

S1. Descriptions of geothermal features and landmarks at Lake Rotomahana in 1859

The first three quotes (a-c) are from Hochstetter (1867), while the last one (d) is from Hochstetter (1864). They describe his eyewitness encounters and familiarity with springs, geothermal features and physical geography of Lake Rotomahana. Page number is provided in brackets at the end of each quote. Please see main reference list for the full citation.

a - *“A little beyond the lake, in a small side-valley lies the Ate-tuhi (Ngawha a Te Tuhi); and in the marshy flats, at the N.W. end of the lake, the Te-Waiti fountain. Also at the outlet of the Rotomahana towards lake Tarawera, on both sides of the Kaiwaka river, there are still numerous Ngawhas (springs) observed, which have special appellations such as Te aka manuka, Te mamaku, Te poroporo, Tamariwi, Makrowa, Te karaka etc., which, however, I had no opportunity of examining more closely.”* (Page 418)

b- *“Near Te takapu there are some deserted huts, and a few yards farther there is a ravine, called Waikana-panapa (the coruscating water), extending in a N.E. direction for a short quarter of a mile, in the background of which lies the Rotopunamu (green lake). The entrance to the ravine is overgrown with thicket, and rather difficult; it also requires considerable caution, because very suspicious places have to be passed where the traveller is in danger of being swallowed up in heated mud.”* (Page 414)

c- *“East of Puai and separated from it by a channel only 40 feet wide is a second island Pukura (red lump). It is of the same description as Puai, smaller in circumference, but higher by several feet, and has likewise several huts, which some of my Maoris chose for their dwelling place. On these islands we had our headquarters during two days, and from them we undertook our excursions round the lake.”* (Page 408)

d- *“Visitors who intend to stay a few days at the lake are recommended by the natives to select as their quarters the small island Puai. This is a rock, 12 feet high, 250 feet long and nearly 100 feet wide.”* (Page 68).



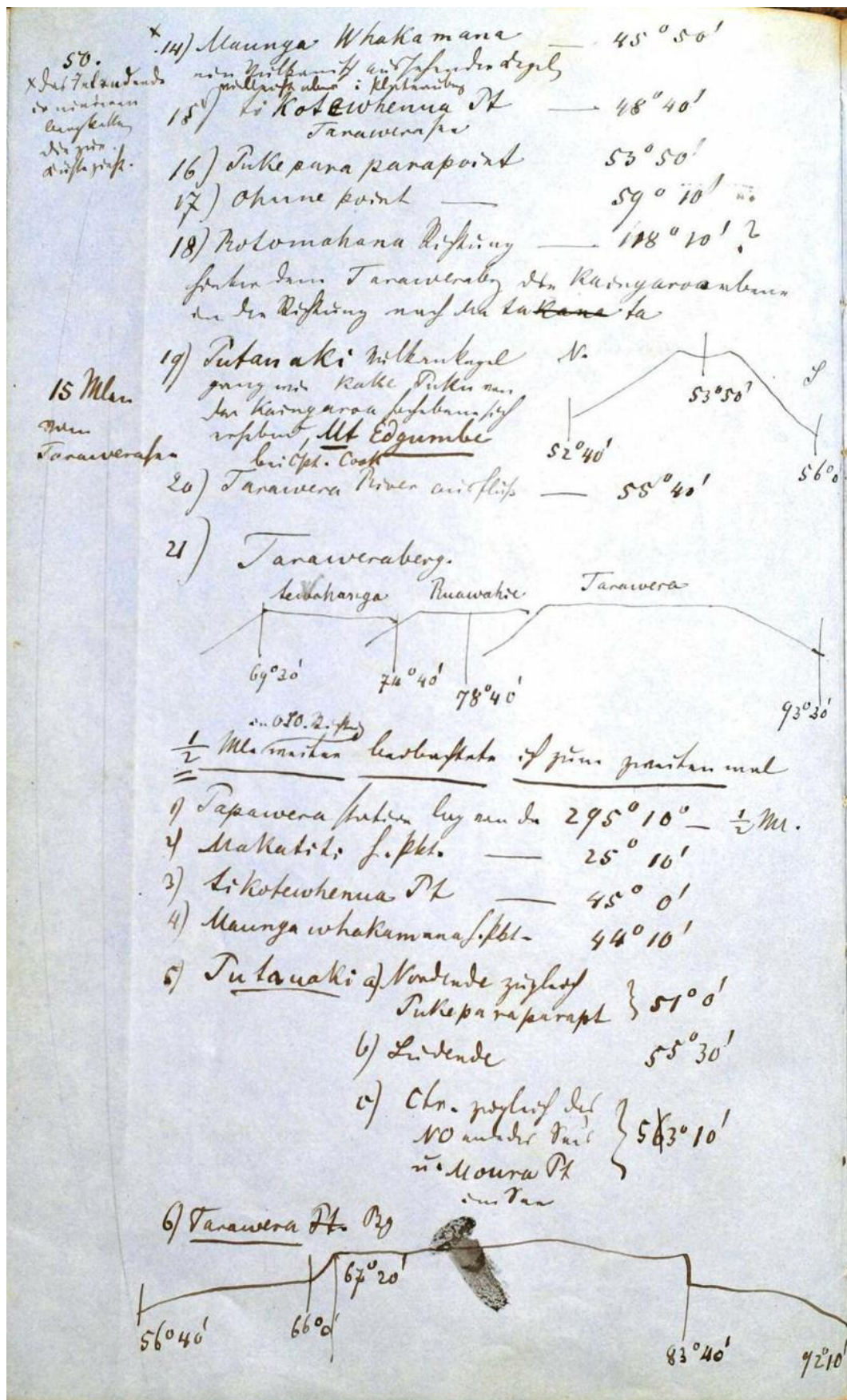
Supplementary Figure 1. LIDAR over Topo50 for the region between Lake Tarawera (northeast corner), Te Kumete summit (northwest corner, 543 trig), the access roads in the area of the Black Terrace Crater and Lake Rotomahana centered on the Kaiwaka Valley. Contour interval is 2 meters.

Beobachtungen von i Hügel am Südende des
Rotomahana.

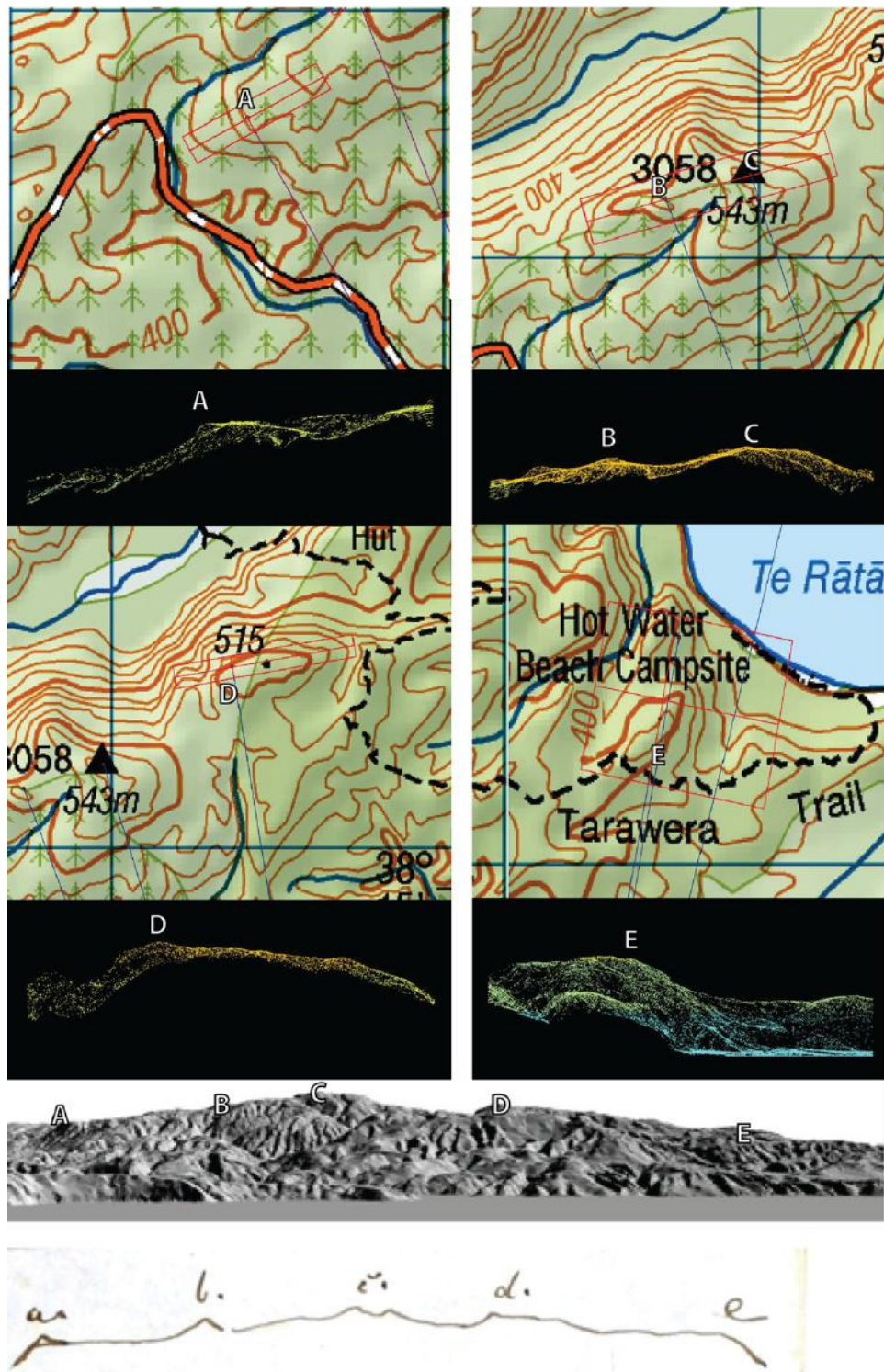
57

- 1) Mr. Spence 306° 30' an b. c. d. e
2. Tekumede Rücken
- a) 314° 40' P. K. am M. g.
- b) 322° 40' P. K.
- c) 326° 0' P. K. am M. g.
- d) 334° 20' P. K.
- e) P. K. am Tarawera 355° 0'
3. Makatiti P. K. am M. g. 359° 20'
4. Teaniki P. K. am Tarawera } 3° 10'
- N. P. K. am M. g. der }
Teaniki M. g. —
5. Te Karata, P. K. am M. g. 8° 10'
6. Ngahapu M. g. — 5° 20'
7. Te Takapo M. g. — 7° 30'
8. Te rua Kiwi M. g. — 11° 10'
9. Ngawhana — 17° 0'
10. Olu Kapuarangi — 322° 20'
11. Loff. am M. g. am P. K. am M. g. — 336° 0'
- bei Olu Kapuarangi
nammt
Te Wkakatara
12. Te mamaku M. g. — 349° 20'
13. Loff. am Teangipakaru 65° 40' 43° 10'
14. Wa Kach M. g. — 17° 50'
15. Teel Pua M. g. — 18° 0'
16. Teel Pukura M. g. — 14° 20'
17. P. K. am M. g. am P. K. am M. g. — 357° 0'
18. P. K. am M. g. am P. K. am M. g. — 65° 40'
19. Tarawera M. g. am P. K. am M. g. — 43° 30'
- N. W. P. K. am M. g. am P. K. am M. g. — 46° 10'
- P. K. am M. g. — 33° 0'

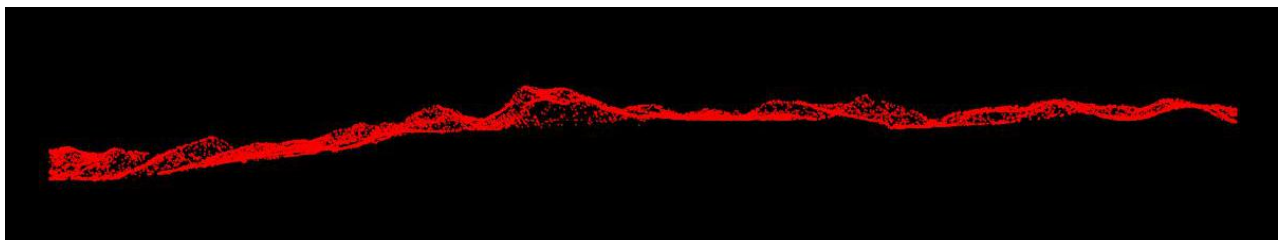
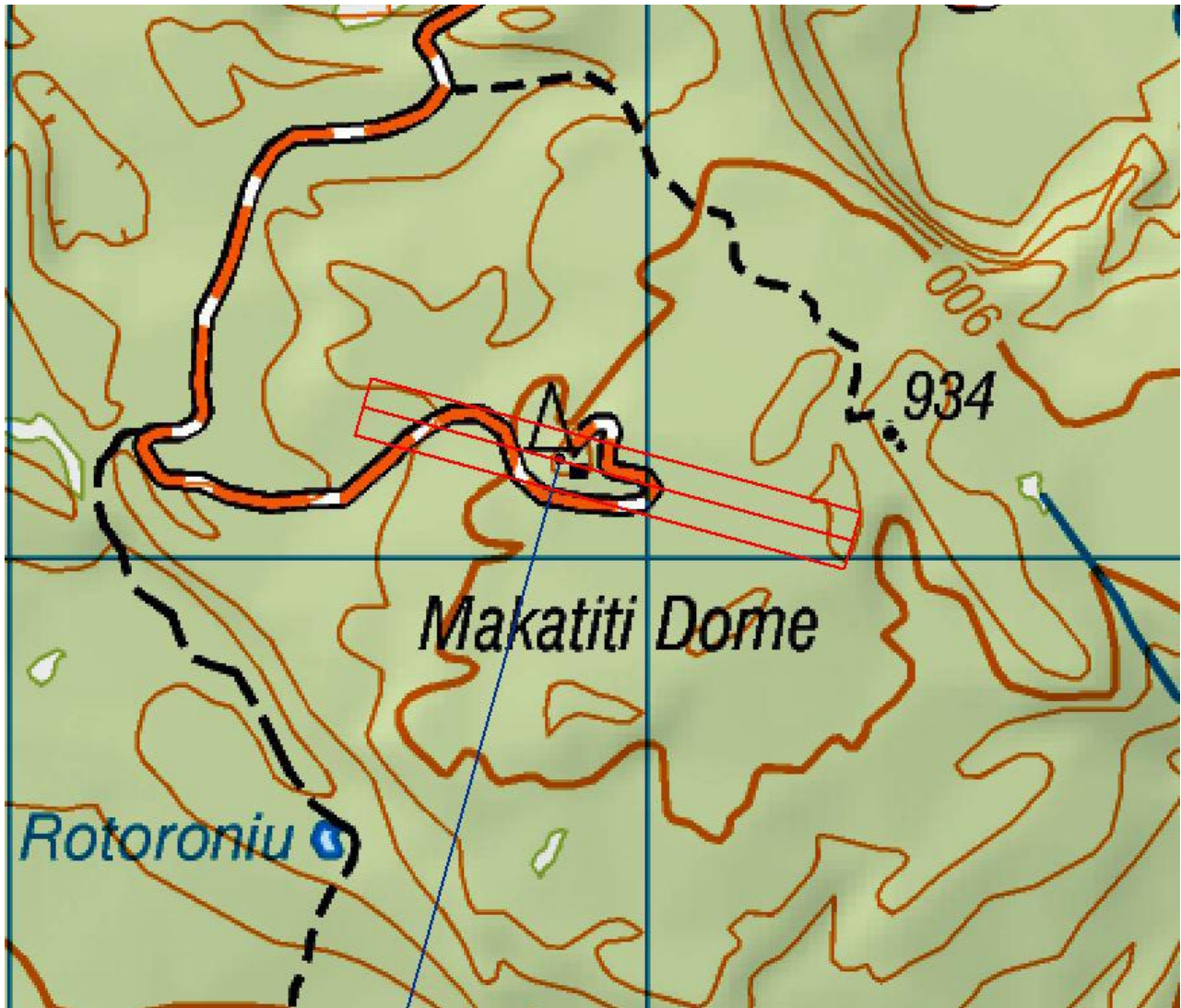
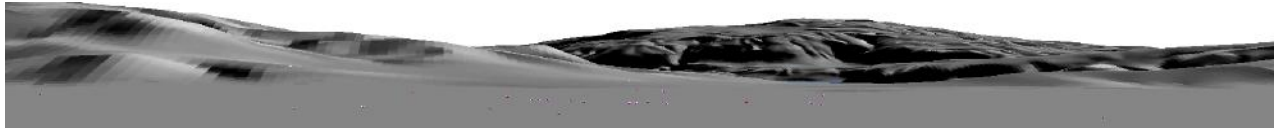
Supplementary Figure 2. (a) Page 57 of Hochstetter's survey data taken at Observation Station 21 on the southern shore of Lake Rotomahana in 1859. From Bunn and Nolden, 2018.



Supplementary Figure 4. (continued)



Supplementary Figure 5a. Topo50 map locations for Te Kumete ridge peaks surveyed by Hochstetter, showing LIDAR data point profiles (black frames with colour points, each with different horizontal and vertical scale) based on a perspective from the reconstructed position for Station 21. Full foreground digital elevation profile of Te Kumete Ridge and Rotomahana (modern) are shown below with corresponding profile sketch from Hochstetter's notes.



Supplementary Figure 5b. (top) Oblique perspective of Makatiti Dome using a digital elevation model from the reconstructed position of Station 21 with the full foreground; (middle) Topo50 location of bearing shot to Makatiti Dome highest point perceived by Hochstetter, red box shows the location of point swarm for LIDAR; (bottom) point swarm of LIDAR data showing cross section of Makatiti dome as viewed from Station 21. The view extends eastward into the line of sight of the 934m geodetic marker, which does not appear as high as that centered close to the mast symbol.

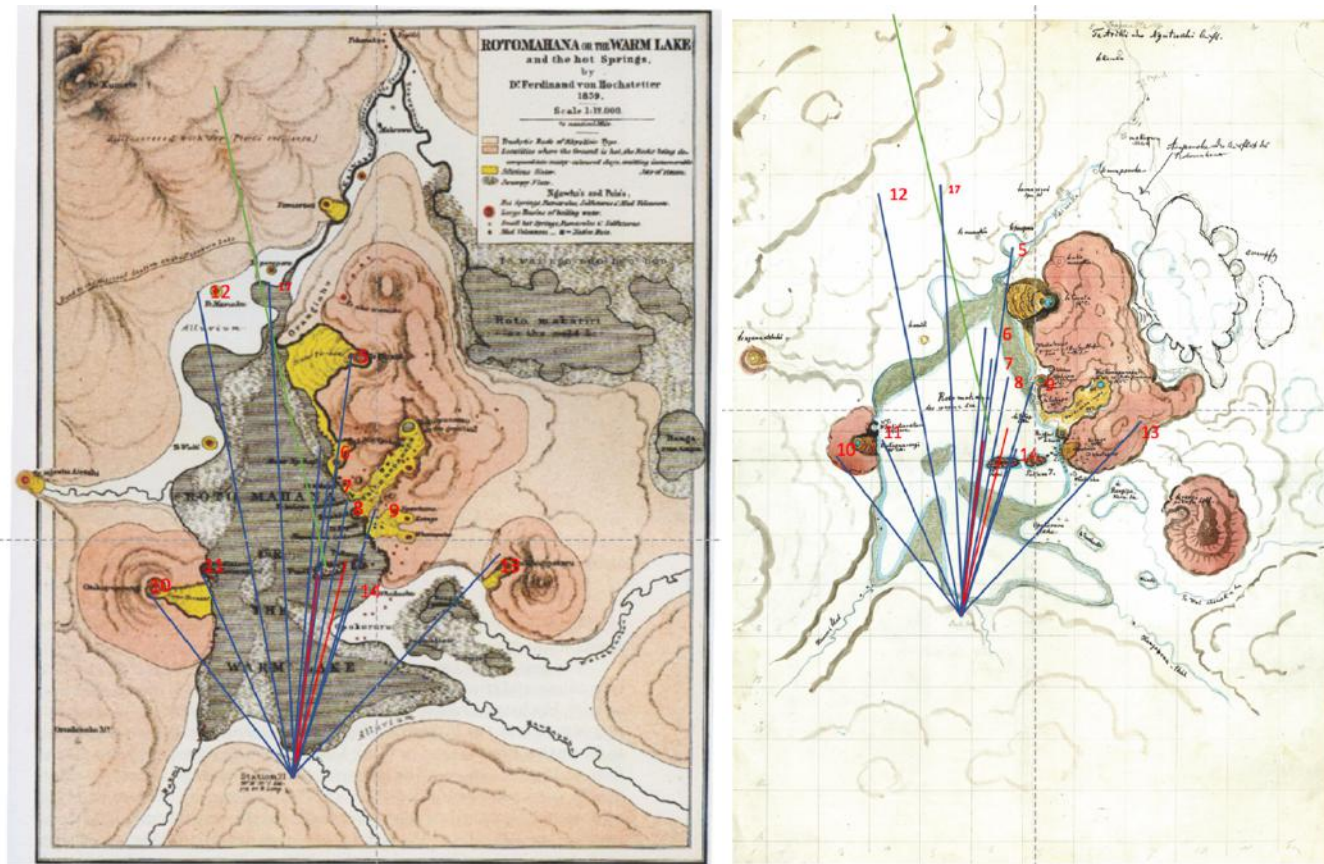
Auckland.

Auf der Spitze Depot-Point (s. Seite 26).

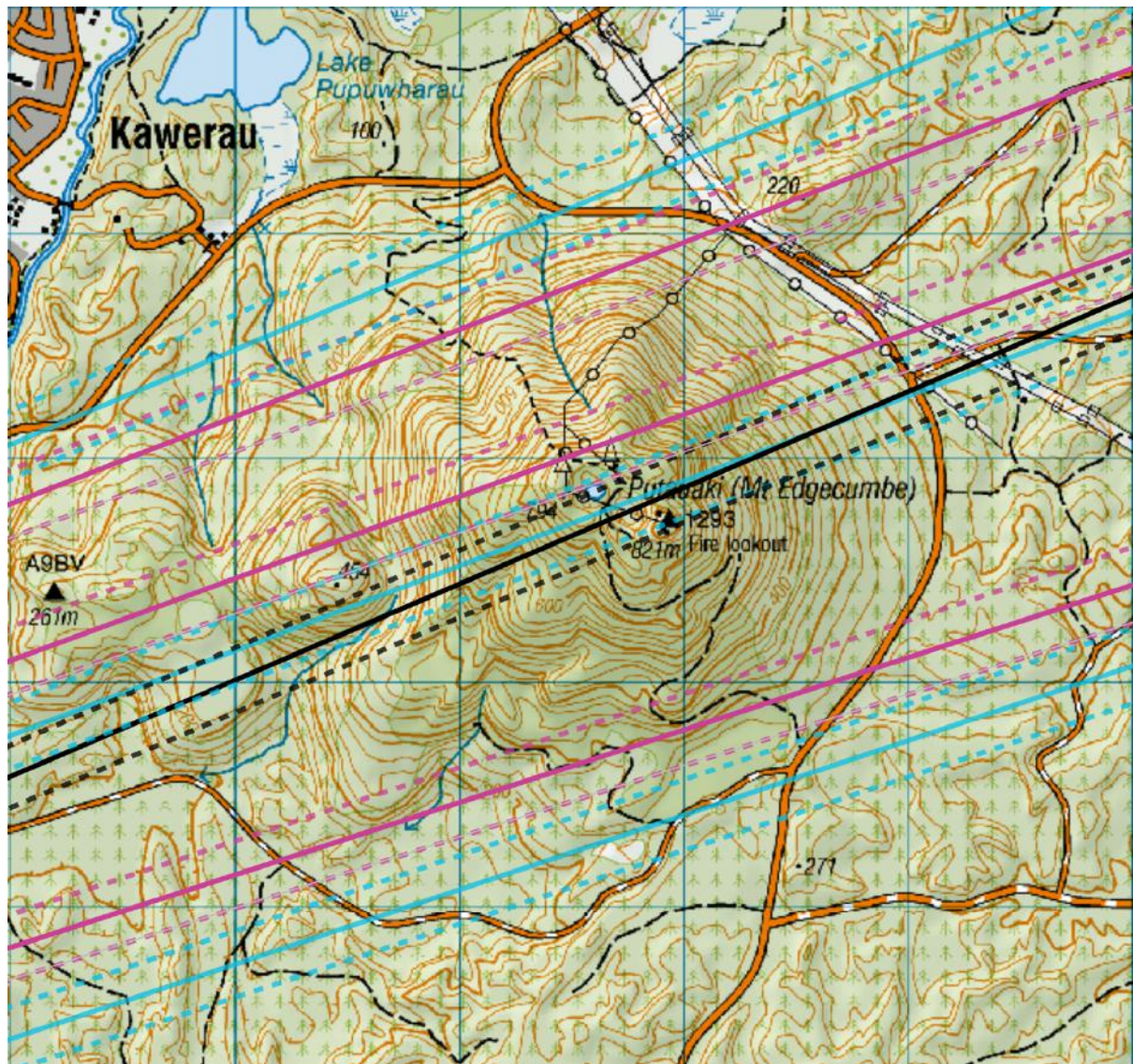
Breite: (Englische Karte) $36^{\circ} 50' 5''$ Sd; Länge: { Englische Karte: $174^{\circ} 49' 10''$ Ost,
Beobachtet: $174^{\circ} 49' 35''$ }

Zeit	Bezeichnung	Theodoliten- Ablesung	Thermo- meter R.	Schwingsungs- Dauer Bogen		Rechnungsergebnisse und Anmerkungen
der Beobachtung						
1859, Januar 1.						Azimuth der Mire: Nord $124^{\circ}27'25''$ West.
V. M. $11^h 12^m$	Magnet IV	. . . .	28.98	3.7120	4.1	Nordpunkt des Kreises:
11 25	" III	. . . .	29.6	3.0068	4.1	Januar 7. Bis N. M. $0^h 28^m$. . . $315^{\circ}17'45''$
11 39	" II	. . . .	28.0	2.7104	4.0	Januar 7. Nach N. M. $0^h 50^m$. . . $315^{\circ}16'20''$
11 51	" I	. . . .	26.5	2.7127	4.0	Torsions-Coefficient (Annahme) 0.65
11 58	Mire	$200^{\circ}52'0''$				Spiegelfehler der D. N. $6'93''$ (bei S. U. +)
N. M. 0 10		61 9.2				Der Spiegel war seit Sidney abermals heraus-
0 11	K. I. A. O. A.	61 9.2				genommen worden.
0 12		61 8.8				Declination.
0 17		89 42.9				Januar 7., N. M. $0^h 14^m$. . . $13^{\circ}50'15''$ Ost.
0 20	Abl.	88 56.4	19.8			0 19 . . . $50^{\circ}8''$ "
0 24	Magnet I	32 48.4				0 24 . . . $50^{\circ}7''$ "
0 27		32 24.5				0 28 . . . $51^{\circ}0''$ "
0 33		32 22.8				0 58 . . . $54^{\circ}2''$ "
0 36	Abl.	32 47.3	18.8			1 2 . . . $54^{\circ}0''$ "
0 40	Magnet II	88 58.8				1 4 . . . $53^{\circ}9''$ "
0 43		89 49.9				1 8 . . . $54^{\circ}1''$ "
0 46		61 9.1				1 10 . . . $54^{\circ}2''$ "
0 47	K. I. A. O. A.	61 8.9				1 15 . . . $54^{\circ}5''$ "
0 48		61 9.0				1 17 . . . $54^{\circ}3''$ "
0 52		61 53.4				1 23 . . . $55^{\circ}0''$ "
0 53	G. I. A. O. A.	61 53.2				1 37 . . . $54^{\circ}1''$ "
0 54		61 53.2				1859, JANUAR 7. . . Declination: $13^{\circ}53'2''$ Ost.
0 58		88 44.6				Gang des Chronometers: -2.5
1 3	Abl.	87 55.8	17.9			
1 8	Magnet III	35 5.6				
1 11		35 23.5				
1 13		45 9.9				
1 15	Abl.	43 34.8	18.0			
1 17	Magnet IV	78 22.7				
1 19		80 20.9				
1 22		61 52.9				
1 23	G. I. A. O. A.	61 53.2				
1 24		61 53.3				
1 30	Mire	$200^{\circ}51'8''$				

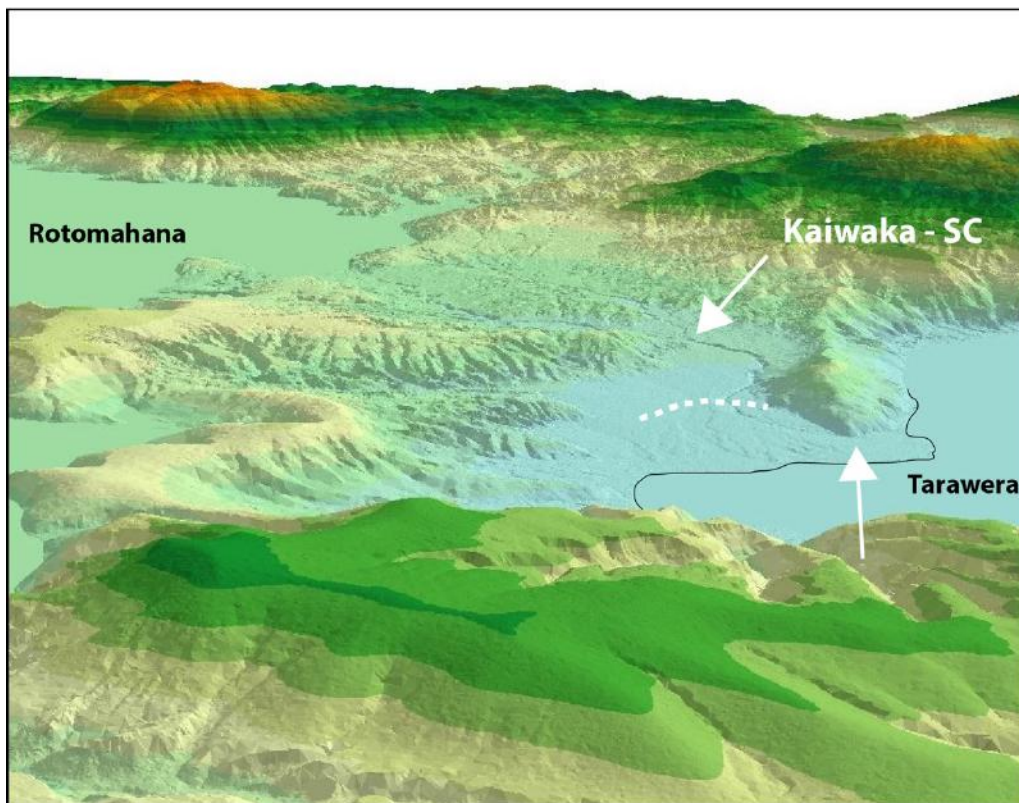
Supplementary Figure 7. Page 106 from the Scientific Report of the "Novara" with geomagnetic measurements (see right hand column) from the chapter "Magnetische Beobachtungen auf dem Land" (Magnetic observations on land) (Mueller, 1862-1865)



Supplementary Figure 8 (a, left). Hochstetter's primary bearings (uncorrected for declination) for internal landmarks surveyed from Station 21 plotted against the 1863 published map, demonstrating it was drafted relative to magnetic north. Note, there is a consistent offset of each bearing to the left of the surveyed landmark (b, right). Hochstetter's 1859 watercolour (used by BN18), with the same bearings in Supplementary Figure 8a overprinted. This demonstrates a poor fit between the uncorrected compass measurements and features in the watercolour map, and possibly represents an incomplete attempt at correcting the bearings and drawing for declination (see Section 5.1). Rays projecting out from the Rotomahana stations are: Red = Station 21 bearings to Puai and Pukura Islands; Blue = Station 21 bearings to all other internal landmarks; Green = bearing from Puai to Te Poroporo spring. Landmarks in red are numbered as per Supplementary Figure 2. For each map, dark red shaded areas indicate warm ground, yellow shading indicates sinter terrace.



Supplementary Figure 9. Bearings to Putauaki (Mount Edgecumbe) from reconstructed positions for Station 18 (pink lines), Station 19 (blue lines) and Station 20 (black lines). Solid line represents the primary bearing from the datum, and the dashed lines show the ± 0.25 error bound to account for 1-sigma compass precision as well as declination and convergence angle corrections. 2-sigma bounds are twice as wide. Only one bearing to the center of this landform was shot from Station 20. See Supplementary Figure 4 for bearings and profiles of Putauaki drawn at these stations.



Supplementary Figure 10. (top) Photograph “Rotomahana from summit of Tarawera, after eruption June 10 1886” New Zealand, by Burton Brothers studio, Frederick Muir (1886). Te Papa (C.010712), showing the oblique view of Puke kiore Point (white arrow pointing bottom to top) on the southern Lake Tarawera shoreline and the Kaiwaka valley from Mount Tarawera after the eruption. (bottom) A similar perspective using LIDAR 3D imagery. Kaiwaka-SC arrow = junction of modern Kaiwaka coming (partly) off of Te Kumete Ridge with a “south channel”; either the former Kaiwaka or Te Awa Porohe. Dashed white line is location of 1886 shoreline scarp backing the delta seen in the Muir photograph.

METEOROLOGICAL OBSERVATIONS.

Rotorua, New Zealand, for the Month of June 1886.

Altitude above the sea 961 1/2 feet.

RECORDED AT 9 28 A.M.

DATE.	Barometer uncorrected.	Attached Thermometer.	Barometer corrected, and reduced to 32° Fahr and Sea level.	SELF-REGISTERING INSTRUMENTS, FOR 24 HOURS PREVIOUS.										Rain-fall in inches on the ground.	Wind, Direction & Force in previous 24 hours.	Amount of Cloud—0 to 10.	Direction of Wind or Motion of Clouds.	GENERAL REMARKS.
				Dry Bulb (corrected).				Wet Bulb (corrected).			Radiation (corrected).							
				Maximum.	Minimum.	Mean.	Range.	Maximum.	Minimum.	Mean.	Solar.	Terrestrial.						
1			29.22	54	42.5	48.2	11.5	52	44	48	73.5	43.5	0.04		10	NE		
2			29.42	58	38	48	20	55	39	47	89	34	0.01		10	Calcu		
3			29.12	58.5	40.5	49.5	18	57.2	41.5	49.3	75	40			10	NE		
4			29.78	59	41	50	19	56	41.5	48.7	90	37	1.26		4	N.E		
5			28.53	61	49	55	12	56	47.5	51.7	108	47	0.58		10	S.		
6			29.08	56	34	45	22	50	34.5	42.2	101	30			6	S		
7			29.35	56	32	44	24	46	38.2	39.1	108	28			1	S		
8			29.42	58.5	31	44.7	27.5	50	31.5	40.7	110	28.5			1	S		
9			29.20	55	39	47	18	48.5	39.5	44	104	40			9	NW.		
10			29.21	55	32.5	43.7	22.5	51.5	33.5	42.5	88	30			10	S	Eruption of Tarawera	
11			29.28	46	31	38.5	15	39.5	31.2	35.3	88				1	SW	first Earth. tremors felt at	
12			29.28	52.5	32.5	42.5	20	43.5	32.5	38	92	32	0.22		1	SW	2 o'clock A.M. almost contin	
13			29.22	54.5	36	45.2	18.5	47	36.5	41.7	92	35			4	SW	none until 6 AM in	
14			29.08	60	31	45.5	29	51	32	41.5	100	30			10	SW	direction NW to SE	
15			28.90	53.5	32.5	43	21	48.5	33.5	41	84	29	0.05		0	Calcu	Shower of volcanic dust	
16			28.85	54	29	41.5	25	48.5	30	39.2	107	27			4	Calcu	with rain fell between	
17			29.10	48	32.5	40.2	15.5	43.5	31.5	37.6	97	29			1	SW	5.15-5.30 AM	
18			29.26	51	29.5	40.2	21.5	42	30	36	96.2	25			0	S	Lake Rotorua rose 18 inches	
19			29.21	56	30.5	43.2	25.5	46.5	31	38.7	104.5	29			10	SW	Hot springs at Rotorua	
20			29.03	57	42	49.5	15	51.5	43	47.2	102.5	40			9	NW	increased in temperature	
21			28.73	56	39.2	47.6	16.8	51.5	40	45.7	87	37	0.44		4	SW	+ volume	
22			28.91	52.5	41	46.7	11.5	48.5	39.5	44	97	38			9	SW		
23			29.03	55.8	40.5	48.1	15.3	50	41	45.5	92	37			10	W		
24			28.78	55.5	46.5	51	9	50	46.5	48.2	100	47	0.14		10	N.E		
25			28.47	53	39.5	46.2	13.5	50	39	44.5	76.5	38	0.77		9	NW		
26			28.80	47	32.5	39.7	14.5	43	33.2	38.1	91	30	0.67		2	NW		
27			29.12	49.5	28.5	39	21	46	29	37.5	92.2	25.5	0.56		0	SW		
28			29.23	48.5	32	40.2	15.5	45	32.2	38.6	93.2	29			9	Calcu		
29			29.22	53.5	42.2	47.8	11.3	47.8	42.5	45.1	92.5	39.5			7	SW		
30			29.35	56	32.5	44.2	23.5	48	33.5	40.7	104.5	31			10	Calcu		
31																		
Totals.			873.15	630.8	1073.4	1354.9	557.4	1463.3	1092.6	1277.3	2835.6	986.0	14.74		190			
Means.			29.10	54.3	35.7	45.1	18.3	48.7	36.4	42.5	94.5	32.8			6.3			
No. of Column.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		

Thermometers compared with Standard on _____

Corrections from Observation.

Max. D. Th. No. _____ Cor. _____

Max. W. " " " " " "

Min. D. " " " " " "

Min. W. " " " " " "

Summary of Wind, from Column No. 17.

N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.	Total Days.
0	4	0	0	6	10	1	4	5	30

Barometer No. _____

Barometer Corrections. _____

Gales or High Winds occurred on High wind on 25th

Thunder on 18th

Remarkable Rain on _____

Snow fell on 24th

Hail fell on 25th

Fog on _____

Earthquakes From 10th to 24th at frequent intervals direction

Auroras, Meteors, &c. Consistent from N.W. to S.E.

(Signed) W. J. Genders Observer.

Supplementary Figure 11. Meteorological record for Rotorua in June 1886. The remarks on 10 June describe onset of earthquakes and direction of shaking, with comments about Lake Rotorua rising 18 inches and other hot springs increasing in temperature and volume coinciding with the eruption. From the NIWA national climate archive courtesy of Gregor Macara.