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Geophysical Measurements at Merseburg Cathedral

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Merseburg Cathedral has been founded in 1015 by Bishop Thietmar von Merseburg and has been converted into a gothic cathedral from 1510 to 1517 by Bishop Thilo von Trotha. The cathedral together with the cloister, the castle and several appurtenant buildings are well preserved. The entire complex represents one of the most complete examples of medieval royal palaces and bishop's sees in Germany northeast of the Roman Limes. Here we present examples of geophysical measurements at the cathedral namely ultrasonic surface measurements, ground penetrating radar (GPR) as well as thermographic measurements.
Ultrasonic surface measurements have been carried out at epitaphs made of sandstone to quantify changes in stone properties due to weathering. The 95 measurements reveal a strong variability in Rayleigh wave velocities ranging from about 800 m/s to 2000 m/s. Unweathered parts of the sandstone epitaphs show Rayleigh wave velocities of about 1500 m/s. A reduction in Rayleigh wave velocities hints at loosening of the rock surface whereas an increase is due to surficial black crusts with pores filled mainly by gypsum. Waveform inversion of the dispersed Rayleigh waveform yields depth profiles of the shear-wave velocity indicating the thickness of altered surficial layers. Also a loosening below the black crust may be detected non-destructively. A number of measurements have been repeated after one year and after a rainy day. Statistical analysis shows that random errors in Rayleigh wave velocities are less than about 3 %. Increase of moisture in porous sandstones leads to stronger damping of the Rayleigh wave and consequently to a reduction in Rayleigh wave velocities by up to about 10 %. At strongly altered epitaphs a reduction in Rayleigh wave velocity by up to 20 % has been observed within one year. Within one day an increase of up to about 7 % may indicate stiffening of black crusts due to moisture absorption.
GPR measurements have been performed at several locations within the cathedral and in the cloister to clarify the location of medial graves. The measurements partly confirm archaeological reports from the 19th century. In addition, a number of hitherto unknown graves have been detected. An east-west oriented high-reflective anomaly at a depth of about 1 m with a width of about 0.6 m and a length of about 2 m in the central crossing of the cathedral may be related to the unknown location of the grave of the anti-king Rudolf von Rheinfelden who was buried at Merseburg Cathedral in 1080. Graves have also been detected in the cloister of the cathedral. Moreover, we show that archeological excavations may lead to significant changes in the reflectivity of electromagnetic waves by the ground so that the location of previous excavations may be detected by GPR measurements.
Furthermore, a number of passive and active thermographic measurements reveal increased moisture, detachments of plaster and the structure of the stonework below the plaster.