Geophysical Research Abstracts
Vol. 16, EGU2014-12492-2, 2014
EGU General Assembly 2014

Non-destructive investigations at the Dionisiac Frieze in the Villa of Mysteries, Pompeii

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The Villa of Mysteries with its Dionisiac Frieze is one of the well-known buildings of ancient Pompeii. It has been excavated in the early 20th century. Since then many initiatives have been taken for its preservation. Currently, the Frieze is investigated in detail and tests have been made to clean the wall paintings.
Non-destructive investigations as infrared thermography (IR), Ground penetrating radar (GPR), and ultrasonic measurements have been performed in order to test if these methods are well suited to reveal the walls' and paintings' structure and to identify the detachments or cracks.
IR, GPR and ultrasonic measurements have different penetration capabilities and resolution in depths. So, using these three methods simultaneously can improve the knowledge of the investigated structures at several depths from millimetres and centimetres to metres.

It has been tested if detachments of the paintings, cracks, or alterations of the paintings can be detected by passive and active IR measurements. 6 passive and 3 active measurements have been conducted on the Dionisiac Frieze. Lateral temperature differences present at the Frieze are mapped by passive measurements. Here, we show that temperature differences up to about 0.3°C are present and detectable. These small changes in temperature may be related to detachments, cracks, or wet areas. By active IR measurements the paintings are artificially heated by about 1°C and the cooling to normal temperature is observed and analyzed. Lateral differences in the heating and cooling behavior are related to variability in the heat absorption properties and in thermal conductivity. It is shown that detachments as well as restorative treatments are associated with changes in the thermal behavior.

In order to image the construction and the condition of the investigated walls, Ground Penetrating Radar (GPR) was measured with a 2 GHz antenna. Each profile was 1.2 m long, the spacing cross-line was 3 cm and in-line 1 mm. The vertical sections contain reflection horizons of the plaster layer, the second wall layer and the back wall. Additional diffractions of objects with high differences in electrical properties i.e. bricks, cavities, cracks enables to estimate the travelling velocity of electromagnetic waves and the deep penetration. In addition, calculated time slices show areas with concentrated high and low reflection energy of different depth layers of the wall inside structure, which can related to changes in the composition and the water saturation.

Ultrasonic experiments with frequencies between about 5 kHz and 500 kHz may be applied to non-destructive testing of structures made of natural stone for example facades, engineering structures,
Usually, traveltimes of first-arriving P-waves are measured in ultrasonic transmission experiments. The resolution for changes of uppermost structures in transmission configuration is however limited. Therefore, we firstly perform surface measurements and secondly the full waveform is investigated. That means source and receiver are coupled to nearly plane parts of the object's surface and the receiver is moved along profiles with lengths between about 10 cm to 30 cm. These measurements are simple to perform because the object under consideration has to be accessible only from one side and the source and receiver configuration is easier to control. In this configuration, P-waves show generally very low signal-to-noise ratios but surface waves propagating along the free surface – here Rayleigh waves - show large amplitudes and are well suited for the investigation of superficial layering. Furthermore, surface wave dispersion is sensitive also to gradual changes of the structure with depth as usually present in real structures. This is another advantage of ultrasonic surface wave studies as body waves are not reflected by gradual internal changes in the structure and methods based on reflected body waves may not be applied in these cases. Here, we show examples for ultrasonic surface measurements that are generally of high quality. Forward modelling and inversion of ultrasonic waveforms reveal strong changes of the material properties with depth: in the upper millimetres, high shear-wave velocities are observed while the plaster below is

characterized by much lower shear-wave velocities. The paintings form a layer of about 3 mm to 6 mm thickness with larger strength than the underlying plaster. Furthermore, a pronounced lateral changes in the properties of the paintings are detected by the strong variability of the ultrasonic surface measurements. They are caused by changes in the structure of the paintings as well as by alterations as detachments or cracks.