

## **Integrating XRF and XCT for Understanding Medieval Ceramic Production from Wawel Royal Castle**

R. Abdelrahman<sup>1,3</sup>, S. Wroński<sup>1</sup>, B. Makowiecki<sup>2</sup>, L. Samek<sup>1\*</sup>

<sup>1</sup>AGH University of Krakow, Faculty of Physics and Applied Computer Science, 30-059 Krakow, Poland

<sup>2</sup>Wawel Royal Castle – State Art Collection, Ceramic and Glass Department, PL 31-001 Kraków, Poland

<sup>3</sup>Future University in Egypt (FUE), Faculty of Engineering and Technology, Cairo, Egypt.

\*e-mail: Lucyna.Samek@fis.agh.edu.pl

This study examines five tile fragments from Wawel Royal Castle using X-ray fluorescence (XRF) and X-ray computed tomography (XCT) to investigate their composition and internal structure. XRF analysis revealed similarities to Carpathian Basin ceramics in SiO<sub>2</sub>, K<sub>2</sub>O, P<sub>2</sub>O<sub>5</sub>, and MnO contribution but higher TiO<sub>2</sub>, Fe<sub>2</sub>O<sub>3</sub>, and CaO levels as well as lower Al<sub>2</sub>O<sub>3</sub>, MgO, and Na<sub>2</sub>O content, suggesting local production with different clay sources despite shared motifs.

XCT provided high-resolution imaging of inclusions, voids, and porosity, complementing XRF findings by revealing variations in clay refinement, tempering methods, and firing conditions. Correlating XCT structural data with XRF chemical composition highlighted craftsmanship differences from rudimentary to advanced techniques. Despite voxel resolution limitations, XCT proved valuable in identifying internal inaccessible ceramic structures.

This research contributes to the understanding of medieval ceramic production, offering valuable insights into cultural exchanges, trade networks, and regional influences in Central Europe while highlighting the role of local craftsmanship in creating historically significant artifacts. Additionally, the synergy of XCT and XRF enhances archaeological research methodologies, demonstrating the advantages of multi-modal, non-destructive material characterization for heritage conservation and material studies.

**Acknowledgments:** This research project was supported/partly supported by the program “Excellence initiative—research university” for the University of Science and Technology. The subsidy of the Ministry of Science and Higher Education, grant number 16.16.220.842 partially financed this study.