Japanese Achievement in CO_2 Geological Storage and Future Contribution

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Toward Implementation of CO_2 Geological Storage

1990: Tanaka examined oversea EOR possibilities using CO_2 from Japan

1992: Koide *et al.* examined world potential of CO_2 storage with a proposed novel concept of aquifer storage.

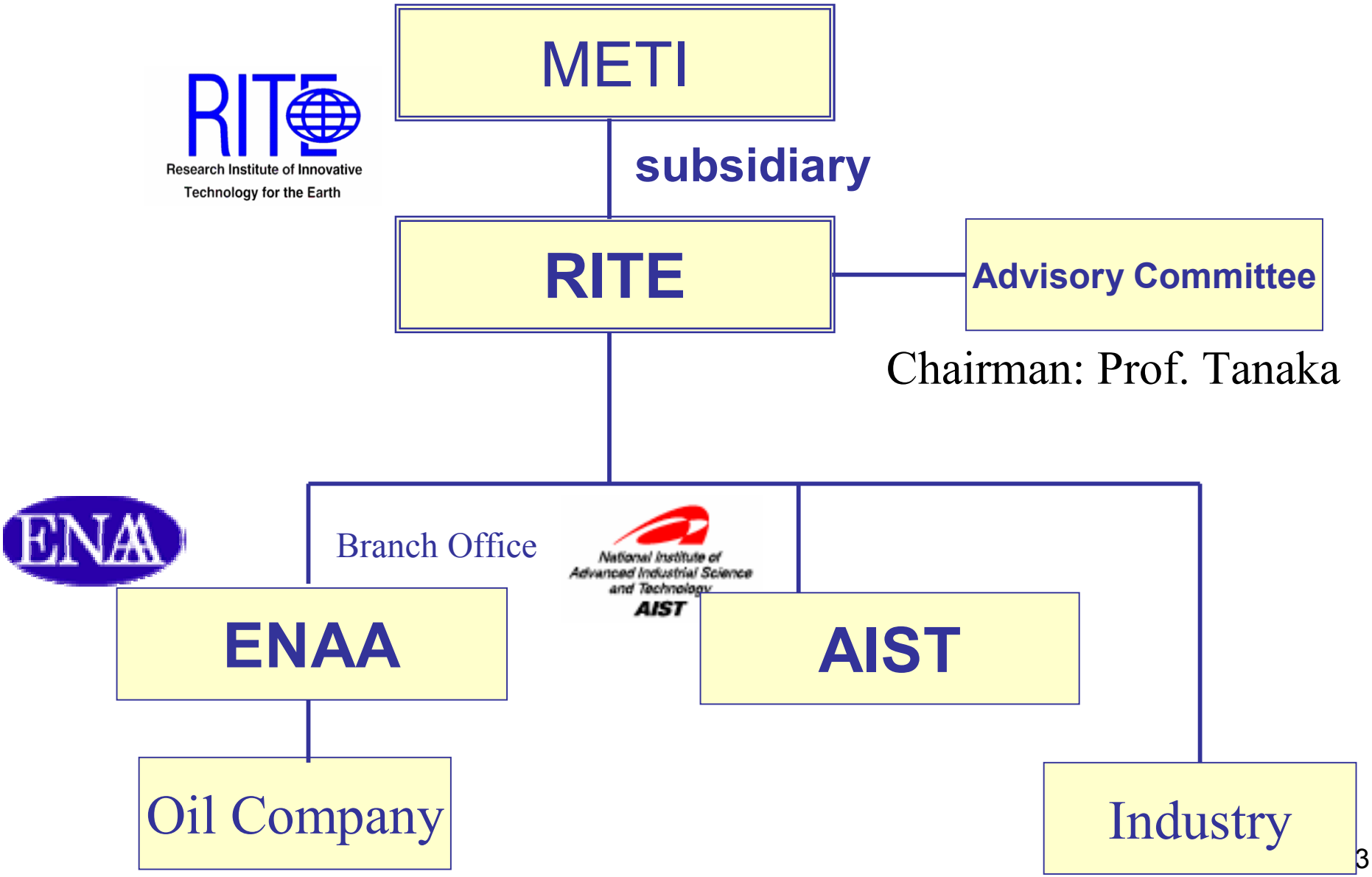
1993: At Oxford meeting, Olav Kaarstad talked to Ohsumi on Statoil's plan of SLEIPNER

1993: Tanaka *et al.* 's work on estimation of potential capacity for CO_2 aquifer storage in Japan.

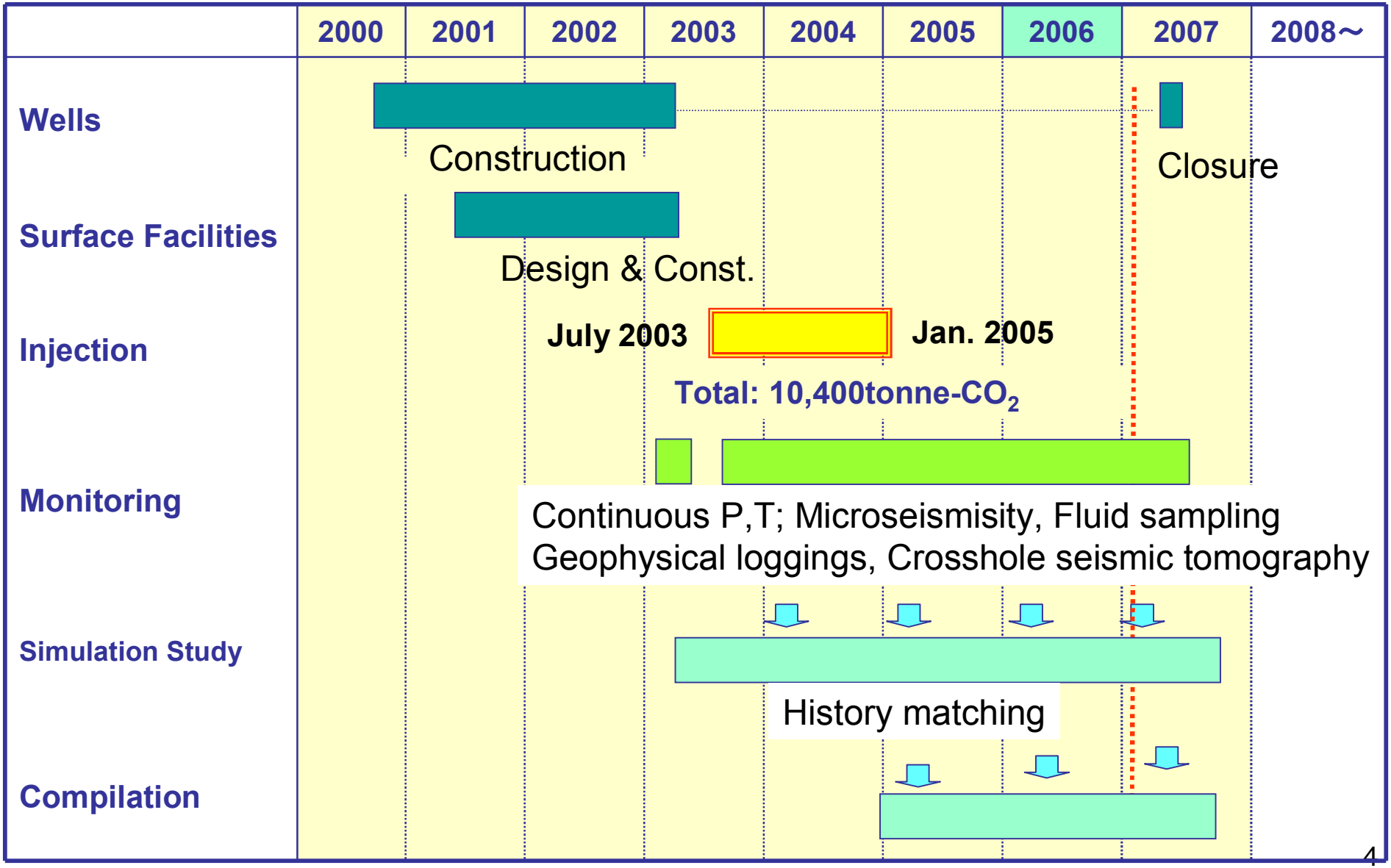
1996: start of Sleipner

2000: start of Nagaoka project

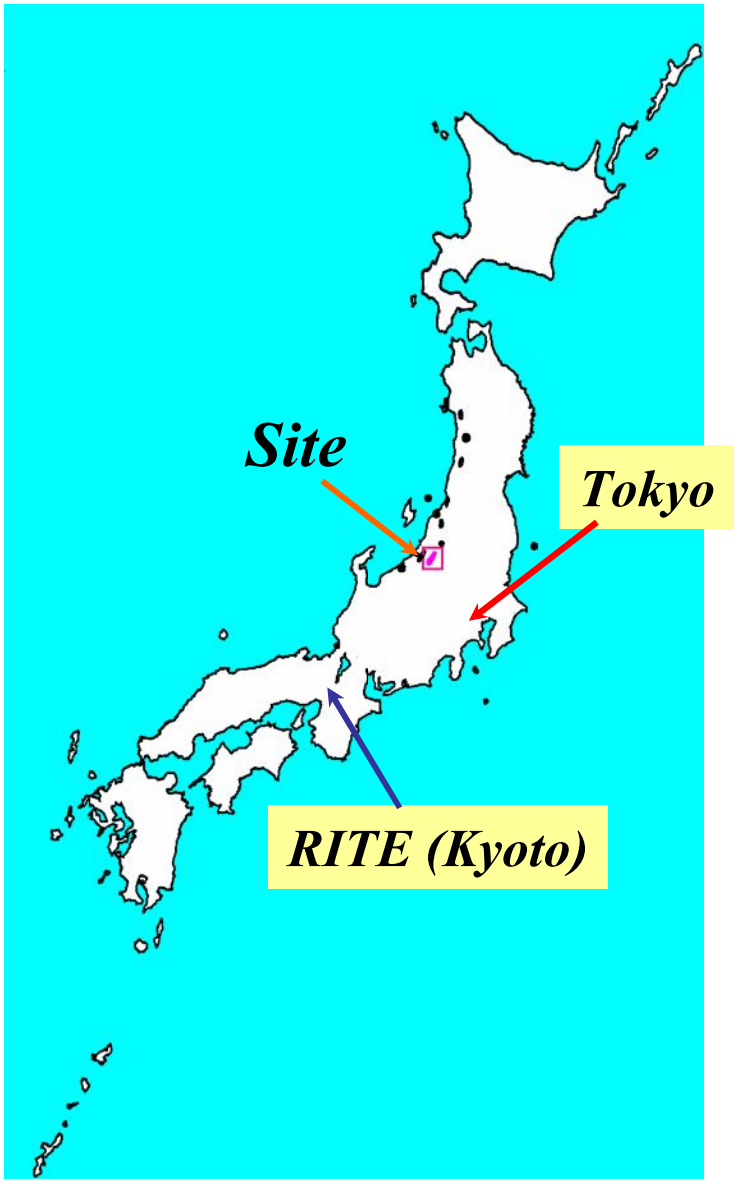
Project Scheme



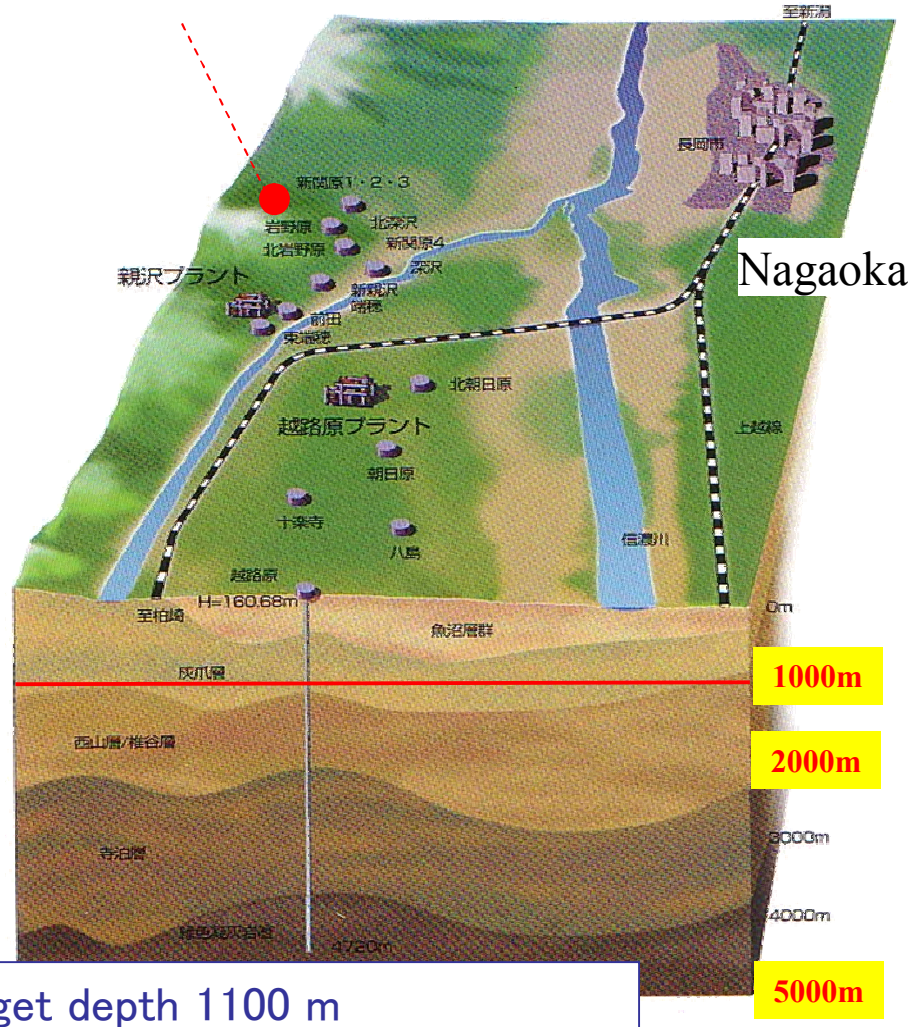
Project timeline



Nagaoka Site



Injection well



Nagaoka city

Target depth 1100 m

Gas production from 4500 m depth

Feature of Nagaoka Project

1 Injection Test in suburb area of a large city with population of 0.3 million

2 New Injection well for core recovery

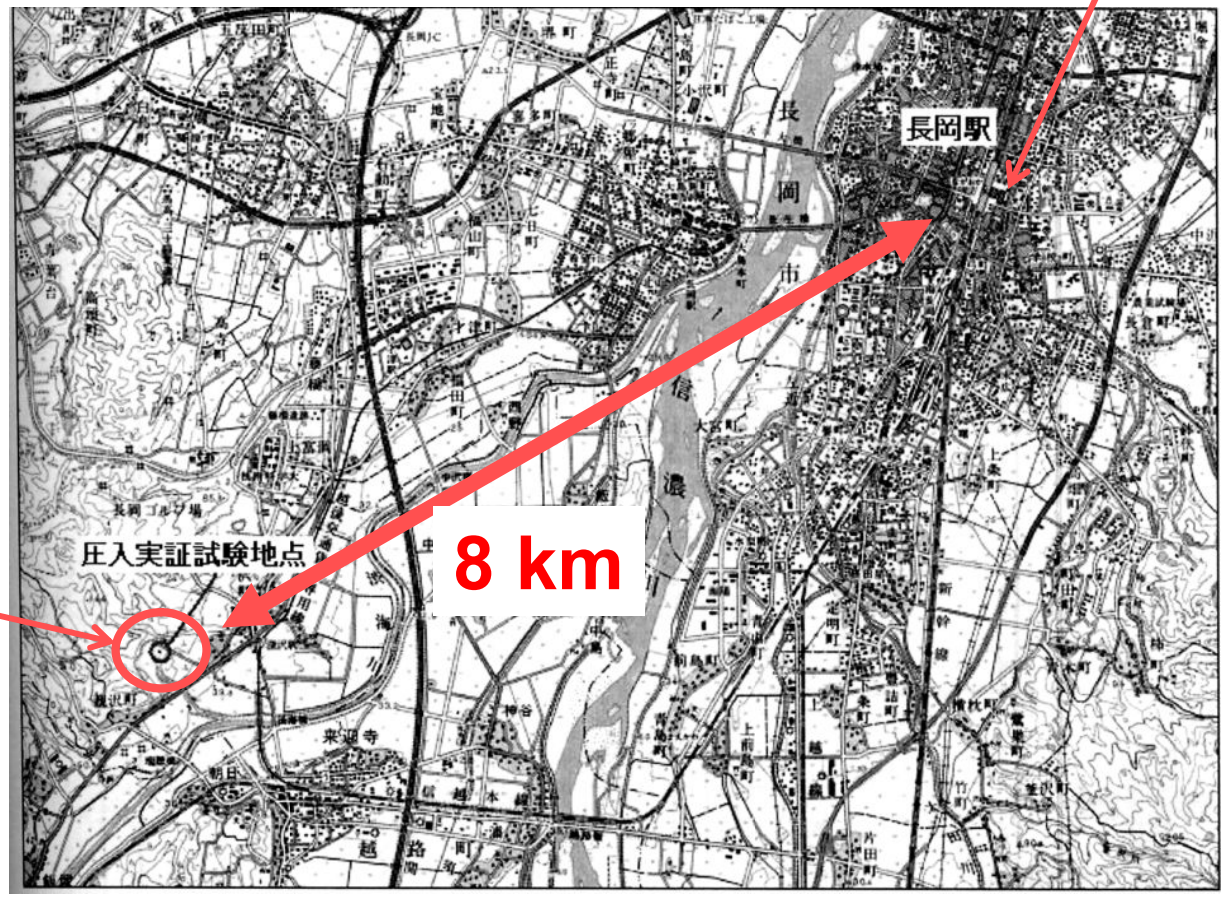
three wells dedicated for observation (with FRP casing at target zone)

3 relatively low permeability:

1.6 ～ 11.2 md（ave. 6.7 md ）

Location of injection well

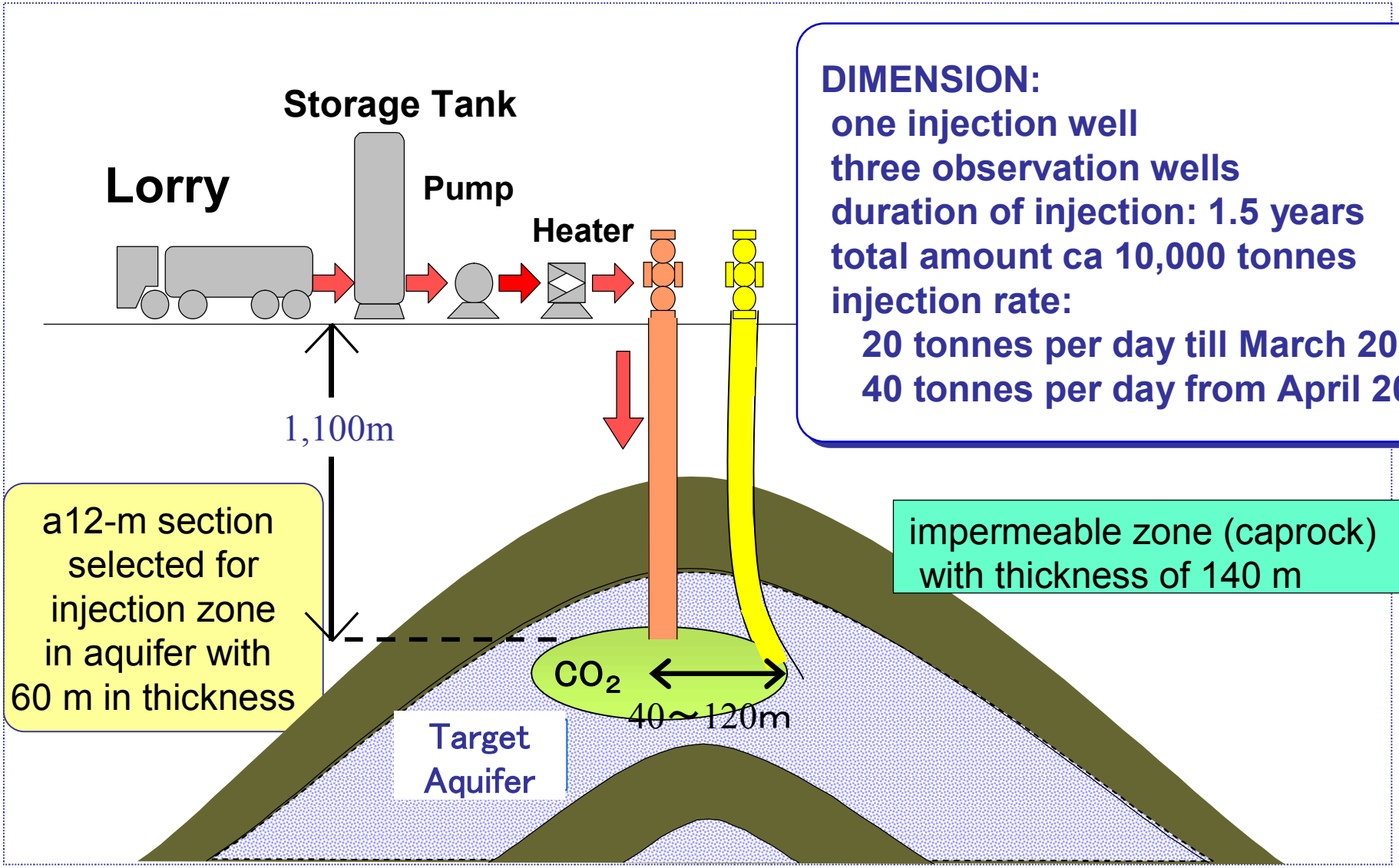
NAGAOKA Shinkansen Railway Station



Injection site

Completed surface Facilitie in June 2003

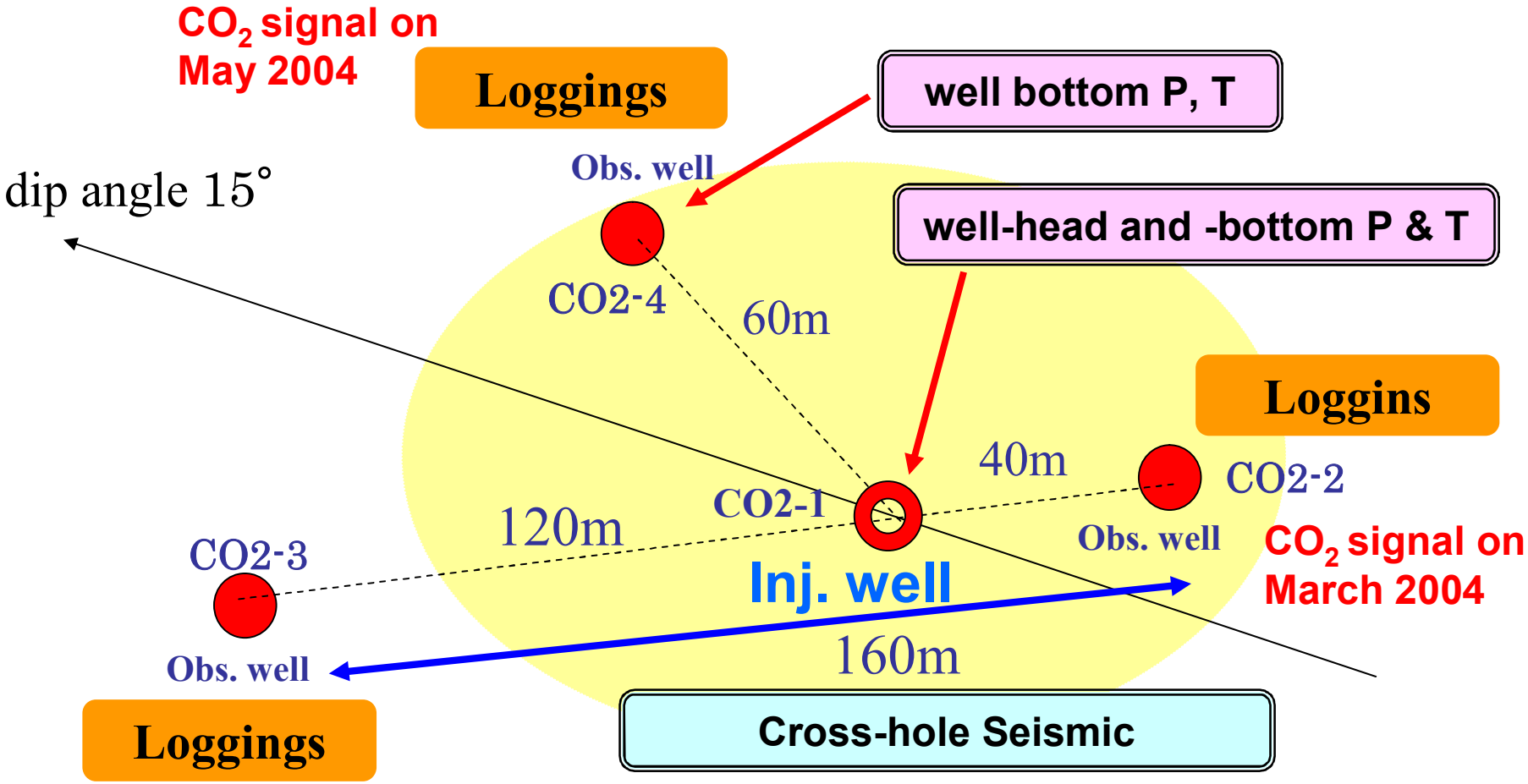
Injection Test



DIMENSION:
- one injection well
- three observation wells
- duration of injection: 1.5 years
- total amount ca 10,000 tonnes
- injection rate:
  - 20 tonnes per day till March 2004
  - 40 tonnes per day from April 2004

Core samples form target aquifer zone recovered from injection well

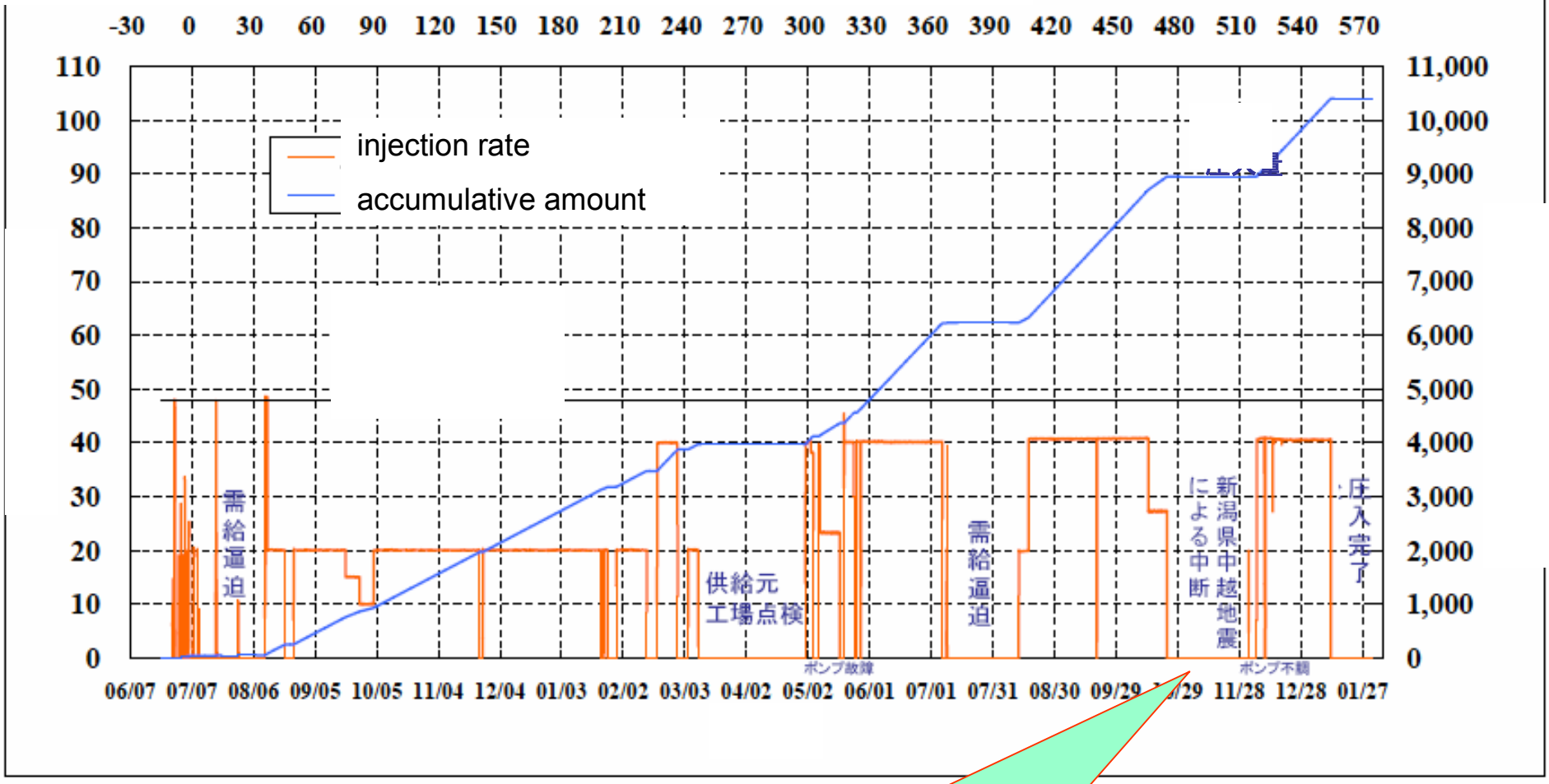
Monitoring


CO_2 signal on May 2004
Loggings
well bottom P, T
Obs. well
dip angle 15°
well-head and -bottom P & T
CO2-4
60m
Loggins
40m
CO2-2
CO2-1
120m
Obs. well
CO_2 signal on March 2004
CO2-3
Inj. well
160m
Obs. well
Loggings
Cross-hole Seismic

Injection operation

from July 7,2003 through January 11,2005

Rate **Total Amount**



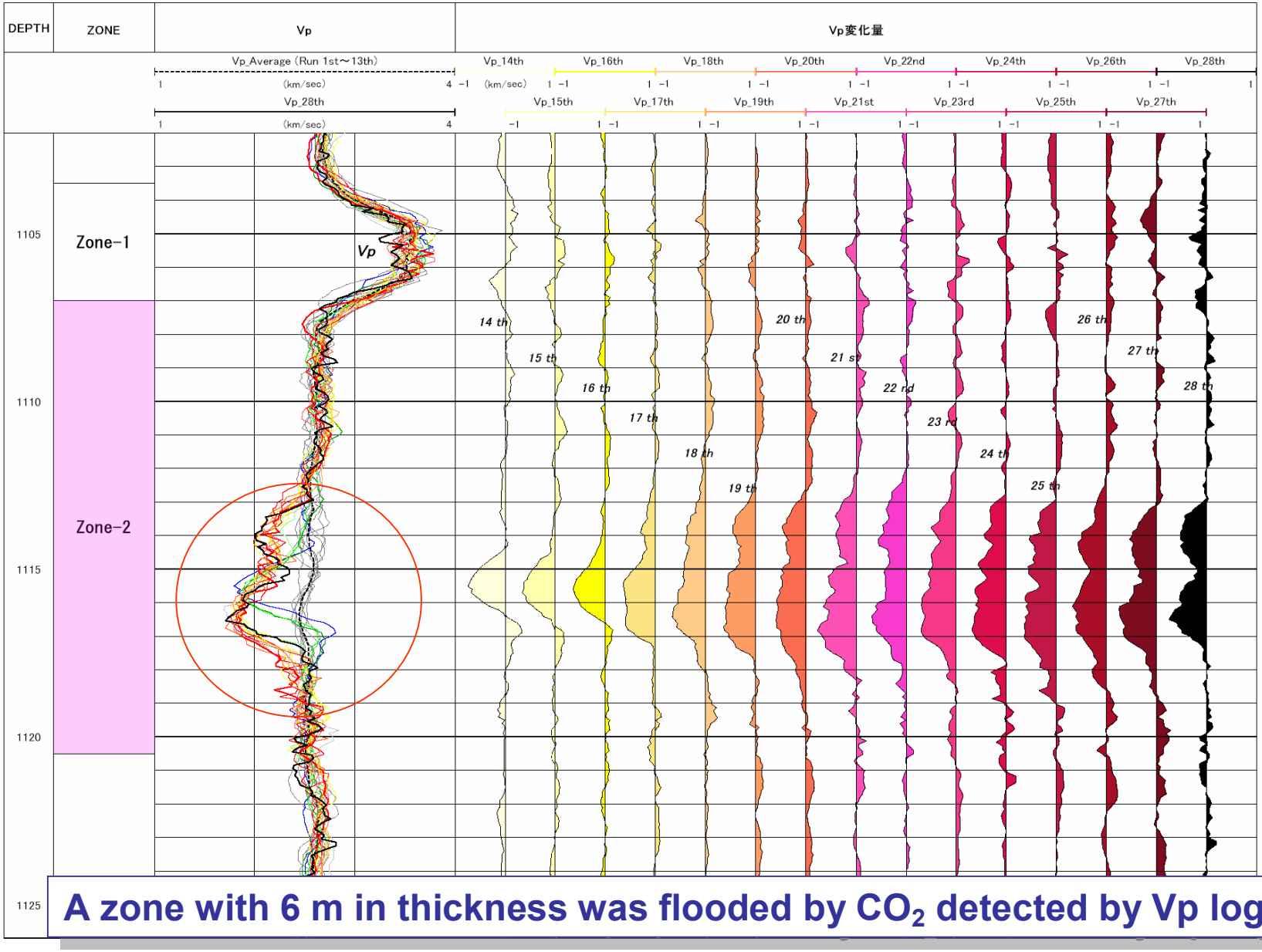
Earthquake

Geophysical Loggings

Lowering a sensor unit

well head of Obs well

V_p log at CO2-2



A zone with 6 m in thickness was flooded by CO_2 detected by Vp log

Cross hole seismic tomography

Receiver array in CO2-3 well
24 ch hydrophones (to 24 bit A/D)

Signal source in CO2-2: 2-m interval

travel time measurement

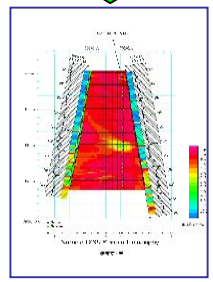
↓

Vp distribution

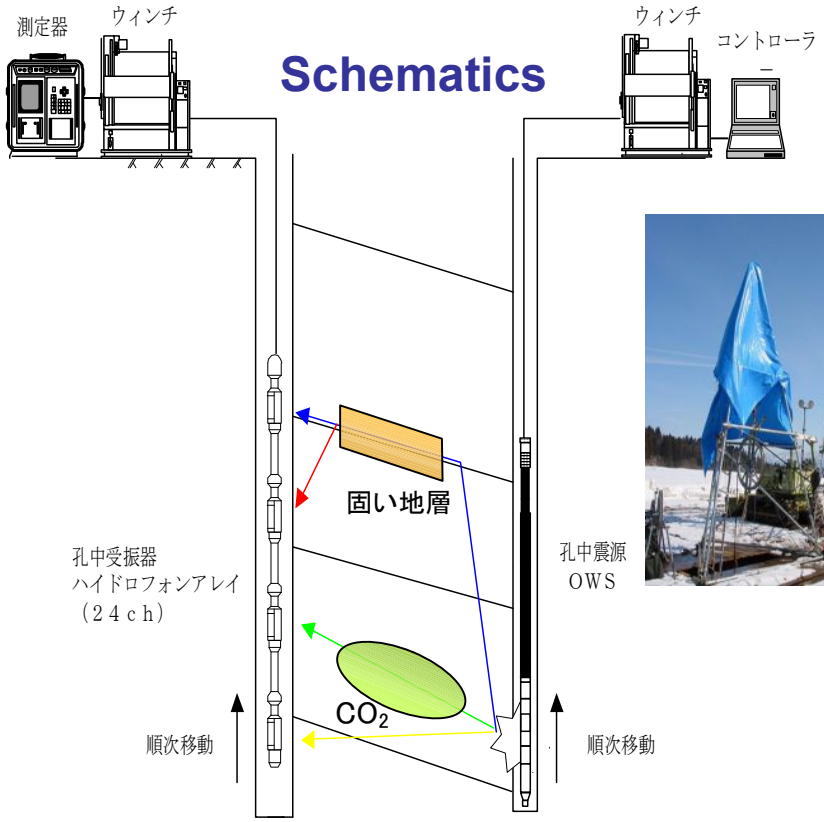
↓

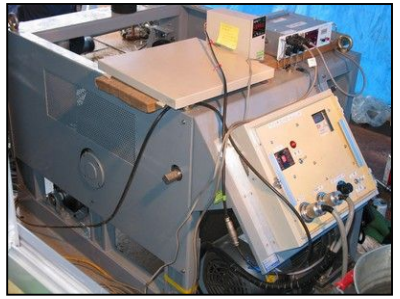
comparison with baseline

↓



Schematics



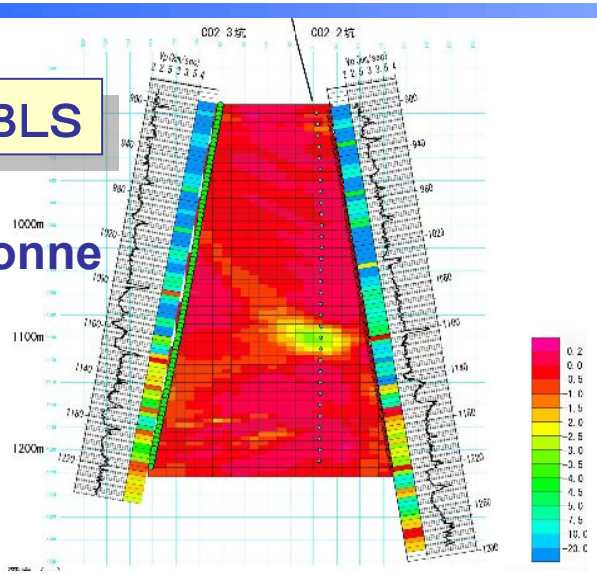


CO_2 imaging by crosshole seismic tomography

MS1／BLS

2004／1

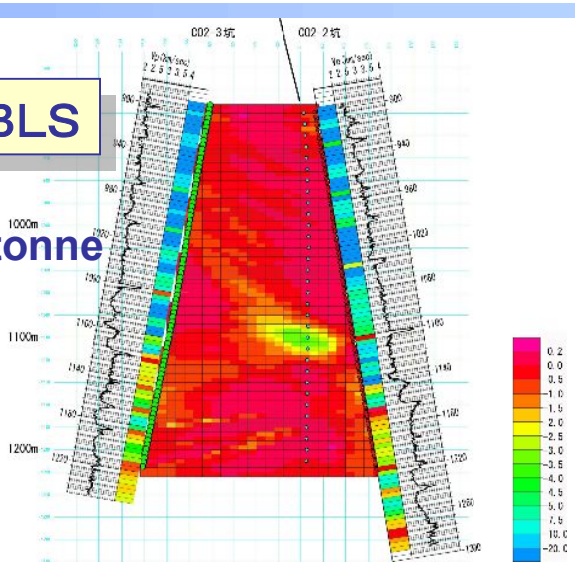
3，200 **tonne**



MS2／BLS

2004／7

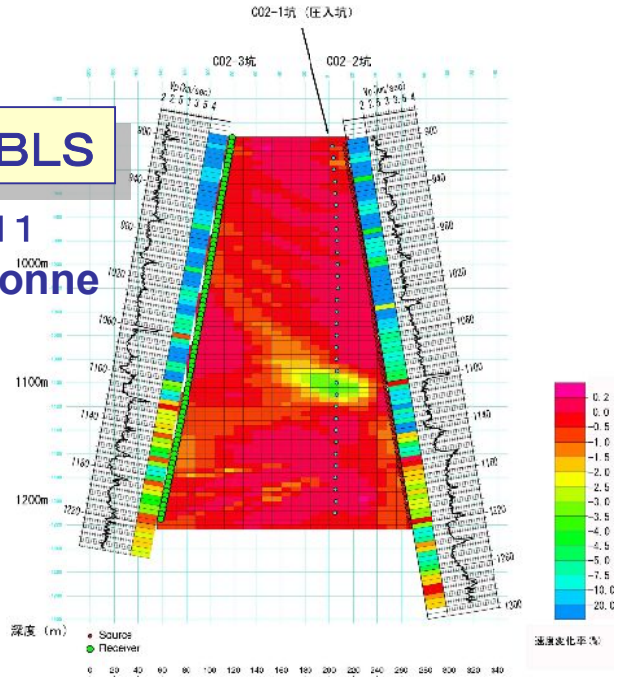
6，200 **tonne**



MS3／BLS

2004／11

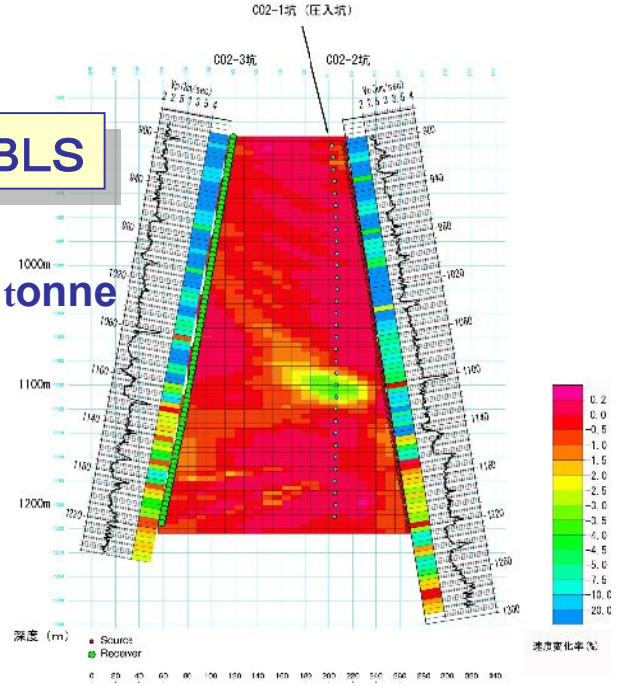
8，900 **tonne**



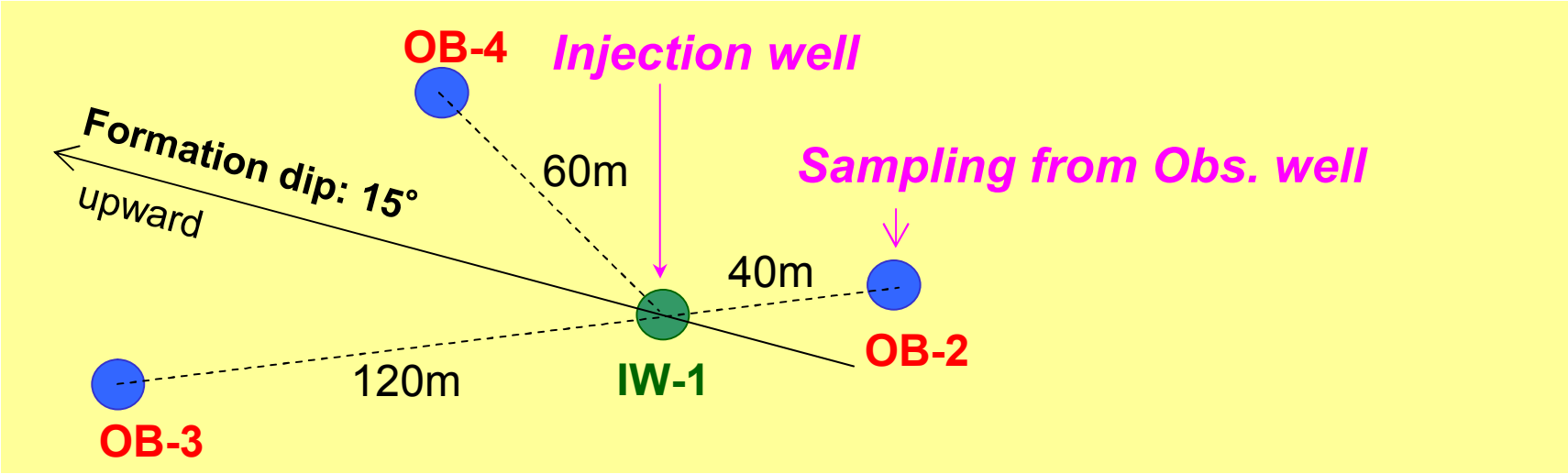
MS4／BLS

2005／1

10，400 **tonne**



Sampling of fluid in aquifer



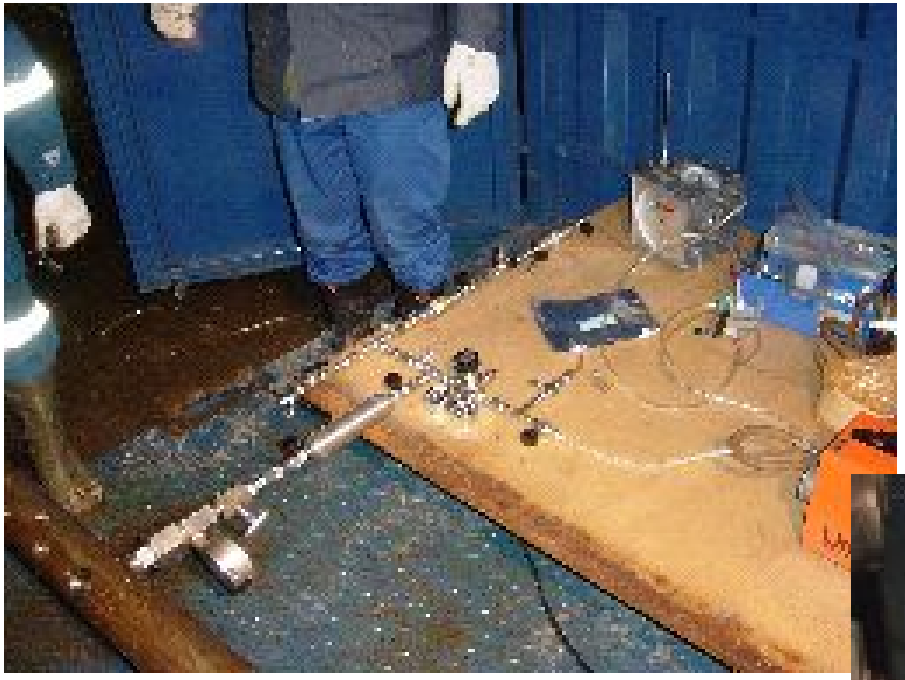
Before injection

- May 2002
- IW-1
- Air Lift

After CO_2 front reaching to obs.well

- Dec. 2005
- OB-2
- CHDT: Cased Hole Dynamics Tester,)

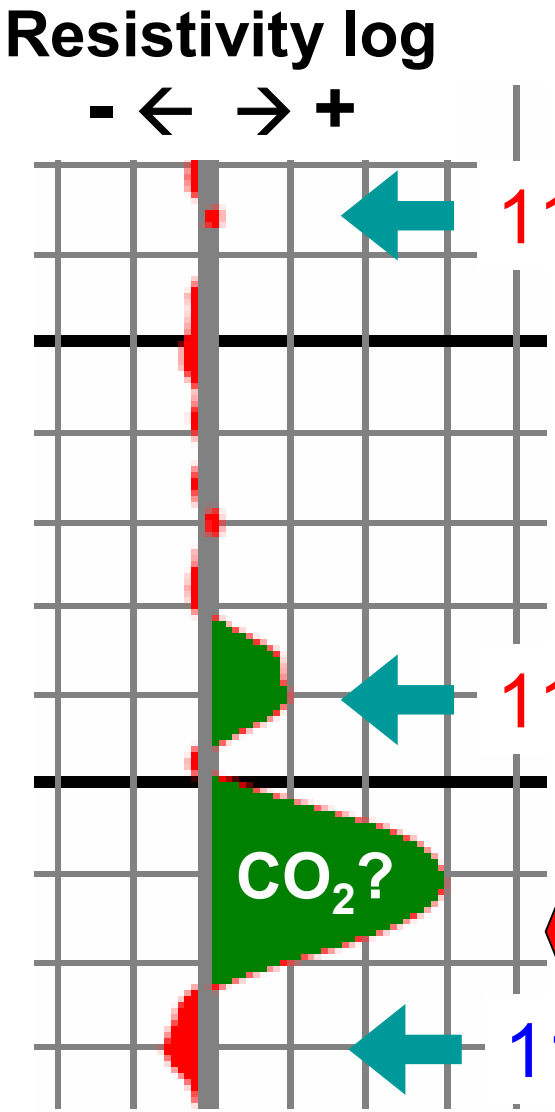
Fluid Sampling by CHDT



Extraction of gas phase

Sampling aqueous phase

Sampling location depth from wellhead



the same composition
as original formation water

overwhelmingly of CO_2 gas

CO_2 have been partly migrating to cause water chemistry change

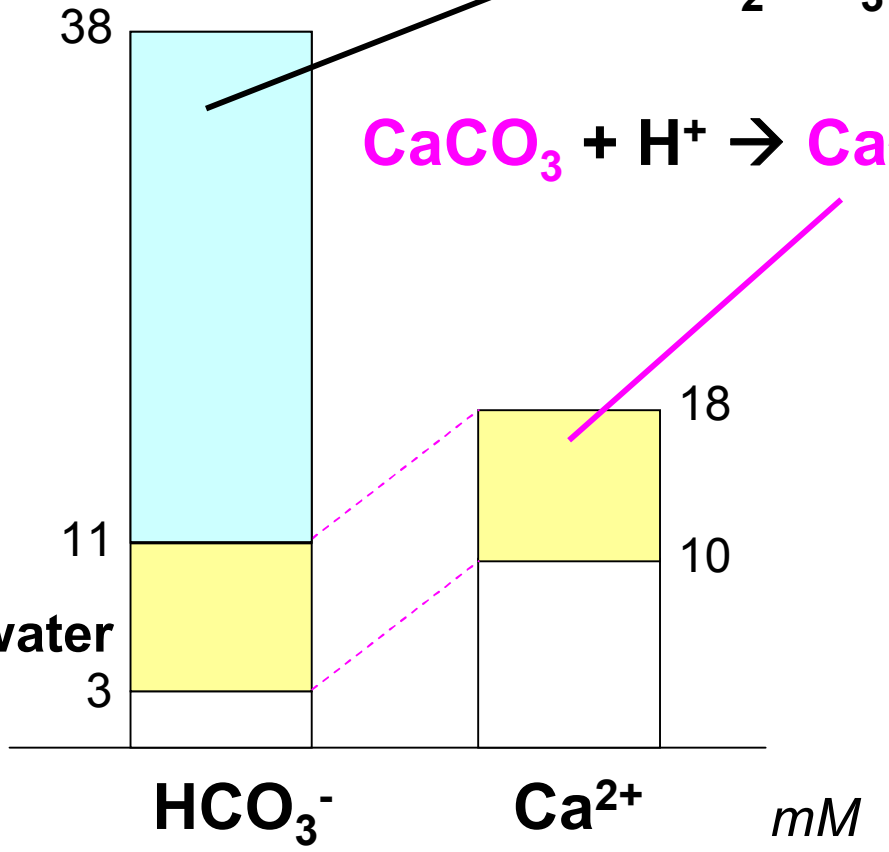
Change of water chemistry affected by migrating CO_2

Blue & Yellow :
Change observed on Dec. 2005

$$CO_2 + H_2O \rightarrow H_2CO_3$$

$$H_2CO_3 \rightarrow H^+ + HCO_3^-$$

$$CaCO_3 + H^+ \rightarrow Ca^{2+} + HCO_3^-$$

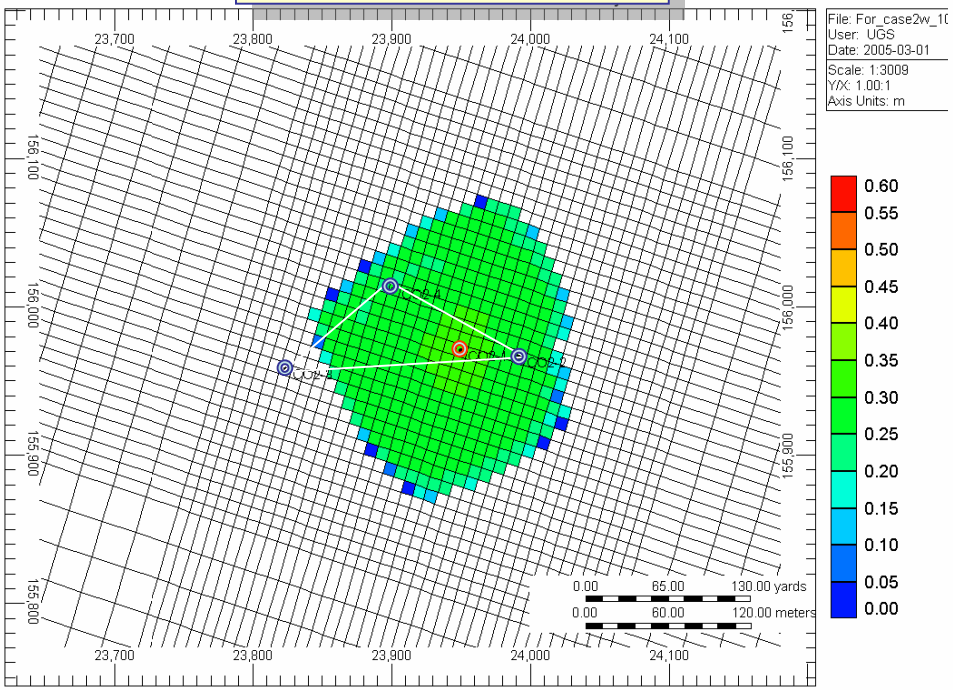


While :
original formation water

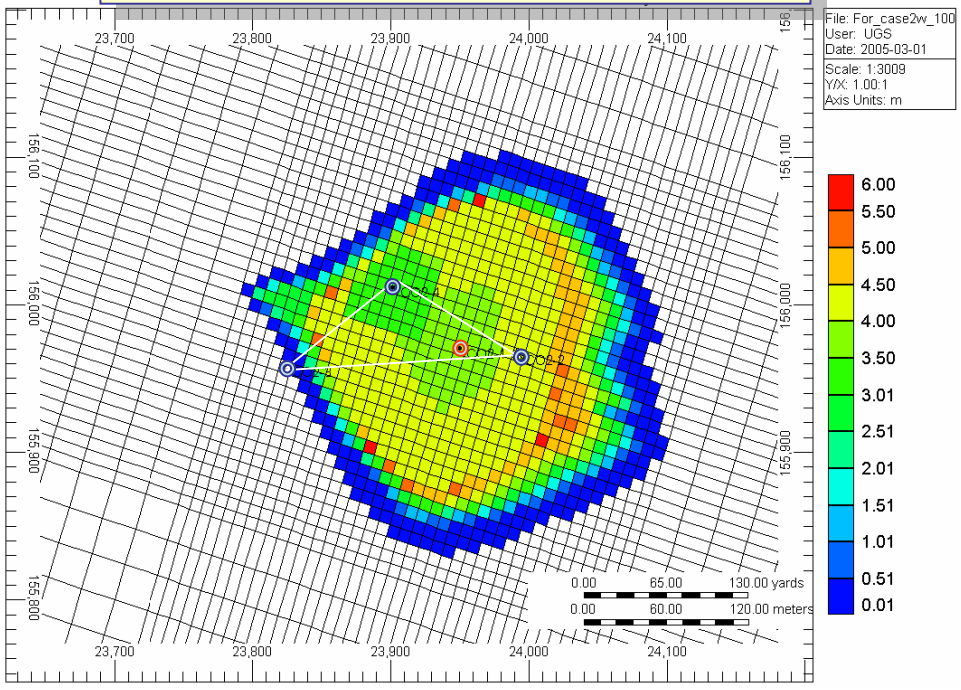
CO_2 simulation

Prediction after 1000 years

Sg、Fraction



aqueous CO_2（Sm^3/m^3rock）



Gaseous CO_2 = 63.1 % of total injected

Sgrmax=0. 33

CO_2 in Solution = 36.9 % of total injected

Outcomes of Nagaoka Project

1 successful and meaningful continuous operation of CO_2 injection; 500days and 10 thousand tonnes

2 geophysical logging using observation wells revealed CO_2 migration and distribution

3 imaging by cross-hole seismic tomography]

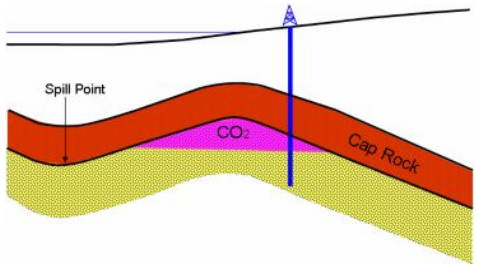
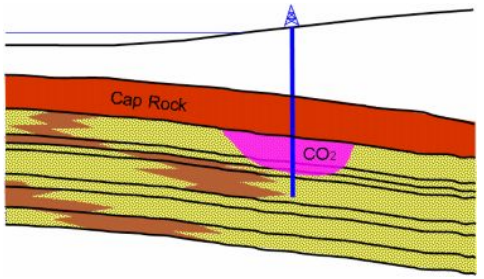
4 computer simulation of CO_2 migration prediction underground

5 experience of a big earthquake with M6.8: well integrity confirmed

6 pressure test to check for well and seal rock integrity before injection operation: up to 19.2 MPa (compare to the predicted injection pressure of 18.6 MPa)

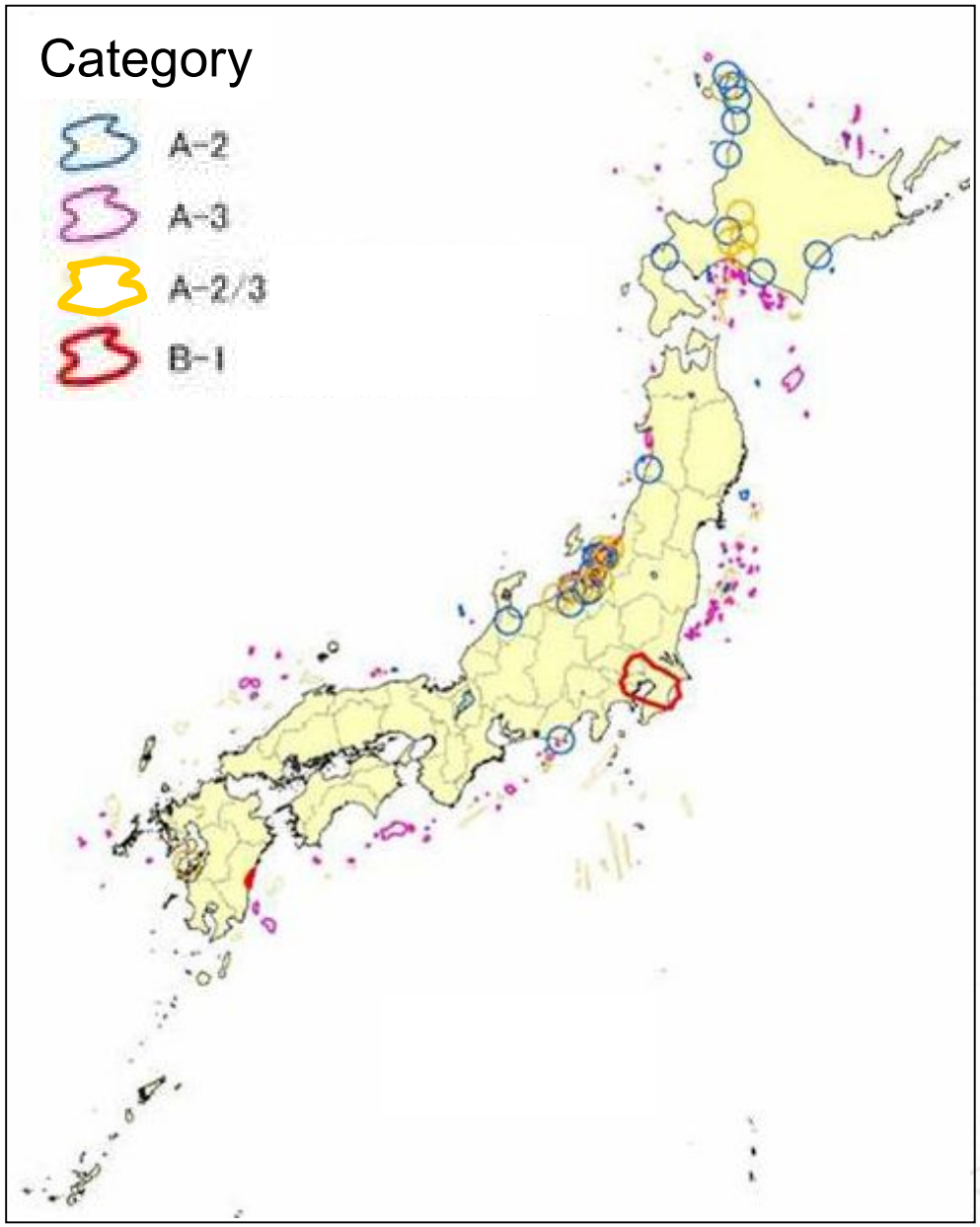
actual injection pressure of 12.6 MPa for injection rate of 40 tonnes per day

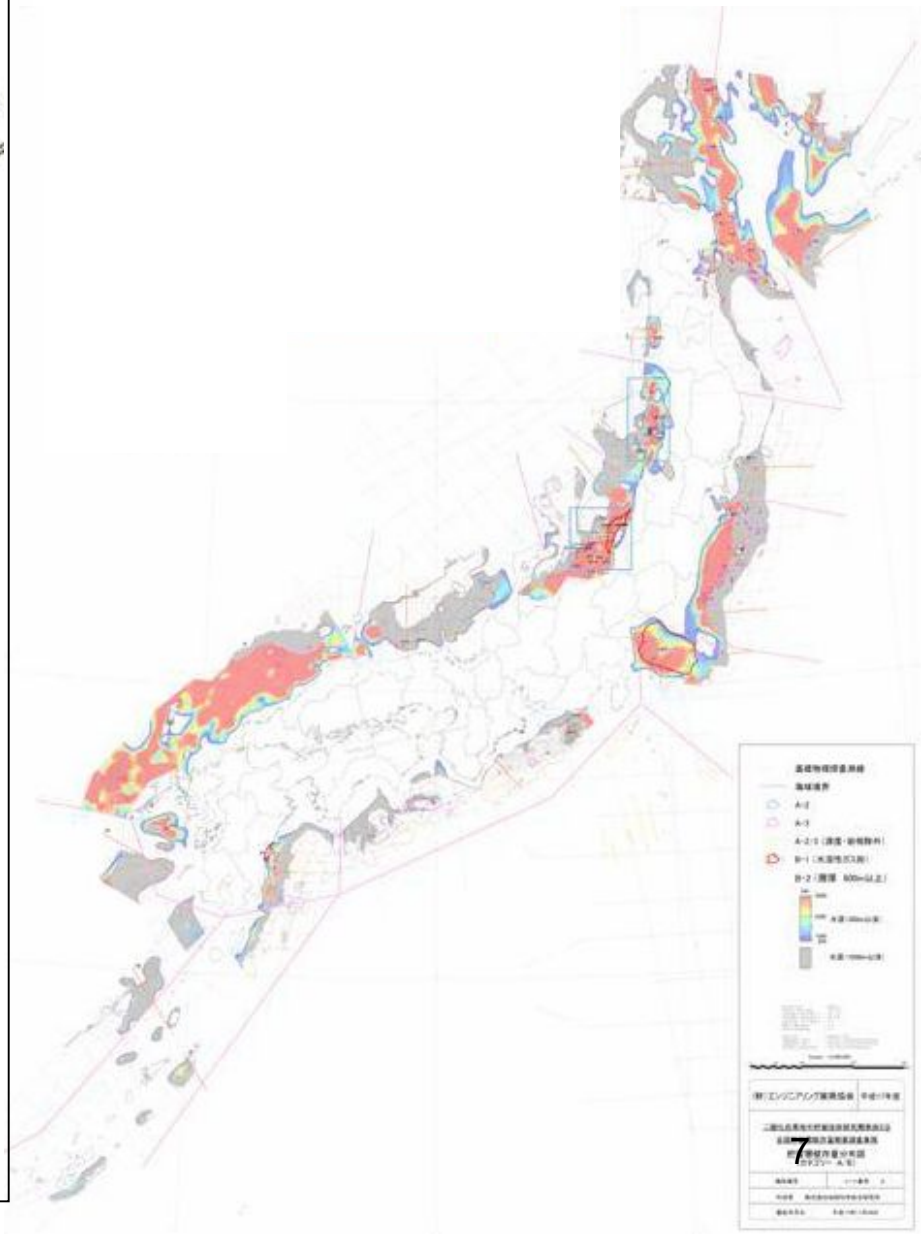
Re-evaluation for Aquifer Storage Potential in Japan

data source		Category A (Aquifer with Closure)	Category B * (Geological formation of stratigraphic trapping)
oil & gas field	data obtained during operation	A1: 3.5 Billion t-CO_2	B1: 27.5 Billion t-CO_2
Basic boring	public domain data by seismic and drillhole	A2: 5.2 Billion t-CO_2	
Basic survey	public domain data by seismic only	A3: 21.4 Billion t-CO_2	B2: 88.5 Billion t-CO_2
scheme			
sum		30.1 Billion t-CO_2	116.0 Billion t-CO_2
total		146.1 Billion t-CO_2	

Inland basins, such as Seto in land sea, Osaka Bay are excluded: based only on Public Domain Oil & Gas Exploring activity. *) deeper than 800m and shallower than 4,000m, located in waters shallower than 200m.

Identification of potential storage sites





Recent Discussions on the London Convention and Protocol

- On 10 February 2007, the amendment of London Protocol will take into force, allowing CO_2 sequestration in sub-seabed geological formations.

- In the SG Intersessional Technical WG, the framework of risk assessment of CO_2 sequestration in sub-seabed geological formations is now being discussed. Its conclusions will be treated as basic concepts of the CO_2 Waste Assessment Guidelines, which should be the basis for domestic procedures of permitting in each country.

- Japan will be the London Protocol country in mid-2007; ratification of London Protocol by National Diet

- Public comment procedure is now underway for the amendment of domestic law corresponding to London Convention.