Professor OLAF SCHUILING in Hyderabad 2010:

Olivine

Against Climate Change and Ocean Acidification

It is better to light a candle,
than to curse the darkness
- Gandhi

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Earth's CO_2 balance

Yearly natural emission:

- 2 to 2,5 billion tons
- by volcanoes and through dissociation of subducted limestones

If Earth had no effective feedback mechanism, our atmosphere would be like the one on Venus

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Feedback mechanisms

- weathering of silicate rocks converts CO_2 into bicarbonate solutions
- rivers transport solutions to the oceans
- there these are stored as carbonate rocks

- a smaller part is stored as organic carbon

Distribution of carbon on Earth

	Amount ($\times 10^{15}$ kg)	Relative (%)
Limestones ($CaCO_3$)	35,000	46.6
Dolomites ($CaCO_3.MgCO_3$)	25,000	33.3
Sedimentary carbon	15,000	20
Recoverable fossil fuels	4	0.005
Oceanic CO_2	42	0.056
Atmospheric CO_2	3	0.004
Biomass	0.56	0.0007

Anthropogenic emission	0.03 / year
Input from Earth's interior	0.0025 / year

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Sedimentary rocks

- contain 1500 times more carbon than oceans, atmosphere and biomass combined
- therefore they are the *ultimate sink* for CO_2

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Weathering

Through weathering rocks neutralise (carbonic) acid:

$$Mg_2SiO_4 + 4\ CO_2 + 4\ H_2O \rightarrow 2\ Mg^{2+} + 4\ HCO_3^- + H_4SiO_4$$

greenhouse gas → innocuous bicarbonate ion

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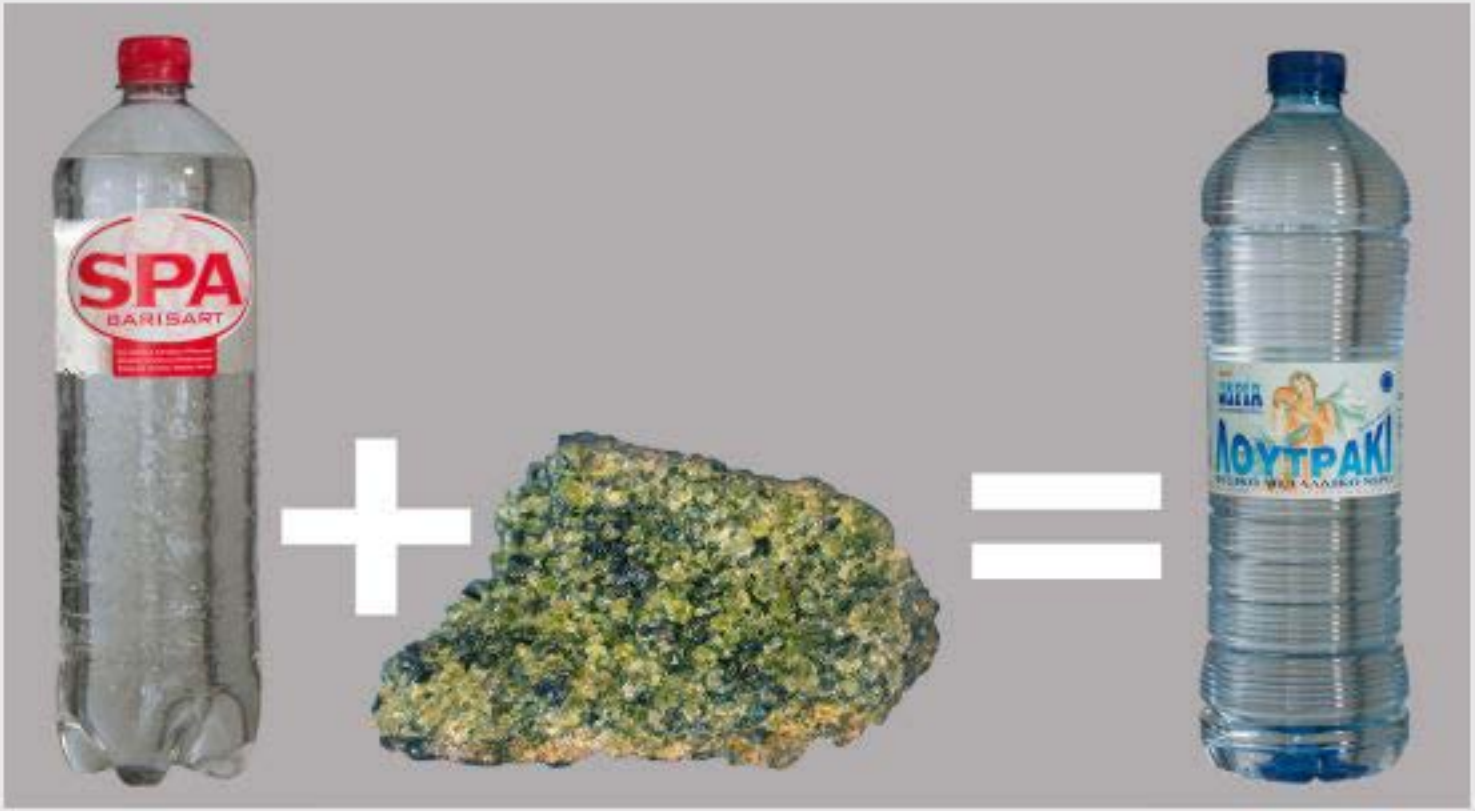
The proof



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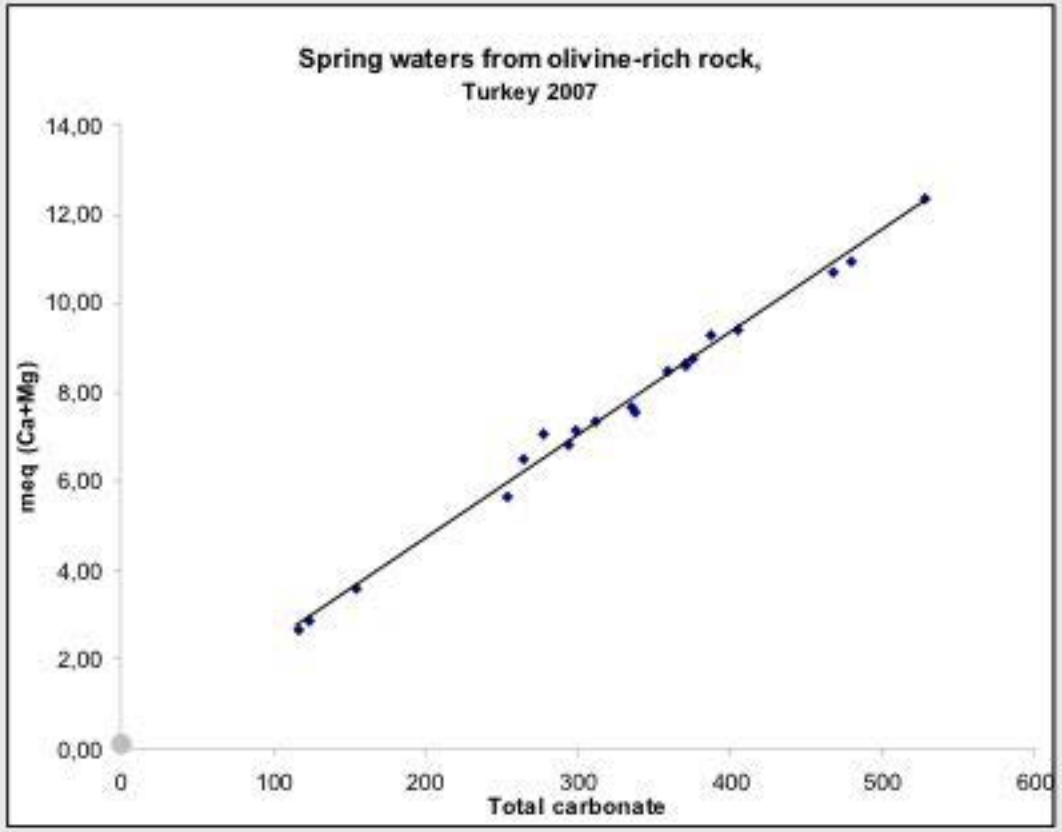

Concentration in meq [$Ca_2^+ + Mg_2^+$] in spring waters in dunite massifs versus total carbon as mg CO_2

Out of balance

Mankind emits ten times more CO_2 than nature

Earth can't compensate this

→ CO_2 content of the atmosphere rises rapidly

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Can the Earth fight back?

Natural weathering is a slow process

→ enhance weathering to reach a new balance!

This can be achieved by:

- mining and grinding large volumes of olivine-rich rocks
- spreading the grains in the wet tropics

- let nature do the work

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Why olivine?

92% Mg_2SiO_4, 8% Fe_2SiO_4

- most abundant silicate on earth
- deposits are large and widespread
- weathers quickly and captures CO_2

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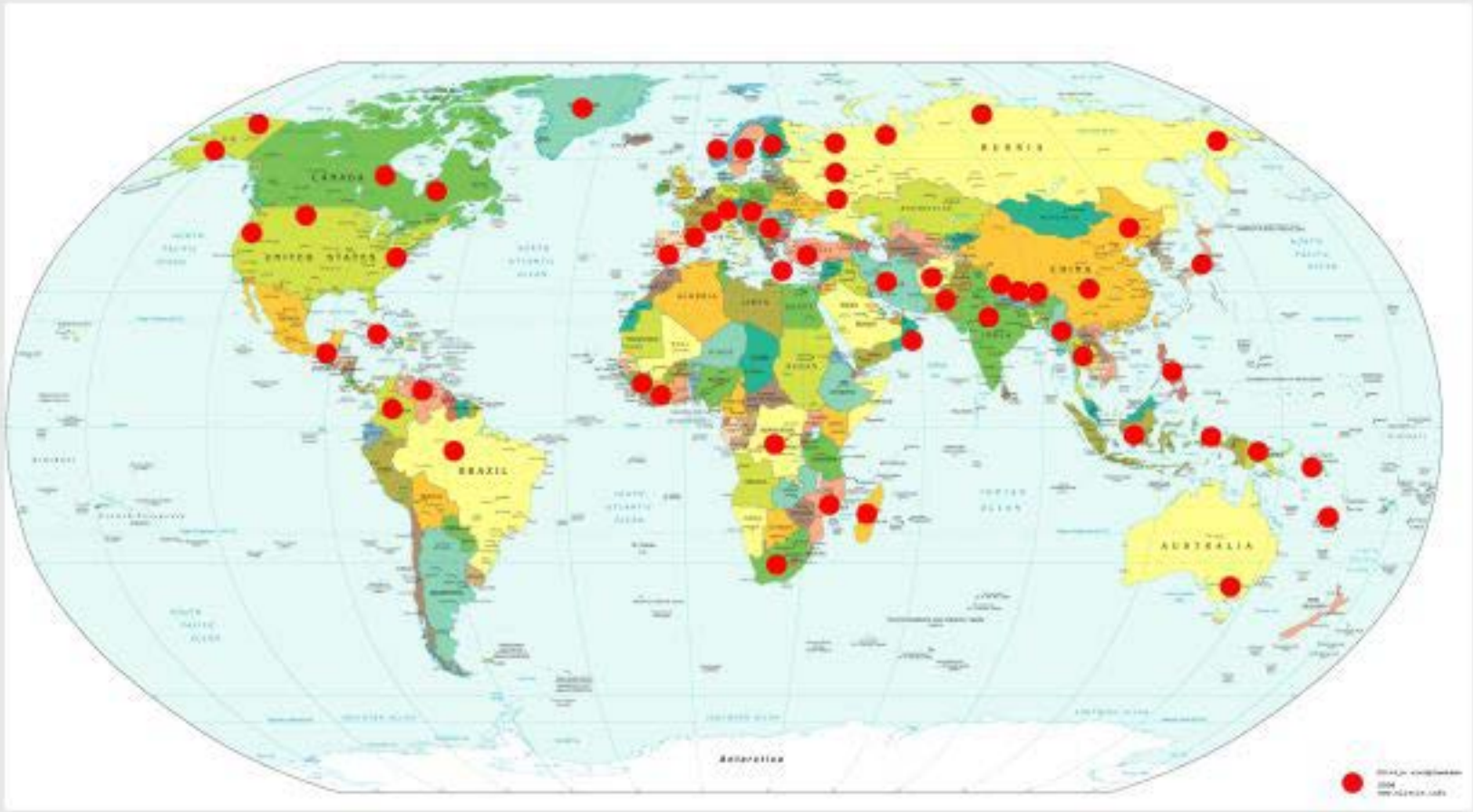
Where is it found?



Laboratory versus the real world

Laboratory: 0.2 – 0.3 micron per year

Nature : 10 – 20 microns per year

Why this discrepancy?

- symbiosis of fungi with higher plants
- fungi secrete acids
- acids dissolve minerals rapidly

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Why the wet tropics?

- faster weathering
- lower wages
- usually low transport costs
- provides employment and economical growth
- large open pit mines profit: economy of scale
- mining for olivine in dunite combined with mining for ores of chromite, nickel or platinum group minerals can be economically beneficial

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Costs olivine method

1 ton of olivine captures 1.25 ton of CO_2

- mining, crushing and grinding bulk rock in large open pit mines: 6 euro
- average transport costs: 6 euro

→ **1 ton** captured CO_2 = just below **10 euro**

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Costs olivine method

Yearly

To capture **all** CO_2 produced by mankind:
20 to 25 billion (7 km3) tons of olivine

→ costs: around **200 billion euro**

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Enhanced weathering is the most cost-effective way to counteract climate change

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Carbon Capture Storage (CCS)

is 5 to 10 times more expensive and less sustainable

CCS only has a modest future in cases where:

- there is a more or less pure CO_2 source available near an abandoned gas field
- a propellant gas is needed to recover gas and oil more fully. Then CO_2 is the evident choice

- CO_2 can be injected into reactive rocks to recover heat

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Limiting ecological damage

In the tropical zone the weathering crust is often mined for nickel

- continue to mine the underlying dunite rock
- no need to clear new mining sites
  - mining equipment already in place
  - trained workforce nearby
  - people keep their jobs

Conclusion: mining olivine becomes cheaper and ecologically more acceptable

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Organisation

- open 30 to 50 large olivine mines in the wet tropical zone
- preferably on sites of existing nickel laterite mines
- crush and grind olivine to sizes around 100 microns
- spread within 300 km from the mine

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Keeping costs low

- add olivine powder to sandstorms
- throw into flooding rivers
- use barges for transportation and spreading
- let locals use oxcarts for transportation
- mix olivine with fertilizers or pesticides

Also: olivine enriches tropical soils,
especially with magnesium

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To compensate effectively

Spread 0.7 mm of olivine on 10 million km^2 a year

Cheaper solution:

- cover 2 million km^2 with 3.5 mm
- another area of 2 million km^2 the year after
- repeat this four times
- return to the first area after 5 years

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Position of India, China and Brasil

'Copenhagen' wants everyone
to limit CO_2 emissions

Industrializing nations have not profited
from the absence of restrictions in the past

For them emission control is unfair
and not necessary

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Position of India, China and Brasil

Instead of controlling their emissions they can compensate them

Means are available:

- all three have huge dunite deposits
- raw materials and work force at hand

Compensation:

- much cheaper than CCS
- sell surplus carbon credits!

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India: Olivine-rich rocks

From Assam to South India

- many deposits; from chromite mines in Orissa to the Kolar and Chittadurga greenstone belts

The Deccan traps

- opportunity to inject and capture CO_2
- investigate possibility to recover heat

Kerala, Kakkaponnu District

- unusual dunite: high in Mg, low Ni-content

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An interesting side step: save the Maldives !?

- waste sulfuric acid from industry
- large olivine deposits

1. Lift the land surface

- inject waste sulfuric acid

→ gypsum with twice the volume

→ the ground is uplifted

2. Construct olivine hills

- clean and healthy drinking water
- refuge during storms and flooding

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Dream no small **dreams,**
for they have no power
to move the hearts of men

- Goethe

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This is my reactor...

... and this is my technology!