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Investigating the Secrets of Stonehenge with Raman Spectroscopy: Provenance of the Ancient Altar Stone

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Abstract: In-field compositional analysis of large prehistoric relics, such as the Altar Stone at Stonehenge (England), is limited due to the size of the relics and difficulty in obtaining samples that can be analyzed in a laboratory. In this study, a portable Raman spectroscopy system was used to analyze the Altar Stone to help determine its origin and classification, which appears to differ from other bluestones at Stonehenge. While the study is ongoing and the definitive origin of the Altar Stone is not yet known, this study demonstrates the applicability of a portable Raman spectroscopy system in the compositional analysis of large samples in the field.

Keywords: Raman spectroscopy, Stonehenge Altar Stone, micaceous sandstone, bluestone

Introduction

Located in Salisbury, UK, Stonehenge is the most architecturally sophisticated prehistoric stone circle in the world. In the quest to unravel the mysteries of Stonehenge, Renishaw had the privilege to assist in analyzing the Altar Stone *in situ* using a Renishaw Virsa™ Raman analyzer. The Altar Stone is unusual and differs in appearance when compared to the other main bluestones of Stonehenge. The aim was to use Raman spectroscopy and mineralogy to understand the provenance of the stone. Raman spectroscopy is ideal for this analysis as it is sensitive to the chemical composition and mineralogical makeup of geological samples. To ensure the site was free from tourists, Renishaw was on-site from dusk until dawn with a team of experts in geology, headed by Professor Richard Bevins.

Professor Bevins is an Honorary Professor at Aberystwyth University and was formerly Honorary Research Fellow at the National Museum of Wales. He has dedicated significant effort to determining the provenance of some of the bluestones at Stonehenge. Prof. Bevins and his team previously confirmed that most of the bluestones were linked to Pembrokeshire, Wales [1]. The research team also includes Professor Sergio Andò and Dr. Marta Barbarano, both Raman spectroscopy experts in geology from the University of Milano-Bicocca, Italy (Figure 1). Professor Andò is a researcher in heavy minerals and sedimentology applied to provenance studies. He has previously analyzed debitage (small fragments of rock removed from larger pieces) derived from the Altar Stone using Raman spectroscopy at Renishaw's applications laboratory in Gloucestershire, UK.

The Altar Stone is a gray-green micaceous sandstone, otherwise known as Stone 80. It is anomalous in its composition, size, and weight when compared to the other bluestones. A recent publication by a team of geologists, which included Professors Bevins and Andò, proposed that the Altar Stone be declassified as a bluestone. Based on X-ray and Raman analysis in the laboratory on fragments of the stone using a Renishaw inVia Raman microscope, they hypothesized that the stone did not originate from the Anglo-Welsh Basin, as previously thought [2]. Instead, they are looking at other possibilities for where the Altar Stone originated, such as rocks of the same age or younger in Northern England or Scotland, for which Raman spectroscopy will help elucidate the source.

With small samples, this work is easily done in a lab using a Raman microscope. However, this is almost impossible in remote locations and with gigantic samples, such as the Altar Stone, which is partly buried and an estimated six tons in weight.

Figure 1: Some of the team who analyzed the Altar Stone at Stonehenge. (Left to right) Professor Sergio Andò, Dr. Jorge Diniz (Renishaw plc), and Dr. Marta Barbarano.

Figure 2: A versatile portable Raman laboratory. The Virsa Raman analyzer at Stonehenge, powered by a portable battery pack (left). The flexible Virsa SB200 stage carefully positioned close to the Altar Stone (right). The inset shows the Virsa probe focusing on a region of the Altar Stone.

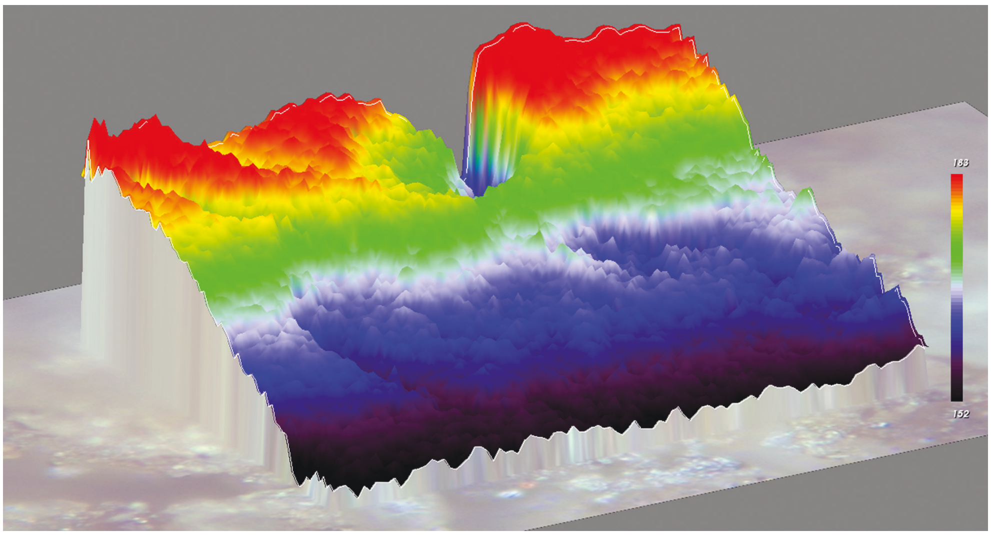

Figure 3: The topography map of a ca. 115 × 90 μm^2 area of the Altar Stone, showing a variation of approximately 31 μm^2 in height (black to red). Although no chemical information can be presented now, the topographic information is displayed obtained using LiveTrack technology during the Raman analysis.

The Transportable Virsa™ Raman Analyzer

This application is ideal for the transportable Virsa analyzer (Figure 2) equipped with LiveTrack™ focus-tracking technology (Figure 3). This enabled automated Raman imaging across the uneven surface of Altar Stone with the probe at constant optimum focus across the surface. The Virsa positioning system allowed quick movement of the point of analysis with micrometer precision allowing *in situ* automated Raman imaging with microscopic resolution, which would not have been achievable with handheld instruments. Due to the immense flexibility of the stage, the probes were positioned to precisely focus on the Altar Stone to enable Raman analysis, without any damage to the surface (Figure 3). The low power requirements of the Virsa analyzer meant that it could be powered by a portable battery pack for over 11 hours. Its use on-site at Stonehenge demonstrated that the system is a truly portable high-performance Raman system.

The Altar Stone's Chemical Secrets to be Revealed

The team acquired Raman spectra from different areas of Altar Stone with the aim of obtaining a clear mineralogic fingerprint and chemical images to support the characterization of the specimen. The data are being carefully analyzed in Italy by Professor Andò. Ultimately, this could confirm the provenance of this unique stone and, along with comparison to other rock samples, its geographical source. This is a great example of how the Virsa analyzer allows users to take the lab to the sample, when it is not possible to take the sample to the lab.

References

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