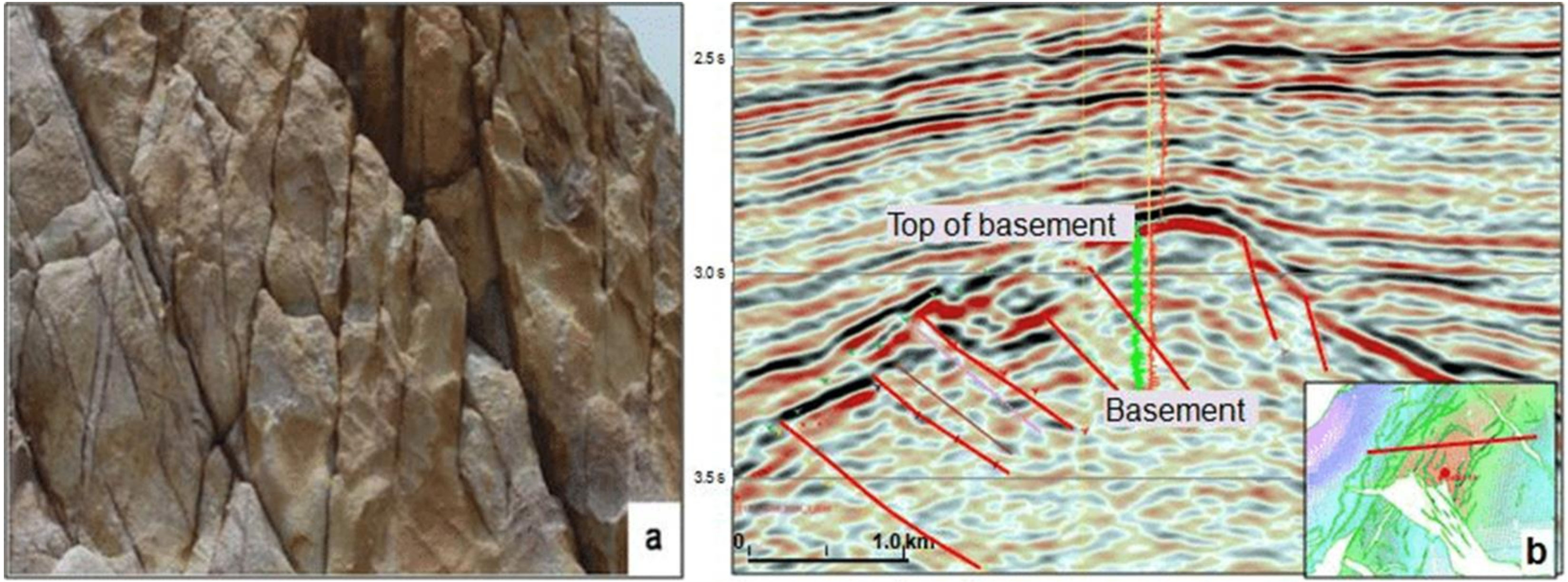


Arnal, et al.,2009



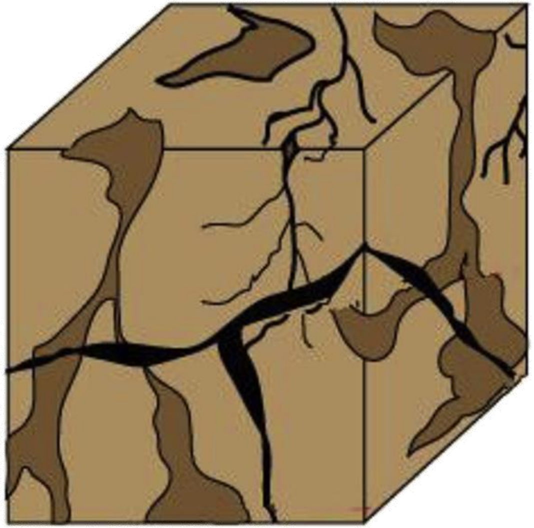
https://www.geoexpro.com/articles/2019/11/are-

Reservoir – Crystalline Rock

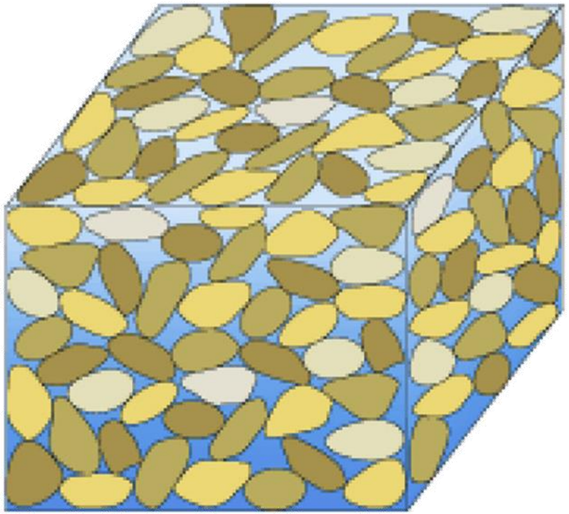


Tan, et al., 2016

Reservoir (Porous & Permeable)



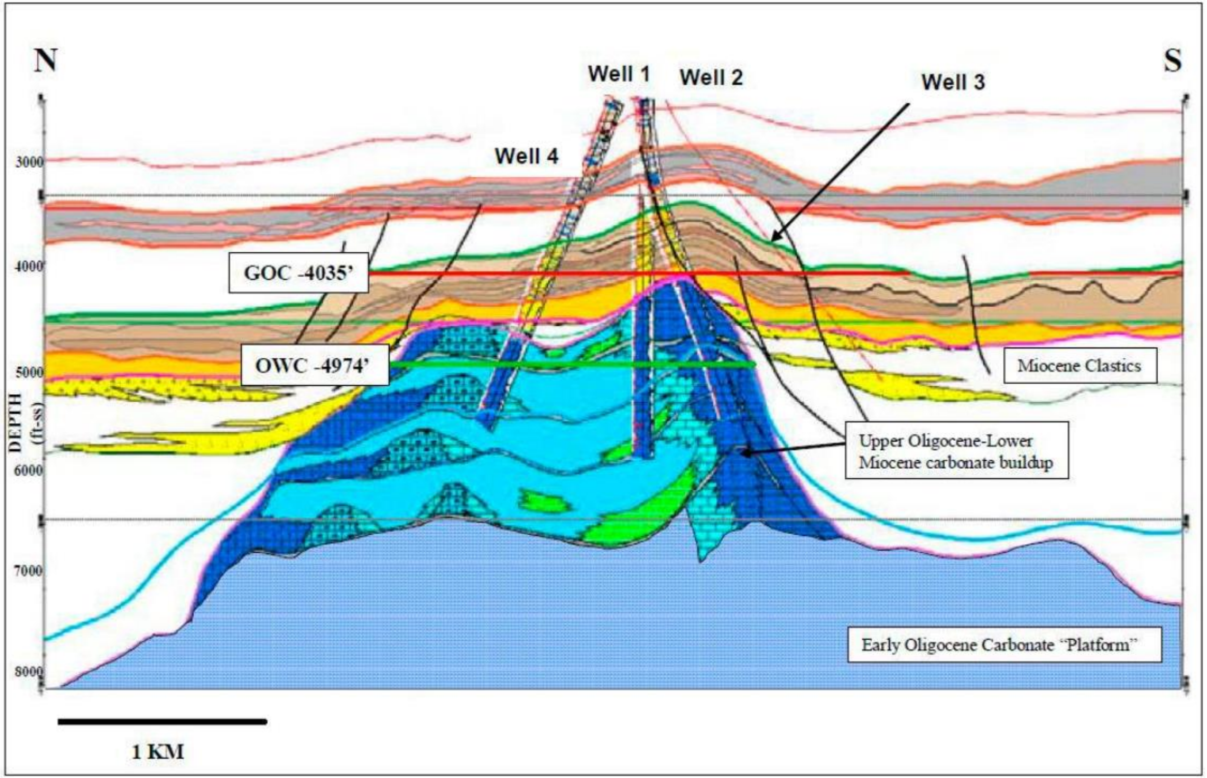
fracture



Pore

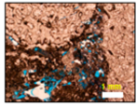
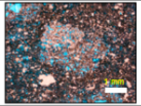
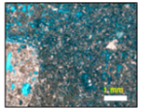
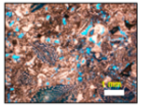
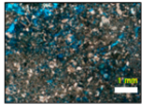
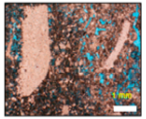
Chen, et al., 2016

Banyu Urip Reservoir



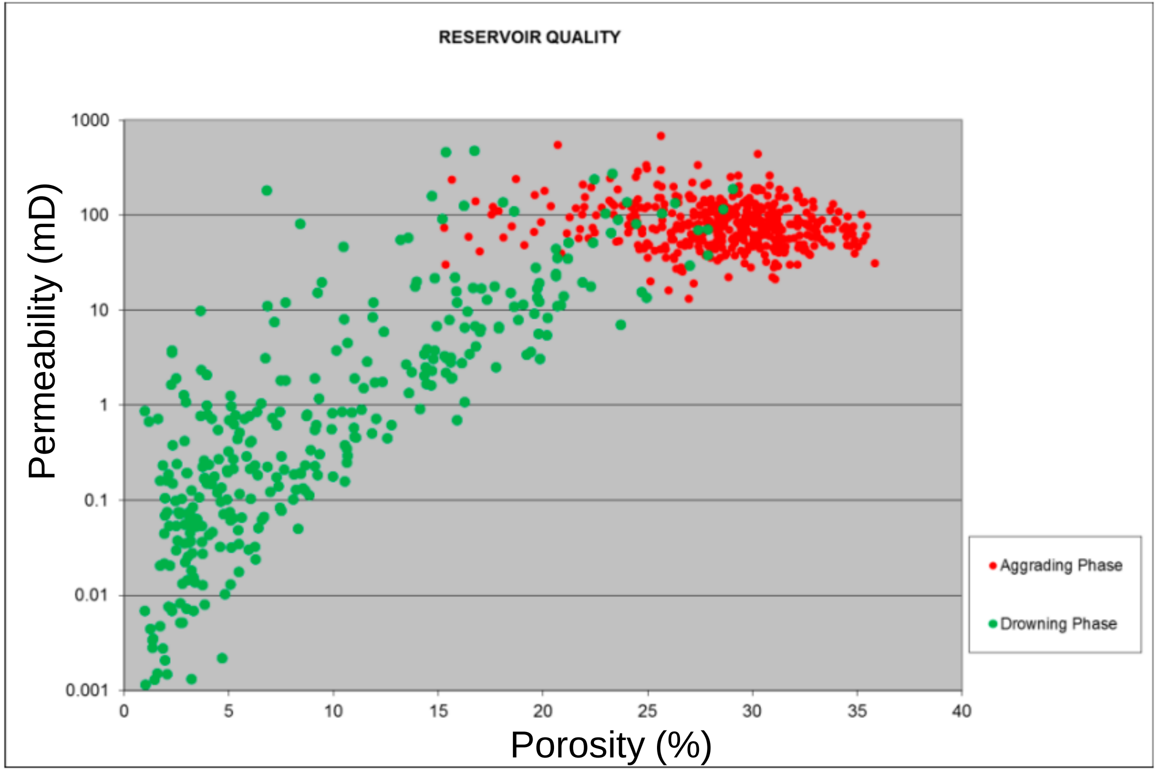
Simo, et al., 2012

Banyu Urip Reservoir

	Lithofacies	Texture	Reservoir Characteristics	Common Features	Depositional Environment	Thin Section Photos
1	Coral Boundstone / Coral Rudstone **CB/CR**	*Matrix:* P to MLP	• Low to moderate porosity. • Low to permeability permeability. • Pore types: Touching Vugs and enhanced moldic abundant porosity and; minor microporosity, and interparticle porosity.	• Coral rich facies. Abundant biotas: corals and coral fragments, encrusting red algae and foraminifera on corals, large benthic foraminifera (LBF), gastropods and echinoderms. Minor red algae fragments. • High/abundant recristalization of corals. • Bladed isopachous rim early marine cement.	• Shallow subtidal, moderate to high-energy, above fair weather wave base. • Platform Margin or Platform Interior (Patch Reefs).	
2	Patchy Cemented Skeletal Packstone - Rich **PSP-R**	*Matrix:* P	• Moderate to high porosity • Moderate to high permeability • Pore types: Enhanced Moldic and microporosity abundant.	• Skeletal packstone with abundant distribution of patchy cemented rock. • Dominant biotas: large benthic foraminifera (LBF), echinoderms, pelloids, and minor coral fragments. • Moderately sorted. • Bladed isopachous rim early marine cements.	• Shallow subtidal, moderate-energy, at fair weather wave base. • Platform Interior.	
3	Patchy Cemented Skeletal Packstone - Poor **PSP-P**	*Matrix:* P to W	• High porosity • High permeability • Pore types: Microporosity and enchanced moldic abundant.	• Skeletal wackestone - packstone with rare to common distribution of patchy cemented rock. • Dominant biotas: large benthic foraminifera (LBF), echinoderms, pelloids, and minor coral fragments. • Moderately sorted. • Bladed isopachous rim early marine cements.	• Shallow subtidal, moderate-energy, at fair weather wave base. • Platform Interior.	
4	Skeletal Packstone to Grainstone **SPG**	*Less common:* G	• Low to high porosity. • Low to high permeability. • Pore types: interparticle and moldic porosity abundant; minor intraparticle porosity.	• Large benthic foraminifera (LBF), echinoderms, bivalve fragments, and gastropods. • Moderate – well sorted. • Grain size vary from fine to coarse. • Blocky calcite cements. • Commonly preserve primary porosity.	• Shallow subtidal, high-energy, above fair weather wave base. • Platform Margin (Shoals) or Platform Interior (Shoals).	
5	Skeletal Wackestone to Packstone **SWP**	W to P	• high porosity. • high permeability • Pore types: microporosity and enhanced moldic abundant.	• Fine-grained skeletal fragments. • Dominant biotas: benthic foraminifera, sponge spicules and unidentified sekeletal fragments. • Moderate – well sorted. • Bioturbated.	• Deeper subtidal, low-energy, below fair weather wave base. • Platform Interior (deeper part).	
6	Echinoid Wackestone to Packstone **EWP**	W to P	• High porosity. • High permeability • Por types: Microporosity and enhanced moldic.	• Dominant biotas: echinoderm, large benthic foraminifera (LBF), skeletal fragments, and red algae fragments. • Poorly sorted. • Bioturbated. • Abundant leaching.	• Deeper subtidal, low-energy, restricted, below fair weather wave base. • Platform Interior (deeper part).	

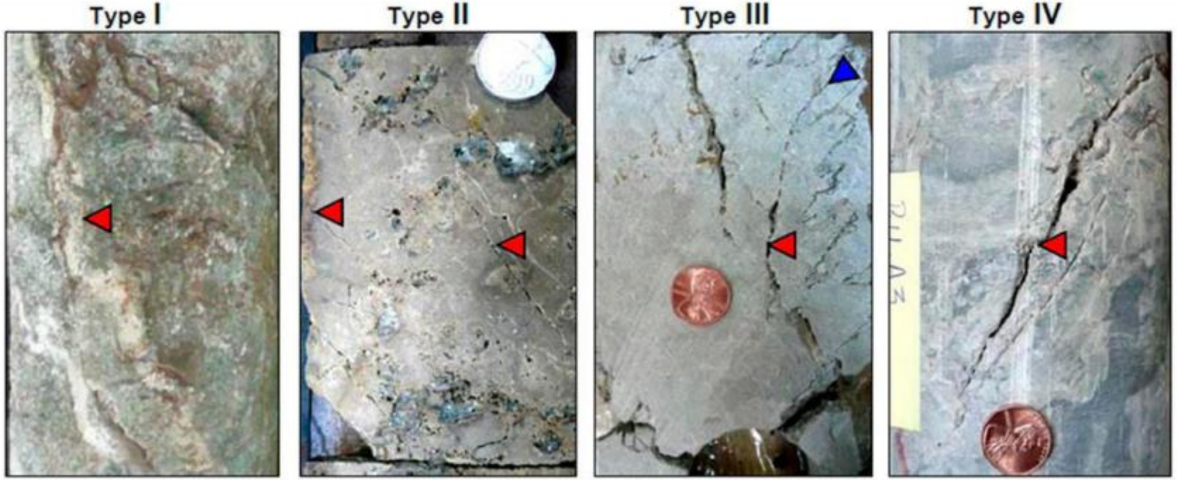
Simo, et al., 2012

Banyu Urip Reservoir



Simo, et al., 2012

Banyu Urip Reservoir



Type I

- Length: cm's to meters
- Often canabalized by stylolites
- Usually nearly 100% filled
- Probably insignificant flow potential

Type II

- Length: 1 to 5 cm
- Usually bounded between adjacent stylolites
- Perpendicular to stylolite teeth
- Often solution enhanced forming "mega-pores"
- Local perm multiplier

Type III

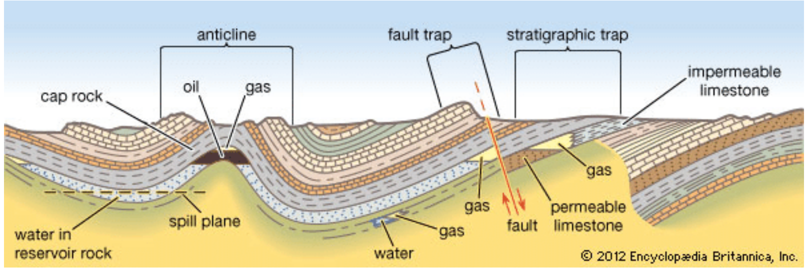
- Length: ~cm to meter
- Often low angle to stylolites
- Cut stylolites and / or terminate on Type II fractures
- Often solution enhanced, may form continuous clusters.
- Significant for flow

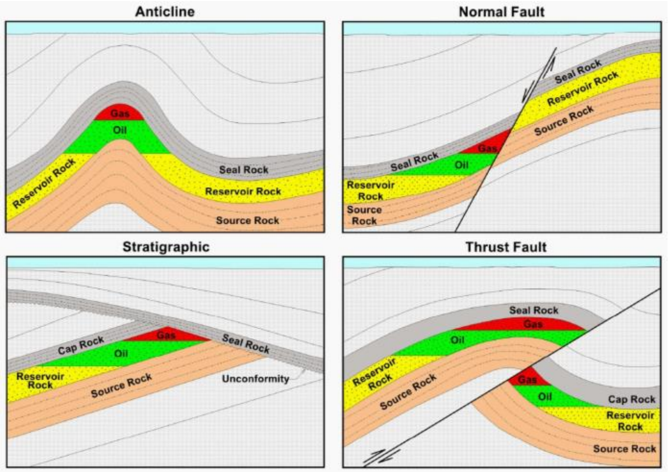
Type IV

- Length: ~1 to 10's m (?)
- Cross-cut all but thickest stylolites
- Usually open, up to several mm's aperture
- Significant for flow

Simo, et al., 2012

Trap

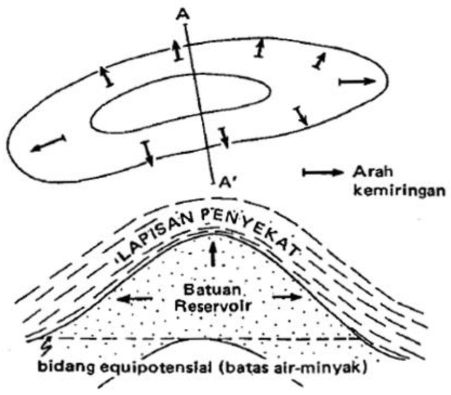




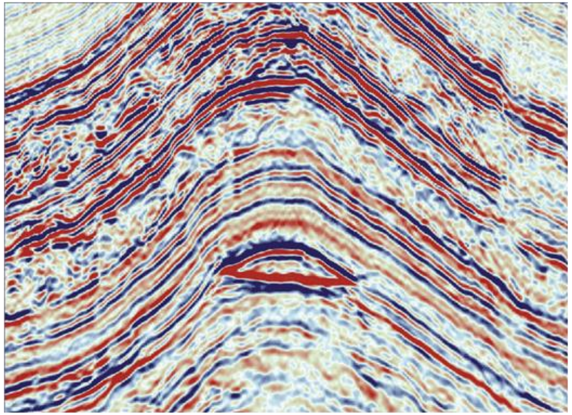
- HC is always moving vertically and settling above the water.
- A trap is needed therefore the HC cannot move anywhere in term of shape and barrier

https://www.geologyin.com/2014/12/hydrocarbon-traps.html

Fold – Anticline



Koesoemadinata, 1980

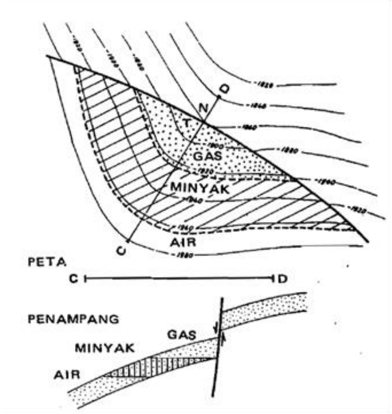


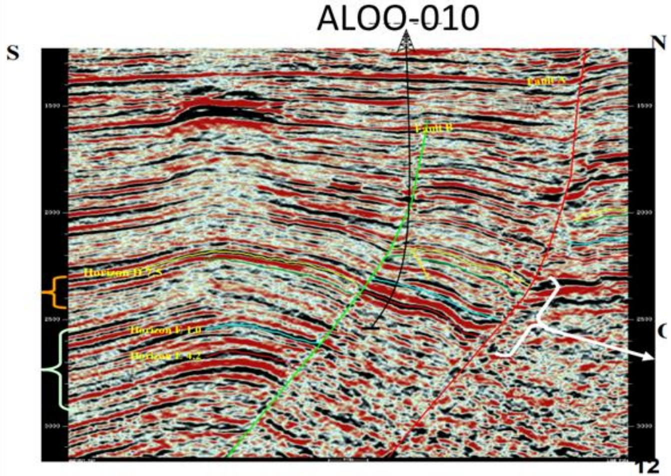
Eldrige & Robert Jr., 1992

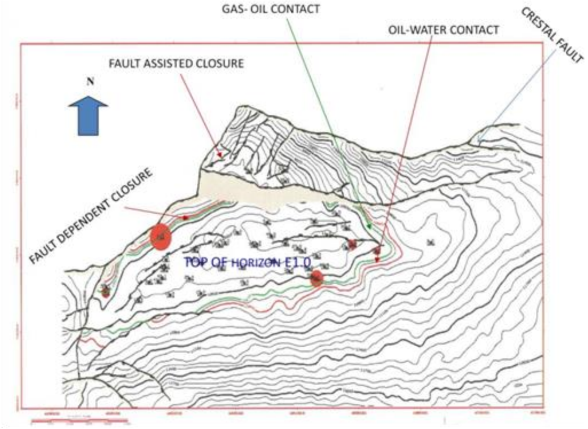
https://courses.lumenlearning.com/geo/chapter/reading-folds/

4 ways dip closure

Fault





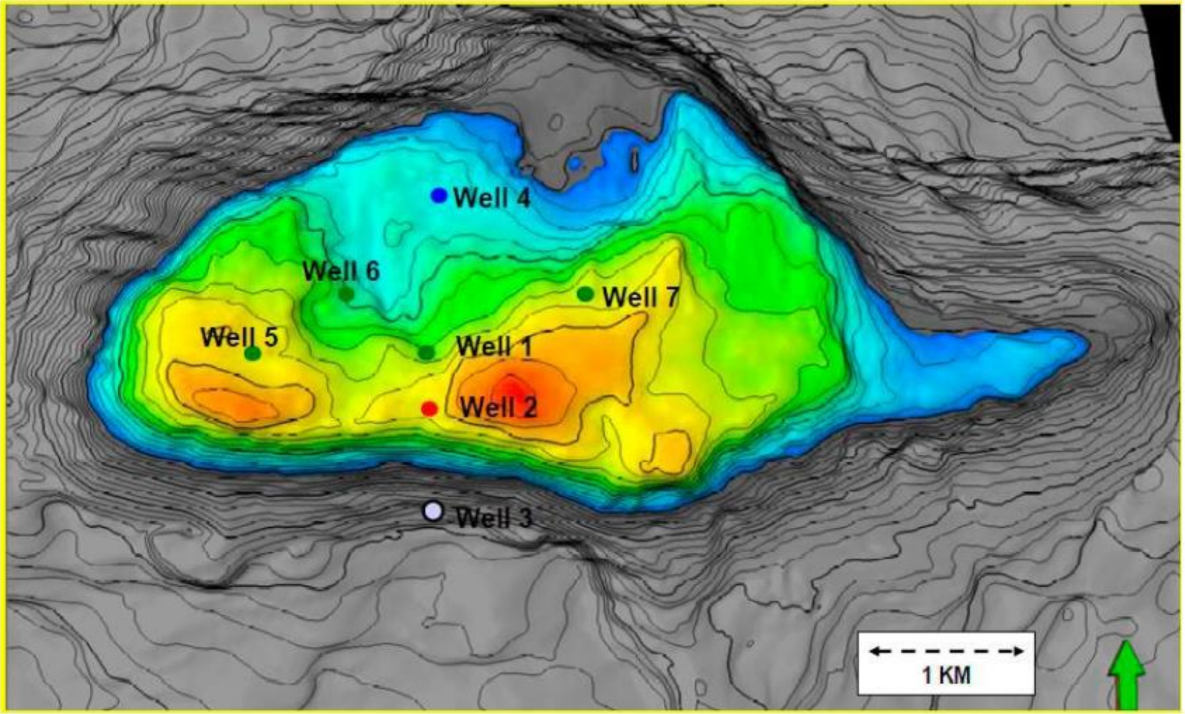


Koesoemadinata, 1980

Oluwatoyin, et al., 2013

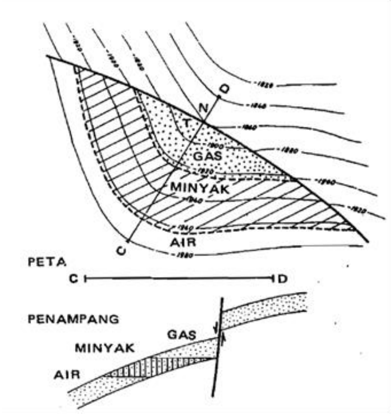
3 ways dip closure

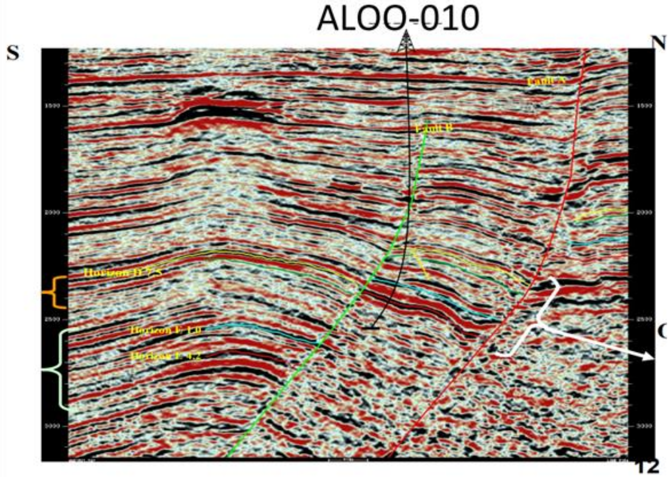
Anticline Banyu Urip

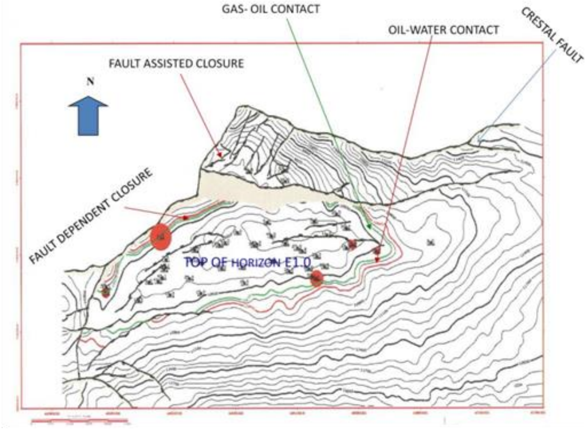


Simo, et al., 2012

Fault





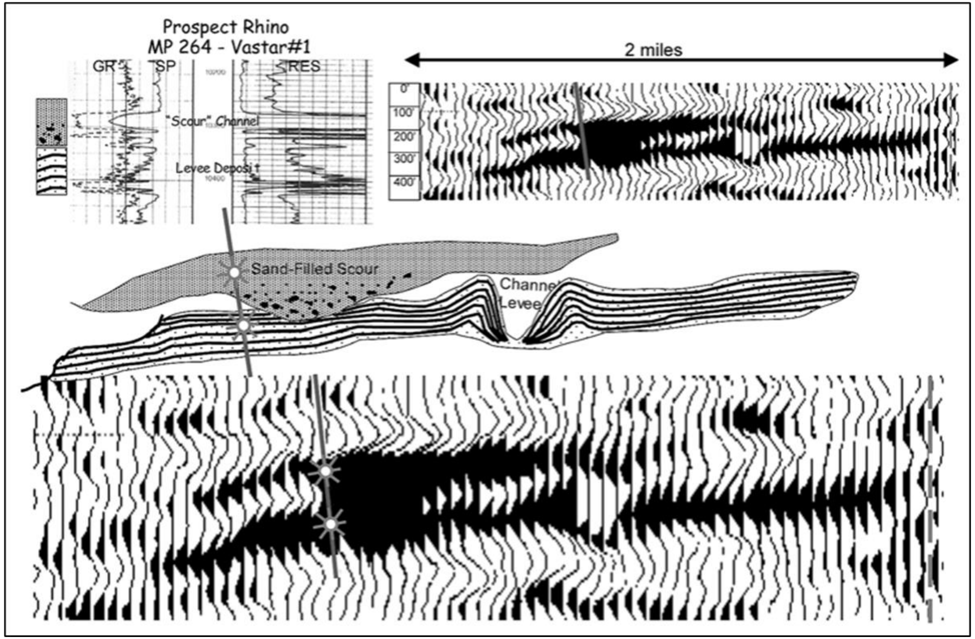


Koesoemadinata, 1980

Oluwatoyin, et al., 2013

3 ways dip closure

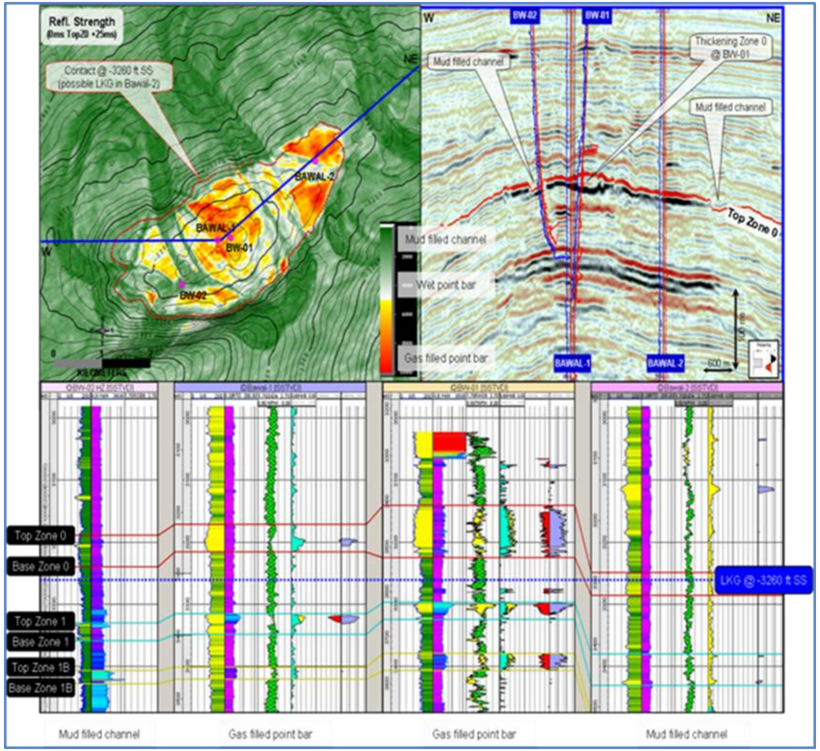
Stratigraphy



Good, 2006

- Stratigraphical trap : HC was trap by vertical and lateral barrier during the migration because of facies changing
- Conditions:
    - Permeability property changes
    - Vertical and lateral seal capacity

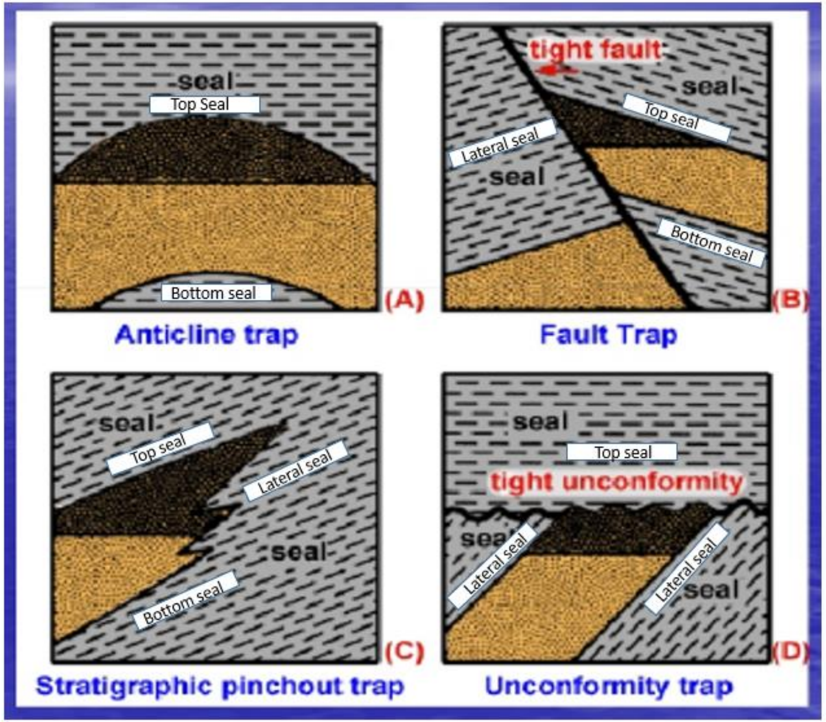
Combination



Firdaus, et al., 2015

- In the real world most of the hydrocarbon traps are the combination between structural trap and stratigraphical trap
- In a practical way, structure trap is the first trap to explore
- In the structural trap is proven in a basin, next exploration might be stratigraphical trap

Seal

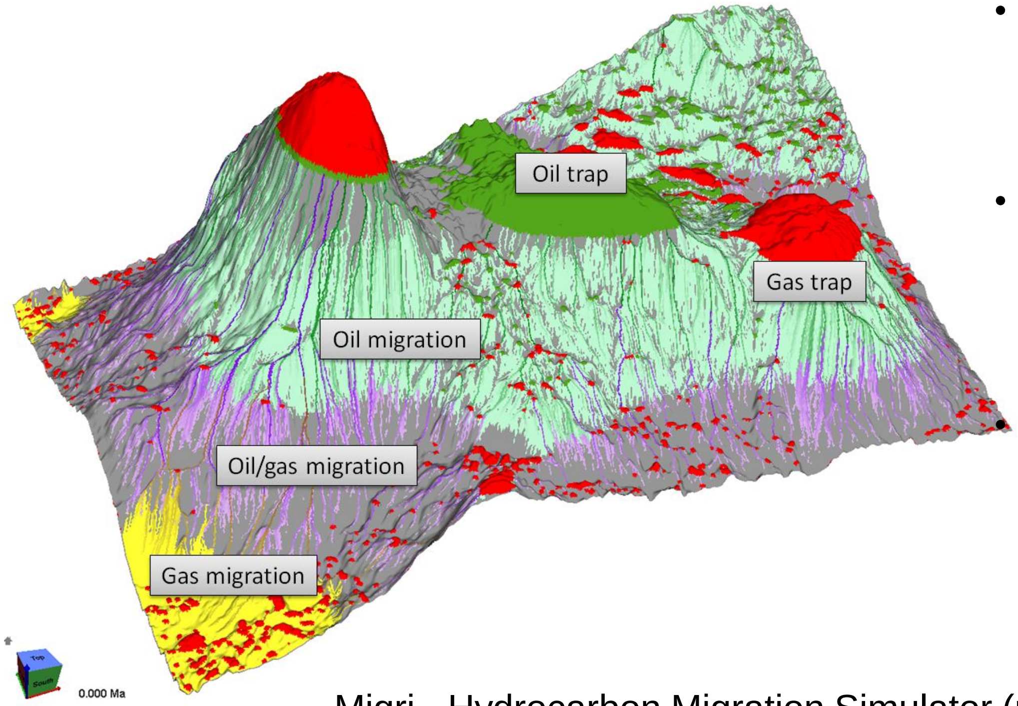


Modified from Mustafa, 2012

- A seal is a relatively impermeable, a seal is a layer of rock that forms a barrier or cap above and around a reservoir rock.

- Commonly composed of shale, chalks, clays, anhydrite or salt, a seal helps prevent fluids from migrating beyond the reservoir. It is sometimes also referred to as a cap rock.

Migration



- Expulsion → Expulsion describes the movement of hydrocarbons from the petroleum source rock into the carrier bed or migration conduit

- Migration → Hydrocarbon migrates through an aquifer when it is "buoyed" upward due to AP caused by the density differential of the hydrocarbons and the formation water.

- Accumulation → A hydrocarbon accumulation forms when migrating hydrocarbon filaments encounter a zone (the seal), either laterally or vertically, with pore throat sizes smaller than the carrier bed

Migri - Hydrocarbon Migration Simulator (migris.no)

Figure 9. (upper left) scenery of traditional oil mining in Wonocolo Village (photo : Alan Yudhis); (lower left) final residue of traditional distillation. One well could produce 2-3 barrel oil of diesel and gasoline; (right) wooden oil rig.

Husein, 2014