7 Soil

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7.1 Geologic origins

The Island lies on the Nazca plate 350 km east of the East Pacific Rise – a tectonic fault-line characterised by “superfast” movement of 150 mm per annum [1]. The Island is part of the Easter Seamount Chain – a volcanic chain extending 2,500 km east from the East Pacific Rise. Proximity to the active fault-line yields consistent seismic activity on Rapa Nui, as demonstrated by 9 earthquakes of magnitude greater than M 5.0 registered at the Island during the 365 days to 20 August 2018.[1] Notably, the depth and distance of epicentres from Rapa Nui is such that most seismic activity affecting the Island is imperceptible to inhabitants and poses no significant risk. Earthquake-induced tsunamis entail a second source of seismic risk on the Island, specifically, earthquakes associated with the Atacama fault-line near the west coast of South America.

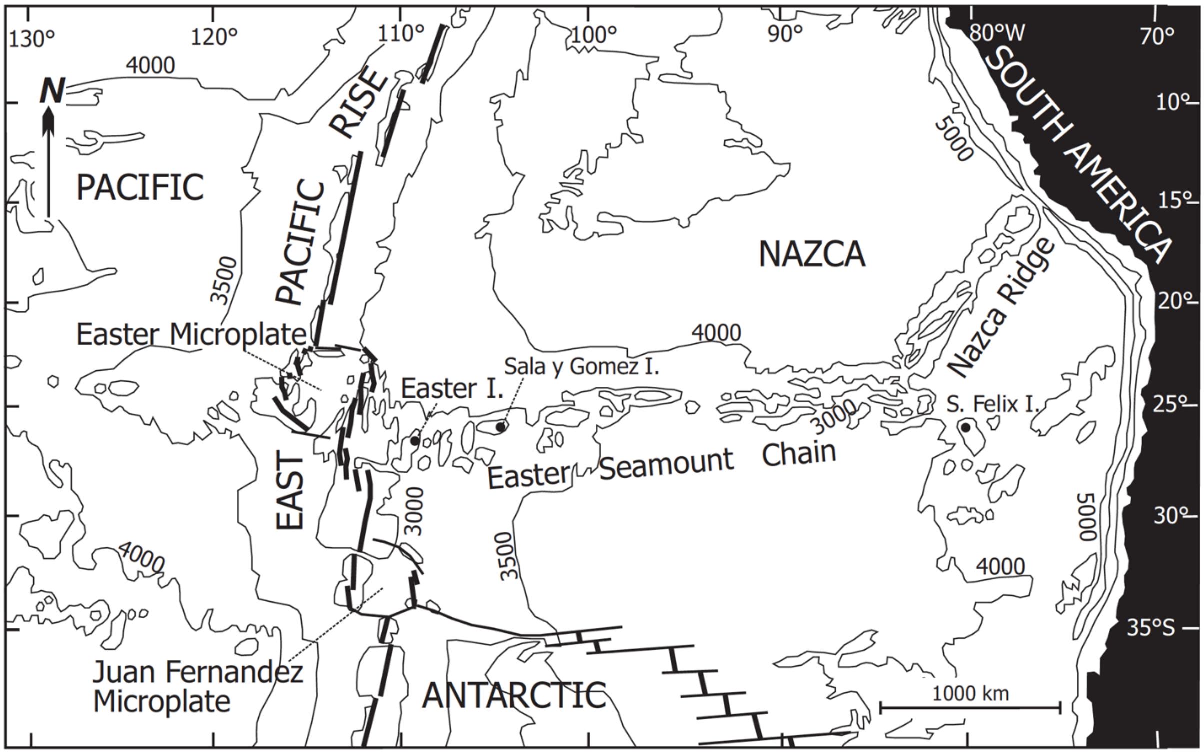

Figure 7.1 Tectonic location of Rapa Nui (from [1]).

Rapa Nui formed as a result of volcanic activity. Three principle volcanos contributed to the formation of the Island in three stages [3]: 1) Poike, a strata-volcano around 370m high to the south-east; 2) Terevaka, a fissure complex near the centre of the Island comprising many volcanic cones; and 3) Rano Kau, a caldera to the south-east [2]. Earlier lava flows from Poike have been dated at 3 million years old, later flows from Terevaka at 300,000 years old, with flows from Rano Kau falling between these two ages [2]. These stages of formative volcanic activity are 780,000 to 120,000 years old [1]. Following

[1] As recorded by Earthquake Track (https://www.earthquaketrack.com/r/easter-island/recent)

volcanic formation, subsequent marine erosion, particularly of Poike and Rano Kau, defined the contemporary limits of the Island.

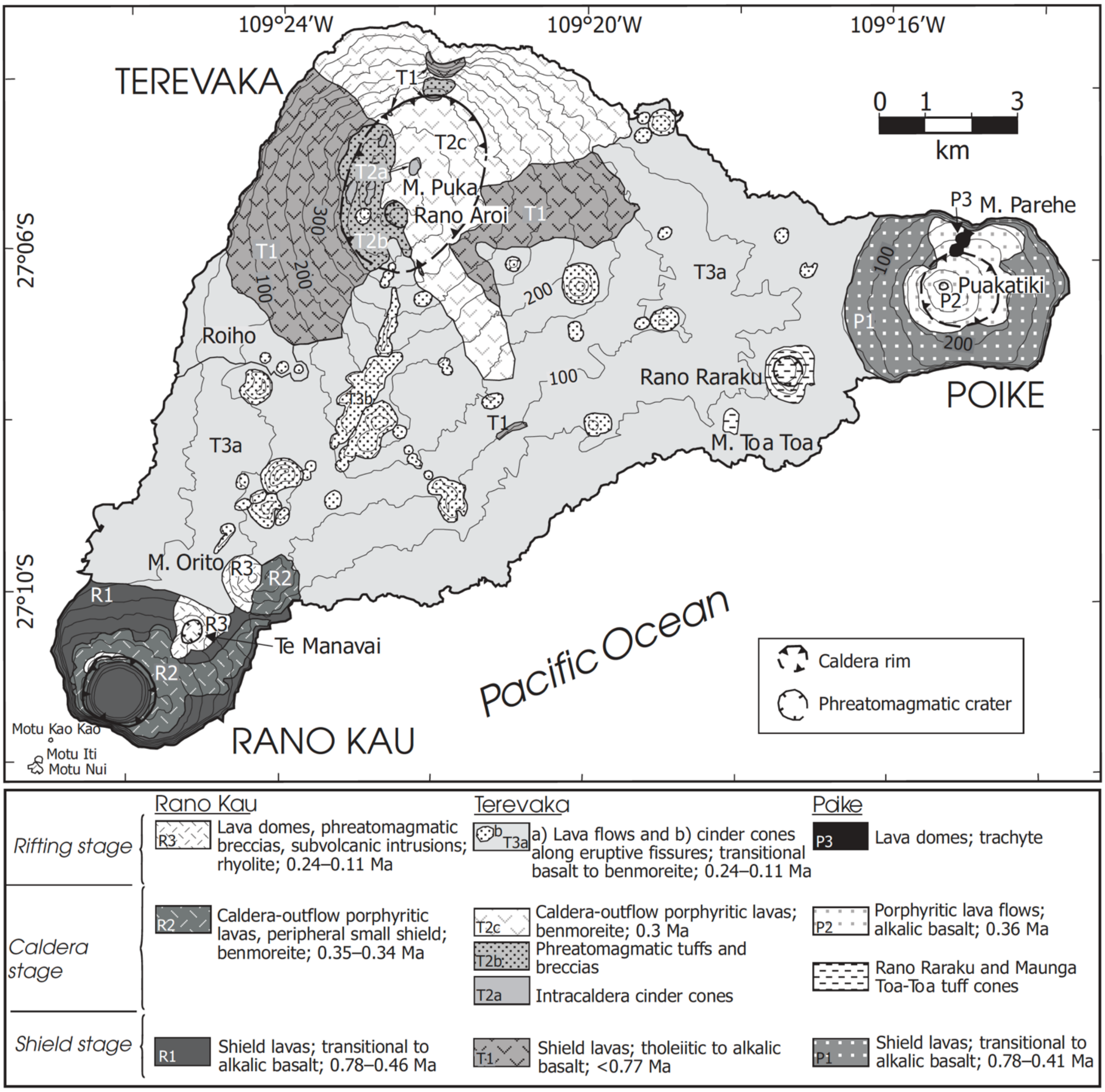

Figure 7.2 Geological formation of Rapa Nui (from [1]).

Although basaltic eruptions predominated in the formation of the Island, basalts, in the strict sense, are relatively rare [2]. Nevertheless, basalt together with *hawaiite* and *mugearite*, both of which are mineralogical variations of basalt, comprise more than 80 per cent of the Island. Basaltic rock on the Island is generally medium-dark to light grey and features small to medium-coarse *vesicules* – holes in the rock that give it a highly porous appearance and low density. Other harder rock types comprising the Island noted by Baker et al. are: *benmorite* (around 8 per cent), *trachyte* (around 6 per cent) and *rhyolite* (around 6 per cent). This small proportion of rhyolite includes limited deposits of rhyolitic obsidian – that is, a rhyolitic glass resulting from the failure of crystals to form in rapidly cooled lava. Several studies note that stone tools produced by prehistoric cultures on Rapa Nui were predominately made from rhyolite and obsidian deposits in the south-west ([2–4]). The wide distribution of obsidian on the Island due to productive usage contrasts the relatively small natural distribution. Significant prehistoric productive use of basalt from Poike for implements including knives, hoes and fish hooks has been identified [4]. Productive use of rhyolite appears to have continued into contemporary times, with two small quarries associated with the production of aggregate for concrete located within the zone of rhyolite deposits.

Other pyrolclastic rocks – that is, rocks formed directly from volcanic eruption – have played a more significant cultural role on Rapa Nui, specifically in the production of the *moai*. The *moa*i are carved from volcanic *tuff* – rock formed by the compaction of volcanic ash. Specifically, tuff desposits at the Rano Raruku cone – part of the Terevaka fissure complex – are the source of material for the *moai*. Tuff is fine-grained and soft, making it suitable for carving with rudimentary tools. Harder basaltic *xenoliths* – fragments of harder stone – are present within tuff deposits at Rano Raraku. Abandoned moai are perhaps the result of harder xenolithic deposits encountered while carving softer tuff. The *pukao* (top-knots) of the *moai* were produced from a different pyroclastic rock – red scoria quarried from a deposit associated with the Puna Pau cone towards the south-west of the Island. Scoria formed from upper, more gaseous (frothy) layers of lava, creating highly vesicular rock characterised by high porosity and low density.

7.2 Soil

Soil conditions on Rapa Nui are the product of this volcanic formation and of subsequent modes of erosion that occurred during several eras. Soil on the island is primarily the product of volcanic ash that oxidizes under prevailing conditions, yielding the observed bright-red soil colour [3]. Bandy notes the high porosity of the soil, such that heavy rains were observed to sink immediately into the soil. Flenley and Bahn (2002) note that the soils on Rapa Nui are produced through the erosion of volcanic rock, with soil quality varying with the age of each volcano. They observe wide variation in the depth of soil cover on the Island depending upon the extent of basaltic erosion, with soil being sparse in some areas and abundant and fertile in others. Soil cover on the Poike peninsula has been profiled to a typical depth of more than 2 m [5]. Soils are best-developed on the oldest rocks of Poike and least-developed on the younger rocks of the Terevaka field [6].

Numerous authors discuss prehistoric surface erosion arising from massive deforestation around 1300 – 1500 AD and subsequent effects upon the Island's population. More recently, continued surface erosion has been highlighted as a significant problem on the Island. Eucalyptus plantations were first established in 1969 as part of a strategy to control wind erosion [5], though suggest limited effectiveness of such strategies given the potential for plantations to exacerbate wind turbulence. However, overland water flow is the predominant factor in contemporary surface erosion on Rapa Nui. Intensive sheep farming on the Island that commenced in the 1930s led to cattle tracks in which surface flow was concentrated, establishing concentrated water flow patterns and associated gullying. In 1999 it was estimated that over 50% of the surface of the island could be categorized as highly vulnerable to erosion, 20.7% of the surface was already experiencing erosion and 3.2% was severely eroded [7]. The continued expansion of gullies and gully networks despite erosion control measures is readily seen on site (Figure 7.3).

Figure 7.3 Images of gullying (from [5]).

7.3 Coastal erosion

Continued coastal erosion entails a further dimension of geological transformation of Rapa Nui. The proximity of sites of cultural heritage to the coast, particularly *moai* at Tongakiri, Hanga Roa, Tahai and Anakena, exacerbate potential problems associated with coastal erosion. Due to greater wave heights and increased energy of the waves hitting the *ahu*'s stone walls, the *ahu* are expected to undergo worsening damage and the *moai* that sit on top of them could topple [8]. Considering the coastal impacts of climate change upon Rapa Nui in relation to coastal inundation, beach erosion, and cliff instability, recent studies suggest that one of the Island's two beaches in likely to be permanently inundated by 2100, cliff instability will be exacerbated with climate change, and that *ahu* and *moai* at Tahai and Hanga Roa are at greatest risk of marine damage due to rising wave heights [9].

7.4 References

[1] L. Vezzoli, V. Acocella, Easter Island, SE Pacific: An end-member type of hotspot volcanism, Geol. Soc. Am. Bull. 121 (2009) 869–886. doi:10.1130/B26470.1.

[2] P.E. Baker, F. Buckley, J.G. Holland, Petrology and geochemistry of Easter Island, Contrib. to Mineral. Petrol. 44 (1974) 85–100. doi:10.1007/BF00385783.

[3] M.C. Bandy, Geology and Petrology of Easter Island, Bull. Geol. Soc. Am. 48 (1937) 1589–1610.

[4] D.F. Simpson, M.I. Weisler, E.J. St Pierre, Y. Feng, R. Bolhar, The archaeological documentation and geochemistry of the Rua Tokitoki adze quarry and the Poike fine-grain basalt source on Rapa Nui (Easter Island), Archaeol. Ocean. 53 (2018) 15–27. doi:10.1002/arco.5132.

[5] A. Mieth, H.-R. Bork, History, origin and extent of soil erosion on Easter Island (Rapa Nui), CATENA. 63 (2005) 244–260. doi:10.1016/J.CATENA.2005.06.011.

[6] C.M. Stevenson, T.L. Jackson, A. Mieth, H.-R. Bork, T.N. Ladefoged, Prehistoric and early historic agriculture at Maunga Orito, Easter Island (Rapa Nui), Chile, Antiquity. 80 (2006) 919–936. https://www.cambridge.org/core/services/aop-cambridge-core/content/view/5D4C954B6DB796B76518976CEB36A4FC/S0003598X00094515a.pdf/prehi

storic_and_early_historic_agriculture_at_maunga_orito_easter_island_rapa_nui_chile.pdf (accessed May 18, 2018).

[7] R. Honorato, G. Cruz, Erodabilidad y Erosion Actual de los Suelos de Isla de Pascua, Cienc. e Investig. Agrar. 26 (1999) 27–36.

[8] UNEP, World Heritage and Tourism in a Changing Climate, Nairobi, Kenya, 2016.

[9] L. Quilliam, R. Cox, P. Campbell, M. Wright, Coastal climate change impacts for Easter Island in 2100, Rapa Nui J. 28 (2014). http://islandheritage.org/wordpress/wp-content/uploads/2014/07/Quilliam_et_al_RNJ_May20141.pdf (accessed May 14, 2018).