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### Réfuter l'existence d'affinités neurocrâniennes avec les *Homo erectus* indonésiens sur Maré (Îles Loyauté, Nouvelle-Calédonie) : évidence d'influence Polynésienne par morphométrie linéaire

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**Abstract** – During an expedition in Maré (Loyalty Islands, New Caledonia), Father Marie-Joseph Dubois conducted anthropological studies that led him to postulate the presence of inherited Indonesian *Homo erectus* neurocranial features and biological Polynesian influences. To test these hypotheses, five archaeological crania from Maré were analysed by linear morphometry to: 1) assess the presence of affinities with Indonesian *H. erectus*, 2) determine biological affinities with a heterogeneous sample of modern *H. sapiens*, and 3) contextualise the results in the light of current knowledge and oral traditions about the peopling of the Pacific region. The results show no evidence of affinities with Indonesian *H. erectus* neurocrania, so that the hypothesis postulated by Dubois has to be refuted. The Maré crania present morphometric affinities with the Australo-Melanesian and Chinese-Micronesian-Polynesian population clusters. The Chinese-Micronesian-Polynesian affinities provide new evidence of Polynesian influence in Maré. The LMA001 archaeological site offers the earliest evidence of Polynesian presence in Maré about a millennium ago. The morphometric diversity within the sample evokes certain aspects found in oral traditions, such as the presence of Polynesians and their admixture with the Maré population.

**Keywords** – Maré, Indonesian *Homo erectus*, linear morphometry, Polynesian influence, morphometric heterogeneity

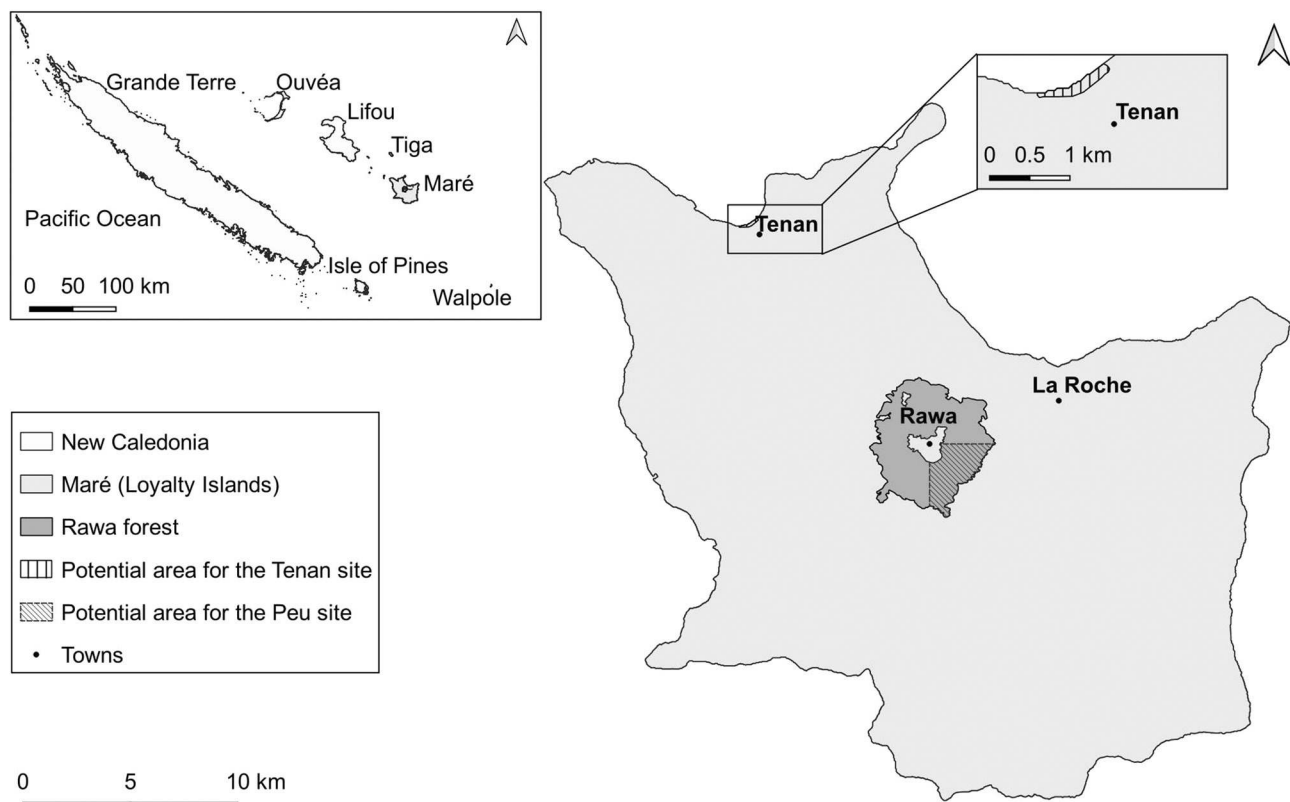
**Résumé** – Au cours d'une expédition sur Maré (Îles Loyauté, Nouvelle-Calédonie), le père Marie-Joseph Dubois conduit des recherches anthropologiques l'amenant à théoriser sur la présence de traits neurocrâniens d'*Homo erectus*

indonésiens et d'influences biologiques polynésiennes. Pour tester ses hypothèses, un total de cinq crânes archéologiques de Maré ont été analysés par morphométrie linéaire pour : 1) estimer la présence d'affinité avec les *H. erectus* indonésiens, 2) déterminer les affinités biologiques avec un échantillon hétérogène d'*H. sapiens* moderne, 3) contextualiser les résultats obtenus avec ce qui est connu du peuplement du Pacifique et les traditions orales. Les résultats de cette étude ne démontrent aucune affinité entre les crânes de Maré et les *H. erectus* indonésiens, ainsi l'hypothèse postulée par Dubois doit être rejetée. Les crânes de Maré présentent des affinités morphométriques pour les groupes Australo-Mélanésien et Chinois-Micronésien-Polynésien. Les affinités observées pour le groupe Chinois-Micronésien-Polynésien témoignent d'une influence polynésienne sur Maré. Le site archéologique LMA001 marque l'arrivée la plus récente des Polynésiens sur Maré il y a un millénaire. L'hétérogénéité morphométrique des crânes de Maré rappelle certains aspects des traditions orales, tel que la présence de Polynésiens sur l'île et leur métissage avec la population de Maré.

**Mots clés** – Maré, *Homo erectus* indonésiens, morphométrie linéaire, influence polynésienne, hétérogénéité morphométrique

### Introduction

The New Caledonia archipelago (figure 1) is located in the southernmost part of the Melanesian arc and encompasses the mainland, called Grande Terre, and the Loyalty



**Figure 1.** Map of New Caledonia and detail of Maré island, with potential areas for the archaeological sites of Peu and Tenan (from Hartweg 1949; 1950 and Dubois 1984) / *Carte de la Nouvelle Calédonie et Maré avec les zones potentielles où se trouvent les sites archéologiques Peu et Tenan (à partir de Hartweg 1949 ; 1950 et Dubois 1984)*

Islands chain comprising Ouvéa, Lifou, Tiga and Maré. During his stay on Maré, Father Marie-Joseph Dubois (1975a; 1984), a Marist missionary with a particular interest in botany, linguistics and ethnology, collected and analysed local oral traditions (Lormée et al., 2011). Prompted by his interest in these oral traditions, Dubois excavated human remains from seven archaeological burial sites during the 1940s (Hartweg 1948; 1950; Dubois, 1975b; 1976). On the calvaria of the *Homme de Peu*, an individual from the *si Peu* clan dated at the time to  $1680 \pm 120$  AD<sup>1</sup>, Dubois (1975b; 1976) observed a receding frontal bone and a supraorbital torus with a glabella projecting anteriorly. Parallels were drawn with the crania excavated during the 1960s-1970s at the Kow Swamp site (Victoria, Australia) (Thorne, 1971; Thorne and Macumber, 1972), as Dubois speculated on the cranial robusticity of the *Homme de Peu* and concluded as to a possible retention of Indonesian *Homo erectus* traits in Maré (Dubois, 1975b; 1976; 1984). Such speculation from Dubois is not surprising for the period of his publications, as Oceanian cranial features were often

thought to be inherited from Indonesian *H. erectus* (e.g. Weidenreich, 1946; Rivet, 1953; Coon, 1965; Macintosh, 1965; Thorne, 1971; Thorne and Wolpoff, 1992). Furthermore, when discussing Maré oral traditions, Dubois postulated that Polynesian groups arrived and became established as chief-led clans (Dubois, 1975a), which may have led to biological Polynesian influences (Dubois, 1975a; 1984). According to Dubois' anthropological research (Dubois, 1975a; 1975b; 1976; 1984), Maré's past populations were somewhat heterogeneous, with individuals sharing characteristics with *H. erectus* while others were considered to be of admixed Polynesian ancestry. Therefore, to test his statement on the origin of the biological variation of past populations in Maré, this paper aims to: 1) assess the presence of affinities with Indonesian *H. erectus*, 2) determine biological affinities with a heterogeneous modern *H. sapiens* sample, and 3) contextualise the results in the light of current research and oral traditions on the peopling in the Pacific.

### *A brief contextualisation of the analysis*

In physical anthropology, “robust” is a term commonly used to describe strongly or heavily built bone structures and their ability to resist loads (Chevalier, 2022). Robust cranial features observed on human skeletal remains from Oceania were often used to support the multiregional

<sup>1</sup> New dating of the individual was unsuccessful (WK-47566, Waikato Radiocarbon Dating Laboratory, New Zealand), see *The sample from Maré* in the *Material and Methods* section and the *Acknowledgements*.

model of human evolution, in which it was hypothesised that Oceanians inherited cranial traits from Indonesian *H. erectus* populations (e.g. Weidenreich, 1946; Rivet, 1953; Coon, 1965; Macintosh, 1965; Thorne, 1971; Thorne and Macumber, 1972; Thorne and Wolpoff, 1992; Curnoe, 2007). However, the concept of regional continuity from *H. erectus* has long been disproved with increasing evidence for an African origin of *H. sapiens* coming to light (e.g. White et al., 2003; Smith et al., 2007; 2017; Hublin et al., 2017; Nielsen et al., 2017; Ponce de León et al., 2018). The current variants of the Out of Africa model are accepted by most of the scientific community: it is recognised in all cases that *H. sapiens* originated in Africa, although some disagree with or minimise the relevance of the influence that archaic non-African populations had in shaping the variation of *H. sapiens* (White et al., 2003; Smith et al., 2007; 2017; Hublin et al., 2017; Nielsen et al., 2017; Ponce de León et al., 2018).

While the qualitative use of robusticity to infer archaic phylogenetic relationships is ill-advised (e.g. Lahr and Foley, 1994; Lahr and Wright, 1996; Sémah and Détroit, 2006; Curnoe, 2009; 2011), quantitative cranial research has shown patterns of gracilisation in anatomically modern humans (AMH), with examples that include selection of smaller masticatory features associated with the use of tools and meat consumption (Zink and Lieberman, 2016) or facial reduction resulting from complex basicranial spatial influences (Bastir and Rosas, 2016). Neither morphometric studies (Lahr, 1994; Lahr and Wright, 1996; Sémah and Détroit, 2006; Curnoe, 2009; 2011) nor genomic analyses have been able to find evidence for an introgression of *H. erectus* into modern *H. sapiens* (Teixeira et al., 2021; Taufik et al., 2022), which makes Dubois' statement on the *Homme de Peu* and the Maré population more open to question.

Along with the inheritance of *H. erectus* traits, the Polynesian influence hypothesised by Dubois in Maré is another unresolved question. Dubois discussed the arrival of Tongans from the eastern side of Maré and Polynesian influences from Lifou, which might have had cultural, ethnic and religious impacts on the Maré clans (Dubois, 1975). The east-to-west Polynesian migrations during the 2<sup>nd</sup> millennium AD (e.g. Shutler and Shutler, 1966; Garanger, 1972; Leach and Ward, 1981; Kirch, 1982; Davidson, 1992; Carson, 2002; Leach and Davidson, 2008; Kirch and Swift, 2017; Flexner et al., 2018) led to the establishment of around 18 Polynesian outliers, which can be defined as localities presenting Polynesian linguistic and cultural affinities (Kirch, 1984; 2000; Feinberg and Scaglione, 2012), distributed across Melanesia and Micronesia (Buck, 1938). Ouvéa (Loyalty Islands, New Caledonia) is the southernmost Polynesian outlier and the only one identified for New Caledonia (Carson, 2002; 2012; Flexner et al., 2018; 2019). Polynesian cultural traits in Maré are sparse, with both linguistic (Leenhardt, 1946; Tryon, 1967; Pawley, 1967) and archaeological (Sand and Ouetcho, 1993; Sand et al., 1995) evidence lacking, but rectangular-shaped houses presenting structural characteristics from Western Polynesia, possibly

Samoa, have been reported (Leenhardt, 1937; Boulay, 1990). Biological data have also contributed to the resolution of this problem, as genomic (Posth et al., 2018) and osteological (Pietruszewsky, 1977; Valentin and Sand, 2000) studies could not entirely refute a Polynesian influence in Maré.

The Dubois collection was first analysed by Hartweg (1948; 1950), more than 20 years before the publications discussing the *Homme de Peu* (Dubois, 1975b; 1976; 1984) and the Polynesian influences in Maré (Dubois, 1975a; 1984). Hartweg (1948; 1950) observed biological consistency with Melanesian affinities when looking at cranial indexes and non-metric traits, but without providing a statistical framework. Similar results were obtained from a second collection: LMA001 was excavated in 1977 by Jean-Pierre Maître at the La Roche site (Maré) (Maître, 1977). However, while most influences reported were Melanesian, this affinity must be nuanced due to the presence of a rocker jaw in the mandible (Valentin and Sand, 2000). Rocker jaw is a trait occurring when mandibles lack the antegonial notch (Scott et al., 2021). Since this trait is found at a higher frequency in Polynesian populations (Houghton, 1978), its presence or high frequency could be evidence of Polynesian ancestry. Consequently, the best preserved Maré crania from the Dubois and LMA001 collections are re-investigated in this study using a multivariate methodology to better discern the biological variation of past groups from the Loyalty Islands. Thus, to review the hypothetical presence of archaic traits in Maré, the morphology of crania from the Dubois collection was first compared to Indonesian *H. erectus* specimens. The biological variation of individuals from the Dubois and LMA001 collections was then assessed against a heterogeneous sample of recent *H. sapiens* from the Howells (1973; 1989; 1995) database. Finally, we discuss these results in the context of research on the biological variation present in collections from Remote Oceania and alongside oral traditions, in order to shed light on the past history and demography of Maré.

## Material and Methods

### *The sample from Maré*

Of the 38 cranial remains available (appendix 1) in the Dubois collection, which are stored in the *Muséum National d'Histoire Naturelle* (Paris, France), only four adult individuals (table 1) presented enough landmarks to enable morphometric analyses. The *Homme de Peu*<sup>2</sup> calvaria was unfortunately missing from the collection and could not be located to include it in this study. Cranium C6 was found in the Denge cave burial site in a cliffside in the region of

2 Hartweg's inventory (1950) of the remains of the *Homme de Peu* include fragmented cranial remains, a fragmented scapula, right clavicle, right radius, left femur, left tibia and left fibula. Only the right clavicle of the *Homme de Peu* was present when this study was conducted.

	Crania ID				
	Dubois collection <sup>1</sup>				LMA001 collection
	C6	E1	T1	X1	ID3_LaRoche
Sex estimation <sup>2</sup>	Male	Female	Male	Male	Male <sup>5</sup>
Age estimation <sup>3</sup>	≥ 24 years	≥ 24 years	≥ 23 years	≥ 24 years	≥ 25 years <sup>6</sup>
Site	Denge	Peu	Tenan	Xacace	LMA001
Burial type	Cave on cliffside	Rock shelter	Cave on cliffside	Subsurface burial	Open-air site, subsurface burial
Region	La Roche	Peu	Tenan	Near La Roche	La Roche
Maré clan	<i>si Xacace</i>	<i>si Peu</i>	-	<i>si Xacace</i>	-
Chronological estimation <sup>4</sup>	2 <sup>nd</sup> millennium AD	≥ 1 <sup>st</sup> millennium AD	2 <sup>nd</sup> millennium AD	2 <sup>nd</sup> millennium AD	1040 ± 110 AD <sup>5</sup>

<sup>1</sup> Crania ID from Hartweg 1948; 1950; <sup>2</sup> sex estimation using Ferembach et al. 1979; <sup>3</sup> age estimation using Meindl and Lovejoy 1985; <sup>4</sup> estimation made using the available archaeological data (Hartweg, 1948; 1950; Dubois, 1975b; Valentin and Sand, 2008) and ethnographic data (Dubois 1975a); <sup>5</sup> from Valentin and Sand 2000; <sup>6</sup> from Zinger 2021.

**Table 1.** List of the five Maré crania selected from the Dubois and LMA001 collections / *Liste des cinq crânes de Maré sélectionnés de la collection de Dubois et LMA001*

La Roche (figure 1). C6 could represent the *si Xacace* clan<sup>3</sup> (Hartweg, 1948; Dubois, 1975a). Cranium E1 is from section E of the site known as Peu (figure 1), located in the south-eastern area of the forest of Rawa (Hartweg, 1950; Dubois, 1984) and recognised as a *si Peu* burial ground by the Kanak community (the native population of New Caledonia) in Maré (Dubois, 1984). E1 was in a rock shelter located to the southeast of section C, where the *Homme de Peu* was found (Hartweg, 1950). Cranium X1 was found in a *si Xacace* subsurface burial site<sup>3</sup>, near La Roche (figure 1) (Hartweg, 1950). Cranium T1 was retrieved from a seaside cave burial in a cliffside in the Tenan region (figure 1).

In addition to the Dubois collection, individual ID3\_La Roche (ID3\_LR) from the LMA001 archaeological funerary site was included (Valentin and Sand, 2000; 2008). This individual, along with five others, was excavated in 1977 from an open-air site at La Roche (figure 1) (Maître, 1977; Valentin and Sand, 2000; Zinger, 2021) and the collection is currently housed at the *Musée de la Nouvelle Calédonie* (Nouméa, New Caledonia). Only ID3\_LR was considered because the other two crania available are poorly preserved and lack data.

A clavicle fragment from the *Homme de Peu* was submitted for radiocarbon dating to re-evaluate the initial dating published by Dubois (1975b; 1976), but unfortunately did not produce sufficient collagen for the analysis (WK-47566, Waikato Radiocarbon Dating Laboratory in New Zealand). The four crania selected from the Dubois collection were not submitted for radiocarbon dating and previous studies provided little contextual information specific to their chronology (Hartweg, 1948; 1950). Nevertheless,

it has been shown that rock shelter and cave funerary sites were used in Maré from at least the early 1<sup>st</sup> millennium AD (Valentin and Sand, 2000; 2008) and 2<sup>nd</sup> millennium AD (Hartweg, 1950; Dubois, 1975b), respectively. In the light of oral traditions, the past history of the *si Xacace* at La Roche might date back to the 2<sup>nd</sup> millennium AD (Dubois, 1975a). The LMA001 collection was radiocarbon dated using unidentified bone fragments to 1040 ± 110 AD (Ly-2310, calibrated 775(1010)-1230 AD) at the end of the 1970s (Valentin and Sand, 2000), a result that needs to be considered with caution (Wood, 2015) and that could be revised in the future. To summarise, both archaeological data and oral traditions indicate that the individuals presented in this study could not predate the 1<sup>st</sup> millennium AD (Dubois, 1975a; 1975b; Valentin and Sand, 2000; 2008).

### Assessment of Indonesian *H. erectus* neurocranial features

Aspects of the *H. erectus* neurocranial *bauplan* described by Antón (2003) were noted by Dubois (1975b; 1976) in his description of the *Homme de Peu*, specifically a marked frontal recession and a supraorbital torus. An interesting detail provided by Dubois (Dubois, 1975b; 1976) is that he described the glabella projecting anteriorly, which is a morphological characteristic of Indonesian *H. erectus* (Antón, 2002; 2003). For this study, only Indonesian *H. erectus* specimens were considered, as Dubois specifically compared the *Homme de Peu* morphology to that observed on the *H. erectus* of Java (Dubois, 1984). Furthermore, Indonesian specimens are the closest geographically and the most numerous in the region. Additionally, Oceanian crania were often used to support the multiregional model of human evolution, in which the shape and size of their cranial traits were hypothesised to be inherited from Indonesian *H. erectus* populations (e.g. Weidenreich, 1946; Rivet, 1953; Coon, 1965; Macintosh, 1965; Thorne, 1971; Thorne and Macumber,

3 Clans attributed by Hartweg (1948; 1950), who did not specify the reasoning and may have had access to undisclosed information from Dubois.

Measurement	Definition	Abbreviation <sup>1</sup>
Mid supraorbital thickness	Vertical thickness measured from the supraorbital surface to the orbital roof	mSOT
Lateral supraorbital thickness	Measured diagonally from the temporal crest to the orbital roof	ISOT
Maximum cranial length	Greatest length from glabella to the opisthocranium in the mid sagittal plane	GOL <sup>2</sup>
Maximum cranial breadth	Maximum distance between both euryons	XCB <sup>2</sup>
Minimum frontal breadth	Shortest length between both fronto-temporals and perpendicular to the median plane	M9
Maximum frontal breadth	Maximum breadth at the coronal suture and perpendicular to the median plane	XFB <sup>2</sup>
Post-orbital breadth	Minimum distance between both temporal fossae. May correspond to or exceed the minimum frontal breadth (M9)	LFB
Lambda-opisthocranium chord	Distance from lambda to opisthocranium	L.opc
Parietal chord	Distance from bregma to lambda in the midplane	PAC <sup>2</sup>
Glabella-bregma chord	Distance from glabella to bregma in the midplane	W17

<sup>1</sup> Howells 1973; 1989; 1995; “M” = Martin (Bräuer, 1988); “W” = Wood 1991; <sup>2</sup> measurements available to analyse the Maré sample against the *H. erectus* specimens and a heterogeneous sample of modern *H. sapiens*.

**Table 2.** List of the ten neurocranial linear measurements used to compare the four individuals from the Dubois collection with ten Indonesian *H. erectus* specimens / *Liste des dix mesures linéaires neurocrâniennes utilisées pour comparer les quatre individus de la collection de Dubois avec dix H. erectus indonésiens*

1972; Dubois, 1975b; 1976; 1984; Thorne and Wolpoff, 1992; Curnoe, 2007). It must be emphasised that the phenotypic expressions of inter-species admixture are not fully understood and that assessing them from skeletal remains can be complex (Ackermann, 2010; Harvati and Roksandic, 2016). However, if such pronounced *H. erectus* traits were still present in Maré, similarities in neurocranial shape should be visible.

Statistical analyses of linear data can easily differentiate the neurocrania of *H. erectus* from geographically heterogeneous samples of modern *H. sapiens*, as previous studies have shown (Antón, 1997; 1999; 2002; Antón and Leigh, 2003; Sémah and Détroit, 2006). To test whether neurocranial similarities exist between the Maré individuals and the fossils from Java, linear data on Indonesian *H. erectus* were recovered from Kaifu et al. (2008) and Rightmire (2013). A total of ten variables (table 2) were selected to maximise the number of *H. erectus* specimens and data available (cf. Kaifu et al., 2008; Rightmire, 2013), taking the state of preservation of the four Maré crania into consideration. The four Maré individuals are compared to ten adult Indonesian *H. erectus* specimens: one specimen from Sangiran (Sg 17), three from Sambungmacan (Sm 1, 3, and 4), five from Ngandong (Ng 6, 7, 10, 11, and 12) and one specimen from Bukuran (Buku). Additionally, an analysis using four linear measurements was computed to assess the neurocranial shape of the Maré sample against the *H. erectus* specimens and a heterogeneous sample of modern *H. sapiens* from the Howells (1973; 1989; 1995) database<sup>4</sup>. Finally, a series of bivariate analyses are presented in appendix 3 to better

appreciate the morphological variations between the Maré sample and the *H. erectus* specimens. ID3\_LR was not included due to the lack of available data (cf. Kaifu et al., 2008; Rightmire, 2013).

Neurocranial shape affinities were assessed using a principal component analysis (PCA) on the log shape ratio (LSR) of the neurocranial linear measurements selected (table 2). The LSR were calculated to reduce the effect of size, which also helps to neutralise the effect of sexual dimorphism and to distinguish shape variations between samples (Jungers et al., 1995). All craniometric data taken for the individuals from the Dubois collection are given in appendix 2. The PCA was produced using the statistical software R<sup>®</sup> (64-bit version 4.2.2).

### *Biological affinities within the Pacific region*

The earliest peopling of Maré can be traced back to ~3000 BP and is associated with the Austronesian expansions and their Lapita cultural complex (Sand et al., 2002; Sand, 2010; Chiu et al., 2020). Morphometric and genomic studies indicate that the Lapita expansion into Remote Oceania (islands located to the east and north of the Solomon Islands) probably originated from Southeast Asia (Skoglund et al., 2016; Valentin et al., 2016; Lipson et al., 2018; Zinger et al., 2019). Following the Lapita period, the Papuan expansion at ~2500 BP (Lipson et al., 2018; Posth et al., 2018) brought a Melanesian biological influence to the eastern and southern parts of the Melanesian arc, which includes New Caledonia (Pietruszewsky, 1977; 1983; 1990; 2005; 2006; Ward and Houghton, 1991; Valentin and Sand, 2000; Skoglund et al., 2016; Valentin et al., 2016; Zinger et al., 2019). Unlike the populations located in the Melanesian arc, the Polynesian and Micronesian groups retained morphological characteristics inherited from their East Asian

4 See sampling method for the modern *H. sapiens* sample in the section on *Biological affinities within the Pacific region*. The shape space of the PCA was computed based on all individuals included in the analysis.

ancestors (Pietrusewsky, 2005; 2008; Valentin et al., 2016). This is evident from craniometric analyses using modern samples, where individuals from Australia and Melanesia cluster together, while samples from Micronesia and Polynesia cluster with Southeast and East Asian groups (Pietrusewsky, 2005; 2008; Valentin et al., 2016). To account for the biological diversity present in Oceania, nine samples from the Howells (1973; 1989; 1995) database representing five geographical groups were selected: Australian, Melanesian, Chinese, Micronesian and Polynesian (table 3).

The sex assessment of the human sample was done by Howells (1989) using cranial features with cross-validation from postcranial elements when available. Among the 707 human individuals selected, there is an unequal number of individuals between groups and an unbalanced sex representation (table 3), with the female Micronesian group presenting the smallest sample at 27 individuals. Little is known about cranial sexual dimorphism for past populations in New Caledonia. The Maré crania were not associated with infracranial elements to cross-check sex estimations and were analysed using a pooled sex sample. A subset of 54 individuals (n=27 males, n=27 females) comprising 270 recent individuals was randomly generated for each geographical group. This sampling method, used by Valentin et al. (2016), provides insight into the biological diversity of remains from the Pacific region.

Due to the lack of common morphometric variables between the Dubois collection and ID3\_LR, several analyses were conducted to better evaluate the biological variation present in the sample. First, a PCA using the LSR of six linear measurements from all Maré crania was computed to assess morphological variation among the five geographical groups (table 4). Craniofacial shape affinities of the five geographical groups were then assessed with PCA on the LSR of two sets of measurements (table 4) to analyse the Dubois collection and ID3\_LR separately, with eleven measurements and nine linear measurements, respectively. Two sets of individual coordinates (PCs) were extracted from each PCA to be analysed independently using a linear

discriminant function analysis (LDA). The PCA used to extract the PCs are presented in appendix 5-6, and all individuals from Maré were plotted as supplementary individuals and did not contribute to the distribution of the major groups. The LDA analyses were conducted using the first ten PCs for the Dubois collection and the first eight PCs for ID3\_LR, to cover nearly 100% of the shape variation. Confusion matrices were computed to estimate the quality of assignments of each LDA and are presented in appendix 7-8. The predicted probabilities for posterior assignment were computed from each LDA to predict the classifications of the Maré individuals. All craniometric data taken from the individuals from the Dubois and LMA001 collections are given in appendix 2. The distributions within and between each sample of all variables selected (table 4) are presented in appendix 4. All the statistical analyses and graphics were produced using the statistical software R® (64-bit version 4.2.2).

## Results

### *Morphometric analysis of the four crania from the Dubois collection against Indonesian H. erectus*

The scatter-plot using PC1 and PC2 with ten linear measurements (LSR) covers 78.1% of the total shape variation, with no overlap between samples (figure 2A). Along PC1 we were able to observe a separation of the two groups, with most Javanese fossils located in the PC1 negative values while the Maré individuals are located in the extreme positive values of PC1 (figure 2A). The main variables negatively correlated to PC1 are the lateral supraorbital thickness (ISOT), mid supraorbital thickness (mSOT) and lambda-opisthocranion chord (L.opc) (figure 2B), while the major contributors for the individuals positively correlated to PC1 are the minimum frontal breadth (M9), maximum frontal breadth (XFB), postorbital breadth (LFB), maximum cranial length (GOL), glabella-bregma chord (W17) and parietal chord (PAC) (figure 2B).

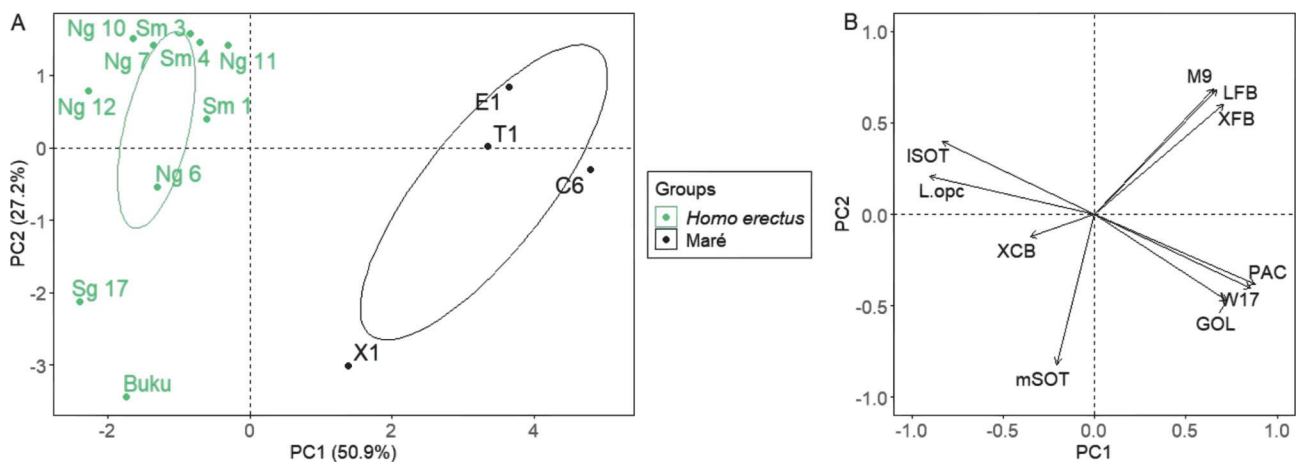
Clusters	Geographical groups	Sample	Female	Male	Total
Australo-Melanesian	Australia	Australia	49	52	101
	Melanesia	Tolai	54	56	110
Chinese-Micronesian-Polynesian	China	Anyang	-	42	42
		Hainan	38	45	83
	Micronesia	Guam	27	30	57
	Polynesia	Easter Island	37	49	86
		Maori	-	20	20
		Mokapu	49	51	100
	Moriori	51	57	108	
<b>Total</b>			<b>305</b>	<b>402</b>	<b>707</b>

**Table 3.** List of the recent humans from five geographical groups selected from the Howells (1973; 1989; 1995) database for comparative analyses / *Liste des individus récents de cinq groupes géographiques sélectionnés dans la base de données d'Howells (1973 ; 1989 ; 1995) pour échantillonnage*

Measurement	Definition	Abbreviation <sup>1</sup>	Collection <sup>2</sup>
Maximum cranial length	Greatest length from glabella to opisthocranium in the mid sagittal plane	GOL <sup>3</sup>	Dubois, LMA001
Maximum cranial breadth	Maximum distance between both euryons	XCB <sup>3</sup>	Dubois, LMA001
Maximum frontal breadth	Maximum breadth at the coronal suture, perpendicular to the median plane	XFB <sup>3</sup>	Dubois, LMA001
Biasterionic breadth	Distance between both asterions	ASB	LMA001
Mastoid height	Maximum height of the mastoid process in projection	MDH	LMA001
Mastoid breadth	Width of the mastoid process at its base, through its transverse axis	MDB	LMA001
Parietal chord	Distance from bregma to lambda in the midplane	PAC	Dubois
Frontal chord	Distance from nasion to bregma in the midplane	FRC	Dubois
Nasal height	Average height from nasion to the lowest point on the border of the nasal aperture	NLH	Dubois
Nasal breadth	The distance between the anterior edges of the nasal aperture at its widest extent	NLB	Dubois
Orbital height	Height between the upper and lower borders of the orbit, perpendicular to the long axis of the orbit and bisecting it	OBH <sup>3</sup>	Dubois, LMA001
Orbital breadth	Breadth from ectoconchion to dacryon, approximating the longitudinal axis which bisects the orbit into equal upper and lower parts	OBB <sup>3</sup>	Dubois, LMA001
Biorbital breadth	Distance between both ectoconchions	EKB	Dubois
Interorbital breadth	Distance between both dacryons	DKB <sup>3</sup>	Dubois, LMA001

<sup>1</sup> Howells 1973; 1989; 1995; <sup>2</sup> measurements selected to analyse each collection; <sup>3</sup> measurements selected to analyse the Maré individuals together.

**Table 4.** List of the fourteen measurements selected to characterise the four crania of the Dubois collections and the cranium from the LMA001 collection against five geographical groups (from Australia, Melanesia, China, Micronesia and Polynesia) / *Liste des quatorze mesures sélectionnées pour caractériser les quatre crânes de la collection de Dubois et celui de LMA001 avec cinq groupes géographiques (Australie, Mélanésie, Chine, Micronésie et Polynésie)*



**Figure 2.** A: Scatter-plot of PC1 vs. PC2 using ten neurocranial variables (log shape ratio) comparing the shape of the neurocrania from the Dubois collection with Indonesian *H. erectus*; Sg: Sangiran; Ng: Ngandong; Sm: Sambungmacan; Buku: Bukuran; B: Correlation circle showing the variables as vectors indicating the direction of their influences on the PCA / A: Nuage de points de PC1 vs. PC2 utilisant dix variables neurocrâniennes (log shape ratio) pour comparer les formes des quatre neurocrânes de la collection de Dubois avec celles d'*H. erectus* indonésiens; Sg : Sangiran ; Ng : Ngandong ; Sm : Sambungmacan ; Buku : Bukuran ; B : Cercle de corrélation présentant les variables comme vecteurs indiquant la direction de leurs influences sur l'ACP

Indonesian *H. erectus* fossils are characterised by thicker lateral supraorbital ridges with longer lambda-opisthocranium chords (L.opc) and broader neurocrania, but with shorter parietals (figure 2B). The Maré individuals present the opposite morphometric characteristics with narrower neurocrania, longer parietals and thinner supraorbital ridges (figure 2B). X1 is distinguishable from the Maré sample by being mainly characterised by a robust mid supraorbital thickness (mSOT) (figure 2B).

This assessment requires nuancing, however, because the Maré individuals seem to be characterised along PC1 (figure 2B) by having longer crania and broader frontals overall. These results contrast with the bivariate analyses (appendix 3, figures A, C and F), which show that the *H. erectus* specimens have, on average, broader frontals and longer crania overall. *H. erectus* specimens would be expected to be strongly characterised by their post-orbital breadth (LFB), minimum (M9) and maximum frontal

breadth (XFB) as well as maximum cranial length (GOL) on the PCA. This contradiction on the PCA (figure 2B) could be caused by the variables that are strongly negatively correlated with PC1 (i.e. lateral supraorbital thickness (LSOT), mid-supraorbital thickness (mSOT) and lambda-opisthocranion chord (L.opc)), which might be skewing the effect of other variables. Even if some heterogeneity is observed within each group, there is a clear separation between the Maré and Indonesian *H. erectus* samples.

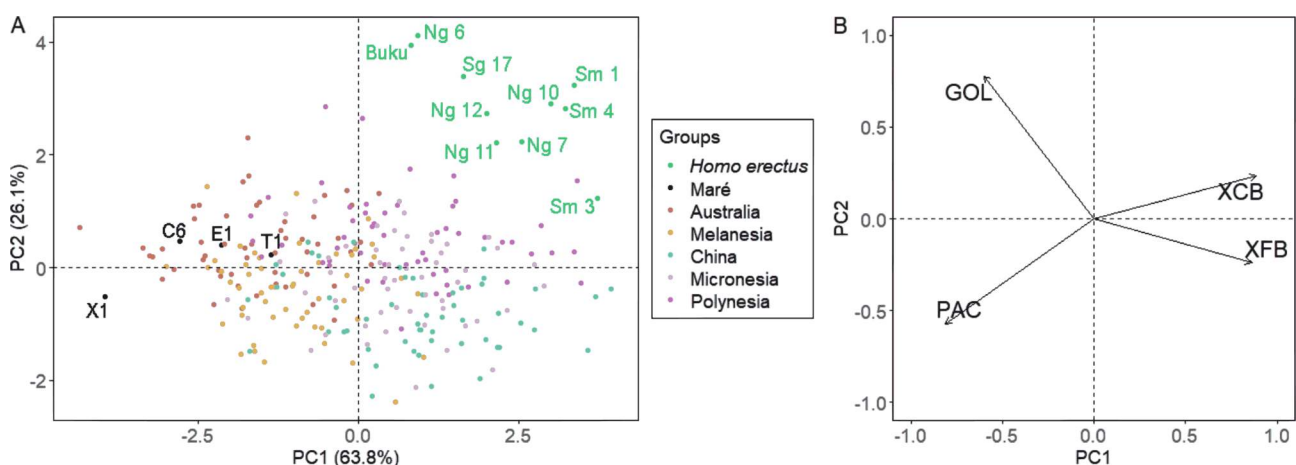
### Morphometric analysis of the four crania from the Dubois collection against a heterogeneous modern *H. sapiens* sample and the Indonesian *H. erectus* specimens

The scatter-plot using PC1 and PC2 with four linear measurements (LSR) covers 89.9% of the total shape variation, with a strong overlap between the Maré sample and the heterogeneous modern *H. sapiens* sample (figure 3A). Within the modern *H. sapiens* cluster, morphological trends at each end of PC1 can be noted, with an Australo-Melanesian (A-Me) cluster towards the negative values and a Chinese-Micronesian-Polynesian (C-Mi-P) cluster defined by positive values (figure 3A). The A-Me cluster is defined by longer and narrower crania, with longer parietals and narrower frontals (figure 3B; appendix 4, figures A, B, C and K), while the C-Mi-P cluster presents the opposite morphological characteristics (figure 3B; appendix 4, figures A, B, C and K). The Maré individuals plot towards the

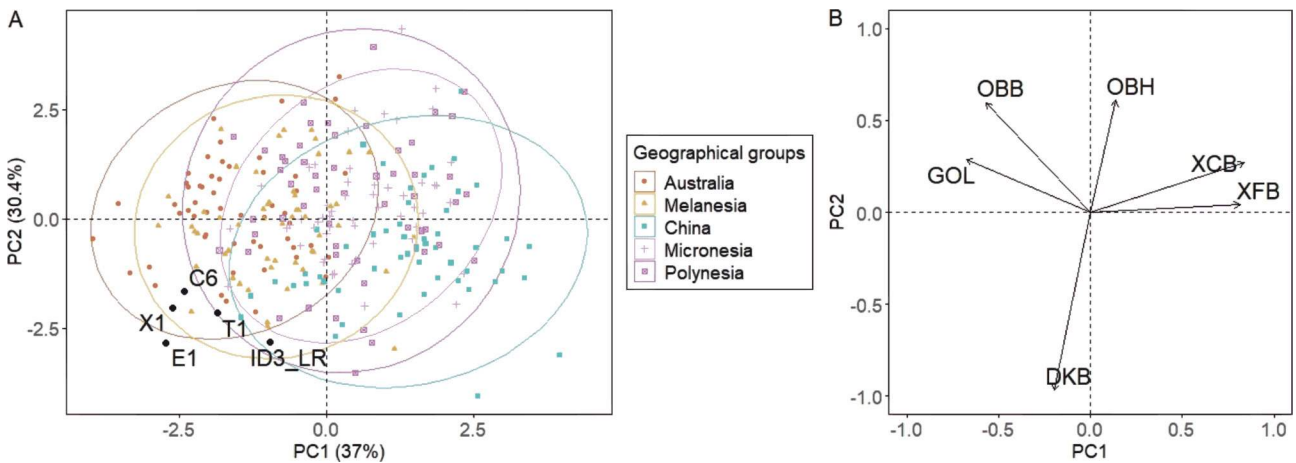
negative values of PC1 and seem to share more biological affinities with the A-Me cluster, while being clearly differentiated from the *H. erectus* sample (figure 3A). The *H. erectus* specimens mostly differ from the Maré and modern *H. sapiens* cluster with their broader and longer crania, as well as their shorter parietals (figure 3B; appendix 3, figures A and E).

### PCA analysis of the four crania from the Dubois collection and ID3\_LR against a heterogeneous modern *H. sapiens* sample

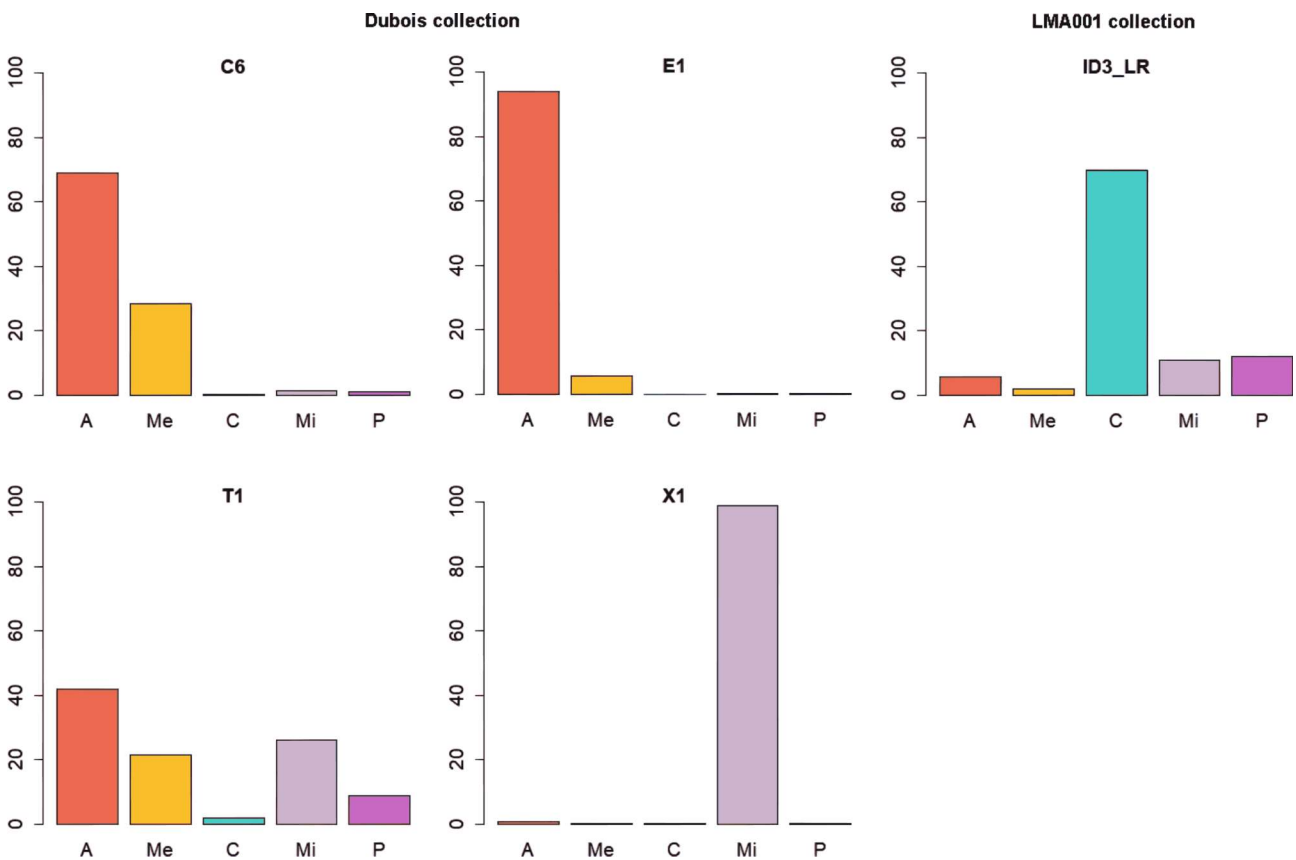
The scatter-plot using PC1 and PC2 with six linear measurements (LSR) covers 67.4% of the total shape variation, with a strong overlap between the heterogeneous modern *H. sapiens* samples (figure 4A). Morphological trends are again visible at each end of PC1, which differentiate an A-Me cluster towards the negative values from a C-Mi-P cluster defined by positive values (figure 4A). The A-Me cluster is mostly characterised by longer but narrower crania, narrower frontals and broader but shorter orbits, while the C-Mi-P cluster presents the opposite morphometric characteristics (figure 4B; appendix 4, figures A-E). All the Maré crania are defined by negative values along PC1 with some heterogeneity: C6, X1 and E1 plot toward the extreme end of the A-Me cluster (figure 4A), T1 plots where the A-Me cluster overlaps with the Polynesian group (figure 4A), while ID3\_LR plots at an extremity where the groups from Melanesia, Polynesia, and China overlap (figure 4A).



**Figure 3. A:** Scatter-plot of PC1 vs. PC2 using four neurocranial variables (log shape ratio) from 270 recent individuals (from Australia, Melanesia, China, Micronesia, and Polynesia) and compared to the neurocranial shape of the four crania from the Dubois collection with Indonesian *H. erectus*; Sg: Sangiran; Ng: Ngandong; Sm: Sambungmacan; Buku: Bukuran; **B:** Correlation circle showing the variables as vectors indicating the direction of their influences on the PCA / *A*: Nuage de points de PC1 vs. PC2 utilisant quatre variables neurocrâniennes (log shape ratio) d'un échantillon de 270 individus récents (Australie, Mélanésie, Chine, Micronésie et Polynésie) et les comparant aux quatre crânes de la collection de Dubois et les *H. erectus* indonésiens; Sg: Sangiran; Ng: Ngandong; Sm: Sambungmacan; Buku: Bukuran; **B:** Cercle de corrélation présentant les variables comme vecteurs indiquant la direction de leurs influences sur l'ACP



**Figure 4. A:** Scatter-plot of PC1 vs. PC2 using six cranial variables (log shape ratio) from 270 recent individuals (from Australia, Melanesia, China, Micronesia and Polynesia) and the four crania from the Dubois collection and ID3\_LR plotted as supplementary individuals; **B:** Correlation circle showing the variables as vectors indicating the direction of their influences on the PCA / *A : Nuage de points de PC1 vs. PC2 utilisant six variables (log shape ratio) crâniennes d'un échantillon de 270 individus récents (Australie, Mélanésie, Chine, Micronésie et Polynésie) et les quatre crânes de la collection de Dubois et ID3\_LR ajoutés en tant qu'individus supplémentaires ; B : Cercle de corrélation présentant les variables comme vecteurs indiquant la direction de leurs influences sur l'ACP*



**Figure 5.** Histograms of predicted probabilities for posterior assignment of the five Maré crania to the five geographical groups. The probabilities were computed using a LDA on the first ten PCs for the Dubois collection and the first eight PCs for ID3\_LR, which cover nearly 100% of the shape variation; A: Australia; Me: Melanesia; C: China; Mi: Micronesia; P: Polynesia / *Histogrammes des probabilités prédites d'assignations postérieures des cinq crânes de Maré aux cinq groupes géographiques. Les probabilités ont été obtenues à partir de la LDA utilisant les dix premières PCs pour la collection de Dubois et les huit premières PCs pour ID3\_LR, ce qui couvre presque 100 % des variations morphologiques ; A : Australie ; Me : Mélanésie ; C : Chine ; Mi : Micronésie ; P : Polynésie*

### PCA-LDA analyses with predicted probabilities for posterior assignment of the five Maré crania

The separate PCA analyses of the Dubois collection (PCA using the LSR of eleven linear measurements and covering 48.2% of total shape variation; a total of ten PCs were extracted) and ID3\_LR (PCA using the LSR of nine linear measurements and covering 55.6% of total shape variation; a total of eight PCs were extracted) also indicate the presence of two main clusters (appendix 5-6). The overall contribution of variables on the PCA (appendix 5-6) indicates that the A-Me cluster has longer and narrower crania with shorter and narrower frontals, broader biasterionic breadths and shorter and broader orbital and nasal regions, while the C-Mi-P cluster presents the opposite morphological characteristics (also see appendix 4, figures A-L). Heterogeneity is observed in the Maré sample: C6 and E1 plot within the A-Me cluster, while T1 and X1 plot where the A-Me cluster overlaps with the C-Mi-P cluster (appendix 5); ID3\_LR plots where all the geographical groups overlap (appendix 6).

The confusion matrices (appendix 7-8) indicate that the LDA assigned individuals to a major cluster with 93.2% and 87.3% accuracy when using ten and eight PCs, respectively. The predicted probabilities (figure 5) for posterior assignment computed from the LDA analyses of the crania from the Dubois collection and ID3\_LR roughly follow the heterogeneity observed on the PCA (appendix 5-6). C6 and E1 present affinities exclusively with the A-Me cluster, especially the Australian group at 68.9% and 94.1%, respectively. T1 presents a 63.4% affinity with the A-Me cluster and a 36.6% affinity with the C-Mi-P cluster, with the highest assignment towards the Australian group at 42%, while the highest assignment in the C-Mi-P cluster is with the Micronesian group at 26%. In the Dubois collection, X1 is the only individual classified exclusively in the C-Mi-P cluster, with a 98.8% assignment to the Micronesian group. Similarly to X1, ID3\_LR is mostly classified in the C-Mi-P cluster at 92.5%, with a 69.8% affinity with the Chinese group.

## Discussion

### Absence of morphological affinities with Indonesian *H. erectus*

The cranial morphology of Australo-Melanesian groups had been central to the discourse surrounding the multiregional model of modern human origins (e.g. Weidenreich, 1946; Rivet, 1953; Coon, 1965; Macintosh, 1965; Thorne, 1971; Thorne and Macumber, 1972; Thorne and Wolpoff, 1992), a model which often associated cranial robusticity with archaism. Therefore, the parallels drawn by Dubois (1975b; 1976; 1984) between Maré and Kow Swamp, and the use of robust neurocranial features to infer archaic *H. erectus* phylogenetic links, is not surprising for the period of his publications. The clear differentiation in

neurocranial shape between Indonesian *H. erectus* and the Maré sample (figures 2A-3A) was to be expected since the regional continuity hypothesis has long been refuted and no archaic introgression from *H. erectus* in *H. sapiens* has been detected so far (Lahr, 1994; Lahr and Wright, 1996; Sémah and Détroit, 2006; Curnoe, 2009; 2011; Teixeira et al., 2021; Taufik et al., 2022). Furthermore, the results of the PCA and LDA analyses (figures 3-5; appendix 5-6) showing craniometric similarities to modern *H. sapiens* individuals allow all five Maré individuals to be identified as AMH.

Most of the features differentiating the Indonesian *H. erectus* neurocrania in the PCA were anticipated from previous descriptions, including the characteristic lateral thickness of the supraorbital hypertrophy as being due to the wide frontal squama and neurocranium (Wood and Collard, 1999; Antón, 2002; 2003; Baba et al., 2003; Baab, 2008; 2015; Kaifu et al., 2008). The overlapping of *H. erectus* and Maré individuals was expected if a retention of “archaic” features was present in Maré, as postulated by Dubois (Dubois, 1975b). Although E1, like the *Homme de Peu*, is from the *si Peu* (Hartweg, 1950), no neurocranial shape affinities with the Indonesian fossils have been identified. X1 is distinguishable for its greater mid-supraorbital thickness (mSOT), echoing the observations of Hartweg (1950) who assessed a “prominent brow bone” in this individual. The “robust” supraorbital ridges<sup>5</sup> observed on Pleistocene Australian crania were among the traits considered to reflect regional continuity from Indonesian *H. erectus* to *H. sapiens* (Thorne, 1971; Thorne and Macumber, 1972; Thorne and Wolpoff, 1981). While it has been shown that the size and shape of crania in modern *H. sapiens* is not necessarily evidence of “archaic” phylogenetic relationships (Lahr, 1994; Lahr and Wright, 1996; Sémah and Détroit, 2006; Curnoe, 2009; 2011), it has been argued that supraorbital regions can be of use when testing taxonomic affiliations and to identify outliers within a sample (White et al., 2022). However, the evolution and morphological changes of the supraorbital ridges in modern *H. sapiens* are still much debated, as research can support both structural factors (e.g. Moss and Young, 1960; Shea, 1985; Ravosa, 1991; Enlow and Hans, 2008; Kupczik et al., 2009; Bastir and Rosas, 2016) and biomechanical factors (e.g. Carlson and Van Gerven, 1977; Russell et al., 1985; Zink et al., 2014; Zink and Lieberman, 2016) as shaping this anatomical structure. Godinho et al. (2018) brought nuances to this discussion and argued that AMH frontal and brow bone evolution led to the ability to express affiliative emotions, suggesting social communication as another selective factor.

5 The Kanak community talked to Dubois (1975a) about the “robust” supraorbital structures on the crania from the *si Peu* clan, which prompted him to conduct archaeological excavations in search of the *si Peu*.

Therefore, the large mid-supraorbital thickness (mSOT) of X1 is more likely to be a biological variant inherent to every AMH than an inheritance of *H. erectus* traits. It is unfortunate that the *Homme de Peu* is missing from the Dubois osteological collection in Paris, and analysing five crania does not provide a proper representation of the morphological variation in Maré. However, considering previous research on cranial morphology (Lahr, 1994; Lahr and Wright, 1996; Sémah and Détroit, 2006; Curnoe, 2009; 2011) and genomic studies (Teixeira et al., 2021; Taufik et al., 2022), the hypothesis of inherited Indonesian *H. erectus* traits in Maré must be rejected.

### A discussion of the *Homme de Peu* analysis by Dubois

When analysing the *Homme de Peu* calvaria, Hartweg (1950) did not report traits comparable to those found in *H. erectus* but rather Melanesian morphological features, some of which were also observed here (figure 4; appendix 4-6), such as long and narrow crania with broad nasal and orbital regions. Therefore, the question remains as to why Dubois (1975b; 1976; 1984) postulated the inheritance of Indonesian *H. erectus* to explain the robust features that he observed in Maré individuals many years after the first analyses conducted by Hartweg (1948; 1950).

The first *H. erectus* specimens were discovered at Trinil (Java, Indonesia) in 1891 (Dubois, 1894). In the following decades, further excavations were conducted in Java at Ngandong (1931-1941) and Sangiran (1952-1972) (Jacob, 1973). Overlapping with the discoveries at Sangiran, modern *H. sapiens* remains were found at the Australian archaeological site of Kow Swamp during the 1960s-1970s (Thorne, 1971; Thorne and Macumber, 1972). The *Homme de Peu* was found in 1947 (Dubois, 1975b; 1976), a pivotal year between the discoveries at Ngandong and Sangiran/Kow Swamp (Thorne, 1971; Thorne and Macumber, 1972; Jacob, 1973). Furthermore, the analysis of the *Homme de Peu* by Dubois (1975b) was published in 1975, soon after the first publications on the Kow Swamp crania (Thorne, 1971; Thorne and Macumber, 1972). While it could be hypothesised that Dubois (1975b; 1976) was influenced by the many exhilarating anthropological discoveries being made in Indonesia and Australia<sup>6</sup>, the analysis of the *Homme de Peu* needs to be discussed in a broader historical context.

As previously mentioned, the shape and size of equivalent cranial traits through time were commonly used to infer regional continuity between Oceanians and Indonesian *H. erectus* (Weidenreich, 1946; Rivet, 1953; Coon, 1965; Macintosh, 1965; Thorne, 1971; 1976; 1980; Thorne and

Macumber, 1972; Thorne and Wolpoff, 1981; 1992). Weidenreich (1946) and Coon (1965) were among the first to hypothesise that modern *H. sapiens* evolved globally from regional populations of *H. erectus*. A similar idea was postulated by Rivet (1953), who proposed a *H. erectus* lineage leading to modern Oceanians and Africans. With the discoveries of Pleistocene Australians after the 1960s, debates about AMH origins grew even more contentious (Coon, 1965; Macintosh, 1965; Thorne, 1971; 1976; 1980; Thorne and Macumber, 1972; Thorne and Wolpoff, 1981; 1992). The “dihybrid” multiregional model suggested by Thorne (Thorne, 1976; 1980; Thorne and Curnoe, 2000) is of particular interest, since this author led the research on Kow Swamp referred to by Dubois (1984). The proponents of this model argued that the modern Australian phenotype was the result of admixture between “robust” and “gracile” populations, both originating from *H. erectus* and arriving in Pleistocene Australia at different times. Dubois (1975b; 1976; 1984) did not specify which model should be considered when discussing the *H. erectus* features present in Maré. However, some passages from his 1984 publication (Dubois, 1984) are worth quoting. To justify his analysis of the *Homme de Peu*, Dubois (1984:14) proposed “analogical reasoning to that given for the Kow Swamp crania”. Furthermore, Dubois (1984:14) described the *si Peu* as an “ancient population” that “mixed with other people from Maré”. Therefore, it is possible that Dubois (1984) was alluding to a dihybrid model for the Maré population.

To look beyond the discussions surrounding modern *H. sapiens* origins, the social context in which Dubois conducted his research is also a major factor. From the 19<sup>th</sup> century to the first half of the 20<sup>th</sup> century, the Kanak community was often dehumanised (Bernard, 1895; Pionnier, 1911; Leenhardt, 1945; 1947; Poirier, 1951; Dauphiné, 1998). An example of blatant dehumanisation of the Kanak community are the “human zoos” organised in parallel with the colonial exhibition of 1931 in Paris, where dozens of Kanak men and women were considered an “attraction”, thus reinforcing European racial ideologies (Dauphiné, 1998). The analyses of osteological remains from Maré (Hartweg, 1948; 1950; Dubois, 1975b; 1976) took place during a dark period for physical anthropology, when the discipline had yet to move away from racial concepts, a shift that occurred progressively after World War II (Zuckerman and Armelagos, 2011; Smocovitis, 2012; von Cramon-Taubadel, 2014; Ellison, 2018; Valentin, 2020). Furthermore, archaeology and anthropology in Oceania evolved through a complex socio-political context of colonialism and post-colonialism, with knowledge built up from a Eurocentric perspective (Dotte-Sarout et al., 2020). The effect of the rampant racial ideologies of the time is visible in the osteological analyses and ethnographic research of the Maré population (Hartweg, 1948; 1950; Dubois, 1975a; 1984). Dubois (1975a; 1984) even discusses a drive to “whiten” chief-led clans in Maré, arguing that a European admixture was sought by local clans to “transform the race”. These ideologies carried by the colonisers of New

6 It is also worth noting that Dubois (1984) noticed the presence of boomerangs in Maré, as he speculated on a potential link with Australian populations. These artefacts were most likely brought back from Queensland at the end of the 19<sup>th</sup> century, when Kanak workers were sent, usually against their will, to work in Australian plantations.

Caledonia had lingering effects: social and economic inequalities between Kanak and non-Kanak communities are still present, with access to higher education and employment being more difficult for the former (Hadj et al., 2012; Ris, 2013; Berrah and Ris, 2015; Gorohouna and Ris, 2017; Ferriere et al., 2023). It must be emphasised that our analyses here aim to retrace the past history and demography of the Maré population and do not, in any way, support essentialist racial classification. Overall, it is highly probable that the archaeological and social context of the time played a significant role in the anthropological evaluation of the *Homme de Peu* by Dubois (1975b; 1976; 1984).

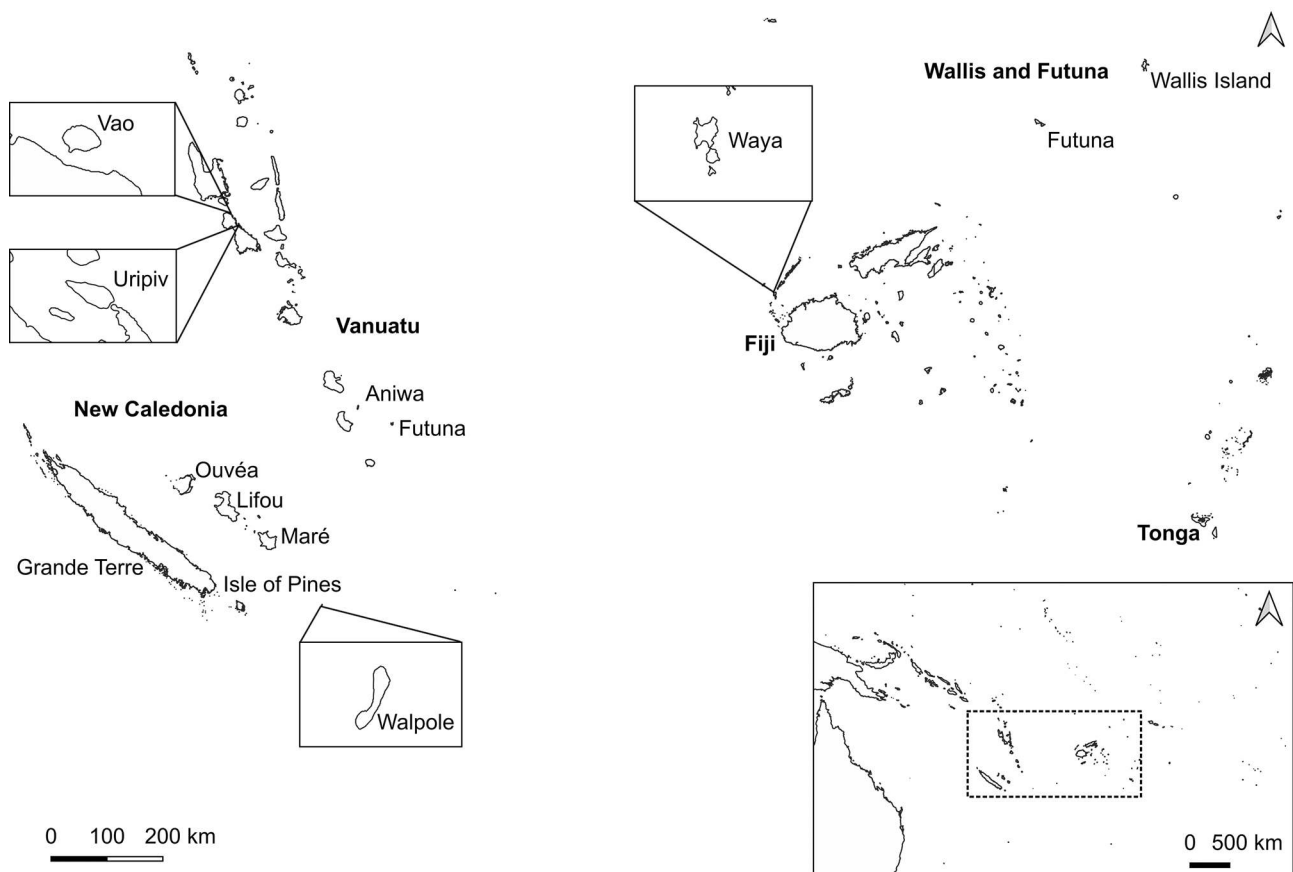
### *Biological affinities of the sample from Maré*

The statistical analyses of the five crania indicate considerable biological variation among the individuals from Maré. C6 and E1 present biological affinities with the A-Me cluster, T1 shows biological affinities with the A-Me cluster and the C-Mi-P cluster, while X1 and ID3\_LR fall into the C-Mi-P cluster. These results run counter to those of previous analyses, where biological affinities with Melanesian morphology were argued for individuals from the Dubois and the LMA001 collections (Hartweg, 1948; 1950; Valentin and Sand, 2000). This highlights the importance of using multivariate statistical analyses for a finer assessment of biological affinities based on shape variation (e.g. Howells, 1973; 1989; Valentin et al., 2016; Zinger et al., 2019; Zinger, 2021).

The results obtained for C6 and E1 reflect the well-documented Melanesian genetic influence resulting from the Papuan dispersals currently visible at ~2500 BP (Pietrusewsky, 1977; 1983; 1990; 2005; 2006; Ward and Houghton, 1991; Valentin and Sand, 2000; Skoglund et al., 2016; Valentin et al., 2016; Lipson et al., 2018; Posth et al., 2018; Zinger et al., 2019); finding these affinities was to be expected in the light of previous research on remains from post-Lapita periods in New Caledonia. Melanesian traits were observed in WKO0-13B and WKO0-13C from the Lapita site (Koné, Grande Terre) dated to 2100-1990 cal BP (Wk-22480 and OxA-4908) and 2500-2350 cal BP (Beta-125136 and Wk-23255), respectively (Pietrusewsky et al., 1998; Valentin and Sand, 2000; Petchey et al., 2011). The most complete individual excavated from Ihusie Bay (Tina peninsula, Grande Terre) presents Melanesian features (Valentin and Sand, 2000) and was dated to 860 ± 70 BP (Beta-112994, calibrated 1020(1205)-1285 AD) (Sand et al., 1995). Melanesian biological affinities were also observed in remains excavated in Maré from the TLA037 site at Hneningec (Valentin and Sand, 2000), which was dated to 1775 ± 60 BP (Lyon-521 (OxA), calibrated 125(250)-400 AD) (Sand, 1998). Furthermore, several multivariate statistical analyses have shown Melanesian affinities in recent cranial and mandibular collections from New Caledonia (Pietrusewsky, 1977; 1983; 1990; 2005; Pietrusewsky et al., 2014). New Caledonia is not an isolated case and Melanesian affinities have been observed in post-Lapita remains from

other regions of Remote Oceania, such as Santa Cruz, Vanuatu and Fiji, echoing the Melanesian genetic influence shown by morphological data (Pietrusewsky, 1977; 1983; 1990; 2005; 2006; Ward and Houghton, 1991; Valentin and Sand, 2000; Valentin et al., 2016; Zinger et al., 2019) and by archaeogenetic data (Skoglund et al., 2016; Lipson et al., 2018; Posth et al., 2018).

The 98.8% Micronesian affinity presented by X1 should be questioned due to the high frontal chord (FRC; appendix 4, figure J) mirroring the “receding forehead” and “great depression of the nasal root” observed by Hartweg (1950). Interestingly, the mid-supraorbital thickness (mSOT) of X1 was also the highest, and along with the frontal shape, both features were described by Hartweg (1950) as “strong Melanesian traits”. Various levels of heritability have been observed among cranial measurements, and the frontal chord (FRC) is among the variables with the lowest heritability (Sjøvold, 1984; Carson, 2006). A low heritability indicates that the phenotypic variance of a trait is less likely to be a result of variance in the inherited genetic material than of environmental variability (von Cramon-Taubadel, 2014). However, caution was recommended by Carson (2006), who argued that further research on various populations was needed, as the heritability of cranial proportions might in fact be population-dependent. While environmental factors can influence cranial vault shape (Harvati and Weaver, 2006a; Hubbe et al., 2009; Cui and Leclercq, 2017; Menéndez, 2018), neurocranial patterns in modern *H. sapiens* are primarily influenced by neutral factors such as gene flow, migration and genetic drift (Harvati and Weaver, 2006a; 2006b; von Cramon-Taubadel, 2009; 2014). Gene flow post-dating the Lapita expansion at ~3000 BP (Sand et al., 2002; Sand, 2010; Chiu et al., 2020) and the Papuan expansion at ~2500 BP (Posth et al., 2018) in New Caledonia is unknown. In the Pacific Ocean regions, the scattered islands separated by bodies of water are a hindrance to gene flow. The islands of South Vanuatu are the closest to the Loyalty Islands at 200-250 km, while Fiji is 1000 km away (Sand, 2010) (figure 6). Furthermore, the 1<sup>st</sup> millennium AD in Maré is likely to have been a time of isolation, precarity and warfare (Sand and Ouetcho, 1993; Sand, 1995; 1996; Valentin and Sand, 2000), as indicated by a halt in the trading of goods from other regions (Sand, 1995; 1998), the presence of monumental forts (Sand and Ouetcho, 1993; Sand, 1996), the high proportion of non-adult remains (4/7 individuals) at the TLA037 site and the presence of a defensive wound at the LMA001 site (Valentin and Sand, 2000). If isolation and conflicts did indeed occur, they probably limited gene flow leading to genetic drift, which would explain the biological homogeneity observed for the 1<sup>st</sup> millennium AD (Valentin and Sand, 2000). Stochastic phenomena related to the isolated geographic location of Maré (figure 6) and a secluded 1<sup>st</sup> millennium AD could have led to the appearance of very particular biological features. Caution is needed, however, as the high frontal chord (FRC) value of X1 could reflect Melanesian biological characteristics in Maré individuals.



**Figure 6.** Geographical location of New Caledonia in its regional Melanesian context / *Localisation géographique de la Nouvelle Calédonie dans son contexte régional mélanésien*

T1, ID3\_LR and, to some degree, X1 attest to Polynesian influences in Maré through their biological affinities with the C-Mi-P cluster. Even though the X1 and T1 phenotypes are comparable to older individuals from Vanuatu and Fiji (Valentin et al., 2016; Zinger et al., 2019), it is unlikely that they date from the Lapita to the immediate post-Lapita period and must be understood in the context of later Polynesian arrivals. Indeed, the high Micronesian affinity observed in X1 is reminiscent of that obtained for Y2-25-1, the late to immediately post-Lapita individual from Waya (Yasawa, Fiji; figure 6) and dated to  $2530 \pm 50$  BP (CAMS-24946) (Valentin et al., 2016; Pietruszewsky et al., 1997). However, X1 was excavated in a *si Xacace* burial site, whose potential antiquity at La Roche is traced by oral traditions to within the 2<sup>nd</sup> millennium AD (Dubois, 1975a). Therefore, it is unlikely that X1 dates from the early 1<sup>st</sup> millennium BC, for which Lapita to immediately post-Lapita individuals present morphometric affinities with Southeast Asian (i.e. Chinese and Vietnamese), Micronesian and Polynesian samples (Valentin et al., 2016; Zinger et al., 2019). Similarly to X1, the admixed affinity of T1 echoes that of the post-Lapita individuals such as those from Uripiv and Vao (Vanuatu; figure 6), which have been dated to 2500-2000 BP (Bedford et al., 2011; Kinaston et al., 2014; Zinger et al., 2019). However, T1 was found

in a cave burial of a type identified for periods post-dating the 1<sup>st</sup> millennium BC in Maré (Hartweg, 1950; Dubois, 1975b; Valentin and Sand, 2008).

The hypothesis that T1 and X1 phenotypes are evidence of later Polynesian arrivals in Maré may be further supported by the Polynesian influence observed for ID3\_LR. It is also worth noting that ID5\_La Roche (ID5\_LR) from LMA001 has a rocker jaw (Valentin and Sand, 2000), a trait frequently found in Polynesian populations (Houghton, 1978). The LMA001 burial site was dated to  $1040 \pm 110$  AD (Valentin and Sand, 2000), placing ID3\_LR and ID5\_LR at a pivotal period between the 1<sup>st</sup> and 2<sup>nd</sup> millennium AD, although dates obtained four decades ago must be considered with caution (Wood, 2015). This LMA001 dating also correlates with the earliest estimated arrival date of Polynesians, at 950-850 BP, in the outlier of Ouvéa (Carson, 2002), indicating that Polynesian groups might have settled in both Loyalty Islands at around the same period. As of now, LMA001 is the earliest site attesting to a Polynesian presence in Maré. Furthermore, Polynesian migrations into Melanesia are only known for the 2<sup>nd</sup> millennium AD (e.g. Shutler and Shutler, 1966; Garanger, 1972; Kirch, 1982; Carson, 2002; Leach and Davidson, 2008; Kirch and Swift, 2017; Flexner et al., 2018). Biological evidence of these Polynesian migrations has been found on the Polynesian

outliers of Futuna (Vanuatu; figure 6) and Taumako (Solomon Islands), where remains dated to the last millennium show affinities with Melanesian and Polynesian groups (Katayama, 1988; Houghton, 2008; Leach and Davidson, 2008; Valentin et al., 2011; Pietruszewsky et al., 2014; Zinger et al., 2019; 2024). It can therefore be assumed that T1 and X1 are likely to indicate Polynesian influences from the 2<sup>nd</sup> millennium AD.

The numerous potential Polynesian influences in Maré described by Dubois (1975a) include contacts between the *si Xacace* and a group called the *Xetriwaan* (a group potentially related to the Tongan maritime empire) on Lifou (Guiart, 1963; Sand, 1995; 1998; Spriggs, 1997), the settlement of Tongans on the east coast and the arrival of Polynesians from the Muli islet (Ouvéa, New Caledonia). While the present morphometric analyses support the contacts between Polynesian groups and Maré individuals reported in local myths (Guiart, 1963; Dubois, 1975a; Sand, 2002), Dubois' interpretation of oral traditions (1975a) must be considered with caution.

This is because much oral tradition was lost during the colonisation and depopulation of the Kanak community. Following the first contacts with Europeans, multiple epidemics caused a dramatic decline of the Kanak population, after which, from 1853, French colonial rule drove the Kanak communities off their lands with considerable violence, triggering conflicts and numerous casualties (Sand, 2023). Demographic research on the Kanak community before their contact with Europeans and the quantification of the Kanak depopulation that resulted from the colonisation of New Caledonia are still hotly debated (Sand, 2023). Furthermore, Maré experienced a series of religious conflicts between Catholics and Protestants during the 19<sup>th</sup> century, which caused multiple casualties and deportations from Maré to the Isle of Pines (Dubois, 1981). Given the politico-religious context of Maré, it is possible that the religious beliefs conveyed by Dubois, as a Catholic missionary, influenced the contacts from whom he derived his ethnographic research. Oral traditions can be altered, or re-created to suit socio-political purposes, so that their veracity is ultimately limited by the ability of the speakers to remember and convey them accurately.

## Conclusion

During the 1940s, skeletal remains from seven archaeological sites were excavated on the Loyalty Island of Maré. Analyses of the fragmented calvariae of the *Homme de Peu* led Dubois (1975b; 1976; 1984) to conclude that inherited Indonesian *H. erectus* traits were present in Maré. The morphometric analyses presented here show no similarities with Indonesian *H. erectus*; instead, the craniometric variation of the five Maré crania fall within AMH biological variation. The Maré sample is heterogeneous, and the biological affinities with the C-Mi-P cluster in Maré provide evidence of Polynesian ancestry. LMA001 sets the earliest Polynesian presence in Maré at a pivotal period between

the 1<sup>st</sup> and 2<sup>nd</sup> millennium AD, which correlates with the earliest estimated Polynesian arrival in Ouvéa (Carson, 2002). These results provide new insights into the dynamic past history of the southernmost part of Melanesia.

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## Appendices

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**Appendix 1.** Inventory of the cranial remains in the Dubois collection at the *Muséum National d'Histoire Naturelle de Paris* (France) /

*Inventaire des éléments crâniens présents dans la collection de Dubois préservée au Muséum National d'Histoire Naturelle de Paris (France)*

Site	Cranial Inventory			
	Left fragments	Right fragments	Not lateralised	Total
<b>First osteological samples sent by Dubois (Hartweg, 1948)</b>				
<i>Peu</i>	-	-	Cranio-facial remain Facial fragment	<b>2</b>
<i>Rawa</i>	-	-	Cranio-facial remain	<b>1</b>
<i>Denge</i>	-	-	Cranio-facial remain (C6)	<b>1</b>
<b>Not localised</b>	Parietal	-	-	<b>1</b>
<b>Second osteological samples sent by Dubois (Hartweg, 1950)</b>				
<b>Site A (<i>Peu</i>)</b>	Temporal	Temporal	Occipital fragment Facial fragment	<b>4</b>
<b>Site B (<i>Peu</i>)</b>	-	-	Facial fragment	<b>1</b>
<b>Site C (<i>Peu</i>)</b>	-	-	Non adult cranio-facial remain	<b>1</b>
<b>Site E (<i>Peu</i>)</b>	-	-	Cranio-facial remain (E1)	<b>1</b>
<b>Isolated burial (<i>Peu</i>)</b>	-	-	Cranio-facial remain	<b>1</b>
<b>Udé</b>	-	-	Two cranio-facial remains	<b>2</b>
<b>Xacace</b>	-	-	Cranio-facial remain (X1)	<b>1</b>
<b>Tenane</b>	-	-	Cranio-facial remain (T1)	<b>1</b>
<b>Not localised</b>	Maxilla Temporal Occipital Two parietals Frontal	Sphenoid Temporal Parietal Frontal Orbit Zygomatic Petrous bone	Four frontal fragments Four neurocrania fragments	<b>21</b>
<b>Total</b>	<b>8</b>	<b>8</b>	<b>22</b>	<b>38</b>

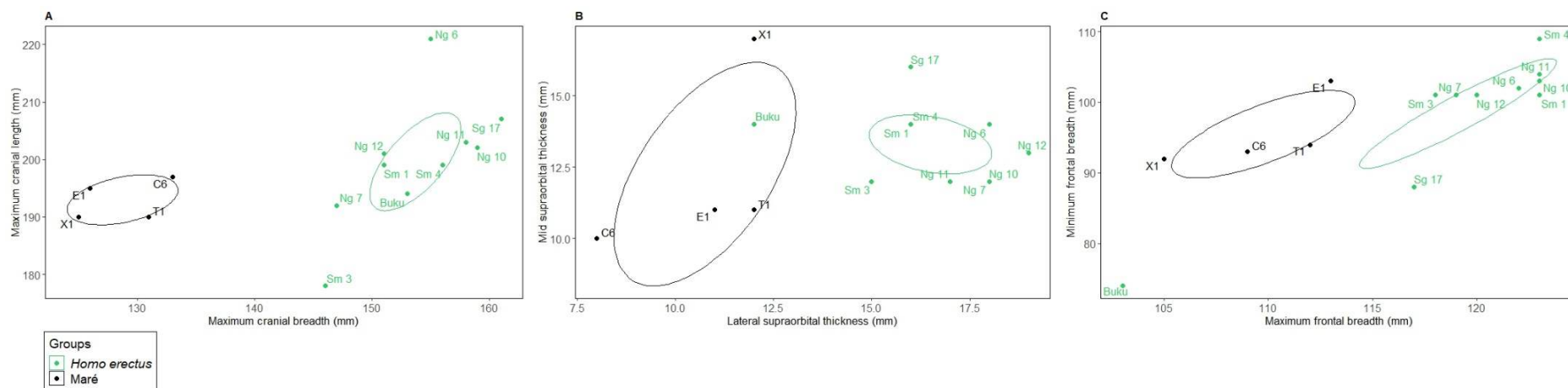
**Appendix 2.** List of all measurements and metric data (mm) taken on the four crania from the Dubois and LMA001 collections / *Liste de toutes les mesures et données métriques (mm) prises sur les crânes des collections de Dubois et LMA001*

Measurements	Abbreviations <sup>1</sup>	Crania ID				
		Dubois collection <sup>2</sup>				LMA001 collection
		C6	E1	T1	X1	ID3_LR
Maximum cranial length	GOL	197	195	190	190	187.5
Maximum cranial breadth	XCB	133	126	131	125	136
Biasterionic breadth	ASB	-	-	-	-	108
Maximum frontal breadth	XFB	109	113	112	105	102
Minimum frontal breadth	M9	93	103	94	92	-
Mastoid height	MDH	-	-	-	-	38.5
Mastoid breadth	MDB	-	-	-	-	11
Nasal height	NLH	49	48	49	46	-
Nasal breadth	NLB	29	26	29	26	-
Orbital height	OBH	34	34	35	31	30
Orbital breadth	OBB	41	41	41	39	36
Interorbital breadth	DKB	25	27	26	24	24.5
Biorbital breadth	EKB	102	102	102	97	-
Post-orbital breadth	LFB	97	105	99	94	-
Frontal chord	FRC	118	117	121	153	-
Parietal chord	PAC	123	117	116	127	-
Lambda-opisthocranium chord	L.opc	34	37	32	34	-
Glabella-bregma chord	W17	110	113	117	111	-
Mid-supraorbital thickness	mSOT	10	11	11	17	-
Lateral supraorbital thickness	ISOT	8	11	12	12	-

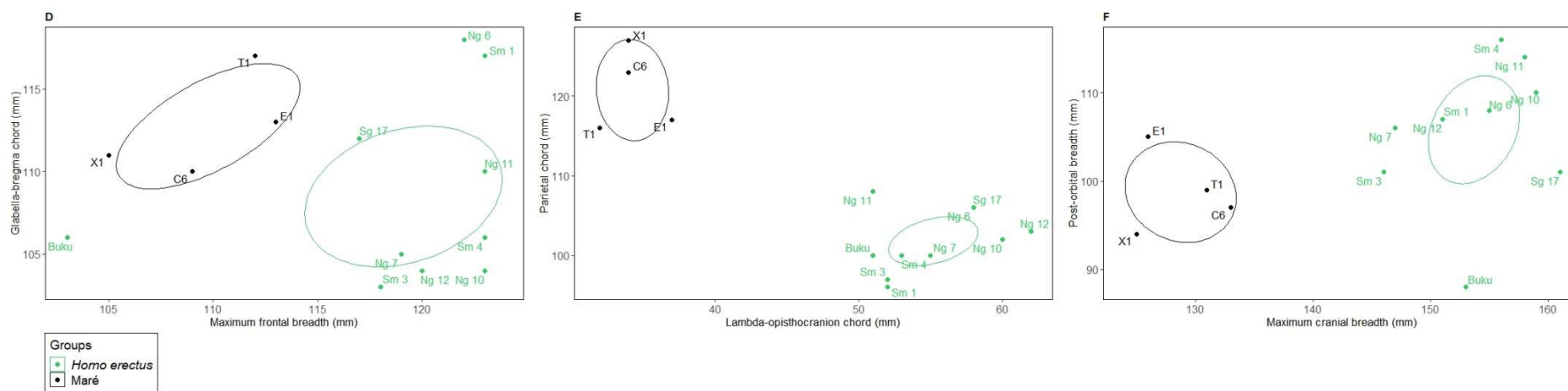
<sup>1</sup>Howells (1973; 1989; 1995); “M” = Martin (Bräuer, 1988); “W” = Wood (1991).

<sup>2</sup>Crania ID from Hartweg (1948; 1950).

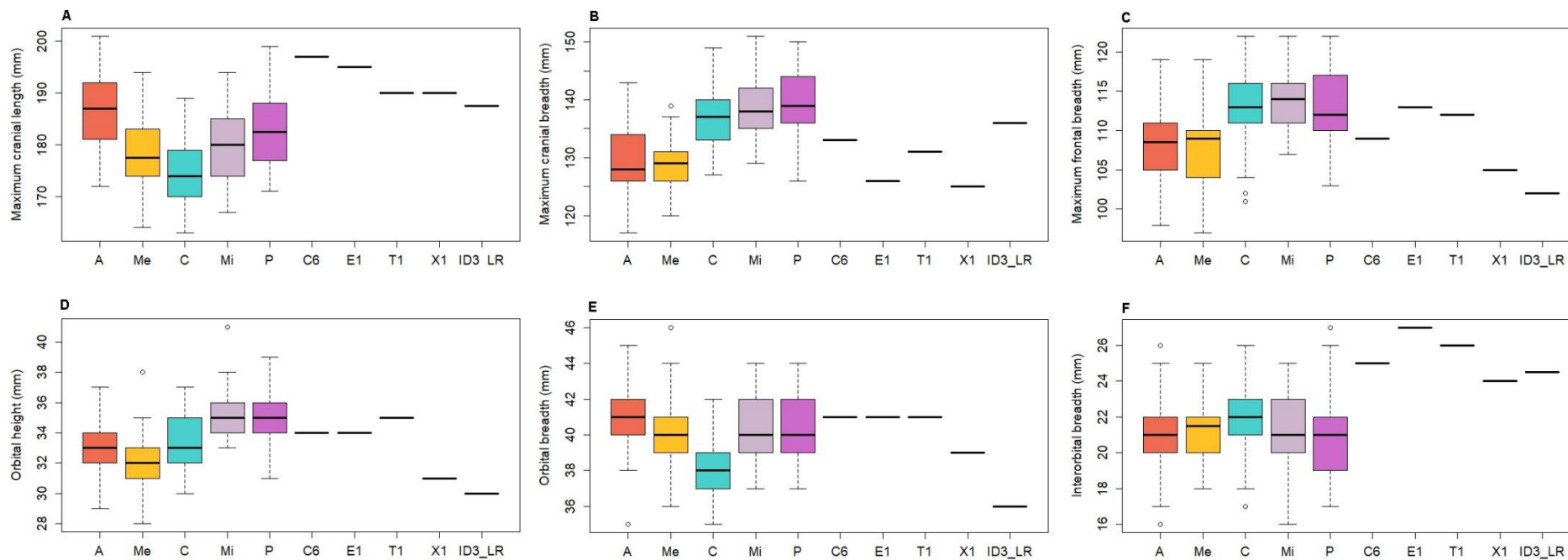
**Appendix 3. (1/2)** Bivariate plot (measurement in mm): A: Maximum cranial breadth on maximum cranial length; B: Lateral supraorbital thickness on mid-supraorbital thickness; C: Maximum frontal breadth on minimum frontal breadth / *Analyses bivariées (mesures en mm) : A : Largeur crânienne maximale sur longueur crânienne maximale ; B : Épaisseur latérale supraorbitaire sur épaisseur médiale supraorbitaire ; C : Largeur maximale frontale sur largeur minimale frontale*



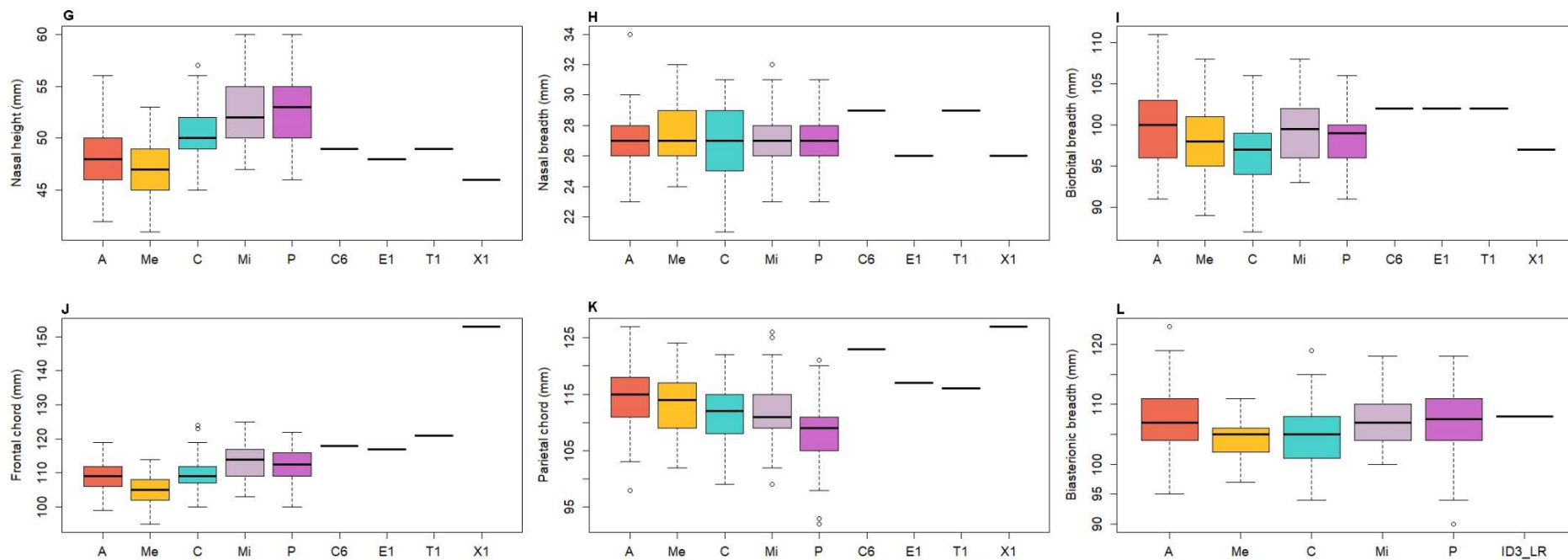
**Appendix 3. (2/2)** Bivariate plot (measurements in mm): D: Maximum frontal breadth on glabella-bregma chord; E: Lambda-opisthocranion chord on parietal chord; F: Maximum cranial breadth on post-orbital breadth / *Analyses bivariées (mesures en mm) : D : Largeur maximale frontale sur la corde glabelle-bregma ; E : Chorde Lambda-opisthocranion sur corde pariétale ; F : Largeur maximale crânienne sur largeur post-orbitaire*



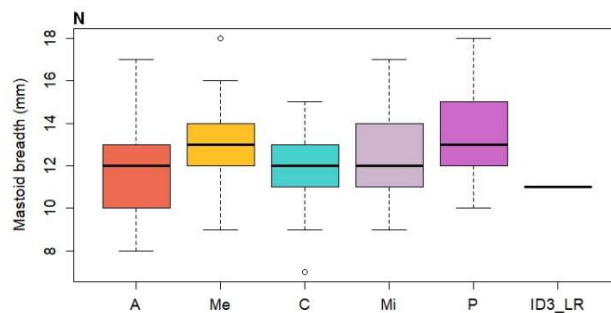
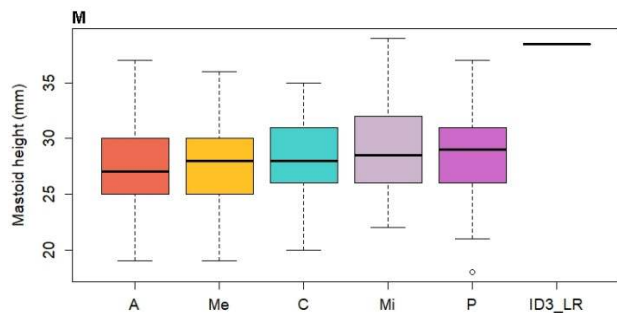
**Appendix 4. (1/3)** Distribution of variables (measurements in mm) within and between samples; A: Maximum cranial length; B: Maximum cranial breadth; C: Maximum frontal breadth; D: Orbital height; E: Orbital breadth; F: Interorbital breadth; Samples abbreviations: A: Australia; Me: Melanesia; C: China; Mi: Micronesia; P: Polynesia / *Distribution des variables (mesures en mm) dans et entre les échantillons ; A : Longueur crânienne maximale ; B : Largeur crânienne maximale ; C : Largeur maximale frontale ; D : Hauteur orbitaire ; E : largeur orbitaire ; F : largeur interorbitaire ; Abréviations des échantillons : A : Australie ; Me : Mélanésie ; C : Chine ; Mi : Micronésie ; P : Polynésie*



**Appendix 4. (2/3)** Distribution of variables (measurements in mm) within and between samples; G: Nasal height; H: Nasal breadth; I: Biorbital breadth; J: Frontal chord; K: Parietal chord; L: Biasterionic breadth; Samples abbreviations: A: Australia; Me: Melanesia; C: China; Mi: Micronesia; P: Polynesia / *Distribution des variables (mesures en mm) dans et entre les échantillons ; G : Hauteur nasale ; H : Largeur nasale ; I : Largeur biorbitaire ; J : Chorde frontale ; K : Chorde Pariétale ; L : Largeur biastérionique ; Abréviations des échantillons : A : Australie ; Me : Mélanésie ; C : Chine ; Mi : Micronésie ; P : Polynésie*



**Appendix 4. (3/3)** Distribution of variables (measurements in mm) within and between samples; M: Mastoid height; N: Mastoid breadth; Samples abbreviations: A: Australia; Me: Melanesia; C: China; Mi: Micronesia; P: Polynesia / *Distribution des variables (mesures en mm) dans et entre les échantillons ; M : Hauteur du mastoïde ; N : largeur du mastoïde ; Abréviations des échantillons : A : Australie ; Me : Mélanésie ; C : Chine ; Mi : Micronésie ; P : Polynésie*



**Appendix 5. A:** Scatter-plot of PC1 vs. PC2 using eleven cranial variables (log shape ratio) from 270 recent individuals (from Australia,

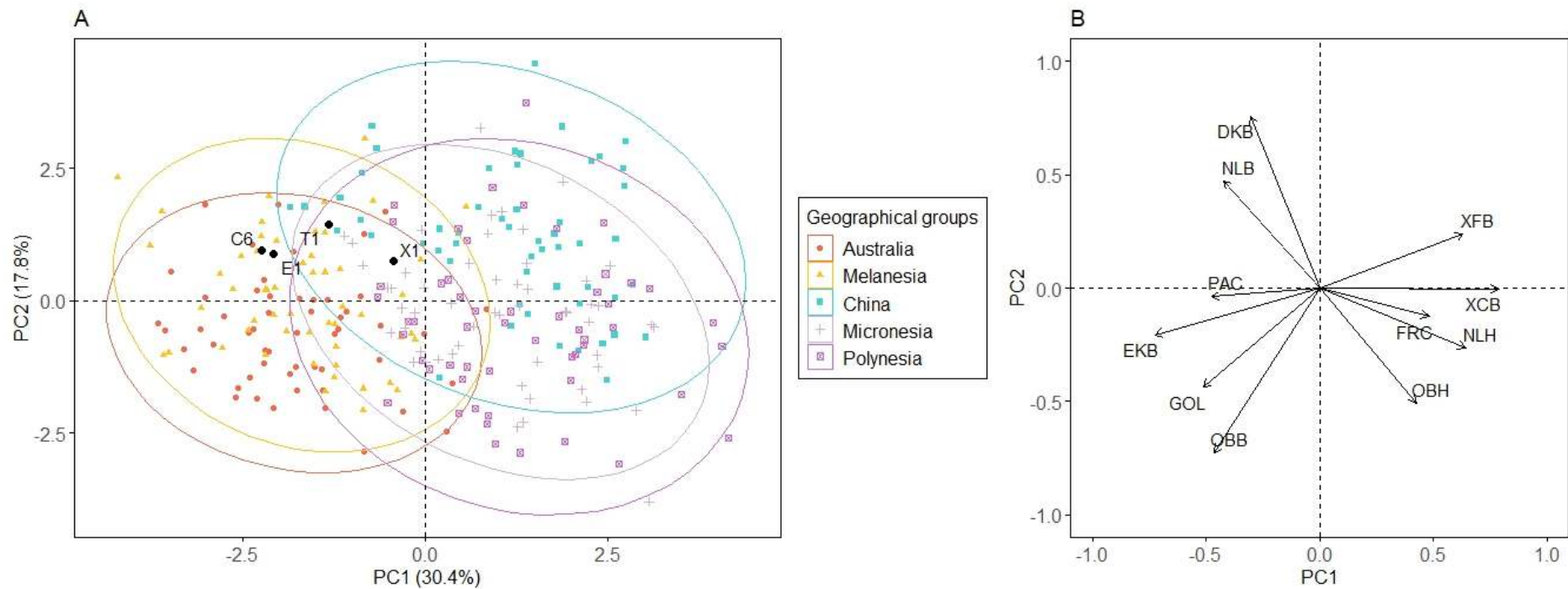
Melanesia, China, Micronesia, and Polynesia) and the four crania from the Dubois collection plotted as supplementary individuals; **B:**

Correlation circle showing the variables as vectors indicating the direction of their influences on the PCA / *A : Nuage de points de PC1 vs. PC2*

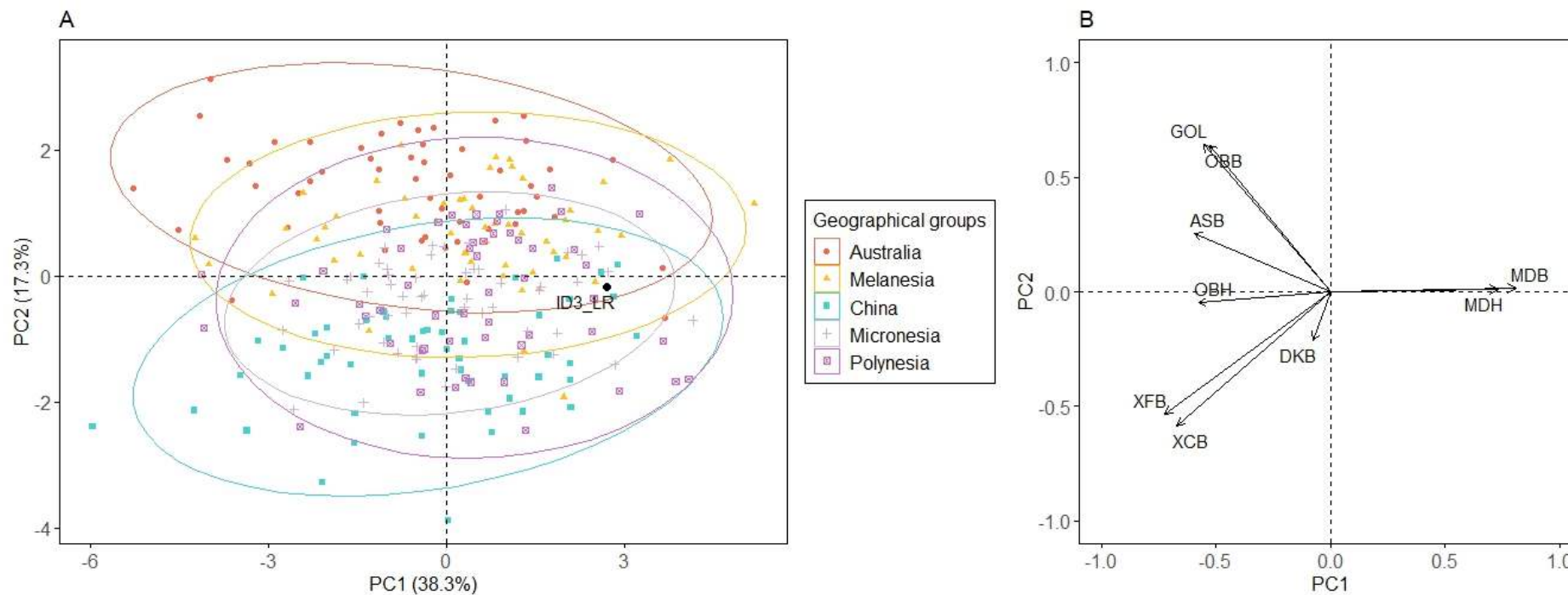
*utilisant onze variables (log shape ratio) crâniennes d'un échantillon de 270 individus récents (Australie, Mélanésie, Chine, Micronésie et*

*Polynésie) et les quatre crânes de la collection de Dubois ajoutés en tant qu'individus supplémentaires ; **B :** Cercle de corrélation présentant les*

*variables comme vecteurs indiquant la direction de leurs influences sur l'ACP*



**Appendix 6. A:** Scatter-plot of PC1 vs. PC2 using nine cranial variables (log shape ratio) from 270 recent individuals (from Australia, Melanesia, China, Micronesia, and Polynesia) and ID3\_LR plotted as a supplementary individual; **B:** Correlation circle showing the variables as vectors indicating the direction of their influences on the PCA / *A : Nuage de points de PC1 vs. PC2 utilisant neuf variables (log shape ratio) crâniennes d'un échantillon de 270 individus récents (Australie, Mélanésie, Chine, Micronésie et Polynésie) et ID3\_LR ajouté en tant qu'individu supplémentaire ; B : Cercle de corrélation présentant les variables comme vecteurs indiquant la direction de leurs influences sur l'ACP*



**Appendix 7.** Assignment of individuals to geographical groups by the LDA on the first ten PCs from the PCA using eleven variables (log shape ratio) from 270 recent individuals (from Australia, Melanesia, China, Micronesia, and Polynesia) and the four individuals from the Dubois collection. Assignments obtained with a confusion matrix / *Assignations des individus à un groupe géographique par la LDA sur les dix premières PCs de l'ACP utilisant onze variables (log shape ratio) sur 270 individus récents (Australie, Mélanésie, Chine, Micronésie et Polynésie) et les quatre individus de la collection de Dubois. Assignations obtenues avec une matrice de confusion*

<b>Geographical groups</b>	<b>Australia</b>	<b>Melanesia</b>	<b>China</b>	<b>Micronesia</b>	<b>Polynesia</b>	<b>Total</b>	<b>Percent correct (%)</b>	<b>Total cluster</b>	<b>Percent correct cluster (%)</b>
<b>Australia</b>	39	13	0	0	2	54	72.2	108	<b>94.4</b>
<b>Melanesia</b>	13	37	2	0	2	54	68.5		
<b>China</b>	0	4	35	12	3	54	64.8	162	<b>91.9</b>
<b>Micronesia</b>	1	2	10	28	13	54	51.8		
<b>Polynesia</b>	4	2	3	15	30	54	55.5		
<b>Total</b>	57	58	50	55	50	270	<b>62.5</b>		<b>93.2</b>

**Appendix 8.** Assignment of individuals to geographical groups by the LDA on the first eight PCs from the PCA using nine variables (log shape ratio) from 270 recent individuals (from Australia, Melanesia, China, Micronesia, and Polynesia) and ID3\_LR. Assignment obtained with a confusion matrix / *Assignations des individus à un groupe géographique par la LDA sur les huit premières PCs de l'ACP utilisant neuf variables (log shape ratio) sur 270 individus récents (Australie, Mélanésie, Chine, Micronésie et Polynésie) et ID3\_LR. Assignations obtenues avec une matrice de confusion*

<b>Geographical groups</b>	<b>Australia</b>	<b>Melanesia</b>	<b>China</b>	<b>Micronesia</b>	<b>Polynesia</b>	<b>Total</b>	<b>Percent correct (%)</b>	<b>Total cluster</b>	<b>Percent correct cluster (%)</b>
<b>Australia</b>	33	16	1	1	3	54	61.1	108	<b>85.1</b>
<b>Melanesia</b>	19	24	3	5	3	54	44.4		
<b>China</b>	1	3	35	10	5	54	64.8	162	<b>89.5</b>
<b>Micronesia</b>	0	6	8	24	16	54	44.4		
<b>Polynesia</b>	3	4	10	11	26	54	48.1		
<b>Total</b>	56	53	57	51	53	270	<b>52.5</b>		<b>87.3</b>



# BMSAP

*Bulletins et Mémoires de la Société d'Anthropologie de Paris*