Boise State University

ScholarWorks

2015

A Transdisciplinary Approach to Determining the Provenience of a Distorted, Pre-Columbian Skull Recovered in Rural Idaho

Jennifer K. Watkins

Gordon A. Alanko

Samantha H. Blatt

Cynthia A. Bradbury

Matthew J. Kohn
Boise State University

See next page for additional authors

A Transdisciplinary Approach to Determining the Provenience of a Distorted, Pre-Columbian Skull Recovered in Rural Idaho

Abstract

Transdisciplinary research involves cooperation, exchange of information, sharing of resources and integration of disciplines to achieve a common scientific goal. In this study, collaborators utilized tools and knowledge of materials science, anthropology, archaeology, geosciences and biology in an attempt to determine the provenience of skeletal remains of unknown origin. The exchange of ideas and skills along with the crossing of disciplines in this study sucessfully allowed the incorporation of expertise from many team members. This transdisciplinary approach to research provided a more comprehensive and detailed analysis than any one field alone could provide. An archaeological assessment of a human skull recovered in rural Idaho recognized cranial deformation and post-mortem application of a red pigment. A combination of scanning electron microscopy (SEM), x-ray fluorescence (XRF) and energy-dispersive x-ray spectroscopy (EDS) identified the major and trace elements present in the red post-mortem pigment as cinnabar and rare earth metals. Analysis via carbon and oxygen stable isotopes from teeth and bone to provided insight into the diet and habitat for distinct segments of the individual's life, indicating a regional separation in early life versus late adulthood. Radiocarbon dating determined the approximate age of the skull to be between 600-700 years old and a forensic mtDNA assessmentcategorized a mitochondrial haplogroup for the remains as originating from the East African or Arabian Peninsula.

Keywords

provenance, radiocarbon dated, trace element analysis, DNA analysis

Disciplines

Materials Science and Engineering

Authors

Jennifer K. Watkins, Gordon A. Alanko, Samantha H. Blatt, Cynthia A. Bradbury, Matthew J. Kohn, Marion Lytle, Deborah Lacroix, Joanna Taylor, John Dudgeon, Rebecca E. Hazard, Erin O'Leary-Jepsen, and Darryl P. Butt

A Transdiciplinary Approach to Determine the Provenience of a Distorted, Pre-Columbian Skull Recovered in Rural Idaho

Jennifer K. Watkins[1,2]

Gordon A. Alanko[1,2], Samantha H. Blatt[1], Cynthia A. Bradbury[1], Marion Lytle[1], Matthew J. Kohn[1], Deborah Lacroix[3], Joanna Taylor[3], John Dudgeon[4], Rebecca E. Hazard[4], Erin O'Leary-Jepsen[5], Darryl P. Butt[1,2]

1. Boise State University, Boise, ID   2. Center for Advanced Energy Studies, Idaho Falls, ID
3. University of Idaho – CAES, Idaho Falls, ID 4. Ancient DNA Extraction Laboratory, Idaho State University, Pocatello, ID
5. Molecular Research Core Facility, Idaho State University, Pocatello, ID

Introduction and Background

Provenance, a history of ownership, helps provide contextual evidence of an item's origin, or *provenience*. A transdisciplinary collaboration utilized a variety of techniques including archaeological and anthropological assessments, scanning electron microscopy (SEM), energy dispersive x-ray spectrometry (EDS), x-ray fluorescence (XRF), laser ablation inductively coupled plasma quadrupole mass spectrometry (LA-ICP-QMS), stable isotope analysis, radiocarbon dating and DNA analysis to yield information about the skull's background. Researchers hope to obtain enough information in order to repatriate the individual's remains.

Frontal view of the distorted skull

Left side view of skull

The skull is thought to be that of a Native American due to
- Post-mortem application of red pigment embedded fibers
- Artificial cranial deformation (flattening at back of skull)

Analysis of pigment and fibers was completed using
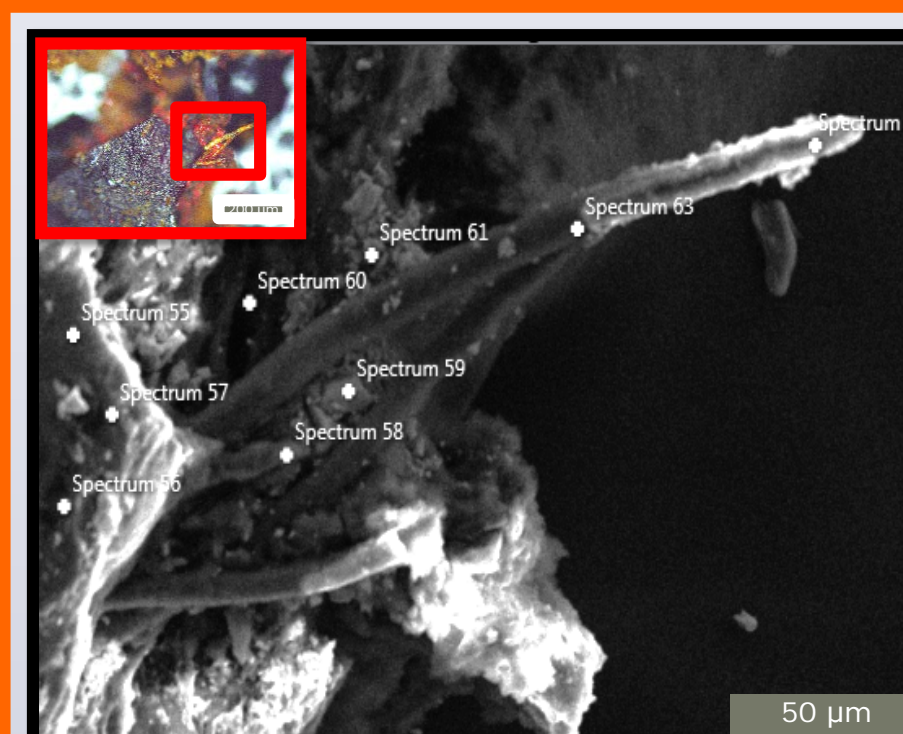- Anthropological assessment
- SEM/EDS
- LA-ICP-MS and XRF

Age, habitat information, and lineage obtained by
- Radiocarbon dating and stable isotope analysis
- Forensic mitochondrial DNA for comparison to known Native American populations
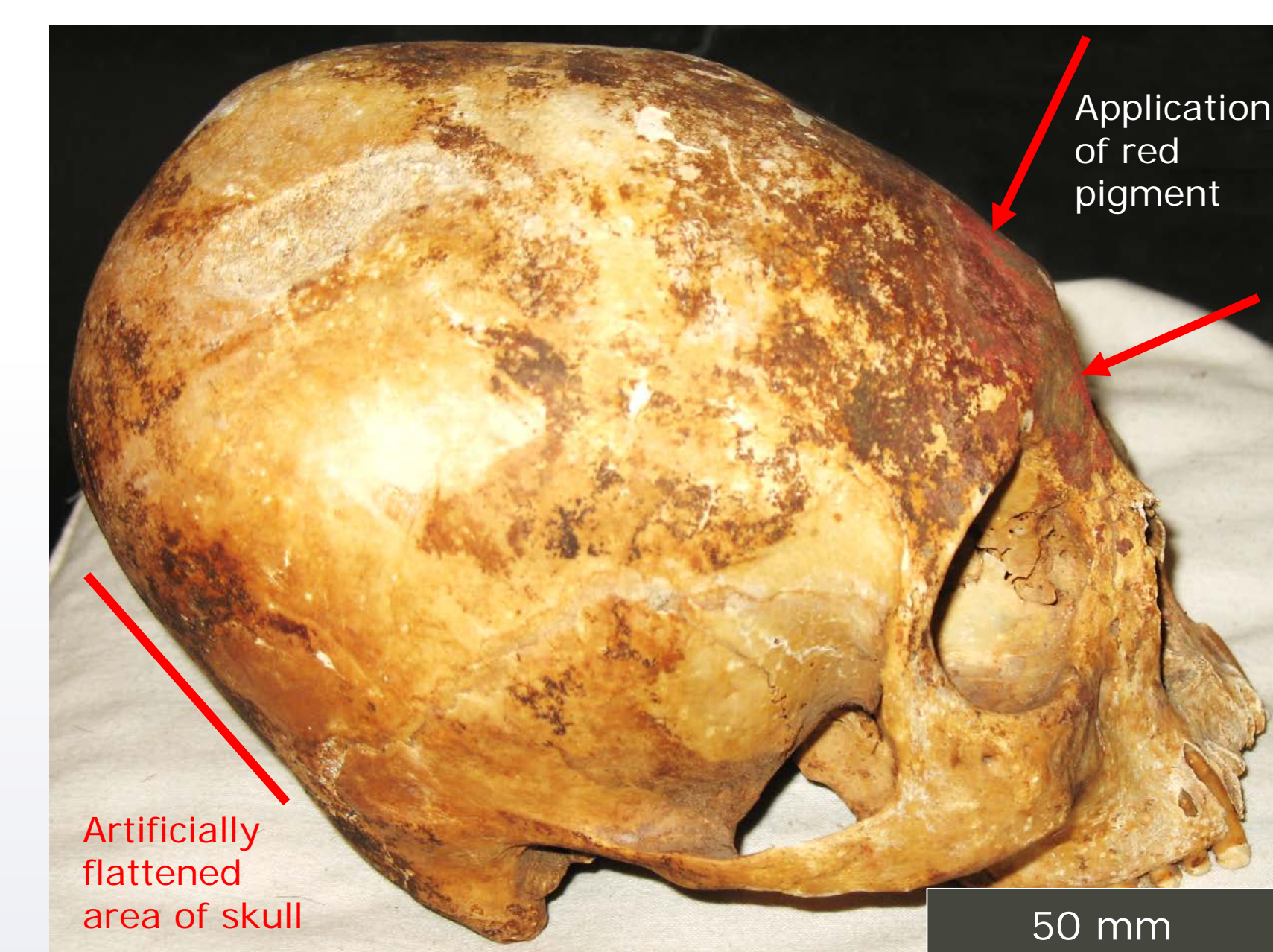
Artificial cranial deformation evident at back of skull where flattening is seen

Experimental Techniques

Optical Microscopy, Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDS)
- Similar to the beam of light used in an optical microscope, the SEM uses a beam of electrons to image the pigment
- EDS analysis was used to identify the elemental composition of the pigment

EDS electron image of elemental analysis locations. Inset: optical photo of same location
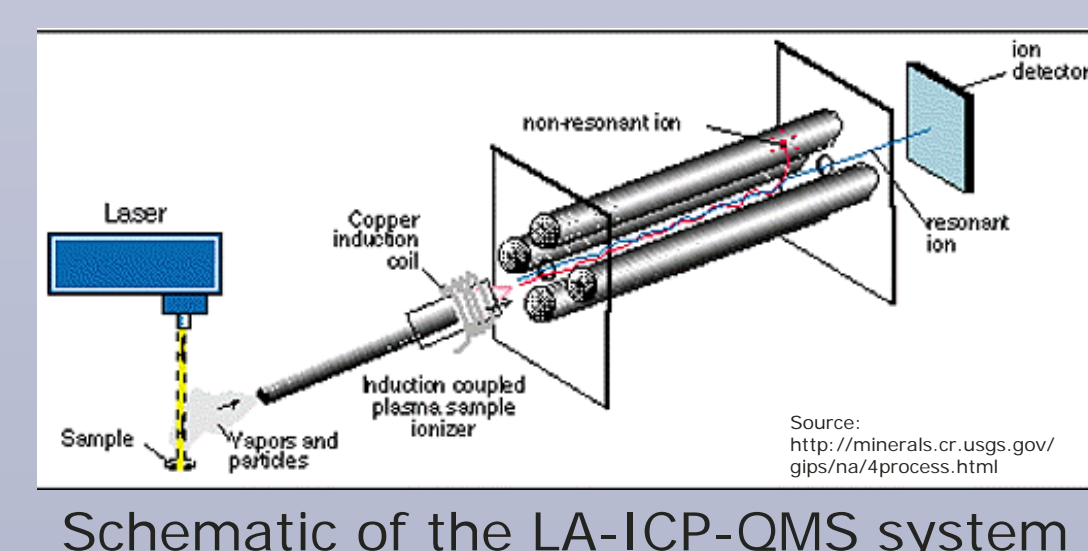

Close-up of skull where pigment samples were taken from
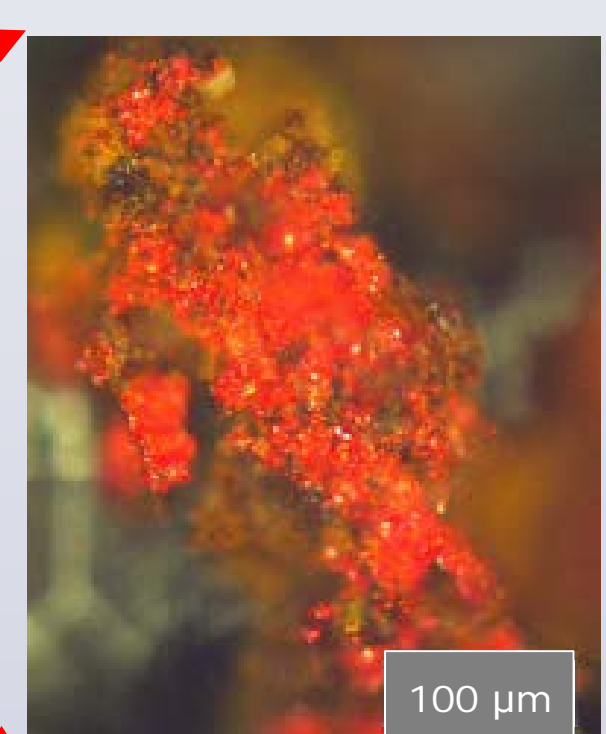
Optical photograph of red pigment

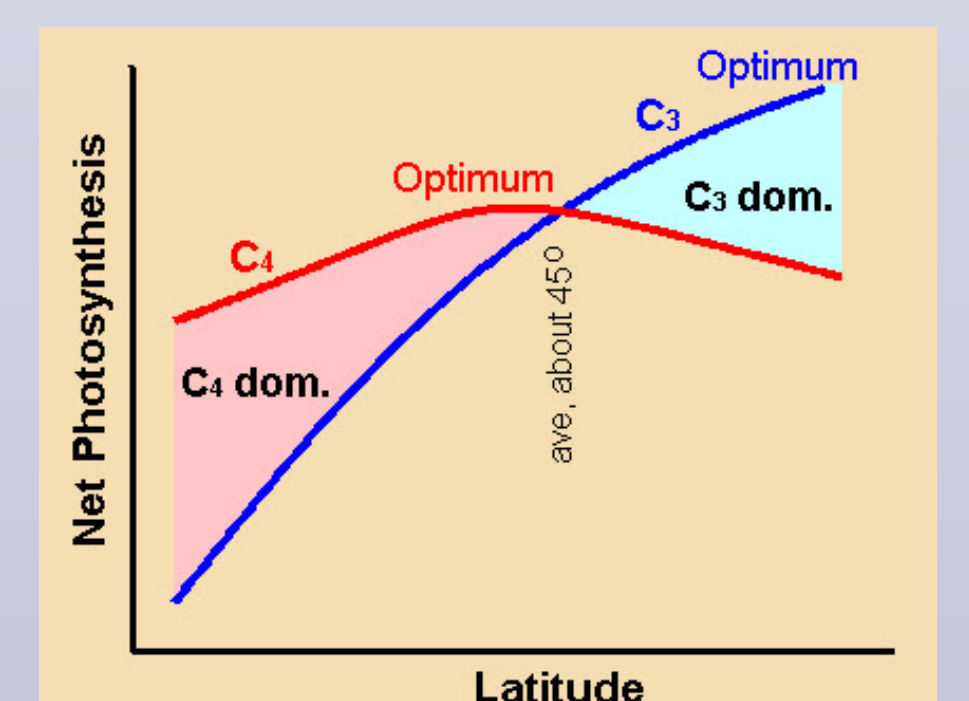### Laser Ablation Inductively Coupled Plasma Quadrupole Mass Spectrometry (LA-ICP-QMS)
- Sample is vaporized and ionized in the plasma
- The quadrupole rod charge determines which ions will be carried to the detector for counting
- Samples were analyzed using a ThermoElectron X-Series II and New Wave Research UP-213 ND:YAG UV (213 nm) laser ablation system

Schematic of the LA-ICP-QMS system

Radiocarbon Dating
- Plants and animals absorb Carbon-14 from CO_2 during their lifetimes
- At death, the exchange of carbon with the biosphere stops and the C-14 content decreases at a rate determined by the law of radioactive decay
- Radiocarbon dating is a method designed to measure residual radioactivity and thus, date the sample

Decay of Carbon 14
Radioactivity vs time
$$R(t) = R_0 e^{\lambda t}$$
where:
R(t) is the decay rate t
R_0 is the initial decay rate (at time zero)
e is the base of the Naperian logarithms
λ is the decay constant of the radioactive isotope
Radioactivity vs. time of Carbon-14
http://wwwchem.csustan.edu/chem3070/images/c14decay.gif
http://littlebits.cc/browse-lessons/geiger-counter-and-radioactive-decay-half-life
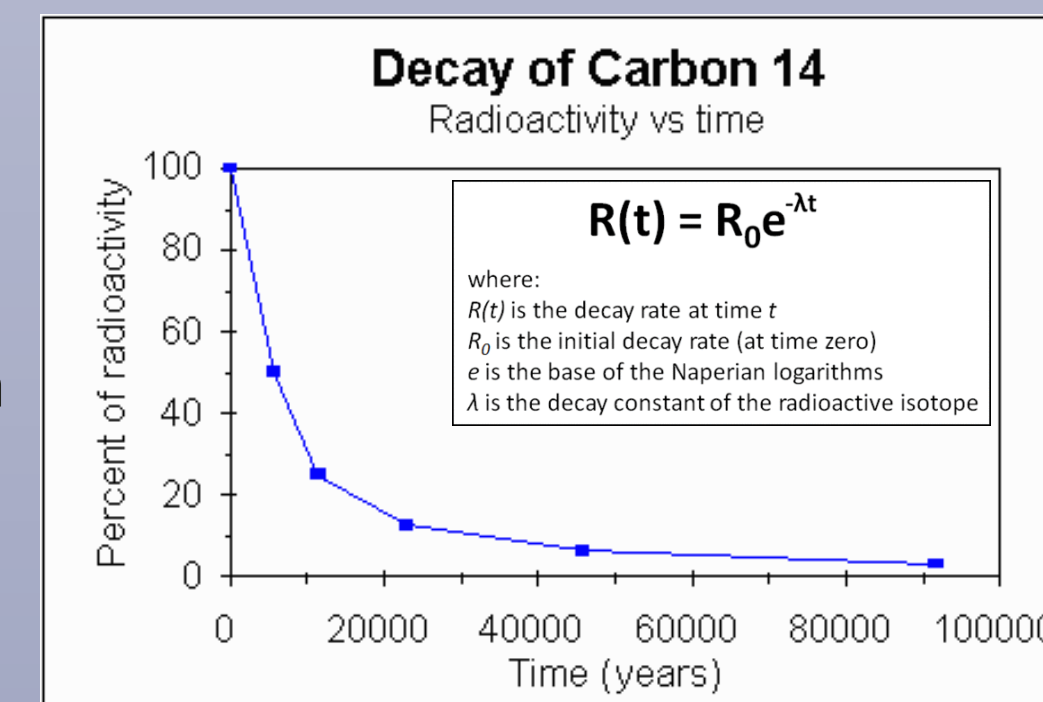
Stable Isotope Analysis
- Ratio of C_3 to C_4 in plants varies in different geographical locations
- This ratio, when measured in an animal, can identify the type of climate the animal lived in based on the kinds of plants it ate

Net photosynthesis vs. Latitude for C_3 and C_4 plants. C_3 plants dominate at higher latitudes. [1]
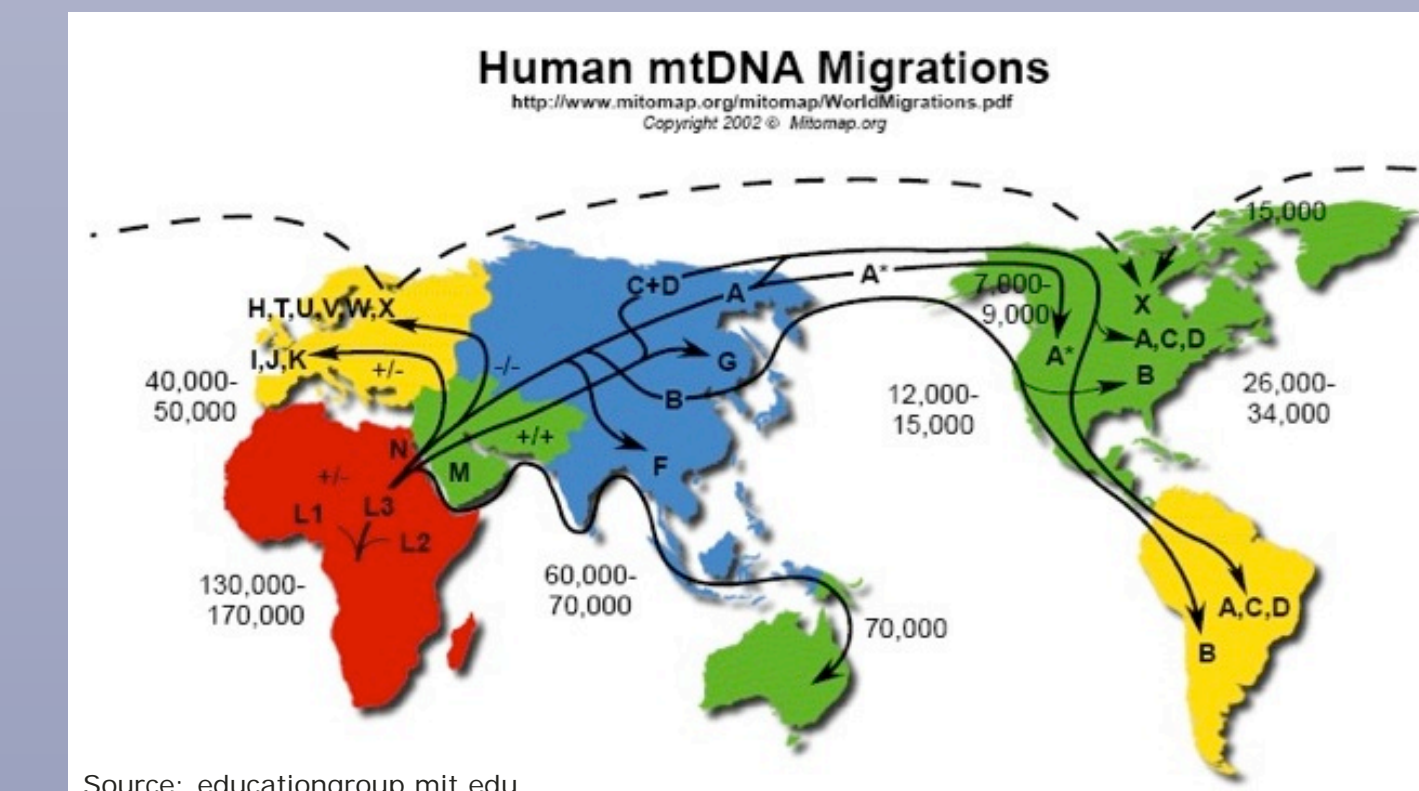
X-Ray Fluorescence (XRF)
- Uses emission of secondary x-rays from samples excited with high energy x-ray or gamma rays to identify elemental composition
- Samples analyzed using a Horiba XGT-7200 XRF Spectrometer

Forensic mtDNA Analysis
ISU's Ancient DNA Extraction Lab and Molecular Research Core Facility specialize in extraction, amplification, sequencing and analysis of mitochondrial and genomic DNA from old, degraded, or fragmented samples.
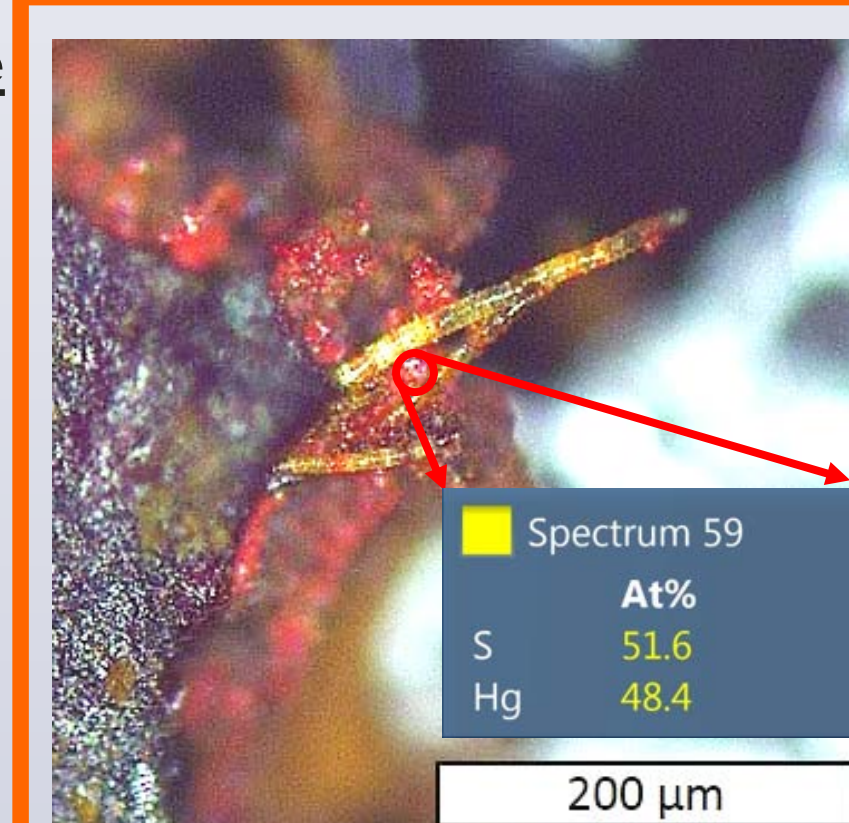

Human mtDNA Migrations
http://www.mitomap.org/mitomap/WorldMigrations.pdf
Source: educationgroup.mit.edu

Results and Discussion

Optical image of red pigment with EDS inset showing elemental atomic %

Red pigment identified as mercury sulfide (HgS)
- Expected ratio of Hg to S would be 1:1
- Average ratio for all spectra was 1.12:1, possibly indicative of loss of sulfur due to microbial activity

Major Trace Elements (mass %)		Minor Trace Elements (ppm)	
Silicon	12.7	Phosphorus	8300
Calcium	9.7	Titanium	6000
Iron	3.3	Zirconium	5400
Potassium	2.2	Bromine	1400
Dysprosium	1.1	Nickel	1300
Aluminum	0.9	Manganese	1200
		Europium	1200
		Neodymium	800

LA-ICP-QMS Red Pigment Trace Elements (ppb)			
Phosphorus	189,000	Neodymium	180
Titanium	57,000	Lanthanum	90
Potassium	47,000	Dysprosium	75
Cerium	330	Europium	5

Stable Isotope analysis identified different values for teeth and bone
- Indicates individual lived in one area during youth and another area closer to death
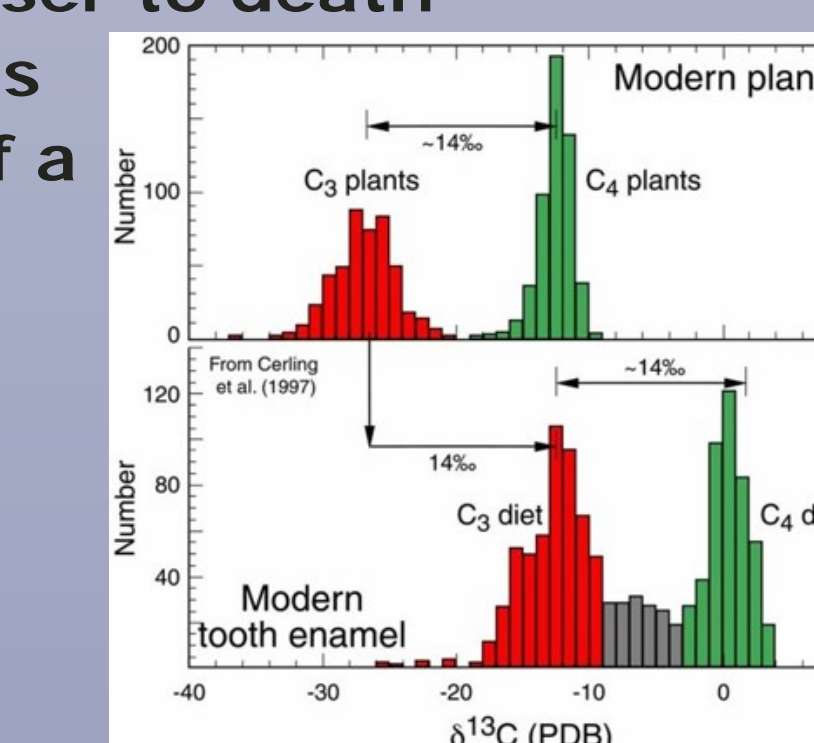- Bone value suggests C_3 type plants while tooth enamel is indicative of a mixed C_3/C_4 environment
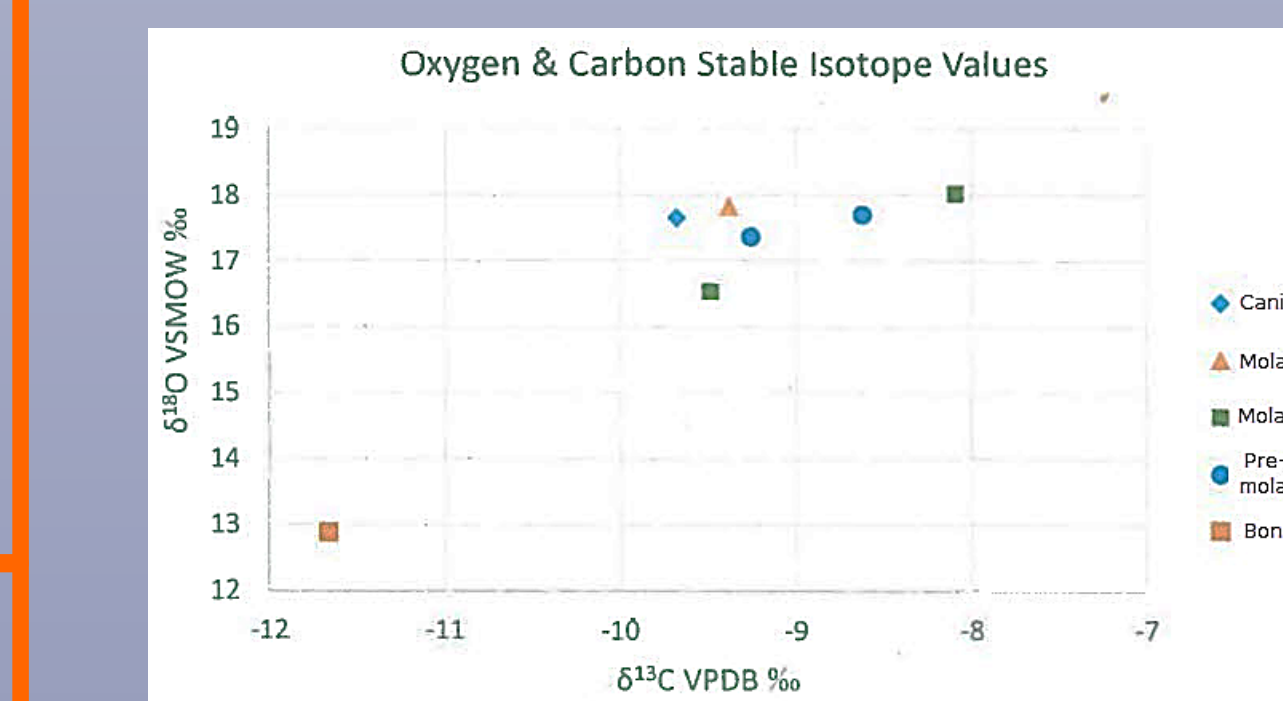
O and C stable isotope values from carbonate component of bone and teeth

Relationship between carbon isotope values of C_3 and C_4 in modern plants and enamel

Hair and fiber samples sent for anthropological analysis to the University of Delaware Department of Art Conservation
- Hair samples (top) match the consistency of human hair
- Animal fibers (bottom) most likely sheep's wool or fine strands of cattle, deer, dog, goat, marmot or musk ox

- XRF identified major and minor trace elements also present in the HgS
- Suggests the cinnabar is of a silica/calcium or silicate mineral origin and not a refined mineral as would be found in artworks

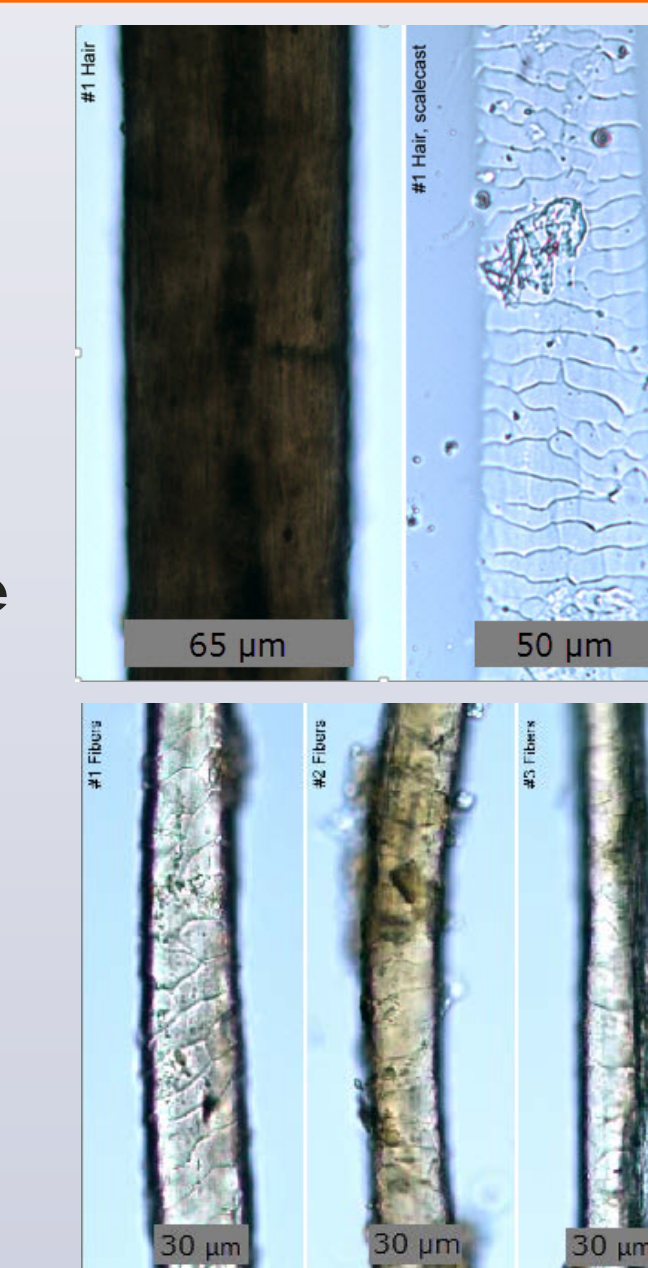LA-ICP-QMS is a more sensitive technique than XRF
- Identified additional trace elements in red pigment
- Data can potentially be used to identify a geological cinnabar source

Radiocarbon Dating
- Skull is ~550-620 years old
- Pre-Columbian (i.e. pre-European contact)
- Possibly of Chinook or Fremont culture, late pre-historic agricultural groups that extended into other states
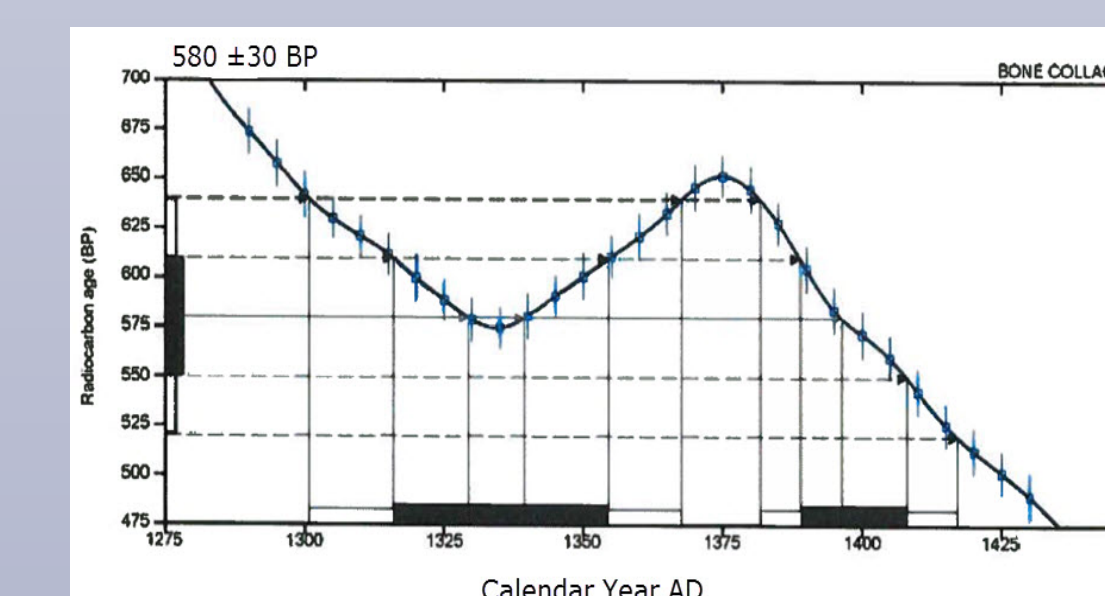
Calibration of radiocarbon age to calendar years from Beta Analytic (Beta-393782) dating the skull to 1330-1400 AD

Forensic Mitochondrial DNA
- Haplogroup R0a1a identified, although it is not associated with known Native American populations
- Area where Haplogroup R0a1a originated is from the Arabian Peninsula or western Eurasia
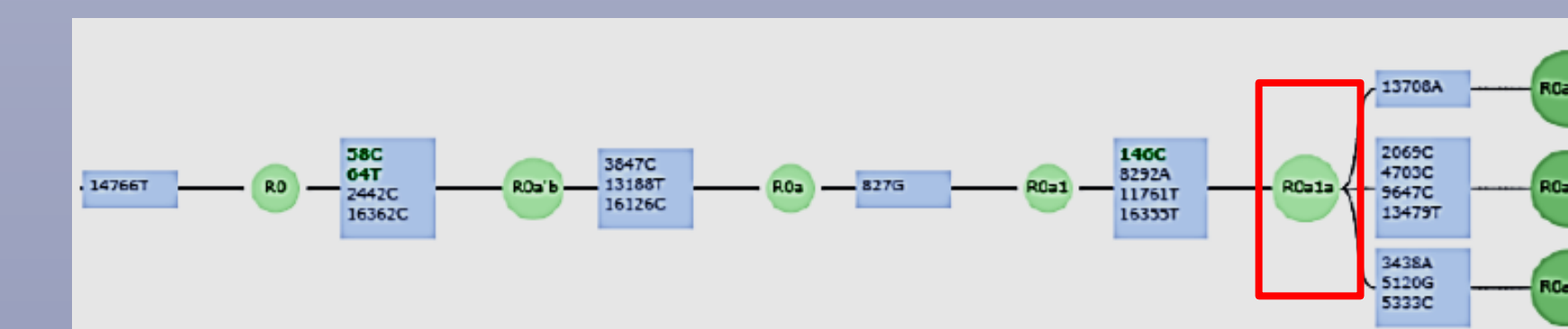
Haplogroup sequence identifying the skull's lineage from a maternal contribution as being from the Arabian Peninsula or western Eurasia

Conclusions and Future Work
- Skull possibly of Chinook or Fremont culture
  - Cranial deformation and post-mortem application of HgS with adhered animal hair
- Trace elements in the HgS may potentially identify a geological source for the cinnabar
- Radiocarbon dated age ~ 550-620 years old
- Stable isotope analysis suggests habitation in different locations as a child and as an adult; locale characterized as cooler than would have been found in Idaho

- Forensic mitochondrial DNA identified haplogroup R0a1a which originated on the Arabian Peninsula; this is not consistent with the rest of the data in the study
- Future work will include
  - Additional trace element analysis from the bone to provide constraints to the duration of burial independent of C-14 dating
  - A secondary ancient DNA analysis to confirm or disprove the initial findings

Acknowledgments