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The use of radiation in the study of cultural heritage artefacts

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HIGHLIGHTS

- We describe a diverse range of techniques used to study cultural heritage artefacts.
- IR X-ray and particle beam techniques were used to study:
- The structure and composition of Australian Indigenous bark paintings.
- The effects of iron-gall inks on parchment.
- The results of corrosion and corrosion protection in machinery and vehicles.

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ABSTRACT

Patrons of art galleries and museums, tourists visiting historic buildings, and sightseers viewing archaeological sites are generally unaware of the extent to which science and technology has contributed to the value of what they see. Many countries rely on cultural tourism to generate national wealth. The use of radiation of many kinds to assist in the conservation/restoration of cultural heritage artefacts is described in this paper. In particular, the paper will describe studies of the pigments used in historic Australian Indigenous art, the degradation of manuscripts written using iron-gall inks, the protection of statues against corrosion and the selection of lubricants for use in old machinery.

1. Introduction

Patrons of art galleries and museums, tourists visiting historic buildings, and sightseers viewing archaeological sites are generally unaware of the extent to which science and technology has contributed to the value of what they see. Many nations rely on cultural heritage tourism to assist in generating foreign exchange. For example: in Australia the nett value of the service industries to which tourism is a significant contributor is comparable to the earnings of the mining industry. Finding appropriate scientific strategies for the solution of problems is therefore very important.

The scale of objects and artefacts which comprise our cultural heritage is extremely large. In **size** it ranges from large archaeological installations such as stone henges and burial mounds, the Great Wall, the pyramids, prehistoric towns, and forts, medium scale constructions such as tombs (the Ming Tombs and the Terracotta Warriors burial at Sian), to cave paintings, and to everyday objects such as paintings, statues, and so on. The **time span** is from 4000 BCE to the present day. Every conceivable type of material has been used. All this makes the task of protecting and conserving our cultural heritage extremely difficult.

The methods used in cultural heritage investigations should *in principle* be non-destructive. The first tenet of conservation is "primum non nocere: first do no harm".

Almost all modern methods involve the use of photon-in-photon-out techniques and therefore meet this criterion. The range of photon wavelengths used to illuminate the artefacts can be from the THz region to the γ-ray region (1000 nm to 0.01 nm). Photon-material interactions may include: elastic scattering, inelastic scattering, Raman scattering, photo-electric absorption and fluorescence.

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Other techniques can be used when it is permissible to take samples from the artefacts. These destructive tests can include photon-in photon-out interactions as well as techniques involving particle interactions. Particle interactions include electron diffraction, neutron scattering, particle (usually proton) induced X-ray and γ-ray emission (PIXE; PIGME), Particle accelerators can be used to date specimens found in archaeological sites (See, for example: Creagh and Bradley, 2000).

Other equipment used in Cultural Heritage Investigations include: Ground Penetrating Radar (GPR) and satellite remote sensing systems used extensively in archaeological research; portable Infrared and Raman spectroscopy systems used in the study of the composition of small inaccessible objects and images in museums, galleries, caves, and the outdoors; portable and laboratory-based X-ray diffraction (XRD) and X-ray fluorescence (XRF) (Creagh and Bradley, 2000). Synchrotron radiation (SR) facilities are hosts to most of the foregoing techniques (Creagh, 2007). Neutron radiation facilities (both reactor and spallation) provide support to Cultural Heritage Conservation groups.

This paper describes how the authors have used a diverse range of the physical techniques to solve particular problems in the field of cultural heritage conservation in the past 25 years. Examples have been chosen to illustrate how radiation of different kinds is used to examine different artefacts.

2. Projects undertaken

2.1. Aboriginal indigenous art

Aboriginal communities in Arnhem Land and two major collecting institutions were concerned about the stability of traditionally produced bark paintings. The collecting institutions were concerned about maintaining their collections in good condition and the traditional owners were concerned that paintings which European and Japanese collectors had problems when located in an air conditioned environment.

A project was set up to trace the causes of the problem. Barks of the eucalyptus tetradonta tree which grows in the clan regions, and they were prepared in the usual way, namely: they were placed on a fire and heated on both sides for a time to dessicate the bark. Optical microscopy was then performed on cross sections of the bark. This showed that the heating destroyed the starch grains in the bark leaving a much more homogeneous surface for the painters to paint on.

Time lapse photography of the barks in a chamber in which both temperature and humidity could be controlled showed that the barks moved warped significantly when temperature and humidity were cycled. This led to the development of mounts which would gently restrain the warping and to the development of guidelines for the storage and display of the paintings.

Arising from this project was the question of whether the provenance of traditional bark paintings could be established by analysing the paintings. The question had arisen because copying of paintings has become a problem, and the indigenous communities depend on the sale of paintings for their livelihood.

The principal pigments in bark paintings are ochres, white pigments, black pigments. The provenance of old and new bark paintings is generally known: new bark paintings are sold by the community, and old bark paintings have generally been acquired by collecting agencies from the traditional owners or their representatives. But problems exist when there is a break in the custodial chain. This is most common for old (>50 years) paintings. Curators then assign provenance on the basis of painting style.

The ochres used in traditionally produced old bark paintings come from a few mine sites (Fig. 1).

Each mine produced ochre of its own special character. Some locations produce ochres are red (due to a dominance of Fe_2O_3), some blood red (due to inter-mixture of Fe_3O_4), some glisten with particles of muscovite (mica), some have admixtures of goethite (FeO(OH)). And so on. Samples of old ochres taken from these mine sites were given to the project by Dr Mike Smith (National Museum of Australia (NMA)) for reference purposes.

These samples, and samples of bark paintings, were analysed using laboratory-based X-ray diffraction and Synchrotron Radiation X-ray diffraction (SRXRD) (Creagh et al., 2007). Because SRXRD requires a much smaller sample size it is the more commonly used analytical technique (Creagh, 2007). Fig. 2 shows the diffraction pattern for a pink ochre. The light red colour is due to an admixture of kaolinite ($Al_2Si_2O_5(OH)_4$).

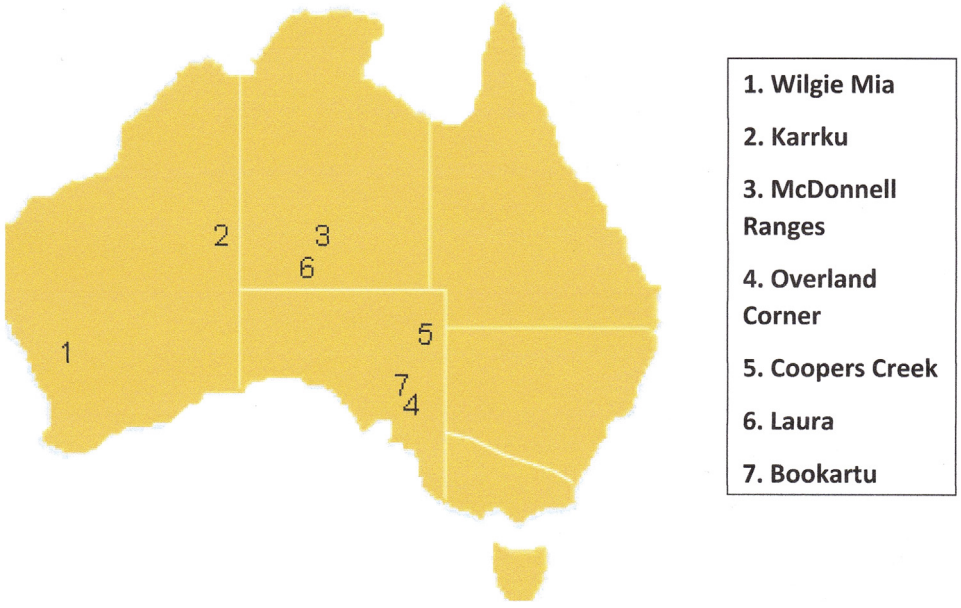

Fig. 1. Traditional ochre mines in Australia pre-1900.

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