A systematic non-invasive optical investigation of wall paintings at a UNESCO world heritage site

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The Mogao caves near Dunhuang at the edge of the Gobi desert is a Buddhist temple site with a history that extends over 1000 years from the 4th C to the 15th C. There are 735 caves (492 with wall paintings) and 45,000 square metres of wall paintings at the site, which is an immense resource for the study of the history of art and architecture, religion, science and technology, politics and cultural exchange along the Silk Road. The wall paintings are vulnerable and therefore any examinations conducted for art conservation or historical and archaeological studies should preferably be non-invasive and non-contact.

In this paper, we show an example of a systematic in situ study of the wall paintings using a range of non-invasive optical imaging and spectroscopic instruments. PRISMS, the remote spectral imaging system developed in our group, has the capability of high resolution remote multispectral/hyperspectral imaging at distances of tens of metres making it convenient to examine ceiling paintings at a height of 11–12 m. Since these paintings have been in caves with very low natural lighting over the centuries, it is important to ascertain the stability of the paint to light before using strong illumination. While imaging is generally considered non-invasive, all imaging techniques need some sort of illumination which can potentially cause photo-chemical changes in the artefacts being examined. A microfading spectrometer developed in the group, which can monitor the change in spectral reflectance of a material while subjected to accelerated light ageing using a focused beam of light of high intensity at a tiny sub-mm sized spot, was used to examine the light stability of various paints in a cave before imaging. Spectral imaging revealed faded writings, preparatory sketches and allowed pigment identification. Optical coherence tomography (OCT) equipment was brought to this remote site for the first time. It was initially thought that unlike European paintings, East Asian paintings have very thin paint layers and higher pigment to binding medium ratios and would therefore not be suitable for OCT examinations. However, our results showed that OCT was very effective in separating the layers on which the preparatory sketches and the final sketches were drawn. This paper demonstrates through examples how a combination of these non-invasive imaging and spectroscopic methods can yield a wealth of information for conservation and art history.