Applied Geochemistry

Ferian Anggara

Schedule and Outline

JADWAL KULIAH APPLIED GEOCHEMISTRY S2 REG, MGP & AUN
SM II TA 2014-2015
KULIAH REG INDONESIA & MGP SELASA (11.00-12.50, R 34)
KULIAH AUN KAMIS (09.00-10.50, R 34)

		Februari		Maret					April				Mei				Juni			
NO.	MATERI	17	24	3	10	17	24	31	UTS	UTS	23	30	7	14	21	28	4	MT	UAS	UAS
1	Dasar Kimia Organik & Geokimia HC	DHA																		
2	Geokimia Migas		DHA																	
3	Geokimia Batubara			DHA																
4	Biomineralisasi				DHA															
5	Geokimia HC Lingkungan					FA														
6	Geokimia HC Lingkungan						FA													
7	Geokimia Greenhouse Gas							FA												
	UTS - Ujian Tengah Semester								X	X										
1	Dasar Kimia Organik & Geokimia HC										DHA									
2	Geokimia Migas											DHA								
3	Geokimia Batubara												DHA							
4	Biomineralisasi													DHA						
5	Geokimia HC Lingkungan														FA					
6	Geokimia HC Lingkungan															FA				
7	Geokimia Greenhouse Gas																FA			
	Ujian Akhir Semester																		X	X

14 Mei libur kenaikan Isa Alms

Outline

- Introduction
- Carbon cycle
- Mitigation

Greenhouse gases

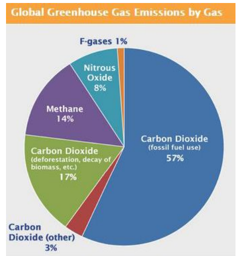
- The gases in the atmosphere that absorb radiation are known as "greenhouse gases" (sometimes abbreviated as GHG)
- Gases that trap heat in the atmosphere are called greenhouse gases
- The most important greenhouse gases carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and chloroflorocarbons (CFCs such as $CFCl_3$ and CF_2Cl_2) – the latter are strictly man-made or anthropogenic.

GHG

- **Carbon dioxide (CO_2)** : Carbon dioxide enters the atmosphere through burning fossil fuels (coal, natural gas and oil), solid waste, trees and wood products, and also as a result of certain chemical reactions (e.g., manufacture of cement). Carbon dioxide is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle.
- **Methane (CH_4)** : Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills.
- **Nitrous oxide (N_2O)** : Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.
- **Fluorinated gases** : Hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. Fluorinated gases are sometimes used as substitutes for stratospheric ozone-depleting substances (e.g., chlorofluorocarbons, hydrochlorofluorocarbons, and halons). These gases are typically emitted in smaller quantities, but because they are potent greenhouse gases, they are sometimes referred to as High Global Warming Potential gases ("High GWP gases")

EPA, 2015

GHG



IPCC, 2007; Data GHG from 2004

Carbon cycle

- Short-term
  - "the carbon cycle"
  - occurs on time-scale less than millions years
  - involves photosynthesis, respiration, air–sea exchange of carbon dioxide and humus accumulation in soils
- Long-term
  - take places over geologic time
  - involves the exchange of carbon between rocks and the Earth's surface

Berner (2003, 1998)

Long-term cycle

Berner (2003)

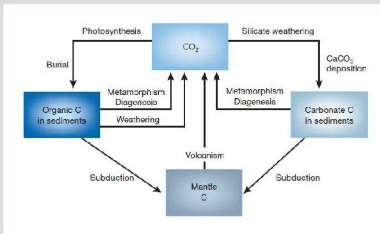


Figure 1 A model of the long-term carbon cycle. The deposition of carbonates derived from the weathering of carbonates is not shown because these processes essentially balance one another over the long term as far as carbon dioxide is concerned. However, carbonate deposition derived from carbonate weathering leads to additional degassing of carbon dioxide upon deep burial and thermal decomposition. Diagenesis, chemical changes at low temperatures during burial. The cycle can be subdivided into two subcycles involving organic matter (left side of figure) and silicate weathering and carbonate deposition (right side of figure).

$$CO_2 + CaSiO_3 \leftrightarrow CaCO_3 + SiO_2 \quad (1)$$

$$CO_2 + H_2O \leftrightarrow CH_2O + O_2 \quad (2)$$

Long-term cycle

- Equation (1):
  - *left to right*: atmospheric carbon dioxide (CO_2) is up-taken during the weathering on land of calcium (Ca, and magnesium-Mg) silicates, resulting dissolved Ca^{2+}, Mg^{2+} and HCO_3^-. The weathering products are precipitated as calcium and magnesium carbonates in sediments.
  - *right to left*: CO_2 is released to atmosphere and ocean as a result of deep burial and thermal decomposition of carbonates.
- Equation (2):
  - *left to right*: organic matter (CH_2O) in sediments are the manifestation of the photosynthesis process in left side. Hydrocarbon (oil, gas and coal) is generated from the transformation of organic matter to kerogen.
  - *right to left*: the weathering process of organic matter by erosion.

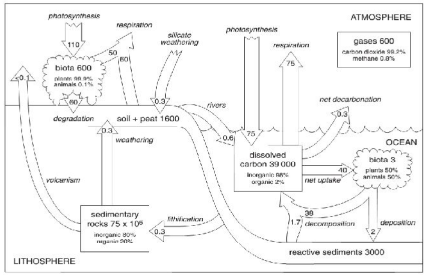
Berner (2003, 1998)

Balance of CO_2 in nature

- The balance between CO_2 input and CO_2 output is controlled by "a negative feedback response of rock-weathering to climate change".
- When there is an event of volcanic activity, the atmospheric CO_2 concentration is increasing and resulting the global climate warms as a result of the greenhouse effect, it will compensate in more CO_2 uptake by faster rock-weathering.
- In global climate warms, the weathering is enhanced by increasing rainfall and warm land temperature.
- In contrast, slower weathering occurs in cool climate where less of volcanic activity.

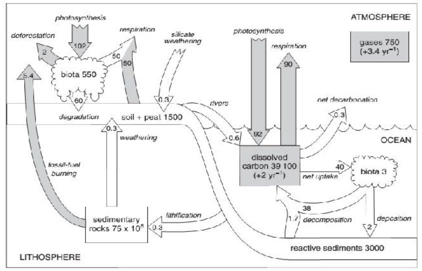
Berner, 1998; Caldeira, 1995; and Walker et al., 1981

Pre-industrial global carbon cycle



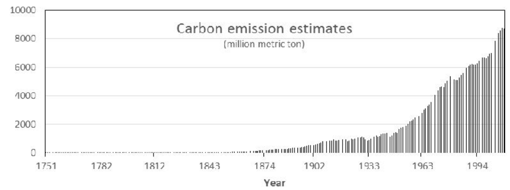
Killops and Killops, 2005

Global carbon cycle for the 1980's



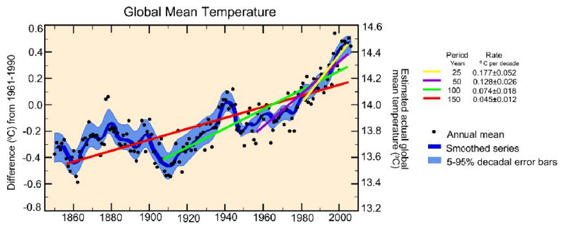
Killops and Killops, 2005

Global CO_2 emission from fossil fuels (1900-2008)



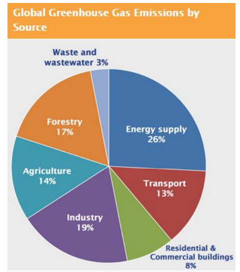
Boden et al., 2012

Annual global mean observed temperature



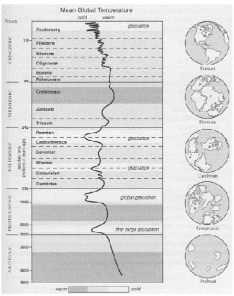
IPCC, 2007

GHG by source



IPCC, 2007; Data GHG from 2004

Generalized temperature history of the Earth

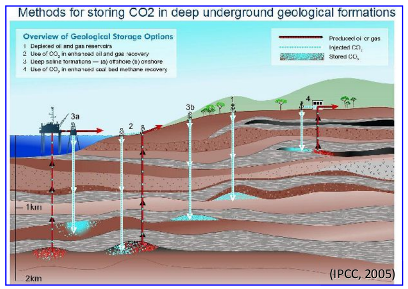


Hart and Hart, 2000

CO_2 balance in nature

- After industrial revolution, the utilization of fossil fuels and forest conversion has caused a large increase in the rate of organic matter oxidation compared with that of the natural weathering process (Aplin et al., 1999).
- This increase is an acceleration by a factor of about 100 (Berner, 2003, IPCC 2001).
- Does humans greatly perturb the long-term carbon cycle ?

Geological storage



1. Geological CO_2 sequestrations (GS) offer potential for large scale, low-cost, and long-term sequestration
2. Four options for GS: (1) oil and gas reservoirs, (2) deep saline formations, (3) unminable coal beds and (4) mineral carbonation

The benefits of Geological Storage

1.doesn't depend on climate condition

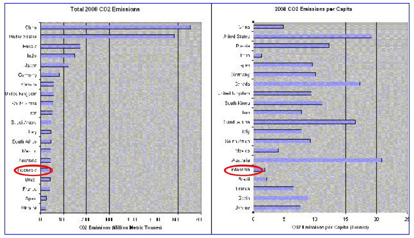
2.doesn't compete with agriculture, forestry, fishing, other industries and land use

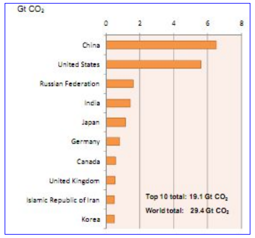
3.the cost transporting is cheap

4.the technology is well developed and widely practiced,

5.no associated environmental problem and can be safely undertaken within national boundary.

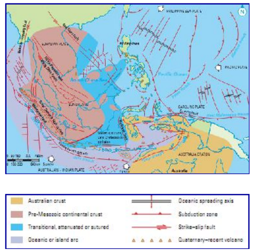
CO_2 Emissions





IEA, 2010

Indonesia Opportunities



1. Geologically, Indonesia is divided into 2 regimes: Western and Eastern regimes.
2. The Western regimes: tectonically southeastern promontory of Sundaland,
3. The Eastern regimes: fragment of the ancient continental Australian plate.
4. The demarcation line is coincidence with Wallace line (British botanist)

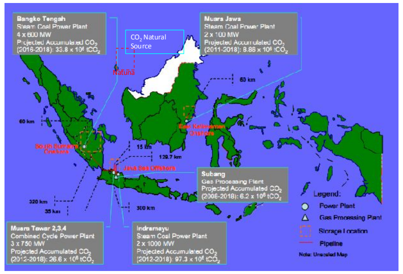
Western Regimes:
1. proven and exploited hydrocarbon systems
2. mature stage of exploration.

Eastern Regimes:
1. underexplored
2. almost half of the basins have not been drilled.

Site selection criteria:
1. basin maturity
2. existing support facilities
3. CO_2 emissions sources
4. Seismic activity

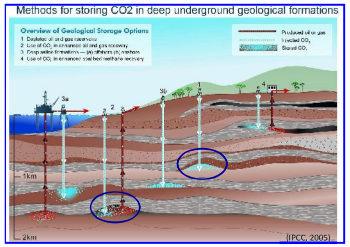
Western Regimes

CO_2 Emission sources



Hadiyanto, 2010 with modification

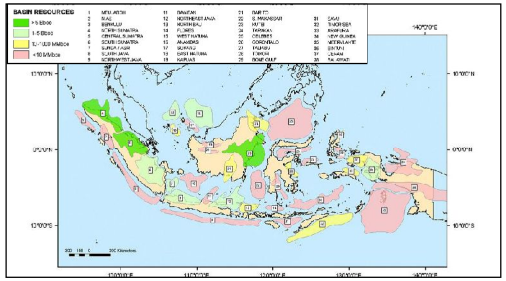
Oil and Gas Reservoirs



Benefits:
- HC did not escape many millions of years
- Geologically have been extensively studied and characterized,
- computer models have been developed
- the infrastructures were already developed

The main consideration:
Cap rock leakage caused by injection pressure

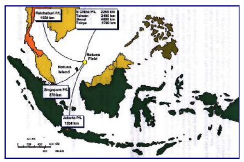
Location map of Indonesian basins



60 Tertiary sedimentary basins, but only around 38 basins have been explored (Darman & Sidi 2000)

Doust and Noble, 2008

Natuna Gas Field



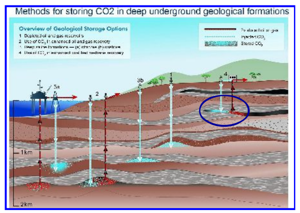
1. The Natuna gas field is one of the world's largest natural gas accumulations
2. 222 TCF gas in-place
3. 71% CO_2
(Hadiatno and Fenter, 1996; Dunn et.al., 1996)

1. Very high concentration CO_2 is becomes the most difficult problems
2. GS might be one of the best solutions.

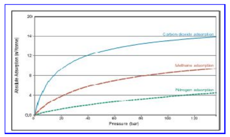
- 60 Tcf Natural Gas
- 8 Gt CO_2

The other options are depleted oil/gas reservoir and abandon oil/gas reservoir i.e :
1. Central Sumatra Basin (CSB) oil/gas field,
2. South Sumatra Basin (SSB) gas field,
3. Kutai Basin oil/gas field,
4. North West Java Basin (NWJB) oil/gas field,
5. East Java Basin oil/gas field

Unminable Coal Seam



1. CO_2 injection into coal seams can displace methane, thereby enhancing CBM recovery ECBM).
2. ECBM increase produced methane to nearly 90% of the gas, (50% by conventional recovery)



The main consideration:
- Coal swells as CO_2 absorbed which reduces permeability and injectivity
- Cap rock leakage caused by injection pressure

Enhanced Coal Bed Methane Recovery (ECBMR)

1. Indonesia has one of the largest CBM reserves in the world
2. 453 Tcf (12.8 Tcm)
3. SSB the largest CBM basin in Indonesia : 183 Tcf (10.4 Tcm)

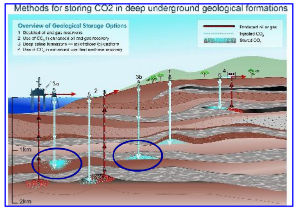
Site selection criteria for CO_2-ECBM:
1. adequate permeability
2. coal rank
3. suitable coal geometry
4. simple structure, homogeneous, laterally continuous and vertically isolated coal seam
5. adequate depth (less than 1500 m)
6. suitable gas content
7. ability to dewater the formation

\+

1. basin maturity
2. existing support facilities
3. CO_2 emissions sources
4. Seismic activity

(IEA-GHG, 1998 vide IPCC, 2005; Anggara et al, 2010)

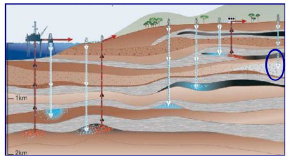
Deep Saline Formation



1. deep sedimentary rocks saturated with formation water or brine containing high concentrations of dissolved salts
2. widespread and contain enormous quantities of water, but are unsuitable for agriculture or human consumption.
3. take place at depths below 800 m, (CO_2 being in a liquid or supercritical state).
4. estimates of potential storage volume are lower, ranging from as low as a few percent to over 30% of the total rock volume
5. the Sleipner Project, North Sea, is expected to store of 20 $MtCO_2$

The main consideration:
A well-sealed cap rock over the selected storage reservoir is important to ensure that CO_2 remains trapped underground.

Mineral Carbonation



1. the conversion of CO_2 gas into stable carbonate minerals i.e calcite ($CaCO_3$), dolomite ($CaMgCO_3$), magnesite ($MgCO_3$) and siderite ($FeCO_3$)
2. Basalt or peridotite have been considered as promising reactants, because of high concentrations of calcium, magnesium silicate minerals.

The main consideration:

1. low permeability in the igneous rocks
2. CO_2 dissolution into groundwater is slow
3. limits the mineral dissolution and precipitation reactions
4. no economically added value

Summaries

- Throughout geological time, the Earth has migrated between “greenhouse” and “icehouse” condition
- Experiencing warmer temperature compared to todays
- Some scientist believed that increasing temperature is natural process
- Warmer temperature in the past was not a major problem since there was no human activity
- It became a disaster when the human activity is disturbed
- Disaster is a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources (ISDR, 2009)

Take-home message

Whatever the cause (of global warming), the outcome is the same. The Earth is experiencing a rapid rise in global temperature and this, coupled with the associated rise in global sea levels, will directly impact on human life

End