Geoheritage (2021) 13: 50
https://doi.org/10.1007/s12371-021-00578-4

ORIGINAL ARTICLE

Geopark Impact for the Resilience of Communities in Samoa, SW Pacific

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Received: 9 November 2020 / Accepted: 25 May 2021 / Published online: 5 June 2021
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Abstract

Both Savai'i Island and Upolu Island of Samoa are home to numerous potential geosites that could form the basis of geopark projects at a range of scales from local, regional, or global. During the Samoa Geoparks Project Phase 1, intensive research identified Samoa's geoheritage values, resulting in the selection of the island of Savai'i as a location for development of geosite inventories, using a first-order approach to create a scientific basis for future geoheritage, geoconservation, and geotourism ventures. The rationale behind this decision was based on the size of the island; the geodiverse and largely untouched landscapes with high geodiversity values; and superbly exposed young volcanic features that are relatively accessible. Most of these volcanic features derived from Holocene and even historical volcanic activity. Within the potential areas of geosites, volcanic features currently utilized as tourist attractions (*mataaga* in Samoan) are mostly associated with living cultural activities in terms of traditional stories, myth, and place names. These geoheritage components are a very significant part of the Samoa Geoparks Project in general. Workshop and training for further development of the Samoa Geoparks Project are recommended in this study to co-design and co-develop the geopark concept with local communities working in collaboration with geoscience experts. The role of external geoscientists has been redefined as facilitators of participatory methods using iterative, step-by-step processes, where each facet of the geopark is co-produced through truly inclusive methods and frameworks.

Keywords Pacific · Geoheritage · Geotoursim · Geopark · Volcanic island · Scoria cone · Lava flow · Tuff ring · Pāhoehoe

Introduction

The concept of a "geopark" was first introduced during the ProGeo Symposium "Geological Heritage of Europe" in 1998 at Sofia, Republic of Bulgaria (Alexandrowicz and Alexandrowicz 2004). The original idea of geoparks was to create a global network of natural parks with significant geological features and classified as UNESCO Global Geoparks. UNESCO promotes both the sustainable and the healthy environment while striving for sustainable economic development (Eder 1999). While there is no general conceptual framework on which geoparks should be formed, there are strong indications that geoparks should not only be a material value–centered hub, but also fulfill the human desire for higher order, and philosophical needs similar to the systematics of Maslow's Hierarchy of Needs (Maslow 1943). As human psychology strongly depends on fulfillment of various needs, the non-living (geo) environment can be seen as a platform from where natural resources can be harvested for physiological needs, contribute to some safety

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needs, and develop strong feelings of emotional connection to the land. Ideally, a geopark program should observe this human ecology aspect of social evolution by understanding and incorporating this concept into the geopark framework. Geoparks are also practical tools to educate society to better understand the geological heritage of the Earth; highlight its relevance to the evolution of human society; and disseminate knowledge and awareness enabling harmonious living supported by our abiotic environment. Geoparks have the potential to utilize educational methods such as humanistic education (Maslow 1979); alternative pedagogies including Montessori Method (Kim and Németh 1995; Németh 2017; Németh 1995; Németh and Martin 2004); and virtual realities (Cayla 2014; Giardino et al. 2014; Giordano et al. 2015; Rapprich et al. 2017) not considered part of mainstream education. These could act as catalysts for the formation of new ideas and fields of research not traditionally considered in the context of geoheritage and geoparks. Geoparks are also considered to be territories where the geological heritage of the Earth is safeguarded and sustainably managed (Sa dos Santos et al. 2019; Štrba et al. 2020; Swierkosz et al. 2017; Williams et al. 2020). The original geopark idea was submitted as a new UNESCO label (Patzak and Eder 1998) in accordance with a plan of activity adopted at the 29th General Conference (November 1997). In 2002, UNESCO outlined the three goals underlying the concept of geoparks: Conserving a healthy environment, education in the earth sciences, and fostering sustainable, local economic development.[1]

Although geoparks have existed in Europe since 2000, and elsewhere since 2004, it was only in November 2015 that UNESCO recognized them[2] alongside the World Heritage Sites and Biosphere Reserves. "UNESCO Global Geopark" was the first new designation recognized by UNESCO since 1972. UNESCO also agreed for existing global geoparks to bear the new label. As of October 2020, there are 161 UNESCO Global Geoparks spread across 44 countries.[3]

The motto of the Global Geoparks is "Celebrating Earth Heritage, Sustaining Local Communities." A significant goal is empowering local people by sharing the heritage of the Earth in a way that will lead to sustainable economic development grounded on the values of the local people (Brilha 2018b; Catana and Brilha 2020; Han et al. 2018; Henriques and Brilha 2017; Justice 2018; Newsome and Dowling 2018; Nikolova and Sinnyovsky 2019). The UNESCO Global Geoparks adopts a "bottom-up" approach (Brilha 2018b; Errami et al. 2015b; Pijet-Migon and Migon 2019). Only when a local community agrees to develop a geopark aspiring for the UNESCO Global Geopark label will UNESCO agree to support and facilitate it. However, this should not prevent any local community from considering a geopark concept at a local or regional scale, and how it could benefit their living environment and local economy through sustainable community-based development. Pursuing the long-term goal of a UNESCO Global Geopark label requires: focused, community-based work (Azman et al. 2011); establishment of geosite inventories (Brilha 2016); co-developed geoeducation programs (Lim 2014; Macadam 2018; Zangmo et al. 2017) and sustainable geotourism (Cai et al. 2019; Escorihuela 2018; Guo and Chung 2019; Shahhoseini et al. 2017; Zeng 2014). These need to be incorporated into larger-scale tourism goals through best-practice governance frameworks (Canesin et al. 2020).

Samoa's National Park designation was established in 1989 under the Western Samoa Lands, Surveys and Environment Act 1989, with the goal of protecting the nation's finest landscapes and facilitating community engagement with these special qualities (Schuster 1993). Geoparks play a similar role as the National Parks, but the geopark emphasis is on business and communities working together to make the most of their natural landscape and cultural heritage, thereby bringing economic benefits to those areas (Brilha 2018b). The concept of a geopark is a relatively new idea in the South Pacific (Fepuleai and Németh 2019; Fepuleai et al. 2017; Németh and Cronin 2009; Németh et al. 2017a), but unlike continental Asia and Europe, it is yet to become a reliable source of revenue. The concept of a geopark is relatively new in Samoa, reflected in the absence of any geoparks on the islands or even in the broader SW Pacific region as per the UNESCO's July 2020 list. However, the presence of natural geological and geomorphological features of admirable qualities and quantities that fit in any geopark classification scheme on local to international scales has existed for years. Geological, geomorphological, and coastal marine abiotic features are an integral part of village life respected and valued by the community, and can be considered anchors of the Samoan culture and language.

Important aspects of geoparks are links between geology and the communities, recognized through stories, culture, and history. Additionally, geoparks bring jobs to rural and indigenous people, in turn helping to protect sites of importance and promote geoheritage (Brilha 2018b). They also complement work of local government bodies through partnership with different government ministries. Furthermore, geoparks will contribute to conservation, education, and promotion of sustainable development through "geotourism" (Ólafsdóttir 2019; Shekhar et al. 2019; Štrba et al. 2020; Williams et al. 2020; Zgłobicki et al. 2020). They are

[1] http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/sc_geoparcs_2010guidelines.pdf.

[2] http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco-global-geoparks/

[3] http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco-global-geoparks/frequently-asked-questions/where-are-the-unesco-global-geoparks/.

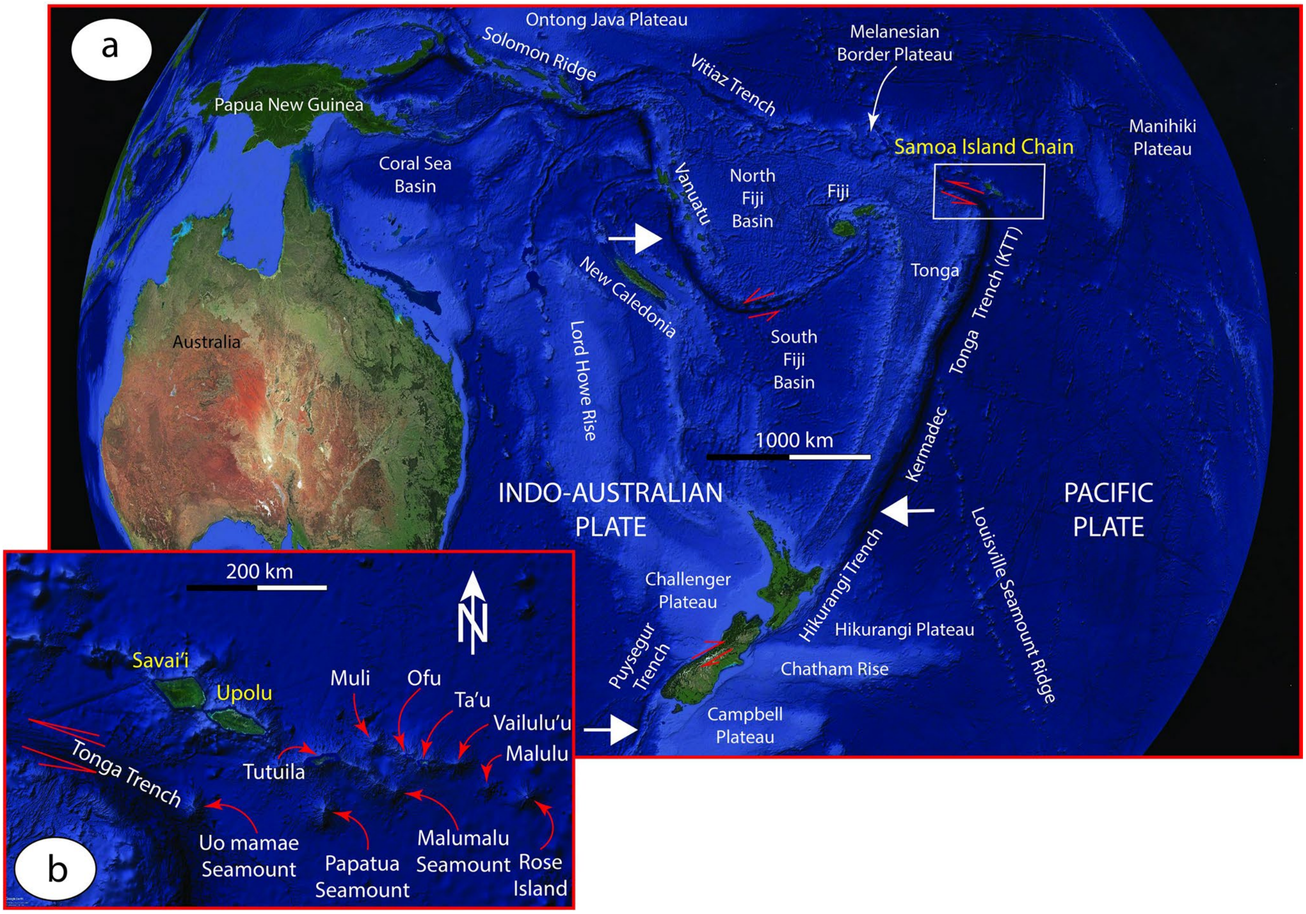

Fig. 1 Location maps of the Samoan island chain in the SW Pacific. **a** Samoa Island located on the southern part of the Pacific Ocean. **b** The island chain is located to the northeast of the sharp bend of the KTT at the Northern Terminus region. White arrows show plate movement, opposing red arrows indicate transform faults

spectacular outdoor classrooms that have something to offer students and visitors (Lim 2014). In addition, geoparks can make explicit the link between geodiversity and biodiversity (Boothroyd and McHenry 2019; Gray 2018a; Manriquez et al. 2019) and provide a location for demonstrating the concepts of ecosystem and geosystem services to the public (Gordon et al. 2018a, 2018b; Gray 2018b; Hjort et al. 2015).

The Geoscience Division (GSD) of the Pacific Community (Fiji) and Food Agriculture Organization of the United Nations (FAO) have initiated a geopark project for Samoa in 2016. The idea of a geopark project for Samoa arose from an ongoing in-country forestry project by the FAO and previous volcanic-geology projects by the GSD in Samoa. Savai'i, the biggest island of the Samoan group (Fig. 1a & b), was selected as a proposed geopark based on the size of potential geopark; the great geodiversity of the landscapes; the well-exposed features along the coastal section; and the accessibility. All these factors were recognized as important to the establishment of a geopark in the region.

The formation of the islands of Savai'i and Upolu in Samoa can be told through sites of geological and cultural significance. These geosites could form the basis of a geopark project at the local community level, with a broader relevance at the wider Pacific regional scale and beyond. Despite their existence and value to the community, there has not been any systematic attempt at identifying and taking inventory of these geosites. The Samoa Geoparks Project Phase 1, a collaboration by Pacific Community (PC), Food and Agriculture Organization of the United Nations (FAO), and the Government of Samoa, addresses this gap. It aims to develop an inventory of such sites for present and future (geo) heritage, (geo) conservation, and (geo) tourism ventures. An extensive initial search selected the Island of Savai'i for the initial phase. This was based on its size, diversity of sites, and relatively untouched features of exceptional (geo) heritage value derived from the Holocene period. Easy accessibility of sites and villages associated with the sites also made this area suitable for ongoing research. Initial visits to the sites and consultations with villagers revealed that some

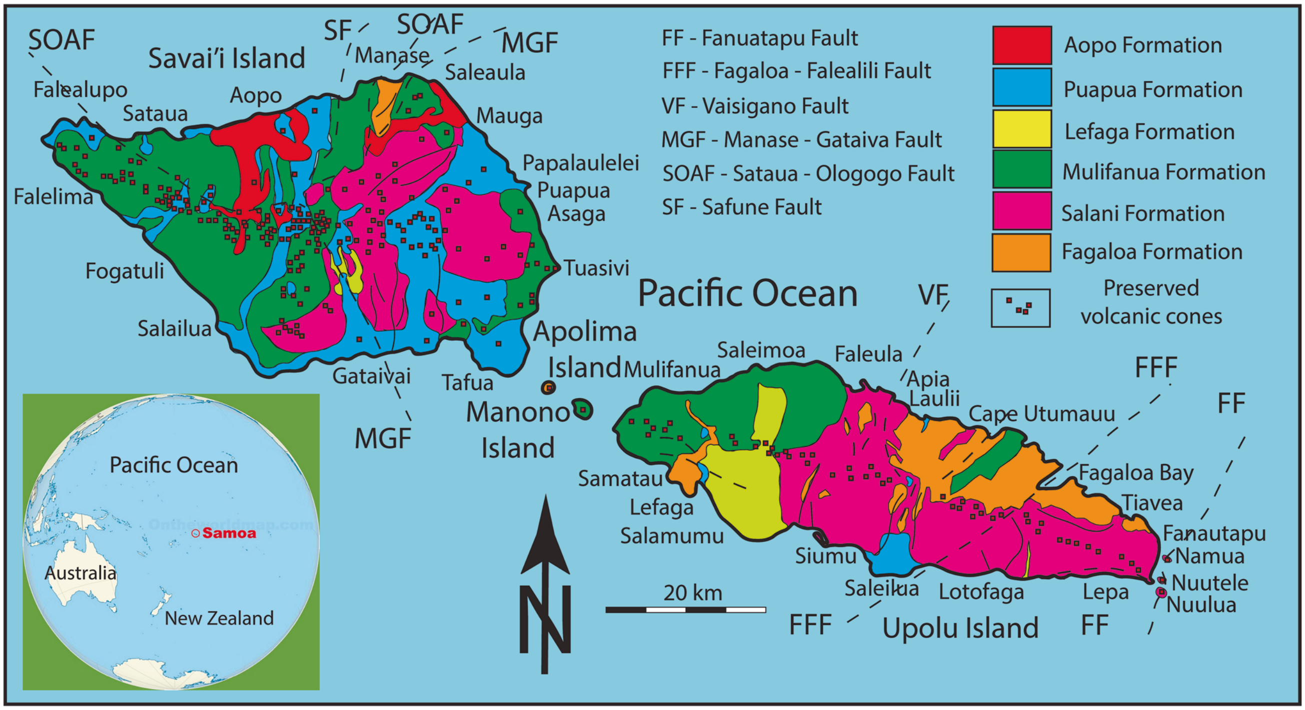

Fig. 2 Geological map of the western group of Samoa showing the six major stratigraphy units composed exclusively of primary effusive and explosive volcanic rocks occasionally intercalated with some immediately reworked volcaniclastic successions. The map also shows the known position of preserved volcanic cones that are mostly scoria and spatter cones commonly aligned along rifts. Major faults recognized on the islands are also shown (modified from Fepuleai (2016))

volcanic features are already part of local tourist attractions (*mataaga*) showcasing a vibrant history and culture. To integrate other sites on Savai'i to the Samoa Geopark Project is a sensible proposal that received the support of village communities. While the future of geoparks is promising, closer consultation and open exchange of information among stakeholders should be featured predominantly in the next phases of the project.

This paper reports on our experiences of phase 1 of the Samoa Geoparks Project. The next section sets out the aim and objectives of the project as well as the methodology used. Later sections identify the geosites on the Islands of Savai'i. This paper concludes that systematic inventory building, community-based workshops, and assessment of the vulnerability of geosites are needed to establish a globally significant and locally relevant geopark in Samoa that can function as a flagship of geopark projects within the SW Pacific.

Geological Setting

The Samoan volcanic island chain covers an area 1400 km by 380 km located in the southern part of the Pacific Ocean (Fig. 1a) aligned northwest to southeast between latitudes 13° and 15° S and longitudes 168° and 171° W (Fig. 1b). Politically, the Samoa group of islands is subdivided into the western group, referred as the independent nation (Western Samoa), while the eastern group is the US-administered group (American Samoa). The western group has two main islands (Upolu and Savai'iSavai'i), while Tutuila and Manua are the main islands of the eastern group. The island of Upolu has a landmass surface area of 1114 km^2, while Savai'iSavai'i occupies approximately 1709 km^2.

A deep ocean basin of 800 to 5000 m (Fig. 1a & b) surrounds the Samoa island chain along the northeast of the sharp bend of the Kermadec Tonga Trench (KTT) region, known as The Northern Terminus (Fig. 1a). The deep KTT represents a boundary between two major plates, the Indo-Australian Plate and Pacific Plate. GPS tracking of movements suggest that the Indo-Australian Plate moves north east at 6.6 cm/year, while the Pacific Plate advances westward at 7.1 cm/year (Falloon et al. 1999; Hart et al. 2004; Hawkins and Natland 1975).

The volcanic activity in Western Samoa can be divided into six geological formations based on several criteria such as mineral composition; texture; physical appearance; extent of soil profiles; the presence of a reef and degree of weathering; and erosional features (Kear and Wood 1959) (Fig. 2). From oldest to youngest, the volcanic formations are termed as the (i) Fagaloa Formation (or Fagaloa Volcanics) (Pleistocene-Pliocene); (ii) Salani Formation (or Salani Volcanics) (Middle to Late Pleistocene); (iii) Mulifanua Formation (or Mulifanua Volcanics) (Late Pleistocene); (iv) Lefaga Formation (or Lefaga Volcanics) (Early Holocene); (v) the Puapua Formation (or Puapua Volcanics) (Middle to Late Holocene); and (vi) Aopo Formation (Aopo Volcanics) (Historical) (Fig. 2). Potassium-Argon dating (lava), radiocarbon dating (organic material under or enclosed within lava, volcanic tephra, and coral clasts), and Paleomagnetism (lava), from Upolu and Savai'iSavai'i, have been used to refine this lithostratigraphic division (Fepuleai 2016; Goodwin and Grossman 2003; Keating 1991; Keating and Tarling 1985; Koppers et al. 2008; Natland and Turner 1985; Németh and Cronin 2009; Workman et al. 2004).

It is suggested that Samoan volcanism is a product of tension-stress activities associated with the sharp bend of the Tonga Trench at its Northern Terminus region. This has resulted in a series of major and minor fault networks dissecting the central part of the main islands (Fepuleai 2016; Natland 1980; Natland and Turner 1985). The development of the Samoan island chain has been dominated by a complex process of shield (old activity) and post-erosional volcanism (young activity) (Fepuleai 2016; Natland 2003; Workman et al. 2004). Post-erosional volcanism is widely spread along the central rift of the main islands (Fig. 2).

Overall, Samoa has a great variety of volcanic geoforms, both onshore and offshore, that are associated with ocean island volcanism. These demonstrate its evolutionary stages and show details of individual volcanic geoform growth stages. The volcanic origin of the island and its active status make Samoa a geologically active region because of a convergent plate margin and some upwelling of juvenile mantle source material in a special geotectonic situation. In addition, the islands are in a tropical climate surrounded by the Pacific Ocean, providing a unique ecosystem underlain by the abiotic foundation. The island's high geodiversity can be linked to its volcanic geology, providing an exceptionally unique tropical volcanic island environment with numerous globally significant geosites. During the initial geosite inventory building with an aim to develop a geopark, several key questions were raised such as "Why does Samoa need a geopark? What and where are the geological features that would be the basis of establishing a geopark? How can a geopark educate and promote geosciences to local communities and visitors? What are the indigenous values, beliefs, and connection to the natural environment such as land, ocean, volcanoes? In what way does geological education and geo-process awareness fit into the geopark conceptual framework? How can the Samoa Geoparks Project help to increase the islands touristic values through its geoheritage and how would geosites provide a strong foundation of diverse tourist attraction (termed *mataaga* in Samoan) in the region?".

Aim and Objectives of the Samoa Geoparks Project

The Samoa Geoparks Project was designed to record the geoheritage values of identified geosites and form a basic, first-order inventory. The Samoa Geoparks Project aims to improve the development of rural regions where geosites are aligned strong with Samoan village communities in several ways:

(i) Assist in tourism industry revenue through extension of the existing tourist attraction (*mataaga*) boundaries. In this process, the geopark concept incorporates other significantly large territories which are neither part of the current tourist attractions nor part of key conceptual frameworks for local and regional tourism developments. Extension of tourism attractions through identification and supply of information of specific geosites to current tourist attractions took place in several villages. Examples include the Holocene reef at Falealupo (westernmost part of Savai'iSavai'i), and onion-skinned weathering outcrop at Sataua (western part of Savai'iSavai'i) and tumulus (eastern part of Saleaula village);

(ii) Provide proper scientific descriptions (English) of every identified tourist attraction (*mataaga*) in addition to providing geological information of newly recognized geosites;

(iii) Provide scientific information about the landscape, its origin, and processes involved in its development;

(iv) Precisely and explicitly link the exposed and preserved geological and volcanological features to the wealth of traditional knowledge (myths/stories) associated with many *mataaga* without altering their integrity;

(v) Assist in identifying areas for conservation projects that will result in effective community-based and legislatively supported geoconservation in Upolu and Savai'i Island, especially in extensive and highly visible landscape forming elements such as normal fault scarps, deep valleys, razor back ridges (termed *faatuaia)*, and marine fossil locations, for example, the Cape Tapaga (Lalomanu, Upolu);

(vi) Introduce awareness of volcanology and geology through presentations designed in participatory methods with village communities, workshops, or training in various schools from elementary to colleges. This can be achieved through short courses and workshops in collaboration with the National

University of Samoa, the University of the South Pacific, and various government ministries such as the Ministry of Natural Resources and Environment; the Ministry of Samoa Tourism Authority; the Ministry of Agriculture and Fisheries; the Ministry of Education, Sports and Culture; and the Ministry of Women and Social Development-Internal Affairs);

(vii) Working alongside and in partnership with the local community to develop a mutual awareness of every aspect of geology and volcanology with the view to attract more local and international tourists to the geopark sites;

(viii) Working alongside and in partnership with the local community to co-design and co-product workshops as well as static and dynamic information outlets within local communities. Use the geoheritage elements of volcanism, tectonism, mass movement, flooding, and coastal processes to raise awareness of various geohazards the communities face and identify through participatory methods basic skills to live alongside with those geohazards in a resilient way.

In a broader socio-economic sense, geoparks commonly function as important socio-economic elements of society (Xun and Ting 2003). Geoparks also function as important structures providing ecosystem services — more precisely geosystem services — where identified geoheritage sites serve human socio-economic needs. This in turn has a direct effect on the well-being of the community, driving cultural evolution and strengthening integrity of human communities (Ali et al. 2015; Gray 2011, 2012, 2018a; van Ree and van Beukering 2016; van Ree et al. 2017). Within the geopark framework, geodiversity is commonly observed as a precious national resource that can be used for various levels of geoeducation, demonstrating utilization of and learning to live with the resources in a sustainable way (Galas et al. 2018; Han et al. 2018; Ruban 2017). However, this can also result in conflicting needs and processes, requiring a complex approach to providing solutions for coexistence. Geotourism could interfere with local communities' goals of development or geoconservation that may be perceived as in conflict by local communities as external observers (Errami et al. 2015b; Henriques et al. 2020; Herrera-Franco et al. 2020; Mat Stafa et al. 2018; Ólafsdóttir 2019; Wang et al. 2019). This paradox may be more common and real in local communities that struggle in a cash economy such as those in the islands of the SW Pacific as they live on geographically remote islands; have limited livelihood opportunities; and their day-to-day needs are largely provided by a subsistence-based village economy supplemented by agriculture and fishery (Lockwood 1971; Paulson and Rogers 1997; Schoeffel 2007). Geoparks may be developed in regions where the geological and geomorphological asset of the land has driven development of cultural traditions and provided a backdrop to day-to-day life of the human population. (Henriques and Brilha 2017). Geoparks can be the core frameworks to provide additional avenues to diversify livelihood potential, especially in communities like those across the SW Pacific, including Samoa. The Samoa Geoparks Project aims to identify the region's geoheritage values, co-design, and then co-produce a geopark framework within the concept of environmental sustainability (Mauser et al. 2013). In this process, the indigenous cosmovision of the Polynesian society is given equal importance alongside western scientific knowledge, an increasingly common approach to conservation and land management globally (Forster 2010; Mills 2003; Morehu 2016; Nalau et al. 2018; Poelina et al. 2019).

Methodology

The Samoa Geoparks Project consultation process was initiated in September 2016 through meetings, presentations, and geosite visits with government ministries (Ministry of Foreign Affairs and External Trade, Ministry of Natural Resources and Environment, Samoa Tourism Authority, Ministry of Agriculture and Fisheries, Ministry of Education, Ministry of Women and Social Development—Internal Affairs). This process identified a path for the Samoa Geoparks Project, leading to consultation at various community levels. Consultations were carried out on tourist attractions with landowners in Upolu and Savai'iSavai'i, ensuring every component of the geopark project should be clear and understandable. As education is one of the major components of the Samoa Geoparks Project, the geopark concept was also introduced through schools, colleges, and various departments of the National University of Samoa. This allowed students to become familiar with, and better understand, geological processes associated with the development of Samoa's islands and their geoforms and landscape elements.

The basic characteristics of the Samoa Geoparks Project Phase 1 can be summarized as:

- An opportunity to define expectations of the project, and identify appropriate government ministries, village community members (especially women's committees), and landowners that would support the Samoa Geoparks Project and make it a reality.
- Introduction of the geopark concept to communities and government ministries enabling design of activities appropriate for the proposed phase 2.
- Identification of several *mataaga* that need to be extended to cover some left-out geoheritage sites, e.g., Saleaula village and Falealupo.

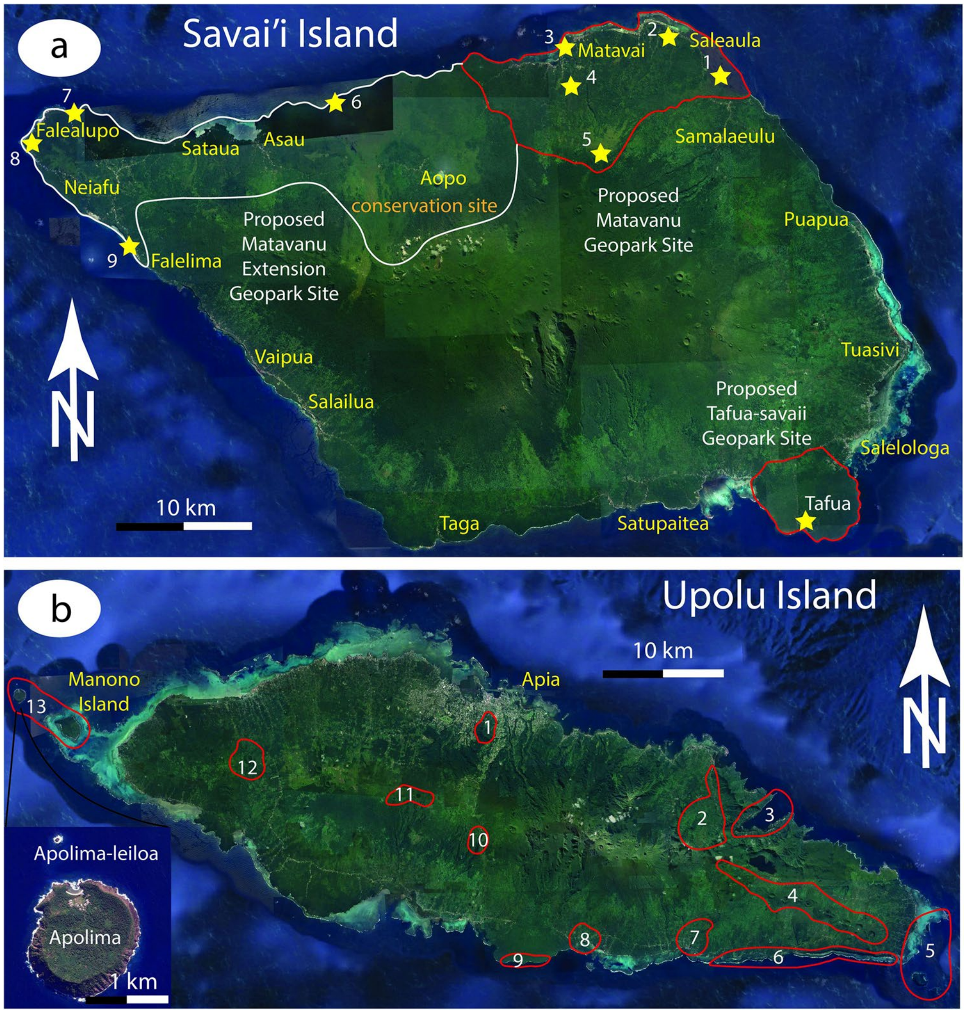

Fig. 3 Google Earth map of Savai'i Island (**a**) and Upolu Island (**b**) shows potential geosites as part of a geopark concept on the northern part and the south eastern end of Savai'i. Significant geosites associated with the Matavanu 1905–1911 eruption include the barren lava field in the coastal region including the demolished village of Saleaula (1), coastal sections and reefs formed as a result of the emplacement of the extensive Matavanu lava flow (2), coastal section in the interface of the young and old lava flow fields of the Matavanu region (3), lava tubes (4), and the Matavanu scoria and spatter cone complex with deep pit craters (5). A proposed Matavanu Extension Geopark sites include volcanic geosites with high geocultural values such as the (6) Aopo lava flow system, (7), Falalupo, (8) Cape Mulinuu, and (9) Samata-Falelima cliff (Le-mako). The coastal offset of the Ologogo-Sataua Arc Fault near Sataua and the young volcanic cone of Tafua in the SE of Savai'i are also important provisional geosites. Significant geosites identified on Upolu Island (**b**) show a great variety of geological features associated with volcanic processes: (1) Mauga Vaea, (2) Lemafa road section, (3) Fagaloa Bay, (4) Mauga o Aleipata, (5) offshore islands, (6) Tuialamu Cliff, (7) To-sua and To-le-sua, (8) Fagaloa-Falealili Fault, (9) O Le Pupu Pu'e National Park Coastal Lavafield, (10) Tiavi Fall, (11) Lake Lanoto'o, (12) Tafu-a-upolu, and (13) Apolima-leiloa

– Identify sites requiring incorporation into the geopark project enabling generation of tourist revenue for communities such as Falealupo and Sataua village.

From phase 1 of the Samoa Geoparks Project, the following implications and recommendations can be drafted.

– Co-design and co-produce workshops and training for communities in Upolu, Savai'iSavai'i, Apolima, and Manono Islands to ensure the "geopark message" will reach every part of Samoa.

– A geopark workshop provides a way to create an intensive educational experience in a short amount of time when the time for a more comprehensive effort may not be available. Participants may be working and may be too far apart to meet regularly or may simply be unwilling to commit large amounts of time. A workshop is a way for someone to pass on to villagers ideas and methods developed by experts and considered important to the process. This is especially important for those who work together to create a sense of community or common purpose among participants.

- Participants to the workshop in Savai'iSavai'i should be part of the 3 zones shown in Fig. 3 (Matavanu Geopark, proposed Extension Zone, and Tafua-Savai'iSavai'i Geopark). Based on the village structure and existing levels of management and authority, participants must include women representatives, a youth representative, matai council representatives, and a village mayor. We are aware that to proceed with the geopark project, a detailed analysis of the various elements of the community is needed. As there are significant traditional power asymmetries within local communities (e.g., Chiefs vs women vs youth) these elements must be factored into any co-design and co-production. We recognize this as a very challenging task and no obvious guidelines in place presently. We do suggest utilizing aspects of government procedures for induction and training which have been deployed for several years and could be used for Geopark Workshops. Additionally, hotel, motel, beach *fale* (a Samoan house with open sides and a thatched roof), and other tourist providers in the area should be all part of the workshop.
- Based on previous work, and experience of phase 1 individual consultations of the Samoa Geoparks Project for every *mataaga*, the workshop may not only save time but also save a huge cost as a participatory workshop with community and geoscience experts would interlink in one single location and event every member of the community. The community asset of time is highly valued and should be effectively harnessed to satisfy every member of the community and external experts. It is recommended that this can be achieved through upskilling local community members through regular communication sessions over long periods of time within the community, a process normally impossible for external outsiders like geologists involved in the project. In this method, the role of the "outsider" becomes less "the essential expert", but rather the "occasional" visitor/up-skiller/catalyst/bridge to the "external world." We suggest a holistic approach to developing workshops and community engagements (e.g., Savai'i-centric), reducing the significance and role of the outside "expert" and highlighting community-driven processes. Ideally, the geopark should be "by the people for the people" and not an activity where outsiders with great ideas "shake the community into action." The Samoa Geoparks Project would provide an avenue for implementing new "conceptual frameworks of interconnected geosciences" (Petterson 2019). Within this framework, interconnected geoscientists would draw on a deep expertise in the relevant geoscience area, and hold an equivalent deep expertise/consciousness in understanding the developmental situation and conditions they are working in, including the "world view" of people affected by a geoscience intervention (Petterson 2019) such as co-design geoparks;
- The workshop will recap and follow on from where the Samoa Geopark Project Phase 1 ended;
- The workshop provides an improved method to share ideas among *mataaga* management and identify positive and negative approaches associated with establishment of the Geopark Project;
- A great opportunity for locals to view their world through a scientific lens and gain knowledge about the origin of their landscape and geological processes involved;
- An opportunity for locals to share their unpublished heritage stories, myths, and other cultural activities relevant to understanding the geological origin and formation of the landscape. We acknowledge that there are important considerations to sharing of cultural information and traditional knowledge, and we stress that this process must be driven by acknowledged holders and teachers of cultural knowledge chosen and respected by the relevant communities (Diver 2017; Hutchings and Greensill 2010; Mackay 2010).
- The holiday season brings huge numbers of visitors to the shores of Savai'I, and a Geopark Workshop would provide an ideal forum for preparation of every *mataaga* in utilizing expected revenue streams during holiday seasons, and also in anticipation of a sudden influx of visitors in response to lifting of COVID travel restrictions;
- The workshop would act as a platform for e speakers (local and overseas) experienced in disciplines including but not limited to Geotourism, Geoheritage, Geoeducation, and Geoconservation. Support would be provided to assist local people to organize these events and take the lead alongside the identified experts in their fields. This will be an opportunity to share experience and expertise from UNESCO, FAO SPC Geoscience, and Government Ministries of Samoa, and lead to establishment of appropriate guidelines and a stable foundation for a future geosite project;
- Lessons learnt from the Samoa Geopark Workshop will be valuable in the development and implementation of the next Geopark Project in the Pacific;
- Consultation will identify all geosites suitable for the geopark project in Upolu, Manono, and Apolima;
- Identify opportunities to develop and implement the idea of a Samoa Geopark manual for every geosite that could be distributed across a range of media and platforms through the Samoa Tourism Authority;
- Investigate feasibility of using the Samoa Geoparks idea as an aspect of the national education curriculum in collaboration with the Ministry of Education, Sports and Culture.

Proposed Geopark Sites

On the island of Savai'i, there are 3 significant areas, proposed for geopark sites in the future (Fig. 3). The northern sector of Savai'i is proposed for recognition as the Matavanu Geopark Site (this study). The geosite evaluation followed valorization methods where scientific values were considered to the main or fundamental values (Brilha 2016, 2018a). While these methods are widespread and applied for many parts of the world, they underrate traditional knowledge, indigenous values, and other geocultural aspects that may underlie legends, ritual sites, and religious geo-locations (Gravis et al. 2020; Oprea et al. 2012; Panisset Travassos et al. 2018; Paskova 2018; Ramsay 2017; Unjah and Halim 2017). While following the mainstream approach to valorization of geosites is a valuable first step, we stress that future project development must explore, compare, and co-design geosite valorization methods that include the geocultural aspect of geosites. This recognizes that the area is dominated with significant geological features of active volcanism and has high aesthetic values such as the well-exposed features of the Matavanu volcanic crater that was active from 1905 to 1911. This volcano records the latest volcanic activity of the main islands of Samoa (Anderson 1910; Anonymus 1910). The Matavanu Geopark Site covers an estimated area of up to 264 km^2, and includes currently operating general tourist attraction sites such as a littoral cone (Mauga village), lava field (Saleaula village), lava tube (Paia village), water spring (Matavai), and the Matavanu cone and its pit craters (Fig. 3).

A further proposed geopark extension project (blue dotted line) toward the north western part of Savai'i represents a continuation of more volcanic features in this part of the island (Fig. 3). This region of Savai'i is also dominated by exposures of recently formed (Holocene in age) volcanic elements.

Like the Matavanu Geopark Site, the Tafua-Savai'i cone complex on the southern east end of Savai'i is also proposed as a potential geopark site based on its accessible volcanic features forming a complex scoria cone and lava flow field formed during Holocene activity (Németh and Cronin 2009) (Fig. 3).

Several sites in Upolu have also been considered to be labeled as geopark sites (Table 1) such as those of (1) Mount Vaea (Fig. 4a); (2) Lemafa road section (Fig. 4b); (3) Fagaloa Bay; (4) simultaneous volcanoes (Fig. 4c) (Lanoto, Lano-o-lepa, Olomauga, Lanotai, and Lanomoa); (5) tuff cones of Nuutele Island, Nuulua Island, Namua Island, and Fanuatapu Island (Fig. 4d); (6) upthrown section of the Lepa Fault; (7) collapsed section of a 7-km long lava tube (To-sua and To-le-sua); (8) Fagaloa-Falealili Fault limb (Fuipisia Fall); (9) O Le Pupu Pu'e National Park Coastal Lavafield (Fig. 4e); (10) collapsed lava tunnel associated with central ridge fault network (Tiavi Fall); (11) Lanoto'o crater; (12) Tafu-a-upolu crater; and (13) collapsed tuff cone of Apolima (Fig. 4f) (evident of a cone collapse event (Apolima-leiloa)) and Manono Island lava shield (Fig. 3). Apolima-leiloa (known as lost island) is formed by a rock-pile exposed above sea level to the north of Apolima Island and is likely part of a 14-km long block sitting at the north eastern foot of Savai'i at about 5 km depth.

Consultation and Scientific Explanation of the Proposed Geosite of Saleaula Lava Field

The village of Saleaula (northern part of Savai'i) is one of the main sites of the proposed Matavanu Geopark Site (Fig. 3). The proposed site covers an area of approximately 10 km^2 and encompasses many of the features formed during the eruption of the Matavanu volcano that erupted between 1905 and 1911 (Anderson 1910). The eruption site with its unique volcanic landforms and eruptive products was the prime reason for selection of this part of the island for future geopark development. The identified geological elements of the Matavanu volcano are similar to most scoria cones in other regions on Earth and include welded scoria, a deep pit crater, lava outbreak sites, lava tunnels, and various pyroclastic successions suggesting magmatic gas-driven explosive and effusive eruptions resulting in the volcanic geoforms. Some of these volcanic features are unique in the Samoan geological context as they are young and well-preserved with tropical vegetation blanketing the dramatic landscape elements of extensive Pāhoehoe lava flow fields and providing graphic examples of vegetation recovery since the eruption took place. The lava fields of Saleaula hosts tumuli, lava tubes, columnar jointing, Pāhoehoe flow inflation and deflation features, and a black sand spit paralleling the fringing reef with captured fragmented pyroclasts formed during littoral explosions when the lava flow entered and interacted with the Pacific Ocean. These geosites are unique in a Samoan context as they are the best exposed and preserved geoforms in the region. In a global comparison, they are like those features known from Hawaii or other ocean islands and other extensive volcanic fields related to mantle upwellings.

The tumulus near Saleaula village is also known locally as "mauga maa" formed from an upwelling (up to 30 m) of magma beneath a thick lava crust (Fig. 5a & b). An obstruction of the molten lava associated with high pressure has pushed the overlying crust and formed a dome structure (Anderson et al. 2012; Diniega and Németh 2014; Glaze

Table 1 Provisional geosites that can form the basis of the geoparks development in Upolu primarily based on their scientific values commonly considered main or fundamental values within geosite valorization methods (Bratic et al. 2020; Brilha 2016, 2018a; Carrion-Mero et al. 2020; Miljkovic et al. 2018; Vujicic et al. 2011)

Location number and name	Geological feature	Surface area	Accessibility	Rarity	Current ownership
1—Mauga Vaea	Older rock Fagaloa Formation surrounding by younger rock of Salani Formation (inlier)	Up to 6 km^2 in size with 350 m above sea level	Very good access	Thick weathered lava suites of the Fagaloa Formation exposed along the track. The site is popular for cross-country, walking and running exercise. It is a best spot to get an overview of Apia and surrounding area	It is a part of Conservation Project and the National Park of Samoa
2—Lemafa road section	Older Fagaloa rock formation (Lower Unit) intruded by younger rock (Upper Unit), referred to dike and sill outcrop	About 6-km road section	Very good access (beside the road). The site is vulnerable for rock fall and landslide during heavy rain season	Massive intrusion of columnar joint lava known as “Lemafa Intrusion” solidified and form sharp razor backer ridge exposed very well at this part of Upolu. It has a width of 15–100 m and at least 10 km in length	Several local farms (taro plantation) in the area but it is also part of the National Park
3—Fagaloa Bay	Same rock type as the Lemafa road-cutting outcrop, well-exposed rock of Fagaloa Formation lava suites	About 20 km^2 in size	Very good access	Good spot to have an overview of the Lemafa Intrusion with steep a scarp surrounding. The bay dissects by the Fagaloa-Falealili Fault oriented northeast-southwest direction	Village land (customary land)
4—Mauga o Aleipata (easternmost volcanic crater of Upolu): Lanoto, Lano-lepa, Olomauga, Lanotai, and Lanomoa	Volcanic craters (scoria cones, tuff rings, pit craters, and lava flows) that erupted several times (represent simultaneous style of eruption)	Lanoto-240 m^2, Lano-lepa-360 m^2, Olomaga-270 m^2, Lanotai-165 m^2, and Lanomoa-300 m^2	Good access (4 WD then walk to all these locations)	Crater lakes are part of the volcano-myth at this part of Upolu. Naming of these craters also corresponds with movement of people from Savai’i to Upolu, e.g., Mauga o Savai’i to the west of Lano-lepa	Part of the National Park, despite several farmlands in the areas
5—Nuutele Is, Nuulua Is, Namua Is, and Fanuatapu	Tuff cone of Salani Volcanic Formation commonly collapsed or erode	Nuutele-1990 m^2, Nuulua-125 m^2, Namua-200 m^2, Fanuatapu-125 m^2	Good access by boat	Well-exposed geology at several section of the islands. The islands represent an extension of Upolu Fissure System	Tourist attraction operated by local owner but also part of the National park
6—Tuialamu Cliff	Lepa Fault of Salani Volcanic Formation lava suites (upthrown of up to 120 m north)	3.5-km road section	Very good access (road section)	May be used as a bay watch spot during first occupation in the area and generate series of landslide in the past and the present	Village land (customary land)

Table 1 (continued)

Location number and name	Geological feature	Surface area	Accessibility	Rarity	Current ownership
7—To-sua and To-le-sua	Lava tunnel (7–8 km of the Fogalepulu Volcano Complex exposed along the main road at Afulilo site (in the Fagaloa Formation zone) erupted during last 3400 years ago during Lefaga Volcanic Formation	To-sua (50-m diameter and 100 m deep). To-le-sua (25-m diameter, 100 m deep)	Very good access	Very deep and wide crater. To-sua use as a wide natural swimming pool. Several sections of the coastline had been isolated and form islet (very common feature at this part of Upolu), good indicator of high wave energy environment. This could be the same mechanism that trigger the formation of To-sua and To-le-sua	Tourist attraction (customary land)
8—Fagaloa-Falealili Fault	Major Upolu fault system that dissected the Fagaloa Bay and extended toward Falealili district (south) of 14 km. It seems responsible in offsetting the alignment of the Mulifanua Formation volcanic cones at the eastern central part of Upolu	Extend about 14 km NE-SW direction	Very good access at several section	Very deep dissected (narrow valley) on the southern end, up to 180 m depth that generate the Fuipisia Fall	Tourist attraction (customary land)
9—O Le Pupu Pu'e National Park Coastal Lavafield	Coastal section of young lava flow field	Area is about 3 km long along the coast	4 WD access and easy walking access	Pāhoehoe lava flow field with various surface textures, eroding high coastal cliffs	Tourist attraction, National Park territory
10—Tiavi Fall	Collapsed lava tunnel of Salani Formation associated with central ridge fault network	About 1 km^2 (elongated NE-SW direction at least 3.5 km)	Good access (beside cross-island road)	Very deep narrow valley of up to 120 m in depth	Tourist attraction (private landowner)
11—Lake Lanoto'o	Crater lake in volcanic highland	About 85 km^2 area including the scoria cone with a crater lake	4 WD access and walking track	Water-filled volcanic cone	Tourist attraction
12—Tafu-a-upolu	Tuff cone of the Puapua Volcanic Formation	About 640,000 m^2 in size and expose about 659 m above sea level	Very good access	The highest point on the western part of Upolu. It represents the return of the Tonga people to Samoa	It is a part of the National Park despite the fact that it is a customary land
13—Apolima-leiloa (lost island)	A left behind part of a collapsed tuff cone expose about 35 m above the sea (volcanic shoal)	About 1260 m^2 in size	Good inter-island ferry view	Pile of rock in the middle of the deep ocean. It suggests that a part of a 14-km long block of rock sits at 5 km depth at the north eastern foot of Savai'iSavai'i Island	It is a part of the National Park

Fig. 4 Significant geosites identified on Upolu Island: (**a**) Mauga Vaea, a large scoria cone just above Apia town; (**b**) Lemafa road section not only exposing the oldest volcaniclastic successions of Samoa but also exhibit some large water falls across the oldest lava flow units such as at the Falefa Falls; (**c**) Mauga o Aleipata shows young tuff rings and scoria cones, (**d**) offshore islands in eastern Upolu are eroded tuff cones, (**e**) O Le Pupu Pu'e National Park Coastal Lava-field exposes young Pāhoehoe lava surfaces and dramatic coastal erosion features, and (**f**) Apolima Island is a large tuff cone with a breached crater allows access to the island

et al. 2005). Tumulus associated with a large fracture along the central section has solidified at approximately 10 m height (Fig. 5a), while external tumulus may have reached a height of more than 20 m before they collapsed (Fig. 5b). It is suspected that tumuli located near the coastline experienced explosions due to lava and seawater steam explosions as captured in some historic photos inferred to have occurred in the same location as large tumuli left standing today (Fig. 5c). The tumuli on the young lava fields are superbly exposed, and they are unique geoforms with high aesthetic and scientific values that make them significant and globally comparable to sites considered to be their best examples on Earth (Gao et al. 2013; Ma et al. 2019; Németh et al. 2017b; Ollier 1964; Xiao and Wang 2009).

A broad lava flow of up to 1 km in width generated from the Matavanu eruption in 1905 almost destroyed the entire village. Evidence of this volcanic disaster such as churches, houses (Fig. 6a), and emergency wells became significant features of the Saleaula tourist attraction (*mataaga*) (Fig. 6b & c). The source of the eruption is a complex scoria cone located about 12 km to the SW from Saleaula. Mapping of the scoria cone formed after the eruption (Fig. 6d) clearly shows the cone and its relationship with the lava outflow. Since then, the cone has become heavily revegetated and is a significant adventure tourism destination (Fig. 6e).

Saleaula village is one of many tourist attractions (*mataaga*) where the boundary of the proposed geopark could be extended to ensure all features are included. During the 2016 census, the population of the Saleaula village was counted as 1010 (500 female and 510 male) in comparison with 864 in the 2011. These numbers could be triple compared to the population that left the village during Matavanu eruption in 1905–1911.Since that time, most of these evacuees did not return but settled on the southern part of Upolu at Salamumu village (Fepuleai 2016). The Saleaula *mataaga* is operated and managed by the Village Women's Committee, while many other tourist sites on Upolu and Savai'i are managed by the landowners. During the last 20 years, the *mataaga* has brought an average revenue of $104,000 Western Samoan Tala per year (approximately $40,000 US dollars or $60,000 New Zealand dollars) to the community. We note that the *mataaga* appears to be the only

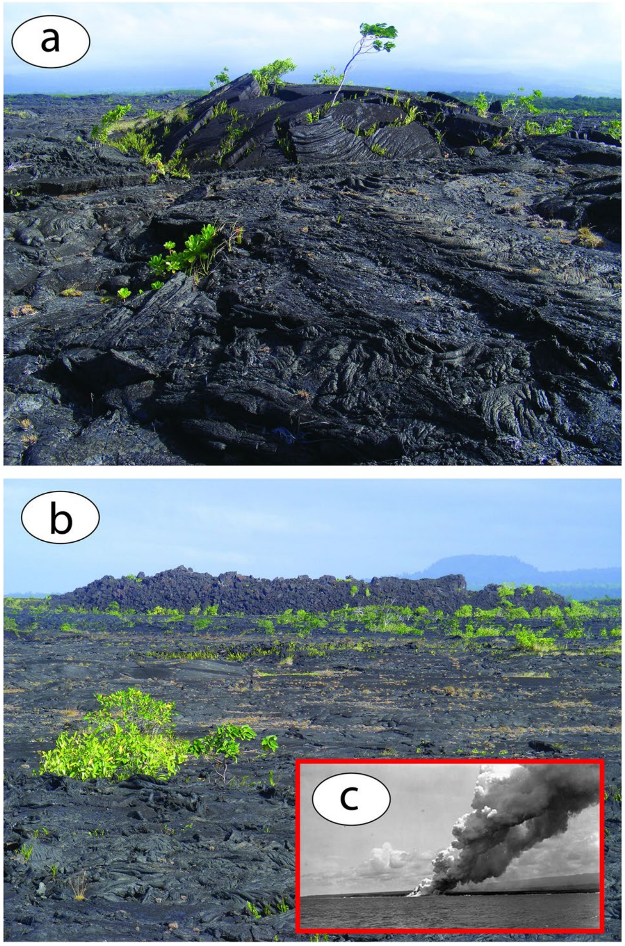

Fig. 5 (a) Tumulus (about 2 m across) with crack along the central part of the lava flow field of the Matavanu eruption near Saleaula, (b) collapsed tumulus of about 5 m high and 50 m across within the Saleaula lava field with potential littoral explosions as marked by a historic photograph taken from the ocean, (c) National Library of New Zealand by Alfred John Tattersall (1905): http://mp.natlib.govt.nz/detail/?id=16687&l=en

successful ongoing business operating in this community. Based on information from the Saleaula Women's Committee, the numbers of visitors to the Saleaula *mataaga* from 2015 to 2019 are estimated to be at least 120,000 including local visitors, overseas tourists, local school students, and researchers.

The Saleaula village mayor and several members of the council of chiefs, known as "matai-ole-nuu," were provided with a "geopark concept" brief during the welcome meeting. The team also presented appropriate gifts of money and food to the village as part of the cultural requirement to obtain permission to carry out the geopark project consultation. The village representative during the initial early meeting requested for the geopark concept seminar to be held in the evening, so all members of the community over the full range of ages would be able to participate and become familiar with scientific processes associated with the formation of many volcanic features (mostly lava flow surface textures) exposed near the village. It is estimated that about 60 people attended, including people who had to be accommodated outside the main seminar room.

The geopark seminar was attended not only by the matai council of the village but also children from the primary and secondary school (Fig. 6f). As education is one of the significant components of the Samoa Geoparks Project, it was a major consideration to invite the younger generation, as they are "the future of Saleaula community." The entire village including church ministers are fully supportive the idea of the proposed geopark, and aspire to make the Saleaula geosite one of the best on the island. Saleaula is an important location as it exposes numerous Pahoehoe lava surface textures (Fig. 7a & b). Such lava surface textures are common across both Samoan Islands (Fig. 7c), and they are also linked to everyday life such as stone wall creations (Fig. 7d) or part of legends and oral traditions (Fig. 7e & f).

The village supports the geopark project in a way that would enable expansion of the *mataaga* to include left-out features, e.g., tumulus. This extension should include improvement of the ecosystem services within the Saleaula Bay as part of ecotourism activity, such as cleaning the bay of thick mud and coral eating organisms replanting coral species within the lagoon and reef, improving habitat for beneficial marine organisms, and replanting salt tolerant plant species along the coastline to reduce erosion.

In addition, Saleaula village sent a representative (Aufai Toma Aufai) to the 2004 Ecotourism and Biodiversity Conservation for Asian-Pacific Communities Workshop in China, in response to an invitation for *mataaga* project owners in Upolu and Savai'iSavai'i through the Ministry of Agriculture Forestry and Fishery Program. This demonstrated that the Saleaula communities had already expressed their interest in the geopark project. Aufai Toma Aufai shared some of his experiences from the China geopark workshop during the discussion session of the presentation. The Women's Committee representatives support the idea of the geopark concept extension and the training of locals to improve the Saleaula *mataaga*. Church ministers and the council of chiefs (matai-ole-nuu) also echoed this with a parallel recommendation.

The village requested geological documents, maps, and display materials to set up billboards of the volcanic features of the lava field and the Matavanu volcano. They reasoned that the presence of correct scientific information will drive the Saleaula *mataaga* to the next level, and will not only be for beneficial for visitors, but also provide key information about geohazards of the region for the young generation that can be incorporated in the local education system. The importance of this request from the community is it demonstrates the empowerment process through education

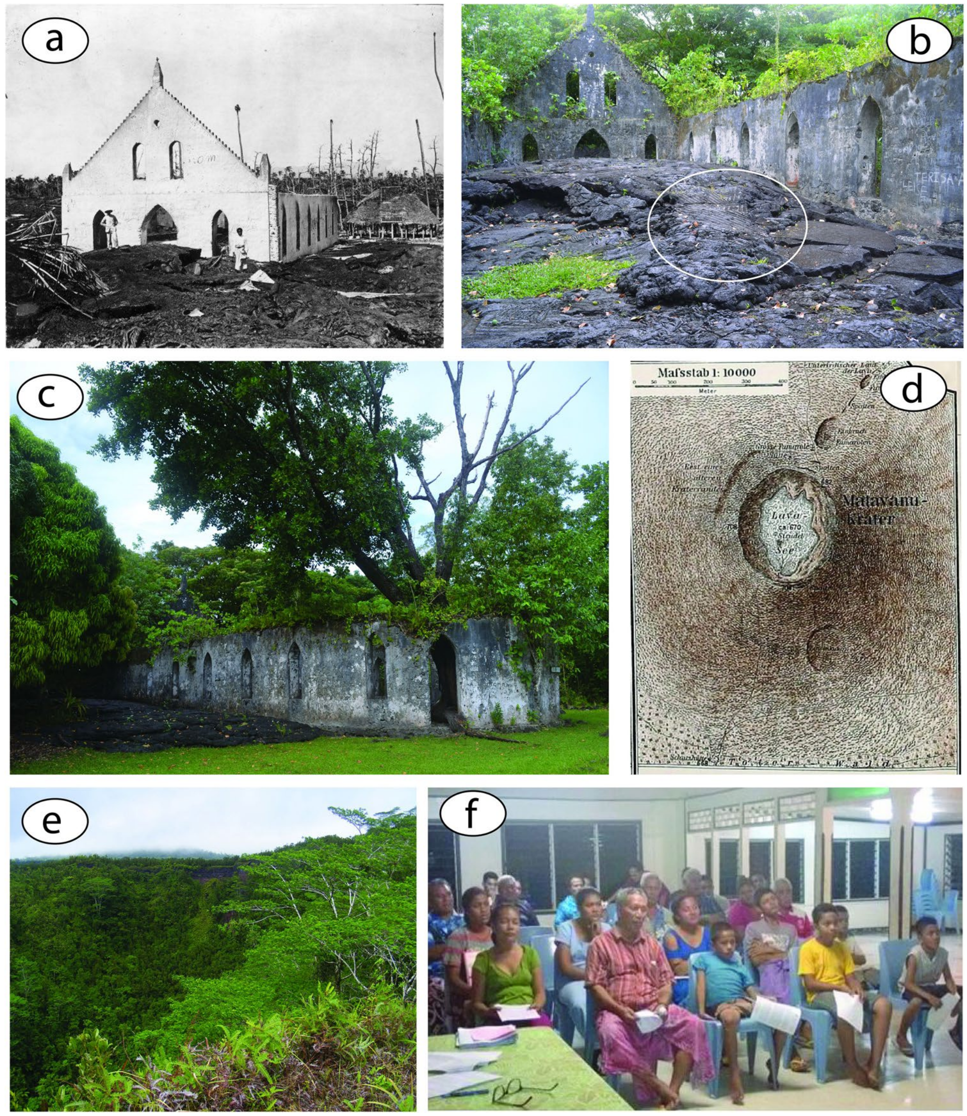

Fig. 6 (**a**) The LMS church in Saleaula damaged by lava of the 1905 Matavanu eruption on an original photo during the eruption: photo AJ Tattersall (**b**), the LMS church at Saleaula today showing Pāhoehoe lava flow that flowed to the interior of the church. The collapse of the corrugated iron roof made a print on the still molten lava flow surface (white circle); (**c**) the LMS Saleaula church from outside without roof and a terminus of a Pāhoehoe lava flow today; (**d**) map of Matavanu Volcano, Samoa, from 1910. Note the steep inner crater wall and the row of pit craters in the NE side of the volcano along the main artery of the lava outpouring; (**e**) the active crater today of the Matavanu eruption is vegetated, and clastogenic lava with agglutinated scoriaceous pyroclastic successions crop out in the crater wall; (**f**) evening seminar at Saleaula village, attended by the council of chiefs (matai-ole-nuu), church ministers, women committee, youth, and children.

initiatives as part of this geopark project. This aim is in line with the aims of one of the current UNESCO International Geoscience Programme; #692—Geoheritage for Geohazard Resilience.[4]

Sites Within the Geopark Extension Zone (North Westernmost Part of Savai'i)

Selective sites to the north westernmost part of Savai'i are associated with astonishing geological features and a dynamic environment, and provide cultural links to the traditional knowledge associated with this part of the island, represented in myths, stories, and legends. These localities include villages that may not have considered themselves as possessing "*mataaga*" (tourist attractions). However, the community engagement processes demonstrated rare and beautiful volcanic features and other geological exposures worthy of recognition to be found within their local landscape. These villages include Samata-Faleima, Tufutafoe, Falealupo, Sataua, and Aopo on the westernmost to the north westernmost part of Savai'i (Fig. 3a).

Samata-Falelima

Samata-Falelima cliff (Le-mako) is an exposure approximately up to 100 m long against the backdrop of the deep blue ocean of the north westernmost coast of Savai'i (Fig. 8a). Le-mako *mataaga* is associated with a well-known traditional story of a "suicide mission by a mother and a daughter, expressing their disagreement with high-ranking chiefs of the area, and a way to save a husband from

[4] [http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/international-geoscience-programme/igcp-projects/geohazards/project-692/] (Guilbaud et al. 2020).

Fig. 7 (**a**) Pāhoehoe lava flow surface gradually reoccupied by vegetation after the 1905–1911 Matavanu eruption near Saleaula village and demonstrate great variety of ropy textures (**b**). Pāhoehoe lava flow surface textures (like this from the Saleaula lava field) are abundant on both Samoan Island (**c**) and especially slabby Pāhoehoe used as building stones for rock fences over centuries (such as these examples from South Upolu) (**d**). Legends are also associated with Pāhoehoe surface textures (**e**) such as the "Moso footprint" in NW Savai'i (**f**).

a punishment of death." This *mataaga* (tourist attraction) extends about 8 km and is part of an uplifted portion of Savai'i suggested to be triggered by a massive earthquake occurring 22,300 years ago (Fepuleai 2016), and could correspond with the collapse of the southern part of Manua Island (American Samoa territory) of a similar geological age (Williams 2009; Williams et al. 2013; Williams et al. 2014a; Williams et al. b).

West of Tufutafoe-Cape Mulinuu

The Tufutafoe region located at to the westernmost end of Savai'i is a site where a broad coastal area is dominated by a series of domes formed byof columnar-jointed outcrops. These hexagonal columnar joints are products of the Puapua Formation (Fig. 8) outpoured from the eruption of Mauga Muli and Mauga Fuiono to the southeast of Falealupo village. The lava flows overrun organic material, and the generated charcoal has been dated by radiocarbon dating techniques to provide an age between 0.23 and 0.19 ka (Németh and Cronin 2009). The lava dome structure formed in a similar style to tumulus features of Matavanu volcano (Fig. 3), before shrinking as they cooled down and form hexagonal jointing (Fig. 8b). Fepuleai (2016) inferred that these hexagon joints are roughly perpendicular to the surface of the flow and useful features to establish lava flow 3D geometry.

According to a traditional myth of the area, the columnar joints were initiated by the first human residents to inhabit this part of the island. The big crack in Fig. 6c corresponds with the fact that this is the main road for spirits from Upolu when they visited Savai'i. According to the myth, the columnar joint features along the lava suite are related to a type of seismic activity believed to be caused by these spirits

Fig. 8 (**a**) Le-mako cliff at Fagafau, Samata; (**b**) dome of columnar-jointed outcrops (up to 5 m high with diameter of 15–20 wide) along the broad coast area of the Tufutafoe region at Cape Mulinuu; (**c**) dome of a tumulus has a crack of almost a meter in width, elongates along the central part. Hexagon columnar-jointed outcrop has dominated dome outcrops; (**d**) broad fringing reef of the Mulifanua Formation (Early Holocene) overlying by the Puapua Formation (Late Holocene) lava.

arriving at Savai'i. This site is not yet a part of the *mataaga* and includes an extensive white coral sand beach that is easily accessed by tourists and other visitors.

East of Tufutafoe-Cape Mulinuu

Columnar-jointed lavas continue to crop out along the eastern part of the Tufutafoe village, where they form part of a *mataaga* (tourist attraction) known as "Ala-o-Upolu" meaning "the track of high-ranking ghosts of Upolu (known as Vaea, Tagaloalagi, Salevao, Nafanua, Timuialatea, Saveasiuleo, Vasivasi, Uila, Faititili ma Mafuie)." Series of joints/cracks dissecting these columnar-jointed lavas have informed the popular legend of Samoa known as "Fafa-o-Saualii" or "the meeting place of the highest-ranking ghost-spirit in Samoa" (Fig. 8c). Columnar joint features relate to a kind of force represented as a type of seismic activity generated as the track (Ala-o-Upolu) becomes overcrowded. The word "aitu" (ghost) in Samoan language does not have a human equivalent, in contrast to those of ghost-spirits that sometimes turn into humans known as "itu-lua." The high-ranking ghost-spirits of Samoa overseeing both Eastern Samoa (American Samoa) and Western Samoa were referred to Tagaloalagi, Nafanua, and Timuialatea. This explains an old saying used during oratory speech "O paia o Samoa e sau mai Saua se ia paia le Fafa-o-Saualii." That is, the godliness of Samoa starts from Saua, a place in Manua Island, on the easternmost end of the Samoa Island chain, until the Fafa-o-Saualii, the westernmost end. The Ala-o-Upolu *mataaga* is a part of a tumulus, which has a crack of almost a meter in width dissecting the central part of the columnar-jointed dome, like those shown in Fig. 4a.

This *mataaga* is currently operated and managed by landowners and matai chiefs (Mr Tuimaualuga Makelaioi and Mr Tuifaiga Filo) of the Tufutafoe village. To Mr Tuifaga Filo, the feature of the site has always been of interest to tourists and other visitors due to its relation to traditional myth. The Fafa-o-Saualii was where all decision-making had final approval by the ghosts and ghost-spirits. This could generate wars between islands, tribes, districts, villages, and families. The arrival of the high-ranking ghosts and ghost-spirits at the westernmost part of Savai'i was responsible for the formation of big cracks and columnar-jointed lava suites. In addition, the wide spread of columnar jointing along coastal lava suites of the Puapua Volcanic Formation was also because of many ghosts and ghost-spirits meeting at this part of Savai'i. The community leaders requested scientific information and description of the features of the

Fig. 9 **a** Steep cliff of the western end of the Sataua-Ologogo Arc Fault to the west of Sataua village. **b** Thick columnar joint associates with onion-skin weathering of the Salani Formation and locates to the mid-section of Sataua village.

site. This will make the traditional myth more accessible to visitors and provide a better understanding of the geological features of the local area.

Falealupo Site (Eastern Part of Tufutafoe Area)

The Falealupo coastline is dominated by a broad Mulifanua Formation reef (Early Holocene), overlain by the Puapua Formation of Late Holocene age (Fig. 8d). The significance of the Mulifanua Formation reef is that it represents a rise in sea level between 2.3 and 11 ka (Holocene time) before the initiation of eruptions formed rocks of the Puapua Formation. Kear and Wood (1959) use the relationship between the volcanic extrusions and the reef to determine the age of many Holocene eruptive phases on Upolu and Savai'i. This part of Falealupo village has no *mataaga*. However, the relationship between the Puapua Formation lava and the Mulifanua Formation reef could create an interesting site for Holocene volcanic activity of value to visitors and local communities. The reef is surrounded by a wide white sandy beach (Fig. 8d).

Sataua Village (Southeast of Falealupo)

Like other locations on Savai'i, Sataua village is another site that has no *mataaga*. However, the steep headland (exposed up to 50 m high) (Fig. 9a) to the northwest of the village represents the western part of the Ologogo-Sataua Arc Fault (Fepuleai 2016). The Ologogo-Sataua Arc fault extends approximately about 24 km in diameter to the west and outcrops at the proposed Matavanu Geopark Site. Fepuleai (2016) stated that the arc fault likely produced a large-scale submarine debris avalanche at the foot of the westernmost part of Savai'i Island, with a depth of more than 4000 m.

Additionally, an excellent outcrop of spherical weathering forming an onion-skin structure can be seen to the east of the village (Fig. 9b). This example of onion-skin weathering is perhaps the best exposed feature compared to other locations in Samoa. This feature has been used as a lava suite marker for the presence of Salani Formation (Middle Pleistocene) in Samoa.

Lava Tube Cave (North of Aopo Village)

The lava tube caves *mataaga* known as "The Aopo Lava Tube" at Aopo village are examples of the features of Aopo Formation that erupted from series of volcanic cones on the highlands to the south of the area during an eruption that occurred around 1760 (Fig. 1). Mr Masoe Umamoa Laauoleola, chief of the village of Aopo, operated and managed the *mataaga* and expressed support for the Samoa Geoparks Project. His request for scientific information and maps will be used for a billboard to disseminate information about the site.

Discussion and Recommendation

The discussion and recommendation for the Samoa Geoparks Project Phase 1 is presented in two parts: (i) culture versus volcanism and (ii) elements required to improve and incorporate to Samoa Geoparks Project Phase 2.

(i) Culture Versus Volcanism

The conservation of sites of geological interest is a core value of the Samoan Geoparks Project. All sites relate to traditional stories and myths. Past volcanic eruptions find their way into the Samoan language and local culture, suggesting that much more can be learnt by analyzing people's myths and stories, social structure, behavior, and oral traditions (Fepuleai et al. 2017). It is clear that volcanism has created natural features of importance to Samoa's natural and cultural heritage. These sites are holders of valuable information of previous volcanic activities and landforms shown elsewhere (Alvarado and Soto 2008; Cashman and Cronin 2008; De Benedetti et al. 2008; Gaillard et al. 2005; Nunn 2003; Nunn et al. 2019; Scarlett and Riede 2019; Schlehe 1996; Viramonte and Incer-Barquero 2008). Future assessments need to build on the geoheritage value of these sites.

Volcanic geoheritage recently became the focus of geoheritage studies to evaluate the value of volcanic geosites. It aims to provide an inventory to effectively design geoconservation, geotourism, and geoeducation programs (Erfurt-Cooper 2011; Errami et al. 2015a; Henriques and Neto 2015; Hoon et al. 2014; Kazanci 2012; Moufti and Németh 2013; Moufti et al. 2015; Wang et al. 2014). Places with strong links between land formation and inhabitants expressed through well-established long-lived and still alive traditions should be highly valued in any future geosite evaluation (Gravis et al. 2017). Volcanic landforms act as initiation points of human occupation and underlie protective and fertile regions allowing human society to flourish (Alvarado and Soto 2008; Ferrand et al. 2014; McGlynn et al. 2013; Riede 2008, 2016; Sik et al. 2013). Small-volume, monogenetic volcanoes commonly erupt with relatively brief phases producing small volumes of eruptive products and leading to formation of volcanic fields (Németh and Kereszturi 2015). They provide good agricultural lands, easy-to-modify defense systems, and relatively accessible regions to allowing movement associated with early human settlement. In this context, volcanic geoheritage is a complex and interrelated aspect of geoheritage that links the natural environment with its human occupants.

(ii) What Can Be Done to Improve the Samoa Geoparks Project Phase 2?

Following the completion of the Phase 1, the Samoa Geoparks Project recommendations are as follows:

- Initial establishment of the Matavanu Geopark Site. This would coincide with the conservation project of the FAO in this part of the island;
- Establishment of the Tafua-Savai'i Geopark Site would not only expose volcanic features, but would also promote and facilitate various conservation activities in the area;
- The boundary of the Matavanu Geopark Site should be extended further west and include several tourist attractions at the westernmost part of Savai'i (Fig. 2). This extension will not only include geological features of this part of the island but also include re-forestation activity covering several portions of the western part of Savai'i that had been depleted through deforestation processes in the past;
- Saleaula village should be fully supported to be incorporated into the proposed geopark, extending the tourist attraction (*mataaga*) to include volcanic features not considered part of the *mataaga* to date. This would fully highlight the place of geotourism as a new foundation for future sustainable tourism development in Samoa;
- Future activities should include the Samata-Falelima site, Tufutafoe site, Falealupo site, Sataua site, Lava Tube Cave of Aopo, Tafua-Savai'i, and Matavanu Crater. These are all individual landowner *mataaga*, and each of the landowners support the Samoa Geoparks Project;
- Development and management of the geopark in all selected sites should be implemented by landowners, women's committees, or other relevant entities, providing social and economic benefits to local communities;
- A workshop is proposed as the Samoa Geoparks Project Phase 2. The proposed workshop will be carried out in Savai'i Island and should involve *mataaga* representatives from the three zones: "Matavanu Geopark Site, the proposed Extension Zone, and the Tafua-Savai'i Geopark Site" (Fig. 2).

Conclusion

In this report, we outlined the focused program of the Samoa Geoparks Project. Initially, the Samoa Geoparks Project Phase 1 has been completed with clear positive results for the future of the vision to establish a nationally and globally significant geopark in Samoa that would be the first to aim to gain the UNESCO Global Geopark status within the SW Pacific. The Samoa Geoparks Project Phase 1 demonstrated that the idea is widely supported and understood by local communities, with villagers and landowners involved in the community-based discussion forums. Work undertaken to date demonstrates the current standing of the geopark concept and provides a good foundation for design of the Samoa Geoparks Project Phase 2 activities.

This work presented here is the first step in the ongoing exploration of geoheritage within the Samoan community. Major questions surfaced through this work about how to apply best practice to the development and evolution of the geopark concept. In our work, we recognized that while all geoparks (regardless of where they are and how deeply they are linked to indigenous geocultural aspects) need an "outsider" to help initiate, stimulate, and guide the process, if the community does not take ownership from an early stage and actively engage in the co-design and co-production of the geopark, it will become moribund. This is particularly likely in the case of dynamic Pacific Island cultures. This problem raises a rarely considered significant geoethical question, in spite of geoethics recently becoming an important concept within geosciences (Abbott 2017; De Pascale 2017; Di Capua and Peppoloni 2014, 2019; Di Capua et al. 2017; Gordon 2018; Groulx et al. 2017).

An ideal and largely theoretical framework to successfully co-design and co-produce a geopark within Samoa requires continuous engagement, inclusion, and communication between "outside" experts and local community. The outside expert role should be redefined and restricted to provide the co-identified support materials for the community to develop further. This is reflected in frequently mentioned statements such as "geoparks are bottom-up." In our work, it became evident that "community partnerships are essential from the earliest stages" of the geopark co-design. We also conclude that the end-product of a co-designed geopark framework could differ from expectations of "outsider" parties such ass expert visiting geologists, and this should not view as a failure of the process. Rather this demonstrates how such co-production is intended to work. In fact, we recognize that "local definition of a geopark/site" may be different from other "mainstream" definitions commonly associated with the general "western science literature." We also conclude that the external/outsider involved in the co-development of the geopark, such as geological experts, should possess different attributes and hold roles in the entire process, and we embrace the concept of "interconnected geoscientists" as a main criteria to fulfill this role (Petterson 2019). In the entire geopark co-design, the "role of the community" is paramount and should be driven by actions such as "raising awareness" and "sharing knowledge." Through this process, a gradual and iterative path should reach "gaining consensus." The process should also include iterative progression to identifying values of geosites including monetary, cultural, conservation, geological, educational, landscape, and linguistic values, all of which are relevant to the co-designed geopark. Most importantly, this process should be based on numerous participatory methods of knowledge sharing and co-development — following a truly inclusive approach at all stages of the geopark co-development. In this report, we showed the first inception of the geopark concept in Samoa and highlighted the challenges in establishing geoparks.

Acknowledgements The work was carried out in close cooperation with the Meteorology Division of the Ministry for Natural Resources, Environment (MNRE) and FAO (Samoa). Managerial support was provided by Mulipola Ausetalia Titimaea (MNRE), Lameko Talia (MNRE), Katie Pogi (MNRE), and Lemalu Sami (FAO) and has contributed to the success of the Geopark Project Phase 1. The Samoa Geoparks Project is also endorsed by the UNESCO IGCP #692—Geoheritage for Geohazard Resilience Programme. Fruitful discussions about Geoconservation and suggestions for improvements of the manuscript provided by Mr Ilmars Gravis and Chris Twemlow (both from Geoconservation Thrust Aotearoa) are greatly appreciated. Formal reviews by Prof Michael Petterson (AUT) and an anonymous reviewer provided valuable and very progressive ideas to improve the final version of this report, many thanks for them. The professional handling of the manuscript by Editor-in-Chief, Prof Kevin Page, made the review process very effective; thank you for it.

Funding The Samoa Geoparks Project Phase 1 was funded by the Geoscience Division of the Pacific Community (SPC) and the Food Agriculture Organization of the United Nations (FAO).

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