Tomakomai CCS Demonstration Project

- Project Update -

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UT-CCS5
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Objective and tasks of Tomakomai CCS Demonstration Project

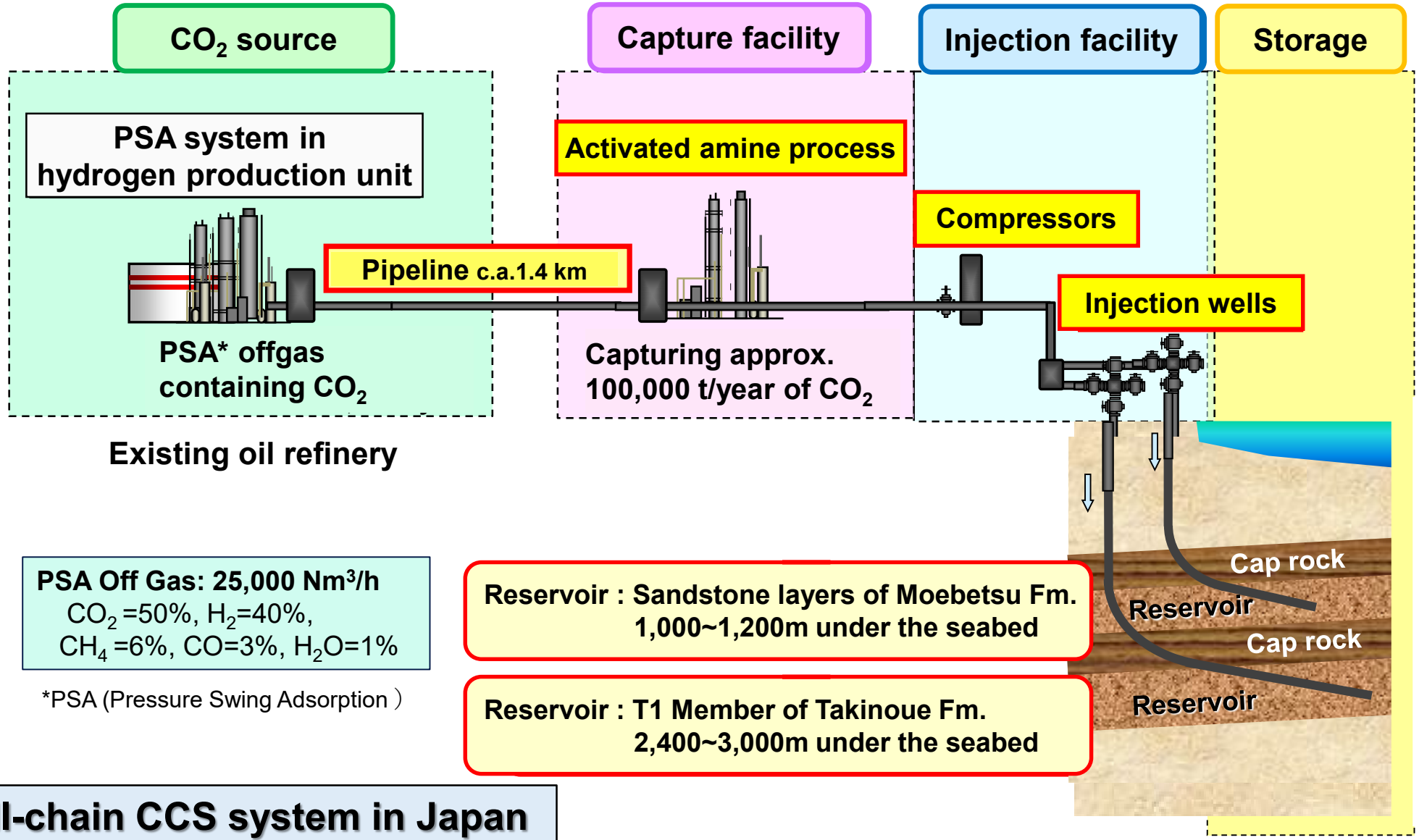
Objective

- ◆Develop practical CCS technology by around 2020

Tasks

- ◆Demonstrate full-chain CCS system from capture to storage
- ◆Confirm existing technologies adopted in the system work properly and efficiently
- ◆Demonstrate CCS system is safe and reliable
- ◆ Remove concerns about earthquakes by the data collected;
  - No influence by natural earthquakes on CO_2 stored
  - No perceptible earth tremors induced by CO_2 injection
- ◆Disclose project information & data and enhance understanding of CCS by local residents
- ◆Clearly define areas to be improved or solved toward commercialization

Schematic Diagram of Tomakomai CCS Demonstration Project



PSA Off Gas: 25,000 Nm^3/h
CO_2 =50%, H_2=40%,
CH_4 =6%, CO=3%, H_2O=1%

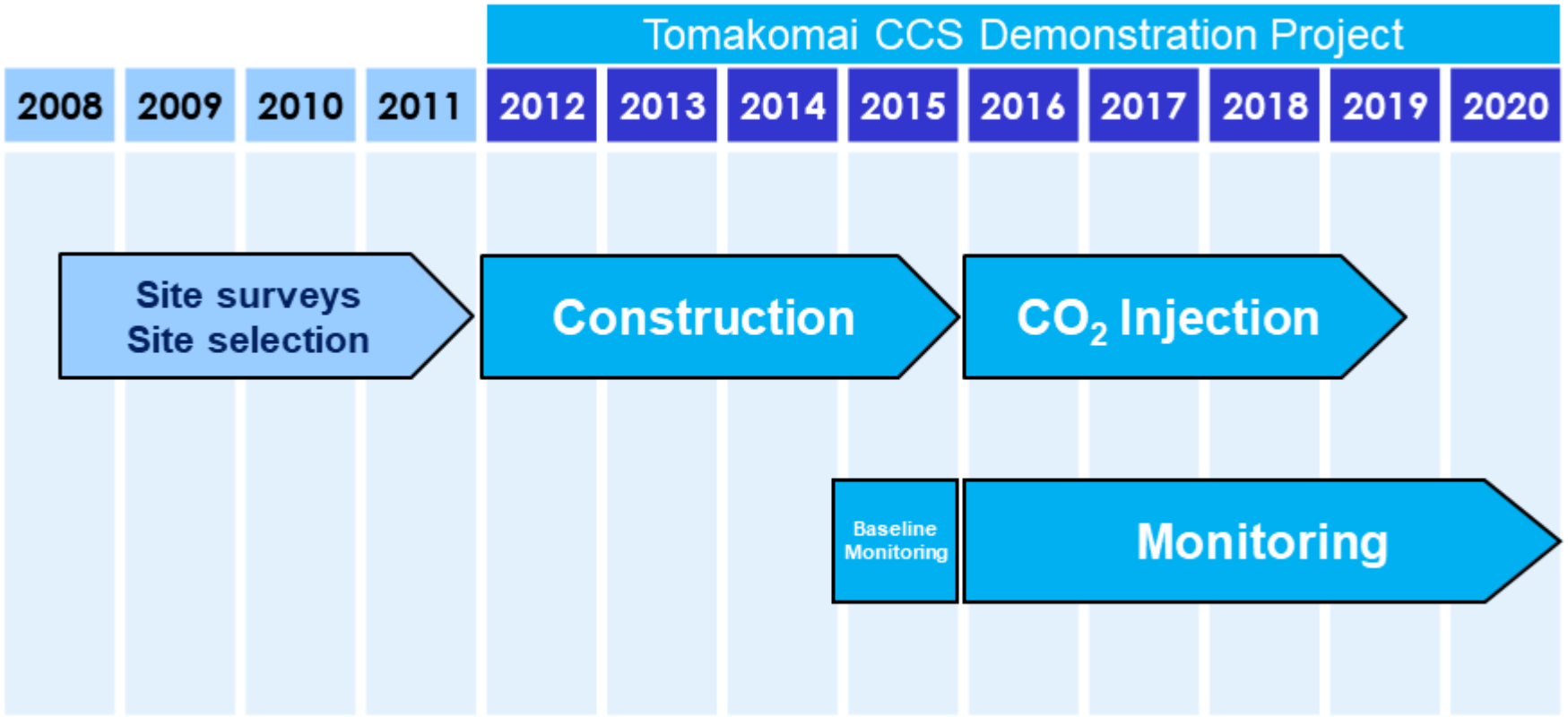
*PSA (Pressure Swing Adsorption）

Reservoir : Sandstone layers of Moebetsu Fm.
1,000~1,200m under the seabed

Reservoir : T1 Member of Takinoue Fm.
2,400~3,000m under the seabed

◆ **First full-chain CCS system in Japan from capture to storage**

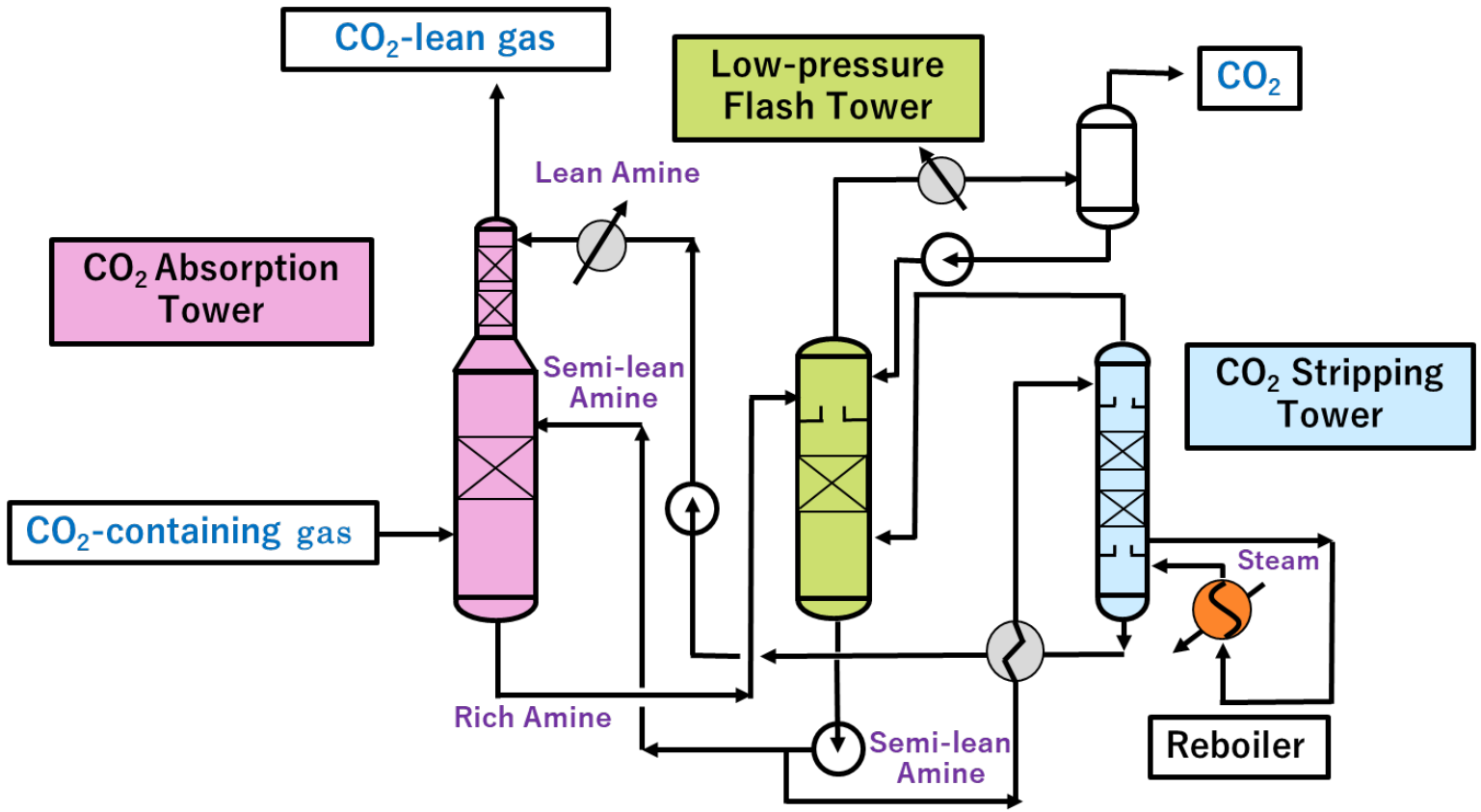
Schedule of Tomakomai CCS Demonstration Project



- Target of 300,000 tonnes of CO_2 injection achieved on November 22, 2019
- Monitoring operations are being continued

Years are in Japanese Fiscal Years (April of calendar year to March of following year)

CO_2 Capture Process



- In LPFT (Low-pressure Flash Tower), CO_2 is stripped by depressurization; thermal energy of steam of CO_2 Stripping Tower is also utilized to strip CO_2
- Major part of semi-lean amine solution from LPFT is returned to CO_2 Absorption Tower for CO_2 absorption; as only the remaining minor part of semi-lean amine solution is sent to CO_2 Stripping Tower, reboiler heat required can be reduced

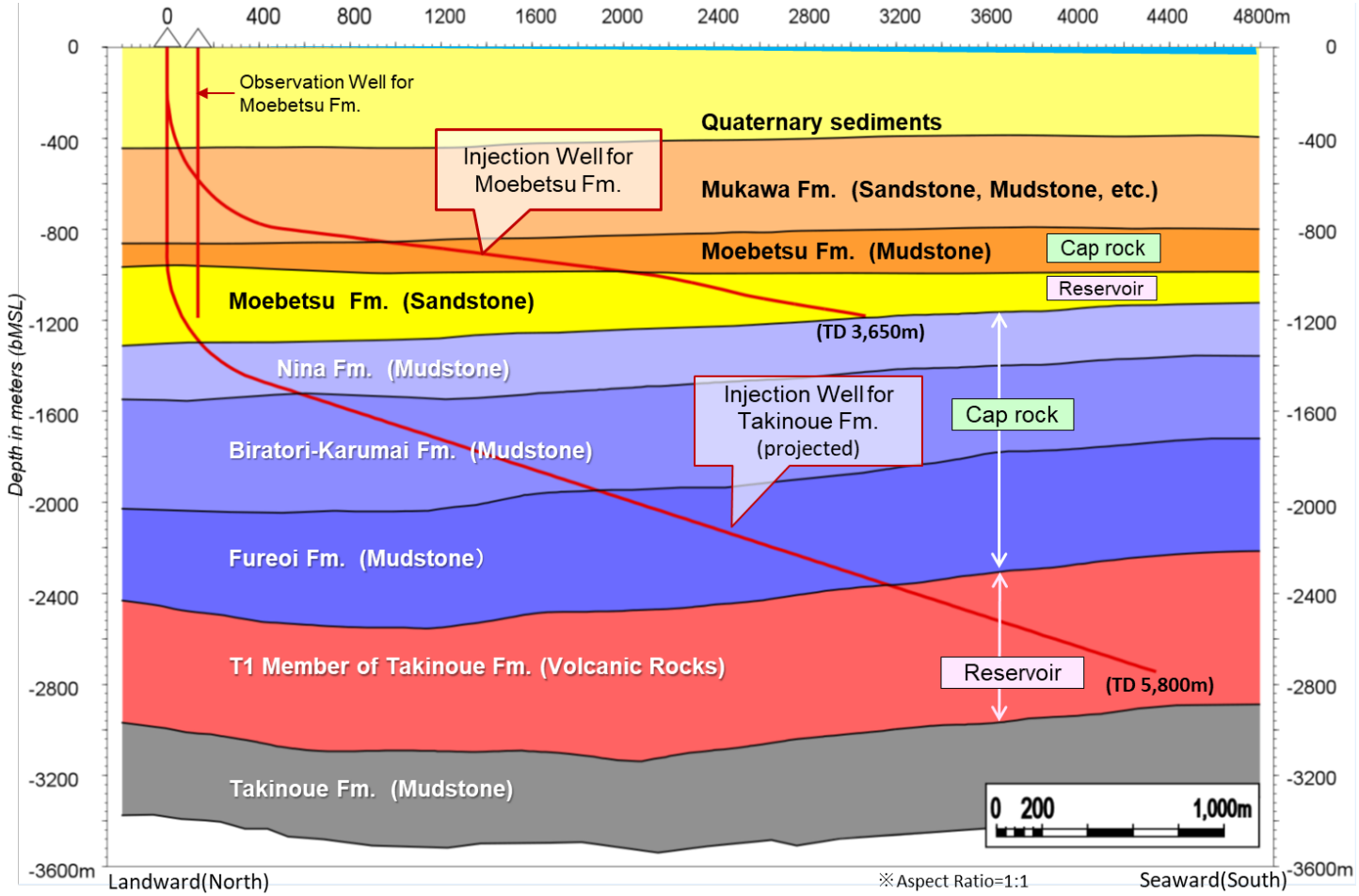
Loading Factor:98% (100%=25.3 t-CO_2/h)

CO_2 recovery rate %	99.97
Reboiler duty (GJ/t-CO_2)	0.88
Heat energy [1] (GJ/t-CO_2)	0.98
Electric energy (GJ/t-CO_2)	0.18
CO_2 capture energy [2] (GJ/t-CO_2)	1.16

Note 1) : Reboiler duty/steam boiler efficiency
Note 2) : Heat energy + Electric energy

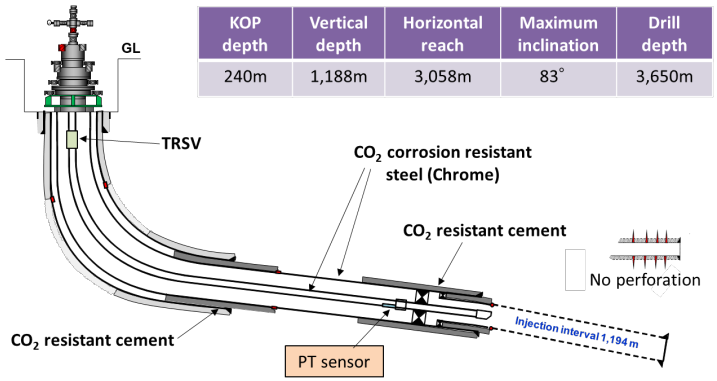
Onshore-to-offshore injection scheme

- Deviated CO_2 injection wells drilled from onshore into offshore reservoirs
  - Cost reduction of drilling, operation and maintenance
  - No disturbance on marine environment and harbor operation
- Injection interval length exceeding 1,100m to enhance injection efficiency

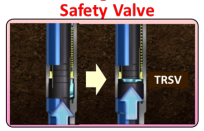


Injection well for Moebetsu Formation

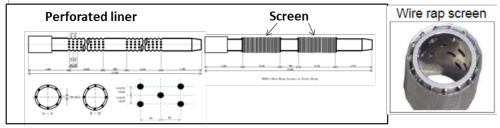
KOP depth	Vertical depth	Horizontal reach	Maximum inclination	Drill depth
240m	1,188m	3,058m	83°	3,650m



TRSV:Tubing-Retrievable Safety Valve

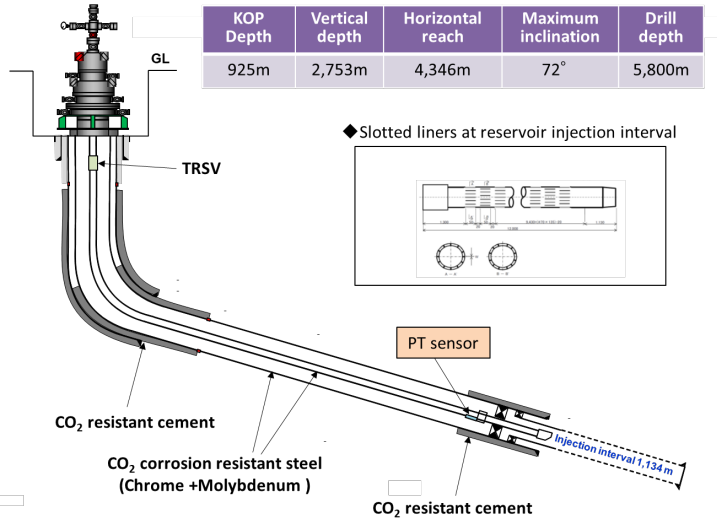


◆Perforated liner covered by screens at injection interval



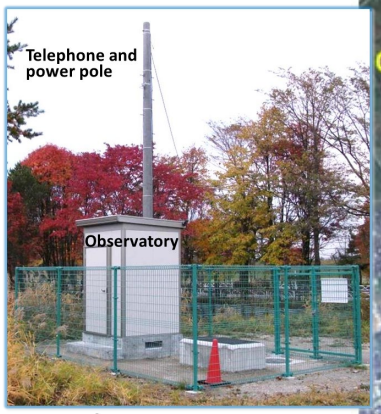
Injection well for Takinoue Formation

KOP Depth	Vertical depth	Horizontal reach	Maximum inclination	Drill depth
925m	2,753m	4,346m	72°	5,800m

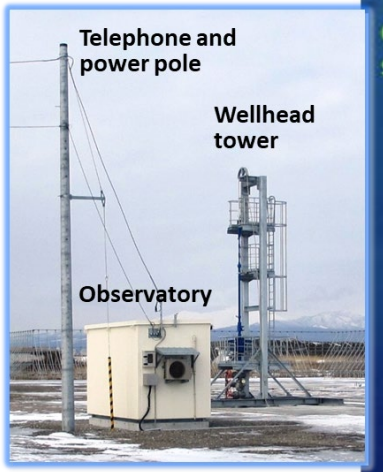


Layout of monitoring system

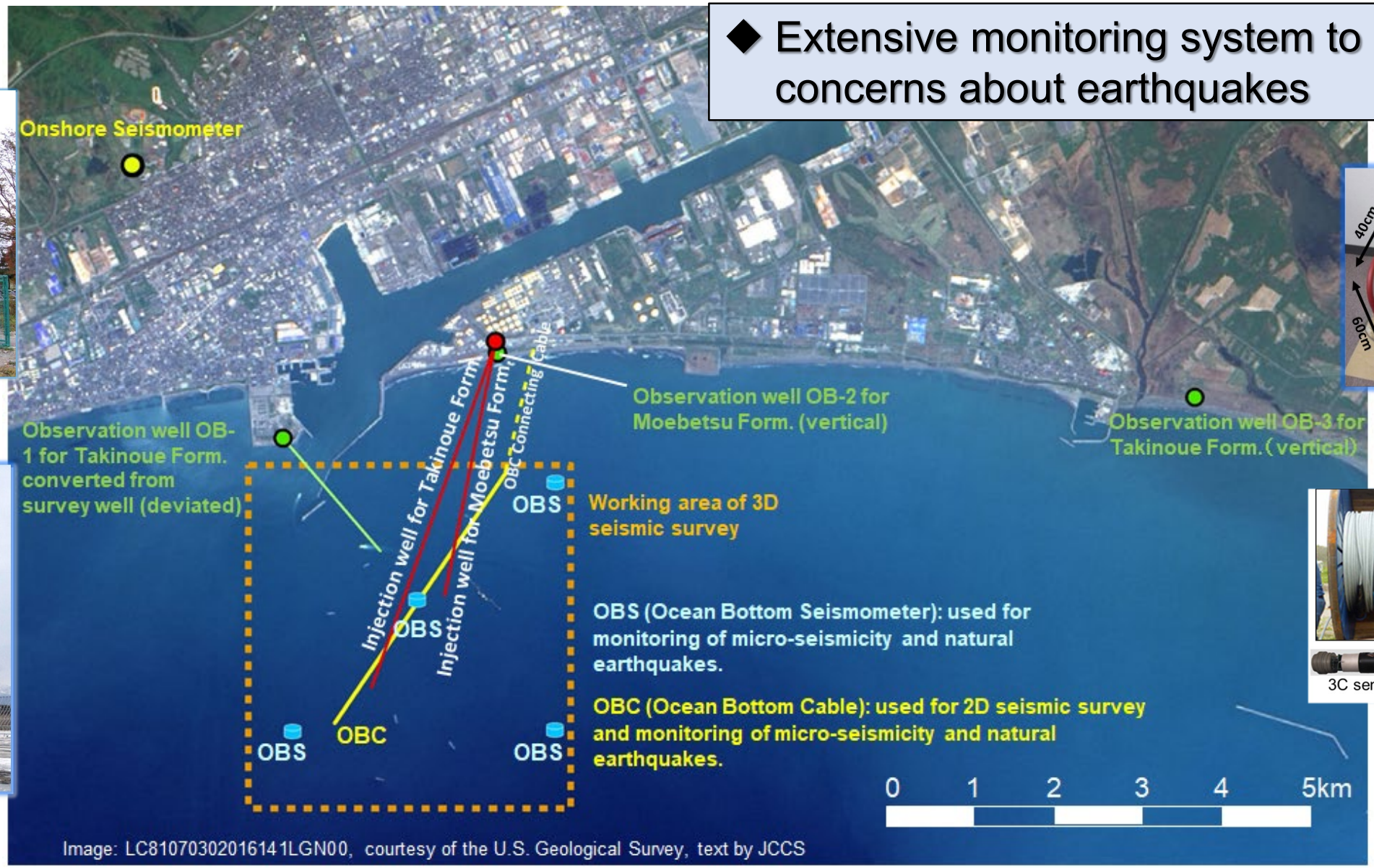
◆ Extensive monitoring system to address concerns about earthquakes



Onshore Seismic Station



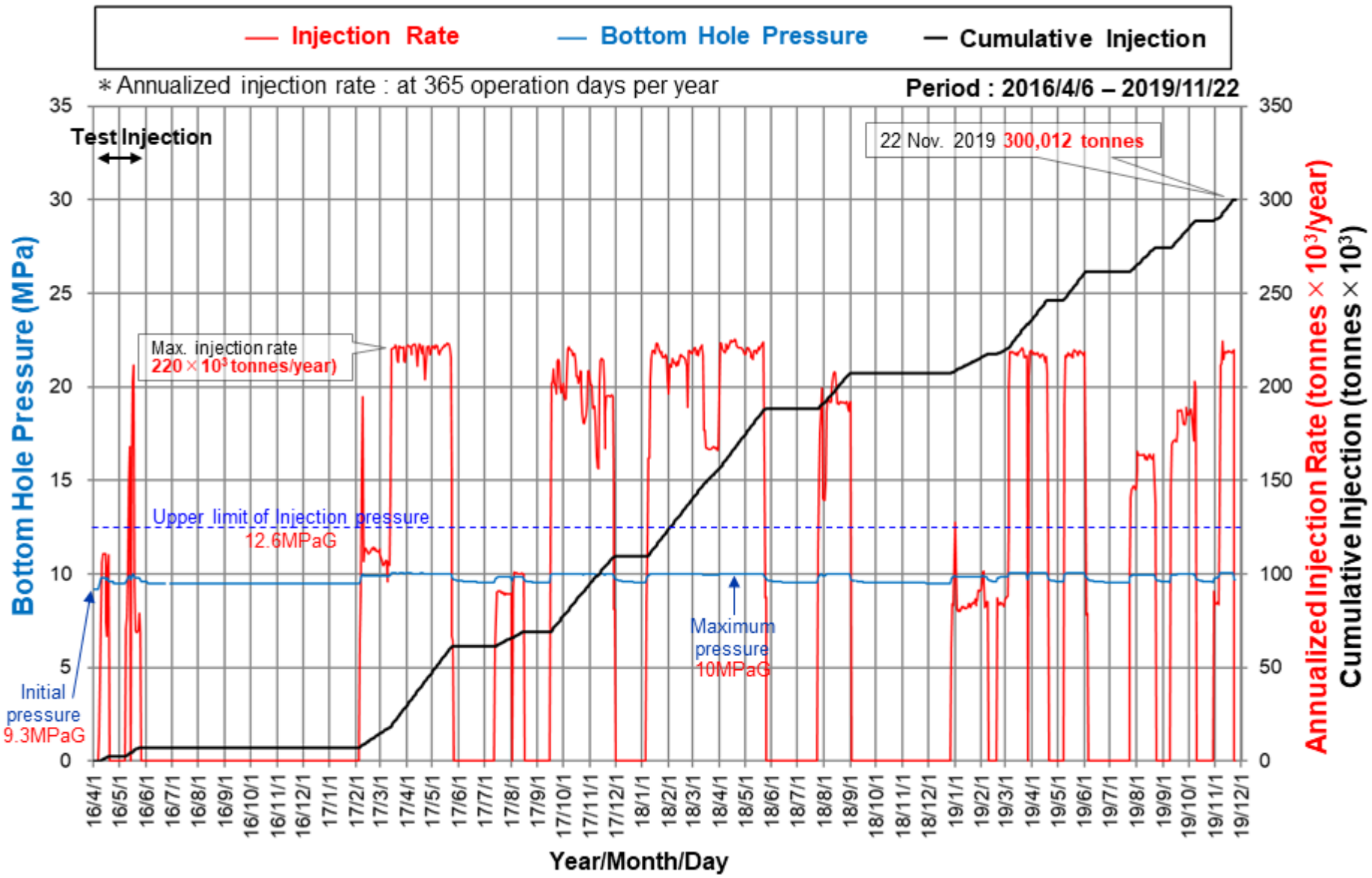
Observation well OB-1



OBS

OBC

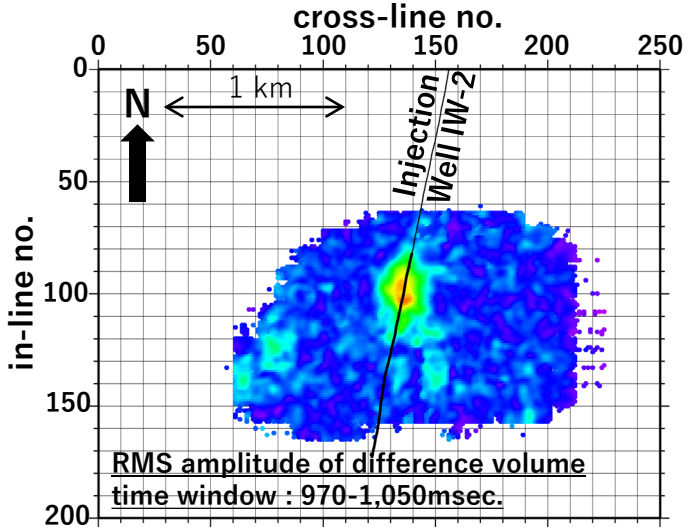
CO_2 Injection Record of Moebetsu Formation

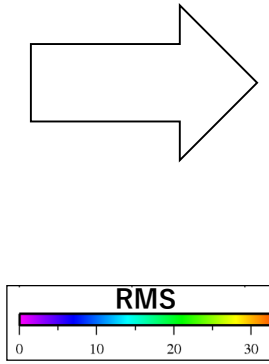


- Injection of 300,012 tonnes of CO_2 into Moebetsu Formation was achieved on Nov. 22, 2019
- Initial Pressure of Bottom Hole Pressure was 9.3MPaG
- Maximum Pressure of Bottom Hole Pressure was 10MPaG at maximum injection rate
- Maximum pressure was much lower than upper limit of injection pressure (12.6MPaG)

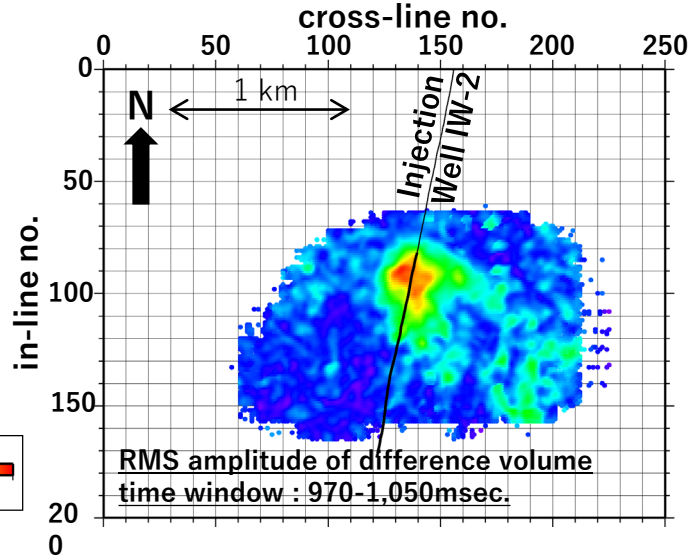
Results of 2nd & 3rd monitor surveys

2nd monitor survey (61,239 - 69,070 tonnes; JFY2017)

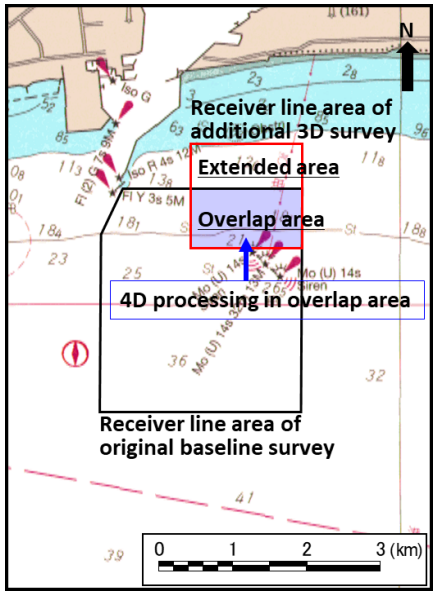




3rd monitor survey (207,209 tonnes; JFY2018)

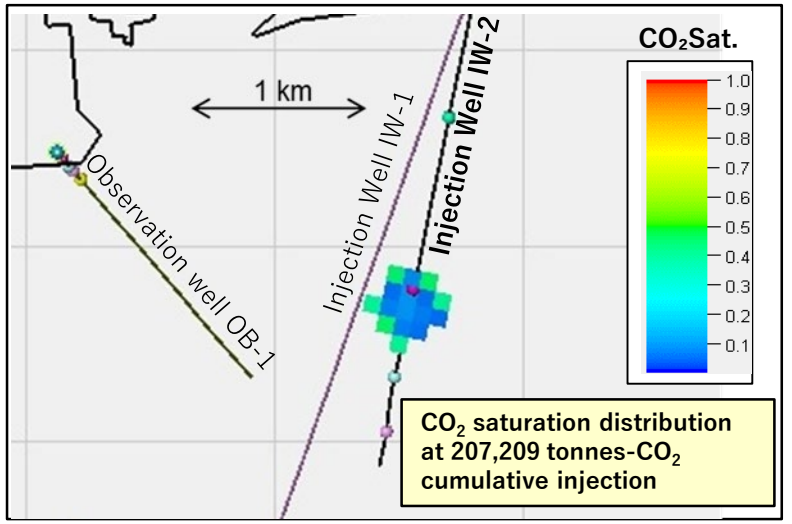


Receiver line area

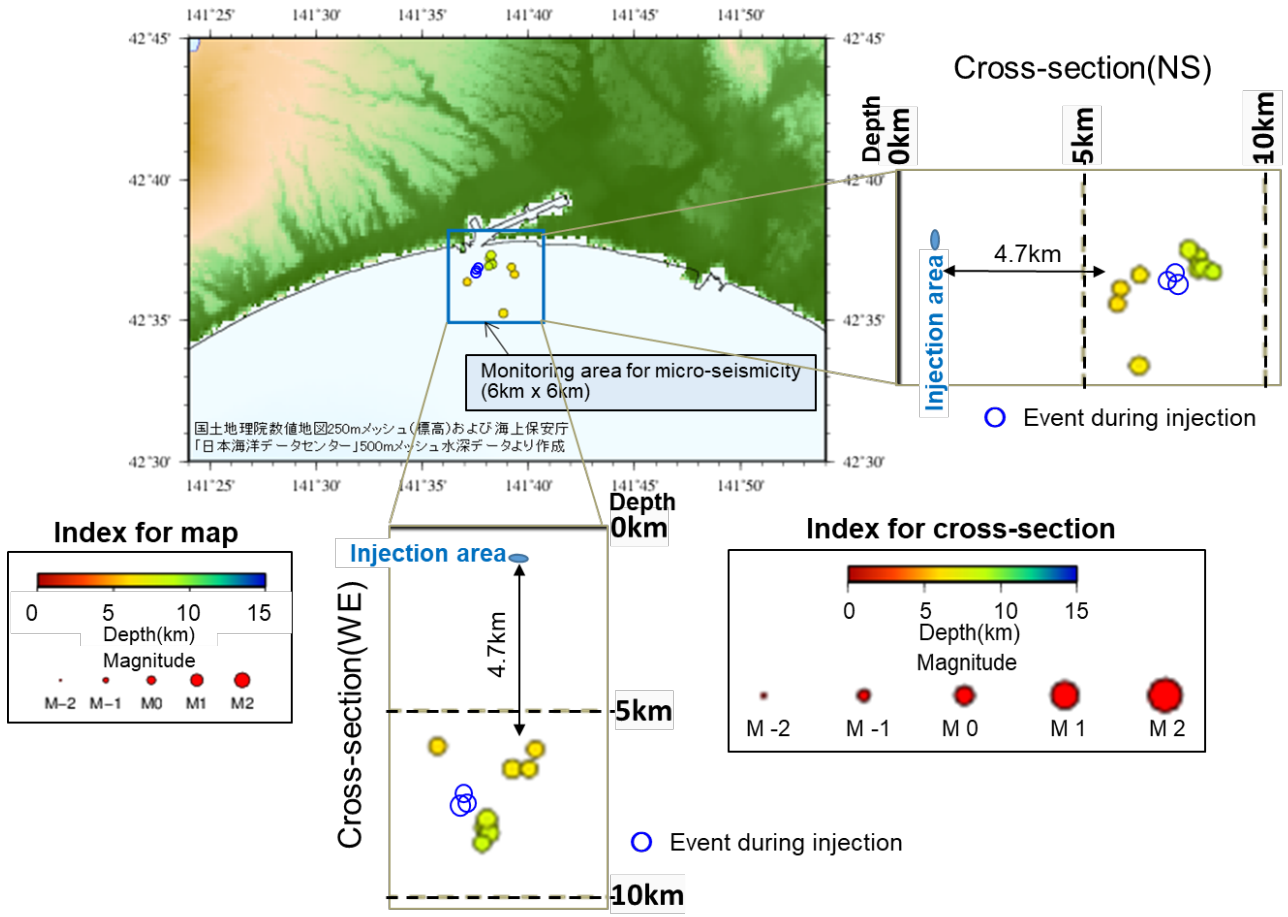


※As only the overlapping portion of the 2009 Baseline Survey and Small-scale 3D Baseline Survey was utilized, the S/N ratio, particularly the peripheral area is low, and the accuracy of the difference calculation is low.

CO_2 saturation prediction by 2018 reservoir model



Results of micro-seismicity monitoring



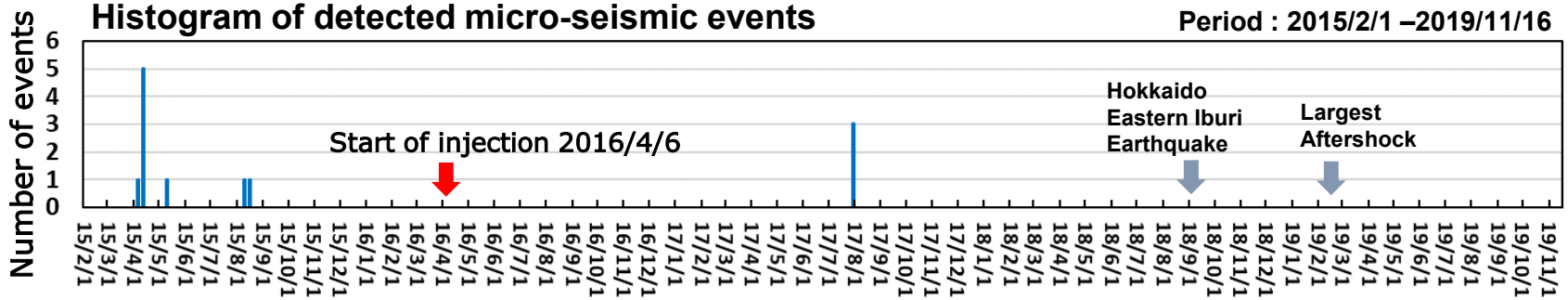
◆ **No micro-seismicity (Mw > -0.5) in/around the depth range of the reservoirs before and during injection**

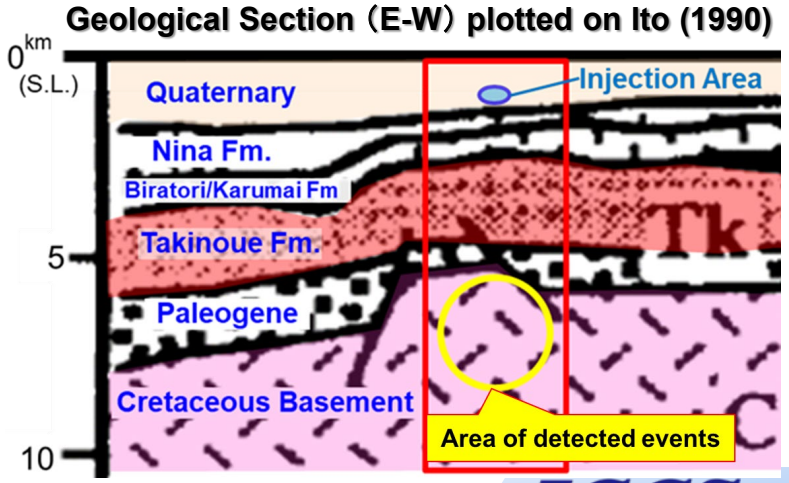
- Before Injection 2015/2/1-2016/4/5

  Total 9 events
  Depth: 5.9km - 8.6km
  Mw: -0.09～0.24

- During Injection 2016/4/6-2019/11/16

  Total 3 events(blue circle)
  Depth: 7.4km – 7.7km
  Mw: 0.31～0.52
  Date: Aug. 2, 2017

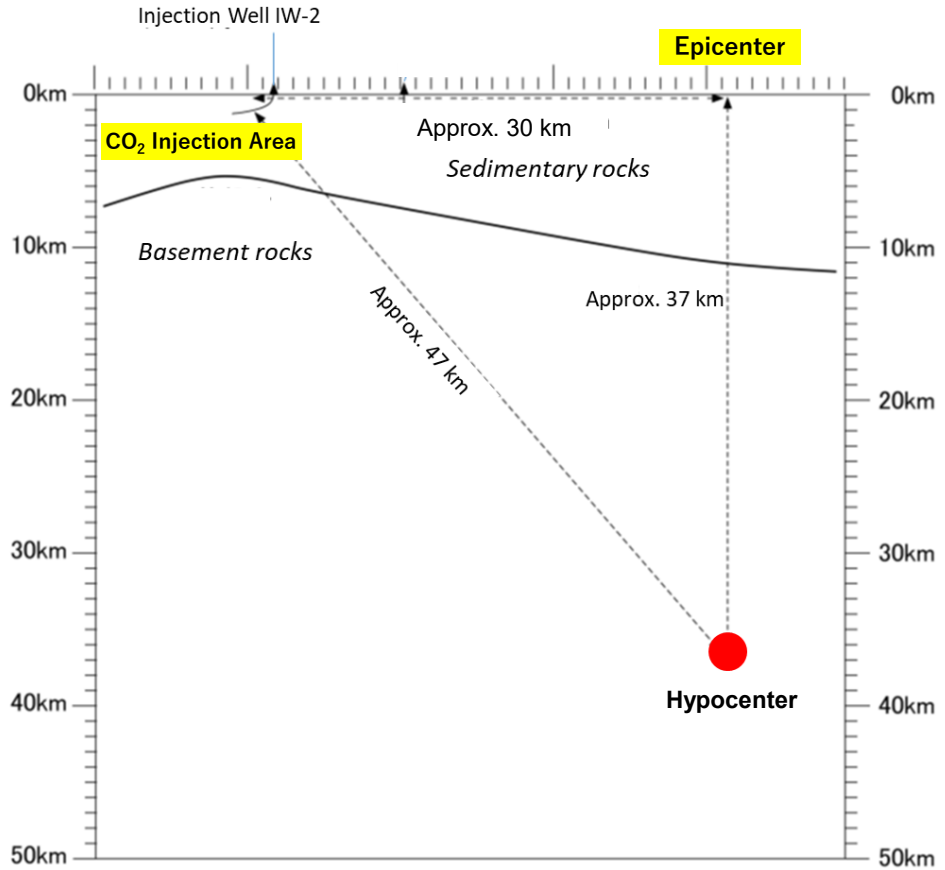




Hokkaido Eastern Iburi Earthquake: location of epicenter

- Magnitude 6.7 at 3:07am on 6th Sept. 2018
- The epicenter was about 30km in horizontal distance from the Tomakomai Project CO_2 injection point, and the hypocenter was at a depth of about 37km; the direct distance between the injection point and the hypocenter was about 47km
- Acceleration of 158 gal was observed at the capture facility (no damage to plant facilities)

Plan view



Cross section view

Positional relationship between epicenter (hypocenter) and injection point

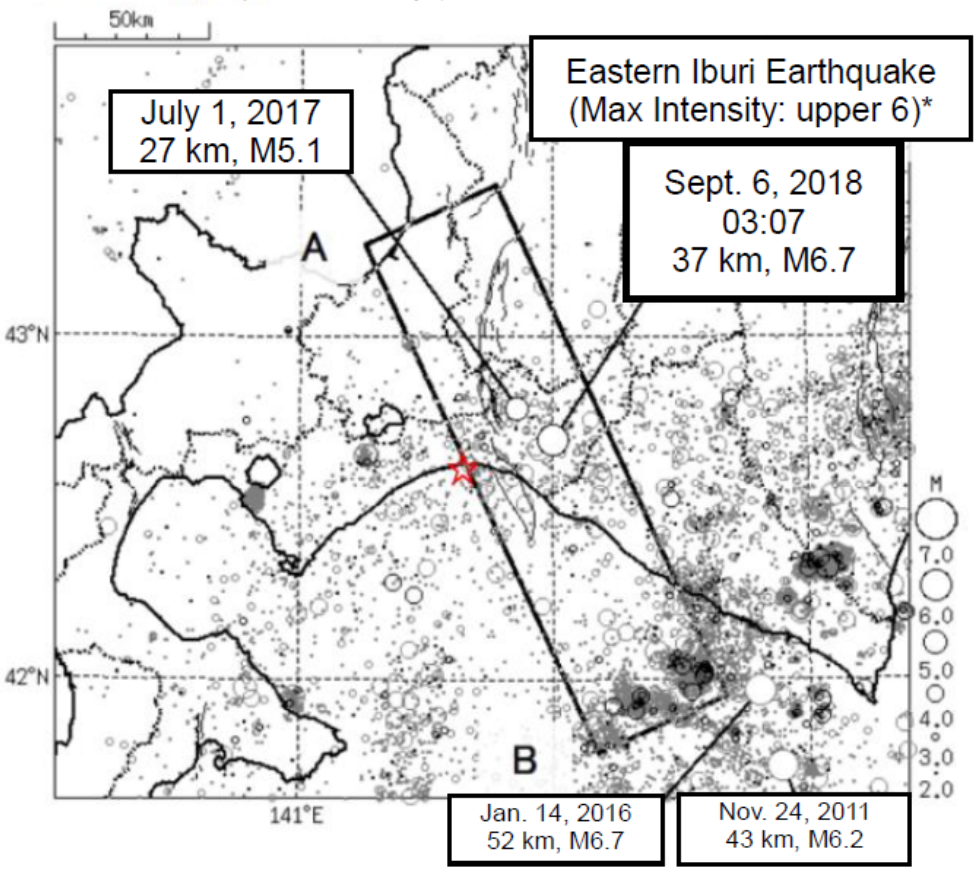
Hokkaido Eastern Iburi Earthquake – Triggering Mechanism (1)

Central Eastern Iburi Region Earthquake on Sept. 6, 2018 (Detail of earthquake location)

Epicenter Distribution Map

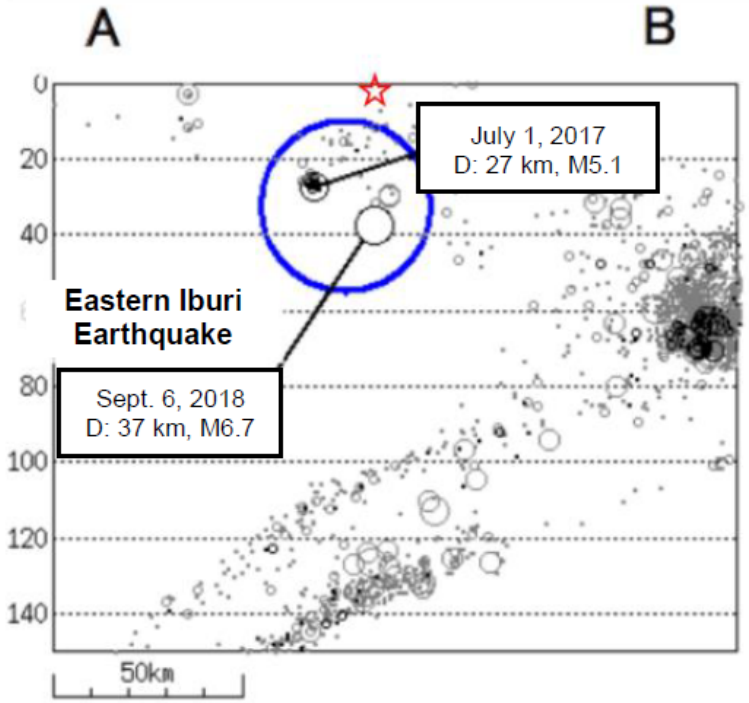
(Earthquakes from Oct. 1, 1997 to 03:30 Sept. 6, 2018; Depth: 0 to 150 km; M2.0 or over)

Earthquakes from January 1, 2018 onwards shown in darker color.



*Third Report by Japan Meteorological Agency (15:30 Sept. 6): maximum seismic intensity was corrected to 7.
Size of circles denote magnitudes.

Cross-section along A-B within square zone of left figure



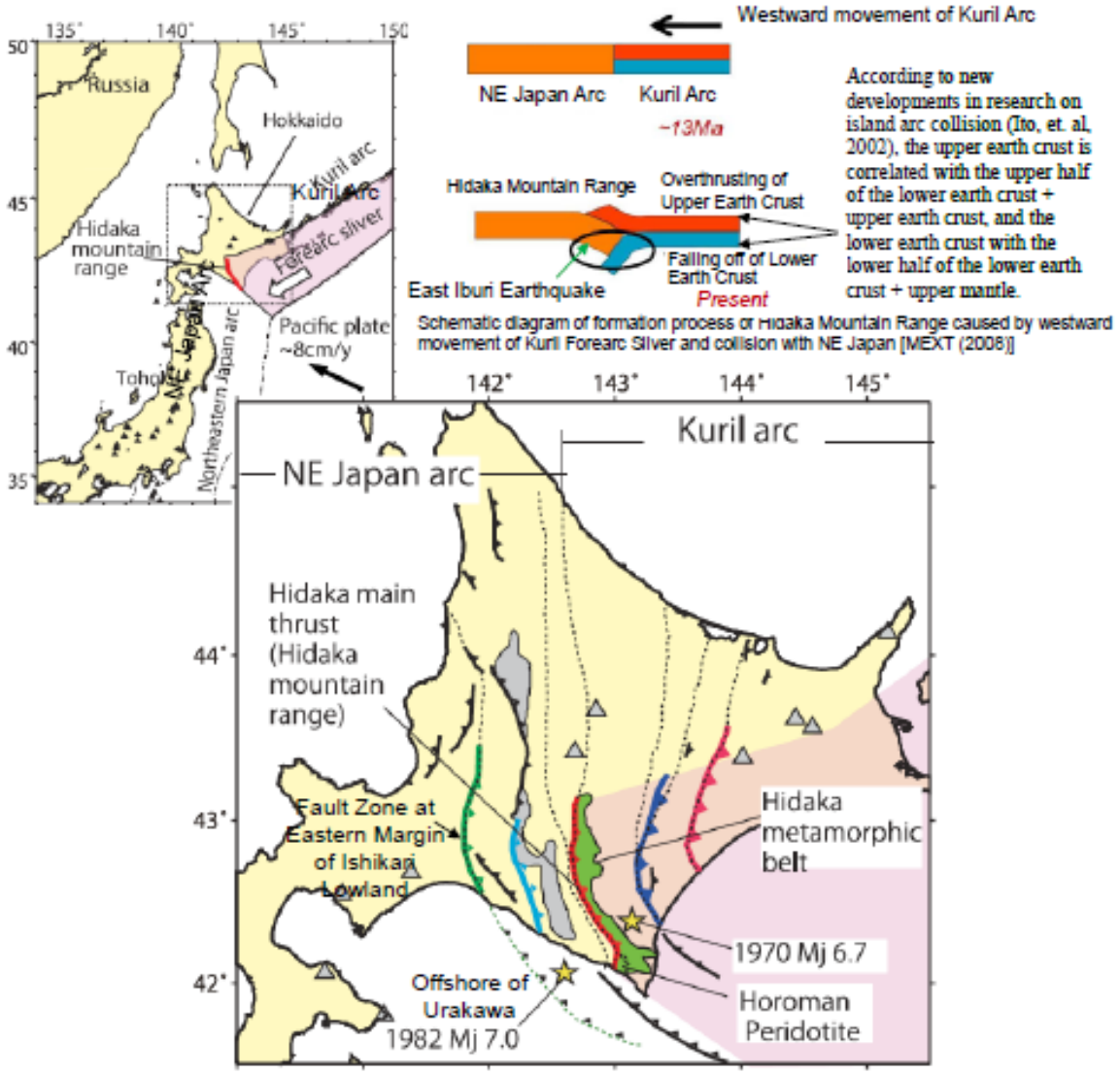
Vertical axis denotes depth; size of circles denote magnitudes.

☆ **CO_2 Injection Location**

Source: First Report by Japan Meteorological Agency (05:10 Sept. 6)

- On September 6, 2018 at 03:07am, a M6.7 earthquake occurred at 37 km depth in the central eastern Iburi region, and seismic intensity of 7 was recorded at Atsuma Town, Hokkaido (lower 5 (158 gal) at Demonstration Project Center).
- Seismic activity since October 1997 indicates earthquakes of around M4.0 and greater have occurred from time to time around the hypocenter of East Iburi Earthquake; on July 1, 2017, a M5.1 earthquake occurred at 27 km depth (Japan Meteorological Agency).

Hokkaido Eastern Iburi Earthquake – Triggering Mechanism (2)



Tectonic structure image of southern Hokkaido

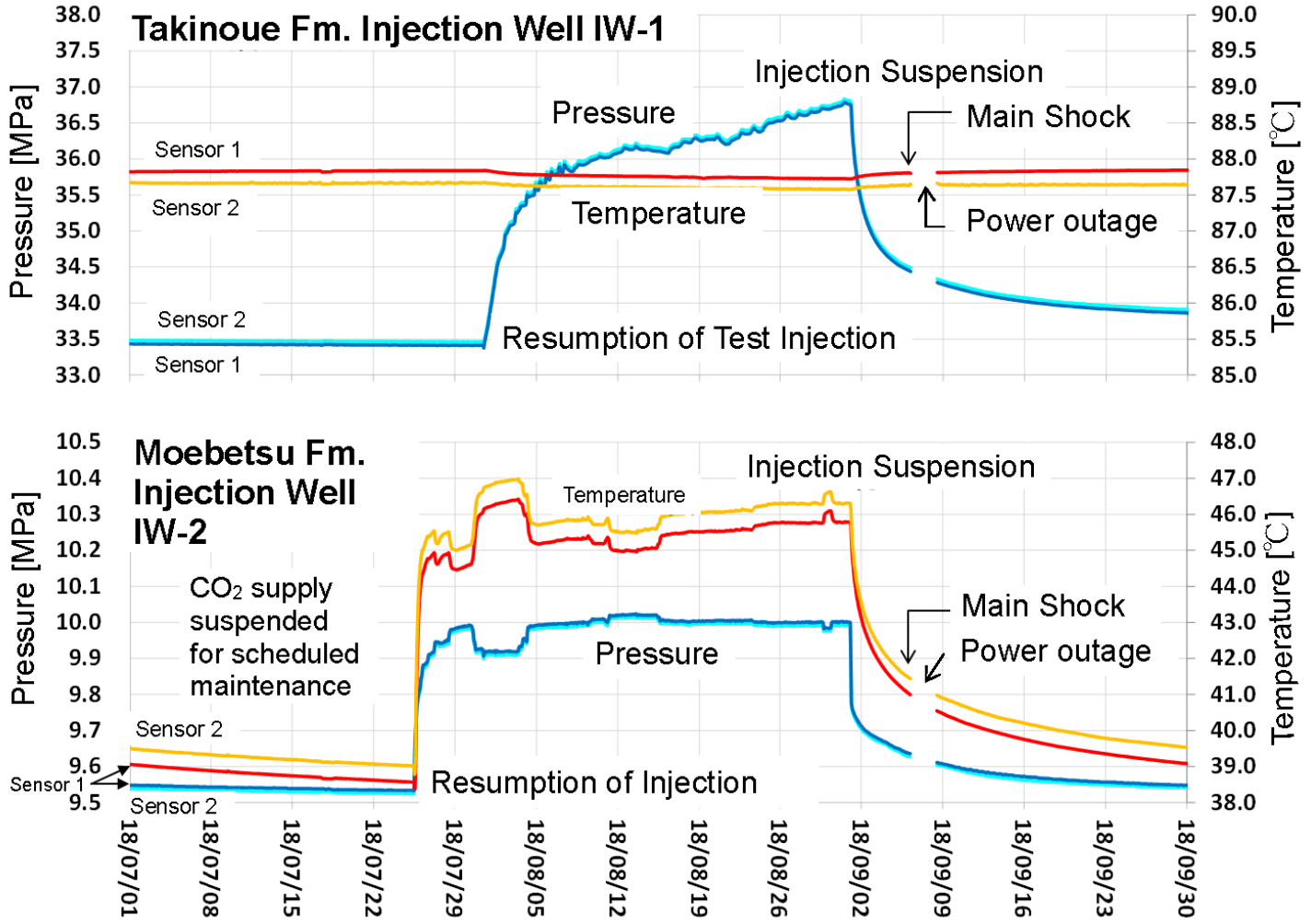
- Regarding the Kuril Arc, it is believed that the upper crust* is thrusted upwards forming the Hidaka Mountains, whereas the lower crust subducts beneath the NE Japan Arch, dragging the NE Japan Arc downwards as well. As a result, the earth's crust is thicker around the Hidaka Mountains and to the west.
  * Surface area of earth from surface to mantle boundary; thickness of oceanic crust is approx. 5km; continental crust is 30～60km
- The Eastern Iburi Earthquake is believed to have occurred near the bend of the crust.
- The Earthquake Research Committee expressed the view on September 6 that "the regions around eastern Iburi, Hidaka to offshore Urakawa are characterized by many earthquakes also occurring in locations deeper than where earthquakes usually occur in the onshore earth crust, and the latest seismic activity occurred in an area having such characteristics."
- The Eastern Iburi Earthquake is not believed to have occurred in an unordinary location; i.e., it occurred within the range of seismic activities expected in the area concerned.

Source: High-resolution seismic velocity structure beneath the Hokkaido corner, northern Japan (Saeko Kita et al., 2012), Estimation of 3D Inhomogeneous Crustal Structure at Plate Boundaries and Peripheral Regions (MEXT, 2008)

Effect of earthquake on CO_2 reservoir — pressure & temperature

◆ No temperature or pressure change indicating abnormality was observed before or after earthquake.

- In the Takinoue Injection Well (IW-1), test injection was resumed on 30th July, 2018; in the Moebetsu Formation Injection Well (IW-2), full injection was resumed on 25th July.
- CO_2 injection was suspended on 1st Sept. 2018 due to stoppage of PSA offgas supply.
- Injection well bottom hole pressures were in declining trend at time of main shock of earthquake.
- At time of main shock, bottom hole temperature of IW-1 was in rising trend as CO_2 temperature was lower than formation temperature, whereas in IW-2, temperature was in declining trend as CO_2 temperature was higher than formation temperature.
- No shifts in trends of bottom hole pressures and temperatures are observed before and after earthquake.

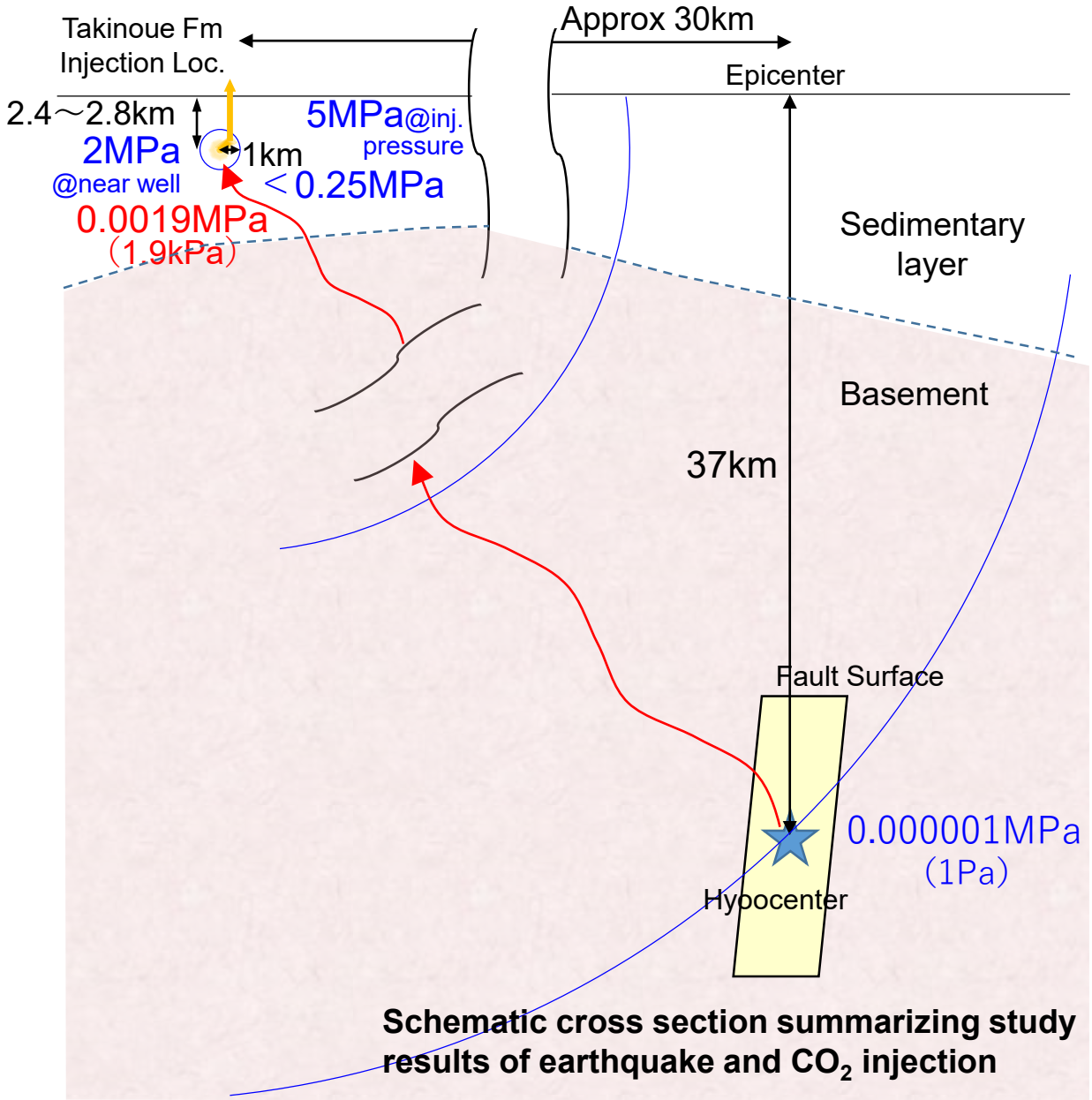


Bottom hole pressures and temperatures of injection wells before/after earthquake

Relationship between CO_2 injection and Eastern Iburi Earthquake – Summary of Expert Review

- ◆ Effect of CO_2 injection on earthquake fault
- Injection location is in sedimentary layer with no continuity with hypocenter in basement rock.
- The effect of CO_2 injection pressure on hypocenter is about 1Pa, and it is inconceivable that the earthquake occurred in relation to CO_2 injection at Tomakomai.

- ◆ Effect of earthquake on CO_2 reservoir
- No abnormality of CO_2 reservoir was caused by earthquake, and no leakage of CO_2 was observed.
- The increase in stress in the Takinoue Formation due to the earthquake is estimated at about 1.9kPa.



Schematic cross section summarizing study results of earthquake and CO_2 injection

Measures taken by JCCS after earthquakes

- 6th Sept. 2018 : Magnitude 6.7 earthquake occurred
- 12th Sept. 2018 : Posted JCCS's views on HP
- 19th Oct. 2018 : Convened an expert review meeting
- 21st Nov. 2018 : Posted summary of review meeting on HP
- 21st Feb. 2019 : Magnitude 5.8 aftershock occurred
- 26th Feb. 2019 : Posted JCCS's views on HP

Key points on JCCS HP:

1. No relationship between CO_2 injection and earthquake
2. No CO_2 leakage

Key principles to minimize concerns of local community and general public:

- *Respond quickly*
- *Include technical explanation*

Public Engagement

◆ The Tomakomai CCS Demonstration Project is being conducted with the understanding and support of the local government, industries and local community

Tomakomai CCS Promotion Association

Establishment : April 2010 (prior to selection of Tomakomai site)

Activities : 1) Promotion of Tomakomai CCS Demonstration Project
2) Dissemination of information to Tomakomai citizens

Chairman : Tomakomai City Mayor

Members : All major corporations in Tomakomai and industrial associations, Tomakomai Fishery Cooperative

Secretariat : Tomakomai City

Construction site visit by members

Annual publication

Public Outreach Activities

⊖**Panel Exhibitions**
Held in Tomakomai and nearby cities, other cities in Japan

⊖**CCS Forum**
Held annually for Tomakomai citizens since 2011; attendance 300~400 people

⊛**Site Tours**
Facilities and observation wells are shown to general public

④**Information Disclosure System**
Disclosure of CO_2 injection volume, borehole pressure & temperature, seawater CO_2 concentration, earthquake & micro-seismicity data on JCCS website

⑤**Mini seminars for students**
Held in universities in Hokkaido as well as nationwide

⑥**Kids' lab classes/site tours**
Held in primary and secondary schools i Tomakomai; enhance understanding of global warming and CCS through CO_2 experiments. Site tours for children

Summary

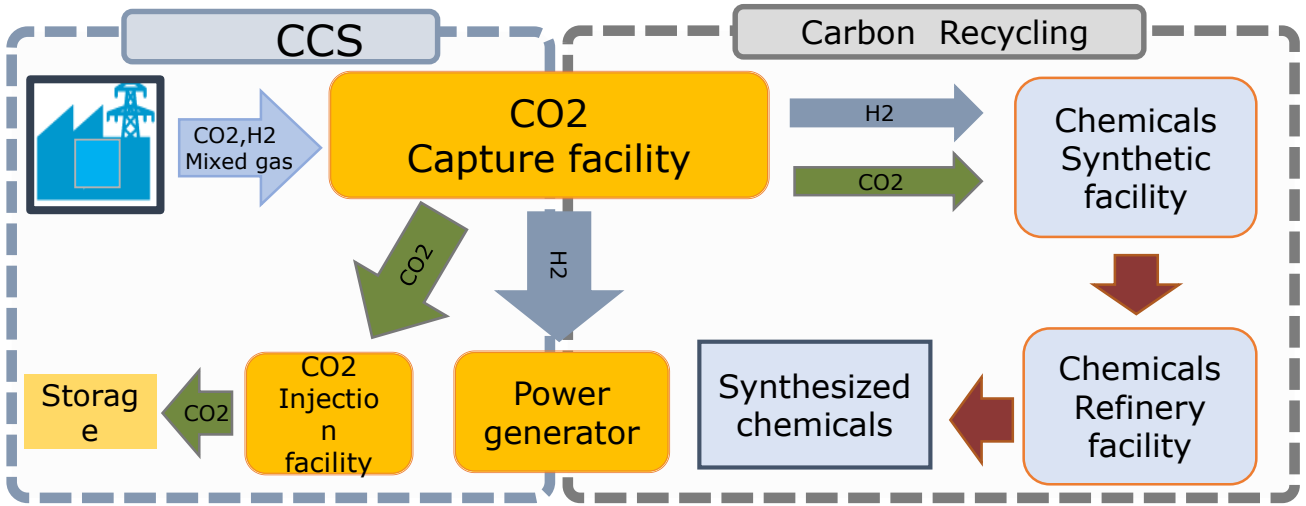
- Operation of full chain CCS system from capture to storage has been conducted successfully and target of 300,000 tonnes of CO_2 injection has been achieved
- CO_2 capture process comprising a two stage absorption system with a low pressure flash tower has achieved significantly lower capture energy than conventional system
- Deviated injection wells from onshore site into offshore reservoirs saved drilling cost and avoided disturbance of local livelihood
- The "Moebetsu Formation" (shallow reservoir) has demonstrated superior injectivity, with only minor pressure buildup
- Concerns about earthquakes and induced seismicity have been addressed
  - Natural earthquakes have not caused any damage to reservoirs
  - No seismicity (Mw > -0.5) has been detected in/around the depth range of the reservoirs before and during injection
- Safety and reliability of CCS system has been demonstrated
- Project is being conducted with understanding and support of local community

Japanese CCUS policy for the future

The injection of CO2 at Tomakomai reached our initial target of 300,000 tons in total in November.

As a next step;

- ⊖ Review the Tomakomai CCS Demonstration Project
- ⊜ Consider the process and business environment for introducing CCS in Japan. Such as,
  - ✓ Analyze the contribution of CCS toward the reduction of GHGs emissions by 80% by 2050
  - ✓ Consider the suitable division of roles between the public and private sectors
- ⊛ Utilize the Tomakomai CCS facility effectively and promote the development of carbon recycling



<The image of Carbon recycling demonstration at Tomakomai>

Courtesy of the Ministry of Economy, Trade and Industry

Thank you for your attention.

http://www.japanccs.com/

This presentation is based on results obtained from a project commissioned by Ministry of Economy, Trade and Industry (METI) and the New Energy and Industrial Technology Development Organization (NEDO).