Surface area and volume of the human mastoid based on micro-CT-scanning.

Parameters dependence on image resolutions.

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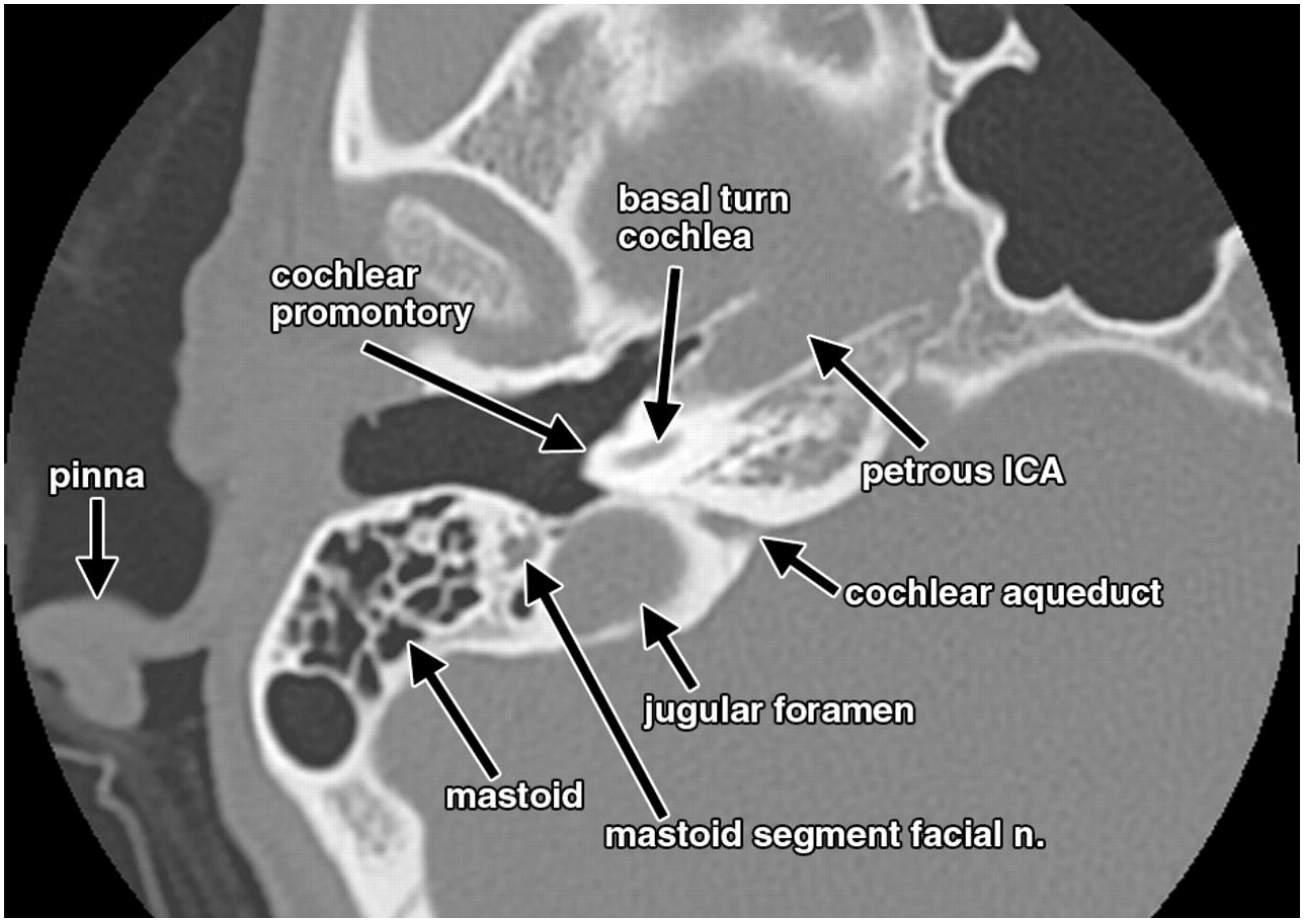
Introduction – The mastoid air cell system

- The mastoid air cell system
  ➔ *Structure versus function*
- Surface area (SA) vs. volume (V) ratio
  - (Passive pressure buffer)
  - Enhances gas exchange
  - Enhances effects of mucosal volume change
  - Final effects ➔ ME pressure changes

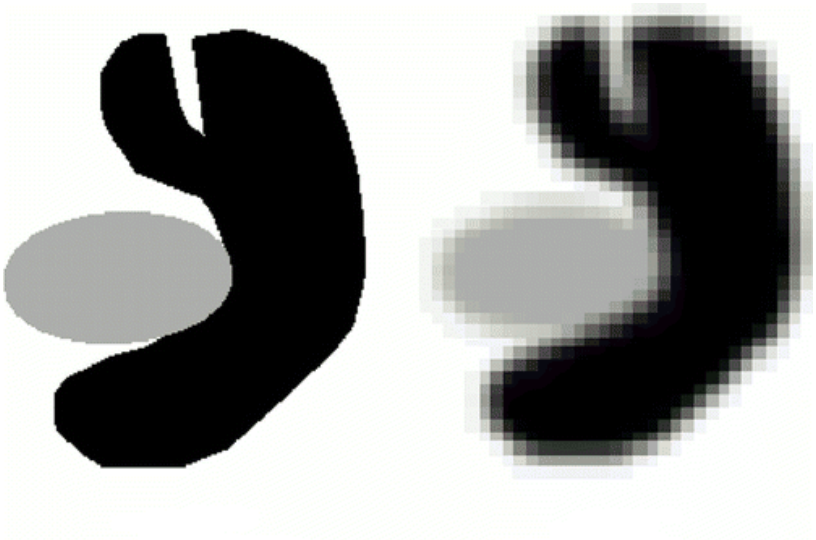
- CT-scanning studies – Clinical scannings
  - Resolution around 0.6 mm
  - Data for physiological models of the ME (Park et al. 2000; Swarts et al. 2010)

Clinical CT-scanning of the temporal bone



PVE or partial volume effect

- Transition between *air and bone* is hampered by partial volume effect
- Blurring over sharp edges
- The computer tries to average out the two densities or structures, and information is lost.
- Air cells smaller than the scan resolution will disappear.



Micro-CT scanning

- Micro-CT scanning
  - Higher radiation dose
    (not for "*in vivo*" investigations – laboratory studies)
  - Provides higher resolution scanning
  - Transitions between air and bone better defined
  - Smallest air cells are visible

- Altogether,
  - higher resolution may reveal more details, and so
  - geometric parameters may be more accurately determined (SA and V)

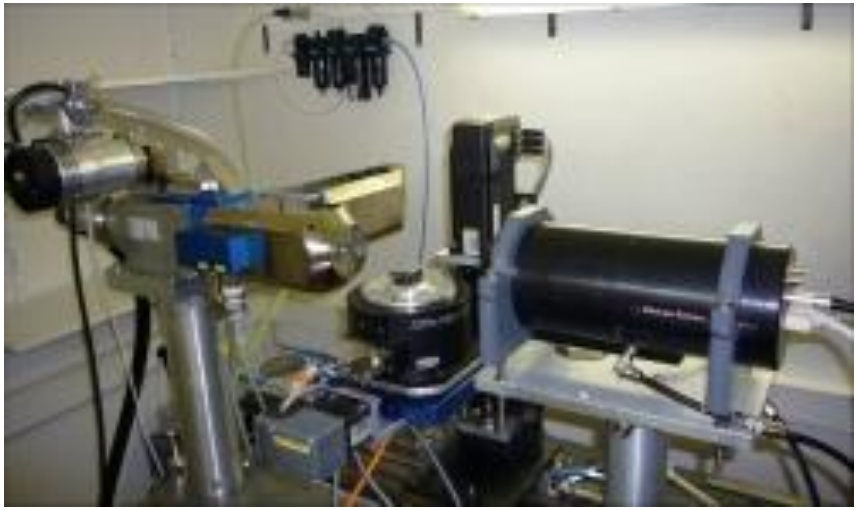
Aims of the study

Determination of

- the surface area and volume of the human mastoid by micro-CT-scanning, and
- the correlation between the scanning resolution and these geometric parameters

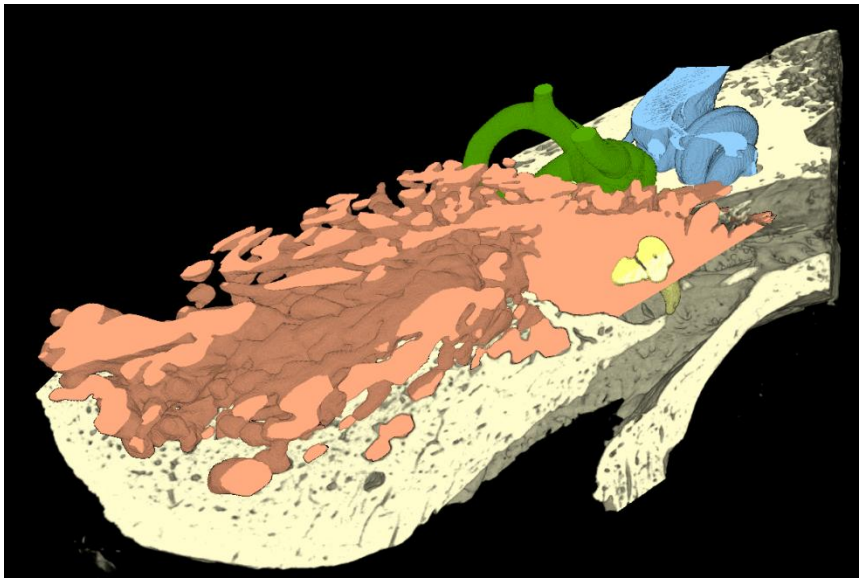
Materials and Methods

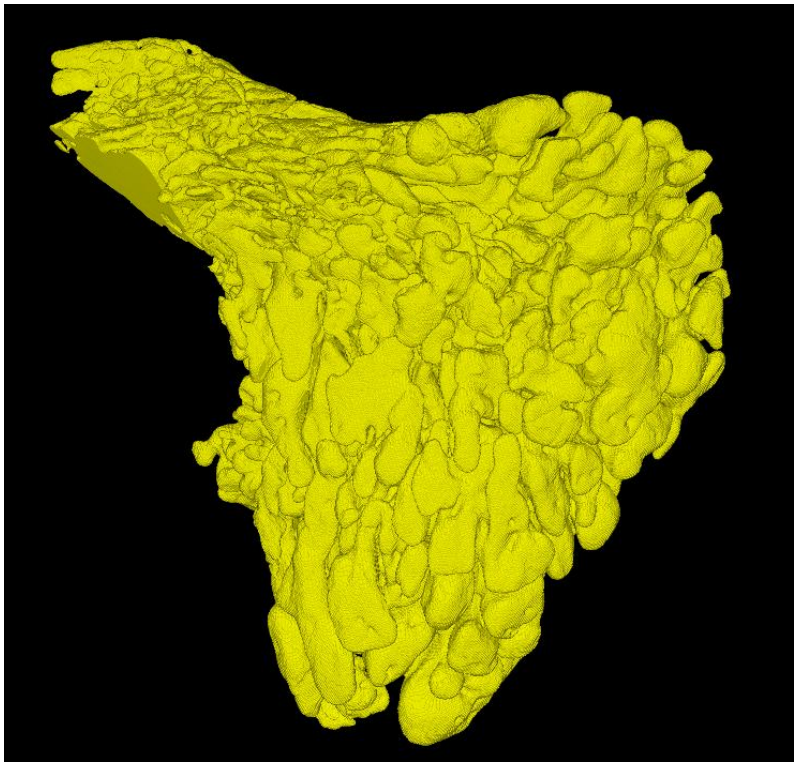
- Six human temporal bones were scanned
- Micro X-ray scanner providing resolutions ~50 µm



Materials and Methods – Data Segmentation

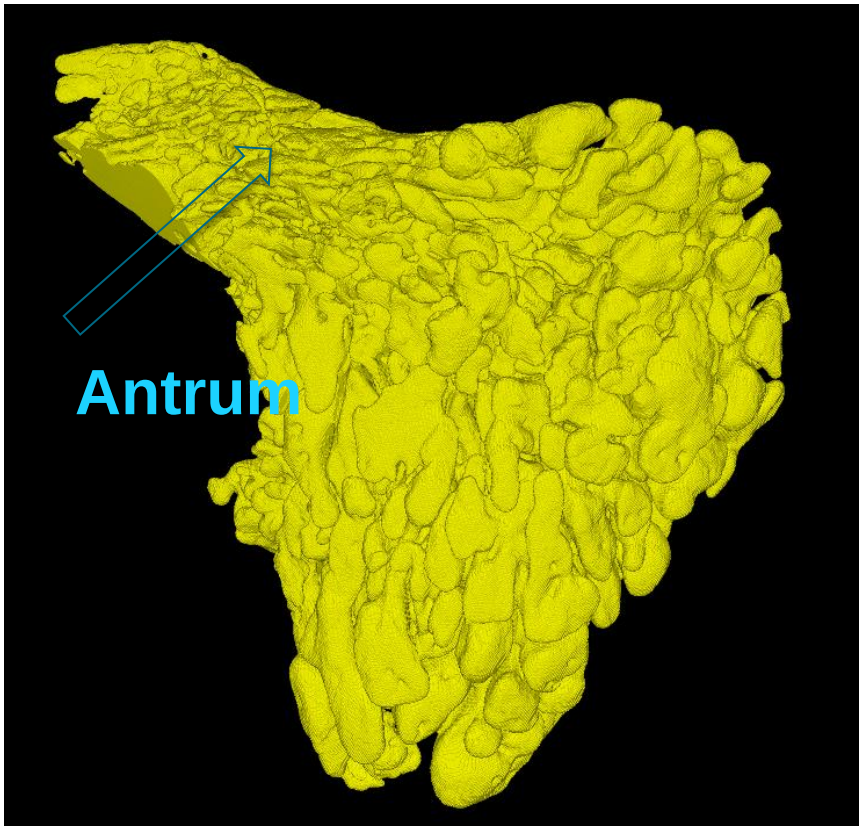
- These original data were analysed by a semi-supervised image processing, which allowed careful segmentation of the mastoid into *a final binary volume*.





Materials and Methods – Mastoid vs. Tympanum

- The antrum was separated manually from the tympanum between the head of the incus and malleus.



Materials and Methods – Volume and surface area

Volume (V)

- Summation of all "air voxels" multiplied by the volume of one voxel (volume element) =
- The total air volume of the mastoid

Surface area (SA)

- The surface was fitted with triangles onto the binary volume ➔
- The total surface area = the sum the areas of all triangles forming the fitted surface

The SAV ratio was calculated by SA/V

Materials and Methods – Down-sampling data

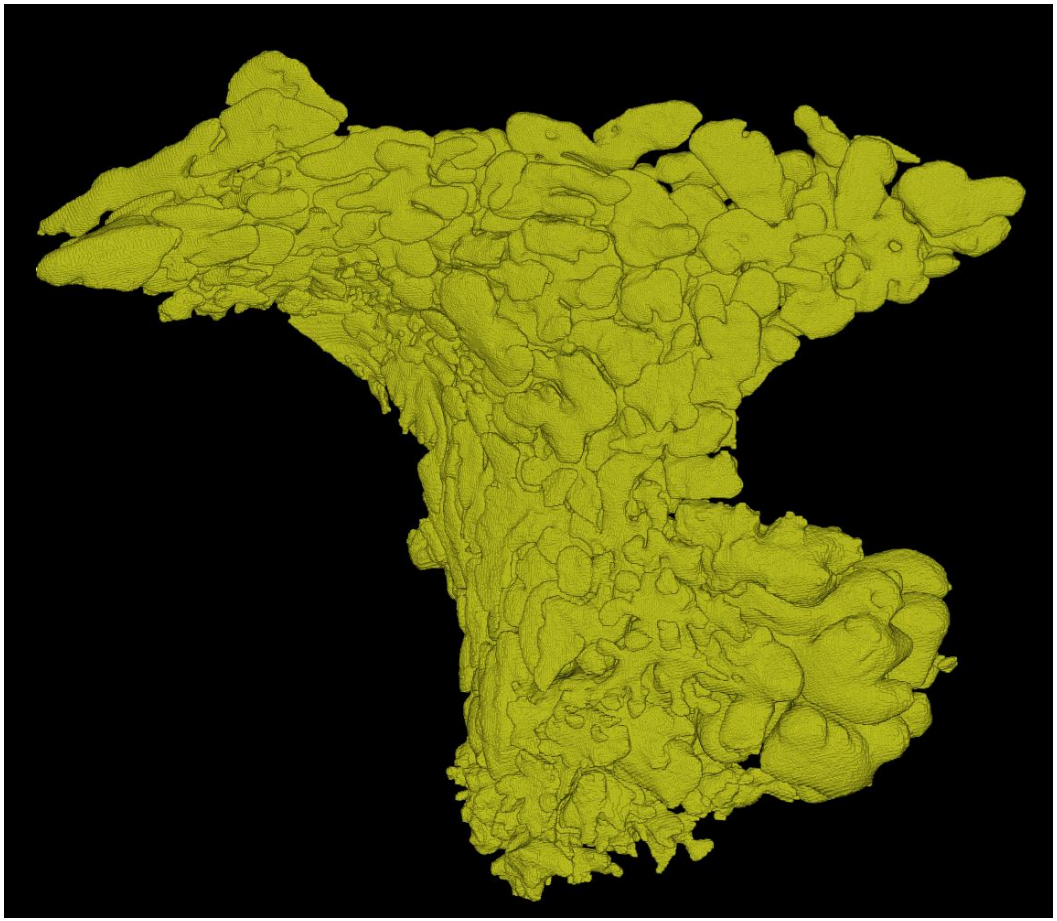
"Micro-CT" ➔ "Clinical CT"

- In order to determine the SA, V, and SAV-ratio for scannings at lower resolutions, the original data were mathematically down-sampled four times

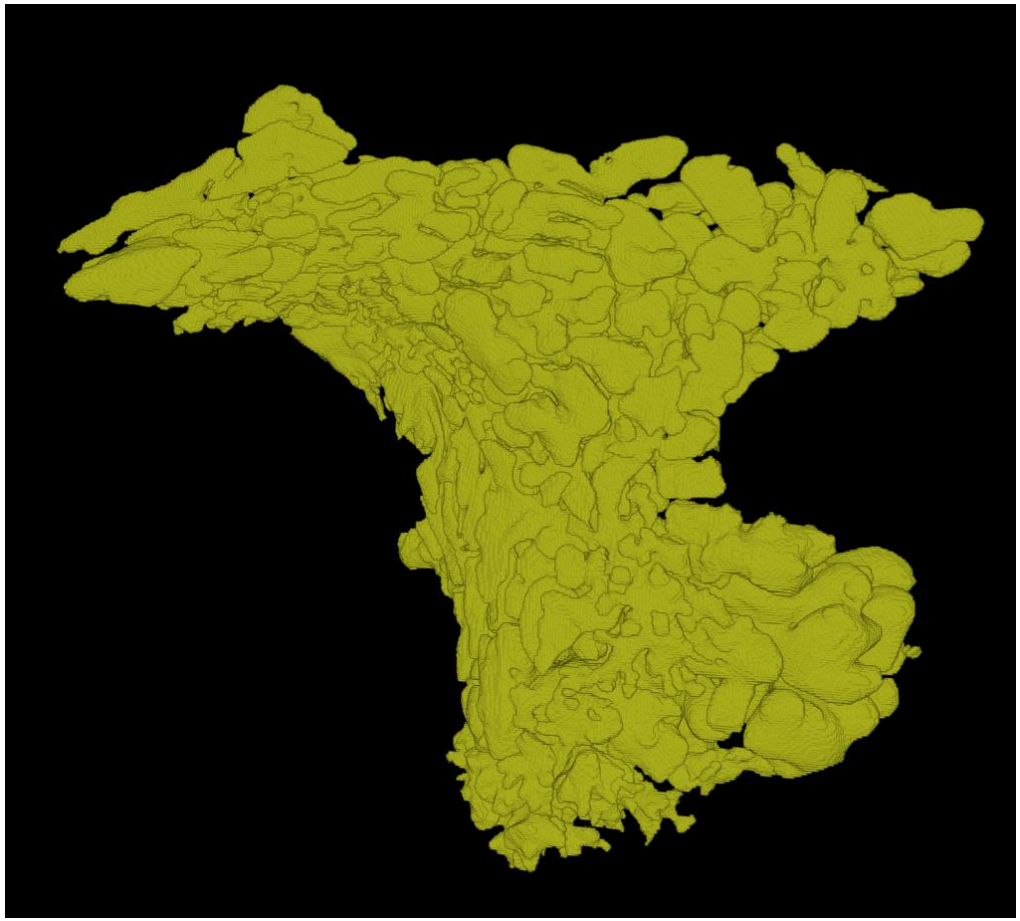
- The resolution ranged from the original scan ~50 µm to resolutions for clinical CT scanning ~600 µm.

Down-sampling: Analogy

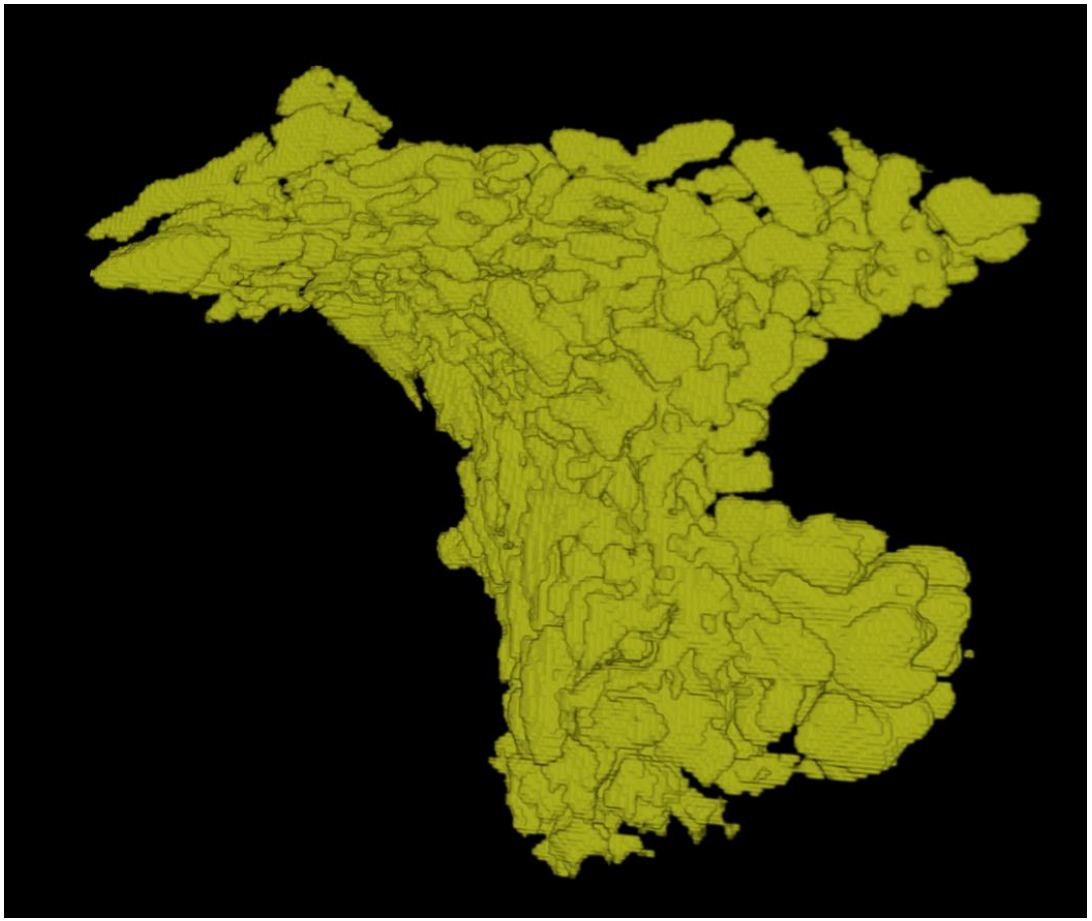
Original resolution = 59 µm



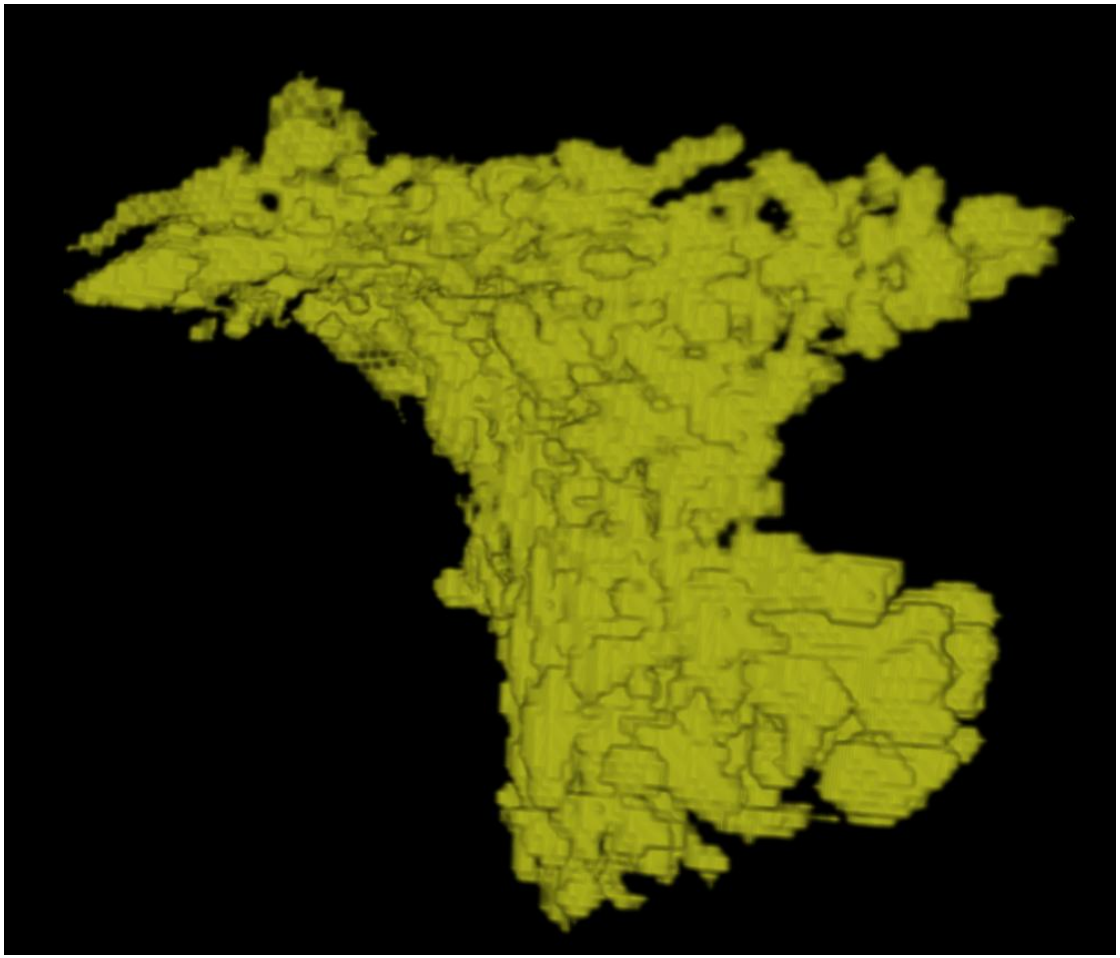
Down-sampling 1; resolution = 119 µm



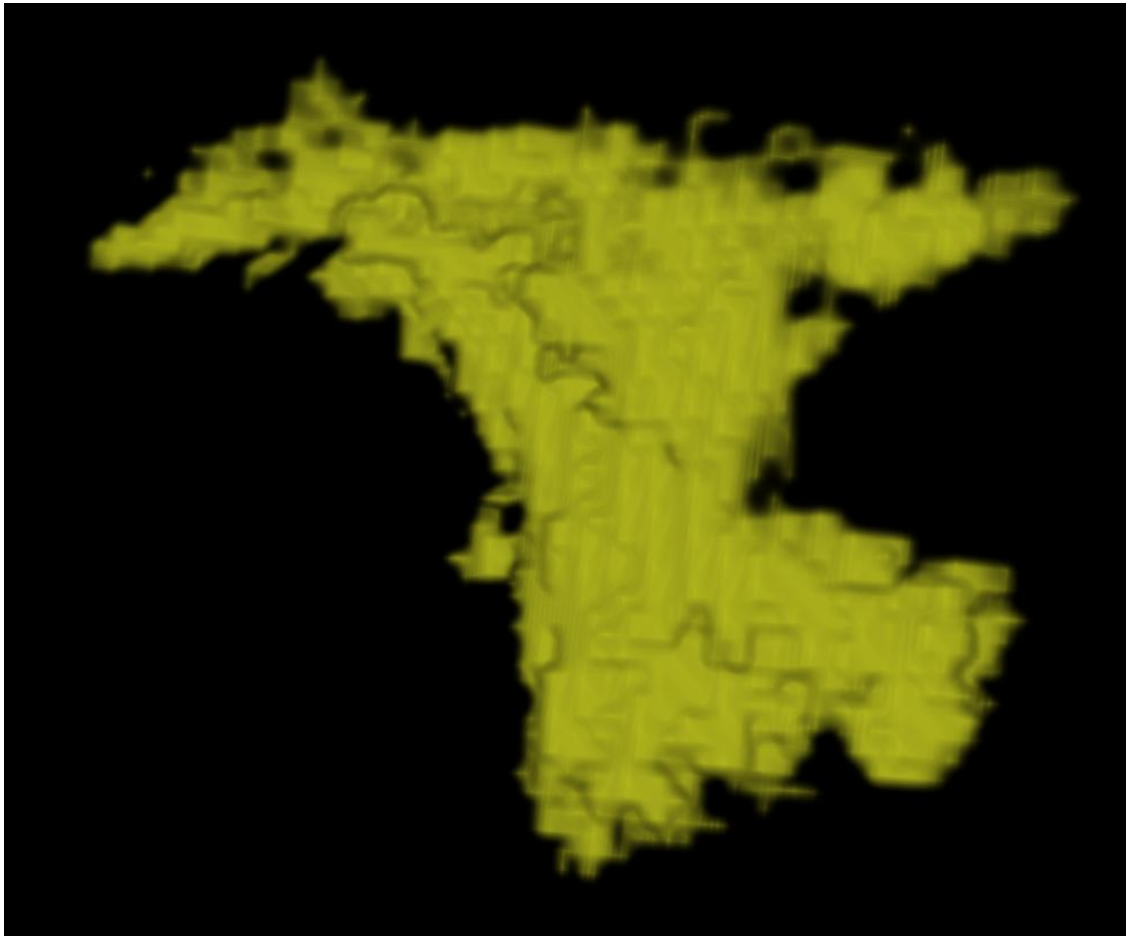
Down-sampling 2; resolution = 238 µm



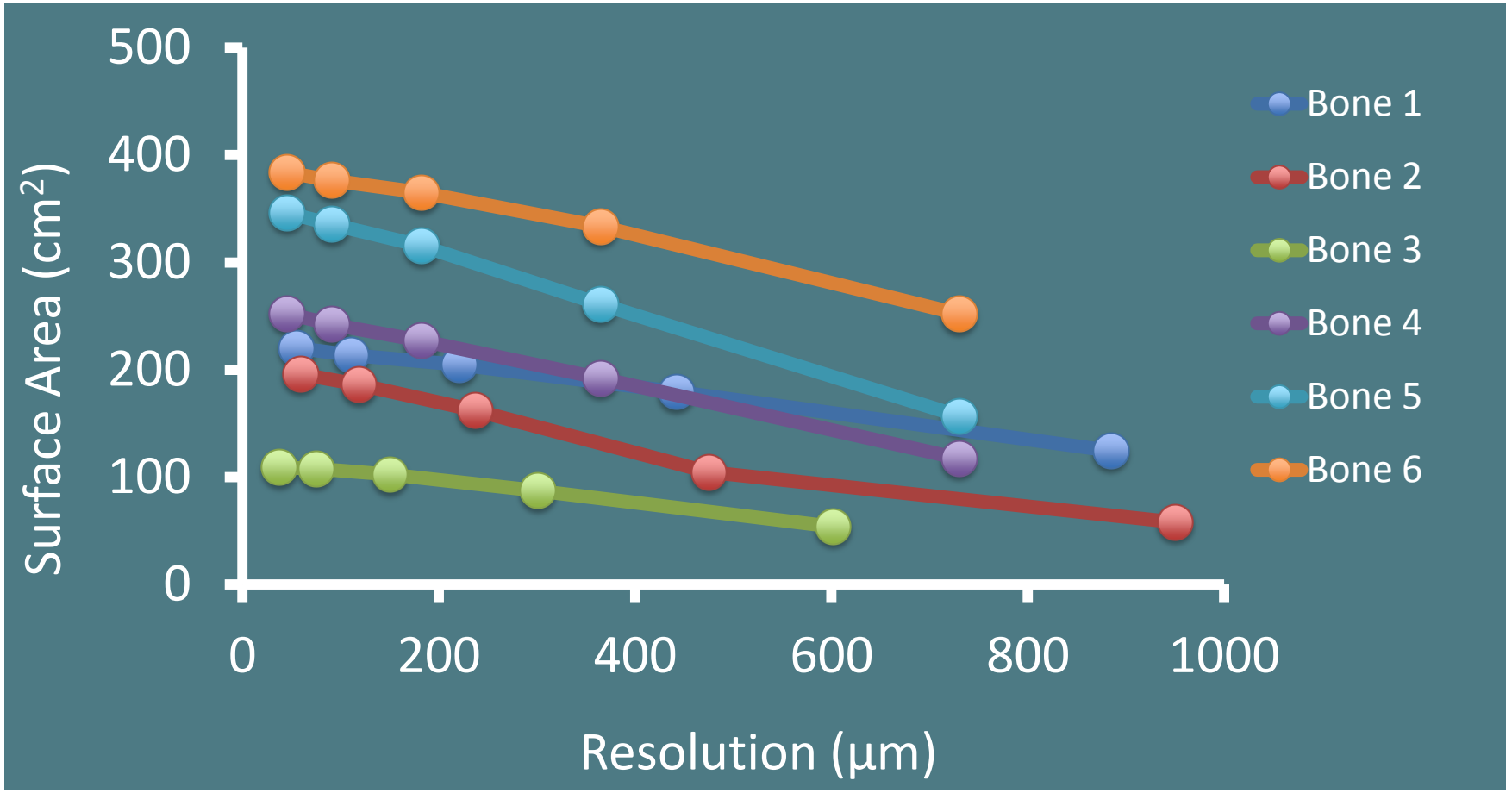
Down-sampling 3; resolution = 475 µm



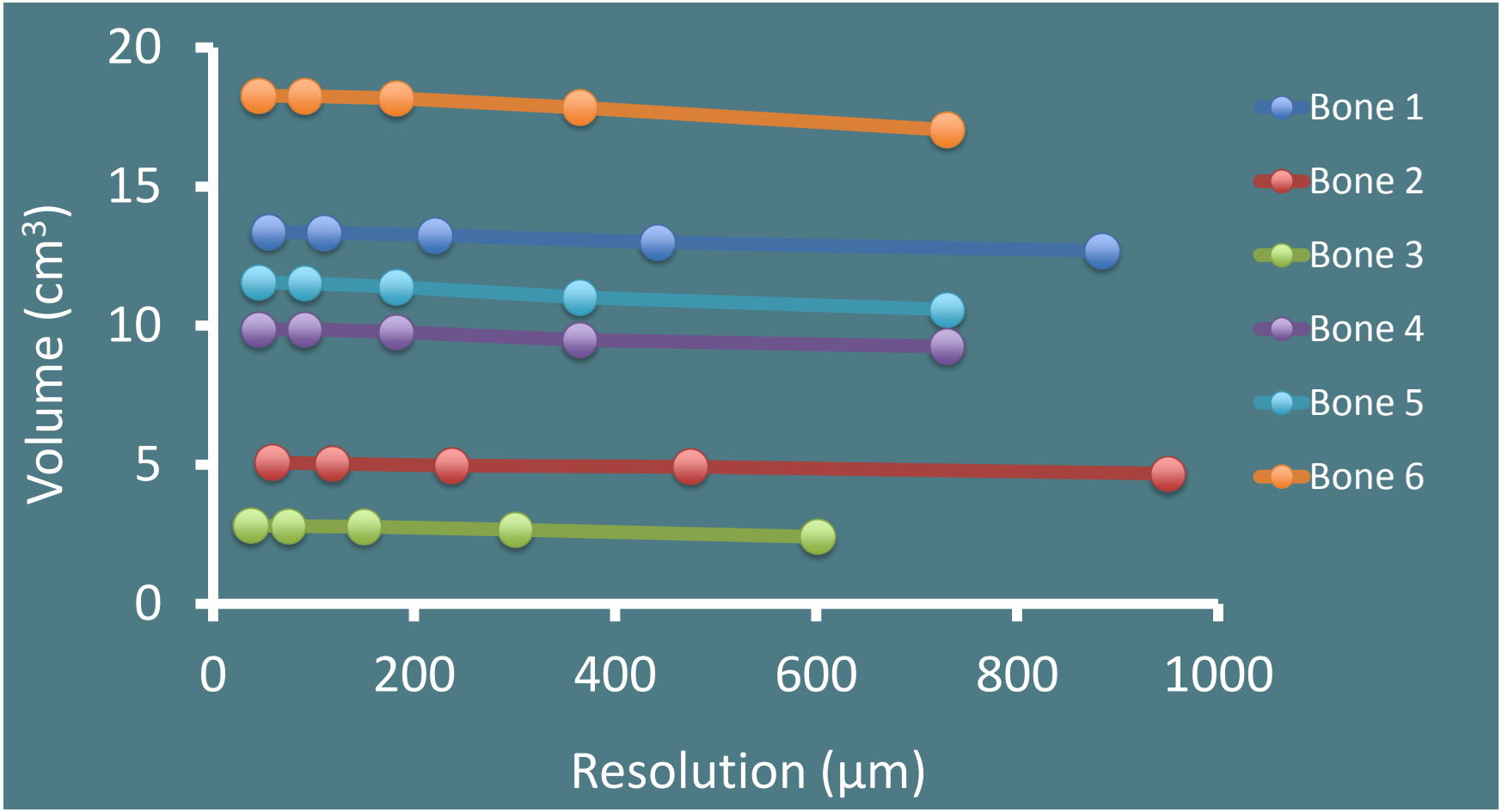
Down-sampling 4; resolution = 950 µm



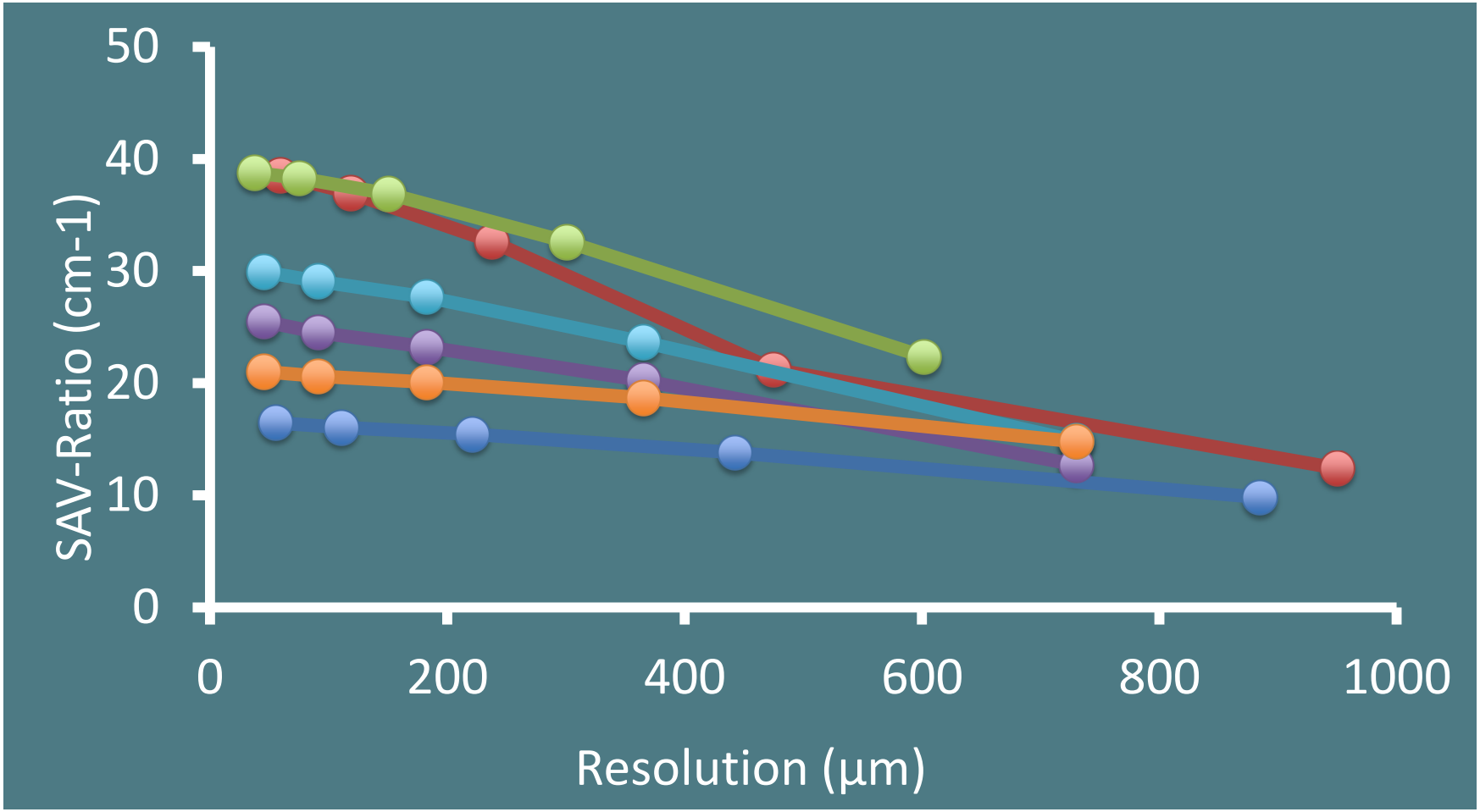
Results – Surface Area vs. Resolution



Results – Volume vs. Resolution



Results – SAV-ratio vs. Resolution



Results – summary

Resolution	Surface Area (cm^2)	Volume (cm^3)	SAV-ratio (cm^{-1})
50 µm	251 (102) [110 to 387]	10 (6) [3 to 18]	28 (9) [17 to 39]
600 µm	127 (73) [55 to 280]	9 (5) [2 to 17]	14 (4) [12 to 23]

* Mean; (SD); [Range]

Discussion

- The mastoid volume appeared constant ~10 cm^3
- The surface area increased by a factor ×2
  (127 ➔ 251 cm^2)
- The SAV ratio increased by a factor ×2
  (14 ➔ 28 cm^{-1})
- *State of the art* – unprecedented accuracy
  - Limitations by only 6 bones
  - Normal temporal bones?

Discussion – Clinical vs Micro-CT scanning

	Surface area (cm^2)	Volume (cm^3)	SA/V ratio (cm^{-1})
Park et al. (2000)	167	10	16
Swarts et al. (2010)	85	5	17
Current study(2014)	251	10	28

Conclusion

Mastoid air cell system – Function?

- Gas sink (gas exchange) and not a
- ~~Passive pressure buffer~~ (Swarts et al., 2010).

References

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Thank you for your attention

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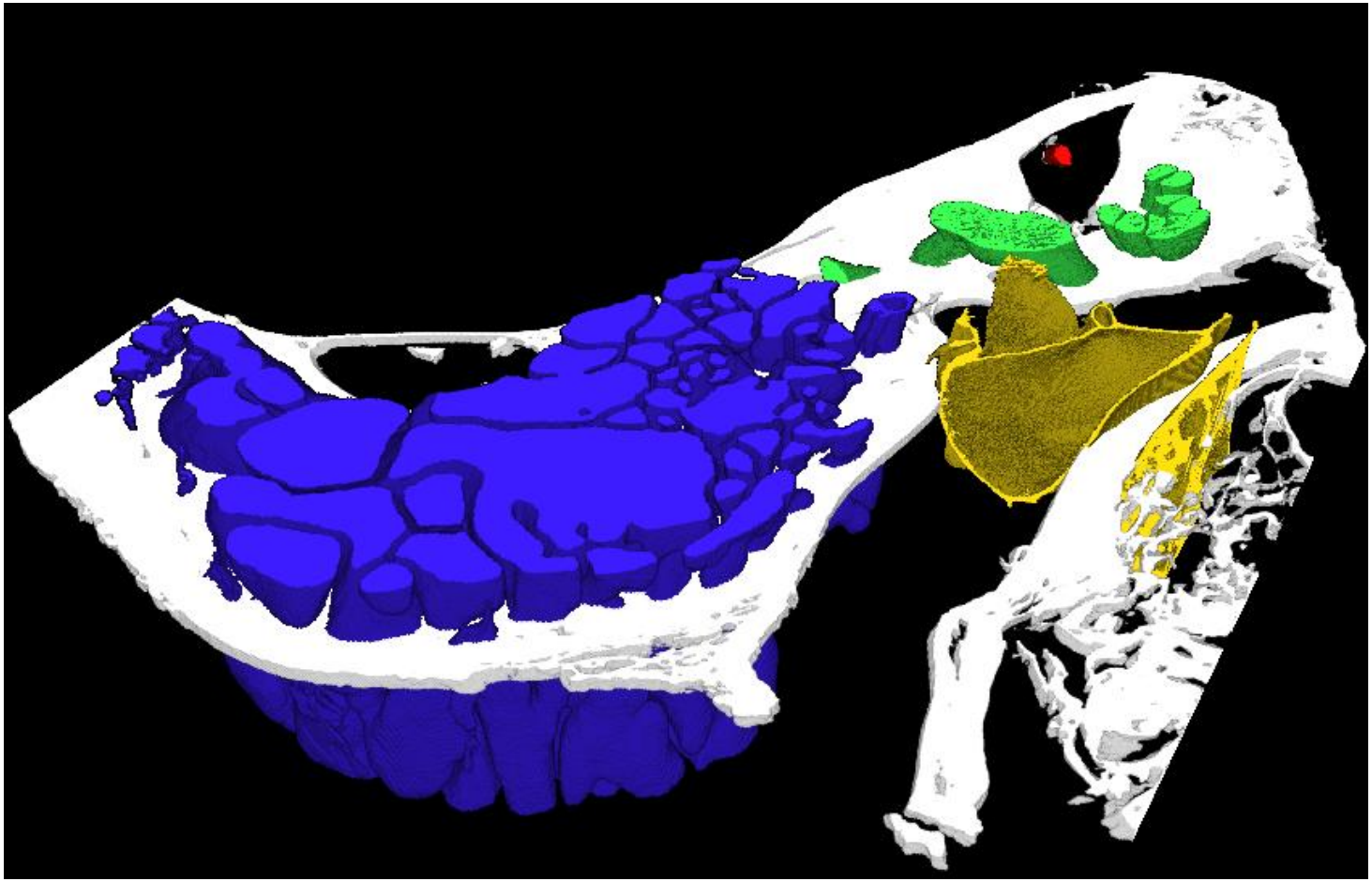
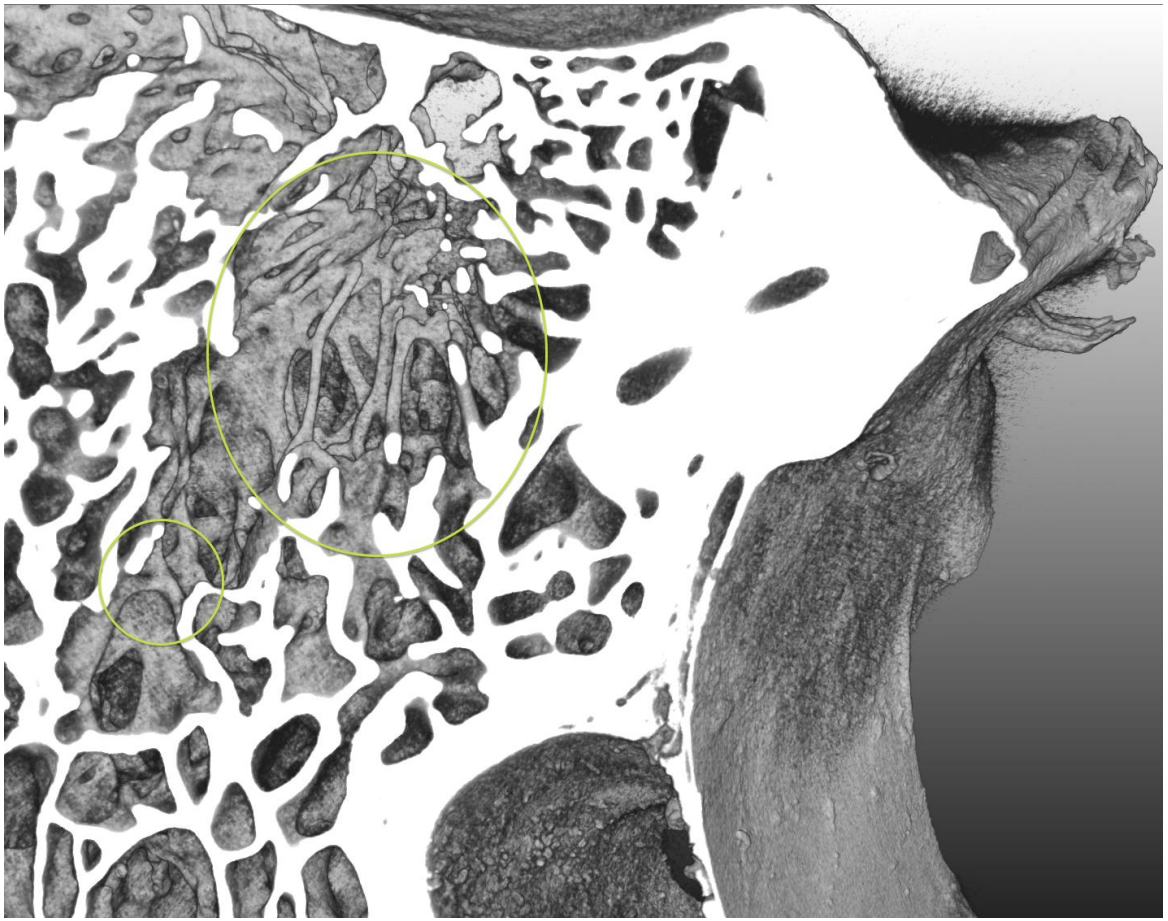
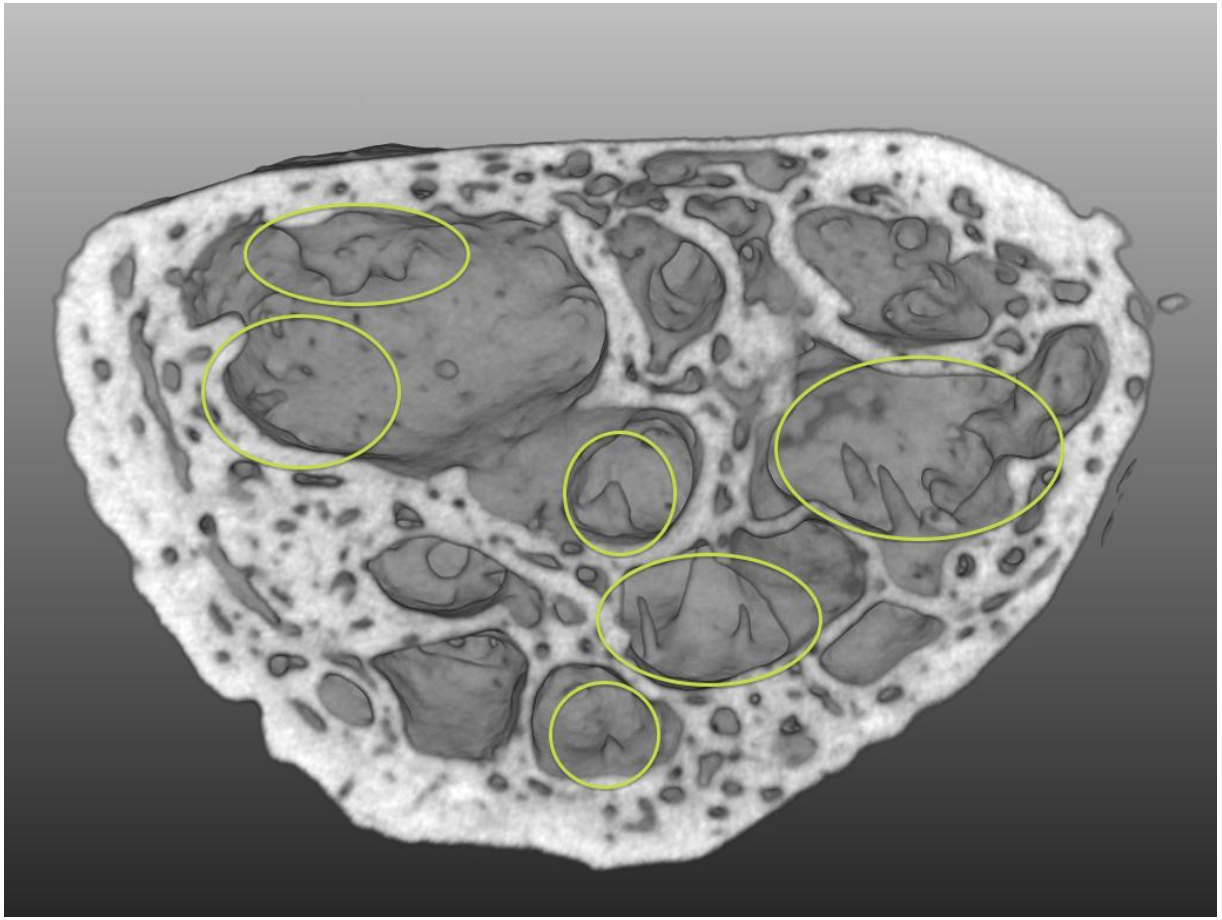
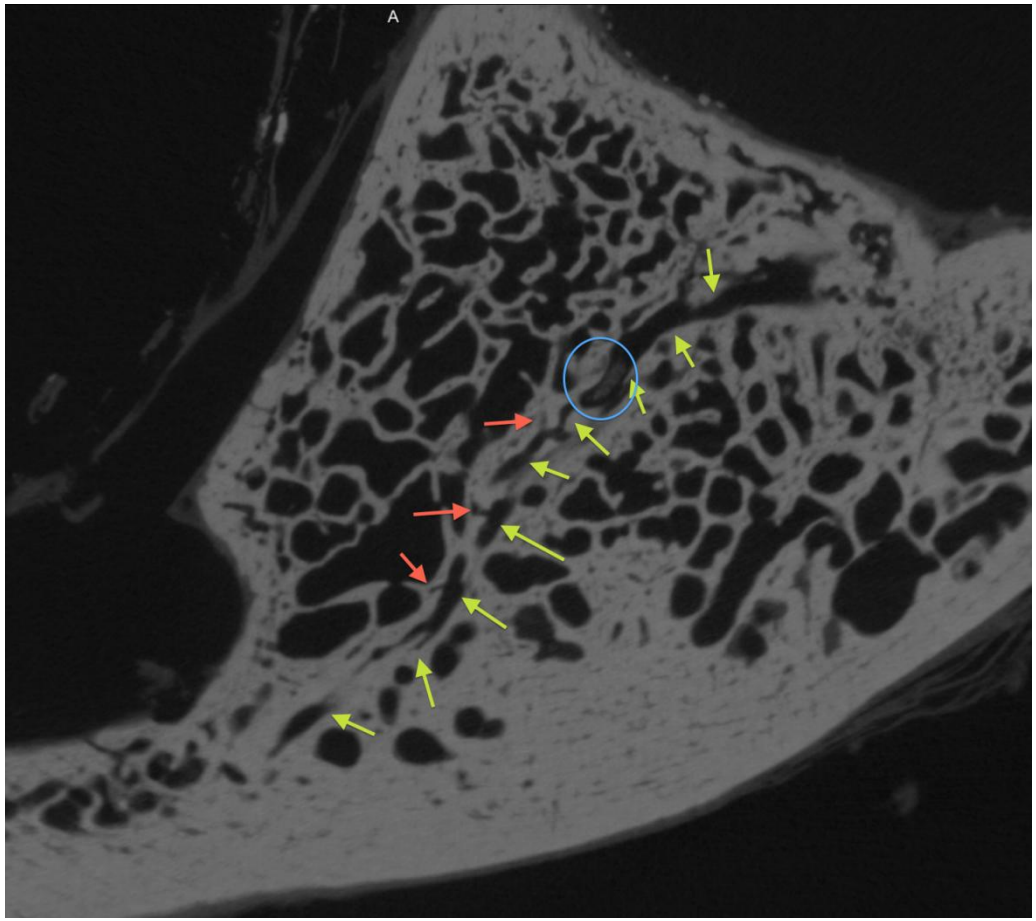


Anti-neutrophil cytoplasmic antibody (ANCA)



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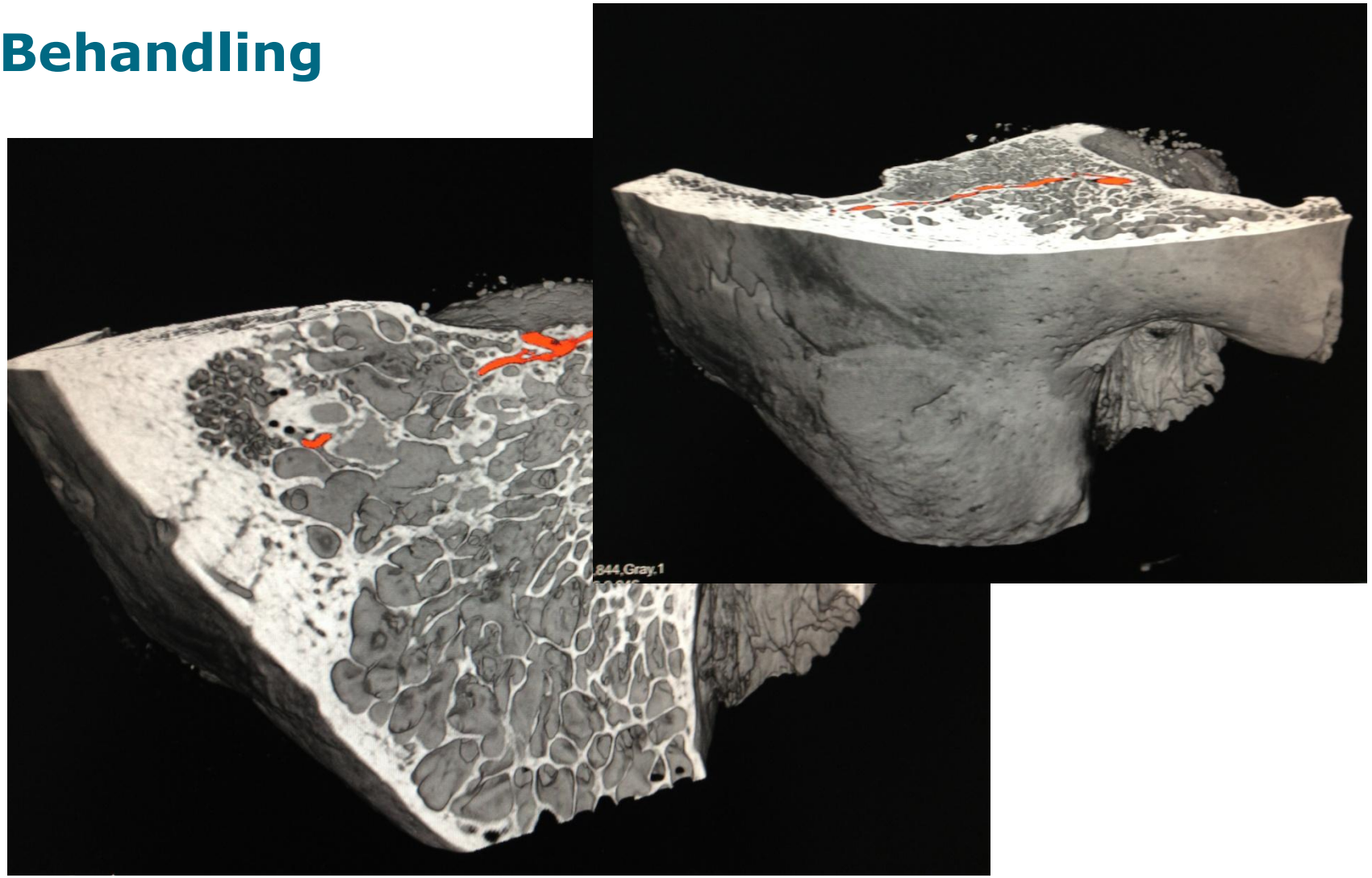
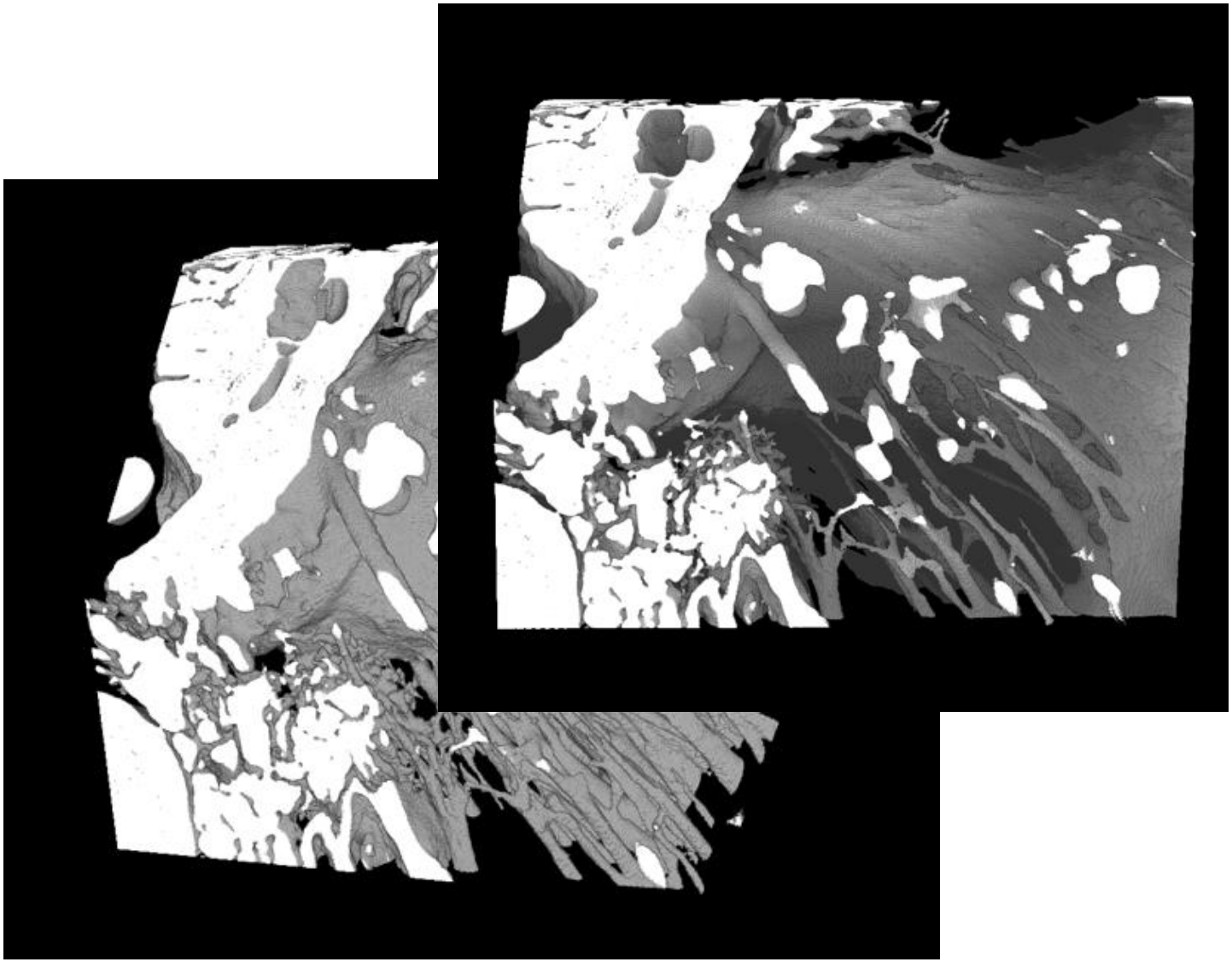
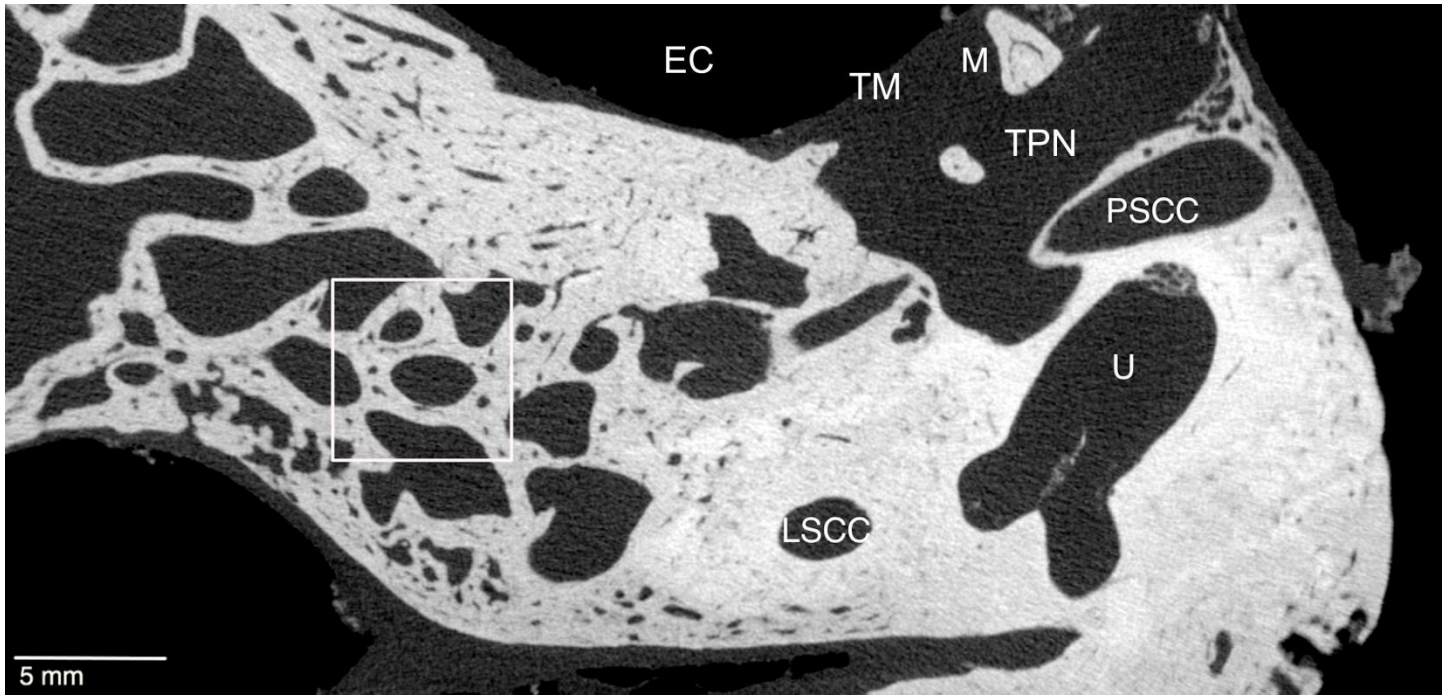
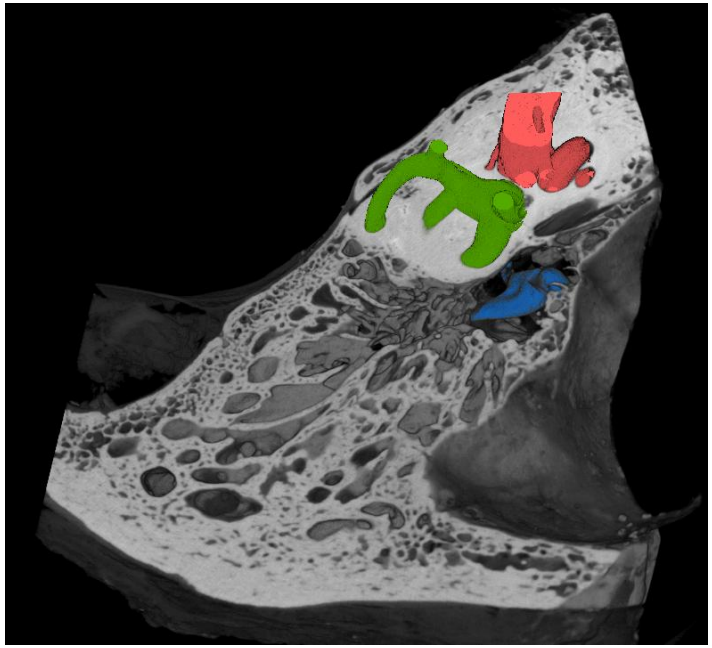




2D Slice of Micro-CT



Volume rendering of Micro-CT



**3D visualization of a set of slice with segmented ossicles (blue), part of the semi-circular
canals (green), and the cochlea (red) overlayed on it.**