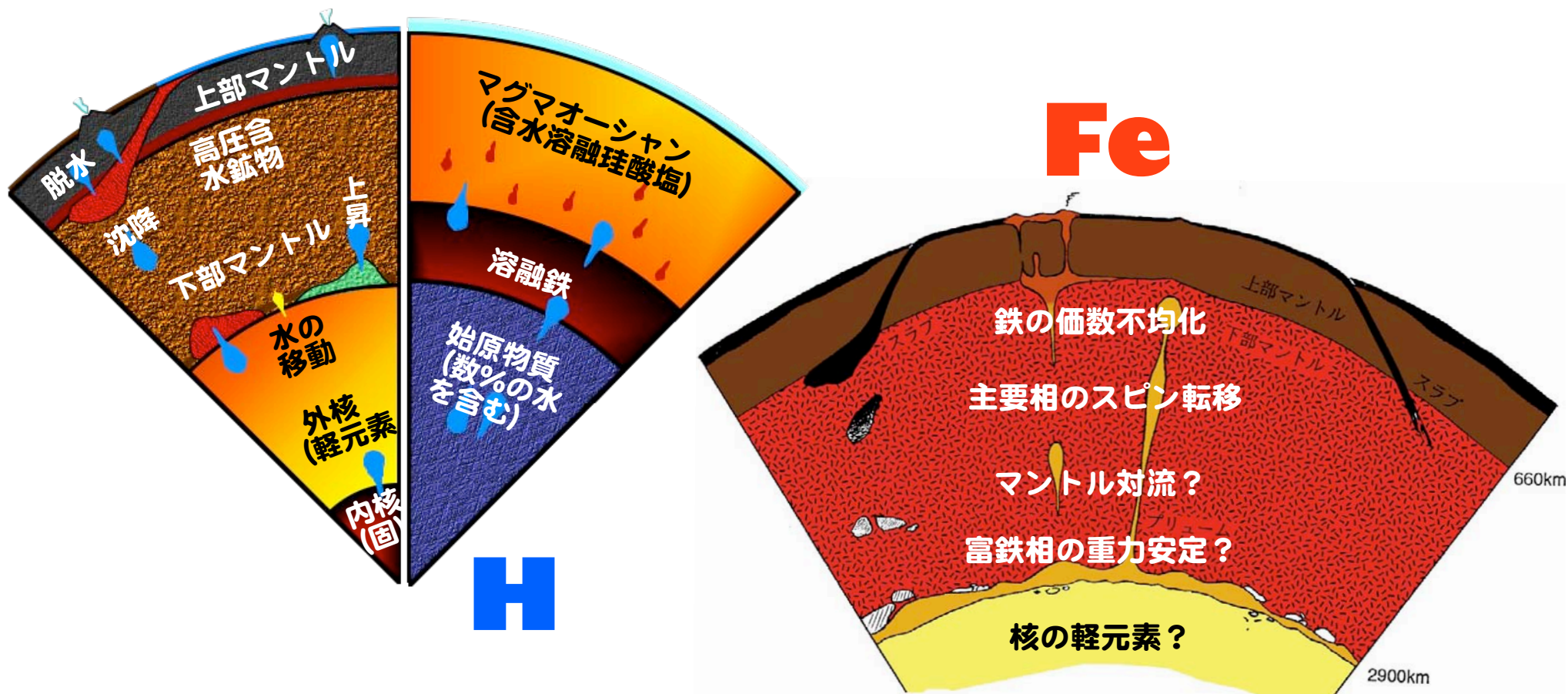


極限環境下プロジェクト

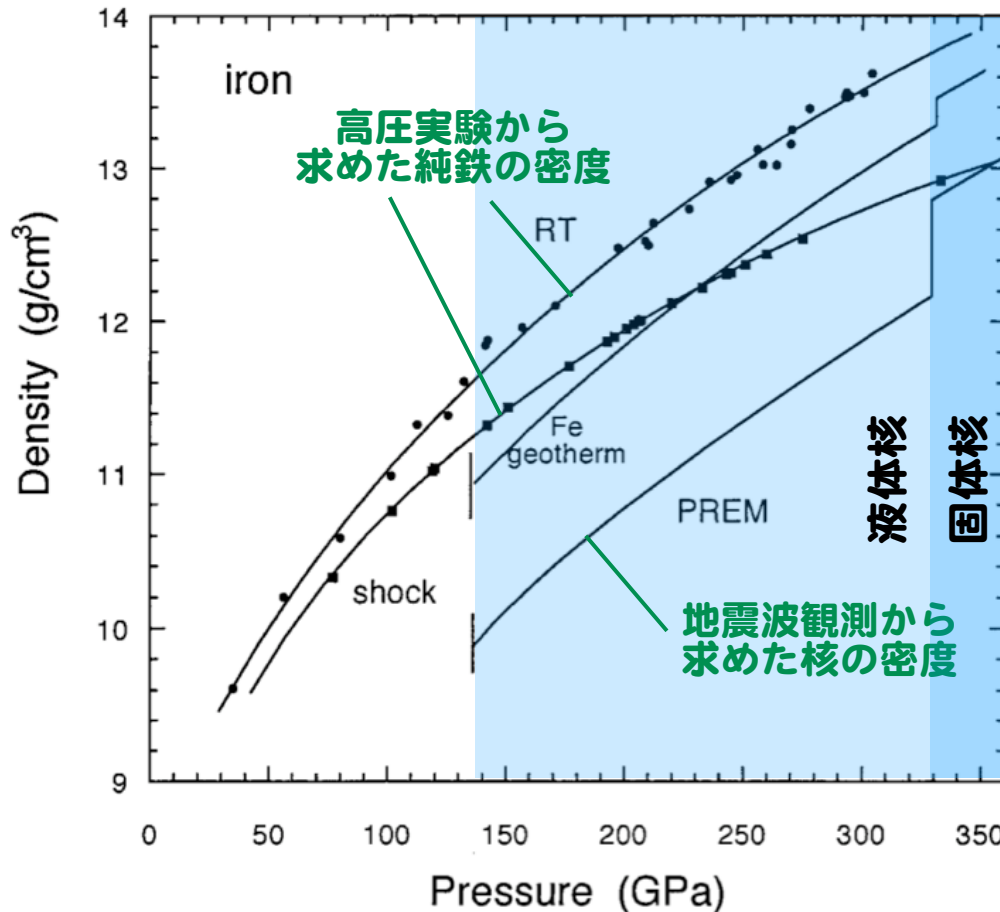
「遷移金属元素と軽元素の挙動から見る地球内部の構造と物性」



プロジェクトメンバー

近藤忠 (阪大・理)、亀卦川卓美、村上洋一、中尾裕則、山崎祐一 (IMSS・PF)
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質・材料研究機構) 鍵裕之、船守展正 (東大・理) 八木健彦、井上徹 (愛媛大・地
球深部研) 久保友明 (九大・理)

地球核中の軽元素の謎



軽元素候補
O, S, H, C, Si, K...

密度・音速・融点・
固容量・粘性・
電気伝導度...

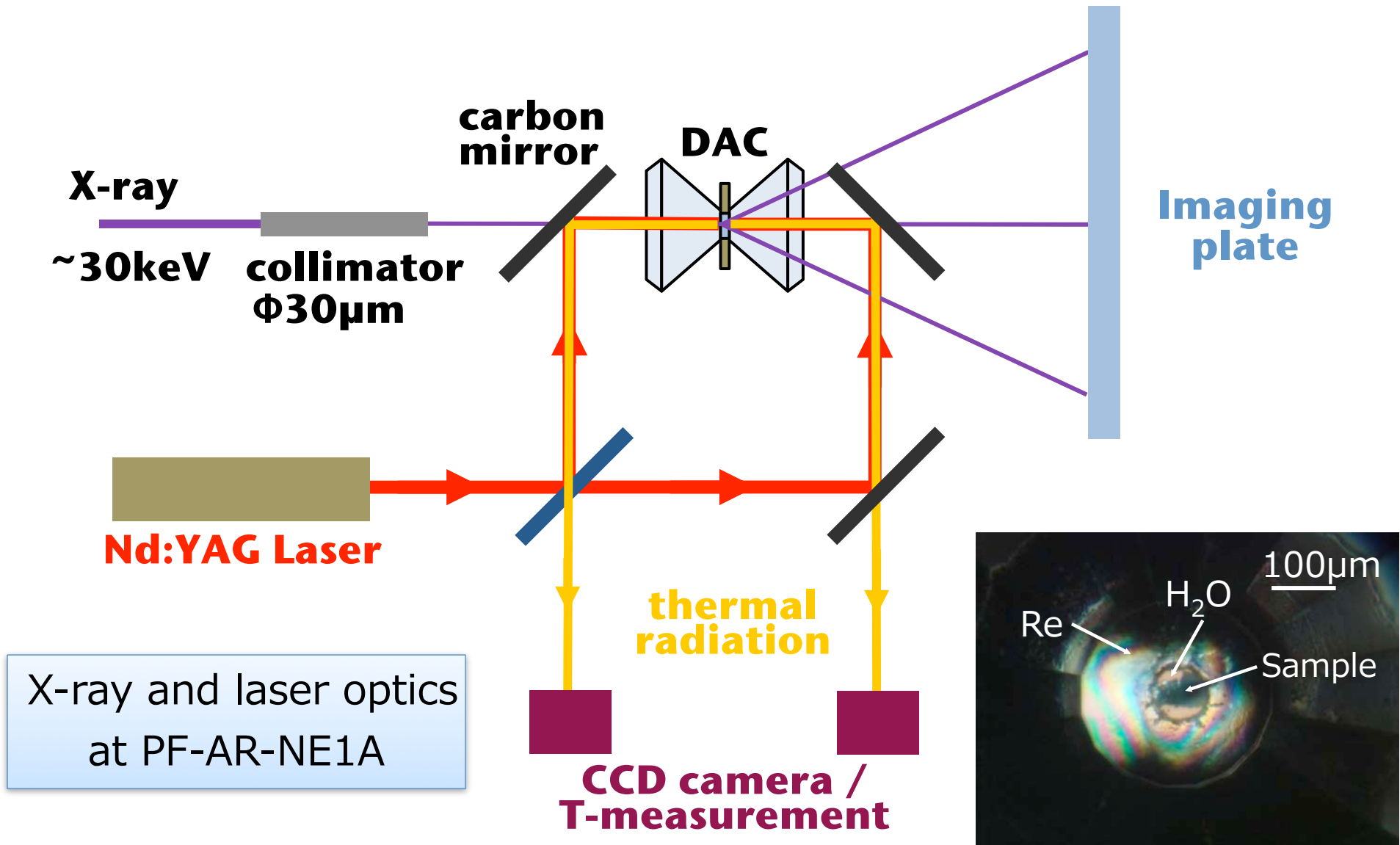
侵入型での鉄に固溶
水素は物性への効果大
実験的には扱いが困難
水素化物は回収不可
他の元素との共存関係
→ 多成分系実験が必要



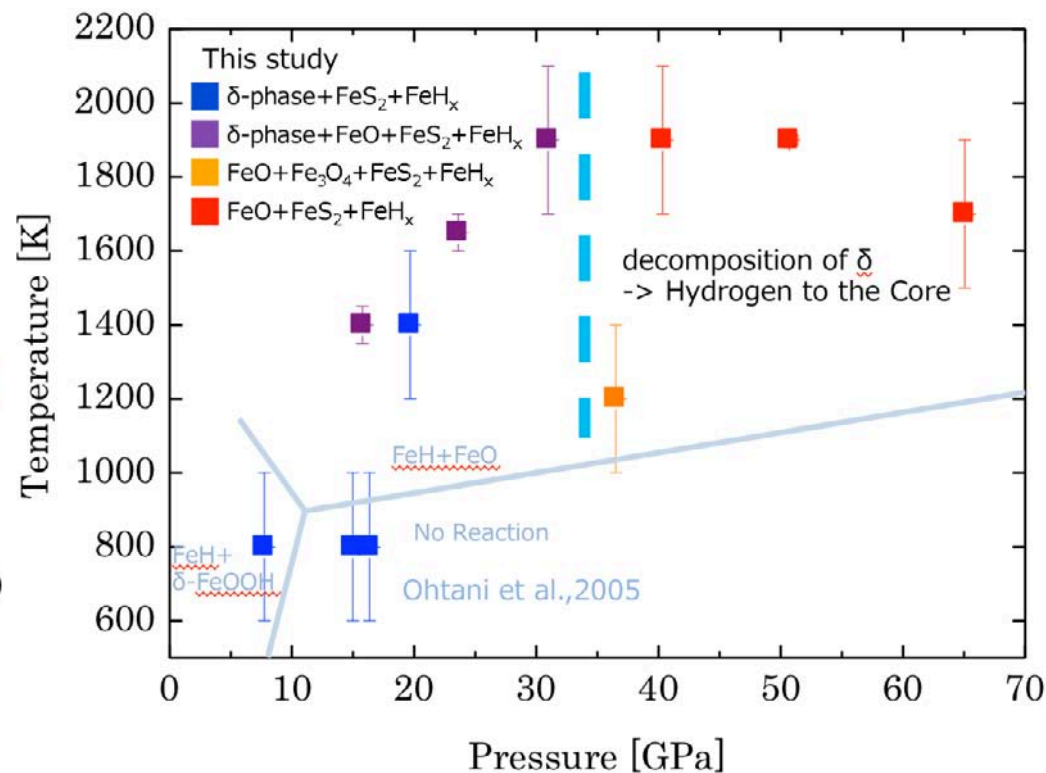
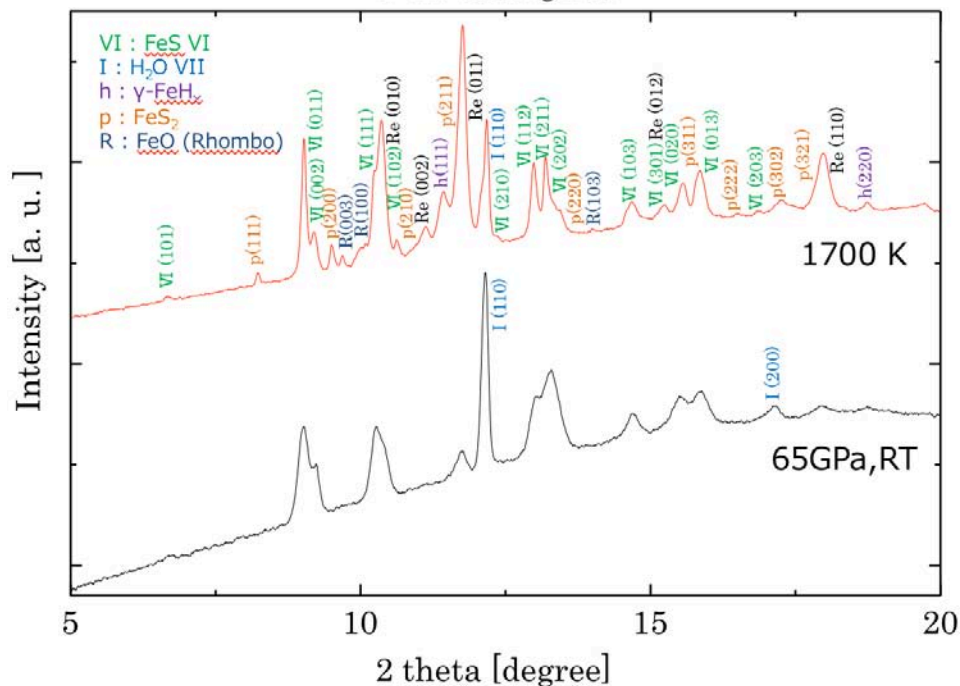
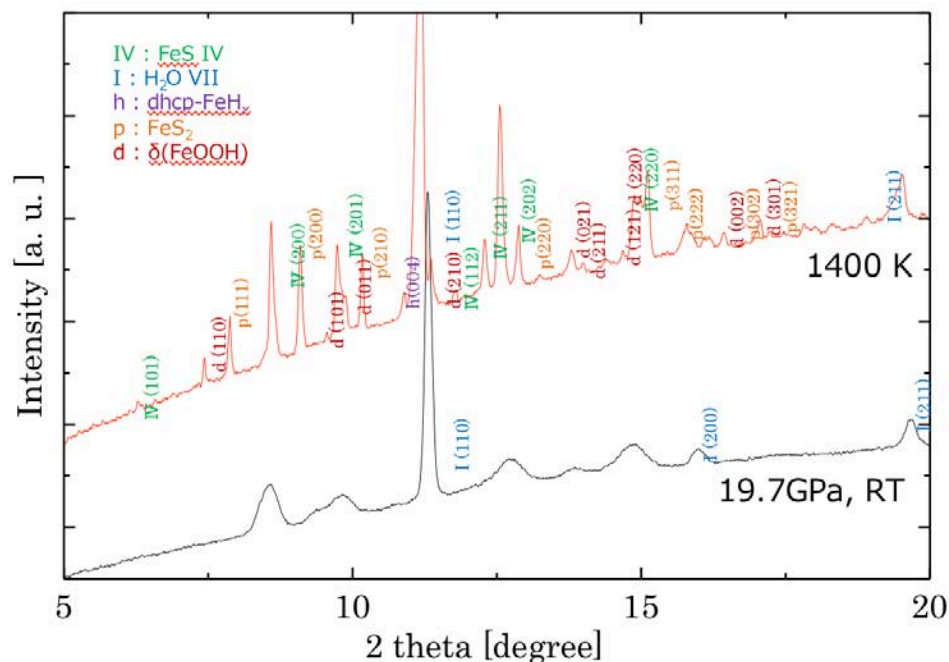
Figure 11. Densities of iron in comparison with seismically derived core densities (preliminary reference Earth model [Dziewonski and Anderson, 1981]). Room temperature measurements are from diamond cell work [Mao et al., 1990]. Shock densities along an isentrope are from Brown and McQueen [1986]. The density of pure iron along a geotherm is calculated from the room temperature density and taking a thermal expansion coefficient $\alpha = 1/V_0(dV/dT)_T = \alpha_0(V/V_0)^5$ (see text and Table 1). The volume change of melting is assumed to be 1%. Density error bars of 2% are shown. The density difference between liquid iron and the outer core is 9% and is 5% for solid iron and the inner core.

Boehler, 1993

KEKにおける高温高圧下X線回折実験



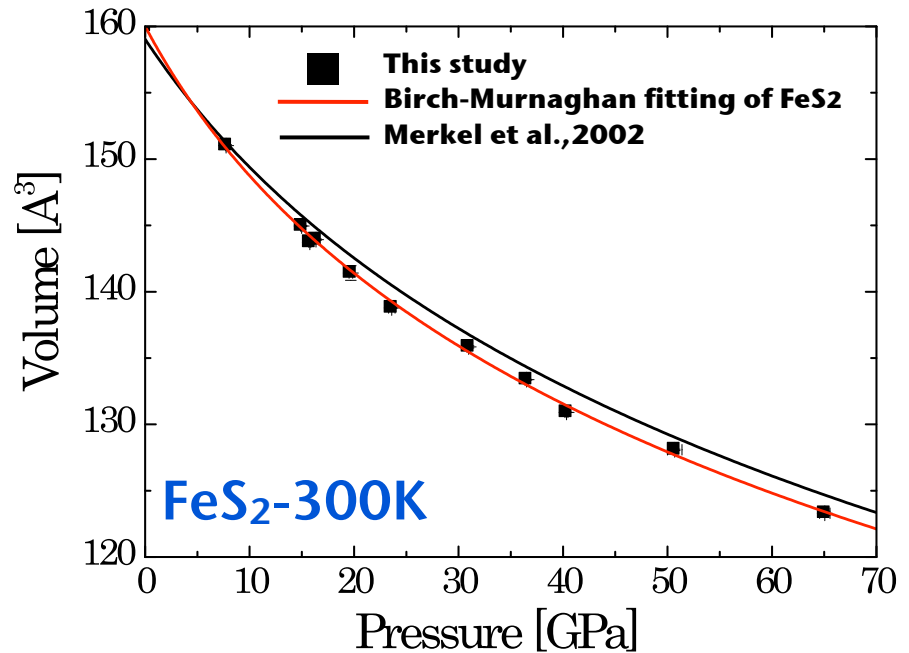
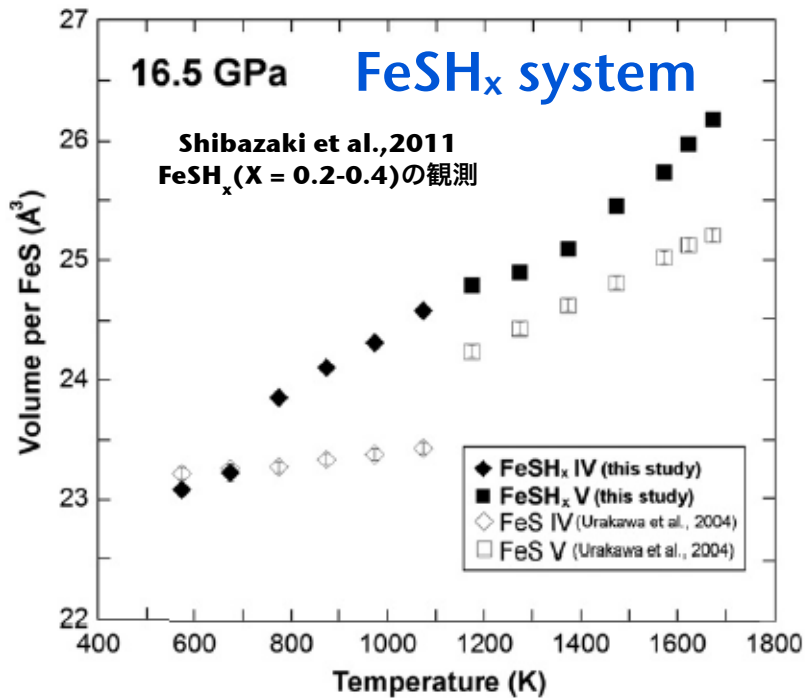
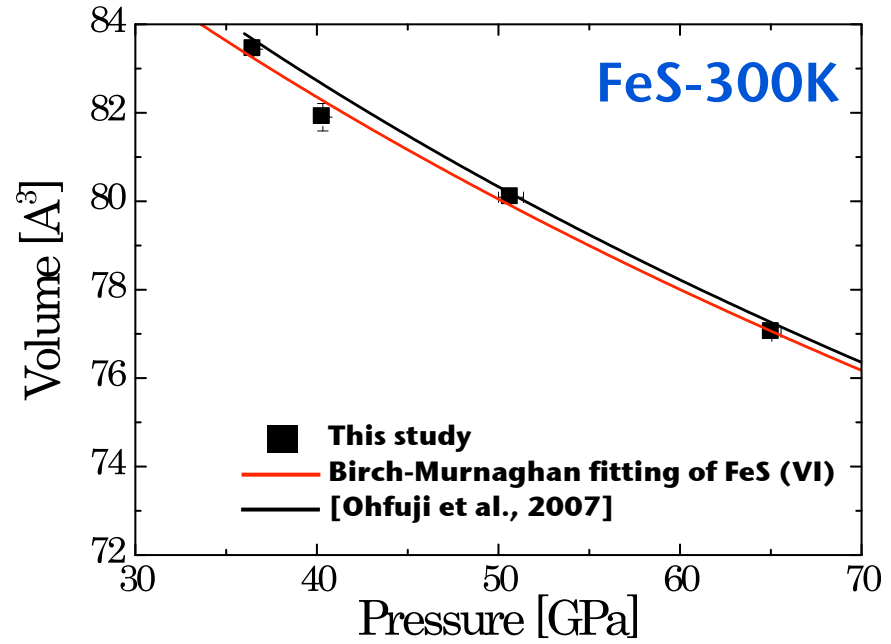
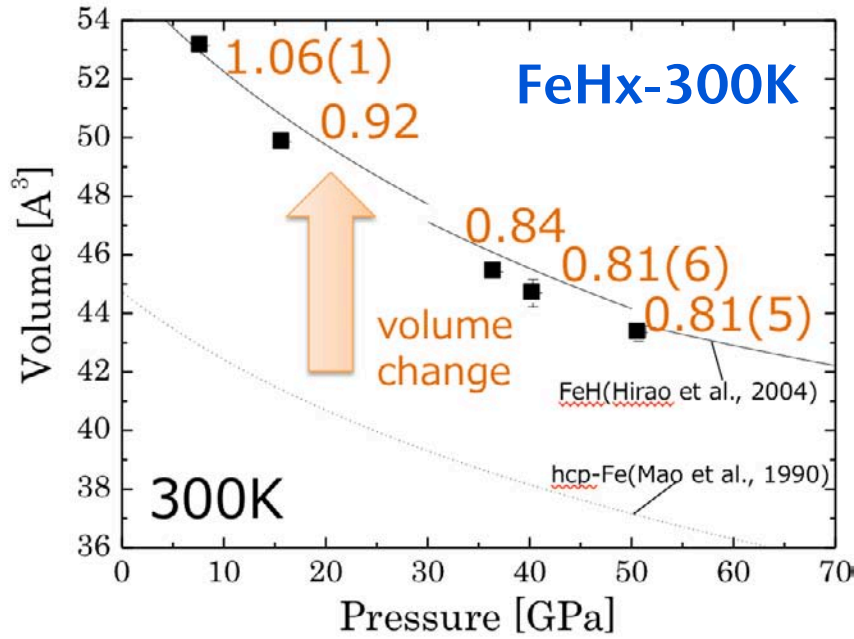
FeS-H₂O系における反応生成物



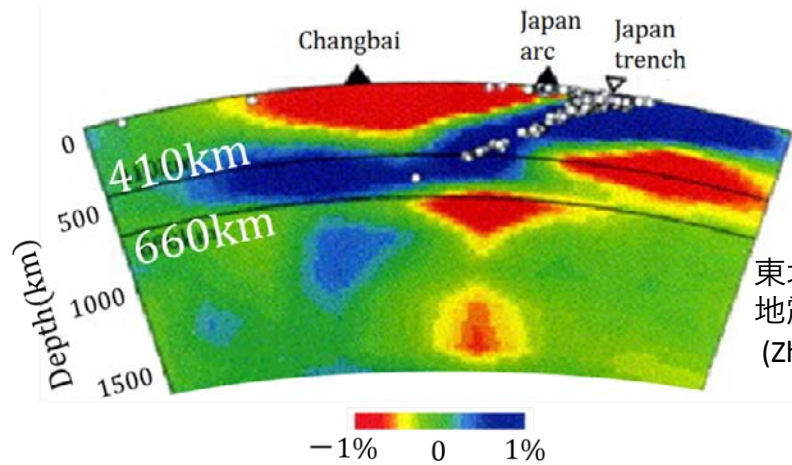
35GPa付近で δ 相(FeOOH)の分解が起こる

δ , FeO → マントルへ
FeH → 核へ

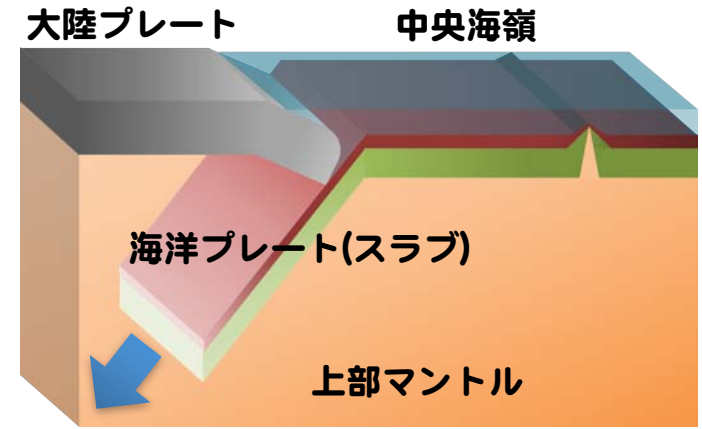
各相中の水素の評価



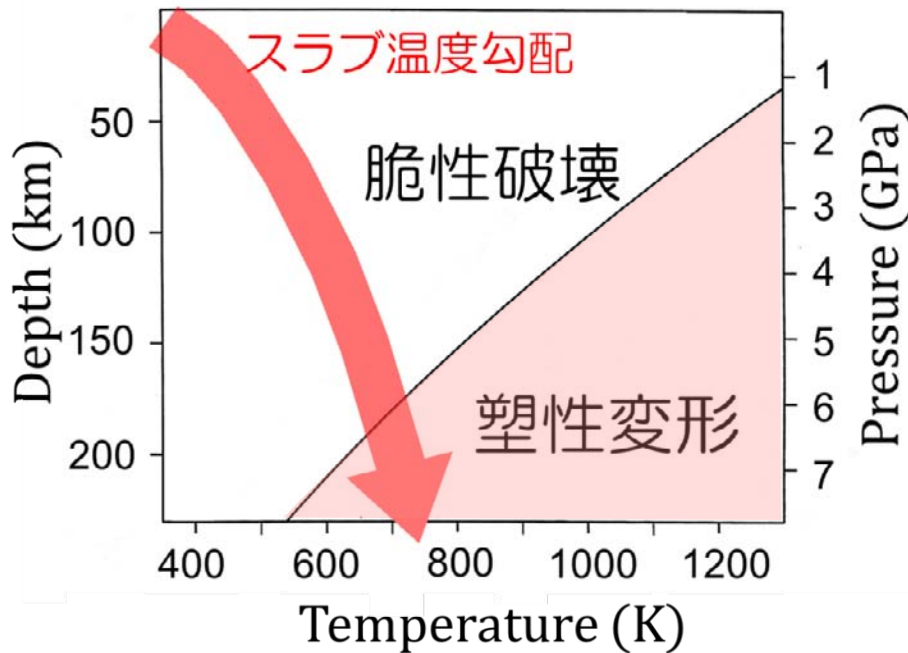
地球深部の不思議な地震



東北日本直下の地震波トモグラフィー像 (Zhao, 2004を改変)



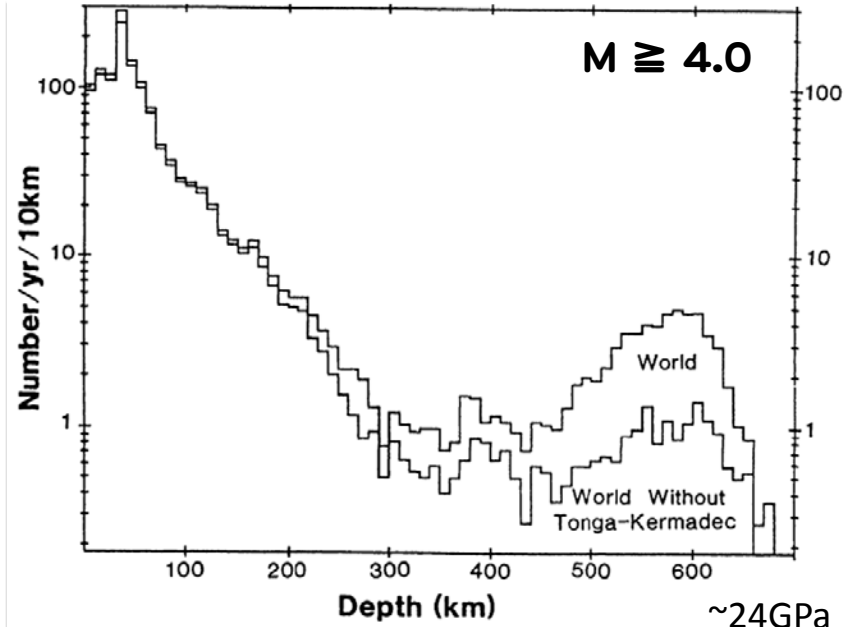
脆性-塑性転移



(Houseman and England, 1986, Ganguly et al., 2009に基づく)

何故、深部で(脆性)破壊が起こる？

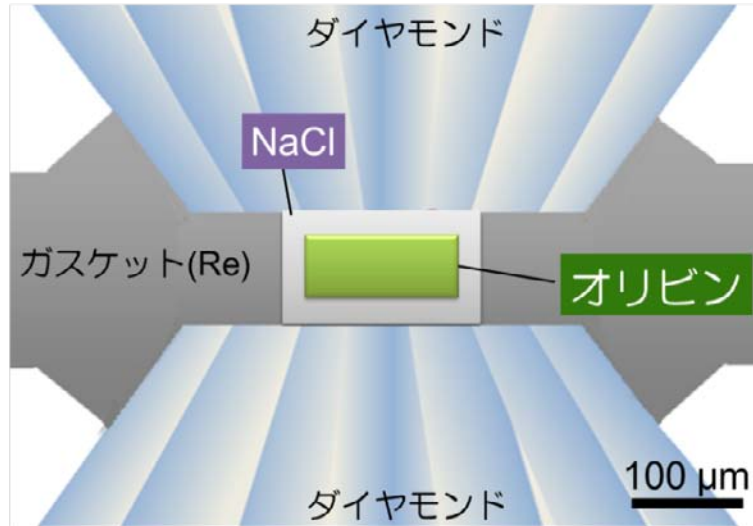
震源の深さ分布



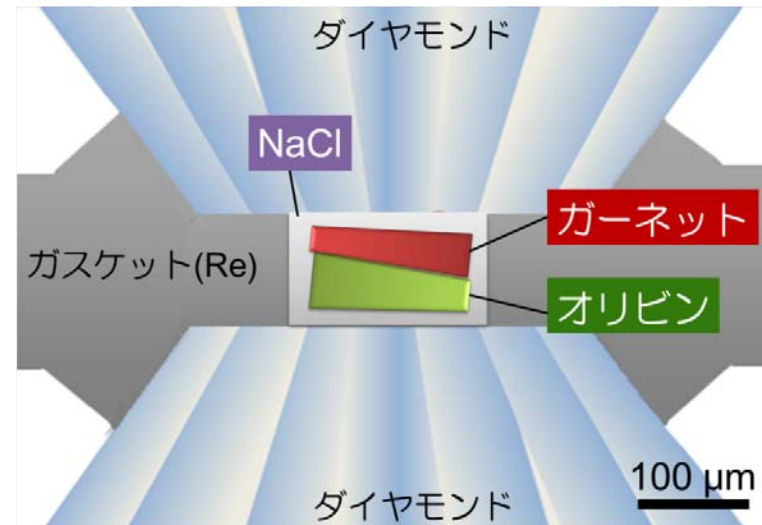
(Frohlich, 1989)

400-700kmで別の地震発生機構？

超高压下変形実験手法の開発



通常のDAC実験



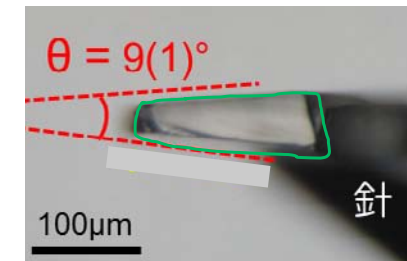
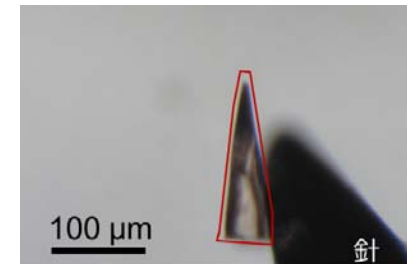
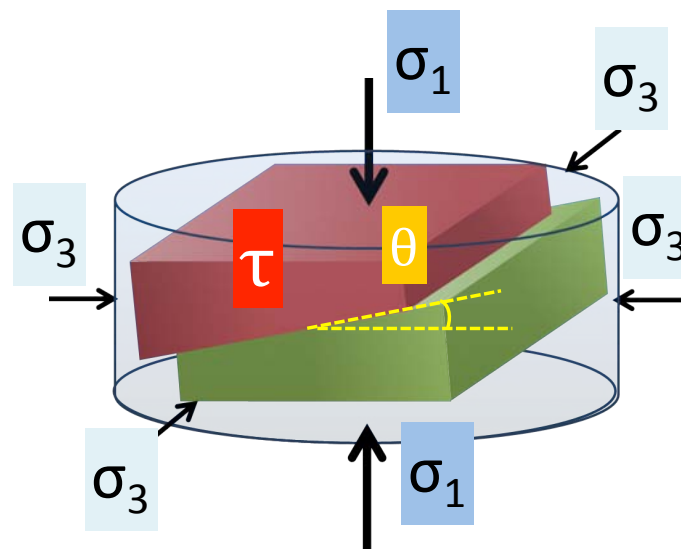
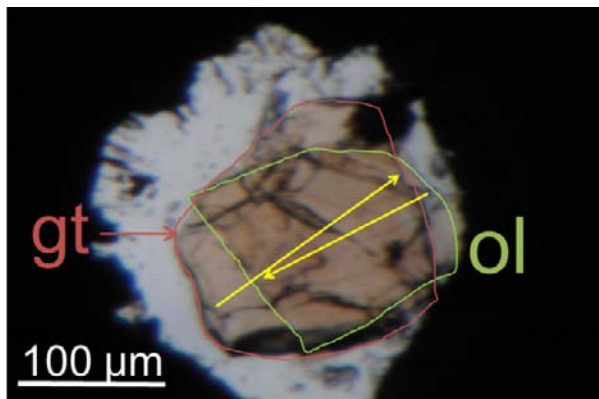
本実験手法



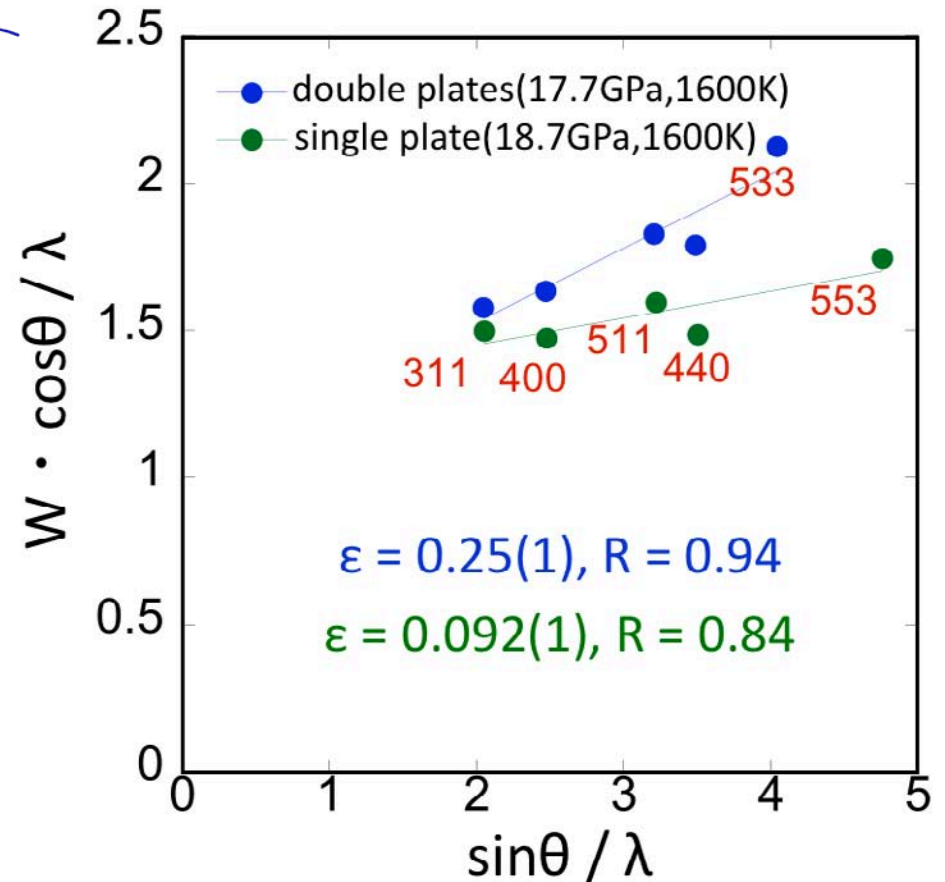
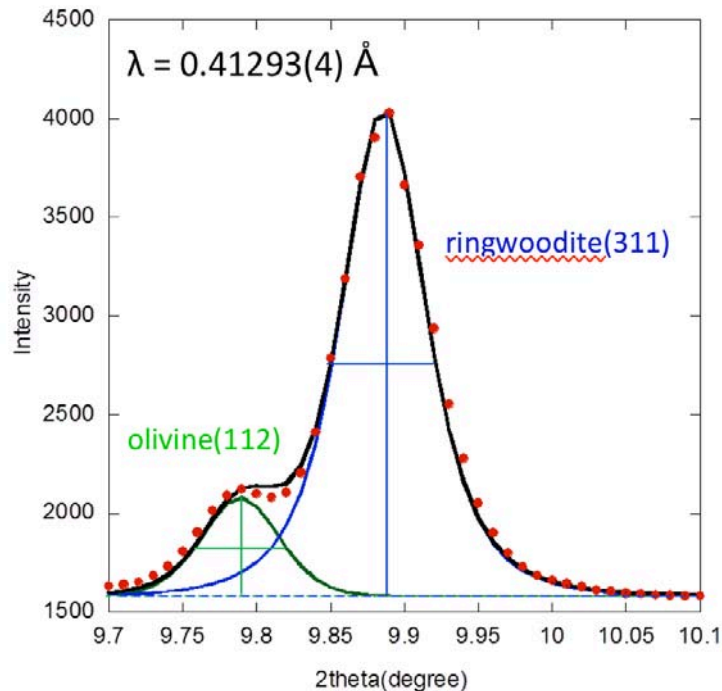
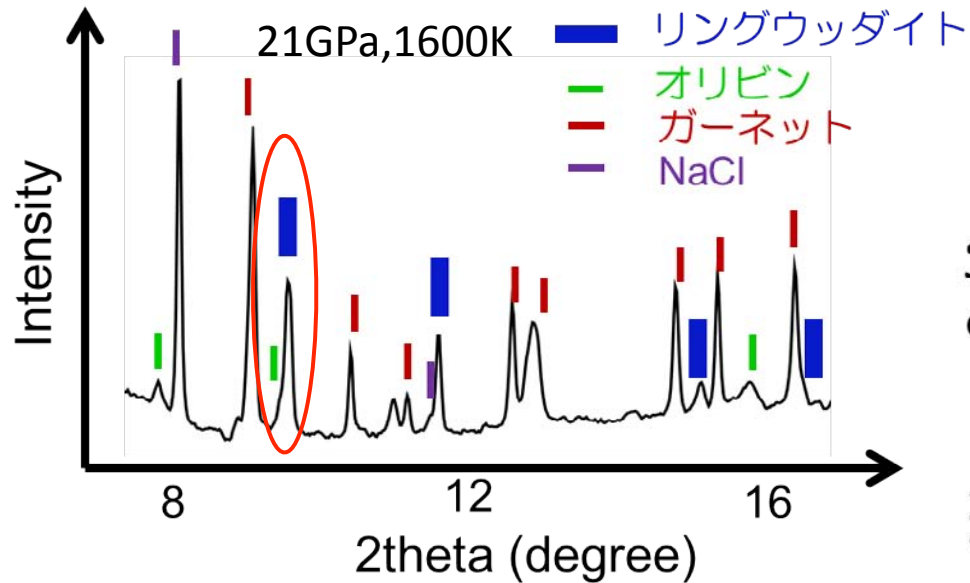
かんらん石



ガーネット



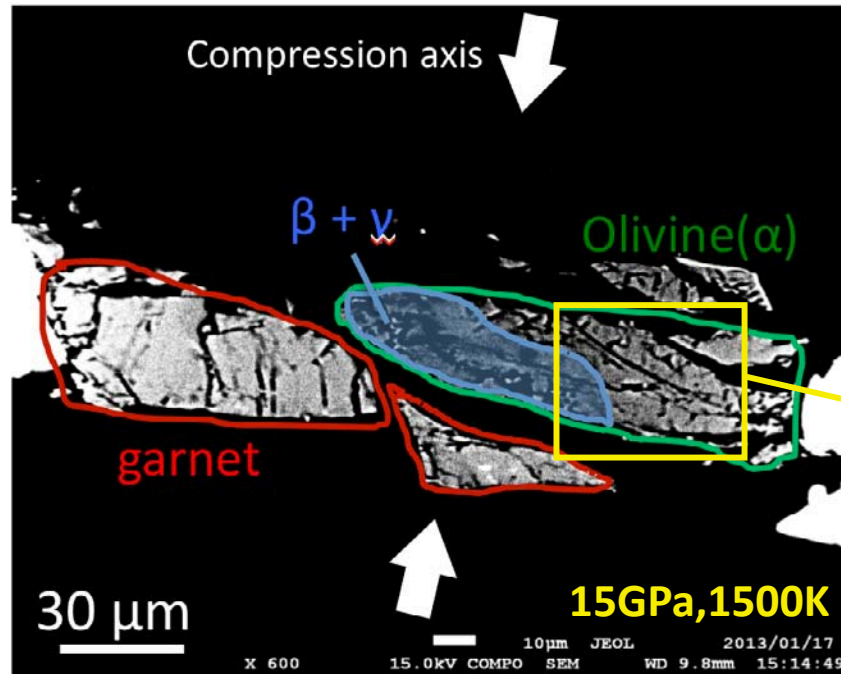
高圧相中の不均質歪の評価



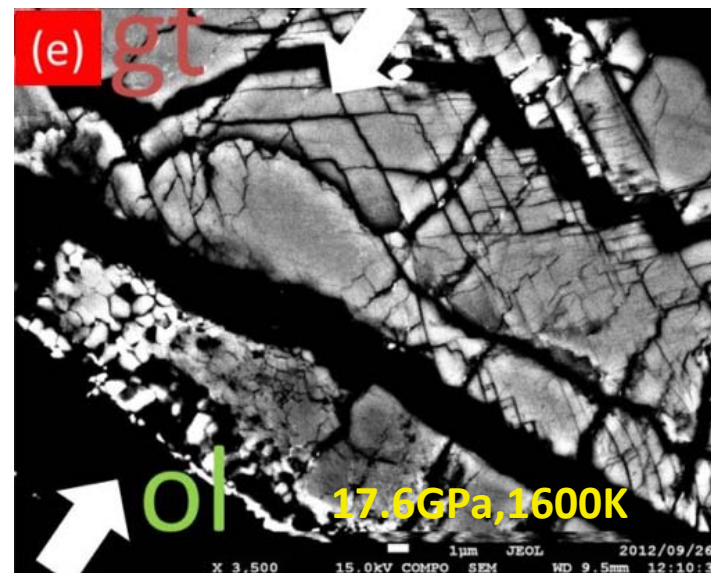
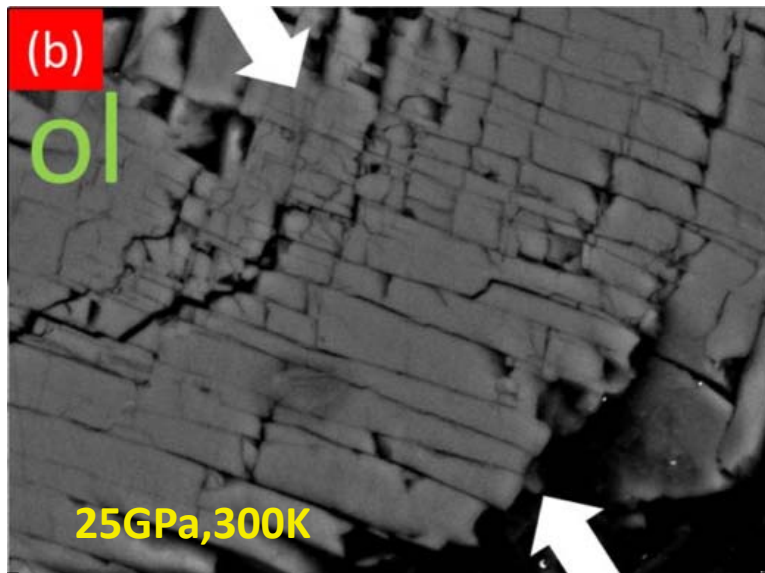
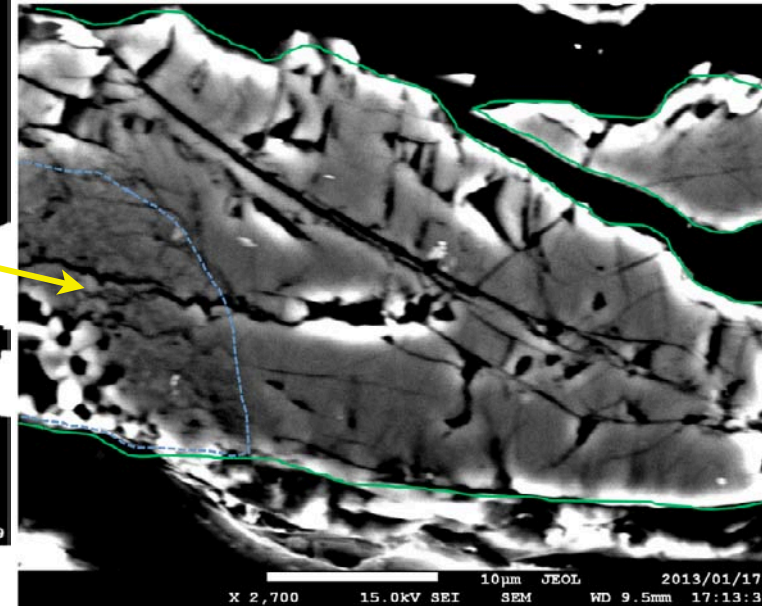
Hall-Williamson plot of Ringwoodite

変形構成の高圧実験では
 反応後の不均質歪みが大きい
 → 変形実験手法として有効

回収試料の反応領域観察



2つの試料の接触面（剪断応力場）
に相転移した領域が見られる



未転移の試料では
剪断クラックが
多数見られる

高温高压下の複合測定の実現

反応速度、粒成長、応力と歪

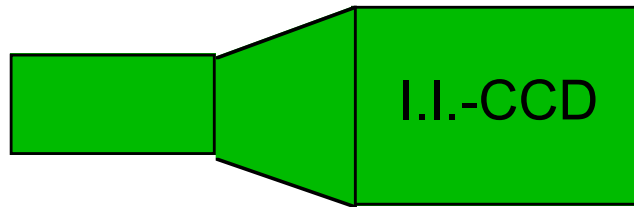
High-speed diffraction

- High P-T kinetics
- grain growth
- High P-T stress meas.

X-ray Fluorescence

- absorption
- chemistry

定性分析、化学結合



粘性、界面エネルギー

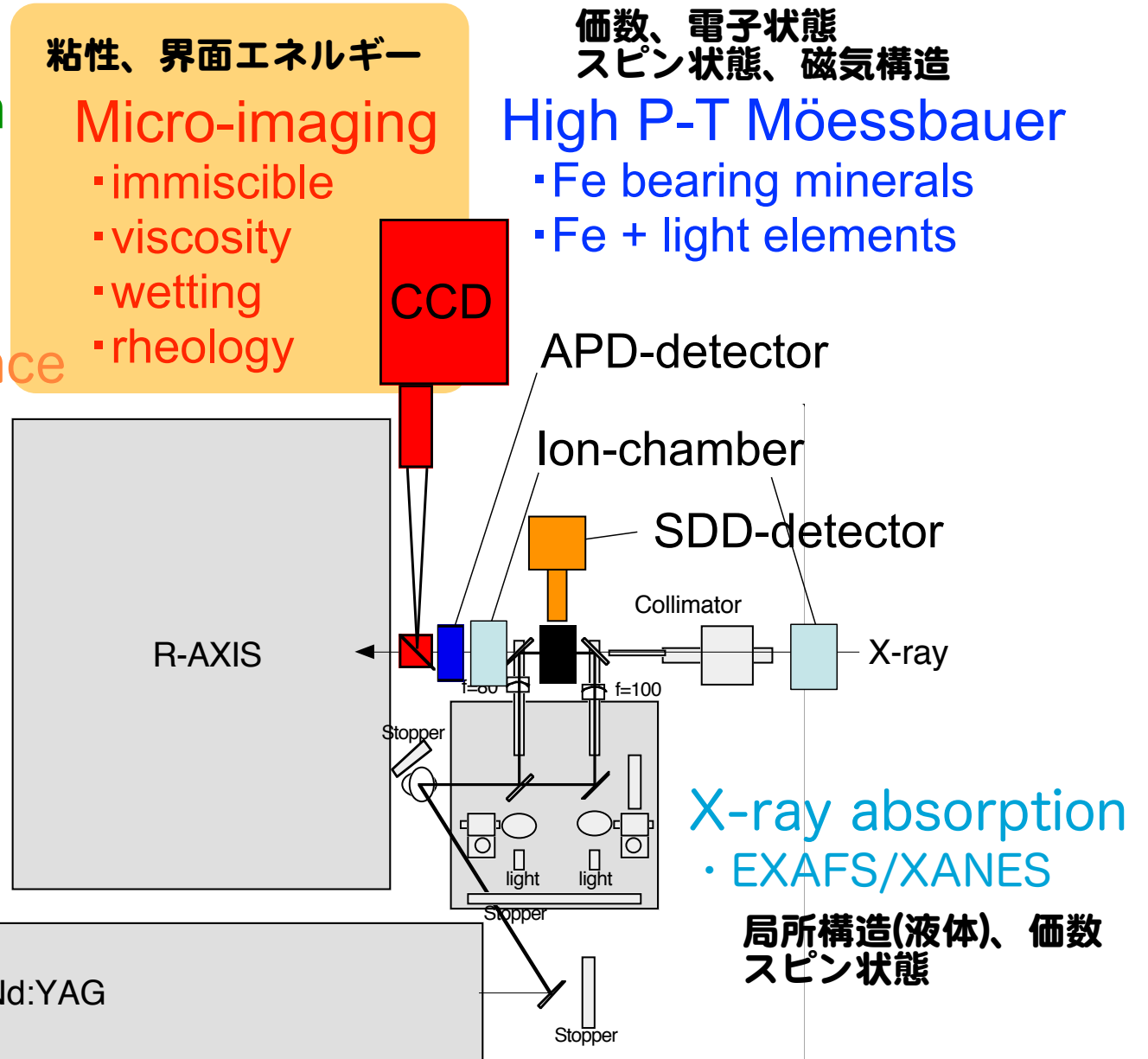
Micro-imaging

- immiscible
- viscosity
- wetting
- rheology

価数、電子状態
スピン状態、磁気構造

High P-T Mössbauer

- Fe bearing minerals
- Fe + light elements



X-ray absorption

- EXAFS/XANES

局所構造(液体)、価数
スピン状態

DACを用いた高压下の粘性測定

Viscosity of Fluids in Subduction Zones

Andreas Audéat* and Hans Keppler

The viscosities of aqueous fluids with 10 to 80 weight percent dissolved silicates have been measured at 600° to 950°C and 1.0 to 2.0 gigapascals by in situ observation of falling spheres in the diamond anvil cell. The viscosities at 800°C range from 10^{-4} to 10^{-5} pascal seconds. The combination of low viscosities with a favorable wetting angle makes silicate-rich fluid an efficient agent for material transport at low-volume fractions. Our results therefore suggest that there may be a direct relationship between the position of the volcanic front and the onset of complete miscibility between water and silicate melt in the subducting slab.

Science, 2004

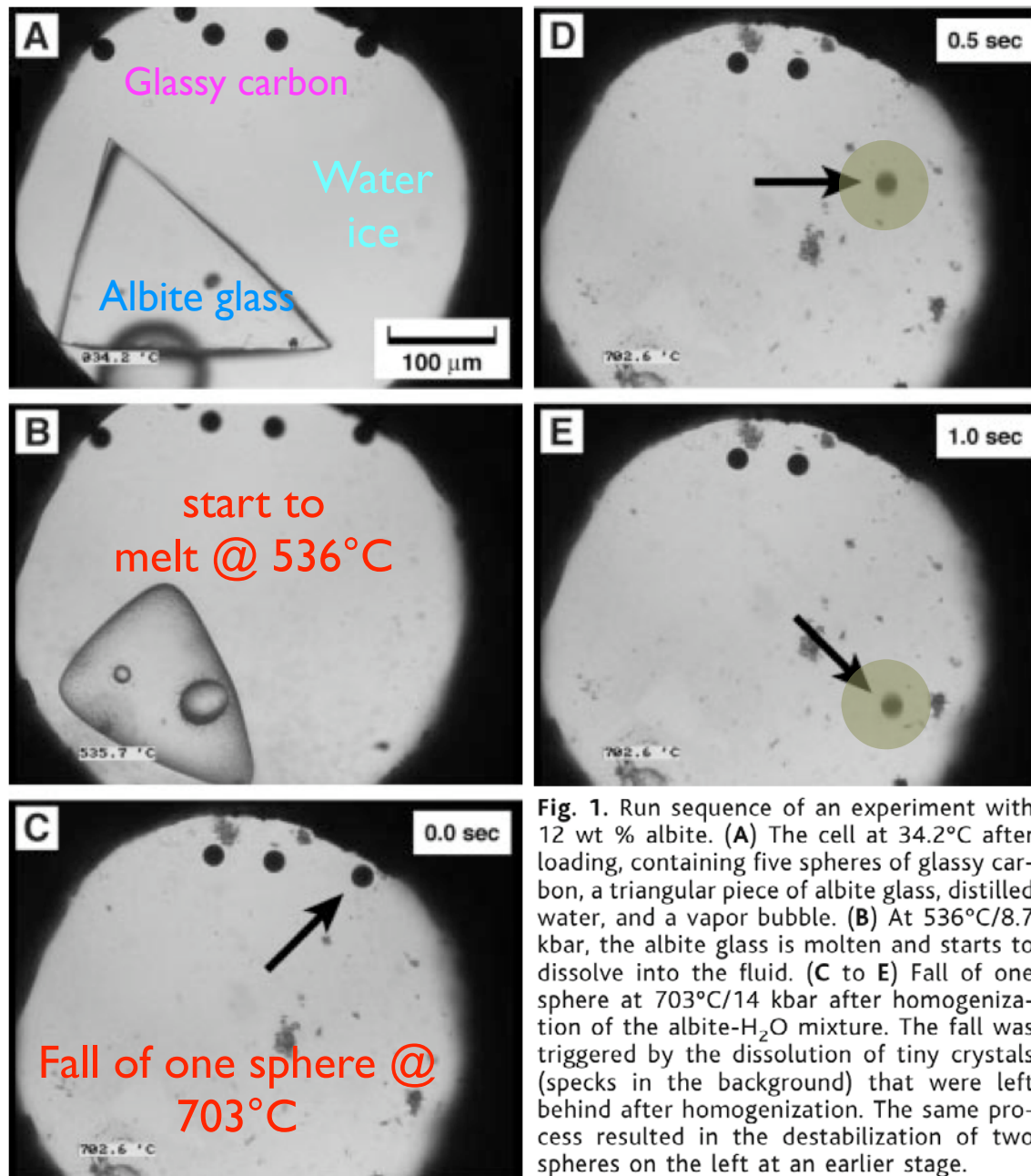
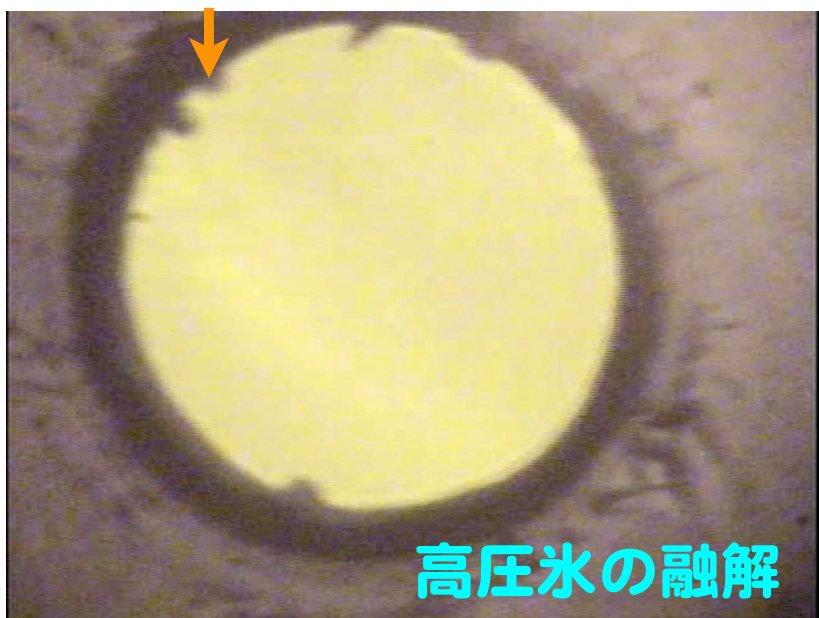
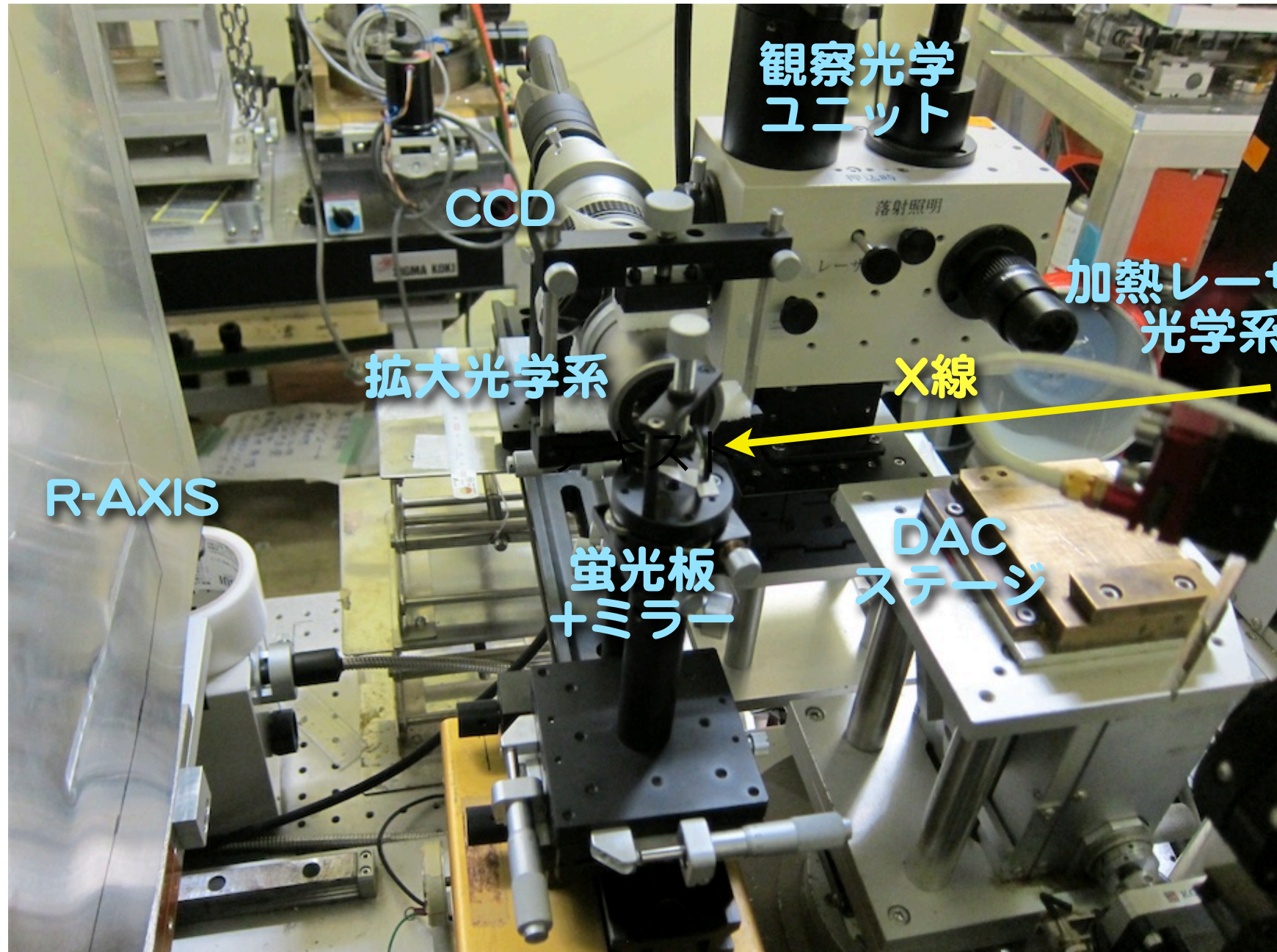
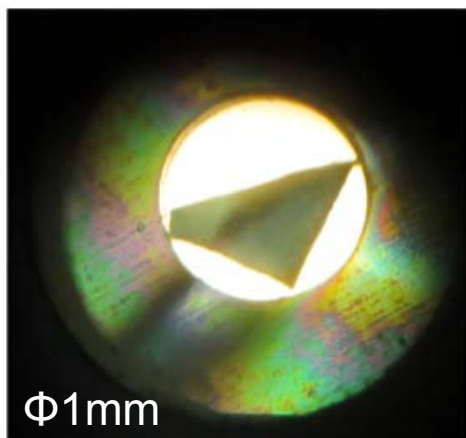


Fig. 1. Run sequence of an experiment with 12 wt % albite. (A) The cell at 34.2°C after loading, containing five spheres of glassy carbon, a triangular piece of albite glass, distilled water, and a vapor bubble. (B) At 536°C/8.7 kbar, the albite glass is molten and starts to dissolve into the fluid. (C to E) Fall of one sphere at 703°C/14 kbar after homogenization of the albite-H₂O mixture. The fall was triggered by the dissolution of tiny crystals (specks in the background) that were left behind after homogenization. The same process resulted in the destabilization of two spheres on the left at an earlier stage.

DAC試料のX線イメージング

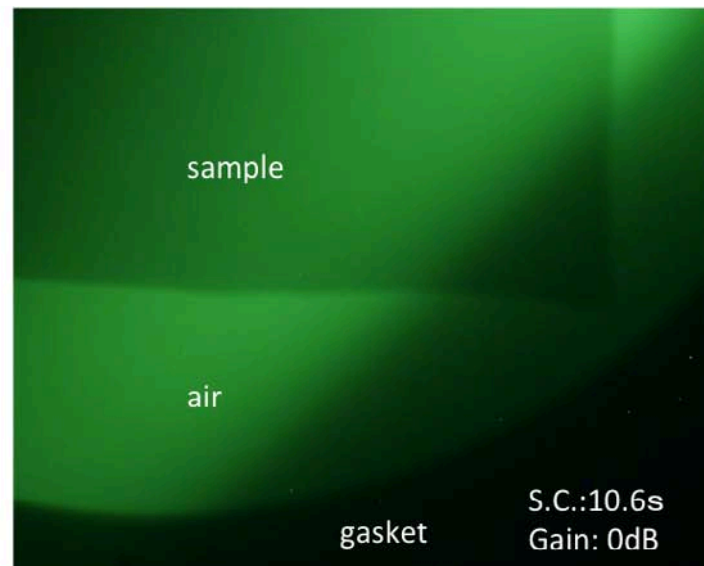
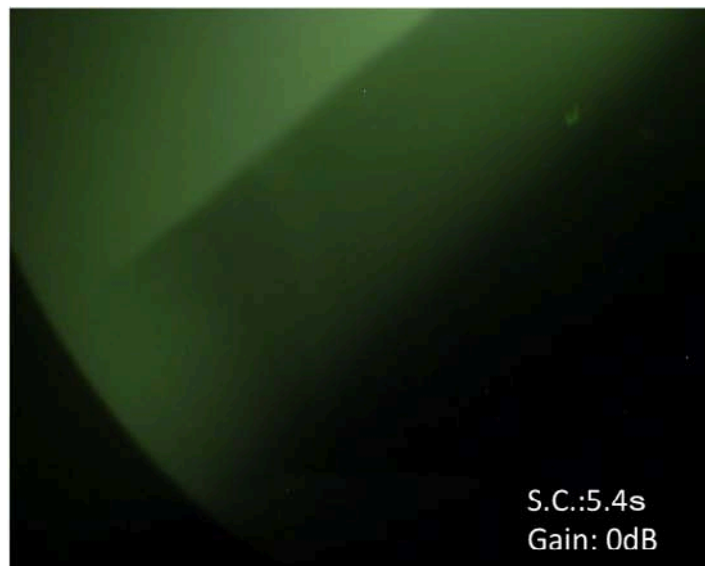
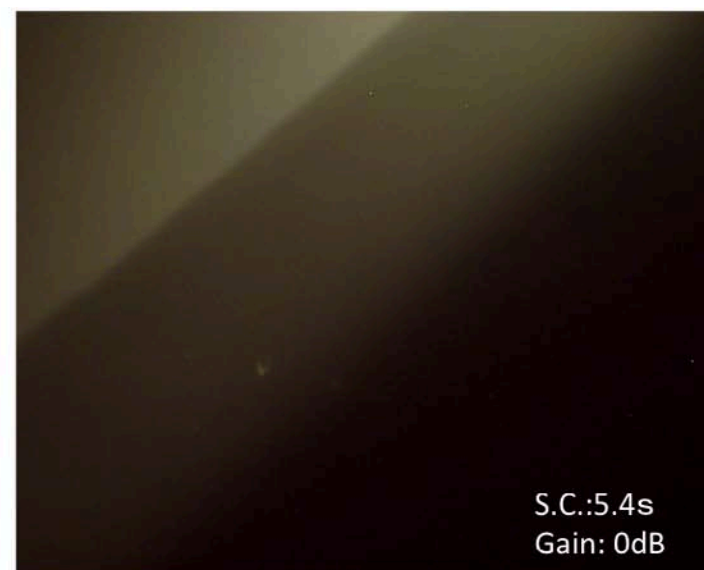
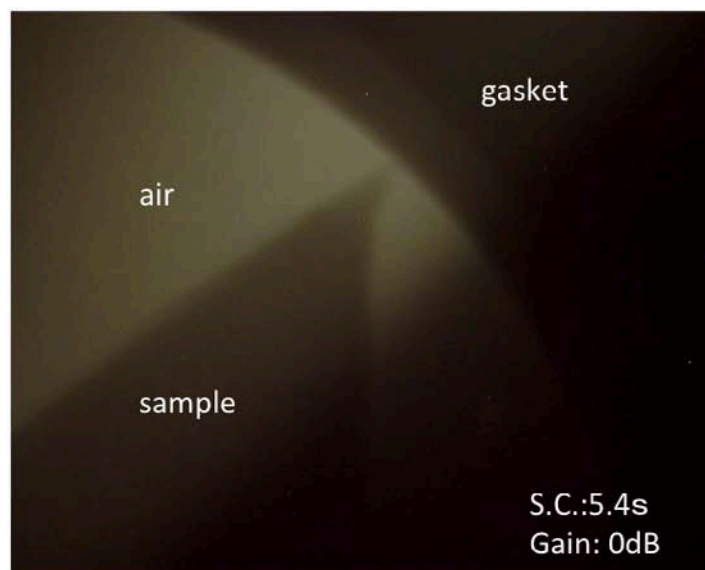


DAC中試料のX線イメージング

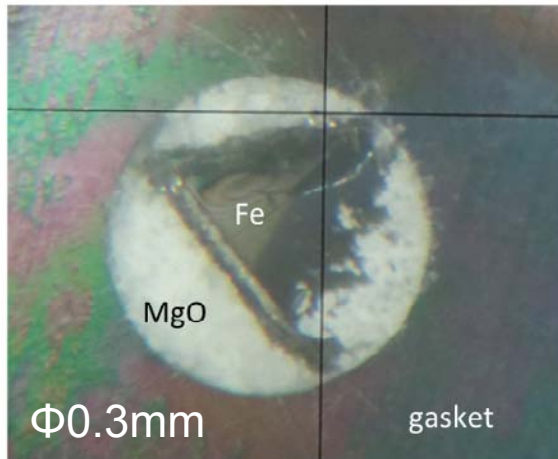


顕微鏡画像

先端径: 2mmΦ (dia3mm厚)
試料室: 1mmΦ
試料: SUS304(三角形状)
厚さ 200um
(厚媒体なし)
X線エネルギー: 30KeV



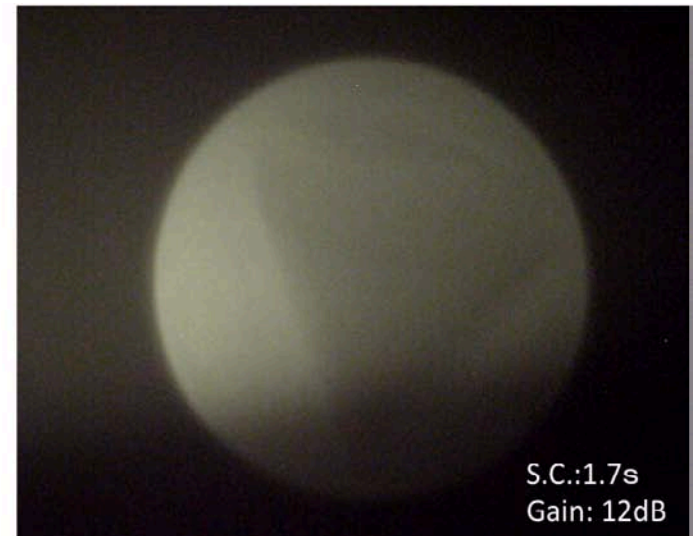
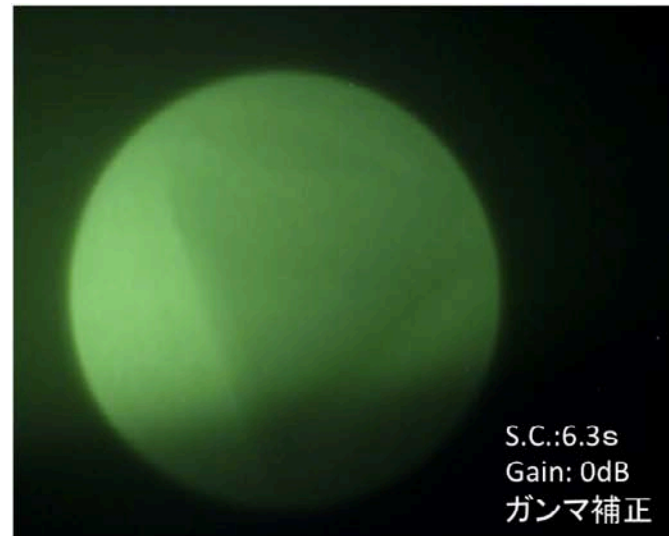
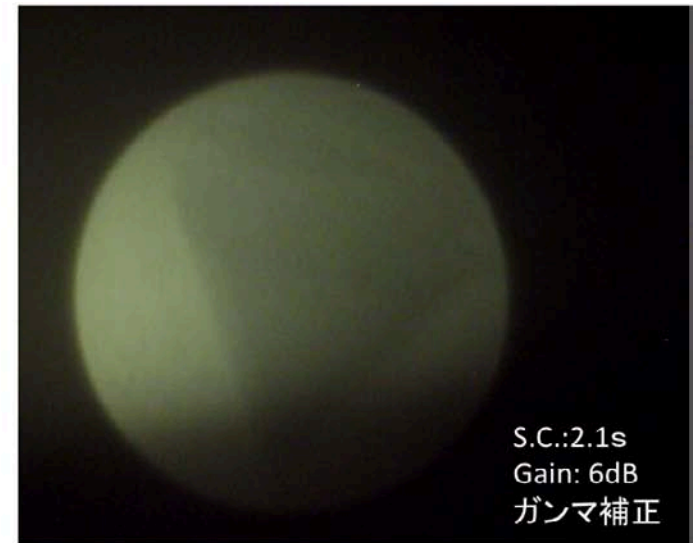
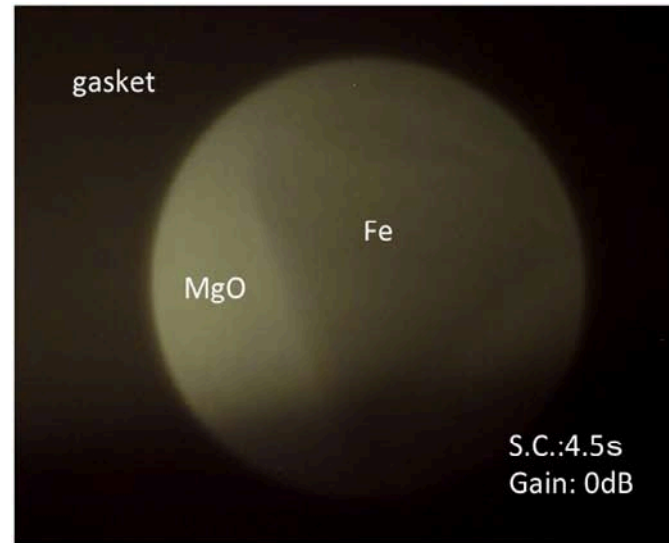
DAC中試料のX線イメージング



顕微鏡画像

先端径: 2mm Φ (dia3mm厚)
試料室: 0.3mm Φ
試料: 50 μm 厚Fe(三角形状)
+ MgO粉末
X線エネルギー: 30KeV

**数十GPa領域での
組織観察・相分離観察
吸収密度測定・粘性測定
等に応用が期待**



まとめ

- 地球核中の水素に関する初競合元素例
→ 他の物性の測定による核の軽元素決定
- 超高压下における剪断応力実験の技術開発
→ 深発地震の発生メカニズムへの応用
- DAC試料のマイクロイメージングの開始
→ 超高压下での粘性測定・密度測定・組織観察
- 高压中性子実験開始@J-PARC
→ 含水鉱物や融体中の水素位置・結合変化