

Application of a portable XRF analyzer to investigate the medieval wall paintings of Yemrehanna Krestos Church, Ethiopia

Kidane Fanta Gebremariam,* Lise Kvittingen and Florinel-Gabriel Banica

Despite the large body of ancient Ethiopian works of art in the form of murals, icons, and illuminated manuscripts, the physicochemical examinations carried out on them are few. This study is an *in situ* investigation of the wall paintings in the early 12th century Yemrehanna Krestos Church, Ethiopia. Fast, onsite, nondestructive analysis of the painting materials was carried out using a portable X-ray energy fluorescence dispersive spectrometer. It is believed to be the first *onsite* technical examination of Ethiopian mural paintings. This work resulted in information about the painting materials and the existence of different painting programs. The analysis revealed that the main pigments were red and yellow ochre, minium, cinnabar, orpiment, gypsum, lead, and white and carbon black; those typically employed in medieval times with no indication of later conservation–restoration intervention. Correlation between concentration of elements and multivariate statistical analysis was used to identify the most probable compounds and to classify sets of pigments used in two painting programs. The portable X-ray energy dispersive fluorescence spectrometer analyzer is found valuable to guide the *in situ* analysis and assess potential sites for microsampling for further investigations with complementary analytical techniques. However, in this expedition, we were unable to collect sufficient microsamples to warrant adequate complementary analyses. Characterization and documentation of the materials of the church murals support art historical studies and eventually conservation intervention plans. Copyright © 2013 John Wiley & Sons, Ltd.

Introduction

This is an *in situ* investigation using a portable X-ray energy dispersive fluorescence spectrometer (pXRF) to study paintings belonging to the 12th century Yemrehanna Krestos Church, which was built in a cave at an altitude of 2650 m on the west side of Mount Abuna Yosef, 12 km slightly northeast of Lalibela, a United Nations Educational, Scientific and Cultural Organization cultural heritage site. The church is one of the oldest surviving examples of Christian architecture in medieval Ethiopia decorated with paintings. It is constructed in the form of a basilica with three aisles, a cupola, and a tall saddle roof. The church's architecture is derived from an earlier Aksumite building tradition of alternating layers of wood and stone.^[1] It was, and still is, an important site of pilgrimage used by the local people. The church was built by the priest-king of the Zagwe Dynasty who ruled at the end of the 12th century. Several of the Zagwe rulers were great church builders with the tradition claimed to have begun during the reign of Yemrehanna Krestos.^[2–4] There are both figural and geometrical decorations in the church. These are located on walls, arches, capitals, columns, and ceilings. Part of the ceiling is also carved into medallions and painted. The wall paintings represent various religious themes.^[1] The paintings are suffering from continued deterioration and disfiguration, as well as being covered with dust and soot. They have apparently never been restored but are clearly in need of a conservation intervention. This investigation is a step on the ladder to well-informed restoration and conservation. It could also add to the knowledge we have about the materials and techniques of the paintings for art historical studies.

Despite the large body of extant Ethiopian art in the forms of murals, icons, and illuminated manuscripts, their study from the

chemical perspective is scant. No onsite investigations, as far as we know, have previously been carried out on Ethiopian wall paintings to identify the chemical composition of the pigments or artistic techniques. This is not surprising as undertaking investigations onsite in Ethiopia is challenging. These sites, which are still sacred, are located in remote areas, some accessible only on foot or even by climbing in addition to being at high altitudes, e.g. in the Lalibela area between 2600 and 3700 m. Time for an investigation may also be limited, due to various concerns and activities. Thus, a range of ad hoc changes have to be accommodated in the field work.

X-ray fluorescence spectrometry, XRF, as a fast and nondestructive method, has in recent decades proven versatile for cultural heritage studies.^[5] Examples of both portable and stationary XRF systems used for *in situ* and *ex situ* studies are numerous and diverse in the literature. Some recent applications are for paintings,^[6–8] investigation of paintings and other cultural heritage objects along with complementary analytical techniques,^[9–15] a remote-controlled system used for field investigation,^[16] and analysis of murals using confocal synchrotron micro-XRF.^[17] The typical characteristics of a handheld XRF were also deemed appropriate for investigations of Ethiopian artifacts in the field. In particular, the extreme portability of the analyzer (weight ~ 1.3 kg), the short analysis time, and the nondestructive nature of the

* Correspondence to: Gebremariam, Kidane Fanta, Norwegian University of Science & Technology (NTNU), Department of Chemistry, Trondheim, Norway. E-mail: fanta@ntnu.no

Department of Chemistry, Norwegian University of Science & Technology (NTNU), Trondheim, Norway