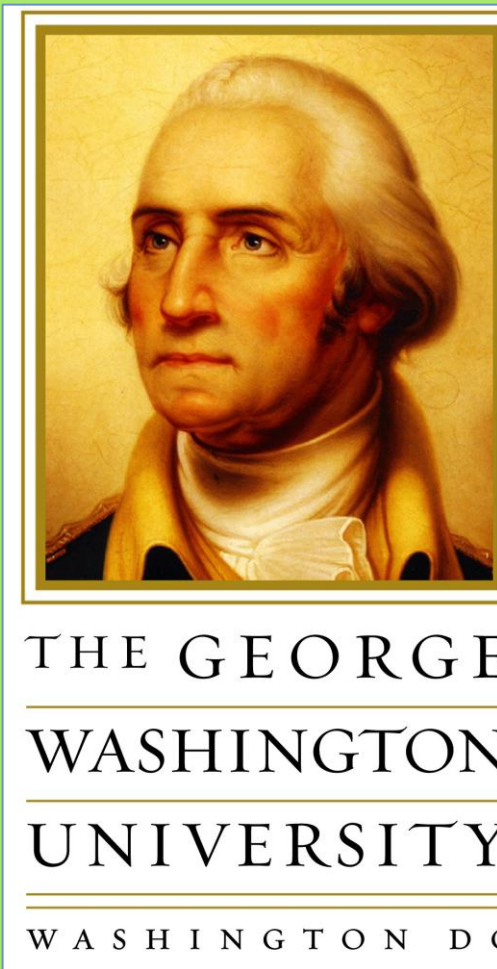


Three Geochemical Approaches to Ochre Pigment Provenance in northern Malawi

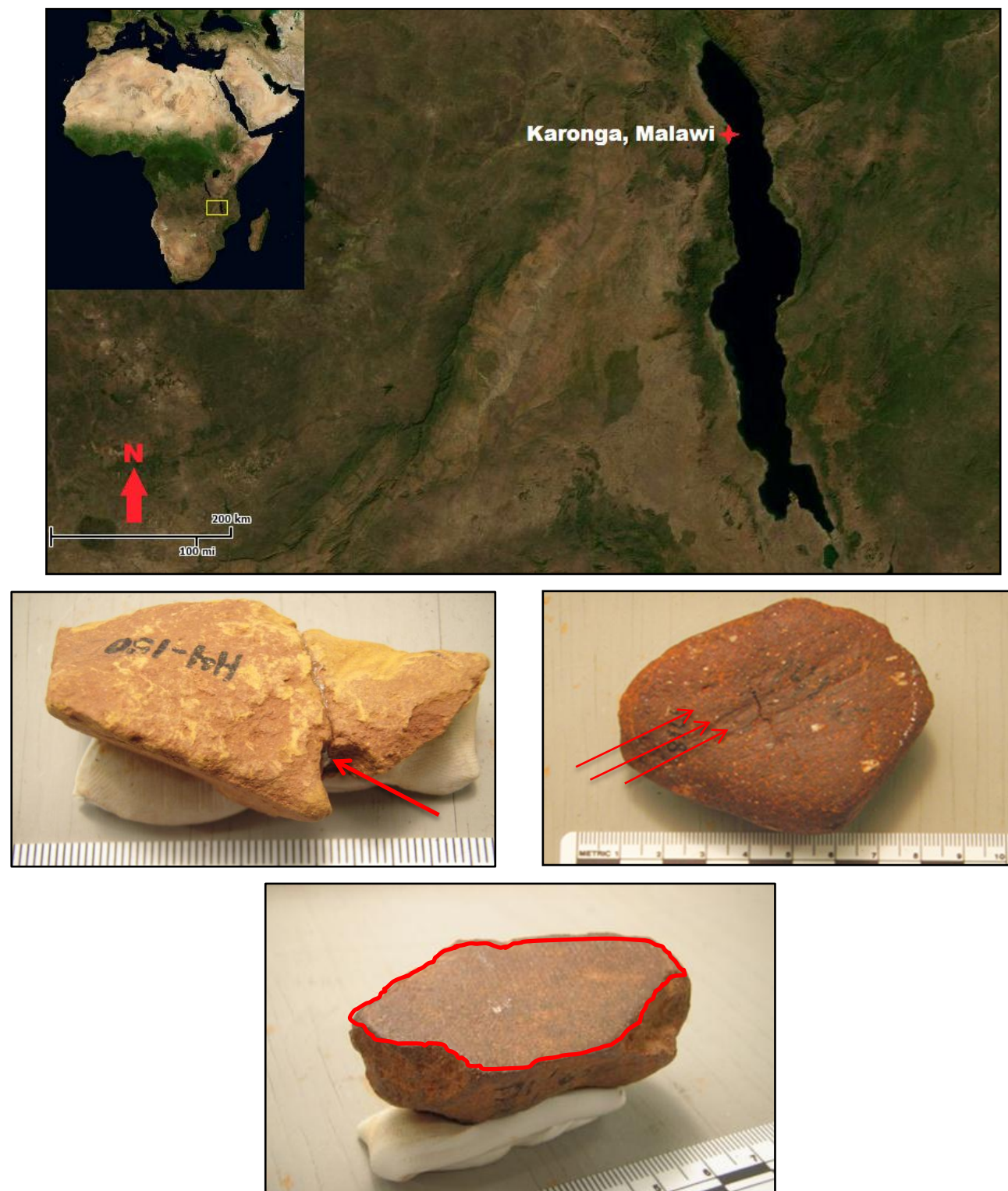
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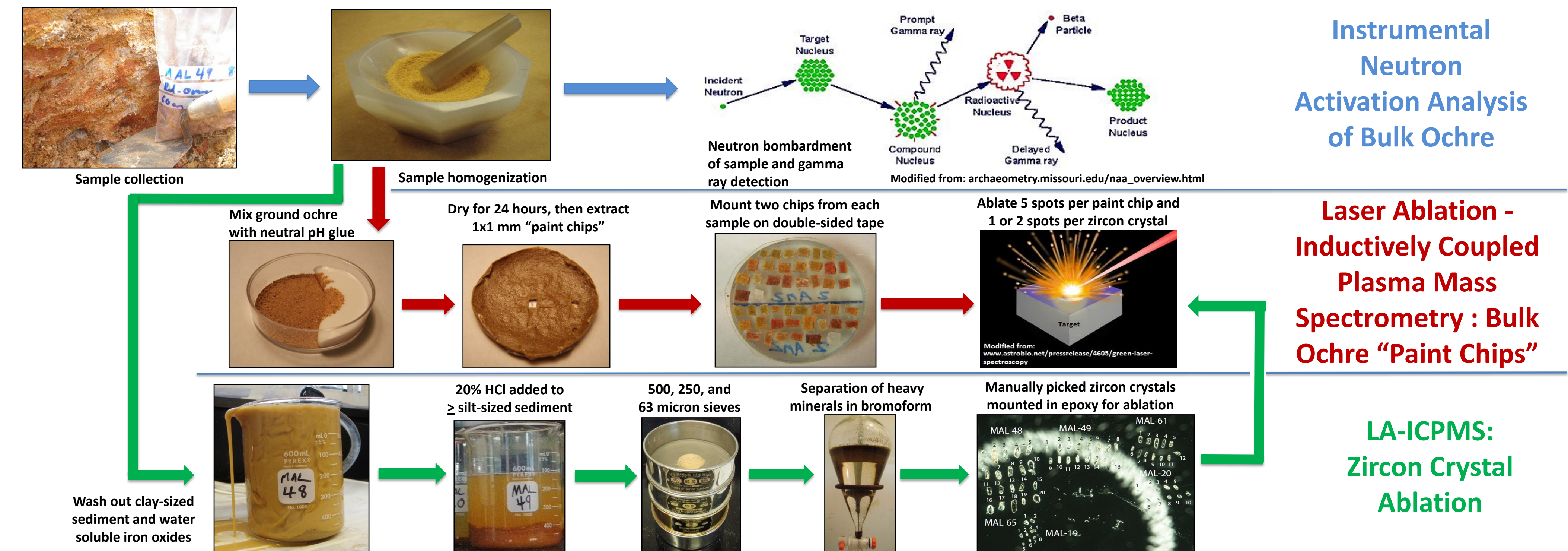


INTRODUCTION

- The Chaminade 1A (CH-1A) Middle Stone Age (MSA) site, near Karonga, Malawi, was excavated by J. Desmond Clark and colleagues in 1965.
- > 2 kg of ochre artefacts were recovered from the site and are now curated at the Stone Age Institute. Several artefacts exhibit evidence of abrading and incising (below right) consistent with pigment production.
- In 2011 the Malawi Earlier-Middle Stone Age Project opened new excavations near the CH-1A site and began sampling geological sources of ochre in the region through collaboration with local guides.
- Conducting a provenance study of ochre artefacts will facilitate the study of procurement preferences, transport patterns, and early material symbolism.
- Rather than forming *in situ*, Malawian sources identified thus far are challenging-to-characterize sedimentary deposits with detrital minerals from multiple parent rocks.
- Research Questions**
 - What is the most effective method of distinguishing among ochre from different geological sources?
 - What parent rocks weathered to form the extant sources of ochre in Malawi?



MATERIALS AND METHODS

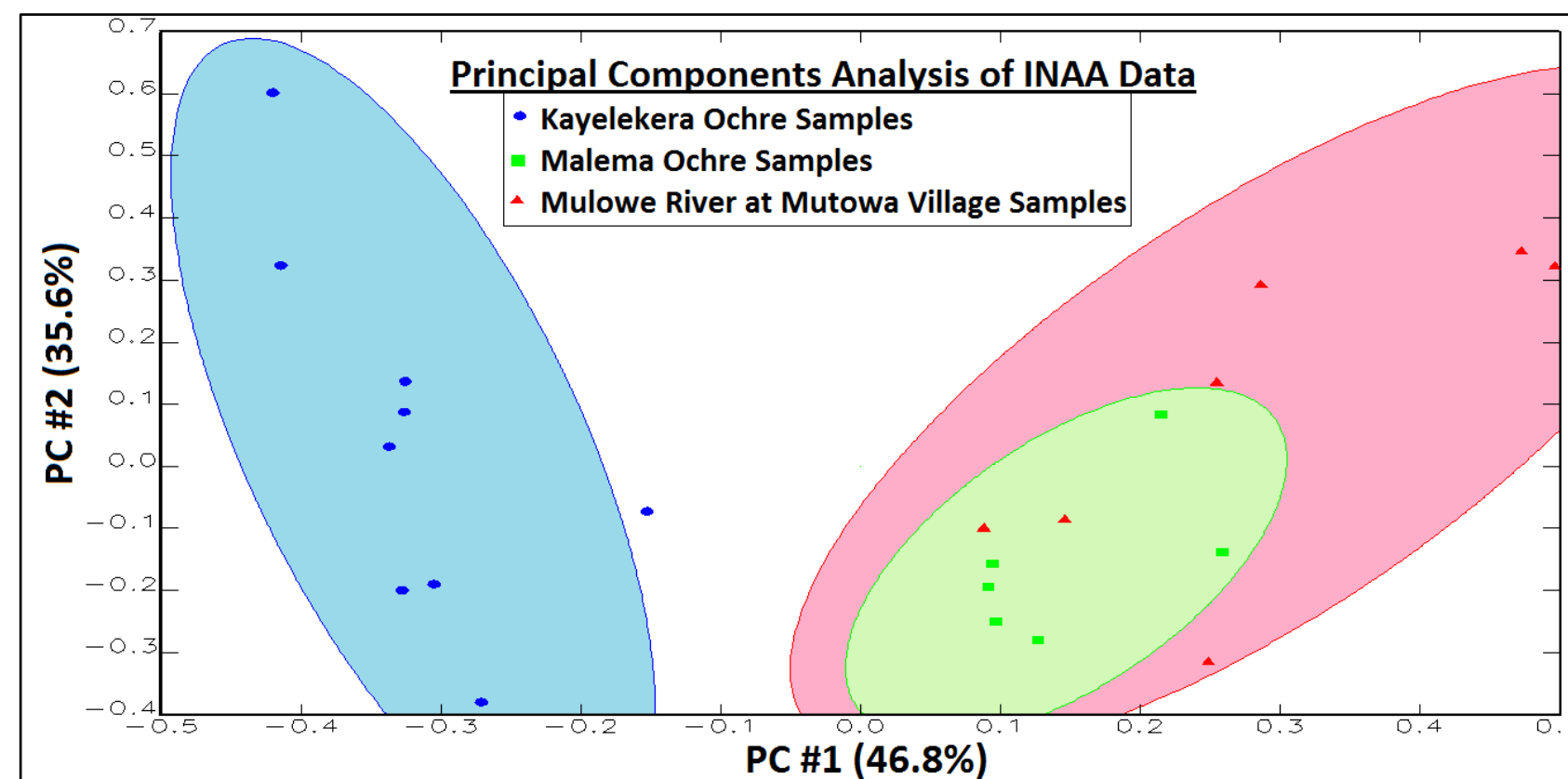


RESULTS

Sources Sampled and Neutron Activation Analysis Results

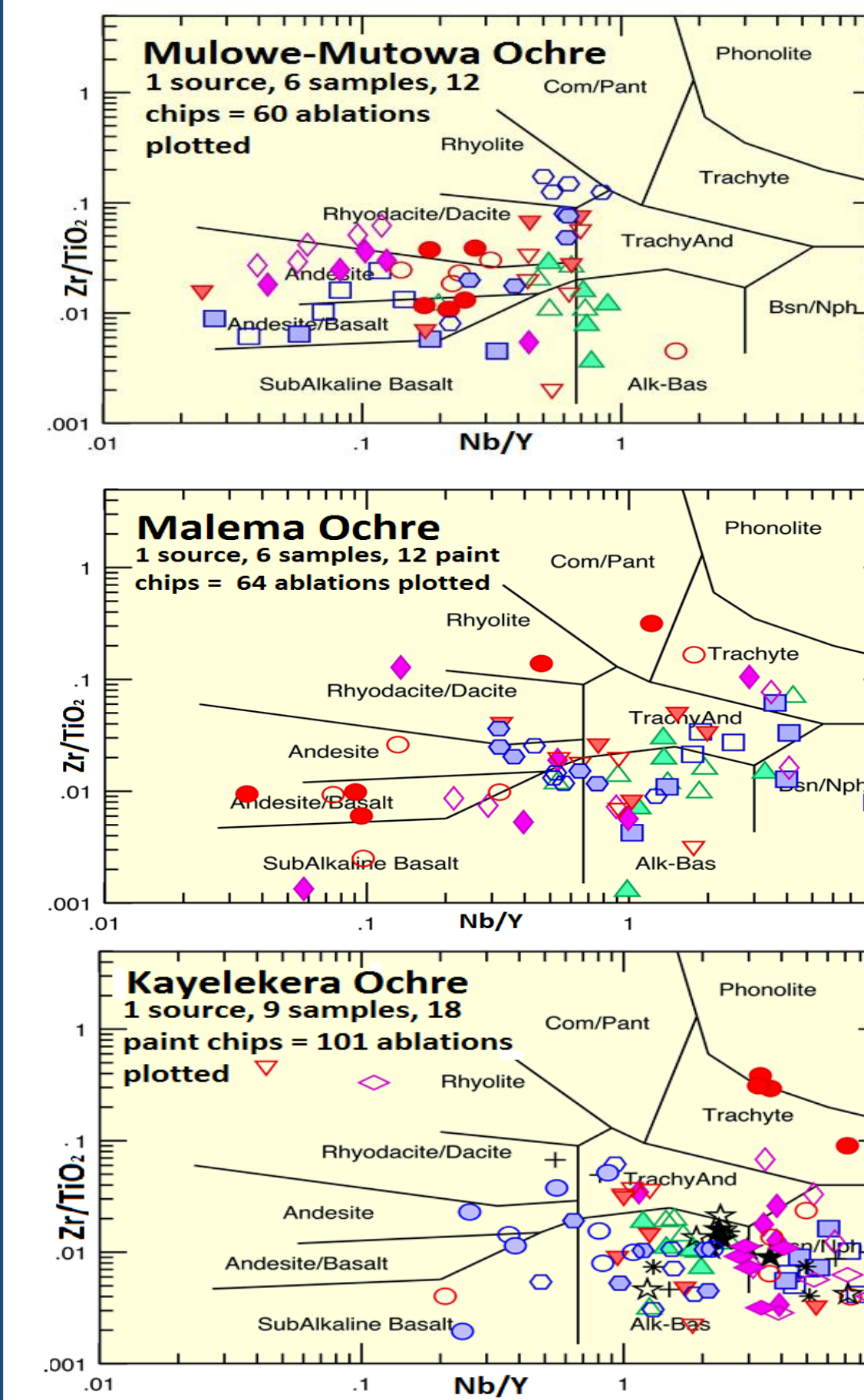


Source	n	Description
Kayelekera	9	Unlithified ochreous clay in open-air pit
Mulowe	7	Ochreous mudstone clasts in conglomerate
Malema	6	Band of ochreous clay exposed by river cut



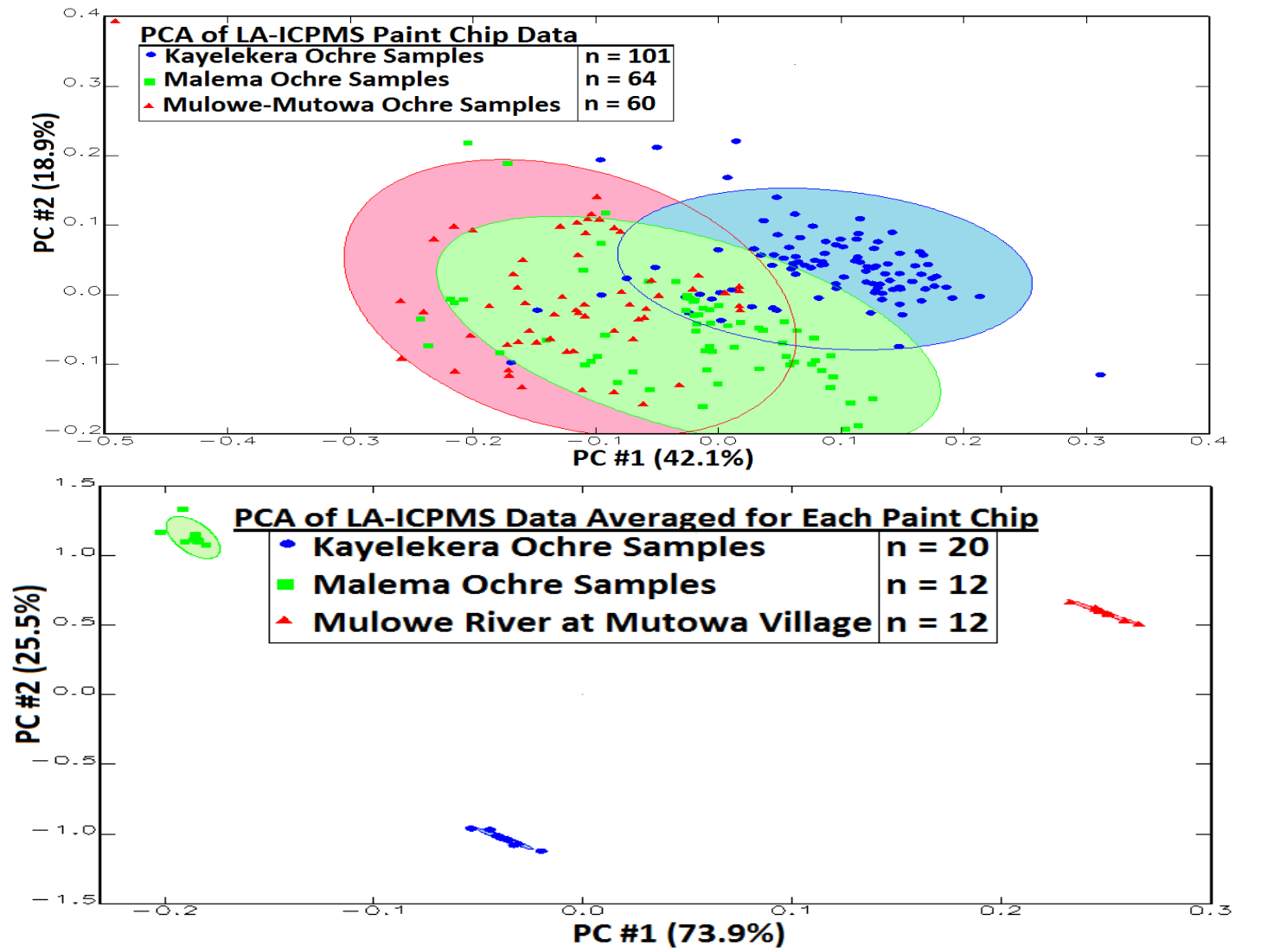
- 7 ochre sources were identified during the 2011 field season; the 3 most thoroughly sampled are used here as a case study.
- 1 bulk analysis of homogenized ochre was conducted per sample for 22 analyses total.
- Long count INAA element data used in Principal Components Analysis (PCA), below left
- 33 elements detected by INAA, 30 used in PCA, data normalized to ratio with Fe-content, then log10 transformed
- 90% confidence ellipse for each group shown (left)
- Intra-source variation in the Mulowe-Mutowa group is too great to separate it from the Malema source group.

LA-ICPMS Paint Chip Results

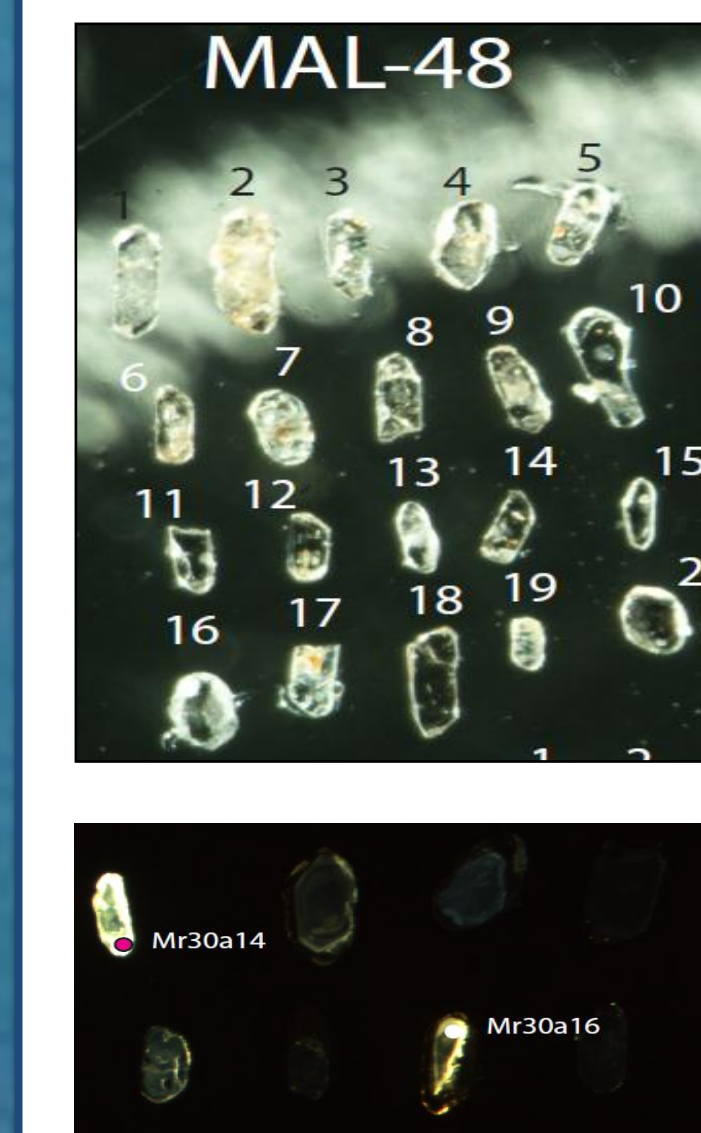


3 Immobility Element Ratio Plots (left):
Sample MAL-21 from Malema
Each ochre sample yielded 2 paint chips and each paint chip was ablated ~5 times for a total of ~10 data points per sample. Symbol shape indicates sample and filled vs unfilled indicates paint chip in order to highlight within sample variation.

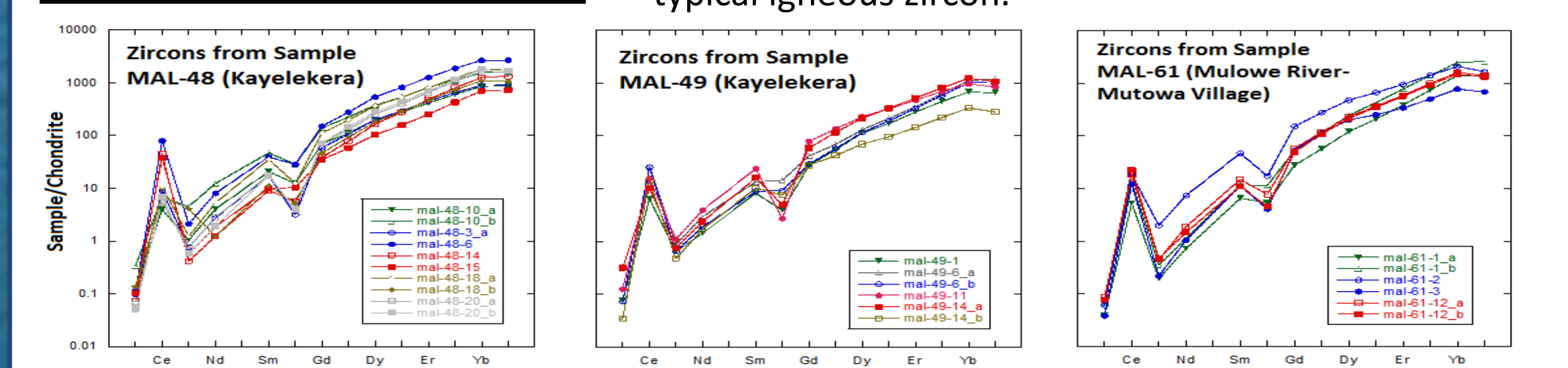
PCA (below): 40 elements detected, normalized to Fe-content, log10 transformed



LA-ICPMS Zircon Crystal Results



- 6 ochre samples, 2 per source, were processed to determine if zircon crystals were present.
- Heavy minerals separated by bromoform were primarily composed of iron oxides and zircon.
- Heavy weathering (left) and the heterogeneity amongst zircons from a single ochre sample under cathodoluminescence (below left) suggest that the grains were transported from the rocks in which they crystallized and that multiple parent rocks contributed to a single ochre deposit.
- Log-normal chondrite-normalized REE plots (below) for zircons from the 3 samples containing the most crystals viable for ablation indicate that all contain typical igneous zircon.



CONCLUSIONS

- INAA is not precise enough nor does it detect enough elements to distinguish between multiple sources of ochre in which each source has a substantial detrital mineral component. The Kayelekera source may be distinctive due to the Permian Karoo rocks (N. Rukuru Sandstone and Shale Formation) which underlie it, while the other 2 sources are situated in recent lacustrine, alluvial, and colluvial deposits.
- Plots of immobile element ratios indicate that the Malema source is the most heterogeneous, reflecting diverse parent rocks and variability in each paint chip. The Kayelekera and Mulowe groups are more homogeneous and indicate strongly alkaline and subalkaline parents, respectively.
- Paint Chip LA-ICPMS generated a 225 point dataset; by reducing the ~5 ablations per chip to an average for each chip and running a PCA on the means, 3 very distinct groups appeared and ~99.4% of variation in the data set was explained by PC1 and PC2.
- Data processing rather than the data collection technique may be the key to characterizing heterogeneous ochres. Technique development should focus on reducing sample size to facilitate analysis of artefacts.
- For the first time, refractory mineral grains (zircon) have been isolated from an ochre sample and analyzed for Heavy Rare Earth Element composition. LA-ICPMS targeted at zircon crystals may not be applicable to artefact sourcing due to the large sample mass of ochre required (0.5 – 1.0 kg). However, this technique may eventually facilitate the distinguishing of ochre sources from one another on the basis of the age of crystallization for zircons found in each source.

ACKNOWLEDGEMENTS

- Funding Agencies**
- National Science Foundation: IGERT DGE-0801634 and Graduate Research Fellowship 201116368
 - Australian Research Council: Discovery Projects Grant and Australian Postdoctoral Fellowship
 - Cosmos Club Foundation: Cosmos Scholars Grant - "Identification of Archaeologically Relevant Malawian Ochre Deposits"
 - Explorers Club Washington Group: Exploration and Field Research Grant - "Ochre Exploitation in the Middle Stone Age of northern Malawi"
- Collaborators**
- Professor Chris Cahill and Mr. Andrew Kerr (Department of Chemistry, The George Washington University)
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 - Dr. Jeffrey Ferguson and Dr. Michael Glascock (Archaeometry Laboratory, University of Missouri Research Reactor)
 - Ms. Marina Bravo Foster (School of Earth and Space Exploration, Arizona State University)
 - Mr. Harrison H. Simfukwe (Senior Antiquities Officer/Senior Curator, Karonga Museum, Malawi)

REFERENCES

A list of references is available in hard copy or by e-mail upon request. Please send inquiries to amzipkin@gwmail.gwu.edu