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# The rua whetu joint: Detail as origin

INTERSTICES 17

## Introduction

Architecture has often retreated from its obligations of contemporary relevance back to the comforts of origins. Architectural history has provided the mechanisms that bestowed authority on the notion of the origin and therefore on architecture itself.

But to return to origins comes with costs. The ever-reducing tendencies of the journey to origin lead inevitably to simplification and omission. This paper examines the architectural detail, not as a peripheral element of the more important and larger whole, but as a microcosm in which the geometrical, structural and cosmological dimensions of the building activate the architectural whole. However, the conceptualisation of this joint as a microcosm of the house will be argued to simultaneously enact a return to the geometrical, material and cosmological origins of the Maori world itself, as contained in the Te Ao Marama construct.<sup>1</sup>

This paper is concerned specifically with the development of one structural joint characteristic of whare Māori, and in particular the wharenui (large meeting house) of the 19th century. However, the joint is more specifically characteristic of those houses constructed from individually crafted components; “of whakano-ho, wrought timber, properly fitted together” (Best 1924: 562). It is within this fitted character of whare construction that this paper will examine the development and trajectories of the joint.

The junction with which this paper is concerned is that between the poupou (wall posts) and the heke (rafters). If the heke and the recess into which it slots is square or rectangular, the joint is known as the waha paepae. If the heke are semi-circular in cross section and the recess in the top of the poupou corresponds, then it is known as the whakarua whetu or rua whetu (Fig. 1). These drawings represent the two basic types of joint. There are, however, variants of these joints which developed within different iwi rohe (tribal territory).

The paper documents and examines the development of these joints as foundational artefacts in the evolving structural/cultural entity of the meeting house. The paper suggests that these joints have not received critical attention. Instead,

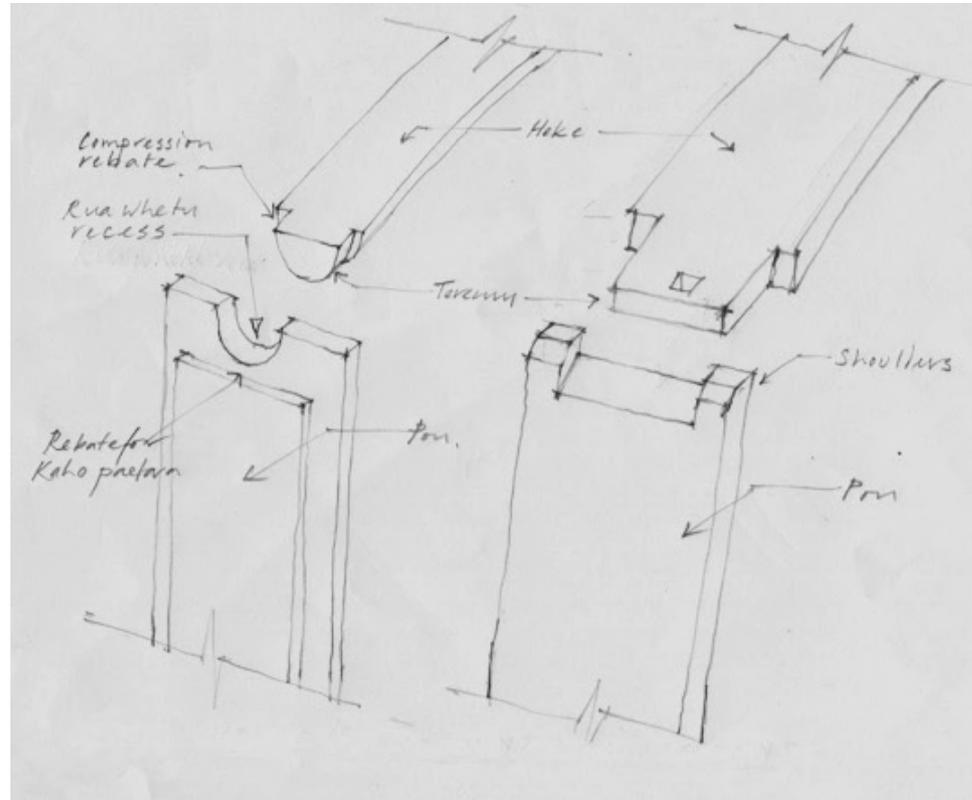


Fig. 1 Jeremy Treadwell (2015). Waha paepae and Rua whetu joints

it is proposed that these joints have been categorised and confined within existing Western constructional paradigms without reference to their role in the cosmological formation of the meeting house, or in their contribution to a distinctly Māori conception of building. The rua whetu joint, for example, is typically described and simplified as a ‘mortice and tenon’ joint. However, the rua whetu and waha paepae are both formally and functionally more complex than this Western joint. The Maori joint functions outside the conventional right-angled parameters of the mortice and tenon technique and is designed to operate not only as a junction of dissimilar components, resistant to both lateral and vertical loads, but also to lock against rotational forces.

The evolution of these joints into the 19th and early 20th century is traced chronologically through analysis of their representation in historic imagery, examination of artefacts in museums and examples of standing construction. It is clear that these examples do not represent a comprehensive record of the variations and distribution of the development of this joint, but do serve to indicate the scope and developmental direction.

The development of the waha paepae and the rua whetu joint is argued to reflect a formalisation of the building process which, by the 19th century, had become a refined technical practice which prescribed the geometry and the three-dimensional volume of the house. It is the angle of the slot cut into the top of the pou pou to accommodate the heke that predicts the angle of the roof of the house and consequent shape of its interior volume. Similarly, it is the materialisation of this geometry as a locked joint which enables the formation of the whare as a sequence of structural arch forms.

The functional development of the waha paepae and the rua whetu joints as

compression joints will be examined in relation to their participation in the evolving structural system of the 19th century whare, particularly with respect to their increasing size and subsequent structural loads.

Equally invested in the structural and geometrical implications of this junction is a set of cosmological relationships essential to the wider stability of the house. This paper will therefore consider the joint through the complexity of its forms, meanings, functions and carpentry. It will propose that the late 19th century manifestation of the joint cannot be attributed to any single historical event, region, or structural requirement; rather that it emerged as a key element in the maintenance of the active cultural relationships embedded in the structural development of the house.

### Cosmology

The building of a wharenui is understood to recapitulate the cosmological opening-up and illumination of the inhabitable space of the world—te Ao Marama. In their whare wānanga, (house of esoteric lore) tohunga passed on their iwi's version of the creation narrative to selected pupils. Hone Sadler provided the Ngāpuhi account in 'Ko Tautoro Te Pito O Toku Ao: a Ngāpuhi narrative' (Sadler 2014: 1340–1441). Sadler had previously expanded the narrative to make clear its implications for the construction of the whare, describing the general metaphor in which the roof of the whare is seen as Ranginui (sky father), the floor as Papatūānuku (earth mother) and, in more explicitly tectonic terms, how the toko (props) that Tāne used to keep his parents apart become metaphorically manifest in the house as the poutokomanwa and the poutāhu which support the ridge beam of the whare (Sadler 2013:).

Teone Taare Tikao narrated a largely Ngāi Tahu version of the creation story in which Tāne propped Ranginui from Papatūānuku with a great pole later laid horizontally across the sky, as in a ridge pole in a whare. Suspended from Tāne's great pole were the nine layers of heaven. In traditional whare construction, this account mirrors the suspension of the kaho (purlins) on either side of the tāhuhu (ridgepole) (Tikao 1939: 29).

However, it is in the formation of the roof and walls of the whare (in which the world of being is reconstructed) that the whakarua whetu contributes cosmologically as well as structurally. The etymology of the terms 'rua whetu' and 'whakarua whetu' suggest the nature of its intersection with the te Ao Marama paradigm. 'Rua' has several meanings including 'two', 'hole', 'storage pit', 'gap' and 'cave', whereas 'whetu' means star unequivocally (Williams 1892: 235).

The connection with the miniature radiance and seeming immateriality of stars does not appear to link readily with the incised hollow of the rua whetu. However other readings of te Ao Marama narrative confirm the role of ngā whetu. From these we learn that it is within the world's wider sources of luminescence, and the subsequent cycle of light and dark, that the 'rua whetu' (literally the hollow of stars) is connected to its metaphorical and structural origins.

Light did not immediately radiate into the space created by the separation of Ranginui from Papatūānuku. From the darkness that lay over Papatūānuku following Ranginui's elevation, Tāne nui a Rangi (departmental god and son of Ranginui and Papatūānuku) went forth to procure light for the world. He

Māori Language offers several meanings for ‘waha’, including ‘entrance’ and ‘mouth’. There is a direct logic of ‘entrance’ to describe the slotted engagement of the heke within the top of the poupou (Williams 1892: 222). ‘Paepae’, in contrast, has a broader reach within the dictionary. The first definition of ‘pae’ is ‘horizon’.

Polynesian marae have been identified as spatial markers of important navigational stars. Professor Paul Tapsell wrote,

“Pacific anthropologists [and] historians ...noted that particular ancient marae appeared to provide earth bound (Papatūānuku) reference points by which accurate readings could take the place of celestial (Ranginui) pathways of sun, moon and stars as the navigators crossed the horizon” (Tapsell 2009:39).

In writing this, Tapsell connects the horizontality of the marae to navigational knowledge. (Horizon)tality, in this context becomes the reference point between the celestial and earthly opposition of te Ao Marama. At the horizontal junction of the waha paepae joint, between the celestial heke and the earthbound poupou, night becomes day, and beyond the interior of the whare and the paepae that stretches between the walls, light creeps over the land.

### **Documenting the development of the poupou/heke joint in whakanoho construction**

#### **Pre-contact evidence—waha paepae construction**

Because timber structures tend to decay quickly in the ground, intact remnants of pre-contact Māori houses are relatively rare. The most significant finds are from kainga on and beside inland lakes such as Maungakaware in the Waikato, excavated by Peter Bellwood (1971), and at Kohika in the Bay of Plenty (Irwin and Wallace 1995). These sites have contributed much of what is currently known about the early whare whakanoho.

From the lakebed at Maungakaware Bellwood retrieved notched poupou and tenoned rafters. The drawings of these elements show somewhat irregularly tapering tenons and a majority of equally variable ‘V’ed notches on the tops of the poupou (Figs. 2–3). The drawings of these components suggest that construction was not driven by a requirement for consistent controlled fabrication. The joints of the heke and poupou from Kohika have consistently constructed rectangular sockets and parallel bearing surfaces, which together demonstrate the intention to achieve secure component location and predictable load bearing. One explanation of this difference can be attributed to the clearly demonstrated use of cross-sectional post tensioning at Kohika with its additional requirements to control forces and loads (Irwin & Wallace 2004: 141–144).<sup>2</sup>

journeyed to Tangotango (the darkness of the celestial night) and Wai-nui (the ocean), whose whānau marama (children of the light) included the sun, the moon, the stars and phosphorescence.

Tāne explained his need to Tangotango, “*To lighten us in our darkness; that Light may shine across the breast of our mother.*” (Best 1899:93) And so Tāne collected *Nga Whetu—the Stars* “*whose dimmer rays only glimmered in the darkness*” (Best 1924:563).

Through this narrative ngā whetu entered into the body of the whare. But the next question is how the rua whetu joint was played out in structure. While most commonly known as ‘rua whetu’, the term ‘whakarua whetu’ was used by Elsdon Best (Best 1924:562), translating literally as ‘towards the space of the stars’. By adding the article ‘whaka’, meaning towards and in the direction of, the implication of movement is added to the term (Williams 1971:485). ‘Heke’ (rafter), the member which connects to the rua whetu, also means ‘to descend’. In the structure of the whare this is, by implication, the rafter’s physical descent from the tāhuhu to the poupou. In genealogical terms it could be read as the ancestral descent depicted in the repeating patterns of kōwhaiwhai. As Neich summarised, “...the structure of the house constitutes a genealogical plan...” and more specifically, “the rafters (heke) were equated with branching lines of descent leading down to the ancestral representations of the poupou” (Neich 1993:130).

It becomes possible in this wider context to see the heke as a pathway for the stars from one side of the whare to the other, mirroring the nocturnal passage of stars from horizon to horizon across the dark vault of the sky, finally sinking below the horizon into the rua whetu. W.J. Phillipps wrote that the house Mataatua “when first erected conformed to the ancient rule that the tahu must run north and south” (Phillipps & Wadmore 1950:6). If this is the understanding of the traditional orientation of the whare, then the stars simultaneously traverse the night sky and the roof of the whare.

Interestingly, the Ngai Tahu narrative about the stars links metaphorically to both house structure and to the figure of the waka. Tikao wrote,

After he Tane laid his pole across the topmost heaven Tāne returned to earth, leaving his big canoe Tutepawharangi—the canoe of Ruatapu, many centuries later, was named after it—to the family of Tamarereti, and it can still be seen, renamed as the Te Waka-a-Tamarereti, as a cluster of stars among the constellations adorning the sky. These Tamarereti people were lifted there by Tane when he lifted Rangī and they are there yet as they do not die like mortals (Tikao 1939:30).

The association of waka and their celestial navigation with Polynesian architecture is well known. Used as a representation of the night sky for navigational instruction, the Kiribati maneaba was traditionally built with the ridgepole (tau-buki) aligned with the north/south axis. (Maude 1980:10) Similarly, the Samoan fale had stars and the moon in both ornamentation and structure (Craighill & Handy 1924:8, Treadwell & Austin 2009:42).

The term ‘waha paepae’ (the angled rectangular slot in the top of the poupou for a rectangular-sectioned heke) does not seem to offer a specific reading from within the narrative of te Ao Marama but its etymology suggests a connection with the discussion above. The 1892 edition of W.H. Williams’ Dictionary of the

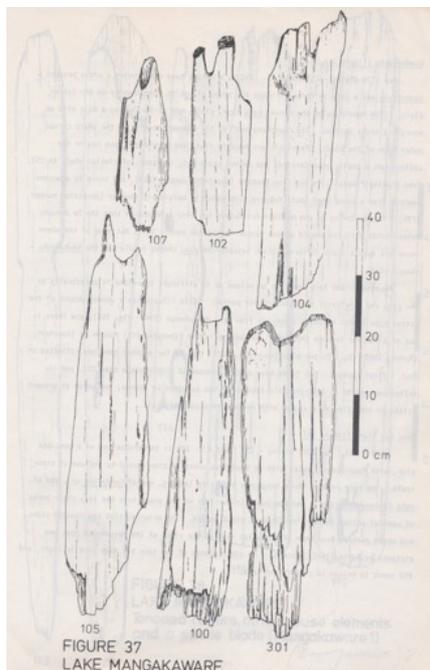


Fig. 2 P. Bellwood (1971). Poupou informally notched at top to accept the heke. With permission from the Department of Anthropology and Archaeology, University of Otago

Fig. 3 J. Treadwell (2014). Poupou from Kohika showing squared waha paepae slot and lashing eyelets. With permission from the Kohika Trust and Trustees of NARA (Ngāti Awa Research and Archives Trust) and Whakatane Museum and Research Centre

## Early contact evidence

### The Pourewa Island and the Hinematiaro poupou

The most significant extant artifact of whakanoho construction from the period of initial Māori and Pākehā contact is the now well-known stone-carved poupou, collected by Joseph Banks from an unfinished house on Pourewa Island near Tolaga Bay during the Endeavour's 1769 visit (Salmond 1991:174) (Fig. 4).

With its squared format and refined figure carving, this poupou has been considered an exemplar of the Te Rāwheoro stone tool carving style (Ellis 2016:174). Appropriate to the fine definition of its carved surfaces and reflecting a concern with precise construction the top of the poupou and the waha paepae joint recess is accurately squared. Implicated by this carefully defined rectilinear slot is an absent heke of matching cross section.

There is another surviving stone-carved poupou from the same region and period which has been associated with the influential Ngāti Porou ariki Hinematiaro. Much has been written about a possible relationship between these two potentially contemporaneous poupou and whether or not they were components of the same Pourewa Island house. This discussion has been based on historical accounts and comparison of carving styles. More importantly for this paper is the fact that there is significant tectonic difference between the two poupou. While the Pourewa Island poupou has a rectangular waha paepae joint (discussed above), the 'Hinematiaro' poupou, by contrast, features a distinctly semi-circular rua whetu joint. This difference is of some complexity and importance.

Close examination of the back of the Hinematiaro poupou shows evidence that the poupou, at different times, supported both rectangular sectioned and semi-circular sectioned heke. The top of the poupou has been damaged on one side but shows, on the undamaged side, the recessed bevelled slot and locating shoulder characteristic of the waha paepae joint (Salmond 1991:174).



Fig. 4 (2015). *Pourewa Island* poupou showing the characteristic 'rectangular cavity' of waha paepae construction [https://upload.wikimedia.org/wikipedia/commons/e/ec/Klein\\_MUT-007.jpg](https://upload.wikimedia.org/wikipedia/commons/e/ec/Klein_MUT-007.jpg)

Fig. 5 (2014). *Hinematiore Poupou* showing the 'semi-circular' rua whetu joint at its top. Auckland War Memorial Museum Tāmaki Paenga PH-NEG-AM5017



One interpretation of this is that the poupou, originally part of a waha paepae house, was modified when it became part of a whare that had rua whetu construction. Significantly for this paper, the recovery of the poupou in 1885 after approximately 60 years in swamp makes this, the Hinematiore poupou, by far the earliest known example of rua whetu construction.

### Early Ngāi Tūhoe poupou

In the back room store at Te Papa Tongarewa are three Ngāi Tūhoe poupou from the Ruatahuna district in the Urewera ranges. Roger Neich concluded that while the poupou were carved between 1820 and 1860, it is probable that at least three of the poupou were carved before 1840 (Neich 1976:132). It is clear from the rectangular slot across their top edges that these poupou were part of a house, or houses, constructed with waha paepae joints.

### The houses drawn by George French Angas

In 1844, naturalist and artist George French Angas arrived in Wellington, where he began a meandering traverse of Aotearoa. During the course of this journey, Angas carefully recorded a number of whare whakanoho.

Rangihaeata's house 'Kai Tangata'on Mana Island, the first of the whare to be painted, was represented in great detail, including the depiction of the poupou/ heke joint as of waha paepae construction. The houses recorded by Angas can be understood as a dispersed sample of the constructional practices of various Tainui hapū from one discrete period of history. They all were recorded as utilising waha paepae construction.

### **Te Hau Ki Tūranga (1840–1845)**

About the same that Angas visited Aotearoa a beautifully carved and technically refined house was completed near Manutuke on the East Coast of the North Island. Te Hau ki Tūranga was built by Ngāti Kaipoho between 1840 and 1845 (Brown 1996:12).

While famous for its carving, this whare survives in Te Papa Tongarewa as a unique and definitive example of an early meeting house of waha paepae and post-tension construction. Figures 7 and 8 illustrate the the pou pou and heke of Te Hau ki Tūranga as the simultaneous embodiment of structural and genealogical relationships. These images depict carved representations of principal ancestors (pou pou) supporting the carved representations from the next generation. This figural relationship is both metaphorical and structural, the more recent ancestor ‘standing on’ and tensioned against the head of the principal ancestor.<sup>4</sup>

### **Whare karakia: Waikane (c.1843) and Rangiātea (1851)**

In the 1840s, two important whare karakia were constructed along the coast north of Wellington. These buildings indirectly inform development of the rua whetu joint and its structural context. The first of these was a large chapel constructed by Te Āti Awa about 1843 at the Kenakena Pā at Waikenae (Treadwell, S. 1995: 147). This was a large whare structure of Gothic revival proportions. It was the subject of a sketch by engineer T. B. Collinson in 1846 (Treadwell, S. 1995:149). In 1852, Charles Barraud printed a lithograph of the interior of the second church, Rangiātea at Otaki. Despite certain limitations in technical detail, there remains enough information in these, and in later forensic drawings by architect Chris Cochran, to conclude that these buildings connected the heke to the pou pou with waha paepae construction.

These two buildings are also crucial to a wider discussion fronted by art historian Richard Sundt. Sundt explores the Māori use of mid-span rafter props and under-purlins in these churches to remedy or prevent rafter deflection, citing their use as early examples of Māori adopting Western building technology (Sundt 2009:101). However, it appears that Māori, in their move away from the missions, extended their own technologies to construct large scale structures, and it is these technologies that influenced the development and proliferation of the rua whetu joint in the second half of the 19th century. Although beyond the scope of this paper, these technologies included semi-circular cross sectioned and pre-cambered heke, compression joints, and post tensioning.

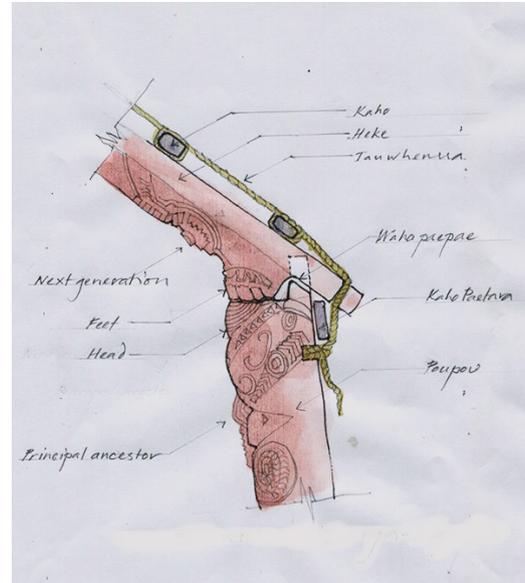
### **The development and proliferation of the rua whetu joint**

In 1855, Reverend Richard Taylor published his major work ‘Te Ika a Maui—New Zealand and its inhabitants.’ In this text we find an early reference to the rua whetu joint as a general feature of whare whakanoho construction. “The sides (pou pou) are seldom more than four feet high... having a small circular groove or opening cut into the top to receive the rafters (heke)” (Taylor 1974: 387). Despite this, there is little evidence in drawings or in securely identified museum artefacts from the 1850s and 60s to confirm Taylor’s account of the widely spread rua whetu joint.



Fig. 7 (1976). National Publicity Studios. *Te Hau ki Tūranga: Representation of generational support*. Archives New Zealand. <https://creativecommons.org/licenses/by/3.0/>

Fig. 8 Jeremy Treadwell (2012). *Te Hau ki Tūranga: Sectional detail—generational support conflated with structural support*



Following the New Zealand Wars of the 1860s, iwi built increasingly large whare to reaffirm tribal identity and provide places of worship. These buildings became characterised by semicircular and part-circular sectioned heke which were typically also pre-cambered. These heke required a new joint with the supporting poupou that would act in compression and ‘lockup’ (resist rotation) under load while accommodating existing artistic traditions. This was the rua whetu joint (see Fig. 1).

It is proposed that the rua whetu joint represented the continuation of the functional role of the waha paepae joint (also a compression joint) to accommodate the shift from rectangular section heke to semi-circular section heke, a shift motivated by the need to build larger whare with longer rafter spans.

In the second half of the century the rua whetu joint had several variants but virtually all were associated with semi or partly circular section heke. The bearing surfaces of these joints varied in accordance with the characteristics of the heke: a.) rua whetu with rebated teremu (tongue) and compression shoulder (Fig. 9) rua whetu without a compression shoulder and with vertical load bearing surface (Fig 10). These differences had constructional implications in terms of the achievement of lateral stability.

We will see that in the latter half of the 19th century the pre-cambering of heke was to develop further and become characteristic of much meeting house construction. This was to occur in the context of further significant changes to the heke and the expansion and development of the rua whetu joint. The use of the post-tensioning implicated in these changes will be the subject of another paper.

### Maui Tikitiki-a-Taranga (1865)

The earliest physical evidence of post-1850 rua whetu construction with secure provenance was the heke and poupou of Maui Tikitiki-a-Taranga (1865) located at the Tairāwhiti and Auckland Museums. The heke at Tairāwhiti Museum feature part-circular cross sections, a pre-camber of 100mm, rebated top joints and a teremu with compression shoulders to socket into rua whetu joints (Fig.9). The

poupou from this at the Auckland Museum have corresponding rua whetu joints.

An early 1865 photograph of the house Tumoanakōtore at Hicks Bay shows the house with same broad structural characteristics as discussed above, suggesting that rua whetu technology was well established on the East Coast at this time.<sup>9</sup>

### **Tokanganui-a-Noho (1873) and Tāne Whirinaki (1874)**

Te Tokanganui-a-Noho was built near Te Kuiti in 1873 by Te Kooti's followers in recognition of the shelter afforded Te Kooti by King Tāwhiao. Tāne Whirinaki was built at Waioeka in 1874 to bolster the mana whenua (power from the land) of Ngāti Ira following the land confiscations of 1865. Both houses were rebuilt and expanded in the 1880s 'by Te Kooti' and carvers from several iwi (Phillipps 1955:139).

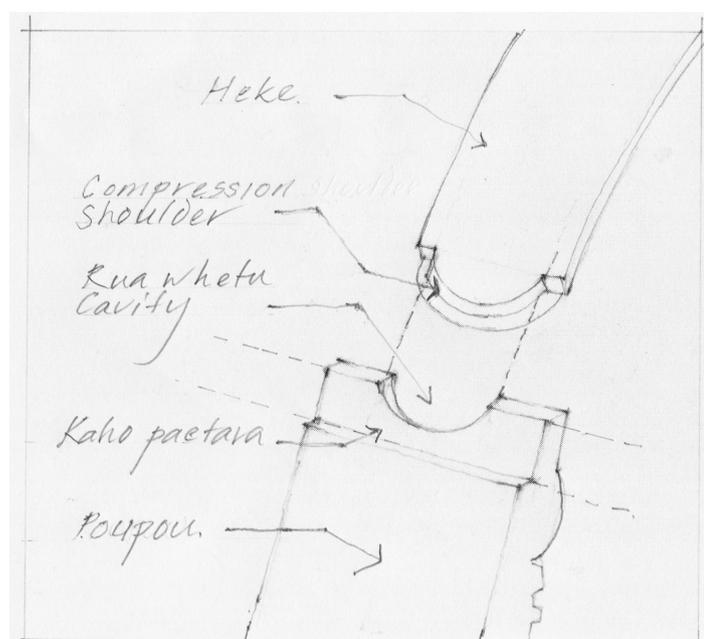
These houses shared both artistic and tectonic features. From the junction with the poupou and for a short distance up their shafts the full semi-circular section of the heke of both houses were further thickened. This had the effect of increasing the depth of their vertical intersection within the top of the poupou. This configuration effectively constructed a form of pre-cambering. Both sets of heke also featured compression rebates at their intersection with the poupou as did the heke of Maui Tikitiki-a-Taranga.

### **Mataatua (1875) and Hotunui (1878)**

In an adjacent rohe (tribal area) of the same period, Ngāti Awa used the tectonics of the rua whetu joint in a significantly different way. As Te Tokanganui-a-Noho was being built at Te Kuiti, and Tāne Whirinaki at Waioeka, Ngāti Awa were building the great house Mataatua at Whakatāne. Three years after its opening in 1875, Ngāti Awa carvers also completed Hotunui at Parawai in Thames.

The heke of both of these houses have a wide and partly-circular cross section. Hotunui's heke are about 530mm wide and 140mm deep and are slightly curved

Fig. 9 Jeremy Treadwell (2016). Maui Tikitiki-a-Taranga c.1865. Detail: rua whetu junction with teremu and compression shoulder



along their length (Fig. 10). In striking contrast to Te Tokanganui-a-Noho and Tāne Whirinaki, the heke lack compression rebates at the rua whetu recess and their upper end is tapered to be parallel with the inclined top face of the tāhuhu. Instead of butting against the near vertical face of the poupou, the heke from these houses are simply slotted into and onto the poupou. Without a rebate on the heke, resistance to the horizontal load component was necessarily passed to the kaho paetara, a continuous horizontal batten fixed to the top of the back of the poupou. The implications of this are still being investigated.

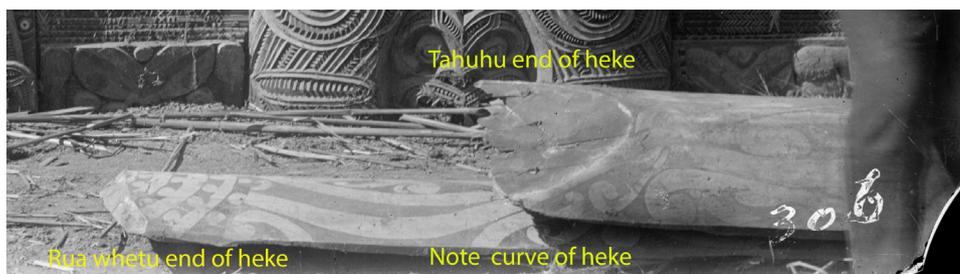


Fig. 10 Thomas W. G. Hammond, (c1925). Dismantling of Hotunui. Details of heke. Note absence of compression shoulder at the rua whetu end. Auckland War Memorial Museum Tāmaki Paenga PH-NEG-PH-NEG-A907

These examples of rua whetu construction represent the broad scope of rua whetu construction as it can be accessed in museum collections, identified in contemporaneous images and through description in literature. The distribution and variation of the joint is currently the subject of ongoing research. However, early evidence is clear that the rua whetu construction was in use predominantly across the middle of the North Island from the 1860s until the turn of the century.

## Conclusion

This paper has investigated the cultural and tectonic development of the rua whetu joint and its precursor the waha paepae joint in the context of the 19th century meeting house. In doing so, it provides the first written exposition to specifically address the joint as an individually fabricated component of pre-20th century Māori building practice. In its broad explanation of the joint's development, the paper seeks to provide a reference for the examination of tectonic relationships implicit in whakanoho construction. In doing so, the paper identifies these tension and compression joints as complex, crafted, and high performance technology.

The paper has argued that these joints have played complex structural/cultural roles and should be seen as foundational components in the evolution of the 19th century meeting house. Argument has been presented that these joints have not received critical attention either in terms of the sophistication of their fabrication or their function. The rua whetu joint has been distinguished from the simple 'precision joining' function of the familiar mortice and tenon technique as a much more complex junction, which integrates locating and locking functions while also controlling environmental and applied forces at a structural scale.

While there is a predictable emphasis in the discussion of the functional roles of the joints, the integration of the technology within the cosmological and environmental dimensions of Māori building is explored. It is proposed that both joints were invested within Māori origin constructs and likely reference Māori voyaging origins and technologies.

Evidence from artifacts, images, and literature showed that the waha paepae joint and rectangular-section rafters were characteristic of late 18th and early 19th century whare construction. During this latter period, political and religious movements required larger buildings for assembly. The expansion of building width generated increased rafter spans, and with them the problem of deflection. While some whare karakia of the period were modified by Pākehā agency with struts and under-purlins, it appears that at the same time Māori builders had already been combating the deflections of large structural spans by pre-cambering and other processes.

immediately prior to the New Zealand wars. During the wars there was widespread destruction of Māori houses in the Waikato, Taranaki and the Bay of Plenty. For example there were no carved houses left in Whakatohea following the land confiscation and the invasion of the militia.

<sup>7</sup>Pre-cambered rafters were common from the 1860s onwards: Insitu heke measured in Hotunui in the Auckland museum still showed a pre-camber of approximately 50mm. Rafters from the Tolaga Bay house, possibly Te Kani a Takirau at Firenze Museum of Anthropology and Ethnology have obvious camber. Heke prepared (c1960) for Tāne Whirinaki have cambers averaging about 150mm. Irapuaia, built at Waioweka marae 1902, was also built with cambered rafters.

<sup>8</sup>In this context pre-cambered rafters, while not providing extra stiffness, provided Māori with a means to visually manage deflection. However pre-cambering plus, a semicircular cross section, compression joints, top and bottom, in conjunction with post tensioning provided Māori with improved spanning performance. This will be discussed in detail in a future paper.

<sup>9</sup>Photo of Tumoanakōtore Museum of New Zealand Te Papa Tongarewa MA\_B.01337

<sup>10</sup>Both these houses had both carving and figurative painting. Not much is known about the interior of Tāne Whirinaki but figurative portraits can be seen on the bottom of the heke in the porch much as they appear in nearby whare Tutamure built at Omaramutu c1902.

<sup>11</sup>Measured in place at the Auckland Museum. Rafter curvature was variable but up to approximately 50mm at mid span.

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## Endnotes

<sup>1</sup> Sadler, Hone, (2014) wrote, "On entering the house Ranginui stands above and Papatūānuku lies below. The world of enlightenment is inside". Location 1410.

<sup>2</sup> Post-tensioning in relation to Māori construction refers to the cross-sectional tensioning of each pair of poupou and heke over the tāhuhu creating a sequence of structural arches.

<sup>3</sup> Anne Salmond wrote, "Chiefs houses were commonly decorated with carved side posts or poupou and indeed these were quite commonly shifted from old decaying houses to newer structures." (Salmond 1991: 173)

<sup>4</sup> The top figure is carved integrally with heke thereby implicitly involved in the transfer of vertical and horizontal loads to the poupou. Te Hau ki Turanga is the earliest whare surviving from the 19th century to feature the lashing holes characteristic of post tensioning as first first described on the whare at Kohika.

<sup>5</sup> The T.B Collinson drawing (Alexander Turnbull Library TePuna Matauranga o Aotearoa Wellington, M-SPI038-01) does not show an underpurlin spreading the load of the roof onto the props and neither the Collinson drawing or the Barraud drawing shows the kaho paetara linking the top of the poupou.

<sup>6</sup> This was the period before photography in New Zealand and