◆ 革新的環境技術シンポジウム 2019 ◆

CO_2地中貯留技術実用化に向けての安全管理技術開発の取り組み

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）
CO_2貯留研究グループリーダー

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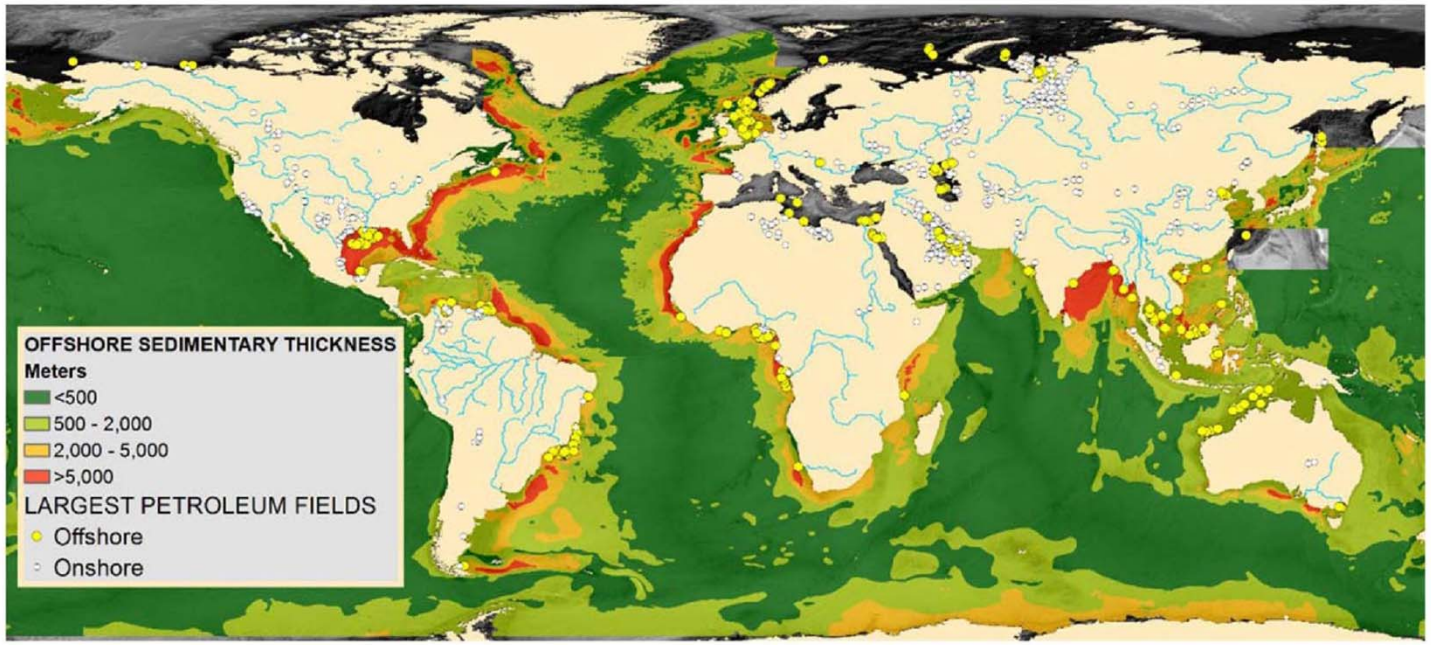
Maturing global CO_2 storage resources on offshore continental margins to achieve 2DS emissions reductions

P. S. Ringrose[1,2*] & T. A. Meckel[3]

SCIENTIFIC REPORTS



Study shows world has sufficient CO2 storage capacity

Make CCS Great Again!!

Dec 10 2019 achieved by installing 10,000 to 14,000 injection wells worldwide in the next 30 years.

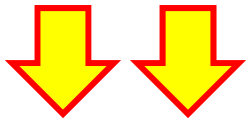
The study concludes there is easily enough space in the world's nearshore continental margins to meet the IPCC's goal of storing 6 to 7 gigatons of carbon dioxide a year by 2050.

➢大規模CO_2地中貯留の実用化に向けて

✓油ガス田開発技術・経験・ノウハウを活用しても、取り組むべき技術課題がある

✓ 安全性（リスクマネジメント）、経済性（コスト削減）、社会的受容性の向上

社会実装



A Social Licence for Carbon Dioxide Capture and Storage: How Engineers and Managers Describe Community Relations

Anne Maree Dowd ✉ & Mallory James

Social License to Operate (SLO)

地下への流体圧入

（地熱開発、水圧破砕、非在来型資源開発）

↓

地層の間隙水圧力（pore pressure）増加、

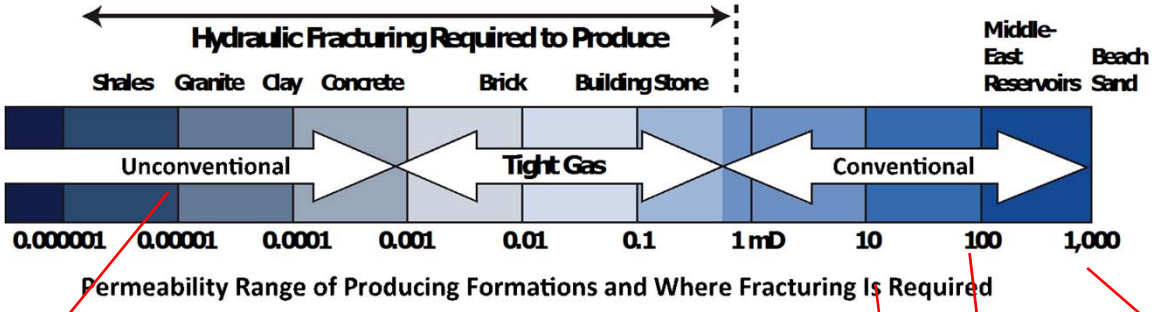
有効応力（effective stress）減少

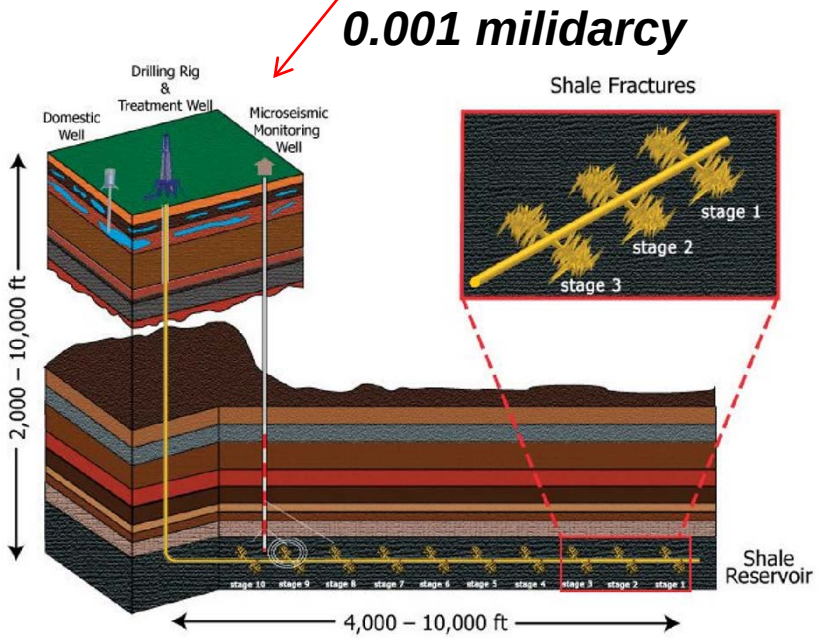
↓

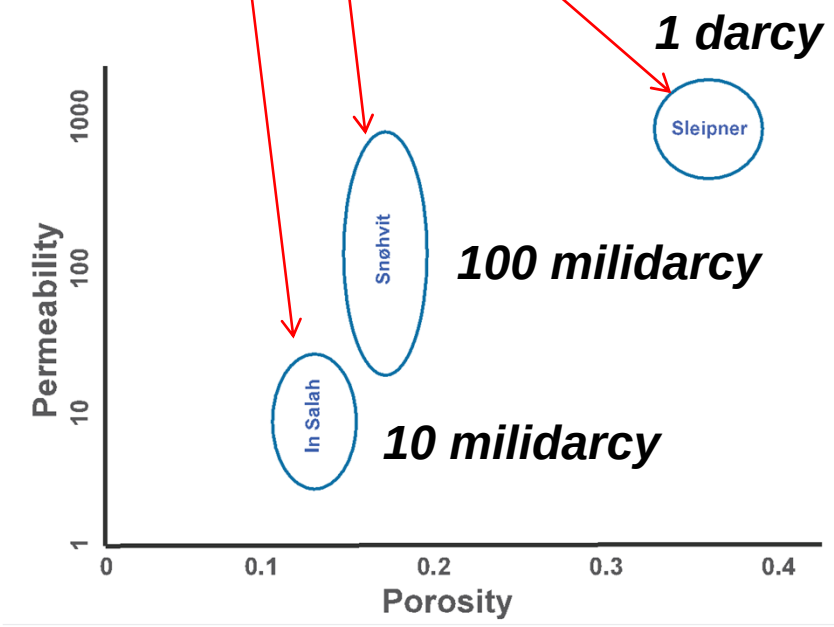
Injection-Induced Seismicity

地下資源開発、CO_2地中貯留

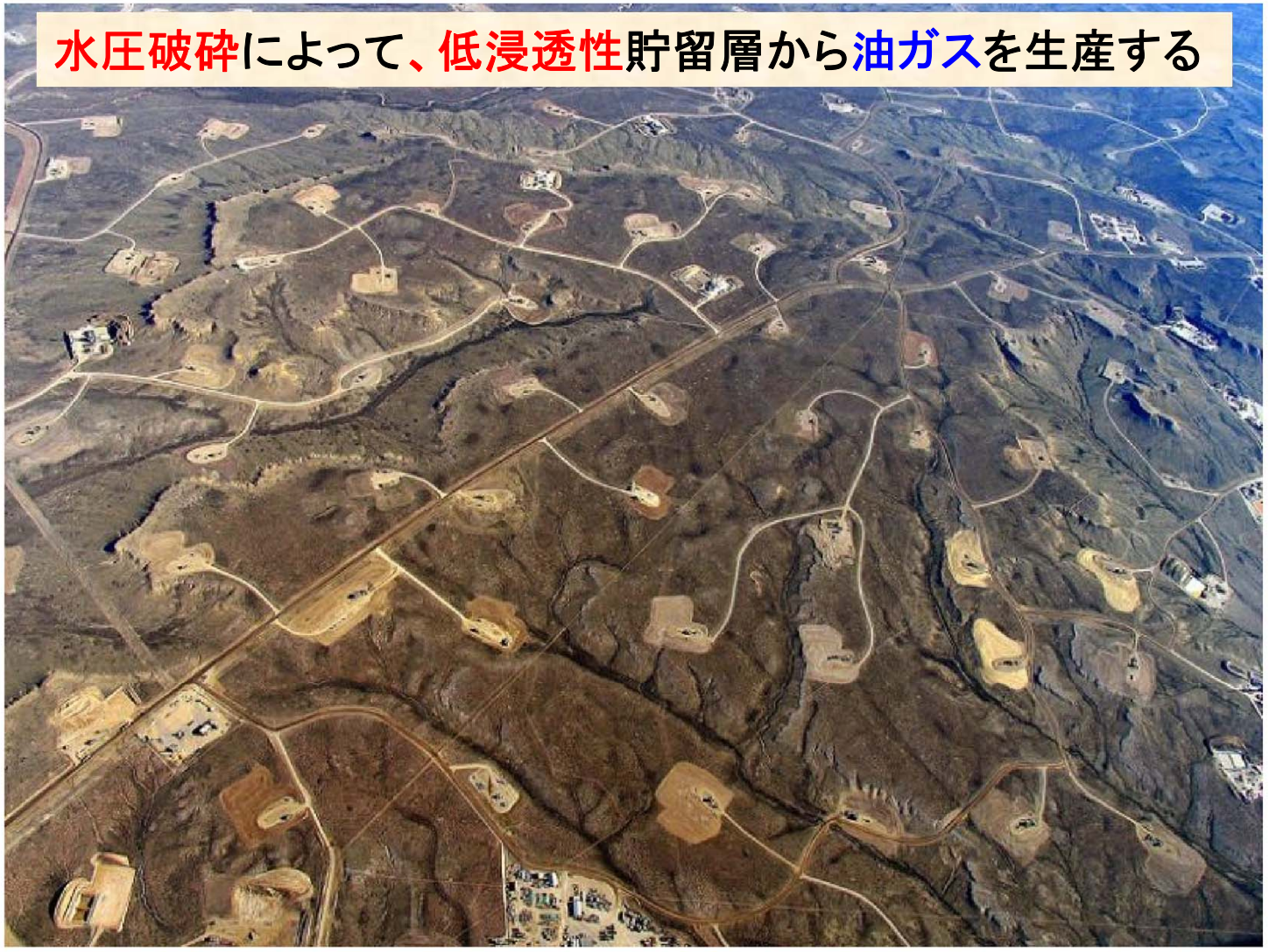
地熱、非在来型油ガス、CO_2地中貯留における流体圧入







米国の非在来型油ガス田サイトの例



Shale gas drilling has a visual impact on the landscape, as seen here in Wyoming,

Stage 1 began at 13:04:48 UTC on July 7th and ended at 15:01:09 UTC on July 7th.
Depths: ~ 3.53 km – 3.44 km (11547 ft. – 11295 ft.)
Stage 2 began at 23:32:18 UTC on July 7th and ended at 01:30:15 UTC on July 8th.
Depths: ~ 3.43 km – 3.35 km (11230 ft. – 11005 ft.)
Stage 3 began at 16:35:32 UTC on July 8th and ended at 18:34:56 UTC on July 8th.
Depths: ~ 3.34 km – 3.23 km (10971 ft. – 10826 ft.)
Stage 4 began at 22:16:20 UTC on July 8th and ended at 00:22:24 UTC on July 9th.
Depths: ~ 3.29 km – 3.22 km (10797 ft. – 10558 ft.)

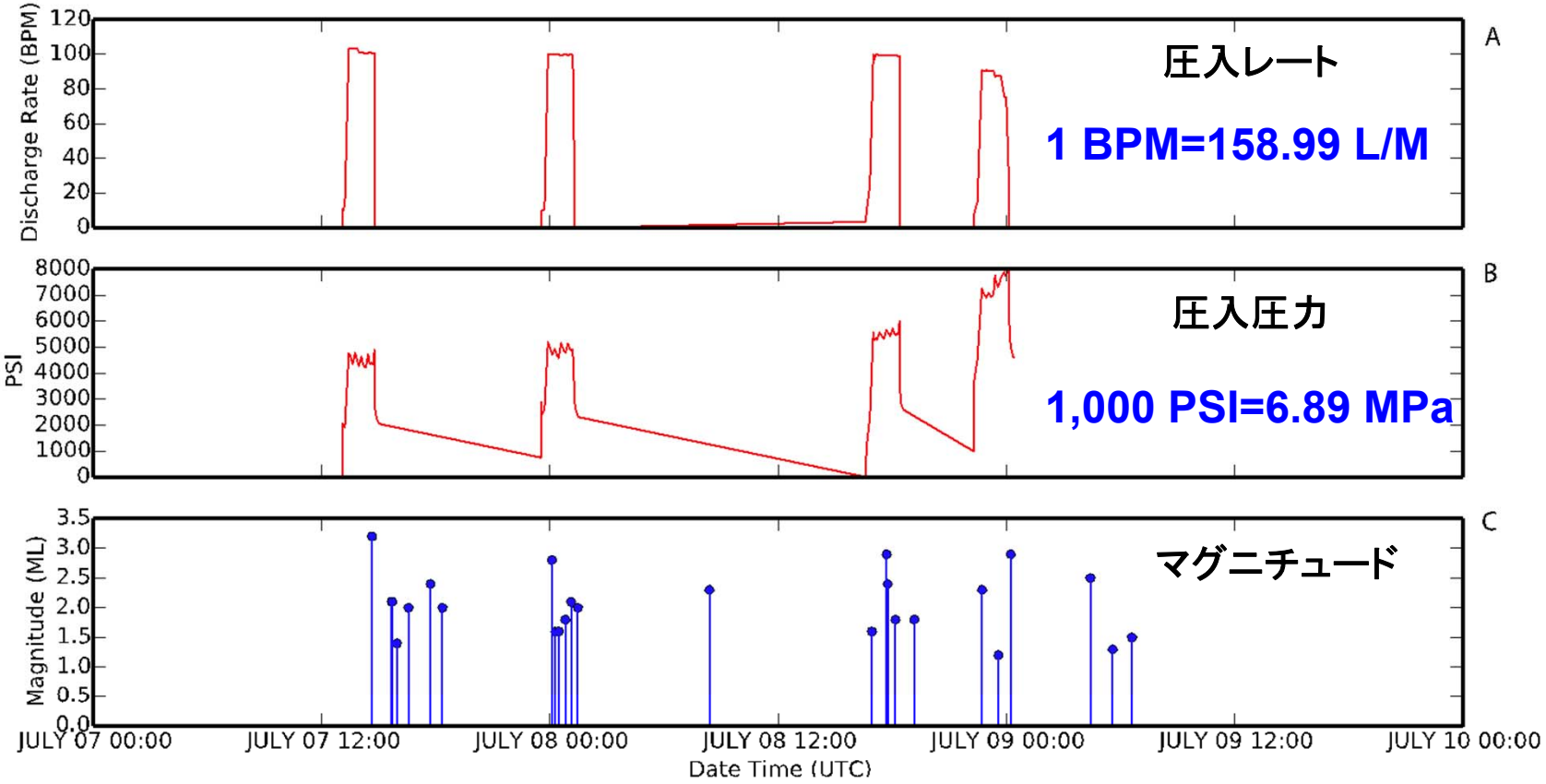
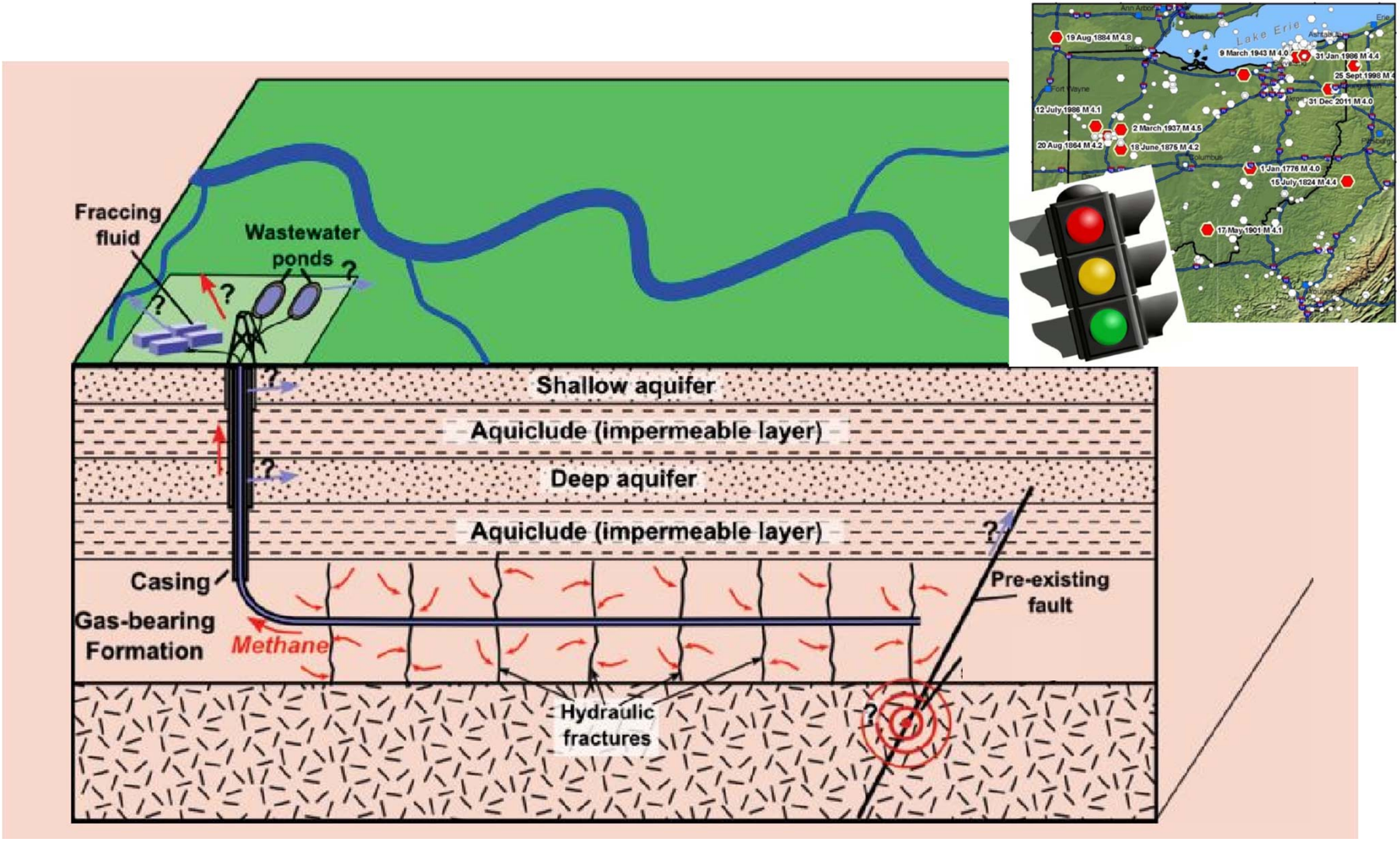
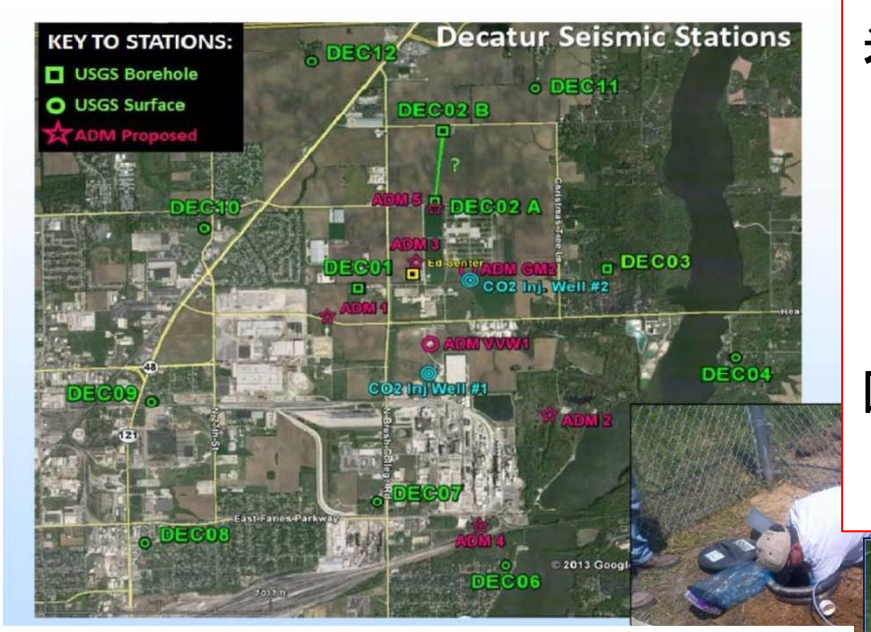


Figure 4. The plots span, in UTC time, the four fracking stages of Eagleton 1-29 well between July 7th 2014 and July 9th 2014. Plot A shows the discharge rate in BPM, or rate of injection, through time, plot B shows the pressure in PSI through time and plot C shows magnitude of earthquakes occurring within 7.0 km of the Eagleton well through time.

Induced and Triggered Events in Fluid Injection



Creating Value from Seismic Monitoring



米国陸域：Decatur（Illinois）サイト観測事例

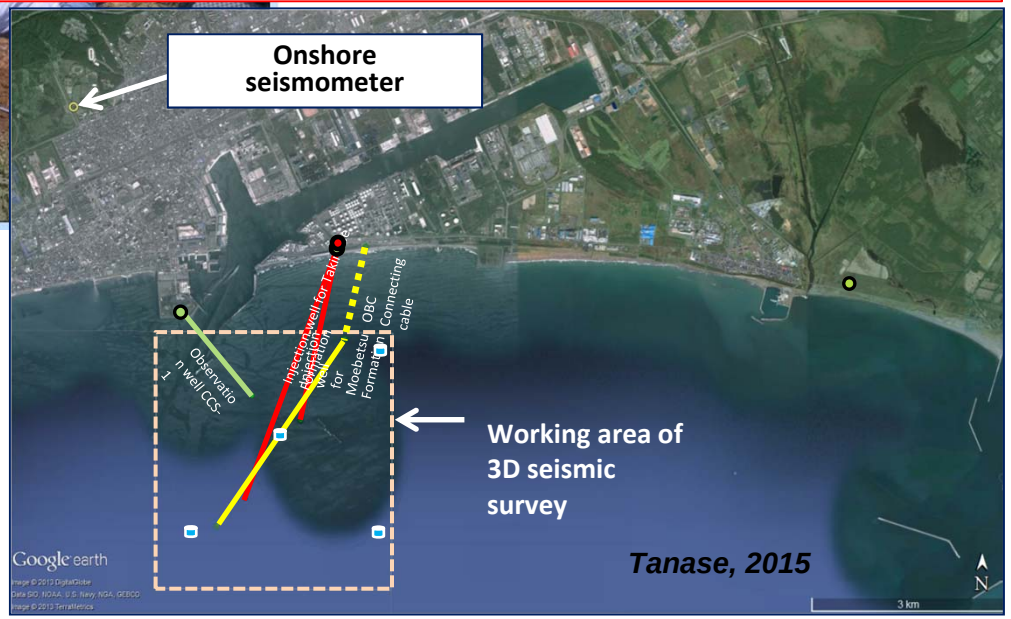
（研究開発PJ: 3年間で約100万トン

商業PJ: 約100万トン／年、圧入継続中）

国内海域：苫小牧大規模実証サイトの観測事例

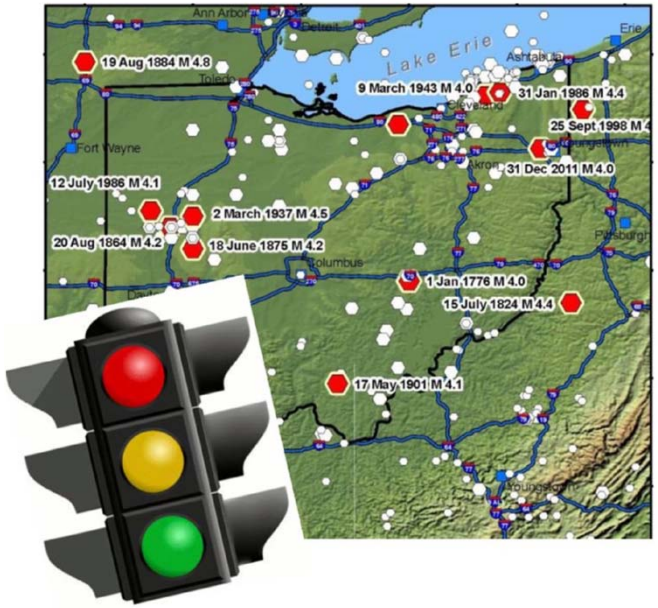
（実証試験: 計30万トン）

圧入安全管理



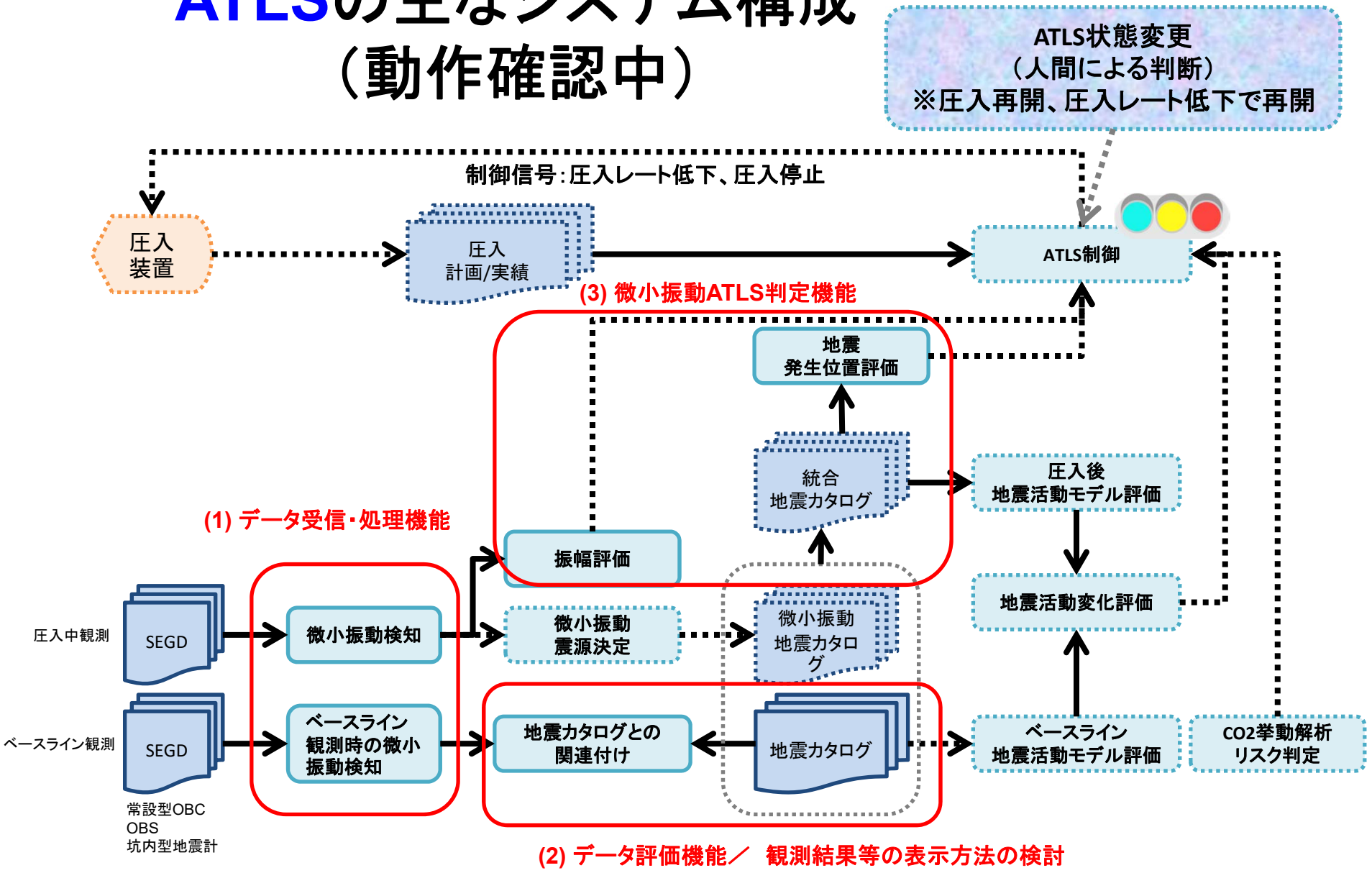
CO_2圧入サイトの安全管理技術開発

ATLS: Advanced Traffic Light System



CO_2地中貯留サイトの観測事例
ATLSの実用化に向けて

ATLSの主なシステム構成（動作確認中）



（嶋本, 2019）

ポハンEGSプロジェクトの概要

[1] 順調な準備をして進めたのではないか.

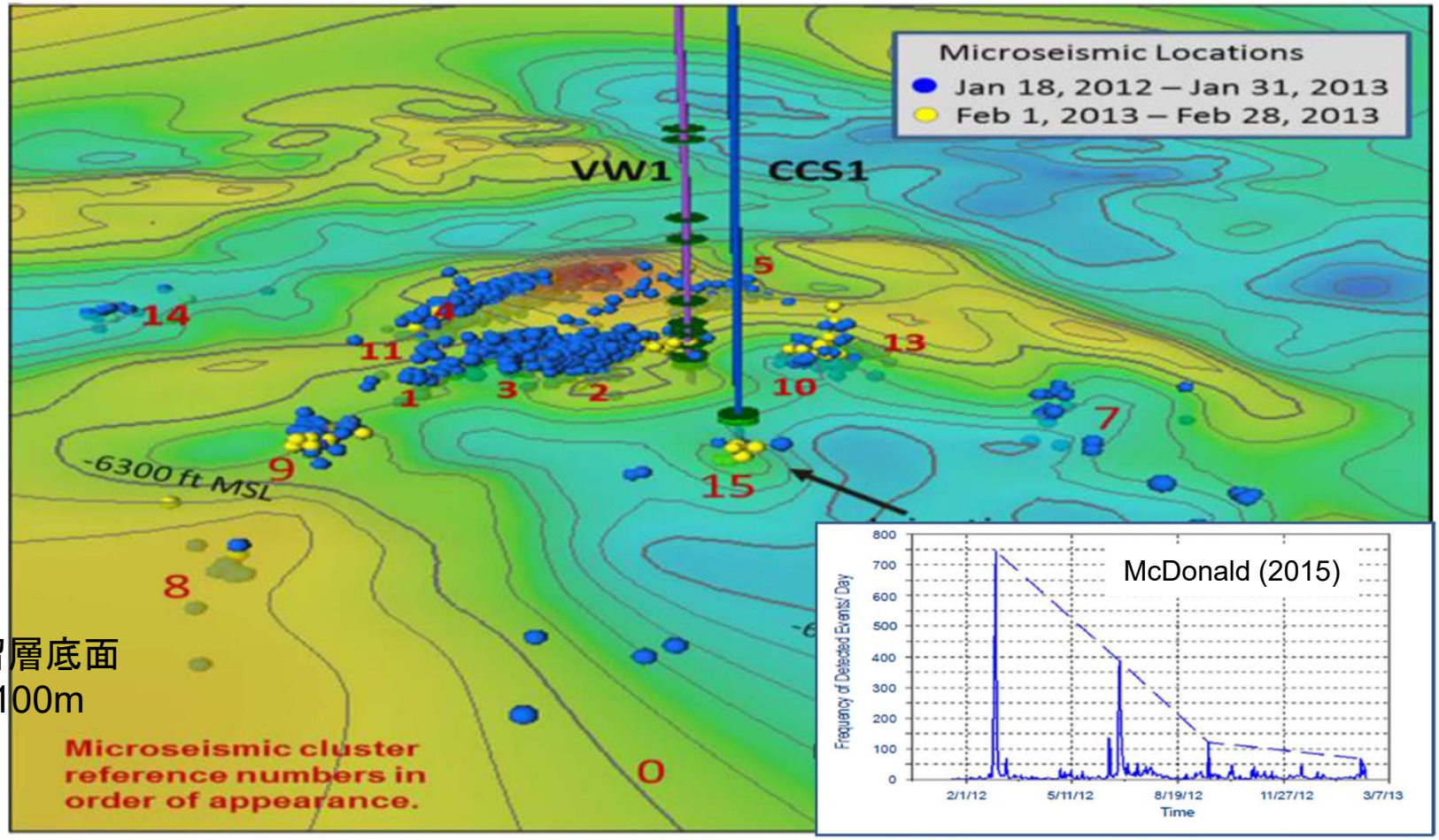
[2] 但し，ポハン市との連携，住民への説明
などは不十分ではなかったか.

[3] 2つの掘削孔の間に断層帯があったことが
極めて不運であった. 透水性の乏しい断層
帯を突き抜けて注水の回収はできない.
会社は投資したお金を回収するために，
M3.2の地震がおこっても注水を続けたので
はないか？ Traffic Light Systemは無視された.

ATLSシステムの完成に向けて

- 気象庁の地震観測情報（データベース）を活用して、解析対象イベントの絞り込み
- 信号機の色（判断基準）や圧入再開条件等の検討
  （他分野の事例や知見を参照）
- 圧入サイトにおいて、どの範囲（Area of Review）まで重点的に監視するか
- 圧入時の観測データを有する海外機関との協力
- Science-basedのリスクコミュニケーション
  （社会的受容性向上の手法論からの転換）

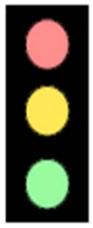
米国イリノイのDecaturサイトの観測事例



貯留層底面
～2100m

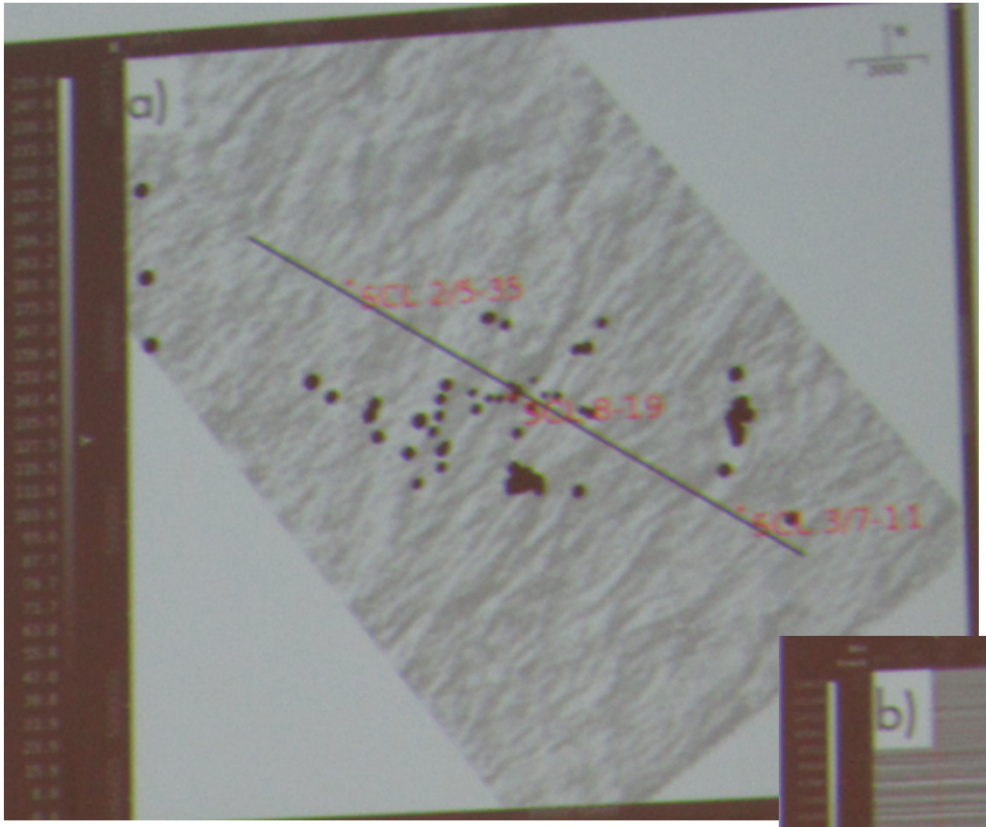
・微小振動が多発する時期がある
・クラスター状に震源域が分布する
・下位の基盤と圧入対象層で発生

AoRは12.8km



>M2.0かつ地表で被害: 圧入中止
>M2.0で有感 : 圧入レート低減
>M2.0で無感 : 関係機関報告、関連調査
>M1.5が1月以内に5回 : 関係機関に報告
<M1.5 : 継続

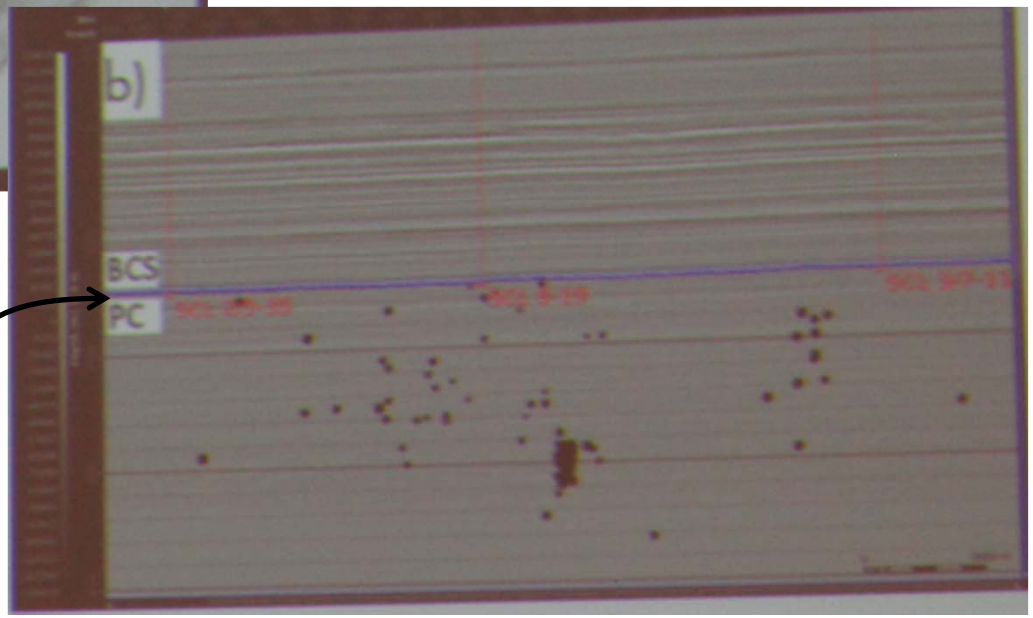
QUESTサイトの微小振動観測結果



O'Brien (2018)

>M4.0: 圧入中止
>M2.0: 関係機関に報告
<M2.0: 継続

- 貯留層内のM-2程度の地震まで検知
- Area of Review（AoR）は10km
- 2018年（圧入開始後1年5月後）から年回100回程度微小振動が発生
- これまでの最大M=0.1



貯留層下部

Micro seismicity monitoring

Performances of the network, Alarms thresholds

- Very good performance of whole network

Detection sensitivity map
-3 : near the injection wellbore
-2 : near the shallow wells

フランスの警報・警告の運用事例
（閾値設定）

In 2010, with subsurface network
Very near seismic event : 6

Magnitude : -1.1 to -0.2

Since April 2011, micro-seismic events detected by the deep seismic array in the injection well

Magnitude : -3.1 to -1.4

- French administration asked for alarms thresholds

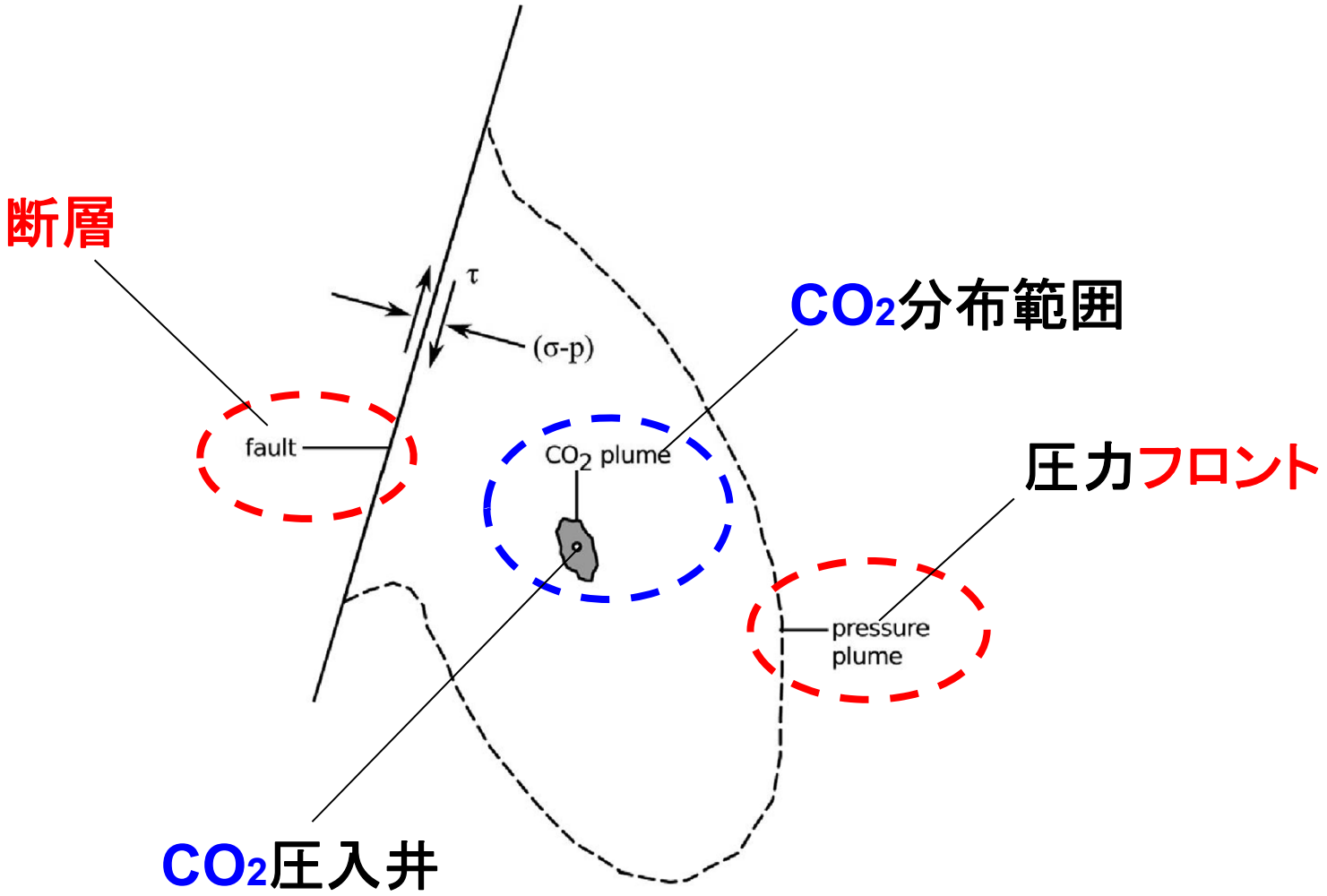
Official alarms thresholds

According to magnitude and number of events, alarm procedure is activated

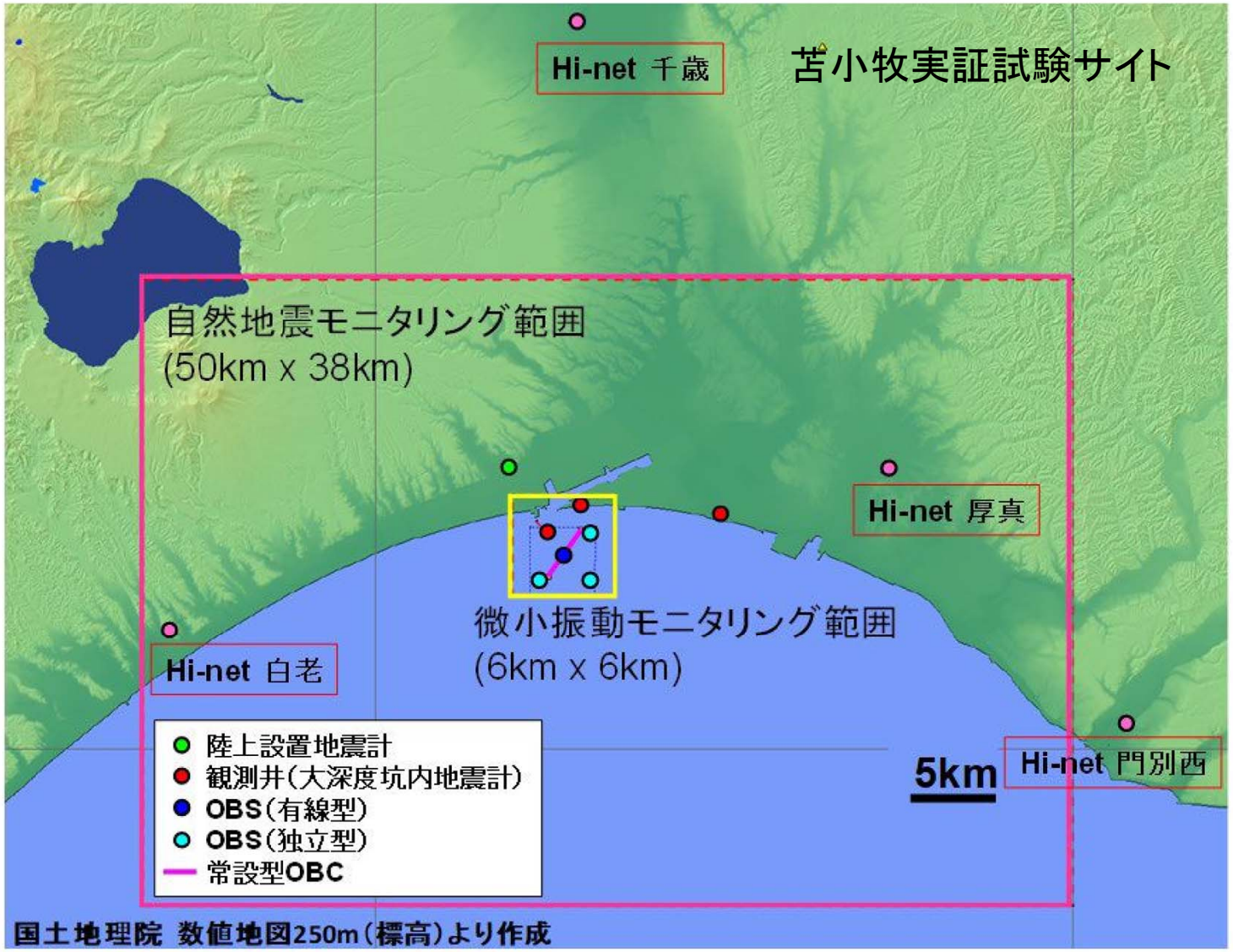
- For seismic events with magnitude above 2, in the circle given by the subsurface network
- For magnitude above -1, if there is evidence of propagation in space and in time of seismic events external to the reservoir

Billiot (2011)

圧入サイト周辺の地震観測：どこまでの範囲？



地震観測点配置及びモニタリング対象範囲

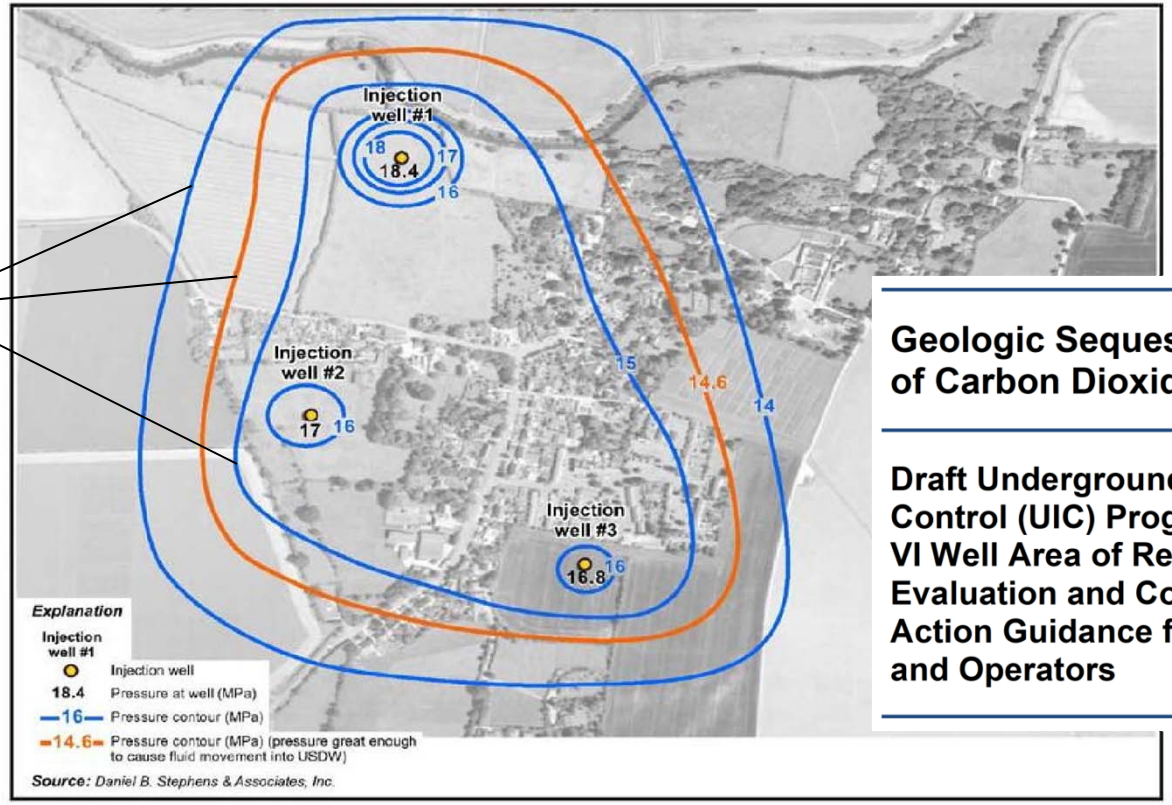


米国EPAの観測範囲決定概念図

EPA United States Environmental Protection Agency

Area of review (AoR): The region surrounding the geologic sequestration project where USDWs may be endangered by the injection activity. The area of review is delineated using computational modeling that accounts for the physical and chemical properties of all phases of the injected carbon dioxide stream and displaced fluids, and is based on available site characterization, monitoring, and operational data as set forth in §146.84.

地質モデルを用いた数値解析結果



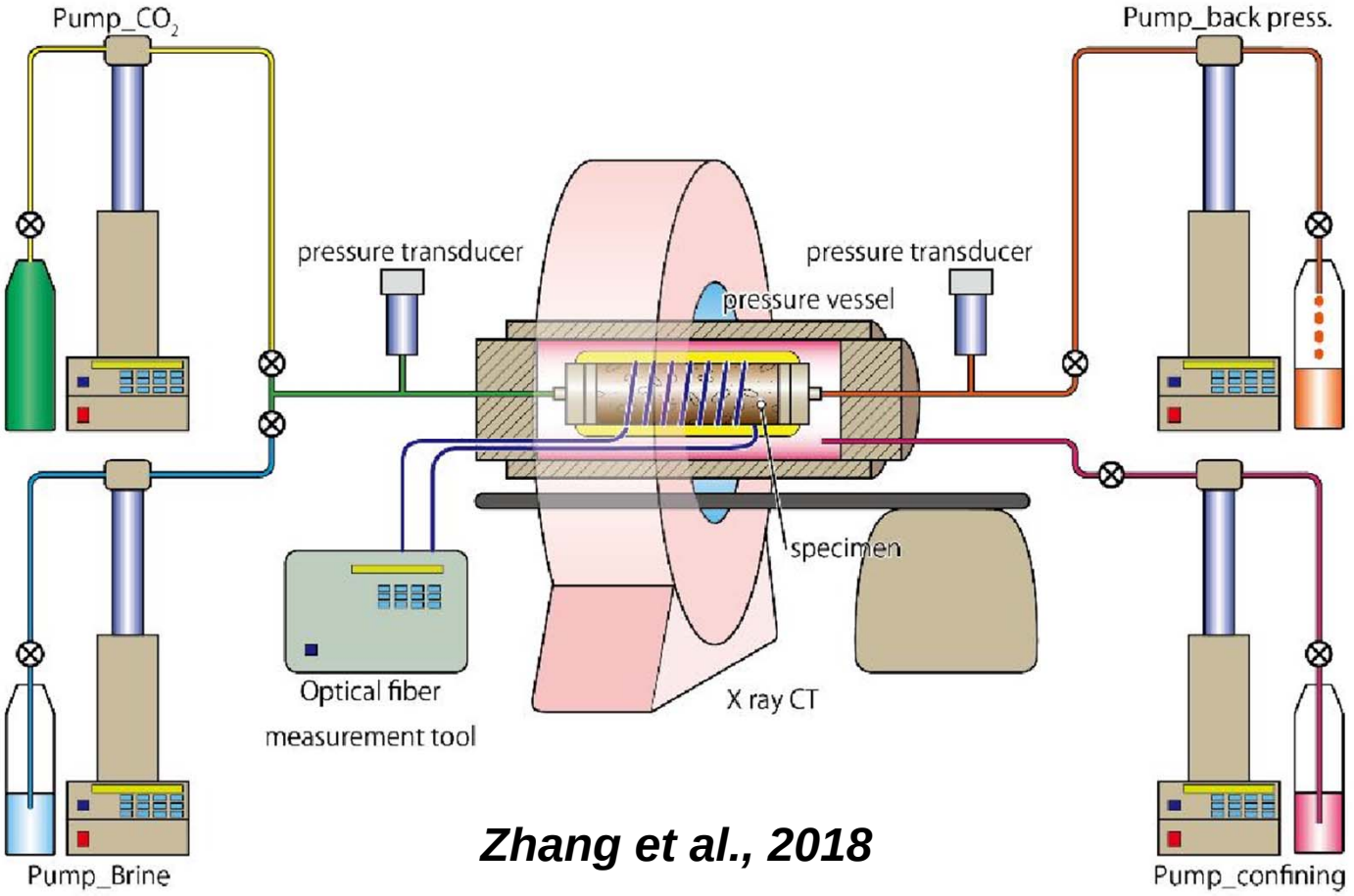
Geologic Sequestration of Carbon Dioxide

Draft Underground Injection Control (UIC) Program Class VI Well Area of Review Evaluation and Corrective Action Guidance for Owners and Operators

Figure 3-3: Hypothetical Geologic Sequestration Site: Model Predicted Maximum Pressure Within the Injection Zone

CO_2 Plume Front and Pressure Front

-- *Insights from a lab experiment* --

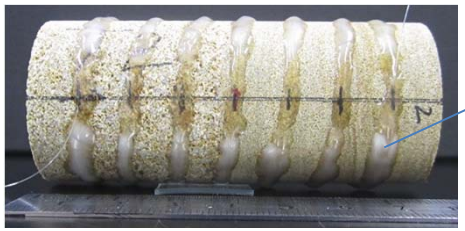


Zhang et al., 2018

Doi :10.1029/2018WR023415

不均質砂岩試料を用いた流動と変形の同時測定実験

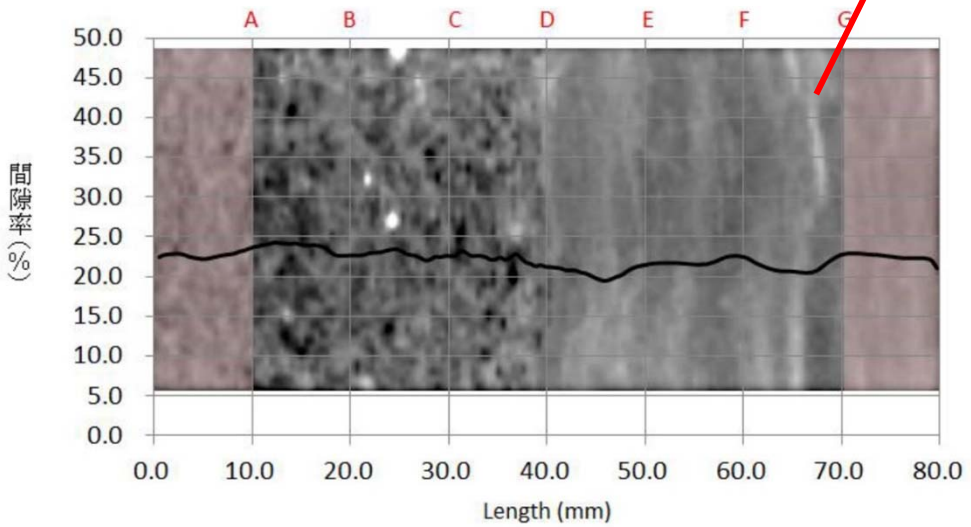
貯留層（粗粒）



巻き付けた光ファイバー

遮蔽層（細粒）

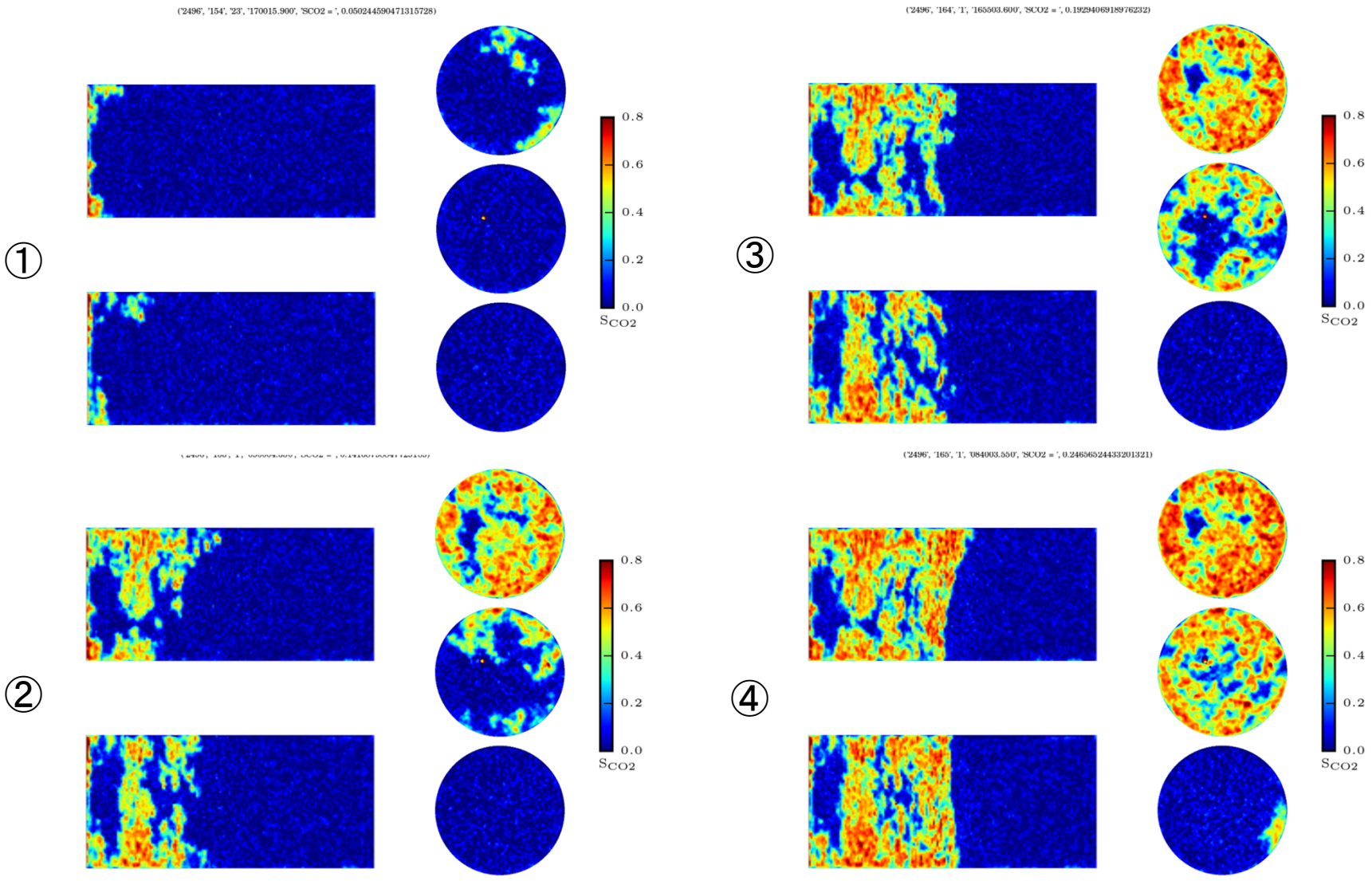
X-CT画像



Zhang et al., 2018

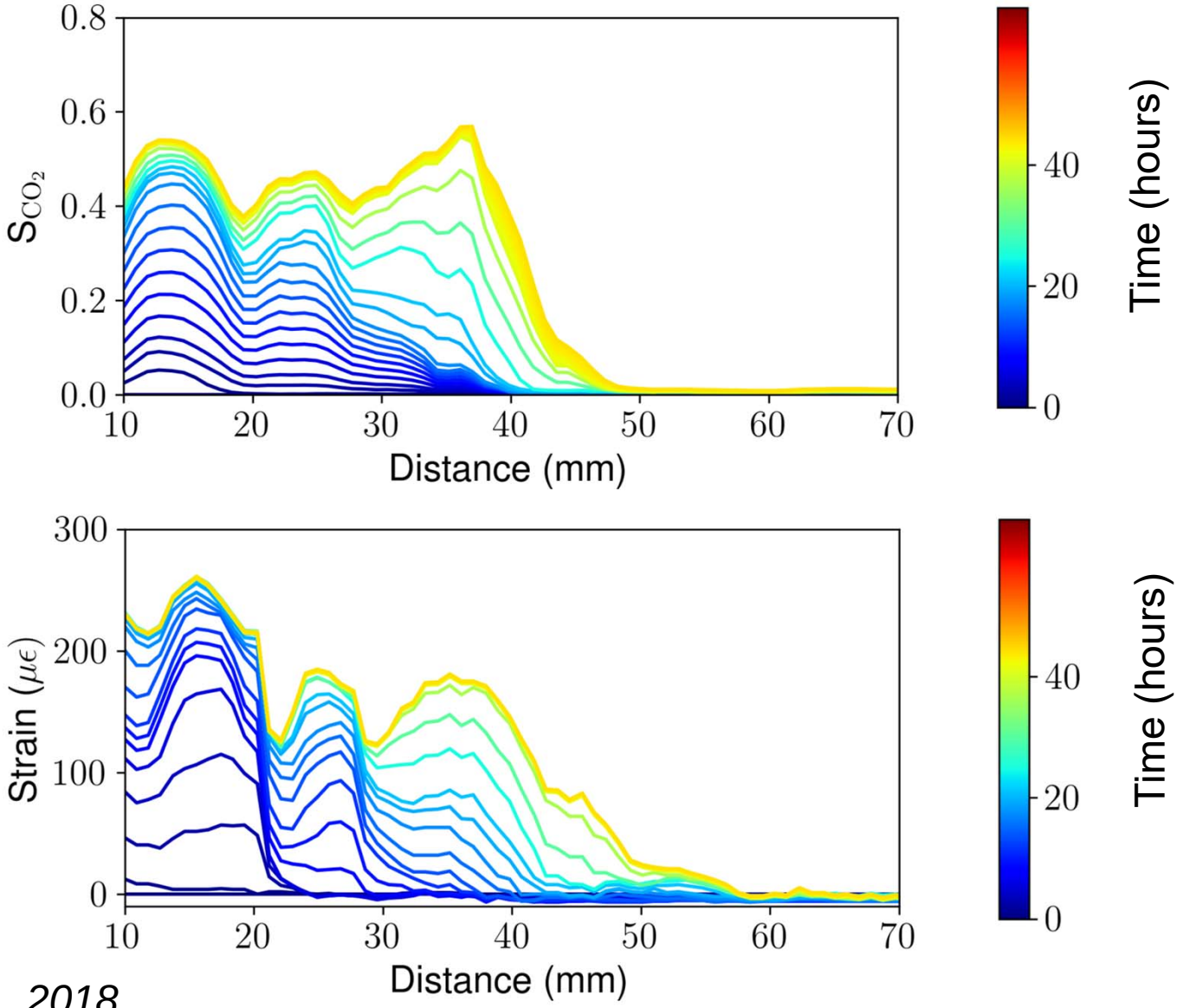
遮蔽層の安定性監視、圧力フロントの観測

粗粒部（貯留層）内のCO_2分布状況（X-CTイメージ）



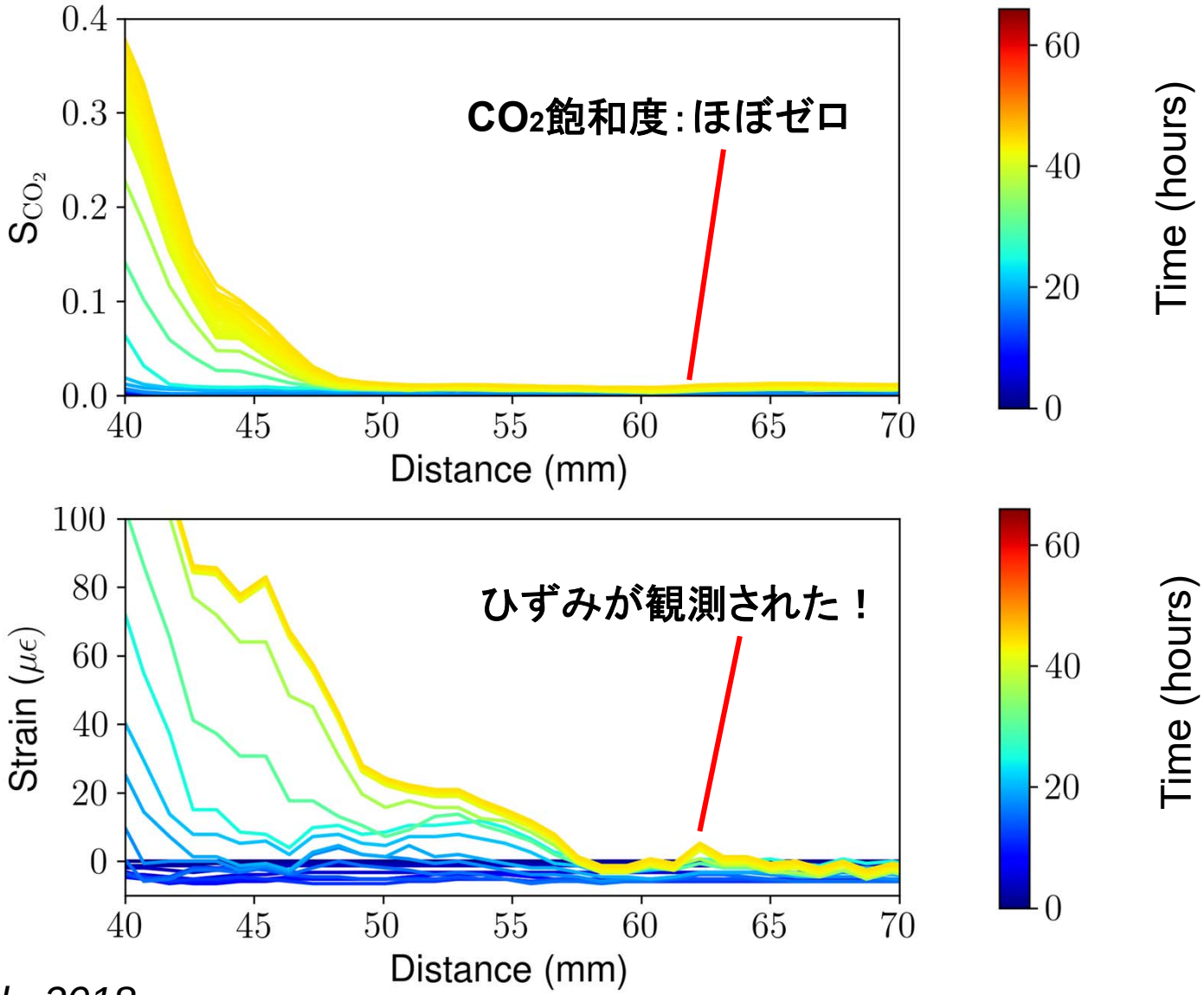
Zhang et al., 2018

粗粒部（貯留層）におけるCO_2飽和度とひずみの対応関係



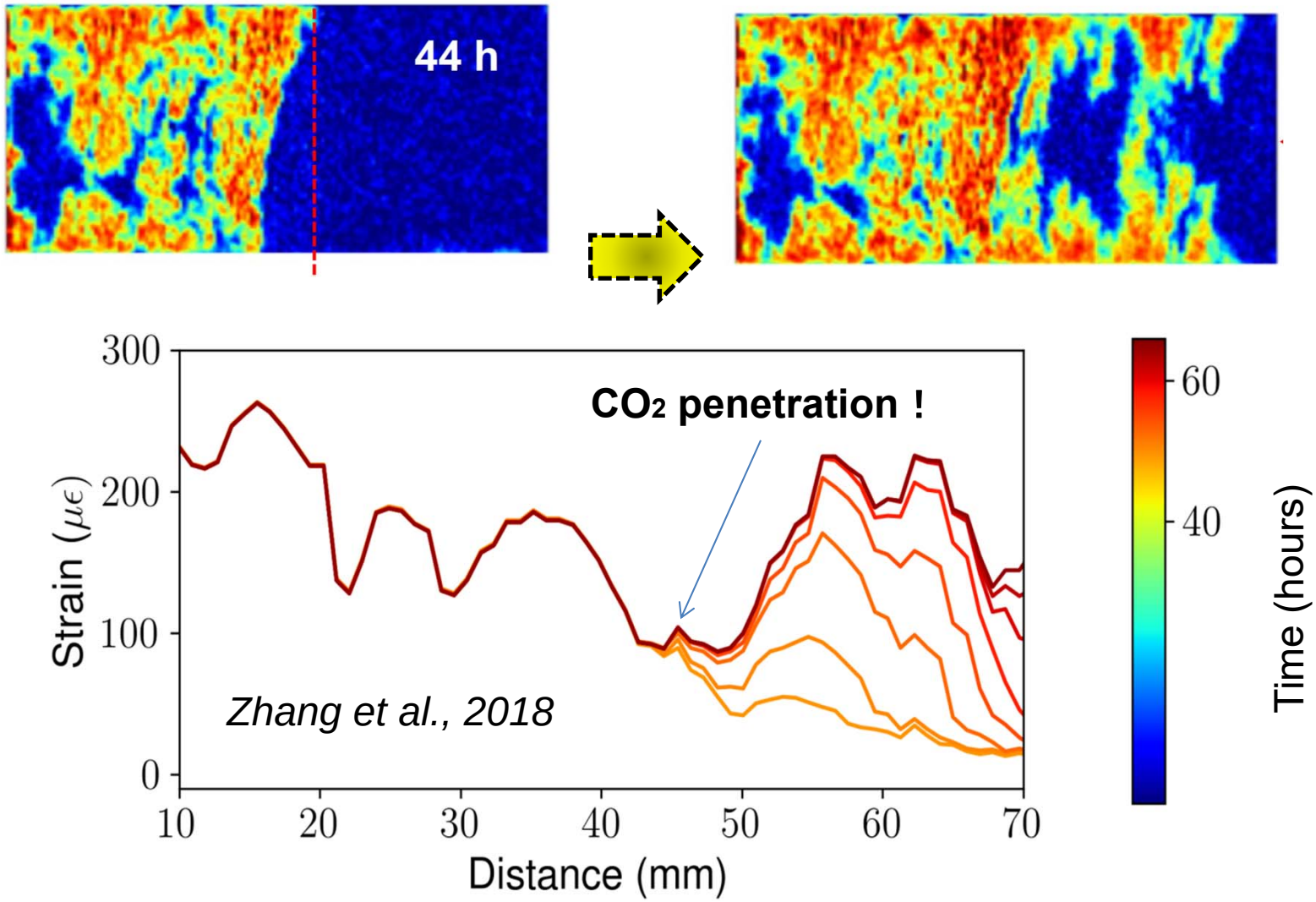
Zhang et al., 2018

粗粒部のCO_2飽和度が増える過程で、細粒部のひずみ発生状況

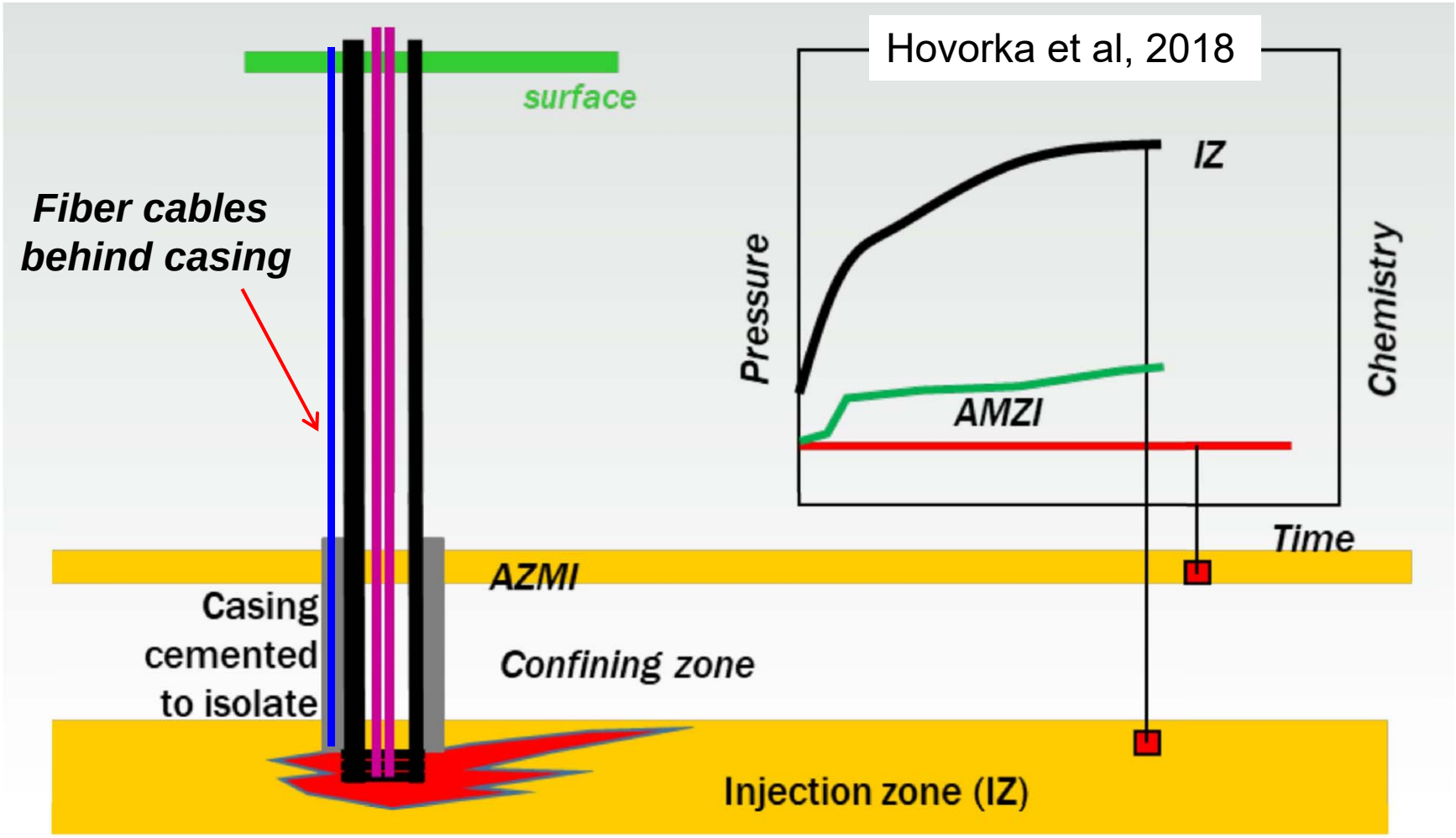


Zhang et al., 2018

Strain response: CO_2 penetrating into the fine grain part



Application for well integrity monitoring, combined with AZMI (Above-Zone Monitoring Interval) pressure monitoring



技術組合（RITEほか）光ファイバーによる地震観測にも取り組んでいる！

謝 辞

この成果は、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）の委託業務の結果得られたものです。

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