Microstructure and origin of faults in siliceous mudstone at the Horonobe Undergroud Research Laboratory site, Japan

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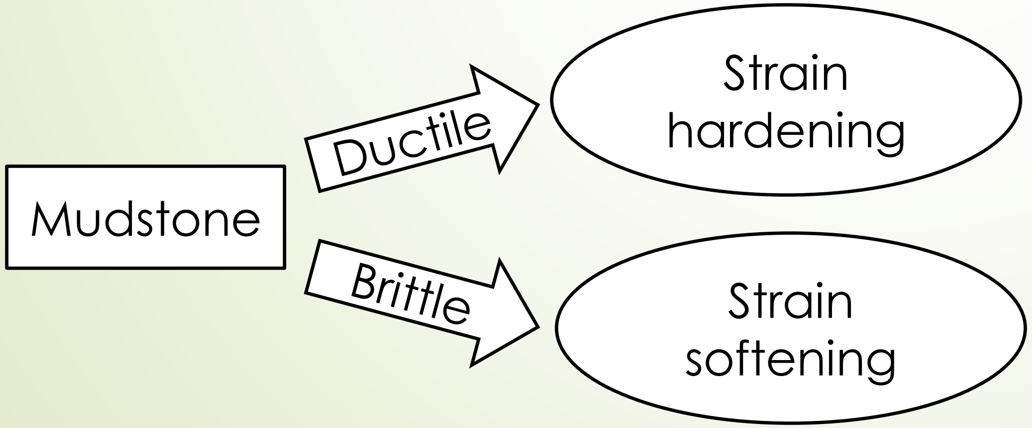
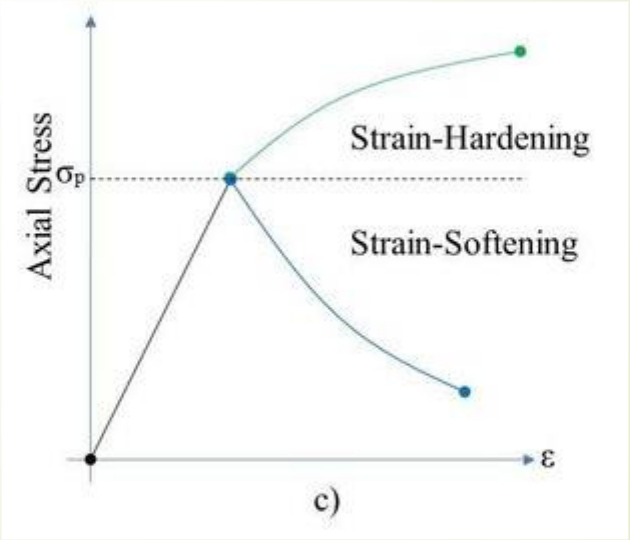
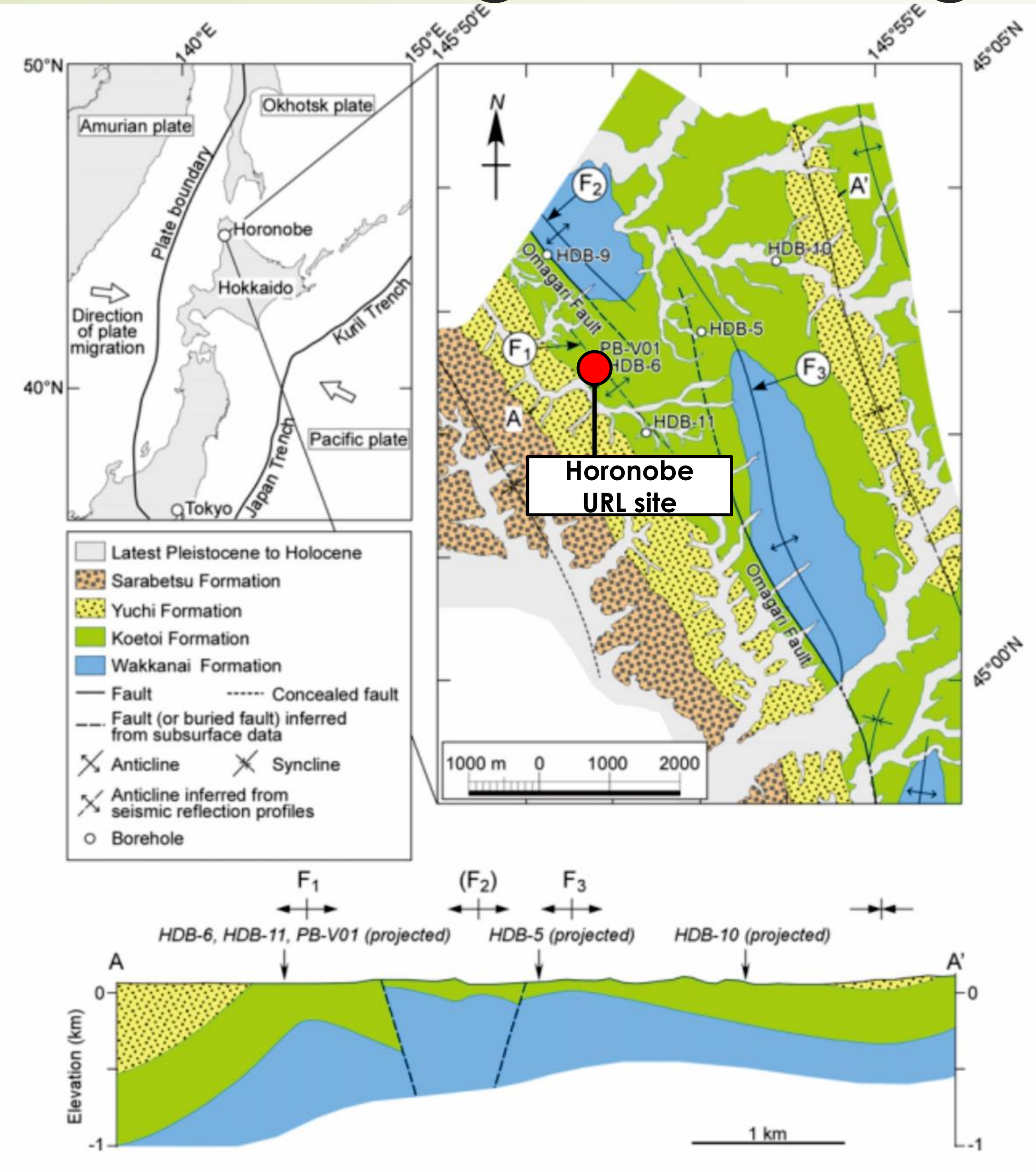
Introduction

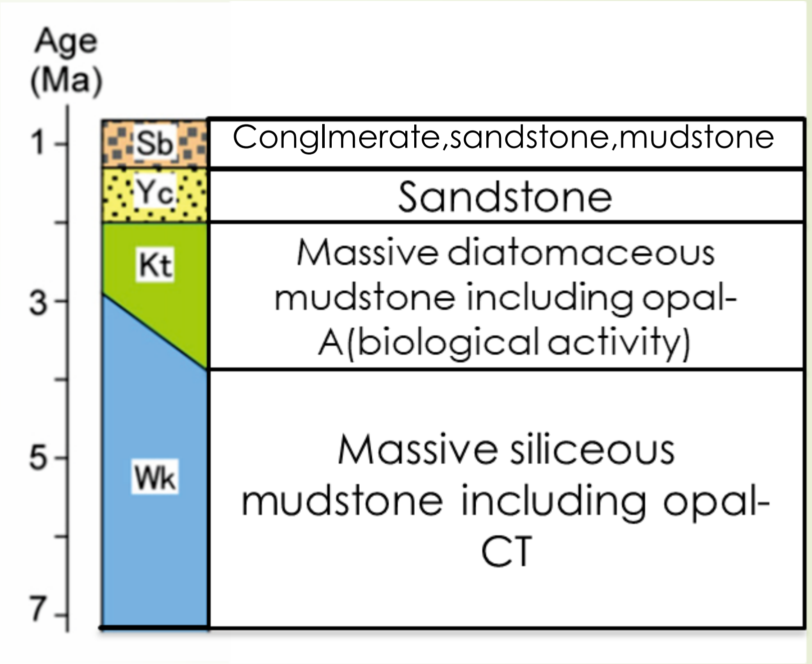
- The low permeability and high sorption capacity
- Deformation behavior in mudstone is crucial for assessing the long-term efficacy of mudstone as a barrier in disposal repositories for radioactive waste
- Ductile deformation is characterized by weakly dilatant or non-dilatant behavior associated with strain hardening
- Brittle deformation is characterized by strongly dilatant behavior associated with strain softening





Geological background

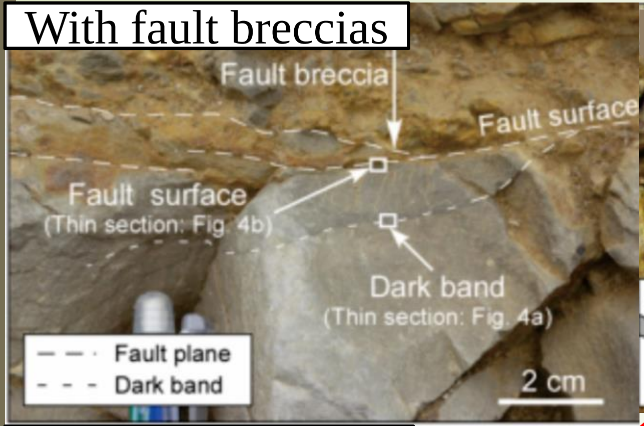


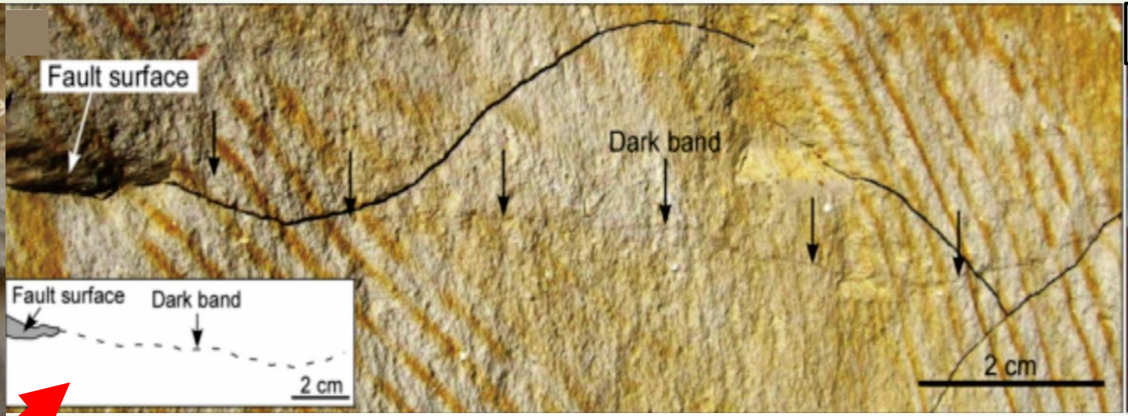


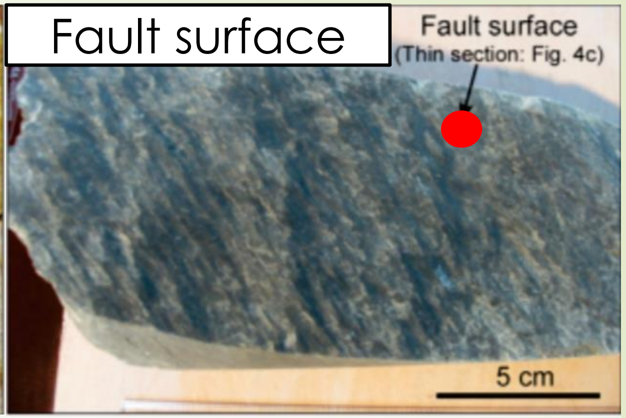
- Some anticline hinge lines developed with NW-SE trends, plunging gently to the northwest or southeast
- Strike-slip faults, bedding-parallel faults, strike-slip faults with fault breccias
- This study focuses on the faults that crosscut bedding planes at a high angle

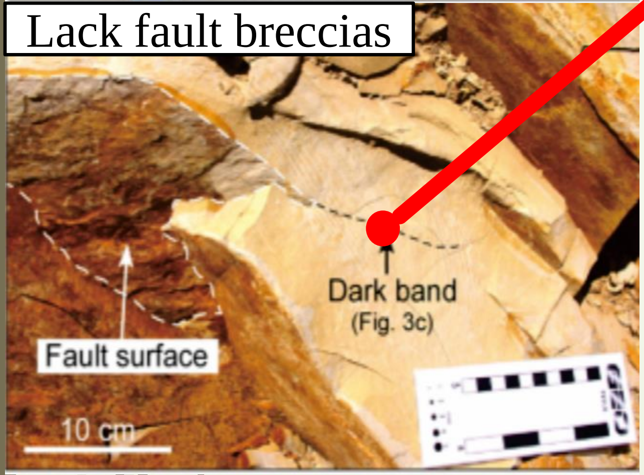
Observation and results

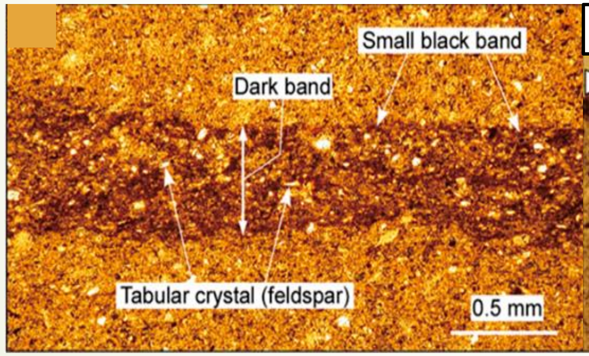
Microstructure in siliceous mudstone

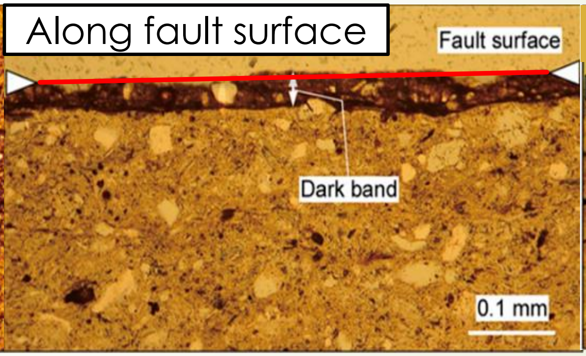


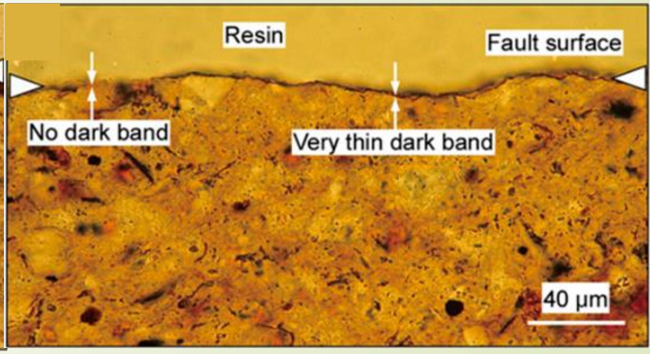












A weak foliation oriented sub-parallel to dark bands in siliceous mudstone is defined by the preferred orientation of tabular crystals

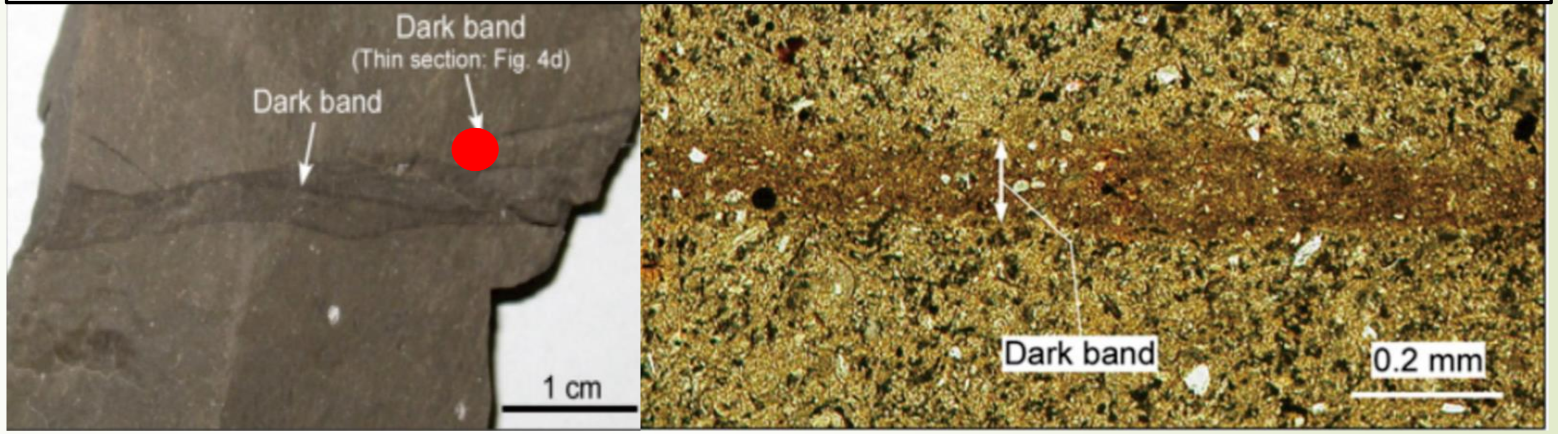
It is not possible to measure band thicknesses, even in thin section

Observation and results

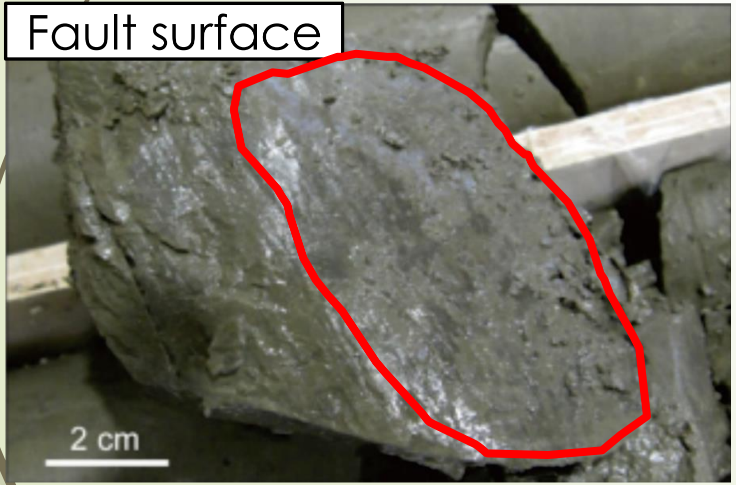
Microstructure in diatomaceous mudstone

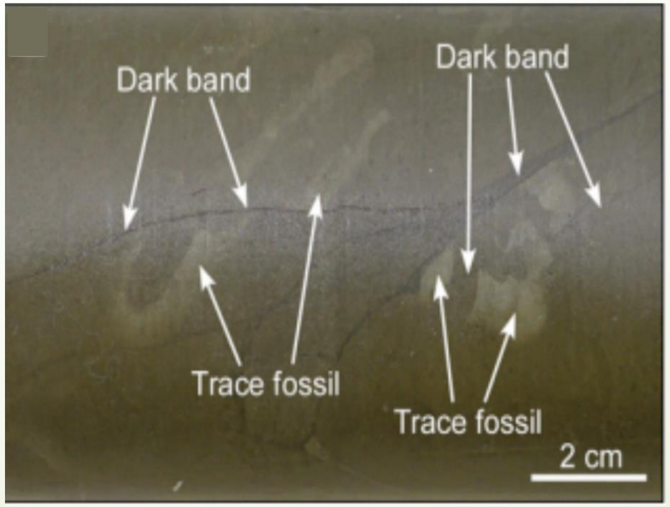
A weak internal foliation occurs sub-parallel to the dark band and is absent in the surrounding matrix. The boundary between the dark band and the matrix is diffuse.

Dark band in diatomaceous mudstone



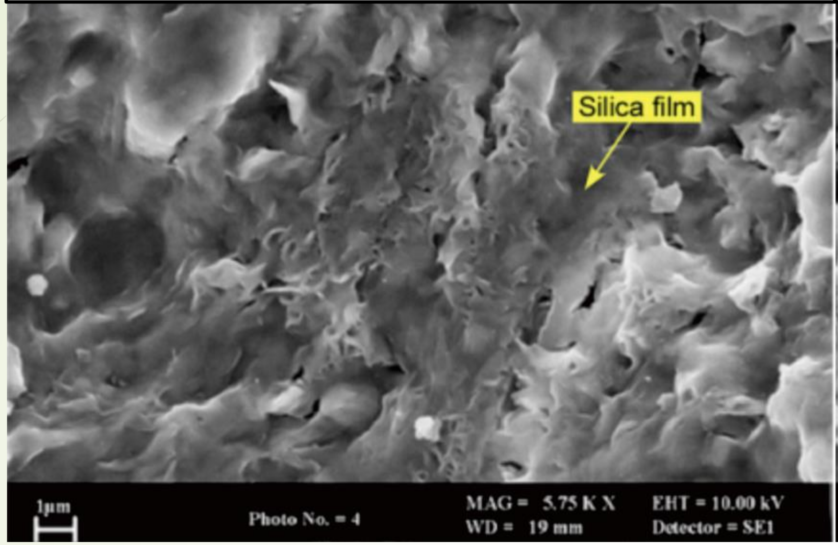
Fault surface



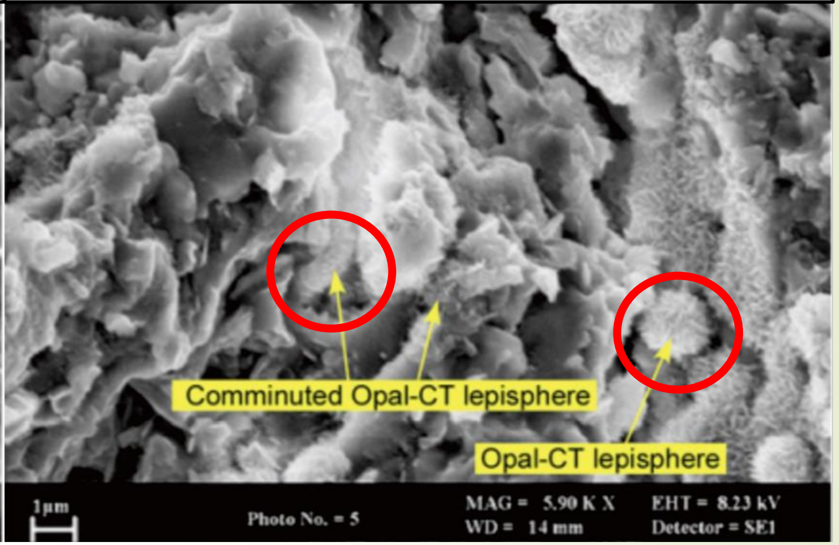


Numerous trace fossils that serve as markers and that record millimeter-scale displacements

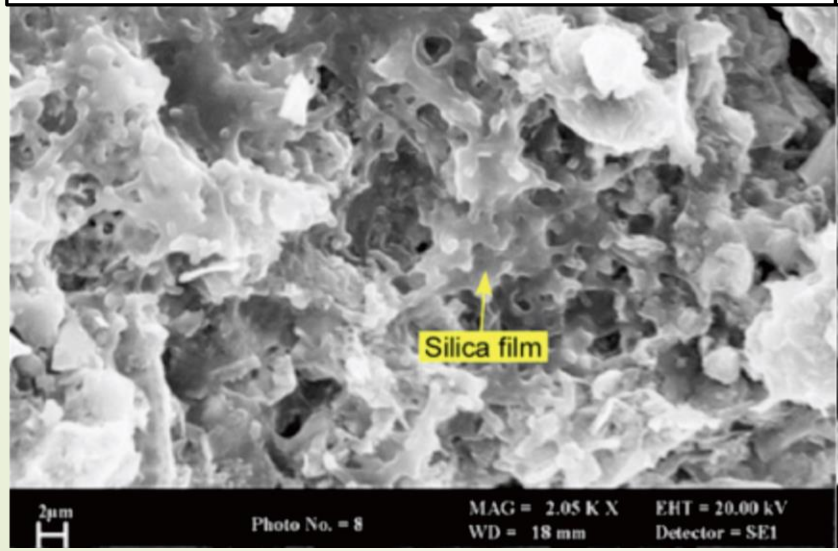
Fault surface in **siliceous mudstone**



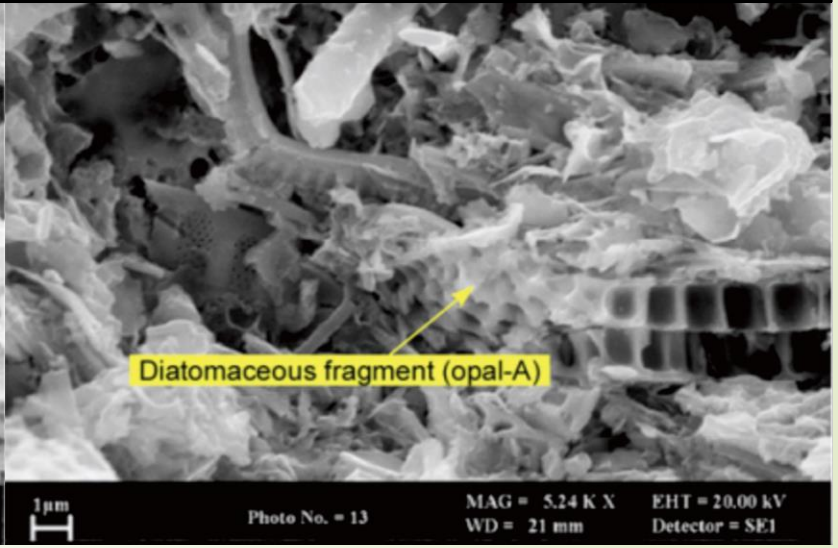
Matrices in **siliceous mudstone**



Fault surface in **diatomaceous mudstone**



Matrices in **diatomaceous mudstone**

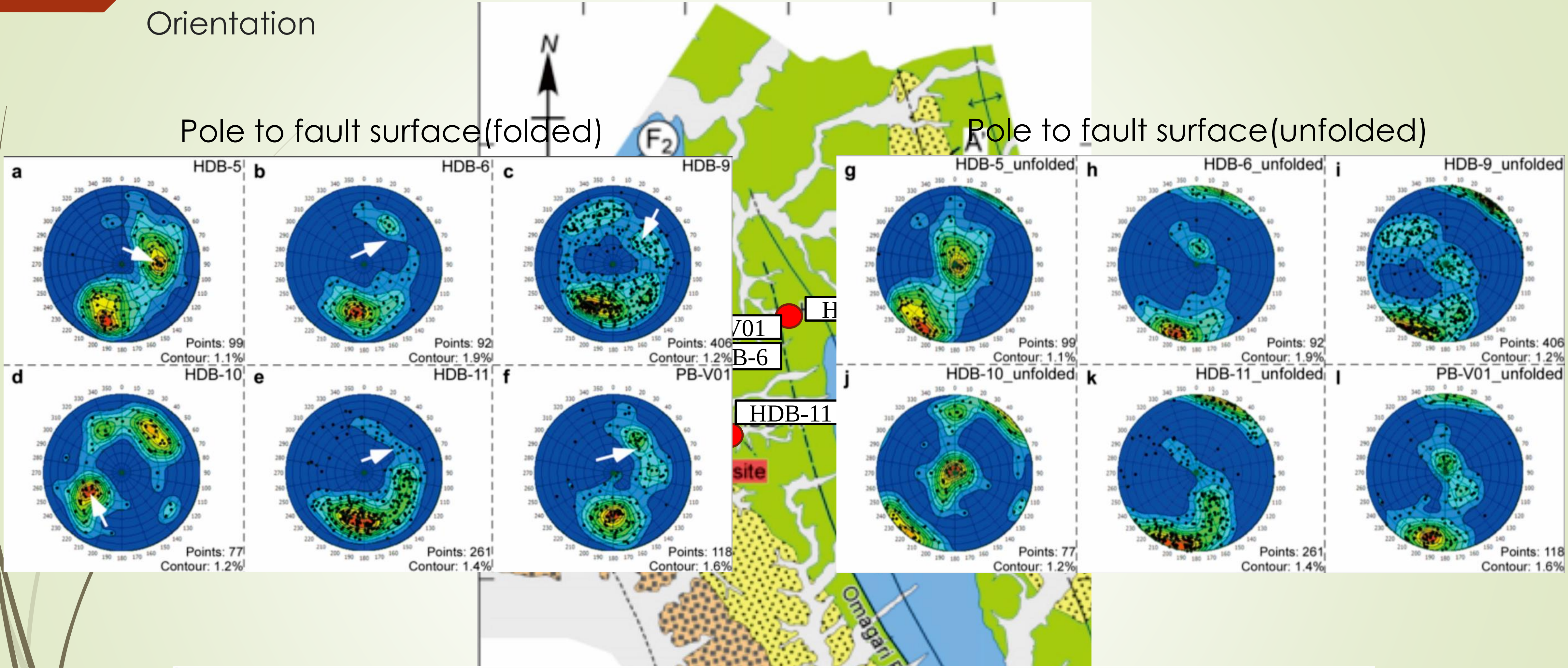


Observation and results

Orientation

Pole to fault surface(folded)

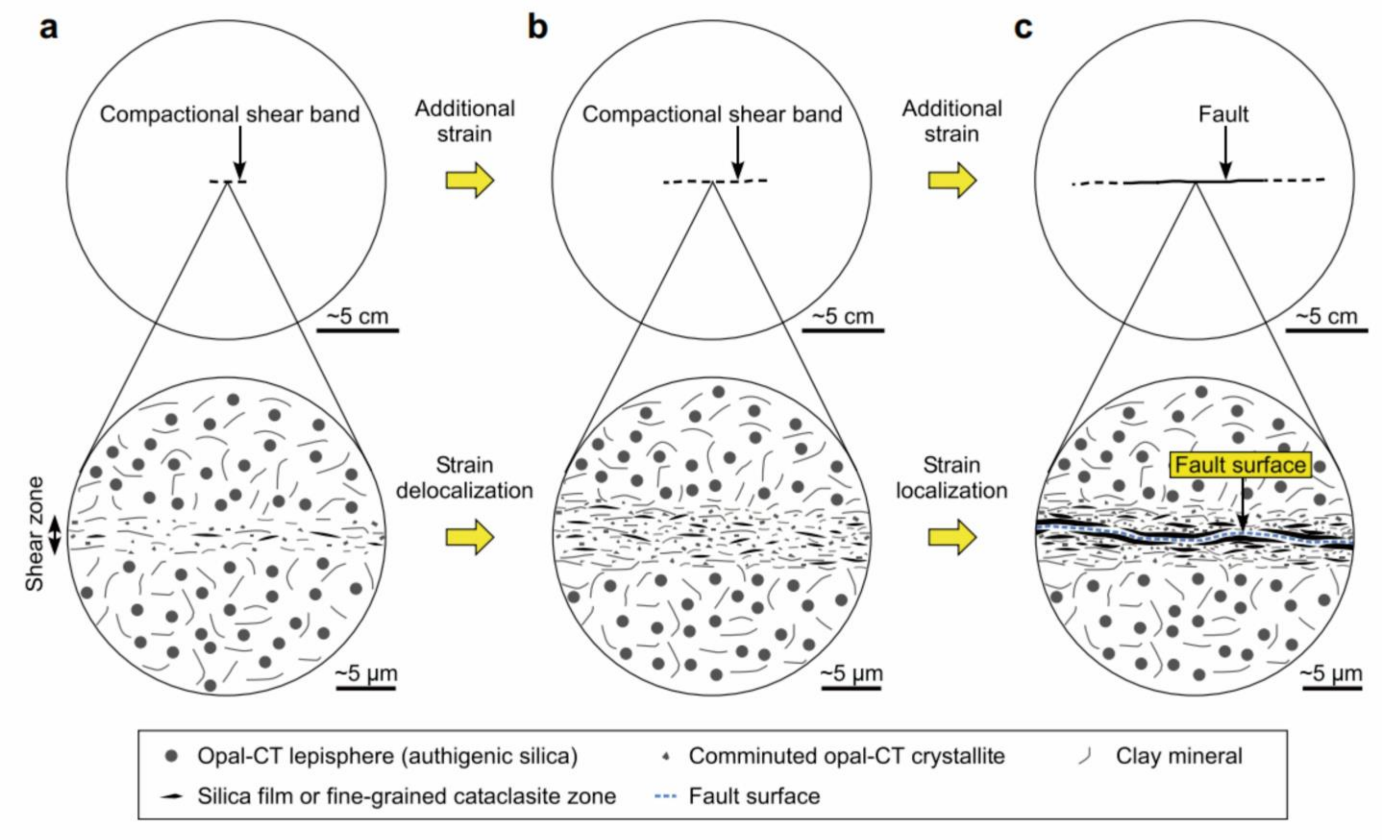
Pole to fault surface(unfolded)



Borehole	Bedding plane	Fault		Fault (unfolded)		Fold hinge used to rotate back to horizontal
		Major orientation	Minor orientation	Major orientation	Minor orientation	
HDB-5	265/35	015/65		29/81		335/13 (F_3)
HDB-6	225/35	010/53		17/83		140/3 (F_1)
HDB-9	230/40	030/50	170/57, 315/55	35/88	138/47, 341/61	140/0 (F_2)
HDB-10	055/40	217/57	160/50	37/85	180/68	335/8 (F_3)
HDB-11	230/40	005/55	280/45	15/86	331/34	140/0 (F_1)
PB-V01	225/35	000/45	269/43	13/73	316/28	140/3 (F_1)

Discussion

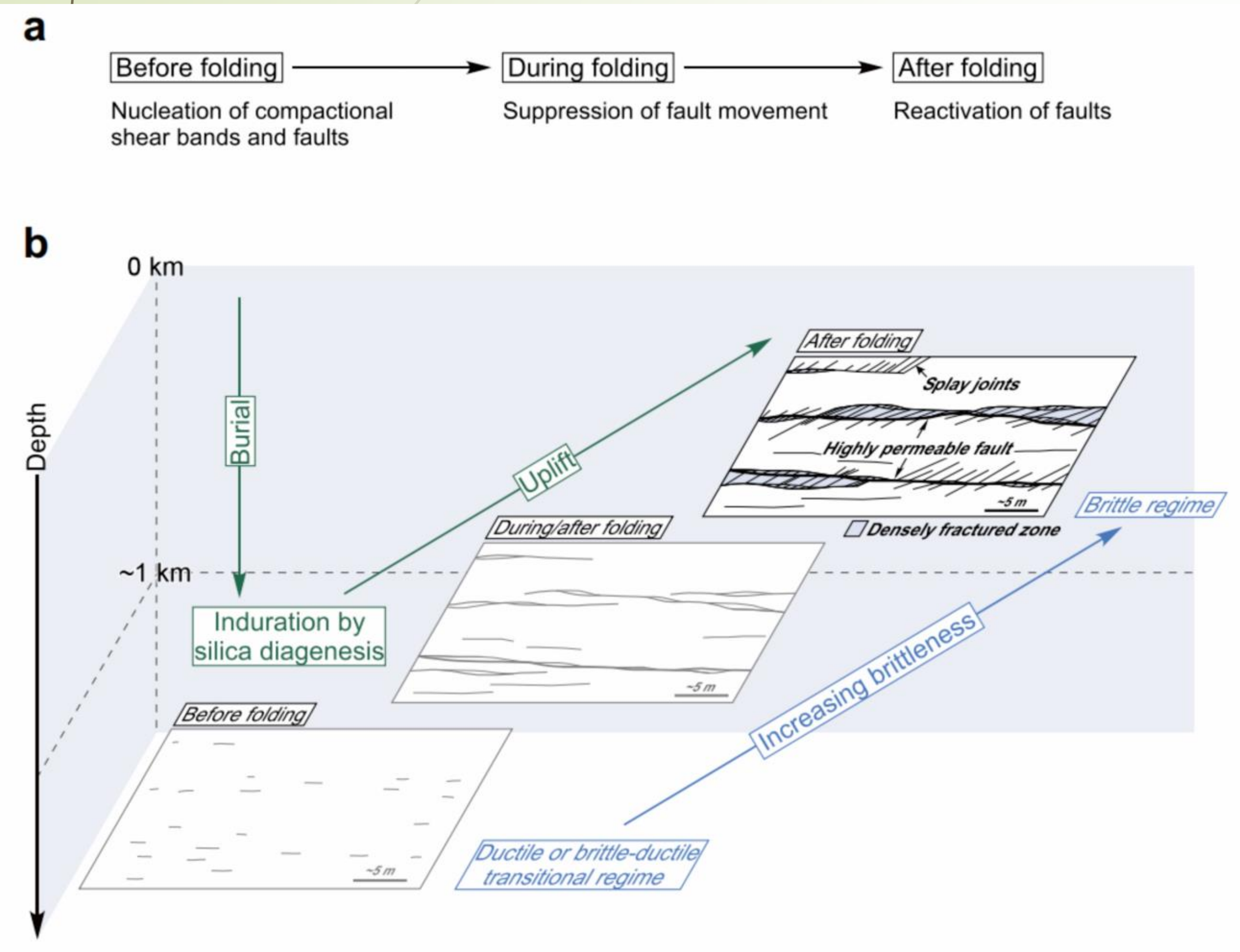
Origin of the faults



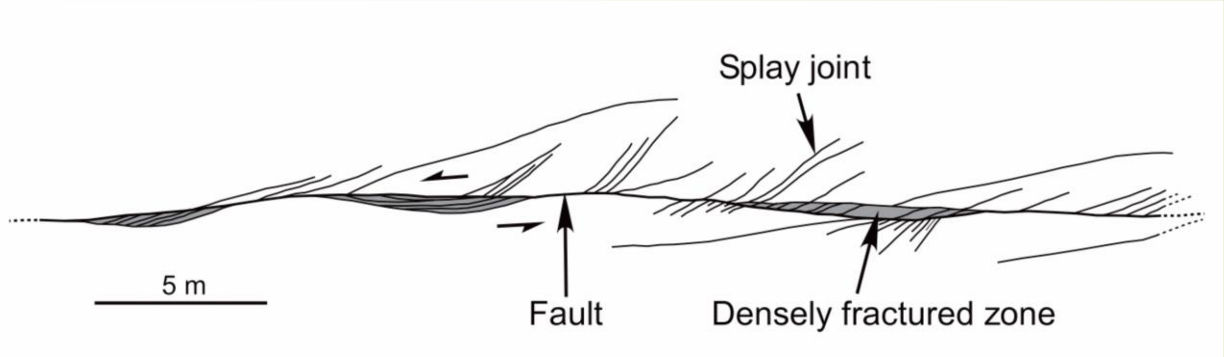
- Observations supporting the interpretation of the dark bands as compactional shear bands
- The dark bands were also observed at and beyond fault tips
- Compactional shear bands formed through strain hardening resulting from initial strain localization
- Additional strain produced weak fabrics
- Fault surfaces nucleated along the developed fabrics
- The faults formed along compactional shear bands

Discussion

Growth history of the faults



- The strike-slip compactional shear bands and faults nucleated just before the initiation of folding
- propagation of the previously formed compactional shear bands may have facilitated linkages between the faults at extensional step-over fault positions
- The faults associated with fault breccias formed after folding
- Fault movement appears to have been suppressed during folding
- Compactional shear band formation slightly preceded fault formation
- The development of numerous secondary splay joints



Conclusion

- Observations suggest that faults formed along compactional shear bands that nucleated in the ductile or brittle-ductile transitional regime
- The formation of compactional shear bands preceded fault formation, just before the initiation of folding, in response to E-W compression due to the eastward migration of the Amurian plate
- This type of information on the origin of faults is fundamental in understanding the relationship between brittleness and the deformation behavior of rock

THANK YOU FOR LISTENING !

Discussion

Relationship between fault origin and burial/uplift history

- In the case of a normally consolidated sedimentary rock that is being progressively buried, ductile deformation generally occurs during shearing
- In the case of an overconsolidated sedimentary rock that may be subjected to uplift and denudation or to induration during mineral diagenesis, brittle deformation typically occurs during shearing
- The faults probably formed at or near the maximum burial depths
- The siliceous mudstone was indurated by burial silica diagenesis
- The overconsolidated state created by silica diagenesis enabled the development of very thin compactional shear bands