Elliptical Fourier analysis of two hominoid teeth from Middle Pleistocene Sanxieshan cave, Daxin, Guangxi, China

Elissa M. Ludeman[1,2], Wei Wang[3], Daweli Li[3,4], Shara E. Bailey[1], Terry Harrison[1],Christopher Bae[5]

[1]Department of Anthropology and CSHO, New York University, [2]NYCEP, [3]Department of Archaeology, Guangxi Museum of Nationalities, [4]China University of Geosciences, [5]Department of Anthropology, University of Hawai'i at Manoa

Introduction

Shape analysis of tooth crowns has proved to be a useful method for taxonomic classification of extant hominoids and fossil hominins (e.g., Bailey and Lynch, 2005; Gómez-Robles et al., 2007; Skinner et al., 2009). This study uses elliptical Fourier analysis of crown outlines to investigate species affinity in two recently discovered permanent molars from the Sanxieshan Locality 2 cave site in Daxin, Guangxi, China. One left lower molar (SX15) and one right upper molar (SX09) were found in situ directly below travertine deposits securely dated to ~300 ka (uranium series dated).

Materials and Methods

The fossil molars SX15 and SX09 (see Figure 1) were compared to upper and lower first, second, and third molars of extant hominoids (n=225; see Table 1), *Gigantopithecus* and Early to Middle Pleistocene hominins including *Homo heidelbergensis*, *Homo neanderthalensis*, *Homo ergaster*, and *Homo erectus* (n=97; see Table 2). Standardized coordinate outlines collected for use in elliptical Fourier analysis of tooth shape. Canonical variates analyses (CVA) of molar shape were conducted using the elliptical Fourier coefficients (60 cosine and sine components of x and y increments) from 15 generated harmonics (elliptical Fourier descriptors) that describe outline shape with positional translation and size normalized away.

Table 1. Number of first, second, and third molars for extant comparative sample (n=225)

Species	Lower M1	Lower M2	Lower M3	Upper M1	Upper M2	Upper M3
Gorilla gorilla	10	10	10	10	10	10
Hylobates agilis	10	10	10	10	10	10
Pongo pygmaeus	14	15	16	20	20	20

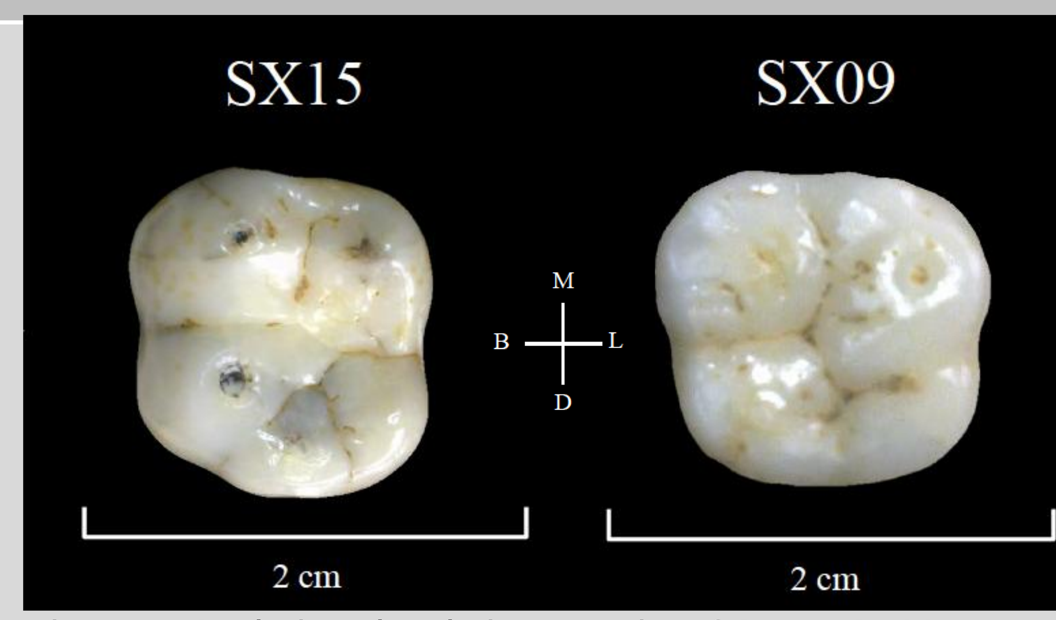

Figure 1. Scaled occlusal photographs of SX15, SX09.

Table 2. Number of upper and lower molars used in elliptical Fourier analysis

	Lower molars	Upper molars
Gorilla gorilla	30	30
Pongo pygmaeus	45	60
Hylobates agilis	30	30
Gigantopithecus	25	14
MP hominins	11	17
Asian *Homo erectus*	17	15

Shape discrimination- canonical variates analyses of elliptical Fourier descriptors

- CVA groups assigned a priori; SX09 and SX15 group assignment determined by discriminant analysis
- CVA results of 158 extant and fossil lower molars (see Figure 2) assign lower hominoid molar SX15 as:
  - ✧ a lower *Pongo* molar with 99.95% (98.1% assigned correctly)
  - ✧ a lower *Pongo* second molar with 93.4% probability (96.2% assigned correctly).
- CVA analyses of 164 extant and fossil upper molars (see Figure 3) assign lower hominoid molar SX09 as:
  - ✧ a *Homo erectus sensu strictu* upper molar with 86% probability (93.1% assigned correctly)
  - ✧ a *Homo erectus sensu strictu* upper first molar with 77.8% probability (94.5% assigned correctly).

Figure Key: *Gorilla gorilla* = light blue, *Hylobates agilis* = black crosses, *Pongo pygmaeus* = black dots, *Gigantopithecus* = magenta, Mid-Paleolithic hominins = brown, *Homo erectus sensu strictu* = green, Sanxieshan molars = purple diamonds

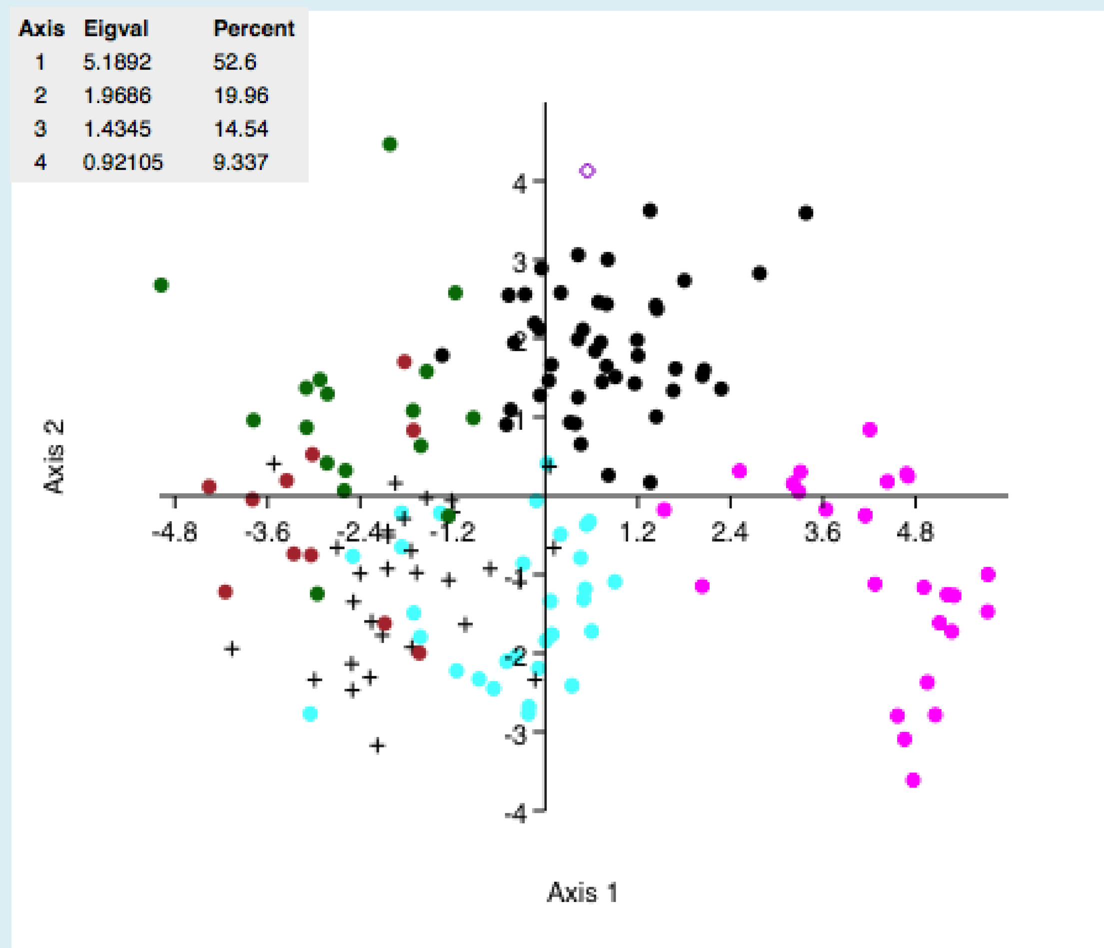

Figure 2. Canonical variates analysis elliptical Fourier coefficients of lower molar SX15 with extant and fossil sample.

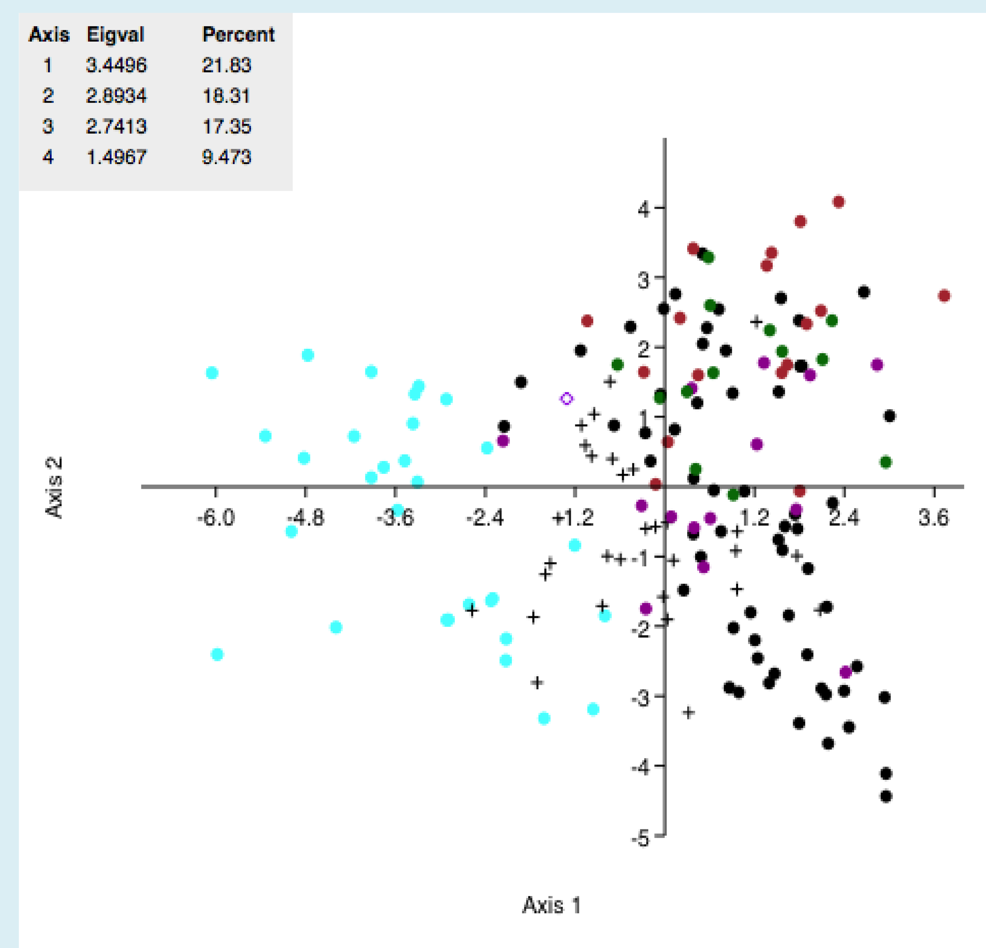

Figure 3. Canonical variates analysis of elliptical Fourier coefficients of lower molar SX15 with extant and fossil sample.

Shape visualization- elliptical Fourier analysis principal components analyses tooth outline shape

- Principal component analyses (PCA) of elliptical Fourier descriptors (EFDs) generated in elliptical Fourier analysis (size and positional rotation normalized away) to visualize shape changes and spread of variation without regard to group affiliation
- PCA of lower molar EFDs (see Figure 4); first 5 PCs account for 99.13% of the variation
  - ➢ PC1 (component 1) accounts for 73.67% of the variation:
  - ➢ PC2 (component 2) accounts for 18.71% of the variation
- PCA of upper molar EFDs (see Figure 5); first 5 PCs account for 99.41% of the variation
  - ➢ PC1 (component 1) accounts for 79.82% of the variation
  - ➢ PC2 (component 2) accounts for 12.87% of the variation

Figure Key: *Gorilla gorilla* = light blue, *Hylobates agilis* = black crosses, *Pongo pygmaeus* = black dots, *Gigantopithecus* = magenta, Mid-Paleolithic hominins = brown, *Homo erectus sensu strictu* = green, Sanxieshan molars = purple diamonds

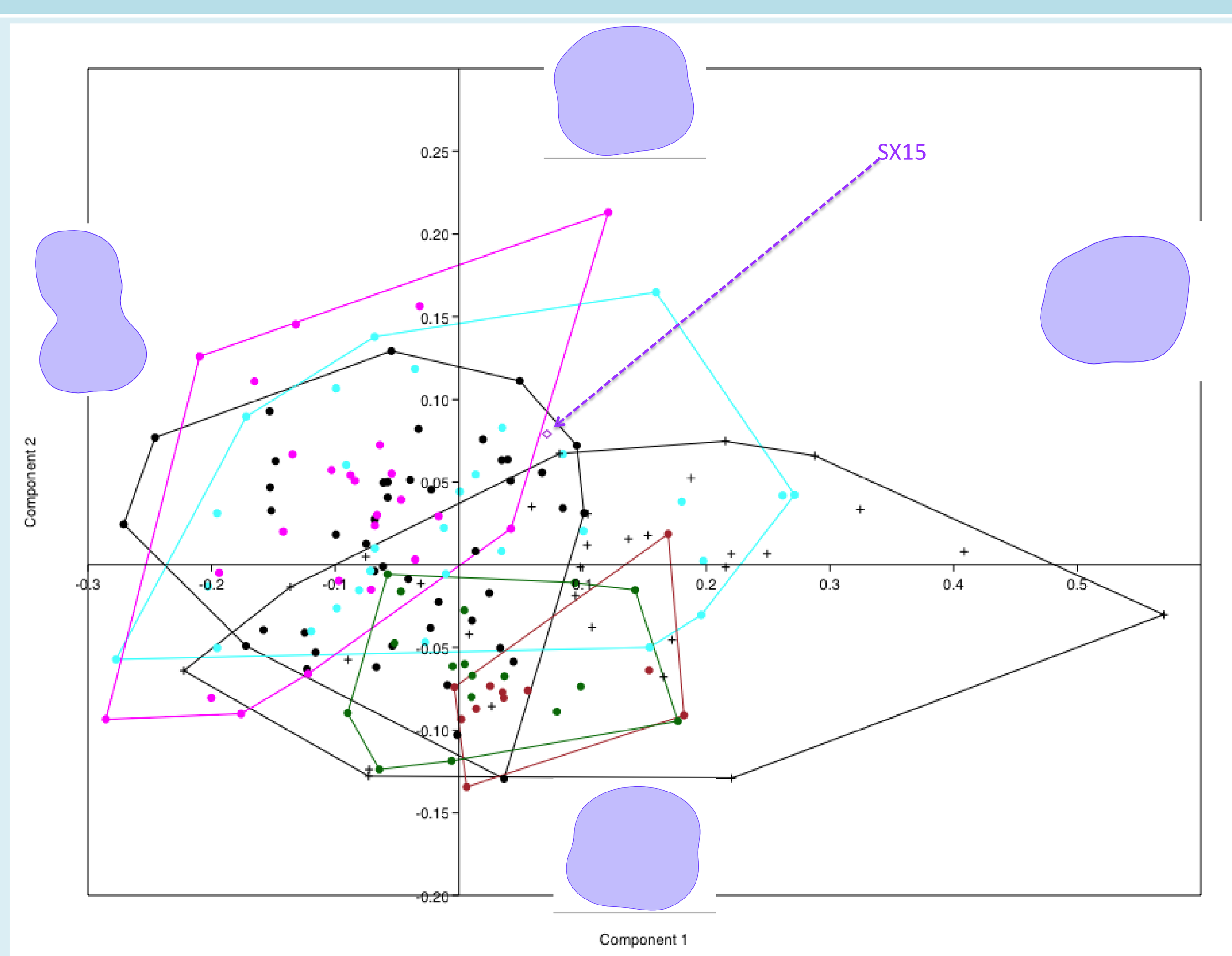

Figure 4. Principal components analysis to examine shape differences of lower molar SX15 with extant and fossil sample.

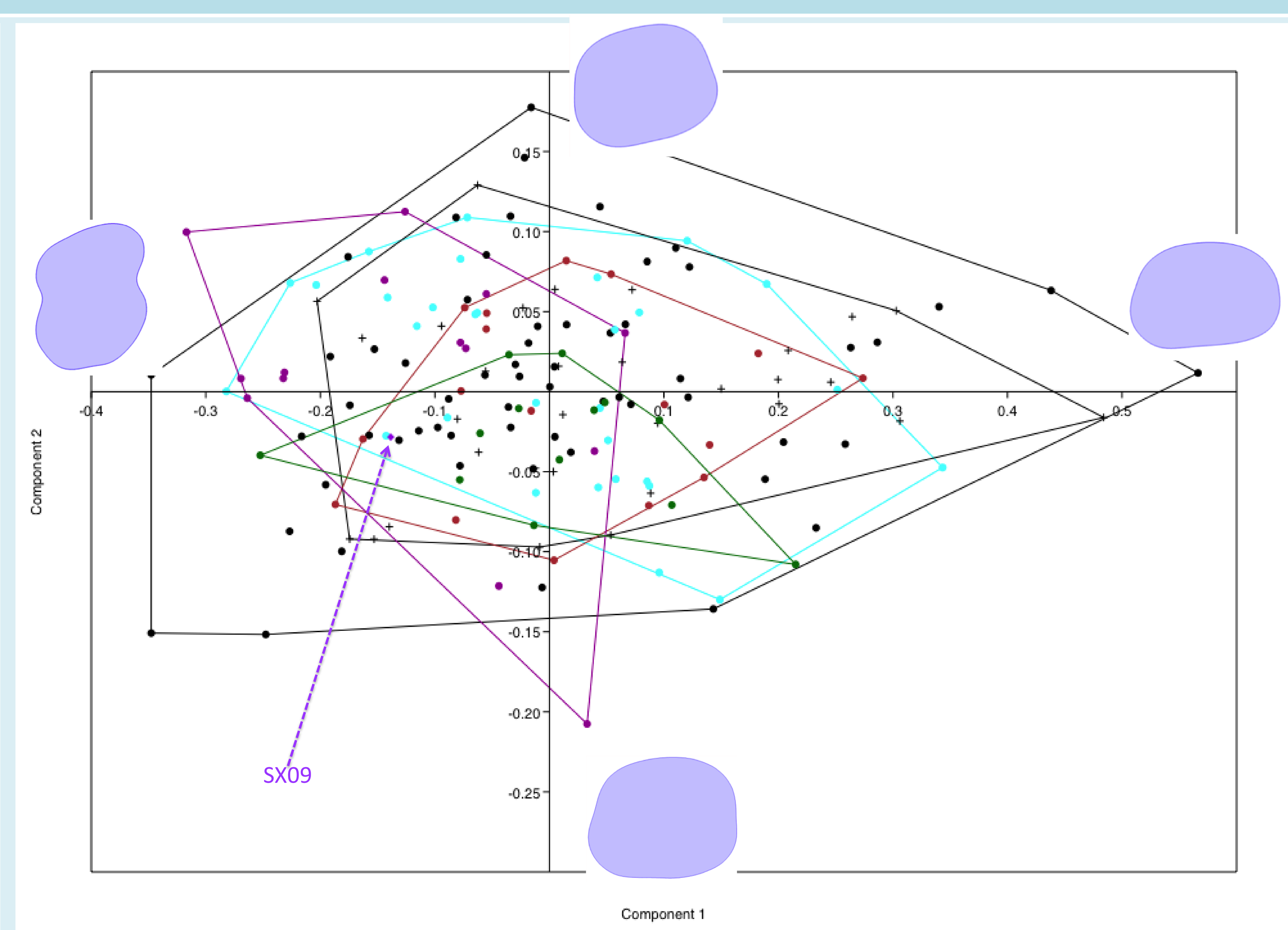

Figure 5.Principal components analysis to examine shape differences of upper molar SX09 with extant and fossil sample.

Conclusions

- These results of the discriminant geometric morphometric analyses indicate that SX15 and SX09 are similar in aspects of their crown outline shapes to *Pongo* and *Homo erectus sensu stricto*, respectively.
- These results of species assignment are preliminary; although outline shape is a useful identifier of species status there is also considerable variation in occlusal outline shape, particularly in Genus *Pongo*.
- Future directions will assess other aspects of molar morphology used for species designation such as cusp areas and inter-cusp distances to attempt confirmation of these preliminary species assignments.

Acknowledgements:

We kindly thank the curators at the Senckenberg Museum fur Naturkunde and the American Museum of Natural History for access to specimens. This research was supported in part by NSF IGERT Award 0966166, NYU Antonina S. Ranieri International Travel Grant, and 2014 University of Hawai'i at Manoa College of Social Sciences Research Award.

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