

Appendix D. Supplementary Material to Support Chapter 4

Table D1 shows additional earthquake swarms and earthquakes of $M4-6$ from 1953 to 1967.

Table D2 summarizes tilt volume, eruption efficiency, and magma supply rate during 1950–1967.

Table D3 summarizes tilt data for deformation centers plotted in text figures 4.2 and 4.3.

Figures D1 and D2 show earthquake swarms using the same data as in text figures 4.1 and 4.9

Figures D3A–N show the same data as text figures 4.1 and 4.9 plotted at 1-year intervals.

Figures D4A–N show earthquake swarm data as in figures D1 and D2 plotted at 1-year intervals, but beginning 3 years earlier at 1 February 1950

Figures D5–9 show time series plots of earthquakes associated with eruptions and traditional intrusions between 1954 and 1965.

Figures D10–17 show map plots of earthquakes associated with eruptions and traditional intrusions between 1954 and 1965.

Figures D18–25 show map plots of deep (20–35 km, m_s4) earthquake swarms in and near the magma supply path, organized chronologically.

Appendix Table D1ⁱ. Additional earthquake data, 1953-1967

Date begin	Date end	Class. ⁱⁱ	Type ⁱⁱⁱ	No. ^{iv}	Tilt ^v	Lag ^{vi}	Comment	Ref. ^{vii} ; Fig.
6/15/1953	9/16/1953	ms5gln	eqs?				Earthquakes with similar arrival pattern to the later documented deep swarms	(1)
04:17 10/25/1953 17:26 10/26/1953 04:30 10/27/1953 06:20 10/27/1953 04:47 10/29/1953	14:13 10/25/1953 06:20 10/27/1953 14:42 11/1/1953	er2 sf3 sf3 sf3 koae	II? eq eq II?	3 6 4	inflati on		additional er3 event at 17:51 10/26 additional sf2 event at 03:37 10/27 M 4.51 M 4.11 3 additional er3, er4, sf4 events	(1)
15:38 11/28/1953		ms2	eq				M 4.03; additional M 3.85 event at 19:44 11/29	(1)
20:43 11/29/1953		sf2	eq				M 4.40	(1)
01:56 12/1/1953	01:54 12/3/1953	ms5gln	eqs	21				(1)
03:29 12/8/1953	10:43 12/9/1953	ms1	eqs	7	flat tilt			(1)
06:27 4/15/1954	07:15 4/15/1954	ms1	eqs	5				(1)
5/1/1954	5/31/1954	er1	eqs	24			See above—events with no date/time	(1)
6/1/1954	6/30/1954	er1	eqs	24			See above—events with no date/time	(1)
20:20 6/18/1954 6/18/1954	21:42 6/18/1954 6/21/1954	ms5gln ms5gln	eqs eqs	4 23			located earthquakes minimum number of additional unlocated events	(1); 4.1ab, 4.5c
7/1/1954	7/31/1954	er1	eqs	22			See above—no date/time; 2 located on 7/22	(1)
11:52 7/3/1954		sf2	eq				M 5.24	(1)
8/1/1954	8/31/1954	er1	eqs	24			See above—no date/time; 1 located on 8/16	(1)
13:40 8/2/1954		er3	eq				M 4.09	(1)
14:25 8/7/1954		ms4kc	eq				M 5.0; 25 km deep	(1)
8/30/1954		er2	eq				M 4.08	(1)
9/1/1954	9/30/1954	er1	eqs	24			See above—no date/time; 2 located 9/7, 25	(1)
10/1/1954	10/31/1954	er1	eqs	21			See above—no date/time; 2 located on 10/9, 16	(1)
10/7/1954		er3	eq				M 4.02	(1)
11/1/1954 07:47 11/23/1954 02:30 11/26/1954	11/30/1954 08:21 11/23/1954 05:50 11/26/1954	er1 er1 er1	eqs eqs eqs	>80 20 41			see above—no date/time; 1 located 11/27 2 located, others no date/time 3 located, others no date/time	(1)
12/1/1954	12/31/1954	er1	eqs	76			See above—no date/time; 3 located 12/14, 22, 27	(1)
06:35 12/4/1954	20:59 12/5/1954	ms5gln	eqs	>200			3 located in large swarm	(1)
1/1/1955	1/31/1955	er1	eqs	178			See above—no date/time; 6 located 1/8-11, 22-31	(1)
15:44 1/6/1955	18:33 1/6/1955	er2	eq	2			located	(1)
02:54 1/21/1955	22:00 1/21/1955	er2	eq	3			located; 1 located 06:18 1/27	(1)
2/1/1955	2/23/1955	er1	eqs	127			See above—no date/time	(1)
01:00 2/12/1955	06:00 2/12/1955	er1	eqs	52			no date/time	(1)
2/17/1955	2/17/1955	er1	eqs	171			no date/time	(1)
13:58 2/23/1955		ms4kc	eq				M 4.08; 25 km deep; 1 sf3 on 19:17 2/21	(1)
14:21 3/1/1955		er2	eq				M 4.51; 1 er3 event at 14:32 3/4	(1)
00:00 3/8/1955	23:59 3/8/1955	er1	eqs	326			no time; 1 located at 20:03	(1.3)

Date begin	Date end	Class. ⁱⁱ	Type ⁱⁱⁱ	No. ^{iv}	Tilt ^v	Lag ^{vi}	Comment	Ref. ^{vii} 0; Fig.
00:00 3/9/1955	23:59 3/9/1955	erl	eqs	601			no time; 2 sf2 at 09:16, 21:08, M 3.5, 3.8	(1.3)
00:00 3/10/1955	23:59 3/10/1955	erl	eqs	1385			no time	(1.3)
00:00 3/11/1955	23:59 3/11/1955	erl	eqs	76			no time	(3)
00:00 3/12/1955	23:59 3/12/1955	erl	eqs	11			no time	(1)
00:00 3/13/1955	23:59 3/13/1955	erl	eqs	9			no time	(1)
00:00 3/14/1955	23:59 3/14/1955	erl	eqs	6			no time; intermittent to 3/29/1956	(1)
00:00 3/16/1955	23:59 3/16/1955	msl	eqs	21			no time	(1)
01:00 3/17/1955	13:35 3/17/1955	msl	eqs	9			6 located; 3 unlocated erl	(1)
09:54 3/18/1955	22:43 3/18/1955	msl	eqs	48			3 located	(1)
00:00 3/19/1955	23:59 3/19/1955	msl	eqs	18			1 located at 18:03; 1 erl located at 12:09	(1)
00:00 3/20/1955	23:59 3/20/1955	msl	eqs	6			1 located at 18:10	(1)
00:00 3/21/1955	23:59 3/21/1955	msl	eqs	51			no time	(1)
00:00 3/22/1955	23:59 3/22/1955	msl	eqs	52			no time; 2 erl located at 00:42, 20:46	(1)
00:00 3/23/1955	23:59 3/23/1955	msl	eqs	324			2 at 00:10, 07:54; 3 erl at 02:06, 03:42, 12:08	(1)
04:27 3/25/1955	08:55 3/25/1955	msl	eqs	590			8 located; 1 ms5gln at 20:17	(1, 3); 4.4 e
3/26/1955		msl	eqs	1103			no time	(1)
00:00 3/26/1955	23:59 3/26/1955	ms5gln	eqs	>197			1 located at 06:34	(1)
00:00 3/27/1955	23:59 3/27/1955	msl	eqs	482			no time; 1 at 09:23, 1 ms2 at 16:02	(1)
00:00 3/28/1955	23:59 3/28/1955	msl	eqs	278			1 at 20:39	(1)
00:00 3/29/1955	23:59 3/29/1955	msl	eqs	165			no time	(1)
00:00 3/30/1955	23:59 3/30/1955	msl	eqs	111			no time; 1 at 16:57	(1)
00:00 3/31/1955	23:59 3/31/1955	msl	eqs	44			44 events w no time—see above	(1)
04:24 4/1/1955		ms4kc msl	eq eqs	88			M 5.1 30 km deep; M 3.6 as at 04:35 no time	(1)
00:00 4/2/1955	23:59 4/2/1955	msl	eqs	77			no time; 2 at 05:09, 06:37	(1)
00:00 4/3/1955	23:59 4/3/1955	msl	eqs	10			no time	(1)
01:27 4/7/1955		ms4kc	eq				M 4.25	(1)
8/9/1955	8/10/1955	ms5gln	eqs	>600			1 located at 21:33 8/9	(1)
02:28 8/14/1955		ms4kc	eq				M 5.84 25 km deep	(1)
12/12/1955	12/13/1955	ms5gln	eqs	>200			1 located at 12:33 12/12	(1)
4/18/1956	4/19/1956	ms5gln	eqs	small				(1, 5)
4/24/1956	4/30/1956	msl	eqs	small	tilt flat		a sequence of tiny, shallow eq	(1, 5)
00:00 6/30/1956	23:59 6/30/1956	ms5gln	eqs	>300				(1, 5)
7/25/1956	8/1/1956	msl	eqs	780			Tilt 7/27-28	(1, 6)
07:05 10/25/1956		ms4kc	eq				M 3.97 30 km deep	(1, 8)
14:03 2/11/1957		sf3	eq				M 4.0 30 km deep	(1, 9)
9/9/1957		ms5gln	eqs	>10				(1)
9/14/1957	9/15/1957	ms5gln	eqs	>182				(1)
2/15/1958		ms4sf4	eq				M 4.10 35 km depth	(1)
04:00 4/1/1958	18:00 4/1/1958	ms5gln	eqs	>200			time bracketed	(1)
23:32 7/3/1958	13:25 7/6/1958	ms5gln	eqs	>2100			50 located ^{viii}	(1)
23:43 10/22/1958	17:24 10/24/1958	sf2	eq				offshore; M 4.41, 5 as 1 M 4.47	(1)
11/2/1958		ms4kc	eq				M 4.40 30 km depth	(1)
15:41 1/5/1959	19:30 1/6/1959	ms5gln	eqs	>600			29 located	(1)
20:00 2/19/1959		sf2	eq				M 4.69; foreshock at 19:58, as at 20:35	(1)

Date begin	Date end	Class. ⁱⁱ	Type ⁱⁱⁱ	No. ^{iv}	Tilt ^v	Lag ^{vi}	Comment	Ref. ^{vii} ; Fig.
00:00 5/5/1959	23:59 5/5/1959	ms5gln	eqs	>60			no time	(1)
23:44 8/14/1959	04:34 8/18/1959	ms5gln	eqs	>2300			280 located ^{ix} ; eqs to 8/20--no times	(1)
9/18/1959		er2	eq				M 4.00	(1)
10:07 12/12/1959	12/15/1959	ms5gln	eqs	56			located; 43.57±2.24 km depth	
10:07 1/26/1960	03:19 1/29/1960	ms1	eqs	28			broken eqs; cont. summit subsidence deepening swarm	(11)
23:04 1/27/1960	03:29 3/11/1960	ms2	eqs	19				
09:10 1/29/1960		sf3	eq				M 4.18	
13:05 1/29/1960	00:57 2/6/1960	ms1	eqs	170			broken swarm	
12:35 2/6/1960	18:12 2/29/1960	ms1	eqs	131				
16:35 2/12/1960		sf3	eq				M 4.11	
01:27 3/1/1960	14:31 3/3/1960	ms1	eqs	51			broken swarm more: 1/26, 2/17, 3/23, 26, 31, 4/5, 17 scattered; also on 1/25, 2/21, 3/1-2	
23:59 3/3/1960	09:26 6/19/1960	ms1	eqs	121				
15:04 3/5/1960	21:51 3/5/1960	ms4	eqs	3				
10:45 3/13/1960	19:06 4/11/1960	ms3	eqs	9				
23:16 6/14/1960	09:26 6/19/1960	ms1	eqs	21			broken swarm; continued summit subsidence	(11)
12:07 12/13/1960	19:48 12/13/1960	ms4	eqs	6			M 4.06 at 12:07	(11)
09:31 1/8/1961	00:28 6/28/1961	ms4	eqs	43			Elevated deep magma supply seismicity; small swarms of 3 events on 5/14, 16, 6/10, 18; average for entire period of 1.79 per week	(11)
00:32 5/28/1961		sf3	eq				M 4.11	(11)
17:00 7/24/1961	11:48 11/1/1961	ms4.5	eqs	29			continued deep magma supply; 2.03 per week	(11)
06:48 8/21/1961	16:10 8/22/1961	ms1	I?	7	2.6 331		Tilt 8/20-25; broken swarm	(11)
19:25 9/24/1961		sf2	eq				M 4.42 38.5 km; mantle eq (not magma supply)	(11)
02:58 1/7/1962		sf2	eq				M 4.23	(11)
10:21 2/7/1962	20:40 2/7/1962	ms4	eqs	5			5 preceding on 2/4 (2), 2/5, 2/6, 2/7	(11)
18:16 3/31/1962		ms4	eq				M 4.48	(11)
07:49 6/12/1962	14:19 6/16/1962	ms4	eqs	11			broken swarm; M 4.03 6/13 16:35	(11)
16:51 11/17/1961	09:41 11/18/1961	ms4.5	eqs	7			8 on 11/5 (3), 11/10 (2), 11/16 (3) 1 more at 11/21 16:11 M 4.11 23.7 km (first eq in swarm) broken swarm broken swarm	16 ms4.5-3
13:25 11/20/1961	03:42 11/21/1961	ms4	eqs	7				
23:23 11/21/1961	07:25 11/23/1961	ms4	eqs	21				
22:42 12/28/1961	23:08 12/30/1961	ms4	eqs	17				
19:07 1/1/1962	16:19 1/3/1962	ms4	eqs	6				
00:12 6/22/1962	2:15 6/22/1962	sf2	eqs	5			deep rift intrusion?; more on 6/21, 23 (4), 26, 27	(11); 16 si-1
22:12 6/24/1962	23:48 7/1/1962	ms4	eqs	9			broken swarm	(11)
03:06 7/14/1962	04:59 12/27/1962	ms4.5	eqs	44			scattered; 1.85 earthquakes per week	(11)
16:08 11/20/1962	12:05 11/23/1962	sf2	eqs	8			slow intrusion? broken swarm; M 4.05, 4.28	(11); 16 si-2
12:12 1/14/1963	04:02 12/31/1963	ms4	eqs	56			scattered; 1.12 earthquakes per week	(11)
00:11 8/4/1963	07:17 8/4/1963	sf3	SI?	4			slow intrusion?; 2 more on 8/3, 5	(11); 16 si-3
06:19 1/3/1964	13:19 11/24/1964	ms4.5	eqs	49			scattered--1.05 earthquakes per week	(11)
01:06 1/7/1964		sf3	eq	4			eq with as?; M 4.45, 2 on 1/8, 10	(11)
10:43 7/1/1964		sf2	eq				M 4.36	(11)
06:28 8/16/1964		ms4	eq				M 4.40	(11)
00:25 9/18/1964	02:22 9/18/1964	sf2	eqs	3			deep rift intrusion?; 6 on 9/14, 16, 18, 19, 22, 24	(11); 16 si-4
01:54 12/10/1964		sf2	eq				M 4.86	(11)
06:10 2/7/1965	17:55 2/8/1965	sf2	eqs	7			deep rift intrusion?; 1 more on 2/5	(11); 16 si-5.6
04:21 9/16/1965	14:22 9/17/1965	ms4	eqs	5			broken swarm	(11)
07:29 11/13/1965	18:21 11/13/1965	sf3	SI	7			also 11/12 (3), 14 (2)	(11); 16 si-10

Date begin	Date end	Class. ⁱⁱ	Type ⁱⁱⁱ	No. ^{iv}	Tilt ^v	Lag ^{vi}	Comment	Ref. ^{vii} ; Fig.
		ms4	eq				M 4.03	
05:22 8/19/1966	06:26 8/19/1966	ms4.5	eq	3			M 4.08 (first eq in series); 8/20, 21, 22, 23 (2)	(11)

ⁱ Bibliographic reference file “wf kil ms.scienceen9.enl”

ⁱⁱⁱ Earthquake classification abbreviations are given according to the classification in Appendix table 4 and locations are shown on Appendix figure 2

ⁱⁱⁱ Eruption (E); intrusion (I); Earthquake $\geq$ M5 (EQ); Earthquake swarm (EQS); Collapse of Kīlauea’s summit (C)

^{iv} Minimum number of events defining a swarm: 20 for south flank; 10 for all other regions

^v Magnitude in seconds and azimuth of daily tilt measurements from the Bosch-Omori tiltmeter in Whitney vault (1953-1957); water-tube tiltmeter in Uwēkahuna vault (1957-1967)

^{vi} Lag times compare onset of tilt deflection and the beginning of an eruption or earthquake swarm. (+) tilt leads, (-) tilt lags. Instruments in Uwekahuna vault: Press-Ewing seismometer (PE); Ideal-Arrowsmith tiltmeter E-W component (IA).

^{vii} References coded as follows: (1) (Klein and Wright, 2000, additional references given), (3) (Macdonald and Eaton, 1964), (5) (Macdonald and Eaton, 1956), (6) (Eaton and Byerly, 1957), (8), (Eaton and Fraser, 1957), (9) (Eaton and Fraser, 1957), (11) HVO seismic catalog

^{viii} Seismic network now sufficient to locate larger events—total number of events given with number of located events in comment column

^{ix} Beginning in the third quarter of 1959 earthquake data are taken from the modern catalog for which earthquakes were relocated in 2006. Prior to that time earthquake data is from the catalog compiled by F.W. Klein and T.L. Wright (Klein and Wright, 2000).

Appendix table D2. Tilt volume, E efficiency and magma supply rate 1950-1967

a. Whitney tilt data

Cycle	Event ⁱ	begin date	end date	Δt (yr)	T _{mag} ⁱⁱ	T _{az}	T _{vol} ⁱⁱⁱ	E _{vol} ^{iv}	E _{eff} ^v	msr ^{vi}	Comment
1950-1952	Net	3/5/1950	6/27/1952	2.3135	135.5	27.85	.0870				Pre-eruption inf
	Inf	3/5/1950	9/15/1950		111.5	^{viii}					
	Def	9/15/1950	12/8/1950		13.7	32.7	.0088				
	Def	12/8/1950	12/16/1950		78.9	218.1	.0507				
	Inf ^{vii}	12/16/1950	6/26/1952	2.3135	106.2	210.0					
	Sum					34.4	.1465				
	E	6/27/1952	11/10/1952	0.37045				.0370		.063 .100	Pre-eruption msr Halema'uma'u filling rate
1952-1955	Net	6/26/1952	2/19/1955	2.6475	78.8	355.46	.0506				Pre-eruption inf
	Def	6/26/1952	10/2/1952		50.3	193.37	.0323				
	Def	3/10/1954	3/24/1954		12.7	199.96	.0082				
	E	5/31/1954	6/3/1954	.00808				.0050			
	Def	5/31/1954	6/1/1954		5.5	249.80	.0025				
	Def	12/13/1954	1/17/1955		17.7	198.19	.0114				
	Sum			2.6475			.0943				
	E	2/28/1955	5/26/1955	0.2382				.0701	0.69	.036	Pre-eruption msr E rate: .2942 km ³ /yr
1955-1959	Net	2/19/1955	11/14/1959	4.7337	129.8	168.13	.0834				Pre-eruption <i>def</i>
	Def	2/19/1955	3/8/1955		9.5	184.43	.0061				
	Def	3/8/1955	4/13/1955		148.2	211.29	.0952				
	Sum	2/19/1955	4/13/1955		157.6		.1013				
	Def	4/13/1955	12/29/1955		74.9	160.66	.0481				Draining of uer?
	Def	2/19/1955	12/29/1955		213.4	194.35	.1371				
	Def	8/31/1959	11/14/1959		16.9	203.47	.0011				
	Sum			4.7337			.2876	.0298		.061	Pre-eruption msr E rate: .3066 km ³ /yr
	E	11/14/1959 ^{ix}	12/20/1959	0.0972							
1959-1960	Net	11/15/1959	1/17/1960	.1752	16.1	252.27	.0103				Pre-eruption <i>def</i>
	Def	11/15/1959 ^{ix}	11/23/1959		33.1	224.34	.0213				Episode 1 def
	Inf	11/23/1959	12/23/1959		36.1	28.13					Episodes 2-17 inf
	Def	12/23/1959	12/29/1959		7.8	229.89	.0050				Continued def
	Def	12/29/1959	1/17/1960		8.2	209.74	.0053				Continued def
	Sum	11/15/1959	1/17/1960	.1752			.0316				Pre-eruption msr
	E	1/13/1960	2/19/1960	.1013				.0906	.64	.180	E rate: .8944 km ³ /yr
1960-1961	Net	1/17/1960	9/21/1961	1.6783	68.1	197.17	.0438				Pre-eruption inf
	Def	1/17/1960	2/11/1960		151.7	213.73	.0974				
	Def	2/11/1960	5/8/1960		69.8	201.28	.0448				
	Avg	1/17/1960	5/8/1960		221.5		.1422				
	Def?	5/8/1960	10/21/1960		14.7	109.34	.0066				
	Def	11/4/1960	11/11/1960		9.5	242.58					
	E	2/24/1961	2/25/1961	.000889				.00002			
	E	3/3/1961	3/5/1961	8				.0002			
	E	7/10/1961	7/17/1961	.060005				.0101		.1160	Pre-eruption msr
	E	9/22/1961	9/25/1961	.018309 0.0082	151.1	29.63		.0018	.03		E rate: .2195 km ³ /yr
1961-1962	Net	9/21/1961	12/6/1962	1.2074	46.2 ^x	241.13	.0297				Pre-eruption <i>def</i> ^{xi}
	Def	9/21/1961	9/30/1962		92.9	225.96 ^x	.0597				
	Sum	9/21/1961	12/6/1962	1.2074			.0597				Pre-eruption msr
	E	12/7/1962	12/9/1962	0.0071				.00025	.053	.0494	
	Def	12/6/1962	12/9/1962		7.3		.0047				
1952-1960	Net	6/26/1952	1/17/1960	7.5592	31.1	114.53	.0200				Net <i>def</i>
	Def						.2270				Total incremental def
	Sum			7.5592			.2270	.0718		.0395	Average msr
1952-1961	Net	6/26/1952	9/21/1961	9.2367	78.4	174.01	.0504				Net <i>def</i>
	Def						.3675				Total incremental def
	Sum			9.2367			.3675	.0821		.0487	Average msr

b. Uwēkahuna tilt data

Cycle	Event ⁱ	begin date	end date	Δt (yr)	T_{mag}^{ii}	T_{az}	T_{vol}^{iii}	E_{vol}^{iv}	E_{eff}^v	msr^{vi}	Comment
1959-1960	Net Def Sum E	11/14/1959 11/14/1959 11/14/1959 1/13/1960	1/17/1960 11/22/1959 1/17/1960 2/19/1960	0.1752 0.1752 0.1013	26.1 19.3	348.65 104.42	.0118 .0087 .0205			.117	Pre-eruption inf Episode 1 def Pre-eruption msr E rate: .8944 km ³ /yr
1960-1961	Net Def Def Def Avg Def E E E Sum E	1/17/1960 1/17/1960 2/11/1960 5/8/1960 1/17/1960 11/5/1960 2/24/1961 3/3/1961 7/10/1961 1/17/1960 9/22/1961	9/21/1961 2/11/1960 5/8/1960 10/21/1960 10/21/1960 11/10/1960 2/24/1961 3/25/1961 7/17/1961 9/21/1961 9/25/1961	1.6783 1.6783 1.6783 1.6783 1.6783 1.6783 .000890 .006001 .018309 1.6783 0.0082	39.9 225.7 104.9 37.7 344.2 12.9	110.08 116.74 133.05 188.08 127.68 106.12	.0180 .1015 .0472 .0169 .1548 .0058			.113	Pre-eruption inf Pre-eruption msr E rate: .2195 km ³ /yr
1961-1962	Net Def Def Sum E	9/21/1961 9/21/1961 10/28/1961 12/7/1962	12/6/1962 9/30/1961 11/4/1961 12/9/1962	1.2074 1.2074 0.00705	63.0 173.2 10.3	164.66 135.82 128.32	.0283 .0779 .0046 .0825			.0683	Pre-eruption <i>def</i> Pre-eruption msr
1962-1963	Net Def Def Def Sum E Net Def Sum E	12/6/1962 12/6/1962 5/8/1963 6/28/1963 8/21/1963 8/21/1963 8/11/1963 10/5/1963	8/21/1963 12/9/1962 5/12/1963 7/2/1963 8/23/1963 10/4/1963 8/22/1963 10/6/1963	.7064 .7064 0.00433 0.12047 0.12047 0.0326	30.3 20.5 35.0 19.0 104.8	4.95 130.50 126.27 122.07	.0136 .0092 .0157 .0085 .0471			.0667 .1292	Pre-eruption inf Pre-eruption msr Pre-eruption inf Pre-eruption msr
1963-1965	Net Def Def Def Sum E Net Def Sum E	10/4/1963 10/4/1963 11/11/1964 11/27/1964 3/5/1965 3/5/1965 3/5/1965 12/24/1965	3/5/1965 10/10/1963 11/18/1964 12/1/1964 3/15/1965 12/23/1965 3/9/1965 12/25/1965	1.4182 24.2 583.7 219 .80219 .000913	114.9 390.8 54.3 5.0 583.7	294.52 124.36 121.48 121.06 160.44 128.36	.0107 .0362 .0050 .0022 .0541 .0208 .0395 .0395			.0382 .0492	Pre-eruption inf Pre-eruption msr Pre-eruption <i>def</i> Pre-eruption msr
1965-1967	Net Def Def Def Sum E	12/23/1965 12/23/1965 10/1/1966 8/9/1967 11/5/1967	11/5/1967 12/29/1965 10/7/1966 8/18/1967 7/15/1968	1.8672 1.8672 .69268	390.8	327.41 99.37 139.40 120.85	.0555 .0213 .0044 .0038 .0850			.0455 .1083	Pre-eruption inf Pre-eruption msr Halema'uma'u filling rate
1960-1967	Net Def Sum	1/17/1960	11/5/1967	7.8001	54.3	312.14	.0192 .3925 .4117			.0528	Net inf Average msr Net inf
1961-1967	Net Def Sum	9/21/1961	11/5/1967	6.1218 6.1218		301.48	.0364 .2319 .2683	.0103		.0438	Average msr

ⁱ Abbreviations (also in comment column): avg=average; inf=inflation; def=deflation; trans=transfer; I=intrusion; E=eruption; ks=Kīlauea's summit; erz=East rift zone; uer=upper east rift zone; swr=Southwest rift zone; kfz=Koa'e fault zone

ⁱⁱ Whitney tilt magnitude in microradians

ⁱⁱⁱ The tilt volume in cubic kilometers=Whitney tilt magnitude/0.7 (Uwēkahuna equivalent magnitude)*.00045 (see text for explanation)

^{iv} Values are equivalent magma volume obtained by multiplying published volumes by 0.8 to account for vesiculation

^v Eruption efficiency calculated for non-sustained rift eruptions as erupted volume/deflation volume associated with the eruption. For consistency eruption efficiencies are only calculated using the Uwēkahuna tilt.

^{vi} Minimum magma supply rate calculated as described in text. The volume equivalent for pre-eruption inflation is added to the sum of volume equivalents for subsequent deflations and then divided by the elapsed time. Values used in the calculation are shown in **bold** text. The volume equivalent of pre-eruption *deflation* (italics used for emphasis) is not used as it is already included in the deflation sum.

^{vii} Ignore deflationary period from 10/31/1951-12/16/1951 (30.4 yr at azimuth 218.3)—central south flank M 4.5 earthquake on 12/6/1951 affected tiltmeter (4.1 second subsidence at azimuth 152.6—toward earthquake source region)

^{viii} Values corrected for effects of south flank earthquake of 12/6/1951. N-S—add 3.63; E-W—subtract 1/88.

^{ix} Whitney tilt offset at beginning of eruption. Tilt after 11/14/1959 calculated from the value for 11/15 by comparison with the tilt record at Uwēkahuna

^x Tilt corrected for two offsets on 11/19-21/1961 and 11/21-22/1962

^{xi} Whitney tilt offset between 11/21 and 11/22 1962. Tilt to 12/6 corrected by taking the 11/21 value and adding the difference in the N-S and E-W components between 11/22 and 12/6.

Appendix Table D3. Tilt data for deformation centers plotted in figures 4. 2 and 4.3

Date begin	Date end	Tilt ¹		Location	Comment
		magnitude	azimuth		
6/27/1952	2/27/1955	15.91	355	Whitney	Center A in figure 4.2
12/4/1952	1/7/1953	4.2	199	Whitney	Center B in figure 4.2 is the mean of three azimuths for small deflations extrapolated to an assumed point within the Fiske-Kinoshita array.
1/6/1954	2/5/1954	2.3	180		
12/13/1954	1/17/1955	3.7	198		
3/7/1955	4/13/1955	31.3	211	Whitney	Center C in figure 4.2.
2/28/1955	11/14/1959	26.5	168	Whitney	Center D in figure 4.2.
11/14/1959	11/15/1959	9.8	31	Whitney	Center E in figure 4.2: Whitney azimuth only.
11/14/1959	11/15/1959	1.5	169	Uwēkahuna	
11/15/1959	11/21/1959	5.9	229	Whitney	Center F in figure 4.6: intersection of Whitney and Uwēkahuna azimuths.
11/15/1959	11/21/1959	9.8	96	Uwēkahuna	
11/21/1959	11/24/1959	1.1	161	Whitney	Center H in figure 4.6.
11/24/1959	1/14/1960	4.2	11	Whitney	Center G in figure 4.6: intersection of Whitney and Uwēkahuna azimuths.
11/24/1959	1/14/1960	13.3	308	Uwēkahuna	
1/17/1960	7/1/1960	44.1	208	Whitney	Center I in figure 4.6: intersection of Whitney and Uwēkahuna azimuths. ²
1/17/1960	7/1/1960	74.4	123	Uwēkahuna	

¹ Magnitude in seconds and azimuth of daily tilt measurements from the Bosch-Omori tiltmeter in Whitney vault (1953-1957); water-tube tiltmeter in Uwēkahuna vault (1957-1967). 1 second of arc = 4.848 microradians (ur)

² Compare with the intersection of vectors from the long-base tiltmeter array (point J) and leveling done over a time period that includes most, but not all the deflation and that may include some pre-eruption inflation (point K).

Cross references, chapter 4 tables and appendix D map figures

[Table column heads are row “0;” only rows with information are counted; “do,” same as above; color coding indicates eruptions (red), traditional intrusions without eruption (blue); inflationary intrusions (green), and suspected deep intrusions (magenta)]

Chap. 4 page	Chap. 4 table	Row in table	App. D figure
60	4.1	8, 18,	D10
62	4.1 cont	12, 18, 23	D11
do	do	31	D12
do	do	27	D19
do	do	29	D20
63	4.1 cont	1	D21
do	do	2,3	D22
do	do	4	D23
do	do	6	D13
do	do	10	D24
do	do	21	D14
do	do	24	D15
do	do	30	D25
do	do	32	D16
64	4.1 cont	7	D17

Figure D1. 1953–1961 earthquake swarms. Plotted data are the same as in text figure 4.1. Short vertical lines correspond to 3–10 events for magma supply, koae and rift regions, >5–20 events for the south flank regions. Long vertical lines correspond to >10 events for magma supply, koae, and rift regions and >20 events for the south flank regions. Swarm data are plotted at exact beginning and ending times. Dates on figure in mm/dd/yyyy format.

Figure D2. 1961–1967 earthquake swarms. Plotted data are the same as in text figure 4.9. Short vertical lines correspond to 3–10 events for magma supply, koae, and rift regions, >5–20 events for the south flank regions. Long vertical lines correspond to >10 events for magma supply, koae, and rift regions and >20 events for the south flank regions. Swarm data are plotted at exact beginning and ending times. Dates on figure in mm/dd/yyyy format.

Figure D3A–N. 1953–1967. Earthquakes per day and magnitudes above 4 are shown at yearly intervals. Plotted data are the same as in text figure 4.1. Dates on figure in mm/dd/yyyy format.

Figure D4A–N. 1953–1967. Earthquake swarms are shown at yearly intervals. Plotted data are the same as in appendix figure D2. Dates on figure in mm/dd/yyyy format.

Figure D5. 1 March 1954–1 June 1955. Earthquake swarms showing the long buildup to the 1955 lower east rift eruption. Plotted data are the same as shown in text figure 4.4A. Swarm symbols are explained on the plot and in appendix figure D1. Dates on figure in mm/dd/yyyy format.

Figure D6. Earthquake swarms and tilt changes related to the 1959 and 1960 eruptions. Dates on figure in mm/dd/yyyy format.

Figure D7. 1 November 1960–1 November 1962. Earthquake swarms associated with the 1961 eruptions and intrusions. The top panel shows times of eruptions and intrusions with beginning times shown as dotted lines extending to the x axis. The second panel

shows tilt magnitude measured at the Uwēkahuna and Whitney Vaults. The bottom panels show, from bottom to top, magma-supply, rift and koae, and south flank earthquake swarms. The regions are separated by thin horizontal lines. Symbols for 1 or 2 events are given above the top panel of each plot. Earthquake swarm criteria are given next to the double-headed arrows. Dates on figure in mm/dd/yyyy format.

Figure D8. 1 November 1962–1 November 1963. Earthquake swarms associated with the 1962 and 1963 eruptions and intrusions. The top panel shows times of eruptions and intrusions with beginning times shown as dotted lines extending to the x axis. The second panel shows tilt magnitude measured at the Uwēkahuna and Whitney Vaults. The bottom panels show, from bottom to top, magma-supply, rift and koae, and south flank earthquake swarms. The regions are separated by thin horizontal lines. Symbols for 1 or 2 events are given above the top panel of each plot. Earthquake swarm criteria are given next to the double-headed arrows. Dates on figure in mm/dd/yyyy format.

Figure D9. 1 February 1965-1 February 1966. Earthquake swarms associated with the 1965 eruptions and intrusions. The top panel shows times of eruptions and intrusions with beginning times shown as dotted lines extending to the x axis. The second panel shows tilt magnitude measured at the Uwēkahuna and Whitney Vaults. The bottom panels show, from bottom to top, magma-supply, rift and koae, and south flank earthquake swarms. The regions are separated by thin horizontal lines. Symbols for 1 or 2 events are given above the top panel of each plot. Earthquake swarm criteria are given next to the double-headed arrows. Dates on figure in mm/dd/yyyy format.

Figure D10. Map showing locations of earthquakes associated with the summit eruption of 31 May-3 June 1954, including location of a *M*6.5 south flank earthquake on 30 March 1954. The aftershock zone is shown as a blue rectangle, the size of which is based on analogy with later, better documented south flank earthquakes. Dates on figure in mm/dd/yyyy format.

Figure D11. Map showing earthquake swarms 40-60 km deep following the 1960 eruption, which are co-located with earlier swarms shown in figure 4.7, all north of Kīlauea Caldera. All swarms include earthquakes shallower than 35 km located closer to Kīlauea Caldera than the earthquakes at depths >35 km. The earthquakes on 5–6 October are the last swarm of these deep earthquakes to be seen at Kīlauea, although a few more earthquakes at this location and depth occur through the end of 1960. See text for further explanation. Dates on figure in mm/dd/yyyy format.

Figure D12. Map showing locations of earthquakes before (blue), during (orange), and after (green) the eruption and intrusion of 22–25 September 1961. Symbol-coded depth ranges are shown on the plot. Dates on figure in mm/dd/yyyy format.

Figure D13. Map showing locations of earthquakes before (blue), during (orange), and after (green) the eruption and intrusion of 7–9 December 1962. Symbol coded depth ranges are shown on the plot. Dates on figure in mm/dd/yyyy format.

Figure D14. Map showing locations of earthquakes before (blue), during (orange), and after (green) the eruption and intrusion of 21–23 August 1963. Symbol coded depth ranges are shown on the plot. Dates on figure in mm/dd/yyyy format.

Figure D15. Map showing locations of earthquakes before (blue), during (orange), and after (green) the eruption and intrusion of 5–6 October 1963. Symbol coded depth ranges are shown on the plot. Dates on figure in mm/dd/yyyy format.

Figure D16. Map showing locations of earthquakes before (blue), during (orange), and after (green) the eruption and intrusion of 5–15 March 1965. Symbol coded depth ranges are shown on the plot. Dates on figure in mm/dd/yyyy format.

Figure D17. Maps showing locations of earthquakes before (blue), during (orange), and after (green) the eruption of 24 December 1965 and intrusion of 25–30 December 1965. Symbol coded depth ranges are shown on the plot. Dates on figure in mm/dd/yyyy

format. *A*, Data for 25–30 December from Boshier (1981). Data for 12/24 December obscured by tremor. *B*, U.S. Geological Survey data from 28 December 1965–2 January 1966.

Figure D18. Map showing deep (20–35 km) earthquake swarms during 1961 through 1965. Dates are distinguished by color and are labeled on the plot. Dates on figure in mm/dd/yyyy format.

Figure D19. Map showing deep (20–35 km) earthquake swarm, 29–30 June 1961. Seismicity is shown from 17 June to 3 July 1961. Earthquakes are color coded as to whether they occurred before the swarm date (blue), during the swarm (orange), or after the swarm (green). Dates on figure in mm/dd/yyyy format.

Figure D20. Map showing deep (20–35 km) earthquake swarm, 23–24 July 1961. Seismicity is shown from 23 to 29 July 1961. Earthquakes are color coded as to whether they occurred before the swarm date (blue), during the swarm (orange), or after the swarm (green). Dates on figure in mm/dd/yyyy format.

Figure D21. Map showing deep (20–35 km) earthquake swarm, 21–23 November 1961. Seismicity is shown from 20 to 25 November 1961. Earthquakes are color coded as to whether they occurred before the swarm date (blue), during the swarm (orange), or after the swarm (green). Dates on figure in mm/dd/yyyy format.

Figure D22. Map showing deep (20–35 km) earthquake swarm, 31 December 1961. Seismicity is shown from 28 December 1961 to 3 January 1962. Earthquakes are color coded as to whether they occurred before the swarm date (blue), during the swarm (orange), or after the swarm (green). Dates on figure in mm/dd/yyyy format.

Figure D23. Map showing deep (20–35 km) earthquake swarm, 9–11 May 1962. Seismicity is shown from 9 to 14 May 1962.

Earthquakes are color coded as to whether they occurred before the swarm date (blue), during the swarm (orange), or after the swarm (green). Dates on figure in mm/dd/yyyy format.

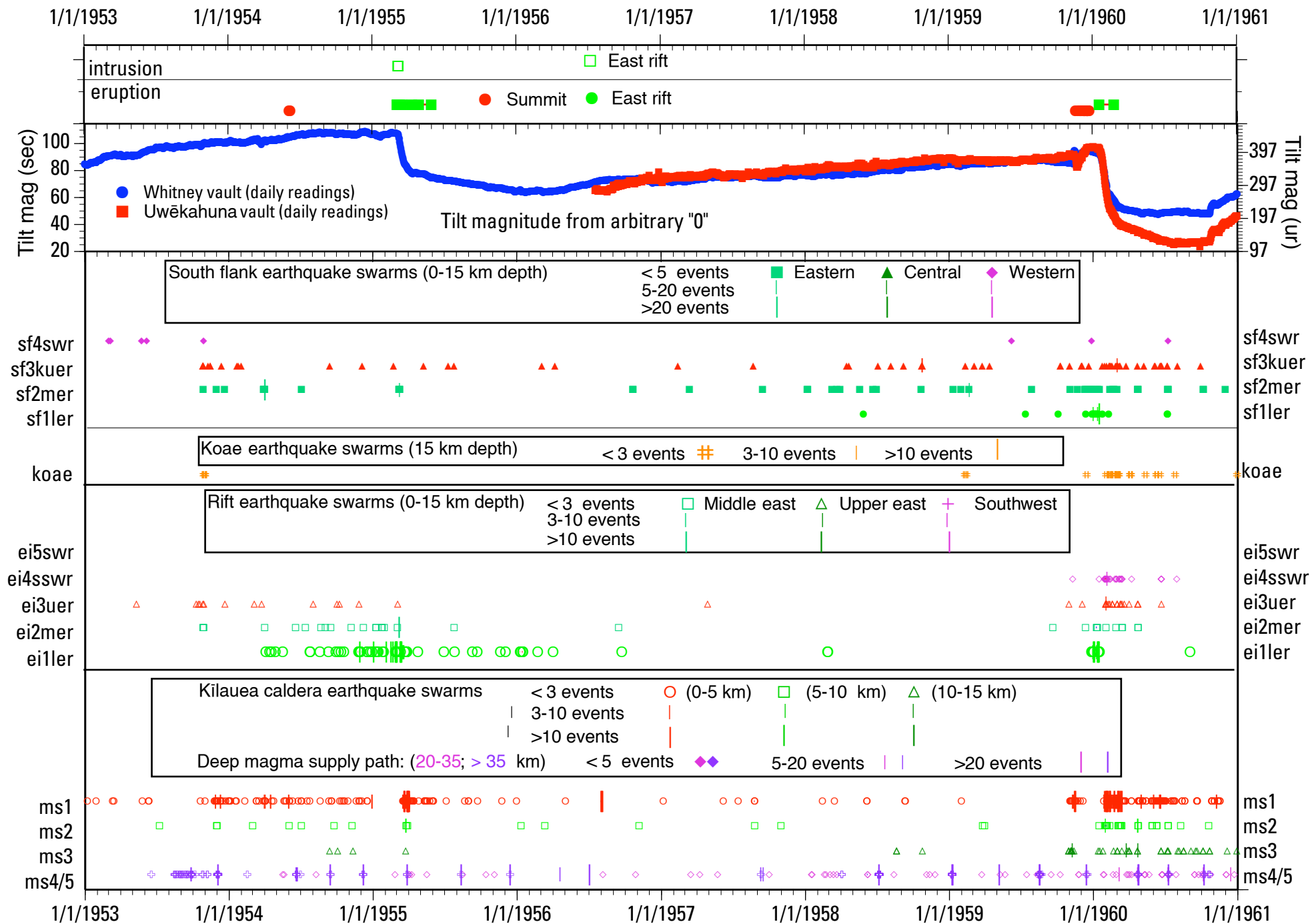
Figure D24. Map showing deep (20–35 km) earthquake swarm, 8 January 1963. Seismicity is shown from 8 to 14 January 1963.

Earthquakes are color coded as to whether they occurred before the swarm date (blue), during the swarm (orange), or after the swarm (green). Dates on figure in mm/dd/yyyy format.

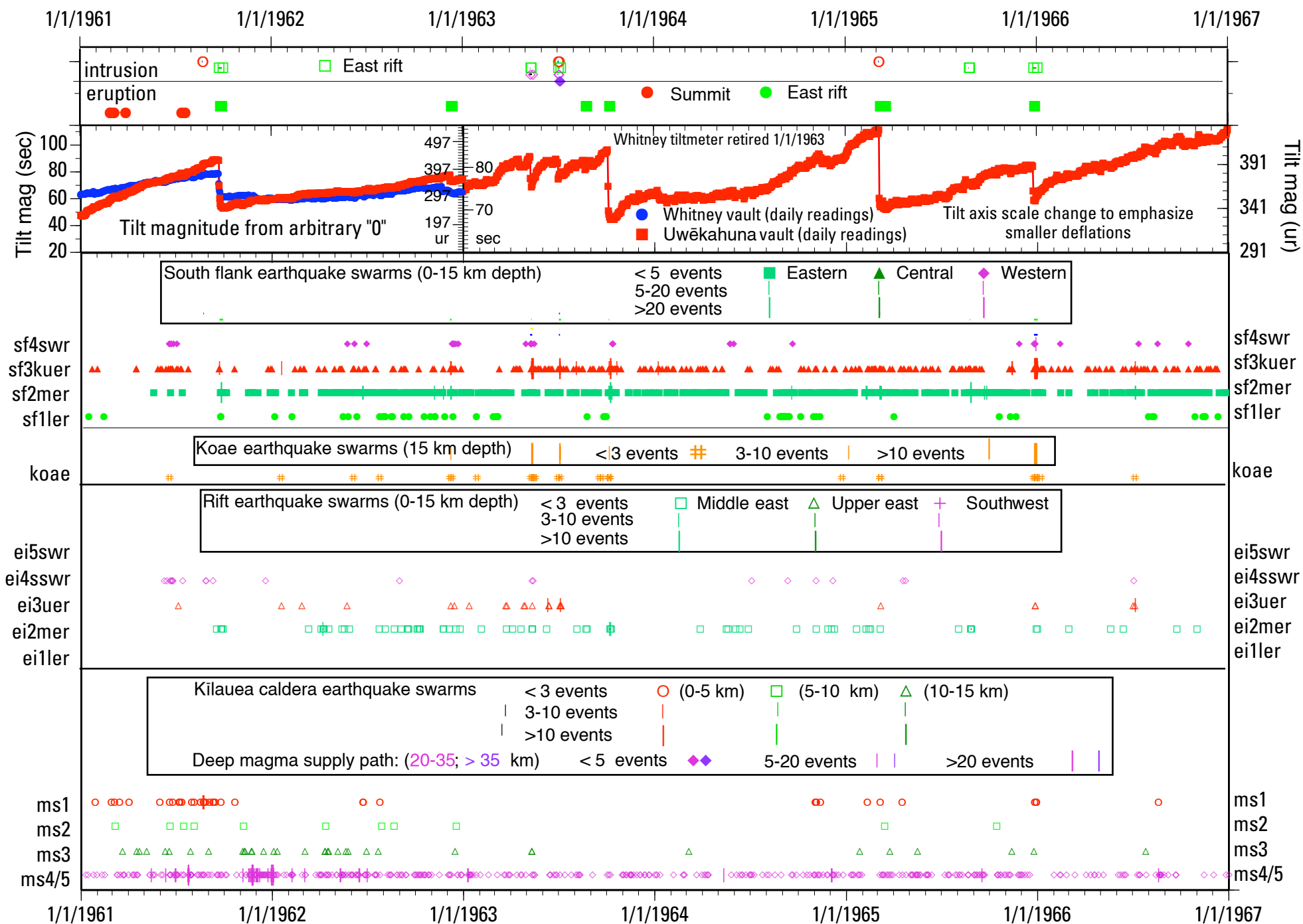
Figure D25. Map showing deep (20–35 km) earthquake swarm, 2–3 December 1964. Seismicity is shown from 12/2-4/1964.

Earthquakes are color coded as to whether they occurred before the swarm date (blue), during the swarm (orange), or after the swarm (green). Dates on figure in mm/dd/yyyy format.

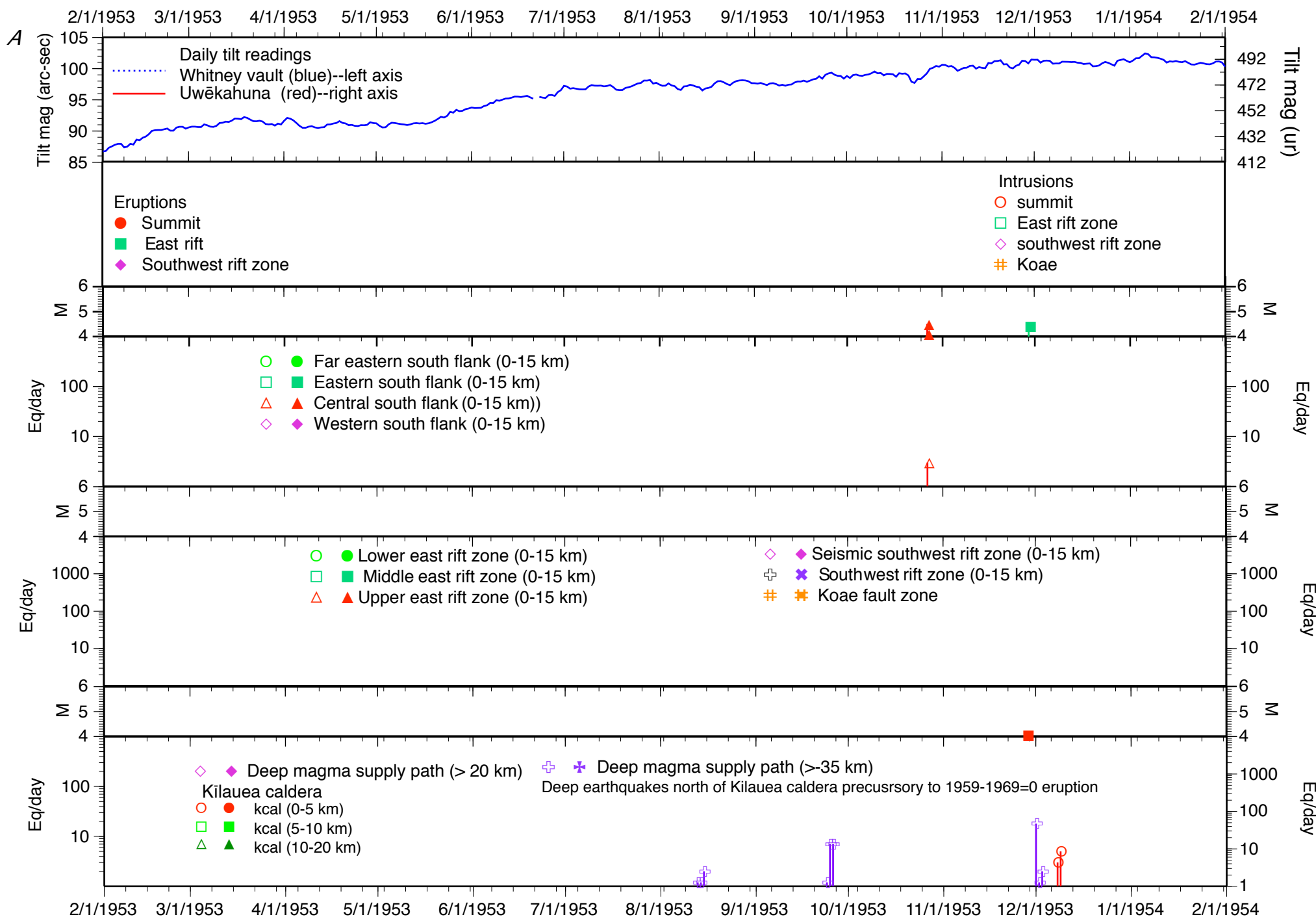
Appendix D Figure D1

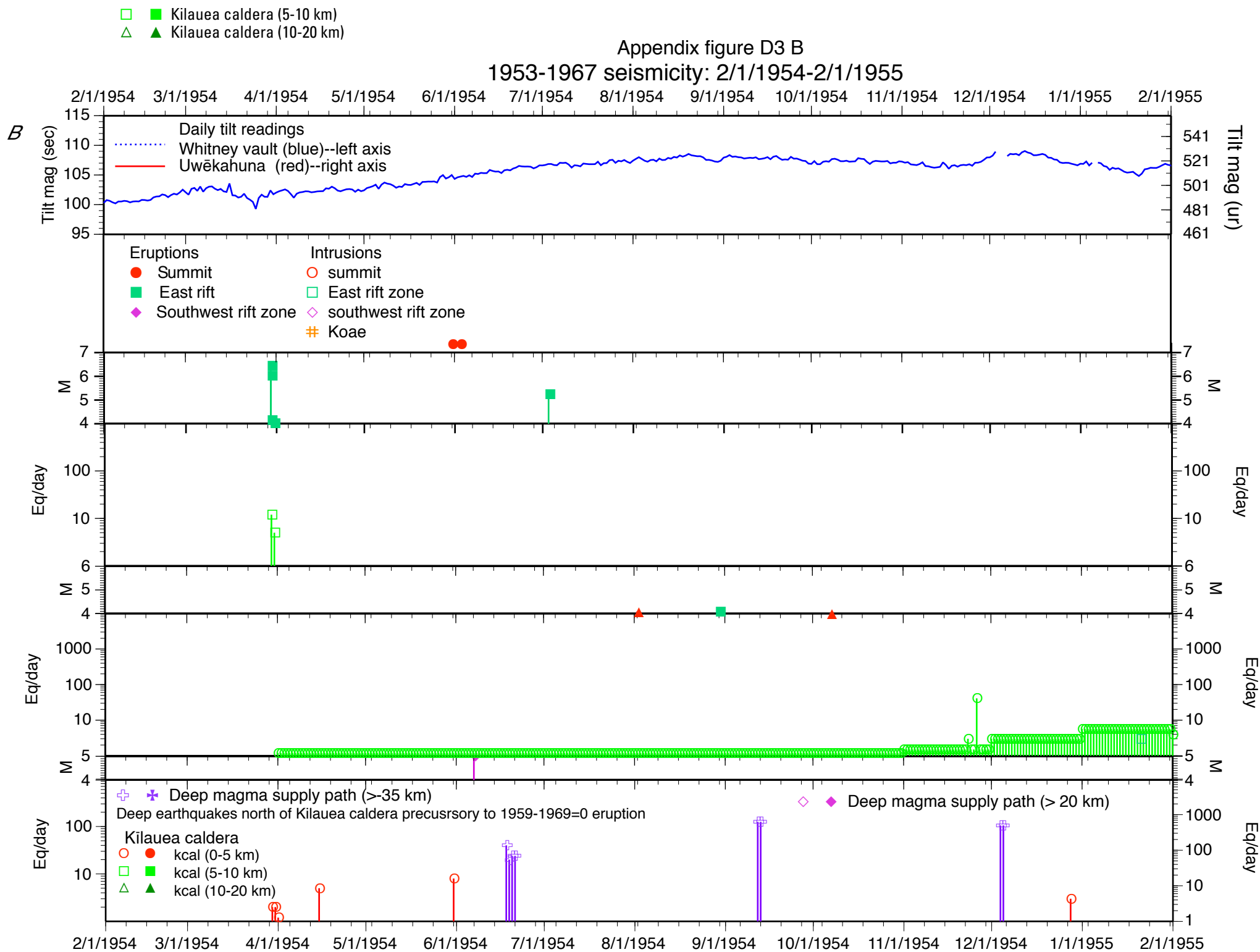


Appendix D Figure D2



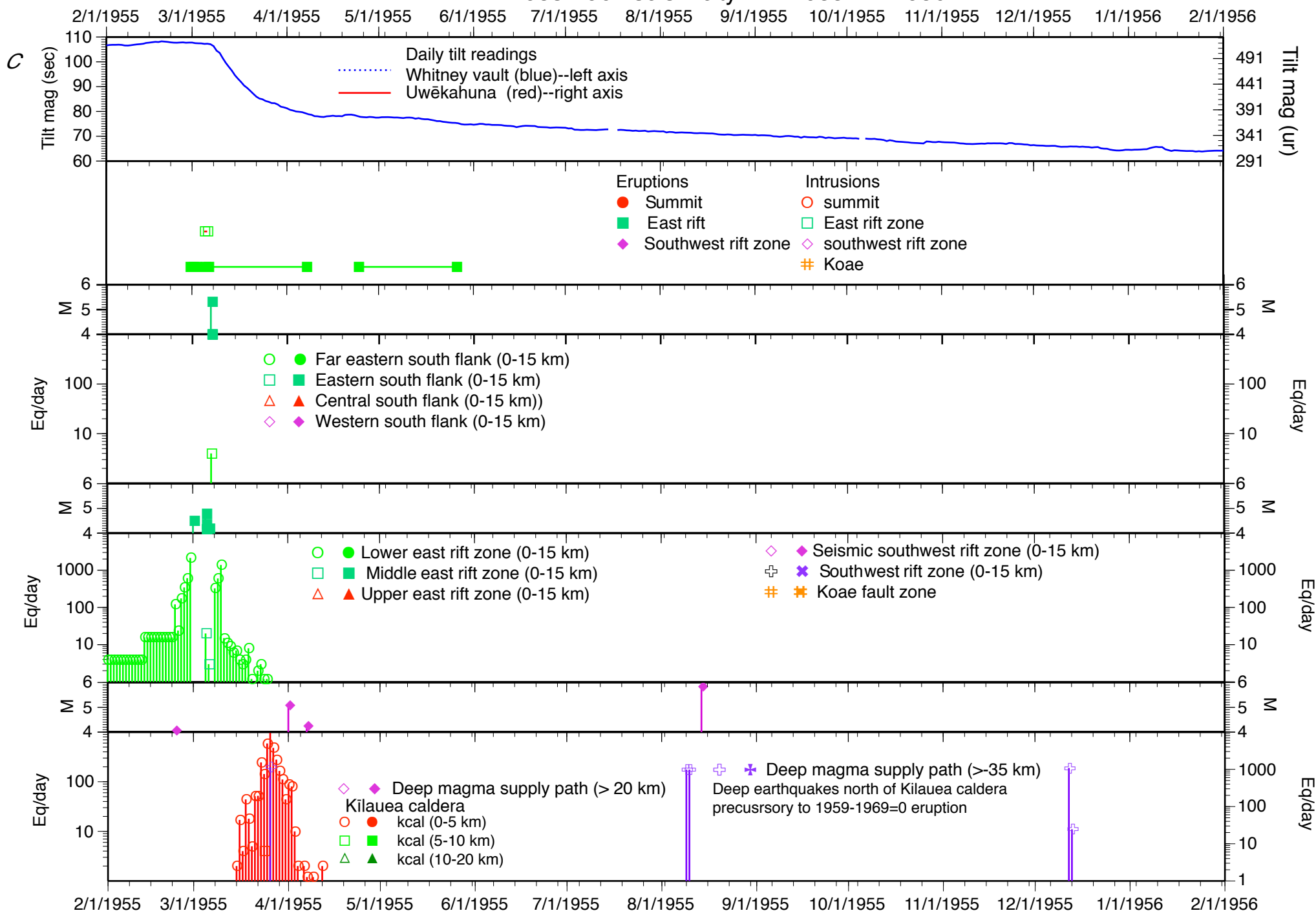
Appendix figure D3 A
1953-1967 seismicity: 2/1/1953-2/1/1954



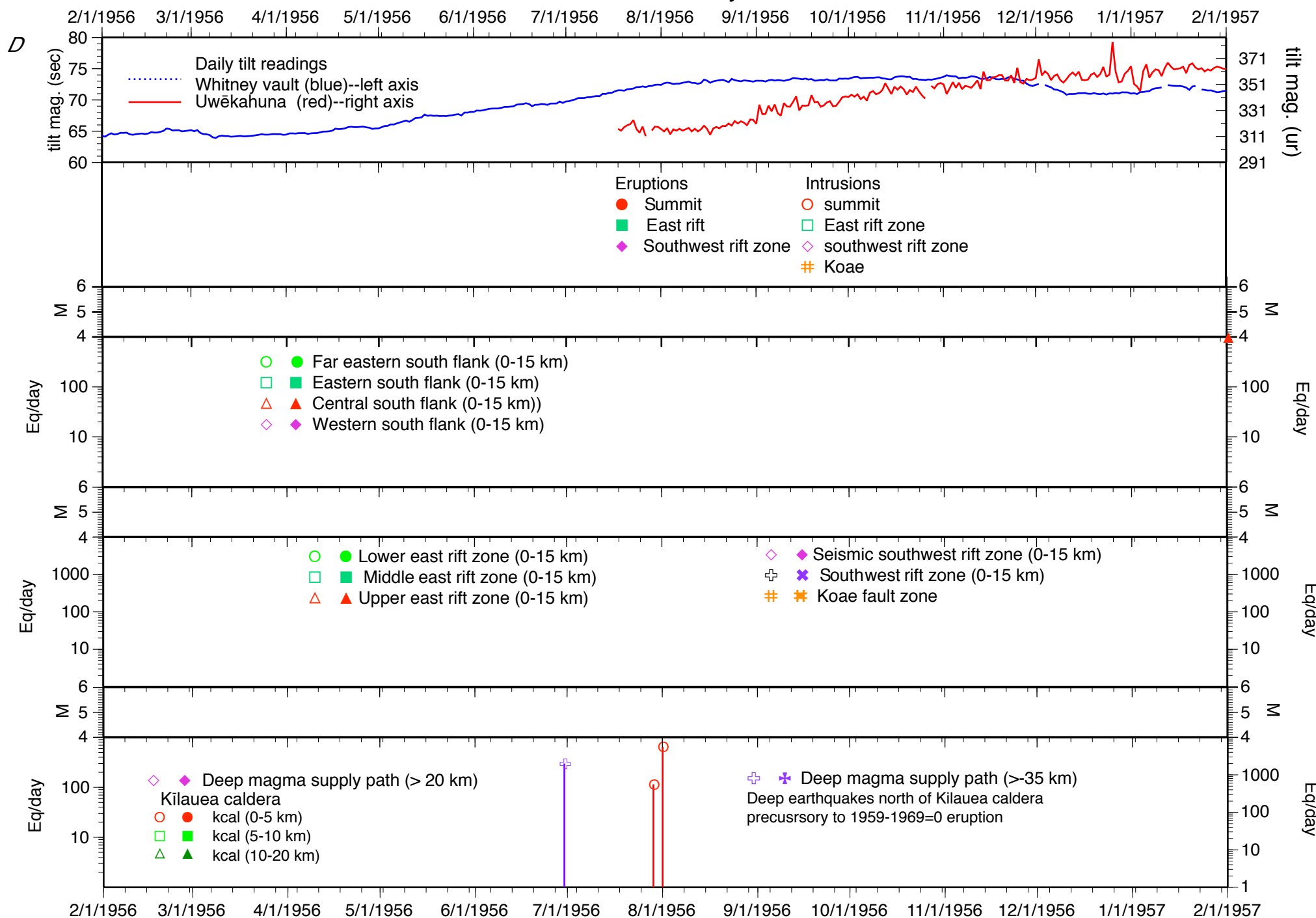


Appendix figure D3 C

1953-1967 seismicity: 2/1/1955-2/1/1956

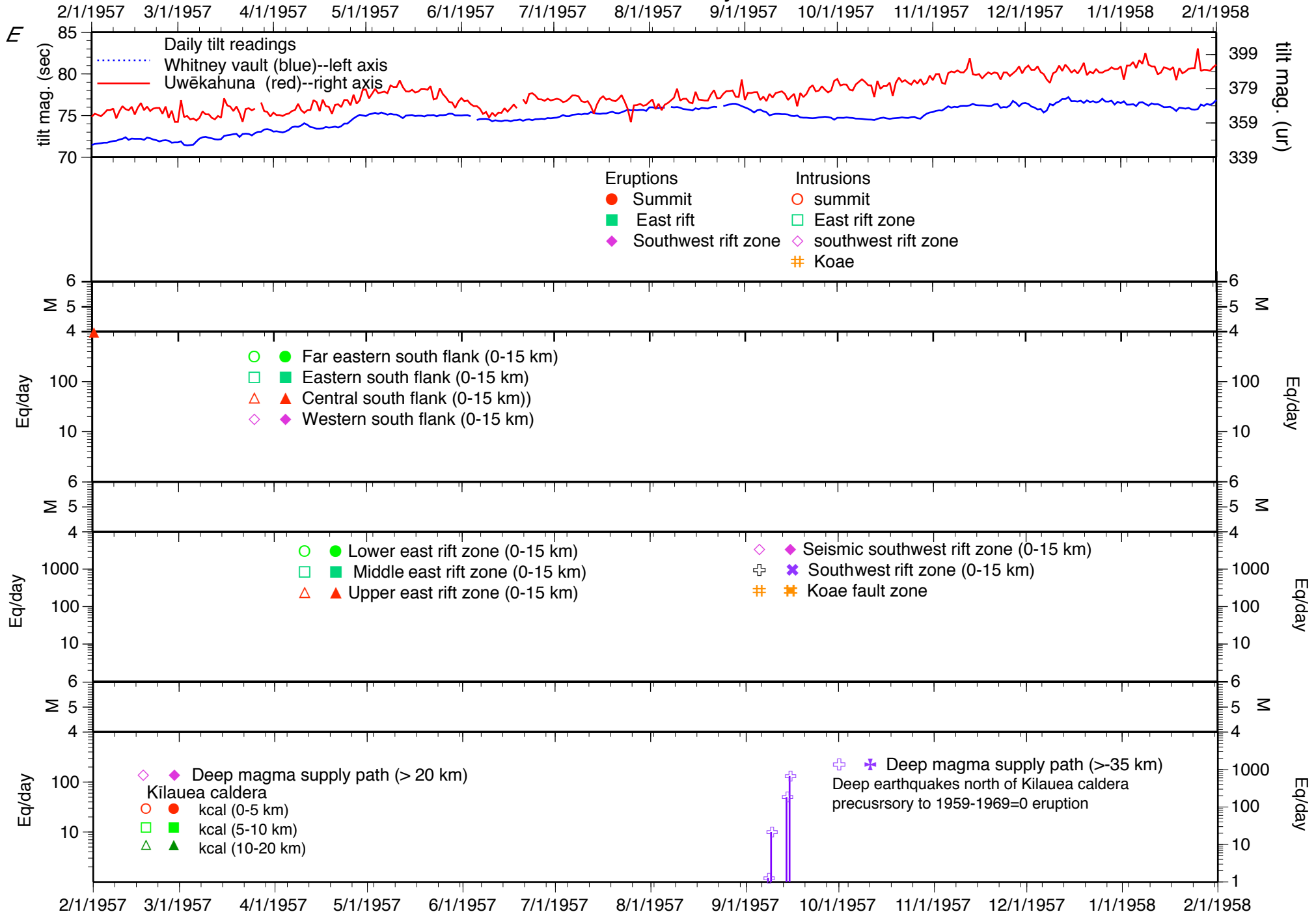


Appendix figure D3 D
1953-1967 seismicity: 2/1/1956-2/1/1957

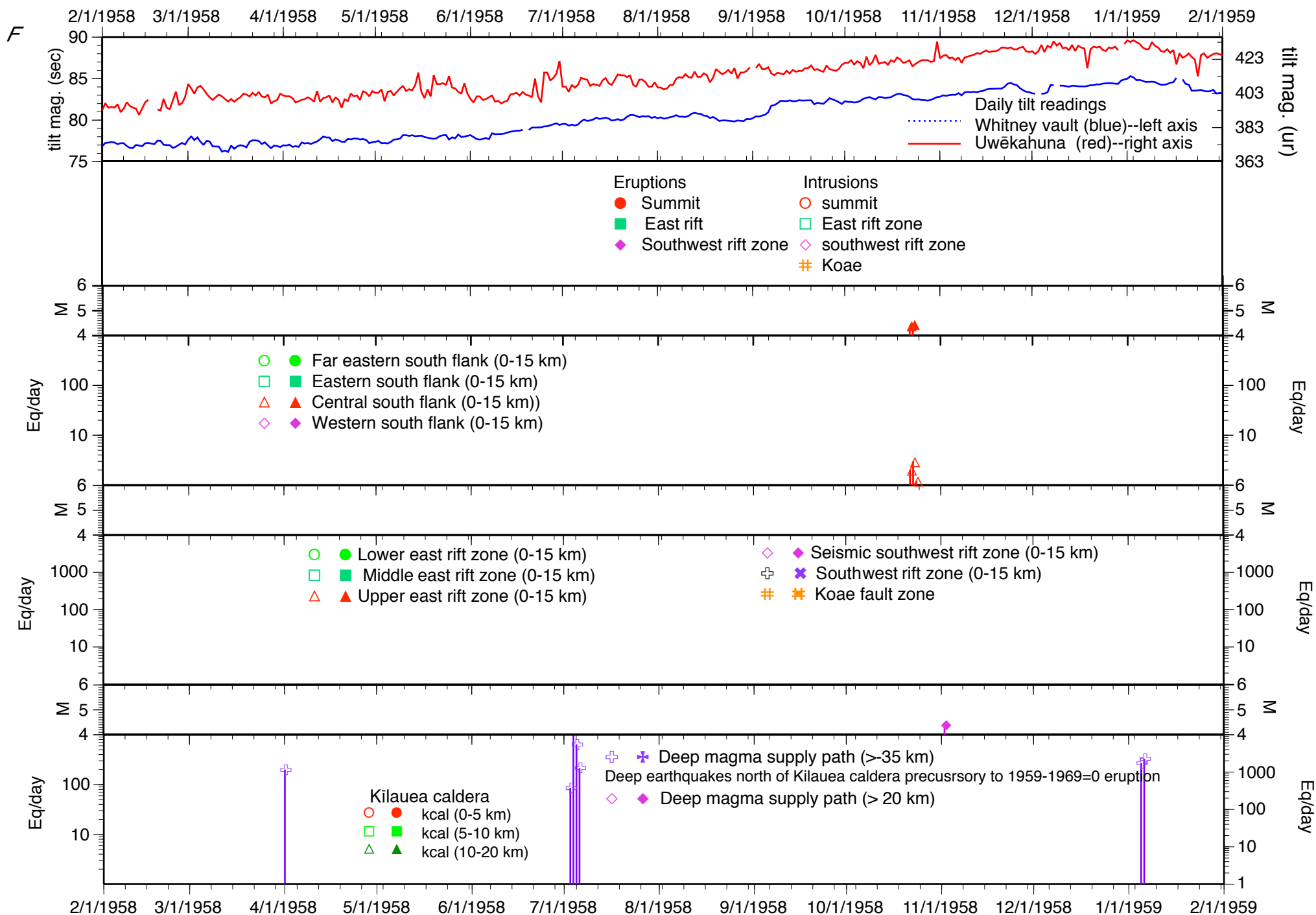


Appendix figure D3 E

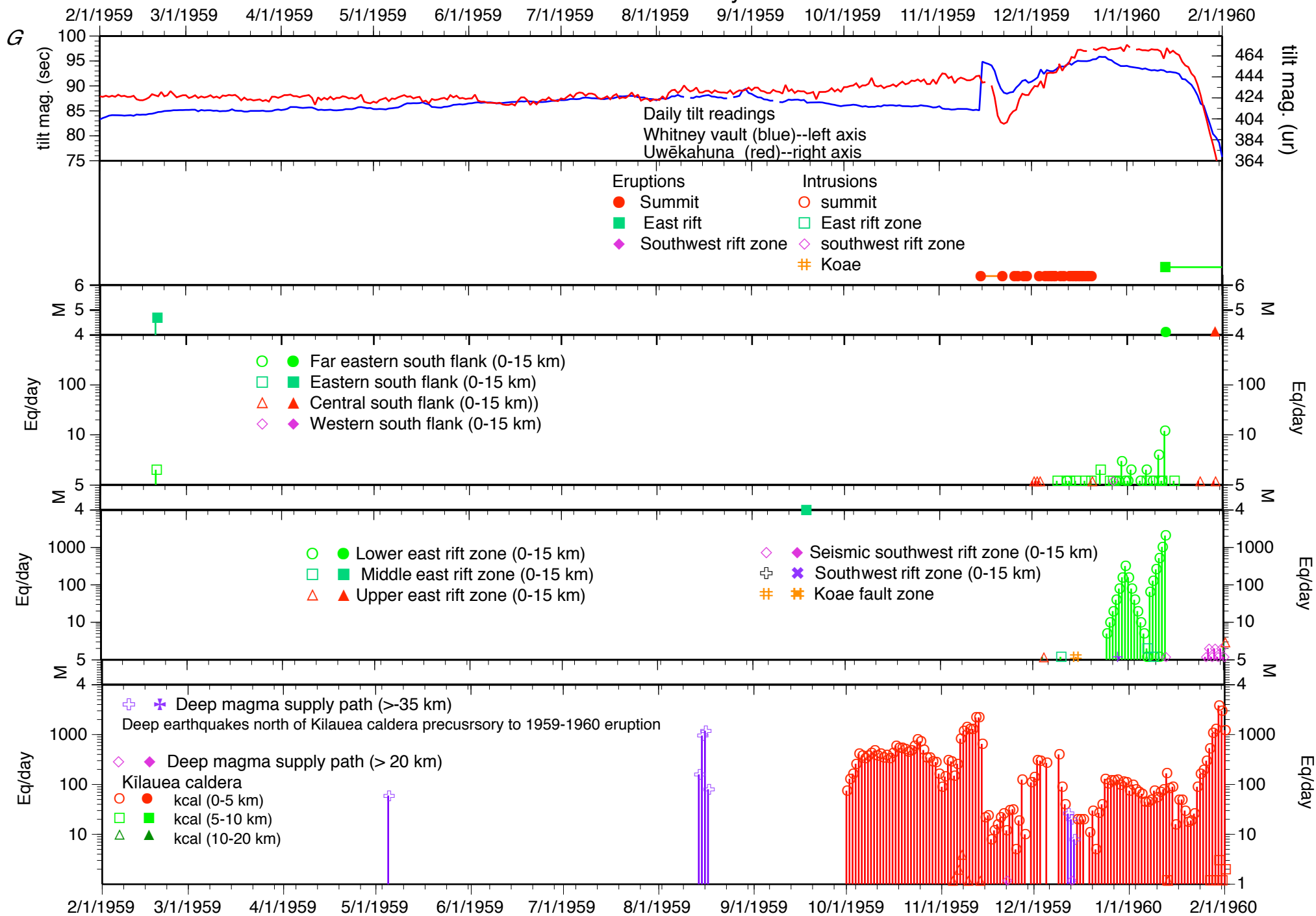
1953-1967 seismicity: 2/1/1957-2/1/1958



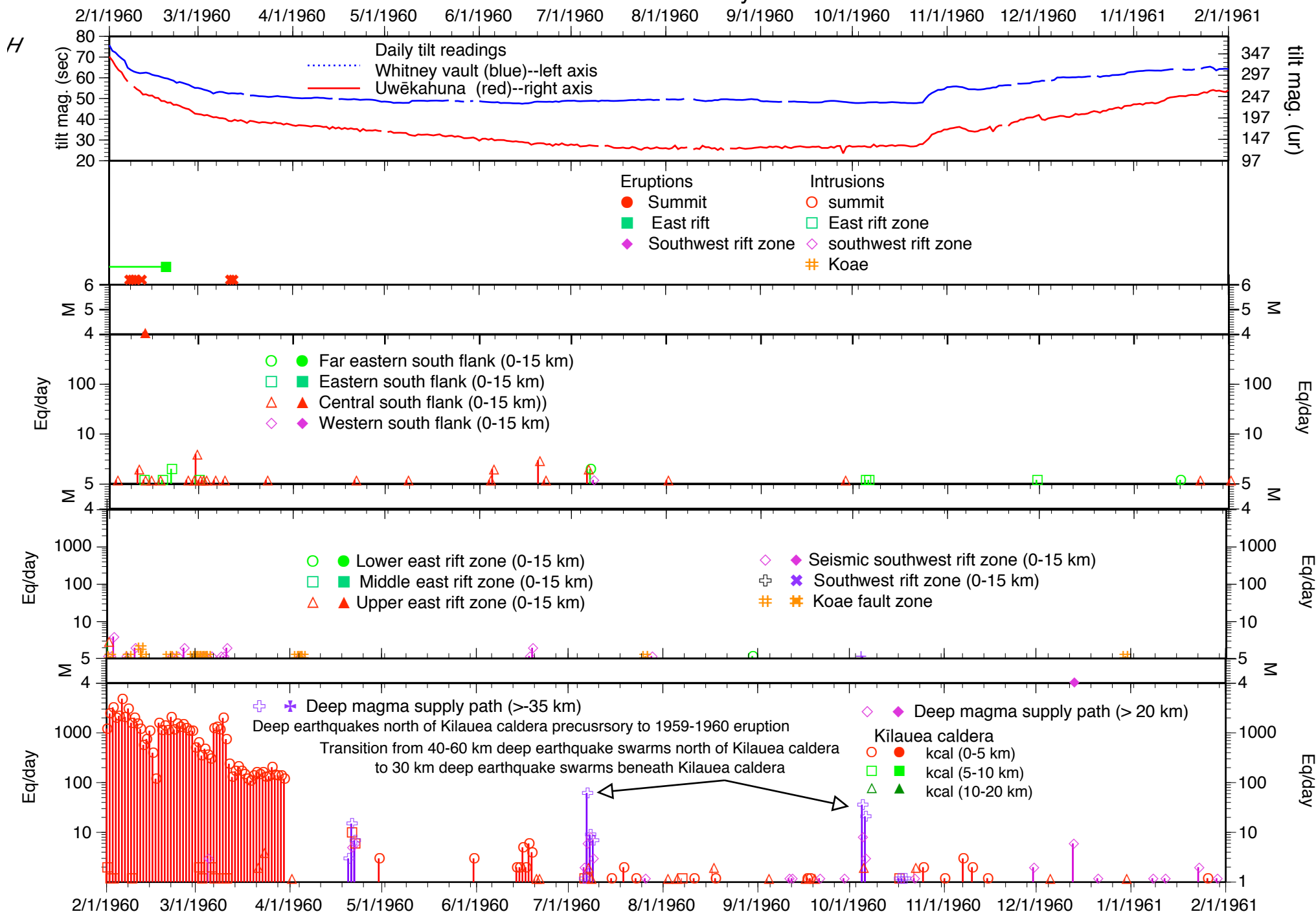
Appendix figure D3 F
1953-1967 seismicity: 2/1/1958-2/1/1959



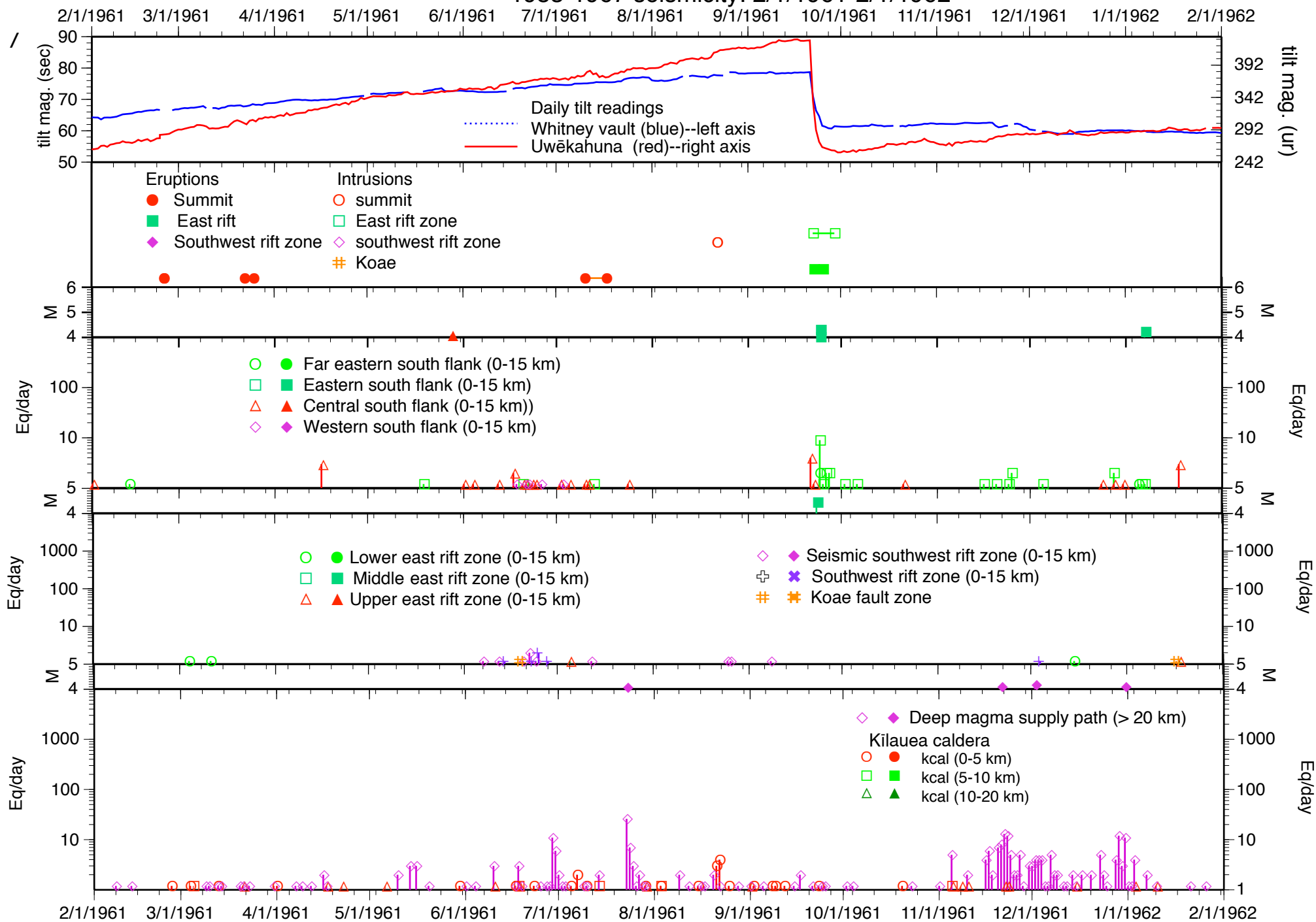
Appendix figure D3 G
1953-1967 seismicity: 2/1/1959-2/1/1960



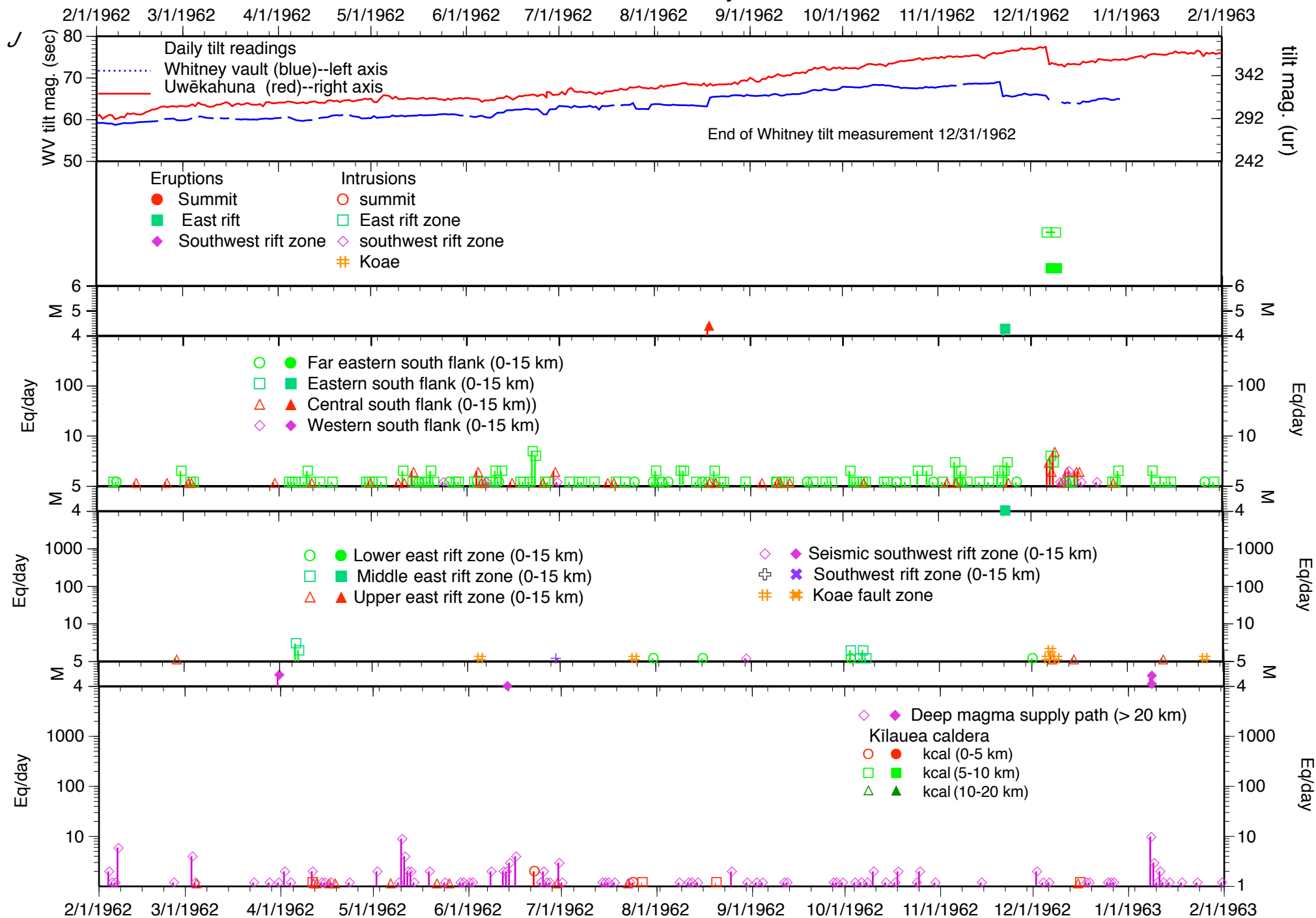
Appendix figure D3 H
1953-1967 seismicity: 2/1/1960-2/1/1961



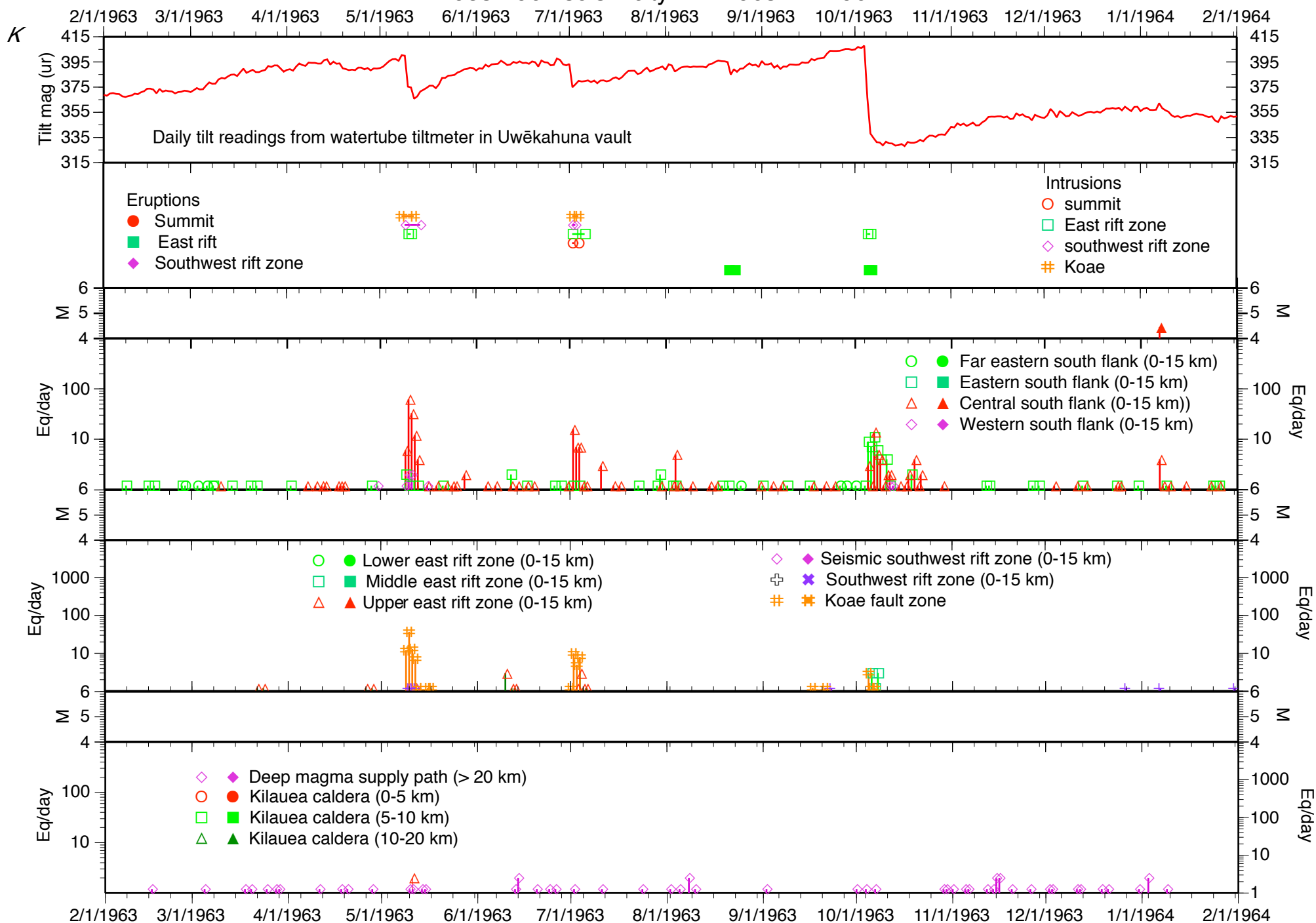
Appendix figure D3 I
1953-1967 seismicity: 2/1/1961-2/1/1962



Appendix figure D3 J
1953-1967 seismicity: 2/1/1962-2/1/1963

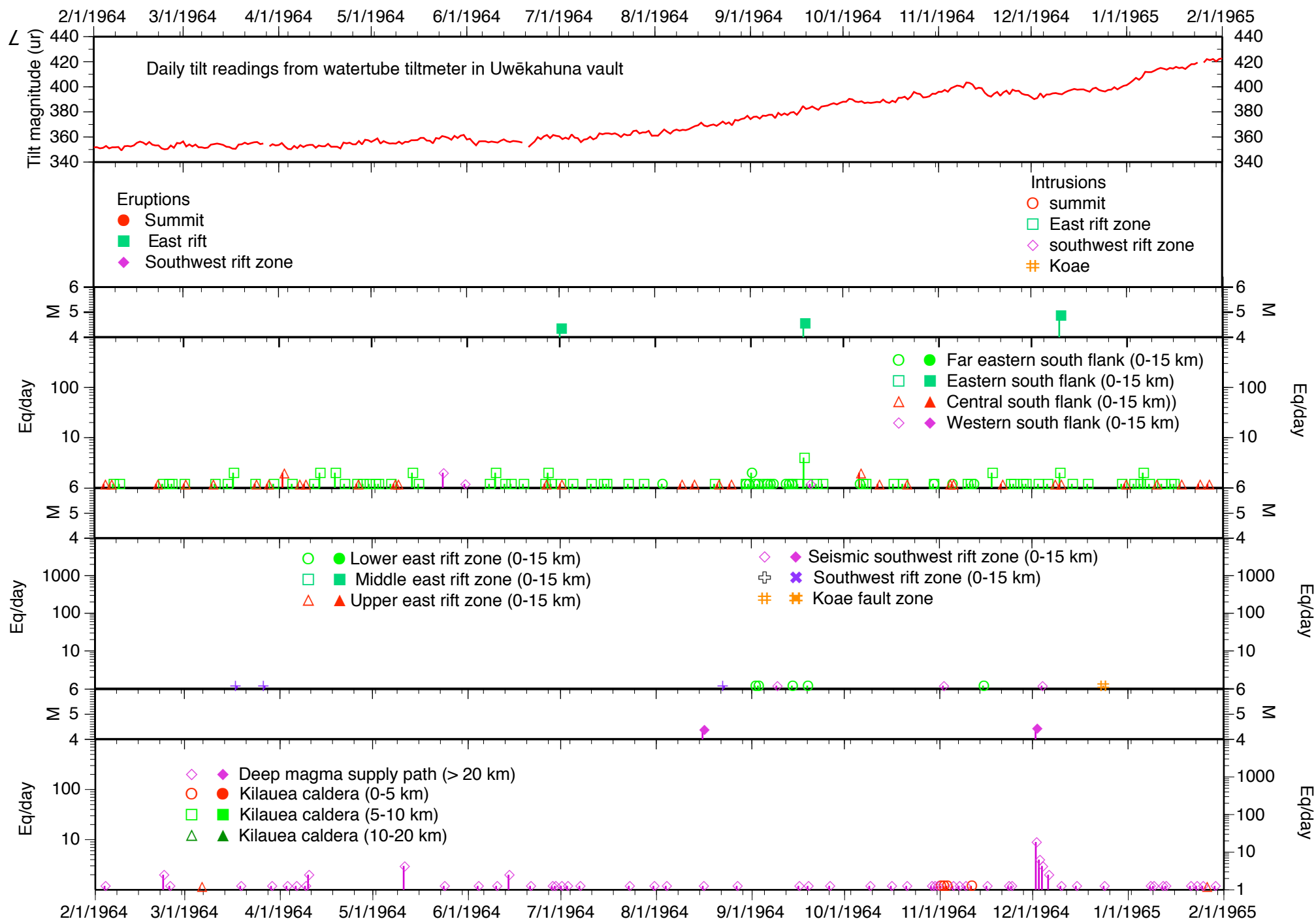


Appendix figure D3 K
1953-1967 seismicity: 2/1/1963-2/1/1964

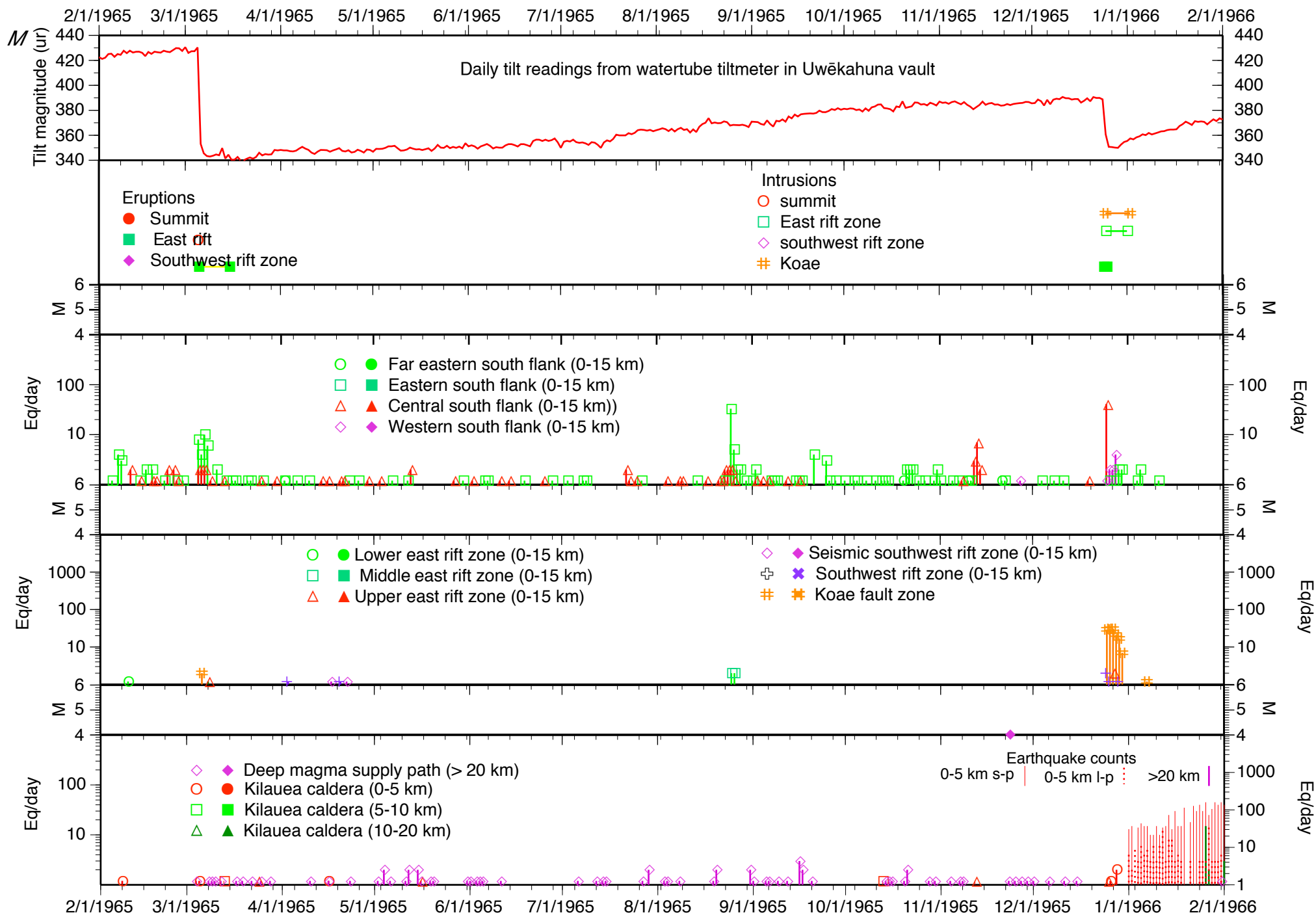


Appendix figure D3 L

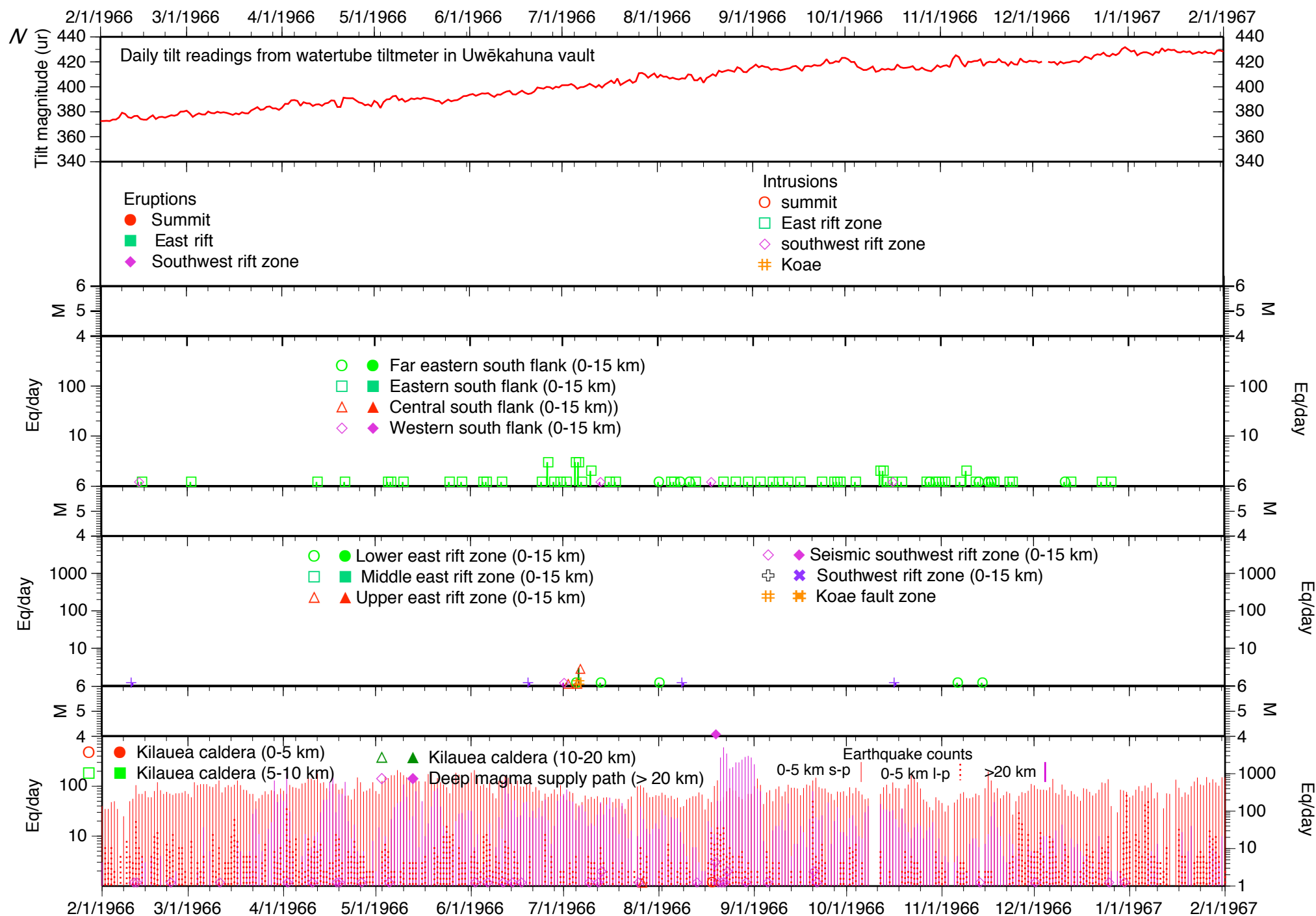
1953-1967 seismicity: 2/1/1964-2/1/1965



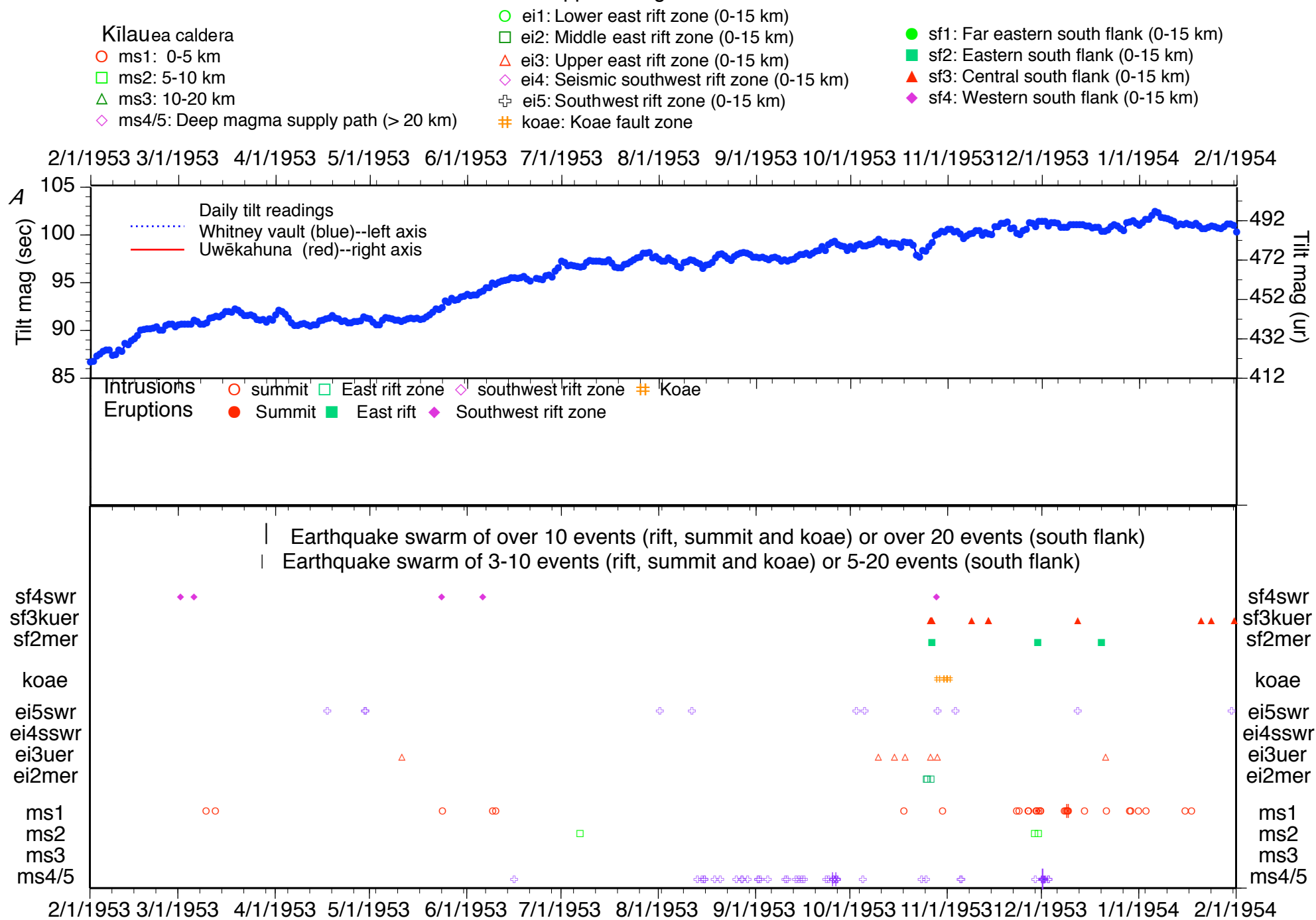
Appendix figure D3 M
1953-1967 seismicity: 2/1/1965-2/1/1966



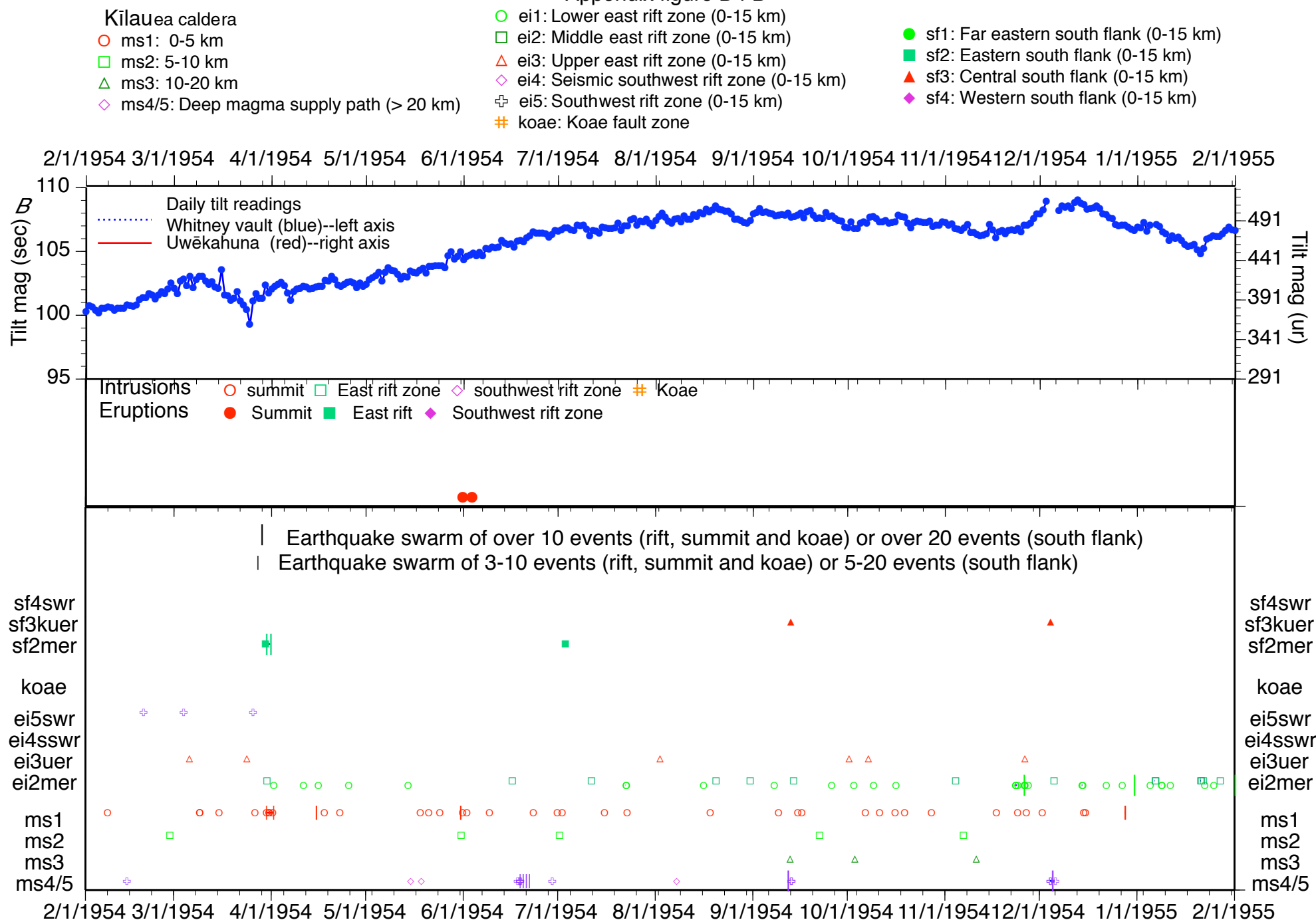
Appendix figure D3 N 1953-1967 seismicity: 2/1/1966-2/1/1967



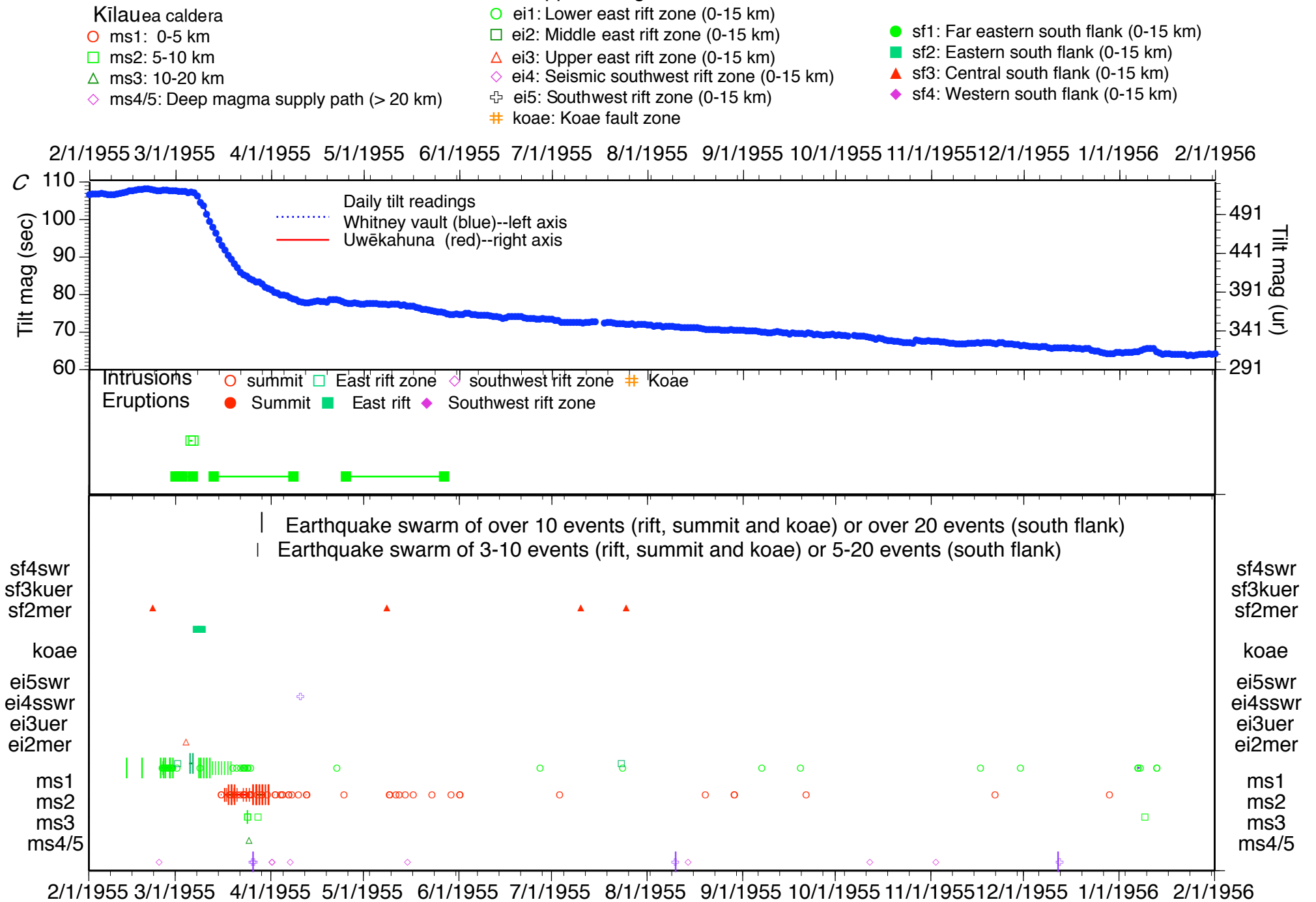
Appendix figure D4 A



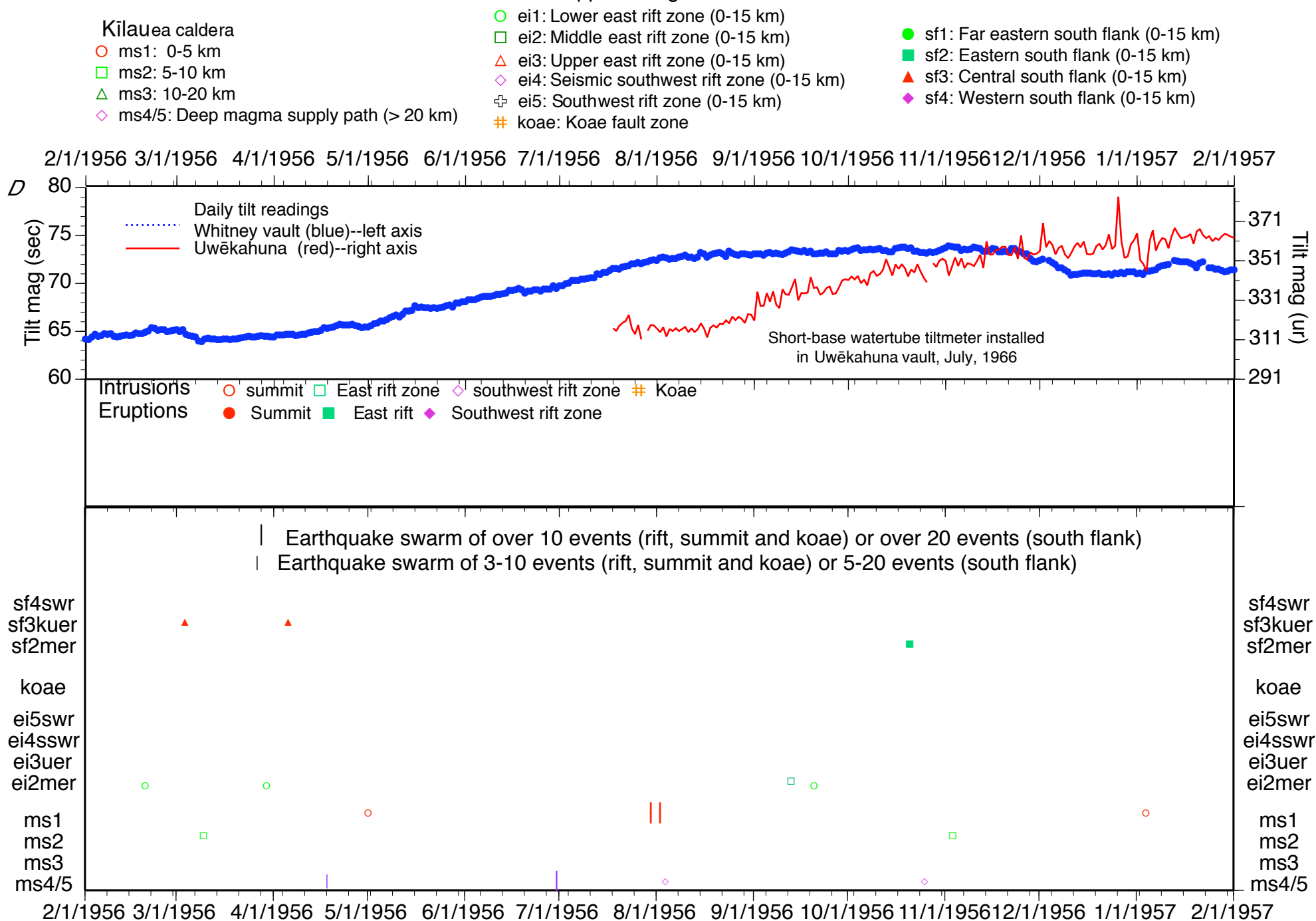
Appendix figure D4 B



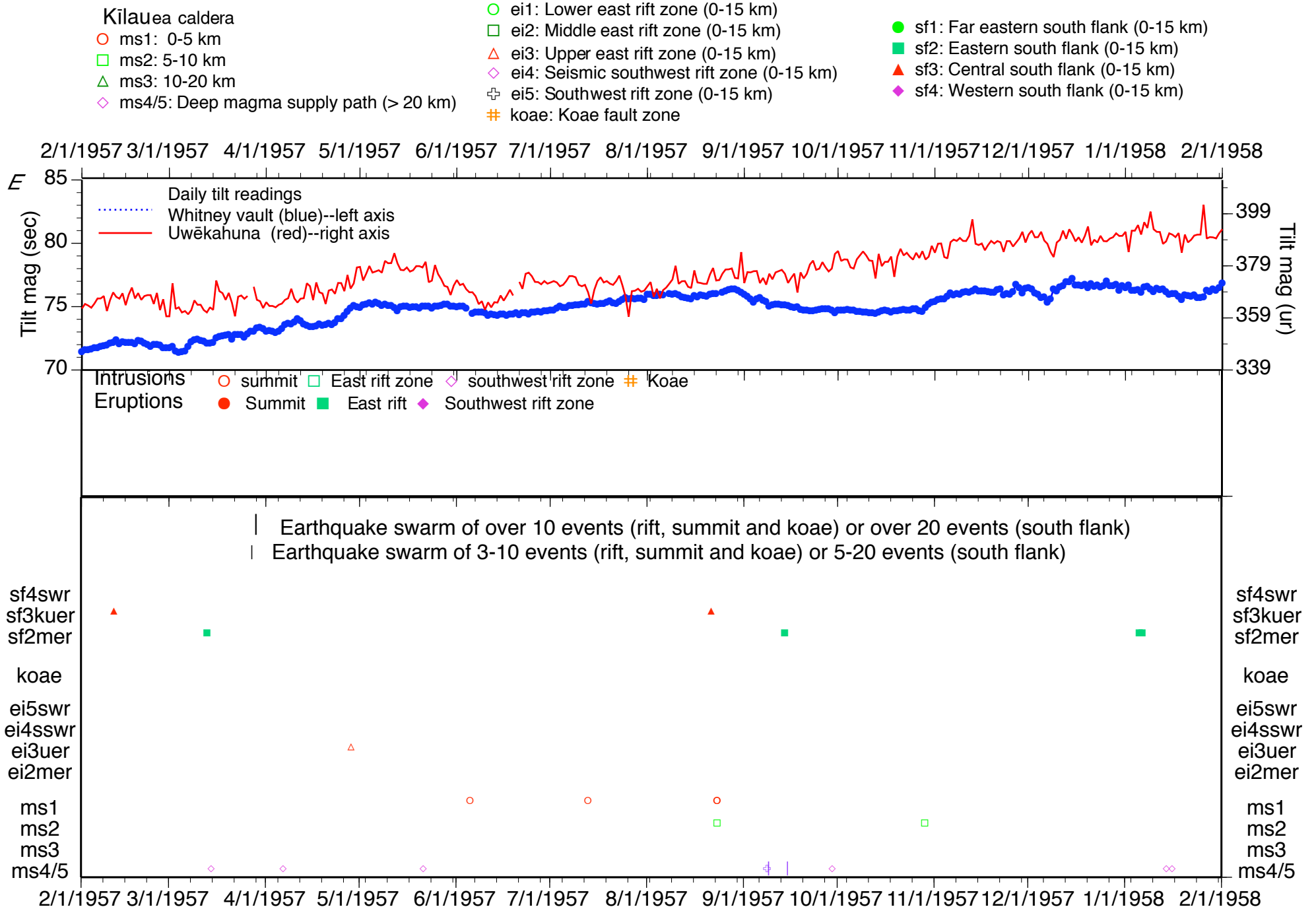
Appendix figure D4 C



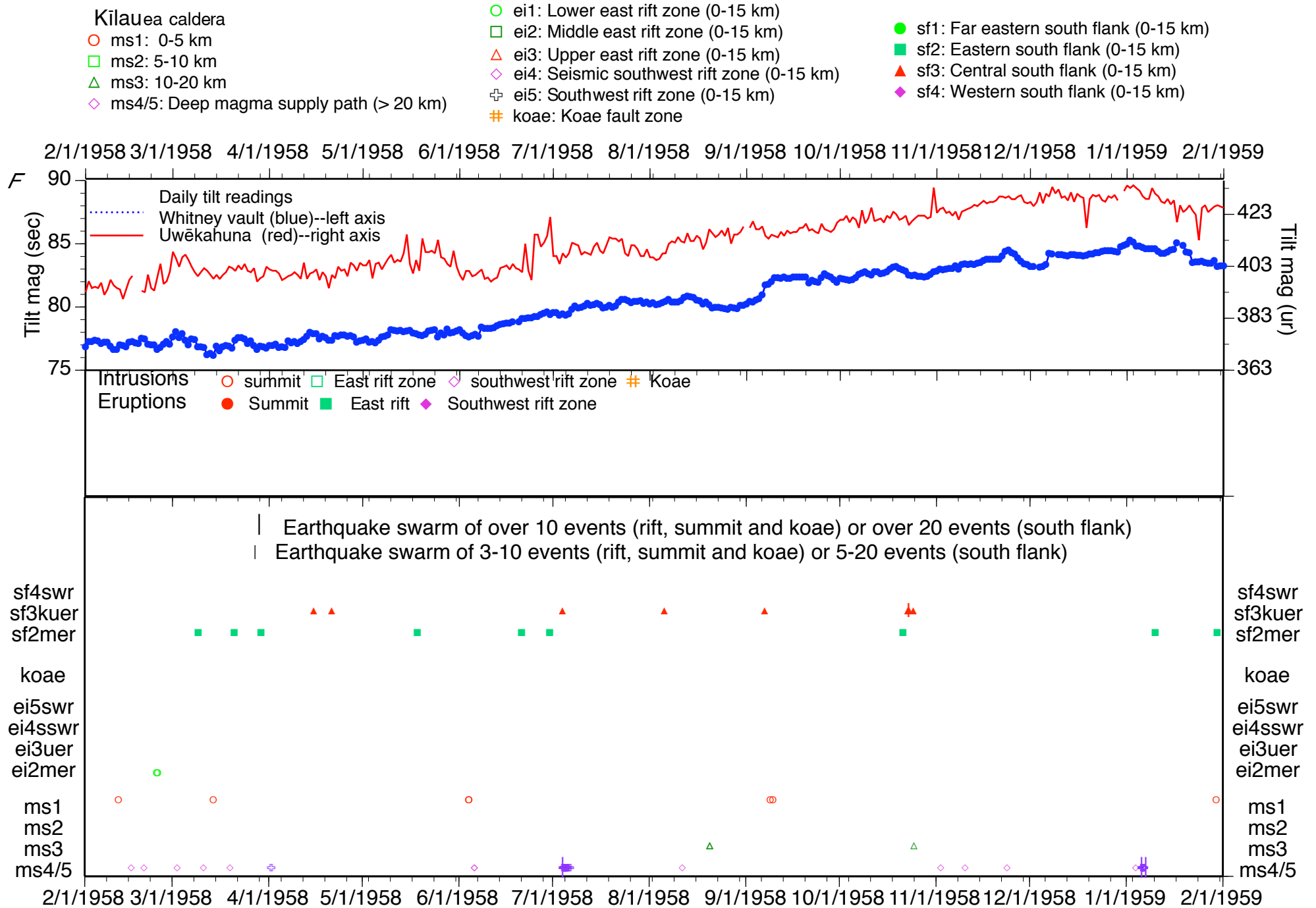
Appendix figure D4 D



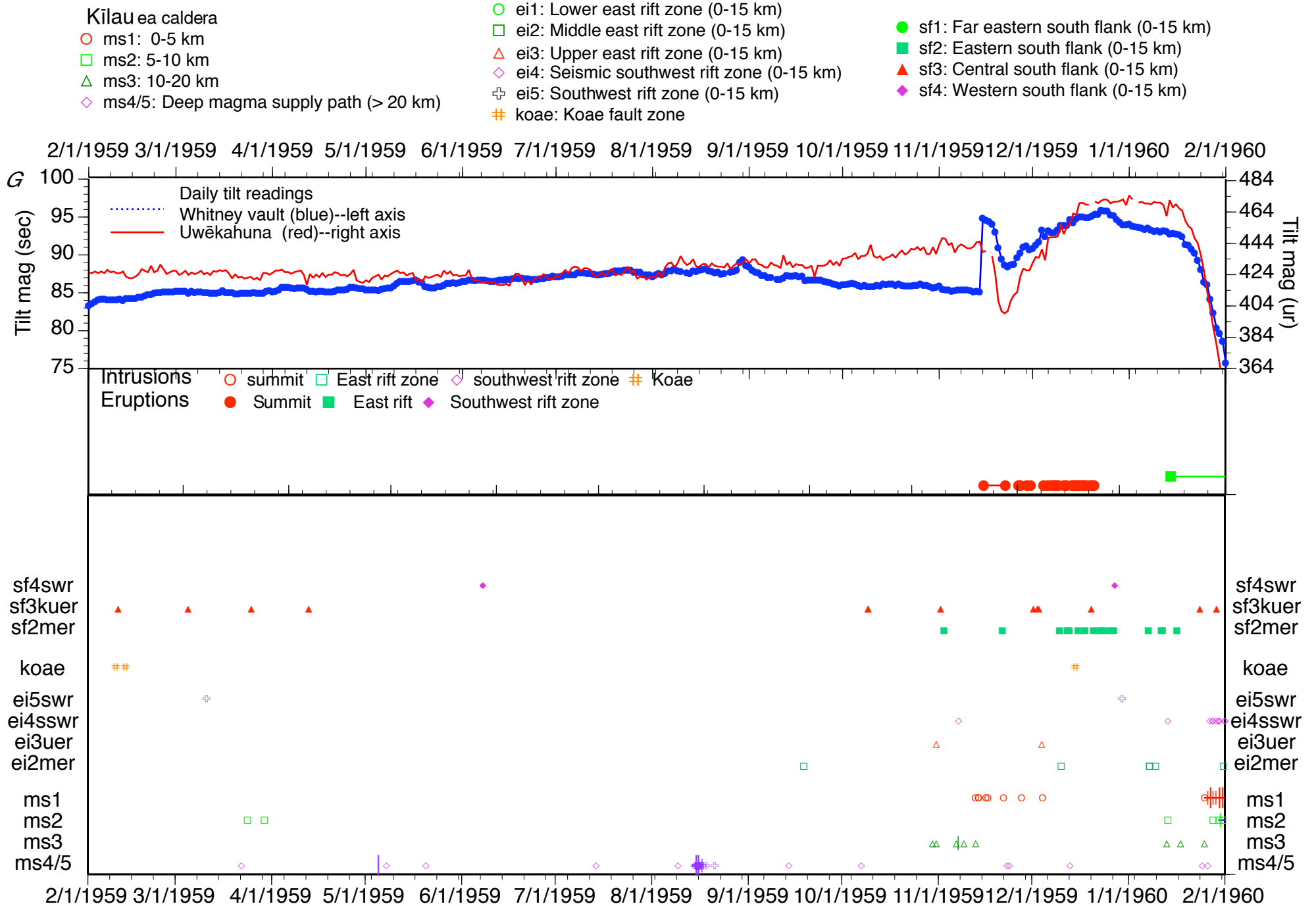
Appendix figure D4 E



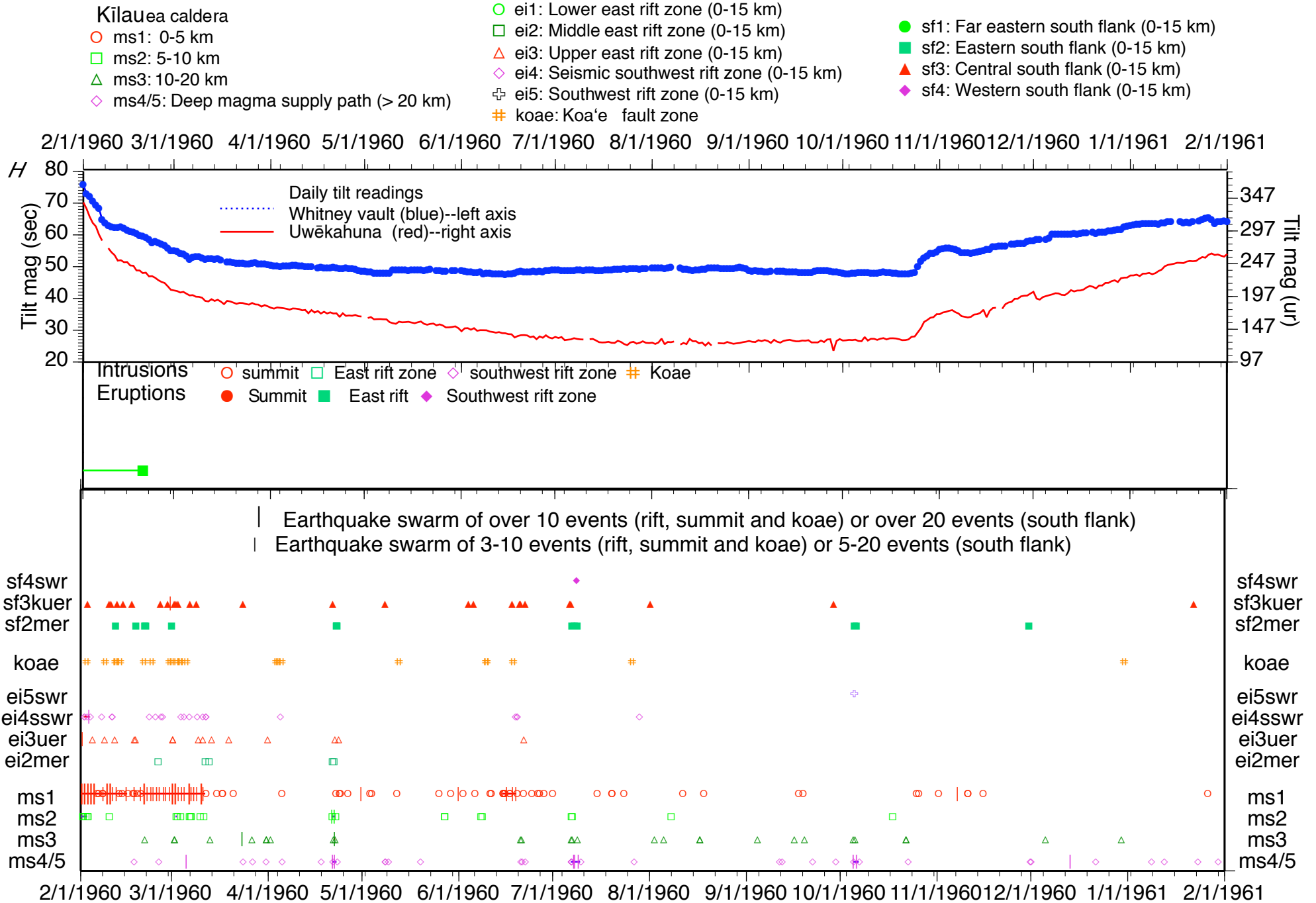
Appendix figure D4 F



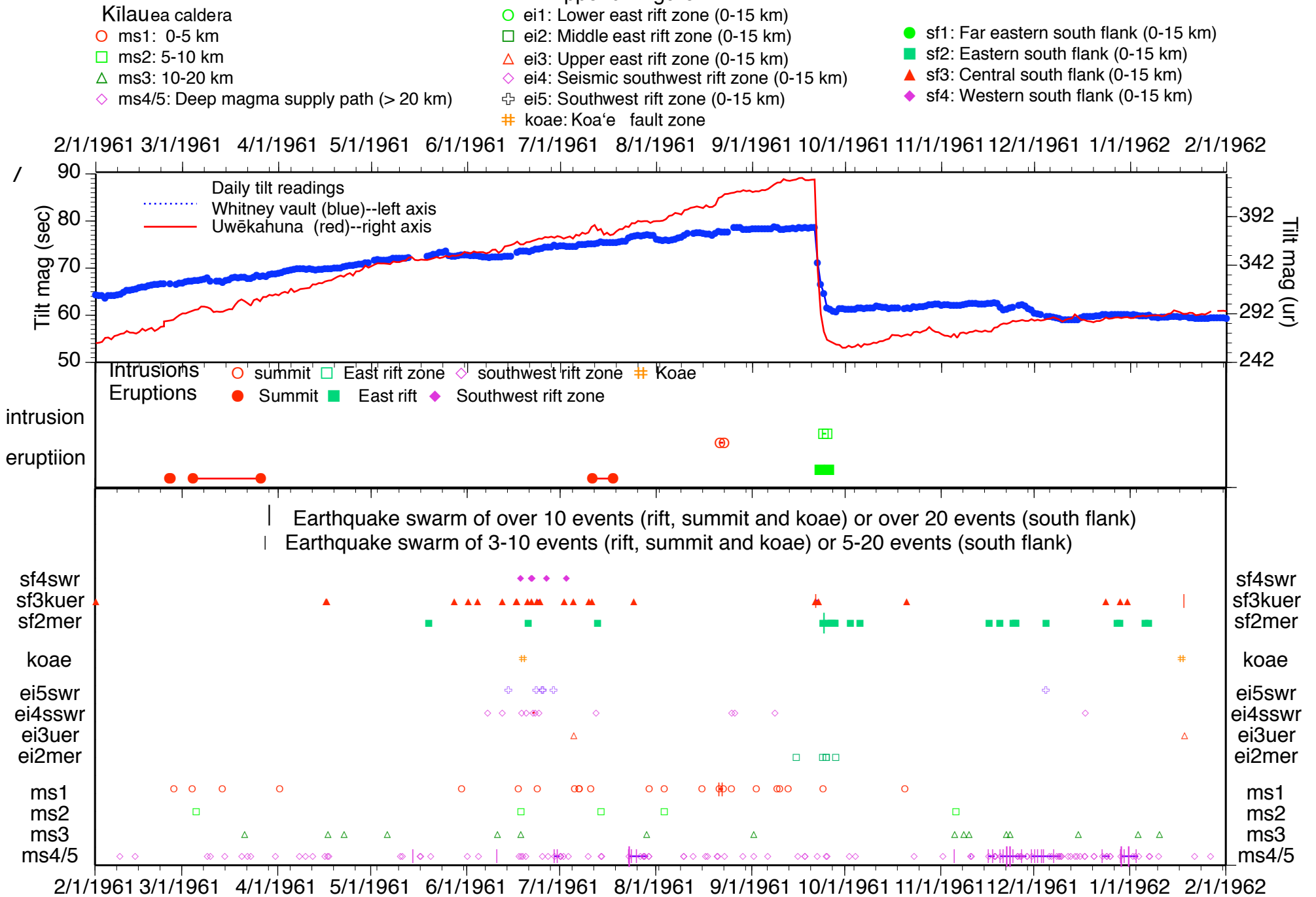
Appendix figure D4 G



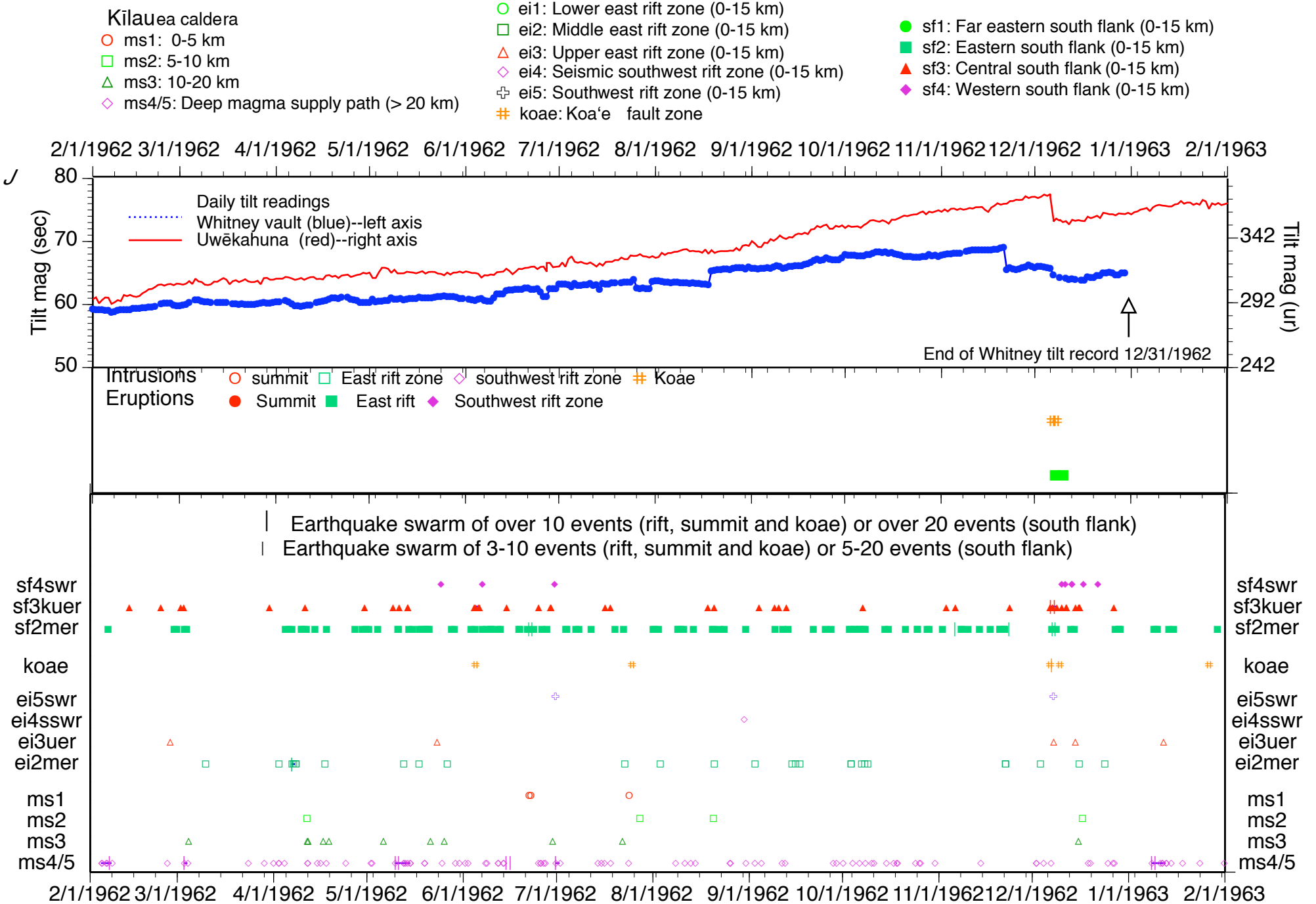
Appendix figure D4 H



Appendix figure 4.D2 I



Appendix figure D4 J



Appendix figure D4 K

Kilauea caldera

○ ms1: 0-5 km

□ ms2: 5-10 km

△ ms3: 10-20 km

◇ ms4/5: Deep magma supply path (> 20 km)

○ ei1: Lower east rift zone (0-15 km)

□ ei2: Middle east rift zone (0-15 km)

△ ei3: Upper east rift zone (0-15 km)

◇ ei4: Seismic southwest rift zone (0-15 km)

⊕ ei5: Southwest rift zone (0-15 km)

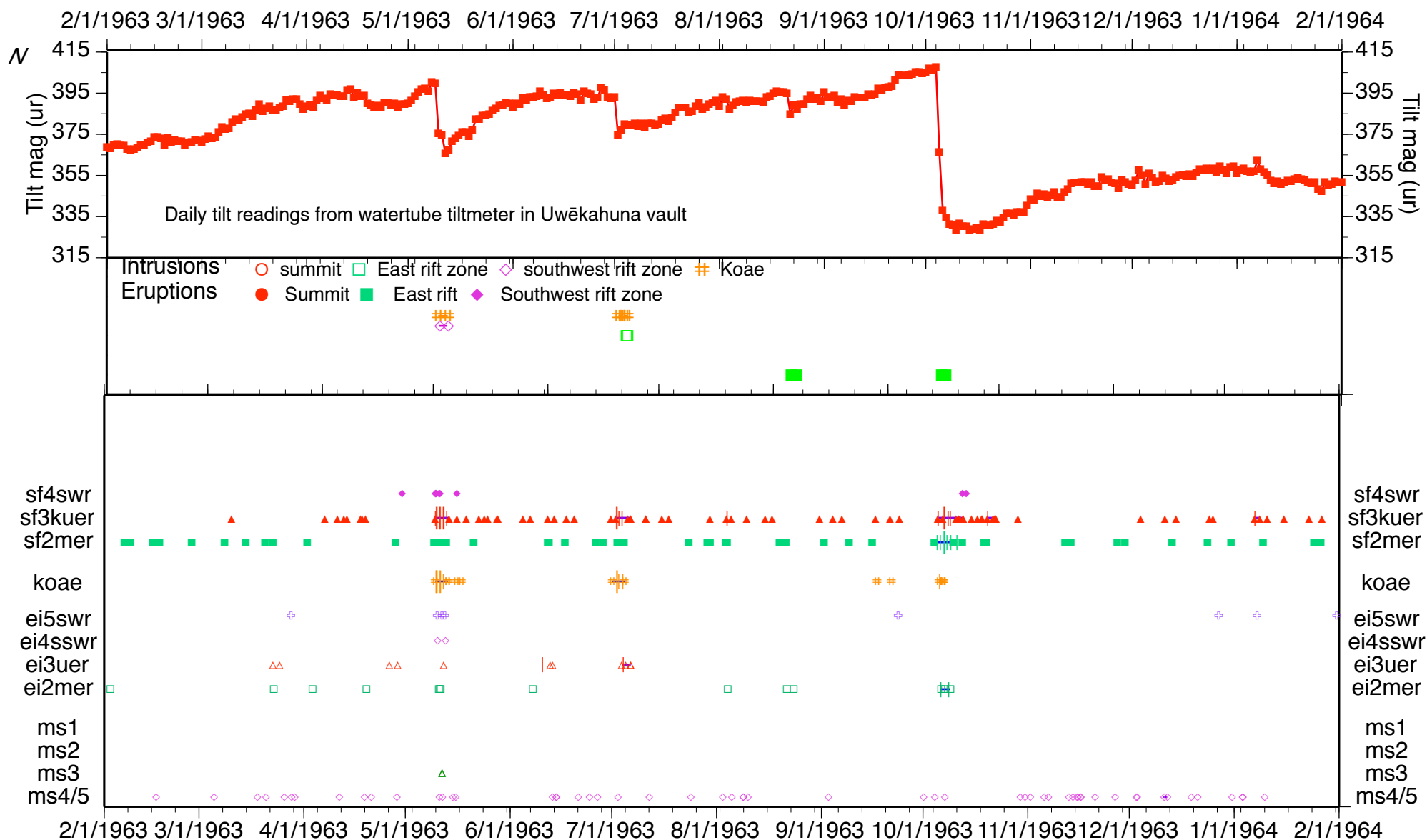
⊞ koae: Koa'e fault zone

● sf1: Far eastern south flank (0-15 km)

■ sf2: Eastern south flank (0-15 km)

▲ sf3: Central south flank (0-15 km)

◆ sf4: Western south flank (0-15 km)



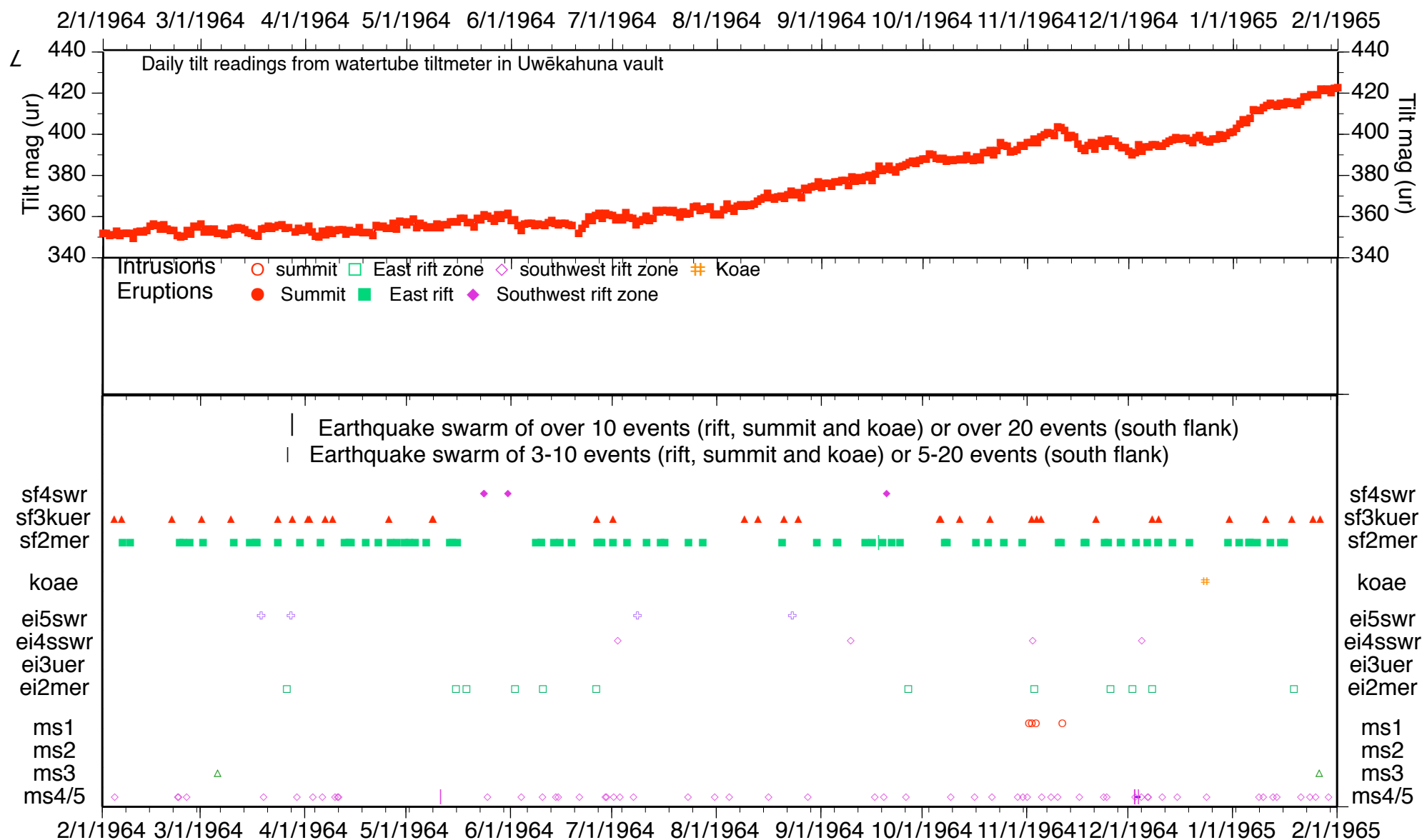
Appendix figure D4 L

Kilauea caldera

- ms1: 0-5 km
- ms2: 5-10 km
- △ ms3: 10-20 km
- ◇ ms4/5: Deep magma supply path (> 20 km)

- ei1: Lower east rift zone (0-15 km)
- ei2: Middle east rift zone (0-15 km)
- △ ei3: Upper east rift zone (0-15 km)
- ei4: Seismic southwest rift zone (0-15 km)
- ⊕ ei5: Southwest rift zone (0-15 km)
- ⊕ koae: Koa'e fault zone

- sf1: Far eastern south flank (0-15 km)
- sf2: Eastern south flank (0-15 km)
- ▲ sf3: Central south flank (0-15 km)
- ◆ sf4: Western south flank (0-15 km)



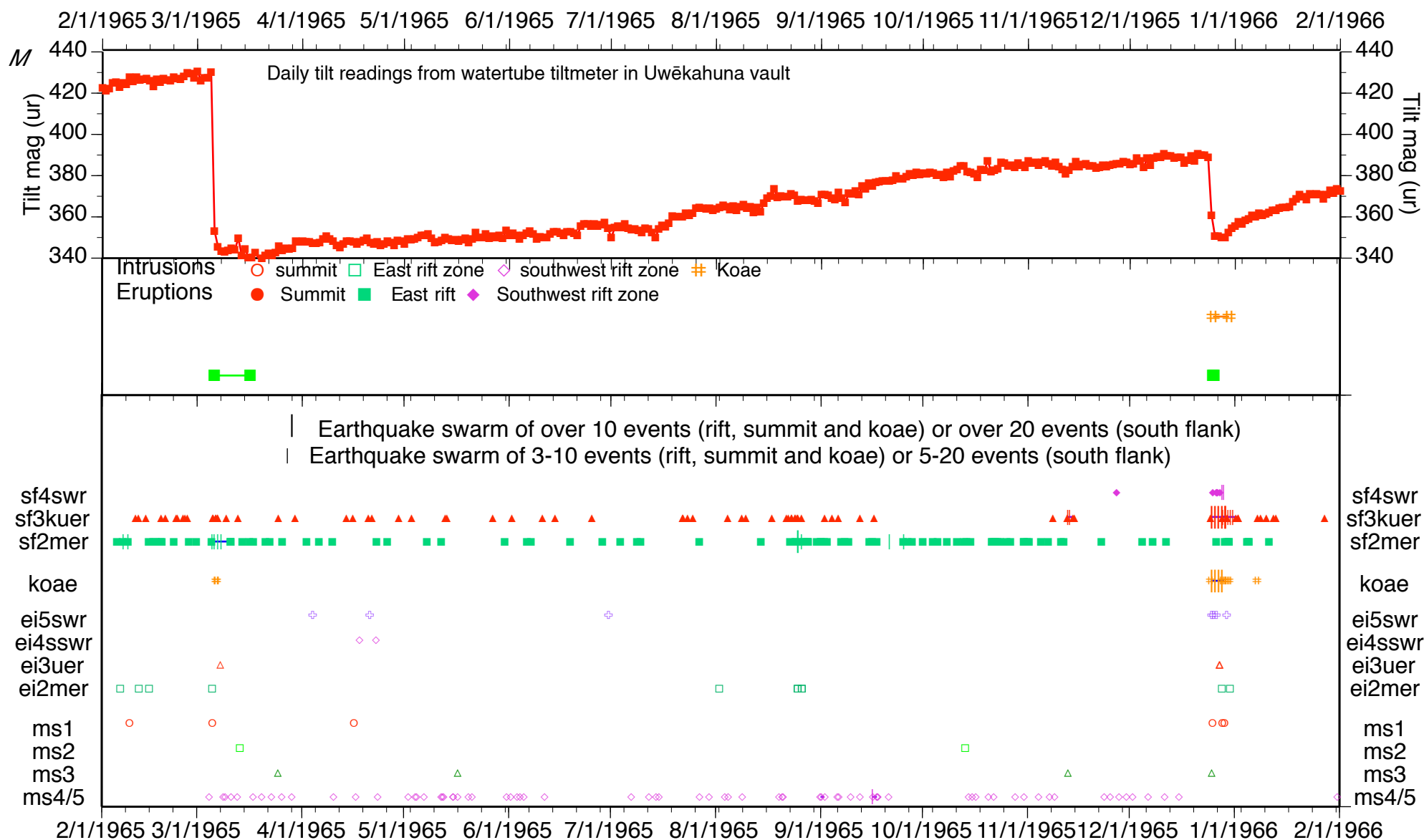
Appendix figure D4 M

Kilauea caldera

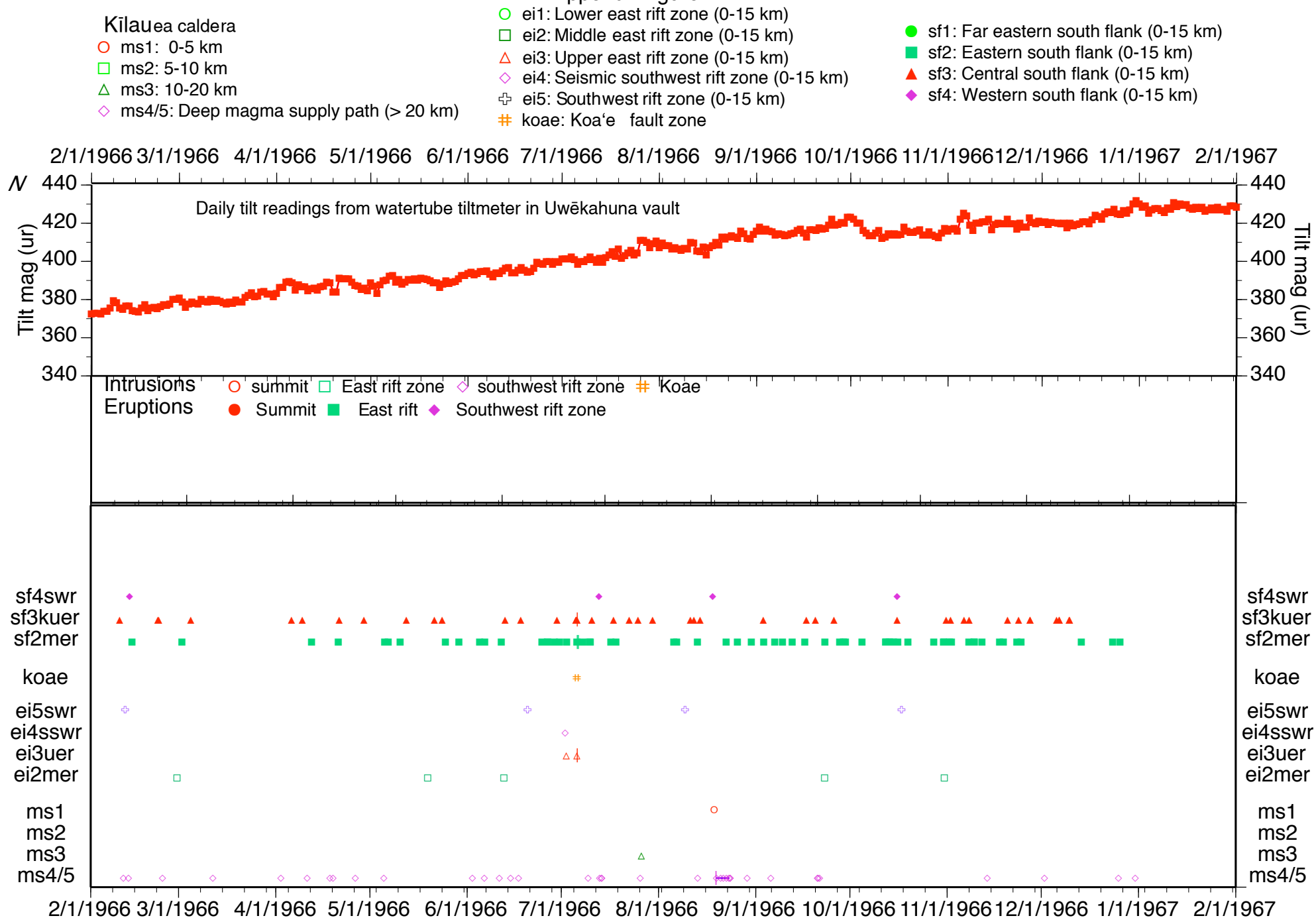
- ms1: 0-5 km
- ms2: 5-10 km
- △ ms3: 10-20 km
- ◇ ms4/5: Deep magma supply path (> 20 km)

- ei1: Lower east rift zone (0-15 km)
- ei2: Middle east rift zone (0-15 km)
- △ ei3: Upper east rift zone (0-15 km)
- ◇ ei4: Seismic southwest rift zone (0-15 km)
- ⊕ ei5: Southwest rift zone (0-15 km)
- ⊞ koae: Koa'e fault zone

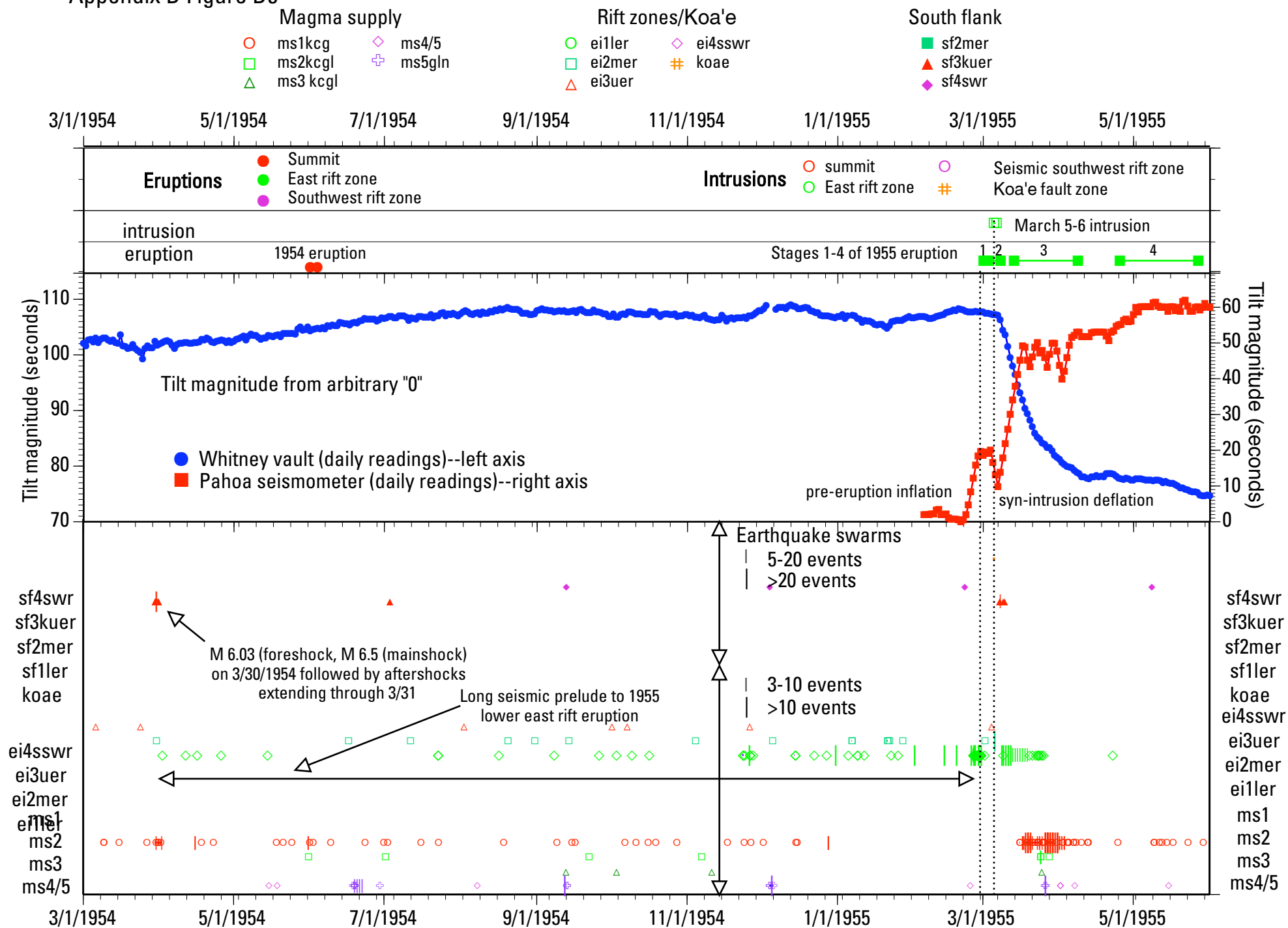
- sf1: Far eastern south flank (0-15 km)
- sf2: Eastern south flank (0-15 km)
- ▲ sf3: Central south flank (0-15 km)
- ◆ sf4: Western south flank (0-15 km)



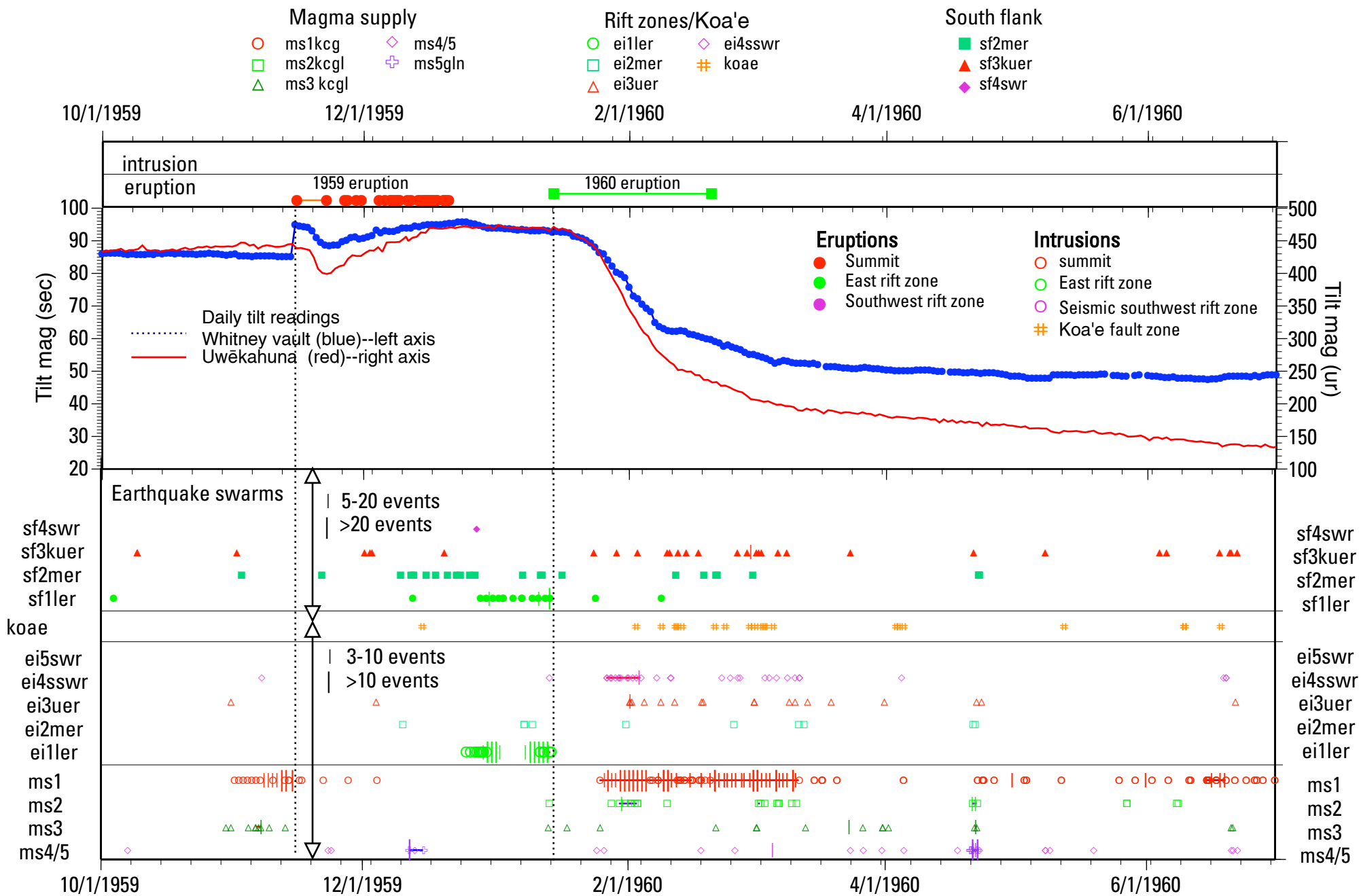
Appendix figure D4 N



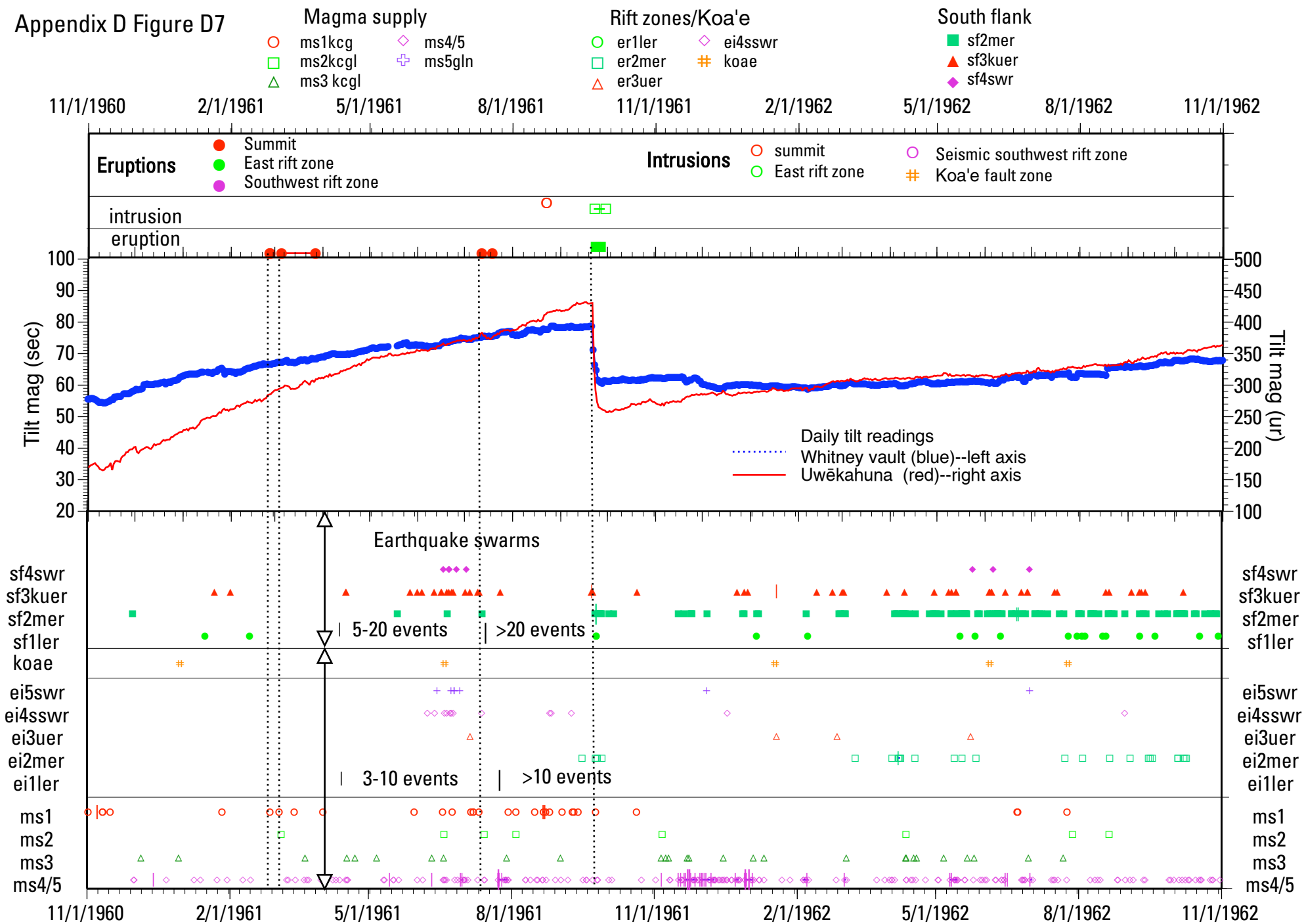
Appendix D Figure D5



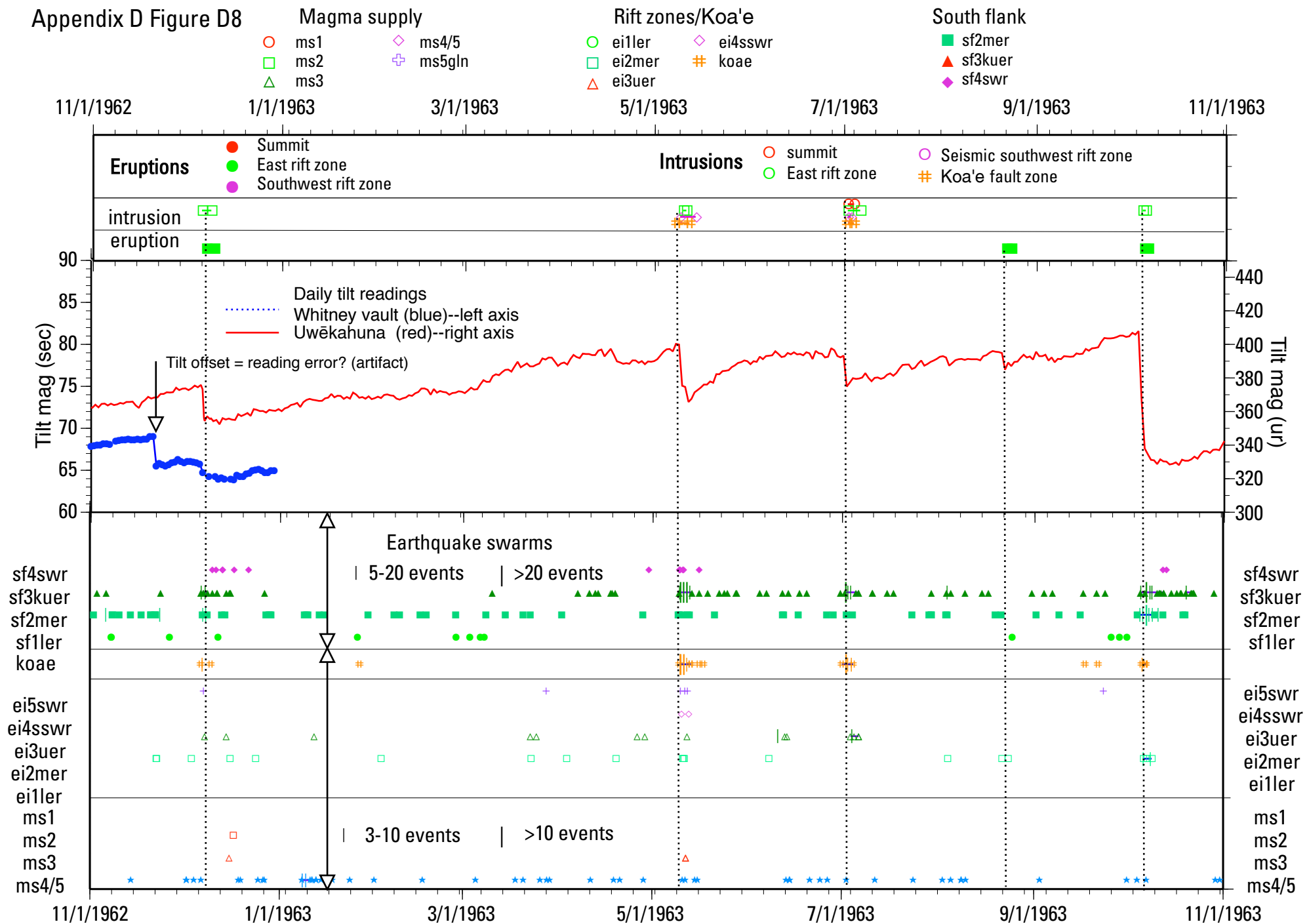
Appendix D Figure D6



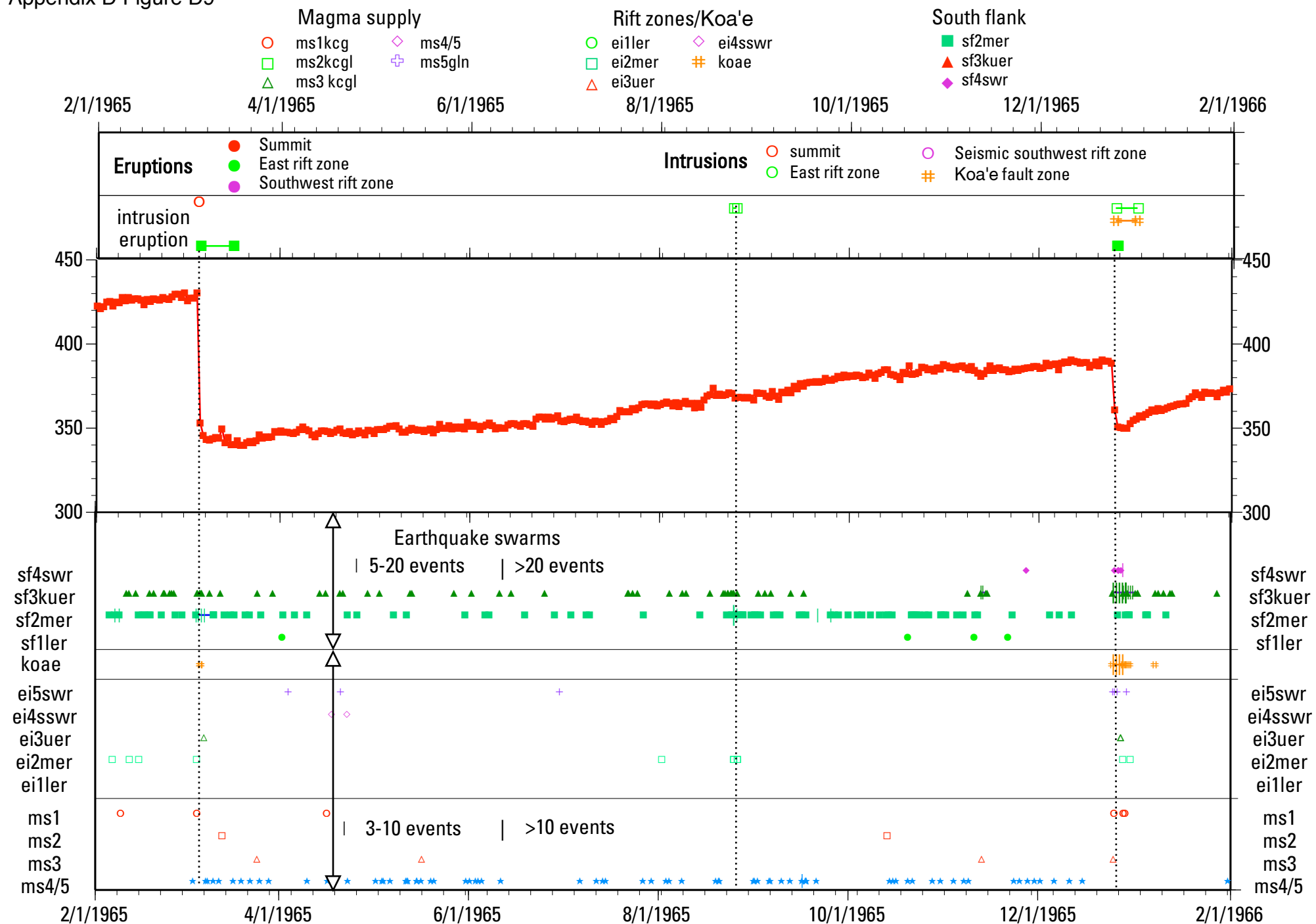
Appendix D Figure D7



South flank

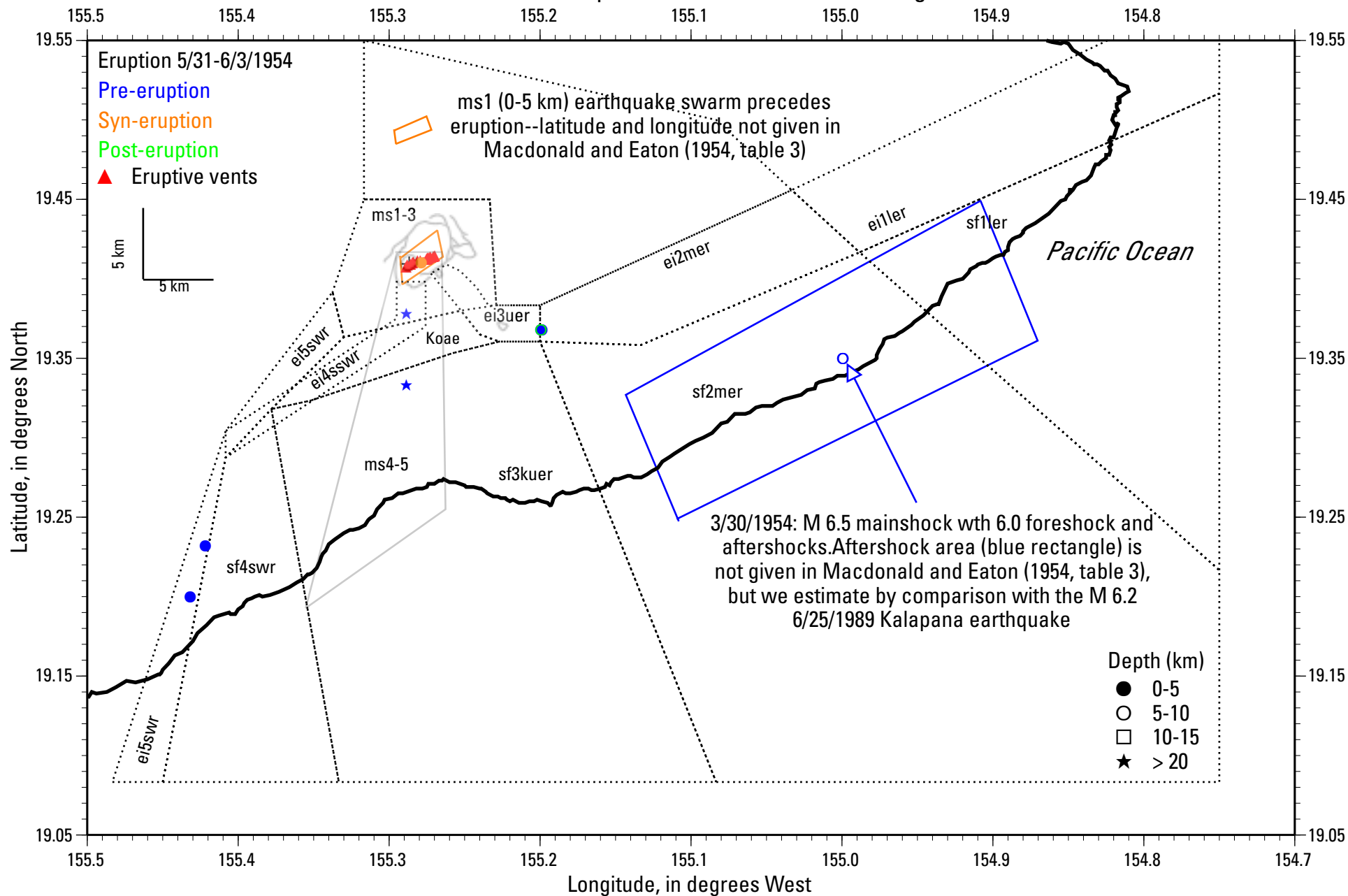


Appendix D Figure D9

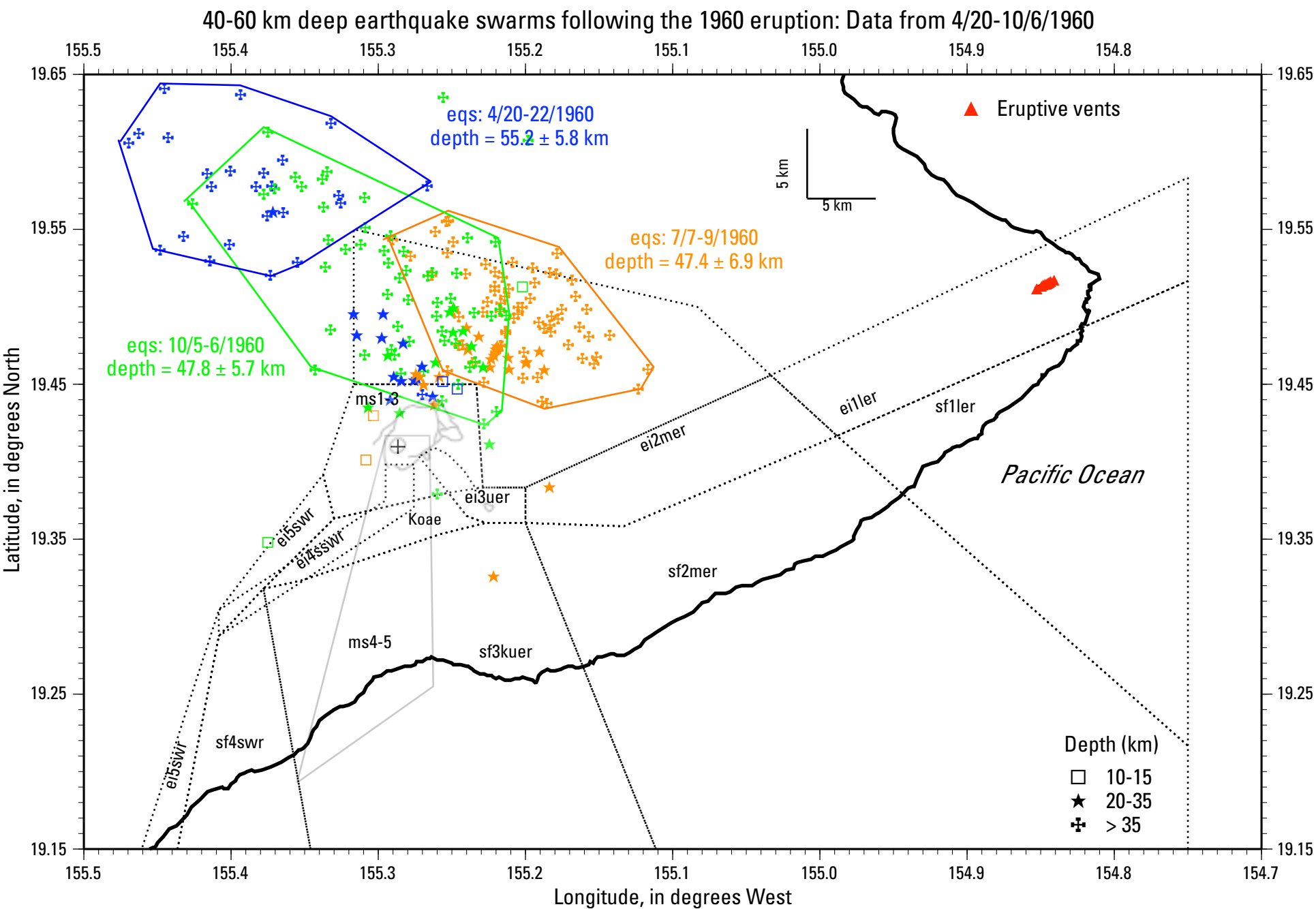


Appendix D Figure D10

5/31-6/3/1954 summit eruption: Data from 1/1/1954 through 7/1/1954

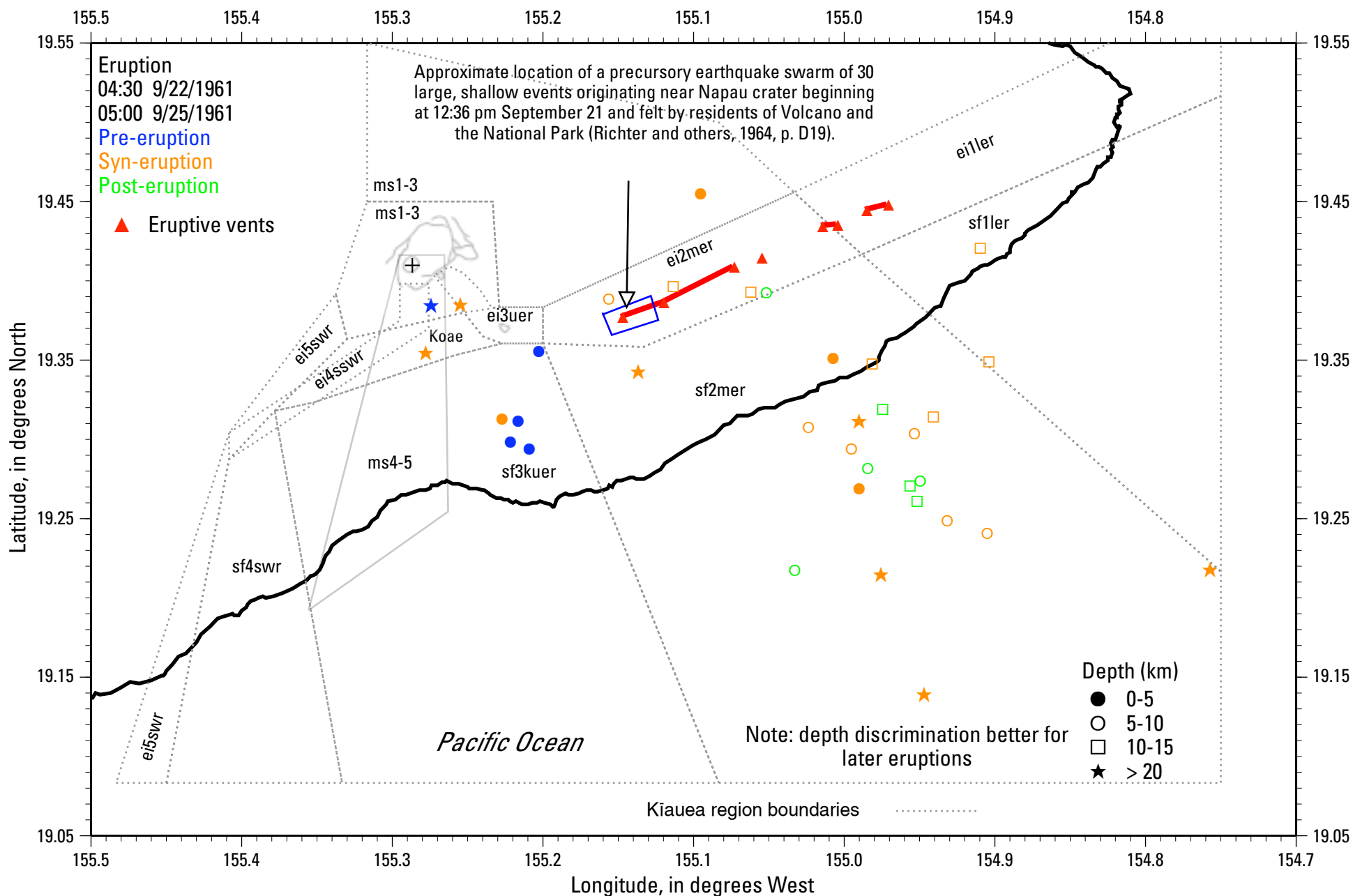


Appendix D Figure D11



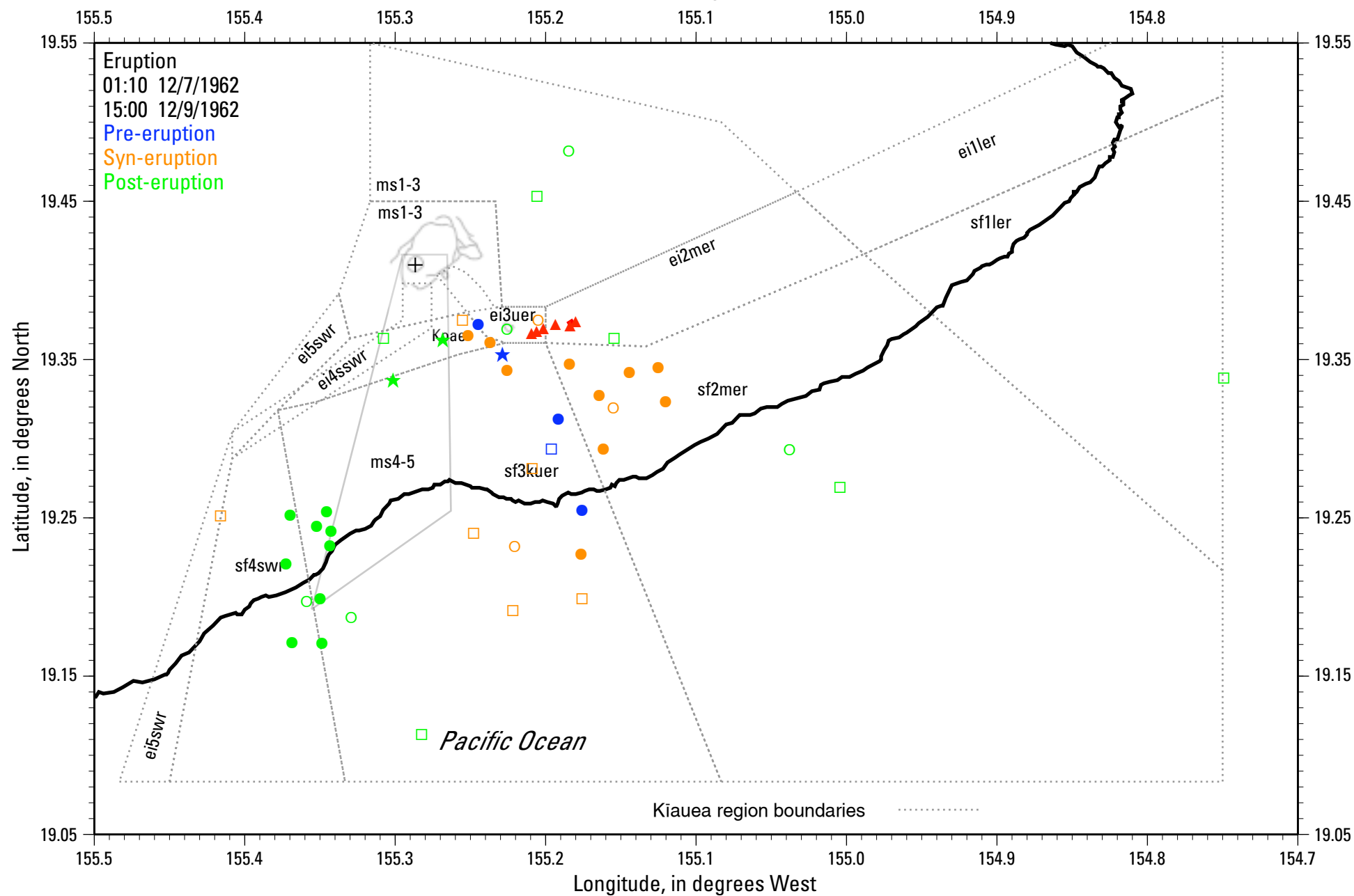
Appendix D Figure D12

Kīlauea 1961 flank eruption: data from 9/21-27/1961



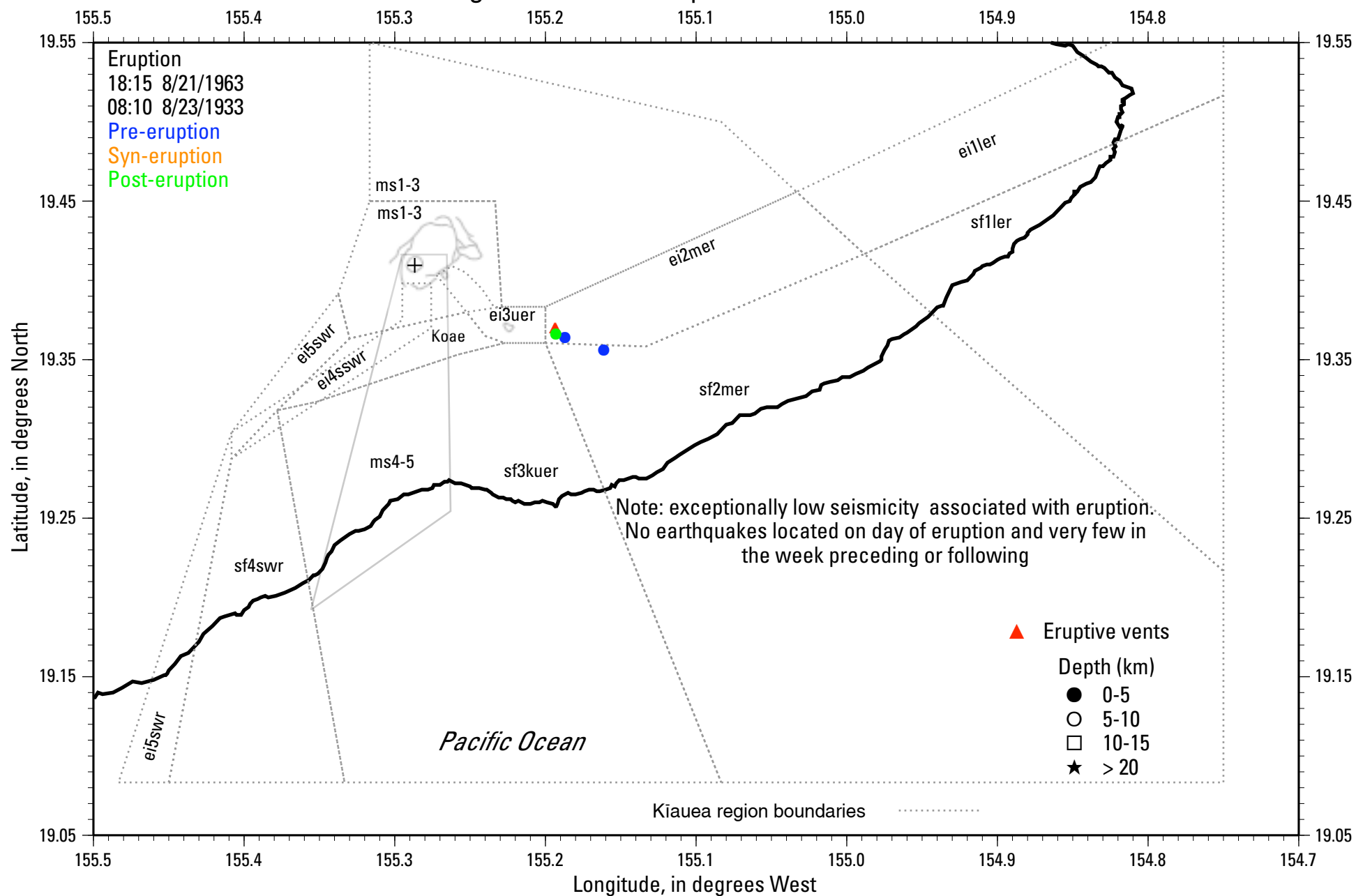
Appendix D Figure D13

Kilauea 1962 flank eruption: data from 12/6-19/1962



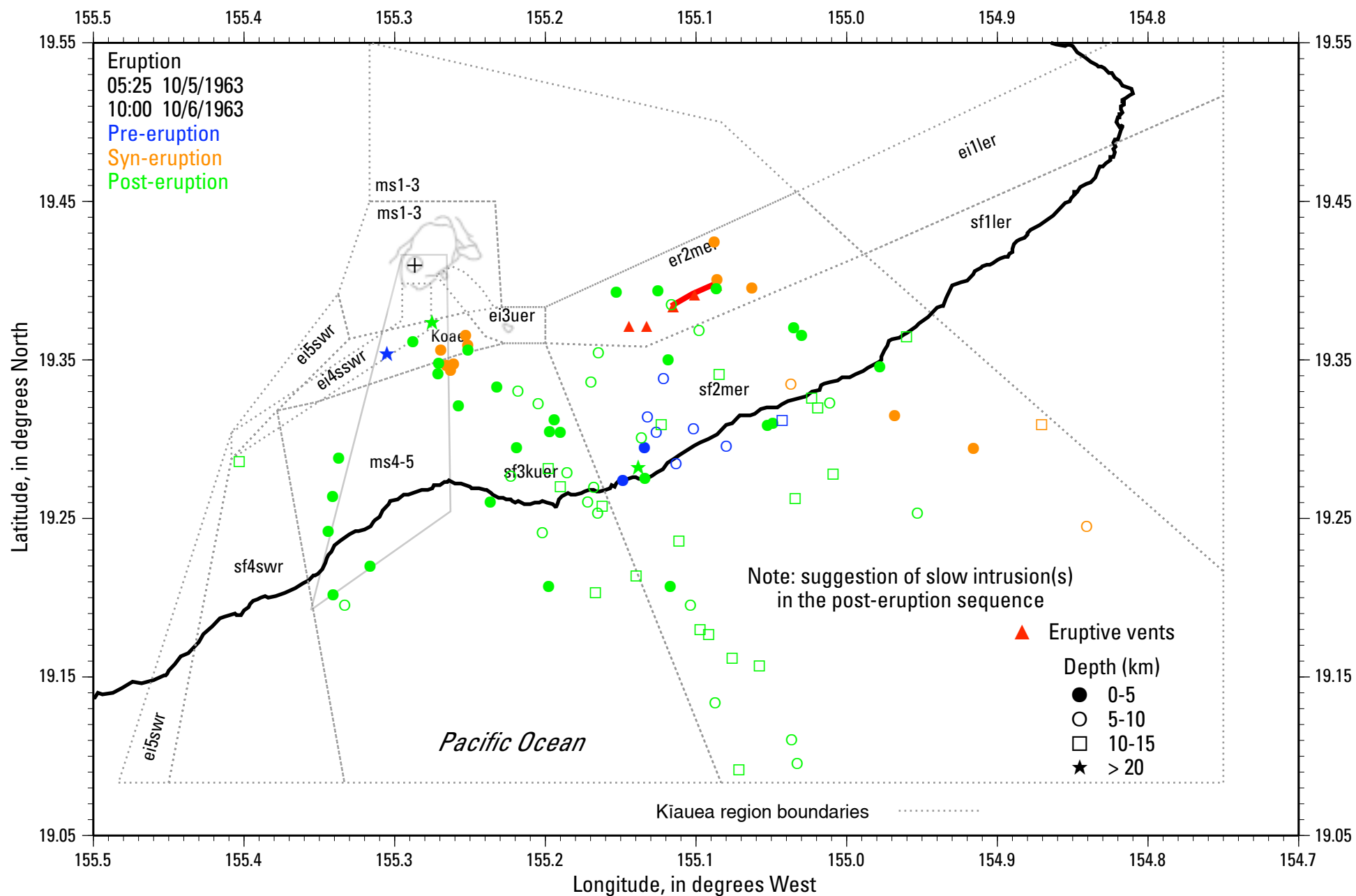
Appendix D Figure D14

Kīlauea August 1963 flank eruption: data from 8//21-23/1963



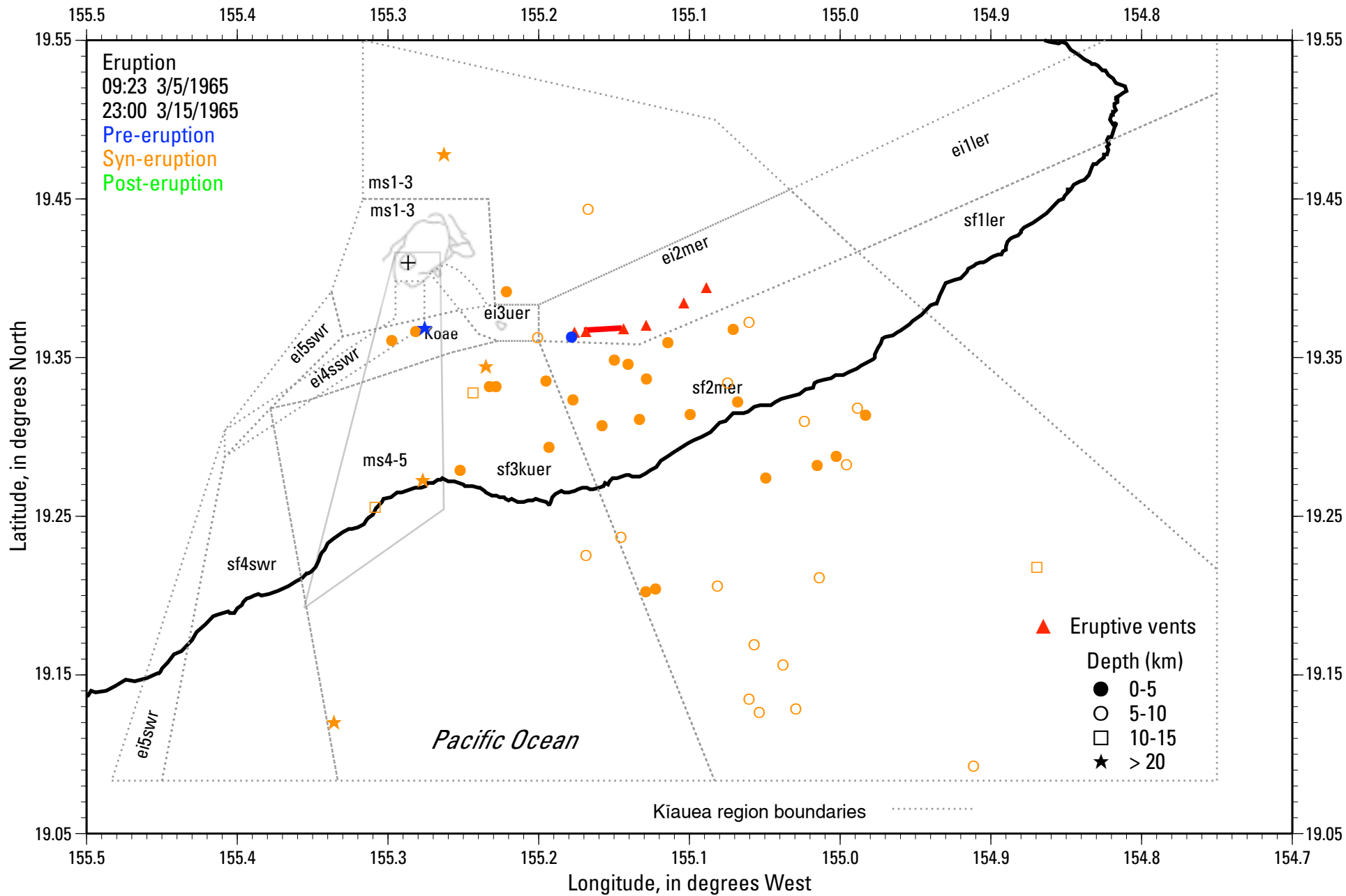
Appendix D Figure D15

Kīlauea 1963 east rift eruption: data from 10/4-19/1963



Appendix D Figure D16

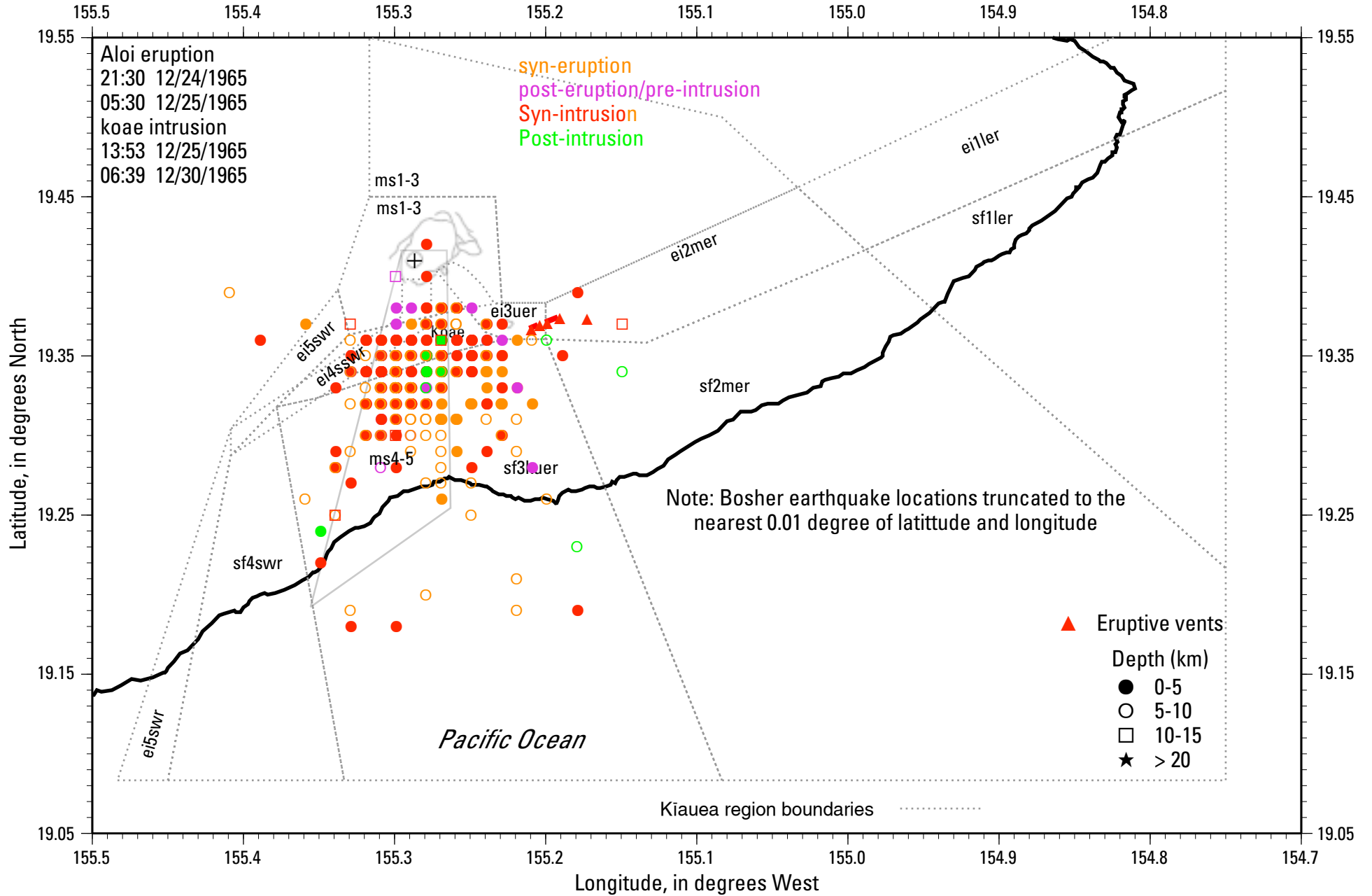
Kīlauea March 1965 flank eruption: data from 3/5-14/1965



Appendix D Figure D17A

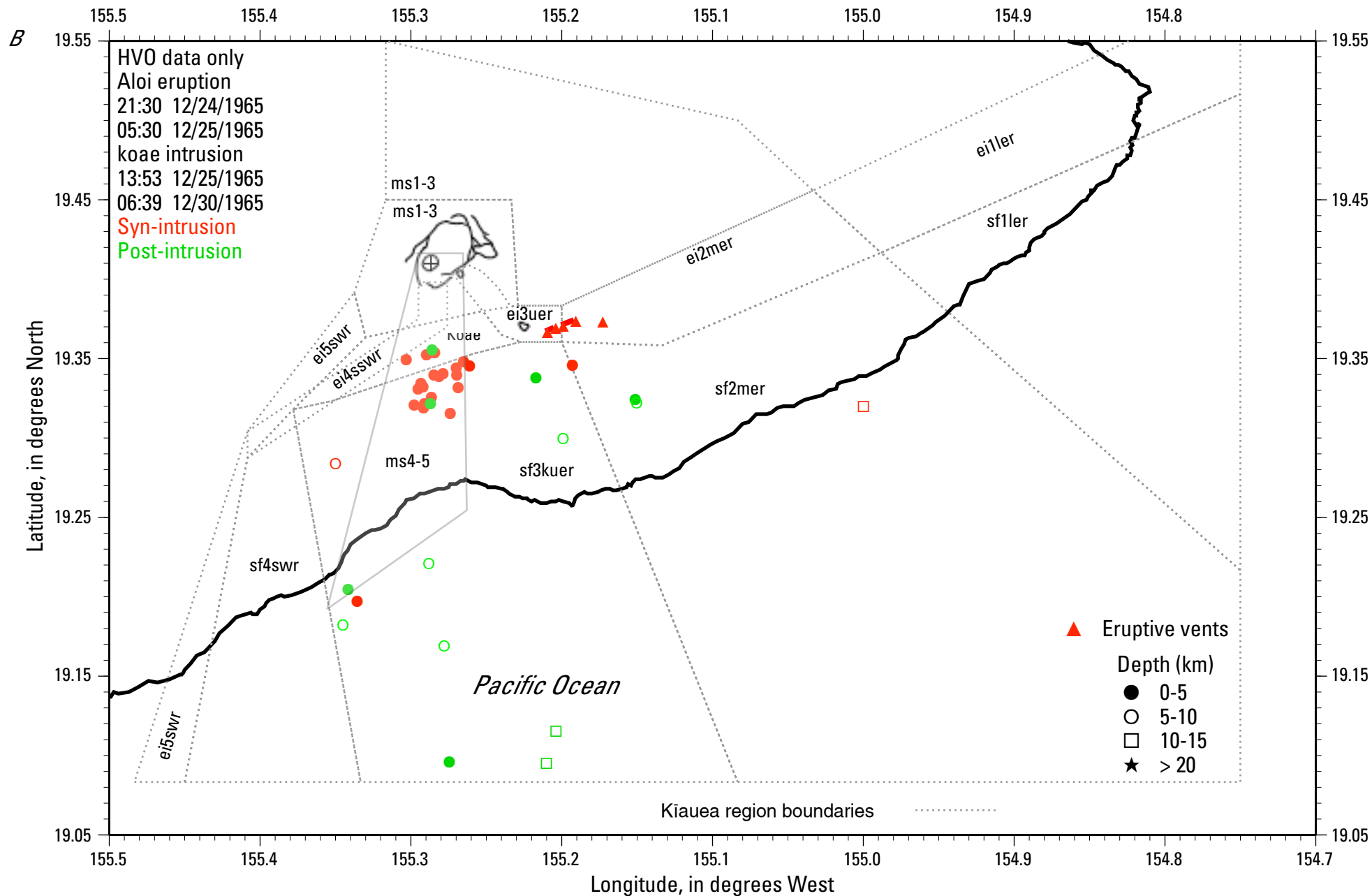
Kilauea December 1965 eruption/intrusion: data from 12/25-30/1965--Bosher data

A



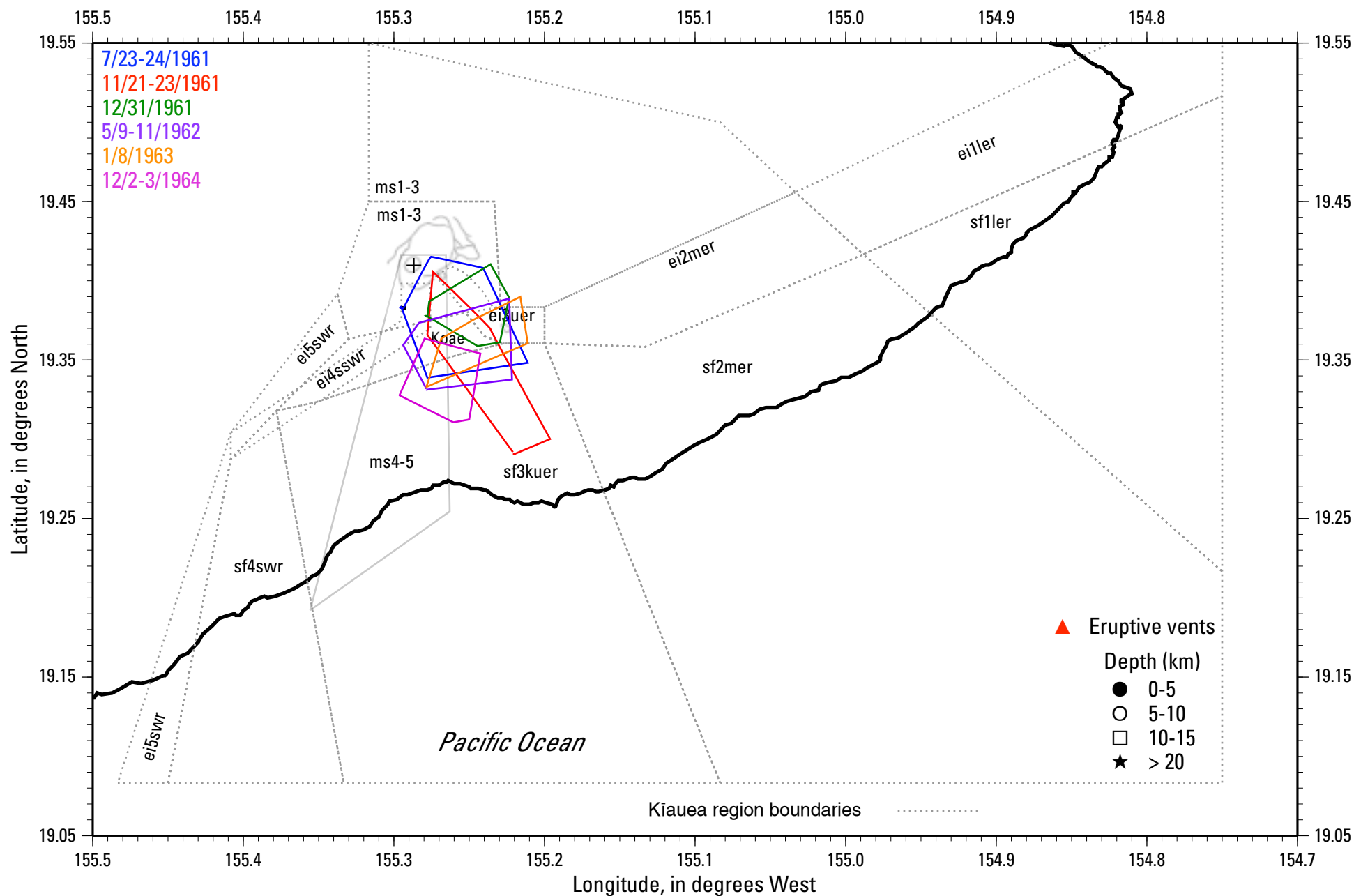
Appendix D Figure D17 B

Kilauea December 1965 eruption/intrusion: data from 12/28/1965-1/2/1966--HVO data only



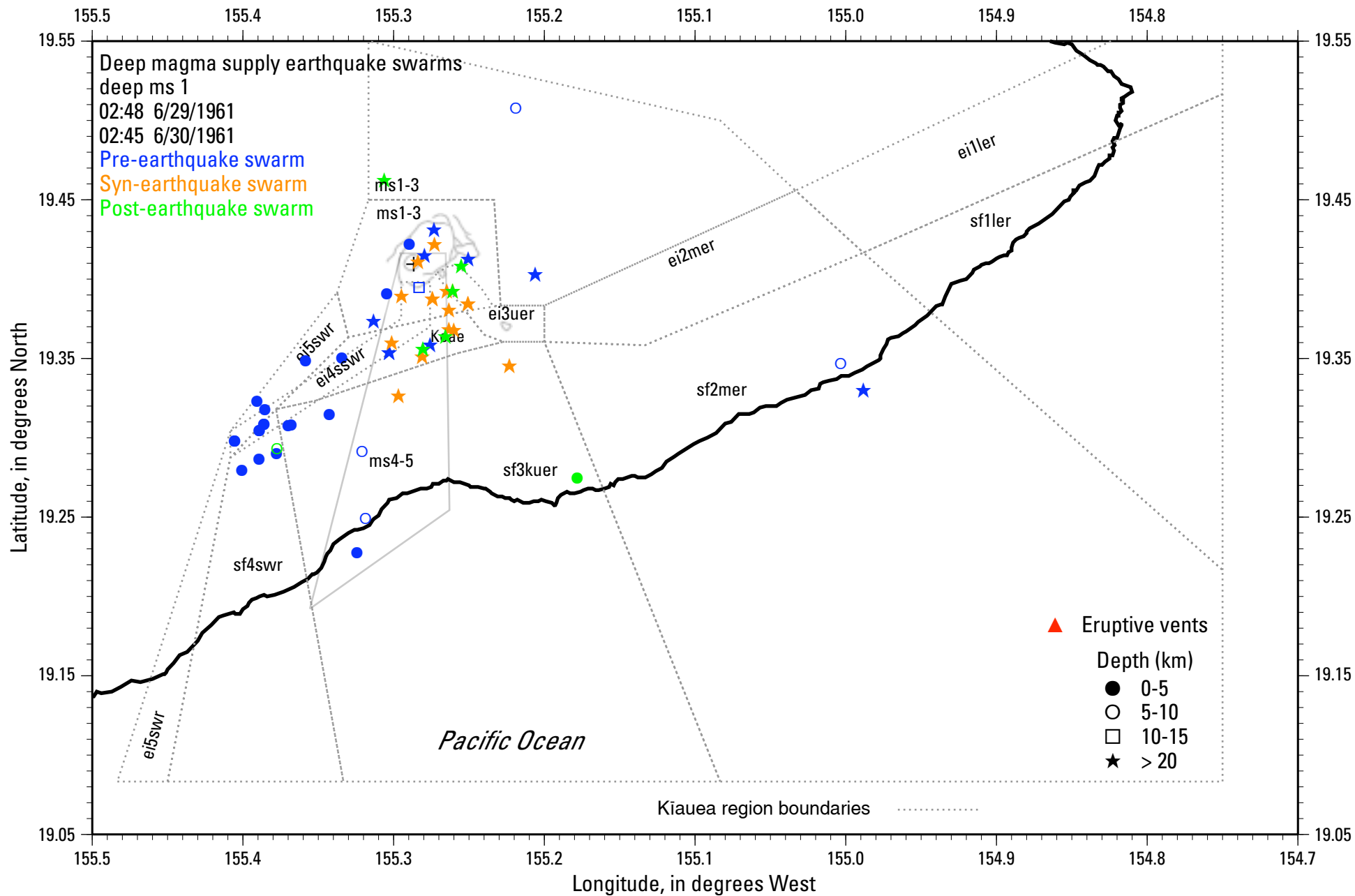
Appendix D Figure D18

1961-1965 30 km earthquake swarms



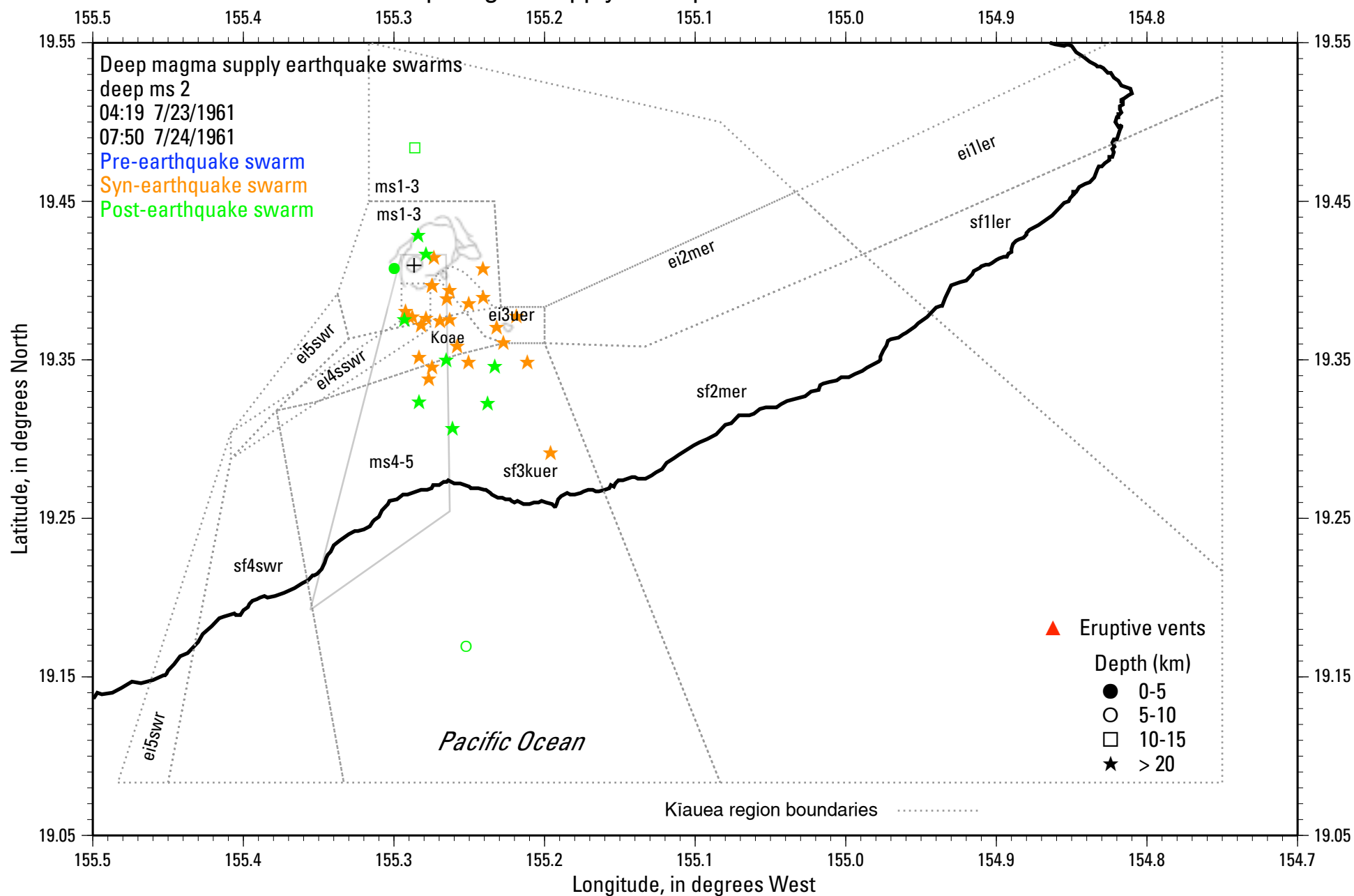
Appendix D Figure D19

Kilauea 1961 deep magma supply earthquake swarms: data from 6/17-7/3/1961

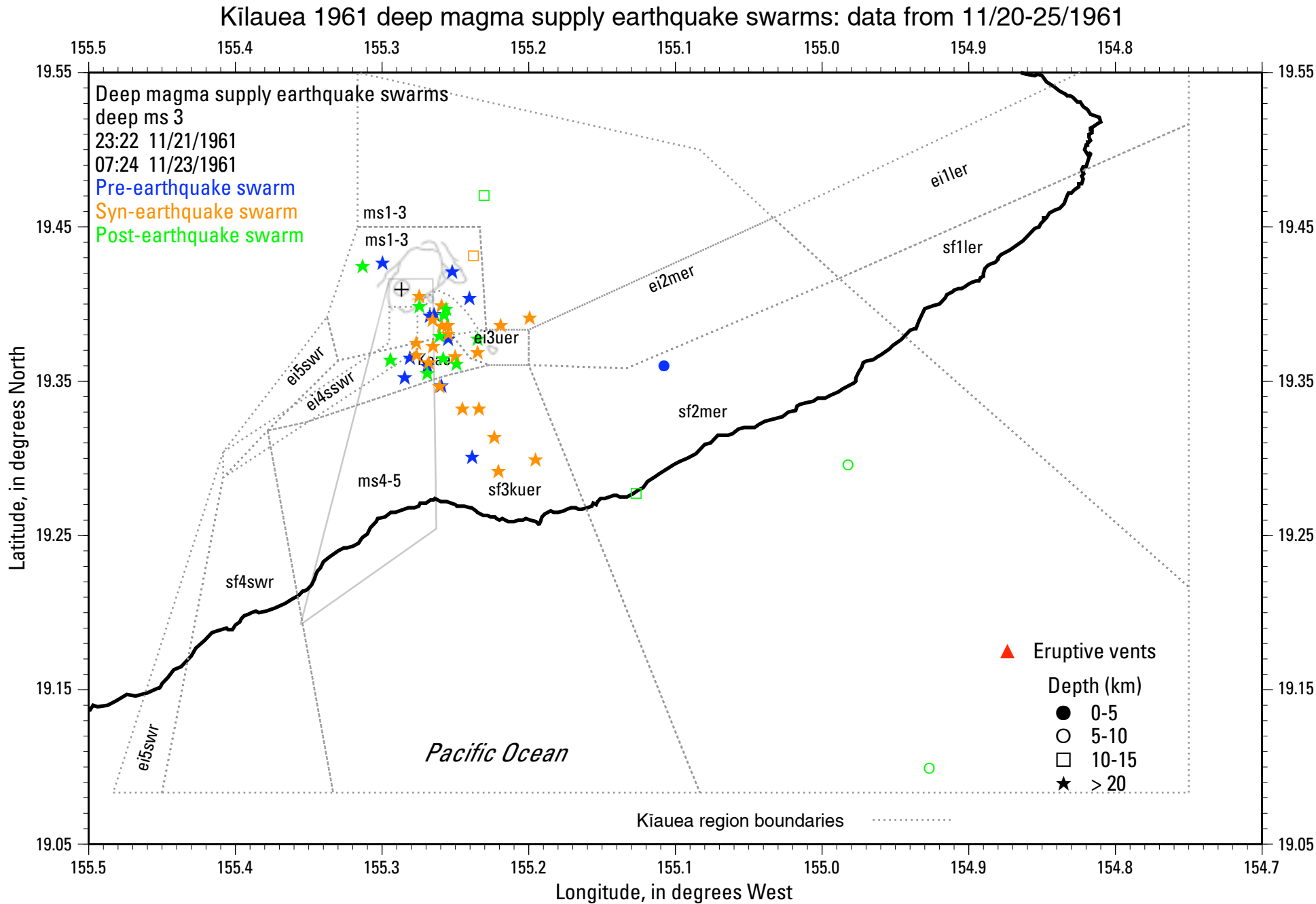


Appendix D Figure D20

Kīlauea 1961 deep magma supply earthquake swarms: data from 7/23-29/1961

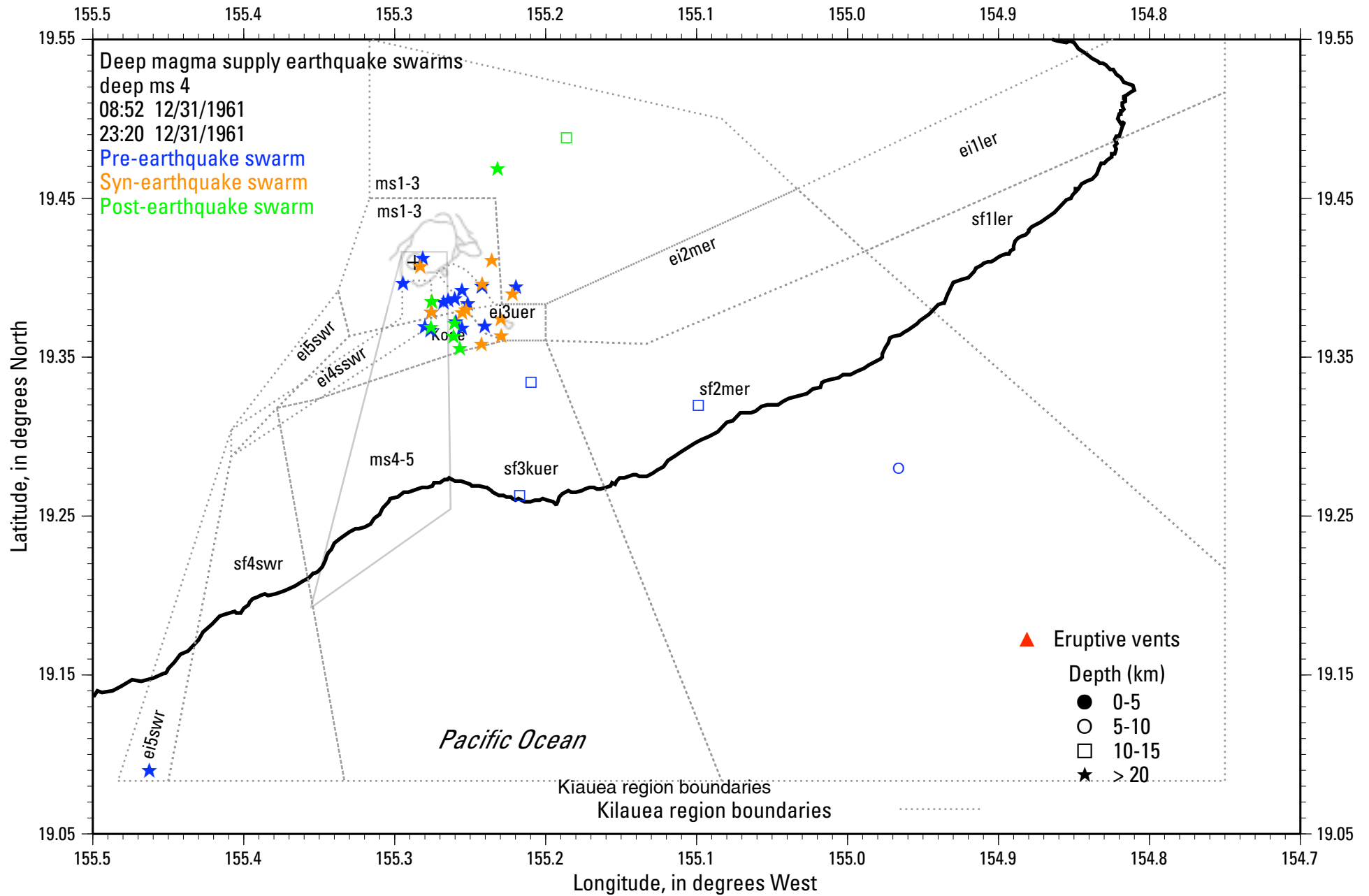


Appendix D Figure D21

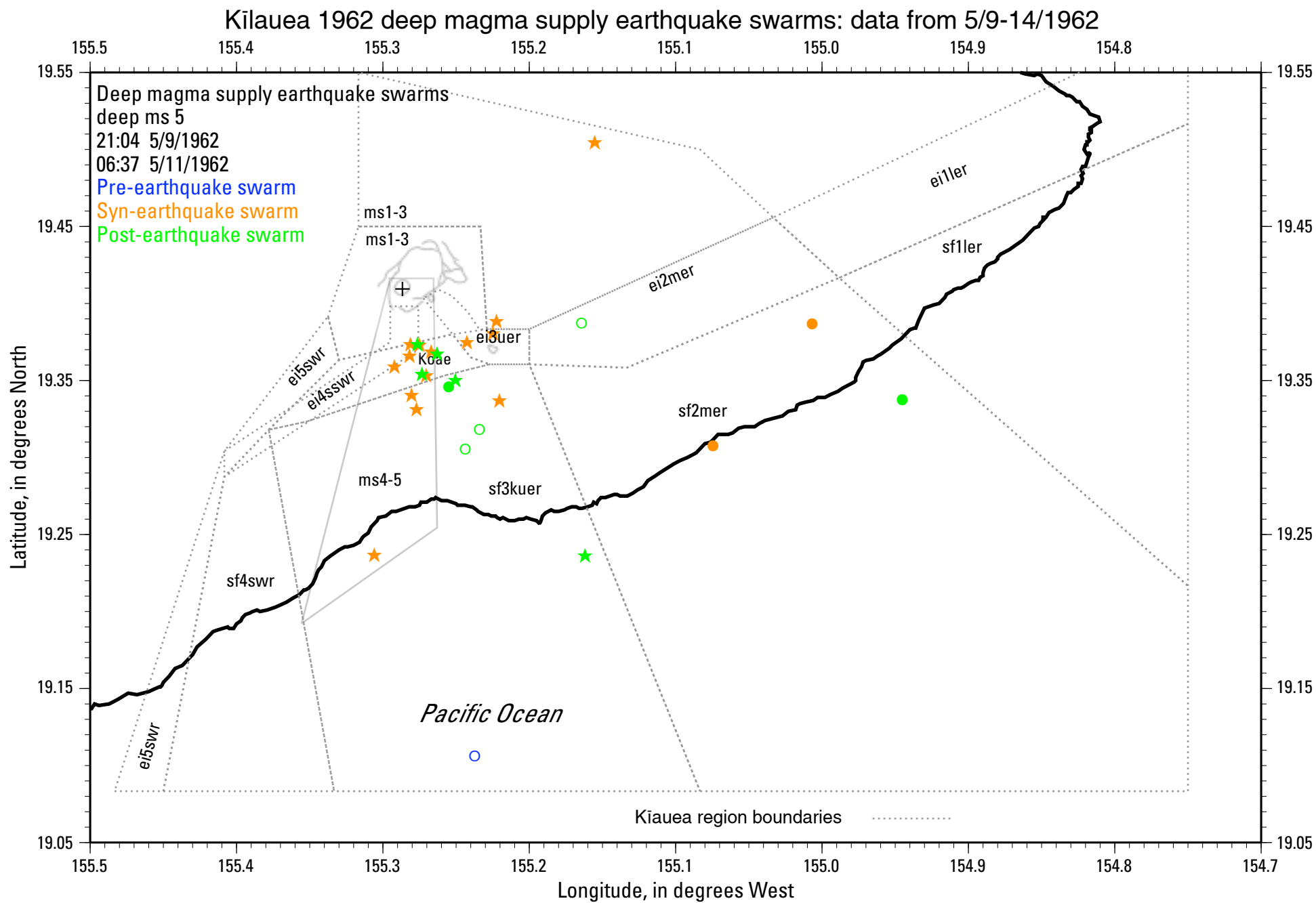


Appendix D Figure D22

Kīlauea 1961 deep magma supply earthquake swarms: data from 12/28/1961-1/3/1962

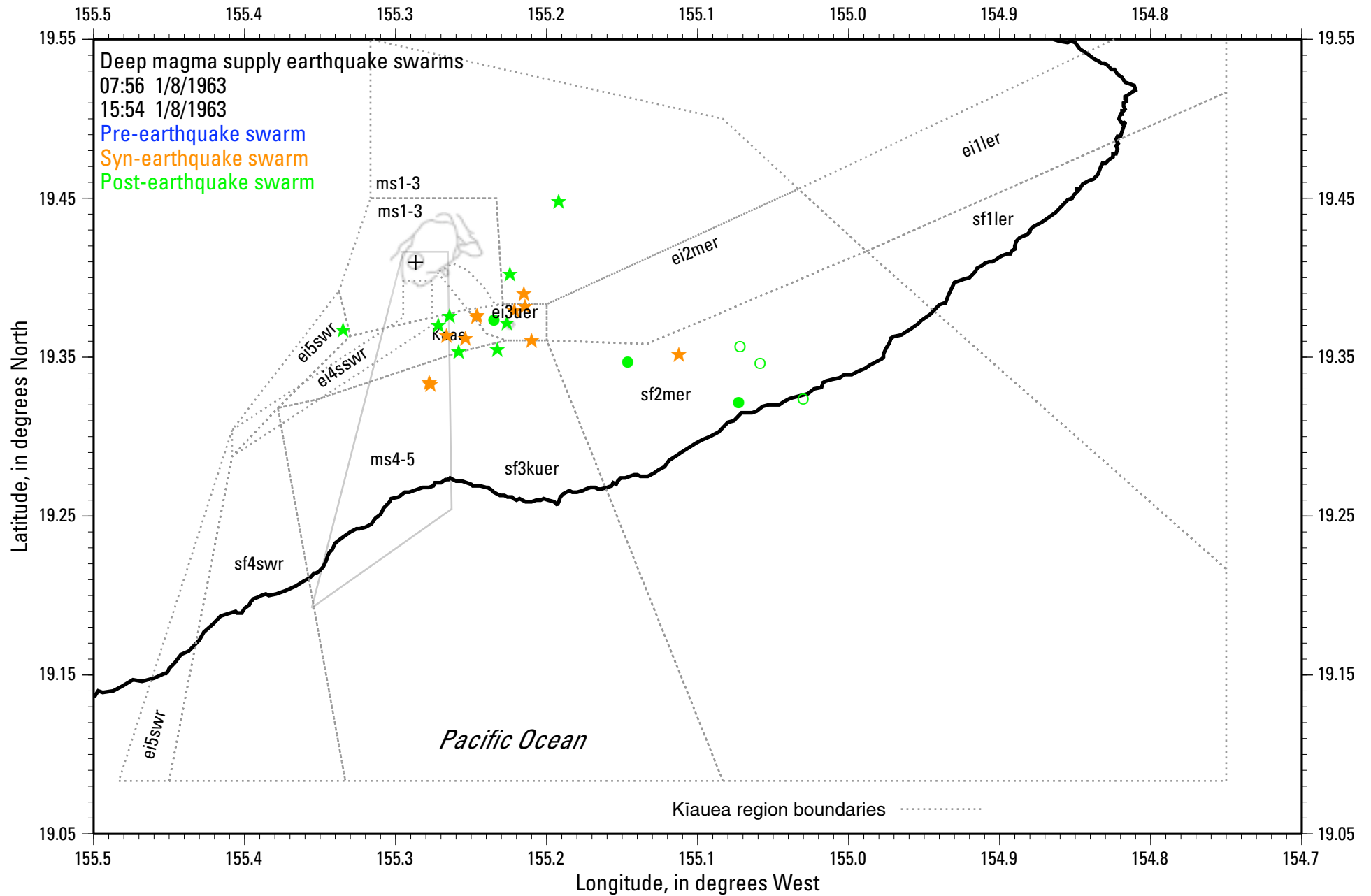


Appendix D Figure D23



Appendix D Figure D24

Kīlauea 1963 deep magma supply earthquake swarms: data from 1/8-14/1963



Appendix D Figure D25

