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A Late Pleistocene woman from Tham Lod, Thailand: The influence of today on a face from the past

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Abstract

Creating a facial appearance for individuals from the distant past is often highly problematic, even when verified methods are used. This is especially so in the case of non-European individuals, as the reference populations used to estimate the face tend to be heavily biased towards the average facial variation of recent people of European descent. To evaluate the problem, a facial approximation of a young woman from the Late Pleistocene rockshelter of Tham Lod in north-western Thailand was compared against the average facial variation of datasets from recent populations. The analysis indicated that the Tham Lod facial approximation was neither overtly recent in facial morphology, nor overtly European. The case is of particular interest as the Tham Lod individual probably belonged to a population ancestral to extant Australo-Melanesian peoples.

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There is genetic evidence that Thailand has been at the crossroads of human migration patterns between Mainland and Island Southeast Asia from the Pleistocene to the present (Wangkumhang *et al.* 2013), with the Northern Highlands of Thailand constituting one of the main migratory routes involving southern China (Sun *et al.* 2013). The original inhabitants of Northern Thailand are understood to be the Lawa people, and evidence from autosomal STR loci (Kutanan *et al.* 2011) shows that the Lawa people from the Northwestern Highlands have the greatest genetic distance from population groups within the region (i.e. the Khon Mueang, Mon, Shan, Lue, Khuen, Yan, and Yong). Following recent large-scale genetic studies there is a growing consensus that the people who first colonised and dominated Mainland and Island Southeast Asia are ancestral to extant Australomelanesian peoples, and that the composition of this founder population remained relatively stable until approximately 5,000 years ago (Duggan & Stoneking 2014; Lipson *et al.* 2014). These findings are further corroborated by a large scale study of Southeast Asian population variation in dental morphology (which is a proxy for genetic variation), and which includes the dental remains of Southeast Asian individuals from the Late Pleistocene (Matsumura & Oxenham 2014).

The Tham Lod Rockshelter is a north-facing overhang located within the Pang Mapha District of the Northwestern Highlands of Thailand. Pang Mapha is a mountainous region (elevation of 600-1700 m above current sea level) with a distinctive karst topography. Although Pang Mapha has a low population density compared to the rest of Thailand, it has high ethnic diversity, with current residents including the Hmong, Karen, Red and Black Lahu, Shan and Thai peoples as well as the Lawa (Shoocongdej 2006). Excavation of the Tham Lod Rockshelter commenced in 2002 by The Highlands Archaeology Project in Pang Mapha District (Shoocongdej 2003-2005; Shoocongdej 2006; Shoocongdej 2007), and the Tham Lod Rockshelter is acknowledged as one of the oldest and most robustly dated sites to be excavated in Mainland Southeast Asia (Marwick 2008). The excavation findings include evidence of periodic human occupation from 32,380 (±292) BP until the terminal Late Pleistocene (Khaokhiew 2004; Shoocongdej 2007), though a subsequent analysis of Mussel shell (*Margaritanopsis laosensis*) recovered in 2002 from the lowest excavation layer, indicates occupation may have commenced as early as 39,960 (±1,050) BP (Marwick & Gagan 2011). The distribution of lithics, faunal remains and molluscs indicates most human activity took place over a period of approximately 10,000 years (25-15,000 BP), and that foraging was maintained as a subsistence strategy (Khlaewkhampud 2003; Shoocongdej 2006; Wattanapituksakul 2006; Shoocongdej 2007; Amphansri 2011; Chitkament *et al.* 2015). From approximately 13,500 years ago, and possibly following a rock fall, the area became primarily used for human burials.

During April-August 2002 the skeletal remains (~ 65% complete) of a woman were recovered from Area 1, which is the excavation pit that abuts the north-facing cliff constituting the Rockshelter overhang. This individual was found orientated on the left side and in a flexed position. Across the radius and ulna was a hammerstone, and above the burial was a circle consisting of five large pebbles and rounded limestone fragments. The remains are estimated as having belonged to an adult woman (25-35 years) on the basis of the width of the greater sciatic notches of the pelvis, complete fusion of the epiphyses of the left radius and the complete eruption of the upper third molars (Pureepatpong 2006). Using the height of the left radius and a regression equation developed for Thai and Chinese populations (Sangvichien 1985), stature is estimated at 152 (± 4) cm. Accelerated Mass Spectrometry (AMS) radiocarbon dating of the sediment located adjacent to the pelvis indicates this individual lived 13,640 (±80) BP (^{14}C dates are calibrated using OxCal 4.2 (Ramsey 2009) using the IntCal-13 Calibration Curve, and age range is within 95.4% probability). This woman from the Tham Lod Rockshelter is therefore the oldest human burial to be excavated from the Northwestern Highlands of Thailand, and is likely a direct descendent of the founder population of Southeast Asia.

An estimation of the facial appearance of this Late Pleistocene woman was undertaken in 2015 using a suite of verified methods (see Figures 1-2 and Supplementary Materials) often referred to as "facial approximation". This estimation was primarily undertaken because of the archaeological significance of the remains, but also because, as an individual who lived in the Northwestern Highlands of Thailand more than 13,500 years ago, this woman constitutes a test of the methods' ability to retain, rather than overwrite, the unique facial morphology of the deceased. The importance of such a test cannot be overstated. As was clearly demonstrated by the unfortunate face given to the 9,000 year old remains of the North American 'Kennewick Man' (Holden 1998), inappropriate population inflections have serious socio-cultural as well as scientific consequences.

The face of 'Kennewick Man' was achieved through application of the extraordinarily popular method of "(forensic) facial reconstruction". Since 2002 nearly all of the recommendations associated with most, if not all, facial reconstructions have been proven invalid, but nonetheless facial reconstruction continues to be the technique of choice for nearly all forensic artists, anthropologists and palaeo-artists (for detailed methodological reviews, see Hayes *et al.* 2013; Hayes 2014; 2015). Although the application of verified methods to estimate a face should be less subjective, and more reliable, than a facial reconstruction, it is still the case that most of the verified methods applied in a facial approximation have an inherent chronological and population bias. As can be seen in Table 1, the relationships we used to estimate the facial appearance of this Late Pleistocene woman from Tham Lod are unavoidably derived from studies involving recent individuals, and furthermore, predominantly of recent individuals of a European population affinity (15 European out of 27 populations).

Some of the methods we applied to estimate facial appearance include verification of applicability to recent non-European populations, but many do not. Stephan and Simpson (2008) report no practical difference between the different population groups that comprise their large facial Soft Tissue Depth (fSTD) dataset (the average number of individuals from which the weighted means have been derived is 3,250). In their analysis Stephan and Simpson found that the differences in fSTD measures within each of the population groups comprising the total data set are consistently larger than the differences between population groups, and furthermore the standard measurement error (when reported) is also greater than differences arising from population affinity, sex, adult aging and body mass. Relative population neutrality is also reported for eyeball projection (Stephan 2002a), eyebrow position (Stephan 2002b), the orientation of the mouth in relation to the mental foramen and lateral iris (Stephan 2003; Song *et al.* 2007; Stephan & Murphy 2008), and, by implication, the relationship between the malar tubercle and the exocanthion (Whitnall 1911; Stephan & Davidson 2008). Average interpupillary distance and average mouth widths have also been found to have no statistically significant difference between Australian European and Central/Southeast Asian populations (Stephan 2003), and while a study concerning lip height reports Europeans displaying thinner lips (Wilkinson *et al.* 2003), the Indian Sub-Continent data from this study was applied to the woman from Tham Lod given the closer geographic proximity. The facial features that appear to be most dominated by findings derived from individuals of European population affinity are nasal projection and nasal dimensions (Rynn *et al.* 2010), the position of the eyeball within the orbit (Stephan & Davidson 2008; Stephan *et al.* 2009; Guyomarc'h *et al.* 2012), the average diameters of the eyeball and iris (Driessen *et al.* 2011; Guyomarc'h *et al.* 2012), and the height of the ears (Farkas & Munro 1987).

It is likely, therefore, that our facial approximation of a Late Pleistocene woman from the Northwestern Highlands of Thailand is inflected by the facial morphology of recent women, and European women in particular. In order to guage the extent to which this inappropriate inflection occurs, we undertook an anthropometric analysis that involved comparing our results with the average facial dimensions derived from 720 contemporary women living in 25 different countries and across three continents.

Materials and methods

The facial Soft Tissue Depth (fSTD) data set applied for this facial approximation is, as discussed above, comparatively population neutral. To verify the extent of this neutrality with regards to Thailand, a subset of the Stephan and Simpson (2008) fSTDs that account for the same landmarks as fSTDs taken from cadavers of Thai women (n=36, Puavaranukroh & Srettabunjong 2011) were compared. Significant differences are taken to be those that are greater than one standard error.

The dataset of 10 anthropometric means we used for our statistical comparison are from a single study (Farkas *et al.* 2005) under the research leadership of Leslie Farkas, a person internationally well regarded and renown for precision in anthropometry. The women comprising this study are of a comparable biological age to the Tham Lod remains (18-30 years) and the measures are the anthropometric means of 30 women per population group. The 25 population groups are from Europe, the Middle East, Africa, Asia and North America, though as can be seen in Figure 3, the populations comprising this study are dominated by Western and Central Europeans. However, while the populations measured by Farkas and colleagues (2005) are somewhat eclectic, this research is a comparatively robust international dataset of average facial measures, with the same landmark definitions and methods to achieve the 10 measures being applied throughout.

Because the Tham Lod facial approximation references scaled orthogonal CT scans, direct measures are able to be taken that are compatible with the *in situ* measurements taken from the living women in the Farkas study (Farkas *et al.* 2005). The Tham Lod facial measurements were extracted from the soft tissue terminal landmarks of the relevant fSTDs, and from the landmarks of the feature estimations. These landmarks are as shown in Figure 1 (see Supplementary Materials Table 1 for the landmark definitions and fSTDs). The estimation of ear height was analysed separately using Pearson's correlation. The 10 measures covering the facial dimensions and dimensions of the internal facial features (eyes, nose, mouth) were entered into a cluster analyses by population group, and by facial feature, using Ward's Method with Euclidian distances, and these were undertaken in tandem with Principle Components Analyses (PCAs) and Box Plots. The 10 measures taken from the 25 extant population groups were first analysed independently of the Tham Lod facial approximation to note the overall pattern of clustering, and then analysed with the Tham Lod data to show indications of recent population inflection in the facial approximation. All analyses were accomplished using the statistical software PAST v.3.08 (Hammer *et al.* 2001) with the cluster analyses and PCAs set to a bootstrap of 1000. The 10 measures used in the analyses are listed, together with the Tham Lod facial approximation measurements and the means for each population, in Table 2.

Results

The comparison the global weighted fSTD means calculated by Stephan and Simpson (2008) with fSTDs taken from cadavers of Thai women (n=36, Puavaranukroh & Srettabunjong 2011) is shown in Figure 4. As can be seen, the global dataset (Stephan & Simpson 2008) displays greater tissue depths at all landmarks except for the zygion (the maximum width at the cheekbones), with the larger differences occurring predominantly along the cheeks and mid-face. However, most of the global weighted means fall within one standard deviation of the Thai female mean (note that the Thai fSTD paper does not report the standard error), with the exceptions being the nasion and philtrum.

For this, and other facial approximations, the relationship of ear height to lower face height (subnasale to menton) was sourced from an anthropometric study of 18 year old North Americans (Farkas & Munro 1987). This relationship, however, was found to bear no correlation (Pearson's r = -0.15) with any of the international populations of women aged 18-30 years, including the North American women (Farkas *et al.* 2005). Given this inaccurate estimation of ear height could confound the multivariate analyses, it was not included as a comparative measure.

The analyses of the 10 extant population measures independently of the Tham Lod facial approximation results in Singaporean Chinese, Vietnamese, Thai and Japanese women clustering separately from Indian women, and Zulu women clustering with African American women, but not Angolan women. The Middle East populations do not cluster but are spread throughout, and the European women do not clearly cluster by population geography. PC1 (36% variance) is weighted towards facial widths, and show Japanese women to have the widest faces, followed by Thai, Vietnamese and Singaporean women. PC2 (22% variance) is weighted towards eye spacing and facial height, and shows Indian women to have the widest spaced eyes, relative to the other facial features, followed by Thai women. There is a relatively high variance in jaw width and inter-canthal width across the populations. Nasal dimensions tend to be dominated by relatively long and narrow noses, which is in keeping with the dataset containing a large number of European population groups.

When the facial measurements of the Tham Lod facial approximation are entered into the cluster analyses, the results indicate that this Late Pleistocene woman shares no close affiliation with any individual extant population, but is co-joined with a discrete cluster of Thai, Japanese, Singaporean Chinese and Vietnamese women (see Figure 5). Examination of the PCAs (see Figure 6) shows the main effect of including the Late Pleistocene woman from Tham Lod is to retain the East Asian/Southeast Asian grouping, but with the facial approximation occupying the extreme of PC1

(46% variance). PC1, as with the analysis undertaken without the Tham Lod facial approximation, is weighted towards facial widths, and, as indicated by the Box Plots according to facial measure (see Figure 7), Tham Lod is an outlier in bizygomatic width. PC2 (18% variance) is, as before, weighted towards eye spacing and facial height, with the facial approximation located close to the mean, and sharing this location with African Americans, Bulgarians and Turkish women. PC3 (12% variance) and PC4 (10% variance) are less clearly separated by facial measures, but indicate a closer affinity between the Tham Lod facial approximation (which is again close to the mean on PC3) and extant modern women of North American, Azerbaijan, Greek and Polish population affinity, though still grouping loosely with Vietnamese and Singaporean Chinese women.

Figure 8 shows individual cluster analyses by specific facial features: the overall facial dimensions (bizygomatic width, bigonial width, facial height), eye width, nose (nasal width and height), and mouth width. In facial dimensions the Tham Lod facial approximation is affiliated with recent Japanese women, and this pairing is discrete from all of the other populations when only facial widths (bizygomatic and bigonial) are analysed. For eye dimensions the facial approximation is linked to Vietnamese women, and co-clusters with a pairing of Singaporean Chinese and Angolan women. This double-paired cluster is retained when eye spacing, and not eye width, is entered into the analysis. Nasal dimensions result in the facial approximation being paired with Angolan women, and located within a discrete cluster containing Vietnamese women and a pairing of Thai and African American women. Mouth width effectively separates the facial approximation and women of African population affinity from all of the other populations, but within this cluster the facial approximation is paired with Hungarian women. In effect, the cluster analyses (the results of which are mirrored within parallel PCA analyses) show the Tham Lod facial approximation to have a mix of East-Southeast Asian and African population attributes, with only one European population pairing (Hungary) occurring in regards to mouth width.

Discussion

A facial approximation differs from most, if not all, facial reconstructions when it involves applying verified skull-soft tissue relationships to estimate facial appearance. Although many of these verified relationships have involved studies of non-European populations, it is still the case that European craniofacial relationships predominate, and all have of necessity been derived from recent human populations (see Table 1). Studies that have been tested for relative population neutrality include the global weighted means of facial Soft Tissue Depths (Stephan & Simpson 2008) and estimation of mouth width (e.g. Stephan 2003; Song *et al.* 2007; Stephan & Murphy 2008). Estimations of the shape and projection of the nose, the position of the eyeball within the orbit, and the average diameters of the eyeball and iris, have not been tested, and are more likely to inflect a facial approximation with European characteristics.

Late Pleistocene skulls have been found to display larger jaws (e.g. Velemínská *et al.* 2008) and bigger teeth (e.g. Brace *et al.* 1987) than Late Holocene skulls, and the craniofacial measurements of Late Pleistocene skulls from Africa, East Asia and Europe are mostly, on average, larger than the average craniofacial dimensions displayed by recent humans (Curnoe *et al.* 2012). Late Pleistocene crania have also been found to show a high level of within group diversity compared to recent crania (Harvati 2009) which is likely related to the limited number of individuals available for study, and that poor preservation is characteristic of the comparatively few Late Pleistocene individuals excavated to date. Nevertheless, if the facial approximation methods we applied retain differences in the robustness of a skull, it is likely that facial widths will most clearly distinguish our facial approximation from modern populations. The results of the analyses do indicate that our Tham Lod facial approximation is an outlier in bizygomatic width. In all other facial dimensions, however, the facial approximation groups with the mean anthropometric data taken from recent women, but not recent women of European population affinity.

In essence this comparative analysis involving extant modern women from 25 different population groups indicates that our facial approximation of Tham Lod is not overly influenced by European facial characteristics. Instead, when all facial dimensions are analysed together, the facial approximation is discrete from all populations, shows closest affiliation with recent women from East and Southeast Asia, and is most closely affiliated (albeit at a distance) with Japanese women in facial widths and facial height. The analyses of individual facial features – eyes, nose, mouth – indicate that the Tham Lod facial approximation shares morphological similarities with women of African population affinity, and particularly in the dimensions of the nose and mouth. Other than a clustering with extant modern Hungarian women with regards to the width of the mouth, European women, despite dominating both the comparative population study and the methods used to estimate facial appearance, are noticeably absent.

Conclusion

Due to her chronology this Late Pleistocene woman from the Northwestern Highlands of Thailand is most likely ancestral to the people who first colonised and dominated Mainland and Island Southeast Asia up until approximately 5,000 years ago (Duggan & Stoneking 2014; Lipson *et al.* 2014; Matsumura & Oxenham 2014). Given when and where this woman lived, all of the relationships we applied to estimate her facial appearance are inappropriate. We therefore anticipated that the results of our facial approximation would be indistinguishable from recent populations, and that the face would most likely group with recent European facial dimensions. Instead, when we compared our facial approximation to the mean facial measurements of extant modern women from 25 populations spanning the globe, the results suggest our estimated facial appearance is distinct from women of today at a global level, being generally more robust in facial width. Furthermore, while the estimated facial features (eyes, nose, mouth) share morphological similarities with recent women, these are almost exclusively women of East Asian, Southeast Asian and African population affinity. However, although these results indicate there is some population neutrality in the facial approximation methods we applied, these results are indicative rather than conclusive.

As is noted earlier, the anthropometric means of recent women on which our comparative analysis is based (Farkas *et al.* 2005) is population eclectic. That is, the populations included in the Farkas and colleagues' study are not representative of the diversity of extant human populations, and this includes the major regions claimed to be covered by the study: Europe, the Middle East, Asia, Africa and North America (refer Figure 4). In addition, the facial measures we analysed do not fully encapsulate facial variation, and as indicated by the multivariate analyses, do not clearly distinguish between extant populations from quite distinct geographic regions. Therefore, while our facial approximation of Tham Lod is clearly able to be distinguished from women of European population affinity, the apparent inflection in our facial approximation of East Asian, Southeast Asian and African facial morphologies needs to be treated with caution. More research with a more representative global dataset, and more facial means, may produce more nuanced, and perhaps different, results.

What is suggested by this study is that the methods we applied to estimate the facial appearance do not markedly colonise the face and its features. Although these research methods are dominated by relationships derived from recent European skulls and faces, our estimation of the face of a Late Pleistocene woman from the Tham Lod Rockshelter in the Northwestern Highlands of Thailand is neither overtly recent nor overtly European. Therefore, it seems likely that at least some of the methods we applied to estimate the face are shaped by, and thereby retain, aspects of this individual's unique craniofacial morphology and location within the archaeological record.

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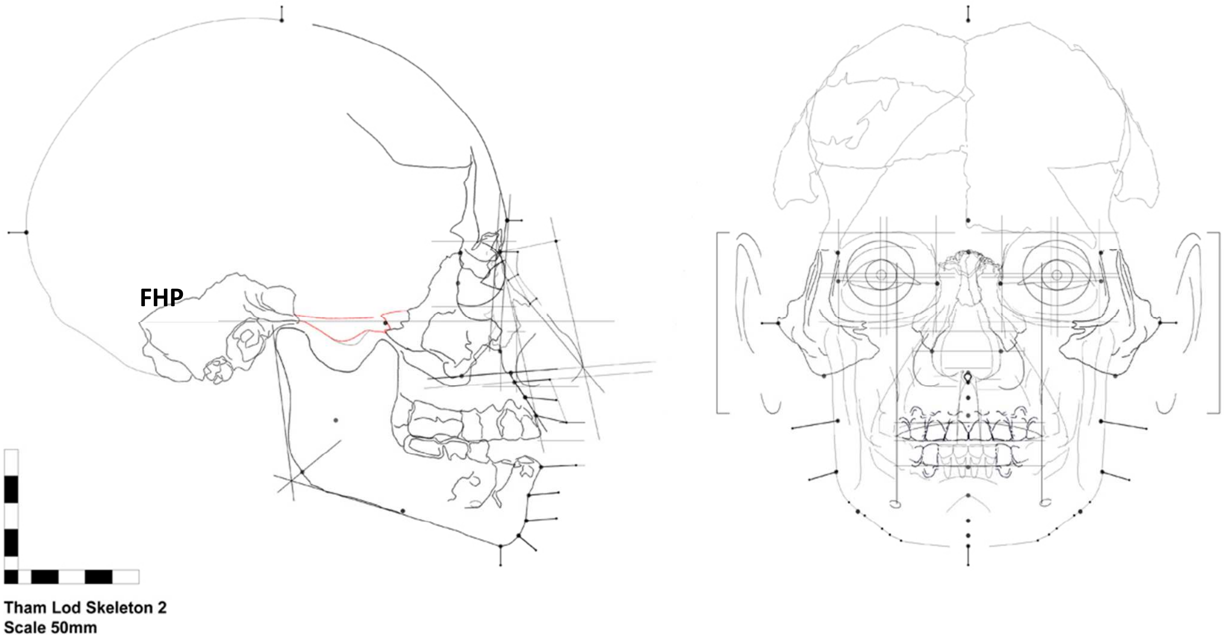


Figure 1. Tham Lod estimation of facial Soft Tissue Depths (fSTDs) and the facial features (eyes, nose, mouth, ears)

Refer to Table 1 for a summary of research articles referenced to estimate the location, shape and size of the facial features. The Supplementary Materials contains details the methods used to estimate the face and a table of the facial Soft Tissue Depths. FHP: Frankfurt Horizontal Plane. Scale 50 mm.

Figure 2. The completed Tham Lod facial approximation
Scale 50 mm.

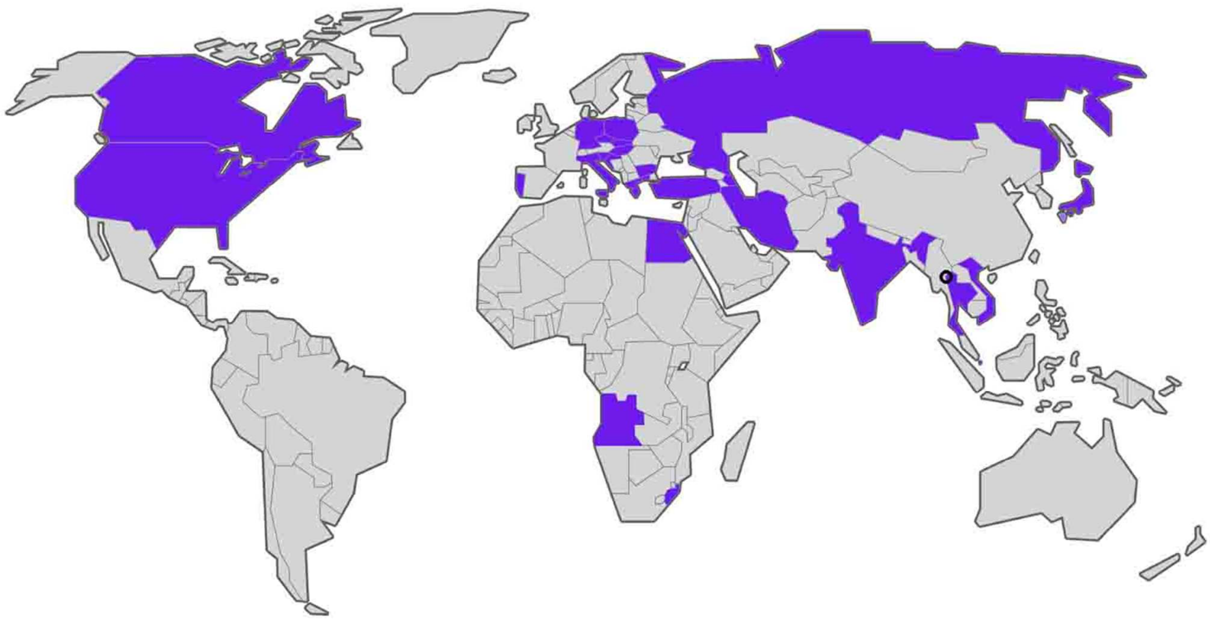


Figure 3: The comparative populations

The 25 international population groups (Farkas *et al.* 2005) are shown shaded. The Thai village of Tham Lod is indicated by a black circle (northern Thailand). Map modified from *Simplified angular world map*, accessed 27.08. 2015. Creative Commons licence, https://commons.wikimedia.org/wiki/Maps_of_the_world.

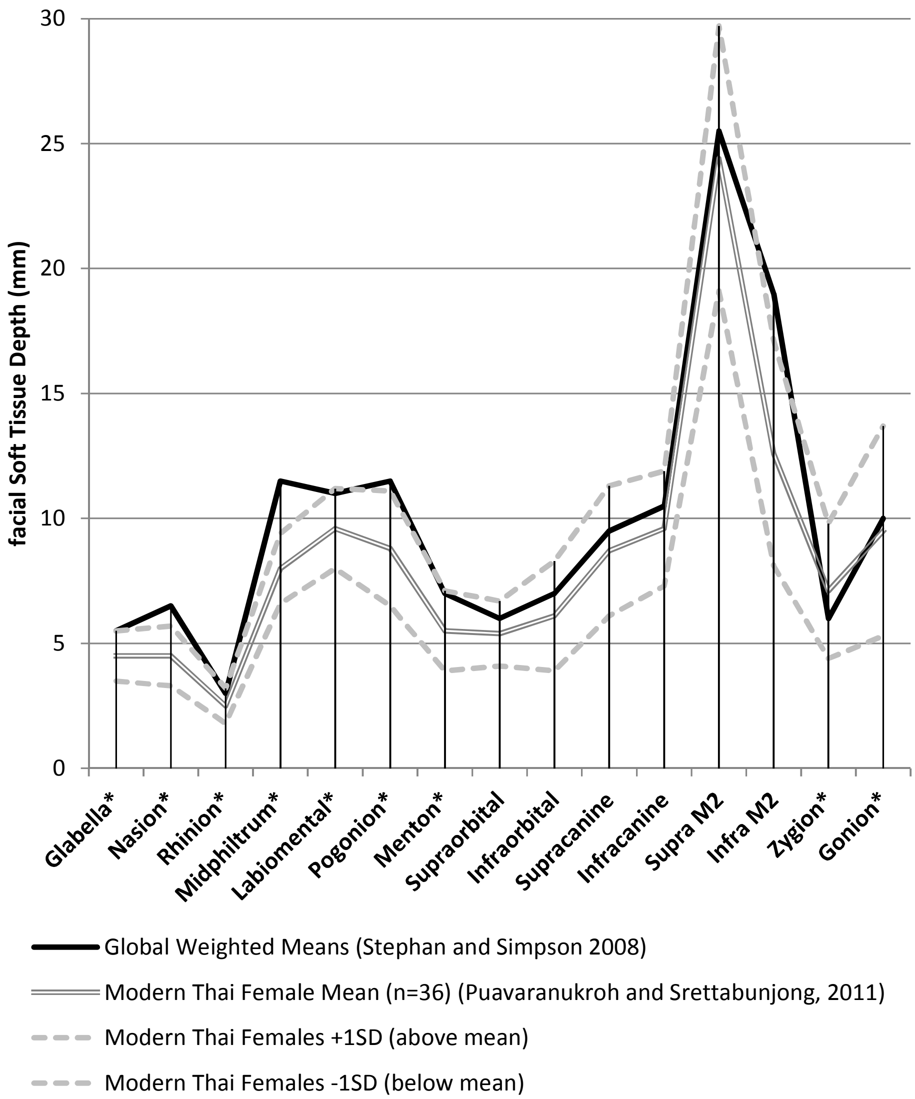


Figure 4: Comparison of global weighted means (dark line, from Stephan & Simpson 2008) with fSTD collected from 36 recent Thai female cadavers (grey line, from Puavaranukroh & Srettabunjong 2011). The reported Thai standard deviations are indicated with dashed grey lines.

The two datasets contain 15 homologous landmarks. The landmarks are as described in the Supplementary materials. The fSTDs applied in this facial approximation are indicated with an asterisk*.

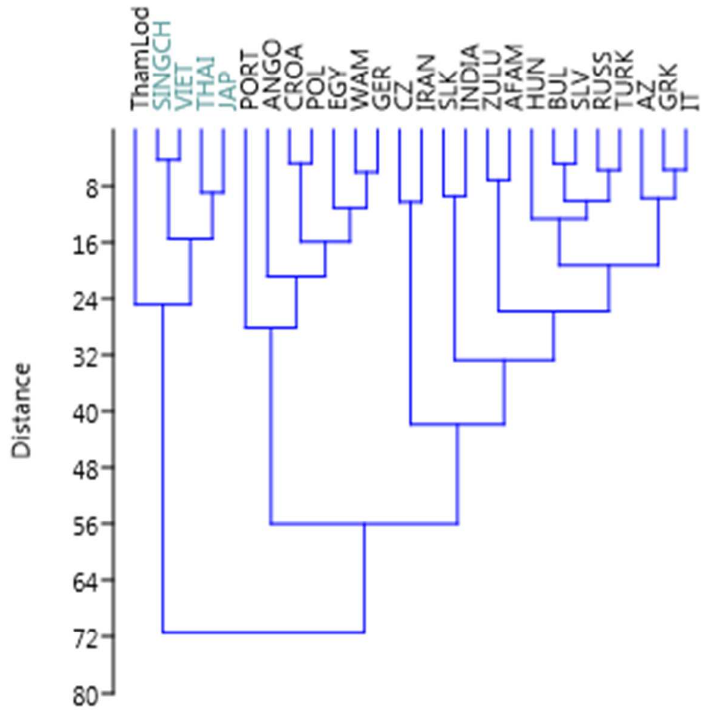


Figure 5: Hierarchical clustering by population and the Tham Lod facial approximation

Cluster analysis using Ward's Method in PAST v.3.08 (Hammer *et al.* 2001) of the Tham Lod facial approximation and 25 extant female populations (Farkas *et al.* 2005). As can be seen, the facial approximation clusters with populations from Mainland and Island Southeast Asia, and is clearly distinct from all of the European populations.

KEY:

Abbreviation	*Recent Population*
AFAM	*African American*
ANGO	*Angolan*
AZ	*Azerbaijian*
BUL	*Bulgarian*
CROA	*Croatian*
CZ	*Czech Republic*
EGY	*Egyptian*
GER	*German*
GRK	*Greek*
HUN	*Hungarian*
INDIA	*Indian Sub-Continent*
IRAN	*Iranian*
IT	*Italian*
JAP	*Japanese*
POL	*Polish*
PORT	*Portuguese*
RUSS	*Russian*
SINGCH	*Singaporean Chinese*
SLK	*Slovakian*
SLV	*Slovenian*
THAI	*Thai*
TURK	*Turkish*
VIET	*Vietnamese*
WAM	*"White" North American*
ZULU	*Zulu*

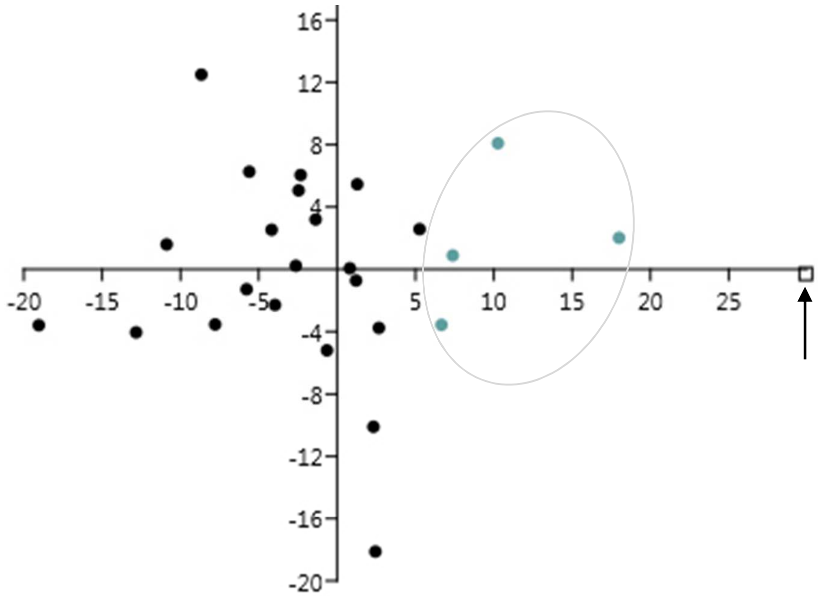


Figure 6: Principle Components analysis (PC1 and PC2)
Scatter plot of Principle Components analysis in PAST v.3.08 (Hammer *et al.* 2001). The Tham Lod facial approximation is represented by an open square and is positioned to the far right of PC1 (indicated by an arrow on the horizontal axis). The four East and Southeast Asian populations cluster (light coloured dots) and are indicated by an ellipsis.

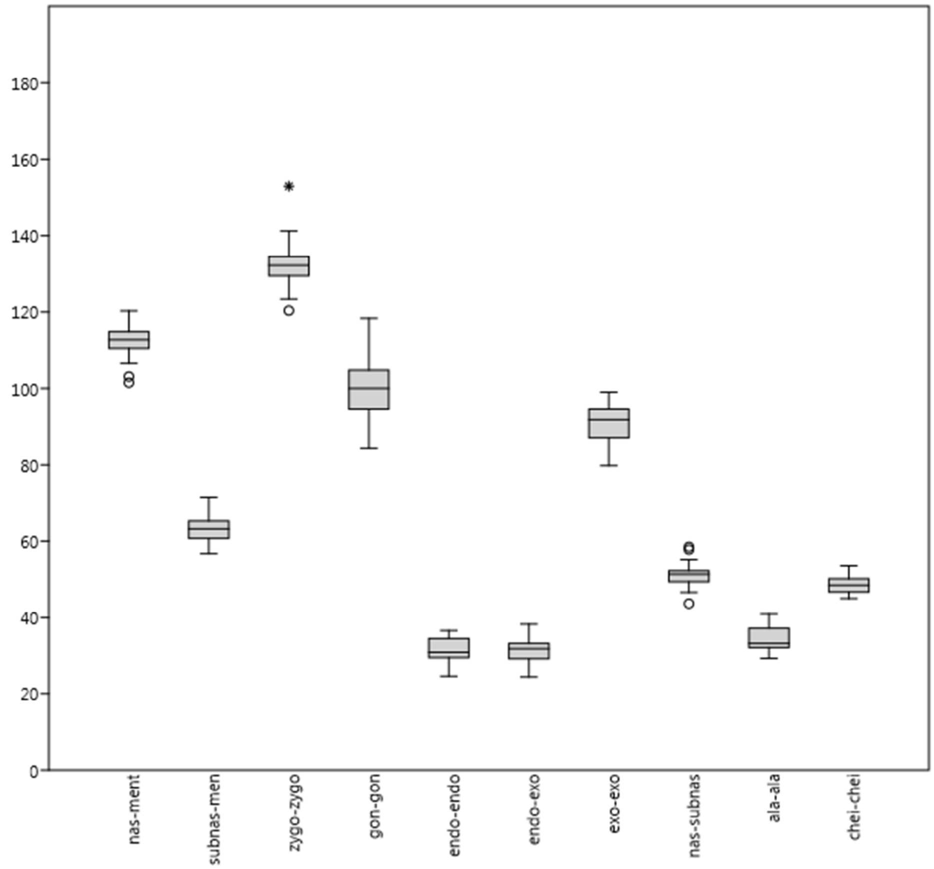


Figure 7: Box plots of the facial measures

Box Plot of facial measure variation generated in PAST v.3.08 (Hammer *et al.* 2001). Open circles are outliers; Tham Lod is the extreme outlier (indicated by an asterisk) for bizygomatic width.

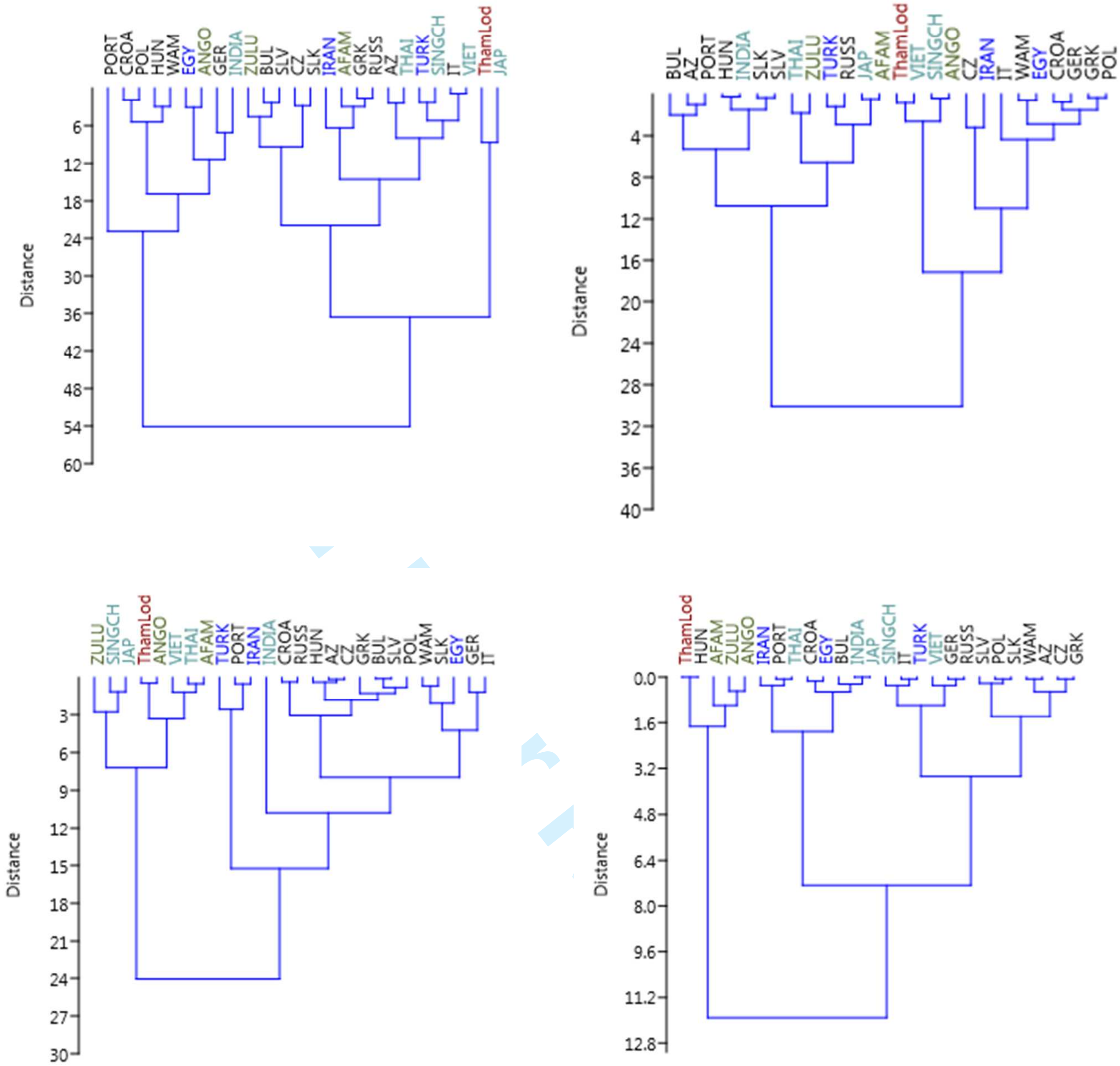


Figure 8: Hierarchical Clustering by Facial Features:

Top Row: Facial height and width (left), Eye spacing (right)

Bottom Row: Nose height and width (left), Mouth width (right)

Cluster analysis using Ward's Method in PAST v.3.08 (Hammer *et al.* 2001) of Tham Lod and the 25 populations measured by Farkas et. al (2005). As can be seen, Tham Lod is clearly distinct from extant European populations in all aspects, except for mouth width, which includes Hungary but is both separate to the remaining European populations and is dominated by women of African population affinity. For the key to population abbreviations, see Figure 5.

Table 1: Population affinity associated with the facial approximation methods applied

Where multiple methods were used to estimate one aspect of the face, the population affinity of the subjects used to derive or test the relationship is reported in the same order as the method referenced. Non-European populations are in bold type.

Feature	*Aspect estimated*	*Method referenced*	*Population affinity*
facial Soft Tissue Depths (fSTDs)	*Weighted means of facial Soft Tissue Depths (14 median, 3 bilateral)*	(Stephan & Simpson 2008)	*European* ***African American*** ***Amerindian*** ***Japanese***
Eyes	*Canthi*	(Whitnall 1911; Stephan & Davidson 2008)	*Australian European* ***'23 races'***
	Eyeball diameter	(Guyomarc'h *et al.* 2012)	*French European*
	Iris diameter	(Driessen *et al.* 2011)	*Netherlands European*
	Eyeball position	(Stephan & Davidson 2008; Stephan *et al.* 2009; Guyomarc'h *et al.* 2012)	*French European* *Australian European* *Australian European*
	Eyeball projection (lateral view)	(Stephan 2002a)	***Chinese*** ***African*** ***Mexican*** ***African American*** *American European*
	Eyebrow position	(Stephan 2002b)	*Australian European* ***Central and Southeast Asian***
Nose	*Nasal projection, dimensions, position and tip shape*	(Rynn *et al.* 2010)	*British European* *American European*
Mouth	*Mouth width/mouth corners*	(Stephan 2003; Song *et al.* 2007; Stephan & Murphy 2008)	***Korean*** *Australian European* ***Central and Southeast Asian*** *Australian European*
	Position of the oral fissure	(Standring 2008)	*Not reported*
	Lip height	(Wilkinson *et al.* 2003)	***Indian Sub-Continent***
Ears	*Ear height*	(Farkas & Munro 1987)	*American European*
Underlying anatomy	*Masseter depth*	(Kiliaridis *et al.* 2003)	*Northern European (possibly Swiss, Swedish and/or Netherlands European)*

Table 2. Facial measurements of Tham Lod (n=1) and recent women populations (mean, n=30)
The recent population data are taken from Farkas et. al (2005) and are the means of 30 women (18-30 years) per population group listed (N 720 = 30 x 25). Measures and landmarks: facial height (nasion-menton), jaw height (subnasale-menton), facial breadth (bizygomatic breadth), jaw breadth (bigonial breadth), outer eye spacing (bi-endocanthal breadth), eye width (left endocanthion-exocanthion); nose height (nasion-subnasale), nose width (inter-ala breadth), mouth width (cheilion-cheilion).

	Facial Height	*Jaw Height*	*Facial Breadth*	*Jaw Breadth*	*Outer Eye Spacing*	*Eye Width*	*Inner Eye Spacing*	*Nose Height*	*Nose Width*	*Mouth Width*
Tham Lod	116.1	68.9	152.9	118.4	35.6	26.9	89.3	47.2	41.5	51.6
African American	116.5	71.5	130.5	96.7	34.4	32.2	92.9	48.8	40.1	53.6
Angolan	106.5	63.2	132.8	90.3	36.6	27.1	87	46.6	40.8	52.9
Azerbaijan	111.5	63.6	138.7	102.9	30.5	33.8	94.2	52.3	33.8	49.7
Bulgarian	111	61.6	130.9	98.7	29.7	30.4	91.9	52.1	33	46.2
Croatian	110.4	60.7	133.2	94.6	29.7	38.3	86.3	50	32.9	46.9
Czech Rep.	112.6	66	126.4	107.1	29.1	28.2	80.3	52.1	33.8	50.2
Egyptian	103.1	57.8	130.3	91.2	30.9	30.8	86.3	47.4	29.3	46.7
German	109.5	63.3	123.4	91.5	28.6	31.8	86.4	51.4	31	48.2
Greek	116.4	63.3	132.2	99.2	29.5	32	87.8	52.8	32.4	50.3
Hungarian	112.4	56.7	131.3	95	31.2	34.9	97.3	52.5	33.5	51.6
Indian Sub-Continent	101.5	57.2	124.9	97.4	30.9	31.3	97.5	43.7	33.8	46.5
Iranian	120.3	66.2	131.7	102.7	24.6	24.4	79.8	58.5	32.1	45
Italian	113.8	64.4	133.3	104.9	27.6	32.7	89.5	52.1	29.5	47.7
Japanese	113.8	62.8	141.2	115.6	35	29.2	93.3	53.3	37.1	46.5
Polish	111.6	60.5	135.5	93.9	29.2	32.8	87.4	51.2	32.6	49
Portuguese	118.2	62.8	120.4	84.3	29.1	35.9	93.9	57.8	31.9	45.3
Russian	114.2	61.4	132.3	98.6	32.7	34.5	94.6	50.4	33.2	48.1
Singaporean Chinese	114.9	66.4	136.2	102.3	36.1	28.4	87.3	51.7	37.2	47.3
Slovakian	109.3	58.6	125	105.4	30.7	32.3	96.1	49.4	30.6	48.9
Slovenian	108.8	61.4	129.5	100.7	30.2	33.2	96.1	52	33.1	49.2
Thai	112.8	62.6	138.3	106	36	28.9	99	49.5	40.2	45.4
Turkish	116.4	59.1	134.5	100	31.7	29.8	93.2	55.2	32.9	47.6
Vietnamese	113.1	64	134.3	104.8	36.6	29.2	89.9	50.4	39.8	48.5
White North American	111.8	65.5	129.9	91.1	31.6	30.7	86.8	48.9	31.4	49.8
Zulu	113.7	65.4	128.4	102	34.5	33.4	96.9	49.5	38	52.2

Supplementary material:

A Late Pleistocene woman from Tham Lod, Thailand: the influence of today on a face from the past

The methods applied in the facial approximation are presented here as discrete elements, but in practice each is highly inter-related. This includes the identification of the facial landmarks and application of the facial Soft Tissue Depths (fSTD), estimation of the facial features (locations and dimensions of the eyes, nose, mouth and ears), application of the underlying anatomical layers, and estimating surface appearance. Although each facial approximation undertaken differs according to the individual differences displayed by the bones and teeth, more detail regarding the overall approach can be found in prior publications involving forensic, archaeological and palaeoanthropological remains (Hayes *et al.* 2013; Hayes 2014; 2015).

Landmarks and facial Soft Tissue Depths (fSTDs)

The facial landmarks used for this facial approximation are defined in supplementary material Table 1, and are shown, together with the facial Soft Tissue Depths (fSTDs), in main text Figure 1. The fSTDs applied are weighted means calculated by Stephan and Simpson (2008), derived from the more robust fSTD datasets taken from contemporary individuals. Because this facial approximation is accomplished in 2D, only a subset of the available fSTDs have been applied to the right lateral and frontal orthogonal views of the Tham Lod skull reconstruction (14 median landmarks in the lateral view, and 8 landmarks in the frontal view: 3 bilateral and 2 median).

Facial Features (eyes, nose, mouth, ears)

For this approach, estimations of each of the facial features refer to published, and mostly verified, averages of skull-soft tissue relationships, many of which are averages of the head, face, feature and craniofacial variation displayed in recent European populations (summarised in main text Table 1 and shown applied in main text Figure 1).

Eyes: The location of the exocanthion has been found to be approximately on the same horizontal plane as the malar tubercle (Whitnall 1911; Stewart 1983; Stephan & Davidson 2008). Because the medial orbital walls were not recovered during excavation, the endocanthion was estimated as being on a horizontal plane approximately 1 mm lower than the exocanthion (Stephan & Davidson 2008). Eyeball dimensions are approximately 24 mm (Guyomarc'h *et al.* 2012), and are displaced from the orbital centres 1.4 mm superiorly and 2.3 mm laterally (Stephan & Davidson 2008; Stephan *et al.* 2009; Guyomarc'h *et al.* 2012). Iris width has been found to have a low level of variation, and is on average 11.65 mm (Driessen *et al.* 2011). In the lateral view eyeball protrusion is, on average, 3.7 mm anterior to the location of the orbital rims (Stephan 2002a).

Nose: Nasal protrusion, nasal width, nasal wing shape and height, and nasal tip shape was estimated following the algorithms and morphological observations of CT scans of recent populations by Rynn et al. (2010). These findings, however, have been further modified to correct for the authors' reliance on a mistranslation of Gerasimov's popular science text, *The Face Finder* (1971). This general misunderstanding and misapplication of Gerasimov's 'two tangent method' was first noted by Ullrich and Stephan (2011), and the more accurate reference to the angulation of the aperture base lateral to the anterior nasal spine has recently been verified by a CT scan study (Maltais Lapointe *et al.* 2015). The naso-labial fold follows Gerasimov's unverified observation that it commences at the height of the alar wing and follows an angulation towards the second molar and gonial angle (Gerasimov 1955).

Mouth: Oral fissure width was estimated in reference to the position of the left mental foramen (Song *et al.* 2007; Stephan & Murphy 2008), and checked against the medial border of the left iris, which on average is 1 mm anterior to the mouth corner (Stephan 2003). Lip height was calculated using the height of the preserved left lateral upper incisor and lower canine, and referenced algorithms derived from extant individuals of Indian Sub-Continent population affinity (Wilkinson *et al.* 2003). There are unsupported claims in forensic art and facial reconstruction handbooks that lip shape is related to the arc displayed by the alveolar ridge, and that philtrum width corresponds to the distance between the centres of the upper central incisors (Taylor 2001; Wilkinson 2004). The shape of the vermillion was estimated in relation to lip height, mouth corner location, and the shape of the curve of Spee (the arc formed by the occlusal line), while philtrum shape was estimated referencing the central incisor mid-distance. The relationship of lip shape to the curve of Spee is mentioned in orthodontic aesthetic research, which notes (but does not include statistical frequency) a parallel convexity of lower lip shape with the 'smile line' (Ritter *et al.* 2006), and indicates that this convexity reaches stability in adulthood (Kumar & Tamizharasi 2012). The use of the curve of Spee is therefore an unverified relationship. Position of the oral fissure follows the anatomical recommendation of approximately corresponding to the inferior edge of the upper canine (Standring 2008).

Ears: Other than its anatomical location in relation to the external auditory meatus, there is no known correlate between the skull and ear shape, size and protrusion (Guyomarc'h & Stephan 2012). Ear height has, however, been statistically related to the soft tissue distance subnasale-menton for young adults (Farkas & Munro 1987), and this relationship was applied referencing the fSTD derived soft tissue landmarks.

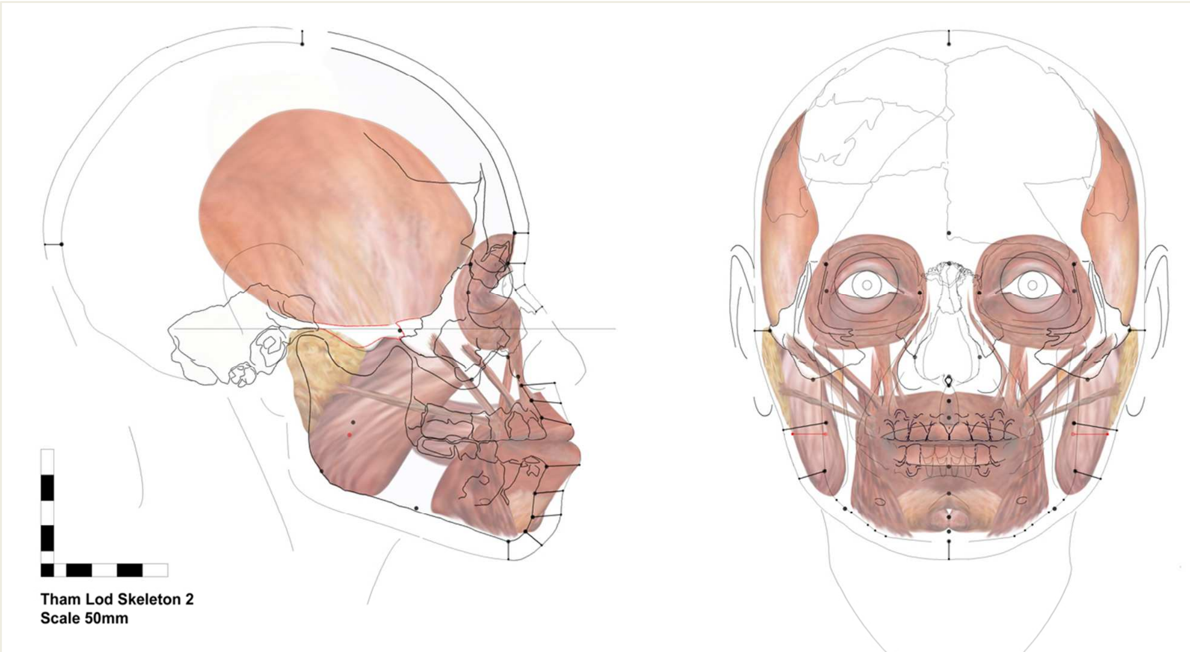
Underlying Anatomy

Warping of each of the virtual muscles and glands followed the deep to surface layers described in relatively recent facial approximations of a prehistoric Amerindian (Hayes 2015), the *Homo floresiensis* holotype (Hayes *et al.* 2013), and is described in more detail within a forensic application

(Hayes 2014). Calculation of the maximum depth of the masseter followed the algorithm determined by Kiliaridis et al. (2003), which is considered relatively robust by Stephan (2010). This algorithm, however, was derived from 60 individuals aged 7-18 years, and therefore the maximum age (18 years) is somewhat younger than the estimated age of the Tham Lod woman (25-35 years). Muscle attachment patterns were largely indistinct on the Tham Lod remains, and for the most part followed their anatomical locations and descriptions in the more reliable anatomical texts (e.g. Warwick & Williams 1973; Mcminn *et al.* 1999; Standring 2008). Estimation of the inferior temporal line was achieved by referencing the 2,000 year old cranium of a woman excavated from Long Long Rak, which is located nearby the Tham Lod Rockshelter, and bears a very similar cranial shape to Tham Lod in the frontal and temporal regions. The completed lateral and frontal view of the underlying anatomy, together with the maximum masseter tissue depth (frontal view), is shown in supplementary material Figure 1.

Surface Appearance

The final rendering of the surface appearance of the face and features (see main text Figure 2) was largely achieved in reference to historical photographs of Hill Tribe individuals from the Tham Lod region (in particular, Spies 2013), but only those individuals whose photographs display similarity in aspects of size, shape and/or projection to the Tham Lod woman's estimated face and features. There are no currently known relationships between terminal scalp hair and the skull, and therefore indeterminate dark hair was applied keeping to the general shape of the cranial arc, and covering the highly speculative upper ear shape. Eyebrow position follows the general shape of the superior orbital rim, which is an unverified recommendation (Fedosyutkin & Nainys 1993). The location of the eyebrow peak references research undertaken by Stephan (2002b), though Stephan notes that the average eyebrow peak location (2.7 mm lateral to the border of the medial iris) has high standard deviations and is therefore not a reliable recommendation.



Supplementary material Figure 1
Tham Lod estimation of underlying anatomy, outer face shape and neck.
FHP: Frankfurt Horizontal Plane. Scale 50 mm.

Supplementary material Table 1. Definitions of the landmarks and facial Soft Tissue Depths (fSTD) applied in the facial approximation

All fSTD and their landmark definitions are from Stephan and Simpson (2008)

Landmark	***Landmark Definition***	***Landmark Reference***	***fSTD (mm)***
Anterior nasal spine (ANS)	*Apex of the anterior nasal spine*	(Buikstra & Ubelaker 1994)	*na*
Alare	*The widest points of the nasal aperture*	(Buikstra & Ubelaker 1994)	*na*
Christa conchalis	*Where the inferior nasal concha meets the anterior edge of the nasal aperture wall*	(Mcminn *et al.* 1999)	*na*
Endocanthion	*Point of insertion of the medial tendon within the lacrimal fossa*	(Stephan & Davidson 2008)	*na*
Fronto-zygomatic	*The most laterally positioned point on the fronto-zygomatic suture*	(Buikstra & Ubelaker 1994)	*na*
Glabella	*The most anterior midline point on the frontal bone*	(Stephan & Simpson 2008)	5.5 mm
Gonion	*A point on the mandibular border where a tangent bisects the angle formed by the posterior ramus and inferior corpus borders*	(Stephan & Simpson 2008)	10 mm
Gnathion	*Midline point halfway between the pogonion and menton*	(Stephan & Simpson 2008)	8.5 mm
Lower lip	*Midline point on the maxilla at the most anterior edge of the inferior alveolar ridge*	(Stephan & Simpson 2008)	13 mm
Malar tubercle	*A tubercle situation on the orbital surface of the frontal process of the maxilla, just within the orbital margin*	(Whitnall 1911)	*na*
Labiomental	*Deepest midline point on the groove superior to the mental eminence*	(Stephan & Simpson 2008)	11 mm
Menton	*The most inferior point of the mandible*	(Stephan & Simpson 2008)	7 mm
Mid-nasal	*Point on the internasal suture midway between the nasion and rhinion*	(Stephan & Simpson 2008)	4 mm
Mid-mandibular border	*Point on inferior border of mandible, midway between pogonion and gonion*	(Stephan & Simpson 2008)	*na*
Mid-philtrum	*Midline point on the anterior edge of the maxillae, halfway between the base of the subnasale and prosthion*	(Stephan & Simpson 2008)	11.5 mm
Mid-ramus	*A point at the centre of the mandibular ramus*	Stephan & Simpson 2008	17.5 mm
Nasion	*Midline point on the naso-frontal suture*	(Stephan & Simpson 2008)	6.5 mm
Opisthocranion	*Midline ectocranial point at the farthest chord length from the glabella*	(Stephan & Simpson 2008)	6.5 mm
Pogonion	*Most anterior midline point on the mental eminence of the mandible*	(Stephan & Simpson 2008)	11.5 mm
Prosthion	*Midline point on the maxillae at the most anterior edge of the superior alveolar ridge*	(Stephan & Simpson 2008)	11.5 mm
Rhinion	*Midline point at the inferior free end of the internasal suture*	(Stephan & Simpson 2008)	3 mm
Subnasale	*Just below the anterior nasal spine on the midline*	(Stephan & Simpson 2008)	13 mm
Vertex	*The highest midline point on the ectocranium*	(Stephan & Simpson 2008)	5 mm
Zygion	*Most lateral point on the zygomatic arch*	(Stephan & Simpson 2008)	6 mm
Zygo-maxillary	*Most inferior point on the zygomatico-maxillary suture*	(White & Folkens 2000)	*na*

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