Chapter 19
Environmental Change and Cultural Continuity: Extraordinary Achievements of the Rapanui Society after Deforestation

Andreas Mieth, Annette Kühlem, Burkhard Vogt, and Hans-Rudolf Bork

1 Introduction

The exact timing of the first settlement of Rapa Nui is still subject of debate. Some authors argue for a settlement around 800 to 1000 AD (Steadman et al. 1994; Martinsson-Wallin and Crockford 2002; Mieth and Bork 2010). Other authors advocate the scenario of initial settlement around 1150 AD at the earliest (e.g., Hunt and Lipo 2006; DiNapoli et al. 2020). Undoubtably, however, the first settlers found an island covered in pristine woodland. The presence of an initially dense vegetation consisting of relatively few tree species and an understory of diverse shrub species, herbs, and ferns has been extensively documented in recent decades by palynological, anthracological, and geoarcheological research, and most recently summarized in detail by Rull (2020b). A now extinct palm species of the Cocosoidae subfamily played a dominant role in the species composition of the woodland. The palm species was probably closely related to the Chilean wine palm (*Jubaea chilensis*), whose exact taxonomic classification either to the genus *Jubaea* or as a separate species of a new genus *Paschalococcus* has been discussed (Dransfield et al. 1984; Zizka 1991). Biotic evidence for the former existence of more than one palm species has also been discussed (Delhon and Orliac 2007). The former existence of the now extinct palm species is undoubtedly proven by their remains

A. Mieth (✉) · A. Kühlem · H.-R. Bork
Institute for Ecosystem Research, Kiel University, Kiel, Germany
e-mail: amieth@ecology.uni-kiel.de; akuehlem@ecology.uni-kiel.de; hrbork@ecology.uni-kiel.de

B. Vogt
German Archaeological Institute (DAI), Commission for Archaeology of Non-European Cultures (KAAK), Bonn, Germany
e-mail: burkhard.vogt@dainst.de

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in geoarchives and/or anthropogenic contexts: pollen, phytoliths, charred wood, and especially by nutshells (endocarps) that appear either as deposits in protected places or as charred pieces in fireplaces. The most impressive indication of the former spatial distribution of the palm-dominated woodland is provided by palm root imprints preserved in the autochthonous soils that are attributable to the respective locations of individual trees. These imprints were found by Bork et al. (2019a) on more than 80% of Rapa Nui's surface area and up to an altitude of 500 m asl on the Terevaka volcano. In their latest calculations, the authors arrived at a total number of 19.7 million palms that once grew on Rapa Nui.

In the first centuries after the arrival of the Polynesian settlers on Rapa Nui, the human impact on the island's forest ecosystem remained relatively minor. There may have been local clearings for the construction of settlements and cultural sites, which changed the natural woodland into an anthropogenically altered forest ecosystem. However, horticulture with introduced crops as an essential form of land use took place for several centuries under the protection of the forest canopy. The islanders created loose, humus-rich garden soils (anthrosols) through mechanical soil cultivation, presumably in combination with organic mulching. Calculations show that millions of planting pits which form these anthrosols were carefully inserted between the individual locations of the palms. These anthrosols represent the oldest verifiable traces of cultivation on Rapa Nui, and they contain practically no charcoal (Mieth and Bork 2010). Anthrosols from this first phase of gardening have recently been found also on the southern slope of the Terevaka volcano at 375 m asl at the edge of the Quebrada Vaipú, not far from the study area described in this chapter (Bork et al. 2019b).

In the first half, at the latest in the middle, of the thirteenth century, the Rapanui then began to successively clear extensive areas of Rapa Nui's woodland. It is undisputed that this clearing process was accompanied by burning. Along with the clearing, the occurrence of charcoal in the cultural layers increased significantly. Over the course of approximately four centuries, the deforestation finally extended over the entire island, divided into spatial-temporal phases (Rull 2020a, b; Cañellas-Boltà et al. 2013; Mieth and Bork 2010). According to the simplified hypothesis that was put forward in the pioneering phase of paleoecological research, the forest was first eliminated in the coastal areas and only in the later phase in the higher elevations of the island (cf. Flenley and Bahn 2003, p.165). This was not confirmed in studies that are more recent. Instead, early evidence of forest clearance was found even on the remote Poike Peninsula at above 100 m asl (Mieth and Bork 2003). Seco et al. (2019) found evidence for intense forest clearance around 1070 AD at Rano Kau above 100 m asl., and the investigations described in this chapter show for the southern slope of the Terevaka volcano at ca. 240 to 275 m asl that the forest was cleared before ca. 1220 to 1290 AD. These findings not only contradict the thesis of a so-called late settlement around 1200 AD put forward by some scholars (e.g., Hunt and Lipo 2006) but also show that the clearing of the forest and the associated land use, settlement, and cultural processes were spatially and diachronically complex and did not follow a simple pattern (cf. Rull 2020a, p 225ff).

The loss of the forest had severe consequences for the ecosystem and the culture. Plant and animal species dependent on the forest were decimated or became extinct (cf. Steadman 1995). Thus, biotic and material resources were lost. The meso- and microclimate changed significantly, with far-reaching consequences for the cultivation of crops. After the loss of the forest cover the soils were unprotected and exposed to desiccation, wind, and heavy rain. Soil erosion first washed away fertile anthrosols on steeper slopes. Then, the unfertile, weathered volcanic rock underneath these garden soils was eroded, partially washed or blown into the sea, or deposited in downslope areas. In turn, not only gardens but also cultural sites in the depositional areas were shrouded or buried by sediments (Sherwood et al. 2019; Mieth and Bork 2003, 2017; Vogt and Kühlem 2018; Stevenson et al. 2006; Mann et al. 2003).

The extensive diminution of natural resources, the massive complications for horticulture, and the destruction of cultural installations in combination with the extremely isolated location and limited area of Rapa Nui suggest that the logical conclusion would be a cultural and social collapse as a consequence of the complete deforestation. Accordingly, the pioneers of archeological research on Easter Island such as Mulloy (1979) but also more recent paleoecological studies, e.g., by Flenley and Bahn (2003) postulated a causal connection between the deforestation of the island and a presumed massive decline, or even collapse, of the Rapanui society in the pre-contact period. Diamond (2005) repeated this thesis in his best-selling book "Collapse" with reference to the undoubtedly far-reaching consequences of the deforestation.

However, in recent years there has been an increase in research results that clearly contradict the collapse theory (e.g., DiNapoli et al. 2020; Simpson and Dussubieux 2018; Mieth and Bork 2015; Flas 2015; Boersema 2015; Stevenson et al. 2015; Mulrooney et al. 2010; Hunt and Lipo 2007). The authors of such studies by no means negate the extreme challenges that the dramatic forest loss on Easter Island posed for the Rapanui. But, recent investigations show that the Rapanui society was able to successfully contend with the consequences of the man-made changes to their environment and to secure the continuity of their culture with targeted and effective adaptations until the arrival of the first Europeans.

To counteract the impending loss of fertile soil, the Rapanui developed the technique of lithic mulching (Wozniak 1999). They covered the garden soils on the deforested areas with stones obtained from local quarries. On the surface of the soils, the stones protected them from wind and water erosion, from drying out, and from severe temperature fluctuation. Stones placed in the planting pits provided nutrients. Organic mulching also maintained and improved soil fertility

(Ladefoged et al. 2010). Over the course of about four centuries, the inhabitants of Rapa Nui spread approximately 1.14 billion stones on the garden soils. The amount of labor required to accomplish this probably far exceeded that of creating the *moai* and erecting the numerous *ahu* (Bork et al. 2004; Mieth and Bork 2005). Besides stone mulching, other new horticultural techniques were developed. They were diverse in their design and adapted to specific growing conditions of the different crops. Amongst these features are *manavai*, *pu*, planting circles, stacked boulder concentrations, and others (cf. Stevenson et al. 2002; Wozniak and Stevenson 2008).

The adaptation to new horticultural techniques is only one of various examples of how the Rapanui withstood changing environmental conditions. Despite the fact that natural factors such as the extreme geographical isolation, the subtropical climate, the low biodiversity (especially regarding the diminution of (still) available tree species), and the scarcity of fresh water, posed particular challenges for survival on the island. The research results presented in this chapter provide further evidence of such a successful convergence of environmental and cultural change on Rapa Nui.

2 Freshwater Resources and Freshwater Access on Rapa Nui: The Quebrada Vaipú

Compared to many volcanic islands in Polynesia where rivers and springs are abundant, easily accessible fresh water is a scarce resource on Rapa Nui. Even the earliest European explorers, desperate to reprovision their drinking water after long crossings, remarked on the scarcity and brackish quality of the water (cf. la Pérouse 1994: 65; Hixon et al. 2019). The fact that such a vital resource was not readily available posed a real challenge to the successful colonization of the island.

The sources of surface water on Rapa Nui are few. In pre-contact times the three crater lakes, Rano Aroi, Rano Raraku, and Rano Kau, stored most of the available surface water (Rull 2020c). The access to the water and its quality was less than ideal. In the case of Rano Kau accessing the water meant a perilous climb down the steep cliffs of the crater walls. Rano Aroi is located on the highest part of the island with no evidence of bigger settlements in the vicinity. The formation of peat in the lake (cf. Horrocks et al. 2015; Margalef et al. 2014) indicates that the water is paludal, acidic, and rich in tannins. The water of Rano Raraku is of rather poor quality as well, due to its high iron and aluminum content (Hanif 2018: 48). Extended dry climatic phases may have additionally reduced the water resources in the crater lakes (Rull 2020b: 222ff). Clan boundaries and the related taboos may have also limited the access to the crater lakes.

Freshwater was more abundant in some of the subterranean caves that riddle the island. But again, the access was probably restricted by taboos and in many cases physically challenging (cf. Ryn et al. 2010). In most areas the aquifer of the island was too deep to be reached by hand-built wells (cf. Herrera and Custodio 2008). But in the littoral areas where the aquifer is much closer to the surface there are a number of wells and water basins (cf. Hixon et al. 2019; Englert 2012; Forster 1777).

According to oral traditions, Hotu Matu'a, the legendary king of the first settlers of Rapa Nui, was aware of the problem of freshwater accessibility. He ordered wells to be built and, on his deathbed, ascertained that there was a supply of drinking water even in times of drought (Englert 2012: 286).

Droughts seem to have been a recurring calamity on Rapa Nui (Mann et al. 2008, Englert 2012, Rull et al. 2015, Rull 2020b: 222ff, Rull 2020c). Just a few months without substantial rainfall were enough to deplete the water reserves. Englert describes how priests would perform rituals in the mountains to bring rain that was so essential for the crops and for drinking water (Englert 2012: 290–291). Rainfall monitoring by Stevenson et al. (2015) shows that today the mean annual rainfall can locally be up to 2000 mm a year depending on height asl and exposition to the prevailing trade winds.

The role of coastal seeps for the fresh water supply was recently investigated by DiNapoli et al. (2019) and Brosnan et al. (2018). They conclude that despite its brackish nature coastal seeps played an important role in supplying drinking water. However, diatom analysis on dental calculus could demonstrate that individuals from different areas on the island relied on different drinking water sources (Dudgeon and Tromp 2014). Skeletons found on the south and southeast coasts have a high frequency of diatoms that are indicative for standing ponded water. Skeletons from the northeast and north coast show diatoms that typically develop in ephemeral water that originates in one of the many shallow basins (*taheta*) that are hacked into outcrops across the island. Survey data by Morrison (2012) show a significant number of such *taheta* on the northwest coast and also at high elevations. These investigations show that even those small receptacles were important in supplying the Rapanui with drinking water.

Englert points out the difficulty of transporting water, mentioning only gourds as possible vessels, albeit with only small capacity (Englert 2012: 282). Another means of transport described by him are spongy roots that absorbed water and were then wrapped in banana leaves for transport (Englert 2012: 282). Again, only a small amount of water could be carried this way.

Nowadays the Quebrada Vaipú is the only seasonal stream on Rapa Nui that carries a significant amount of water every year. It runs down the southern flank of the Terevaka volcano from the Rano Aroi crater lake to the shore at O Pipiri (Fig. 19.1). Its upper course lies within a mostly collapsed lava tube; in a limited area the roof of this tube is still intact and the water runs underground. Today the stream only carries running water after strong or prolonged rainfall. That this unique water course once held a great importance to the Rapanui is attested to by many hydraulic installations along the course of the creek.

Fig. 19.1 Aerial view of the Quebrada Vaipú on the southern flank of the Terevaka volcano (drone image: Christian Hartl-Reiter, DAI)

The stream is fed by Rano Aroi lake. In prehistoric times the outflow of water was controlled by modification of the lake outlet. At the lake outlet the Rapa Nui excavated the saprolite to a depth of 1.5 m in order to increase the amount of water flowing out if required (Fig. 19.2). This made it possible to let water run down the Quebrada Vaipú independent of rainfall. A side effect of the increased outflow was the reduction of the lake surface height and thus a significant reduction in evaporation rates. During the phase of intense sheep farming in the twentieth century the pre-contact facility was filled with sediment and a dam was raised. The new dam significantly increased the lake level height and thus the evaporation of lake water.

All along the course of the stream there are a number of prehistoric hydraulic installations such as bank enforcements, anthropogenic cascades, canals, basins, and retaining walls. The mouth of the Quebrada Vaipú lies in a small bay called O Pipiri, close to the ceremonial center of Akahanga (Fig. 19.3). Here again, the water is directed into a basin that is part of an elaborate series of megalithic constructions before flowing into the sea.

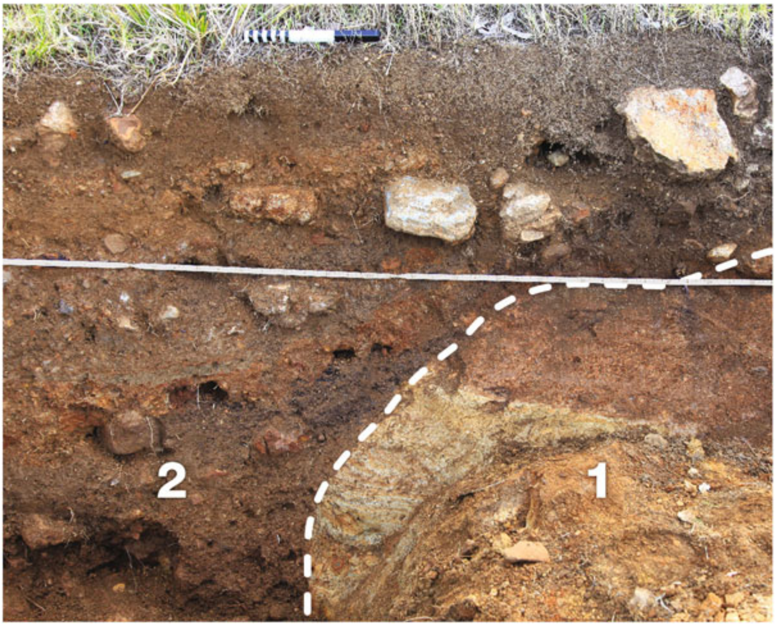

Fig. 19.2 Outlet at the southern edge of Rano Aroi lake. In prehistoric times, the Rapanui cut an artificial outlet into the saprolite. In the European period of sheep farming in the twentieth century, the outlet was filled with heterogeneous sediment and a dam was raised. (1) in situ saprolite, (2) prehistoric outlet filled with sediment (photo: Hans-Rudolf Bork)

The main practical reason for the installations along the course of the stream surely was to slow and control the flow of the water and to minimize the effects of erosion and flash floods (Vogt and Kühlem 2017: 327). Other important reasons seem have been to control the access to the water and to the enforce access taboos, resulting in the transformation of the landscape along the course of the creek with a strong ritual component (Vogt and Kühlem 2018; Kühlem 2016).

It is noteworthy that settlement structures in the vicinity of the Quebrada Vaipú are not more frequent than the general site distribution on the island as demonstrated by a large-scale survey in the late 1970s and early 1980s (cf. Cristino et al. 1981). DiNapoli et al. 2019 showed a strong correlation between the location of nearshore water sources and the location of *ahu* and settlements. Since inland access to freshwater is an even rarer commodity, one would also expect a concentration of settlement structures along the course of the only significant seasonal stream. The fact that this is not the case points towards a limited, regulated, and/or sanctioned access to the water in the Quebrada Vaipú. The most elaborate architectural framework for this water management was found at the site of Ava Ranga Uka A Toroke Hau in the very center of the island (Fig. 19.3).

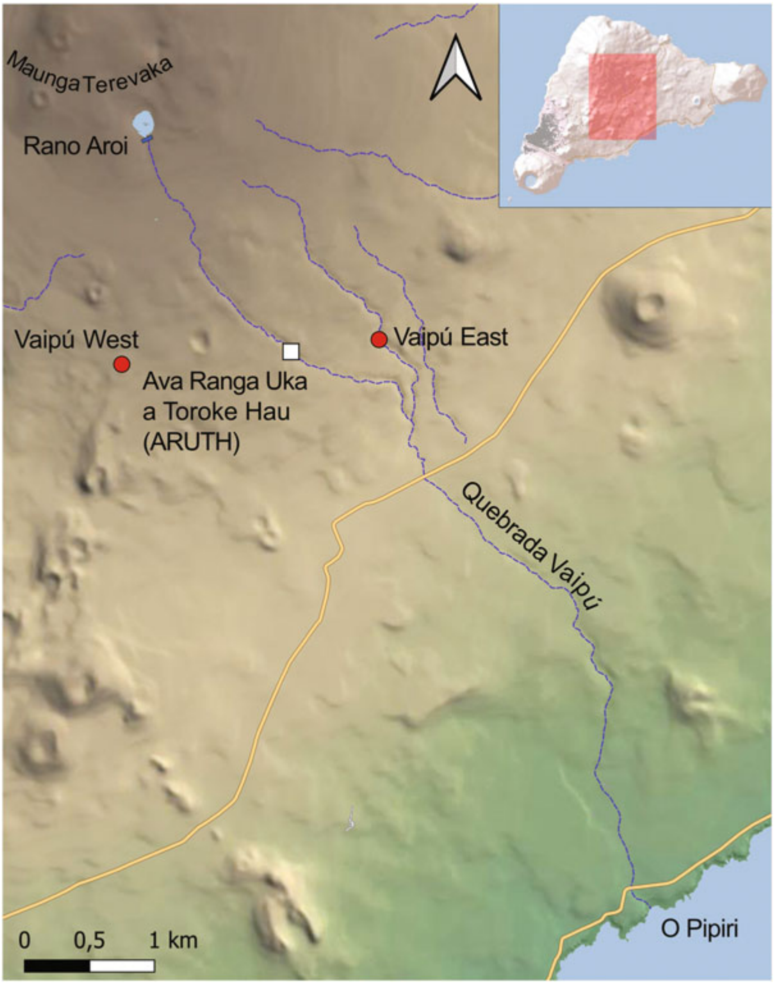

Fig. 19.3 Study sites on the southeastern flank of the Terevaka volcano (graphic: Christian Hartl-Reiter, DAI)

3 Monumental Installations at Ava Ranga Uka A Toroke Hau in the Quebrada Vaipú

The site of Ava Ranga Uka A Toroke Hau (hereafter ARUTH) is unique in many respects. It comprises an elaborate system of hydraulically active architecture alongside ritual elements that have completely transformed a segment of the valley in the center of the island (Fig. 19.4). The site lies in a widening of the Quebrada Vaipú. Besides the immense landscape alteration caused by large areas of stone mulching on Rapa Nui (see above), the degree of landscape transformation at Ava Ranga Uka A Toroke Hau is without parallel on the island.

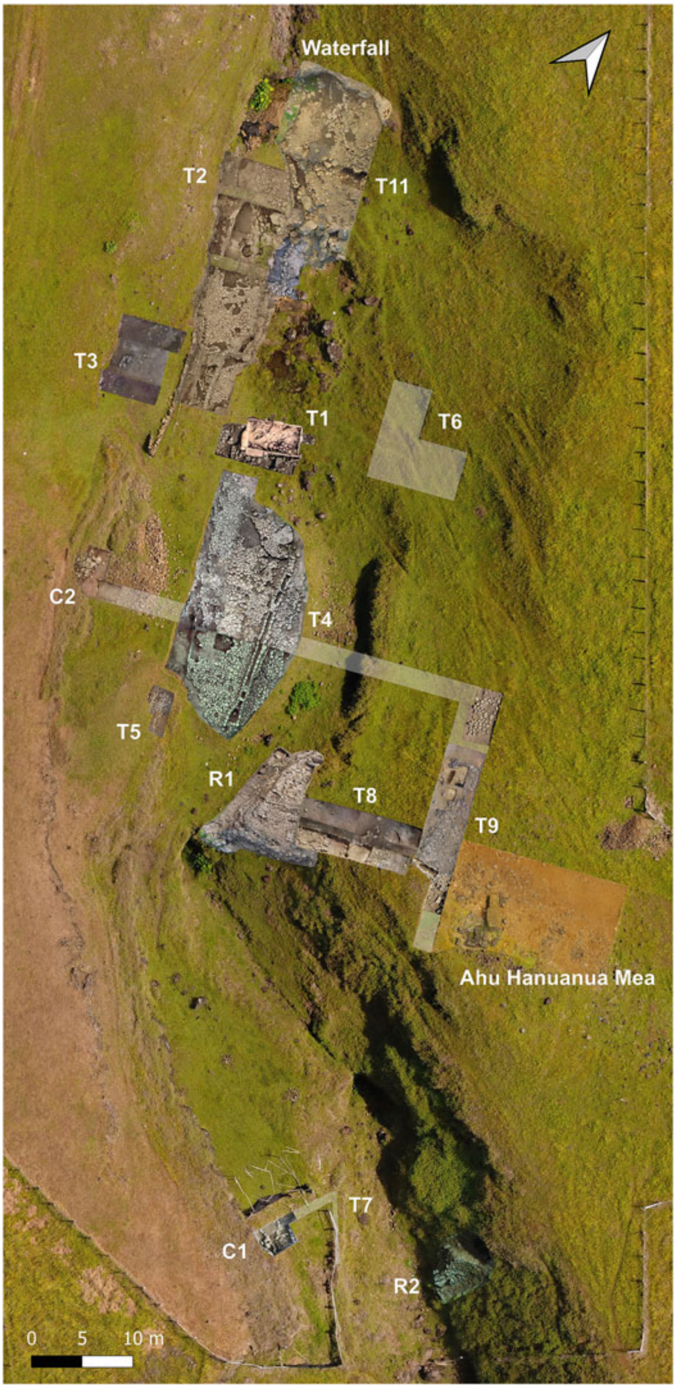

Fig. 19.4 Composite photo of the ARUTH site showing the widening of the Quebrada Vaipú and with the location of the waterfall, the Ahu Hanuanua Mea, Cave 1 (C1), and the different excavated trenches. The numerous paved areas are shown as georeferenced orthophotos (photo/graphic: Christian Hartl-Reiter, DAI)

Apart from the unique hydraulic features ARUTH is also the location of the most inland *ahu* on Rapa Nui. Ahu Hanuanua Mea, or “Rainbow Ahu,” has a single *moai* that rests on its front with its base on the *ahu* masonry. It is a rather small *moai* of 3.34 m in height (Kozub and Kozub 2019) and it does not have carved eye sockets, which is characteristic for most of the statues standing on *ahu*. The fact that an image *ahu* is associated with the site of ARUTH attests to its religious significance and the fact that it was under the control of religious and/or political elites (see below).

The transformation in the widening of the valley begins at a small waterfall at the northern end of the site. Often there is only a small rivulet coming down the cascade but after even a few hours of intense rain the water comes gushing into the kolk. The edge of this natural pool was fortified by a massive stone wall (T11). A few remains of paving stones indicate that the entire floor of the basin was once paved. South of the kolk lies a big rockface with a perfectly circular *taheta*, a small shallow basin, carved into the rock.

In the streambed there are two canals that guide the water out of the kolk. One runs alongside a curved terrace wall that fortifies the western bank of the quebrada, the other runs underneath a series of big stone blocks and then follows the natural course of the streambed. Over time the area around the kolk was disturbed by the force of water but the remains of pavements and stone walls show that it was once intensely transformed.

A massive terrace of almost two meters in height runs along the western bank of the creek (T2, T3). It consists of a stone packing and is bordered by a retaining wall. In the lower levels of the northern part of the terrace a water basin, canals, and an elaborate circular oven made from rounded beach pebbles (*poro*) were found. The surface of this terrace is covered in an extensive pavement which later was concealed by an anthropogenic layer of highly compacted soil with a high content of charcoal. This sequence of pavement and compacted soil, as well as a circular pit in the paved area is analogous to the findings in the central area of the site (T4, see below).

A little further down the course of the creek lies a monumental rectangular stone basin made from *paenga* blocks, which are usually found as the foundation stones of boat-shape houses (*hare paenga*) (Vogt and Moser 2010; Vogt et al. 2018). The humid conditions in the basin enabled an extraordinary preservation of different seeds that were deliberately placed in a cache underneath a layer of white clay. A multitude of gourd seeds (*Lagenaria vulgaris*) possibly indicates the former use of gourds as vessels for water. In addition, 227 fragments of palm endocarps were found. Two endocarps were radiocarbon dated. The first showed an age of 1500–1620 cal AD (these and all further radiocarbon results refer to 2 sigma modeled dates), and the second was dated to 1460–1580 cal AD, giving a time for the construction of the basin (cf. Fig. 19.17; Table 19.1: No. 3, 4). These dates also show that palm trees still grew somewhere on the island by the second half of the fifteenth century and possibly even into the seventeenth century. Two other dates from directly above a small paved area inside the stone basin returned dates of 1530–1640 cal AD, and 1550–1670 cal AD (Table 19.1: No. 2, 1).

Table 19.1 List of 14C-dates from cultural contexts in Ava Ranga Uka A Toroke Hau. 14C-dates were calibrated with SHCal20 (Hogg et al. 2020). Bayesian phase modeling of the ages was performed using OxCal 4.4 (Bronk Ramsey 2009). No. 1–4 previously published in Vogt and Kühlem (2018). No. 18–21 previously published in Out et al. (2020) and here re-calibrated with SHCal20

	AMS-Lab-ID	Sector	Depth bls (m)	Height asl (m)	Age (yr BP)	+/−	δ13C (‰)	Age (yr cal AD, 2δ) (SHCal20)	Modeled calibrated age (yr cal AD, 2δ) (SHCal20)	Sample material	Anthracology	Context
1	Erl-13250	T1	1.35	267.06	349	40	−24.9	1464–1471 (1.6%) 1481–1651 (93.9%)	1550–1670	Charcoal	tbd	Megalithic basin, directly above pavement
2	Erl-13247	T1	1.45–1.63	266.78 to 266.96	384	40	−27.4	1458–1632 (94.5%)	1530–1640	Charcoal	tbd	Megalithic basin, directly above pavement
3	Erl-13248	T1	1.62	266.79	360	39	−23.4	1463–1472 (2.4%) 1480–1648 (93%)	1500–1620	Charcoal	palm endocarp	Megalithic basin, under pavement
4	Erl-13249	T1	1.68	266.73	307	39	−22.8	1500–1601 (48.5%) 1611–1674 (39.2%) 1740–1756 (2%) 1763–1799 (5.8%)	1460–1580	Charcoal	palm endocarp	Megalithic basin, under pavement
5	COL3982.1.1	T4	0.55	268.66	366	36	−24.9	1463–1473 (3%) 1479–1642 (92.4%)	1550–1660	Charcoal	tbd	Fireplace, layer 11

(continued)

Table 19.1 (continued)

	AMS-Lab-ID	Sector	Depth bls (m)	Height asl (m)	Age (yr BP)	+/−	δ13C (‰)	Age (yr cal AD, 2δ) (SHCal20)	Modeled calibrated age (yr cal AD, 2δ) (SHCal20)	Sample material	Anthracology	Context
6	COL4569.1.1	T4	0.67	268.17	443	33	−26.4	1436–1510 (72.7%) 1550–1560 (1.2%) 1579–1623 (21.6%)	1490–1630	Charcoal	tbd	Planting pit, layer 12
7	COL4568.1.1	T4	0.79	267.90	338	33	−19.7	1496–1657 (95.4%)	1480–1600	Charcoal	palm endocarp	Layer 10
8	COL4564.1.1	T4	0.99	268.47	495	32	−20.8	1408–1489 (94.5%)	1450–1510	Charcoal	palm endocarp	Fireplace, layer 5
9	COL4565.1.1	T4	1.02	268.38	506	33	−23.5	1404–1464 (94%) 1472–1480 (1.5%)	1450–1500	Charcoal	palm endocarp	Fireplace, layer 5
10	COL4567.1.1	T4	1.14	267.57	412	32	−25.9	1450–1518 (52.2%) 1537–1628 (43.3%)	1450–1500	Charcoal	tbd	Posthole, layer 2
11	COL3979.1.1	T4	1.31	267.90	475	35	−27.7	1417–1504 (87.9%) 1595–1616 (7.5%)	1440–1490	Charcoal	tbd	Palm tree planting pit, pavement 3
12	COL3980.1.1	T4	1.35	267.88	426	35	−24.2	1445–1514 (59.7%) 1544–1625 (35.8%)	1440–1480	Charcoal	sophora sp.	Fireplace, pavement 3

(continued)

13	COL3981.1.1	T4	1.47	267.88	438	35	−27.4	1437–1513 (66.4) 1556–1625 (29%)	1420–1470	Charcoal	tbd	Fireplace, pavement 3
14	COL4566.1.1	T4	1.52	267.41	557	32	−28.4	1329–1334 (1.1%) 1393–1450 (94.4%)	1390–1450	Charcoal	tbd	Pit, layer 2
15	KIA 46459	T7	1.06	260.10	650	25		1303–1363 (71.1%) 1380–1403 (24.4%)	1300–1410	Charcoal	tbd	Anthropogenic debris layer, layer 5
16	KIA 46460 (1)	T7	1.68	259.48	725	20		1281–1319 (51%) 1355–1385 (44.4%)	1270–1380	Charcoal	tbd	Anthropogenic debris layer, layer 4
17	KIA 46460 (2)	T7	1.68	259.48	770	30		1226–1311 (83.7%) 1360–1382 (11.8%)		Charcoal	tbd	Anthropogenic debris layer, layer 4
18	Beta-321021	Vaipú East	0.16		320	30	−25.10	1502–1595 (60%) 1615–1665 (35.4%)	1500–1670	Charcoal	tbd	Fill pit 2b
19	KIA 49033	Vaipú East	0.19		443	28	12,39	1440–1508 (76.7%) 1588–1620 (18.8%)	1430–1620	Charcoal	tbd	Fill pit 2b
20	Beta-321020	Vaipú East	1.46		680	30	−27.1	1292–1394 (95.4%)	1290–1400	Charcoal	tbd	Fill pit 1
21	KIA 48426	Vaipú East	1.46		807	17	−23.61	1226–1282 (95.4%)	1220–1290	Charcoal	tbd	Fill pit 1

On a lower level a canal seems to connect this basin to the central area of the site (T4). A small, paved area also seems to be a continuation of the extensive pavement that once spanned the entire width of the valley. The area between the stone basin T1 and the central area T4 was strongly affected by destruction due to a flash flood (see below). Therefore, a definite connection could not be established.

The central area of the site (T4) is characterized by a sequence of pavements and anthropogenic layers that created a platform with a cultural stratigraphy of up to 6 m in height (Fig. 19.5; details see below). The large-scale excavations of the upper pavement (Pavement 3) showed that it spans the entire area and is intersected by two canals. The eastern canal is connected to a shallow stone trough at the northern end of the platform and terminates in a small trapezoid basin at its southern end (Fig. 19.6). The canals are shallow and narrow with a rather small flow volume. This must be seen in the light of the scarceness of fresh water on the island, bearing in mind that during most of the year the deliberate opening or closing of the outlet at the Rano Aroi crater lake determined how much water came down the Quebrada Vaipú.

Three radiocarbon results date the extensive pavement with the water canals in the central part of the site: 1440–1490 cal AD, 1440–1480 cal AD, and 1420–1470 cal AD (cf. Fig. 19.17; Table 19.1: No. 11–13).

In a continuation of the western flank of the *ahu*, a massive retaining wall (R1) reaches across the creek bed. It is constructed by a succession of fine soil and stone packings and has a stone facing (cf. Vogt 2013). The construction was too loose to serve as a dam that holds back water. Instead, it seems to have served to slow the flow of water through the site. Forty meters further downstream a second massive wall, that is very similar yet of smaller dimensions, was built into the streambed (R2). Most probably both constructions were destroyed by the same flash flood that eroded the western sides of both walls.

On the western escarpment between R1 and R2 a small cave (C1) was excavated (cf. Moser 2013). The use in pre-contact times is attested to by lithic tools and manuports in the excavated layers. The area directly in front of the cave was intensely used as attested by stone structures and fireplaces. Within the valley of ARUTH this seems to be the only area where settlement activities took place, albeit on a small scale. The findings in the archeological layers and post-contact sheep bones on the surface inside the cave demonstrate a long use of this part of the site. Just below the cave lies profile T7 that runs along the western bank of the Quebrada and was analyzed in detail (see below).

4 The Stratigraphy of the Monumental Installations in the Central Area of ARUTH (T4)

In the central area of the site (Fig. 19.4, T4) it was possible to identify different phases of site use. The stratigraphy consists of up to 6 m of cultural deposits with different use-surfaces (Fig. 19.5). The body of layers forms an artificial platform on

Fig. 19.5 Embankment profile showing the succession of pavements and compacted layers of trench T4 (photo: Burkhard Vogt)

Fig. 19.6 Orthophoto of T4 with partially covered canal and stone-rimmed palm tree planting pits (photo/graphic: Christian Hartl-Reiter, DAI)

the western bank of the Quebrada. The eastern edge of this platform was eroded by the stream during an extreme runoff event (see below). The resulting embankment profile shows a succession of three pavements that are separated by compacted layers (cf. Kühlem 2016, Kühlem et al. 2014; Fig. 19.5).

The above-mentioned Pavement 3 that spans the entire widening of the valley is the lowest level of large-scale surface excavation that was reached to date (Fig. 19.6). It corresponds to the uppermost pavement in the embankment profile. Even though the direct connection between this pavement and the paved areas around the megalithic basin T1 is disturbed, the stratigraphic context and the height of the pavement slabs indicate that Pavement 3 of T4 merges with the pavement around the basin.

There are several noteworthy features within the excavated paved area of T4. A number of circular stone-rimmed pits were found amidst the pavement slabs (Fig. 19.7). In ten of them, in situ palm root imprints were visible, demonstrating that a small grove of the now-extinct palm species grew in the central area of ARUTH and the trees were integrated into the paved area. In some of the pits the root clusters were over 1 m in diameter. The assumed closest genetic relative of the extinct Rapa Nui palm, the *Jubaea chilensis*, grows mainly in diameter for the first 20 years, before growing tall (Guzmán et al. 2017). Also, the roots at the base of the trunk tend to be wider than the trunk itself. If this was also the case for the palm trees in the central area of ARUTH, then they need not have been large and mature specimens. The radiocarbon dates for the succession of layers in T4 show that the palm trees most probably did not have time to grow to their full height between the time when they were planted to when the area was altered again (see below).

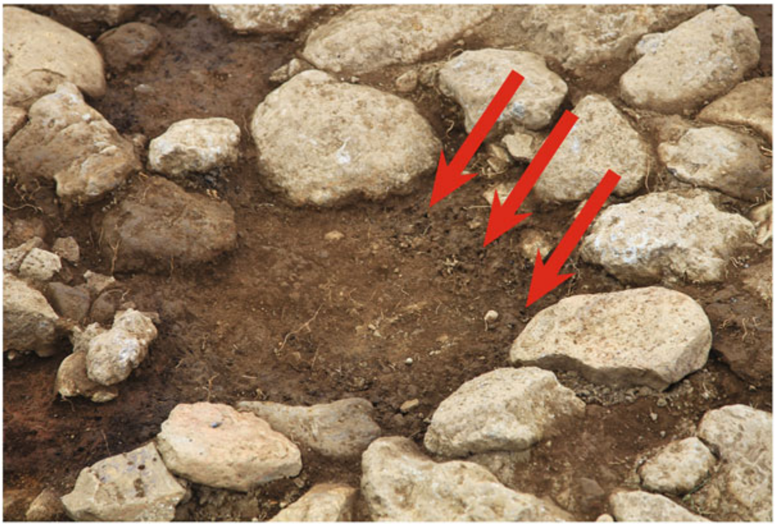

Fig. 19.7 Stone-rimmed palm tree planting pit with root imprints (marked by arrows) (photo: Annette Kühlem)

An example for the deliberate planting of a palm tree was found within the plaza of the Ahu Hanuanua Mea. Here, a planting pit was carved into the weathered bedrock and filled with garden soil. Within this soil, the marks of the root imprints were found, attesting to the fact that a palm tree was planted in front of the *ahu* and formed part of the ritual architecture of ARUTH.

The palm grove in the central area of the site shows that the palm trees were an integral component of the architectural ensemble and the transformed cultural landscape (cf. Kühlem et al. 2019). The ^{14}C-dates for Pavement 3 and the associated palm tree planting pits are 1440–1490 cal AD, 1440–1480 cal AD, and 1420–1470 cal AD (cf. Fig. 19.17; Table 19.1: No. 11–13). Between the late fourteenth century and the beginning of the sixteenth century (1390–1450 cal AD, 1450–1500 cal AD, 1450–1500 cal AD, and 1450–1510 cal AD, cf. Fig. 19.17; Table 19.1: No. 14, 10, 9, 8) the extensive elaborate pavement with the integrated palm trees and the water canals was intentionally covered by a compacted layer of loamy soil. The closeness of the radiocarbon dates shows that the pavement and the installations herein were not used for more than a few decades.

The geomorphological and sedimentological analyses on site showed that the soil had been transported to the area, leveled out, and then compressed probably by repeated trampling. This was done in several steps, where different layers of different material were applied (Fig. 19.8: Layers 1–5). These layers practically

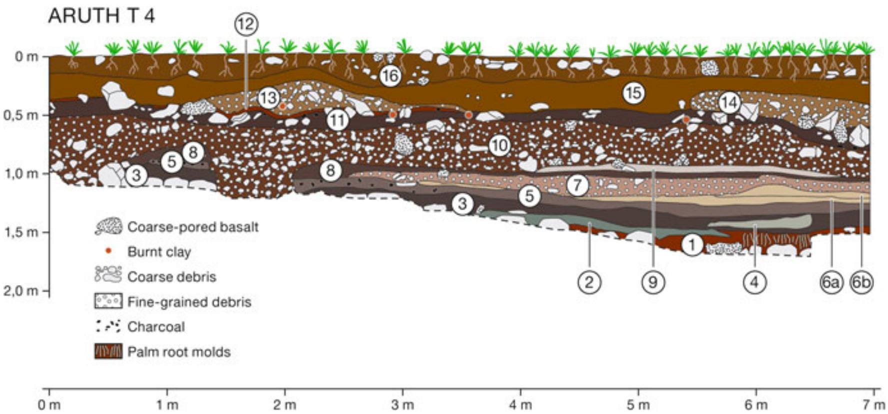

Fig. 19.8 Layers and characteristics of the North-West profile in T4 (field documentation: Annette Kühlem, graphic: Annette Kühlem, Doris Kramer). Layer 1: slightly humic loam with palm roots imprints. 2–5: different applications of sediments that were transported from other cultural deposits to the site and compacted, high content of charcoal. 6–9: body of thin layers of silty material intermixed with fine-grained debris that were deposited by runoff events, 10: thick body of sediment and debris that was deposited during and after a catastrophic flood event. The sorting of the material does not correspond to the natural deposition but shows that it was anthropogenically reworked and leveled out. 11: layer of silty loam that was transported to the site from different cultural deposits and spread out, high content of charcoal and organic material, numerous pits of up to 0.8 m in diameter. 12: powdery humic material that was transported to the site and fills the planting pits in the surface of layer 11. 13, 14: erosion gullies representing singular runoff events. 15: loamy silt deposited by numerous weak runoff events. 16: humic loamy silt deposited by numerous weak runoff events, grass roots, and human-deposited stones in the upper layers

sealed off the underlying pavement and the installations within. It is unclear what happened to the planted palm trees during this process. In some cases, the root imprints inside the planting pits were associated with burnt soil, indicating that at some point the trees in the central area of the site were felled and the stumps burned (cf. Mieth and Bork 2003). There is one example (cf. Fig. 19.8: at 1.4 m to 2.1 m profile length) where a palm tree planting pit was not covered with the compacted sediment. Instead, here the material had been applied around the trunk of the tree.

The eastern water canal (see above; Fig. 19.6) was also still in use after the pavement level had been sealed off by the compacted soil. Some areas of the canal are covered with flat stone slabs, probably to prevent evaporation and/or pollution of the water while the canal still ran at the surface. When Pavement 3 was covered the canal ran underground. In some places along the canal, small shafts were dug into the overlying compacted layer, presumably to clean the canal or to remove blockages. Despite the fact that the pavement and all the installations within were sealed off by the anthropogenic layers there are a few features from the level of Pavement 3 that were still in use.

Excavations in the paved central part of the site were continued in a limited area to investigate the lower levels. Within the 2 x 2 m test pit, approximately 0.4 m

Fig. 19.9 Earliest documented megalithic basin with white sealant around the rim (photo: Annette Kühlem)

below Pavement 3 the rim of an earlier megalithic basin was found (Fig. 19.9). A layer of whitish clay, analogue to that had been found at the base of basin T1, had been applied around the massive stone blocks that make up the walls. Here again, it seems like this material was used as a sealant as it was also smeared into the cracks between the large boulders. The basin has a maximum depth of 1.6 m and the one excavated block in the western wall measures 1.3 m x > 1.4 m. The basin tapers downwards and has a paved floor. Whether this paved floor corresponds to one of the lower pavements that are visible in the embankment profile cannot be said with certainty at this point. The complete dimensions will only be known after further excavations but even at this stage the basin is evidence for megalithic hydraulic architecture in the early phases of the site use.

At some point between 1480–1600 cal AD (cf. Fig. 19.17; Table 19.1: No. 7) a severe flood event descended upon the site of ARUTH (see below). Along with the destructive water mass vast amounts of sediment and rocks were carried down the Vaipú creek. They completely covered the elaborate and labor-intensive installations in the central area of the site with a thick layer of sediment, including rocks (cf. Fig. 19.8: Layer 10, Fig. 19.10). Even the one palm tree (see above) that was still growing was destroyed by this event and the planting pit filled with the sediment that was washed down the creek (cf. Fig. 19.8: Layer 10, between 1.4 m and 2.1 m profile length).

Instead of abandoning the site after such a catastrophic flood event, the ancient Rapanui made use of the fluvial sediment that was deposited in the widening of the valley. On-site geomorphological and sedimentological analysis demonstrate that the matrix of Layer 10 is not entirely naturally deposited but also a product of human

Fig. 19.10 Trench T4 during the excavations (photo: Hans-Rudolf Bork)

activity. The washed in material was anthropogenically relocated and leveled out to form yet another nearly horizontal use-surface. Again, anthropogenic layers were applied on top (cf. Fig. 19.8: Layers 11 and 12). Layer 11 consists of loamy soil with a high content of intermixed charcoal and other organic material. A series of planting pits were found in this layer (Fig. 19.11). The pits were filled with very fine-grained humus sediment (cf. Fig. 19.8: Layer 12) and a multitude of porous rocks. These findings are interpreted as an optimized gardening technique using stone mulching to protect the cultivars from harsh winds and to trap moisture in the planting pits while adding nutrients (cf. Stevenson et al. 1999; Bork et al. 2004). Phytolith analyses are under way. So far, a banana (*Musa sp.*) phytolith from one of the pits attests to horticulture in the late occupation phases in ARUTH (1490–1630 cal AD, 1550–1660 cal AD, cf. Fig. 19.17; Table 19.1: No. 6, 5).

The flood event and the resulting covering of the central area of the site with a thick layer of sediment seem to have brought about a functional and cultural change at the site of ARUTH. The lower levels with the succession of pavements, water basins, canals, and the palm tree grove point to a ritual significance, while the garden pits in the upper levels show a more profane use of the site for horticulture.

Fig. 19.11 Series of later horticultural planting pits in the uppers layer of T4 after the catastrophic rain event (photo: Annette Kühlem)

5 The Stratigraphy of the Southern Embankment of the Monumental Installations of ARUTH (T7)

Trench T7 runs parallel to the Quebrada Vaipú at the western bank of the stream through the former southern embankment of ARUTH (cf. Fig. 19.3). The profile shows the complex stratigraphy of the spacious southern terrace complex of ARUTH. Like in the central area (T4) a sequence of different construction and use phases could be documented (Figs. 19.12, 19.13, 19.14). At the base of T7 there is a body of loose rock debris (Fig. 19.12: Layer 1), the surface of which is covered with a pavement made of slightly weathered small yellowish volcanic rocks (Pavement 1). It is the man-made, water-permeable, former outer wall of the earliest documented terrace at ARUTH. The noticeably yellowish volcanic rocks that had been selected for the pavement possibly had a ritual display function. Above the surface of this earliest terrace lies another anthropogenically deposited layer (Fig. 19.12: Layer 2). It consists of up to 0.45 m of rock debris intermixed with a brown humus fine soil. The surface of this layer is covered by a rough stone pavement (Pavement 2). Layer 3 consists of up to 0.2 m of anthropogenically deposited rock debris intermixed with a brown humus fine soil.

By constructing an embankment (Fig. 19.12: Layer 4), the terrace body of the ceremonial complex was extended by its builders by more than 13 m to the southeast. Layer 4 is a body of rock debris with a trough-shaped, smooth, and carefully assembled surface. In the southern part of this layer, stones with a diameter of up to 1.25 m dominate the matrix. They obviously served to stabilize the downhill part of the structure. In the upper part of Layer 4 the gaps between the large stones

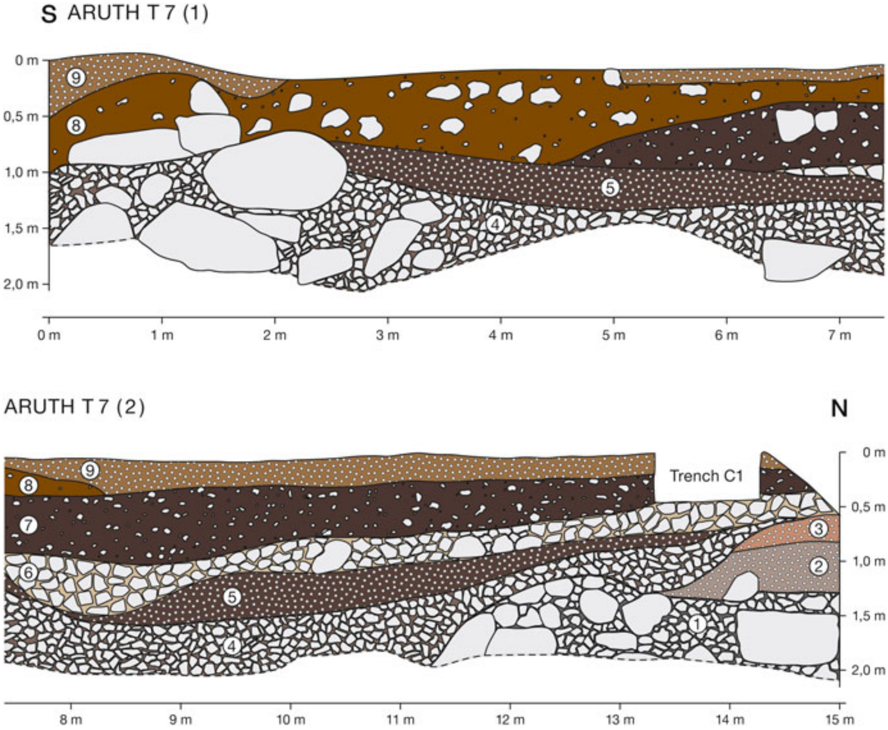

Fig. 19.12 Layers and characteristics of the southern profile in T7 (field documentation: Hans-Rudolf Bork and Andreas Mieth; graphic: Doris Kramer, Hans-Rudolf Bork, Andreas Mieth). 1: loose rock debris with an extraordinary high water permeability with pavement 1 at the surface of layer 1; 2: rock debris intermixed with brown fine soil with pavement 2 at the surface of layer 2; 3: rock debris intermixed with brown fine soil; 4: loose rock debris stabilized with large stones and an extraordinary high water permeability, pavement 3 at the surface of layer 4; 5: rock debris intermixed with brown fine soil; 6: angular rock debris with elaborated smooth pavement 4 at the surface of layer 6; 7: charcoal-rich fine loamy sediment interspersed with small rocks; 8: rock debris with stabilizing stone blocks at the southern rim; 9: brown humic fine sediment intermixed with small rocks; layers 1–9: all deposited by humans

are filled with smaller stones on the seaward side. In the rest of Layer 4 the large gaps between the stones have been preserved to this day. Obviously, the planning of this construction phase involved deliberately leaving gaps between the stones in order to enable the non-destructive subsurface drainage of runoff down the valley. The construction did not serve to retain water, but, on the contrary, had a draining function. The documented profile represents the outer wall of the second oldest terrace profile in T7. A charcoal sample taken from this layer at 3.32 m length of the profile was radiocarbon dated to 1270–1380 cal AD (cf. Fig. 19.17; Table 19.1: No. 16, 17).

Fig. 19.13 View of the southern part of the site ARUTH with profile T7 and the cave in the steep cliff (photo: Hans-Rudolf Bork)

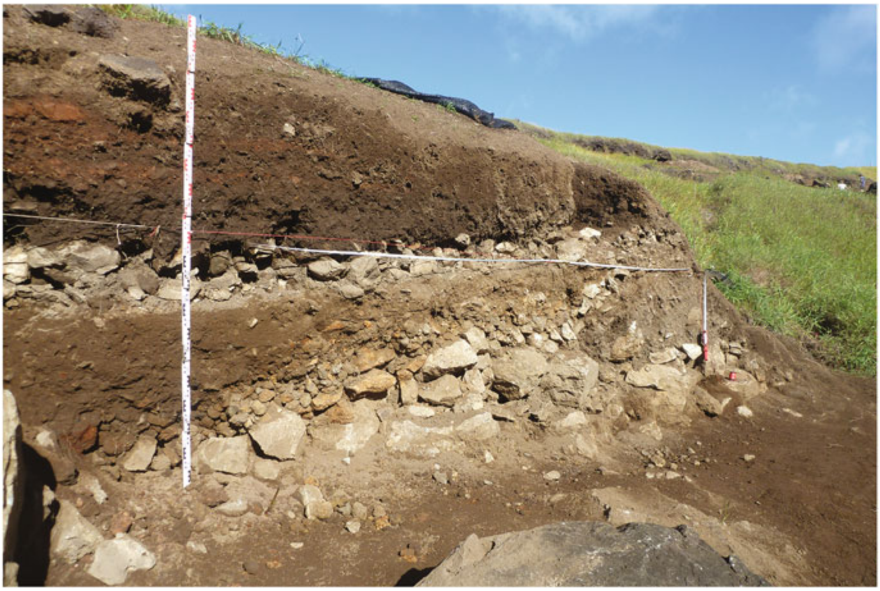

Fig. 19.14 Northern part of the section through terrace complex T7 (photo: Andreas Mieth)

In the central and northern part, Layer 4 consists of anthropogenically deposited, angular stones with a diameter between 0.1 m and 0.3 m. Brown humic sediment with a fine texture lines the cavities between the topmost stones. Layer 4 accordingly forms the stable and deliberately water-permeable outer terrace wall in the southern section of the site. Additionally, it forms the foundation of another elaborate stone pavement further up the creek (Pavement 3).

Layer 5 (Fig. 19.12) is an anthropogenically applied layer of stones intermixed with fine sediment and high amounts of charcoal fragments. A charcoal sample taken 1 cm below the surface of Layer 5 at 10.7 m length of the profile showed a radiocarbon age of 1300–1410 cal AD (cf. Fig 19.17; Table 19.1: No 15). This means that Layer 5 is probably only a few decades younger than Layer 4. Accordingly, Pavement 3 was only in use for a short time before it was deliberately covered with Layer 5.

Layer 6 is made up of angular rock debris broken from larger stones. The surface of it is covered by an elaborate and smooth pavement (Pavement 4). Above Layer 6 lies an anthropogenically applied charcoal-rich layer of up to 0.6 m thickness (Fig. 19.12: Layer 7). The matrix consists of fine loamy sediment with a loose, crumbly texture interspersed with up to 40% small rocks and reddish-brown bands of loam.

Between 0 m and 1.7 m of the profile length Layer 8 consists of stabilizing stone blocks with a diameter of up to 1.1 m (Fig. 19.12). Between and above these there lies a body of rock debris that is rich in fine sediments. Above it a deposit of rough, angular stones forms an extremely stable outer terrace wall. The large cavities between the stones, that were obviously deliberately created by the builders, are still visible today. Evidently this construction layer was also fashioned to reduce the risk of destructive hydraulic pressure. Between 1.7 m and 8.3 m of the profile, Layer 8 is made of rough, angular stones (Fig. 19.12). Between 3 m and 5 m of the profile, the surface is perfectly horizontal, coinciding with the current terrain surface. Layer 9 lies above Layer 8. It consists of brown humic sediment intermixed with small rocks that also forms a nearly horizontal surface (Fig. 19.12: at 5 m to 14.1 m profile length).

Summary of the interpretation: Profile T7 reveals a multi-phase construction and covering of terrace surfaces in the southeastern part of the ARUTH ceremonial complex. Repeatedly, stone pavements were laid only to then be covered again by new terrace constructions. In some cases, the paving was very elaborate with a careful selection of stones according to color. The entire structure does not contain any natural sediments. All layers were intentionally applied demonstrating excellent hydrological and structural knowledge of the builders. The construction shows how the engineers were able to meet the requirements of gravity and hydraulic stability in an outstanding manner by skillfully selecting and combining the materials used. Remarkable is the early beginning of the monumental construction with respect to its location in the island's interior, around 1270 to 1380 AD.

6 ARUTH as a Water Sanctuary

As mentioned above, the most inland *ahu* of the island, Ahu Hanuanua Mea, towers over the elaborate installations of ARUTH. The existence of a ceremonial platform tells us that there was a strong ritual component to the site and that it was under the control of the religious or political elites (cf. Hamilton 2013: 106, Martinsson-Wallin 1994: 129). The single *moai* can be seen as an ideological token of a chiefly lineage, whose power is displayed at the site (cf. Martinsson-Wallin 1994:130). The findings of a crematorium and a stone cist with human remains are evidence that burial rituals were once carried out in ARUTH (cf. Vogt et al. 2018). Water is the defining element at the site and as such was surely intertwined with the funerary rites that once took place there. The outlet at Rano Aroi made it possible to deliberately introduce water into the system of hydraulic installations even during the dry seasons.

Usually, *ahu* are part of a settlement site (cf. Martinsson-Wallin 1994) with remains of house foundations (*hare paenga, hare oka*), cooking pits (*umu pae*), and other manifestations of domestic use. These, along with typical finds from domestic contexts such as food waste or remains of labor tasks such as fishhooks or bone needles, are missing in ARUTH. The few *paenga* blocks that were found in different contexts here all seem to have been taken from other buildings, transported to the site, and used secondarily.

As mentioned above, the availability of fresh surface water did not result in a concentration of settlements along the course of the Quebrada Vaipú. The same is the case for ARUTH itself, where the elaborate hydraulic installations such as canals and basins would have made access to the water even easier. Obviously, the water in the Quebrada Vaipú was not for mundane use and was not available to just anyone. Most likely this is the expression of a taboo relating not only to the site of ARUTH but also to the water in the Quebrada Vaipú. This concept of restricting access to scarce and valuable resources is of utmost importance in Polynesian societies. On Rapa Nui, water was one such scarce resource.

Not only is there no concentration of settlement sites in the vicinity of the water course but the hydraulic installations of ARUTH also did not serve a utilitarian purpose such as the irrigation of crops. There is no evidence for horticulture associated with the canals and water basins.

Comparative research with other Eastern Polynesian islands and the evaluation of sources of oral traditions shed light on the purpose and significance of ARUTH. Water basins are often connected to fertility rituals and/or reserved for elite women (cf. Henry 2004: 545, Douaire-Marsaudon 2002, Ottino 1998: 86, Taaroa 1971: 90, 149). For example, at the site of Puri te Puna on Nuku Hiva in the Marquesas Islands a very similar water basin is known to have been used for ritual baths of elite women after giving birth (Yvonne Katupa, pers. comm.). Here, as at ARUTH, there are petroglyphs on the floor of the water basin, an elaborate pavement covers the ground around it, and a series of trees were planted in the paved area. From other islands, such as Tubuai in the Australs, water basins are known to have been used to discard sacred objects (Aymeric Hermann, pers. comm.). Such objects like tattooing tools, combs, or the like were considered to hold spiritual power (*mana*). To even accidentally touch such objects was considered a breach of taboo and harmful to the mental and/or physical health of the perpetrator (cf. Winthrop 1991: 295).

The fact that at some point the elaborate installations in ARUTH were deliberately covered by compacted layers of sediment, and as such sealed off, also points towards ritual practices. As documented in the stratigraphy of Trench T4 and Trench T7 the ancient Rapanui repeatedly laid extensive pavements, then covered them with sediment, only to lay a new pavement on top. From an engineering standpoint, a practical reason for this is not apparent.

A similar practice has been observed at Ahu Motu Toremo Hiva on the cliff of the Poike Peninsula. There a layer of ground red scoria (*hani hani*) was applied and marks different use phases of the ceremonial platform. As in ARUTH, the material was transported to the site and then spread out (cf. Cauwe et al. 2010).

Another example for a similar sealing of use-surfaces was documented at the Kauri Point site in New Zealand. Here, anthropogenic layers covered a large number of wooden combs that were most likely used to cut the chiefs' hair. Presumably, the sealing layers were applied to prevent that these tabooed objects, that still held the chiefly *mana,* from falling into the wrong hands (cf. Shawcross 1964).

A similar scenario seems likely for the water-related architecture in ARUTH. The fact that there is a repetitive sequence of pavements and compacted layers in a relatively short time frame without any apparent technical reason suggests that the sealing of use-surfaces had a ritual background and was linked to taboos. Possibly, the short intervals between the installation of elaborate pavements and the covering of them is a manifestation of a transfer of power or generational succession.

Rapanui oral traditions describe how in times of drought the high priest was sent to the "highest mountain" (Terevaka) to perform fertility rituals and pray to the God of Rain, Hiro, to bring much-needed rain to the fields. The priest used pigments to paint his face black and white and buried offerings of seaweed and coral that had been soaked in water. The priest continued to evoke the God of Rain until finally "the long tears of Hiro," began to fall. He would then run down the hillside in big circles to make the clouds follow him and bring rain to the fields at the foot of the mountain (Englert 2012). ARUTH is located on the highest mountain of the island, and pieces of coral were found in many of the water-related features at the site. The elaborate installations for the management of water may have been the setting for these rituals that were recorded by Englert.

Over centuries a sacred landscape was created and maintained on the southern flank of the Terevaka. It seems to have served for a fertility cult centered around the site of ARUTH, which was not only a water sanctuary but also a haven for some of the last palm trees on the island.

7 Post-deforestation Pigment Workshops on the Southern Slope of Maunga Terevaka

Pigments played an important role in the cultural history of Rapa Nui. In particular, red and white pigments were used on textiles, stone and wooden artifacts, in the painting of petroglyphs, in the decoration of houses with ritual images, and in body painting. Specific ritual or sacred meanings were assigned to certain colors. For example, the frequently used color "red" was associated with power, spiritual strength (*mana*), fertility, life, and struggle (Lee 1992; Horley and Lee 2012).

So far, there are only a few specific references in the literature in regard to the production technique and local sources of the pigments once used. Even today, the sources of the pigments used for skin painting in the Tapati festival are kept a secret in many families. Many of the island's soils and weathered volcanic rocks contain reddish iron oxides. But the color intensity and especially the texture of the material often do not meet the criteria required for specific and practical application. Thus, the red pigments suitable for ritual use have always been considered particularly valuable because they were only available very locally (Fischer 2005).

The great cultural importance and value of red pigments is exemplified by concentrated deposits of red pigments (ki'ea) in special archeological contexts such as in connection with *ahu* and *moai* (Sherwood et al. 2019; Cauwe 2011). Therefore, recent findings concerning the production and stockpiling of reddish pigments are of particular importance. These findings date to the post-deforestation period and result from geoarcheological fieldwork on the southern flank of the Terevaka volcano and comprehensive laboratory analysis.

Numerous lenticular to u-shaped pits filled with reddish substrate were found at about 240 m asl on the southern slope of the Terevaka in a side valley east of the Quebrada Vaipu. Like the Quebrada Vaipú, its eastern side valley (here named "Vaipú East," cf. Fig. 19.3) only occasionally carries water. The pits, up to 2.4 m in diameter and 0.4 m deep, lie embedded in the sediments of a fluvial terrace (Figs. 19.15, 19.16). A total number of 370 pits were calculated for the entire terrace area, based on the spatial density of 18 excavated pits. Two 7.6 and 5.8 m long profiles showed that the sediments in which the pits are embedded lie above the autochthonous soil with root imprints of palm trees. Sediments and pits therefore date to the time after the palm forest was cleared at this site. Radiocarbon dating of sediments and pit fill from one of the two profiles placed the construction of the pits between 1430 and 1670 cal AD (Table 19.1: 18, 19). In addition, at the base of this profile, a pit filled with reddish substrate from an earlier post-clearance phase was dated to 1220 to 1400 cal AD (Table 19.1: 20, 21) (Mieth et al. 2019; previously modeled dates in Out et al. 2020; recalibrated and modeled dates cf. Fig. 19.17; Table 19.1: No. 18–21).

The main part of the finely stratified pit fillings consists of a silty, reddish substrate of very low bulk density with an average of only 0.58 g cm^{-3}.

Micromorphological and geochemical analyses proved that these reddish pit fill deposits were of geogenic origin and consisted predominantly of the iron

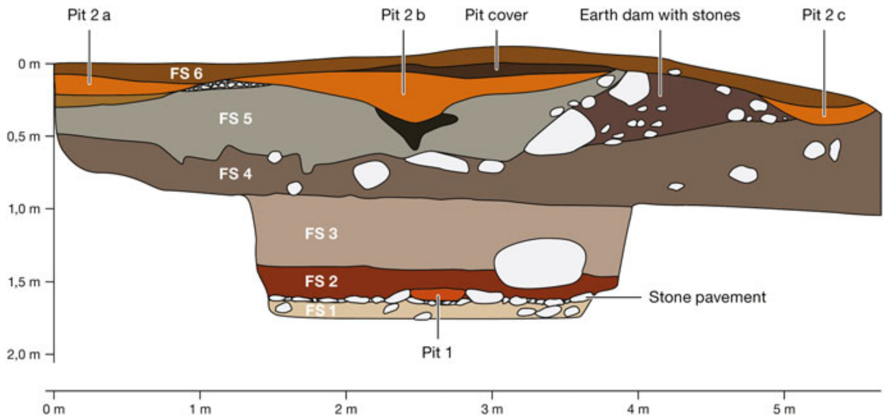

Fig. 19.15 Section from Vaipú East with pigment pits embedded in fluvial sediments (FS) (graphic: Doris Kramer, after Mieth et al. 2019)

Fig. 19.16 Pit filled with reddish pigments from a section in Vaipú East (photo: Andreas Mieth)

minerals hematite and maghemite in very fine and homogeneous grain sizes. The geochemical composition and physical properties of the minerals in the pit fill differ significantly from those of the sediments in which the pits are embedded. Dark brownish to blackish layers embedded in the reddish fill contain concentrations of miniscule flakes of charred plant material. Larger, taxonomically identifiable charcoal fragments were not found. Furthermore, the pit fill deposits contained thin, whitish to light gray layers, which contain a high concentration of phytoliths. The composition of the phytoliths was studied in detail for both the pit fill deposits and the surrounding sediments. While the fluvial sediments are rich in palm phytoliths, the pit fill contains very few phytoliths of palms. Instead, high numbers of grass

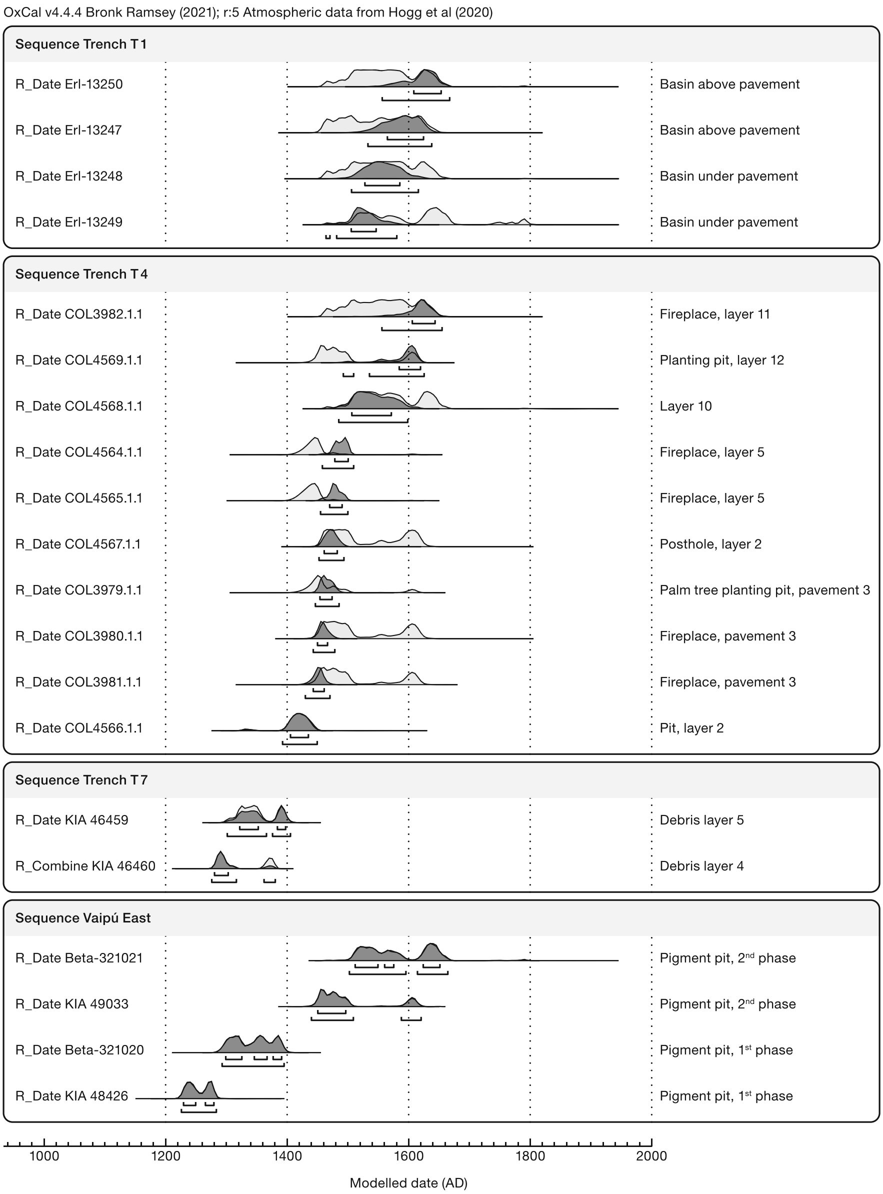

Fig. 19.17 Calibrated ages and OxCal age model of the 14C dates: Calibration and Bayesian phase modeling of the ages was performed using OxCal 4.4 (Bronk Ramsey 2009) with respect to SHCal20 (Hogg et al. 2020). The dates from Vaipú East previously published in Out et al. (2020) and here re-calibrated with SHCal20

phytoliths are concentrated in the whitish-gray layers. Some of the pits are covered with man-made covering layers up to 10 cm thick. These “lids” consisted of a silty loam, brownish substrate.

The following conclusions on the genesis and function of the pits could be derived from these findings. After forest clearing, the runoff of several heavy rainfalls created fluvial deposits in the widening of the valley of the Quebrada Vaipú and its eastern side valley. These fluvial deposits were used for the creation of pigment workshops where pits were dug for the purpose of producing reddish pigments. The geogenic, iron-rich substrate was probably ground to a fine and uniform grain size after its extraction. In an iterative process, single layers, each not exceeding a few centimeters in thickness were placed into the pits and heated by fire. The initially dominant yellowish iron mineral goethite was thereby oxidized to reddish hematite. Grasses served as fuel—presumably the only fuel of which sufficient quantities were still locally available after the forest clearance. The minimal vertical penetration of heat generated from the short-lived grass fires required the mineral raw material to be brought in and heated in numerous steps (layers)—a very elaborate process. Once the pits were completely filled the valuable content was preserved by a human-made sealing and thus protected from wind and water erosion (Khamnueva et al. 2018; Mieth et al. 2019; Out et al. 2020).

The intended use of the pigments is still unclear. The very fine, powder-like texture suggests a use on human skin, perhaps in combination with other substances such as sap from certain plants. While many of the pits and their fill deposits have survived untouched to this day, some have been partially emptied and some have been refilled with pigments during the active time of the workshop. The pigment production ended at its peak when the pits were covered (and thus preserved) by a thick fluvial sediment during an extremely strong and disastrous runoff event (see below).

The pigment pits found at Vaipú East are not the only ones on Rapa Nui. The authors also found pits filled with reddish pigments on a ridge about 1300 m west of the Quebrada Vaipú (Vaipú West, Fig. 19.3) as well as in connection with the monumental installations of ARUTH, where they were embedded in the terrace complexes and anthropogenic layers. Further pigment pits were discovered downstream of the monuments of ARUTH. There as at Vaipú East they are embedded in fluvial sediments (Vogt et al. 2018; Out et al. 2020). It is obvious that pigment production and use in the Vaipú area was not only spatially but also culturally and ritually related to the ARUTH installations and was part of the flourishing cultural manifestations of this particular site.

8 The Destruction of the Monumental Installations at ARUTH and the Spillage of the Pigment Workshops by a Flash Flood

Over the centuries, cultural layers and natural deposits accumulated in the widenings of the Quebrada Vaipú valley and in its eastern side valley (Vaipú East). In ARUTH, a succession of three pavements was built (see above). These pavements were divided by a sequence of anthropogenic layers of compacted earth and reworked sediments deposited by strong runoff (see above; Figs. 19.5 and 19.8; Vogt and Kühlem 2017). After the first phase of pigment production at Vaipú East, fine and coarse sediment carried by the runoff from heavy rainfall was deposited layer upon layer in the area of the pigment workshop (see above; Fig. 19.15). Subsequently, the production of pigments at an almost industrial scale began on the almost flat sediment surface (see above).

Then, during the phase of ritual use of ARUTH and the by far most intense phase of pigment production, a presumably completely unexpected catastrophe hit the unprepared people in the Vaipú area: a flash flood of unprecedented proportions irreversibly destroyed both complexes. Water volumes from an exceptionally heavy rainfall cut through many meters of the ritual site of ARUTH, rendering the ritual and hydraulic installations unusable. It seems that this event led to a functional change in ARUTH with no further evidence of ritual use.

In the Quebrada of Vaipú East the torrent of water tore away part of the fluvial sediment deposits together with the carefully covered pigment pits. On another part of the sediment body, slightly rounded gravel was deposited at the end of the flash flood resulting in an up to 1 m thick stone layer. The largest deposited stones weigh up to around 200 kg, showing the force with which the water came down the Quebrada during this catastrophic event. This youngest sediment layer protected the remaining older sediments of the pigment workshop from further erosion until today.

An undated legend that is directly linked to the toponym of the ARUTH describes the dramatic effects of such a flash flood. Ko te Ava Ranga Uka a Toroke Hau is translated as "Place where Uka, the daughter of Toroke Hau, floated in the stream." The legend describes how one night her parents left Uka alone at home to attend a feast. While they were gone, a heavy flash flood washed away the house with the sleeping girl. Upon their return Uka's parents found her lifeless body floating in the stream. In remembrance, the place where she was found was named after this tragic incident (Englert 2012).

What caused this catastrophic event? Why had the Rapanui not taken any precautions to protect themselves from such a disastrous event? What role could land use have played for such an event to occur? In the centuries after deforestation and before the main pigment production started, the garden soils in the Quebrada Vaipú catchment had been largely eroded (Mieth and Bork 2015, 2017; Mieth et al. 2019; Bork et al. 2019b). As a result, solid volcanic rocks, which were previously covered by the soils and were barely weathered, came close to the surface in many locations. The erosion of the soil greatly reduced the infiltration capacity. As a result, frequent moderate rainfall was enough to cause runoff, which further eroded the remaining soils and deposited the eroded soil particles in the valley floor and in the sea. Subsequently, during the period of intensive pigment production, a considerable part of the grass vegetation which had developed in the catchment area of the Quebrada Vaipú after deforestation was apparently needed for the complex pigment production process. As a result, the soils lost any erosion protection. This led to a cumulative effect of the now very low infiltration capacity of the remaining soils and the volcanic rocks with the lack of erosion protection provided by vegetation. The combination of both factors enabled the devastating and simultaneous destruction of the ritual site of ARUTH and the pigment workshops during one exceptionally heavy rainfall event. The Rapanui had no chance to prevent this catastrophe. After the extensive erosion of the soil and the removal of the grass vegetation cover, such an event was inevitable. It was just a question of time.

9 Synthesis and Conclusions

The research presented here shows that forest clearing on the southern slope of Maunga Terevaka at an elevation around 240 to 275 m asl and about 5 km from the coast had already begun before ca. 1220 to 1290 AD. This is further evidence that already at this time at least parts of the highlands were affected by intense human activities. And this in turn is another link in the chain of evidence that around 1200 AD Rapa Nui must have already been populated by a larger population.

Forest clearing on the southern slope of Maunga Terevaka was followed by cultural activities that are unique for Rapa Nui. Along the Quebrada Vaipú and especially at ARUTH, people erected monumental hydraulic installations and terraces. These constructions dominated the drainage valley of Lake Rano Aroi, crowned by the most inland image *ahu* of the island. At ARUTH, the islanders transformed the landscape in ways that are without parallel on Rapa Nui. The oldest part of the terrace complex has been dated to ca. 1270 to 1380 cal AD! early cultural dates for Rapa Nui's highland region.

The monumental structures at ARUTH are not single phased constructions. Over generations, the terraces with their elaborately paved surfaces were sealed with artificially applied layers of sediment, covered with new paved surfaces, then built-over again, and in the process also expanded in surface area. In the end, the monumental complex extended over a total area of at least 4800 m^2. This is the largest architectural complex known on Rapa Nui to date and proof of an enormous amount of labor that was invested here over at least 15–20 generations. An outstanding finding is the evidence of planted palms in the plaza of Ahu Hanuanua Mea and the small palm grove amidst the pavement in the central area of the site. They date to a time when palms had already disappeared or had at least become scarce in the surrounding landscape. The *ahu*, the site's location in the island's only water-bearing valley, the findings of carefully constructed megalithic basins and canals, the palm planting, and the absence of ordinary settlement structures all point towards a ritual use as a water sanctuary. There is much evidence to suggest that the water of the Quebrada Vaipú, as a scarce and valuable resource, was placed under taboo with its management and use reserved for the elites. Comparative studies on other East Polynesian islands and oral traditions of the Rapanui support this.

During the dry season, the flow of water in what now appears to be a largely dry valley was not left to chance. An artificially created outlet dug into the weathered rock at the southern edge of Lake Rano Aroi enabled the ancient Rapanui to control and manage the flow of the water. In turn the stability of the loosely fitted stone layers in the terraces ensured a non-destructive outflow of the water after passing through the sacred installations at ARUTH. The monumental constructions prove that the Rapanui were not only excellent structural engineers but also knowledgeable hydraulic engineers. Such hydrological knowledge as part of landscape transformation is a new aspect of Rapanui cultural expressions, as is the existence of a water-related fertility cult. The findings described here may also shed new light on the results presented by DiNapoli et al. (2019) regarding not only the spatial coexistence, but perhaps also ritual connection of coastal *ahu* and coastal water sources on Rapa Nui.

In the eastern side valley of the Quebrada Vaipú, intensive production of reddish pigments began around the same time as the installations at ARUTH after the clearing of the forest around 1220 to 1290 cal AD. The pigments were produced by burning ground minerals using large quantities of dry grasses as fuel. A considerable amount of labor was required for this pigment production on an industrial scale.

After the forest clearing, many generations of Rapanui successfully managed stronger runoff events in the catchment area of the Quebrada Vaipú and its eastern tributary valley. At ARUTH material from fluvial deposits was deliberately used in the construction of the monumental terraces. At Vaipú East, pits for pigment production were specifically integrated into the fluvial sedimentary bodies. However, progressive soil erosion following the loss of the palm forest and then the gradual destruction of even the protective grass vegetation due to the demand for fuel in the pigment production increased the risk of an extreme runoff event. Such a catastrophic, once-in-a-lifetime event occurred in the period between 1480–1600 cal AD. This runoff event cut through and destroyed a significant part of ARUTH's monumental structures and simultaneously ended the pigment production at Vaipú East. Although this event probably meant the end of ritual activities in ARUTH, it did not mean the complete abandonment of the site. Horticultural activities in the upper sedimentary layers provide evidence of continued use of the site, albeit of a horticultural nature.

The findings on the southern slope of Maunga Terevaka are an important component in the reconstruction of the cultural history of Rapa Nui. They attest to the early beginnings of an active, ambitious, and extremely industrious culture with a strong ritual component after the clearing of the palm forest. They provide evidence of the persistence of extremely labor-intensive and skilled engineering over many generations. They provide evidence of the persistent adaptation of cultural activities to the natural challenges of the island ecosystem and man-made environmental changes. They do not, however, provide evidence for a post-deforestation collapse of the Rapanui culture in pre-European history.

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