An Overview of the Nagaoka Project

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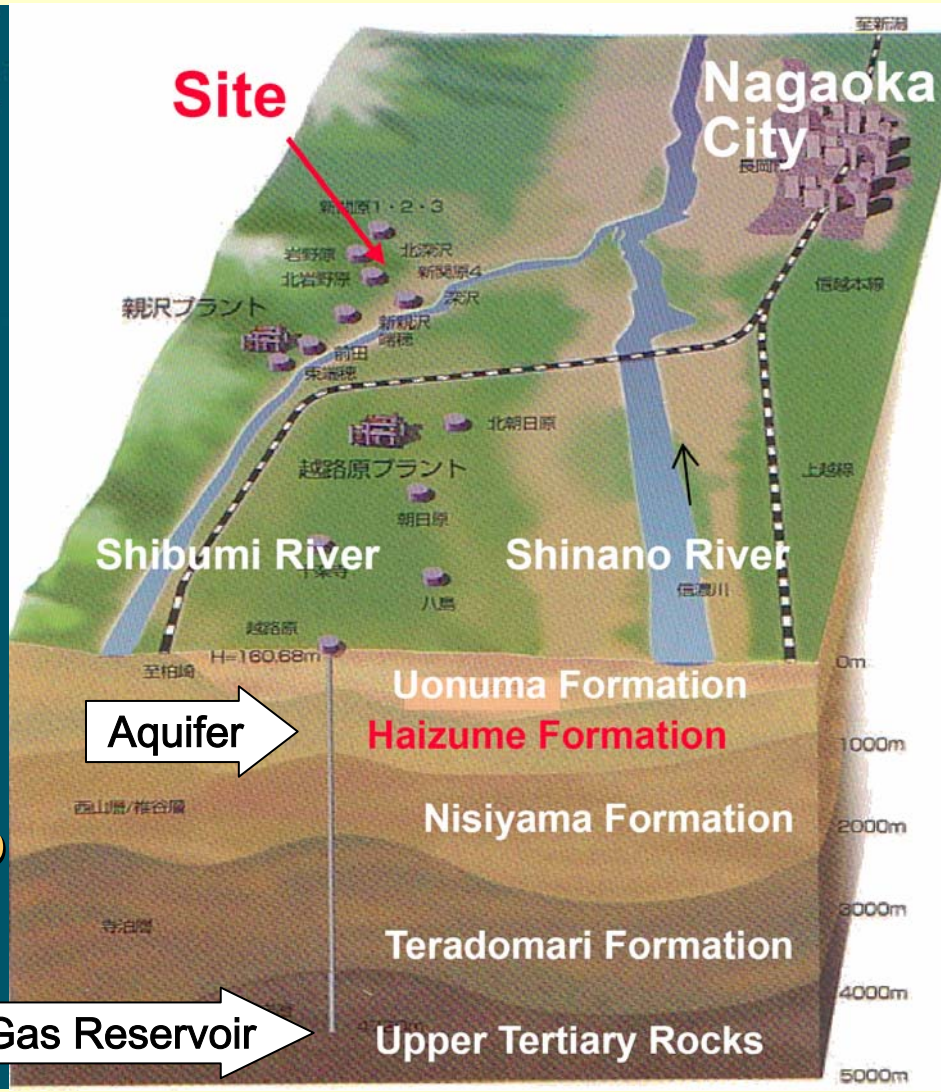
Presentation Outline

- **Test Site Overview**
  - Location, Topography and Geology
  - Chronicle of Pilot Test
  - Well Configuration
  - Geology of Test Site
- **CO_2 Injection**
  - Injection Facilities
  - Sketch of Injection
  - Main Feature of Injection
  - Progress of Injection

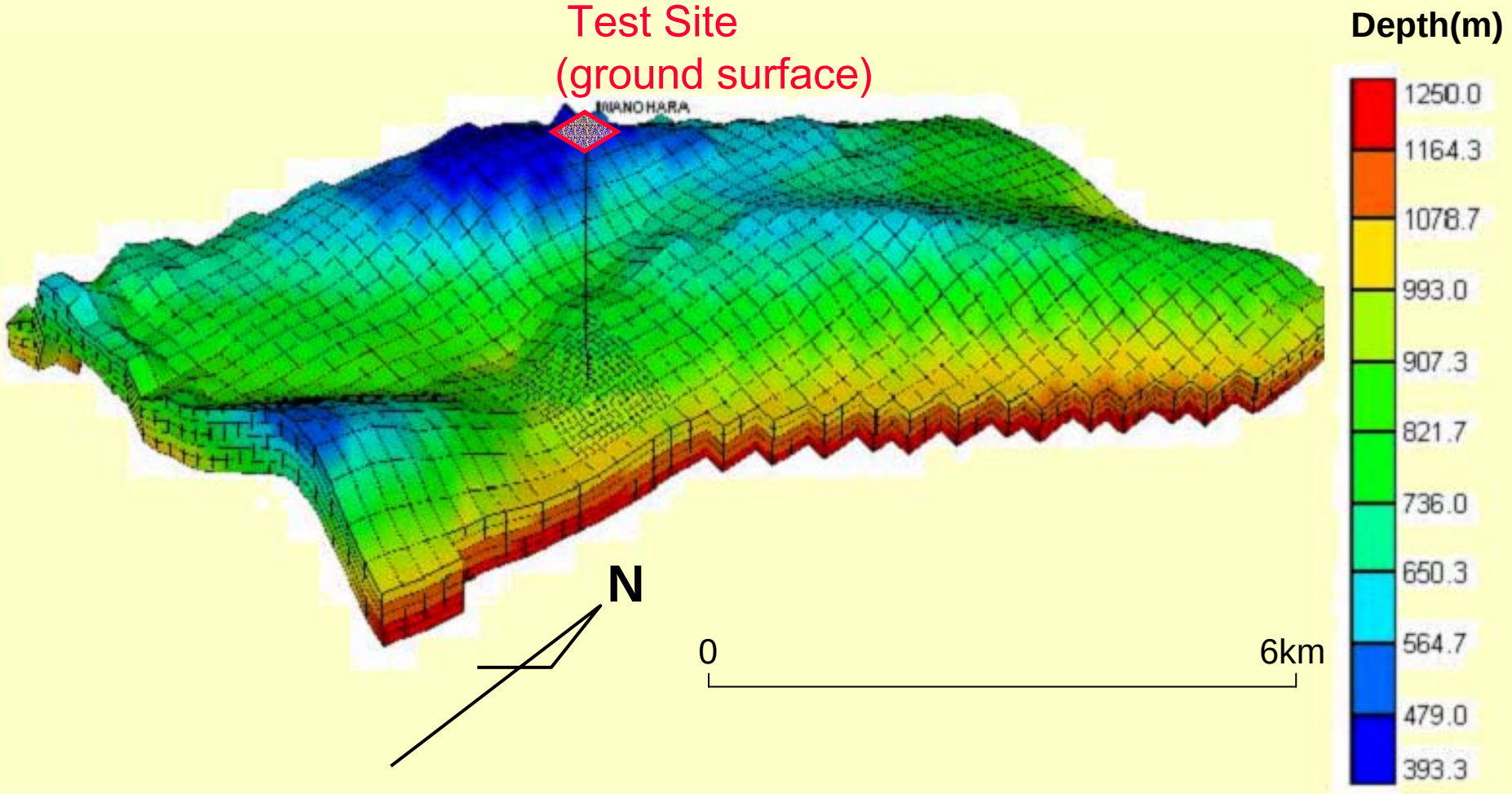
- **Monitoring**
  - Pressure/Temperature measurement
  - Time-lapse Geophysical Logging
  - Time-lapse Cross-well Seismic Tomography
  - Micro earthquake observation
- **Simulation Study**
- **Summary**

Test Site Overview

Location, Topography and Geology



Geology : 3D Shape of the Targeted Aquifer



Chronicle of Pilot Test

- **JFY 2000 : Site Selection ･･･South Nagaoka Gas Field**
- **Drilling of Wells, Well logging and Test of Core Sample**
  - ✧ JFY 2000 : Injection well (IW-1) drilled
  - ✧ JFY 2001 : Two observation wells (OB-2, OB-3) drilled
  - ✧ JFY 2002 : One observation well (OB-4) drilled
- **JFY 2003 : Construction of the Facilities**
- **FY 2003 – 2004 : Injection of CO_2 ･･･10,405t**
- **FY 2002 – present :Monitoring of CO_2**
- **FY 2000 – present : Simulation Study**

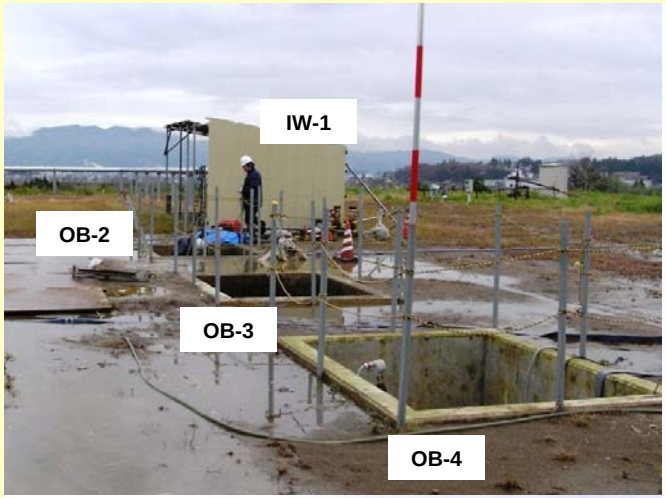
  - ✧ FY 2000 – 2002 : Simulation prior to the injection start
    ･･･Optimum arrangement of CO_2 monitoring etc.
  - ✧ FY 2003 - present : History matching simulation after the injection start
    ･･･ Long-term CO_2 behavior anticipation

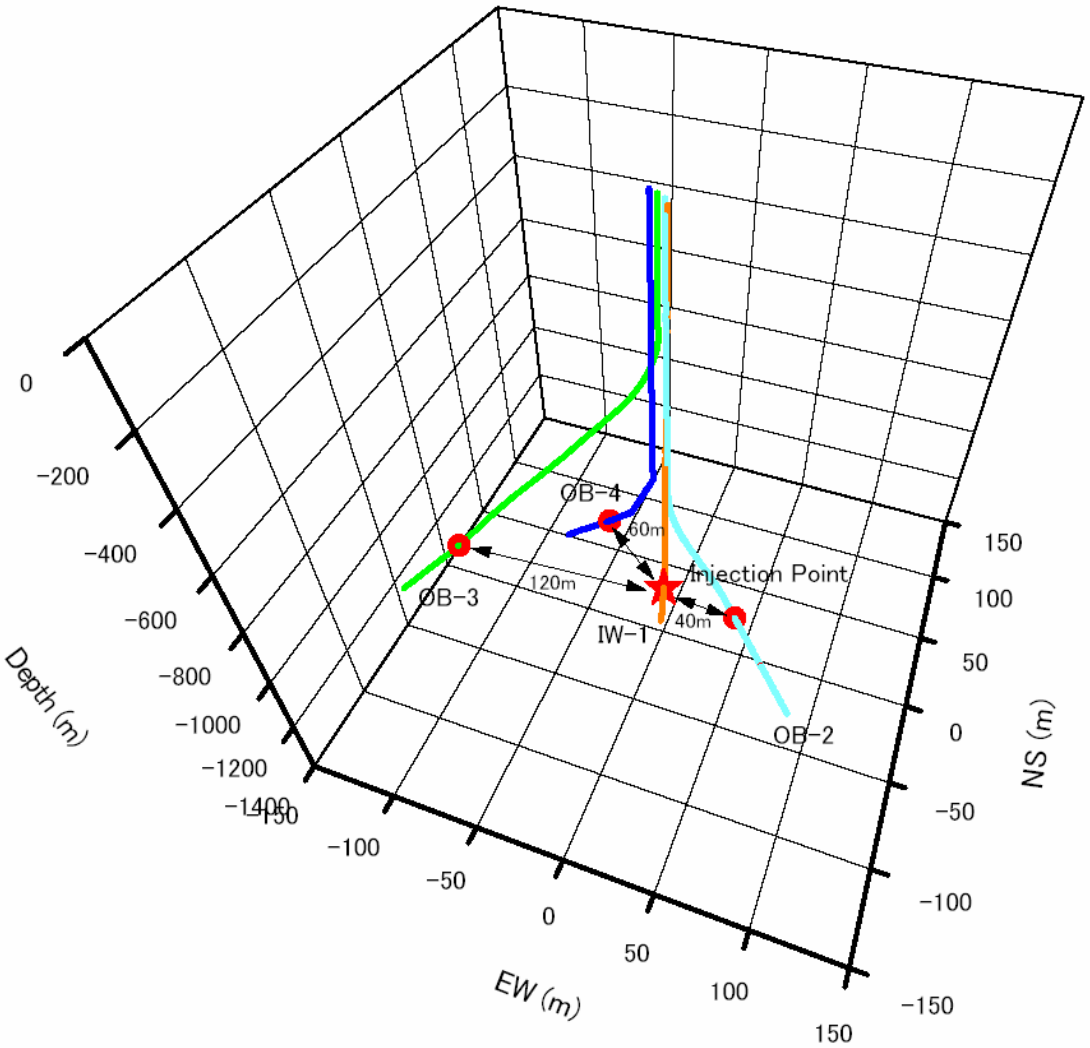
Test Site Overview

Well Configuration

Injection well : IW-1

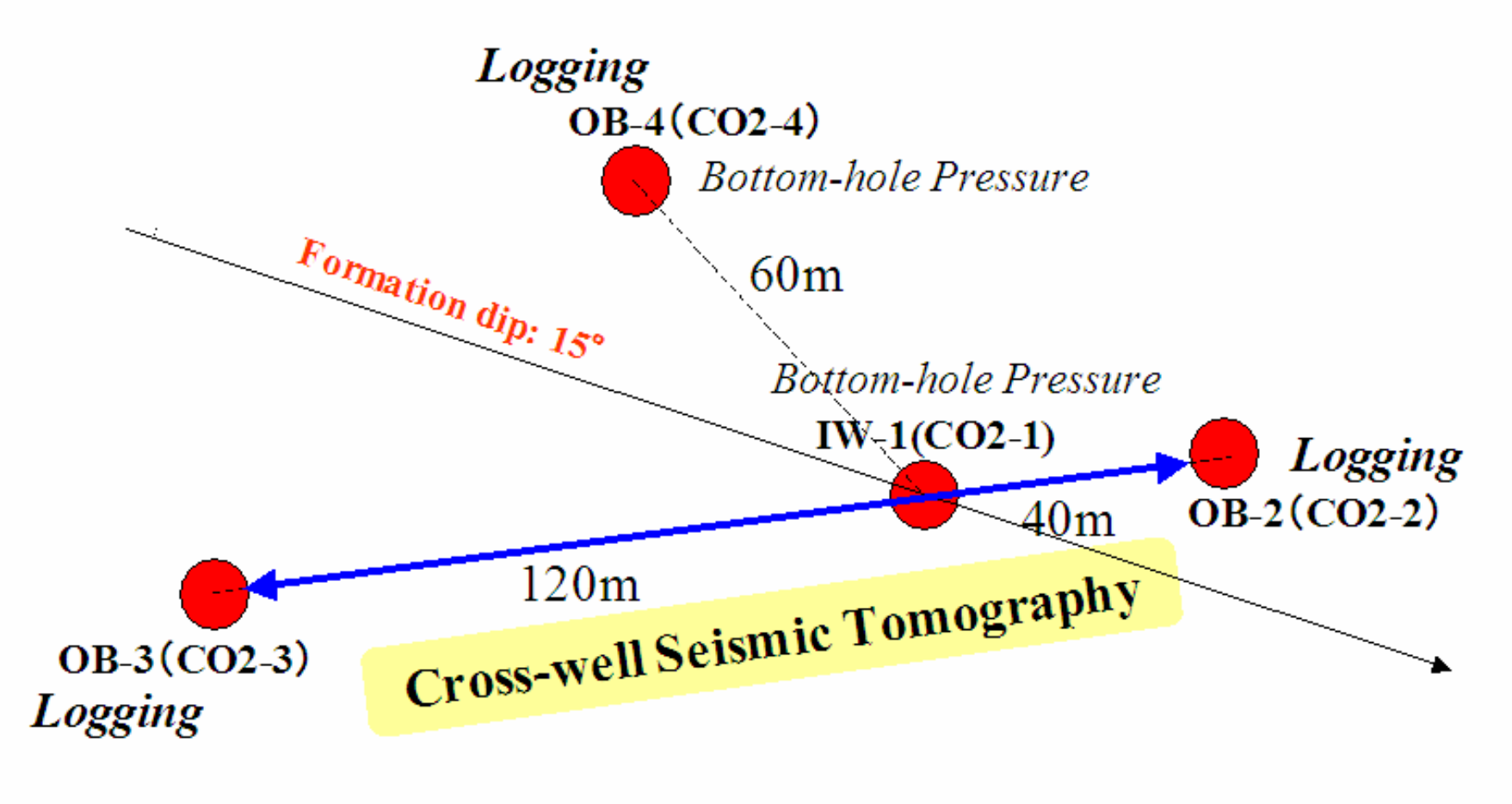
Observation well :OB-2, OB-3, OB-4





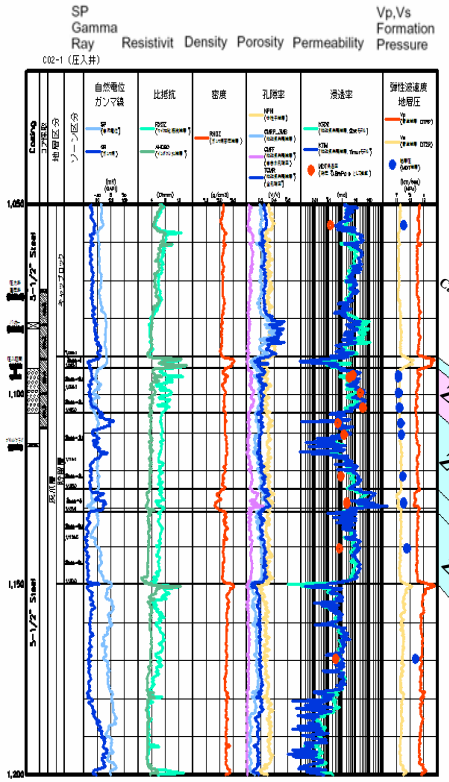
Well Configuration

Arrangement of Wells at Reservoir Level



Geology of Test Site

Injection well
IW-1



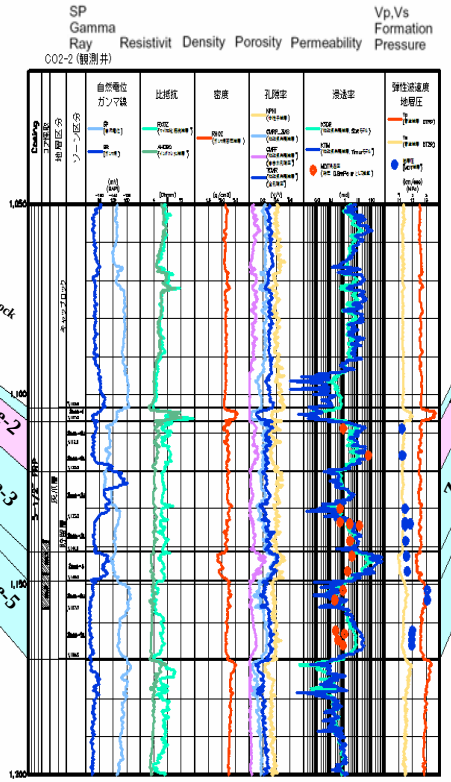
Net thickness

Cap rock : 134.7m

Zone-2 : 11.9m

Reservoir : 59.5m

Observation well
OB-2



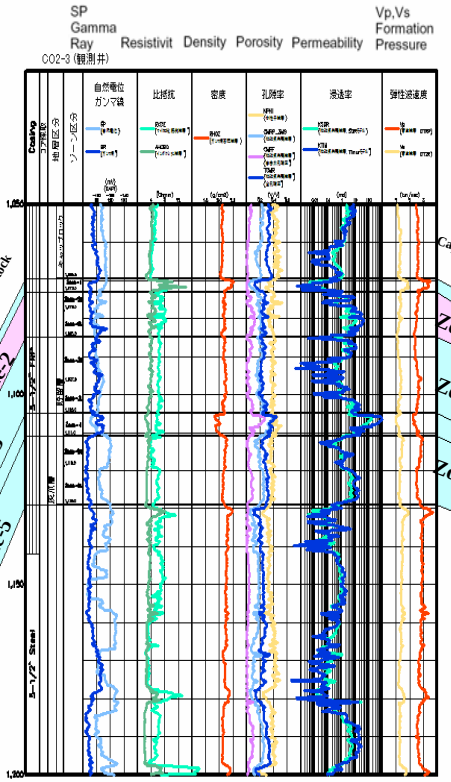
Net thickness

Cap rock : 134.0m

Zone-2 : 11.8m

Reservoir :59.2m

Observation well
OB-3



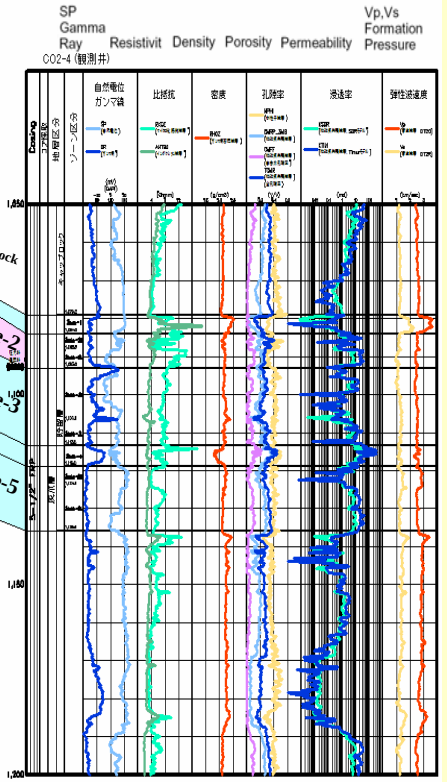
Net thickness

Cap rock : 131.4m

Zone-2 : 12.0m

Reservoir : 59.4m

Observation well
OB-4



Net thickness

Cap rock : 131.9m

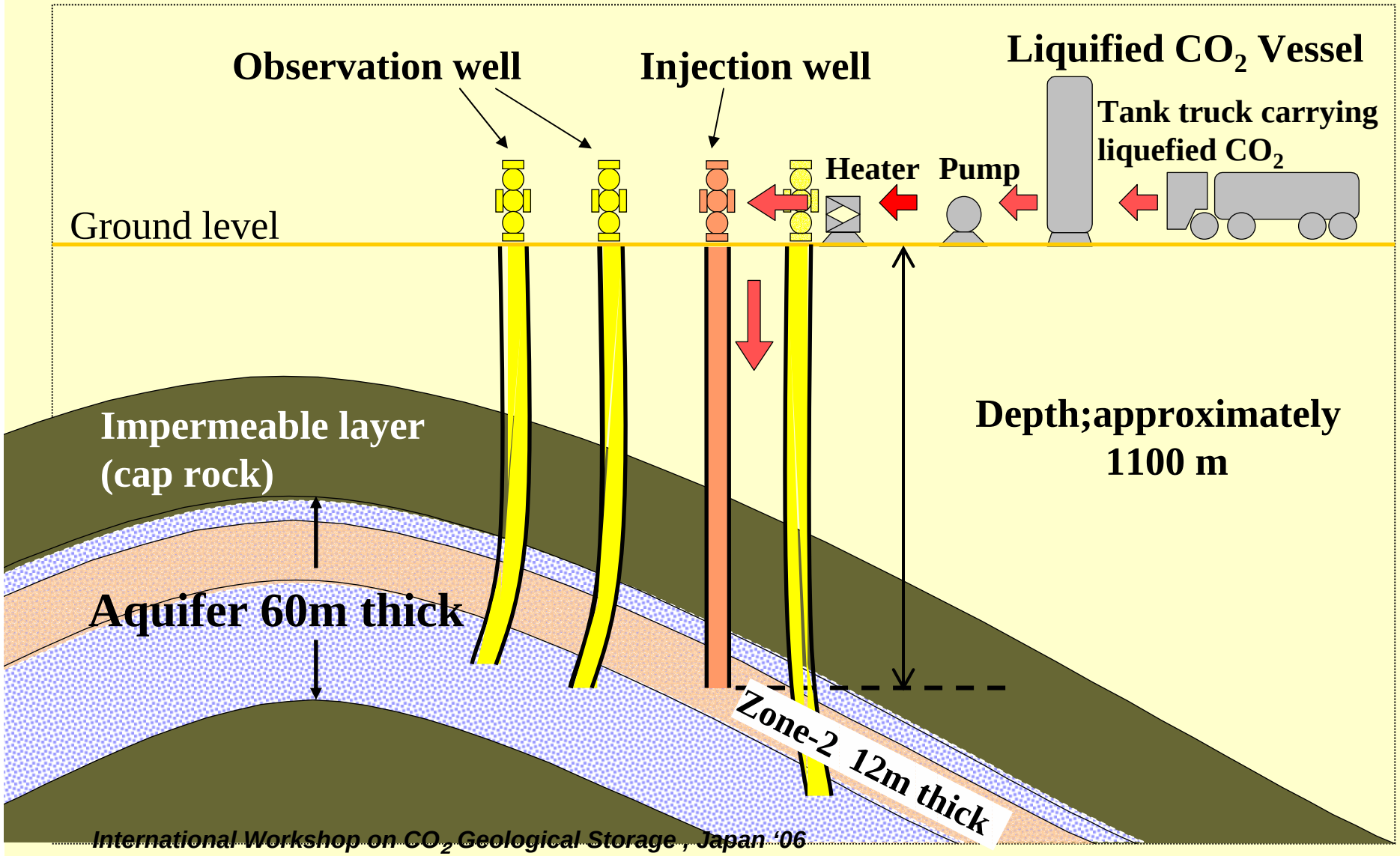
Zone-2 : 9.0m

Reservoir : 56.5m

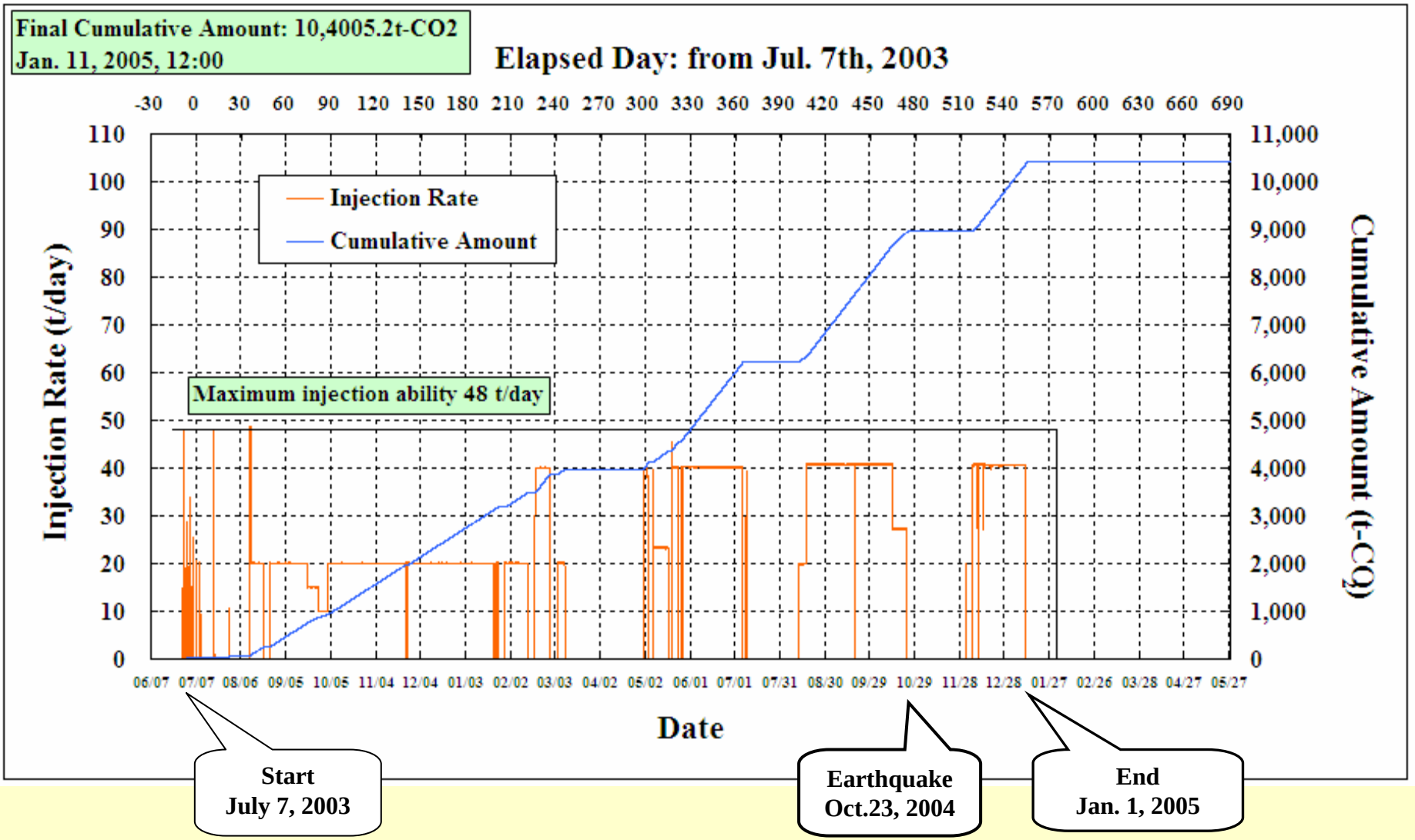
Injection Facilities

Capacity 95t-CO2
H=18m
D=3.5m

Sketch of Injection



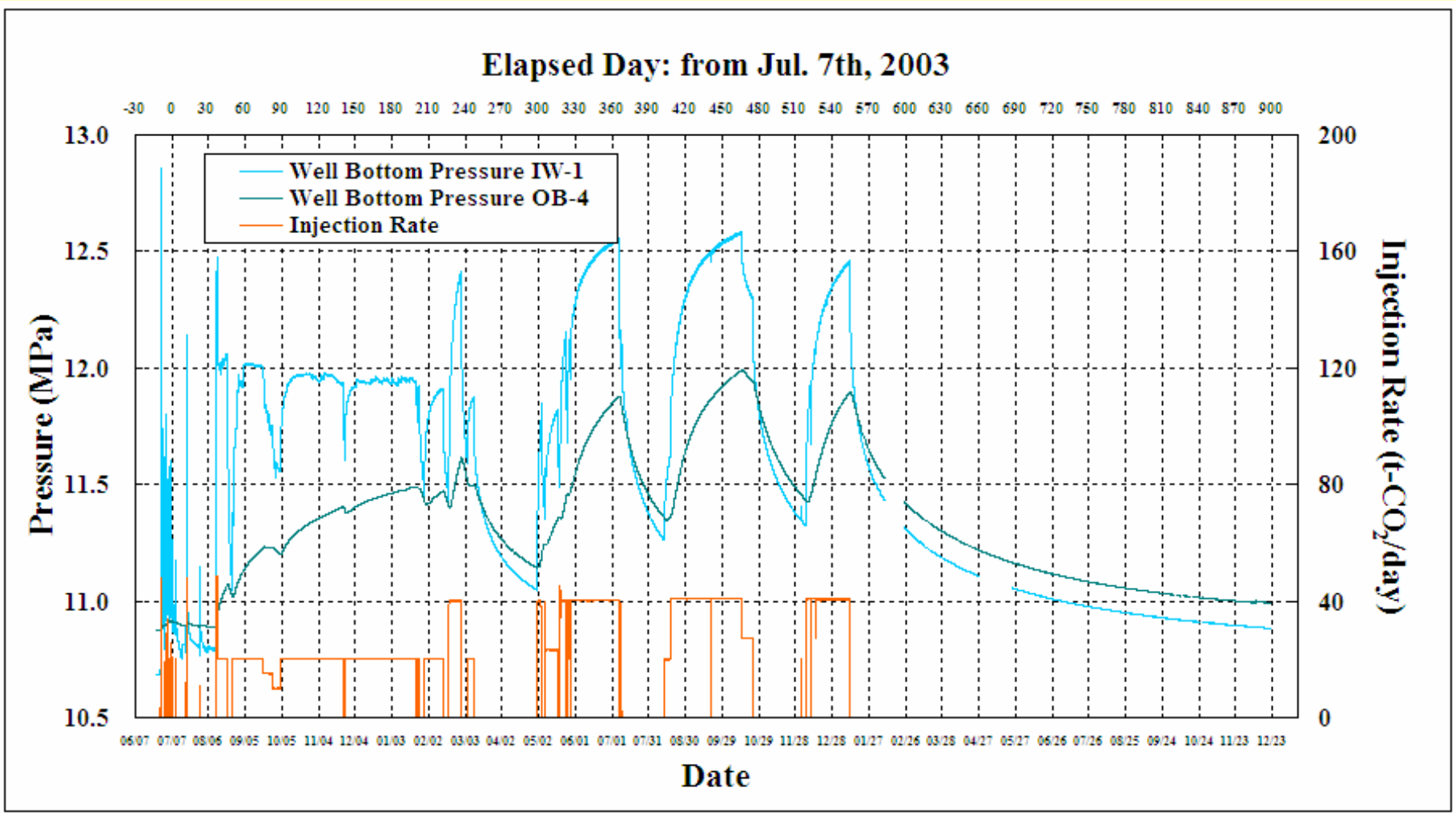
Progress of Injection



Monitoring

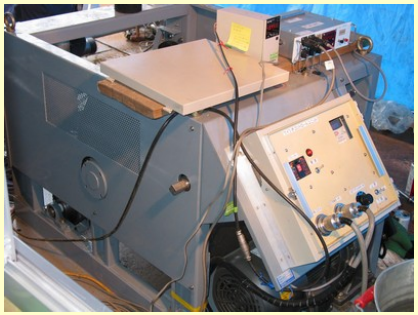
- **Measurement** (continuously)
  - Pressure & Temperature (well bottom and well head)
- **Time-lapse Logging** (at about one month interval)
  - Induction Log
  - Neutron Log
  - Acoustic Log
  - Gamma Ray Log
- **Time-lapse Cross-well Seismic Tomography**
  - Six times : Before the injection – After the injection
- **Observation** (continuously)
  - Micro earthquake

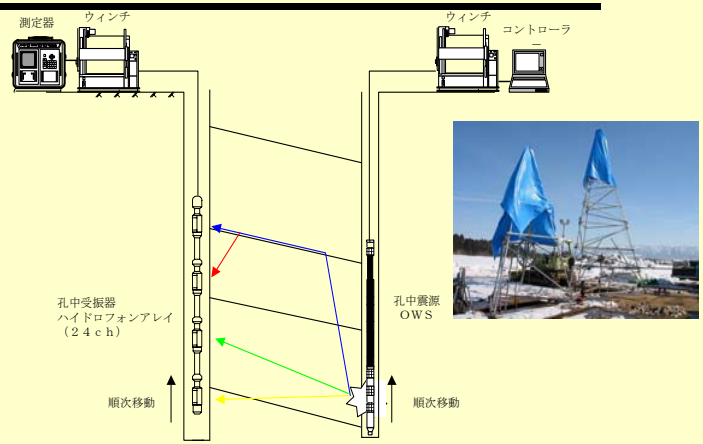
Pressure Measurement



Crosswell Seismic Tomography

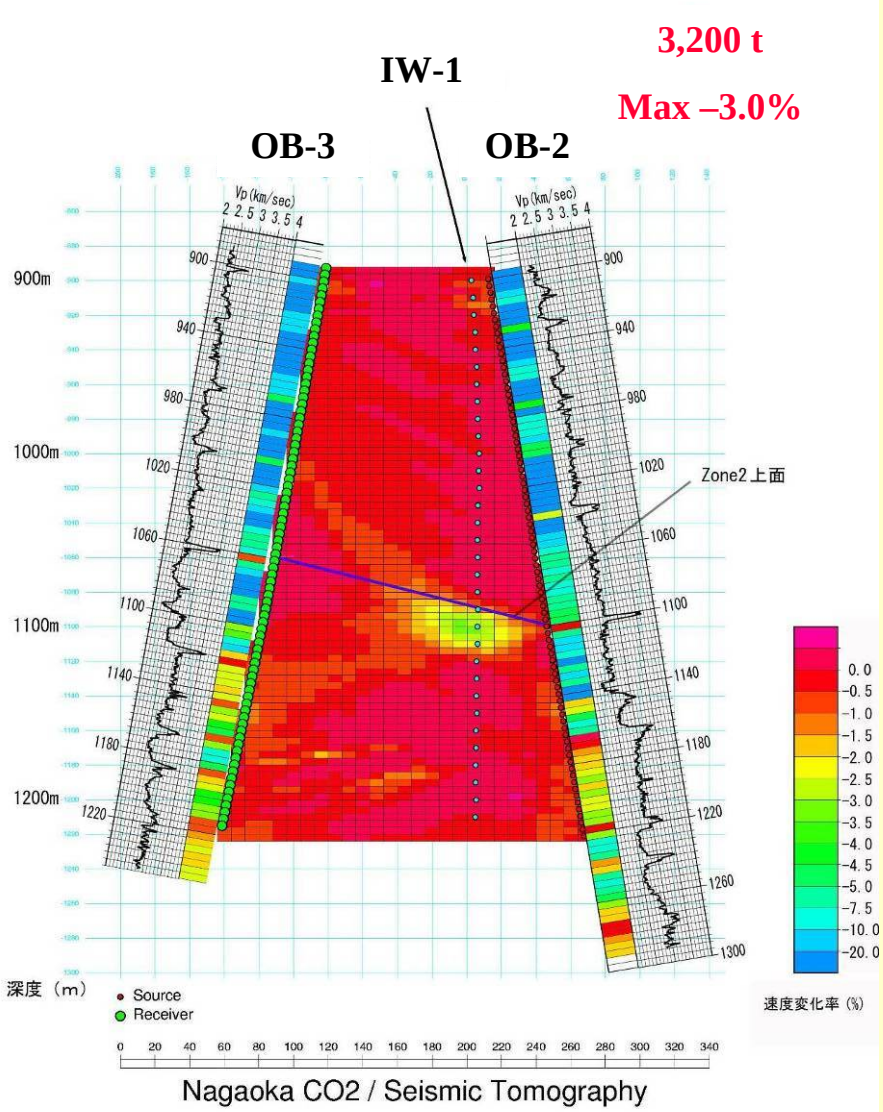
Baseline Survey	BLS	Before injection	Feb. 2003
Monitoring Survey		Injection started	Feb. 2003
	MS1	3,200t-CO_2	Jan. 2004
	MS2	6,200t-CO_2	Jul. 2004
	MS3	8,900t-CO2	Nov. 2004
		Injection ended	Jan. 2005
	MS4	10,400t-CO2	Jan. 2005
	MS5	10,400t-CO2	Oct. 2005



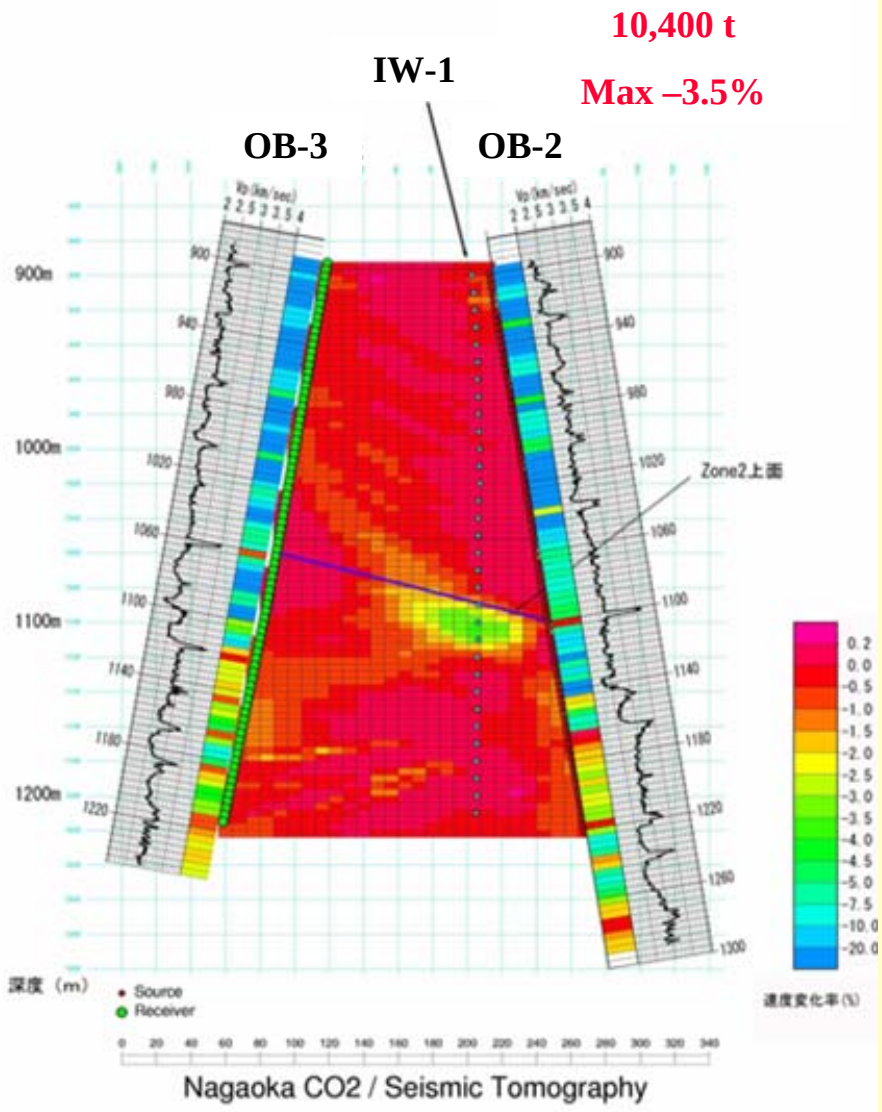


Monitoring : Time-Lapse Crosswell Seismic Tomography

Rate of Velocity Reduction



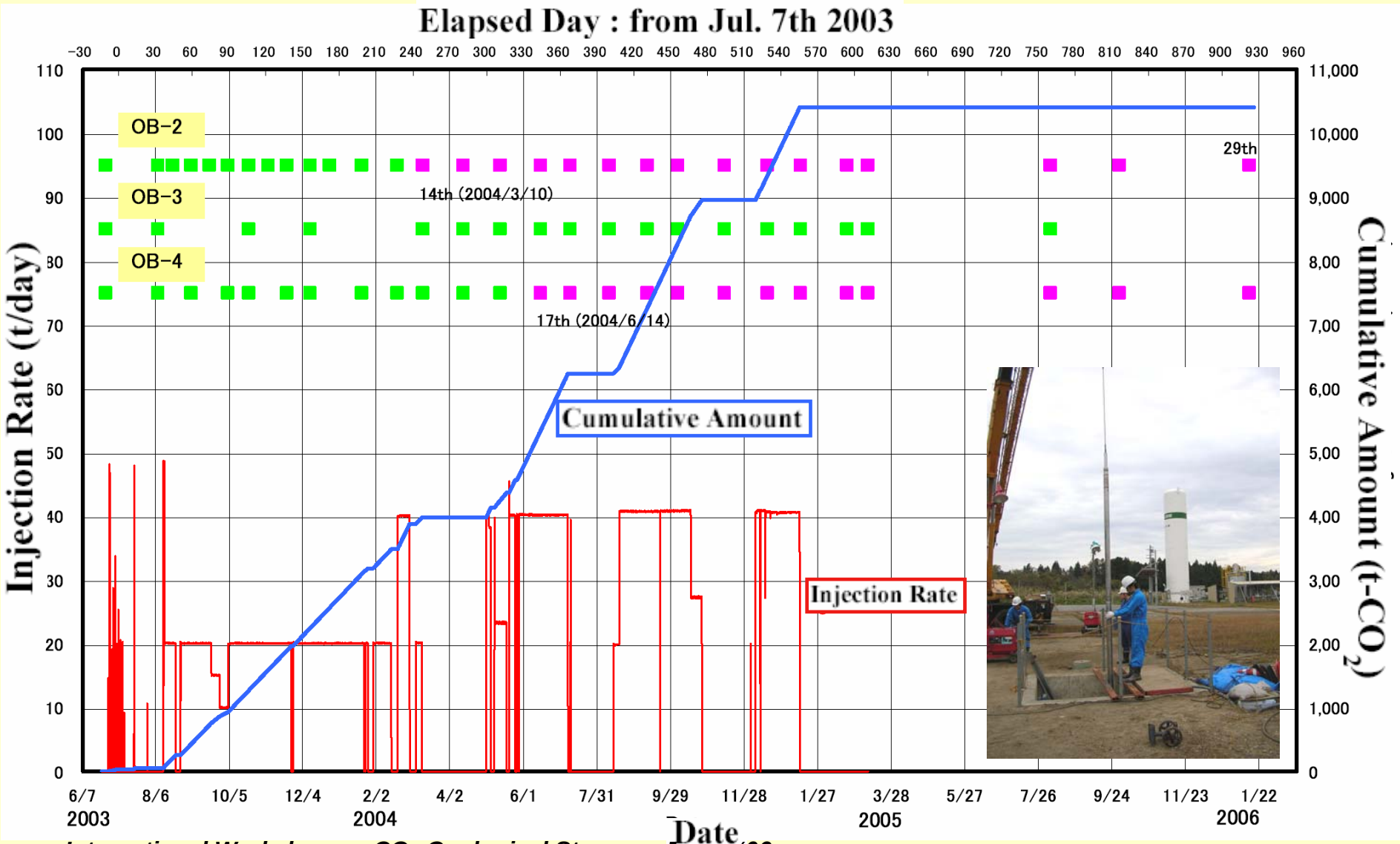
MS1/BLS



MS4/BLS

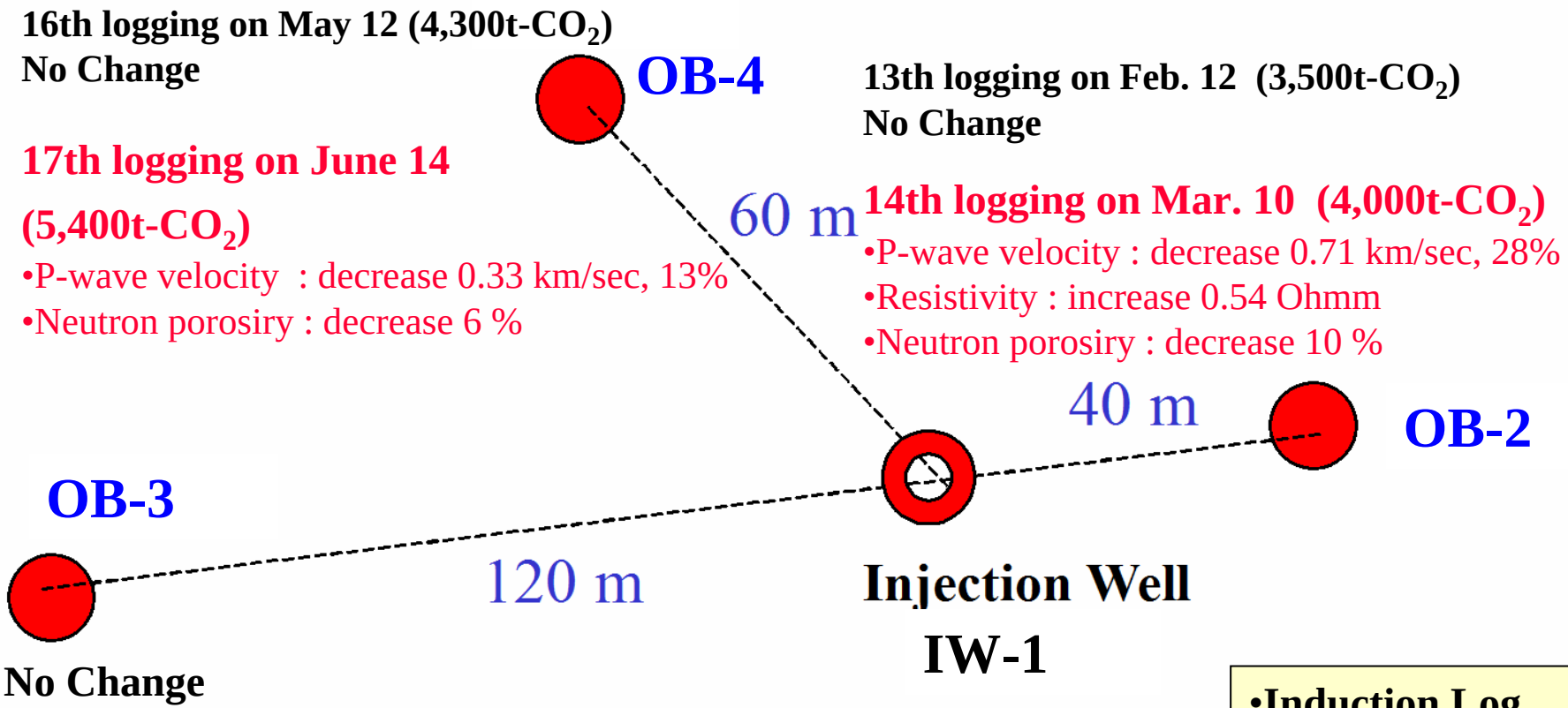
Monitoring : Time-Lapse Logging

Time-lapse Well Logging



Monitoring : Time-Lapse Logging

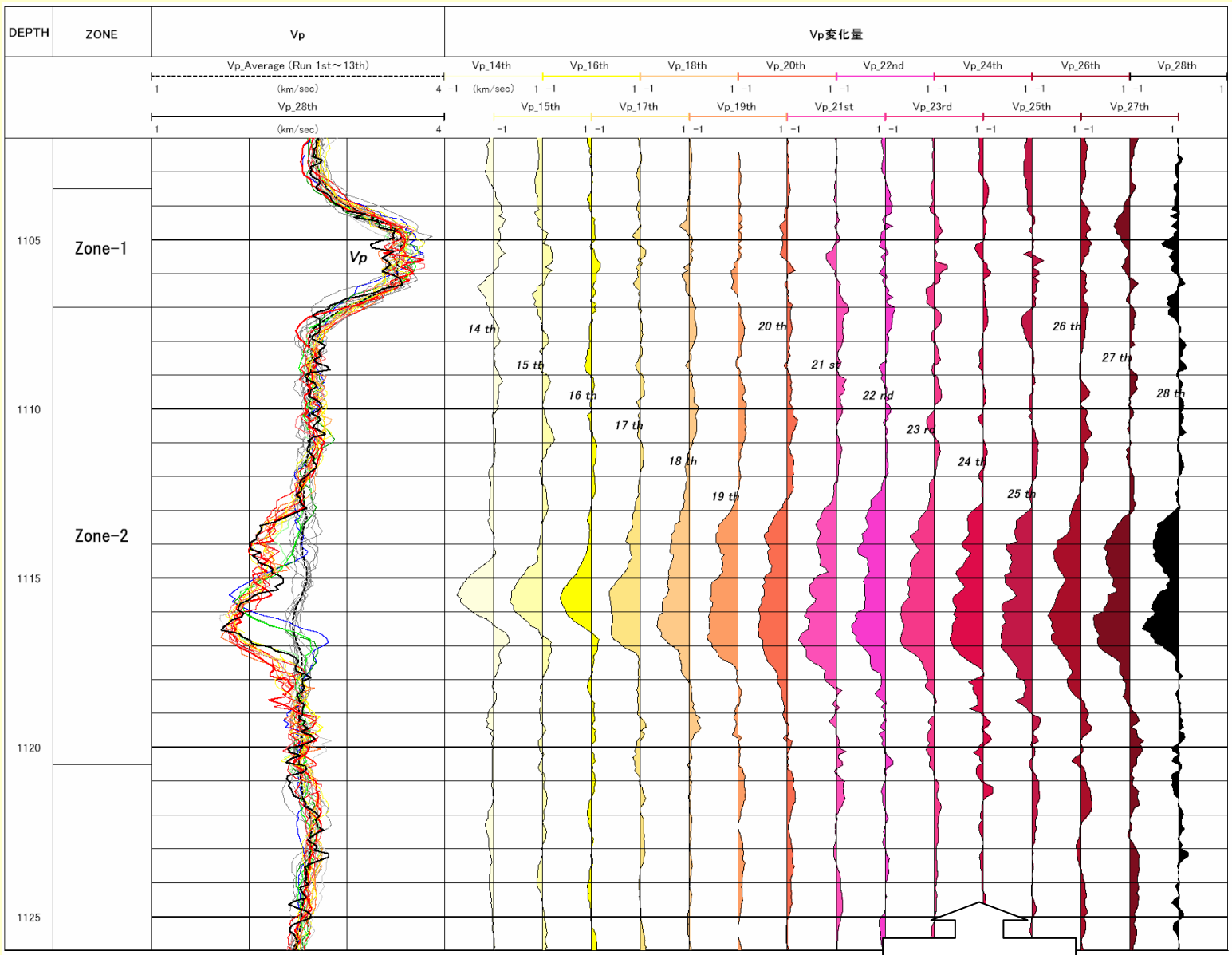
Well Logging and Breakthrough



- Induction Log
- Neutron Log
- Acoustic Log
- Gamma Ray Log

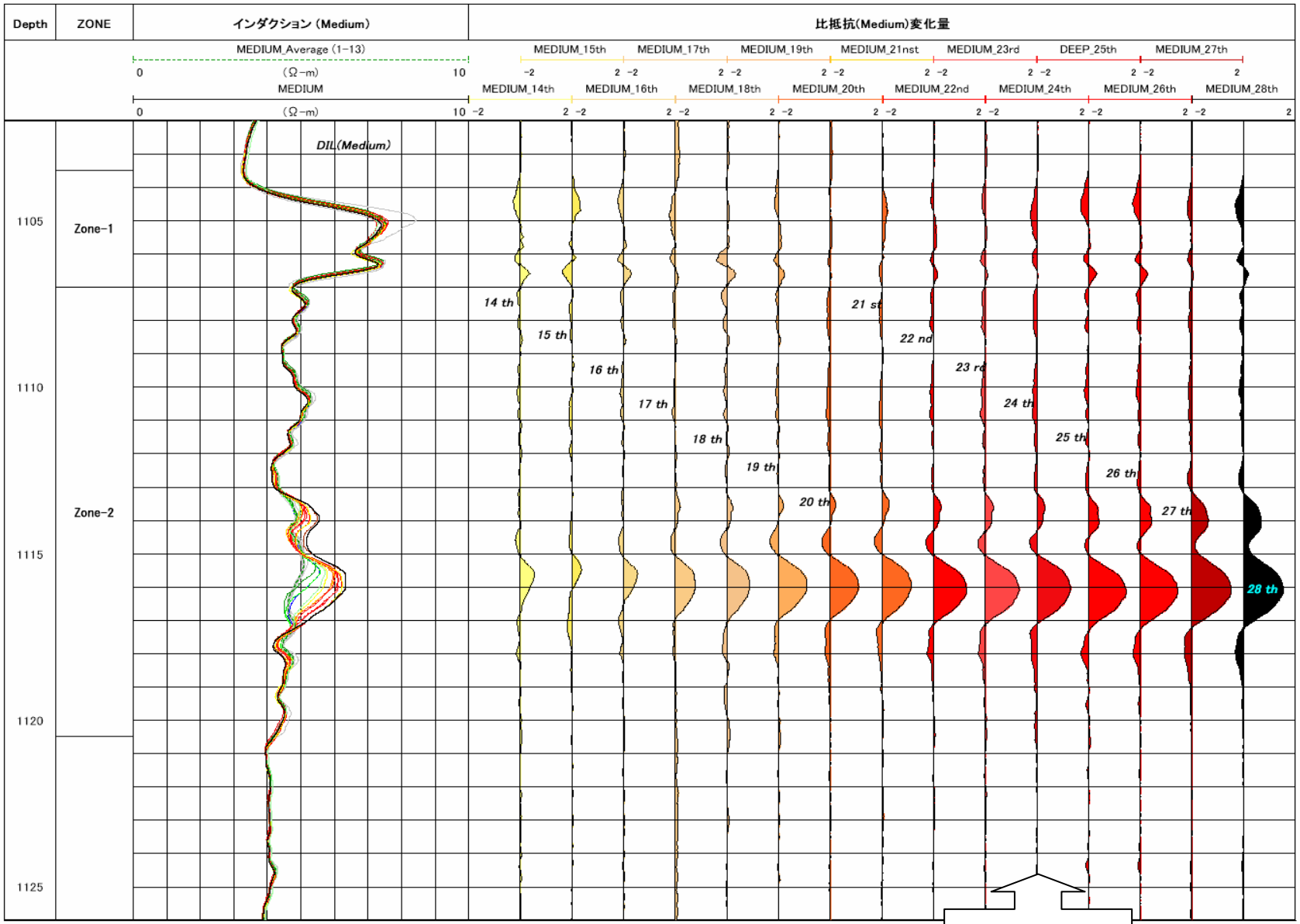
Monitoring : Time-Lapse Logging

Well Logging Result :OB-2 (Vp)



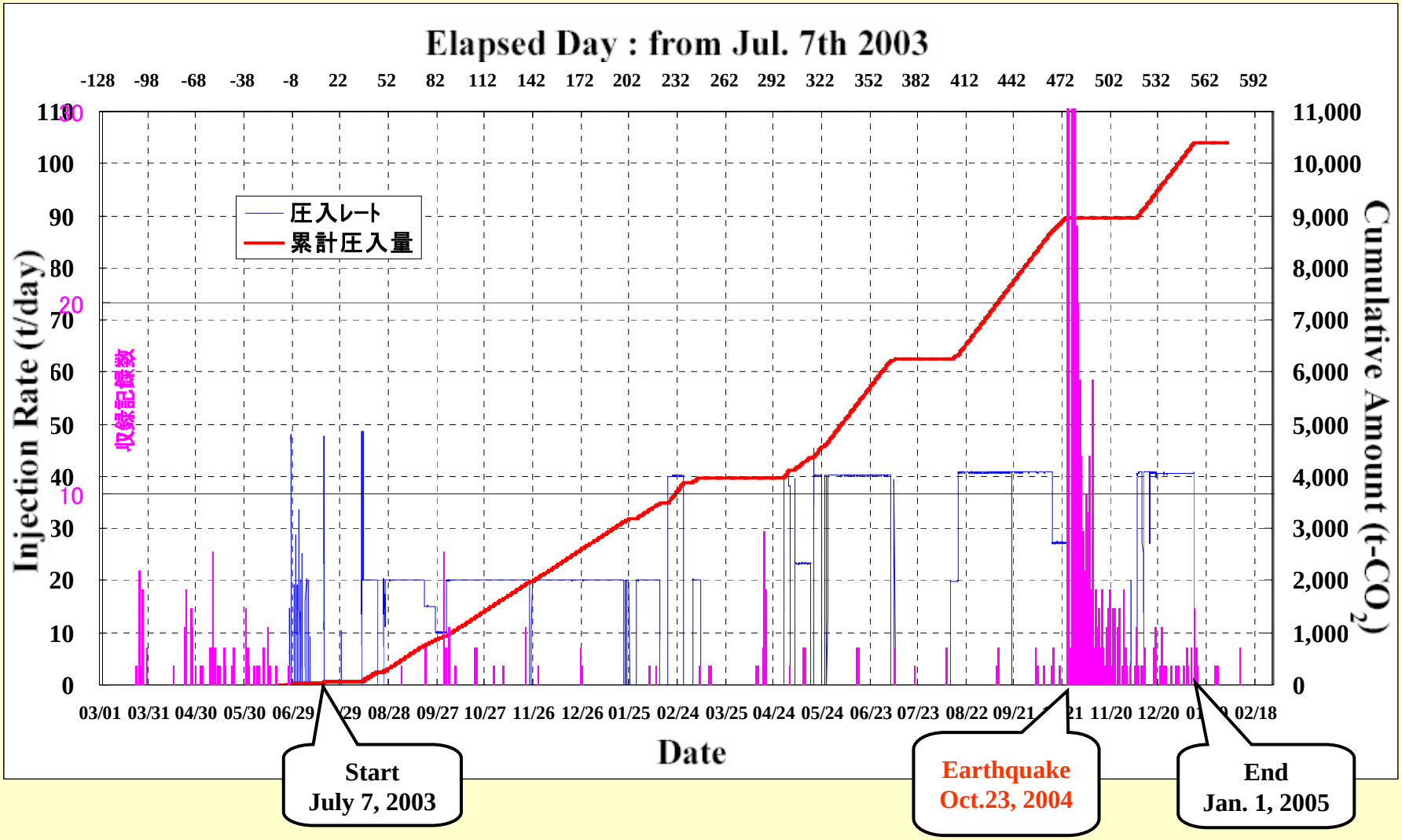
Monitoring : Time-Lapse Logging

Well Logging Result :OB-2 (Induction)



Monitoring

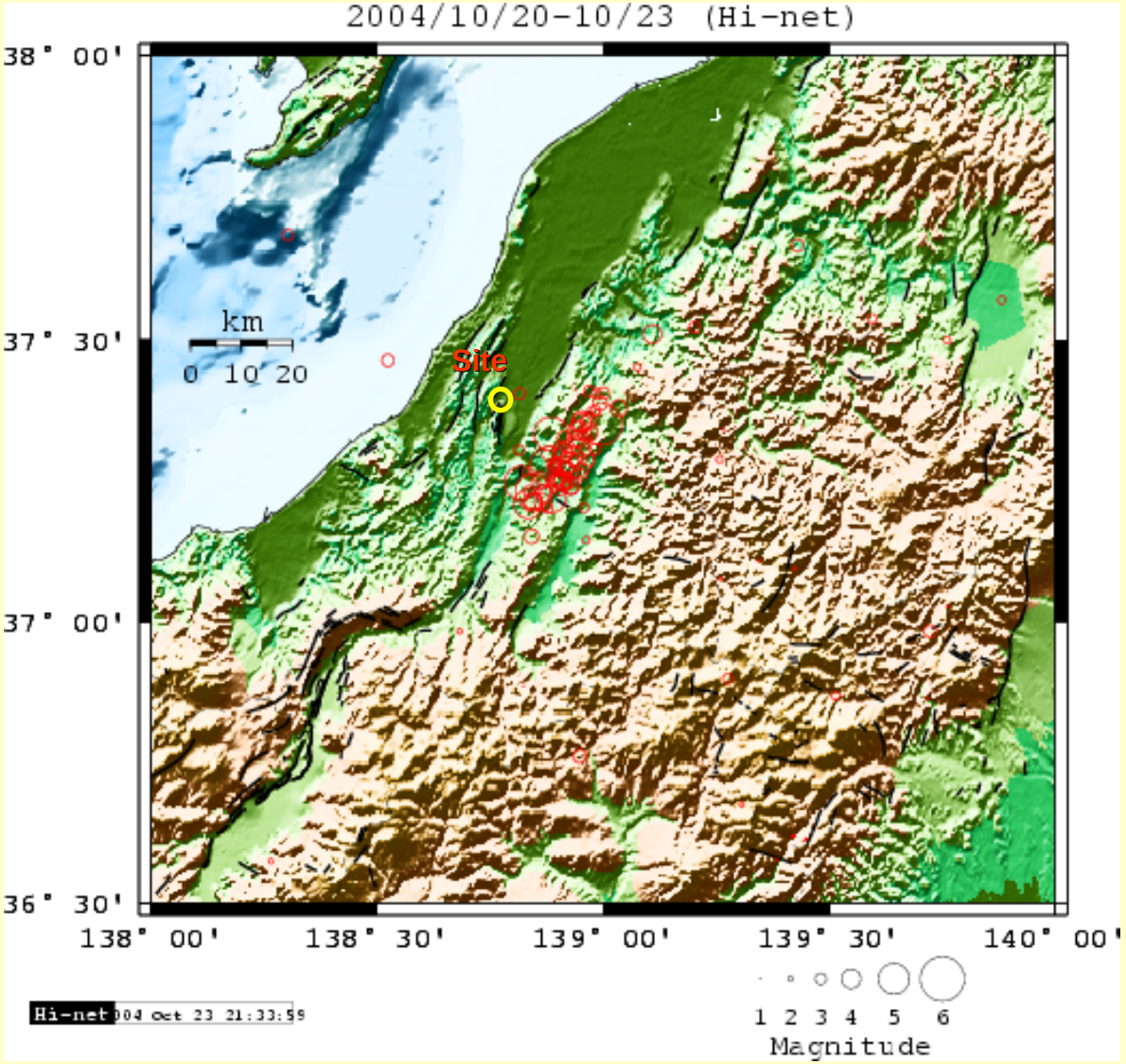
Micro earthquake Observation



- No correlation between earthquake occurrence and daily injection rate
- No correlation between earthquake occurrence and cumulative injected CO_2 amt.

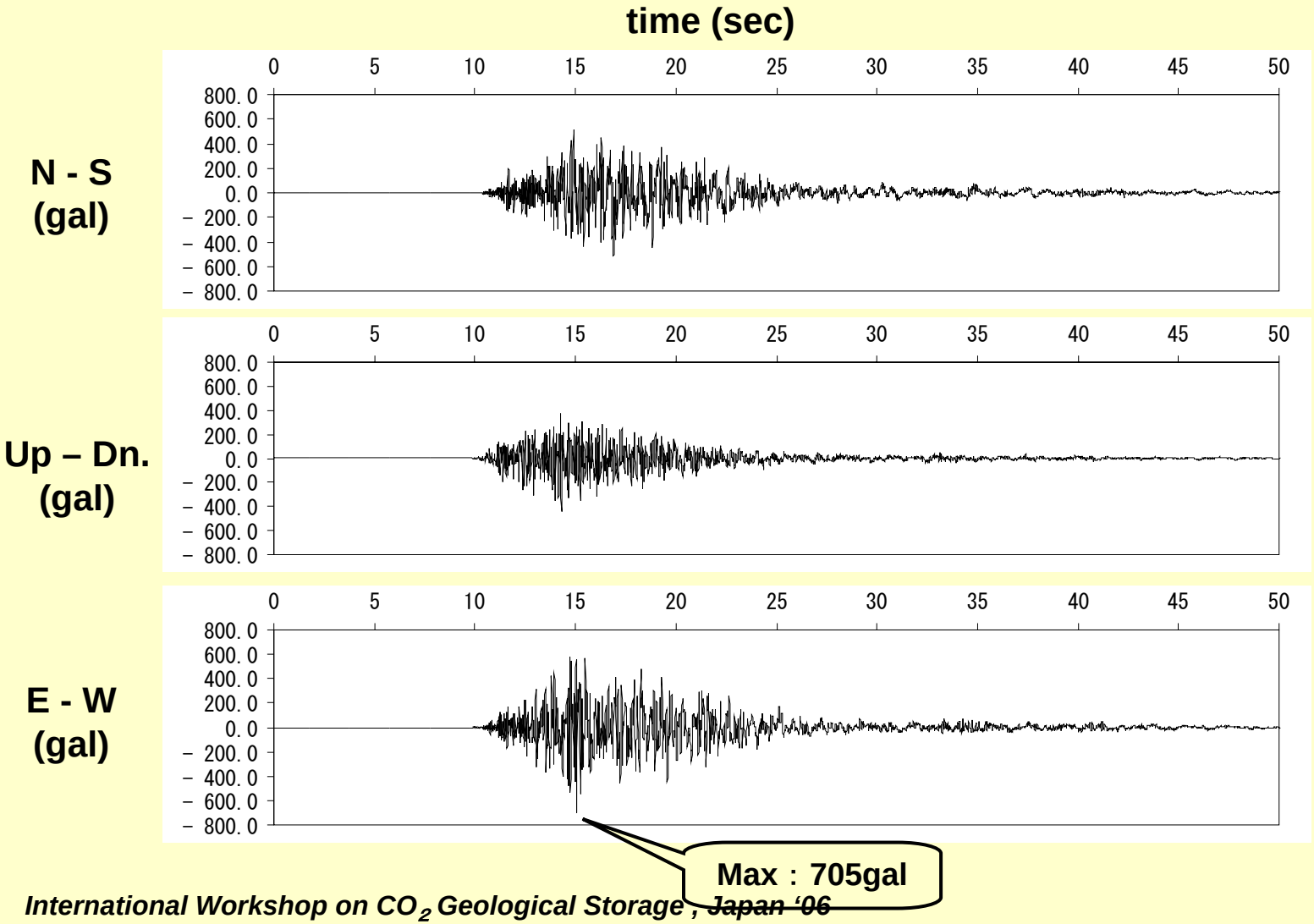
International Workshop on CO_2 Geological Storage , Japan '06

Mid-Niigata Chuetsu Earthquake



Date : 23 Oct. 2004
Time: 17:56
Magnitude: 6.8
Depth : 10 km

Record of Niigata Prefecture Chuetsu Earthquake 2004/10/23 17:56 M6.8

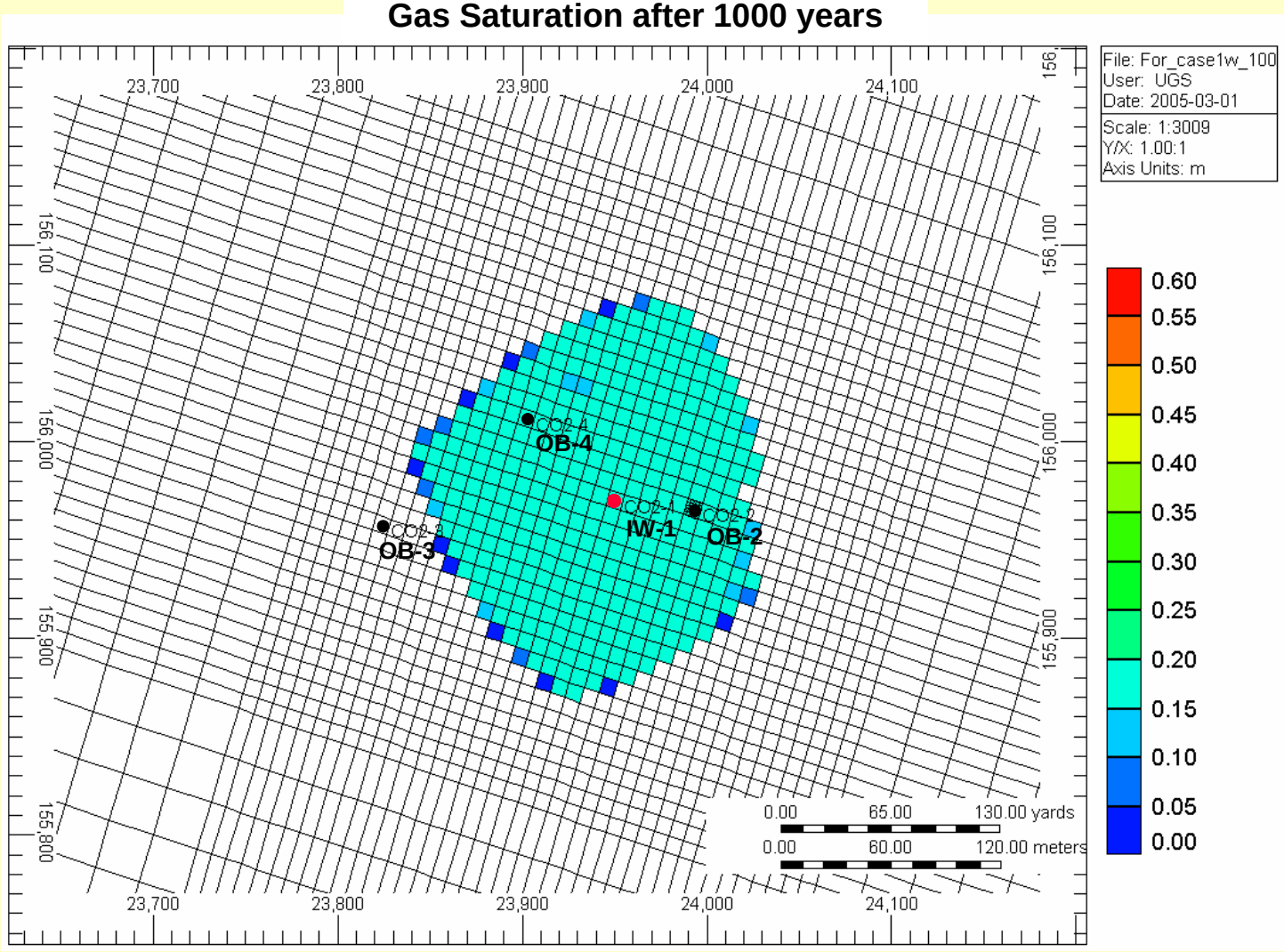


Chronicles of Pilot Test and Simulation

Japanese Fiscal Year	Events	Simulation Study
2000	· Geological study · IW-1 drilled	· Determination of observation well locations
2001	· OB-2, BO-3 drilled	· Adjustment of well locations · Examination of test plan
2002	· Pumping test at IW-1	
2003	· Acidizing at IW-1 · OB-4 drilled	
	· CO_2 injection started · CO_2 breakthrough at OB-2	· History matching · Long-term prediction of CO2 fate
2004	· CO_2 injection continued · CO_2 breakthrough at OB-4 · CO_2 injection completed	
2005	· CO_2 monitoring continued	

CO_2 Distribution

Gas Saturation after 1000 years



Removal of Facilities

- Feb. 2, 2005

Summary

- **10,400 tonnes of CO_2 was injected into an onshore saline aquifer within eighteen months in Nagaoka, Japan.**

- **By time-lapse logging, we detected the CO_2 breakthrough and estimated CO_2 saturation history.**

- **By crosswell seismic tomography, we could recognize the CO_2 distribution in the aquifer.**

- **Using the final reservoir model of history matching, long-term fate of the injected CO_2 was predicted.**

- **The follow-up monitoring in Nagaoka will be continued till 2007.**