

カーボンニュートラルに向けてのCO₂地中貯留の役割 ー 研究開発から実用化・事業化への推進 ー

*From Research and Development
to Demonstration for Commercial Deployment*

二酸化炭素地中貯留技術研究組合・技術部長

(公財)地球環境産業技術研究機構 (RITE)

CO₂貯留研究グループリーダー

せつ じきゅう

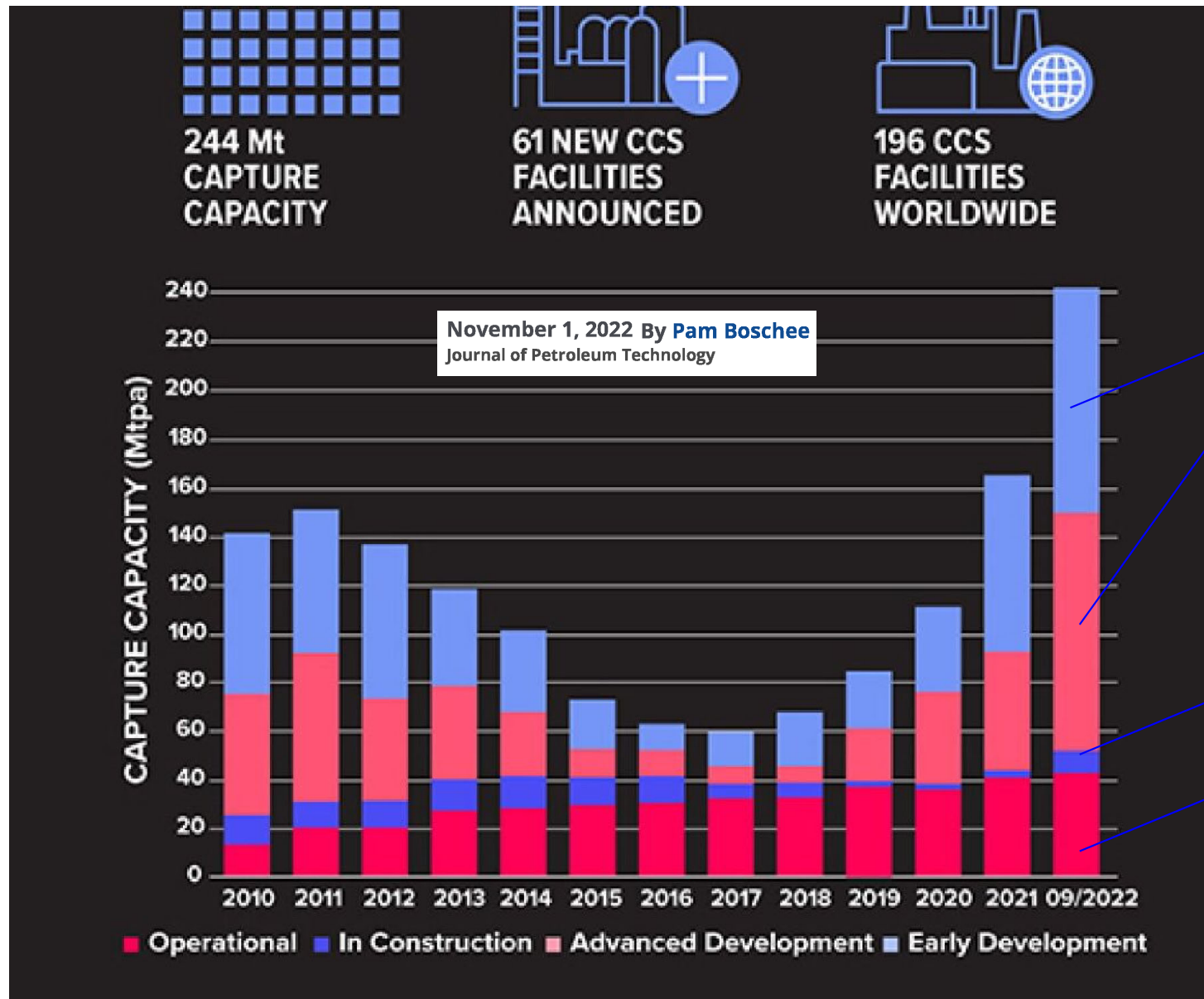
薛 自求

Ziqiu Xue (xue@rite.or.jp)



1. CO₂地中貯留： 誰が必要か →→ どう実施するか

Who needs →→→ How to deploy



計画中

建設中

稼働中

Global CCS Projects' CO₂ Capture Capacity Grows Nearly 50% in 2022

The CO₂ capture capacity of all CCS facilities under development increased 44% over the past 12 months, bringing the total capacity of those projects to 244 mtpa of CO₂.

The US Inflation Reduction Act of 2022 includes enhancements to Internal Revenue Service Section 45Q and \$369 billion in funding for climate and energy. The legislation extends the start of construction timing to the end of 2032; lowers capture thresholds, including direct pay; and expands transferability. The US Infrastructure Investment and Jobs Act includes more than \$12 billion to be spent on CCS over the next 5 years.

Canada's 2022 federal budget includes an investment tax credit: the credit rate is 60% for direct air capture projects, 50% for all other carbon capture projects, and 37.5% for transportation, storage, and use from 2022 to 2030. From 2031 to 2040, the tax rates drop to 30%, 25%, and 18.75%.

CCS will not advance meaningfully without an extraordinary shift in commercial incentives.

Sectoral Pathways to Net Zero 2050 Include CCS and CDR

Transportation

- H₂ from natural gas & CCS
- Biofuels with CCS

Buildings

- H₂ from natural gas & CCS

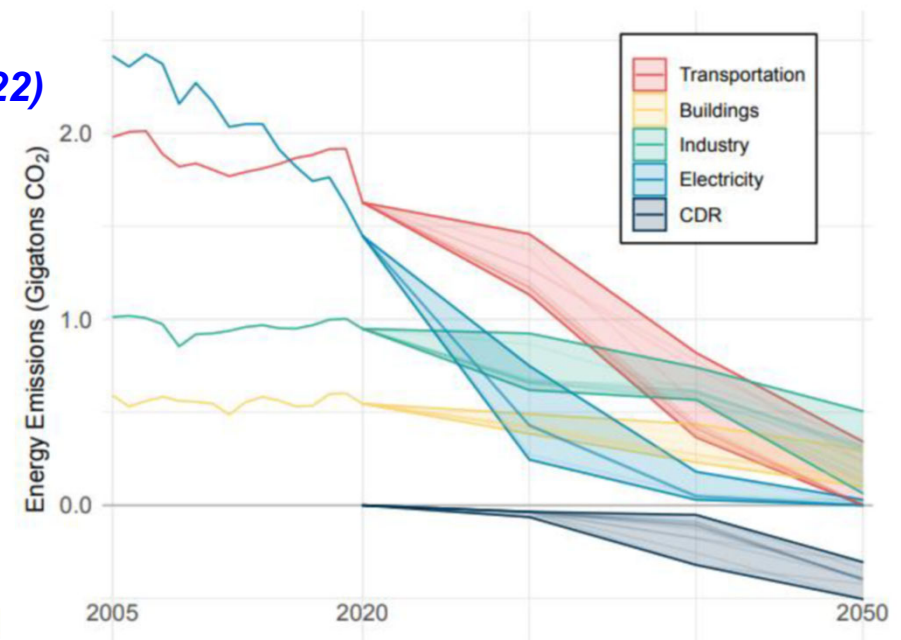
Industry

- CCS for steel, cement, ammonia and chemicals
- H₂ from natural gas & CCS

Electricity

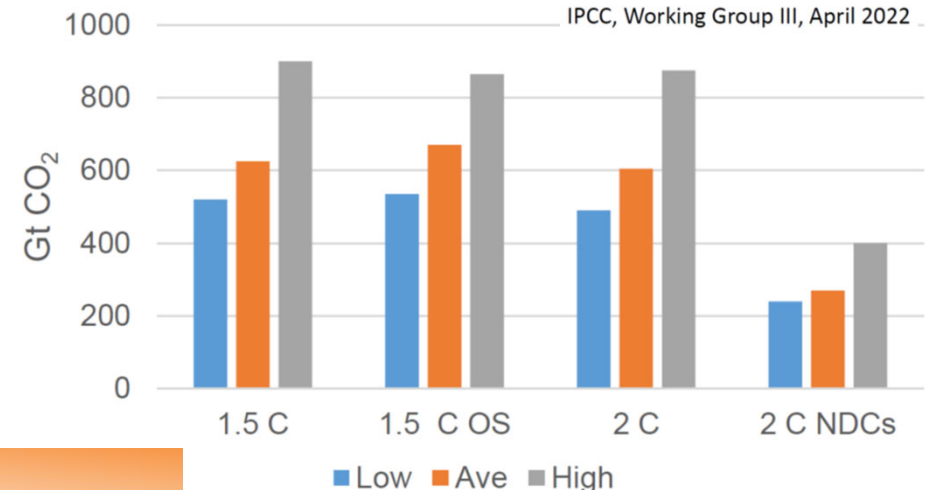
- Natural gas or coal & CCS
- Biomass plus CCS
- H₂ from natural gas & CCS
- H₂ from biomass & CCS

(DOE, 2022)



Cumulative Global CCS to 2100

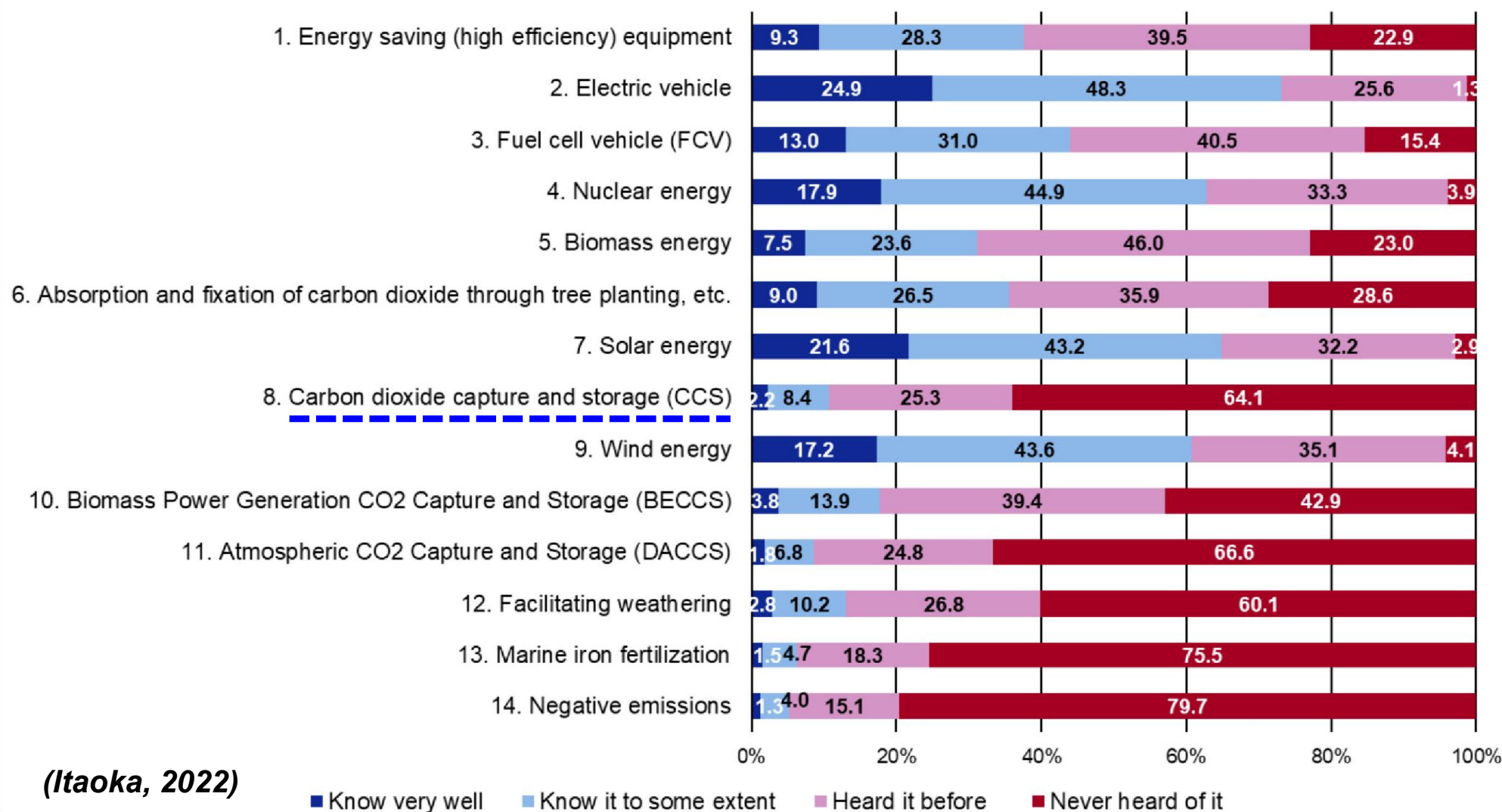
IPCC, Working Group III, April 2022



✓ **社会的認知度**、技術的(安全性)、経済性(コスト)

Awareness of global warming countermeasure technologies In Japan

Do you know about the technologies below? (N=3904)



技術開発(technology development)から 話術(art of conversation)への変身(transforming)

PASSIVE SEISMIC SERIES

Geophysics Role of Non-technical Issues Integral to Full-scale CCUS Deployment



Dr. Carpenter

Full-scale deployment of CCUS in the United States today is not dependent on the advancement of technical issues alone. There are a host of integrated issues that are necessary for the full-scale industry-wide deployment of CCUS that include, but are not limited to regulatory considerations (e.g., permitting, Class VI, etc.), economic considerations (e.g., financial lending, 45Q tax credits, etc.), risk evaluation, stakeholder engagement, Environmental Social Governance (ESG), Environmental Justice (EJ), and political/policy needs.

In many cases, technologists such as reservoir engineers, chemical engineers, geologists, geoscientists, etc., either overlook or are not exposed to these non-technical considerations. This presentation will discuss and illuminate the integrated nature of these issues and provide some insights for technologists to become more literate and therefore more valuable and engaging to their teams advancing CCUS projects.

Risk Communications Approaches

Uncertainties in Subsurface Characterization (Geology, Science and Technology), Policy and Regulation

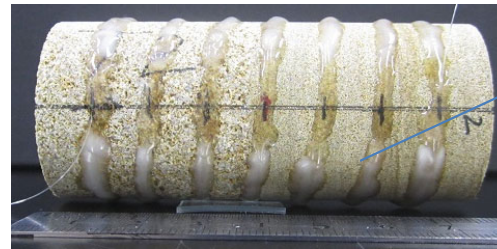
→→ ***Public Concerns*** over ***Potential Risks*** →→ ***Sending Experts*** into the Community & ***Building***

Relationships and Trust!

地下深部の砂層へのCO₂貯留の可視化(X線CT)

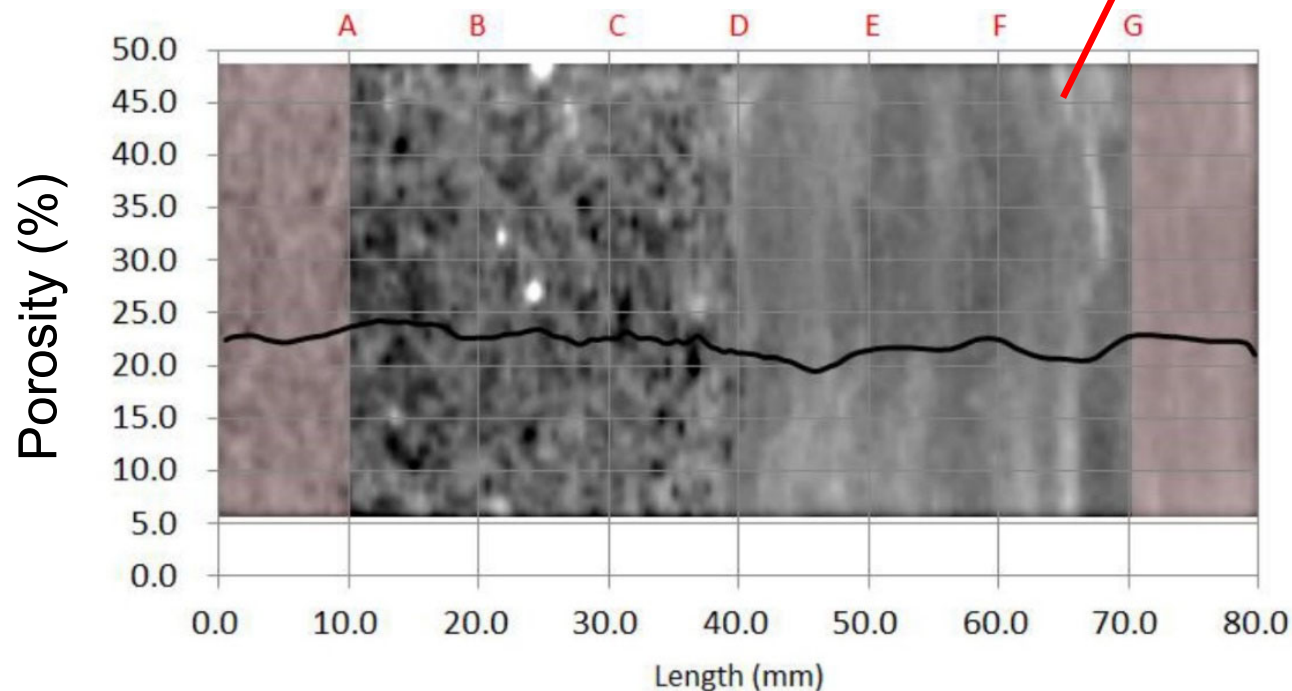


reservoir



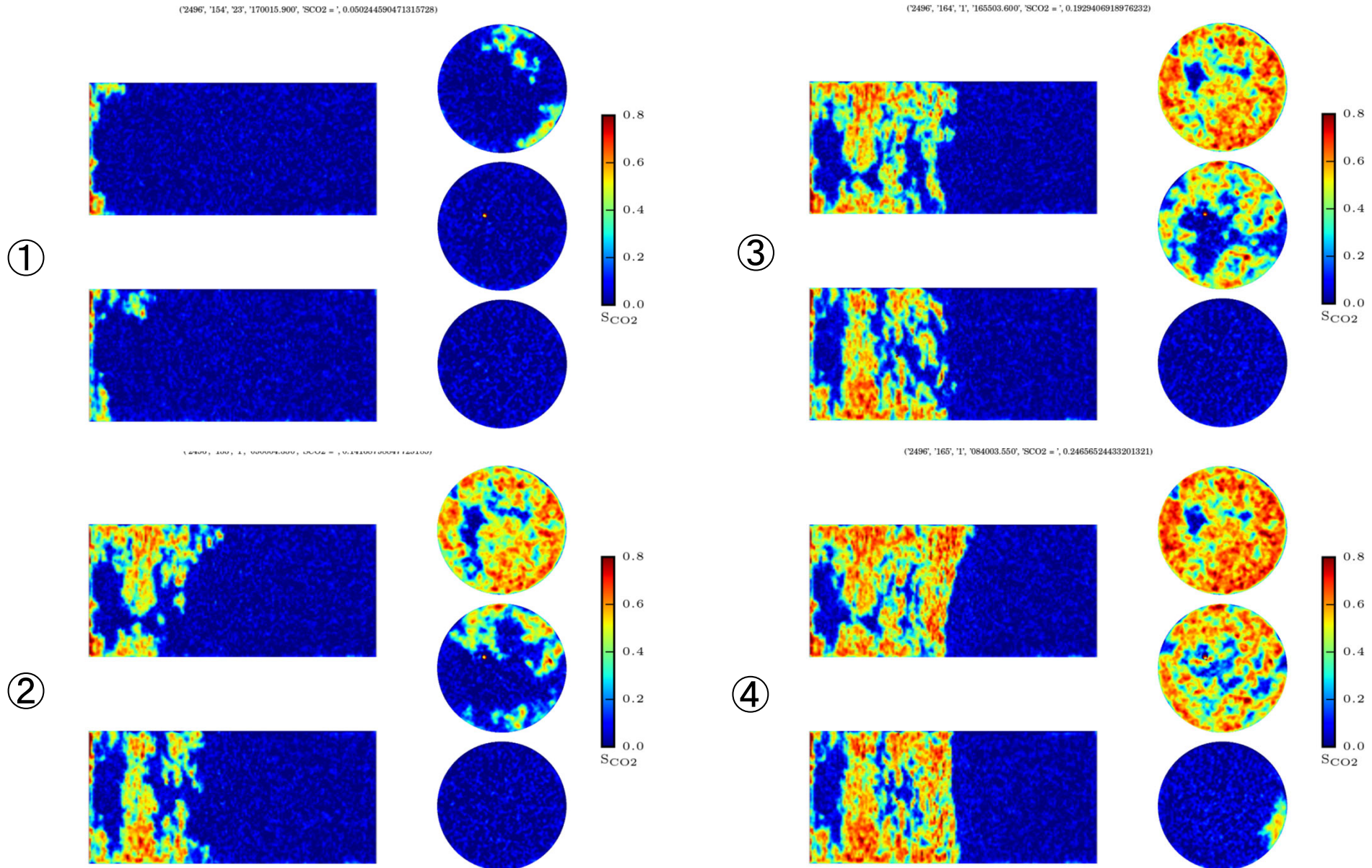
optic fiber cemented on the rock sample

X-CT image



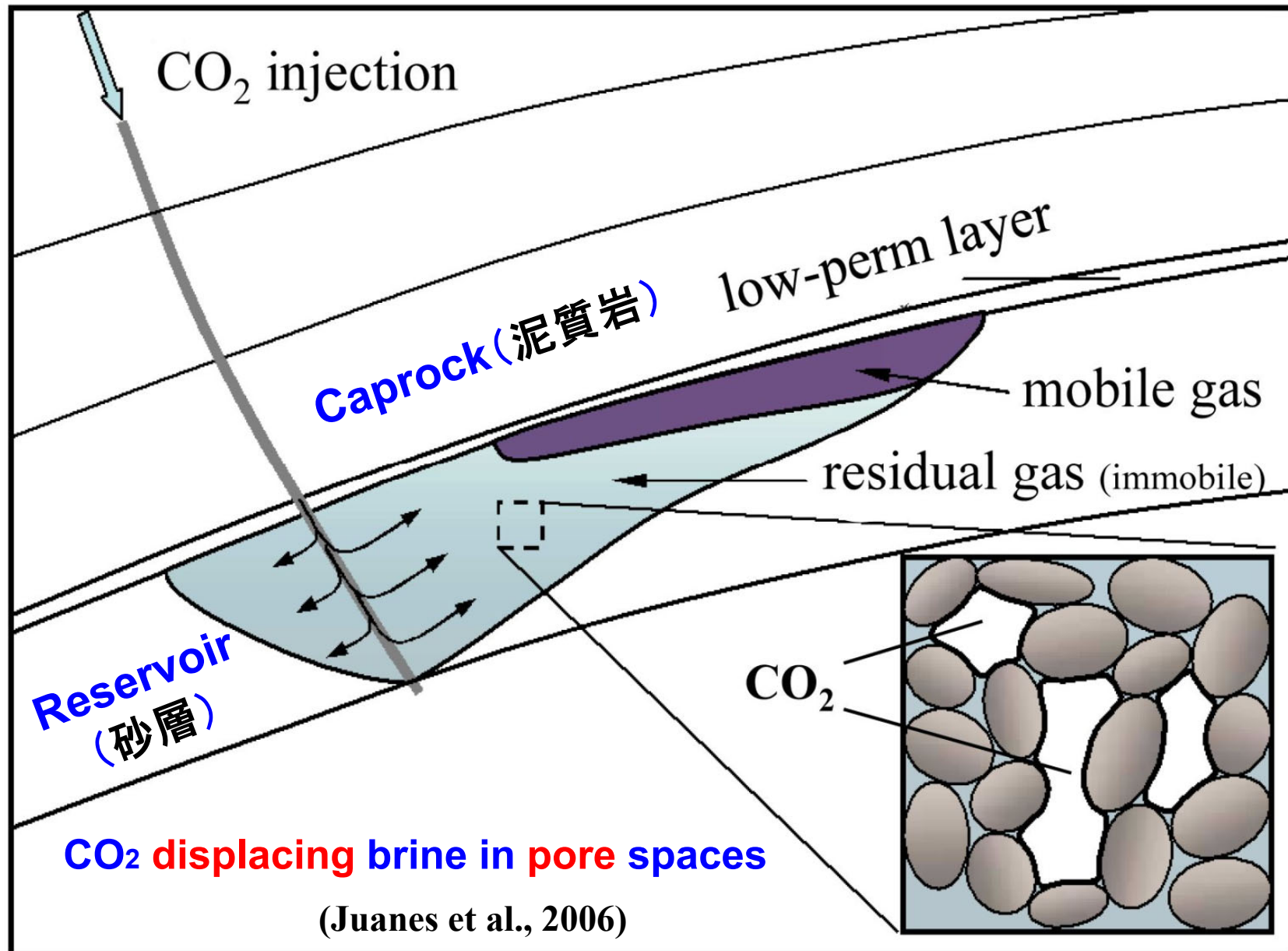
どのようにCO₂が砂層に溜まるか、遮蔽層がどうCO₂を砂層に閉じ込めるか？

CO₂が徐々に砂層に溜まっていくが、遮蔽層に閉じ込められる



Storing CO₂ in deep saline aquifers

(地下深部塩水層へのCO₂貯留 →→ 地中貯留)



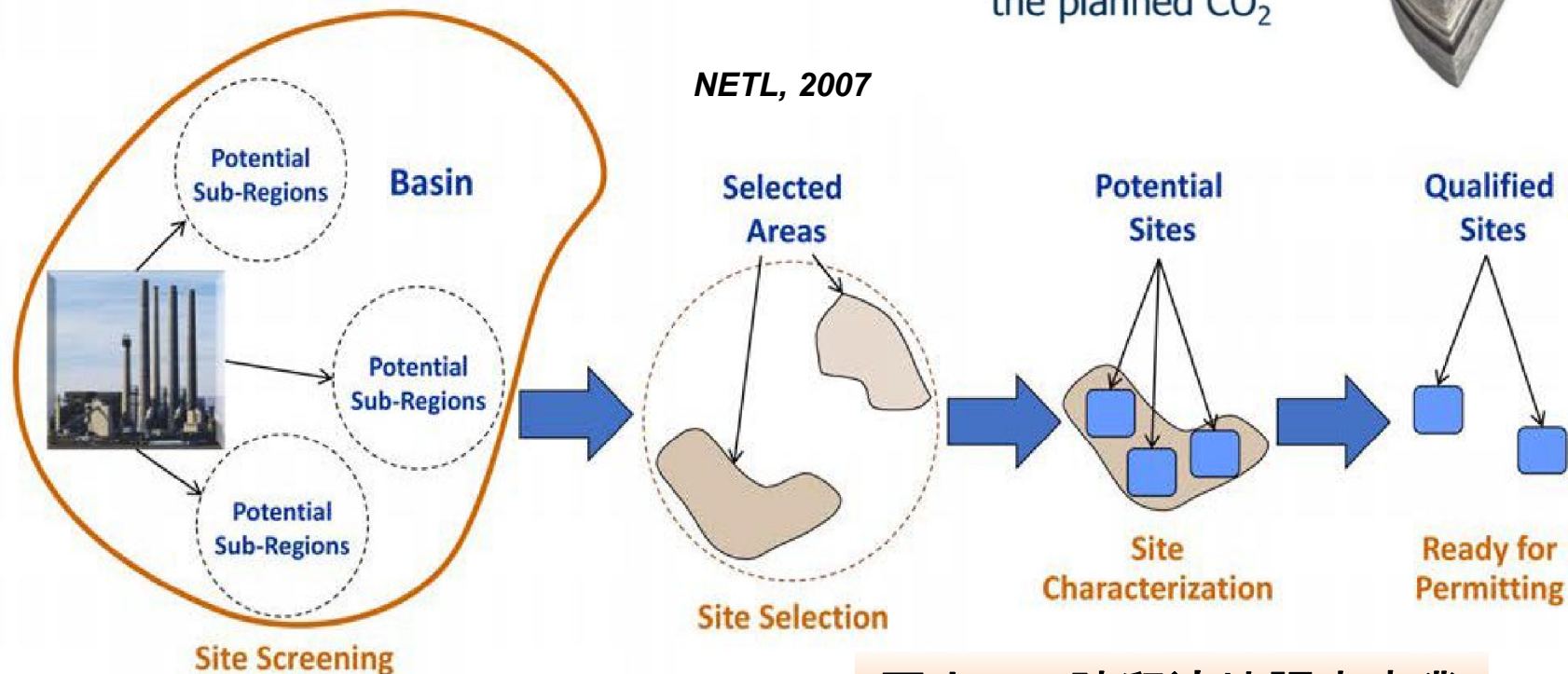
地中貯留の長期安全性に係る CO₂ 貯留(トラップ)メカニズム

- Mobile phase trapped by seal
- Dissolution in water
- Precipitation as a mineral
- Immobile phase as residual, nonwetting saturation

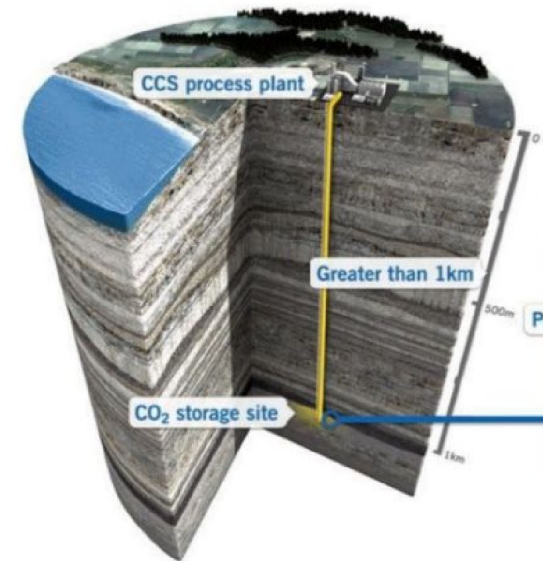
Nagaoka pilot project demonstrated all trapping mechanisms from both lab- and field- scale studies, including 15 years post-injection monitoring.

Storing CO₂ in Saline Aquifers (1/2)

Major Steps in Process of Finding and Developing Qualified Sites



1. **Depth:** > 1 km
2. **Location:**
 - reservoir and containment
 - accessible
3. **Capacity:**
Space to hold all the planned CO₂



国内CO₂貯留適地調査事業

CO2貯留適地調査事業

- 過去のRITE及びNEDO・AISTによる調査から、国内には、約2,400億トンのCO2貯留ポテンシャルがあると推定されていたが、基礎データに基づく推定であり、貯留適地の特定に至っていなかった。
- CCSの事業化をする上で、貯留適地の特定は不可欠であるため、2014年から、3D弾性波探査などの調査を実施中。これまでの調査により、R4年1月末までに、10地点で約160億トンの貯留可能量を推定。
- 貯留適地と見込まれるエリア（下表、赤枠に示す堆積層厚1000m以上）のうち、未だ調査できていない地点について、引き続き調査を実施。

CO2貯留層賦存量マップ

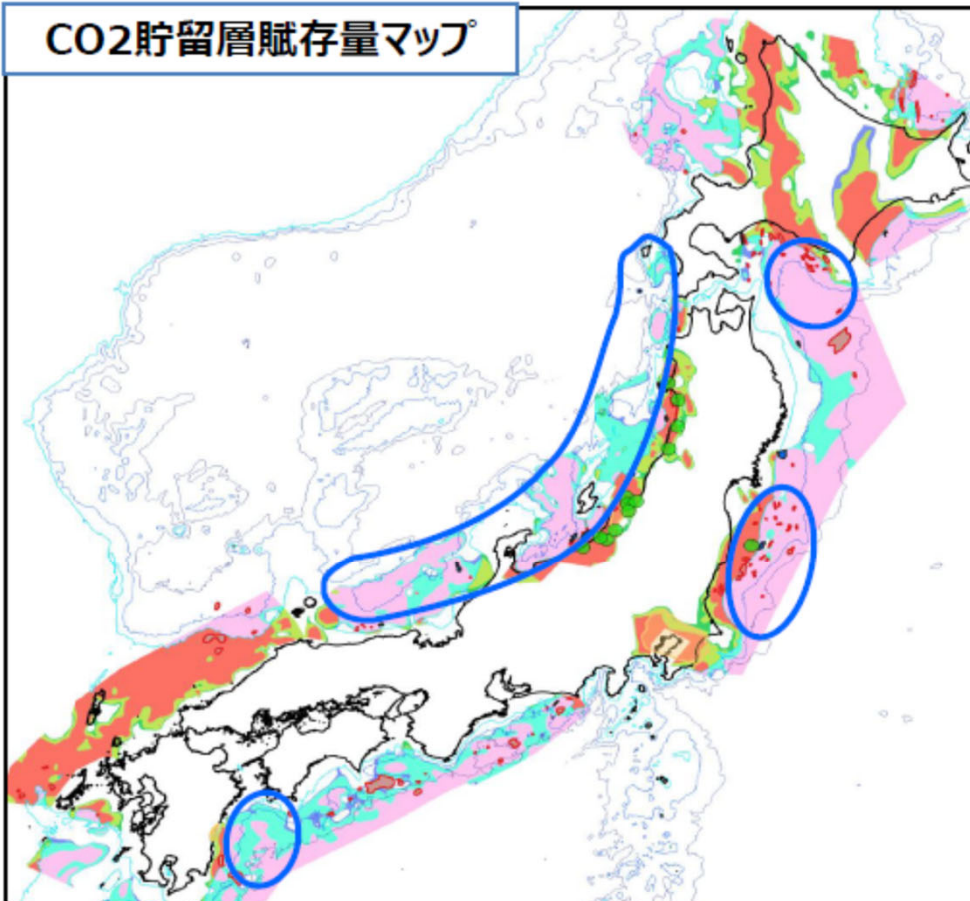


表. 堆積層厚 RITEの区分(2006, 2008)

● A1 (油ガス田)	背斜構造 断層構造	— 水深 2,000m
■ A2 (既掘構造)		— 水深 1,000m
■ A3 (未掘構造)		— 水深 200m
■ B-1 (水溶性ガス田)	同斜構造	
■ B-2 (堆積層厚 >2,000m, 水深 <200m)		
■ B-2 (堆積層厚 1,000~2,000m, 水深 <200m)		
■ B-2 (堆積層厚 800~1,000m, 水深 <200m)		
■ B-2 (堆積層厚 >2,000m, 水深 >200m)		
■ B-2 (堆積層厚 1,000~2,000m, 水深 >200m)		
■ B-2 (堆積層厚 800~1,000m, 水深 >200m)		

RITE(2006, 2008)を基にJCCSにて編集

○ 3D/2D精査データを用いた地質解析エリア
(楕円内の一部で実施。楕円の大きさに意味なし)

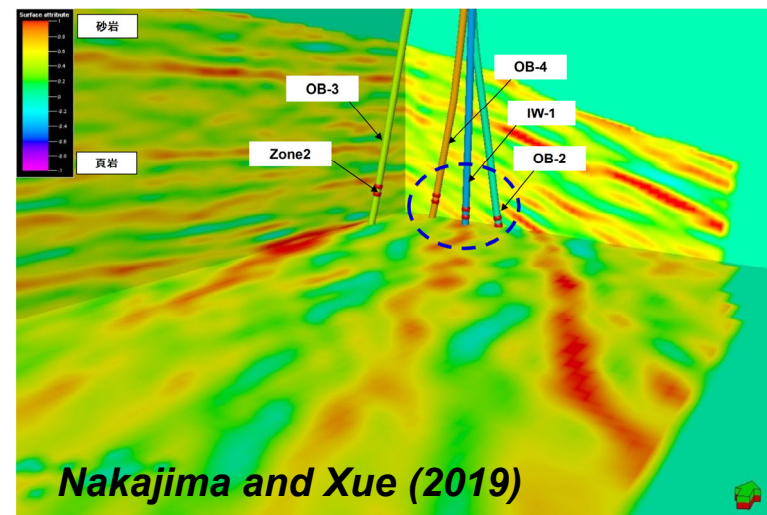
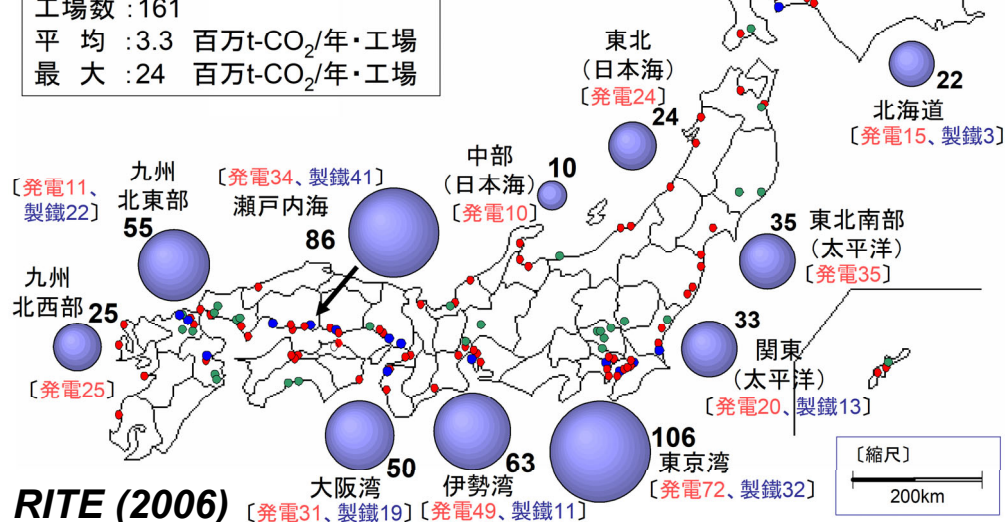
CO₂排出源—貯留サイトのマッチング
(輸送方法、事業コストなど)

SRM: CO₂ Storage Resources Management (経済性評価込み)

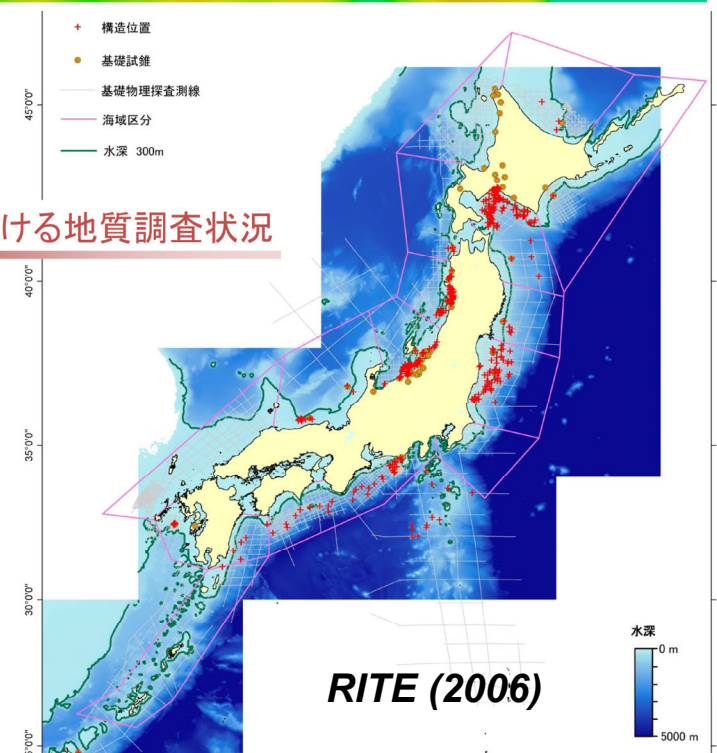
全国的主要大規模排出源 (数字は推定排出量 百万t-CO₂/年)

● 火力発電所 ● 一貫製鉄所 ● セメント工場

合計 : 539 百万t-CO₂/年
工場数 : 161
平均 : 3.3 百万t-CO₂/年・工場
最大 : 24 百万t-CO₂/年・工場



国内における地質調査状況



1. Depth: > 1 km

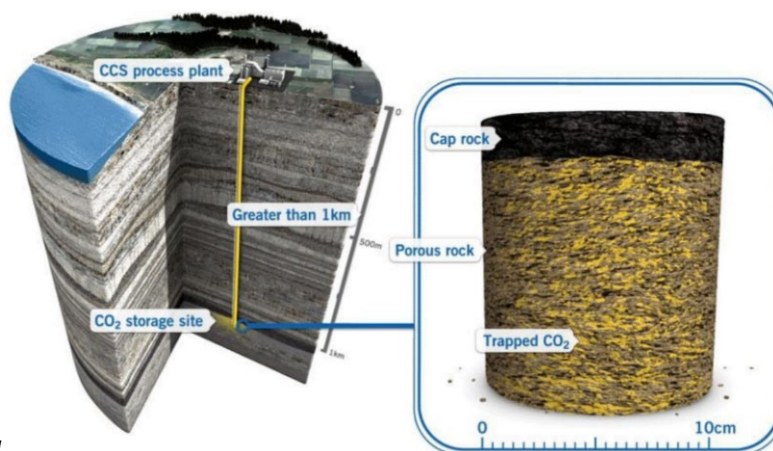
2. Location:

- reservoir and containment
- accessible

3. Capacity:

Space to hold all the planned CO₂

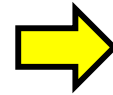
Source: GCCSI



貯留可能量、排出源(排出量、距離)、輸送手段、貯留規模、経済性、社会的受容性(SLO)、複数の実想定サイトを選定！

複数の実想定サイトを対象とする SRM検討の取り組み

- 貯留対象層の差異: 深部塩水性帯水層、水溶性ガス地層、生産性低下ガス田
- 地域特性の差異: 堆積盆規模、既存データ・情報量 & 品質



国内の未調査地域／既存データが乏しい地域(基礎調査対象外)の貯留サイト調査への知見提供

SRM検討の目標

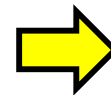


開発シナリオ

How do we provide investment assurance?

How do we get adequate capacity with minimal cost of characterization and development?

CO₂回収・輸送・貯留トータルシステムの
コスト試算ツール作成中
(石炭火力、ガス火力、製鉄所など)



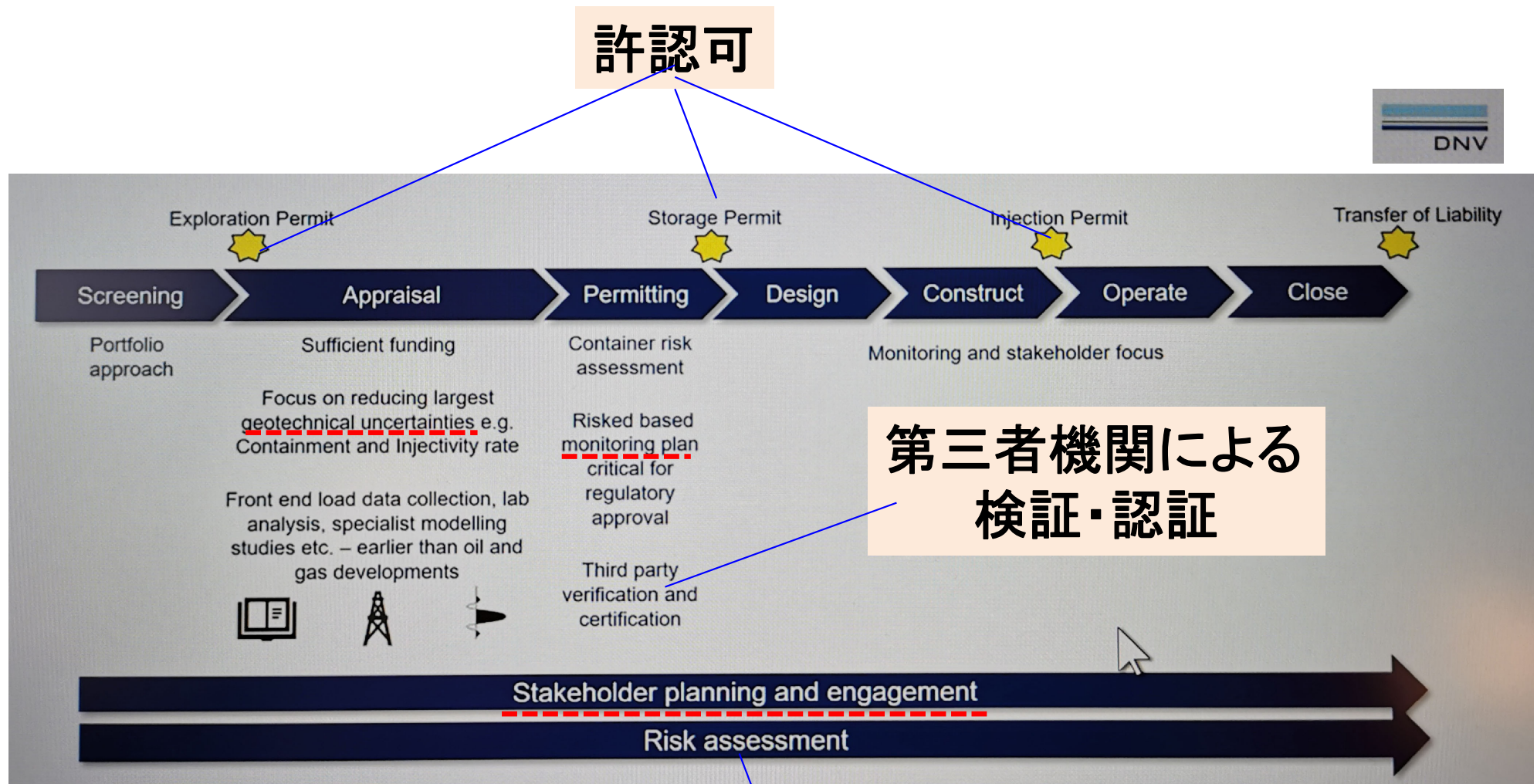
民間主導のCCS事業促進

CCS技術事例集に反映

国内CCS事業化の推進

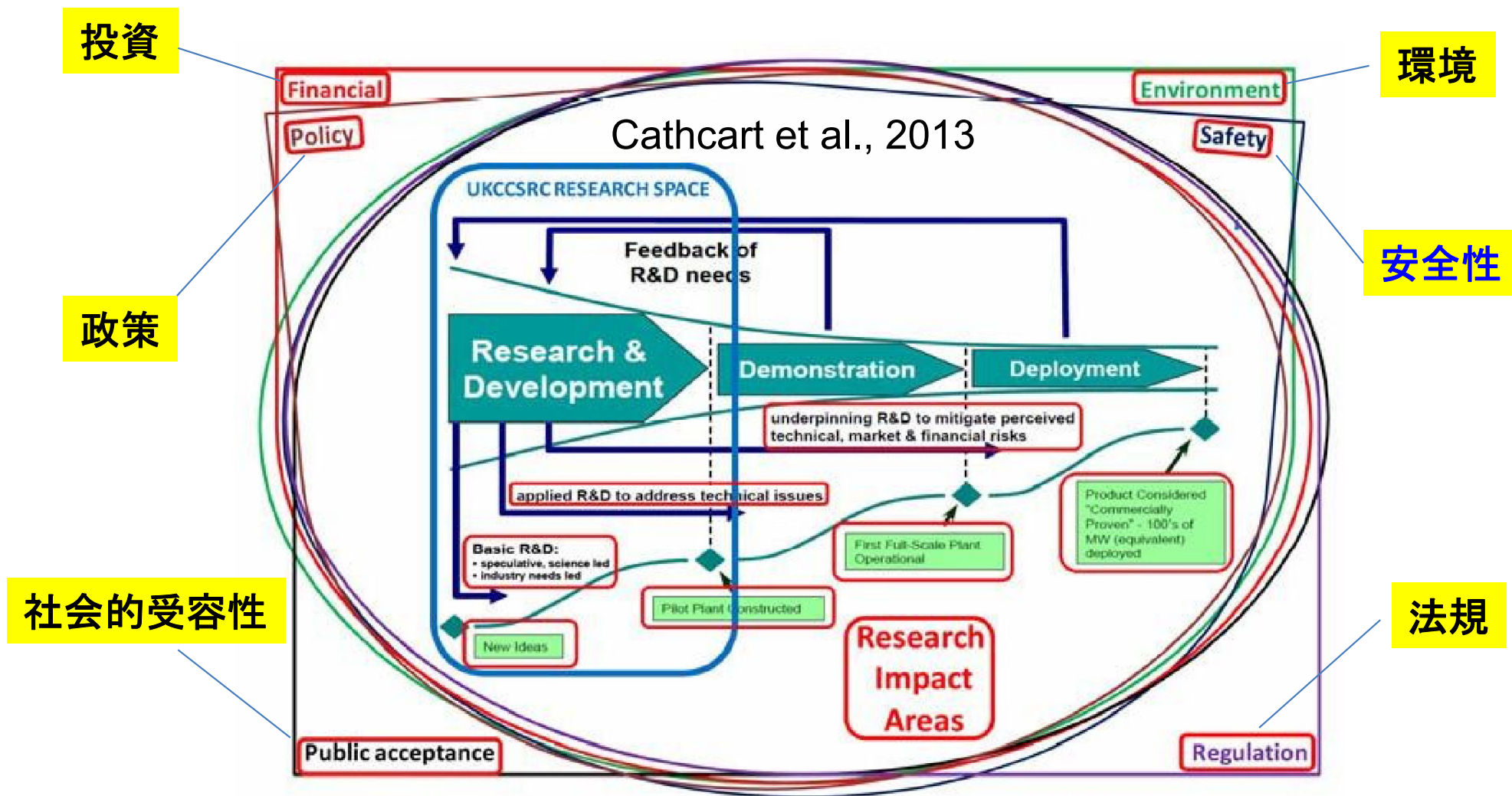
CCS事業の経済性モデル検討

Storing CO₂ in *Saline Aquifers* (2/2)



Community Concern, Risk Communication →→ Public Support

2. CO₂地中貯留技術の実用化・事業化(社会実装)へ



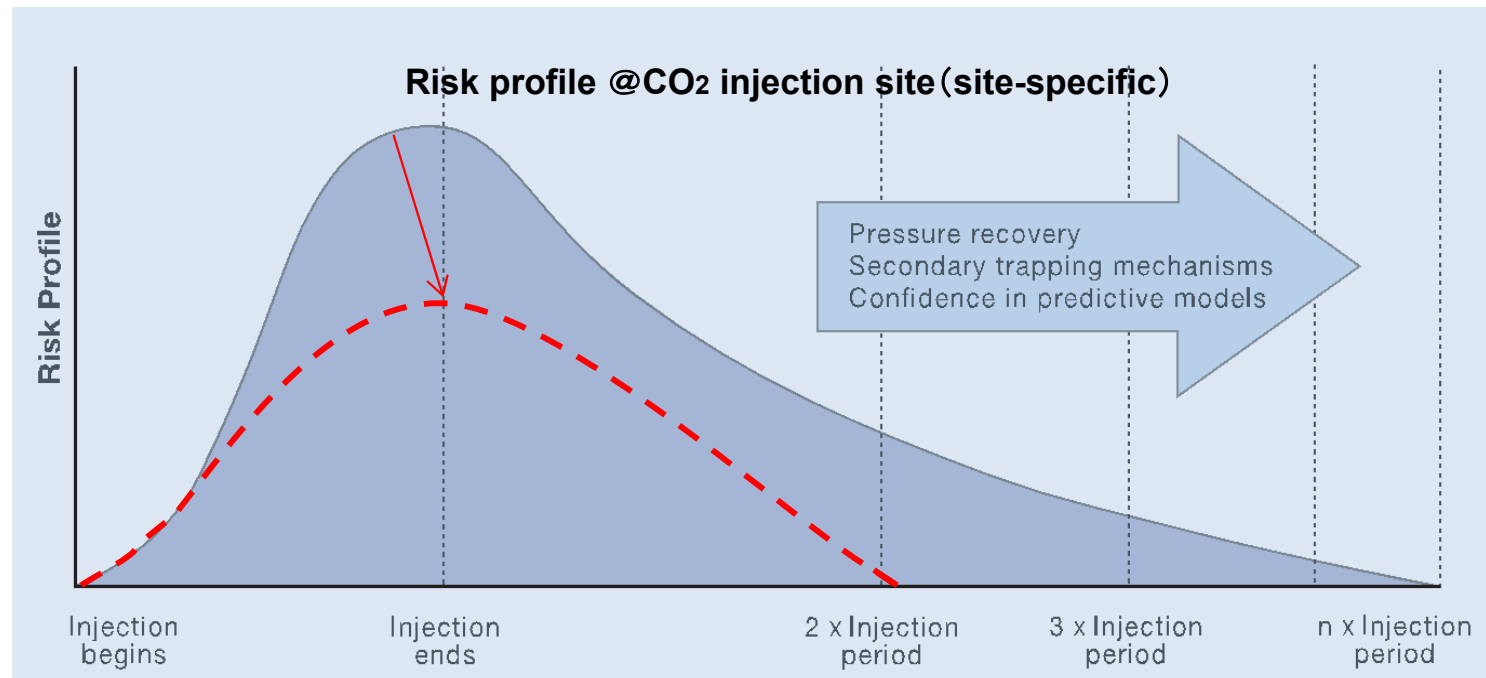
技術移転や知見提供

Research & Development → **Demonstration, Deployment**

実用化には、安全性以外の要素(経済性、社会的受容性、法整備)

地下情報の不確実性、**潜在的**リスク、リスクマネジメント(1/3)

Scientific Knowledge & Evidence-based **Risk Communication**



[Illustration source: Benson, 2007]

Reducing Uncertainty / Mitigating Risks to the **Manageable** Levels !

*Loses of Injectivity, Capacity and Containment,
Induced Seismicity, Environmental Impacts*

Examples to develop a *Local Screening Criterion* for CO₂ storage in Saline Aquifers (in Europe)

The screening criterion proposed for the CO₂ storage by [Chadwick et al. \(2008\)](#).

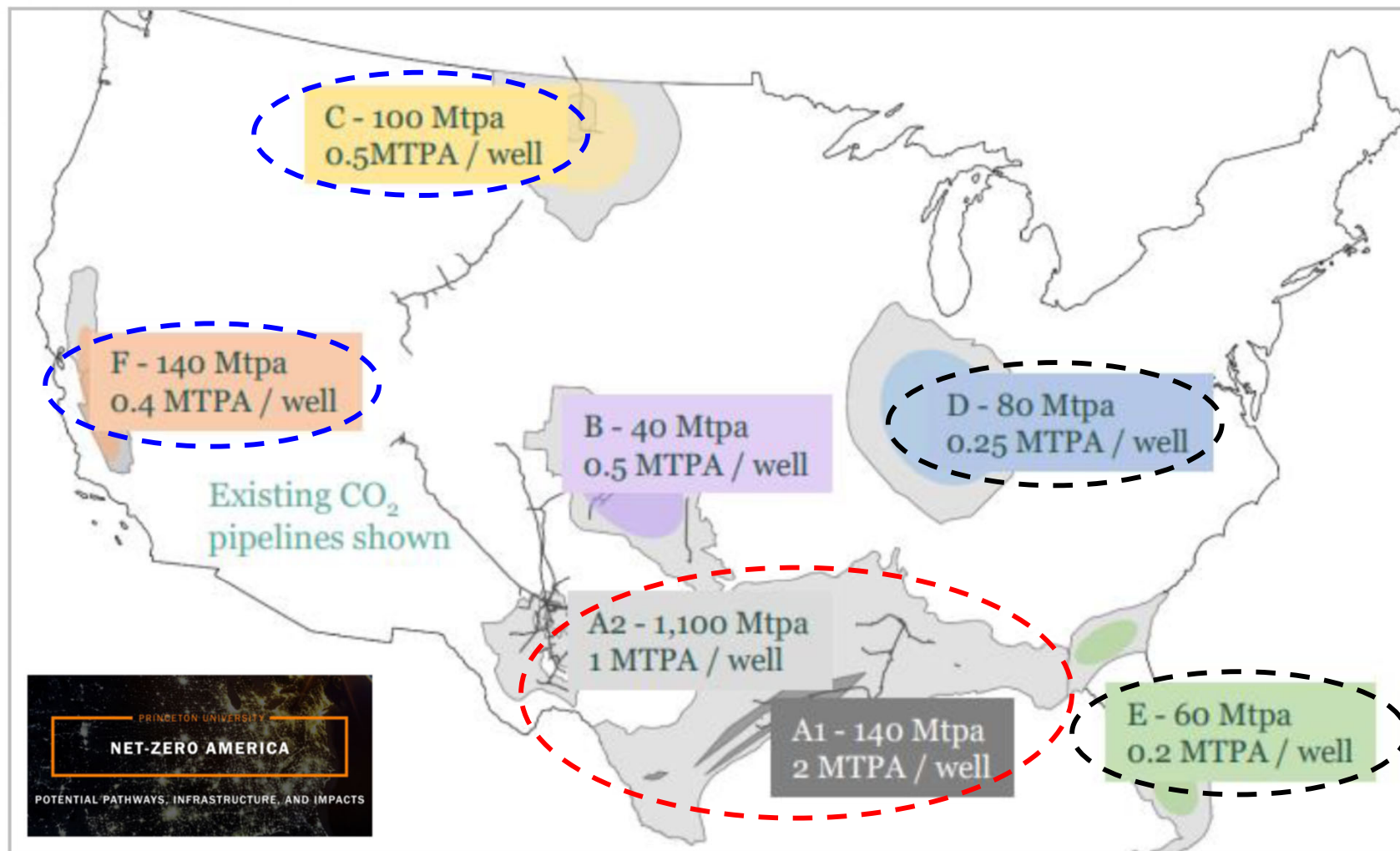
Parameters	Positive indicators	Cautionary indicators
Total storage capacity	Total capacity of reservoir estimated to be much larger than the total amount produced from the CO ₂ source	Total capacity of reservoir estimated to be similar or less than the total amount produced from the CO ₂ source
Depth	1000e 2500 m	<800 m or >2500 m
Thickness (net)	[50 m	<20 m
Porosity	>20%	<10%
Permeability	>300 mD	10e 100 mD
Salinity	>100 g/L	<30 g/L
Seal properties		
Lateral continuity	Un-faulted	Laterally variable faults
Thickness	>100 m	<20 m
Capillary entry pressure	Mush greater than buoyancy force of maximum produced CO ₂ column high	Similar to buoyancy force of maximum produced CO ₂ column height

Thresholds used for the pre-screening of CO₂ storages in Netherland ([Ramírez et al., 2010](#)).

Parameter	Threshold
Capacity	≥4 Mt for gas/oil and ≥2 Mt for aquifer
Thickness reservoir	>10 m
Depth top reservoir	≥800 m
Reservoir porosity	Aquifers: >10%
Reservoir permeability	Aquifers: an expected permeability of 200 mD or more
Thickness seal	≥10 m. Both simple seals as well as complex seal have been taken into account
Seal composition	Salt, anhydrite, shale or claystones
Reservoir composition	Aquifers: sandstone, hydrocarbon fields: limestone, sandstone, siltstone, carbonates
Initial pressure	Overpressure excluded
Salt domes	Relevant for aquifers. Traps located alongside/near salt domes/walls have been excluded because there is a high risk of salt cementation

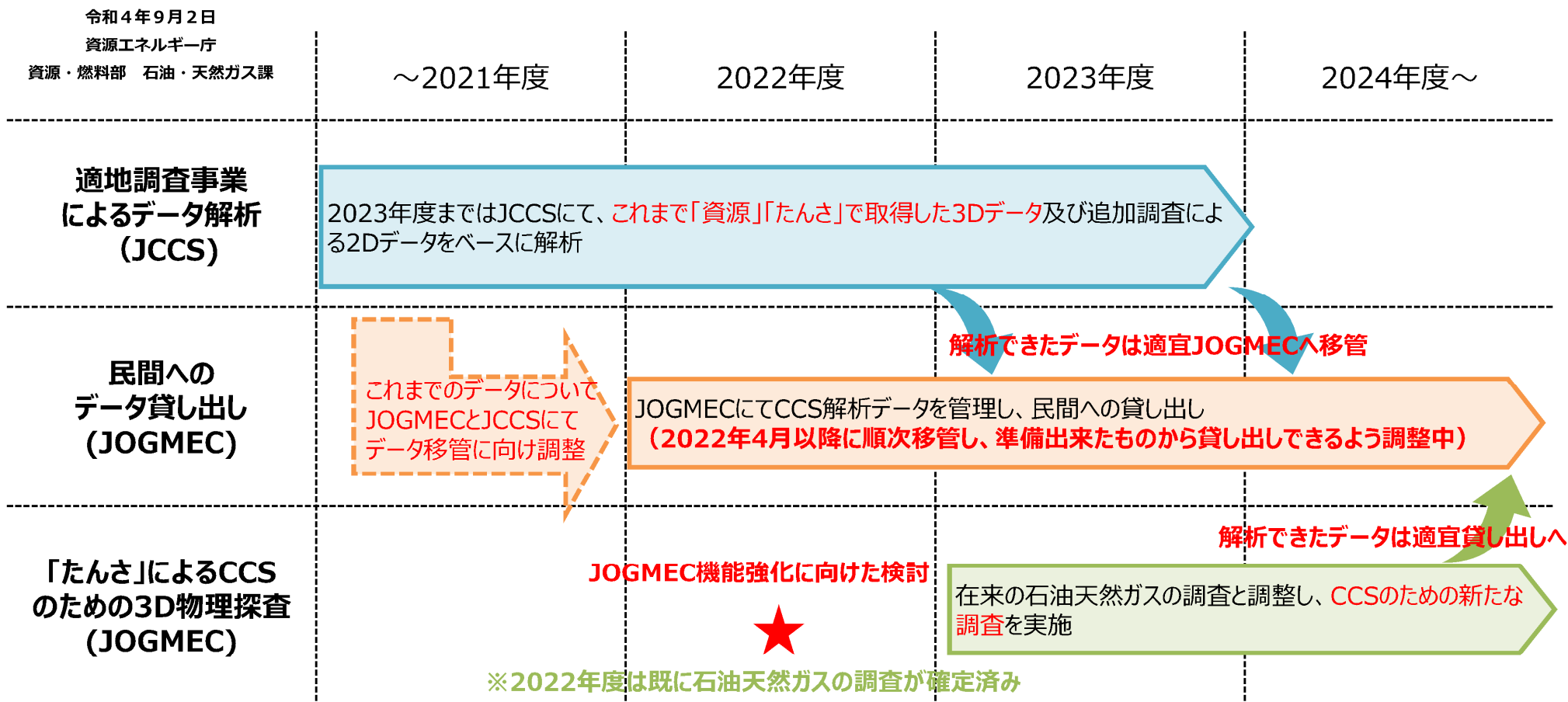
Total storage capacity: to be **much larger** than the total amount from CO₂ source
Reservoir: depth, thickness, porosity, permeability, salinity
Caprock: lateral continuity, un-faulted, thickness, threshold pressure

米国全土が**6つの地域**に、各地域では**年間圧入量**
や坑井当たりの**圧入能力**が大きく異なる (DOE, 2022)



年間圧入量の合計: 1,660 Mtpa 1本の坑井の圧入能力: 0.2, 0.25, 0.4, 0.5, 1, 2 MTPA /well

国内の主な調査地域における貯留性能 (storage capacity, injectivity) 分布について



→→ 石油天然ガス開発地域以外は、今後の調査に期待

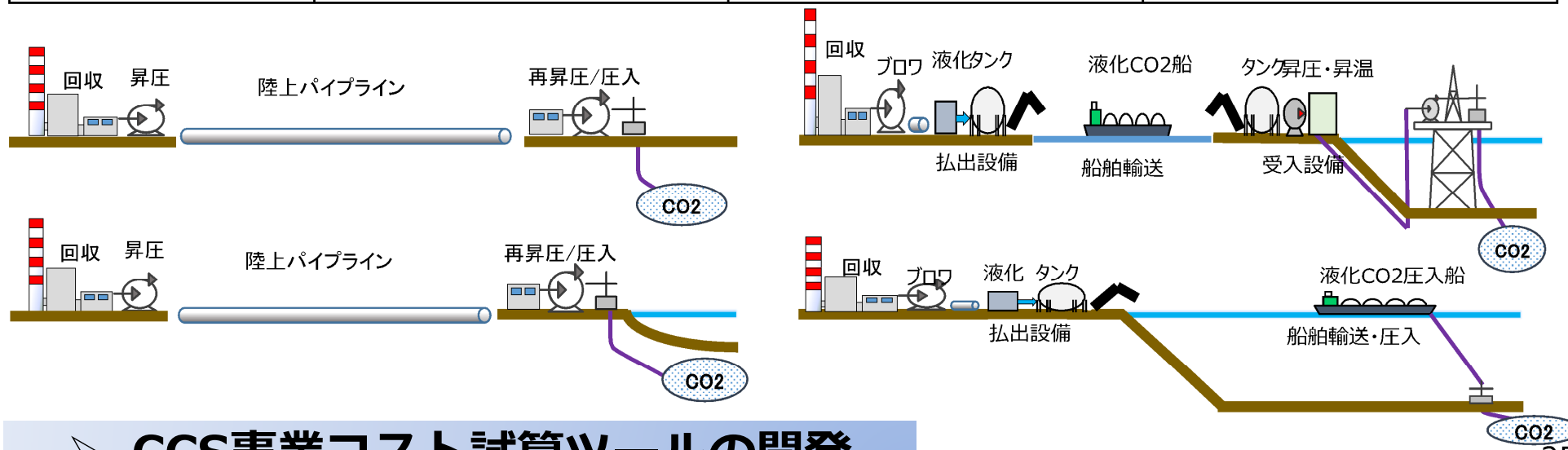
輸送方法や貯留方法には複数の選択肢があり、**排出源と貯留適地の距離や貯留適地の場所に合わせた最適な輸送・貯留拠点が設置される**

令和4年9月2日

資源エネルギー庁

資源・燃料部 石油・天然ガス課

排出源と貯留地の距離 \ 貯留地の場所	地下	沿岸から近い海底下	沿岸から遠い海底下
近い	パイプライン輸送 + 地下貯留	パイプライン輸送 + 陸域から海底下へ貯留	パイプライン輸送 + 海底下へ貯留
遠い	船舶輸送 + 地下貯留	船舶輸送 + 陸域から海底下へ貯留	船舶輸送 + 海底下へ貯留



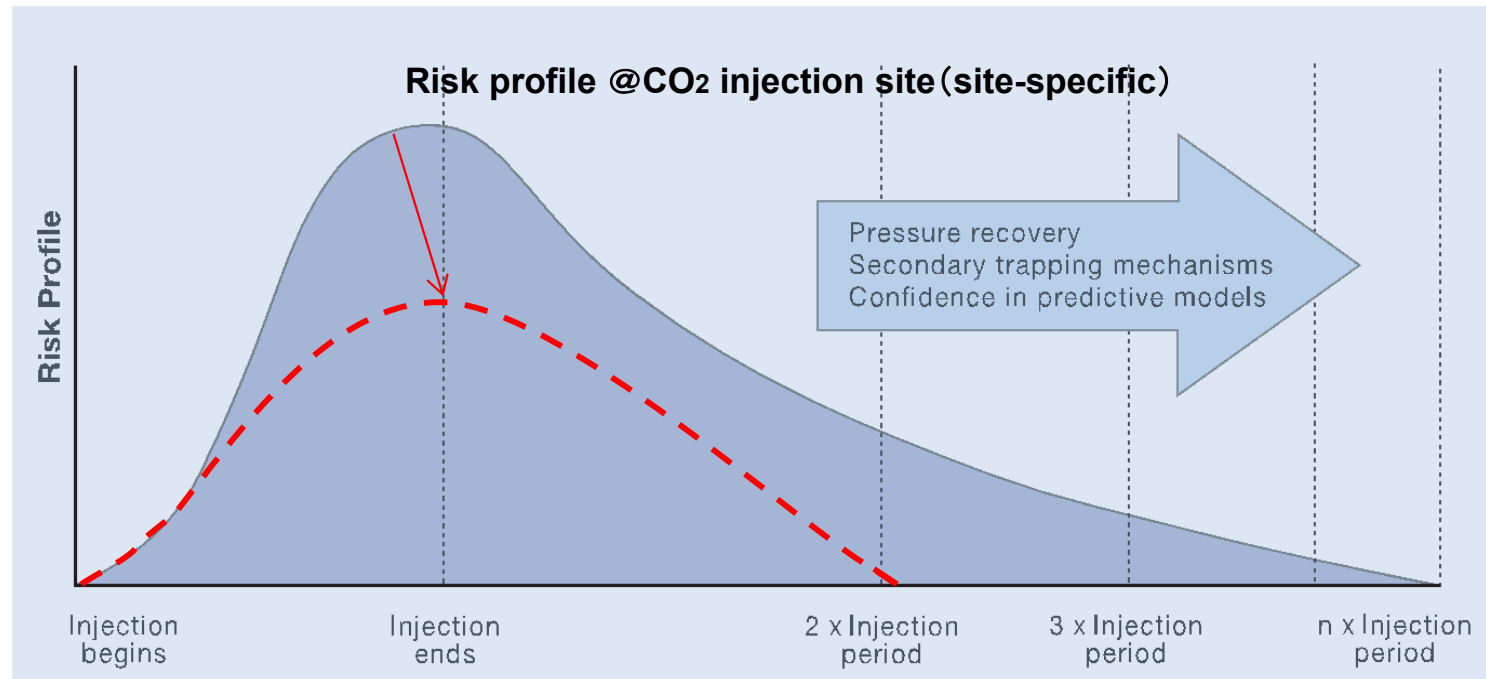
➤ **CCS事業コスト試算ツールの開発**

貯留可能量、**排出源**(排出量、**距離**)、**輸送手段**、貯留規模、経済性(コスト)

複数ケーススタディ →→→ **最適な**サイトを決定

地下情報の不確実性、**潜在的**リスク、リスクマネジメント(2/3)

Scientific Knowledge & Evidence-based **Risk Communication**



[Illustration source: Benson, 2007]

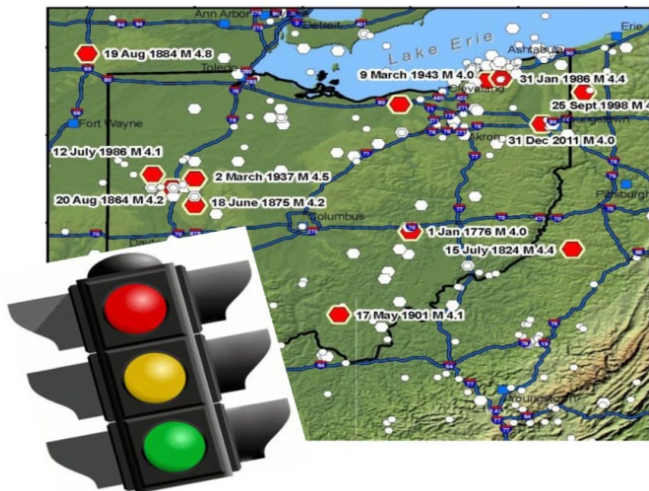
Reducing Uncertainty / Mitigating Risks to the **Manageable** Levels !

***Loses of Injectivity, Capacity and Containment,
Induced Seismicity, Environmental Impacts***

➤大規模CO₂地中貯留における**安全性** **向上**に向けてのリスクマネジメント①

- ✓ 圧入サイト周辺の自然地震や微小振動(極微小地震)の観測(圧入安全性管理ツールATLSの開発)

ATLS: Advanced Traffic Light System



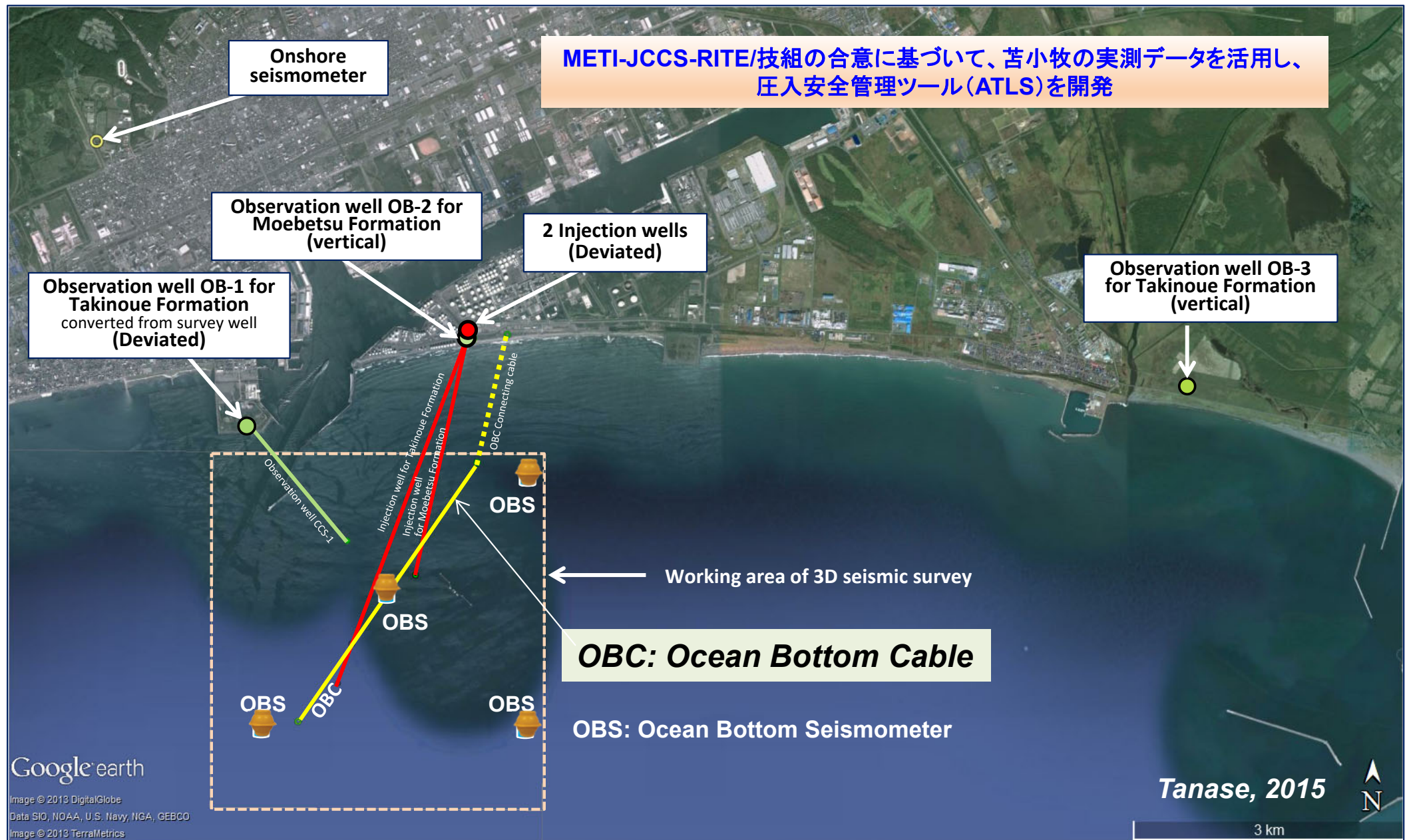
2018 : システムがほぼ完成

2019-2020

: 試験運用・検証 →→ **実適用**へ

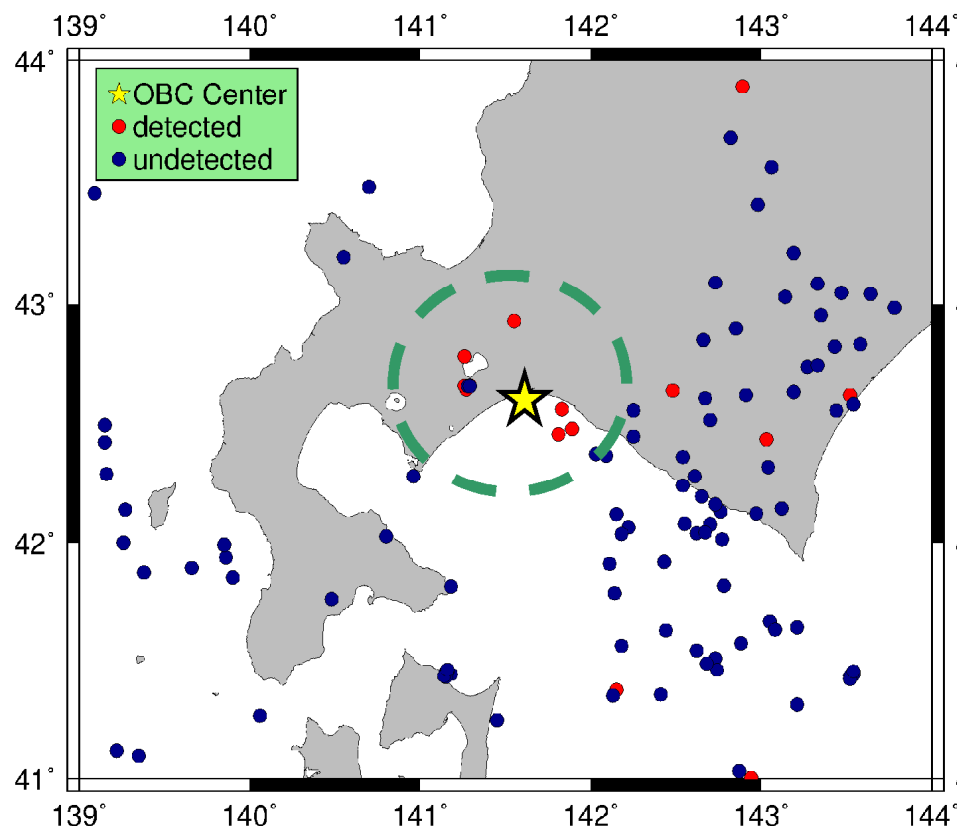
地熱開発、非在来型資源開発にも同様な動き

A Dense Microseismic Monitoring Network @Tomakomai

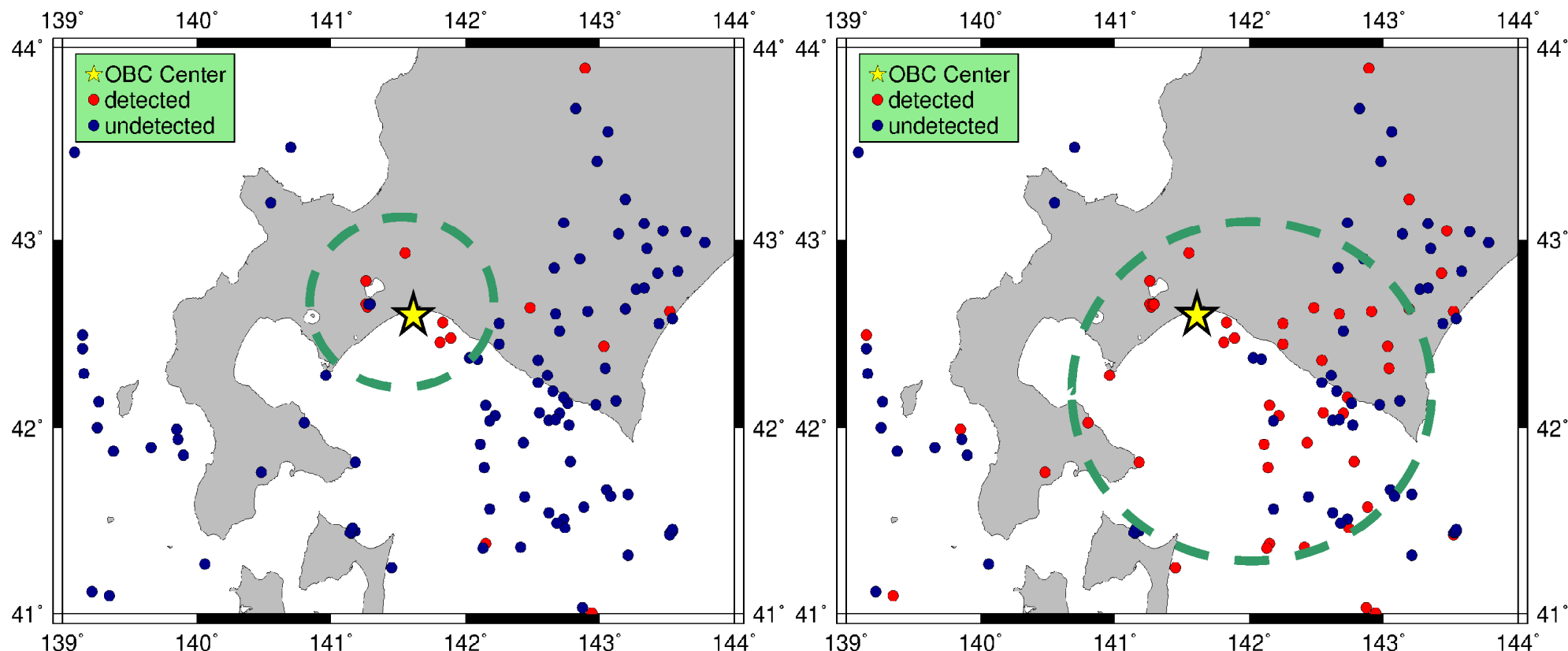


自然地震イベントを効果的に検出@苫小牧

STA/LTA



SDAR

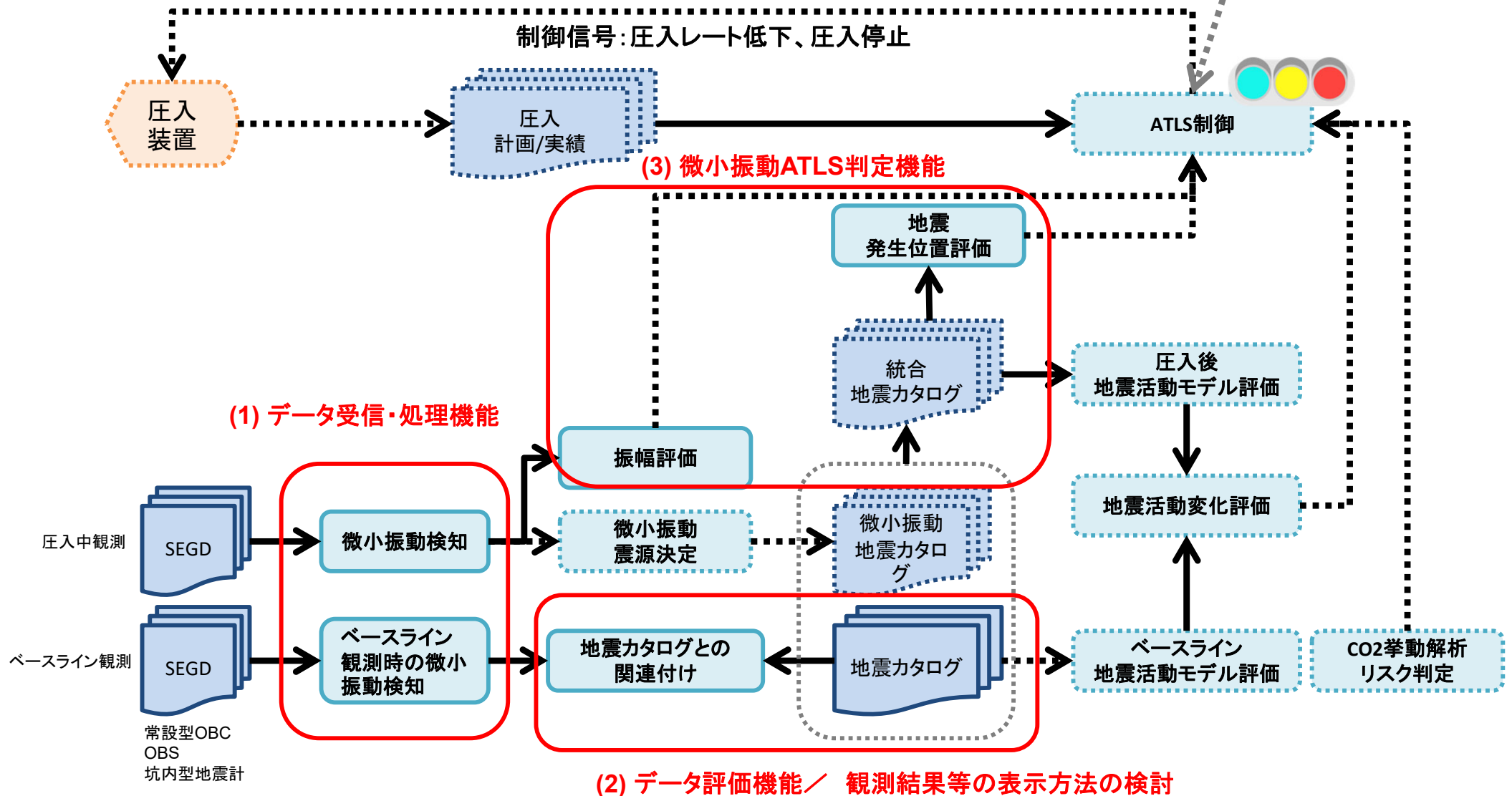


圧入前の自然地震の観測データ : 2015.02.01 -- 2015.02.28

従来のSTA/LTA法と新しいSDAR法の有効性の検証例

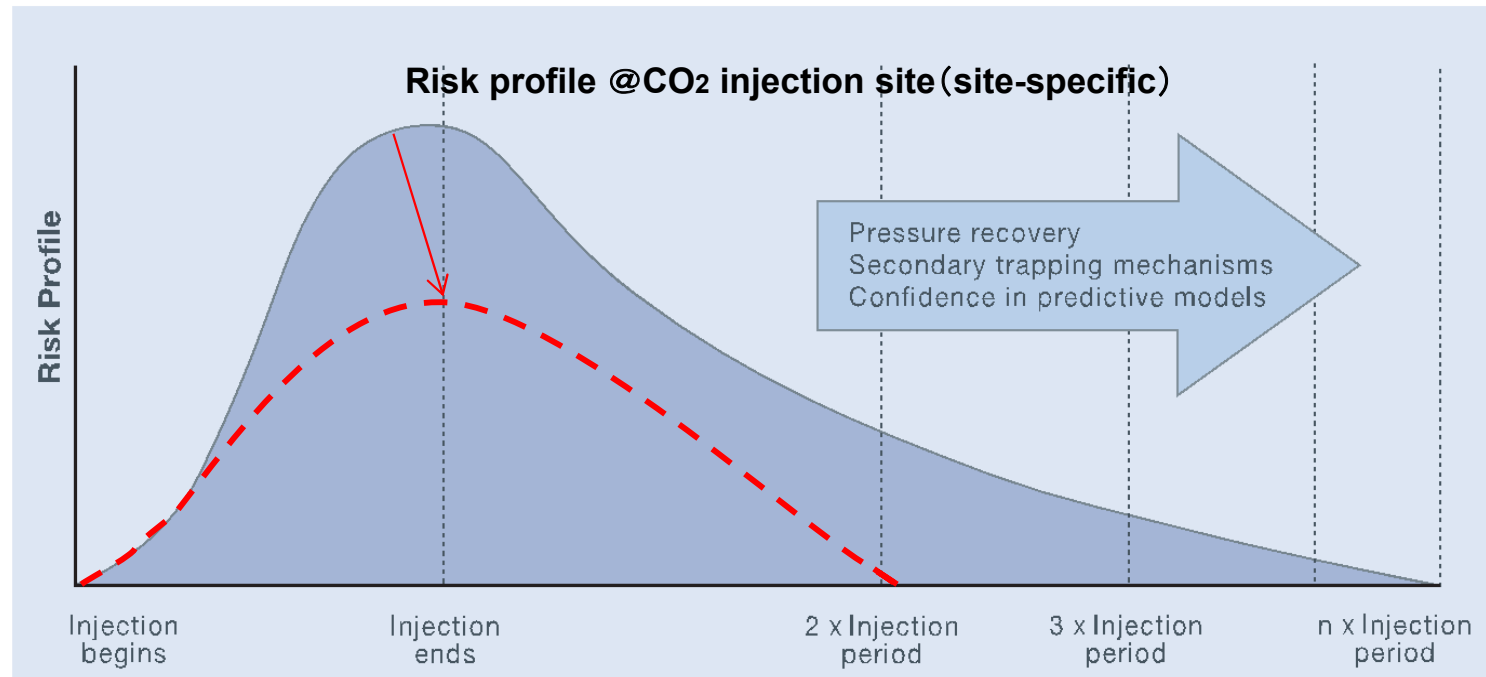
ATLSの主なシステム構成

ATLS状態変更
(人間による判断)
※圧入再開、圧入レート変更で再開



地下情報の不確実性、**潜在的**リスク、リスクマネジメント(3/3)

Scientific Knowledge & Evidence-based **Risk Communication**



[Illustration source: Benson, 2007]

Reducing Uncertainty / Mitigating Risks to the **Manageable** Levels !

*Loses of Injectivity, Capacity and Containment,
Induced Seismicity, Environmental Impacts*

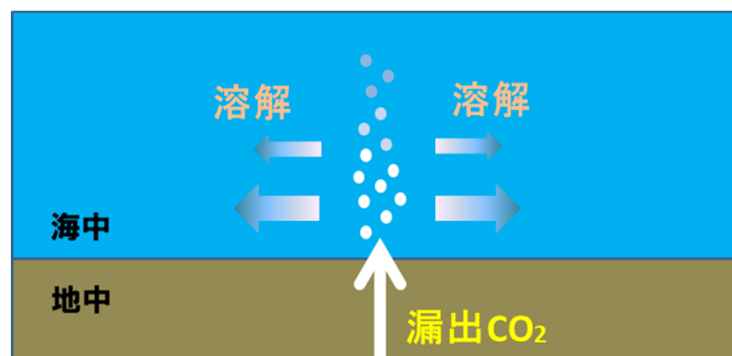
➤大規模CO₂地中貯留における**安全性** **向上**に向けての**リスクマネジメント②**

- ✓ 海域貯留におけるCO₂漏出検知および海洋環境影響評価技術開発



報道発表資料

平成28年2月29日 | 水・土壌



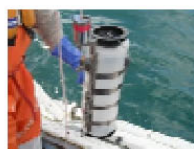
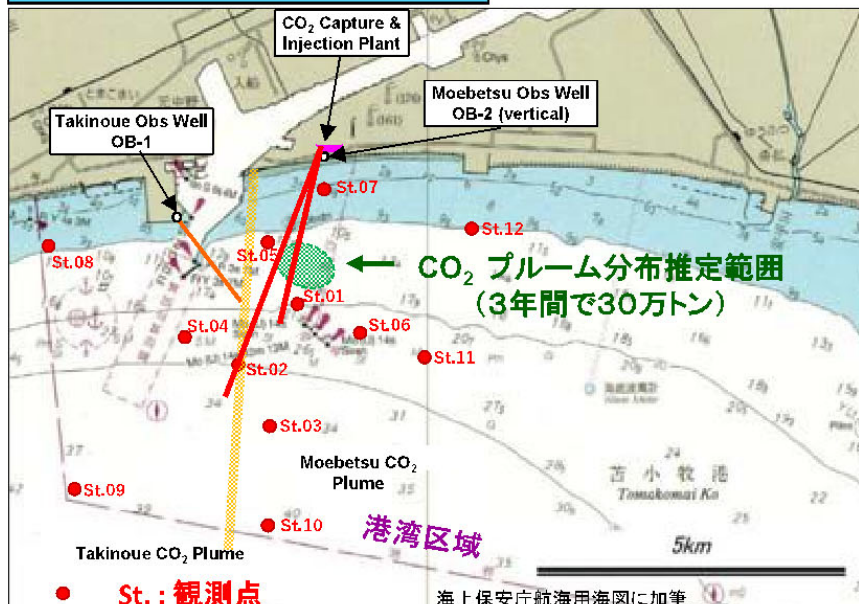
➤ 万が一のCO₂漏出に備えて

(お知らせ) 「海洋汚染等及び海上災害の防止に関する法律第18条の15第1項に基づき環境大臣が特定二酸化炭素ガスの海底下廃棄がされた海域を指定海域として指定する件」(仮称)に対する意見の募集(パブリックコメント)について

海洋環境調査@苫小牧実証試験サイト

国際条約であるロンドン条約1996年議定書を反映した「**海洋汚染等及び海上災害の防止に関する法律(海洋汚染防止法)**」に則り、海洋環境調査の実施が求められている。

海洋環境調査地点



採水器



採泥器



簡易ドレッジ



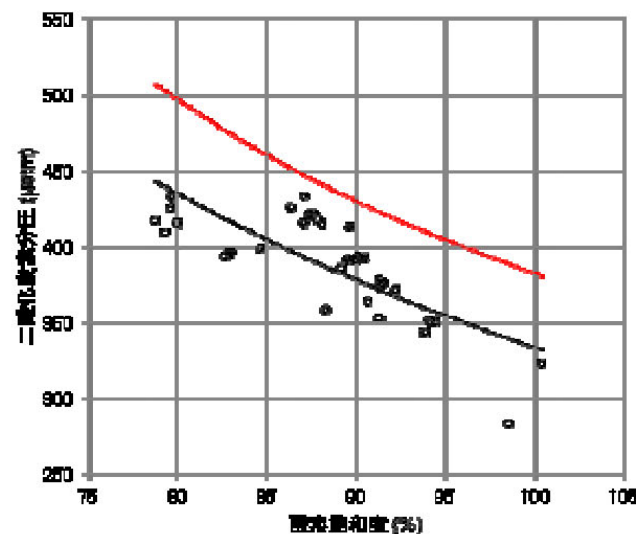
ROV

◆ 海水の化学分析に基づく移行基準(環境省指導)

- 観測点: 8測点(12測点中、沿岸4測点を除く)が対象
- 自然変動の基準の算出: ベースライン調査(H25年8月~H26年5月)で得られた底層(海底面上2m)の酸素飽和度(%)と二酸化炭素分圧(μatm)との累乗近似曲線
- 上側95%予測区間を超えた観測値が得られた場合は監視段階に移行

通常時監視 → 確認調査 → 懸念時監視 → 異常時監視

(澤田, 2018)



St.01- St.12: 観測点(採水ポイント)、年4回(四季)の採水より海中の**CO2漏出を監視**
海水中のCO2分圧と溶存酸素の関係を基に、圧入前の調査より**ベースライン**を作る。

ベースライン=自然変動範囲 <<< **何年分あれば、ベースラインになりうるか**

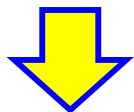
海域環境調査のあり方

CO₂漏洩(地中)・漏出(海中)検出

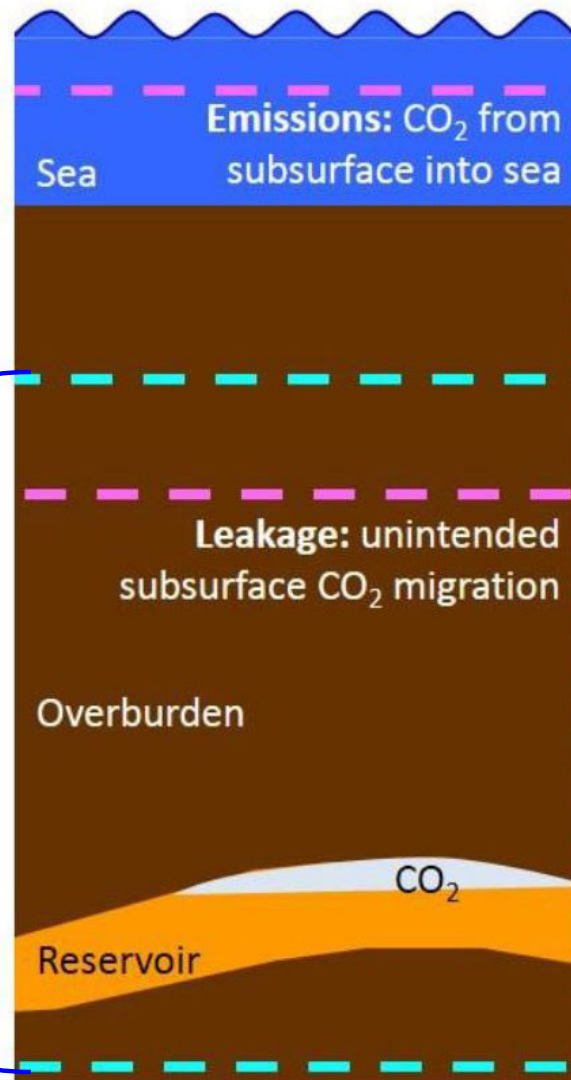
漏出点の特定: 音響ソナー
による漏出気泡検知
+
採水調査

貯留層から上位層
へのCO₂漏洩検出方法

検出能力
Vs
Early Warning



Remediation Plan

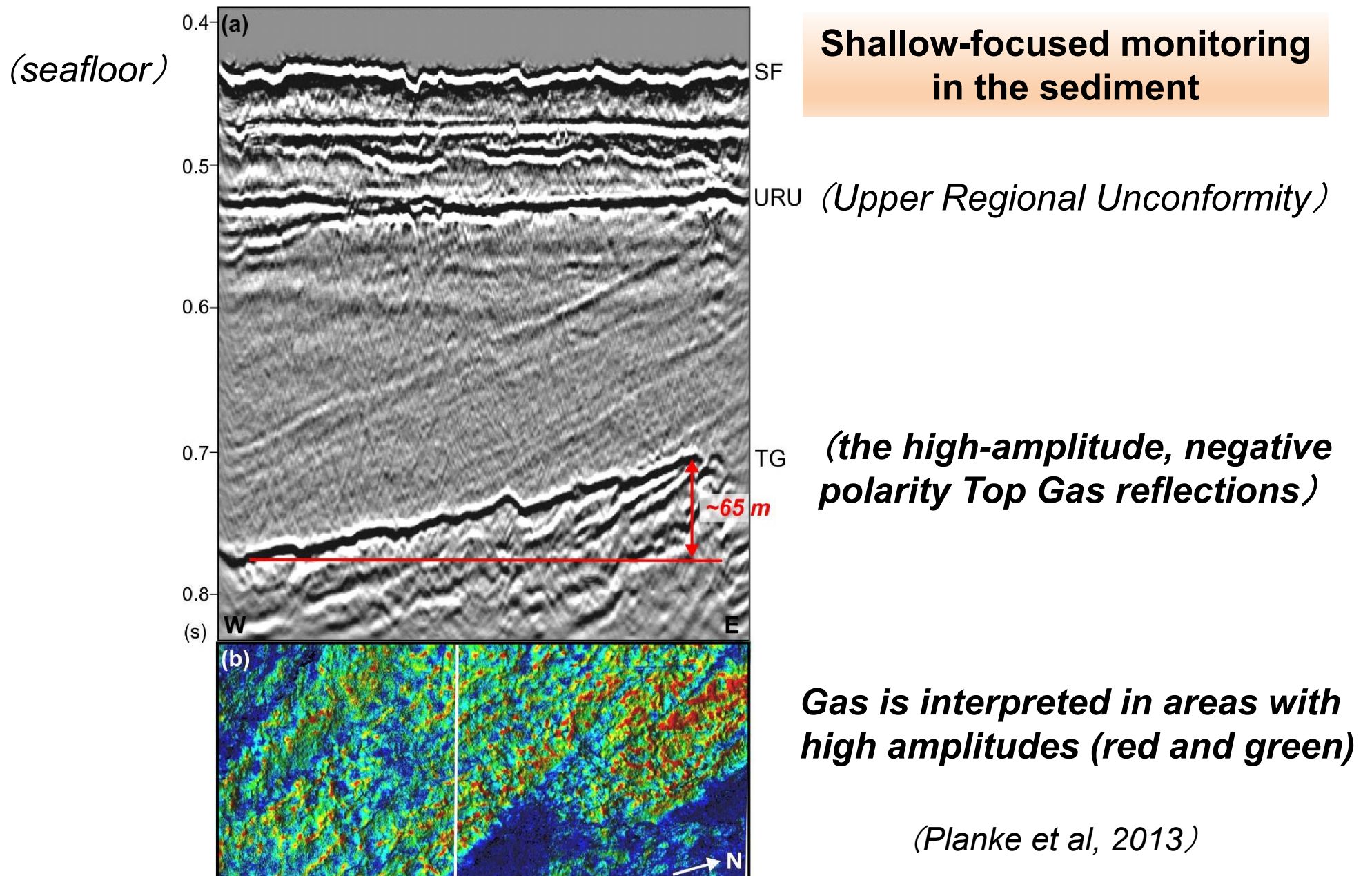


効果的・経済的な
調査方法を提案

Shallow-focussed: To detect CO₂ leakage in the sediment or sea bed emissions – that could pose a health and safety threat or environmental impact.

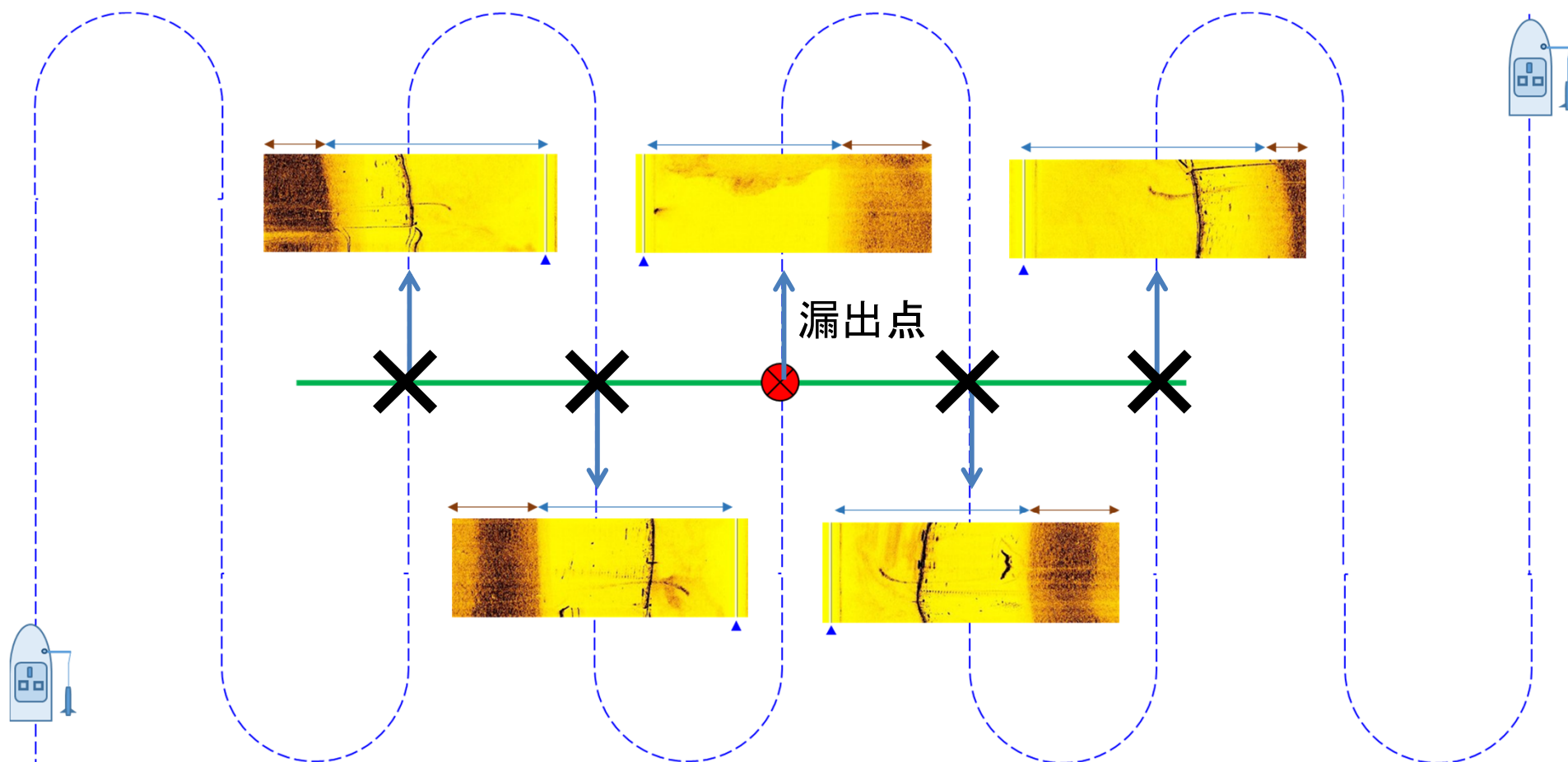
Deep-focussed: To give early warning of unexpected migration – that could compromise the greenhouse gas mitigation function of the storage.

P-Cable High-Resolution 3D Seismic Imaging of Gas Hydrates and Shallow Gas



CO₂気泡検出

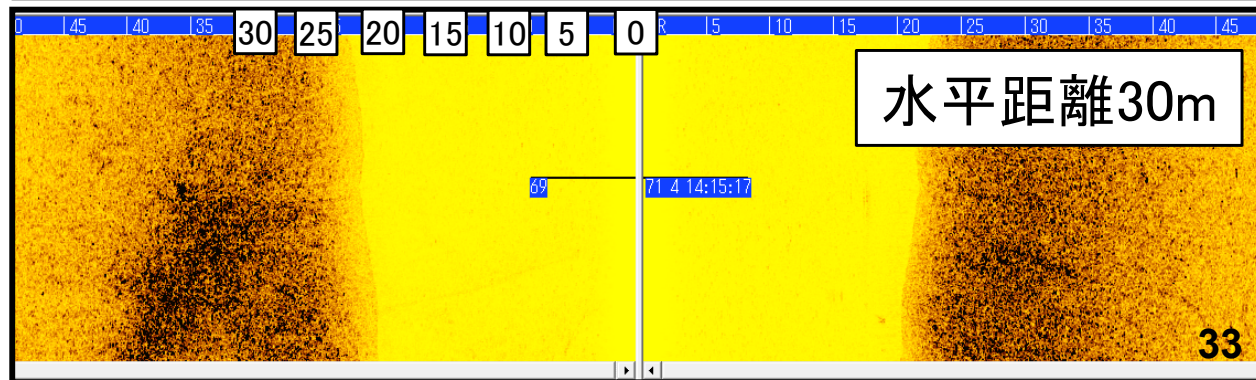
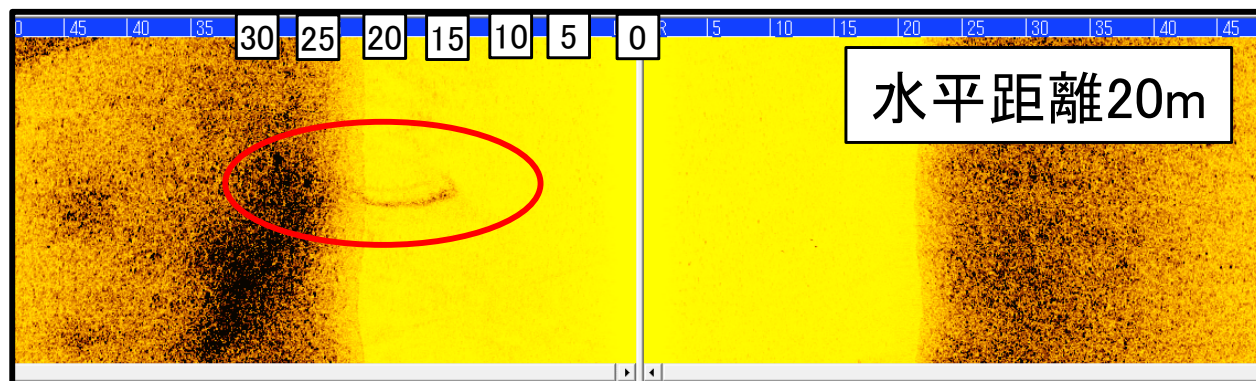
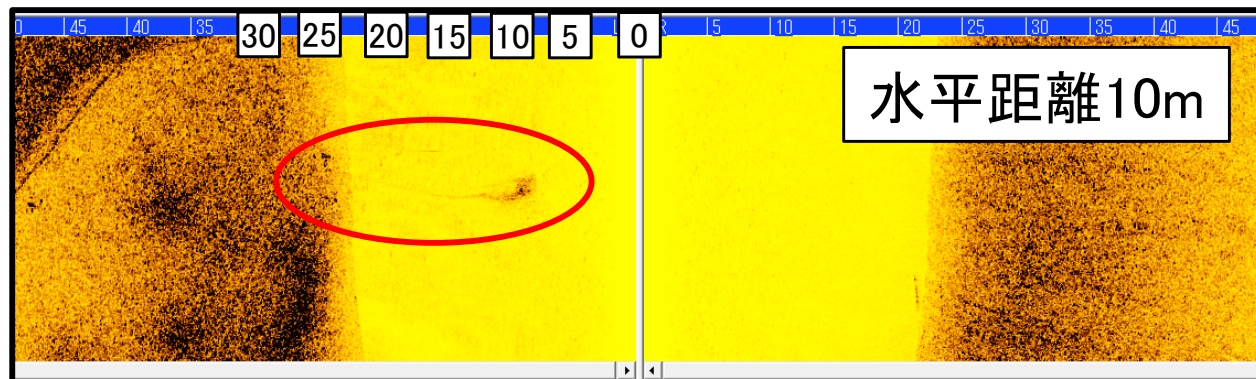
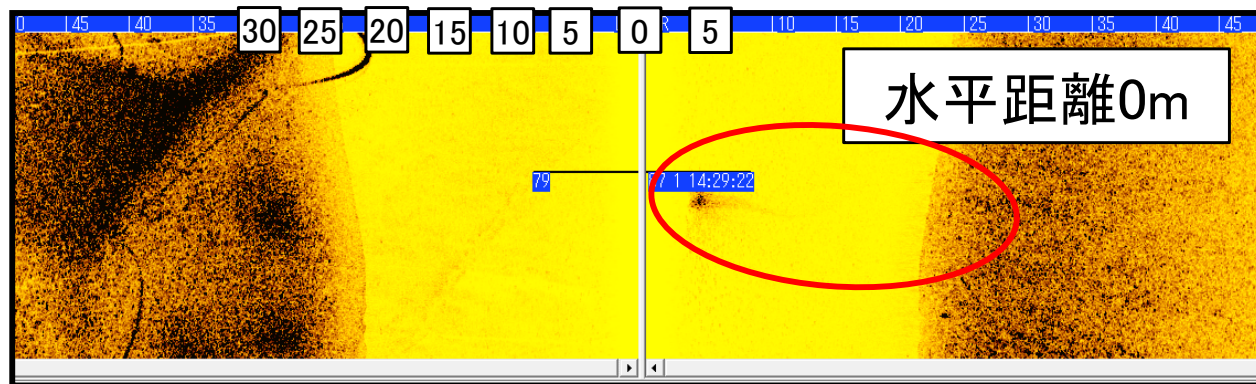
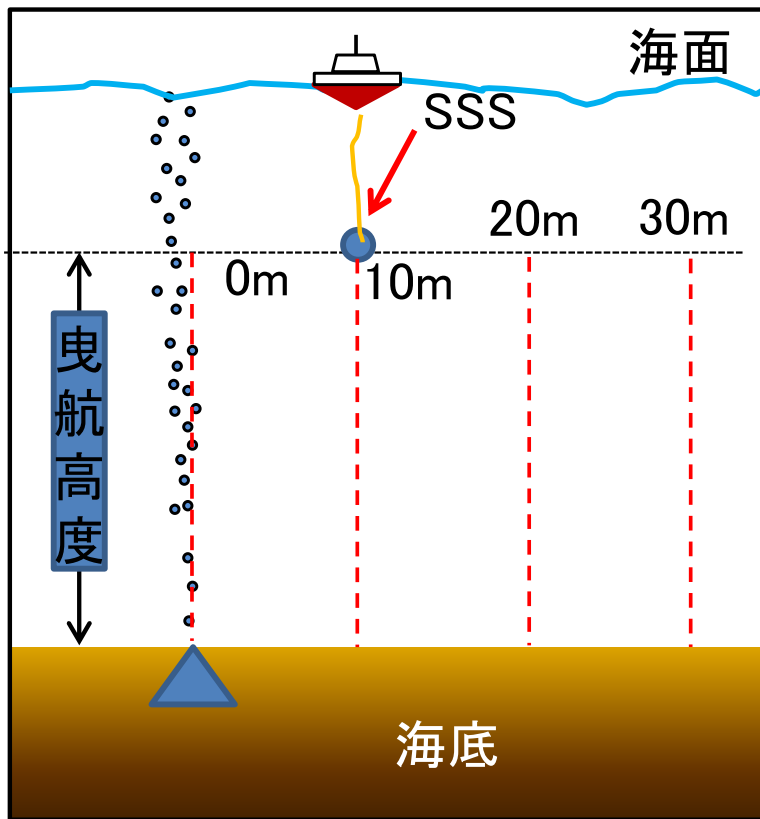
- 測線間隔
 - 船速
 - 検出可能フラックス
- 実用的な漏出監視のためにはどう設定すればよいか？



水平距離(測線間隔)

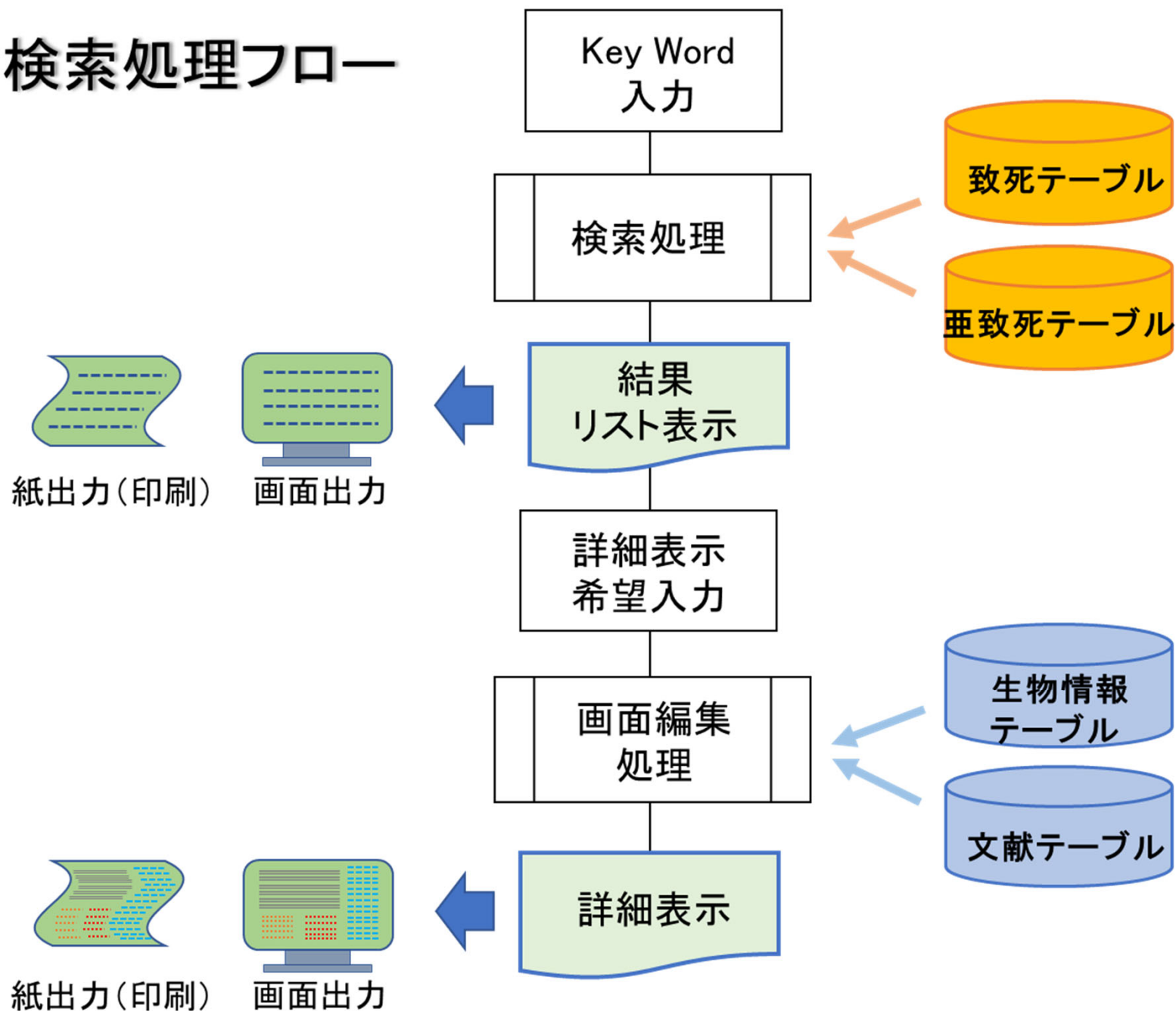
【觀測條件】

- CO₂氣泡徑; 7.1mm
- 放出率; 5,000ml/min
- 觀測線(水平距離)
; 0, 10, 20, 30m
- 曳航高度; 20~25m
- 船速; 3~4knot



生物影響データベース構築

検索処理フロー



- **事業者の意思決定支援へのAdvanced Monitoring (US/DOE)**
- **Creating Value from Monitoring (well placement optimization, cost cutting)**

- Monitoring at a carbon storage site is necessary to track the movement of CO₂ and assure permanence for geologic storage.
- **Advanced monitoring** technologies are needed to decrease the cost and uncertainty in measurements and satisfy regulations.
- Giving site operators the ability to: (1) measure **critical subsurface parameters** associated with the injected CO₂, (2) provide measurements of **down-hole** and reservoir conditions for real-time decision making and process optimization, and (3) provide long-term post-injection monitoring of the fate of injected CO₂.

Fiber Optic Sensing: temperature, pressure, strain, acoustic, fluid chemistry

Fiber Optic Sensing (DTS, DAS, DFOSS)

Optic Fiber and Back Scattering



Distributed Fiber Optic Strain Sensing (DFOSS)

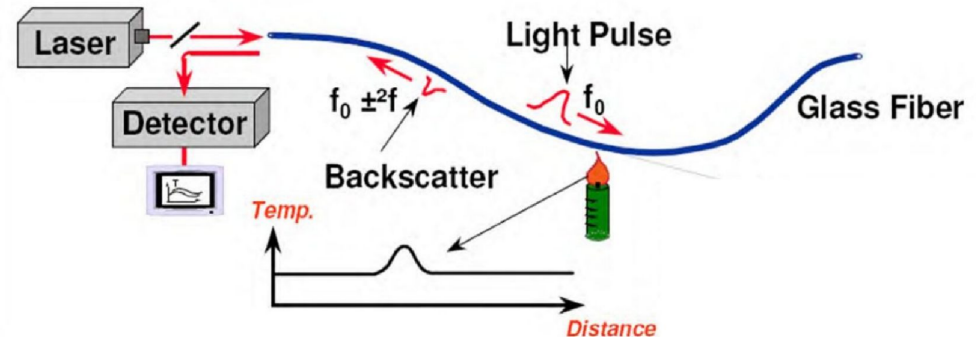
Distributed Temperature Sensing

Dria, 2011

Distributed Strain Sensing

with Rayleigh Scattering

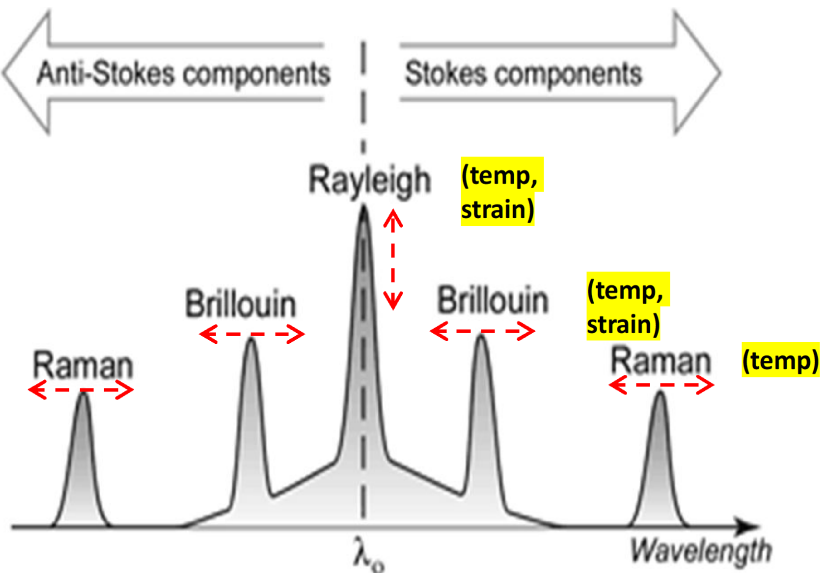
Raman Scattering



• Temperature value = Anti-Stokes/Stokes

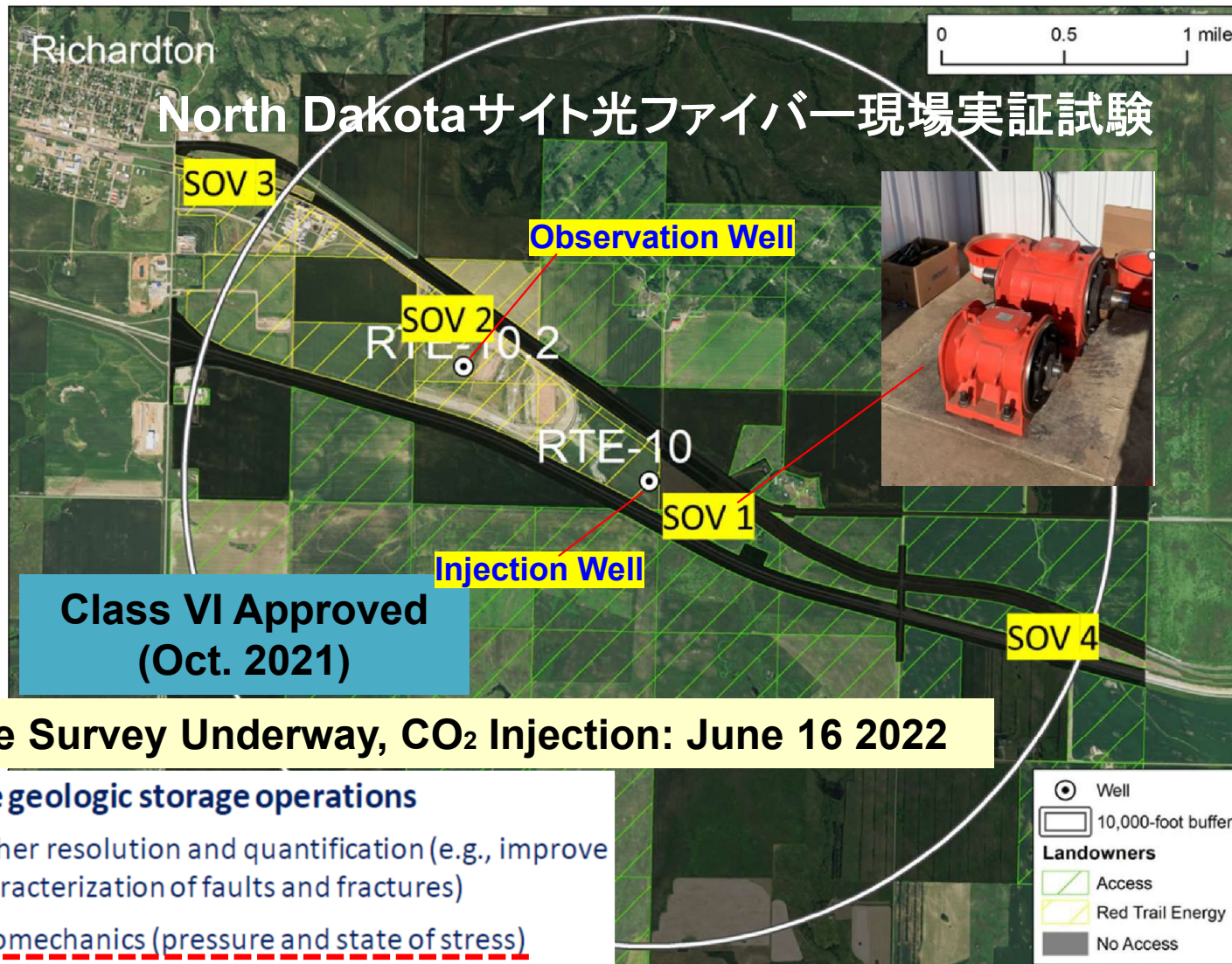
• Location = travel time

DAS: Distributed Acoustic Sensing (VSP)

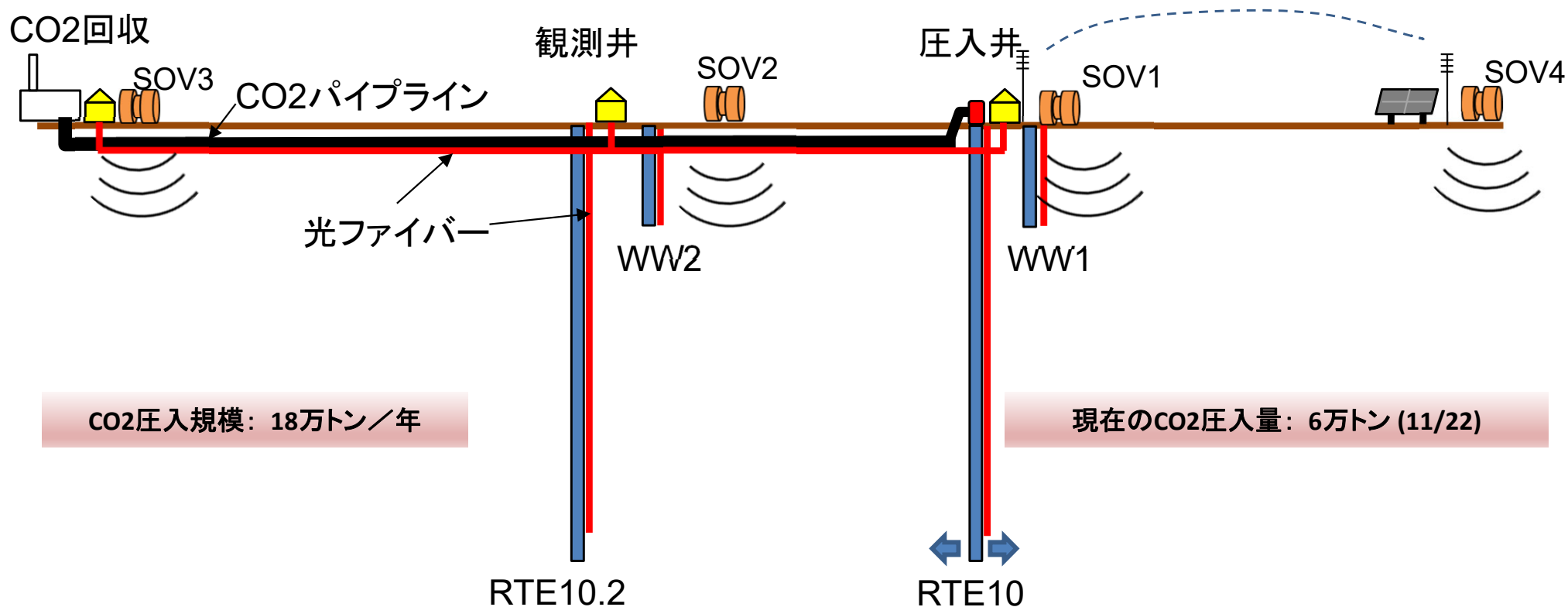


Fiber Optic Sensing for Multi-purpose Data Acquisition (DTS, DAS, DSS) and Permanent Monitoring for CO₂ Storage

(日米CCUS協力事業)



光ファイバーによるCO₂モニタリング



DAS (音響計測)	CO ₂ プルームの広がり把握 (DAS/VSP)
DSS (ひずみ計測)	坑井健全性、貯留層/遮蔽層安定性監視、CO ₂ 挙動監視
DTS (温度計測)	坑井周辺のCO ₂ 挙動監視 (坑井健全性)

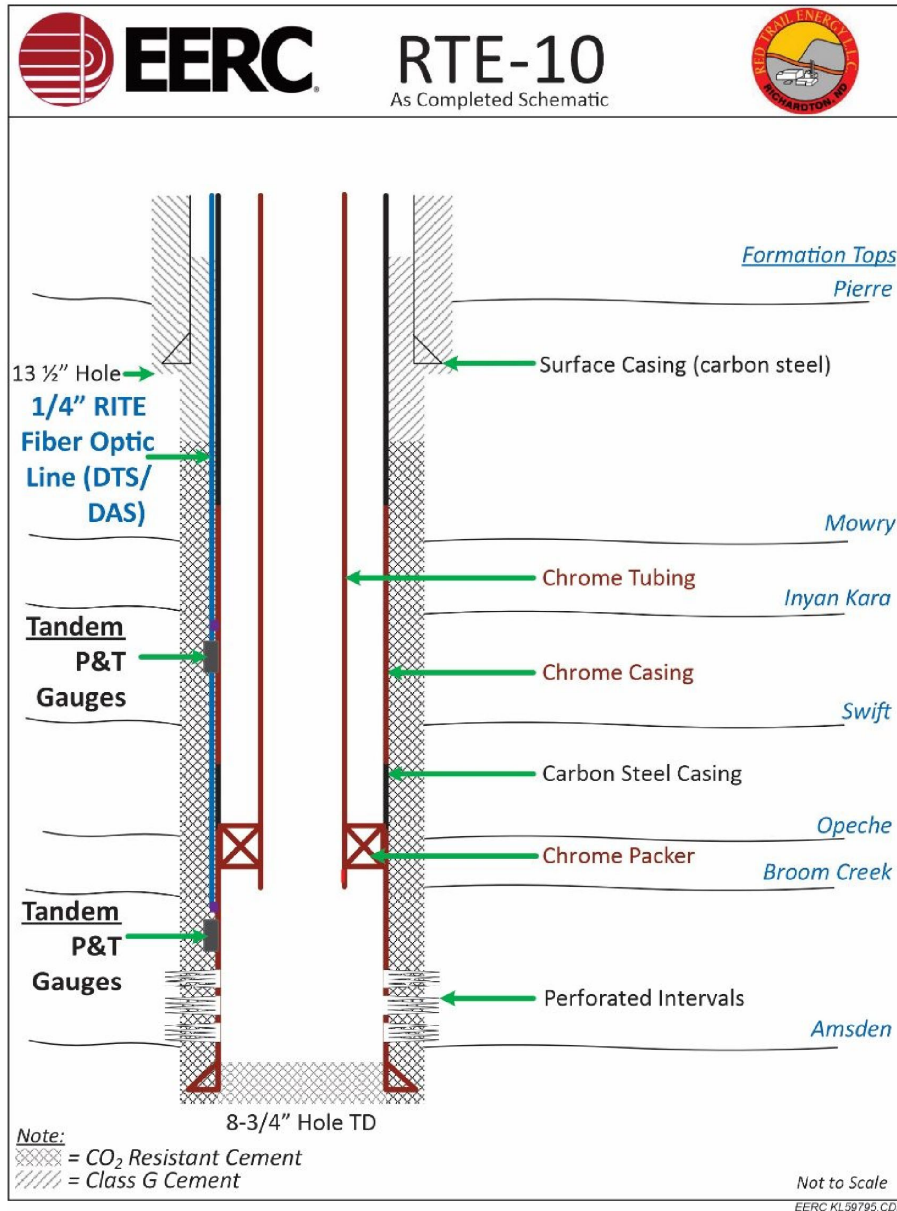
Summary of the Underground Injection Control (UIC) Class VI Permit MVA program

Monitoring Type	RTE Monitoring Program	Structure/Project Area
Analysis of Injected CO ₂	Compositional and isotopic analysis of the injected CO ₂ stream	Wellhead
CO ₂ Flowline	DTS/DAS and DSS	Capture facility to the wellsite
Continuous Recording of Injection Pressure, Rate, and Volume	Surface pressure/temperature gauges and a flowmeter installed at the wellhead with shutoff alarms	Surface to reservoir (injection well)
Well Annulus Pressure Between Tubing and Casing	Annular pressure gauge for continuous monitoring	Surface to reservoir (injection well)
Internal and External Mechanical Integrity	Tubing-casing annulus pressure testing (internal) DTS/DAS fiber-optic cable , ultrasonic imager tool (USIT) (external)	Well infrastructure
Corrosion Monitoring	Flow-through corrosion coupon test system for periodic corrosion monitoring	Well infrastructure
Near-Surface Monitoring	Groundwater wells in the area of review (AOR) dedicated to Fox Hills monitoring wells and soil gas sampling and analyses	Near-surface environment, USDWs
Direct Reservoir Monitoring	Wireline logging, external downhole pressure and temperature gauges, and DTS/DAS fiber-optic cable	Storage reservoir
Indirect Reservoir Monitoring	Time-lapse geophysical surveys, gravity surveys, InSAR and passive seismic measurements	Entire storage complex

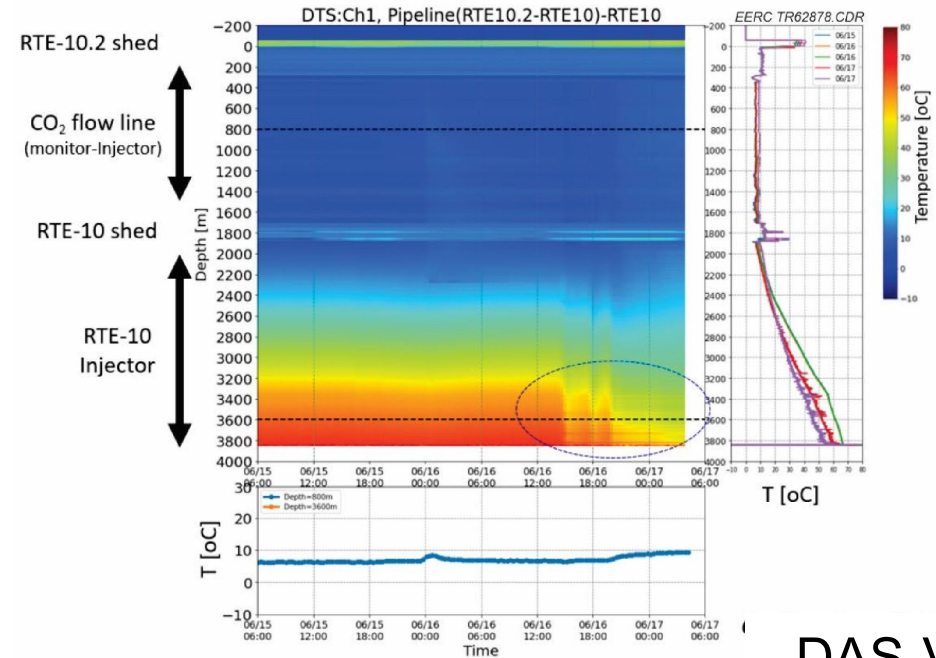
Richards et al_(2022)

*A fully coupled analysis with **DSS** at ground water wells*

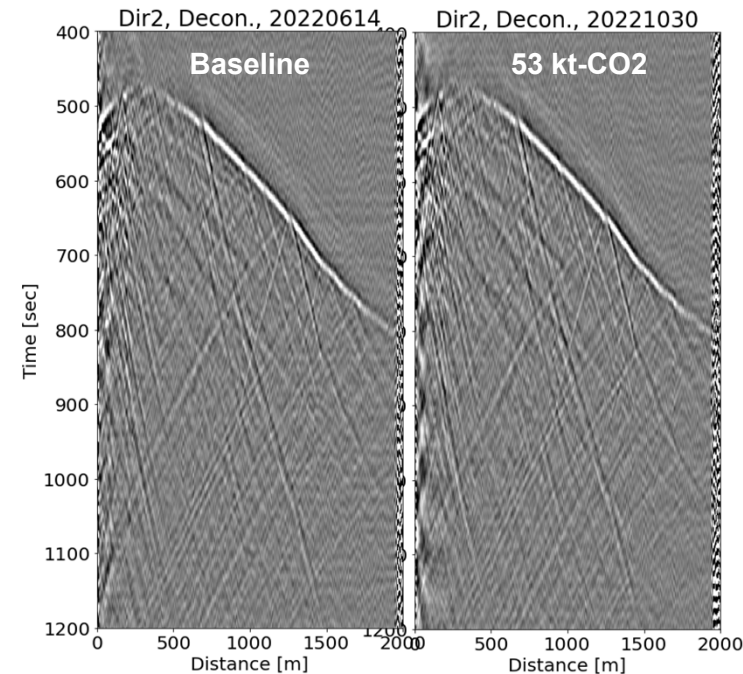
Fiber installation at injection well



DTS-pipeline and injection well



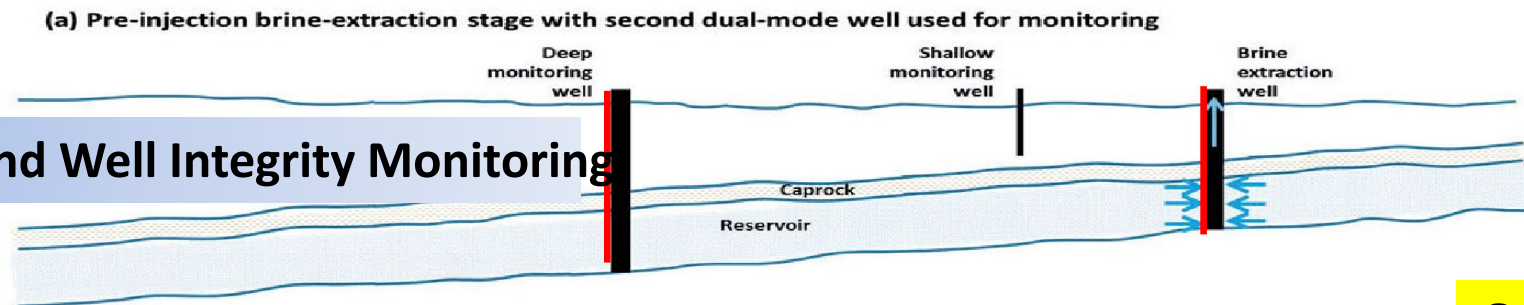
DAS-VSP



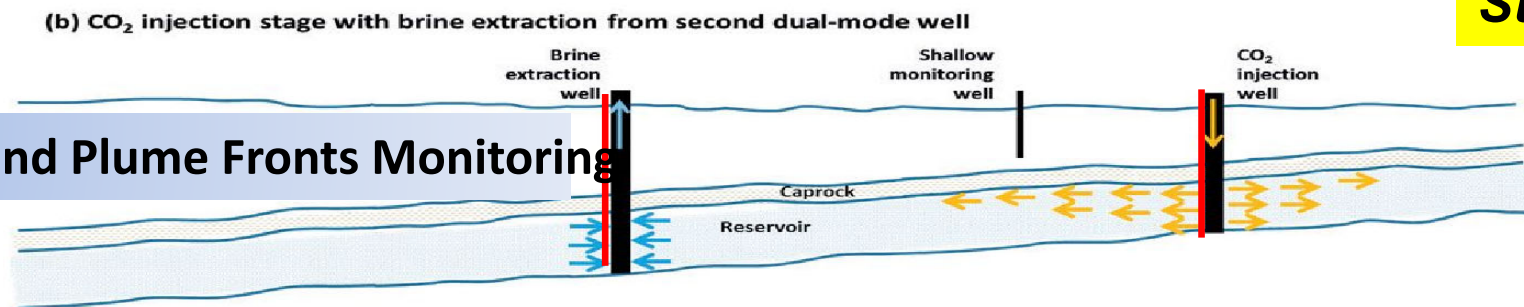
SOV2-RTE10
(Offset ~1,080m)

Applications of Optic Fiber Sensing in CO₂ Storage

➤ Caprock and Well Integrity Monitoring

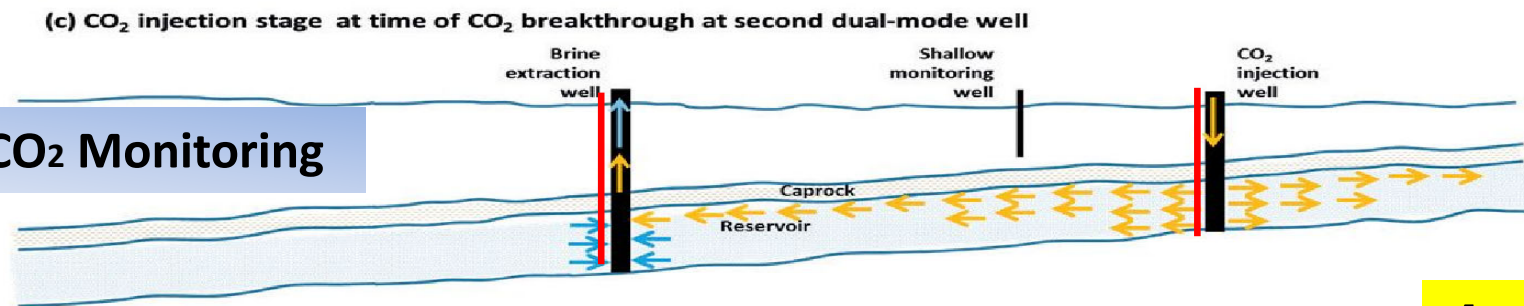


➤ Pressure and Plume Fronts Monitoring

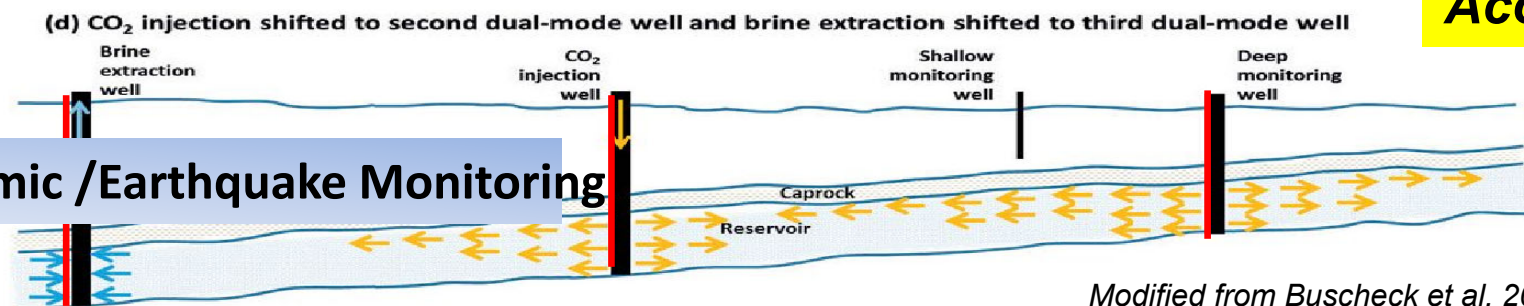


Strain

➤ DAS/VSP CO₂ Monitoring



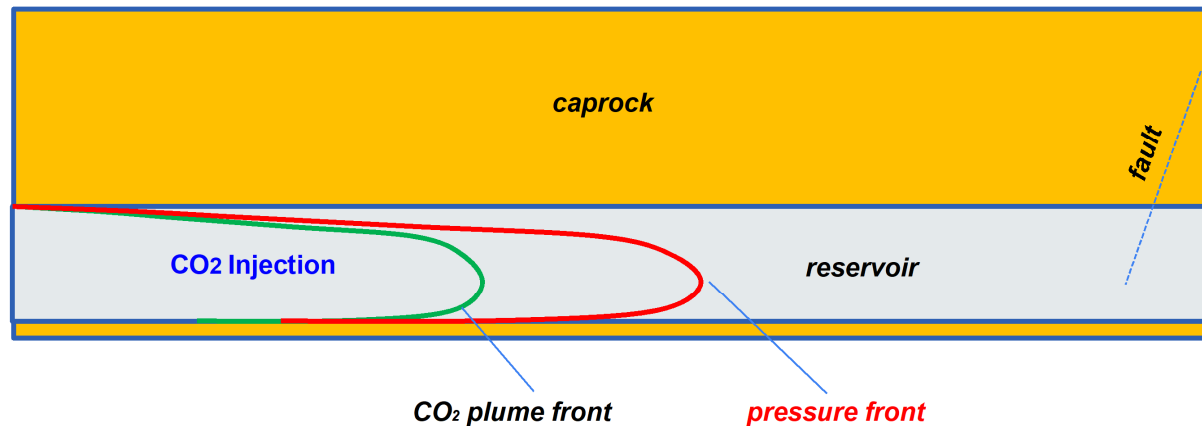
➤ Microseismic /Earthquake Monitoring



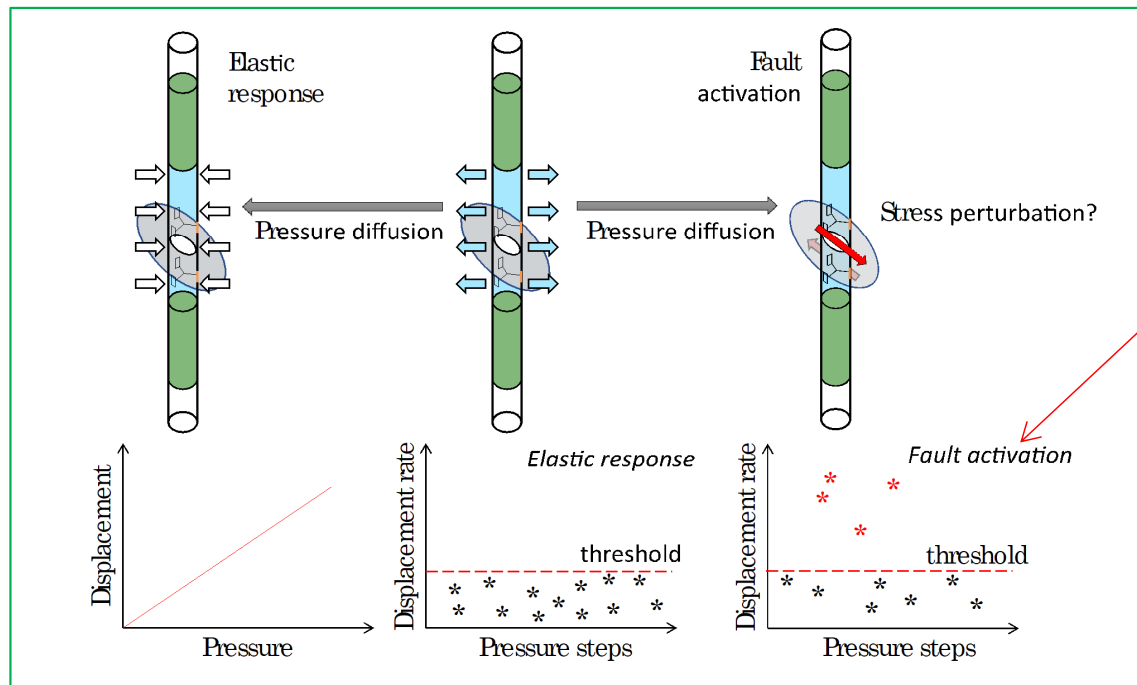
Acoustic

Modified from Buscheck et al. 2014

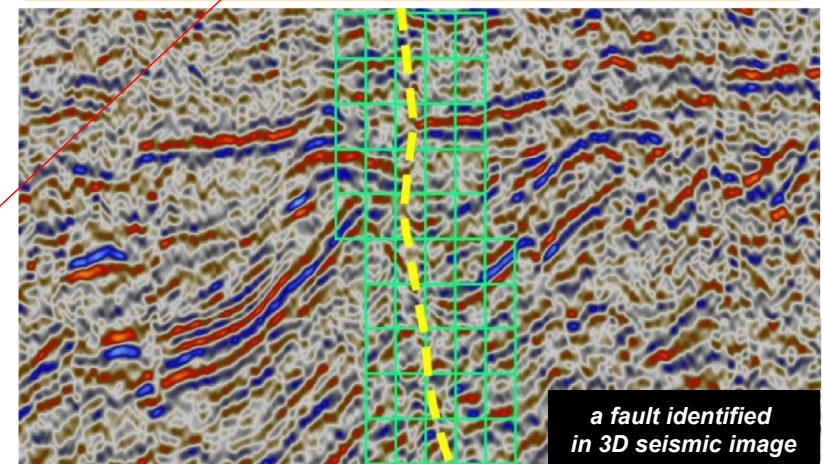
Fault Integrity Monitoring (reactivation, leakage) with Fiber Optic Sensing



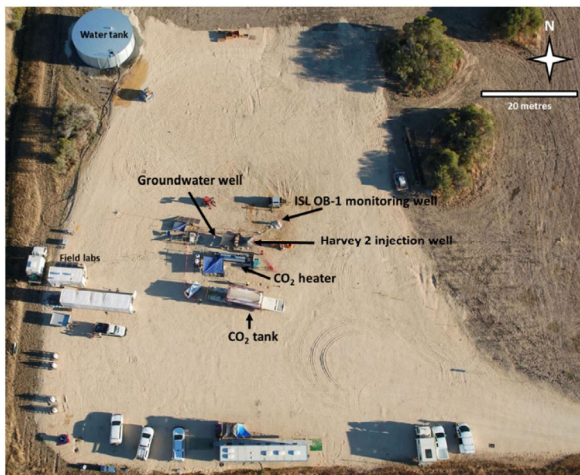
Kakurina et al, 2020



Installing **fiber optic cables** behind casing of monitoring wells for Distributed **Strain**, **Temperature** and **Acoustic** sensing



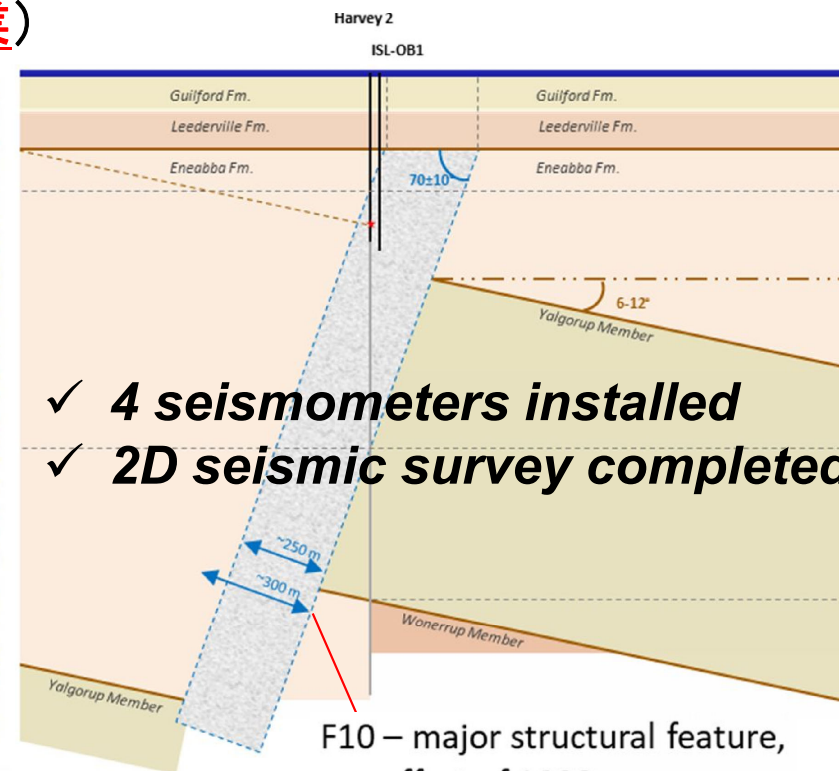
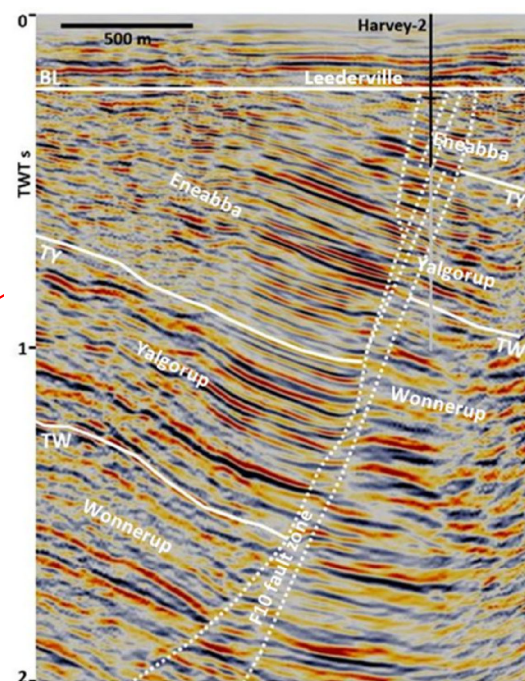
**Fault zone characterization
hydraulic property**



In Situ Lab / SW-Hub: South Perth

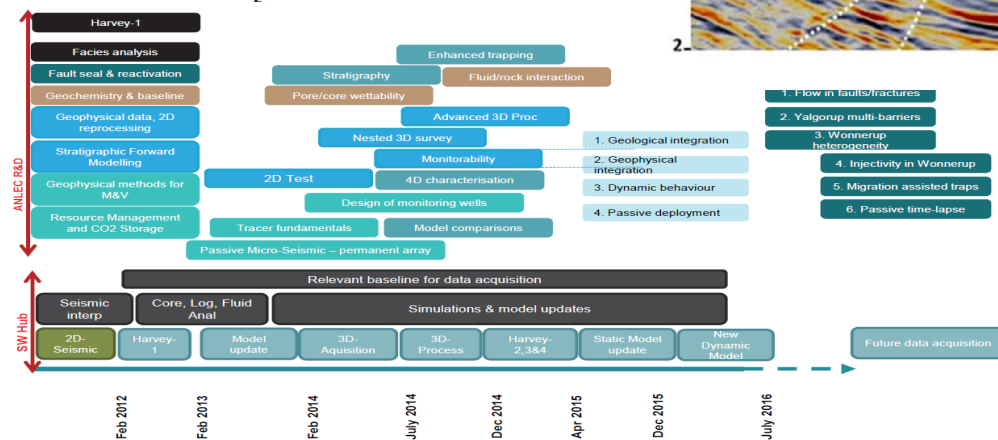
Collaborations: **RITE-CSIRO** Fiber Optic Sensing for Fault Zone Mapping and Stability Monitoring

(日豪CCUS協力事業)



- ✓ **4 seismometers installed**
- ✓ **2D seismic survey completed**

F10 – major structural feature,
- offset of 1000 m
- fault zone 250 m wide

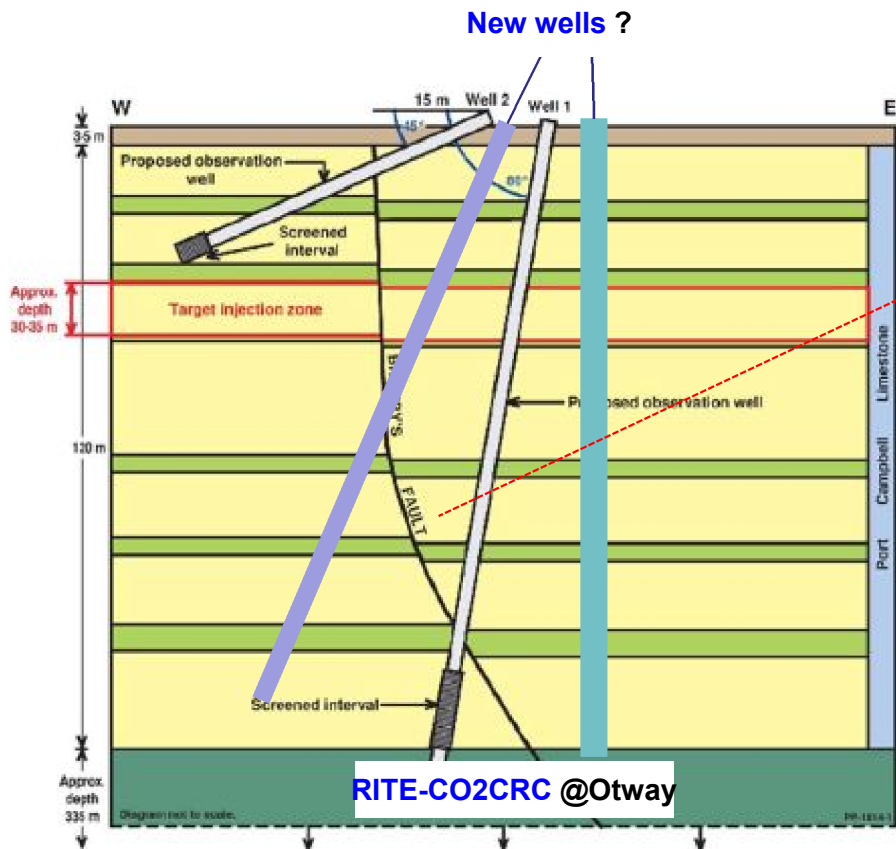


➤ **Fault zone mapping and monitoring with Strain Sensing (RITE) coupled with temperature and acoustic sensing (CSIRO)**

Collaborations Between RITE-CO2CRC Fiber Optic Sensing for Fault Leakage Monitoring

DAS (Acoustic), DSS (Strain), DTS (Temperature)

(日豪CCUS協力事業)



Otway International Test Centre

Otway Stage 1 (Concept): 2004–2009

- ✓ Demonstrated safe transport, injection and storage of CO₂ into a depleted gas reservoir

Otway Stage 2 (Risk Reduction): 2009–2019

- ✓ Demonstrate safe injection of CO₂ into a saline formation
- ✓ Stage 2B – Near well residual & solution trapping characterisation
- ✓ Stage 2C – Minimum detection, 4D M&V & Plume stabilisation

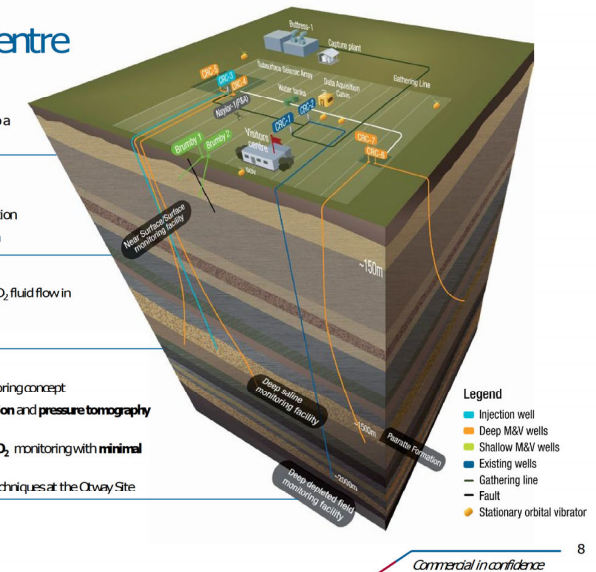
Otway Shallow CO₂ Migration

- ✓ Improve capability to predict the role of faults in controlling CO₂ fluid flow in the near surface;
- ✓ Improve near surface monitoring capabilities

Otway Stage 3: 2015–2022

- ✓ Develop an "on-demand", sub-surface and permanent monitoring concept
- ✓ Two primary technologies - sub-surface seismic data acquisition and pressure tomography (4 new monitoring wells)
- ✓ Field test the various techniques to demonstrate lower cost CO₂ monitoring with minimal surface and environmental impact
- ✓ Demonstrate regulatory and community acceptance of the techniques at the Otway Site

CO2CRC
Building a low emissions future



Commercial in confidence

8

- FY2022: shallow well drilling, fiber cable installation, baseline (strain, temp) monitoring
- FY2023~: water / CO₂ injection, fault leakage detection, DAS/DSS/DTS monitoring

CO₂地中貯留技術事例集の作成・英訳・公開



長岡・苫小牧・海外の事例に基づき、2023年度末までに完成・逐次公開・英訳





CO₂ 地中貯留技術事例集

Phase 01

基本計画



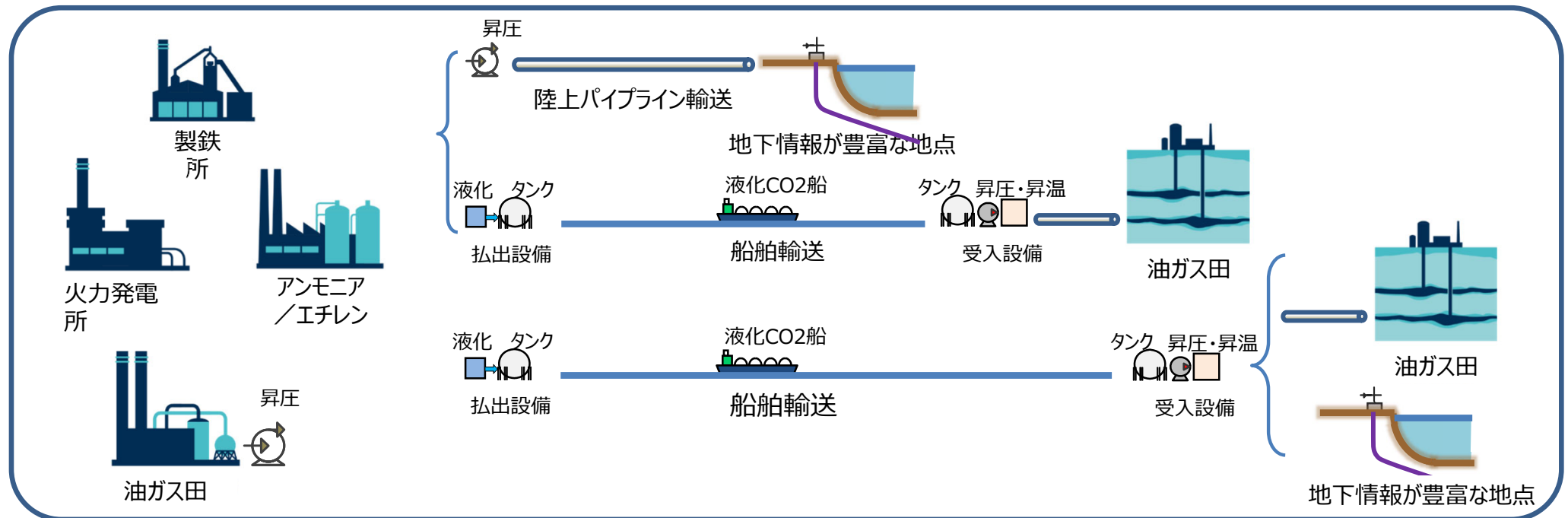
Practical Guidance for
Geological CO₂ Storage

Phase 01

Overview of
Geological CO₂ Storage

我が国における初期のCCSプロジェクトのイメージ

①商用設備（製鉄所、火力発電所）、②油ガス田、③化学産業（アンモニア、エチレンプラント）
+ 輸送（PL・船） + 油ガス田 and/or その他地下情報が豊富な地点



関係する業界と研究組合員

CO2排出企業

電力(電源開発)、化学産業
油ガス田(三菱ガス化学)

コンサル・ エンジニアリング企業等

大成建設、応用地質

商社（ファイナンス、 ビジネスモデル）

伊藤忠商事

石油・天然ガス 関連企業

INPEX、JAPEX、JX石油開発

商社技術 サポート企業

伊藤忠石油開発

謝 辞

この講演は、国立研究開発法人新エネルギー・産業技術総合開発機構(NEDO)の委託業務より得られた成果に基づくものです。

This presentation is based on results obtained from a project (JPNP18006) commissioned by the New Energy and Industrial Technology Development Organization (NEDO) and the Ministry of Economy, Trade and Industry (METI) of Japan.