Symposium for W. Dickinson – SAA 2015

"Geological subsidence and sinking Islands: the case of Manono (Samoa)"

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Abstract

W. Dickinson, as part of his wide study of the geological history of the Pacific islands, has ~~proposed in a series of papers to explain~~linked the unique case of the deeply submerged Lapita site of Mulifanua in Western Upolu (Samoa)~~, as linked~~ to the slow subsidence of Upolu Island. Recent archaeological research on the neighbouring small island of Manono, has brought new and detailed data on this geological process. A series of new dates has allowed us to define ~~chronologically~~ the speed of the subsidence and demonstrate~~as well as~~ the massive environmental changes that the local population had to adapt to over the past 2500 years.

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Introduction

The geological diversity of the Pacific region defies any simple categorization. The region is~~,~~ divided between different tectonic plates and~~,~~ cut in two on its western side by the active “belt of fire”, with i~~I~~slands ~~ranking~~ being derived from continental fragments to old eroding or still active volcanic summits to simple coral a~~A~~tolls~~, defies any simple categorization~~. Volcanic activity, earthquakes and possible tsunami-related events, associated to episodes of extreme weather devastation through cyclones/typhoons or prolonged droughts make Oceania a region that often defies the idyllic image built by Western imagination. Amongst the different natural events that shape everyday life in the Islands, oral traditions ~~have since~~for generations have transmitted stories of sinking and rising Islands (Nunn 2009). While some of these stories might be related to small isostatic sea level changes over time, the vast majority ~~is~~ are unquestionably linked to tectonic activity. W. Dickinson, as a geologist, studied in detail the diversity of the ~~building~~ geological building process of most of the archipelagos of the Pacific, explaining the structural specificities of each region though a number of scientific demonstrations. This paper would like to present an archaeological case of one of his most recently debated studies~~ in this field,~~ focused on the Upolu-Savai’i alignment forming the western part of Samoa in the central Pacific. After having synthesized the geological data on these two Islands and some archaeologically-related outcomes, we will ~~detail~~ outline the results of excavations ~~fulfilled~~ undertaken on the small Island of Manono, positioned at the western point of the Upolu plate. These have demonstrated the progressive subsidence of this part of the archipelago, allowing for the first time to date precisely the chronology of this process over the nearly 3000 last years of~~, associated to~~ human presence. The consequence~~s~~ of the progressive subsidence and the resilience of the local inhabitants to the loss of large expanses of arable land ~~in this case of~~because of the “sinking Island”, will be discussed~~ in the analysis part~~.

The geological setting of the Upolu-Savai’i Islands of Samoa

~~While~~ In Western Polynesia~~, regrouping~~ the archipelagos of Samoa, Tonga, Wallis-Futuna and Tokelau, ha*ve*~~s~~ been defined as a coherent cultural entity (Burrows 1939), but the regions~~its~~ geology is characterized by only two contrasting geological structures. The region is divided by the Andesic Arc, that separates the s~~S~~ubduction zone of the c~~C~~ontinental ~~P~~plate of the Western Pacific from the Oceanic p~~P~~late on which ~~emerge~~ are found only volcanic Islands. Most of the Tongan i~~I~~slands, as well as Fiji to the West, stand on the c~~C~~ontinental ~~Plate~~plate, separated from Samoa by the Tongan fa~~o~~ult. The Samoan i~~I~~slands chain, which exceeds 1000km in ~~total~~ length from Wallis (‘Uvea) Island in the west to Rose Atoll in the east, appear~~s~~ to result mainly from the volcanic activity of a “magmatic plume-driven hotspot” that progressively expands eastward due to the plate movement (Staudigel et al.

2006). The ~~Islands~~ islands of Upolu ~~and Savai'i, as well as~~ Apolima and Savai'i~~ in between them,~~ are aligned in a south-east/north-west axis. No active volcano is today present on the 1119km^2 wide Upolu, but a number of former cones can easily be identified on the main axis of the Island, ~~forming its diverse summits, who top at~~with the largest at 1100m (Mount Fito). This is in contrast to the i~~I~~sland of Savai'i in the west, whose active craters continue to ~~shape the~~ form ~~of~~ the 1858m high ~~(~~Mount Silisili~~)~~ and 1707km^2 wide conic island. The origin of the recent volcanism on Savai'i is probably related to the relative migration of the edge of the Tonga trench (Hart et al. 2004). While the eastern part of the Upolu seashore is rugged, it's western part is enclosed today by a reef~~,~~ with an extensive lagoon on its western point~~,~~ enclosing the small island of Manono. The cause of this~~e presence of the~~ reef formation has been ~~explained by~~attributed to ~~a geological specificity, Upolu lying within the depressed flexural cone of lithospheric subsidence surrounding the growing volcano load of Savai'i. More simply said,~~ the ~~rising process of~~growing volcanic load of Savai'i creating ~~es~~ a depression into which the western part of Upolu is slowly tilting (Dickinson 2007).

T~~he consequence of t~~his geological subsidence process has resulted in a ~~is a~~ progressive loss of coastal flats, which has~~. This has~~ implications for archaeology since ~~, as~~ all first settlement sites as well as a large number of post-discovery settlements in the Pacific Islands have ~~been~~ been in coastal locations~~coastal occupations since millennia~~. The ~~explicit demonstration of the~~ implications of this -for ~~the~~ understanding ~~of~~ past human settlement patterns was made ~~clear~~ evident by the discovery in 1973 of ~~the presence of~~ 2800 year~~s~~ old Lapita sherds buried ~~at about~~ 2.5m deep in the Mulifanua lagoon~~, located~~ at the north-western tip of Upolu (Jennings 1974; Green and Richards 1975; Leach and Green1989; Petchey 2001). This unique example of a deeply buried first settlement occupation led W. Dickinson to use the ~~well dated~~ archaeological site to refine geological chronology (Dickinson and Green 1998), allowing him to propose a subsidence process of about 1.1-1.4mm/year for this part of Samoa (Dickinson 2007). Expanding on this data, ~~the late~~ R.C. Green extrapolated on the possible locations of other early sites along the coasts of Samoa (Green 2002).

Testing the model: first results from Manono

Most researchers accept th~~Although the core of~~e basis of the model proposed by Dickinson to explain the geological setting of Upolu~~ is agreed by most researchers~~, ~~it is of notice that over the last years,~~ a number of papers have recently addressed criticisms on different aspects of the model. One of the aspects highlighted is the speed of the tilting (Goodwin and Grossman 2003), another being the formation process of the Lapita layer of Mulifanua (Addison, perso. com. 2011). Recent archaeological data from the small Island of Manono ~~allow~~ enable us to address these ~~question~~ issues~~through archaeological analysis~~.

Manono is positioned on the edge of the large lagoon that forms the western tip of Upolu, ~~in front~~directly opposite~~ of~~ Savai'I (fig. 1). It is a gently raised cone about 2.4km long and 1.8km wide, in the form of a large keyhole. The summit at about 60m altitude is the remnant of a former crater. Although of small size compared to its two large neighbours, Manono holds a prevalent position in the oral traditions of Samoa, having been a powerful political ~~center~~centre. Today the island is divided in two entities, Faleu/Lepuia'i in the southern half and Salua/Apai in the northern half. S~~ As elsewhere in Samoa since European times (Davidson 1969), present s~~ettlements are restricted to the narrow coastal flats, as elsewhere in Samoa since European times (Davidson 1969), although a great number of former occupation remains are visible inland.

Between 2012 and 2015, a research program on the archaeology of Manono was carried out by the Institute of Archaeology of New Caledonia and the Pacific (IANCP) and the National University of Samoa. The main aim of the project was to study the former settlement patterns of the Island through mapping of surface sites and recording of the related oral traditions. As part of the overall understanding of the chronology of human occupation of the Island, excavations have been opened on the coastal flats of Salua village. Some of these have given a unique record on the geological subsidence process underway on Manono.

Excavation EX.1 of Pagai

Pangai is a coastal ridge on the east coast of Manono Island, directly facing the Lapita site of Mulifanua and the large lagoon of western Upolu. The site was chosen for excavation because it is the main sandy flat on this side of Manono, extending over more than 45m inland, with only a gentle rising slope at its back. The seashore is under severe erosion, with ~~the presence of~~ numerous stone artefacts found~~identifiable~~ during surveys on the rocky beach at low tide. To test the model of a progressive subsidence of western Upolu, this appeared to be an ideal location. Moreover, t~~T~~he landowner ~~having~~ informed us that earlier ~~excavations~~ earth works for house-building had discovered large basaltic boulders in the sand. T~~, t~~he 1m^2 test-pit EX. 1 was positioned at 20m from the eroding shore-cliff, with point 0 at 150cm over the main high tide level. The excavation led to the identification of 4 different episodes of formation of the site fill (fig. 2).

Layers 1-4: From the surface to about 45cm deep, the ~~occupation is~~remains are related to post-contact settlement. ~~Excavations have identified as~~L~~ l~~ayer 3 is a paved surface of house platform. L~~, l~~ayer 4 forms the~~ing the~~ fill of the house platform in which ~~-~~European items were~~have been~~ found~~, in the fill~~ as well as on the surface of the house floor.

Layers 5-8: From 45cm up to about 135cm, a~~s~~ series of distinct layers of sand ~~formation~~ characterize regular occupation of the area, under the sterile layer 5. Artefacts are nearly absent. A post-hole and a pit characterize t~~T~~he basal surface of layer 8~~. is characterized by a post-hole and a pit.~~

Commented [FP1]: I am not sure what you mean by this. Are there sterile sand layers separated by evenidence of occupation ?

Layer 9: Between about 135cm and 210cm~~ deep,~~ there is a ~~the stratigraphy is formed of a~~ sterile sand layer containing ~~, with~~ only a few natural shells~~ present~~. To prevent the baulk ~~wall~~ collapsing, the excavation was reduced ~~fulfilled~~ from this layer down, with only on a small central portion of the test-pit being investigated.

Layers 10 to 11: At 210cm, abruptly topped by the sand of layer 9 with no ~~phase~~ evidence of mixing, layer 10 is a compact dark soil~~ formation~~. Its fill is characterized by the presence of potsherds, volcanic glass, fish bones and shell remains. The underlying layer 11 is of the same general clay texture~~,~~ but ~~characterized by the presence of brackish water, the excavation having reached the~~sits below the ~~-~~water table. Archaeological remains of the same type as in layer 10 are present. The excavation was stopped at 275cm deep without having reached the bottom of this layer.

The archaeological material

The complete record of the archaeological remains found in excavation EX.1 is presented in table 1. Unexpectedly, the sandy deposits are very poor in cultural material aside from shells. In the uppermost three layers of the excavation ~~were discovered~~ 4 metal needles, one cloth button and one porcelain marble were discovered. The only cultural ~~remain~~ material found in the lower part of the sand deposit (layer 8) was a small sized basalt adze (fig. 3). This overall absence of cultural remains contrasts with the data from the lower clay layers 10 and 11~~,~~ where pottery and small volcanic glass flakes are present~~ in numbers~~. The potsherds are mostly of small size, with a median thickness of about 4-7mm on average. The temper identified is only terrestrial. The outer ~~color~~ colour of the sherds is brown, with only a few cases of blackened surface. The only two rim-types identified are straight and come from bowl shaped vessels of the *Samoan thin ware* type (fig. 3).

Commented [FP2]: Expand ? with reference ?

Bone fragments and crustacean pieces in low numbers were present in all the layers related to human presence, ~~alongside~~ as well as one human to~~e~~o~~e~~th at ~~present in spit~~ 60-70cm. The shell data from EX1 shows a low proportion of shell remains, indicating mainly an opportunistic process of collection. Furthermore, the analysis shows a significant difference between the density of shell remains from the ~~archaeological layers in the~~ sand matrix and those ~~present~~ in the clay matrix under the thick sterile sand fill (Layer 9). In the upper layers ~~can be identified variations of shell numbers between spits, without a clear pattern appearing aside from the~~there is a rise in density of shells ~~in~~ within each layer~~s~~ that is interpreted as occupation floors. Gastropods compose the highest amount of shells in the sandy layers, with *Cerithium salebrosum* (565g) presenting the highest amount, followed by *Cypraeidae* (310g), *Trochidae* (185g), *Conidae* (143g), *Strobidae* (91g) and *Turbinidae* (42g). Bivalves are represented near exclusively by *Tridacnidae* (111g) and *P~~h~~aphies striata* (64g). Most importantly, considering the small size of the lower excavation trench for layers 10 and 11, ~~it appears statistically that~~ the shell remains are in quantities about three to four times greater in the clay layers than in the sand layers above. A stronger reliance on shell consumption was though present during the first millennium BC on Manono. Only two species have been identified, *Trochidae* (98g) for the bivalves and *Tridacnidae* (90g) for the bivalves, taking into account that more than a third of the shells couldn't be identified.

Commented [FP3]: Not sure what you mean here…do you mean the upper layers are dominated by bivalves ?

Dating sequence

The results from excavation EX.1 show clearly that Manono is slowly sinking. The oldest layers occupied by humans during the ceramic period are today under the water table. In order to get a better understanding of the chronology identified through the excavation, a series of ~~10~~ samples collected from EX.1 were sent for dating. The results are presented in Table 2~~Here we present the results obtained (Table)~~.

The ~~first~~ upper most result (Wk-37438) confirms the modern date ~~of the occupation related to~~for the ~~the~~ house platform found in~~of~~ layers 3-4. One ~~of the~~ sample~~s~~ from~~of~~ layer 8, the lowest human occupation of the sand fill ~~(layer 8)~~ gave an anomalous result of AD ~~834+/-20BP~~1160-1260 (95% prob.). The other three dates for this layer fall between AD …? and ?...

range at 2 sigma (95% certainty) between 1281-1070 BP, though around 800 AD.

T~~A moment of t~~he sterile sandy layer has been dated on shell to AD ~~1700~~240-~~1510~~440 ~~cal BP~~. The top part of the clay layer, between 210-220cm, marking the appearance of pottery in the fill, is dated to ~~197+/-21 BP~~170-1 BC (W~~K~~k-37445)~~, corresponding to a calibrated date of1950-1875 cal BP.~~ The underlying fill at 225cm is dated on shell to a calibrated range of ~~2040-1830 cal BP~~100-120 BC~~, around the time of Christ~~. The deepest sample that was able to be collected from EX.1, at 246cm before the appearance of the water, was dated to ~~2155+/-20 BP~~BC 360-110 (W~~K~~k-37447)~~, calibrated to 2300-2240 cal BP~~.

Analysis

The data from the test-pit excavation EX.1 ~~fulfilled~~ undertaken at Pagai on the east coast of Manono, complemented by excavation EX.3 nearby (Sand et al. 2015), reveal a clear process of sedimentary change, from clayish soils to sand. At first human occupation, this area was clearly inland, with no close ~~presence~~ proximity of a sandy beach. Archaeological data ~~allow to hypothesize~~suggest that the area was mainly used for some kind of human settlement, possibly a garden dwelling. The presence of numerous potsherds as well as volcanic glass and shells, indicates ~~clearly~~ a continuous use of an inland location, at least starting by 2600-2700 cal. BP ~~from dates obtained from the bottom layer of~~at EX.3. This is only about one century after the main Lapita settlement at Mulifanua (2880-2750 cal BP at 68% prob.), highlighting a rapid process of human settlement of Upolu and contradicting earlier hypothesis about a two-step occupation of Samoa (Addison and Matisoo-Smith 2010).

Commented [FP4]: Do you want cal BP or AD/BC ??

Commented [FP5]: This statement is a mixture of BP and AD/BC calibrated ranges. They all belong to a layer – which isn't defined. I cannot tell from the information provided which dates fall in this age range.

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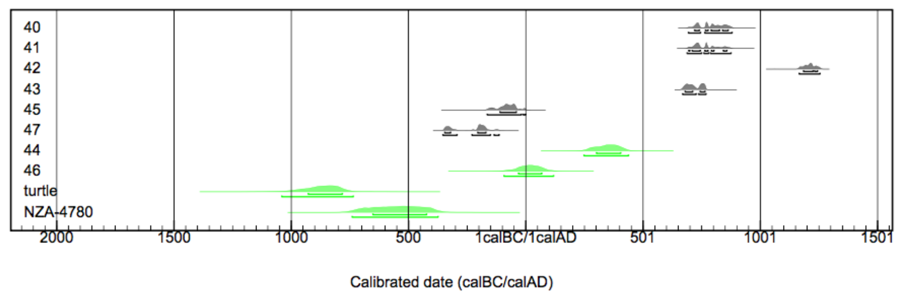
Commented [FP6]: Here you are talking in cal BP…above it was a mixture of uncal BP and AD/BC.

Commented [FP7]: I have taken this from my paper. Note it is at 68% prob. At 95% prob. The date will very nearly overlap with your EX3 dates..ie the turtle bone is 3010-2710 cal BP. I suggest an OxCal figure showing all early Samoan dates ?...including those from EX 1 and EX 3 ?? example of some of the data below – I can separate out the Mulifanua, EX1 and EX3 dates ?

Commented [FP8]: Very difficult to say one way or other when dealing with dates at 95% prob..



The ~~brutal~~ encroach~~ing~~ment of sand from the seashore is best ~~identified~~ demonstrated by~~with~~ the sterile layer 9 of excavation EX.1, which tops the soil layer without any process of mixing. A similar observation has been made in a number of other excavations fulfilled in Salua. ~~A general dating of the~~This event occurred~~is possible,~~ somewhere around the beginning of the first millennium AD. By associating this result with the dating of layer 8 at around 800 AD and considering that the soil surface has most probably been stable over the past three millennia, the subsidence rate of western limit of the Upolu plate is around 1.1-1.2mm/year; in keeping with ~~. This is the same general result as the one proposed by~~ rates proposed by W. Dickinson (2007)~~, confirming if needed the overall scheme~~. ~~Though,~~ B~~b~~y 2800 BP when Samoa was first discovered by Lapita sailors, Manono was at the end of a large peninsula that covered part of what is today the Wasa lagoon. However, f~~F~~lat cultivable land originally extended over an area of at least 10km^2 (fig. 4), before its size ~~shrinked~~ shrank rapidly over the succeeding centuries, finally ending in the separation of Manono from Upolu.

Commented [FP9]: Should be a range not a single value – too hard for me to know which is layer 8 from the information provided.

The loss of a massive proportion of the cultivable soils trough the erosion of the flat plain must have fostered a radical although progressive change in settlement patterns for the groups ~~centered~~centred on the small island. ~~In excavation~~At EX.3, in the layer dated around 2000 BP, the presence of a set of large boulders placed in an alignment perpendicular to the seashore (Sand et al. 2015)~~,~~ might signal a first phase of land divisions through stone-walls, a tradition that is well identified in Western Polynesia in traditional times. The~~But more significant archaeologically, this~~ period around the beginning of the first millennium AD also marks the end of pottery production in Samoa as well as elsewhere in the West Polynesian region (Rieth and Hunt 2008). The data from the Manono excavations clearly point to the end of pottery production sometime ~~at the maximum~~ around 1800-1700 cal BP, although no direct relationship between the subsidence process and the abandonment of ceramics in Samoa is to be expected.

By 1200 cal BP, when people started to use the now sandy flat of the Pagai plain, pottery use had vanished. Mapping of part of the inland area of Manono around Salua, has highlighted how much the succeeding millennium saw a massive intensification process of the land-use of the hill~~-~~sides (Sand et al. 2015). This is identified by the dense array of walled enclosures~~,~~ with ~~the presence of different sets of~~ house platforms and~~s well as~~ roads ~~in a number of cases,~~ covering the ~~different~~ slopes leading to the central flattened hill-top. This central location of the island is itself covered with numerous platforms of a more ritual/political function: high stone platforms, star-mound shaped platforms, possible pigeon catching structures of Tongan type, raised roads, etc.. The hill itself is defended on most of its sides by a set of ~~protective~~ stone walls built along the cliff side or as proper structures, some reaching over 7m in high. All the ^{14}C dates obtained from shells collected in the building material of these different structures, indicate that the main development of the Manono intensification process was confined to the second millennium AD. Clearly, the answer to land-loss due to geological tilting was in this case not abandonment of the Island but intensification of the land that was still present, in a process of resilience to environmental changes.

Conclusion

W. Dickinson has been instrumental in the use of geological data by archaeologists in the Pacific over the past 40 years. For Polynesia as well as Melanesia, his long-term commitment in understanding the subtle processes of land rise and subsidence that affected coastal areas since first human settlement, alongside isostatic fluctuations (Dickinson 2001) have been of critical importance for our understanding of archaeological site locations. Archaeological data ~~on their side~~ are able to highlight with precision the geological processes identified, through the study and dating of human-related ~~stratigraphies.~~activities. It is an exercise of this type that has been proposed in this paper, allowing with the help of data from coastal excavations on the small Island of Manono, to propose a process of subsidence of the western part of Upolu at a rate of about 1.1-1.2mm/year. This is in line with what W. Dickinson had proposed through other data. The concluding outcome of this research is that geology and archaeology are in this case able to produce compatible results for a better and coherent understanding of Oceania's past. Associated ~~to~~ with sea-level fluctuations and sometimes massive erosional processes that have covered early settlement sites, the recent tectonic histories of the Pacific Islands are today one of the important natural hazards that archaeologists need to integrate into their analysis of former settlement patterns, to disentangle the complex processes of human occupations ~~and sites formations~~ in the geologically active Islands chains of the wide Pacific plate.

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C. Sand would like to thank W. Dickinson for his long-lasting interest in the archaeological research that he carries out in the Western Pacific. He first started exchanging letters with Bill in the late 1980s, as a young scholar trying to make sense of pottery types in Wallis and Futuna. Bill was kind enough to analyze a decade later some of our sherds from Cikobia island in North-eastern Fiji, complaining that we hadn't had the good idea to sample the sand of each beach. He proposed a number of times to study the New Caledonia potsherds retrieved from our excavations, although it must be confessed that in most cases, we have still not finalized the papers/monographs that should have been published as an outcome. When Bill joined the conference celebrating the 50th anniversary of the first excavation at Lapita in 2002 in New Caledonia, we made sure to organize for him a visit to the Nickel mines on the peridotite plateaus of Grande Terre: seeing his excitement when he came back was so rewarding! After numerous other correspondences, it was though with great excitement that C. Sand wrote to him in late 2013 to inform him of the discoveries in Manono. He replied instantly, getting into geological details and calculations. Thanks to the invitation of David and Marshall to present this paper at the SAA session in San Francisco in April 2015, we had a last opportunity for a short discussion on the details of the Pagai results. As life follows sometimes strange paths, the team of the IANCP flue over Tongatapu on the 2nd of August 2015, on our way to Manono, just a few hours after Bill had been put into Polynesian soil for his eternal rest in Nukuleka. A last *fa'afetai* to a Big Man.

REFERENCES

Addison, D. and E. Matisoo-Smith, 2010. Rethinking Polynesian Origins: a West-Polynesia Triple-I Model. *Archaeology in Oceania* 45(1):1-12.

Bronk-Ramsey, C., 2015. OxCal Program v4.2, Radiocarbon Accelerator Unit. University of Oxford.

Burrows E.G. 1939. *Western Polynesia: A Study in Cultural Differentiation*. Ethnological Studies 7. Gothenburg.

Davidson, J. 1969. Samoan settlement patterns before 1840. *Journal of the Polynesian Society* 78(1): 44-82.

Dickinson, W.R. 2001. Paleoshoreline record of relative Holocene sea levels on Pacific Islands. *Earth-Science Reviews* 55: 191-234.

Dickinson W.R. 2007. Upôlu (Samoa): Perspective on Island Subsidence from Volcanic Loading. *Journal of Island & Coastal Archaeology* 2: 236-238.

Dickinson W.R. and R.C. Green, 1998. Geoarchaeological context of Holocene subsidence at the ferry berth Lapita site, Mulifanua, Upolu, Samoa. *Geoarchaeology* 13(3): 239-263.

Goodwin I.D. and E.E. Grossman, 2003. Middle to late Holocene castal evolution along the south coast of Upolu island, Samoa. *Marine Geology* 202: 1-16.

Green R.C. 2002. A retrospective view of settlement pattern studies in Samoa. In T.N. Ladefoged and M.W. Graves (eds), *Pacific Landscapes: Archaeological Approaches*, pp. 125-152. Los Osos: Easter Island Foundation.

Green, R.C. and H.G. Richards, 1975. Lapita pottery and a lower sea level in western Samoa. *Pacific Science* 29: 309-315.

Hart S.R., M. Coetzee, R.K. Workman, J. Blusztajn, K.T.M. Johnson, J.M. Sinton, B. Steinberger and J.W. Hawkins, 2004. Genesis of the Western Samoa seamount province: age, geochemical fingerprint and tectonics. *Earth and Planetary Science Letters* 227: 37-56.

Jennings J.D. 1974. The ferry berth site, Mulifanua District, Upolu. R.C. Green and J. Davidson (eds), *Archaeology of Samoa* (volume II), pp. 176-178. Auckland: Bulletin of the Auckland Institute and Museum 7.

Leach H.M. and R.C. Green, 1989. New Information for the Ferry Berth site, Mulifanua, western Samoa. *Journal of the Polynesian Society* 98: 319-329.

Patrick D. Nunn, 2009. *Vanished islands and hidden continents of the Pacific*. Honolulu : University of Hawaii Press.

Petchey, F.J. 2001. Radiocarbon determinations from the Mulifanua Lapita site, Upolu, western Samoa. *Radiocarbon* 43: 63-68.

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Petchey, F., Anderson, A., Zondervan, A., Ulm, S., Hogg, A., 2008. New marine ΔR values for the South Pacific subtropical gyre region. Radiocarbon 50(3):373-397.

Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Haflidason, H., Hajdas, I., Hatté, C., Heaton, T.J., Hoffmann, D.L., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., Manning, S.W., Niu M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Staff, R.A., Turney, C.S.M., van der Plicht, J., 2013. IntCal13 and Marine13 radiocarbon age calibration curves, 0-50 000 years cal BP. Radiocarbon 55 (4):1869-1887.

Rieth T.M. and T.L. Hunt, 2008. A radiocarbon chronology for Samoan prehistory. *Journal of Archaeological Science* 35: 1901-1927.

Sand C. D. Baret, J. Bolé and A. Ouetcho, 2015. *Manono Archaeology Project. Field Report 2014*. Nouméa: Institute of Archaeology of New Caledonia and the Pacific Report.

Staudigel H., S.R. Hart, A. Pile, B.E. Bailey, E.T. Baker, S. Brooke, D.P. Connelly, L. Haucke, C.R. German, I. Hudson, D. Jones, A.A.P. Koppers, J. Konter, R. Lee, T.W. Pietsch, B.M. Tebo, A.S. Templeton, R. Zierenberg and C.M. Young, 2006. Vailulu'u seamont, Samoa: life and death of an active submarine volcano. *Proceedings of the National Academy of Science USA* 103: 6448-6453.

Manono 2013 Excavation EX 1 PAGAI (Samoa)											
SPITS	GASTEROPODS	BIVALVES	URCHINS	CORAL	BONES	CRUSTACEANS	Non diagnostic sherds*	Diagnostic sherds*	Lithics*	Metal	Other
0 - 10					55					4 needles	1 button, 1 cement
10 - 20	107	36			22						
20 - 30	60	26			34	1					1 porcelain marble
30 - 40	68	5			13						
40 - 50	44				6						
50 - 60	154	14			8		1				
60 - 70	220	44			11						1 human teeth
70 - 80	170	40			15						
80 - 90	102	26			8						
90 - 100	144	8			10						
100 - 110	340	60			13						
110 - 120	224	68		78	15	1					
120 - 130	190	25			6				1		
130 - 140	145	49		22	6						
140 - 150	96	9			8						
150 - 160	60	5			10						
160 - 170											
170 - 180											
180 - 190											
190 - 200											
200 - 210											
210 - 230	156	48	3	115	6	10	19	1			
230 - 250	191	34		290	5	4	9		2		2 obsidian flakes
250 - 265	116	12	4		7		7	1	5		3 obsidian flakes
265 - 275	6		1	56	2	12	2		1		1 flake

Table 1: Remains from excavation EX.1 at Pagai, Manono.

Sample ID	Lab number	Context	Material	$\delta^{13}C$ ±0.2‰ (IRMS)**	CRA (BP)	Calibrated age (68.2% prob.)^	Calibrated age (95.4% prob.)^
IANCP-263	Wk-37438*	??	Charcoal	-27.9	100.1 ± 0.3%	Modern	Modern
IANCP-265	Wk-37440*	??	Charcoal	-25.4	1227 ± 20 BP	720-870 AD	690-880 AD
IANCP-266	Wk-37441*	??	Charcoal	-24.1	1235 ± 20 BP	690-860 AD	680-750 AD
IANCP-267	Wk-37442*	??	Charcoal	-25.6	834 ± 20 BP	1180-1250 AD	1160-1260 AD
IANCP-268	Wk-37443 *	??	Charcoal	-25.8	1287 ± 20 BP	680-770 AD	660-770 AD
IANCP-269	Wk-37444	??	Shell: *Tridacna* sp.	2.0	2061 ± 25 BP	300-410 AD	240-440 AD
IANCP-270	Wk-37445*	??	Charcoal	-27.9	1971 ± 21 BP	120-40 BC	170-1 BC
IANCP-271	Wk-37446	??	Shell: *Tridacna* sp.	2.1	2347 ± 25 BP	40 BC-70 AD	100 BC – 120 AD
IANCP-272	Wk-37447*	??	Charcoal	-26.5	2155 ± 20 BP	350-170 BC	360-110 BC

Table 2. Results of the ^{14}C samples of excavation EX.1 at Pagai.

* Radiocarbon dates measured by AMS at the Waikato Radiocarbon Dating Unit.

** Isotope ratio mass spectrometer value measured directly on CO_2 collected during combustion of sample for dating.

^ All radiocarbon dates were calibrated in OxCal v4.2 (Bronk Ramsey 2015) using the Marine13 and Intcal13 curves (Reimer et al. 2013). A location-specific reservoir correction value (ΔR) of 28±26 ^{14}C years has been applied to calibrations of the shells to adjust for regional oceanic variation in ^{14}C (Petchey et al. 2008).

Commented [FP10]: Context information for each

Commented [FP11]: I assume unidentified to species ?

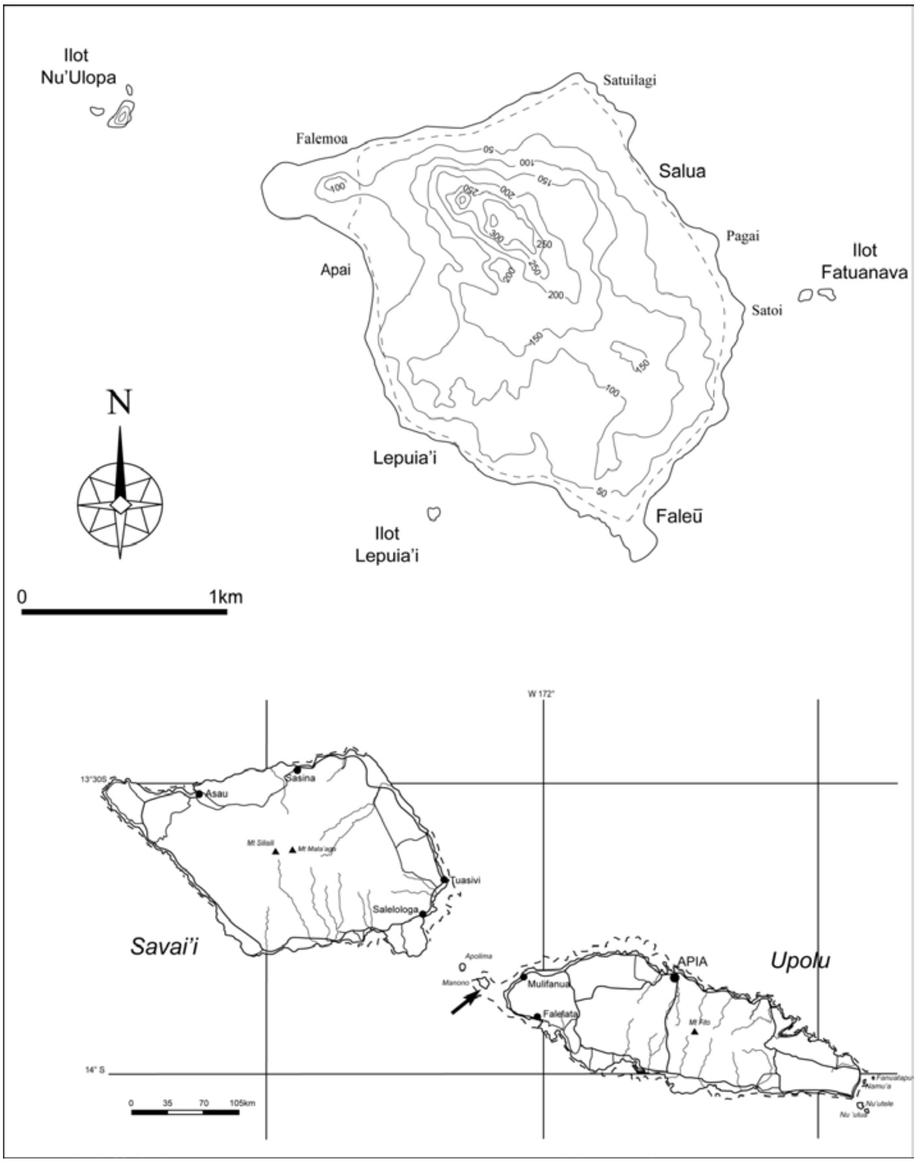
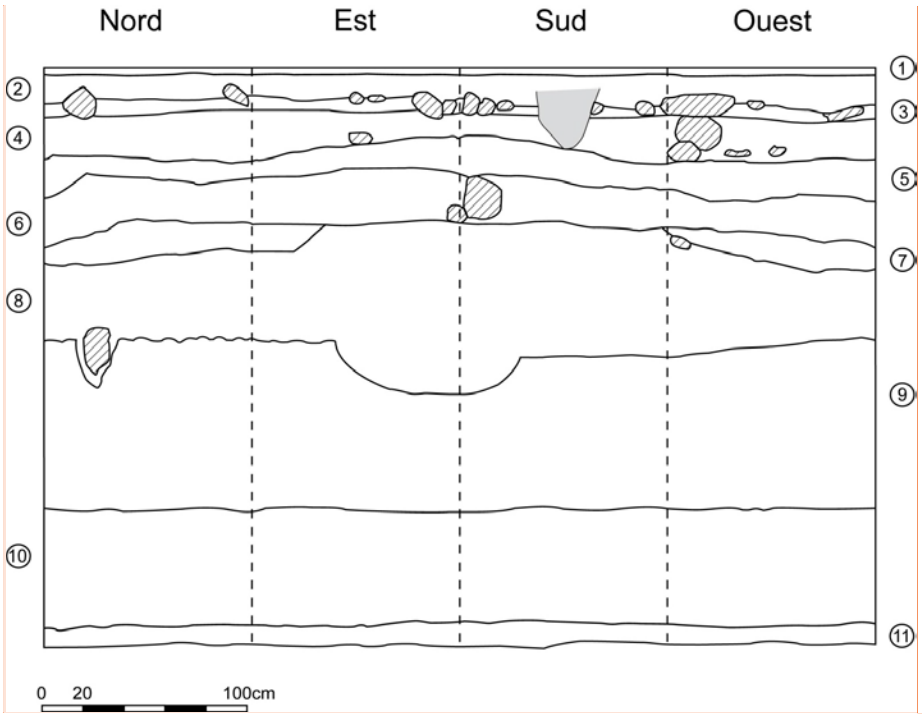


Figure 1. Position of Manono Island in between Savai'i and Upolu, and map of the Island locating the area of Pagai.



Commented [FP12]: North South East West ??

Figure 2. Stratigraphic profile of excavation EX.1 at Pagai.

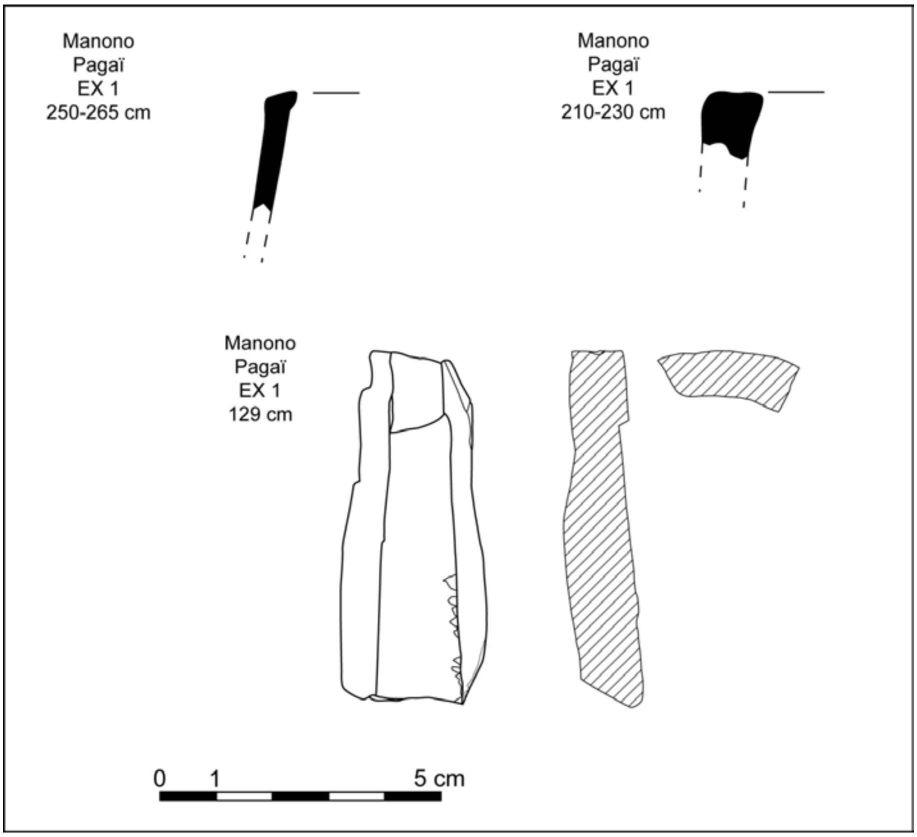


Figure 3. Rim sherds and adze fragment from excavation EX.1 at Pagai.

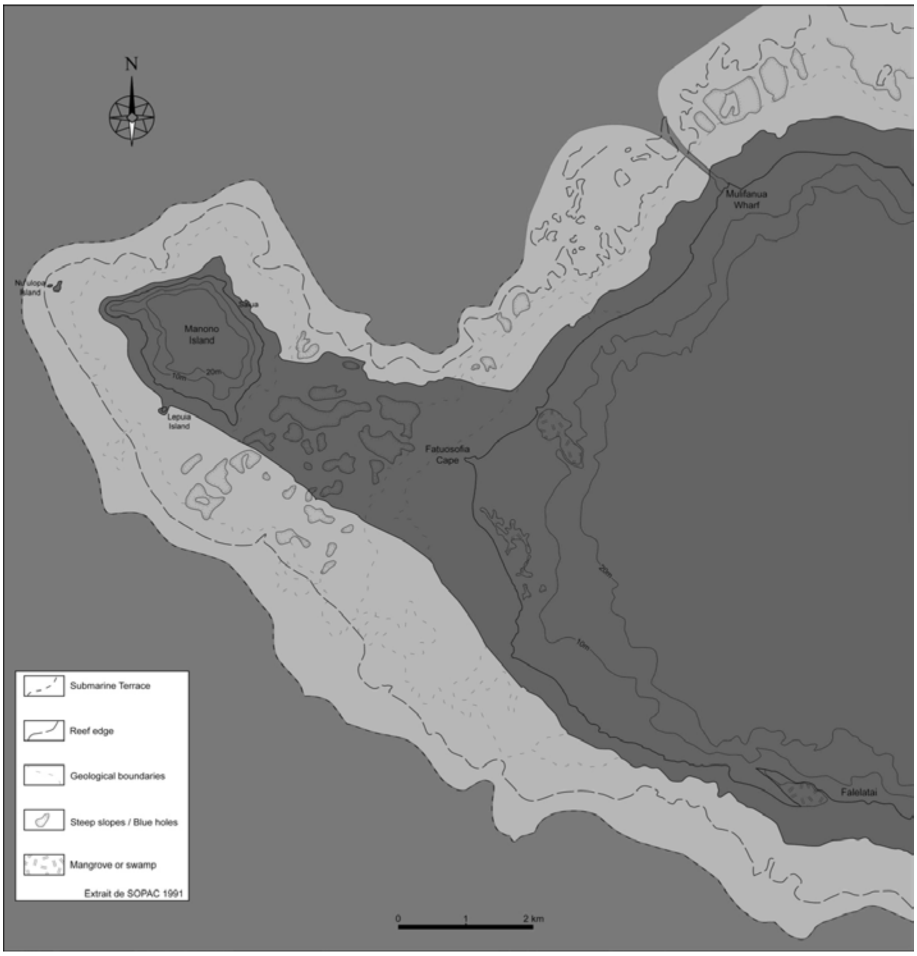


Figure 4. Broad coastal limits of the western end of Upolu at first human settlement of Samoa 2800 years ago.