Flume Studies with Graded Quartz and Mixtures of Quartz, Kaolinite and Illite - Implications for Silt Laminated Shales in the Rock Record*

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Abstract

Natural muds contain a substantial quantity of detrital quartz in the 62 – 1 micron grain size range. For a better understanding of potential transport and depositional processes, a series of flume experiments were conducted with commercial quartz powders that had maximum grain sizes of 50 microns, 40 microns, 30 microns, and 5 microns. The finer fraction of each sediment batch was removed in an initial experiment step, and the coarse fraction was tested for critical velocity of sedimentation. These quartz powders show critical velocities of sedimentation of 45cm/sec (50 and 40 microns); 40 cm/sec (30 microns), and 20 cm/sec (5 microns). Ripple migration stopped at 20 cm/sec (50 and 40 microns), 25 cm/sec (30 microns), and 10 cm/sec (5 microns). Floccule formation was observed in the finer grain sizes (30–5 microns) and at smaller flow velocities (probably aided by the formation of biofilm in the flume). The coarser size grades (50, 40, 30 microns) form migrating barchan ripples and the finest grade (5 microns) forms migrating transverse ripples once the flow velocity drops below critical. In a separate step the finest grade (5 microns) and the coarsest grade (50 microns) silica was mixed with kaolinite to observe the interplay between silica and kaolinite under uniform low velocity (20cm/sec) flow regime. Initial observation revealed that the finer component of silica (5 microns) would co-mix with kaolinite forming kaolinite rich laminae with fine silt distributed through the clay matrix. The coarsest component of silica however produces silica rich laminae with little contribution from the kaolinite. Because kaolinite forms bedload floccules and floccule ripples at the used velocity setting, the observations indicate that fine silt grains are integrated into clay floccules and form mixed silt-clay laminae after compaction. The coarse silt forms separate ripples that travel through the flume channel at the same time as floccule ripples, and over time a deposit of interlaminated coarse silt and clay (with fine silt) accumulates. This relationship is directly matched by silt laminated shales form the rock record and suggests a comparable origin. Although in a number of ancient shales, the dissemination of fine silt within clay beds has been interpreted as an indication of eolian input, the process observed in our experiments is most likely a better explanation for the majority of cases.

Flume Studies with Graded Quartz and Mixtures of Quartz, Kaolinite and Illite

Implications for Silt Laminated Shales in the Rock Record

Zalmai Yawar & Juergen Schieber

IU Shale Research Consortium

http://www.shale-mudstone-research-schieber.indiana.edu

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Experiments with Fine-Grained Quartz in combination with Kaolinite and Illite

- **Fine grained quartz common in most mudstones**
  - Common as Individual grains
  - mm to sub-mm scale lamina
  - Discontinuous lenses
  - Type of shale lamination provides clues in identifying sedimentary process
- **Mode of transport and Deposition**
  - **A) Fine grained quartz 50, 40, 30 and 5 micron**
  - **B) Fine grained quartz + kaolinite**
  - **C) Fine grained quartz + illite**

Flumes & Specifications

Racetrack design, 11 m long, 3 m wide, Flow Lid at 10 cm

25 cm channel width, 5 cm effective flow depth

Paddle Belt instead of Centrifugal Pump

Floccule Friendly

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Ripple Formation Range for Quartz

Ripple Formation Starts

50 microns – 55 cm/sec
40 microns – 40 cm/sec
30 microns – 40 cm/sec
5 microns – 20 cm/sec

Ripple Migration Stops

50 microns – 15 cm/sec
40 microns – 10 cm/sec
30 microns – 10 cm/sec
5 microns – 10 cm/sec

Fine-Grained Quartz mixed with Kaolinite

Fine grained quartz + kaolinite

Natural muds show wide range of grain sizes
mix of 5 & 50 micron silica

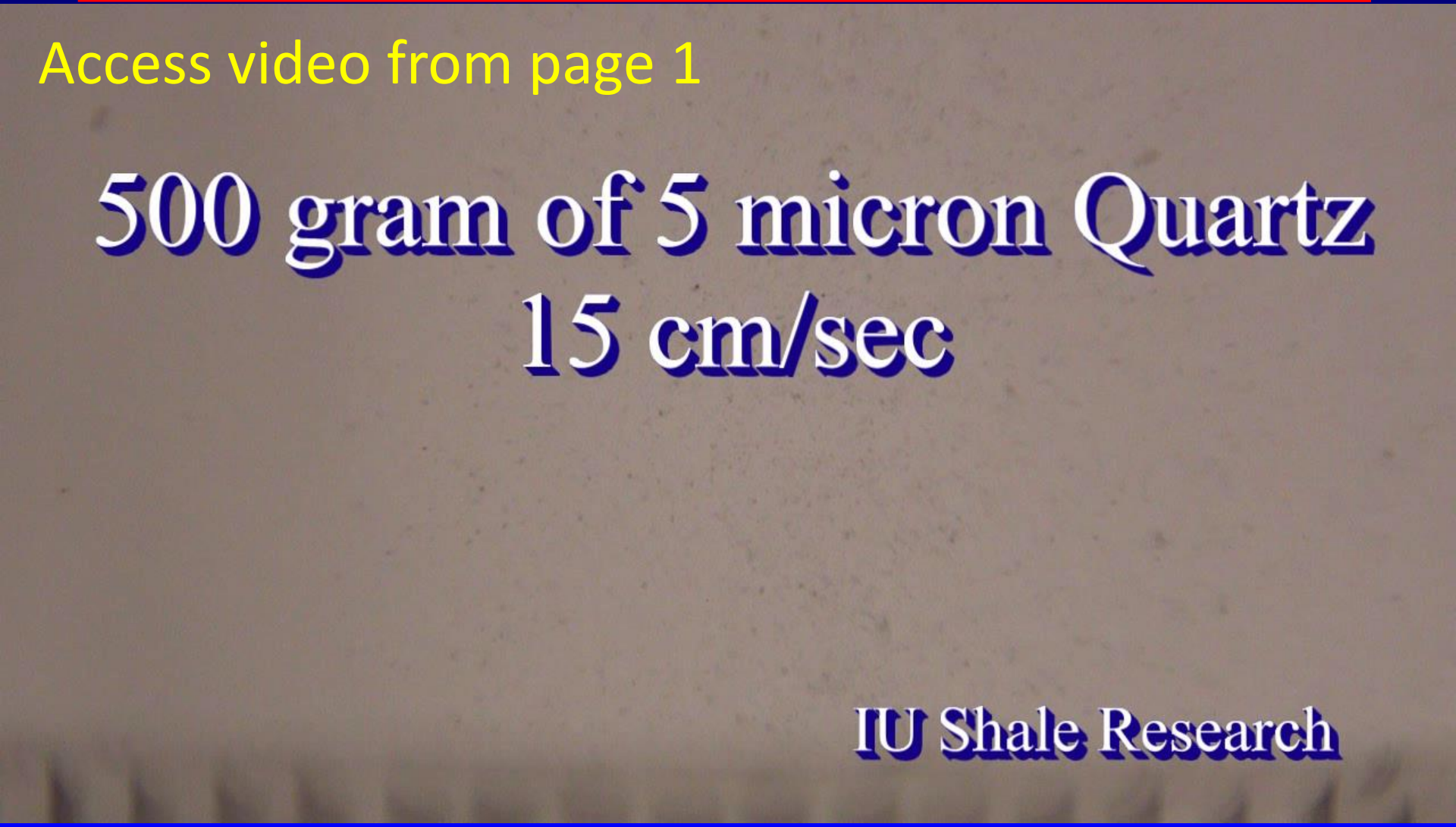
Stages of Experiment:

- 5 micron quartz, 500 gram
- 1000 gram kaolinite
- Hematite dust (marker)
- 50 micron quartz, 500 gram
- 1000 gram kaolinite
- 50 micron quartz, 500 gram
- 1000 gram kaolinite

Total sediment load = 4.5 kg

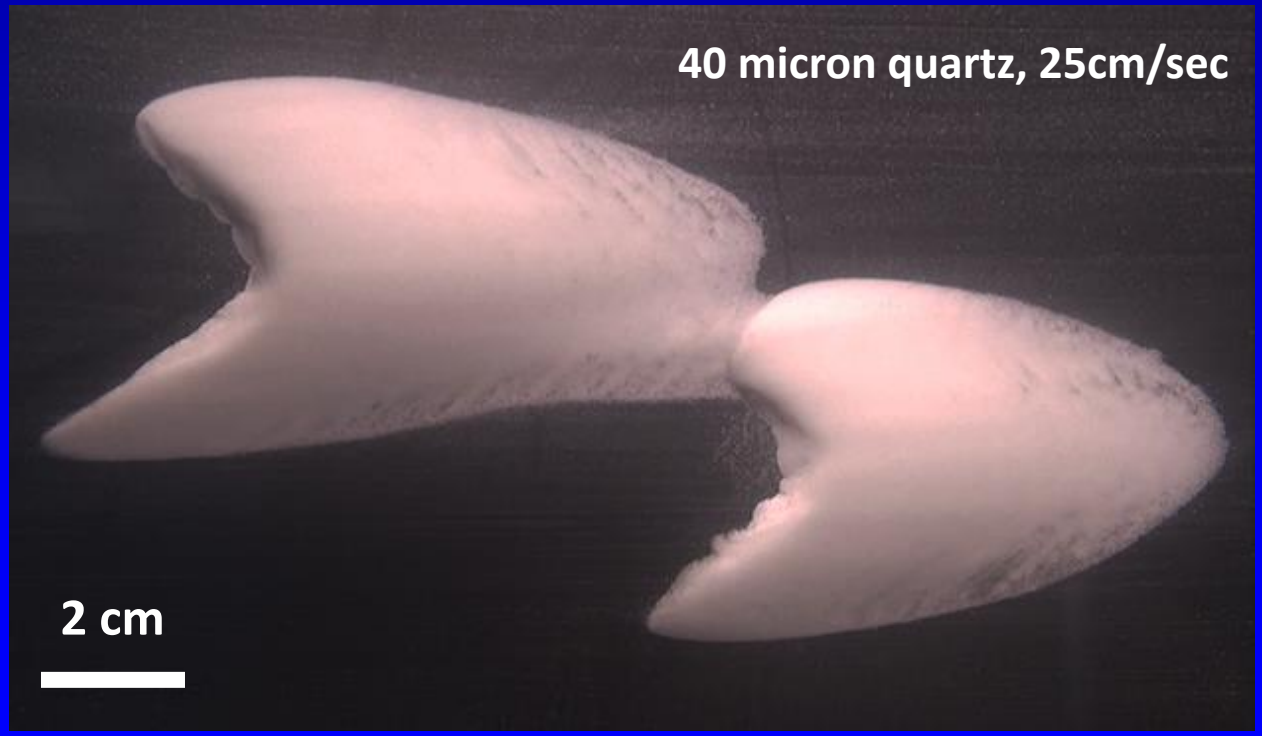
Fine grained Quartz in combination with Kaolinite

Access video from page 1



Surface features document ripple migration

- As ripples move they deposit thin sheets of sediment
- Rib & Furrow structure visible
- Indicates flow direction



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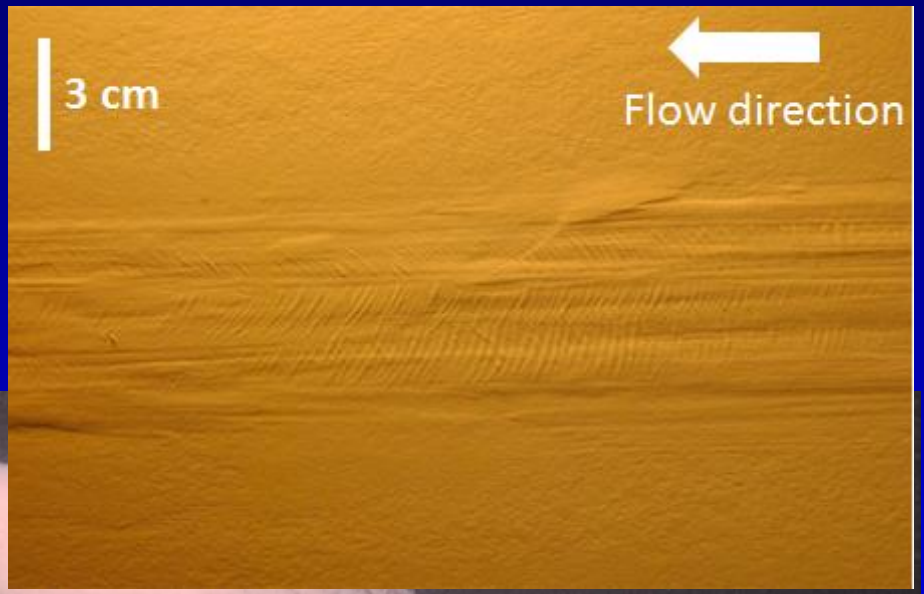

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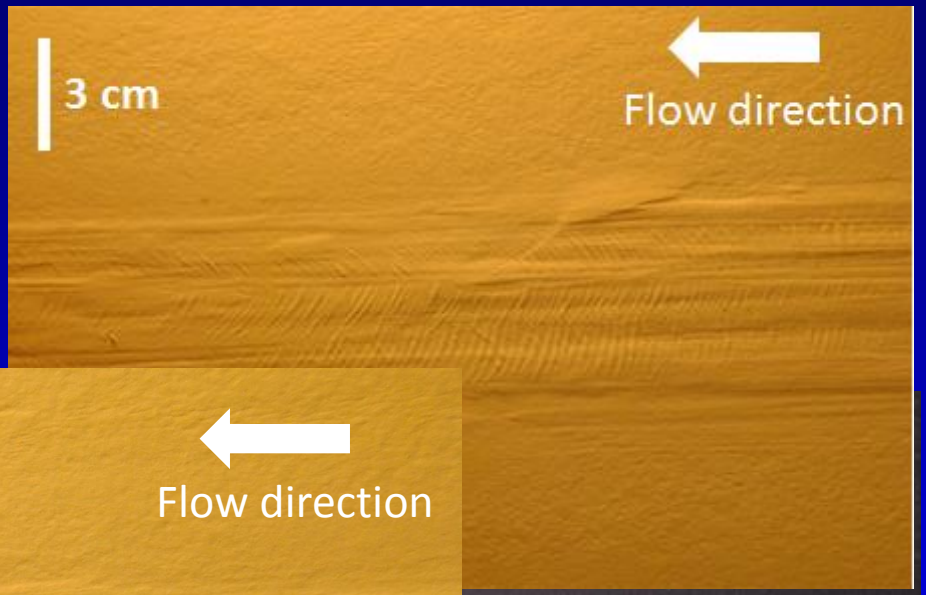
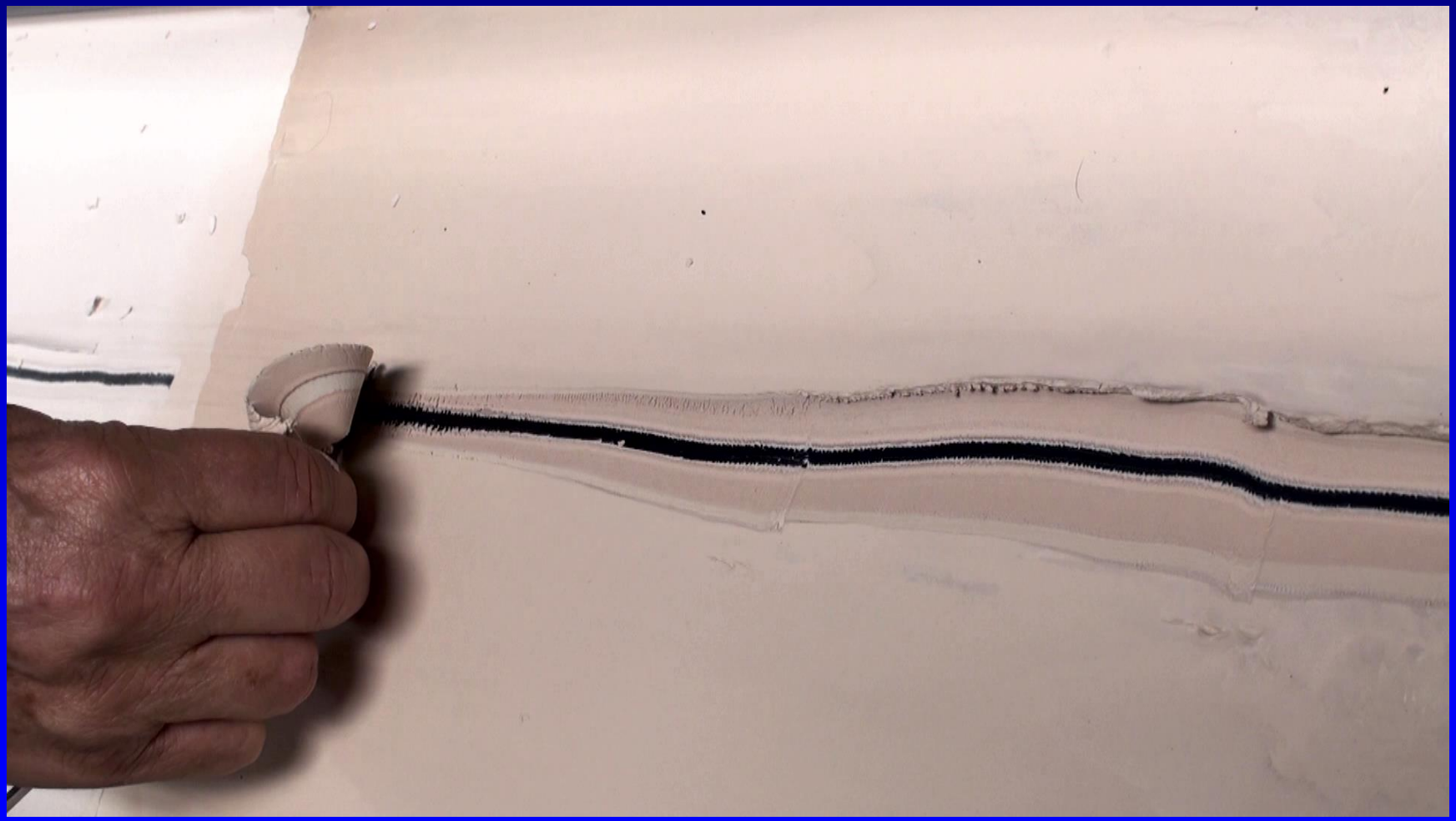


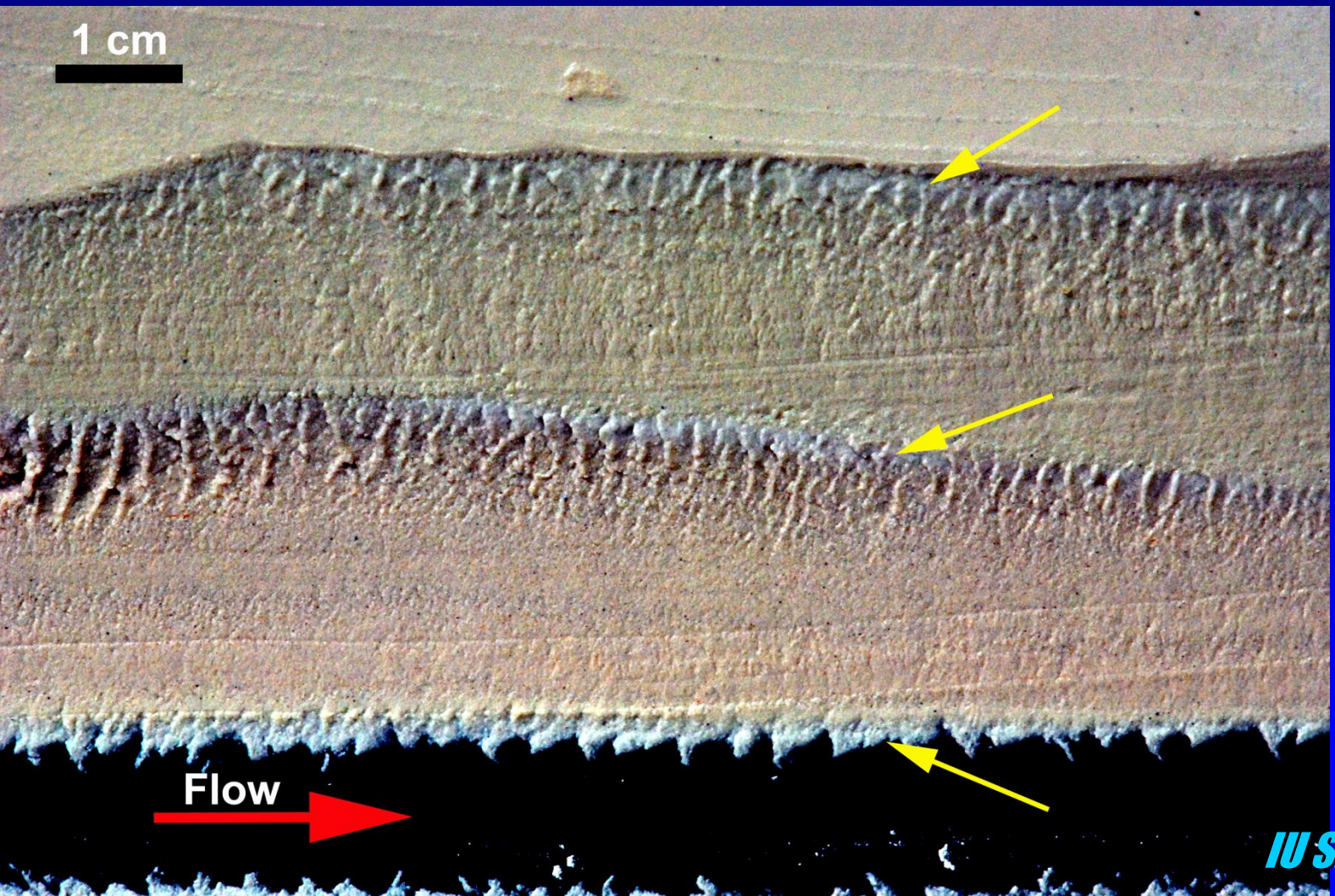
Silica and kaolinite mixture

- Scraping the sediments to expose internal layering
- Samples ion-milled for SEM examination

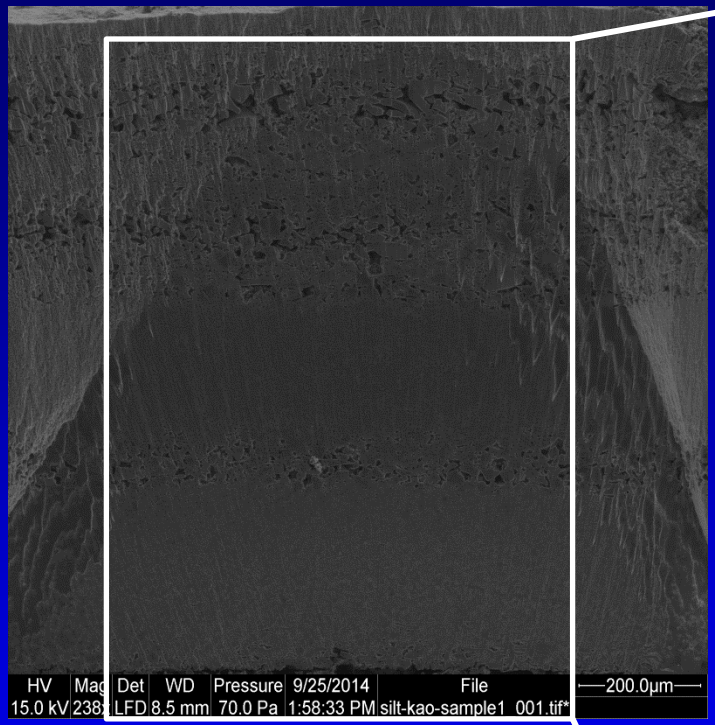


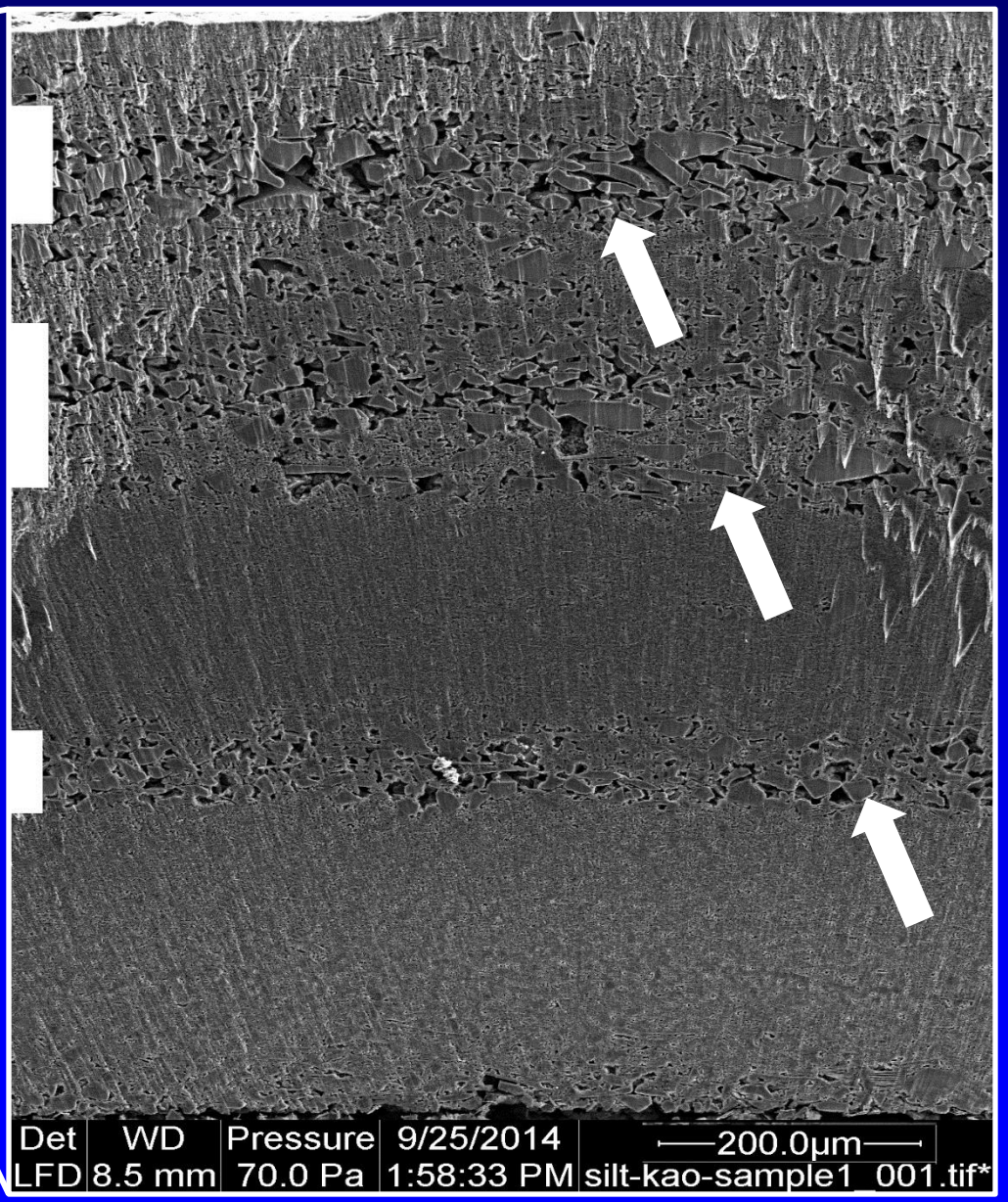
Silica and kaolinite

- Scraped surface shows layering
- Coarse grained quartz silt laminae visible (arrows)
- Brownish color of lower bed due to hematite dust



Internal Structure of Dried Sediments

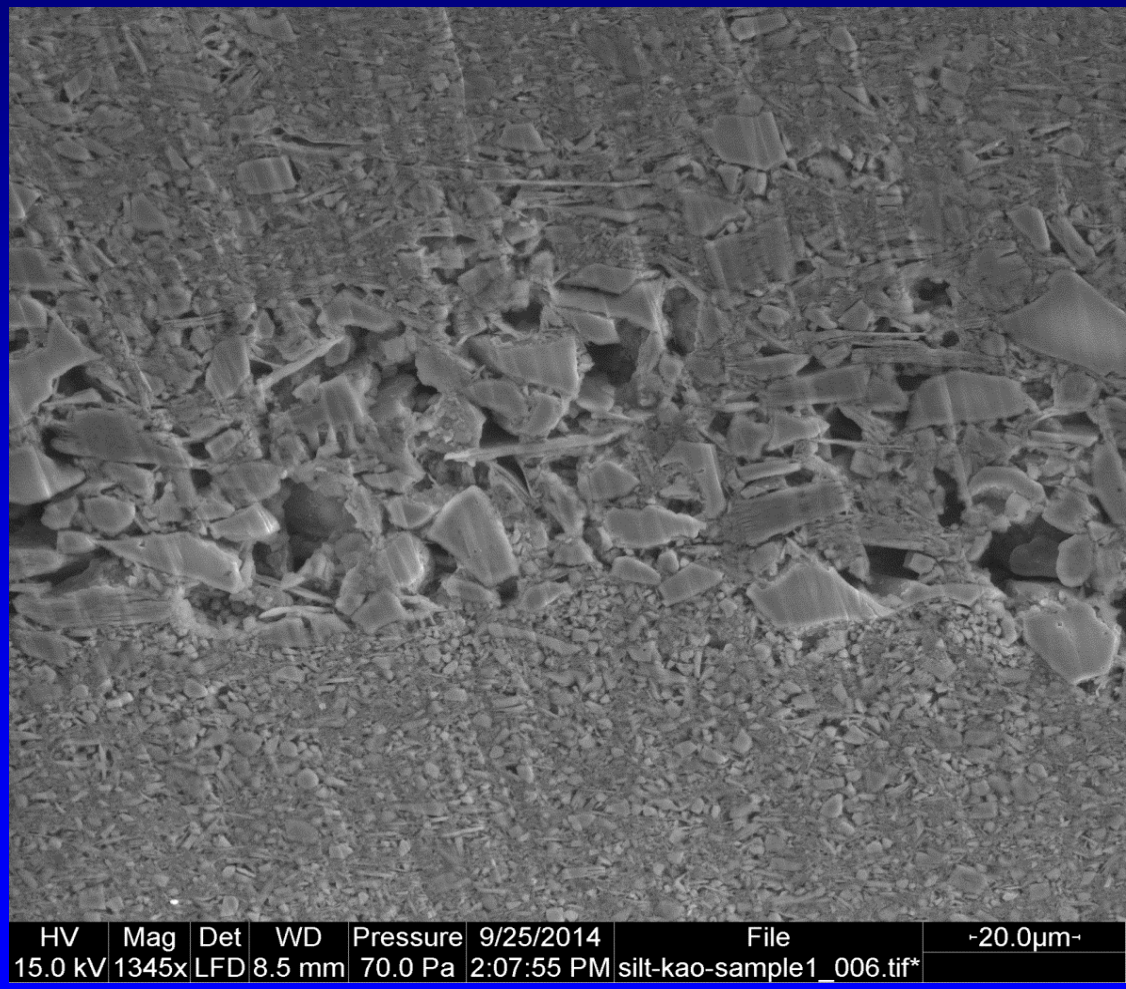




- Ion Milled X-sections
- Flow Velocity Constant
- Coarse Silt Ripples travel at the same time as Floccule Ripples
- Ripples leave behind veneer of Coarse Silt or Clay Floccules
- Coarse Silt Lamina marked by (arrows)

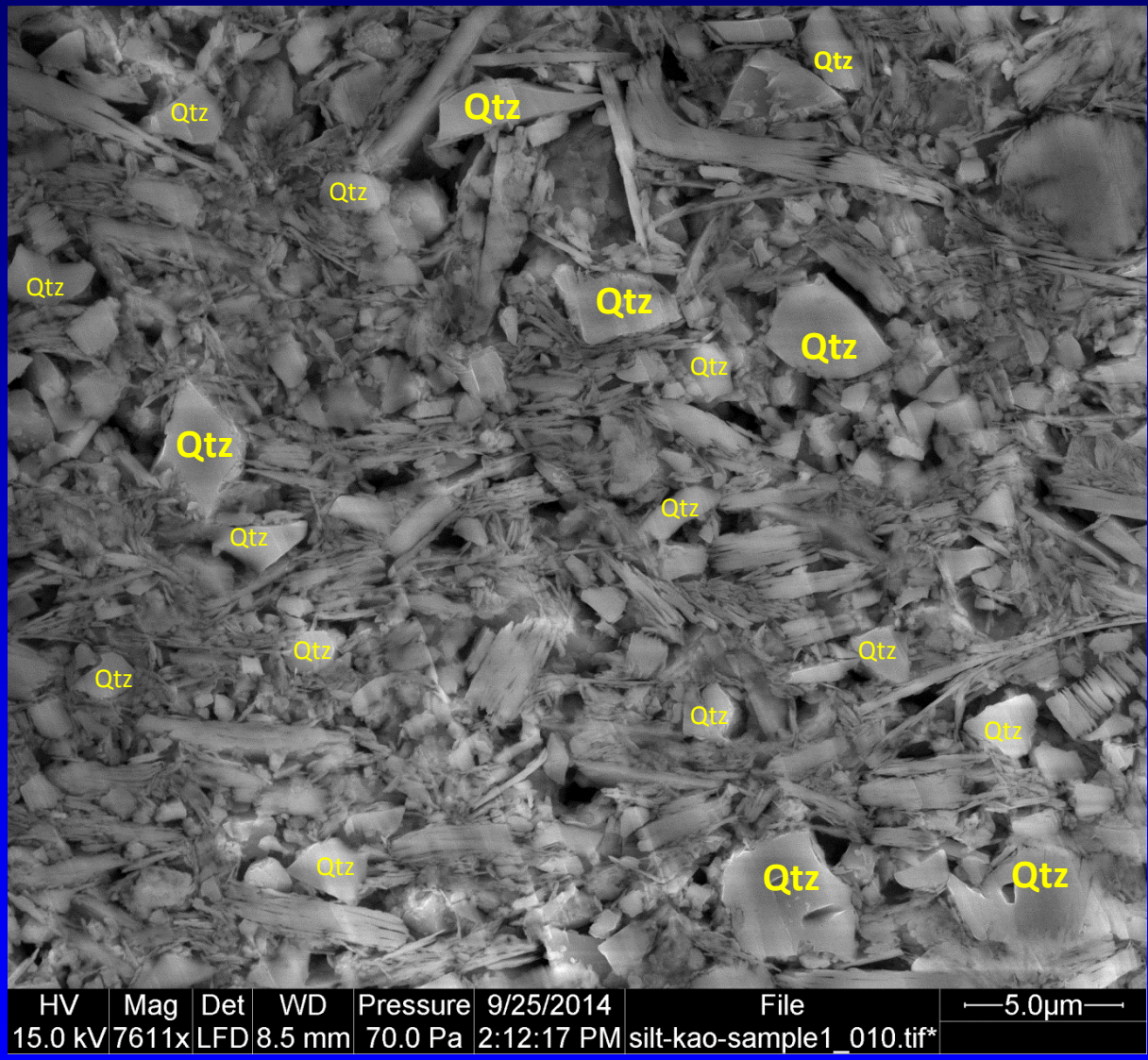
Internal Structure of Dried Sediments

- Clay Floccules can NOT incorporate Coarse Silt
- Only Fine Silt integration possible
- Produces Segregation and simultaneous movement of Coarse Silt and Floccule Ripples
- **Result: Laminated Mud with Coarse Silt Laminae**



Fine Quartz and Kaolinite

- Fine quartz randomly mixed with kaolinite
- Kaolinite deposited as floccules
- Fine quartz incorporated in floccules



Dried sediment

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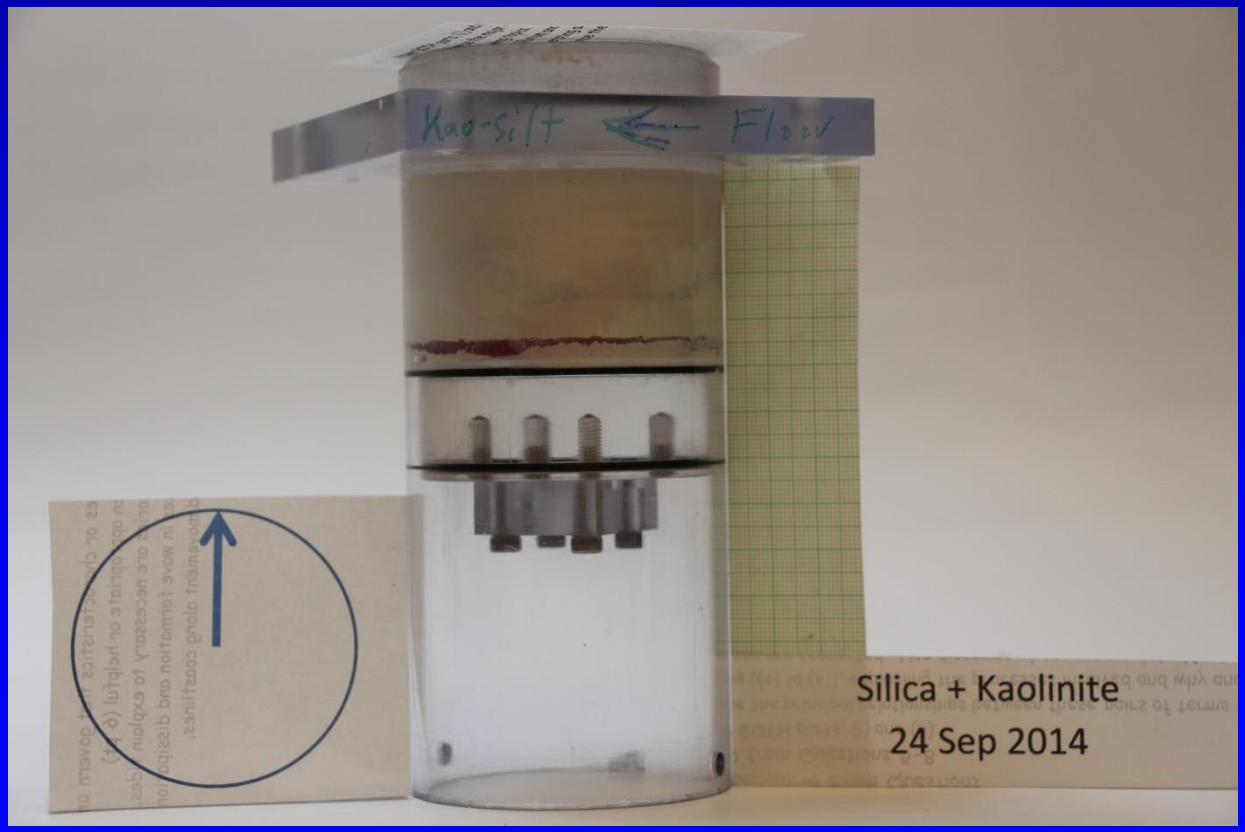
Sediment Fabrics in Uncompacted Samples

- Sediments collected with piston sampler
- Shows coarse silt and clay interlamination
- Embedded with Spurr Resin (wet-uncompacted)



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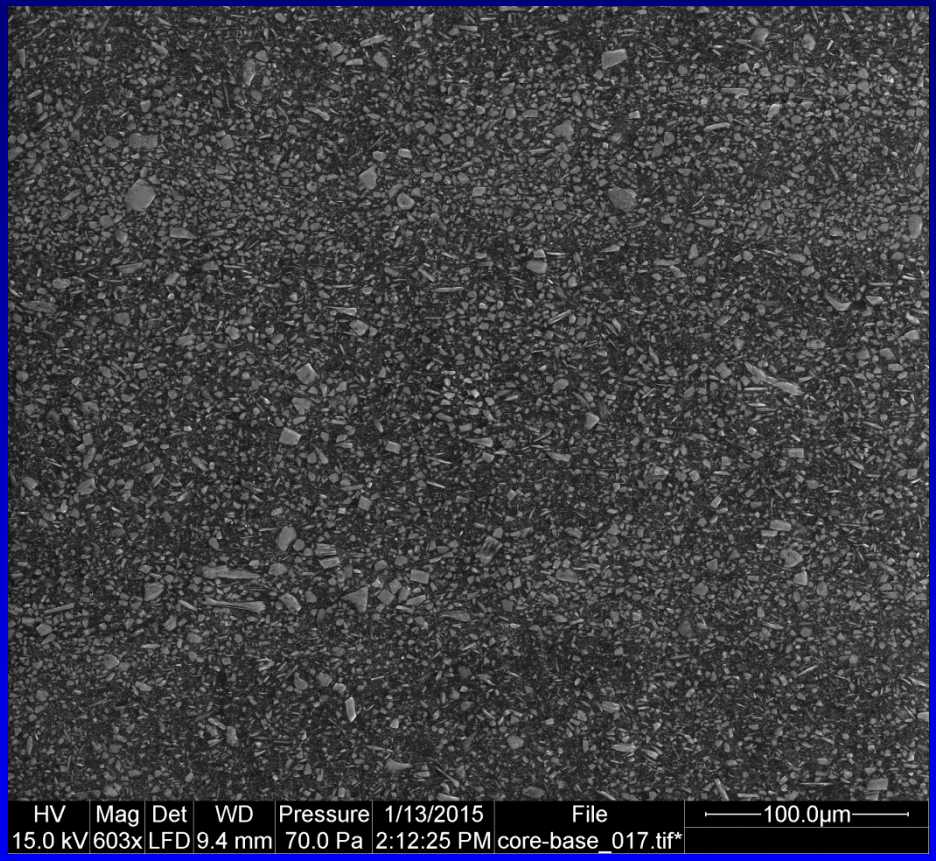
Fine Quartz & Kaolinite – Spurr Embedded

- Kaolinite and Fine Quartz (5 micron)
- Flocculated Clay Fabric (cardhouse)
- Randomly scattered quartz
- Field of View approximately 1/10 of floccule width



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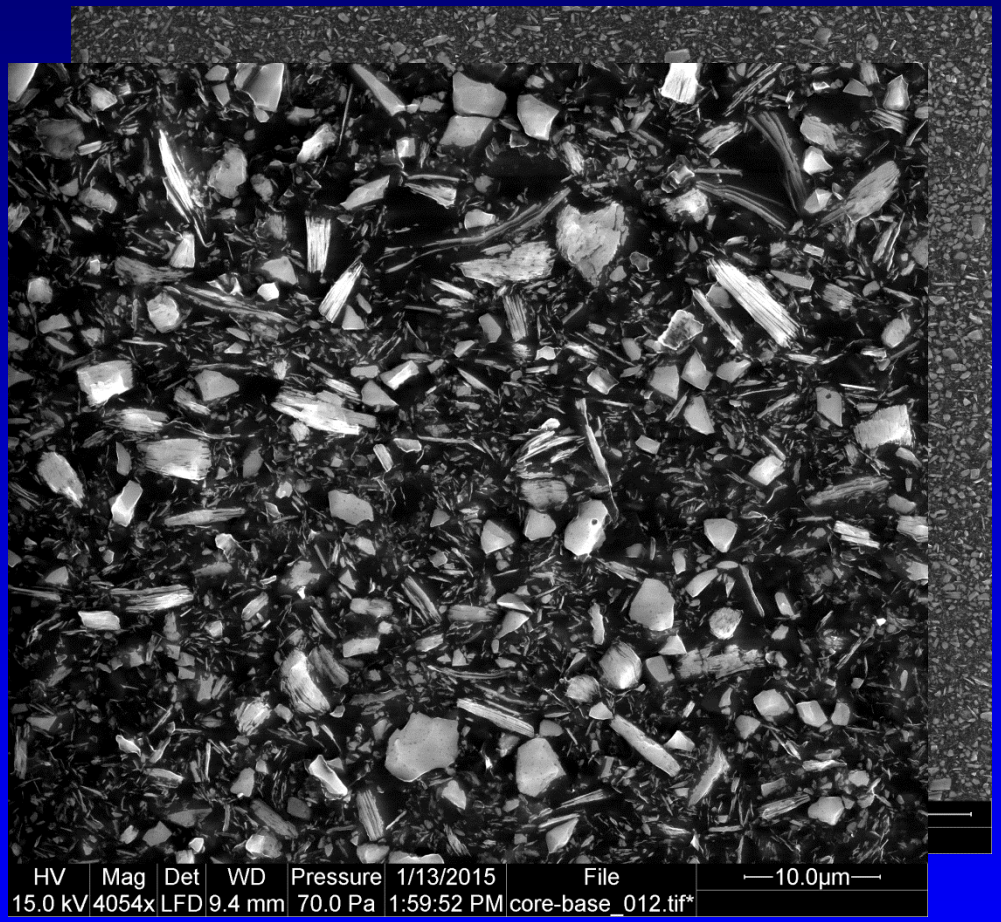

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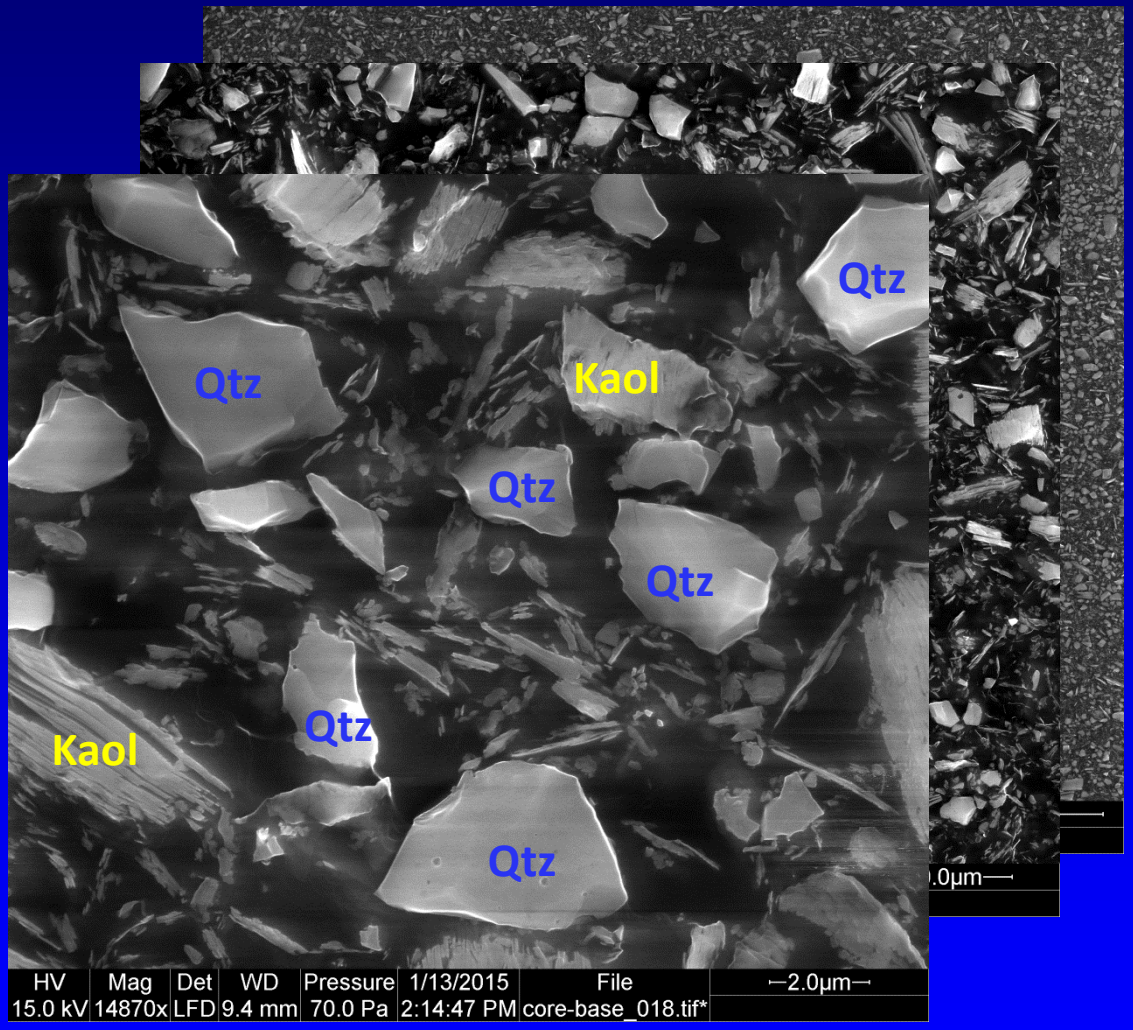


Fine-Grained Quartz mixed with Illite

Fine grained quartz + illite

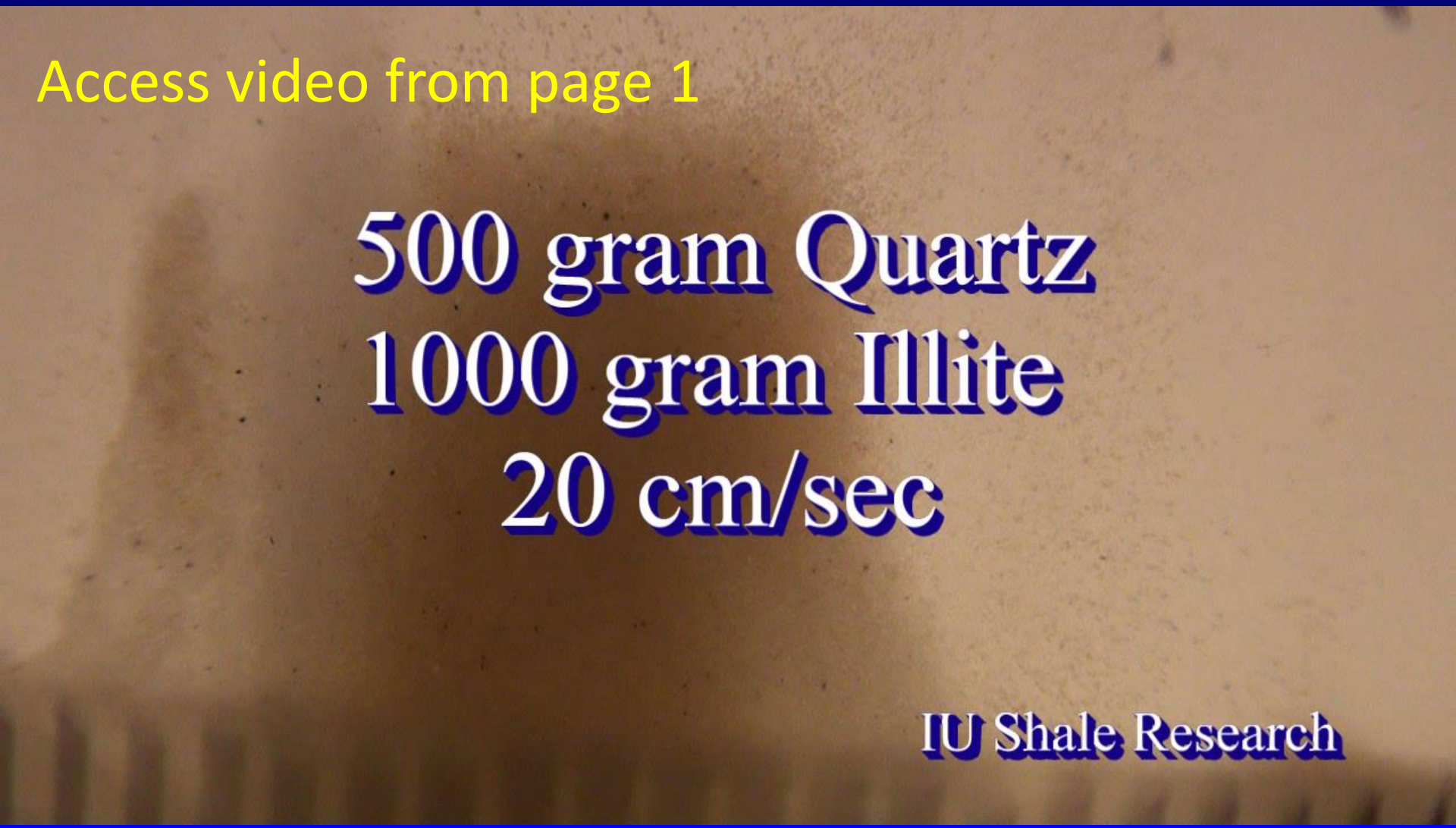
Stages of Experiment :

- 50 micron quartz, 500 gram and 1000 gram illite
- Hematite dust (marker)
- 50 micron quartz, 500 gram
- 1000 gram illite
- Salt added, 1% salinity
- 50 micron quartz, 500 gram
- 1000 gram illite

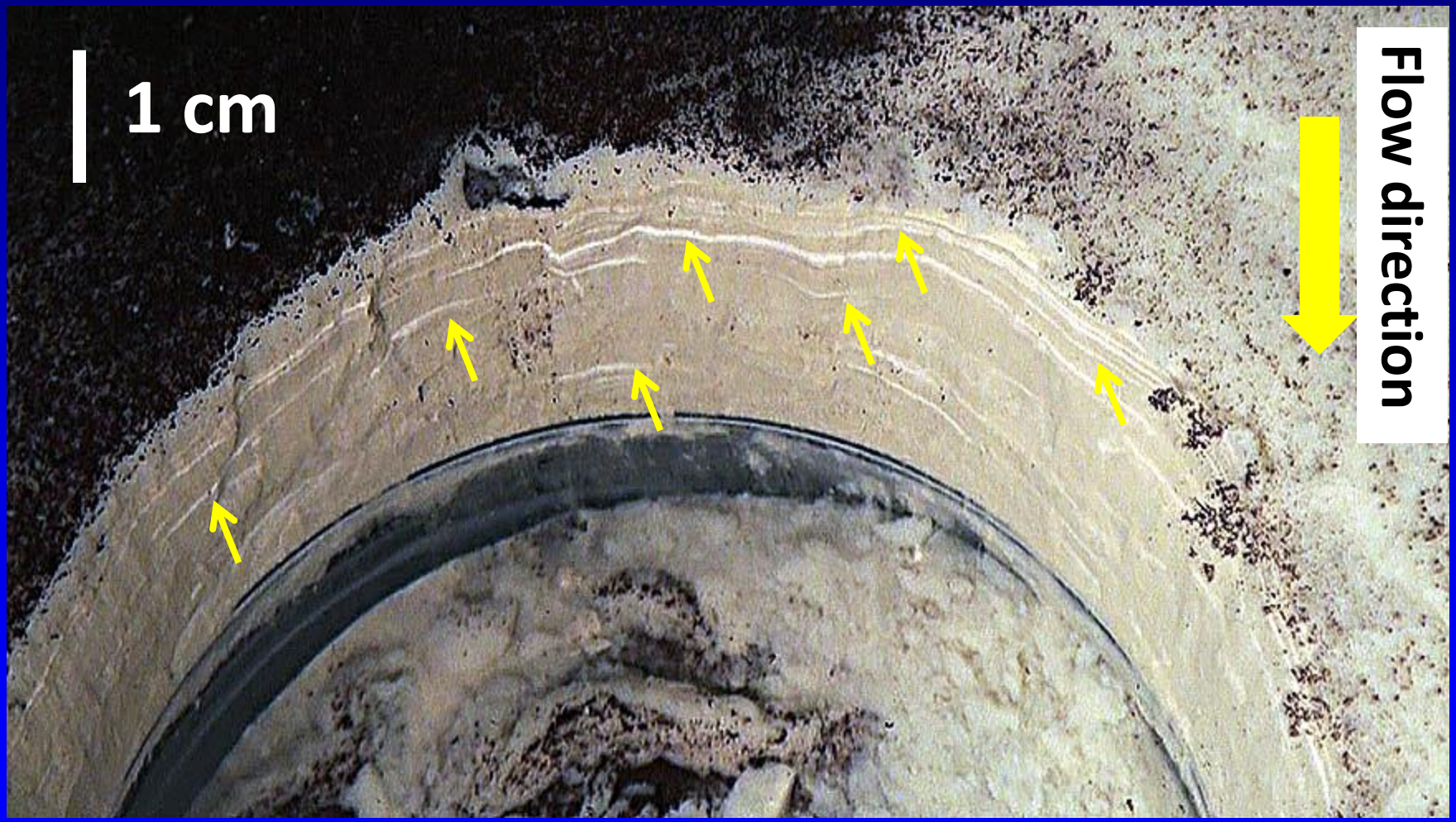
Total sediment load = 4.5 kg

Fine-Grained Quartz mixed with Illite

Access video from page 1



Continuous and discontinuous laminae of Coarse Silt

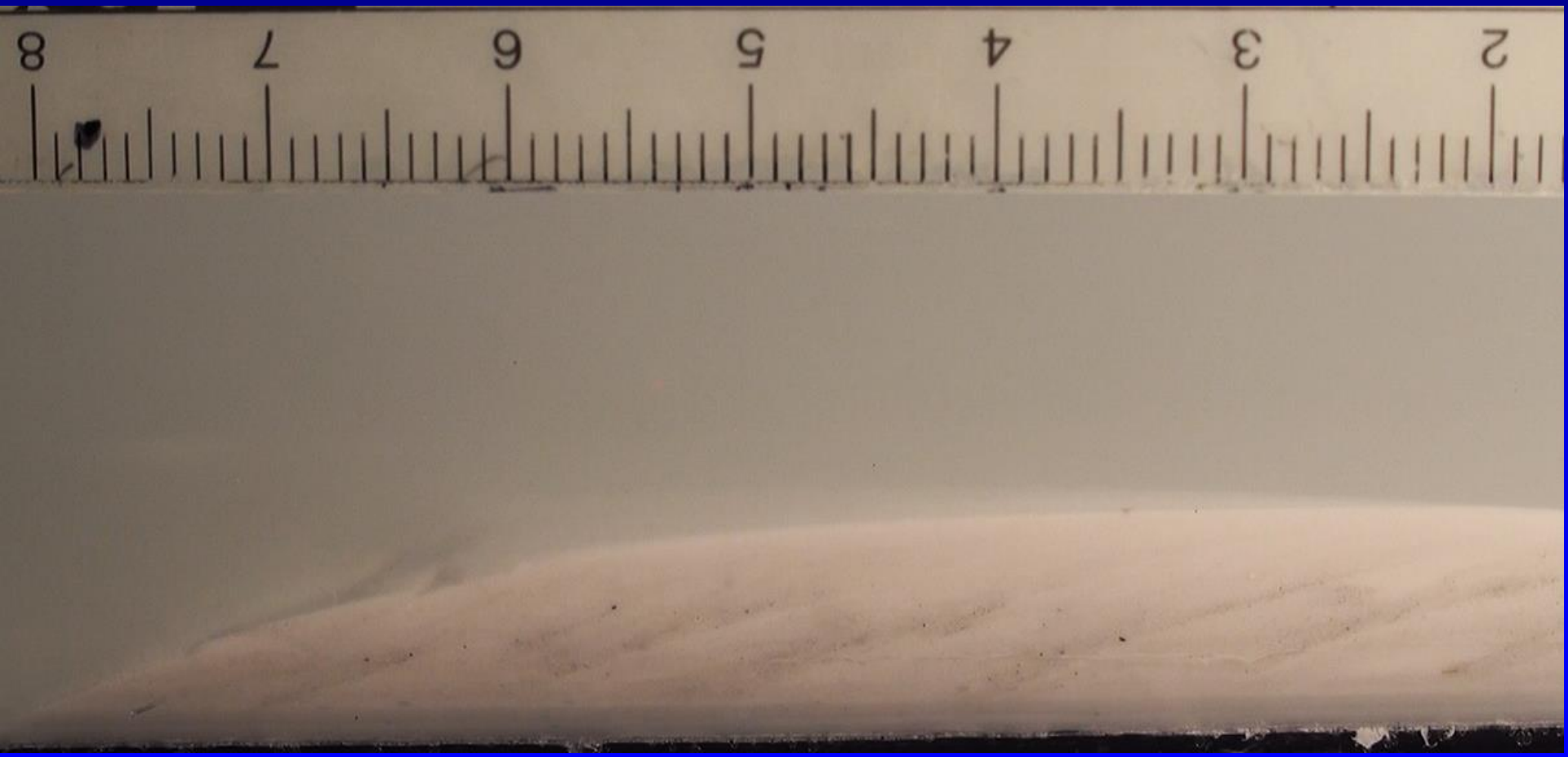


Sediment Buildup

- Sediment builds up by passage of Ripples that consist either of coarse quartz silt or floccules (illite + fine quartz silt)
- In plan view, preserved forset toes, result in rib and furrow structure

Ripple Movement

- Ripples are comparable in size and geometry to sand ripples
- Internal cross laminae



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Quartz - Illite Mixture

- Scraped sediments
- Desiccation causes splitting of layers along coarse silt laminae (no cohesion)

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Ripple Characteristics

- Higher sediment input causes
- Climbing ripples
- Ripple buried by successive layers

Coarse Silt and Clay rich beds may have accumulated under similar flow conditions
On-Off NOT needed

Illite Floccule Ripples vs Coarse Quartz Silt Ripples

- IlliteFloccule ripples have high water content (80-85 vol %)
  When dehydrated they flatten out and are barely visible
- Coarse Quartz Silt ripples have lower water content, compact less, and in rock record would look lenticular

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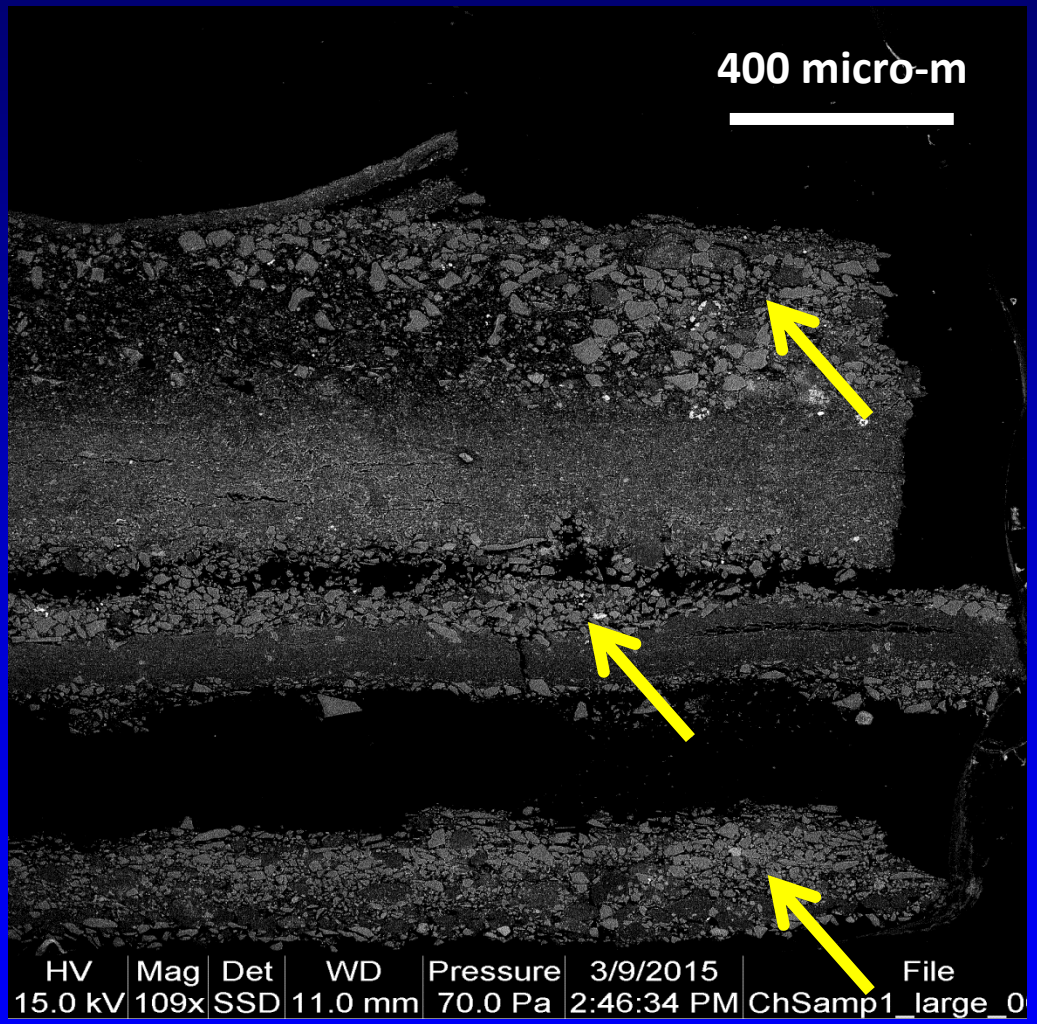
Quartz-Illite Mixture

- Concentration of coarse qtz silt in laminae
- Fine qtz silt mixed in with illite



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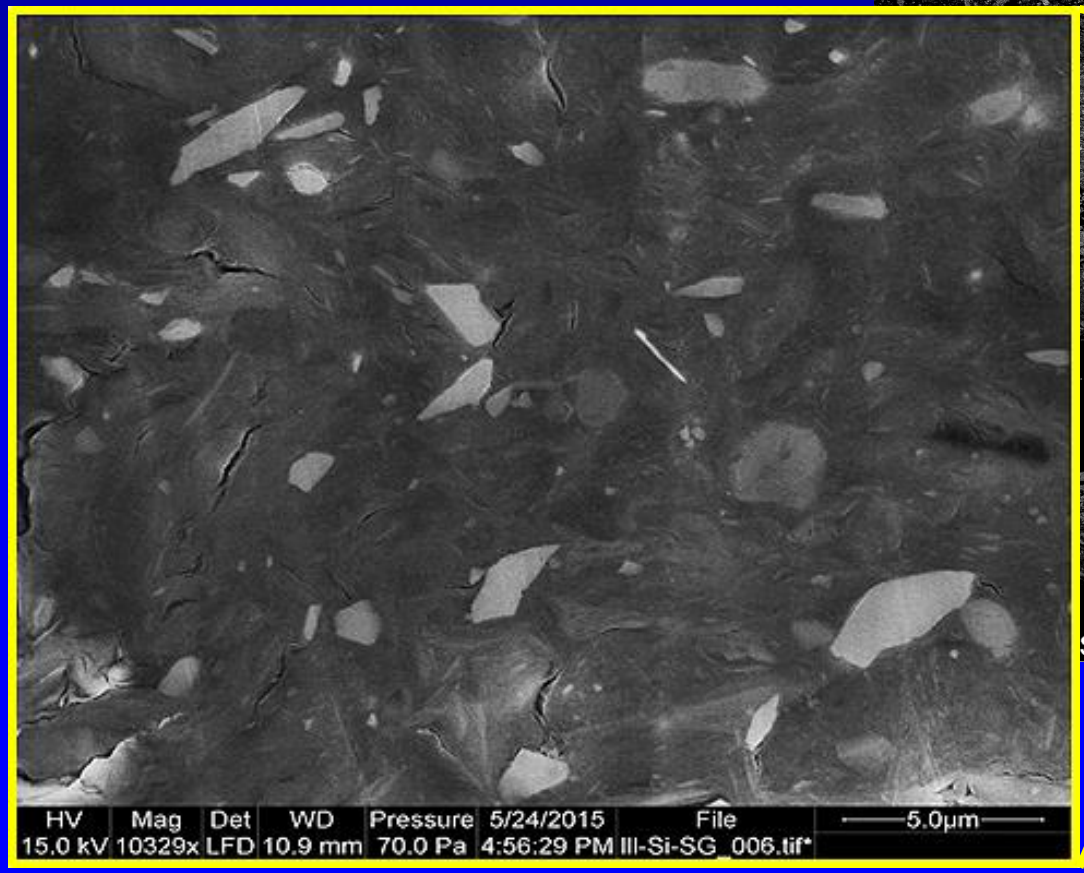

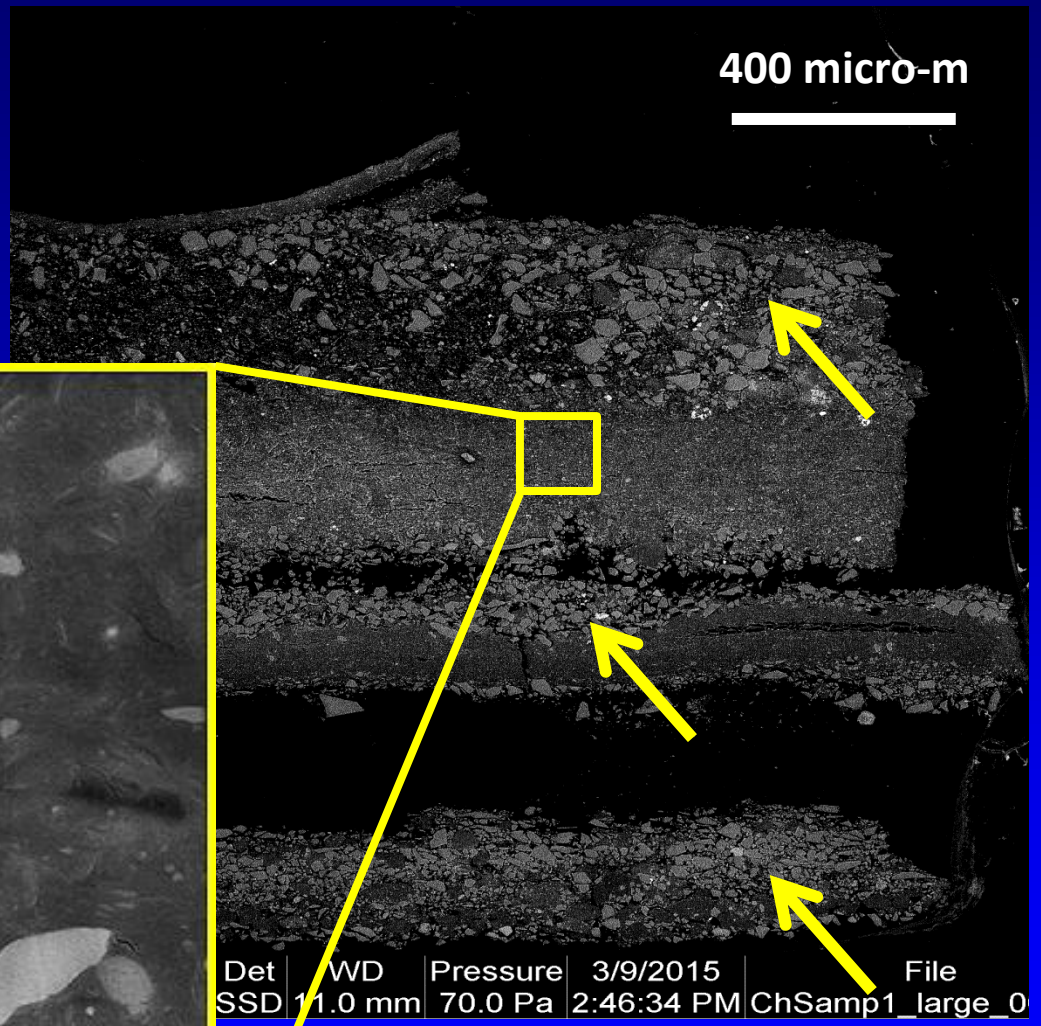

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Conclusions

- During bedload transport, coarse silt (25-63 µm) is segregated (as ripples) from flocculated clays
- Clay floccules form separate floccule ripples
- These incorporate fine silt (<20 µm) and travel over the bed together with coarse silt ripples
- Coarse Silt ripples deposit thin silty beds
- Floccule ripples deposit thin sheets of clay
- Over time, ripple migration produces interlaminated silt-rich and clay-rich layers and builds up a bed of laminated mud
- Disseminated fine quartz silt in clay beds more likely a product of floccule formation than of eolian input