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The *marae* of Taputapuātea (Ra'iatea, Society Islands) in 2016: nature, age and origin of coral erected stones

by

Bernard SALVAT*, Tamara MARIC**, Tyler GOEPFERT*** & Anton EISENHAUER***

ABSTRACT

The Taputapuatea marae *of Ra'iatea is an emblematic landmark known throughout the world and sacred place for the Ma'ohi of Eastern Polynesia and the centre of a vast political-religious-cultural network in the Polynesian triangle. The erected stones constituting the* ahu *have been described as "limestone slabs" without precision by previous authors. These are in fact microatolls: corals (*Porites*) living in very shallow water and developing laterally, with a growth in height being limited by the lowest tide at the time of growth. A total of 38 samples were U/Th dated, of which 19 microatolls result in ages between 3 and 5 millennia. These are fossil microatolls that existed at a Holocene sea level of 0.80 m higher than today, when the Polynesians had not yet arrived. Other samples (molluscs, coral filling blocks) date back to the construction of the marae during the 17th-18th centuries. We hypothesize that the erected microatolls of the* ahu *were collected by Polynesians at the site and that others are still underground.*

Keywords: archeology, *marae*, microatoll, Polynesia, datation

RÉSUMÉ

Le marae *Taputapuatea de Ra'iatea est un site emblématique mondialement considéré et un lieu sacré pour les Ma'ohi de la Polynésie orientale et le centre d'un vaste réseau politico-religieux-culturel du triangle polynésien. Les pierres érigées constituant l'*ahu *avaient été nommées « dalles calcaire » sans autre précision par les auteurs précédents. Ce sont des microatolls : coraux (*Porites*) vivant dans des eaux très peu profondes et se développant latéralement, la croissance en hauteur étant limitée par le bas niveau de la mer. Un total de 38 échantillons ont été datés (U/Th) sur dix-neuf microatolls, donnant des âges de 3 et 5 millénaires. Il s'agit de microatolls fossiles dont l'existence remonte à un niveau de la mer Holocène de 0,80 m plus élevé qu'aujourd'hui, époque où les Polynésiens étaient absents. D'autres datations (mollusques, blocs de remplissage de corail) datent la construction du* marae *des* XVII*e*-XVIII*e* *siècles. Nous émettons l'hypothèse que les microatolls fossiles érigés de l'*ahu *ont été collectés par des Polynésiens Polynésiens sur le site et que d'autres sont toujours sous terre.*

Mots-clés : archéologie, *marae*, microatoll, Polynésie, datation

Marae are sacred sites where Polynesians built lithic temples, prior to the 19th century. They are the testimony of ancient ceremonial and religious sites where Polynesians invoked their gods and ancestors. Some important *marae* also had a strong political role through the hierarchical socio-political system of the *Hui Ari'i* (High Chiefs) in the Society Islands, French Polynesia. The most monumental stone temples caught the attention of the first explorers of Oceania, such as Sydney Parkinson, Sir Joseph Banks and Hermann Dietrich Spöring, Cook's companions on his first trip when they visited the Taputapuātea site on Ra'iatea in the Society Islands in July 1769 (Eddowes, 2001: 78-85). Such temples were constructed in all the high volcanic islands and on the atolls of French Polynesia, with a great variety of architectural types.

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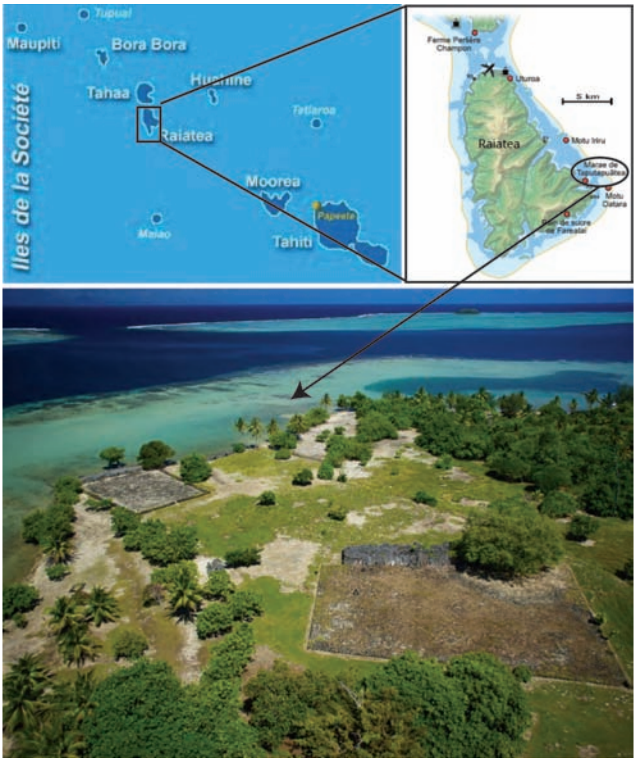

Photo 1. – Map of Leeewards Society Islands, localisation of the Taputapuātea site on Raiatea, aerial view of the site with the pass Te Ava Mo'a, the lagoon and its fringing reef, the *marae* Taputapuātea with a large plaform and the *marae* Hauviri on the left (© Matarai, *in* Herrenschmidt *et al.,* 2016: 71, fig. 45)

In the Society Islands, a specific architectural plan of *marae* developed around the 14th to 15th centuries. This plan regrouped essential elements that are present through east-central Polynesia temples according to different arrangements (Kirch & Green, 2001). An open space (*tahua*) became the quadrangular courtyard, sometimes enclosed by a stone wall. The *ahu*, an enclosed space made of stone alignments or an elevated platform, corresponded to the most sacred part of the *marae*, where upright stones were erected (*'ofa'i ti'a*). The *marae* were constructed with stones, metric to decimetric elements of basalt or coral, either in a natural or a worked form. Corals or limestone were collected from the reef or beaches.

According to the main ethno-historical sources, Henry (2000: 150), *marae* were constructed from local materials, those collected on the land where the *marae* was supposed to be implanted. But the construction of a prestigious *marae* for an *ari'i* (chiefly class) may have been an exception, as the whole community participated in this construction, mobilized by the chief and the priests. Every family of the political district had to bring a stone for this purpose (Morrison, 1981: 149), suggesting that non-local materials may have been used in high status *marae* construction. But one should consider that this testimony (James Morrison visited only Tahiti and Tubuai islands) concerns the Tahitian – Windward case, while we know that there were cultural differences in the Leeward islands (Handy, 1930: 85, 104). Some *marae* were founded from a stone taken on a more ancient *marae* of the same lineage – the term *ahutapae* meaning such a foundation of a new *marae* from a previous one (Davies, 1851). In this sense, many *marae* should have been constructed with a foundation stone, which was in principle more ancient than the other stones used for the construction. However, the way in which archaeologists can discover such testimony remains unclear.

Traditional temple construction technique, as elsewhere in Polynesia, used the stones without mortar, implying the relative fragility of such monuments. Thus, the *marae* were frequently maintained, reconstructed, and sometimes embellished and enlarged. Far from the vision of a « motionless » monument, the *marae* was as a « living » structure. It evolved with the generations, their changes in socio-political status and the re-dedication to new gods. Previous archaeological excavations on *marae* have shown that they have been repeatedly modified, and enlarged (among the most famous examples, see Garanger, 1975; Wallin and Solsvick, 2005; Kahn, 2013).

Between the 15th and the end of the 18th centuries, Tahitian society evolved through the emergence of local chiefdoms, and in the following centuries, into an increasing competition for prestige between chief families within the archipelago and also within some of the islands (Kahn, 2013; Maric, 2016: 256-258; Kirch, 2017). Thus the development of ceremonial architecture has been interpreted as a phenomenon resulting from these aspects of east-Polynesian socio-political dynamics.

The historical and archaeological complex of Taputapuātea in Ra'iatea, Leeward Islands in the Society archipelago (photos 1-2), as we will see in this article, is a particularly representative example from this point of view. In these islands, *marae* dedicated to the elite's (*ari'i*) social class were constructed with a specific architecture from the 16th to 17th centuries onwards (Wallin & Solsvik, 2005). The *ahu* were constructed with large, upright coral slabs, delineating a platform which was filled with basaltic, cobbles and pieces of coral, while the courtyards were often open, devoid of enclosing walls (Emory, 1933: 32-36; Gérard, 1974). Another characteristic of the main chief ceremonial centres of the late 18th century is their geographical location – on the shore of the lagoon and facing a reef pass – while the population of the district (*mata'eina'a*) lived through the entire territory, including the coast, the valleys and the mountains (Maric, 2016).

The Taputapuātea complex from Ra'iatea had a strong historical importance in the archipelago history during the 18th century, during which other *marae* Taputapuatea were founded in the islands of Tahiti and Mo'orea (Henry, 2000: 135-138; Gérard, 1974; Maric, 2016). Those Windward *marae* Taputapuātea were constructed during the mid-18th century after marriages between local *ari'i* with the chiefly family of Tamatoa from Opoa. In this sense, *marae* Taputapuātea from Opoa represents an emblematic case of tahitian *marae* and elite *hui ari'i* ceremonial centre. It provides an important case study to understand when and how high status chiefly *marae ari'i* were constructed with specific raw materials.

We worked on the *marae* Taputapuātea in 2016 with several objectives: defining what types of corals and other materials constitute the *ahu* – in order to determine and discuss the origins of these materials –, dating some elements – in order to establish as far as possible the date or dates of construction of the *marae.*

Photo 2. – Taputapuātea *marae*, view from north to south. The *marae* is 42.5 m long and 8.20 m wide on its northern facade in the foreground. Its south part is covered by a banian tree (© Matarai)

Description of the Taputapuātea complex

The *marae* Taputapuātea (photos 1-2) is located on the shore of the ancient district of Opoa, in the southeast region of Ra'iatea Island also known as Havai'i, the sacred island of the Society archipelago. The monument is part of a ceremonial complex founded on the Matahiraitera'i coastal promontory which faces the sacred reef pass, Te-ava-moa. It is made of five principal *marae* and other ceremonial structures such as platforms and other smaller *marae* (Herrenschmidt *et al.*, 2015).

Marae Hauviri was devoted to the chiefly family of the *ari'i* Tamatoa (Henry, 2000). The structure which today is named Ōpū Teina is interpreted as related to the junior lineage of the Tamatoa's line *marae*. The *marae* today named Tau'aitu on the land Hititai was a district *marae*. Those last three *marae* are situated directly in front of the lagoon with their *ahu* platform facing the reef pass, while Taputapuātea occupies a central place within the space of a coastal promontory, oriented north-south (photo 2). The small *marae* named *Ahu* o Hiro is located just at the south side of the *marae* Taputapuātea. Each of these *marae* globally share the same principal architectural components, notably a paved courtyard (*tahua marae*), an *ahu* being a rectangular platform delimitated with large coral and basaltic slabs which are vertically erected or set on edge, and an *ahu* interior filled with natural coral and basaltic blocks. We used the term "block" for these decimetric building elements which are natural and not worked by humans.

Taputapuātea is the most monumental *marae* on the site. The rectangular *ahu* platform is oriented south (mountain side) to north (lagoon side and towards the pass of the barrier reef). The west facade near the courtyard is 42.5 m long and made up of 23 slabs, erected or set on edge, 21 of which are limestone and two of which are basalt. The east facade is constructed of 27 limestone slabs. The short north facade (lagoon side) measures 8.20 m and the south facade measures 6.9 m and is covered by a banyan (*Ficus prolixa*) tree. The courtyard facing the west facade measures 60 per 40 m.

The interstices between some slabs of the west facade clearly reveal the presence of another internal facing of upright slabs of coral. As we will see, this structure corresponds to an ancient *ahu* platform, which was covered by the later platform.

On the top of the exterior *ahu* platform lies a rectangular enclosure measuring 14.30 m long and 5 m wide, made up of large rectangular elements of coral 2 m long. This structure may correspond to the "*ava'a rahi*", the place where the gods' images were exposed during the religious ceremonies (Henry, 2000). Another small platform is located on the courtyard, backed at the middle of the west facade of the *ahu* platform, corresponding to the "*ava'a*", another ceremonial platform. Several basaltic uprights are set in the courtyard.

According to various oral traditions and ethno-historical information, this prestigious site had a complex and sometimes controversial history (Eddowes, 2001). The period of its first construction is not known precisely. Oral traditions note that the Taputapuātea *marae* was founded from a stone coming from *marae* Vaeara'i, located in the lower Opoa valley. This site was locally known as the first *marae* constructed and dedicated to the god Ta'aroa (Handy, 1930). When the Taputapuātea *marae* was later founded at Matahiraitera'I, it was first dedicated to the god Ta'aroa and named "Tinirau-Hui-Mata-Te-Feoro". At another period, its name changed to "Vai'otaha", being dedicated to the new god 'Oro (son of Ta'aroa, god of fertility and war), and finally named Taputapuātea (Henry, 2000). Thus, according to this creation myth, we can infer that this *marae* had a long-time period and evolution. This is supported by the multiple periods of construction as observed in its material remains.

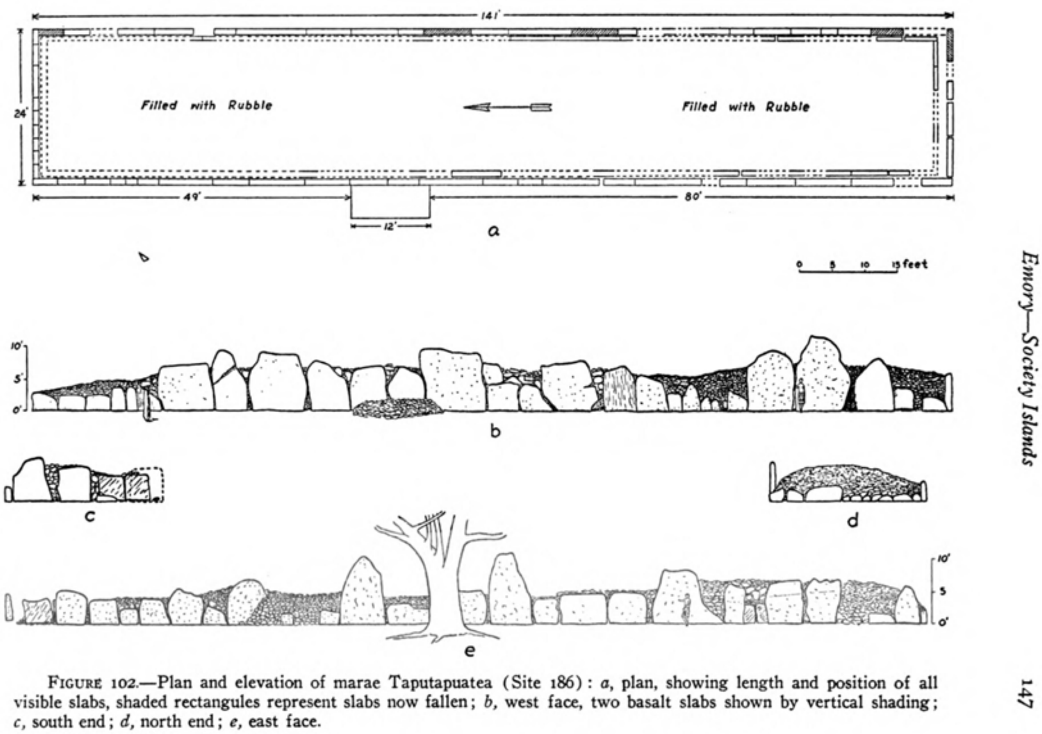

Figure 1. – The 4 facades of the Taputapuātea according to Emory (1933: 147). Below the slabs of the west and east facades

History of research

Archaeologist Kenneth Pike Emory from the Bishop Museum of Honolulu, Hawaii, was the first to conduct an extensive surface study of *marae* in French Polynesia (Emory, 1933). In Ra'iatea, he worked among others on the Taputapuātea complex by recording toponyms as well as the principal surface structures and the architectural components of the most important *marae* Taputapuātea. Emory (1933) published a sketch of the *marae* (fig. 1). Thus we have precise records about the architecture of *marae* Hauviri and *marae* Taputapuātea, including plan and sketches of the *ahu* platform facades in addition to traditional information such as the principal names of *marae* and natural and sacred boundaries that symbolically enclosed the site. Handy (1930) in parallel to Emory recorded the oral traditions and genealogies of the site with the help of Ro'ometua, a man whose ancestral family was devoted to the funeral treatment of the *ari'i* of the Tamatoa family; Ro'ometua likewise helped Emory in his recording of the sites and toponymy at the complex.

In 1962 and 1963, Kenneth Emory and Yoshihiko Sinoto from the Bishop Museum led an extended archaeological program in the Society Islands. Among numerous studies on archaeological sites in Ra'iatea, they test-excavated the Taputapuātea complex around the *marae* Taputapuātea and near the ceremonial platform providing the first radiocarbon dates on shells (Emory and Sinoto, 1965).

In 1968, in the context of restoring *marae* in the Society Islands, Sinoto carried out a first restoration of the principal *marae* Taputapuātea (Sinoto, 1969).

In 1994 and 1995 the second and last important restoration of the complex were directed by the Tahitian département d'Archéologie from the Centre polynésien des sciences humaines (Navarro *et al.*, 1995). During this major operation, *marae* Hauviri was entirely restored, the courtyard of Taputapuātea entirely scoured and its pavement restored up to the neighbouring small *ahu* of Hiro.

In 2005, the cultural association Tuihana in collaboration with archaeologist Paul M. Niva completed a new record of the complex, comprising all the archaeological structures. Three test-excavations were carried out: two on the ceremonial platform and the third one on the paved court of Taputapuātea, just below the *ahu* (Niva et Tuarau, 2006). This last operation confirmed the presence of an underlying pavement at a depth of about 50 centimetres.

In 2013, the service de la Culture et du Patrimoine - Te Pu o te Ta'ere e o te Faufa'a tumu (Office of culture and heritage which depends on the French Polynesian government) began a new study of the site, as part of the World Heritage program. A complete topographic recording was carried out with photographic and fieldwork observations focussing on the management of the whole site.

The present research was funded by the service de la Culture et du Patrimoine, in order to collect new chronological and descriptive elements of the future property (Herrenschmidt *et al.,* 2015). The ceremonial complex has been inscribed on the World

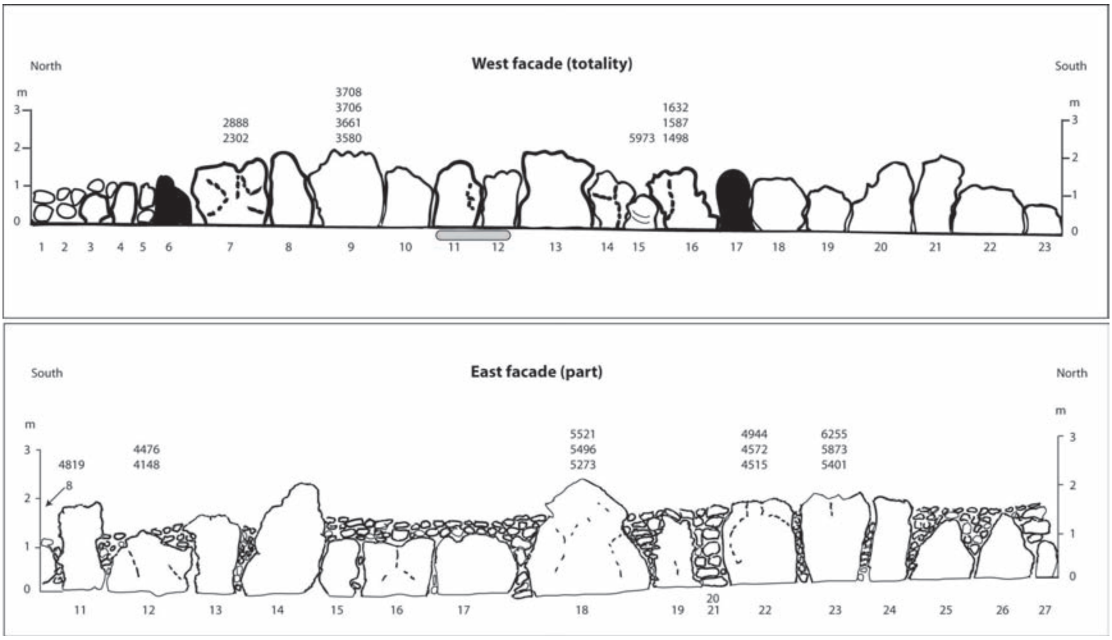

Figure 2. – The west and east facades of the Taputapuātea in 2017. West facade in totality and east facade with central and north parts. Numbering of the erected slabs (microatolls) except two basalt stones (black) on the west facade. Dating results of samples as ages before present. Examples: 5511 = 5511 years before present (2016) = 3495 years before Jésus-Christ; 1632 = 1632 years before present (2016) = 384 anno domini, after Jésus-Christ (ive siècle)

Heritage List since 2017, as a part of the cultural landscape property. The primary objective of our research was to establish a detailed description of the *ahu* of *marae* Taputapuātea as it existed in 2016, with a marine biologist's perspective of its core elements, namely the erected calcareous slabs of the *ahu* and its filling blocks. These elements had never been specifically identified more precisely than « coral » or « limestone ». The second objective was to determine when these *ahu* stones were erected, some of which correspond to coral formations well known by marine scientists as to their origin and growth as microatolls. Well-selected elements taken from these circular and tabular coral colonies could be dated indicating, as we hypothesized, the date when these colonies have been harvested from the lagoon by the Polynesians for the construction of the *marae*.

The *marae* of Taputapuātea: past descriptions, restorations, and situation in 2016

Past observations and restorations

The first descriptions of *marae* Taputapuātea come from Banks (1896) who was aboard the *Endeavor* during Cook's first voyage in 1768 (Cook, 1893). Emory (1933) and Eddowes (2001) reported on these descriptive elements. The first European visitors to the site describe very large *ahu* with coral slabs sometimes some 8 feet high with interstices filled with small blocks. Other components are described as "an extended courtyard without a curb, paved with basalt and coral stones".

Emory (1933) noted that Taputapuātea has the only *ahu* known to have a double alignment of coral elements: the exterior one having been added after the interior one by lengthening, widening and increasing the height of the structure. He noted that the west facade of the *ahu* platform, in front of the paved courtyard and corresponding to the *ahu* facade, comprises two basalt stones, while all other components were limestone.

Emory and Sinoto (1965) cleaned the *marae* in 1962 by removing trees on the *ahu* and straightening up some of the coral slabs that had fallen. They noted the fallen position of three slabs on the east facade, near the northern side. They remarked "test pits just outside of the paved court of the *marae* indicate that there is another pavement under the present one" (*ibid.*: 62). They took several samples of a coral slab from the *ahu*. They returned to the two aforementioned *ahu* (Emory, 1933), stating that the slabs of the internal *ahu* are small and sunk deeply into the ground, while those of the external *ahu*, which were put in place during a second phase, are larger and set shallower in the ground.

Sinoto directed in 1968 the partial restoration of four *marae* at the Taputapuātea site, "stabilizing them as much as possible using the stones available on the site" (Sinoto, 2001). The restoration of the *ahu* platform of Taputapuātea implied the recovery of tall slabs that had fallen, and thus the clearance of piles of fallen filling blocks. Sinoto then could observe the original first *ahu* platform under the surface one. The restoration report by Sinoto (1969) is unfortunately poorly documented but a photo of this underlying *ahu* and some archaeological notes were

Photo 3. – Taputapuātea *marae*, north and central parts of the west facade (© P. Bacchet)

found. Some of the fallen slabs have been restored by gluing their fragments with cement. This implies that there was no replacement of original slabs by new ones during the restoration. This point is particularly important, as it allowed us to suppose that all the erected slabs seen today are the original ones, and that the sample process for dating wouldn't be disturbed by modern slabs.

By the end of 1994, the département d'Archéologie in Tahiti conducted an intensive restoration of the entire complex found at Matahiraitera'i (Navarro *et al.,* 1995). Apart from the restoration of *marae* Hauviri and Hititai, the staff worked on the paved courtyard in front of the *ahu* of Taputapuātea *marae* and the *ahu* of Hiro *marae*. The excavation of the courtyard revealed a buried pavement situated between Taputapuātea's courtyard and Ahu o Hiro's courtyard. Thus, both *marae* seem to have shared the same courtyard. The *ahu* platform of Taputapuātea, already restored by Sinoto, was in a good state of preservation and was not further restored at this time.

The archaeological notes from Emory (1933) and Emory and Sinoto (1965) thus tend to correspond to information derived from the traditional history of the site, supporting the information that there were several phases of dedication of Taputapuātea. From an archaeological point of view, those rededications imply several construction, restoration and/or enhancement episodes, as has been documented in several other *marae* sites in the archipelago (Garanger, 1975; Sinoto, 2001; Wallin & Solsvick, 2005; Kahn, 2013).

The marae in 2016

Figure 1 is a reproduction of the arrangement of the slabs making up the four facades from Emory' sketch (1933). On this figure we numbered the slabs on the west and east facades. Figure 2 shows the 2016 slabs making up the west facade (slab n°1 to 23) and central and northern parts of the east facade (slabs n°11 to 27) with the same number as indicated in figure 1 of Emory in order to allow comparisons.

The courtyard, paved with basaltic stones, had been entirely restored in 1968 and 1995.

On the west facade (photo 3), facing the paved courtyard, all of the erected *ahu* slabs conform in size and shape with those represented on the Emory's sketch (Emory, 1933) except slabs numbered 19 to 23 on our figure 2 which do not correspond to Emory's slabs 19 to 29 on figure 1. The small platform *ava'a* is always in the same place in front of the stones erected from number 11 to 13 on Emory's figure 1 as we noted ourselves. Of note, slab 15 on figure 2, a triangular part of a limestone slab, has a surface with ridges and swales opposite to all other limestone slabs which surfaces are plainness.

The north facade (photo 4) is totally different in 2016 from that figured in Emory's original sketch. At the time of the first record (Emory, 1933) it seemed to have corresponded to a partly ruined wall of coral elements based on small upright slabs. This part of the *ahu* was restored by Sinoto in 1968 in following his first record: an initial alignment of upright slabs served as a foundation and were covered by 9 to 10 courses of coral elements. The present assemblage of these elements, large and small, forms a vertical and perfectly rectangular wall not revealing the interior of the *ahu* as figured on Emory's sketch (fig. 1) which shows only a few elements at the bottom and a lenticular pile above, corresponding to the inside of the *ahu*.

On the east facade (photo 5) almost all of the slabs of the *ahu* correspond in their sizes but not exactly in shapes to those shown in Emory's sketch when comparing figures 1-2. There are two exceptions. The

Photo 4. – Taputapuātea *marae,* north facade 8.20 m wide in 2017 as restored by Sinoto in 1998 that is very different from the one in the sketch of Emory, 1933 (© T. Maric)

first one is at the southern part of the facade where the stone numbered 1 represented in Emory's sketch is replaced by an assemblage of small *Porites* colonies. The second exception is at the opposite side of the east facade, namely at its northern part where original slabs after number 23 (mainly an accumulation of small blocks and only one erected slab) have been replaced by 4 erected slabs. The tree shown on Emory's *ahu* facing sketch at the slabs 12 and 13 on figure 2 has been removed.

Photo 5. – Taputapuātea *marae,* long east facade and south wide facade (© T. Maric)

The south facade (photo 6) is presently covered by banyan tree roots and ferns. The banyan tree was not depicted on Emory' sketch (1933). The east part of the facade (left on the photo 6) is similar to Emory' sketch but not the west part (right on photo 6).

With regard to the internal *ahu* and in light of a photograph reproduced by Sinoto (2001: 23) of the *marae* in 1968 that this one is no longer accessible in 2016 because is covered by decimetric blocks of fill.

In conclusion, although fallen upright slabs were straightened during the restoration in 1968, it appears that those which today constitute the *ahu* (external) are indeed those observed earlier by Emory (1933). However there are major exceptions to this on the north facade, on the southern part of the west facade and of the northern part of the east facade where modern materials have been incorporated into the original structure.

Identification of the coral materials constituting the *marae*

A vague qualification as limestone in the past

Previous studies of East Polynesian *marae* attempting to date the them lack detail on the types of limestone

Photo 6. – Taputapuātea *marae,* south facade 6.9 m large, almost entirely covered by banyan roots and ferns (© T. Maric)

materials used in their construction. They rarely use the word limestone but rather "coral slab" or "coral", the latter term being considered in contrast to basaltic materials often referred to as "volcanic" or "basalt stones". Concerning the *marae* in the Tuamotu atolls Souhailé (1972) used the following terms "pierre dressée" (erected stones) and "dalle" (slab). Molle et Conte (2015) uses the terms "coral block", "coral tile", "coral stones" and "coral gravel" and concerning the erected stones he writes "coral slabs, mostly extracted from sandstone beach". Wallin (1993) mentions "volcanic rocks like basalt, tuff and pumice stone – limestone coral, sandstone and coral". Solsvik and Wallin (2010) use "huge limestone or coral slabs, pieces of coral, coral lumps". Sharp *et al.* (2010) mention "coral used as architectural elements (facing veneers, cut-and-dressed blocks, and offerings)" and "living corals, coral heads". Sharp *et al.* (2010) study of the dating of corals sampled from a *marae* of Moorea is the only one to specify the identity of the coral colonies studied: decimetric colonies of *Acropora* (branching formation most often in parasol) and *Porites* (globular formation) but these are cut coral blocks of *marae* structure or filling pieces which are typical of Tahiti and Moorea *marae* and not erected stones as those on other Leeward Islands (Emory, 1933). All the other authors could not specify either the identity of the corals (genus) or the shape of the colony.

Identification of coral stones of Taputapuātea in 2016

For Taputapuātea the only descriptions of Emory (1933), Emory and Sinoto (1965), mention the following terms for calcareous erected formations of the *ahu*: "coral slabs", "limestone slabs". Stones/blocks constituting part of walls intercalated between these slabs and represented on the sketch of the facades of the *marae* (fig. 1) are shown but the authors do not mention their specific nature in their text. Inside the

Photo 7. – Alive microatoll of *Porites* (3 m diametre) on fringing reef, lagoon of Toau, Tuamotu archipelago (© P. Bacchet)

ahu the fill is either named "rubble" (Emory, 1933) or "stones" (Emory et Sinoto, 1965).

Figure 2 provides details on the identity and shape of these erected slabs for the two long west and east facades of the *ahu*. These are of 3 different types: 2 basaltic stones on the west facade (number 6 and 17 on fig. 2), sandstone beach (or beach rock) for a single unit on the east facade (number 11 on fig. 2), the remaining are particular formations of *Porites* called "microatolls" which are large colonies as opposed to *Porites* colonies in the fill material which are small with mean diameters of 30 to 50 centimetres. Material at the junction between tall and/or important erected slabs include small blocks of colonies of *Porites* of the same dimension as the fill. The identification of these formations sheds light on their origin.

Sandstone beach or beach rock is the result of an inorganic chemical cementation of grains and small debris of corals and a multitude of organisms such as foraminifers or skeletal fragments or tests of organisms (sea urchins, molluscs, etc.). Beach rock is formed in a beach (soft sediment) in contact with seawater and fresh water (freshwater lens or percolation of rainwater). These sandstone beaches are common around reefs, especially barrier reefs, and always have a gentle slope. Beach rock develops during marine regressions as a result of erosion and/or sea level change. This formation is very different from the "conglomerate" or cemented decimetric corals which are horizontal formations. Cemented corals were deposited when the sea level was about 80 cm higher than current, formed between 6000 and 1500 BP during a high Holocene sea level in French Polynesia (Pirazzoli *et al.*, 1988b; Hallmann *et al.,* 2018; Rashid *et al.*, 2014). This conglomerate constitutes the basis of the islet on atolls.

Small blocks filling the *ahu* and also found between upright *ahu* slabs are corals of the genus *Porites*. This coral builds massive formations whose size depends on its age and its environment, including the height of the water where it grows. The coral larva is established on a shell or dead coral fragment on the floor and will grow in an almost perfect hemispherical shape. The increase in thickness is a few millimetres per year and after about ten years the colony has the appearance of coral blocks of a diameter of about thirty centimetres, similar to the filling blocks inside many Society Island *ahu*. Given that the colony is located in shallow intertidal water, it is restricted in its vertical growth and continues to develop horizontally becoming a so-called "microatoll" form with a circular shape (Woodroffe and McLean, 1990; Woodroffe *et al.*, 1990).

Erected slabs of the *marae* are microatolls coral colonies of the genus *Porites.* When alive they were able to expand only laterally by giving a circular formation whose central part is often necrotic as shown on photo 7 representing a live microatoll in the lagoon of Toau atoll. They are named microatolls because they recall the shape of an atoll with its living exterior barrier reef and central lagoon. Microatolls (photo 7) can reach considerable sizes of several meters in diameter. Radiometric dating of the center showed that their rate of lateral growth is usually around 1 cm per year (Smithers, 2011). Some microatolls can reach a diameter exceeding 9 meters and are several centuries old (Siegrist and Randall, 1989). If the microatoll lives in shallow water (fringing zone) growth in height may reflect changes in sea level over time. They display in their morphology some ridges to different levels of the sea or to the displacements they underwent during periods of strong waves which could move them and change the height of water allowing them to grow in height. Their ridges and swales are characteristic of a "multiple-ringed microatoll" (Hopley, 1982). Microatolls are common in fringing lagoon areas with their living margins but are also found in emerged formation as "fossil" microatoll dating from the recent Holocene high sea level some 80 cm higher than present such as on photo 8 (Pirazzoli *et al.*, 1988a-b; Woodroffe and McLean, 1990; Woodroffe *et al.*, 1990; Scoffin, 1993; Fagerstrom and Weidlich, 2005; Woodroffe, 2008; Yamagushi *et al.*, 2009; Richmond *et al.*, 2011; Rashid *et al.*, 2014; Yamagushi et Yamano, 2014; Woesick *et al.*, 2015; Hallman *et al.*, 2018). The lower part of a microatoll rests on the sandy bottom, it is perfectly flat and is attacked by lithophagous and perforating molluscs like *Lithophaga*. These bivalves feed by filtering the water and bore their accommodation into the coral, which is revealed by small holes. Nearly all the erected microatolls of the *marae* present these observations with their lower surface punctuated by a multitude of holes (diameter of less than one centimetre) which are *Lithophaga* accommodations, sometimes occupied later by other lamellibranch tests.

The varied calcareous elements of the Taputapuātea *marae* are represented on figure 2. Two of the largest microatolls of the *ahu* are found on the east facade: number 22 (photo 9) and 18 (photo 10) height 2 and 2.5 m. Their thickness, depending on the height of the water in which they lived is about 0.40 m and their weights must be between 2 and 3 tons. With a lateral growth of 1 cm per year one can estimate that they grew from their first coral corallite for about 250 years. All the microatolls which are placed in the *ahu* display their flat lower face, the one which rested on the sand and with the perforations dug by the *Lithophaga*. The only exception is microatoll number 15 on the west facade which shows its upper face that has a multiple-ring corded form with ridges and swales.

Photo 8. – Fossil microatoll, lagoon of Takapoto, Tuamotu archipelago. This microatoll was alive 1000-2000 years before present when the sea level was about 0,80 m higher than present (© B. Salvat).

Sampling on Taputapuātea for dating

A long term objective of archaeological and ethnological studies is to date the construction of the *marae* and the activities that took place in such sites. For this, materials are collected on and around the *marae* for dating their age by the radiocarbon ^{14}c method and more recently the U/Th method. The harvested materials are most often fragments of coral. For example, Wallin and Solsvik (2006), in a survey of carbon-14 dating in the Society's Islands *marae*, reports dating on 36 charcoal samples, 2 wood samples, 2 coconut samples, 2 whale bones and 2 human skeleton fragments. Similarly, Wallin and Solsvik (2005) report 12 new dating on a Huahine *marae*: 9 on charcoals, 2 on pig bones and 1 on human skeletal remains.

Corals and sea shells have rarely been dated. A shell has been dated from the Taputapuātea *marae* (Emory and Sinoto, 1965). Solsvik and Wallin (2005) dated (via C-14) a fill inside the *ahu* of a Huahine *marae* without mentioning its species. Sharp *et al.* (2010) studying 19 *marae* in the Opunohu Valley, Mo'orea, dated 41 samples (U/Th) of which 32 were considered reliable; they were decimetric colonies of *Porites* and *Acropora* collected inside the *ahu* and "cut-and-dressed *Porites* coral blocks forming a base course in the *ahu* facade". Martinsson-Wallin *et al.* (2013) comparing radiocarbon dates on Rapa Nui (Easter Island) and Society monumental ceremonial sites, illustrating that of 53 results, most (35) were from charcoal samples and only 4 on corals and 1 on shell. We will refer later to this last sample and dating published by Sinoto in 1965 (sample Gak 299).

Our objective was to establish the date of construction of the *marae* from the samples collected on the limestone formations of the structure itself via carbon 14 and U/Th analysis. The strategy was to sample coral colonies that were alive before being removed from the water by the Polynesians. The beach rock represented by a single erected stone did not lend itself to this exercise. The *Porites* filling blocks lent themselves well with the sampling of a superficial part of the colony where corallites were still clearly visible. For microatoll slabs it was necessary to collect samples at the periphery of the colony when the *Porites* was still growing laterally in shallow water. The periphery of the microatolls always offer conspicuous and well conserved corallites for sampling. Finally, molluscs extracted from the small holes of the lower faces of the microatolls were dated since they were living in the coral structure at the moment when the microatoll was quarried from the lagoon for *marae* construction.

Emory and Sinoto (1965) had already seized the opportunity to date bivalves extracted from a "coral slab" but had not considered dating the corals themselves, ignoring the possibilities offered by *Porites* and microatolls:

> "Clam shells taken from the slabs of *marae* Taputapuātea were dated ad 1250 ± 100 years, using fresh shell for the control sample, and to ad 1670 ± 110, using modern wood for control, at Gakushin University, Tokyo (Gak 299, 1 and 2 respectively). Dr. K. Kigoshi of the laboratory reported that the second date was more accurate." (Emory and Sinoto, 1965: 63)

However, this date is unreliable because in 1965 alpha counting was still used as well as different radiocarbon half-lives, and there was no calibration or correction for marine reservoir ages. Nevertheless these data were burdened with large error bars and are not comparable to modern dating (Anderson et Sinoto, 2002). Martinsson-Wallin *et al.* (2013) con-

Photo 9. – Erected microatoll of the Taputapuātea *marae*, n°22 east facade, 2 m high, 2 tons estimation, 3 samples were dated 4944, 4572 and 4515 BP. Many small colonies of *Porites* are supporting the structure between erected microatolls (© B. Salvat)

Photo 10. – Erected microatoll of the Taputapuātea *marae*, n°18 east facade, more than 2,5 m high including buried part, 2.5 tons estimation, 3 samples were dated 5521, 5496 and 5273 BP. Many small colonies of *Porites* are supporting the structure between erected microatolls (© B. Salvat)

sider that an "age span of cal AD 1460-1890" for the Gak 299 dating has to be considered.

Samples taken in 2016 for dating include fragments of *Porites* colonies (microatolls and filling blocks) and mollusc tests. Careful sampling allowed preservation of the integrity of the *marae* during this World Heritage candidate process.

To sample the *Porites* corals we used a drill equipped with a mini-corer to harvest a superficial disk of the colony of 2.5 cm in diameter and 1.5 to 3 cm thick (photo 11) on a microatoll or sometimes with hammer and chisel. It should be noted that the greyish surface of the *Porites* is due to the presence of epilithic algae of the species *Entophysalis crustacea* (Salvat and Denizot, 1982) that colonize all limestone in the open air. The clear round spot after the sampling, depth 1-2 cm, left by the collected disk will be grey again after two years. For the microatolls a choice was made for dating on 4 units of the west facade and of 5 units of the east facade. Photos 9 and 10 illustrate 2 microatolls that have been sampled according to the drilling technique with, photo 12 showing a small fill coral colony inside the *ahu*. The samples were collected on the upper surface of the microatolls representing the living part of the colonies before being extracted from the water. All the samples extracted were localized on the faces of the microatoll inside the *ahu*, thus invisible for all visitors to the site. A total of 29 *Porites* samples were collected on microatoll slabs.

For bivalves harvested from the holes of the underside of the microatolls (the one faced to visitors) they were extracted with pliers (*Asaphis, Tellina*). For bivalves attached to *Porites* (*Ostrea, Chama*) or built in coral (*Tridacna*), a hammer and chisel were used (photo 13 for the sample of *Ostrea*). Shells were taken preferentially from the faces of the microatolls inside the *ahu*, or at the base of the slabs if it was on the outer facade visible to visitors. A total of 10 shellfish testes were collected.

Dating

Uranium/Thorium Age Dating

Uranium series measurements of corals were performed at the Helmholtz Centre for Ocean Research Kiel, in Kiel, Germany. In brief, separation of uranium and thorium from the sample matrix was done using Eichrom-uteva resin following previously published methods (Blanchon *et al.*, 2009; Douville *et al.*, 2010; Fietzke *et al.*, 2005). Uranium and thorium isotope ratios were determined using the multi-ion-counting inductively coupled plasma mass spectroscopy (mc-icp-ms) approach using the method of Fietzke *et al.* (2005). The ages were calculated using the half-lives published by Cheng *et al.* (2000). For isotope dilution measurements, a combined 233u/236uspike was used with stock solutions calibrated for concentration using nist-srm 3164 (u) and nist-srm 3159 (th) as combi-spike, calibrated against crm-145 uranium standard solution (formerly known as nbl-112a) for uranium isotope composition and against a secular equilibrium standard (hu-1, uranium ore solution) for the precise determination of 230th/234u activity ratios. Whole-procedure blank values of this sample set were measured between 0.5 and 1pg for thorium and between 10 and 20pg for uranium. Both values are in the range typical of this method and the laboratory (Fietzke *et al.*, 2005).

Photo 11. – Sampling on erected microatoll n°9 west facade of the Taputapuātea *marae*. This sample has been dated 3580 years BP and 3 others samples on the same microatoll were datet 3708, 3706 and 3661 years BP (© T. Maric)

Photo 12. – Filling block of the Taputapuātea *marae*, reference block D, 29 cm long, 10 kg estimation. The sample (white hole on the block) has been dated 270 years BP (© B. Salvat)

Table 1 summarizes all measured uranium and thorium data and the calculated U/Th ages. Recommendations of Dutton *et al.* (2017) were followed for the presentation. Table 2 presents the results of dating according to all samples collected on microatolls and filling blocks inside the *ahu*.

For uranium and thorium isotope analysis only samples with no detectable traces of calcite were used for measurements. The data show that 238U concentrations vary between 3.945 ± 0.008 ppm (R39, aragonitic coral) and 0.1172 ± 0.0003 ppm (R14, calcitic mollusc) with a mean 238U concentration of 2.91 ppm for the corals and 0.3 ppm for the mollusc samples. The concentrations of 232Th vary from 7.68 ± 0.07 ppb (R21) to 0.143 ± 0.003 ppb (R20) with an average value of 1.235 ppb for the corals and 1.123 ppb for the molluscs. Both the measured 232Th and 238U values are in the typical range for young corals from oceanic islands (Chen *et al.*, 1991). The δ234U(T) values show lowest values for sample R16 of 1.138 ± 0.007 and highest value of 1.155 ± 0.04 for sample R33. It is obvious that most of the δ234U(T) values fall within their statistical uncertainties in the range of the presently most precise δ234U seawater value of 146.8 ± 0.1 (Andersen *et al.*, 2010). Hence, all data can be considered to be robust and reliable.

Calculated U/Th ages for the coral samples vary between 6255 ± 78 (sample R38) to 244 ± 37 years (sample R17). These ages reflect the ages of emerged microatolls as they can be found all around the Polynesian islands (Rashid *et al.*, 2014). The average age uncertainty for the coral ages is in the order of ±60 years corresponding to an age uncertainty varying from 24 and 1% of the calculated coral age.

The U/Th age uncertainties for the mollusc samples (R14, R26, R33) are much higher and unreliable. The U/Th age of sample R14 of 559 years has an uncertainty of 1022 years corresponding to an uncertainty of more than 180%. Similar to it sample R26 (table 1) has a negative age corresponding to a large statistical uncertainty. Only mollusc sample R33 shows a relatively reliable U/Th age of 3025 ± 33 years. The tendency towards less reliable U/Th ages for molluscs is a consequence of the low U content of the calcitic mollusc shell in comparison with the U rich aragonitic corals. As a consequence the correction for inherited 230Th affects the age calculation to a large extend even producing negative ages as seen for sample R26. In order to avoid U/Th age dating problems the radiocarbon method is much more appropriate for molluscs.

Photo 13. – Sampling of a bivalve mollusc (*Saccostrea cucullata*) on the erected microatoll n°8 of the Taputapuātea *marae*, east facade. The bivalve has been dated 370 years BP (© T. Maric)

Radiocarbon ^{14}C Age Dating

Radiocarbon ^{14}C measurements on molluscs were performed at the AMS Facility of the Christian Albrechts University of Kiel, Germany, following standard procedures and protocols (Grootes *et al.,* 2004; Nadeau *et al*., 1998). Results of 8 radiocarbon dates are shown in table 3. For comparison and verification we additionally dated one coral fragment (R16) and two molluscs samples (R14, R26) by the radiocarbon method summarized in table 4. The measured conventional radiocarbon ages have been corrected for a reservoir age of 400 years and then calibrated to calendar year ages in order to be compatible with our U/Th data using the "Calib radiocarbon calibration Program, (Calib 6.11 program-Marine09)" by Stuiver and Reimer (1993). Based on the non-linear radiocarbon-calibration curve for sample R16 two suitable ages and for sample R26 three suitable ages have been calculated. In order to simplify the comparison with the U/Th ages we calculated weighted mean ages for samples R16 and R26. As can be seen from table 1 and 2 the calibrated radiocarbon ages and the U/Th ages are in general accord and are indistinguishable within their respective age uncertainties. This is in particular true for the coral fragment (R16) that could be U/Th and radiocarbon dated with about the same precision. However, the radiocarbon dating results are much more precise for the molluscs which emphasizes again that radiocarbon technique is more appropriate for calcitic molluscs than the U/Th method.

Results of dating

Table 2 reports the results of the dating U/Th on the samples performed on the microatolls and filling blocks and make possible the following observations:

1. When several samples were collected on the same microatoll, the obtained ages are very close to one another as can be seen on the column indicating the minimum and maximum ages. Each microatoll displays a different age from each other. This demonstrates the reliability of our sampling.

2. The age of 8 out of 9 microatolls is between 2600 y BP and 5953 y BP (the calendar years Anno Domini 583 and 3818 BC – Before Christ). The ninth microatoll, no. 16 of the west facade, is an exception with its 3 samples giving ages between 1498 y BP and 1632 y BP with a mean age of 1560 y BP (calendar year 457 AD – Anno Domini). The conclusion is that all microatolls were born, grew and died well before the 6th century AD and for the most part (8 out of 9), thousands of years ago.

3. The age of these coral samples indicates when the microatoll was in the lagoon, alive and growing. When we first noted that the erected slabs of the *ahu* were microatolls, we speculated that the Polynesians collected them in the lagoon to build the *marae* and that the dating of the coral at its exit from the lagoon, ie. when the coral died, would give us the age of area construction. The ages obtained correspond to a time when the Polynesians were not yet settled in East Polynesia (Conte, 2000, 2019; Kirch, 2017) supporting that older beached fossil corals were used in *marae* construction rather than newly quarried corals from the lagoon.

4. All sampled microatolls are fossils which were alive during the high Holocene sea level between 6000 y and 1200 y BP (see above), about 80 cm higher than present. They were collected by Polynesians on emerged shorelines after the lowering of sea level, presumably at the time of *marae* construction.

5. All filling blocks inside the *ahu* have a recent age between 236 and 339 years old. These decimetric colonies of *Porite*s, which were different from large metric erected microatoll slabs, were still alive and therefore in the lagoon in the 18th century. They were taken from the lagoon near the site to fill the platform *marae* surrounded by erected microatolls of the *ahu.*

6. The two samples R 21 and R 22 on *Porites* identified as part of the ava'a rahi enclosure indicate two different ages: R 21 dated 1535 y BP (calendar year 482 Anno Domini) being part of a fossil microatoll while R 22 dated 271 y BP (calendar year 1746 Anno Domini) was a wrong selection of sample in the field; it was not part of the ava'a rahi but a filling block.

7. In conclusion, the age of the samples mentioned in Table 2 clearly indicate that the microatolls used in the *marae* construction are fossil formations of several millennia that were later collected by Polynesians on land. In contrast, the small filling blocks are colonies of *Porites* collected alive in the lagoon during the 18th century.

Table 3 reports on shells dating sampled on fossil microatolls of the *ahu*. We have previously indicated that the fossil microatolls rested in an emerged zone bordering fringing reefs. They were generally resting on the sand without indurated attachments with the underlying substructures. The height of a microatoll is about 20 to 30 cm but sometimes up to 40 cm. These microatolls could have their bases regularly flooded by high tide, with seawater stagnating in their depressions in (photo 8). Under these conditions, bivalve molluscs whose diet consists of filtering water to feed on suspended particles could live in these protected habitats. This was the case of perforating bivalves such as *Lithophaga*. Likewise, Genus *Asaphis* (*Psammobiidae*) and *Tellinella* (*Tellinidae*) which live in coarse to medium sand under the microatoll where marine water is always present; their shells are a few centimetres long. *Saccostrea* (*Ostreidea*) and *Chama* (*Chamidae*) attach their inferior valve to coral; their shells are large, up to 5 centimetres. Mollusc samples collected on fossil microatolls reveal ages corresponding to calendar years between 2701 Before Christ and 1854 Anno Domini. Their deaths could have been simultaneous with that of the microatoll when the sea level lowered but it could have taken place afterwards if the base of the microatoll remained bathed by the marine water. The most recent ages are the most important as they relate to molluscs that were still alive at the time Polynesians collected microatolls to build the *ahu*. Considering samples R25, R36 and R09, table 3, we note that the molluscs were still alive respectively in 1659, 1742 and 1797 Anno Domini with an uncertainty for each date of the order of 50 to 60 years. One shell of *Chama* has been dated on a filling block inside the *ahu* and was 163 years old BP, 1863 Anno Domini. These shells of the erected microatolls constituting the *ahu* suggest that they have been collected in the field on the 17th-19th centuries causing the death of these molluscs which completely dried up.

In conclusion, dating on molluscs taken from the fossil microatolls indicates that these were collected on 17th-19th centuries by the Polynesians in the emerged littoral zone and that in no case were microatolls taken alive while thriving in the lagoon.

Discussion and conclusions

We started our research on the *marae* of Taputapuātea by noting that the erected stones of the *ahu* were microatolls of the *Porites* species. Previous authors failed to identify them as such and had not considered how their analysis could provide data on construction of the *marae*. We had initially hypothesized that Polynesians had quarried these microatolls from the lagoon, providing a date for their extraction from the water as well as a date for the construction of the *marae*. It is according to this hypothesis that samples from the *Porites* coral erected microatolls were dated. In addition, some shells of molluscs housed in the crevices of the erected microatolls were collected and dated with the same intention. In the same way some blocks filling the *ahu*, small rounded blocks of *Porites*, were sampled for dating.

All the dates on erected microatolls indicate that they are fossil formations well known to coral reef ecologists. These dead colonies can be found in an emerged position a few decimetres above the present high sea level. The ages of the vertically erected fossil microatolls that make up the *ahu* are between 1498 and 6255 BP, and most of them are more than two millennia old. These microatolls were living formations in the high Holocene sea level between 6,000 and 1,200 BP, about 80 cm higher than the current one. Following marine regression, microatolls became dry and emerged on a shoreline that was partially backfilled by alluvial deposits in the watershed and lagoon sediments. Given their height, sometimes more than 40 cm, they were nevertheless visible by the Polynesians who collected them. These microatolls were collected by the Polynesian on the shoreline already as fossil microatolls. Consequently the ages of these fossil microatolls themselves are without any relation to the construction of the *ahu*.

Considering that the topography of the entire *marae* Taputapuātea complex is less than 1 meter above sea level, we hypothesize that these fossil microatolls were harvested locally from the beach and then erected vertically after being rolled by Polynesians to build the *ahu*. Given the huge size of the microatolls used as dressed slabs on the construction of *ahu* platform, it is hard to admit that the ethnohistorical information about the construction of *ari'i marae*, where people of the district had to bring their own stone (Henry, 2000) would apply for this type of coastal temples. The littoral zone where these fossil microatolls were located was the shoreline which was periodically flooded by high tides thus receiving only high tide submersions ensuring the presence of marine water at the base of these dead-fossil microatolls. Molluscs living at the base of these fossil microatolls died when the microatolls were erected by the Polynesians. Hence, their ages indicate that this happened during the 18th century.

The dated filling blocks give ages assuring that their harvest in the nearby lagoon also dates to the 18th century. And the mollusc radiocarbon dating indicate dates between the mid-17th to the end of the 18th centuries. All these ages converge to a date for the construction of the Taputapuātea *marae* between mid-17th to 18th century, which remains consistent with the "return date" of the clam radiocarbon dating of Emory and Sinoto (1965) as corrected by Martinsson-Wallin (2013): "age span of cal AD 1460-1890".

This period, mid 18th century, is consistent with the dating done on the largest *marae* of the island of Mo'orea, in the Windward Islands (Sharp *et al.*, 2010; Kahn, 2010). This recent study shows that these *marae* associated with the elite *ari'i* had been modified and enlarged, often in several stages, and that the final period of monumental architecture in the Society Islands, and more specifically the Windward islands, began in the 18th century. The mid-17th century dating on molluscs would add data in favor of an older development of monumental architecture in the Leeward islands, or specifically in Taputapuātea. Indeed, the ultimate architectural development of the temples, as observed in the Windward islands, is supposed to be related to the cult of 'Oro, god of fertilty and war (Babadzan, 1993). This new god, son of the paramount god Ta'aroa, is closely linked to *marae* Taputapuātea, which was the original and principal ceremonial center at the end of the 18th century – according to the "official traditional version" – while in another version, the origin of 'Oro is related to the island of Bora Bora (Eddowes, 2001). This monumental development of ceremonial architecture was halted by christianization in the early 19th century in the Windward Islands, mid to late 19th century in the Leeward Islands.

Further research is necessary to document the *marae* complex in the Society Islands. Evaluating the time of the initial construction of the *marae*, and any subsequent successive reconstructions, is needed in order to put our results within chronological context. Current data suggests that the period of extension of *marae* Taputapuātea falls at the end of the first half of the 18th century, which is contemporary with the monumental development of the Windward Islands coastal *marae*. In this perspective, our new dating of *marae* Taputapuātea, one of the initial – and supposedly the most ancient – major ceremonial complex in the Society Islands falls in a general tendency in the archipelago. Considering that *marae* Taputapuātea is not the most monumental *marae* of the Leeward Islands, it would be interesting to date other major ceremonial complexes as *marae* Tainu'u on the same island, and similar *marae* complexes on Huahine, Bora Bora and Maupiti.

Additional work at *marae* Taputapuātea should be applied to the internal slabs and fill of the interior *ahu* platform, whose real function remains unknown. It can be hypothesised to be an initial and smaller *ahu* platform, constructed before the enlargement of the *ahu* platform. Yet Emory and Sinoto (1965: 63), in their first observations, supposed it was a substructure whose purpose was to consolidate the huge platform. In his article published in 2001, Sinoto (2001: 16-18) proposed an hypothesis of a chronological sequence for the development of coastal/*ari'i marae* architecture in the Society Islands. Considering the existence of a two-stepped *ahu* platform on the most monumental of the Leeward Islands, *marae* Anini and *marae* Manunu in the island of Huahine, he interpreted the internal *ahu* platform of Taputapuātea as one of the first two-degree *ahu*. This new type may have been imitated in a monumental way in Huahine. Then the builders of Taputapuātea would decide to enlarge the Taputapuātea *ahu*, but would not have the time to finish the final erection of the second step before the arrival of the Europeans.

The data on the Taputapuātea site as well as on the global context of the Leeward Islands' *marae*, are insufficient for the moment to discuss further. In order to collect new data on the stages of construction of Taputapuātea, archaeological excavation of the platform will be necessary, and this will only be possible during the next restoration. This study should be coupled with test-excavation under the courtyard pavement, in order to collect radiocarbon sampling connected with the underlying pavement found by Emory and Sinoto in 1963, and from which we know that this level has been preserved from the successive modern restorations performed in 1968 and then in 1995. Such a study should also be coupled with a geomorphological study of the littoral zone and a new approach by echo sounding in order to determine if other fossil microatolls are underground in the zone, reinforcing the hypothesis that erected microatoll slabs of the *marae* have been raised locally by Polynesians.

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TABLE 1. – Uranium/Thorium data analysis

sample	lab Nr.	Age	±	min-Age	max-Age	U238	±	Th232	±	Th230	±	Th230/Th232	±	U238/Th232	±	Th230/U238	±	Th230exc/U238	±	U234/U238	±	U234/U238 initial	±
external	internal	ky	ky	ky	ky	ppm	ppm	ppb	ppb	ppt	ppt	dpm/dpm	dpm/dpm	dpm/dpm	dpm/dpm	dpm/dpm	dpm/dpm	dpm/dpm	dpm/dpm	dpm/dpm	dpm/dpm	dpm/dpm	dpm/dpm
R3	lab nr. 452-16	2,302	0,053	2,250	2,355	2,505	0,009	0,907	0,026	0,981	0,016	219	9	9142	366	0,024	0,000	0,024	0,000	1,143	0,007	1,144	0,007
R4	lab nr. 453-16	2,888	0,061	2,827	2,949	2,486	0,006	1,154	0,015	1,214	0,020	209	6	7001	169	0,029	0,000	0,030	0,001	1,140	0,004	1,141	0,004
R5	lab nr. 454-16	3,580	0,059	3,522	3,640	3,170	0,009	0,190	0,003	1,915	0,022	2934	512	79514	13838	0,036	0,000	0,037	0,000	1,143	0,005	1,145	0,005
R6	lab nr. 455-16	3,661	0,049	3,612	3,710	2,617	0,003	0,478	0,005	1,620	0,016	739	40	19550	1038	0,037	0,000	0,038	0,000	1,145	0,003	1,147	0,003
R7	lab nr. 456-16	3,706	0,058	3,648	3,765	2,603	0,007	0,192	0,001	1,628	0,017	2545	481	66579	12564	0,038	0,000	0,038	0,000	1,144	0,005	1,146	0,005
R8	lab nr. 457-16	3,708	0,057	3,652	3,765	2,941	0,007	0,164	0,002	1,844	0,018	3727	892	97338	23267	0,038	0,000	0,038	0,000	1,146	0,006	1,148	0,006
R15	lab nr. 458-16	0,264	0,044	0,220	0,308	2,125	0,005	0,226	0,002	0,097	0,016	118	26	42368	6216	0,003	0,000	0,003	0,000	1,146	0,006	1,146	0,006
R16	lab nr. 459-16	0,236	0,036	0,201	0,272	2,549	0,007	0,996	0,011	0,106	0,015	21	3	8420	221	0,003	0,000	0,002	0,000	1,145	0,005	1,145	0,005
R17	lab nr. 460-16	0,244	0,037	0,208	0,281	2,746	0,008	0,436	0,004	0,116	0,016	60	9	23359	1554	0,003	0,000	0,003	0,000	1,138	0,007	1,138	0,007
R18	lab nr. 461-16	0,339	0,033	0,306	0,373	2,743	0,007	0,219	0,001	0,161	0,015	201	34	55992	8052	0,004	0,000	0,004	0,000	1,152	0,005	1,152	0,005
R27	lab nr. 464-16	4,476	0,080	4,397	4,557	3,501	0,009	2,946	0,040	2,657	0,033	173	4	3722	60	0,046	0,001	0,046	0,001	1,149	0,005	1,151	0,005
R28	lab nr. 465-16	4,148	0,075	4,073	4,224	3,914	0,013	4,770	0,038	2,760	0,033	110	2	2546	25	0,043	0,001	0,043	0,001	1,149	0,006	1,150	0,006
R29	lab nr. 466-16	5,496	0,070	5,427	5,567	2,978	0,008	0,762	0,007	2,742	0,021	741	25	13183	439	0,056	0,000	0,056	0,000	1,144	0,005	1,146	0,005
R30	lab nr. 467-16	5,521	0,075	5,446	5,596	3,034	0,007	0,628	0,006	2,799	0,025	933	37	16547	641	0,056	0,001	0,056	0,001	1,141	0,005	1,144	0,005
R32	lab nr. 468-16	4,515	0,070	4,445	4,585	3,220	0,011	0,297	0,003	2,440	0,023	2019	200	43627	4301	0,046	0,000	0,046	0,000	1,142	0,006	1,143	0,006
R34	lab nr. 469-16	4,572	0,061	4,511	4,633	2,746	0,008	0,525	0,004	2,117	0,017	863	41	18332	849	0,046	0,000	0,047	0,000	1,146	0,005	1,148	0,005
R37	lab nr. 470-16	5,873	0,085	5,788	5,958	3,648	0,012	0,548	0,003	3,580	0,030	1400	65	23358	1075	0,059	0,001	0,060	0,001	1,143	0,006	1,146	0,006
R38	lab nr. 471-16	6,255	0,078	6,177	6,334	3,052	0,008	0,615	0,004	3,193	0,023	1088	43	17020	660	0,063	0,000	0,064	0,000	1,146	0,005	1,149	0,005
R39	lab nr. 472-16	5,401	0,064	5,337	5,465	3,945	0,008	0,475	0,003	3,551	0,023	1641	91	29837	1634	0,054	0,000	0,055	0,000	1,138	0,005	1,140	0,005
R10	lab nr. 475-16	5,973	0,085	5,889	6,059	3,204	0,009	5,895	0,024	3,210	0,028	103	1	1681	11	0,060	0,001	0,061	0,001	1,142	0,005	1,144	0,005
R11	lab nr. 476-16	1,587	0,048	1,540	1,635	2,498	0,012	0,173	0,002	0,674	0,016	1225	259	74241	15604	0,016	0,000	0,016	0,000	1,142	0,007	1,143	0,007
R12	lab nr. 477-16	1,498	0,055	1,444	1,553	2,645	0,007	0,211	0,002	0,679	0,022	944	170	60155	10655	0,015	0,000	0,016	0,001	1,150	0,005	1,151	0,005
R13	lab nr. 478-16	1,632	0,044	1,588	1,676	2,975	0,013	0,496	0,006	0,830	0,016	363	20	21327	1126	0,017	0,000	0,017	0,000	1,147	0,008	1,147	0,008
R20	lab nr. 479-16	0,270	0,041	0,229	0,311	2,214	0,007	0,143	0,003	0,103	0,015	257	82	90574	25806	0,003	0,000	0,003	0,000	1,147	0,007	1,147	0,007
R21	lab nr. 480-16	1,535	0,044	1,492	1,579	3,579	0,008	7,684	0,067	0,960	0,020	24	1	1437	14	0,016	0,000	0,016	0,000	1,144	0,006	1,145	0,006
R22	lab nr. 481-16	0,271	0,038	0,234	0,309	2,479	0,007	0,228	0,003	0,116	0,015	138	27	48218	6755	0,003	0,000	0,003	0,000	1,150	0,006	1,150	0,006
R23	lab nr. 482-16	4,819	0,065	4,755	4,885	2,769	0,006	3,314	0,023	2,251	0,019	130	2	2610	26	0,049	0,000	0,049	0,000	1,144	0,005	1,146	0,005
R31	lab nr. 483-16	5,273	0,076	5,198	5,350	2,843	0,008	0,460	0,004	2,528	0,023	1205	67	22184	1221	0,054	0,001	0,054	0,001	1,150	0,005	1,153	0,005
R35	lab nr. 484-16	4,944	0,078	4,867	5,022	2,696	0,005	0,672	0,007	2,242	0,026	700	29	13786	554	0,050	0,001	0,051	0,001	1,146	0,004	1,148	0,004
R14-tridacna	lab nr. 493-16	0,559	1,022	-0,451	1,592	0,117	0,000	0,179	0,003	0,012	0,020	26	47	4324	1553	0,006	0,011	0,006	0,011	1,151	0,008	1,151	0,008
R26-Ostrea	lab nr. 494-16	-0,176	-0,656	0,478	-0,834	0,163	0,000	0,273	0,003	-0,004	0,018	n.d.	n.d.	2676	386	-0,002	-0,007	-0,002	-0,007	1,151	0,007	1,151	0,007
R33-Chama	lab nr. 495-16	3,025	0,329	2,698	3,356	0,621	0,001	2,917	0,017	0,330	0,033	22	2	681	11	0,032	0,003	0,032	0,003	1,154	0,004	1,155	0,004

All statistical errors are two standard deviations of the mean (2σ mean). All samples have been corrected for initial ^{230}Th by using a $^{230}Th/^{232}Th$ activity ratio of 0.66 ± 0.25. Non reported data consist of $^{230}Th/^{232}Th$ ratios which became negative due to background corrections. 238U concentrations are not corrected for the background. n.d. = not detectable; act.ratio=activityratio

Table 2. – U/Th dating results either on erected microatolls or filling blocks. Analysis 2017

	Sampling number	Dating number	AGE ky	± ky	Mini Age ky	Maxi Age ky	Microatoll Age mini - maxi ky	Mean Age microatoll ky	Before Christ (BC) Anno Domini (AD)
East Facade									
Microatoll 7	T 7 A	R3	2,302	0,053	2,250	2,355	2,250 - 2,949	2,600	BC 583
	T 7 B	R4	2,888	0,061	2,827	2,949			
Microatoll 9	T 9 A	R5	3,580	0,059	3,522	3,640	3,522 - 3,765	3,643	BC 1626
	T 9 B	R6	3,661	0,049	3,612	3,710			
	T 9 C	R7	3,706	0,058	3,648	3,765			
	T 9 D	R8	3,708	0,057	3,652	3,765			
Microatoll 15	T 15 A	R10	5,973	0,085	5,889	6,059	5,849 - 6,059	5,953	BC 3936
Microatoll 16	T 16 A	R11	1,587	0,058	1,540	1,635	1,444 - 1,676	1,560	AD 457
	T 16 B	R12	1,498	0,055	1,444	1,553			
	T 16 C	R13	1,632	0,044	1,588	1,676			
West Facade									
Microatoll 8	T 8 A	R23	4,819	0,065	4,755	4,885	4,755 - 4,885	4,819	BC 2602
Microatoll 12	T 12 A	R27	4,476	0,080	4,397	4,557	4,073 - 4,557	4,315	BC 2298
	T 12 B	R28	4,148	0,075	4,073	4,224			
Microatoll 18	T 18 A	R29	5,496	0,070	5,427	5,567	5,198 - 5,596	5,397	BC 3380
	T 18 B	R30	5,521	0,075	5,446	5,596			
	T 18 C	R31	5,273	0,073	5,198	5,350			
Microatoll 22	T 22 A	R32	4,515	0,070	4,445	4,585	4,445 - 5,022	4,733	BC 2716
	T 22 B	R34	4,572	0,061	4,511	4,633			
	T 22 C	R35	4,944	0,078	4,867	5,022			
Microatoll 23	T 23 A	R37	5,873	0,085	5,788	5,958	5,337 - 6,334	5,835	BC 3818
	T 23 B	R38	6,255	0,078	6,177	6,334			
	T 23 C	R39	5,401	0,064	5,337	5,465			
Filling blocks							**Block Age mini - maxi**	**Mean Age block**	
Block A	T A	R 15	0,264	0,044	0,220	0,308	0,220 - 0,308	0,264	AD 1753
Block B	T B	R 16	0,236	0,036	0,201	0,272	0,201 - 0,272	0,236	AD 1781
Block C	T C 1	R 17	0,244	0,037	0,208	0,281	0,208 - 0,373	0,290	AD 1727
	T C 2	R 18	0,339	0,033	0,306	0,373			
Block D	T D	R 20	0,270	0,041	0,229	0,311	0,229 - 0,311	0,270	AD 1747
Ava'a of ahu									
T Ava'a A	T A A	R 21	1,535	0,043	1,492	1,579	1,492 - 1,579	1,535	AD 482
T Ava'a B	T A B	R 22	0,271	0,027	0,234	0,309	0,234 - 0,309	0,271	AD 1746

TABLE 3. – Radiocarbone dating results on molluscs either on erected microatolls or filling blocks (Analysis 2017)

Studied Microatoll	**Mollusc sampling**	**Sampling number**	**Dating number**	**(C14) Age ky**	**Calibrated Range, BP 2017 mini - maxi Ag - ky**	**Corresponding U/Th age BP ky**	**Before Christ (BC) Anno Domini (AD)**
Microatoll 3 West facade	*Asaphis* - T 3	R01	KIA51856	2,650 ± 0,025	2,280 - 2,430	2,355 ± 0,075	BC 338
Microatoll 7 West facade	*Tellina* - T 7	R02	KIA51857	1,620 ± 0,025	1,110 - 1,260	1,185 ± 0,075	AD 832
Microatoll 9 West facade	*Asaphis* - T 9	R09	KIA51858	0,660 ± 0,020	0,260 - 0,380	0,320 ± 0,060	AD 1797
Microatoll 8 East facade	*Tellina* 1 - T 8 1	R24	KIA51860	1,680 ± 0,020	1,180 - 1,285	1,233 ± 0,053	AD 784
Microatoll 8 East facade	*Tellina* 2 -T 8 2	R25	KIA51861	0,715 ± 0,015	0,295 - 0,420	0,358 ± 0,063	AD 1659
Microatoll 22 East facade	*Chama* - T 22	R33	KIA51862	4,510 ± 0,020	4,630 - 4,805	4,718 ± 0,087	BC 2701
Microatoll 22 East facade	*Asaphis* - T 22	R36	KIA51863	0,625 ± 0,020	0,225 - 0,325	0,275 ± 0,050	AD 1742
Block D inside *ahu*	*Chama* - T D	R19	KIA51859	0,525 ± 0,015	0,075 - 0,250	0,163 ± 0,088	AD 1854

TABLE 4. – Comparison of radiocarbone and Uranium/Thorium dating on coral and molluscs

Sampling number	**Dating number**	**Coral or Mollusc**	**Radiocarbon Age**	**Correction for reservoir effect**	**Calibrated Radiocarbon Age**	**U/Th Age**	**Calibrated Absolute Age (AD)**
R 14	KIA51428	*Tridacna*	2010 ± 30 BP	1610 ± 30 BP	1550 BP		465 ± 73 (95.4%)
R 16	KIA51429	*Porites*	520 ± 25 BP	120 ± 25 BP	193 ± 42 BP (31.4%) 145 ± 69 BP (64.0%) Mean: 161 ± 69 BP	236 ± 36 BP	1822 ± 73 1870 ± 69
R 26	KIA51430	*Ostrea*	655 ± 25 BP	255 ± 25 BP	469 ± 69 BP (13.3%) 384 ± 20 BP (65.2%) 225 ± 10 BP (15.7%) Mean: 370 ± 69 BP		1546 ± 69 1631 ± 20 1790 ± 10

BP: Before Present, present set to 2015