Geochemical changes and fracture development in Woodford Shale cores following hydrous pyrolysis under uniaxial confinement

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U.S. Geological Survey

Key issues

- Hydrous pyrolysis experiments with crushed rock don’t yield samples appropriate for petrophysical characterization
- Whole cores needed to assess effects of artificial thermal maturation on fracturing
- Pyrolysis of cores without confinement leads to expansion that is not representative of rocks under the influence of overburden

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Study objectives

- Examine how hydrous pyrolysis on cores with and without confinement affects fracture development and enhancement

- Determine if confinement affects gas and oil yields and spent rock geochemical properties

- Assess changes in core porosity and resistivity under different time/temperature combinations with confinement

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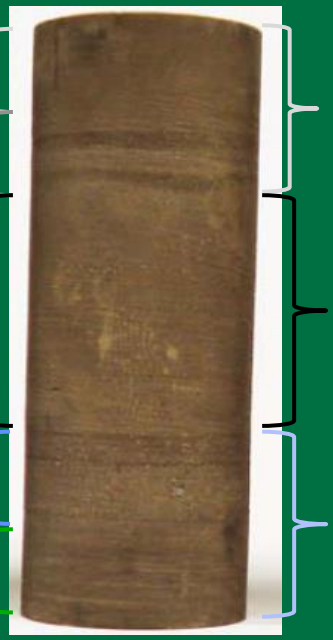
Woodford Shale sample – Collection site

Springer outcrop, west side of I-35 near mile marker 44 Carter County, Oklahoma (N 34° 21.117', W 97° 8.931').
Collected on December 11 and 12, 2011

Woodford Shale sample



TOC = 7.28 wt.%
HI = 701 mg-HC/g-TOC
OI = 12 mg-CO_2/g-TOC
T_{max} = 430 °C

TOC = 7.38 wt.%
HI = 702 mg-HC/g-TOC
OI = 12 mg-CO_2/g-TOC
T_{max} = 426 °C

TOC = 7.01 wt.%
HI = 725 mg-HC/g-TOC
OI = 11 mg-CO_2/g-TOC
T_{max} = 433 °C

COMPOSITE

Lab 1

TOC = 7.33 wt.%
S1 = 2.8 mg-HC/g-rock
S2 = 43.7 mg-HC/g-rock
HI = 596 mg-HC/g-TOC
OI = 5 mg-CO_2/g-TOC
T_{max} = 431°C

Lab 2

TOC = 7.20 wt.%
S1 = 2.3 mg-HC/g-rock
S2 = 50.0 mg-HC/g-rock
HI = 695 mg-HC/g-TOC
OI = 10 mg-CO_2/g-TOC
T_{max} = 433°C

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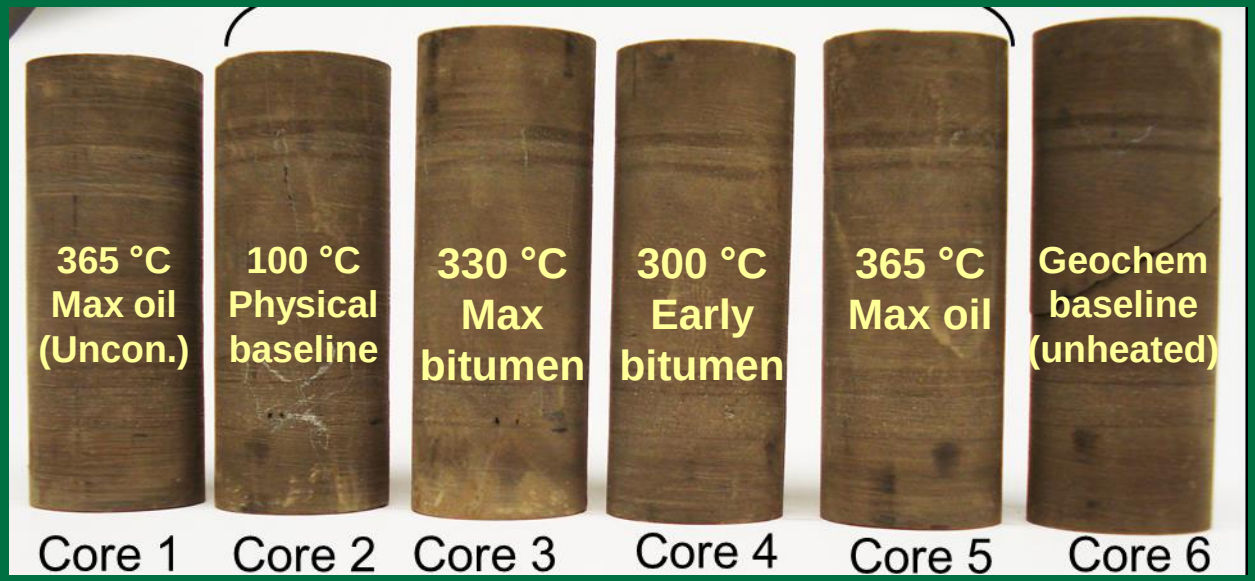
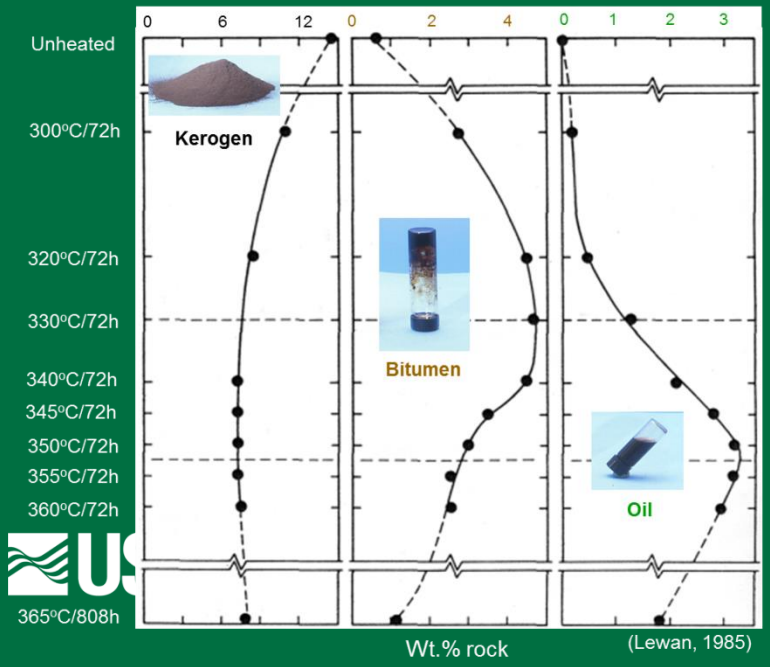
Experiments

Core properties
Diameter 2.54 cm
Height 6.35 – 6.75 cm
Mass 74.9 – 79.2 g

Experimental duration:
72 hours

All pyrolyzed samples were confined except **Core 1**



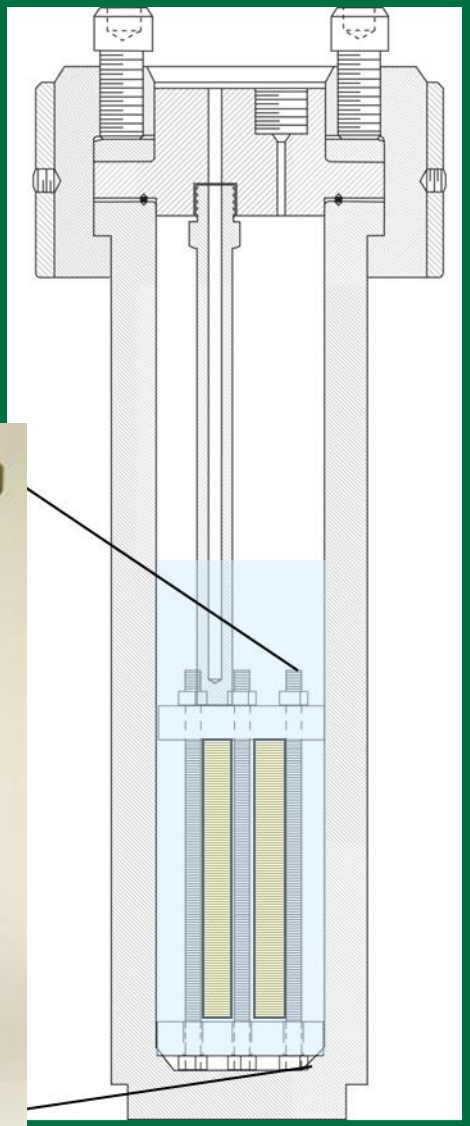


Woodford Shale slab

Uniaxial Confining Clamp

- Prevents expansion normal to bedding fabric (mimics overburden)
- Sample confining pressure determined by steam or helium added
- Allows for collection of expelled gas and oil products at different levels of thermal maturity using standard HP procedure
- Intact core is available for petrophysical characterization

1-L non-stirred reactor with confining rig



Shale core confining clamp

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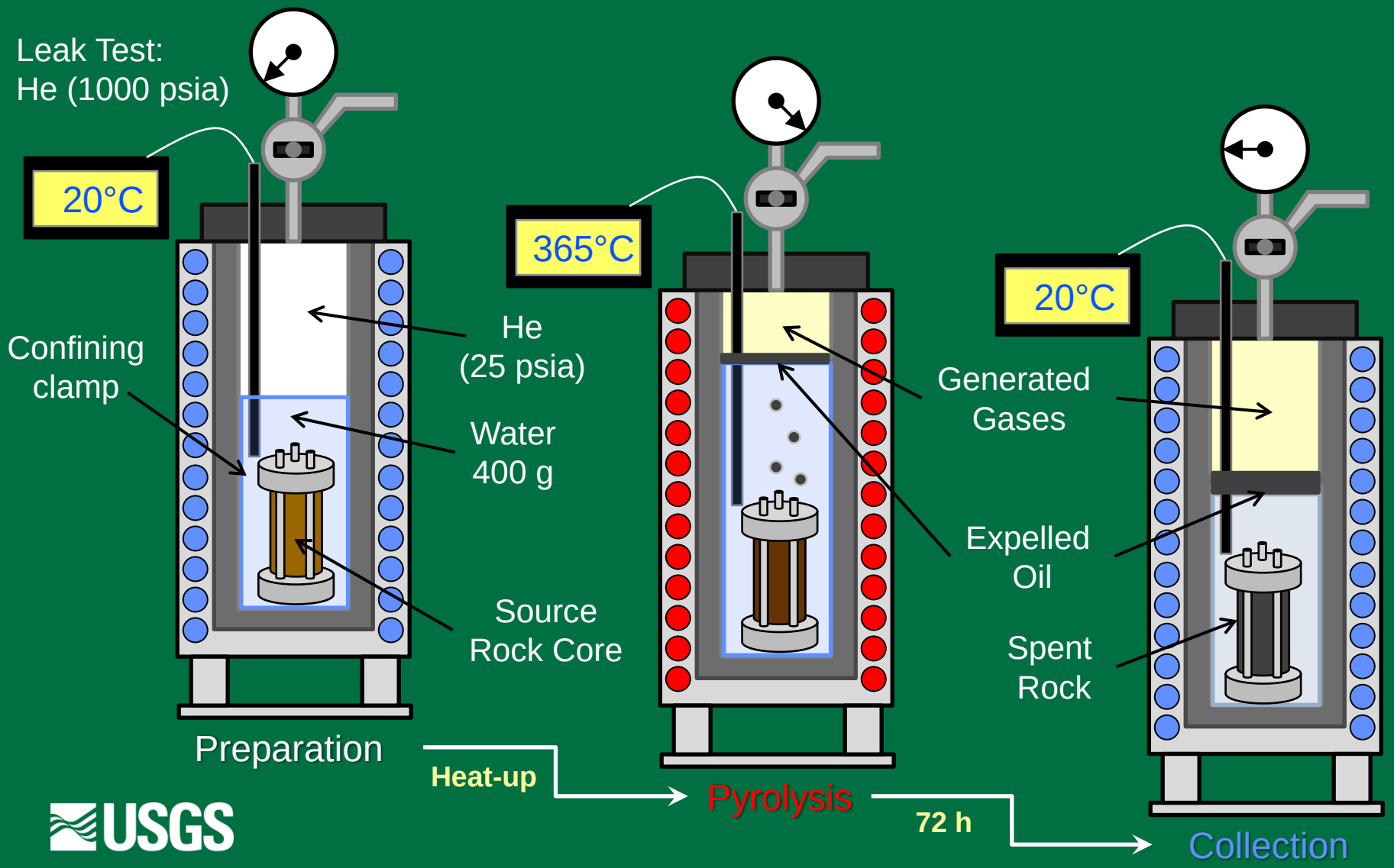
Hydrous Pyrolysis



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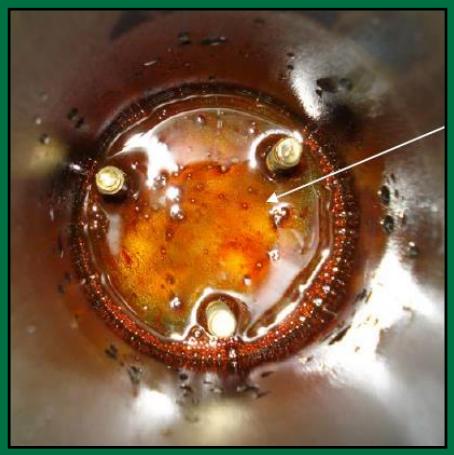
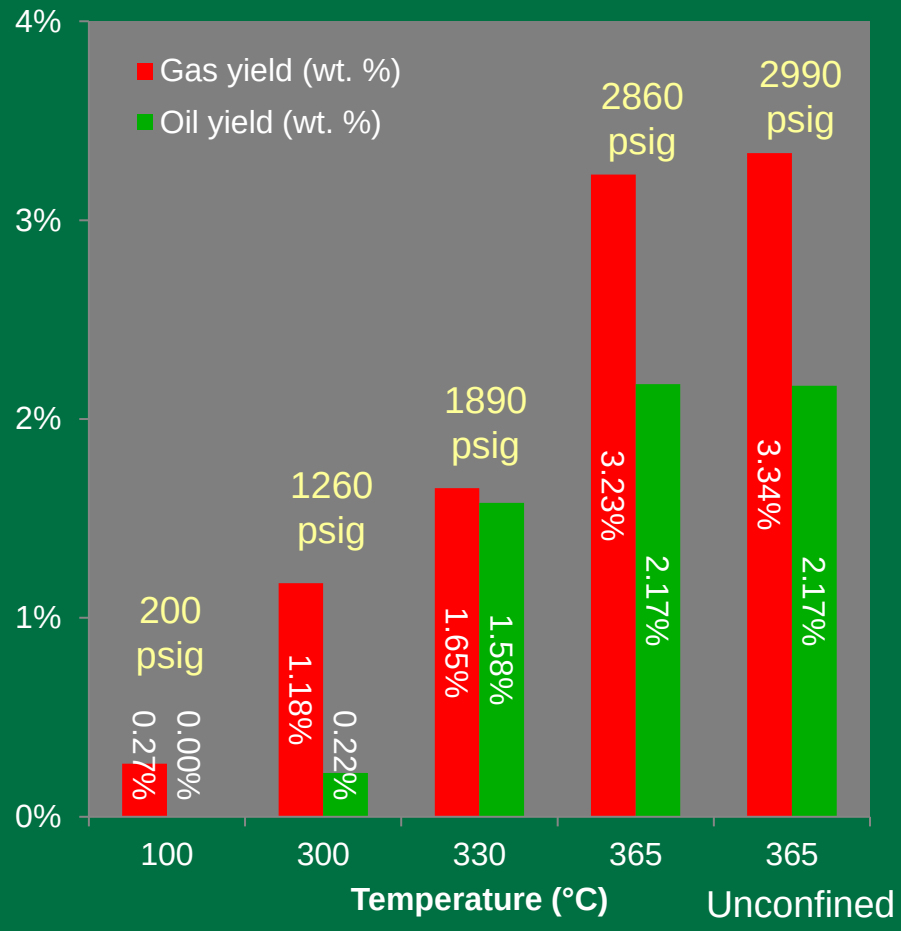
Hydrous Pyrolysis yields

Before pyrolysis

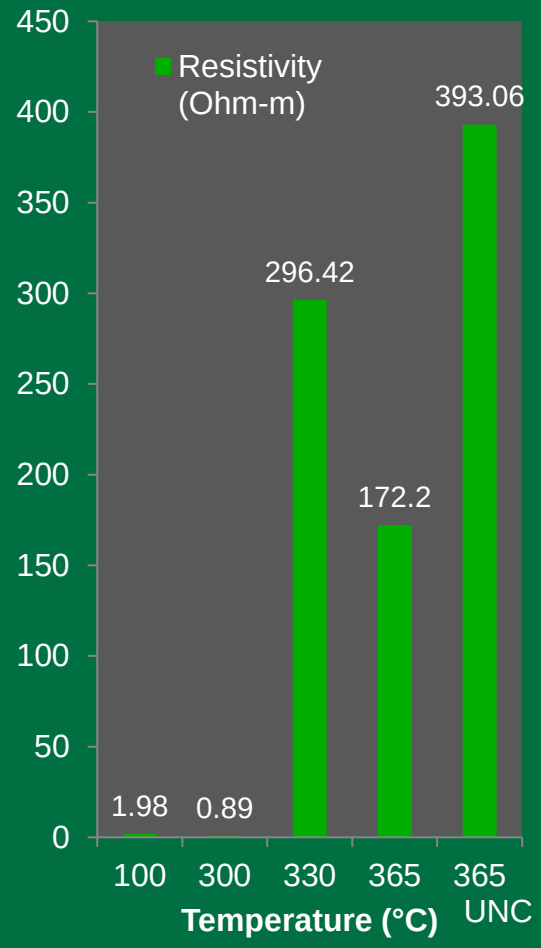
After pyrolysis
(330°C, 72 h)

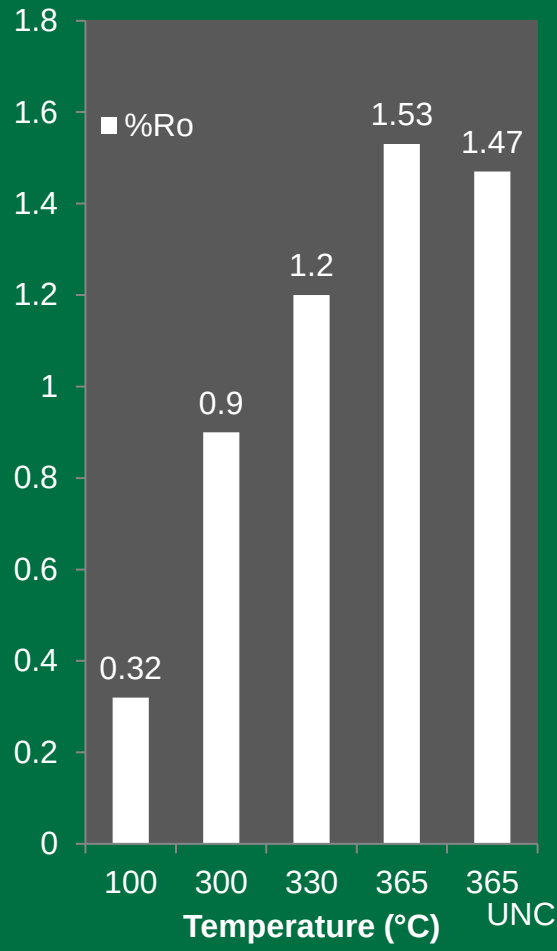


Expelled oil



Characteristics of Recovered Cores





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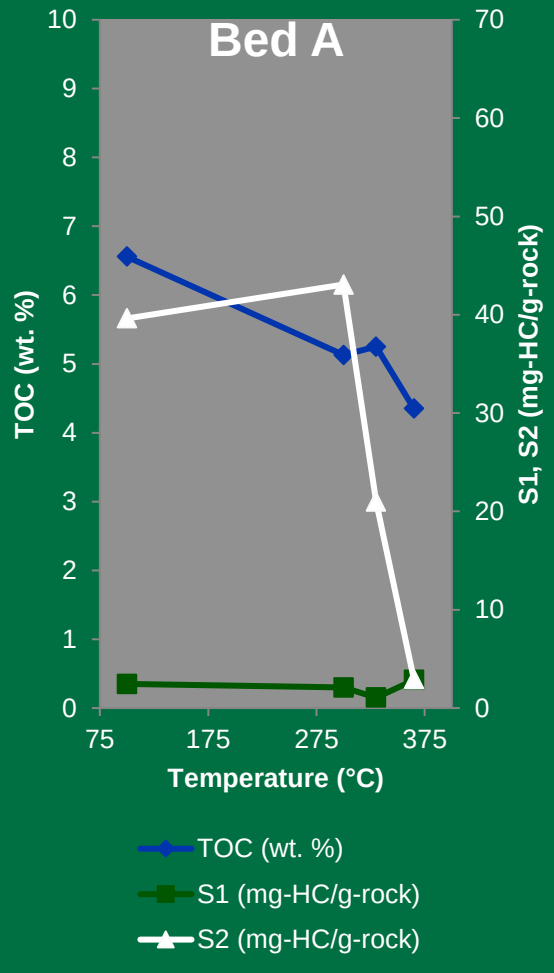
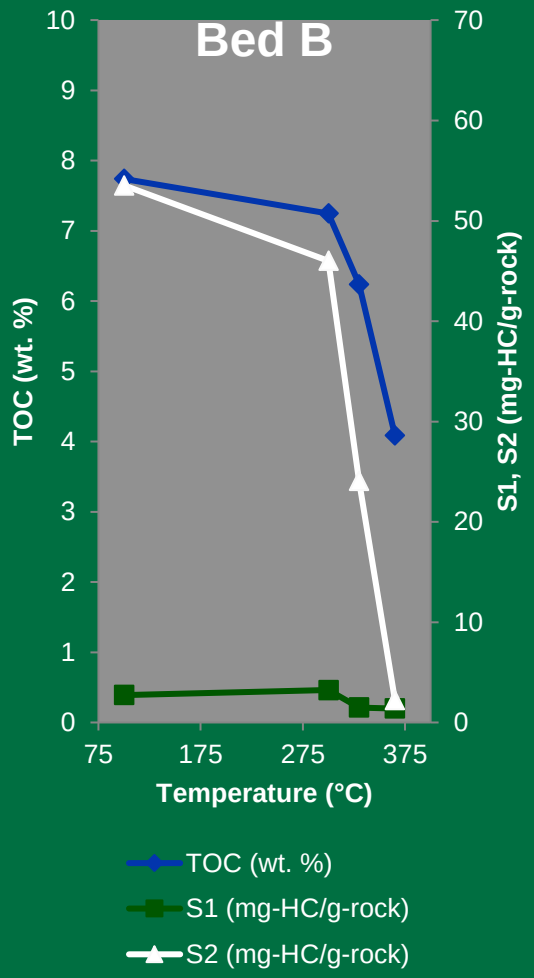
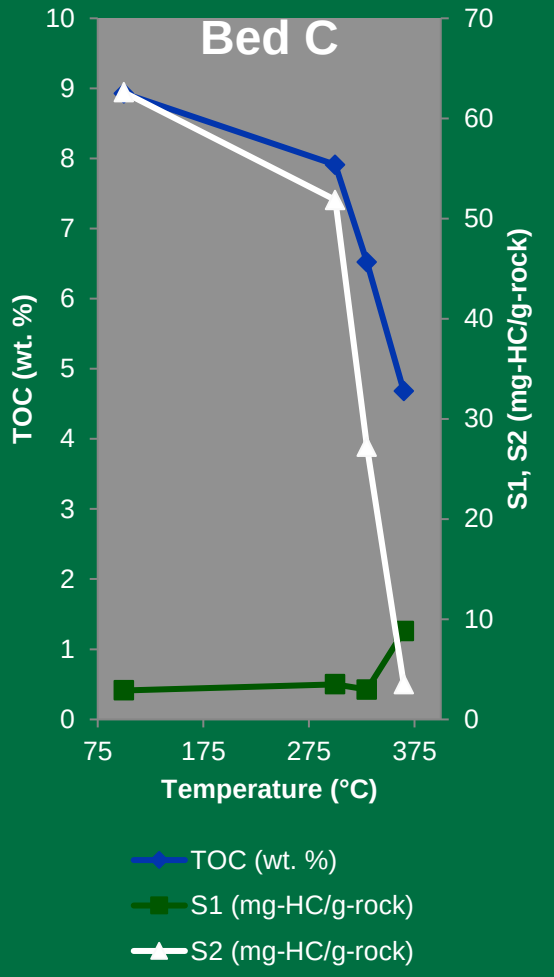
Bulk properties for whole cores
%Ro determined on lignite internal standard

Characteristics of Recovered Rocks







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Bed B data for the **unconfined core** (365 °C, 72 hours) were indistinguishable from results for the confined sample.

X-ray CT Imaging

Instrument: Toshiba Aquilion helical scanner (130 kV/200 mA x-ray tube operating in 64-slice mode and 1.5 seconds per rotation)

225 slices were obtained on each core

Slices were 0.5-mm thick and the voxel size was:
0.28 × 0.28 × 0.30 mm.

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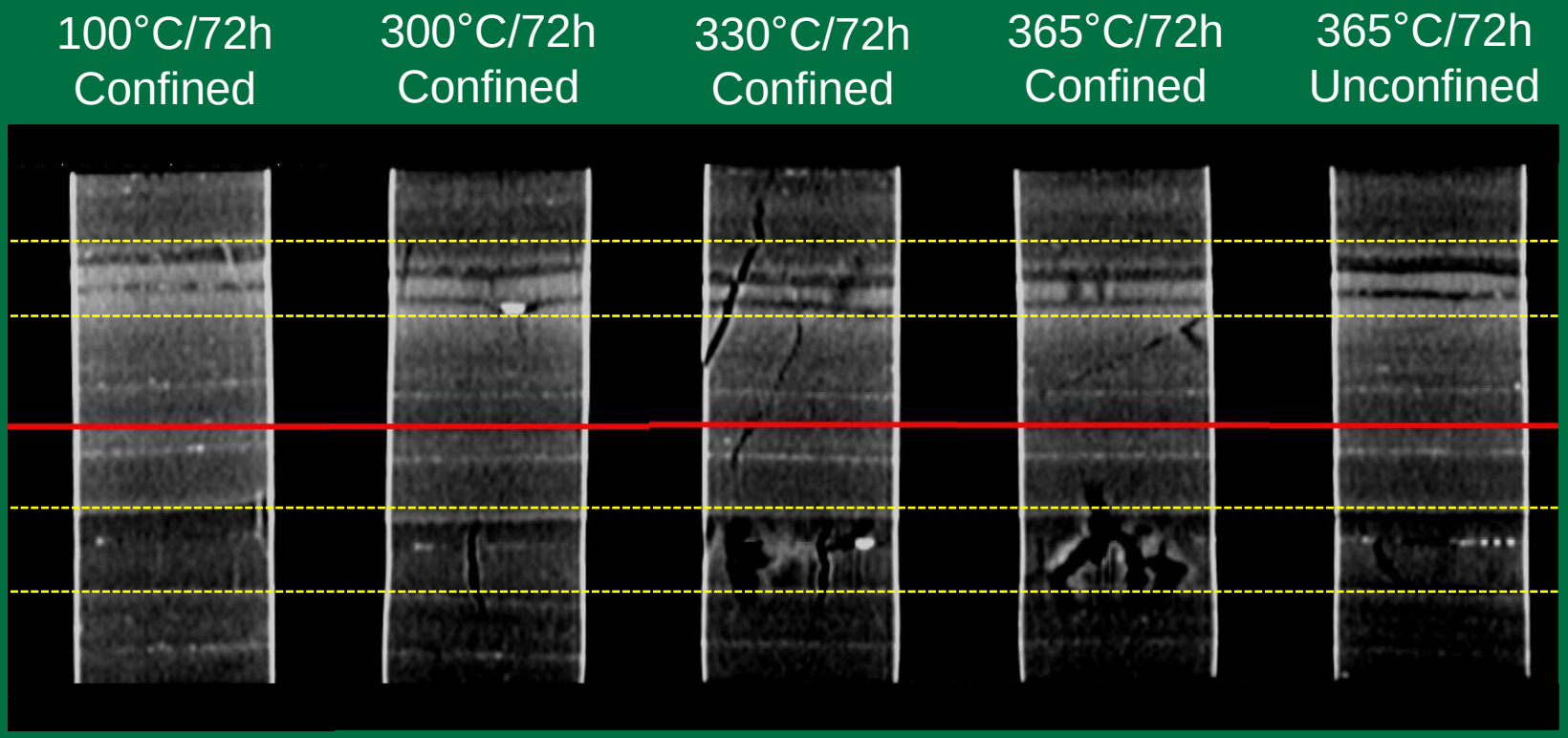
X-CT Summary



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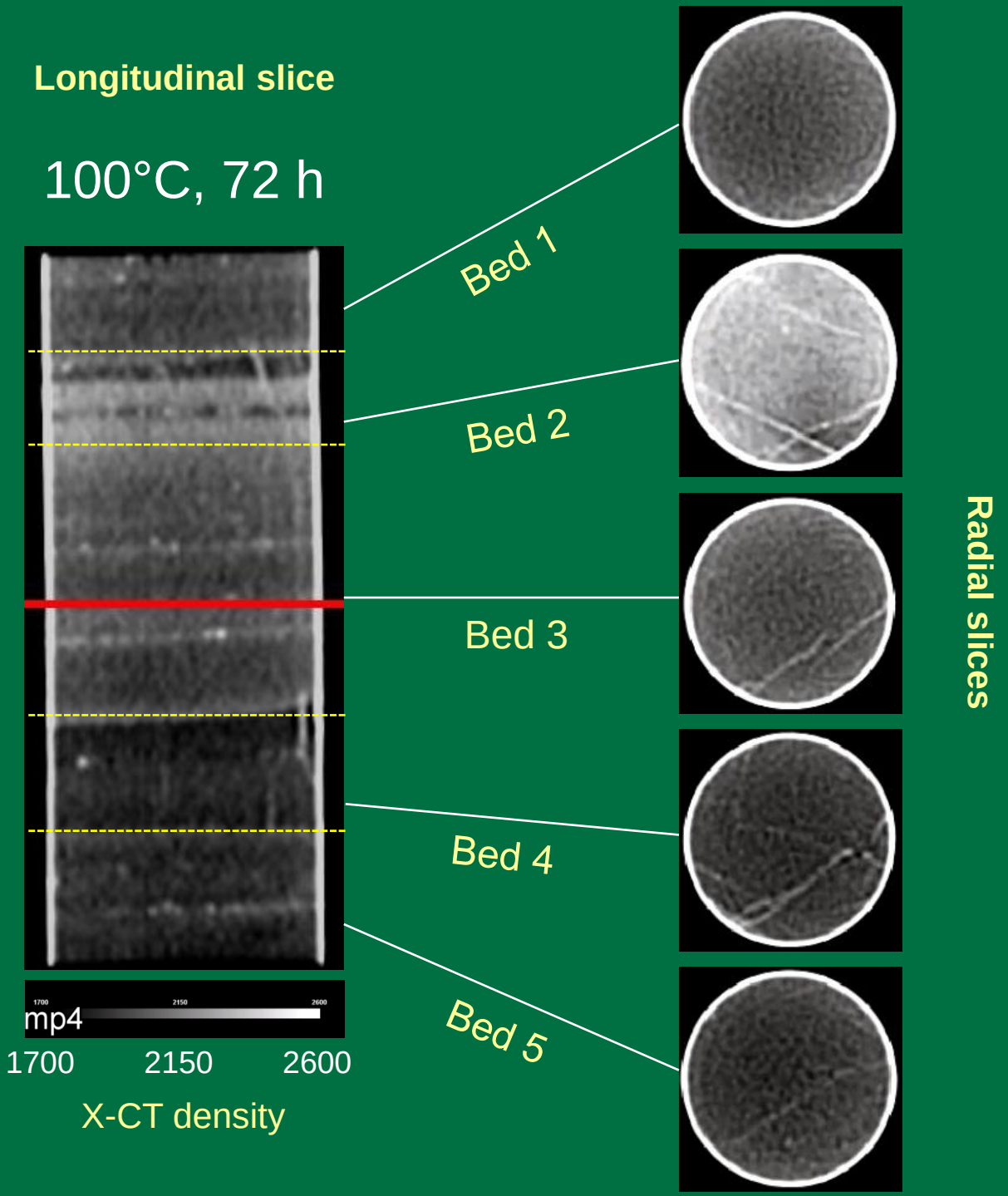
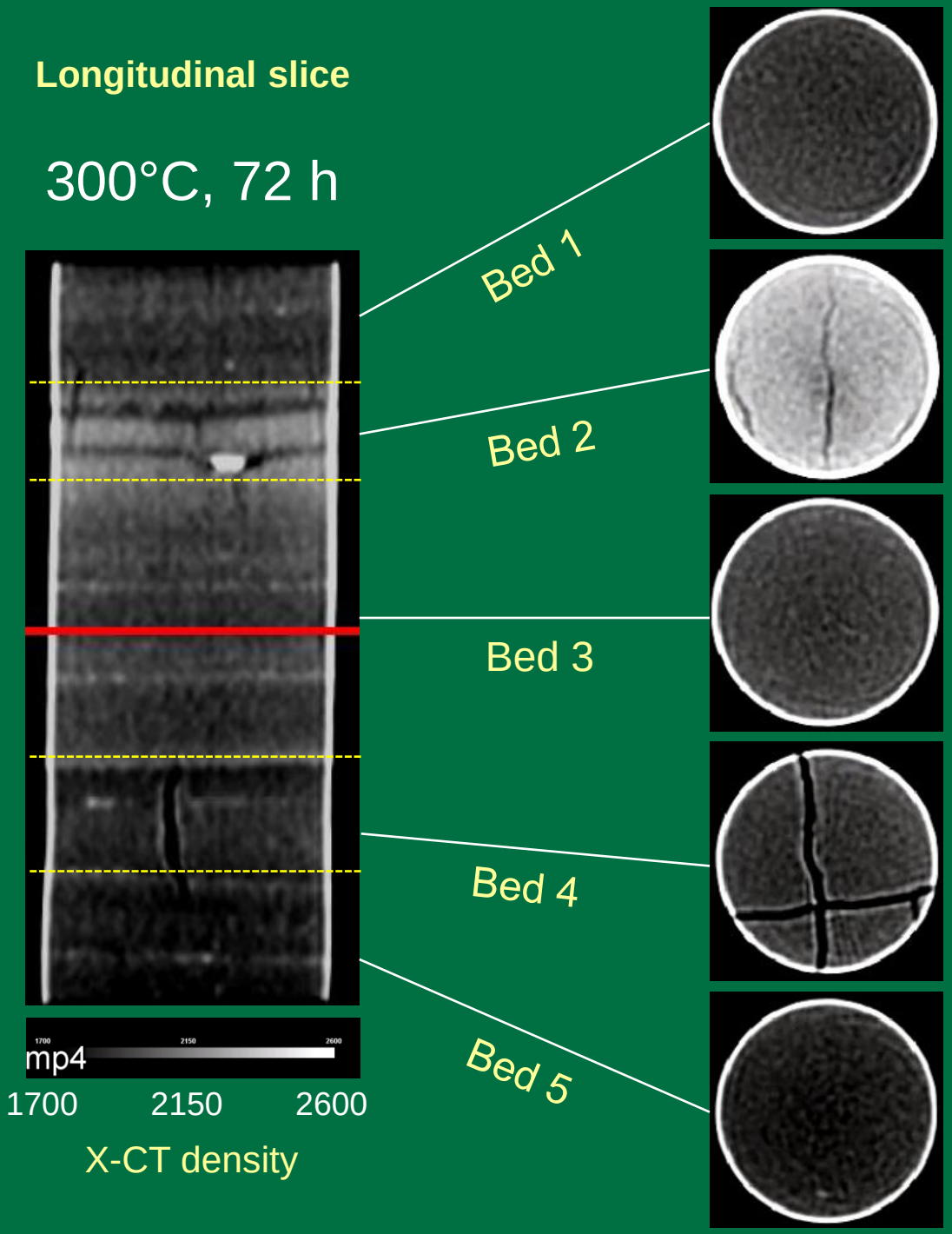

Longitudinal slice
100°C, 72 h
Bed 1
Bed 2
Bed 3
Bed 4
Bed 5
Radial slices
mp4
1700
2150
2600
X-CT density


Longitudinal slice
300°C, 72 h
Bed 1
Bed 2
Bed 3
Bed 4
Bed 5
Radial slices
1700
2150
2600
mp4
1700
2150
2600
X-CT density

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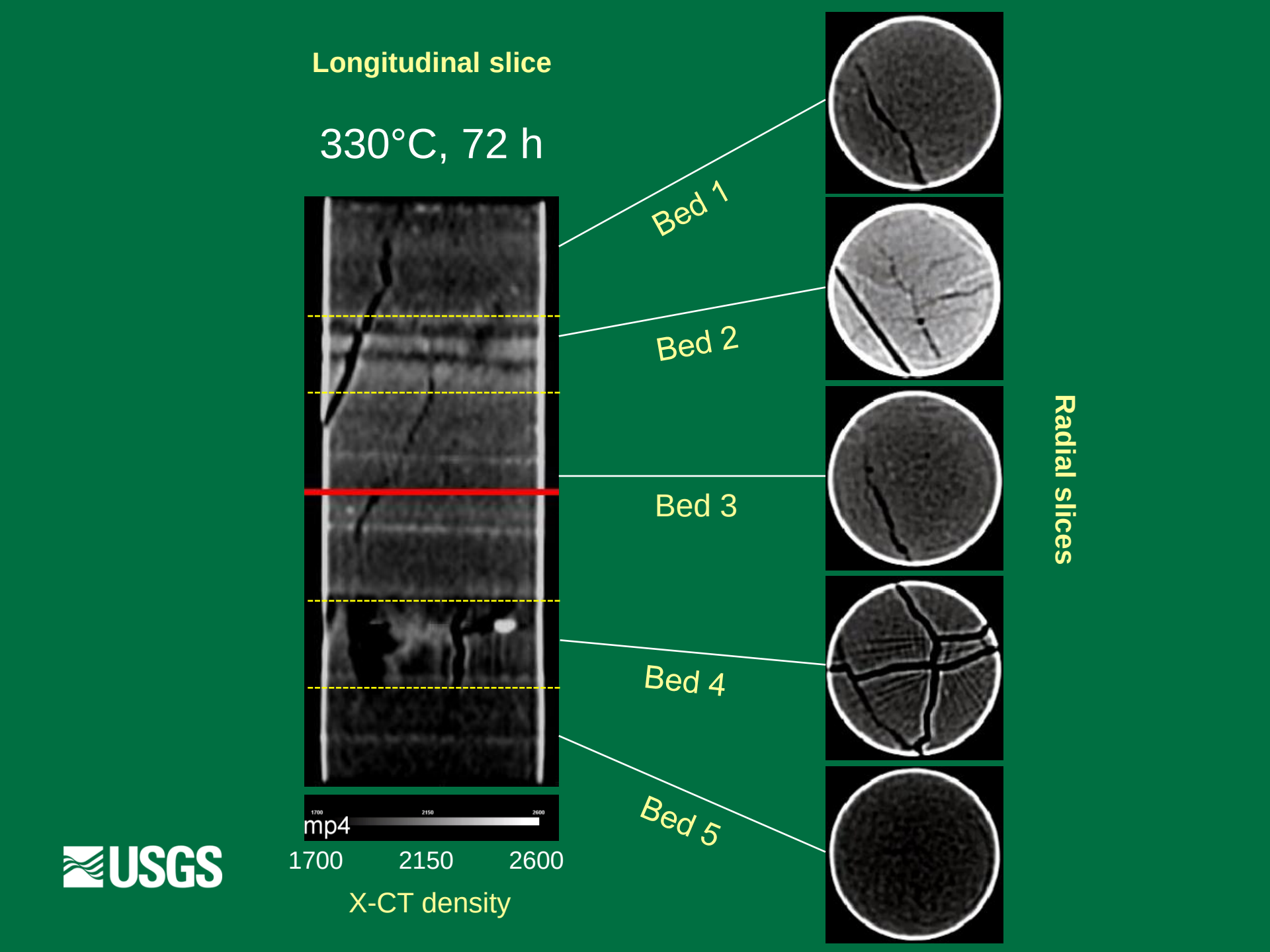
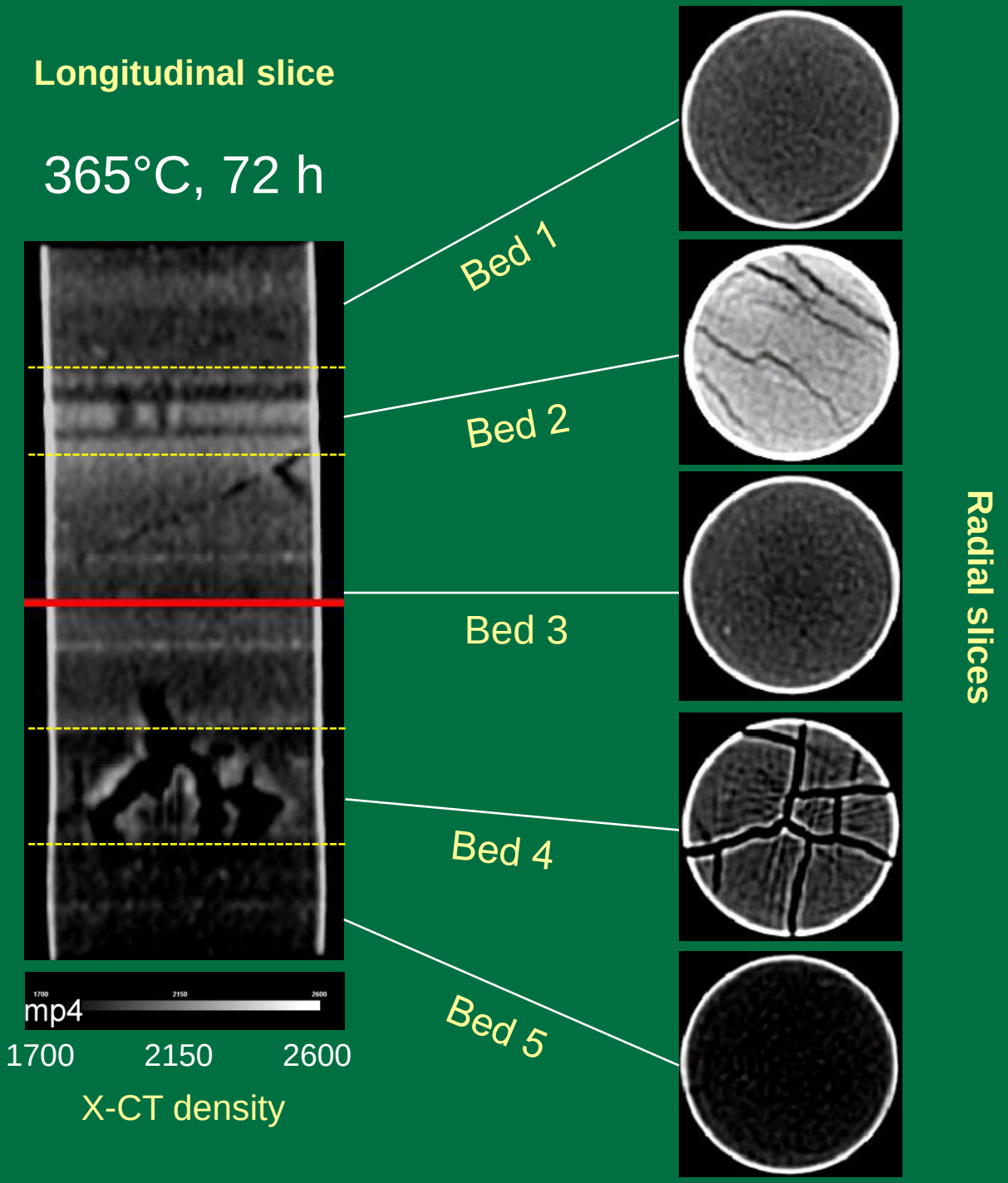
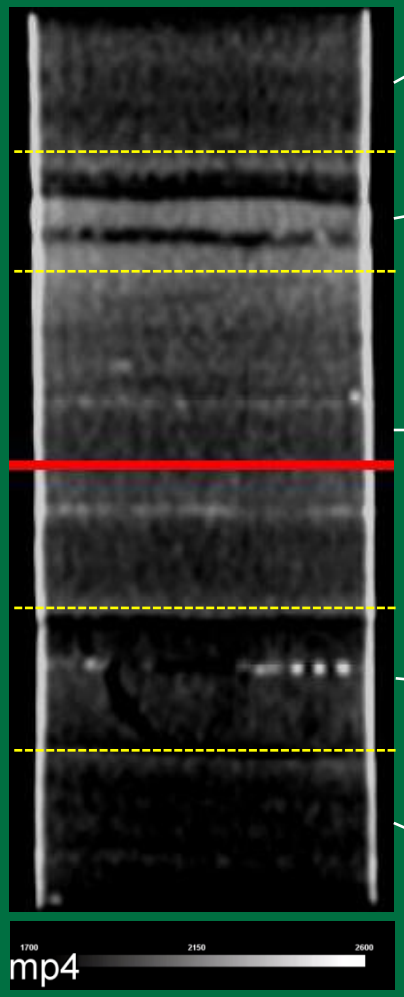

Longitudinal slice
330°C, 72 h
Bed 1
Bed 2
Bed 3
Bed 4
Bed 5
Radial slices
1700
2150
2600
mp4
1700
2150
2600
X-CT density
USGS


Longitudinal slice
365°C, 72 h
Bed 1
Bed 2
Bed 3
Bed 4
Bed 5
Radial slices
1700
2150
2600
mp4
1700
2150
2600
X-CT density
USGS

Longitudinal slice

365°C, 72 h
Unconfined



1700 2150 2600

X-CT density

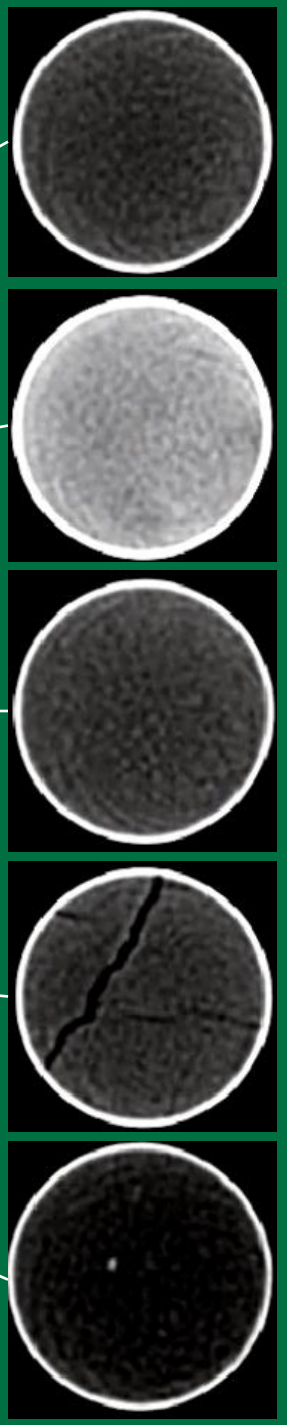
Bed 1

Bed 2

Bed 3

Bed 4

Bed 5



Radial slices

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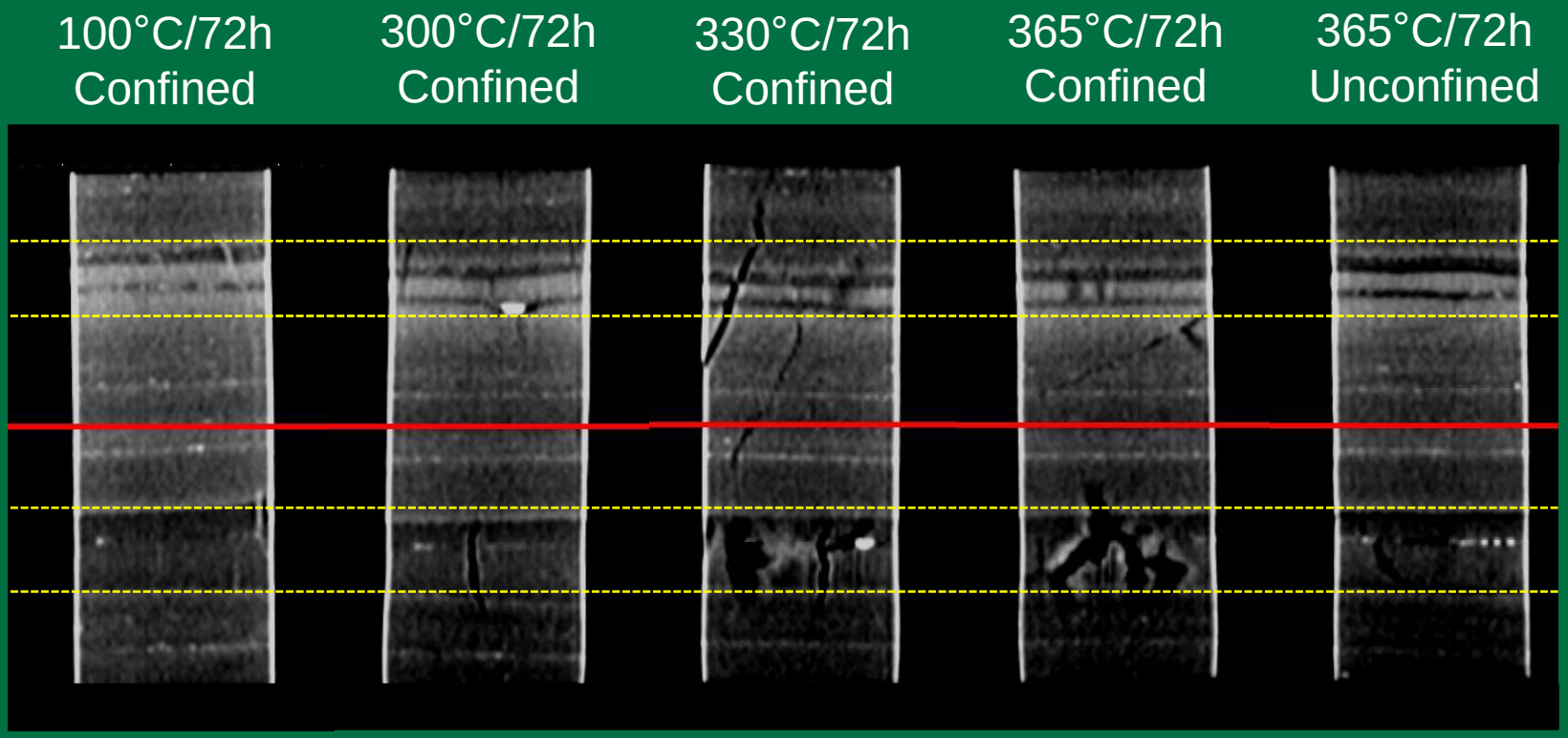
X-CT Summary



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Conclusions

- Fractures do not appear to be generated during artificial maturation by Hydrous Pyrolysis
- Under confinement, existing fractures are enhanced
- Fracture density appears to vary by lithofacies within Woodford Shale samples
- Product yields and geochemical properties are unaffected by core confinement

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QUESTIONS?

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