Neutron Activation Analysis of Medieval Limestone Sculpture at the University of Missouri Research Reactor Center

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INTRODUCTION

Since the mid-1980s, NAA of Medieval limestone sculpture has resulted in the analyses of more than 1500 historical objects and 500 quarry samples in collaboration with more than 30 museums in the USA, France, Great Britain and elsewhere, both public and private institutions, university Departments of Art History and private foundations. The INAA analyses, which until recently were directed by Gar Harbottle and Lore Holmes (Brookhaven National Laboratories), have resulted in a large number of publications (see www.limestonesculptureanalysis.com). In fall 2005, the entire Limestone Sculpture Project, including archival samples, documentation, and database was transferred to the University of Missouri Research Reactor Center (MURR).

DESCRIPTION

In 2006, The Metropolitan Museum of Art (MET) acquired a Medieval "angel head" limestone sculpture (MET 2006.41). This sculpture is morphologically and stylistically similar to one housed at Duke University (1966.179) that was previously analyzed by instrumental neutron activation analysis (INAA). Based on INAA of the Duke sculpture, it was determined that Duke Head of Angel could be linked to a production center near Paris, and possibly the Notre Dame Cathedral in Paris. Given the similarity of the recent MET acquisition to the Duke University sculpture, it was suggested that 2006.41 also might have originated from Notre Dame. INAA analysis was conducted at the University of Missouri Research Reactor Center (MURR) to determine, if possible, the provenance of the limestone used to manufacture the sculpture.

This analysis of MET 2006.41 represents MURR's attempt at comparing MURR-derived limestone data to the Brookhaven (BNL)-derived limestone database. Because all of the extant limestone data have been generated at BNL (using a completely different suite of standards), it was necessary to ascertain whether the MURR analyses were comparable with numbers generated at BNL. As a first step in this process, all BNL data were converted from ppm-oxide to ppm in order to facilitate comparisons. Eight samples previously analyzed at BNL were then fully reanalyzed at MURR using standard preparation and irradiation procedures[1]. These numbers were then compared to their BNL counterparts. An intercalibration factor based on the % recovery (by element) was calculated to adjust for the small analytical differences that exist between laboratories. Because of high standard deviations and/or poor precision Ba, U, Co, Zr, and K are not considered in the analysis of data. Additionally, several elements measured at MURR (Al, Dy, Nd, Tb, Ti, V, and Zn) were not measured at BNL. Quantitative analyses were subsequently conducted on the following 19 elements: La, Lu, Sm, Yb, Ce, Cr, Cs, Eu, Fe, Hf, Rb, Sb, Sc, Sr, Ta, Th, Ca, Mn, and Na.

RESULTS

A Euclidean distance search was conducted to identify the 10 closest specimens to MET 2006.41. This search which was conducted on both corrected and uncorrected data yielded similar results. The search suggests that (1) Vernon Quarry provided the material used for the sculpture, and (2) the closest match with a historic object is a MET object (29.100.28). A principal components analysis was conducted based on the variance-covariance matrix of the entire BNL limestone database. A principal components analysis clearly shows that MET 2006.41 is distinct from the Paris area limestone and Duke's head of angel (1966.179). Reference groups were constructed for Jumieges (which includes Vernon Quarry) and for Amiens. For the Notre Dame reference group we used samples identified in the limestone database. The validity of the proposed Jumieges and Amiens reference groups was confirmed using Mahalanobis distance-based probabilities based on the first 8 PCA scores (accounting for more than 96% of the cumulative variation) derived from PCA of the combined Jumieges, Amiens, and Paris: Notre Dame reference

groups. A biplot based on PCA of the three reference groups (Figure 2) supports the distinctiveness of these groups.

In conclusion, it very probable that MET objects 2006.41 and 29.100.28 were produced using limestone obtained from the same quarry/geologic outcrop. This quarry is likely Vernon Quarry or a nearby and geologically similar quarry. Several samples previously attributed to the Amiens West Façade source (Tables 1 and 3) can be attributed to the Jumieges reference group. The attribution of the Duke Head of Angel to the Paris: Notre Dame reference groups is problematic. Although this sample clearly originates from the vicinity of Paris, it is essentially outlier to the centroid of the BNL Paris: Notre Dame reference group.

REFERENCES

1. Glascock, M. D., Characterization of archaeological ceramics at MURR by neutron activation analysis and multivariate statistics. In *Chemical Characterization of Ceramic Pastes in Archaeology*, edited by H. Neff, pp. 11–26. Prehistory Press, Madison, WI (1992).

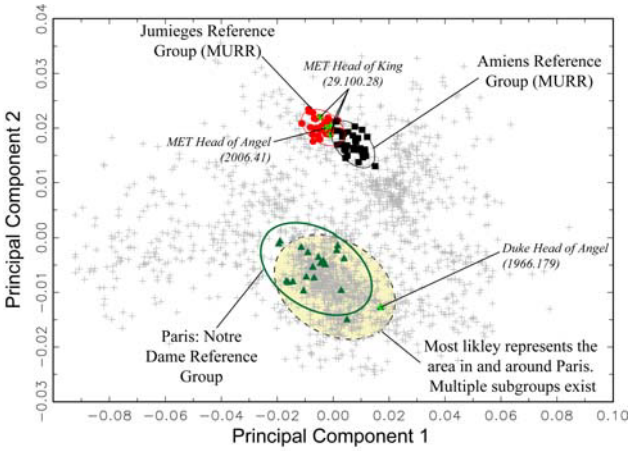

Figure 1. Variance-covariance matrix plot based on PCA of the entire 2100+ specimen limestone dataset. The MURR-derived Jumieges and Amiens reference groups, the BNL Paris: Notre Dame reference group, and samples 2006.41, 29.100.28, and 1966.179 are plotted. Ellipses represent the 90% confidence interval for group membership.