Non-invasive multi-modal analysis of Cave 465 murals in Dunhuang, China

Sotiria Kogou[1*], Haida Liang[1], Chi Shing Cheung[1], Andrei Lucian[1], Bomin Su[2]

[1]*School of Science & Technology, Nottingham Trent University, Clifton Lane, NG11 8NS, Nottingham, UK*
[2]*Conservation Research Institute, Dunhuang Academy, Gansu Province 736200, China*
*Sotiria.kogou2013@my.ntu.ac.uk

The Mogao Cave complex near Dunhuang in the Gobi desert is a UNESCO site of great cultural and historical importance. This study is focused on the analysis of the murals in these caves and more specifically cave 465. Cave 465 is of particular interest as it is the only cave in Mogao containing Tantrayana Buddhist iconography in typical Tibetan style and its murals are the oldest of such art preserved outside Tibet. The aim of this project is to understand the painting techniques and materials of these murals, exploring the history of this monument and more specifically the exchange between the Tibetan and Chinese painting culture, as well as to examine the material degradation through the years.

Conventional analytical techniques are usually invasive where samples are collected from the paintings which, apart from being destructive, restricts the information to materials contained in the detached samples and therefore may not even be representative of the artwork as a whole. For this reason, a range of non-invasive imaging and spectroscopic techniques has been applied to examine the murals. The multimodal non-invasive analytical approach introduced here combines coherent light-based imaging and spectroscopic systems, optical coherent tomography (OCT) and Raman spectroscopy, with other techniques such as remote multispectral imaging (PRISMS), as well as X-ray Fluorescence (XRF) and fibre optic reflectance spectroscopy (FORS). This approach enables a holistic analysis of the murals combining the strength and overcoming the limitations of individual techniques.

Optical coherence tomography (OCT) is a non-invasive, non-contact imaging technique capable of three dimensional imaging of subsurface microstructure using a fast scanning Michelson interferometer. OCT has been successfully applied to the non-invasive imaging of historical paintings and other cultural artefacts as, due to its non-invasive nature, it is the only method that can provide cross-sectional microstructure imaging without causing any damage. In this project, OCT imaging was used for the examination of the sequence of paint and drawing applications in high resolution. Given the large scale of the murals, PRISMS was used for their preliminary examination, using the near infrared bands, in order to highlight the areas with underdrawings that should be analysed in details with the OCT system. Moreover, the OCT signal contains absorption and scattering information which provides an extra tool for the characterization of painting materials.

Raman spectroscopy is a non-destructive analytical technique widely used for pigment identification that provides highly specific pigment identification. It is a technique successfully used for the identification of both inorganic and a few organic colorants, but with limitations in the identification of highly fluorescent materials such as aged binders and the majority of organic colorants. In our study this limitation is partially overcome by using high resolution reflectance spectroscopy in the 350-2500 nm range. XRF measurements provide elemental identification. Both pigment identification and the examination of the painting techniques were extended to areas at a distance up to 12 m (e.g. ceiling) using PRISMS data collected from them.