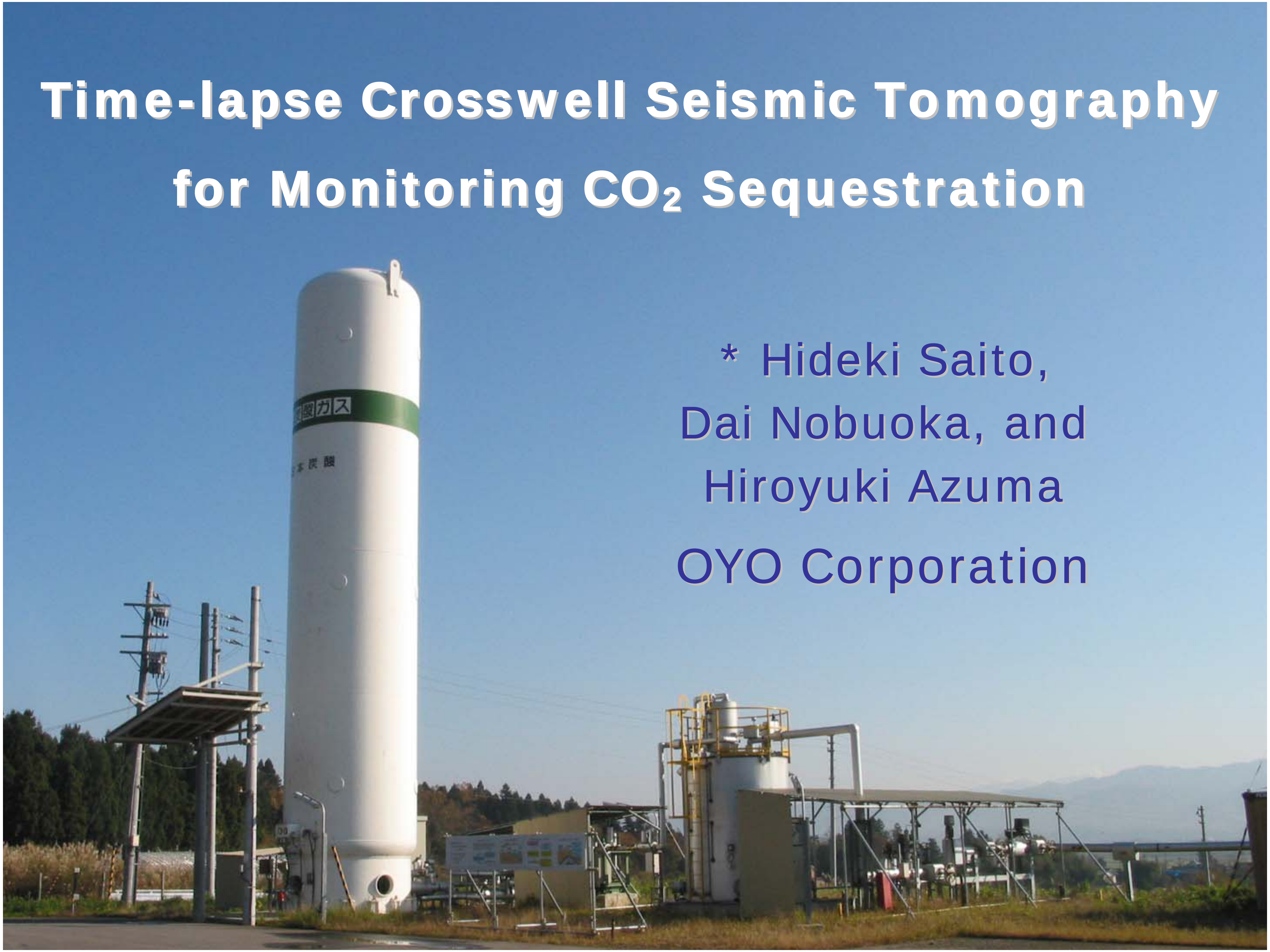
Time-lapse Crosswell Seismic Tomography for Monitoring CO_2 Sequestration

* Hideki Saito,
Dai Nobuoka, and
Hiroyuki Azuma

OYO Corporation



Contents

1. Borehole arrangement

2. Method of seismic tomography

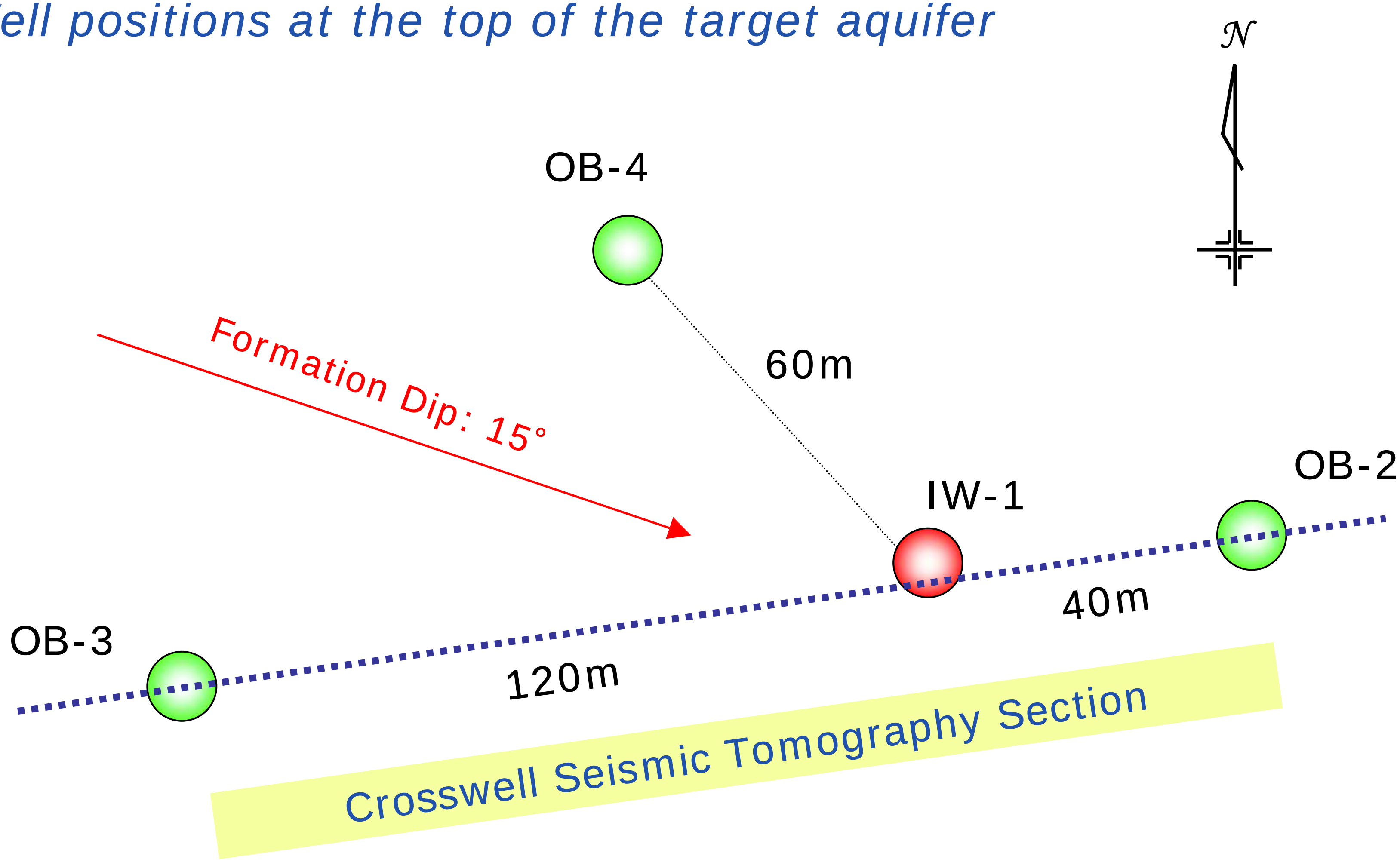
3. Time-lapse tomography

4. Numerical experiments

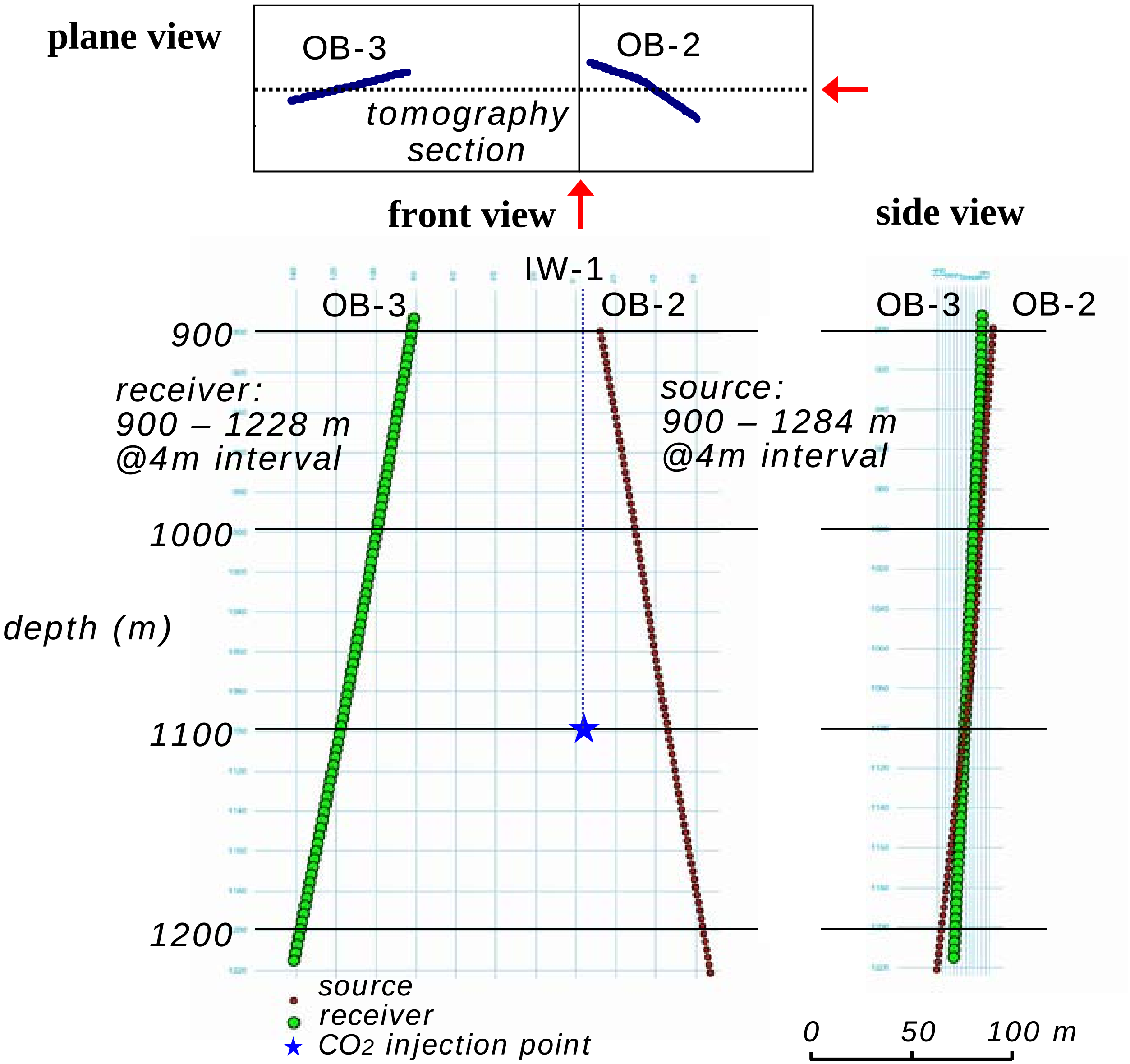
5. Conclusions

Borehole Arrangement

Well positions at the top of the target aquifer



Source – Receiver Geometry

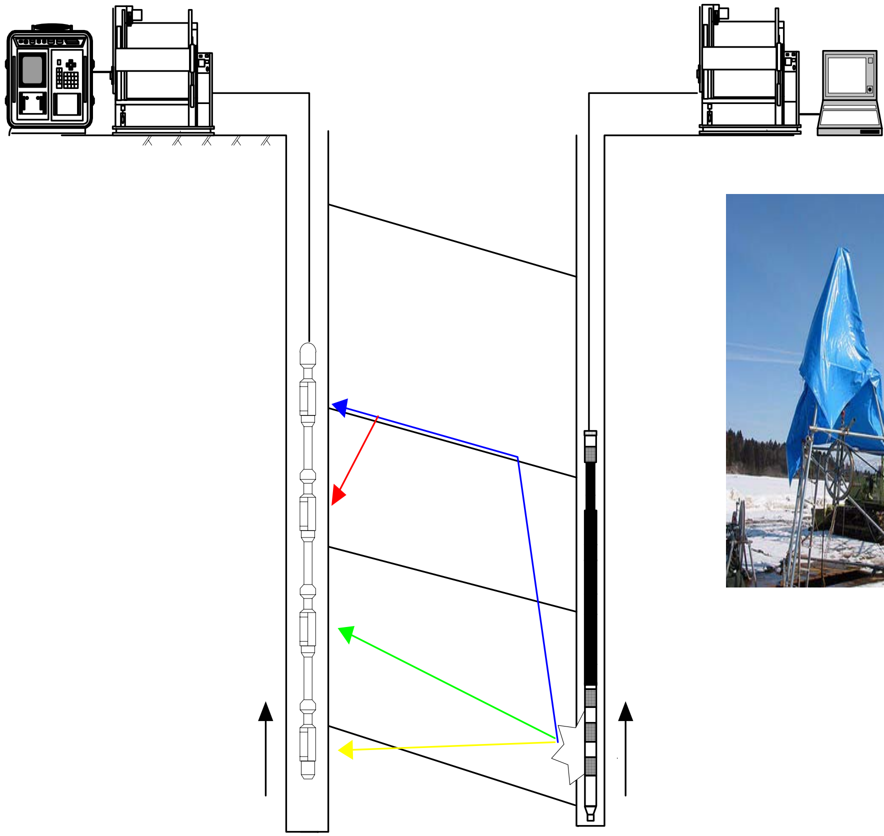


Data Acquisition System

Energy Source: Oyo's OWS

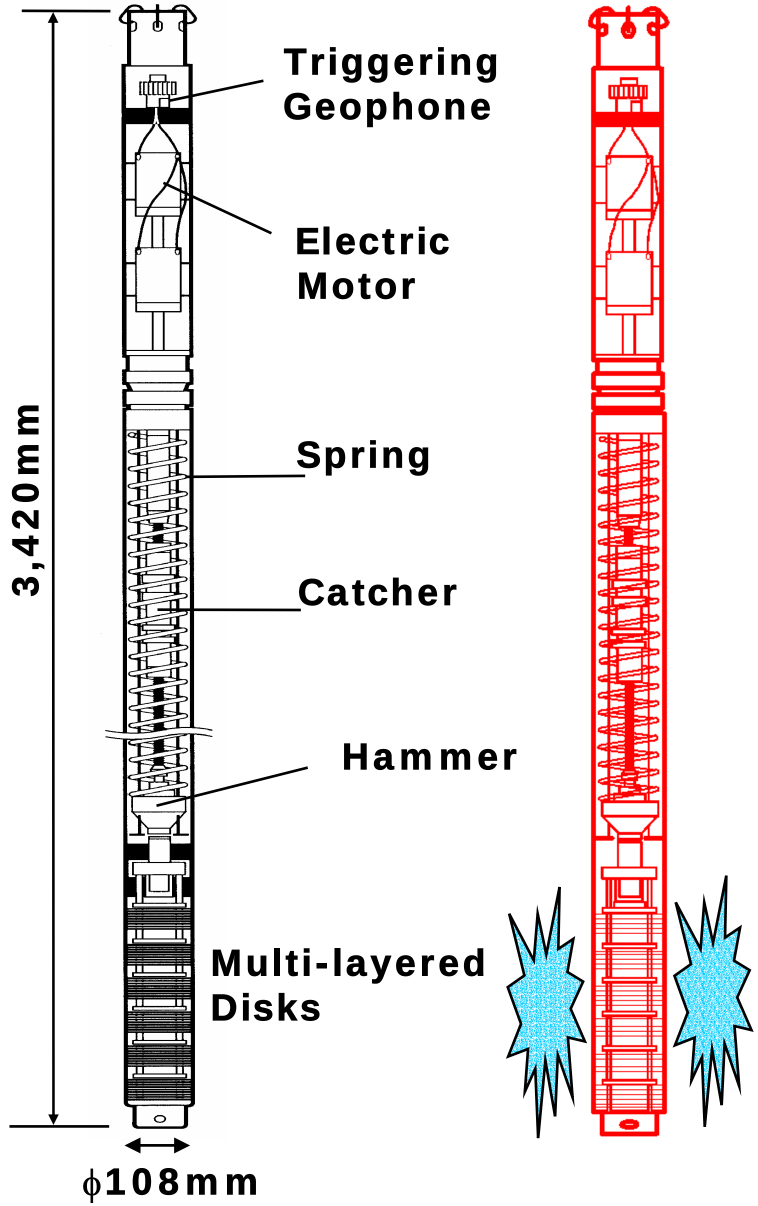
Receiver: 24-channel hydrophone cable

Data acquisition: Oyo's DAS-1 (24bit A/D)

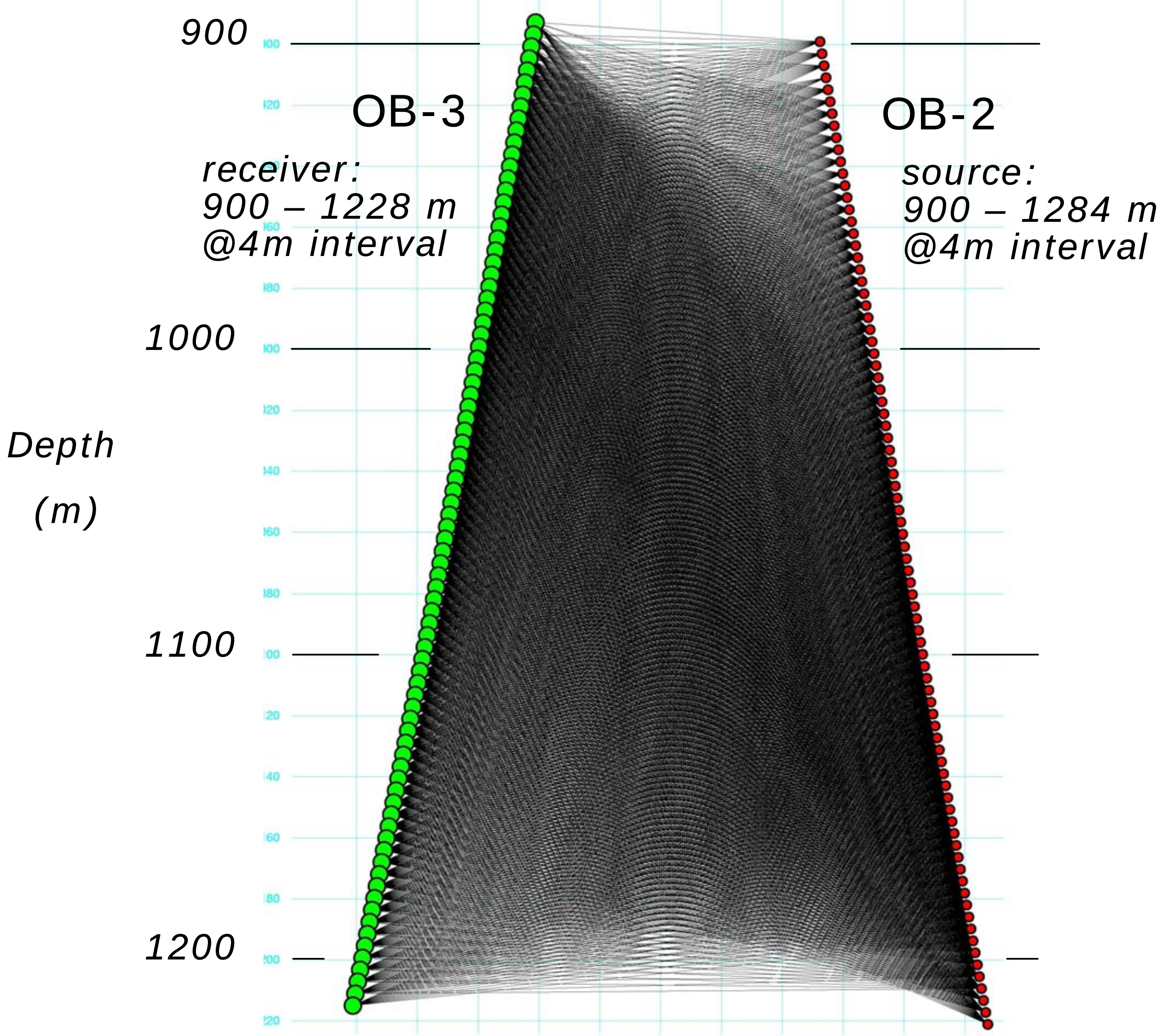


Oyo's OWS Downhole Source

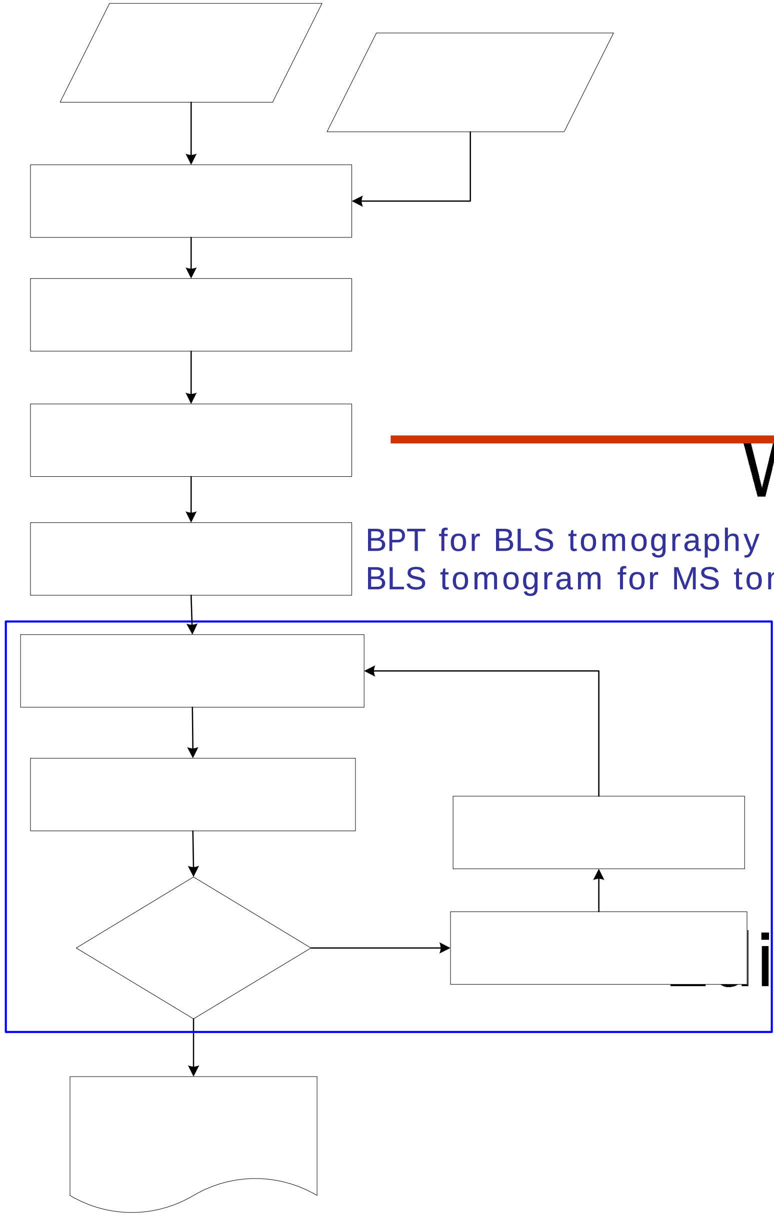
- Diameter:	108mm
- Length:	3,420mm
- Weight:	150kg
- Pressure:	30MPa (3,000m)
- Temperature:	150° C
- Wire line:	7 conductor armored cable
- Cable head:	Gearheart type 1-1/2" 7 conductor head
- Energy	max. 3,000J/shot
- Shot interval:	20 – 60 sec
- Electric power:	700W(AC100V)
- Trigger sensor:	Geophone



Observation Pattern: Source-Receiver Combinations



Flow Chart of Tomography

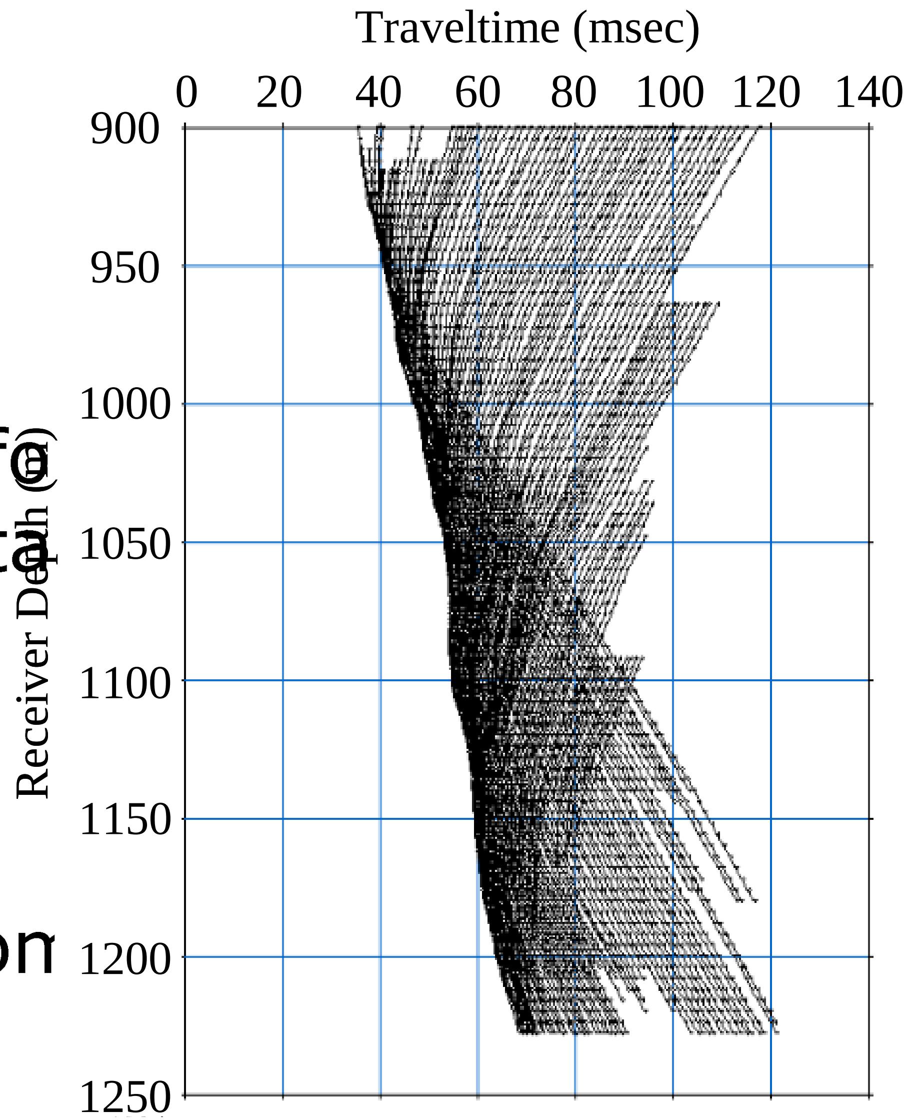


BPT for BLS tomography
BLS tomogram for MS tomography

Wavefo
Data

it Geon

ry

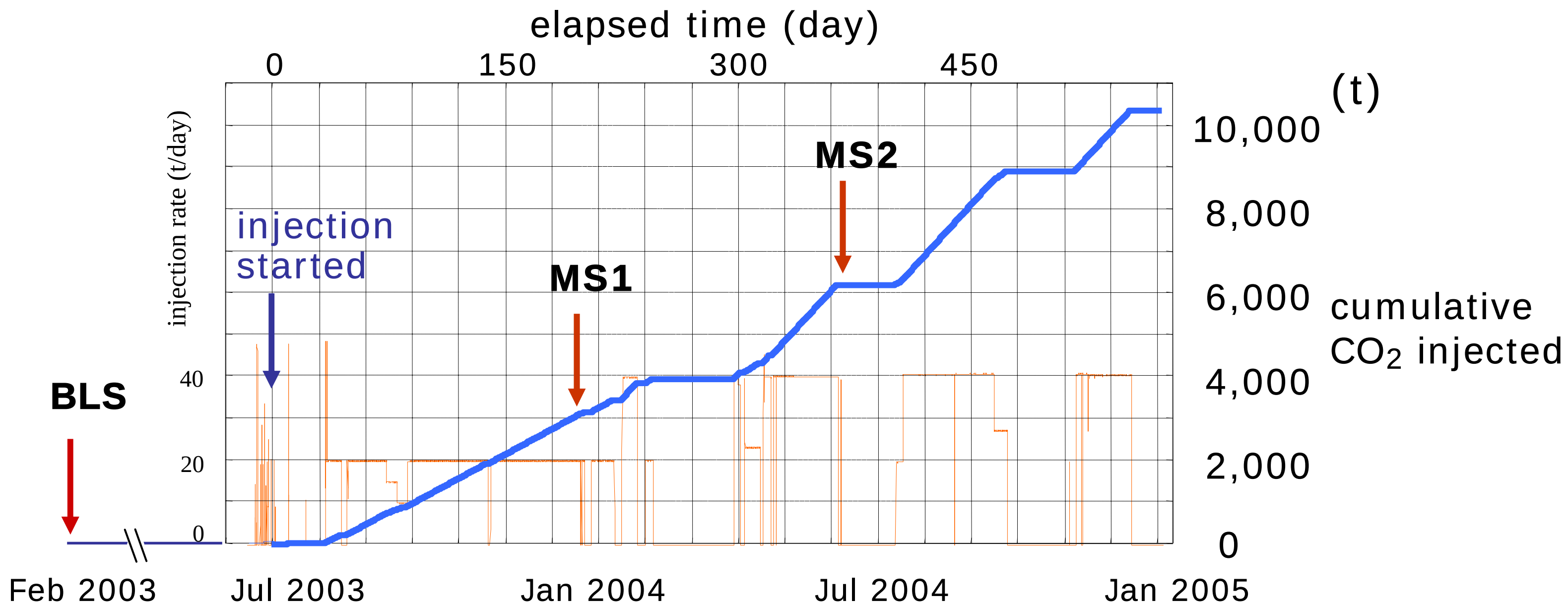


BLS Traveltime Curves

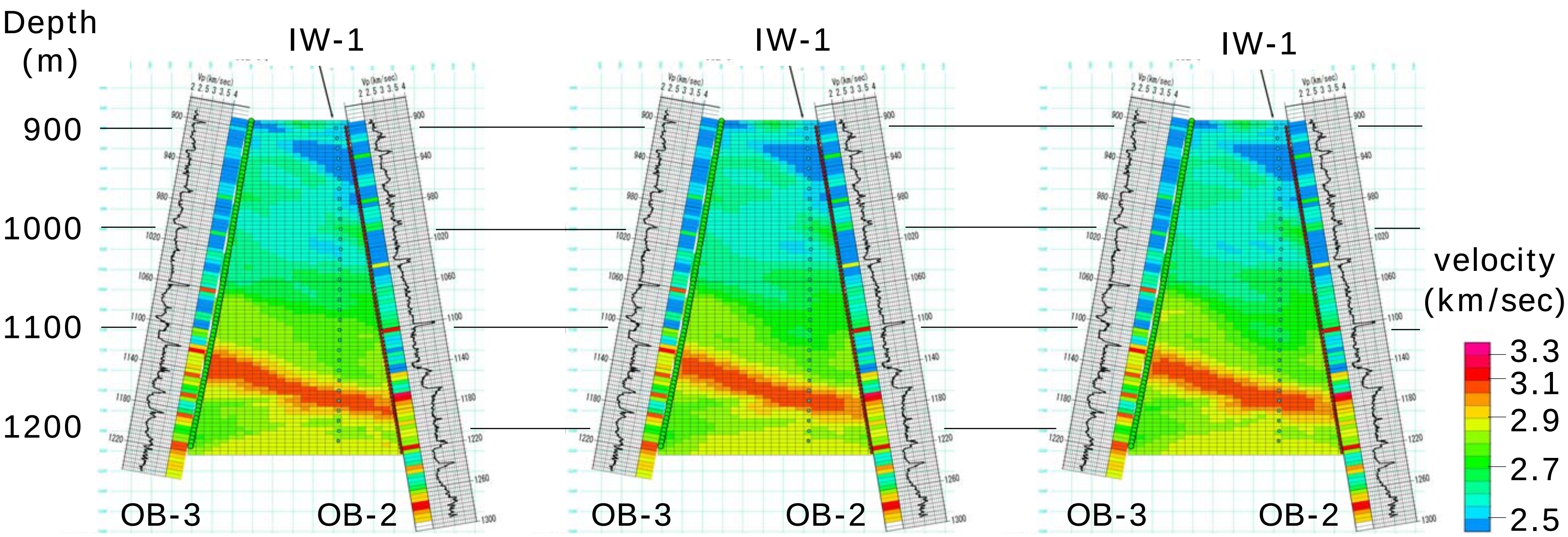
Pick Up
First Arrival Time

Time-lapse Crosswell Seismic Tomography

baseline survey	BLS	before injection	Feb 2003	
			Jul 2003	injection started
monitoring surveys	MS1	3,200 t-CO_2	Jan 2004	
	MS2	6,200 t-CO_2	Jul 2004	

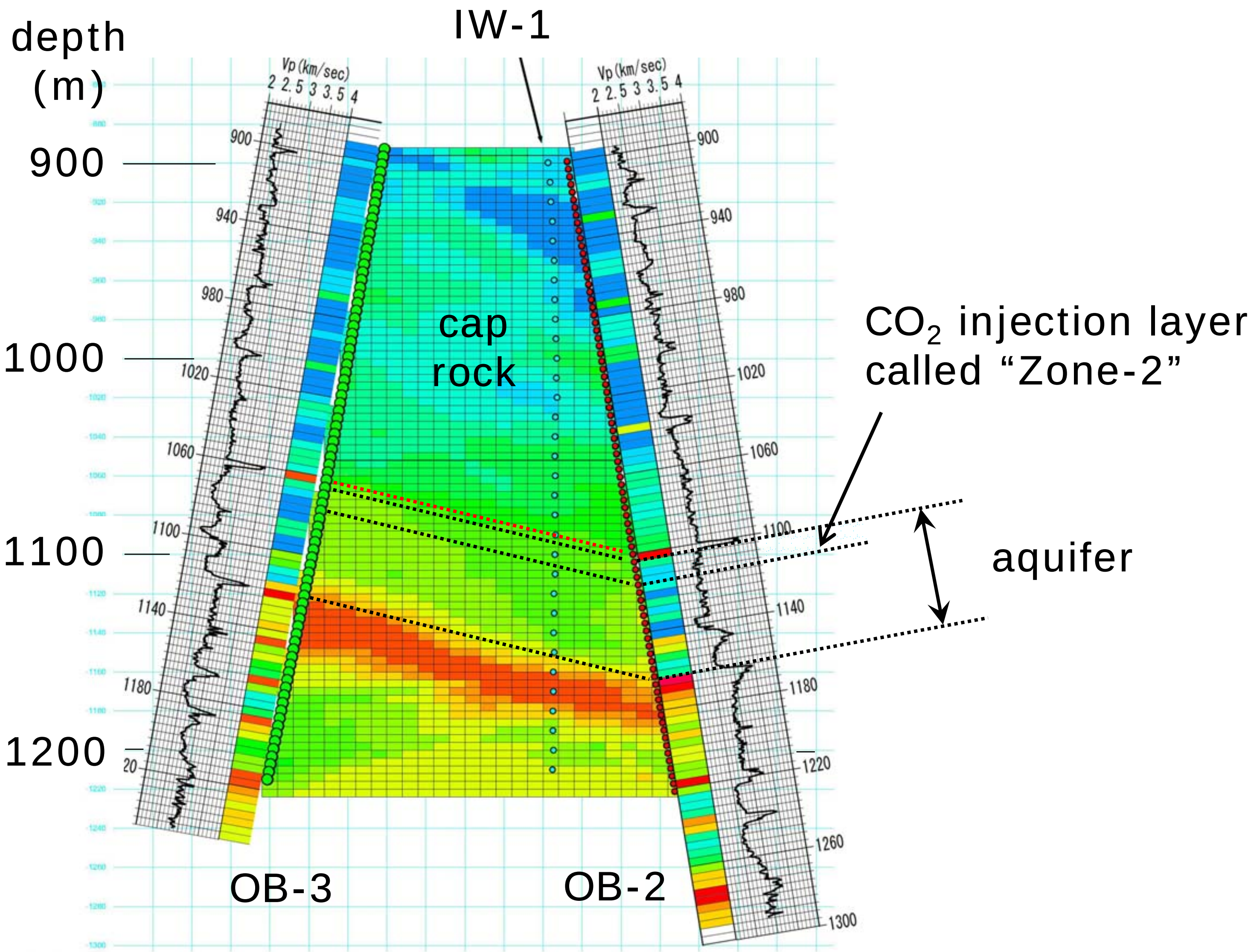


Reconstructed Velocity Tomograms

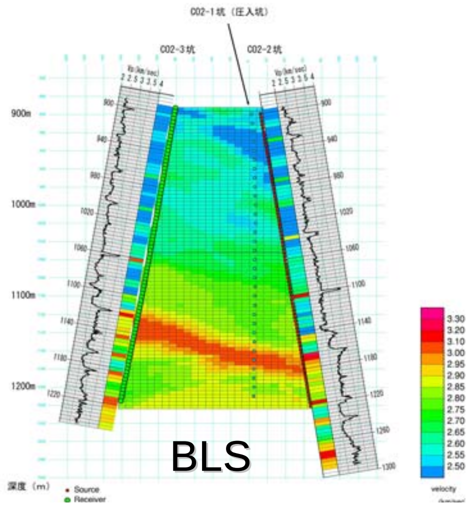


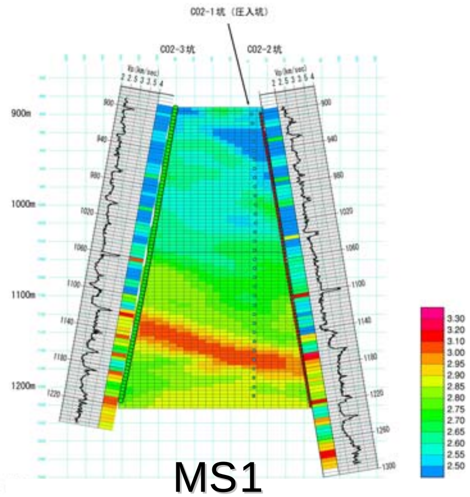
BLS	MS1	MS2
before injection	3,200 t-CO_2	6,200 t-CO_2

BLS Tomogram

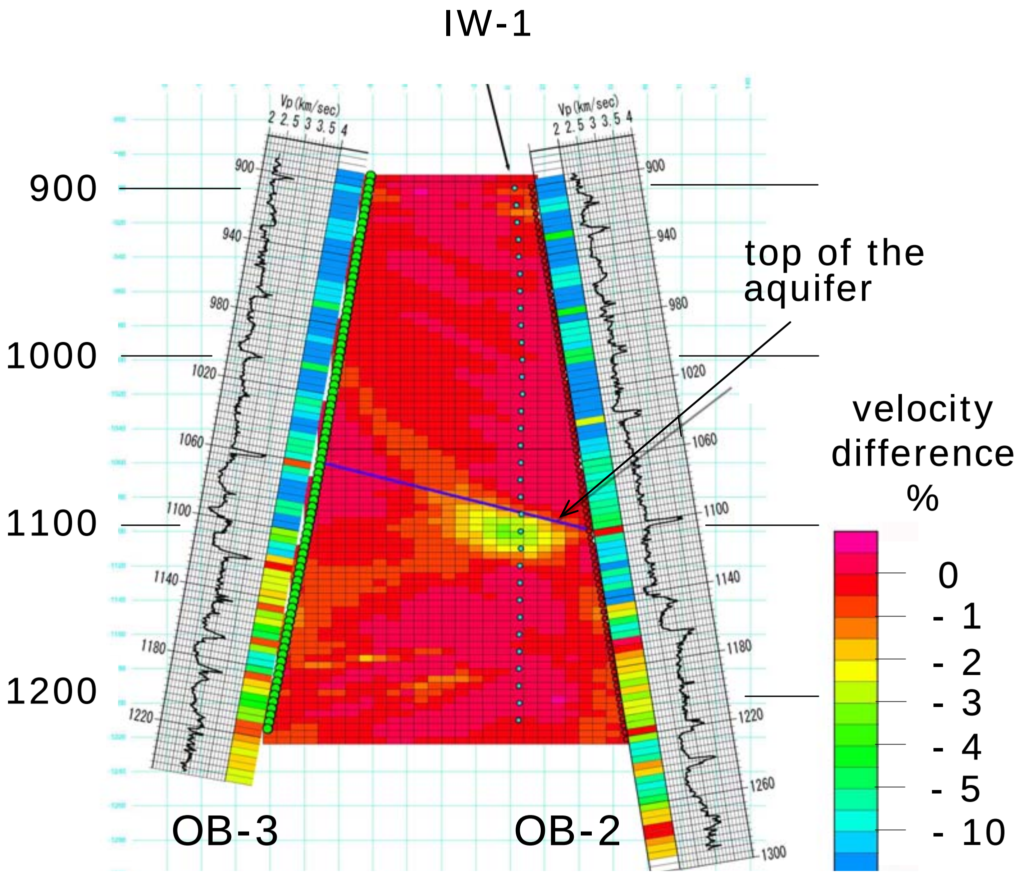


Velocity Difference Tomogram (BLS / MS1)





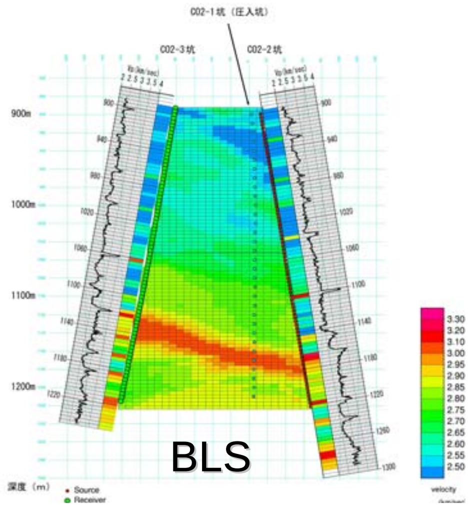
3,200 t -CO_2



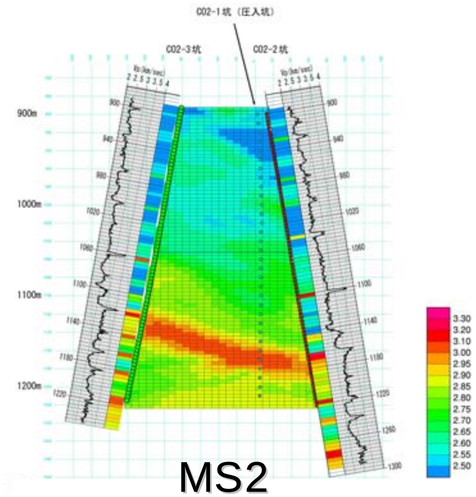
max. velocity reduction = 3.0 %

Velocity difference = $(V_{MS1}-V_{BLS}) / V_{BLS}$

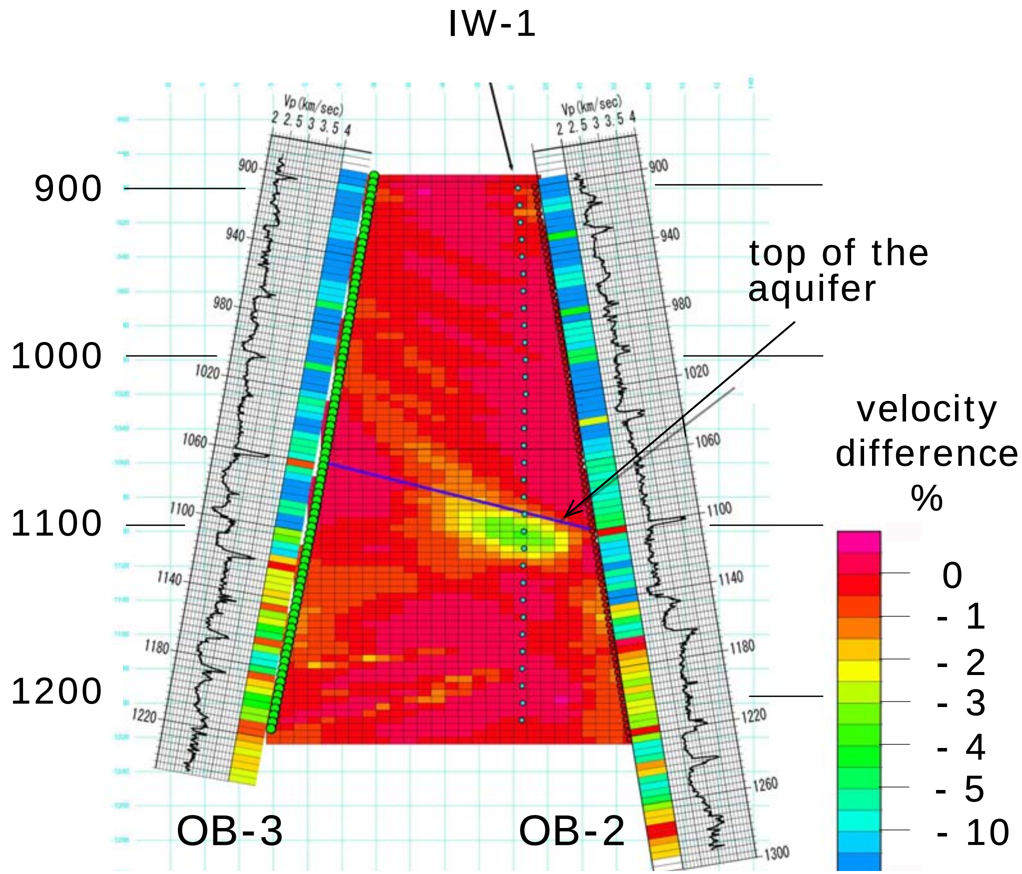
Velocity Difference Tomogram (BLS / MS2)



BLS



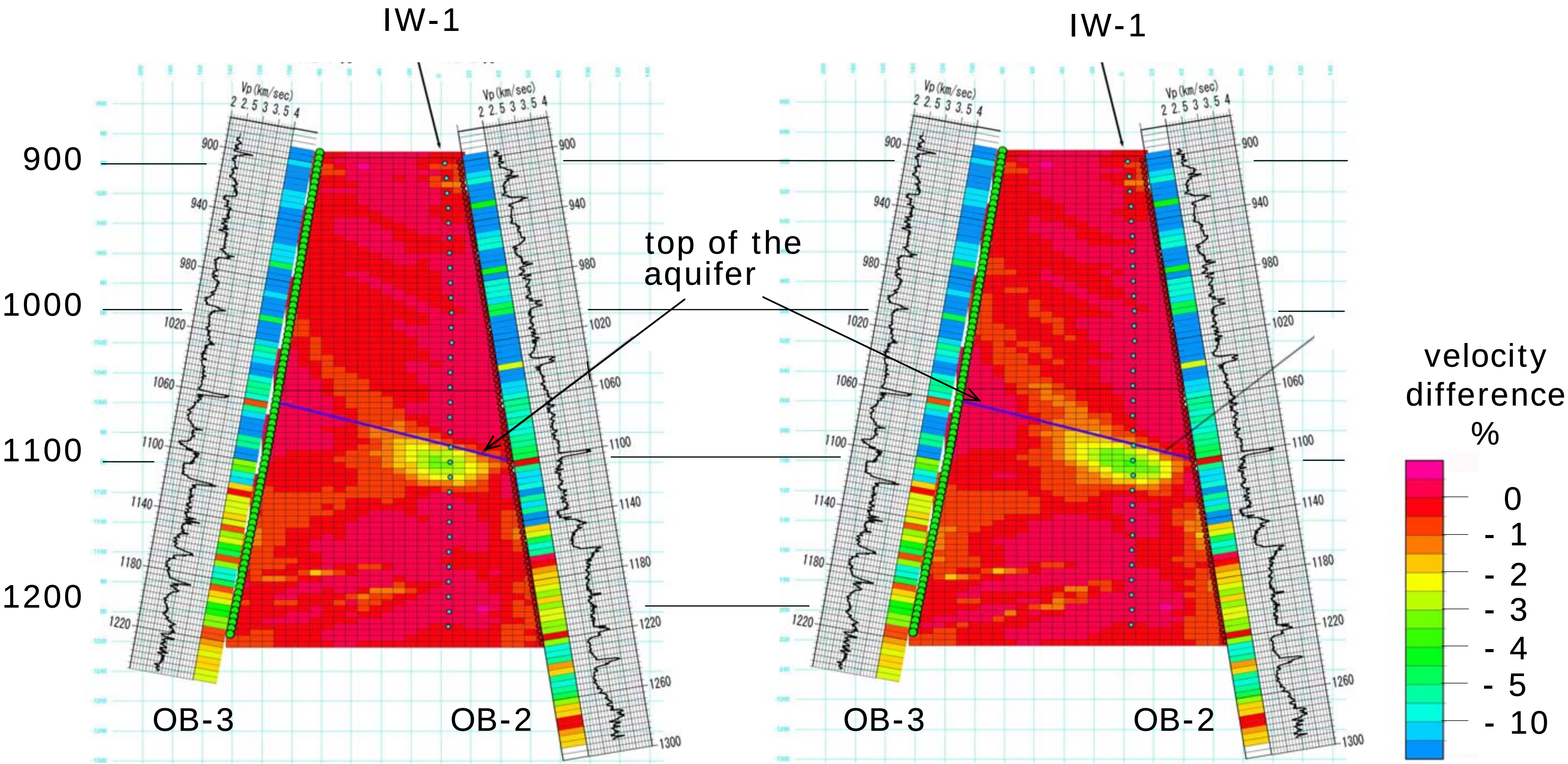
MS2
6,200 t -CO_2



max. velocity reduction = 3.5 %

Velocity difference = $(V_{MS2}-V_{BLS}) / V_{BLS}$

Velocity Reduction



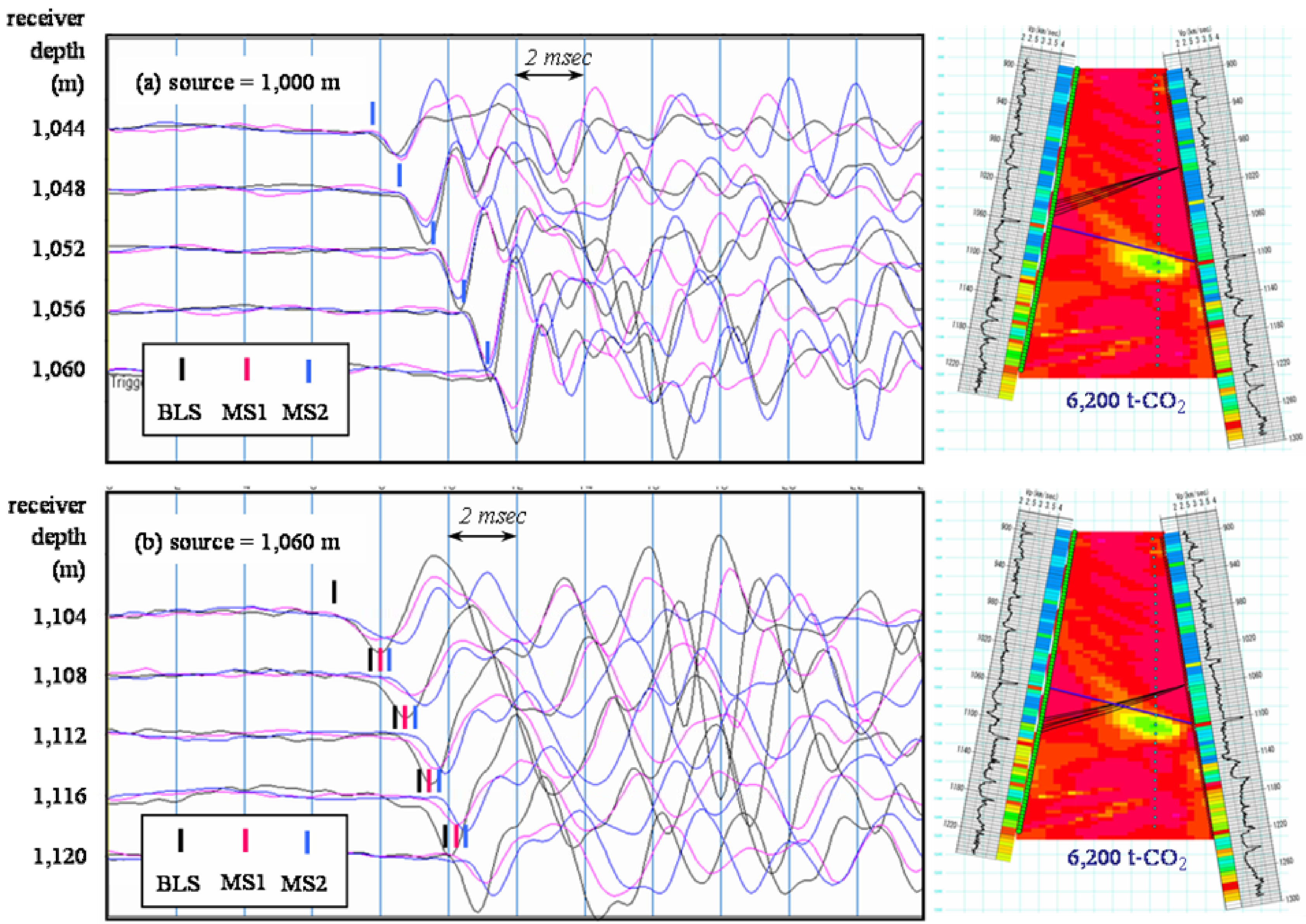
MS1: 3,200 t-CO_2

MS2: 6,200 t-CO_2

max. velocity reduction = 3.0 %

max. velocity reduction = 3.5 %

Traveltime Shift

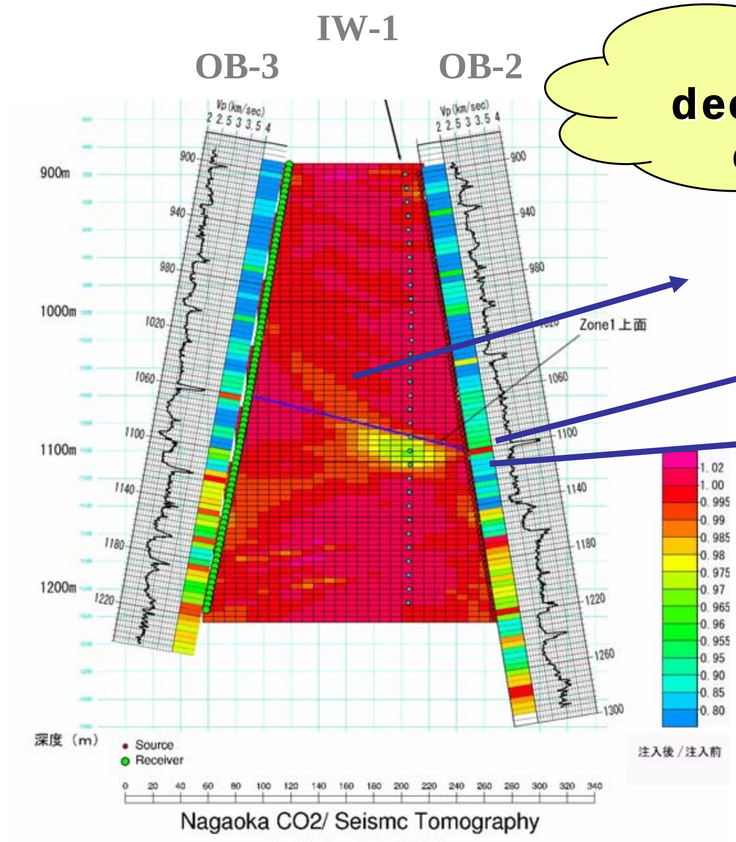


Contradictions

Velocity decrease in the cap rock ?

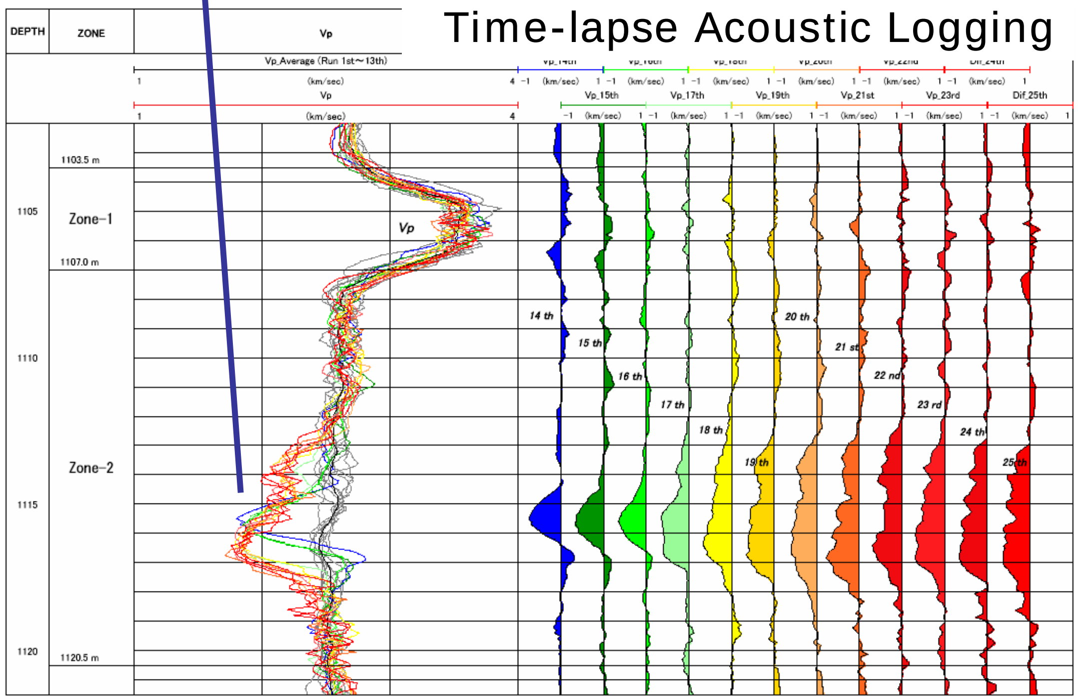
No breakthrough ?

Small velocity reduction ?

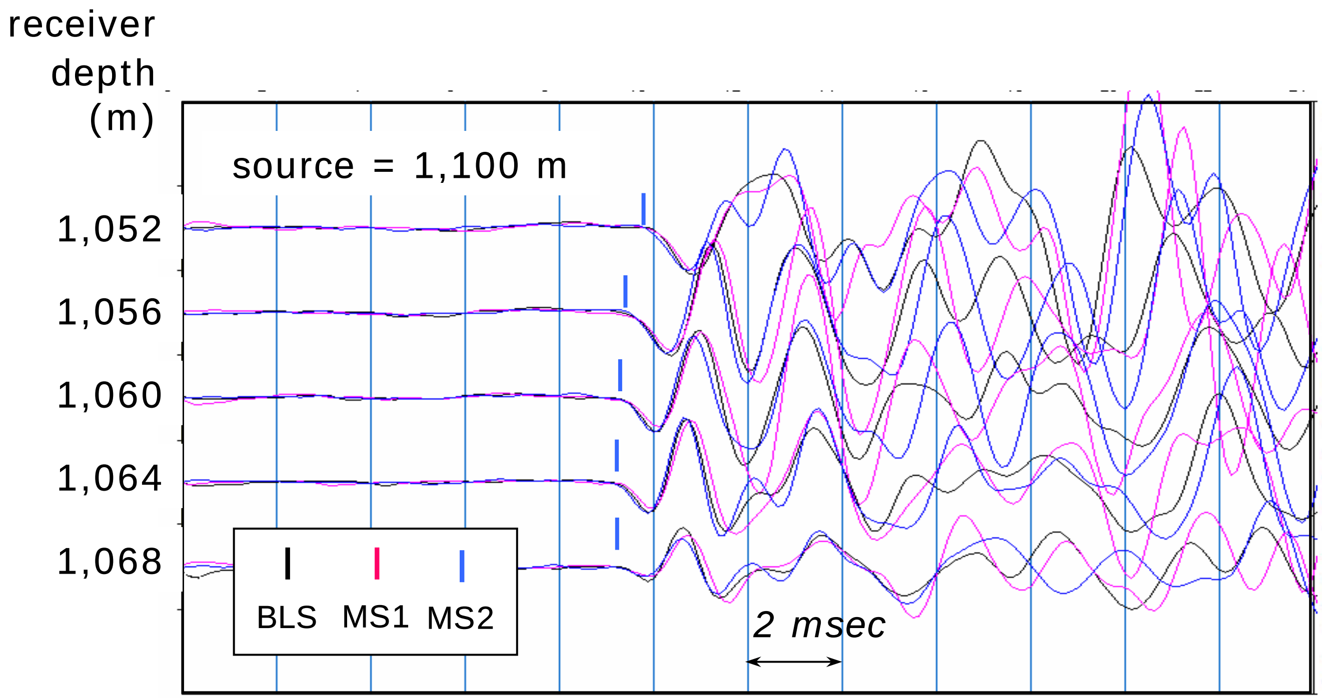


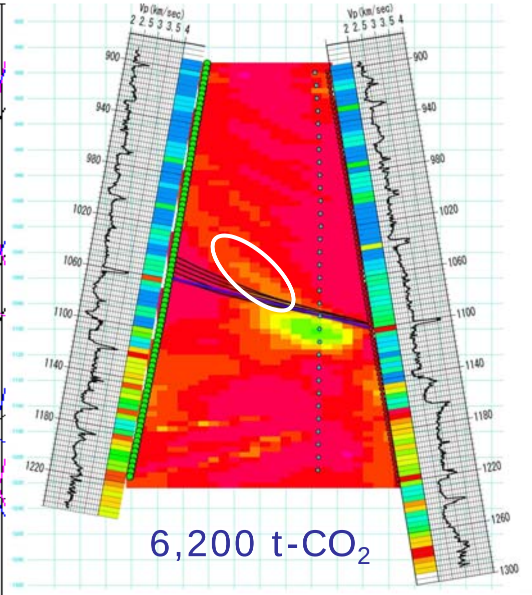
Velocity difference tomogram

Time-lapse Acoustic Logging



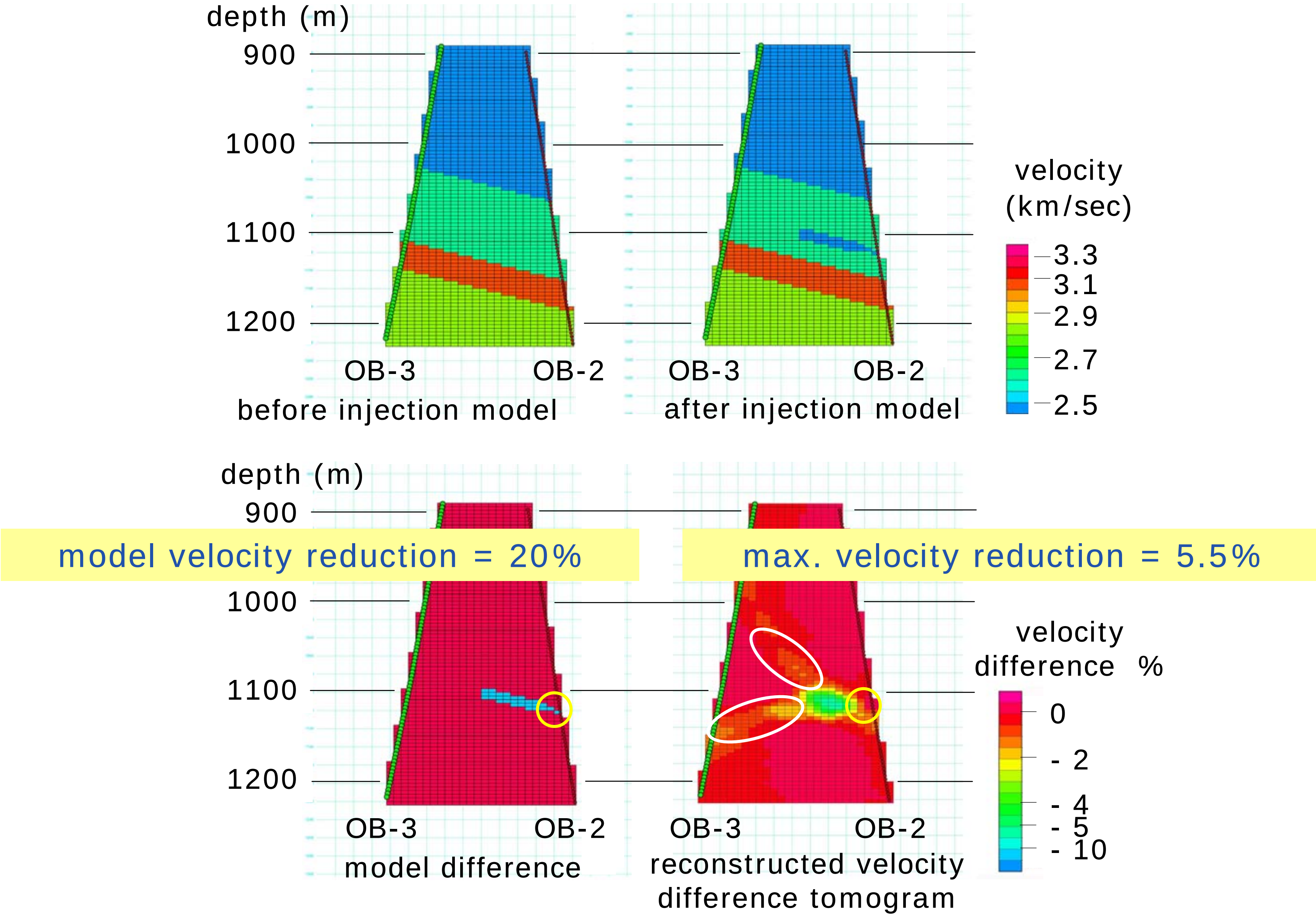
Evidence of Artifact





The velocity anomaly extending into the cap rock did not produce any traveltime delays for rays passing through the area. This apparent velocity anomaly must be an artifact or ghost.

Numerical Experiments



Conclusions

The distribution of CO_2 injected into the aquifer can be imaged as area of velocity reduction.

The velocity reduction was found to be 3.5% for MS2 (6,200 t-CO_2 injected), though the value obtained from acoustic logging was more than 20%. Judging from the result of numerical experiment, actual velocity reduction could be much larger than the 3.5% observed in MS2 velocity difference tomogram.

Although some anomalous velocity reduction zones were observed, the numerical experiments revealed that those anomalies must be artifacts or ghosts.

The velocity determination in a thin, low-velocity layer is one of the basic problems of traveltime tomography. However, some sophisticated inversion schemes (e.g. adequate constraints) can solve the problem.

Acknowledgments

This project is funded by Ministry of Economy, Trade and Industry (METI) of Japan.