Field Experiment of CO2-ECBMR in Ishikari Basin of Japan

Sixth International Forum on Geologic Sequestration of CO_2 in Deep, Unmineable Coalseams
"Coal-Seq VI"

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Marriott Westchase
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JCOP (Japan CO_2 Geosequestration in Coal Seams Project)

◆ JCOP is the Japan's first CO2-ECBM field trial which has been designed to evaluate technical and economical feasibility of extracting methane gas while storing CO_2 in Japanese coal seams.

◆A six-year project fully supported by METI has been taken place at Yubari city in the Ishikari Coal Basin of Hokkaido. The project was completed in March 2008.

◆A micro-pilot and two multi-well CO_2 injection test, involving an injection and production well, were carried out in the period between May 2004 and November 2007.

Characteristics of the Project

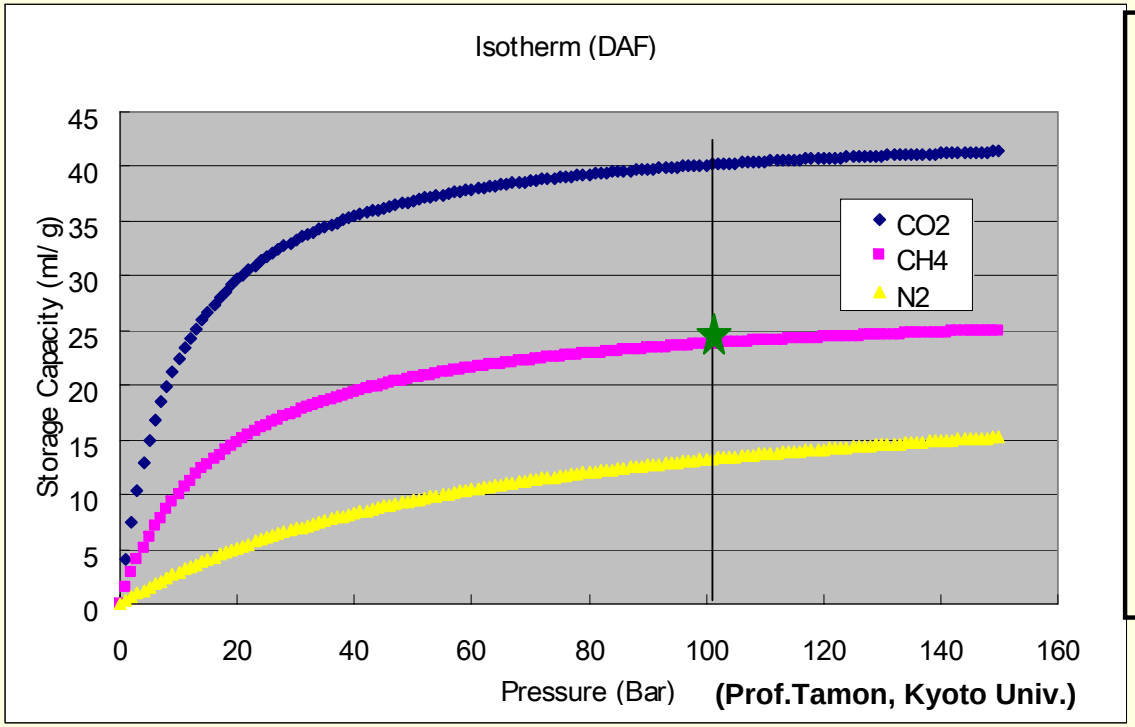
Coal Characterization

- Coal Rank : Bituminous HV A
- Reservoir Property
  - Initial Pressure : 10.2MPa
  - Cleat Opening Pressure : 15.8MPa
  - Absolute Permeability : 1.1md
- In-site Gas Content : 24.35Nm³/t (DAF)
- 5-6m thickness Coal Seam at 890m depth
- Coal Seam: Steep Dipping (25-35°)
- Coal was saturated with water and gas
- (The area had never been developed for CBM)

Site Characterization

During winter season all test activities were suspended due to snow fall and rugged hills. So the wells were shut-in for at least 4 months.

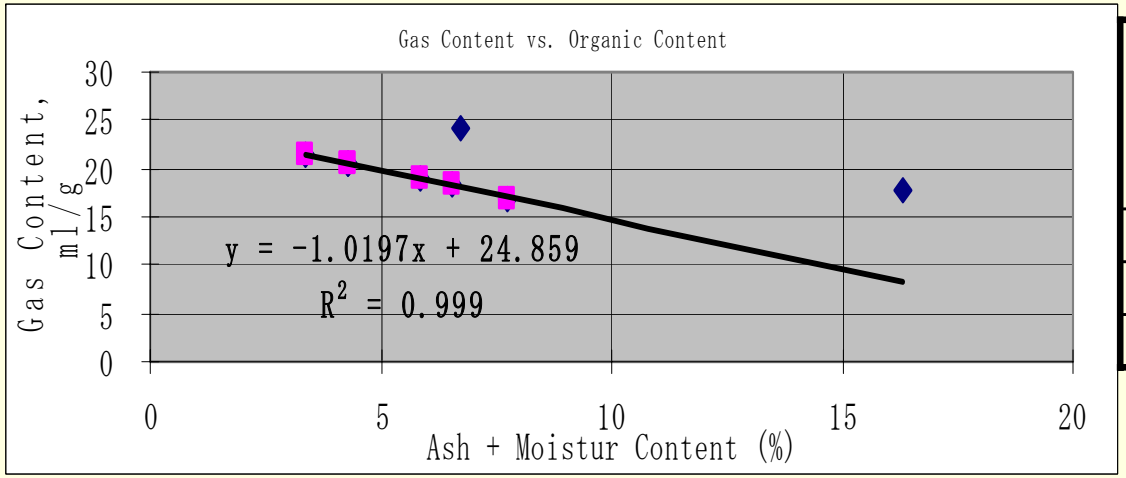
Gas Content



(Prof.Tamon, Kyoto Univ.)

Gas Content

- Gas adsorbed capacity; The relationship between the storage capacity and pressure is described using a Langmuir isotherm.
- Gas-in-place can be estimated using canistor test.
- From the results of both test, it is estimated that coal matrix is saturated with gases.



	Langmuir volume (m3/t)	Langmuir pressure (1/bar)	Storage Capa. At 102bar(m3/t)	Ratio of CH4 storage
CO_2	44.05	0.1029	40.22	1.68
CH_4	28.01	0.0560	23.84	1
N_2	21.93	0.01524	13.34	0.56

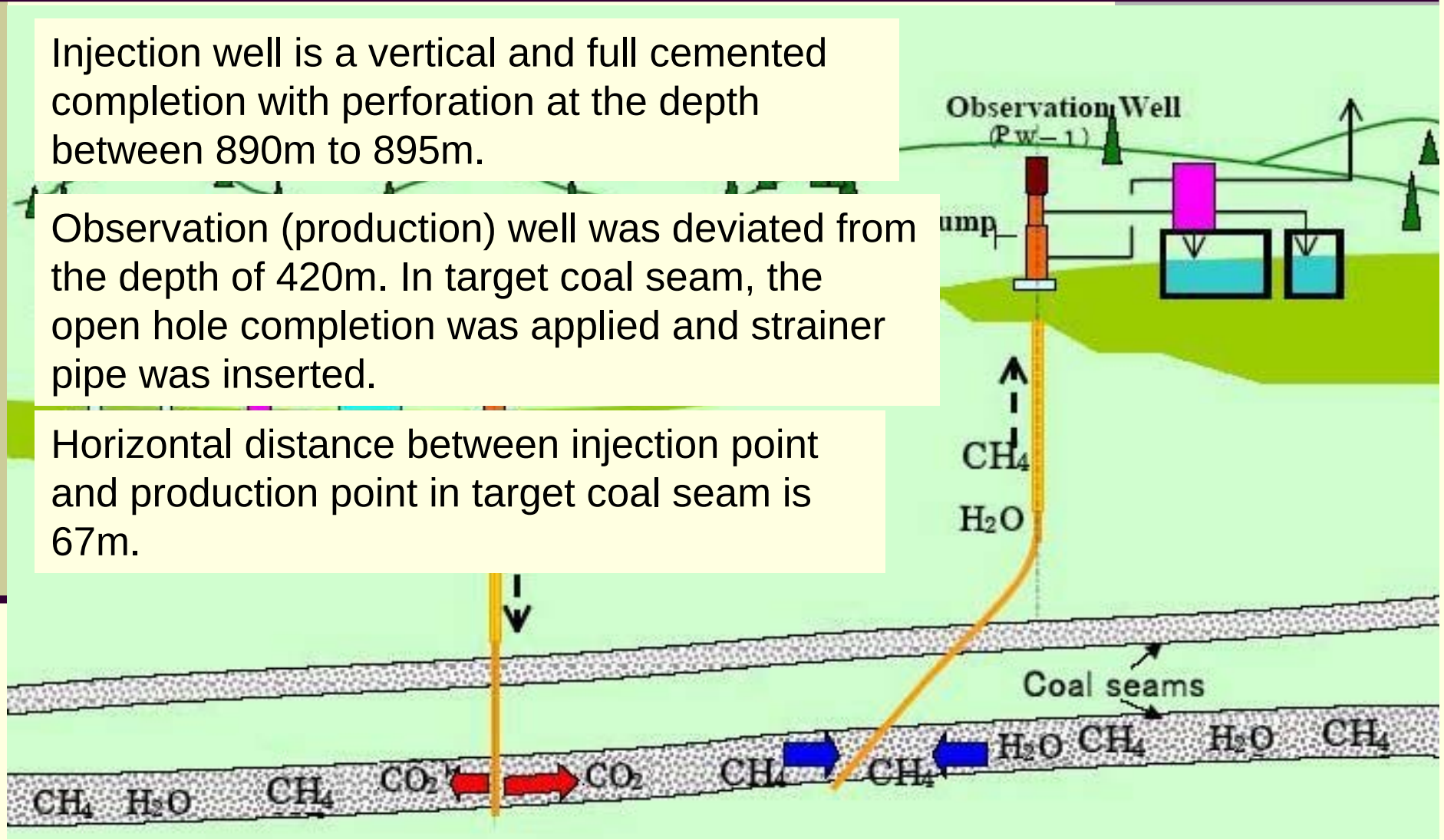
Langmuir Properties for CO2, CH4 and N2

Conceptual Design of Yubari Pilot Test

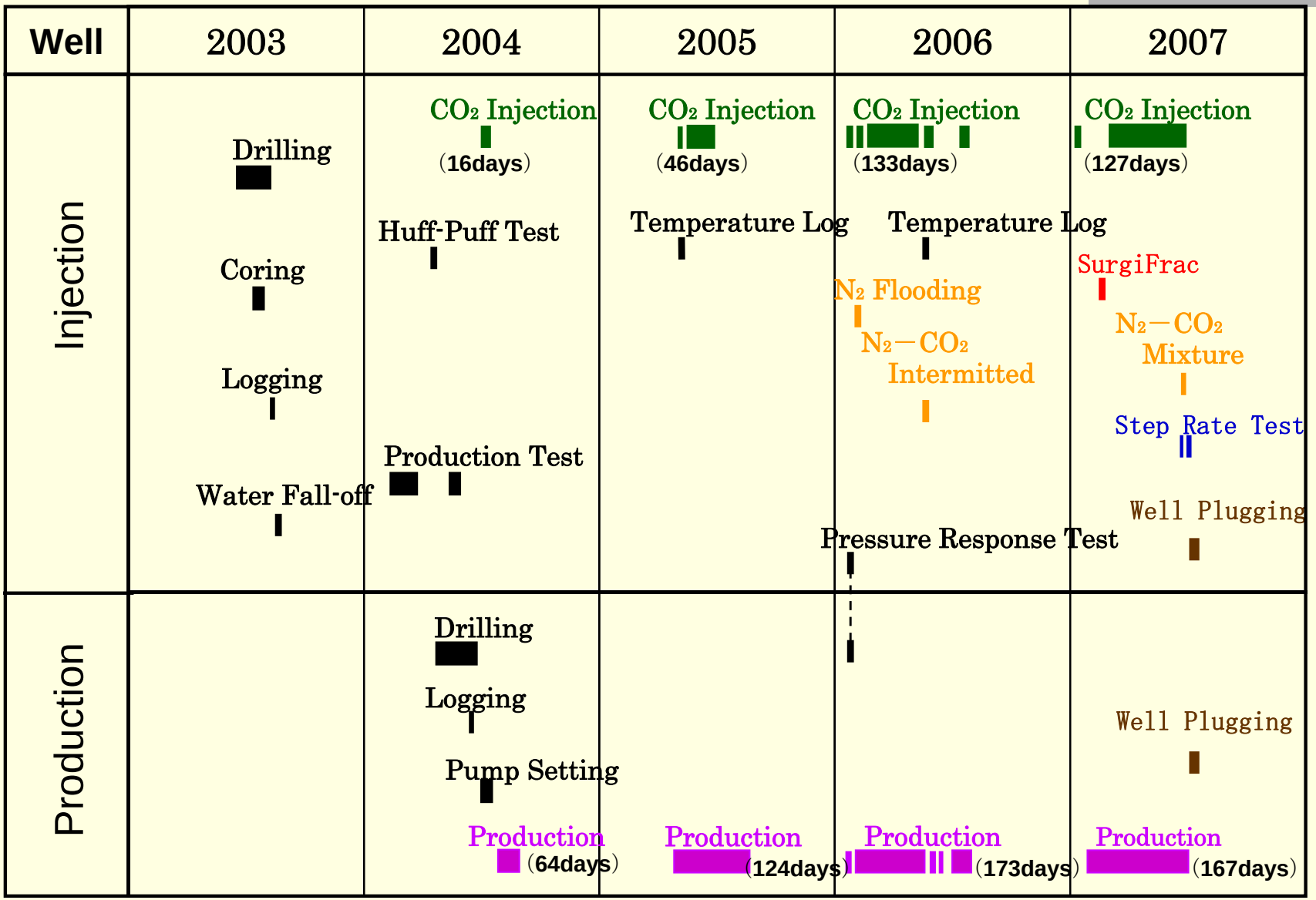
Injection well is a vertical and full cemented completion with perforation at the depth between 890m to 895m.

Observation (production) well was deviated from the depth of 420m. In target coal seam, the open hole completion was applied and strainer pipe was inserted.

Horizontal distance between injection point and production point in target coal seam is 67m.

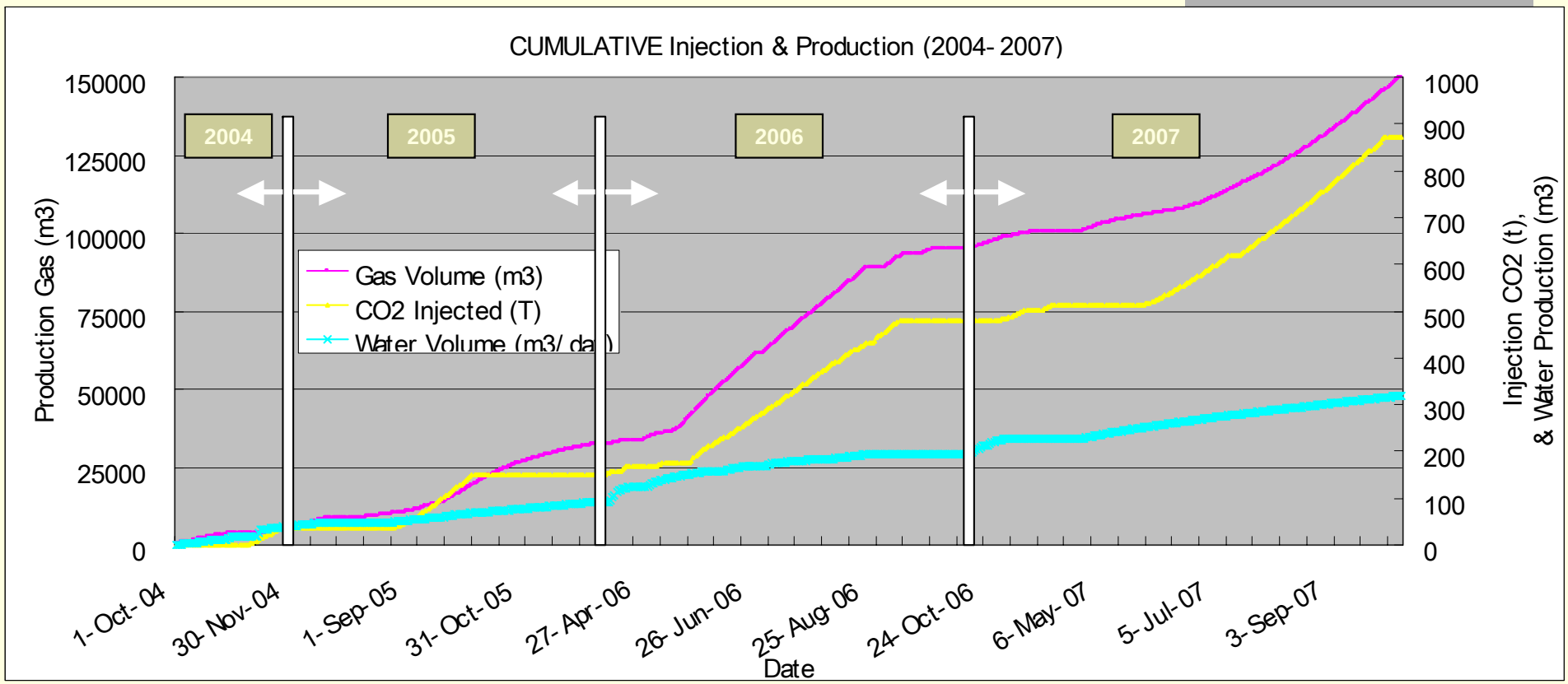


Schedule


Well
2003
2004
2005
2006
2007
Injection
Drilling
Coring
Logging
Water Fall-off
CO2 Injection
(16days)
Huff-Puff Test
Production Test
CO2 Injection
(46days)
Temperature Log
CO2 Injection
(133days)
Temperature Log
N2 Flooding
N2—CO2
Intermitted
Pressure Response Test
CO2 Injection
(127days)
SurgiFrac
N2—CO2
Mixture
Step Rate Test
Well Plugging
Production
Drilling
Logging
Pump Setting
Production
(64days)
Production
(124days)
Production
(173days)
Well Plugging
Production
(167days)

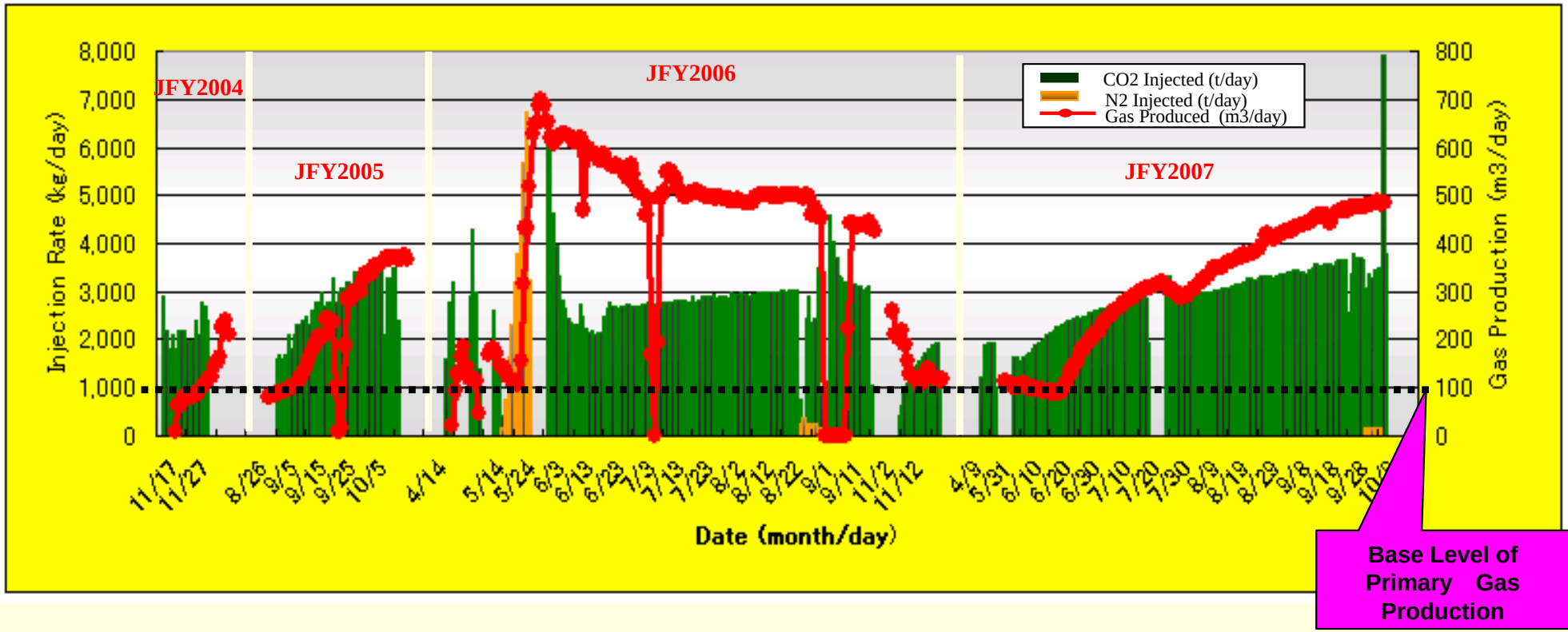

液化炭酸万入
内容積:15000ℓ
火気油脂注意

Summary of Injection and Production



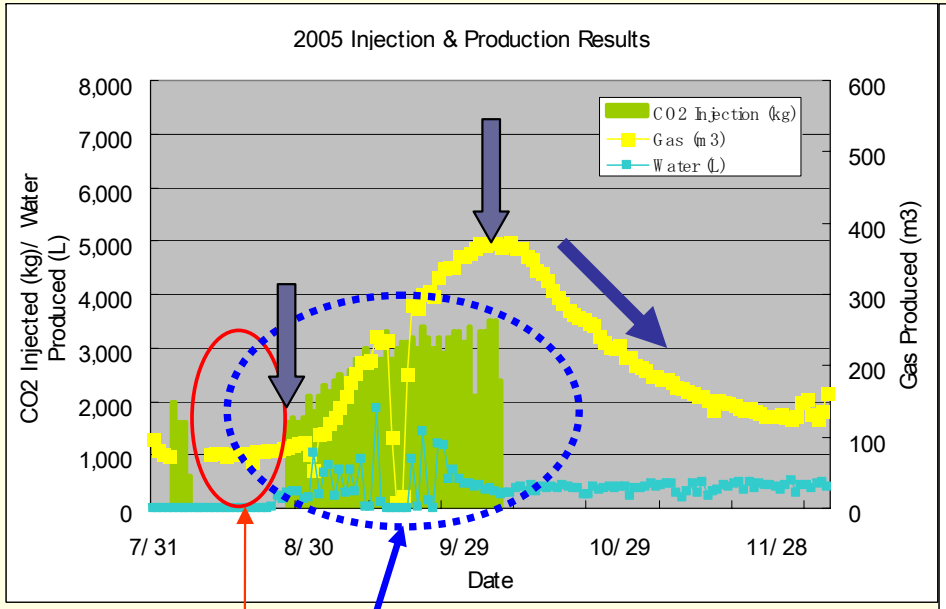
- Condition of CO_2 injection = BHP should be less than 15.8MPa which is assumed to be cleat opening pressure
- Total Gross CO_2 injected = 884 ton
- Total measured gas production= 150,672 m^3
- Total measured water production= 321 m^3
- Average injection rate for 2007 = 2.7t/day

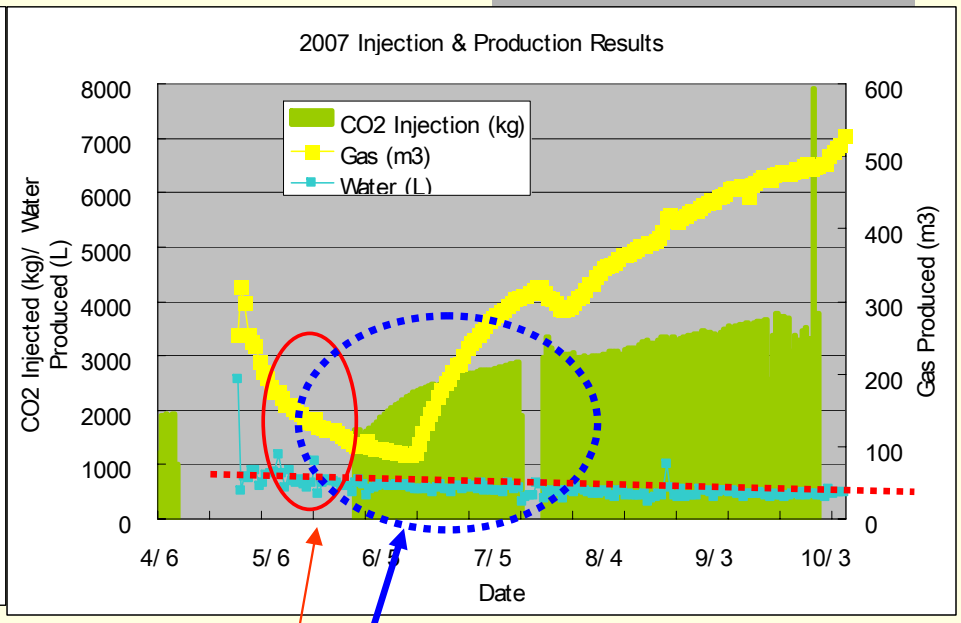
Annual Results of Injection and Production



- JFY2004 : Very short term injection and production test under a virgin conditions.
- JFY2005 : Gas production was clearly enhanced by CO_2 injection.
- JFY2006 : N_2 flooding test showed permeability was lowered by swelling affect
- JFY2007 : Injectivity was eventually increased due to (a) lowering of water saturation and (b) compressibility

Effect of Water Saturation (Year 2005 & 2007)



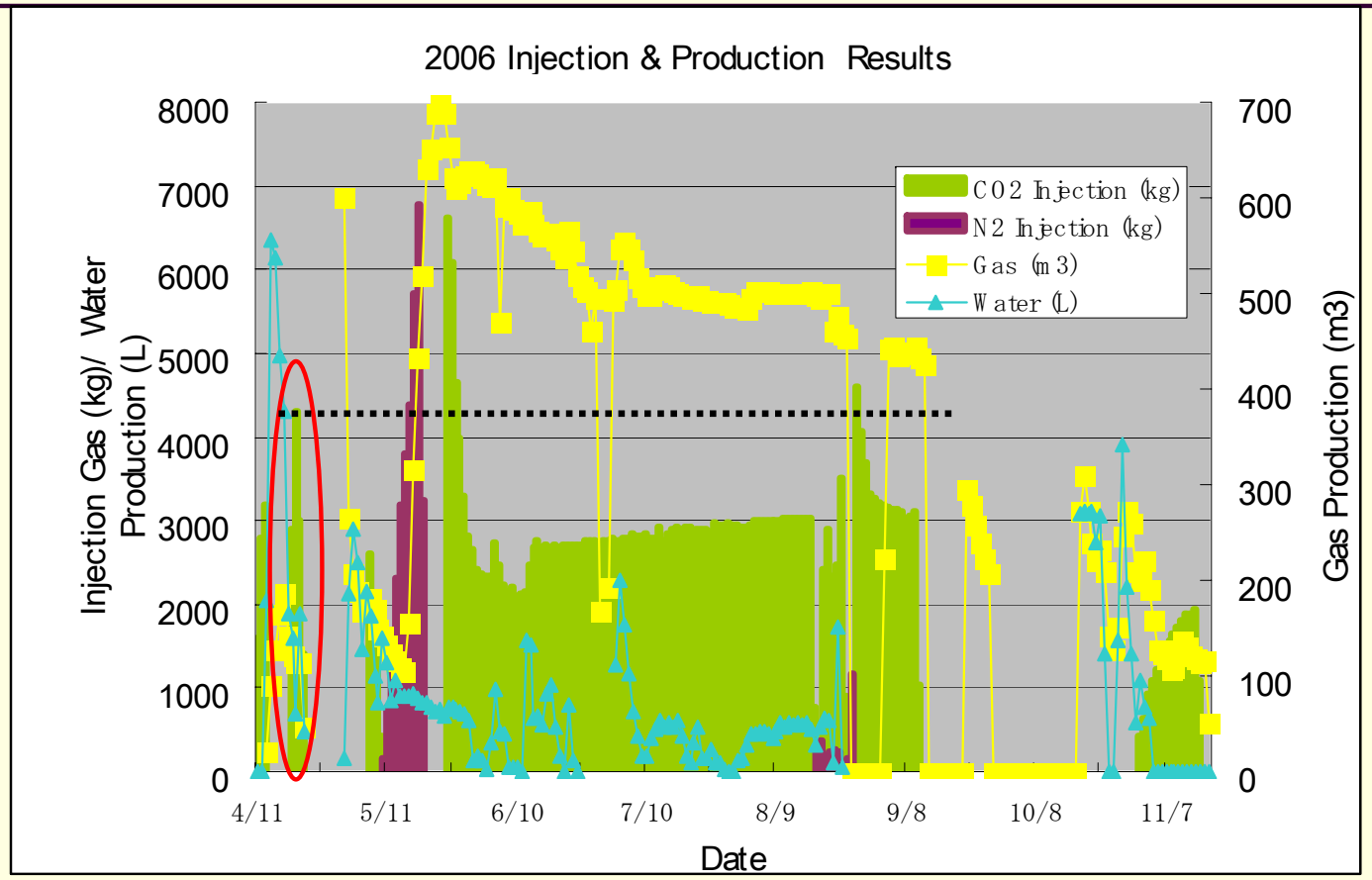


For Year 2007

✓**CO2 injection rate was gradually increased by change in water saturation and high injection pressure (compressibility factor).**

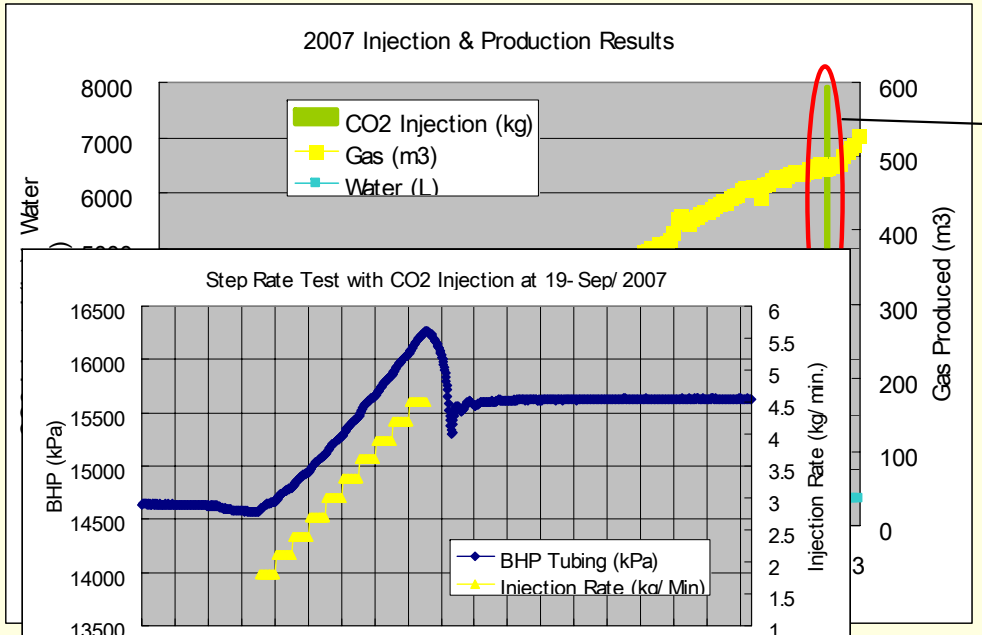
✓**Gas production was increased by increment volume of CO2 injected and lowering water saturation near the production well (higher relative permeability to gas).**

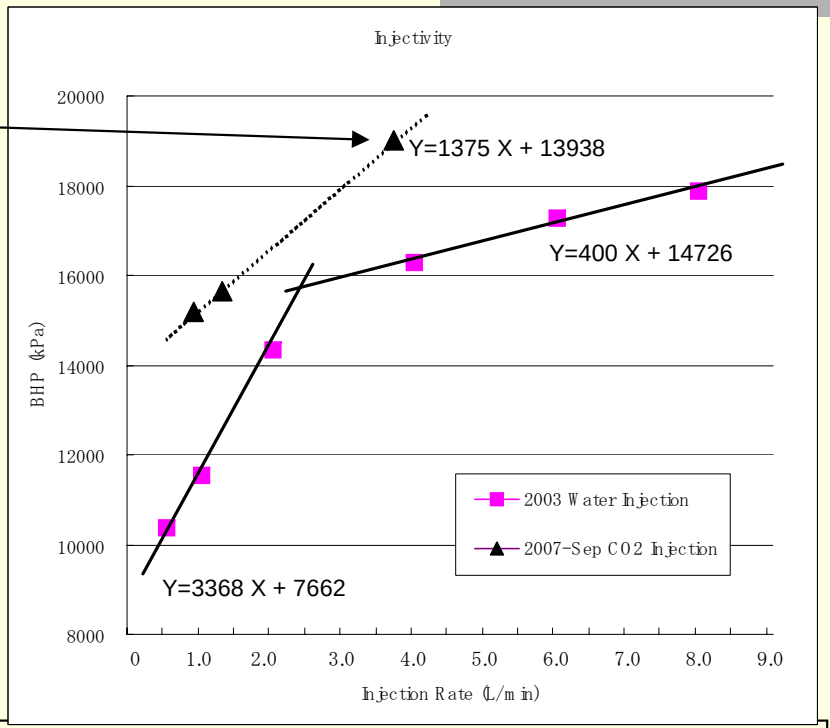
N_2 Flooding Test (Year 2006)



The injection rate of CO2 did not recover to pre-N2 flooding level (excepting the period immediate after N2 flooding test). Permeability might not show reversible nature if repeatedly injection of CO2 and N2 was carried out due to fine coal plugging (?).

Cleat Opening Pressure Change?





Micro-Fracture Step-Rate Injection Test with water was carried out just after IW-1 well was drilled in year 2003. Cleat opening pressure was estimated at 15.8MPa. Injectivity of CO2 was estimated at 1.22kg/D-kPa (BHP – Reservoir Pressure).

Cleat Opening Pressure could not be identified up to 19MPa of BHP at September 2007. Injectivity of CO2 was estimated at 0.71kg/D-kPa. Injectivity was drastically deteriorated by swelling. The reason why cleat opening pressure was increased might be 1) swelling creates high stress zone near the well, or 2) coal near the well was substantially crushed.

Closing Remarks

- Gas production can be enhanced by CO_2 injection.
- CO_2 injection rate is 10 times lower than expectation due to low permeability induced by swelling.
- N_2 flooding could be used not only to reverse the permeability reduction due to matrix swelling but also boost, even if temporarily, well injectivity
- There are many challenges to a routine application of CO2-ECBM.

Suggestion

- It was noted that the stabilised injection rate after N_2 injection was less than the range observed in the 2005 test due to fines creation, movement and plugging?
- Skin Factor might not effect the enhanced CBM production
- Cleat Opening pressure might be increased by matrix swelling. Injection rate could be increased by higher injection pressure.


Mt. Yubari
Thank You

Strain Measurements under the condition of confining pressure

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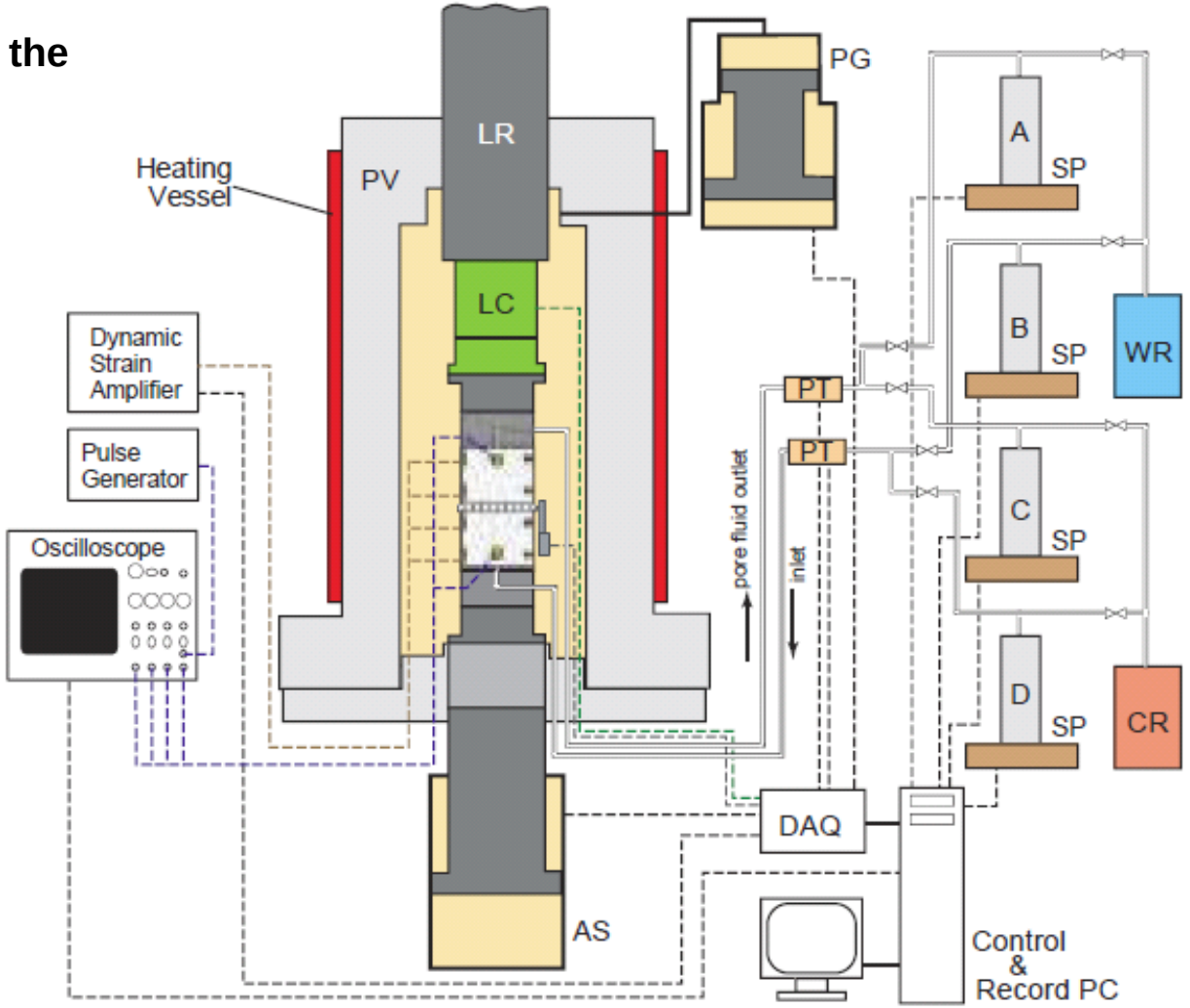
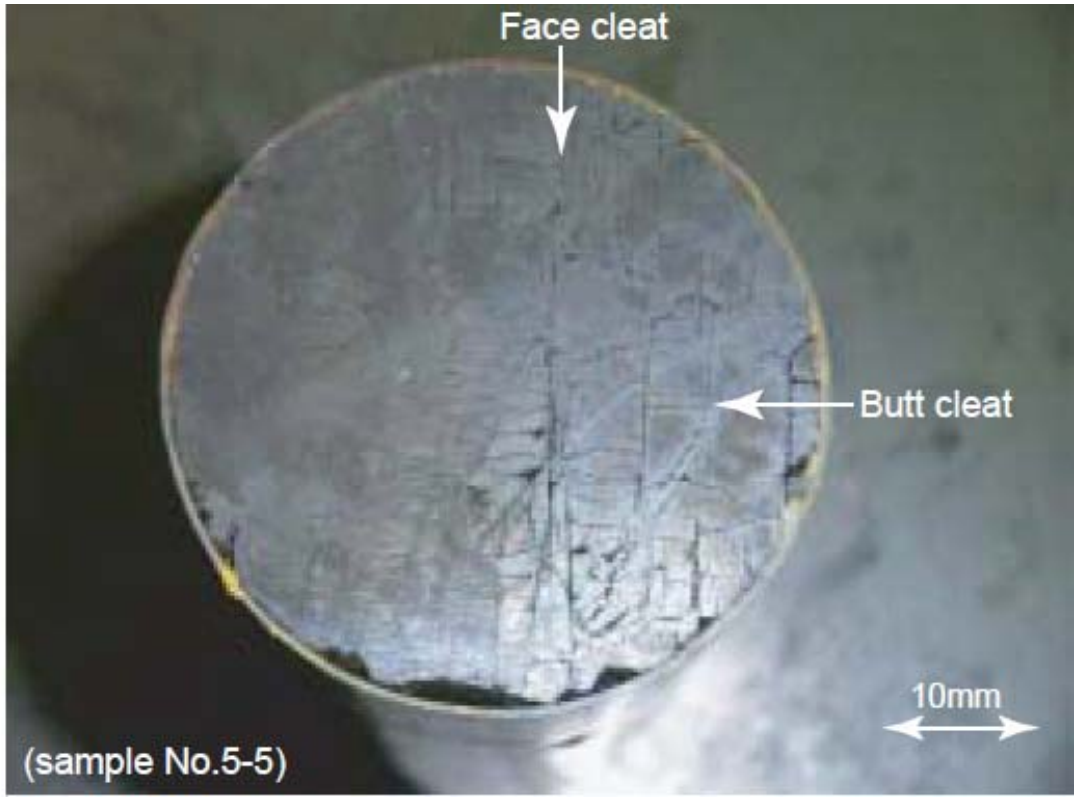
The triaxial test was carried out by the material testing system apparatus.



abbreviation; PV: pressure vessel, LR: loading rod, PG: pressure generator and intensifier, LC: load cell, AS: actuator and servovalve, DAQ: data acquisition system, PT: pressure transducer, SP: syringe pump, WR: water reservoir, CR: carbon oxide reservoir

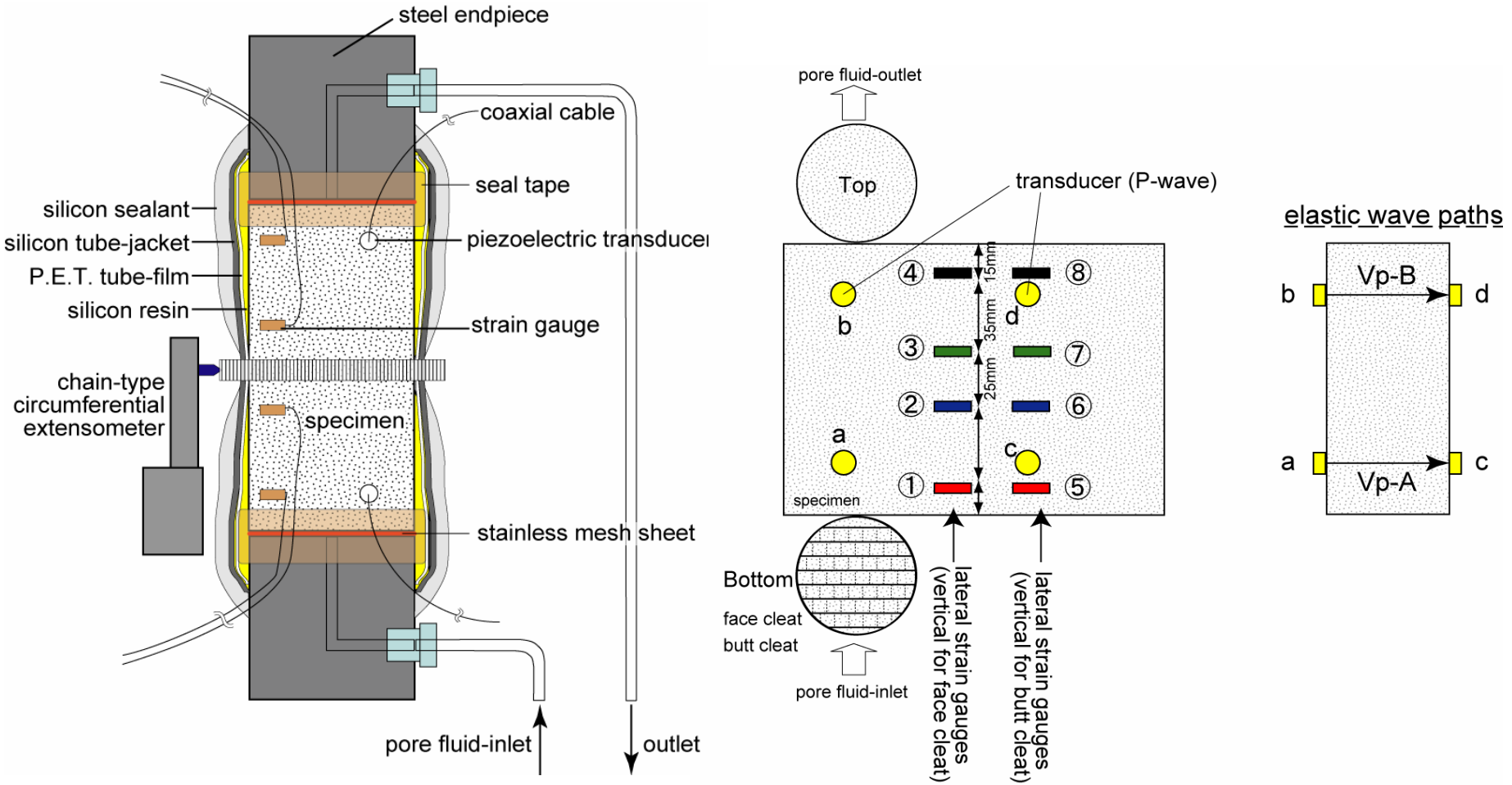
The pore fluid, pore pressure and flow rate were controlled using the spring pump. All data were recorded on the same time series through the DAQ board.

Specimen (Bibai Coal in Ishikari Basin)



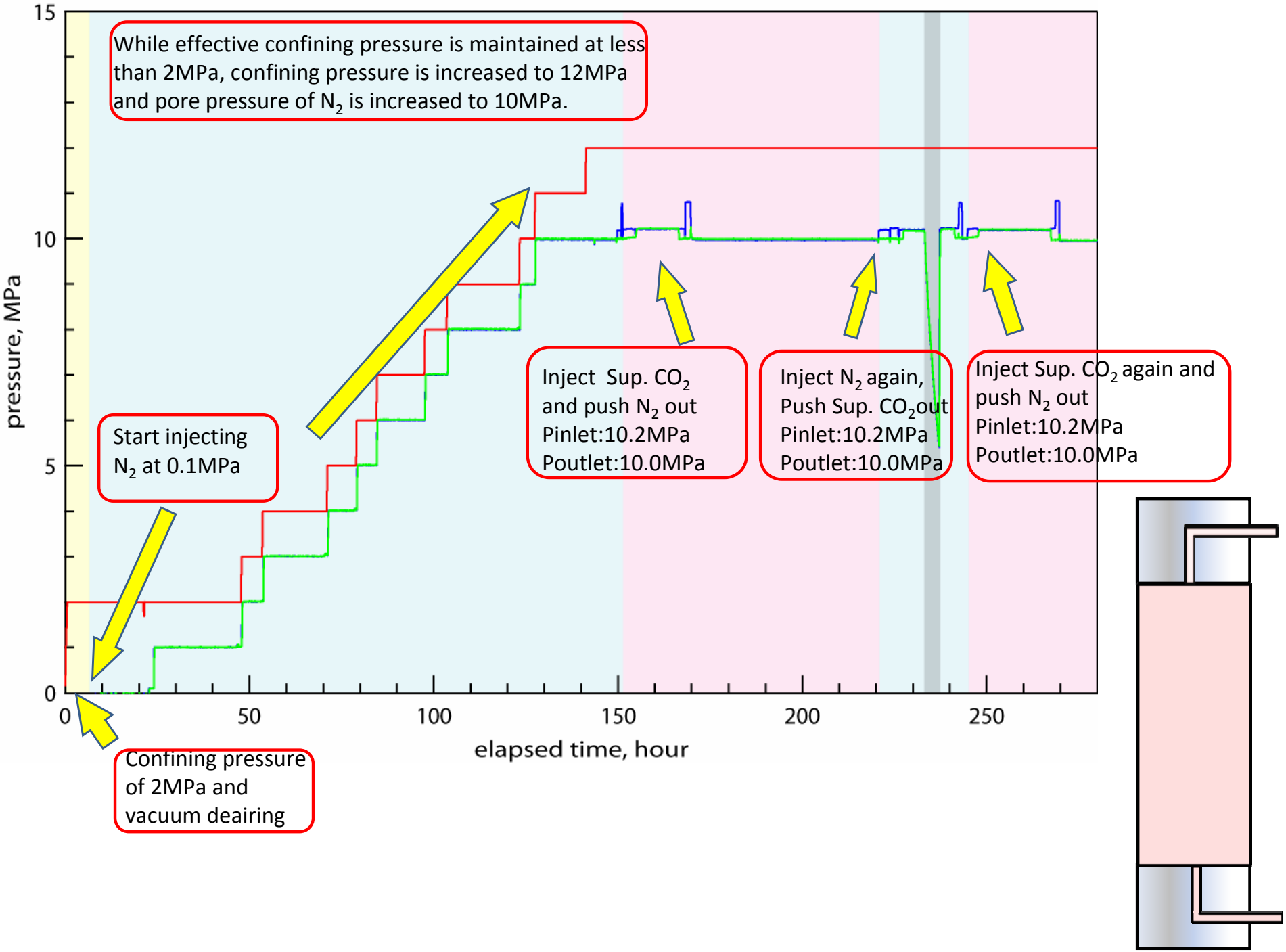
In the test, the Bibai coal sample in Ishikari Basin of Hokkaido was used. A sample length was cut into about 50mm diameter core and double polished to a length of about 125mm. The sample was jacketed to prevent the permeation of pressure oil into the sample and the leak of CO_2 out of the sample, and to install meters during the experiment.

Location of Transducers and Strain Gauges

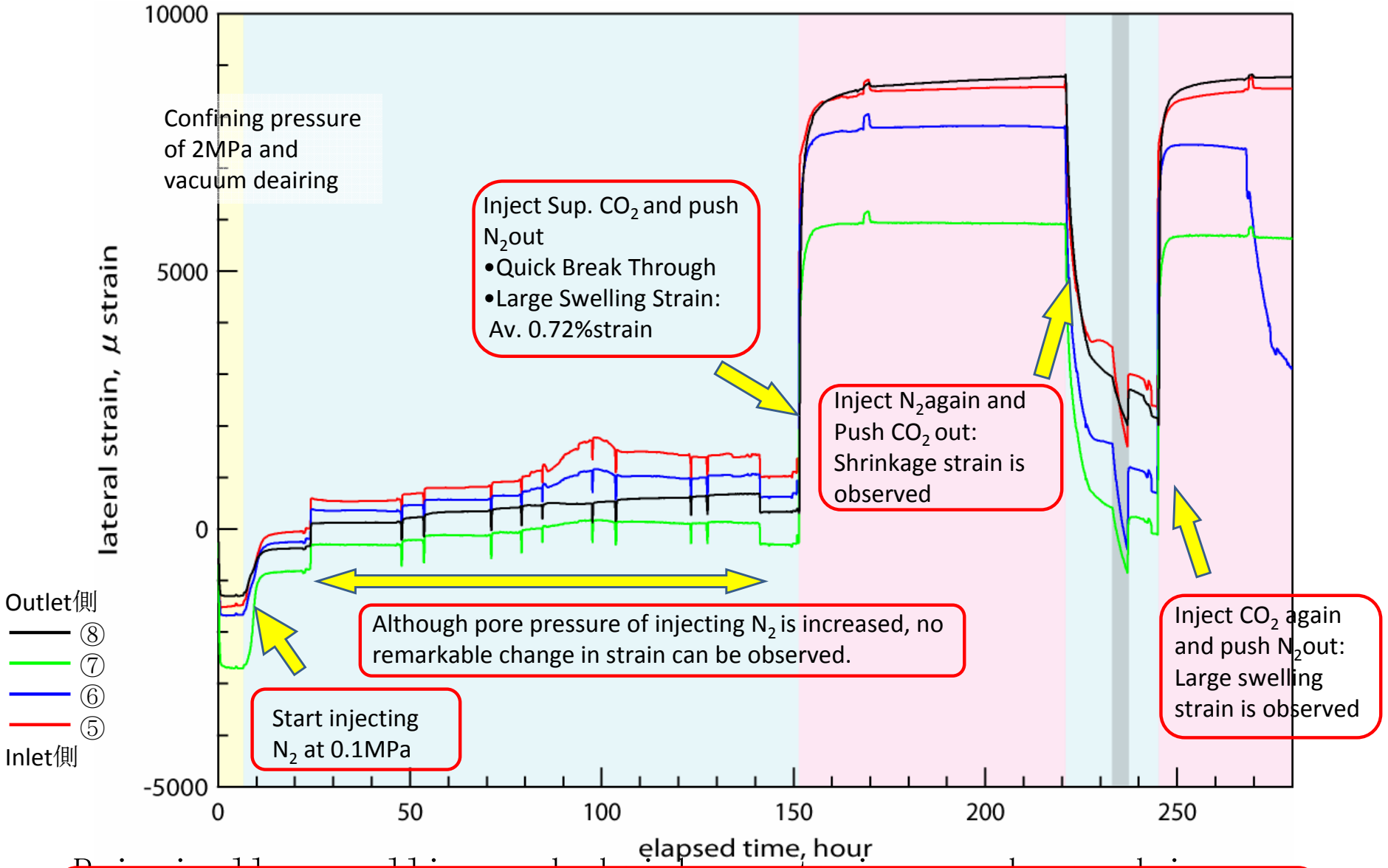


The apparatus consists of the hydraulic power unit, triaxial cell, confining pressure generator, circumferential extensometer, load cell and the axial actuator. Eight strain gauges and four piezoelectric transducers were cemented on the specimen to measure strain and elastic-wave.

Experimental Procedure

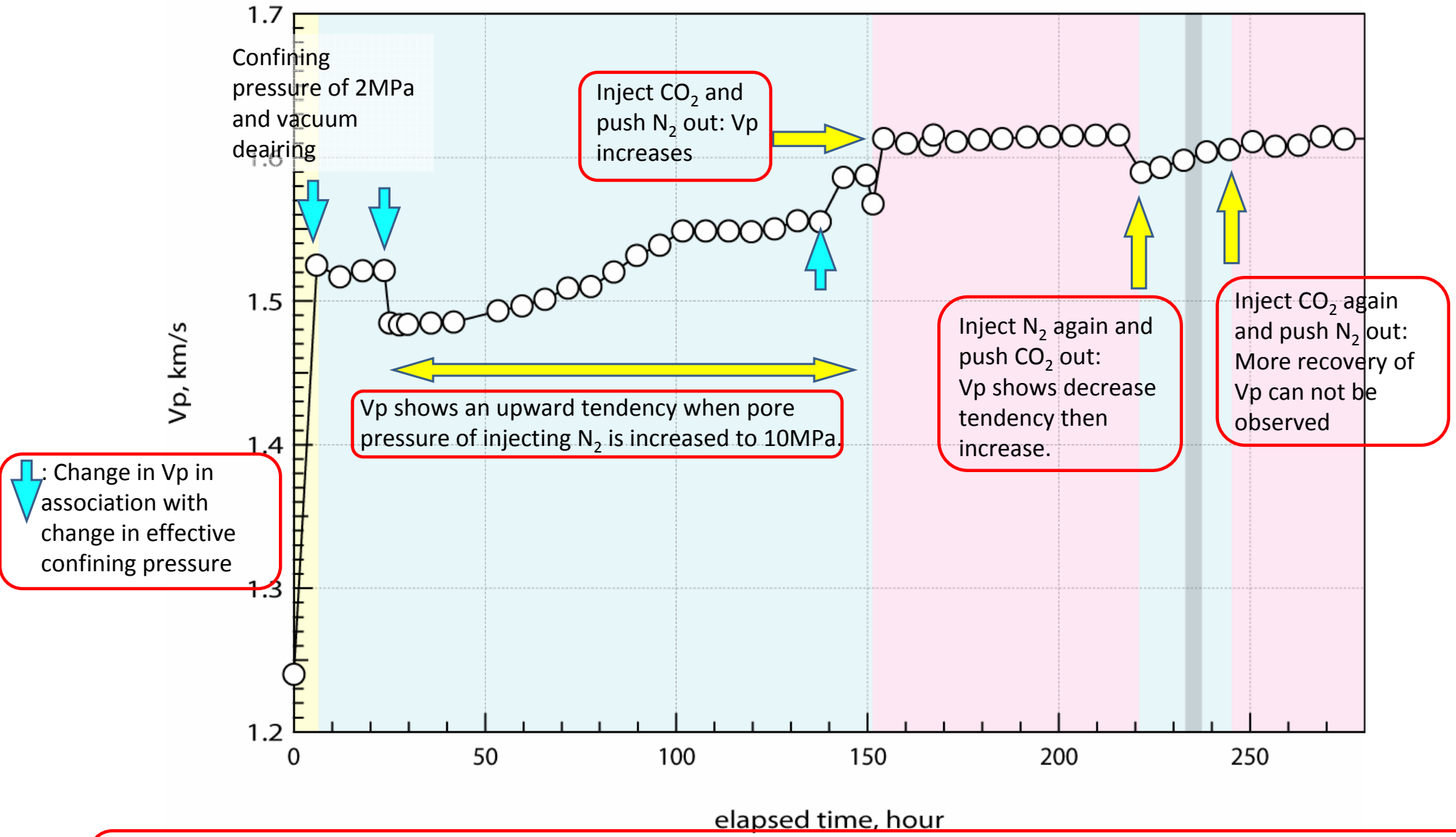


Change in Strain at Butt Cleat associated with Injection



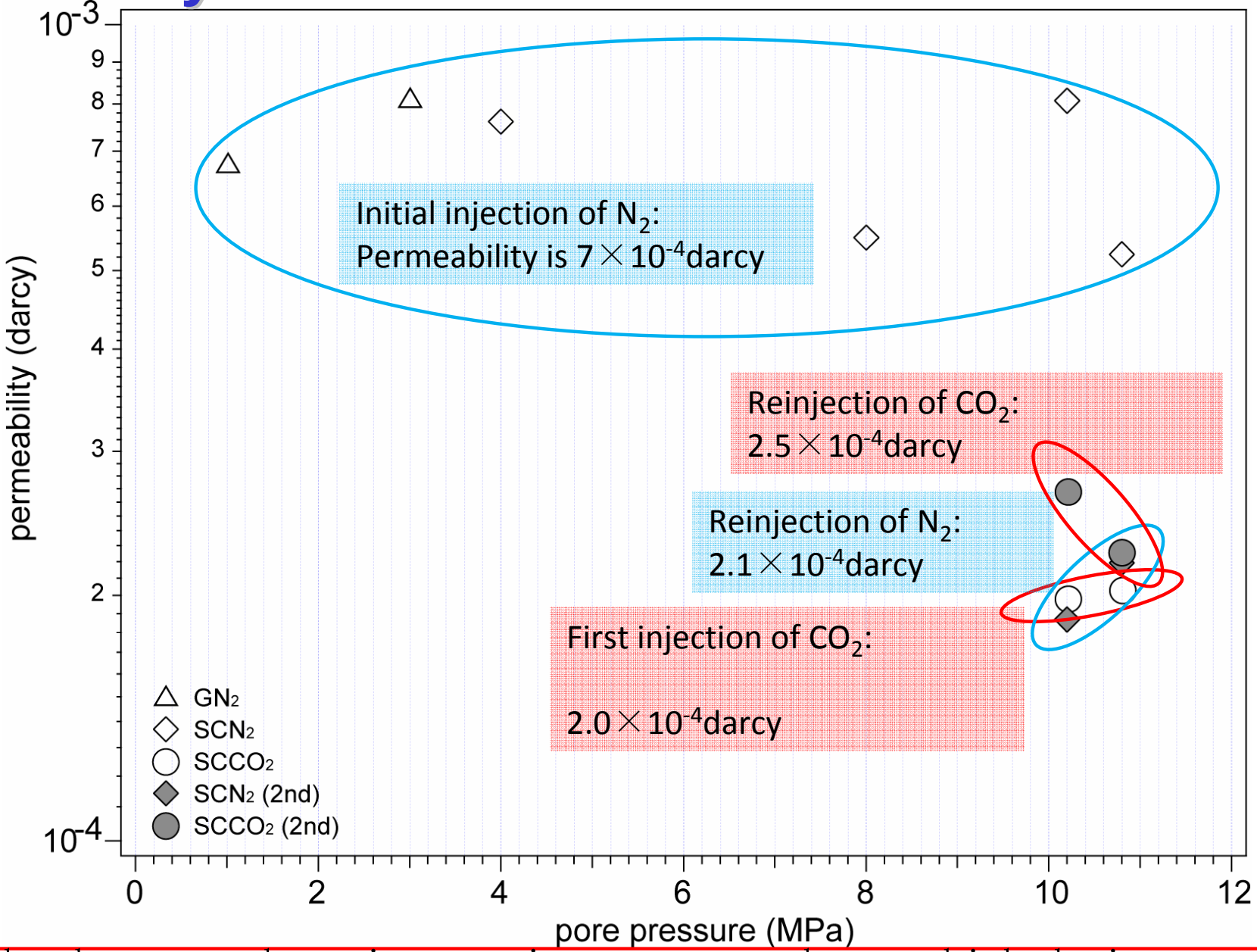
Principally, swelling and shrinkage strain was observed in a reversible fashion in accordance with repeatedly injection of Supercritical CO_2 and N_2.

Change in Vp associated with Injection



It is hard to say that microscopic structure change which dominate Vp did not show a reversible fashion in associated with swelling and shrinkage when supercritical CO_2 and N_2 were injected repeatedly.

Permeability Measurements



It is hard to say that microscopic structure change which dominate permeability did not show a reversible fashion in associated with swelling and shrinkage when supercritical CO_2 and N_2 were injected repeatedly. Note that this test is implemented under confining pressure condition.