# Limitations in Laboratory Stone Analysis: Micro-CT Attenuation Values Alone or FT-IR Alone Can be Unreliable Indicators of Mineral Type

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## Aims

Early reports of micro computed tomography (micro CT) of urinary stones showed non-overlapping ranges of x-ray attenuation values for most minerals. However, extended work in our laboratory has shown that size of stone fragments and scanning parameters can each influence the apparent x-ray attenuation value of minerals. The purpose of the present study was to test the correlation of mineral composition and micro CT attenuation values using small fragments of stone that were presumed to be pure based on results of FT-IR analysis.

## Method

Pieces of stones were dissected for FT-IR analysis (IR), but first were photographed and scanned by micro CT, and then crushed and pressed into pellets for transmission-mode FT-IR, using a Bruker Alpha-T Spectrometer. Settings for the SkyScan 1172 Micro CT System were 50 kV and 199 mA, with a 0.5 mm Al filter, with a resulting voxel size of 3.6µm. Reconstruction parameters included a beam hardening setting of 43, ring artifact 5, and mapping the attenuation scale between 0 and 0.175 of the raw indicator scale. Attenuation values were found by taking rectangular regions of interest in at least 7 separate slices of the reconstruction of each fragment.

## Results

By FT-IR analysis, 35 stone fragments were found to be pure: 14 carbapatite (CA), 3 calcium oxalate monohydrate (COM), 6 cystine, and 12 struvite. Overall patterns of correlation of mean attenuation values with mineral were as seen previously[1], but individual values overlapped between mineral types. Overlap in attenuation values occurred between cystine and struvite, and between COM and CA. However, even with overlapping attenuation values, these mineral types can be distinguished by morphology visible with micro CT.

Although pure by FT-IR, only 14 of the 35 fragments were homogeneous by micro-CT. The other 19 showed regions of mineral with varying x-ray attenuation values (grayscale). These mineral differences gave unique morphologies, visible by microCT, to the 4 stone types analyzed, as previously seen[2].

Cross-section slices of CA stones, shown in figure 1, analyzed as pure CA by IR, showed attenuation values of 32,831±6076. 8 of the 14 pure CA stones displayed the distinct thin-layering morphology previously seen for CA mineral[2]. The other 6 showed larger regions of distinct mineral without thin layers. This morphological pattern is unusual for CA stones. Other work will have to be done with additional methods to verify that these morphologies represent pure CA stones.

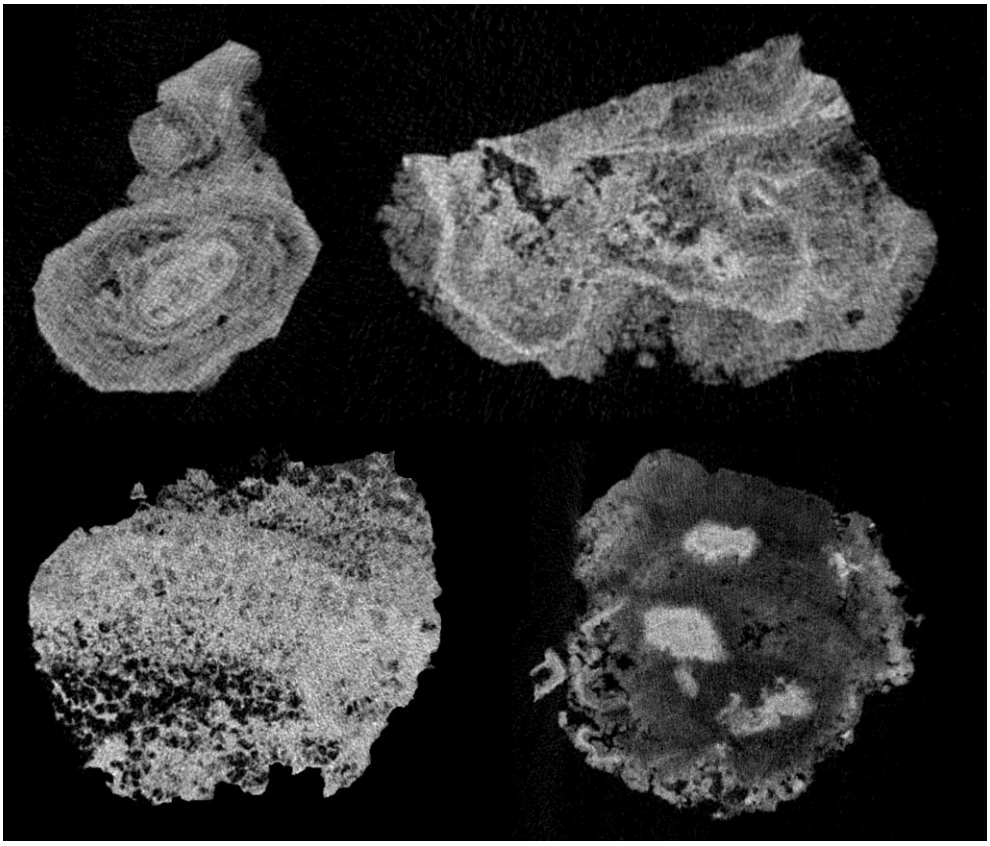

Figure 1: Cross section images from microCT scans of different stones analyzed as pure CA mineral. Top two slices show the layering for apatite mineral previously seen[2]. The lower two slices display different morphologies visible by microCT. The bottom left shows larger layers of different absorbing mineral minerals. The bottom right slice shows regions of highly absorbing mineral (probably apatite) surrounded by lower absorbing mineral.

Three COM stones appeared pure by FT-IR. Two of these (shown in figure 3) showed only slight inhomogeneities, most likely due to phosphate mineral (probably CA). Overall attenuation values averaged 27,357±1537. These values overlap with CA data; however differences in microCT visible morphology between the 2 stone groups allowed for distinction between groups. The layers visible in CA mineral were absent in these COM stones.

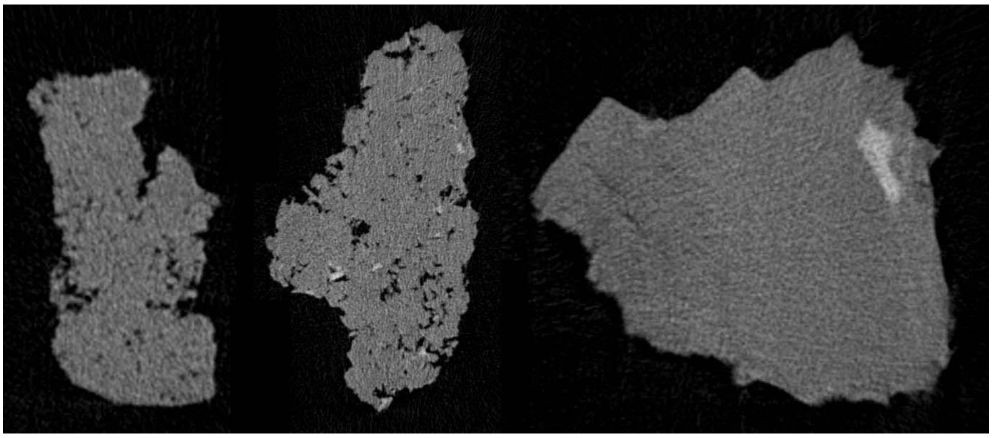

Figure 2: Examples of cross section microCT images of 3 stones analyzed as pure for COM. Morphology without layers is distinct from the layered morphology of CA stones, even though attenuation values overlap between the two groups. The bright spots throughout the two right slices are most likely due to phosphate mineral. The slice on the left did not exhibit any phosphate (bright region by microCT) throughout the entire stone.

Cystine was the only mineral in this study found consistently pure by both micro CT and FT-IR analysis. Cystine attenuation values averaged 11,587±1602, overlapping with struvite (averaged 9751±1690). The morphology of cystine and struvite stones differed greatly as shown in figure 3. Even though attenuation values overlap between these two stone groups, interior structure seen by microCT still enables the groups to be identified distinctly.

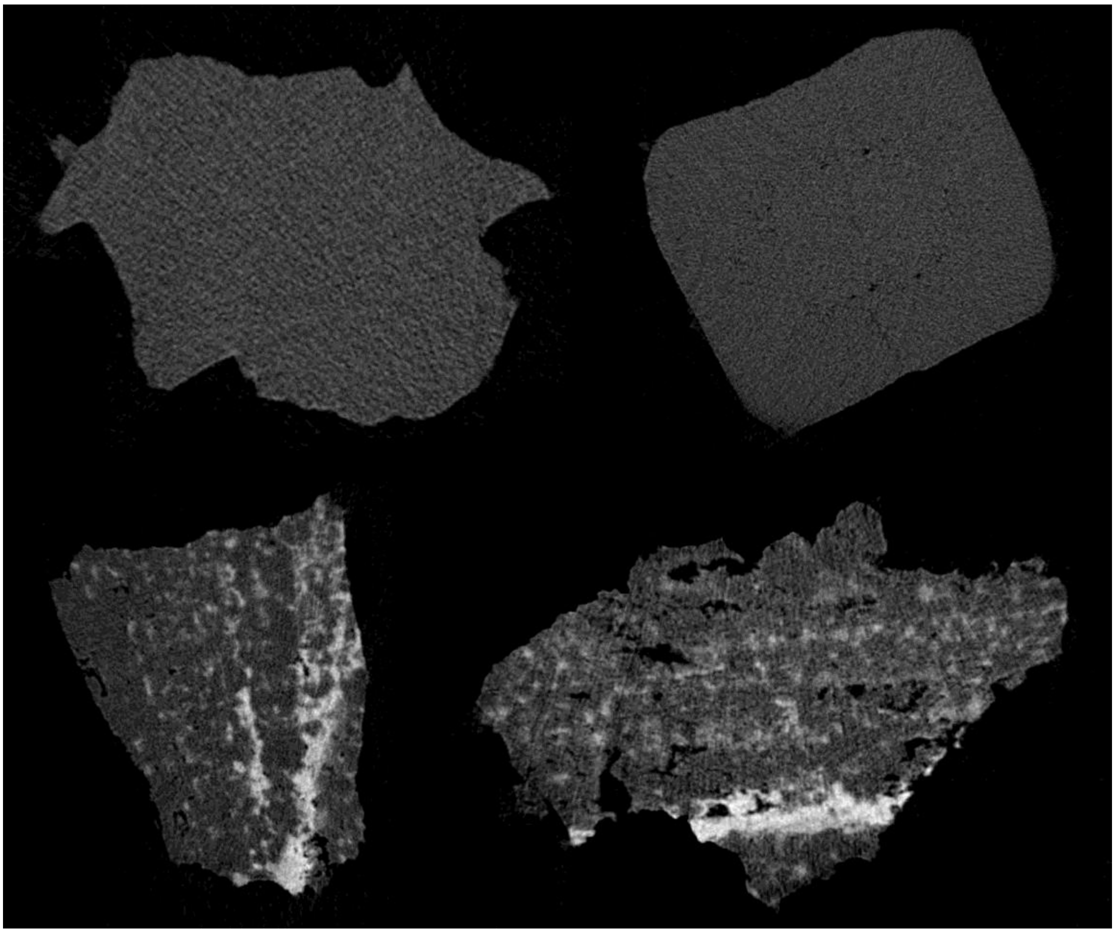

Figure 3: Four cross section microCT images of stones analyzed as pure by IR. The top two slices show the smooth, homogeneous morphology of Cystine. The bottom two slices, from struvite stones, exhibit microCT-visible layering between high and low X-ray absorbing regions.

## Conclusion

The use of attenuation values alone is an unreliable indicator of mineral type in micro CT, even when specimen size and scanning settings are carefully controlled. Thus, morphological characteristics are often required to identify mineral type by micro CT. We also show that specimens that appear to be pure by FT-IR may contain significant amounts of another mineral, as revealed by micro CT.

**Acknowledgements**
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## References:

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