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Integrated electromagnetic methods for archaeological prospection and stability assessment of anthropogenic mounds: insights into the English Cemetery in Florence

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The archaeological interest in anthropogenic mounds as historical products of human occupation generally concerns the understanding of their stratigraphic sequence and the discovery of buried structures. Nevertheless, a further key element relies on the assessment of their stability. This is particularly crucial when the conservation history induced relevant alteration of the former configuration, and a potential collapse might cause damages to heritage and actual risk for public safety.
To respond to such dual diagnostic need, we propose an integration approach based on Very Low Frequency Electromagnetic (VLF-EM) qualitative method and 2D-Electrical Resistivity Tomography (2D-ERT), to make the best out of these two techniques in light of their frequencies/bandwidth and methods of soil investigation (15-30 kHz and DC, respectively).
We present here the results from the experiments performed on one of the test sites selected to validate the proposed methodology, i.e. the Protestant Cemetery (the so-called "English Cemetery") in Florence, Italy, which is a demonstrative example of a huge sample of anthropogenic mounds within urban and rural environments.
Located on a topographic relief, the cemetery testifies a long history since Roman times, as proved by historical documentation and the ceramic findings still now discovered on the (sub-)surface. Converted into a cemetery in 1827, the mound appeared as an anomalous outcrop adjacent to the town walls, prior to the final arrangement and reshaping due to the urban renewal of Florence in 1877, which definitely transformed it into a raised graveyard surrounded by boulevards.
A campaign of VLF-EM and ERT measurements was performed to ascertain the presence of a buried part of the ancient eastern wall and identify the key areas of concern for the stability. High values of resistivity were clearly detected and mapped by means of 2D-ERT along the AA' array intercepting the hypothesized location of the buried wall. This measure was cross-validated with the corresponding VLF-EM anomaly profiles, thereby retrieving reliable geophysical evidences suggesting the presence of buried remains.
To correlate the effects of inner structures and soil properties with the stability condition of the mound, crack pattern survey was carried out over the wall containing the mound, jointly to an inspection of the cavities and the interspaces between the exterior masonry surfaces and the rear terrain. The spatial distribution of the opened cracks allowed the actual threat for the stability of the mound to be assessed also in relation to the current positions of the cypresses, periodically replanted for landscape reasons. Interesting insights were obtained by mapping the inclination and tilt direction of the gravestones and funerary monuments, as superficial indicators of ground subsidence and soil compaction/collapse at the top of the mound.
The benefits achieved for site management and tombstones maintenance have encouraged the exportation of this approach (highly adaptable to include also GPR and seismic methods) to other case studies, and open to a sustainable implementation for the investigation of funerary mounds, such as the Etruscan burial mounds.