Compaction State of Aggregate Grains in Carbonaceous Mudstones: Evidence from Microfabric Studies of the Upper Cretaceous Colorado Group, Western Canada Foreland Basin*

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Abstract

Intraparticle microporosity within clay aggregate grains is a principal contributor to storage capacity in self-sourcing carbonaceous mudstone reservoirs of the Upper Cretaceous Colorado Group in the Western Canada foreland basin. Prediction of the volumes, phase distribution, and deliverabilities of hydrocarbons from these reservoirs requires a comprehensive understanding of the physicochemical processes governing the formation and preservation of this mode of microporosity. FIB-SEM studies of microfabric in the Colorado Group mudstones reveal that the intraparticle microporosity occupies submicron-scale interstitial voids between clay platelets arranged in both edge-to-face and face-to-face stacking arrangements within discrete spatial domains. The local domains, which are typically scaled between 2 to 5 microns in diameter, are interpreted as microflocs. These microflocs are themselves component grains ("zero-order aggregates" of Krone (1963)) of larger, higher-order aggregate particles. One salient feature of the microflocs is that the particles commonly retain an approximately equant cross-sectional form, regardless of the burial depth, which ranges from hundreds to several thousands of metres in the sample suite. This suggests that at least some of the flocs have not been subjected to significant compaction following deposition and burial. This observation stands in stark contrast with the prevailing expectation of flattening of flocs due to dewatering at very shallow burial depths; it may reflect early diagenetic cementation resulting from oxidation of high concentrations of disseminated organic matter in the consolidated gel below the sediment-water interface. The conditions required to prevent early compactional loss of intraparticle microporosity in clay aggregate grains are governed by the depositional processes that impart the primary sediment microfabric, in concert with net flux of labile organic matter and pore-water composition below the sediment-water interface. Ultimately, these factors respond to basin-scale allogenic drivers (e.g., climate, tectonism, eustacy)

that modulate the character of the sedimentary record. Prediction of the spatial and temporal preservation of inherited microporosity, therefore, must be informed by the context of basin evolution.

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AAPG Annual Convention & Exhibition 2014

Theme 2 Unconventional Resources: Shale Plays

April 9 2014

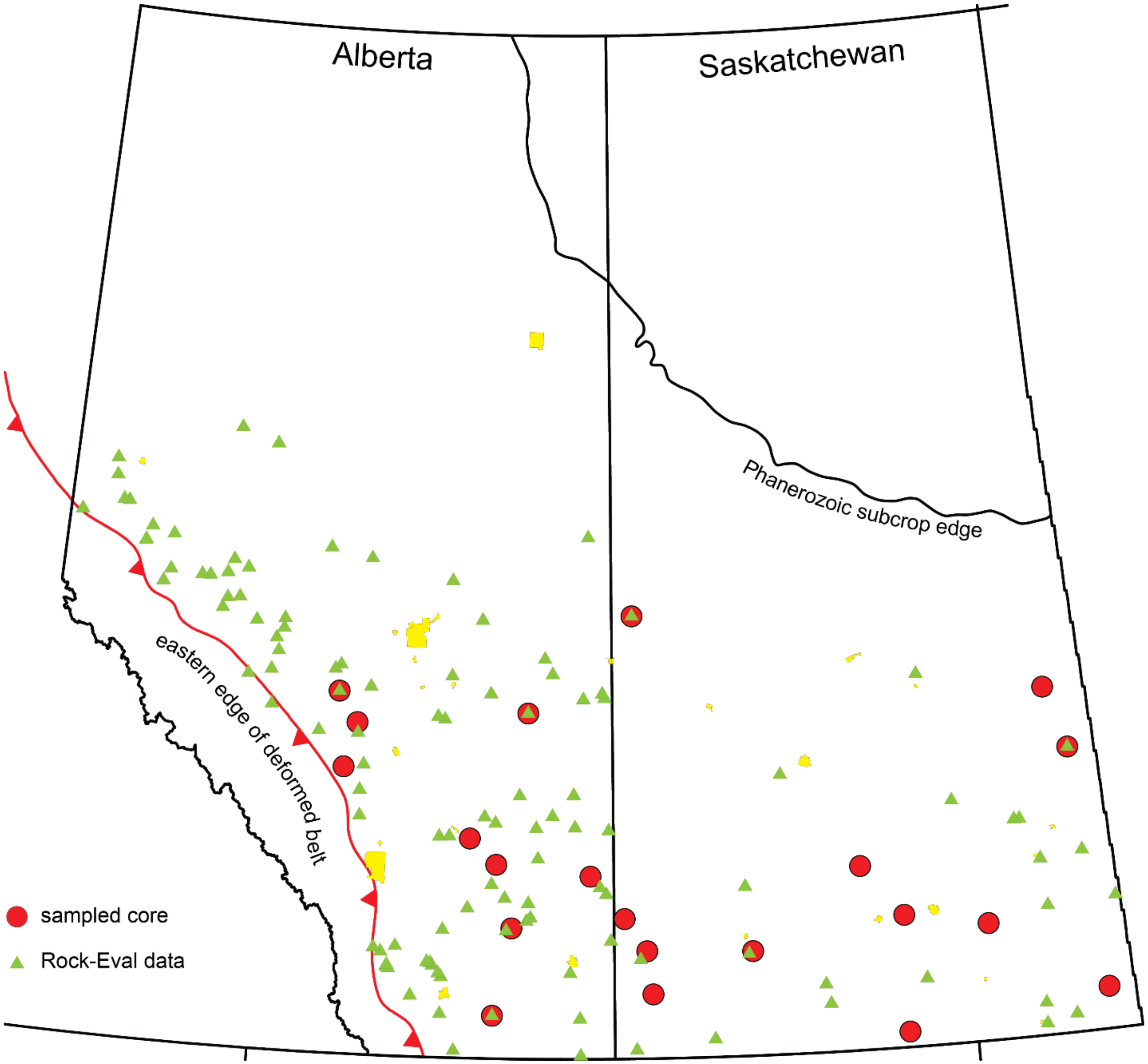

Archaeopteryx lithographica, Eichstätter specimen | source: H. Raab (CC-SA)

A Brief History of the Colorado Group

Textural Evidence of Clay Aggregates

Implications of Undercompaction

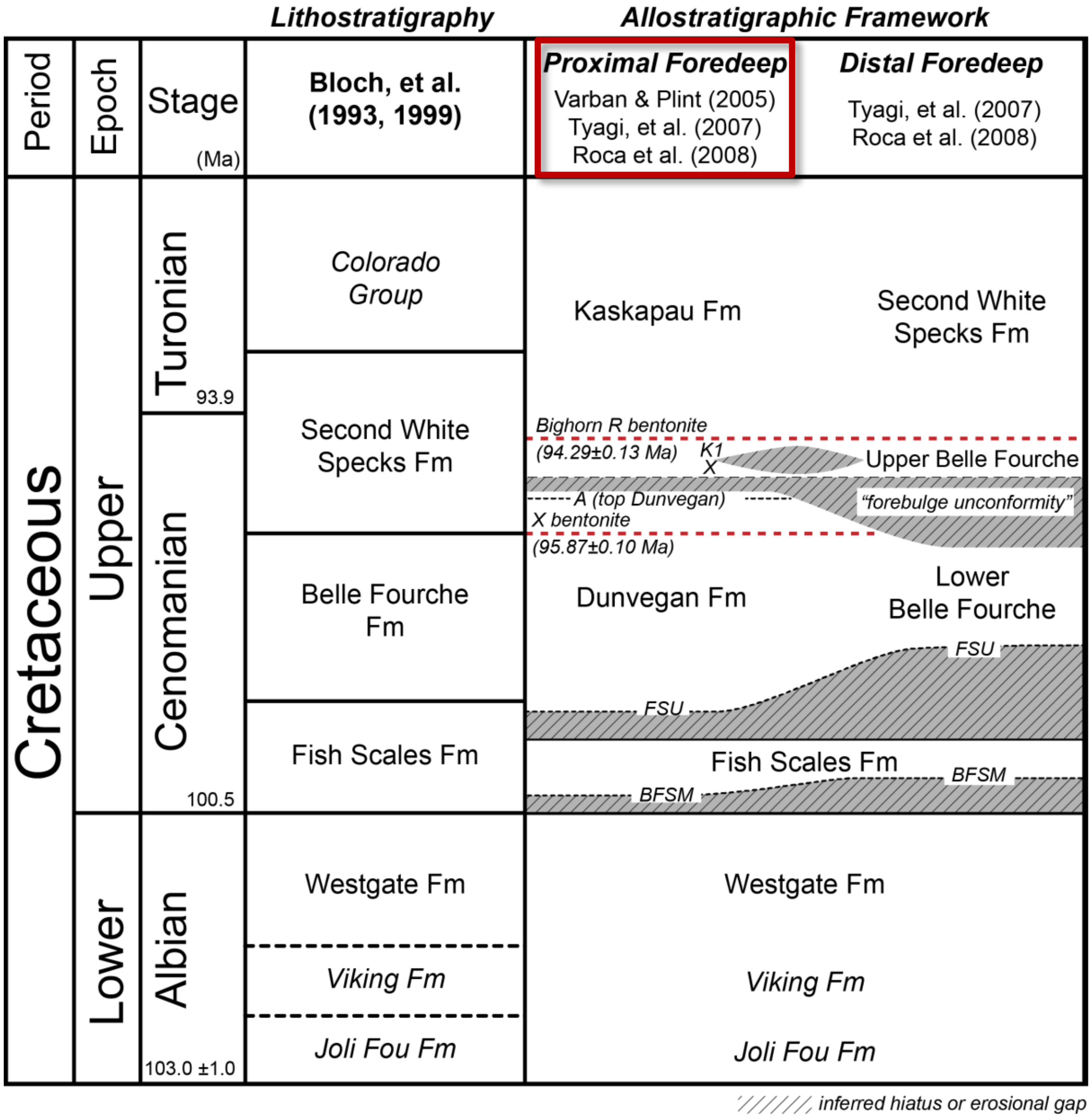
New Questions New Opportunities



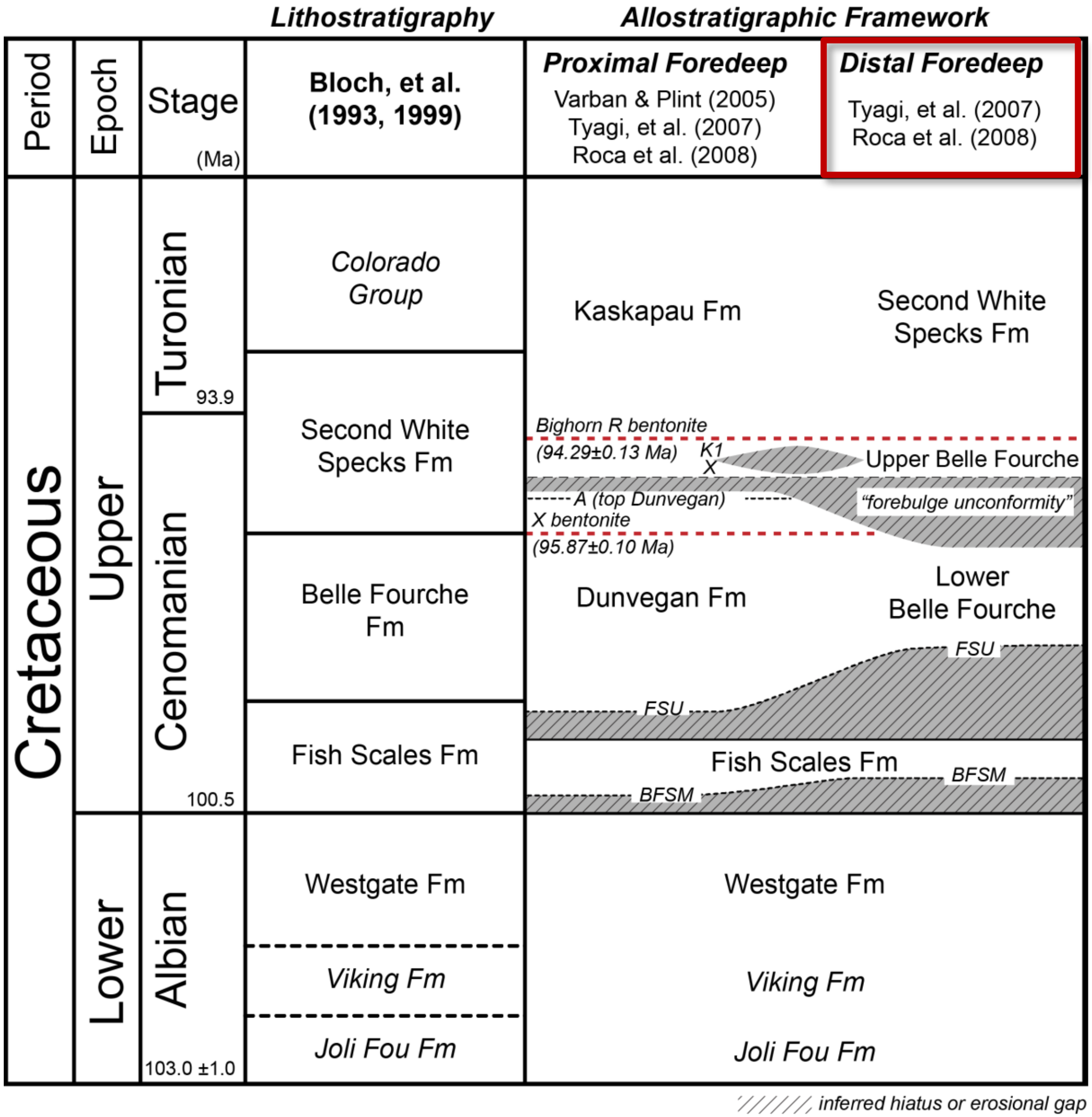
public domain data

variable compaction

stratigraphic control


Lithostratigraphy
Allostratigraphic Framework
Period
Epoch
Stage
(Ma)
Bloch, et al. (1993, 1999)
Proximal Foredeep
Varban & Plint (2005)
Tyagi, et al. (2007)
Roca et al. (2008)
Distal Foredeep
Tyagi, et al. (2007)
Roca et al. (2008)
Cretaceous
Upper
Lower
Turonian
93.9
Cenomanian
100.5
Albian
103.0 ±1.0
Colorado Group
Second White Specks Fm
Belle Fourche Fm
Fish Scales Fm
Westgate Fm
Viking Fm
Joli Fou Fm
Kaskapau Fm
Second White Specks Fm
Bighorn R bentonite
(94.29±0.13 Ma)
K1
X
Upper Belle Fourche
A (top Dunvegan)
"forebulge unconformity"
X bentonite
(95.87±0.10 Ma)
Dunvegan Fm
Lower Belle Fourche
FSU
FSU
Fish Scales Fm
BFSM
BFSM
Westgate Fm
Viking Fm
Joli Fou Fm
inferred hiatus or erosional gap


1021.5 m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FSU
FSU
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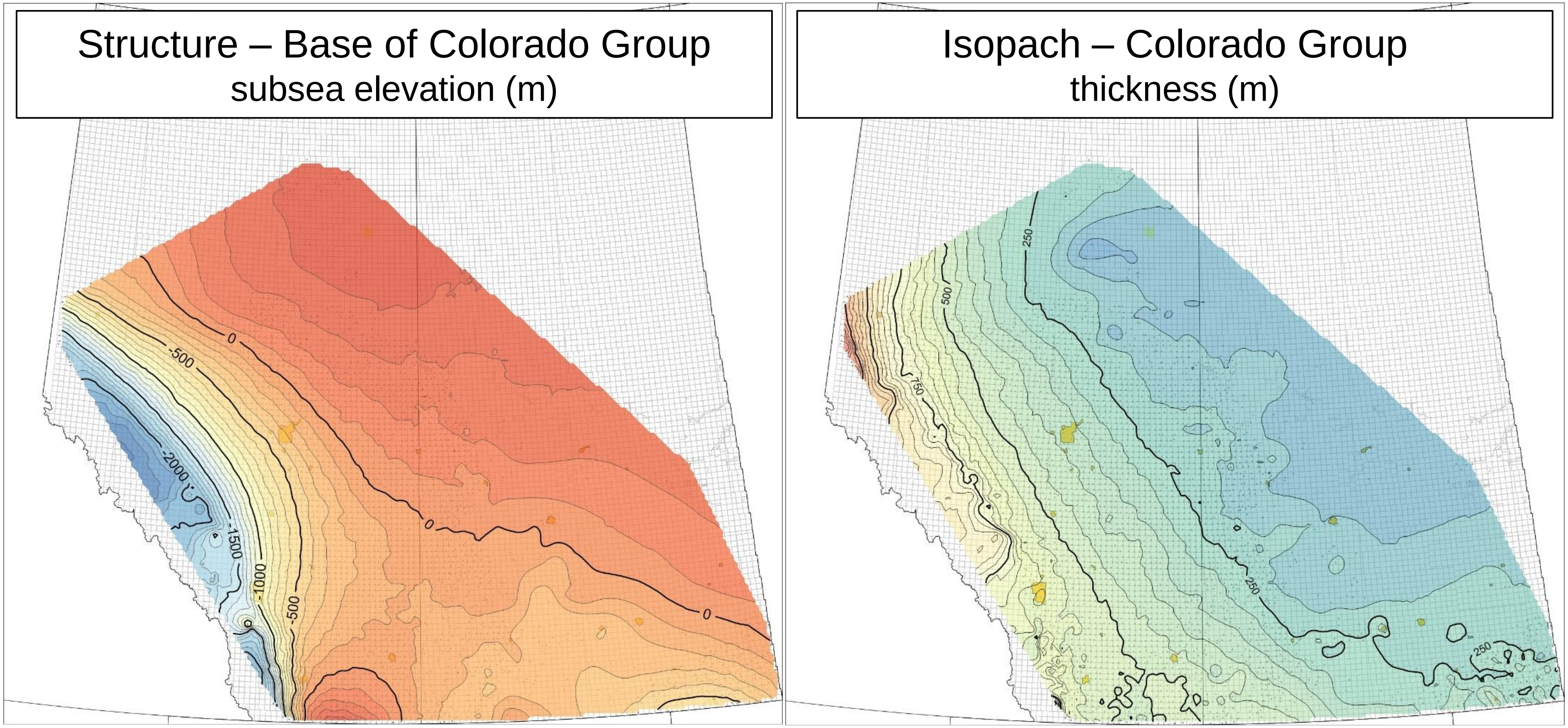
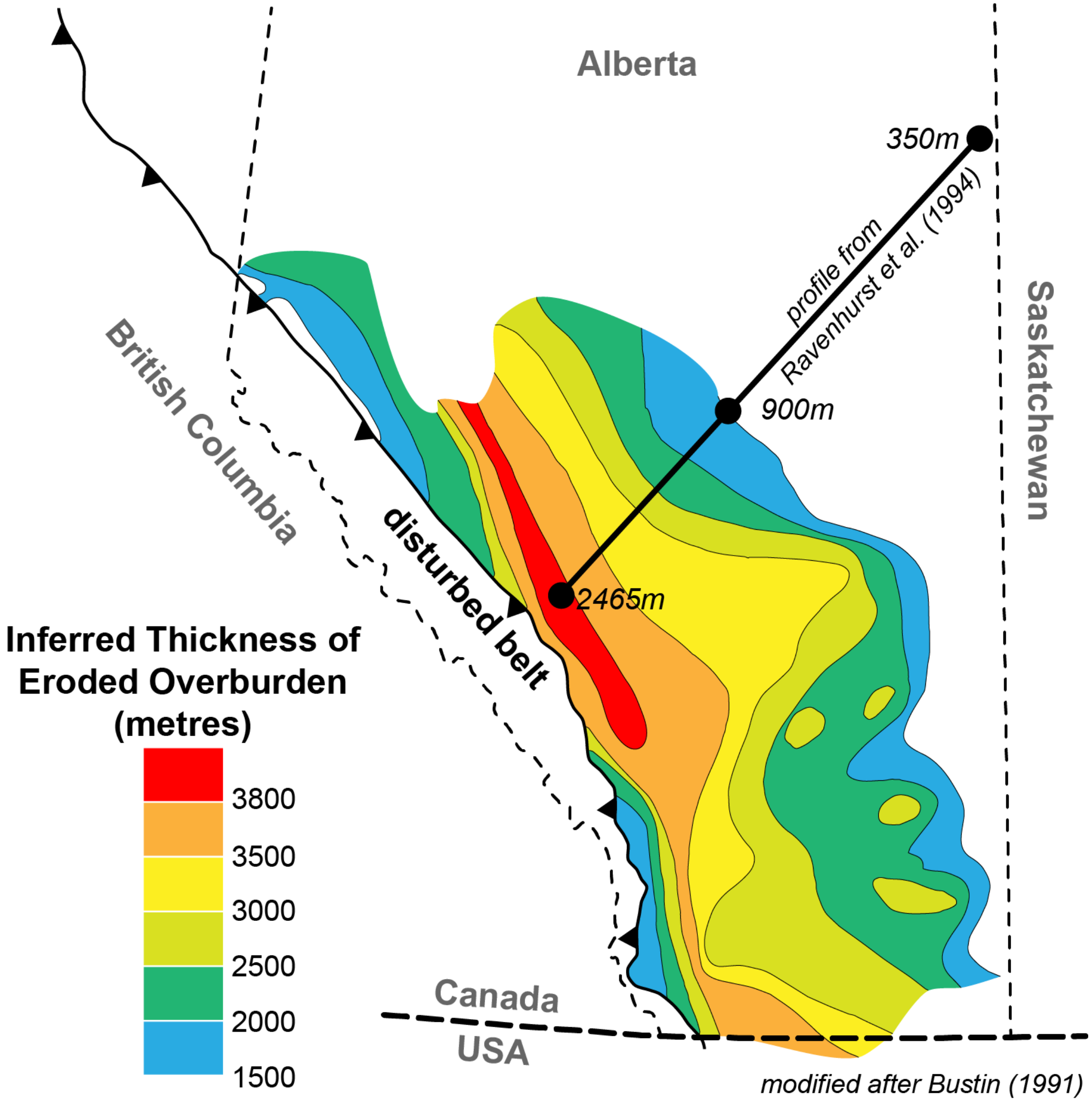
BFSM
BFSM
Westgate Fm
Viking Fm
Joli Fou Fm
inferred hiatus or erosional gap


TOP: 620.16 m
TOP: 618.68 m
BASE: 621.59 m
101 6-15-015-13W2
BASE: 620.16 m
101 6-15-015-13W2

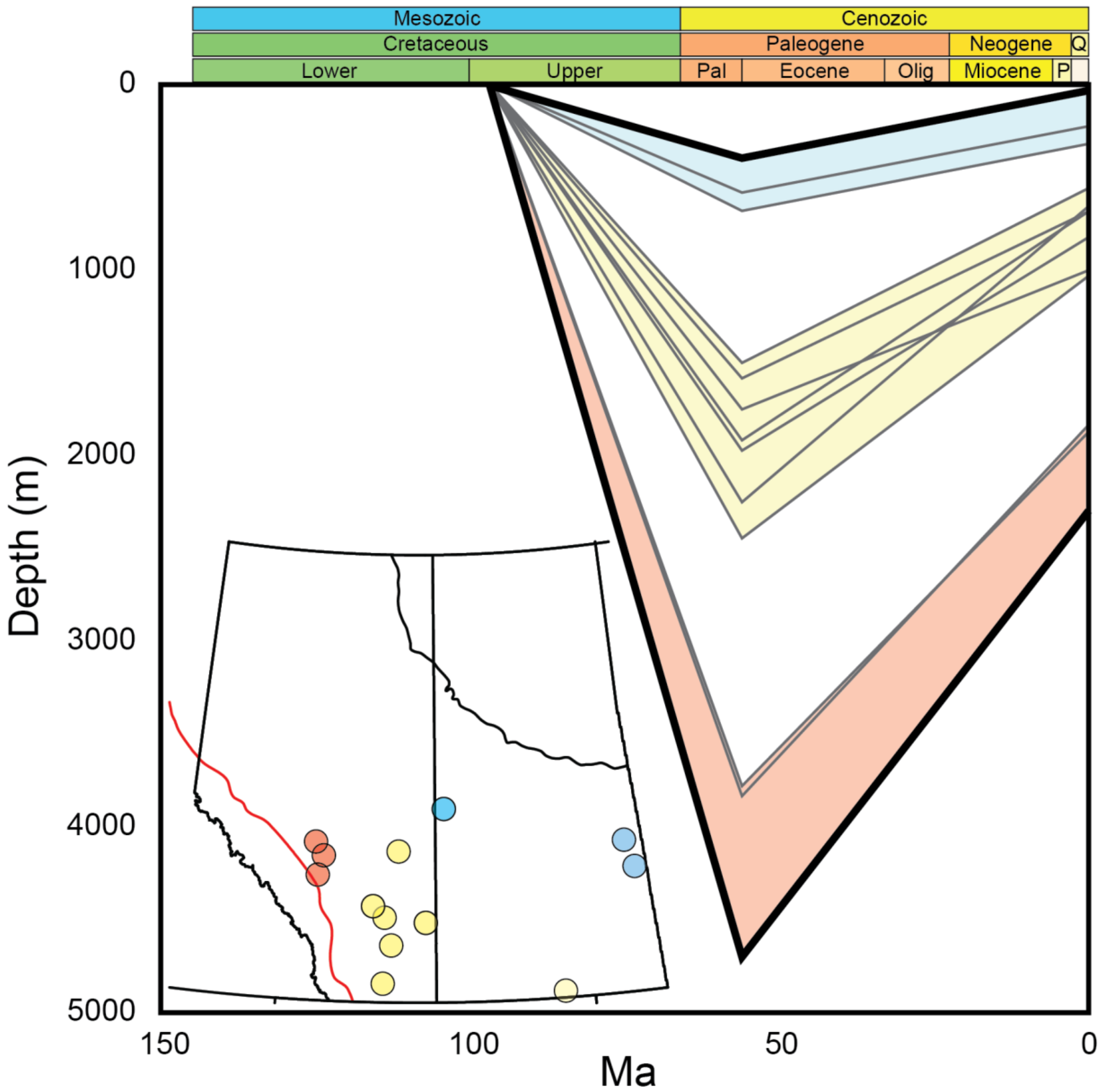


maximum burial depth / thickest preserved succession in foredeep depozone



Post-Laramide uplift and erosion have removed several thousands of metres of overburden

conservative estimates used to determine maximum burial depths



Maximum Burial

Subcrop margin (3)

400 – 675 m

Distal foredeep (7)

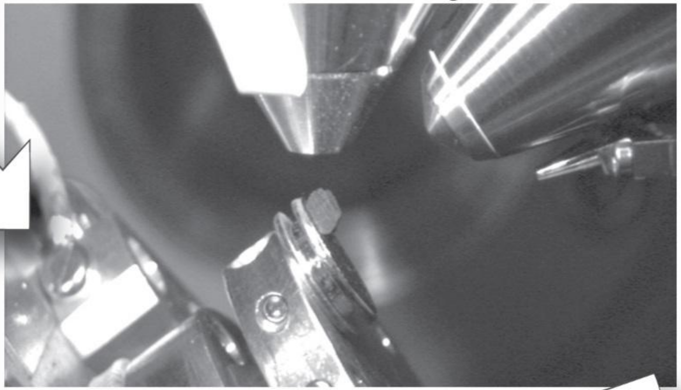
1500 – 2450 m

Proximal foredeep (3)

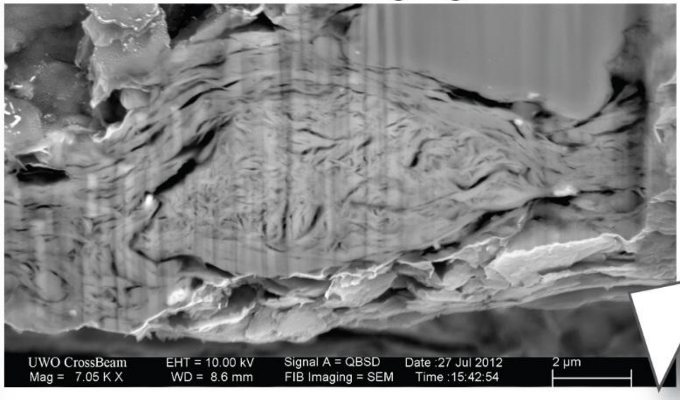
3800 – 4700 m

Core Description / Sampling

FIB Polishing



BSE Imaging



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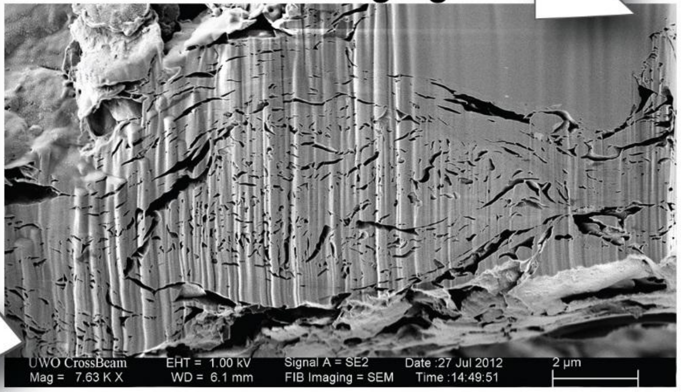
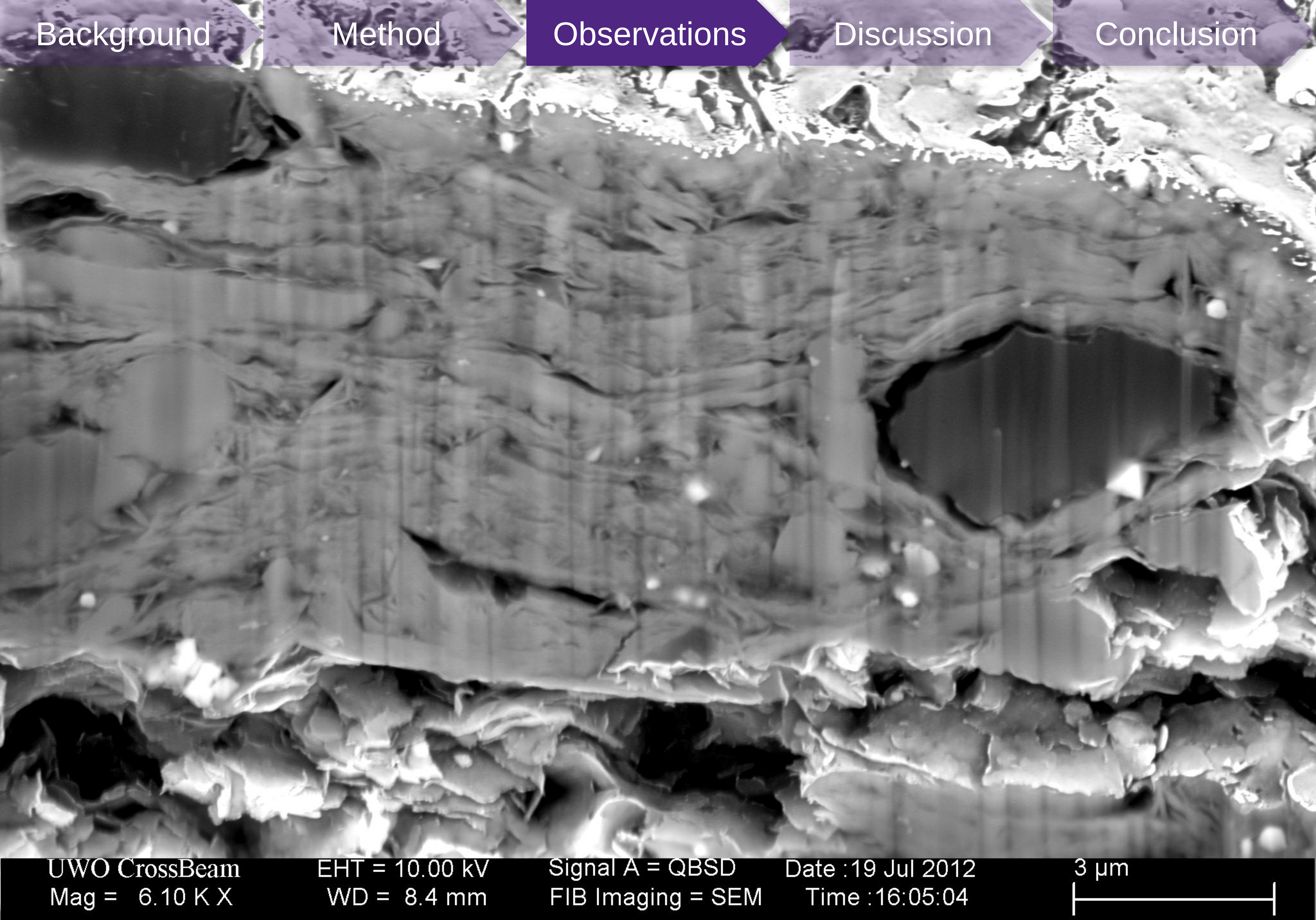
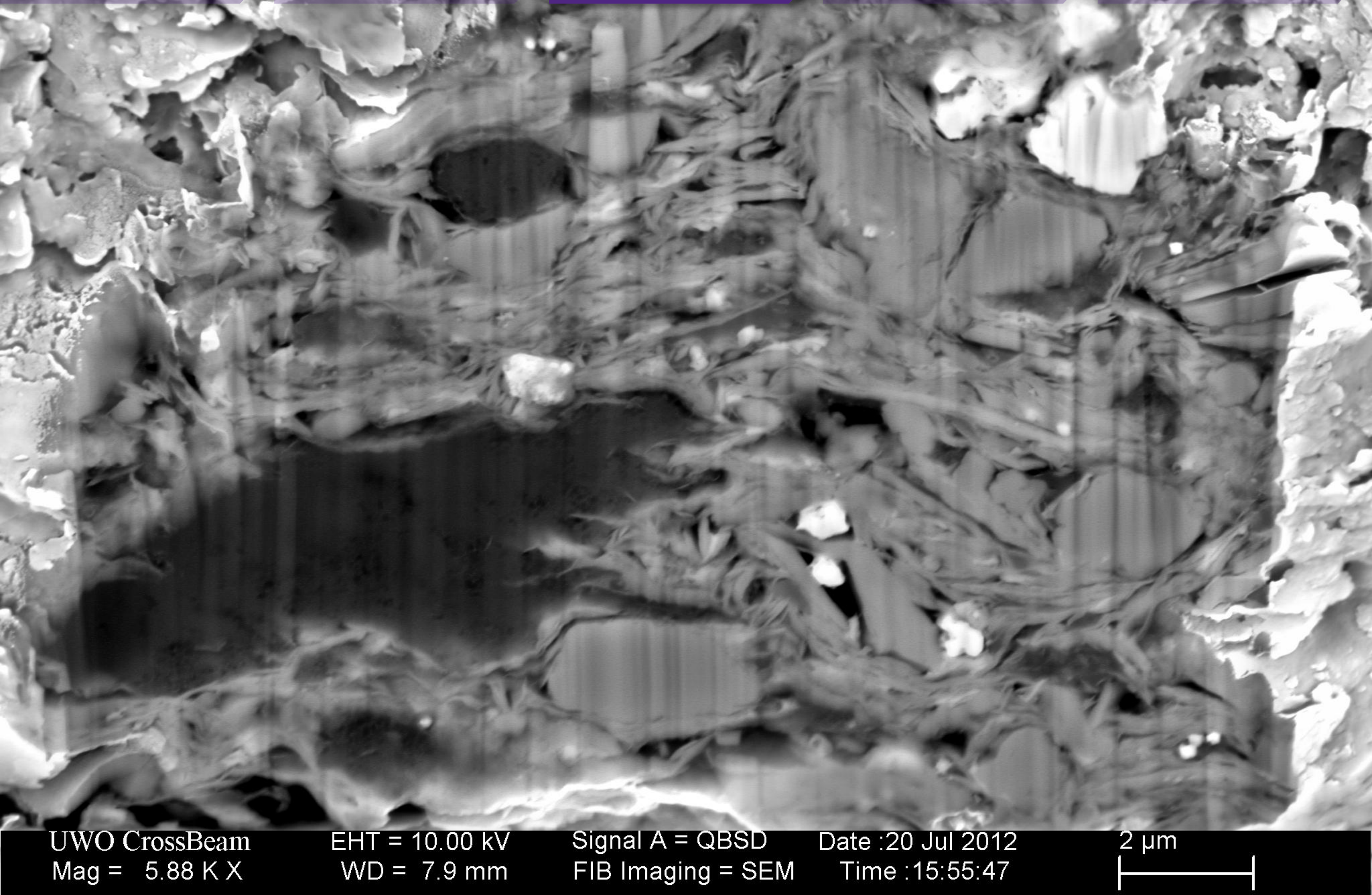
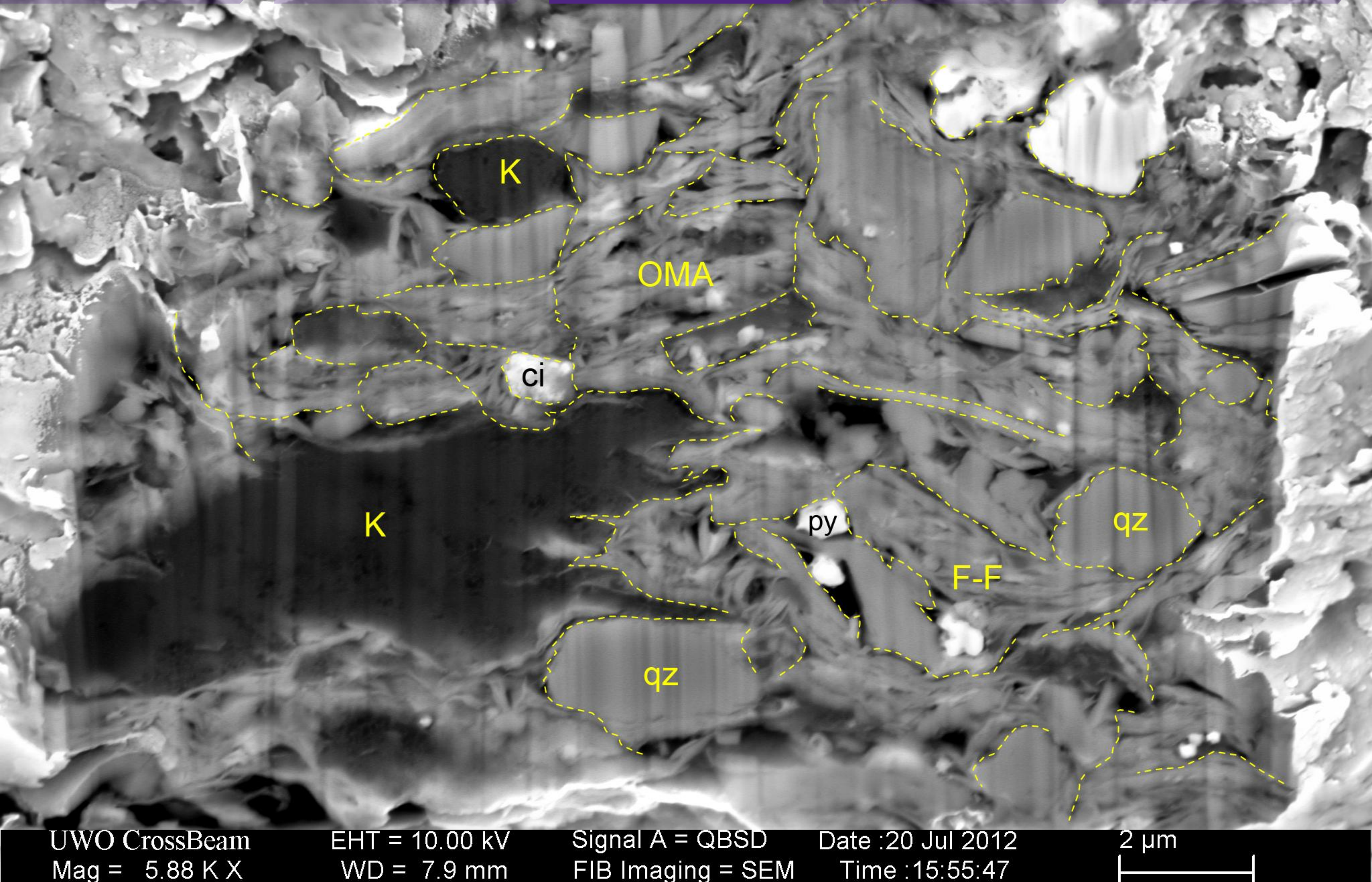




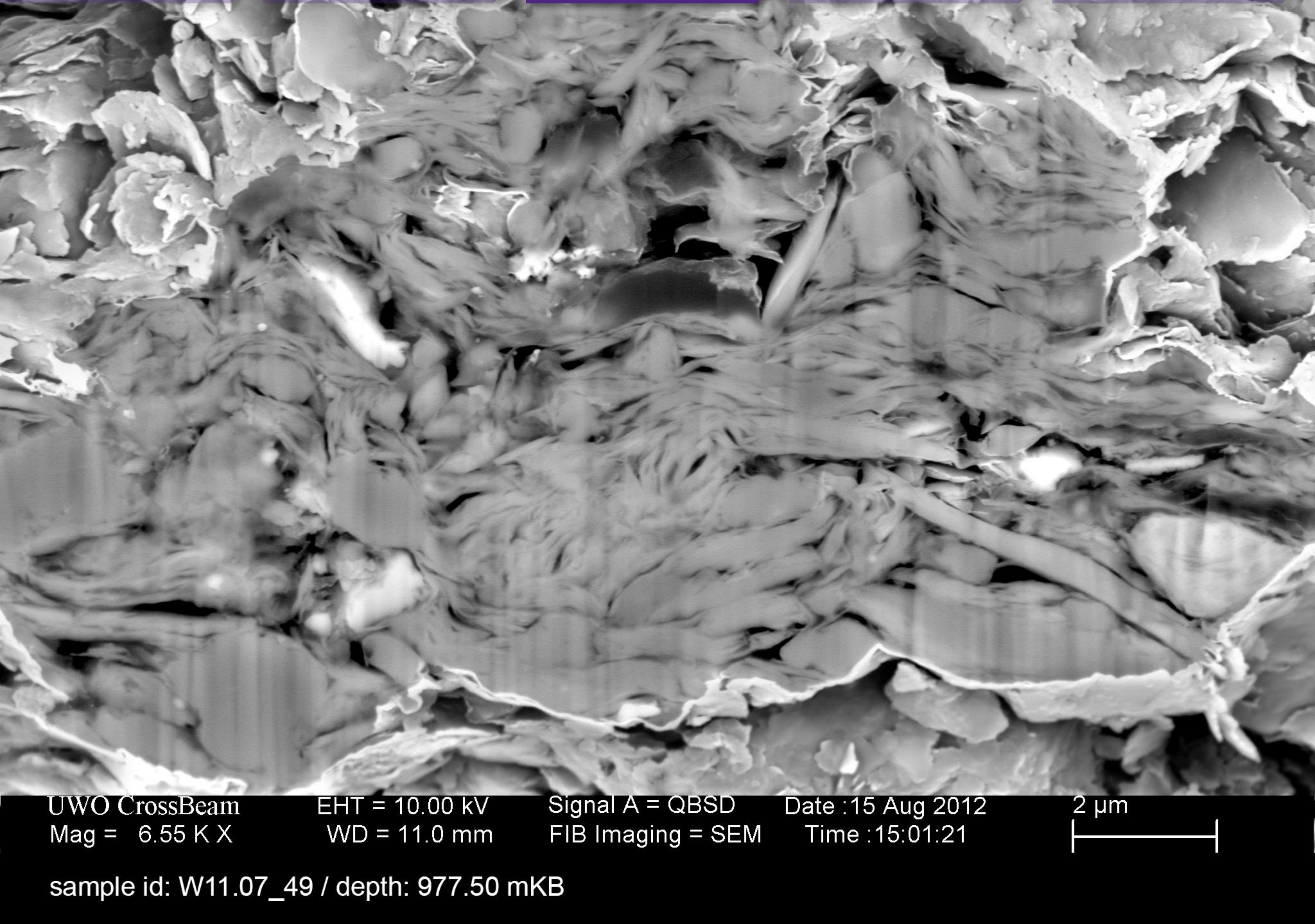
sample id: W08.03_39 / depth: 15.90 mKB (~350m max. burial)



sample id: W08.02_46 / depth: 13.71 mKB (~350m max. burial)



sample id: W08.02_46 / depth: 13.71 mKB (~350 m max. burial)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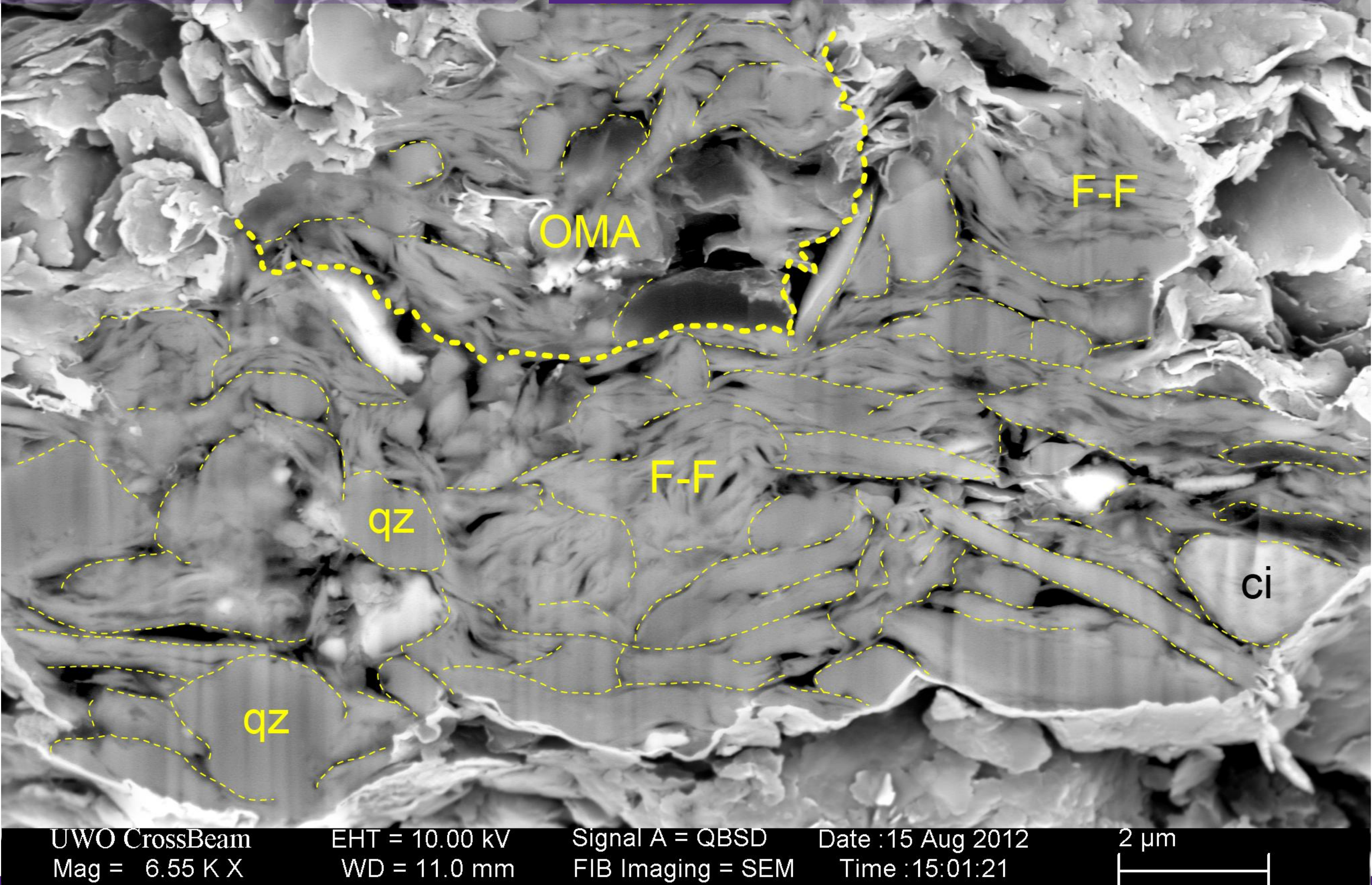
EHT = 10.00 kV
WD = 11.0 mm
Signal A = QBSD
FIB Imaging = SEM
Date :15 Aug 2012
Time :15:01:21
2 µm
sample id: W11.07_49 / depth: 977.50 mKB



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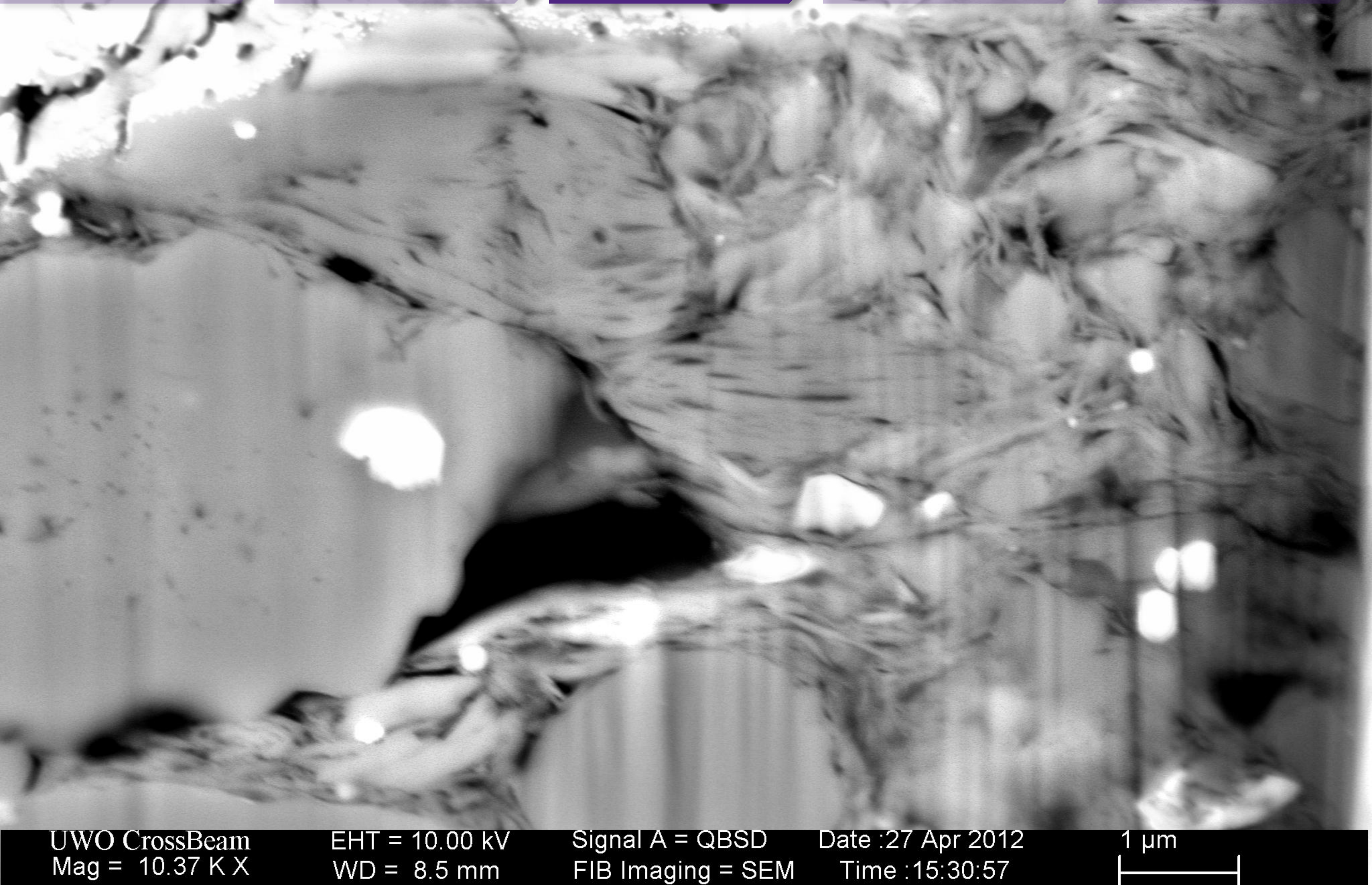
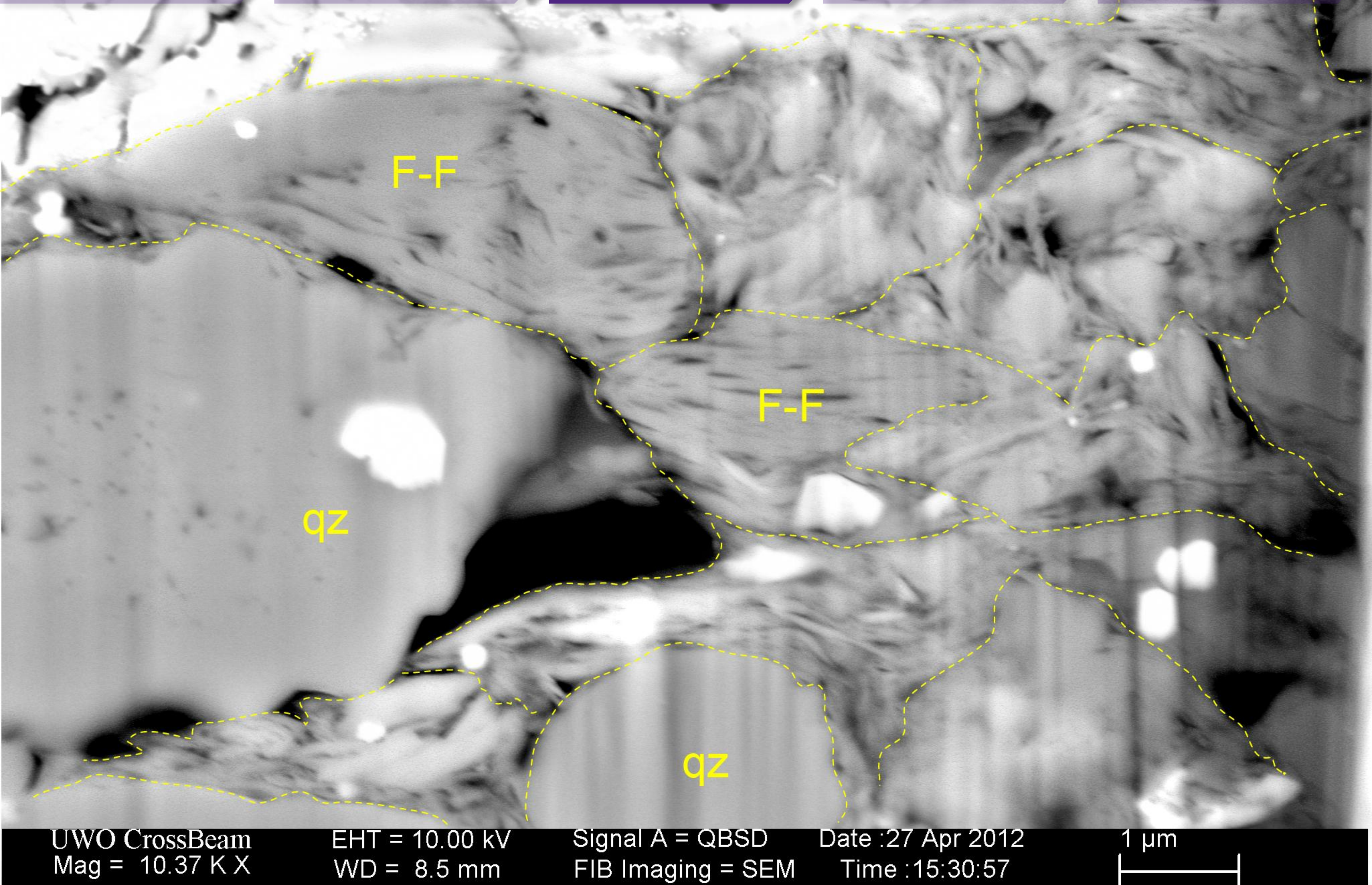
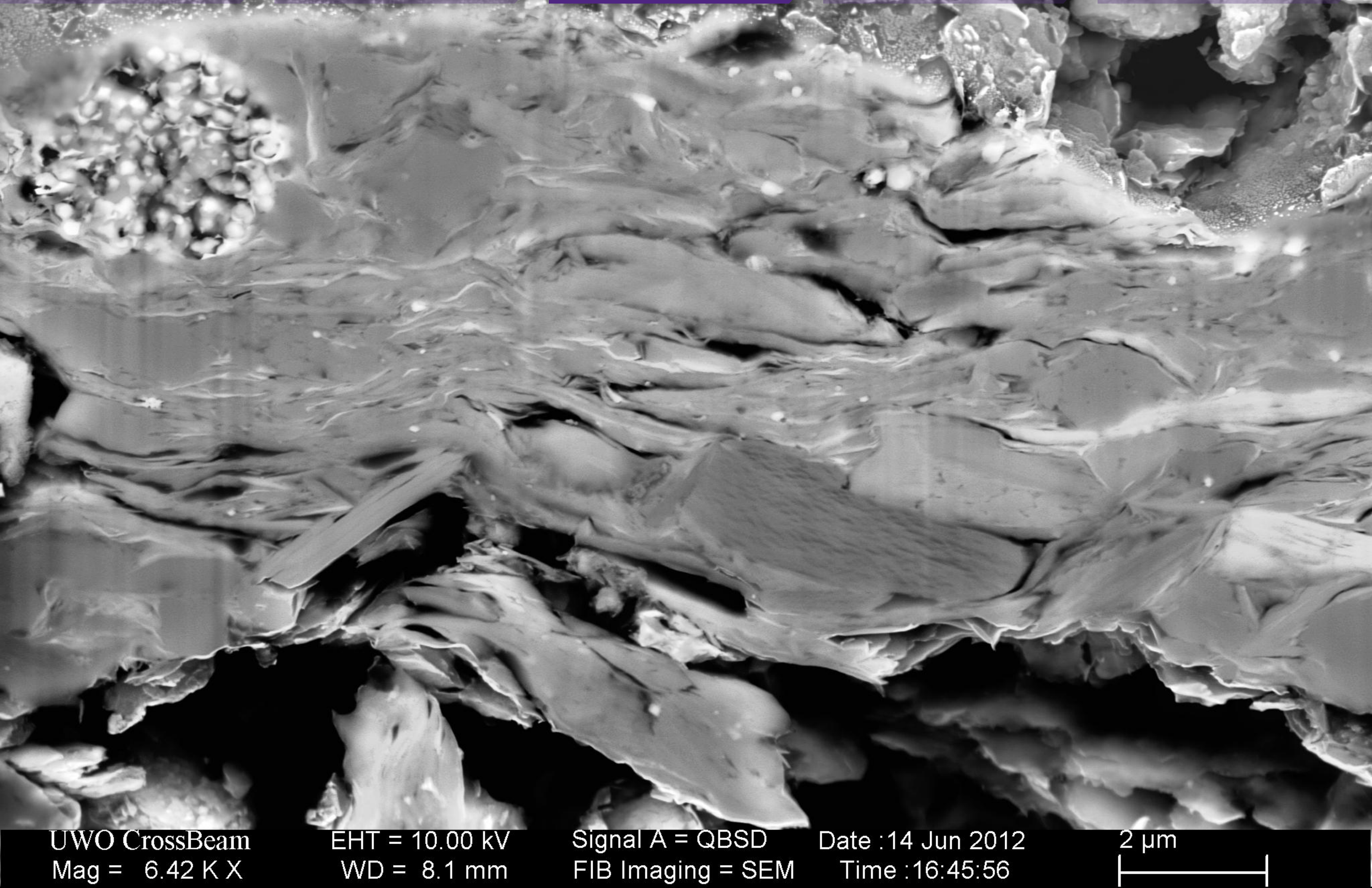


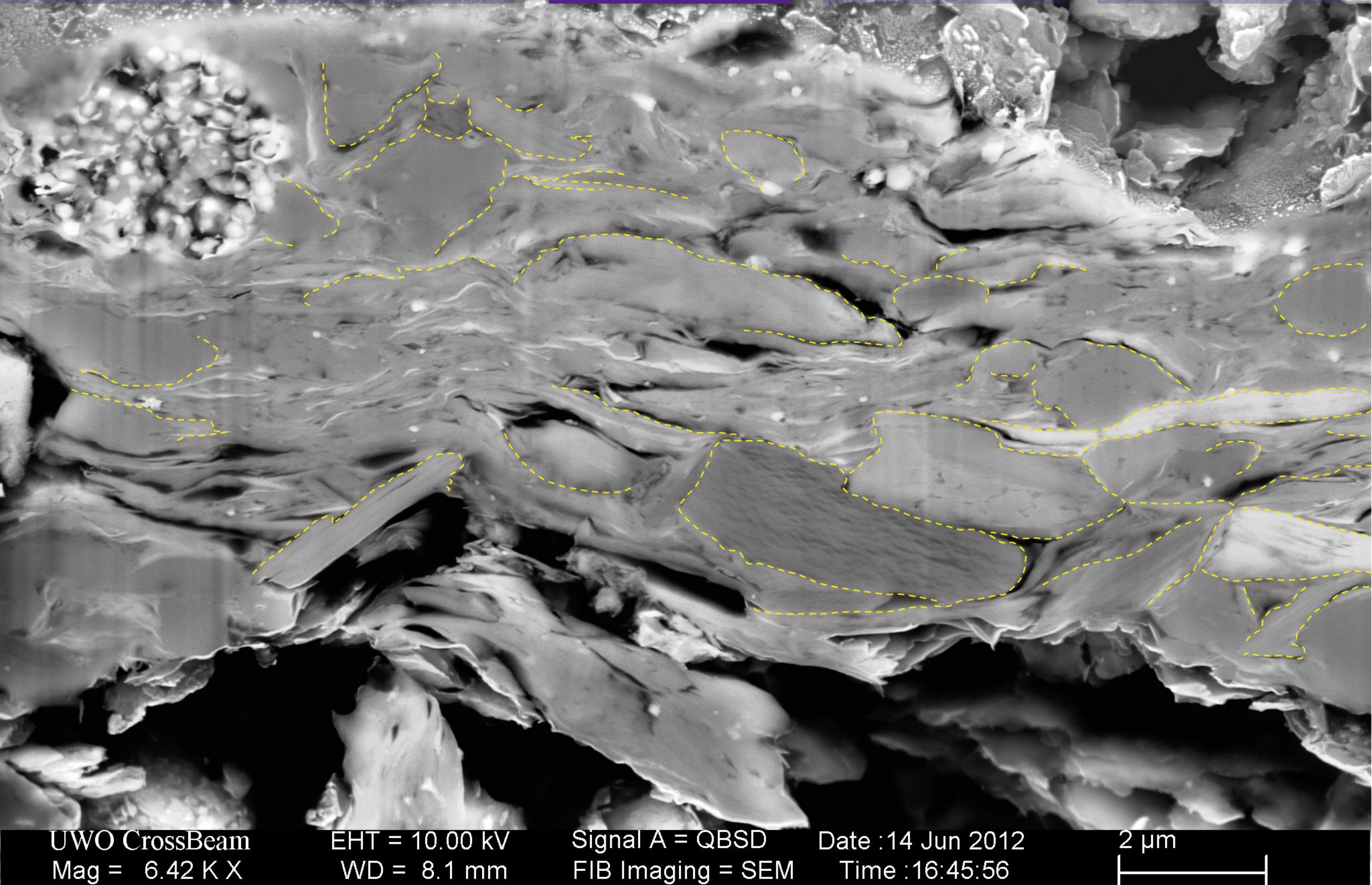
sample ID: W02.69_63 / depth: 1866.0 mKB



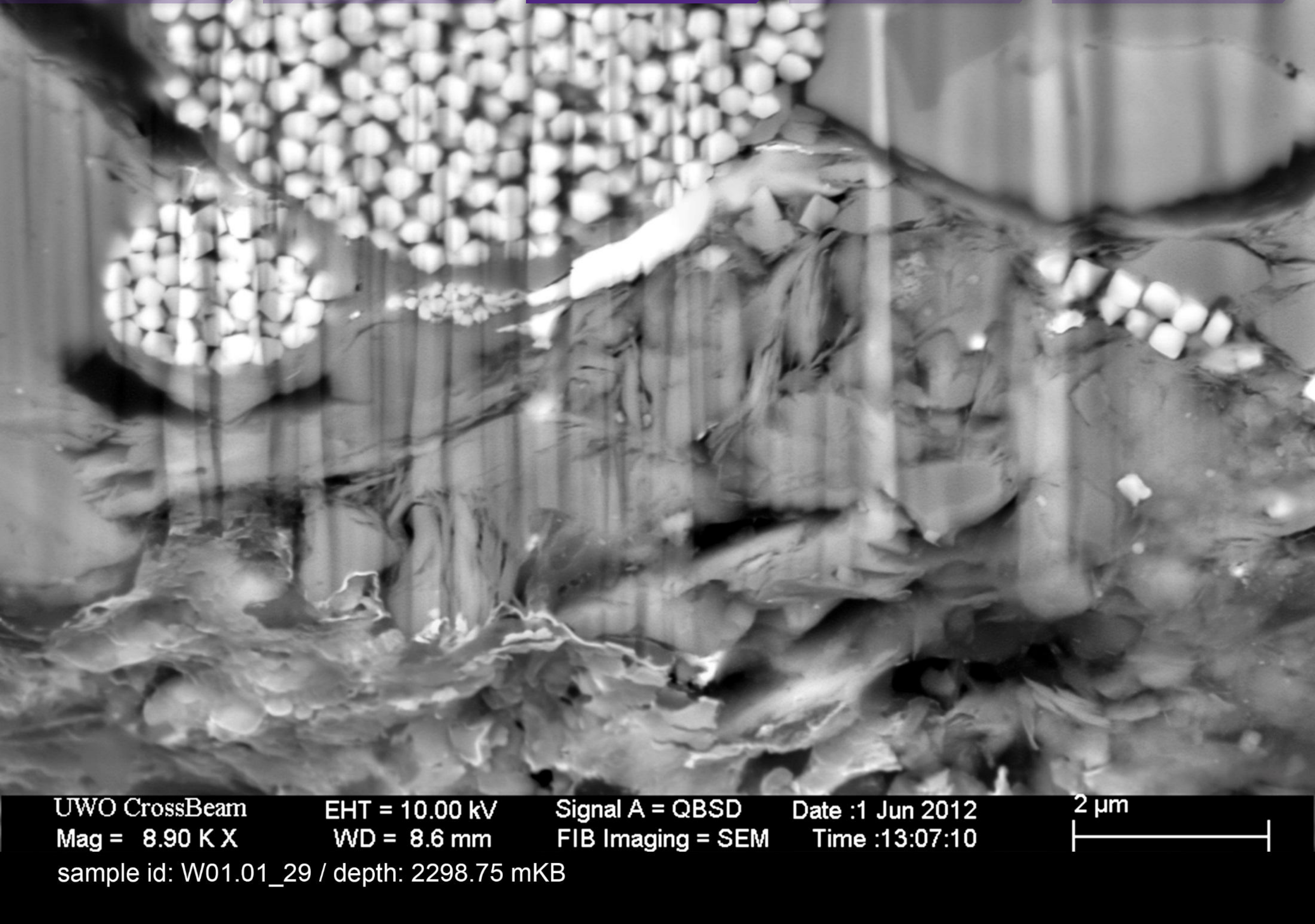
sample id: W02.69_62 / depth: 1866.0 mKB (~3780 m max. burial)



sample id: W04.02_29 / depth: 1980.33 mKB



sample id: W04.02_29 / depth: 1980.33 mKB (~2250 m max. burial)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EHT = 10.00 kV
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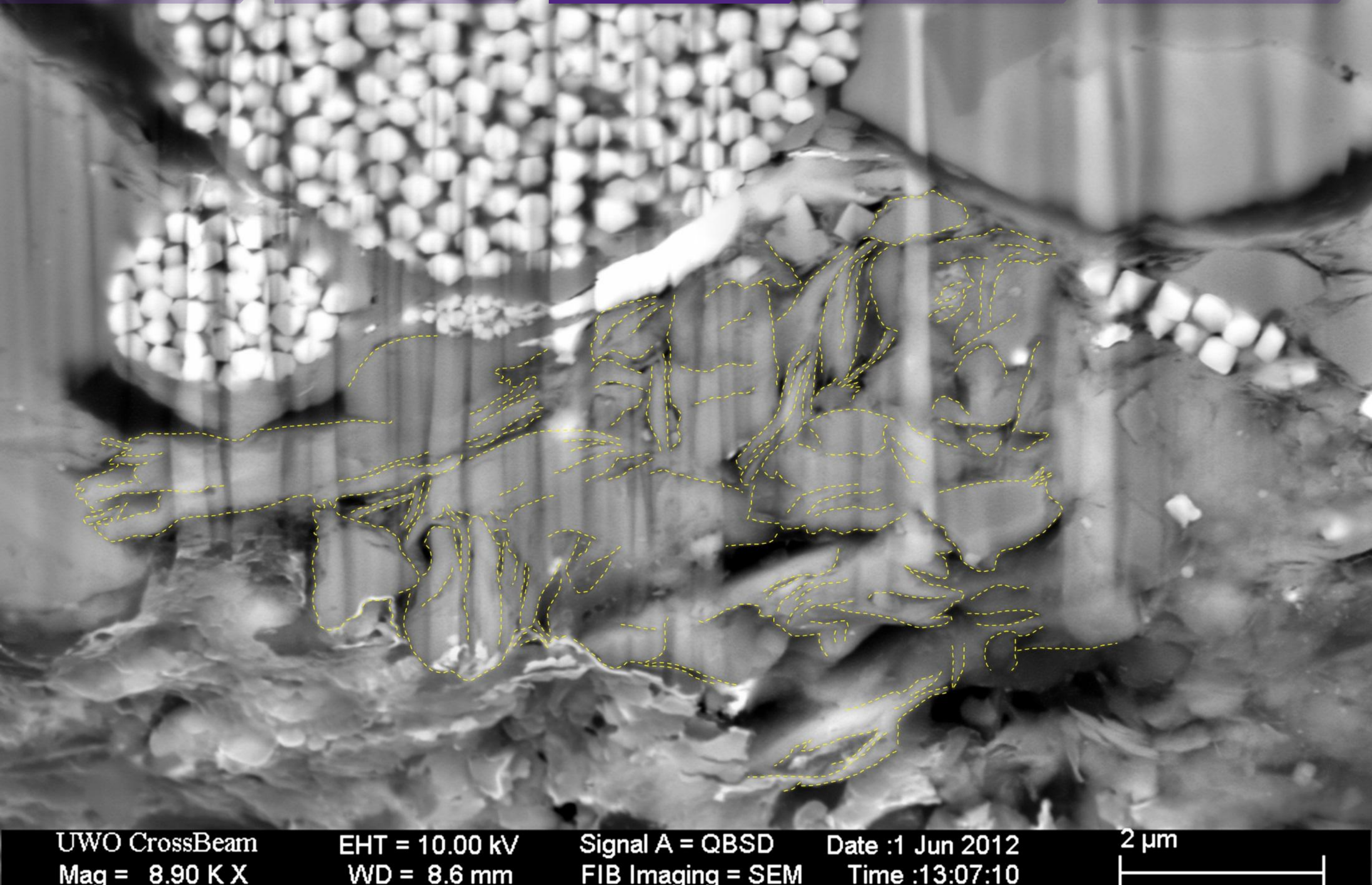
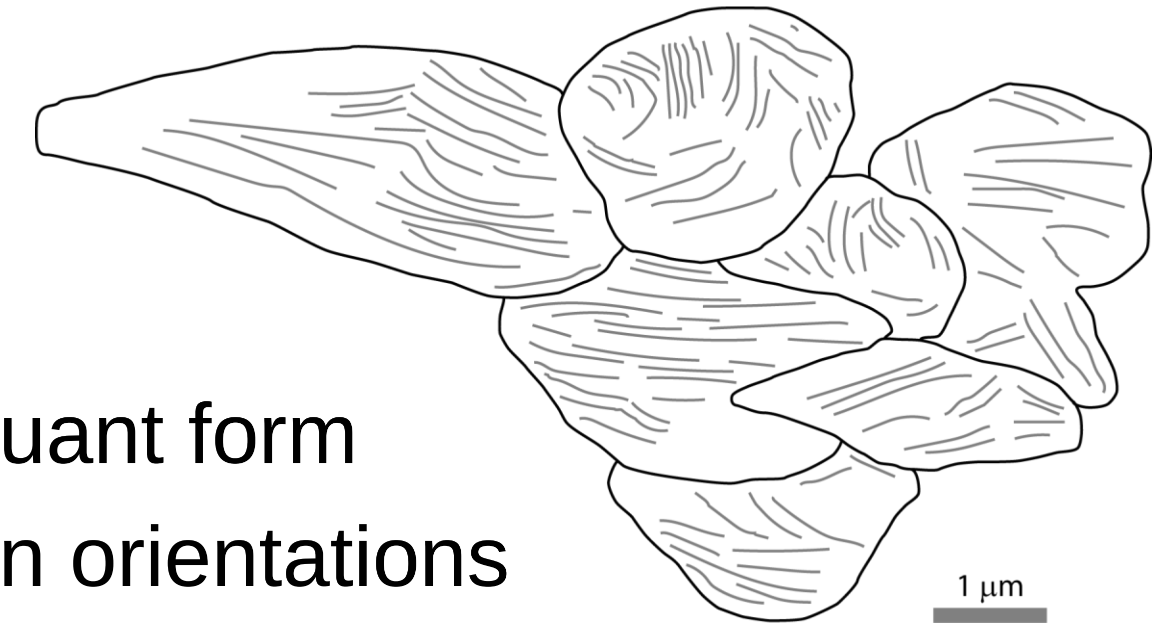
Time :13:07:10
2 µm
sample id: W01.01_29 / depth: 2298.75 mKB



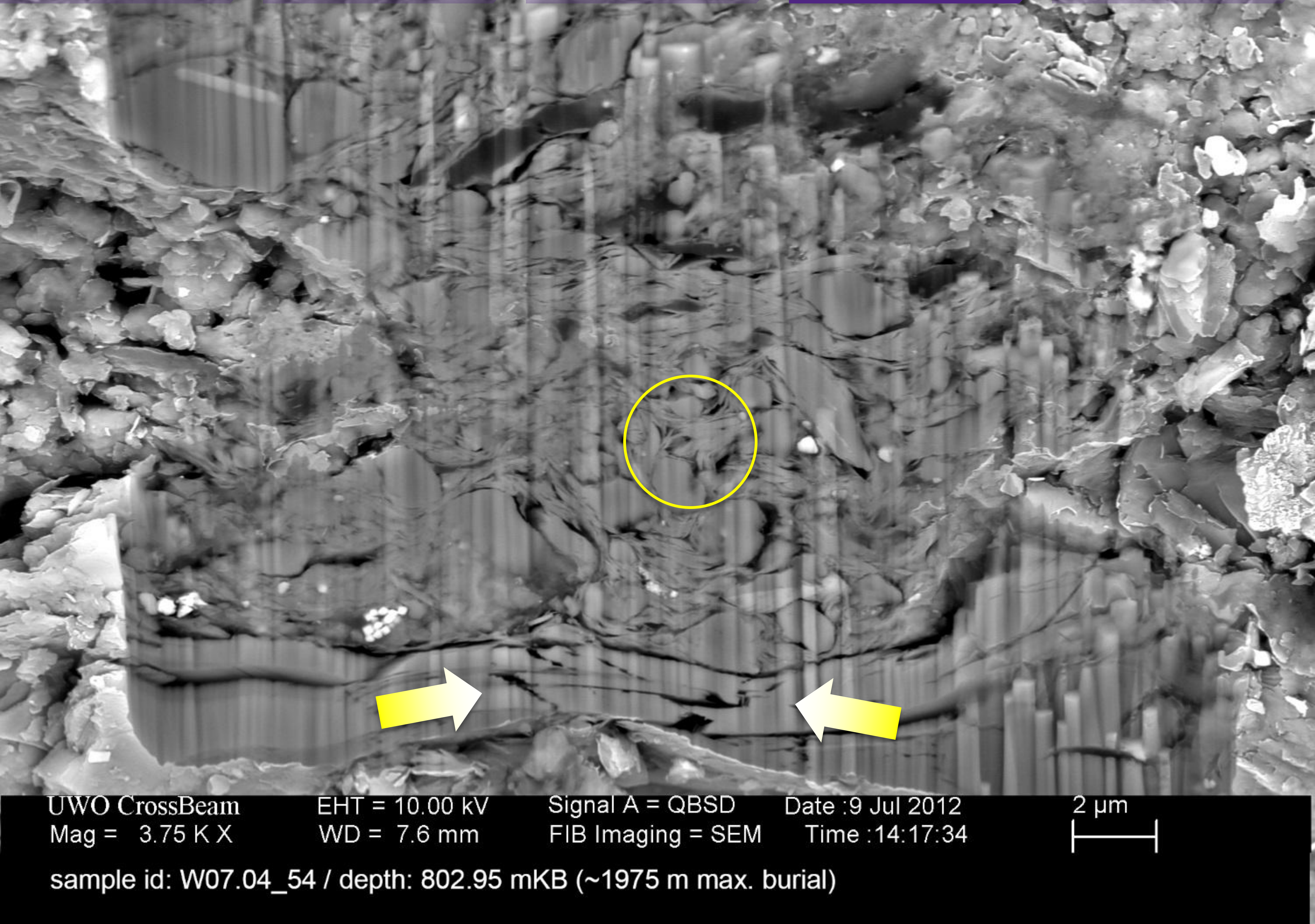
sample id: W01.01_29 / depth: 2298.75 mKB (~4650 m max. burial)

Precompaction Consolidation



Evidence:

- retention of equant form
- random domain orientations
- intrinsic pore preservation
- kerogen preservation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EHT = 10.00 kV
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Signal A = QBSD
FIB Imaging = SEM
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Time :14:17:34
2 µm
sample id: W07.04_54 / depth: 802.95 mKB (~1975 m max. burial)

A Riddle Wrapped In A Mystery, Inside an Enigma

- variable composition
- no apparent cement phase
- scaling relationships unclear
- “stress shadow” context inconsistent

Implications

- preservation of intraparticle porosity
- contribution to storage, flow capacity
- OM preservation / redistribution

- insight into depositional and early diagenetic process mud microfabric dominated by aggregate particles

consolidated aggregates resist compaction

undercompaction preserves storage capacity

RQ prediction requires understanding of consolidation mechanism

Acknowledgements

Husky Energy

devon

TUZO

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Western Nanofabrication Facility, ZAPLab

Western
Science

AAPG Eastern Section Meeting

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Discovered at Oil Springs 1858

First Commercial Well in North America

O.P.I.

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