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Volcanic structures and oral traditions of volcanism of Western Samoa (SW Pacific) and their implications for hazard education

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ABSTRACT

The Samoan Islands have experienced >2 million years of volcanism, culminating in historic eruptions at both the east and western ends of the chain including a major lava-producing episode on the island of Savai'i from AD 1905–1911. Upolu in Western Samoa has several areas mapped as early Holocene in age (>5 ka), but here we present new evidence for fresh volcanic landforms and deposits, supported by a radiocarbon date of 1915 ± 65 yrs B.P., giving a maximum age to a phreatomagmatic tuff cone offshore of Cape Tapaga, east Upolu. In addition, we report on a parallel investigation of the oral traditions of communities surrounding fresh volcanic landforms that may reflect distant "volcanic memories" passed down over generations. To accommodate Samoan cultural structures, oral traditional knowledge was sought through semi-structured interviews with small groups (3–4) or individuals. Samoan facilitators focused on high-ranking and traditionally respected (particularly elderly) individuals for explanations of the origins of local features, including their genesis, use and any related geo-hazards. Areas targeted were those where young eruptions (<3500 yr BP) were suspected from geological mapping. In stark contrast to communities in Vanuatu, Papua New Guinea or the Solomon Islands, the village communities show extremely limited knowledge of their volcanic heritage. Youthful volcanic landforms are often not recognised as such and appear to play little role in everyday life. Few, if any, legends are attached to any volcanic feature. Instead, oral traditions deal primarily with the origins of Samoans (overlain by strong Christian teachings), and past disputes/battles and wrongdoings between tribes/neighbours. The only exceptions to this were identified in legends from East Upolu, where offshore islands (tuff cones) are associated with late Holocene explosive phreatomagmatic volcanism. Maps drawn by individuals and groups interviewed, highlighted the resources and landscapes important in their lives. The majority of these were prepared as 3D oblique-view sketches, rather than plan-views, showing little in common with typical hazard maps used in the area. In addition, maps were commonly restricted strictly to boundaries of local communities, ignoring major features (such as fresh volcanic cones) that were in the territory of "next door" villages. These perspectives need to be focused upon in future iterations of hazard maps and hazard-education programmes for Samoa and similar Polynesian communities.

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1. Introduction

Traditional knowledge about natural hazards, disasters, and hazard management in indigenous communities has recently been recognised as a useful information that could be combined with modern western science to develop a better understanding of natural hazards and their management (Mercer et al., 2007). Such traditional knowledge not only includes practical information about the way the community would act in the event of a natural disaster, but also detailed legends, myths, and stories that could be linked to various natural phenomena or disasters, and stories how the community managed to cope with such events (Cashman and Cronin, 2008). People living with volcanoes commonly have great diversity of legends and myths about them (Elson et al., 2007; Alvarado and Soto, 2008; Viramonte and Incer-Barquero, 2008). Such stories are also vivid in communities where the transmission of information through generations is only orally. The Samoan community, a Polynesian society maintains its strong cultural and oral traditions alongside increasing levels of development. Western Samoa last experienced volcanic eruptions around 100 years ago, and the volcanic origins of the nation's major islands are evident. Therefore legends and myths around volcanoes are expected to exist in communities in Western Samoa. To test this, a combined research project was carried out to gather geological information on the volcanic history of the older parts of the Western Samoan islands, and legends, myths and stories, if they exist, from the rural communities.

The hypothesis of this study was based upon experience in neighbouring Tonga and Fiji (Taylor, 1995; Cronin and Neall, 2001; Cronin et al., 2004a) that volcanic eruptions up to a few thousand years

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old often leave traces within oral traditions, place names, artistic views, motives, patterns of dance, and legends. Such cultural records are also known from North-American tribes affected by volcanism (c.f. Ort et al., 2008). In general, Polynesian culture is strongly reinforced by oral traditions concerning origins, lineage and major developments that may pass through many generations (Nunn, 2001; Mageo, 2002; Nunn, 2003). Due to the uncertainty in both the geological knowledge of Upolu as well as the potential existence of any trace of distant "volcanic memories" of the local communities, this was a reconnaissance study to help build a perspective of how volcanism and other geological hazards are perceived and portrayed by Upolu communities.

Savai'i and Upolu (Fig. 1) are the westernmost and largest islands of the Samoan group (Fig. 2) and have experienced a long period of volcanism (>2 My) (Kear and Wood, 1959). Reliable estimation of recurrence intervals between eruptions and hence an accurate assessment of volcanic hazard for these islands is hindered by a lack of age data on past events. Recent eruptions occurred on Savai'i (Fig. 1) in 1905–1911 (Matavanu) (Sapper, 1906; Anderson, 1910a,b, 1912; Anonym, 1907, 1910), 1902 (Mauga Mu and Mata o le Afi [fire peak]) (Anderson, 1910a,b) and 1760 (Maunga Afi [fire mountain]) (Kear and Wood, 1959). Other evidence for repeated volcanic activity on both islands during human occupation includes fresh tuff/scoria cones such as Tafua Savai'i (possibly as young as 610±60 yrs B.P), as well as another 5 radiocarbon dates of between 700 and 2500 yrs B.P. for individual lava flows and tephra falls in various locations around

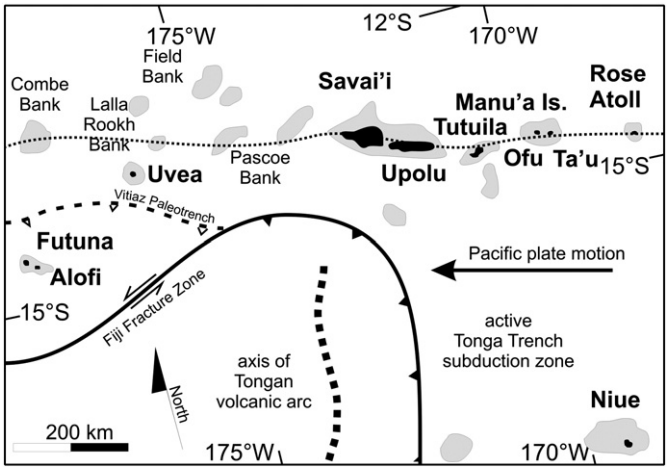

Fig. 2. Geotectonic overview of the Samoan islands. Black fields represent islands while grey fields correspond to submarine platforms.

Savai'i (Cronin et al., 2000). Although Upolu does not have the youngest of the mapped Holocene volcanic rocks, it has several areas mapped as early Holocene in age (>5 ky) and fresh volcanic landforms/deposits (Kear and Wood, 1959). Apparently fresh lava flows (O le Pupu lava field) cover the southern part of Upolu and are

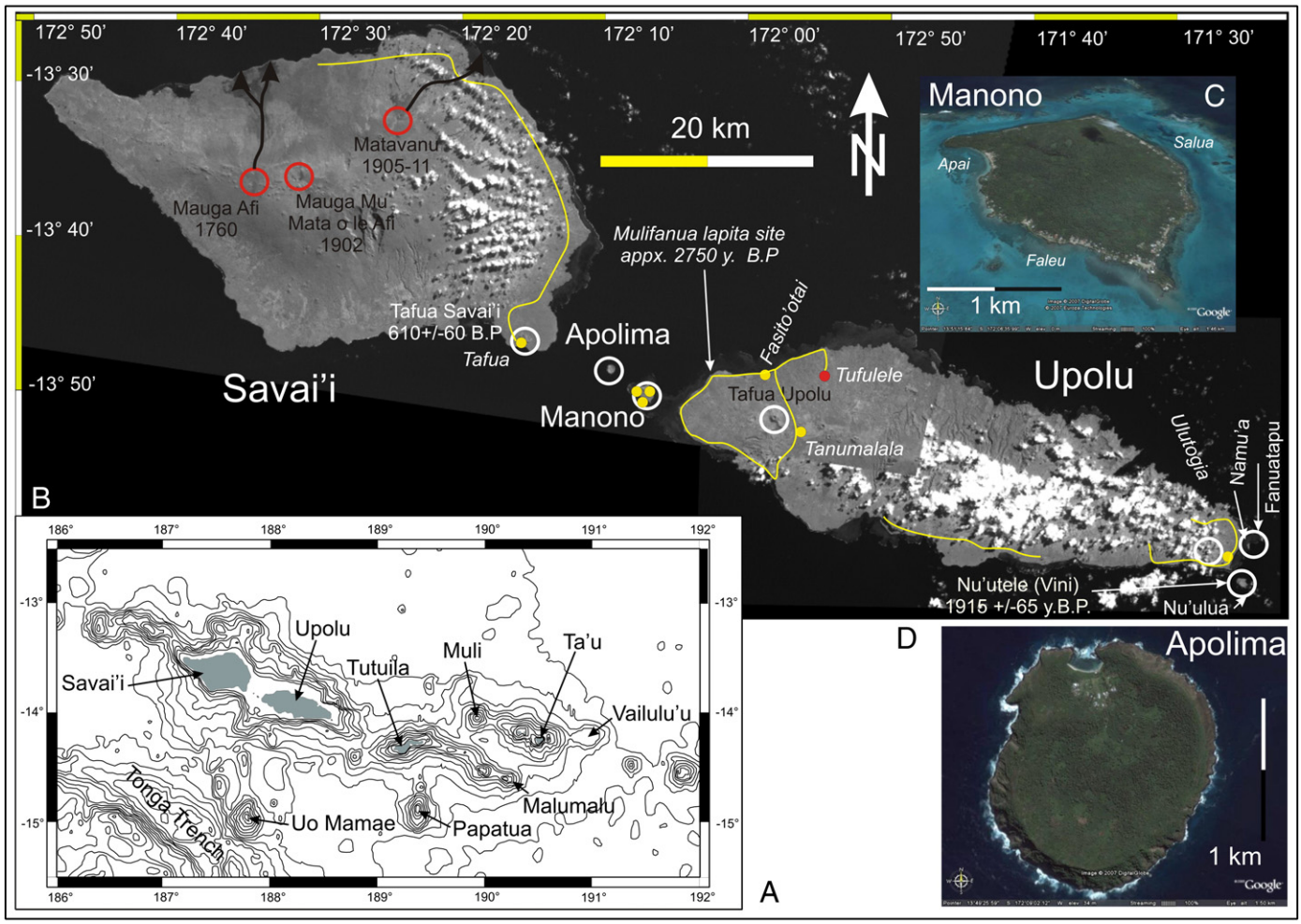

Fig. 1. A) Overview map of the Samoan islands and the associated bathymetry of the seafloor based on Hart et al. (2004). B) Western Samoa shows a NW–SE trending elongated island chain with young volcanoes along the axis of the islands. Red circles in Savai'i mark the youngest known volcanic eruption locations. White circles mark the morphologically young volcanic landforms suspected to be active during the human occupation of the islands. Yellow dots mark the village communities where oral tradition data was collected, while yellow lines mark the routes along informal conversation was taken with locals to find any distant volcanic memory of the communities. C) Oblique satellite image of Manono Island on GoogleEarth 2008 image. D) Apolima Island on GoogleEarth 2008 satellite image.

part of the youngest Holocene volcanic mapping unit, probably erupted very recently (Fig. 3). Direct evidence of young volcanism in Upolu includes a radiocarbon date of 1915 ± 65 yrs B.P., giving the maximum age of a phreatomagmatic tuff cone offshore of Cape Tapaga, east Upolu (Grant-Taylor and Rafter, 1962). Many of the dated pre-historic eruptions occurred after the known onset of human occupation in Samoa (c. 3500 yrs BP) (Martinsson-Wallin, 2007). One of the earliest occupation sites known in Mulifanua (Fig. 3), northwest Upolu contains a Lapita pottery assemblage dated at around 2750 B.P. (Green, 1974; Petchey, 1995; Dickinson and Green, 1998). Other such sites dating back to c. 3000 yrs B.P. occur on neighbouring islands (Clark and Herdrich, 1993; Clark and Michlovic, 1996; Kirch, 1990).

2. Geological setting

The Samoan islands form a roughly east–west trending chain of islands and submarine volcanoes about 800 km in length (Fig. 2) (Hart et al., 2004). The islands are almost entirely composed of basaltic volcanic products (Kear and Wood, 1959). The volcanic lineament (Fig. 2) has many characteristics reflecting a magmatic plume-driven hotspot (Hart et al., 2004; Staudigel et al., 2006). Its proximity to the Tonga trench (Fig. 2), and the widespread young volcanism in the westernmost island (Savai'i) and seamounts, do not fit this model (Hart et al., 2004). However, a hotspot origin is still implied for the eastern edge of the Samoan volcanic chain (Workman et al., 2006).

A characteristic change is recognised in volcanic morphologies from east to west, with youthful shield morphology in the east on Ta'u island, to well-advanced erosion of Tutuila showing an incipient post-erosional veneer. Upolu has a major post-erosional veneer covering a deeply eroded shield and Savai'i is likely to be thickly covered by young post-erosional volcanic products (Hart et al., 2004; Workman et al., 2006). Young volcanism in Upolu and Savai'i can perhaps be explained by the relative migration of the edge of the Tonga trench (Fig. 2), which is presently just few hundred kilometres to the south of the island (Hart et al., 2004; O'Leary et al., 2007).

The oldest mapped rocks in Western Samoa are the 3–1 Ma Fagaloa Volcanics and Salani Volcanics (1–0.1 Ma), effusive rocks that occur in central and north-eastern parts of Upolu Island (Fig. 3) (Kear and Wood, 1959; Kear, 1967). Mulifanua Volcanics (0.1–0.01 Ma) are represented by large numbers of strongly eroded and dissected scoria cones and associated lava flows that cover most of the central rift zone and western flanks of Upolu (Fig. 3). The Puapua Volcanics (0–5000 yrs) comprise, by contrast, well-preserved scoria cones along the rift zones of both Savai'i and Upolu Islands. Distinctive large and fresh scoria cones on Upolu include Tafua Upolu and Mt. Fito (Fig. 3), and extensive young lava flows are mapped along the southern central shores of Upolu and in narrow lobes near Apia. Historic volcanism on Savai'i Island is mapped as the Aopo Volcanics (Fig. 3). Well preserved scoria cones (Fig. 4) as well as lava flow fields represent the youngest volcanism in Savai'i. The older volcanics in Samoa are potentially suitable for extensive K–Ar and/or Ar–Ar age determination surveys applying new sampling and analytical techniques (c.f. Balogh and Németh, 2005; Gray and McDougall, 2009), a tool could help to refine the early volcanic history of the islands.

3. Method

Field mapping was carried out to identify sites where long-established villages are located nearby volcanic landforms that are either distinctively volcanic, or show evidence for being only a few thousand years old. The basic geological map of Western Samoa (Kear and Wood, 1959) was used to pre-select sites; however, previous field campaigns (Cronin et al., 2006a) had already suggested that stratigraphic problems may exist on these maps. Therefore before village visits, key volcanic sites were investigated. In the second part of this activity, participatory style activities (c.f., Chambers, 1994) were planned to gather information about the local knowledge of geological/landscape history and geo-hazards of the localised areas of the village surroundings. By contrast to group-based activities applied in Vanuatu and the Solomon Islands (Olson, 2002; Cronin et al., 2004b,c) where communities have constant experience of volcanism, traditional geological history and hazard information was anticipated to be much more subtle and hidden on Samoa (especially Upolu). Hence, data were collected via a series of personal one-by-one semi-structured interviews with individuals nominated by their communities. Samoan villages are structured around extended families, where both men and women have significant roles in daily life, village organisation and decision making, as well as shielding

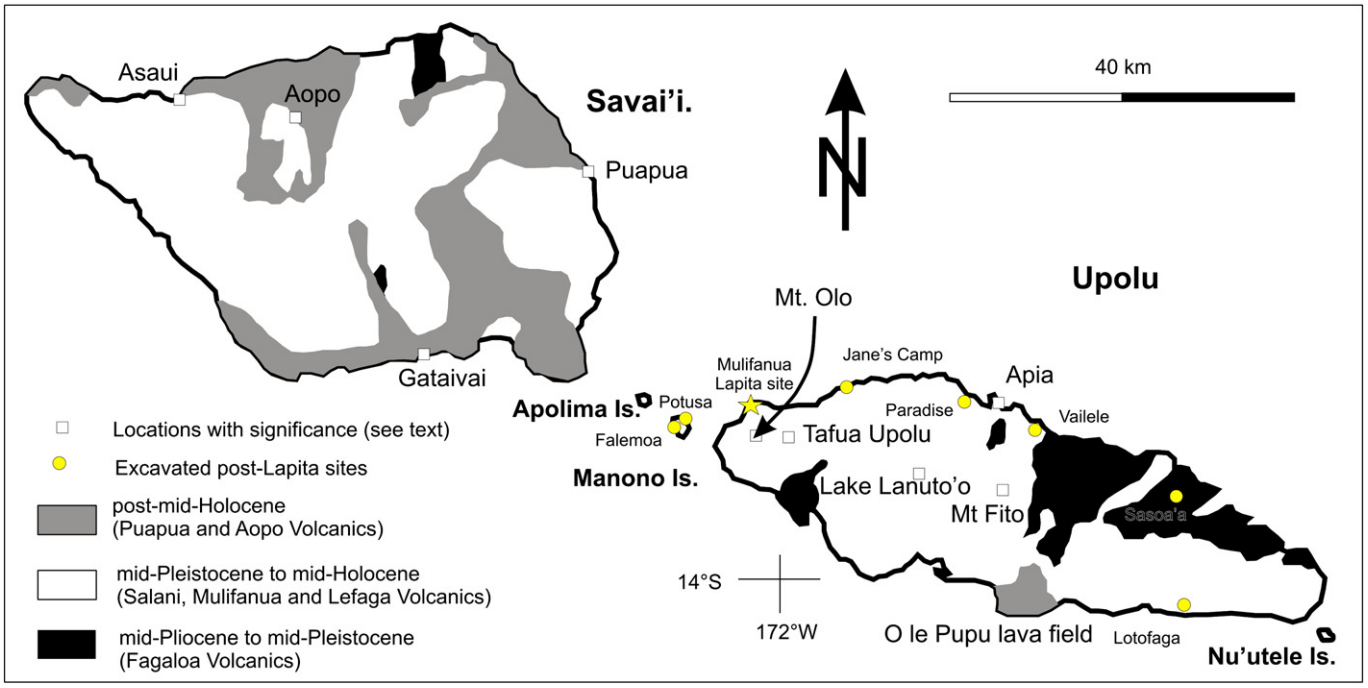

Fig. 3. Surface distribution of volcanic stratigraphy units of Western Samoa.

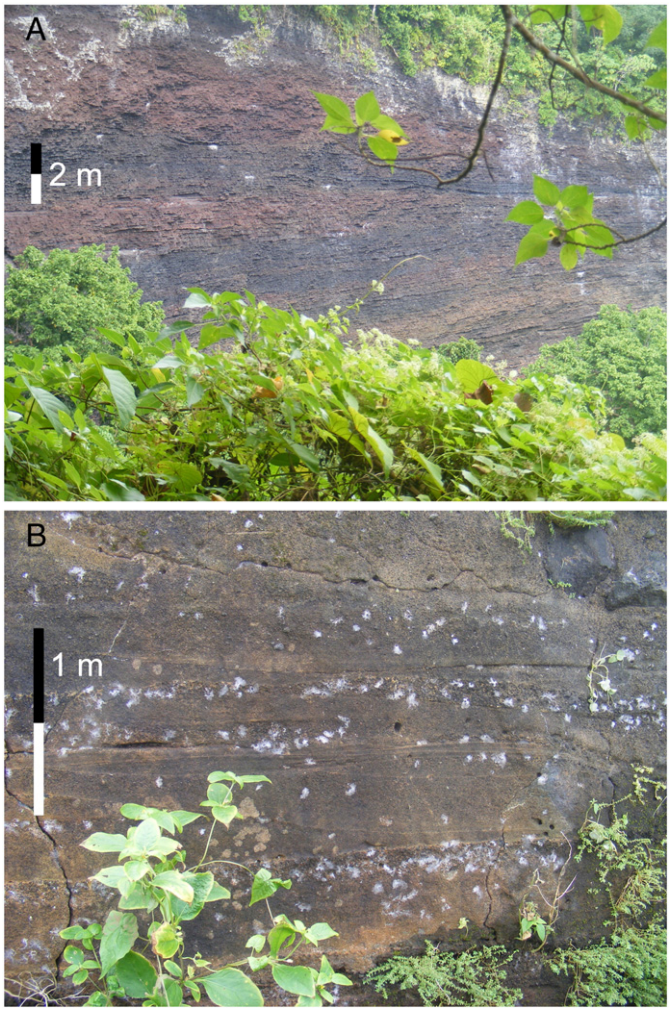

Fig. 4. A) Inner crater wall of the morphologically young scoria cone of Tafua Savai'i in the south-east of Savai'i Island, Western Samoa. The crater is about 50 m deep, steep sided and exposed lava-spatter layers forming the majority of the proximal pyroclastic rocks of this cone. B) Distal pyroclastic surge beds form an about 10 m thick pyroclastic succession of the base of the Tafua Savai'i volcano in south-east Savai'i Island in Western Samoa. The exposure is about 1 km distance from the crater of the Tafua Savai'i cone shown in A.

family life from outside world influences (both social and natural) (Mead, 1961; Lockwood, 1971; Milner, 1972; Shankman, 1972; Fairbair, 1974; Schoeffel, 2007). Since villages in Samoa are loose amalgamations of extended families, organising any community based event or workshop that immediately influences any individual extended family requires a well-balanced approach to avoid conflicts with other families. For these reasons, the group-workshops successfully used in Melanesian communities (Cronin et al., 2004b,c) were not applied here.

Interviews were conducted in community houses, or the "house of chiefs" (*matai* houses), with high raking chiefs (*matais*) being usually elderly people who were often very willing to participate. The questions started by gathering basic information about the village physical surroundings and history, and progressed to more direct questions of the knowledge of volcanism in general and its relationship to the local environment. Questions were formulated and discussed at length with Samoan interpreters and facilitators to make sure the meaning was clear. It was very important to ensure that the translated questions were not leading to expected answers and that the Samoan facilitators were not pre-anticipating possible outcomes. In cases when interview subjects gave signs of attempting to provide the "right" answers for their interpretation of our objectives, the Samoan interpreters changed the conversation topics. In addition to interviewing and visiting Upolu communities, a comparative visit to Savai'i was made to talk to communities with more recent memories of volcanic processes only 100 years ago.

4. Geological evidence for Late Holocene volcanism

4.1. Savai'i Island

Geological mapping and sample collection over the past decade has been targeted at finding datable material to refine the eruption history of Savai'i. The large number of apparently morphologically young scoria cones, and associated lava flows, suggested that volcanic eruptions were frequent. The newly obtained and published ^{14}C radiocarbon dates (Fig. 5; Table 1) indicate that many lava units appear to be significantly younger than suggested by earlier mapping (Fig. 5). The best known activity from Savai'i includes three historical eruptions in AD1760, 1902 and 1905–1911.

The 1905–11 Matavanu eruption covered large coastal plains in NE Savai'i, and appears to have been typical volcanic event on Samoa. The 1902 eruption was considerably smaller and occurred in the high rift zone of the island, far from human habitation, hence very little is known about it (e.g. Whistler, 1978). The Matavanu 1905–11 eruption begun on 4 August 1905 with ash emission from a scoria cone (Fig. 6A, B) followed by lava flows that eventually reached the sea (Anderson, 1910a). Some littoral and steam explosions occurred at the flow front in early 1906, and once the lava field had developed much lava flowed through tubes (Anderson, 1912). Several lava bench collapses into the sea generated local tsunami with 2–2.5 m waves in late 1906 and throughout 1907 (Anderson, 1910a). Four settlements and one major village, Saleaula were destroyed by lava (Fig. 6C), with the walls and upper parts of two stone churches being the sole remnants (Fig. 6D). The 1905–11 Matavanu eruption was a significant event in Samoan history, however it probably only interrupted the life of the inhabitants near the eruption site, with those on Upolu well isolated from the events.

4.2. Upolu Island

Landforms within Puapua Volcanics (Fig. 7A) were targeted in this study, along with volcanic islands immediately east of Upolu and those to the west between Upolu and Savai'i (mapped as Vini Tuff; Kear and Wood, 1959). Western Upolu's most prominent landform is Tafua Upolu (Fig. 7B). The names Tafua Upolu or Tafua Savai'i imply a volcanic origin or application of a volcanic analogy to their shape, where Tafua = fire mountain/volcano, which is a cognate of "Tofua" — the active Tongan volcano and "Tavuyaga" in Fiji (Cronin and Neall, 2000). This linguistic feature and the fresh morphology of Tafua Upolu focused our investigations in its vicinity. Tafua Upolu stands about 100 m above older lava flows and has a 650 m wide and well-preserved crater (Fig. 7C) with its floor near the same elevation as the external base of the cone. Agglutinated lapilli and bomb beds form the uppermost cone successions. Outer volcanic flank exposures show scoria lapilli and ash beds inter-bedded with irregularly shaped spatter-fed lava flows. The outer slope of 35–40° is steeper than the exposed bedding plains, suggesting that the original landform has been significantly eroded. This corresponds with the presence of a broad talus collar of reworked scoria, showing a pattern similar to other older scoria cones in arid areas (Martin and Németh, 2006). The size of this cone is comparable to larger scoria cones worldwide (e.g. Luhr and Simkin, 1993), and its eruption may have produced locally significant volumes of ash (c.f. Cronin and Neall, 2001; Valentine et al., 2006).

In central Upolu another series of scoria cones form along a NW–SE-trending rift axis and are grouped predominantly into the older Salani or Mulifanua Volcanics (Fig. 3). Many of these look morphologically

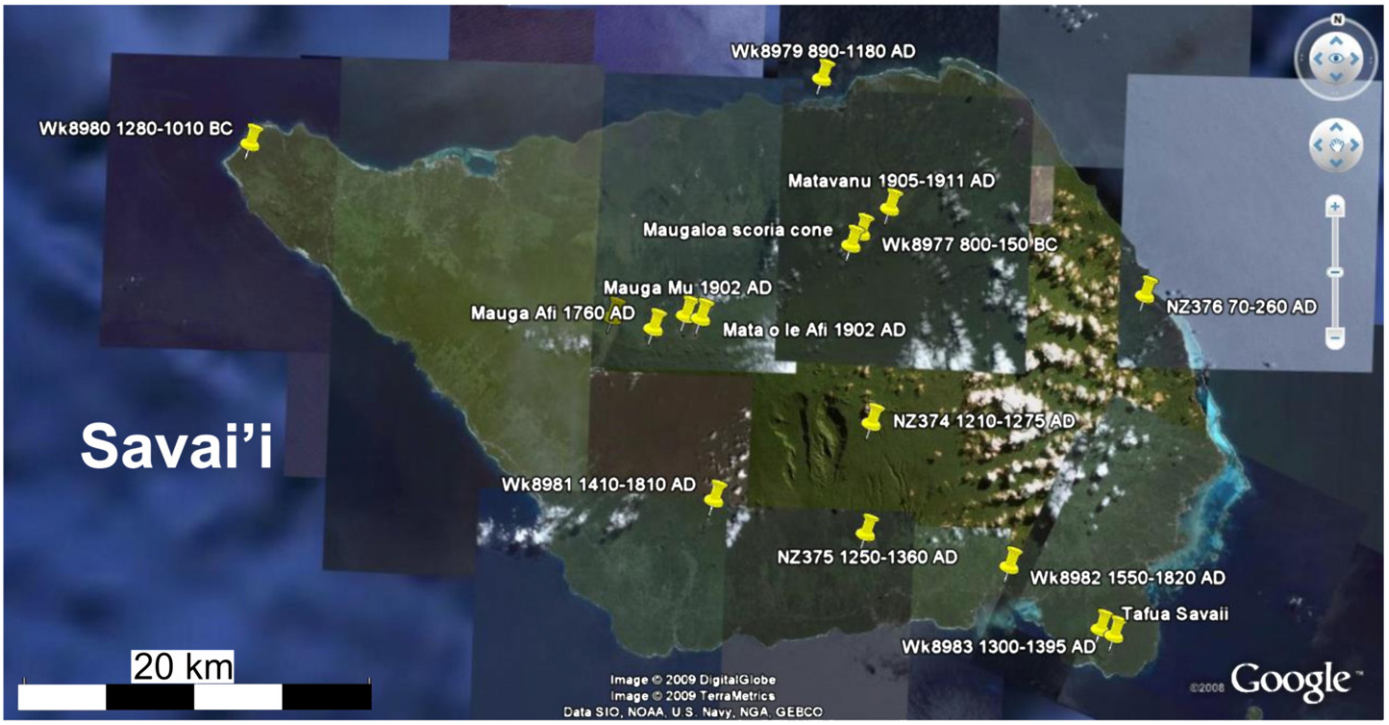

Fig. 5. Available C^{14} dates from Savai'i demonstrate extensive and repeated volcanic activity during the human occupation time of Samoa.

young, showing steep outer slopes, well-preserved and deep craters (Fig. 7D). Due to heavy vegetation cover, exposures that would allow confirmation of ages are limited or absent. Deep weathering profiles and thick soil formation attest to the great age of many cones, but not all could be confirmed as pre-Holocene structures. In central and eastern Upolu many volcanic cones host lakes, such as Lake Lanuto'o (Fig. 3) within a Salani-aged cone. The lakes may be due to higher rain fall in this part of the island, or could also relate to the presence of basal tuff rings as a result of initial phreatomagmatic eruptions.

4.3. Offshore islands

Namu'a and Fanuatapu islands are small, individual tuff cones located off eastern Upolu. Namu'a has a simple architecture with a steeply dipping cone flank and a half-open crater zone facing toward the east (Fig. 8A). A similar geometry can be reconstructed for Fanuatapu (Fig. 8B) and the other two offshore islands, Nu'utele and Nu'ulua. They are predominantly composed of accretionary lapilli-rich, tuff and lapilli-tuff successions with common slumping and dewatering features (Fig. 8C). The pyroclastic successions are rich in juvenile glassy pyroclasts, but also contain common coral fragments (about 5 vol.% of total volume). These observations indicate that at least the two islands visited (Namua and Fanuatapu) were formed from explosive magma and water interaction (c.f. Kokelaar, 1983; Sohn, 1996; Auer et al., 2007; Németh and Cronin, 2009). The explosion locus must have been shallow and the volcanic conduit open, enabling relatively small amounts of country rock to be incorporated. The presence of coral and mollusc fragments in the pyroclastic successions indicates that the explosion locus was in surface units of a shallow seafloor during the onset of volcanism (Fig. 8D). The asymmetry of the islands with breached eastern sides is likely the result of wave action, rather than a reflection of original tephra dispersion. These eruption styles, like those of early Tafua Savai'i events, were likely the most violent and spectacular to occur in the Samoa group (c.f. Németh et al., 2006). These could reasonably be expected to have had some influence on local communities if they occurred during the period of human occupation. The only available age data just offshore of Cape Tapaga on Nu'utele Island is a ^{14}C age of 1915 +/− 65 yrs. B.P. (Grant-Taylor and Rafter, 1962).

Table 1

Code	Age (years BP)	Calibrated age	Location	Significance	Source
Wk8982	230 +/− 70	1550–1820 AD	S13°44.98′ W172°18.60′	Maximum age of a possible volcanic ash layer in the Lalofasa area, minimum age of lava flows in this area (Puapua volcanics)	This study
Wk8981	340 +/− 210	1410–1810 AD	S13°42.98′ W172°29.67′	Minimum age of Mt Le'ele cone/crater (Puapua volcanics)	This study
Wk8983	610 +/− 60	1300–1395 AD	S13°47.32′ W172°14.59′	Minimum age of Tafua Savai'i tuff deposits that overlie Puapua lavas	This study
NZ375	715 +/− 50	1250–1360 AD	S13°40′ W172°24′	Minimum age of Puapua lavas in the Gataivai area	Grant-Taylor and Rafter (1962); Kear pers. comm. (1999)
NZ374	760 +/− 50	1210–1275 AD	S13°40′ W172°24′	Minimum age of Puapua lavas in the Gataivai area	Grant-Taylor and Rafter (1962); Kear pers. comm. (1999)
Wk8979	980 +/− 140	890–1180 AD	S13°27.66′ W172°26.31′	Minimum age of Puapua lava flows in the Sasina area	This study
NZ376	1850 +/− 80	70–260 AD	S13°35′ W172°14′	Maximum age of Puapua lavas in the Puapua area	Grant-Taylor and Rafter (1962)
Wk8977	2310 +/− 180	800–150 BC	S13°33.21′ W172°24.67′	Maximum age of ash producing-eruption in the Maugaloa (Mulifanua volcanics)	This study
Wk8980	2920 +/− 90	1280–1010 BC	S13°30.83′ W172°47.44′	Minimum age of Puapua lavas in the Falealupo area	This study
Wk8978	3610 +/− 110	2150–1830 BC	S13°33.21′ W172°24.67′	Minimum age of Maugaloa tephra cone and lava flows (Mulifanua volcanics)	This study

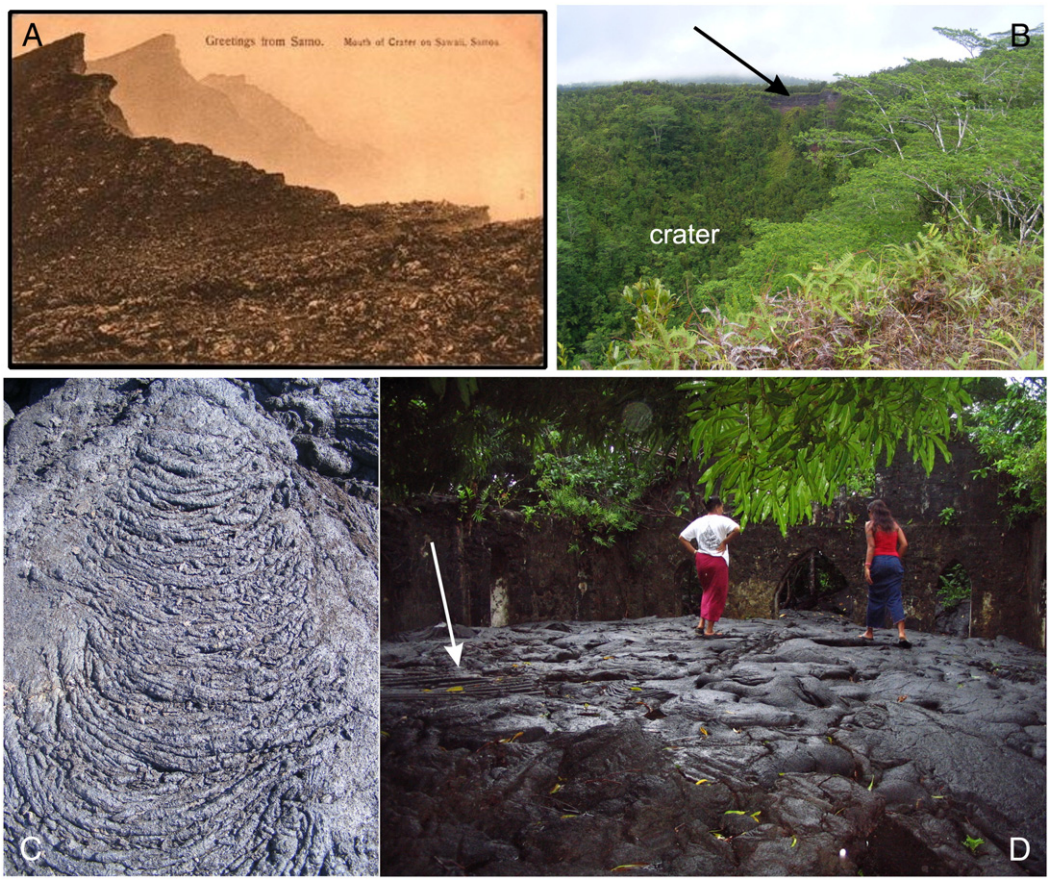

Fig. 6. A) Historic postcard shows the Matavanu crater rim. B) The crater rim of Matavanu volcano today. Arrow points to an area where strongly welded lava spatter and scoria beds form a steep inner crater wall. C) Typical pahoehoe lava flow surface of the Matavanu lava field, near the coast. D) The church of Saleaula invaded by lava. Lava flow entered to the church via its door and windows filling it up halfway. Arrow points to print caused by the collapsed iron roof to the hot lava surface.

Manono Island is located in the strait between Upolu and Savai'i. It is a youthful-appearing small volcanic shield with a base composed predominantly of thin pahoehoe lava flows overlain by a spatter cone that rises to c. 60 m above sea level. The island is vegetated, surrounded by coral reefs and has no active hot springs, or post-volcanic activity. The neighbouring Apolima Island is, by contrast, a tuff cone complex (Fig. 9A) similar to the islands described to the east of Upolu. The crater rim is about 80 m above sea level and forms a castle-like architecture with an almost complete circular rim breached toward the east. The pyroclastic succession of the island is brownish-grey lapilli tuff in a semi-consolidated state. The tuff cone slopes at about 25–35° following the original bedding angle, which possibly indicates its relative youth (Fig. 9B). The diameter of the island appears to be close to the original rim diameter of the original tuff cone. Apolima appears to have formed from multiple explosive phreatomagmatic eruptions (c.f. Cole et al., 2001) with shifting vent sites across a broad vent area.

5. Likely impacts of past volcanic events

Five potential volcanic hazard scenarios encompassing the major volcanic processes evidenced by geological deposits on the island were defined (Cronin et al., 2006a) including: 1) Long-term lava field eruptions, such as the 1905–1911 Matavanu eruption in Savai'i; 2) Short-term spatter cone eruptions, evidenced by the multitude of lava-spatter dominated cones dotted over both main islands; 3) Explosive phreatomagmatic eruptions, such as those producing the Surtseyan-style tuff cone islands east and west of Upolu, as well as part of the Tafua Savai'i structure at the south eastern edge of Savai'i; 4) Explosive scoria cone eruptions including the 1902 Savai'i eruption and shown by the large number of fresh cones along the rift axis in both main islands, including Tafua Upolu; and 5) Submarine flank collapses, based on morphological features on the islands as well as submarine flanks (Keating et al., 2000). A simplified three-zoned volcanic hazard map was also created by Cronin et al., 2006a (Fig. 10), with a red zone signifying the highest probability for new vent openings expected (majority of the northern rift axis of Savai'i); an orange zone of medium probability (majority of the NW–SE trending rift axis in both islands); a yellow zone for low probability of new vent opening (the southern rift axis of Savai'i and eastern edge of the NW–SE rift on Savai'i). The characteristic feature of all of these onshore or island-forming eruptions is that their impacts were localised. Even with large-scale lava flow eruptions, communities 10 km away, those on neighbouring islands or on opposite sides of islands would have been isolated from the volcanic impact. In situations like this, it has been recognised that the preservation of volcanic legends and traditional knowledge is weak (Cronin and Neall, 2000).

6. Investigation of traditional knowledge

Missionaries in the 19th century documented important facts about the Samoan culture and life, but very little directly relating to volcanic memories. George Turner, based in Samoa in the last half of the 19th century, described (Turner, 1884, 1979) an origin tale "the rocks married the earth, and the earth became pregnant. Salevao, the God of the rocks, observed motion in the moa or centre of the earth. The child was born and named Moa, from the place where it was seen moving. Salevao ordered the umbilicus to be laid on a club, and cut with a stone; and hence the custom ever after on the birth of a manchild. Salevao then provided water for washing the child and made it sa, or sacred to Moa. The rocks and the earth said they wished to get some of that water to

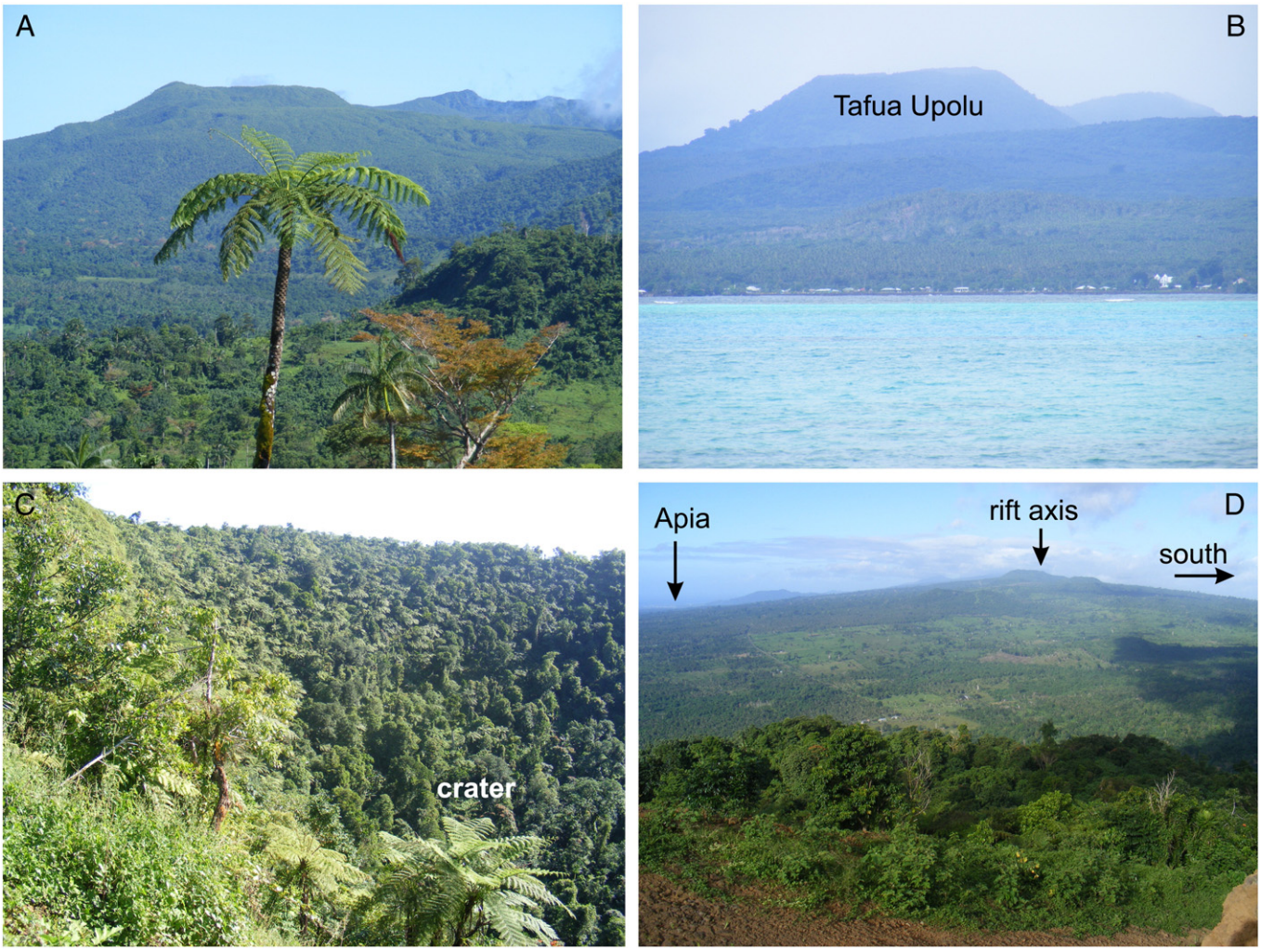

Fig. 7. A) Morphologically young typical scoria cone in the eastern rift axis of Upolu Island. The cones have steep slopes, wide and deep craters, many of them commonly filled with lake. The cones formed over older volcanic units associated with the initial volcanic shield building phase of the island. B) One of the largest scoria cones in Upolu called Tafua Upolu is located nearby the International Airport of Western Samoa. From the distance the cone has steep slopes, and the cone morphological parameters indicative for young age, however in close up, it is evident, that the present day slopes are masked by thick volcanic talus deposit, suggesting significant erosion. C) The crater of Tafua Upolu (the cone on B) is steep sided and deep, but heavily vegetated. The lower slopes of the interior of the crater are covered by thick volcanic talus deposits suggestive of the cone older age. D) Along the axis of Upolu Island a chain of intact scoria cones marks a rift zone. The morphological parameters of the cones along the about 80 km long rift zone do not show significant changes in any direction as it has been suggested earlier. Instead, various stages of erosion of scoria cones can be recognised anywhere along the rift axis, suggesting random development of new cones.

drink. Salevao replied that if they got a bamboo he would send them a streamlet through it, and hence the origin of springs. Salevao said he would become loose stones, and 'that everything which grew would be sa ia Moa, or sacred to Moa, till his hair was cut. After a time his hair was cut and the restriction taken off, and hence also the rocks and the earth were called Sa ia Moa, or as it is abbreviated, Samoa."

Turner (1884, 1979) also depicted a potential link between the origin of a youthful crater lake (Lake Lanuoto'o) in central Upolu and human occupation (Fig. 11).

"Faleata, or the 'House-of-Ata', embraces a number of small villages, and was so named from the chief Ata. Ata was killed in battle, and his brother Too took it so much to heart that he went away inland, scooped out a great hollow, and filled it with his tears; and hence the lake there called Lanutoo, or 'Lake-of-Too'."

Interpreting legends and oral traditions can be highly speculative (Cashman and Cronin, 2008), and their meanings are commonly overshadowed by recent societal changes in traditional island cultures. In this study we concentrated on the key sites of pre-historic volcanism, based on the geological information; 1) Manono, 2) Apolima, 3) near Tafua Upolu, 4) the eastern coast of Upolu, and 5) near Tafua Savai'i (Fig. 1).

On Manono Island, three villages were visited; Faleu, Salua, and Apai. Near Tafua Upolu scoria cone, the two largest villages Fasito'otai (near the coast) and Tanumalala (in the foothills of Tafua Upolu) were visited. Despite being located farther from the volcano, Fasito'otai village is one of the oldest and most traditional in the area, has a good view of the cone and being a coastal location, and was likely occupied since the earliest of settlers. Tanumalala is, by contrast, a settlement of planters only since German colonial times, c. 100 years ago with people from all parts of Samoa, including a chiefly family from Apolima Island. In Eastern Upolu interviews were concentrated in the village of Ulutogia, the traditional owners of the offshore islands. This village is also an old settlement with traditional structure. Other interviews were held with further inhabitants along the southern shoreline during geological surveying. On Savai'i a village meeting was also held in Tafua near the Tafua Savai'i tuff ring/scoria cone complex and other informal interviews were carried out with inhabitants near Matavanu.

6.1. Interviews

Formal interviews were led by Samoan facilitators that had been pre-briefed and trained. Informal interviews and discussions were also held with numerous people interested in our activities during geological surveying, or had heard of the project aims during village

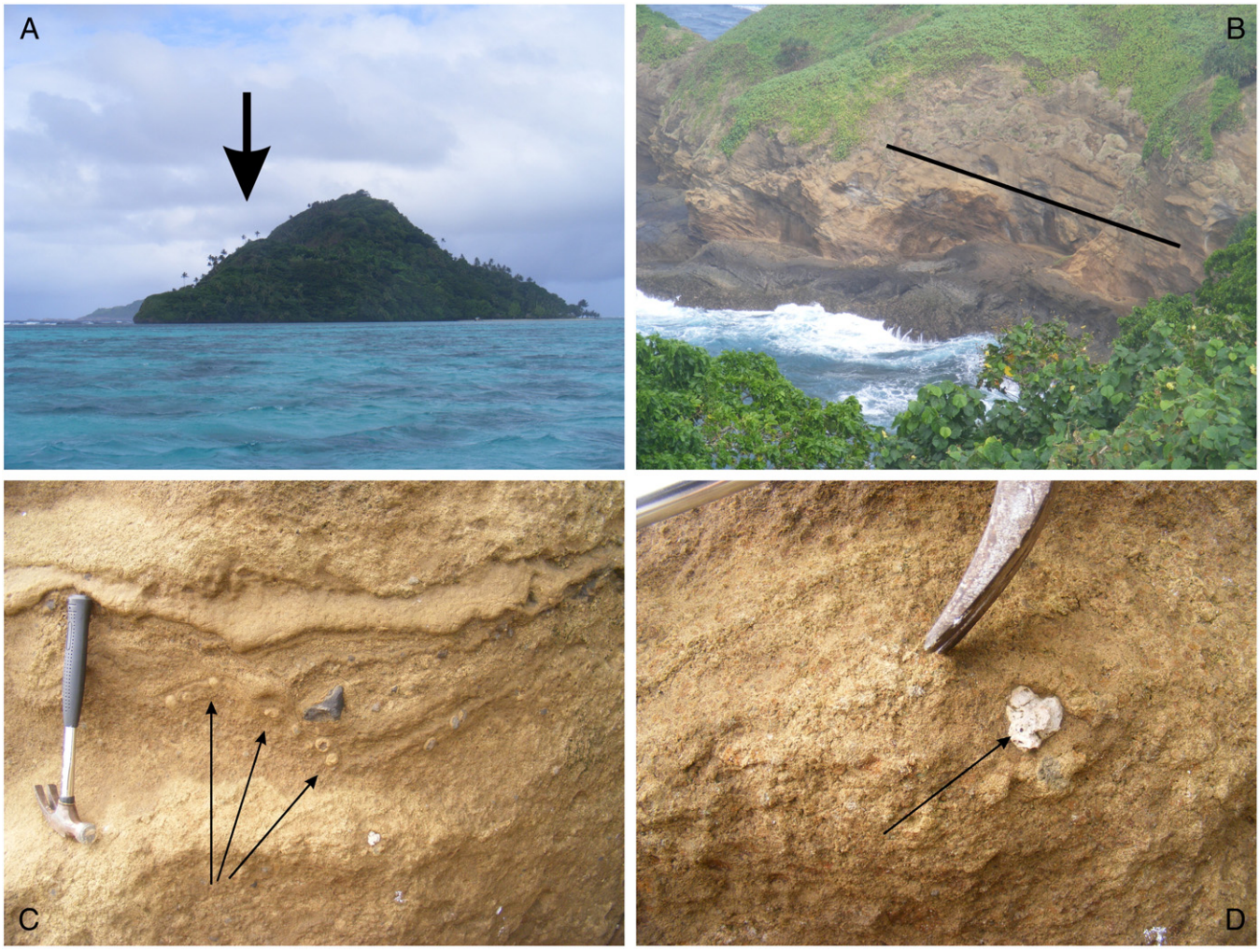

Fig. 8. A) Namua half tuff cone open to the east is a relatively well-preserved phreatomagmatic volcano in the eastern offshore of Upolu. B) Faunatapu is similar in geometrical and size parameters to Namua in the eastern offshore of Upolu. Its pyroclastic rock units show evidences of phreatomagmatic explosive eruption origin. The basal pyroclastic beds are shallow dipping, sub-horizontal (line), while the basal units are capped with steep sided tuff cone units. C) The pyroclastic succession of Faunatapu is typical phreatomagmatic tuff and lapilli tuff. The pyroclastic beds consist of chilled, blocky, moderately to strongly palagonitized volcanic glass shards, accretionary lapilli (arrows) and volcanic lithic lapilli (circle). D) The phreatomagmatic pyroclastic units of the eastern offshore islands of Upolu are rich in coral fragments (arrow) suggesting that the explosion took place in the near surface coral reef.

inquiries. These were also carried out with the same Samoan facilitators, recorded and transcribed later in English. Prior to the interviews we introduced ourselves and the goals of the survey. The following basic questions were followed during each official semi-structured interview or village meeting with subsets of these questions used during informal interviews:

1. What is the origin of the name of your village/island?
2. What do you think or know about the origin of your village/land?
3. Is there any story, legend, children's story about the genesis of your village/land/island?
4. What do you know about the origin of your people? Where did they come from and why?
5. How did your people reach their village? Is there any legend about the travelling of your ancestors?
6. Do you know any history/tales/traditions about the formation and changes of your village/island (e.g. are there any legends of sudden changes of the landscape of the surroundings of the village/island?
7. Do you know any stories about changes of the population of the village/islands? (e.g. are there any legends/stories about sudden changes of number of people in the villages — e.g. drop or increase, reasons for this?)
8. Do you know any stories about movement of the land surrounding the village/islands? (e.g. hint for past earthquake events)
9. Do you know that your village is located close to an old volcano?
10. Do you know anything (story/legend/tradition) about volcanoes nearby your village or overall in Samoa? [this question could be an alternative in case the Q9 is positive, e.g. the person is aware that volcanoes exist in Samoa).

6.2. Community discussions

Community discussions were introduced by a long welcome ceremony in each village. During this time food, drink and *ava* (kava) were offered to pay respect to the visitors. Discussions after the "official" questions were wide ranging, covering many aspects of Samoan life, focused on their understanding of their natural environment.

7. Results of community studies

7.1. Manono Island

7.1.1. Faleu–Manono Island

Interviews were with the local village council leader and one of the village elders known to be a person of "knowledge" (Fig. 12A). The

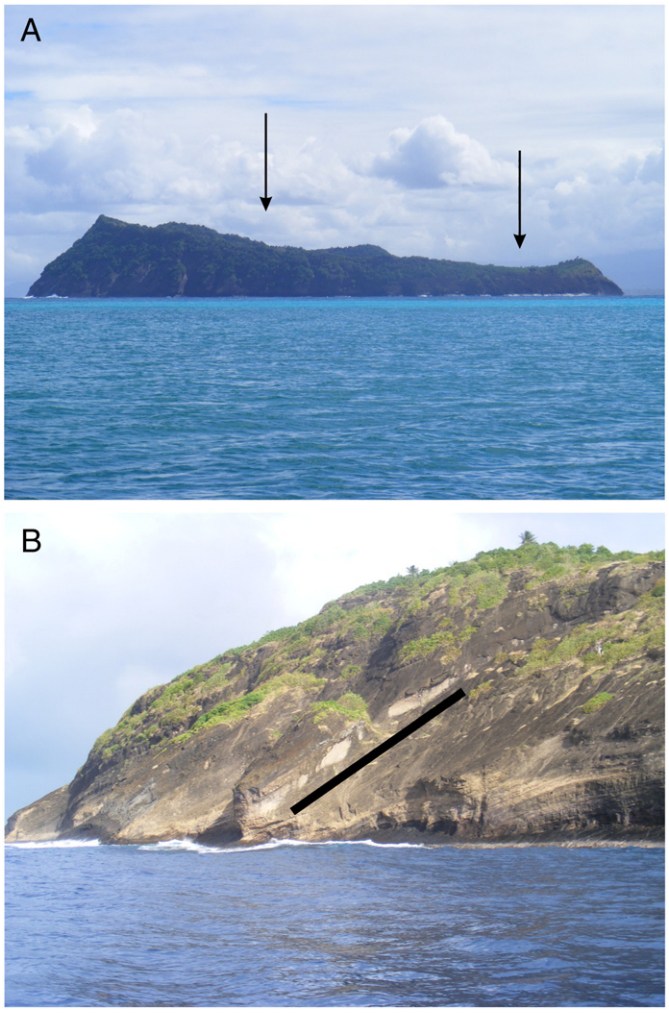

Fig. 9. A) Apolima between Upolu and Savai'i Islands is a well-preserved double-cratered (arrows point to the main craters) phreatomagmatic volcano, tuff cone. B) The pyroclastic succession of Apolima is typical volcanic glass shard-rich lapilli tuff and tuff succession deposited from base surges, phreatomagmatic fall and debris jets. The dip direction of the original pyroclastic rock beds is similar to the present day external slope of the island suggesting young morphology and therefore young age for this volcano.

informants were aware of the volcanic heritage of Manono and viewed the origin of their island in a similar way to their knowledge of the eruption of 1905–11 at Matavanu in Savai'i. There were no legends relating to volcanism on Manono or the nearby Tafua Upolu or Apolima. A common story described how Apolima stole the water from Manono, which may relate to the contrasting geomorphology and geology of the two islands. Manono is regarded as having always been a "dead" volcano when the first settlers arrived as a result of land disputes within communities in the "mainland" islands of Upolu and Savai'i. Settlement reportedly occurred around 10 generations ago, which coincides (although may not be directly linked) with traditional estimates of the time of a very large lava flow eruption in c. 1760 AD on Savai'i.

7.1.2. Salua–Manono Island

In this large village of around 2000 people, the house of chiefs organised an open interview in front of the hosts with the oldest and most respected man in the village. The interview subject was previously briefed for this meeting, and had time to summarise his views, following discussions with other community members. This report was similar in many aspects to that from Faleu, with the "water" legend between Apolima and Manono also being described. Volcanism knowledge was solely based on the 1905–11 eruption in Savai'i including description of the displacement of people from Northern Savai'i to many parts of Upolu. They regarded Apolima as being an old volcano, but not their own island. In later discussions this view was clarified that Manono might have been a volcano, but only a very, very long time ago.

7.1.3. Apai–Manono Island

During a ceremonial meeting the leading chiefs and an elderly woman gave individual reports. The informants demonstrated a high level of knowledge about their island's volcanic heritage, but they all described that the island was already vegetated and therefore not active when their ancestors arrived. Settlement was estimated to be a few tens of generations ago. They all pointed out the volcanic origin of neighbouring Apolima Island and the hard life of its inhabitants, particularly the limited access to drinking water that may have generated the "water stealing" legend.

7.2. The legend of Manono and Apolima

The following is based on the amalgamation of stories described from each village in Manono.

A long time ago Manono had plenty of water for drinking and bathing for everyone on the island. At that time, Manono was rich with flowering gardens and happy people. The nearby Apolima was, by contrast, a hostile island with only a monster in residence. Because Apolima had no water, the monster got really thirsty one hot day and decided to look for water on Manono. When he arrived he saw a beautiful lady washing her clothes in a running stream. The monster asked her for some water. The lady replied, "if you can finish all the water from this river, you can have it always". The monster bent down and in one deep breath started to drink. The lady looked on in astonishment as the water gradually diminished, until the last of it was gone. The monster then shook his head, and smiled. As he shook his head, water dropped down from his mouth and face to form small pools on the ground. The monster returned to Apolima, and since then, people on Manono have only been able to source water from these pools.

7.3. Legend on the origin of the name of Manono and Apolima

This story is also an amalgamation of versions from each visited village in Manono.

A long, long time ago a lady left Savai'i with her son and daughter. Her son's name was Nono. On the way from Savai'i, she decided to settle on Apolima Island. They started a new life there, but the children were not happy, because life was difficult. So they moved forward to the lush neighbouring island of Manono, leaving their mother behind. When they arrived in their new home, the siblings fell in love with one another, and soon a baby was born. The other people on Manono were surprised about their relationship and the boy, Nono, became very shy ("Ma" in Samoan). The story spread quickly and soon after the island became known as Manono. Running from this shame, the girl tried to return to her mother on Apolima. As she swam back, her mother saw her in the rough seas and happily opened her arms wide to seize her from the water. Apo-Lima means, in Samoan, to grab or retrieve by hand (from water e.g.). Later on when the people arrived on Apolima, they named the island after this story, Apolima, the place of the grabbing hand.

7.4. West Upolu

7.4.1. Fasito'otai–West Upolu

In this village with a good view of the scoria cone the mayor answered questions and directed some parts of the discussion to additional people. This community demonstrated an excellent understanding of natural hazards, such as tsunami or cyclone, but little

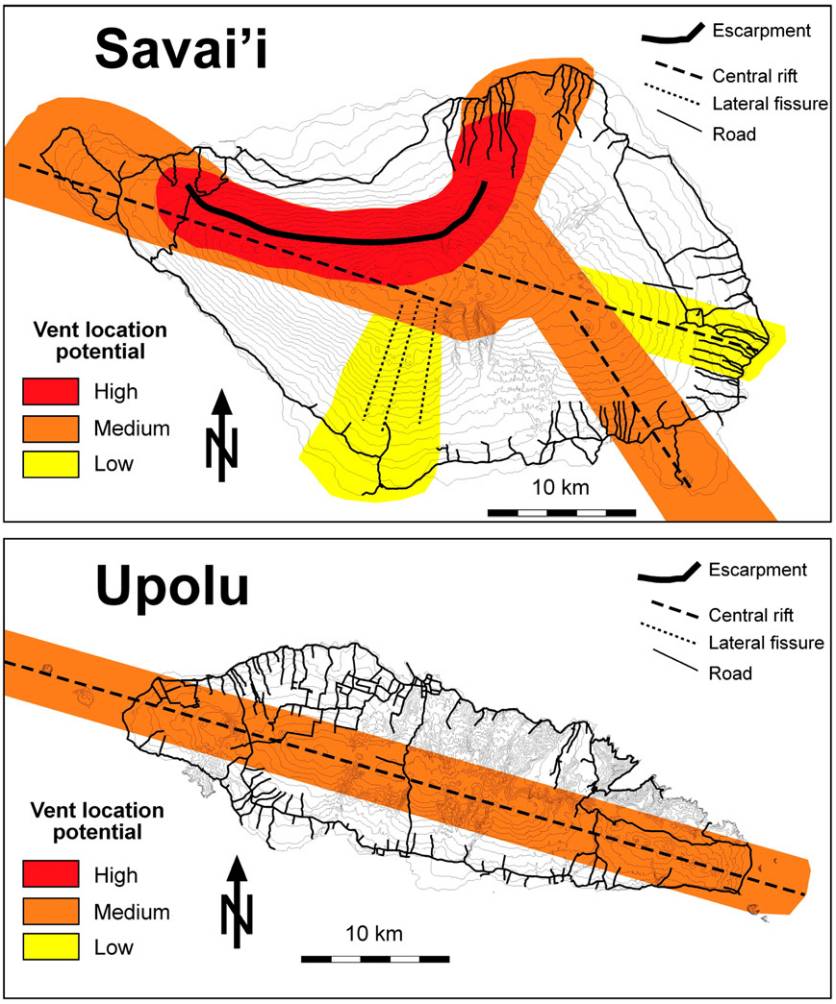

Fig. 10. A) Volcanic vent location potential map of Savai'i after Cronin et al. (2006a,b). Hypsometric curves are in 100 m intervals. B) Volcanic vent location potential map Upolu after Cronin et al. (2006a,b). Hypsometric curves are in 100 m intervals.

knowledge about volcanism. Very little was also known about the 1905–11 Savai'i eruption. The scoria cone Tafua Upolu has no apparent significance, most informants appeared to ignore its existence and no-one recognised its volcanic origin. Not a single person had seen the top of the cone or its deep crater that contains a colony of thousands of flying-foxes. Similarly in nearby Tufulele village, only two people had been to the top of the cone. In all, the community has very little knowledge of the geography of the neighbouring villages, gardens and especially their landforms. The long-established village limits in these heavily populated coastal areas has apparently formed barriers, over which very little curiosity is raised, especially in relation to natural habitats in neighbouring village lands.

7.4.2. Tanumalala–West Upolu

Informants explained the origin of this village as a 20th century plantation workers colony that includes families from every part of Samoa. The mayor's family was from Apolima and they were well aware that the island was of volcanic origin.

7.5. East Upolu

7.5.1. Ulutogia–East Upolu

The mayor and other local chiefs were aware of existence of volcanoes in the highlands behind the plantations of Ulutogia (along the rift axis), as well as the volcanic origin of their offshore islands. Other informants, including a fisherman, knew indirectly of stories surrounding a giant explosion in the sea, which changed the landscape of East Upolu. This story closely resembles "fished up" stories from other parts of the Pacific (e.g. Nunn, 2001). The location of the story coincides with the geological evidence for highly explosive Surtseyan-style eruptions in near-shore islands off the eastern coastline of Upolu.

7.6. Savai'i

7.6.1. Tafua — near Tafua Savai'i, Savai'i Island

An elderly man, considered to hold the greatest traditional knowledge in the community (Fig. 12B) explained that they live near a volcano that was once very "angry". However, the volcanic cone itself does not play a key role in local legends and stories. A family that operates a small tourist business for visiting the crater of Tafua Savai'i explained the origin of the volcano well, although they believed that Tafua Savai'i was the place where the 1905–11 eruption occurred. This belief may result from the Matavanu eruption having been now 2–3 generations ago.

8. Mapping exercise

Mapping exercises were vital parts of the community based workshops on natural hazards in Vanuatu, Solomon Islands and Fiji (Cronin et al., 2004a,b). These helped to understand the way in which different communities viewed their natural and social resources, and

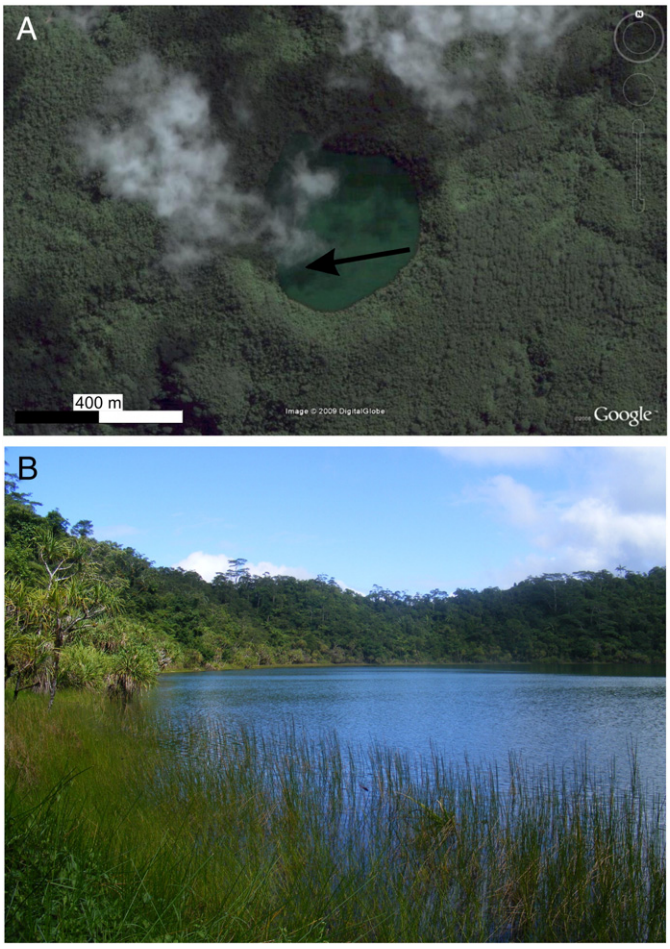

Fig. 11. A) Lake Lanuoto'o in the central highland of Upolu on a GoogleEarth 2009 satellite image. Arrow points toward the view shown on B. B) Lake Lanuoto'o crater lake is a potential site where drilling into the lake sediment could help to refine the volcanic stratigraphy of Upolu. The lake is in perfect central location and nearby major scoria cones.

how they would envision the representation of natural hazards in the form of drawings or maps. Mapping exercises were also performed during many of the individual semi-structured interviews in this study, accompanied with brief questions (Fig. 13A). Here we used the same approaches to the mapping exercises described by Cronin et al. (2004b,c).

8.1. Example for mapping exercise

Prepare a simple map of the village area, reaching from the closest hills to the village to the coast and the boundaries (such as: lakes, landmarks, family land boundaries) of the area known around the village.

A. Draw on the map (with symbols and lines) natural features of the landscape including:
   - hills/mountains, streams/rivers, coast, swamps, volcano, crater, hot springs or hot gas areas
B. Draw on the map (with symbols) all the village resources, e.g.:
   - crops of different types, house locations, water supplies, roads and tracks, community buildings and resources, forests, building materials, animal houses (type of animals)
C. Draw on the areas affected by different natural hazards:
   - cyclones — listing when they occur, tsunamis/storm surge — when, earthquakes — when, volcanism (lava, mudflows, ash and volcanic gas) — when, floods — when
D. Draw on safe areas and dangerous areas in your personal opinion
E. D. Choose the safest area you have identified on the main map (a check-point) and show its nearest food, water and shelter supplies
F. Draw on the safest pathways to your check-point.

Tasks A. and B. were relatively easy for the participants; however, C. gave great difficulty in most instances. The local understanding of geo-hazards, especially volcanic hazards, was very limited. Even after explanation, hazards other than cyclones were never identified. Consequently, also tasks D., E. and F. were difficult. The exception was for cyclone protection, where it was identified that the safest point is indoors in the strongest house available, preferably with the entire family nearby. This highlights the prevalence of cyclones as the major environmental hazard, but a dearth of knowledge for other hazard types.

The mapping exercise also rendered important information on the visualisations most intuitive to the Samoan communities visited. The majority of the maps were prepared as 3D oblique landscape sketches with an enlarged (disproportional) representation of the local community located at the centre of drawings (Fig. 13B). The drawings contained detailed information about highly localised natural and social resources, with almost no cognisance given to that of neighbouring communities, even if the neighbouring village "owned" the region's most significant landform, e.g. a large scoria cone. This result is consistent with the cultural habitat of Samoan people found in some studies, such as has been stated in relation to

Fig. 12. A) Report in a chief-house in Faleu (Manono). B) Report in a private house in Tafua Savaii (Savaii).

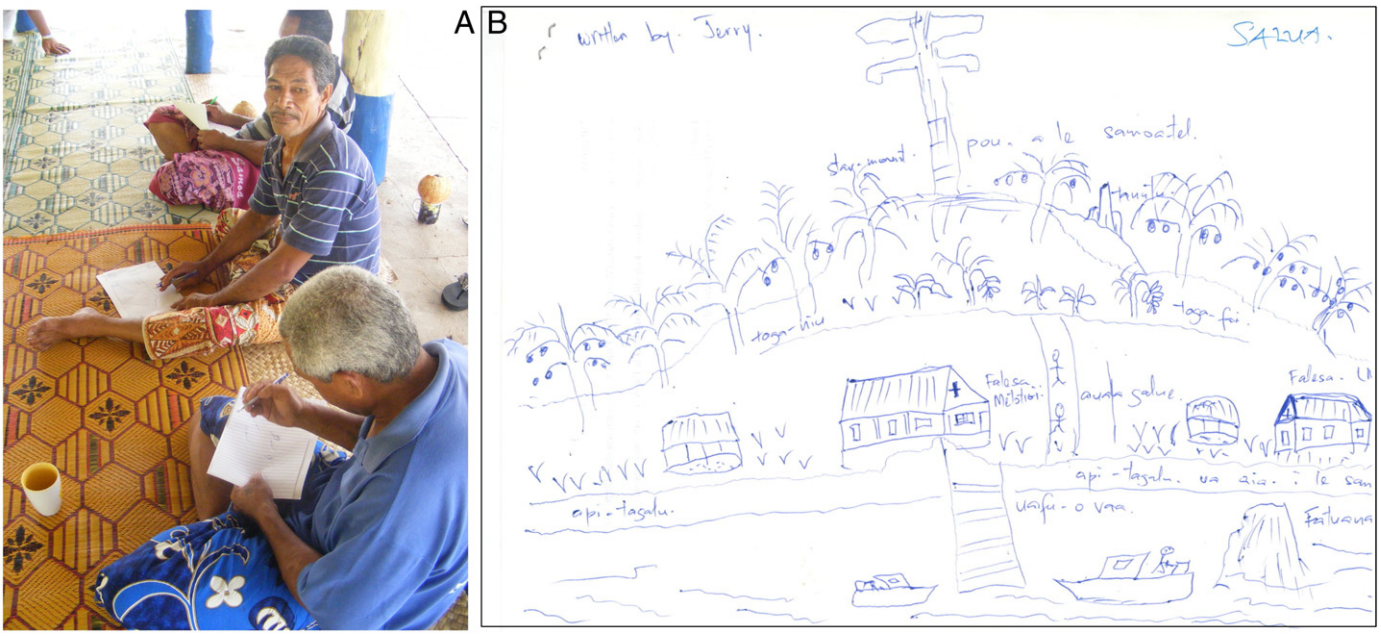

Fig. 13. Mapping exercise in Manono Island with well-respected chiefs in the chief-house. Three dimensional map of Manono Island produced by a chief in the local community. The map highlights main features important in the everyday life of the person, however, has no sign of volcanic features that maybe indicative of distant volcanic memory of the community.

the economic development of a village: "Samoans are generally content with the life they lead. They have little interest in the outside world which intrudes on them in the form of the market sector. They likewise have little evident concern for the future, little interest in productive investments, little willingness to 'develop'" (Lockwood, 1971). Such statements might be controversial today, but such anthropological background must be incorporated in any future attempts to engage Samoan communities with infrequent hazards such as volcanism.

9. Informal data collection

In the course of the programme, it became evident that data collection was arguably more-efficient outside of "official" interviewees and with high-ranking members of the society. This observation was the same as noted in past work in Fiji, Vanuatu and the Solomon Islands, and dealt with by separating the "power figures" in the community from other sectors during group participatory activities (Cronin et al., 2004b,c). During associated geological field work and investigation of target areas, informal interviews were commonly carried out following a shortened form of the formal semi-structured interviews. These discussions were free of traditional and public requirements, and provided very useful candid information.

These discussions also revealed that the people on Upolu have very limited knowledge of their natural environment, especially about the volcanic origin of their landscape. Often black basaltic rocks were identified as coral fragments from reef or beach rock baked by the sun. On the other hand, they were very interested in hearing more about the origin of their landscape. On the western coastline of Upolu, people typically had no inkling that Tafua Upolu was a volcanic feature and did not regard it as a special landmark. However, Manono, and Apolima were typically seen (especially by fisherman) as being volcanic. On the SW edge of Upolu, the inhabitants had no knowledge that Tafua Upolu existed just about 7 km from their land. However, the landscape in that part of Upolu is rugged, and the hills show similar morphologies, hence, Tafua Upolu was just one of those hills in their view. Along the southern coast of Upolu, interviews were similar and even communities on both sides of the young lava fields of O le Pupu were not aware that these rocks were volcanic.

Along the east Upolu shoreline, near the young volcanic offshore islands, people generally knew of their volcanic origin, and many people also pointed to comparable large craters in the mainland in the highlands. Some reported that Upolu was once connected to the offshore islands (e.g. Nu'utele). One family recalled a vivid story, apparently transferred over many generations, that one of their ancestors saw a fire, heard huge explosions from the sea, and then saw new islands growing in the glowing sky. This account was surprisingly detailed and possibly out of context with the remainder of the area accounts, hence its origins and further evidence for the story should be sought before it is considered further. Nunn (2001, 2003) highlighted the common oral tradition pattern of Melanesian and Polynesian cultures about two major themes, 1) "Fished up" versus 2) "Thrown down". The "fished up" theme commonly associated with birth of volcanic islands, especially by Surtseyan-style eruption (Nunn, 2003). Eruption clouds may look very similar to a giant fish that is jumping out of the water. If the villages in East Upolu were already inhabited during the formation of the East Upolu offshore islands, similar oral traditions should occur.

Informal interviews with people in Savai'i in the eastern coast between the region of Tafua Savai'i and the Matavanu eruption site gave a very mixed impression about their knowledge of volcanism. In spite of the eruption in 1905–11 in Matavanu, about half of those questioned did not know about the eruption, and/or if they knew, they had no idea where it took place. Many people placed the eruption site at Tafua Savai'i. None knew that eruptions also occurred in AD 1902 or 1760 on Savai'i. This may be due to many of the people being directly affected by the eruptions that were resettled in other areas of Samoa.

10. Discussion

This pilot project has demonstrated a very low potential for discovering volcanic memories within Western Samoa through oral traditions. This is contrary to the geological investigations that show evidence for considerable, albeit localised, volcanic activity during the period of human occupation in the past 3000 years. New ^{14}C radiocarbon dates demonstrate that volcanic activity in the Holocene was more frequent than previously thought and therefore there has been some overlap between volcanism and human occupation in Samoa. Our knowledge on the young volcanism in Samoa, and particularly in Upolu

is still very limited. Moreover, the new data from Savai'i show clearly, that the volcanic stratigraphy may need revision, since volcanic mapped as Pleistocene-aged, appear to be significantly younger. Some K/Ar age determination was performed in Tutuila (American Samoa) (e.g. McDougall, 1985), but isotopic dating methods have not be applied systematically to Savai'i or Upolu.

The unexpected lack of volcanic memory in the studied communities may be due in part to the small scale of this study. Countering this, however, is that our investigation was directed to areas where the chances for finding such records were greatest. This expectation is even more highlighted in light recently obtained ^{14}C dates suggesting a high frequency of volcanism, at least on Savai'i. It could be argued that impacts of primarily effusive eruptions were hidden in the tropical vegetation or localised, thus not leading to widespread oral traditions. Similar conclusions were reached in Taveuni, Fiji (Cronin and Neall, 2000), although greater evidence of oral traditions was present there. The longetivity and scale of the 1905–1911 eruptions suggest that past eruptions with similar style were also long-lived, and therefore noticed by many people. The 1760 AD eruption near Aopo village on Savai'i produced even larger lava flows over an area that was known as "the coast of one hundred villages" before the eruption (http://www.botany.hawaii.edu/pabitra/samoa/aopo_report3.htm). This suggests that a fertile and densely populated area must have been evacuated and communities relocated. Scattered remains of human occupation sites have been found in coastal areas covered with AD 1760 lavas but there is little evidence in oral history about this eruption, except the genealogy indicators of its timing (Thompson, 1921). Several early inland settlement sites are known from Upolu, Savai'i and Tutuila. Among the largest inland settlements the Mt. Olo region of Upolu, near the Tafua Upolu scoria cone was a stable populated area from 1650 to 500 B.P. (Holmer, 1980). The settlement must have had a good view toward the strait between Savai'i and Upolu, and the entire Savai'i highland. Hence the population should have seen several eruptions, at least during the night.

The lack of volcanic oral traditions could result from either 1) no volcanic eruptions were noticed by the communities, 2) eruption events were not significant to the community and its activity, or 3) the information simply vanished over the most recent history of Samoa. The dominantly effusive style and low explosivity of most eruptions expected on Samoa make option 2 likely, although option 3 may also be extremely important. The localised expression of the volcanic processes means that past eruptions may not have affected any more than one or two villages, a feature also noted for cultural memories of recent Taveuni volcanism in Fiji (Cronin and Neall, 2000). In Taveuni at least one volcanic eruption less than 290 BC to 100 AD destroyed a human occupation site that was abandoned for over 1000 years afterward leaving only a place name as a possible volcanic memory (Cronin and Neall, 2000). The scattered nature of the evolution of scoria cone fields, and their infrequent activity with long periods of repose also could be responsible for the disappearance of any knowledge of distant volcanic eruptions.

Samoan history has been through several important turning points that may strongly influence preservation of any long-lived oral traditions. The first was the disappearance of decorated Lapita ceramics, replaced by Polynesian plainware in several sites on Upolu, Manono, and Apolima islands in Western Samoa between 3000 to 2000 years ago. In addition, several plainware ceramic sites show that ceramic production in Samoa ended sometime in the first few centuries A.D. (Davidson, 1979). The causes of ceramic decline and abandonment remain unclear, but it clearly shows changes in material use and technology that occurred (Hunt and Erkelens, 1993). This may imply major associated cultural changes that could have erased any traditional memory of natural events. Further, archaeological data suggest that by about 850 years ago the population in Samoa was at such high levels (or coastal areas were so dangerous due to Tongan invasion or other conflicts) that major inland centres with fortification and significant structures had developed over much of the habitable landscape (Clark, 1996). Eruptions on the scale of the 1760 AD and 1905–1911 AD would have increased this population pressure by reducing available agricultural land and permanently displacing population. Around 350–200 years ago, the Mt. Olo area in Upolu was abandoned and reverted to bush vegetation (Holmer, 1980), along with inland settlements in Upolu and Tutuila (Clark and Herdrich, 1993). These migrations are not fully understood, but could also be responsible for loss and/or transformation of oral traditions concerning the natural environment and immediate village surroundings. Further major changes included a rapid drop in the population after European contact, and increasingly dense coastal population, with associated life-style changes of the community.

Despite the lack of volcanic knowledge, this study has given a valuable snapshot of the state of geological hazards knowledge in the present day communities visited on Samoa. It has also given insights into methods whereby natural hazard-education programmes could be most effectively targeted to these areas. Samoan social structure and culture, especially social hierarchy had to be accommodated into this research design, resulting in the dependence on semi-structured interviews for data collection, in contrast to all-community exercises that were successfully applied in other areas of the SW Pacific. It is of interest to note the general lack of preservation of oral traditions concerning the natural environment in contrast to other South Pacific locations with equivalent geological histories. This may also be due to the highly regimented nature of the Samoan society which in the last 100 years has been strongly influenced by Christian beliefs.

Official meetings with ceremony and traditional information exchanges were often insisted upon by focus communities, but these tended to be expensive, time consuming, and refocused attention on the "power figures" in the community, rather than allowing a broader view of the information held by the group. Such meetings were needed, however, to spur-on later informal meetings and interviews. A potentially effective way to proceed on this theme in the future would be to organise a formal island-wide meeting (or two) with the village mayors, such as when they have their usual monthly meeting in Apia in the house of chiefs. During this meeting all the necessary information could be distributed to the village mayors using the experience from this project. A follow-up meeting could identify villages where there is interest to proceed with further investigative or hazard-education work. Once in areas of interest, however, methods will need to be adopted to allow a broader audience to have a say, if necessary, in private to a facilitation team.

The mapping exercise also highlighted the need for rethinking the standard preparation method for natural hazard maps used in Samoa. The difficulty of understanding maps in general by local communities has been highlighted (e.g. Haynes et al., 2007). This problem is even more evident, when Western-style scientific knowledge is intended to be applied for traditional communities (e.g. Cronin et al., 2004c). Research has suggested that 3D volcanic hazard maps are most effective to disseminate information to the community, based on experiences at Montserat (Haynes et al., 2007). This along with combining Western-style and traditional knowledge and facilitated map exercises with local communities are a feasible way to create useful natural hazard maps. For Samoa, where village boundaries are an extremely important part of the world, view, highly localised mapping approaches are essential, so effectively the hazard maps would look different for each village. For hazard and emergency planning, it is highly likely that a central Government representative would have better knowledge of the overall landscape of several villages, than individuals within any of the settlements. This fact could seriously affect response and relief efforts based on local resources in case of emergency.

11. Conclusion

The volcanic geology of Western Samoa can be easily conceptualised with existing volcanic analogues in Hawaii, Fiji or the Canary Islands.

However, given the dearth of well-dated volcanic events, the frequency of recent volcanism can only be guessed at. Previous field campaigns and this work demonstrated that eruption frequency could be higher than expected from regional geological mapping. Many of the conceptually separated volcanic mapping units appear to overlap in time, and a revision of the volcanic stratigraphy is needed. In this field campaign it is concluded that detailed fieldwork in the offshore islands east and west of Upolu should be targeted at constraining the age of volcanism and characterising the potential hazards from this most explosive form of volcanism on Samoa. Eruptions forming these islands appear to have been Sutseyan-style involving pyroclastic density currents and possibly also local tsunami. Tafua Upolu, being one of the largest and best-preserved scoria cones in Upolu, should also be studied in more detail, including investigation of any related ash fall associated with it in soil or lake sequences. Lake Lanoto'o appears to be within a very old volcanic crater, which, along with its central location, would make it suitable for coring to develop a high-precision tephra stratigraphy.

In addition to geological studies, a programme working with local communities to promote their understanding of their natural surroundings and potential geological hazards should be started to complement existing initiatives around cyclone hazards. This could include village visits of Samoan facilitators' targeted high-ranking (titled, elderly) individuals for explanations of local features, including their genesis, use and associated geo-hazards. Any visual materials prepared as part of geo-hazard education initiatives should use 3D oblique-view sketches, as reflected in the dominant self-representations of the Samoan communities in this study. The highly localised perspectives of Samoan communities should also be taken into account and respected in the development of tailored approaches to hazard map development and hazard-education programmes.

In stark contrast to communities in Vanuatu or the Solomon Islands, the Samoan communities appear to have very limited knowledge of their volcanic heritage. Major youthful volcanic landforms show from their names that they were once significant (e.g. Tafua Upolu or Tafua Savai'i; Tafua = fire mountain/volcano, a cognate of the Tongan "Tofua"). However, these no longer appear to play an important role in local culture or heritage. The only exceptions to this were distal volcanic memories identified in legends from East Upolu, where offshore islands were associated with locally dramatic explosions.

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References

Alvarado, G.E., Soto, G.J., 2008. Volcanoes in the pre-Columbian life, legend, and archaeology of Costa Rica (Central America). In: Cashman, K.V., Giordano, G. (Eds.), Volcanoes and Human History, Special Issue: J. Volcanol. Geotherm. Res., vol. 176, pp. 356–362.

Anderson, T., 1910a. The volcano of Matavanu in Savaii. Q. J. Geol. Soc. 66, 621–639.

Anderson, T., 1910b. An ascent of Matavanu in Savaii (German Samoa). Alp. J. 25, 305–308.

Anderson, T., 1912. Volcanic craters and explosions. Geogr. J. 39 (2), 123–129 (Feb., 1912).

Anonym, 1907. The eruption of Matavanu in Savaii, 1905. Nature 75, 351-351 (07 February 1907) | doi:10.1038/075351a0 [News].

Anonym, 1910. Matavanu: a new volcano in Savaii (German Samoa). Nature 85, 92–93 (17 November 1910) | doi:10.1038/085092a0.

Auer, A., Martin, U., Németh, K., 2007. The Fekete-hegy (Balaton Highland Hungary) "soft-substrate" and "hard-substrate" maar volcanoes in an aligned volcanic complex — implications for vent geometry, subsurface stratigraphy and the palaeoenvironmental setting. In: Martin, U., Németh, K., Lorenz, V., White, J.D.L. (Eds.), Maar-diatreme volcanism, Special Issue: J. Volcanol. Geotherm. Res., vol. 159, pp. 225–245.

Balogh, K., Németh, K., 2005. Evidence for the neogene small-volume intracontinental. volcanism in western Hungary: K/Ar geochronology of the Tihany Maar volcanic complex. Geol. Carpath. 56, 91–99.

Cashman, K.V., Cronin, S.J., 2008. Welcoming a monster to the world: myths, oral tradition, and modern societal response to volcanic disasters. In: Cashman, K.V., Giordano, G. (Eds.), Volcanoes and Human History, Special Issue: J. Volcanol. Geotherm. Res., vol. 176, pp. 407–418.

Chambers, R., 1994. The origins and practice of participatory rural appraisal (PRA). World Dev. 22, 953–969.

Clark, J.T., 1996. Samoan prehistory in review. In: Davidson, J., Irwin, G., Leach, F., Pawley, A., Brown, D. (Eds.), Oceanic culture history: Essays in Honor of Roger Green: Special Publication. Dunedin, New Zealand J. Archaeology, pp. 443–460.

Clark, J.T., Herdrich, D.J., 1993. Prehistoric settlement system in Eastern Tutuila, American Samoa. J. Polyn. Soc. 102, 147–185.

Clark, J.T., Michlovic, M.G., 1996. An early settlement in the Polynesian homeland: excavations at 'Aoa Valley, Tutuila Island, American Samoa. J. Field Archaeol. 23, 151–167.

Cole, P.D., Guest, J.E., Duncan, A.M., Pacheco, J.M., 2001. Capelinhos 1957–1958, Faial, Azores: deposits formed by an emergent Surtseyan eruption. Bull. Volcanol. 63, 204–220.

Cronin, S.J., Neall, V.E., 2000. Impacts of volcanism on pre-European inhabitants of Taveuni, Fiji. Bull. Volcanol. 62, 199–213.

Cronin, S.J., Neall, V.E., 2001. Holocene volcanic geology, volcanic hazard, and risk on Taveuni, Fiji. N.Z. J. Geol. Geophys. 44, 417–437.

Cronin, S.J., Taylor, P.W., Malele, F., 2000. Final report — Savai'i, volcanic hazards project Samoa, October 2000. SOPAC Tech. Rep. (Suva, FIji) 343, 1–34.

Cronin, S.J., Ferland, M.A., Terry, J.P., 2004a. Nabukelevu volcano (Mt. Washington), Kadavu — a source of hitherto unknown volcanic hazard in Fiji. J. Volcanol. Geotherm. Res. 131, 371–396.

Cronin, S.J., Petterson, M.G., Taylor, P.W., Biliki, R., 2004b. Maximising multi-stakeholder participation in government and community volcanic hazard management programs, a case study from Savo, Solomon Islands. Nat. Hazards 33, 105–136.

Cronin, S.J., Gaylord, D.R., Charley, D., Alloway, B.V., Wallez, S., Esau, J.W., 2004c. Participatory methods of incorporating scientific with traditional knowledge for volcanic hazard management on Ambae Island, Vanuatu. Bull. Volcanol. 66, 652–668.

Cronin, S.J., Bonte-Grapentin, M., Németh, K., 2006a. Samoa technical report — review of volcanic hazard maps for Savai'i and Upolu. EU-SOPAC Proj. Rep. 59, 1–27.

Cronin, S.J., Németh, K., Stewart, B.R., 2006b. Volcanic hazards planning on rifting island and fissure volcanoes. Geol. Soc. N.Z. Misc. Publ. 122-A, 13.

Davidson, J.M., 1979. Samoa and Tonga. In: Jennings, J.D. (Ed.), The Prehistory of Polynesia. Harvard University Press, Cambridge, pp. 82–109.

Dickinson, W.R., Green, R.C., 1998. Geoarchaeological context of Holocene subsidence at the Ferry Berth Lapita site, Mulifanua, Upolu, Samoa. Geoarchaeology 13, 239–263.

Elson, M.D., Ort, M.H., Anderson, K.A., Heidke, J.M., 2007. Living with the volcano: the 11th century A.D. eruption of Sunset Crater. Living under the shadow: Cultural impacts of volcanic eruptions. InLeft Coast Press, Walnut Creek, pp. 107–132.

Fairbair, I.J., 1974. Samoan village economy — Lockwood, B. Oceania 44, 241–243.

Grant-Taylor, T.L., Rafter, T.A., 1962. New Zealand radiocarbon age measurements — 5. N.Z. J. Geol. Geophys. 5, 331–359.

Gray, C.M., McDougall, I., 2009. K–Ar geochronology of basalt petrogenesis, Newer Volcanic Province. Victoria Aust. J. Earth Sci. 56, 245–258.

Green, R.C., 1974. Pottery from the lagoon at Mulifanua, Upolu (Report 33). In: Green, R.C., Davidson, J.M. (Eds.), Archaeology in Western Samoa, vol. 11. Auckland Institute and Museum, Auckland, pp. 170–175. Bulletin No. 7.

Haynes, K., Barclay, J., Pidgeon, N., 2007. Volcanic hazard communication using maps: an evaluation of their effectiveness. Bull. Volcanol. 70, 123–138.

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

Holmer, R.N., 1980. Mt. Olo settlement pattern interpretation. In: Jennings, J.D., Holmer, R.N. (Eds.), Archaeological Excavations in Western Samoa. Pacific Anthropological Records, No. 32, pp. 93–103.

Hunt, T.L., Erkelens, C., 1993. The To'aga Ceramics. In: Kirch, P.V., Hunt, T.L. (Eds.), The To'aga Site: Three millenia of Polynesian occupation in the Manu'a Islands, American Samoa. In: Contributions of the University of California Archaeological Research Facility, No. 51. University of California at Berkeley, Berkeley, pp. 123–149.

Kear, D., Wood, B.L., 1959. The geology and hydrology of Western Samoa. Bull. - N.Z. Geol. Surv. 63, 1–90.

Kear, D., 1967. Geological notes on western Samoa. N.Z. J. Geol. Geophys. 10, 1446–1451.

Keating, B.H., Helsley, C.E., Karogodina, I., 2000. Sonar studies of submarine mass wasting and volcanic structures off Savaii Island, Samoa. Pure Appl. Geophys. 157, 1285–1313.

Kirch, P.V., 1990. An ancestral Polynesian occupation site at To'aga, Ofu Island, American Samoa. Archaeol. Ocean. 25, 1–15.

Kokelaar, B.P., 1983. The mechanism of Surtseyan volcanism. J. Geol. Soc. London 140, 939–944.

Lockwood, B., 1971. Samoan Village Economy. Oxford University Press, New York. and London.

Luhr, J.F., Simkin, T., 1993. Paricutin. The Volcano Born in a Mexican Cornfield. Geosciences Press, Phoenix.

Mageo, J., 2002. Myth, cultural identity, and ethnopolitics: Samoa and the Tongan "empire". J. Anthropol. Res. 58, 493–520.
Martin, U., Németh, K., 2006. How Strombolian is a "Strombolian" scoria cone? Some irregularities in scoria cone architecture from the Transmexican Volcanic Belt, near Volcan Ceboruco, (Mexico) and Al Haruj (Libya). In: Cas, R.A.F., Giordano, G. (Eds.), Explosive mafic volcanism, Special Issue: J. Volcanol. Geotherm. Res., vol. 155, pp. 104–118.
Martinsson-Wallin, H., 2007. Samoan archaeology: a review of research history. Archaeol. Ocean. 42, 11–27.
Mead, M., 1961. Tau — stability and change in a Samoan village — Holmes, LD. Am. Anthropol. 63, 428–430.
Mercer, J., Dominey-Howes, D., Kelman, I., Lloyd, K., 2007. The potential for combining indigenous and western knowledge in reducing vulnerability to environmental hazards in small island developing states. Environ. Hazards 7, 245–256.
Milner, G.B., 1972. Samoan village economy — Lockwood, B. Man 7, 680–681.
Németh, K., Cronin, S.J., 2009. Phreatomagmatic volcanic hazards where rift-systems meet the sea, a study from Ambae Island, Vanuatu. In: Taddeucci, J., Spieler, O., Németh, K. (Eds.), Models and products of mafic explosive activity, Special Issue: J. Volcanol. Geotherm. Res., vol. 180, pp. 246–258.
Németh, K., Cronin, S.J., Charley, D., Harrison, M., Garae, E., 2006. Exploding lakes in Vanuatu — "Surtseyan-style" eruptions witnessed on Ambae Island. Episodes 29, 87–92.
Nunn, P.D., 2001. On the convergence of myth and reality: examples from the Pacific Islands. Geograph. J. 167, 125–138.
Nunn, P.D., 2003. Fished up or thrown down: the geography of Pacific Island origin myths. Ann. Assoc. Am. Geogr. 93, 350–364.
O'Leary, J.A., Hauri, E.H., Hart, S.R., Staudigel, H., 2007. Hydrogen isotope geochemistry of basalts from Samoa. Geochim. Cosmochim. Acta 71, A737-A737.
Olson, M.D., 2002. 'Indirect rule' and the rule of law in Samoa. J. Histor. Geogr. 28, 380–396.
Ort, M.H., Elson, M.D., Anderson, K.C., Duffield, W.A., Hooten, J.A., Champion, D.E., Waring, G., 2008. Effects of scoria-cone eruptions upon nearby human communities. Geol. Soc. Am. Bull. 27, 476–486.
Petchey, F.J., 1995. The archaeology of Kudon: archaeological analysis of Lapita ceramics from Mulifanua, Samoa and Sigatoka, Fiji. MSc Thesis, University of Auckland, New Zealand.
Sapper, K.T., 1906. Der Matavanu–Ausbruch auf Savali 1905–06. Z. Ges. E. Berlin 1906, 686–709.
Schoeffel, P., 2007. The social structure of a Samoan village. J. Pacific Hist. 42, 280–281.
Shankman, P., 1972. Samoan village economy — Lockwood, B. Am. Anthropol. 74, 1443–1444.
Sohn, Y.K., 1996. Hydrovolcanic processes forming basaltic tuff rings and cones on Cheju Island, Korea. Geol. Soc. Am. Bull. 108, 1199–1211.
Staudigel, H., Hart, S.R., Pile, A., Bailey, B.E., Baker, E.T., Brooke, S., Connelly, D.P., Haucke, L., German, C.R., Hudson, I., Jones, D., Koppers, A.A.P., Konter, J., Lee, R., Pietsch, T.W., Tebo, B.M., Templeton, A.S., Zierenberg, R., Young, C.M., 2006. Vailulu'u seamount, Samoa: life and death on an active submarine volcano. Proc. Natl. Acad. Sci. U. S. A. 103, 6448–6453.
Taylor, P.W., 1995. Myths, legends and volcanic activity: an example from northern Tonga. J. Polyn. Soc. 104, 323–346.
Thompson, J.A., 1921. The geology of Western Samoa. New Zealand J. Sci. Tech. 4 (2), 49–66.
Turner, G., 1884. Samoa, a hundred years ago and long before. London Missionary Society. Reprinted by Pacific Studies, University of the South Pacific, p. 395. [full text available on www.gutenberg.net — EBook #14224].
Turner, G., 1979. Samoa, a Hundred Years Ago And Long Before: Together with Notes on the Islands of the Pacific. AMS Press, New York, p. 395 (Reprint of 1884 ed. pub. by Macmillan, London).
Valentine, G.A., Perry, F.V., Krier, D., Keating, G.N., Kelley, R.E., Coghill, A.H., 2006. Small-volume basaltic volcanoes: eruptive products and processes, and posteruptive geomorphic evolution in Crater Flat (Pleistocene), southern Nevada. Geol. Soc. Am. Bull. 118, 1313–1330.
Viramonte, J.G., Incer-Barquero, J., 2008. Masaya, the "Mouth of Hell", Nicaragua: volcanological interpretation of the myths, legends and anecdotes. In: Cashman, K.V., Giordano, G. (Eds.), Volcanoes and Human History, Special Issue: J. Volcanol. Geotherm. Res., vol. 176, pp. 419–426.
Whistler, W.A., 1978. Vegetation of the montane region of Savai'i, Western Samoa. Pacific Sci. 32, 79–94.
Workman, R.K., Hauri, E., Hart, S.R., Wang, J., Blusztajn, J., 2006. Volatile and trace 859 elements in basaltic glasses from Samoa: implications for water distribution in the 860 mantle. Earth Planet. Sci. Lett. 241, 932–951.