ENERGY POLICIES, GEOPHYSICAL CHALLENGES AND 4D MICROGRAVITY DEVELOPMENT FOR RESERVOIR MONITORING DURING EOR (Water and CO2 Injection) IN INDONESIA

Wawan Gunawan A. Kadir, Djoko Santoso, Eko Widianto, Rachmat Sule

Institut Teknologi Bandung – Indonesia

Presented on CCS Technical Workshop: CO_2 Behavior Monitoring Technology, Thursday, December 9th 2010 in Kyoto - Japan

Indonesian's President Message

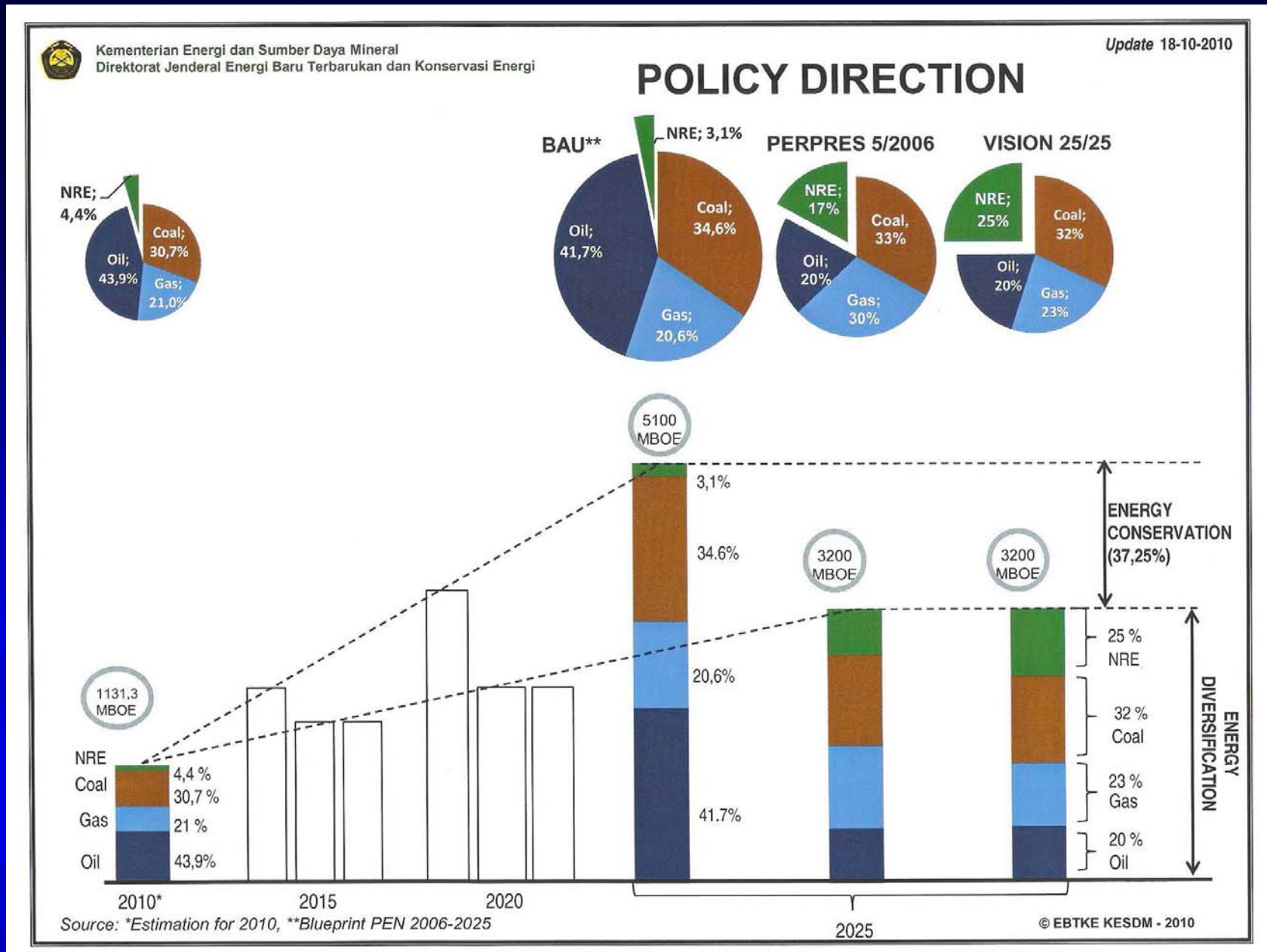
The president stressed Indonesia's commitment to reducing emissions by 26 percent by 2020, and up to 41 percent if international support is forthcoming

Two Main Contributions can be given by Indonesian Earth Scientists (also through international cooperation) in reducing Carbon Emission

1. **Increasing the use of renewable energy (geothermal).**

2. **Introducing CCS and CO2-EOR to the community and implementing those approaches in Indonesian Hydrocarbon Fields**

Vision of Energy supply and demand on 2025



CHANGES IN ENERGY MANAGEMENT PARADIGM

ENERGY SUPPLY SIDE MANAGEMENT

SUPPLY → **DEMAND**

SUPPLY	DEMAND
Fossil energy regardless of cost (Even subsidized)	Sectorial Energy Needs that have not been efficient: - Housing - Transport - Industry - Commercial
Renewable Energy as an Alternative	

Currently:

1. Energy needs has not been efficient
2. Energy needs are supplied with fossil energy at a cost of whatever and even subsidized
3. Renewable energy as an alternative only
4. Unutilized Renewable energy sources is wasted God's gift

ENERGY DEMAND SIDE MANAGEMENT

SUPPLY → **DEMAND**

SUPPLY	DEMAND
Efficient Sectorial Energy Needs: -Housing -Transport - Industry - Commercial (CONSERVATION)	Maximizing the use of Renewable Energy Supply and price of Avoided Fossil Energy Costs (DIVERSIFICATION) Fossil Energy as a Balancing Factor

Future:

1. Efficiently the energy needs
2. Maximize the supply and demand of renewable energy, at least with the price of avoided fossil energy cost, if necessary subsidized
3. Fossil energy is used as a counterweight
4. Unutilized Fossil energy sources is as a legacy to children and grandchildren /exported

EOR of Mature-Old Field in Indonesia

- Background:
  - Oil production in Indonesia is dominated by onshore mature fields that are :

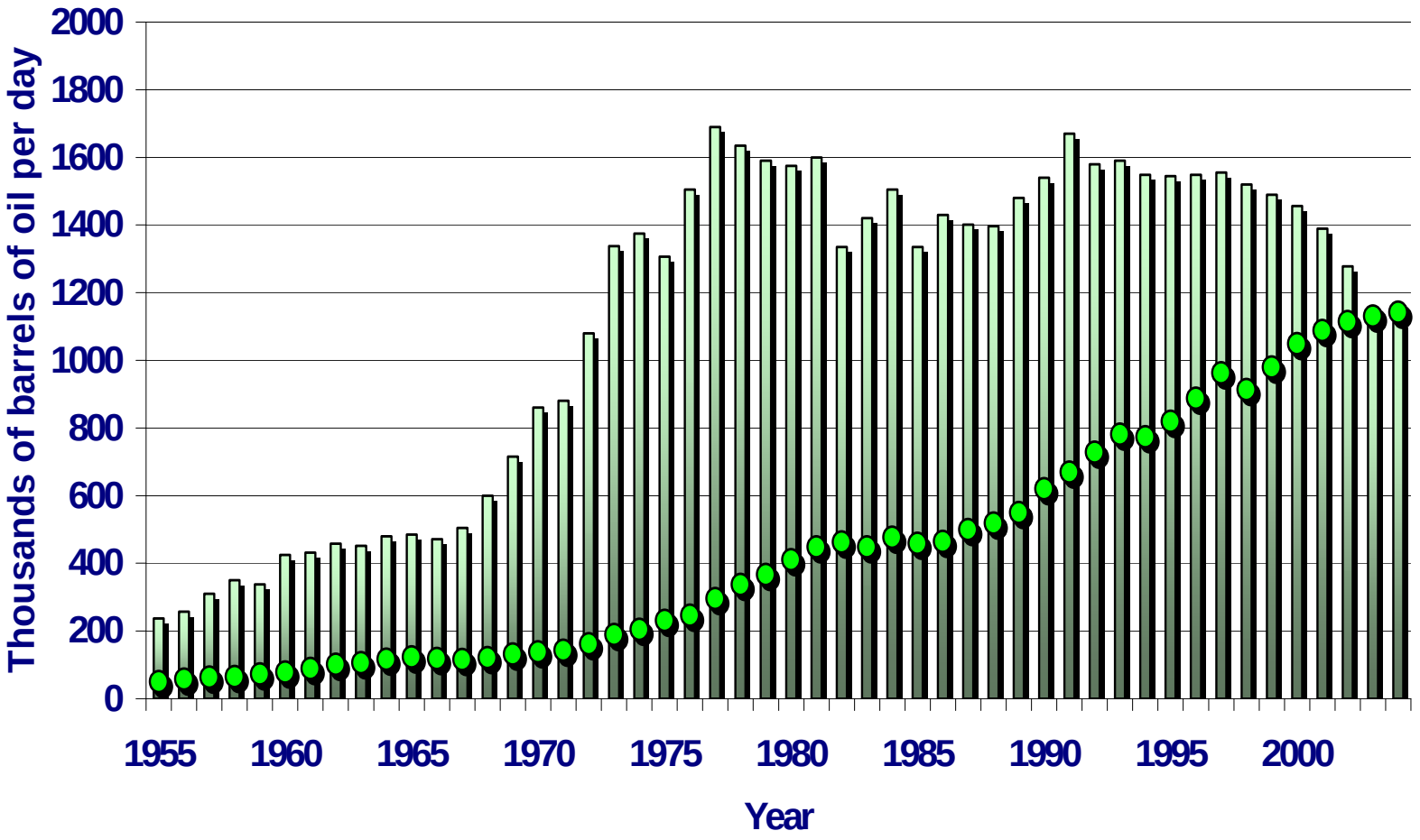
    experiencing rapid rates of decline,

    yet hold significant remaining reserves.

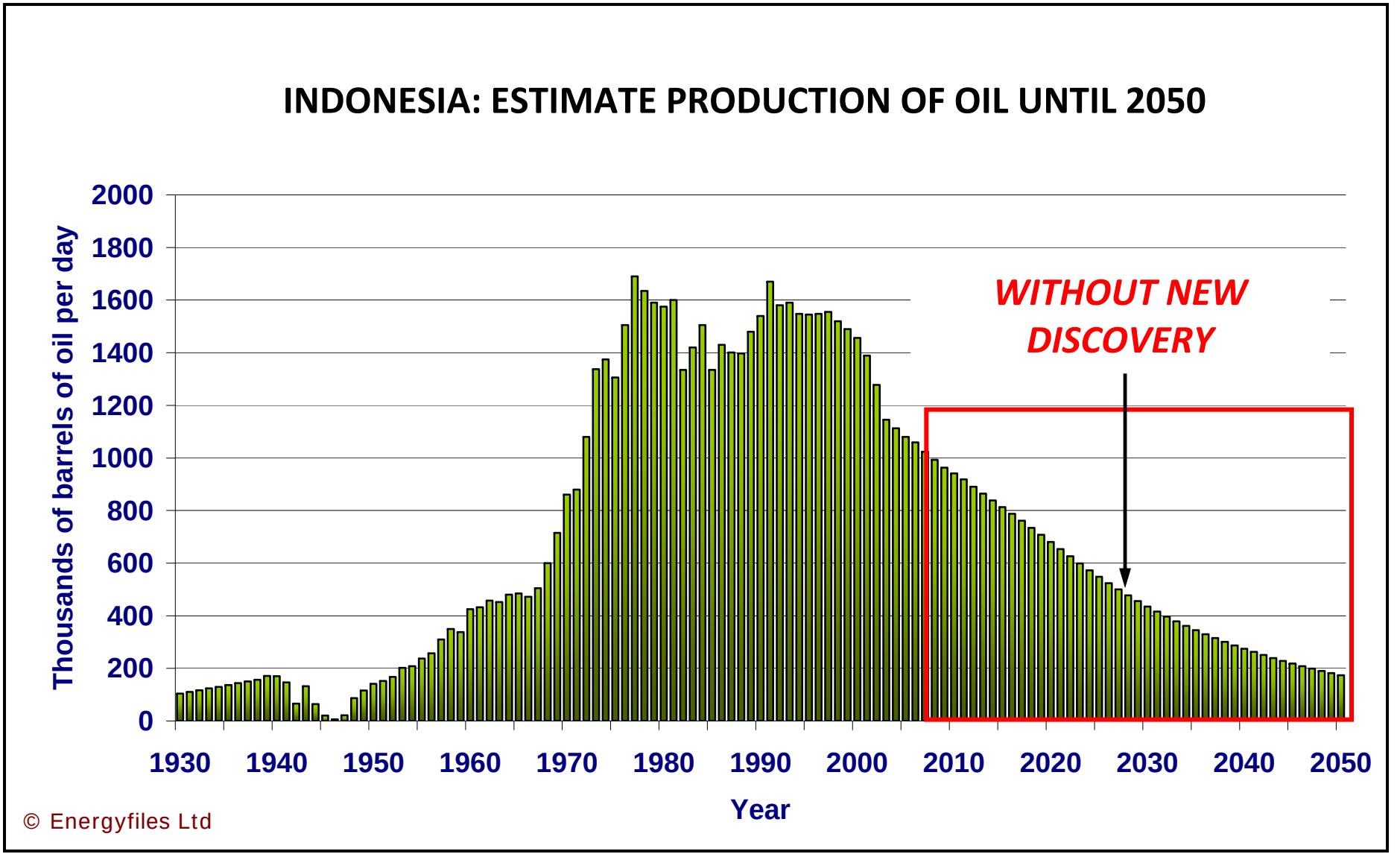
  - Mature/Old oil field in Indonesia: 70%.
  - Contribution to production from oil field: 90%
  - Common blockers include a lack of appropriate technology, poor processes, etc

Oil production in Indonesia peaked 15 years ago and is now in steep decline

INDONESIA: Oil production (bars) & consumption (dots)



To maintain Oil production :
- **Exploration on new area (new potential)**
- **EOR ⟶ using CO2 Injection (and CCS)**
- **etc**



(Satyana, 2008)

EOR of Mature-Old Field in Indonesia

- To maintain/ improve production
  ⟶ Mature/Old Oil field should be developed
  - Reason:
    - Existing infrastructure and current technology improvement

EOR
(WATER AND GAS (CO2) INJECTIONS)

Prospective New Technology on Reservoir monitoring

Mostly mature/old oil field locate in/close to the country area

Needs technology with : small team, handy equipment(moveable),
⟶ Easy in station to station movement, no environmental damage,
Min. 'electricity support', nearly no social conflict

- **4D (Surface and Bore Hole Microgravity measurements)**
- **Seismic modeling combined to 4D microgravity**

Long term monitoring

Objectives:

1. Characterize the reservoir

   Goal → produce information on structure and fluid movement
2. Characterize the cap rocks

   Knowledge of the extent, nature and sealing capacity of the cap rock is perhaps the key purely geological element in assessing and establishing the long-term safety case for the CO2 repository.
3. Elucidate CO2 migration pattern and its performance to oil production EOR.

Geophysical and Geodetic methods offered for monitoring:

- Time-lapse gravity
- Microseismic
- GPS
- InSAR
- EM

4D MICROGRAVITY

THEORETICAL BACKGROUND

4D Reservoir Monitoring (x,y,z,t)

A Paradigm Shift in Production Management

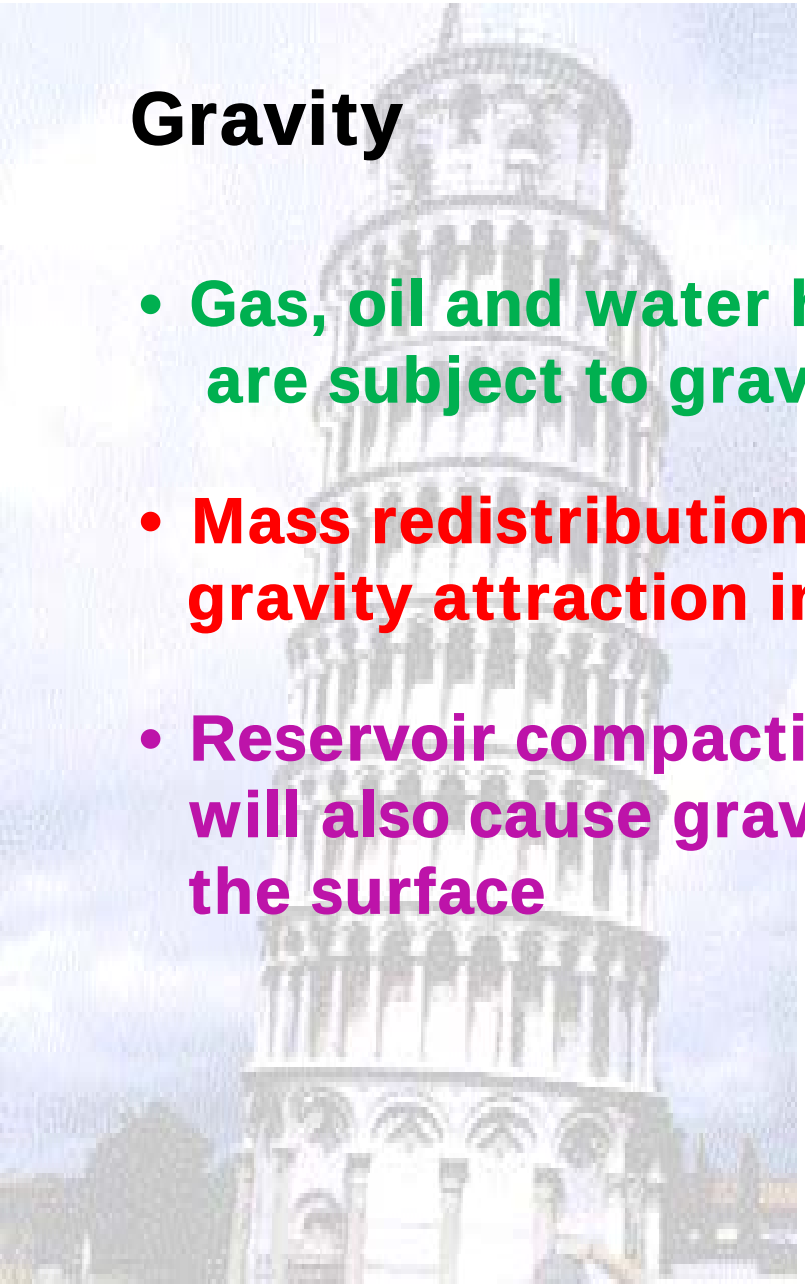
Science & Technology Components

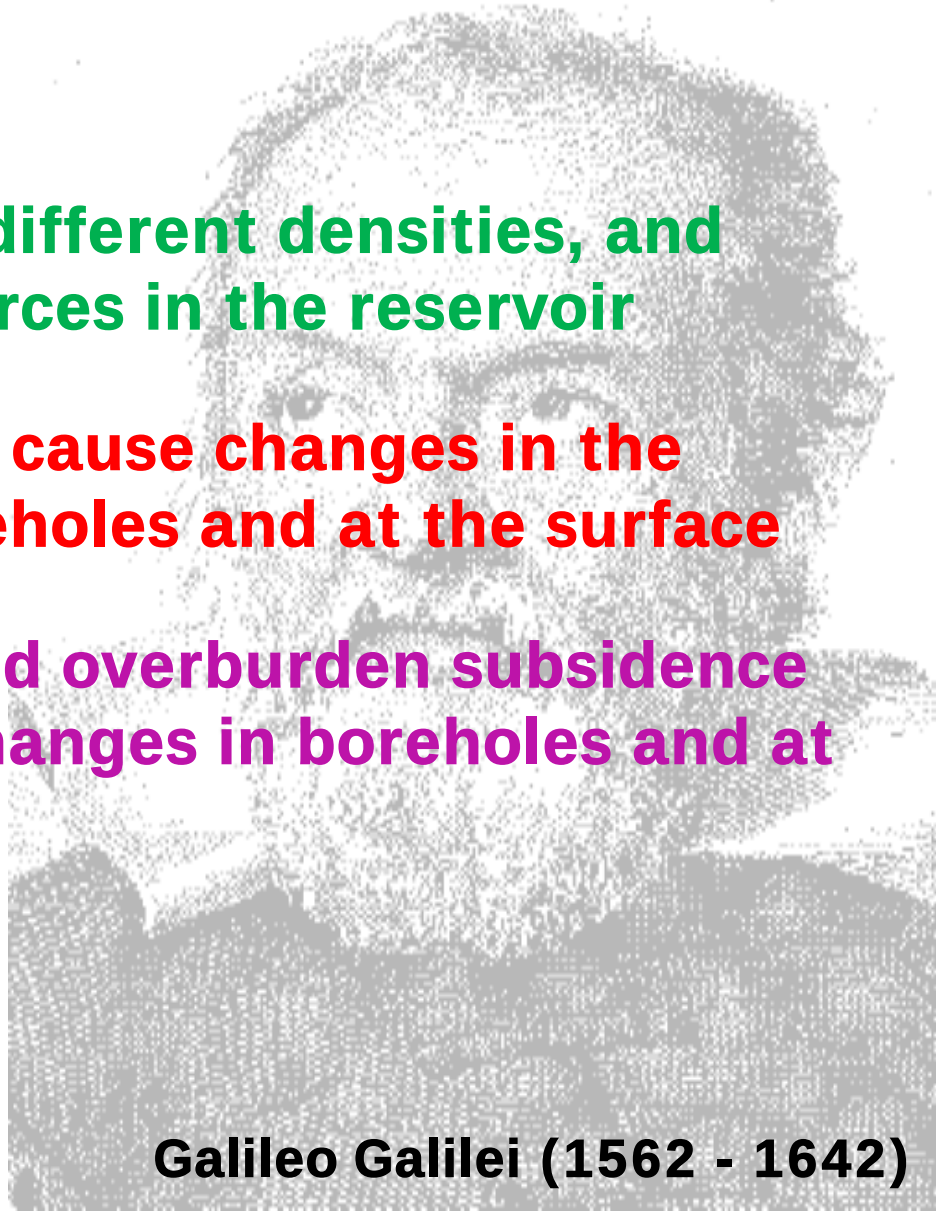
(Gravimeter and processing technology)

- **Integration of Disparate Data (Kinds & Scales)**
  - **Cased Hole Logs**
  - **Production Histories**
  - **Pressures & Temperatures**
  - **4-D Seismic Monitoring**
  - **Gravity Monitoring** → **Survey repeatability is less than 5 μGal**
  - **Borehole Seismic**
  - **Remote Sensing**

Gravity

- Gas, oil and water have different densities, and are subject to gravity forces in the reservoir
- Mass redistributions 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





Galileo Galilei (1562 - 1642)

Gravity Monitoring (4D)

- 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

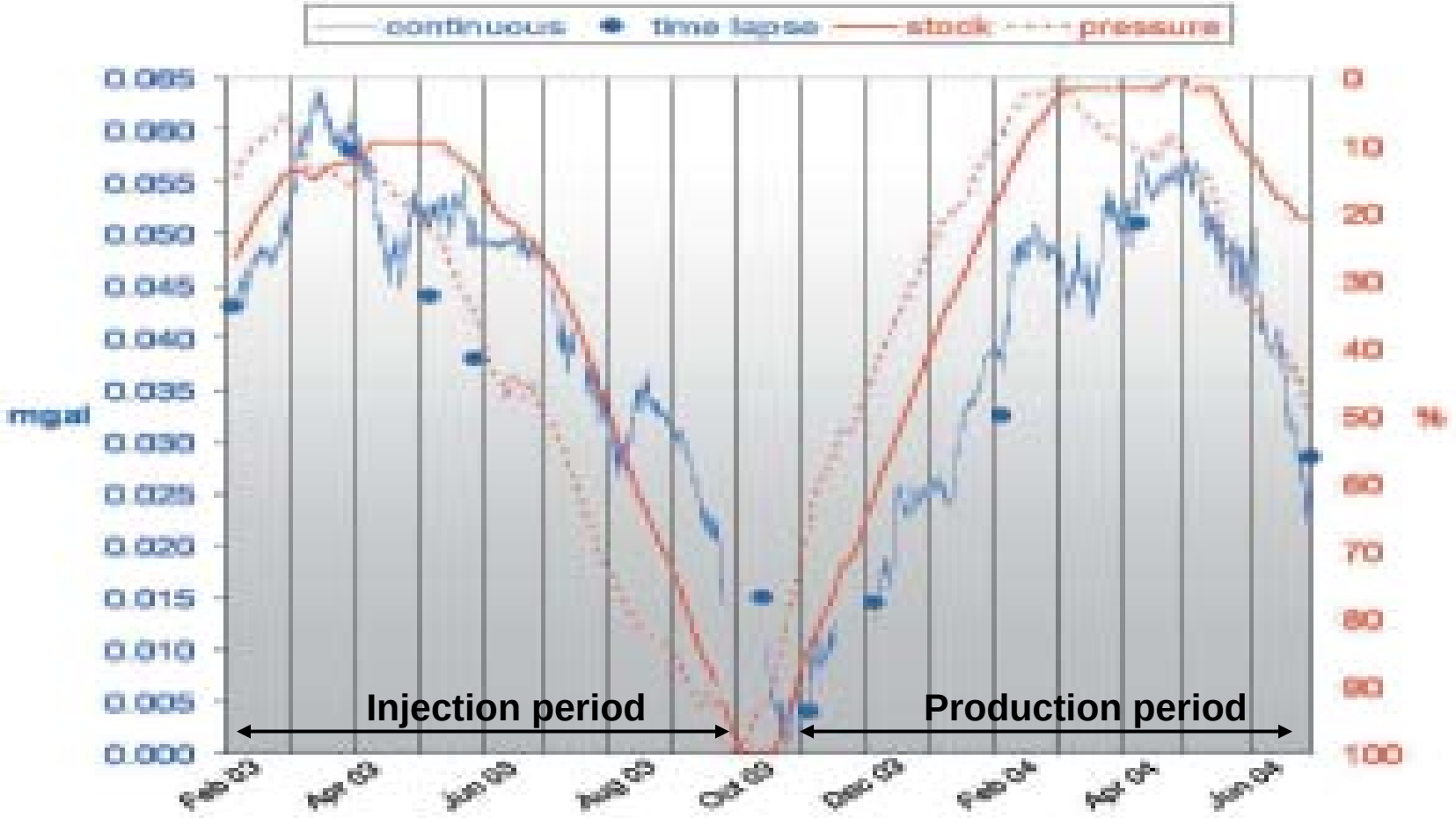


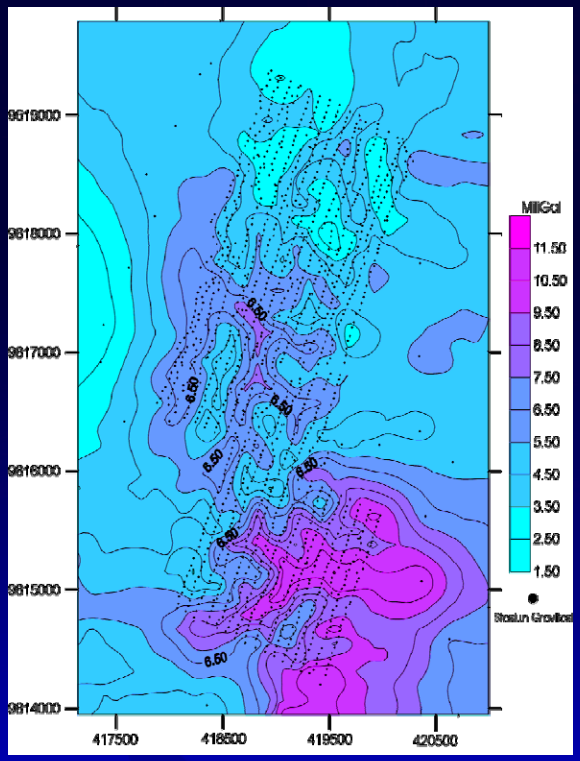
Figure 3 *Diagram showing the time-lapse gravity (blue dots), continuous gravity (blue trace), gas stock levels (red trace), and reservoir pressure (red dashed trace) at a monitoring well over a 16 month period. As the reservoir is depleted, the gas/water contact rises, resulting in an increase in the time varying gravity field. Note that the polarity of the gravity data has been inverted to facilitate easier comparison.*

Source of 4D Microgravity Anomaly

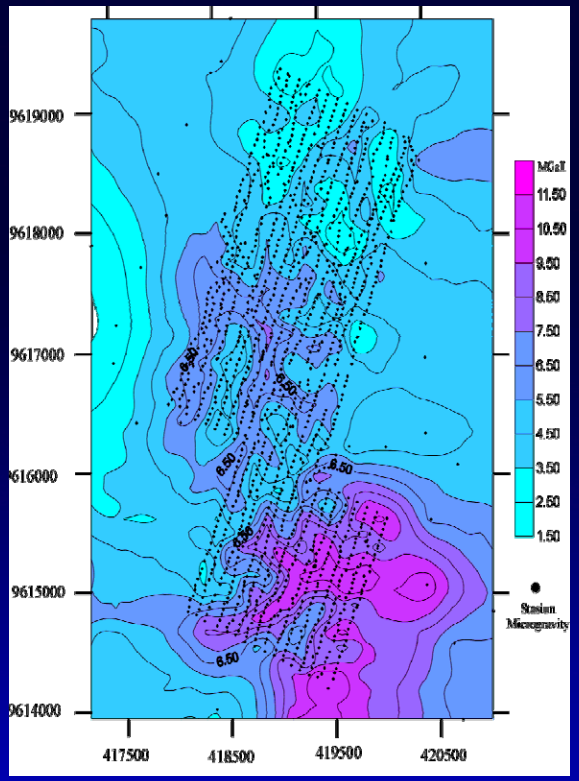
1. Dry and Wet Seasons
2. Land Subsidence
3. Ground water level change
4. Mass Decrease in Subsurface (Oil and Gas Production in Reservoir)
5. Mass Increase in Subsurface (Water and Gas Injection in Reservoir)
6. Pressure increase and decrease in the reservoir

4D MICROGRAVITY

CASE STUDY (Water Injection)
-X Field (sandstone reservoir)
- Y Field (Carbonate reservoir)



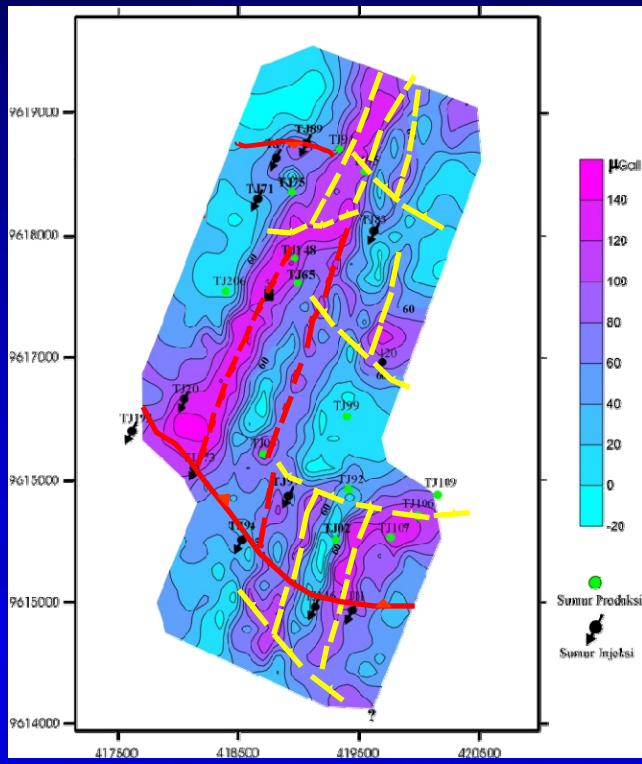
first measurement
(Dec' 2002)



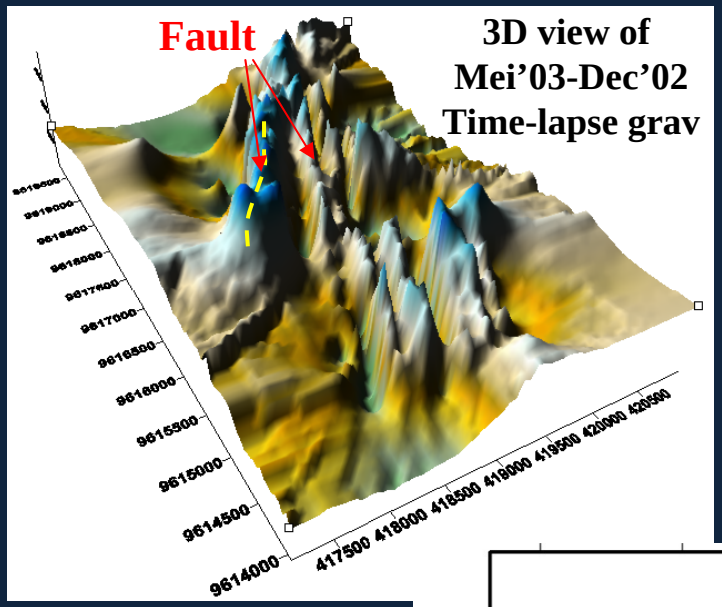
second measurements
(May 2003)

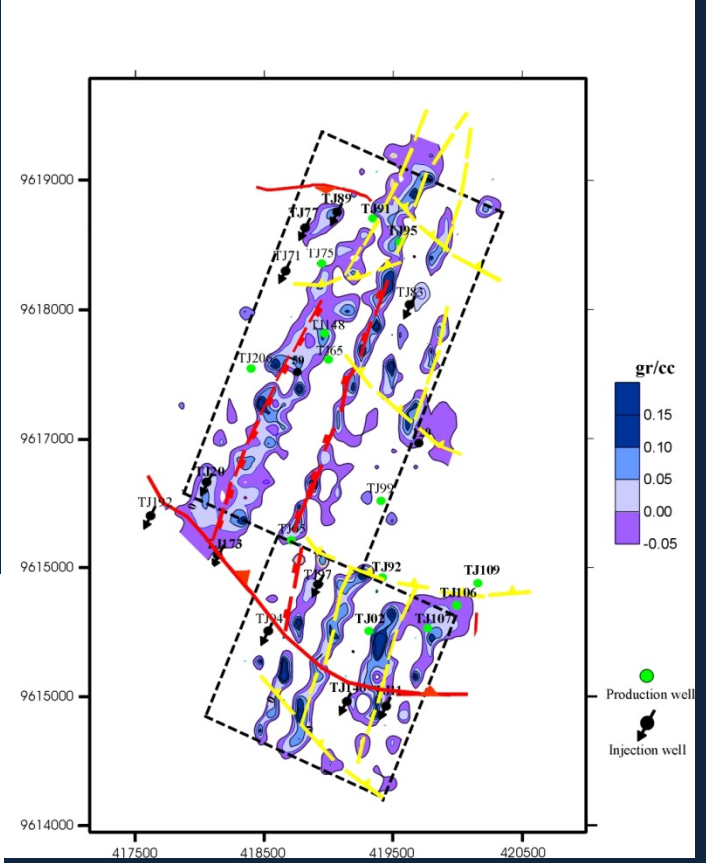
Total of water injection is 30.000 barrel/day

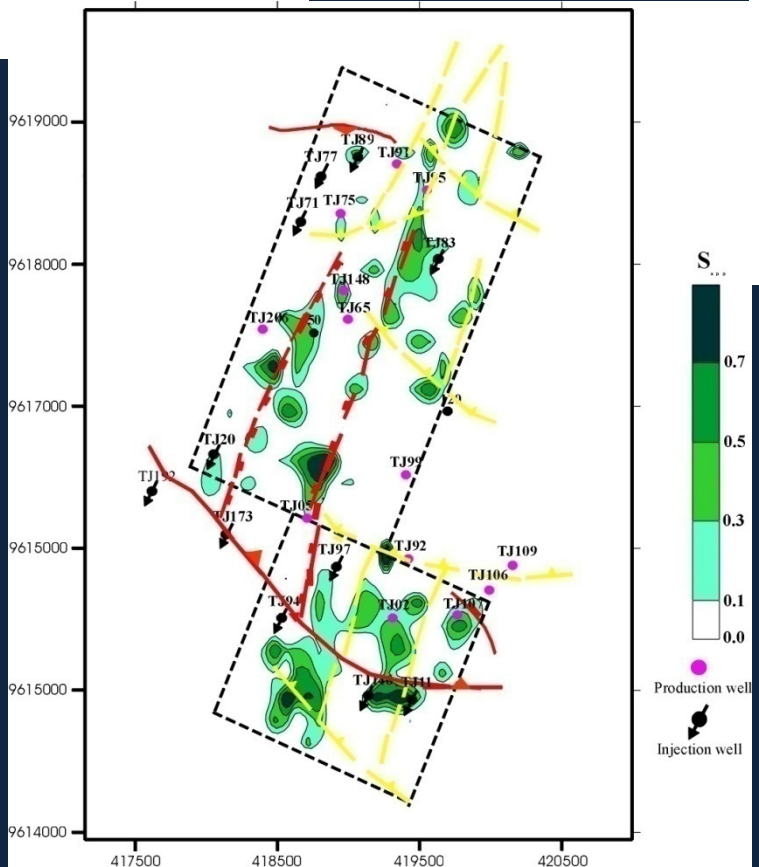
Time-lapse microgravity of May03-Dec'02 after corrected by surface water



Gravity value of the X field and surrounding areas (sandstone reservoir) and its station distribution







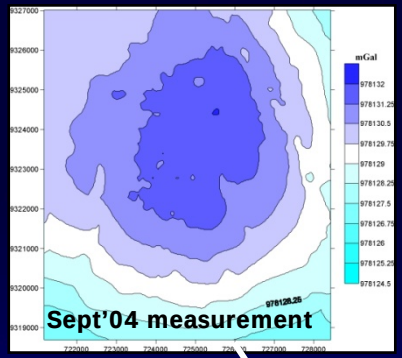
Increasing Oil production from re-opening Wels based on 4D microgravity

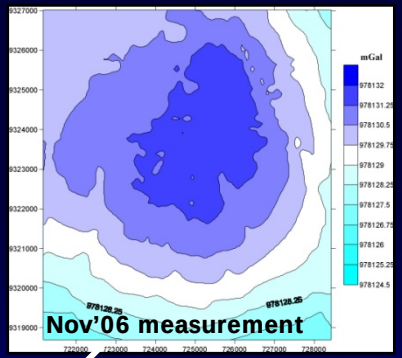
Density contrast map

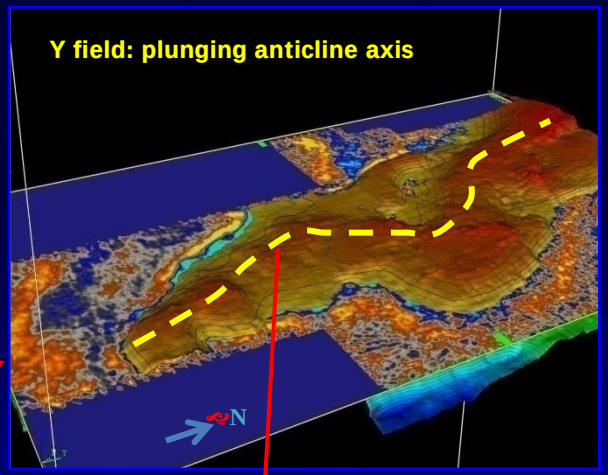
Apparent saturation (indicate injection water increase)

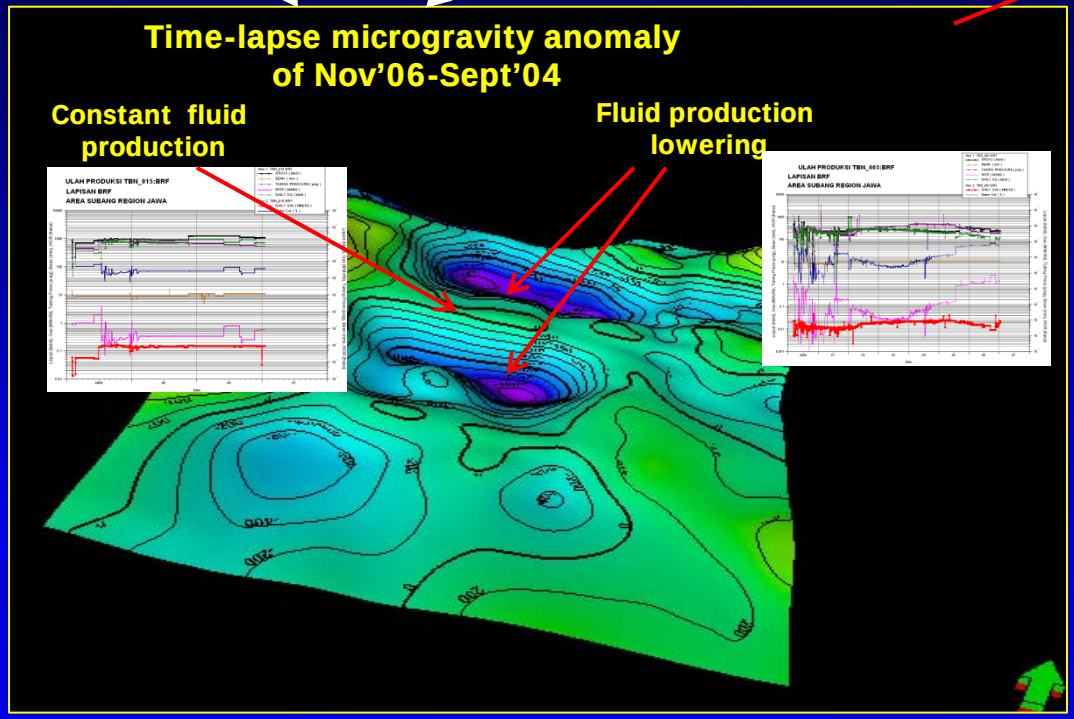
Second Case Study is Y Field (Carbonate Reservoir): COMBINED SEISMIC DATA AND 4D MICROGRAVITY

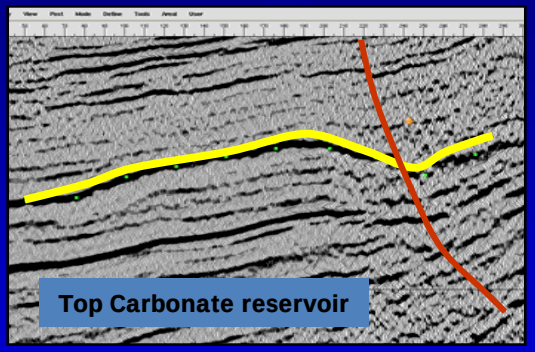
- EXISTING SEISMIC DATA
- STRUCTURE DERIVED FROM SEISMIC DATA
- STRUCTURE FROM COMBINED SEISMIC AND 4D MICROGRAVITY DATA



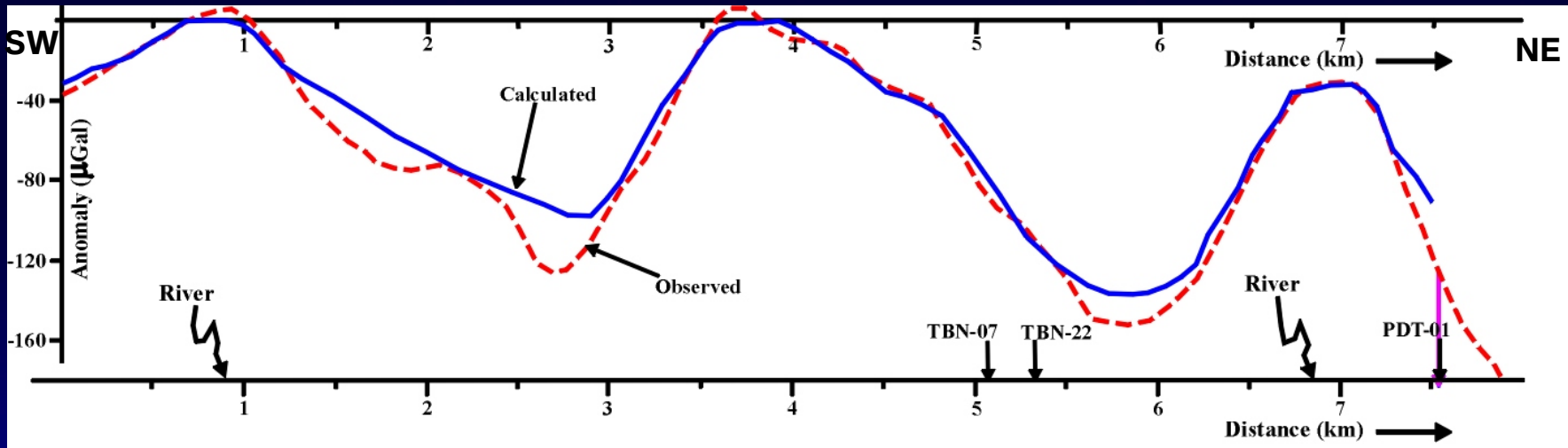


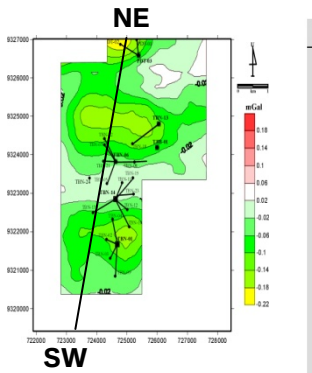


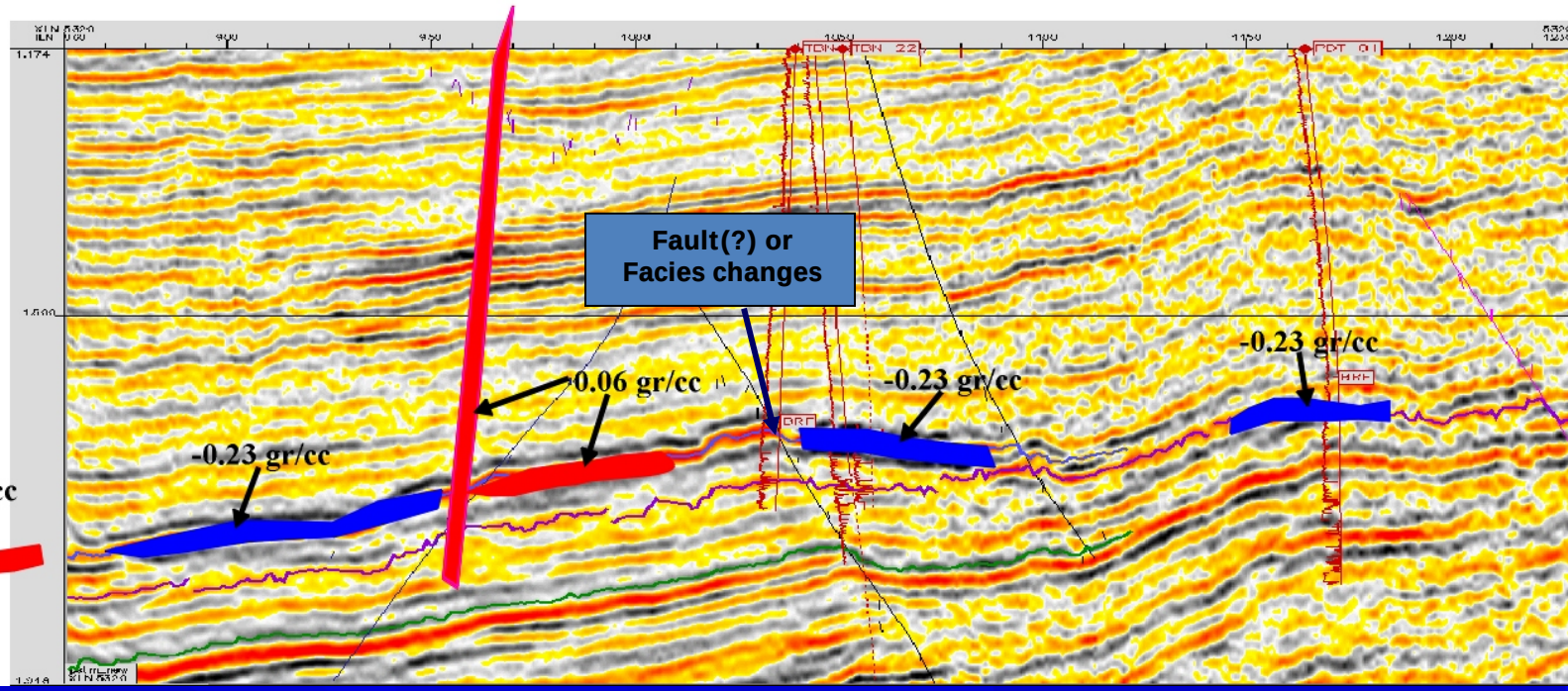




Time-lapse microgravity, gross production and its top carbonate reservoir

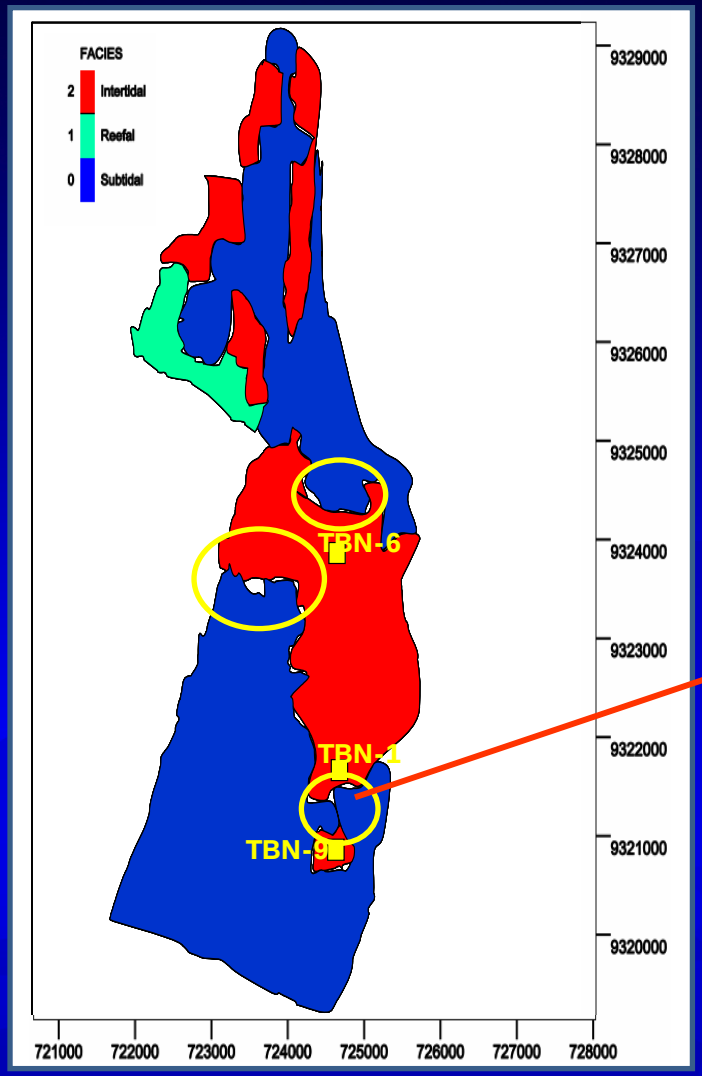


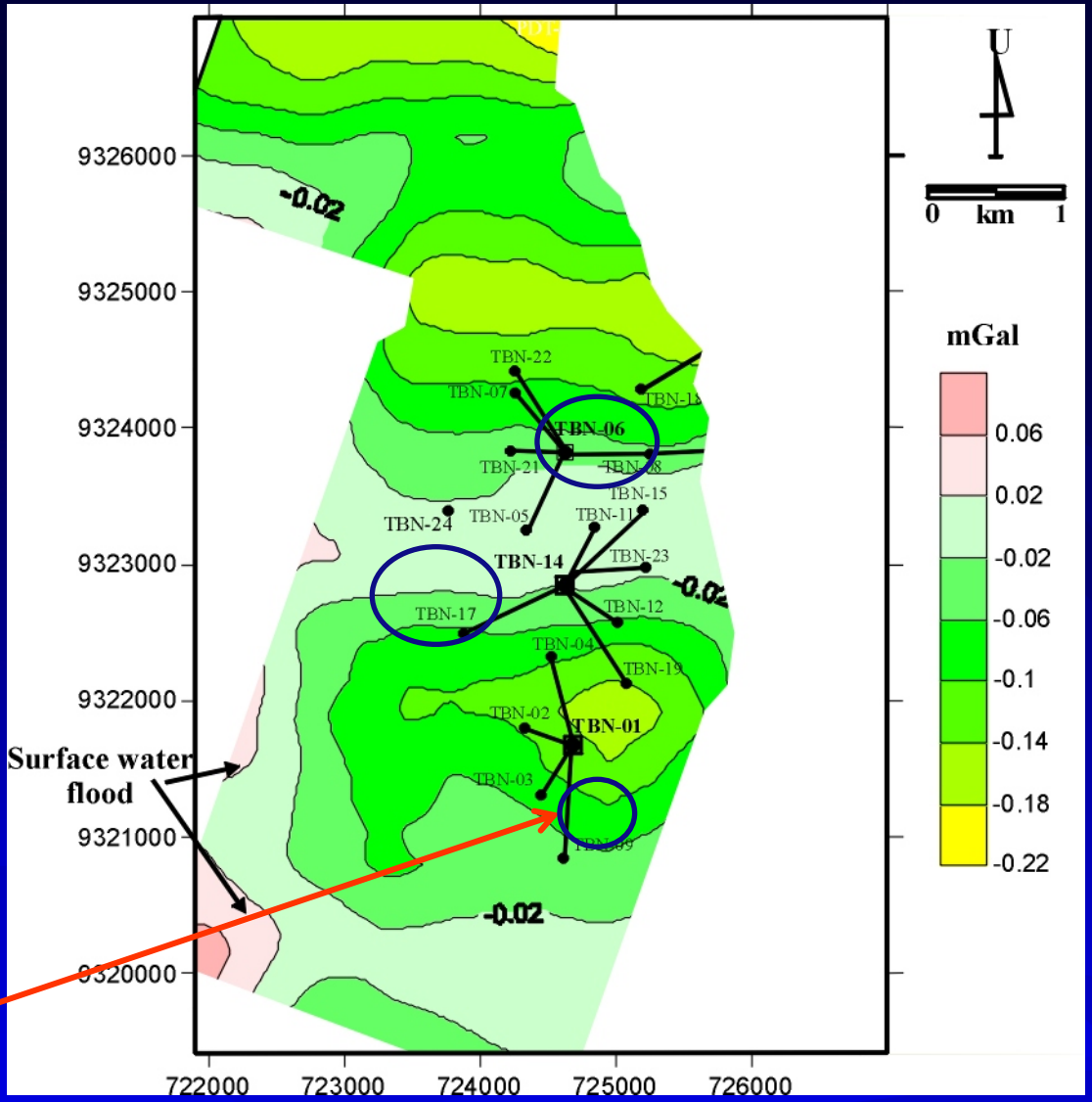




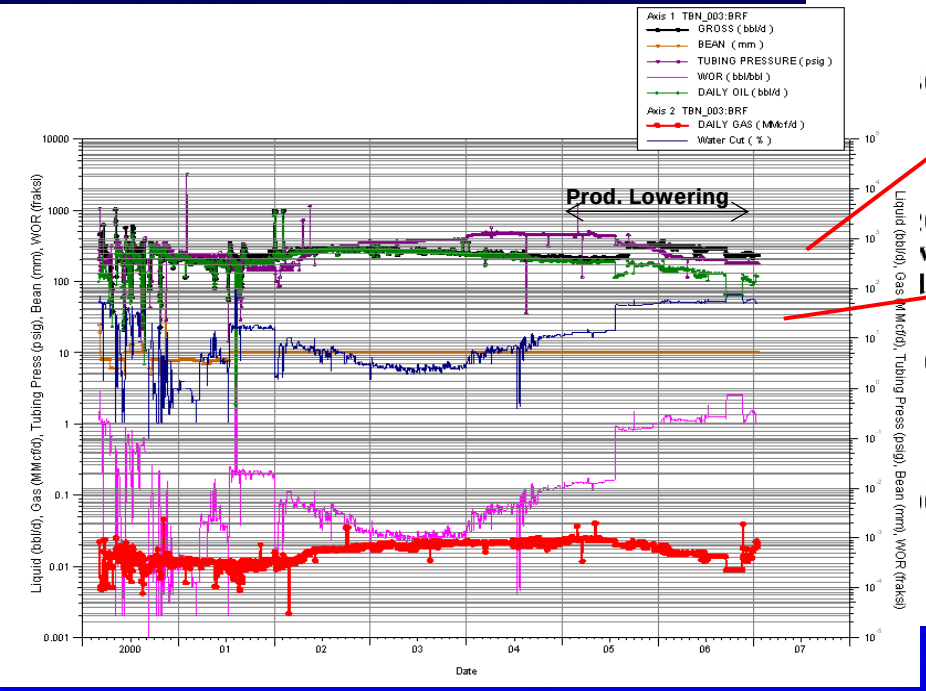
Correlation between subsurface model of Time-lapse microgravity anomaly (Nov 06 – Sep 04) and Its seismic section

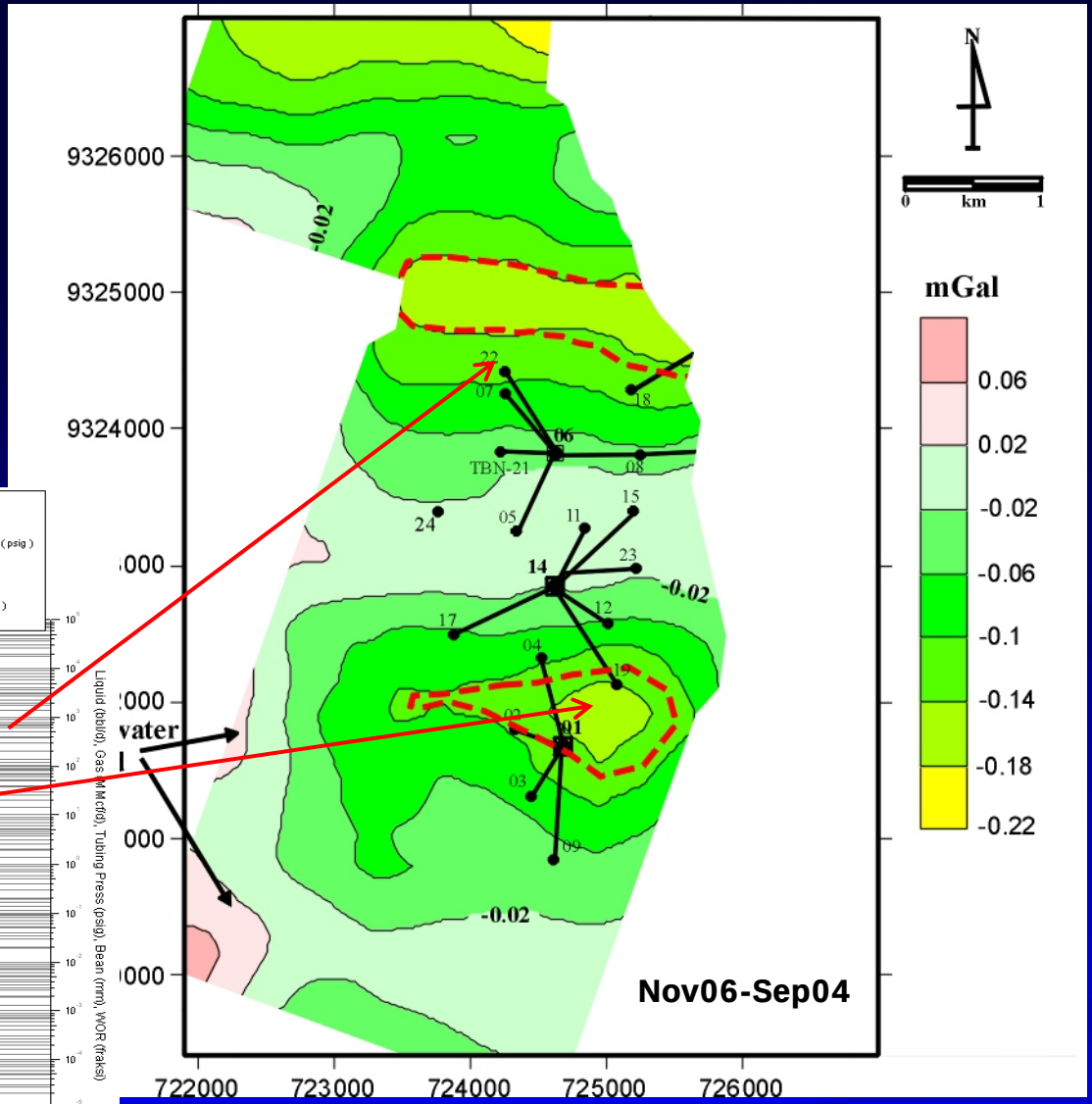
Facies change on BRF Carbonate



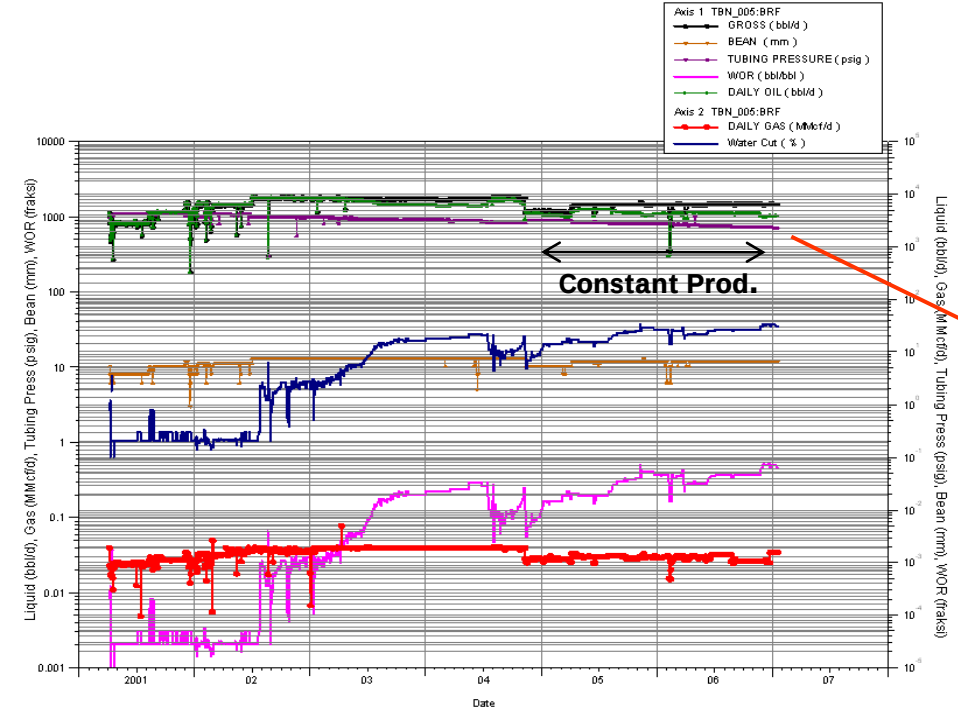


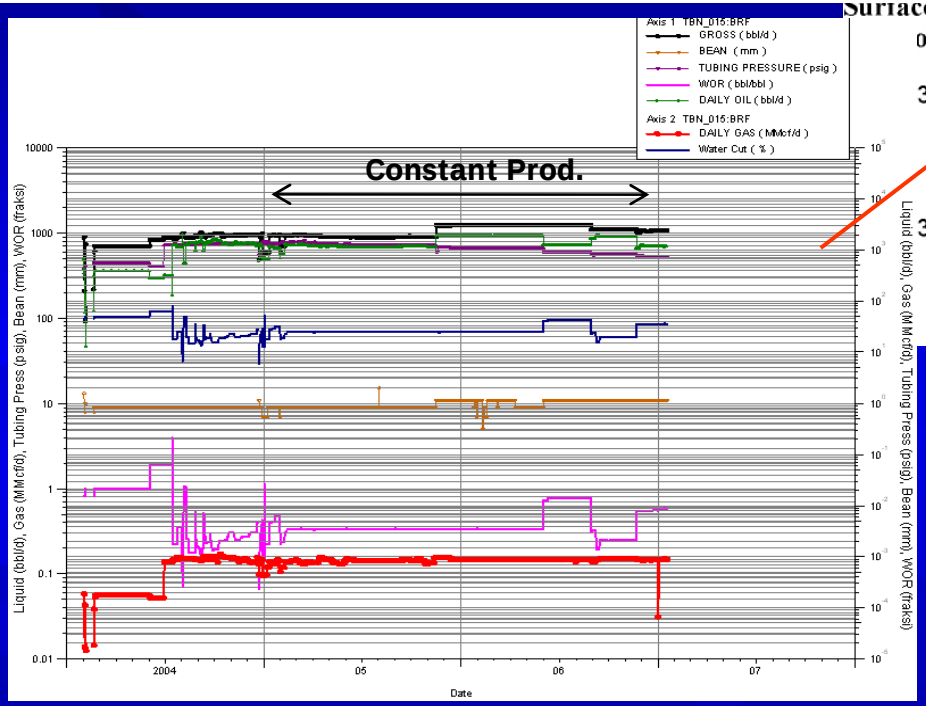
Time-lapse microgravity of Nov 06 – Sept 04

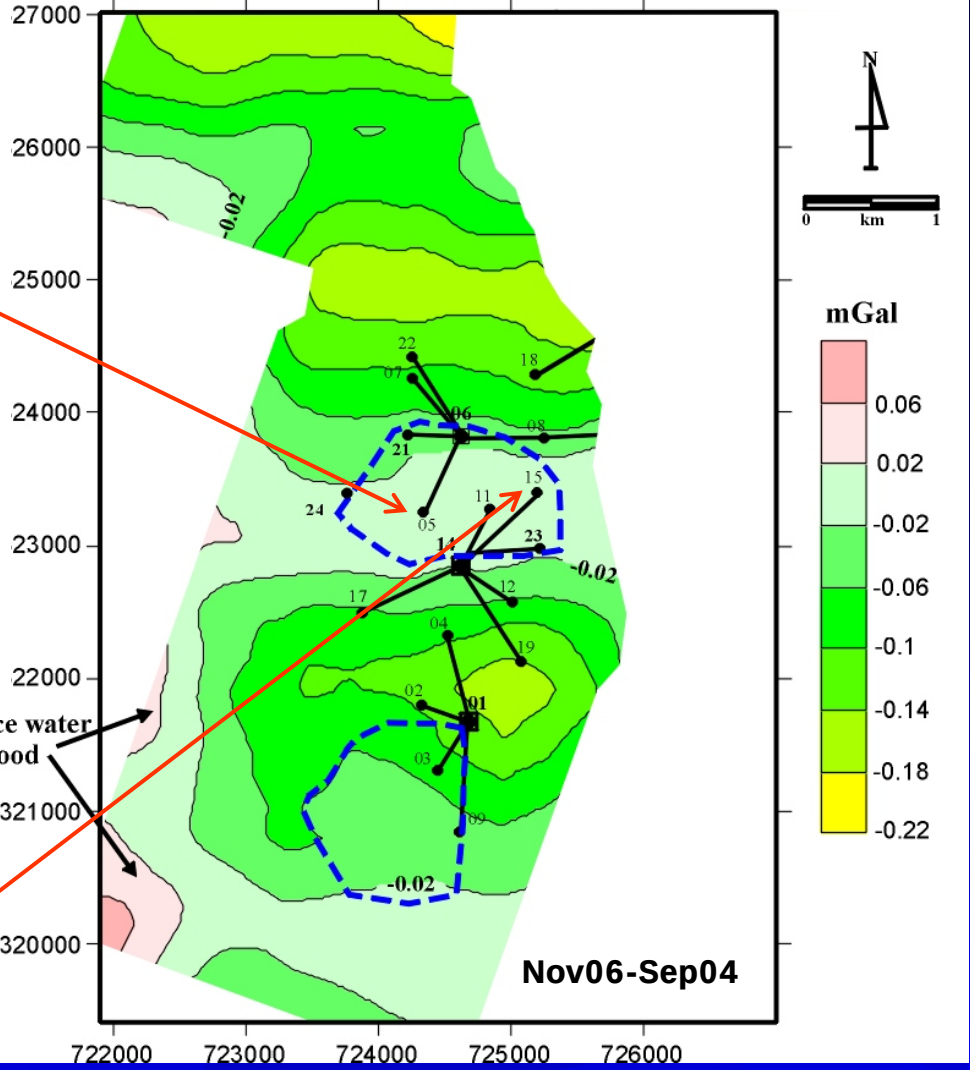




Estimated area in which production will be lowering (no more fluid production in Sept'07 at TBN-19)







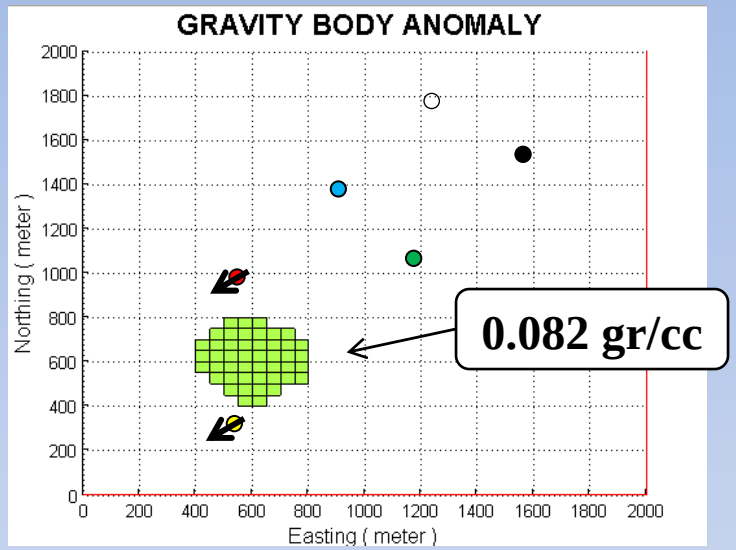
Estimated area in which production will be constant or rising (positive injection impact on pressure maintenance)

COMBINED SURFACE AND BORE-HOLE TIME-LAPSE MICROGRAVITIES

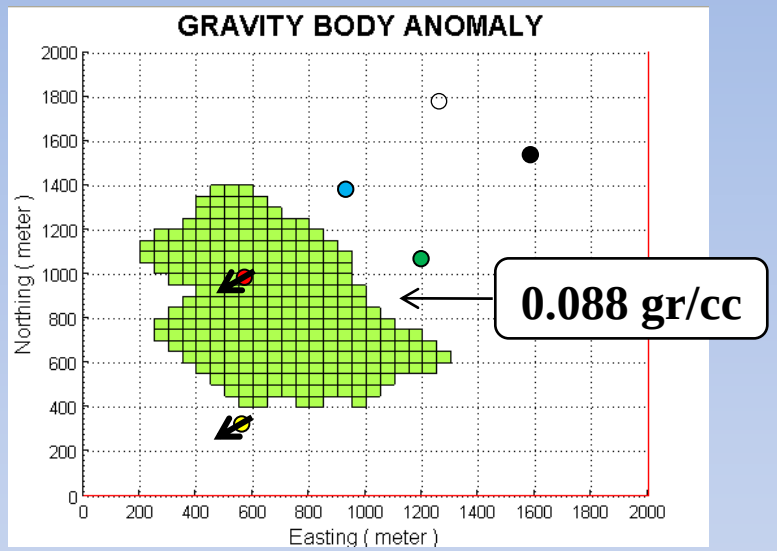
STUDY ON SYNTHETIC MODEL

Model of fluid movement (705 m depth)

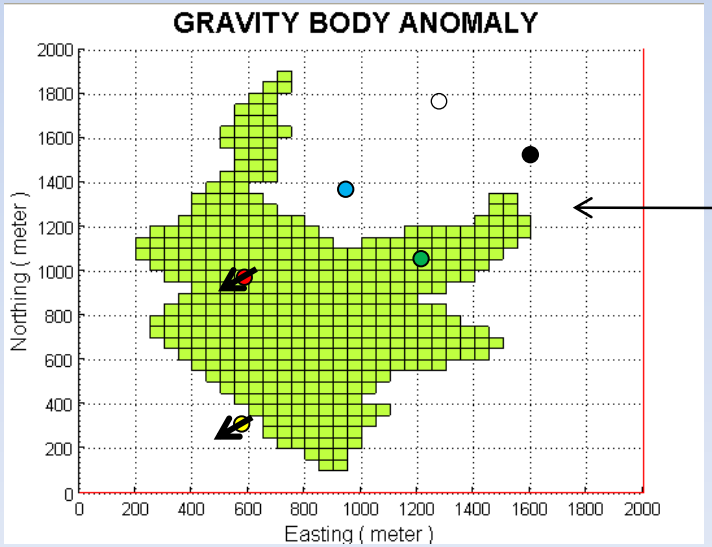
t_0



t_1



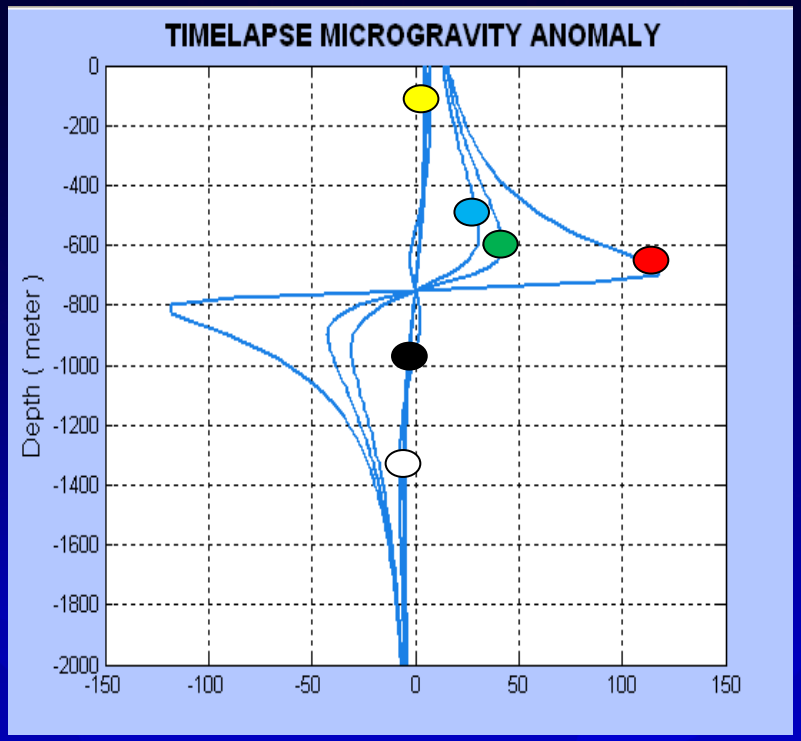
t_2



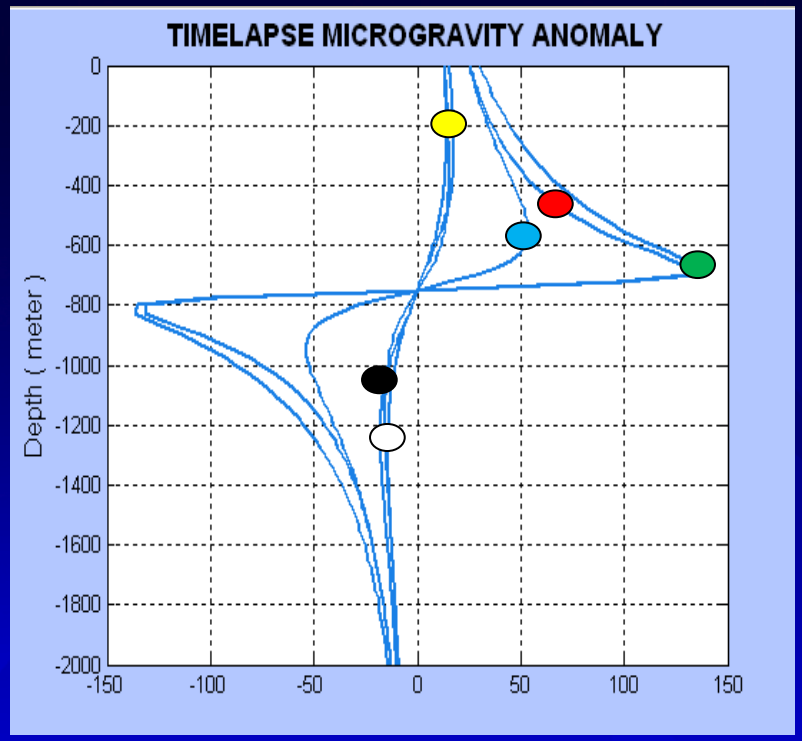
- Well R1
- Well R2
- Well P1
- Well P2
- Well P3
- Well P4

Bore-hole time-lapse microgravity

Scheme 1

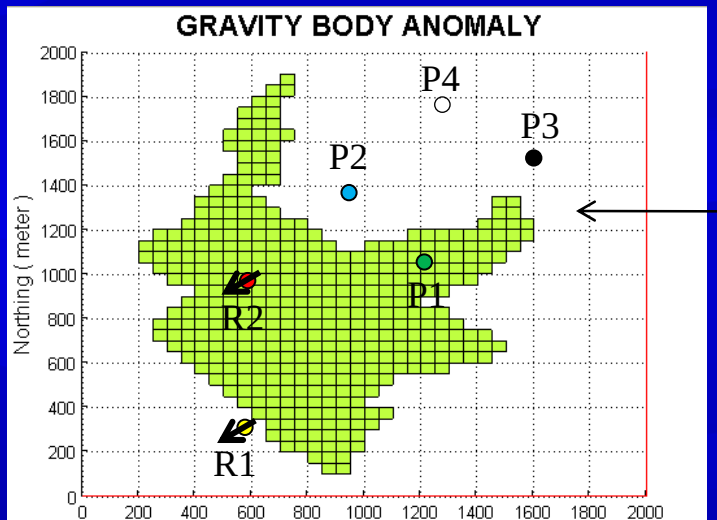


Scheme 2

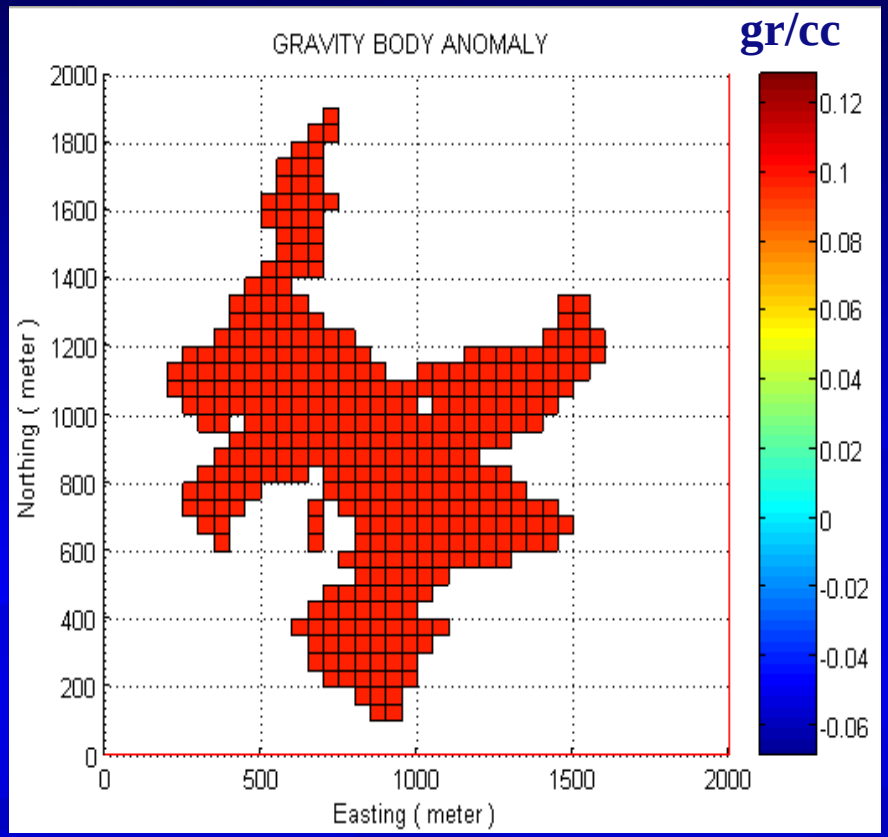


- Well R1
- Well R2
- Well P1
- Well P2
- Well P3
- Well P4

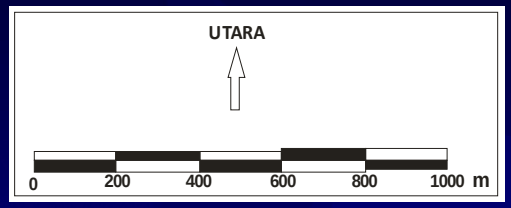
Explanation:
Scheme 1 = $t_1 - t_0$
Scheme 2 = $t_2 - t_0$

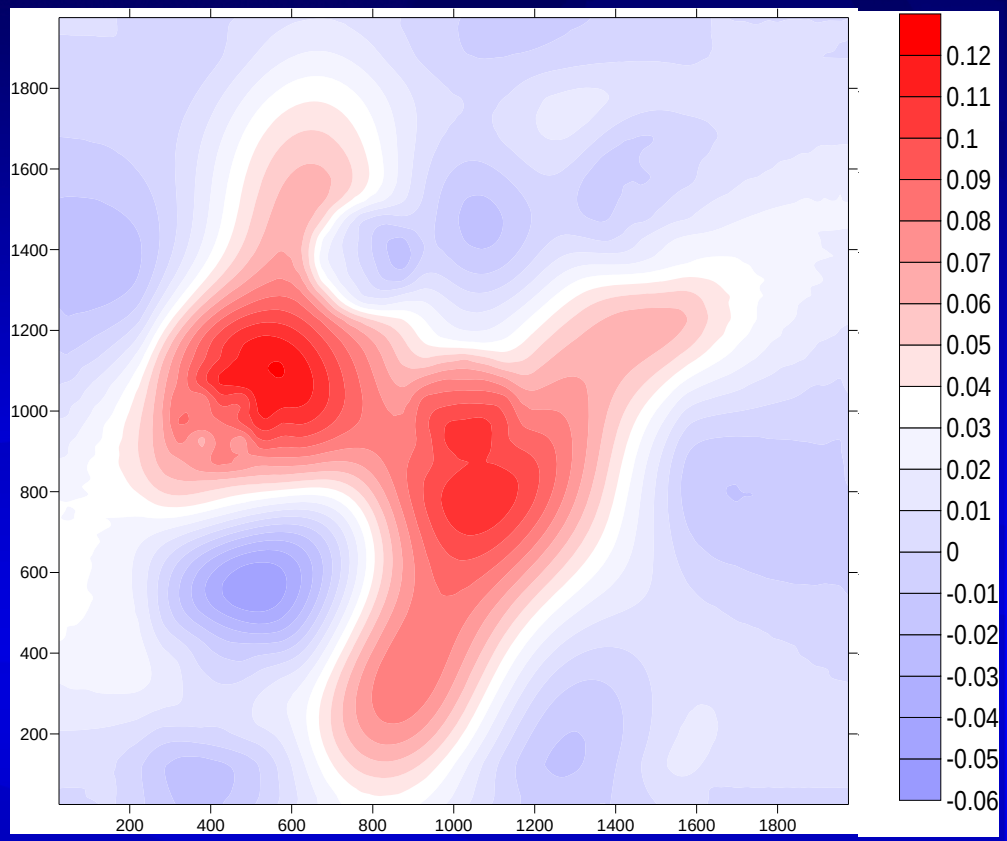


Comparison density change at 705 m depth between synthetic model and result of *Joint Inversion* (surface and bore-hole time lapse microgravity) for Scheme 2



Synthetic Model

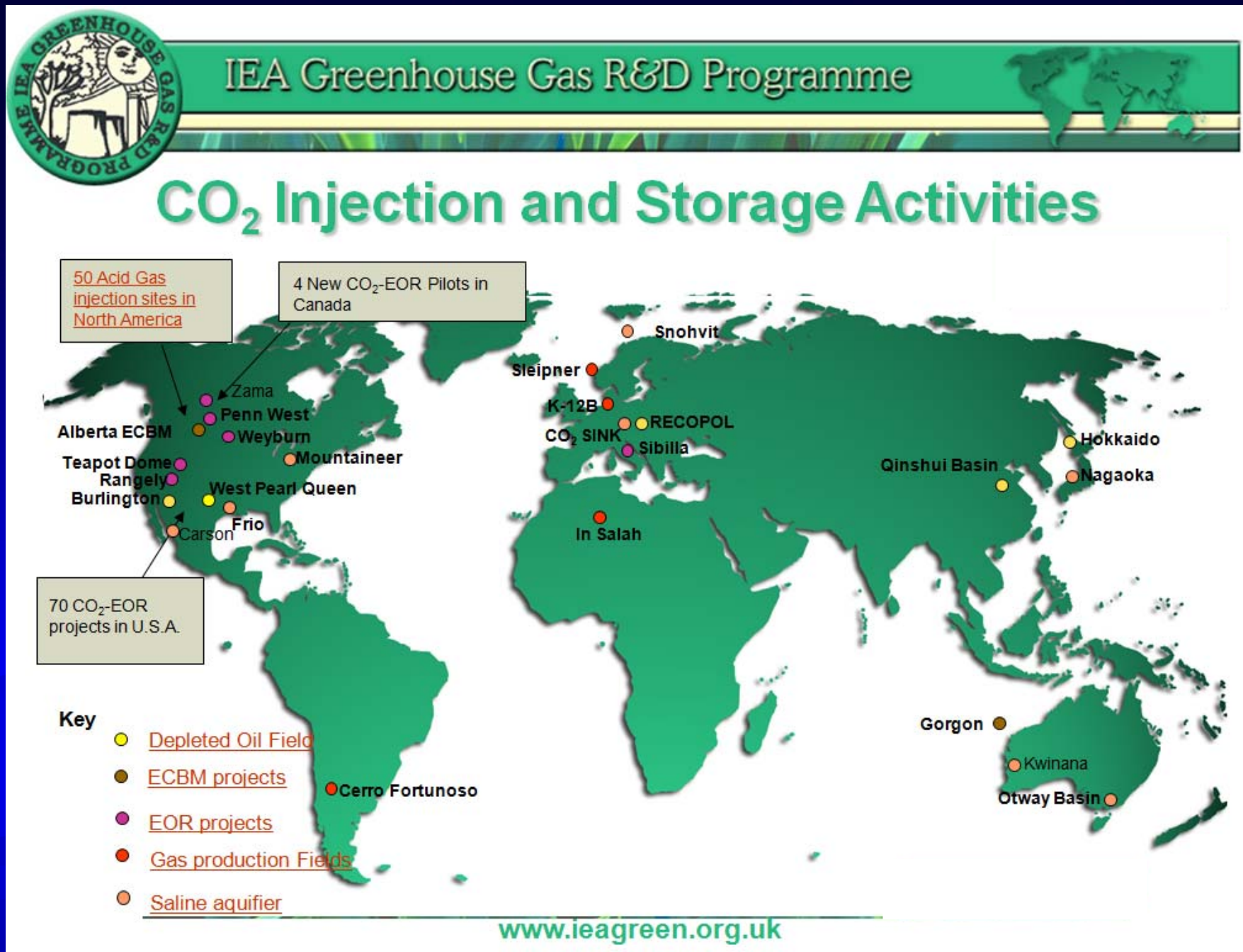




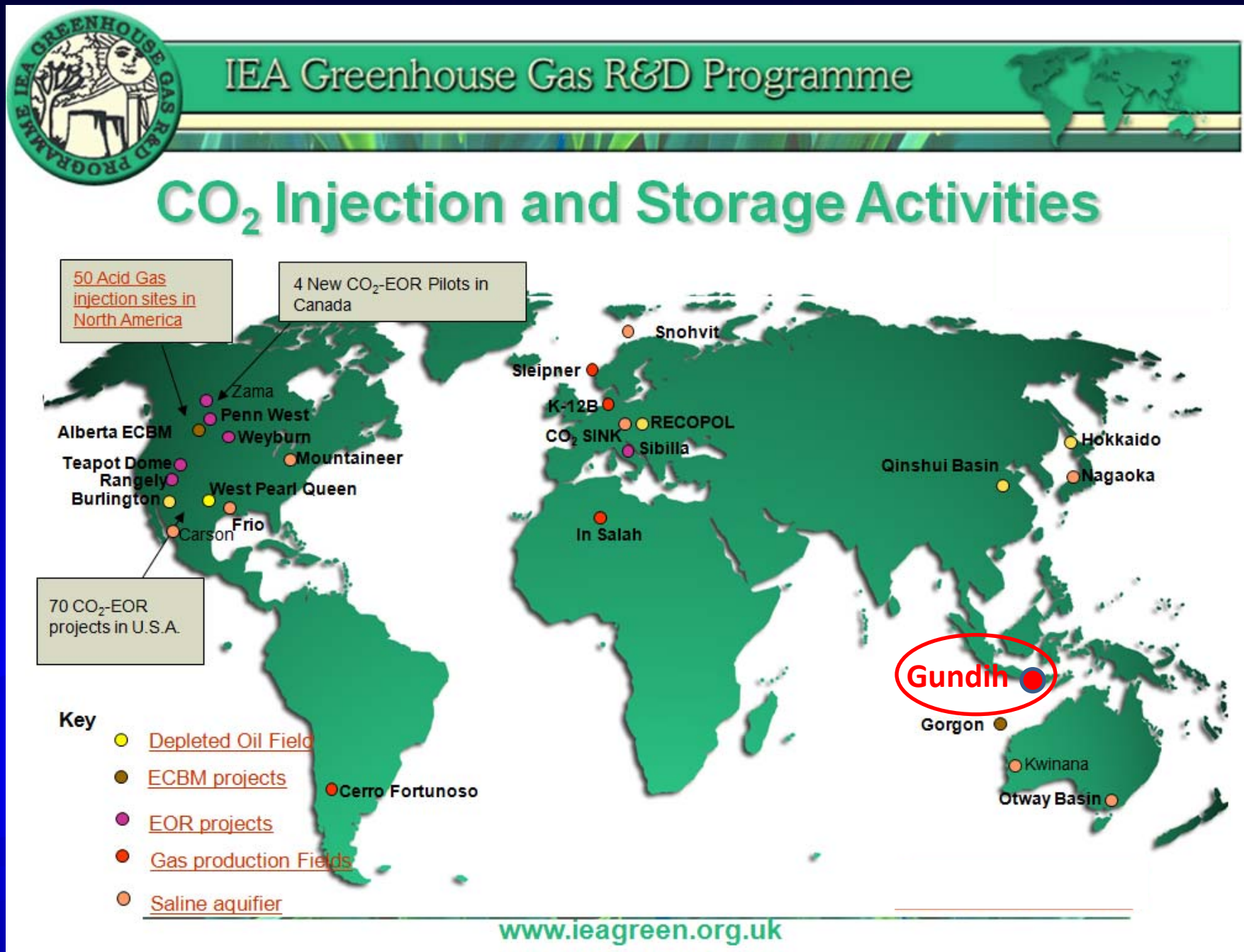
Inversion result

Our Provocative Goal on CCS Program

Present Situation (2010)



The situation in 2016, if Indonesian – Japan cooperation is completed



Summary

1. To maintain Oil Production and Decreasing CO2 emission:

- CO2 injection for EOR
- CO2 storage
- Technology improvement in monitoring activity

Technology Improvement on reservoir monitoring using 4D microgravity

2. Separation between oil and gas location

- the area impacted by water injection (pos anomaly)

→ location in which oil production still maintained

- the area without water injection (neg. anomaly)

→ decreasing oil production, secondary gas cap

→ no more fluid and/or remaining gas

3. Better understanding of the reservoir model

- to understand heterogeneity of reservoir relating with fluid movement
- to know lateral distribution of injection water
- reposition of injector to optimize injection activity
- identify geological structure (fault) that relate with fluid movement
- geological compartmentalization

Thank you very much

Terima kasih

Arigatou Gozaimasu