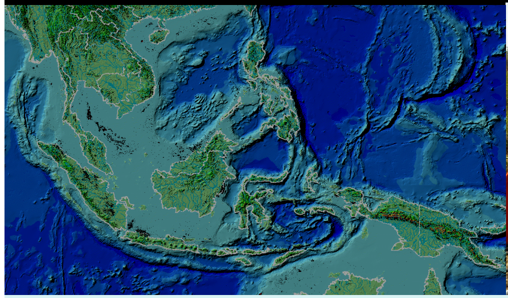
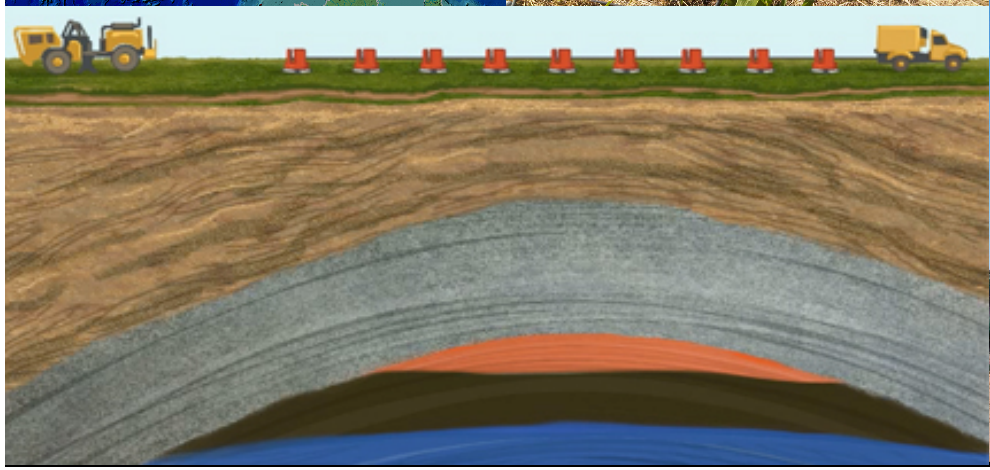
GRAVITY DATA UTILIZATION IN OIL AND GAS INDUSTRY
The New Paradigm

UNIVERSITAS TRISAKTI





Presented in ITS
7 June 2021

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CURRICULUM VITAE

Name	: Dr. Ir. Eko Widianto, MT, IPU
Place of Birth	: Semarang, 3 September 1955
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Address	: Rancho Indah, Jl. Tanjung 19 / Blok G-21 Tanjung Barat, Jakarta Selatan 12530 Email: ewidianto@trisakti.ac.id drekowidianto@gmail.com
Education	1982 : Bachelor Degree in Geology of UGM 2000 : Magister Degree in Applied Geophysics of ITB 2008 : Doctoral Degree in Applied Geophysics of ITB

Work History

1982 – 1985	: Pertamina Exploration Division Jakarta
1986 – 1993	: Pertamina Exploration Department Plaju
1993 – 1994	: Pertamina BPPKA Jakarta
1994 – 1997	: Head of Exploration Planning Jakarta
1998 – 2000	: Exploration Manager JOB Pertamina – Greka Energy
2000 – 2002	: Chief Geophysics Pertamina Upstream President of Indonesian Association of Geophysicists (HAGI)
2002 – 2006	: General Manager of JOB Pertamina-ConocoPhillips (Sakakemang) Ltd.
2006	: Vice President of Pertamina Upstream New Venture Business Development
2006 – 2007	: Board of Director of Joint Venture Pertamina – Petronas – Petro Vietnam
2006 – 2008	: Vice President of Pertamina EP Technology Center
2009 – 2011	: Senior Geophysicist
2011 – now	: Lecturers of: Geology and Petroleum Engineering of Trisakti University

LECTURE MATERIALS

1. Indonesian Energy Resources Condition
2. Level of Petroleum Investigation
3. Oil & Gas Challenges and Opportunities
4. Methodology and Case Study
5. Indonesia Basin Re-Mapping using Gravity Data
6. Prospect Generation using Gravity Data
7. Reservoir Monitoring using Time-Lapse Technology

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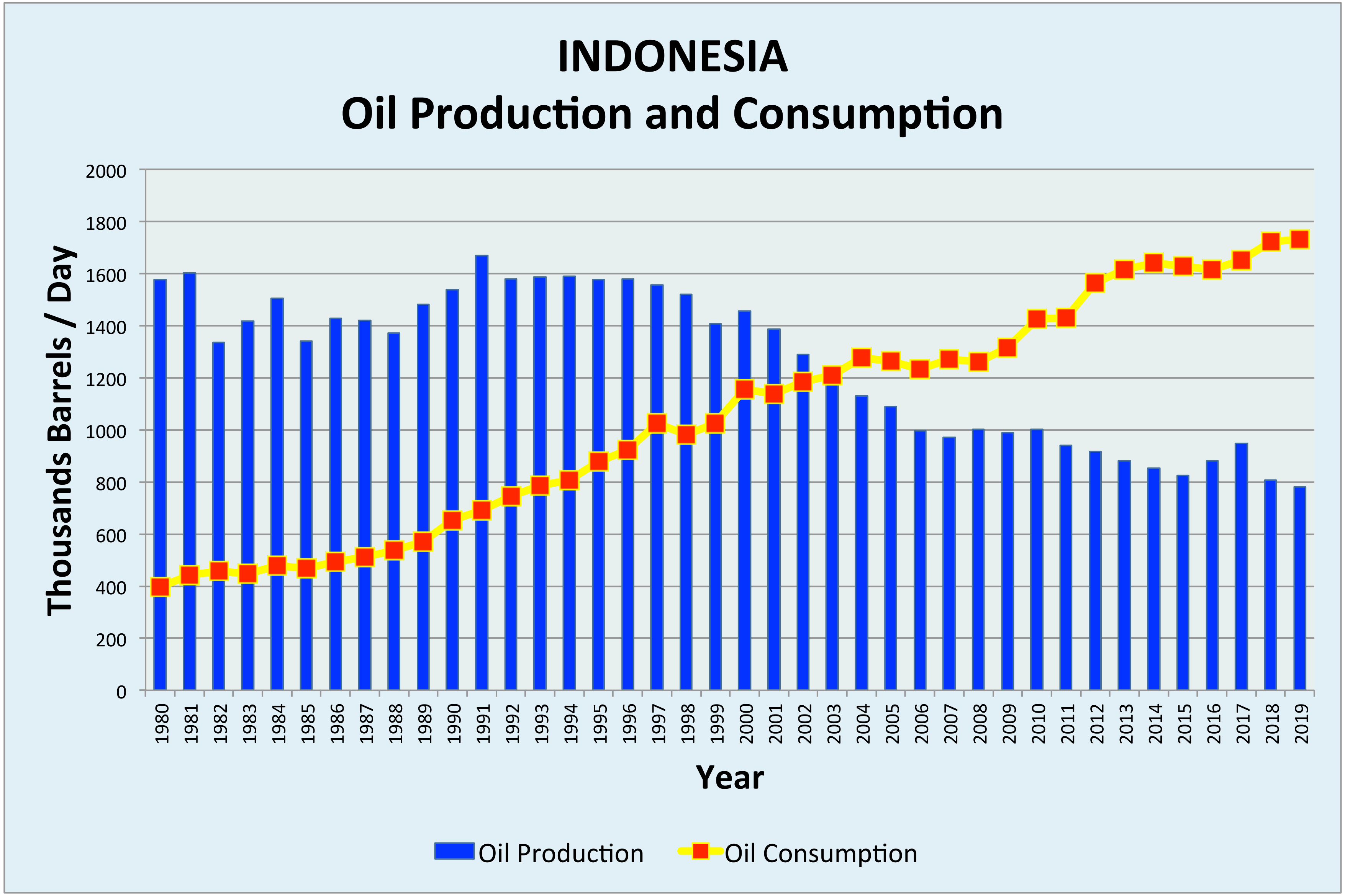
Indonesia

Oil and Gas Resources Condition

Indonesia Oil and Gas Situation

1. Oil Production Declining. Oil production in Indonesia is dominated by onshore mature fields that are experiencing rapid rates of decline (5 – 15%), yet hold significant remaining reserves.
2. Less new giant field discovery.
3. Some of the current obstacles to brown fields revitalization in Indonesia.
4. Common blockers include a lack of appropriate technology, poor process, conflicting objectives, unacceptable risk, and economic disincentives.
5. Declining the National Oil R/P.



Source: BP Statistical Review of World Energy (2020)

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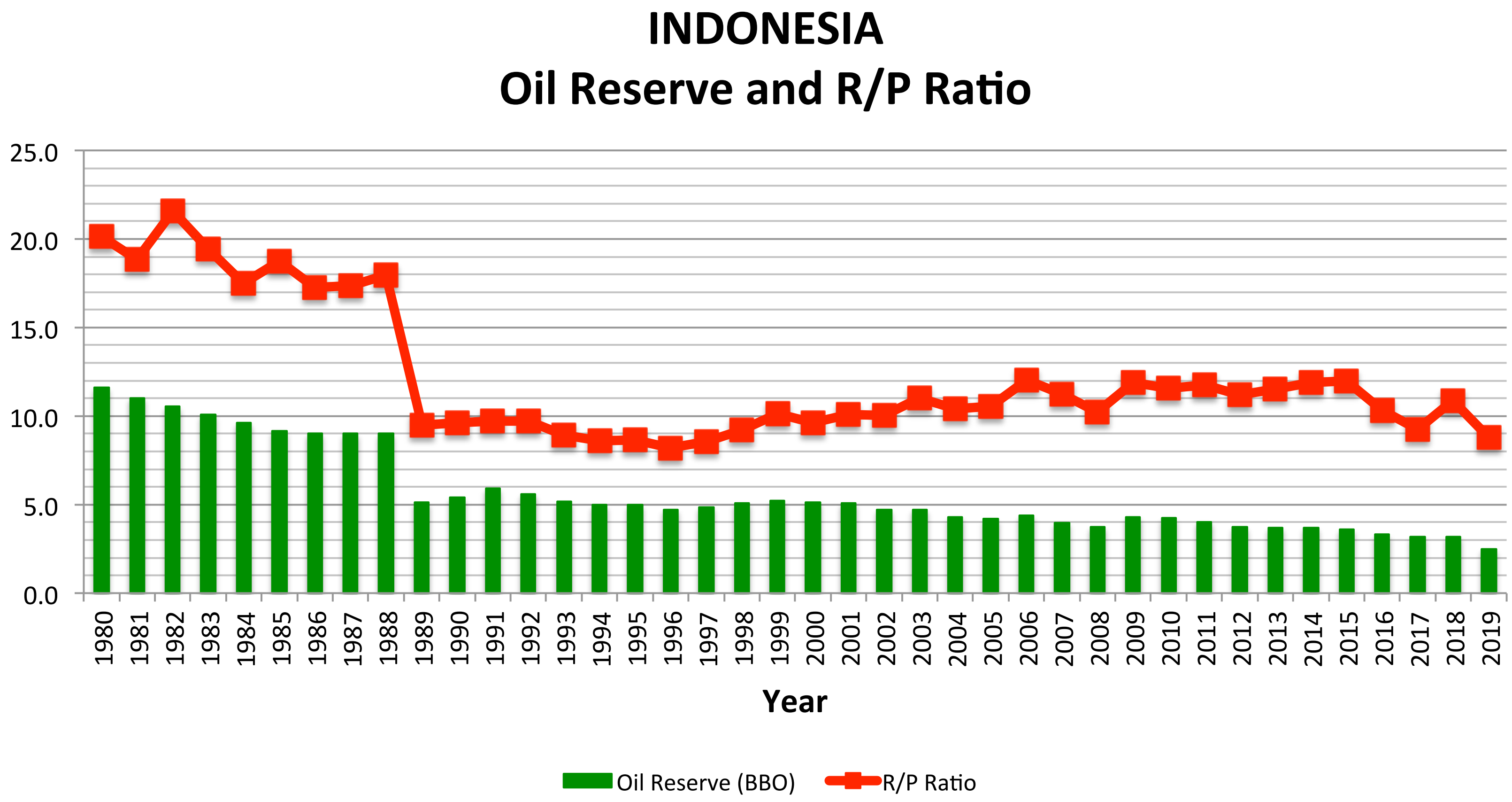
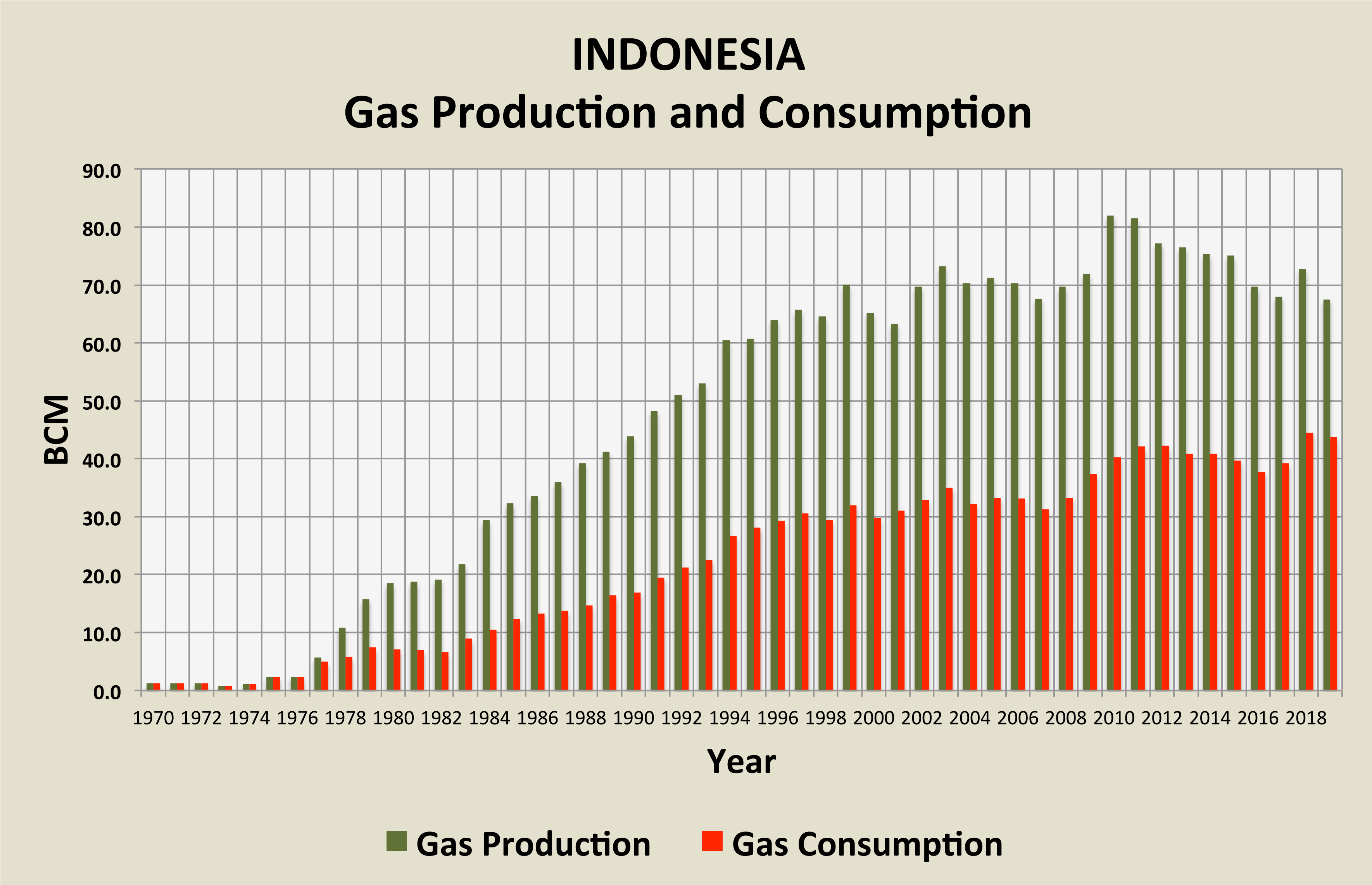
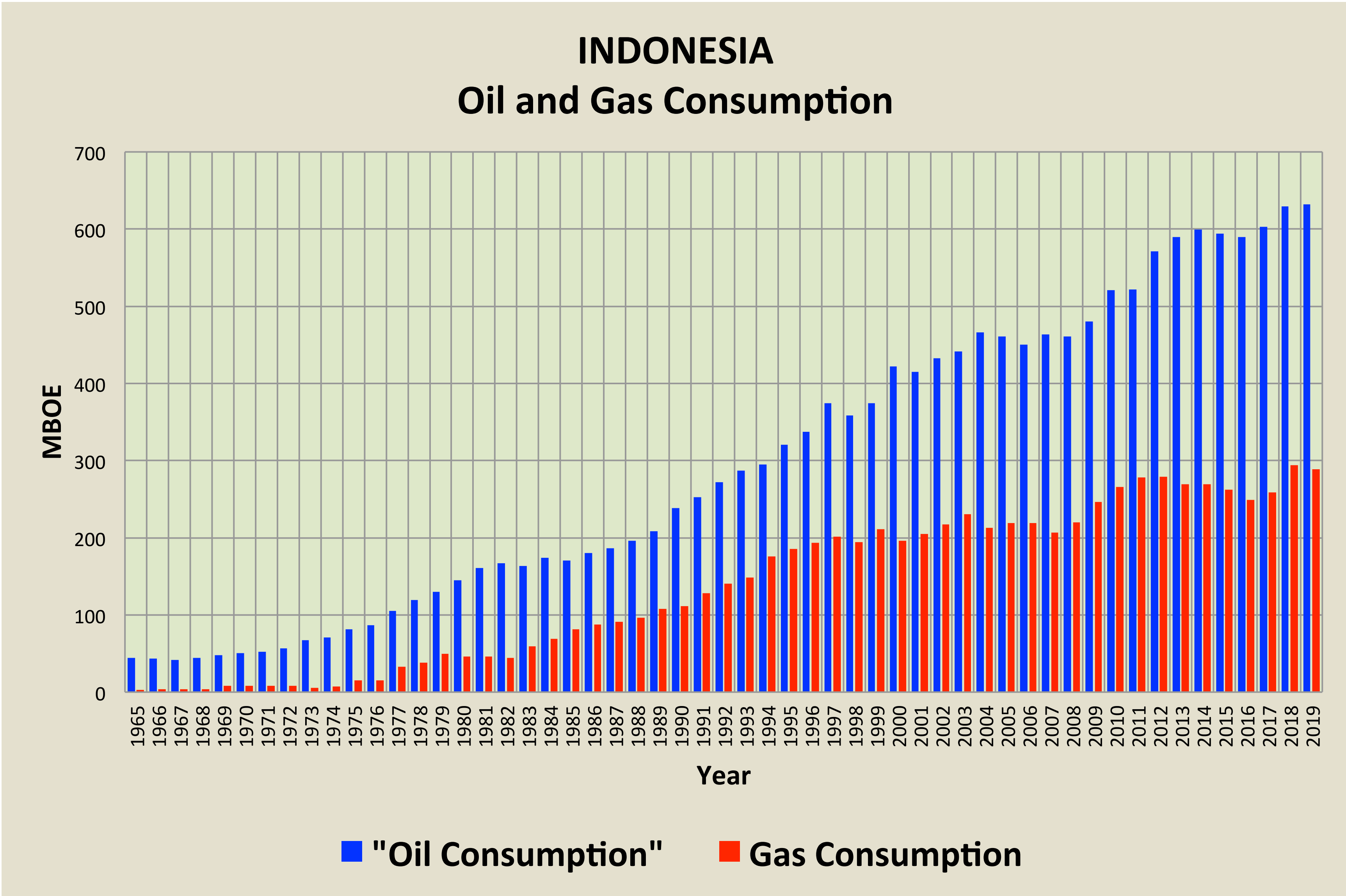


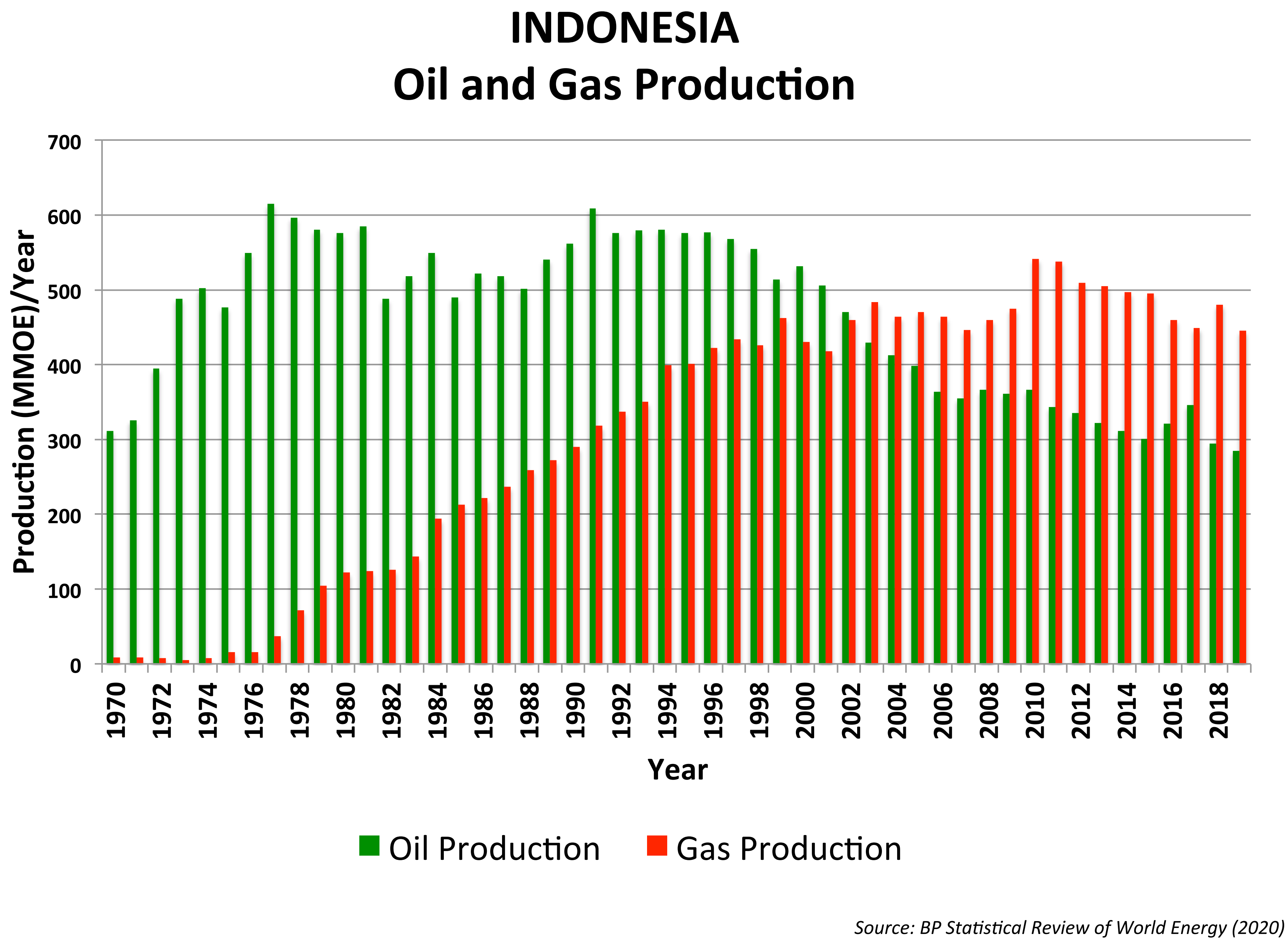
Source: BP Statistical Review of World Energy (2020)

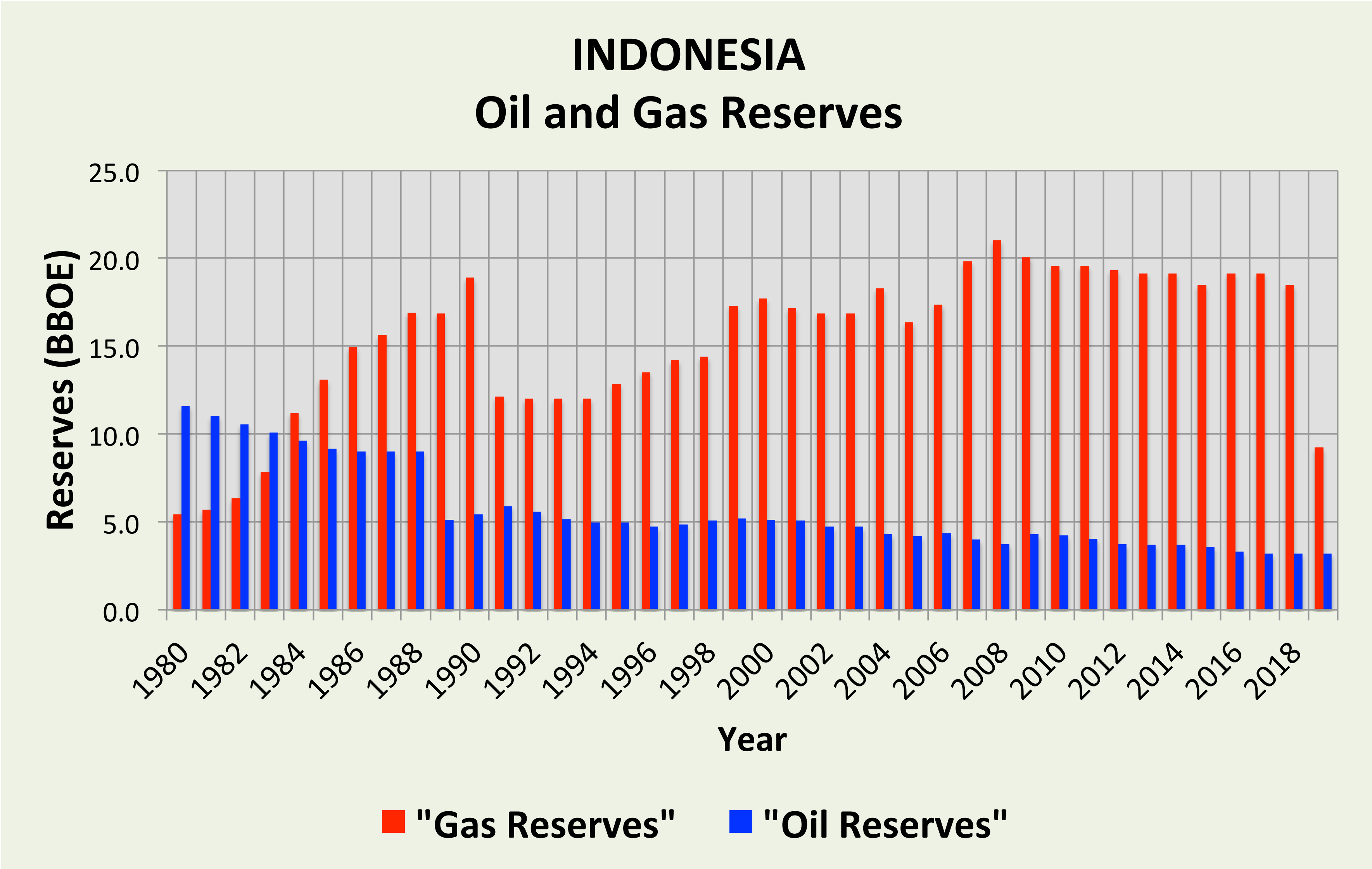


Source: BP Statistical Review of World Energy (2020)

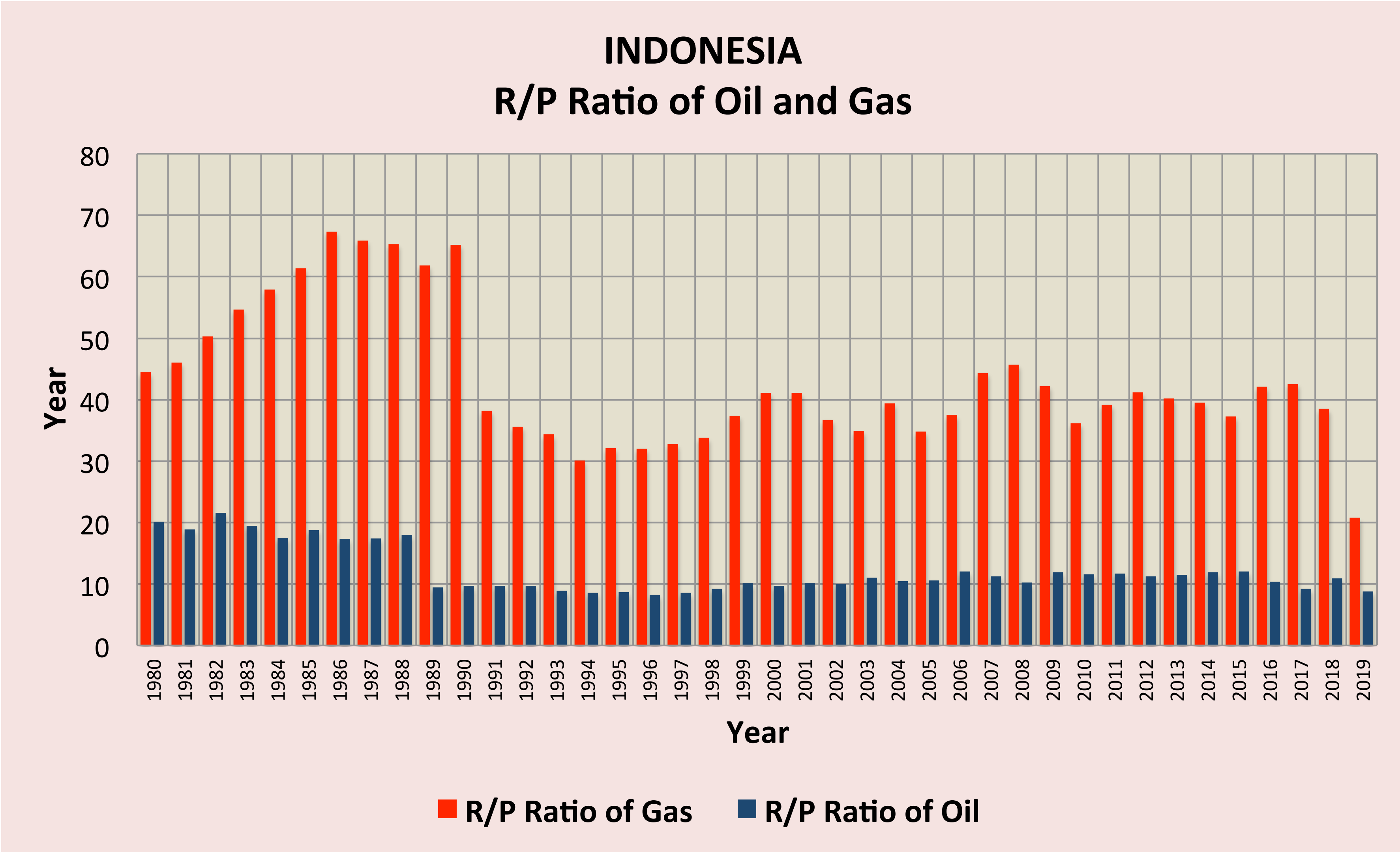


Source: BP Statistical Review of World Energy (2020)

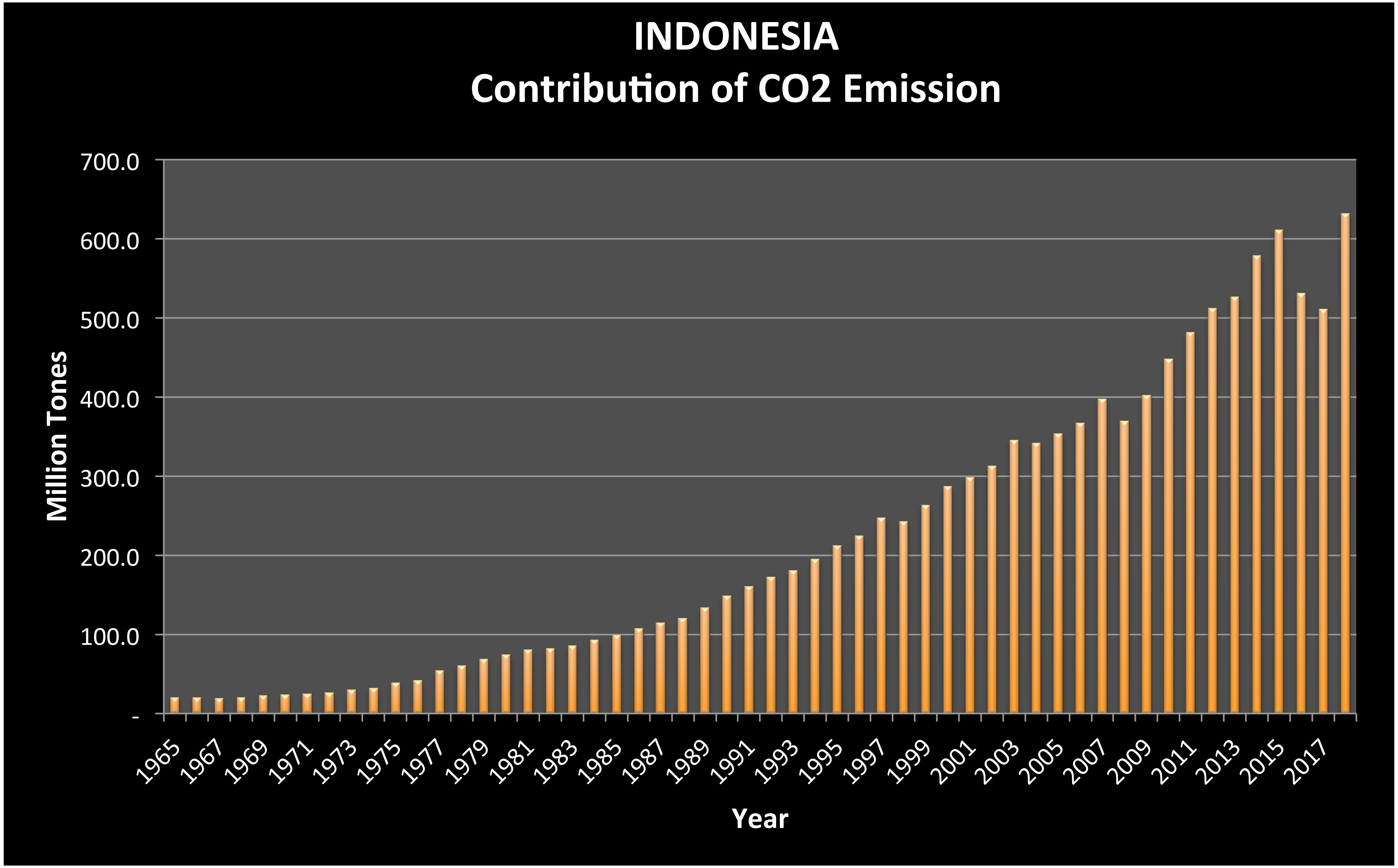

INDONESIA
Oil and Gas Production
700
600
500
400
300
200
100
0
Production (MMOE)/Year
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year
Oil Production
Gas Production
Source: BP Statistical Review of World Energy (2020)



Source: BP Statistical Review of World Energy (2020)



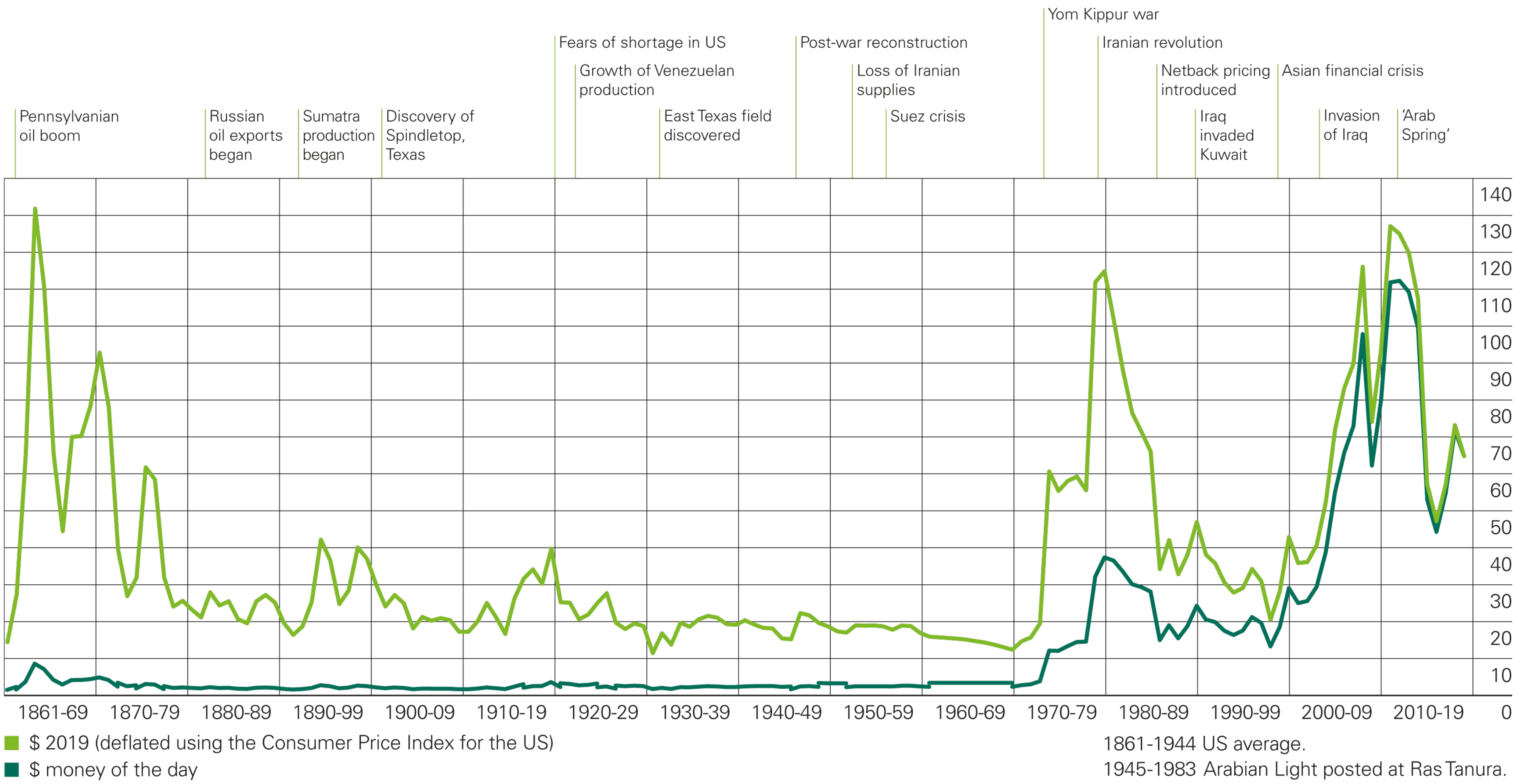
Source: BP Statistical Review of World Energy (2020)



Source: BP Statistical Review of World Energy (2020)

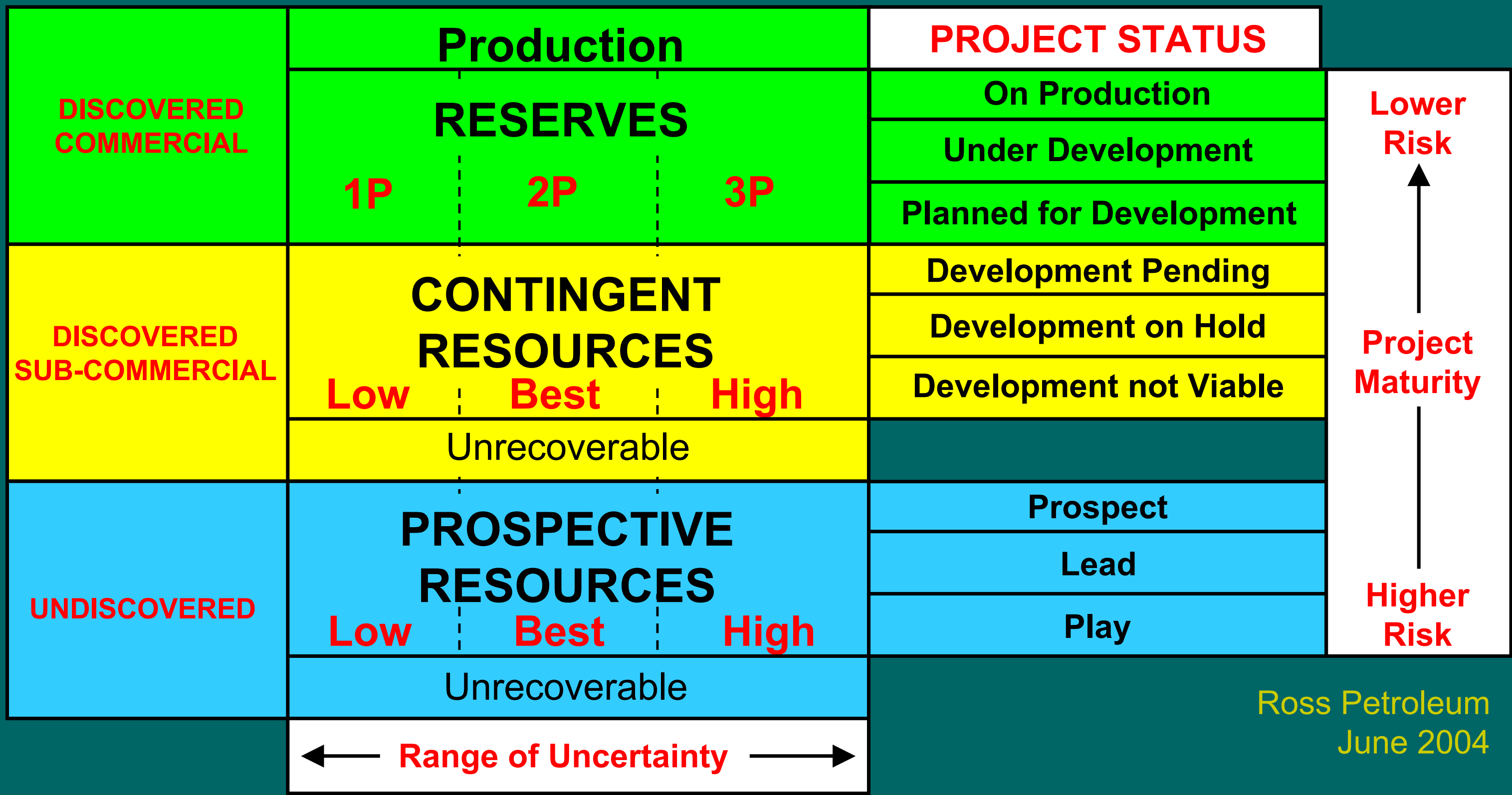
Crude oil prices 1861-2019

US dollars per barrel, world events



1861-1944 US average.
1945-1983 Arabian Light posted at Ras Tanura.
1984-2019 Brent dated.

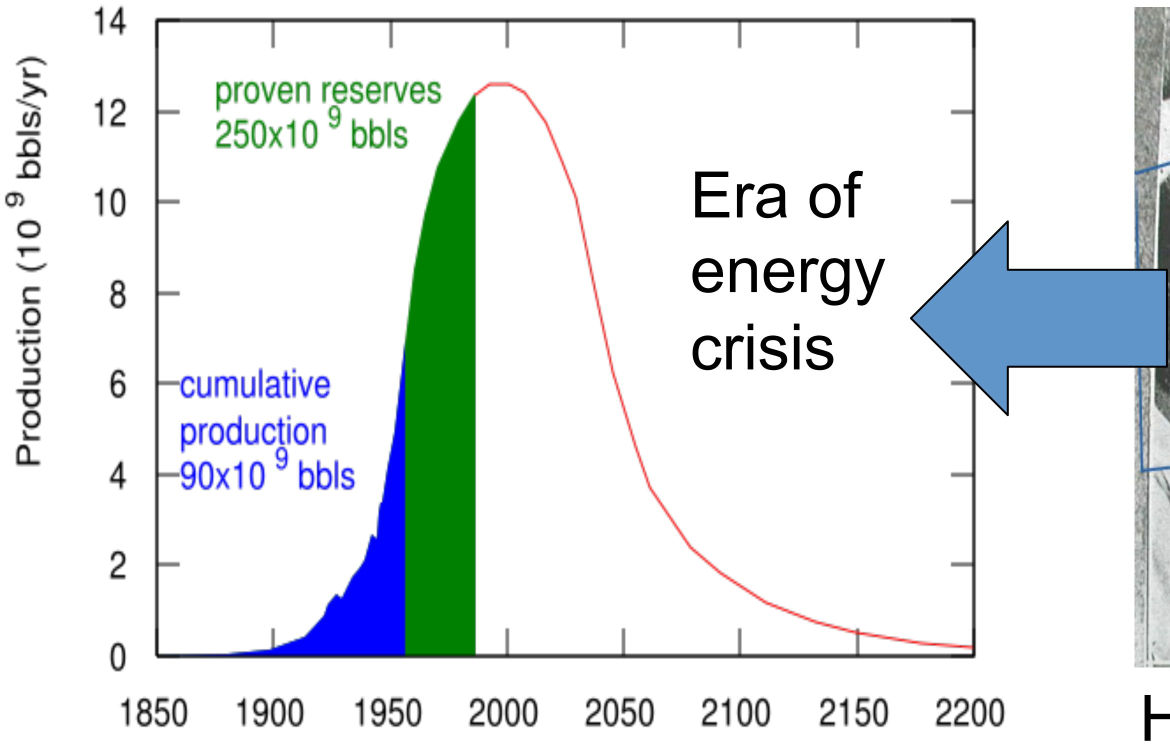
SPE/WPC/AAPG
Resource Classification System



Ross Petroleum
June 2004

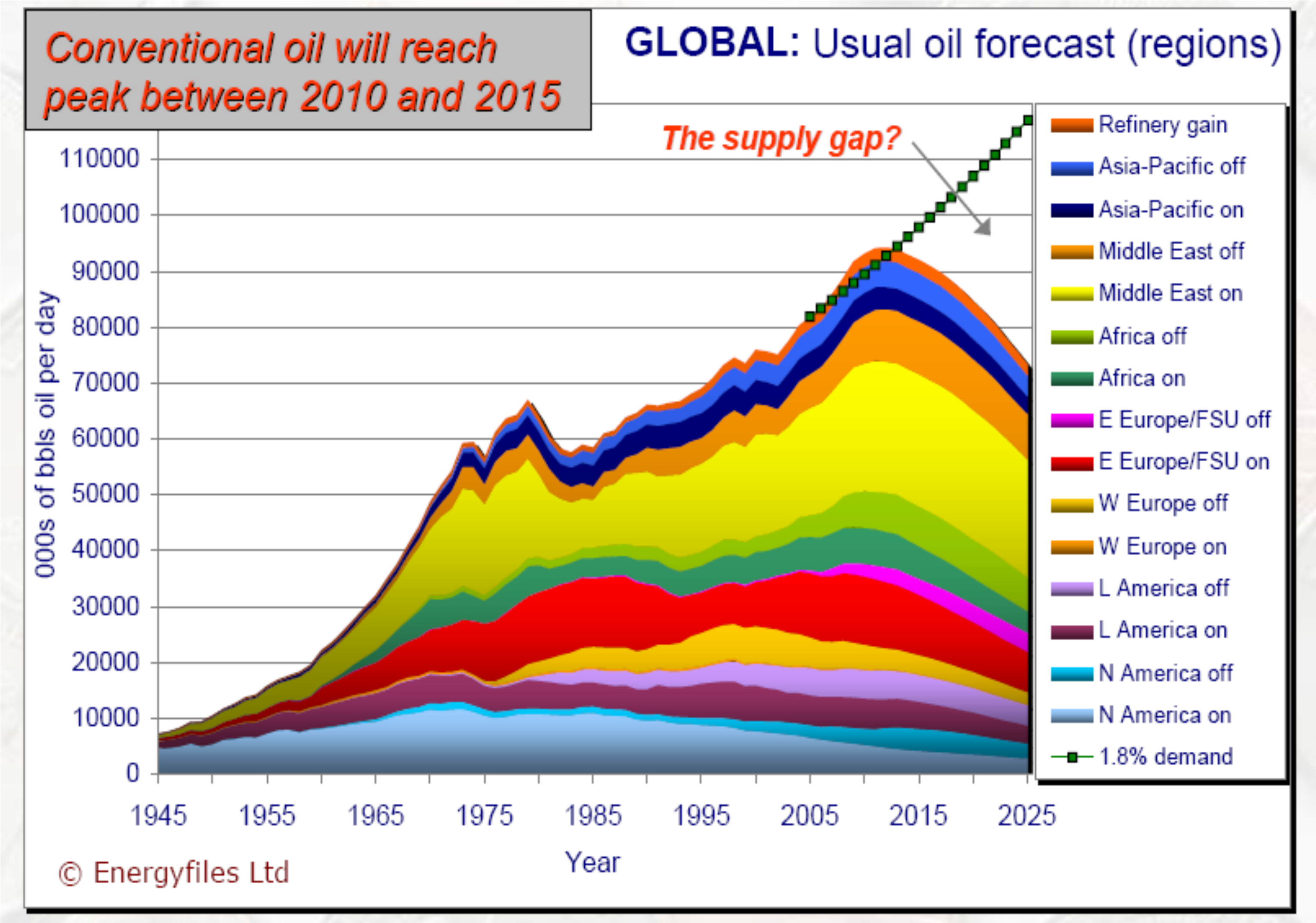
Peak Oil

en.wikipedia.org/wiki/Image:Hubbert_peak_oil_plot.svg



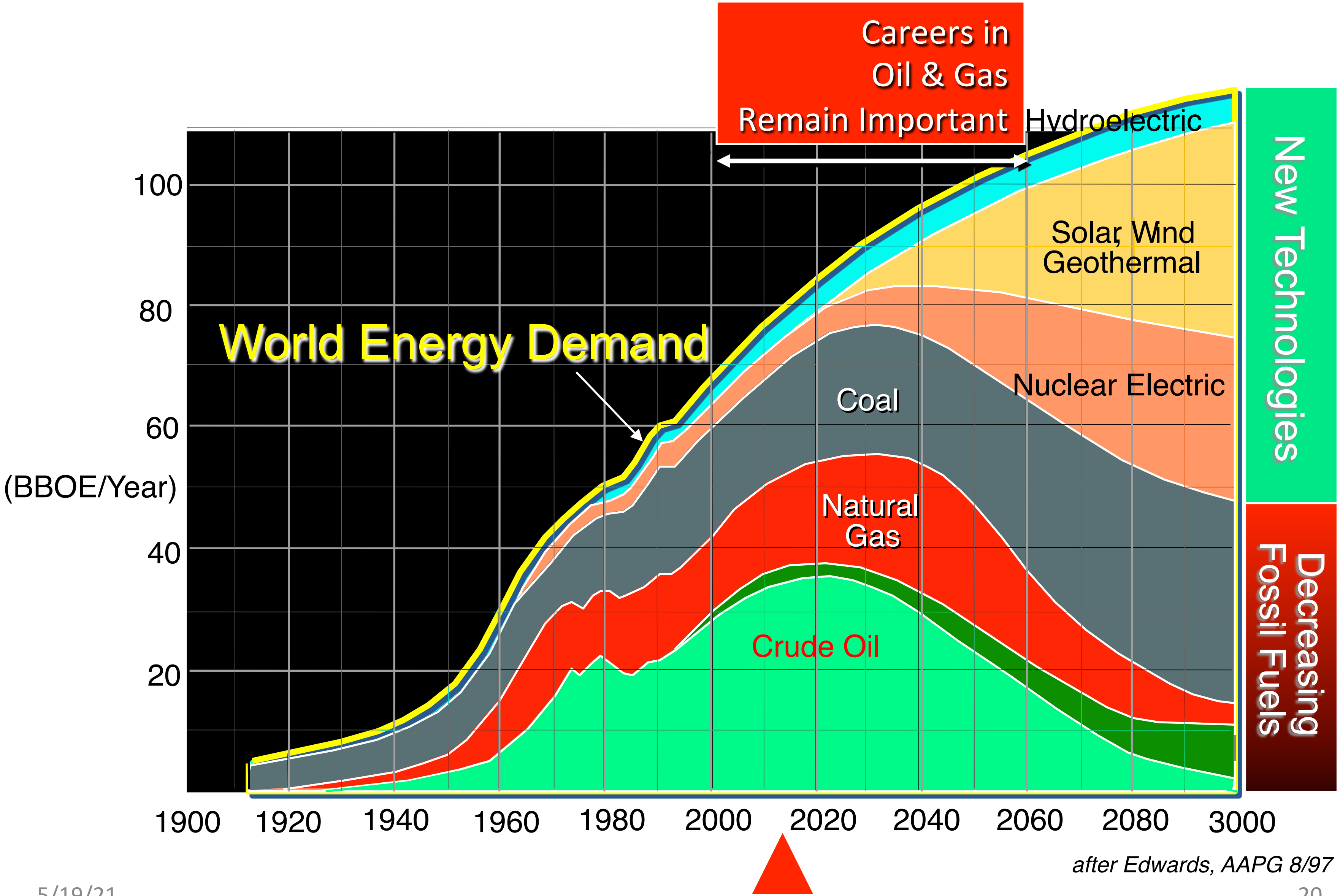
Hubbert (1903-1989)

In 1956, Hubbert predicted that global oil production would peak around the Year 2000 and trigger an Energy Crisis with power blackouts and rising costs of energy and fuel



Projection of world oil supply and demand up to 2025 (Energyfiles Ltd)

Projected World Energy Demand



after Edwards, AAPG 8/97

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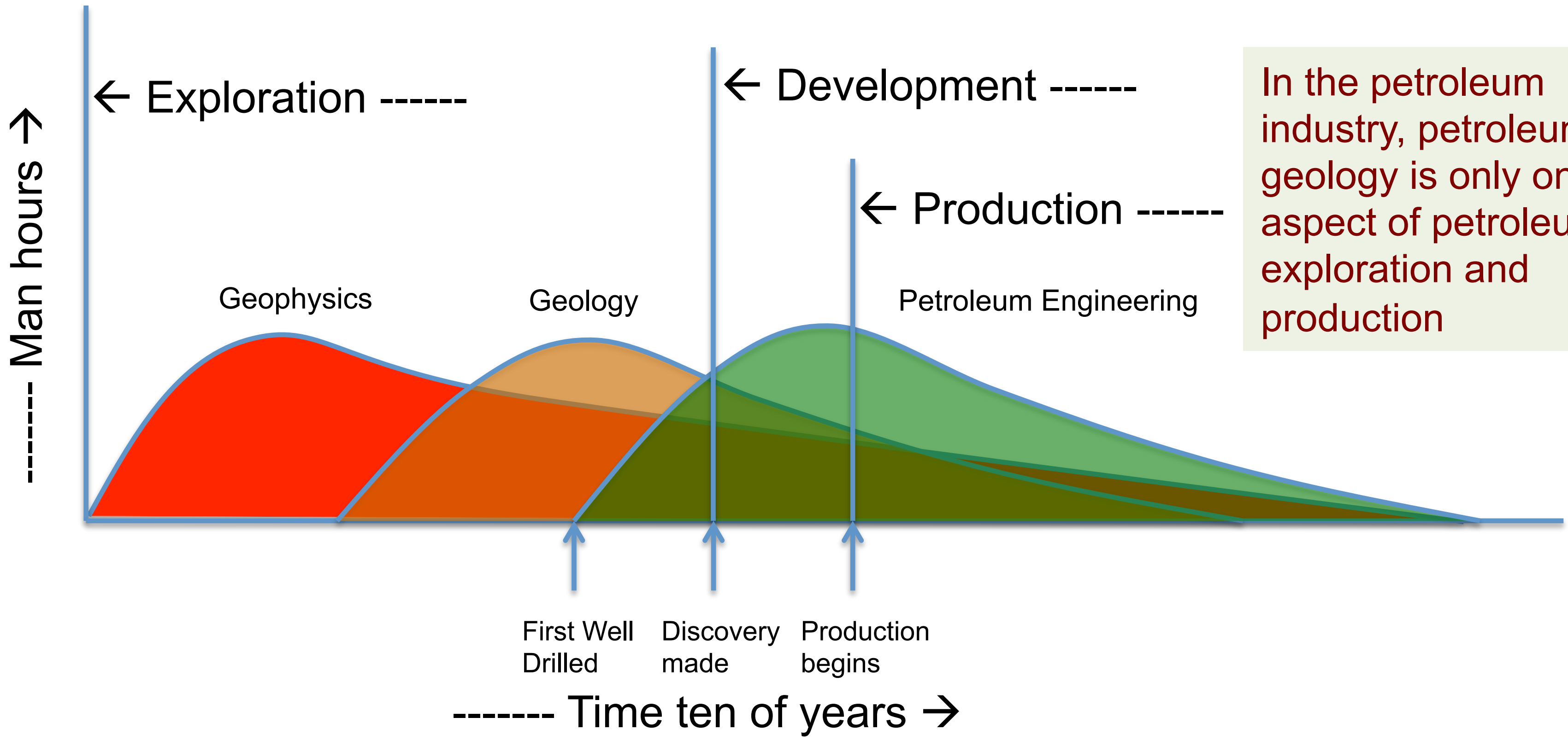
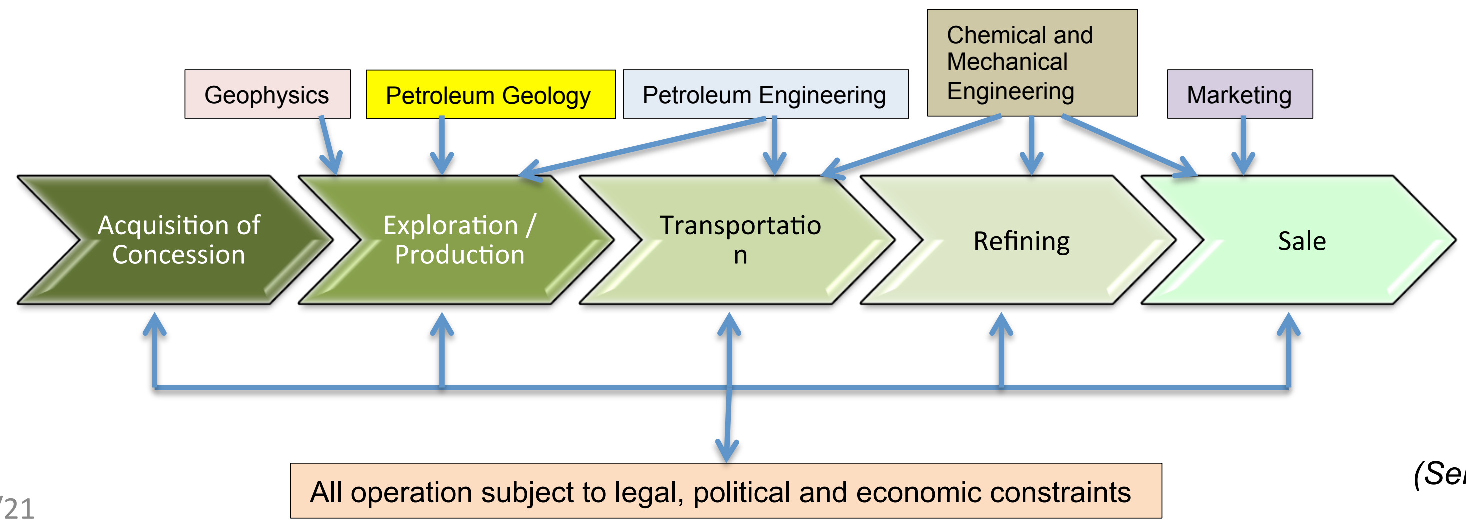
Level of Petroleum Investigation

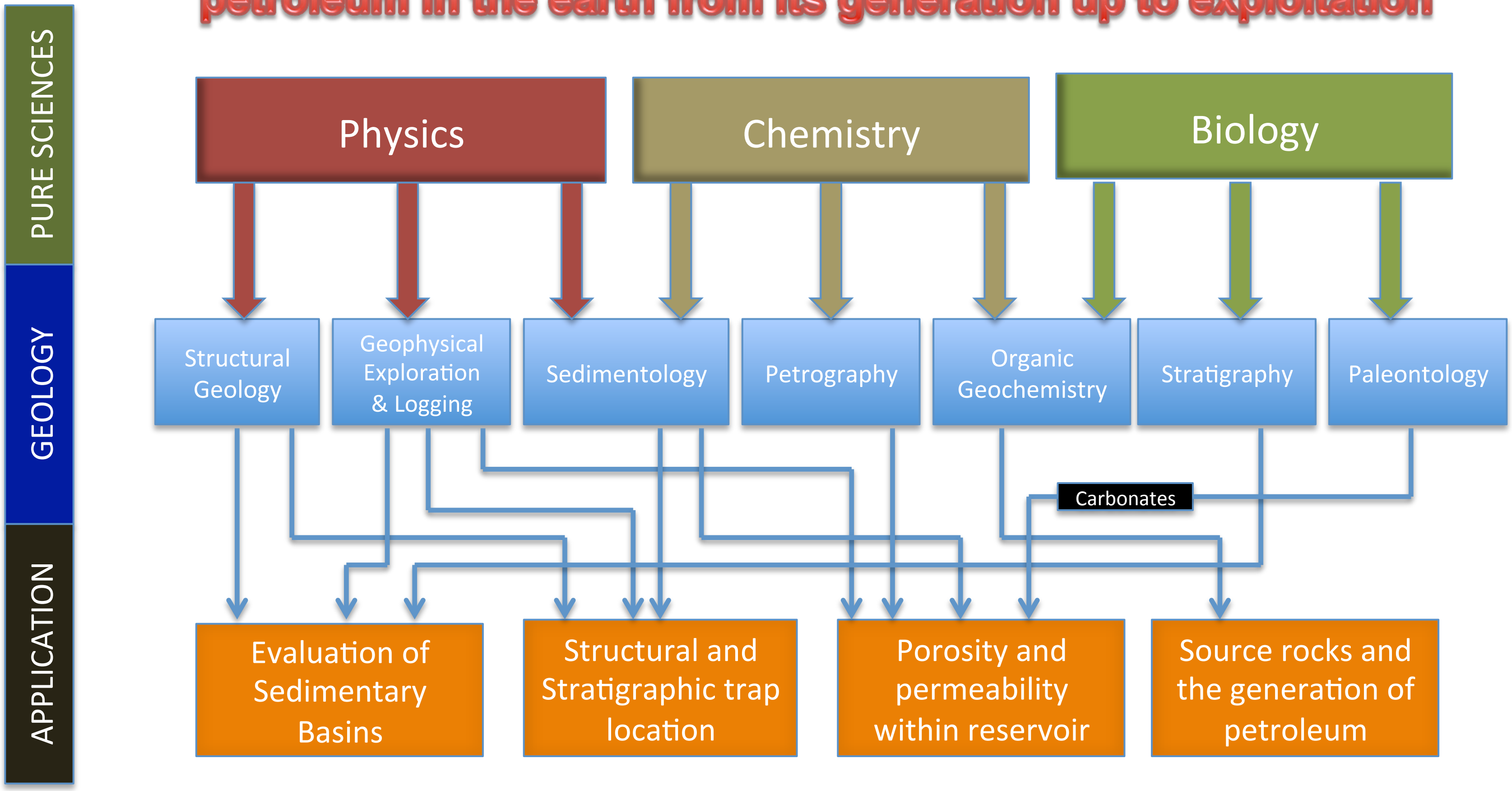


In the petroleum industry, petroleum geology is only one aspect of petroleum exploration and production



(Selley, 1998)

Petroleum Geology is branch of geology which study petroleum in the earth from its generation up to exploitation

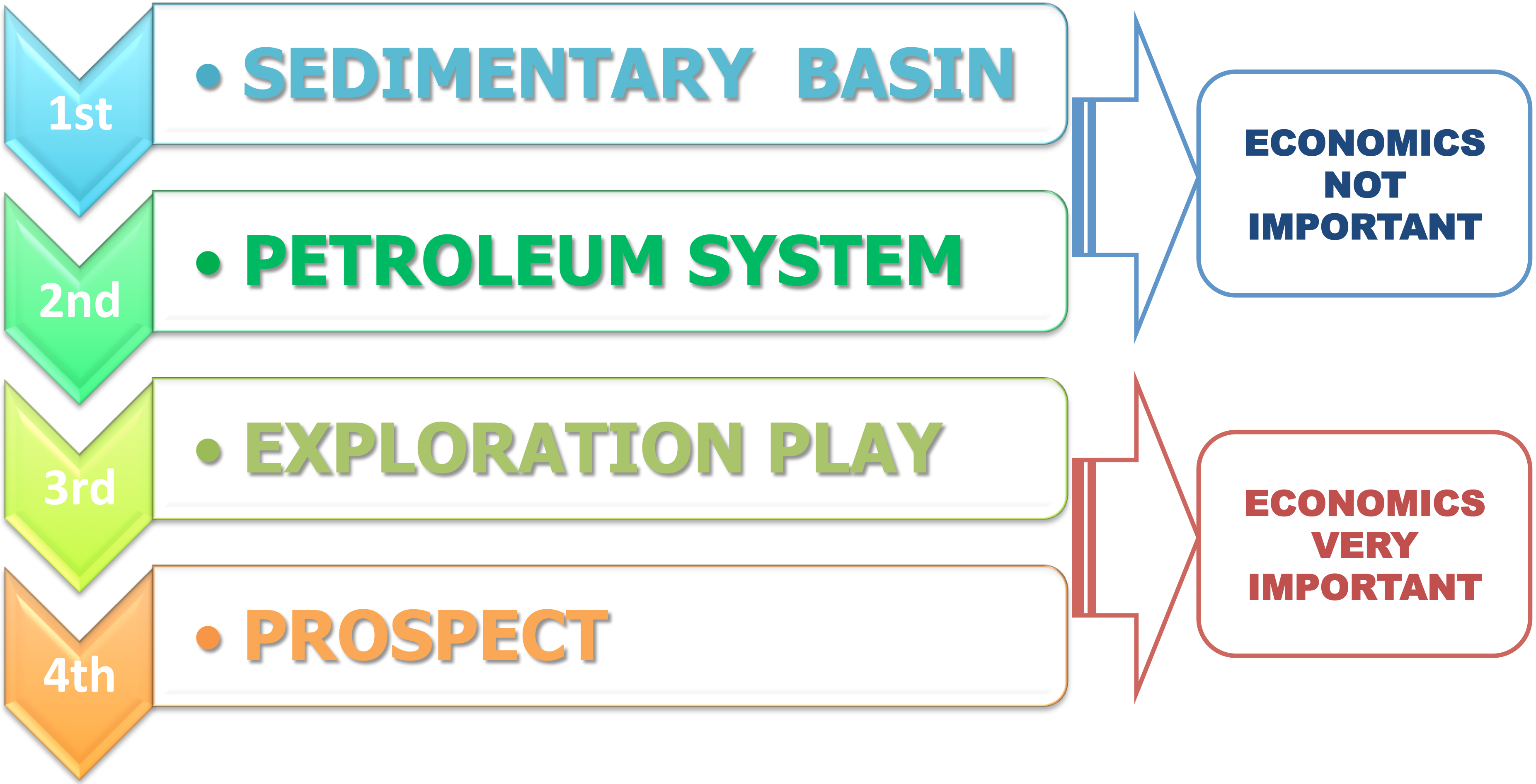


The relationship of petroleum geology to the pure science (Selley, 1998)

FRONTIER BASIN ANALYSIS

If plate tectonics involves all phases of global geology, it follows that it directly influences petroleum geology. There is no field of petroleum geology that is not controlled by (or at least connected with) plate tectonic processes, including basin formation processes, certain sedimentation processes, the type of sediments present, and the thermal maturation of kerogen-thus, the entire history of oil and gas. For example: a petroleum geologist will ask "To what degree is a certain area a prospect for oil?" To arrive at a correct answer, he or she must first answer a number of individual questions:

1. In what type of basin does the area lie?
2. How old is the sedimentary section?
3. Are source beds, reservoirs and cap rocks present?
4. What is the thermal history of the basin and the surrounding area?
5. Are there hydrocarbon migration possibilities?
6. Are there traps and, if so, of what type and age?
7. Have hydrocarbons leaked?
8. What is the possibility of discovering oil reserves?

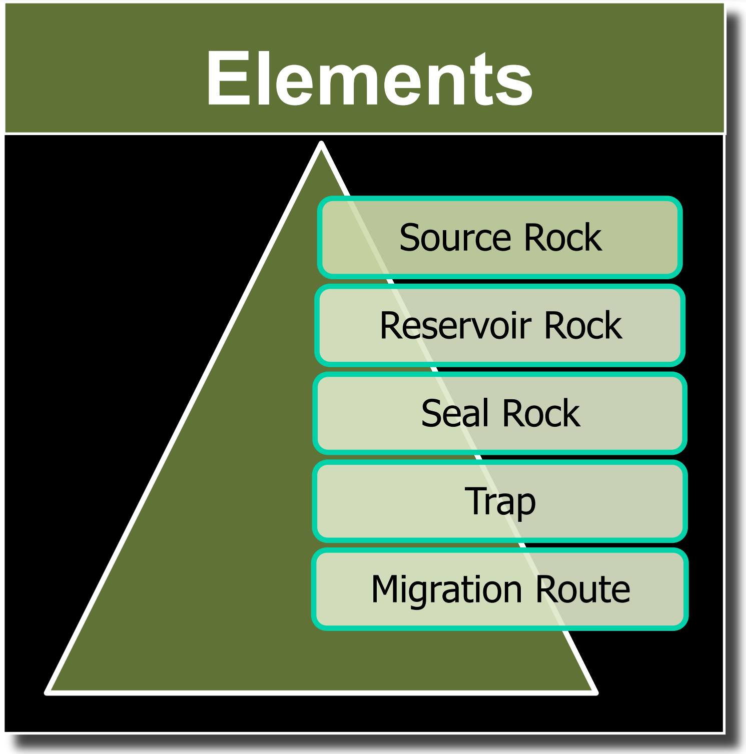


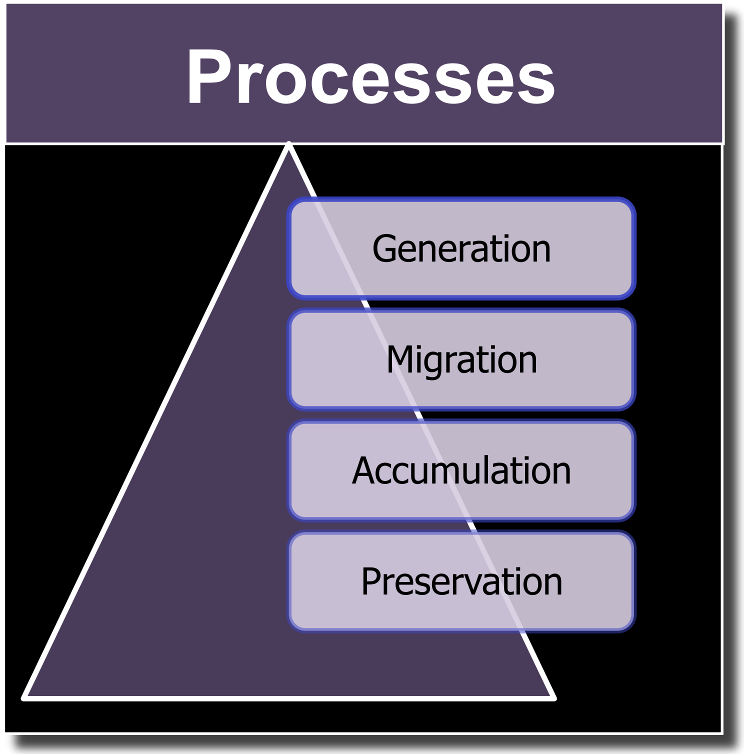
Four Levels of Petroleum Exploration

Magoon and Dow (1994)

Petroleum System Definition

[Geologic](#) components and processes necessary to generate and store hydrocarbons, including a mature source rock, [migration](#) pathway, [reservoir](#) rock, [trap](#) and [seal](#). Appropriate relative timing of [formation](#) of these elements and the processes of [generation](#), migration and [accumulation](#) are necessary for hydrocarbons to accumulate and be preserved. The components and critical timing relationships of a [petroleum](#) system can be displayed in a chart that shows geologic time along the horizontal axis and the petroleum system elements along the vertical axis. [Exploration](#) plays and prospects are typically developed in basins or regions in which a complete petroleum system has some likelihood of existing.

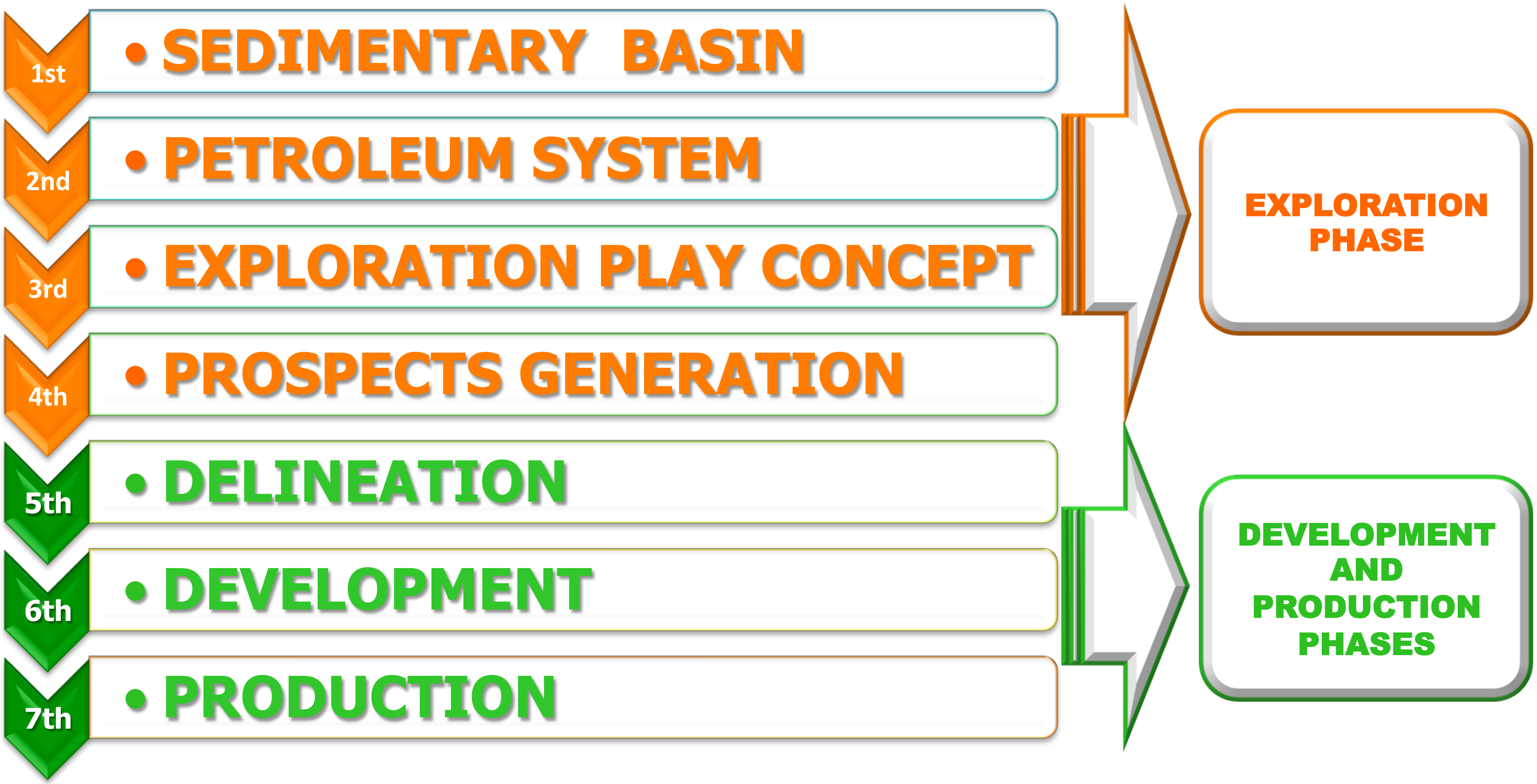




Factor Comparison
in the Four Levels of Petroleum Investigation

Factor	Sedimentary Basin	Petroleum System	Play	Prospect
Investigation	Sedimentary Rock	Petroleum	Traps	Trap
Economics	None	None	Essential	Essential
Geologic Time	Time of deposition	Critical Moment	Present-day	Present-day
Existence	Absolute	Absolute	Conditional	Conditional
Cost	Very Low	Low	High	Very high
Analysis & Modeling	Basin	System	Play	Prospect

Magoon and Dow (1994)



Seven Levels of Petroleum Investigation

Magoon and Dow (1994)

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The Challenges and Opportunities

Oil and gas operational phases and Technology Involvement

Project phase	Critical subsurface information	Technology Involvement
1) Exploration	▪ Proven Petroleum System and Play Concepts ▪ Resources and Reserves information	▪ Geophysics ▪ Geology Concept ▪ Drilling
2) Delineation	▪ Total hydrocarbon volume ▪ Areal limits of petroleum reservoir ▪ Deliverability	▪ Geophysics ▪ Geology Concept ▪ Drilling ▪ Reservoir
3) Development	▪ Compartmentalization ▪ Bypass Oil ▪ Exact locations of development wells	▪ Geophysics ▪ Development Geology ▪ Drilling ▪ Reservoir
4) Production	▪ Hydrocarbon saturation and pressure changes ▪ Flow restrictions and channeling	▪ Production ▪ Reservoir ▪ Geophysics

Oil and Gas Exploration and Production Challenges and Opportunities

How we can

- Re-Mapping of Sedimentary Basins of Indonesia
- Define the Petroleum System and Exploration Play Concepts of each Sub-Basins of Indonesia
- Define the Oil and Gas Resources of entire Basins of Indonesia
- Prove the resources to be reserves, including the areas where seismic method doesn't work
- Build reservoir model accurately
- Monitor and image the dynamic properties of reservoir until field termination
- Optimize production and Improve Recovery Factor
- Reduce CO_2 Emission

OIL PLAY CHALLENGE

Declining Conventional Oil and Gas Reserves and Production

Are still have possibility to increase its? Where, how much and what concept and technology to be applied

?

PROBLEM STATEMENT

How can we double the production and still have bigger reserve than we started with?

New Concept and High Technology

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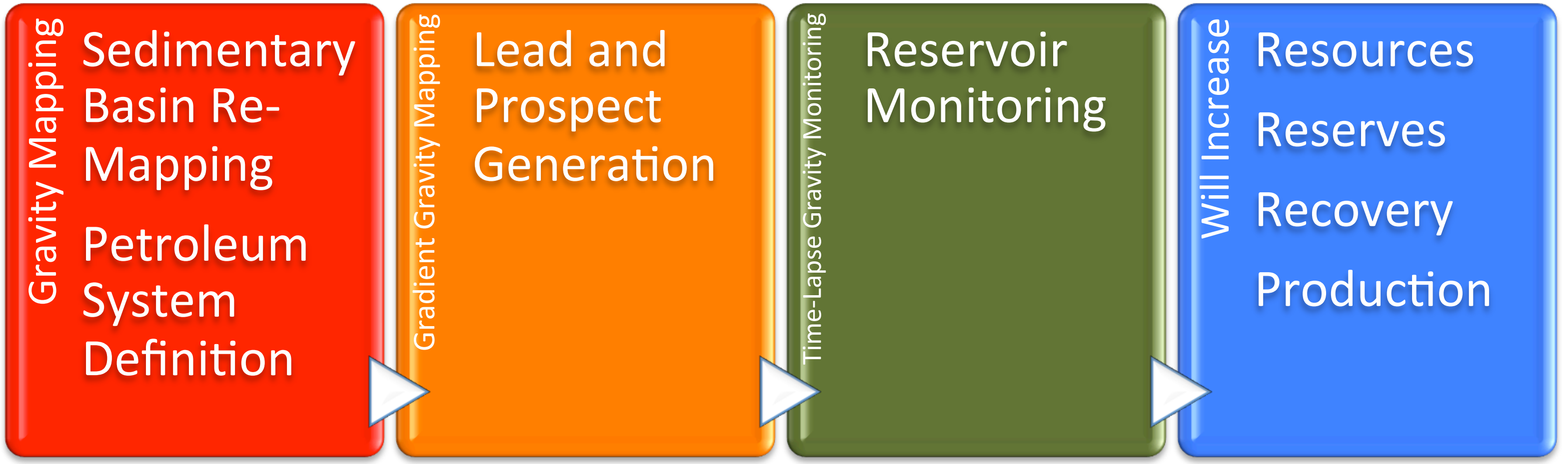
Paradigm Shift of Gravity Technology Utilization In Oil and Gas Industry

Stages	Geophysical Tools
1. Regional Study	Gravity, Magnetic, 2D Seismic
2. Leads and Prospect Generation	2D or 3D Seismic
3. Drillable Prospect Generation	2D or 3D Seismic
4. Drilling	Borehole Seismic (Checkshot, VSP)
5. Plan of Development	3D Seismic Reflection, Resistivity
6. **Reservoir Monitoring**	**Time lapse Geophysics (4D Gravity, 4D Seismic)**

Opportunities to Increase Reserve and Production Using Gravity Technology



Indonesia Oil and Gas Opportunities

1. National Exploration and Production Data Availability
2. National Experts
3. Technology Availability
4. Opportunities to discover
   - *New Basins for future exploration activities*
   - *The extension of proven play area in mature basins*
   - *New exploration play*
   - *Additional resources and reserves*
   - *Recovery Efficiency*

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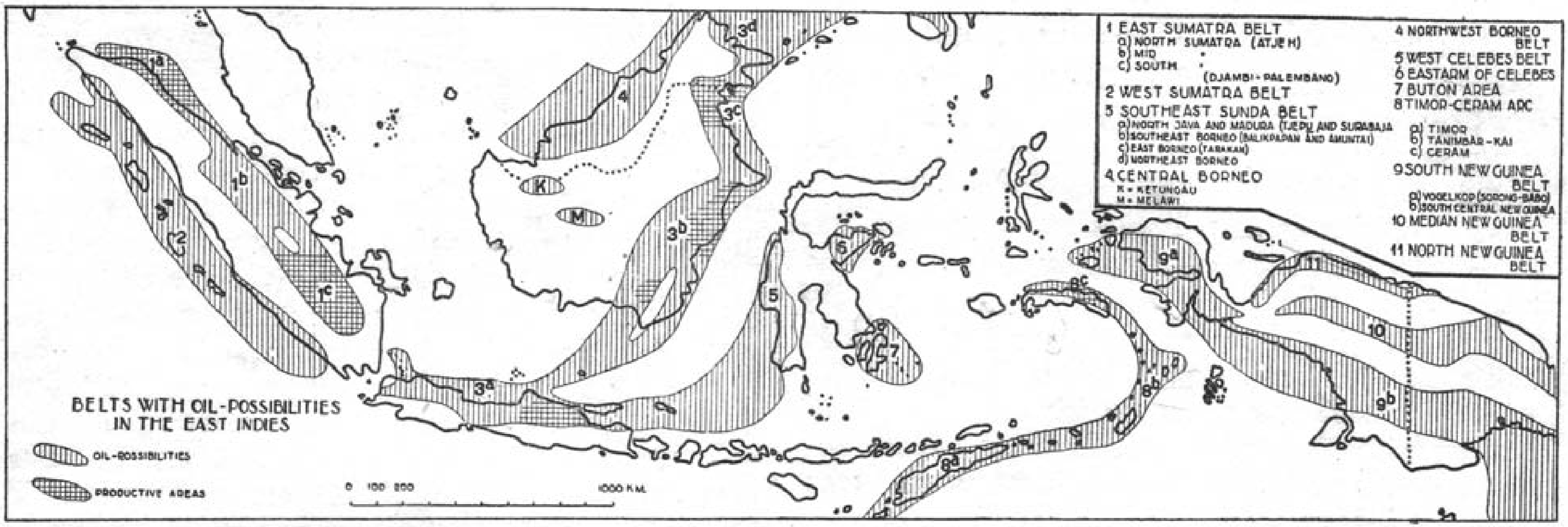
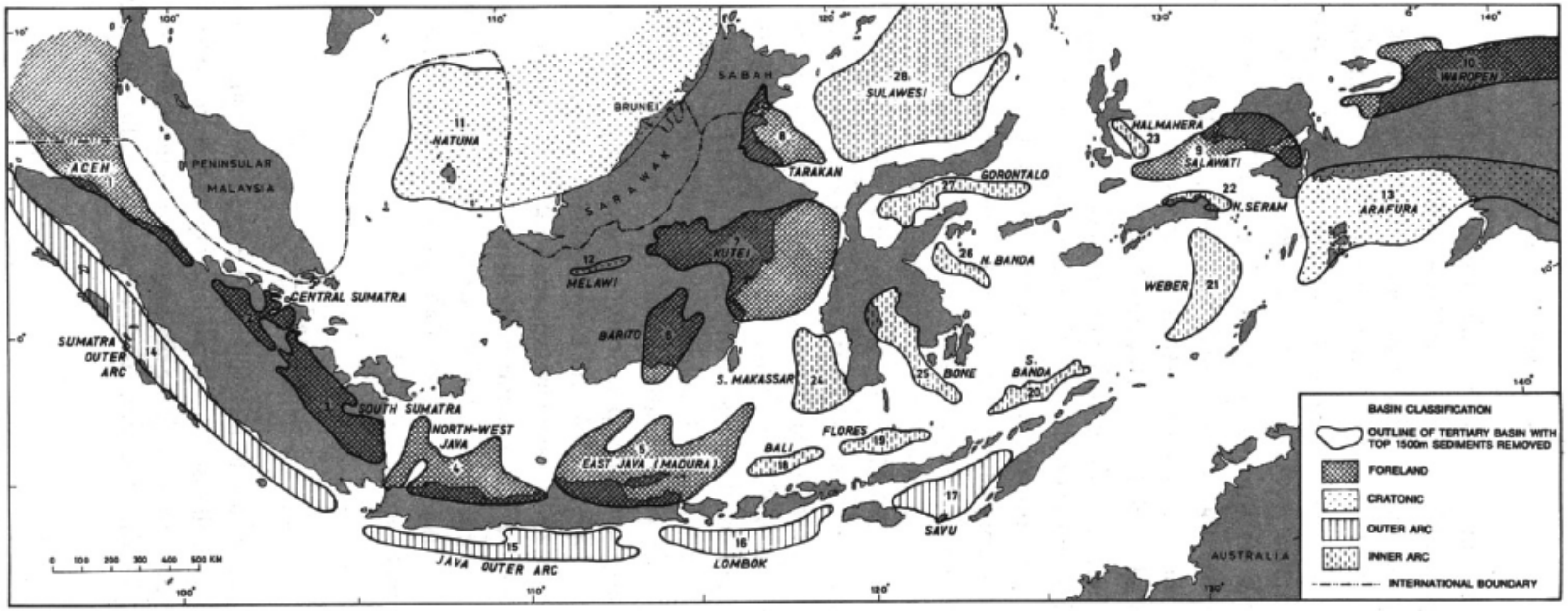
INDONESIA'S PETROLEUM SEDIMENTARY BASIN HISTORY



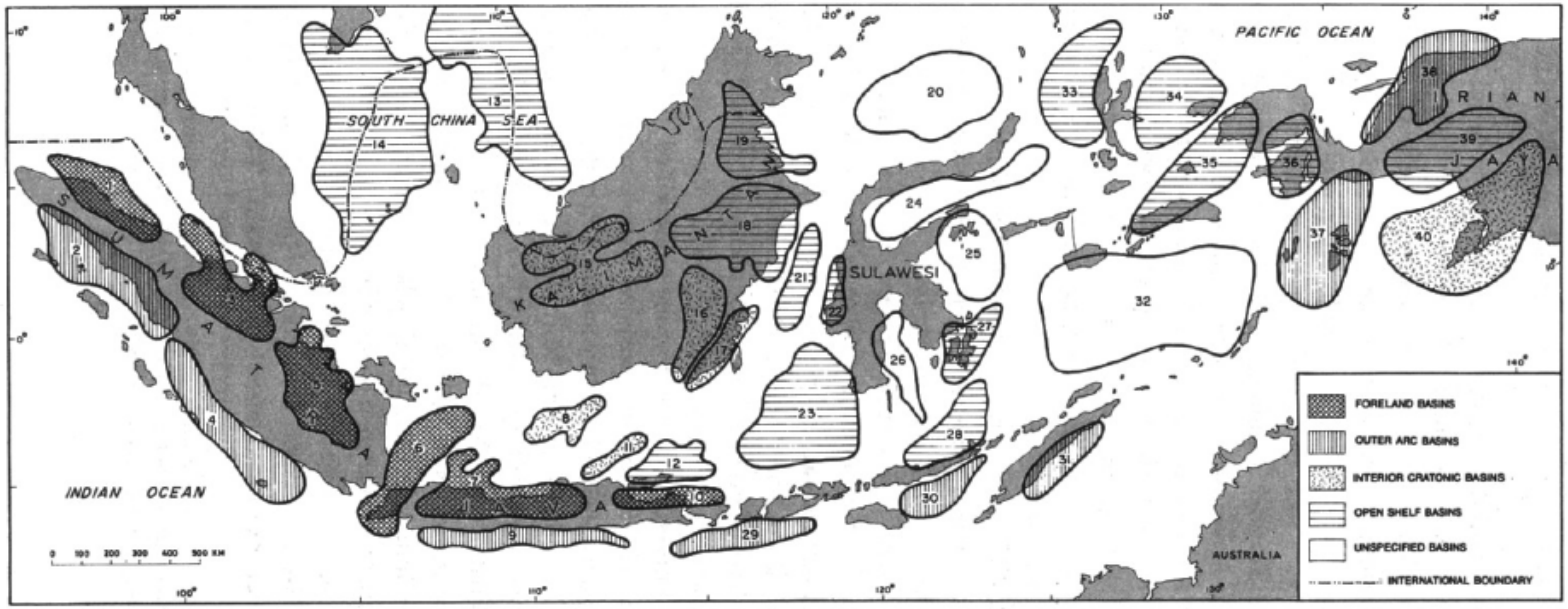
Peta awal penyebaran jalur minyak Indonesia (van Bemmelen, 1949)



Tertiary basins types in Indonesia

28 basins (Fletcher and Soeparjadi, 1976)

Satyana (2006)



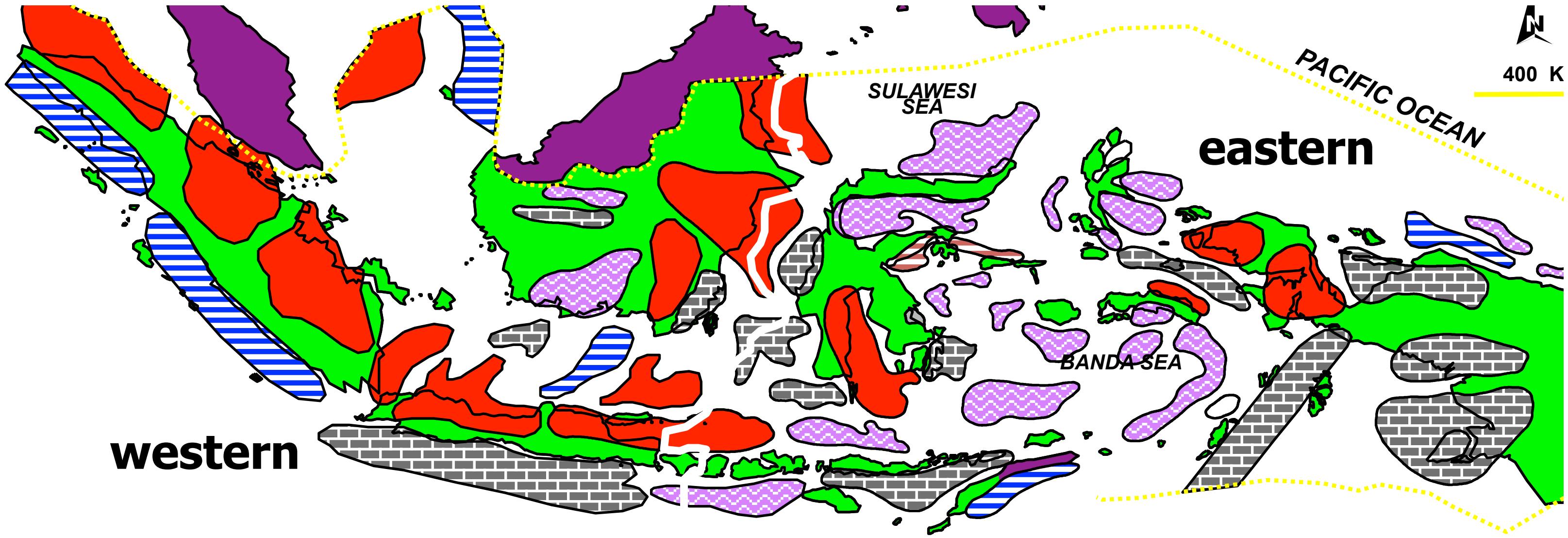
Tertiary basins types in Indonesia

40 basins (Nayoan et al., 1979; IAGI, 1980)

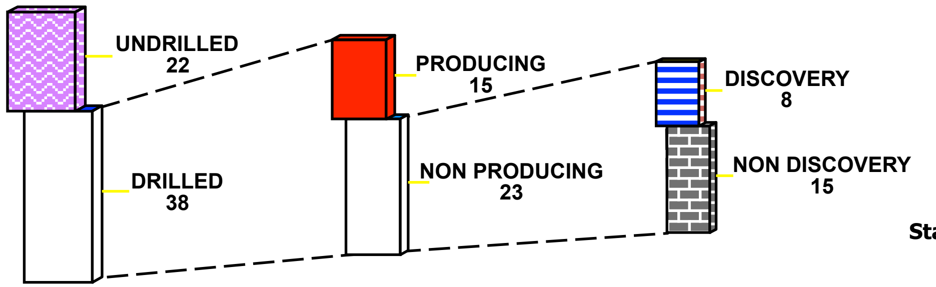
Satyana (2006)

ENERGY RESOURCES MAP OF INDONESIA (IAGI, 1985)

INDONESIA TERTIARY SEDIMENTARY BASINS



TOTAL OF 60 BASINS



Status : Jan 01, 1999

Indonesia Basins Re-Mapping Using Gravity Data

BASIC CONCEPT AND OBJECTIVE

Old Data New Technology and Concept

Gravity	Magnetic	Seismic	Well Log	Landsat	Surface Geology

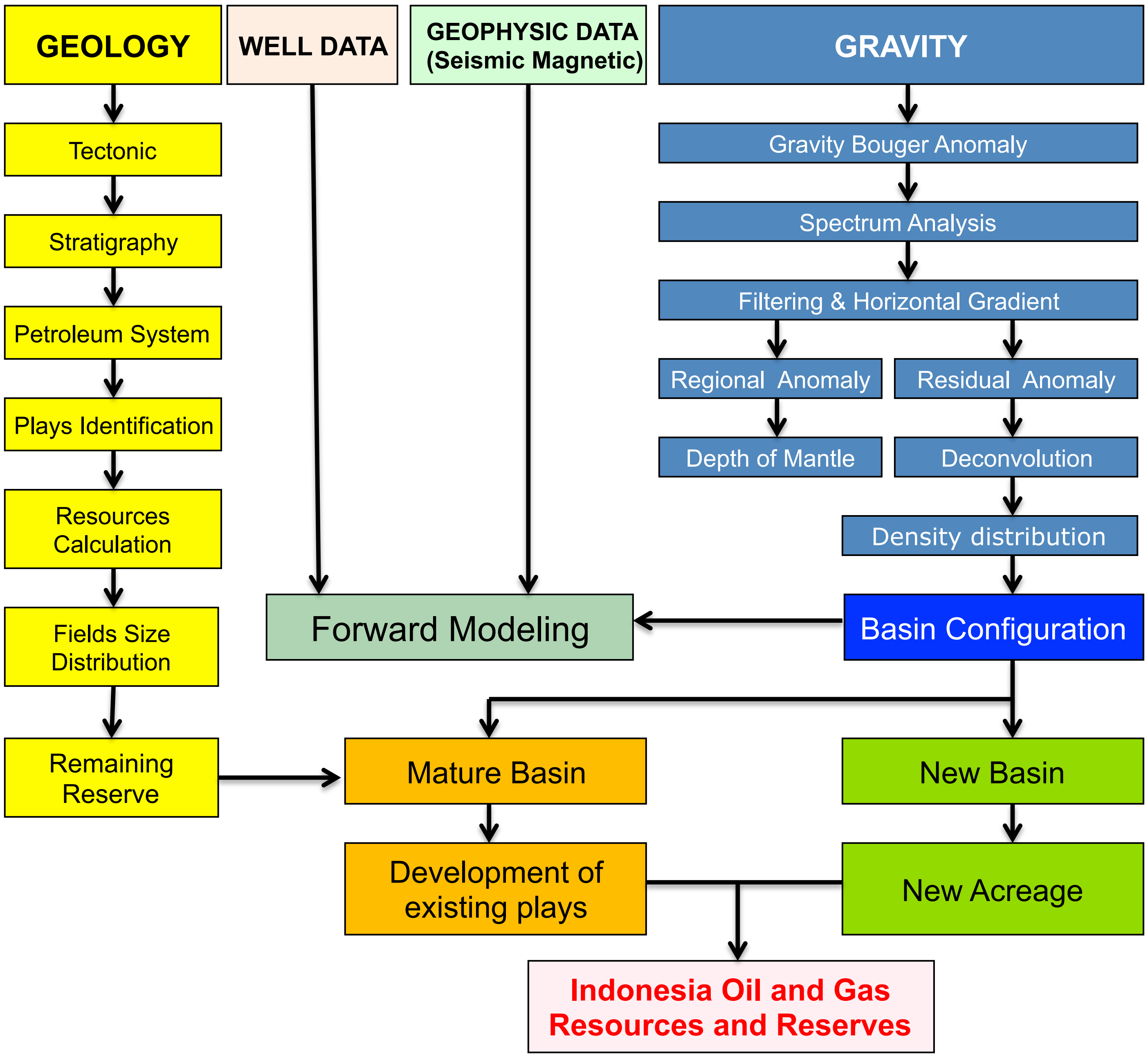
Better Understanding of Geology

Basin configuration	Tectonic	Structure	Depth to Basement	Petroleum System

New Exploration and Acquisition Strategy

New View on Mature Basins: *New Plays and Development of Existing Plays*	Opportunities Discover New Basins

Integrated Basin Mapping Methodology Using Gravity Data



Indonesia's Basin Re-Mapping

(The Challenges, Approach and Deliverable)

PETROLEUM SEDIMENTARY BASIN MAPPING

- Basin Mapping History
- Recent Status
- Geodynamic Analysis
- Tectonic Inversion Analysis
- Basin Validation
- *Validated Petroleum Basin Map*

BASIN CLASSIFICATION

- Tectonic History
- Basin Evolution
- Sedimentary History
- Heat Flow Pattern
- *Heat Flow Map*
- *Basin Type Classification*
- *Indonesia Basin Codification*

PETROLEUM SYSTEM AND PLAY

- Source Rocks Types and Oil Expelled
- Regional Migration Pathways
- Reservoir Development
- Traps
- Exploration Play Concepts
- *Oil Expelled Calculation*
- *Regional Migration Pathways Map*
- *Reservoir Development Map*
- *Petroleum System Chart*
- *Exploration Play Concepts Map*

BASIN STATUS

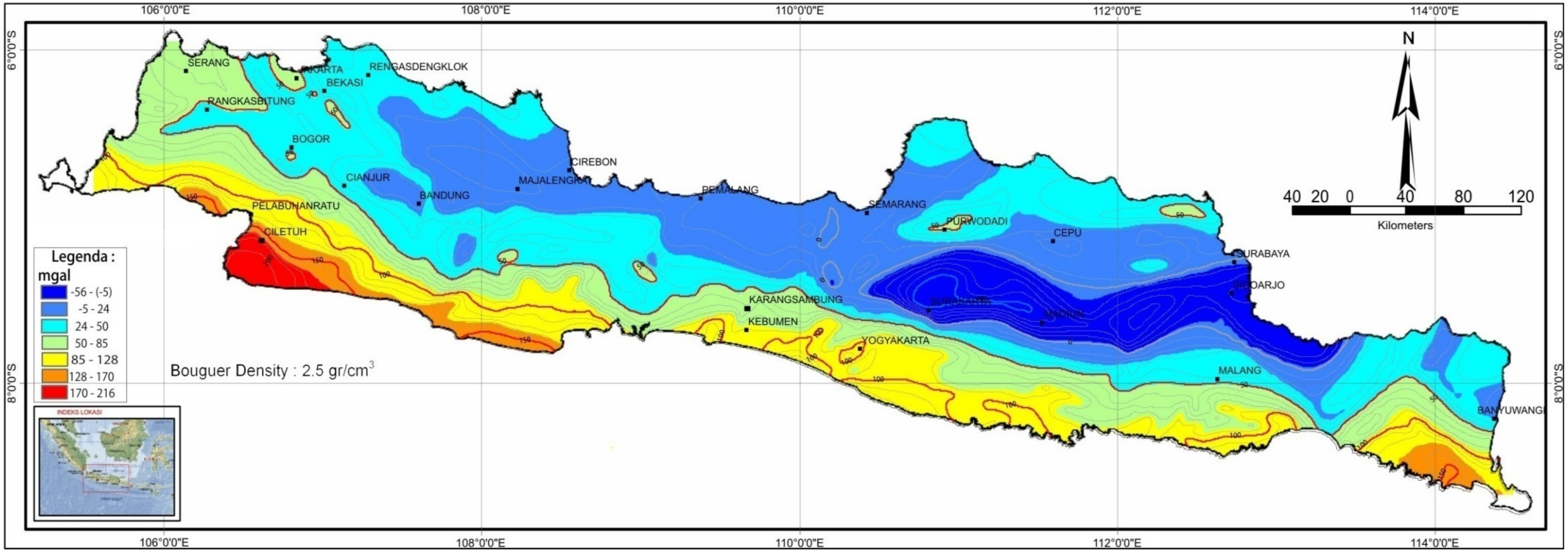
- Basin's Fields Size Distribution
- Play's Field Size Distribution
- Exploration Efficiency
- Remaining Reserve
- *Basin's Fields Size Distribution Chart*
- *Play's Field Size Distribution Chart*
- *Exploration Efficiency*
- *Remaining Reserve*

RECOMMENDATION

- New Frontier Area
- New Plays
- Development of Existing Plays
- Technology Support (Passive Seismic)
- *New Frontier Area*
- *New Plays Area*
- *Development of Existing Plays Area*
- *Technology Support (Passive Seismic)*

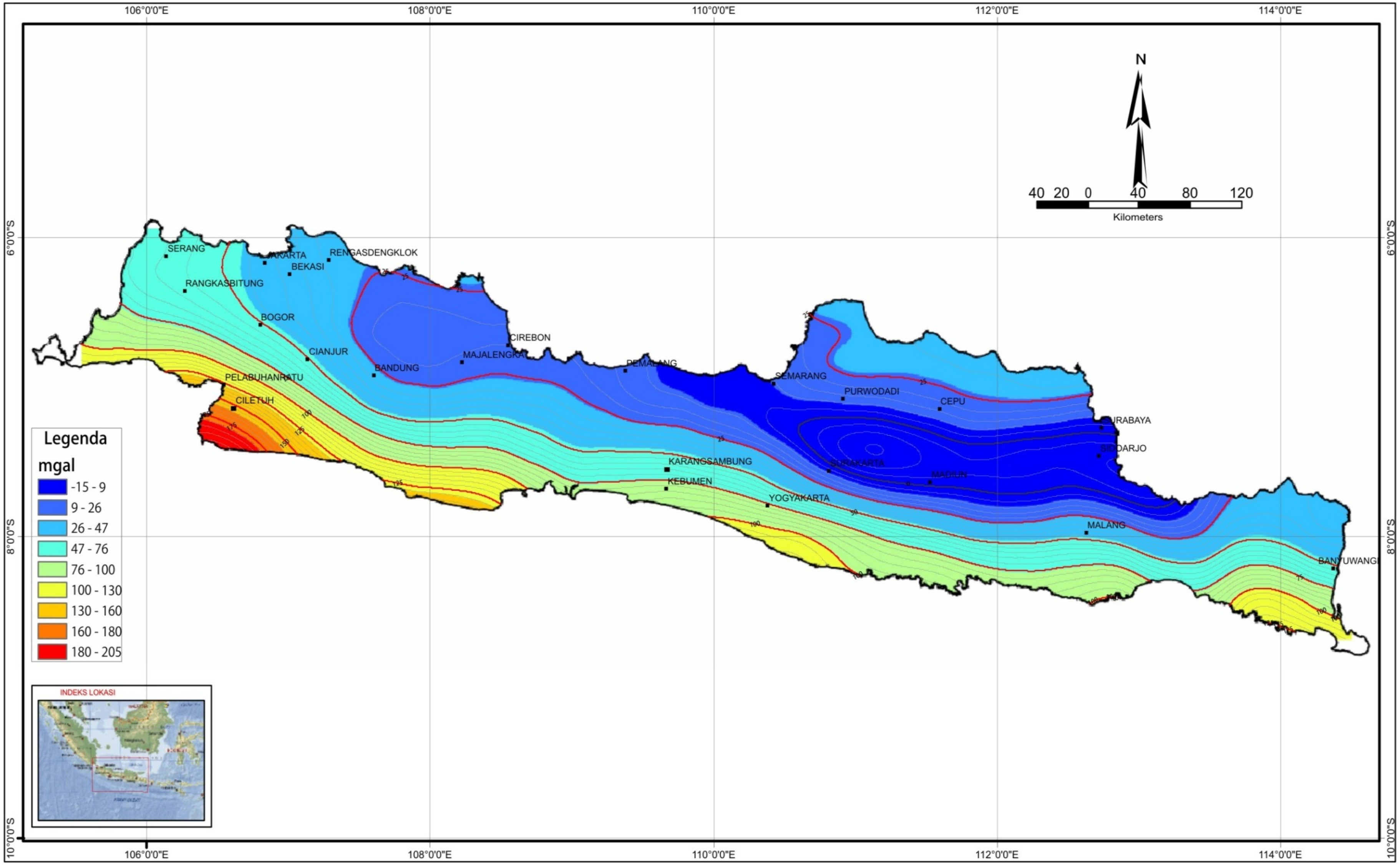
Modified from (Eko Widianto, 2008)

CASE STUDIES



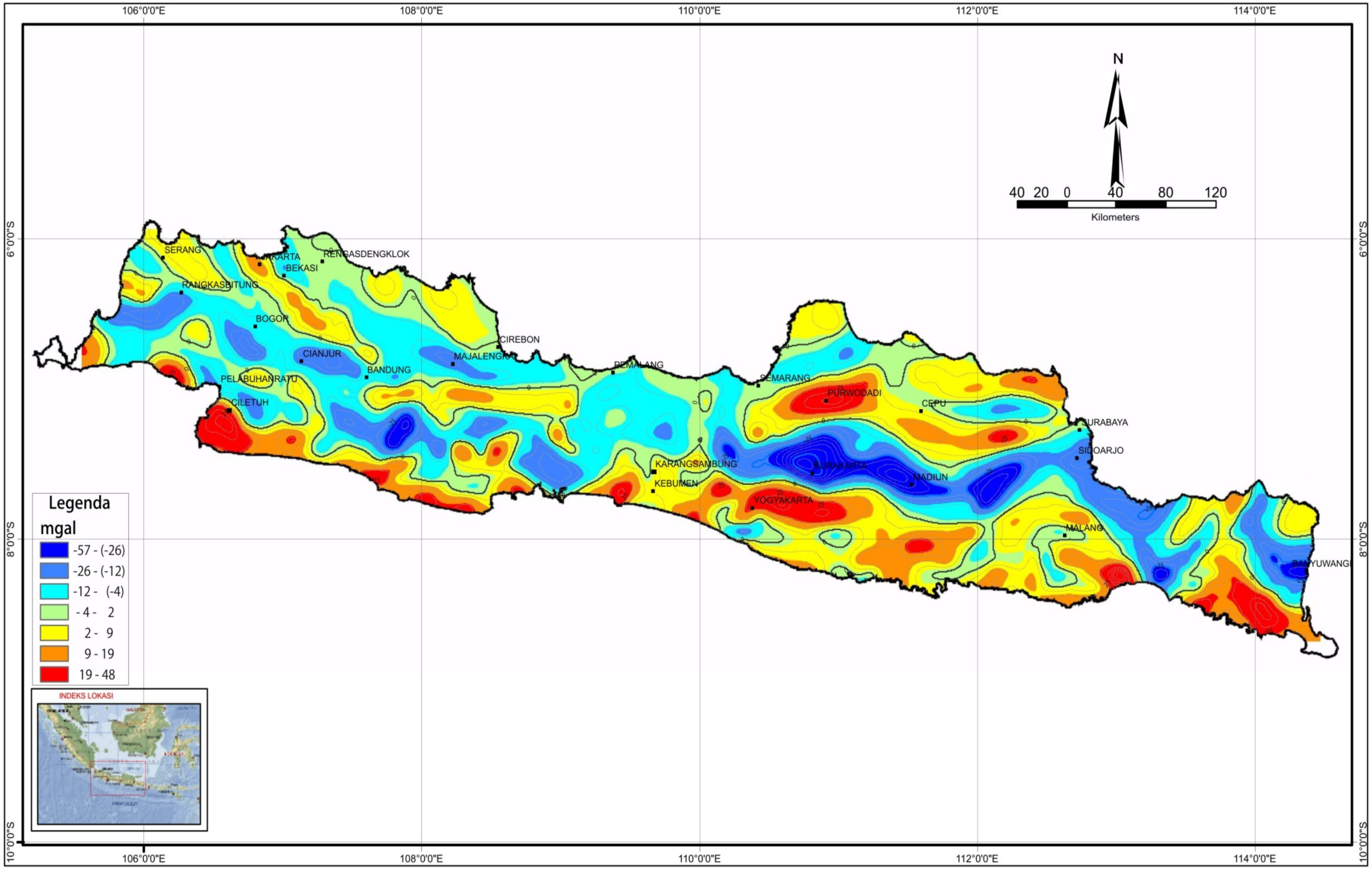
Eko Widianto, 2008

Bouguer Gravity Anomaly map of Java Island



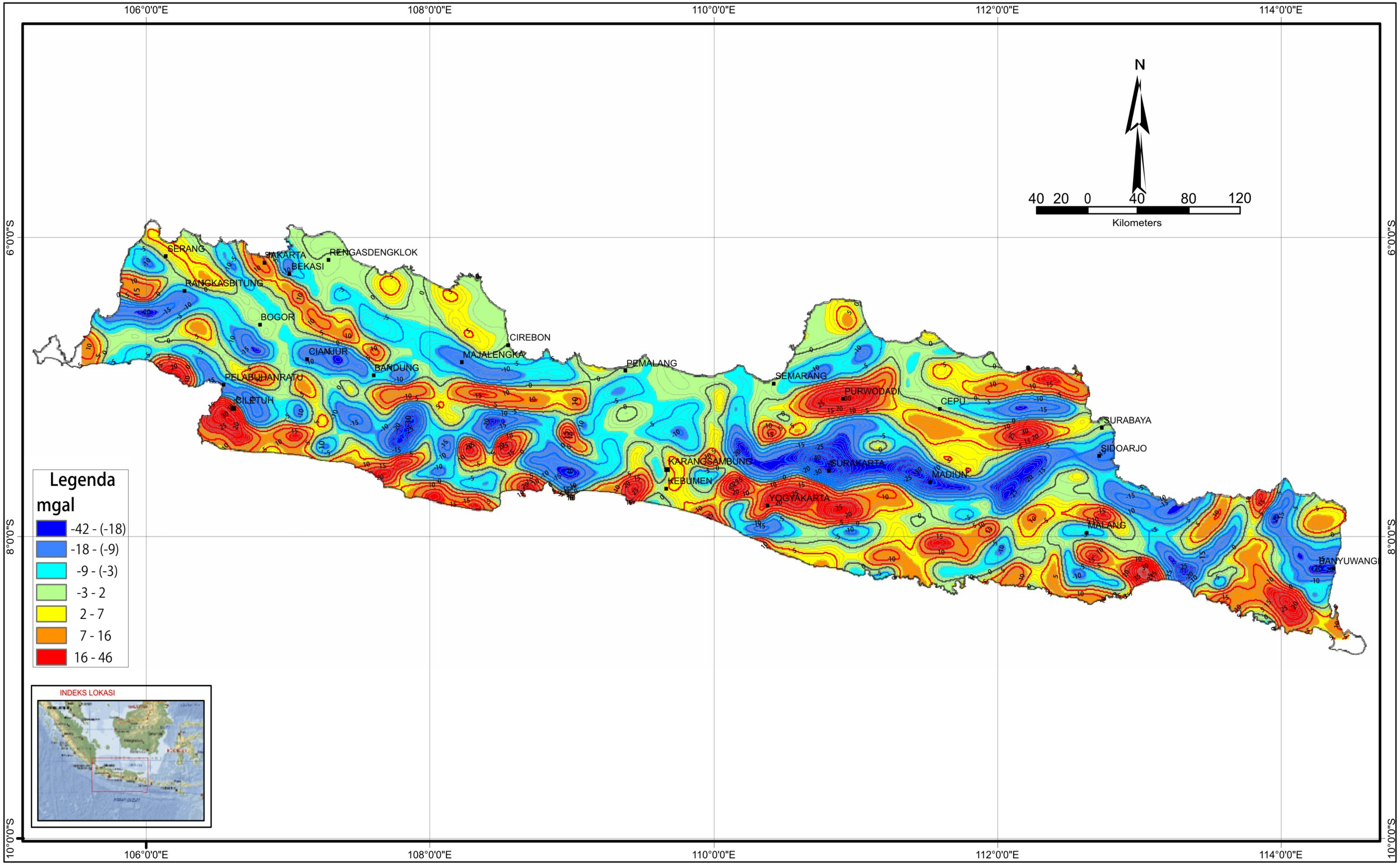
Eko Widianto, 2008

Regional Gravity Anomaly map of Java Island



Eko Widianto, 2008

Residual Gravity Anomaly map of Java Island



Eko Widianto, 2008

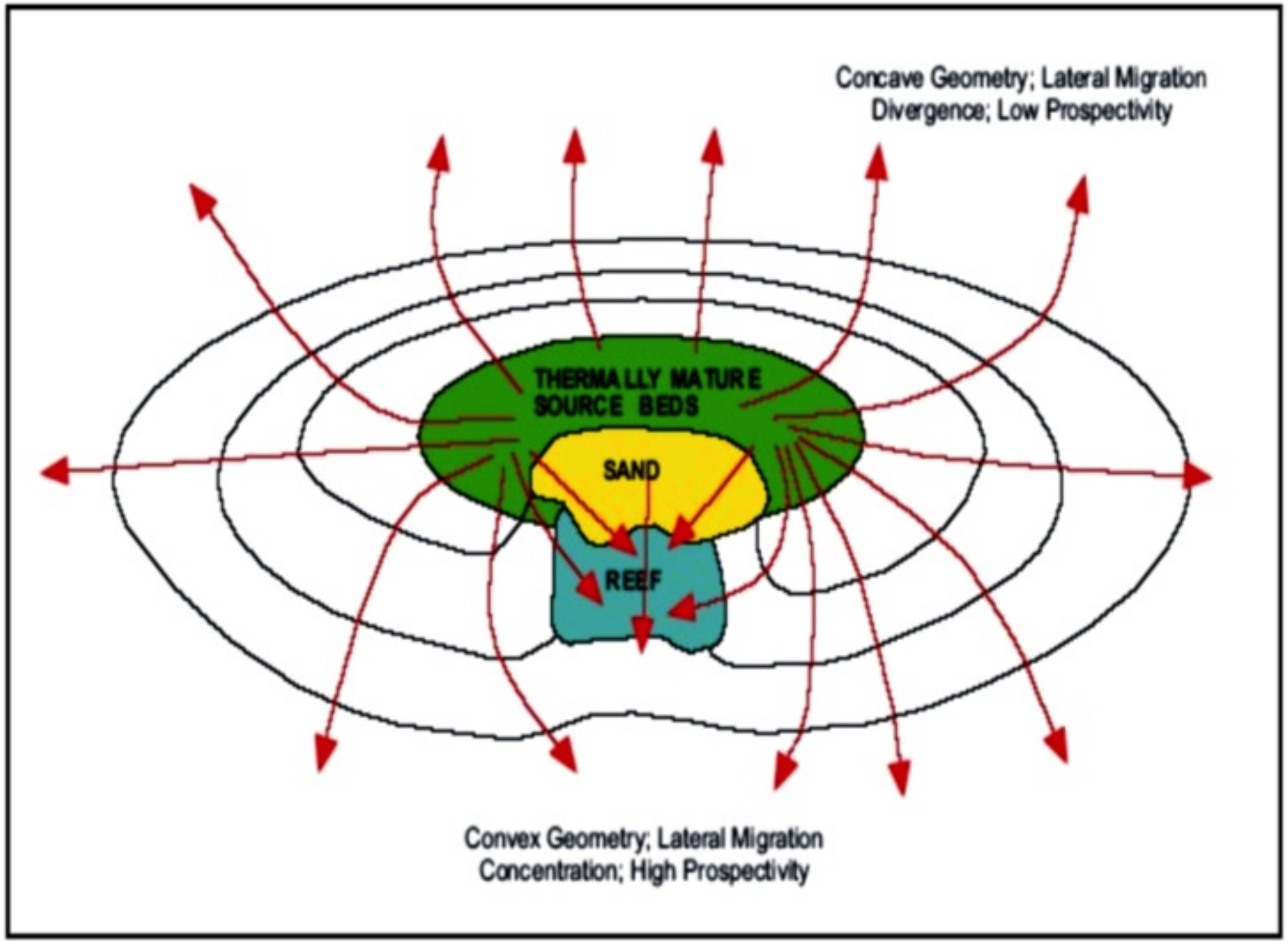
Sedimentary Basin Configuration based on SVD Gravity Anomaly map of Java Island

Basin Configuration and General Migration Pathways

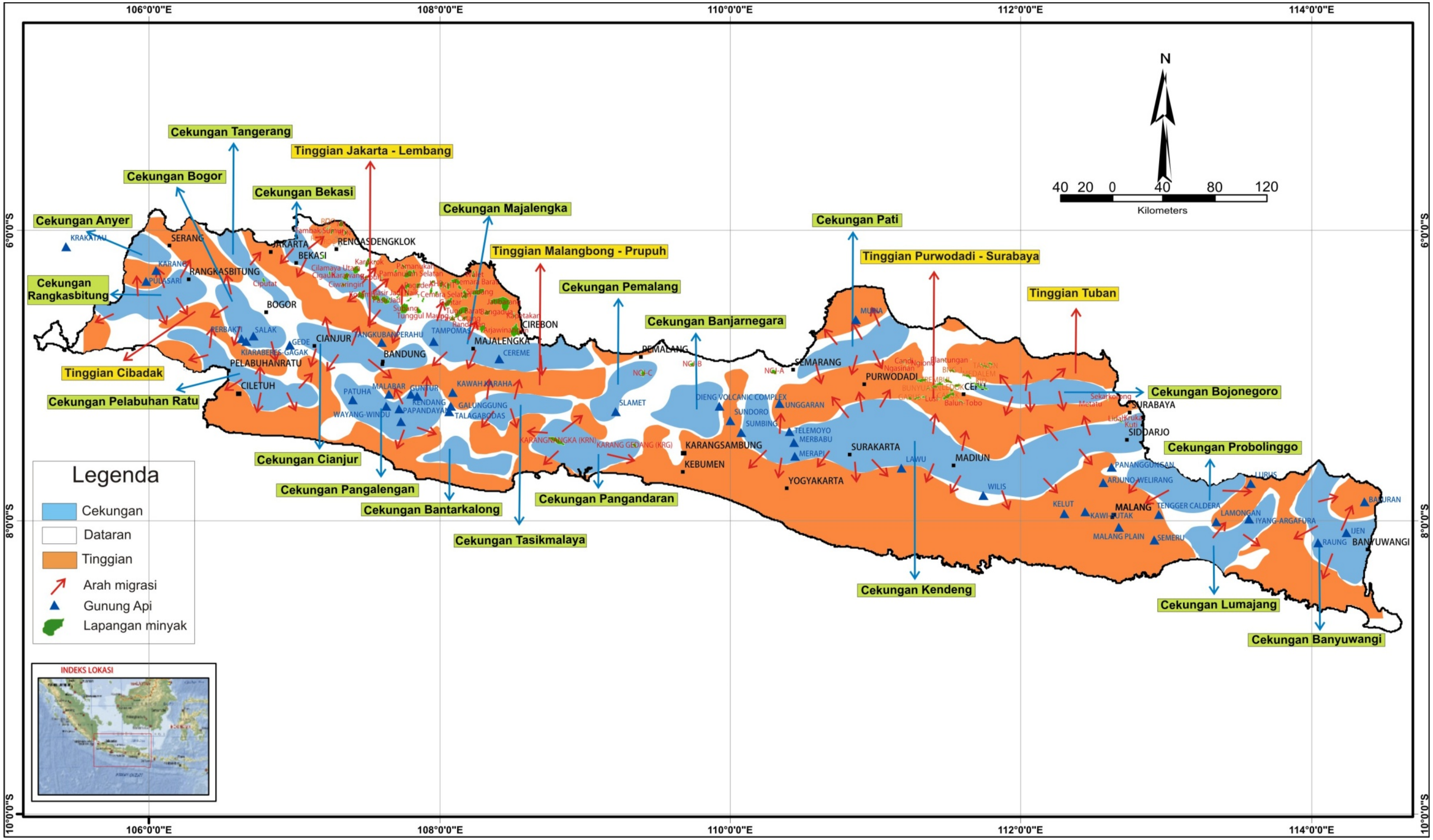
Hydrocarbon Migration

Regional structure maps are used in the analysis of preferred hydrocarbon migration pathway position and directions, because:

1. Hydrocarbons migrate under the influence of subsurface pressures, and
2. Subsurface isobars are parallel to regional structure, so that
3. Hydrocarbon migration occur in a preferred ways in direction that lie parallel to pressure gradient or perpendicular to subsurface pressure isobars and perpendicular to regional structure contours.
4. Convex structural elements concentrate flow lines
5. Concave structural elements diverge flow lines
6. 75% or more of basin’s oil production is contained in only 25% or less of the basinal area.



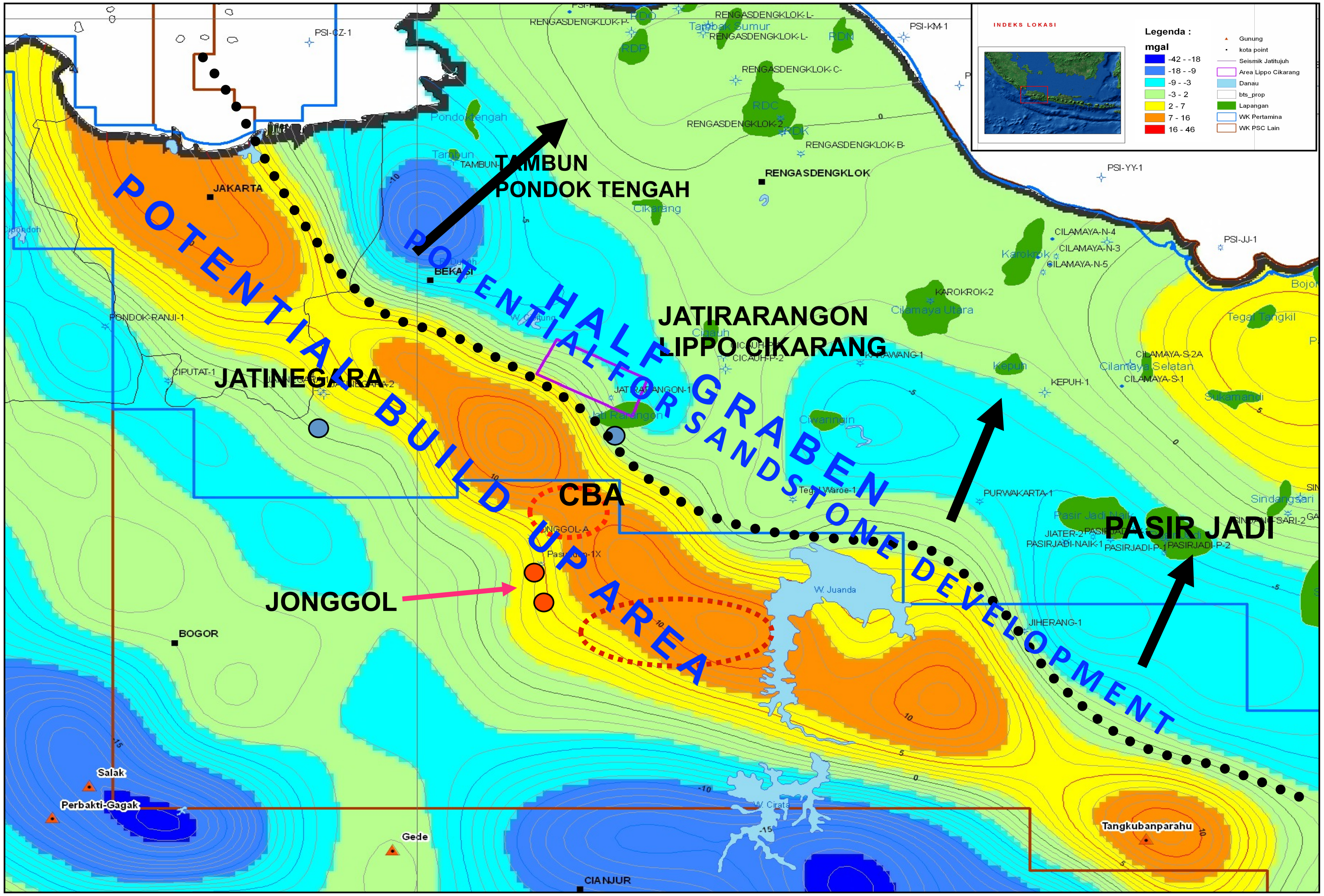
Hydrocarbon migration pathways in the sedimentary basin (Pratsch, 1998)



Eko Widianto, 2008

Basin configuration and general migration pattern map

Reservoir Development



Eko Widianto (2008)

Petroleum System Analysis from Gravity Data

Hydrocarbon Resources Calculation

Subdivide source rock into more homogeneous units (if necessary)

1	2	3	......	N

For each unit

Evaluate equation 1

TOC / 100 (wt %) x Formation density (g/cc) x Volume of Unit (V. cc) = Mass of organic carbon (M, g TOC)

Evaluate equation 2

Hydrocarbon Index prior to Hydrocarbon generation (HIo, mg HC/g TOC) - Present day Hydrocarbon Index (Hip, mg, HC/g, TOC) = Hydrocarbon generated per gram organic carbon (R, Mg, HC/g TOC)

Multiply (equation 3)

R (mg HC/g TOC) x M (g TOC) x 10^{-6} (kg/mg) = Hydrocarbon generated by unit (HCG, kg HC)

Flow diagram of method for approximate calculation of mass of hydrocarbons generated

Schmoker, (1994)

Comparison of Hydrocarbon Resources Calculation of Java Island

Researcher / Year	West Java (BBOE)	Central Java (BBOE)	West + Central Java (BBOE)	East Java (BBOE)	Java (BBOE)
Noble et al., (1997)	7.04				7.04
BP Migas (2004)			9.95	30.8	40.75
Eko Widianto (2008)	38	8		67	113

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Prospect Generation Using Gravity Data

Gravity Gradiometry

- Gravity gradiometry is the study and measurement of variations in the acceleration due to gravity. The gravity gradient is the spatial rate of change of gravitational acceleration.
- Gravity gradiometry is used by oil, gas and mining companies to measure the density of the subsurface, effectively the rate of change of rock properties. From this information it is possible to build a picture of subsurface anomalies which can then be used to more accurately target oil, gas and mineral deposits.

http://www.gradiometry.com

Measuring the gravity gradient

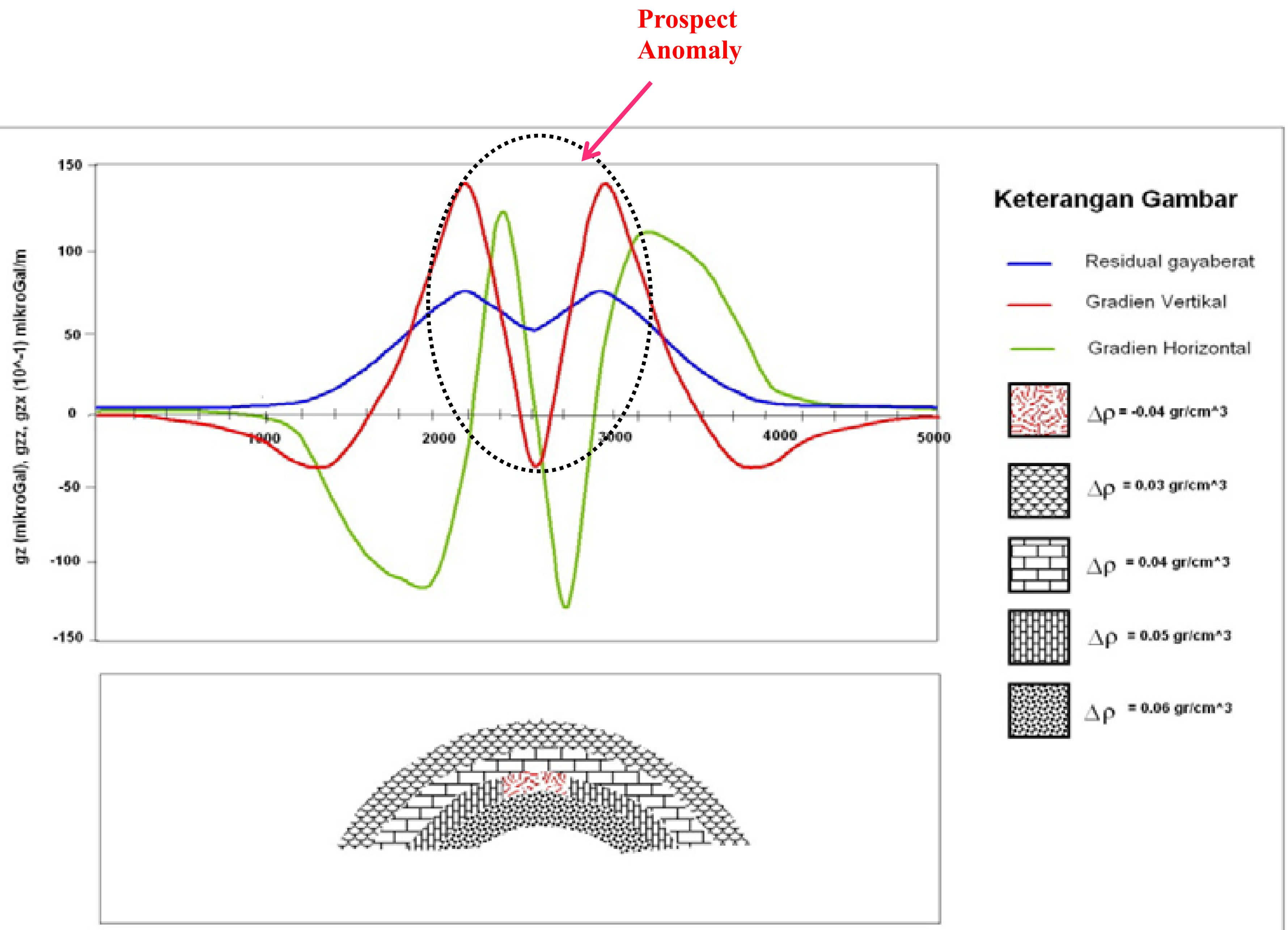
- Gravity gradiometers measure the spatial derivatives of the gravity vector. The most frequently used and intuitive component is the vertical gravity gradient, Gzz, which represents the rate of change of vertical gravity (gz) with height (z). It can be deduced by differencing the value of gravity at two points separated by a small vertical distance, l, and dividing by this distance.

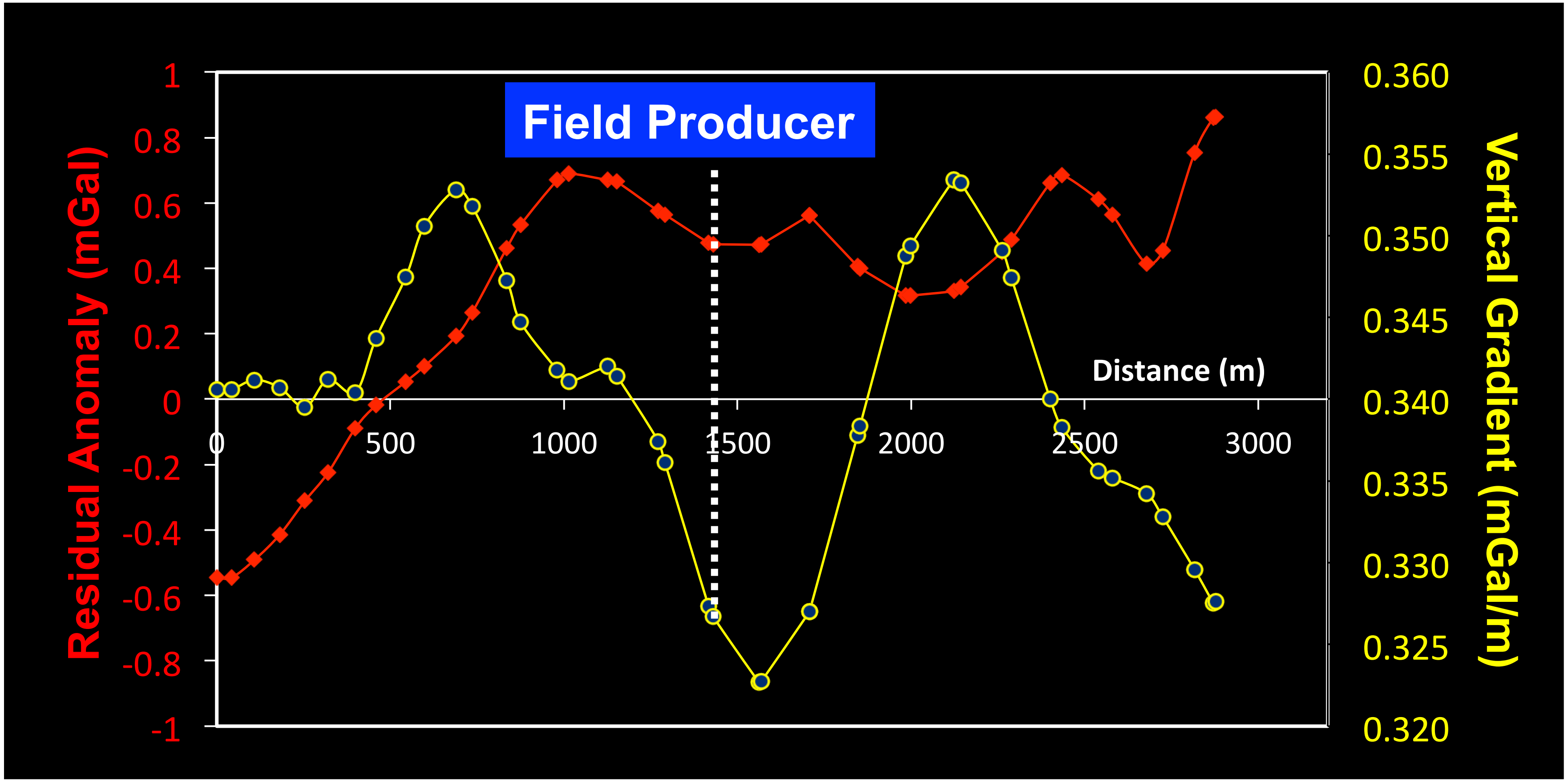
http://www.gradiometry.com

Gravity gradient calculation

$$\frac{\partial g}{\partial z} = \left(\frac{g_{(i-1)} - g_{(i)}}{h_{(i-1)} - h_{(i)}} \right) \text{ miliGal/m}$$

Residual Anomaly Analysis and Vertical Gradient


Prospect
Anomaly
150
100
50
0
-50
-100
-150
gz (mikroGal), gzz, gzx (10^-1) mikroGal/m
1000
2000
3000
4000
5000
Keterangan Gambar
Residual gayaberat
Gradien Vertikal
Gradien Horizontal
Δρ = -0.04 gr/cm^3
Δρ = 0.03 gr/cm^3
Δρ = 0.04 gr/cm^3
Δρ = 0.05 gr/cm^3
Δρ = 0.06 gr/cm^3

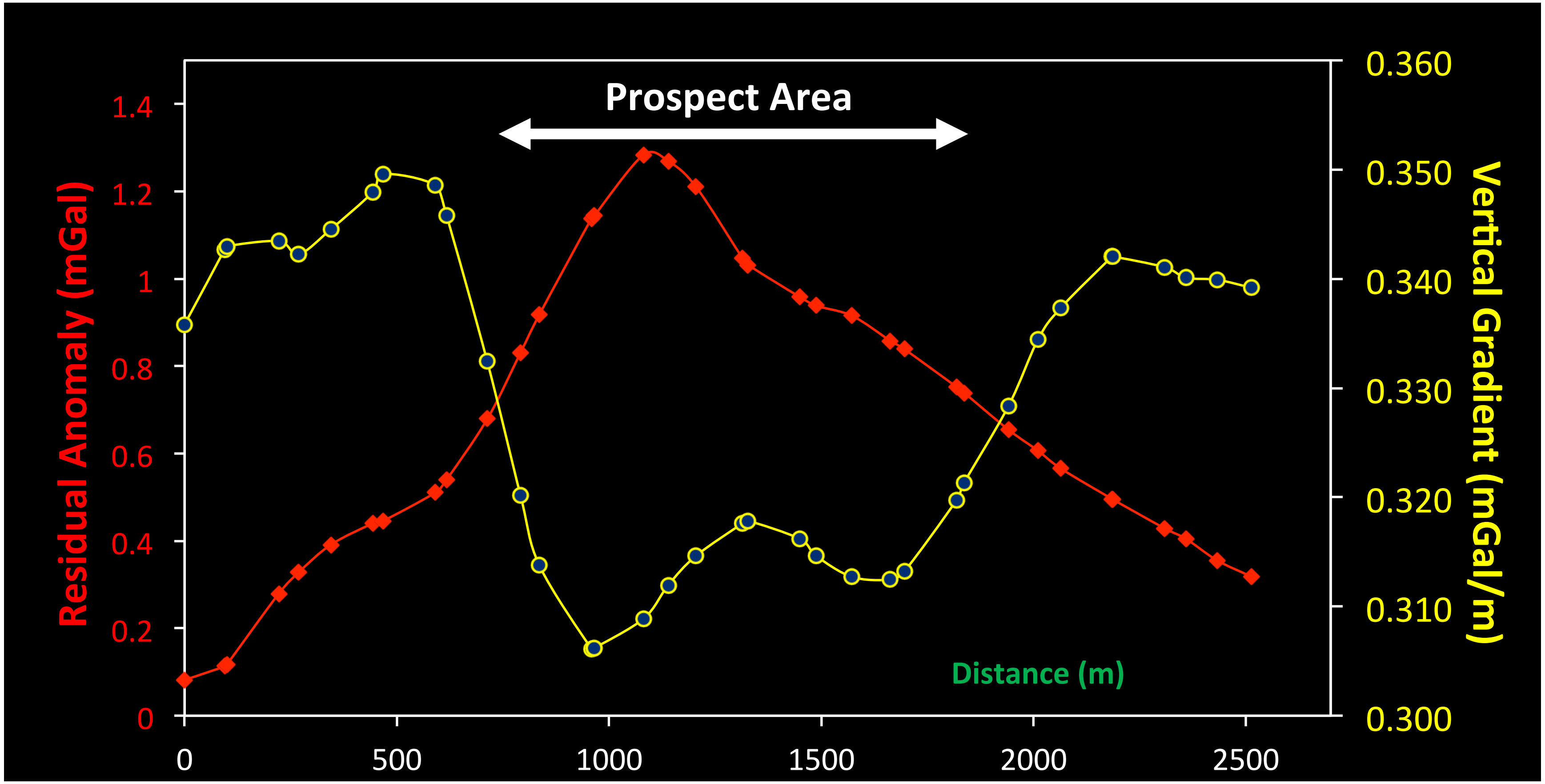


Typical Anomaly of Producer Field

Residual Anomaly : High

Vertical Gradient : Low

A

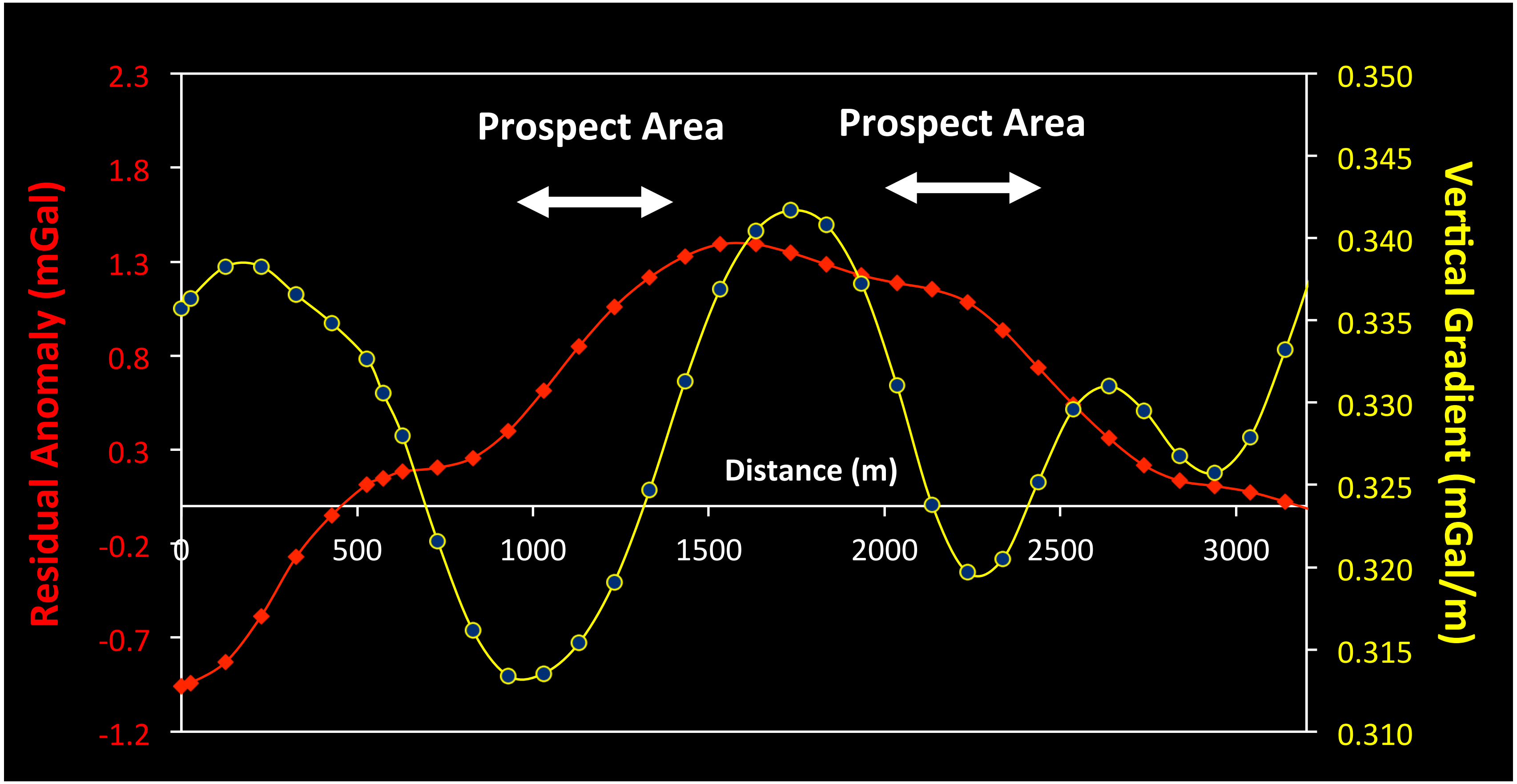


Prospect Area

Residual Anomaly : High

Vertical Gradient : Low

B

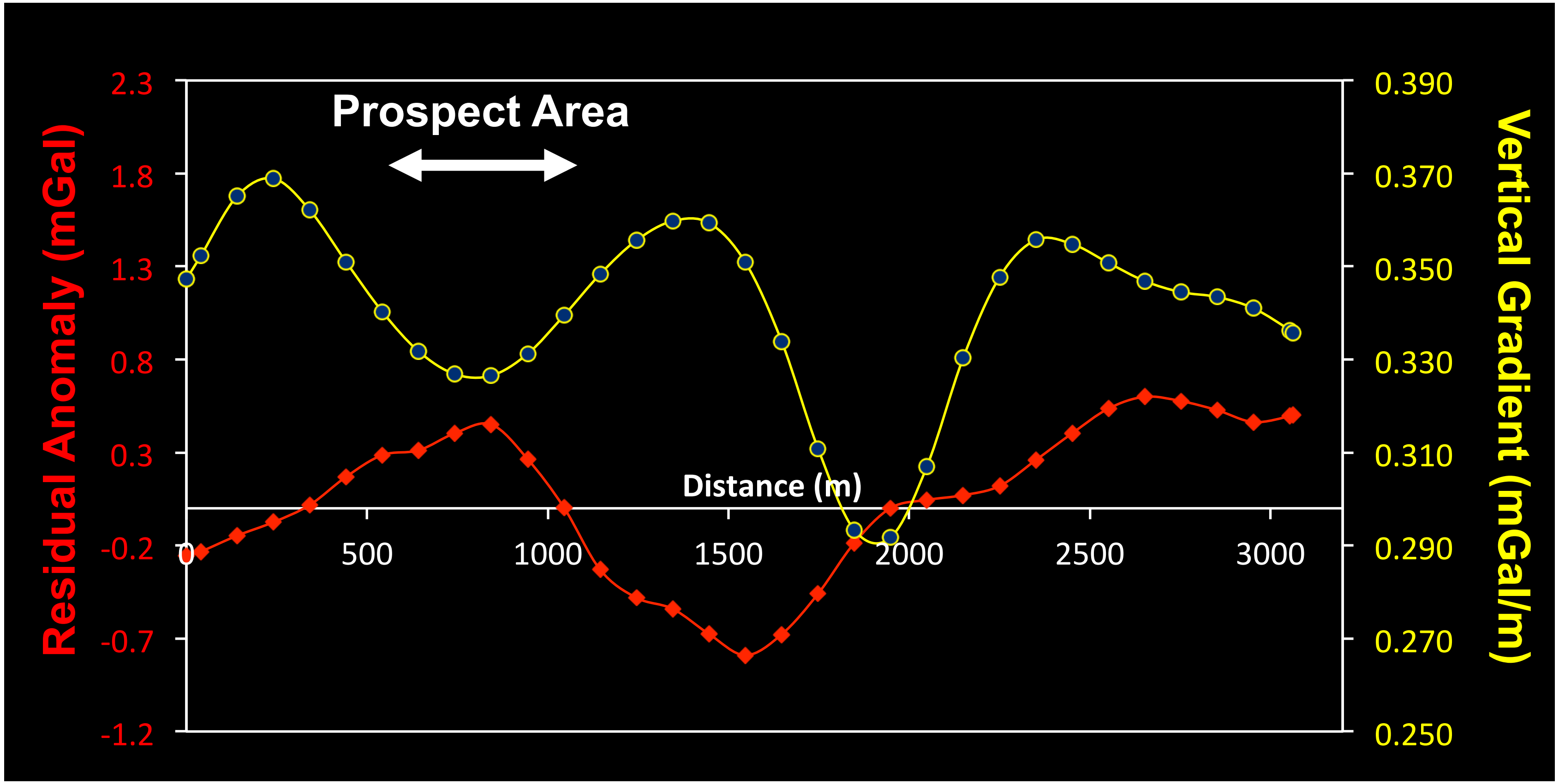


Prospect Area

Residual Anomaly : High

Vertical Gradient : Low

C



Prospect Area

Residual Anomaly : High

Vertical Gradient : Low

D

LECTURE MATERIALS

1. Indonesian Energy Resources Condition
2. Level of Petroleum Investigation
3. Oil & Gas Challenges and Opportunities
4. Methodology and Case Study
5. Indonesia Basin Re-Mapping using Gravity Data
6. Prospect Generation using Gravity Data
7. **Reservoir Monitoring using Time-Lapse Technology**

Reservoir Monitoring Using Time-Lapse Technology

1. Introduction

1. Recently significant declined of oil and gas production relates to natural condition of the reservoir happened in over the world.
2. In order to increase total oil production not only exploring the new area but also applying latest technology have been implemented in mature fields. New prospective technology have been tested and applied to estimate the dynamic state of reservoir properties.
3. The 4D microgravity method combined with existing seismic data already applied in several oil fields in Indonesia. Experience in these fields gave a better understanding of the reservoir model.
4. The 4D microgravity method has some advantages compare with other method in term of less time consuming, repeatability, environmentally friendly and less cost.

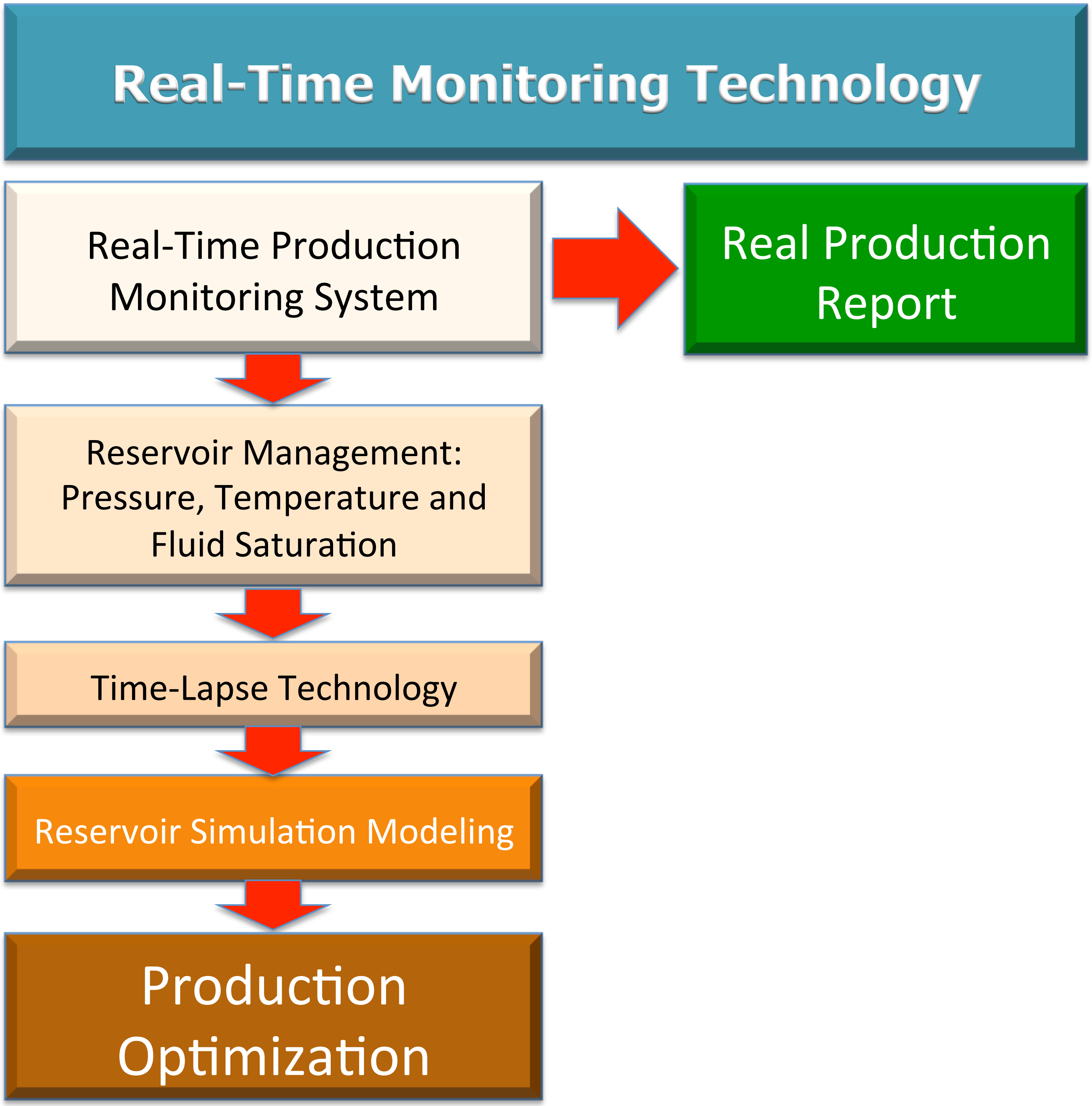
What dynamic changes of reservoir properties do we want to predict using time-lapse technology?

- Compartmentalization
- Pressure changes
- Phase changes
- Reservoir connectivity
- Permeability
- Porosity
- Areal extent of the trap
- Bypass Oil
- Well deliverability

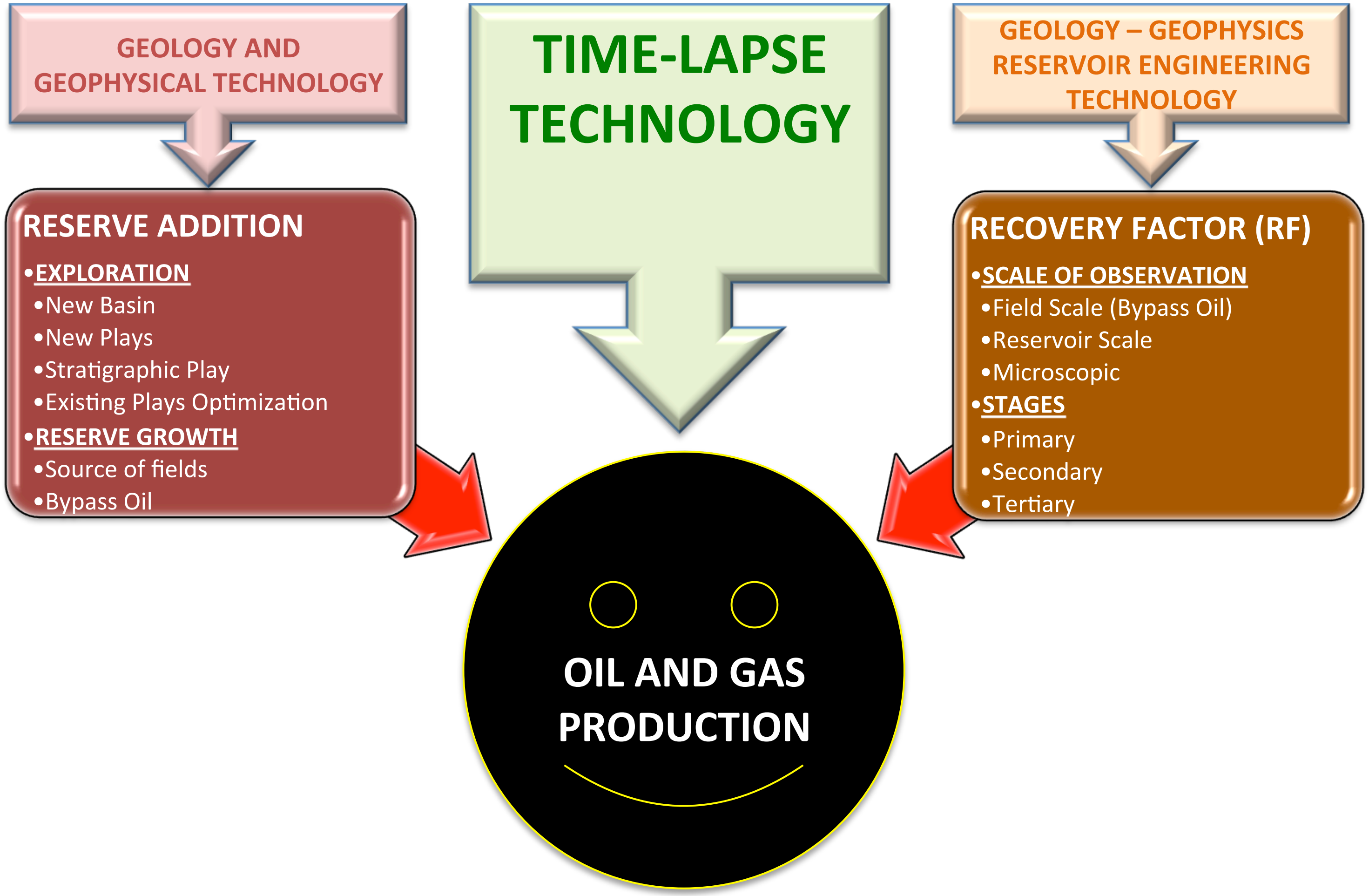
Oil & Gas Business Challenges and Technology Application

Stages	Business Challenges	Technology Applied
Exploration	Define the oil and gas resources Prove the resources to be reserves (New Discoveries)	Seismic Methods Gravity Method Passive Seismic Seismic Attributes and Direct Hydrocarbon Indication
Development and Production	Build the reservoir model accurately Find bypass oil Improve Recovery Factor Optimize Production	**Time-lapse Technology (4D Microgravity, 4D Seismic)** Seismic Attribute and Inversion Reservoir Characterization

REAL TIME MONITORING TECHNOLOGY


Real-Time Monitoring Technology
Real-Time Production Monitoring System
Real Production Report
Reservoir Management: Pressure, Temperature and Fluid Saturation
Time-Lapse Technology
Reservoir Simulation Modeling
Production Optimization

Integrated Approach to Increase Reserve, Recovery Factor and Production of Oil and Gas



Time-lapse Technology

1. Reservoir management demands and economic benefits have been the drivers for development of the technology to detect time-lapse anomaly from successive geophysical surveys.

2. Time-lapse or 4-D geophysical surveys use to measure production and reservoir properties periodically during the life of the reservoir. Observed changes assist in the characterization of the reservoir.

3. Time-lapse surveys may indicate the presence of barriers to reservoir connectivity, changes in reservoir saturation and pressure.

4. Applications of time-lapse technology now span the life of the reservoir, from initial production to identify pressure cells through mid-field life monitoring of waterflood fronts to late-field life where the primary driver is identifying bypassed oil to extend economic recovery.

(Stephen Pickering, 2006)

Time-lapse Technology

Production improvement of hydrocarbon field

1. Optimizing Existing Production wells
2. Pressure Maintenance
3. Optimizing Injection and production wells
4. Re-opening and drilling bypassed oil
5. Improve Recovery Factor

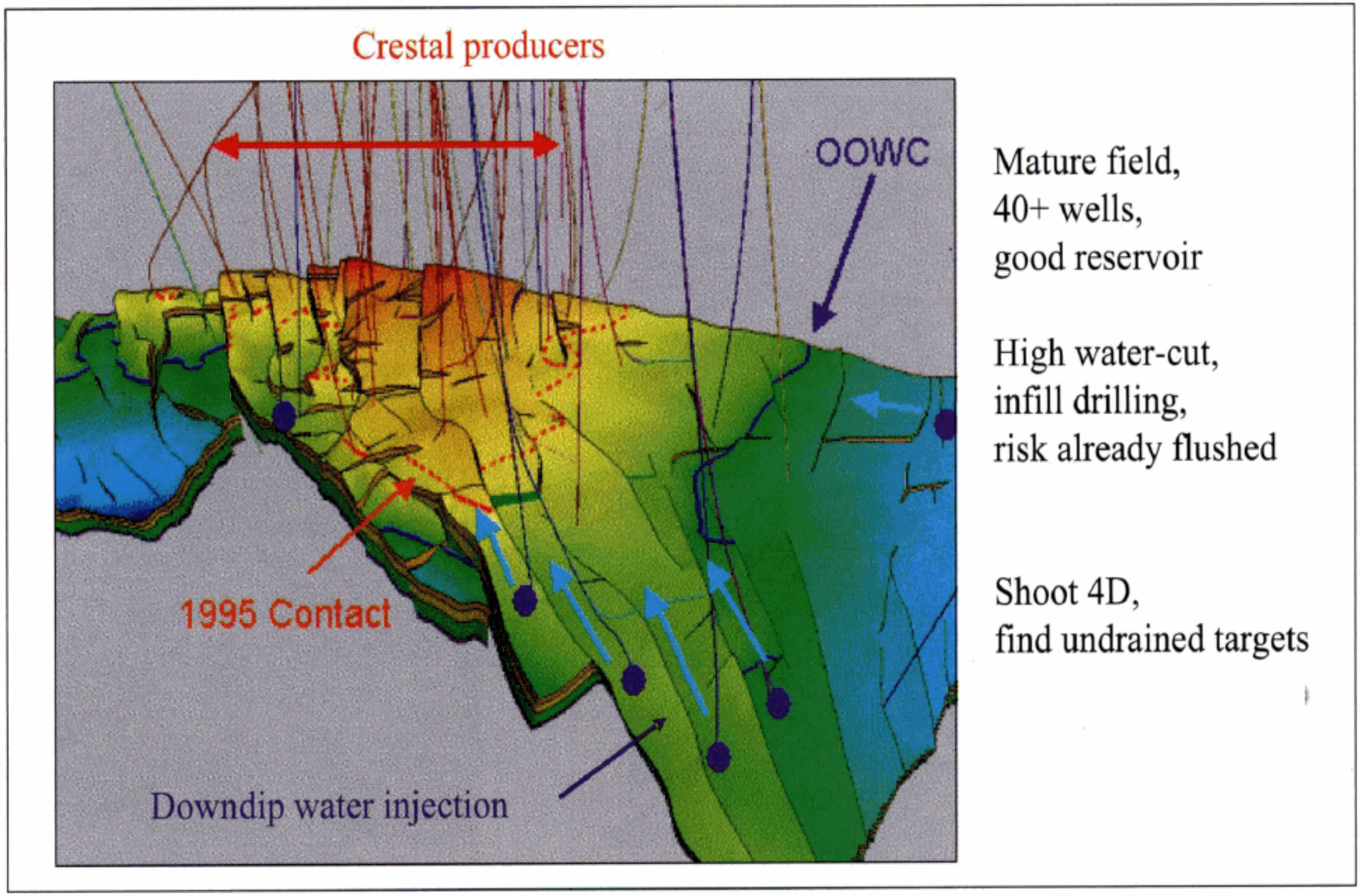


Figure 2-13. Many 4D surveys are being used late in the life of a field to locate bypassed oil. Given a suitable baseline survey and a repeat monitoring survey, we can determine the parts of the field that have not changed and thus might not yet have been produced.

Calvert, 2005

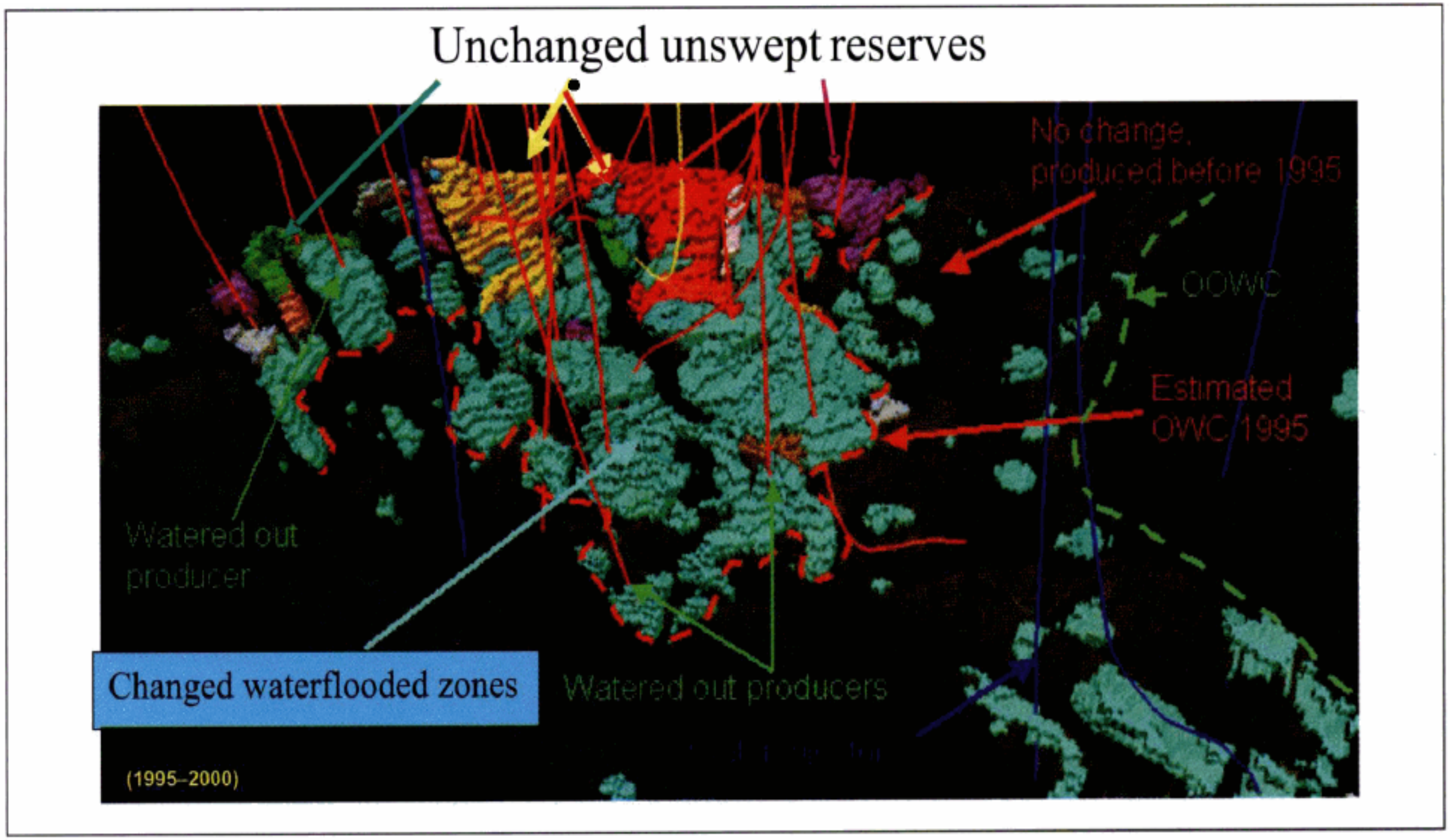
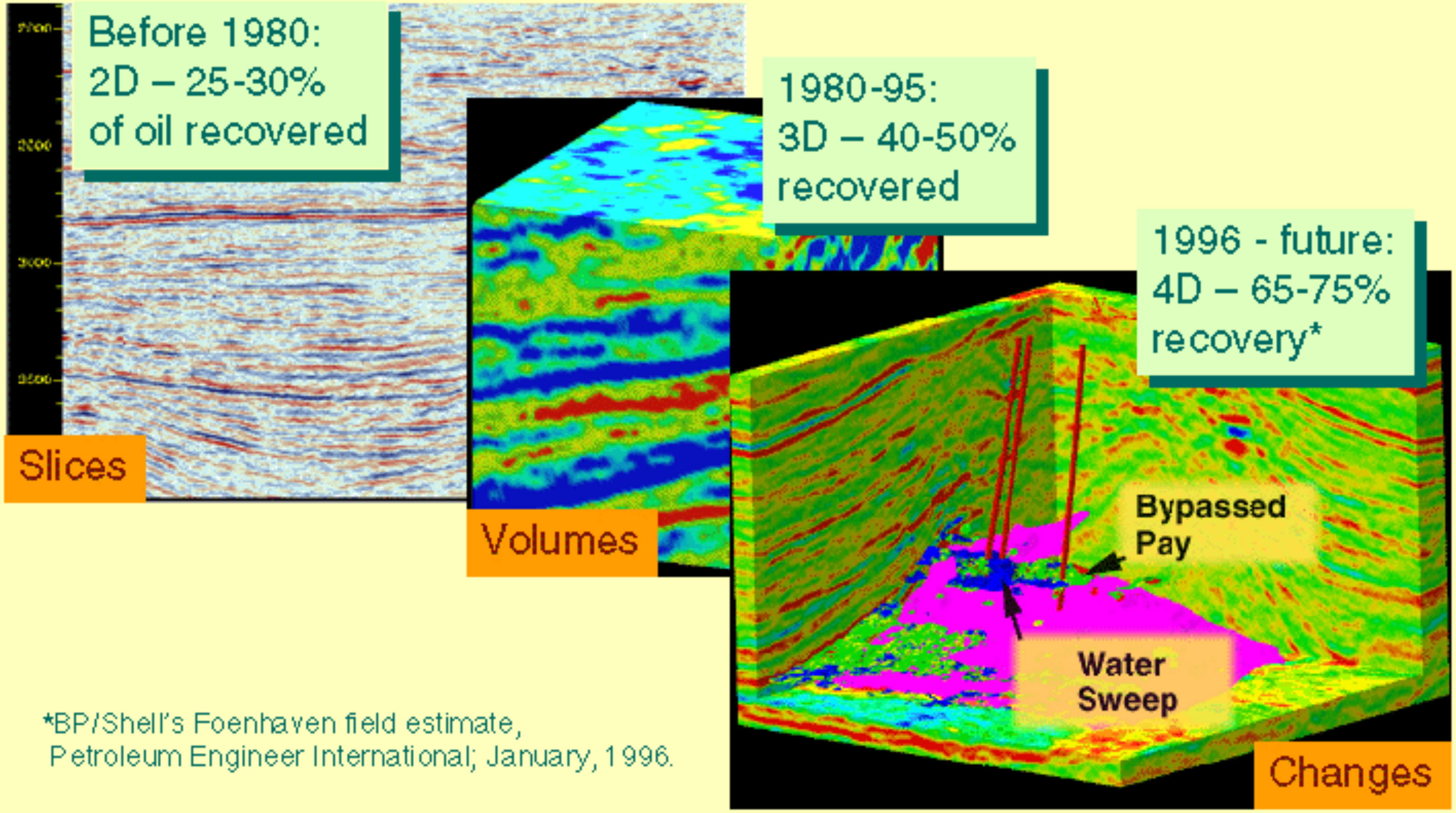


Figure 2-14. In this case, we can compare the results of a midlife survey with those of a recent monitoring survey. Thus, the sweep progress can be determined. We can see that although water is approaching the structural crest, there also are volumes that have not changed, indicating bypassed oil and sidetrack targets.

Calvert, 2005

4D Technology is Expected to Improve Recovery



*BP/Shell's Foenhaven field estimate, Petroleum Engineer International; January, 1996.

http://www.ldeo.columbia.edu/res/pi/4d4/what-is.html

4D Microgravity and Fluid Movement in Reservoir

THE PARADIGM SHIFT IN GRAVITY DATA UTILIZATION BY USING THE HIGHER RESOLUTION OF GRAVITY DATA

GRAVITY DATA	PLAY IDENTIFICATION	PROSPECT CAPTURE	PROSPECT EVALUATION	RESOURCES APPRAISAL	RESERVOIR MANAGEMENT
GRAVITY UTILIZATION	Isostatic residual Regional tectonic analisis Basin and depocenter enhancement Regional modeling Digital data integration (with remote sensing, etc)	Semiregional structural / stratiigraphic modeling Target-spesific enhancements Layer stripping for improved delineation of exploration targets Sensitivity studies tied to density and lithology	Detailed, integrated 2D / 3D modeling (with seismic horizons, density, and velocity information) Porosity / pressure prediction Salt edge / base determination Enhanced velocity analysis	Integrated 3D rock properties and velocity modeling Integrated depth migration (pre-or poststack) Borehole gravity-remote porosity detection Detection of shallow hazards	Integrated reservoir characterization Borehole gravity **Time-lapse precision gravity , including for Carbon Storage Monitoring**
GRAVITY RESOLUTION REQUIRED *	1 – 5 mGal 2 – 20 km wavelength Continental grids, satelite gravity, airborne gravity	0.2 – 1 mGal 1 – 5 km wavelength Conventional marine and land surveys	0.1 – 0.5 mGal 0.5 – 2 km wavelength High-resolution land and marine surveys	0.1 – 0.5 mGal 0.2 – 1 km wavelength 0.01 – 0.005 mGal (borehole) High-resolution land, marine, and gradiometer surveys	0.02 – 0.1 mGal 1 – 5 years

Theoretical Background

- Gas, oil and water have different densities, and are subject to gravity forces in the reservoir
- Mass redistribution will cause changes in the gravity attraction in boreholes and at the surface
- Reservoir compaction and overburden subsidence will also cause gravity changes in boreholes and at the surface.

Gravity Monitoring

- Surface gravity changes reflect underground mass redistribution caused by production and re-injection of hydrocarbon fluids
- Precise measurement and analysis of gravity changes can thereby help reveal changes in reservoir conditions

- establish a systematic procedure for micro-gravity monitoring of operating Hydrocarbon fields

4-D microgravity anomaly caused by:

Gravity tide	Land subsidence	Groundwater level / season change	Topographic change	Subsurface fluid dynamics	Subsurface pressure change

↓

Microgravity anomaly response is very small (order < 100 µgal)

↓

Need good survey planning

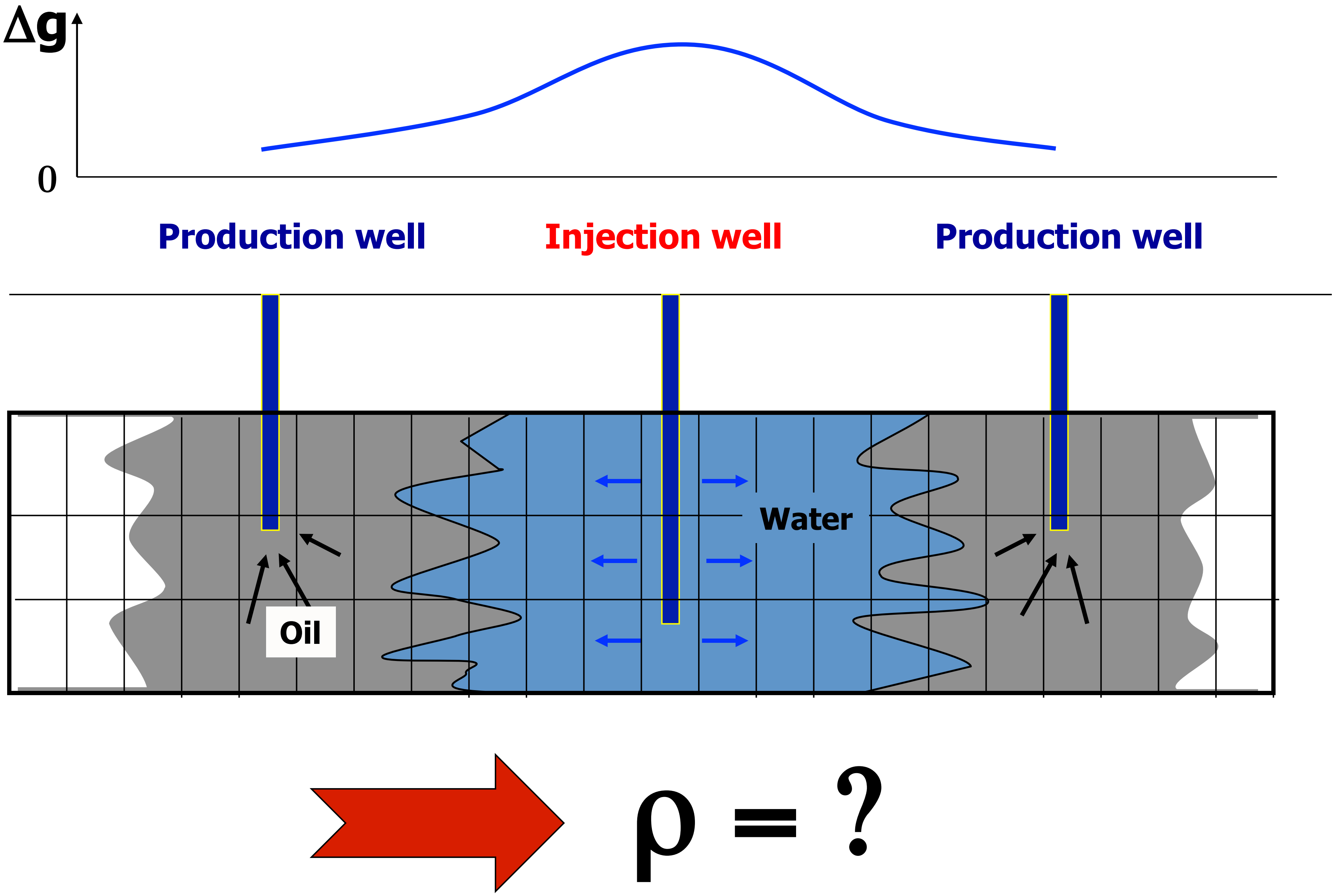
4D Gravity Anomaly :

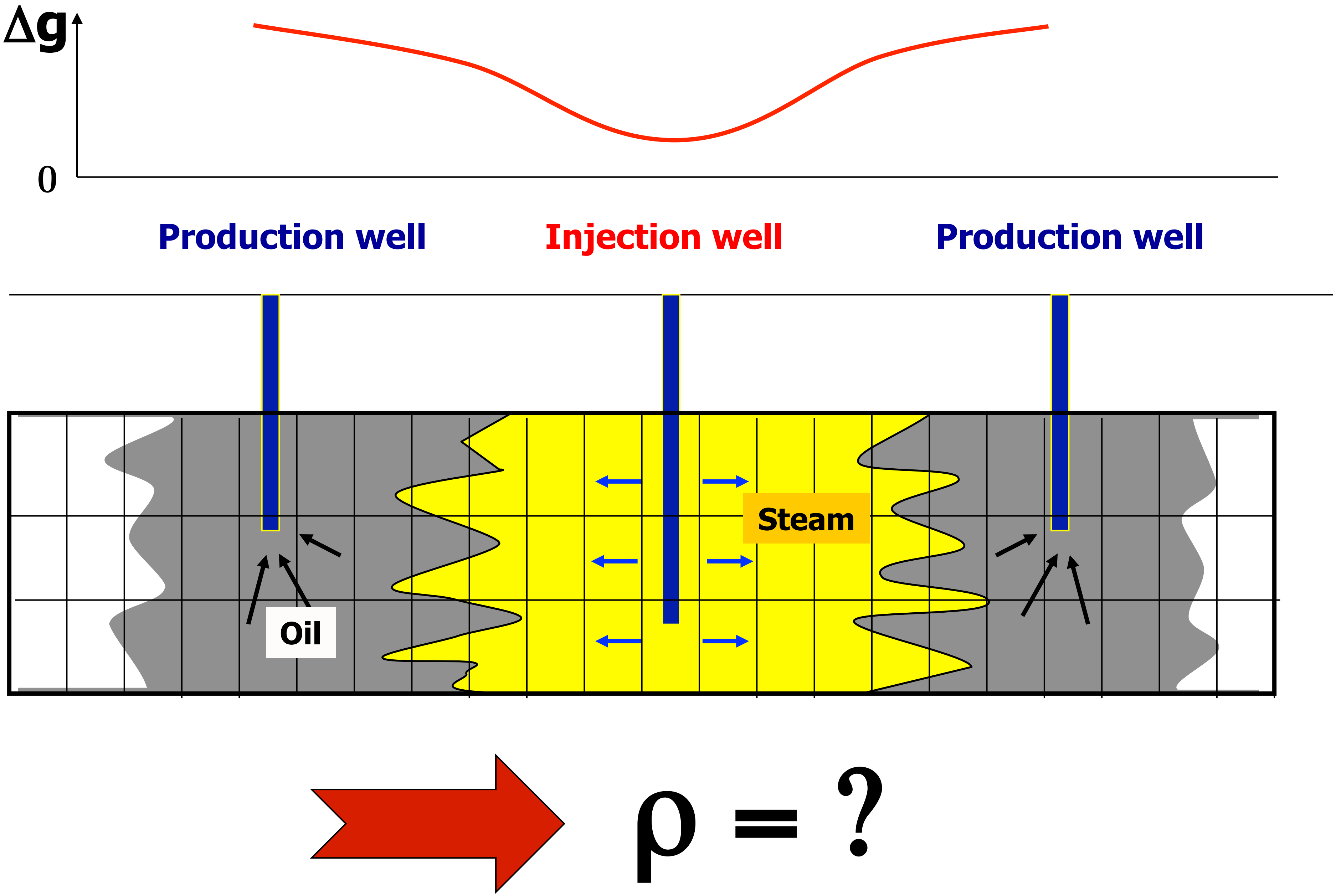
First measurement called base line survey
Next measurement called monitoring survey

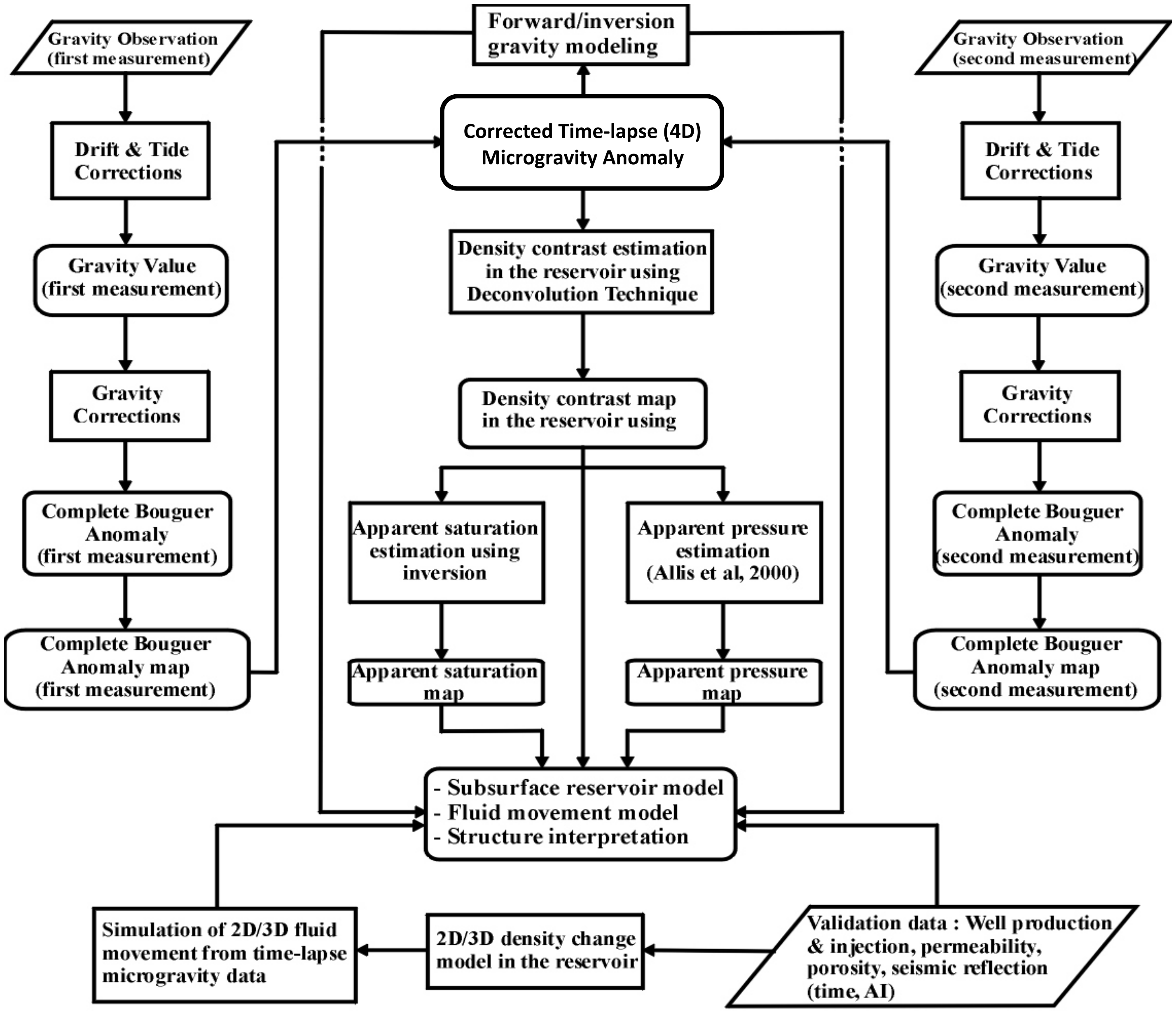
Time-lapse gravity anomaly is given by:

$$\Delta g\left(x,y,z,\Delta t\right) = g_{obs}\left(x,y,z,t_2\right) - g_{obs}\left(x,y,z,t_1\right)$$

Time lapse microgravity anomaly reflects vertical ground movement (subsidence) and subsurface density change

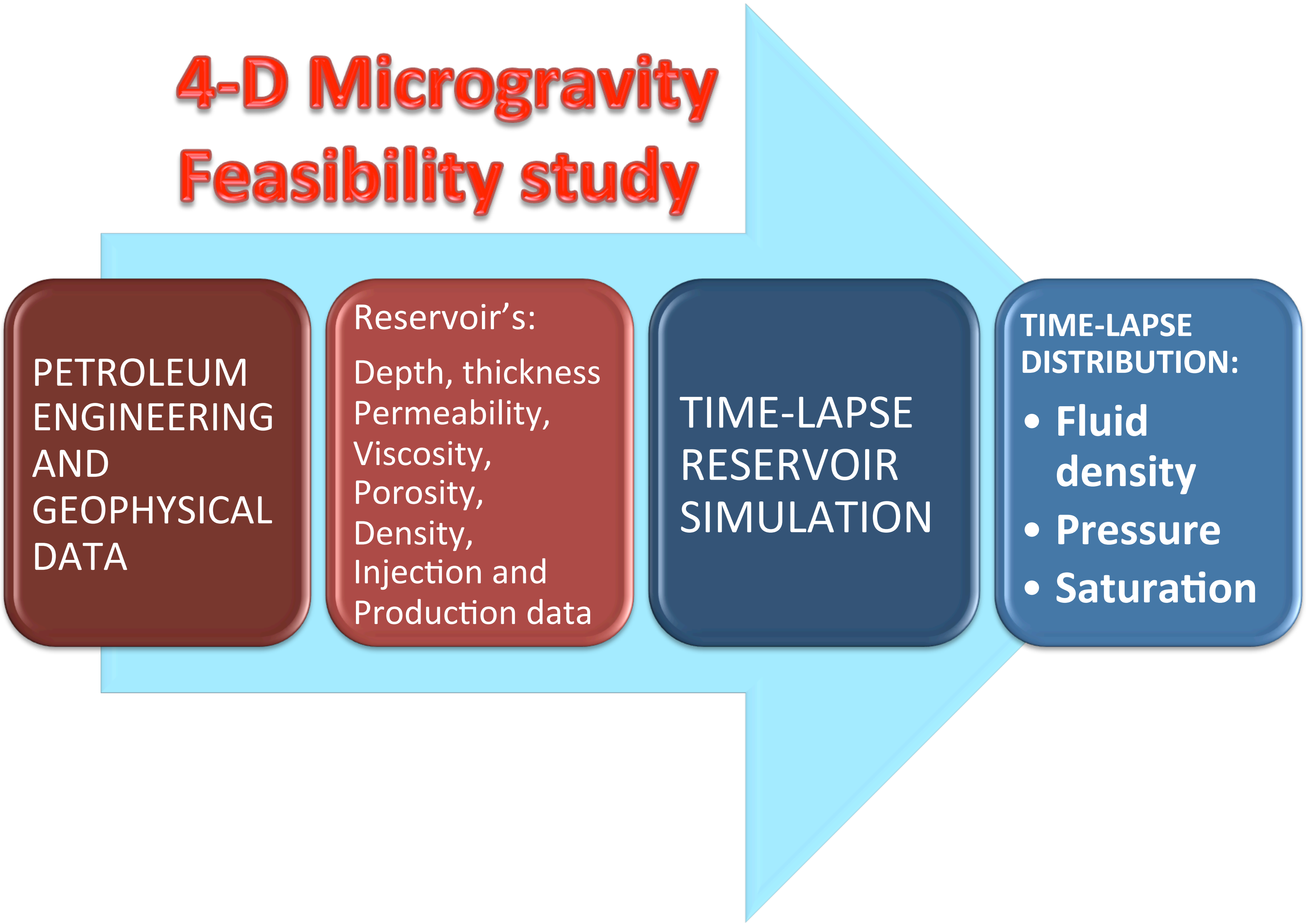

Δg
0
Production well
Injection well
Production well
Water
Oil
ρ = ?


Δg
0
Production well
Injection well
Production well
Steam
Oil
ρ = ?



Flow chart of time-lapse microgravity processing

4-D Microgravity Feasibility study



Feasibility Study

TIME-LAPSE RESERVOIR SIMULATION

↓

GRAVITY PARAMETER CALCULATION

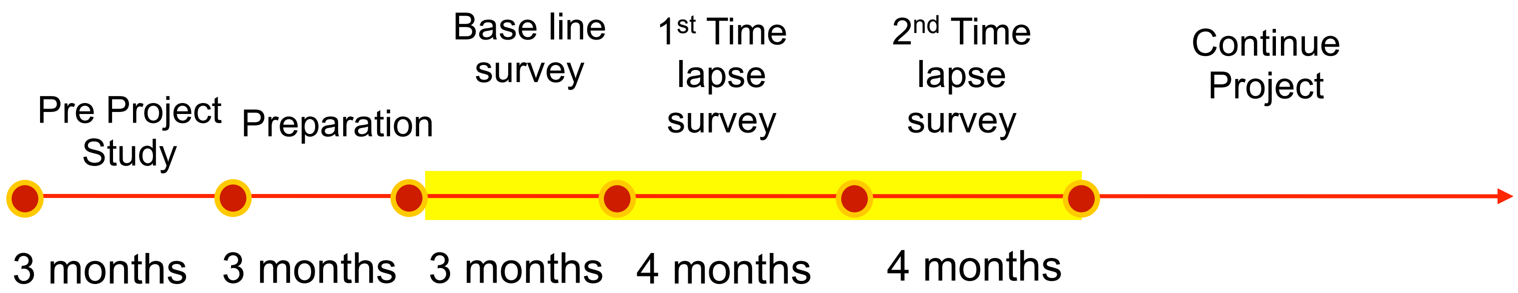
Density Change	Gravity Response	Wavelength Analysis

↓

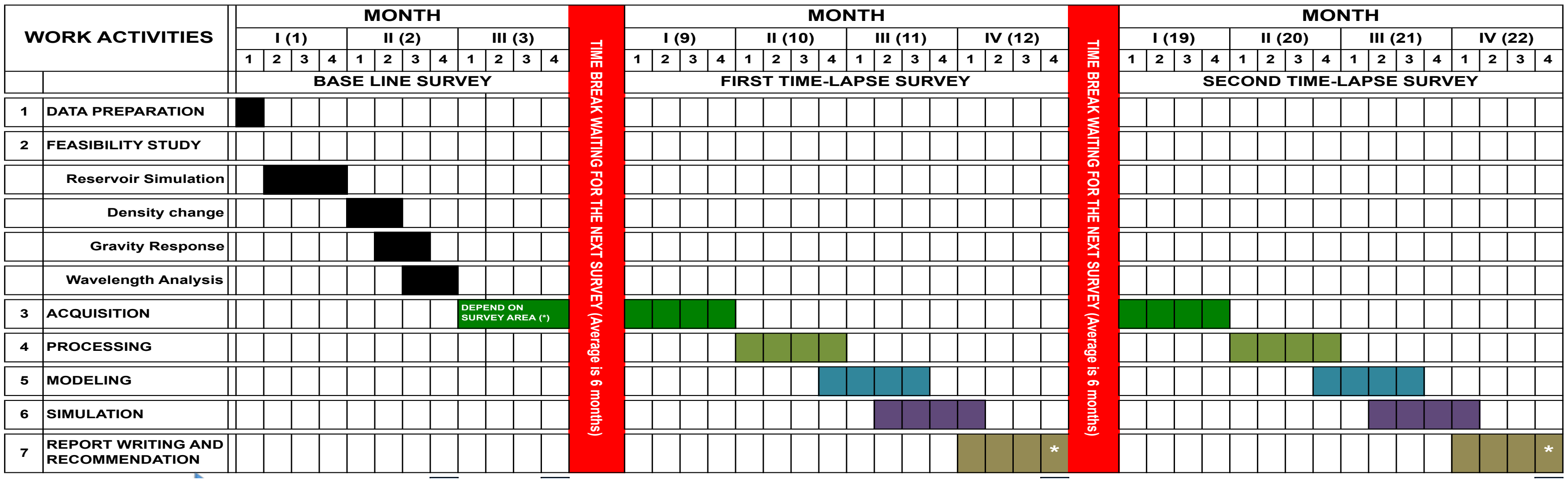
OUTPUT

Surface gravity response	Time interval gravity measurement	Gravity Acquisition parameter

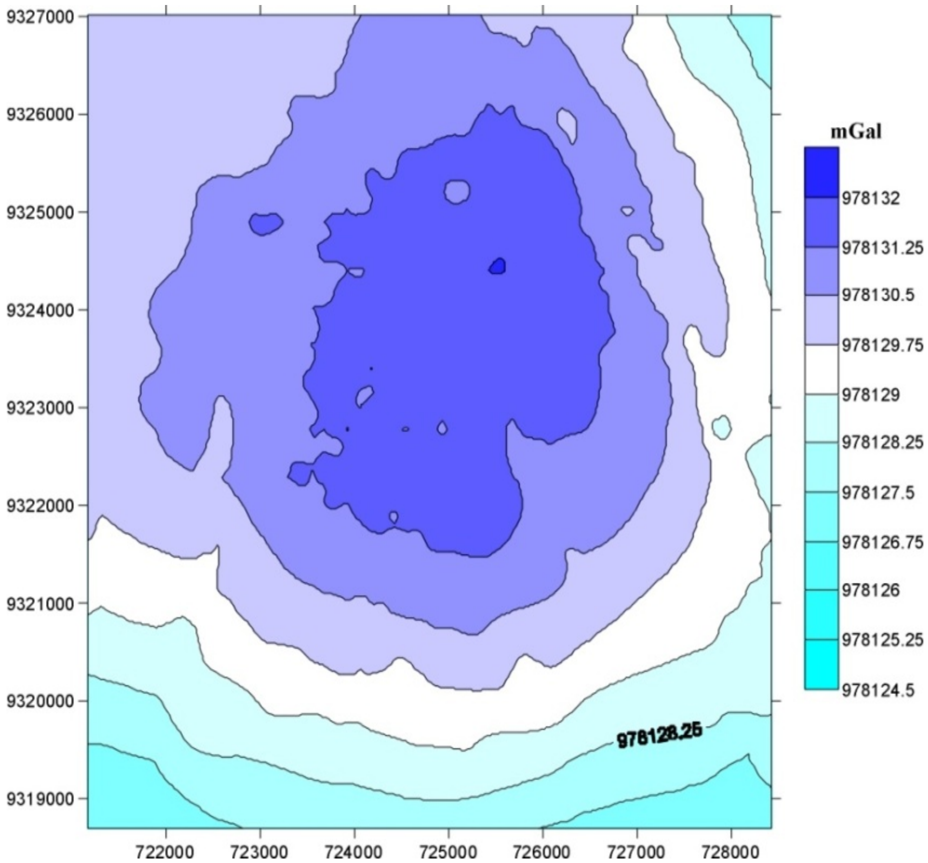
Project Design : 4D Microgravity to Improve RF



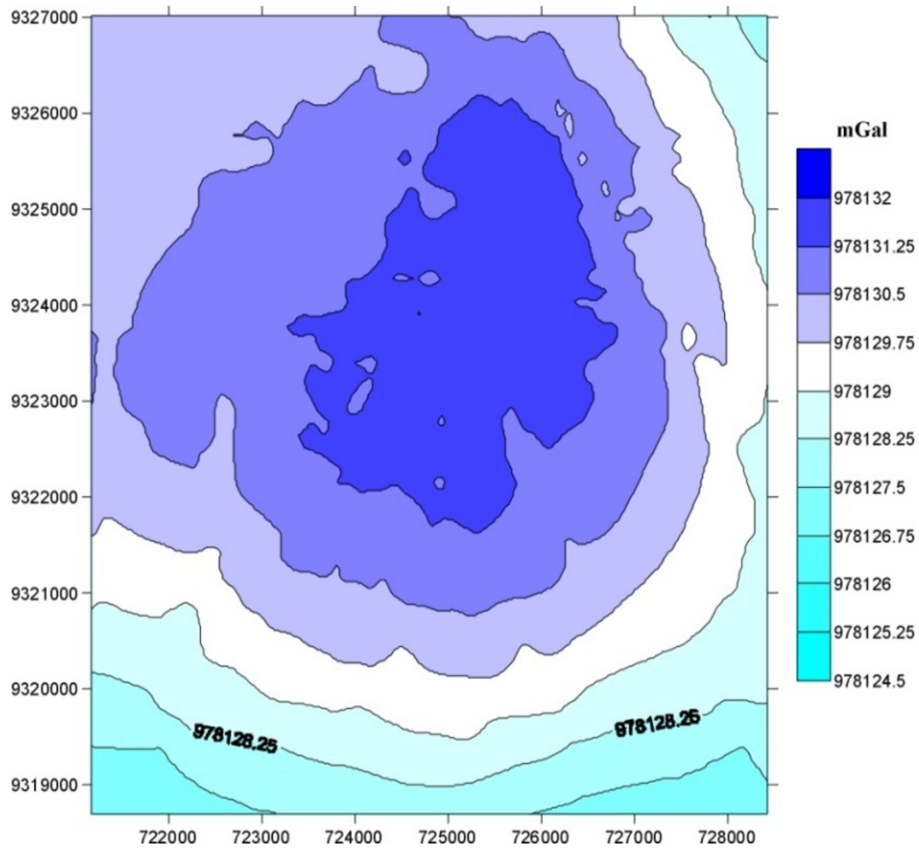
4-D MICROGRAVITY ACQUISITION AND INTERPRETATION TIME LINE



Case Study
Carbonate Reservoir Field

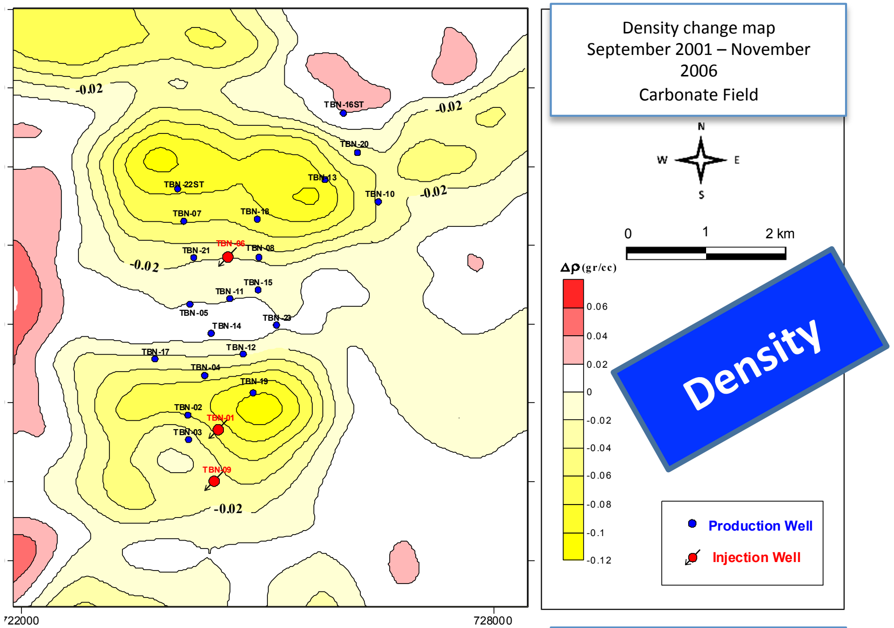


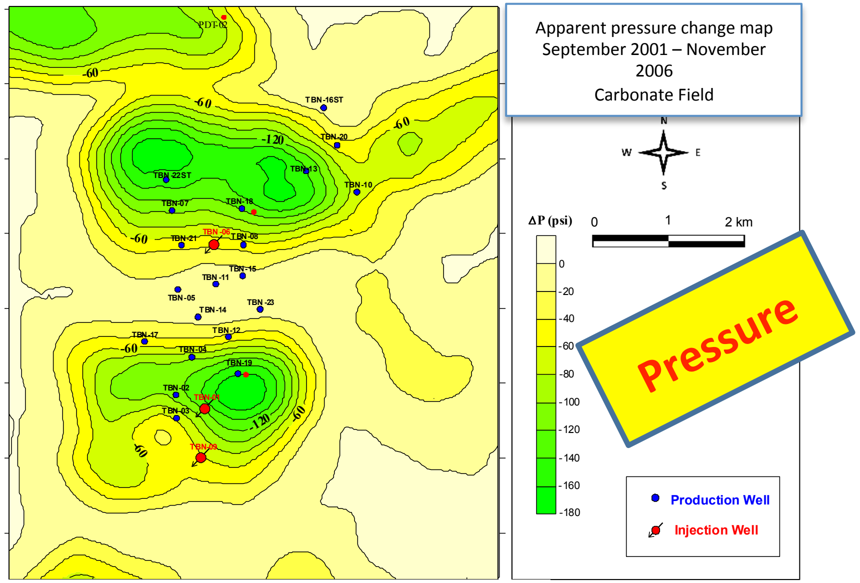
Sept’04

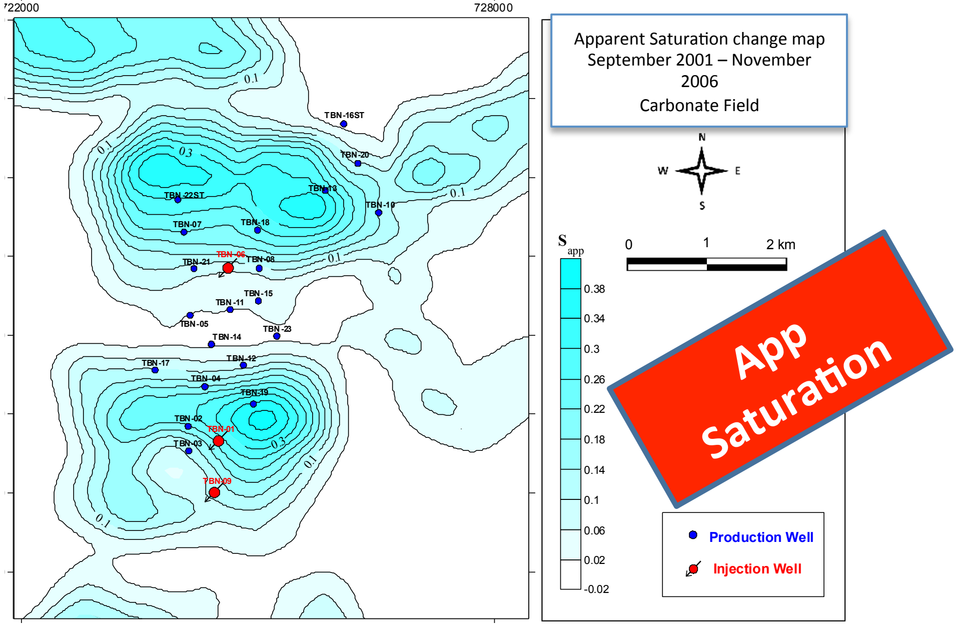


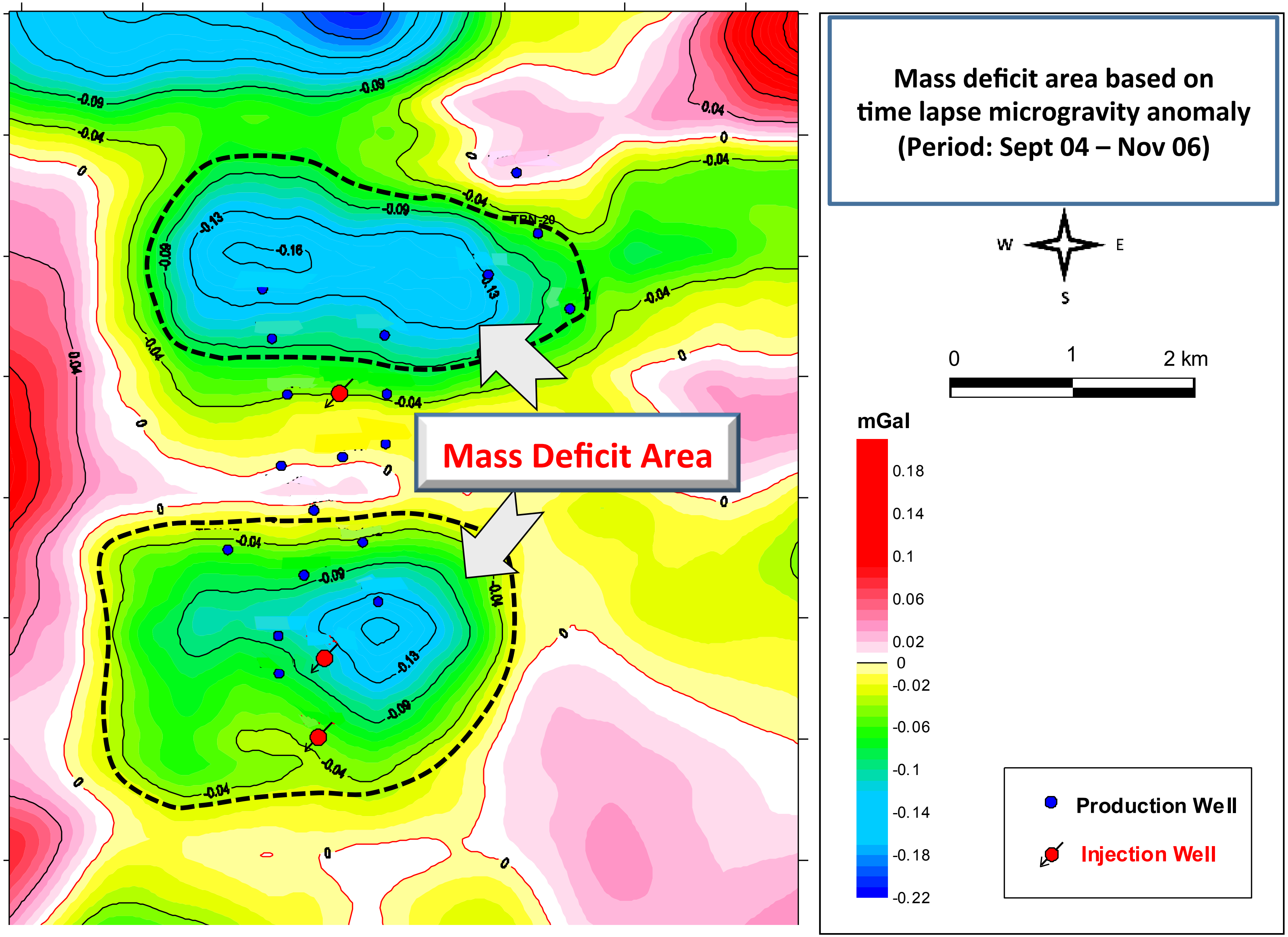
Nov’06

COMPARISON OF g_{obs} SEPT’04 AND NOV’06


Density change map
September 2001 – November 2006
Carbonate Field
N
W
E
S
0
1
2 km
Δρ (gr/cc)
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
Density
Production Well
Injection Well
722000
728000


Apparent pressure change map
September 2001 – November 2006
Carbonate Field
N
W
E
S
ΔP (psi)
0
1
2 km
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
Pressure
Production Well
Injection Well

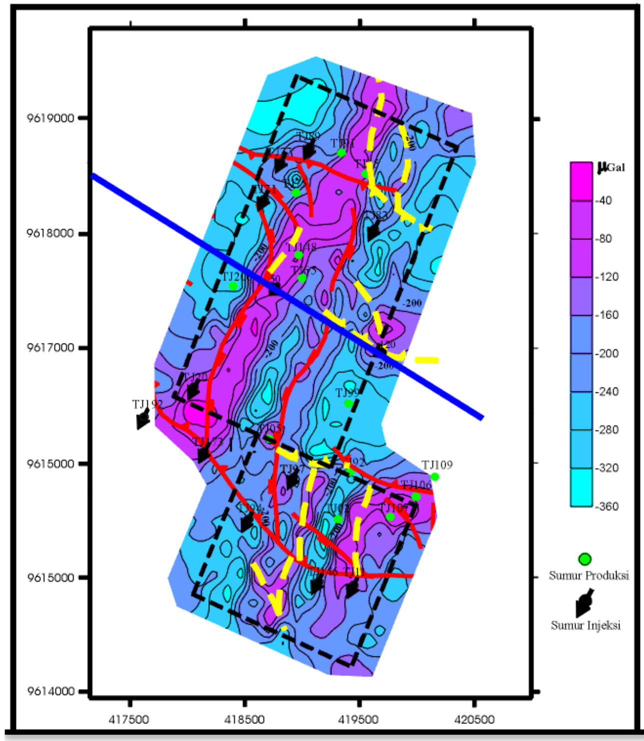

Apparent Saturation change map
September 2001 – November 2006
Carbonate Field
N
W
E
S
0
1
2 km
S app
0.38
0.34
0.3
0.26
0.22
0.18
0.14
0.1
0.06
0.02
-0.02
App Saturation
Production Well
Injection Well



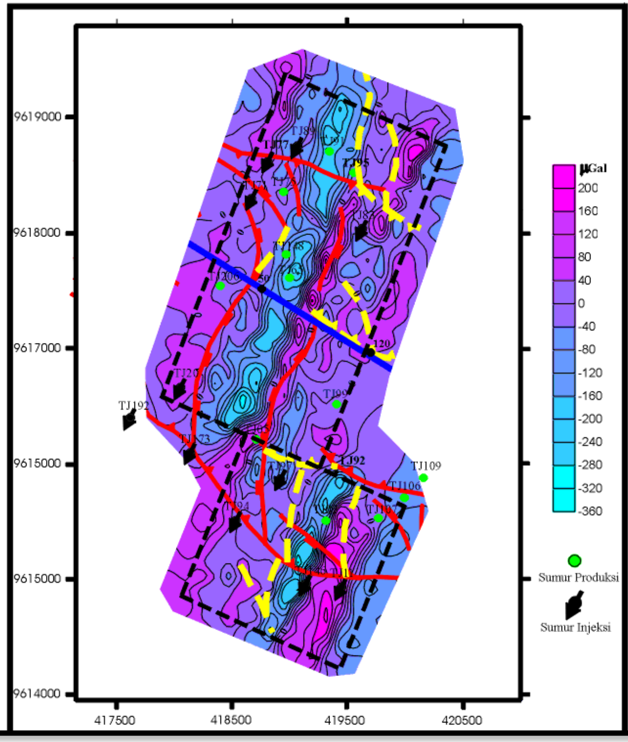
Mass deficit area based on time lapse microgravity anomaly (Period: Sept 04 – Nov 06)
W
E
S
0
1
2 km
mGal
0.18
0.14
0.1
0.06
0.02
0
-0.02
-0.06
-0.1
-0.14
-0.18
-0.22
Mass Deficit Area
Production Well
Injection Well
-0.09
-0.04
0
-0.13
-0.16

Case Study
Sandstone Reservoir

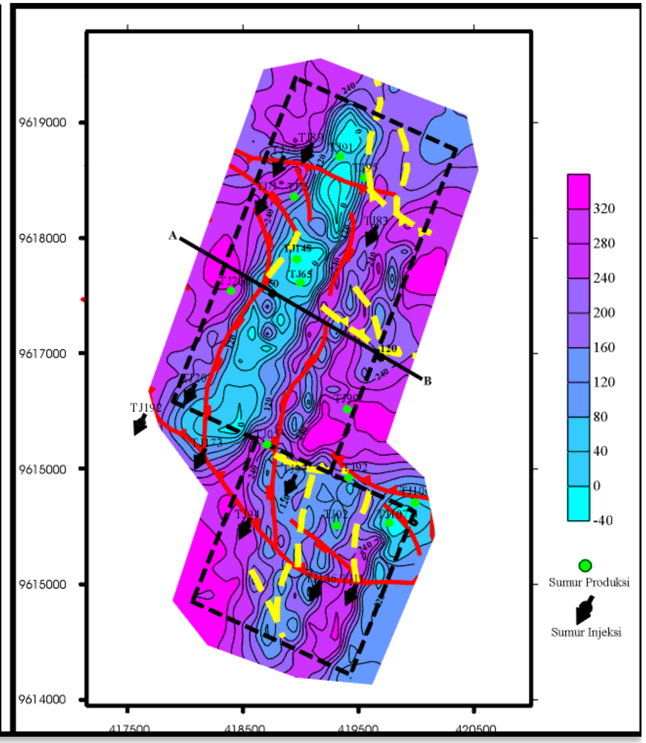
4D Microgravity Anomaly of Sandstone Field



Mei-Jan' 03

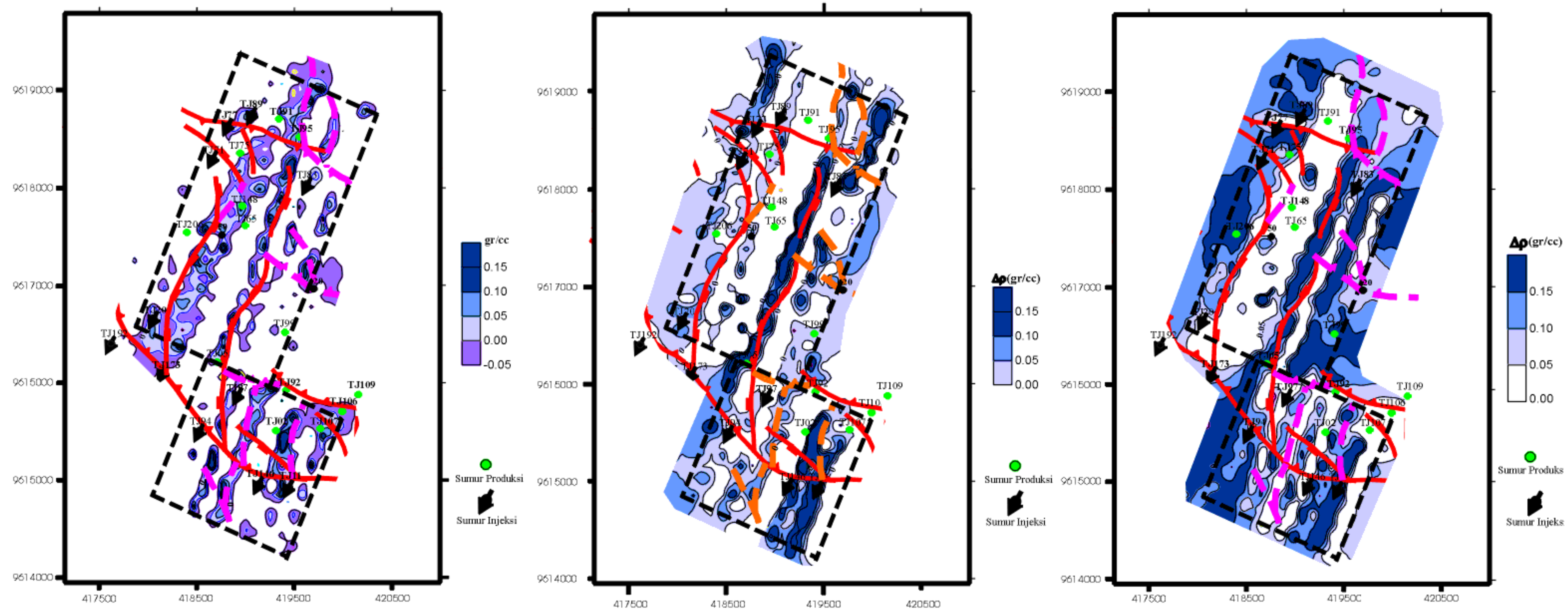


Sept-Jan' 03



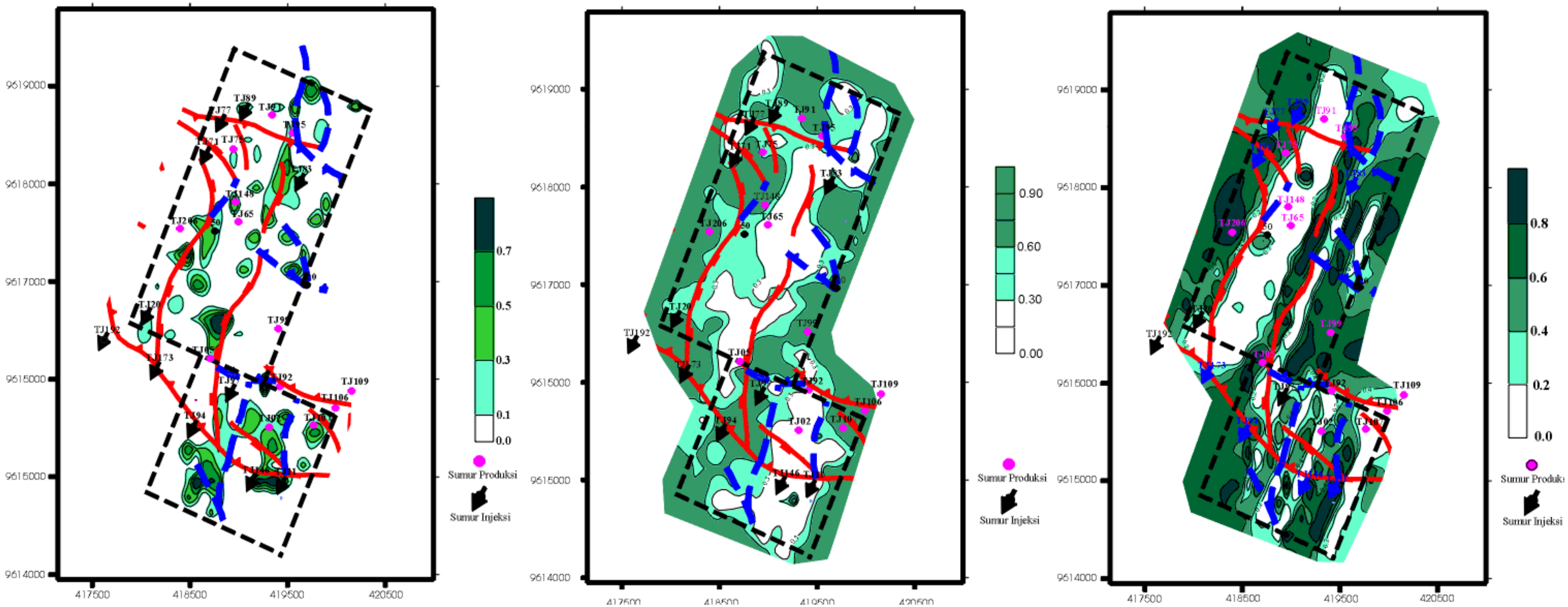
Sept-Mei' 03

Density Contrast Map of Sandstone Field



Mei-Jan’ 03　　Sept-Jan’ 03　　Sept-Mei’ 03

Apparent Saturation Map of Sandstone Field



Mei-Jan' 03 | Sept-Jan' 03 | Sept-Mei' 03

CONCLUSIONS

1. Indonesia's oil and gas resources are estimated to be very large in all sedimentary basins of Indonesia.
2. Indonesia's reserves can still be improved through the discovery of new fields with the gradient gravity method, as well as the development of production fields with Time-Lapse Technology applications, especially to search for bypass oil in mature fields.
3. With the relatively low oil prices being the right moment to use economical and environmentally friendly gravity technology to map resources and reserves in Indonesia.

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THANK YOU