Human teeth characteristics and its development during Holocene time until Current Era in the Lowland part of Papua Indonesia

A Dissertation
Submitted in Partial Fulfillment of the Requirements
for the Degree
Doctor of Philosophy
at the Department of History and Cultural Studies
Freie Universität Berlin - Germany

by

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Berlin
2024

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Date of defense: 28.05.2024

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I hereby declare that I have completed the submitted dissertation independently and without the use of sources and aids other than those indicated. I have marked as such all statements that are taken literally or in content from other writings. This dissertation has not yet been presented to any other examination authority in the same or a similar form and has not yet been published.

Sorong, 03.10.2024

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Acknowledgments

Throughout the writing of this dissertation, I have received great support and assistance. I would like to thank my supervisor, Professor Dr. Dominik Bonatz, who gave me the opportunity to be his student, for his patience guidance for administration regulations at University, and his kind feedback for my dissertation writing. I would like to thank Professor Dr. Cosimo Posth for his willingness to be my reviewer and his guidance for genetic laboratories analysis. To Professor Dr. Susan Pollock, Professor. Dr. Reinhard Bernbeck, Dr. Georg Roth, thank you that you have helped me to complete this journey for being on my dissertation committee. I acknowledge the PhD office team of Department for History and Cultural Studies for their patience assistance for my PhD administration. I would like to acknowledge Professor Dr. Nicole Boivin and Professor Dr. Johannes Krause as the head of the Department of Archaeology and Department of Archaeogenetics from the Max Planck Institute For the Science of Human History Jena, for the laboratory analysis of stable isotopes and genetic study. I would like to acknowledge Dr. Patrick Roberts from the Department of Archaeology, Max Planck Institute for the Science of Human History, Jena, for his unconditional support and direction of the stable isotope method in this study. I would like to thank Dr. Kathrin Nagele from the Department of Archaeogenetics from the Max Planck Institute For the Science of Human History, Jena, who provided simulation for genetic analysis in this study. I would like to thank Marie Luca, and Rita Radzeviciute for their assistance with laboratory works for the stable isotope and genetic analysis.

I would like to acknowledge the Indigenous Papuan who have supported me during my fieldwork in Papua, the Big-family of Kawer and Menufandu clans in the Biak-Sowek region, the tribe leader/Ondoafi of Kayu Batu-Jayapura, Bapak Elvis Kabey from Dinas Kebudayaan Jayapura. The family of Josua Wambrauw in Asrama Polsek-Teminabuan and the family of Bapak Guru Marthin M. Rumbiak in Ayamaru Utara for their hospitality during my fieldwork in this area. The clan member of Aronggear and Aritahanu including Bapak Decky Aritanahu and family, Bapak Petrus Imburi from Kepulauan Moore-Nabire. Fighter Simbiak for his kind help during my research in Biak Kota, Bapak Melianus Srefi for his help in my fieldwork in Sorong-Selatan. I would like to thank my family for all their prayers and motivation during my research, to my husband, Micha K-F, M. Sc, thank you for all your support through all the situations I have in my research. Finally, to Drs, Gusti Made Sudarmika, Amurwani Putri, M.Si, Hari Suroto S S, Sonya M. Kawer, M.Si, Erlin Djami, M.Si, Bau Mene S.S, Rini Maryone M.Si, Irmawati, Hotlan Tamba Siagian S.E, Meida

Berlianty S.S, Adi D.S, Klementin Fairyo, M.Si and all my colleagues from Balai Arkeologi Papua-Indonesia, thank you for all of your kind support, Tuhan memberkati semua kebaikannya!

I dedicated this dissertation to my grandfather Yesaya Mattaro and my grandmother Lai'- Urang

Abstract

The human teeth characteristics in this study carried out two different themes, namely human demography and behavior from the late Holocene to the Current Era. The human teeth were unearthed in the seven archaeological sites in the lowlands of Papua Indonesia was analyses to answer the questions about human ancestry, kinship group relationship, and their diet behavior in the past. The molecular analysis was performed with two different methods: ancient DNA and stable isotope analysis, to answer the study questions. In addition, the morphological metric dental study and wear pathology identification was conducted to provide another perspective on human ancestry and diet behavior. The results present evidence of human genetic impact from Asia in the lowlands of Papua, using two different pathways, from Taiwan through the Philippines to the coastland part of Papua and from Peninsular Southeast Asia by the use of Sundaland as a route to eastern Indonesia until Oceania. At the same time, intermarriage happened between population lineage: Papuan and Asian, derived from the mtDNA and Y-haplogroups results in this study. The diet behavior identification resulted from the evidence of the humans living in the late Holocene time, their diet subsistence by gathering the marine sources and foraging the terrestrial foods. The impact of these diet activities is displayed by the morphological analysis of their teeth, presenting a high wear rate due to food consumption. Because of the tropical climate, high temperatures, high humidity, and other preservation factors, not all samples processed in this study could go through all intended molecular analyses. Hence, it is hoped that future scientific discoveries will reveal further details or harden the theories derived from this study. This dissertation is organized as follows:

Chapter 1 gives an introduction about Modern Human history, including the theory about human dispersal originating from Africa into all parts of the world, including to the area of Papua or New Guinea, which was developed in several decades.

Chapter 2 provides a literature review with a broad overview of human history based on linguistic studies, archaeology, physical anthropology, and genetic studies done in New Guinea island. The brief review of human history from these study sources helps explore human migrations, contact, diet behavior, and other human cultural practice in this area. Thus, these studies were performed to understand human history and behavior in the lowland area of Papua-Indonesia.

Chapter 3 presents the methods and materials employed in this dissertation. The metric teeth traits are described in this section, and the statistical methods used to divine the frequency of trait variation. The ancient DNA analysis contains several steps, including sampling, DNA extraction,

library preparation, and genomic data processing, to compare the DNA of the individuals in this study for ancestry identification. Finally, the stable isotope study is performed to determine the past human diet intake and identify teeth wear and pathology impacted by human diet behavior and diseases experienced by the lowland Papuan.

Chapter 4 provides the statistical analyses of metric dental traits, aDNA result, the stable isotopes of nitrogen, carbon, and oxygen, and the results from wear and teeth pathology analysis.

Chapter 5 presents the discussion of the statistical metric analysis and aDNA results, compares them to the hypothesis, and describes the resulting interpretation and implications. The discussion of stable isotope results and their correlations to the ecofact distributions provide human diet patterns and movement behavior in the past. The discussion about wear, including macro and microwear and teeth pathology, is discussed in this chapter and connected with the stable isotope results.

Chapter 6 provides a conclusion and the potential future directions of research to understand the history and behavior of the lowland inhabitants of Papua in terms of metric traits, ancient DNA results, diet behavior, teeth wear, and teeth pathology. The literature, appendices, and glossary are provided at the end of this dissertation.

Abstract (German language)

Die menschlichen Zahnmerkmale aus dem Tiefland von Papua-Indonesien beleuchteten zwei verschiedene Themen, nämlich die Geschichte der Demographie und des menschlichen Verhaltens vom späten Holozän bis zur heutigen Zeit. Die menschlichen Zähne in dieser Studie wurden in sieben archäologischen Stätten im Tiefland von Papua-Indonesien ausgegraben, um die Fragen über die menschliche Abstammung, ihre Verwandtschaftsgruppenbeziehungen und ihr Ernährungsverhalten in der Vergangenheit zu beantworten. Die molekulare Studie wurde mit zwei verschiedenen Methoden durchgeführt: alte DNA und stabile Isotopenanalyse, um die Studienfragen zu beantworten. Darüber hinaus wurden die morphologisch-metrische Zahnstudie und die Bestimmung der Abnutzungspathologie durchgeführt, um Evidenz aus einer anderen Perspektive über die menschliche Abstammung und das Ernährungsverhalten zu liefern. Die Ergebnisse dieser Studie präsentieren Hinweise auf einen genetischen Einfluss des Menschen aus Asien in das Tiefland von Papua, wobei zwei verschiedene Wege benutzt wurden: von Taiwan über die Philippinen in den Küstenlandteil von Papua und von der südostasiatischen Halbinsel durch die Nutzung von Sundaland als Route nach Ostindonesien bis nach Ozeanien, einschließlich des Tieflandteils von Papua. Zur gleichen Zeit kam es zu Mischehen zwischen der Papua- und der asiatischen Bevölkerungslinie, die sich aus den Ergebnissen der mtDNA und Y-Haplogruppen in dieser Studie ableiten lassen. Die Identifizierung des Ernährungsverhaltens ergab sich aus den Spuren der Menschen, die im späten Holozän im Tiefland lebten und ihre Ernährung durch das Sammeln von marinen Quellen und die Nahrungssuche auf dem Land sicherstellten. Die Auswirkung dieser Ernährungsaktivitäten wird durch die morphologische Analyse ihrer Zähne gezeigt, die eine hohe Abnutzungsrate aufgrund der Nahrungsaufnahme aufweisen. Aufgrund des tropischen Klimas, der hohen Temperaturen, der hohen Luftfeuchtigkeit und anderer Konservierungsfaktoren konnten nicht alle in dieser Studie bearbeiteten Proben alle vorgesehenen molekularen Analysen durchlaufen. Es bleibt daher zu hoffen, dass zukünftige wissenschaftliche Entdeckungen weitere Details aufdecken oder die aus dieser Studie abgeleiteten Theorien erhärten. Diese Dissertation ist wie folgt gegliedert:

Kapitel 1 gibt eine Einführung in die Geschichte des modernen Menschen, einschließlich der Theorie über die Ausbreitung des Menschen von Afrika aus in alle Teile der Welt, auch in das Gebiet von Papua oder Neuguinea, die in mehreren Jahrzehnten entwickelt wurde.

Kapitel 2 bietet eine Literaturübersicht mit einem breiten Überblick über die menschliche Geschichte, basierend auf linguistischen Studien, Archäologie, physischer Anthropologie und

genetischen Studien, die auf der Insel Neuguinea durchgeführt wurden. Der kurze Überblick über die menschliche Geschichte aus diesen Studienquellen hilft dabei, menschliche Migrationen, Kontakte, Ernährungsverhalten und andere menschliche kulturelle Handlungen in diesem Gebiet zu untersuchen. So wurden diese Studien durchgeführt, um die menschliche Geschichte und das Verhalten im Tieflandgebiet von Papua-Indonesien zu verstehen.

Kapitel 3 stellt die Methoden und Materialien vor, die in dieser Dissertation verwendet wurden. In diesem Abschnitt werden die metrischen Zahnmerkmale beschrieben und die statistischen Methoden, die verwendet wurden, um die Häufigkeit der Merkmalsvariation zu ermitteln. Die Analyse alter DNA beinhaltet mehrere Schritte, einschließlich der Probennahme, der DNA-Extraktion, der Aufbereitung und der Verarbeitung der genomischen Daten, um die DNA der Individuen in dieser Studie zur Identifizierung der Abstammung zu vergleichen. Schließlich wird die Studie der stabilen Isotope durchgeführt, um die frühere menschliche Nahrungsaufnahme zu bestimmen und die Abnutzung der Zähne und die Pathologie zu identifizieren, die durch das menschliche Ernährungsverhalten und Krankheiten der Menschen im Tiefland von Papua beeinflusst wurden.

Kapitel 4 liefert die statistischen Analysen der metrischen Zahnmerkmale, der stabilen Isotopen von Stickstoff, Kohlenstoff und Sauerstoff und die Ergebnisse der Abnutzungs- und Zahnpathologie-Analyse.

Kapitel 5 präsentiert die Diskussion der statistischen Ergebnisse der metrischen Analyse, vergleicht sie mit der Hypothese und beschreibt die daraus resultierende Interpretation und Implikationen. Die Diskussion der Ergebnisse der stabilen Isotope und ihre Korrelationen zu den Verteilungen der Ökofakten geben Aufschluss über menschliche Ernährungsmuster und Bewegungsverhalten in der Vergangenheit. Die Diskussion über Abnutzung, einschließlich Makro- und Mikroabnutzung und Zahnpathologie, wird in diesem Kapitel erörtert und mit der Analyse der stabilen Isotope verbunden.

Kapitel 6 bietet eine Schlussfolgerung und die möglichen zukünftigen Forschungsrichtungen, um die Geschichte und das Verhalten der Tieflandbewohner Papuas in Bezug auf metrische Merkmale, DNA-Ergebnisse, Ernährungsverhalten, Zahnabnutzung und Zahnpathologie zu verstehen. Die Literatur, Anhänge und Begriffsdefinitionen befinden sich am Ende dieser Arbeit.

Chapter 1: Introduction

1.1 Background

The modern human subject was the primary focus of multidisciplinary studies across various fields in the twentieth century, including anthropology, paleoanthropology, and archaeology. These disciplines concentrated on understanding human origins and evolution, with a particular emphasis on biological and physical characteristics. The perspective on human classification initially developed based on traditional anthropometric and morphological studies, which were primarily discussed by European and American scientists such as Carleton S, Coon, Stanley M. Garn, and Joseph Birdsell. Their work, particularly in the book entitled Races: A Study of the Problems of Race Formation in Man (1981), explored the concept of race and the physical differences among human populations. The study of modern humans has evolved to encompass various aspects, including anatomical definitions, behavioral and social-technology aspects, and other characteristics that contribute to the understanding of what defines modernity in humans (Wolpoff, 1980; Caspari & Wolpoff, 2013). In addition, modern human history has begun to shed light on anthropological themes that were prominent in the nineteenth century, such as human definitions, the origins of human species, the timing of human migrations, the extinctions of other hominins, and the physical differentiation between groups of populations (Armelagos and van Gerven, 2003). In this period, the scientists were keen on defining what it meant to be human, and establishment of criteria for classifying Homo sapiens, including anatomical, cultural, and intellectual characteristics. These definitions were often based on comparisons with other primates and fossil hominins, contributing to a clearer understanding of human species' unique attributes. The central components outlined in the definition of Homo are physical feature characteristics, human behavior, adaptations, and cognitive ability (Lockard, 2008; Wood, 1992).

The morphology characteristics of the modern human group are unique (Hanihara, 1986a), and contain valuable information that can be used to study the history of modern humans and related aspects. These morphological traits provide insights into evolutionary processes, population movements, and adaptation strategies. Nevertheless, the lack of scientific research on the morphological characteristics and biological evidence from certain groups, including the Papua-Indonesia population, has indeed limited their involvement in broader anthropological and evolutionary discussions. This gap in research is compounded by social issues such as racism, discrimination, and other social concerns, which further marginalize these groups and their contributions to the understanding of human diversity and history. The advance our understanding

of human diversity, it is essential to identify and study human groups with both universal and local characteristics, including their physical and biological appearances. This includes a focus on the inhabitants of the lowland regions of Papua-Indonesia. Such research can contribute significantly to the broader discourse on human evolution, adaptation, and cultural diversity.

The researcher has developed the definition of 'Homo' based on the physical feature characteristics, human behavior, adaptations, and cognitive ability as the central part in this term (Lockard, 2008; Wood 1992). These traits, include features of the skull, pelvis, mandible, a globular cranial vault of fossils, a narrower and less flared pelvis, and a bony chin on the mandibular, which are used to distinguish various species within the genus Homo and are often associated with cognitive abilities and other sophisticated behaviors (Day and Stringer, 1991). The exact timing of the modern humans existence is still debated among researchers, but generally, anatomically modern traits are presumably to have developed within the last 200 and 300 ka. H.sapiens appeared before this range of time or before the earliest separation of present-day ancestries (Bergström et al. 2020) related to the fossils found in several areas in Africa. These fossils, including the H.sapiens fossils of Omo Kibish 1 from Ethiopia, dated to around 195 ka, and Herto 1 and 3 about 160 ka (Stringer, 2016). While from Kenya, the Guomde fossil dated about 240 ka (Stringer, 2016), and the fossil from Greece, Apidima dated to more than 210 ka (Harvati et al. 2019).

The discussions about the origin of modern humans and their dispersal are developed by two major models: The Recent African Origin model (RAO) and the Multiregional Evolution model (MRE). The comparative age and physical characteristics of fossil in Africa, for example the Omo-Kibish 1 skull in Ethiopia, became the foundation of the RAO for H.sapiens interpretations (Day and Stringer 1982; Bräuer, 1984 at International Congress of Human Paleontology, Nice-France). This theory proposed that modern humans originated in Africa and subsequently dispersed across the world, replacing all other hominin populations (such as Neanderthals and Denisovans) without significant interbreeding. This model, implying a single African origin of modern humans about 200,000-100,000 years ago (ka) and it subsequent replacement of all archaic populations (Mounier and Lahr, 2019).

The Multiregional Evolution model (MRE) was established in the modern human perspectives advocated by Weidenreich, Thorne, and Wolpoff in the 1980s, who used regional continuity and chronology to explain the modern human origin and evolution scheme. The Multiregional Model of modern human origins suggests the gradual evolution of global archaic hominin populations concerning a modern human morphology over the course of the last 2 million years (Wolpoff et al. 1994; Brauer 2008). The human morphological fossils such as H. neanderthal

from Vindija in Central Europe (Smith & Spencer, 1984), H. erectus and H. sapiens from the Pleistocene layer from the Zhoukoudian site in China (Shang et al., 2007), H. erectus from Java-Indonesia, H. sapiens from Niah cave-Borneo and Mungo skeletons from southeastern Australia (Bowler, 1972; Bowler et al., 1970), indicate-specific morphology characteristics related to cranial capacity, and the face size reductions. The traits retain regional differences, such as shovel-shaped incisors, point-out the past and present morphology of the Asian population's characteristics. Also, these morphological descriptions are used as a basis for models by the multiple-origin group to narrate modern human existence (Ahmed 2014:130). Before the human fossils found outside of Africa, MRE researchers hypothesize that modern living humans are descended from archaic-looking ancestors that are not exclusively localized in Africa (Delisle 2016: 343). In terms of genetic, the Multiregional model agrees on the concept of modern human origin in Africa, proceeding through a coherent genetic network of non-modern and modern humans, perhaps 1.4 to 2 million years ago, through significant gene flow/local selection (Stoneking, 2012:13). Both models, the Recent African Origin and Multiregional Evolution hypotheses, have claimed that modern humans' origin from Africa and the earlier migrations contributed to modern humans' appearance (Stoneking, 2012:13).

The two models for the H.sapiens origins: Multiregional model of human origins and the Recent African Origin have been refined and updated over time to incorporate new evidence and address the complexities of late Quaternary hominin evolution., proposing multiple out-of-Africa dispersals and accounting for the impact of African population structure on diversification (Lahr & Foley, 1998). With a better understanding of evolutionary mechanisms and a growing number of genetic studies (Malaspinas et al. 2016), the models have considering varied demographic and genetic outcomes of recent hominin interactions in this terms (Post et al. 2017; Stringer 2016; Lahr 2016).

In an attempt to discover the modern human birthplace in Africa, several specific places have been demonstrated by researchers in the past. In Northern region for example, the discovery of Jebel Irhoud fossils in Morocco dated to 160 kya (Smith et al. 2007), provide important evidence suggesting that North Africa could have been a key region for the emergence of anatomically modern humans.. This hypothesis, supported by the Y chromosomal phylogenetic tree model based on resequencing of male-specific regions, presents the result about the deepest clades were rooted in Northwest and Central Africa (Cruciani et al. 2011). However, this evidence is limited by the factor of admixture events, levels of migration, and genetic drift in North Africans, which is still needed to answer in the future. In Southern Africa, the trend populations from this area exhibit the highest levels of genetic diversity and possess the earliest branching positions in tree-like models of history

that further suggested as an origin of modern humans (Tischkoff et al. 2009; Schebush et al. 2012; Veeramah et al. 2012). However, recent studies of the gene flow present evidence that strands of ancestry that are found in southern African are present in Central, eastern, and western Africa (Lipson et al. 2020). More importantly, given that individuals are probably to have relocated from their ancestral homes over 200 ka, it is unlikely that the present-day individuals with the most divergent ancestry would have a location corresponding to the point of origin. Besides that, the ancestral relationship between southern and eastern Africans shows in the result of genetic analysis between Khoisan and the Hadza and Sandawe in eastern Africa, which has implications for the geographic origin of modern humans. The results from the TreeMix method analysis show that both of these locations, eastern and southern Africans, as the origin of modern humans (Pickell et al. 2012). The ancestors of modern humans lived in distinct but interconnected populations throughout large portions of the African continent is the hypothesis that received more attention recently (Scerri et al. 2018; 2019).

The theory of modern humans originating in Africa is widely accepted based on substantial evidence from genetics, fossil records, and archaeological findings. However, the details of how and when early modern humans dispersed from Africa have been the subject of extensive research, debate, and refinement. The maxilla and associated dentition from Misliya Cave, Israel dated to 177,000 to 194,00 years ago, implying that H.sapiens left Africa earlier than previously thought. The H. sapiens appearance in Misliya site marked through the fledged Levallois technology associated the Misliya maxilla. Based on genetic analyses of modern human fossils, the Out of Africa migrations assumed to have occurred between 70 and 52 million years ago (Pagani et al. 2016; Kuhlwilm et al. 2016), presenting evidence that all contemporary non-African peoples descended from the same ancestor, as well as minor genetic contributions from earlier H.sapiens dispersal (Pagani et al. 2016; Nielsen et al. 2017). The earlier dispersal of H.sapiens, also supported by the radiocarbon evidence of fossils found in several areas, including the Skhul and Qafzeh from the cave in Israel and Al Wusta in Saudia Arabia, dated to around 90 Ka. The fossils found in China dated between 80 and 113 ka (Liu et al. 2015), in Arabia around 85 ka (Groucutt et al. 2018), in Levant and Greece by 200-185 ka (Harvati et al. 2019; Hershkovitz et al. 2018), and Southeast Asia around 73-63 ka (Westaway et al. 2017). Above al, the genetic studies continue to refine our understanding of human origins, migration, and interaction with other hominin species, providing a clearer picture of how modern humans populated the world.

Two possible routes (not mutually exclusive) were suggested by researchers in the past: the Northern and Southern routes. For the Northern routes, the evidence from the genetic, archaeological, and climate records suggested some support for this area as a route for modern

human expansion from Africa. The evidence from the Northern routes shown through the Skhul and Qafzeh hominins presents an early exit of modern humans, approximately 120 kya, traveling across the Sinai Peninsula through western Asia via the Levant (Grun et al. 2005). Based on the climatic records, the global glacial period 90 kya, presents two different scenarios for the Skhul and Qafzeh exodus: before or after the glacial event (Pope & Terrell. 2008). Besides that, the archaeological record from an empty corner of the Arabian Peninsula presents the stone tools and assemblages dated to 100-80 kya, providing information about the early settlement from this area (Hovers, 2009).

The genomics studies demonstrated the presence of a Southern route expansion by H.sapiens, as evidenced by the basal Eurasian ancestry located in Morocco (van de Loosdrecht et al.2018) at 15 ka an in Georgia (Lazaridis et al. 2018) at 26 ka, which are unlikely to be associated with the Out of Africa before 60 ka (Bergström et al.2020). It appears that the initial Eurasian ancestry was most likely situated in North Africa and Southwest Asia, and this provides insight into the dispersal of modern humans into West Eurasia and South Asia during the Holocene time (Lazaridis et al. 2014; Lazaridis et al. 2016; Skoglund et al. 2012, 2014). The Southern dispersal route hypothesis is supported by the recent finds from Madjedbebe in northern Australia, indicates that groups of H.sapiens likely colonized South Asia by 65 ± 6 ka (Clarkson et al. 2017). A retouched point and centripetal core have been discovered in east African sites from 100to 47 ka, and in northern Australia ca.65 ka (Clarkson 2014; Groucutt, 2018), provide evidence of a technological continuity between Africa and Australia (Petraglia et al.2007; Clarkson et al. 2018).

The modern human migrations from Africa to Eurasia were confirmed through two schemes: the inland and coastal migration routes (Sauer 1962; Field and Lahr, 2005; Field et al. 2007; Mellars et al. 2013). The coastal migration theory explains how H. sapiens left Africa no earlier than 70,000 years ago and initially lived on coastal resources along the Arabian coast and the southern edges of India before migrating to Southeast Asia 10,000 years later (Lahr & Foley, 1994). This theory was supported by genetic markers from 1,000 Indian genomes, indicating that modern humans did not arrive in Asia until 60,000 years ago (Kumar & Reddy, 2003). The Toba volcano explosion around 74,000 years ago reinforced the idea that the H. sapiens migration took place after this event (Ambrose, 1998b). Also, migration events most likely occurred before Toba exploded, based on evidence of fossils from Laos's uplands dated about 50,000 years ago (Shackelfor et al.2018), which provided the inland routes of migrations hypotheses (Demeter et al. 2012).

The present island of Southeast Asia covered an archipelago area about 5,000 km from Sumatra continued east to the island of New Guinea and from north of Luzon to the south, where the island of Timor was located. In relation to the early migration of modern humans into the island

of Southeast Asia, the brief discussion highlighted several pathways that generally indicate South Asia's region as a starting point to reach the islands of Southeast Asia (Roychoudhury et al., 2000; Thangaraj et al. 2005). GIS analysis results confirmed the area of South Asia to be a pathway to Southeast Asia, stating the inland route using the river deltas of Narmada-Indus crossed towards Southeast Asia regions (Field et al. 2007). Ciochon (2010) proposed a coastal migration along the Bab-el Mandeb Straits to Southeast Asia.

The Pleistocene layers yielded abundant human fossil remains in the past ,which were used as critical chronology in human history narration. The Pleistocene period began around 2.6 million years ago and was characterized by glacial and interglacial cycles (Noss, 2012:49). Evidence from archaeological sites on Southeast Asia islands, including New Guinea and Australia, confirmed that the characteristics of the significant climate have a tight correlation with the spatial pattern and environment, which played a significant role in Hominin diversity demography (Foley, 1999), and dispersal process (Rabett, 2012). The dating results of modern human fossils discovered in numerous archaeological sites reveal the Late Pleistocene period, including the fossils of a young woman from Niah cave in Sewarak dated 40,000 BP (Brothwell 1960; Barker et al. 2007; Curnoe et al. 2016). Five skeletons from the Pleistocene layer have been discovered on the islands of the Philippines (Bailen 1967). While the human cranial from Alor Indonesia date to 13 kya, provide insights on the Late Pleistocene modern human occupation in Island of Southeast Asia (Carro et al. 2019). While three partial skeletons unearthed from Lake Mungo, New South Wales, Australia, were confirmed as the H. sapiens fossils, known as the Mungo skeletons, dated at 34.000 to 24.000 ya (Bowler et al. 2003).

The migration of early modern humans into mainland and island Southeast Asia, as well as Australia, during the Pleistocene time was driven by their unique capabilities to adapt and exploit diverse environmental conditions and annual climate cycles. This was signified by the fossils evidence was found in this period; for instance, H. sapiens, and H. floresiensis were discovered in this region. The H. floresiensis or "dwarf-Hobbit" discovered on the island of Flores by the team of researchers from Australia collaborated with the National of Archaeological Research Center of Indonesia (Brown et al. 2004; Morwood et al. 2004), have released an evidence of modern humans dispersed outside Africa into the eastern region of Indonesia where the Sahulland existed. In Pleistocene times, deepwater straits barriers surrounded Wallace Line, presenting animals and living organisms, including humans from crossing into Sahulland (Pratt & Beehler, 2015:23). The discovery of human fossils and associated findings from archaeological sites in this area, on the other hand, has supported interpretations of modern humans' maritime capabilities, such as H. floresiensis' ability to cross the Wallacea deepwater barriers at the time.

By geographical characters, the region of Southeast Asia displayed significant ecological zones, varied from the swamp, plains, lower montane to the environment's alpine zones. Every zone contains biodiversity features that differ significantly in structure and composition. Along with the tropical environment, the climate and temperatures in Southeast Asia are stable throughout the year; sun and rainfall occur throughout year-round established tropical rain forests, which are favorable for animal species and microorganisms to live. During the transition from the Late Pleistocene to the early Holocene, the climate and environment of the tropical rainforest in Southeast Asia were alluring to human occupation, as is evidenced by archaeological sites in the Philippines, Malay Peninsula, northern Thailand, Vietnam (Rabett, 2013), and Indonesia (Piper & Rabett, 2014:124–132). This region is made up of a variety of ecological systems, including swamps, arboreal zones, and lowland and highland evergreen rainforests. This landscape is suitable for both plants and animals, and it allows humans to perform foraging activities. During this time, hunting knowledge advanced significantly. The findings which includes animal species, mammals and birds, was abundant found in Niah's cave, implying the evidence of food availability has been fulfilled at this time. In addition to the Niah site, the archaeological findings from Ille Cave on the Philippine island of Palawan provide significant insights into human-environment interactions during the Pleistocene time. These discoveries including remains of marsupials, extinct species of deer, the Palawan bearded pig, and marine species, highlight the adaptability and environmental management skills of early humans in Southeast Asia (Lewis et al. 2008).

New Guinea island, situated in the tropical region of Southeast Asia, is one of the most exciting areas for studying human origins and past behavior. Many factors contribute to this, including the island's location along the equatorial lines, its rich natural biodiversity, population history, ecological zone, and the variants of topography and altitudes. The island of New Guinea was formed by the interaction of the Pacific and Australian Plates, with associated microplates and island arcs (Scotese et al., 1988; Beehler 2020 :65). In the Jurassic and early Cenozoic time, the ocean crust in most of the west-central Pacific basin and the broken corner of the Pacific Plate north of New Guinea led to the formation of transform boundaries that created the Caroline Plate to the northeast of Papua New Guinea (Weissel & Anderson, 1978). The regional sea level in the Pacific basin fluctuated significantly from 12,000 BP until <3,000 BP (Late Pleistocene to Late Holocene). As the second-largest island globally, New Guinea covers an area of 785,753 km² of land area, with 77% of its land characterized by tropical rainforest that extend from the lowlands to the upper montane regions. The language families used by the indigenous people in New Guinea are extremely diverse, consisting of 862 unique languages (not dialects) with speaker populations

ranging from very small to (Palmer 2018:13). These elements provide valuable insights into human history and behavior on this island.

It its current political division, the island of New Guinea is split into two parts: the Papua region, part of Indonesia, occupy the western half, while the eastern half is the independent State of Papua New Guinea. Geographically, the shape of New Guinea resembles that of a bird, with distinct regions identified as the Bird Head, Body, and Tail. The Indonesian territory of Papua, formerly known as Irian Jaya, extends from the Bird's Head in the west, through the Bird's Neck, and across half of the island's body to the east, ending at the Keerom regency, which marks the border between Papua-Indonesia and Papua New Guinea (Latitude 2° 08' 30" South, Longitude 141° 01' 30" East). The Papua- Indonesia territory also includes the northern coast area along Cenderawasih bay adjacent to the island of Biak in the northern border of the Pacific Ocean, while its southern coast, it is adjacent to the Halmahera and Ceram Seas. Researchers have extensively studied migration events into the island of Papua in prehistoric times, including the timing, routes, and populations involved in these migrations. During the last glacial period until ~12,000 years ago, a landmass known as Sahulland connected New Guinea, Australia, Tasmania, and a submerged shelf in the Arafura Sea. At the maximum of the glacial period, the sea level was 120 meters lower than its current position (Inger and Voris 2001). Colonization of Sahulland by the early migrants during the Pleistocene time likely involved people with coastal adaptations and maritime skills, utilizing seaworthy watercraft (Summerhayes et al. 2010).

Birdsell (1977) discussed the concept of voyager routes in relation to migration events into Sahulland, which involved the Pleistocene continental shelf fringing Asia known as Sundaland encompassing present-day Sumatra, Borneo, and Java. The Pleistocene time, lasting from approximately 2,588,000 to 11,700 years ago was characterized by fluctuating climates marked by alternating cold and warm periods. Wallacea, situated between Sunda and Sahulland, served as a crucial stepping zone into the Sahulland. Evidence from genetic studies (Malaspinas, et al. 2016; Pugach et al. 2013; Teixeira & Cooper, 2019) suggests that modern human presence in Sahul began at least 50 thousand years ago, possibly as early as 65 thousand years ago (O'Connell, et al 2018; Clarkson et al. 2017). The maritime voyaging capabilities of early humans to enter Sahul remained a topic of debate (Bird et al., 2019; Anderson, 2018; O'Connor et al. 2017). Despite the challenges such as the distance (~ 100 km) and open ocean between Wallacea and Sahul, with no direct land bridge connecting them, human dispersals into Sahul required sophisticated maritime and coastal adaptation (Anderson, 2018).

Researchers (Birdsell, 1977) proposed two major routes for modern human expansion into Sahul: the northern path from Sunda through Sulawesi into New Guinea, and the southern path

from Sunda through Bali, Timor, and onto the northwestern coast of Australia. According to findings by Kealy et al (2018), using crossing distance and the least-cost pathway approach, the northern route was preferred route for early humans entering Sahul. This result is further supported by demographic modeling analysis by Bird et al. (2019), indicating that the northern route was likely to less demanding and more conducive to establishing a viable population due to the time and effort required for successful crossing into Sahul. According to this study, the voyage after reaching Sulawesi would take approximately 2-3 days.

The term "Holocene" was originally coined by Gervais (1867-1869) to describe the warm period that began at the end of the last glacial period and was officially adopted by the International Geological Congress (IGC) in 1885. It is a geological epoch within the Quaternary System, representing the most recent stratigraphic unit within geological periods (Lyell, 1839). During the Holocene period, melting of ice sheet in the northern hemisphere occurred from the Last Glacial Maximum (LGM) around 22-20 ka to the early-mid Holocene (Wallace & Woodroffe, 2014:322). The time is characterized by significant regional and simultaneous climate changes that have played a crucial role in influencing human behavior and related aspects. The Holocene is divided into three distinct periods: the early Holocene (12,000-6,000 BP), the middle Holocene (6,000-3,000 BP), and the late Holocene (3,000 BP) (Nunn 2001, 2007:44; Dickinson 2001). During the early Holocene, the rise in post-glacial sea levels affected shorelines worldwide, leading to the development of submerged terraces and drowned reefs in various coastal areas.

In the middle Holocene, warm temperature significantly impacted terrestrial and near-shore environments, while the sea level remained stable compared to the early Holocene. The late Holocene, sea-levels decline accompanied by reduced precipitation and cooling across various parts of the Pacific Basin (Nunn, 2007:45). During the early Holocene, the history of modern human occupations in Papua is evidenced through palaeoecological records that document environmental changes in both lowland and highland regions (Yen, 1996; Denham et al. 2004; Haberle, 2007). Haberle et al. (1991) identified human occupations in the highlands based on pollen records from sites such as the Baliem Valley dating back to around 9000 BP and the Tari Basin dating back to around 8000 BP (Haberle, 1993). Pollen record from these sites showed an increase in Casuarina pollen and charcoal particles, suggesting human activities such as land preparation for plant cultivation, including Casuarina species (Haberle and David, 2004). In the lowland area near Lake Hondorli in Jayapura, Papua province, palaeoecological evidence from Hope and Tulip (1994) indicates land disturbance began around 10,500 BP, with secondary forest plant species appearing as a result of subsequent minor human activities from around 7000 BP (Hope and Tulip 1994).

Various methodologies have been employed to link human behavior with diet or subsistence among different communities, including ecological perspectives, resource intensification studies, and biological reconstructions. Archaeology, which examines long-term patterns of human behavior, plays a crucial role in addressing significant societal challenges such as economic inequality and diseases, etc. Th archaeological record provides abundant data that are distinctly observable, facilitating investigations compared to other aspects of human behavior. Teeth and bones are particularly valuable for evaluating historical cultural behaviors, aiding in biological reconstructions that include assessing pathological conditions within populations. One of the most studied aspects influenced by nutrition in archaeological contexts is dental health, which includes issues like dental wear, caries, and fluorosis. Tooth condition offers critical insights into the diet and health status of individual or groups, as food directly impacts tooth wear and decay due to their contact during chewing and the chemical composition of consumed food (Soames & Southam 2005). Tooth wear, characterized by the gradual loss of enamel and dentin from tooth surfaces, results from the combined effects of attrition and abrasion. Fluorosis, a condition affecting human teeth, has been studied since 18th and 19th centuries, focusing on the formation and durability of hard tissues in the body. Early studies examined prehistoric bones and teeth to understand their resistance to decay, leading to hypotheses about fluoride's role in promoting dental and skeletal durability. Fluoride, naturally present in soil, bedrock, and drinking water, is an essential mineral that, when consumed within certain levels, strengthens tooth enamel and acts as a cariostatic agent (Guo et al. 2021; Wang et al.2021). However, excessive fluoride intake, particularly through drinking water, can be harmful to both skeletal and dental health (WHO 2002).

1.2 Statement of the problem

The lack of knowledge regarding human diversity derived from physical characters and osteological studies in archaeological contexts has significantly hindered the understanding of human history in various societies, including the populations inhabiting the lowland part of Papua-Indonesia. The limited understanding of human diversity, especially in terms of morphological traits and paleodietary studies from societies living in what is often referred to as "pristine lands," has led to social issues such as disrespect, discrimination, and racism. These issues further contribute to social instability and imbalance. Therefore, this research aims to address these gaps by providing data, particularly from the populations where limited information is available, regarding human dental morphology and behaviors in the lowland areas of Papua-Indonesia. The study also seeks to establish databases of teeth from the Late Holocene and Current Era population to analyze characteristics of human dentition and paleodietary behaviors. The variations and uniqueness

observed in human dental remains found at lowland sites in this research contribute to understanding Papuan history at local and regional scales. Furthermore, evaluating dental characteristics of Holocene humans will shed light on biological and behavioral aspects specific to the lowland regions of Papua. Globally, this research will provide complementary data to identify patterns among different populations worldwide. Understanding human populations one a broader scale is challenging without comprehensive data, including dental information from diverse population such as those in Papua.

Morphological data from the teeth have been crucial in fields such as dental anthropology and dental forensics, where tooth characteristics contribute in understanding evolutionary processes, analyzing population history, and studying human behavior, including diet. Common dental conditions such as caries (decay), dental wear, erosion, attrition, and fluorosis are prevalent in most people's lives, however detailed statistics on their historical prevalence are limited. Defects in dental and bone tissues, such as enamel and dentin, remain relevant issues in present-day human health. These dental conditions can lead to more serious health problems, including imbalanced food selection and susceptibility to other diseases. The study of prehistoric human teeth provides valuable reference data for understanding dental diseases in ancient population and offers comparative insights into oral and dental health in contemporary society. By examining dental conditions in prehistoric humans, researchers can gain insights into historical patterns of oral health and disease, helping to inform modern approaches to dental care and public health. This comparative approach contributes to a broader understanding of human health across time and populations.

1.3 Conceptual Framework for the study

Several demographical events in the history of New Guinea, including the initial dispersal of pre-Austronesian populations, known as Australo-Papuan, occurred approximately 47 ka to 50 ka, as indicated by genetic studies (Allen & O'Connell 2020, 2014; O'Connell et al. 2018; Veth 2017). Genomic data suggests that Australo-Papuans diverged from Eurasians populations between 51- 72 million years ago and from each other around 10-32 million years ago (Malaspinas et al. 2016). In the mid-Holocene period, Austronesian groups migrated from mainland East Asian into coastal areas of Papua, a process well-documented in archaeological and genetic studies (Bellwood 2005; Skoglund et al. 2016; Kayser et al. 2008). Their arrival is associated with advancements such as maritime trade networks, the introduction of pottery, and the exchange of spices (Bellwood 2017, 2019; Ono 2018; O'Connor 2015).

The dispersal of Australo-Papuan and Austronesian speakers into the Papua region have indeed influenced and shaped human dental traits and genetic patterns in this area. Studies focusing on human dental morphology among Highlanders have revealed a low frequency of Asian dental attributes, whereas the lowland areas show a higher frequency of Asian characters. This disparity in dental traits reflects the historical migration and settlement patterns of different population in Papua. Genetic and dental studies have shown heterogeneous patterns in the lowland areas compared to the highlands. The Papua highlands, due to their relatively remote and isolated nature, exhibit higher genetic variability. This variability is thought to be influenced by the geographical characteristics of the highlands and the historical patterns of human movement and interaction. Evidence from genetics and dental studies suggests a clinal pattern in both genetic and dental traits across the lowland and highland regions of Papua. This clinal pattern reflects how environmental factors, demographic movements, and interactions between different populations shaped the genetic and dental diversity observed in modern populations.

Human dental studies, a key focus of physical anthropology, provide insights into human origins, variation, and behavior through the analysis of tooth morphology, including crown and root characteristics (Scott & Turner, 1997:9). Since the mid-20th century, dental morphology has been instrumental in biological anthropology, with themes ranging from odontometrics to dental wear (Brothwell in 1963). All human dentitions share a common blueprint (Dahlberg,1951:140), but variations in non-metric and metrical traits distinguish populations from each other (Scott & Turner 1997:2). Dental morphology begins to form during the embryonic stage and continues to develop throughout an individual's life, influenced by genetic factors and environmental conditions (Lesot et al., 2001; Ferrario et al., 1999). Butler (1965) highlighted how the timing of tooth crown development influences crown shape, which is valuable for phylogenetic research.

The unique characteristics of teeth serve as a 'fingerprint' within population, aiding in identifying evolutionary processes, origins, interbreeding events, and other aspects of human behaviors (Scott et al., 2018: 10). By analyzing, both crown and root morphology, researchers gain deeper insights into human history and significant life events (HrdliČka, 1920; Dahlberg, 1945a; Brothwell, 1963). Studies on human dental morphology, encompassing nonmetric and metrical traits, reveal variations within and between populations, offering valuable data for anthropological research purposes (Gregory & Hellmann, 1926; Wood et al., 1983; Martinon-Torres et al., 2012). One notable study by Dahlberg et al. (1982) focused on Indian-American dentition, yielding significant insights into population history studies. Such research underscores the importance of

dental morphology in understanding human diversity and the evolutionary processes that have shaped populations over time.

Chapter 2: Literature Review

The history of population of Southeast Asia including Papua, is vast and complex, marked by a long history of diverse occupations since the area was first inhabited (Pawley et al., 2005). However, our understanding is hindered by challenges such as small ample sizes and scarcity of radiocarbon dates for human specimens, which complicate explanations of modern humans dispersal in this region.

The term “Two-layer” model, proposed by scholars including Von Koenigswald (1952); Jacob (1967), Van Stein Callenfels (1936), described two different groups of modern humans in Southeast Asia: the Australo-Melanesian or Papua, and immigrants from the mainland, East Asia. The Australo-Papuan term refers to current inhabitants of Australia, New Guinea, and Melanesia, characterized by regional phenotypes. Archaeological finds in Southeast Asia have revealed cranial morphology consistent with Australo-Papuan traits. For example, human skulls from sites like in Gunung Runtuh (dated about 11,000 years old) (Majid, 2005), the human skull from Moh Khiew Cave in Southern Thailand, (Matsumura & Pookajorn, 2005) and the 13,000 years old Hang Cho cave human remains in northern Vietnam., exhibit these characteristics. Similarly, cranial remains from Niah Cave (Brothwell 1960; Barker et al. 2007) and Tabon in Island Southeast Asia show variations from gracile to robust, resembling Pleistocene remains from Australia. These archaeological discoveries are associated with the Hoabinhian culture, named after caves in Hoa Binh Province, Vietnam. The Hoabinhian culture, known for its postglacial stone tool industry using unique pebble tools, thrived as a hunter-gatherer society until approximately 4000 years ago. Subsequent agricultural developments led to an increase in farming economies, pushing foraging societies into more isolated regions, particularly in Thailand and Malaysia.

The term “Hoabinhian” has been used since the 1920s to describe these societies, characterized by their tool industry and burial practices. Hoabinhian people typically buried their dead in pits, often in a flexed or seated position without grave offerings. Various Mesolithic sites in Peninsular Malaysia, such as Tampanian sites, have also yielded human remains. These include discoveries by Evans (1918) at Gua Kajang and Gordon, Evans, and van Stein Callenfels at Gunung Pondok’s Gua Kerbau (Evans 1928), which were classified as Australo-Melanesian by Duckworth (1934). Mijsberg (1940) discovere human jaws at Guar Kepah, identifying them as "Palaeo-Melanesian," while van Stein Callenfels (1936) discovered bones from the Neolithic period associated Hoabinhian culture.

The recent data presents a scheme of modern human dispersal known as ‘multi layer of migration (Lipson et al.2014, 2018; Deng et al. 2015; Hill et al. 2006; Jinam et al. 2012; Mccoll et al. 2018), provides on the four model. The initial migration wave is originated from the ancestors of the Australo-Melanesian. These early populations likely had roots in the broader Australo-Melanesian group and were among the earliest inhabitants in this region. Following by Austroasitic-speaking migration which spoken by various ethnic groups in Southeast Asia and parts of South Asia, suggesting a significant demographic movement into the region. Austronesian-speaking peoples represent the third migration wave. Known for their maritime skills and extensive voyages, Austronesian speakers originated in Taiwan and began expanding southward into the Philippines, Indonesia, and eventually reaching as far as Madagascar in the Indian Ocean. The fourth migration wave includes movements from East Asia into the Southeast Asian islands. This migration wave reflects ongoing interactions and migration between mainland East Asia and the islands of Southeast Asia, contributing to the genetic and cultural diversity of the region. These migration highlight the complex history of human movements and interactions in Southeast Asia, shaping the genetic, linguistic, and cultural diversity observed in the region today. Each wave brought new populations, languages, technologies, and social practices, contributing to the rich tapestry of Southeast Asian societies. The recent genome analysis provide compelling evidence for multiple migration waves and genetic interactions in Southeast Asia. The presence of Denisovan introgression in the Papuan and Philippine Mamanwa populations, while absent in native populations from Peninsular Malaysia, Borneo, and the Andamese Negrito, suggests distinct regional histories of genetic exchange with archaic hominins (Yew et al. 2018a; Jinam et al. 2017). Besides that, a report from the Philippine Ayta population revealed that this group had 30-40% Denisovan ancestry, which is higher than that of Papuan, supports the idea of separate Denisovan admixture events in different Negrito populations, indicating complex patterns of interbreeding and migration among ancient human groups in the Philippine (Yew et al. 2018a). Furthermore, the ancient genome data revealing mixed East Asian and Eastern Eurasian Austroasiatic ancestry among early farmers in Vietnam, akin to South Indonesia, underscores the diverse genetic makeup shaped by interactions between population from different geographic and genetic backgrounds over millennia (Lipson et al. 2018). These findings collectively contribute to our understanding of the dynamic population history and genetic diversity across Southeast Asia, highlighting the complex interplay of migrations, admixture events, and cultural exchanges in shaping the genetic landscape of the region.

The skeletal remains found in Sulawesi, the North Molluccas, and East Nusa Tenggara provide archaeological support for the idea of multiple human migration waves into Southeast Asia,

as discussed in Oliveira et al. (2022. These findings indicate that various populations have inhabited and migrated though these regions over time, contributing to the genetic and cultural diversity seen today. The genome analysis of the 'besse' remains from South Sulawesi, as studied by Carlhoff et al. (2021), reveals a significant East Asian ancestry component mixed with Denisovan gene flow. This genetic profile suggests that East Asian genetic influences were present in Wallacea much earlier than previously thought, potentially predating the Austronesian expansion. This challenges earlier hypotheses about the origins and timing of genetic diversity in the region and suggests a more complex history of human interactions and migration across Southeast Asia and Wallacea.

The evidence from Toe and Kria caves in the Bird's Head area of Indonesian Papua, along with the Ivana valley site and Buang Merabak in Papua New Guinea (Leavesley et al., 2002), provides compelling insights into the early human presence on New Guinea island. The findings of human fossils, tools, pottery, and ecofacts liken marine shells and obsidian not only indicate the span of human habitation from the late Pleistocene to the early Holocene but also shed light on the cultural and technological developments of these early societies (Leavesley & Allen, 1998). On the other hand, the Kria site was found to have been occupied during the early Holocene-8000 years ago (Pasveer, 2004: 72). The modern human occupations in these two sites are supported by archaeological findings, including human fossils, bones and shell tools, stone artifacts, potteries, ecofacts, etc.

The study of the inhabitants of Papua has been a significant focus for various disciplines like anthropology, genetics, archaeology, and linguistics. Early researchers, such as Crawfurd (1848, 1856), Coon (1965), Birdsell (1972), and Bellwood (2017:257), used physical characteristics to categorize and define populations, often using terms like "Negritos". These classifications were part of early attempts to understand and categorize human diversity and migration patterns in the region. The study of the inhabitants of Papua has evolved significantly, moving beyond early physical classification to incorporate linguistic divisions and genetic research. Terms like "Australoid" introduced by Coon (1965) and later discussed by Bellwood (1985a), were used to describe certain physical characteristics observed among populations in the region. However, genetic studies, particularly those involving mitochondrial DNA (mtDNA) and Y-chromosome data, have provided new insights. Research by Kirk (1980) and others has suggested multiple human dispersal into Sahul (the ancient landmass that included New Guinea and Australia), with significant events occurring around 8,000 years ago (Kirk,1980, 1992). Genetic analyses of New Guineans and Australian Aborigines have highlighted distinct ancestral roots for these populations, indicating separate evolutionary paths despite their geographic proximity (Kayser et al. 2001:187).

Linguists such as Wurm S. (1975), Ross M. D. (1988,1989), and Foley W. A. (1986) have extensively studied the linguistic diversity of Papua (Palmer 2017:13), highlighting two major language groups: Papuan and Austronesian languages. The distinction between Papuan and Austronesian languages in Papua is based on various linguistic and grammatical features, as noted by Dunn et al., (2005). Papuan languages are predominantly spoken by groups inhabiting the inland or highland regions of Papua, with some also found along the coast (Wurm 1964; Foley 1986). This distribution highlights the geographical and linguistic diversity within Papua, where Papuan languages exhibit structural differences from Austronesian languages spoken in the lowlands and coastal areas. In comparison, Austronesian languages spoken in the lowlands of Papua are associated with cultural practices originating from the southern area of Taiwan (Solheim II 1994: 472; Blust 1999). This group is known for developing a suite of cultural innovations often referred to as the "Neolithic package" as documented by Bellwood et al., (2002). These innovations include pottery-making, the use of stone tools, the technology of outrigger canoes, and the practice of tattooing. This cultural complex spread as Austronesian-speaking peoples migrated through Island Southeast Asia and into the Pacific, influencing diverse societies along the way.

Howells (1976) described the regions of Sundaland, Wallacea, and Sahulland as an 'Old Melanesia'. This description builds on and modernizes the earlier viewpoints of anthropologists Carleton S. Coon. Howells (1973a:192) study presents a model of human population distribution and migration in the Pacific region, identifying a 'Modern Melanesia' province flanked by the populations of Southern Mongoloids who have settled in eastern Indonesia, Polynesia, and Micronesia since 3000 BC. The linguists including Stephen Wurm (1975), Malcolm Ross (1988), and William A. (1986) have utilized the terms 'non-Austronesian' and "Austronesian" speakers to describe the language group distributions spoken by the inhabitants of New Guinea Island and the surrounding areas in eastern Indonesia and Oceania. The linguistic diversity of New Guinea is immense, encompassing 862 distinct languages, not dialects, as noted by Palmer (2017: 13). According to Dunn et al. (2005), the Papuan and Austronesian languages are distinguished by their structural and grammatical features. These differences highlight the unique linguistic characteristics of each language family and provide insight into their distinct evolutionary paths. According to Foley (1986), the linguistic distributions in New Guinea encompass populations inhabiting both the highlands and lowlands of the island, as well as several nearby regions. These populations speak languages from both the Papuan phylum and the Austronesian language family. The regions include the island of Bougainville, the Solomon Islands, the Bismarck Archipelago, and parts of eastern Indonesia. In contrast, the Austronesian language is the group of languages that represents family members closely related and expressed like genealogy links passed by offspring from the oldest to

the most recent language. The Austronesian language family was argued to have originated in the society that occupied the southern area of Taiwan (Blust, 1999; Bellwood, 2002). It spread across a vast area encompassing the lowland parts of New Guinea, eastern part of Indonesia, Polynesia, and Micronesia (Tyron 2011: 13). Austronesian languages are spoken widely in coastal areas of Papua, Indonesia including the Birds Head region and the north coast. Blust (1978) and subsequent studies have documented the presence and distribution of these languages among the population in these pacific areas, highlighting highlighting their linguistic and cultural connections with broader Austronesian speaking communities across the region. The linguistic differences between Austronesian and non-Austronesian (Papuan) languages are supported by genetic evidence, which indicates a significant genetic divergence between these two groups.

During the Holocene time, Austronesian speakers originating from Taiwan spread across Oceania, including into Papua, as indicated by Bellwood (2017) and supported by linguistic distributions documented by Blust (1978). This culture was brought together in their migration outside of Taiwan, entering eastern Indonesia at about 3500 BP. The Austronesian speakers expanded the New Guinea area 3,000 years ago in the coastal area of New Guinea (Terrell & Kelly, 2001).This migration facilitated the spread of what is often termed the 'Neolithic package' – a complex of technologies and cultural practices such as agricultural, pottery-making, and domestication of plants and animals (Bellwood et al., 2006: 3). However, these Neolithic packages were not all been applied to the colony of Austronesian speakers, e.g., in the lowland part of Papua island, indicated through the limited evidence of the agricultural practices from this area. The evidence of palaeoecological data resulting from New Guinea's highland, for instance, taro, sugar cane, yams, and bananas. Palaeoecological data from New Guinea’s highlands indicates the presence of these plants in this area before the arrival of Austronesian speakers (Lebot, 1999; Ross, 2005).

A substantial effect originated from mainland and island Southeast Asia in the mid-to-late Holocene, establishing the Lapita cultural complex in the Bismarck Archipelago, particularly on the offshore islands of this area. Archaeologically identified as the Lapita culture, these people spread from Island Southeast Asia through the northern coast of New Guinea into the Bismarck Archipelago, particularly inhabiting offshore islands in this region. This migration is a key event in the prehistory of Oceania, reflecting cultural interactions and expansions across maritime Southeast Asia and into the Pacific Islands (Reith, & Athens 2019; Kirch 2021; Hill & Serjeantson, 1989; Bellwood, 2017). The Lapita culture is distinguished by ceramic design features, initially described by Father Meyer in 1909 in Watom Island (Jones & Spriggs, 2002: 278; Meyer, 1909). The term “Lapita” originates from the site of Lapita in New Caledonia and refers to the cultural complex

associated with these ceramics. The Lapita pottery were developed by the Lapita people in Admiralties to the Vitiaz Straits, eventually reaching the Bismarck Archipelago and New Guinea island about 100 BC to 500 BC (Spriggs, 2006: 119; Summerhayes et al., 2010a). Archaeological investigations, such as Lapita potsherds uncovered at the KLK site on Tuam island (Lilley, 2002), provided valuable insights into the movement of Lapita culture into New Guinea. Pottery sherds discovered at these sites have been dated to approximately 3612-2752 cal. BP (Reimer et al., 2013), confirming the presence and activities of Lapita-associated populations in these areas during the specified time period.

This dating evidence from Mussau Island supports, the spread of Lapita culture along the north coast of New Guinea and into the Bismarck Archipelago approximately 3350–3100 years ago (Kirch 2021; Reith & Athens 2019). Lapita pottery is distinguished by its various shapes adorned with elaborate dentate-stamped geometric motifs, reminiscent of designs found on tattooing chisels. These motifs are typically highlighted with a red slip coloration (Kirch, 1988b; Spriggs, 1991b). The intricate designs on Lapita pottery were created using techniques such as incising, applying, and impressing decorations onto the vessel surfaces, often using tools made from perishable materials. In the island of New Guinea, Lapita pottery has been discovered along the south coast dating to around AD 200, according to Irwin (1991), and in the north coast area and Madang Province, as documented by Lilley (1988). These findings contribute to our understanding of the spread and cultural dynamics of the Lapita complex across the region during the prehistoric period.

Lapita culture is associated with a range of cultural elements beyond its distinctive pottery decorations. These include tools such as shell adzes, polished stone, chert-flake tools, and obsidian artifacts, as well as items like shell fish-hooks, CONUS-shell disks and pendants, scrapers, pearl-shell knives (Spriggs, 2006). Despite these archaeological findings, there remains a lack of direct evidence linking the initial Lapita settlers with Indigenous New Guineans. This gap limits our understanding of the interactions and influences between these populations during the early phases of Lapita expansion.

The revolutionary progress in science and technology have significantly advanced scientific research, particularly in genomic studies related to human history, origins, migration patterns, and behavior. Scholars have utilized mtDNA and Y-chromosome analysis to uncover important insights into these aspects, particularly in the context of New Guinean populations. Studies referenced by Pedro et al. (2020), Kayser et al. (2002, 2003, 2006), and Mona et al. (2007) have contributed extensively to our understanding of genetic diversity, ancestral origins, and population movements in Papua New Guinea and Indonesia. These studies often use genome-wide markers to trace maternal (mtDNA) and paternal (Y-chromosome) lineages, revealing patterns of migration, genetic

admixture, and cultural interactions over millennia.. The genetic studies on Papuan populations, particularly focusing on mtDNA and Y-chromosome lineages, have provided significant insights into the genetic diversity and historical dynamics of these regions. For instance, studies have compared populations from Papua-Indonesia, and Papua New Guinea, revealing distinct patterns of Y-chromosome diversity. In Papua Indonesia, a study involving 183 samples from 11 regional populations showed lower Y-chromosome diversity compared to Papua New Guinea with 131 individuals. Four main Y-chromosomal haplogroups were identified M-M4, K-M230, C-M208, and C-M38, with a total of 94% (Kayser et al., 2003: 1). This indicates a dominance of specific Y haplotype lineages among the populations in this area. The Y-chromosome lineages associated with haplogroup M-M4, was significantly prevalent among highlanders including Una clan, Yali, and Ketengban who spoken Papuan language (Kayser, 2010). Studies on NRY (non-recombining Y-chromosome) variation and mtDNA (mitochondrial DNA) in the Papuan population have revealed interesting patterns of genetic diversity and complexity. Research by Bergstrom et al (2016, 2017) and Mona et al. (2009) has shown that paternal lineages (Y-chromosome) tend to exhibit more diversity and complexity compared to maternal lineages (mtDNA) among Papuan populations.

The ongoing efforts to sequence human genomes from Papua and other regions provide crucial insights into human history, particularly in understanding the genetic diversity and evolutionary processes in these areas. Similar studies, such as ancient DNA (aDNA) analysis from human fossils in Siberia, have contributed significantly to our understanding of human migrations and interactions. For instance, aDNA analysis has revealed admixture signals and genetic continuity patterns that support multiregional models of human evolution. These findings, as highlighted by Stoneking (2016), suggest that genetic continuity over time in certain regions, including Southeast Asia and Oceania, reflects ancient population interactions, migrations, and adaptations. The discovery of Denisovan remains, including the “pinky” bone found in South Central Siberia, has provided fascinating insights into ancient human migrations and interactions. DNA analysis of these remains has revealed that modern populations in New Guinea, Aboriginal Australians, Eastern Indonesians, Filipinos, and Oceania, including Polynesians, carry genetic traces derived from Denisovans. Studied by Reich et al. (2010, 2011), Vernot et al, (2016), and Jacobs et al, (2019) have estimated that approximately 3-6% of the genomes of these modern populations can be traced back to Denisovan ancestry.

The mtDNA studies conducted among populations in Southeast Asia and Oceania have provided valuable insights into ancient maternal lineages and their origins. Research by Friedlander et al. (2007) has confirmed the presence of haplogroups P and Q, which are predominant among populations in this region, with their development estimated to have occurred during the Pleistocene

time, roughly between 30,000 to 50,000 years ago. Three specific mtDNA lineages characterized by substitutions at positions 16176, 16266, and 16357 have been widely distributed in Southeast Asia and Oceania. The position at 16357 is particularly noteworthy, with frequencies varying across different populations. For example, among the highlanders of New Guinea, it is found in approximately 25% of individuals, while among the Andaman Islanders, it appears in about 50% of the population (Hagelberg, 2001:173). The mtDNA findings among New Guinea's highlanders suggest that this group descended from early waves of immigrant who arrived on the island during the Pleistocene period and subsequently inhabited the highlands (Hagelberg, 2001: 173).

The genetic markers between highlanders and lowland populations in New Guinea indeed reflect significant differences, which can be attributed to their distinct evolutionary histories and adaptations to different environmental conditions. The 9 base pair deletion within the fourth subgroup within B (B4a1a1) (Trejaut et al., 2005; Mirabal et al., 2012), known as a 'Polynesian motif,' shows its highest frequency in populations from Southeast Asia, as well as among populations inhabiting the lowland aras of New Guinea, Near and Remote Oceania. The 'Polynesian motif' genetic markers, shows a high frequency 85% - 100% among populations in Polynesia. However, this genetic marker is notably absent in populations that historically occupied New Guinea's highlands (as noted by Stoneking and Wilson, 1989) as well as in populations from the Philippines, Borneo, and Taiwan. The presence of the mtDNA haplogroup B4 in Polynesian populations indeed provides important clues about their recent expansions from Southeast Asia. The nine base pair deletion, associated with haplogroup B4, is believed to have originated in East Asia. This genetic marker has been found in populations dispersed widely across the Pacific, from Madagascar to Easter Island, indicating extensive migrations and settlement patterns originating from East Asia. Studies by Wrischnik et al. (1987) and Stoneking & Wilson (1989) have contributed to our understanding of how these genetic markers trace the movements and expansions of ancient populations across vast distances in the Pacific region.

The geographical characteristics of New Guinea's Highlands likely played a role in shaping the distribution of mtDNA haplotypes in this region. Evidence from studies, such as those by Redd and Stoneking (1999), suggests that mtDNA restriction site polymorphisms among people inhabiting the Eastern Highlands of Papua New Guinea show low variation. This low variation can be indicate of factors such as geographic isolation, limited gene flow, or specific historical population dynamics that have influenced the genetic diversity in this particular area (Stoneking et al., 1986a: 96). Related to Australian Aborigines and New Guineans, the genetic dissimilarities observed between them provide strong evidence for multiple origins of modern human migrations

into Sahul. Studies, such as those by Redd and Stoneking (1999), highlight significant genetic differences between these populations, suggesting separate and distinct ancestral origins.

The seminomadic lifestyle of populations in New Guinea likely influenced genetic patterns, as supported by studies analyzing hair samples from various regions. Tommaseo-ponzetta et al. (2002) conducted hair sample analyses on 202 individuals from the central and southwestern highlands of West Papua and the Arafura coastline area. This research likely aimed to explore genetic diversity and structure among these populations, possibly revealing genetic markers indicative of mobility patterns, gene flow, or regional adaptations. In present time, several groups in New Guinea, including those in the central and southwestern highlands of West Papua and the Arafura coastline area, speak languages belonging to the Trans-New Guinea language phylum. This phylum is a major branch of the broader Papuan language phylum, which encompasses the vast majority of languages spoken in New Guinea. The application of mtDNA analysis using enzymatic digestion with proteinase K from hair roots, as conducted by Tommaseo-ponzetta et al. (2002), revealed a high frequency of mtDNA variability among populations in the central and southwestern highlands of West Papua and the Arafura coastline area. This variability is attributed to admixture events involving small groups of semi-nomadic peoples in these regions (Tommaseo & Attimonelli, 2002: 58). In the lowland areas of New Guinea, evidence of genetic exchange and shared haplotypes between populations is more pronounced. This phenomenon is largely attributed to the practices of semi nomadic riverine populations. These groups often relocated seasonally, facilitating frequent interactions and exchanges with neighboring communities. The study by Tommaseo and Attimonelli (2002) highlights how the mobility and social practices of riverine populations in lowland New Guinea contribute to genetic exchange. Such movements and social interactions have historically played a significant role in shaping the genetic landscape of the region, fostering diversity and interconnectedness among different groups.

The island of New Guinea is home to two distinct populations: pre-Austronesian and Austronesian speakers, as has been widely studied. Since they arrived and occupied the same island of New Guinea, the interaction or contact between them may have occurred. This interactions have created a complex genetic, cultural, and linguistic in the region, highlighting the dynamic history of migration, settlement, and cultural exchange. The admixture between pre-Austronesian (Papuan) and Austronesian speakers is also reflected in linguistic aspects, particularly in the counting systems used by speakers of the Papuan phylum and Trans-New Guinea languages in the Bird's Head and north coast regions of Papua, Indonesia. The adoption of counting system by pre-Austronesian (Papuan) groups from Austronesian speakers is well-documented and illustrates the significant

linguistic influence resulting from historical interactions. This evidence is highlighted in the works of Laycock (1973a, 1973b), Wurm (1982), Owens et al.(2017).

The interaction between pre-Austronesian and Austronesian speakers is also evident in the material culture, particularly through the appearance of pottery. The discovery of Lapita pottery, characterized by red-slip and human-face designs, in lowland areas of New Guinea and across Melanesia, provides significant evidence o Austronesian influence. This interaction is well-documented in the works of Pawley & Green (1973) and Bellwood (1978) underscore the significance of these findings in understanding the complex interactions and exchanges that shaped the material culture of the region. Lapita is derived from the name of an archaeological site in New Caledonia (Moore, 2003:34). Pottery-making traditions among Papuan speakers such as those of the Abar tribes in Sentani Lake and the Tobati tribes in Humboldt Bay, provide valuable insights into local cultural practices. These traditions often reflect distinct regional styles, techniques, and the cultural significance of pottery in daily life, rituals, and social contexts. The presence of non-dentate-stamped pottery among Papuan speakers, developed before the arrivals of the Lapita culture in New Guinea, suggests longstanding indigenous pottery traditions that predate Austronesian influences. This evidence indicates that Papuan speakers had established their own-pottery-making techniques and styles prior to any significant interaction with Austronesian cultures (Spriggs, 2006).

The relationship between ancestry and teeth has been a significant focus of dental anthropologists, with extensive studies examining various aspects such as dental morphology, genetics, and evolutionary implications. Studies referenced by Haeussler (1998); Hanihara & Ishida (2005), Harris & Rathbun (1991), Hemphill et al. (1998), Irish (2006), Lukacs (1998), Scott & Turner (1997) contribute to our understanding of how dental traits can provide insights into population history, migration patterns, and genetic diversity among different ancestral groups. Dental anthropology emerged from early studies of population-based dental morphological variation, influenced by works such as Dahlberg (1963, 1971) and Hrdlicka (1920). The discipline applies method to study the shape and size of crown and rooth teeth, as explored by Kieser (1991), Scott and Turner (1988), Scott (1991a), and Townsend et al., (1994). Researchers categorize dental traits into metric and nonmetric types, assessing their frequencies across populations, typically classified as high, intermediate, and low levels.

The geological history of New Guinea as part of Sahul during the Pleistocene suggests a shared ancient landmass with Australia and Tasmania. This historical connection implies a potential for common ancestry and genetic affinity among populations inhabiting these regions. However, studies analyzing dental traits from nine individuals on the New Guinea island indicate distinct trait frequencies compared to Aboriginal population in Australia. This differentiation could reflect

unique evolutionary paths, environmental adaptations, or historical factors influencing dental morphology and genetic diversity between these regions despite their shared geological history. The similarity in dental traits, such as shoveling, 4-cusped traits on the mandibular second molar (LM2), and cusp six on the mandibular molar (LM) between New Guinea populations and European dentition suggests a shared common ancestry in dental morphology. These traits, was found aligned more closely with European dental patterns than with Australian Aboriginal populations. This coherence supports the idea of historical connections or genetic influence that have shaped dental morphology in both regions, despite their geographical separation and distinct evolutionary paths since the Pleistocene. The study by Itou and Matsuno (2011) examining 17 crown traits from the highlands of New Guinea highlights a disconnect between dental traits in New Guineans and Australian Aboriginal populations. This divergence suggests significance differences in dental morphology between the two populations, despite their geographic proximity and shared history as part of Sahul in the Pleistocene. In parallel with this, the result of dental comparison between New Guinean, 13 (thirteen) Sinodont samples, and 17 (seventeen) samples from Sundadont groups highlights significant dissimilarity among these groups. However, there are notable similarities between New Guineans and Australians, particularly in the high frequency of cusp seven on the upper molars. Interestingly, New Guineans show a divergence towards the simplified crown pattern observed in Europeans for some traits. At the same time, they retain more complex dental traits that are common in Australian Aboriginal populations. This pattern reflects the complex evolutionary history and genetic interactions influencing dental morphology in the region as discussed by Scott & Schomberg, (2016).

In an attempt to cluster the populations based on the human group affinity, the researchers have applied several methods to classified the group of populations in this world based on the teeth trait characters were the Australo-Papuan, African, European, Asian, and Asian was grouped in the same branch of the cluster (Hanihara, 1996). Clustering methods can help researchers understand how these groups may share certain dental characteristics, reflecting their evolutionary and genetic relationships. In studies of modern humans in New Guinea, particularly focusing on the metric and nonmetric characteristics of human teeth, researchers have found interesting patterns. Specifically, among populations from the eastern part of the Highlands in New Guinea, there is a notable absence or low frequency of dental traits typically associated with Asian populations. This suggest that the dental morphology of these New Guinean populations differs significantly from that of Asian groups. Brace and Hinton (1980a,1981) proposed a theory regarding the extension of Southern Mongoloid populations, suggesting that the advancement of agriculture led to a reduction in average tooth size among these populations. They hypothesized that the Austronesian groups, characterized

by smaller teeth, spread into Indonesia through the Philippines. This migration event, according to their theory, resulted in the replacement of earlier populations in the region, such as larger-toothed Australians and Melanesians and established the theory that agriculture's advancement has decreased the teeth' average size. The soft foods resulted from the food processing by the use of pottery-jar by the Southern Mongoloid was considerate could relax the selection pressures large teeth. In Papua's highlands, the indigenous people practiced no pottery culture for food processing; their teeth were still classified as having big teeth. The evidence supporting this view points to dental gradients observed across different populations. Southern China is noted for having populations with smaller teeth, while larger teeth are more prevalent in Australia and New Guinea. This gradient suggests variations in dental morphology across geographical regions. Brace et al. (1991) proposed a model based on these observations, suggesting that small-toothed Southern Mongoloid populations from Southern China migrated into Indonesia and the Philippines. They hypothesized that these Southern Mongoloid groups replaced earlier populations characterized by larger teeth, which they term the 'Australo-Melanesian Cluster'. Overall, this model underscores how dental morphology can reflect populations dynamics, migrations, and the interplay between genetic heritage, cultural practices, and environmental factors over time.

The study conducted by Doran and Freedman in 1974 on tooth size among populations in the PNG highlanders, specifically in Lufa-eastern Highlands and Wabag provided insightful findings including the tooth size of PNG highlanders was characterized as megadont, indicating larger teeth compared to samples from the islands of Melanesia. In contrast to Australian samples, the tooth size of PNG highlanders fell into the middle range (Harris and Bailit, 1987). This suggest that while PNG highlanders have larger teeth than Melanesian populations, their dental characteristics are intermediate compared to Australians. The studies by Pietrusewsky (2006) involved 24 cranial measurements of male groups from New Guineas, Australians, and Melanesians. The results showed clustering among these groups, indicating similarity in cranial characteristics. Hanihara et al (2003) study focused on 20 nonmetric cranial traits across 70 samples from various populations in Asia. They found similarities in cranial traits between populations from New Guinea, Melanesia, and Australia. These studies provide evidence of cranial similarity among populations from New Guinea, Melanesia and Australia. The study by Itou and Matsuno (2011) analyzed the dentition of New Guinean populations and compared it to 31 Asian populations. Their findings revealed distinct characteristics in the New Guinean dentition. The Sinodonty and Sundadonty are dental traits found in Asian populations. Itou and Matsuno's study found that New Guinean dentition did not exhibit these characteristics traits observed in Asian groups. In contrast to Australian dentition, the New Guinean dentition showed simplified morphological characteristics.

This suggests that New Guinean populations have unique dental features that differentiate them from both Asian and Australian populations.

The analysis of dental traits among New Guinea samples, as conducted by Scott and Turner in 1997, initially suggested a clustering with Western Eurasian populations based on 23 crown and root traits. Western Eurasians typically include populations from Western and Northern Europe, as well as North Africa. However, subsequent studies and additional samples have produced varying results. Scott and Schomberg (2016) applied clustered methods that incorporated samples from South Asia and Africa. Their findings indicated that New Guinean samples no longer clustered with European populations. This suggests that the initial clustering with Western Eurasians might be influenced by specific dental traits that are not universally shared across all populations.

The concept of Sahulland during the Pleistocene period, which connected Australia and New Guinea as a single landmass, does suggest the potential for genetic similarity among populations inhabiting this region. However, studies carried out by Scott and Turner in 1997, indicate that the dental traits of these populations do not necessarily reflect a close genetic relationship. It was suggested that a distant relationship between the dental characteristics of Australian and New Guinean populations. They hypothesized that this divergence could be due to extensive genetic drift, particularly in isolated mountain valleys of New Guinea. The studies by Scott and Schomberg in 2016 the findings of dental dissimilarity between Aboriginal Australians and New Guineans. This suggests that despite historical and geographical connections, these populations exhibit distinct dental characteristics. In the highlands of Papua, specifically among the Kassi villagers, Asian-Mongoloid dental traits such as shoveling, deflecting wrinkle, protostylid, cusp 6 and cusp 7 were reported to have low frequencies. This indicates that while there may be some presence of Asian-Mongoloid dental traits in Papua's highland populations, they are not prevalent and do not dominate the dental morphology as seen in other Asian-Mongoloid populations. Kanazawa et al. (2000) conducted a comparative study examining nonmetric dental traits among Papua New Guinea Highlanders, Asians, and Pacific populations. The results demonstrated a lower frequency of Asian dental traits in the highlanders of Papua New Guinea. This low frequency of Asian dental taints in the highlanders of Papua New Guinea aligns with linguistic evidence, as indigenous highlanders predominantly speak languages from the Papuan phylum rather than Austronesian languages, which are more common among populations with higher frequencies of Asian dental traits. This correlation between dental morphology and language distribution suggest a distinct evolutionary and cultural history of the highlanders, separate from that of Asian and Pacific populations. In attempt to understand human group affinity, researchers have used various methods to classify populations based on dental trait characteristics. Howell (1989) and Hanihara (1996) applied

clustering methods based on teeth trait characteristics, grouping Austromelanesian, African, European, and Asian populations in the same branch of a cluster. This suggests shared dental traits and possible historical connections among these groups. In a different approach, Scott and Turner II (1997) found that New Guinean populations clustered with Western Eurasian populations, which include Western Europe, Northern Europe, and North Africa. This clustering was based on cranial dimensions and genetic markers, indicating similarities in these features between New Guineans and Western Eurasians. These contrasting results from different methods underscore the complexity of human population studies. The clustering of New Guineans with Western Eurasians based on cranial and genetic data might be due to unique evolutionary pressures, genetic drift, or historical migrations that have influenced these populations differently from those in the Austromelanesian cluster based on dental traits.

Chapter 3: Materials and Methods

3.1 Materials

In this study, the human dental materials represent the lowland-coastal populations from the Papua-Indonesia region (Figure 1). The examined dental remains were found in the five different archaeological sites: Mamorikotey, Karas, Srobu, Namatota, Yomokho. These sites were dated using charcoal analysis, placing them in the Late Holocene period. Additionally, dental remains from two other sites, Kayu Batu and Biak-Sowek, were unearthed from the four caves in the northern coastal area. The Kayu Batu sites have never been through a dating process before; however, based on grave goods such as glass beads, jewelry made from shells, and animals-teeth, these two sites suggests that these sites represent the Eighteenth Century (Figure 2).

Figure 1*: Archaeological site distribution in this study. 1: Mamorikotey, 2: Karas, 3: Namatota, 4:Biak, 5: Srobu, 6: Kayu Batu*

The assumption that the Kayu Batu and Biak-Sowek sites date back to the eighteenth century is based on the presence of trade goods such as glass beads and ceramics which introduced and used by Chinese traders in coastal Papua in the early eighteenth century, primary for trading

Massohi trees and other local goods (d'Urville 1853; Reisenfeld 1951). These trade goods also suggest a certain level of social stratification and ceremonial context among the indigenous Papuan populations in the lowland areas.

***Table 1**: Dating sites in this study derived from the Charcoal sample analysis*

Sites	Dating	Samples dating	Sources
Karas	3400 BP	Charcoal	Suroto, 2012 & Mas'ud 2013
Yomokho	2590± 120 BP	Charcoal	Suroto, 2016
Mamorikotey	2520± 50 BP	Charcoal	IHME-3995/Current Study
Srobu	1720 BP	Charcoal	Djami, 2020
Namatota	110± 40 BP	Charcoal	IHME-3994/Current Study
Biak-Sowek	Eighteenth-century	Glass-beads	Current Study
Kayu Batu	Eighteenth-century	Glass-beads	Current Study

The human teeth samples from the seven archaeological sites are categorized into two distinct temporal groups: the Late Holocene and the Current-Era. The Late Holocene group comprises 61 teeth, while the Current-Era group, which includes samples from Biak-Sowek and Kayu Batu, consists of 249 teeth. The teeth data in this study has never been studied before. Teeth from the group Late Holocene have been written in the preliminary research report in Balai Arkeologi Papua, but have never been analysed and published in a scientific journal. At the same time, the teeth from the group of Biak-Sowek & Kayu Batu which represented the Current Era group, were done in this study project and have never been reported before. The radiocarbon and AMS dating for Late Holocene in the three sites (Srobu, Karas, and Yomokho) have been done within the field project of Balai Arkeologi Papua (Regional research for archaeology in Papua/Ministry of Education and Culture Republic of Indonesia). Whereas two samples: Namatota and Mamorikotey, were done in this study project was performed using OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal 13 atmospheric curve (Reimer et al., 2013). Four samples from Biak group have been dated where the results show the age range between 291.404 – 122.091 (Table 2). The descriptions of the teeth from the seven sites will be explained in the following paragraph.

***Table 2**: Dating results of four individuals from Biak Island (Source: Kathrin Nägele 2021) Curt-Engelhorn-Zentrum Archäeometri gGmbH, Mannheim-Germany*

Sampe Number	User_label	Samples dating	C14 age
51981	2 - ISD001	Molar tooth	282,157
51983	4 - SWM002	Molar tooth	291,404
51984	5 - SWU001	Molar tooth	122,091
51985	6 - YEN001	Molar tooth	226,152

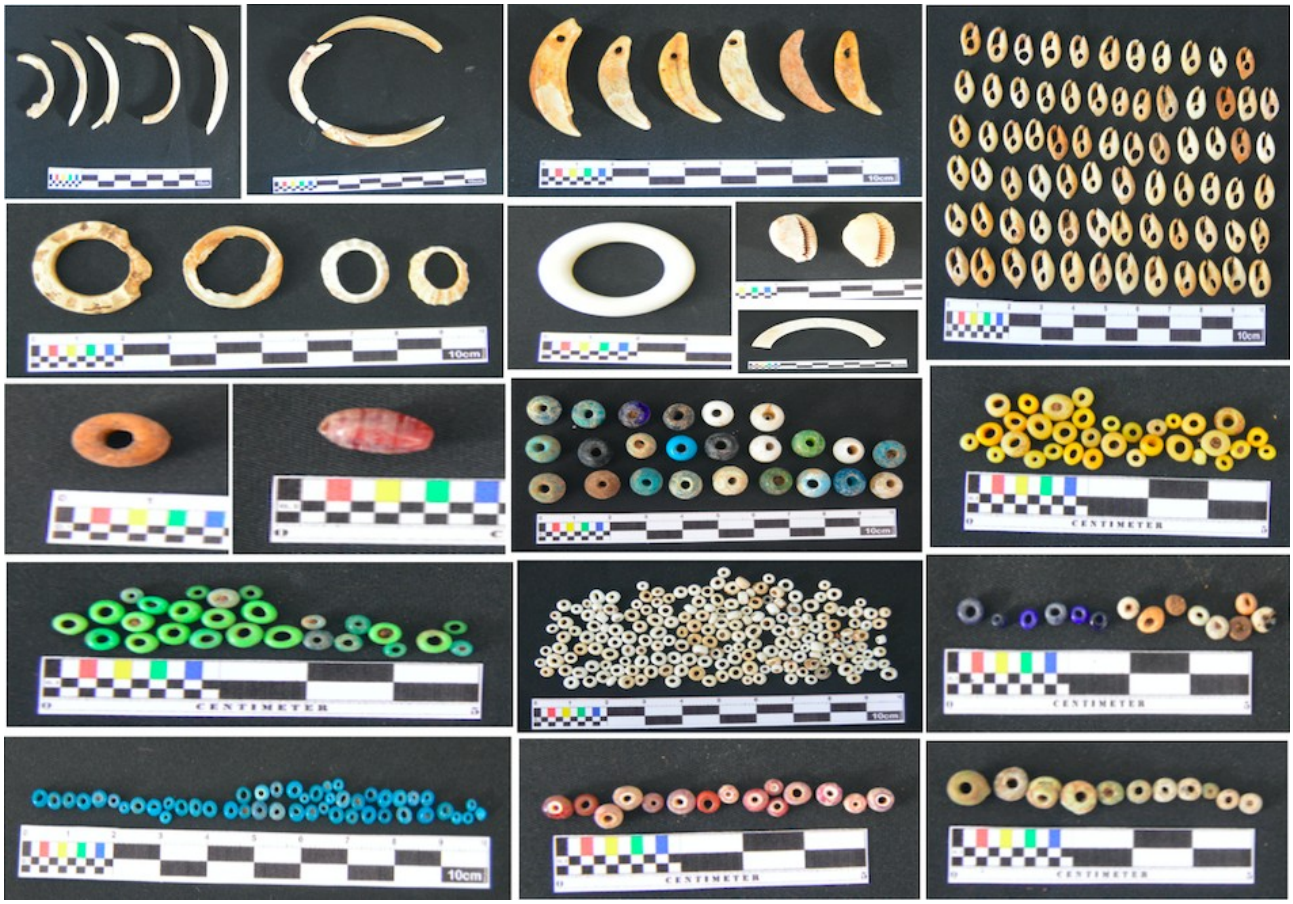


***Figure 2**: Grave goods were found in the Kayu Batu and Biak-Sowek Sites. Top to down: the first row from left to right: sea-shells bracelet, jewelry made from canines dog-like (?), jewelry made from sea-shells. The second row left to right: the first and second column is the sea-shells bracelet. The third, four, and five columns, from left to right rows: glass-beads with different shapes, forms, sizes, and colors.*

3.1.1 Mamorikotey

Mamorikotey (Figure 1) is an open site is situated at coordinates S.3073667º; E 135.590278º on Kapotar Island, Nabire Regency. It is in a hilly area at 75 m above sea level (asl) and about 20-30 m horizontally from the shoreline. Three square-meter excavation boxes were opened on the site

named MMK1, MMK2, an MMK3. These boxes were excavated in ten-centimeter spits. Fragmentary human remains were found in all three excavations. MMK1 is located 18m southwest of MMK2, while MMK3 is positioned 15 m east of MMK1 (Figure 3). Ten identified human teeth from the Mamorikotey site employed in this metric study. In the MMK/Ktk01, four human teeth (MMK/405/LP, MMK/78/UI1, MMK/49/LC, and MMK/79/UI2, (Figure 4) were found ninety cm from the string level. Two teeth from the Mamorikotey site, including a lower premolar (MMK_333) and lower molar (MMK_419), from two different humans were selected for enamel apatite in this study.

Figure 3*: Excavation activity in Mamorikotey site. Upper-left: MMKktk1/, upper-right: MMK/ktk2, lower-left: MMK/ktk3, lower-right: screening during excavation.*

The lower premolar (MMK_333) was discovered in MMK3 at a depth 25 cm. The sediment at this depth was described as dark brown, wet, and fine in texture. Alongside MMK_333, the excavation yielded human incisors, pottery fragments, shells, marsupial teeth, seeds, the femur of a pig, molar teeth, fish bones and teeth, and several unidentified animal bones. A charcoal sample was radiocarbon dated to 2520±50 BP (IHME-3995) from MMK3 at a depth of 115 cm, providing a

maximum possible age for MMK_333. The charcoal was found associated marine shells and pig bones. The lower molar (MMK_419) was found in MMK1, at 35 cm from the surface. The sediment associated with this depth was dark brown, moist and fine in texture with a ph of 7. The radiocarbon dates have yet been obtained from the MMK1 excavation unit, post-dates 2520±50 BP.

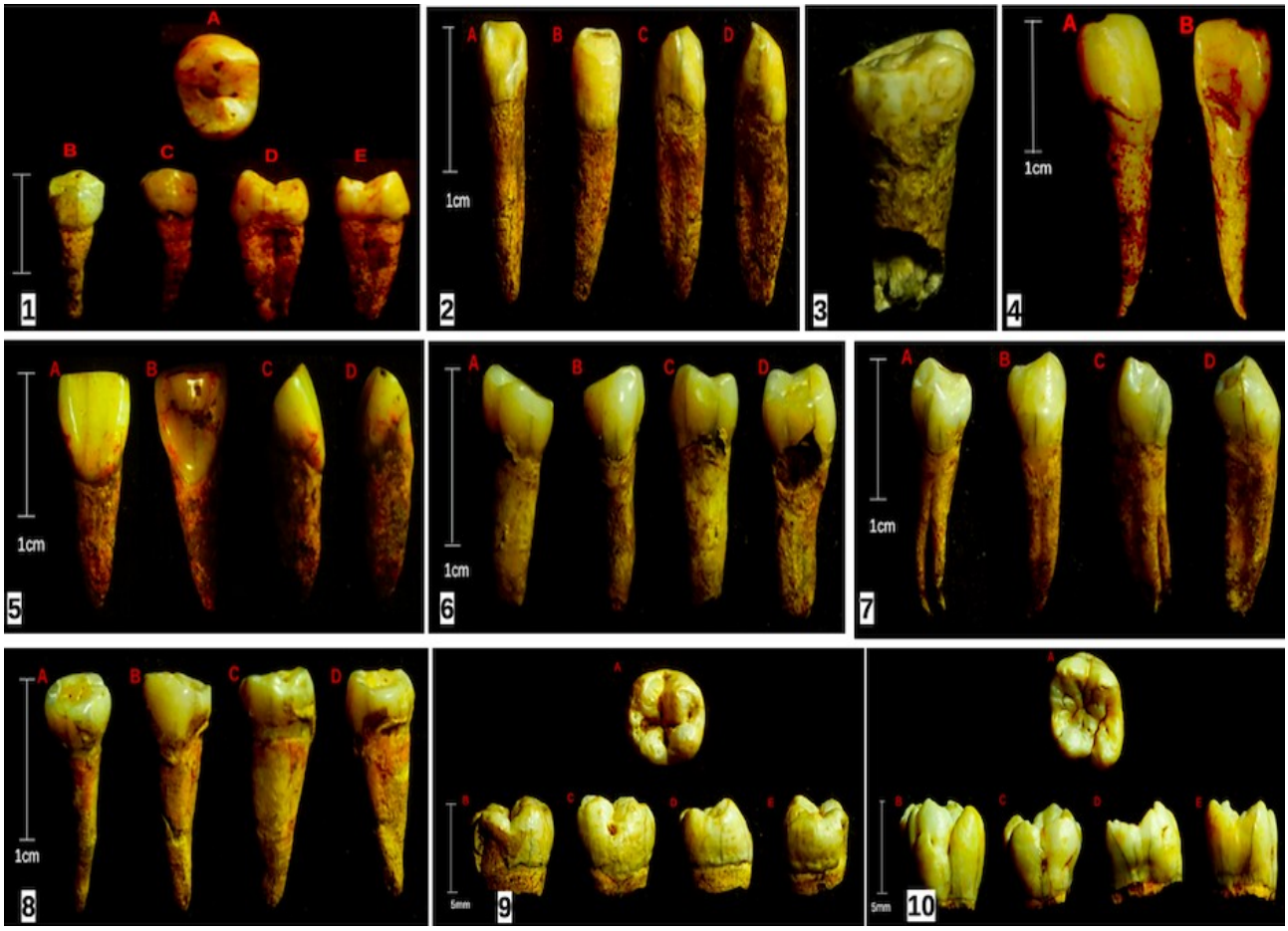


Figure 4*: E (distal view); 2:MMK/49/LC/ A (lingual), B (buccal), C (mesial), D (distal); 3:MMK/640/LP1; 4:MMK/79/UI2. A (labial), B (Lingual),C (Mesial), D (distal); 5: MMK/78/UI1. A (lingual), B (buccal), C (mesial), D (distal);6: MMK/405/LP1. A (lingual), B (buccal), C (mesial), D (distal); 7: MMK/332/LP1. A (lingual), B (buccal), C (mesial), D (distal); 8: MMK/333/LP2. A (lingual), B (buccal), C (mesial), D (distal); 9: MMK/419/LM2. A (Occlusal), B (Lingual), C (Buccal), D (Mesial), E (Distal); 10: MMK/638/UM1. A (Occlusal), B (Lingual), C (Buccal), D (Mesial), E (Distal)*

3.1.2 Yomokho Site

Yomokho is an open site situated along a hill on the north coast of Lake Sentani in Jayapura Regency (S 2.590125º; E 140.610278º) (Figure 5). At Yomokho, two excavations unit were opened in this site. The first unit was open on the top of the hills/ It is situated at the northeast part of second unit. The human remains in this study were found in the second unit include Ymk/1-R

(radius), and Ymk/2-P (phalange) bones. These bones were selected for collagen stable isotope analysis. Ymk/1-R was discovered at a depth 54 cm below the surface, and it was associated with mollusks and pottery fragments (Figure 6). The sediment associated with the Ymk/1-R was dark brown in color, with a grain size ranging between 2-0.02 mm, reflecting a sandy loam. On the other hand, Ymk/2-P was found associated with pottery fragments at 135 cm. The sediment at this depth had a finer grain size size ranging from 0.02-0.002 mm. One radiocarbon determination is available for this site, based on charcoal that dates to 2590±120 BP (Suroto, 2016:1). Two human mandible jaws (Figure 7 and 8) were found in the Yomokho site. The lower left jaw was discovered on the cliffs of the Yomokho site, with half of it partially buried in the hills-walls (Figure 7). Two teeth were preserved: the lower left second premolar (LLP2) and the lower-left first molar (LLM1). The crown of the second premolar is lost, leaving only the root part intact. Whereas in the first molar, the crown part is still present. However, it shows signs of wear, including loss of the crown, dentin, and pulp areas. From the morphology characters, the jaw exhibits typical of male adult, based on the shape of the chin with the square shape and robust appearance, which is a common trait observed more frequently in males than females. Charcoal found in the same layer as Ymk/2-O has been dated using radiocarbon methods, providing an approximate age for that specimen. Ymk.1-R found in upper spits, where radiocarbon dating has not yet been conducted. However, given the dated charcoal and the stratigraphic context, it's inferred that Ymk/1-R dates layer 2590±120 BP.

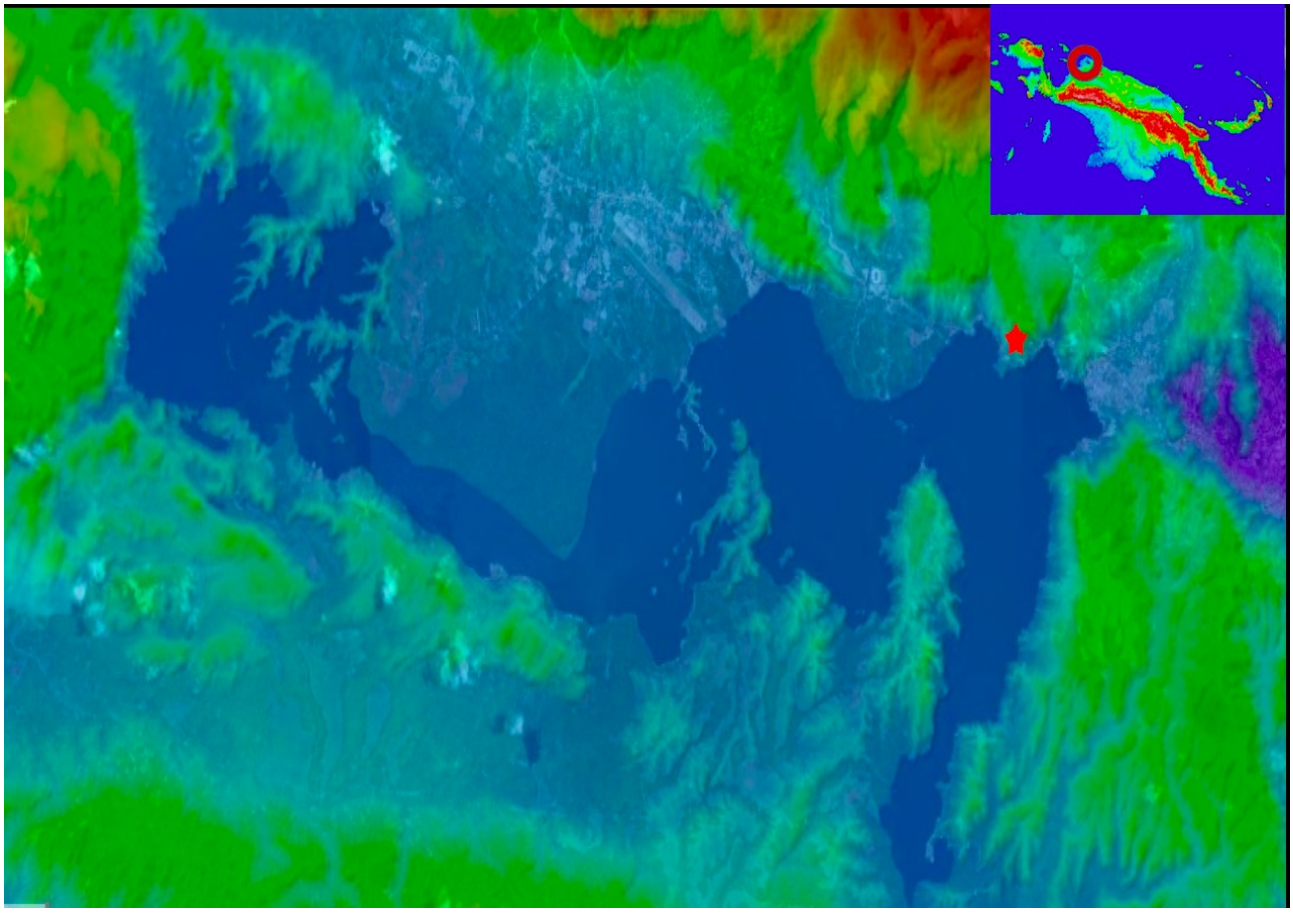


Figure 5*: Yomokho site in Papua Map. The star (red) sign shows the Yomokho site's location in Lake Sentani bay, Jayapura.*

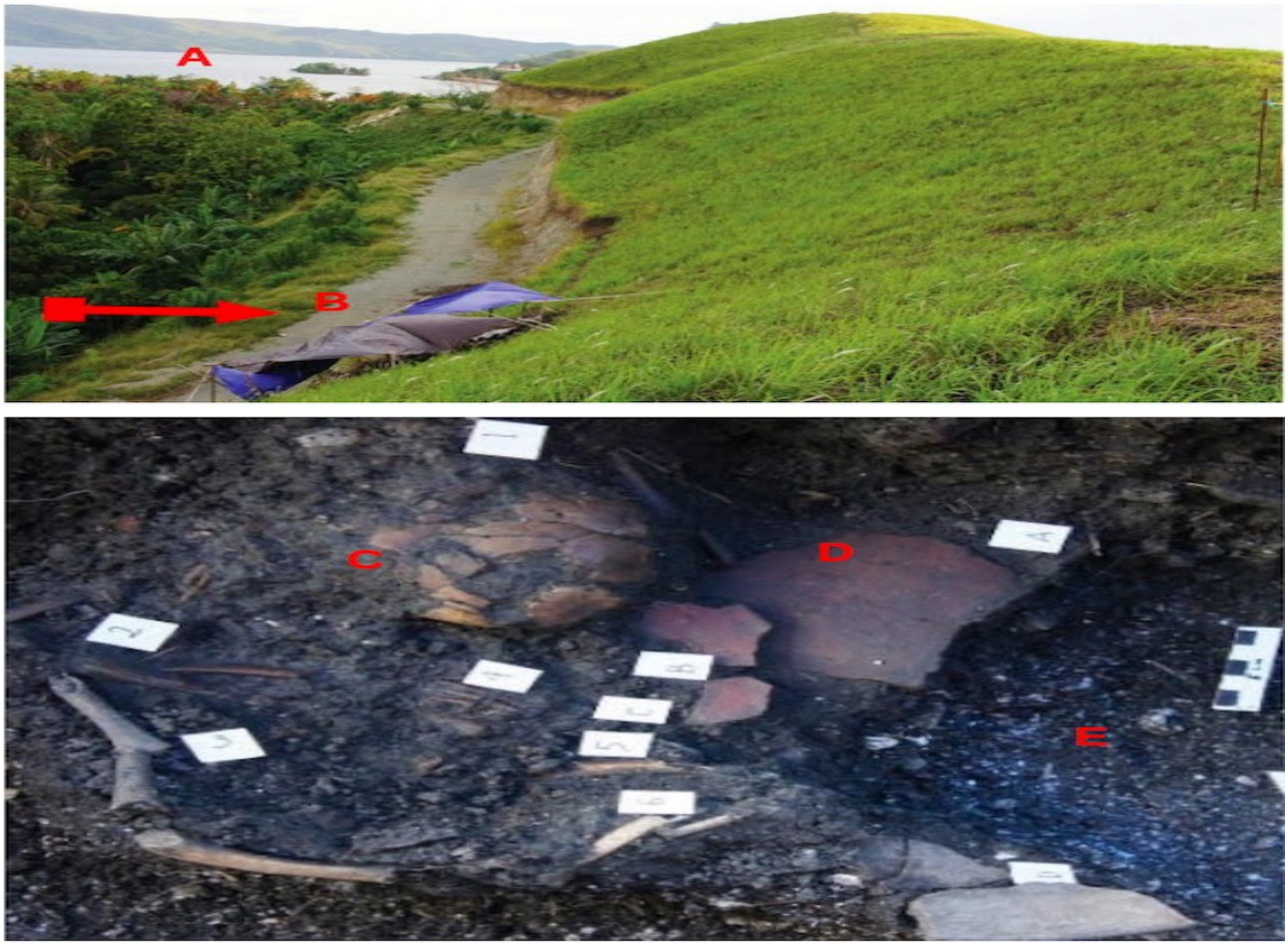


***Figure 6**: The situation of Yomokho site in Lake Sentani bay. A: the water surface, B: the excavation-box, C: Human cranial encountered in the soil layers associated with shells and potteries fragments, D: vessel fragment.*

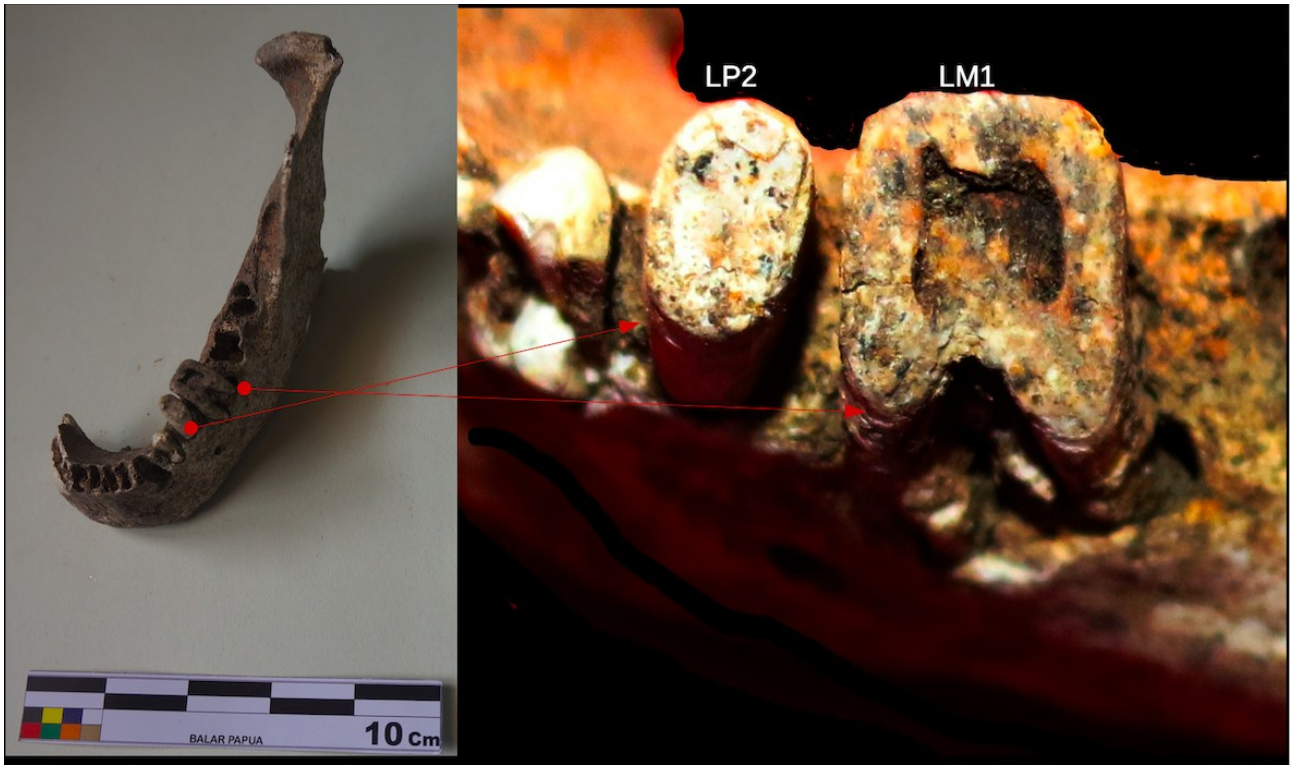


***Figure 7**: Lower left jaw from Yomokho site. Two teeth are present in this jaw, second premolars and first molar*

***Figure 8**: Lower jaw. The left second molar present at the front of third molar. The red star sign signified that there is no third right molar yet present as sign of juvenile individual*

3.1.3 Karas

Karas cave, located in the Arguni District of Kaimana Regency, Papua Barat Province, Indonesia, is situated at S 3.306583º; E 133.750556° longitude. The site is positioned about 45 m asl on a hill in the Arguni Bay area (Figure 9). Rock art with various paintings of figures such as anthropomorphs, fish, geometric, circles, pyramids, grids, and unidentified paintings were found on the cave walls (Mas'ud, 2013).

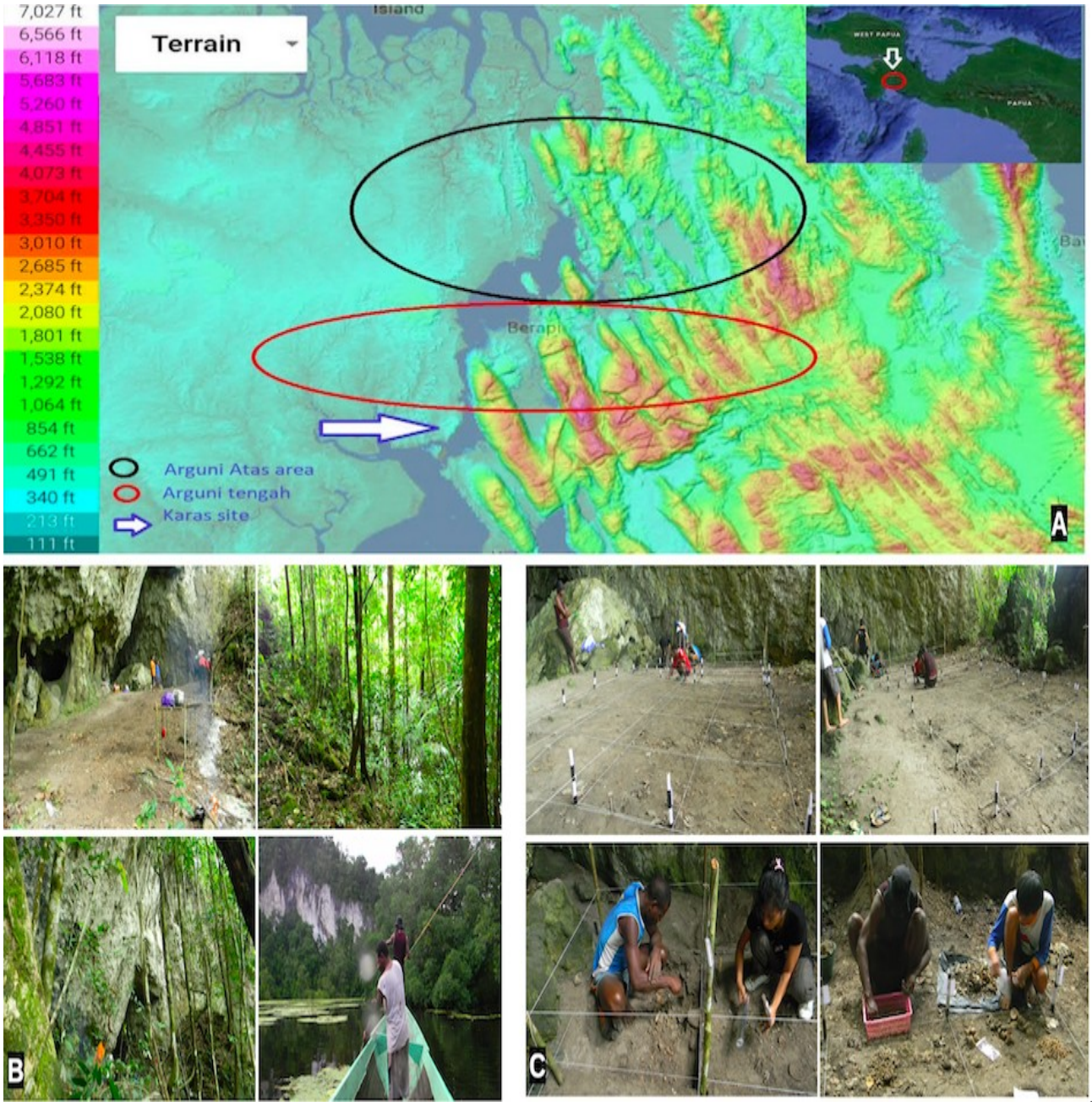


***Figure 9**: A. The location of Karas site in the Arguni bawah area, Kaimana, south lowland of Papua. The environment situation of Karas site. C: the excavation activities in Karas site together with Indigenous Papuan who occupied the Arguni bawah area.*

A research team from Balai Arkeologi Papua excavated this site in 2012 and 2013. The archaeologists focused on three boxes including GKQ1 (I6), GKQI (F5), and GKQ1 (F6) were located in the same sector.

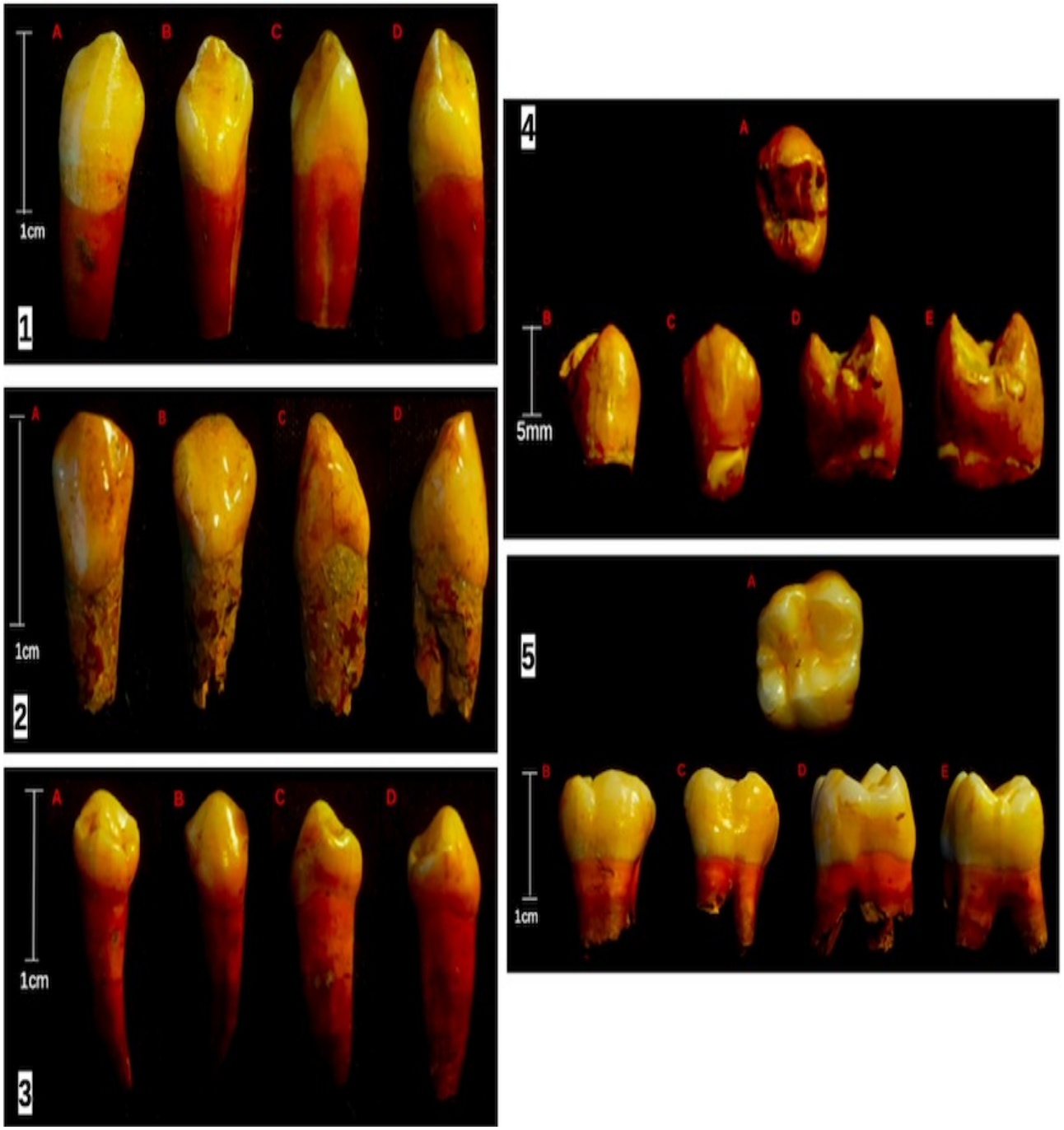


***Figure 10**: Krs/41/LLC. A (labial view), b (lingual view), C (mesial view), D (distal view); 2: Krs/649/UC. A (buccal view), B (lingual view), C (mesial view), D (distal view); 3: Lower left first premolar (Krs/334/LLP1). A (lingual view), B (Buccal view), C (Distal view), D (Mesial view); 4:Krs/649/UP1. A (Occlusal view), B, (Lingual view), C (Buccal view), D (Mesial view), E (Distal view); 5: Krs/638/UM2. A (Occlusal view), B (Lingual view), C (Buccal view), D (Mesial view), E (Distal view)*

The depth of each box was dug differently related to the different amounts of findings found in each box. The human remains in this study were encountered in GKQ (F6), which was located in a flat part of the cave. The excavation at GKQ1 (F6) extended to a depth of 150 cm. The digging was stopped at this depth based on the density and distribution of archaeological findings in the deepest spit. At 10 cm until 40 cm from the surface, the matrix was dominated by light gray sediment with a silty texture. At a depth of 40 cm to 60 cm, the sediment became mixed with shell fragments. From 70 cm deep, the gray sediment became a sandy silt with several small limestone fragments present. The archaeological findings in this layer were dominated by marine shells, fish bones, and unidentified animal bones. Various archaeological findings, such as human skeletons that were found at spit 12 (120 cm), pottery fragments, shells, and ecofacts consisting of animal bones and plant remains, were discovered in several sediment layers (Suroto, 2012).

Minimally, five different human individuals were identified in the excavation box GKQ1 (F6). The five teeth were unearthed in the two different layers of soil. Two teeth, including the lower-left canine (Krs/41/LLC; 1) and the upper second molar (Krs/638/UM2; 5), were discovered from the Spit 6 associated charcoal, along with one fish bone, two turtle bones, twelve marsupial bones, and one human bone fragment from the tibia. Two upper canines were assigned to individual Krs/649/UC; 2, and the lower-left first premolar (Figure 10), Krs/334/LLP1, 3); one was selected for collagen isotope analysis, while the other was selected for enamel apatite analysis. The Krs/649 specimens were excavated from a soft, sandy loam at 104 cm below the surface, associated with charcoal, fish bones, nut shells, animal bones, two fragments of human long bones, seashells (Arcidae and Veneridae), and freshwater shells (Littorinidae, Naticidae, and Terebridae) (Suroto, 2012:17). Another sample of a phalange assigned to individual Krs/638 was selected for collagen isotope analysis. The Krs/638 specimen was unearthed from a dark gray, soft, and moist sandy loam at 120 cm from the surface. The archaeological findings associated with Krs/638 consisted of nut shells, human long bones, as well as marine and freshwater mollusks (Arcidae, Veneridae, and Littorinidae). A single charcoal fragment from 70 cm from box GKQ1 has produced a radiocarbon date of 3400 BP.

3.1.4 Srobu site

Srobu is an open site located on a steep peninsula in Youtefa Bay, Abepura district, Jayapura, Papua Province (S 2.617937º E 140.703464º). The site sits at about 85 m above sea level and covers around 20,059 m² of the peninsula. The archaeological material covering the surface of the site includes small megaliths, stone tools, human remains, pestles and mortars, pottery fragments, and a huge array of seashells (Figure 11) (Mene, 2014; Djami, 2015, 2016, 2017, 2018, 2019).

Figure 11*: upper right: the Srobu site marked by the red-cycle, upper left, the environment situation in the area of the Srobu site. Lower left and right: megalithic building in the Srobu site area.*

Two different tribes occupy the surrounding area of the Srobu site at present, including the Nafri tribe and the Biaknese tribe. The two different tribes speak languages differently; the Biaknese speak an Austronesia language, whereas the Nafri tribe speaks a language classified within the Papuan phylum of languages.

Materials findings were found remarkably in type and form, including megalithic buildings, stone tools, pestles and mortars, pottery fragments, and a huge number of shells form-like a *Kjokkkenmoddinger* covered the surfaces of this site (Figure 11). Based on the material findings from the Srobu site, several hypotheses have emerged in local journals and research reports from Balai Arkeologi Papua (Djami, 2015, 2016, 2017, 2018, 2019). The hypothesis revolves around the

presence of Austronesian speakers at the Srobu site in Papua, Indonesia, evidenced by the distribution of Lapita pottery ornaments suggests the influence of Austronesian speakers and also indicates connections to early Austronesian cultural practices and trade networks, characterized by distinctive geometric designs and motifs .(Djami et al, 2018).

Figure 12*: Upper left: box excavation, right: the layers of shells make up of midden. Lower left and right: Human remains revealed inside vessels (Djami et al., 2018), Balai Arkeologi Papua-Indonesia.*

The excavations at the Srobu site involved systematically opening several square meters of excavation boxes, revealing a variety of material findings, ecofacts, and human remains with forty-six of human teeth were discovered through excavation. Some of the teeth were found alongside skulls, while others emerged from a fragile jaw. Several human skeletal were discovered inside of pottery-jar associated with jewelry made of glass-beads, and animal teeth identified as dog-teeth (Djami, 2016). The six individuals found with skulls includes (Figure 13): Srb/20 with three teeth: two lower first premolars (LP1) and one tooth from the lower second premolars (LP2). Srb/413 with

five teeth, including the lower right first molar (LRM1), lower right second molar (LRM2), lower left first molar (LLM1), lower left second molar (LLM2), and lower left third molar (LLM3).

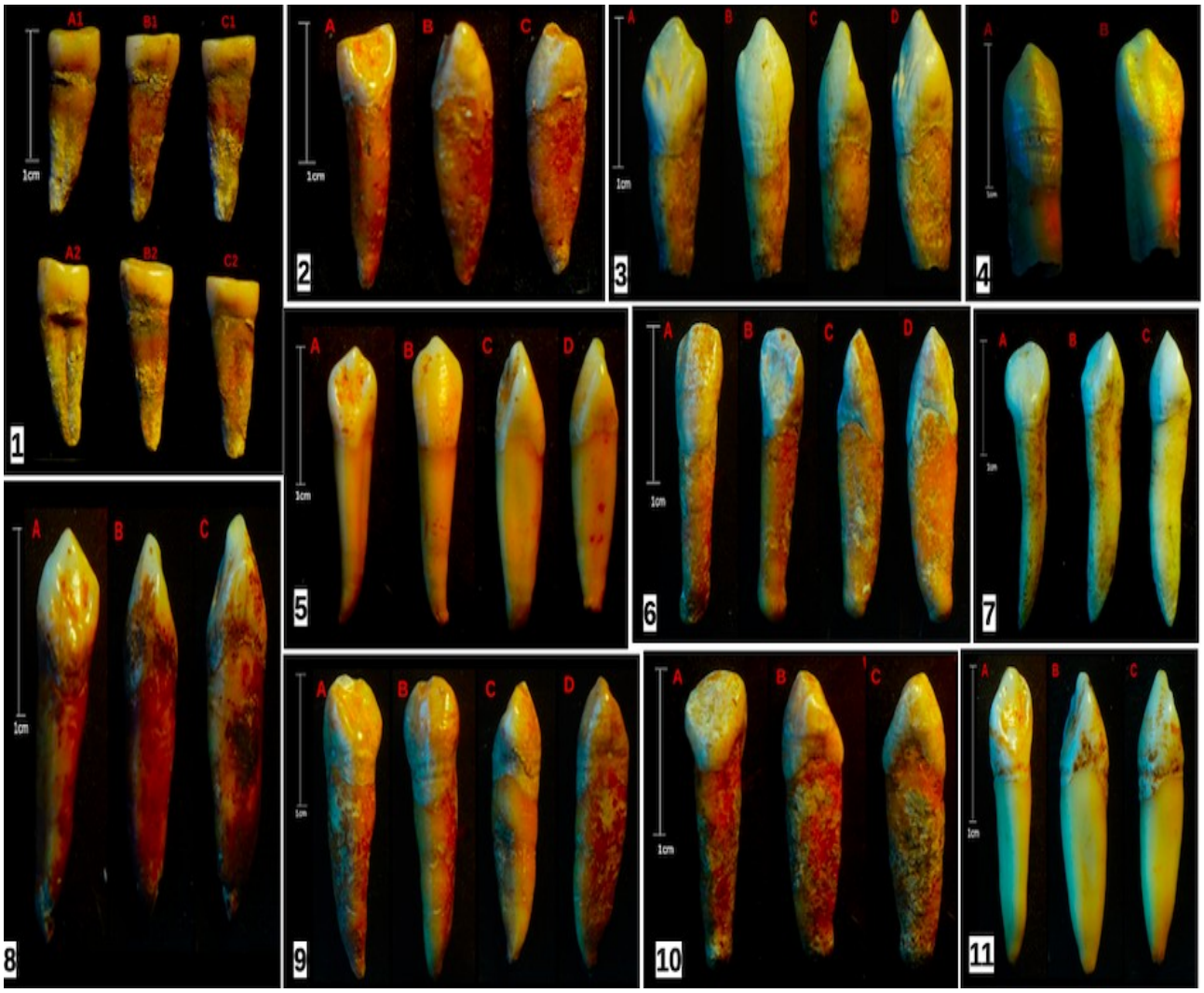


Figure 13: Srb/20/Upper, A1 (LP1-Mesial), B1 (LP2-Mesial), C1 (LP1-Mesial); Lower, A2 (LP1-Distal), B2 (LP2/distal), C2 (LP1-Distal). 2: Srb/32/LC. A (lingual), B (mesial), C (distal). 3: Srb/23/UC. A (lingual), B (buccal), C (mesial), D (distal). 4: Srb/25/LC. A (buccal), B (lingual). 5: Srb/24/LC. A (lingual), B (buccal), C (distal), D (mesial). 6: Srb/30/LC. A (buccal), B (lingual), C (mesial), D (distal). 7: Srb/29/UC. A (lingual), B (distal), C (mesial). 8: Srb/22/UC. A (lingual), B (distal), C (mesial). 9: Srb/28/UC. A (lingual), B (buccal), C (distal), D (mesial). 10: Srb/31/UC. A (lingual), B (mesial), C (distal). 11: Srb/21/UC. A (lingual), B (mesial), C (distal).

Third, Srb/489 had two teeth: upper left first molar (ULM1) and upper left second molar (ULM2), fourth, SRB/624 presented two teeth: lower premolar (LP) and lower second incisor (LI2), fifth, Srb/633 consisted of two teeth: upper right first molar (URM1) and upper first molar (UM1). Six, Srb/636 consisted of two teeth: the lower first molar (LM1) and the lower second molar (LM2). The teeth were found with the fragile jaw in several layers of excavation, including Srb/4/UP,

Srb/21/UC, Srb/22/UC, Srb/23/UC, Srb/24/UC, Srb/25/UC, Srb/27/LC, Srb/28/UC, Srb/29/UC, Srb/30/LC, Srb/31/UC, Srb/32/LC, Srb/33/LC, Srb/34/LC, Srb/35/UP1, Srb/64/UI1, Srb/65/UI1, Srb/66/LI2, Srb/67/LI2, Srb/86/UI2, Srb/90/UI2, Srb/403/LP1, Srb/622/LP, Srb/623/LP, Srb/25/LP, Srb/626/LP, Srb/627/LP, Srb/629/LC, Srb/630/UM2, Srb/ABC/UM1 (Figure 13). Three bones from two different individuals have been selected for stable isotope analysis: one upper canine for collagen analysis, and one upper canine and third molar selected for enamel apatite analysis. Srb_20 was found in unit B2S1 at a depth of 50 cm from the surface. It was found associated animal bones, numerous bivalvia and gastropoda shells, pottery fragments, etc. The soil at this depth was smooth in texture and very friable dug up. In contrast the Srb/413 was found at a depth of 110 cm from the surface. At this depth, the soil was gray-black in color with a smooth texture and loose. The findings at this depth include thousands of mollusks, pottery fragments, and several stone tools (Djami et al., 2017). Radiocarbon dating available from this site yields 1720±30 BP from a charcoal sample in other units, not from unit B2S1 where the human remains used for isotope analysis in this study.

***Figure 14**: The Namatota site marked by blue stars in the Kaimana Regency signed by red color*

3.1.5 Namatota site

Namatota is an open site located in the Namatota District, in the Kaimana Regency of Papua Barat Province, on the southern coast of the Bird's Neck (S 3.313768º; E 132.669722º) (Figure 14). Currently, eight indigenous tribes live in the Kaimana Regency: Maerasi, Iratutue, Kuripasai, Miereh, Koiway, Oburau, Madewana, and Kuri. In the interior areas of Kaimana, hunting and gathering of forest and marine foods are practiced. Kaimana is characterized by irregular limestone karst landscapes. At this site, archaeological materials were recovered from 1 to 100 cm from string level in one square-meter test pit (Figure 15). The findings recovered from this site included pottery fragments, several marsupials mandible fragments, pig molars, and shells. Two individuals were recovered from this site: first, individual (NMT/1) was identified by the left lower jaw, and the second individual (NMT/2) had four teeth-first premolars, second premolars, first molars, and second molars (Figure 16 and Figure 17). The lower jaw of these individuals was found together with ecofacts and pottery fragments at a depth 20cm from the string levels. Based on the morphological characteristics, the left jaw aligned with four posterior teeth lined up with one another from the front: first premolars (LP1) followed by the first molar. Two samples of human long bones including, an ulna and fibula from two different individuals, were selected for collagen stable isotope analysis. Specimen NMT/1-U (ulna) was found at a depth 48 cm from the surface, while the NMT/2-F (fibula) was unearthed at a depth 81 cm. Radiocarbon dating analysis of a charcoal sample from a depth of 76 cm yielded a date of 110±40 BP (IHME-3994). This suggests that the human specimens selected for isotope analysis are very recent.

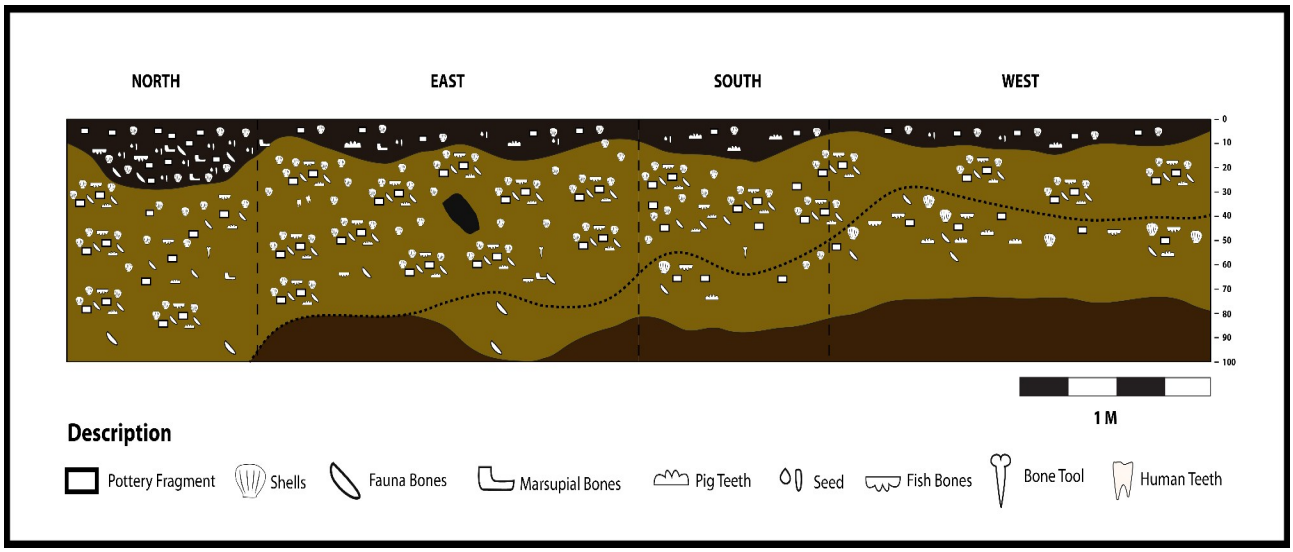


***Figure 15**: The layer stratigraphic of Namatota site. Several types of findings consisting of pottery fragment, shells, fauna bones, marsupial bones, sus-teeth, seed, fish bones, bone tools, and human teeth encountered in this site*

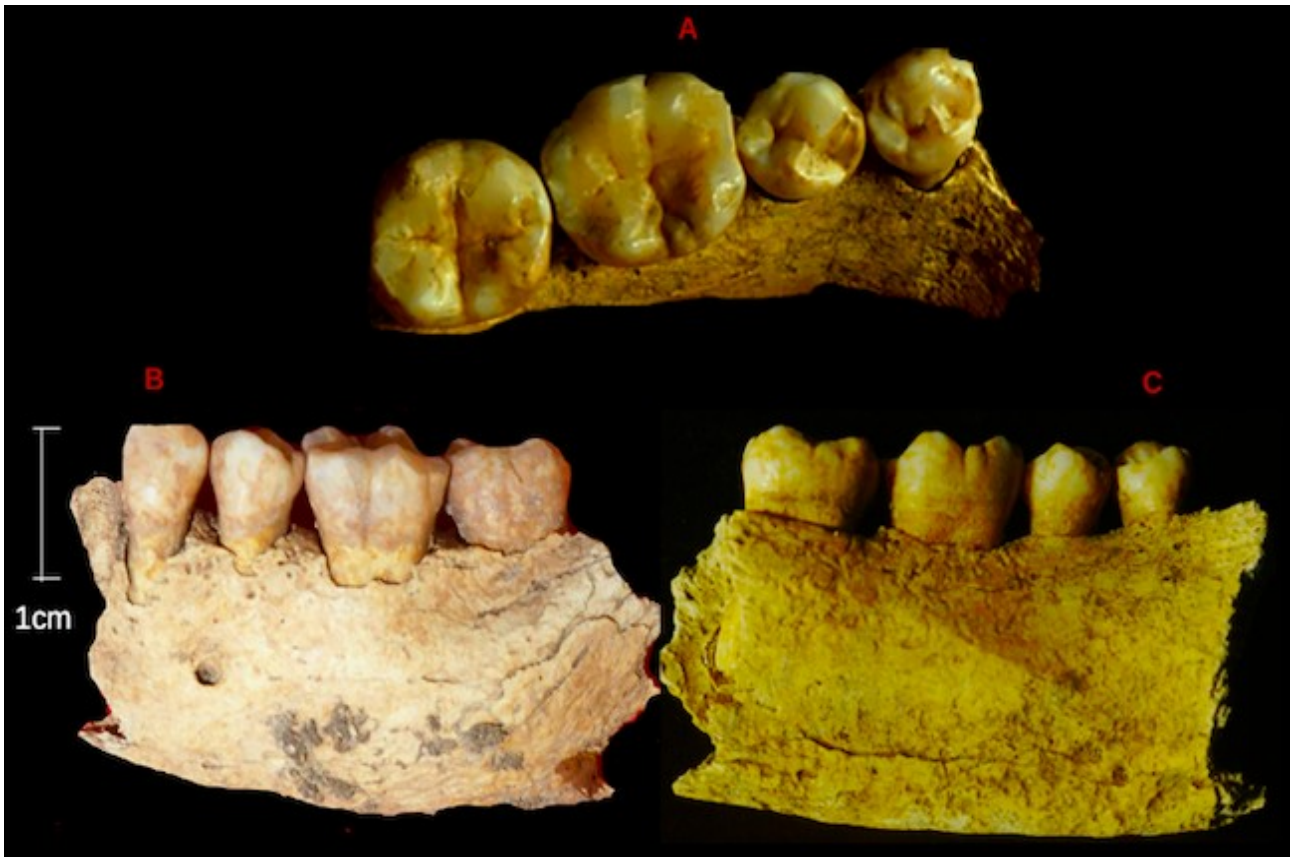


***Figure 16**: Lower Jaw.(A) Occlusal view, (B) buccal view, (C) lingual view*

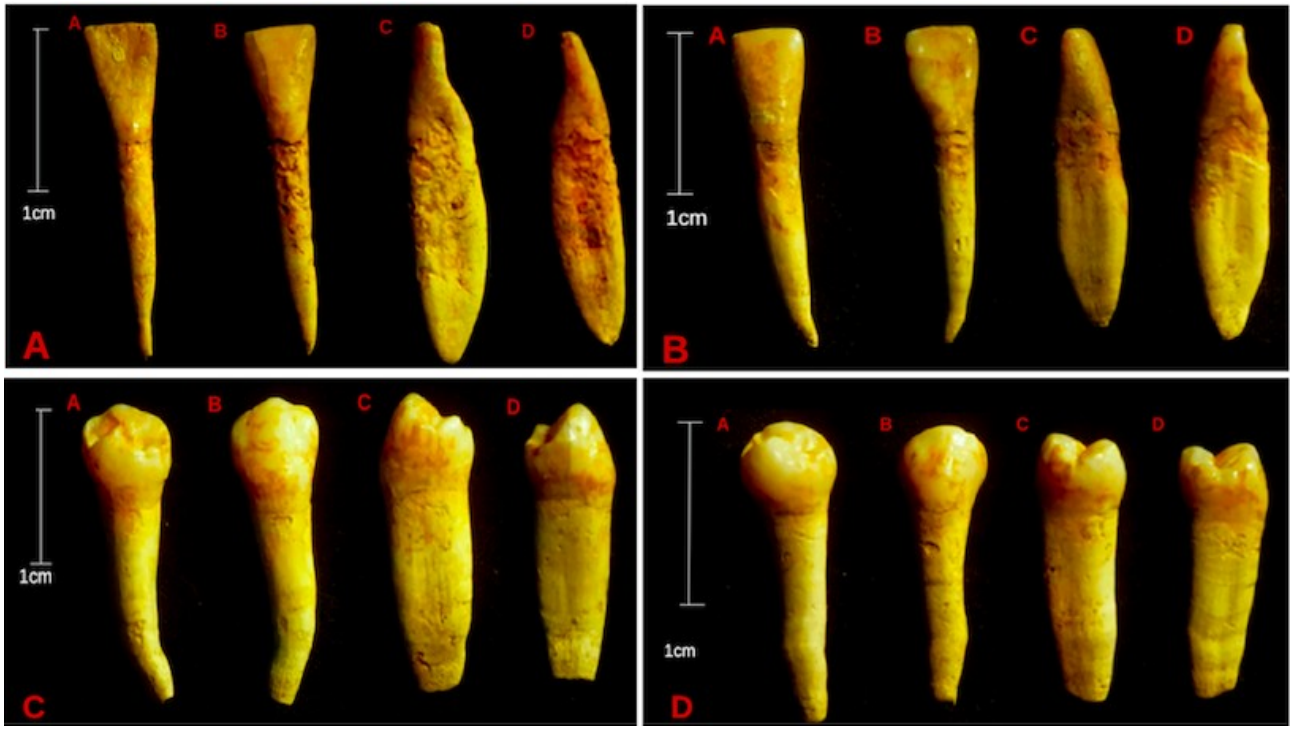


Figure 17*: (AB), distal view (AC), mesial view (AD). (B) Lower second incisors, buccal aspect (BA), lingual aspect (BB), mesial aspect (BC), distal aspect (BD).(C) Lower first premolar. Lingual area (CA), Buccal view (CB), distal view (CC), Mesial view (CD).(D) Lower second premolar. Lingual aspect (DA), buccal aspect (DB), mesial aspect (DC), distal aspect (DD).*

The incisal sloped pointed distally than mesially. The mesio-incisal is sharper, whereas the distal incisal slope is rounded. The cingulum is displaced distally, and the root points distally. Both the first incisors and lateral incisors show attrition on the incisal area. Plaque is present on the first incisor (A) lingual area, while on the second incisor, plaque is displayed on the labial area at the cervical third of the enamel (A). From the lingual view of the lower first premolar, all the surfaces of the occlusal area are visible. The mesial-lingual developmental groove separates the mesial marginal ridge and is much deeper than distal-lingual developmental grooves (A). In the proximal view (D), the buccal cusps' tips are centered on the long axis of the grooves, while the lingual cusps' tips are towards the lingual aspect of the root. The apical third of the root inclines distally in the lower second premolars. The crown is flatter compared to the first premolar and more prominent from the occlusal area (A). The cusp exhibits three types from the lingual area (A): distal marginal ridge, distal buccal cusp ridge, and distal lingual cusp ridge. The mesial lingual cusps are larger than the distal lingual cusp from the lingual view (A). Proximally, the crown points lingually. The distal crown (D) is more cervical than the mesial aspect (C), and the root apex is blunt (D). Both the lower first incisors and second lower incisors have a crown shape resembling a trapezoid from the lingual view (A), and from the proximal view (B) the crown shape is triangular (Figure 17). The incisal

edge is rounded at at the distal point (C), whereas it is sharply pointed mesially. No mamelons are present on the incisal area of either the lower first or second incisors. The cingulum is centrally located on the first incisor. The root in the first incisor is more straighter from the cervical line compared to the second incisor.

3.1.6 Kayu Batu

Kayu Batu is a rock-shelter burial site located in the kampung Kayu Batu, Jayapura district, Papua. By astronomical positions, it places at 2º.534491 South and 140º.738056 East. The shelter faces north towards Yos Sudarso Bay, while the southern border is marked by rocky hills in this area. To the west, Kayu Batu adjoined human settlement in Jayapura city, specifically Dok Sembilan. Human skulls were found irregularly scattered on the surface of the rock shelter at Kayu Batu, accompanied by grave goods such as pottery fragments, glass-beads, jewelry made from shells, and modified-animal teeth. Some of the skulls and bone remains were found entangled in tree roots and wedges between the large boulders scattered around the shelters' corners. The excavation involved a test spit measuring 1x2 meters on the ground shelters, revealing fragile mandibles jaws associated with glass beads and shells-jewelry scattered in sandy soils up to a depth of 25cm. Large bedrocks made of metamorphic stones were vertically embedded at the bottom, defining the layers of soil (Figure 18).

Currently, the Kayu Batu tribe occupies the Port Bay of Jayapura on the northern coast of Papua, neighboring the Tobati and Enggros tribes, who also inhabited the several small islands in Jayapura Bay. This community adheres closely to cultural tradition lead by an Ondoafi, a cultural title for tribal leaders descending from a specific lineage.

***Figure 18**: (leaders) of Kayu Batu tribe. C: the team collected the glass-beads recovered from the layer soils, D: the square-meter of excavation box was opened in the front of shelter, E & F: human remains encountered in the surface of the shelter*

One-hundred sixty teeth were applied for metric study from this site, consisting of fifteen lower first molar (LM1), sixteen lower second molar (LM2), fourteen upper first molar (UM1), twenty upper second molar (UM2), eighteen upper first incisors (UI1), fourteen upper second incisors (UI2), four lower first incisors, three lower second incisors, six upper canines (UC), two lower canines (LC), seven upper first premolars (UP1), twelve upper second premolars (Figure 19).

***Figure 19**: Human teeth from Kayu Batu site*

One-hundred sixty teeth were applied for metric study from this site, consisting of fifteen lower first molar (LM1), sixteen lower second molar (LM2), fourteen upper first molar (UM1), twenty upper second molar (UM2), eighteen upper first incisors (UI1), fourteen upper second incisors (UI2), four lower first incisors, three lower second incisors, six upper canines (UC), two lower canines (LC), seven upper first premolars (UP1), twelve upper second premolars (Figure 19).

3.1.7 Biak-Sowek

The Biak-Sowek burial cave is located in the Biak Supriori regency on the northern coast of Papua. The Biak Supriori is situated in the southern part of Biak Island and is linked by the Sorendiweri Strait to the mainland area of Biak Island. Environmentally, the Supriori regency is dominated by the mountainous region. However, small parts are characterized by flat to sloping areas scattered along the coastal where human settlements are placed. At present, the populations

living in Kampung Sowek inhabit stilt houses made of wood that are built over the surface of the seawater. These stilt houses in Kampung Sowek, which are widespread along the sea banks, stretch about 3km from the southeast to the northwest in this island (Figure 20).

The burial cave is located on a small island standing over the water's body surfaces, about 500 m from the shorelines, at coordinates 0º.827306 South and 135º.491389 East. The cave entrances faces northwest and is situated about 12 m above sea level.

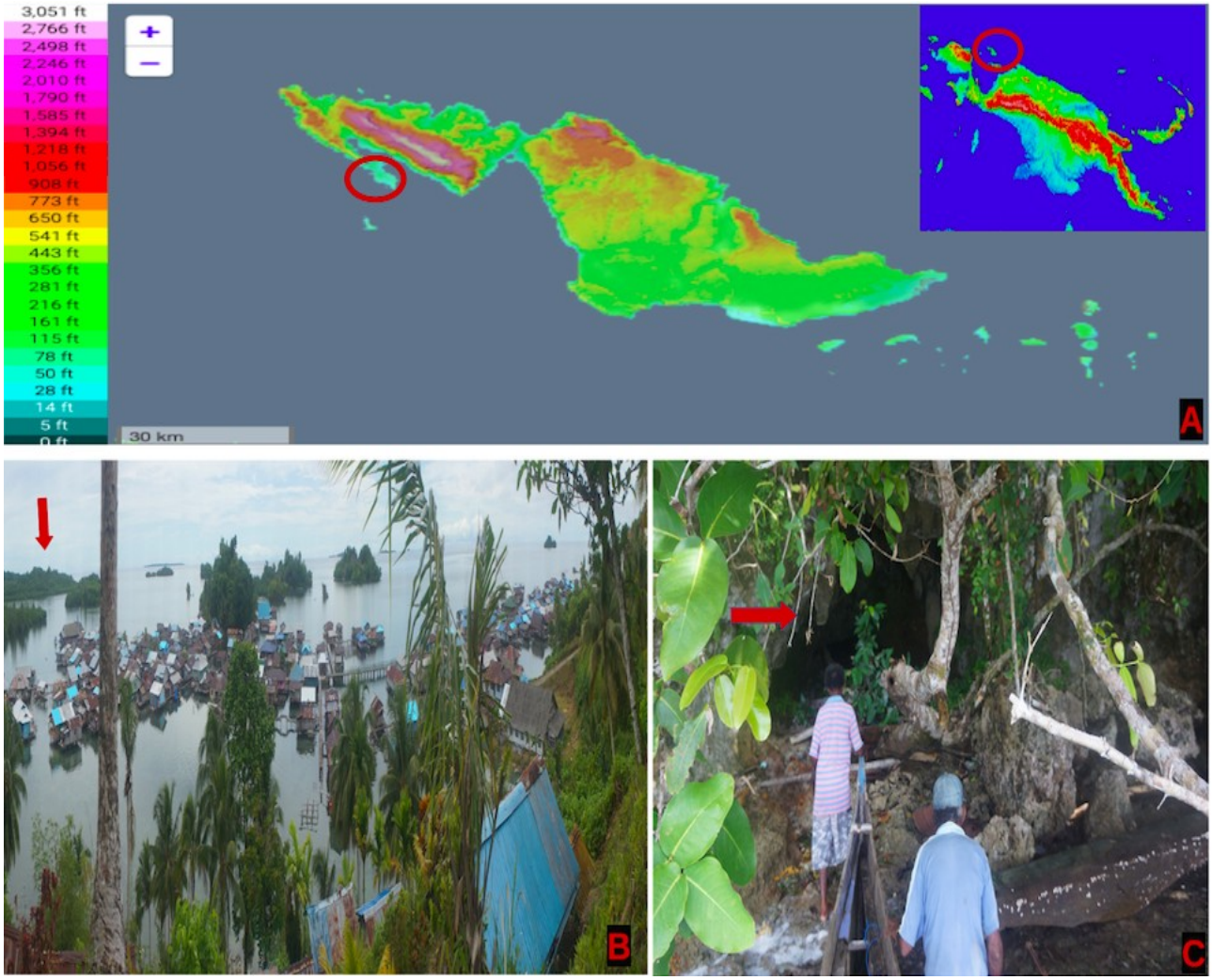


Figure 20*: A: Biak-Sowek site on the Biak island maps, B: the situation of the site in Kampung Sowek, Biak Supiori regency, C: the site where the burial site located*

Human skeletons were generally found at the cave entrance, with skulls and long bones distributed irregularly on the ground and associated with grave goods such as *Karwar* statues and pottery. Several human skulls were found trapped within the tree roots and placed between the rocks in the cave. The *Karwar* statue hold significant meaning for the Biaknese tribe, symbolizing respect and blessings from the ancestors to the living family or relatives (Figure 21).

Eighty-five human teeth (posterior and anterior teeth) from the burial cave in Biak-Sowek were used for metric study. This includes twenty lower first molar (LM1), twenty-three teeth of the lower second molar (LM2), six teeth of the upper first molar (UM1), four teeth of the upper canines, six teeth of the upper first molar (UP1), and three upper second molar (UP2) (Figure 22).

Figure 21*: A & B: the human skulls distributed on the site. C & D: grave-goods were consisting of Karwar and pottery.*

***Figure 22**: Human mandibles from the Biak-Sowek site*

3.2. Methodology

3.2.1. Introduction

The investigation of human dental characteristics in this research concerned on studying morphological variation and the biology-molecular of human dentition in space and time, from the Late Holocene to the Current Era, and their relation with behavior and dietary preferences in the lowland environment. This research aims to understand demography patterns derived from archaeological sites in the lowland area of Papua Indonesia. The study of human physical characteristics in this research will provide insights into human history, the origins, interactions, and behavior in the past.

Human skeletal remains from archaeological sites have long been a subject of interest within paleoanthropological and archaeological to understand origins, behavior, and evolutionary processes (Uberlaker, 1999a; Baker et al., 2005; Schwartz, 2006; White et al., 2012). Human teeth and bone remains discovered during archaeological fieldwork at seven sites offer valuable information for reconstructing human history. Interest in studying human morphological characteristics has grown significantly over the past decades within biological-anthropology,

leading to research on origins, evolution, behavior, and human variations. The study of human teeth in social contexts, initially rooted in physical anthropology, has been further developed by researchers from various fields, including archaeology, to understand human history, behavior, and other theoretical issues (Turner II, 1987, 1989; Hillson 1986, 1996). The study of human physical morphology has expanded into several themes, e.g. forensic and bioarchaeological topics, etc. In archaeological fieldwork, the analysis of human teeth found in archaeological sites helps archaeologists to understand the history of individuals, on a broader scope, the history of populations.

In this study, metric dental teeth and bioarchaeological markers were applied to address questions about the population affinities of the Lowland people in the area of Papua Indonesia. Pathology and wear patterns in human teeth were examined to infer human behavior and related issues, such as diseases. Several methodological approaches were used to understand human paleodiet and oral disease, including caries and lesions, plaque, and dental wear, which indicate abrasion, attrition, and erosion on the teeth crown. The study of the paleodiet and oral diseases in prehistoric humans has been a valuable method in bioarchaeology for identifying human subsistence patterns (Molnar S., 1972; Lukacs and Thompson, 2008; Lukacs et al., 1989).

Human dental characteristics have been used to understand human variation on a global scale, especially to define human affinities and their development in anthropological studies (Hrdlicka, 1911; Gregory, 1922; Sofaer et al., 1972a; Irish and Turner, 1990; Scott & Turner, 1997; Hanihara, 2013). Dental characteristics focus on the structure and form of human teeth, including size and physical features present on the crowns. Research in dental anthropology has produced significant results related to tooth trait variations, which are used as markers to differentiate human populations worldwide (Garn, 1971; Molnar, 1975).

3.2.2. Research Question

Based on the research objectives proposed from the above paragraph, four research questions are outlined in this research:

1. Which are the characteristics of human teeth in this study?
2. Which populations occupied the lowland part of Papua-Indonesia from the Holocene time until Current Era?
3. How did the human diet behavior develop in the Late Holocene?
4. Which factors could play a role in the human teeth characteristics?

3.2.3. Hypothesis

Based on the research questions, the hypothesis of this research I have generated includes:

1. All human teeth collected from the lowland area of Papua-Indonesia display dissimilar sizes of teeth.
   Alternative: All the teeth from the same site will exhibit similar levels of trait variation.
2. The metric dental data of the Lowland Papuan are dissimilar with several groups of populations used as a comparison in this study.
   Alternative: The human metric data of the Lowland Papuan closest to a few of the group populations used as a comparison in this study
3. The ancestry shown by mtDNA and Y-haplogroups of the people in this study derived from Asian and Papuan lineages.
   Alternative: The ancestry of the Lowland Papuan is Austronesian speakers.
4. The population's affinities of the Lowland Papuan derived from the Asian-origins inherited through gene-flow.
   Alternative: The population affinities of the Lowland Papuan dissimilar to Asian-group of populations.
5. The diet-preference between the people from different sites are dissimilar.
   Alternative: The-diet preference relied on the foraging-gathering are similar to all the people in the five sites in this study (Mamorikotey, Karas, Namatota, Srobu, and Yomokho).
6. The human dental wear and pathologies are dissimilar in a range between the teeth in different sites.
   Alternative: The type of wear and pathologies are similarly found in different individuals for all sites in this study.

3.2.4. Research Aims and Objectives

The aims of this study are outlined as follows:

1. To collect the dental metric data of the Lowland Papuan through the dental size measurements.
2. To fulfill the metric dental data from the lowland area of Papua-Indonesia, which is needed to analyze human history among the population wide-world.
3. To investigate the genetic and dental affinities of the Lowland inhabitants.
4. To investigate the range of stable isotope value of the Lowland Papuan for diet - intake investigations.
5. To determine the Lowland inhabitants movements based on the stable oxygen results.

6. To investigate the human teeth diet-behavior through the analysis of wear and pathologies.

The research objectives about human teeth characteristics from the lowland area of Papua-Indonesia in this study as follows:

1. Investigate the Lowland Papuan metric dental size throughout the measurement of the crown area, mesiodistal, and buccolingual.
2. Investigate the relationship between the metric teeth data from the Lowland populations of Papua with the metric data of other groups of populations.
3. Examine the genetic information at the individual level of the Lowland Papuan.
4. Investigate the human diet behavior using simplified experimentally validated isotope carbon and nitrogen signatures to represent the diet-intake of the people from the five sites (Karas, Namatota, Yomokho, Mamorikotey, and Srobu).
5. Examine the human geographical movements, initially using the oxygen isotope results.
6. Determine the wear and pathology developed in the teeth crown in the human teeth from the five sites (Karas, Namatota, Yomokho, Mamorikotey, and Srobu).
7. Investigate the relationship between the wear, teeth pathology and diet-intake by using the stable isotope results.

3.2.5. The ethical view of human skeletal in this study

The human bones and teeth are central to this research, holding valuable information about human physical identity that can be used to understand human history from the Holocene to the Current Era in the lowlands of Papua. Human bones and teeth discovered in archaeological contexts provide direct evidence of individual or groups that lived in the past. These remains are typically discovered through excavation and require careful documentation, photography, sampling, and analysis.

Applying the scientific method in archaeological fieldwork aims to acquire reliable and measurable information about the history and behavior of past human life. This fieldwork followed ethical principles to ensure that archaeological data, including human skeletal remains, are treated with respect and dignity during and after excavation processes. Ethical standards related to archaeological fieldwork entail the procedures, methods, and techniques used to recover, record, and store archaeological artifacts, including human remains. When the site is recognized as a cultural context, ethical practices and techniques in archaeological fieldwork must be used to obtain

information regarding past human life. Nevertheless, respectful behavior is a very subjective concept in many cultural societies, and it is linked to the traditional cultural distinctions in various societies.

In the past few decades, molecular techniques like genetic testing and diet marker detection have significantly advanced social studies and improved research outcomes, especially in archaeology. However, DNA study and stable isotope analysis are two different destructive studies that have been employed since 1985 to identity human identity and behavior, including diet and disease of past people. This has sparked some societal debate, as destructive laboratory analyses on human skeletal remains involve handling human bodies, which necessitates respect and appreciation as part of humanity. Despite this, human skeletal remains found in archaeology context are decaying organic matter that may have been buried for hundreds to a million years. Their presence at archaeological sites holds immense value for contemporary society as they serve as vital sources for narrating human history. Therefore, several analytical methods are employed to present reliable and measurable data for interpretation, providing valuable information about the human skeletal remains.

The implications of respectful treatment are integral to the procedure in archaeological research, including the application of scientific methodologies to deliver accurate information about past human lives. In this research, the highest appreciation for human history involves providing comprehensive information by applying scientific method, including laboratory analyses. The human skeletal remains and associated findings unearthed during this research are part of human culture, preserving the existence of past human lives and warranting the highest respect. The human remains obtained through this archaeological fieldwork aim to to address the history of the people from these five sites while minimizing bias in the interpretation process, which is part of the ethical consideration and appreciation for human history. These remains are highly meaningful as they represent the ‘living human memories’ of past people and should be treated with respect and dignity by accurately presenting the data and narratives associated with them. Two different methodologies, morphological analysis and destructive laboratory work, were employed to provide the scientific result expected to limit the bias that may arise during interpretation.

In the last few years, the Indonesian archaeologist association has discussed the ethical standards of guidance for archaeological research in this country. These standards have been widely reviewed in seminar to address ethical dilemmas in archaeological fieldwork. This is particularly relevant to the cultural customs still practiced by tribes in Indonesia, which must be respected in all aspects. This research was conducted in accordance with the normative standards observed by the tribes living around the archaeological site, involving them from the beginning to the end of the

research. The fieldwork was conducted in several stages, starting with introducing the research aims to the village leaders and officials, explaining the fieldwork steps to the indigenous people, and discussing the end process of the findings. This included explaining that some findings would undergo destructive processes for laboratory analysis. The involvement and consent of the indigenous Papuan people were sought throughout the research to ensure cultural customs and ethical standards were respected.

The fieldwork paper permit for administration regulations was done within the National Archaeological Research of Indonesia in Jakarta (Puslit Arkenas)/Ministry of Education and Culture, Republic of Indonesia, as the government institutions responsible for the archaeological research in the region of Indonesia, including the Papua region. Additionally, permits were secured from the regional office of archaeological research in Jayapura-Papua (Balai Arkeologi Papua), and the local government of the Papua and Papua Barat Province. This project was conducted with the agreement and involvement of the tribes that own the land where the fieldwork took place. Indigenous people were actively involved in the fieldwork process as local helpers and respondents for anthropological information. Communication with the indigenous people has continued to this day, particularly to inform them about the results of the analysis of the skeletal remains collected during the fieldwork.

3.2.6. Research Design

Human dentistry is a primary focus in biology-anthropology and archaeological research for understanding human life history and behavior through morphological and molecular studies. The human biological characteristics, specifically teeth, are central to this research and are used to determine human phenetic relationships by analyzing dental metric traits. In past centuries, scientific studies have included minor variations in teeth, such as marginal ridges, cusps characteristics, root traits, and other physical traits used for human population classification. This study's focus on human teeth traits involves examining the variables, feature, and size of the teeth crown to understand human history from Papua's lowland area. Human teeth characteristics vary between individuals and populations, making them useful for assessing population affinities (Hanihara K, 1984, 1989a, 1990a; Hanihara T, 1992b, 1993, 1994). Teeth are composed of inorganic components, primarily calcium hydroxyapatite (Ca10(PO4)6(OH)2, which makes them highly preservable in the taphonomic context of archaeological sites (Scott et al., 2018).

In this study, to investigate the lowland population history and their behavior, four (4) design strategies were employed: firstly, to identify the lowland population’s tooth characteristics, the crown tooth was measured to determine the tooth size, mesiodistal, and buccolingual. Second, to

examine whether the human teeth metric traits are dependent on other groups of populations or are independent, the statistical analyses were applied to determine the distance of teeth size between the Lowland group teeth and the seventeen (17) populations involved for the study comparison. Third, to investigate the human origins of the people in this study through mtDNA (maternal) and Y-chromosome (paternal) identification. Four, the human behavior in terms of paleodietary and the human's oral disease from the five sites in this research will be investigated using macro and microscopic tools to visualize the wear and pathology present in the teeth crown. Five the human diet behavior and their geographical movement will be determined by applying the stable isotope analysis obtained in tooth tissues.

3.2.7. Theoretical framework

Studying biological materials, such as human remains, within an archaeological context is a fundamental aspect of archaeological research. Human remains preserve valuable information that helps address questions about human history question (Hagelberg et al., 1989, 2001). This study focuses of human skeletal analysis to identify the ancestry, population affinities, and dietary behaviors of Lowland inhabitants from Indonesian Papua, spanning from the Holocene to the Current Era.

Variation in the shape and size of organisms distinguishes between and within species, often grouping into distinct populations. Certain physical traits of human bodies, including tooth size may be more prevalent in specific groups compared to others, or the average measurements may differ. Additionally, there exists variation among individuals within any given population, presenting a spectrum of measurable sizes (Hillson, 2005:257). While some individuals' dental features and sizes may overlap with those of other populations, the overall distribution of sizes can differentiate one population from another. Understanding human history through the lens of diversity is crucial for appreciating the richness of the human species. This study acknowledges that diversity enhances human societies and enables us to celebrate our differences rather than view them negatively (Brown, 2020). Human teeth, as part of the skeletal system, provide data for studying metric dental traits and ancient DNA. These studies, incorporating data from around the globe, contribute to our understanding of human diversity on a global scale.

To understand human diversity, researchers have increasingly focused on studying human history within and across geographic regions (Lewontin, 1972; Cann et al., 1987; Nei and Roychoudhury, 1982; Cavalli-Sforza et al., 1988; Stoneking et al., 1997; Scott and Turner, 1997, etc). These studies address topics such as genetic and morphological variation, particularly traits of crown and root tooth traits (Dahlberg, 1963b, 1971a; Scott and Turner, 2000). Research underscores

the divergence of human teeth from one another (Scott and Turner, 2000). Over the years, researchers have analyzed morphological variation in human history through traits present in crown and root teeth (Dahlberg, 1963b, 1971a; Scott and Turner, 2000). Dental trait studied often correlate with ancestral human groups; metric traits show a relationship to population ancestry (Pilloud et al., 2014; Hrdlckâ 1920, 1921; Dahlberg, 1971a). The diameters of tooth crowns are influenced by complex environmental and genetic factors passed down through generations (Potter & Nance, 1976; Goose & Lee, 1971; Townsend & Brown, 1980, 1981b; Townsend et al., 1992). When examining populations independently, crown diameters consistently exhibit positive or significant inter-correlation patterns. In this way, the diameters of various permanent teeth are correlated (Harris & Rathbun, 1991). Genes factors significantly impact the size and shape of human teeth across multiple loci, reflecting multifactorial inheritance. These loci interact with varying environmental influence, resulting in continuous size variance (Hillson, 2005). The more independently confirmed these features are, the more likely it will be to inherit phenotypic differences. Genetic isolation and uniformity characterized ancient human societies, where malocclusion was less prevalent compared to modern communities. In populations where everyone shares the same genetic material for tooth size, the probability of individuals inheriting discordant characteristics is minimal.

The reconstruction of human origins and evolution in biological anthropology and archaeological has seen significant advancements since the development of DNA methods in the 1980s (Päabo S, 1995). Genetic studies, particularly ancient DNA (aDNA) analysis, have been crucial in understanding human population history, evolution, diseases, the timing of modern humans' initial movements, etc (Hagelberg et al.1989; Hagelberg, 2001). DNA preserved in human tissues provides essential information such as biological affinities, sex determination, and family relationships (Hagelberg et al. 1991a; Matisso-Smith & Horsburg, 2012). The extraction of aDNA from biological sources, including human remains like teeth and long bones, has revolutionized archaeological research (Hänni et al. 1990). In this study, material genetic lineages (mitochondria DNA) and paternal or Y-chromosome were identified to trace individuals' ancestry and relationships within and between the group of populations. Mitochondrial DNA is inherited maternally through successive generations, while Y-chromosome DNA is inherited paternally (Torres & Torres Colon. 2021). These genetic markers are invaluable in studying human history, as applied in this research.

Over the past decades, archaeological have used bioarchaeological methods, integrating zooarchaeology and palaeobotany, to study human dietary behaviors (Yarnell, 1973; van der Merwe and Vogel 1978; Ambrose, 1987 et al.). Bioarchaeology combines human remains with

archaeological site investigations, offering insights into past human lifeways and environment (Martin & Anderson, 2014:3). Advancements in bioarchaeological techniques and theoretical frameworks have enhanced our ability to interpret past diets and nutritional patterns preserved in human tissues, which also provide information on diseases, trauma, and malnutrition (Turner, 1979; Larsen, 2015).

Studying tooth wear and pathology helps understand human dietary preferences and interactions with the environment, reflecting broader archaeological evidence of environmental change (Kirch, 1997). Teeth, divided into anterior (incisors and canines) and posterior (premolars and molars) types, play distinct roles in food processing, including chewing and grinding. They directly reflect the diet consumed by ancient humans, providing insights into their behavior and dietary choices. Microscopic analysis of dental wear records offers clues about past dietary habits and their impact on human populations.

The analysis of microwear on teeth provides valuable insights into the diet preferences and behavioral patterns of past human populations, illustrating transitions from hunting-gathering to agricultural practices (Teaford, 1991; Teaford et al., 2001; Pastor and Johnston, 1992). The examination of human teeth from archaeological sites offers a unique perspective on these behaviors, revealing the types of foods consumed and the methods of food processing used. The morphology of teeth is influenced by the mechanics of chewing, which vary according to diet. Hard and abrasive foods, for example, leave distinct wear patterns compared to softer, processed foods. This mastication process can alter tooth morphology over time, as teeth interact with food and each other during chewing. Tooth pathologies, such as cavities and wear, also provide evidence of dietary habits. High-carbohydrate diets, often associated with agricultural societies, can increase the prevalence of dental caries, while the wear patterns on teeth can indicate the consumption of tougher, more fibrous plant materials typically found in hunter-gatherer diets. These dental records thus allow researchers to reconstruct aspects of ancient human diets and the broader socio-economic changes, such as the shift from foraging to farming.

3.2.8 Procedures and Instruments

3.2.8.1 Teeth Terminology

Dentists, dental anthropologists, paleontologists, and other specialists develop the terms and concepts of dental anatomy used in the study (Scott & Turner, 2000: 15).

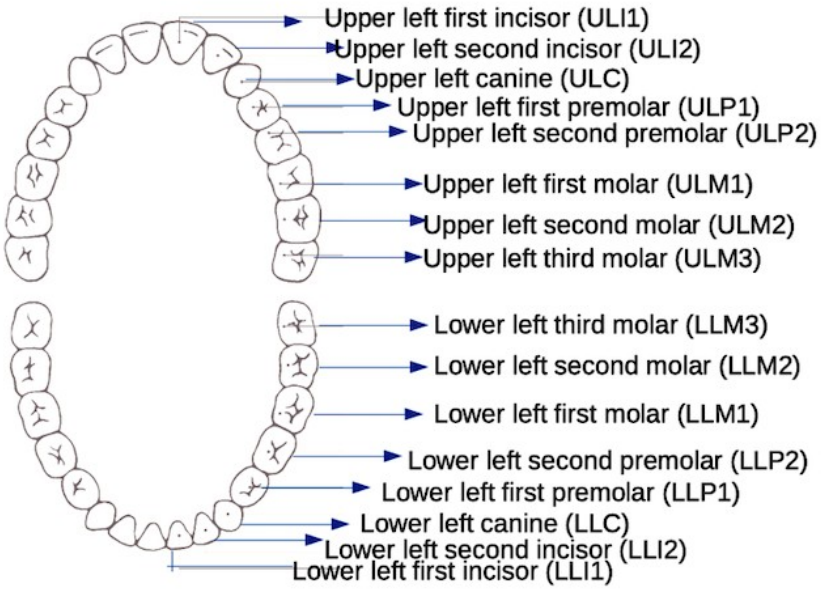


***Figure 23**: Human permanent teeth (upper/maxillary, and lower/mandible)*

Related to this, two sets of teeth passes through the developmental stages. The first set begins during the fourth or fifth month of pregnancy, establishing the deciduous dentition, which emerges into the mouth after birth and forms primary dentition from 20-32 months. These primary teeth are further replaced by permanent teeth from 6-21 years, known as adult dentition (Hillson, 2014:2; Dofka 2013:52).

The human teeth discussed in this study consist of permanent adult teeth, using terminology from Hillson (1996) with the following abbreviated notations used as follows: I, Incisor, consist of two, I1 and I2; one canine, C; two Premolar (P), P1 and P2; three Molar (M), M1, M2, M3. Positional abbreviations include L for left, R for right, BL for buccolingual, MD for mesiodistal. These four different types of permanent teeth will be explained as follows (Figure 23):

- **Incisor** (I) divided by first/central and second/lateral. First incisor (I1); second incisor (I2). By positions is divided into two: upper and lower. Upper: upper first incisor (UI1); upper second incisor (UI2). Lower: lower first incisor (LI1) and lower second incisor (LI2).
- **Canine** (C), upper canine (UC); lower canine (LC). The positions on the mouth is divided into left and right: lower right canine (LRC); lower left canine (LLC); upper right canine (URC); upper left canine (ULC).
- **Premolar** (P): first premolar (P1), second premolar (P2). Lower premolar (LP); Upper premolar (UP); Lower first premolar (LP1); lower second premolar (LP2); upper first

premolar (UP1), upper second premolar (UP2). By positions on the mouth, is divided by left and right. Right: lower right first premolar (LRP1); lower right second premolar (LRP2). Right: upper right first premolar (URP1); upper right second premolar (URP2).

- **Molar** (M); first molar (M1); second molar (M2); third molar (M3). Abbreviations for upper and lower; Upper first molar (UM1); upper second molar (UM2); Upper third molar (UM3). Lower: lower first molar (LM1); lower second molar (LM2); lower third molar (LM3). By positions, left and right: Upper right first molar (URM1); upper right second molar (URM2); upper right third molar (URM3). Left: lower left first molar (LLM1); lower left second molar (LLM2); lower left third molar (LLM3).

3.2.8.2 Tissue Structure of the teeth

According to dental anatomists and dentists classification, human teeth are divided into four different types: incisor (I), canine (C), premolars (P), and molars (M). These teeth share a common structure consisting of four tissues: enamel, dentin, cementum and pulp (Dofka, 2013).

- **Enamel** is a hard tooth covering 96 percent inorganic tooth place in outer layer of a tooth. Tooth enamel exhibits of a few component including cuticle, lamellae, tuft, spindles, rods and gnarled enamel.
- **Dentin** is the second layer in a tooth after enamel and as the main tissue of tooth surrounding the pulp. Compared to enamel, dentin has less inorganic (70 percent) and soft and by color it is sightly yellow-brown, it is present in crown and root area. Dentin is formed by two components, tubules and fibers, both help the dentin transmit nutrition and register sensation (Dofka, 2013: 54).
- **Cementum** is made of 55 percent inorganic and covering the tooth root. Located at the neck of the tooth, it meets the enamel tissue at cement-enamel union (cementoenamel), it function is provide rough surface anchorage for attachment of Sharpey's fibers and also protect the root.
- **Pulp** is located in the center and the root tooth. Pulp is composed of multiple cells, fibroblasts that it performed for connecting tissue and supported tooth for dentin protection, nourishment, registration of pain and sensation etc (Dofka, 2013: 54).

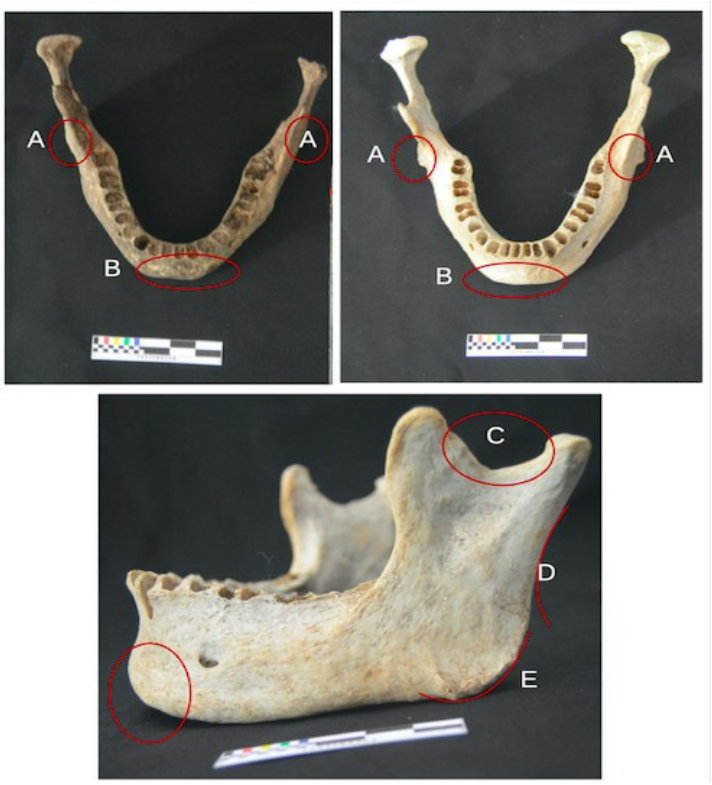


***Figure 24**: A & E: Gonial region exhibited a greater degree of muscle B: Chin shape (mentum) is square and robust, C: The coronoid process shaped triangular with a tip pointing straight upwards, D: Ramus present flexure shape*

The human dentition is anatomically organized with specific terms to describe its various aspects: Anterior teeth, such as incisors and canines, are located in the front of the jaw. Posterior teeth are, like premolars and molars are positioned towards the back. The labial surface refers to the outer surface of incisor and canine that faces the lips. The buccal or facial surface is the outer surface of premolars and molars that faces the cheeks. The incisal surface is the biting edge of incisors and canines. In contrast, the occlusal surface refers to the chewing surface of premolars and molars. The mesial side is the surface of a tooth closest to the midline of the face (abbreviated M). The distal side is the surface farthest from the midline (abbreviated as D). These terms provide a standardized way to describe the location, surfaces, and characteristics of different types of human teeth (Dofka, 2013: 61).

3.2.8.3 Dental Metric Data

Metric traits in dental anthropology are quantifiable characteristics measured on a continuous scale, such as tooth breadth and length, which theoretically range from 0 and ∞

(infinity). These traits are empirically measured and analyzed to understand various aspects of dental morphology and population affinities. In this study, metric analysis of teeth is conducted to assess affinities within the Lowland Papuan population. This involves measurement of tooth sizes, calculation of relevant metrics, and estimation of distance values using statistical methods. The results are then presented in diagrams, utilizing software like JMP Pro 15, to illustrate the relationships between metric data from Lowland Papuans and seventeen other groups studied for comparison (DiGangi & Hefner, 2013; Sutton 2021: 31). This approach allows researchers to discern patterns of dental variation and to explore genetic and environmental influences on dental morphology among different populations.

In this study, only male teeth are used to interpret inter-sample phenotypic affinities following the approach outlined by Matsumura &Hudson, 2005. The human skull, including the mandible, is known to exhibit sexual dimorphism (Harrison, 2019), making the mandible and maxilla crucial for sex determination in this research. For sex determination, mandibular features such as the mentum (chin shape) and gonial angle are analyzed. At sites like Mamorikotey and Karas, where complete mandibles are not available, these features play a critical role. Male teeth (Figure 24) are identified based on criteria such as ramus flexure, mental protuberance, gonial flaring, coronoid process, and chin shape, following established methodologies by researchers like Loth & Henneberg (1996), Bass (1987), and Harrison (2019), which are know to reliable with a 88% accuracy in differentiating human sexes. In males, the ramus of the mandible tends to be more flexed compared to felames, whose ramus is typically straighter. Male chin shapes are larger, more robust, and square-shaped, whereas females have smaller, more pointed chins. The gonial flaring, or angle between the vertical and horizontal parts of the mandible, is more pronounced in males compared to the more rounded angle seen in females. Additionally, the coronoid process in males often exhibits a triangular process of 72% (Prajapati et al., 2011).

3.2.8.3.1 Mesiodistal and Buccolingual measurements

Modern human teeth are the same; however, the study found that the tooth crown sizes and shapes vary among human populations (Kieser, 1990; Matsumura & Zuraina, 1999; Hanihara and Ishida, 2005; Matsumura & Hudson, 2005). For this, the human teeth are useful to determine the population affinities, as will be analyzed in this study. The basic standard measurements of mesiodistal length and buccolingual breath are essential for evaluating the overall proportions and shapes of human teeth. This measurement provide crucial data that can be used to interpret population affinities, particularly in the context of the Lowland Papuan groups studied. The human teeth involved in the measurement are between the left or right sides, or one of these parts is used depends on their availability. Mesiodistal measurement (length) is the maximum diameter of the

crown in the mesiodistal direction; it is parallel to the buccolabial surface. Buccolingual measurements constitute the maximum crown diameter in the buccolingual direction parallel to the mesiodistal surface (Figure 25). The mesiodistal – buccolingual dimension of the permanent left and right of the upper and the lower posterior (premolars and molars) and anterior teeth (incisors and canines) were measured by using the vernical caliper Mitutoyo 0.02mm following the Standards for Data Collection from Human Skeletal Remains (Buikstra and Ubelaker 1994). The mesiodistal and buccolingual measurement is marked as the most significant distance between contact points on the tooth's long axis.

To ensure the reliability of the recorded measurements, intra-observer measurements were applied for each tooth category at intervals a few weeks following the first measurement to assess consistency. Any differences observed between measurements promoted additional re-measurements as needed. The results from the intra-observer measurements were analyzed using statistical methods, specifically Pearson's correlation coefficient (r). Pearson's evaluates the strength and direction of the linear relationship between two sets of continuous variables-in this case, the initial measurements and the re-measurements. A high correlation coefficient (close to +1 or -1) indicates strong agreement between the two sets of measurements, confirming the consistency and reliability of the recorded data. The statistical analysis was performed using software like JMP statistic, which allows rigorous assessment of measurement consistency and provides insights into the reliability of the dental measurements conducted in this study.

3.2.8.3.2 Statistical analysis

In this study, metric dental traits were measured using the mesiodistal and buccolingual crown dimensions, following Fujita's system (1949) as referenced in Matsumura & Hudson (2005). Third molars were excluded from the analysis due to their significant size and shape variation in human dentition. The two different human tooth groups are divided by periodization: the Late Holocene and the Twentieth-century group. The Late Holocene group consists of human teeth from the Mamorikotey site, Srobu, Karas, and Namatota site, whereas the twentieth-century group contained human teeth from the Biak-Sowek and Kayu Batu sites. Basic statistical operations employed in the study included independent samples t-test. This test was used to assess differences between the means of two independent distributions of dental measurements. It helped determine whether there were statistically significant differences between the dental traits of the Late Holocene and twentieth-century groups. P-value analysis were calculated to determine the probability of obtaining observed differences in dental measurements between groups purely by chance. A lower p-value indicates a higher level of statistical significance, suggesting that observed differences are unlikely to be due to random variation.

In this study, metric trait analysis focused on crown measurements (mesiodistal-buccolingual) to determine tooth sizes among Lowland populations from Papua-Indonesia. These populations were compared to several other groups involved in the study to investigate their relationships. The lowland populations from the region of Papua-Indonesia, represented by two groups: the late Holocene population (Mamorikotey, Namatota, Karas, and Srobu) and the group of Eighteenth Century (Biak-Sowek & Kayu Batu) are compared with seventeenth populations from East/Southeast Asia: Australian-Aborigines, Negritos, Early-Holocene Laotians, Andaman Islanders, Loyalty-Islanders, Lesser-Sunda, and Java Islanders, Sumatra Islanders, Dayak, Malay, Philippines, Vietnamese, Laotians, Amami-Okinawa Islanders, Gua Kepah, Gua Cha, Ban Kao, and Non-Nok Tha were adapted from Matsumura & Hudson (2005) by using multivariate statistical procedures. The metric data from these populations was computed carefully with Excel, JMP, and it was checked a few times to avoid errors or mistakes during the computing process.

The mean, standard deviation (SD), and coefficient of variation (CV) were computed for the two populations. The hypothesis developed in this study is that the human teeth from the lowland archaeological sites are not related to or have unequal variances among the seventeen (17) groups of populations involved in this study. The unpaired t-test was used for hypothesis testing by applying the formula:

$$t = \frac{\mu_A - \mu_B}{\sqrt{\frac{\sigma_A^2}{n_A} + \frac{\sigma_B^2}{n_B}}}$$

t: t-Value

μ_A: Average for population A

σ_A: Standard deviation for population A

n_A: Number of values for population A

In case of chosen significance level of $\alpha = 5\%$, a probability > 5% ($P > 0.05$) is interpreted as no significant difference, while < 5% ($P < 0.05$) is seen as significant difference; a probability < 1% ($P < 0.01$) as highly significant; and < 0.1% ($P < 0.001$) as very highly significant. The multivariate statistical procedures were undertaken using the data sets of dental metrics, which comprised twenty eight (28) crown diameters (14 mesiodistal and 14 buccolingual) were examined using metric dental traits. Furthermore, the mean values are used to visualize hierarchical clusters in a dendrogram created by the JMP statistics software. The hierarchical clustering dendrograms or phylogenetic trees are employed in the human population study to represent the distance or dissimilarity between populations based on the statistical analysis results and to conclude which

populations the Lowland populations are affiliated with, as evidence of the closest group of populations.

3.2.8.4 Ancient DNA method

Ancient DNA analysis was performed on twenty-four (24) human remains from 24 individuals, consisting of twenty-two samples derived from teeth, one petrous bone, and one metatarsal bone (Table 4). Several steps were accomplished to obtain the DNA from these individuals, including laboratory analysis and population genomic analysis, processed was performed in the laboratories at the Max Planck Institute for the Science of Human History in Jena, Germany, as will be explained in the following paragraph.

The laboratories analysis was performed through pretreatment and extraction including sampling process, DNA extraction, library preparation, targeted enrichment, and high-throughput sequencing, genomic data processing, and quality control as will be explained as follows:

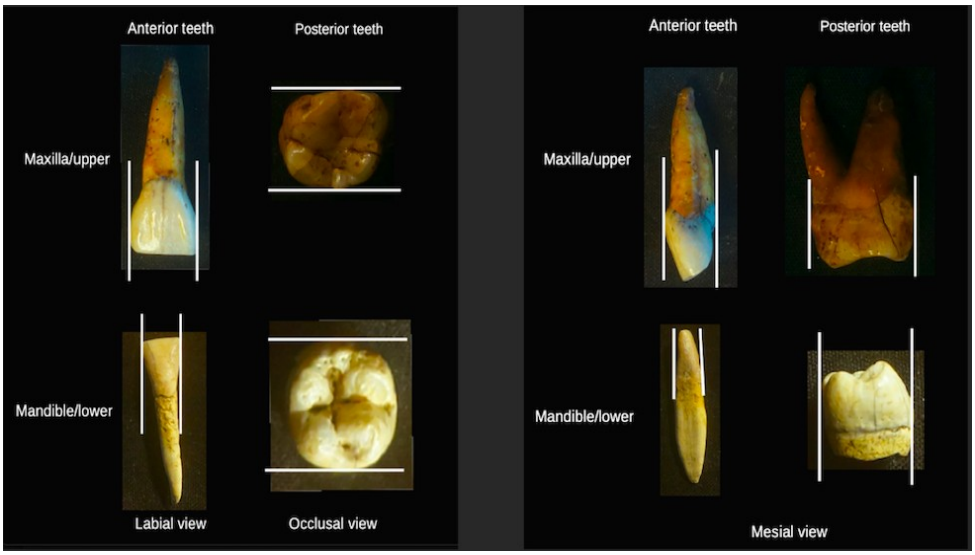


***Figure 25**: Tooth measurements. Left: Mesiodistal (MD) crown length (diameter); right: Buccolingual (BL) crown breadth (diameter)*

3.2.8.4.1 Sampling

The bone powder was sampled from teeth by cutting along the *cementoenamel* junction and drilling approximately 50-100 mg from the pulp chamber with a dentist drill. Bone powder from the petrous part of the temporal bone was obtained through the cutting process along the *margo superior partis petrosal* (crista pyramids) and drilling 50-150 mg bone powder from the densest part around the cochlea (Pinhasi et al.2015).

3.2.8.4.2 DNA Extraction

DNA extraction was carried out following established protocols (Dabney et al., 2013). Negative and positive controls were included. To release DNA from 50-100 mg of bone powder, a solution of 900 µl EDTA, 75 µl H2O and 25 l Proteinase K was added. In a rotator, samples were digested for at least 16 hours at 37°C, followed by an additional hour at 56°C (Rohland and Hofreiter 2007). The suspension was then centrifuged and transferred into a binding buffer as previously described (Dabney et al., 2013). Silica columns for high volumes (High Pure Viral Nucleic Acid Large Volume Kit; Roche) were used to bind DNA. After two washing steps using the manufacturer's wash buffer, DNA was eluted in TET (10 mM Tris, 1 mM EDTA, and 0.05% Tween) in two steps for a final volume of 100 µl.

3.2.8.4.3 Library preparation

Single-stranded libraries (Gansauge et al.2017) were produced in an automated protocol as detailed in (Gansauge et al.2020). Negative and positive controls were carried alongside each experiment. Libraries were quantified using the IS7 and IS8 primers (Meyer and Kircher 2010) in a quantification assay using a DyNAmo SYBP Green qPCR Kit (Thermo Fisher Scientific) on the LightCycler 480 (Roche). Each aDNA library was double indexed (Kircher, Sawyer, and Meyer 2012) in 1-4 parallel 100 µl reactions using PfuTurbo DNA Polymerase (Agilent). The indexed products for each library were pooled, purified over MinElute columns (Qiagen) eluted in 50 µl TET. After this, it was quantified using the IS5 and IS6 primers (Meyer and Kircher 2010), applying the quantification method described above; 4 µl of the purified product were amplified in multiple 100 µl reactions using Herculase II Fusion DNA Polymerase (Agilent) following the manufacturer's specifications with 0.3 µM of the IS5/IS6 primers. After another MinElute purification, the product was quantified using the Agilent 2100 Bioanalyzer DNA 1000 chip. An equimolar pool of all libraries was prepared for shotgun sequencing on Illumina platforms in 75 base pair single-end-run cycles using the manufacturer's protocol.

3.2.8.4.4 Targeted enrichment and high-throughput sequencing

Libraries were further amplified with IS5/IS6 primers to reach a concentration of 200-400 ng/µl as measured on a NanoDrop spectrophotometer (Thermo Fisher Scientific). Mitochondrial DNA capture (Fu et al.2013) was performed on screened libraries which, after shotgun sequencing, showed the presence of aDNA, highlighted by the typical CtoT and GtoA substitution patterns towards 5' and 3' molecule ends, respectively. Furthermore, samples with a percentage of human DNA in shotgun data around 0.1% or greater were enriched for a set of 1,237,207 targeted SNP2 across the human genome (1,240K capture) as described in (Fu et al. 2015). The enriched DNA product was sequenced on an illumina HiSeq 4000 instrument with 75

single-end-run cycles using the manufacturer's protocol. The output was demultiplexed using bcl2fastq version 2.17.1.14 (Illumina conversion Software) and dnaclust version 3.0.0 (Ghodsi, Liu, and Pop 2011).

3.2.8.4.5 Genomic data processing

Pre-processing of the sequenced reads was performed using EAGER version 1.92.55 (Peltzer et al.2016). The resulting reads were clipped to remove residual adaptor sequences using *Clip&Merge* (Peltzer et al.2016) and AdapterRemoval version 2 (Schubert, Lindgreen, and Orlando 2016). Clipped sequences were then mapped against the human reference genome hg19 using the Burrows-Wheeller Aligner (BWA) version 0.7.12 (Li and Durbin 2009) disabling seeding (-l 16500, –n 0.01). Duplicates were removed with DeDup version 0.12.2 (Peltzer et al.2016), which removes reads with identical start ad end coordinates. Additionally, a mapping quality filter of 30 was applied using SAMtools version 1.3 (Li et al.2009). Different sequencing runs and libraries from the same individuals were merged, duplicates removed, and sorted again using SAMtools (Li et al., 2009). Reads were genotyped based on the untrimmed reads using the -singleStrandMode of pileup callers version 8.6. (https://github.com/stschiff/sequenceTolls/tree/master/srcpileupCaller), a tool that randomly draws one allele at each of the 1,240 K-targeted SNPs covered at least once. The final genotypes of all ancient individuals were merged to a pulldown of the 1,240 K SNPs from the Simon Genome Diversity Project (Mallick et al.2016), a set of individuals from Asia and the Pacific as reported in Skoglund et al., 2016 (Skoglund et al.2016) genotyped on the Human Origins array and previously published ancient Asian and Oceanian individuals (Yang et al.2020; Skoglund et al. 2016; Posth et al.2018; Lipson et al.2018).

3.2.8.4.6 Quality control

The typical features of ancient DNA were inspected with DamageProfiler version 0.3.1 (http://bintray.com/apeltzer/EAGER/DamageProfiler) (Peltzer et al.2016) (Table 7). Sex determination was performed by comparing the coverage on the targeted X-chromosome SNPs normalized by the coverage on the targeted autosomal SNPs to the coverage on the Y-chromosome SNPs, again normalized by the coverage on the autosomal SNPs (Fu et al.2016) (Table 7). For male individuals, ANGSD version 0.919 was run to measure the rate of heterozygosity of polymorphic sites on the X-chromosome after accounting for sequencing errors in the flanking regions (Korneliussen 2014) (Table 7). For male individuals, ANGSD version 0.919 was run to measure the rate of heterozygosity of polymorphic sites on the X-chromosome after accounting for sequencing errors in the flanking regions (Korneliussen 2014) (Table 7). This provides an estimate of nuclear contamination in males that are expected to have only one allele at each site. All male samples

exhibited X-chromosome contamination levels below 7% with at least 100 X-chromosome SNPs covered twice; hence all reads were retained for further analyses. For both male and female individuals, the reads mapping to the mitochondrial genome were used to reconstruct the mtDNA consensus sequence and estimate contamination levels with schmutzi (Renaud et al., 2015). For specimens where a relatively low proportion of mtDNA molecules compared with nuclear DNA was observed, mtDNA contamination estimates are used as reliable predictors for nuclear contamination (Key et al., 2017; Furtwangler et al., 2018) (Table 7).

3.2.8.5 Stable Isotopes: Bone collagen and Enamel Apatite

The human body is a biologically chemical element and made up of isotopic compositions such as oxygen, carbon, hydrogen, nitrogen, and several trace elements. Carbon and nitrogen stable isotope ratios of human bone and teeth reveal a strong correlation with the diet intake of individuals (Katzenberg 2000; Lee-Thorp 2008). The measurement of stable-isotope ratios in various biological tissues, including teeth and human skeletal tissue, can provide important information about human biological, behavioral, and paleoenvironmental aspects in the past (Alexander, 2020). A major factor influencing the isotopic composition of the human body is food, most pronounced with carbon and nitrogen isotopes. Because bones and teeth reflect the isotopic ratios of foods, researchers employ stable isotope analyses for diet reconstructions (DeNiro and Epstein, 1978; Ambrose and DeNiro, 1986; Keegan, 1989; Katzenberg, 1992). Stable isotope analysis has been confirmed as a reliable method for identifying paleodietary because stable isotopes record aspects of a plant's photosynthesis, nutrition, and source mineral or water (Chesson et al., 2011:705). Bone is a mineralized connective tissue consisting of an organic matrix composed of 90% collagen fibrils and other proteins (Nadar et al., 2020:254; Schwarcz & Schoeninger 1991).

The basis for the stable ratio of isotopes is that each of these materials exists in nature in more than one isotopic form. There are three isotopic forms of carbon: ^{12}C, about 99 percent of carbon, with 6 protons and 6 neutrons. 13C makes up approximately 1 percent of carbon with 6 protons and 7 neutrons, and 14C is unstable and decomposes with 6 protons and 8 neutrons. The nitrogen isotopes of the other petroleum sources used as stable isotope ratios consist of 14N, 99.6 percent, and 15N, 0.36 percent. While for the isotope oxygen, the ^{16}O, 99.8% and ^{18}O is 0.02% (Wang & Stout, 2007:208).

The isotope elements, including Carbon ($^{13}C/^{12}C$), nitrogen ($^{15}N/^{14}N$), and oxygen (^{18}O), are three stable isotope components used in this study to provide insight into dietary compositions between plant vs animal in the human diet (^{13}C and ^{15}N) and water drinks or mineral ratio (^{18}O). The carbon and nitrogen isotope analysis focuses mainly on investigating the consumers' trophic level of

protein. It is used to identify the dietary components between terrestrial and marine diet, as well as C_3 and C_4 resources (van der Merwe et al., 1982; Schwarcz, 1991; Schwarcz & Schoeninger 1991**).**

Oxygen isotope is integrated in human body tissues via drinking water and foods contained water consumed by humans (D'Angela & Longinelli, 1990; Sponheimer and Lee-Thorp, 1999b). In archaeological contexts, the oxygen isotopes preserved in human enamel teeth are used to investigate human history related to human movement and origins. This because the oxygen isotope in water consumed by humans varies in values between the region related to temperature, climate, altitude, and latitude where the region is located (Kendall & Coplen 2001; Rubenstein & Hobson 2004).

3.2.8.5.1 Stable isotope method

All samples (bone collagen and enamel apatite) were prepared and processed at the department of Archaeology Max Planck Institute for the science of Human History Jena-Germany.

For the bone collagen, the pretreatment method is as follows: after cleaning the sample's surface with a sandblaster, roughly 1g of the sample is drilled from the original sample and put into a test tube. 10ML of 0.5M HCl is then added to the sample. The sample is covered with aluminum foil and put in the fridge for 48 hours. After that, the 0.5M HCl is decanted and replaced with new 0.5M HCl until the sample is completely demineralized. After demineralization, the sample is rinsed three times with ultra-pure water before 10mL of a pH3 HCl solution is added to the sample. The sample is then put on a heat block at 70º C for 48 hours. After that, the sample is filtered using an EZEE filter and transferred to a freeze-drier safe plastic tube with a known weight. The tube is covered with parafilm and transferred to the freezer overnight. The sample is then freeze-dried for 24 hours or until it is scorched. The tube+sample's weight is then taken and subtracted that weight from the weight of the empty tube, calculate the sample weight, and then the collagen yield using the formula below. After this, roughly 1mg of the extracted collagen is weighed in duplicate into tin capsules and run on an EA IRMS.

The enamel pretreatment method for enamel apatite analysis is as follows: after the tooth's surface is cleaned using a sandblaster, approximately 10mg of enamel powder is drilled from the enamel surface onto an aluminum foil surface. The sample is weighed and then carefully transferred to a labeled micro-centrifuge tube. Then approximately 1mL of 1% bleach solution is added to the sample for 60 minutes, vortexing the sample periodically. The sample is then centrifuged to separate the supernatant from the sample, and the supernatant is decanted. The sample is then rinsed three times with ultra-pure water, vortexing and centrifuging to rinse the sample continuously and then separate it from the supernatant. After the last rinse is removed, approximately 1mL of 0.1M acetic acid is added to the sample for 10 minutes, vortexing like before mixing the sample with the acid.

The sample is then centrifuged, and the supernatant is removed. The sample is then rinsed the same way as after the bleach step. After the water from the last rinse is removed, the sample rube is covered with parafilm and put into the freezer overnight. The sample is then put on the freeze drier for four hours or until the sample is completely dry. After this, roughly 3mg of the sample is weighed into a culture tube. After the tube is flushed with helium, approximately 20µL of phosphoric acid is added to the sample and the sample is run on a gas bench irms system.

With the small number of isotopic ratios in different parts of the natural environment, the ratios of the stable isotopes are written as delta units expressed in terms of parts per thousand (per mille) using the symbol ‰, and calculated according to the formula. Bone collagen analysis: Carbon Isotope Ratios δ $^{13}C/^{12}C$ ‰ (PDB) and δ $^{15}N/^{14}N$ ‰ (AIR) are conventionally referenced to an internationally recognized standard, and are expressed in δ (delta) notation:

$$\delta X[‰] = (R_{sample}/R_{standard} - 1) \cdot 1000$$

The average range formula for isotope ^{13}C explained as follows:

$$\delta C_M = \frac{\delta C_A + \delta C_B}{2}$$

δ C_A: δ $^{13}C/^{12}C$ result from test A in ‰

δ C_M: δ $^{13}C/^{12}C$ result from test B in ‰

δ C_M: Average/mean δ $^{13}C/^{12}C$ result, based on test A and test B in ‰

while the standard deviation is calculated using the formula:

$$\sigma = \sqrt{\frac{(\delta C_M - \delta C_A)^2 + (\delta C_M - \delta C_B)^2}{1}}$$

σ: Standard deviation for δ $^{13}C/^{12}C$ test A and B results in ‰

The average and standard deviation for isotope ^{15}N were calculated using the following formulas:

$$\delta N_M = \frac{\delta N_A + \delta N_B}{2}$$

δ N_A: δ $^{15}N/^{14}N$ result from test A in ‰

δ N_M: δ $^{15}N/^{14}N$ result from test B in ‰

δ N_M: Average/mean δ $^{15}N/^{14}N$ result, based on test A and test B in ‰

$$\sigma = \sqrt{\frac{(\delta N_M - \delta N_A)^2 + (\delta N_M - \delta N_B)^2}{1}}$$

σ: Standard deviation for δ $^{15}N/^{14}N$ test A and B results in ‰

The C/N ratio is calculated with the following formula:

$$C/N = \frac{\delta C \cdot 14}{\delta N \cdot 12}$$

3.2.8.6 Tooth wear and pathology

This section will describe the methodology and application of human teeth to reconstruct human behavior at the five archaeological sites studied (Mamorikotey, Srobu, Karas, Namatota, and Yomokho). Human teeth from each site will be examined, focusing on paleophatology such as caries, fluorosis, and dental calculus. Various standardization methods will be used to assess the frequency of pathologies affecting human teeth across these locales. This study aims to use the prevalence of infectious diseases such as caries, plaque, and fluorosis in the teeth to gain insights into human dietary behavior. The types and extents of diseases present in each tooth will be analyzed using scoring techniques previous employed by researchers. The scoring results will contribute to understanding human diet behavior and other cultural aspects.

Human teeth from five sites in this study, were analyzed using macro-microscopic techniques to determine wear pattern on the tooth crowns, as well as to identify diseases such as caries, fluorosis, and calculus. In archaeological studies, macro- and microwear and tooth disease on tooth crowns, along with dental diseases, have long been considered influenced by human behavior providing evidence regarding diet preferences, masticatory mechanisms, etc (Turner, 1979; Larsen, 1981, 1995). These types of wear features reflect the habitual behavior and health of past populations, which will be investigated by applying several method analyses. Given that tooth plaque, fluorosis, and caries manifest in different forms and severities, each of these pathologies will be discussed separately in the following paragraph:

3.2.8.6.1 Caries

Dental caries is defined as the localized destruction of tooth tissue by bacterial action (Gibbons and van Houte, 1975). Carious lesions initiate on the enamel surface and, without treatment, can progrss to tooth loss (Hillson, 1979). Carious lesions in past populations provide insights into human adaptation to their physical and cultural environments (Erdal and Duyar, 1999).

Caries in human teeth are defined by the pits or lesions develop on various parts of the tooth surface, which can sometimes be challenging to identify. The Novex Holland microscope was used to identify carious lesions in teeth from the five study sites

In the scoring process, there are four features were observed including:

- The number of caries per tooth
- The area of the lesion in human teeth established at the lingual, buccal, and the lingual area of the tooth
- The location of the lesion present on the crown, cementum enamel junction, and root

- Because the human teeth obtained from archaeological sites often encounter some problem in the observations process (Hillson, 2001), thus, for simple identification and to minimize errors in the scoring process, the lesion present on the teeth classified into three different stages of scales including:
    - Stage 1: small lesion which affects the enamel and less than 10% of the tooth surface
    - Stage 2: medium lesion, which affects both enamel and dentin and spread from 10% to 50% of the tooth surface
    - Stage 3: large lesions penetrating all the dental tissues, enamel, dentin, and pulp. They take more than 50% of the tooth surface.

3.2.8.6.2 Fluorosis

Dental fluorosis in human teeth is characterized by white or brown spots or lines in the enamel, resulting from high fluoride intake (de Souza et al., 2012: 362; Den Besten & Li, 2011). These characteristics were used to identify teeth in this study and assess the degree of fluorosis. The next step is to provide discussions about what factors contributed to human enamel fluorosis at these sites by explaining potential indicators using isotope analysis results, as well as archaeological contexts such as ecofacts and other findings that can be used to explain the causes of tooth fluorosis.

The Bresser microscope was used to examine fluorosis on the tooth surfaces. Employing a microscope during fluorosis examination enhances the feasibility and effectiveness of analysis. The Tooth Surface Index of Fluorosis (TSIF) method, developed by Horowitz et al., (1984) provides explicit criteria and detailed information about the distribution and severity of fluorosis in teeth, particularly in populations where severe fluorosis is prevalent. Fluorosis examination for each tooth utilized the standard scoring system described by Horowitz et al., (1984). The diagnostic criteria and scoring systems as follows:

1. Enamel shows no evidence of fluorosis.
2. Enamel shows definite evidence of fluorosis, namely areas with parchment-white color that total less than one-third of the visible enamel surface. This category confined only to incisal edges of anterior teeth and cusp tips of posterior teeth.
3. Parchment-white fluorosis totals at least one-third of the visible surface, but less than two thirds.
4. Parchment-white fluorosis totals at least two-thirds of the visible surfaces.
5. Enamel shows staining in conjunction with any of the preceding levels of fluorosis; staining is defined as an area of definite discoloration that may range from light to very dark brown.

6. Discrete pitting of the enamel exists, unaccompanied by evidence of staining of intact enamel. A pit is defined as a definite physical defect in the enamel surface with a rough floor that is surrounded by a wall of intact enamel. The pitted are is usually stained or differs in color from the surrounding enamel.
7. Both discrete pitting and staining of the intact enamel exit.
8. Confluent pitting of the enamel surface exists. Large areas of enamel may be missing and the anatomy tooth may be altered. Dark-brown stain is usually present.

3.2.8.6.3 Plaque/dental calculus

Dental calculus is calcified plaque that accumulates on both subgingival and supragingival tooth surfaces over a person's lifetime (Clerehugh et al., 2009). For many years, calculus has been used to assess overall diet and oral health (Klepinger et al., 1977; Kelley and Larsen, 1991; Lieverse, 1999). The formation rates of calculus vary across individuals, influenced by diet and the bacterial ecology of the mouth (Hanihara et al., 1994; Lieverse, 1999).

Dobney and Brothwell (1986, 1988) categorized dental calculus into three types-mild, moderate, and severe- as a method to assess and document the presence of calculus found on human teeth in archaeological sites. The objectives of this method apply in this study including:

- To find out the location of calculus presence on the surface of each tooth from each site.
- The next step is to determine the calculus rate on each tooth and individual in term of mild, moderate, and severe.
- To understand the calculus disease conditions in each tooth from the four sites (Mamorikotey, Srobu, Karas, and Namatota) using the score results of calculus description on each tooth summed by the number of teeth individually to yield the calculus score per person (Rao, 2017: 698).

Scoring criteria:

1. Absence of calculus
2. Supragingival calculus prolonging only lightly below the free gingival margin (not more than 1 mm)
3. Moderate number of supragingival and subgingival calculus or subgingival calculus alone
4. An abundance of supragingival and subgingival calculus.

It is expected that, the use of this scoring method, the pattern and differences in calculus severity will be reveals from each individual from different sites in this research.

3.2.8.6.4 Dental wear

Human dental wear refers to the loss of dental hard tissue caused with fibrous and coarse diet, as well as masticatory behavior on the crown tooth (Smith, 1984; Molnar, 1972; Kaifu et al., 2003). According to dental and anthropological studies, human teeth wear through three primary processes: abrasion, attrition, and erosion, which are commonly observed throughout human life. Examining the presence of wear on teeth reveals insights into human behavior across the five study areas. Tooth wear exhibits diverse pattern in individuals, and the wear rate was measured using a scoring method. Tooth wear investigation involved detailed descriptions and extensive photographic documentation of all teeth, employing the Novex Holand microscope with medium resolution. This microscope enables better identification of macro and microwear features such as pits and scratches on the tooth surfaces. Human teeth including incisors, canines, premolars, and molars are susceptible to various types of macrowear, such as attrition, abrasion, and erosion- each influenced by the morphology of the tooth. In this study, the intensity, frequency, and size of tooth wear were recorded to provide insights into human habits and oral health. Therefore, Smith's (1984), and Brothwell's (1981) scoring methods are relevant to these four teeth categories, widely applied by researchers from the different disciplines, including archaeologist, to investigate the wear on the human teeth found in archaeological site (Mummery, 1870; Brothwell, 1963, 1981; Smith, 1984; Buikstra & Uberlaker, 1994). Smith's (1984) proposed a scoring system to estimate the wear in the incisors, canines, and premolars teeth, while the method described by Brothwell's is using to identify the wear in the molars presented in the following paragraphs:

B. Holy Smith's (1984) scoring system is used to identify the wear on the incisors, canines, and premolars teeth as will explained as follows:

Incisors and Canines:

1. Unworn to polished or small facets (no dentin exposure)
2. Point or hairline of dentin exposure
3. Dentin line of distinct thickness
4. Moderate dentin exposure no longer resembling a line
5. Large dentin area w/enamel ring complete
6. Large dentin are w/enamel ring lost on one side or very thin enamel only
7. Enamel rim lost on two sides, or small remnants of enamel remain.
8. Complete loss of crown, no enamel remaining; crown surface takes on the shape of roots

Premolars:

1. Unworn to polished or small facets (no dentin exposure)
2. Moderate cusp removal (blunting)

3. Full cusp removal and/or moderate dentin patches
4. At least one large dentin exposure on one cusp
5. Two large dentin area (maybe slight coalescence)
6. Dentinal areas coalesced, enamel rim still complete
7. Full dentin exposure, loss of rim on at least one side
8. Severe loss of crown height; crown surface takes on the shape of roots

Chapter 4: Results

4.1 Metric traits results

In this study, metric dental features are utilized to generate dental genetic maps of lowland populations from two separate groups: the Late Holocene group (Mamorikotey, Srobu, Karas, and Namatota), and the Eighteenth Century, represented by human teeth from Biak-Sowek & Kayu Batu.

The measurements of the teeth size show a 0.1mm difference among observes, indicating that the results are highly reliable (Hunter & Priest, 1960). Multivariate statistical procedures were undertaken to test the level of variation of the average tooth size and to measure the distance between the group in this study. Data sets of dental metrics from 17 populations were added to investigate the Lowland Papuan population affiliations (Table 4). The statistics results show four (4) distinct patterns:

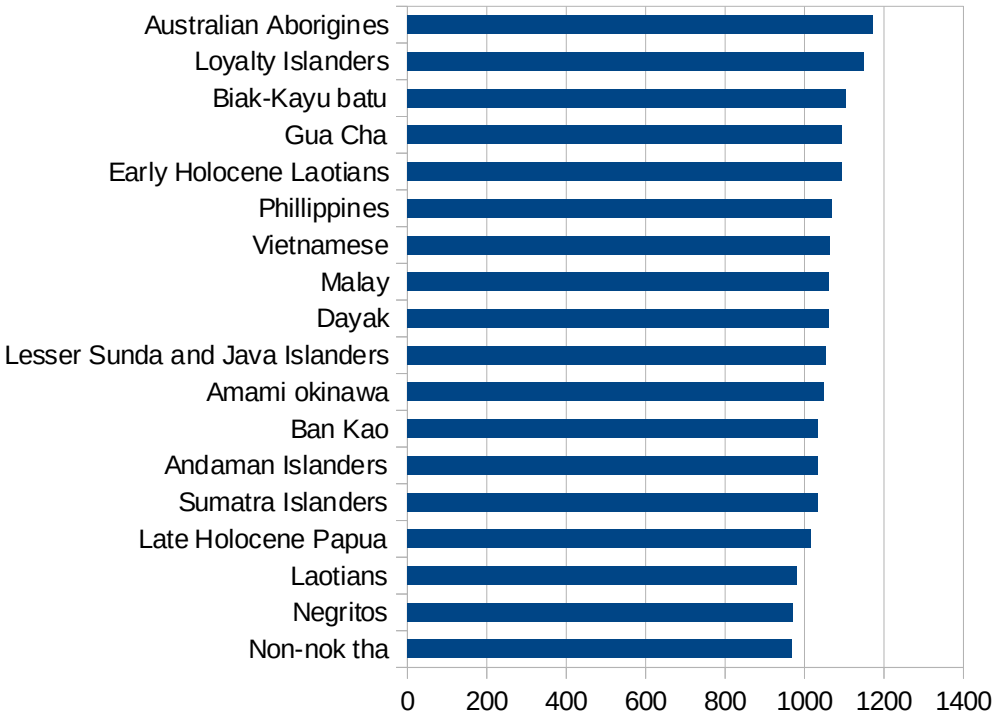
1) Table 4 provides sample size, means, standard deviations for mesiodistal and buccolingual diameters, t-test values, the number of degrees of freedom (df), and p-values from all the crown measurements. A p-value below 0.05 is considered a significant difference, while a value p-value above 0.05 is considered insignificant. Most mesiodistal diameters were not found to be significantly different, or the related sample size in the Late-Holocene group was very low. Exceptions are the LP2 and LM2 mesiodistal diameters, which were found to be significantly smaller in the Late-Holocene group, with 5 samples each. Most buccolingual diameters, however show a significant difference. Specifically, the UP1 diameter in the Late-Holocene group was found to be significantly smaller, while their UM1 and UM2 diameters were found to be significantly larger, although with a small sample size. In general, the results show a tendency for larger tooth diameters among the Current Era group.

2) Table 5 shows the triangular distance matrix result for all populations in this study based on the raw data of mesiodistal, buccolingual measurements. The distance values marked in bold in the table represent the close relationships of population groups. The Andaman Islanders and Loyalty Islanders show the closest relationship in this study. The two groups from Papua Indonesia present a relationship with each other; in any case, it does not indicate excessively intimate kinships between them.

3) The results obtained from the distance matrix data set analysis, used for the Tree diagram of the Neighbor Joining and UPGMA Cluster method that was measured excluding three groups of populations including, Amami Okinawa, Vietnamese, and Negritos to simplify the cluster, demonstrates that the samples from Papua (Late Holocene and Current Era group) are clustered together with Guar Kepah indicating their close affinities (Figure 26 and 28). Nine populations share the same branch, including Early Holocene Laotians, Ban Kao, Lesser Sunda and Java Islanders, Laotioans, Non-Nok Tha, Malay, Sumatra Islanders, Dayak and Philippines. In addition, the Gua Cha group, Loyalty Islanders, Andaman Islanders, and Australian Aborigines are joined together in the same branch.

4) Based on the total average calculation of tooth crown size (Table 3), the results show that the Australian Aborigines have the largest teeth in the entire population group in this study, followed by the Loyalty Islanders, with Biak-Sowek & Kayu Batu in the third number. Thus, it can be assumed that the Current Era group implies a close genetic relationship with Australian Aborigines and Loyalti Islanders, which by genetically inherited Australo-Melanesian affinities. The Late Holocene Papuan group's teeth are placed in the fourth smallest tooth group in this study, followed by the Laotians group, Negritos, and Non-Nok Tha. Therefore, the average tooth size differences between the two Lowland populations may due to the smaller number of teeth applied for the Late Holocene group compared to the Eighteenth Century group.

***Table 3**: The total dental crown size (Mesiodistal x Buccolingual) for all teeth in this research*



4.2 Ancient DNA (aDNA) results

4.2.1 Population genomic analysis

4.2.1.1 Principal component analysis

Principal component analyses were performed using smartpca version 13050 (Patterson, Price, and Reich 2006) with a set of populations from East Asia and the Pacific. Ancient individuals were projected onto the calculated components using the options ‘Isqproject: YES’, ‘shrink mode: YES’, and ‘numoutlieriter: 0’ (Figure 26).

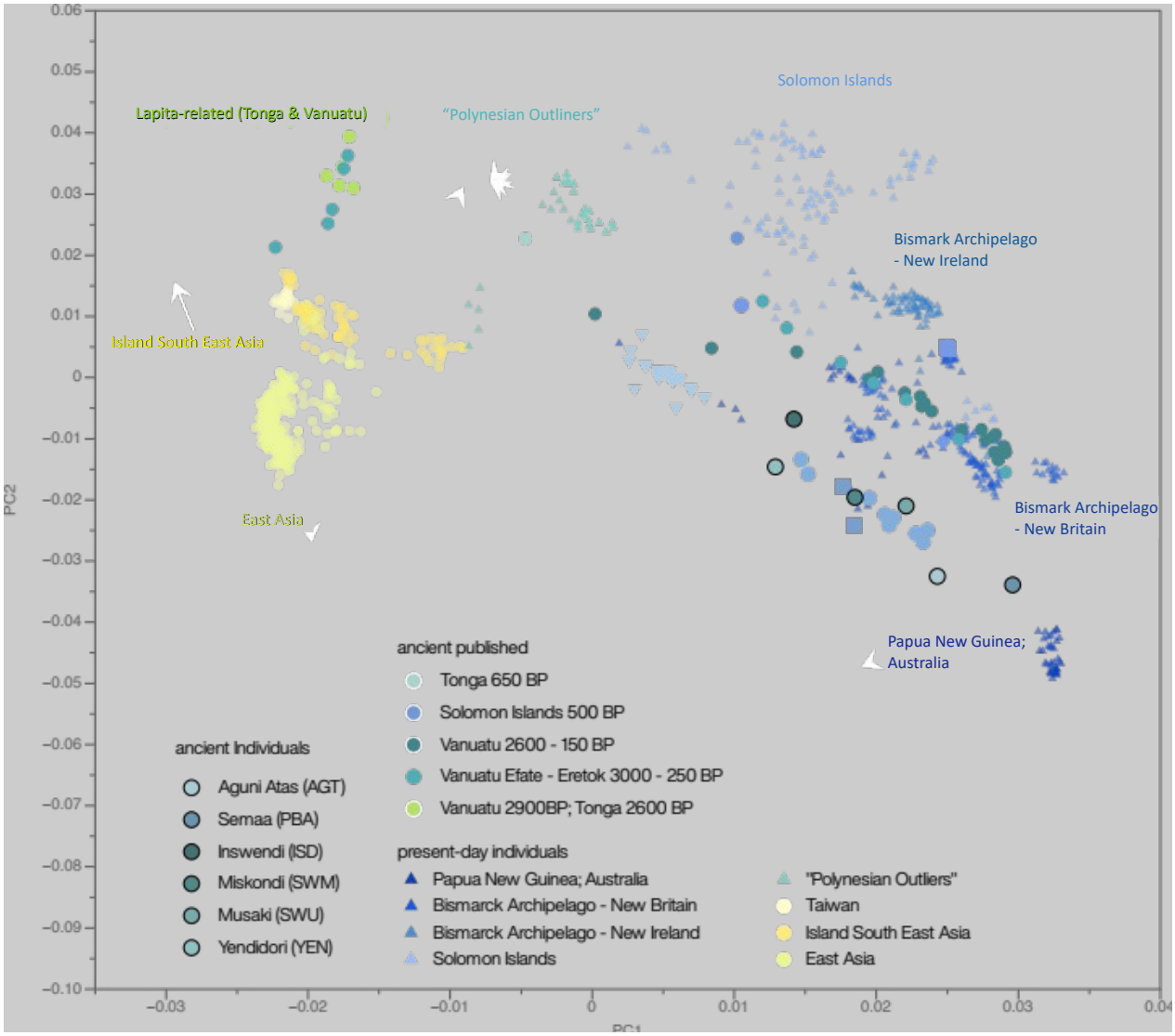


***Figure 26**: Principle Component Analysis (PCA), calculated based on present-day populations genotyped on the Human Origins array from Asia and Oceania. Ancient individuals are projected. The ancient individuals from Papua-Indonesia cluster with present-day individuals from coastal Papua New Guinea, in a space between Papuan Highland communities and Asian individuals, suggesting a mixture of the two components. Individuals from Pulau Biak are more removed towards Asian populations, suggesting a higher Asian ancestry component, while individuals from Papua Barat cluster closer to New Guinean highlanders.*

4.2.1.2 f-statistics

To test which present-day populations represented best the East-Asian related ancestries in the individuals, the f4-statistics was computed of the form and *f4 (Mbuti. DG, Test, X, Ami),* (respectively), testing in X all other populations from the region (Appendix A Table 1). To understand whether the Asian ancestry component was more similar to the Early Remote Oceanians (ERO) from Vanuatu and Tonga (Skoglund et al. 2016) compared to ancient Austronesian from Taiwan (Suogang) (Yang et al. 2020) (Table 8), predating the expansion to Near and Remote

Oceania, and *f4 (Mbuti. DG, Test; Suogang, ERO)* was calculated. This statistic calculation expected positive test scores for a higher affinity to Early Remote Oceanians.

4.2.1.3 Ancestry modeling

The qpWave version 410 (Reich et al.2012) was used to test whether individuals were consistent with deriving from the same group as other individuals from the same site, relative to a set of reference groups (Mbuti, Onge, New_Guinea, Baining_Marabu, Ami, Han, English, Chukchi, Nasioi, Denisova_published. D.G.).To test whether some individuals could be modeled as a single ancestry component, the respective individuals and Ami were modeled to examine exclusively Asian and New Guinea ancestry to test for exclusively Near Oceanian ancestry (Table 9a). For this, the same references were used as detailed above, excluding the respective populations used in the test (Harney et al.2020). After confirming that all individuals were not consistent with deriving from one respective ancestry, the qpAdm version 5.0 was used (Patterson et al.2012) to model all individuals as a two-way admixture between New Guinea and Ami. Mbuti, Onge, Han, Chukchi, English, and Denisova_published. D.G. was used as reference groups (Table 9b, Figure 27).

4.2.1.4 Uniparental markers

Consensus sequences resulting from the reconstruction of the mitochondrial genome (Renaud et al.2015) were filtered for bases with a quality of less than 30, and mitochondrial Haplogroups were assigned through Haplogroup 2.0 (Weissensteiner et al.2016). Y-chromosomal haplogroups were identified by calling the SNPs covered on the Y-chromosomes of all-male individuals by using the pileup from the Rsamtools (M. Morgan 2019) package and assigning haplogroups by analyzing the overlap with the ISOGP SNP index v.14.07 (Rohrlach et al.2021) (Table 7).

4.2.2 DNA damage and contamination

From twenty-four samples processed for aDNA analysis, eighteen of them have shown a series of damage, while the DNA on the six samples were successfully extracted, as will be presented as follows.

DNA analysis is applied to solve the archaeological problems, including the questions about human origin history as one of the aims that needed to be answered in this study. However, related to the analysis result (Table 6), the DNA was not successfully extracted from most of the samples. The samples in this study consist of organic matter, which is easily degraded by the chemistry and temperature of soils as well as micro-organisms living in this environment.

Table 6 shows the list of samples that were presents poor quality of the aDNA that was recognized causes by several aspects as will be explained as follows.

4.2.2.1 Endogenous DNA (Table 6)

The endogenous DNA describes the percentage of authentic molecules in the library, so molecules that map to the human genome and show the characteristic signs of ancient DNA. If the number of those molecules is low (below 0.1%) then it is consider too low to be economical to reconstruct a genome. The library is probably dominated by environmental contamination and modern human contamination, and/or preservation of the individual's DNA is to poor to continue. Most of the samples had to be excluded already based on this value (highlighted in red in the attached table).

4.2.2.2 Damage 1st base 5' end (Table 6)

This value shows the percentage of sites on the first position of the 5' end of the molecule that displays a chemical alteration called deamination, where a cytosine base is deaminated in the presence of water and therefore altered to a uracil, a base usually only found in RNA, not in DNA. The samples in column can not read Uracil and misinterpret it as Tynmine. So this type of damage is also referred to as C to T substitution, or simply 'damage'. It's one of the most important features of ancient DNA.

4.2.2.3 Fragment length (Table 6)

DNA degrades quickly after the death of a person, and after only a few years is usually degraded to molecules of 35-55 base pairs. If molecules are much longer, then we are likely dealing with contamination. While most of the fragment lengths in the eighteenth samples fall within that range.

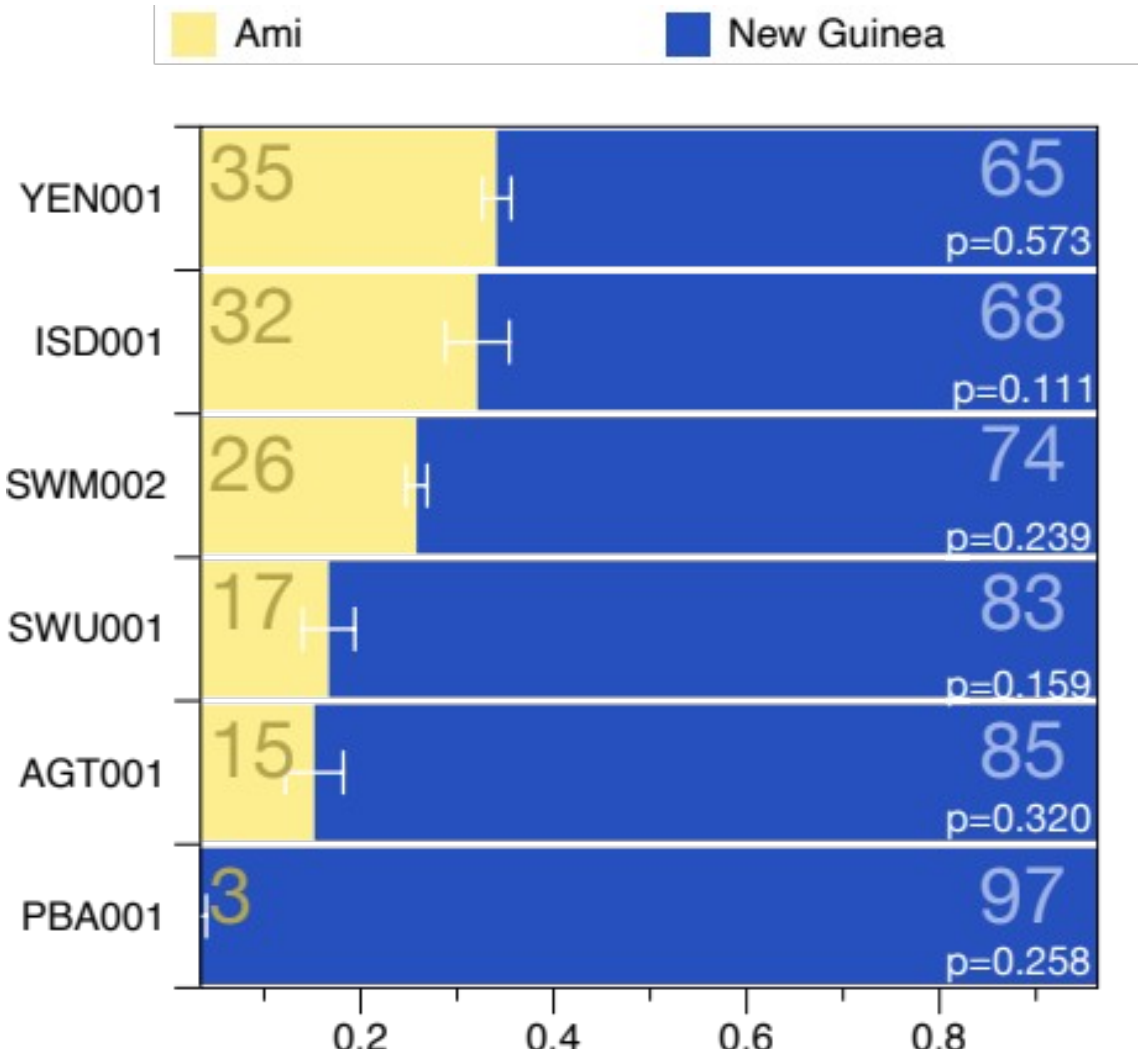


***Figure 27**: Ancestry modeling. qpAdm analysis of all individuals using Ami as the Asian source (yellow) and New Guinean Highlanders as the Papuan source (blue). Numbers in the left and right corner show the percentage of the Asian and Papuan component respectively. While lines indicate the standard errors of the components. p-values are shown in the lower right corner. Values above 0.05 are indicating a good fit of the model. References used are Mbuti, Onge, Baining_Marabu, Han, English, Chukchi, Nasioi, Denisova_published.DG.*

***Table 4**: Descriptive statistics coefficient matrix t-test, df and p-value of crown measurements from 19 populations in this study*

	Late-Holocene Papua			**Kayu batu & Biak Papua**						**Australian Aborigines**						**Loyalty Islanders**				
	n	**Mean**	**SD**	**n**	**Mean**	**Std**	**t**	**df**	**p**	**n**	**Mean**	**SD**	**t**	**df**	**p**	**n**	**Mean**	**SD**	**t**	**df**	**p**
UI1_MD	3	9.57	0.38	18	9.05	0.53	2.06	19	0.026682	19	9.06	0.53	2.03	20	0.027935	11	8.96	0.72	1.98	12	0.035552
UI2_MD	3	7.28	0.35	14	7.78	0.80	-1.70	15	**0.054883**	23	7.26	0.50	0.09	24	**0.464517**	14	7.3	0.51	-0.08	15	**0.468647**
UC_MD	11	7.58	0.79	10	7.02	0.95	1.47	19	**0.078964**	34	8.29	0.52	-2.79	43	0.003913	17	8.44	0.41	-3.33	26	0.001303
UP1_MD	4	7.18	0.77	13	7.12	0.78	0.14	15	**0.445261**	37	7.53	0.47	-0.90	39	**0.186822**	22	7.58	0.54	-1.00	24	**0.163643**
UP2_MD	2	6.14	0.06	15	7.38	0.38	-11.70	15	1E-05	41	7.02	0.49	-10.19	41	1E-05	22	7.28	0.47	-10.57	22	1E-05
UM1_MD	2	10.38	0.40	20	10.84	0.55	-1.49	20	**0.075913**	45	11.19	0.62	-2.72	45	0.004622	27	11.11	0.60	-2.39	27	0.012046
UM2_MD	2	10.70	0.59	20	10.35	0.83	0.76	20	**0.22806**	47	10.48	0.68	0.51	47	**0.306219**	26	10.48	0.63	0.50	26	**0.31064**
LI1_MD	3	5.73	0.33	4	6.37	0.05	-3.32	5	0.010504	12	5.64	0.37	0.39	13	**0.351426**	8	5.24	0.42	2.00	9	0.038276
LI2_MD	2	6.20	0.71	3	6.31	0.21	-0.21	3	**0.423561**	13	6.41	0.72	-0.39	13	**0.351426**	12	5.86	0.35	0.67	12	**0.257772**
LC_MD	7	6.93	0.86	8	7.02	0.41	-0.26	13	**0.399468**	20	7.22	0.45	-0.85	25	**0.201696**	14	7.25	0.30	-0.95	19	**0.17702**
LP1_MD	8	7.10	0.83	30	7.57	0.42	-1.58	36	**0.061427**	29	7.41	0.66	-0.99	35	**0.164485**	18	7.46	0.39	-1.19	24	**0.122843**
LP2_MD	5	7.07	0.62	20	7.63	0.45	-1.89	23	0.035713	27	7.5	0.51	-1.45	30	**0.078717**	16	7.72	0.42	-2.17	19	0.021446
LM1_MD	2	10.38	0.37	35	12.36	0.59	-7.11	35	1E-05	28	12.33	0.66	-6.76	28	1E-05	21	12.2	0.50	-6.45	21	1E-05
LM2_MD	5	10.52	0.70	39	11.66	0.74	-3.42	42	0.000703	36	12.12	0.91	-4.62	39	2.1E-05	21	11.84	0.65	-3.86	24	0.000375
UI1_BL	3	7.98	0.24	18	7.65	0.14	2.32	19	0.015814	18	7.93	0.49	0.28	19	**0.391252**	12	7.82	0.34	0.94	13	**0.182178**
UI2_BL	3	6.60	0.41	14	7.39	0.73	-2.58	15	0.010457	25	6.80	0.51	-0.78	26	**0.221217**	17	6.81	0.44	-0.81	18	**0.21426**
UC_BL	11	7.91	0.64	10	8.40	0.45	-2.06	19	0.026682	39	8.97	0.68	-4.81	48	0.00`001	17	8.73	0.62	-3.37	26	0.001178
UP1_BL	4	7.18	0.77	13	9.88	0.51	-6.61	15	1E-05	34	10.02	0.72	-7.05	36	1E-05	21	10.24	0.69	-7.43	23	1E-05
UP2_BL	2	9.31	0.95	15	9.48	0.65	-0.25	15	**0.402989**	41	10.08	0.64	-1.14	41	**0.130451**	21	10.26	0.65	-1.39	21	**0.089544**
UM1_BL	2	12.84	0.20	20	11.76	0.49	6.04	20	1E-05	47	12.76	0.70	0.46	47	**0.323819**	29	12.57	0.64	1.46	29	**0.07752**
UM2_BL	2	12.90	0.25	20	11.54	0.68	5.77	20	1E-05	48	13.02	0.87	-0.55	48	**0.292435**	26	12.83	0.71	0.31	26	**0.379516**
LI1_BL	3	6.19	0.54	4	6.55	0.30	-1.06	5	**0.168821**	17	6.26	0.51	-0.22	18	**0.414173**	8	6.13	0.44	0.16	9	**0.438207**
LI2_BL	2	6.07	0.24	3	6.85	0.45	-2.51	3	0.043469	23	6.47	0.43	-2.08	23	0.024428	13	6.52	0.5	-2.05	13	0.030548
LC_BL	7	7.18	0.45	8	8.13	0.46	-4.04	13	0.000701	25	8.24	0.67	-4.90	30	1.5E-05	15	8.19	0.54	-4.59	20	8.9E-05
LP1_BL	8	8.13	0.87	30	8.22	0.50	-0.30	36	**0.382951**	29	8.73	0.67	-1.83	35	0.037889	17	8.69	0.48	-1.72	23	0.049431
LP2_BL	5	7.87	0.57	20	8.33	0.53	-1.64	23	0.057306	27	8.95	0.63	-3.84	30	0.000296	16	8.93	0.73	-3.39	19	0.001537
LM1_BL	2	10.71	0.01	35	11.02	0.63	-2.90	35	0.003204	36	11.75	0.60	-10.35	36	1E-05	21	11.2	0.59	-3.79	21	0.000536
LM2_BL	5	9.88	0.49	39	10.58	0.63	-2.90	42	0.002957	36	11.40	0.68	-6.16	39	1E-05	21	10.93	0.77	-3.80	24	0.000436

***Table 4**: continued*

	Early Holocene Laotians						Negritos						Andaman Islanders						Lesser Sunda and Java Islanders					
	n	Mean	SD	t	df	p	n	Mean	SD	t	df	p	n	Mean	SD	t	df	p	n	Mean	SD	t	df	p
UI1_MD	6	8.85	0.45	2.52	7	0.019905	21	8.37	0.67	4.55	22	7.9E-05	8	8.34	0.4	4.71	9	0.000552	6	8.75	0.54	2.64	7	0.016712
UI2_MD	4	7.5	0.48	-0.7	5	**0.257574**	21	6.95	0.75	1.27	22	**0.108677**	13	6.81	0.48	1.94	14	0.036398	6	7.21	0.55	0.23	7	**0.412334**
UC_MD	7	8.02	0.67	-1.26	16	**0.112869**	21	7.74	0.4	-0.62	30	**0.26997**	15	7.84	0.35	-1.01	24	**0.161285**	8	8.1	0.29	-2	17	0.030869
UP1_MD	6	7.68	0.78	-1	8	**0.173297**	23	7.16	0.39	0.05	25	**0.48026**	19	7.3	0.41	-0.3	21	**0.383563**	9	7.59	0.4	-1.01	11	**0.167098**
UP2_MD	7	6.94	0.4	-5.12	7	0.000684	20	6.85	0.47	-6.31	20	1E-05	18	6.69	0.33	-6.29	18	1E-05	8	7	0.4	-5.85	8	0.000191
UM1_MD	8	10.81	0.74	-1.12	8	**0.147605**	20	10.51	0.42	-0.44	20	**0.332328**	25	10.59	0.43	-0.71	25	**0.242137**	10	10.71	0.45	-1.04	10	**0.161416**
UM2_MD	7	9.97	9.97	0.19	7	**0.427351**	18	9.34	0.56	3.09	18	0.003158	25	9.55	0.94	2.5	25	0.009672	10	9.62	0.54	2.38	10	0.019306
LI1_MD	7	5.53	5.53	0.09	8	**0.46525**	20	5.27	0.52	2.03	21	0.027608	6	5.03	0.29	3.09	7	0.008783	5	5.61	0.35	0.47	6	**0.327476**
LI2_MD	6	6.4	0.48	-0.37	6	**0.362046**	22	5.94	0.49	0.51	22	**0.307565**	9	5.34	0.73	1.55	9	**0.077776**	5	6.48	0.28	-0.54	5	**0.306185**
LC_MD	6	7.28	0.84	-0.74	11	**0.237399**	21	6.76	0.49	0.49	26	**0.314122**	11	7.02	0.42	-0.26	16	**0.39909**	5	7.32	0.53	-0.97	10	**0.177461**
LP1_MD	6	7.26	0.61	-0.43	12	**0.337408**	24	6.92	0.44	0.57	30	**0.286461**	14	7.2	0.47	-0.33	20	**0.372416**	5	7.31	0.56	-0.56	11	**0.293351**
LP2_MD	7	7.56	0.66	-1.3	10	**0.111383**	25	7.05	0.56	0.07	28	**0.472346**	17	7.29	0.38	-0.74	20	**0.233949**	5	7.2	0.21	-0.44	8	**0.335791**
LM1_MD	8	12.11	0.5	-5.5	8	0.000287	19	11.34	0.5	-3.38	19	0.001572	18	11.6	0.54	-4.21	18	0.000263	6	11.78	0.47	-4.33	6	0.002464
LM2_MD	6	11	0.86	-1.02	9	**0.167181**	17	10.31	0.67	0.6	20	**0.277622**	17	11.05	0.54	-1.57	20	**0.066051**	5	10.58	0.44	-0.16	8	**0.438424**
UI1_BL	6	7.42	0.45	2.43	7	0.02271	9	7.47	0.59	2.12	10	0.030012	8	7.27	0.36	3.77	9	0.002208	6	7.47	0.46	2.19	7	0.032339
UI2_BL	4	6.8	0.48	-0.59	5	**0.290422**	9	6.26	0.6	1.1	10	**0.148553**	13	6.48	0.58	0.42	14	**0.34043**	7	6.72	0.61	-0.36	8	**0.364083**
UC_BL	7	8.62	0.67	-2.24	16	0.01982	13	7.83	0.57	0.31	22	**0.379739**	15	8.32	0.49	-1.79	24	0.04304	8	8	0.8	-0.27	17	**0.395205**
UP1_BL	6	9.83	0.78	-5.32	8	0.000356	24	9.24	0.51	-5.19	26	1E-05	19	9.85	0.67	-6.47	21	1E-05	9	9.49	0.76	-5.03	11	0.000192
UP2_BL	7	9.8	0.4	-4.22	7	0.001968	20	8.99	0.45	0.47	20	**0.32172**	18	9.58	0.35	-0.4	18	**0.346932**	8	9.51	0.51	-0.29	8	**0.389595**
UM1_BL	8	12.21	0.74	1.78	8	**0.056475**	20	11.38	0.48	8.22	20	1E-05	25	12.13	0.51	4.07	25	0.000207	10	12.16	0.41	3.54	10	0.002678
UM2_BL	7	12.31	0.38	29.96	7	1E-05	18	10.96	0.55	8.75	18	1E-05	24	11.95	0.84	3.82	24	0.000415	10	11.93	0.61	3.68	10	0.002123
LI1_BL	7	6	0.56	-1.05	8	**0.1622**	13	6.05	0.46	0.41	14	**0.344005**	8	5.92	0.52	0.74	9	**0.239079**	4	5.97	0.47	0.56	5	**0.29982**
LI2_BL	6	6.58	0.48	-7.02	6	0.000208	15	6.54	0.39	-2.38	15	0.015506	9	6.25	0.36	-0.87	9	**0.203453**	4	6.44	0.56	-1.13	4	**0.160823**
LC_BL	6	7.89	0.84	-2.93	11	0.006845	9	7.74	0.51	-2.34	14	0.017308	11	7.64	0.53	-1.98	16	0.032585	4	8.16	0.33	-4.14	9	0.001261
LP1_BL	6	8.3	0.61	-1.13	12	**0.140279**	22	7.86	0.45	0.82	28	**0.209571**	14	8.21	0.39	-0.26	20	**0.398761**	5	8.15	0.31	-0.07	11	**0.472725**
LP2_BL	7	8.57	0.5	-10.45	10	1E-05	23	8.09	0.42	-0.83	26	**0.207048**	17	8.72	0.42	-3.11	20	0.002759	5	8.41	0.49	-1.61	8	**0.073032**
LM1_BL	8	11.18	0.5	0.56	8	**0.295405**	19	10.45	0.41	2.75	19	0.006367	17	11.11	0.6	-2.74	17	0.006979	6	10.78	0.58	-0.3	6	**0.38715**
LM2_BL	6	10.61	0.86	-1.76	9	**0.056131**	19	9.84	0.58	0.16	22	**0.437171**	18	10.51	0.68	-2.32	21	0.015248	5	10.23	0.47	-1.15	8	**0.141679**

***Table 4**: continued*

	Sumatra Islanders						Dayak						Malay						Philippines					
	n	Mean	SD	t	df	p	n	Mean	SD	t	df	p	n	Mean	SD	t	df	p	n	Mean	SD	t	df	p
UI1_MD	5	8.61	0.16	4.16004	6	0.002972	5	8.89	0.67	1.83107	6	0.058494	3	9.19	0.57	0.96077	4	0.19571	2	8.94	0.13	2.64848	3	0.038497
UI2_MD	9	7.09	0.51	0.71762	10	**0.244006**	6	7.2	0.58	0.25651	7	**0.401173**	4	6.81	0.43	1.58957	5	0.086353	3	7.05	0.21	0.9728	4	**0.193487**
UC_MD	17	7.96	0.46	-1.43907	26	**0.0809**	14	8.05	0.49	-1.7238	23	**0.049431**	10	8.3	0.4	-2.66516	19	**0.007568**	5	8.34	0.66	-1.99983	14	0.032644
UP1_MD	19	7.52	0.29	-0.87412	21	**0.197068**	23	7.46	0.43	-0.7114	25	**0.242137**	22	7.47	0.34	-0.74354	24	**0.233239**	10	7.62	0.31	-1.11232	12	**0.144374**
UP2_MD	21	7.01	0.49	-7.62064	21	1E-05	26	6.91	0.54	-6.8018	26	1E-05	27	6.91	0.34	-10.0403	27	1E-05	6	7.05	0.45	-4.84001	6	0.00144
UM1_MD	23	10.43	0.49	-0.16626	23	**0.433248**	36	10.58	0.65	-0.6603	36	**0.256727**	46	10.6	0.42	-0.75982	46	**0.225566**	17	10.59	0.38	-0.70593	17	**0.243665**
UM2_MD	20	9.47	0.55	2.81056	20	**0.005408**	35	9.67	0.89	2.30875	35	0.013453	44	9.5	0.56	2.80112	44	0.003781	17	9.62	0.67	2.39819	17	0.014063
LI1_MD	11	5.48	0.22	1.21263	12	**0.124788**	6	5.85	0.42	-0.4787	7	0.322932	5	5.86	0.32	-0.55624	6	0.297876	2	5.51	0.4	0.63349	3	**0.286705**
LI2_MD	13	6.11	0.25	0.17829	13	**0.429964**	7	6.32	0.41	-0.2292	7	**0.412334**	4	6.22	0.3	-0.03831	4	**0.485005**	2	6.29	0.23	-0.17117	2	**0.440326**
LC_MD	12	7	0.39	-0.20659	17	**0.418082**	12	7.12	0.35	-0.5595	17	**0.291392**	6	7.21	0.54	-0.71374	11	**0.246241**	1	6.79		0.42388	6	**0.344555**
LP1_MD	18	7.35	0.42	-0.82728	24	**0.207359**	15	7.35	0.58	-0.7772	21	**0.222047**	6	7.47	0.38	-1.1344	12	**0.140279**	5	7.46	0.48	-1.00734	11	**0.167098**
LP2_MD	18	7.22	0.41	-0.50153	21	**0.311137**	15	7.22	0.67	-0.451	18	**0.329041**	6	7.37	0.57	-0.82055	9	**0.216698**	4	7.08	0.77	-0.01683	7	**0.492301**
LM1_MD	18	11.53	0.42	-4.13359	18	0.000314	22	11.74	0.55	-4.7683	22	4.6E-05	6	11.84	0.45	-4.58607	6	0.001866	8	12.06	0.5	-5.34344	8	0.000347
LM2_MD	20	10.81	0.52	-0.87232	23	**0.196645**	20	11.03	0.82	-1.4111	23	**0.08596**	6	10.92	0.73	-0.92794	9	**0.188321**	7	11.07	0.75	-1.30599	10	**0.109744**
UI1_BL	7	7.25	0.42	3.46443	8	0.004284	5	7.46	0.36	2.44804	6	0.024895	5	7.44	0.76	1.47122	6	0.09598	2	7.56	0.9	0.64486	3	0.283849
UI2_BL	12	6.77	0.36	-0.65973	13	**0.260388**	9	6.88	0.24	-1.1245	10	**0.144446**	4	6.41	0.69	0.45467	5	**0.335775**	4	6.77	0.51	-0.48947	5	**0.322438**
UC_BL	18	8.36	0.52	-1.98564	27	0.028403	13	8.59	0.6	-2.685	22	**0.006688**	10	8.54	0.52	-2.50104	19	0.01087	5	8.81	0.61	-2.70489	14	**0.008628**
UP1_BL	18	9.67	0.47	-6.24182	20	1E-05	24	9.78	0.65	-6.411	26	1E-05	23	9.73	0.56	-6.36503	25	1E-05	10	9.92	0.38	-6.8222	12	1E-05
UP2_BL	21	9.49	0.56	-0.2643	21	0.398698	25	9.59	0.69	-0.4093	25	**0.342649**	26	9.37	0.6	-0.0882	26	**0.464488**	6	9.63	0.32	-0.46878	6	**0.327476**
UM1_BL	23	11.9	0.59	5.01486	23	**2.3E-05**	36	11.89	0.7	5.18182	36	1E-05	46	11.97	0.58	5.26422	46	1E-05	17	12.06	0.53	4.08139	17	0.00039
UM2_BL	20	11.74	0.63	5.075	20	2.9E-05	35	11.85	0.88	4.49665	35	3.6E-05	44	11.78	0.78	5.20917	44	1E-05	18	11.82	0.54	4.89898	18	5.8E-05
LI1_BL	12	5.81	0.33	1.16176	13	**0.133455**	8	6.16	0.36	0.0796	9	**0.468994**	5	5.87	0.49	0.8343	6	**0.219154**	2	5.59	0.58	1.16072	3	**0.16499**
LI2_BL	14	6.29	0.5	-1.01742	14	0.162516	7	6.36	0.71	-0.9129	7	0.196539	4	6.46	0.49	-1.30783	4	**0.130181**	2	6.53	0.14	-2.33831	2	**0.07208**
LC_BL	13	7.81	0.52	-2.83107	18	0.005549	13	7.85	0.58	-2.8678	18	0.005092	6	8.04	0.56	-3.02363	11	0.005828	1	7.9		-4.23237	6	0.00275
LP1_BL	18	8.16	0.54	-0.10535	24	**0.456662**	15	8.16	0.73	-0.0972	21	**0.460646**	6	8.31	0.65	-0.45601	12	**0.198209**	5	8.57	0.42	-1.23684	11	**0.120388**
LP2_BL	19	8.5	0.46	-2.29559	22	0.015654	15	8.38	0.59	-1.7273	18	**0.05037**	6	8.68	0.89	-1.83097	9	0.050248	4	8.18	1.05	-0.53485	7	**0.306251**
LM1_BL	20	10.75	0.6	-0.29732	20	**0.383637**	22	10.94	0.56	-1.9197	22	0.033958	6	11.05	0.66	-1.26099	6	0.127229	9	10.89	0.46	-1.17142	9	**0.136025**
LM2_BL	20	10.29	0.44	-1.70685	23	**0.050362**	21	10.47	0.72	-2.1881	24	**0.019239**	6	10.38	0.62	-1.49346	9	0.085205	7	10.49	0.73	-1.73125	10	**0.057157**

***Table 4**: continued*

	Vietnamese						Laotians						Amami-Okinawa Islanders						Gua Kepah					
	n	Mean	SD	t	df	p	n	Mean	SD	t	df	p	n	Mean	SD	t	df	p	n	Mean	SD	t	df	p
UI1_MD	4	8.87	0.37	2.43918	5	0.029327	2	8.27	0.07	5.78016	3	0.005149	36	8.51	0.45	4.57176	37	2.6E-05	7	9.33	0.34	0.94392	8	0.187364
UI2_MD	3	7.23	0.83	0.09608	4	**0.462578**	5	6.75	0.73	1.37869	6	**0.108402**	36	7.08	0.52	0.90618	37	0.184356	6	7.71	0.45	-1.57066	7	**0.080203**
UC_MD	9	8.09	0.41	-1.85202	18	**0.0404**	8	7.67	0.37	-0.3248	17	**0.376434**	40	7.82	0.45	-0.95906	49	**0.170884**	6	8.26	0.54	-2.09078	15	0.027031
UP1_MD	17	7.41	0.62	-0.55869	19	**0.291011**	16	7.26	0.51	-0.1981	18	**0.421861**	49	7.32	0.45	-0.36028	51	**0.360167**	6	7.89	0.26	-1.78545	8	**0.05562**
UP2_MD	16	7.12	0.99	-3.90888	16	0.000624	21	6.7	0.37	-6.2149	21	1E-05	46	6.84	0.42	-9.49526	46	1E-05	5	7.2	0.52	-4.49217	5	0.003229
UM1_MD	33	10.52	0.49	-0.47389	33	**0.320723**	29	10.36	0.41	0.06828	29	**0.472337**	58	10.42	0.56	-0.13687	58	**0.444573**	4	11.24	0.15	-2.93899	4	**0.021195**
UM2_MD	30	9.5	0.53	2.78421	30	**0.004648**	27	8.99	0.63	3.9117	27	0.000281	44	9.62	0.46	2.53708	44	0.007346	4	10.43	0.34	0.59589	4	0.290421
LI1_MD	5	5.47	0.54	0.83143	6	**0.219154**	2	5.29	0.51	1.06845	3	0.181529	40	5.36	0.34	1.83637	41	0.036508	4	5.87	0.25	-0.62495	5	**0.281209**
LI2_MD	9	6.02	0.51	0.34084	9	**0.370829**	2	6.18	0.01	0.04	2	**0.485864**	41	5.89	0.36	0.61612	41	**0.269344**	5	6.86	0.13	-1.31117	5	**0.123575**
LC_MD	12	7.05	0.36	-0.35398	17	**0.365319**	10	7.13	0.3	-0.5917	15	**0.281987**	43	6.89	0.64	0.11306	48	**0.456434**	6	7.34	0.34	-1.15842	11	**0.135304**
LP1_MD	12	7.34	0.62	-0.71552	18	**0.240385**	15	6.92	0.45	0.557	21	**0.290702**	54	7.12	0.53	-0.08314	60	**0.468252**	8	7.85	0.43	-2.29396	14	**0.019032**
LP2_MD	10	7.75	0.49	-2.12546	13	**0.026425**	12	7.04	0.35	0.1079	15	**0.456934**	52	7.14	0.51	-0.23639	55	**0.405611**	6	7.89	0.78	-1.93265	9	**0.042836**
LM1_MD	17	11.63	0.54	-4.29371	17	0.000248	18	11.48	0.52	-3.8269	18	0.000613	60	11.65	0.45	-4.76706	60	1E-05	5	12.56	0.18	-8.00951	5	0.000245
LM2_MD	20	11.04	0.9	-1.40234	23	**0.087429**	21	10.4	0.63	0.35248	24	**0.364696**	52	10.87	0.63	-1.08202	55	**0.142428**	6	12.19	0.35	-4.87362	9	**0.000442**
UI1_BL	4	8.02	0.42	-0.15899	5	0.439572	2	7.26	0.42	2.197	3	0.057586	2	7.75	0.2	1.16168	3	0.16499	7	8.09	0.25	-0.65587	8	0.263897
UI2_BL	3	6.94	0.41	-1.01761	4	**0.1827**	5	6.15	0.72	1.12754	6	**0.150808**	3	7.13	0.34	-1.72744	4	**0.079341**	6	7.35	0.54	-2.32342	7	**0.026697**
UC_BL	10	8.52	0.6	-2.2684	19	0.017518	8	7.95	0.17	-0.2121	17	**0.418082**	6	8.55	0.89	-1.56355	15	0.069803	6	9.02	0.5	-3.96824	15	**0.000616**
UP1_BL	17	9.65	0.62	-5.99984	19	1E-05	16	9.31	0.51	-5.2738	18	2.6E-05	14	9.77	0.66	-6.13922	16	1E-05	6	10.44	0.31	-8.07754	8	2E-05
UP2_BL	16	9.39	0.65	-0.11604	16	0.452989	21	9.22	0.54	0.1323	21	**0.448902**	11	9.67	0.54	-0.52212	11	**0.306684**	5	9.86	0.76	-0.73208	5	**0.249071**
UM1_BL	34	11.73	0.59	6.38329	34	**1E-05**	29	11.62	0.53	7.0808	29	1E-05	24	11.86	0.54	5.46557	24	1E-05	4	12.77	0.36	0.3058	4	0.38602
UM2_BL	29	11.65	0.69	5.65748	29	1E-05	27	11.6	0.73	5.69338	27	1E-05	19	12.1	0.64	3.44399	19	0.001372	4	12.93	0.56	-0.09013	4	0.466307
LI1_BL	5	6.16	0.46	0.07169	6	**0.473234**	2	6.22	0.1	-0.1049	3	**0.463326**	7	5.83	0.15	1.13208	8	**0.145608**	4	6.82	0.39	-1.72969	5	**0.072096**
LI2_BL	9	6.37	0.43	-1.34916	9	0.104993	4	5.96	0.23	0.53595	4	0.308928	7	6.49	0.25	-2.15943	7	**0.033804**	5	7.32	0.4	-5.06526	5	**0.001934**
LC_BL	12	8.35	0.44	-5.51036	17	1.9E-05	10	7.37	0.48	-0.844	15	0.207049	9	7.79	0.58	-2.3757	14	0.016037	6	8.75	0.76	-4.44096	11	0.000498
LP1_BL	12	8.38	0.56	-0.7352	18	**0.234421**	15	7.98	0.51	0.43423	21	**0.335788**	19	8.22	0.23	-0.3051	25	**0.379565**	8	9.09	0.43	-2.81783	14	**0.006816**
LP2_BL	10	8.68	0.53	-2.66625	13	0.009632	12	8.29	0.47	-1.4642	15	**0.082458**	19	8.57	0.46	-2.54985	22	0.009127	5	9.25	0.71	-3.39732	8	**0.00468**
LM1_BL	19	10.91	0.56	-1.55206	19	**0.068819**	20	10.77	0.56	-0.4776	20	0.318218	32	11.12	0.55	-4.1948	32	0.000102	5	11.76	0.49	-4.78659	5	**0.002463**
LM2_BL	20	10.38	0.73	-1.82983	23	**0.040121**	21	10.02	0.63	-0.5412	24	**0.297086**	28	10.52	0.58	-2.61204	31	0.00691	6	11.18	0.31	-5.13723	9	**0.000306**

***Table 4**: continued*

	Gua Cha						Ban Kao						Non-Nok Tha					
	n	Mean	SD	t	df	p	n	Mean	SD	t	df	p	n	Mean	SD	t	df	p
UI1_MD	3	8.57	0.57	2.52834	4	0.032332	12	8.7	0.35	3.60188	13	0.001616	3	8.29	0.05	5.78442	4	0.002225
UI2_MD	2	6.73	0.65	1.09465	3	**0.177718**	11	6.98	0.59	1.11153	12	**0.144374**	3	6.9	0.2	1.62724	4	0.089217
UC_MD	3	7.5	0.53	0.21108	12	**0.418595**	13	7.88	0.43	-1.1203	22	**0.137396**	4	7.67	0.19	-0.34419	13	**0.369644**
UP1_MD	4	7.38	0.43	-0.45514	6	**0.330857**	16	7.39	0.32	-0.5364	18	**0.297908**	5	7.07	0.59	0.23642	7	**0.408603**
UP2_MD	5	7.24	0.53	-4.57619	5	0.002974	17	6.69	0.49	-4.3862	17	0.0002	4	6.37	0.21	-2.04697	4	0.054845
UM1_MD	4	10.65	0.43	-0.75996	4	**0.244792**	16	10.66	0.44	-0.9226	16	**0.185618**	5	10.31	0.54	0.18822	5	**0.428391**
UM2_MD	7	10.38	0.42	0.7127	7	**0.250333**	15	9.44	0.53	2.85241	15	0.006083	4	8.98	0.77	3.01882	4	0.019582
LI1_MD	2	5.07	0.77	1.13722	3	**0.168531**	12	5.44	0.44	1.2439	13	0.118446	5	5.02	0.35	2.85007	6	0.014591
LI2_MD	5	5.89	0.33	0.59464	5	**0.290422**	15	6.06	0.48	0.27178	15	**0.39542**	5	6.01	0.42	0.35573	5	**0.366777**
LC_MD	6	6.86	0.28	0.198	11	**0.422565**	16	7.15	0.35	-0.6543	21	**0.26137**	6	6.84	0.2	0.26286	11	**0.399833**
LP1_MD	6	7.22	0.44	-0.3647	12	**0.362552**	17	7.23	0.41	-0.4378	23	**0.332022**	6	6.74	0.37	1.08009	12	**0.150685**
LP2_MD	5	7.65	0.48	-1.64258	8	**0.069818**	17	7.24	0.38	-0.5721	20	**0.287513**	6	6.57	0.21	1.72089	9	**0.059773**
LM1_MD	5	11.49	0.46	-3.34799	5	0.010164	14	11.85	0.49	-5.0495	14	8.9E-05	5	11.82	0.33	-4.81662	5	0.002399
LM2_MD	6	11.06	0.51	-1.44141	9	**0.091865**	16	10.74	0.6	-0.6364	19	**0.264908**	5	10.12	0.81	0.8373	8	**0.212649**
UI1_BL	3	7.21	0.61	2.03455	4	0.056106	12	7.26	0.38	4.07402	13	0.000663	5	7	0.15	6.36578	6	0.000352
UI2_BL	2	7.04	0.5	-1.03537	3	**0.187395**	12	6.49	0.27	0.44293	13	**0.333582**	4	6.29	0.26	1.15131	5	**0.151079**
UC_BL	4	8.86	0.61	-2.64252	13	0.010198	11	8.24	0.38	-1.4867	20	**0.075913**	5	8.34	0.2	-2.04076	14	0.030342
UP1_BL	6	10.36	0.62	-6.92396	8	6.1E-05	13	9.59	0.56	-5.8282	15	1.7E-05	6	9.25	0.71	-4.30798	8	0.00129
UP2_BL	6	10.13	0.62	-1.1449	6	0.14887	15	9.37	0.59	-0.0873	15	**0.464739**	5	8.91	0.39	0.57776	5	**0.293534**
UM1_BL	6	12.23	0.49	2.48997	6	**0.023581**	15	12.08	0.61	3.5904	15	0.00134	6	11.93	0.62	3.13855	6	0.010034
UM2_BL	7	12.45	0.35	2.01448	7	0.042183	14	11.7	0.59	5.01463	14	9.5E-05	4	11.06	0.54	5.67027	4	0.002386
LI1_BL	2	6.49	0.34	-0.77336	3	**0.248688**	12	5.92	0.34	0.82031	13	**0.213498**	5	5.5	0.25	2.08421	6	**0.041367**
LI2_BL	6	6.66	0.28	-2.88005	6	0.014029	14	6.19	0.44	-0.5805	14	0.285566	6	6.15	0.27	-0.39485	6	**0.355003**
LC_BL	7	8.29	0.27	-5.59342	12	5.9E-05	17	7.74	0.47	-2.7411	22	0.005977	6	7.69	0.36	-2.27611	11	0.021768
LP1_BL	7	8.68	0.38	-1.63806	13	**0.062483**	17	8.15	0.47	-0.0764	23	**0.468465**	6	7.89	0.51	0.63371	12	**0.270253**
LP2_BL	6	8.84	0.21	-3.6222	9	0.002786	18	8.41	0.6	-1.8628	21	**0.038475**	6	8.34	0.59	-1.3476	9	0.104993
LM1_BL	5	11.34	0.64	-2.19979	5	**0.039547**	16	11.05	0.57	-2.3801	16	0.015046	4	10.99	0.6	-0.93282	4	0.202507
LM2_BL	7	10.81	0.66	-2.80089	10	**0.009397**	17	10.52	0.66	-2.3584	20	**0.014274**	4	10.12	0.62	-0.63219	7	0.274349

***Table 5**: The distances (1-r) between the 19 population, derived from the comparing the crown distance matrix*

	LH- Papua	B.S-KB Papua	Aus-Abo	Negritos	EH-Laotians	Andaman Isl	Loyalty Isl	L.Sunda Java Isl	Sumatra Isl
B.S-KB Papua	**0,972**								
Aus-Abo	**0,926**	1,400							
Negritos	1,128	**0,952**	1,462						
EH-Laotians	1,080	1,155	1,055	1,224					
Andaman Isl	1,350	1,351	**0,532**	1,083	1,083				
Loyalty Isl	1,163	1,436	**0,506**	1,165	**0,977**	**0,259**			
L.Sunda Java Isl	**0,959**	1,094	1,443	**0,748**	**0,590**	1,474	1,267		
Sumatra Isl	1,353	1,053	1,532	**0,971**	**0,777**	1,124	1,112	**0,631**	
Dayak	**0,963**	**0,732**	1,444	**0,881**	**0,865**	1,545	1,615	**0,692**	**0,543**
Malay	1,155	1,238	1,164	**0,884**	1,070	1,123	1,216	0,718	**0,741**
Phillipines	1,197	1,235	1,081	**0,862**	1,045	1,231	1,028	1,062	**0,570**
Vietnamese	1,165	**0,805**	1,414	**0,663**	1,377	1,127	1,048	1,041	**0,875**
Laotians	1,092	1,133	1,047	**0,898**	**0,806**	1,087	1,203	**0,621**	1,027
Anami Okinawa Isl	1,155	**0,972**	**0,925**	1,141	1,204	**0,757**	**0,912**	1,482	**0,983**
Gua Kepah	1,045	**0,865**	**0,999**	1,081	1,023	1,075	1,271	1,041	1,246
Gua Cha	1,275	1,008	**0,798**	1,290	1,238	**0,502**	**0,650**	1,545	1,090
Ban Kao	1,211	1,265	**0,722**	1,287	**0,577**	**0,770**	**0,966**	**0,683**	1,001
Non-Nok Tha	1,319	1,214	**0,731**	1,062	**0,816**	**0,981**	1,199	1,035	1,143

***Table 5**: Continued*

	Dayak	Malay	Phillipines	Vietnamese	Laotians	Anami Okinawa Isl	Gua Kepah	Gua Cha	Ban Kao
Malay	**0.689**								
Phillipines	**0.808**	**0.777**							
Vietnamese	1.015	**0.919**	1.037						
Laotians	**0.729**	**0.833**	1.413	1.095					
Anami Okinawa Isl	1.113	1.442	**0.833**	**0.807**	1.387				
Gua Kepah	1.316	1.127	1.127	**0.965**	1.082	1.096			
Gua Cha	1.441	1.388	1.121	1.045	1.195	**0.660**	**0.898**		
Ban Kao	**0.872**	**0.578**	1.166	1.401	**0.577**	1.491	1.085	1.317	
Non-Nok Tha	1.060	**0.926**	**0.853**	1.320	**0.997**	**0.877**	**0.890**	1.096	**0.681**

***Table 6**: The samples on red color in the Site name column presents a poor quality of the aDNA*

Sample number	Sample Name	locality	Site name	Archeological ID	Element	# of Raw Reads prior Clip & Merge (C&M)	# reads after C&M prior mapping	Endogenous DNA (%)	DMG 1st Base 5'	average fragment length	median fragment length
Sample 1/54	ADM001.A0101.SG1	Papua	Andamata	ANDMT (URM3)	Tooth	5897997	1944018	**0.464**	**0.0261**	56.76	57
Sample 2/54	AGT001.A0101.SG1.	Papua	Arguni Atas	AA. (URM2)	Tooth	6302596	5132873	**0.193**	**0.2294**	47.28	43
Sample 6/54	HMK001.A0101.SG1	Papua	Humur Kawang	HK.(LM2)	Tooth	3944609	3332389	**0.02**	**0.119**	35.76	31
Sample 7/54	INU001.A0101.SG1.3	Papua	Inumaki	In.69.INMK (UI1)	Tooth	4745863	3019822	**0.051**	**0.0648**	30.38	30
Sample 8/54	INU002.A0101.SG1.3	Papua	Inumaki	INMK (LM3)	Tooth	6968024	3652395	**0.048**	**0.0355**	30.48	30
Sample 9/54	ISD001.A0101.SG1.3	Papua	Inswendi	INSWND-LRM2	Tooth	6314480	5236799	**0.182**	**0.2606**	46.4	43
Sample 10/54	KRC001.A0101.SG1.	Papua	Karas	Krs.C/S6-190	Tooth	5331102	2548866	**0.04**	**0.0312**	31.45	30
Sample 11/54	KRC002.A0101.SG1.	Papua	Karas	Krs.C/S6-190	Tooth	5816877	3436368	**0.03**	**0.0267**	32.15	30
Sample 12/54	MMO001.A0101.SG1	Papua	Mamorikotey	MMK-LRM3	Tooth	4973203	2918522	**0.034**	**0.0851**	39.93	32
Sample 13/54	MMO002.A0101.SG1	Papua	Mamorikotey	MMK-LM2/Ktk 2	Tooth	4963243	2953874	**0.031**	**0.0103**	33.82	30
Sample 14/54	MMO003.A0101.SG1	Papua	Mamorikotey	MMK. (LLM3)	Tooth	5708240	3645119	**0.029**	**0.0326**	32.12	30
Sample 34/54	NMT001.A0101.SG1.	Papua	Namatota	Nmt-LM1/210s0-20	Tooth	2557347	1497231	**0.055**	**0.2857**	37.93	33
Sample 38/54	PBA001.A0101.SG1.	Papua	Semaa	SMA-Petrous/10	Petrous	5986287	4665067	**10.58**	**0.2556**	53.71	52
Sample 39/54	SBU001.A0101.SG1.	Papua	Srobu	SRB-In.FGH(LLM3)	Tooth	5785768	4345840	**0.057**	**0.3081**	37.25	32
Sample 40/54	SBU002.A0101.SG1.	Papua	Srobu	SRB-In.ABC (UM2)	Tooth	6787569	4738784	**0.051**	**0.2776**	41.8	37
Sample 41/54	SBU003.A0101.SG1.	Papua	Srobu	SRB-(ULM1)	Tooth	5950129	3675642	**0.037**	**0.2387**	35.45	31
Sample 42/54	SWM001.A0101.SG1	Papua	Sowek-Miosko	SWK-Mios.In.a (LLM	Tooth	4899442	3551051	**0.045**	**0.2484**	40.56	35
Sample 43/54	SWM002.A0101.SG1	Papua	Sowek-Miosko	SWK-Krei. ULM3	Tooth	5081864	3497592	**6.349**	**0.2185**	54.2	52
Sample 44/54	SWU001.A0101.SG1.	Papua	Sowek-Musaki	SWK-Musaki.Ind.N (	Tooth	5974049	4265946	**0.111**	**0.269**	47.59	45
Sample 50/54	TUB001.A0101.SG1.	Papua	Tubara	Kb.a (LM3)	Tooth	6862401	5231066	**0.09**	**0.185**	42.22	36
Sample 51/54	TUB002.A0101.SG1.	Papua	Tubara	Kb.b (LM3)	Tooth	6148708	4042059	**0.021**	**0.0488**	30.68	30
Sample 52/54	TUB003.A0101.SG1.	Papua	Tubara	Kb.c (LM3)	Tooth	5189688	3532154	**0.016**	**0.0366**	30.74	30
Sample 53/54	YEN001.A0101.SG1.	Papua	Yendidori	YNDDR (LM2)	Tooth	6659300	4992287	**1.421**	**0.2274**	41.81	39
Sample 54/54	YOM001.A0101.SG1	Papua	Yomokho	Ymk-Metts/10	Metatarsal	4388651	2809665	**0.044**	**0.172**	33.8	30

***Table** 7: Contamination, Sex determination and uniparental markers. Province: Province Papua-Indonesia where individual was recovered. Individuals from Papua Province on Pulau Biak/northern coast of Papua, and from the south coast area. Lab ID: ID assigned in the ancient DNA lab; genetic Sex: Chromosomal sex determined by the proportion of read mapping to the X and Y Chromosome, XX= genetically female; XY= genetically male; contamination X: contamination for male individuals inferred from the overrepresentation of reads mapping to the X chromosome; contamination schmutzi: contamination inferred from the mitochondrial reads; mt-haplogroup: mitochondrial haplogroup assigned through Haplogrep 2; Y-Hplogroup: Y-chromosomal haplogroup identified through referencing with the ISOGG table. Red haplogroups are considered of Asian origin, blue haplogroups are considered to be of Near Oceanic origin.*

Province	Lab ID	Genetic sex	Contamination x	Contamination schmutzi	Mt-Haplogroup	Y-Haplogroup
Papua Barat	AGT001	XX	-	**0.02 (0.01-0.03)**	**Q1d**	**-**
Papua	ISD001	XX	-	**0.02 (0.01-0.03)**	B4a1a1k	**-**
Papua Barat	PBA001	XY	0.009121		n/a	**C1b2a**
Papua	SWM002	XY	0.017953	**0.02 (0.01-0.03)**	E2a	**S1a1b1d2**
Papua	SWU001	XY	0	**0.02 (0.01-0.03)**	**P1d**	**M1**
Papua	YEN001	XY	0.015582	**0.02 (0.01-0.03)**	E1a1b	**C1b1a2b**

***Table 8**: Preservation details. Library statistics as inferred through eager. Site: excavation site; Archaeological ID: ID assigned during excavations; element: skeletal element sampled for DNA; Lab ID: ID assigned in the ancient DNA lab; % endogenous after shotgun sequencing: percentage of molecules exhibiting characteristics of authentic ancient DNA, mapping to the human reference genome after initial sequencing; % endogenous after capture: percentage of molecules exhibiting characteristics of authentic ancient DNA, mapping to the human reference genome after targeted enrichment; damage (after SG): proportion of bases showing typical chemical alterations for ancient DNA in the screening library; median fragment length: median length of DNA molecules in the Library; coverage: number of positions covered out of 1.2 million analyzable sites.*

Site	Archaeological ID	Element	Lab. ID	%endogenous DNA after Shotgun sequencing	%endogenous after Capture	damage (after SG)	median fragment length	Coverage
Arguni atas	AA (URM2)	Tooth	AGT001	**0.193**	9.27	**0.2294**	43	19,734
Inswendi	INSWND (LRM2)	Tooth	ISD001	**0.182**	9.69	**0.2606**	43	16,824
Semaa	SMA-Petrous/10	Petrous	PBA001	**10.58**	32.77	**0.2556**	52	681,797
Sowek-Mioskondi	SWK (ULM3)	Tooth	SWM002	**6.349**	35.85	**0.2185**	52	666,134
Sowek-Musaki	SWK- Ind.N (LLM1)	Tooth	SWU001	**0.111**	13.29	**0.269**	45	21,829
Yendidori	YNDDR (LM2)	Tooth	YEN001	**1.421**	16.72	**0.2274**	39	157,962

Table 9*: Affinities to ancient Individuals from Vanuatu & Tonga and Taiwan. Testing for differential affinities to Early remote Oceanians (ERO) associated with the Lapita cultural complex or ancient individuals from Taiwan (Suogang), representing the genetic ancestry of the Autronesian expansion. Mbuti.DG (Africa) serving as an outgroup. Positive values indicate higher allele sharing with ERO, negative values indicate higher allele sharing with Suogang. Tests with Z-scores of higher than 3 or lower than -3 are considered significant. For tests -3<Z<3 the sources are considered equally good. Test based on less than 10 000 SNPs are to be interpreted cautiously.*

ERO	Suogang	test	Outgroup	f4	z	#SNPns
ERO	Suogang	ISD	Mbuti.DG	-0.008946	-613	1573
ERO	Suogang	AGT	Mbuti.DG	-0.000489	-0.106	2020
ERO	Suogang	PBA	Mbuti.DG	0.001624	1.681	51372
ERO	Suogang	SWU	Mbuti.DG	0.001727	0.36	2315
ERO	Suogang	SWM	Mbuti.DG	0.000871	0.887	50484
ERO	Suogang	YEN	Mbuti.DG	0.003765	2.209	15346

***Table 10**: The results of Bone Collagen Stable Isotopes from the five sites in this study*

		δ15N/14N‰ (AIR)				δ13C/12C‰ (PDB)			
Sample	Element	Test A	Test B	Average	stdev	Test A	Test B	Average	stdev
Ymk/2-P	Phalanges	12.82	12.90	12.86	0.055	-21.27	-21.11	-21.19	0.113
Ymk/1-R	Radius	12.58	12.59	12.59	0.003	-20.53	-20.38	-20.45	0.102
NMT/1-U	Ulna	11.42	11.56	11.49	0.099	-16.51	-16.49	-16.50	0.01
NMT/2-F	Fibula	9.92	9.90	9.91	0.017	-19.98	-19.92	-19.95	0.05
Srb_20	Upper Canine	14.01	14.01	14.01	0.004	-18.48	-18.43	-18.46	0.03
Krs/649	Upper second Incisor	7.66	7.82	7.74	0.112	-25.68	-25.52	-25.60	0.11
Krs/638	Phalanges	4.43	4.16	4.30	0.193	-24.37	-24.9	-24.63	0.38

***Table 11**: The results of Enamel Apatite Stable Isotopes from the five sites in this study*

Sample Name	Tooth	norm 13C	Stdev	norm 18O	Stdev.
KRS/649	Upper second Incisor	-12.3	0.2	-5.6	0.1
Srb_20	Upper Canine	-10.8	0.3	-5.0	0.1
Srb_413	Third Molar	-12.4	0.2	-5.5	0.1
MMK_333	Lower Premolar	-13.1	0.2	-8.2	0.1
MMK_419	Lower Molar	-13.5	0.1	-6.9	0.1

***Table 12**: The collagen weight was resulted from all the samples. Ymk: Yomokho site; NMT: Namatota; Srb: Srobu; Krs: Karas site*

	Test A	Test B	Test A	Test B	Test A	Test B			Test A	Test B	
Sample	‰N	‰N	‰C	‰C	C/N ratio	C/N ratio	2.9-3.5	one weight (g	ollagen weight (g	collagen run (mg)	ollagen run (mg	collagen yield
Ymk/2-P	10.35	10.39	30.10	30.23	3.4	3.4		0.868	0.022	1.149	1.133	2.53%
Ymk/1-R	9.74	9.95	26.68	27.29	3.2	3.2		1.091	0.078	0.936	1.012	7.05%
NMT/1-U	9.84	9.79	27.99	27.84	3.3	3.3		1.021	0.031	1.123	1.155	3.04%
NMT/2-F	14.29	14.32	40.4	40.56	3.4	3.4		0.807	0.043	1.088	0.983	4.47%
Srb_20	9.74	9.95	26.68	27.29	3.3	3.3		1.091	0.042	1.123	1.164	5.20%
Krs/649	0.67	0.65	7.16	6.75	12.5	12		1.066	0.006	0.8	0.802	0.53%
Krs/638	0.18	0.17	1.78	1.64	11.3	11.3		0.98	0.0018	1.01	1.063	1.84%

***Table 13**: Ancestry modeling with qpWave. Testing the ancestry composition for consistency of deriving from only Asian (Ami) related ancestry and Papuan (New_Guinea) ancestry. Low p-values show rejection of the model, indicating more than 1 ancestry needed to fit the model to the data. qpWave model using both ancestries (Test1; Test2). High p-values indicate good fit for the model.*

a

ID	Test	P-value
AGT001		1.50E-137
ISD001		4.60E-75
PBA001		0
SWM002		0
SWM001		2.38E-140
YEN001		0
AGT001	New_Guinea	6.67E-05
ISD001	New_Guinea	1.02E-17
PBA001	New_Guinea	0.002998754
SWM002	New_Guinea	1.91E-96
SWU001	New_Guinea	2.70E-09
YEN001	New_Guinea	8.10E-102

b

ID	Test1	Test2	P-value
AGT001	Ami	New_Guinea	0.3165872
ISD001	Ami	New_Guinea	0.10860769
PBA001	Ami	New_Guinea	0.25429662
SWM002	Ami	New_Guinea	0.2336899
SWM001	Ami	New_Guinea	0.15540536
YEN001	Ami	New_Guinea	0.57051968

4.3 Bone collagen and enamel apatite

Ten samples of human remains (bones and teeth) were analyzed for bone collagen and enamel apatite analysis. The samples for isotope bone collagen analysis include bone remains, such as long bones, resulting from seven samples: one sample from the Srobu site, two samples from Karas site, two samples from Namatota, and two samples from the Yomokho site. Five samples from the same individuals used for bone collagen analyses were employed for enamel apatite analyses, including two tooth samples from the Srobu site and one sample tooth from Karas site. Additionally, two samples of from the Mamorikotey site were employed only for enamel apatite analyses involved no bone collagen analyses.

The expression of isotopic composition resulting from the bone collagen and enamel analysis in this study are interpreted as follows. The samples can have positive or negative delta values depending on whether the sample is enriched or depleted in the heavier isotope. More positive delta values are usually assumed to be isotopically heavier, whereas more negative delta values are considered to be isotopically lighter (Fritz & Fontes,1980: 4-5). Stable isotope ratios are conventionally referenced to an internationally accepted standard, and are presented in the delta notation (δ). The international standard carbonate lies at the heavy end of the naturally occurring carbon range, so most materials have negative δ13C values relative to the VPDB standard (Jeffrey et al., 2016: 483). The bone collagen isotope and enamel apatite values from the twelve individuals are presented in table nine, ten, and eleven.

4.3.1 Isotope Bone Collagen results

The isotopic bone collagen analysis has been conducted to the samples from the four sites in this study including, two samples from Karas site, two samples from Namatota, two samples from the Yomokho site, and one sample from Srobu site (Table 10). The results from the different isotope analyses are summarized in table 10. The isotope bone collagen δ $^{13}C_{col}$ values resulted from the seven individuals from the four sites established the range between -25.60 ‰ to -16.50 ‰ (Table 10). The most depleted result of isotopes 13Ccol was found in the two individuals from Karas site: Krs/638 with -24.63 ‰ and Krs/649 is -25.60 ‰. The average values -20.45 ‰ resulted from the Ymk/1-R and -21.11 ‰ from YMK/2-P individuals. The isotope values resulting from the Namatota site samples present the values -19.95 ‰ in NMT/2-F, while -16.50% of values have resulted from the NMT/1-Individuals. The isotope values -18.46 ‰ have resulted from Srb phal_B, Srobu site.

The average ratio of isotopes nitrogen $^{15}N_{col}$ from seven samples in this signified the range from 14.01 ‰ to 4.30 ‰, as explained as follows. The sample Ymk/2-P shows the number

12.86 ‰, while the average 12.59 ‰ was found in Ymk/1-R. The nitrogen isotopes in NMT/1-U signified the number 11.49 ‰ of values, whereas in NMT/2-F, the value indicates 9.91 ‰. From the Srobu site, the sample Srb_20 presence the number 14.01 ‰, whereas two samples from the Karas site, Krs/649, the value shows 7.74 ‰, while 4.30 ‰ was found in the Krs/638.

The samples from Namatota, Yomokho, and Srobu are considered as the appropriate material for isotope collagen analyses related to the C: N ratio of collagen yielded between 3.3 and 3.4, fulfill the preservation of the sample ranged from 2.9 and 3.6 (DeNiro 1985). However, the ratio yielded from two samples from the Karas site is inadequately related to the collagen yielded from these samples, for Krs/649 0.53 %, while in the Krs/638, the collagen yield was 1.84 %. This number is relatively low compared to the collagen yielded from the Yomokho, Namatota, Srobu, and Mamorikotey site, which shows the range from 2.53 % to 7.05 % (Table 10). Based on the results of the percentage of the % Nitrogen and % Carbon yielded from the Karas site samples (Table 10), the collagen produced from these two samples very low in amount compared to other samples. Because the samples used in the isotope analysis were stored in the soil for thousands of years, the environmental factors, e.g. temperature, pH conditions of soils, and other natural elements around the bones as the factors may have caused the low collagen in the samples from Karas site. Collagen inactivates when hydrogen bonds are broken, and fibrils evaporate relatively quickly afterward. This process explains the sensitivity of collagen under stressful environmental conditions (Lee-Thorp, 2008: 929). Another thing that could cause the isotope pattern from the Karas site is that this value represents the isotope value of the natural sources eaten by these people. This is because the isotope values in natural sources differ from place to place in the world, as discussed in chapter 5.

4.3.2 The results of Carbon Isotope $\delta\ ^{13}C_{apat}$‰ (PDB) and Oxygen Isotope $\delta^{18}O_{apat}$ ‰ (PDB) from enamel apatite analysis

Human enamel, is the outer tissues formed and developed with various isotopic signatures, including carbon and oxygen, develop during childhood, intake into human bodies from the water and food consumption (Luz et al. 1984; Luz and Kolodny 1985; Longinelli 1984). Four types of human teeth including, incisors, canines, premolars, and molars, are developed at a different time during growth (Hillson 2003); providing different information about the mineralization process of teeth. Anterior teeth (incisors and canines) provide information about average water and food consumption during the late stage of pregnancy or early childhood. In contrast, the permanent molar tooth (posterior) erupt later and provide information about an individual's geographic origin during childhood. The start and complete formation process of each tooth are tightly correlated with the

first introduction of water source or foods to individuals (Wright and Schwarcz, 1998; Dupras 2007) (**Table 14**) since water present in the form of mineral calcium phosphates as the element composed of almost entirely the enamel tissue of the tooth (Hillson, 1996: 217).

The carbon isotope ratios $\delta^{13}C_{apat}$ from the five teeth of five individuals from three sites: the Karas site, Srobu site, and Mamorikotey site are implied the range of values from -13.5 ‰ to -10.8 ‰ (Table 11) which are described as follows: Krs/649 (upper second incisor) with a standard deviation 0.2 presence the value -12.3 ‰. The value presents in the Srb_20 (upper canine) is -10.8 ‰ with a standard deviation of 0.3. The value -12.4 ‰ has resulted from Srb_413 (third molar) with a standard deviation of 0.2. Two different individuals from the Mamorikotey site, MMK_333 (lower premolar) value -13.1 ‰ with a standard deviation of 0.2, whereas MMK_419 (lower molar) signified the value -13.5 ‰ with a standard deviation of 0.1 (Table 11).

***Table 14**: Mineralization of human permanent enamel tooth (after Schweissing 2004)*

Sample name	Tooth name	Start of crown mineralization	Crown mineralisation complete
Krs/649	Upper second incisor	10 - 12 months	3.3 - 5.9 years
Srb_20	Upper canine	4 - 5 months	4.0 - 5.8 months
Srb_413	Third molar	7 - 10 years	12 - 13.7 years
MMK_333	Lower first premolar	18 - 24 months	5 - 7 years

The enamel apatite analysis in this study was extracted from the human teeth with no decay or teeth modification, which is an essential element that required attention for suitable stable isotopic analysis (Meier-Augenstein, 2018: 353; Meier-Augenstein & Schimmelmann, 2018). The enamel apatite analyses from the five teeth were done by examining the isotope carbon $\delta^{13}C_{apat}$ and isotope oxygen $\delta^{18}O$ from the five different individuals underlined in the table 11.

The oxygen isotope ratios $\delta^{18}O$ produced from enamel apatite of five individuals as follows: Krs/649 (upper second incisor) -5.6‰ with a standard deviation of 0.1, Srb_20 (upper canine) value -5.0 ‰, Srb_413 with values -5.5 ‰, two samples from two different individuals from the Mamorikotey site: MMK_333 (lower premolar) -8.2‰ and MMK_419 (lower molar) with -6.9 ‰. All the samples were analyzed for oxygen isotope analyses are having 0.1 of a standard deviation (Table 11).

4.4 Human teeth features presence on the wear and teeth pathology

4.4.1 Wear in the incisors, canine, and premolars tooth

The Smith system (B. Holly Smith's, 1984) was used to investigate wear patterns in the incisors, canines, and premolars in this study, using a scale ranging from 0 to 8 based on specified criteria. According to the results of the wear analysis of teeth from the Srobu site (Table 15), 21 anterior teeth (incisor and canines) show wear ranging from mild (1-2), moderate (3-5) to severe (6-8).

In the posterior teeth (premolars and molars), twelve premolars are observed: two teeth exhibit severe wear conditions (Srb/4/UP, Srb/623/LP), five teeth are displayed moderate stage of wear (Srb/20/LP1, Srb/20/LP1, Srb/20/LP2, Srb/40/LP1, Srb/624/LP), five teeth display the mild range of wear (Srb/35/UP1, Srb/622/LP, Srb/625/LP, Srb/626/LP, Srb/627/LP) (Table 15). In the teeth from the Mamorikotey site (Table 16), the examination results reveal mild and moderate wear ranges in several teeth (MMK/42/UP, MMK/49/UC, MMK/78/UI1, MMK/79/UI2, MMK/332/LP, MMK/332/LP, MMK/333/LP, MMK/405/LP, whereas one premolar (MMK/640/LP) exhibits severe macrowear conditions.

Wear in the molar teeth was found at both the Srobu sites and Mamorikotey sites. At the Srobu site wear was noted on the following teeth: Srb/4/UP, Srb/20/LP1, Srb/20/LP1, Srb/20/LP2, Srb/413/LRM1, Srb/413/LRM2, Srb/413/LLM1, Srb/413/LLM2, Srb/413/LLM3, Srb/623/LP, Srb/624/LP, Srb/630/UM2, Srb/633/URM1, Srb/633/UM1, Srb/636/LM2. At the Mamorikotey site, erosion was observed in teeth 332/MMK/LP, 333/MMK/LP (Table 16).

4.4.2 Caries

Caries at stage one were observed in the following teeth: srb/489/ULM1, srb/489/ULM2,srb/636/LM2, and srb/ABC/UM1 (Table 15). At the Mamorikotey site, caries with a score of one were noted in MMK/42/UP, MMK/49/UC, MMK/78/UI1, MMK/79/UI2, and MMK/640/LP1 (Table 16). At Yomokho site, a score of three was observed in the lower first molar (YMK/1/LM1) (Table 19). No caries were found in the teeth from the Karas site and the Namatota site (Table 17 and 18).

4.4.3 Calculus

In the twenty-one anterior teeth (incisors and canines) from the Srobu site (Table 15), all display calculus ranging from slight to moderate. In the twenty-four posterior teeth (premolars and molars), two teeth show slight calculus, twenty teeth show moderate calculus, and one tooth shows

severe calculus. At the Mamorikotey site, ten teeth were examined: two incisors display slight calculus, while no calculus is present on the canine from this site. Among the seven posterior teeth (premolars and molars) from the Mamorikotey site, five teeth reveal calculus in the surfaces, whereas two upper premolar teeth displayed no calculus.

***Table 15**: The scoring results of wear and pathology on the teeth from the Srobu site*

Number	Srobu	Caries	Fluorosis	Calculus	Wear
		(range 1-3)	TSIF (range 0 – 7)	(range 0-3)	I, C, P (range 0-8)
	Sample name	(Hillson, 2001)	(Horowitz et al., 1984)	(Dobney & Brothwell 1987)	B.Holy Smith's (1984)
1	Srb/4/UP1	0	3	2	7
2	Srb/20/LP1	0	7	1	5
	Srb/20/LP1	0	7	2	5
	Srb/20/LP2	0	2	2	5
3	Srb/21/UC	0	4	2	1
4	Srb/22/UC	0	7	2	4
5	Srb/23/UC	0	7	1	1
6	Srb/24/UC	0	4	1	2
7	Srb/25/LC	0	4	1	1
8	Srb/27/LC	0	4	2	5
9	Srb/28/UC	0	7	1	2
10	Srb/29/UC	0	6	1	4
11	Srb/30/LC	0	7	1	4
12	Srb/31/UC	0	7	1	5
13	Srb/32/LC	0	7	1	6
14	Srb/33/LC	1	7	2	7
15	Srb/34/LC	0	5	1	6
16	Srb/35/UP1	0	6	1	2
17	Srb/64/UI1	1	4	1	2
18	Srb/65/UI1	1	5	1	2
19	Srb/66/LI2	0	5	2	4
20	Srb/67/LI2	0	2	2	7
21	Srb/86/UI2	0	4	2	1
22	Srb/90/UI2	0	4	1	5
23	Srb/403/LP2	0	1	2	4
24	Srb/413/LRM1	0	5	2	
	Srb/413/LRM2	0	5	2	
	Srb/413/LLM1	0	6	2	
	Srb/413/LLM2	0	5	2	
	Srb/413/LLM3	0	7	2	
25	Srb/489/ULM1	0	5	2	
	Srb/489/ULM2	1	4	2	
26	Srb/622/LP2	0	6	2	2
27	Srb/623/UC	0	5	2	7
28	Srb/624/LP1	1	1	3	4
	Srb/624/LI2	1	0	2	4
29	Srb/625/LP2	0	7	2	2
30	Srb/626/LP1				2
31	Srb/627/LP1	0	6	2	4
32	Srb/629/LC	0	5	2	
33	Srb/630/UM2	0	4	2	
34	Srb/633/URM1	0	5	2	
35	Srb/633/UM1	0	5	2	
	Srb/636/LM2	1	5	2	
36	Srb/636/LM1	1	4	2	
37	Srb/ABC/UM1	1	4	2	

At the Namatota site (Table 17) both individuals (NMT/1 and NMT2) show a slight range of calculus on their teeth. In the human teeth from the Yomokho site (Table 19), the first individuals' teeth show no calculus because these two teeth have lost their crown (YMK/1). However, in the second individual (YMK/2), the lower second molar and the lower third molar display a severe range of calculus (Table 19). At the Karas site, among the five teeth examined (two canines and three premolars and molars), all teeth show no calculus.

***Table 16**: The scoring results of wear and pathology on the teeth from Mamorikotey site*

Mamorikotey	**Caries**	**Fluorosis**	**Plaque**	**Wear**
	(range 0-3)	TSIF (range 0 – 7)	(range 0-3)	I,C, P (range 0-8)
Sample name	(Hillson, 2001)	(Horowitz et al., 1984)	(Dobney & Brothwell 1987)	B.Holy Smith's (1984)
MMK/42/UP1	1	4	0	4
MMK/49/LC	1	4	0	5
MMK/78/UI1	1	5	1	2
MMK/79/UI2	1	5	1	3
MMK/332/LP2	0	4	1	2
MMK/333/LP1	1	2	2	4
MMK/405/LP1	0	4	1	2
MMK/419/LM2	1	4	1	
MMK/638/UM1	1	4	0	
MMK/640/LP1	0	5	1	7

***Table 17**: The scoring results of wear and pathology on the teeth from Namatota site*

Number	**Namatota**	**Caries**	**Fluorosis**	**Plaque**	**Wear**
		(range 1-3)	TSIF (range 0 – 7)	(range 0-3)	I, C, P(range 0-8)
	Sample name	(Hillson, 2001)	(Horowitz et al., 1984)	(Dobney & Brothwell 1987)	B.Holy Smith's (1984)
1	NMT/1/LLP1	0	6	1	1
	NMT/1/LLP2	0	6	1	1
	NMT/1/LLM1	0	7	1	
	NMT/1/LLM2	0	7	1	
2	NMT/2/LI1	0	7	1	2
	NMT/2/LI2	0	7	1	2
	NMT/2/LP1	1	6	1	1
	NMT/2/LP2	0	6	1	2

***Table 18**: The scoring results of wear and pathology on the teeth from Karas site*

Karas	**Caries**	**Fluorosis**	**Plaque**	**Wear**
	(range 1-3)	TSIF (range 0 – 7)	(range 0-3)	I,C, P(range 0-8)
Sample name	(Hillson, 2001)	(Horowitz et al., 1984)	(Dobney & Brothwell 1987)	B.Holy Smith's (1984)
Krs/41/LC	0	4	0	2
Krs/334/LP1	0	4	0	3
Krs/638/UM2	0	4	0	
Krs/649/UC	0	5	0	2
Krs/649/UP2	0	4	0	1

***Table 19**: The scoring results of wear and pathology on the teeth from Yomokho site*

Number	Yomokho	Caries	Fluorosis	Plaque	Wear
		(range 1-3)	TSIF (range 0 – 7)	(range 0-3)	I,C,P (range 0-8)
	Sample name	(Hillson, 2001)	(Horowitz et al., 1984)	(Dobney & Brothwell 1987)	B.Holy Smith's (1984)
1	Ymk/1/LP2		0	0	
	Ymk/1/LM1	3	0	0	
2	Ymk/2/LM2	Unidentified	Unidentified	3	Unidentified
	Ymk/2/LM3	Unidentified	Unidentified	3	Unidentified

4.4.4 Fluorosis

At the Mamorikotey site, ten teeth were found to have fluorosis with scores ranging from 2 to 5 according to the TSIF scoring system. In table 15, fluorosis with a score of four was observed in teeth MMK/42/UP (A) and MMK/49/UC (B), characterized by white and dark brown of fluorosis. Teeth MMK/78/UI1 (C) and MMK/42/UP (D) exhibited fluorosis with a score of five, showing yellow and dark brown of fluorosis covering almost the entire tooth surface. Table 15 indicates that the scores ranged from 2 to 4 across the four teeth analyzed. Tooth MMK/333/LP (B) had fluorosis with a score of two. Teeth MMK/332/LP (A), MMK/405/LP (C), and MMK/419/LM2 (D), showed fluorosis with a score of four displaying white, yellow, and dark brown of fluorosis on the enamel surface of all these teeth. In table 15, tooth MMK/638/UM1 (A) exhibited fluorosis marked by yellow-brown discoloration on the enamel surface with a score of four, while tooth MMK/640/LP displayed fluorosis covering almost the entire enamel surface, characterized by dark brown discoloration.

All teeth from the Karas site affected were affected by fluorosis, with scores ranging between four and five (Table 18). Score four was observed in teeth Krs/41/LC (A), Krs/334/LP (B), Krs/649/UP (C), and Krs/638/UM2 (E), while scores five was found in tooth Krs/649/UC tooth (E).

Based on the analysis of fluorosis appearance in the two individuals from the Namatota site (Table 17), it indicates a moderate range of fluorosis characterized by irregular shape with brownish-flecked color on the enamel of both posterior and anterior teeth. Additionally, fluorosis was noted on the labial-lingual-buccal, mesial-distal, and the occlusal area in the posterior teeth.

Chapter 5: Discussions

5.1 Introductions

In this study, the human history and behavior of Lowland populations in the Papua-Indonesia region were investigated through the analysis of human teeth from seven sites. The study focused on examining population affinities using metric dental studies and ancient DNA analysis on teeth from six sites. Four of these sites- Mamorikotey, Srobu, Namatota, Karas, represent the Late Holocene group, while teeth from Biak-Sowek and Kayu Batu are grouped into the Eighteenth Century category. Stable isotope analysis was conducted on ten samples from five sites ((Mamorikotey, Namatota, Srobu, Karas, and Yomokho) to infer diet behaviors. Human remains from these sites were subjected to both stable isotope and morphological teeth analyses to gain insights into human diet behaviors. The descriptions and findings related to the human teeth, as presented in Chapters 3 and 4, will be discussed in detail in this chapter of the study.

5.2 The Lowland Papuan affinities based on the metric traits, mtDNA, and Y-haplogroup result

This study used metric dental traits and statistical methods to explore the population affinities of the Lowland inhabitants. A comparison between the tooth variables of the two groups- the Late Holocene group and the Current-Era reveals several differences. The average mesiodistal and buccolingual measurements of the lower first incisors (LI1) and lower second incisors (LI2) were greater in the Current Era group compared to the Late Holocene group. In the upper canines (UC), the mesiodistal size was greater in the Late Holocene samples than in the Current Era group, while the buccolingual size was more prominent in the Current Era group compared to the Late Holocene. For the lower premolar 2 (LP2), both mesiodistal and buccolingual sizes were greater in the Current Era group compared to the Late Holocene group. Since human tooth dimensions are established early in life, tooth size and morphology are strongly influenced by genetic factors and environmental conditions (Scott & Turner, 1997:131). However, since this study aimed to investigate the affinities among Lowland population affinities, environmental factors were not extensively to interpret the metric traits, given the assumption that phenotypic similarities primarily reflect genetic similarities (Scott & Turner, 1997:145).

The average tooth size distances in a few tooth variables from these two groups of Lowland populations suggest that they may have been carried different genetic material. Among the diameters of teeth measurements from these two population groups in this study, the results

tentatively support the hypothesis that these groups were genetically distinct. This result appeared to confirm that independent inheritance of tooth size characteristics could be a significant result of breeding between different group lineage. If both groups carried the same genetic, the tooth size between them should be present the similarity. It can be inferred that the groups from the Late Holocene and the Current Era inherited different genetic-lineages based on variations in metric measurements between them.

The demography history of the lowland inhabitants of Papua is one of the research questions that needed to be answered through analysis of human teeth and bone remains recovered from archaeological sites in this study. Ancient DNA and the metric dental study were performed to reconstruct the populations history of these lowland inhabitants from the Holocene time to the Current Era. For ancient DNA analysis, twenty-four samples were initially examined to identify genetic markers of the people this study. However, due to poor DNA preservation, not all samples could be successfully amplified (Table 6). Laboratory analysis showed that DNA from eighteen samples could not be extracted (Table 6).Two different potential sources of DNA damage were recognized including, postmortem decay and also contamination cause by several aspects, including environmental factors and human errors during handling or recovery from archaeological contexts.

Since the samples were unearthed from a tropical region, DNA damage in eighteen samples may have resulted from several aspects. Firstly, human remains as an organic material, are particularly susceptible to degradation in tropical environments due to factors such as temperature, soil humidity (Colson et al. 1997; Hoss et al. 1996; Poinar et al. 1996). Similar cases of poor DNA preservation in human skeletal remains have been observed at archaeological sites in tropical Southeast Asia, such as the Phum Snay site in Cambodia (Miyatsuka & Yasuda, 2013: 226). For example, at the Man Bac site, Vietnam, DNA was successfully extracted from only 34 out of 70 samples, highlighting challenges in DNA preservation (Oxenham & Domett, 2011). As the regions with high humidity and temperature fluctuations, the tropical area generally presents poor DNA preservations (Kistler et al., 2017). Located in the tropical area, the lowland part of Papua characterize by high humidity and temperature at all seasons with a daily range of 33ºC – 25ºC, which may influence the human remains preservation. Moist warm climates dramatically decrease the quantity of DNA because of fragmentation and extensive damage (Smith et al., 2003). The pH levels, soil type, etc., are the number of aspects that potentially play a role in bone preservation that buried in archaeological context (Andrews 1995; Marden et al. 2013). Secondly, the human remains in this study were unearthed from the archaeological context and were processed through several procedures, including excavation, inventory, analysis, etc., that may affect the DNA damage. Even though the standard procedures have been performed to prevent the samples from decay or damage,

especially during the fieldwork process (excavation, handling, inventory), the DNA molecules at such temperatures in the tropical area may have limited chemical stability (Lindahl, 1993), which further contributed to the DNA damage.

mtDNA and Y-chromosomal DNA analyses indicate hat the colonization history of Papua's lowlands is complex, reflecting multiple migration waves. Genetic evidence suggests that demographic processes on the island of Papua involved repetitive, unidirectional population movements from mainland Asia during the Pleistocene, Neolithic, and historical eras (Cox, 2015:295). This study analyzed ancient DNA from six samples, revealing distinctive patterns of demographic history linked to past human migrations and interactions. Both mtDNA (maternal) and paternal side (Y- haplogroup) were examined. The mtDNA from the six samples presents the haplotypes of E2a, E1a1b, B4a1a1k, Q1d, P1d. At the same time, the Y-haplogroup displays the types of C1b2a, S1a1b1d2, M1, and C1b1a2b. These genetic findings support the presence of both Australo-Papuan and Asian genetic lineages, further elucidating the complex genetic history of Papua's populations.

The study of mtDNA types among Biak people has revealed two different haplogroups, E and B. Within haplogroup E, two main haplotypes, E2a and E1a1b, are believed to have originated on the Southeast Asian island of Borneo, possibly dating back to the Pleistocene time. Compared to the Island of Southeast Asia, where haplogroup E is more prevalent, it is found at lower frequencies in Near Oceania, likely influenced by the pre-Austronesian expansion into Near Oceania and nearby islands through the Sundaland in glacial time (Soares et al. 2008; Matisso- Smith 2016: 398; Duggan et al. 2014:727). In Near Oceania, haplogroup E, including type E2a and E1, is primarily restricted to regions scuh as the Solomons, New Britain, and Bougainville (Duggan et al. 2014: 726). The presence of mtDNA haplogroup E in Sahul is thought to be a descendant of an earlier migration of Asian-derived people that did not accompany the Lapita expansion (Duggan et al. 2014). If this migration occurred before the Lapita period, it would suggest that mtDNA haplogroup E was introduced into lowland Papua from the Philippines region. However, studies have shown haplogroup E to be less frequent, especially in northern and central Philippines populations, with higher frequencies observed in southern regions (Delfin et al. 2014; Tabbada et al. 2010). In the context of this study, the presence of haplotypes E2a and E1a1b among individuals may indicate human dispersals from mainland Southeast Asia, passing through Sundaland into northern Indonesia, and eventually reaching the northern coast of Papua.

During the mid-Holocene Austronesian expansion from mainland Asia to the coastal region of New Guinea and the Bismarck Archipelago, haplogroup B4a1a1 descendant from B4a1a1k (Brandão et al. 2016; Duggan et al. 2014). Haplogroup B is well-known for its widespread

distribution across Taiwan, the Philippines, East and Southeast Asia, Oceania, and Madagascar (Trejaut et al., 2005; Fiedlanender et al. 2005; Delfin et al., 2013). Within haplotypes B, the subtype B4a1a1a, also known as the "Polynesian motif,"notably dominated the lineage of the population that occupied Remote Oceania during the Austronesian expansion in the past (Redd et al.1995; Sykes et al.1995; Melton et al.1995). The haplotype B4a1a1k has also been found in Near Oceania, including in regions such as Samoa, the Solomon Islands, and Tonga. Therefore, the presence of haplotype B4a1a1k in individuals from Biak Island serves as evidence indicating genetic influence from Asian ancestors in the populations studied here.

Maternal haplogroups P and Q, among the earliest colonizers outside of Africa, were found in Southeast Asia, providing insight into he demographic history of Papua's lowland region. Pedro et al. (2020) classified haplogroups P and Q as indigenous Northern Sahul lineages. P1 and Q1 originate from Near Oceanian (Friedlaender et al. 2005). The P1 haplogroup was notably prevalent in southeastern Massim, while Q1 was more common in western Massim. Haplogroup Q and its subhaplogroup Q1 are most frequently found in the Northern Sahul region, encompassing both coastal and highland areas of New Guinea, and Near Oceania, which diversified towards the end of the Last Glacial Maximum around 19 ka. Haplogroup P diverged earlier in Southern Sahul than in Northern Sahul during the last Glacial Maximum, indicating ancient population connections between Southern and Northern Sahul. The present P lineages within and outside Sahul suggest populations interaction, with the most derived lineages showing geographically clustering. The mtDNA P1 and Q1 date back to the initial settlement phase of Sahul, more than 50,000 years ago, reflecting the genetic diversity of the region’s earliest settlers who were isolated there for an extended period (Van Oven & Kayser 2009). Indigenous haplogroups P and Q, belonging to the M and N mtDNA lineages, are associated with Indigenous Aboriginal Australians (Nagle et al. 2017).

Haplogroup C, a branch of haplogroup C1, is commonly found among Aboriginal Australian and exhibits the highest variance of any Y-chromosome haplogroup in India (Kivisild et al. 2003), suggesting divergence during the Pleistocene time. Y-chromosomes haplogroups C1 is widely distributed across East Asia. The distribution of haplogroup C suggests its arrival in Australasia through island Southeast Asia/Sundaland, likely involving populations in New Guinea.

mtDNA and Y-chromosomal DNA analysis further illustrate the complex human occupation of Papua’s lowlands, as indicated by the distribution of haplotypes in this study, potentially resulting from multiple migration waves. It is plausible that the original inhabitants of Lowland Papuan in this study migrated to the area in multiple waves, with various sub-groups taking distinct paths, and entering Sahul through different routes. These ancient migration events are reflected today in the observation that different regions of Sahul exhibit both unique and shared mtDNA

lineages. The mtDNA and Y- chromosome haplotypes identified in the individuals, particularly those from Biak island, provide evidence of the diverse human haplogroup that entered lowland Papua in the past.

In this study, three different Y-haplogroups were identified: C with haplotypes C1b21 and C1b1a2b, haplotype S1a1b1d2, and M1. These haplogroups are widespread in Near Oceania and Australia. The Y-chromosomes C1b21, C1b1a2b, S1a1b1d2, and M1 found in the individuals from Biak Island represent Australo-Papuan lineages that likely arrived in Sahul during the Pleistocene time. In Near Oceania, haplotype M1 is found on islands like Bismarck, Bougainville, Fiji and Western Polynesia. Other variants of M1, such as M175 and M119, are found in location including Tonga, Western Samoa, Cook Island, and Polynesia Maori. It is believed that haplotypes M1–M104 originated in Bismarck's island (Kayser 2010). Haplogroup S1 has been identified in Bismarck Island and Remote-Oceania, including Vanuatu and New Caledonia (Kayser 2010).

The results from the triangular distance matrix analysis, using the Tree diagram of Neighbor-Joining and UPGMA Cluster method, support the assumptions that both Late Holocene and Current Era group are related to each other, but they do not exhibit close kinship (Figure 28 and Figure 29). This relationship is illustrated by the main branch where the Late Holocene and the Current Era diverge from each other. The Late Holocene group forms its own distinct branch, while the Current Era group joined with the Guar Kepah group. Human remains from this site are interpreted as exhibiting Australo-Papuan features (Mijsberg 1940). This result strengthens the hypothesis that the Current Era group inherited characteristics derived from Australo-Papuan ancestry, as indicated by their clustering with the Guar Kepah in the tree branches. Archaeological and genetic investigation of human remains from Guar Kepah, suggest that this group were hunter-gatherer who occupied Peninsular Malaysia and practiced the Hoabinhian culture, which was adapted to coastal environments. Animal remains found at Hoabinhian coastal sites include marine species as well as inland species such as wild pig, indicating a diverse diet and resource exploitation strategy. It is hypothesized that the Hoabinhian people were descended from Australo-Papuan that migrated from Africa to Southeast Asia during the Pleistocene time, and are the ancestors of modern Melanesians and Australian Aborigines. The presence of Australo-Papuan cultural indicators among hunter gatherers in pre-Neolithic Southern China and Southeast Asia is well-documented (Higham 2013; Hung et al., 2017; Matsumura et al., 2019). Hunter gatherers societies are notable for their demographic size and social complexity (Zhang and Hung, 2012; Hung, 2019). Following their arrival in Sahul in Pleistocene time, the Australo-Papuan groups likely initially settled in lowland area where they practiced hunting and gathering. Subsequently, they moved into inland part, as indicated by current language distributions dominated by Trans-New Guinea

language in these areas. As hunter-gatherers, their movements were strategic to exploit a wide range of resources across different environments and seasons. Despite this, interactions between Australo-Papuan and Austronesian-speaking populations likely occurred in lowland regions. The mtDNA and Y-chromosomal analysis of this study, along the metric teeth results and language distribution among populations around Lake Sentani, provide insights into these interactions.

The statistic comparisons applied to the metric size in this study suggest that the Late Holocene group's crown size falls between that of the Sumatra Islanders and Laotians which are close genetic relationships to the East Asian population. Following the initial arrival of Papuan speakers in the New Guinea island, seafarers and traders of Austronesian origin from Taiwan spread down through the Northern Philippines around 3000 BP, entering Eastern Indonesia, including the coastland regions of Papua-Indonesia, and subsequently moving further into the Western Pacific (Bellwood, 2011; Spriggs 2012). These Austronesian migrations from Taiwan through the Northern Philippines are evidenced by material findings, including pottery discovered in shell middens along the Cagayan Valley in northern Luzon, dated to around 3,500 BP. Additional support comes from settlement evidence in Marshall Islands and the Mariana Islands (Carson et al. 2013; Bellwood 2011; Hung et al. 2011). The Austronesian movements into Papua's lowland areas may have influenced the genetic variance in these populations, as indicated by the metric trait results in this study. This is further supported by the mtDNA haplotype B4a1a1k findings, highlighting the genetic impact of these historical migrations.

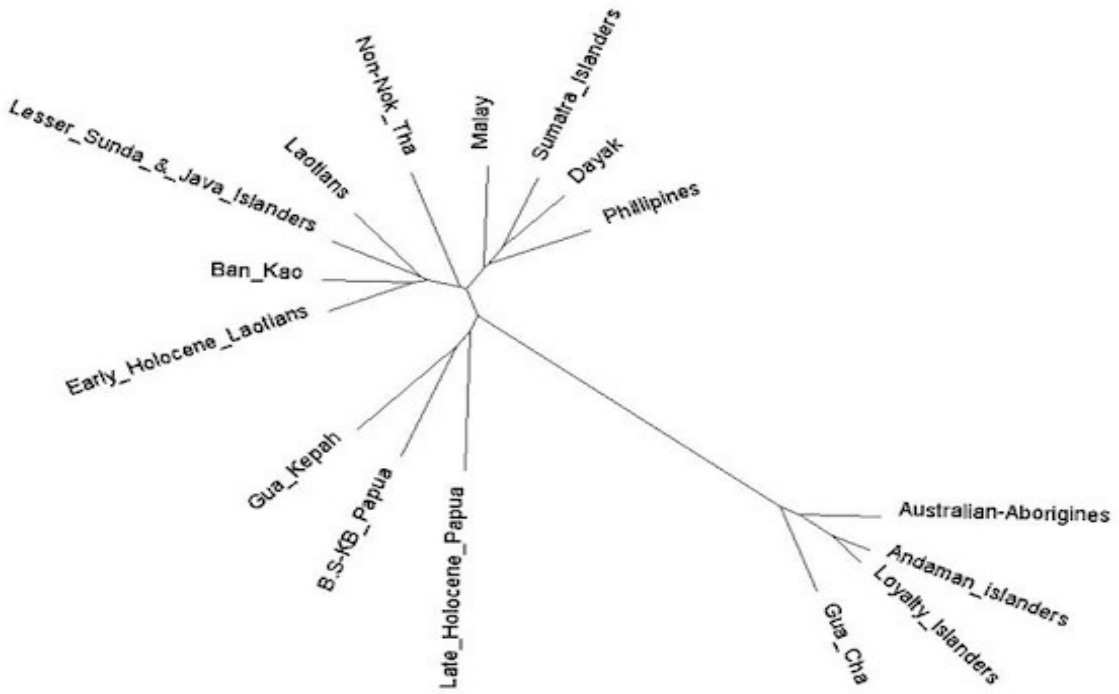


***Figure 28**: UPGM Cluster analysis from the 16 group of population based on Q-mode distance*

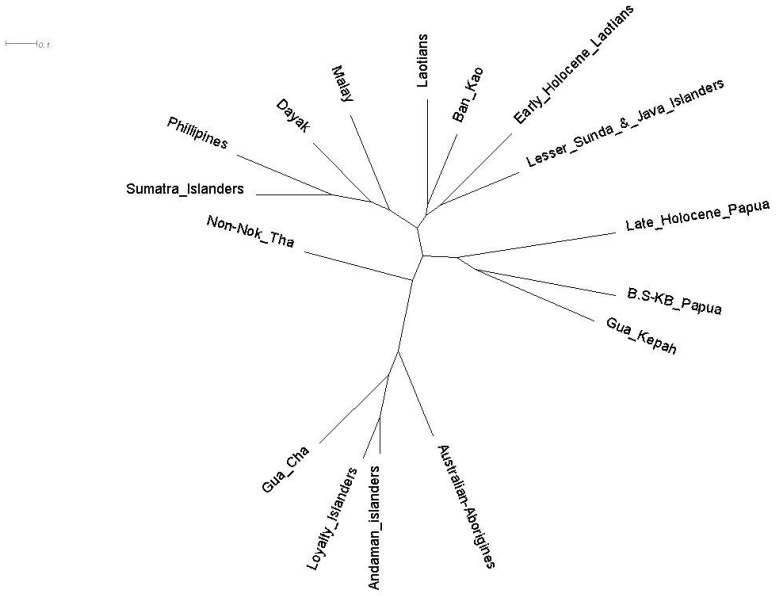


***Figure 29**: NJ tree is a result of NJ tree analysis*

5.2.1 The significance of the language and material culture distributions to the demographic history of the lowland area populations

The significance of the Oceanic language, as part of the Austronesian language family distributed in the lowland area of Papua, offers remarkable evidence for understanding the historical population dynamics in this region. The living tribes occupying the Biak-Sowek and Kayu Batu areas, where this study was conducted, provide crucial insights into this phenomenon. Presently, the Kayu Batu tribe speaks Central Eastern Malayo Polynesia (Blust 1993). Similarly, the Biak-Sowek tribe, inhabiting the Biak-Supriori Island and various small islands in the bay, speaks the South Halmahera-West New Guinea (Van den Heuvel 2006). The distribution of languages along the north coast of Papua and in some areas of Near Oceania is classified into the Western Oceanic linkage, considering geographical areas, linguistic factors, and socio-cultural aspects (Lynch et al., 2011:92–95). This classification suggests that the Western Oceanic language may have evolved locally due to innovations derived from a global language network in the past (Ross 1988; Lynch 2011: 96). The presence and distribution of these languages not only highlight the movements and interactions of

Austronesian-speaking populations but also provide a framework for understanding the complex linguistic and cultural landscape of the region.

The subgrouping of the Oceanic language provides important clues about the social histories of populations in the Oceanic area, including the northern coast of Papua. The socio-economic factors in this region likely developed significantly since the migration of Austronesian speakers during the Late Holocene. The distributions of language in Papua's lowland areas helps specify cultural affiliation and supports evidence of contacts or interaction between different groups in this region. In addition to Oceanic languages, the presence of Australo-Papuan footprints in the Lowland parts of Papua is evident. For instance, the Sentanian clan, living around Lake Sentani, speaks a language from the Trans-New Guinea family. This linguistic evidence, along with demographical and cultural dynamics, suggests that the region has experienced substantial contact and diffusion processes. These processes have contributed to cultural transmission and the blending of diverse influences over time.

This cultural dynamic has significantly impacted several aspects, including the distribution of material culture, as evidenced by the archaeological sites examined in this study. The distribution of archaeological evidence, particularly pottery, from various sites on Papua's northern coast, has been extensively documented by the Archaeological Research Center for Papua-Indonesia over the past decades. This evidence indicates rapid development following the arrival of Asian descendants from mainland and island Southeast Asia into the region. Pottery found in the Late Holocene group sites in this study is characterized by various shapes, motifs and technologies. The pots, mostly found fragmentary, exhibit techniques such as coiling, incising, and stabbing geometric patterns. The vessels often have wide mouth openings, a characteristic of Austronesian pottery. Shell-impressed motifs on pottery surfaces were commonly found in the Late Holocene at sites like Mamorikotey, Srobu, and Yomokho sites. Earthenware pottery with indentation motifs stamped with comb or comb-like (tined) tools is a hallmark of the Lapita cultural complex. Incised motifs created with a sharp-edged instrument and applied relief, also known as appliqué (Spriggs 1997:67), were popular in Oceania and are common in all Late Holocene group sites in this study. Most of the vessels from the Late Holocene group were undecorated, likely due to their use as cooking pots. The majority of the reconstructed pots from sherds are globular in shape with short vertical or everted rims, though some bowls were also discovered.

The Lapita culture, associated with the mainland-East-Asian ancestry populations, developed dentate-impressed decorated pottery and a variety of advances decorated objects. These cultural artifacts were distributed across the Bismarck Archipelago, coastland areas of Papua, New Caledonia, and Western Polynesia. Lapita pottery likely played a significant role in interactions

between different groups and served as trade commodities, alongside obsidian tools. In the lowland area of Papua-Indonesia, a substantial number of pottery findings have been identified from the archaeological sites in this study. These findings present similarities with Lapita motif-form potteries (?) from several archaeological sites in the Near Oceania. Notably, vessel's handles with shapes such as cup kettle-like, phallus-shaped, and a looped handle-like form were found at the Mamorikotey site. These forms are presumed to represent models developed during the Lapita culture period (?). In comparison, vessel handles in Fiji associated with dentate-stamped Lapita sherds exhibit various forms, including vertical looped, channeled protrusions, horizontal looped, and phallus-shaped (Birks 1973; Parke 2001: 142). It is likely that Lapita culture was introduced to the Papuan lowlands, particularly to sites such as Mamorikotey, but its influence may have been limited due to the presence and development of other cultures, such as Australo-Melanesian and other sub-cultures that emerged earlier in the Papua lowlands. Archaeological data from Micronesia, including the Mariana and Palau islands, can provide insight into the pattern of Lapita's introduction in Oceania, particularly in the Lowland parts of Papua.

Early settlements in several sites in Micronesia, including the Mariana Islands and Palau, involved groups of Malayo-Polynesian speakers separate from the proto-Oceanic communities of the Lapita culture. Archaeological findings in these areas indicate that Lapita was not the only one cultural influence in remote Oceania. Linguistic evidence suggests that the origins of the Yapese language trace back to the time of the oldest Oceanic-speaking groups' breakup, inferred to have occurred when Lapita pottery-making groups spread into Remote Oceania (Ross 1996; Carson 2018). However, no Lapita sites has been discovered in Yap so far. The presence of inhabitants in the Mariana Islands and Palau is apparent, although the language lineages and material culture sequences that branched from Lapita suggest overall independence. It is possible that some interactions occurred between Lapita communities and those in the Marianas and Palau, but these had no major effect on the cultural histories of the two areas (Carson 2018).

Ethnographical data provides valuable evidence supporting the material findings such as potteries discoveries in archaeological context. Nowadays, pottery making continues among various tribes in the lowland areas of Papua-Indonesia, like Abar, Kayu Pulo, Serui Laut, and Manokwari. Papuan speakers in the highland traditionally did not have a pottery-making tradition Nevertheless, the discovery of pottery fragments at the Ayai site in the Fef district of Tambrauw Regency (in the Bird-Heads of Papua) suggests that pottery culture was introduced to Papuan speakers in this area. The Sentani tribe, speaking a Papuan phylum language, uses pottery in daily household purposes. For example, the Abar people people, living in the bay of Sentani Lake, maintain a living pottery-making tradition. Other tribes in the area, such as the Nafri, Demta, and Nimboran also speak

Papuan phylum language (Cowan, 1965:2) and use pottery in daily life. The coexistence of anatomically Australo-Papuan and Asian descendants on the same islands indicates possible interactions and contacts in material culture and human admixture.

Several axes were discovered in Srobu and Mamorikotey, including quadrangular axes with and without butt modifications, as well as oval-lenticular types were generally made of basalt and andesite. The axe-adze from the Srobu site was made from Dunit Ultramafik stone, which, by size, ranges from 5-2 cm thick and is wide at 2-3cm (Djami et al. 2017). In contrast the axe- adze from Mamorikotey is larger, ranging from 20 to 20cm long. The Mamorikotey adze blade has a tubular shape and flat style and appears to be unhafted. Currently, adzes are multi-purpose tools in the highlands, used for activities ranging from chopping down trees and splitting wood to finishing work on bows and spears. The stone axes and adzes found at the Late Holocene sites were made from various rocks, likely based on the availability of surrounding materials. Previous research indicates that the axe-adzes were found of the five early-date shelter sites in the highlands and at Kosipe in Papua highlands, occupied between 26 000 and 9000 BP (White et al.1970). In Australia, axe-adzes found in sedimentary deposits date back to 22 000 years ago, suggesting a similar antiquity in New Guinea (White 1967).

Ethnographical data can help trace the existence of stone-axes in Papua, particularly in the highland part. Major stone tool manufacturing and use regions include Damal, Grand Valley Dani, Nggem, Wano, Hupla, Damal, Walak, and Nduga. The Tagime and Yeineri quarry systems provided the majority of stone tools for the highland area, with only an estimated 3% derived from other sources. Blades sourced from Yeineri and even Tagime have been documented as far west as Enarotali. Besides forest clearing, house and fence building, as a hoe-making, axes were also used for trading between clans in the central highlands. Pollen analysis indicates that forest clearing occurred 5,000- 6,000 years ago in the upper Wahgi valley (Powell 1970).

The megalithic findings, mostly found in Late Holocene group sites such as Srobu, Mamorikotey, and in the area surrounding Lake Sentani where the Yomokho site is located, are estimated to have developed during the dispersals of Austronesian speaker, based on radiocarbon results from these sites. Dolmens, monoliths, rounded stones, stone enclosures, stone figures, mortars, and other megalithic finds were discovered at these archaeological sites. To understand the megalithic distributions in these sites, ethnographical data from several areas in Papua might be used to analyze their presence in the sites of this study. Stone-axes are still used as dowries, material exchanges, and blood payments by the Indigenous Papuans who live in the Lake Sentani and Humboldt Bay area. However, the indigenous people's use of stone axes at Lake Sentani contradicts their language, which is Trans-New Guinean rather than Austronesian. Because no

definite dates have been given for the megalithic findings at these sites, the appearance of megalithic structures as one of the cultural traits of Austronesian speakers remains in doubt. Several stone figurines were found at the Mamorikotey site, associated with potteries and other material findings. However, it appears premature to claim that, these discoveries were made by Austronesian speakers because of the lack of analysis done so far. Additionally, megalithic cultures developed not only in the lowland parts of Papua but also in the highlands. For example, in the Baliem Valley area, mortars, pestles and several stone figurines were found. Mortars and pestles, which are firmly connected with Papua New Guinean culture, have a long history in highland and northern Papua New Guinea, particularly in the Sepik-Ramu area, with the oldest known example from Kuk swamp in the highlands dating back to more than 7000 years ago (Golson, 2000). The indigenous people in this area speaking the languages classified into Trans-New Guinea group or Papuan speakers.

For the group of Late Holocene sites, the economy of the settlers was characterized by a broad spectrum of maritime and terrestrial animals, arboriculture, and other activities. The collective evidence from faunal remains presents a picture of a balance between land and sea resources. Several species have been recognized as a part of local hunting, including land mammals like marsupials and rodents. Pig remains were the most commonly discovered in the Late Holocene sites in this study. The pig teeth remains consisted of both adult and juvenile group. Maritime resources were extremely important in all the Holocene sites in this study, with different types of species from various habitats (freshwater, coral, littoral, intertidal). Molluscan remains including bivalves and gastropods, as Vertebrate remains such as reptile and fish, were found. The Coral reef fish were the most frequently spotted in the Mamorikotey and in Srobu sites. The coral reef fish identified from jaw remains site included *parrotfish* or *scaridae*. Turtles of several sizes were also found in the Srobu, Mamorikotey, and Namatota sites. In addition to the known bones, the enormous number of unidentified fish remains found in these sites indicated the wide range of species in each layer of soil of the Late Holocene group sites. This implies that the selection of fish was a largely random activity. Common marine shells among the 23 percent of identified species included *Costellariidae*, *Strombidae*, *Trochidae*, and *Placunidae*, grouped into *Gastropoda*. The *Bivalvia* group, including *Arcidae*, *Mytilllidae*, *Fimbridae*, *Tridacnidae*, and *veneridae*, was the group most commonly found and present in most soil layers in the Mamorikotey, Karas and Srobu sites. Freshwater shells, including *Costellariidae* were observed present in small numbers, while the *Littorinidae* and *Naticidae* families were the most frequently encountered in all layers of Mamorikotey, Yomokho and Karas. Freshwater shells were found more often at the Karas and Yomokho site than seashells, particularly the *Littorinidae*, which might be attributed to the surrounding environment of rivers and lakes. The genera of *Littorina*, characterized by short spires,

round to ovate in form, and lived in rocks and grasses near the tide line, while the *Naticidae* lived through sandy bottoms. The sea and freshwater *molluscs* found in the Late Holocene group sites give some indication of the frequencies and presence of different species or taxa during this time period. In Srobu, shell deposits in the form large mounds were distributed in almost 80 % of the sites area.

The presence of shell middens at these two sites may be due to their proximity to water molluscan habitats. For example, the Srobu site is located at the top of the hills on the shores of Abe Beach in Jayapura. The shellfish remains from marine and freshwater mollusks are found in the Srobu shell midden deposit. The mollusks total 33,913 pieces of shells in box excavation B2S1 at the Srobu site, of which 30,004 pieces are bivalves and 3909 pieces are gastropods (Djami et al. 2017). In this study, the different shellfish species in the Late Holocene sites group demonstrate a high reliance on marine, mangrove, and riverine species employed, which may be related to local environmental change. Some of the shellfish that were identified have undergone modification, including *Bivalvia pectinidae* (chlamys senatoria) (Djami et al. 2017). Shellfish ornaments in various forms have been discovered at the Yomokho site and its surrounds, and they were most likely used as necklaces and bracelets due to their shape and their traces of wear (Suroto 2014). The species used for bracelets from the Lake Sentani sites is from gastropoda family, *Tectus Niloticus* (Tolla 2016), which is also commonly found in Srobu (Djami et al 2016, 2017) as well as the giant seashells or known as *Tridacnidae* species. Several parts of the shell have circular holes with the same diameter that are assumed to have been used for specific purposes. The large quantities of shellfish remains found in the Late Holocene group sites, might be used to estimate the human diets. The appearance of shell middens also suggests environmental change, a decrease the animals resources and population growth. These factors may have forced prehistoric humans to exploit new food resources, such as shellfish.

The general trends of material culture in this study reveal a continuity of cultural practice, including pottery, which are typically present in all layers from all sites. Decorated pottery, such as shell-impressed, incised and applied designs, was commonly found in all the layers, along with undecorated types. This implies that, since the arrival of Asian ancestors in the lowland region of Papua ~3000 BP, pottery culture has continued to be practiced during the Late Holocene and even today, related to the pottery-making tradition in several clans in the lowland part of Papua. The similarity of pottery technologies and decoration identified from the Late Holocene group sites suggests that Austronesian speakers may have instantaneously spread this culture after their arrivals in this area. The shell-impressed, incised, and applied relief pottery styles known as applique' have their origins in Austronesian-Lapita people (Spriggs 1997:67). In this sense, it seems that the

invading Austronesian tradition became 'Papuanized' through contact-induced, innovation, change, resulting in the variety of cultural styles since their arrivals in the Lowland area of Papua.

Stone tools, particularly axes-adzes, were found irregularly at sites in the Late Holocene group. The ax-adze tools were found only on the lower and top layers in the Mamorikotey. The cross-section of ax in the Late Holocene group were mostly lenticular or oval, and also symmetrical with a circular, while adzes were sub-triangular or have a plan-convex of cross-section. In Srobu, the ax-adze were found irregular, sometimes present and sometimes absent in a few layers. While the lack of stone tools in some levels may be due to a shift in food subsistence, as evidenced by the availability of shellfish in the most layers at these sites, the employment of adze and ax in the shellfish collection process may be unnecessary in this term. Like shell artifacts, including shell fishhooks, and armbands, the primary manifestation of the Lapita cultural is ax- adzes commonly made of the hinge section of Tridacna sp. However, the ax-adzes in the sites of the Late Holocene group were made of basalt, siliceous schists, and andesite stones. This evidence raises the question of whether the adze-ax tools from the Late Holocene group were created by Papuan speakers group or Austronesian speakers.

The animal bones, classified as juvenile-pigs and marsupials, were detected in soil layers where stone tools weren't found, potentially indicating that the stone tools weren't used for animal hunting. The size and weight ratio of the ax-adze from Mamorikotey suggest it was designed to perform heavy work. The basic typology sorting can be connected with its purpose for regular activities as opposed to trade activities. This can be seen from the living tradition of stone tools in the Grand Valley, where adzes and axes are employed for logging and finishing boards for house construction.

Although the Austronesian speakers in the Lowland region of Papua are known for their pottery-making and domestication practices, gathering and foraging activities may be practiced, just as the initial settlers, anatomically Australo-Papuan peoples, did. This can be seen from the ecofacts remains encountered in all the sites of the Late Holocene group as well as the results of stable isotopes in this study. This evidence explains how human groups interact and how cultural aspects are retained through practice while incorporating new ideas, beliefs, strategies, and technology as a result of interaction and cultural contact.

The admixture between different genetic lineages in the lowland part of Papua-Indonesia may have been shaped since the arrival of different populations, anatomically Australo-Papuan and Asian ancestry from mainland and island of Southeast Asia, as shown through the metric dental traits and ancient DNA types from humans in this study. The language and archaeological distributions in the lowland area may provide insights into the demographic history and social

contexts of human dispersals and interaction within the group of people in lowland Papua and generally in Near Oceania for the subsequent human dispersal in this region. Interaction between the groups in the Lowland part of Papua and may have had an impact on the genetic traits and cultural development in these areas, which happened by way of introduction, adoption, borrowing, trade, and population admixture.

5.3 Stable isotope results from bone collagen and enamel apatite

Food is an essential element in human life, utilized as an energy source. In archaeological studies, it can be used to understand human behavior related to diet consumption and its impact on human teeth characteristics. Since food substances such as nitrogen, carbon, and oxygen are incorporated into human body tissues, like bone and teeth, to provide energy and form the human body, the isotope signatures of nitrogen, carbon, and oxygen can be traced through bone collagen and enamel apatite. The carbon and nitrogen isotopes preserved in human bones yield abundant proteins, collagen, fats, and lipids, which contain valuable information for human paleodiet studies (Schoeninger and DeNiro 1984). Enamel apatite reflects the total diet consumed, yielded in $\delta^{13}C$ in the form of fats, lipids, and proteins and $\delta^{18}O$, whereas bone collagen values indicate dietary proteins consumed generate $\delta^{13}C$ and δ15N (Lee-Thorps 1989).

Bone collagen and enamel apatite provide a permanent record of human diet, preserved in bones and teeth tissues, allowing us to understand dietary intake from marine or terrestrial foods, herbivore or carnivore sources etc, by analyzing the isotopic values present (Ehleringer & Osmond, 2000: 295; Ambrose and Norr, 1993; Hardy & Buckley 2016:243). The applications of stable isotope analysis to bone collagen and enamel apatite helps determine the food sources incorporated into bone connective tissue, collagen (protein), and tooth enamel (mineral). This study investigates human behavior in terms of diet by focusing on the isotopic composition preserved in body tissue, particularly nitrogen ($\delta^{15}N$) Nitrogen, carbon isotope ($\delta^{13}C$), and Oxygen isotope ($\delta^{18}O$). The carbon and nitrogen isotope values from bone collagen analysis indicate average dietary protein consumption of perhaps 10 to 20 years (Katzenberg, 2000; Sealy, 2001), while the carbon isotopes in enamel apatite present the value of isotope carbon from childhood. The isotope $\delta^{18}O$ value from enamel apatite provides information about mineral intake through drinking water and foods containing water, which can be used to understand individuals' movement or geographical origins (Luz et al., 1984; Luz and Kolodny 1985).

Since the human skeleton were unearthed in the Papua-Indonesia region, the local value of stable isotopes values from Papua and neighboring areas have been employed as a reference to determine human bone collagen from the five sites. Stable isotopes analyses has not been previously conducted in the Papua-Indonesia region, so the results from stable isotope studies by Kinaston et al. (2014) and the archaeozoological findings from the Teoma Lapita site in Vanuatu, Near Oceania, are used to determine dietary sources in this study. Additionally, Schoeninger and DeNiro (1984: 632) are referenced for comparative purposes. The stable isotope results from Vanuatu site serve as a reference due to several considerations. Vanuatu is geographically close to the lowland area of Papua Indonesia and shares similar environmental characteristics, altitude, and distributions of flora and fauna. This similarities make Vanuatu a suitable comparative reference for interpreting stable isotope data from the Papua Indonesia region in this study.

5.3.1 Bone collagen nitrogen isotope (δ15N)

Tissue nitrogen in organism comes from dietary protein, which varies depending on the source (Nash & O'Brien, 2017: 241). The nitrogen isotope values of an organism indicate its tropic level in the food chain (DeNiro and Epstein, 1981). Higher δ15N values typically indicate rich diets in marine or meat-based proteins, whereas lower values suggest primary consumption of plant proteins. The stable isotope values (δ15N) of an organism have a significant linear relationship with diet preference (DeNiro and Epstein, 1981). The isotope $\delta^{15}N$ can be used to infer the trophic positions of living organisms in the food chain (Xu, 2015: 107; Richards, 2008: 522). Isotopic composition becomes more positive along the food chain continuum, from plants to herbivores, then to carnivores, and finally to omnivores- reflecting their position in the ecosystem's tropic levels. Marine-terrestrial animals higher in the food chain generally exhibit higher δ15N (Schoeninger & DeNiro 1984: 1). Based on the animal bone collagen study by Schoeninger & DeNiro (1984), the isotope δ15N values significantly between marine and terrestrial species. Marine animals (birds, fish, and mammals) typically show higher positive values compared to terrestrial animals (birds, herbivores, carnivores, freshwater fish, and terrestrial mammals). The tropical rainforest serves as habitat for the local terrestrial fauna, including herbivores, omnivores, carnivores, marsupials, wild sus, birds, plants, and others.

The nitrogen isotopes from bone collagen sourced from these food types will be utilized in this study. Nitrogen isotopes vary across different regions (Richards, 2020: 136), necessitating the application of local food-web values in interpreting bone collagen data from various studies. Baseline values fro nitrogen isotopes in bone collagen from animals, both terrestrial and aquatic (marine and freshwater), are established to determine the dietary protein sources using isotopic

values obtained from human bone collagen. In this research, nitrogen isotopic values from human bone collagen samples are enriched in $\delta^{15}N$ by approximately +3-4 ‰ relative to the nitrogen values found in human foods (DeNiro and Epstein 1981; Minagawa and Wada 1984; Schoeninger 1985). Consequently, $\delta^{15}N$ values in human tissues increase by about ca.3% per trophic level in the food chain (Richards, 2020: 136). Stable isotope nitrogen ($\delta^{15}N$) value were obtained from the bones of seven individuals from five archaeological sites (Mamorikotey, Yomokho, Srobu, Karas and Namatota). These values ranged from 4.16 ‰ to 14.01 ‰, indicating consumption of three main diet sources: marine-terrestrial (including herbivores, carnivores, and omnivores) primarily plant protein, and vegan diets (Schoeninger and DeNiro, 1984: 632).

5.3.2 Bone collagen carbon isotope ($\delta^{13}C$)

Carbon is a crucial element for living organisms, essential for interpreting the photosynthetic process that fixes fossil organic matter (Shors, 2020: 145). Stable carbon isotopes provide records of photosynthesis in plants, distinguishing between C3 and C4 pathways (Chesson et al., 2011:705). C3 plants use enzymes to produce sugars from carbon dioxide with three carbon atoms, while C4 plants produce sugars with four carbons atoms (Aufderheide, 1996: 146). The 13C isotope values, differ between marine and terrestrial environments due to the varying photosynthetic pathways of plants in different environmental conditions (Hard and Buckley 2016:243). Unlike nitrogen isotopes, which change through tropic interactions, carbon isotopic signatures remain stable, making them useful for tracing material flows in food webs (DeNiro & Epstein, 1978; McCutchan et al., 2003). Human bone composition biologically retains carbon isotopes from plants consumed directly and indirectly through animals during an individual's lifetime (Kelly & Thomas, 2014: 16; Alexander, 2020:62). Isotopic analyses of bone collagen are conducted to determine the primary food sources of individuals throughout their lives. Plants utilizing different photosynthesis pathways, C3, C4, and CAM (Crassulacean acid metabolism) exhibit distinct isotopic ratios in their tissues. C3 plants, characterized by slower carbon dioxide uptake, have $\delta^{13}C$ values ranging from -20 ‰ to -35 ‰, while C4 plants, with rapid carbon dioxide uptake, display values between -9 ‰ and –16 ‰ (van der Merwe 1982). These differences are crucial for interpreting human diets, as they reflect the isotopic values incorporated into plant tissues from which humans derive nutrition (Schwarcz & Schoeninger 1991).

5.3.2.1 The isotope carbon value differences between $\delta^{13}C$ value from bone collagen and isotope $\delta^{13}C$ value from enamel apatite

The carbon isotope composition in tooth enamel apatite, like bones collagen, reflects dietary intake of C3 and C4 plants' (O'Leary, 1988). However, there are significant differences between the

isotope values of bone collagen and enamel apatite, reflecting the types of nutrition present in these tissues. Unlike collagen, carbon isotopes in enamel apatite provide a broader picture of an individuals' entire diet, not just the protein component (Ambrose and Norr 1993). Therefore, enamel apatite values are used to reconstruct dietary patterns during childhood, adulthood diet (Tykot et al., 1996).

This study reveals a substantial range of differences in $\delta^{13}C$ values between bone collagen and enamel apatite. Bone collagen $\delta^{13}C$ values range from -16.50 ‰ to -25.60 ‰, whereas enamel apatite $\delta^{13}C$ values range from -10.8 ‰ to -13.5 ‰. These values signify dietary intake during different life stages- childhood and adulthood (Pierce et al., 2012: 316). The isotope value of $\delta^{13}C$ enamel apatite presents data of diet intake during childhood. In contrast, the isotope $\delta^{13}C$ bone collagen (remodeling at least 10 to 15 per year) represents the information on diet for the last decades of an individual's life, indicating a change in dietary intake in childhood and adulthood. Based on the isotope value used as a reference in this study, the bone collagen in the six samples from six individuals (Krs/649), Krs/638, Ymk/1-R, Ymk 2-P, Srb_20, and Nmt/2-F) indicates a diet primarily based on C3 plants. However, a sample from the Namatota site (Nmt.1-U) shows δ13C values indicating a diet rich in C4 plants. In contrast, the isotope $\delta^{13}C$ values from enamel apatite of individuals from three sites (Karas, Srobu, and Mamorikotey table) suggests consumption of C4. The disparity suggest that carbon-enriched foods were less prevalent in the lowland area of Papua.
The variation in carbon isotopic values between enamel apatite and bone collagen can be attributed to differences in the essential and non-essential amino acids obtained through diet (Schoeller 1999). Essential amino acids are derived solely from dietary proteins, while non-essential amino acids can be synthesized by the body sufficient oxygen, nitrogen, carbon and hydrogen are available (Malainey, 2011). The variation in isotope values between bone collagen and enamel apatite, particularly when influenced by a diet rich in meat, reflects how amino acids are metabolized and incorporated into different tissue types. Essential amino acids must be obtained directly from the diet, whereas non-essential amino acids can be synthesized by the body from various sources, including dietary fats, carbohydrates, and proteins. When an individual consumes a substantial amount of meat, there tends to be a larger difference in the isotope values between bone collagen and enamel apatite. This difference arises because bone collagen reflects dietary patterns over the longer term, incorporating isotopes from proteins consumed over many years. In contrast, enamel apatite primarily records dietary information form childhood, offering insights into early life dietary patterns. Therefore, significant meat consumption can lead noticeable distinction in $\delta^{13}C$ values between these tissues, as observed in this analysis and noted by Schwarcz (2006).

***Table 20**: The carbon isotope value between bone collagen and enamel apatite*

Sample Name	Bone collagen δ 13C ‰ (PDB)	Enamel apatite δ 13C ‰ (PDB)
Krs/649	-25.60	-12.3
Krs/638	-24.63	-
Ymk/1-R	-20.60	-
Ymk/2-P	-21.19	-
Srb_20	-18.46	-10.8
Srb_413	-	-12.4
Nmt/1-U	-16.50	-
Nmt/2-F	-19.95	-
MMK_333	-	-13.1
MMK_419	-	-13.5

The amino acids derived from meals such as meat is contain both essential and non-essential proteins. When individuals consume a large amount of meat, there tends to be a significant difference in isotope values between bone collagen and enamel apatite. This difference arises because bone collagen reflects dietary patterns over the long term, incorporating isotopes from proteins consumed over many years. In contrast, enamel apatite primarily records dietary information from childhood, providing insights into early life dietary patterns. In cases where meat consumption is minimal, essential amino acids are primarily derived from dietary proteins, while non-essential amino acids are generated from fats, carbohydrates, and protein sources. This can lead to a smaller distinction in the values of bone collagen and enamel apatite, as noted by Schwarcz in 2006. The substantial intake of meat may indeed contribute to the variations observed in the isotope values between bone collagen and enamel apatite in analysis.

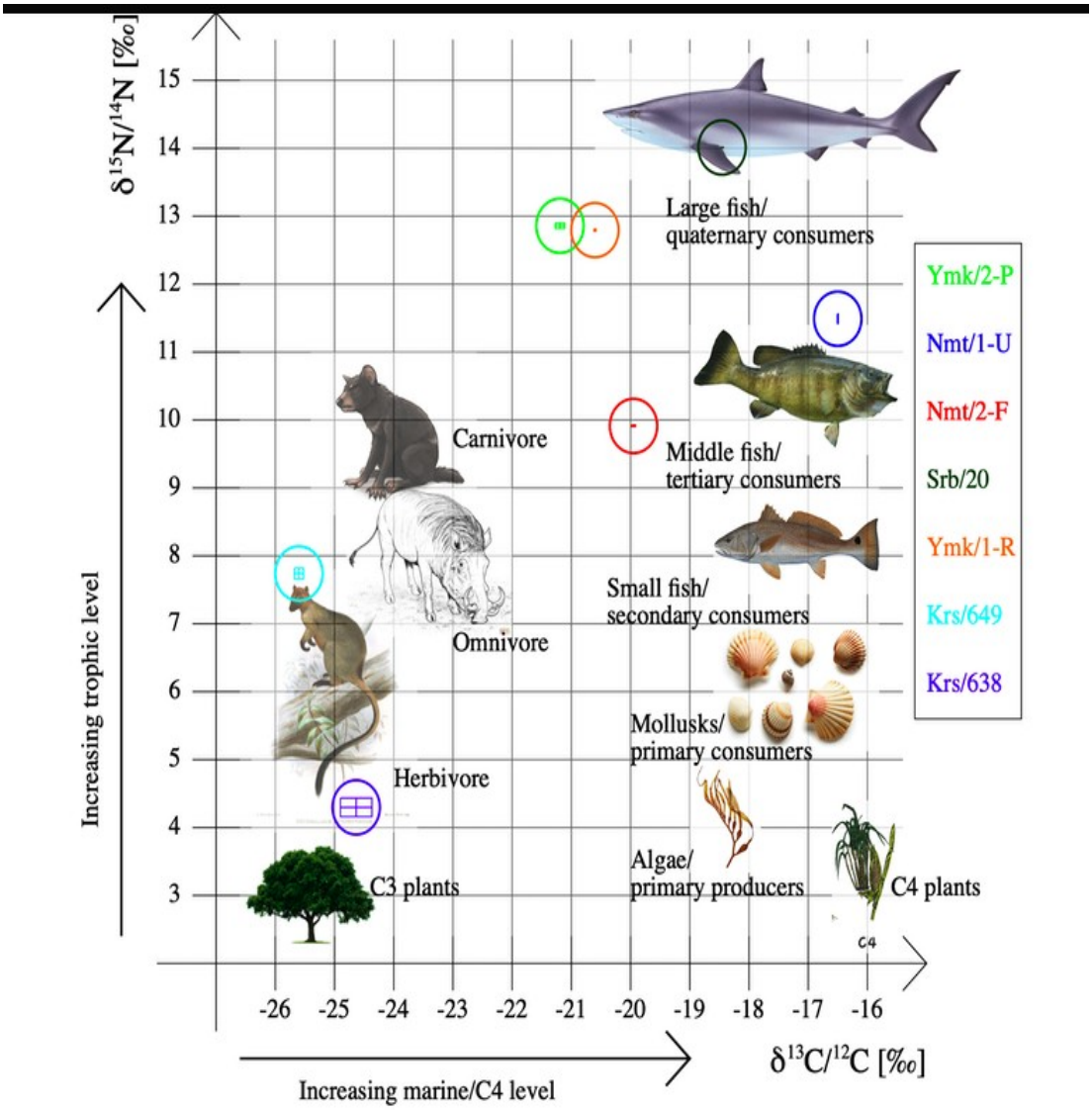


***Figure 30**: Typical Isotope $\delta^{13}C$ and $\delta^{15}N$ values of human bone collagen from 7 samples in this study. After establishing the food web isotopic values of local species based on the ecofact distributions, the bone collagen can be compared to determine if the source of dietary protein was more similar to plants only, herbivores, carnivores, or omnivores. The Yomokho site samples are abbreviated: YMK/1-R and YMK/2-P; the Namatota site has two samples: NMT/1-U and NMT/2-F; one sample from the Srobu site: Srb/20; two samples from karas site: Krs/638 and Krs/649.*

The results of this study have prompted questions regarding the resources and habitats of C3 and C4 plants that formed a significant part of diet in these ancient populations. C3 plants, such as cereals (rice, wheat, and oats), roots and tubers (potato, yams, taro, sugar beet, cassava and sweet potato, sago), fruits (coconut and banana), and trees, utilize a specific photosynthetic pathway that involves a three-carbon molecule. These plants are adapted to environments with sufficient CO2 and moderate water availability, conditions that are suitable for some C3 plants like sago, coconut, banana, and certain tree fruits in Papua's lowland-coastal areas. On the other hand, C4 plants,

dominated by the grasses like maize, sugarcane, and millets (Jalota et al., 2018: 94) use a different photosynthetic pathway involving a four-carbon molecule. These plants typically thrive in environments with higher temperatures, intense sunlight, and lower CO_2 concentrations, conditions less suitable for Papua's coastal environment. Ethnographic data supports that C3 plants, especially root and tuber crops, are extensively cultivated in the higher-altitude valleys of Papua-Indonesia, around 1000 meters a.s.l, but are less common in the lowland-coastal areas where the five archaeological sites are located.

The isotope $\delta^{13}C$ values observed in enamel apatite from this study suggest a dietary inclusion of C4 plants. Given that C4 plants like maize are not native to Papua's coastal environments, these $\delta^{13}C$ values likely indicate consumption of marine resources, such as detritivores and marine fish, which exhibit higher $\delta^{13}C$ values due to their diet derived from marine plants using dissolved CO_2 and carbonic acid in photosynthesis. The environmental diversity of Papua's lowland areas, encompassing marine habitats and canopy rain forests, influences dietary practices. Closed habitats like rain forests where C3 plants predominate tend to produce more negative $\delta^{13}C$ values, reflecting the environment's isotopic composition. Conversely, C4 plants, associated with more open environments or marine ecosystems, show more positive $\delta^{13}C$ values. This isotopic evidence can elucidate dietary preferences and the ecological adaptations of ancient populations in Papua, suggesting a blend of terrestrial and aquatic-marine resources in their diets.

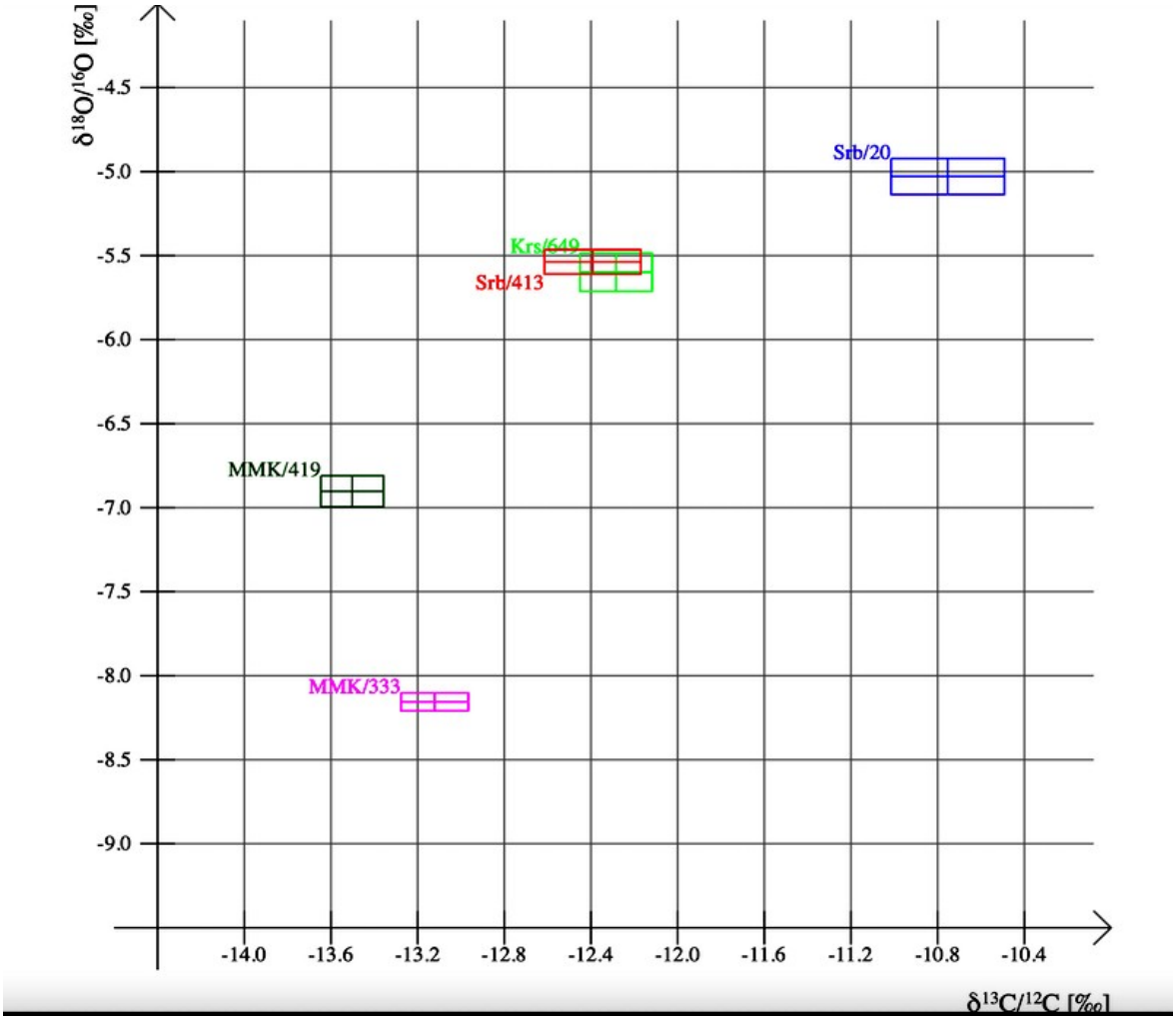


Figure 31*: Isotope enamel apatite result of the carbon and oxygen analysis on the human enamel teeth from four sites in this study. Two teeth samples from the Srobu site: Srb/20 and Srb/413; one sample from the Karas site: Krs/649; two samples from the Mamorikotey: MMK/333 and MMK/419.*

5.3.3 Oxygen and carbon Isotope from enamel apatite analysis

The carbon isotope values derived from the teeth of the five individuals' teeth (Table 11) range from -13.5 ‰ to -10.8 ‰, indicating slightly positive values compared to the isotope $\delta^{13}C$ values obtained from bone collagen. All of the $\delta^{13}C$ values from enamel apatite of these teeth suggests a diet primarily based on C4 plants within this range. Human enamel, as a tissue, incorporates oxygen signals primarily from drinking water. The chemical bonds in crystalline apatite which forms tooth enamel contain oxygen derived from the local water sources where individuals lived (Bryant et al., 1996b: 397). The oxygen found in human tooth enamel is primarily sourced from the water individuals consume, either directly from nearby water sources or natural

water. This process involves the incorporation of oxygen isotopes present in the local water into the crystalline structure of apatite, which forms tooth enamel. Studies by Prowse et al., (2019) and White et al. (1998) have highlighted how the isotopic composition of oxygen in enamel can provide insights into the geographical origin or movement patterns of individuals, reflecting the isotopic signature of the water sources they consumed over their lifetime.

The isotope $\delta^{18}O$ value in enamel tissue provides valuable information about the minerals derived from drinking water and foods containing water that an individual has consumed since childhood (Longinelli, 1984). In the context of lowland Papua, the local or regional isotope $\delta^{18}O$ water ratios are utilized to interpret the $\delta^{18}O$ values found in the enamel apatite of individuals in this study. According to the data compiled by the International Atomic Energy Agency (IAEA), which has conducted that extensive survey of isotopic compositions worldwide since, 1960 until today, $\delta^{18}O$ composition vary significantly between the regions. These variations are influenced by geographic and meteorological factors such as rain, surface air temperature, humidity, distance to the coast, and altitude/latitude (Dansgaard 1964).

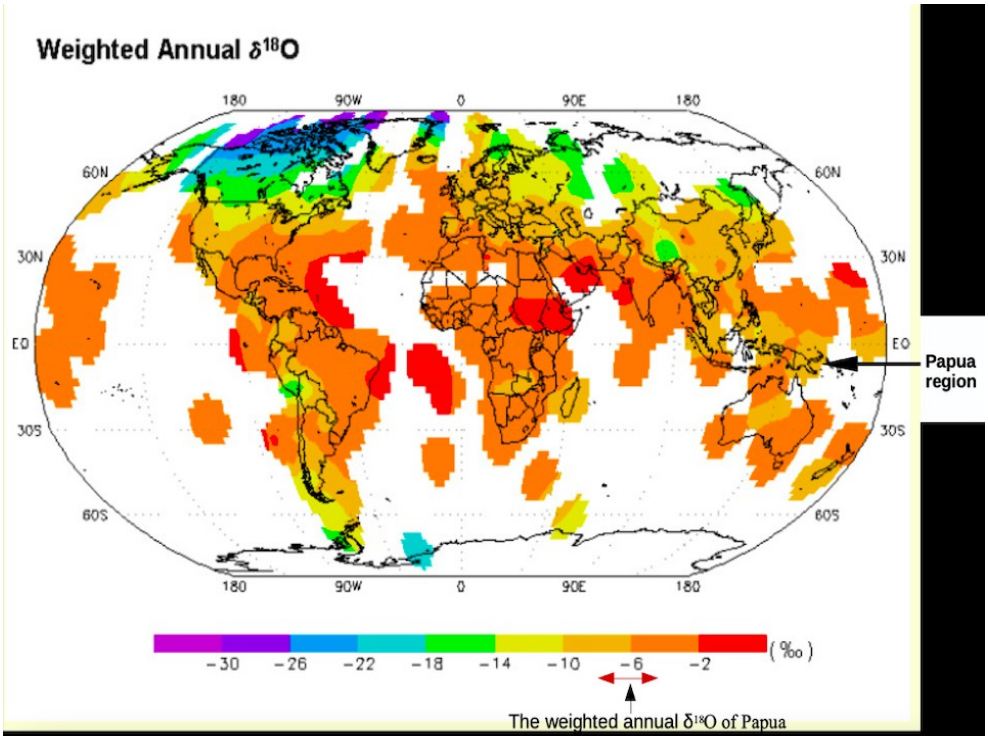


Figure 32: The distribution of isotope $\delta^{18}O$ globally. The Isotope $\delta^{18}O$ in the region of Papua display the value from -2‰ to -10‰ (sources: IAEA.org).

Based on the weighted annual $\delta^{18}O$ value of the Global Network of Isotopes in Precipitation (GNIP) of the IAEA, the isotope $\delta^{18}O$ value in water from the Papua region ranges from -2 ‰ to -10 ‰ (Figure 37). Since the Papua region is located near the equator line, the isotope oxygen value of water is relatively positive compared to regions farther from the equator line (respectively). This

observation aligns with the meteoric water line (GMWL) established by Harmon Craig (1961), which highlights the distinctions in isotope oxygen isotope values between regions near and far from the equator. The isotope oxygen value near the equator is higher than in regions farther away. The $\delta^{18}O$ values from the enamel apatite of the five individuals in this study range from -8.2 ‰ to -5.0 ‰ (Table 21), which falls within the -10 ‰ to -2 ‰ range of water in this region, as provided by the IAEA databases. To understand the $\delta^{18}O$ values from enamel apatite in this study, it is essential to consider the local isotope oxygen values reported in previous research in this area.

According to a study conducted by Permana et al. (2016) on isotope oxygen from rainfall in the lowland-southern area of Papua, Indonesia, the mean value of daily rainfall and seasonal fluctuations varied at different altitudes. The isotope $\delta^{18}O$ value of daily rain at altitudes ranging from 9 m a.s.l is -6.23 at, -10.11 at 1900 m asl, and -15.94 at 3945 m asl. Monthly variability shows that the isotope $\delta^{18}O$ value of rainfall at altitudes 9 and 67 m asl displays -6.8 and -8.3 ‰, whereas at altitudes 1900 m asl, the mean annual rainfall $\delta^{18}O$ presents the values -8.3 and -12 ‰. These results suggest that altitude significantly influences the mean value of oxygen isotopes in water, with more positive values at lower altitudes compared to higher altitudes.

***Table 21**: The descriptive statistics for human $\delta^{13}C$ and $\delta^{18}O$ enamel apatite from the five sites*

The isotope value of enamel teeth from the lowland area of Papua-Indonesia (*N=5)*	
$\delta^{13}C$	
Mean	-12.41
Std. Dev	1.06
Range	-13.5 to -10.8
$\delta^{18}O$	
Mean	-6.24
Std. Dev	1.27
Range	-8.2 to -5.0

Given the mobility of humans, it is important to consider that some individuals may not have lived exclusively in one area. Consequently, the oxygen values from surrounding regions will also be presented in this study. The IAEA's data, covering several areas such as Madang Papua New Guinea (Table 22) provides isotope oxygen values that serve as a comparative reference to estimate the range of isotope oxygen values.

The mineralization process at the third molar occurs at approximately 7-10 years of age, ensuring that the oxygen value in this tooth is unaffected by maternal milk (Table 14 Chapter 4) (Bryant et al., 1996b: 402). Therefore, this study will focus on two third molar teeth to investigate

the geographic origin or movement: Srb/413 (Srobu site) and MMK/419 (Mamorikotey site) from the Mamorikotey site.

5.3.4 Diet Resources: Isotopes collagen and enamel apatite value results and their relationships with the ecofacts distributions

Given that the nitrogen and carbon isotopes in collagen reflect the protein diet intake in humans in the last 10 to 15 years, while the value from enamel apatite reflects the diet from childhood, this study will investigate the types of food sources contributing to these isotope value. The food consumed reflects various nutritions, including protein, carbohydrates, and fats, which are incorporated in human bones and teeth. These can be identified by the values shown in the stable isotope result. Ecofacts, the unmodified remains of biological materials, are often found in archaeological contexts alongside with the human skeleton. They offer insights into past human behavior and can provide valuable information about diet sources. In archaeological study, ecofacts are classified as non cultural findings, like animal bones, plant remains such as pollen, nuts, seeds, roots, etc. Although unmodified, these findings are still representative of human activities and can help reconstruct past diets and lifestyles.

***Table 22**: The altitude and the ^{18}O average of the Srobu site & Mamorikotey site, Jayapura, and several areas in the Oceania region.*

GNIP Station	Altitude	Long-term $\delta^{18}O$[‰] Avg
Srobu Site, Jayapura Papua-Indonesia	85m	-5.5
Mamorikotey site, MMK_LM_Kek 2	75m	-6.9
Jayapura Papua-Indonesia	140.72	-5.90 ± 1.07
Madang- Papua New Guinea	145.8	-7.03 ± 0.60

The ecofacts associated with the human remains from the five sites in this study include biological remains in the form of macro remains and faunal remains. These ecofacts preserve valuable information about past environmental characteristics in the past and provided evidence concerning human behavior related to diet preference. However, in some cases, these findings may have been deposited in the archaeological context by nonhuman agents, which may cause bias in human diet-based interpretations (Brain, 1981). For this reason, to avoid data misuse, the distinction between cultural and natural deposits must be carefully defined (Dincauze, 1987: 287).

To illustrate the causal relationship between ecofacts and human cultural behavior, the first step will be to describe and classify the ecofacts using morphological analysis. It deals with the

anatomy, form, and shape, species, habitat preference, and number of distributions in the layer excavations where the human skeleton was found. This step is expected can shed light on the positions in human life, determining whether they are interdependent or causally linked with past human behavior. Furthermore, the observed ecofacts results will be used to determine their relationship with the types of foods reflected by the nitrogen and carbon isotope values of the individuals in this study.

The stable isotope analyses of nitrogen, carbon, and oxygen were conducted on 12 samples representing ten individuals from five sites (Mamorikotey, Karas, Srobu, Yomokho, and Namatota). These analyses included seven (n= 7) samples for bone collagen analysis: one (1) sample from the Srobu site, two (2) samples from the Karas, two (2) samples from Namatota, and two (2) samples from Yomokho. Additionally, five (5) samples from the same individuals used for bone collagen analyses were employed for enamel apatite analyses, including two (2) samples from the Srobu site and one (1) sample tooth from the Karas site. Two (2) samples of teeth from the Mamorikotey site were employed only for enamel apatite analyses and did not involve bone collagen analyses (Table 11). Further details will be discussed in the following section to provide insights into the dietary behavior of humans from the five sites. The associated findings, such as ecofacts together with the human skeleton, will enlarge the discussion about past human behavior related to diet consumption. At the end of this chapter, the discussion will include the physical characteristics of the teeth and their relationship with diet intake, as well as artifact findings that may be used in food processing, which could have contributed to the wear and pathology in the humans studied. The following analysis will be discussed for each site.

5.3.4.1 Srobu site (Occupations 1720 BP)

The collagen $\delta^{15}N$ value for Srb/20 is 14.01 ‰, which implies a mixed diet of terrestrial omnivorous-herbivorous animals. The intermediate to high collagen $\delta^{13}C$ value of -18.46 ‰, corresponds to marine fish consumption (Nash et al., 2012; Trites, 2019:589). On this basis, the value resulting from bone collagen for these individuals signified a mixed diet that includes terrestrial omnivore-herbivore animals, meat, and marine fish. The combination of a high $\delta^{15}N$ and $\delta^{13}C/^{12}C$ values is strong evidence for marine food consumption, due to the long food chain involved, which also supported by the high $\delta^{13}C$ in the enamel apatite. However, the results cannot yet determine whether the individual primarily consumed C3 or C4 plants.

The significant consumption of terrestrial meat and marine fish resulting from isotope collagen analysis, supported by ecofacts findings, was found at this site. It includes marine shells and fish, marsupial and sus bones, fragmentary unidentified species of fauna bones, and various

plant remains, such as nuts (Djami, 2016; 2017). There is a strong relationship between the ecofact distributions and the environmental characteristics of the area where the Srobu site is located. The environmental features surrounding this site present the different ecological niches, including closed habitats (forest), shrub lands, and sea ecology, as well as several habitats where the animals lived, representing "food markets" for the people in the past. The ecofacts findings, particularly the fauna and flora, have allowed the interpretation of past environmental characteristics related to the habitats where these living organism was derived. The ecofact types consisting of nuts/seeds found at the Srobu site may give a hint of this environment's existence, related to the types of nuts and seeds derived from the closed habitats (forest). Evidence from dental faunas such as marsupials, Sus species, fish, shells, etc., reveals the habitats, whether terrestrial, arboreal, or aquatic ecology. The ecofact distributions, such as nuts and seeds, from this site show relevant results with the C3 values from the carbon isotope. From the morphological analysis results, the seeds/nuts from the Srobu site are recognized as derived from the tree plants in the lowland-forest environment, providing data about the environmental characteristics in the past. The plants density provides habitats, nets, and food for many faunal species, including wild pigs (Sus species), marsupials, and other animals found at this site. Herbivorous animals, including marsupial, primarily consume leaves, nuts, roots, and other plant materials.

The evidence from the animal distributions, which by morphological anatomy consist of herbivorous and omnivorous animal species, such as Sus and marsupial species, supports the terrestrial animal meat diet-consumptions as indicated by the isotope collagen values in individuals from this site. Herbivore marsupials were identified through the morphological characters of their incisors, premolars, and molars. The specific dietary niches of marsupial species are supported by their morphological features (Hume 1999:348). Based on morphological analysis, herbivore species identified through the characters of their incisors were recognized as members of the marsupial-phalanger family. The single-rooted, chisel-like teeth with the two rows-one on the left and one on the right (single pair for the lower incisors), are more forward-pointing and are used as cutting blades to grip and pluck leaves from the branches. These incisor characteristics are categorized as the diprotodont teeth pattern of herbivorous marsupials from the phalanger family group, which includes tree kangaroos, wallabies, wombats, and ringtail possums. According to dietary requirements and habitat preference, 60 % of diprotodont marsupial-phalanger species occupy the arboreal or woody plant areas of tropical rain forests in New Guinea (Cook et al., 2020: 62), including the region of Papua-Indonesia. The second morphological characters used to identify herbivorous marsupial species are the third premolars of the lower jaw area and the permanent third

premolars. These teeth are recognized by their single form with a large ridge area and fewer sharp points at the occlusal part, providing a grinding surface for the mastication process. The morphological characteristics of the premolar teeth indicate the presence of herbivorous marsupial species.

The third character indicates that the fauna bones in this site is herbivores including marsupials, identified through the cusps of molar teeth, which consist of four cusps split into two different parts by crests and ridges, mesially and distally. At the mesial part, the paracone and protocone cusps are joined together by ridges called paraloph/protoloph, while the distal ridges join the hypocone and metacone cusps, or metaloph (Figure 36). The molar cusps from this site are classified as lophodont molars, characterized by cusps that fuse to form elongated ridges (Figure. 36), with a large occlusal area for grinding. The enamel at the occlusal part worn horizontally at the paracone, protocone, hypocone, and metacone cusps, presumably due to high pressure of leaf chewing and food grinding caused dentin tissue exposure in the surface. The morphological characteristics of marsupial molar teeth from this site suggest that they are from the herbivorous group. The lophodont shape has been found in marsupial species from the Srobu site. The lophodont shape is an indistinguishable characteristic of herbivorous mammals (Martin et al., 2001:17).

***Figure 33**: Marsupial dental teeth from Srobu site (Djami et al, 2017), Balai Arkeologi Papua-Indonesia*

Based on the isotope $\delta^{13}C$ and $\delta^{15}N$ collagen isotope analyses from individual Srb/20, the results present an intermediate range of meat consumption values. These isotope values provide insights into the type of food preference and meat consumption at this site. According to the nitrogen isotope analysis of faunal bone collagen from the Teoma site in Remote Oceania (Kinaston

et al., 2014), pig bone samples present a range of values from 9.9 to 9.3 ‰. This corresponds to the bone collagen values and results in the Srb/20, with a +3-4 ‰ of tropic effect in human bone collagen. Comparing this to the ecofact distributions at the Srobu site, the higher number of Sus skeletal remains identified through the jaw and teeth morphology suggests their significant role in past human life, possibly as a food source. Pig species are divided into two groups: feral and domestic. Domestic pigs are defined by their adaptation to omnivorous diets under control, whereas feral pigs live without humans control and are generally adapted to herbivores diets (Hone, 2012).

Studies on isotope values and genetic differences between domestic and feral pigs have been carried out by Balasse et al. (2019). Domestic pigs were reported to have higher isotope values due to their diet intake from human food waste, which contains animal protein sources. Compared to domestic pigs, feral pigs varied in their isotope values, ranging from lighter to higher amounts (Balasse et al., 2019). For the pig remains from the Srobu site, whether domestic or wild, they may have been consumed by the people in this site, contributing to the intermediate isotope collagen values in the individuals from this site. Future studies on stable isotopes from ecofacts at the Srobu site are needed to understand more deeply the isotope values, especially regarding their relationship with human bone collagen values.

The bone collagen value resulted individual Srb/20 indicated marine-fish consumption. Since food consumption is tightly correlated with its availability in habitats, the environmental characteristics of the Srobu site should be considered. The marine environment includes several types of ecosystems, such as estuarine and coral reefs, which provide habitats for species like mollusks and fish that humans may have utilized as food sources.

The marine food sources selected as diet sources by the Srobu site inhabitants are consistent with the ecofact distributions. The accompanying ecofacts of seashells were identified: approximately 33,913 shells were discovered, including 30,004 bivalves and 3909 gastropods, shell midden fragments, and more than 1 m of shell thickness (Djami et al., 2016). A total of 110 marine shell species have been identified from all of the seashells gathered during excavation, comprising 50 bivalve classes and 65 gastropod classes (Djami et al., 2016). The habitat preference of these marine shells is recognized as inhabiting the reef ecosystem distributed on rocky surfaces, coral heads, walls of channels, trenches, etc (Cernohorsky, 1978). The high number and diversity of marine shells from different ecosystem niches established facts about humans' abilities to reach these ecosystem spots and their knowledge of using seashells as a part of their diet in the past. The seashells are part of the ecofacts at this site and are irrelevant to the values produced from isotope collagen. The food-web mechanism of seashells places them at a low trophic level, which may

provide lower values of isotope range in human isotope collagen. The carbon isotope ratios depend on the length of the ratio in the food eaten by a living organism (Ehlinger & Osmond, 2000; 295). Seashells' positions in the food web are relatively lower compared to marine mammals placed at the top of the food chain in the sea ecology. In the food chain scheme, the primary diet of seashells is detritivores planktivorous, which by habitat are generally distributed from the ocean surface to the reef base (Graham et al., 2008:111). The low trophic level of seashells collected and further consumed by humans may present a lighter amount of isotope values in human bone collagen.

Other aquatic faunas recovered from the Srobu site that was part of the ecofacts list distribution are fish bones. Since the bones were found fragmentary, it is difficult to determine whether the fish was from a freshwater or marine habitat. However, it must be noted that the Srobu site's location, which is surrounded by the sea, may support the idea of marine food consumption, including fish. The marine food consumption by this individual is also supported by the fishing net weight that was found in the soil layers, which supports the assumption that the human on this site has practiced fishing in the past (Djami et al., 2016). The fish remains could shed light on the isotope collagen values related to the marine food diet consumed by the people in this site. The isotope range value in sea fish was confirmed to exhibit an intermediate to high isotope δ13C value (Nash et al., 2012). The food web differentiates the range of stable isotopes among sea-fish species; marine mammals have longer food chains, while piscivore fish have intermediary length of the food web (respectively) (Trites, 2019:589). The length of the food chain among fish species affects their isotope values, contributing to the isotope values in human bone collagen when individuals frequently consume these fish. The intermediate values of marine diet intake by individuals from the Srobu site suggest the consumption of medium-sized piscivore fish, which may have been added to the mollusk species in their diet. The isotope bone collagen results from individual Srb/20 indicate a diet that included both terrestrial meat and marine foods. This is supported by the distribution of ecofacts providing evidence of foraging coastal and terrestrial activities to fulfill the dietary needs.

5.3.4.1.1 Isotope enamel apatite results

The isotope enamel apatite analysis was applied to two teeth from two different individuals at this site. The results yielded two different values for isotope oxygen and isotope carbon that will be discussed in the following paragraph.

5.3.4.1.1.1 Isotope Oxygen

As indicated previously, the human third molar mineralizes between the ages of 7 and 12 years; consequently, the isotope oxygen value obtained from enamel apatite can trace an individual's geographical movement. This study will employ the isotope oxygen values of water sources from

the same study region—in this case, the values from Jayapura, where this site is located. Since 1961-1989, the GNIP-IAEA has collected rainwater samples to determine the local isotope oxygen values in the Jayapura area. The long term mean oxygen isotope $\delta^{18}O$ value from the Jayapura region. The long-term mean oxygen isotope value from the Jayapura region is -5.90 ± 1.07, which corresponds to the value 5.5‰ obtained from Srb/413. However, the altitude where the GNIP-IAEA conducted research was 140.72m asl, whereas the Srobu site's altitude is 85m asl. Given that numerous factors influence isotope oxygen values, including altitude, it can be inferred that the individuals from the Srobu site, Srb/413, presumably spent the childhood at an altitude higher than the Srobu. Because the Srobu is positioned lower than the GNIP-IAEA station where the isotope oxygen study was conducted, the isotope oxygen values at the Srobu site are expected to be more positive than those obtained from GNIP-IAEA research.

5.3.4.1.1.2 Isotope Carbon

The isotope $\delta^{13}C$ composition of tooth enamel apatite reflects an individual's entire diet during the mineralization of the tooth enamel in childhood. The isotope carbon value for Srb/20 and Srb/413 are 10.8 ‰ and 12.4 ‰. Based on these results, the diet consumed by these two individuals during childhood was primarily based on C4 plants. This evidence suggest that their included marine foods that have $\delta^{13}C$ values similar to C4 plants like maize (Tykot 2009: 138). This finding is further supported by isotope carbon derived from marine-fish at the Teoma site on the island of Vanuatu, Papua New Guinea, which falls within the range observed in the Srobu samples. From an environmental standpoint, the Srobu site region encompasses a variety of biomes, including to the ocean to the north, neighboring forests to the south, and Lake Sentani approximately 10 kilometers to the west. This diverse environment provides abundant food sources ranging from plants to animals, including marine foods, which could have been utilized for consumption by the inhabitants of the site. The identification of marine foods through δ13C values in the people from the Srobu site is also supported by the distribution of ecofacts at the site, which includes a significant quantity of marine food sources such as shellfish. However, these findings should be further confirmed in future studies using stable isotope analyses from the site to better understand human dietary behaviors and interpretations.

5.3.4.2 Karas site (Occupations 3400 BP)

5.3.4.2.1 Bone collagen analysis

Based on the isotope collagen results from both individuals, there were varying values observed. For individual Krs/649, the isotope collagen $\delta^{15}N$ value was 7.74 ‰, while the isotope $\delta^{13}C$ value display -25.60 ‰. In individual Krs/638, the result of isotope $\delta^{13}C$ nitrogen $\delta^{15}N$ displays

the value 4.30 ‰, while in the isotope $\delta^{13}C$ indicated -24.63 ‰. According to the value provided by isotope analysis in individual Krs/649 signified the intermediate-range diet values, the collagen δ15N ratio for Krs/649 tentatively signifies an intermediate range of protein in the diet and suggests the person was consuming terrestrial foods including herbivores.

In the individuals Krs/638, the value of isotope collagen $\delta^{13}C$ is 4.30 ‰, and the value of isotope $\delta^{15}N$ is -24.63 ‰. For individual Krs/638, the ratio of collagen $\delta^{15}N$ is substantially lower and provides stronger evidence for a reliance on herbivores. Most tissues, including collagen $\delta^{15}N$, have an enriched the value ~3 ‰ relative to the diet, which will be passed up with each step in a trophic level depending on consumers' food intake type (Minagawa and Wada 1984). The differences observed could be influenced by several factors, including potential postmortem diagenetic changes in the bones due to environmental exposure. Diagenesis can alter the chemical and physical properties of bone tissues, affecting the isotopic results obtained from analyses. It's essential to consider these factors when interpreting isotope data from archaeological samples. The isotope values observed in these individuals are consistent with environmental characteristics of food resources available in this region. Similar isotope nitrogen values from modern plants and mollusks in Vanuatu indicate a range from -2.0 to 3.9 ‰ (Kinaston et al., 2014), which aligns with the data observed in Karas. This consistency supports the idea that isotopic analysis of bone collagen can provide valuable insights into past human diets and their environmental contexts.

***Figure 34**: Upper figure: Mollusks analysis process by the Balai Arkeologi Papua team and the Karas site's local people. Lower left and right: the mollusks findings from the Karas site (Suroto et al., 2012).*

The Papua region's ecological diversity encompasses mangroves, swamps, lowland rainforests, montane forest and alpine zone, each supporting a rich array of plant and animal species (Petocz, 1989:23). The Karas site is, situated midstream lowland plains and intersected by various rivers, reflects this ecological richness. It is characterized by a variety of plant species, dominate by lowland rainforest flora and terrestrial that were likely utilized by humans as food resources. Ecofacts recovered from the Karas site included nuts/seeds, seashells, freshwater shells, fish, marsupials, and unidentified faunal bones (Suroto et al., 2012). These ecofacts provide insights into past human cultural behaviors, such as diet preferences and resource utilization (Clark, 1968; Yarnell, 1973). Plant remains, particularly nuts or seeds, found in taphonomic contexts, are crucial for understanding their roles in ancient diets, providing carbohydrates, vitamins, and other nutrients essential for human sustenance. Additionally, plants may have been used for medicinal purposes, clothing, flavorings, and various other practical uses.

Morphological analysis at the Karas site have identified plant distributions, such as *Canarieae* subtribes within the *Myrsinaceae* family and subtribes of *Embelia ribes Burn* (Figure 35) which were prevalent across ten out of fifteen spits excavated (Suroto et al., 2012). The *Burseraceae* family, known for its edible fruit tres among foraged species, is also notable in Oceania, including Papua (Lebot et al., 2008:120). This family consists approximately 700 plant species across 19 genera, encompassing both trees and shrubs (Al-Harassi et al., 2019: 10). In New Guinea, *Burseraceae* family from Canarieae subtribes, are abundant in lowland habitats below, highlighting their ecological significance in the region 1,000 m (Takeuchi, 2011).

***Figure 35**: Nuts findings from Karas site (Suroto et al., 2012), Balai Arkeologi Papua-Indonesia*

The Myrsinaceae family, found at the Karas archaeological site, holds significance in the Asia-Pacific region for its medicinal properties, utilized by local populations (Wiart, 2006:53). Its presence in archaeological contexts at Karas indicates its availability in the lowland rain forest environment around 3400 years ago, suggesting it played a role in ancient human life, potentially as a food source or for medicinal purposes. Plants within ecosystems serve various roles in food webs, with some parts consumed directly by fauna and others used by humans for nutrition. The presence

of these plant remains at Karas raises questions about their specific role in ancient diets-whether they were directly consumed by humans or indirectly through herbivorous fauna that humans subsequently consumed. Isotope analysis of collagen from individuals at Karas provides insights into their dietary habits. For instance, individual Krs/638 exhibited lower isotope values, indicating a diet primarily sourced from C3 plants and potentially mangrove shellfish. C3 plants typically occupy lower trophic levels in food webs as primary producers or self-feeders (Waugh, 2000). In contrast, from individual Krs/649 showed a broader range of isotope values, suggesting a diet derived from terrestrial herbivores, which occupy higher trophic levels compared to plant-based diets. This variability in isotopic signatures between individuals reflects the complexity of diet and resource utilization strategies among ancient populations at Karas, highlighting their adaptability and reliance on diverse ecological resources.

Figure 36*: Marsupial dental teeth findings were unearthed from the Karas site (Suroto et al., 2012), Balai Arkeologi Papua-Indonesia.*

The ecofacts data from this site confirm the diet preference of individuals Krs/649 based on flesh-adapted terrestrial animal herbivores. The distribution of faunal bones from the soil layer at 20cm to 190 cm depth was identified as the group of marsupial species that may have correlated with the past's human activities, e.g. as a diet source. Meat consumption will increase the value of human bone collagen. In an attempt to find out how these faunas are adapted as herbivores, etc., dental teeth have been identified to track feeding behavior. By morphological characters, faunal teeth reflect their uses in the mastication process, which can be used to view foods eaten by this faunal species. The fauna dental teeth discovered at this site are dominated by the lower jaw of marsupial species, with the formula: incisors (I) 1, premolars (P)/1, molar (M)/4. Regarding incisor (I), the morphology observed in these individuals shows chisel-like shapes suited for cutting vegetation. As characteristic of marsupials within the *diprotodontia* group, the incisor shape is

adapted for ground feeding, known as the procumbent shape, featuring two front teeth. Marsupial species found at this site exhibited one incisor on each side of the lower jaw, typical of diprodont marsupials. The premolar (P) teeth in all individuals have fully erupted, indicating adulthood. Morphologically, the premolars teeth are shaped like vertical flutes with serrated cutting edges. The lower molars display four sets of cuspids: paracone and protocone on the mesial side, metacone and hypocone on the distal side, with additional sharp points in the occlusal area. These molar characteristics, known as *lophodont* teeth, suggest adaptation to herbivorous diets, including various plant materials. The lack of isotopic data from ecofacts on this site has limited the understanding of the relationship between bone collagen and ecofact findings. Therefore, a stable isotope analysis needs to be performed on these ecofacts in the near future to understand the diet intake of the people from Karas in the past.

5.3.4.2.2 Isotope carbon and isotope oxygen in Enamel apatite

The carbon isotope produced from Krs/649 individual denoted a value the -12.3 ‰. This indicates that the type of diet consumed during childhood was a C4 diet. This evidence reflects the shift in diet from childhood to adulthood in this individual, with bone collagen showing a carbon isotope value of 25.60 ‰ indicates C3 plants. In contrast, the carbon isotope value from enamel apatite signified C4 plants. Considering that this site is surrounded by different ecological niches, from the river to the sea and canopy forest, the C4 plant's diet intake, as indicated by carbon isotope values, may suggest evidence of marine food consumption related to environmental characteristics. This assumption is also supported by the ecofact distributions, which present a high amount of terrestrial and aquatic remains. Additionally, the carbon isotope values from Vanuatu samples used for comparison, where reef fish and several marine fish present a range of values from -9.7 to -14.3 ‰ (Kinaston et al., 2014), align with the value obtained from the Karas sample. In the future, this assumption may need to be supported by stable isotope analysis of ecofacts found at this site to expand discussions about the stable isotope values between humans and ecofacts.

The oxygen isotope value from the upper second incisor of a Krs/649 individual is -5.6 ‰. Considering the process of mineralization of the human incisor, which is established between 10-12 months and completed at 3.3-5.9 years, the oxygen isotope values present in this tooth were obtained from mother’s milk. Since the tooth mineralized in early childhood, the oxygen isotope value was expected to be more positive than that of the third molar. This is because the breastfeeding process enriches the mother’s molar. This is because the breastfeeding process enriches the mother’s milk in oxygen isotopes by up to 0.7 to 2.69, one trophic level above the mother (Katzenberg, 2008: 430; White et al., 1998).

***Table 23**: Isotope enamel apatite of δ ^{13}C and $\delta^{18}O$ of samples from the Mamorikotey site*

No	Sample Name	Tooth	norm 13C	Stddev	norm 18O	Stddev
1	MMK/333	Lower Premolar	-13,1	0,2	-8,2	0,1
2	MMK/419	Lower Molar	-13,5	0,1	-6,9	0,1

5.3.4.3 Mamorikotey site (occupations 2520± 50 BP): Carbon and oxygen isotopes from enamel apatite

Two different teeth were found from different layers of box excavation at the Mamorikotey site and were analyzed for stable isotope enamel apatite, including the second premolar (MMK/333) and third molar (MMK/419) (Table 23). Based on the isotope carbon values, the range of values represented between -13.5 ‰ and -13.1 ‰ of carbon isotope, implying the C4 plants' diet intake throughout childhood. C4 plant types, as stated in earlier sections, refer to plants such as maize or corn, as well as a category of sources such as marine foods, which have positive stable carbon isotope ratios similar to C4 plants.

Given the ecological characteristics of the Mamorikotey site, which represent a coastal environment, the C4 signals arising from enamel apatite may establish evidence concerning marine food consumption. This evidence is supported by the ecofact distributions from this site, which are dominated by a variety of findings, including sea-fish from reef coral reef habitats, shells, and turtle bones associated with terrestrial animals such as pig bones, marsupials, and other unidentified animal bones. The isotope oxygen value from two teeth in this site was found to be more negative in the premolar -8.2 ‰ compared to the third molar (-6.9 ‰), which displays a slightly more positive value. This evidence may provide insights into the different types of water consumption from which the isotope oxygen was derived. Since the proportion of water obtained from breast milk in the premolar tooth is more enriched in isotope $\delta^{18}O$ than regular water, the amount of isotope oxygen in the early mineralized human tooth, such as premolar, is heavier than the third molar (Wright and Schwarcz 1998).

As described in the previous section, the mineralization process of the third molar occurred between age ranges of 7 and 12 years; consequently, the human mobility or geographic origins of an individual can be tracked using isotope oxygen resulting from enamel apatite from this tooth. As a result, the third molar of MMK/419 will be discussed in this section to better comprehend this individual's origin. The result of isotope oxygen of third-molar (LM3) from the Mamorikotey site (MMK/419 implied a value -6.9‰. Correspondent to the global distribution of isotope δ18Ooxygen provided by the IAEA, which ranges from -2 to -10 for the areas located in the Southern Hemisphere (Figure 37) including Papua, the range of isotope oxygen from the individual

MMK/419 matches this range. However, since the Mamorikotey site is located near shorelines at an altitude of 75 m asl, similar to the Srobu site at 85 m asl, the enamel apatite value from the third molar MMK/419 is expected to present the same value as Srb/413 which is -5.5 ‰, Therefore, this value may provide evidence that this person was not originally from this site. The isotope oxygen becomes more positive as altitude decreases, and vice versa.

The isotope ^{18}O value obtained from the enamel apatite in this study will be compared with the value resulting from previous studies from the same location to further understand the origin of the MMK/449. Permana et al. (2016) investigated the local value of isotope oxygen from waterfalls in the lowland-southern area of Papua, Indonesia, and this value may be utilized to identify the isotope oxygen from this site. The mean value of daily rainfall was found to fluctuate at different altitudes, and the value present was connected to seasonal variability. The isotope oxygen value by daily rainfall in altitudes 9 m asl to 67 m asl shows a mean value of -6.23 ‰, whereas altitudes 1900 m asl show -10.11‰ and at 3945m asl present -15.94 ‰. By monthly variability, the isotope $\delta^{18}O$ value of rainfall at altitudes 9m and 67 m asl display -6.8 and -8.3 ‰, while at altitudes 1900 m asl, the mean annual rainfall δ18O present the value -8.3 ‰ and -12 ‰. On this premise, the findings indicate that altitude effects have a substantial impact in the mean value of isotope oxygen from rainfall in this location. The mean value of oxygen isotopes at lower altitudes is more positive than the oxygen isotope at higher altitudes. The range of values observed at the various study sites was not influenced by the yearly precipitation amount but rather by the altitude effect linked with temperature fluctuations (Permana et al. 2016: 2235).

The variation in isotope oxygen values in Papua's area has been studied in detail, including research conducted by Permana (2016) and the GNIP-IAEA in the Jayapura region of Indonesia and Madang region of Papua New Guinea. Despite both regions being situated in the same Southern Hemisphere zone, the isotope oxygen values differ significantly. In Jayapura, the isotope oxygen value is recorded at -5.90±1.07, at an altitude of 140.72 m asl. In contrast, in Madang, Papua New Guinea, the value is -7.03±0.60 at similar altitude of 145 m asl. These differences in isotope oxygen values can be attributed to variations in altitude and temperature at the sites where he studies were performed, indicating that local environmental conditions play a critical role in influencing these values.

The oxygen isotope values in the third molar of the individual labeled MMK/419 suggest that this person may not have been local to the Mamorikotey site at the time of death. These values indicate that the individual likely spent their childhood in area with a higher altitude than Mamorikotey. As altitude increase, the isotope oxygen value in rainwater becomes more negative, whereas in lower altitude areas, the value is more positive (Gonfiantini et al., 2001). The Nabire

regency, where Mamorikotey is located, consists of three altitude zones: lowland (up to 600 m asl), the valley zone with an altitude 600-1500 m asl, and the highland zone, above 1500 m asl. Temperature decreases by 0.60 ºC for every 100 m asl increase in altitude, ranging from 20 ºC to 34 ºC (Nabirekab.go.id/portal/geografis). This suggest that the MMK/419 individual likely lived in the lowland zone, possibly between the coast and the valley, where the altitude and temperature differ from those at the Mamorikotey site. Another tooth, a premolar labeled (MMK/333, was found 10cm below the third molar MMK/419 in the same layer. Although it is unclear if both teeth belong to the same individual, the isotope oxygen value from the premolar is also worth discussing. Human premolars begin mineralization between 18-24 months (Table 13) during which time the isotope oxygen value is influenced by the mother's milk (Wright et al., 1998). This results in an enriched isotope oxygen value compared to water (White et al., 2000b; Wright and Schwarcz, 1999). Therefore, premolar isotope values can be higher than those of third molars by up to 2.69 ‰ (Gerling 2015:128; Katzenberg, 2008). However, the premolar MMK/333 showered a more negative value -8.2 ‰ compared to the third molar MMK/419 (-6.9 ‰) This discrepancy could be due to additional water or food intake during breastfeeding impacting the isotope oxygen value. To better understand the geographical origins and dietary behaviors of individuals from the Mamorikotey site, further analysis of stable carbon and oxygen isotopes from enamel apatite and ecofacts (faunas- plants) s necessary. This comprehensive approach will provide more accurate insights into the human history of the Mamorikotey site.

Figure 37*: Fish bones from Mamorikotey site*

5.3.4.4 Namatota Site (occupations 110±40 BP)

According to the result of isotope bone collagen analysis from the Namatota site, individual NMT/1-U presents the value of 11.56 ‰ from isotope nitrogen $\delta^{15}N$, while the result for isotope $\delta^{13}C$ exhibit the value -16.50 ‰. This suggests the consumption of marine food resources in the upper ranges of the food chain, such as medium to large sized fish. The bone collagen from individual NMT/2-F shows an isotope nitrogen value of 9.91 ‰, whereas the isotope $\delta^{13}C$ result presents a value of 19.95 ‰ implying a diet with slightly less fish and more terrestrial foods. The differences between the two specimens indicate slight variations in individual diets but a common reliance on fish.

Regarding the environment of the Namatota site, 70 % of the area is characterized by the rocky and mountainous slopes between 20º and 60º covered by lowland canopy forest where the C3 plants such as trees, thrive. The environment, presenting deep rain forest, is classified as a C3 plant area (Smith, 2005:674). Several species of trees and parts of tree, such as leaves, fruit and nuts, are edible for human and animal consumption. The site's surrounding area, along with the seashores and freshwater sources including rivers and lakes located in the northern part, provides habitats for aquatic food sources for humans, including fish and mollusks.

Since the isotope value ranges of fish appeared in the diet of NMT/1-U and NMT/2-F, the ratio of C4 from fish may have influenced the isotopes in their bone collagen. The preference for marine fish in the diets of NMT/1-U and NMT/2-F is also supported by marine fish carbon isotope values from a study at the Vanuatu site, which presented values ranging from -9.7 to -19.2 ‰ (Kinaston et al., 2014). In the future, this ecofacts from this site need to be analyzed for stable isotopes to provide evidence about the isotope values between human skeletal remains and those of animal and marine ecofact findings. The information from each finding is expected to complement each other, especially in understanding human behavior.

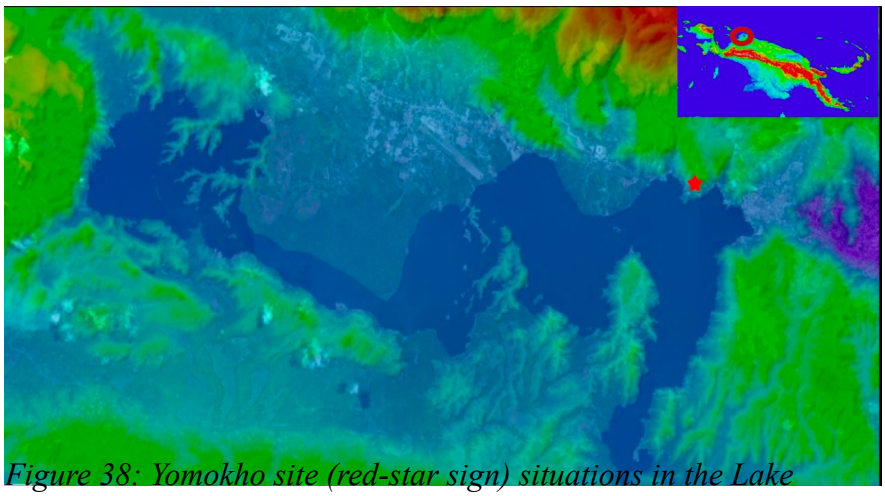


Figure 38: Yomokho site (red-star sign) situations in the Lake Sentani Jayapura, Papua-Indonesia

5.3.4.5 Yomokho Site (occupations 2590±120 BP)

Isotope bone collagen value from individuals YMK/1-R of $^{15}N/^{14}N$ value is 12.79 ‰, $\delta^{13}C/^{12}C$ value 20.45 ‰, whereas isotope result analysis from YMK/2-P 15N/14N value, is 12.86 ‰, isotope $\delta^{13}C/^{12}C$ presents 21.19 ‰. The range of values shown in the isotope result indicates the different nitrogen numbers were 0.027 higher in individuals YMK/2-P than YMK/1-R, while the isotope ^{13}C carbon value displayed a high value in individuals YMK/2-P than YMK/1-R, indicating 0.74 value differences between them. However, the different values resulting from isotope collagen between two individuals do not influence the range of isotopic values between them due to the small range of differences present in both of them.

The isotope nitrogen result from both individuals indicate evidence of consumption of diet including piscivorous-fish, while the carbon isotopes suggest that C3 plants were also eaten. Piscivorous fish primarily consume fish prey based on their morphology and feeding habits. These fish are commonly found in marine, estuarine, and freshwater habitats, varying in size from small to large (Juanes et al., 2002:267). However, the fragmentary fish bones found during excavation limit the reconstruction of their sizes. Nevertheless, morphological analysis of the fish bone fragments indicates that the fish inhabited freshwater habitats across several soil layers.

***Figure 39**: Sago trunk and its processing technique by the Sentani tribe in the Lake Sentani area*

The preference for fish as the main diet may be closely correlated with the availability of fish species in the habitat where these individuals lived, which significantly influenced the bone collagen values. At the Yomokho site near Lake Sentani (Figure 38), situated adjacent to the hills where the site is located, past inhabitants likely accessed the lake to procure fish for consumption.

The lake represents one of the largest freshwater habitats supporting various aquatic fauna species, including fish that were likely utilized as food sources in the past.

Carbohydrates derived from edible plants, classified into three types based on their structure- starch, sucrose, and cellulose (Murphy, 2011:66)- are the essential dietary components for human nutrition. Based on isotope carbon analysis of two individuals from this site, the evidence suggests consumption of C3 plants. This finding indicates a preference for carbohydrate sources derived from plants in their diet. Given the individuals were found in Papua's lowland environment, it is likely they utilized lowland edible plants to meet their carbohydrate needs. The absence of other plant such as seeds, nuts, or other remains during excavations suggests that the ecological context of the Yomokho site and its surrounding supports the hypothesis that these individuals consumed C3 plants in the past.

The coastal ecological zone of Papua, particularly where the Yomokho site is located, is dominated by swamp areas that supports the growth of C3 plant species, such as Metroxylon sagu (sago palm). Metroxylon sagu currently covers 1,406,469 ha of Papua's lowland region (Kertopermono, 1996). Sago palm is widely in the lowland tropical areas of Southeast Asia, including Papua and Oceania, and has long been recognized as a native plant in this region (Oliver, 1989: 95). Starch derived from Sago palm (Metroxylon sagu) has historically been a dietary staple for the indigenous lowland populations, particularly the tribes living in the Sentani area where the Yomokho site is located. Even today, sago palm remains a primary source of carbohydrates in their daily diet. Sag palm is classified as a C3 plant (Uchida et al. 1990), and its widespread growth in the lowlands of Papua suggests it was likely consumed by humans from this site in the past. This dietary practice may have persisted across generations up to the present time.

In addition to Sago palm, other carbohydrate sources in Papua are come from plant species classified as the C3 plants, including yams and sweet potatoes (Ipomea batatas) and *Alocasia taro*. However, these plants are predominantly cultivated in the valley regions of Papua and rarely found in the lowland swamp ecology, where the Yomokho site is located. Yams, sweet potatoes, and *Alocasia taro* require specific soil types and temperatures that are more suitable for the upland environments of Papua’s valleys. Currently, these three roots crops are primarily stables for indigenous highland populations in Papua, along with other plants like sugarcane, bananas, pandanus, and various edible grasses, fruits, and greens used as supplementary food sources. For future scientific discussions on the diet of people at the Yomokho site, stable isotope analysis of ecofacts from the site and human remains will be crucial. This analysis can provide insights into the dietary behaviors of the site’s inhabitants.

5.4 Teeth physical character and its relationship with the diet intake and food processing

This section provides insight into the health conditions resulting from eating disorders, oral health issues, and nutritional deficiencies, as evidenced by tooth wear and pathology. The primary role of human teeth is in the mastication process, which involves cutting, tearing, and chewing. These activities produce various physical features on the tooth crown, such as wear, caries, plaque, and fluorosis. The data reported in Chapter 4 will be reviewed in the following paragraphs to investigate the relationship between diet intake, as inferred from bone collagen and enamel apatite analysis, and the physical appearance of teeth in terms of wear and disease. Human meal intake, influenced by the physical and chemical makeup of food, contributes to tooth decay and wear. As mentioned in Chapter 4, food can cause wear, caries, plaque, and fluorosis on tooth surfaces, ranging from mild to severe. Dietary patterns vary in hardness and texture and contain chemical elements that cause wear and tooth pathology over time and with frequent consumption. According to the micro and macro analysis of human teeth in this study, wear was discovered on various aspects of the tooth surfaces, influenced by diet consumption. This wear pattern is categorized into wear (micro and microwear), fluorosis, caries, and calculus/plaque. The physical appearance of human teeth in this study could be related to food preparations. Information about the type of diet, obtained from bone collagen and enamel apatite analysis, will be used to examine to its relationship with the wear and pathology patterns observed in the human teeth. Artifacts discovered in association with human teeth, such as pottery, mortars and pestles, stone tools, and more, will be included in the discussions to provide a perspective on food preparations methods.

Human remains and related discoveries, such as ecofacts and artifacts, provide significant cultural evidence about the human past, allowing for the analysis of human behavior in terms of diet preference and characteristics associated with tooth pathology. For example, faunal bones from various terrestrial and marine species, as well as nuts and fruits, can offer insights into the food subsistence strategies of past populations.

Stable isotope analysis bone collagen and enamel apatite, was conducted on twelve samples (bones and teeth) from ten (10) individuals: three teeth from two individuals from the Karas site: Krs/649 and Krs/638, two bones from two individuals from the Yomokho site: Ymk/1-R and Ymk/2-P, two bones from two individuals from the Namatota site: Nmt/1-U and Nmt/2-F, two teeth from the Mamorikotey site: MMK/333 and MMK/419, two teeth and one bone from two individuals from the Srobu site: Srb/20 and Srb/413. The stable analysis results on these samples will be used as a reference to examine the relationship between diet sources and the physical characteristics exhibited through tooth wear and pathology in the human teeth in this study. Teeth in

the human body are designed for cutting and chewing the food, causing tooth wear and pathology (Lucas, 2004). The types, structures, and consistence of foods consumed by humans can generate wear, caries, and plaques, as discussed in the following sections.

5.4.1 Wear patterns

The term "tooth wear refers to the loss of dental hard tissues caused by the chemical and mechanical processes of everyday usage, such as food mastication (Ranjitkar et al., 2012:124). In the human teeth study, following the wear classification used by dentists, palaeoanthropologists, anthropologists four (4) types of wear were found in the human teeth from five sites in this study: abrasion, attrition, erosion, and fracture (chipping). These four wear classifications found in human teeth from the five sites will be explained in the following paragraph.

5.4.1.1 Wear in incisors, canines and premolars

Abrasion, erosion, attrition, and cracking were recognized as wear types from the five sites (Srobu, Mamorikotey, Karas, Namatota, and Yomokho). The analysis results showed that the teeth from the Karas site displayed a mild range of microwear, appearing as abrasion, attrition, and cracks, while the teeth from the Namatota site exhibited a light range of wear in the form of abrasions and cracks. All of the macrowear types observed in the four teeth are characterized by the loss of some of the crown tooth material; others show wear by flat enamel surfaces, likely created by tooth contact during the mastication process, demonstrating wear erosion. In premolar and molar teeth, wear defined by the loss of some enamel exposes the dentin tissue at the crown surface. Teeth impacted by abrasion on the crown surface of the front and posterior teeth display an irregular scooped form, apparently connected to the force of abrasive foods during the biting process. The relationship between abrasion and tooth fracture, caused by a strong bite force on hard foods during the mastication process, is supported by results an experiment conducted by paleoanthropologists to discover dietary information in Hominin diets. This study observed a cupped appearance in molar enamel edges (Constantino et al., 2013). These results provide evidence of tooth abrasion appearing in the tissues of the teeth, related to the frequency of consuming substantial food items.

***Figure 40**: Food processing tools from the lowland archaeological site. Mortars: upper-left and upper-middle. Hammer-stones: upper-right, lower-right. Stone tools: Middle-left and middle-middle; lower-left andlower-middle.*

Mechanically, anterior and posterior teeth have different functions in processing foods, which may generate wear in the human teeth. As the teeth are located at the front, the primary function of the anterior teeth (incisors and canines) is to cut and tear food, while the posterior teeth (premolars and molars) function to tear and grind food during the mastication process (Nelson & Ash, Jr., 2010: 75). In the six incisor teeth from Srobu (Srb/64/UI1, Srb/65/UI1, Srb/66/LI2, Srb/67/LI2, Srb/86/UI2, Srb/90/UI2) (Table 15), wear occurred in the incisal area, indicated by the loss of enamel and varying sizes of dentin tissue exposure in five teeth. One tooth (Srb/86/UI2) exhibited abrasion only in in the enamel area without dentin exposure. Additionally, a fracture indicated by craze lines was present in the middle incisal area, extending to the cervical third of the tooth. The incisor wear was characterized by fractures or cracks from the incisal to the cervical third of the enamel, with one incisor showing severe wear indicated by the loss of part of the crown from the incisal to the cervical third. At the Mamorikotey site, two incisors (MMK/78/UI1 and MMK/79/UI2) displayed intermixed wear in the form of attrition, abrasion, and cracks on the incisal edges. Similarly, at the Namatota site, two lower incisors (NMT/2/LI1 and NMT/2/LI2) exhibited the same type of wear (Table 17).

The canine teeth from the Srobu site (maxillary and mandible), fourteen in total eleven individuals, all show the same area of tooth abrasion, which is present from the cusp tip to the cusp slop of teeth. One of the canines has lost enamel from the cusp tip to the middle. The wear pattern found on these fourteen canines is signified by scooping at the cusp tip and cusp slope, likely

resulting from the mastication process. The cusp tip, being the sharpest area on canines, is used to cut and bite foreign substances, including food, while the cusp slope is affected by wear because it is close to the cusp tip and supports it during the food-cutting process. The pattern of attrition shown in the incisors from the three sites, including Srobu (Srb/64/UI1, Srb/65/UI1, Srb/66/LI2, Srb/67/LI2, Srb/86/UI2, Srb/90/UI2), Mamorikotey (MMK/78/UI1, MMK/79/UI2), and Namatota (NMT/2/LI1, NMT/2/LI2), presents parallel scratch marks pattern of attrition in the incisal area. The attrition pattern presumably appeared during the biting process of foreign substances, including food, and may also be related to the tooth contacts (maxillary and mandible) during the mastication process.

The emergence of wear in posterior teeth, characterized by the loss of enamel tissue from the crown, establishes a connection between attrition, abrasion, erosion, and cracking. Premolar and molar teeth (maxillary and mandibular) aid in the masticatory process by allowing food to be swallowed (Hanson & Mason, 2003:157). These teeth are responsible for crushing and grinding the food, which causes wear in many areas of the tooth enamel and dentin tissue, depending on the duration and frequency of their use. During the food chewing process, the occlusal surfaces of the molars require contact between maxillary and mandibular molars to break down food into small pieces. This process involves repeated contact between the upper and lower teeth, leading to the gradual loss of tooth tissue, known as attrition. The frequent contact at the occlusal area between maxillary and mandibular posterior teeth can create inter proximal wear, resulting in a flat and broad crown surface during mastication. The wear on tooth crowns may be caused by the abrasive texture of frequently consumed food, supported by salivary factor (White & Pharoah, 2014: 601).

In the premolar tooth from the Srobu site, the abrasion, signified by the chipping of the tooth enamel at the occlusal and buccal ridge cusps, is related to the formidable forces of objects or foods in the chewing process. According to previous study, tooth abrasion occurs in the tooth crown caused by foreign substances, leading to the loss of enamel and severe conditions of the tooth crown (White & Pharoah, 2014; Rantjitkar et al., 2012: 124). Tooth erosion was generally found at the Srobu site, whereas erosion in the two teeth from Mamorikotey was identified in MMK/332/LP and MMK/333/LP. Erosion occurred in both anterior and posterior teeth, ranging from minor to severe (Table 15). A moderate rate of erosion is indicated by the loss of enamel area over approximately 2/3 - ¾ of the tooth crown, while dentin exposure indicates a severe range of wear, with the enamel covering the dentin being lost from the tooth crown. In molar tooth, erosion is indicated by a flattened or corroded surface in the occlusal area. Tooth erosion may be related to eating disorders. Abrasive and acidic foods are known factors associated with tooth wear, as confirmed by researchers studying human tooth wear (Anderson, 1965; Smith, 1982; Turner & Machado, 1983;

Molnar, 1971). The cumulative effect of consuming abrasive, acidic, and fibrous foods has been identified as the primary agent causing on tooth crowns, especially in the teeth of hunter-gatherer populations.

5.4.1.2 Wear pattern in Molars tooth

The wear pattern observed in molar teeth from five archaeological sites offers valuable insights into the dietary habits and mastication processes of the populations. The physical evidence of wear on these teeth can be attributed to the composition of the diet and the mechanisms of food breakdown during chewing (Ulhaas, 2007: 370). Abrasive and fibrous food materials cause the molar teeth to wear down rapidly and flatter over time, which can ultimately result in tooth loss. Previous research has established that occlusal wear in the molar teeth of primates is primarily due to tooth-to-tooth contact (between lower and upper molars) during the chewing phase. This phenomenon has been well documented by various researchers (Butler, 1952; Mills, 1955; Crompton & Hiiemae, 1970; Gingerich, 1974; Kay & Hiiemae, 1974). These studies have led to development of thirteen labeling systems designed to interpret wear patterns on occlusal molars and the mechanical processes involved in mastication. These systems are utilized to examine and understand the wear patterns in human teeth, shedding light on the dietary practices and food processing techniques of ancient populations.

5.4.1.2.1 The Chewing Cycle in molar tooth

Wear in human molars appeared on the tooth surfaces during the mastication process. To break food into small particles, molars chewing involves two phases: the crushing and grinding phases, which involve contact between the upper and lower molars (Kay & Hiiemae, 1974). The masticatory cycle begins with Phase I, the shearing phase, where opposing molars come into contact and slide nearly parallel to the contact planes. It continues with the crushing phase, where the cusp of the upper and lower molars come into contact in a direction nearly perpendicular to the contact plane. This process primarily causes blunting of the cusps tips due to the abrasion from coarse food structures (Kay & Hiiemae, 1974). In Phase II of the chewing cycle, food is ground by contact between the lingual slopes of the molar cusps and and the buccal cusp surfaces of the upper molar. The wear facets on upper and lower molars are divided into thirteen parts using a numerical system 1–13, with descriptions: the buccal phase I facets are divided into four (1, 2, 3, 4), in the lower molars present on the slopes of *hypoconid* and *protoconid*. In upper molars formed along the slopes of *metacone* and *paracone*. The Lingual Phase I facets, divided into four (5, 6, 7, and 8), developed on the slopes of the *entoconid* and *hypoconulid* in the lower molars, while in the upper molars, the Lingual Phase I is located on the slopes of the *hypocone* and *protocone*. The Phase II facets (9, 10,

11, 12, 13) are placed at the lingual slope of the *hypoconulid* and *protoconid* in the lower molars, whereas in the upper molars, they are present in the *hypocone* and *protocone* areas.

Following the method descriptions of wear on molar teeth made by Kay & Hiiemae (1974) and Maier & Schneck (1981), twenty molar teeth (upper and lower) from the five sites (Srobu, Mamorikotey, Namatota, Karas, and Yomokho) in this study were examined to determine whether the wear was established in buccal phase I, lingual phase I, or phase II. As described in Chapter 3 wear in human teeth consists of three patterns: attrition, abrasion, and erosion, all of which generate the loss of tooth surfaces, enamel, dentin, and other tissue of the tooth (Hillson, 2003). The descriptions of wear present on the occlusal surfaces of lower and upper molars in buccal phase I, lingual phase I, and phase II from the four sites are outlined in the following paragraph.

At the Srobu site, seven lower molars were examined. Six of them were affected by wear in all areas of buccal phase 1, indicated by the loss of enamel surface. One tooth (636/LM2) showed wear in only one feature of the buccal phase but was otherwise in good condition. Four lower molars from Srobu were fully affected by wear in buccal phase 1, lingual phase 1, and phase 2. Except for the Srb/636/LM2, all areas of wear in the buccal phase area, lingual phase 1, and phase 2 of the seven lower molars from Srobu were impacted by wear in all chewing spots. In the upper molars, two teeth (Srb/489/ULMI and Srb/ABC/UM1) displayed mild abrasion in two areas in buccal phase 1, at numbers 1, 2, and 4.

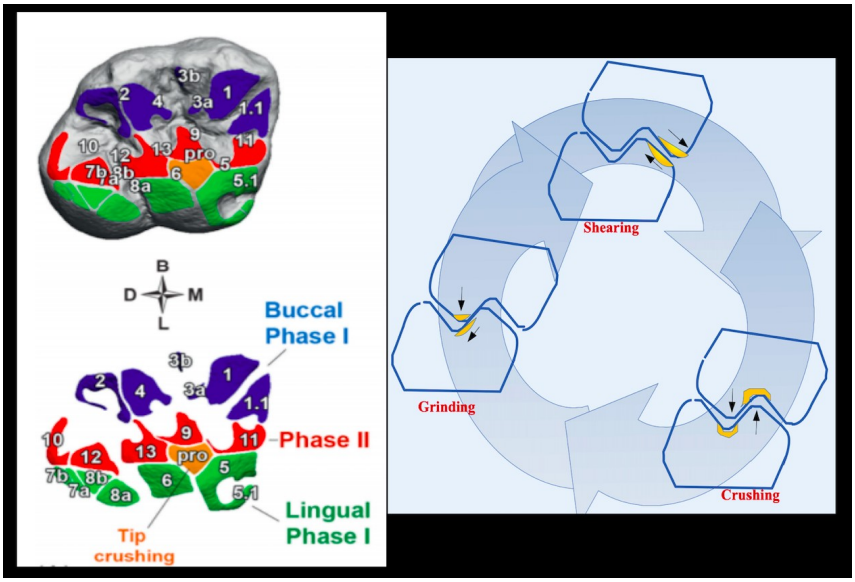


***Figure 41**: The occlusal pattern of wear of the first maxillary molars of Neanderthals. In the left is the 3D polygonal tooth-made and almost detached facets of wear classified into buccal phase I facets (blue), lingual phase I facets (green), phase II facets (red), and the tip crushing regions (orange) The right figure is the chewing process of foods in the molar tooth; it was labeled following the numbering systems developed by Maier & Schneck (1981)and Kay & Hiiemae (1974). Figure source: DOI: 10.1371/journal.pone.0014769.g001.*

The median, standard deviation, and interquartile range (IQR) of the wear analysis data from the five sites were calculated to determine the average value of wear distributions in Buccal Phase I, Lingual Phase I, and Phase II. Based on these results, the Srobu wear in the molar teeth occurred in all three areas of the chewing cycles. The wear is dominated by erosion, as evidenced by the loss of all enamel components, and the exposure of dentin on the cusp's surface. The descriptions of the two upper molars from Srobu identified abrasion in some parts of the area of buccal phase I, while other parts are still in good condition. In lingual phases I and II, erosion was exposed in both upper and lower molars.

The erosion and abrasion on the molar teeth from the five sites were discovered to be a result of mechanical destruction and food particles leading to the loss of tooth tissues. Tooth erosion was present at the occlusal area of the molar teeth, in buccal phase I, lingual phase I, and phase II, from the teeth in five archaeological sites in this study. Molar tooth abrasion from the five sites is generally established at the marginal ridge and cusp tip of the upper and lower molars, while erosion occurs in the occlusal area, with some instances associated with abrasion characterized by the loss of enamel and dentin. The abrasion may occur due to the bite force and hyper-function of this marginal ridge and cusp tips during the mastication process. The abrasion at the marginal ridge

and cusp tip in buccal phase 1, phase 2, and the lingual phase 1 in the molar teeth from the five sites provides information about the consumption of abrasive foods processed at these locations. Two different patterns of abrasion were found on the teeth in this study: firstly, flat, polished, regular biting surfaces established in the mesial and distal marginal ridges at phase 2. Secondly, an irregular pattern present in the form of scarce surfaces of enamel in buccal phase 1 at the mesiobuccal and distobuccal areas.

***Table 24**: Descriptive statistics of wear facet areas of molar teeth from the five sites based on the chewing cycle phases described by (Kay & Hiiemae, 1974; Maier and Schneck 1981). Srb: Srobu, MMK: Mamorikotey, NMT: Namatota, Krs: Karas, YMK: Yomokho.*

Site	N	Buccal Phase 1			Lingual Phase 1			Phase 2		
		Median	SD	IRQ	Median	SD	IRQ	Median	SD	IRQ
SRB	13	0.33333	0.05615	0	0.33333	0.08761	0.01083	0.33333	0.07457	0
MMK	2	0.70588	0.41595	0.29412	0.08824	0.12478	0.08824	0.20588	0.29116	0.20588
NMT	2	0.40047	0.00259	0.00183	0.26248	0.20865	0.14754	0.33705	0.20606	0.14571
KRS	1	0.3271	0	0	0.28037	0	0	0.39252	0	0
YMK	2	0.26282	0.09972	0.07051	0.45513	0.17224	0.12179	0.28205	0.07252	0.05128

Tooth erosion is a significant aspect of dental wear, particularly in the context of mastication processes. Buccal phases I and II are essential in the initial stages of mastication, where the repeated biting of hard foods or objects leads to the flattening and wearing down of tooth surfaces. This continuous contact between the upper and lower teeth results in abrasion, especially in the occlusal areas. Erosion affects all chewing areas during buccal phase I, lingual phase I, and phase II, and characterized by eroded occlusal surfaces where the enamel is worn away, exposing the dentin on the cups surfaces of molar teeth. This process, described as a non-carious loss of tooth tissue, can occur in both humans and animals (Whelton, 2009: 500). The causes of tooth erosion are multifaceted, involving chemical and physical processes. The consumption of acidic foods plays a significant role, as the acids contribute to the dissolution of enamel and dentin. This is further exacerbated by behavioral factors such as dietary habits and oral hygiene practices. Erosion in human teeth are caused by acidic food consumption involving chemical and physical processes alongside behavioral factors (Larsen & Nvad 1999; Zero & Lussi 2005; 2006). In the molar teeth from the five sites, tooth erosion was observed primarily in the occlusal area during phase I, lingual phase I, and phase II. This pattern of erosion highlights the impact of dietary and behavioral factors on dental wear and emphasizes the importance of understanding these processes in both archaeological and contemporary contexts.

5.4.1.2.1.1 The chewing facet in molar tooth and its relationship with the diet type

The type of food consumed by humans significantly influences the macro and microwear observed on teeth. Foods vary in texture, structure, hardness, which can lead to different patterns of dental wear. Abrasive of coarse foods, commonly consumed by prehistoric humans, are well-documented as factors contributing to substantial tooth wear. This has been supported by various studies, including those by Hrdlicka (Hrdlicka, 1945; Ungar and Spencer, 1999; Schmidt, 2001; Scott et al., 2005; Teaford, 1991; Teaford et al., 2001). In the pre-agricultural populations, diets primarily comprised of foods obtained through hunting and foraging wild plants and animals. These diets included hard, fibrous, and abrasive materials, which resulted in severe dental wear. The consistent chewing of such tough and coarse foods caused significant tooth abrasion, as these foods required extensive processing by the teeth. In contrast, agricultural populations experienced less dental wear due tot he consumption of softer, less abrasive foods. The advent of agriculture introduced more processed foods into human diets, which reduced the need for extensive chewing. This shift to softer, more processed foods led to a decrease in the severity of tooth wear compared to pre-agricultural diets. Studies by Bullington (1991) and Larsen (1995) highlight this difference, indicating that food processing methods significantly influenced dental wear patterns in agricultural societies.

The wear on the teeth of hunter-gatherer populations from the Levant site were found to be flatter compared to the cupped or scooped forms of wear observed in agriculturalists (Eshed et al., 2006). The distinction in wear patterns is closely related to the types of foods consumed by these populations. Hunter-gatherers typically consumed harder, more abrasive foods, resulting in flatter wear surfaces. In contrast, agriculturalists diet included softer, processed foods, leading to more pronounced cupped or scooped wear patterns. The relationship between wear patterns in the chewing area and the factors causing this wear, particularly food types, can be determined using data from stable isotopes, ecofacts, and artifacts. These correlations can be visualized using ternary plots, which help illustrate the links between different wear facets and diet types. In this study, JMP Pro 15 software was used to create these plots (Figure 42), providing a statistical comparison that includes descriptions of median, standard deviation, and interquartile range (IQR) results. At the Srobu site, the bone collagen values indicated a mixed diet comprising both marine and terrestrial foods, as supported by ecofact distributions from the site. The analysis revealed that 97% of the wear was in the form of erosion, distributed in all chewing areas, including buccal phase I, lingual phase I, and Phase II. In contrast, only about 3% wear was in the form of abrasion, which was present in small areas within these chewing phases.

The molar teeth from various archaeological sites provide valuable insights into the dietary habits of the populations that inhabited these regions. At the Namatota site, abrasion in molar teeth is associated with erosion, observed in buccal phases I and II, while lingual phase I displays no wear. The bone collagen isotope analysis indicates that the individuals' diet primarily consisted of aquatic foods (marine and freshwater) and terrestrial-meat. At the Karas site, wear in the form of abrasion was found in the molar teeth specifically in the metacone area of buccal phase I, with no wear observed in the lingual phase I or Phase II. The isotope bone collagen results suggest that the diet at this site was based on terrestrial meat and terrestrial plant foods. At the Yomokho site, molar teeth exhibited significant wear, including the loss of half of the tooth crown from enamel to dentin, affecting buccal phase I, lingual phase I, and phase II. At the Mamorikotey site, abrasion was present in the lingual phase I, specifically in the entoconid area, while the buccal phase areas, I and Phase II showed no wear. The carbon isotope values from enamel apatite suggest a diet based on marine and terrestrial foods.

The limited number of molar teeth evaluated in this study from the Yomokho, Karas, Mamorikotey, and Namatota sites poses challenges in identifying significant trends in the relationship between chewing phases and diet intake. Despite this, the stable isotope results and ecofact distributions provide valuable insights into the dietary practices of the people from these sites.

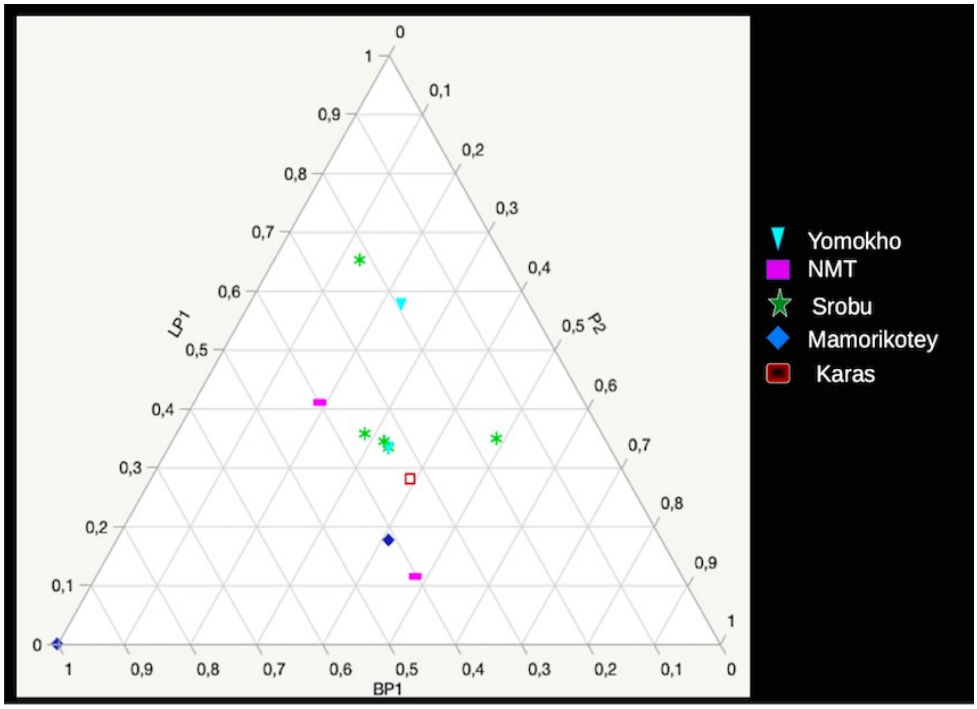


***Figure 42**: The ternary plot diagram presence the ratios of wear in the Buccal Phase 1, Lingual Phase 1, and Phase 2 of 20 molars teeth from the five sites (mamorikotey, namatota, yomokho, srobu, and karas). It is shown that the wear is distributed in all the area of the cycle phases*

5.4.1.3 Erosion and abrasion in the anterior and posterior teeth

The macro-wear analysis identified three different forms of wear affecting the loss of tooth tissue: abrasion and erosion (Tables 15,16,17,18, and 19). These wear types primarily impact the enamel, dentin, and cementum of human teeth and are not related to bacterial activity but rather to eating behavior disorders (Moynihan 2011: 492). In human teeth, the entire crown of the anterior (incisors and canines) and posterior (premolars and molars) teeth is covered by enamel as the outermost tissue. Beneath the enamel are the inner tissues: dentin, cementum, and pulp. Enamel is formed by ameloblast cells and is made up of 96% inorganic crystals, making it the hardest substance in the human body (Schoenwolf et al., 2015:466), while dentin, covered by enamel, contains 70% minerals and is the second hardest tissues after enamel (Ungar 2017:26).

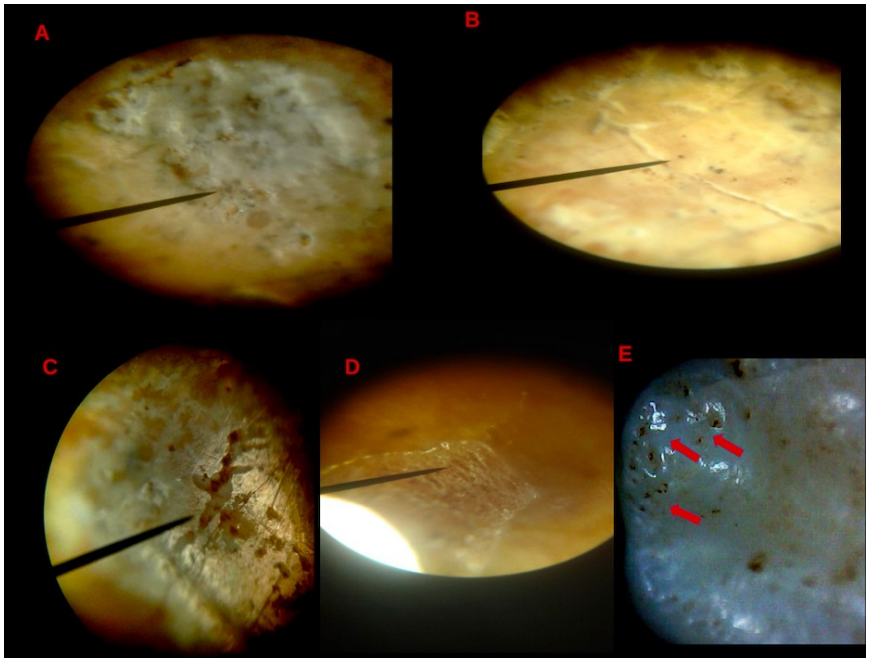


***Figure 43**: The microwear pattern in this study. A and b: the pattern of the line probably causes by the sharp object during mastication process; C, D, E, and F: pitting form of microwear.*

The enamel and dentin tissues' level of hardness may protect the tooth from abrasion, attrition, and erosion during the mastication process. However, the wear pattern in the teeth of the humans in this study presents the scarce, flat, and cupped macro and microwear incisors, canines, premolars, and molars (Figures 43, 44, 45, 46). The loss of enamel and dentin tissue in the human teeth in this study may suggest that these people consumed abrasive foods in the past that were

harder in texture than the enamel tissue. According to the results of bone collagen isotope and enamel apatite analyses from twelve samples from the five study locations, humans' nutritional consumption was dependent on coastal-terrestrial foraging activities, as supported by ecofact distributions. Thus, this evidence may provide insight into the tooth abrasion found in all teeth (incisors, canines, premolars, and molars) that appears to correspond to the diet derived from these activities.

There are three different patterns displayed in response to the microwear present in the canine tooth from the five sites: scratches and pitting. The abrasive texture of substances such as foods that generates wear in a different form in the cusp tip and ridge of canines (Peters, 1982; Puech, 1986a; Teaford and Lytle, 1996; Gugel et al., 2001). The pitting and scratching wear patterns in human canines indicate food consumption that may derive from the categories with higher grit and silica content, such as nuts and woody plants, as shown by the wear pattern in herbivorous animals' teeth (Walker et al., 1978; DeSantis, 2016).

According to the microwear observed in the teeth from the Karas site, the pattern shows pits and scratches on the canine teeth. The isotope bone collagen values from two individuals from two individuals from this site suggest a diet consisting of both plant-based on herbivorous animal meat, which may support the pitted and scratched appearance. The combination of plant and meat consumption, comprising two different abrasive food types, leads to the observed microwear pattern. The variety of food categories inferred to have been obtained through foraging activities includes abrasive wild foods that likely contributed to tooth abrasion in these individuals in the past. These categories encompass marsupials, pigs, and various plants. Wild animal meat, particularly from adult animals, tends to be less tender than meat from domesticated animals under cultural care (Peltenburg & Wasse, 2004; Hoffman & McMillin, 2009: 455).

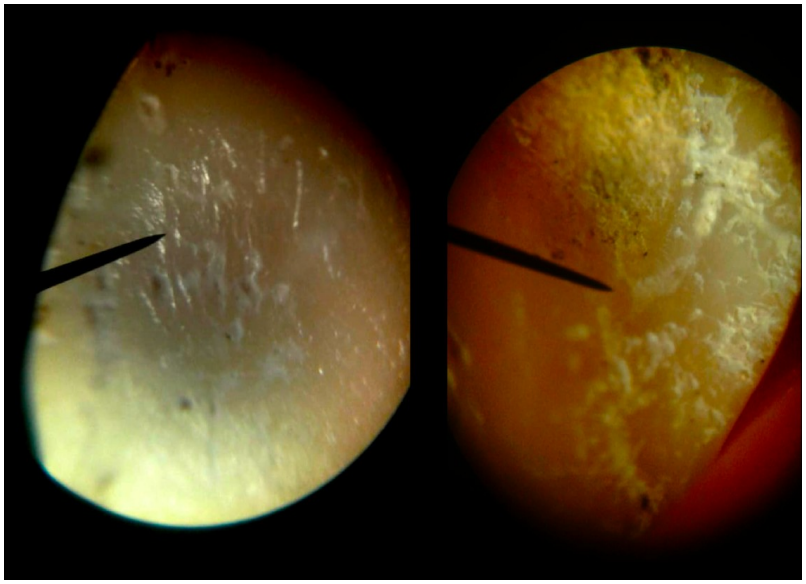


Figure 44*: Microwear pattern in molar teeth from Srobu site*

The hardness of wild meat is influenced by several factors, including the animal's habitat, age at the time of hunting, techniques used for catching or processing the animal, and other factors that affect the meat's structure making it less tender compared to domesticated animals. In studies of the Eskimo population, who consume large quantities of meat regularly, it has been observed that there is minimal wear, particularly in the incisal area of the incisor, where meat is first cut for chewing (Hrdlicka, 1945). This indicates that the impact of meat consumption on tooth wear can vary among different populations. Meat consumption can lead to both macro-and micro-wear in human teeth due to the tough components of meat, such as animal skin or bones, which are sometimes intentionally consumed or inadvertently included in people's diets. Anthropological data from various indigenous populations in Indonesia today show that various parts of animals are consumed, not just the meat, including skin, bones, and other abrasive parts. All these components of an animal's anatomy can contribute to the development of macro-or micro-wear on teeth over time.

The ecofacts findings at sites like Srobu and Yomokho, which indicate a diet rich in aquatic-based foods such as fish and mollusks, suggest that these foods may have contributed to the micro and macro wear observed on teeth from these sites. Humans typically consume the meat or inner layers of mollusk shells. However, when people lack the tools or knowledge to open the hard outer surfaces of mollusk shells, they may use their teeth, a practice observed among several indigenous coastal populations in Papua. This habitual use of teeth as tools can lead to wear patterns on dental enamel. Evidence of microwear caused by seafood consumption has been found in the dental enamel of prehistoric humans, including the Rapa Nui population (Polet, 2011). The outermost

layer of mollusk shells is composed of long crystals of prismatic calcite (Simkiss, 2016), which is relatively hard with tensile strength of 60 Mpa tension, compressive strength 250 Mpa, bending strength of 140 Mpa, and hardness of160 kg mm2 (Currey, 1988). Using teeth as a tools to open mollusk shells can result in macro-or micro-wear related to the surface structure of these shells.

Plants obtained through foraging activities, such as fruit, nuts, and leaves, often have an abrasive structure that could contribute to the microwear observed on human teeth from the five sites. Particles of silica deposited in plants, known as phytoliths, are particularly implicated in creating microwear patterns. This phenomenon has been observed in prehistoric populations, including those from the Lower Pecos region of Texas. The calcium oxalate within phytoliths is believed to be responsible for this microwear on enamel teeth, evidenced by similarities between scratches on enamel teeth and the shape of crystal points and edges found in calcium oxalate phytoliths (Danielson & Reinhard, 1998: 301).

Phytolith, composed primarily of silicon dioxide are exceptionally hard and durable compared to enamel tooth tissue. The silicon dioxide of phytoliths is extremely hard and more durable than enamel tooth tissue, which, by its consumption, will provoke microwear in human teeth. The phytoliths were also found to have generated the microwear in sheep's teeth that consumed plants high in phytolith content. This phenomenon has been observed in various species, including sheep, where consumption of plants high in phytolith content has been linked to microwear on teeth (Baker et al., 1959:163). Similarly, primates have shown microwear patterns on their teeth attributable to the consumption of dietary items, including small objects like phytolith, ranging in size from 5–50 μm (Lucas et al., 2000: 2014). Given that the diet of people from the five sites was based on foraging activities, the regular consumption of plants containing phytoliths likely formed a routine part of their diet. Herbaceous plants, known for their higher phytolith content, could have significantly contributed to the observed microwear patterns in these ancient populations' teeth.

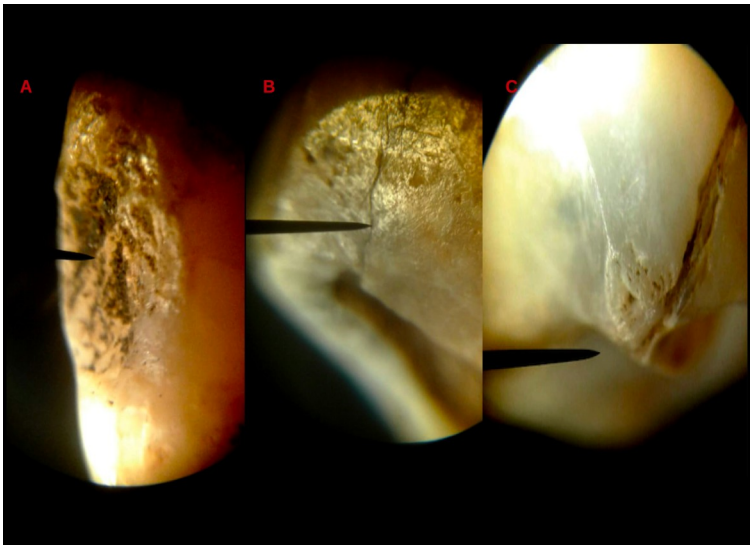


***Figure 45**: Microwear in Mamorikotey Site, A: MMK 79, UI2, B: MMK/49/UC, C: MMK/405/LP1*

The second wear pattern observed in this study is erosion, which involves the loss of hard toot tissues due to various factors including chemical dissolution (from acidic drinks and foods), biological factors (such as saliva), and eating behaviors (Lussi, 2006: 6). At the Srobu site, erosion is evident by the gradual loss of tooth structure at the occlusal area, particularly severe in the molars where the flat teeth surfaces show exposed dentin. This severe erosion pattern is also observed in two premolar teeth from different individuals at this site. Tooth erosion is a chemical process where minerals dissolve due to the complexation of calcium by ions, prolonged exposures to hydrogen ions, and especially strong chelating agents like citric acid (Featerstone and Lussi, 2006: 70). This process can be exacerbated by gastric acid regurgitated into the mouth, particularly with frequent consumption of acidic foods, leading to the development of tooth erosion over time (Bartlett, 2006:120). Based on the isotope bone collagen results from the Srobu site, the diet primarily consisted of marine fish and meat consumption, indicating a potential dietary contribution to the erosion observed in the teeth from this site.

Meat contains fatty acids that are reflected in the tissue composition (Crawford et al., 1984: 473; Fife, 2011: 63). Marine foods like fish also contain various fatty acids, which vary significantly between species (Tasbozan & Gokce, 2017: 145). These fats have different compositions of fatty acids, each with distinct effects on the human body, which can be modified by biological processes, particularly during digestion and metabolism (Christophe, 2003: 59). The ingestion of fats and their subsequent metabolic process can have several impacts on the body. For example, reflux issues can lead to the regurgitation of acidic substances, which can contribute to erosion in human teeth (Bartlett, 2006: 126). This underscores the complex interplay between diet, metabolic process, and dental health.

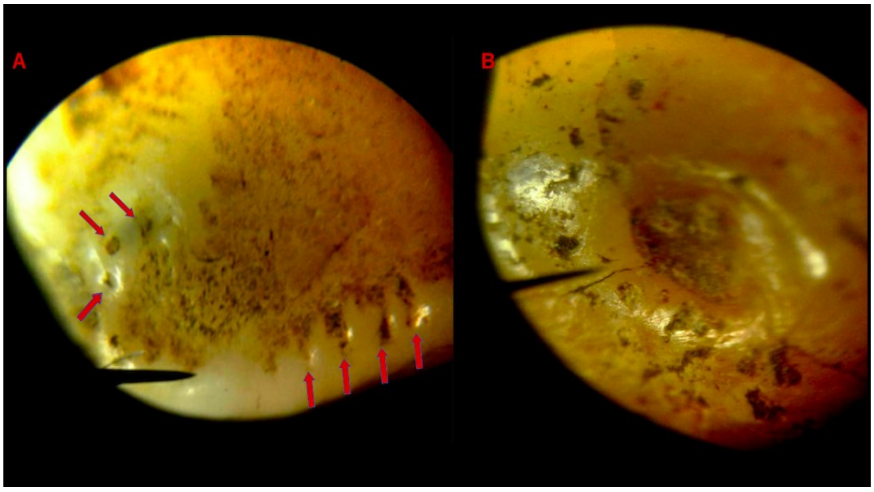


***Figure 46**: Karas Site Microwear, A: Krs/41/LC, B: Krs/649/UC*

Based on the table isotope analysis in the individuals from the Srobu site, diet primarily consisted of marine fish and meat (Crawford et al., 1984: 473; Fife, 2011: 63). Meat contains fatty acids that are reflected in tissue composition, and marine foods, such as fish, also contribute varying fatty acid profiles depending on the species (Tasbozan & Gokce, 2017: 145). These fatty acids have diverse composition with distinct effects on the human body, influenced by biological processes during ingestion and metabolism (Christophe, 2003: 59). The consumption of fats and their metabolic processing can have several impacts. For instance, reflux issues can lead to the regurgitation of acidic substance, which can contribute to tooth erosion, such as fruits or vegetables, especially in high frequency and quantity, can also promote enamel and dentin tissue loss due to their chemical and physical properties (Moynihan, 2011: 492; Zero et al., 2008: 346). These foods, collected from foraging activities like hunting and gathering in forests, were likely part of the diet of individuals from the Srobu site.

Characterized by tropical climates, the rainforest type in Papua host variety edible plants, including fruits and vegetables, regularly consumed by ancient inhabitants. These dietary habits likely contributed to tooth erosion observed in individuals from these sites. To enhance food processing efficiency and quantity, ancient humans developed various tools, such as mortars and pestles, stone tools, and pottery, primarily used in food preparation and processing. Research has shown that food preparation methods involving mortars and pestles can contribute to dental wear, caries, and plaque formation in prehistoric human teeth (Bodley, 2011: 170). Microwear patterns observed in human teeth can be linked to these food processing techniques employed by ancient populations people (Pastor, 1993; Teaford and Lytle, 1996). Artifacts like pestles, mortars, and stone tools found at the he five sites provide archaeological evidence of their use in food processing, potentially contributing tot he observed wear patterns in teeth. Abrasive grit particles such as those

from stones used in mortars and pestles could inadvertently enter food and cause microwear, such as pits and scratches, on dental enamel surfaces. The macro- and micro-wear patterns observes on anterior and posterior teeth indicate the range of tasks these teeth performed and the variety of food textures consumed, which likely influenced wear pattern. Mortars and pestles, typically made from stone, were crucial tools for grinding and crushing food. However, these tools can be accidentally introduced abrasive particles into food, leading to wear on tooth surfaces during chewing. The wear patterns observed in human teeth from this study reflect the diversity of food-processing methods and dietary practices associated with terrestrial and coastal foraging activities. The microwear patterns in human teeth may be related to food-processing methods (Pastor, 1993; Teaford and Lytle, 1996). Related to the wear present in molar teeth, the pattern established the sign of sharp crests of food type when chewing or grinding in this occlusal area, signified through the pitting patterns that cause the enamel and dentin tissues to move away from the occlusal area. Scratches and pits indicate microwear on the surfaces of the occlusal area. The combination of terrestrial and coastal foraging activities among populations from the five sites likely contributed to a wide range of dental wear patterns, dominated by fractures in areas such as cusp tips, marginal ridges, and occlusal surfaces. The diverse food sources obtained through these activities influenced the variety of wear observed in individuals' teeth from these sites.

5.4.2 Caries

Food containing cariogenic substances, which have high levels of sugars and carbohydrates, promotes the development of dental caries or tooth decay. Analysis of caries in 30 teeth from the Srobu site revealed that 24 teeth were affected by caries, with stages ranging from one to two (Table 14). These results indicate the presence of early to mid-stage caries in the individual from Srobu. This pattern suggests that the diet of these ancient people included cariogenic foods, contributing to the dental caries observed in teeth.

The lesions occurring on the surface of incisors, canines, premolars, and molar teeth from the Srobu and Mamorikotey sites are predominantly at stage 1, characterized by tiny brown and black spots in the affected areas. In contrast, the teeth from the Yomokho site show more severe caries, especially in the molar tissues, where caries are exposed to the pulp area. By location of caries varies: in the anterior teeth (incisors and canines), lesions are found in the incisal area, while in the premolars and molars, they are located in the fissures and grooves of the occlusal area. This pattern of lesions, established at the contact points of the anterior teeth and the occlusal area of the posterior teeth, is generally associated with wear. This association suggest that once wear is present in the enamel area, lesions quickly progress in those worn areas.

Caries in human teeth result from the interaction of several components, including pH, saliva flow rate, and the consumption of cariogenic carbohydrates such as sugars and starches, as well as other intrinsic and extrinsic factors (Tayles et al., 2009: 163). Researches have considered caries a multifactorial disease that began to affect human teeth since the advent of agriculture. According to studies, the prevalence of tooth caries varied among prehistoric societies, with differences observed between hunter-gatherers, fisher-gardeners (mixed diet), and farmers due to their subsistence patterns (Tayles et al., 2009). In a study by Turner (1979), the farmer group, consisting of 19 groups, showed the highest caries frequency, ranging from 2.2-26.9%. The mixed diet group, comprising five groups, presented caries frequencies ranging from 0.4-10.3. Meanwhile, the hunter-gatherer group, which included six groups, had the lowest caries frequency, ranging from 0-5.3%. These differences underscore the impact of diet on caries development. Caries are promoted by the consumption of carbohydrates, such as refined sugar and starchy foods like tubers and maize, which are known indicators of caries prevalence. Foods rich in sugars and starches were found to be mildly to highly cariogenic, and their frequency and rate of consumption significantly contributed to the development of caries in human teeth.

Since starches and sugar are synthesized in plants (Woods & Swinton, 1995: 250), severe caries on the teeth from Yomokho may been caused by the consumption of plant-derived carbohydrates. Carbohydrates are present in all parts of plants, including sweet fruits, sugar cane, sugar beets, etc. (Sequin, 2012: 49). The isotope bone collagen value indicate that the C3 plants were part of diet at Yomokho, suggesting that sago plants contributed significantly to carbohydrate intake. The inference extends to the Srobu site, located about 10 km from Yomokho. By nutrition, the carbohydrate content in the dry sago is approximately. 95%, which is higher than the red rice at 95% and maize at 64% (Soejono, 1979: 38). The high carbohydrate content of sago likely contributed to carious lesions in human teeth, especially considering its preparation and cooking processes, which may have included mixing with other food types.

Based on the study of the populations in Papua New Guinea, caries prevalence ranges from low to high, influenced by sago consumption (Schamschula et al., 1978). Sago consumption may also have caused caries in individuals from the Yomokho site, especially when considering that sago processing results in a gelatinized form. Starch in food becomes particularly cariogenic when gelatinized form. Starch in food becomes particularly cariogenic when gelatinized due to high temperatures of cooking, making it more susceptible to enzymatic breakage through saliva, producing highly cariogenic molecules (Grenby, 1997; Lingstrom et al., 2000). At the Srobu and Mamorikotey sites, the mild stage of caries may be attributed to people's mixed diet consumption. A varied diet can provide essential vitamins that may not be obtainable from a single food source.

While some foods may be cariogenic, others may be less cariogenic but rich in vitamins A, B, and C, which are crucial for preventing tooth decay and reinforcing the gums and other tissues in the mouth.

Compared to the Yomokho, Mamorikotey, and Srobu sites, the teeth from Karas and Namatota sites teeth show no evidence of caries. This low prevalence of dental caries likely signifies a lower consumption of sugar and starchy foods. Coastal-terrestrial foragers in these regions may have consumed foods with low cariogenic potential, such as glucose, which is primarily derived from farming activities involving C4 plants like rice, yams, sugar cane, sugar beets, taro, sweet potatoes, and maize. The bone collagen isotope values indicate the presence of C3 plants in the diet, suggesting that C4 plants, which are typically associated with higher levels of cariogenic carbohydrates, were not a significant part of the diet in Papua's lowland areas. The lowland regions of Papua, characterized by shorelines and dense rainforests, are not well-suited for farming due to their solid and ecosystem types. Consequently, farming activities that yield high quantities of sugar and carbohydrates from cariogenic plants may have been difficult to undertaken in this area.

The diet based on terrestrial-coastal foraging activities, generally consisting of fibrous and tough foods such as meat and wild plants, likely contributed to the limited appearance of caries in the human teeth studied. These diet types promote a more alkaline oral environment due to high levels of saliva production, which can lower the rates of caries in human teeth (Prowse et al., 2008; Rohnbogner & Lewis, 2016). This correlation between diet and caries rates is reflected in the range of caries observed in the human teeth from the sites in this study.

5.4.2.1 Wear and caries in the Late Holocene group

For many years, dental macro and microwear have been utilized to analyze prehistoric diets. Teeth interact directly with foodstuffs, and both the physical and chemical composition of food have a direct impact on dental microwear and decay. Prehistoric humans exhibit pronounced dental microwear after accidentally incorporating substantial amounts of grit into their diet during meal preparation by pounding and grinding food between stones. The wear on the tooth crown observed in this study was attributed to the abrasive, acidic, and fibrous foods consumed by the hunter-gatherer group. Mechanical destruction and food particles caused the erosion and abrasion on the molar teeth at the five sites, leading to the loss of tooth tissues. The research showed moderately worn teeth observed on the Late Holocene teeth in this study, demonstrating a hard-food consumption that likely included terrestrial foods such as meat. This is supported by the ecofact

distribution, including pigs, marsupials, marine fish bones, and other remains. Hard-diet foragers have extremely high levels of complexity in their dental wear, with abraded enamel surfaces and many pits, similar to the teeth in this study. The Late Holocene group, identified through metric dental studies, was classified among Austronesian speakers. Since their arrival in the lowland parts of Papua, Austronesian speakers may have adopted hunter-gatherers skills from the earlier Papuan speakers or developed these skills independently as part of their adaptation to the lowlands. The dietary hardness and wear patterns observed in this study are consistent with a forager's wide-ranging diet. The microwear parameters of teeth from the Srobu site are related to a combination of factors, including hard food consumption, such as meet ingestion, and the potential use of teeth as tools for various activities. It is important to note that these factors are complementary. Meat consumption, along with several hard food substances, are the major dietary components explaining the macro and macrowear observed. The archaeological record at Late Holocene sites indicates small to medium-sized animal hunting and gathering of coastal and terrestrial animals. The results indicated that the Late Holocene people in this study show values of complexity consistent with foragers, confirming the initial hypothesis. The pronounced microwear patterns suggest a diet that included significant amounts of hard and abrasive foods, leading to the observed dental wear and erosion.

The mild stage of caries in the Late Holocene population is indicative of a diet that promoted minimal carious lesions. This diet correlates with the general expression of tooth wear within the Lowland Late Holocene population, who were primarily engaged in fisher, hunter-gatherer economies. These groups exhibited low caries prevalence, likely due to several contributing factors including the diet composition, carbohydrates consumption, and local fruits and tubers. Macroscopic tooth wear provides compelling evidence that humans in the Late Holocene were hunter gatherers. Dental wear occurs during mastication through two primary processes: attrition and abrasion. These wear patterns support the hypothesis that the Late Holocene diet, characterized by high-protein and low-carbohydrate foods, resulted in minimal caries formation. The presence of attrition and abrasion marks further suggests a diet comprising tough, fibrous, and abrasive foods typical of hunter-gatherer societies. The combination of these dietary factors contributed to the overall dental health and low prevalence of caries in the Late Holocene populations studied.

5.4.2 Fluorosis

Dental fluorosis is a tooth disease characterized by developmental disruption in dental enamel due to excessive fluoride exposure (Inkielewicz-Stepniak & Knap, 2015: 266). This

condition manifests in varying degrees, with severity determined by the amount and duration of fluoride exposure. In this study, analysis of human teeth revealed evidence of fluorosis, presenting mild, moderate, and severe phases. Fluoride naturally occurs as the fluoride ion, F- (fluorine), in food, air, and drinking water (Vithanage & Bhattacharya, 2015:106). Fluoride ingestion these sources influences the development of fluorosis. Biological mechanisms of fluoride benefit human bones and teeth; however, excessive intake leads to dental fluorosis (Weinstein & Davison 2004:56). The severity of fluorosis is directly related to the amount of fluoride ingested. The range of fluorosis observed in human teeth from Mamorikotey, Karas, Namatota, and Srobu sites indicates site-specific variations in fluoride exposure. These differences could be attributed to the local environment, dietary habits, and water sources. Drinking water is the most abundant source of fluoride (Murray, 1986) and the element that contributes to the development of fluorosis in human teeth (Fawell et al., 2006: 32). The presence of fluorosis in the enamel area of teeth denotes the mild to severe type; it can be caused by high fluoride mineral consumption in drinking water as well as other external factors (Reddy & Deme, 2015:1315). Nutrition received through meal consumption, including water, is the component that provides and initiates the processes of growth and mediates fluorosis exposure in human teeth (Zohoori & Marsland 2017: 539). The total intake of fluoride ions will cause intoxication and reduce collagen in human teeth and bones, further leading to tooth fluorosis and pathological calcification (Annapurna et al., 2005: 512). Fluoride intake will cause fluorosis in human teeth related to the individual's total portion or amount of intake.

Water is an essential component for all living creatures, necessary for various organ systems and physical activities (Razzaque, 2010: 697). Water containing chemical ions like fluoride plays a crucial role in human teeth and bones, enhancing enamel resistance to acid attacks, preventing cavities, and aiding in the remineralization process (Whitford, 1996). Historical studies from the United States in the 1940s highlighted concerns that fluoride concentrations in drinking water could lead to dental fluorosis, observed earlied in German populations in 1874, as well as in Denmark and Sweden (Dean et al., 1942a). It was determined that the optimal fluoride benefit occurs at around 1 part per million (ppm) or 1 p.p.m. per day, primarily to prevent tooth decay (Bird & Robinson, 2020:185). Higher fluoride concentrations, such as 1.5 to 2 p.p.m. daily, have been linked to development and exacerbation of dental fluorosis in tooth tissues. Drinking water fluoridated 1 mg/L, can lead to moderate dental fluorosis, while concentrations of 2 mg/L or higher can cause moderate to severe fluorosis (Ponikvar 2008: 497). Fluorosis affects enamel teeth, both before and after eruption in permanent teeth (Maier, 1972; Bird & Robinson 2020: 184), and its severity is influenced by the amount of fluoride consumed (Reddy & Deme, 2015). In the Papua region where the human teeth in this study were discovered, a tropical environment with high humidity and

temperatures likely encouraged increased water consumption for hydration (Murray, 1986; Fawell et al., 2006: 23). Water not only plays a critical role in maintaining electrolyte balance and regulating body temperature but also affects dental health when naturally containing fluoride. Natural water sources in Papua generally have fluoride concentrations below 1.0 mg/L, including the lake's water (Hem 1985:120; Tikhomirov 2018: 242).

As an indicator of fluorosis in human teeth, fluoride ion concentrations in water vary significantly across different regions due to distinct geological features, salinity levels, water depths, and climates (Edmunds & Smedley, 2013: 321). In tropical areas, frequent and intense rainfall can dilute groundwater and reduce the chemical composition, including fluoride concentrations in both water and vegetation (Edmunds & Smedley, 2013:318–321). This natural process results in lower fluoride content in natural water sources and vegetation (Weinstein & Davison 2004: 45).

In response to the presence of dental fluorosis observed in the four sites in this study, the fluoride composition in the local water sources where these sites are situated may not be the primary factor causing dental fluorosis, given the typically low concentrations of fluoride in tropical areas like Papua. However, historical studies on dental fluorosis in American populations during the 1940s, 1960s, and 1980s have shown that dental fluorosis can still occur even with low fluoride intake from water sources (Ellwood et al. 2008: 301). Currently, the environment surrounding the four sites includes natural water sources such as groundwater, lakes, streams, and rivers, which likely provided drinking water to the inhabitants. However, due to human mobility and potential changes in the environment over time, it is challenging to determine precisely which types of water sources were consumed by individuals at these sites. The ecological diversity of the environment provided various food resources that contributed to the biological and physical fitness of the human populations studied. Nevertheless, specific diets and subsistence practices could have contributed to various health studies, including dental fluorosis, potentially influenced by the fluoride concentrations in certain food sources (Reddy & Deme, 2015: 448). Further analysis using data from isotopic bone collagen and enamel apatite, supported by ecofact distributions, may provide insights into the factors contributing to the occurrence of dental fluorosis related to dietary practices among these past human populations.

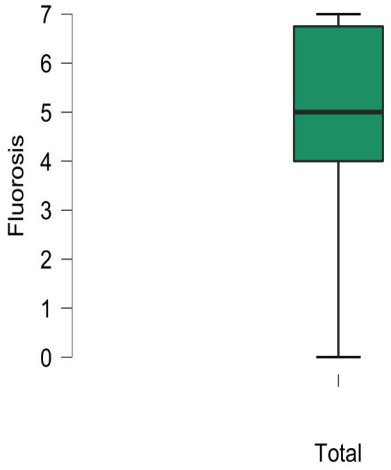


***Figure 47**: Box plots of fluorosis in the teeth from Srobu site*

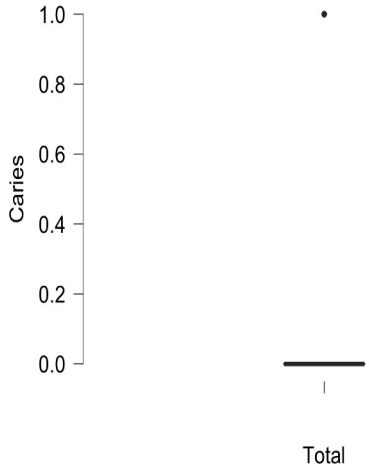


***Figure 48**: Box plots of teeth affected by caries from Srobu site*

The isotope collagen values from the individuals' bone analyses from the Srobu and Namatota sites provide evidence of marine fish and meat consumption, which may contribute to the appearance of dental fluorosis. Fluoride levels in marine fish has been confirmed to range from approximately 0.01 to 0.17 mg/100 g and 2-5 mg kg-1, particularly when fish bones are included in the cooking process (Gropper et al., 2009: 530; Fawell et al., 2006: 8). Additionally seawater, containing about 1.3 ppm/L (Suga et al., 1991: 438), suggests that sea mollusks found in significant quantities at this site may contain high fluoride levels due to their marine environment. However, these factors require further study for reliable evidence. Besides water, fluoride is also present in food and beverages, including beverages including vegetables, fruits, meat, and fish (Fawell et al., 2006: 8; Zohoori et al., 2017: 540). The isotope values from bone collagen from two individuals at the Namatota site and one from the Srobu site indicate a diet rich in meat, which may help explain the appearance of dental fluorosis. The fluoride levels in meat, which general range from 0.2-1.0 mg kg-1 (Fawell et al., 2006: 8). Therefore, the frequency of consuming fluoride containing foods may contribute to dental fluorosis in addition to water the primary factor. Since natural water is the leading factor in human dental fluorosis, future research on fluoride values in water sources in the Papua region is needed. This research will help provide a clearer understanding of fluorosis diseases in human teeth in this area.

5.4.3.1 Caries and fluorosis patterns

Caries and fluorosis were found in the human teeth from the four sites of the Late Holocene, revealing an interesting pattern connected to the rates of scores between fluorosis and caries in this study. The evidence shows a value range of four (4) to seven (7) on scale 0–7 (TSIF, Horowitz, et al., 1984), representing moderate to severe fluorosis. Caries were found only in the human teeth

from the Srobu and Mamorikotey sites. Nine teeth from the Srobu site have a score of 1 (very mild) from the 0–3 scale, while seven teeth from the Mamorikotey site also have a score of 1 (very mild) (Table 16). This pattern indicates that very mild caries were present in the teeth from the Srobu and Mamorikotey sites, while no caries were found in the teeth from the Srobu and Mamorikotey sites, while no caries were found in the teeth from the Namatota and Karas sites (Table15, 16, 17, 18). Additionally, fluorosis was highly prevalent in the teeth at the all four sites. This evidence is interesting to analyze to determine the factors contributing to the observed patterns between fluorosis and caries. Over several years, researchers have studied the relationship between caries and fluorosis in human teeth (Heller et al., 1997; Seppa, 2004; Griffin et al., 2007; Robinson, 2009), and these discussions have considered the role of fluoride in preventing caries in human teeth.

According to the chemical scheme, fluoride ions from calcium fluoride consumed by humans through drinking water, food, and beverages undergo several processes, including remineralization. During this process, fluoride ions are incorporated into the hydroxyapatite crystal lattice as bone tissue, forming fluorapatite (Kalicanin et al., 2015: 194). The calcium fluorapatite resulting from this process is much harder and more resistant to acid than the calcium hydroxyapatite (Kelter et al., 2009: 313). This increased hardness and acid resistance reduce to risk of dental caries and prevent the demineralization of tooth enamel caused by acids produced by plaque bacteria (Kalicanin et al., 2015: 194).

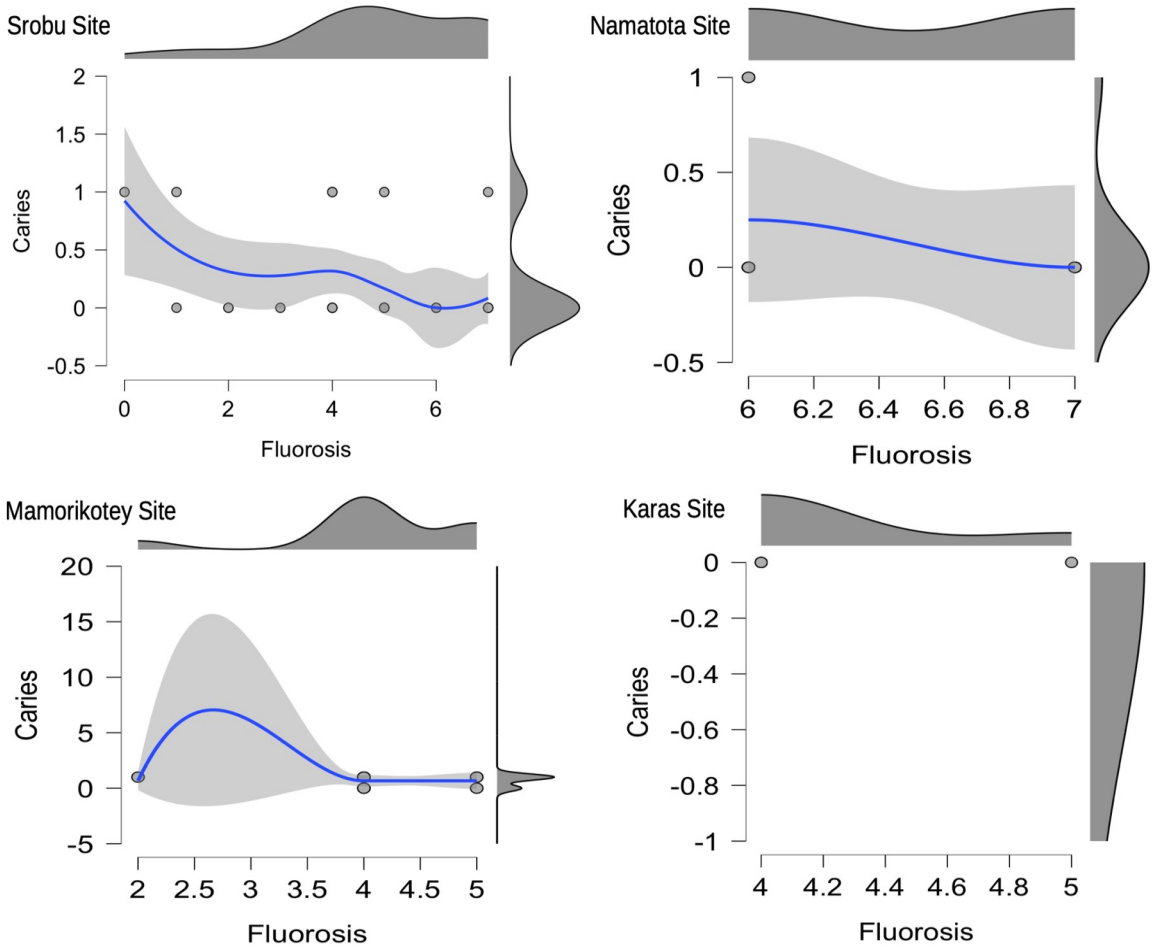


***Figure 49**: The comparison between caries and fluorosis from the four sites in this study*

According to the fluorosis score range at the four sites (Mamorikotey, Srobu, Karas, and Namatota site), it is likely that a high intake of fluoride may consumed, which later reduced dental caries in the teeth of these individuals. Additionally, cariogenic foods such as sugar and carbohydrates may have been consumed less frequently, while fluoride consumption was much higher, as shown by the pattern in the human teeth from the four sites. The high intake of fluoride can lead to fluorosis, which in turn reduces the risk of dental caries.

5.4.4 Teeth Calculus/plaque

The formation of calculus in human teeth occurs through a biological process where mineralized plaque, derived from saliva, calcifies and traps thousands of bacteria and food particles on the surfaces of teeth (Driessesn & Verbeeck, 1989). The calculus observed at the five sites

ranges from mild to moderate, with a small number of severe cases. Examination of calculus presence on anterior and posterior teeth from Mamorikotey, Srobu, Namatota, and Yomokho indicates that it is generally located in the cervical third of the tooth crown, also known as supra-gingival (appendix A-E). Supra-gingival calculus is typically found at the cervical crown (Hanihara et al., 1994). In terms of composition, supra-gingival calculus mineralized 16-80%, while sub-gingival calculus ranges from 46-83% in volume (Driessens & Verbeeck, 1989). The varied morphology and anatomical characteristics of anterior and posterior teeth influence the occurrence of wear, tooth pathology and calculus formation. The cervical third of the crown, being the closest to the 'neck' of the tooth, is where mineral from saliva, bacteria, and food particles are deposited, leading to the formation of calculus in this region.

Dental calculus preserves information about bacterial types and also provides a record of the dietary habits of past human populations. In archaeological research, micro-particles extracted from calculus in Neanderthals and modern humans offer evidence about plant consumption, including both cultivated and wild species. These micro-particles include starch granules from tubers, maize cereals, sweet potatoes, palms and beans. Studies of prehistoric societies in Europe, China, South America, and Oceania have revealed this information (Henry et al., 2011; Li et al., 2010; Piperno and Dillehay, 2008; Tromp, 2012).

Chapter 6: Conclusion

The characteristics of human teeth examined in this study contribute to understanding demographic patterns and human behavior by analyzing teeth and bone remains unearthed from several archaeological sites in the lowland part of Papua. Ancient human DNA and metric traits were studied to determine the ancestry or origins of the Lowland inhabitants of Papua. This research aims to identify the population affinities in this area and to understand human behavior during this period. Situated between Asia, Oceania, and Australia, the island of Papua presents numerous exciting topics for study, including human demographic history, initial occupation, and prehistoric human interaction. Researchers have previously studied various topics related to this region such as genetic, archaeology, and language distribution, yielding remarkable results that have enhanced our understanding of human history in this area. However, studies from the Papa-Indonesia region have been underrepresented in international publications, leading to gaps in our knowledge of human demographics and behavior in a broader context. Foo as a source of nutrition, is essential for human survival. In archaeological studies, diet is not merely about nourishment but also provides data on various topics such as cultural practices, environmental interactions and subsistence strategies.

The topics of human dietary behavior encompasses interdisciplinary content that reflects many aspects of human life, including food source types, diet subsistence and sustainability, environment stability, and diseases. It also includes human adaptation, cultural evolution, creativity, and ecological characteristics. These topics address several essential issues that need to be brought to the social study platform, particularly evidence from the archaeological context, to understand human adaptation and the development of past social cultures during the Holocene in regions characterized by tropical rain forests. Additionally, studying past human behavior can serve as an explanatory model to illustrate the connections between historical human behavior, the present, and the future.

The available genetic data from mtDNA, Y-chromosome, and human metric dental analysis in this study support multiple events of human migration into the lowland part of Papua-Indonesia, indicating both Asian and Papuan ancestry. The combined evidence from genome data, dental metrics, archaeology, and linguistic supports a model of admixture and interaction between Austronesian and Papuan speakers in the past. The appearance of mtDNA haplogroup B4a1a1k in an individual from the Eighteenth Century group provides evidence of Austronesian expansion into the northern lowland of Papua. There is also evidence of human dispersals from mainland Southeast Asia using the Sundaland route to eastern Indonesia and subsequently to Papua, as supported by

metric dental traits and mtDNA from the Eighteenth Century group. The genetic data in this study, support the idea about human expansion from the Island of Southeast Asia, using Sundaland as a route to the lowlands of Indonesia, as confirmed by the mtDNA haplotypes C1b21 and C1b1a2b found in individuals from Biak Island. These haplotypes are widely distributed in Southeast Asia, Taiwan, and western Indonesia, and are also found in Near and Remote Oceania, suggesting their presence in Papua before the arrival of Austronesian speakers. The admixture events between Asian-derived and Near Oceania or Papuan lineages are evidenced by the mtDNA and Y-chromosome data from individuals on Biak Island. The interaction between these populations on the island of Papua likely led to intermixing in the past. Linguistic and archaeological evidence from the lowland area supports the idea that human movement and interactions between different population groups in lowland Papua intensified with the arrival of Austronesian speakers during the Holocene. This interaction likely increased during the Lapita culture in Near Oceania and the post-Lapita period. Today, the lowland indigenous inhabitants of Papua speak languages that reflect the domination of Austronesian speakers in several areas. However, some clans, including the indigenous Papuans in the Lake Sentani area, Kayu Batu, Kayu Pulo, Tobati, and the Lembah Grime region, speak Papuan or Trans-New Guinean languages.

The results from bone collagen and enamel apatite analyses provide evidence of diet shifts between childhood and adulthood among the individuals in this study. Bone collagen indicates a C3 diet-based derived from the terrestrial foods, while enamel apatite suggest a C4 plants derived from marines resources. The environmental landscape of lowland Papua, dominated by terrestrial rain forests and marine habitats, offers both C3 and C4 food sources utilized by human populations. The shifts from C4 to C3 food sources may be linked to historical human movements. Individuals may have spent their childhood in the coastland areas, where marine resources (C4 plants) were predominant, and later settled inland, relying more on terrestrial foods (C3 plants). Diet composition, influenced by physical and chemical factors, impacts dental decay and wear. This study conducted macro and micro studies to understand human diet behaviors and identify the dental pathologies associated with different food types. High frequencies of fluorosis were observed compared to caries, with plaque or calculus occurring less frequently but wear being more prevalent. The wear patterns on teeth, such as macro-micro wear, fluorosis, caries and calculus/plaque, are linked to the types of foods consumed. The high occurrence of terrestrial foods, including meat and rain forest resources, likely contributed to macro-micro wear observed across the five sites. Foods varying in texture, structure, and hardness can cause abrasion and wear on teeth, especially coarse or abrasive foods common in rain forest diets. Fluorosis, characterized by high fluoride intake, likely resulted from drinking water sources, contributing significantly to dental

pathology in this study. Conversely, caries occurred less frequently, possibly due to a diet low in carbohydrates or sugars. The study suggests that the high fluoride intake may simultaneously increase the risk of fluorosis while reducing the risk of dental caries.

Human dental morphology analysis, specifically measuring crown width and length (dental metrics), is a cost-efficient and non-destructive method widely used in archaeological studies to explore questions about population histories and biological relationship among past human groups. These metrics are crucial for studying human biological distances and identifying kinship affiliations among populations. However, challenges such as the small number of teeth available in some tooth types from the Late Holocene group can impact the study's hypotheses. A limited sample size may not adequately represent the entire population under investigation, which is essential for discussing population history accurately. Nonetheless, the dental metric analysis in this study characterizes tooth size differences between the Late Holocene and Eighteenth Century groups from the lowland part of Papua, serving a valuable benchmark for future comparisons with additional dental material.

Molecular studies, including the detection of organic compounds in ancient remains as conducted in this study, provide insights into past populations. However, these studies face challenges due to the degradation of biological materials over time, influenced by factors such as burial conditions humidity, heat, climate), which can damage DNA and affect preservation levels. Despite these challenges, this study has provided clues about admixture events between different populations. Yet, detailed information about when, where, and how these admixture events occurred is lacking in the current study. Future scientific advancements and discoveries are expected to address these gaps and provide more comprehensive insights into ancient human interactions and migrations. In summary, while dental metros and molecular studies offer valuable insights into past populations, ongoing research advancements are needed to further unravel the complexities of human history, including the details of admixture events and their contexts.

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Appendix A: Table 1. Affinities to Asian populations

Testing the best source for the Asian ancestry component using Mbuti (Africa) as an outgroup, testing various Asian groups (Asia test) against Amis. Positive values indicate higher allele sharing with the test group, negative values indicate higher allele sharing with Amis. Tests with Z-scores of higher than 3 or lower than -3 are considered significant. For tests -3<Z<3 the sources are considered equally good. Test based on less than 10 000 SNPs are to be interpreted cautiously.

AsiaTest1	Test 2	ID	Outgroup	f4	Z	#SNs
Malay	Ami	AGT	Mbuti	-0.000123	-0.168	9978
Miao	Ami	AGT	Mbuti	-0.000133	-0.196	10030
She	Ami	AGT	Mbuti	-0.000232	-0.335	10030
Semende	Ami	AGT	Mbuti	-0.000255	-0.388	10030
Kinh	Ami	AGT	Mbuti	-0.000378	-0.547	10030
Cambodian	Ami	AGT	Mbuti	-0.001172	-1.608	10030
Han	Ami	AGT	Mbuti	0.000131	0.228	10030
Barito	Ami	AGT	Mbuti	0.000198	0.282	10030
Thai	Ami	AGT	Mbuti	0.000215	0.305	10030
Vietnamese	Ami	AGT	Mbuti	0.000221	0.328	9978
Dusun	Ami	AGT	Mbuti	0.000245	0.366	9978
Ilocano	Ami	AGT	Mbuti	0.000517	0.480	9978
Murut	Ami	AGT	Mbuti	0.000595	0.815	9978
Atayal	Ami	AGT	Mbuti	0.000955	1.252	10030
Kankanaey	Ami	AGT	Mbuti	0.001438	2.028	9978
Semende	Ami	ISD	Mbuti	-0.000014	-0.019	8407
Barito	Ami	ISD	Mbuti	-0.000175	-0.212	8407
Kinh	Ami	ISD	Mbuti	-0.000579	-0.771	8407
Ilocano	Ami	ISD	Mbuti	-0.000860	-0.817	8350
Vietnamese	Ami	ISD	Mbuti	-0.000636	-0.856	8350
Malay	Ami	ISD	Mbuti	-0.000761	-0.939	8350
Murut	Ami	ISD	Mbuti	-0.000718	-0.972	8350
Cambodian	Ami	ISD	Mbuti	-0.000842	-1.004	8407
Han	Ami	ISD	Mbuti	-0.000763	-1.163	8407
Miao	Ami	ISD	Mbuti	-0.001103	-1.409	8407
Thai	Ami	ISD	Mbuti	-0.002457	-2.965	8407
She	Ami	ISD	Mbuti	0.000081	0.105	8407
Kankanaey	Ami	ISD	Mbuti	0.000293	0.371	8350
Dusun	Ami	ISD	Mbuti	0.000383	0.522	8350
Atayal	Ami	ISD	Mbuti	0.000910	1.067	8407

Murut	Ami	PBA	Mbuti	-0.000005	-0.025	343120
Kankanaey	Ami	PBA	Mbuti	-0.000066	-0.306	343120
Malay	Ami	PBA	Mbuti	-0.000078	-0.355	343120
Atayal	Ami	PBA	Mbuti	-0.000140	-0.590	345901
She	Ami	PBA	Mbuti	-0.000272	-1.247	345901
Vietnamese	Ami	PBA	Mbuti	-0.000263	-1.247	343120
Kinh	Ami	PBA	Mbuti	-0.000307	-1.370	345901
Miao	Ami	PBA	Mbuti	-0.000400	-1.877	345901
Cambodian	Ami	PBA	Mbuti	-0.000605	-2.704	345901
Han	Ami	PBA	Mbuti	-0.000523	-2.832	345901
Thai	Ami	PBA	Mbuti	-0.000703	-3.074	345901
Ilocano	Ami	PBA	Mbuti	0.000023	0.070	343117
Semende	Ami	PBA	Mbuti	0.000039	0.188	345901
Dusun	Ami	PBA	Mbuti	0.000242	1.142	343120
Barito	Ami	PBA	Mbuti	0.000284	1.248	345901

Dusun	Ami	SWM	Mbuti	-0.000025	-0.115	336239
Atayal	Ami	SWM	Mbuti	-0.000031	-0.138	339024
Semende	Ami	SWM	Mbuti	-0.000325	-1.542	339024
She	Ami	SWM	Mbuti	-0.000563	-2.598	339024
Barito	Ami	SWM	Mbuti	-0.000726	-3.145	339024
Vietnamese	Ami	SWM	Mbuti	-0.000679	-3.242	336239
Kinh	Ami	SWM	Mbuti	-0.000790	-3.597	339024
Miao	Ami	SWM	Mbuti	-0.000862	-3.944	339024
Malay	Ami	SWM	Mbuti	-0.000989	-4.214	336239
Han	Ami	SWM	Mbuti	-0.001010	-5.462	339024
Cambodian	Ami	SWM	Mbuti	-0.001623	-6.947	339024
Thai	Ami	SWM	Mbuti	-0.001854	-7.973	339024
Ilocano	Ami	SWM	Mbuti	0.000013	0.045	336235
Murut	Ami	SWM	Mbuti	0.000049	0.210	336239
Kankanaey	Ami	SWM	Mbuti	0.000386	1.757	336239

Kankanaey	Ami	SWU	Mbuti	-0.000046	-0.070	10928
Dusun	Ami	SWU	Mbuti	-0.000156	-0.228	10928
Murut	Ami	SWU	Mbuti	-0.000255	-0.358	10928
Ilocano	Ami	SWU	Mbuti	-0.000657	-0.652	10928
Vietnamese	Ami	SWU	Mbuti	-0.000436	-0.665	10928
Atayal	Ami	SWU	Mbuti	-0.000505	-0.682	11026
Han	Ami	SWU	Mbuti	-0.000674	-1.136	11026
Malay	Ami	SWU	Mbuti	-0.000909	-1.306	10928
She	Ami	SWU	Mbuti	-0.000958	-1.361	11026

Miao	Ami	SWU	Mbuti	-0.000972	-1.416	11026
Kinh	Ami	SWU	Mbuti	-0.001062	-1.478	11026
Thai	Ami	SWU	Mbuti	-0.001452	-2.051	11026
Cambodian	Ami	SWU	Mbuti	-0.001856	-2.428	11026
Barito	Ami	SWU	Mbuti	0.000073	0.102	11026
Semende	Ami	SWU	Mbuti	0.000493	0.713	11026

Ilocano	Ami	YEN	Mbuti	-0.000172	-0.396	79148
Kankanaey	Ami	YEN	Mbuti	-0.000152	-0.478	79150
Murut	Ami	YEN	Mbuti	-0.000160	-0.528	79150
Dusun	Ami	YEN	Mbuti	-0.000471	-1.509	79150
Semende	Ami	YEN	Mbuti	-0.000452	-1.579	79761
Atayal	Ami	YEN	Mbuti	-0.000627	-1.928	79761
Barito	Ami	YEN	Mbuti	-0.000868	-2.752	79761
Vietnamese	Ami	YEN	Mbuti	-0.000993	-3.352	79150
She	Ami	YEN	Mbuti	-0.001108	-3.513	79761
Malay	Ami	YEN	Mbuti	-0.001362	-4.218	79150
Kinh	Ami	YEN	Mbuti	-0.001455	-4.847	79761
Miao	Ami	YEN	Mbuti	-0.001518	-4.864	79761
Han	Ami	YEN	Mbuti	-0.001437	-5.646	79761
Cambodian	Ami	YEN	Mbuti	-0.002101	-6.564	79761
Thai	Ami	YEN	Mbuti	-0.002570	-8.113	79761

Appendix B: Human teeth from the Srobu site

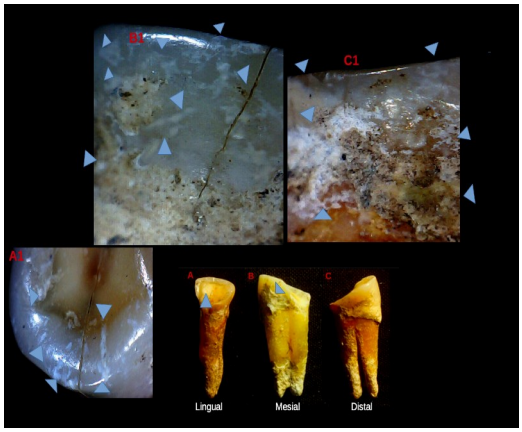

Figure 50: First Premolar tooth. Fluorosis with blue arrow, A1: erosion, C1: Plaque on the teeth surface

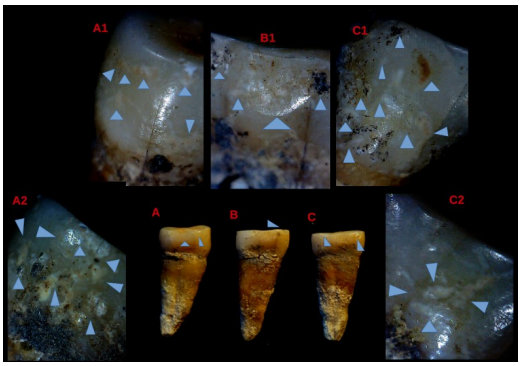

Figure 51: Srb/20/LP1: Lower First Premolar. A: mesial (A1 & A2: the fluorosis with blue-arrow sign); B: distal (B1: abrasion associated fluorosis with the blue arrow- sign), C1 & C2: abrasion associated fluorosis.

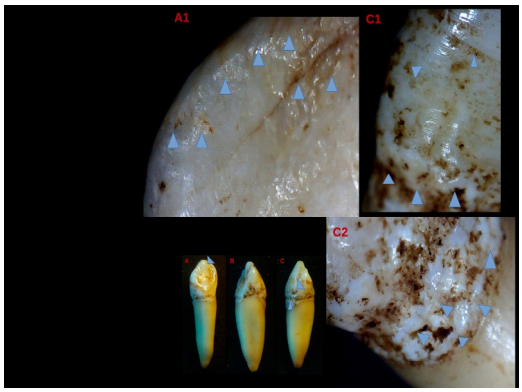

Figure 52: Srb/21/UC. Upper canine. A1: fluorosis marked by the brown color in the lingual surfaces. C1 & C2: Fluorosis (blue-arrow) marked by the white-colors.

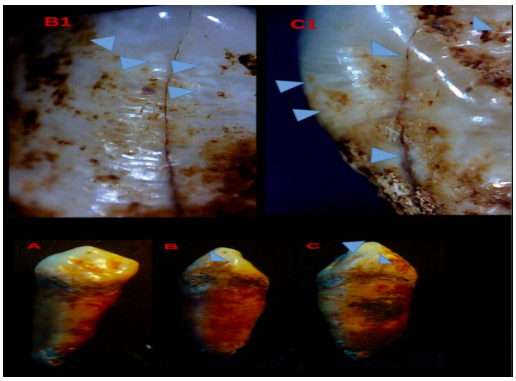

Figure 53: Srb/22/UC. Upper canine. A: lingual aspect; B: buccal aspect, fluorosis with the dark brown color; C1: lingual, fluorosis with brown and white colors. Cracked presence in the lingual and buccal aspect.

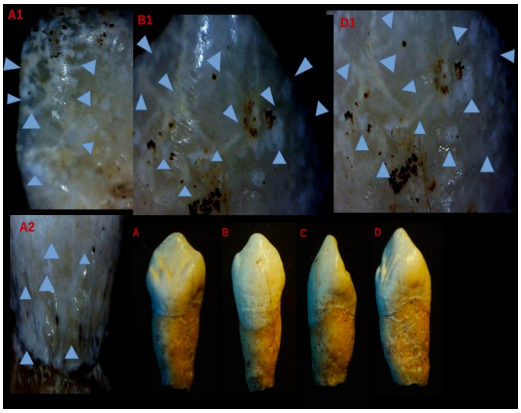

Figure 54: Srb/23/UC. A: lingual aspect, B: buccal; C: mesial; D: distal aspect. Fluorosis is marked by the white and dark-brown color in the teeth surfaces (blue-arrow sign).

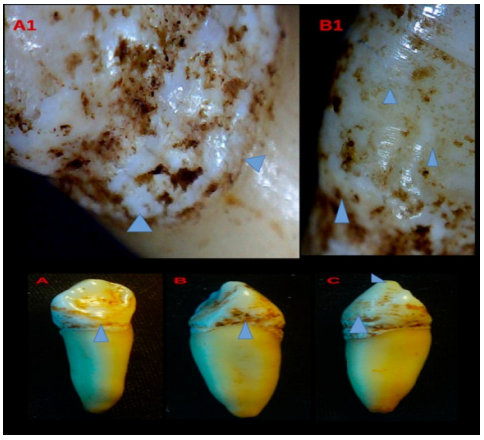

Figure 55: Srb/24/UC. A: lingual aspect, B: mesial aspect, C: distal aspect. A1 & B1: fluorosis marked by white to dark color in the crown surfaces.

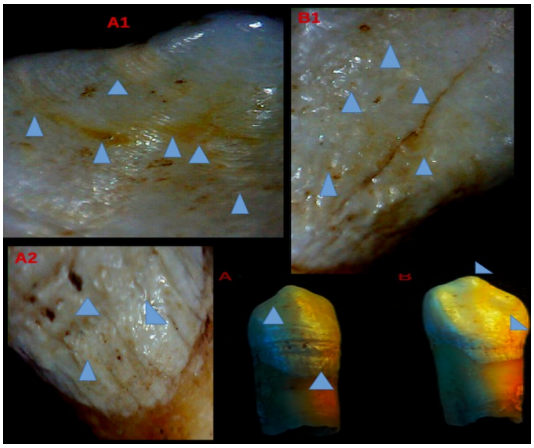

Figure 56: Srb/25/LC. Lower canine. A: labial aspect, B: lingual aspect. A1 & A2, and B1: fluorosis marked by white to yellow-dark color in the crown surfaces.

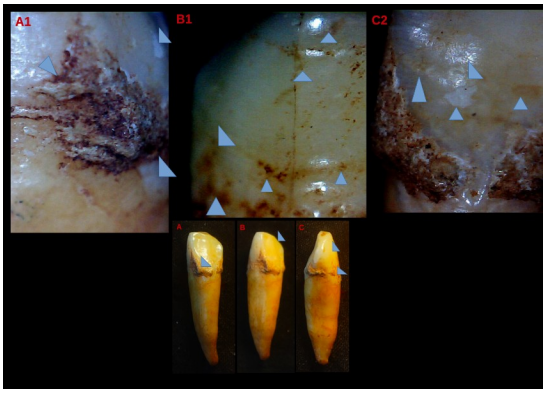

Figure 57: Srb/27/LC: A: lingual, B: mesial, C: distal. A1: plaque/calculus in the disto-lingual, B1: fluorosis marked by dark-yellow color, C2: plaque-associated fluorosis marked by white to yellow-brown color.

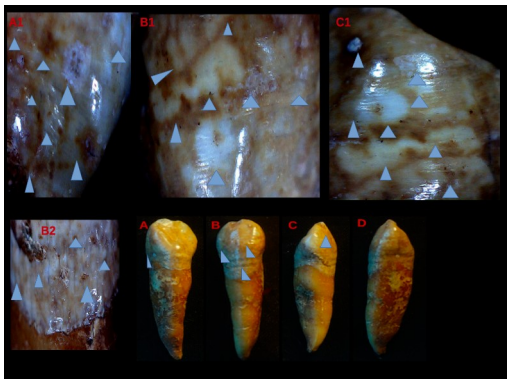

Figure 58: Srb/28/UC. Upper canine. A: lingual, B: buccal, C: distal, D: mesial. A1, B1, C1, B2: fluorosis marked by white to dark-brown color (blue arrow sign).

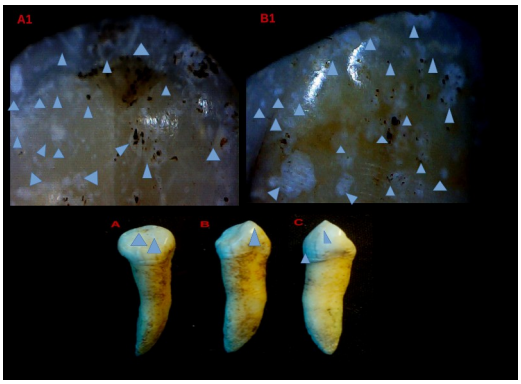

Figure 59: Srb/29/UC. A: lingual, B: mesial, C: distal. A1: Fluorosis is indicated by white to dark-brown color. Abrasion is established on the incisal area. B1: Fluorosis is marked by white color in the inciso-buccal area.

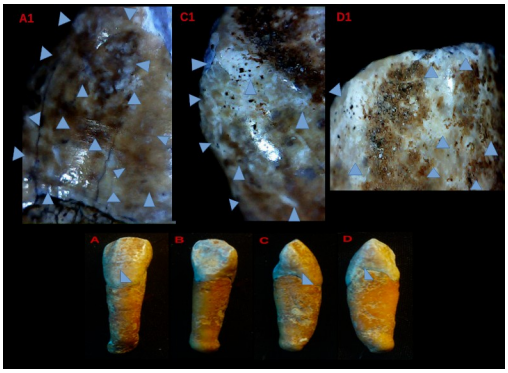

Figure 60: Srb/30/LC. Lower canine. A: labial, B: lingual, C: mesial, D: distal aspect. A1 & C1: fluorosis distributed in the crown surface. D1: Abrasion at incisal area associated with fluorosis.

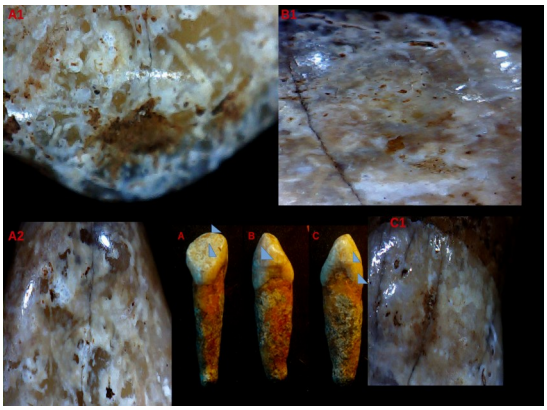

Figure 61: Srb/31/UC. Upper canine. A; lingual, B: mesial, C: distal.A1, A2, B1, C1: Fluorosis signified by white-colour is distributed in the crown surfaces.

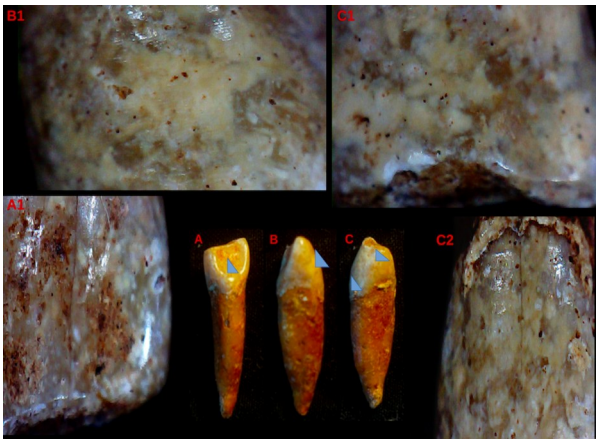

Figure 62: Srb/32/LC. Lower canine. A: lingual, B: mesial, C: distal. A1, B1, C1: fluorosis is indicated by the white color established on the crown surfaces. C2: buccal aspect, fluorosis, and plaque in the crown surfaces.

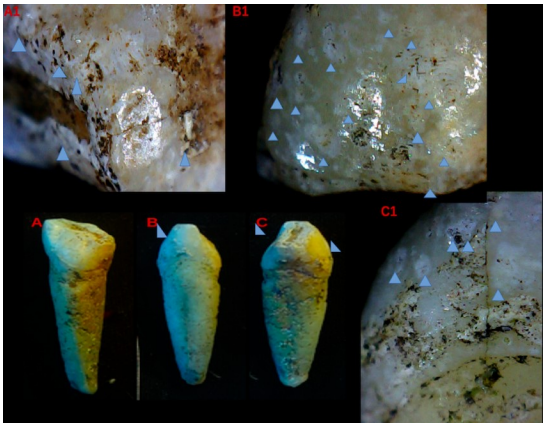

Figure 63: Srb/33/LC. Lower canine. A: lingual aspect, B: mesial, C: distal. A1: fluorosis signified by white color on the tooth surfaces. Abrasion is established in the incisal area. B1: fluorosis marked by white color to dark brown (blue arrow sign). C1: fluorosis and plaque distributed in the tooth surfaces.

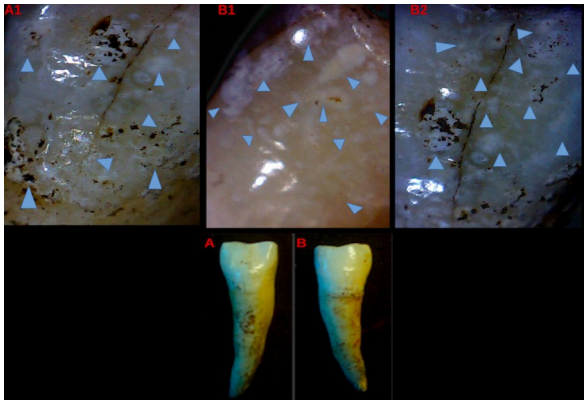

Figure 64: Srb/34/LC. Lower canine. A: lingual aspect, B: buccal aspect. A1, B1, B2: fluorosis is established in the crown surfaces, marked by a blue arrow sign.

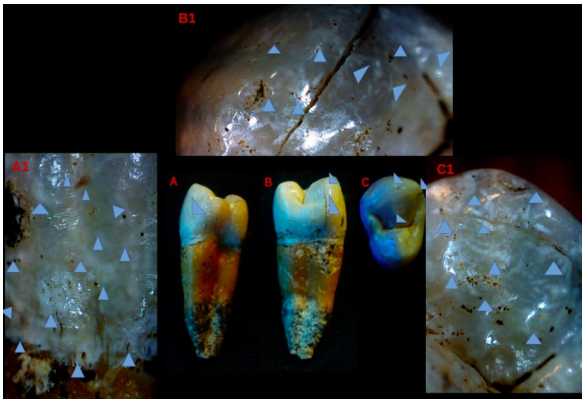

Figure 65: Srb/35/UP1. Upper first premolar. A: mesial, B: distal, C: occlusal aspect. A1, B1, C1: fluorosis established in the crown surfaces associated with crack.

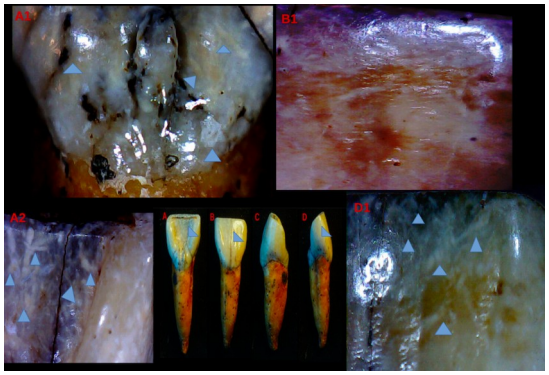

Figure 66: Srb/64/UI1. Upper first incisor. A: lingual, B: buccal, C: mesial, D: distal. A1, A2, B1, D1: fluorosis marked by white, yellow to dark brown distributed almost in all surface tooth.

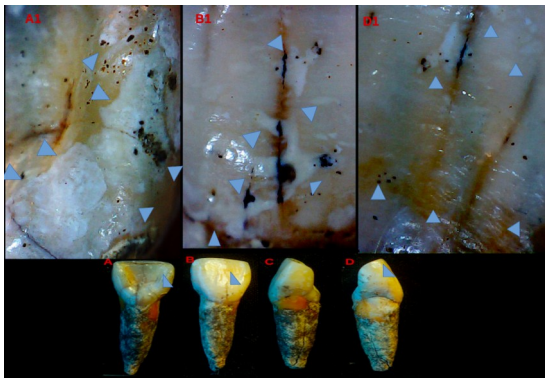

Figure 67: Srb/65/UI1.Upper first incisor. A: lingual, B: buccal, C: mesial, D: distal. A1, B1, D1: fluorosis marked by white and dark yellow color distributed in the crown surfaces.

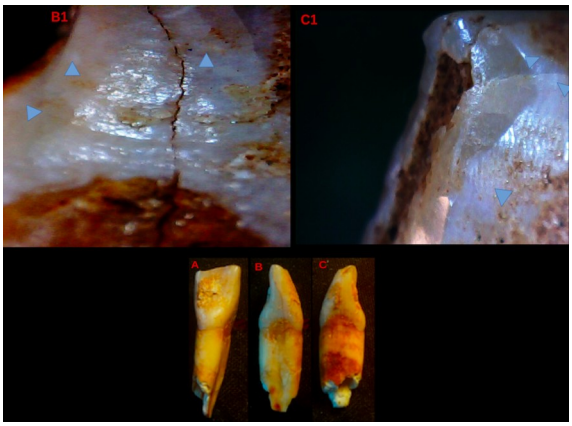

Figure 68: Srb/66/LI2. Lower second incisor. A: lingual, B: mesial, C: distal. B1: fluorosis-associated plaque and crack. C1: Abrasion in the incisal area.

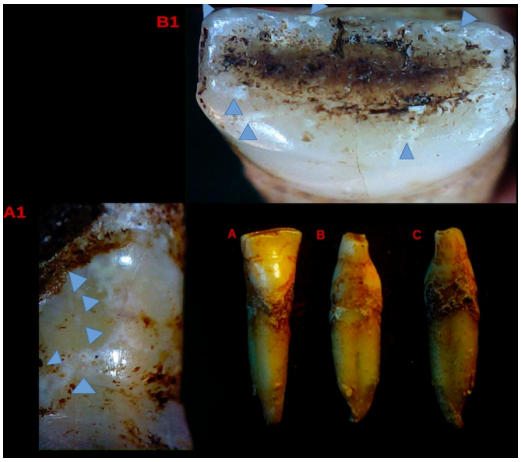

Figure 69: Srb/67/LI2. Lower second incisor. A: lingual, B: mesial, C: distal. A1, B1: abrasion in the incisal area associated plaque.

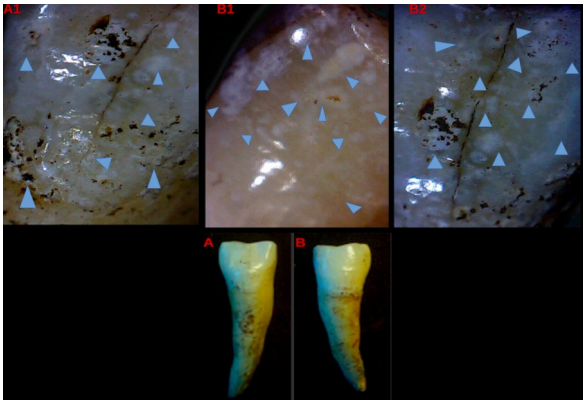

Figure 70: Srb/34/LC. Lower canine. A: lingual aspect, B: buccal aspect. A1, B1, B2: fluorosis is established in the crown surfaces, marked by a blue arrow sign.

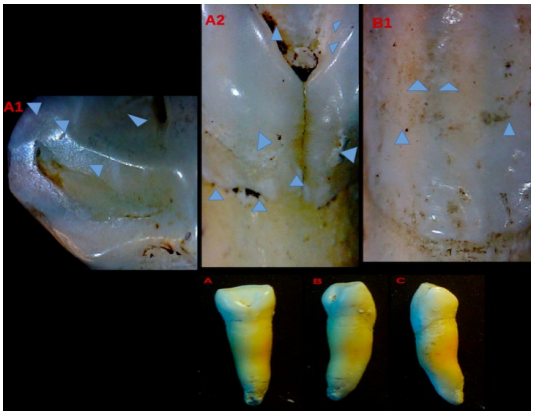

Figure 71: Srb/90/UI2. Upper second incisor. A: lingual, B: mesial, C: distal. A1: abrasion on the incisal area. A2 & B2: fluorosis marked by white-spot in the enamel surface

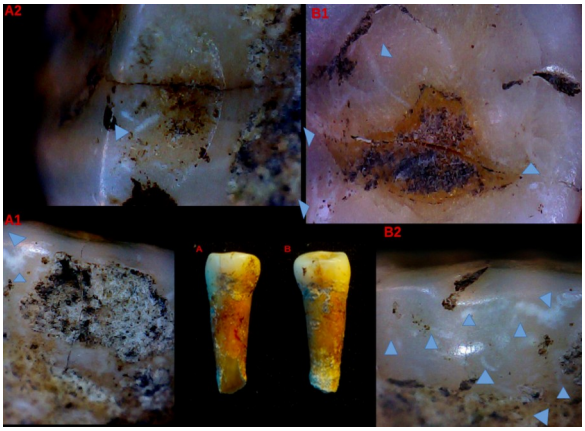

Figure 72: Srb/403/LP2. Lower second premolar. A: buccal, B: mesial aspect. A1: fluorosis-associated plaque/calculus in the crown surface. A2: fluorosis marked by a white color associated with plaque and crack. B1: fluorosis in white marked, and abrasion. B2: Fluorosis marked by white-fleck.

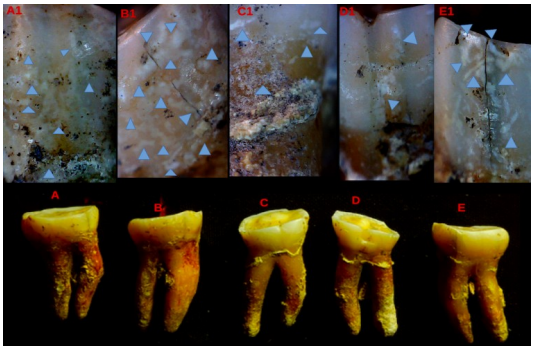

Figure 73: Srb/413/Lower molars. A: lower right first molar (LRM1), B: lower right second molar (LRM2), C: lower first molar (LM1), D: lower left second molar (LLM2), E: lower left third molar (LLM3). All teeth affected by erosion established in the occlusal area, while plaque present in the cervical third of enamel. A1, B1, C1, D1, E1: fluorosis marked by a white color associated plaque in the crown area.

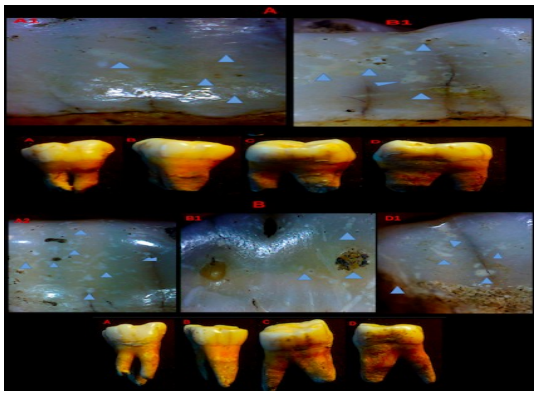

Figure 74: Srb/489/UM. Upper molar. Upper to bottom: A: upper left first molar (ULM1). A1 & B1: fluorosis marked by white color. Third row and four: upper left second molar (ULM2): A2 & D1: fluorosis in the crown surface. B1: erosion established on the occlusal area.

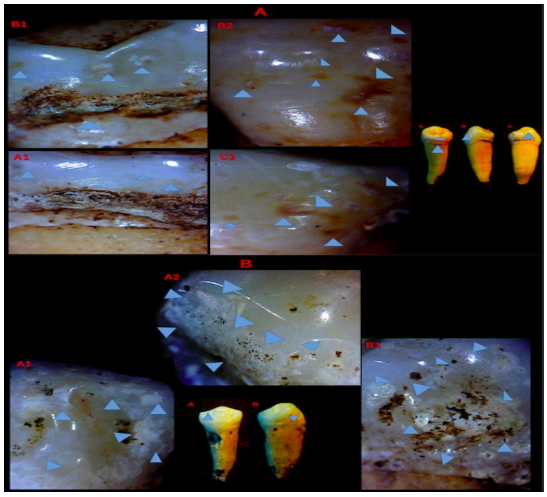

Figure 75: Srb/622/LP2. Lower second premolar. A: lingual aspect, B: mesial aspect. Abrasion, plaque and fluorosis established in the tooth crown

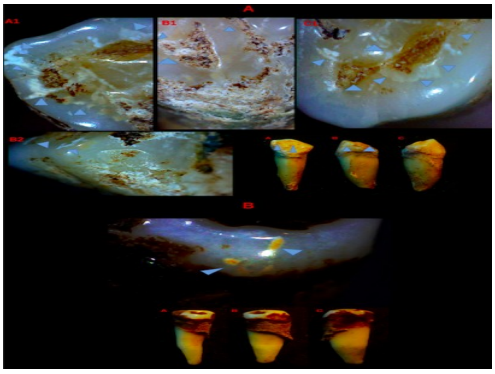

Figure 76: A: Srb/623/ Upper canine (A1, B1, B2, C1: erosion, abrasion, plaque and fluorosis established in the tooth crown. B). Srb/624/lower first premolar (A, B, C: fluorosis associated calculus on the teeth crown)

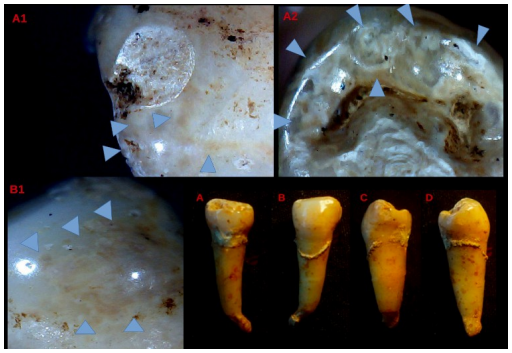

Figure 77: Srb/625/LP2. Lower second premolar. A: lingual aspect, B: buccal, C: mesial, D: distal. Plaque present in the cervical third of the crown. A1: abrasion and fluorosis in the crown surface. B1& B2: fluorosis marked by white color to dark yellow.

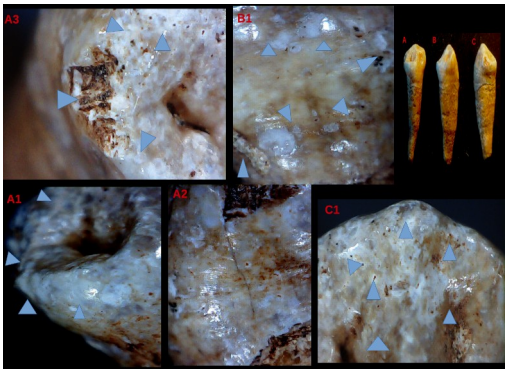

Figure 78: Srb/626/LP1. Lower first premolar. A1, A2, B1, C1: fluorosis marked by white to dark-brown in the tooth surface. A3: abrasion established in the occlusal area.

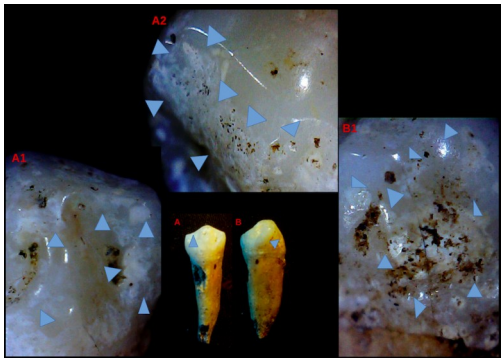

Figure 79: Srb/627/LP1. Lower first premolar. A: lingual aspect, B: mesial aspect. A1, A2, B1: fluorosis marked by white color and dark-brown associated abrasion and crack on the crown surface

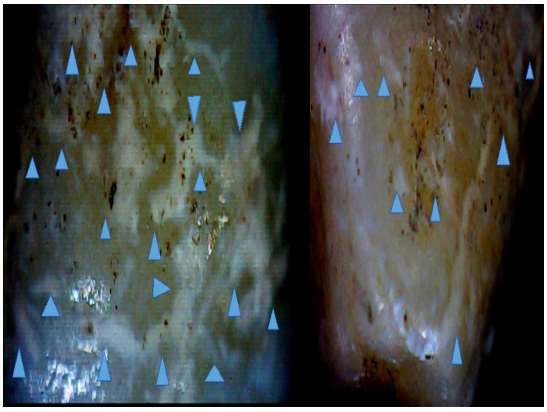

Figure 80: Srb/629/LC. Lower canine. Left and right picture: fluorosis marked by white color in the tooth surface

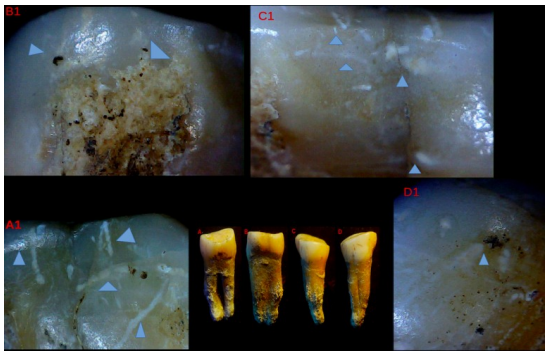

Figure 81: Srb/630/UM2. Upper second molar. A: mesial, B: distal, C: lingual, D: buccal aspect. A1, C1, D1: fluorosis marked by white color. B1: fluorosis associated calculus/plaque in the tooth surface

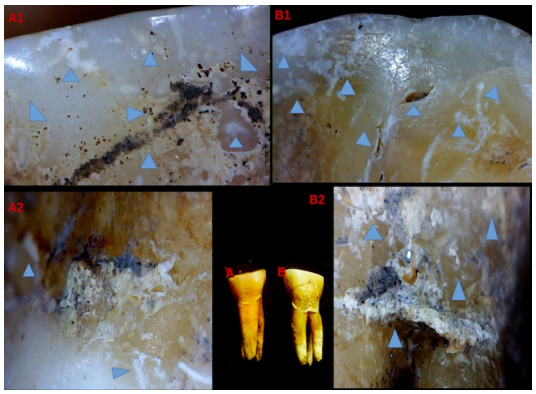

Figure 82: Srb/633/UM. Upper molar. A: lingual, B: buccal. A1, A2: fluorosis and calculus in the crown surface. B1: erosion present in the occlusal area. B2: calculus presence in the cervical third of crown

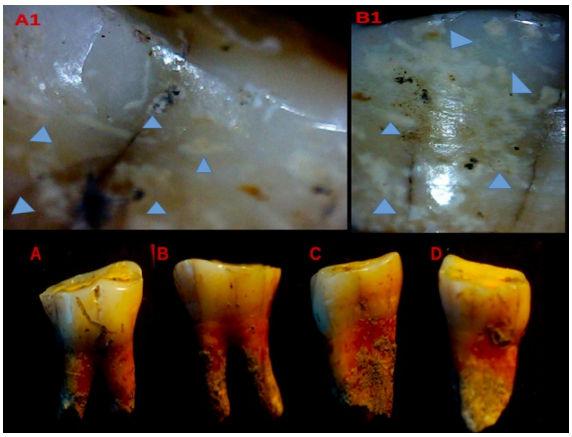

Figure 83: Srb/636/LM1. Lower first molar. A: buccal, B: lingual, C: mesial, D: distal. A1 & B1: fluorosis marked by white color associate abrasion in the tooth surface.

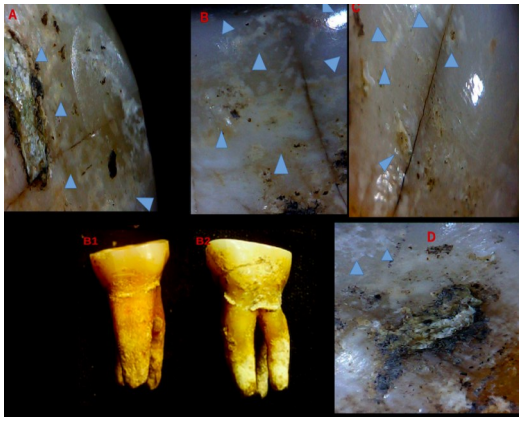

Figure 84: Srb/636/LM2. Lower second molar. Lower second molar. A: abrasion, fluorosis, and plaque in the tooth crown. B, C, D, fluorosis and plaque in the tooth crown.

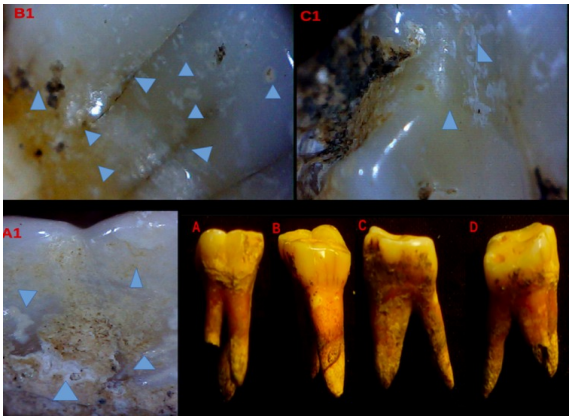

Figure 85: Srb/ABC/UM1. Upper first molar. A: buccal, B: lingual, C: mesial, D: distal. A1, B1, C1: fluorosis marked by white color. C1: abrasion in the tooth crown.

Appendix C: Human teeth from the Mamorikotey site

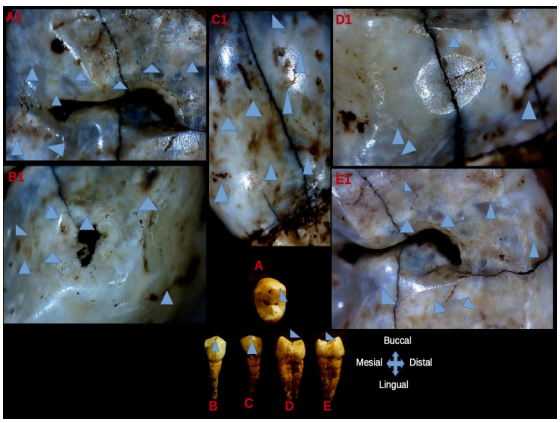

Figure 86: MMK/42/UP1. Upper first premolar. A: occlusal, B: lingual, C: buccal, D: mesial, E: distal. A1 & B1, C1, D1, E1: fluorosis marked by white to dark-brown in the crown surface, abrasion, and cracked is also found in the crown area.

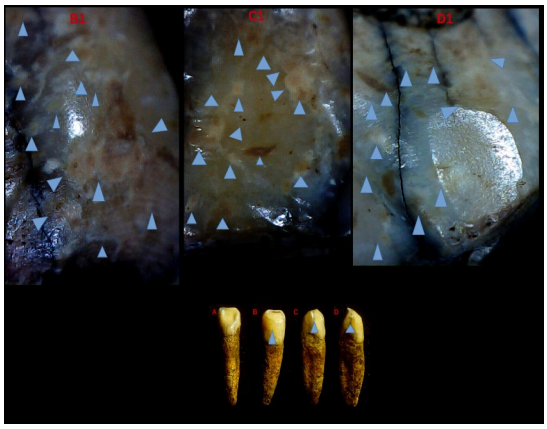

Figure 87: MMK/49/LC. Lower canine. A: lingual, B: buccal, C: mesial, D: distal aspect. B1, C1: fluorosis established in the crown surfaces signfied by white color. D1: abrasion and crack on the crown surfaces.

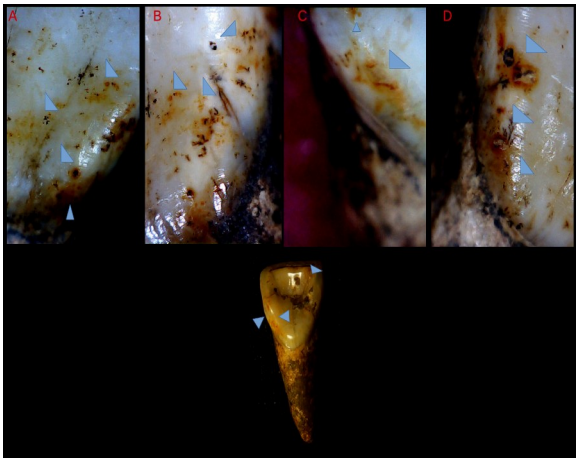

Figure 88: MMK/78/UI1. Upper first incisor. A, B, C, D: fluorosis marked by yellow-brown color

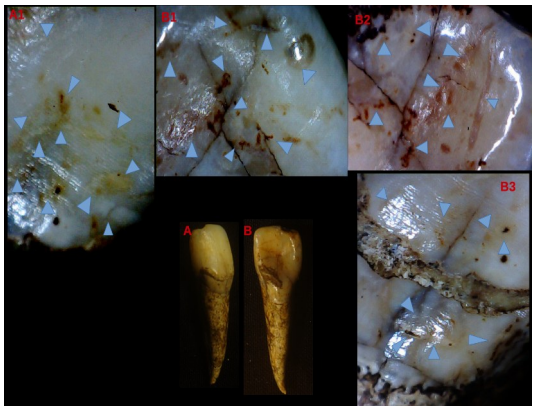

Figure 89: MMK/79/UI2. Upper second incisor. A: buccal, B: lingual. A1, B1, B2: fluorosis marked by yellow to brown, dark associate crack in the tooth crown. B3: plaque and fluorosis established in the crown surfaces.

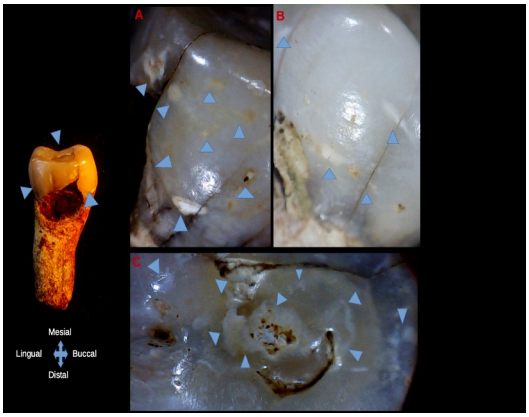

Figure 90: MMK/332/LP2. Lower second premolar. A: fluorosis-associated crack in the crown surface, B: fluorosis and plaque on the crown surfaces, C: abrasion in the occlusal area.

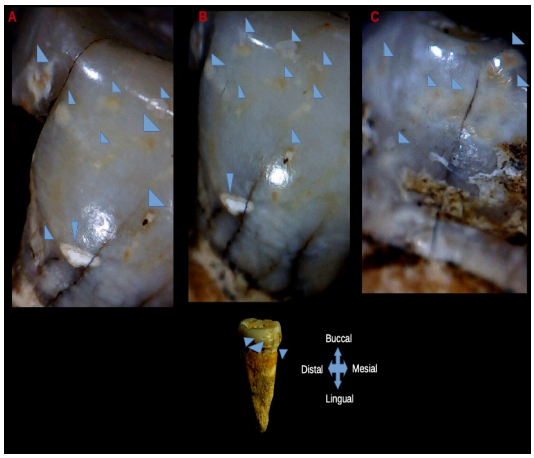

Figure 91: MMK/333/LP1. Lower first premolar. A, B: fluorosis marked by white color, associated cracked in the crown surface. C: fluorosis is associated with plaque and cracked in the tooth crown.

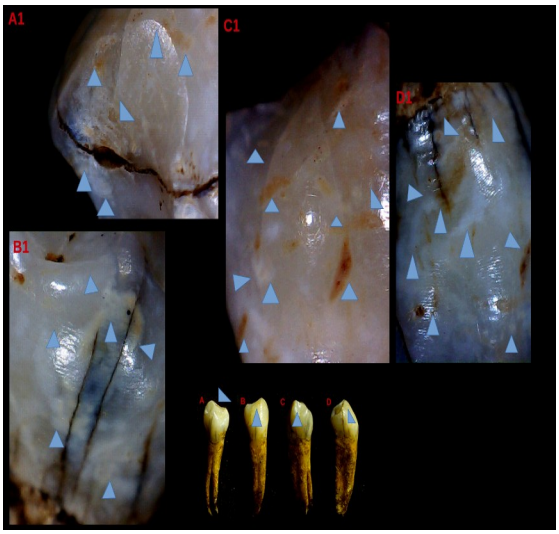

Figure 92: MMK/405/LP1. Lower first premolar. A: lingual, B: buccal, C: mesial, D: distal. A1: abrasion established in the incisal area, B1 & C1: fluorosis marked by white color in the crown.

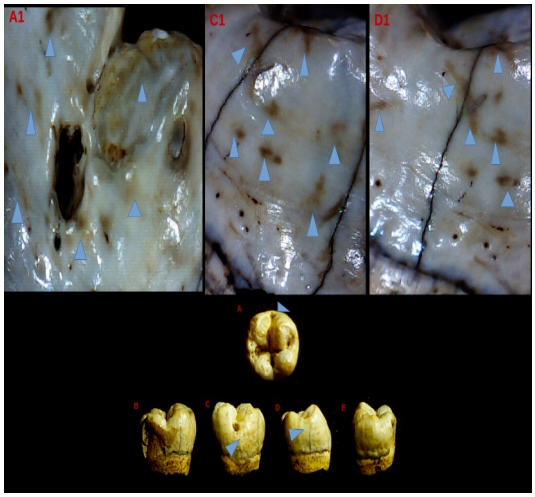

Figure 93: MMK/419/LM2. Lower second molar. A: Occlusal aspect, B: lingual, C: buccal, D: mesial, E: distal.A1, C1, D1: fluorosis marked by dark-brown in the crown surface, associated crack.

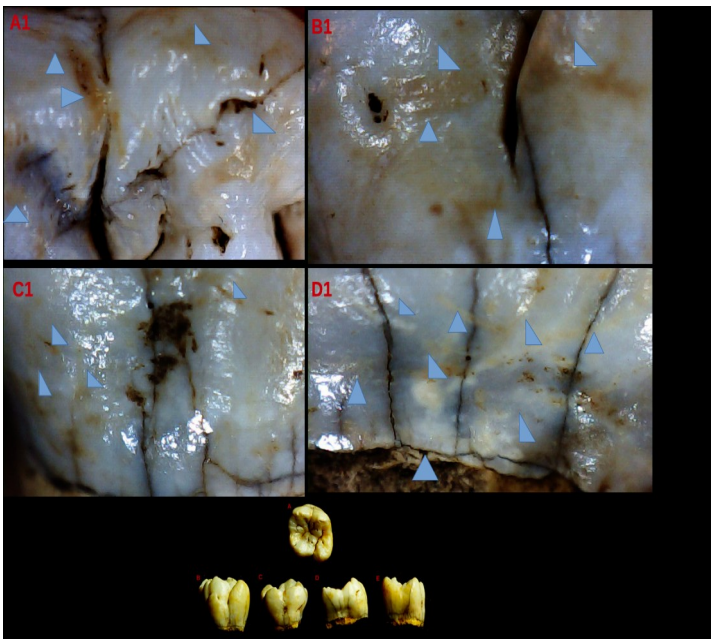

Figure 94: MMK/638/UM1.Upper first molar. A: occlusal aspect. B: lingual aspect, C: buccal, D: mesial, E: distal. A1, B1, C1, D1: fluorosis marked by white, dark yellow, and brown color established on the crown surfaces.

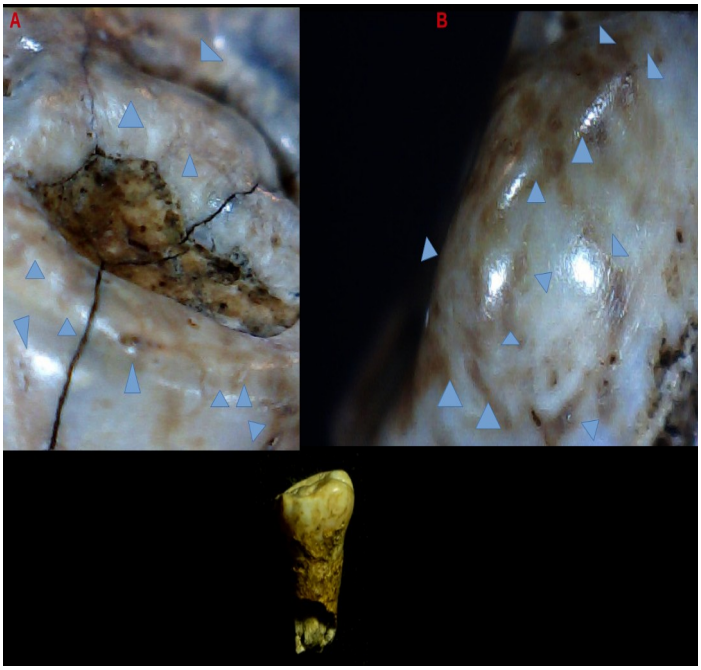

Figure 95: MMK/640/LP1/ Lower first premolar. A: abrasion established in the occlusal area associated with cracked and fluorosis. B: fluorosis marked by dark-brown color on the crown surface

Appendix D: Human teeth from the Namatota site

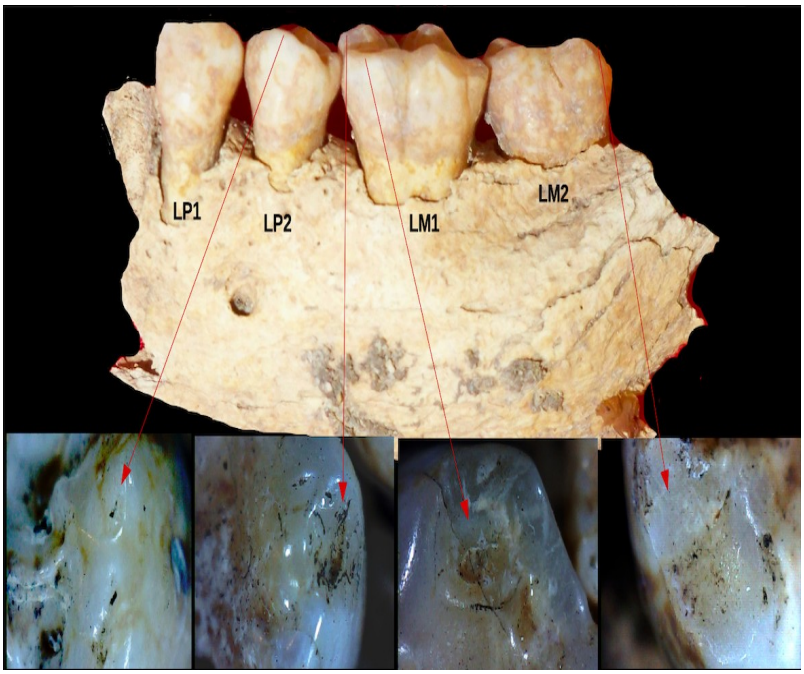

Figure 96: Nmt/Ind1. Left to right: lower first premolar (LP1); lower second premolar (LP2); lower first molar (LM1); lower second molar (LM2). The red arrows sign: wear on the occlusal area

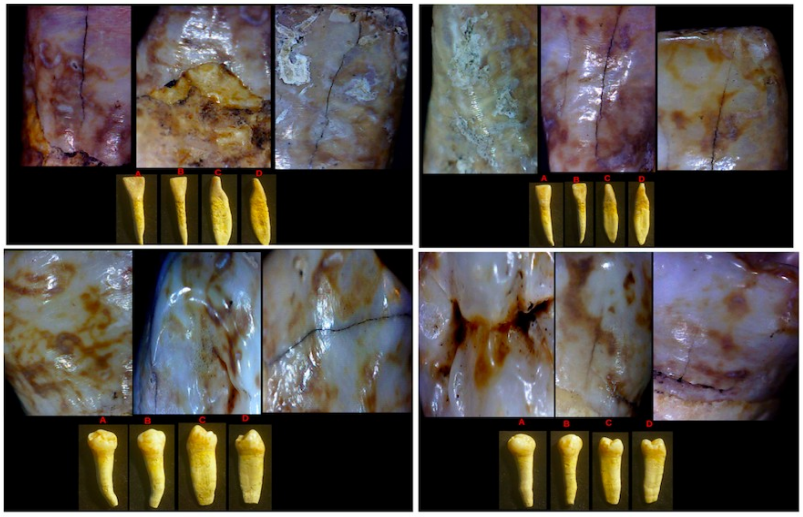

Figure 97: Nmt/Ind2. From left to right: lower first incisor A: lingual, B: buccal, C: mesial, D: distal; upper right: lower second incisor. Lower picture: left: lower first premolar: A: lingual, B: buccal, C: mesial, D: distal. Right: lower second premolar: A: lingual, B: buccal, C: mesial, D: distal. The fluorosis in several colors, from the white-milk, yellow to the dark brown color in the teeth surface. Plaque established scattered the surface of the first incisor (upper left teeth) and in the lower second incisor (upper right picture).

Appendix E: Human teeth from the Karas site

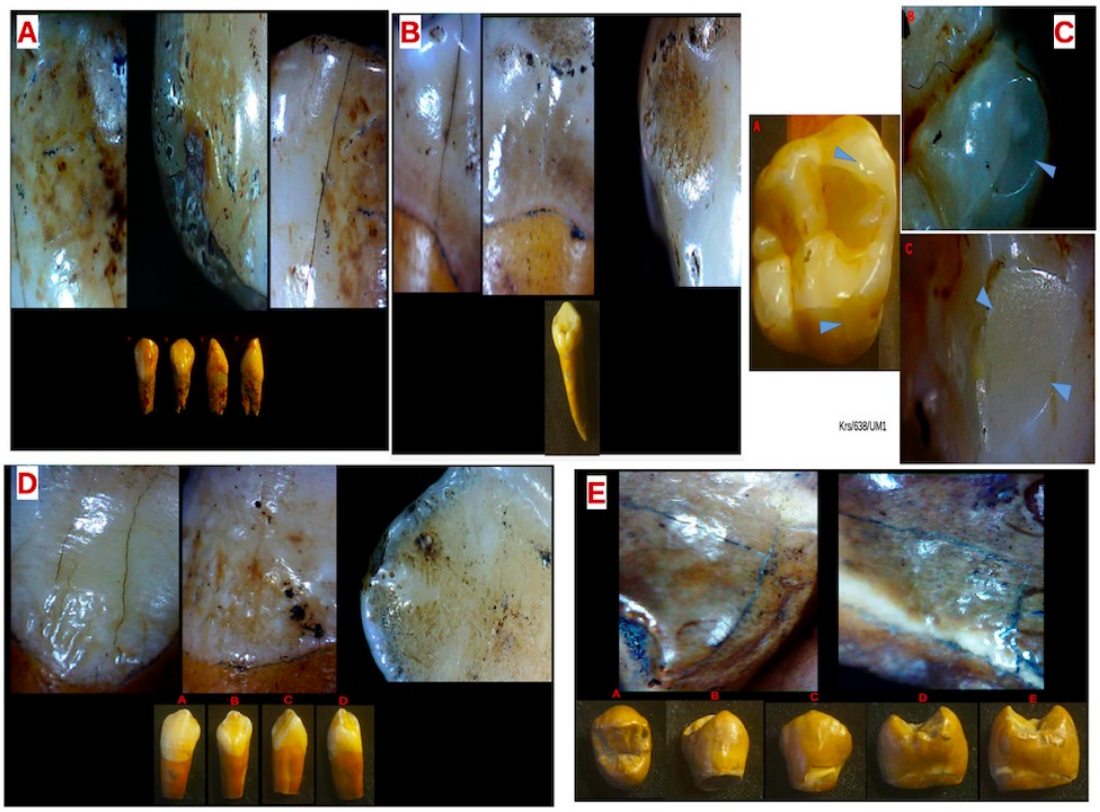

Figure 98: A (Krs/649/UC): Upper canine (fluorosis marked by dark brown color, abrasion established in the incisal area. B (Krs/334/LP1- lower first premolar): fluorosis marked by brown color, the abrasion on the occlusal area. C (Krs/638/UM1- Upper first molar) A, B, C: abrasion established in the occlusal aspect. D (Krs/41/LC-lower canine). Fluorosis is established on the tooth surface. Abrasion placed on the incisal area. E.(Krs/649/UP2- upper second premolars. A: occlusal aspect, B: lingual aspect, C: buccal, D: mesial, E: distal.

GLOSSARY

Abrasion Dental wear caused by the contact of the teeth with food or other materials passed over the teeth

Adaptation An anatomical, physiological, or behavioral response organisms or populations to the environment. Adaptations result from evolutionary change (specifically, as a result of natural selection)

Adaptive niche An organisms entire way of life: where it lives, what it eats, how it gets food, how it avoids predators, and so on.

Allele frequency In a populations, the percentage of all the alleles at a locus accounted for by one specific allele.

Alleles Alternate forms of a gene. Alleles occur at the same locus on paired chromosomes and thus govern the same trait. But because they're different, their action may result in different expressions that trait.

Ancestry Refers to a person's ethnic origin or descent, "roots", or heritage or the place of birth of the person or the person's parents

Anterior teeth Refers as a group to the incisor and canine teeth

Ancient DNA which can be recovered and analyzed from clinical, museum, archaeological and paleontological specimens

Anthropology The scientific study of humanity, concerned with human behavior, human biology, cultures and societies, in both the present and past including past human species

Austronesia A family of languages that includes the Formosan, Indonesian, Malay, Melanesian, Micronesian, and Polynesian subfamilies.

Attrition The dental wear caused by contact of the teeth with other teeth

Bioarchaeology The branch of archaeology that deals with the remains of living things

Bone collagen Material composed principally of collagen proteins; any of a class of extracellular proteins that are composed of three coiled polypeptidee chains, form strong fibers, and are the main constituents of cartilage, bone, and other connective tissues in animals

Buccal Cheek side of the posterior teeth (premolar and molars)

Buccolingual Concerning the buccal and lingual surfaces of a tooth

Calculus or tartar or plaque A solid pathological concentration and usually of organic matter, in a matrix of protein, surrounding the tooth and encrusting it. The substance can be removed.

Carbon isotopes Occur naturally include Carbon 12, Carbon -13, and Carbon -14. Carbon -12 and Carbon -13 are stable isotopes.

Cervical line Continuous anatomic irregular curved line marking cervical end of tooth crown and cementoenamel junction

Coronoid process The anterior part of the upper end of the Ramus of the Mandible

Cranium The large round superior part of the skull, enclosing the brain and made up of the cranial bones

Common Era Replacing anno domini, or AD in Latin in the year of the Lord). Chronology is always 'calibrated' in the sense that the radiocarbon dates that form the backbone of the archaeological chronology for the past 40,000 years are calibrated against real solar time by the dating of annual growth rings counted backwards from the present in overlapping series of ancient trees.

C_3 plants Plants in which the initial product of the assimilation of carbon dioxide through photosynthesis is 3-phosphoglycerate, which contains 3 carbon atoms

C_4 plants A plant in which the CO2 is first fixed into a compound containing four carbon atoms before entering the Calvin cycle of photosynthesis

Dental Relating to or for the teeth; intended for dentistry

Dental anthropology The multi-disciplined field of research which focuses on the study of dental wear and dental morphology in prehistoric and modern populations as a key to the biology and behavior of past and living populations

Dental wear The wear of the (mainly occlusal) surfaces of the teeth due to contact with other teeth, food, erosive chemicals, and other materials

Distal A tooth surface that is away from midline of the face

DNA (deoxyribonucleic acid) A double-stranded linear macromolecule which encodes an organisms genetic information; a complex Nucleic Acid molecule found in the chromosome of almost all organisms, which acts as the primary genetical material, controlling the structure of proteins and hence influencing all enzyme-driven reactions.

DNA Polymerase A group of enzymes that are responsible for the polymerization of free Nucleotides on to the unwound DNA molecule during DNA replication

Enamel-enamel apatite Biomineralization involves a variety of extra cellular events including protein secretion, structural organization of the protein matrix, nucleation and oriented growth of the carbonated apatite crystals and massive protein degradation

Ecofacts Naturally occurring and unmodified materials used by humans; preserve archaeologicall as animal bones and plants and seeds

Enamel The hard, calcareous covering of the crown of a tooth, which contains only a slight amount of organic substance

Excavation The methods used in archaeology studies; the action of excavating archaeological site

Fluorosis A chronic condition of poisoning with fluorosis, causing mottling of enamel.

Fluoride A compound of fluorine with another or group, especially salt of the anion F or an organic compound with fluorine bonded to an alkyl group

Femur The proximal bone of the hind or lower limb that extends from the hip to the knee-called also thighbone

Genomic The branch of molecular biology concerned with the structure, function, evolution, and mapping of genomes

Gonial flaring The angle of the mandible is located at the posterior border at the junction of the lower border of the ramus of the mandible

Genetic Relating to genes or heredity; relating to origin, or arising from a common origin

Haplogroup A group of similar haplotypes that share a common ancestor with a single nucleotide polymorphism mutation

Haplotype A haplotype is a group of alleles in an organism that are inherited together from a single parent

Holocene Denoting or formed in the second and most recent epoch of the Quaternary period, which began 10 000 years ago at the end of the Pleistocene

Humerus The bone that extends from the shoulder to the elbow

Incisor A chisel-edged tooth at the front of the mouth; a tooth adapted for cutting of gnawing

Incisal Relating or being the cutting edge of an incisor or canine tooth

Isotopes Refer to any of the two or more forms of the same element. They have the same number of protons but differ in the number of neutrons in their nuclei. Therefore, they differ in atomic mass number.

Isotopes of nitrogen The naturally-occurring isotopes of nitrogen are Nitrogen -14 and Nitrogen -15. Both are stable isotopes. Nitrogen -14 though is more common, accounting to the 99.63% of natural nitrogen. Nitrogen -15 is the less common stable nitrogen isotope, making up 0.37%of natural nitrogen. Nitrogen -13 is a cyclotron-produced, positron-emitting radioisotope of nitrogen.

Labial The side of a tooth that is adjacent to the inside of the lip
Kampung Is Indonesian word for village
Karwar The statue made of wood and formed like a human body used by the Biaknese tribe as grave goods
Lingual The side of a tooth adjacent to the tongue
Mandible The bone in the lower jaw of a person or animal
Mamelons The lines of fusion are seen as grooves on the incisal edge of newly erupted incisor
Mandible chin The forward pointed part of the anterior mandible (mental region) below the lower lip
Mandibular notch The upper border of the ramus of mandible is thin, and is surmounted by two processes, the coronid process anteriorly and the condyloid process posteriorly, separated by a deep concavity
Marginal ridge An enamel elevation on the crown of a tooth which forms the mesial or distal border of the occlusal surface
Melanesian A member of any of the indigenous peoples of Melanesia; A native of inhabitant of Melanesia; generally with the dark skin and frizzy hair
Mentum Is an anatomical structure, a projecting feature that is near the mouth; the protuding part of the chin
Mental protuberance The projection of the mandible
Mesial The forward side of the tooth
Mesiodistal Relating to the mesial and distal surfaces of a tooth
Mesioincisal Pertaining to or connecting the mesial and incisal surfaces of a tooth
Mesiolingual Relating to the mesial and lingual surfaces of a tooth
Mitochondria (sing., mithocondrion) Structures contained within the cytoplasm of eukaryotic cells that convert energy, derived from nutrients, to a form that can be used by the cel.
Mithodoncrial DNA (mtDNA) DNA found in the mitochondria. Mitochondrial DNA is inherited only from the mother
Molecules Structures made up of two or more atoms. Molecules can combine with other molecules to form more complex structures
Monotremes Any of various egg-laying mammals of the order Monotremata of Australia and New Guinea, whose only living members are the platypus and the echidnas
Morphological Pertaining to the form and structure of organisms
Morphology The form (shape, size) of anatomical structures; can also refer to the entire organism
Multidisciplinary Pertaining to research involving mutual contribution and cooperation of experts from various scientific fields (i.e., disciplines)
Mutation A change in DNA. The term can refer to changes in DNA bases (specifically called point mutations) as well as to changes in chromosome number and/or structure
Natural selection The most critical mechanism of evolutionary change, first described by Charles Darwin, refers to genetic change or changes in the frequencies of certain traits in populations due to differential reproductive success between individuals.
Near Oceania Is the part of Oceania settled 35,000 years ago, comprising Australia, New Guinea, and northwestern Island Melanesia, the Bismarck Archipelago and the Solomon Islands.
Neutrons Electrically neutral elementary particles found all atomic nuclei except light hydrogen; the mass is equal to that of the proton and electron combined and they are unstable when isolated from the nucleus, undergoing beta decay.
New Guinea The name of Papua island given by Spanish explorer Ynigo Ortiz Retez in 1545 referring to the similarities of the features of the indigenous peoples to those of native Africans of the Guinea region of the continent; ultimately meaning ‘land of the blacks’ or similar meanings, in reference to the dark skin of the inhabitants.

Nitrogen is one of the chemical elements found in nature. A chemical element refers to the pure substance of one type of atom. At present, 94 are natural elements whereas 24 are synthetic. Nitrogen is one of the most common elements in living things, together with carbon, hydrogen, and oxygen.

Nucleotides Basic units of the DNA molecule, composed of a sugar, a phosphate, and one of four DNA bases.

Nucleus A structure (organelle) found in all eukaryotic cells. The nucleus contains chromosomes (nuclear DNA)

Paleoanthropology The interdisciplinary approach to the study of earlier hominins-their chronology, physical structure, archaeological remains, habitats, and so on.

Paleopathology The branch of osteology that studies the evidence of disease and injury in human skeletal (or, occasionally, mummified) remains form archaeological sites.

Paleodietary A diet based on the types of foods presumed to have been eaten by early humans, consisting chiefly of meat, fish, vegetables, and fruit and excluding dairy or cereal products and processed food.

Phalanges The small bones of the fingers or toes in humans or the digits in other primates

Phenotypic affinities An inherent similarity between persons or things; A relationship or resemblance in structure between species that suggests a common origin

Phylogenetic Relating to phylogeny or phylogenetics; pertaining to, or based on phylogeny

Photosynthesis The process in green plants and certain other organisms by which carbohydrates are synthesized from carbon dioxide and a source of hydrogen (usually water), using light as an energy source.

Plaque A sticky film of bacteria that constantly forms on teeth, formed largely by the growth of bacteria that colonize the teeth

Posterior Refers as a group to the premolars and molars

Proton An elementary atomic particle with a positive and a mass of about 1 amu

Ramus of mandible The mandibular notch, separating the two processes, is a deep semilunar depression, and is crossed by the masseteric vessels and nerve

Remote Oceania Is the part of Oceania settled within the last 3,000 to 3,500 years, comprising southeastern Island Melanesia and islands in the open Pacific east of the Solomon Islands

Sexual dimorphism Somatic differences within species between male and female individuals that arise as a consequence of sexual maturation; the presence in a population of two sexes each with a different phenotype that arise as a consequence of sexual maturation; the presence in a population of two sexes each with a different phenotype.

Subgingival Below the gum line; calculus deposits are damaging to our gum line

Supragingival Above the gingiva; used in reference to the location of bacterial plaque, or calculus on the tooth

Tibia The inner and larger of the two bones of the lower leg

X-chromosome A type of sex chromosome containing genes which found in female

Y-chromosome A type of sex chromosome found in the male