Smithsonian
Museum Conservation Institute

REPORT
Fabrication Techniques of Pre-Columbian Gold Beads

MCI # 6100.3

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INTRODUCTION

Fabrication Techniques of Panamanian Gold Beads

While the techniques of gold jewelry fabrication in Europe have been extensively studied, to date there has been relatively little research on the production of Pre-Columbian gold ornaments, and more specifically the manufacturing techniques of gold beads. Ongoing research at the Smithsonian Institution on the history of Pre-Columbian gold-working in Panama provided the context within which to undertake an in-depth study of bead fabrication.

Gold beads provide an excellent starting place for looking at specific fabrication technologies used by Panamanian goldsmiths as they are a common and widespread class of artifact in Panama. Beads also represent a range of forming technologies from hammered sheet to lost wax casting, allowing the study of a variety of production methods within one category of artifact. The large quantity of beads that have been found in Panama to date also provides a considerable sample for analysis.

Despite their prevalence, the references to Panamanian gold beads in the literature are rare and often contradictory. According to Emmerich (1965), the necklaces excavated at Sitio Conte were composed of hundreds of identical cast gold beads, many of which were "cast over inner cores." The archaeologist at Sitio Conte, Samuel Lothrop (1937), instead describes the majority of beads as "hammered or pressed" to shape over a perishable substrate. While Stone and Balser (1958) also mention hammered beads amongst those that they examined, they suggest that the majority were made up of different types of cast gold beads, including cast tubes cut at regular intervals to produce identical smaller beads. None of these assertions, however, are supported by analytical work. Analysis was therefore conducted on Pre-Columbian gold beads in the NMAI collections, as well as on gold beads recently excavated in Panama in order to clarify their fabrication.

Using information gathered during technical examination carried out during a prior phase of the larger research project on Panamanian gold (MCI#6100.2), the gold beads from Panama were divided by fabrication technique into two main categories: cast and sheet fabrication. The beads fabricated from sheet were found to be far more numerous than those that were cast. These beads were either coiled with no joined edge or else joined with a bonded overlap (Figs.1a,b). The beads with a bonded join were by far the most common type at 88.9% of all beads examined. Based on the information provided by the preliminary investigation, the sample set for further analysis was narrowed down to the most common category of bead, those formed from rolled and joined sheet metal. The fabrication methods used to make the rolled and joined sheet beads were therefore investigated further using scanning electron microscopy with energy dispersive spectrometry (SEM-EDS) on a subset of representative beads from the NMAI collections and a small group of excavated beads from Panama, which were also approved for metallographic study.

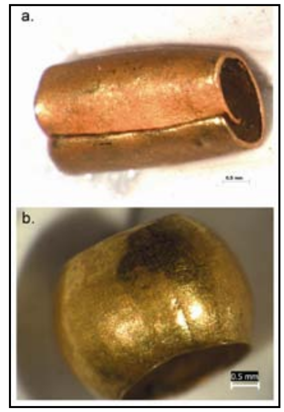

Fig.1 (a) Rolled gold bead with no join; (b) Rolled and joined bead

Comparison of Gold Beads from Central and South America

Initial results from XRF analysis of the Panamanian gold objects in the Smithsonian collections, during an earlier phase of the goldworking research project (MCI#6100.2), had revealed a compositional pattern related to geographic origin (Harrison and Beaubien 2010). Analysis of the gold beads from different regions presented an opportunity to test these findings and place the Panamanian production in a wider geographical context. In order to compare regional variations in style, technology, and composition of gold beads from Panama and elsewhere in Central and South America, additional examination and analysis were conducted on beads in the NMAI collection from Mexico, Nicaragua, Costa Rica, Colombia, Ecuador, and Peru. Through documentation of technology and composition, this study aimed to provide information on the similarities or differences in the preferences for bead types and fabrication methods between Panama and the surrounding regions.

OBJECTS

Several different groups of beads were identified for analysis in this study. Group 1 included five beads from El Caño (2009) currently on loan to MCI. Group 2 included 17 beaded objects already on loan to MCI from NMAI for ESEM-EDS analysis as part of MCI#6100.2. Group 3 included approximately 86 individual beads or multiple-bead objects from Central and South America (outside of Panama) in the NMAI collection. The fourth group of beads was intended to be made up of experimentally reproduced copper and gold/copper beads; however, this part of the project has not yet been carried out due to time constraints. As most of these groups of beads underwent many of the same analyses, these techniques are described together in a section below on Methods. The results are then presented under each bead group. The data and photos generated during this project are also included as Appendices A-G. For additional discussion of the analysis and results of the gold beads from Panama, see Harrison et al. (in press), included here as Appendix A.

Group 1: Beads (5) from El Caño archaeological site (excavated in 2009), Coclé, Panama

The beads that were brought back from El Caño for further analysis in Washington DC were: R4829, R4853, R5101.2 (a and b), R5341, R5352.1 (a and b), and R5352.2 (a and b). See the Loan Request to the Patrimonio Histórico (Attachment 1 in MCI #6100.3 Request) for photos and additional information on each bead.

Provenience: El Caño archaeological site (excavated in 2009), Coclé, Panama

Owner: Panamanian Government, on loan to MCI for non-destructive/destructive analysis

Person Authorized to Approve Requested Actions: INAC/Patrimonio Histórico –objects loan and non-destructive/destructive analysis requested by Beaubien/approved Sept.18, 2009

Group 2: Individual beads or multiple-bead objects (17), NMAI

The object numbers are: 008271.000, 225838.000, 242465.000, 163858.000, 163859.000, 163864.000, 163865.000, 163866.000, 242466.000, 163868.000, 163857.000, 163860.000, 163861.000, 163862.000, 163863.000, 230154.000, 237891.000

Provenience: various, Panama

Owner: National Museum of the American Indian, on loan to MCI for nondestructive analysis

Person Authorized to Approve Requested Actions: NMAI Curatorial Council – collections research (including non-destructive analysis of the above items) initially requested by Beaubien Sept. 2008/approved; objects loan to MCI requested by Beaubien and Harrison/approved July 2009; additional analyses requested by Harrison/approved January 2010

Group 3: Individual beads or multiple-bead objects (86), NMAI

See Attachment 3 of MCI#6100.3 Request for a full list of objects.

Provenience: Colombia, Peru, Mexico, Ecuador and Nicaragua

Owner: National Museum of the American Indian

Person Authorized to Approve Requested Actions: NMAI Curatorial Council -- non-destructive analysis) – requested by Harrison/approved January 2010

Group 4: Experimentally reproduced copper and gold/copper beads

Due to time constraints, these samples were not produced.

METHODS

Examination and Optical Microscopy (Groups 1-3)

Visual examination and optical microscopy were carried out on most of the beads in this study, including those from groups 1-3. For the examination phase, a binocular microscope was used with magnification ranging from 6-50x. A Leica digital camera attachment and LAS EZ software on a computer connected by cable allowed photo-documentation of the microscope images. During examination under the microscope, the operator also entered technical information into the Pre-Columbian Gold FileMaker Pro database including the object description, condition information, and notes on fabrication techniques. Time did not permit for all objects in Group 3 to be examined and documented in the database.

XRF (Groups 1-3)

Every bead in this study was analyzed at one or more locations using a portable bench-top ElvaX X-ray fluorescence spectrometer. The instrument measures elements present at and just below the surface within the beam area (~1cm diam.). The heavy element mode was used, which allows detection of elements from Cl (17) to U (92). Analyses were conducted at 45 keV in count rate stabilization mode, which varies the tube current to achieve a per-sample count rate of 6000-6200 counts per second for 100 seconds live time.

A set of approximately 35 matrix-matched gold reference standards (Royal Canadian Mint BCR 8079) had been analyzed by Jeff Speakman at MCI to create a material-specific calibration in the ElvaX software, reporting results in wt%. A selection of these standards was analyzed periodically during testing to adjust the calibration and monitor instrumental precision and accuracy. The limits of detection for each element vary somewhat according to the matrix in which they are present. For copper and silver in a gold matrix, they are approximately 0.1-0.2% and ~0.25% respectively, and for gold in a copper matrix, ~0.25-0.5%. One or more analyses were made of each bead, with photographs taken of each analysis spot.

ESEM-EDS (Groups 1-3)

Environmental (or low vacuum/variable pressure) scanning electron microscopy-energy dispersive spectroscopy (ESEM-EDS) was performed on selected objects. This technique measures elemental composition and permits high-magnification imaging of objects or samples that fit within the instrument's chamber (30cm diameter x 8cm height). Analyses may be carried out in normal environmental conditions, without need for coating or sampling. ESEM-EDS provides semi-quantitative information on surface elemental composition, similar to that provided by XRF analysis but with much finer spatial resolution and higher magnification. This technique also allows imaging using secondary electrons for detailed surface morphology, and backscattered electrons to provide elemental mapping based on the relative atomic mass of the elements present at and near the object surface.

The instrument used in this study was MCI's Hitachi S-3700N Variable Pressure Scanning Electron Microscope w/Bruker XFlash EDS with Quantax 400 software. Analyses took place at 15 kV accelerating voltage, and at 10mm working distance where possible. Analysis of the whole beads was carried out under full vacuum while the sectioned beads were analyzed in variable pressure mode. Elemental mapping was conducted over the surface of the joins in order to determine whether any compositional variation from joining techniques could be detected. Elemental maps were acquired in the Hypermap mode of the Quantax software for approximately 15 minutes.

Metallography/Cross-Sectional Analysis (Group 1)

After imaging of the whole beads with ESEM-EDS, selected beads from Group 1 (R4853, R5101.2, R5341 and R5352) were prepared for metallography in the conservation laboratory at the Freer Gallery of Art, with the assistance of Paul Jett. The beads were mounted in epoxy and polished down to reveal the cross-section along one edge. Bead number R5341 was also sectioned longitudinally with a low speed diamond saw to reveal the profile of the bead in addition to the remaining half of the cross-section. All of the samples were polished with a series of increasingly finer grit grinding papers up to 600 grit. The final polish was achieved on a lap wheel with 0.05 Alpha Alumina and water on a polishing cloth. The polished cross-sections were examined under the metallographic microscope, photographed, and analyzed by ESEM-EDS. After documentation and analysis of the un-etched samples, the cross-sections were etched in aqua regia and re-examined under the metallographic microscope, followed by carbon coating and analysis once again by ESEM-EDS.

RESULTS

GROUP 1 (Beads from El Caño)

Examination and Optical Microscopy

The 5 beads in this group were among a large number of recently excavated gold finds that had been examined and photographed in Panama City by Rae Beaubien, Kim Cullen Cobb, and Ainslie Harrison; this took place during a research trip to the Smithsonian Tropical Research Institute in September 2009, as part of the prior phase of the gold research project (see MCI #6100.2 Technology of Pre-Columbian Gold in Panama, Research Report Part II: El Caño and Isla Pedro González 2010). The technical information from examination of the beads selected as Group 1 is included in Appendix A of that report; note that for object numbers R5352.1 and R5352.2, which included 54 and 91 beads respectively, only selected beads were examined and photo-documented. Photomicrographs of the beads in Group 1 are included here as Appendix B and also appear in Appendix A.

XRF

The Group 1 beads were among the larger group of recently excavated gold finds that underwent XRF analysis in Panama City by Rae Beaubien, Kim Cullen Cobb, and Ainslie Harrison during the prior research phase in September 2009 (see MCI #6100.2 Research Report Part II:). For object numbers R5352.1 and R5352.2, which included 54 and 91 beads respectively, 24 randomly selected beads were analyzed. For analysis, all beads were centered over the window of the XRF. The results from XRF analysis of the Group 1 beads are listed in Appendix C.

ESEM-EDS and Metallography

Prior to SEM analysis at MCI, the selected El Caño beads were cleaned in an ultrasonic bath by Kim Cullen Cobb. SEM was conducted by Ainslie Harrison and Kim Cullen Cobb. All beads were imaged whole using SEM-EDS; however, only four beads underwent metallography. These were: R4853, R5101.2, R5341 and R5352.1a. The photomicrographs of the bead cross-sections are included here in Appendix C. SEM images of the beads are included as Appendix D. Selections of both also appear in Appendix A.

GROUP 2 (Panamanian Beads in the NMAI Collection)

Examination and Optical Microscopy:

The 17 individual beads or multiple-bead objects in this group were examined and photographed by Ainslie Harrison in the NMAI Conservation Lab in 2008 as part of the earlier research phase (see MCI #6100.2 Technology of Pre-Columbian Gold in Panama, Research Report Part I: NMAI and NMNH 2010). The technical information from examination may be found in Appendix B of that report; thumbnails of SEM images are included in Appendix E of the same report.

XRF

The Group 2 beads were analyzed with XRF by Ainslie Harrison in the NMAI Conservation Lab in 2008 as part of the earlier research phase (see MCI #6100.2 Research Report Part I). The results from XRF analysis are listed in Appendix C of that report.

ESEM-EDS

The Group 2 beads were among a larger group of Panamanian gold objects loaned from NMAI to MCI for ESEM-EDS analysis as part of the earlier research phase (see MCI #6100.2 Research Report Part I). The analysis was conducted between 2009-2010 by Ainslie Harrison and Kim Cullen Cobb. SEM images of these objects are included in Appendix E of that report.

GROUP 3 (Beads in the NMAI Collection from Outside of Panama)

Examination and Optical Microscopy:

Of the 86 individual beads and multiple-bead objects from Central and South American countries (excluding Panama) in this group, time only permitted detailed technical examination of 54 of them. Examination and photomicrography were carried out in the NMAI Conservation Lab in May 2011 by Ainslie Harrison. See Appendix E for a printout of the FileMaker Pro database, reporting information from technical examination. Thumbnails of photomicrographs taken during examination are included as Appendix F.

XRF

XRF was carried out on the 86 beads in Group 3 in the NMAI Conservation Lab in January and February of 2011 by Ainslie Harrison. Data from XRF analysis are included as Appendix G. Photos from XRF analysis are included as Appendix H.

DISCUSSION AND CONCLUSIONS

Fabrication Techniques of Panamanian Gold Beads

Elemental mapping of Au, Cu and Ag concentrations showed homogeneous composition over the exterior surface of visible joins on all beads that underwent SEM-EDS. While no solder or eutectic bonding was detected in this initial step, no conclusions could be reached regarding the presence of these materials inside the seam as only the surface composition of these beads was measured. Variation in composition at the interior of the join therefore required further investigation. Although the Smithsonian beads could not undergo destructive sampling, confirmation of the initial results was possible through cross-sectioning of the representative beads from El Caño. Bead number 5101.2 serves to illustrate the key findings.

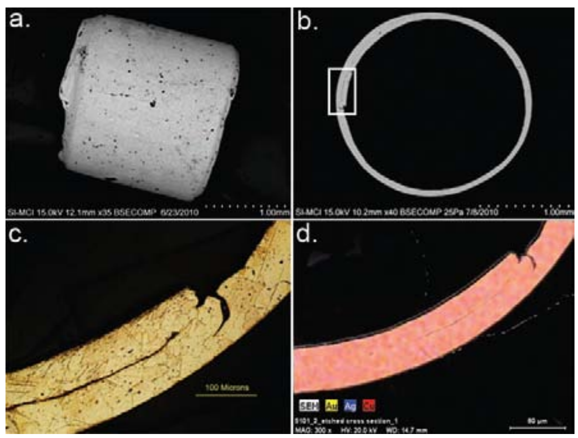

Fig.2 A rolled and joined sheet bead and cross-section showing no evidence of solder.

SEM-EDS analysis of bead number R5101.2 was first undertaken on the whole bead to measure the composition across the surface of the join. This small tubular bead, which measures just 2mm long and 2mm in diameter, has a join visible on both the exterior and interior surface, the overlap of which measures approximately 1.5mm (see Figs. 2a, b). The inner surface of the bead is rough in texture while the exterior is polished with chisel marks present around the circumference of the bead aperture. Elemental mapping at the surface of the join at 160x revealed no variation in Au, Cu, or Ag composition.

Examination of the cross-section with the metallographic microscope after etching in aqua regia revealed an irregularly shaped grain pattern from cold working (Fig.2c). The straight twinned grains throughout indicate that the sheet was annealed after working. Some of the twin lines at the join are slightly curved, however, suggesting additional localized deformation after the final annealing. The zone directly between the two layers at the very end of the overlap is tightly aligned across the grain boundary and a crack is present in the metal sheet adjacent to the end of the overlap, possibly having widened due to working at the join.

No variations in microstructure or color were noted across the join region under the metallographic microscope, suggesting no addition of solder or other material. These initial findings were confirmed using EDS analysis. Elemental mapping of the overlapping region showed no compositional variation across the join other than that related to the variation in the microstructure of the metal itself (Fig.2d). The combined evidence from metallography and SEM-EDS suggests that the bead was joined without any solder or use of any other additive material such as powdered gold or a copper salt. The join may therefore have been achieved by burnishing over a hard material on the interior of the tube. The chisel marks around the bead apertures indicate that the bead was cut from a longer tube. Analysis of the cross-sections from the three other beads produced similar results. The preliminary results from this research are included as Appendix A (Harrison et al. in press).

Comparison of Gold Beads from Central and South America

XRF analysis of Pre-Columbian beads from within Panama and from other regions in Central and South American revealed some distinct compositional patterns (Fig.3). The average silver content of the beads varied by region with Panamanian beads containing the least amount of silver and Peruvian beads containing the most, followed by Mexican and Colombian beads. Ecuadorian beads are not included in the ternary diagram as the frequent presence of platinum in these beads complicated quantification of the composition due to overlap with the gold peaks.

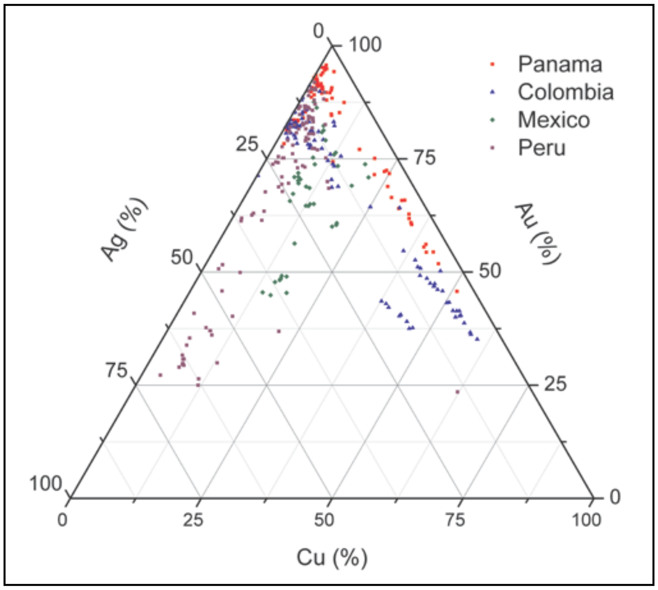

Fig.3 Au, Ag, and Cu composition of gold beads from Central and South America

While it is often difficult to detect Pt in gold objects using XRF due to the peak overlaps, the presence of strong Pt shoulders and in one case, a fully resolved Pt peak in an Ecuadorian bead, suggests that these beads may contain a significant quantity of Pt or Pt inclusions. Pt was not detected in beads from any other regions, however, confirming the potential of this element as a diagnostic feature of Ecuadorian metalwork.

While compositional analysis provided evidence of regional differences, the technology and fabrication methods also varied. Cast beads were found to be far more common amongst the beads examined from areas outside of Panama. While the cast beads from Panama made up 1.3% of all those examined, the cast beads from other countries in Central and South America made up

57.9% of all the beads examined from these regions (see Table 1). Another major difference between the beads from Panama and elsewhere was the presence of solder. While no solder was detected on the beads from Panama, 32 beads from areas outside of Panama were identified as having possible soldered joins. These observations are preliminary; however, and further data analysis is required in order to confirm the relevant variations in technology between the beads of these different regions.

Fabrication Method	Percentage
Cast- Closed Core	56.1%
Cast- Whole	1.8%
Hammered-Sheet	36.6%
Hammered-Sheathing	5.4%

Table 1 Beads from outside of Panama

FUTURE WORK

- Experimental reproduction of beads using the hypothesized methods of fabrication will be carried out. These reproductions will undergo examination and analysis in order to correlate the tool marks and features on the gold beads from Panama (in the NMAI collection and from El Caño) with specific tools and techniques.
- Additional interpretation of the data collected during this project.

REFERENCES

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Harrison, A.C., Cobb, K., and H.F. Beaubien. (In press). A Study of Pre-Columbian Gold Beads from Panama. In *SEM and Microanalysis in the Study of Historical Technology, Materials and Conservation*, Archetype: London.

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Stone, D., and Balser, C., *Aboriginal Metalwork in Lower Central America*, Editorial Antonio Lehmann, San José (1958).

MCI Reports and Requests

MCI #6100.2 Technology of Pre-Columbian Gold in Panama, Research Report Part I: NMAI and NMNH 2009 (A. Harrison, report dated April 26, 2010)

MCI #6100.2 Technology of Pre-Columbian Gold in Panama, Research Report Part II: El Caño and Isla Pedro González 2010 (H. Beaubien, A. Harrison, K. Cullen Cobb, report dated December 10, 2010)

MCI #6100.3 Analysis/Conservation Request: Fabrication Techniques of Pre-Columbian Gold Beads (approved June 2, 2010)

APPENDICES

A: Harrison et al., A Study of Pre-Columbian Gold Beads from Panama (in press)
B: Photomicrographs of El Caño beads (whole and cross-sections)
C: XRF data of El Caño beads (Group 1)
D: SEM images of El Caño beads (Group 1)
E: Technical database of beads outside of Panama (Group 3)
F: Photomicrographs of beads outside of Panama (Group 3)
G: XRF data of beads outside of Panama (Group 3)
H: Photos of XRF locations of beads outside of Panama (Group 3)