Non-Destructive Analysis Shows Aggregate Deterioration Created Air Void System In 1910's Pavements

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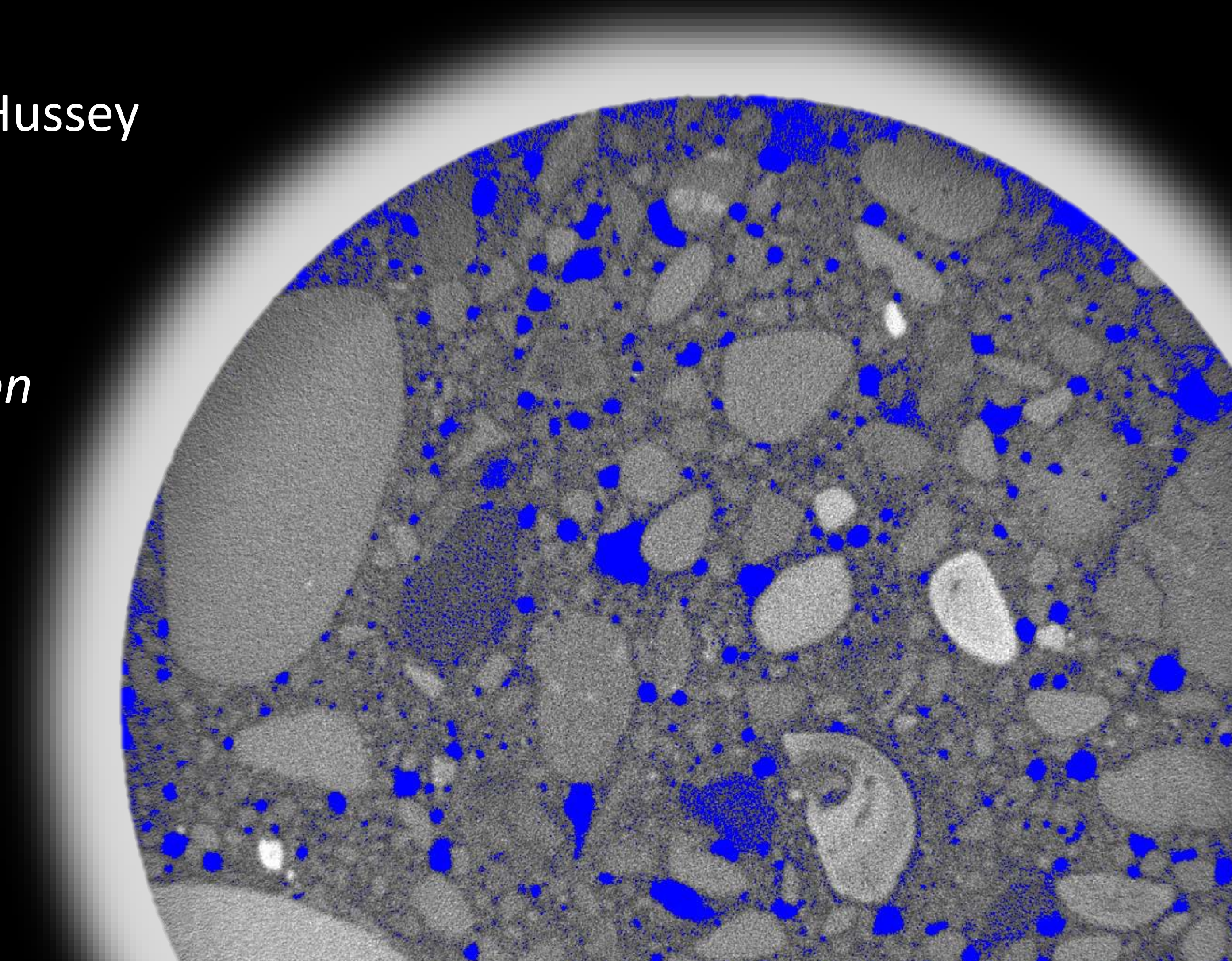


Executive Summary

Some portland cement concrete pavements in Iowa have shown negligible deterioration despite…

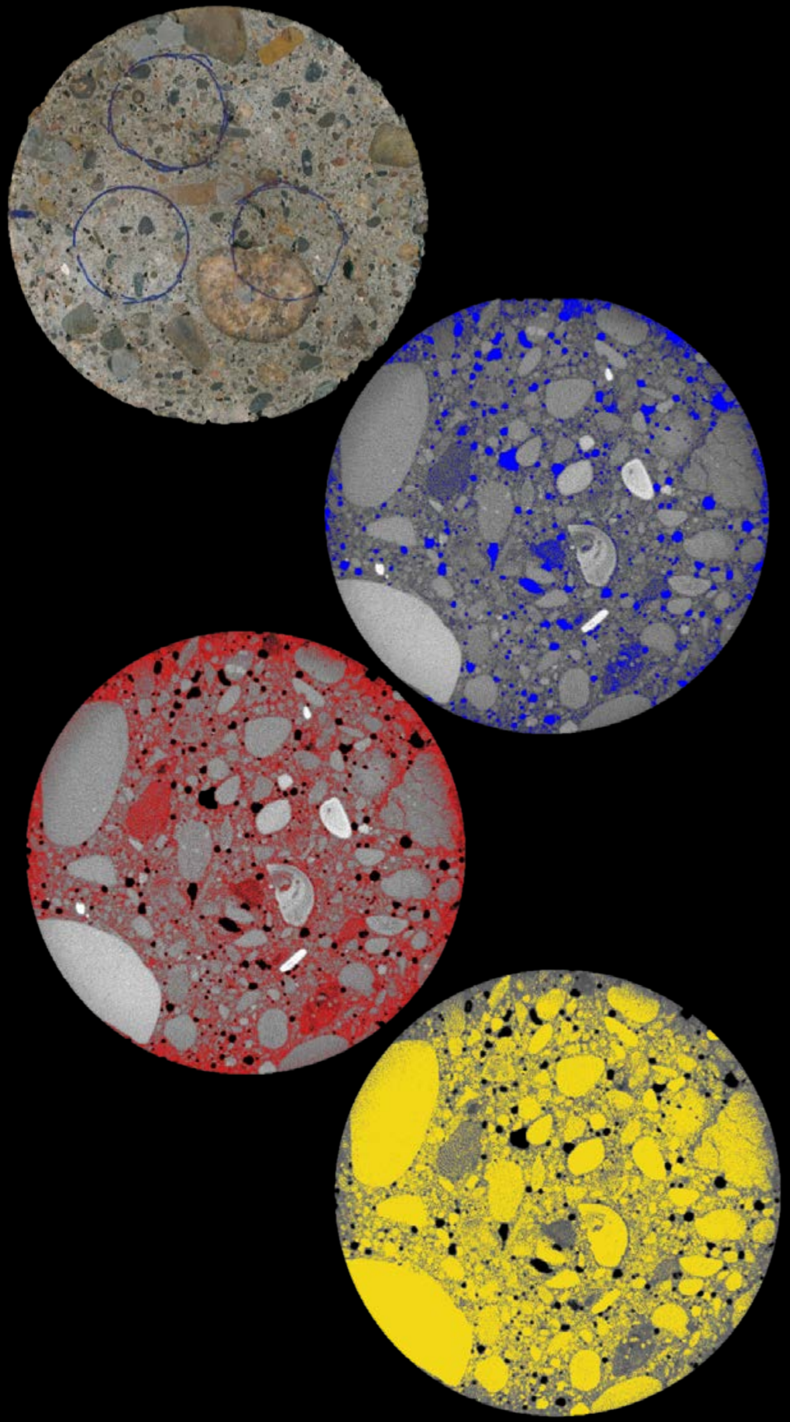
- Long service lives
- No entrained air

Thirteen PCC cores were analyzed by image analysis (ASTM C457) and helium pycnometry.

- Pavement age and porosity are highly correlated ($R^2 \approx 0.8$) for both methods
- Helium porosity was higher than C457 porosity by ~5 percentage points

Three cores were tomographic imaging

- Pores, paste, and grains were clearly distinguishable
- Pores with the shape of coarse aggregate grains suggest dissolution
- These pores may have permitted these pavements to escape deterioration



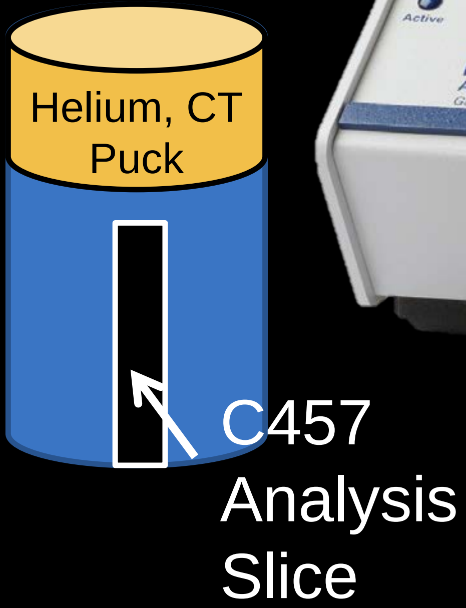
Sample Locations

1914-Mahaska
1921-Woodbury
1929-Wapello
1938-Monona
1946-Pocahontas
1955-Greene
1963-Marshall
1976-Hamilton
1980-Boone
1992-Story
1997-Linn
1999-Story
2002-Jones

Measuring Air Voids

RapidAir Analyzer (ASTM C457)
Analyzes 2D Images

Helium Porosimeter (Pycnometer)
Measures solid 3D volume

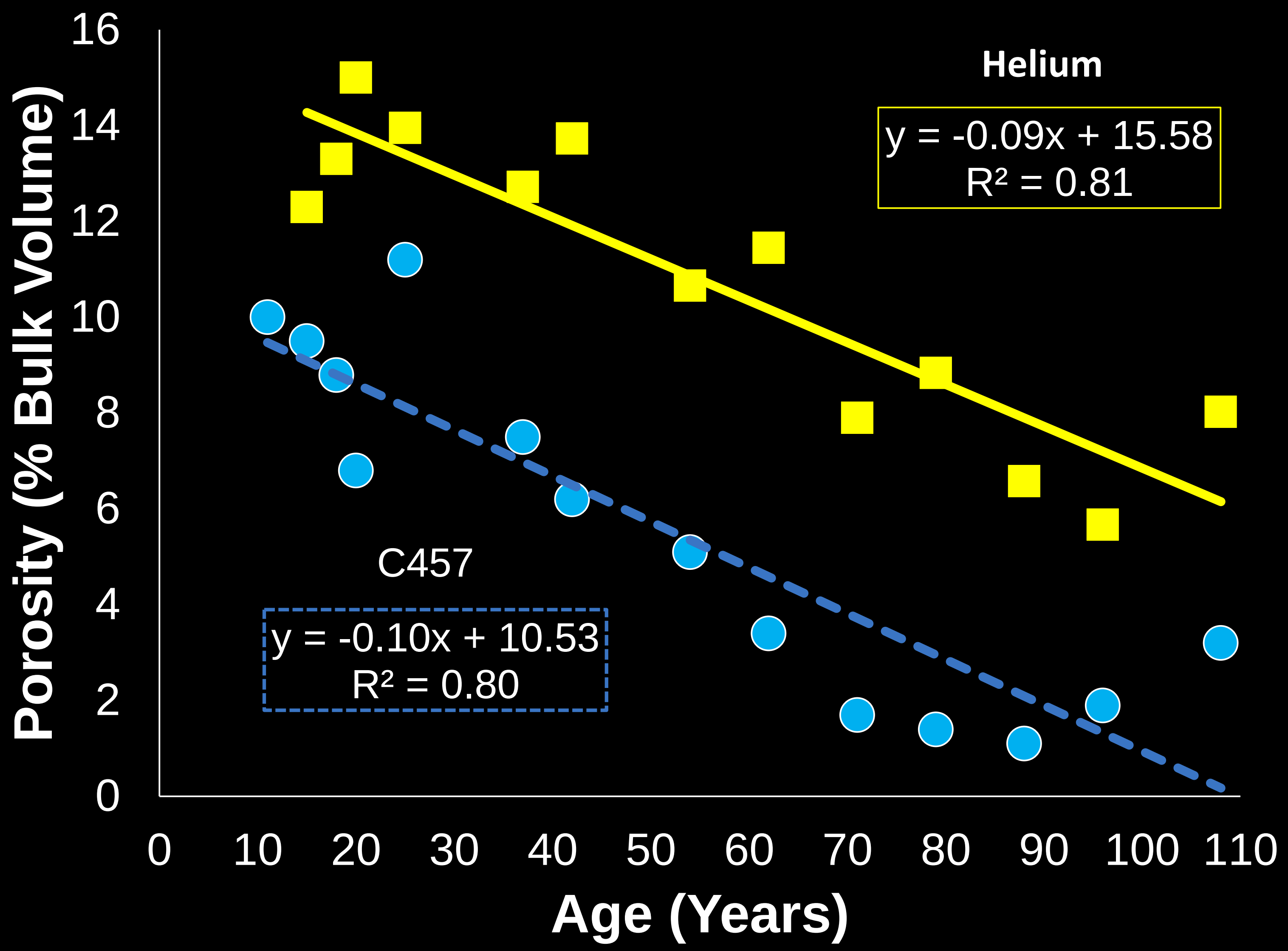


Helium Porosity Results

ASTM C457 image analysis and helium show strong correlation with age.

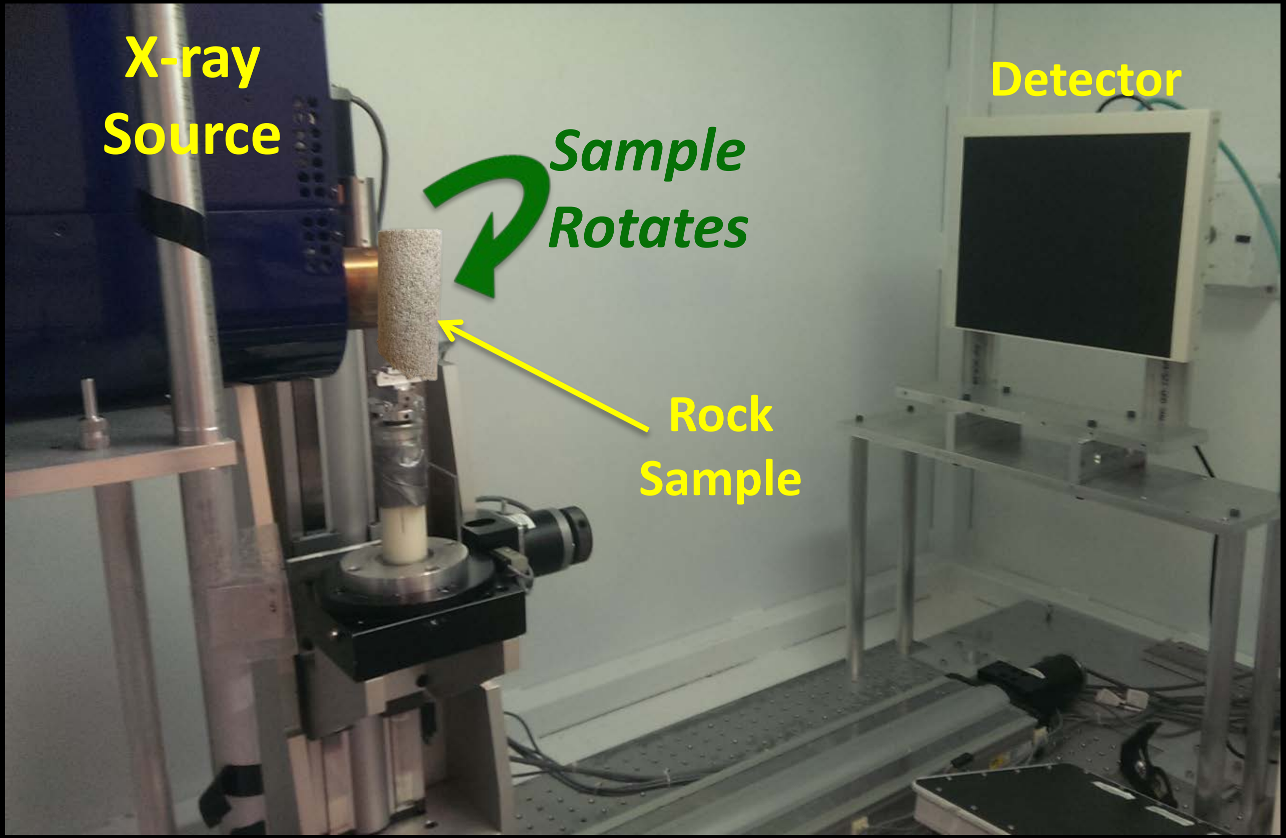
($R^2 \approx 0.8$ for both methods)

Difference could be coarse aggregate porosity and/or porosity below resolution of imaging.



Computed Tomography, *a non-destructive look inside*

Center for Nondestructive Evaluation, Iowa State Univ



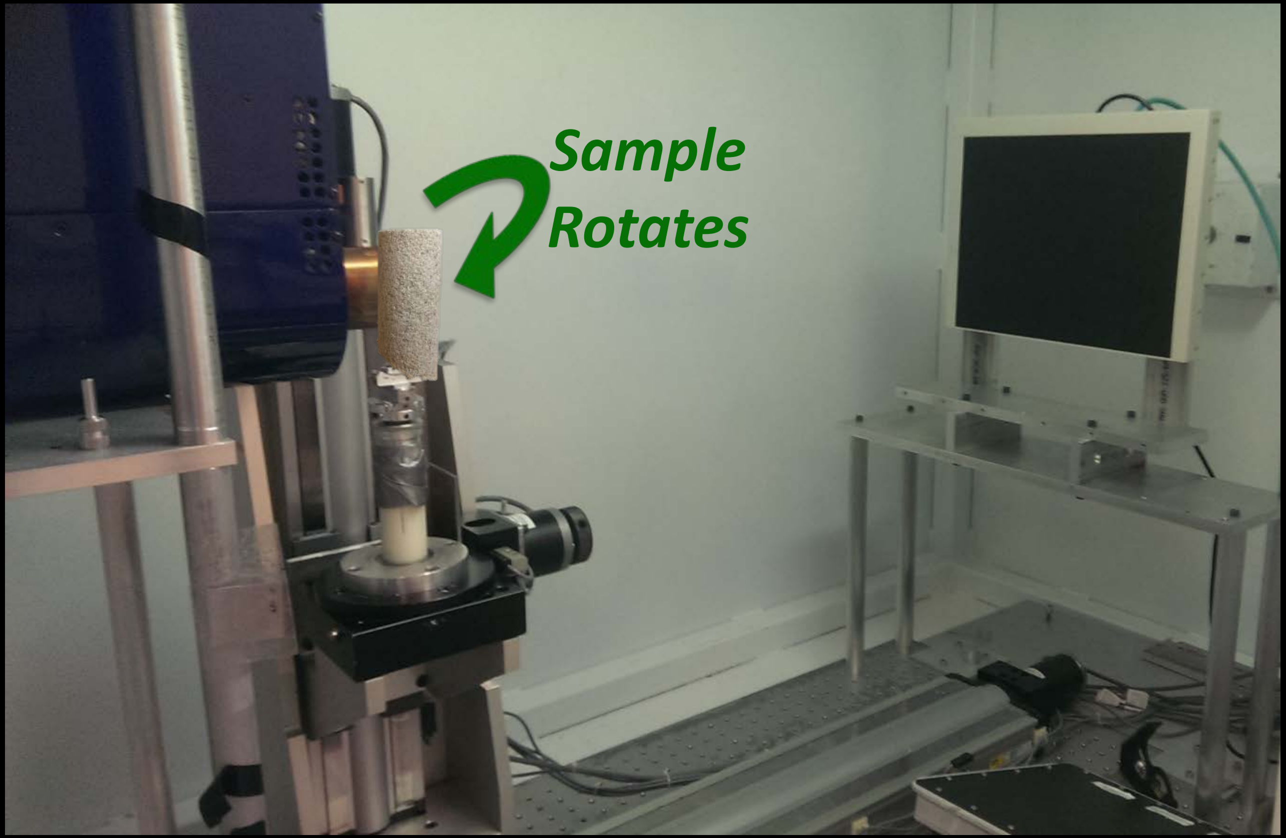
Higher Resolution

→ Smaller Sample Size

→ More Scanning Time

→ Larger File Size

How a Medical CT Scanner Works

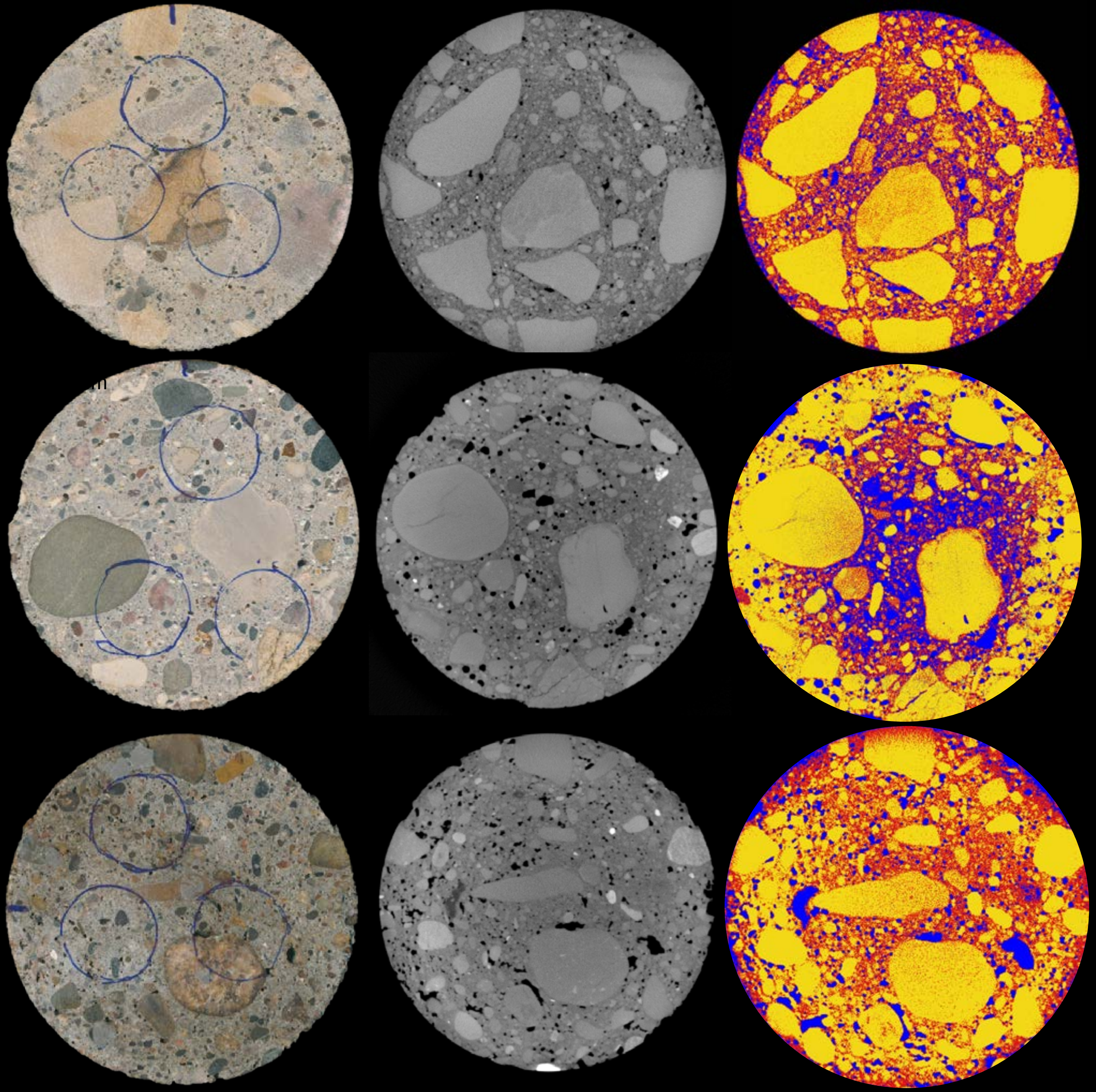


Comparing Samples: Light vs X-Ray

I-35 1999
(Story County)

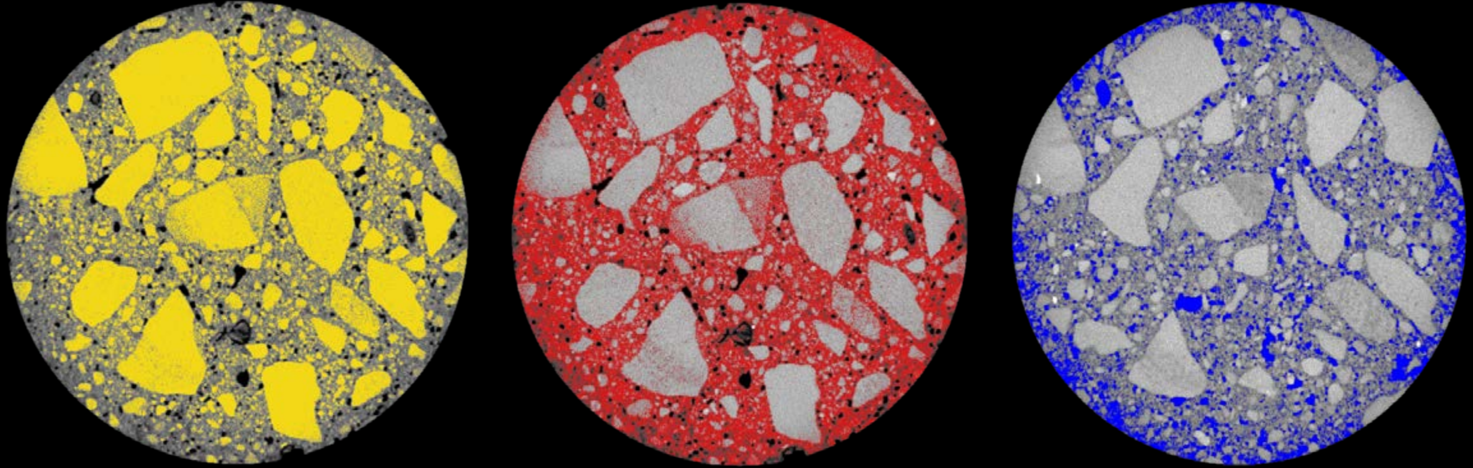
US-20 1921
(Woodbury County)

Eddyville 1913
(Mahaska County)

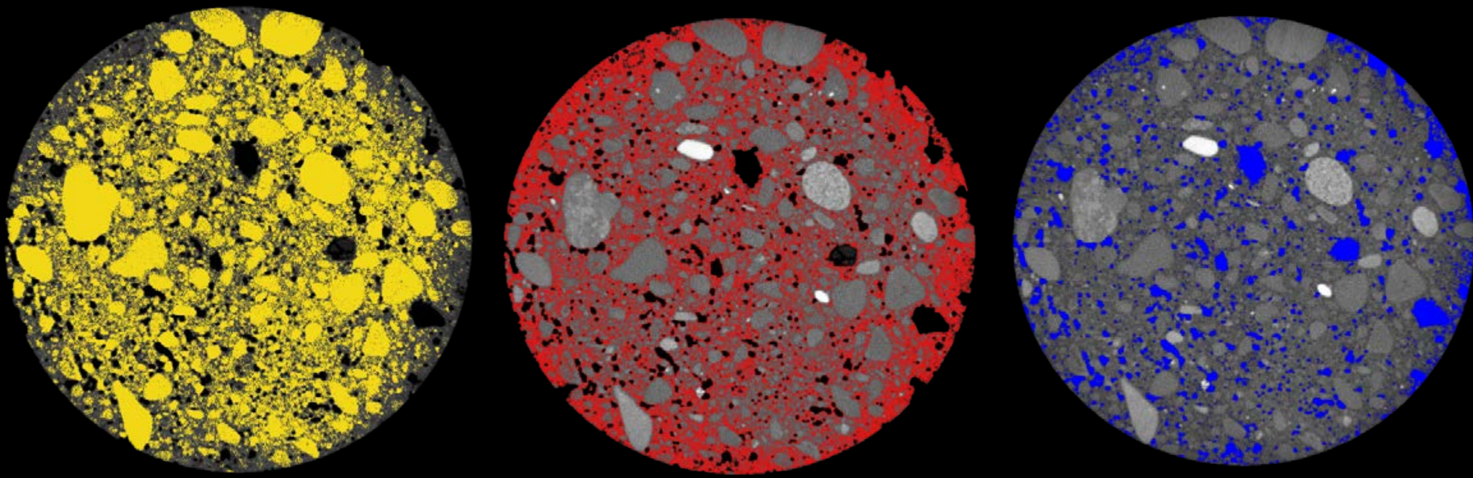


Tomography Data

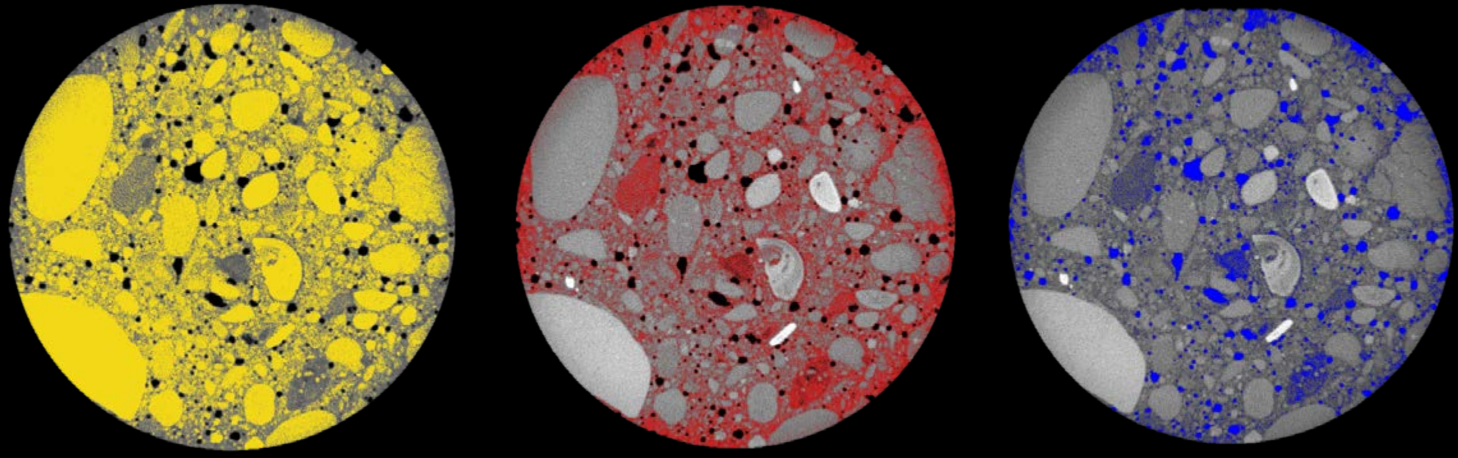
I-35 1999
(Story County)



US-20 1921
(Woodbury County)



Eddyville 1913
(Mahaska County)

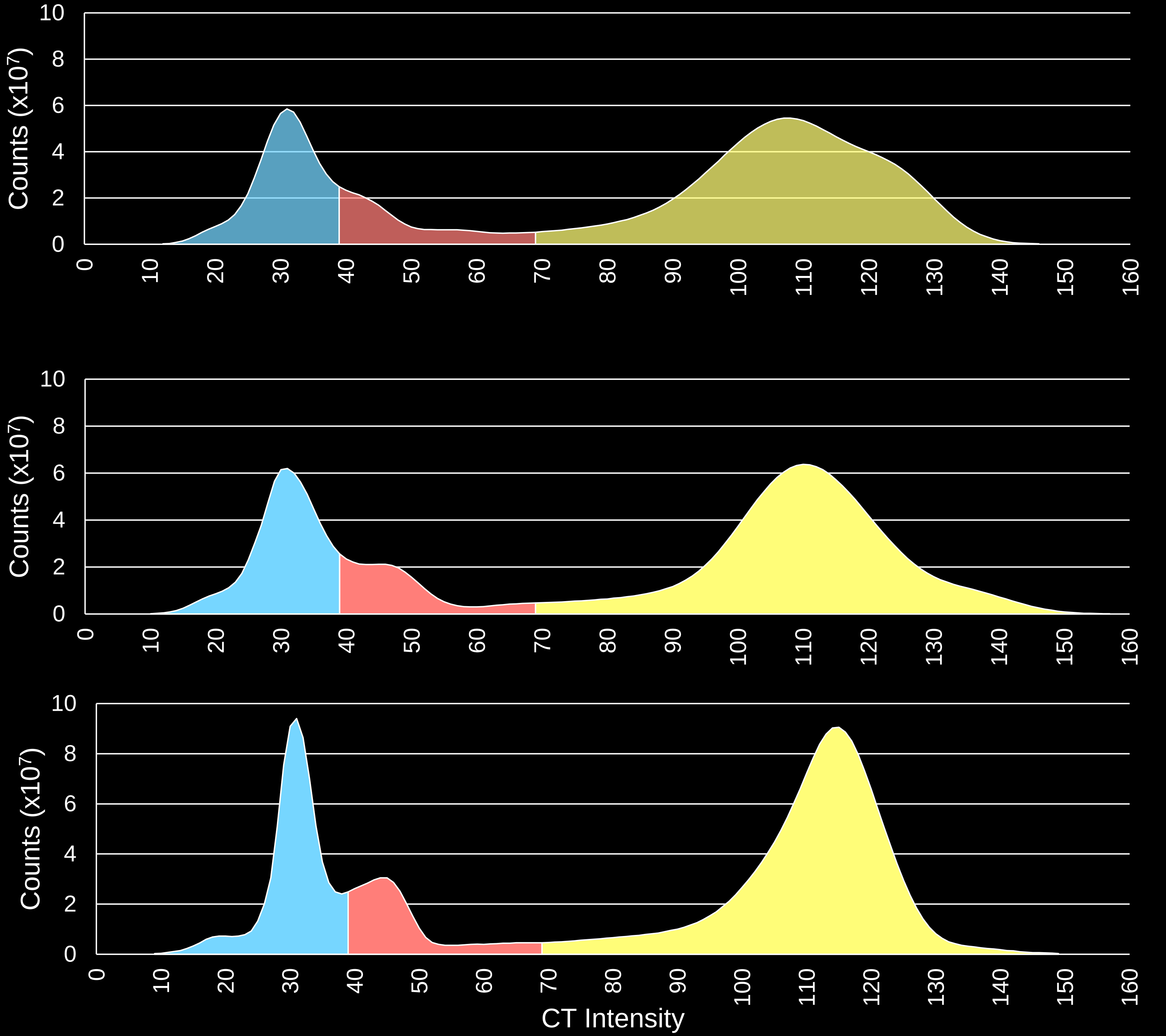


Tomography Histograms

I-35 1999
(Story County)

US-20 1921
(Woodbury County)

Eddyville 1913
(Mahaska County)

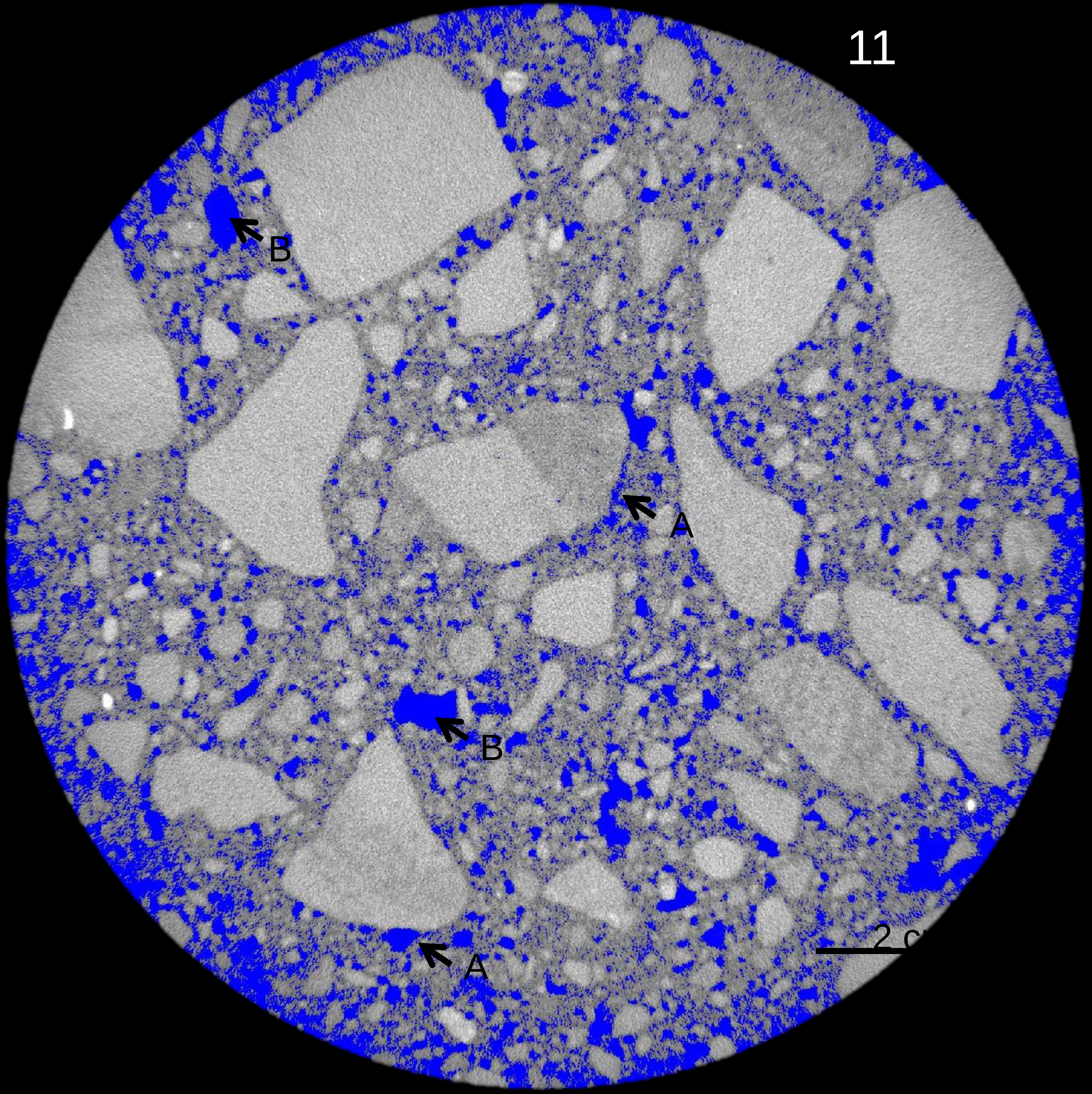


I-35 Pores in Blue

Pores are broadly disseminated throughout the puck and small in size

A. The pores are inter-granular, often grouped around coarse aggregate grains (“circumgranular” pores, A)

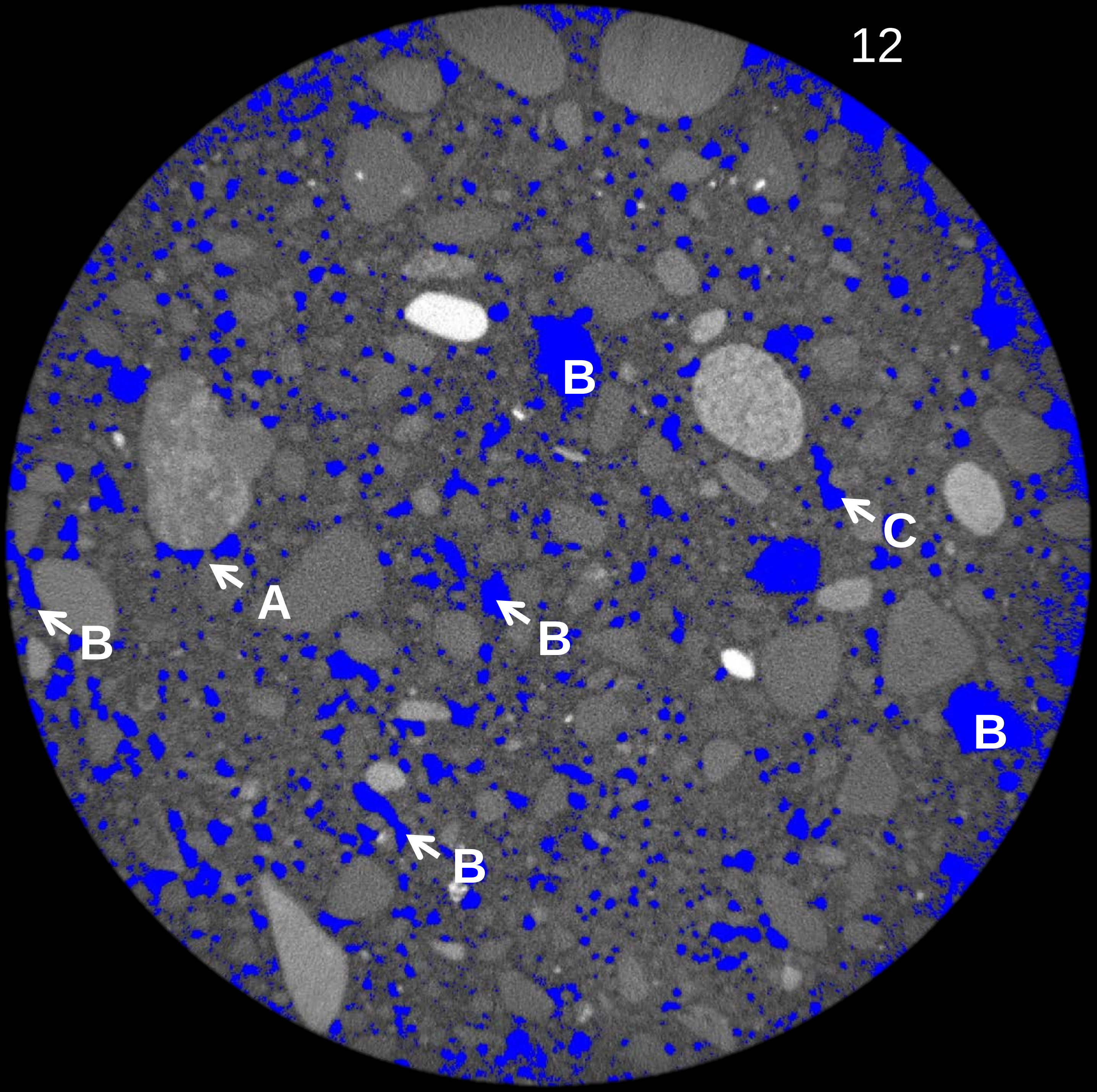
B. There are rare occurrences of what appear to be pores formed by the dissolution of grains (“moldic” pores, B)



US-20 Pores in Blue

Similar circum-granular pores are seen in this image (A), though they are not as common as in I-35.

Moldic pores (B) are more common and some coalesce into larger irregularly shaped pores (C).

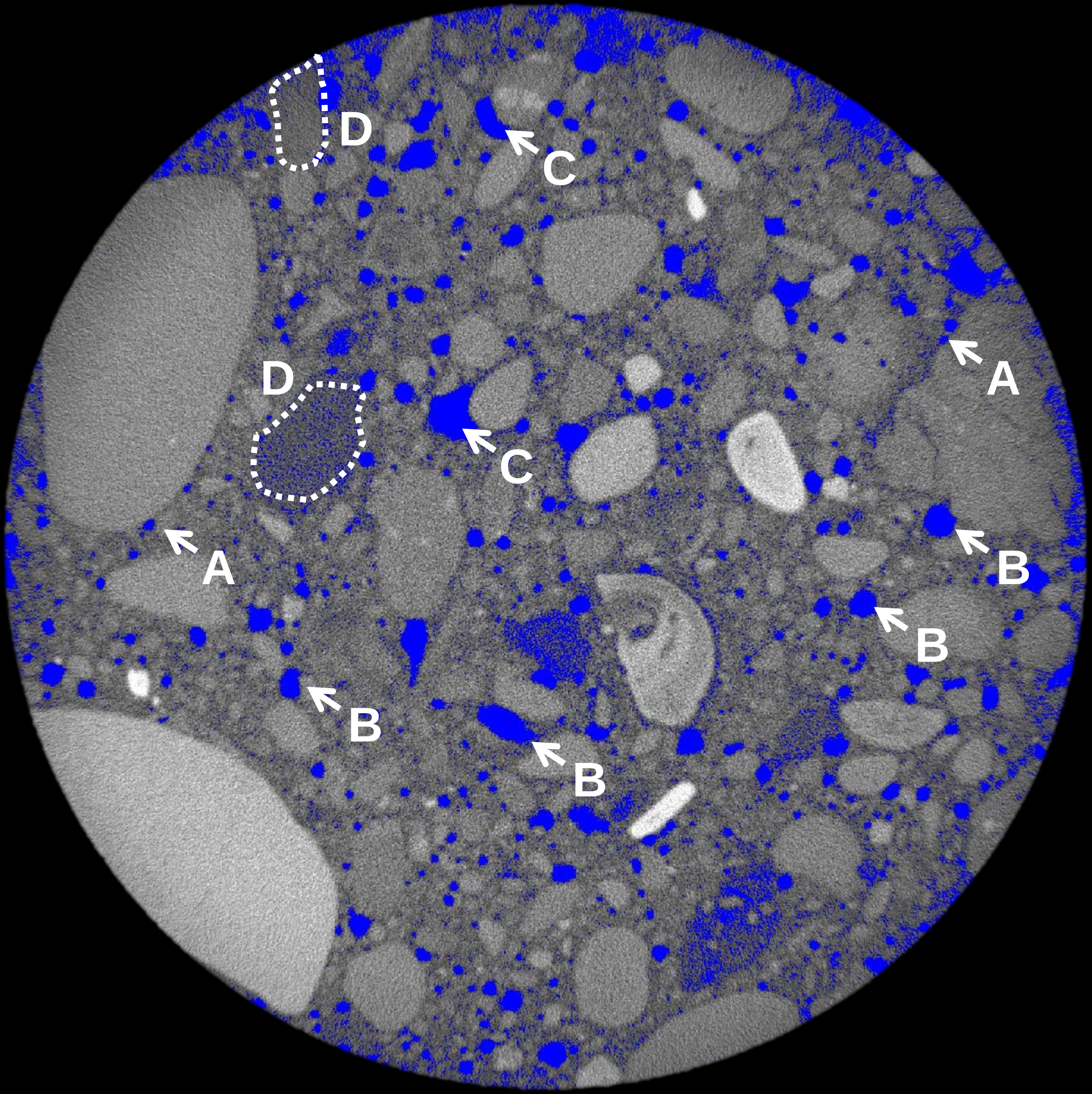


Eddyville Pores in Blue

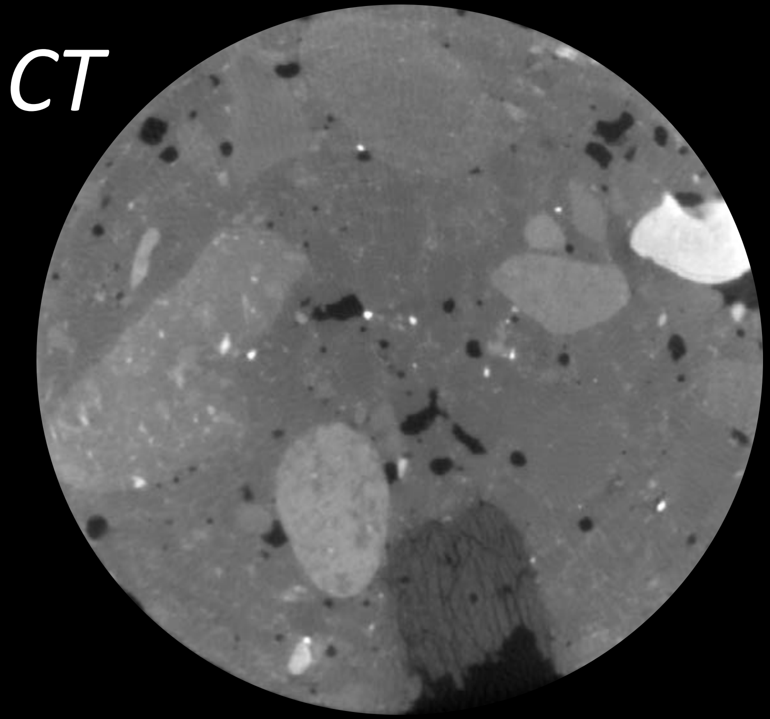
It shows:

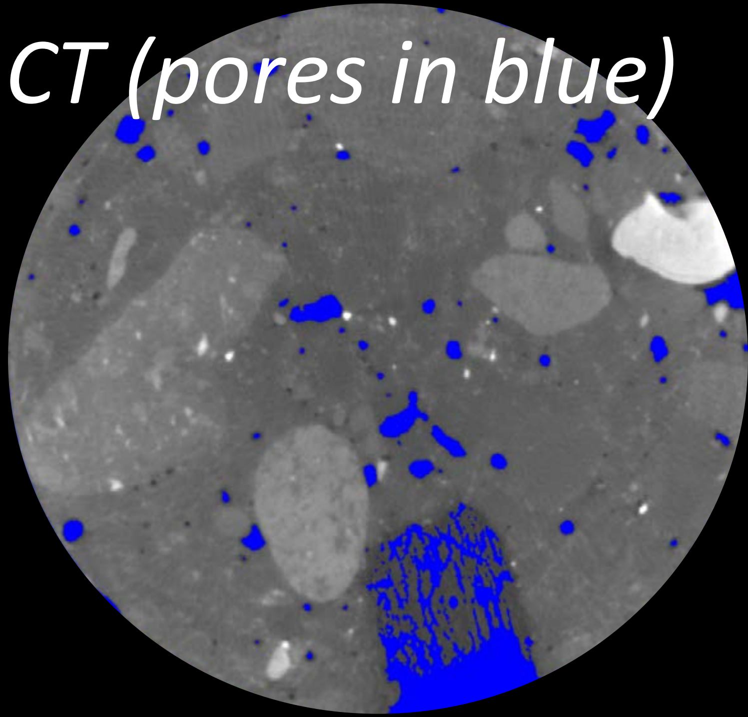
A. circumgranular pores
B. abundant moldic pores
C. common coalescent pores

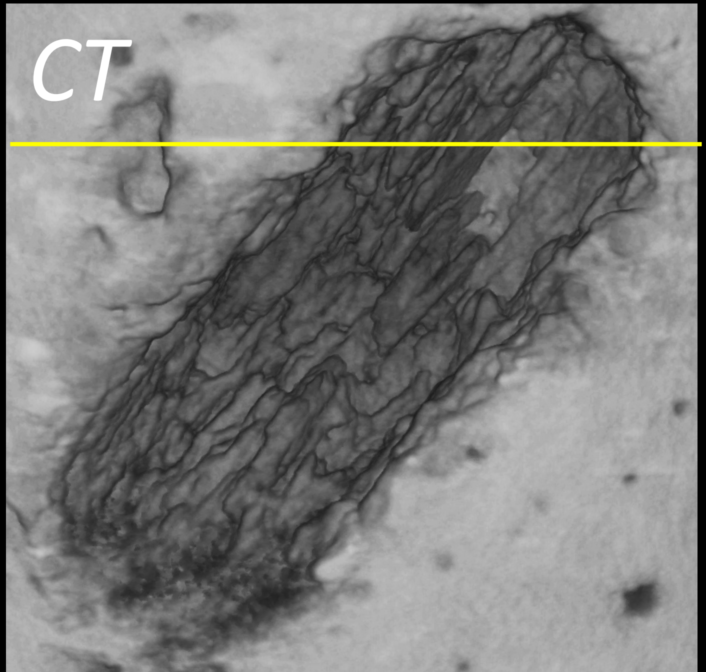
In addition, t36 shows that some large coarse aggregate grains are deteriorating (D).



Deteriorated Coarse Aggregate at Eddyville





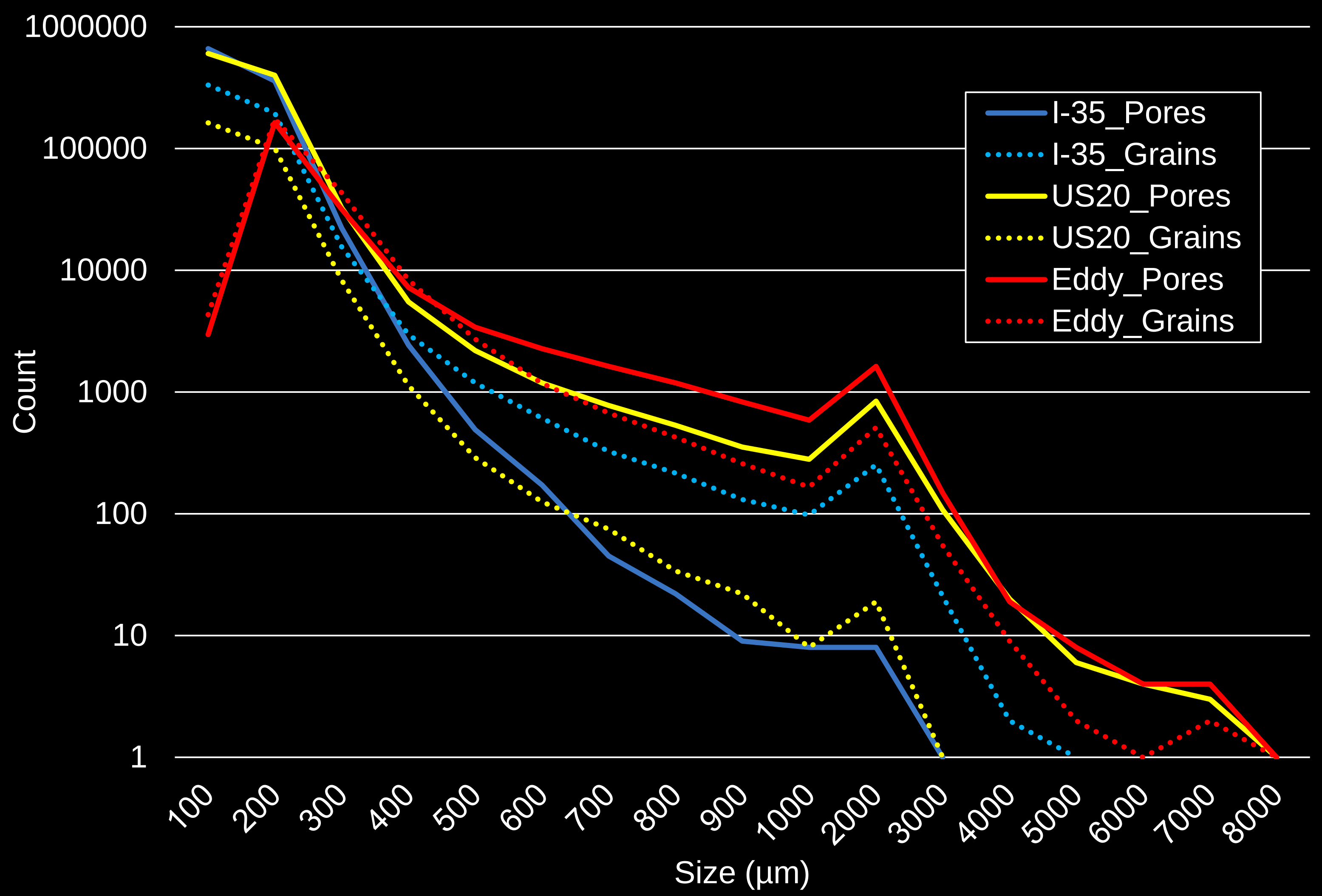


Size distribution histogram of grains and pores

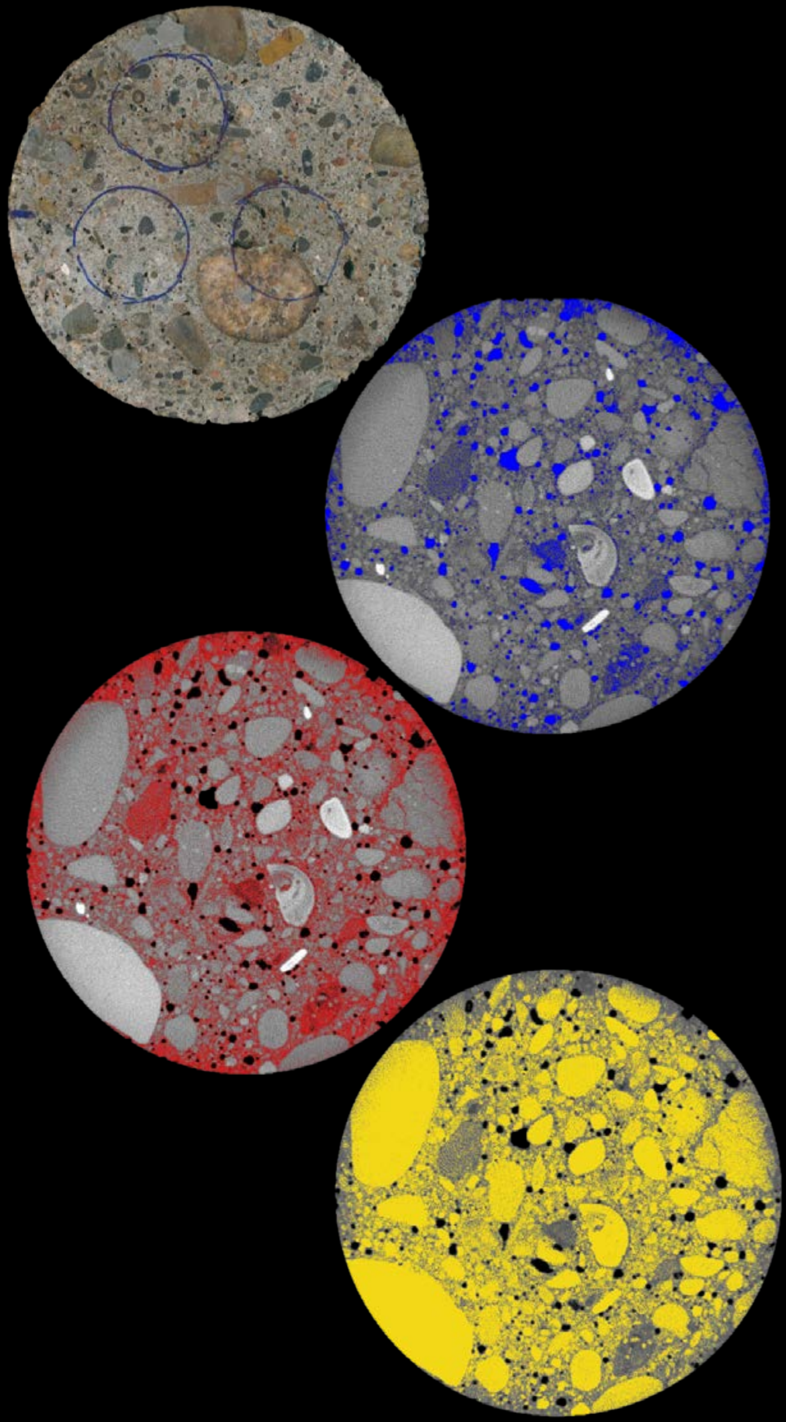
I-35 **grain** size distribution falls between those for US-20 and Eddyville, I-35's **pore** size distribution is much lower.

Construction practices?

Diagenetic processes?



Executive Summary



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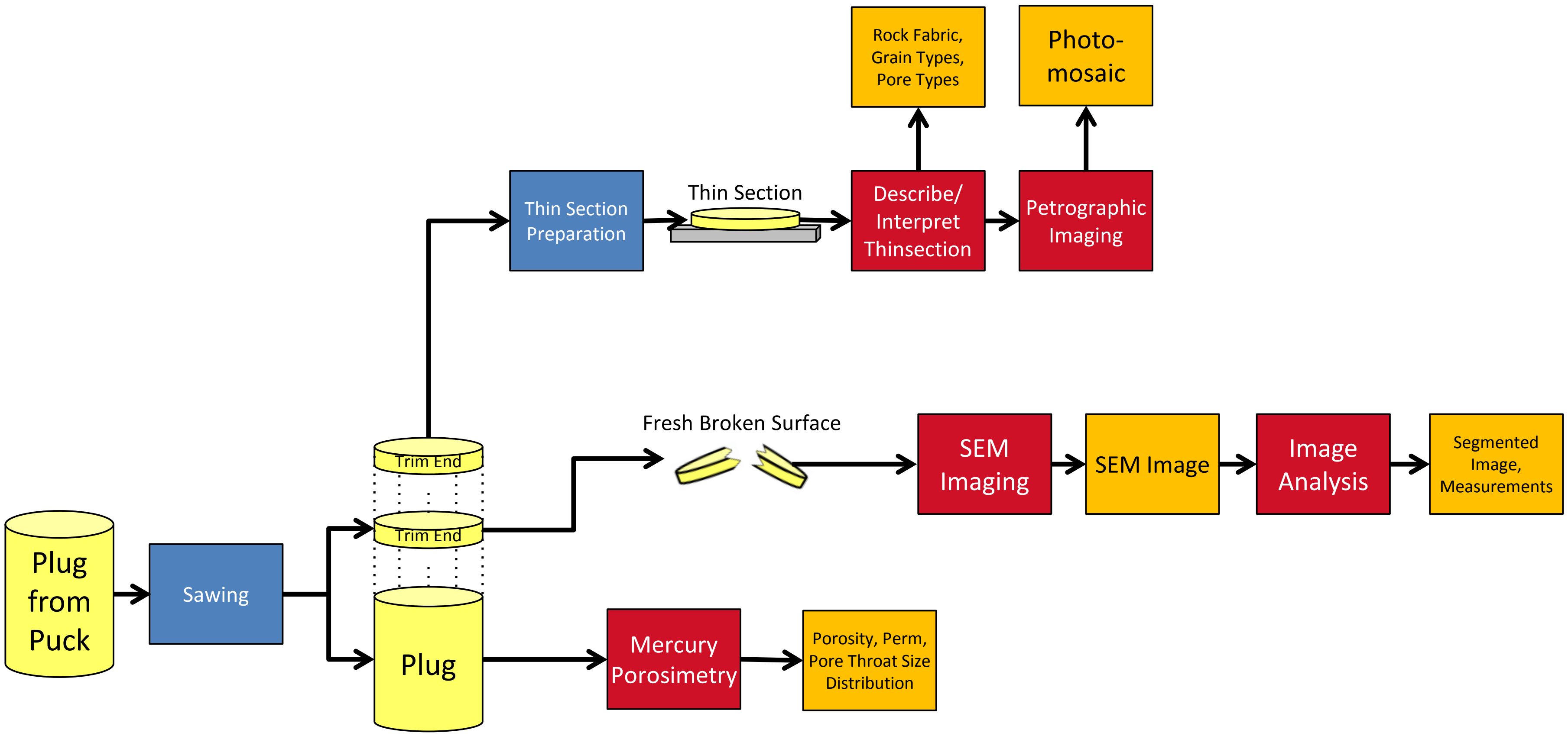
The Road Ahead
Future work
CT-scan & sub-sample remaining pucks
Scanning electron microscopy
Mercury porosimetry
Thin sections

Sample Locations

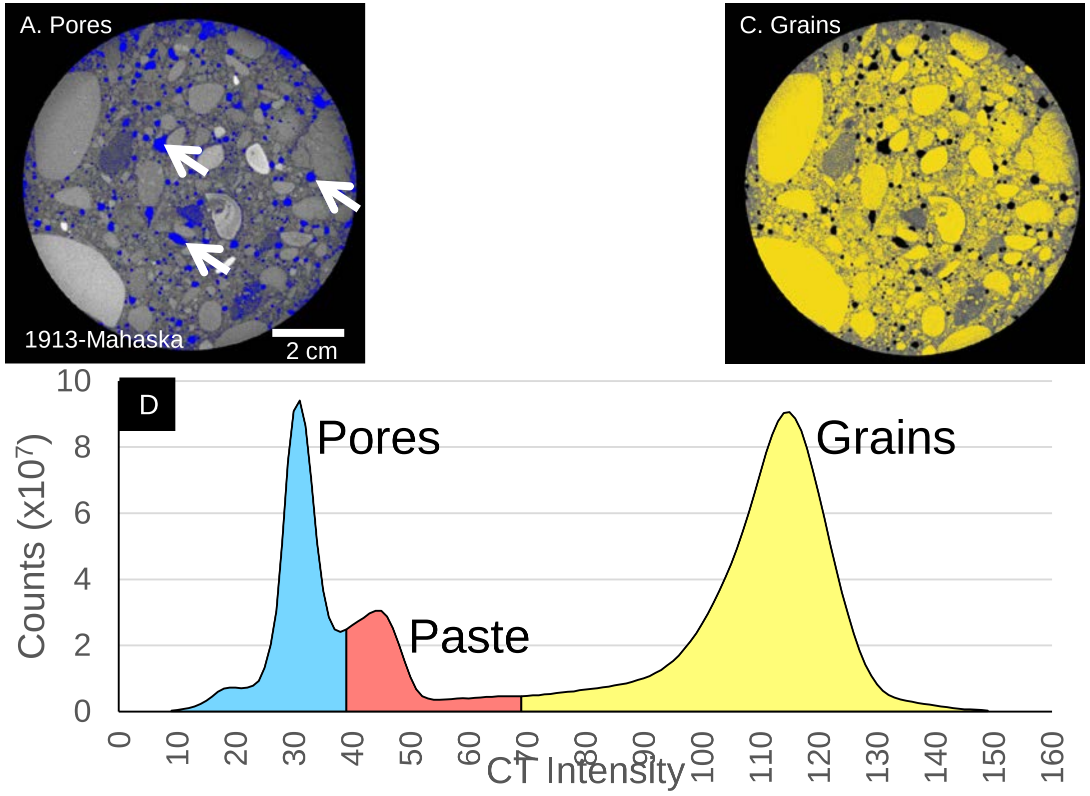
Analysis Workflow

Goal: Collect "control" data from minimally disturbed samples (core plugs) to compare with aggregate samples



Task 1: Identify solid components of PCC and characterize their relative abundance

- Using CT and thin sections (plane- and cross-polarized transmitted light as well as fluorescent reflected light) to characterize relative abundance of major components (paste, coarse and fine aggregate, air voids) as well as measure their size distributions and textural characteristics (e.g., sorting, angularity).
- We will identify the lithology and/or mineralogy of coarse and fine aggregates and assess the extent of alteration of these materials as well as the paste.

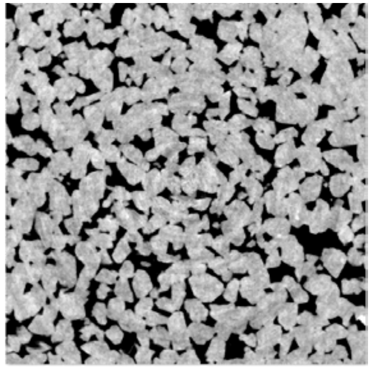


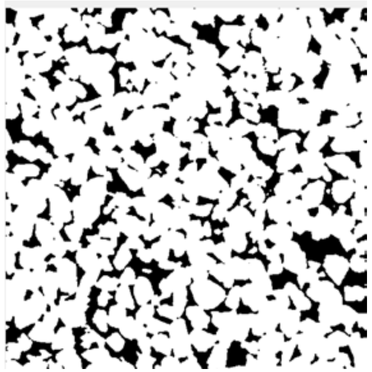
Task 2: Map and quantify the air void networks

By combining CT imagery, thin section petrography, helium porosity, and mercury porosimetry,

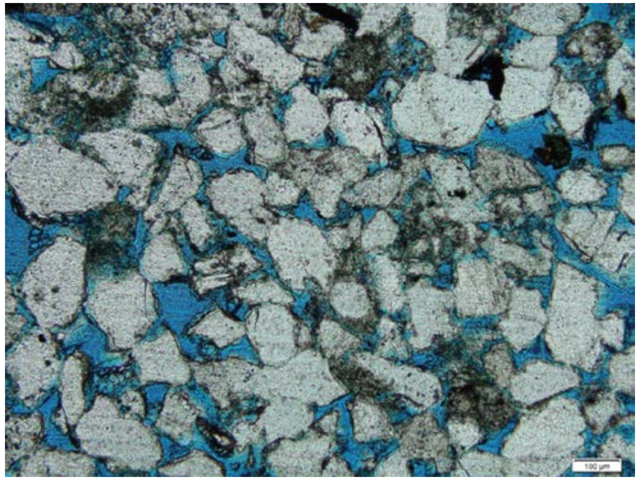
we will characterize the 3D distribution of the samples' air void networks and their connectivity.

2D Grayscale CT Image

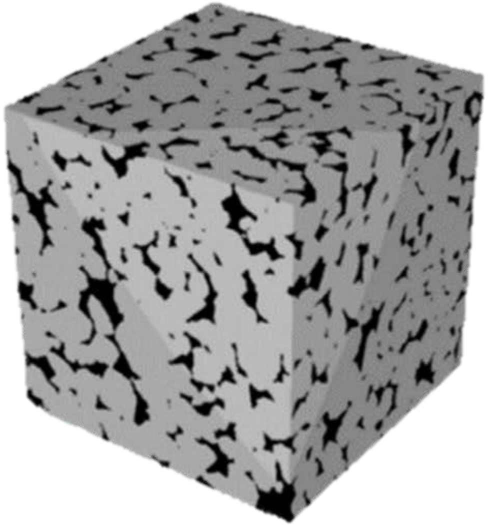




2D Binary CT Image



2D Thin Section Image



3D CT Volume (stack of 2D images)

Field photographs of sampling locations

Figure 1:

A. Interstate Highway 35 Southbound, Story County, Iowa, in service since 1999.
B. Old US Highway 20, Woodbury County, Iowa, in service since 1921.
C. Mahaska County Road T-36 adjacent to Highland Cemetery, Eddyville, Iowa, in service since 1913. View is to the south.
D. Schematic diagram showing orientation of specimen for image analysis in relation to the puck used for helium and CT porosity measurements.