Appendix B–I Digital Files: Read Me First

Appendixes B–H supplement chapters 2–8. Tables are prepared in Microsoft Word, saved as .rtf files. Figures are saved in a .pdf file for each chapter.

Time series plots comprise the beginning pages of all .pdf files and, in chapters 5 and 7, where the eruptive sequence is divided into stages, time series files are interleaved with map plots whose letter and number designation are given in the figure columns of time series text tables for chapters 4, 5, 6, and 7. The time series plots emphasize earthquake swarms and are also divided into year-by-year tabulations in order to more easily enable study of short time periods or individual events.

The map plots show earthquakes occurring before, during, and after tabulated eruptions, intrusions, and a few large earthquakes with foreshocks and aftershocks, as in the plots included in the text chapters.

Appendix I stands alone with text, tables, and figures that describe the application of Mogi models to tilt and level data.

Appendix B. Supplementary Material to Support Chapter 2

Tables B1a and B1b list earthquakes of magnitudes between 5 and 6 for the same time periods as text tables 2.1 and 2.2, respectively.

Table B2 shows azimuth and distance from Uwēkahuna and Whitney Vaults to points within Kīlauea Caldera shown in text figure 2.4.

Table B3 contains Whitney tilt data to support text figure 2.3.

Figure B1 plots occurrence of earthquakes designated as "south Hawaiʻi" on a timeline that also shows (1) Kīlauea eruptions and intrusions, (2) Mauna Loa eruptions, and (3) Kīlauea earthquake swarms.

Appendix B Table B1 a. Earthquakes M 5-6, 1790-1894

Date begin	Date end	Loc.1	Type2	Comment	References
1/9/1826 11/5/1827 4/12/1829 11/22/1829			EQ EQ EQ EQ	Earthquakes, M 5.3—locations unknown, but possibly beneath Kīlauea	(Klein and Wright, 2000)
10/13/1833	1/29/1838	sf??	EQ	M 5.3, 5.6 (4), 5.9-- classified as "south Hawai'i"	(Klein and Wright, 2000)
4/7/1839		sf?	EQ	M 5.3—classified as "south Hawai'i"	(Klein and Wright, 2000)
12/18/1840		sf??	EQ	M 5.6—classified as "south Hawai'i"	(Klein and Wright, 2000)
9/30/1841 11/9/1842		sf??	EQ	M 5.3—classified as "south Hawai'i" M 5.3—classified as "south Hawai'i"	(Klein and Wright, 2000)
9/1/1844	1/8/1856	sf??	EQ	M 5.6, 5.3—17 shocks classified as "south Hawai'i"	(Klein and Wright, 2000)
10/22/1855		hm	C	Earlier dome collapsed, lava 100 ft down, no activity	(Coan, 1856b)
7/30/1857		sf??	EQ	M 6.1	(Klein and Wright, 2000)
9/9/1857		sf?	EQ	M 5.6	(Klein and Wright, 2000)
4/30/1858	6/1/1860	sf??	EQ	M 5.6—three shocks classified as "south Hawai'i"	(Klein and Wright, 2000)
3/12/1861		sf??	EQ	M 5.3—classified as "south Hawai'i"	(Klein and Wright, 2000)
12/30/1861		sf??	EQ	M 5.6	(Klein and Wright, 2000)
5/9/1863		sf??	EQ	M 5.9—classified as "Hawai'i"	(Klein and Wright, 2000)
11/26/1863		sf??	EQ	M 5.9—classified as "south Hawai'i"	(Klein and Wright, 2000)
12/11/1865	11/7/1867	sf??	EQ	M 5.3 (2), 5.6- classified as "south Hawai'i"	(Klein and Wright, 2000)
4/19/1868	5/17/1868	sf??	EQ	M 5.3 (4) aftershocks of the 1868 earthquake classified as "South Hawai'i"	(Klein and Wright, 2000)
6/10/1868 7/12/1868		sf??	EQ	M 5.3--do.[3] M 5.3--do.	(Klein and Wright, 2000)
7/23/1868		sf??	EQ	M 5.9—do.	(Klein and Wright, 2000)
8/7/1868	11/1/1876	sf??	EQ	M 5.0 (2), M 5.3 (45), M 5.4 (2), M 5.5, M 5.6 (12), M 5.9 (3)—do.	(Klein and Wright, 2000)
11/16/1868		sf?	EQ	M 5.6	(Klein and Wright, 2000)
9/13/1871		sf?		M 5.9	(Klein and Wright, 2000)
8/2/1877 3/16/1879		sf??	EQ	M 5.3 (2)--do.	(Klein and Wright, 2000)
5/15/1879	6/20/1880	sf??	EQ	M 5.3 (4), M 5.6--do.	(Klein and Wright, 2000)
5/21/1882	12/2/1885	sf??	EQ	M 5.0, 5.3 (4), 5.4 (3), 5.6 (2)--do.	(Klein and Wright, 2000)
10/18/1886	7/26/1890	sf??	EQ	M 5.6 (2), 5.9, 5.3 (4), 5.9, 5.4, 5.2—do.	(Klein and Wright, 2000)
10/15/1891	6/16/1894	s??		M 5.3 (4), 5.6 (with aftershocks)--do.	(Klein and Wright, 2000)

[1] Location abbreviations: Kīlauea caldera (kc); Halemaumau crater (hm); East rift zone (erz); Southwest rift zone (swr); seismic southwest rift zone (sswr); Koa'e fault zone (koae); South flank (sf)
[2] Eruption (E); intrusion (I); Earthquake ≥ M5 (EQ); Earthquake swarm (EQS); Collapse of Kīlauea's summit (C)
[3] do. = aftershocks of the 1868 earthquake classified as "South Hawai'i"

Appendix B Table B1. b. Earthquakes M 5-6, 1895-1925

Date begin	Date end	Loc.[1]	Type[2]	Comment	References
3/10/1897	5/6/1897	sf??	EQ	M 5.3 (3)--classified as “south Hawai‘i”	(Klein and Wright, 2000)
10/24/1897		sf?	EQ	M 5.3—classified as “Kīlauea south flank?”	(Klein and Wright, 2000)
5/17/1898 9/15/1898 1/4/1899		sf??	EQ	M 5.3--classified as “south Hawai‘i” (3 dates)	(Klein and Wright, 2000)
10/31/1899 7/10/1900 10/12/1900		sf??	EQ	M 5.3--classified as “south Hawai‘i” (3 dates)	(Klein and Wright, 2000)
9/28/1902		sf?	EQ	M 5.6—classified as “Kīlauea south flank??”	(Klein and Wright, 2000)
5/3/1905	5/7/1905	sf?	EQ	M 6.18 w M 5.3 foreshock and many aftershocks, some as strong as M 5—classified as “Kīlauea south flank?”	(Klein and Wright, 2000)
9/5/1907	9/7/1907	sf?	EQ	M 5.16 with at least 2 aftershocks, one of M 5.3—classified as “Kīlauea south flank?”	(Klein and Wright, 2000)
3/13/1909		kcal	EQ	M 5.35, deep beneath Kīlauea caldera??	(Klein and Wright, 2000)
4/19/1910		sf??	EQ	M 5.3 classified as “Kīlauea?”	(Klein and Wright, 2000)
4/10/1912		sf??	EQ	M 5.3--classified as “south Hawai‘i”	(Klein and Wright, 2000)
5/22/1912		sf?	EQ	M 5.9—classified as “Kīlauea south flank?”	(Klein and Wright, 2000)
10/14/1912	10/15/1912	kcal	EQS	Kīlauea caldera 0-5 km?—Halema‘uma‘u obscured, so not sure how shallow earthquakes relate	(Jaggar, 1947, p. 43-45; Klein and Wright, 2000)
10/25/1913	11/9/1913	ksf	EQ	M 5.81-- Kīlauea south flank, at least 14 aftershocks	(Klein and Wright, 2000)
5/24/1914	6/2/1914	sf?		M 5.22 on 6/1/1914	(Klein and Wright, 2000)
5/26/1915		sf?	EQ	M 5.24 classified as “Kīlauea south flank??”—at least 7 as	(Klein and Wright, 2000)
7/11/1916		sf?	EQ	M 5.04 classified as “Kīlauea south flank?”	(Klein and Wright, 2000)
10/3/1916	10/7/1916	sf??	EQS?	12 events 20-30 km	(Klein and Wright, 2000)
10/8/1916		sf?	EQ	classified as “unknown”, but felt generally over south Hawai‘i -- Kīlauea south flank?	(Klein and Wright, 2000)
7/29/1917		sf?	EQ	M 5.2 (2) classified as “Kīlauea south flank?”	(Klein and Wright, 2000)
5/21/1918	5/23/1918	kcal	EQ	M 5.14 deep beneath Kīlauea caldera??—2 aftershocks	(Klein and Wright, 2000)
2/25/1919		sf?	EQ	M 5.2 classified as “Kīlauea south flank?”	(Klein and Wright, 2000)
6/18/1919		hm	EQS?/C	ass. with lowering of Halema‘uma‘u lava lake level?	(Klein and Wright, 2000)
8/26/1919		kcal?	EQ	M 5.00 deep beneath Kīlauea caldera?	(Klein and Wright, 2000)
11/28/1919	12/4/1919	erz	EQS/C/I	> 200 events associated with draining of Halema‘uma‘u lava lake. Assume middle east rift intrusion with south flank response	(Bevens and others, 1988, v. 2, p. 1059; Klein and Wright, 2000)
10/27/1920		sf?	EQ	M 4.2 classified as “Kīlauea south flank?”	(Klein and Wright, 2000)
5/19/1921		sf?	EQ	M 4.5 felt all island	(Klein and Wright, 2000)
2/21/1922		sf?	EQ	M 5.72 classified as “Kīlauea south flank?”—several aftershocks	(Klein and Wright, 2000)
3/12/1922		kcal	EQ	M 4.63 classified as “deep beneath Kīlauea caldera??”—several aftershocks	(Klein and Wright, 2000)
sf	6/1/1922 6/8/1922	kcal erz sf	EQS	earthquake swarm of 560 events (108 at 0-10 km beneath Kīlauea caldera; 432 beneath east rift zone) associated with 850-foot lowering of lava lake south flank response (67 events)	(Bevens and others, 1988, v. 3, p. 287-290; Klein and Wright, 2000)

[1] Location abbreviations: Kīlauea caldera (kc); Halema‘uma‘u crater (hm); East rift zone (erz); Southwest rift zone (swr); seismic southwest rift zone (sswr); Koa‘e fault zone (koae); South flank (sf)

[2] Eruption (E); intrusion (I); Earthquake ≥ M5 (EQ); Earthquake swarm (EQS); Collapse of Kīlauea’s summit (C)

Date begin	Date end	Loc.[1]	Type[2]	Comment	References
7/19/1924	7/30/1924	hm	E	Return of lava to bottom of Halemaʻumaʻu	(Bevens and others, 1988, v. 3, p. 576; Klein and Wright, 2000)

Appendix B table B2. Azimuth and distance to deformation centers[1]

A. Uwēkahuna vault

Location[1]	Azimuth from Uwēkahuna		Distance (km)	Comment
	Inflation	Deflation		
2	287.8	107.8	1.77	northernmost center
1	309.5	129.5	2.49	
9	319	139	3.91	easternmost center
3	323.8	143.8	3.63	
7	331.2	151.2	3.63	
10	334.4	154.4	3.68	southernmost center
6	337.7	157.7	3.63	
8	341.0	161.0	3.03	
4	344.3	164.3	3.11	
5	361.2 (1.2)	181.2	3.08	westernmost center
Halema‘uma‘u	330.5	150.5	1.42	summit eruption center
Keanakāko‘i	305.7	125.7	3.15	southeast caldera
Puhimau	342.6	121.7	4.76	upper east rift zone
Kōko‘olau	339.6	125.0	5.46	upper east rift zone

B. Whitney vault

Location[1]	Azimuth from Whitney		Distance (km)	Comment
	Inflation	Deflation		
2	53.7	233.7	2.16	northernmost center
1	34.6	214.6	2.89	
9	13.0	193.0	3.88	easternmost center
3	21.8	201.8	4.05	
7	25.9	205.9	4.39	
10	27.2	207.2	4.57	southernmost center
6	29.4	209.4	4.67	
8	36.9	216.9	4.47	
4	37.5	217.5	4.58	
5	34.80	224.8	5.12	westernmost center
Halema‘uma‘u	51.7	231.7	3.02	summit eruption center
Keanakāko‘i	11.7	191.7	2.53	southeast caldera
Puhimau	342.6	162.6	3.29	upper east rift zone
Kōko‘olau	339.6	159.6	4.03	upper east rift zone

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[1] Numbers denote deformation centers at Kīlauea’s summit shown on fig. 5 of Fiske et. al., 1969

Table B3. Whitney tilt data associated with Halemaumau draining and collapse (Fig. 2.3)

Event[i]	Begin	End	Dh	Eq_N	T_{mag}	T_{az}[ii]	Comment[iii]	Reference(s)[iv]
lava lake	9/12/1915	9/28/1915	-42.3				draining	BTW2, p. 361-362
eq swarm	9/22/1915	9/29/1915		>100			erz intrusion	(Klein and Wright), 2000
tilt change	8/30/1915	9/19/1915			7.43	196	deflation	
lava lake	5/25/1916	6/6/1916	-124.4				draining	BTW2, p. 463-464
eq swarm	6/4/1916	6/11/1916		>200			erz intrusion	(Klein and Wright, 2000); BTW2, p. 465
tilt change							no record	
lava lake	6/6/1916	2/1/1917	206.0				filling	BTW2, p. 465-561
lava lake	2/1/1917	2/23/1918	18.7				filling	BTW2, p. 561-728
tilt change	-	1/19/1918					incomplete record	
tilt change	1/19/1918	2/21/1918			11.64	42.5	inflation	
lava lake	2/23/1918	3/3/1918	"0"				Halema‘uma‘u overflow	BTW2, p. 733-738
tilt change	2/21/1918	3/26/1918			6.55	161	deflation--mixed[v].	
lava lake	3/3/1918	3/26/1918	2.0				building new levees	BTW2, p738-748
eq swarm	3/26/1918	4/5/1918		41			summit only?	(Klein and Wright, 2000); BTW2, p. 749-755
lava lake	3/26/1918	4/5/1918	-85.3				draining	BTW2, p. 754-755
tilt change	3/24/1918	4/3/1918			2.28	198	minor deflation	
tilt change	4/3/1918	11/8/1918			21.0	124	deflation-mixed	BTW2, p. 757-842
lava lake	4/5/1918	11/8/1918	75.5				filling	
Lava lake	11/81918	11/16/1918	-68.3				draining	BTW2, p. 844-846
eq swarm	11/15/1918	11/17/1918		>79			intrusion?	BTW2, p. 846)
tilt change	11/10/1918	11/17/1918			11.0	358	regional inflation[vi]	
tilt change	10/22/1918	2/1/1919			80.6	355	regional inflation	
lava lake	11/16/1918	2/7/1919	75.8				filling	BTW2, p. 846-885
tilt change	2/1/1919	11/28/1919			7.6	360	regional inflation	
eruption	2/7/1919	11/28/1919	-5.5		5.6	324	"Postal rift" eruption, Kīlauea	BTW2, p. 888-1128
lava lake	11/28/1919	11/30/1919	-187.1				caldera	
eq swarm	11/28/1919	11/30/1919		7			draining	BTW2, p. 1128
tilt change	11/28/1919	11/30/1919			3.34	198		
							deflation	
tilt change	11/30/1919	12/28/1919			3.91	21	inflation	
lava lake	11/30/1919	12/22/1919	194.2				filling	BTW2, p. 1055-1186
Lava lake	12/22/1919	1/15/1920	-95.4				draining	BTW2, p. 1077-1078
	12/15/1919	7/20/1920					Mauna Iki (sw rift) eruption	BWT2, p. 1074-1186
eq swarm	12/15/1919	12/19/1919		83			no tilt change; shallow swr	(Klein and Wright, 2000); BTW2, p.1074-77
	12/22/1919	2/8/1920		30			intrusion	BTW2, p. 1086)
tilt change	12/28/1919	12/31/1919			1.73	194	south flank response	
							deflation; source 2 response to	
							eruption	
lava lake	1/15/1920	3/18/1921	110.6				filling	BTW2, p. 1093-1129
tilt change	1/26/1920	3/20/1921			7.2	40	inflation	
lava lake	3/18/1921	3/25/1921	-1.3				Halema‘uma‘u overflow	BTW3, p. 63-75
lava lake	3/25/1921	7/25/1921	-107.6				draining	BTW3, p. 75-152
tilt change	3/20/1921	7/22/1921			3.5	234	deflation—mixed?	
lava lake	7/25/1921	10/1/1921	86.3				filling	BTW3, p. 152-204
tilt change	7/22/1921	10/10/1921			2.4	152	deflation-mixed	
lava lake	10/1/1921	11/20/1921	-95.5				draining	BTW3, p. 204-216
tilt change	10/10/1921	11/20/1921			0.7	104	mixed	

Event[i]	Begin	End	Dh	Eq_N	T_{mag}	T_{az}[ii]	Comment[iii]	Reference(s)[iv]
lava lake	11/20/1921	5/13/1922	104.3				filling	BTW3, p190-220
tilt change	11/20/1921	5/24/1922			5.8	315	inflation--mixed	BTW3, p. 219
Lava lake	5/13/1922	6/6/1922	-251.2				draining	BTW3, p. 277-317
eq swarm	5/15/1922	6/1/1922		>600			kcal ⇒ erz e/I	BTW3, p. 287-290, 302
eruption	5/28/1922	5/30/1922					Eruption/intrusion east rift zone	BTW3, p. 284-285
tilt change	5/24/1922	6/6/1922			15.4	196	deflation	BTW3, p. 290
Lava lake	12/22/1922	1/3/1923	-57.9				draining	BTW3, p. 372-383
eq swarm	12/31/1922	1/4/1923		133			erz intrusion?	BTW3, p. 375, 384-386
tilt change	12/24/1922	12/31/1922			3.45	220	deflation	BTW3, p. 290
lava lake	1/3/1923	7/21/1923	188.0				filling	BTW3, p. 382-441
tilt change	12/31/1922	8/25/1923			7.0	83	mixed	
Lava lake	7/21/1923	8/29/1923	-128.9				draining	BTW3, p. 451-461
eq swarm	8/3/1923	8/6/1923		76			minor lava lake/tilt change	
eq swarm	8/24/1923	8/27/1923		92			East rift intrusion	BTW3, p. 461-462
eruption	8/25/1923	8/26/1923					Eruption/intrusion east rift zone	BTW3, p. 460
tilt change	8/25/1923	8/27/1923			3.04	261	mixed	
lava lake	8/29/1923	2/9/1924	142.4				filling	BTW3, p. 461-508
tilt change	8/27/1923	1/31/1924			14.2	328	inflation--mixed	
Lava lake	2/9/1924	2/21/1924	-76.2				draining	BTW3, p. 506-508
eq swarm	2/13/1924	2/20/1924		21				BTW3, p. 510
tilt change	1/31/1924	2/12/1924			3.15	201	deflation[vii]	BTW3, p. 510
Lava lake	2/21/1924	3/1/1924[viii]	-85.3				draining	BTW3, p. 512
eq swarm	3/7/1924	4/17/1924		85			mid erz intrusion	(Klein and Wright, 2000)
tilt change	2/25/1924	4/28/1924			14.52	196	net deflation[ix]	BTW3, p. 514, 528
Lava lake	4/28/1924[viii]	6/1/1924	-289.6				draining	BTW3, p. 524, 530-560
eq swarm		4/29/1924		264			lower erz intrusion	BTW3, p. 515-528
eruption	4/17/1924	5/27/1924					Halema‘uma‘u—expl. eruption	BTW3, p. 536-560
tilt change	5/10/1924	5/31/1924			63.8	199	Deflation; mixed—due to deep eq	
tilt change	4/28/1924 5/31/1924	6/1/1924			1.4	285	on 5/30/1924	(Klein and Wright, 2000)
tilt change	6/1/1924	8/1/1924			11.82	172	regional deflation	
eruption	7/19/1924	7/30/1924					Return of lava Halema‘uma‘u	BTW3, p. 581-583
tilt change	8/1/1924	9/14/1924			3.42	38	inflation	
tilt change	9/15/1924	12/29/1924			7.80	194	deflation	
total	2/25/1924	12/29/1924			80.45	194		

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[i] Headings 1-7 as follows: Event = type of measurement; Begin and End = beginning and ending times; Dh = increase or decrease in height of lava lake surface difference measured in meters; Eq_N = number of earthquakes in swarm; T_{mag} = Whitney tilt magnitude in seconds; tilt azimuth in degrees.

[ii] Azimuths from the Whitney vault that fall within the range of centers defined for the inflation preceding the 1967-68 eruption (Fiske and Kinoshita, 1969)—see Chapter 4 appendix table D3--are highlighted in **bold** type.

[iii] Eruptions and well-documented or suspected intrusions are *italicized*. Inflation/deflation of Kīlauea's shallow reservoir are highlighted **bold**. Other inflation/deflation vectors are explained in subsequent footnotes and text.

[iv] Reference to the weekly and monthly reports of the Hawai‘ian Volcano Observatory (Bevens and others, 1988) are abbreviated as follows: Volume 2 = BTW2; volume 3 = BTW 3.

[v] Deflation or inflation azimuths at variance with the centers defined by Fiske and Kinoshita (1969) can be explained as a vector addition of a regional deflation (see the large 1918-1919 inflation and 1924 deflation) and shallow uplift beneath Halema‘uma‘u.

[vi] Azimuths between 270 and 360° (inflation) or between 90 and 180° (deflation) lie outside of the range of azimuths to inflation centers. .preceding the 1967-68 eruption (Fiske and Kinoshita, 1969) and are interpreted as a deeper regional inflation. See text for further explanation.

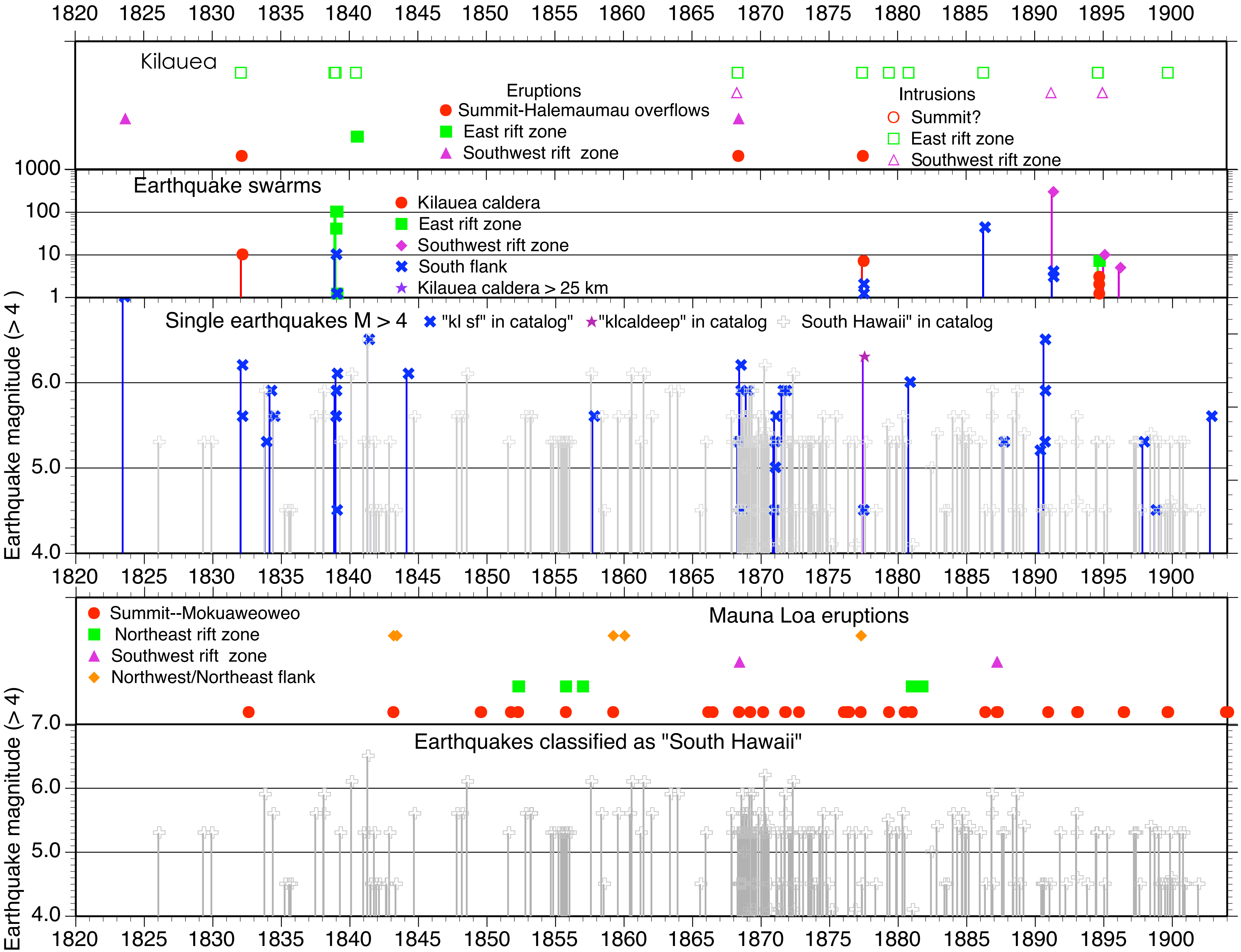
[vii] Followed by inflation between 2/12 and 2/21. Changes in lava lake level are poorly correlated with tilt change in this period.

[viii] No tilt measurement between 3/1/1924 and 4/28/1924.

[ix] During this period an unchanging level of Halema‘uma‘u lava lake is accompanied by alternating episodes of inflation and deflation. The net tilt change for this period (deflation) is shown.

Figure B1. Graphs showing "south Hawai'i" earthquakes related to Kīlauea (middle panel) or Mauna Loa (lower panel) activity, 1820–1904. Earthquakes identified in the Klein-Wright catalog (Klein and Wright, 2000) as "south Hawai'i" are compared to times of Kīlauea and Mauna Loa eruptions and intrusions. Closely spaced events near times of eruption or intrusion are probably associated with that volcano. Earthquakes in blue symbols designated "kl sf" for Kīlauea south flank have a bit more evidence regarding their location than merely "south Hawai'i," such as better felt reports or association with Kīlauea volcanic events. Most of the events designated "south Hawai'i" are probably Kīlauea south flank but with insufficient location information. Isolated events of M>4.0 are most likely either south flank or deep magma-supply earthquakes, although the volcano designation is ambiguous.

Appendix Figure B1. "south hawaii" earthquakes related to activity at Mauna Loa and Kilauea



Appendix C. Supplementary Material to Support Chapter 3

Table C1 contains earthquakes of magnitudes between 5 and 6 for the same time periods as text table 3.1.

Table C2 contains Whitney tilt data to support text figure 3.2.

Figures C1 and C2 show time series plots of earthquakes associated with eruptions and intrusions at Kilauea from 1925 to 1953.

Appendix table C1. Additional earthquakes M 5-6, 1925-1953

Date begin	Date end	Loc.[i]	Type[ii]	Comment	References
7/31/1927	7/31/1927	**kcal?**	**EQ**	M 4.58 30 km deep	(Klein and Wright, 2000)
1/4/1928	1/4/1928	**2035**	**EQ**	M 4.48 **30 km deep beneath Kīlauea caldera?**	(Klein and Wright, 2000)
2/5/1929	2/5/1929	**kcal?**	**EQ**	M 5.36 30.4 km deep	(Klein and Wright, 2000)
5/25/1930	5/25/1930	**sf**	**EQ**	M 4.55	(Klein and Wright, 2000)
9/28/1930	9/28/1930	**kcal**	**EQ**	M 4.53 25.6 km deep	(Klein and Wright, 2000)
10/20/1930	10/20/1930	**kcal**	**EQ**	M 5.25 30.1 km deep	(Klein and Wright, 2000)
1/29/1931	1/29/1931	**kcal**	**EQ**	M 4.40 22 km deep?	(Klein and Wright, 2000)
7/7/1932	7/7/1932	**sf**	**EQ**	2 events M 4.2	(Klein and Wright, 2000)
2/4/1933	2/4/1933	**sf**	**EQ**	40 km deep offshore	(Klein and Wright, 2000)
1/13/1934	1/13/1934	**sf**	**EQ**	40 km deep offshore	(Klein and Wright, 2000)
1/13/1935		**sf**	**EQ**	M 5.28 40 km beneath offshore south flank	(Klein and Wright, 2000)
6/28/1935		**sf**	**EQ**	M 5.76	(Klein and Wright, 2000)
4/9/1937		**sf**	**EQ**	M 4.42	(Klein and Wright, 2000)
5/15/1939		**sf**	**EQ**	M 4.90	(Klein and Wright, 2000)
5/31/1939		**sf**	**EQ**	M 4.67	(Klein and Wright, 2000)
7/14/1939		**sf**	**EQ**	M 5.04	(Klein and Wright, 2000)
8/17/1939		**sf**	**EQ (2)**	M 4.36, 4.0 21 minutes apart	(Klein and Wright, 2000)
3/12/1945		**sf**	**EQ**	M 4.38	(Klein and Wright, 2000)
7/13/1945		**sf**	**EQ**	M 4.79	(Klein and Wright, 2000)
6/11/1951		**erz**	**EQ**	M 4.01	(Klein and Wright, 2000)
12/6/1951		**sf**	**EQ**	M 4.53	(Klein and Wright, 2000)
9/2/1952		**kcal**	**EQ**	M 4.10 30 km beneath Kīlauea caldera	(Klein and Wright, 2000)
11/16/1952		**sf os**	**EQ**	M 4.27 off south coast	(Klein and Wright, 2000)
11/22/1952		**kcal**	**EQ**	M 3.95 20.8 km beneath Kīlauea's summit	(Klein and Wright, 2000)

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[i] Location abbreviations: Kīauea caldera (kc); Halema‘uma‘u crater (hm); East rift zone (erz); Southwest rift zone (swr); seismic southwest rift zone (sswr); Koa‘e fault zone (koae); South flank (sf)
[ii] Eruption (E); intrusion (I); Earthquake ≥ M5 (EQ); Earthquake swarm (EQS); Collapse of Kīlauea's summit (C)

Appendix table C2. Whitney tilt and seismic swarms 1925-1953 keyed to figure 3.2

Date Beg.	Date end	eqs[i]	Tilt[ii]		Comment	Reference[iii]
		No.	Mag.	Az.		
5/13/1927	7/26/1927		6.83	44.6	Precursory inflation continues during eruption	(Bevens and others, 1988, v. 3, p. 989-1007)
7/6/1927		7			Precursory seismicity	
7/7/1927	7/20/1927				1927 Halemaʻumaʻu eruption	
11/24/1928		20				(Bevens and others, 1988, v. 3, p. 1173)
11/24/1928	11/29/1928		3.82	202.1	Summit deflation/seismicity; intrusion?	
2/21/1929	2/25/1929		1.23	223.0	2/1929 Halemaʻumaʻu eruption; tilt mixed	(Bevens and others, 1988, v. 3, p. 1184-1189)
7/25/1929		6			Precursory seismicity	
7/25/1929	7/29/1929				7/1929 Halemaʻumaʻu eruption; tiltmeter out	(Bevens and others, 1988, v. 3, p. 1209-1217)
11/16/1930	11/19/1930	10			Precursory seismicity	
11/19/1930	12/8/1930				1930 Halemaʻumaʻu eruption	(Fiske and others, 1987, VL 309, p. 2-4)
11/23/1930	12/9/1930		4.28	55.9	mixed; net inflation during eruption	
12/17/1931	12/22/1931		3.52	42.9	Precursory inflation	
12/23/1931		5			Precursory seismicity; 5-20 km depth	
12/23/1931	1/6/1932				1931-32 Halemaʻumaʻu eruption	(Fiske and others, 1987, VL 366-367)
7/9/1933	7/30/1933	27			Elevated shallow seismicity	(Fiske and others, 1987, VL 401)
7/13/1933	7/26/1933		2.98	205.0	Summit deflation/seismicity; intrusion?	
2/2/1934		48			tiny (“tremor”) Earthquake swarm; intrusion?	(Fiske and others, 1987, VL 408)
2/1/1934	2/6/1934		2.18	37.18	inflation	
2/28/1934		28			tiny (“tremor”) Earthquake swarm; tilt flat	
9/5/1934	9/14/1934		3.48	227.8	deflation	
9/6/1934	10/9/1934				1934 Halemaʻumaʻu eruption	(Fiske and others, 1987, VL 415-416)
9/14/1934	10/12/1934		5.86	46.7	inflation during eruption	
7/6/1936	1/17/1937		10.60	193.1	deflation;	
1/17/1937	2/21/1937		9.31	207.2	deflation	(Fiske and others, 1987, VL 443-445)
1/28/1937	2/10/1937	13[iv]			**Puhimau hot area** formed by intrusion into	
3/15/1937	3/22/1937	14[iv]			east rift; no east rift eq or ground cracking	
3/17/1937	3/25/1937		5.74	214.4	deflation	
3/6/1938	5/15/1938		9.79	26.6	May 1938 east rift intrusion: Precursory inf.	(Fiske and others, 1987, VL 443-445)
5/28/1938		>88			Many felt	
5/29/1938	5/31/1938		1.27	199.29	Deflation acc intrusion	
6/1/1938		M4.3			South flank	
8/1/1938	8/10/1938		2.16	223.9	August 1938 east rift intrusion: Precursory def	(Fiske and others, 1987, VL 443-445)
8/7/1938	8/8/1938	>353			Many felt	
8/8/1938	8/13/1938				Ground cracking	
8/15/1938	8/25/1938		3.89	208.5	Post-intrusion deflation	
8/25/1938	10/11/1938		4.42	47.2	inflation	
10/11/1938	4/11/1939		11.09	218.9	continued deflation and crack widening	(Fiske and others, 1987, VL 443-445)
9/20/1944	12/5/1944		3.45	44.3	December 1944 intrusion: precursory inf	(Finch, 1944; Fiske and others, 1987)
11/12/1944	12/6/1944				scattered eq at decreasing depth after 11/15	
12/5/1944	12/7/1944		0.98	42.5	continued inflation during earthquake swarm	(Klein and Wright, 2000)
12/6/1944	12/7/1944	29			(16 stronger than tremor); shallow beneath	
					Kīlauea caldera; some felt; erz intrusion?	
12/7/1944	12/17/1944		3.92	230.0	continued deflation	
3/5/1950	9/15/1950		22.99	32.7	December 1950 eqs and Koaʻe? int.	(Finch, 1950; Fiske and others, 1987)
9/15/1950	12/8/1950		2.83	218.1	Slow deflation preceding earthquake swarm	
12/8/1950	12/12/1950	>195			9 events of M 4 recorded on Oahu; epicenters	
					cross Koaʻe fault zone between Kōkoʻolau and	
					Kamakaiʻa Hills	
12/8/1950	12/16/1950		16.28	210.0	major deflation during earthquake swarm	
12/16/1950	10/31/1951		15.60	41.7	post-1950 inflation	
4/22/1951		M6.2			35 km beneath Kīlauea caldera; one foreshock	(Fiske and others, 1987, VL 512; Macdonald, 1951)
					and many aftershocks	
10/31/1951	12/16/1951		6.28	218.3	deflation interval	
12/16/1951	6/27/1952		12.79	27.5	precursory inflation	
3/17/1952	3/31/1952	>600			M 6 (2), M 5-6 (19), M 4-5 (36); offshore sf	(Fiske and others, 1987, VL 515;

Date Beg.	Date end	eqs[i]	Tilt[ii]		Comment	Reference[iii]
4/3/1952	4/12/1952	15			Beneath east rift zone (onshore)	Macdonald, 1952)
6/27/1952	11/7/1952				eruption in Halemaʻumaʻu crater	(Fiske and others, 1987, VL 516-518;
6/27/1952	6/30/1952		2.16	212.8	initial deflation	Macdonald, 1952)
6/27/1952	11/7/1952		6.65	196.5	net deflation during eruption	

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[i] Seismic swarms are defined as 5 or more events occurring at a rate of greater than 1/hour with no gap more than 2 hours. Locations are assumed to be at 0-5 km depth beneath Kïlauea caldera.

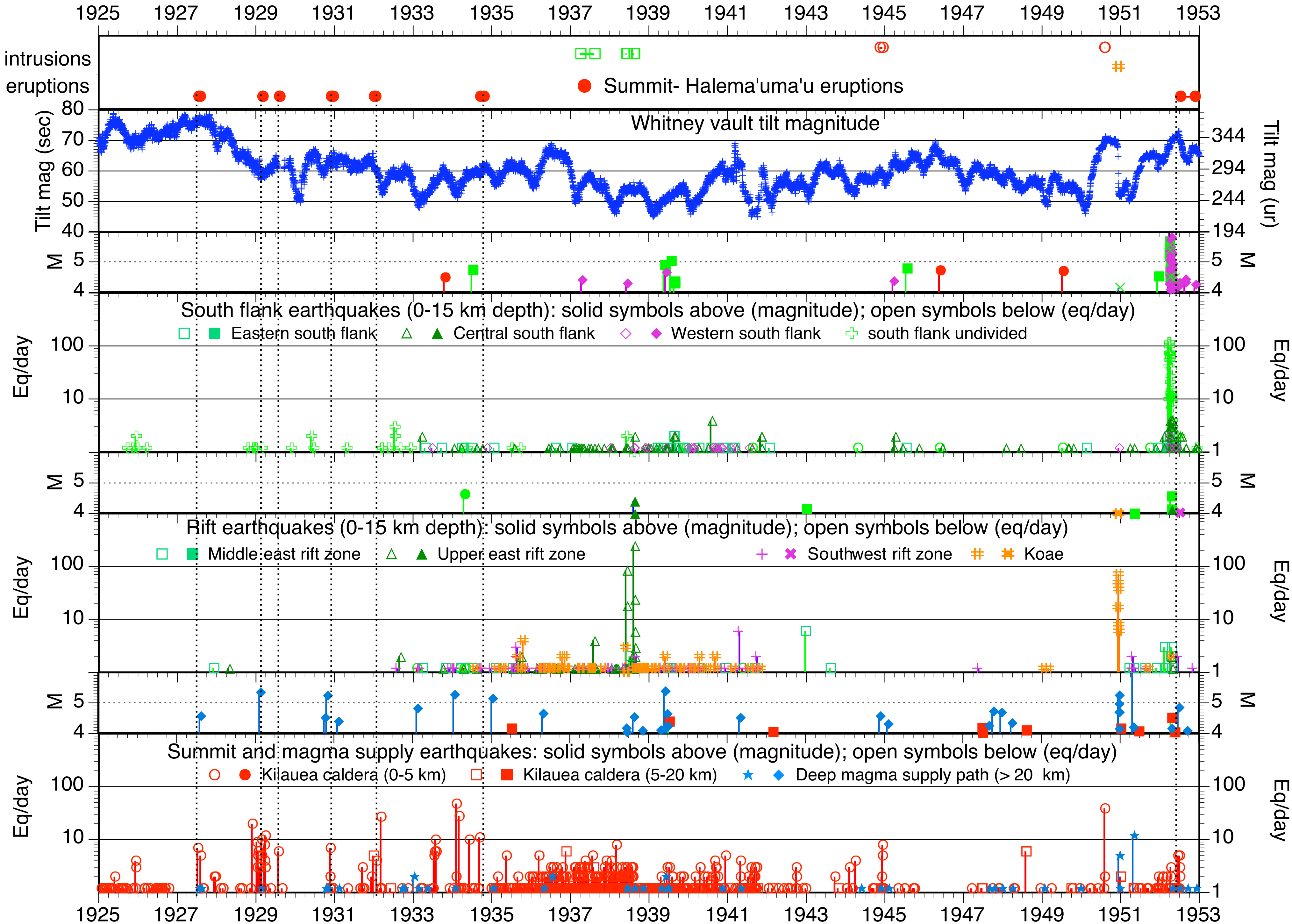
[ii] Tilt magnitudes are in seconds of arc as originally reported. 1 arc-second = 4.848 microradians. Deflation azimuths are between 180 and 270 degrees, normally between 190 and 235 degrees. Inflation azimuths lie between 0 and 90 degrees, normally between 10 and 55 degrees.

[iii] References to seismicity are to the reprinted Early Serial Publications of the Hawaiian Volcano Observatory (Bevens and others, 1988), the reprinted Volcano Letter (Fiske and others, 1987) and the compilation of Hawaiian earthquakes before 1959 (Klein and Wright, 2000). A continuous record of tilt data obtained at Whitney vault are from an unpublished Hawaiian Volcano Observatory archive (HVO, unpub).

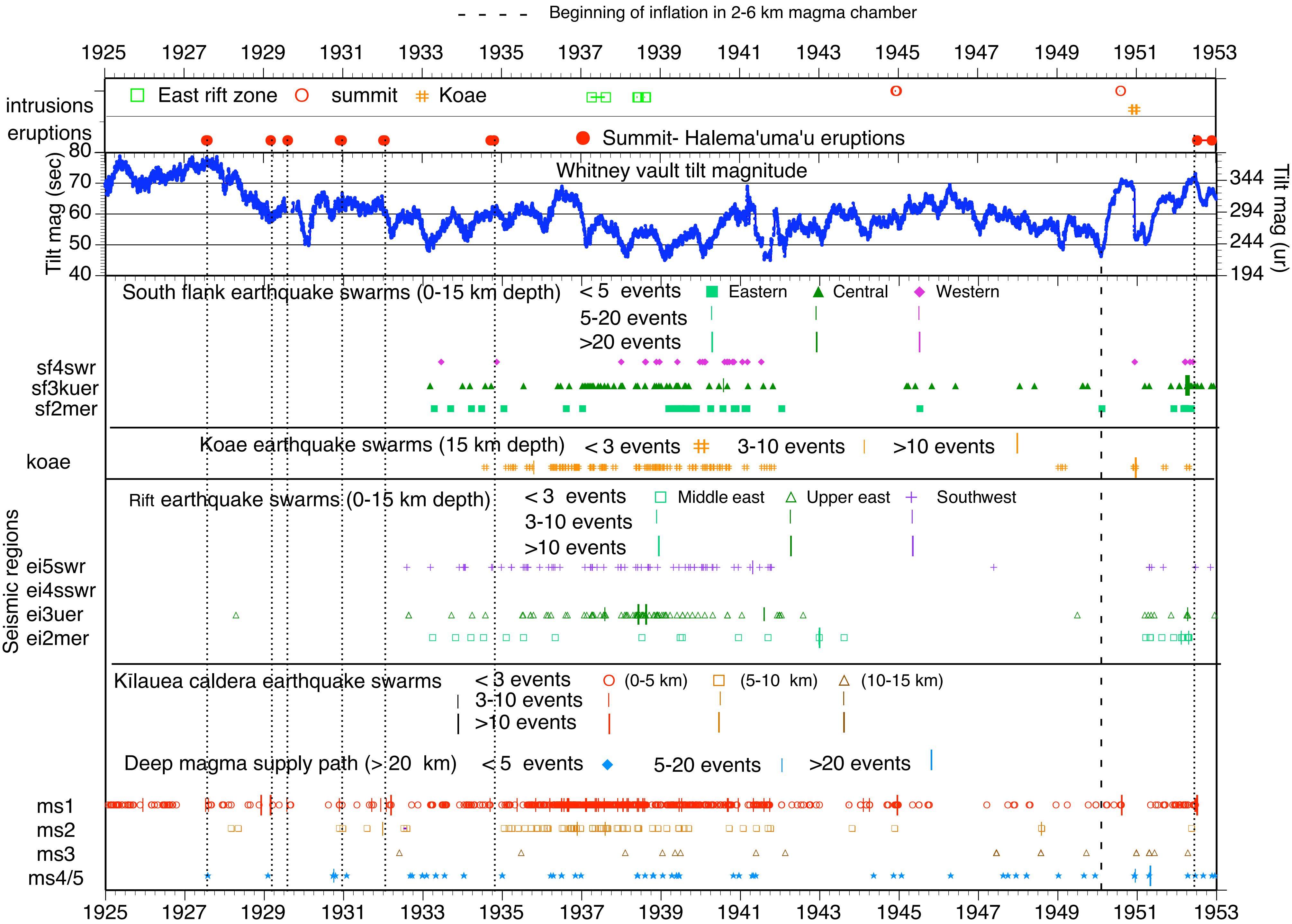
Figure C1. 1925–1953. Time-series summary of earthquakes in all regions of Kīlauea during this period plotted against times of eruption and intrusion (top panel) and Whitney tilt magnitudes (2nd panel from top) as in text figure 3.1. The bottom six panels show (from bottom to top) paired rows showing earthquakes per day (eq/day) and magnitudes >4 for earthquakes in the magma supply (bottom), rift and koae (middle) and south flank (upper) regions. Text figures 3.1–3.3 show shorter time periods that emphasize eruptions and intrusions in this period.

Figure C2. 1925–1953. Time series plots show heightened seismicity in all regions during this time period plotted against times of eruption and intrusion (top panel) and Whitney tilt magnitudes (2nd panel from top). Heightened seismicity is defined as earthquakes that occur with a frequency of less than six hours. We show three levels; the levels differ depending on the region. Background levels of south flank and deep magma-supply seismicity are higher and symbols are given for sequences of less than 5 events, 5–20 events, and greater than 20 events. For all other regions we plot sequences of less than 3 events, 3–10 events, and greater than 10 events.

Appendix C Figure C1



Appendix C figure C2



Appendix D. Supplementary Material to Support Chapter 4

Table D1 shows additional earthquake swarms and earthquakes of *M*4–6 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 D3*A*–*N* show the same data as text figures 4.1 and 4.9 plotted at 1-year intervals.

Figures D4*A*–*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, ms4) earthquake swarms in and near the magma supply path, organized chronologically.

Appendix Table D1[i]. 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](); Fig.
00:00 3/9/1955	23:59 3/9/1955	er1	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	er1	eqs	1385			no time	(1.3)
00:00 3/11/1955	23:59 3/11/1955	er1	eqs	76			no time	(3)
00:00 3/12/1955	23:59 3/12/1955	er1	eqs	11			no time	(1)
00:00 3/13/1955	23:59 3/13/1955	er1	eqs	9			no time	(1)
00:00 3/14/1955	23:59 3/14/1955	er1	eqs	6			no time; intermittent to 3/29/1956	(1)
00:00 3/16/1955	23:59 3/16/1955	ms1	eqs	21			no time	(1)
01:00 3/17/1955	13:35 3/17/1955	ms1	eqs	9			6 located; 3 unlocated er1	(1)
09:54 3/18/1955	22:43 3/18/1955	ms1	eqs	48			3 located	(1)
00:00 3/19/1955	23:59 3/19/1955	ms1	eqs	18			1 located at 18:03; 1 er1 located at 12:09	(1)
00:00 3/20/1955	23:59 3/20/1955	ms1	eqs	6			1 located at 18:10	(1)
00:00 3/21/1955	23:59 3/21/1955	ms1	eqs	51			no time	(1)
00:00 3/22/1955	23:59 3/22/1955	ms1	eqs	52			no time; 2 er1 located at 00:42, 20:46	(1)
00:00 3/23/1955	23:59 3/23/1955	ms1	eqs	324			2 at 00:10, 07:54; 3 er1 at 02:06, 03:42, 12:08	(1)
04:27 3/25/1955	08:55 3/25/1955	ms1	eqs	590			8 located; 1 ms5gln at 20:17	(1, 3); 4.4 e
3/26/1955 00:00 3/26/1955	 23:59 3/26/1955	ms1 ms5gln	eqs eqs	1103 >197			no time 1 located at 06:34	(1)
00:00 3/27/1955	23:59 3/27/1955	ms1	eqs	482			no time; 1 at 09:23, 1 ms2 at 16:02	(1)
00:00 3/28/1955	23:59 3/28/1955	ms1	eqs	278			1 at 20:39	(1)
00:00 3/29/1955	23:59 3/29/1955	ms1	eqs	165			no time	(1)
00:00 3/30/1955	23:59 3/30/1955	ms1	eqs	111			no time; 1 at 16:57	(1)
00:00 3/31/1955	23:59 3/31/1955	ms1	eqs	44			44 events w no time—see above	(1)
04:24 4/1/1955		ms4kc ms1	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	ms1	eqs	77			no time; 2 at 05:09, 06:37	(1)
00:00 4/3/1955	23:59 4/3/1955	ms1	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	ms1	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	ms1	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	
10:071/26/1960	03:19 1/29/1960	ms1	eqs	28			broken eqs; cont. summit subsidence	(11)
23:04 1/27/1960	03:29 3/11/1960	ms2	eqs	19			deepening swarm	
09:10 1/29/1960		sf3	eq				M 4.18	
13:05 1/29/1960	00:57 2/6/1960	ms1	eqs	170				
12:35 2/6/1960	18:12 2/29/1960	ms1	eqs	131			broken swarm	
16:35 2/12/1960		sf3	eq				M 4.11	
01:27 3/1/1960	14:31 3/3/1960	ms1	eqs	51				
23:59 3/3/1960	09:26 6/19/1960	ms1	eqs	121			broken swarm	
15:04 3/5/1960	21:51 3/5/1960	ms4	eqs	3			more: 1/26, 2/17, 3/23, 26, 31, 4/5, 17	
10:45 3/13/1960	19:06 4/11/1960	ms3	eqs	9			scattered; also on 1/25, 2/21, 3/1-2	
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)	(11)
13:25 11/20/1961	03:42 11/21/1961	ms4	eqs	7			1 more at 11/21 16:11	
23:23 11/21/1961	07:25 11/23/1961	ms4	eqs	21			M 4.11 23.7 km (first eq in swarm)	16 ms4.5-3
22:42 12/28/1961	23:08 12/30/1961	ms4	eqs	17			broken swarm	
19:07 1/1/1962	16:19 1/3/1962	ms4	eqs	6			broken swarm	
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"
[iiii] 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 ≥ 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		106.2	210.0					
	Sum			2.3135		34.4	.1465			.063	Pre-eruption msr
	E	6/27/1952	11/10/1952	0.37045				.0370		.100	Halemaʻumaʻu 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			.036	Pre-eruption msr
	E	2/28/1955	5/26/1955	0.2382				.0701	0.69		E rate: .2942 km^3/yr
1955-1959	Net	2/19/1955	11/14/1959	4.7337	129.8	168.13	.0834				Pre-eruption *def*
	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			.061	
	Sum			4.7337			.2876	.0298			Pre-eruption msr
	E	11/14/1959[ix]	12/20/1959	0.0972							E rate: .3066 km^3/yr
1959-1960	Net	11/15/1959	1/17/1960	.1752	16.1	252.27	.0103				Pre-eruption *def*
	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			.180	Pre-eruption msr
	E	1/13/1960	2/19/1960	.1013				.0906	.64		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	151.1	29.63		.0018	.03		E rate: .2195 km^3/yr
				0.0082							
1961-1962	Net	9/21/1961	12/6/1962	1.2074	46.2[x]	241.13	.0297				Pre-eruption *def*[xi]
	Def	9/21/1961	9/30/1962		92.9	225.96	.0597				
	Sum	9/21/1961	12/6/1962	1.2074		[x]	.0597			.0494	Pre-eruption msr
	E	12/7/1962	12/9/1962	0.0071				.00025	.053		
	Def	12/6/1962	12/9/1962		7.3		.0047				
						209.28					
1952-1960	Net	6/26/1952	1/17/1960	7.5592	31.1	114.53	.0200				Net *def*
	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 *def*
	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	11/14/1959	1/17/1960	0.1752	26.1	348.65	.0118				Pre-eruption inf
	Def	11/14/1959	11/22/1959		19.3	104.42	.0087				Episode 1 def
	Sum	11/14/1959	1/17/1960	0.1752			.0205			.117	Pre-eruption msr
	E	1/13/1960	2/19/1960	0.1013				.0906	.585		E rate: .8944 km^3/yr
1960-1961	Net	1/17/1960	9/21/1961	1.6783	39.9	110.08	.0180				Pre-eruption inf
	Def	1/17/1960	2/11/1960		225.7	116.74	.1015				
	Def	2/11/1960	5/8/1960		104.9	133.05	.0472				
	Def	5/8/1960	10/21/1960		37.7	188.08	.0169				
	Avg	1/17/1960	10/21/1960		344.2	127.68	.1548				
	Def	11/5/1960	11/10/1960		12.9	106.12	.0058				
	E	2/24/1961	2/24/1961	.000890				.00002			
	E	3/3/1961	3/25/1961	.006001				.0002			
	E	7/10/1961	7/17/1961	.018309				.0101			
	Sum	1/17/1960	9/21/1961	1.6783			.1786	.0103		.113	Pre-eruption msr
	E	9/22/1961	9/25/1961	0.0082				.00176	.023		E rate: .2195 km^3/yr
1961-1962	Net	9/21/1961	12/6/1962	1.2074	63.0	164.66	.0283				Pre-eruption *def*
	Def	9/21/1961	9/30/1961		173.2	135.82	.0779				
	Def	10/28/1961	11/4/1961		10.3	128.32	.0046				
	Sum			1.2074			.0825			.0683	Pre-eruption msr
	E	12/7/1962	12/9/1962	0.00705				.00025	.027		
1962-1963	Net	12/6/1962	8/21/1963	.7064	30.3	4.95	.0136				Pre-eruption inf
	Def	12/6/1962	12/9/1962		20.5	130.50	.0092				
	Def	5/8/1963	5/12/1963		35.0	126.27	.0157				
	Def	6/28/1963	7/2/1963		19.0	122.07	.0085				
	Sum			.7064	104.8		.0471			.0667	Pre-eruption msr
	E	8/21/1963	8/23/1963	0.00433				.00064	.127		
	Net	8/21/1963	10/4/1963	0.12047	26.7	275.53	.0120				Pre-eruption inf
	Def	8/11963	8/22/1963		11.2	107.97	.0050				
	Sum			0.12047	34.6		.0156			.1292	Pre-eruption msr
	E	10/5/1963	10/6/1963	.00326				.00528	.146		
1963-1965	Net	10/4/1963	3/5/1965	1.4182	114.9	294.52	.0107				Pre-eruption inf
	Def	10/4/1963	10/10/1963		390.8	124.36	.0362				
	Def	11/11/1964	11/18/1964		54.3	121.48	.0050				
	Def	11/27/1964	12/1/1964			121.06	.0022				
	Sum			24.2	5.0		.0541			.0382	Pre-eruption msr
	E	3/5/1965	3/15/1965	583.7	583.7			.01344	.3402		
	Net	3/5/1965	12/23/1965	219		160.44	.0208				Pre-eruption *def*
	Def	3/5/1965	3/9/1965			128.36	.0395				
	Sum			.80219			.0395			.0492	Pre-eruption msr
	E	12/24/1965	12/25/1965	.000913				.00068	.0319		
1965-1967	Net	12/23/1965	11/5/1967	1.8672	390.8	327.41	.0555				Pre-eruption inf
	Def	12/23/1965	12/29/1965			99.37	.0213				
	Def	10/1/1966	10/7/1966			139.40	.0044				
	Def	8/9/1967	8/18/1967			120.85	.0038				
	Sum			1.8672			.0850			.0455	Pre-eruption msr
	E	11/5/1967	7/15/1968	.69268				.07479		.1083	Halemaʻumaʻu filling rate
1960-1967	Net	1/17/1960	11/5/1967	7.8001	54.3	312.14	.0192				Net inf
	Def						.3925				
	Sum			7.8001			.4117	.0103		.0528	Average msr
1961-1967	Net	9/21/1961	11/5/1967	6.1218		301.48	.0364				Net inf
	Def						.2319				
	Sum			6.1218			.2683			.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=Koaʻe 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 ur 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] magnitude	azimuth	Location	Comment
6/27/1952	2/27/1955	15.91	355	Whitney	Center A in figure 4.2
12/4/1952 1/6/1954 12/13/1954	1/7/1953 2/5/1954 1/17/1955	4.2 2.3 3.7	199 180 198	Whitney	Center B in figure 4.2 is the mean of three azimuths for samall deflations extrapolated to an assumed point within the Fiske-Kinoshita array.
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 11/14/1959	11/15/1959 11/15/1959	9.8 1.5	31 169	Whitney Uwēkahuna	Center E in figure 4.2: Whitney azimuth only.
11/15/1959 11/15/1959	11/21/1959 11/21/1959	5.9 9.8	229 96	Whitney Uwēkahuna	Center F in figure 4.6: intersection of Whitney and Uwēkahuna azimuths.
11/21/1959	11/24/1959	1.1	161	Whitney	Center H in figure 4.6.
11/24/1959 11/24/1959	1/14/1960 1/14/1960	4.2 13.3	11 308	Whitney Uwēkahuna	Center G in figure 4.6: intersection of Whitney and Uwēkahuna azimuths.
1/17/1960 1/17/1960	7/1/1960 7/1/1960	44.1 74.4	208 123	Whitney Uwēkahuna	Center I in figure 4.6: intersection of Whitney and Uwēkahuna azimuths.[2]

[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 intusions (green), and suspected deep intrusions (magneta)]

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 D3*A*–*N*. 1953–1967. Earthquakes per day and magnitudes above 4 are shown at yearly inervals. Plotted data are the same as in text figure 4.1. Dates on figure in mm/dd/yyyy format.

Figure D4*A*–*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 4.4*A*. Swarm symbols are expalained 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 instrusion 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 instrusion 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 Bosher (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.

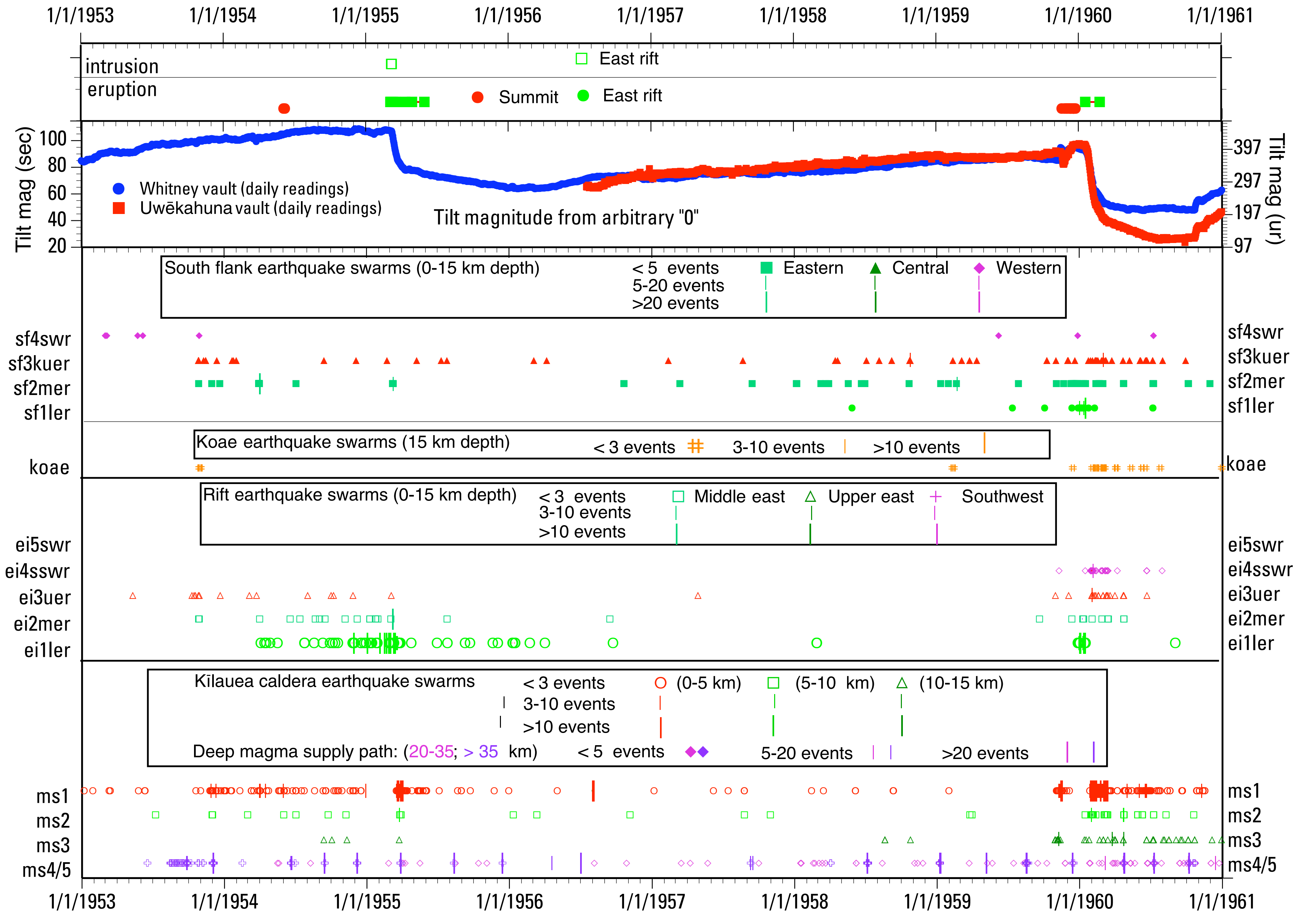
Figure D22. Map showing deep (20–35 km) earthquake swarm, 31 December 1961. Seismicity is shown from 28 December 1961 to 3 January 1962. Earthquakes are color coded as to whether they occurred before the swarm date (blue), during the swarm (orange), or after the swarm (green). Dates on figure in mm/dd/yyyy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

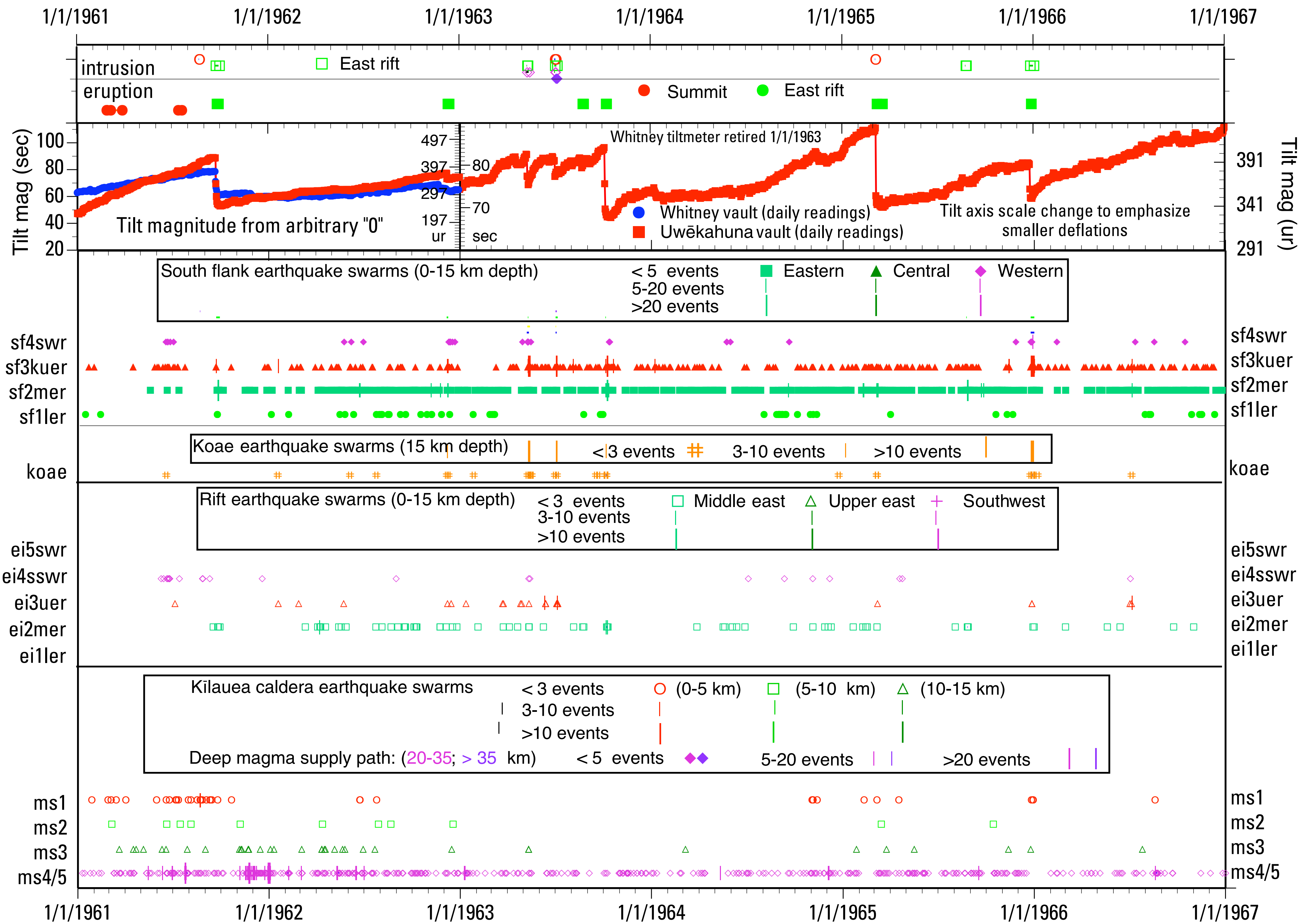
Figure D24. Map showing deep (20–35 km) earthquake swarm, 8 January 1963. Seismicity is shown from 8 to 14 January 1963. Earthquakes are color coded as to whether they occurred before the swarm date (blue), during the swarm (orange), or after the swarm (green). Dates on figure in mm/dd/yyyy format.

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

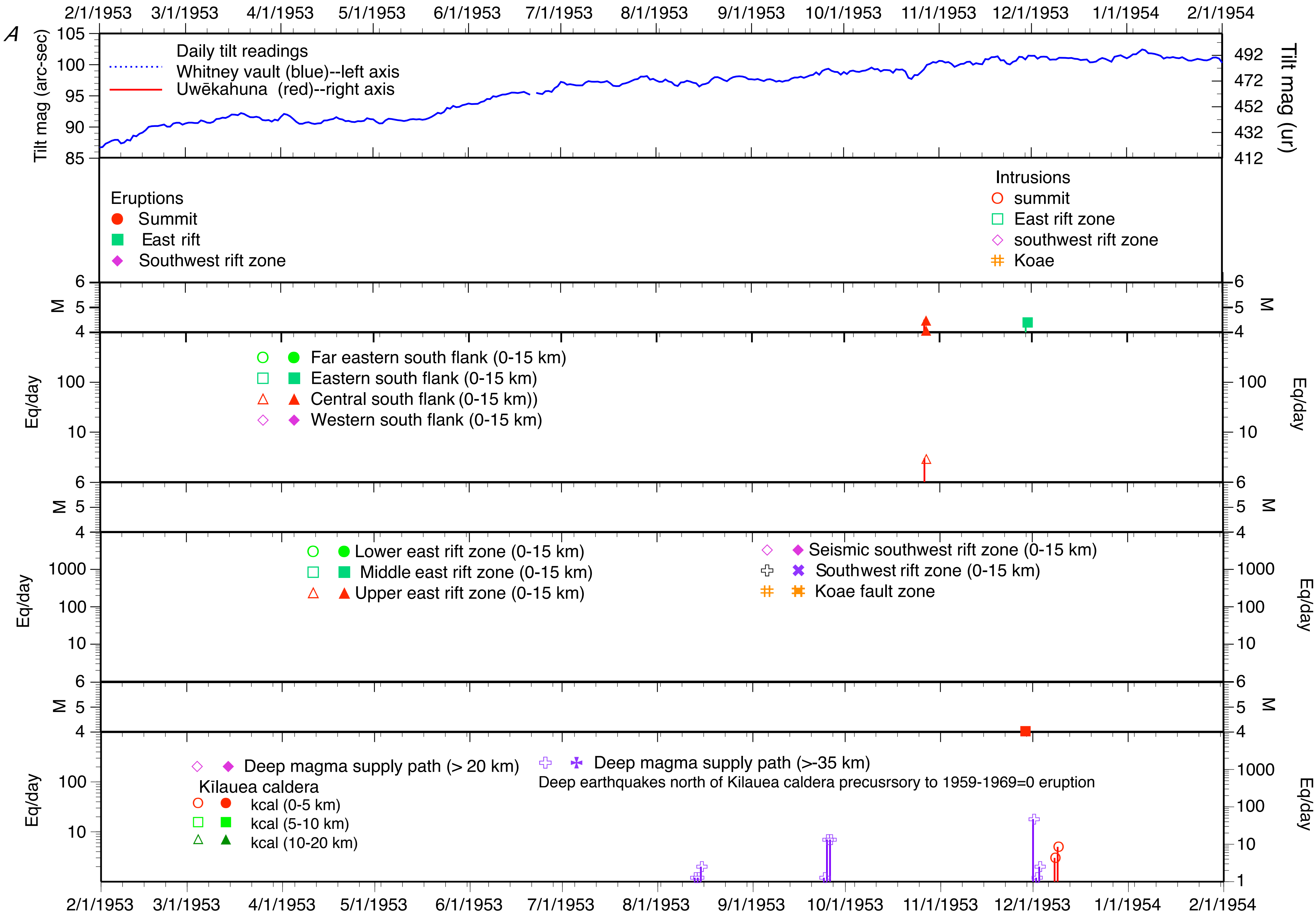


Appendix D Figure D2



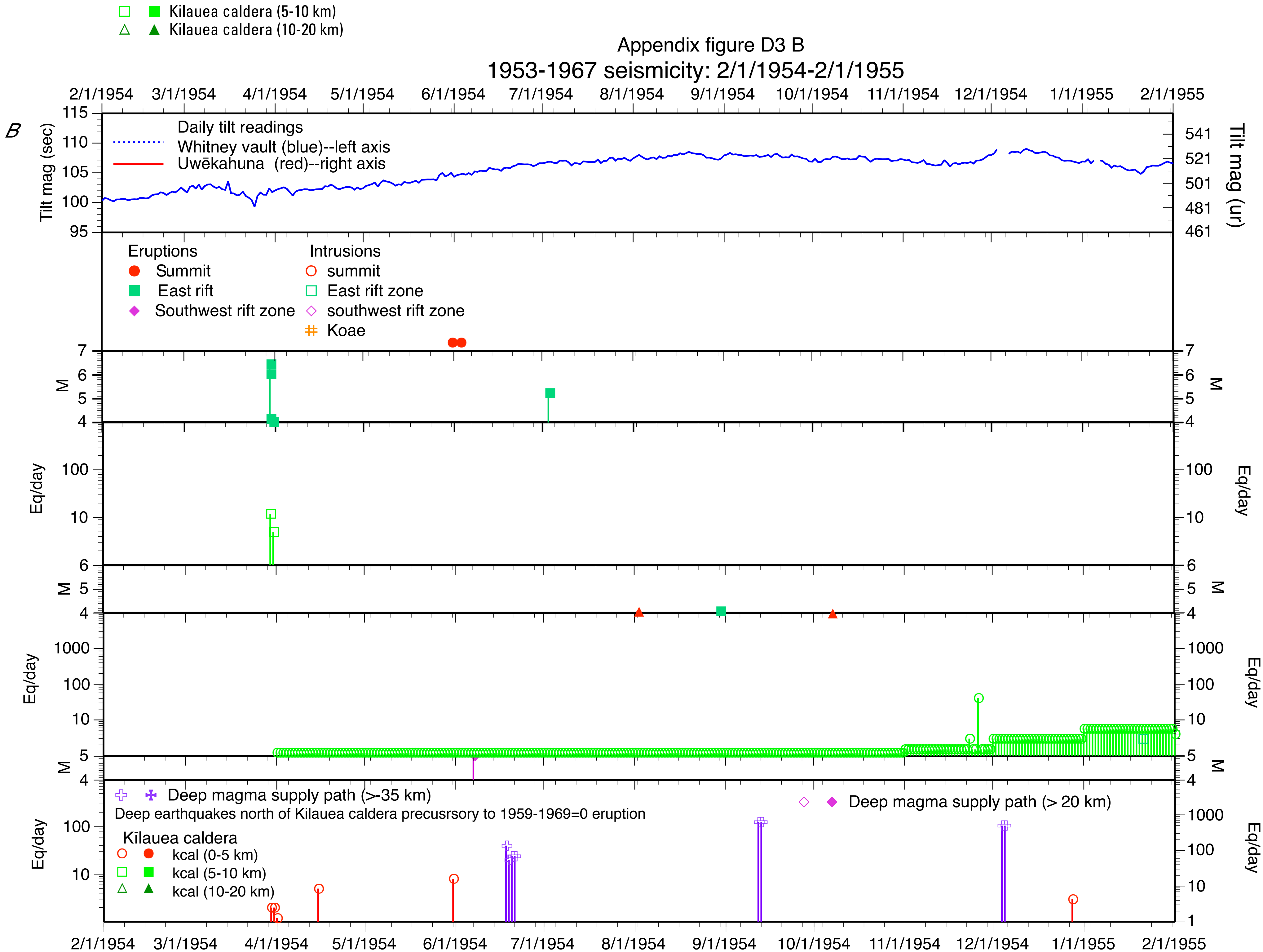
Appendix figure D3 A

1953-1967 seismicity: 2/1/1953-2/1/1954



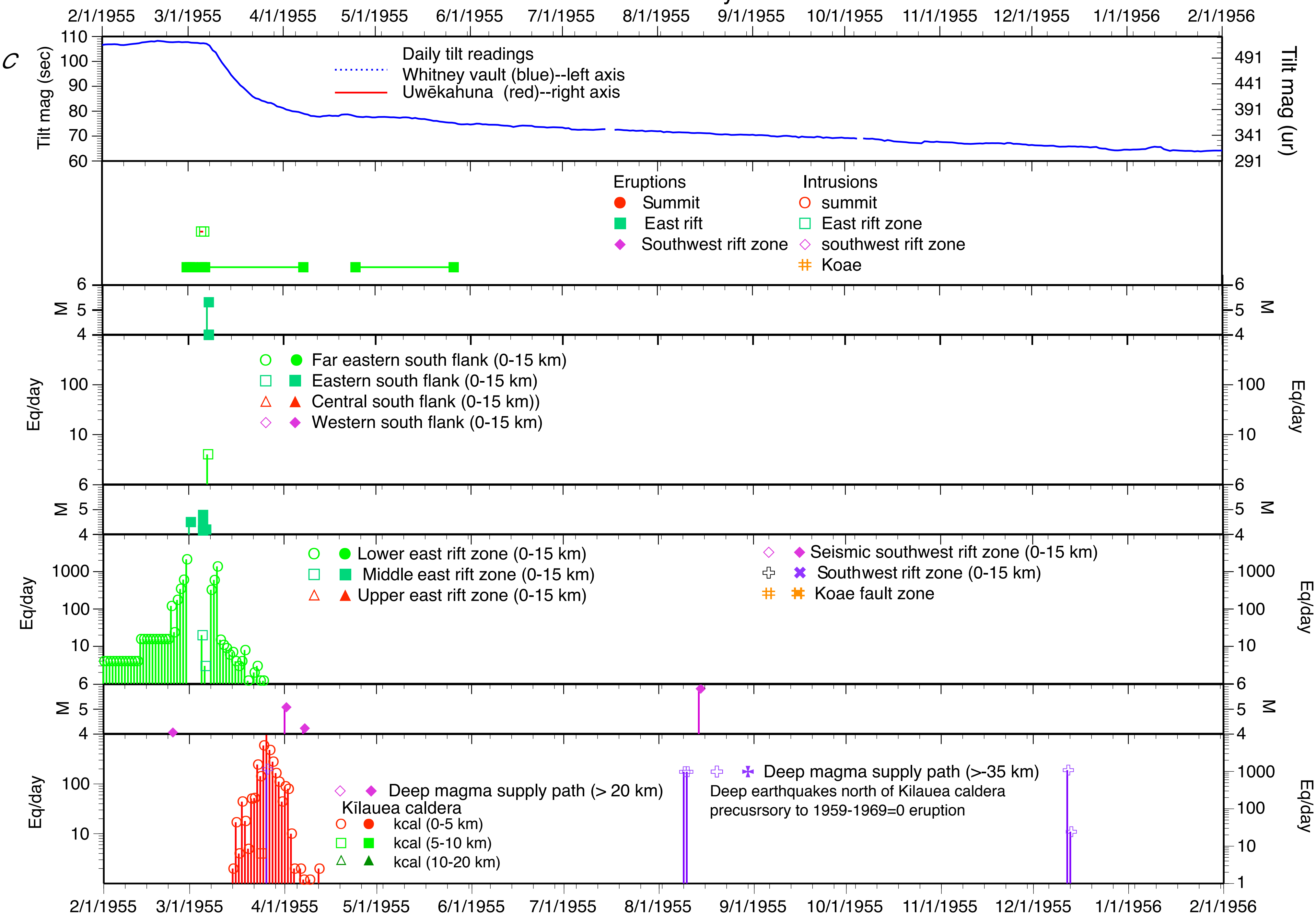
Appendix figure D3 B

1953-1967 seismicity: 2/1/1954-2/1/1955



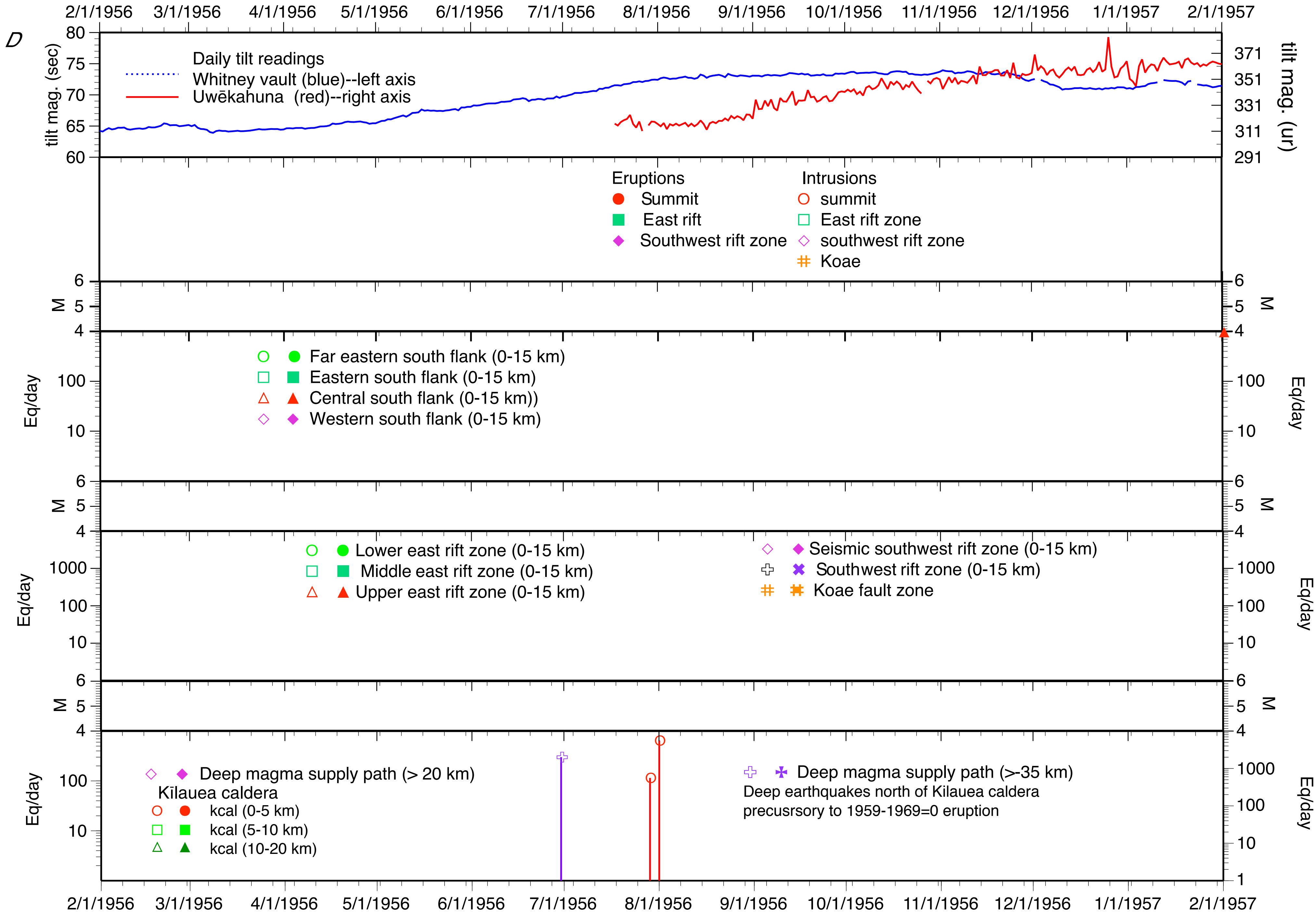
Appendix figure D3 C

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



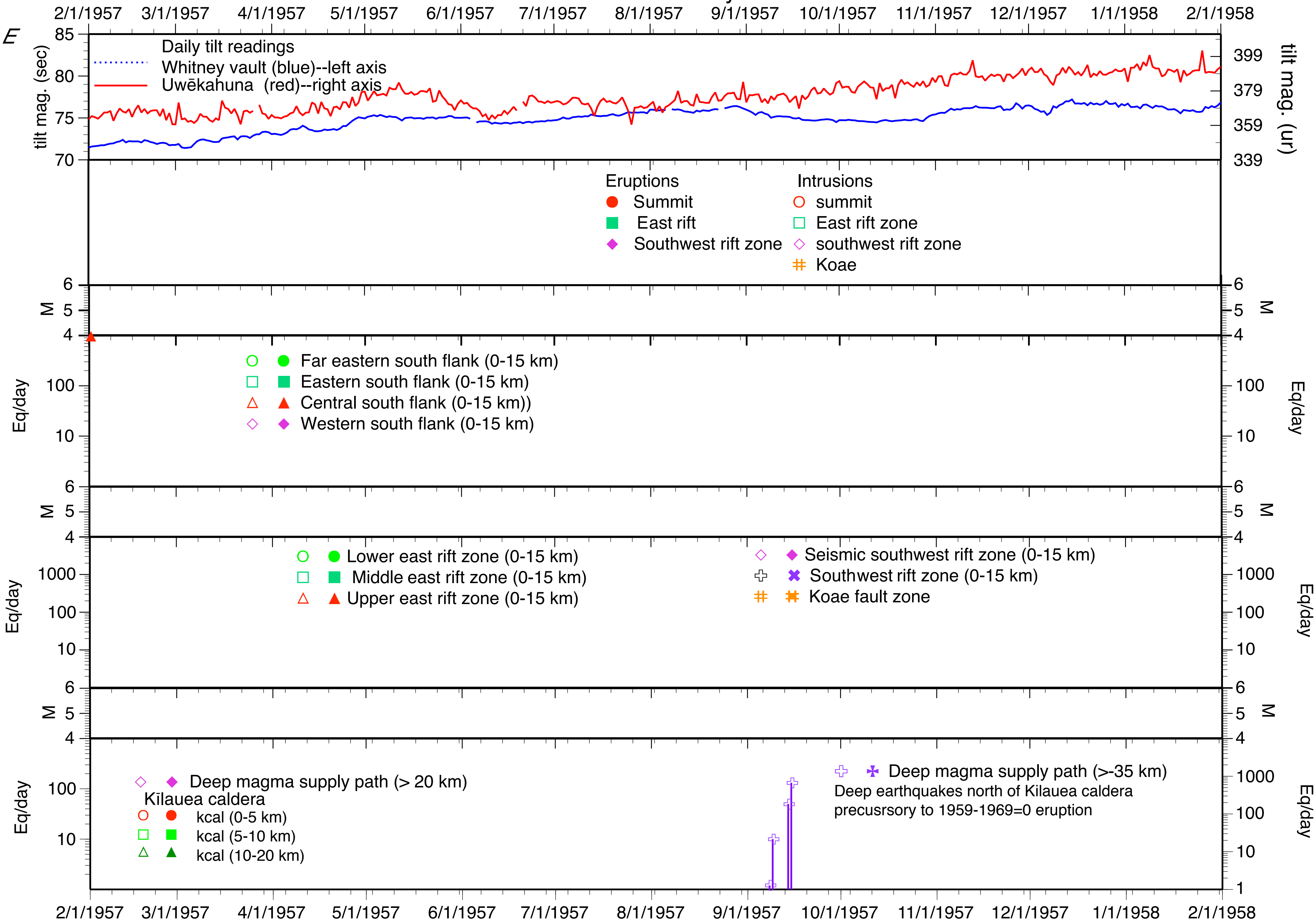
Appendix figure D3 D

1953-1967 seismicity: 2/1/1956-2/1/1957



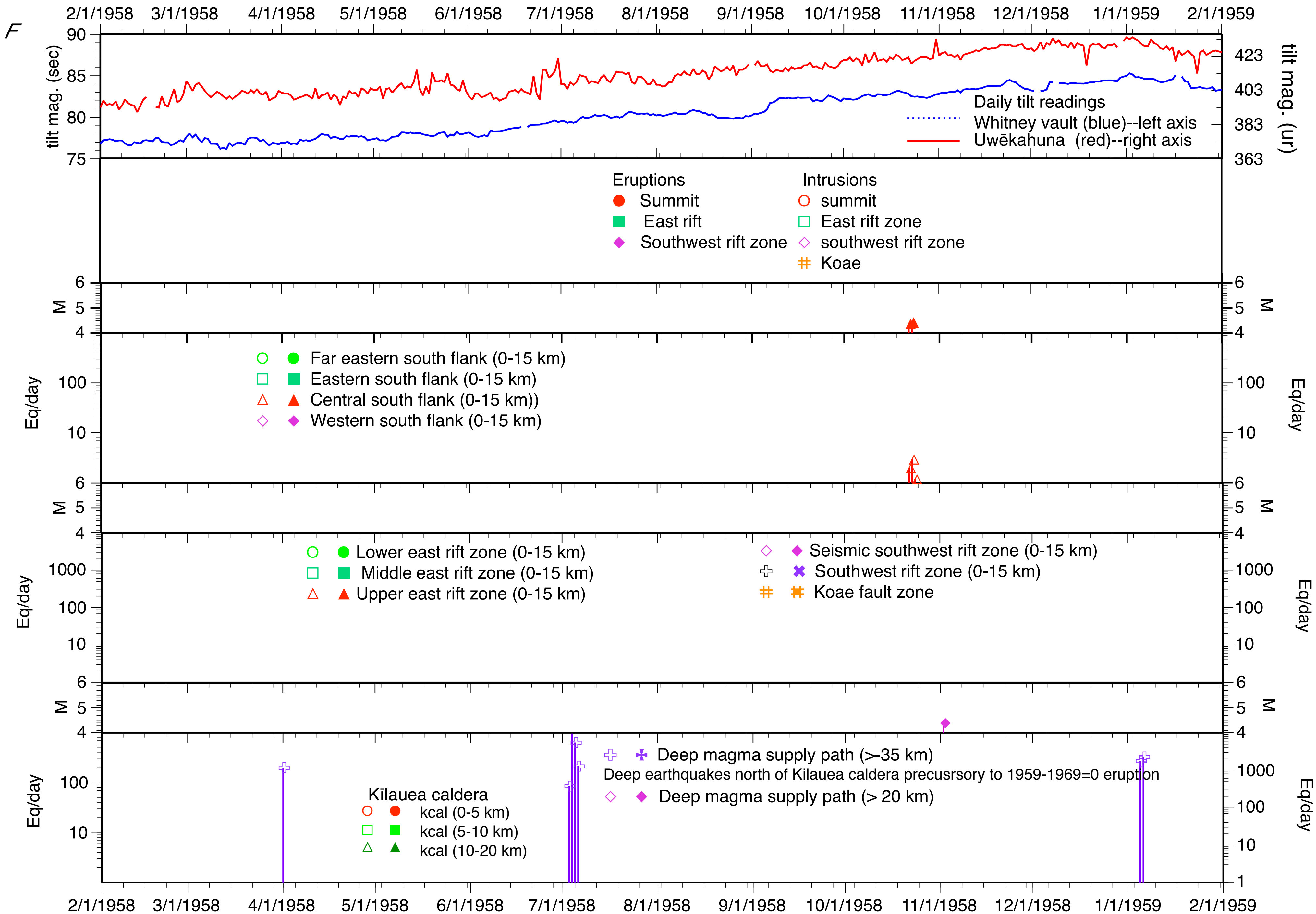
Appendix figure D3 E

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



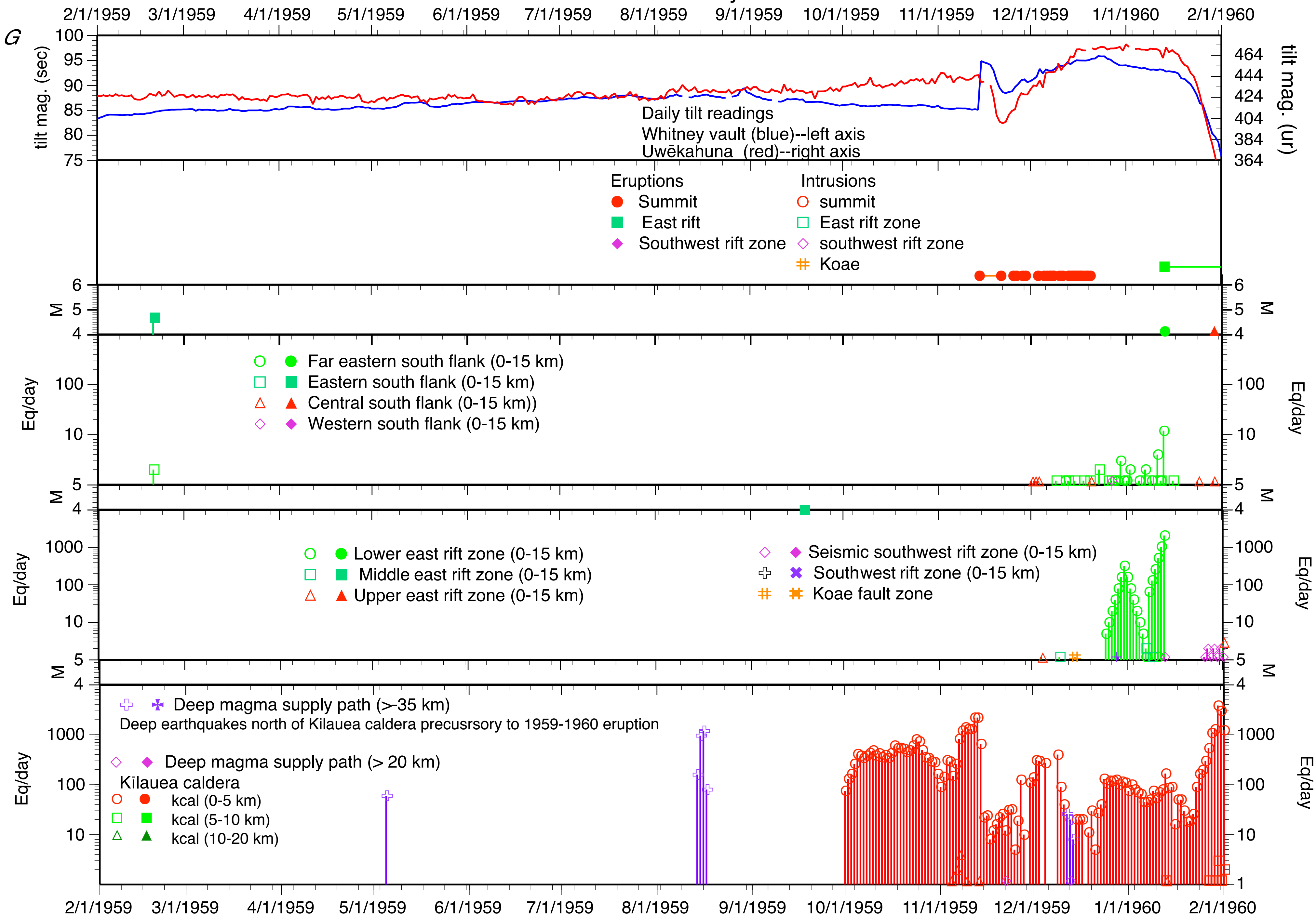
Appendix figure D3 F

1953-1967 seismicity: 2/1/1958-2/1/1959



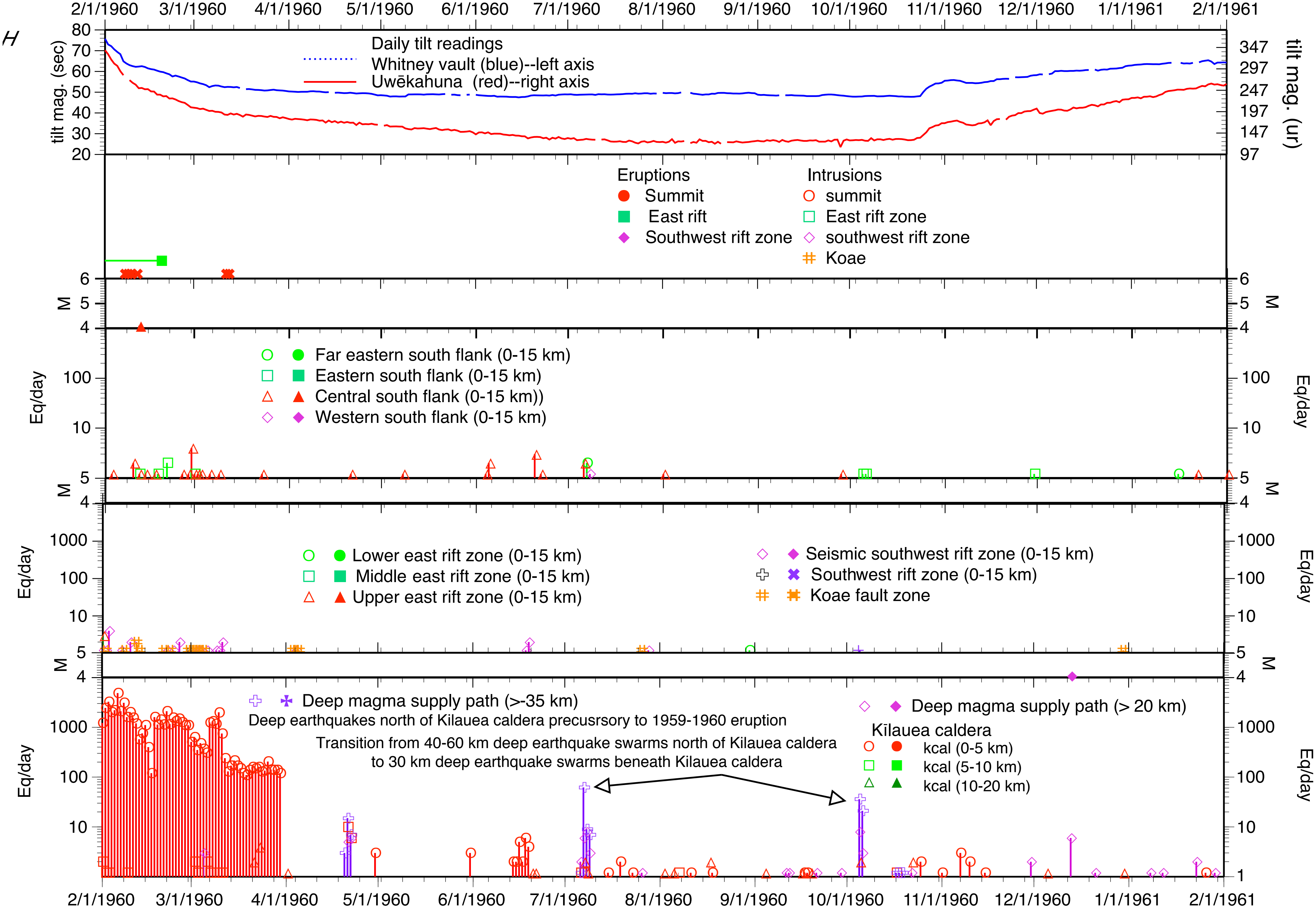
Appendix figure D3 G

1953-1967 seismicity: 2/1/1959-2/1/1960



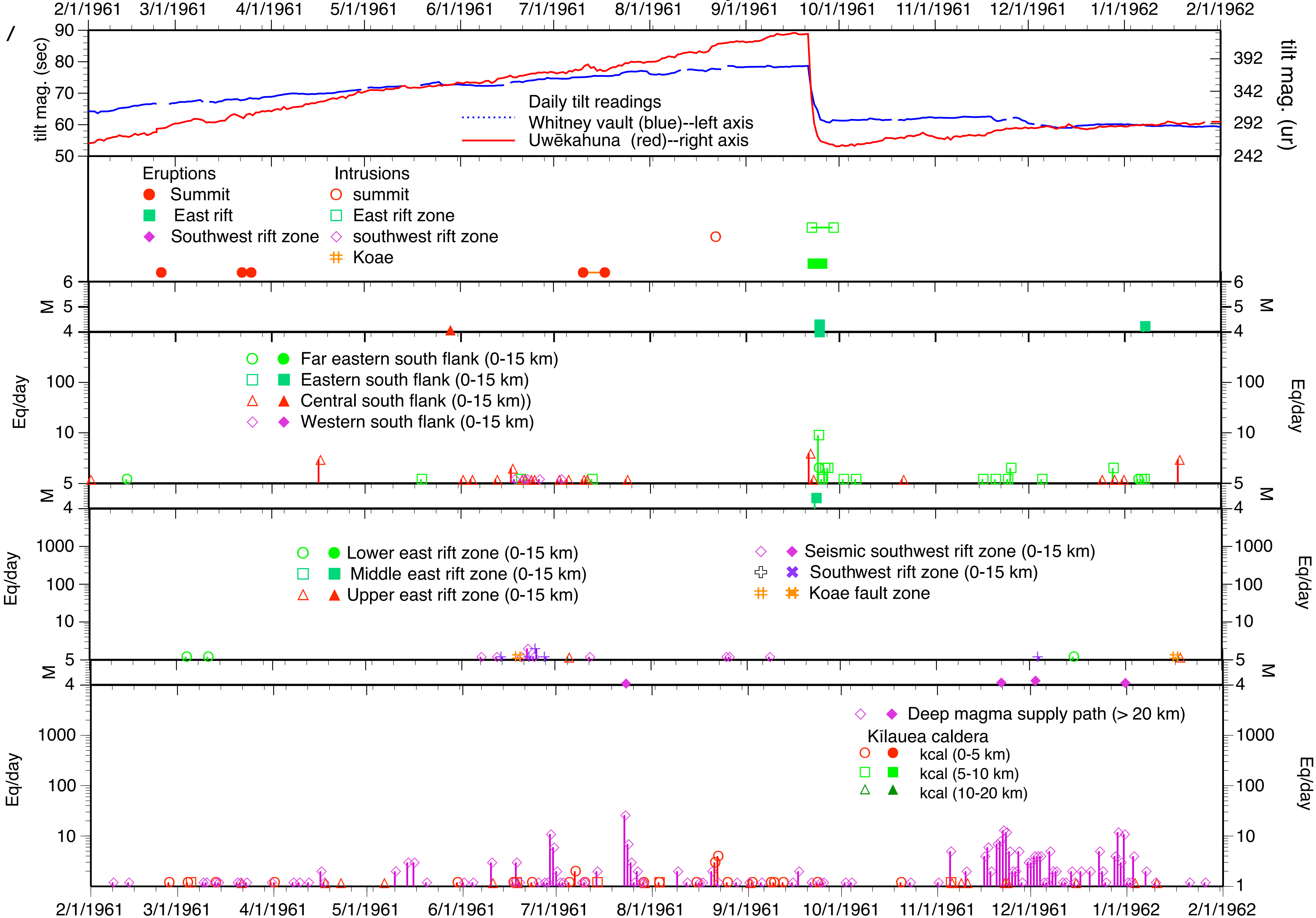
Appendix figure D3 H

1953-1967 seismicity: 2/1/1960-2/1/1961



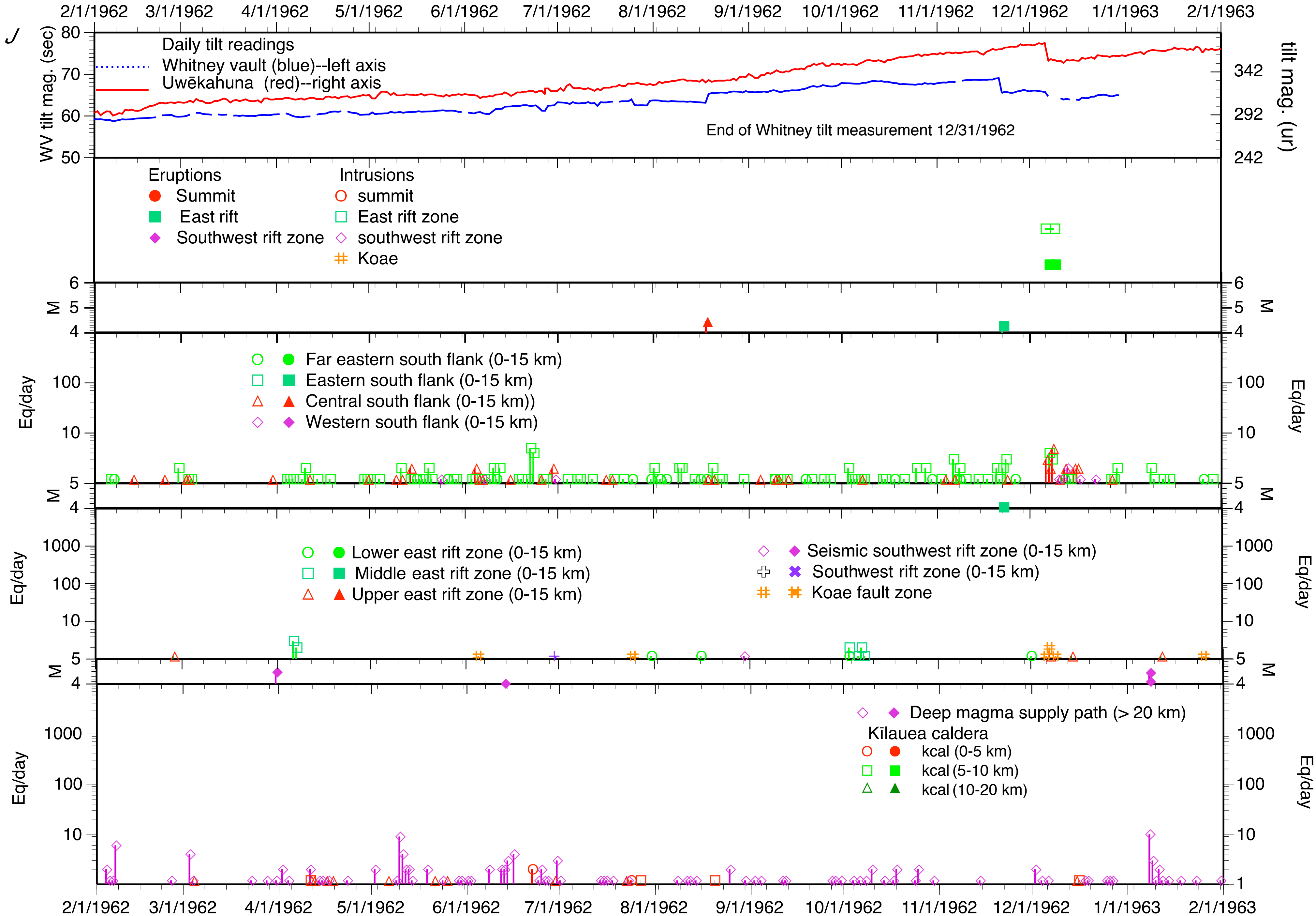
Appendix figure D3 I

1953-1967 seismicity: 2/1/1961-2/1/1962



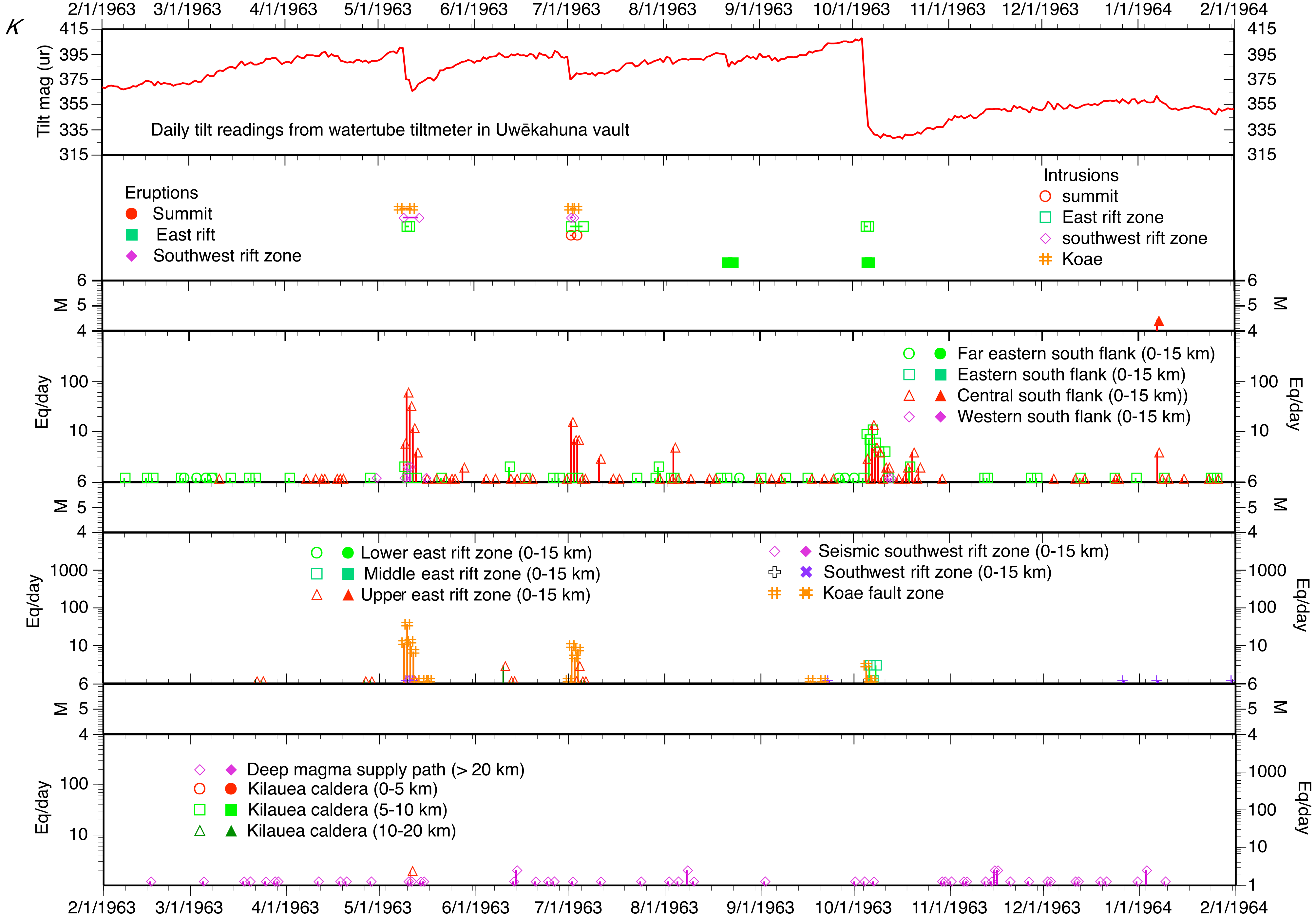
Appendix figure D3 J

1953-1967 seismicity: 2/1/1962-2/1/1963



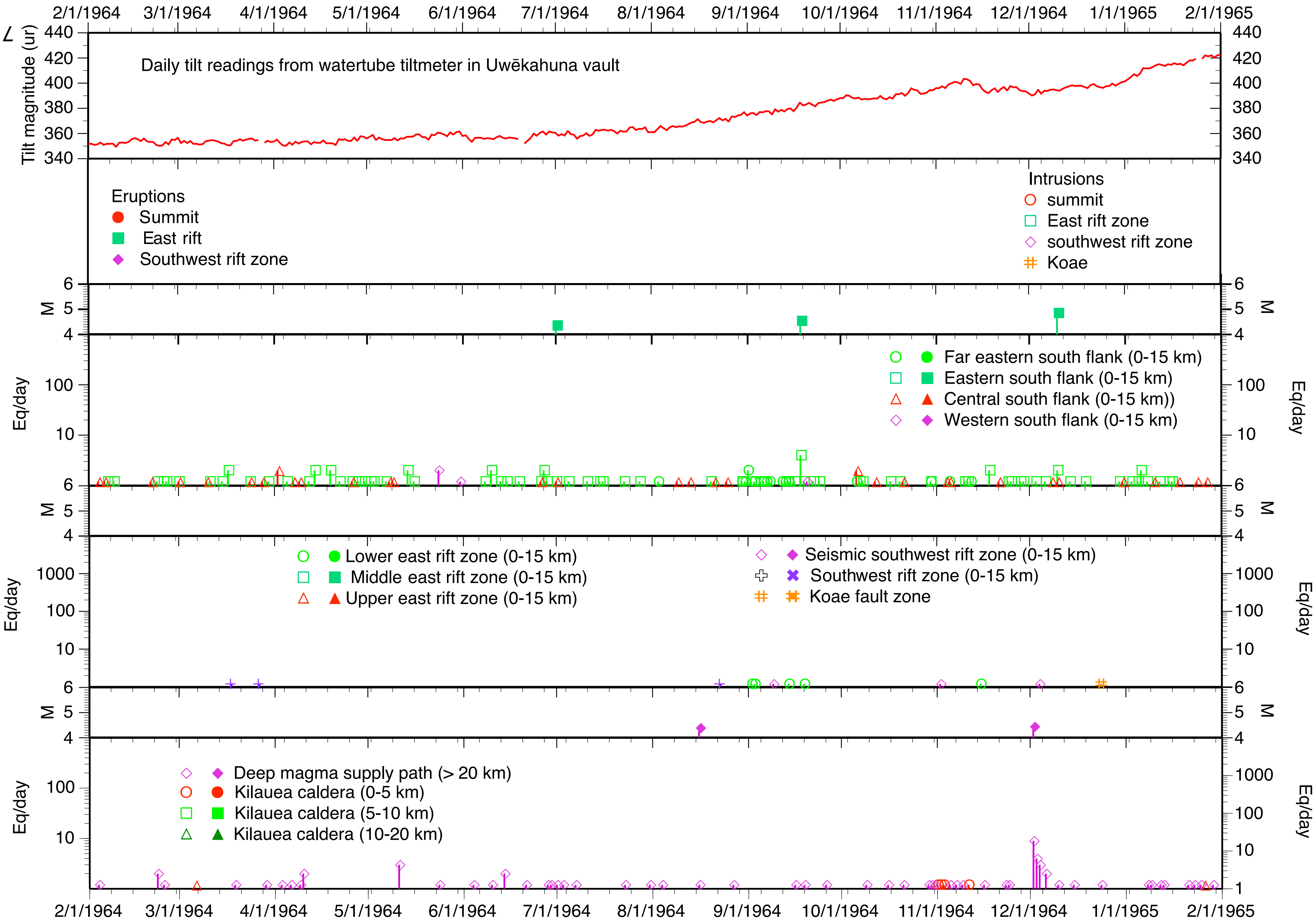
Appendix figure D3 K

1953-1967 seismicity: 2/1/1963-2/1/1964



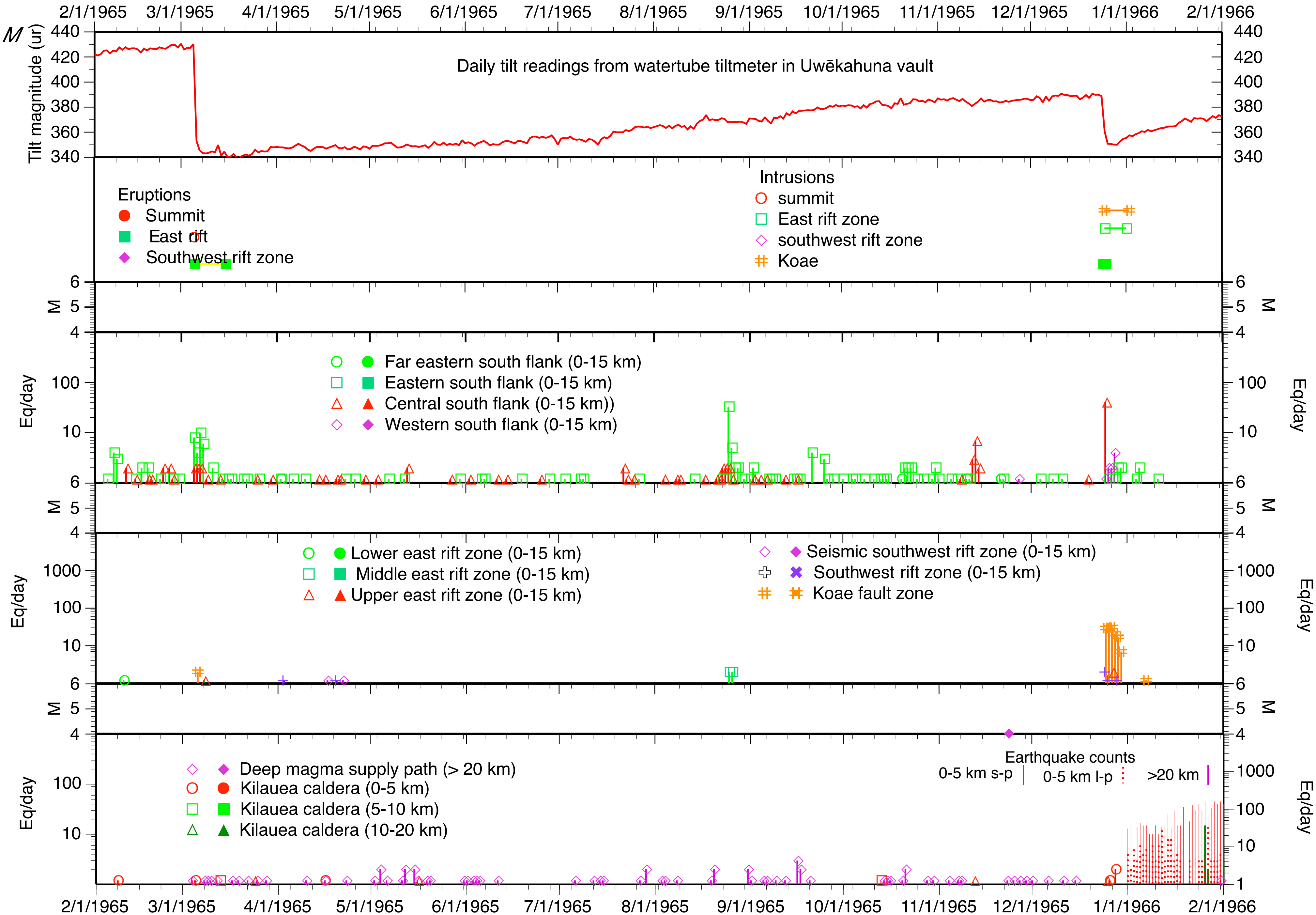
Appendix figure D3 L

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



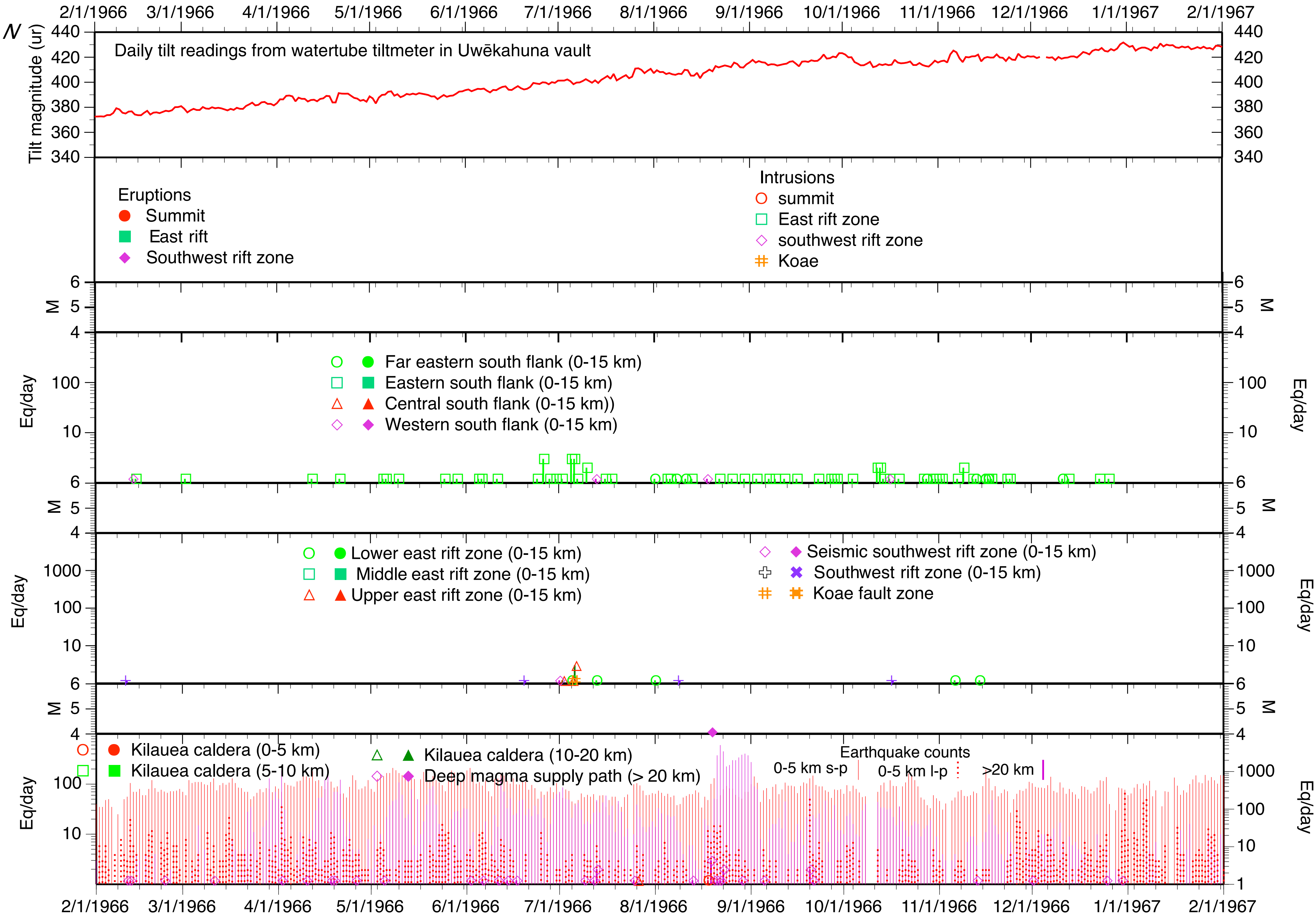
Appendix figure D3 M

1953-1967 seismicity: 2/1/1965-2/1/1966

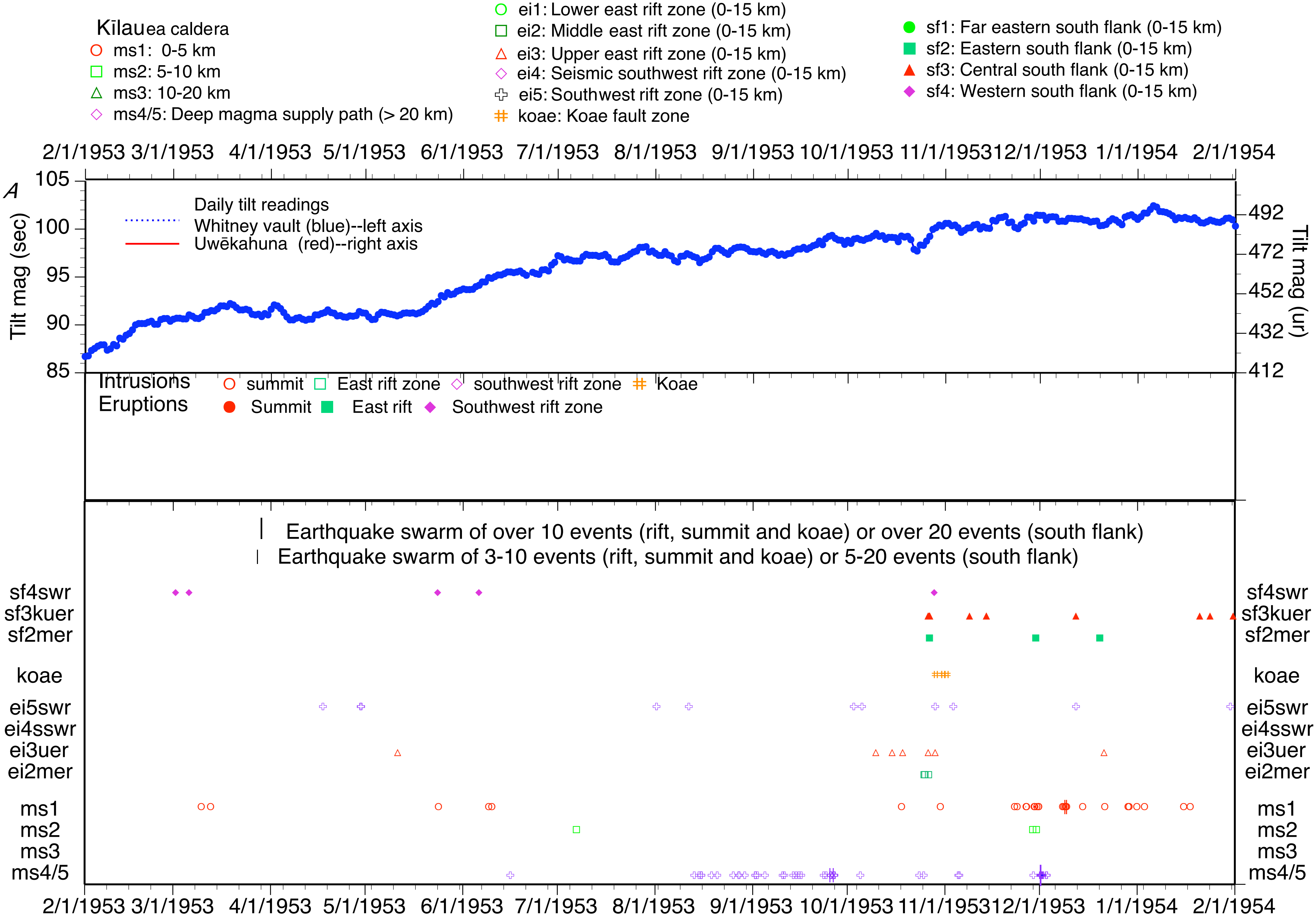


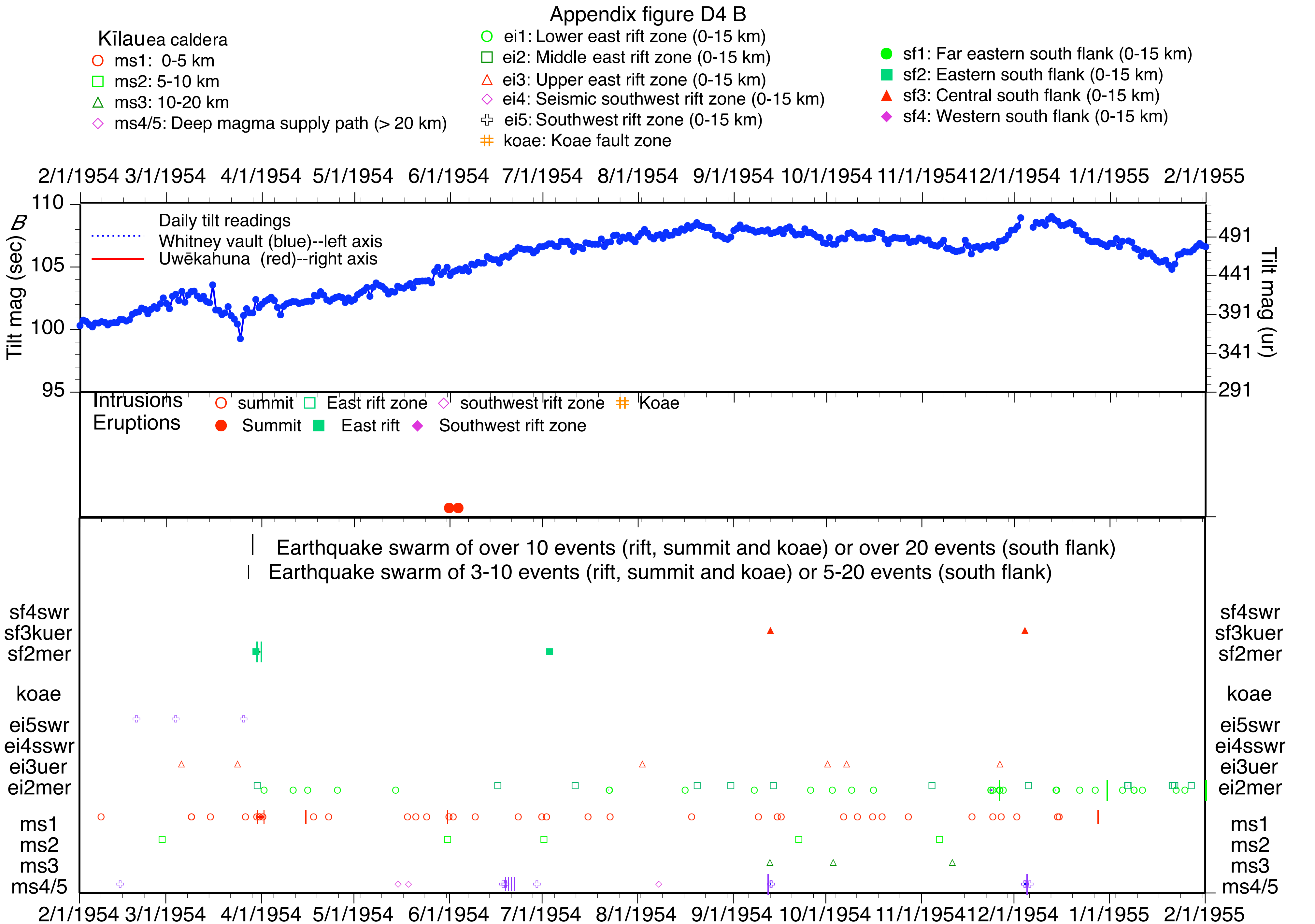
Appendix figure D3 N

1953-1967 seismicity: 2/1/1966-2/1/1967



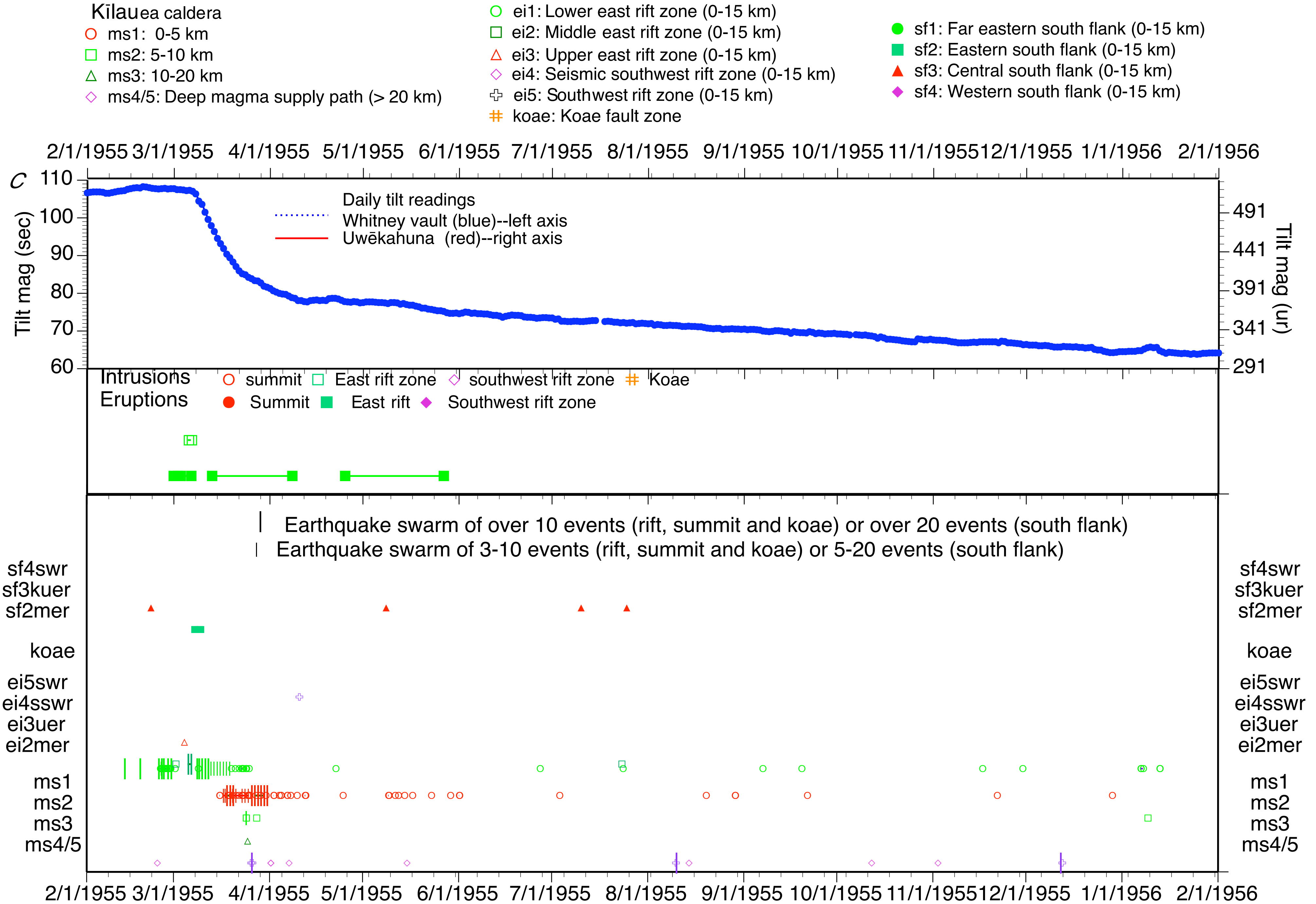
Appendix figure D4 A

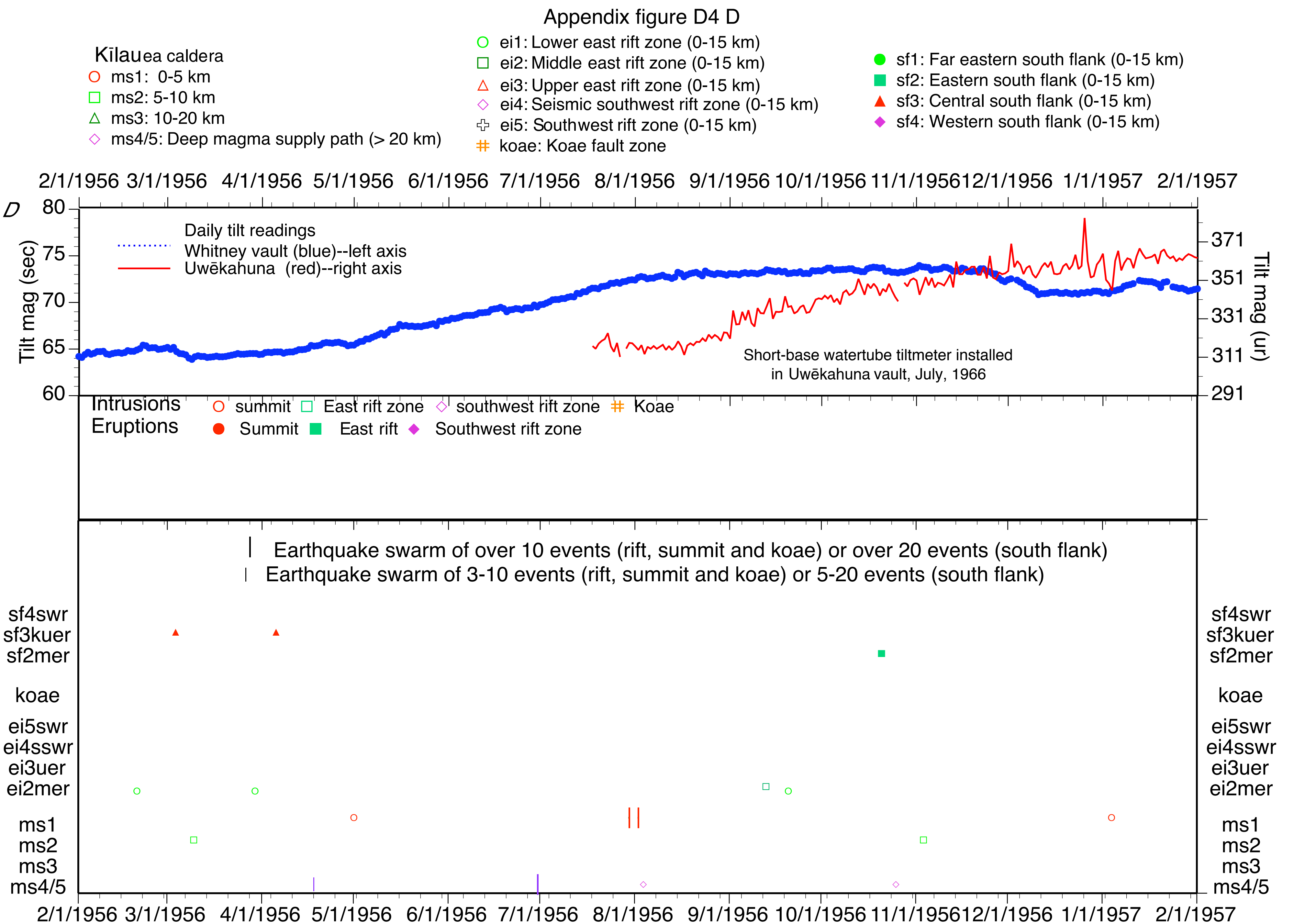




Appendix figure D4 B
Kīlauea caldera
ms1: 0-5 km
ms2: 5-10 km
ms3: 10-20 km
ms4/5: Deep magma supply path (> 20 km)
ei1: Lower east rift zone (0-15 km)
ei2: Middle east rift zone (0-15 km)
ei3: Upper east rift zone (0-15 km)
ei4: Seismic southwest rift zone (0-15 km)
ei5: Southwest rift zone (0-15 km)
koae: Koae 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)
2/1/1954 3/1/1954 4/1/1954 5/1/1954 6/1/1954 7/1/1954 8/1/1954 9/1/1954 10/1/1954 11/1/1954 12/1/1954 1/1/1955 2/1/1955
B
Tilt mag (sec)
110
105
100
95
Daily tilt readings
Whitney vault (blue)--left axis
Uwēkahuna (red)--right axis
Tilt mag (ur)
491
441
391
341
291
Intrusions
Eruptions
summit
East rift zone
southwest rift zone
Koae
Summit
East rift
Southwest rift zone
Earthquake swarm of over 10 events (rift, summit and koae) or over 20 events (south flank)
Earthquake swarm of 3-10 events (rift, summit and koae) or 5-20 events (south flank)
sf4swr
sf3kuer
sf2mer
koae
ei5swr
ei4sswr
ei3uer
ei2mer
ms1
ms2
ms3
ms4/5

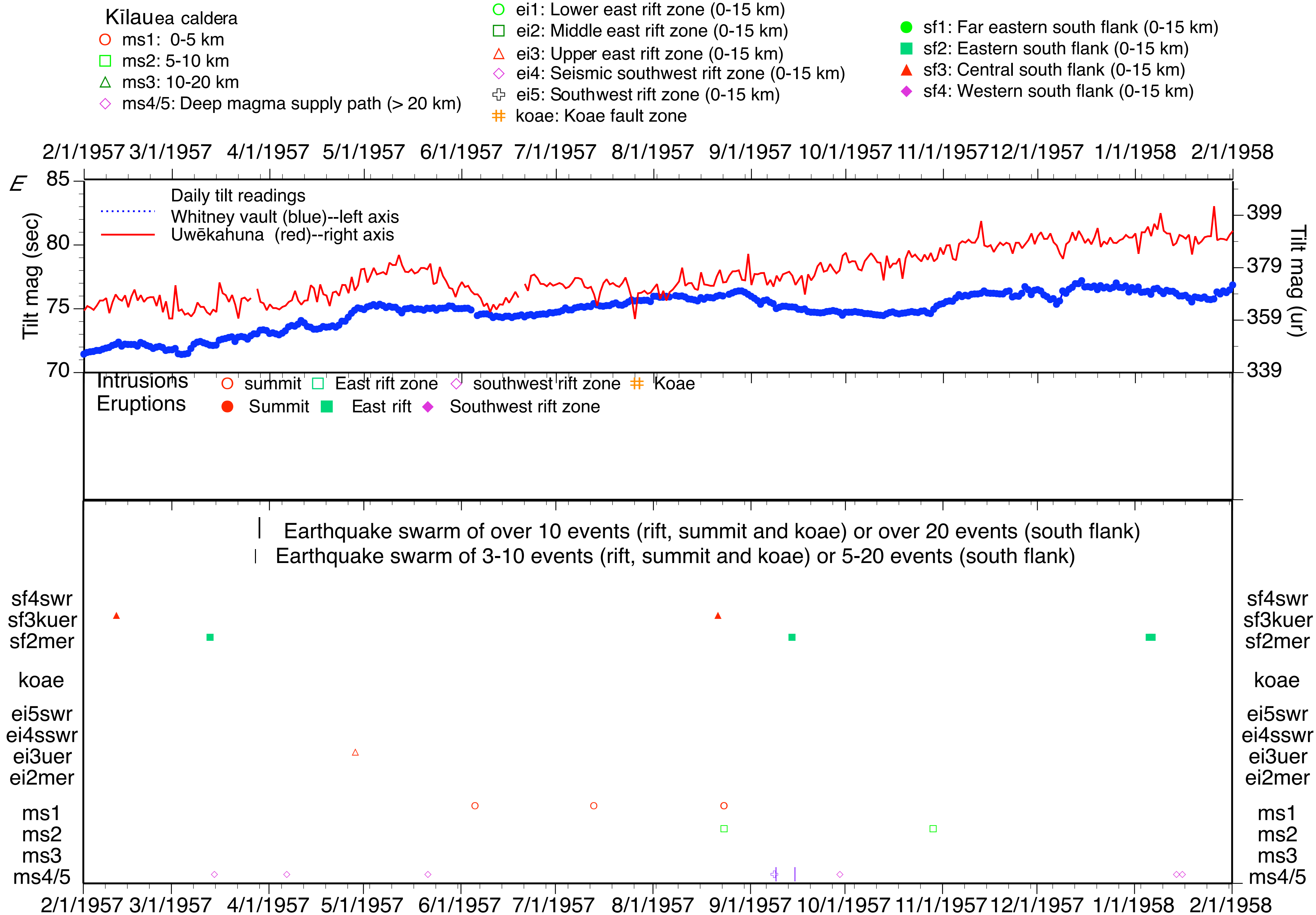
Appendix figure D4 C



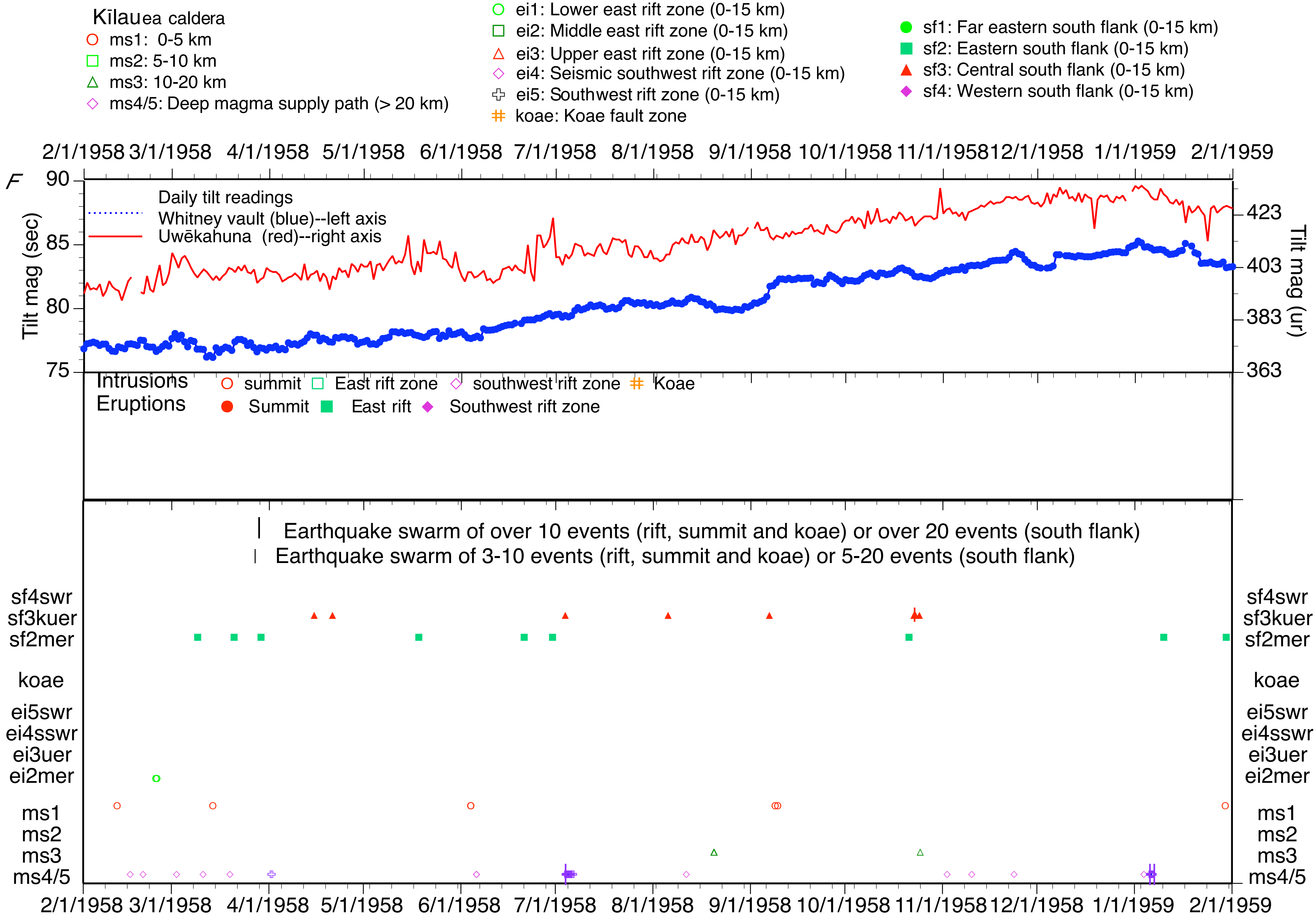


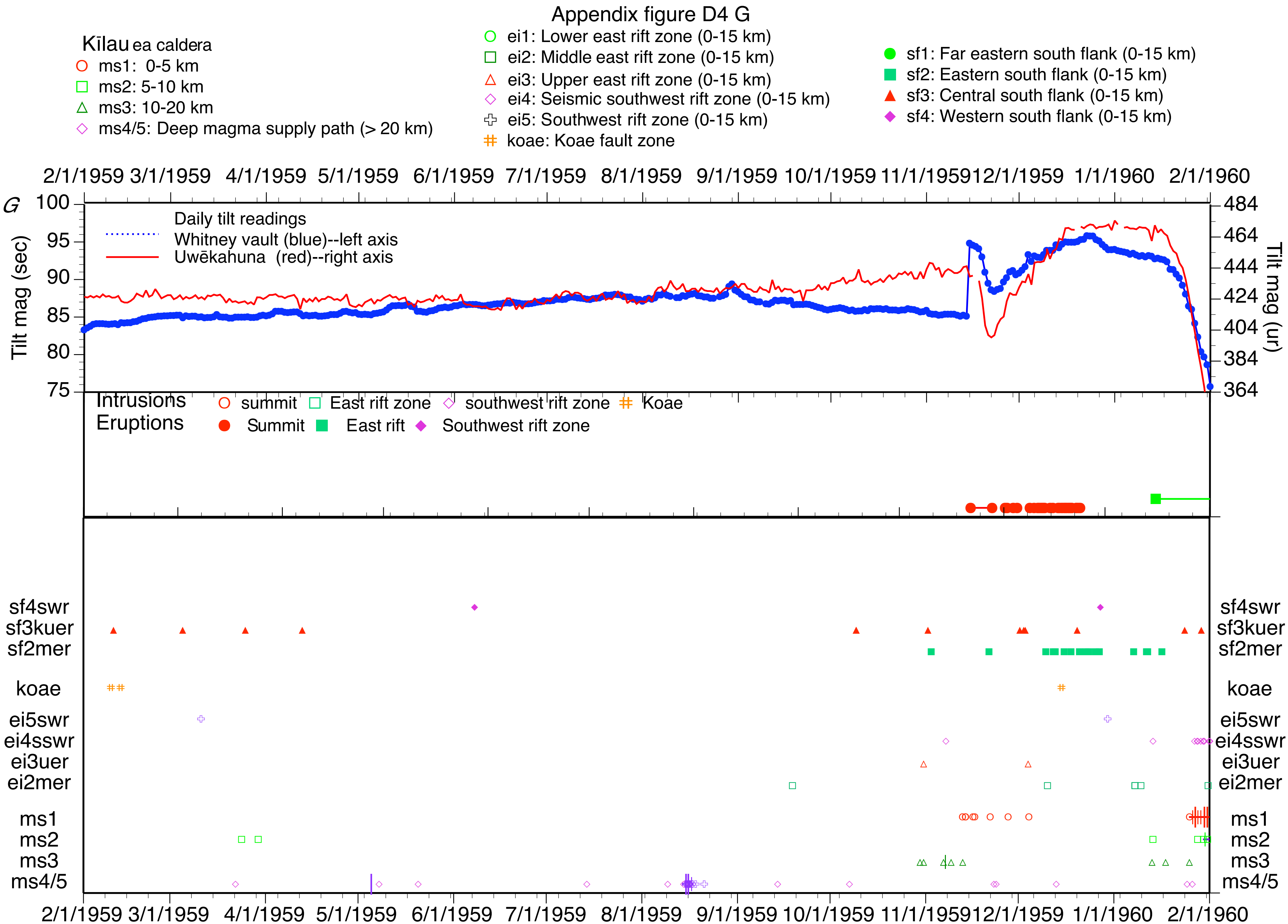
Appendix figure D4 D
Kīlauea caldera
ms1: 0-5 km
ms2: 5-10 km
ms3: 10-20 km
ms4/5: Deep magma supply path (> 20 km)
ei1: Lower east rift zone (0-15 km)
ei2: Middle east rift zone (0-15 km)
ei3: Upper east rift zone (0-15 km)
ei4: Seismic southwest rift zone (0-15 km)
ei5: Southwest rift zone (0-15 km)
koae: Koae 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)
2/1/1956 3/1/1956 4/1/1956 5/1/1956 6/1/1956 7/1/1956 8/1/1956 9/1/1956 10/1/1956 11/1/1956 12/1/1956 1/1/1957 2/1/1957
D
Tilt mag (sec)
80 75 70 65 60
Daily tilt readings
Whitney vault (blue)--left axis
Uwēkahuna (red)--right axis
371 351 331 311 291
Tilt mag (ur)
Short-base watertube tiltmeter installed
in Uwēkahuna vault, July, 1966
Intrusions summit East rift zone southwest rift zone Koae
Eruptions Summit East rift Southwest rift zone
Earthquake swarm of over 10 events (rift, summit and koae) or over 20 events (south flank)
Earthquake swarm of 3-10 events (rift, summit and koae) or 5-20 events (south flank)
sf4swr sf3kuer sf2mer koae ei5swr ei4sswr ei3uer ei2mer ms1 ms2 ms3 ms4/5

Appendix figure D4 E

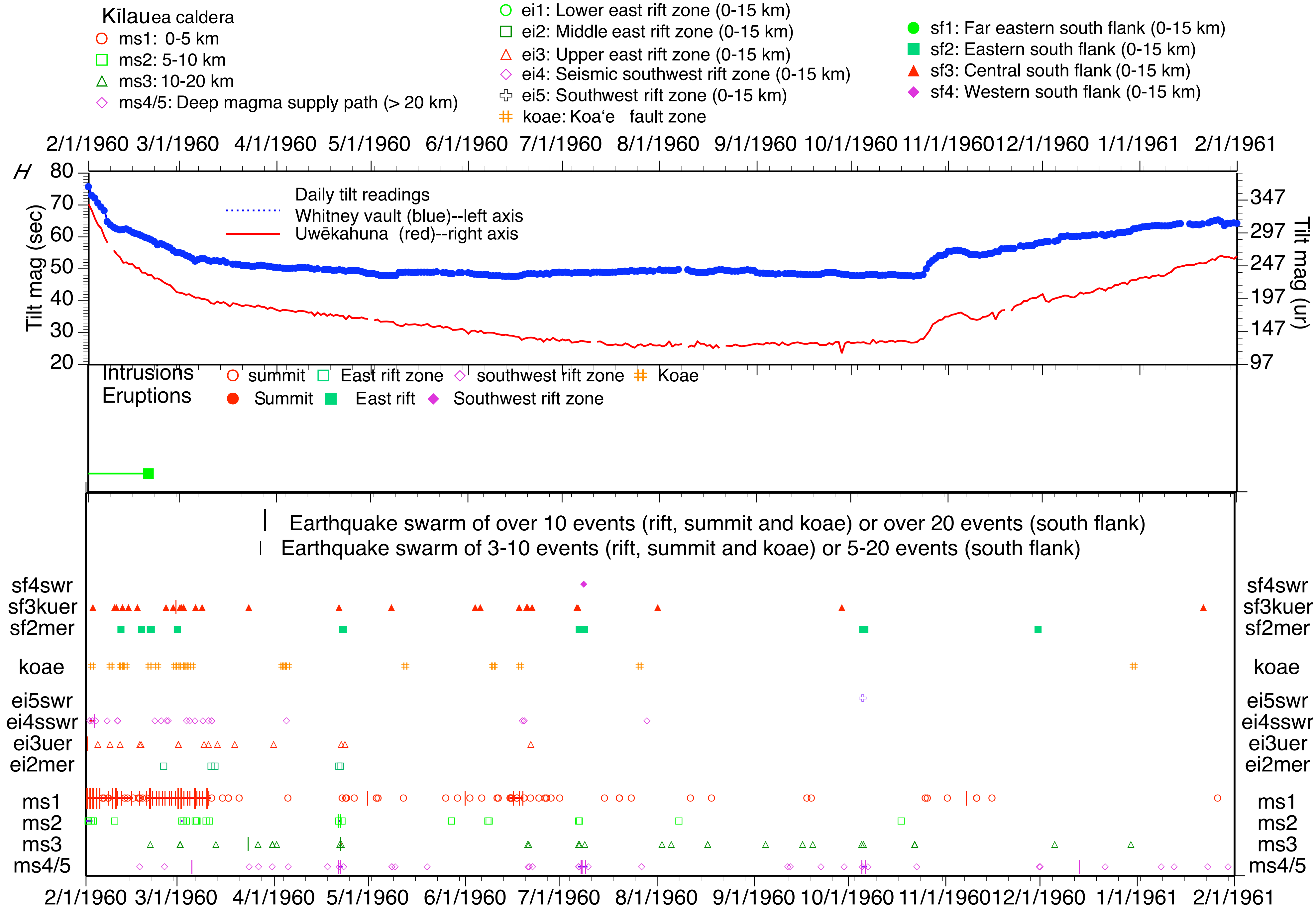


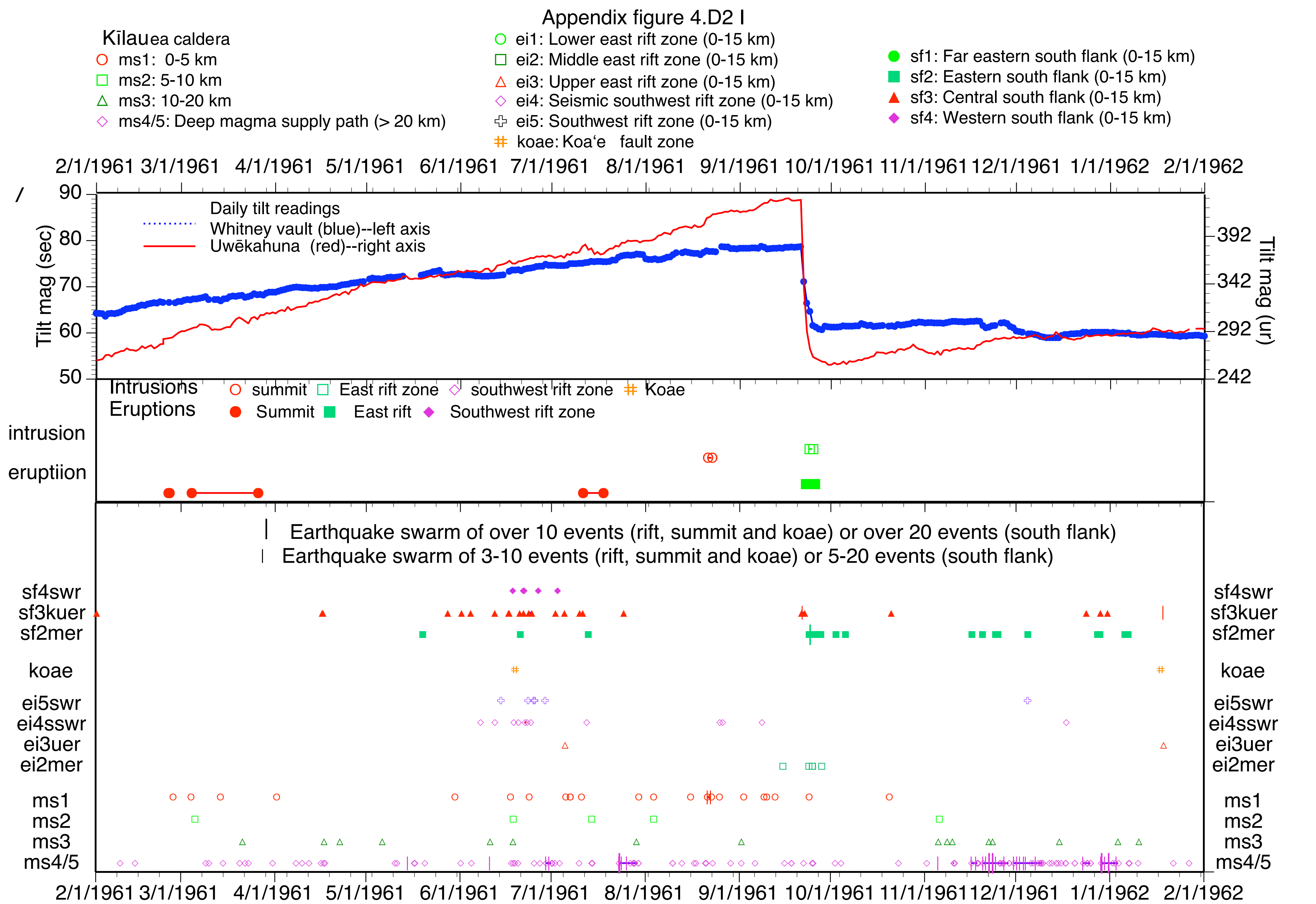
Appendix figure D4 F




Appendix figure D4 G
Kīlau ea 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: Koae 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)
2/1/1959 3/1/1959 4/1/1959 5/1/1959 6/1/1959 7/1/1959 8/1/1959 9/1/1959 10/1/1959 11/1/1959 12/1/1959 1/1/1960 2/1/1960
G
Tilt mag (sec)
Tilt mag (ur)
Daily tilt readings
Whitney vault (blue)--left axis
Uwēkahuna (red)--right axis
Intrusions
summit
East rift zone
southwest rift zone
Koae
Eruptions
Summit
East rift
Southwest rift zone
sf4swr
sf3kuer
sf2mer
koae
ei5swr
ei4sswr
ei3uer
ei2mer
ms1
ms2
ms3
ms4/5

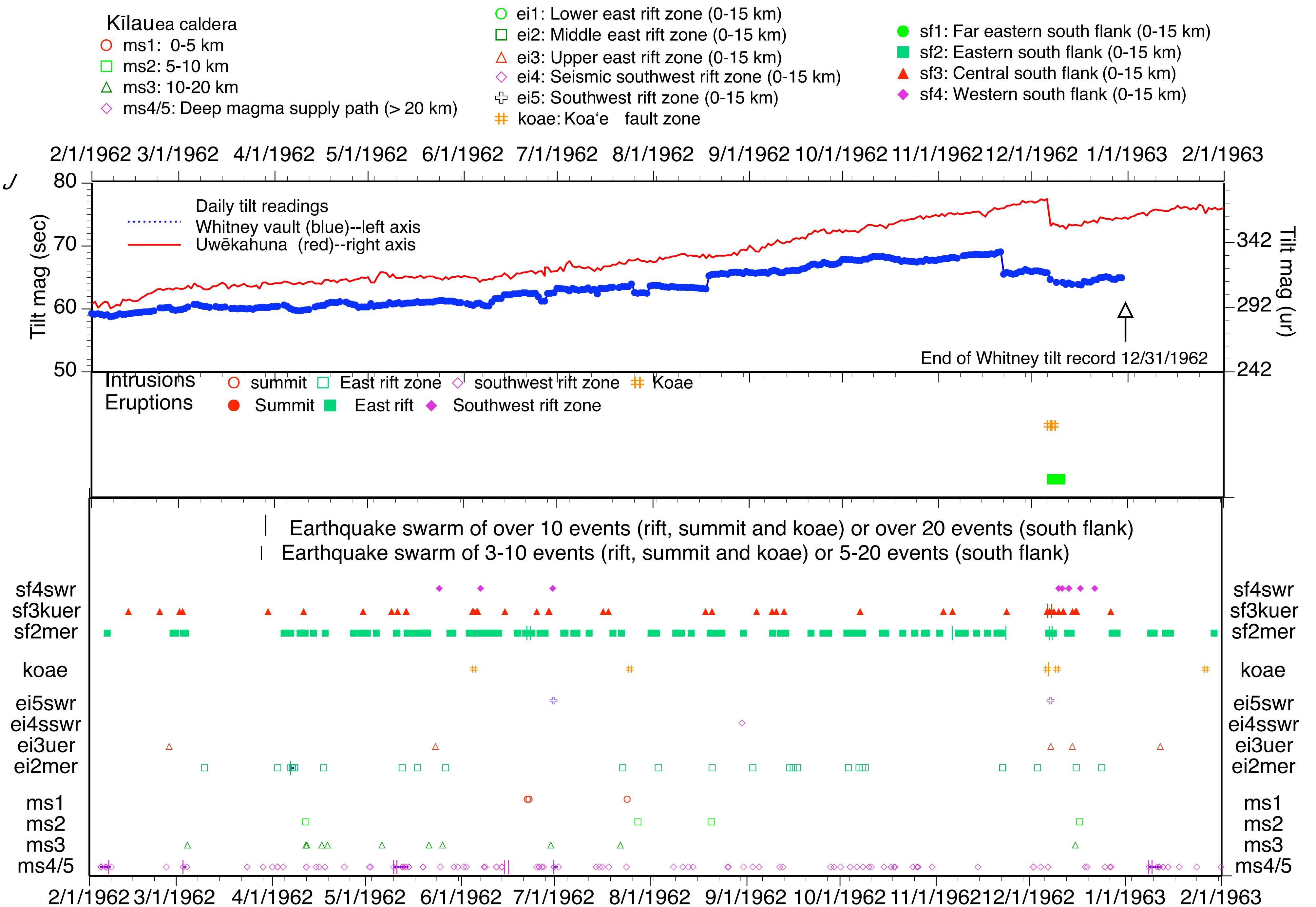
Appendix figure D4 H

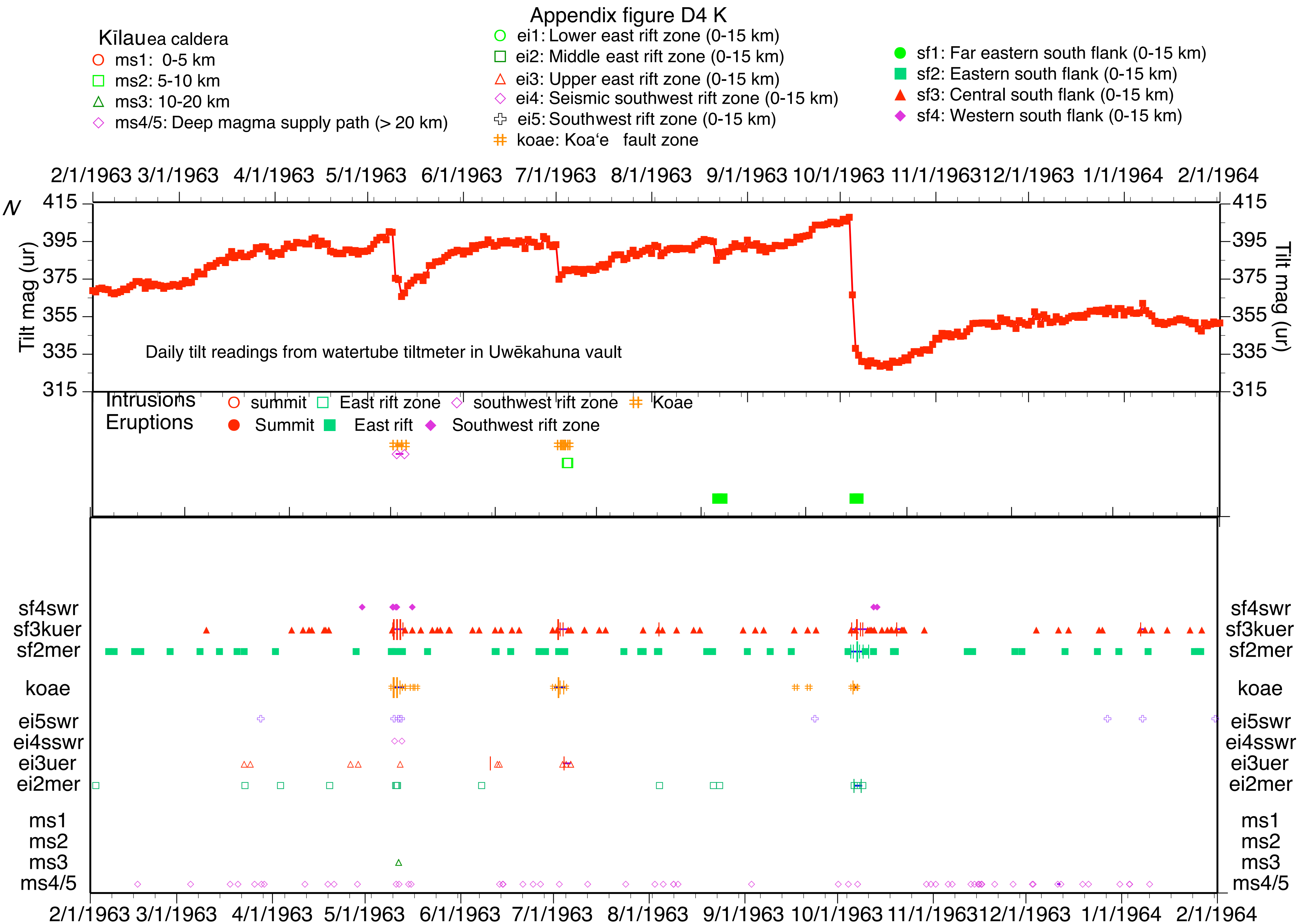




Appendix figure 4.D2 I
Kīlauea caldera
ms1: 0-5 km
ms2: 5-10 km
ms3: 10-20 km
ms4/5: Deep magma supply path (> 20 km)
ei1: Lower east rift zone (0-15 km)
ei2: Middle east rift zone (0-15 km)
ei3: Upper east rift zone (0-15 km)
ei4: Seismic southwest rift zone (0-15 km)
ei5: Southwest rift zone (0-15 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)
2/1/1961 3/1/1961 4/1/1961 5/1/1961 6/1/1961 7/1/1961 8/1/1961 9/1/1961 10/1/1961 11/1/1961 12/1/1961 1/1/1962 2/1/1962
Daily tilt readings
Whitney vault (blue)--left axis
Uwēkahuna (red)--right axis
Tilt mag (sec)
Tilt mag (ur)
90 80 70 60 50
392 342 292 242
Intrusions
Eruptions
summit
East rift zone
southwest rift zone
Koae
Summit
East rift
Southwest rift zone
intrusion
eruptiion
Earthquake swarm of over 10 events (rift, summit and koae) or over 20 events (south flank)
Earthquake swarm of 3-10 events (rift, summit and koae) or 5-20 events (south flank)
sf4swr
sf3kuer
sf2mer
koae
ei5swr
ei4sswr
ei3uer
ei2mer
ms1
ms2
ms3
ms4/5

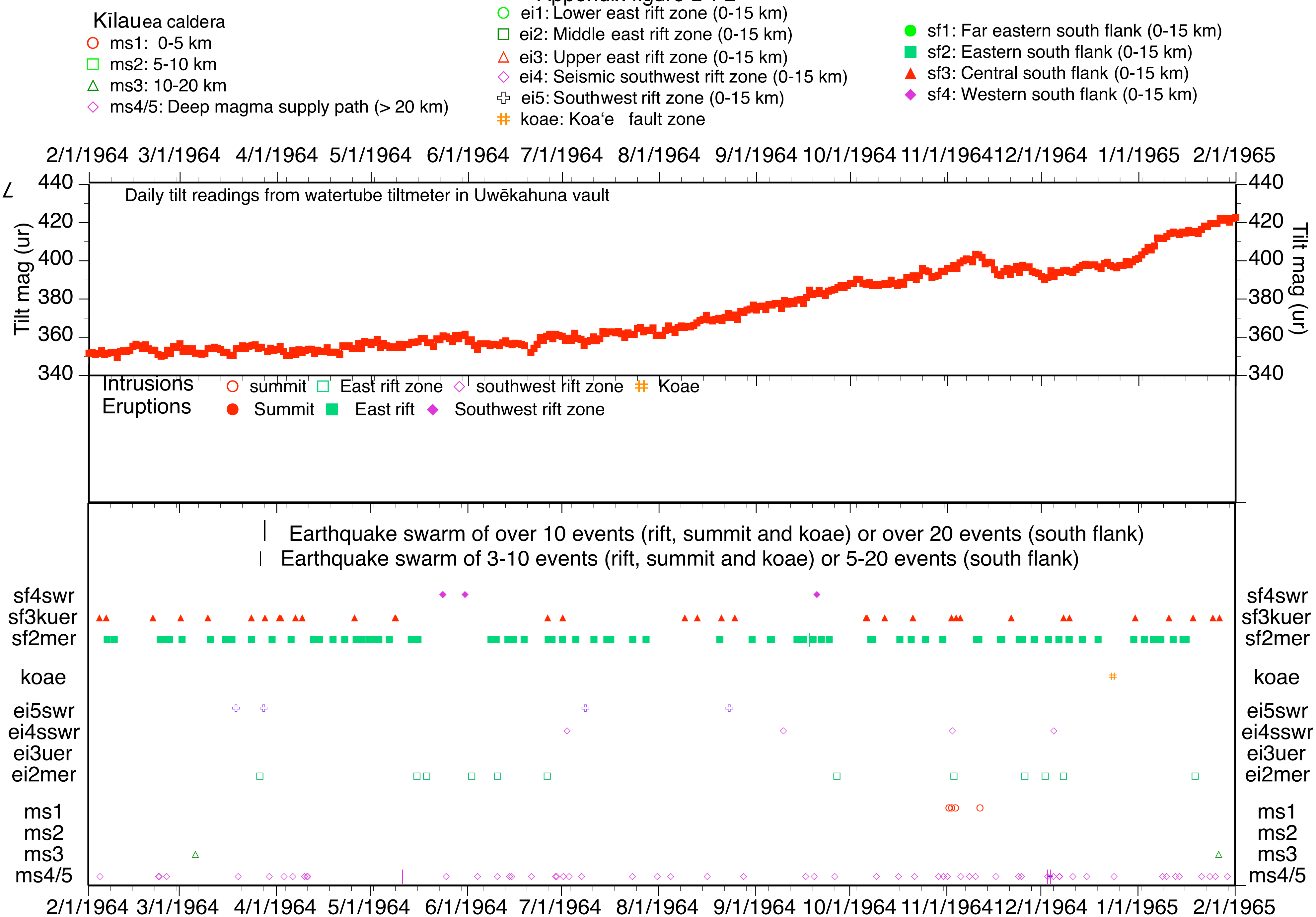
Appendix figure D4 J



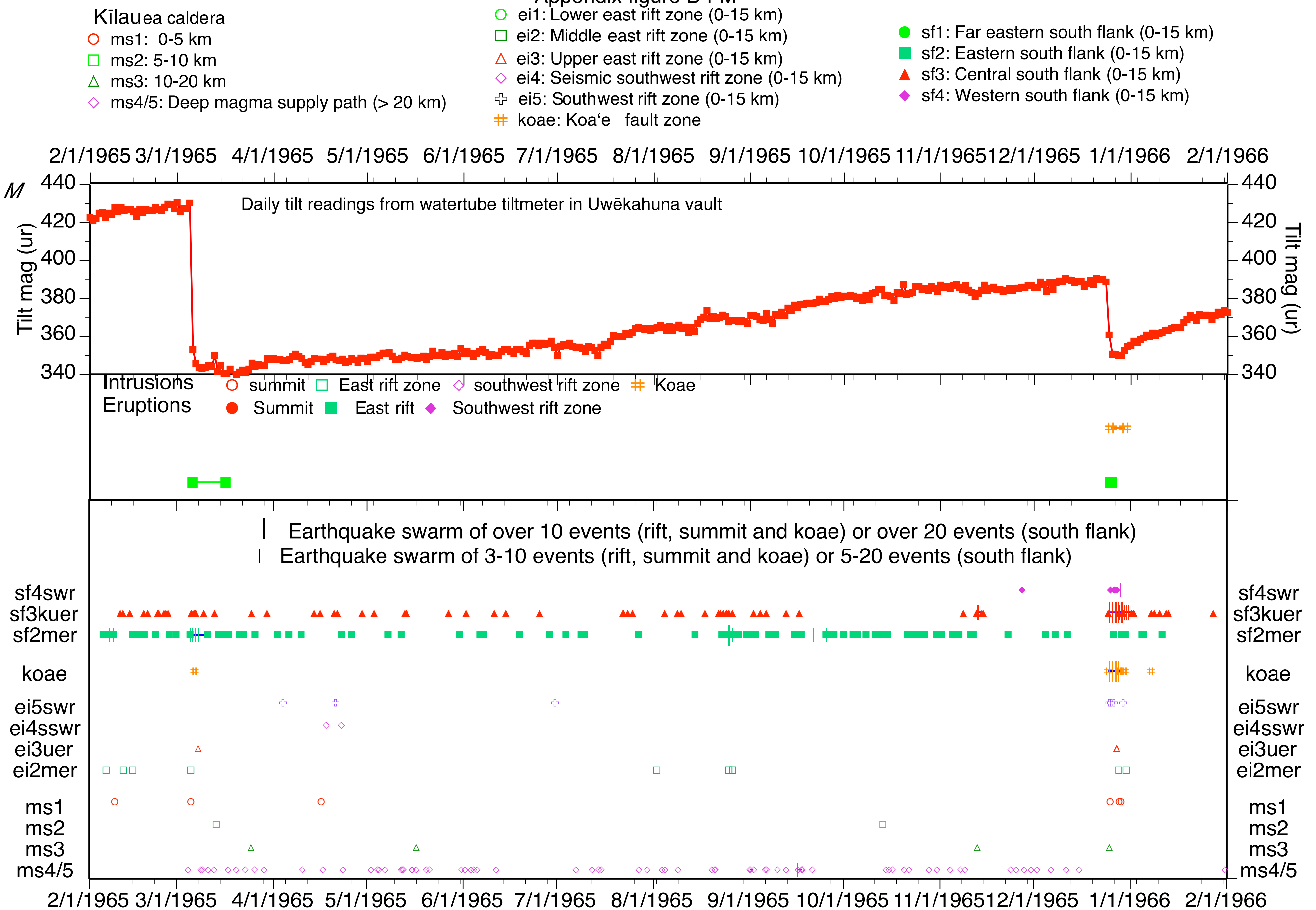


Appendix figure D4 K
Kīlauea caldera
ms1: 0-5 km
ms2: 5-10 km
ms3: 10-20 km
ms4/5: Deep magma supply path (> 20 km)
ei1: Lower east rift zone (0-15 km)
ei2: Middle east rift zone (0-15 km)
ei3: Upper east rift zone (0-15 km)
ei4: Seismic southwest rift zone (0-15 km)
ei5: Southwest rift zone (0-15 km)
koae: Koaʻe 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)
2/1/1963 3/1/1963 4/1/1963 5/1/1963 6/1/1963 7/1/1963 8/1/1963 9/1/1963 10/1/1963 11/1/1963 12/1/1963 1/1/1964 2/1/1964
N
Tilt mag (ur)
415 395 375 355 335 315
Daily tilt readings from watertube tiltmeter in Uwēkahuna vault
Intrusions
Eruptions
summit
East rift zone
southwest rift zone
Koae
Summit
East rift
Southwest rift zone
sf4swr
sf3kuer
sf2mer
koae
ei5swr
ei4sswr
ei3uer
ei2mer
ms1
ms2
ms3
ms4/5

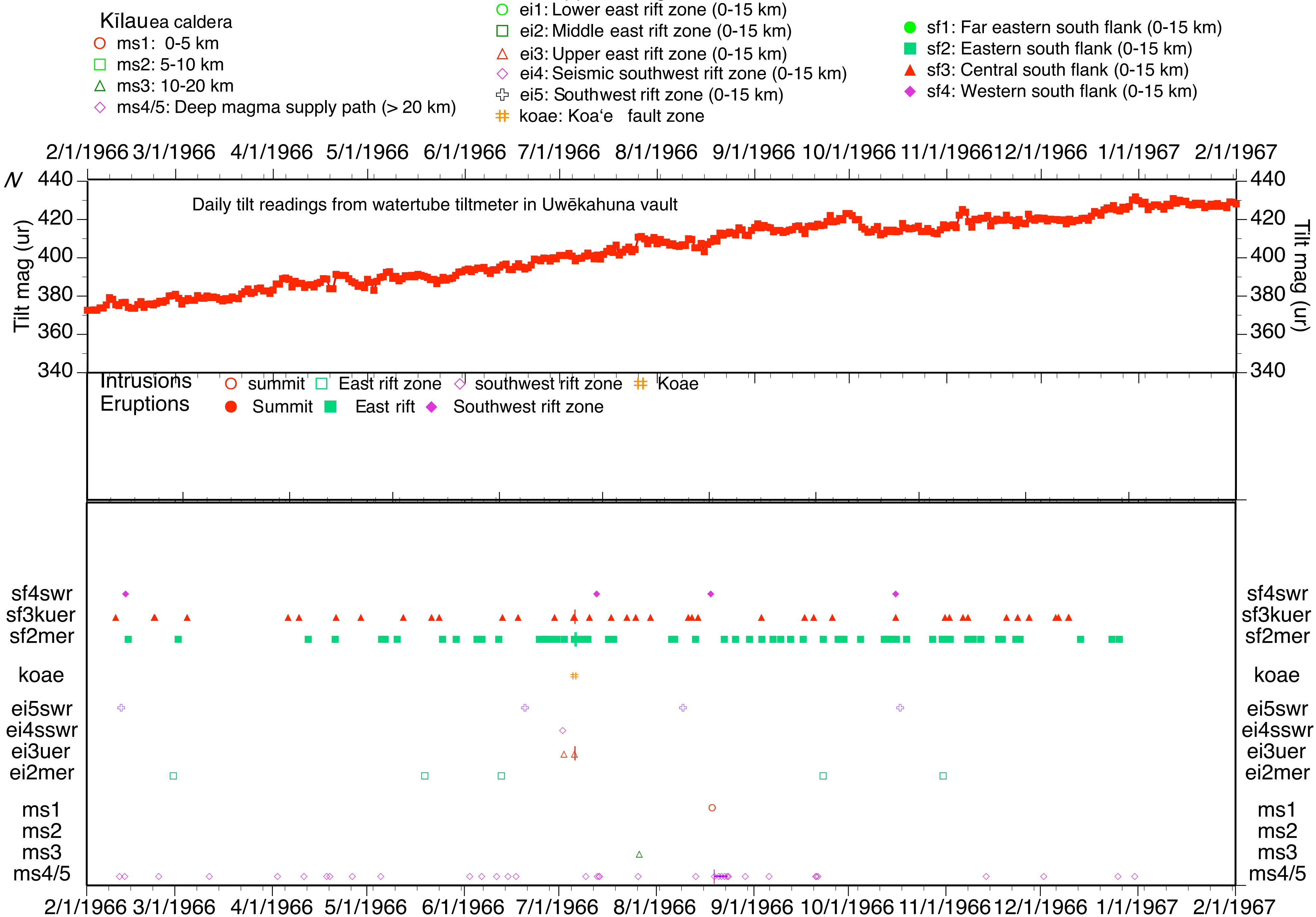
Appendix figure D4 L



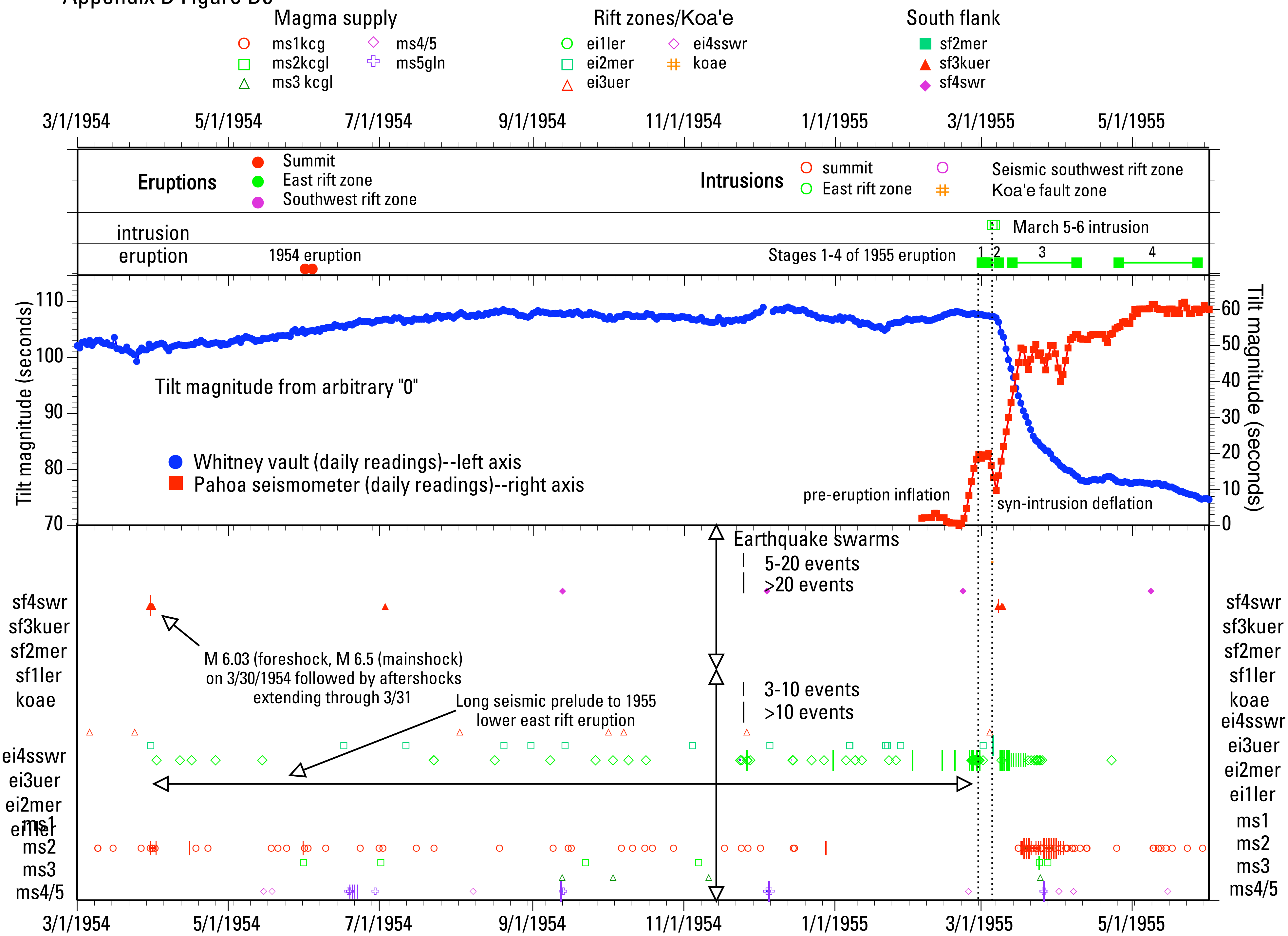
Appendix figure D4 M



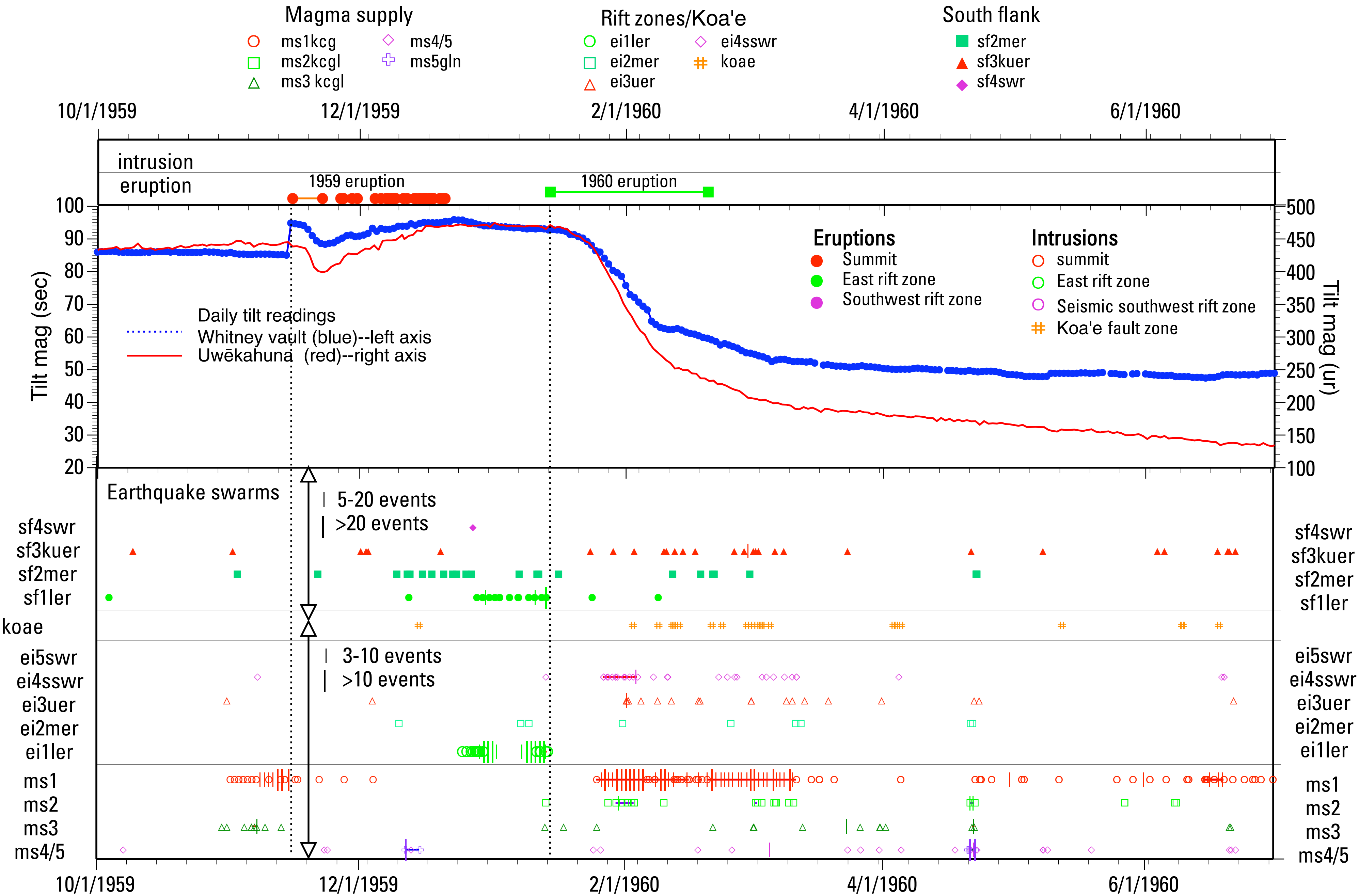
Appendix figure D4 N



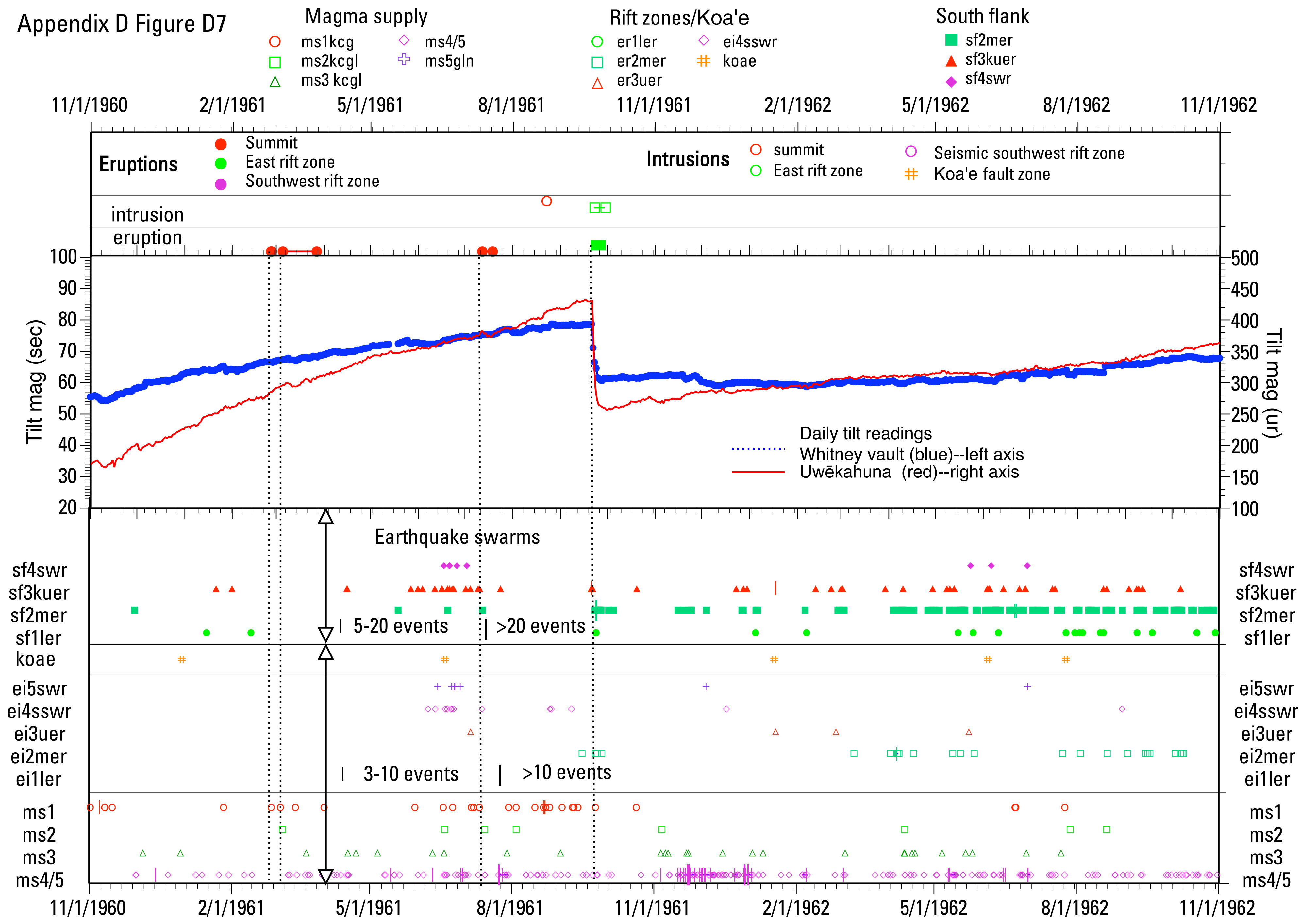
Appendix D Figure D5

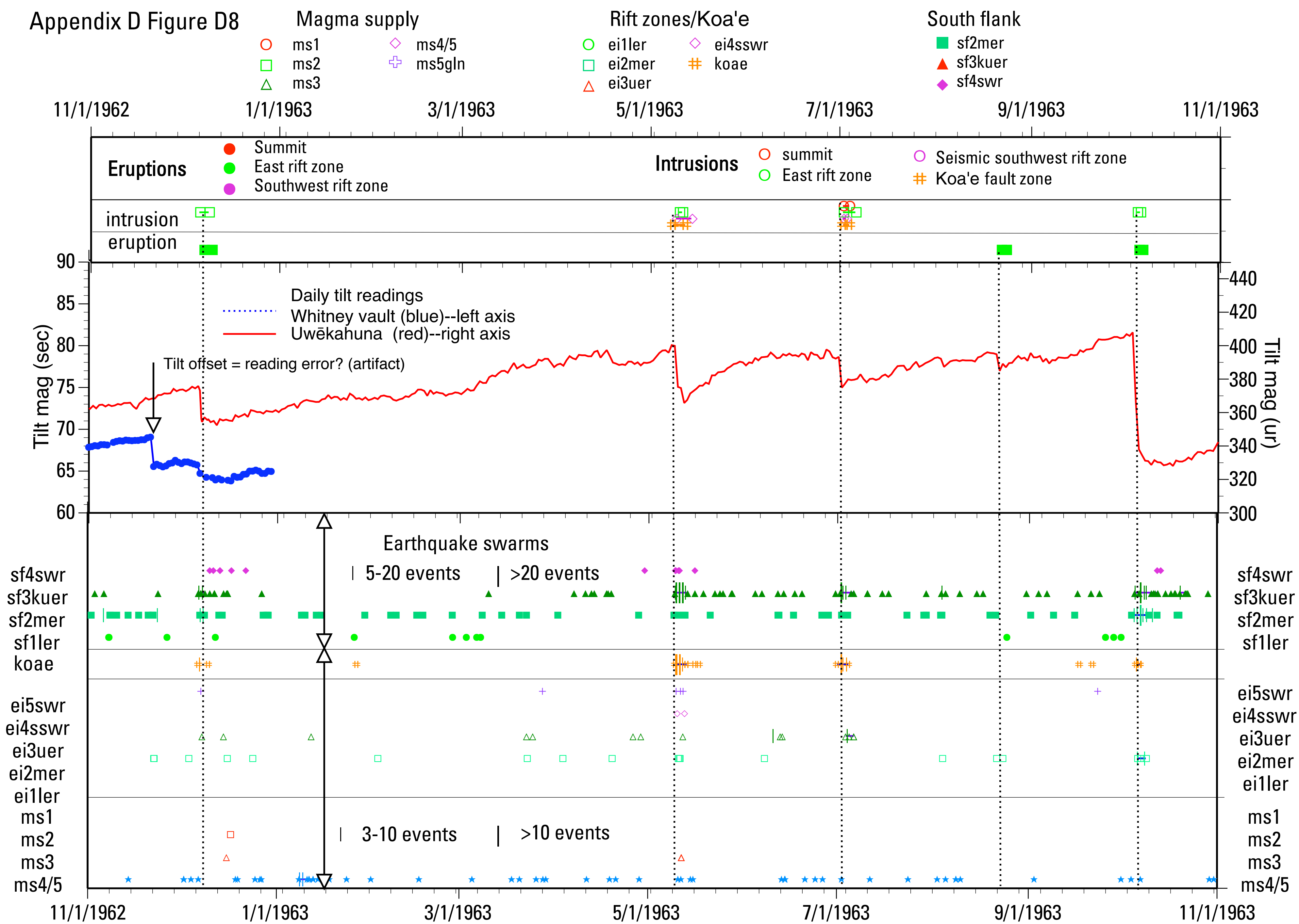


Appendix D Figure D6

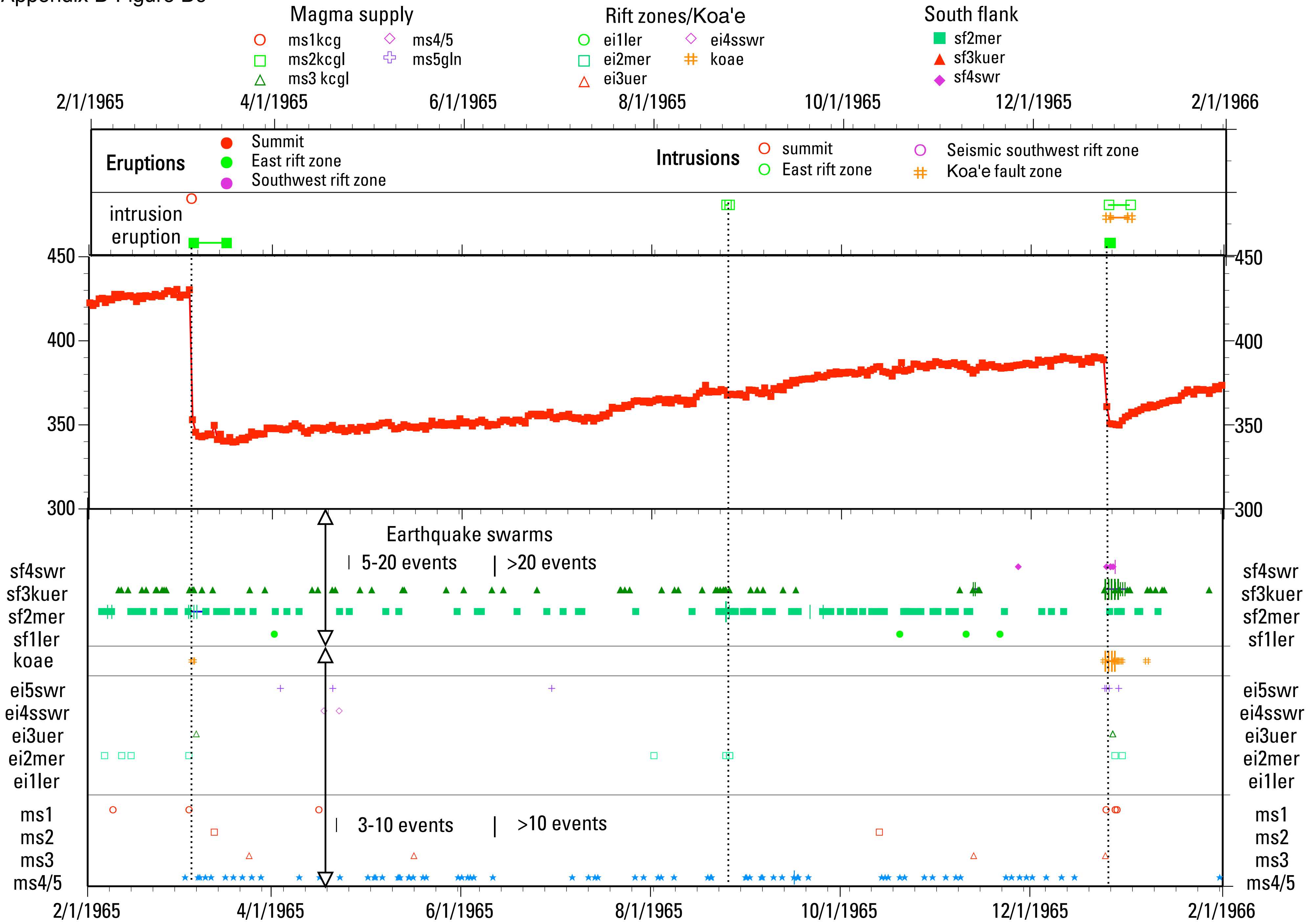


Appendix D Figure D7

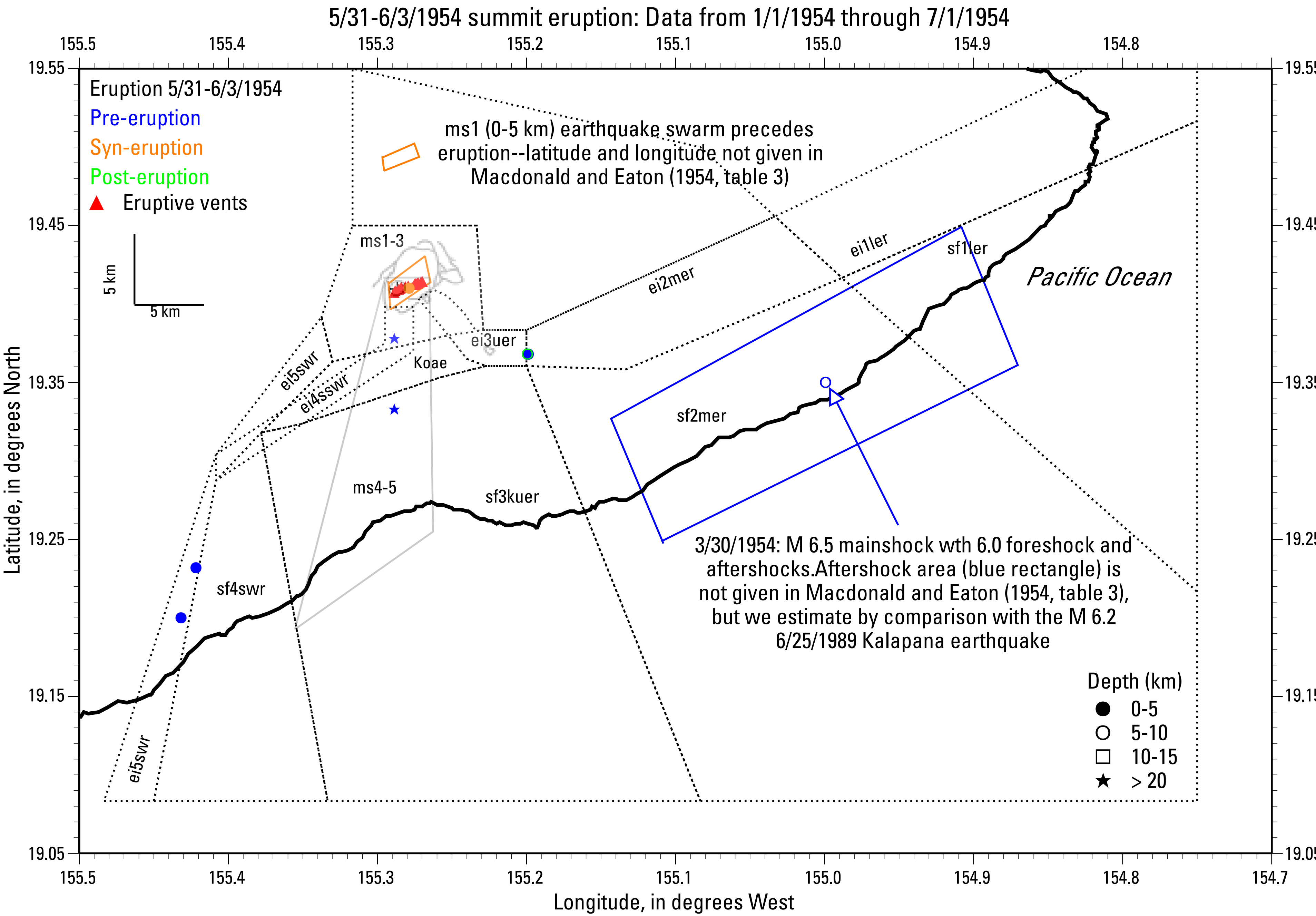



Appendix D Figure D8
Magma supply
ms1
ms2
ms3
ms4/5
ms5gln
Rift zones/Koa'e
ei1ler
ei2mer
ei3uer
ei4sswr
koae
South flank
sf2mer
sf3kuer
sf4swr
Eruptions
Summit
East rift zone
Southwest rift zone
Intrusions
summit
East rift zone
Seismic southwest rift zone
Koa'e fault zone
intrusion
eruption
Daily tilt readings
Whitney vault (blue)--left axis
Uwēkahuna (red)--right axis
Tilt offset = reading error? (artifact)
Tilt mag (sec)
Tilt mag (ur)
Earthquake swarms
5-20 events
>20 events
3-10 events
>10 events
sf4swr
sf3kuer
sf2mer
sf1ler
koae
ei5swr
ei4sswr
ei3uer
ei2mer
ei1ler
ms1
ms2
ms3
ms4/5
11/1/1962
1/1/1963
3/1/1963
5/1/1963
7/1/1963
9/1/1963
11/1/1963

Appendix D Figure D9

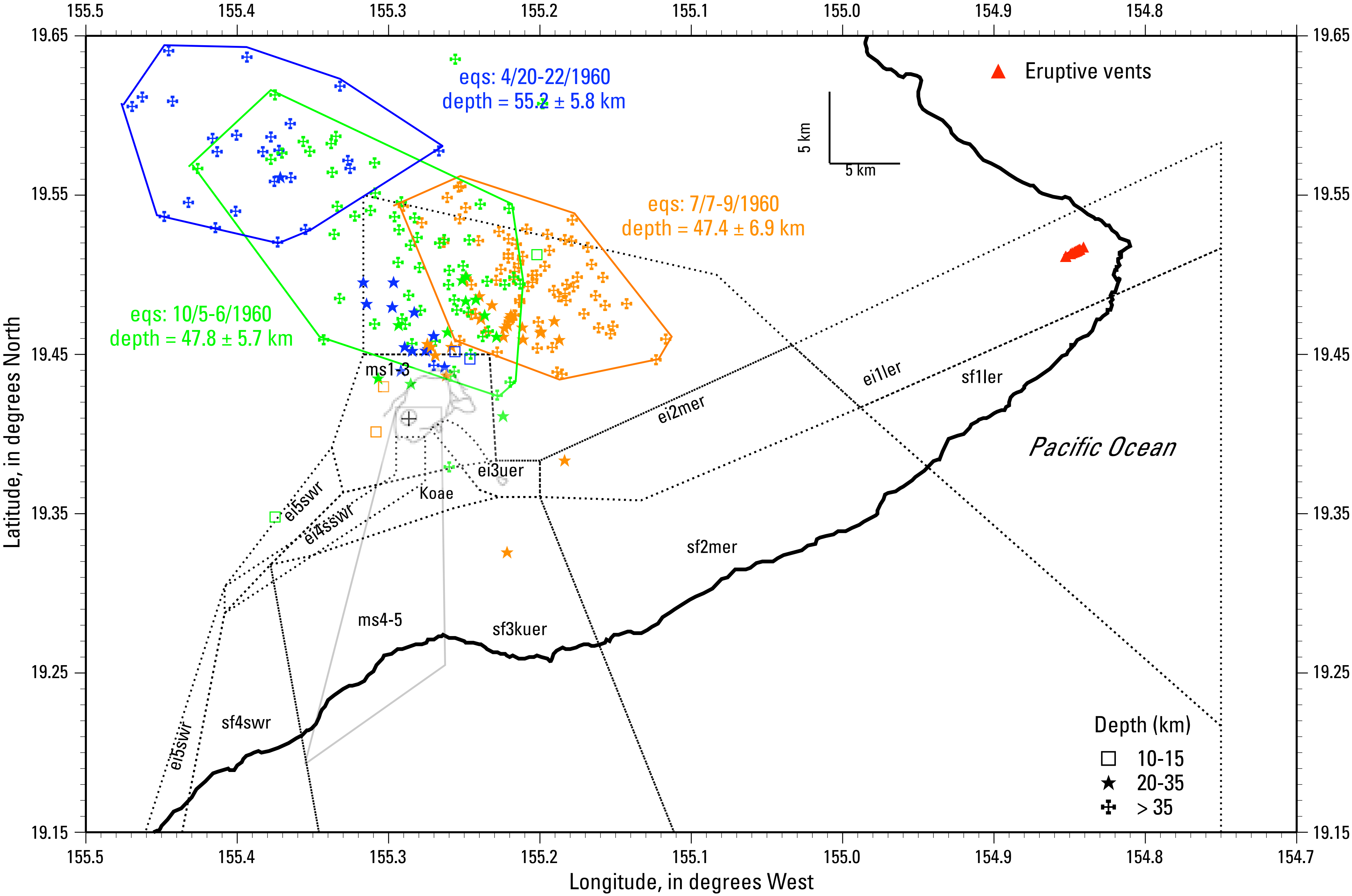


Appendix D Figure D10



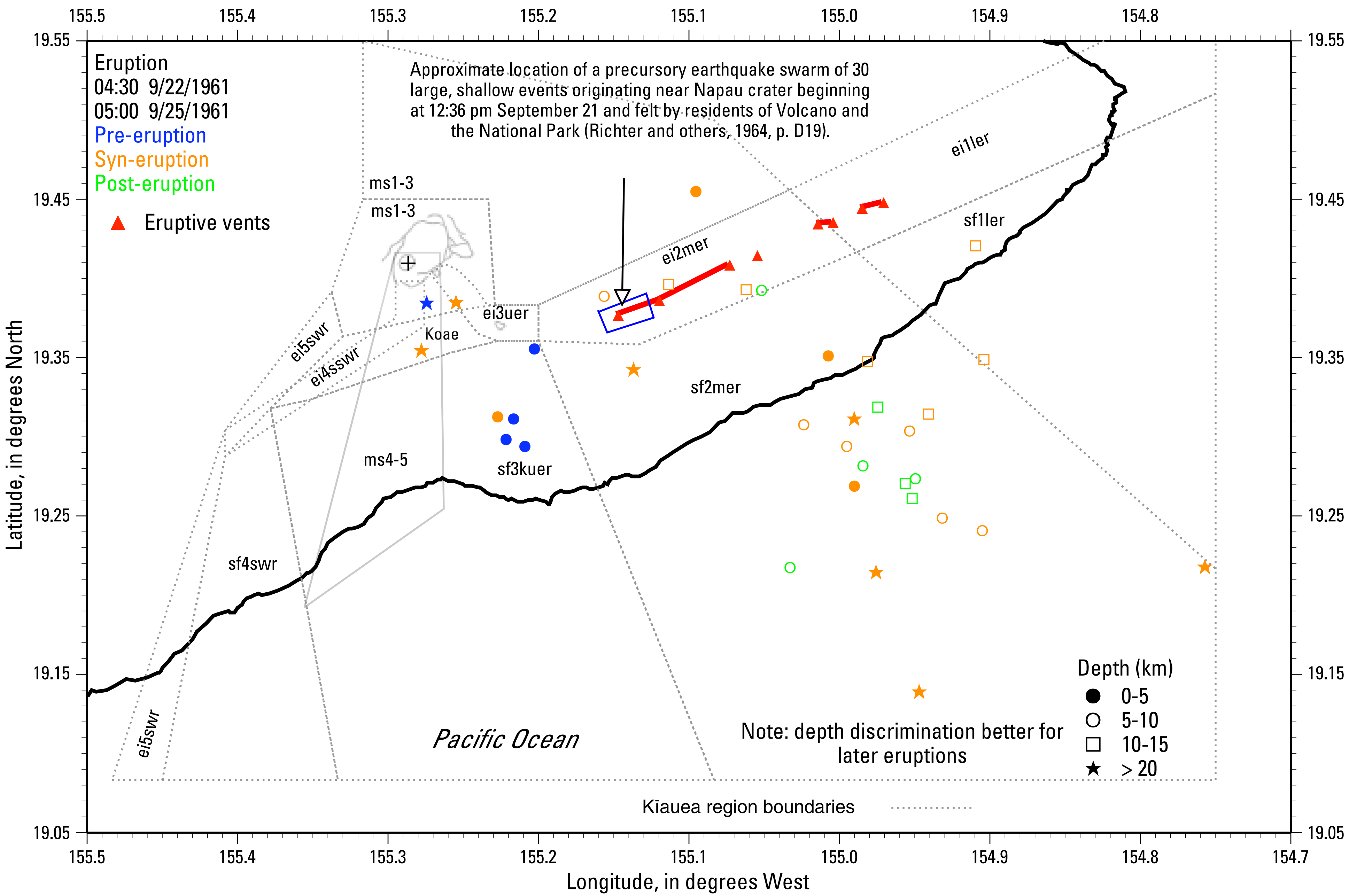
Appendix D Figure D11

40-60 km deep earthquake swarms following the 1960 eruption: Data from 4/20-10/6/1960

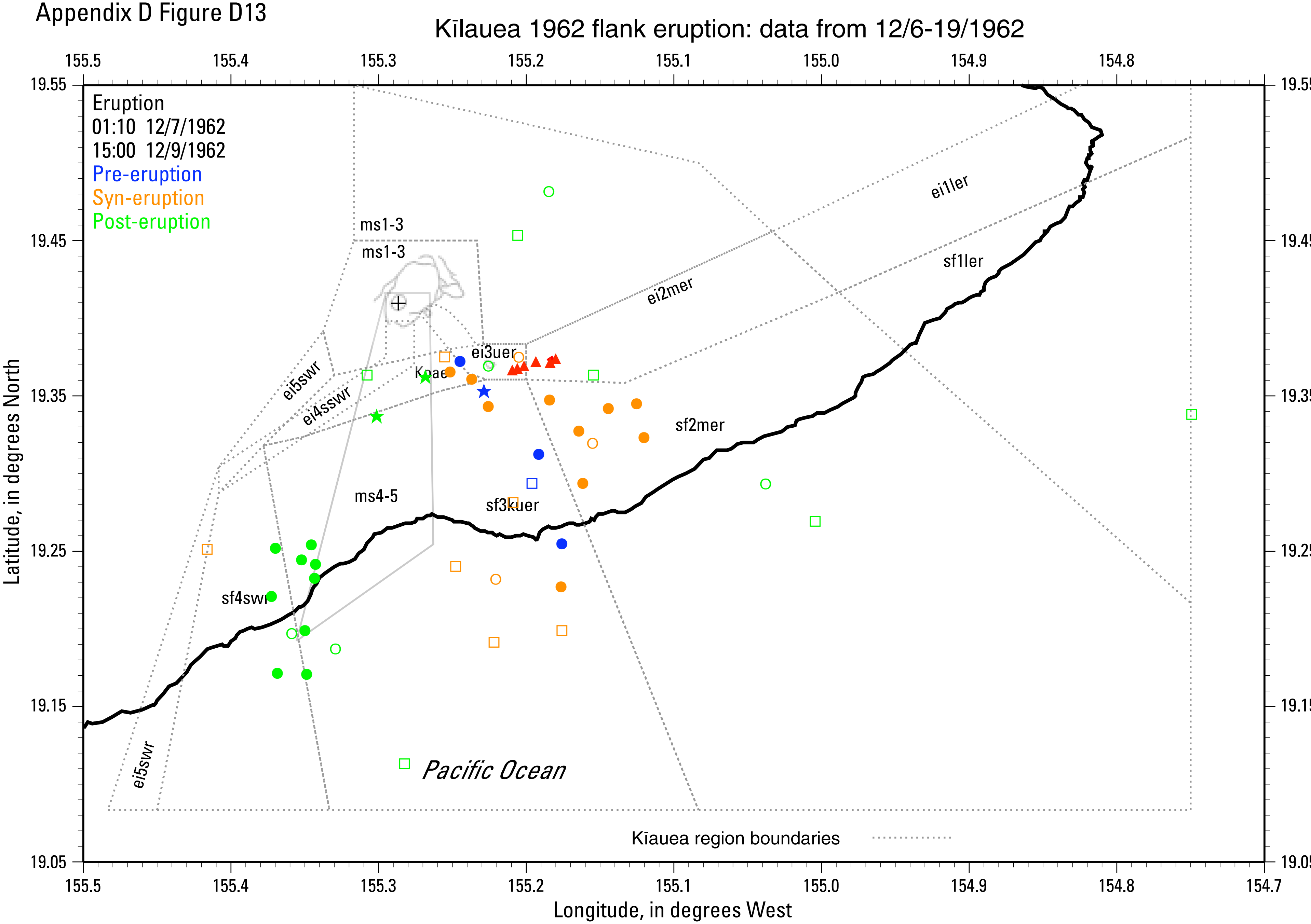


Appendix D Figure D12

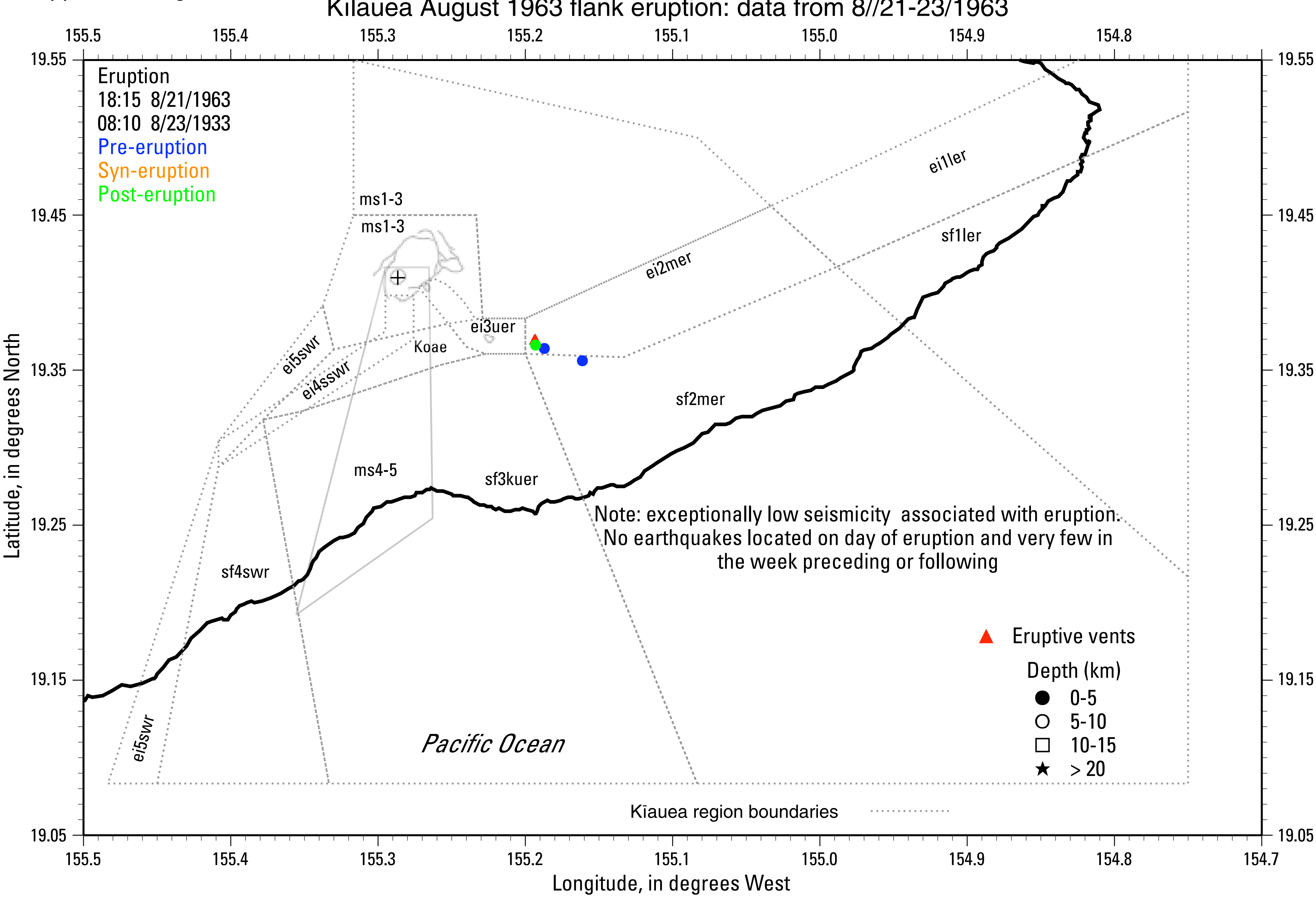
Kīlauea 1961 flank eruption: data from 9/21-27/1961



Appendix D Figure D13

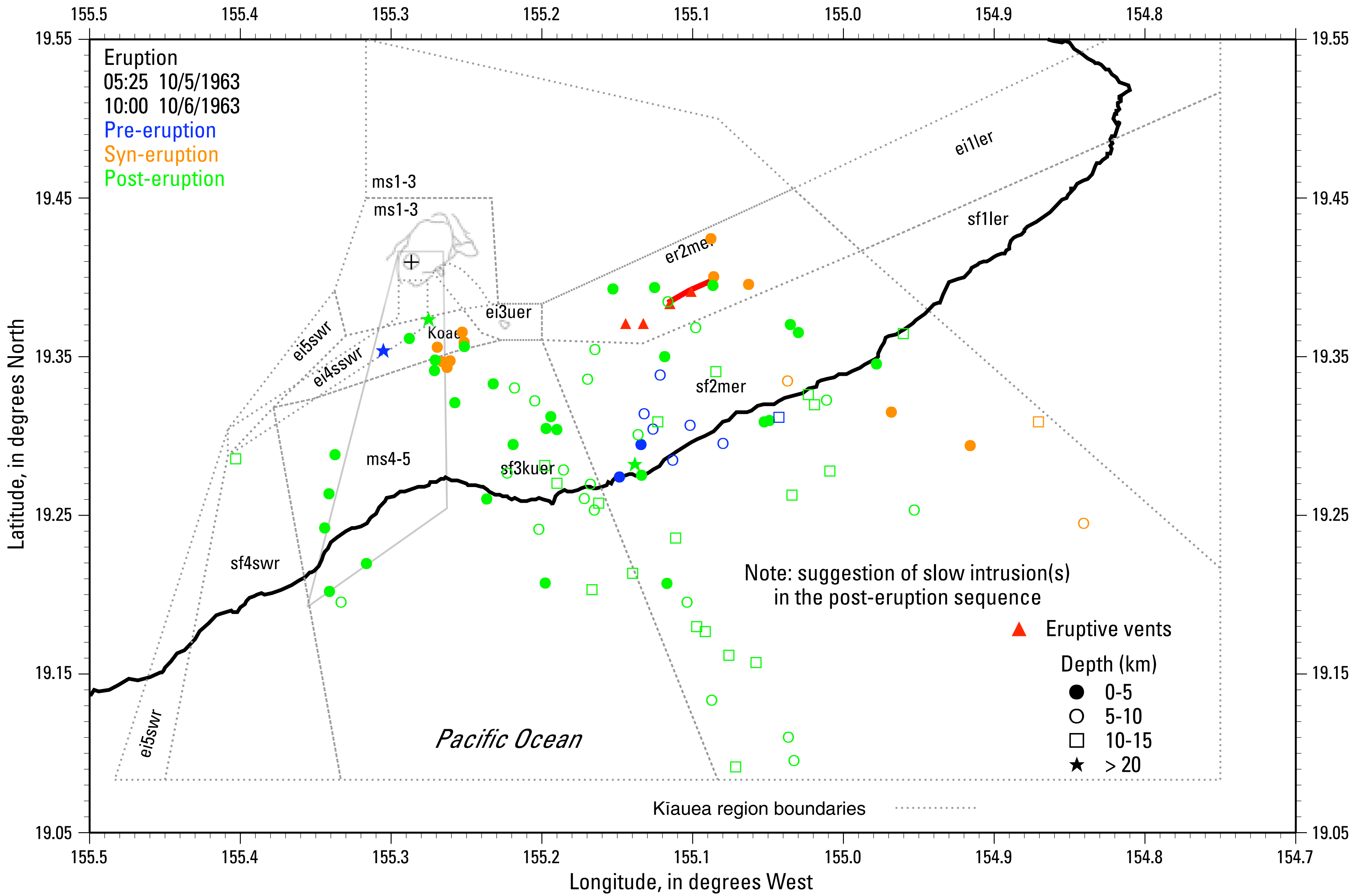


Appendix D Figure D14

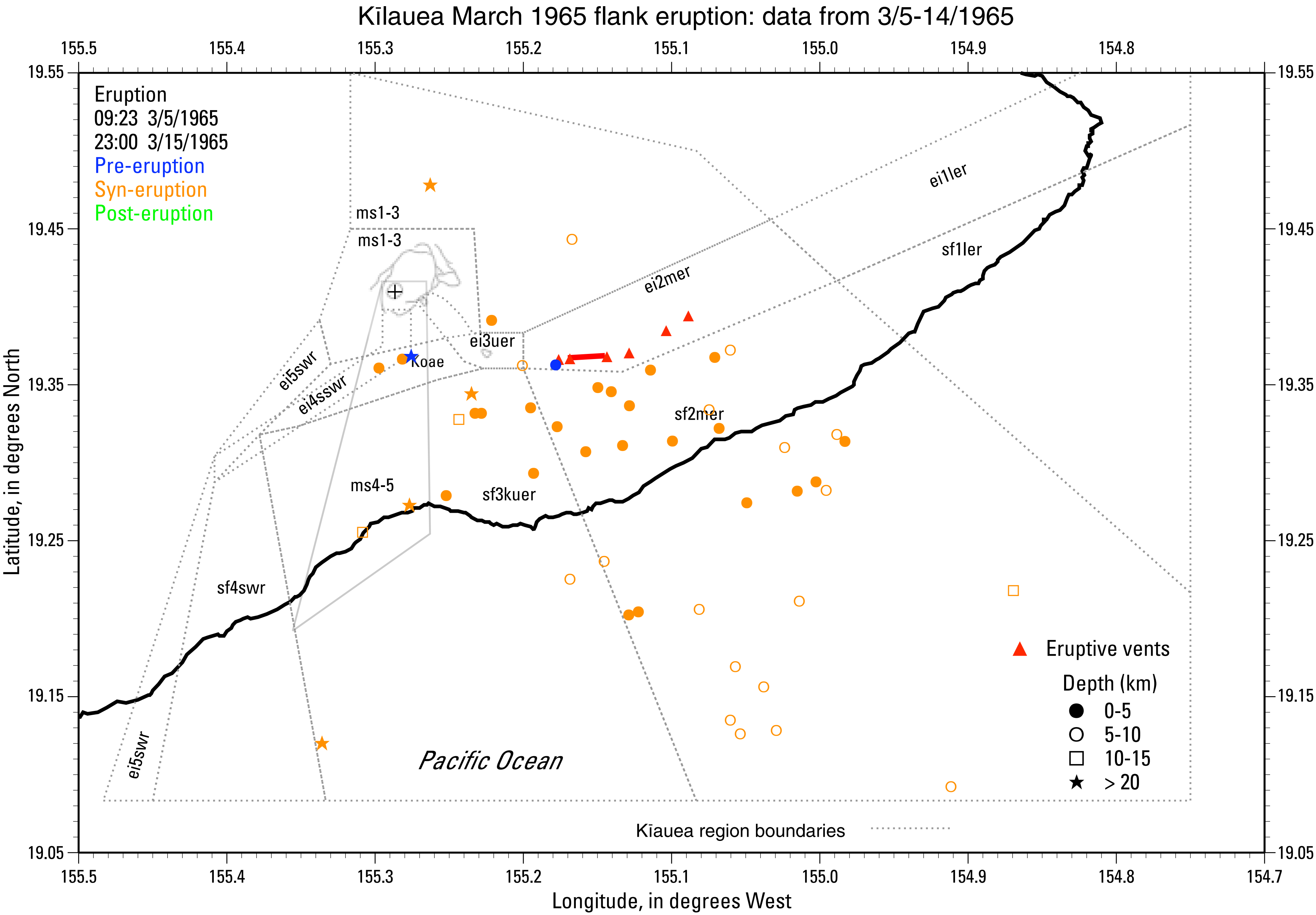


Appendix D Figure D15

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

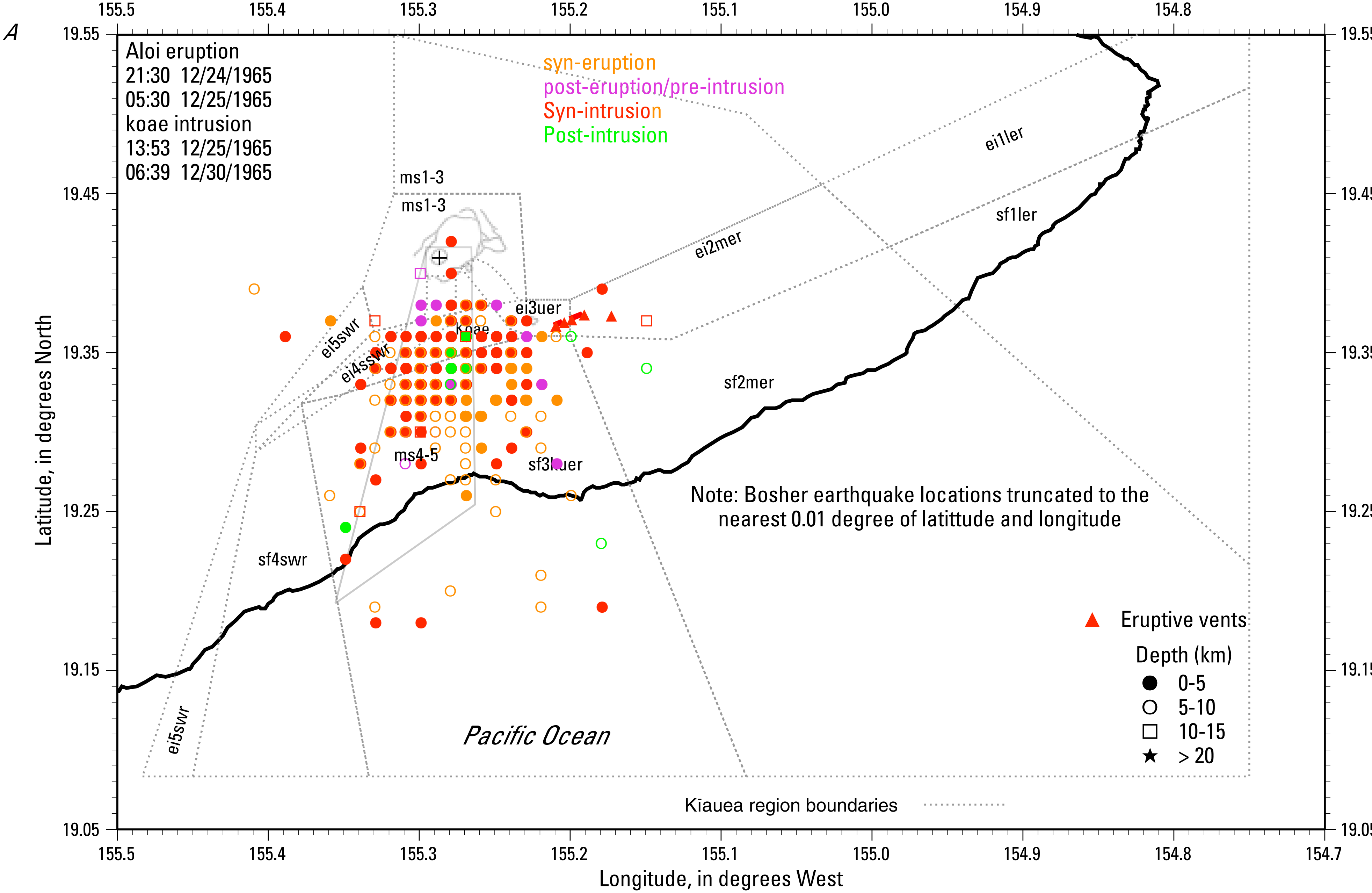


Appendix D Figure D16



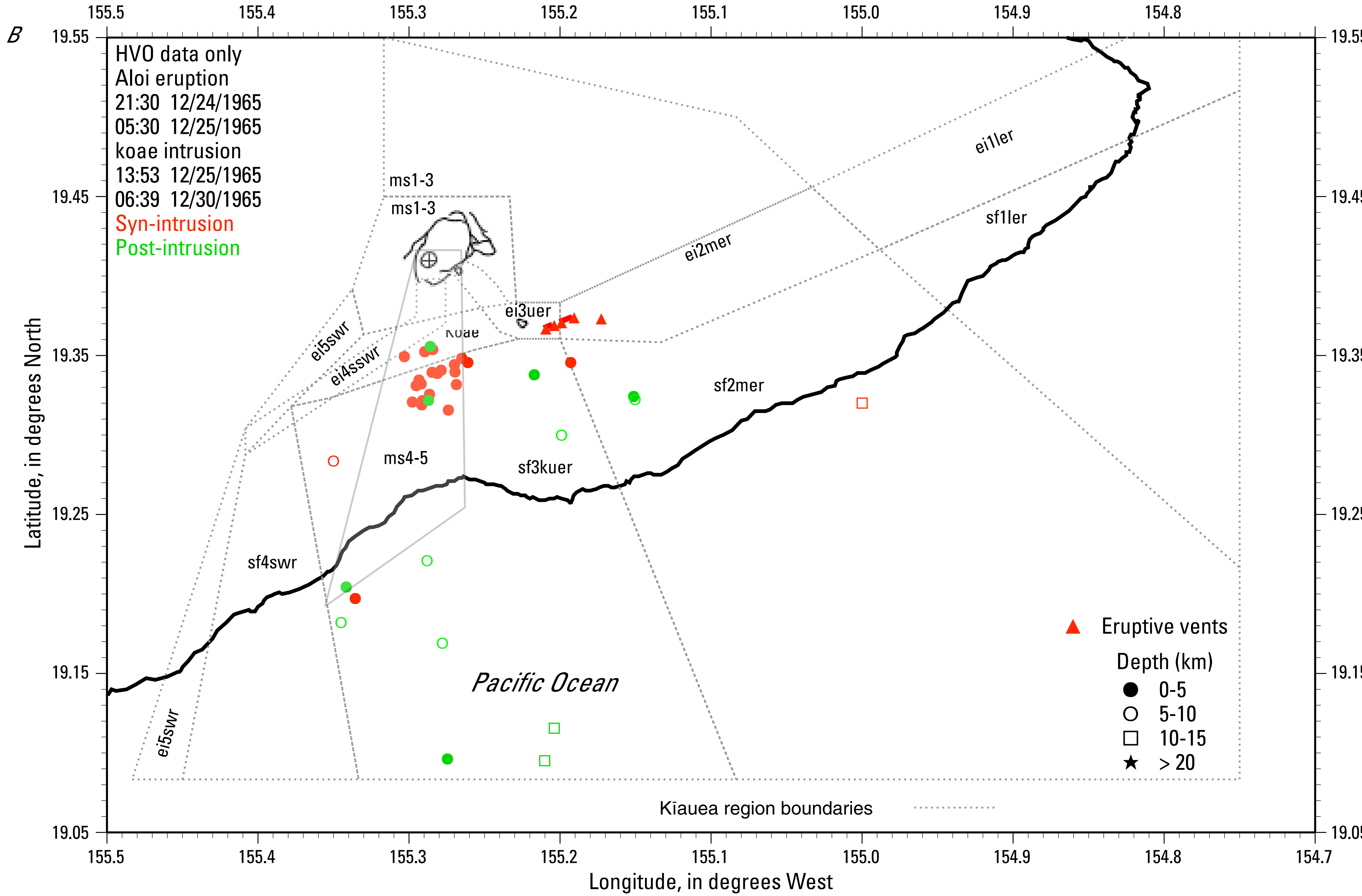
Appendix D Figure D17A

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

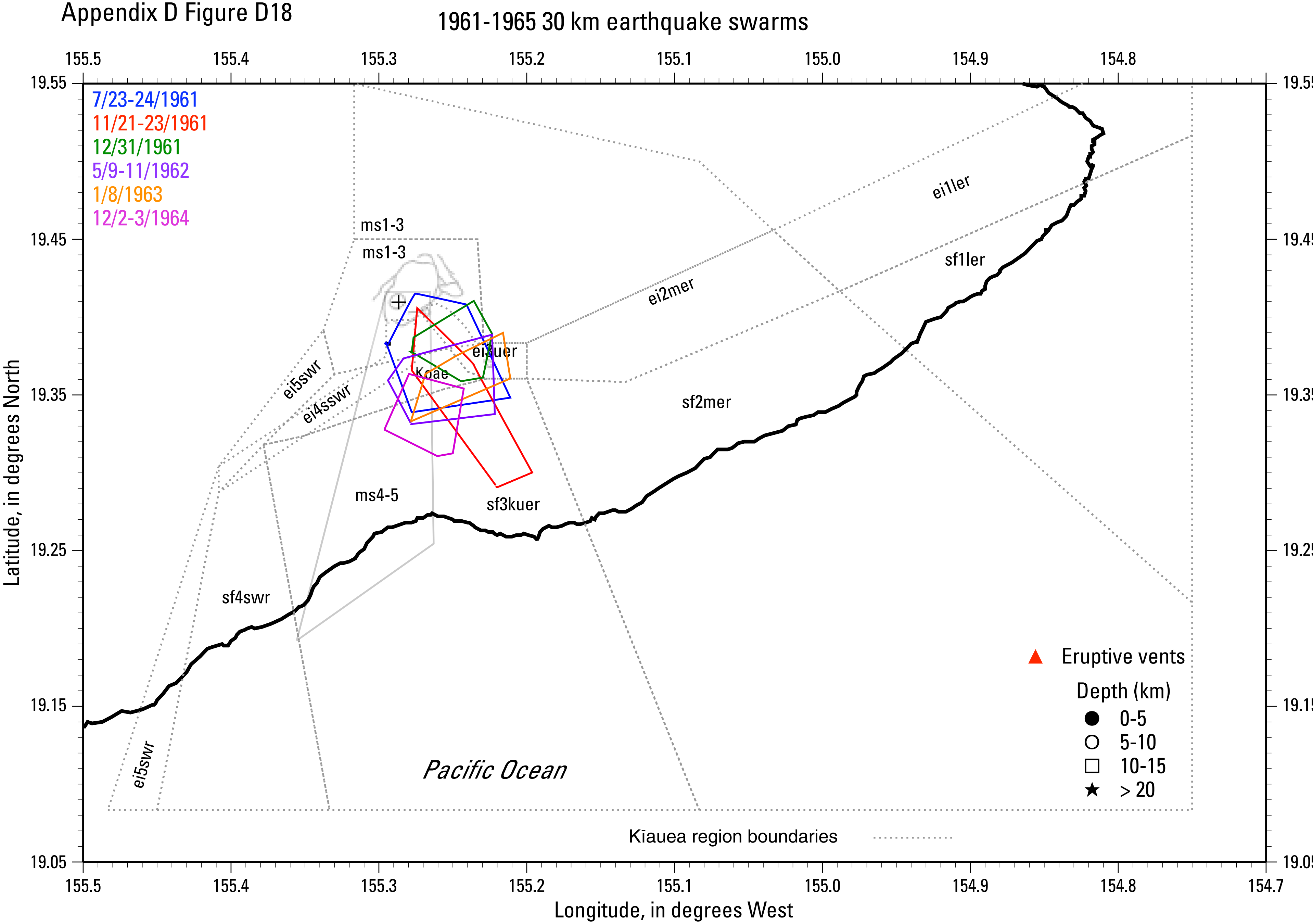


Appendix D Figure D17 B

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

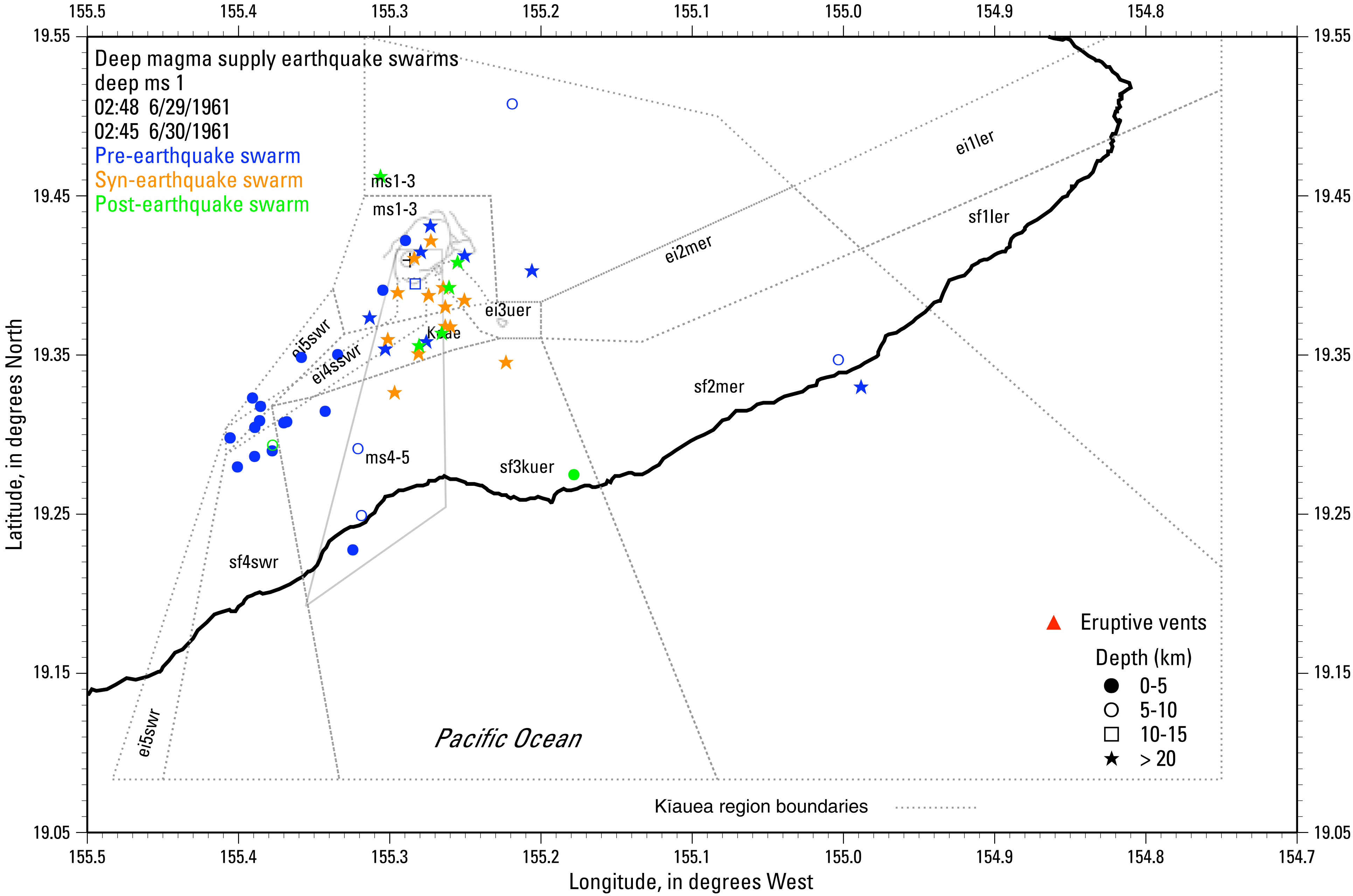


Appendix D Figure D18

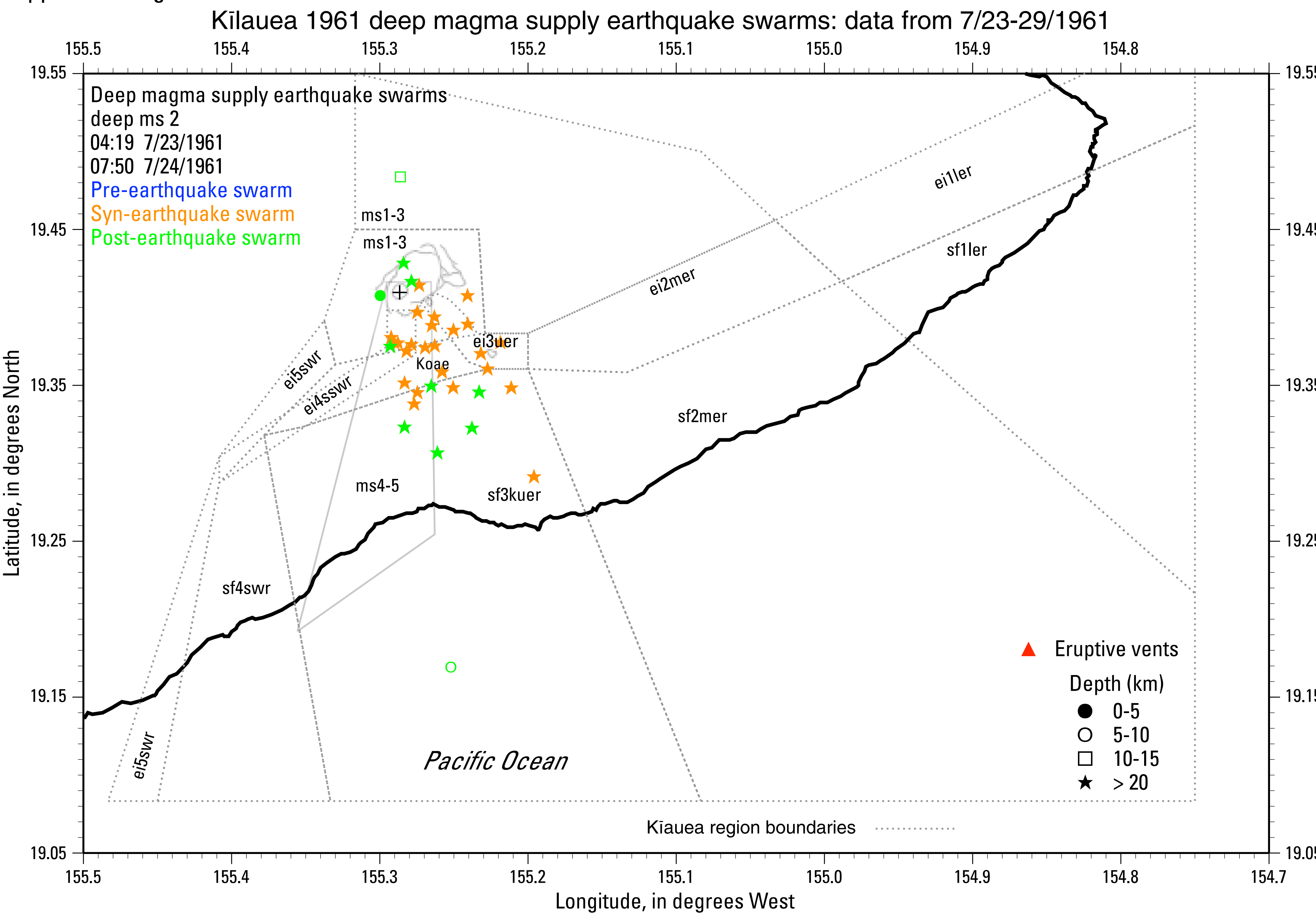


Appendix D Figure D19

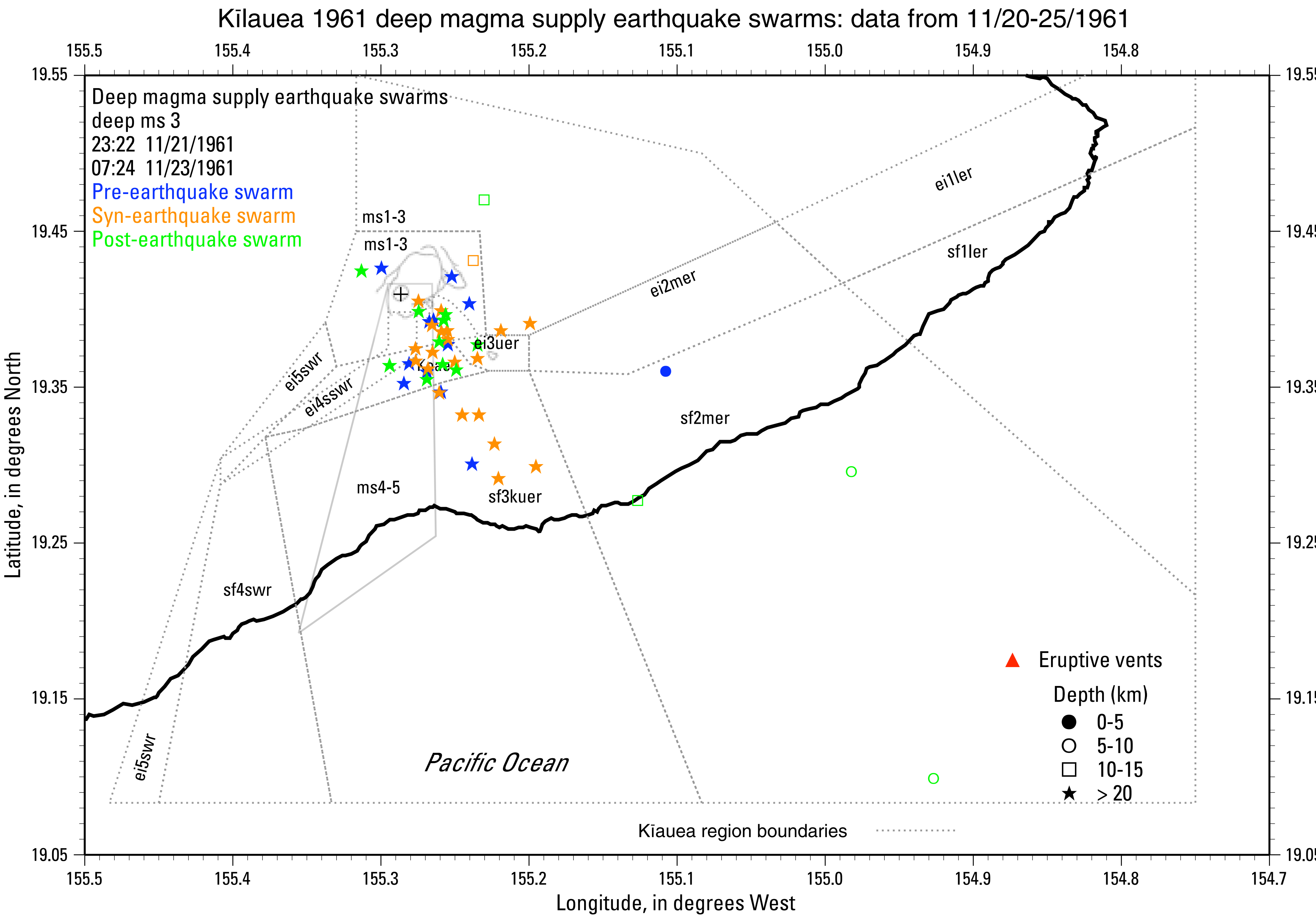
Kīlauea 1961 deep magma supply earthquake swarms: data from 6/17-7/3/1961



Appendix D Figure D20

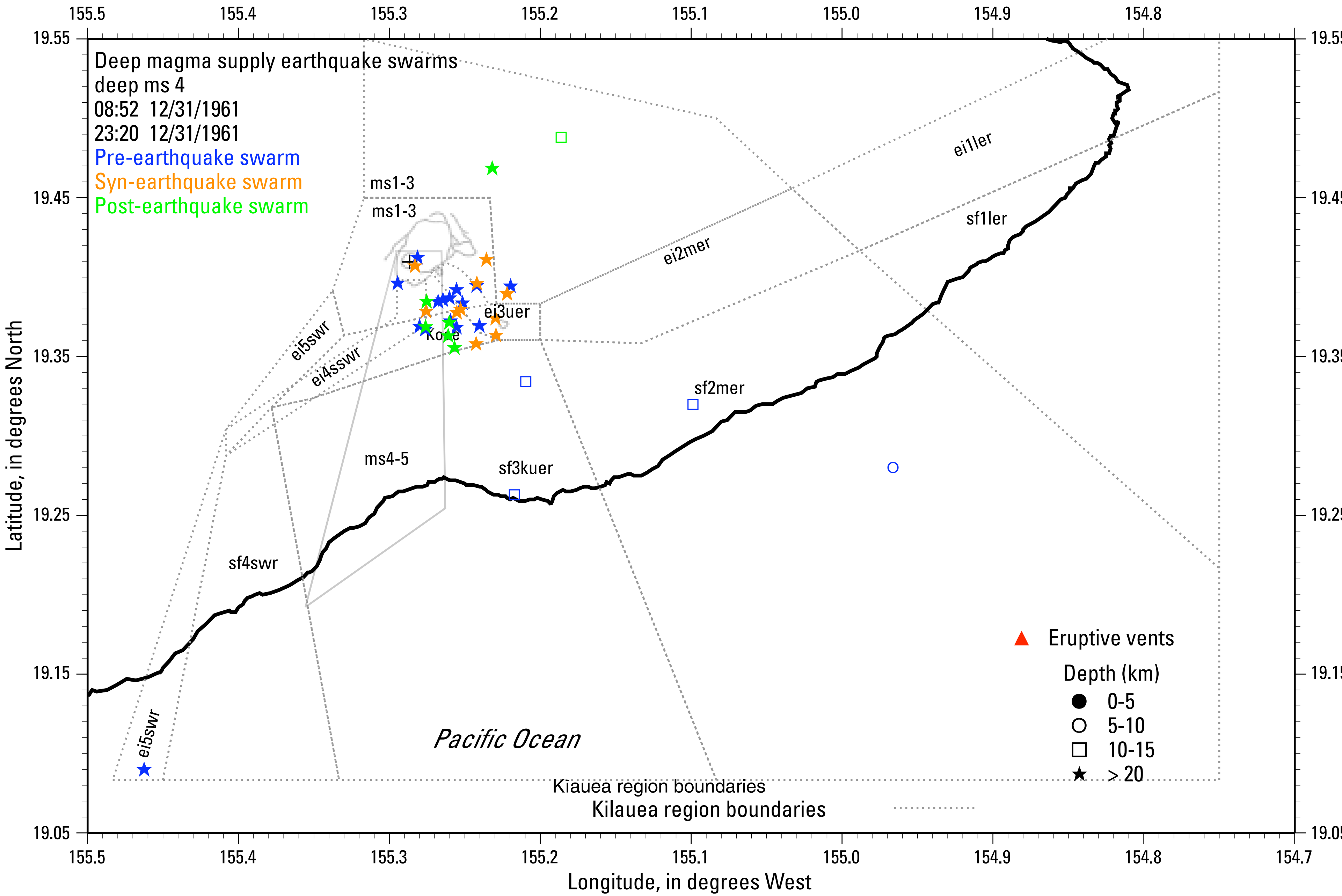


Appendix D Figure D21



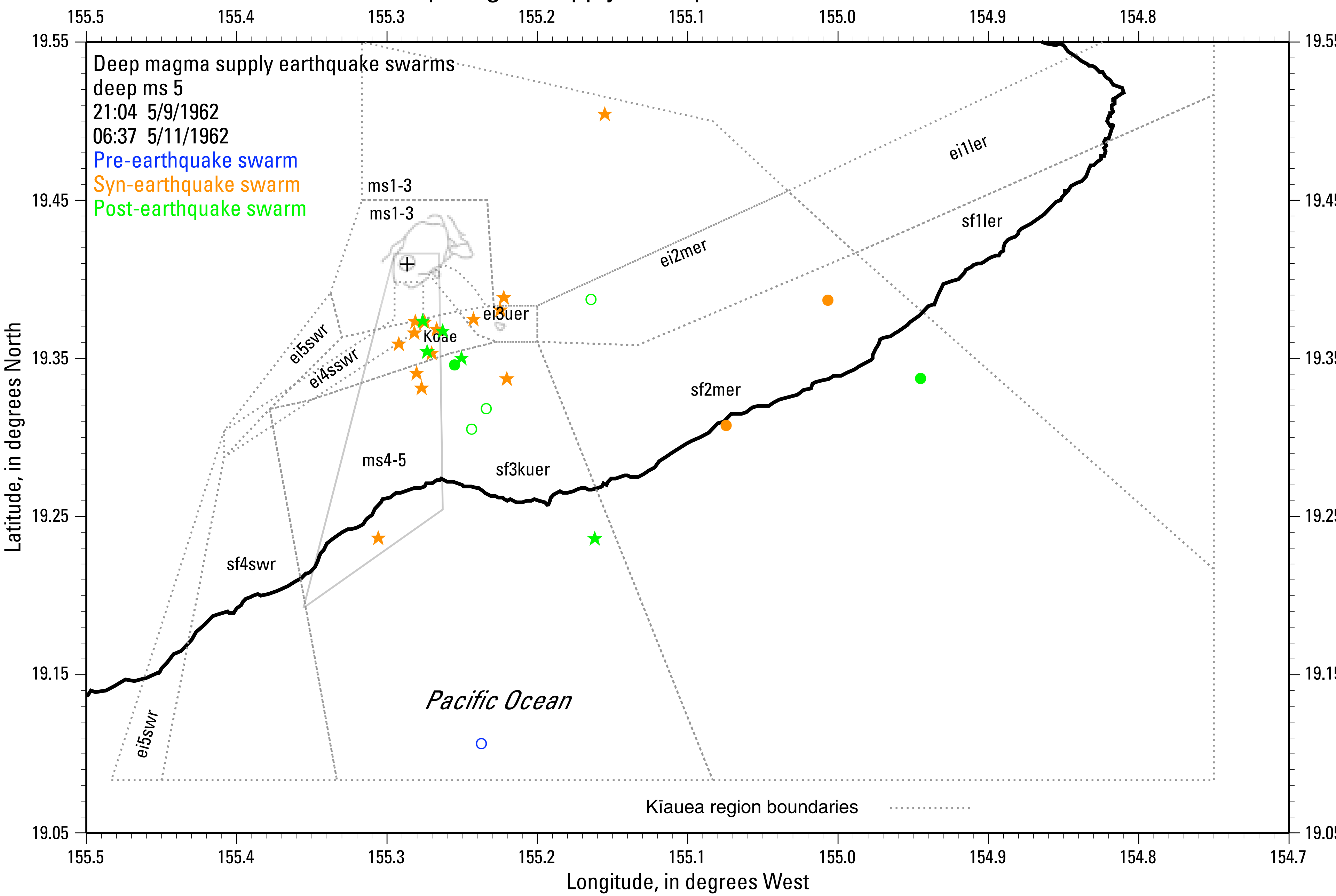
Appendix D Figure D22

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

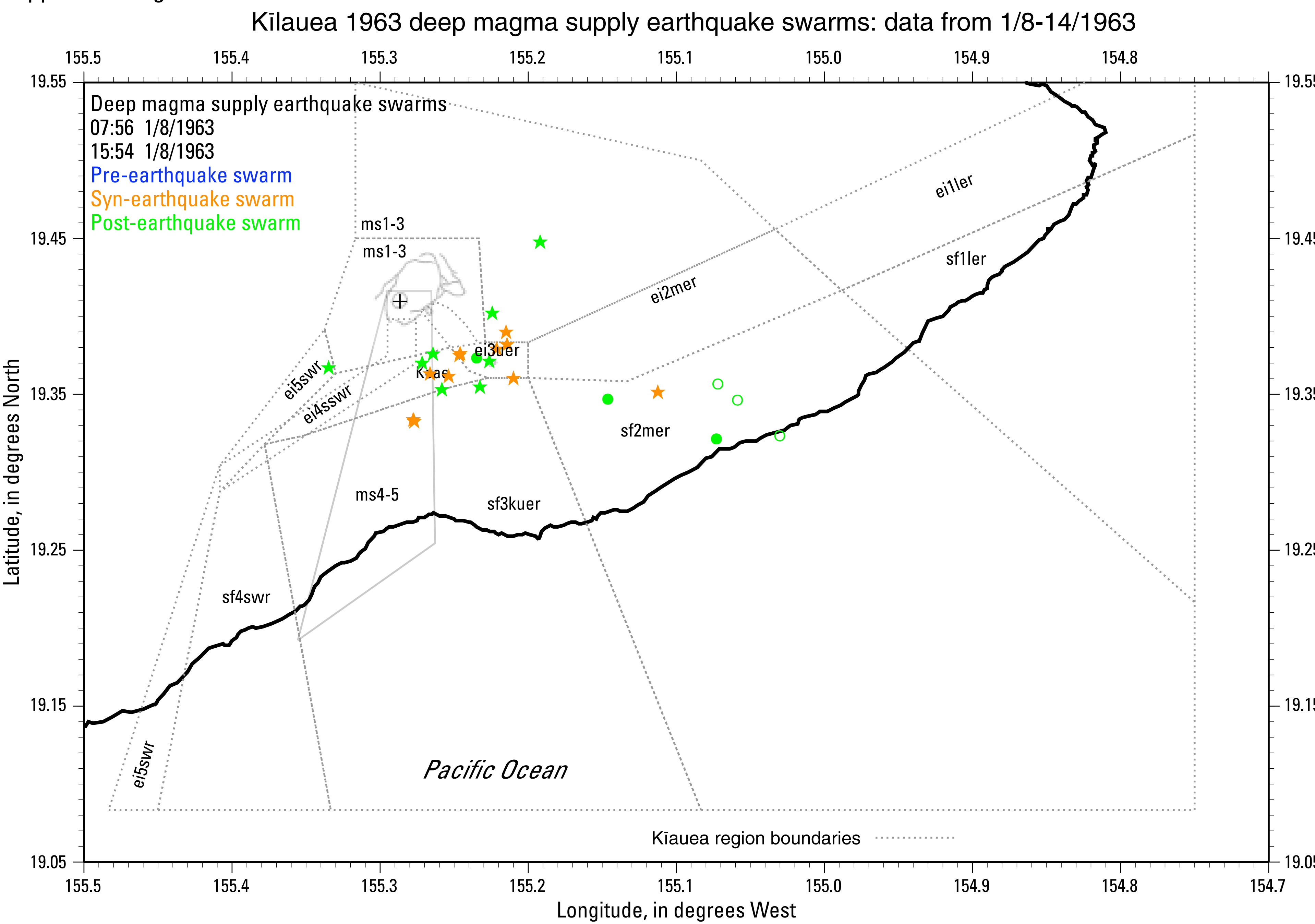


Appendix D Figure D23

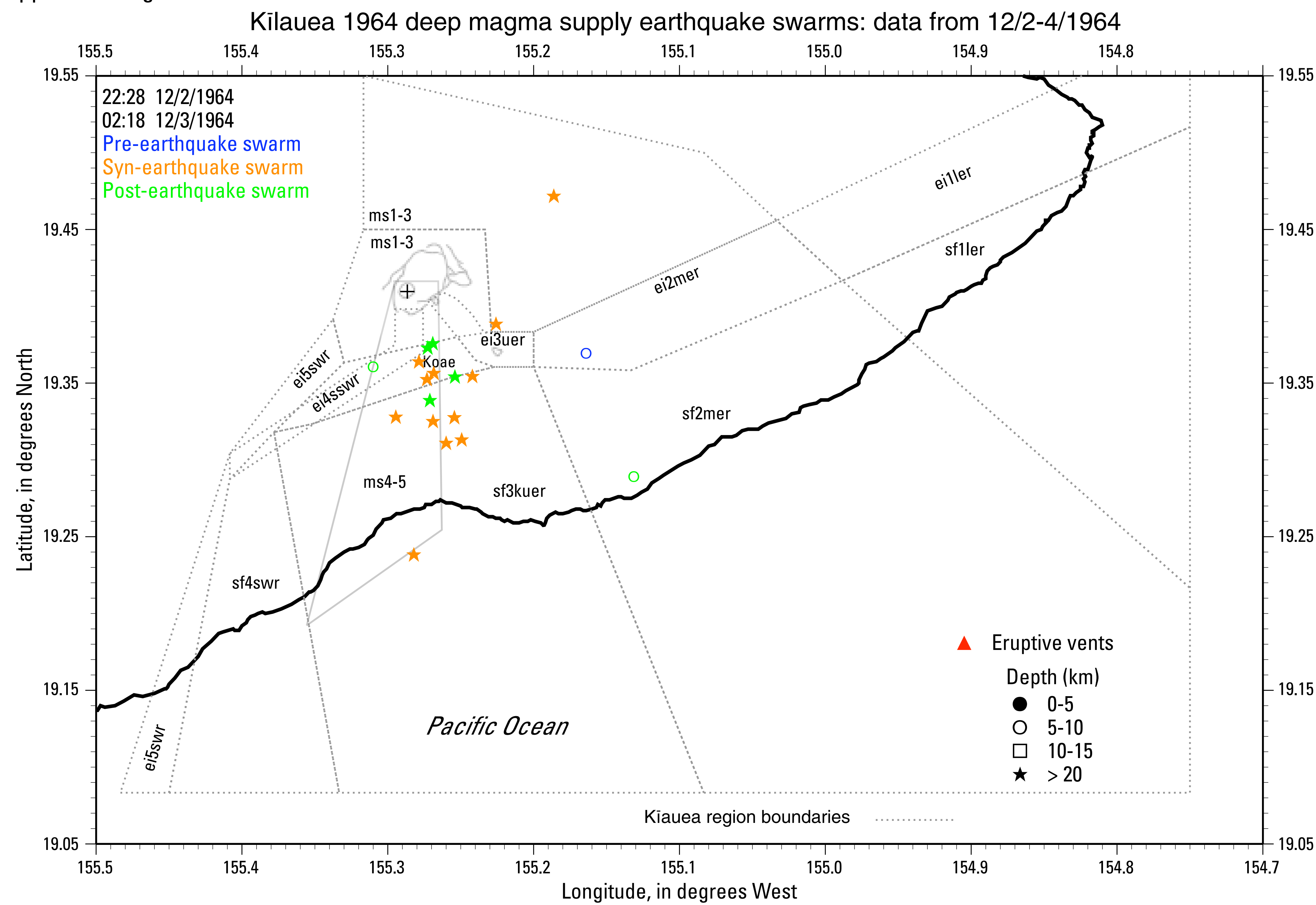
Kīlauea 1962 deep magma supply earthquake swarms: data from 5/9-14/1962



Appendix D Figure D24



Appendix D Figure D25



Appendix E. Supplementary Material to Support Chapter 5

Table E1 shows the calculation of magma supply and eruption efficiency during this period.

Figure E1*A*–*B* presents time series data covering the entire period.

Figure E2*A*–*R* presents yearly data from 1967 through 1976 in plots similar to figures 5.1 and E1.

Figures E3–E8 present time series and earthquake locations for events during the pre-Mauna Ulu period listed in table 5.1 and figure 5.1.

Figures E9–E21 present time series and earthquake locations for events during period IA of the Mauna Ulu eruption listed in table 5.3 and figure 5.4.

Figures E22–E36 present time series and earthquake locations for events during period IB of the Mauna Ulu eruption listed in table 5.4 and figure 5.5.

Figures E37–E56 present time series and earthquake locations for events during the Mauna Ulu pause listed in table 5.5 and figure 5.7.

Figures E57–E70 present time series and earthquake locations for events during period II of the Mauna Ulu eruption listed in table 5.6 and figure 5.9.

Figures E71–E87 present time series and earthquake locations for events during the period between the end of Mauna Ulu II and the 1975 earthquake listed in table 5.7 and figure 5.11.

Appendix table E1. Tilt volume, eruption efficiency and msr 1967-1975

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
1965-1967	Net	12/23/1965	11/5/1967	1.8672	123.5	327.41	**.0555**				Pre-eruption inf
	Def	12/23/1965	12/29/1965		47.4	99.37	**.0213**				
	Def	10/1/1966	10/7/1966		9.8	139.40	**.0044**				
	Def	8/9/1967	8/18/1967		8.4	120.85	**.0038**				
	Sum			**1.8672**	189.1		**.0850**			**.0455**	Pre-eruption msr
	E	11/5/1967	7/14/1968	.69268				**.07479**		**.1083**	Hm filling rate
1967-1969	Net	11/5/1967	8/21/1968	0.7967	16.3	193.90					Pre-eruption *def*
	Def	11/5/1967	11/6/1967		13.4	125.39	**.0060**				Initial def
	Def				18.7	149.49	**.0084**				
	Sum			0.7967	32.1		**.0144**			**.0181**	Pre-eruption msr
	E	8/22/1968	8/26/1968	**.0114**				**.000079**	**.0031**		
	Net	8/21/1968	10/6/1968	.12594	16.3	147.99					Pre-eruption *def*
	Def	8/21/1968	8/25/1968		56.7	113.96	.0255				
	Sum			**.12594**			**.0255**		**.2717**	**.2025**	Pre-eruption msr
	E	10/7/1968	10/12/1968	**.01374**				**.0075**			
	Net	10/6/1968	2/21/1969	.37782	7.0	218.29					Pre-eruption *def*?
	Def	10/6/1968	10/9/1968		61.5	115.24	**.0276**				
	Def	12/1/1968	12/11/1968		8.6	140.44	**.0039**				
	Def	1/7/1969	1/10/1969		8.4	112.17	**.0038**				
	Sum			**.37782**			**.0353**			**.0933**	Pre-eruption msr
	E	2/22/1969	2/28/1969	**.01565**				**.0160**	**.5498**		
	Net	2/21/1969	5/22/1969	.24641	9.6	17.35	**.0043**				Pre-eruption inf
	Def	2/21/1969	2/28/1969		48.7	124.16	**.0291**				
	Def	5/4/1959	5/9/1969		4.5	129.81	**.0020**				
	Sum			**.24641**			**.0354**			**.1437**	Pre-eruption msr
	E	5/24/1969	5/25/1969	.003907				**.00424**			
1967-MU I	Net	11/5/1967	5/22/1969	1.54415	26.1	172.41					Net *def*
	Sum			**1.54415**			**.1106**	**.0744**		**.1198**	1967-MU I msr
MU IA	Net	5/22/1969	12/29/1969	.60507	17.6	265.31	**.00794**				Pre-eruption inf
	E	5/24/1969	5/25/1969					.00424	37.86		Episode 1
	Def	5/22/1969	5/25/1959		25.0	110.54	**.01124**				
	E	5/27/1969	5/29/1969					.00329	99.54		Episode 2
	Def	5/28/1969	5/29/1969		7.4	120.58	**.00331**				
	E	6/12/1969	6/13/1969					.00376	54.49		Episode 3
	Def	6/11/1969	6/13/1969		15.4	112.35	**.00693**				
	E	6/25/1969	6/26/1969					.00424	47.11		Episode 4
	Def	6/25/1969	6/26/1969		20.0	114.72	**.00898**				
	E	7/15/1969	7/15/1969					.00376	60.65		Episode 5
	Def	7/14/1969	7/15/1969		13.9	110.70	**.00623**				
	E	8/3/1969	8/4/1969					.00329	58.75		Episode 6
	Def	8/2/1969	8/4/1969		12.4	107.59	**.00558**				
	E	8/5/1969	8/6/1969					.00376	65.97		Episode 7
	Def	8/5/1969	8/6/1969		12.6	120.07	**.00569**				
	E	8/22/1969	8/22/1969					.00329	64.51		Episode 8
	Def	8/21/1969	8/23/1969		11.3	109.36	**.00508**				
	E	9/6/1969	9/7/1969					.01129	83.63		Episode 9
	Def	9/6/1969	9/7/1969		30.0	114.35	**.01350**				
	E	10/10/1969	10/13/1969					.00376	67.14		Episode 10
	Def	10/8/1969	10/13/1969				**.00563**				
	E	10/20/1969	10/20/1969					.00988	101.90		Episode 11
	Def	10/19/1969	10/20/1969				**0.0097**				
	Sum			.60507			**.08981**			**.1484**	MU IA msr

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
MU IB	Net	12/29/1969	6/21/1971	1.4757	11.5	298.50	**.00517**				Pre-eruption inf
	E	12/30/1969	12/30/1969					.01035	100.50		Episode 12
	Def	12/29/1969	12/31/1969		25.3	113.01	**.01139**				
	Def	1/24/1970	1/26/1970		7.1	121.76	**.00320**				
	Def	4/30/1970	5/16/1970		17.9	117.80	**.00804**				
	Def	11/26/1970	11/30/1970		8.5	125.31	**.00382**				
	E	12/31/1969	6/21/1971	**1.4702**				.0792		**.0539**	Cont. eruption rate
	Sum			**1.4757**			**.03162**	.0984		**.0881**	MU 1B msr
MU pause	Net	6/21/1971	2/5/1972	0.62697	187.2	340.31	**.08417**				Pre-eruption inf
	Def	8/13/1971	8/15/1971		14.3	117.60	**.00643**				
	E	8/14/1971	8/14/1971	**.00115**				**.0080**		**6.956**	ks eruption rate
	Inf	9/24/1971	9/25/1971		101.1	353.79					Summit intrusion
	Def	9/25/1971	9/28/1971		24.2	115.35	**.0109**				
	E	9/24/1971	9/29/1971	**.01382**				**.0064**	**58.72**	**.4361**	ks/swr eruption rate
	Def	12/31/1971	1/2/1972		6.4	129.47	**.00286**				
	Sum			**.62697**			**.10436**			**.1665**	MU pause msr
MU IIA	Net	2/5/1972	5/4/1973	1.22108	19.9[vii]	141.47[vii]					Pre-eruption *def*
	E	2/5/1972	5/4/1973	**1.22108**				**0.100**		**.0819**	**E** rate
	Def	2/5/1972	2/7/1972		6.2	103.39	**.00279**				
	Def	2/26/1972	3/3/1972		9.6	107.35	**.00434**				
	Def	3/18/1972	3/22/1972		13.8	105.78	**.00619**				
	Def	3/28/1973	4/3/1973		6.4	122.28	**.00290**				
	Def	4/8/1973	4/14/1973		7.2	106.26	**.00325**				
	Sum			**1.22108**			**.01947**	**0.100**		**.0978**	MU IIA msr
MU IIB	Net	5/4/1973	6/30/1974	1.15537	28.6	274.62	**.01286**				Pre-eruption inf
Pauahi	**E**	5/5/1973	5/5/1973	.00018				**.000112**		**.6222**	5/1973 eruption rate
Mauna Ulu	**E**	5/6/1973	11/9/1973	.51198				**.002**		**.0039**	MU eruption rate
	Def	5/4/1973	5/9/1973		26.0	108.03	**.01171**				
	Def	6/8/1973	6/9/1973		7.1	101.77	**.00318**				
	Def	7/22/1973	8/3/1973		8.9	125.75	**.00399**				
	Def	8/13/1973	8/23/1973		9.0	112.48	**.00405**				
	Def	9/3/1973	9/7/1973		7.9	118.44	**.00353**				
Pauahi	**E**	11/10/1973	12/9/1973	.07828				**.00216**		**.0276**	11/1973 **E** rate
	Def	11/10/1973	11/13/1973		26.9	109.41	**.01208**				
	Def	3/17/1974	4/6/1974		17.0	113.96	**.00765**				
Mauna Ulu	**E**	12/10/1973	6/30/1974	**.55305**				**.024**		**.0434**	MU IIB **E** rate
	Sum			**1.15537**			**.05905**	**.026**		**.0736**	MU IIB msr
MU post	Net	6/30/1974	11/28/1975	1.41273	43.4	329.69	**.01951**				Pre-earthquake inf
	Def	7/19/1974	7/20/1974		16.0	106.80	**.00717**				
	E	7/19/1974	7/22/1974	.00747				.0052	72.52	**.6961**	7/1974 eruption rate
	E	9/19/1974	9/19/1974	.00156				**.00936**		**6.0**	9/1974 eruption rate
	E	12/31/1974	12/31/1974	.00204				.0047	6.53	**2.304**	12/1974 eruption rate
	Def	12/30/1974	1/4/1975		159.9	133.03	**.07192**				
	Def	1/10/1975	1/17/1975		7.9	126.03	**.00353**				
	Def	2/2/1975	2/4/1975		6.5	105.26	**.00294**				
	Sum			**1.41273**			**.1462**			**.1035**	MU post msr
1967-68Hm		11/5/1967	7/14/1968	**.6899**				**.0744**		**.1078**	1967-68 Hm E rate
		11/5/1967	8/21/1968	**.7967**			**.0144**	**.0744**		**.1115**	Pre-1968 msr
Pre-MU	Net	8/21/1968	5/22/1969	.75017	12.4	144.46					Pre-MU I *def*
	Sum			**.75017**			**.0962**			**.1282**	Pre-MU I msr
MU I	Net	5/22/1969	6/21/1971	2.0808	27.9	278.30					MU I inf
	Sum			**2.0808**			**.12882**	**.0984**		**.1092**	MU I msr
MU pause	Net	6/21/1971	2/5/1972	.62697	187.2	340.31					MU pause inf

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
	Sum			**.62697**			**.10436**			**.1665**	MU pause msr
MU II	Net	2/5/1972	6/30/1974	2.3984	33.7	268.53	**.01515**				MU II inf
	Sum			**2.3984**			**.07852**	**.126**		**.0916**	MU II msr
Post-MU	Net	6/30/1974	11/28/1975								Post MU *def*
	Sum			**1.41273**			**.1462**			**.1035**	Post-MU msr
1967-1975				**8.0657**			**.3801**	**.2817**		**.0953**	Inc. 0.1072 km^3 inf

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[i] inf=inf; def=def; trans=transfer; I=intrusion; E=eruption; ks=Kīlauea's summit; erz=East rift zone; swr=Southwest rift zone; kfz=Koae fault zone; Hm=Halema'uma'u

[ii] Tilt magnitude in microradians

[iii] Tilt volume in cubic kilometers=tilt 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/def volume associated with the eruption. A value of 1.0 corresponds to eruption of all of the magma supplied with none left underground. The intrusion fraction = 1.0- eruption efficiency. For consistency eruption efficiencies are only calculated using the Uwekahuna tilt.

[vi] Minimum msr calculated as described in text. The true msr would include the volume of rift dilation created by spreading during each period. These values are not known because of limitations imposed by the early ground deformation network. The volume equivalent for pre-eruption inf is added to the sum of volume equivalents for subsequent defs and then divided by the elapsed time. Values used in the calculation are shown in bold text. The volume equivalent of pre-eruption def (italics used for emphasis) is not used as it is already included in the def sum.

[vii] Corrected for offset caused by Honomu earthquake

Cross references, chapter 5 tables and appendix E 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 intusions (green), and suspected deep intrusions (magneta)]

Chap. 5 page	Chap. 5 table	Row in table	App. E figure
85	5.1	1	E4
do	do	11	E5
do	do	20	E6
do	do	29	E7
do	do	33	E8
91	5.3	1	E10
do	do	3	E11
do	do	7	E12
do	do	15	E13
do	do	16	E14
92	5.3 cont	1,3	E15
do	do	10, 11	E16
do	do	16	E17
93	5.3 cont	1	E18
do	do	5	E19
do	do	6	E20
do	do	8	E21
95	5.4	1	E23
do	do	2	E24
do	do	3	E25
do	do	7	E26
do	do	10	E27
do	do	11	E28
do	do	21	E29

Chap. 5 page	Chap. 5 table	Row in table	App. E figure
do	do	22	E30
do	do	23	E31
96	5.4 cont	1	E32
do	do	2	E33A
do	do	3	E33B
do	do	4	E33C
do	do	5	E33D
do	do	6	E33E
do	do	8	E34
do	do	9	E35
do	do	10	E36
100	5.5	2	E38
do	do	3	E39
do	do	4	E40
do	do	5	E41
do	do	9	E42
do	do	10-15	E43
do	do	16	E44
do	do	19	E45
do	do	21	E46
do	do	23	E47
do	do	24	E48A-E
do	do	28	E48F
do	do	29	E49A
do	do	31	E49B
do	do	33	E49C
do	do	36	E50
101	5.5 cont	1	E51
do	do	4	E52

Chap. 5 page	Chap. 5 table	Row in table	App. E figure
do	do	5	E53A-E
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do	do	15	E55
do	do	18	E56A
do	do	22	E56B
102	5.6	1	E58
do	do	4	E59
do	do	5	E60
do	do	7	E61
do	do	8	E62
do	do	18	E63
do	do	20	E64
do	do	22	E65
do	do	24	E66
do	do	26	E67
do	do	27	E68
103	5.6 cont	2	E69
do	do	5	E70A
do	do	8	E70B
do	do	10	E70C
108	5.7	3	E72
do	do	4	E73
do	do	11	E74
do	do	12	E75
do	do	15	E76
do	do	17,18	E77
do	do	19	E78
do	do	21	E79

Chap. 5 page	Chap. 5 table	Row in table	App. E figure
do	do	24	E80A-F
109	5.7 cont	1	E81
do	do	5	E82
do	do	6,7	E83
do	do	8	E84
do	do	9	E85
do	do	10	E86
do	do	11	E87

Figure E1. Time series of Kīlauea earthquakes for the entire period 1967-1976. *A*, Earthquakes/day (eq/day) and earthquakes *M*>4. *B*, Earthquake swarms for all regions.

Figure E2. 1967-1976: Time series plots at 1-year intervals for 1967–1976. *A–I*, Uwēkahuna tilt, times of eruption and intrusion, earthquake counts, and earthquakes of *M*>4. *J–R*, Uwēkahuna tilt, times of eruption and intrusion, and earthquake swarms.

Figure E3. Earthquake swarms for the period 1 January 1967 to 1 April 1969 (pre-Mauna Ulu) for all regions. See caption for figure D1.

Figure E4. Map showing earthquake locations for the period 5 November 1967 to 13 July 1968, covering the entire 1967–68 Halema‘uma‘u eruption, on a background of labeled seismic regions (see fig. A4). Suspected deep intrusions are outlined in black. Data are shown for periods before (blue), during (orange), and after (green) the event, and eruptive vents are plotted as red triangles. Dates on figure in mm/dd/yyyy format.

Figure E5. Map showing activity around eruption of 22–26 August 1968. Exceptionally sparse shallow seismicity extends into the Koaʻe Fault Zone. South flank seismicity is distributed parallel to the rift zone with a preeruption concentration suggesting a possible suspected deep intrusion beneath the eastern south flank (sf2mer). Eruption is followed by several earthquakes along the deep magma-supply path. Dates on figure in mm/dd/yyyy format.

Figure E6. Map showing activity around suspected deep intrusion of 16-17 December 1968. A heavy concentration of south flank earthquakes beneath site SDI 2 extends back to the pre-swarm period. Dates on figure in mm/dd/yyyy format.

Figure E7. Map showing activity around ruption of 22–28 February 1969. Shallow seismicity beneath Kīlauea's summit accompanies the eruption. Note the high concentration of precursory south flank earthquakes. Dates on figure in mm/dd/yyyy format.

Figure E8. Map showing activity around traditional intrusion of 21March 1969. Dates on figure in mm/dd/yyyy format.

Figure E9. Earthquake swarms for all regions during the period 1 April 1969 to 1 January 1970 (Mauna Ulu period IA). High-fountaining episodes 1–12 are labeled on the top panel. Dates on figure in mm/dd/yyyy format.

Figure E10. Map showing activity around summit intrusion of 30 April 1969. The intrusion beneath Kīlauea's summit, defined by a small swarm of shallow earthquakes and inflationary tilt (table 5.3) was preceded on the same day by south flank earthquakes suggestive of a deep intrusion. Dates on figure in mm/dd/yyyy format.

Figure E11. Map showing activity around inflationary intrusion of 4–6 May 1969. Dates on figure in mm/dd/yyyy format.

Figure E12. Map showing acitivity around inflationary intrusion of 21–22 May 1969. Note the abundance of precursory earthquakes beneath the south flank. These continue without interruption beyond the end of episode 1 (24–25 May 1969). Dates on figure in mm/dd/yyyy format.

Figure E13. Map showing acitivity around Mauna Ulu episodes 1 (24–25 May 1969) and 2 (27–29 May 1969). South flank earthquakes continue east of the Mauna Ulu vent with little rift seismicity, suggesting the possibility of deeper aseismic intrusion farther downrift. Dates on figure in mm/dd/yyyy format.

Figure E14. Map showing activity around suspected deep intrusion 3–9 June 1969. This is interpreted as an increase in spreading rate associated with increase in magma supply rate. Dates on figure in mm/dd/yyyy format.

Figure E15. Map showing activity around traditional intrusion of 3 July 1969. The intrusion is unaccompanied by summit deflation and perhaps was fed from previously intruded magma stored within the rift zone. Dates on figure in mm/dd/yyyy format.

Figure E16. Map showing activity around episodes 6 (3–4 August) and 7 (5–6 August) of Mauna Ulu phase IA. Most of the episodes following episode 1 are accompanied by very little if any seismicity beneath the rift zone. These episodes are an exception, but rift seismicity is still sparse. Dates on figure in mm/dd/yyyy format.

Figure E17. Maps showing activity around suspected deep intrusions preceding episode 10 (stage I of the Mauna Ulu eruption). Dates on figure in mm/dd/yyyy format. *A*, 29 September to 4 October 1969: Four suspected deep intrusions are concentrated south of the Koaʻe Fault Zone and upper east rift (site SDI 2 of fig. 5.2). *B*, 7–11 October 1970: A suspected deep intrusion is located south of the sesimic southwest rift zone (site SDI 1 of fig. 5.2)

Figure E18. Map showing activity around traditional intrusion of 2–4 November 1969. Dates on figure in mm/dd/yyyy format.

Figure E19. Map showing activity around inflationary intrusion of 11–12 December 1969. This and figures E20 and E21 show the location of earthquakes that heralded the end of high fountaining at Mauna Ulu on 30 December 1969. Rift seismicity is dominantly beneath the seismic southwest rift zone. Dates on figure in mm/dd/yyyy format.

Figure E20. Map showing activity around inflationary intrusion of 23 December 1969. This and figures E19 and E21 show the location of earthquakes that heralded the end of high fountaining at Mauna Ulu on 30 December 1969. Rift seismicity is dominantly beneath the seismic southwest rift zone. Dates on figure in mm/dd/yyyy format.

Figure E21. Map showing activity around suspected deep intrusion (site SDI 2) of 27–29 December 1969 associated with simultaneous inflationary intrusion beneath the upper east rift zone and upper seismic southwest rift zone. The latter intrusions anticipate the paired inflationary intrusions of Mauna Ulu stage IB. This and figures E19 and E21 show the location of earthquakes that heralded the end of high fountaining at Mauna Ulu on 30 December 1969. Rift seismicity is dominantly beneath the seismic southwest rift zone. Dates on figure in mm/dd/yyyy format.

Figure E22. Kīlauea activity, 1 January 1970 to 15 June 1971 (Mauna Ulu eruption stage IB). Earthquake swarms are shown for all regions. See also caption for figure E1. Dates on figure in mm/dd/yyyy format.

Figure E23. Map showing activity around suspected deep intrusions of 15 January 1970. Two suspected deep intrusions are defined by broken earthquake sequences of 3–7 events. The more westerly sequence occurs before 12 January, overlapping in time with the more easterly sequence. Dates on figure in mm/dd/yyyy format.

Figure E24. Map showing activity around summit intrusion of 22 January 1970, which was preceded by a concentration of deep magma supply earthquakes. Dates on figure in mm/dd/yyyy format.

Figure E25. Map showing continuation of the inflationary intrusion through 11 February 1970. Deflationary tilt and earthquake locations indicate dominant magma transfer to east rift zone. Dates on figure in mm/dd/yyyy format.

Figure E26. Map showing activity around paired inflationary intrusion of 17–23 March 1970. Dates on figure in mm/dd/yyyy format.

Figure E27. Map showing activity around paired inflationary intrusion of 4–7 April 1970, preceding a traditional intrusion on 7–8 April1970. Dates on figure in mm/dd/yyyy format.

Figure E28. Map showing activity around a traditional intrusion beneath the east rift zone, 15–18 May 1970. This is an exceptionally energetic event and appears to be accompanied and followed by suspected deep intrusion at site DSDI 2. The intrusion triggered six deep tectonic earthquakes beneath the eastern south flank. Dates on figure in mm/dd/yyyy format.

Figure E29. Map showing activity around south flank earthquake swarm of 15–16 July 1970. Dates on figure in mm/dd/yyyy format.

Figure E30. Map showing activity around south flank earthquake (M4.46) at 01:27 on 21 September 1970, which was preceded by two foreshocks and many aftershocks. The main part of the aftershock sequence resembles a suspected deep intrusion. Dates on figure in mm/dd/yyyy format.

Figure E31. Map showing activity around summit intrusion of 26–27 October 1970. Dates on figure in mm/dd/yyyy format.

Figure E32. Map showing activity around summit intrusion of 12–14 December 1970, possibly preceded and accompanied by a suspected deep intrusion. Dates on figure in mm/dd/yyyy format.

Figure E33. Maps showing activity around a series of inflationary intrusions between 22 December 1970 and 5 January 1971. Small suspected deep intrusions occur before, between and after the intrusions, along with a normal south flank response to rift intrusion. Dates on figure in mm/dd/yyyy format. *A*, 21–23 December 1970. The initial intrusion is beneath Kīlauea’s summit. *B*, 25–26 December 1970. The second and third intrusions extend from the uppermost seismic southwest rift zone westward into the traditional southwest rift zone. *C*, 28–29 December 1970. The second and third intrusions extend from the uppermost seismic southwest rift zone westward into the traditional southwest rift zone. *D*, 29 December 1970 to 1 January 1971. The fourth and fifth intrusions are concentrated beneath the summit and uppermost seismic southwest rift zone. *E*, 3–6 January 1971. The fourth and fifth intrusions are concentrated beneath the summit and uppermost seismic southwest rift zone.

Figure E34. Map showing activity around inflationary intrusion of 1–2 June 1971. Dates on figure in mm/dd/yyyy format.

Figure E35. Map showing activity around inflationary intrusion of 8–10 June 1971. Dates on figure in mm/dd/yyyy format.

Figure E36. Map showing activity around inflationary intrusion of 11–14 June 1971. Dates on figure in mm/dd/yyyy format.

Figure E37. Kīlauea activity, 16 June 1971 to 4 February 1972 (Mauna Ulu pause). Earthquake swarms are shown for all regions. Dates on figure in mm/dd/yyyy format. See also caption for figure E1.

Figure E38. Map showing activity around inflationary intrusion of 12–14 July 1971 beneath upper seismic southwest rift zone, preceded by suspected deep intrusion on 9 July. Dates on figure in mm/dd/yyyy format.

Figure E39. Map showing activity around inflationary intrusion of 18–19 July 1971 beneath upper seismic southwest rift zone. Dates on figure in mm/dd/yyyy format.

Figure E40. Map showing activity around inflationary intrusion of 21–24 July 1971 beneath upper east rift zone. Dates on figure in mm/dd/yyyy format.

Figure E41. Map showing activity around inflationary intrusion of 27–30 July 1971 beneath both rift zones. Dates on figure in mm/dd/yyyy format.

Figure E42. Map showing activity around inflationary intrusion of 5–6 August 1971 beneath both rift zones. Dates on figure in mm/dd/yyyy format.

Figure E43. Maps showing locations of earthquakes associated with the intrusion that heralded the summit eruption of 14 August 1971. Dates on figure in mm/dd/yyyy format. *A*, Precursory seismicity, 8 August. Earthquakes beneath upper seismic southwest rift zone. *B*, Precursory seismicity, 9 August. Earthquakes beneath upper seismic southwest rift zone. *C*, Precursory seismicity, 10 August. Earthquakes beneath upper seismic southwest rift zone. *D*, Precursory seismicity, 11 August. Earthquakes beneath both rift zones, with increasing seismicity beneath east rift zone. *E*, Precursory seismicity, 12 August. Earthquakes beneath both rift zones, with increasing seismicity beneath east rift zone *F*, Precursory seismicity, 13 August.

Figure E44. Map showing acitivity around summit eruption of 14 August 1971, including precursory seismicity on that date ending at the time of eruption. Dates on figure in mm/dd/yyyy format.

Figure E45. Map showing activity around inflationary intrusions between eruptions—27–29 August 1971. Dates on figure in mm/dd/yyyy format.

Figure E46. Map showing activity around inflationary intrusions between eruptions, 6–8 September 1971. Dates on figure in mm/dd/yyyy format.

Figure E47. Map showing activity around inflationary intrusions between eruptions, 12–14 September 1971. Dates on figure in mm/dd/yyyy format.

Figure E48. Maps showing locations of earthquakes associated with the intrusion that heralded the summit eruption of 19 September. Dates on figure in mm/dd/yyyy format. *A*, Activity of 17 September. *B*, Activity of 18 September. *C*, Activity of 19 September. *D*, Activity of 20 September. *E*, Activity of 21 September. *F*, Activity of 22 September, including deep magma-supply swarm.

Figure E49. Maps showing locations of earthquakes associated with the southwest rift eruption of 24 September 1971. Dates on figure in mm/dd/yyyy format. *A*, Preeruption seismicity on 23–24 September. *B*, Posteruption seismicity on 24–25 September. Seismicity masked by tremor and not recorded during this short eruption. *C*, Posteruption seismicity on 26 September to 1 October.

Figure E50. Map showing activity around suspected deep intrusion of 8–9 Octobe 1971. Dates on figure in mm/dd/yyyy format.

Figure E51. Map showing activity around suspected deep intrusion of 14–16 November 1971 at site SDI 1. Dates on figure in mm/dd/yyyy format.

Figure E52. Map showing activity around inflationary intrusion of 12–13 December 1971. Dates on figure in mm/dd/yyyy format.

Figure E53. Maps showing seismicity associated with the suspected deep intrusions of 22-30 December 1971. Dates on figure in mm/dd/yyyy format. *A*, 12/22. Earthquake swarm on 22 December beneath central south flank (suspected deep intrusion?) at site SDI 2. *B*, Activity on 23 December; suspected deep intrusions at sites SDI 1 and SDI 2. *C*, Activity on 24–25 December; continuation of suspected deep intrusion at site SDI 1. *D*, Activity on 26-28 December; continuation of suspected deep intrusion at site SDI 1. *E*, Activity 29–31 December; continuation of suspected deep intrusion followed by intrusion into upper east rift zone and possible new suspected deep intrusion near site SDI 2.

Figure E54. Map showing activity on 1-4 January 1972. Suspected deep intrusion shown by earthquake swarms associated with the return of eruption at Mauna Ulu on 4 February 1972. Dates on figure in mm/dd/yyyy format.

Figure E55. Map showing activity on 10-12 January 1972. Traditional intrusion beneath upper east rift zone with south flank response before and after. Earthquake swarms associated with the return of eruption at Mauna Ulu on 4 February 1972. Dates on figure in mm/dd/yyyy format.

Figure E56. Maps showing activity around the two last intrusions before the return of lava to Mauna Ulu. Dates on figure in mm/dd/yyyy format. *A*, Activity onb 18–25 January 1972. Inflationary intrusion beneath uppermost east rift zone on 20–22 January. *B*, Activity on 26 January-1 February. Inflationary intrusion beneath uppermost east rift zone on 26–28 January.

Figure E57. Kīlauea activity, 4 February 1972–14 June 1974 (Mauna Ulu stage II). Earthquake swarms are shown for all regions. Dates on figure in mm/dd/yyyy format.

Figure E58. Map showing seismic activity, 26 January-1 Feburary 1972, precursory to Mauna Ulu stage II. Dates on figure in mm/dd/yyyy format.

Figure E59. Map showing activity around traditional intrusion of 18 March 1972, followed by an extended south flank response. Dates on figure in mm/dd/yyyy format.

Figure E60. Map showing activity around suspected deep intrusion of 1–2 May 1972 near site SDI 2. Dates on figure in mm/dd/yyyy format.

Figure E61. Map showing activity around suspected deep intrusion(?) of 7–8 March 1973. Dates on figure in mm/dd/yyyy format.

Figure E62. Map showing south flank earthquake on 15 April 1973. The aftershock pattern mimics that of a slow earthquake. Dates on figure in mm/dd/yyyy format.

Figure E63. Map showing activity around traditional intrusion of 8–10 June 1973 into the east rift zone and adjacent Koaʻe Fault Zone. Dates on figure in mm/dd/yyyy format.

Figure E64. Map showing activity around traditional intrusion of 25 July 1973—a small intrusion followed by a large south flank response. Dates on figure in mm/dd/yyyy format.

Figure E65. Map showing activity around 10–11 November 1973 east rift eruption in and near Pauahi Crater. Eruption continues at low level until 9 December 9. Some south flank earthquakes accompanying the extended eruption mimic a slow earthquake pattern, but are not concentrated in time. Dates on figure in mm/dd/yyyy format.

Figure E66. Map showing activity around suspected deep intrusion of 25–26 December 1973. Dates on figure in mm/dd/yyyy format.

Figure E67. Map showing activity around inflationary intrusion of 23 February to 4 March 1973. The intrusion continues for an unusually long time. Dates on figure in mm/dd/yyyy format.

Figure E68. Map showing activity around inflationary intrusion of 10–19 March 1973. Dates on figure in mm/dd/yyyy format.

Figure E69. Map showing locations of earthquakes associated with a traditional intrusion on 24 March 1974. Intrusion is followed by a suspected deep intrusion near site SDI 2 and by a cluster of deep magma-supply earthquakes. Dates on figure in mm/dd/yyyy format.

Figure E70. Maps showing increased seismicity associated with the end of eruption at Mauna Ulu in June 1974. Dates on figure in mm/dd/yyyy format. *A*, Summit intrusion of 22 May 1974. Preintrusion seismicity includes a possible suspected deep intrusion near site SDI 2 and a cluster of three deep magma-supply earthquakes. *B*, Suspected deep intrusion on 24–25 May near sites SDI 1 and 2. *C*, East rift intrusion of 28–30 May.

Figure E71. Kīlauea activity, 15 June 1974–29 November 1975 (Post Mauna Ulu). Earthquake swarms are shown for all regions.

Figure E72. Map showing activity around suspected deep intrusion of 21–22 June 1974. Dates on figure in mm/dd/yyyy format.

Figure E73. Map showing activity around summit intrusion of 27 June 1974. Dates on figure in mm/dd/yyyy format.

Figure E74. Map showing activity around eruption of 19 September 1974. The eruption is apparently aseismic, preceded by intrusion into upper seismic southwest rift zone and followed by south flank seismicity. Dates on figure in mm/dd/yyyy format.

Figure E75. Map showing activity around inflationary intrusion of 6–15 October 1974, a composite of small swarms of earthquakes beneath the east rift zone and south flank. Dates on figure in mm/dd/yyyy format.

Figure E76. Map showing activity around inflationary intrusions of 31 October-2 November and 5–6 November 1974. The first intrusion is confined to the upper seismic southwest rift zone, whereas the second is a paired seismic southwest rift and east rift intrusion. Dates on figure in mm/dd/yyyy format.

Figure E77. Map showing activity around inflationary intrusions of 21–25 November and 1–5 December 1974. Both intrusions are focused beneath the upper seismic southwest rift zone, with the second intrusion showing additional activity beneath Kīlauea's summit. Dates on figure in mm/dd/yyyy format.

Figure E78. Map showing activity around inflationary intrusion of 6–14 December 1974. Locus of this intrusion shifts to the upper east rift zone, and it is followed by a cluster of deep magma-supply earthquakes. Dates on figure in mm/dd/yyyy format.

Figure E79. Map showing activity around inflationary intrusion of 17–21 December 1974. A paired intrusion beneath the upper parts of both rift zones. Dates on figure in mm/dd/yyyy format.

Figure E80. Following the 31 December 1974 southwest rift eruption, intense intrusion continued beneath the lower seismic southwest rift zone, and south flank seismicity resumes beneath the upper east rift zone and Koaʻe. Dates on figures in mm/dd/yyyy format. *A*, Activity on 1 January 1975. *B*, Activity on 2 January 1975. *C*, Activity on 3 January 1975. *D*, Activity on 4 January 1975. *E*, Activity on 5 January 1975. Seismicity begins to diminish beneath the lower southwest rift zone and western south flank. *F*, Activity on 6–8 January 1975.

Figure E81. Map showing activity around suspected deep intrusions of 15–16 and 18–20 March 1975. Clusters of south flank earthquakes at sites SDI 1, 2, and in between 1 and 2 are followed by a cluster of deep magma-supply earthquakes. Dates on figure in mm/dd/yyyy format.

Figure E82. Map showing activity around suspected deep intrusion of 24–26 March 1975. A continuation of seismic patterns shown in the preceding figure. Dates on figure in mm/dd/yyyy format.

Figure E83. Map showing activity around suspected deep intrusions of 2–3 and 5 April 1975. An intensification of the activity shown in March. Dates on figure in mm/dd/yyyy format.

Figure E84. Map showing activity around suspected deep intrusion of 16–18 April 1975 at site SDI 2. Dates on figure in mm/dd/yyyy format.

Figure E85. Map showing activity around suspected deep intrusion of 5 August 1975 at site SDI 1. Dates on figure in mm/dd/yyyy format.

Figure E86. Map showing activity around suspected deep intrusion of 23 October 23 at site SDI 2. Dates on figure in mm/dd/yyyy format.

Figure E87. Map showing activity around inflationary intrusion of 12-14 November 1975. Dates on figure in mm/dd/yyyy format.

Figure E1 a. 1/1/1967-12/1/1975 short-period located earthquakes, single eq (M ≥ 4.0) and tilt

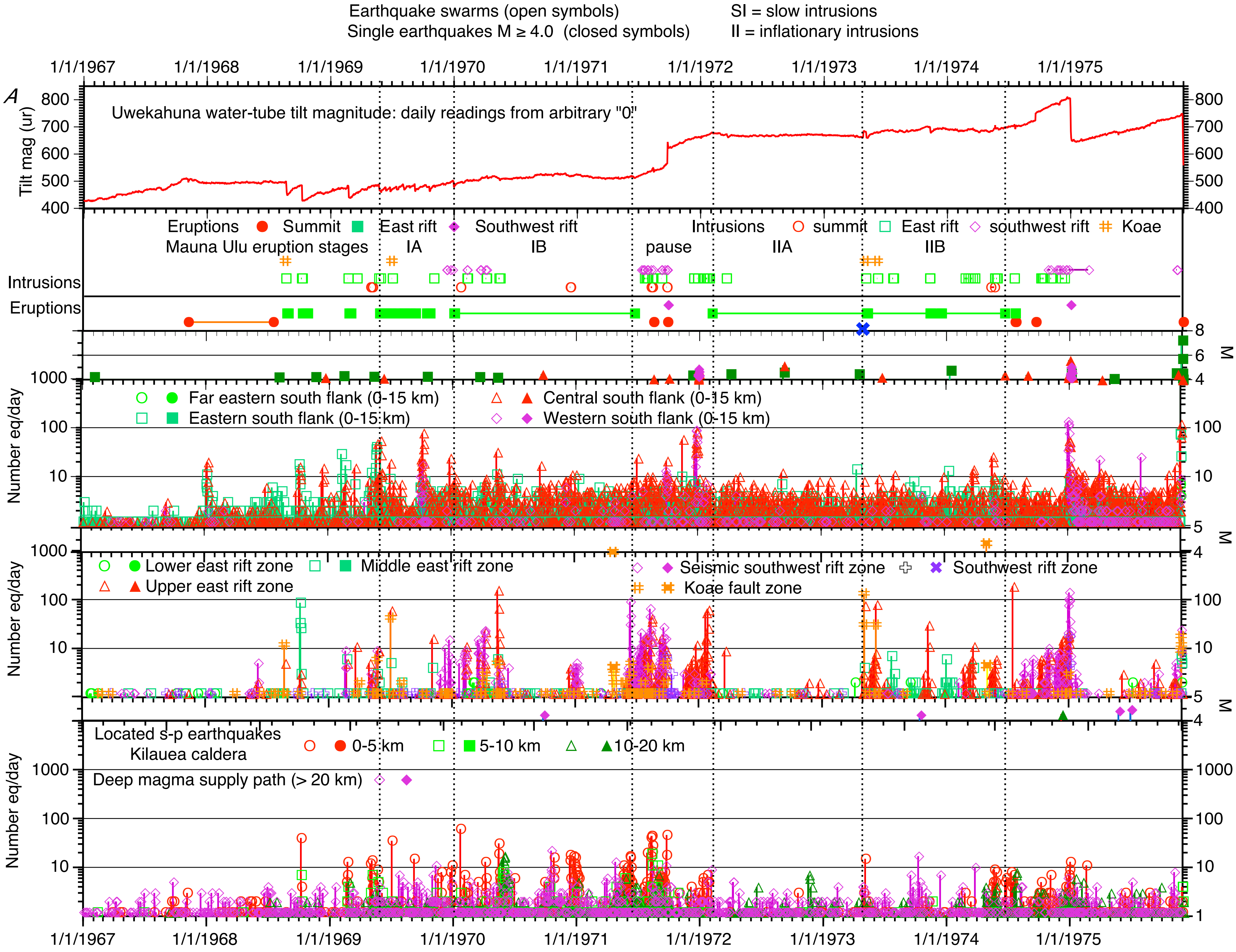
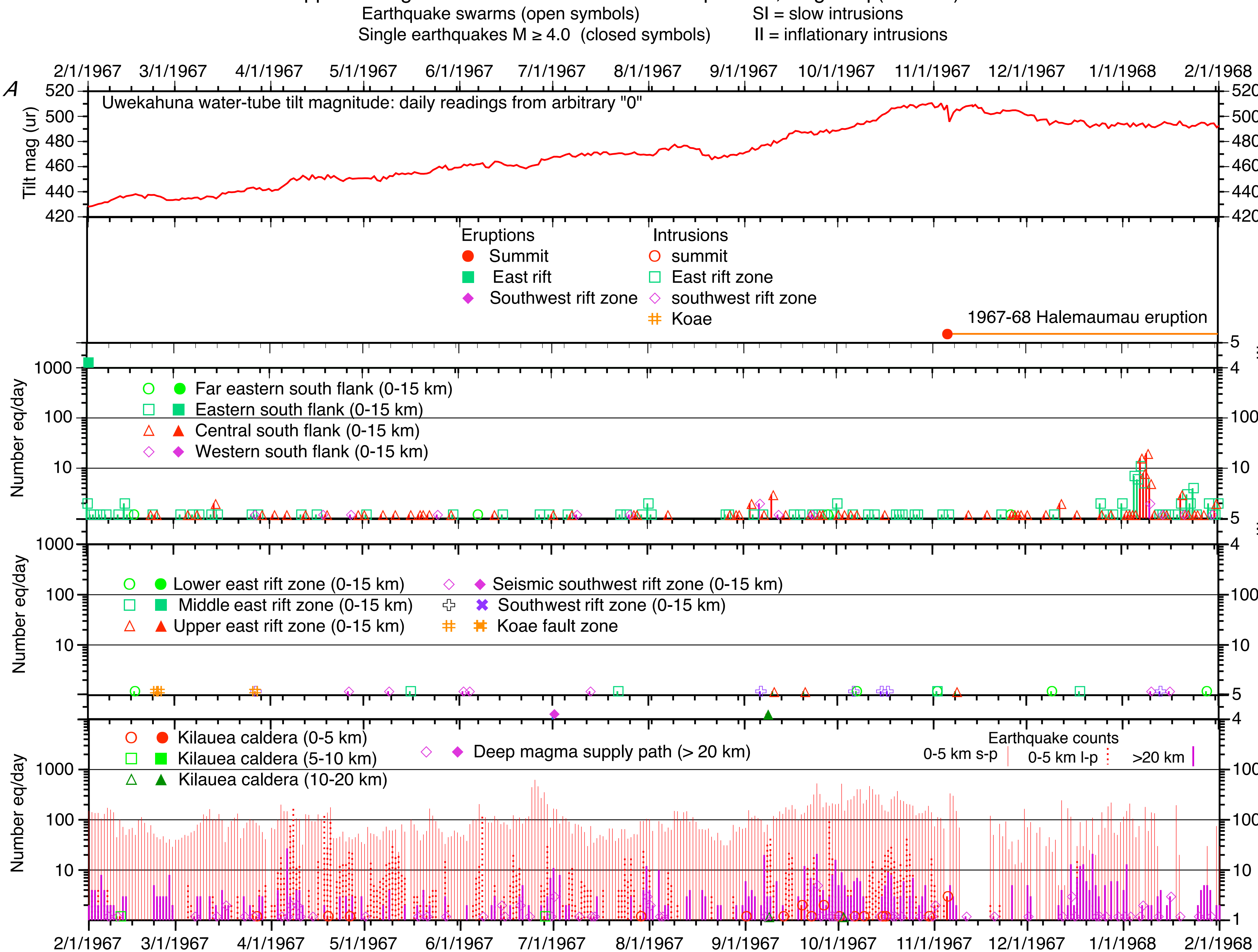


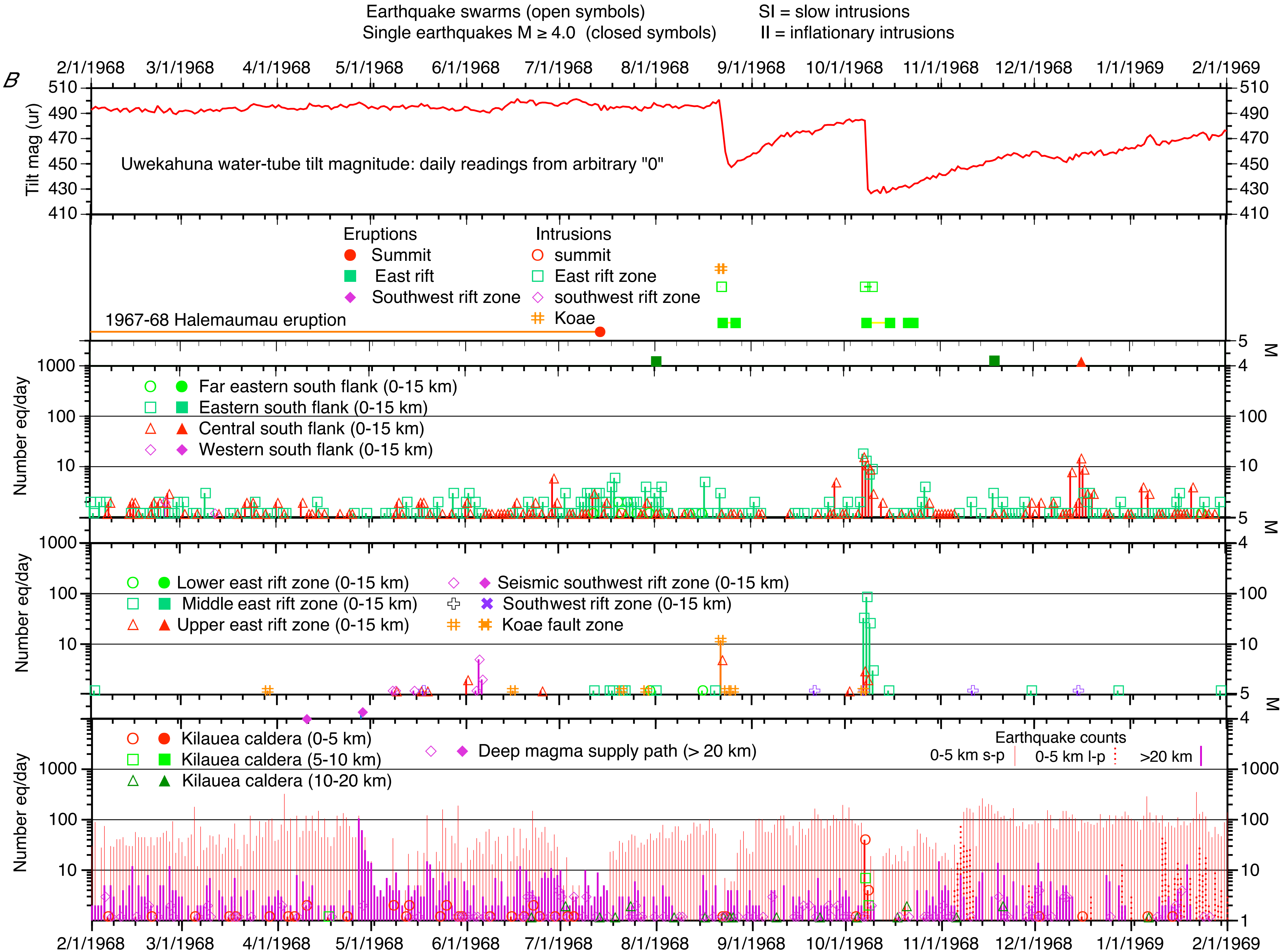
Figure E1b

Mauna Ulu: 1967-68 eruption through 1975 earthquake

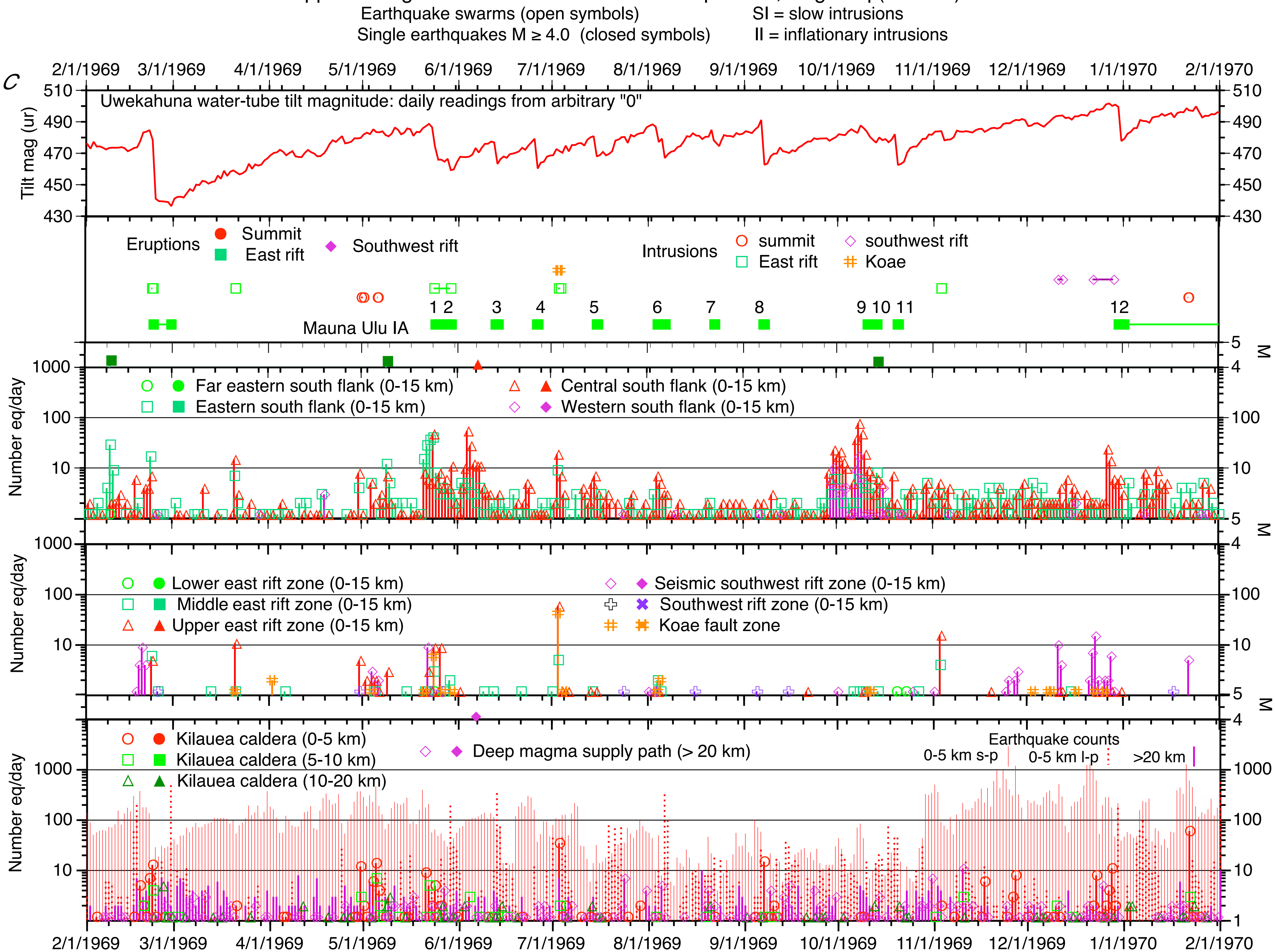
Appendix Figure E2 a. 2/1/1967-2/1/1968 eq counts, single eq (M ≥ 4.0) and tilt



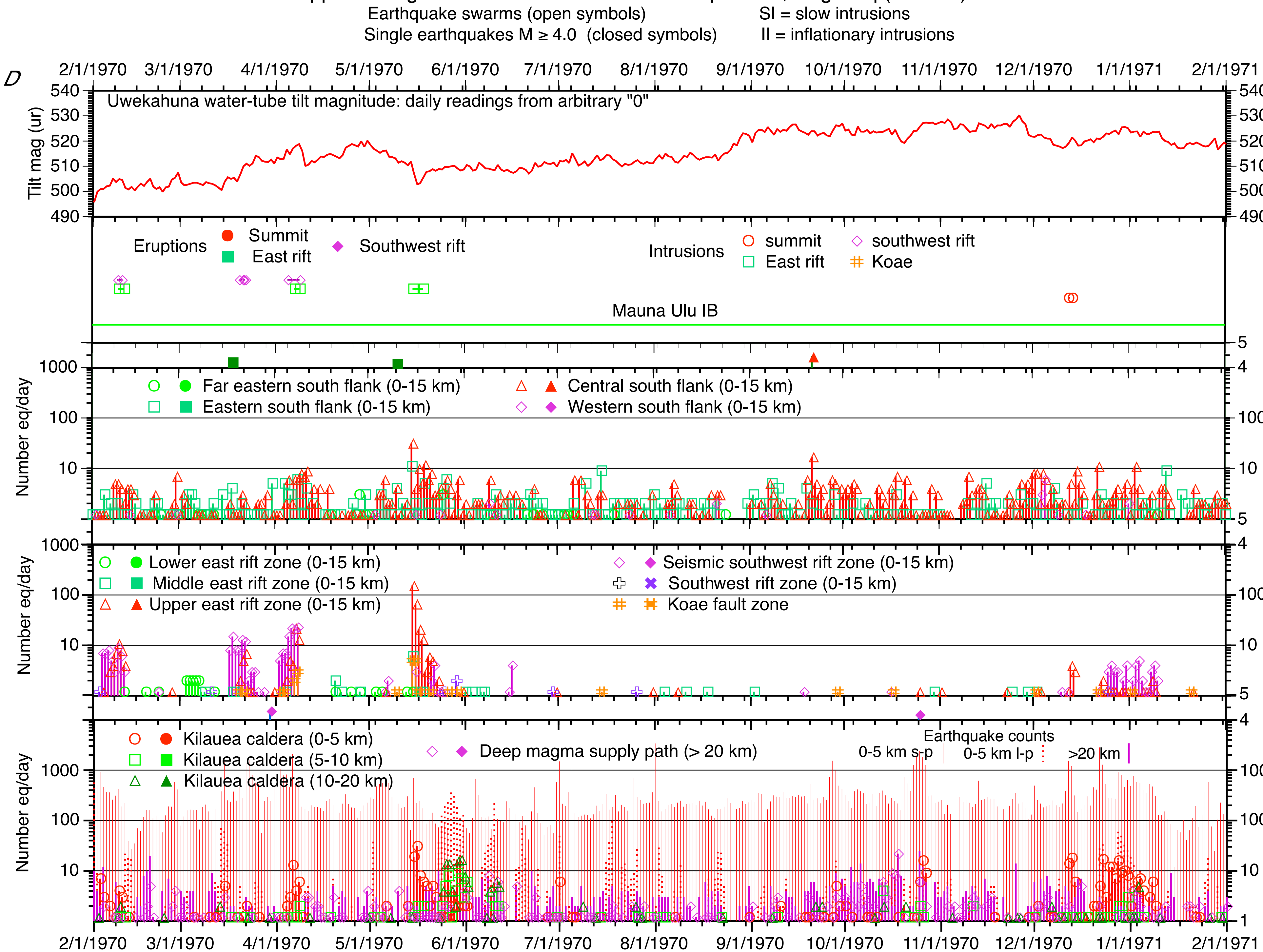
Appendix Figure E2 b. 2/1/1968-2/1/1969 eq counts, single eq (M ≥ 4.0) and tilt



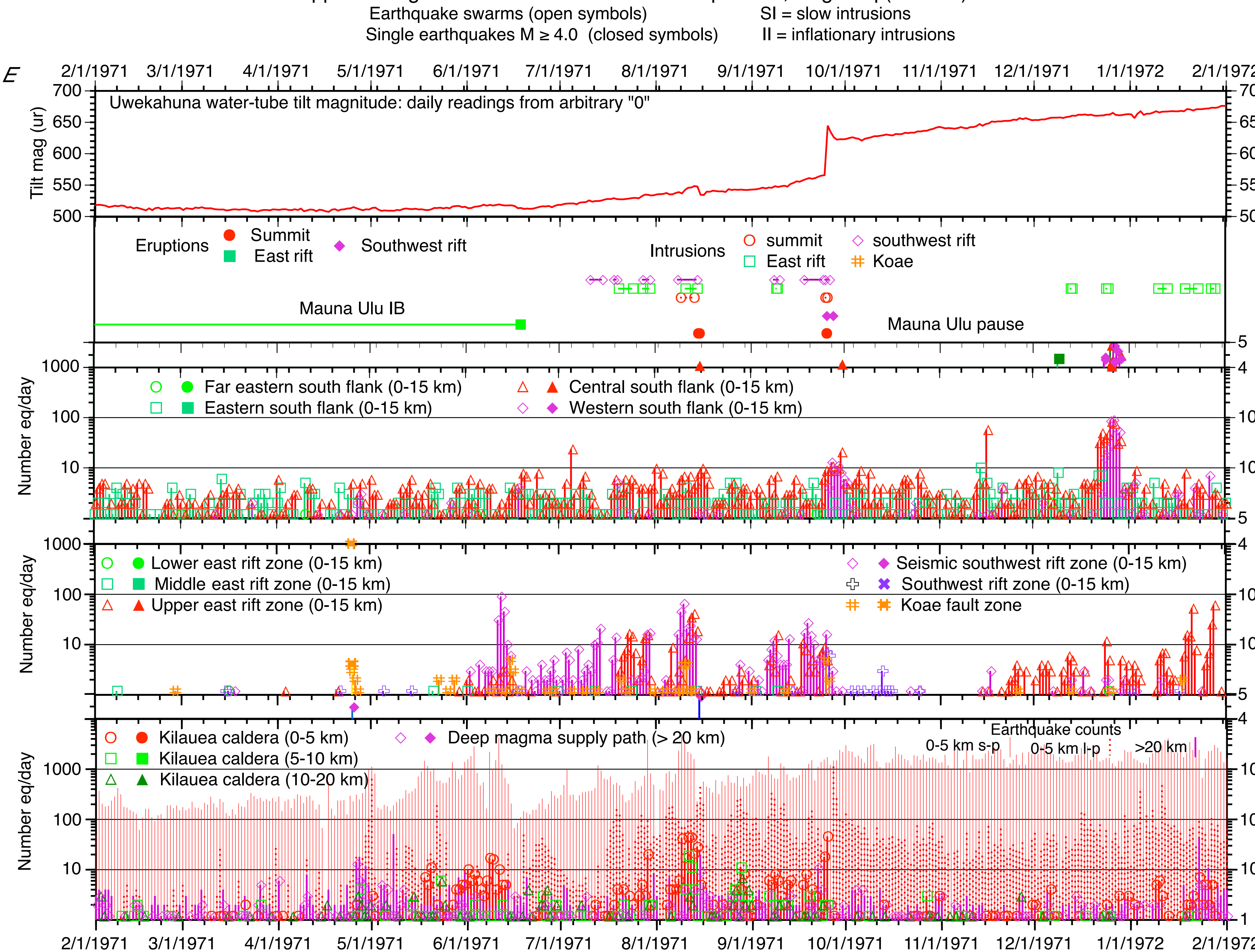
Appendix Figure E2 c. 2/1/1969-2/1/1970 eq counts, single eq (M ≥ 4.0) and tilt



Appendix Figure E2 d. 2/1/1970-2/1/1971 eq counts, single eq (M ≥ 4.0) and tilt



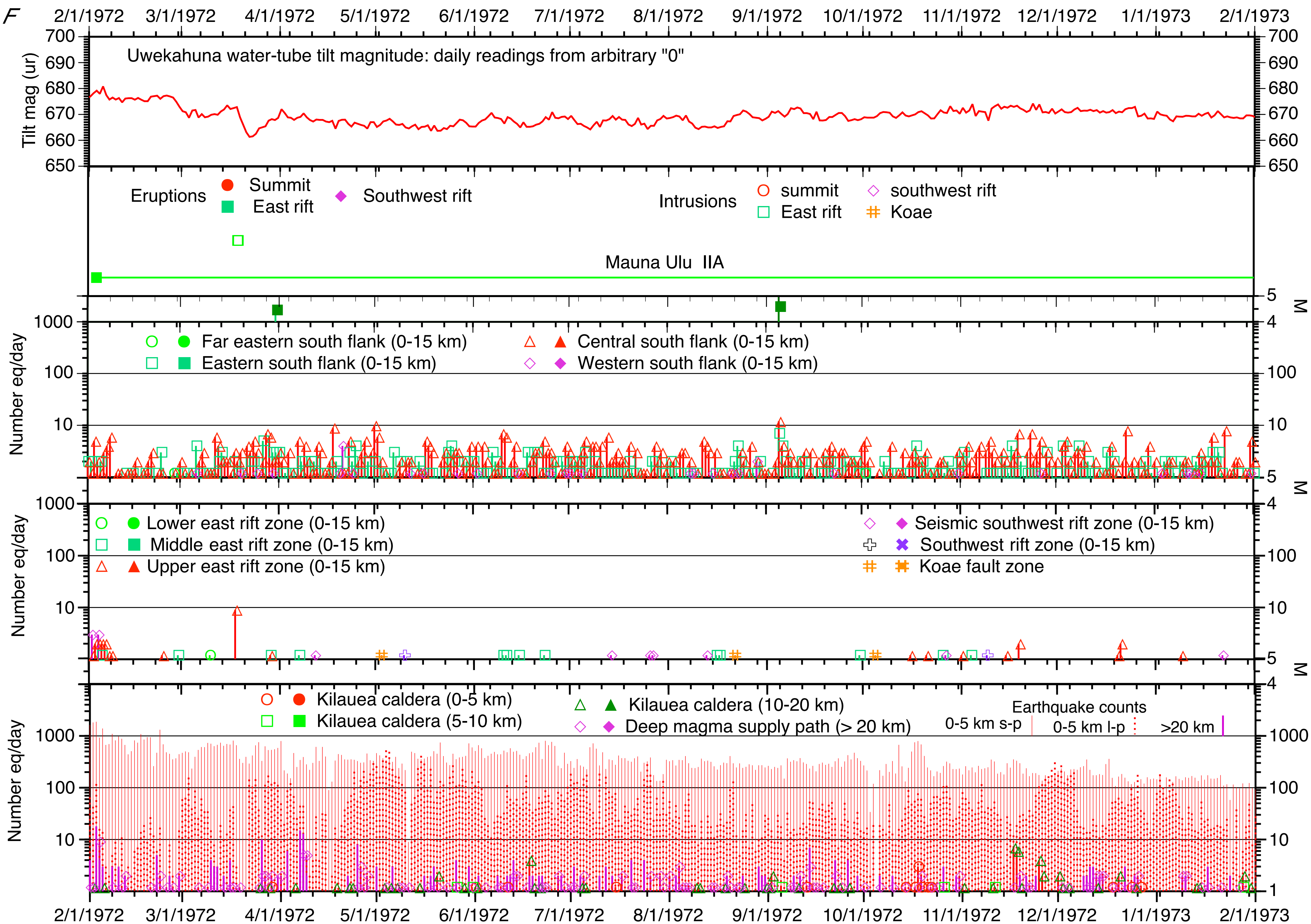
Appendix Figure E2 e. 2/1/1971-2/1/1972 eq counts, single eq (M ≥ 4.0) and tilt



Appendix Figure E2 f. 2/1/1972-2/1/1973 eq counts, single eq (M ≥ 4.0) and tilt

Earthquake swarms (open symbols) SI = slow intrusions

Single earthquakes M ≥ 4.0 (closed symbols) II = inflationary intrusions



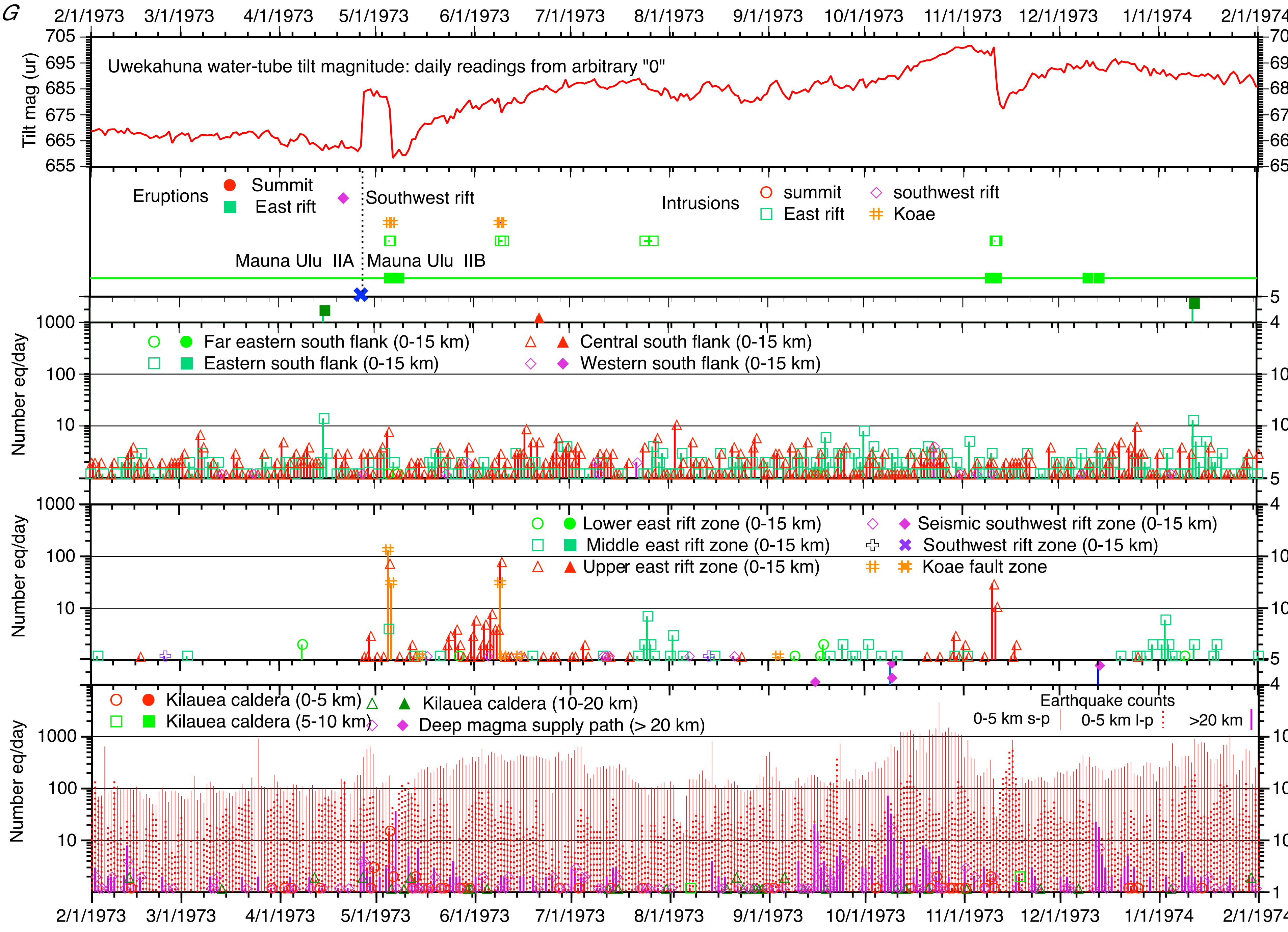
Appendix Figure E2 g. 2/1/1973-2/1/1974 eq counts, single eq (M ≥ 4.0) and tilt

Earthquake swarms (open symbols)

Single earthquakes M ≥ 4.0 (closed symbols)

SI = slow intrusions

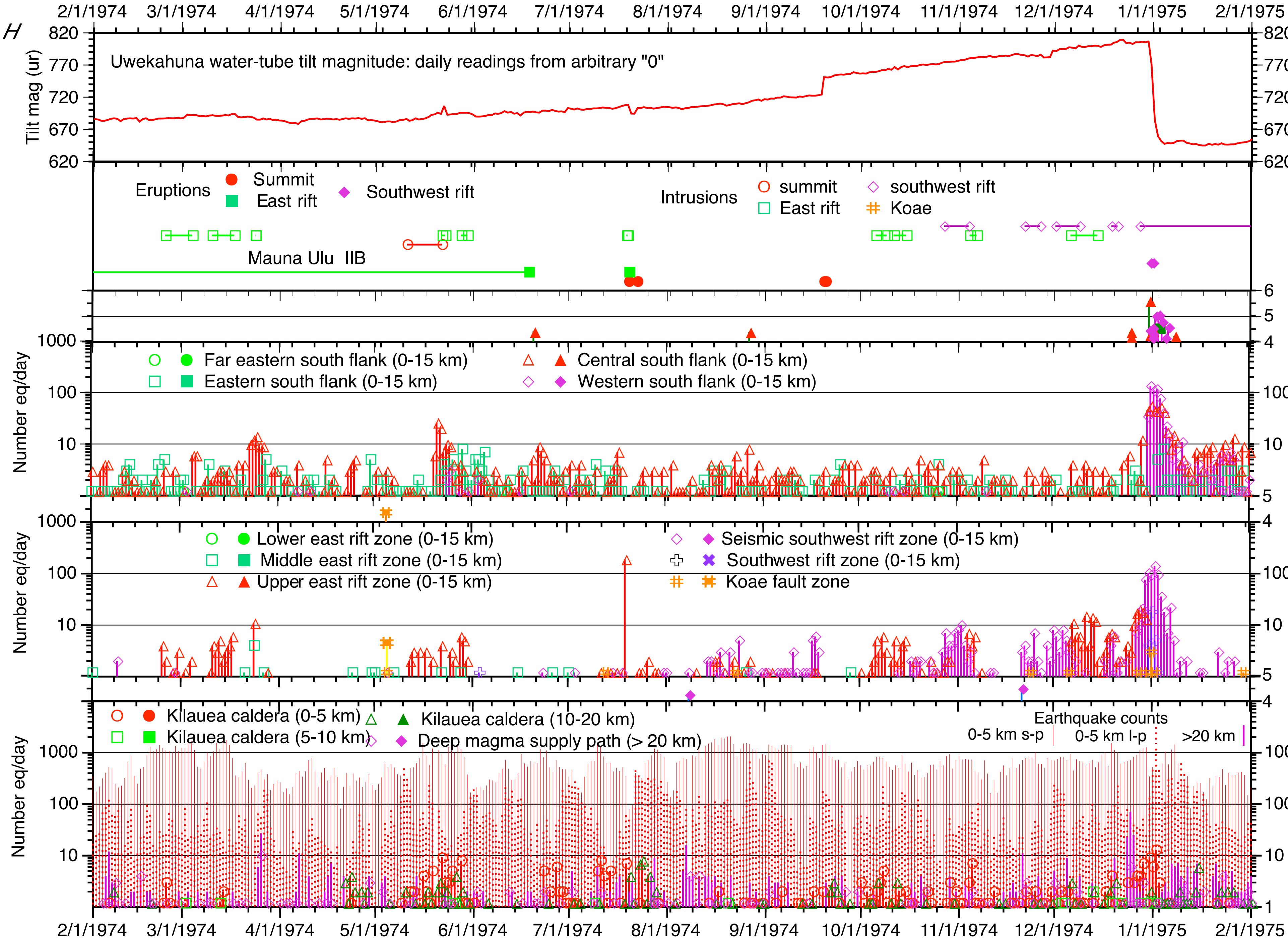
II = inflationary intrusions



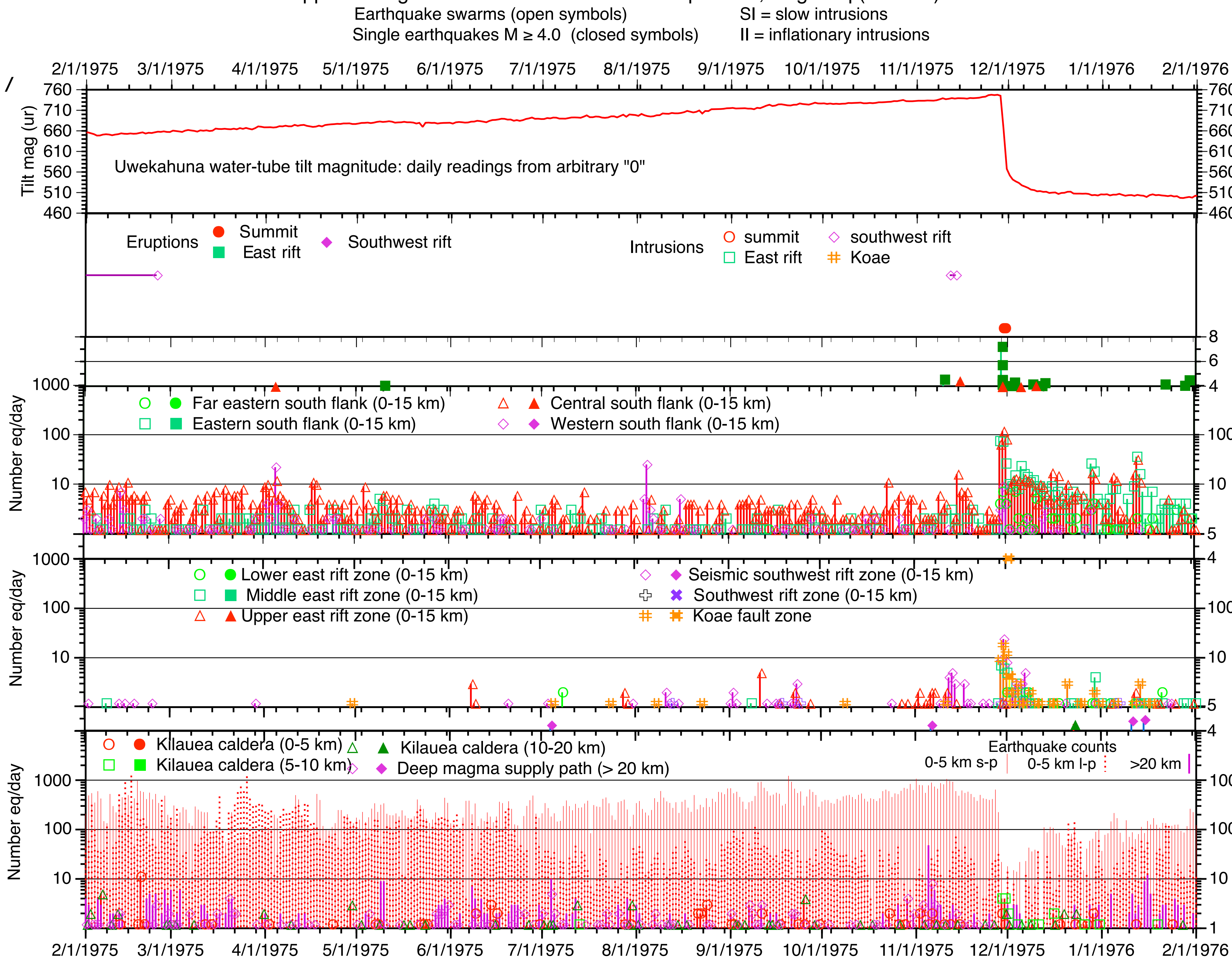
Appendix Figure E2 h. 2/1/1974-2/1/1975 eq counts, single eq (M ≥ 4.0) and tilt

Earthquake swarms (open symbols) SI = slow intrusions

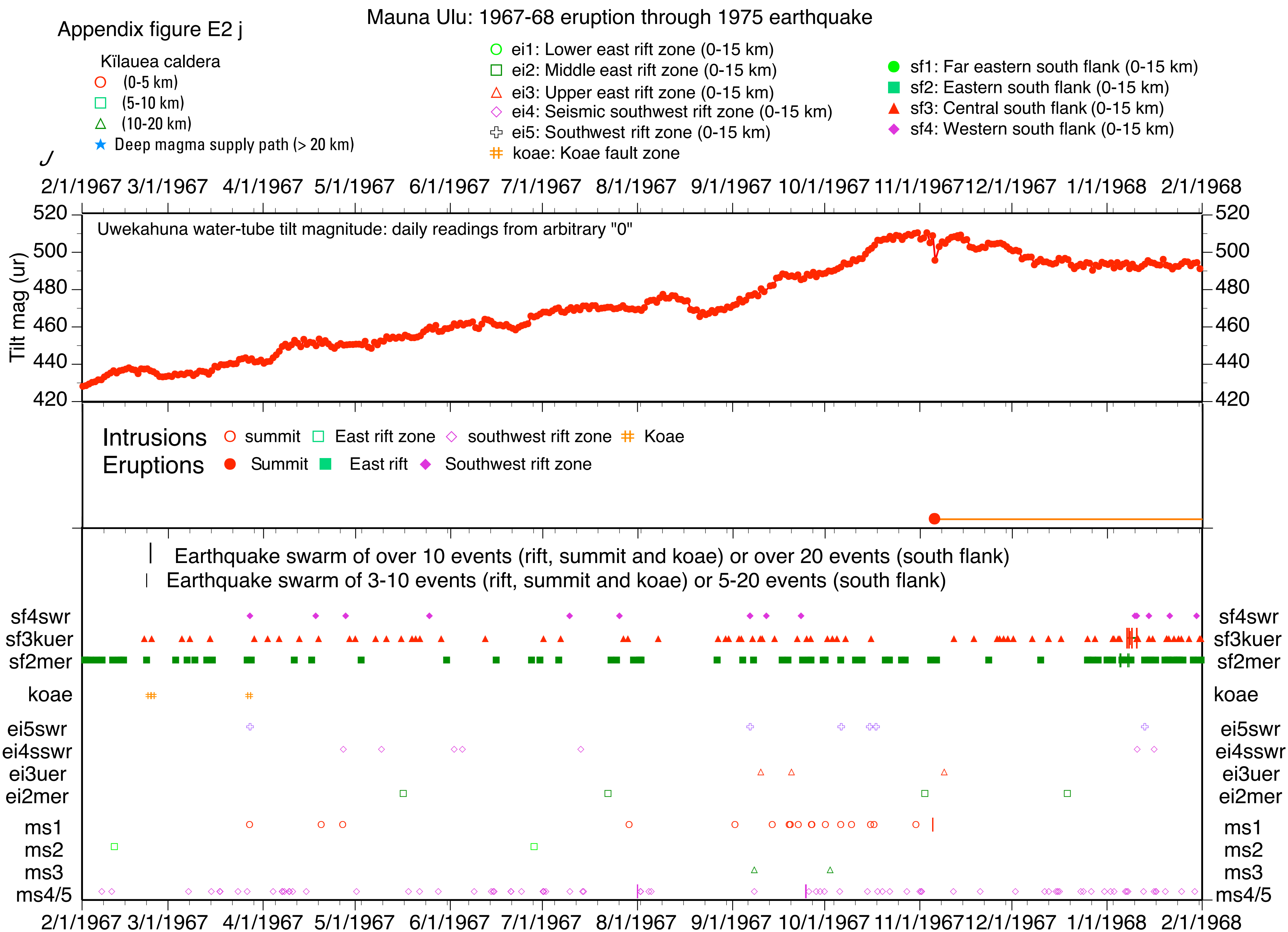
Single earthquakes M ≥ 4.0 (closed symbols) II = inflationary intrusions



Appendix Figure E2 i. 2/1/1975-2/1/1976 eq counts, single eq (M ≥ 4.0) and tilt

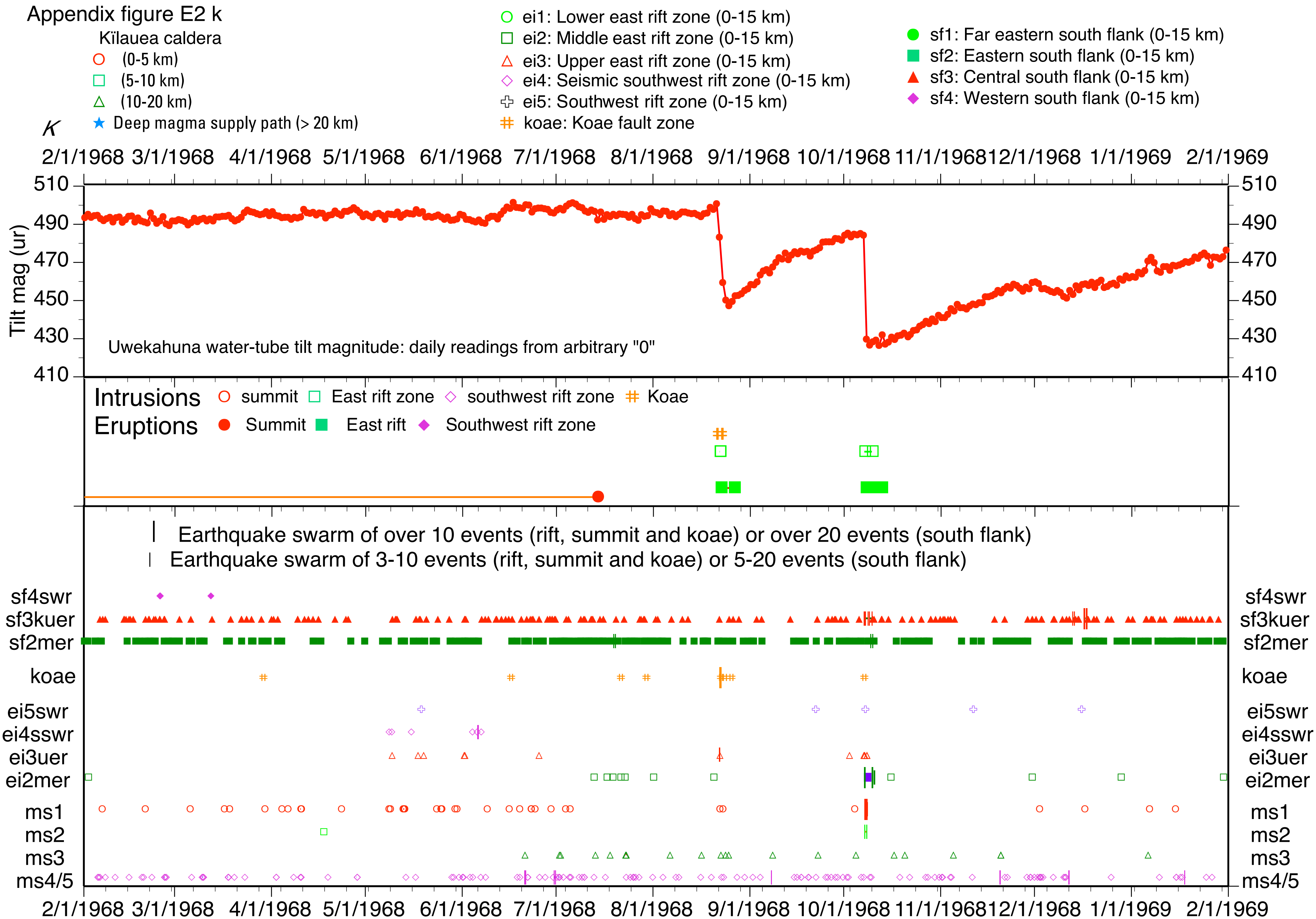


Appendix figure E2 j

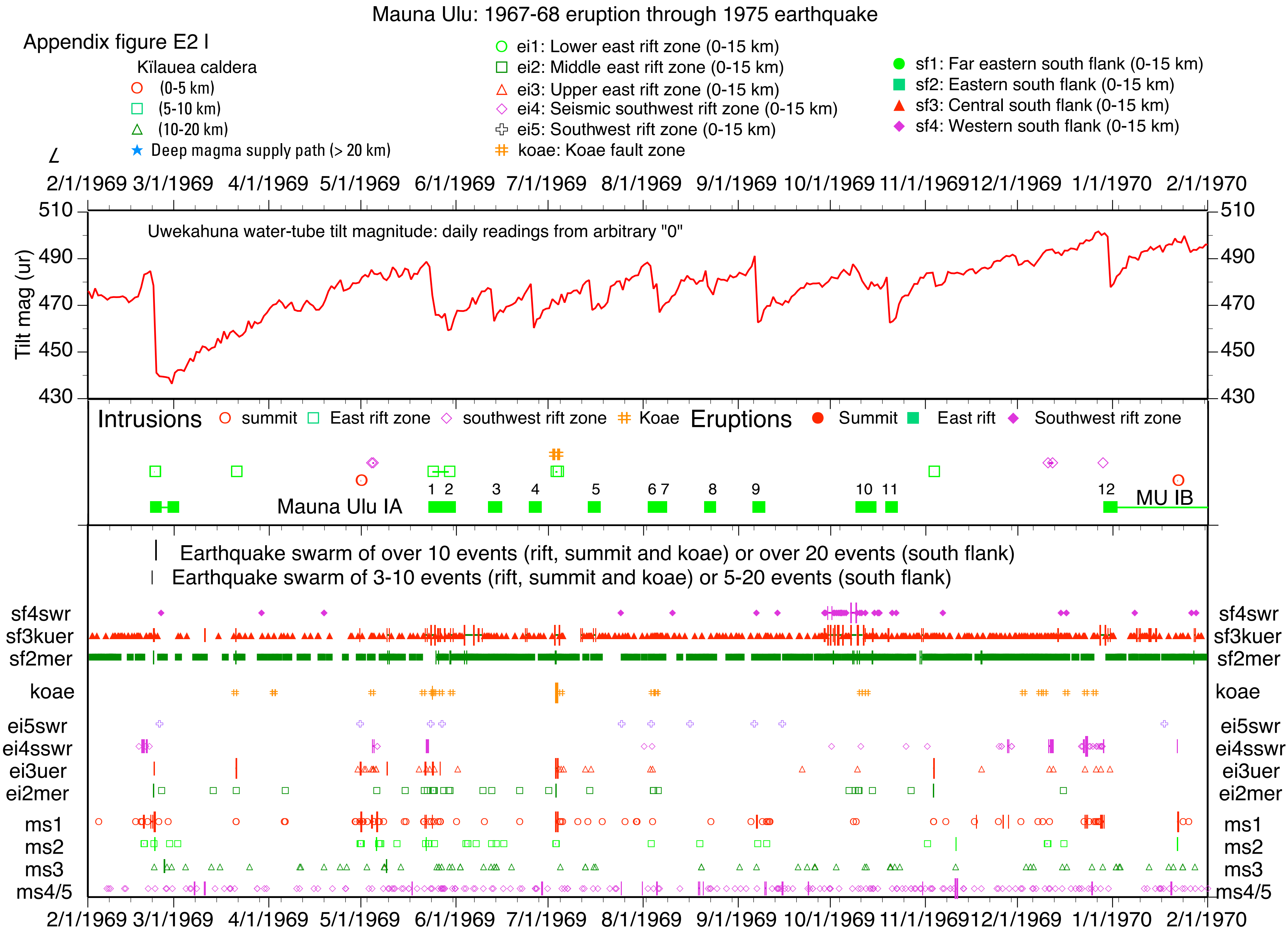


Mauna Ulu: 1967-68 eruption through 1975 earthquake

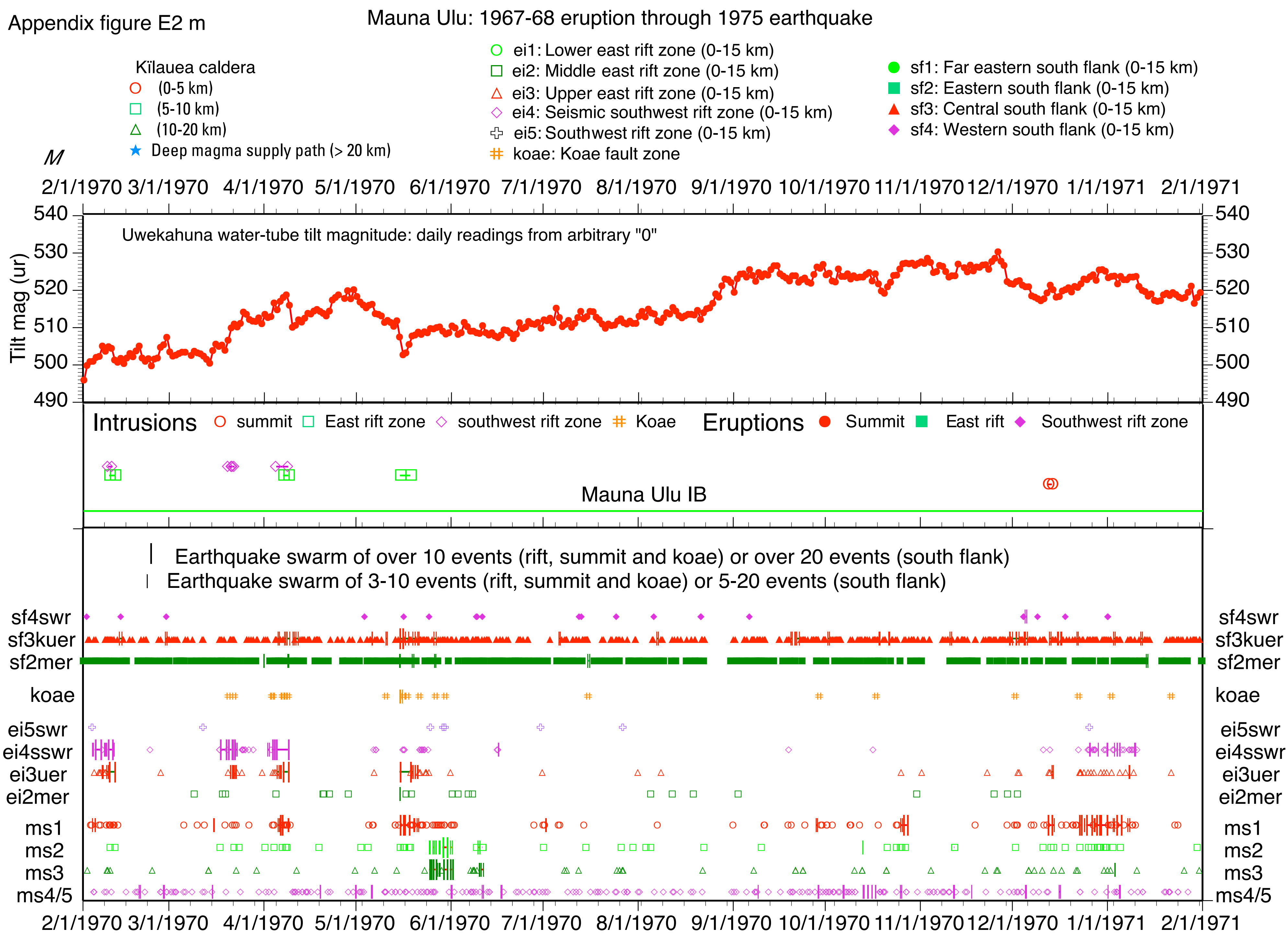
Appendix figure E2 k



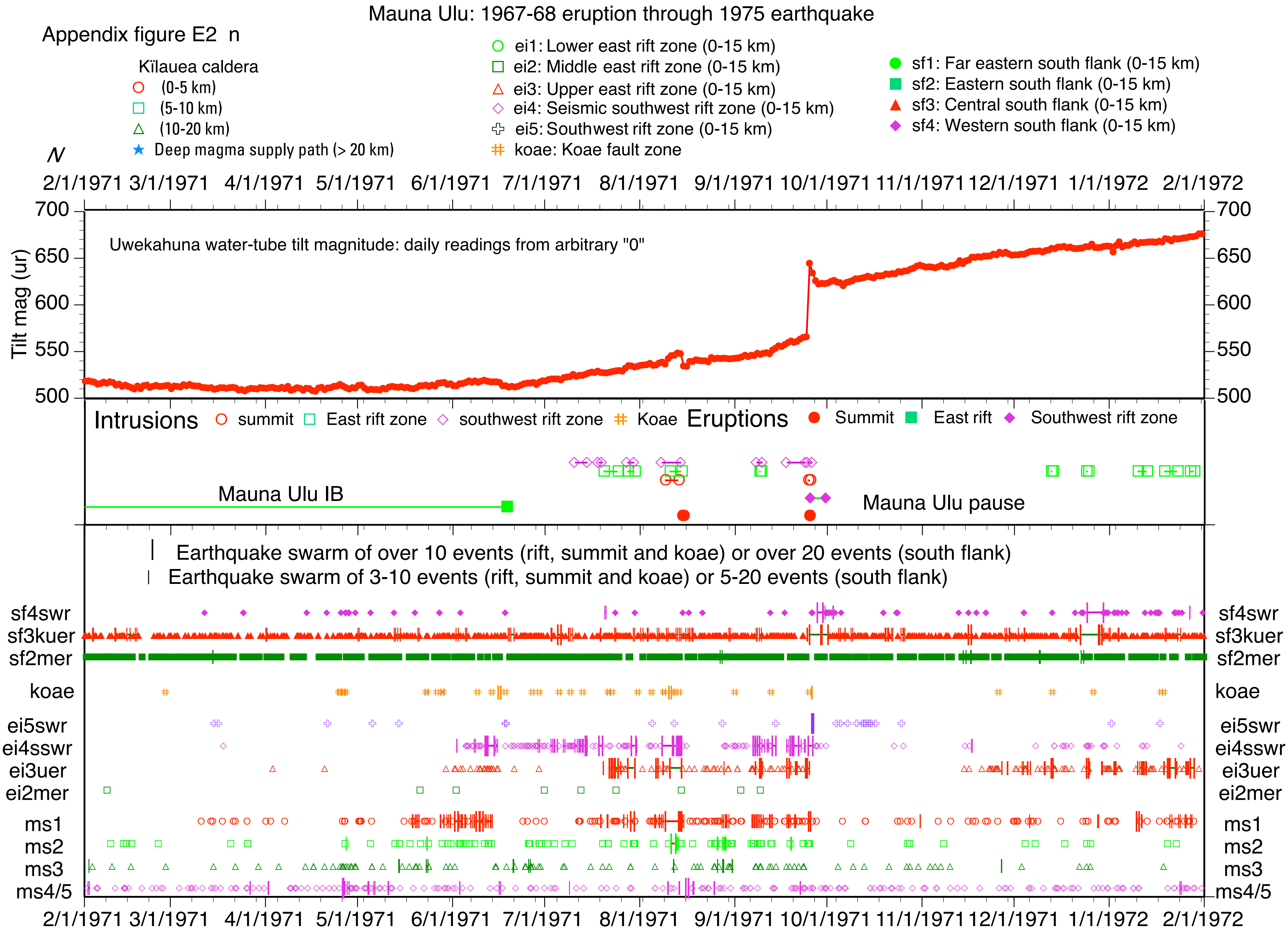
Appendix figure E2 I

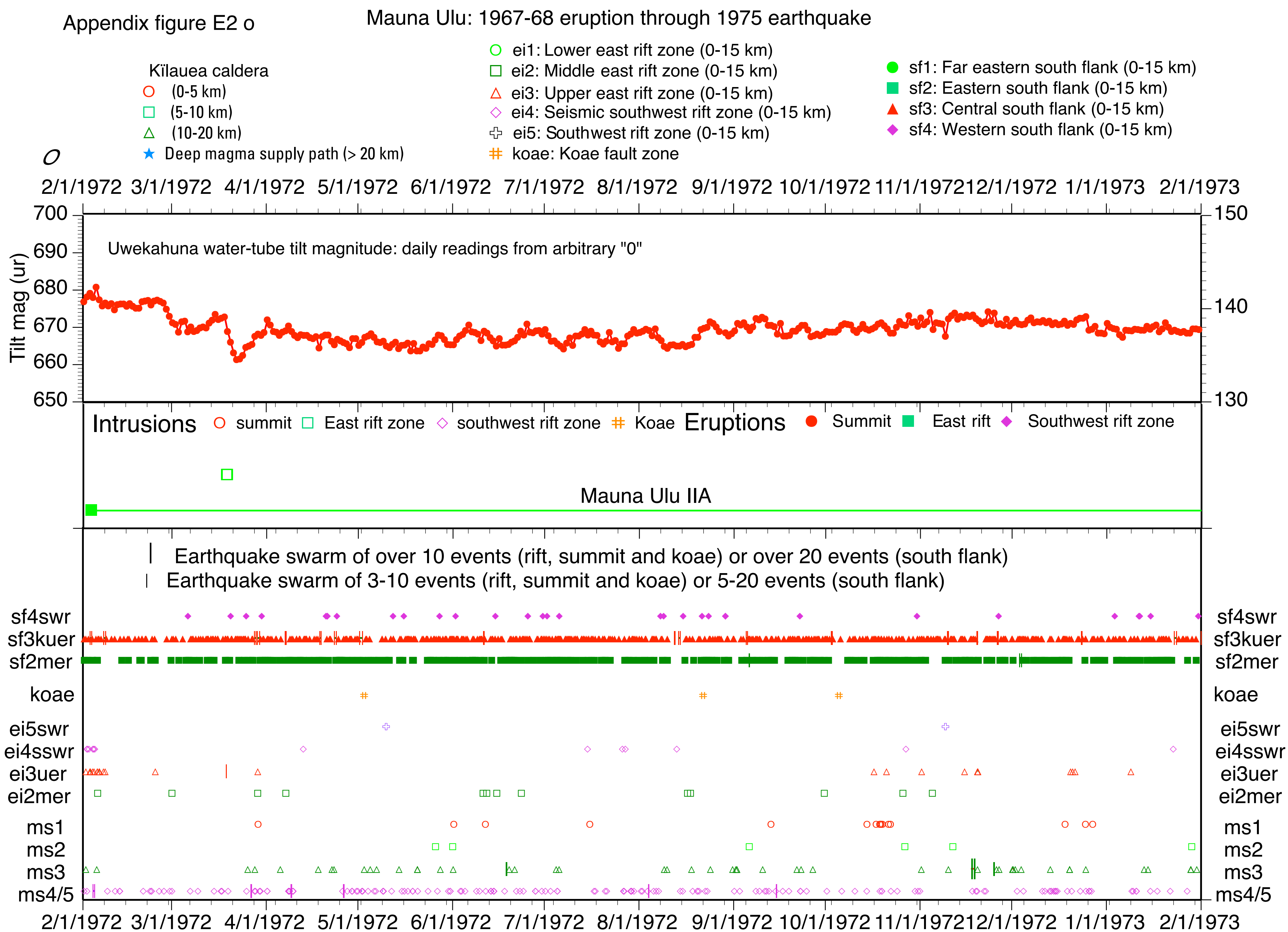


Appendix figure E2 m



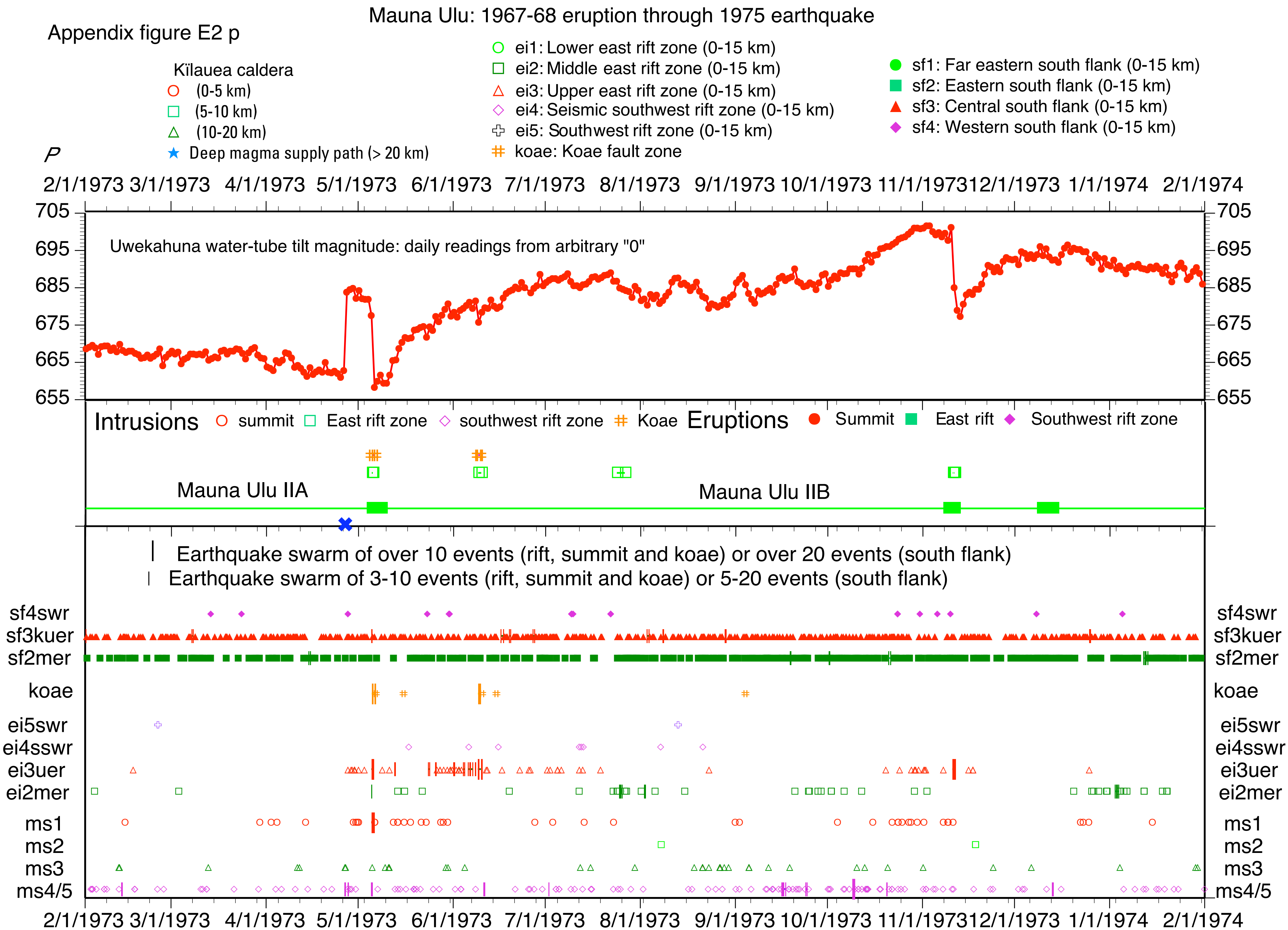
Appendix figure E2 n





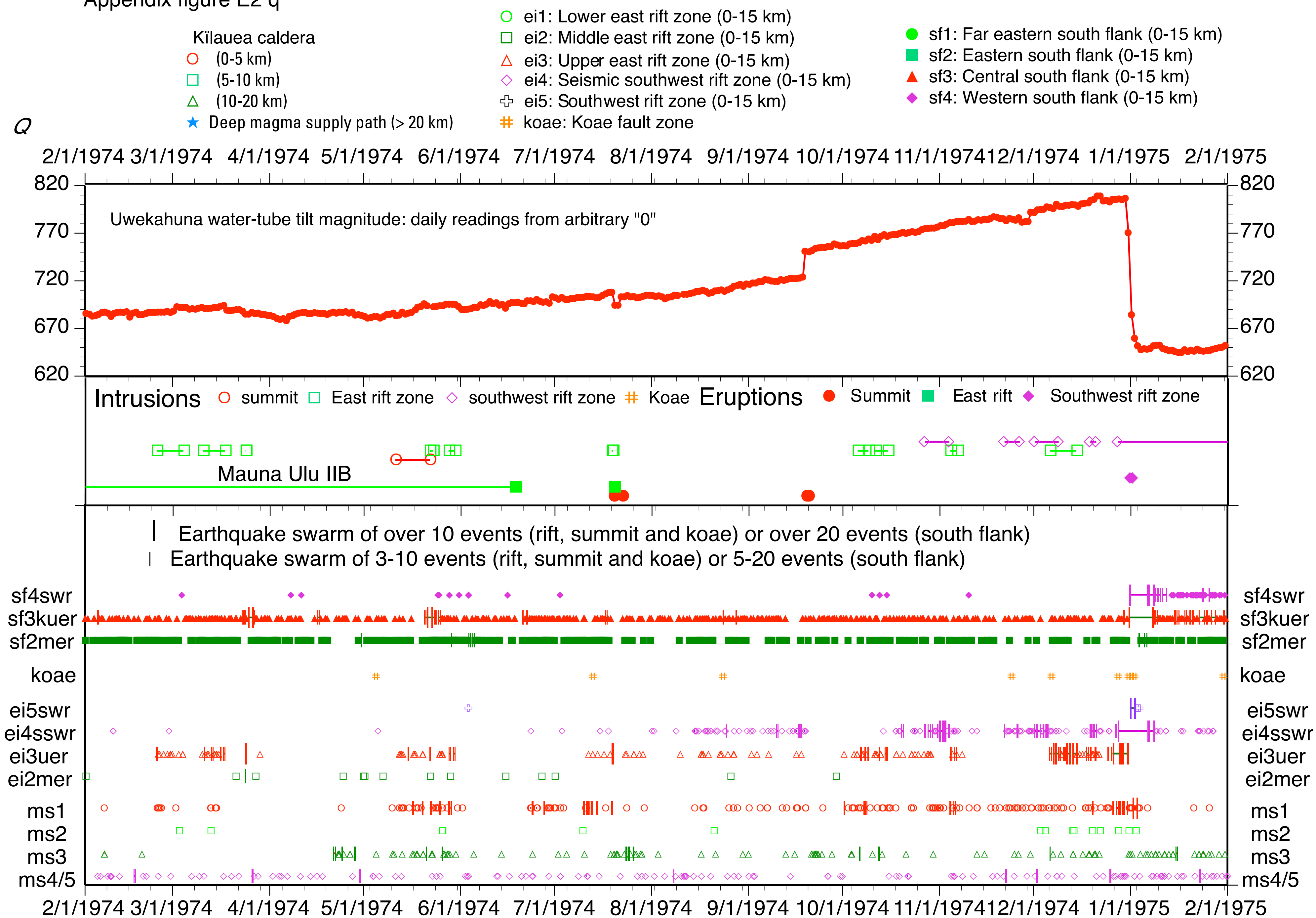
Appendix figure E2 o
Mauna Ulu: 1967-68 eruption through 1975 earthquake
Kīlauea caldera
(0-5 km)
(5-10 km)
(10-20 km)
Deep magma supply path (> 20 km)
ei1: Lower east rift zone (0-15 km)
ei2: Middle east rift zone (0-15 km)
ei3: Upper east rift zone (0-15 km)
ei4: Seismic southwest rift zone (0-15 km)
ei5: Southwest rift zone (0-15 km)
koae: Koae 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)
O
2/1/1972 3/1/1972 4/1/1972 5/1/1972 6/1/1972 7/1/1972 8/1/1972 9/1/1972 10/1/1972 11/1/1972 12/1/1972 1/1/1973 2/1/1973
Tilt mag (ur)
700 690 680 670 660 650
150 140 130
Uwekahuna water-tube tilt magnitude: daily readings from arbitrary "0"
Intrusions summit East rift zone southwest rift zone Koae
Eruptions Summit East rift Southwest rift zone
Mauna Ulu IIA
Earthquake swarm of over 10 events (rift, summit and koae) or over 20 events (south flank)
Earthquake swarm of 3-10 events (rift, summit and koae) or 5-20 events (south flank)
sf4swr
sf3kuer
sf2mer
koae
ei5swr
ei4sswr
ei3uer
ei2mer
ms1
ms2
ms3
ms4/5

Appendix figure E2 p



Appendix figure E2 q

Mauna Ulu: 1967-68 eruption through 1975 earthquake



Appendix figure E2 r

Figure E3. 1967-68 summit eruption through 1968-1969 east rift eruptions: earthquake counts and tilt

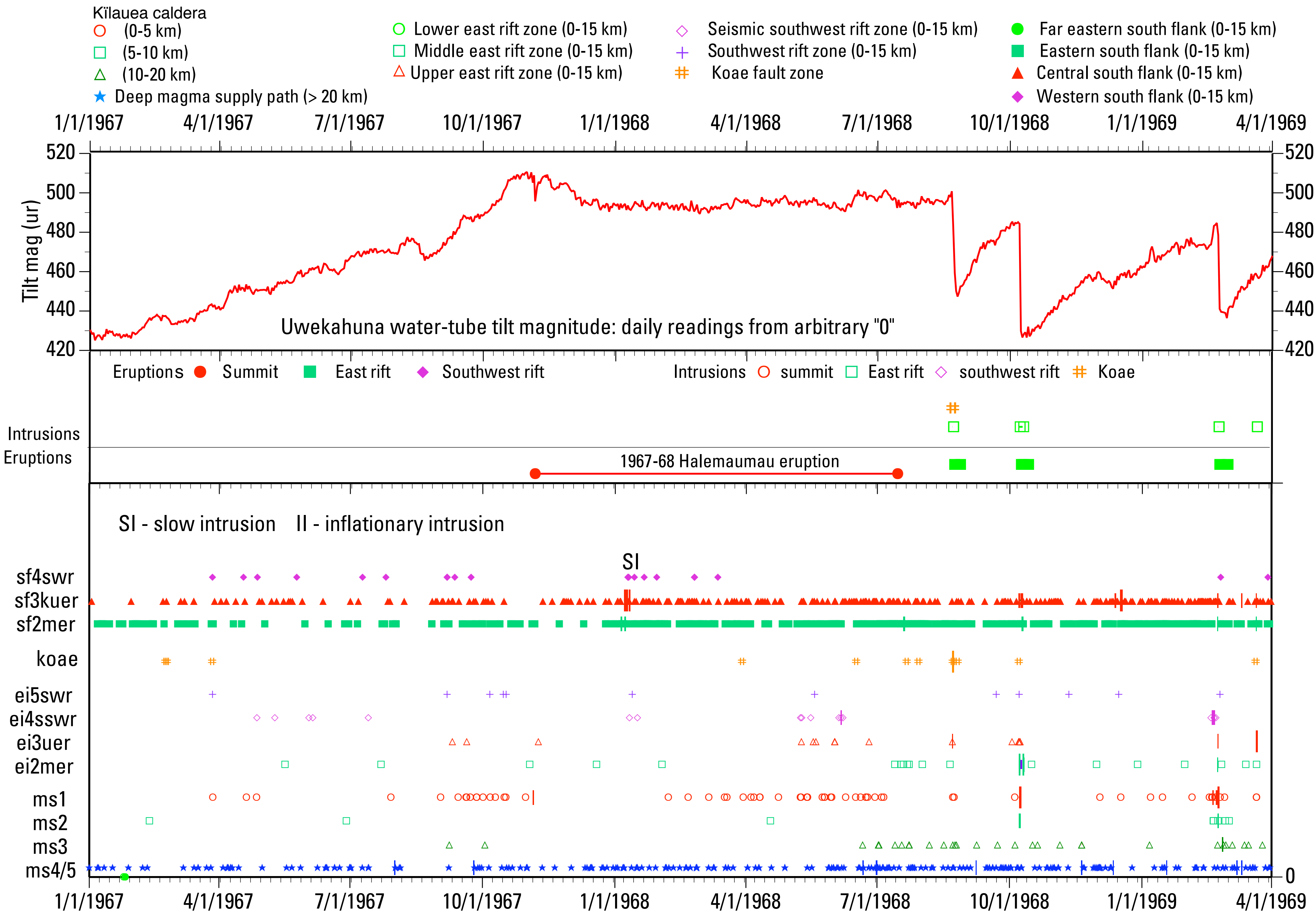
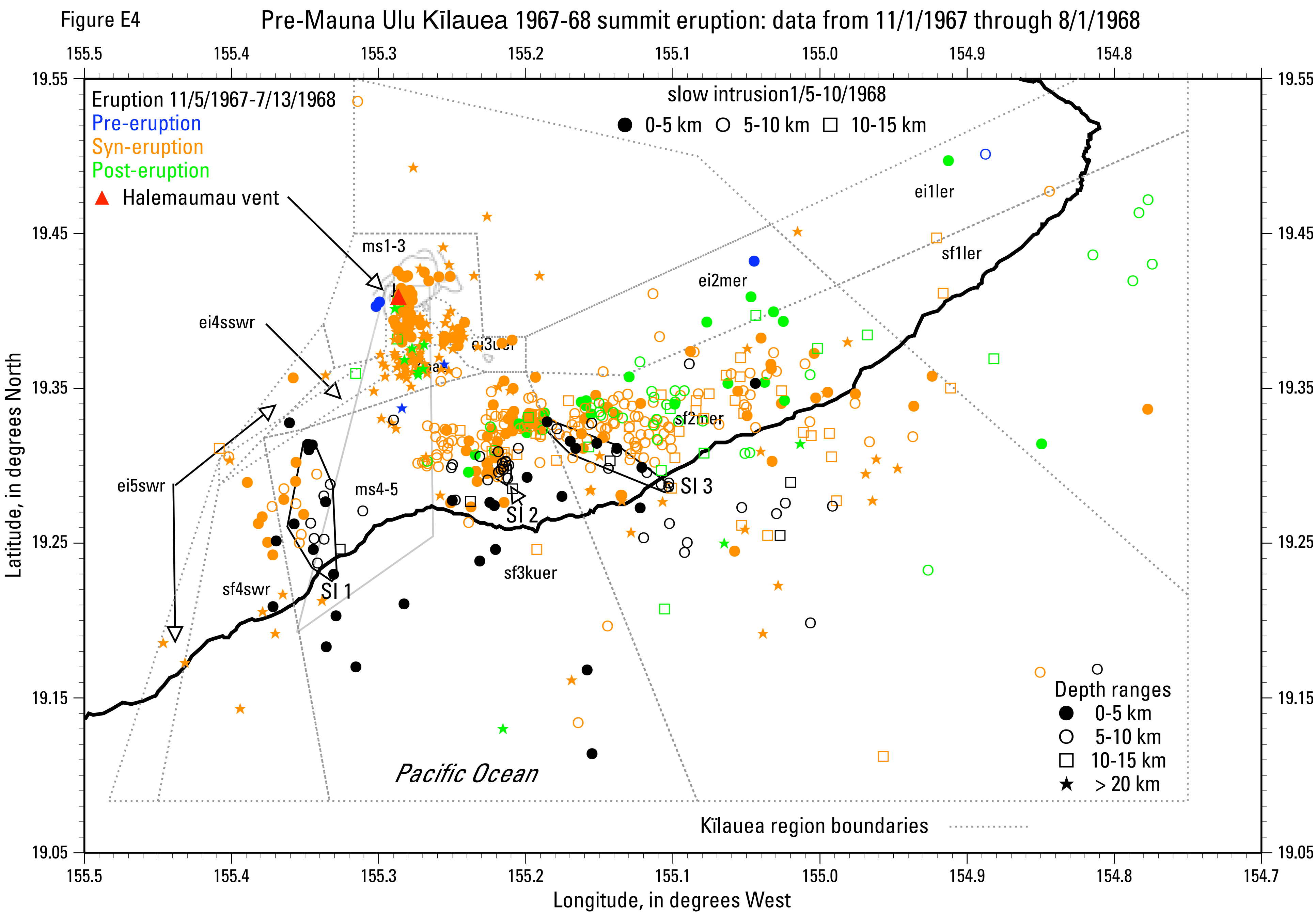
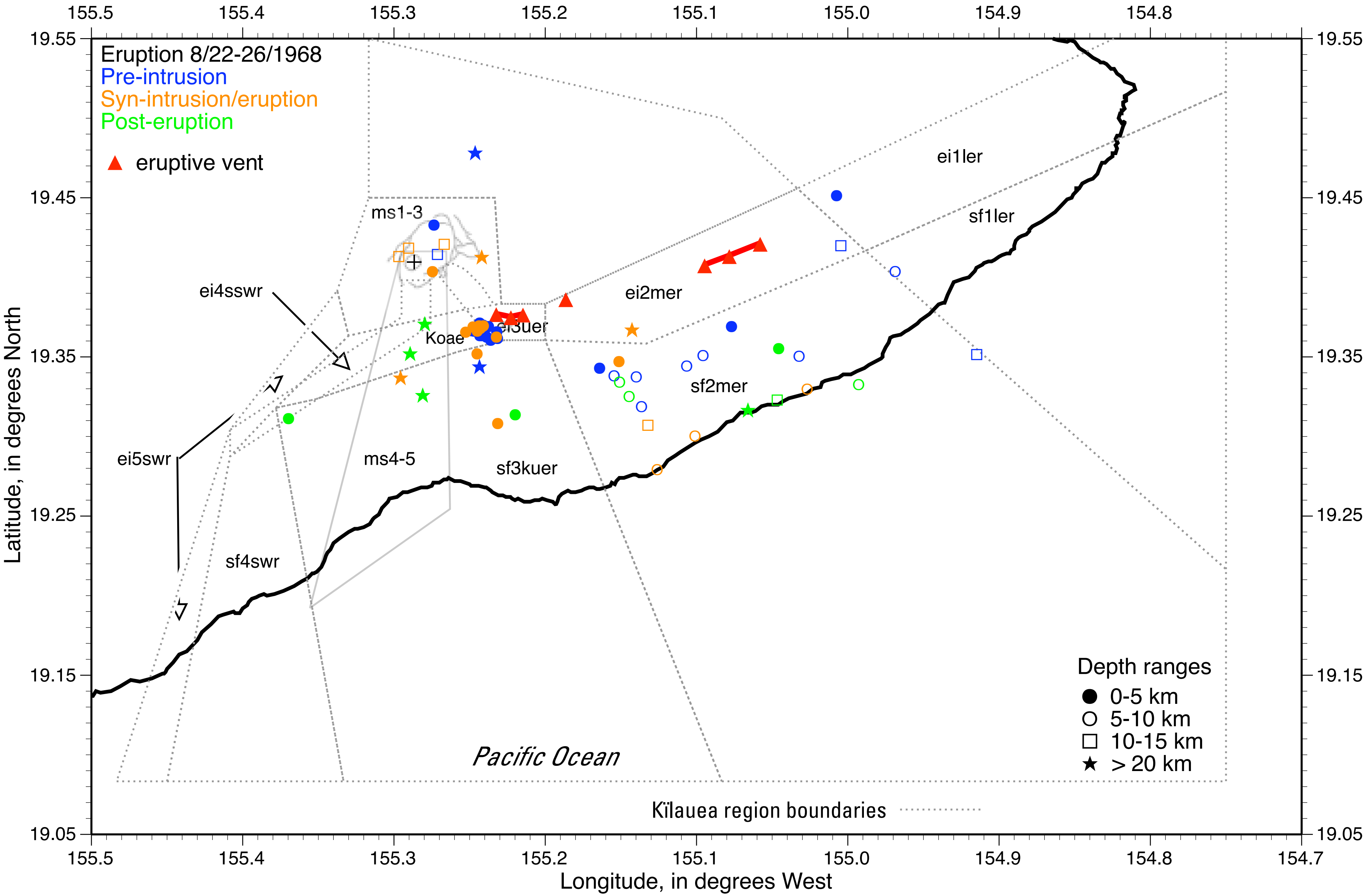


Figure E4


Pre-Mauna Ulu Kīlauea 1967-68 summit eruption: data from 11/1/1967 through 8/1/1968
Eruption 11/5/1967-7/13/1968
Pre-eruption
Syn-eruption
Post-eruption
Halemaumau vent
slow intrusion1/5-10/1968
0-5 km
5-10 km
10-15 km
ms1-3
ei4sswr
ei5swr
ei3uer
ei2mer
ei1ler
sf1ler
sf2mer
sf3kuer
sf4swr
ms4-5
SI 1
SI 2
SI 3
Pacific Ocean
Depth ranges
0-5 km
5-10 km
10-15 km
> 20 km
Kīlauea region boundaries
Latitude, in degrees North
Longitude, in degrees West
155.5
155.4
155.3
155.2
155.1
155.0
154.9
154.8
154.7
19.55
19.45
19.35
19.25
19.15
19.05

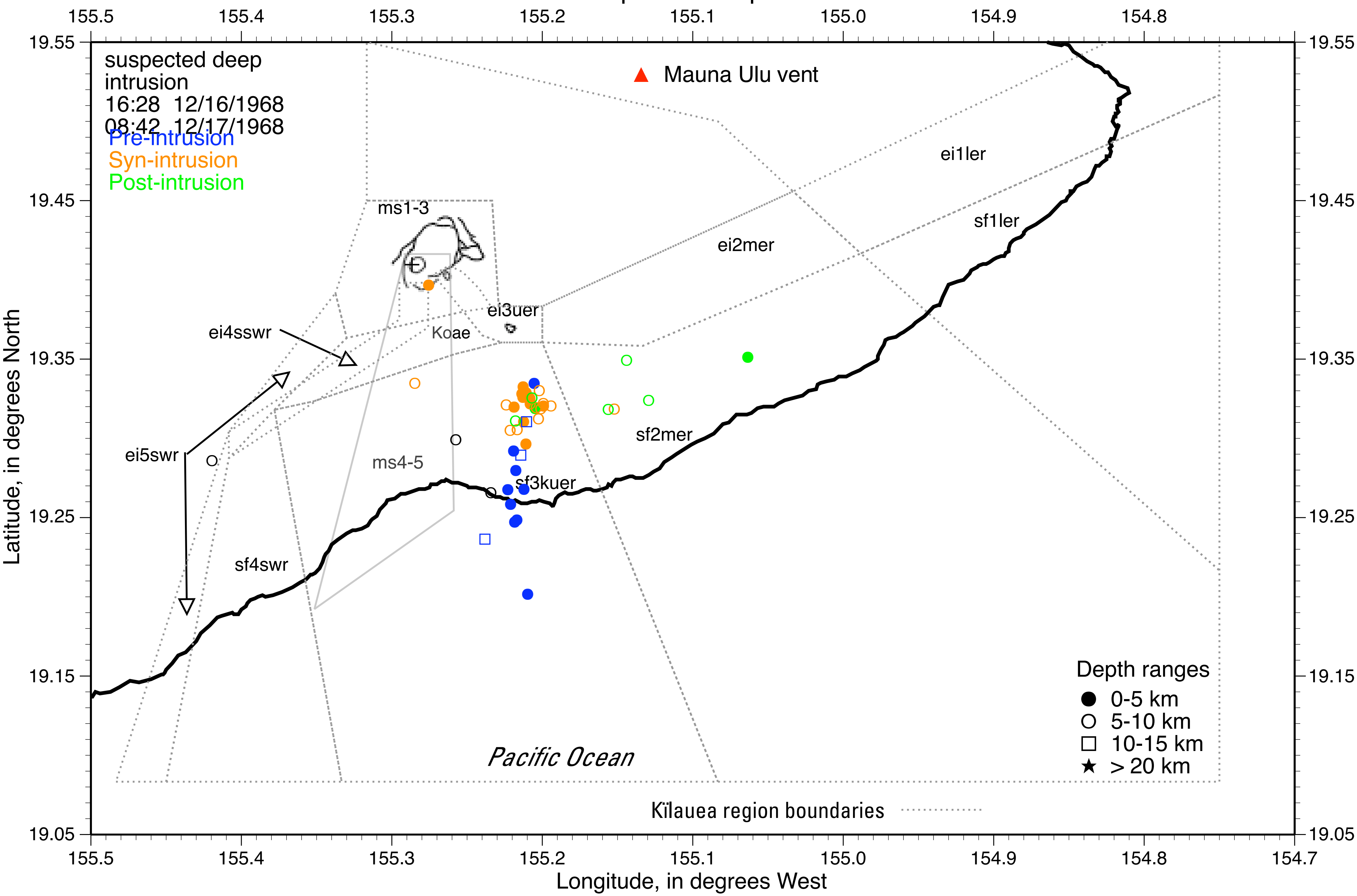
Appendix Figure E5

Pre-Mauna Ulu August 1968 flank eruption: data from 8/15 through 9/2/1968



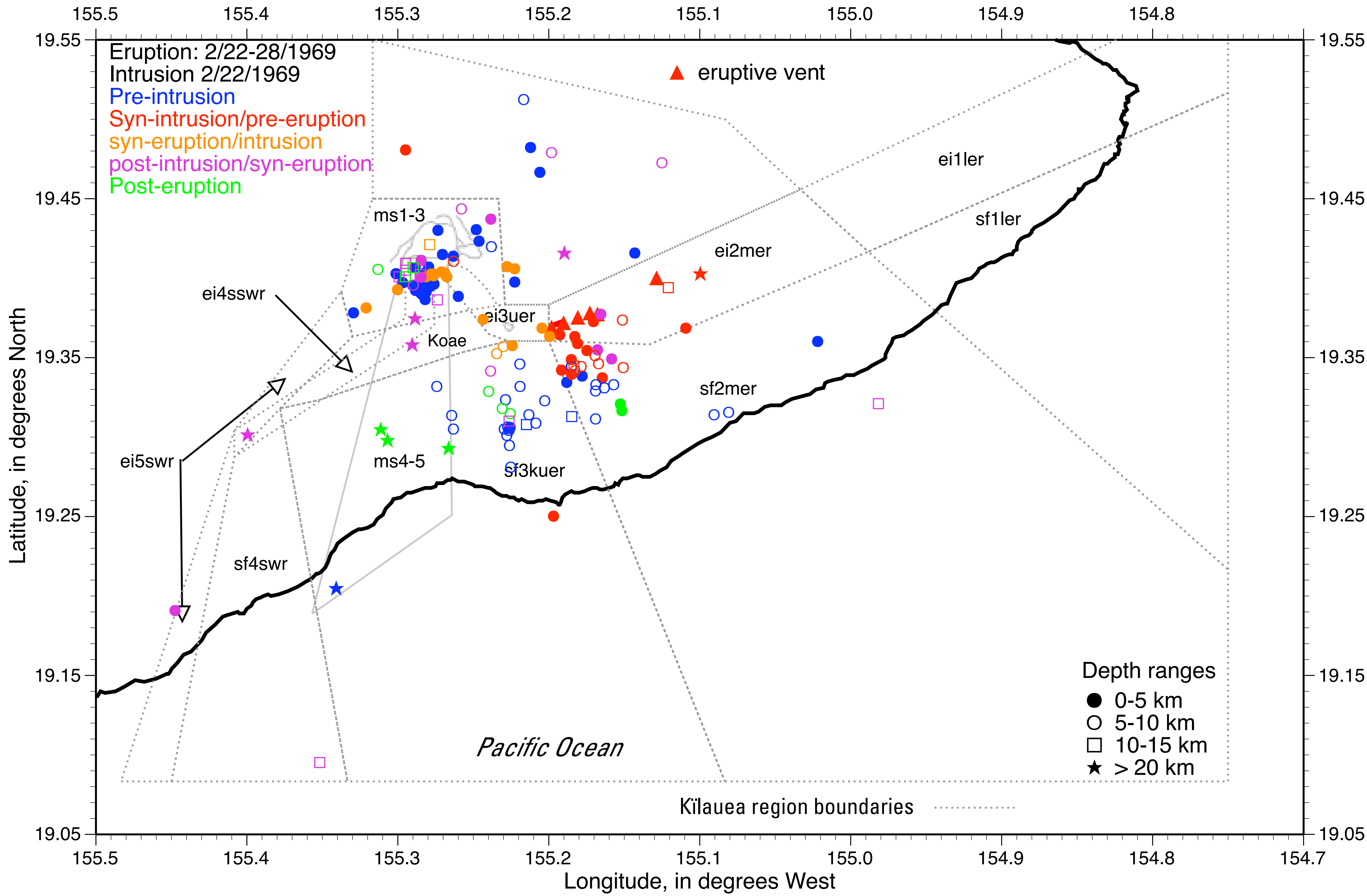
Appendix Figure E6

Mauna Ulu December 1968 suspected deep intrusion: data from 12/13-18/1968



Appendix Figure E7

Pre-Mauna Ulu February 1969 eruption: data from 2/16-3/6/1969



Appendix Figure E8

Pre-Mauna Ulu March 1969 intrusion: data from 3/20-22/1969

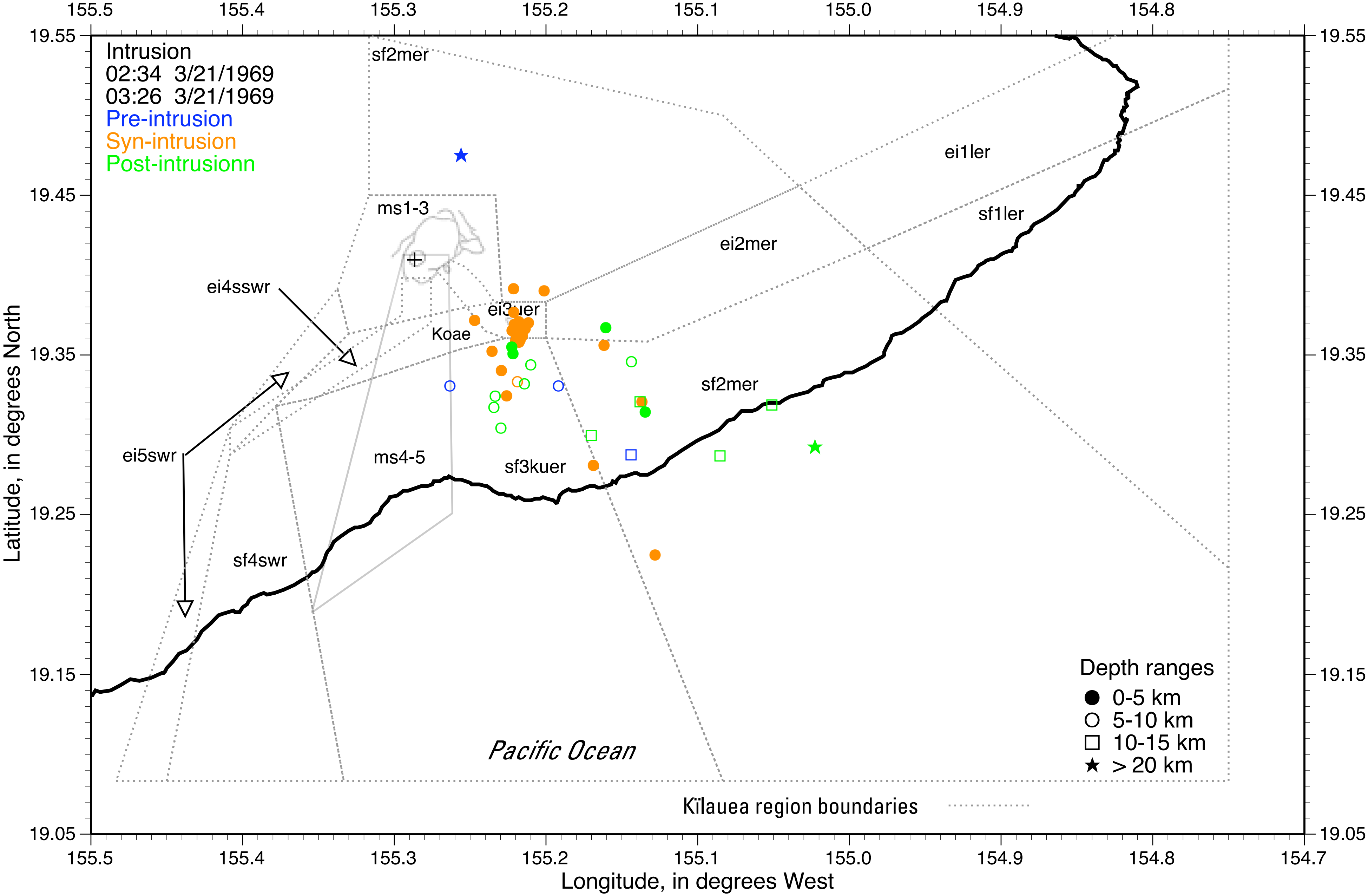
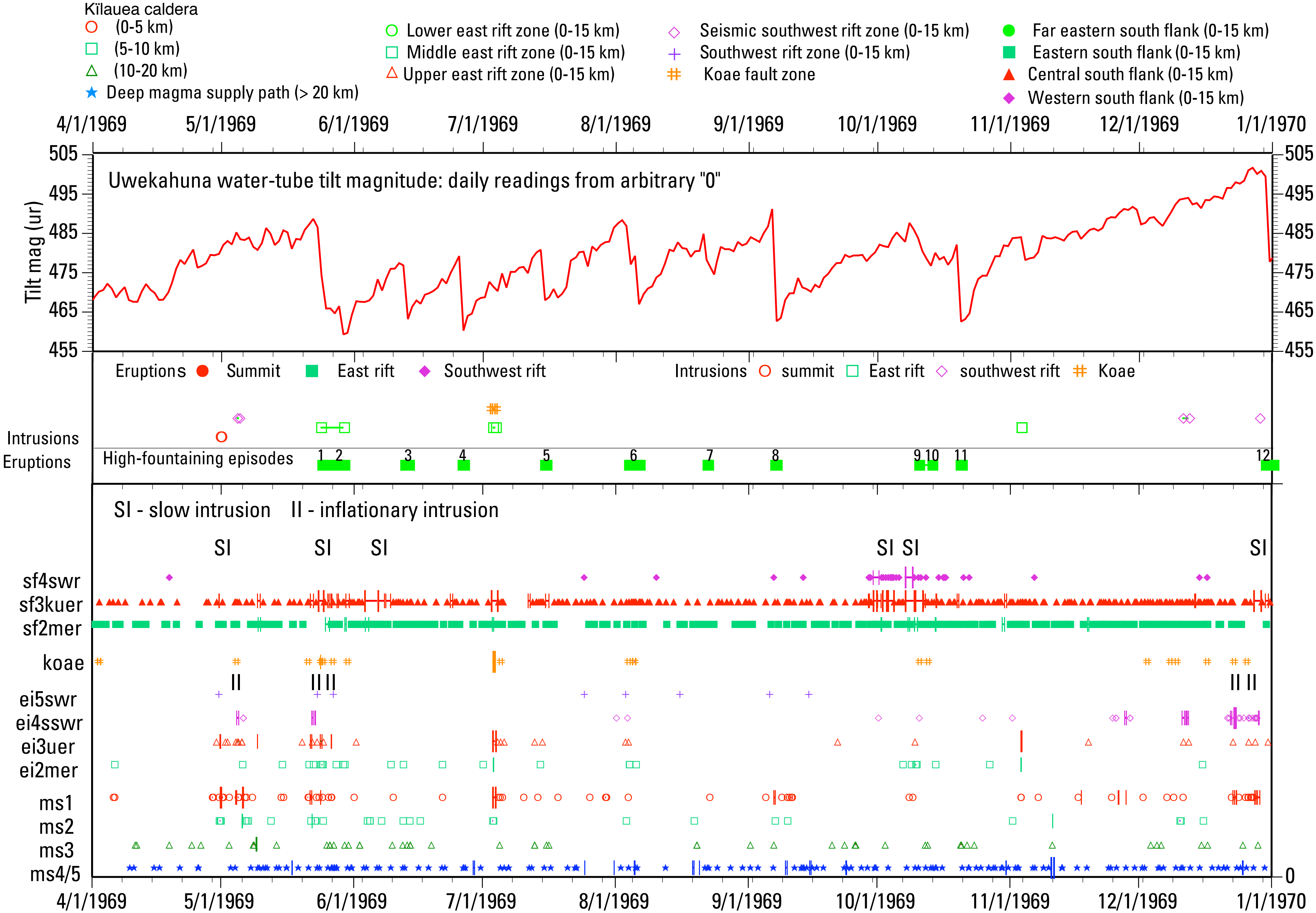
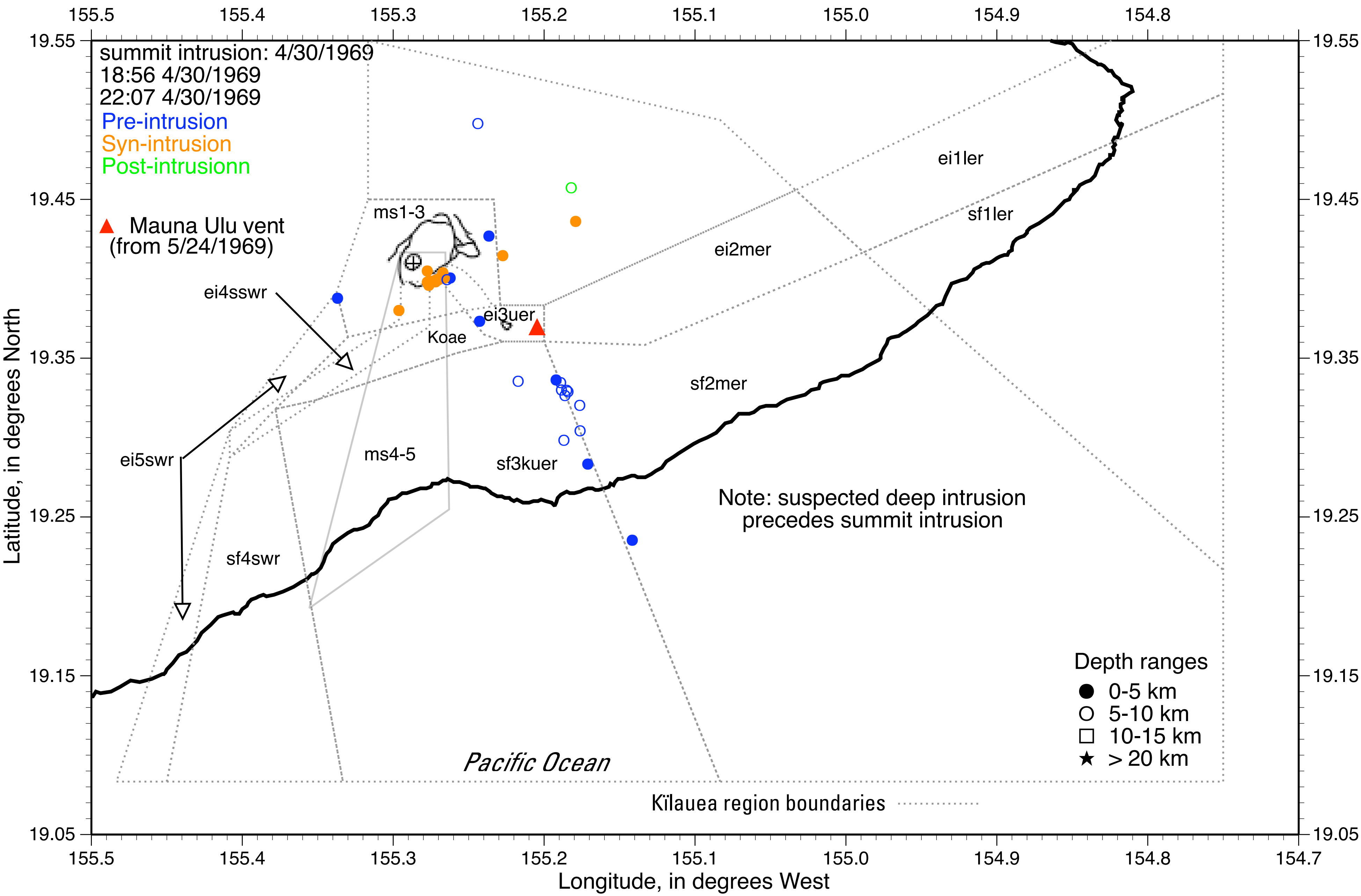


Figure E9. Mauna Ulu IA: earthquake swarms and tilt



Appendix figure E10

Mauna Ulu IA 4/30/1969 intrusion: data from 4/30/1969



Appendix Figure E11

Mauna Ulu IA 5/1969 intrusion: data from 5/3-10/1969

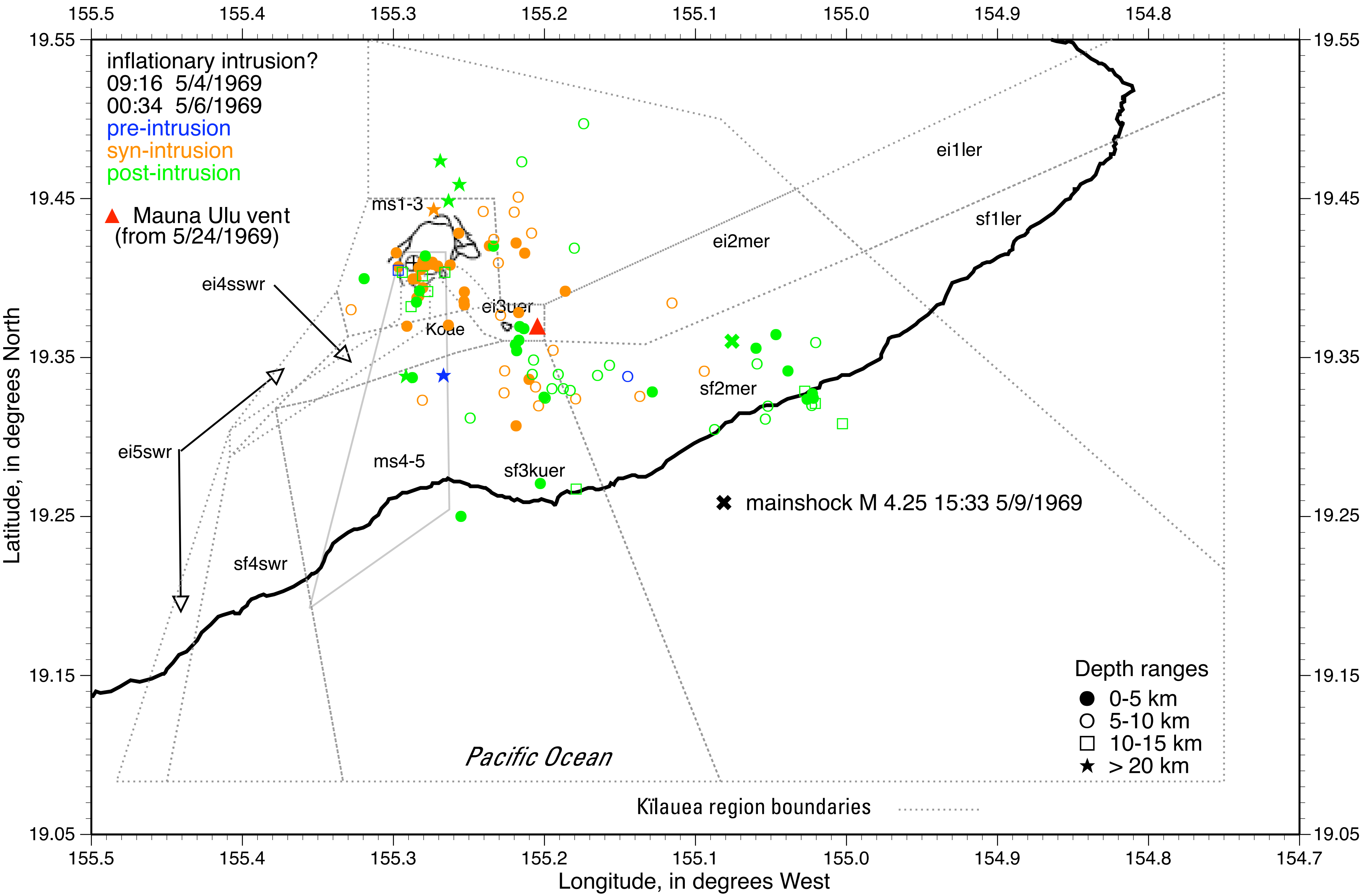
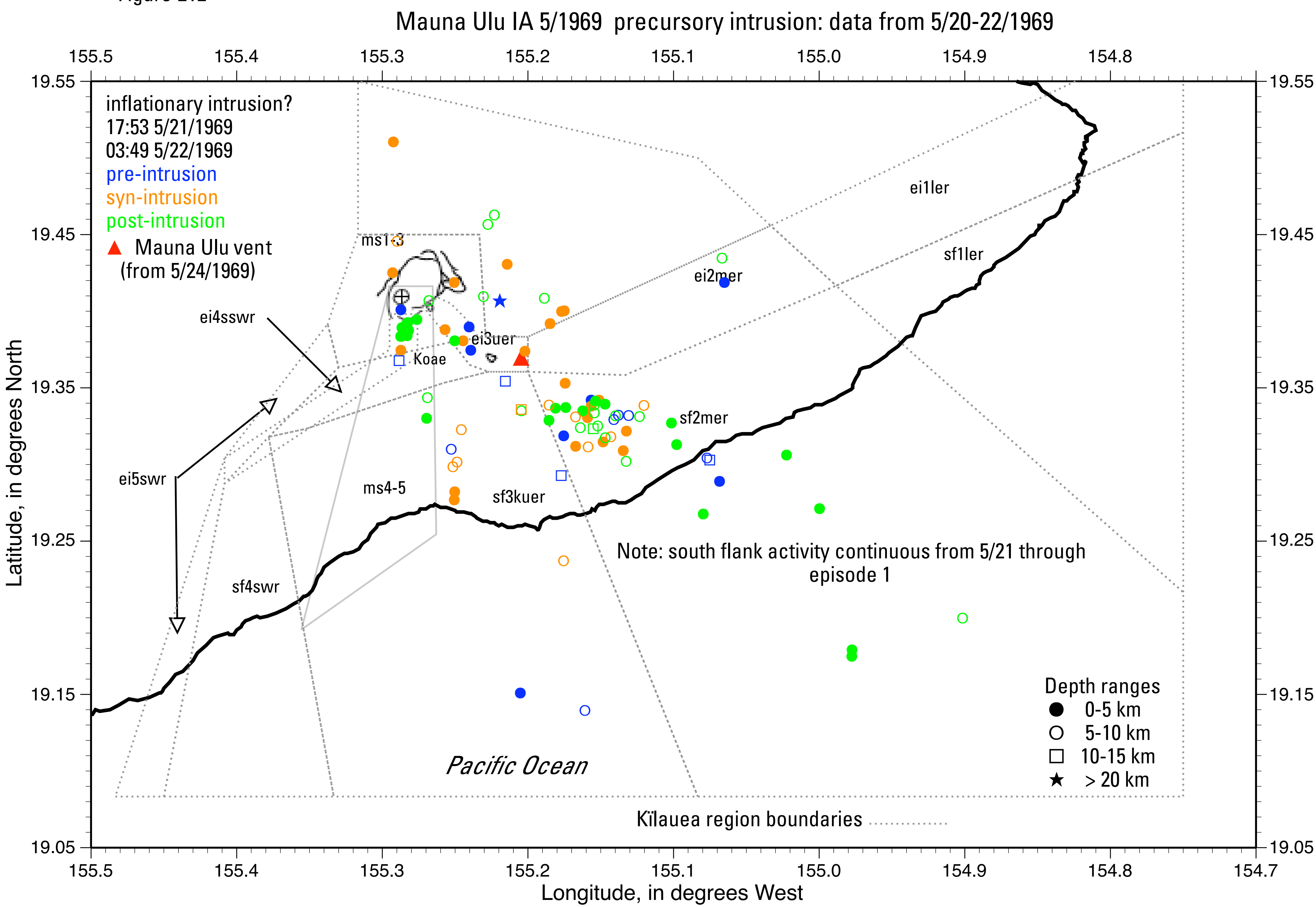
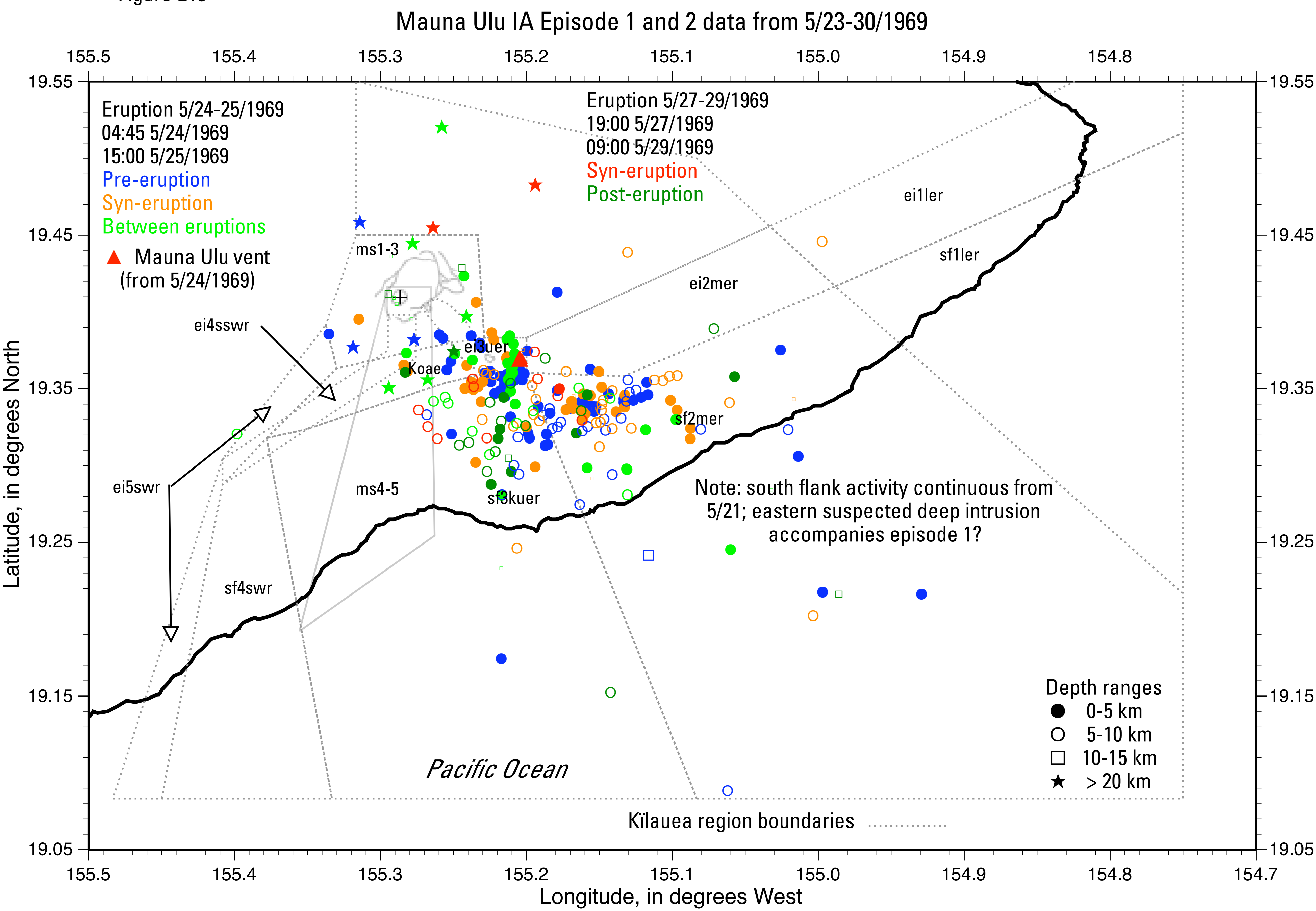


Figure E12



Mauna Ulu IA 5/1969 precursory intrusion: data from 5/20-22/1969
inflationary intrusion?
17:53 5/21/1969
03:49 5/22/1969
pre-intrusion
syn-intrusion
post-intrusion
Mauna Ulu vent
(from 5/24/1969)
Latitude, in degrees North
Longitude, in degrees West
155.5
155.4
155.3
155.2
155.1
155.0
154.9
154.8
154.7
19.55
19.45
19.35
19.25
19.15
19.05
ms1-3
ei1ler
sf1ler
ei2mer
ei3uer
Koae
ei4sswr
ei5swr
sf2mer
ms4-5
sf3kuer
sf4swr
Note: south flank activity continuous from 5/21 through episode 1
Pacific Ocean
Depth ranges
0-5 km
5-10 km
10-15 km
> 20 km
Kīlauea region boundaries

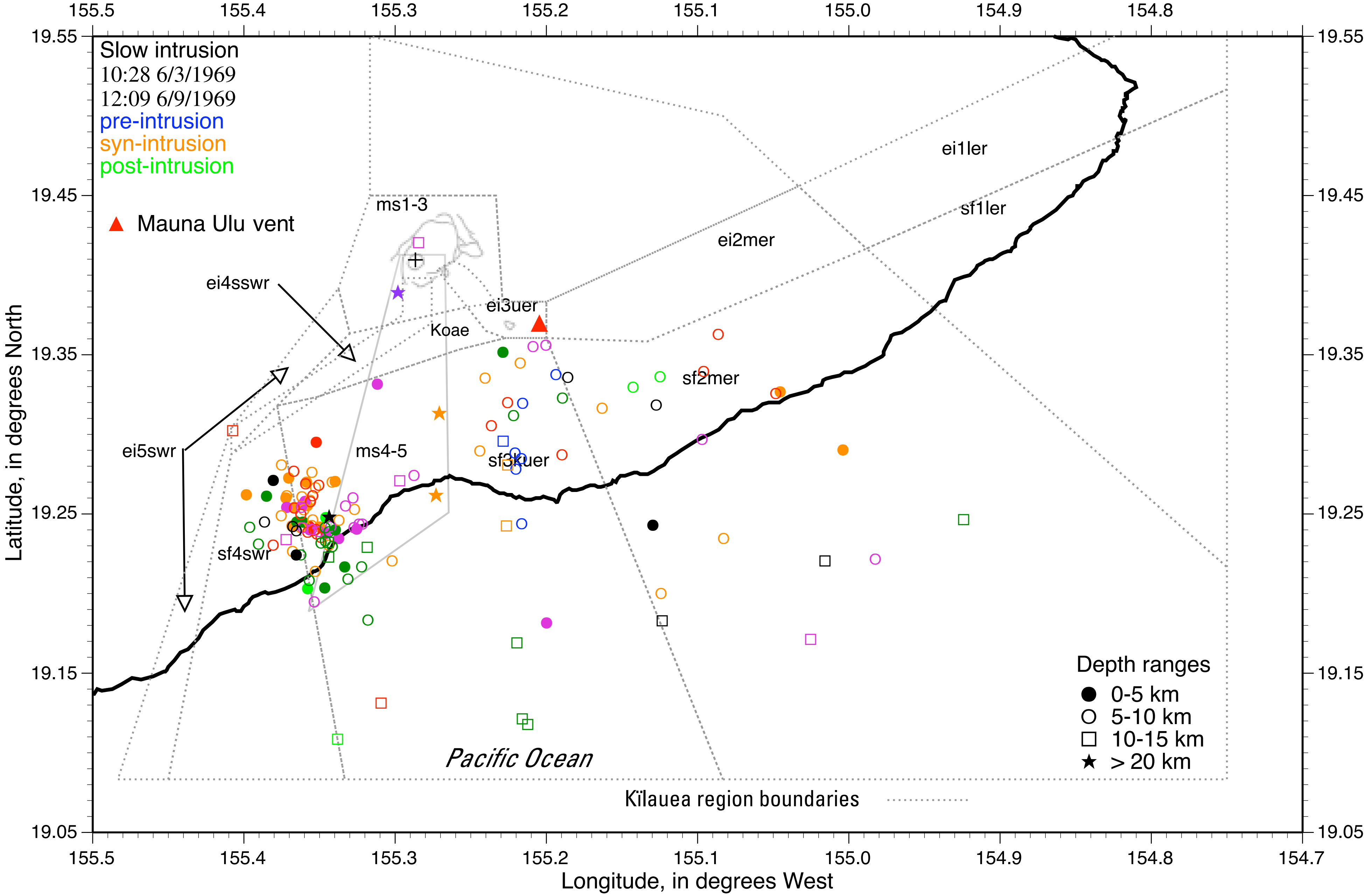
Figure E13



Mauna Ulu IA Episode 1 and 2 data from 5/23-30/1969
155.5
155.4
155.3
155.2
155.1
155.0
154.9
154.8
154.7
19.55
19.45
19.35
19.25
19.15
19.05
Eruption 5/24-25/1969
04:45 5/24/1969
15:00 5/25/1969
Pre-eruption
Syn-eruption
Between eruptions
Mauna Ulu vent
(from 5/24/1969)
Eruption 5/27-29/1969
19:00 5/27/1969
09:00 5/29/1969
Syn-eruption
Post-eruption
ei1ler
sf1ler
ei2mer
ms1-3
ei4sswr
ei3uer
Koae
sf2mer
ei5swr
ms4-5
sf3kuer
sf4swr
Note: south flank activity continuous from
5/21; eastern suspected deep intrusion
accompanies episode 1?
Pacific Ocean
Depth ranges
0-5 km
5-10 km
10-15 km
> 20 km
Kīlauea region boundaries
Latitude, in degrees North
Longitude, in degrees West

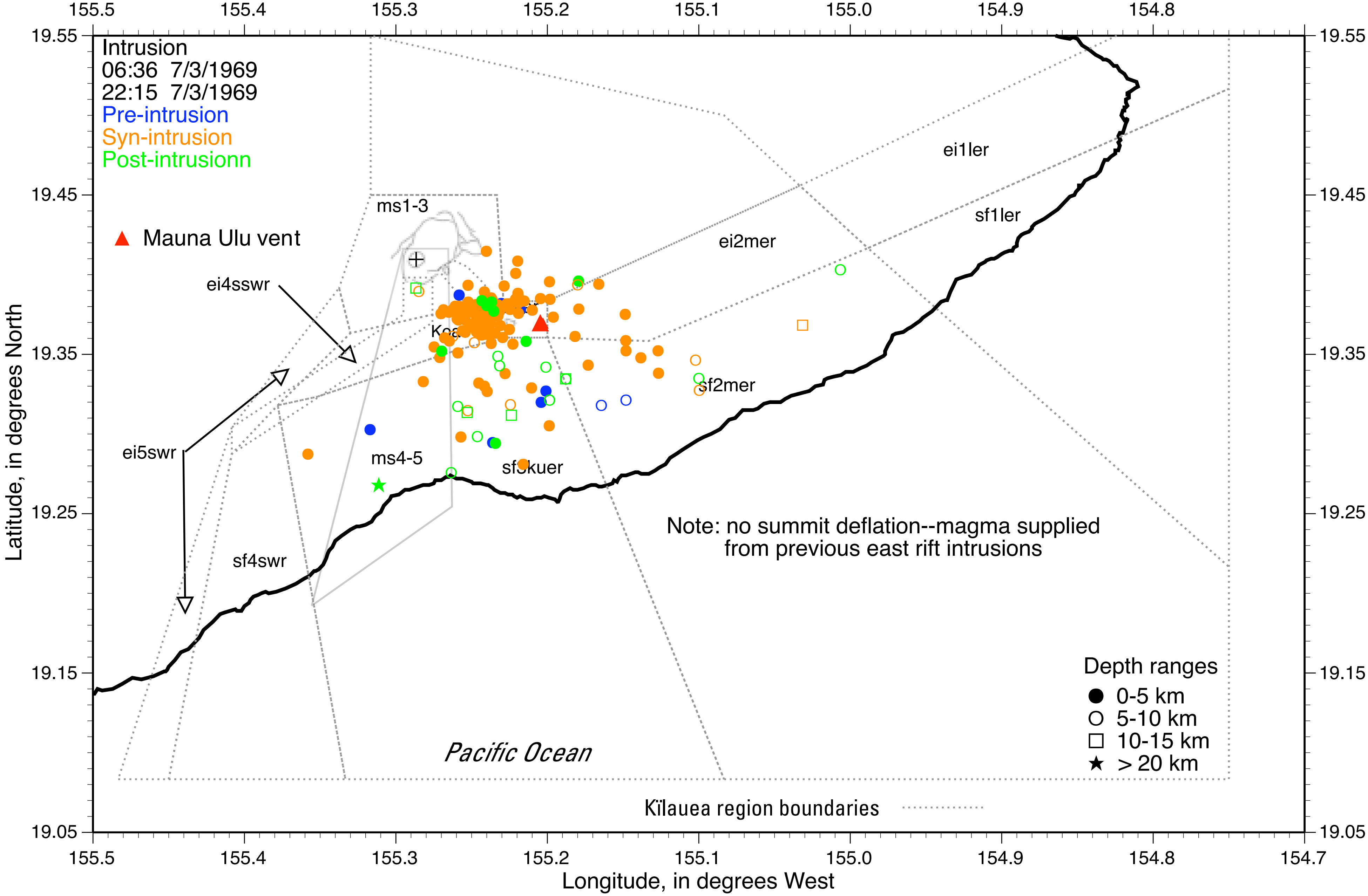
Appendix Figure E14

Mauna Ulu IA 6/1969 suspected deep intrusion: data from 6/2-10/1969



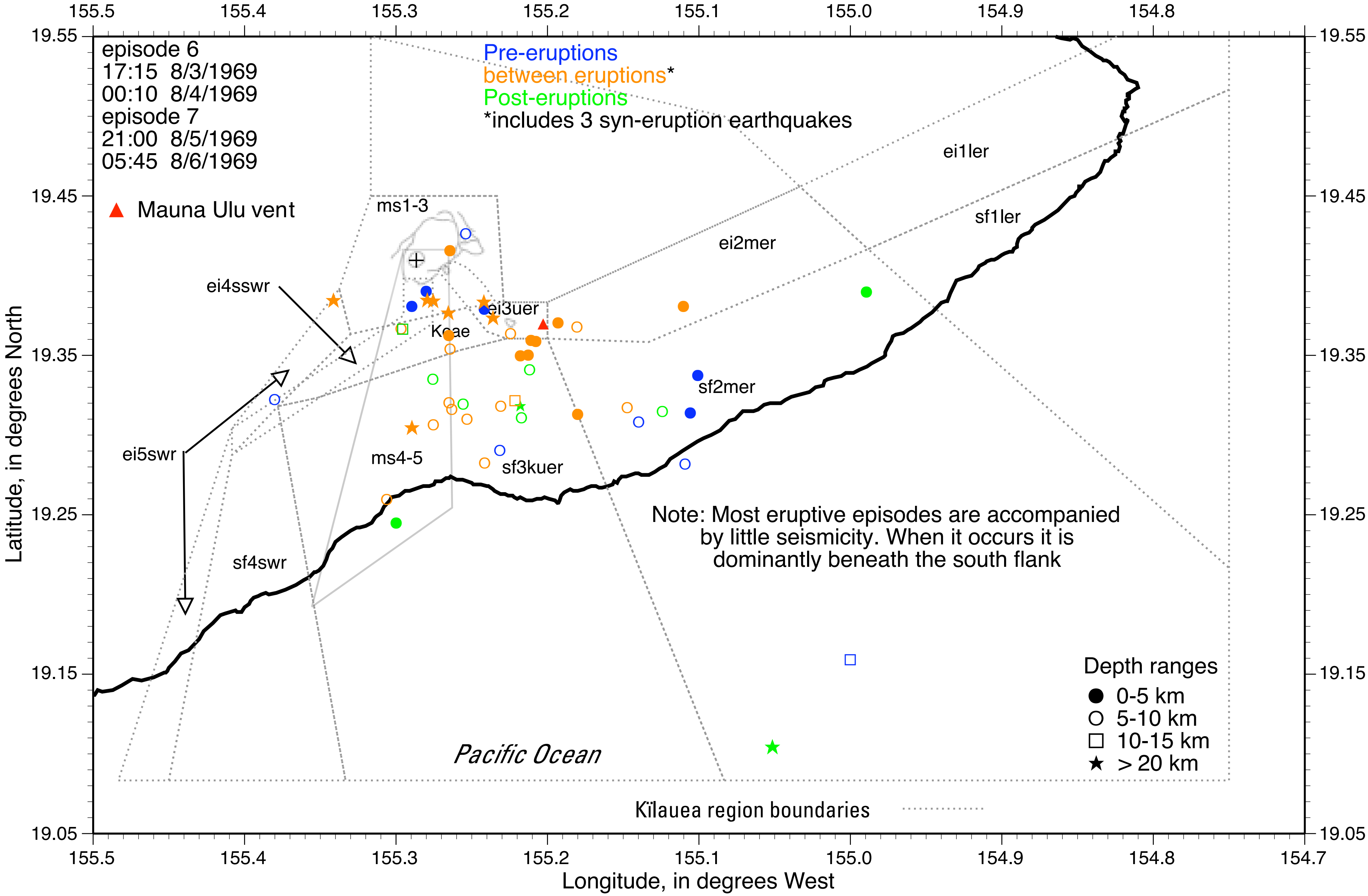
Appendix Figure E15

Mauna Ulu IA Intrusion 7/3/1969: data from 7/2-5/1969



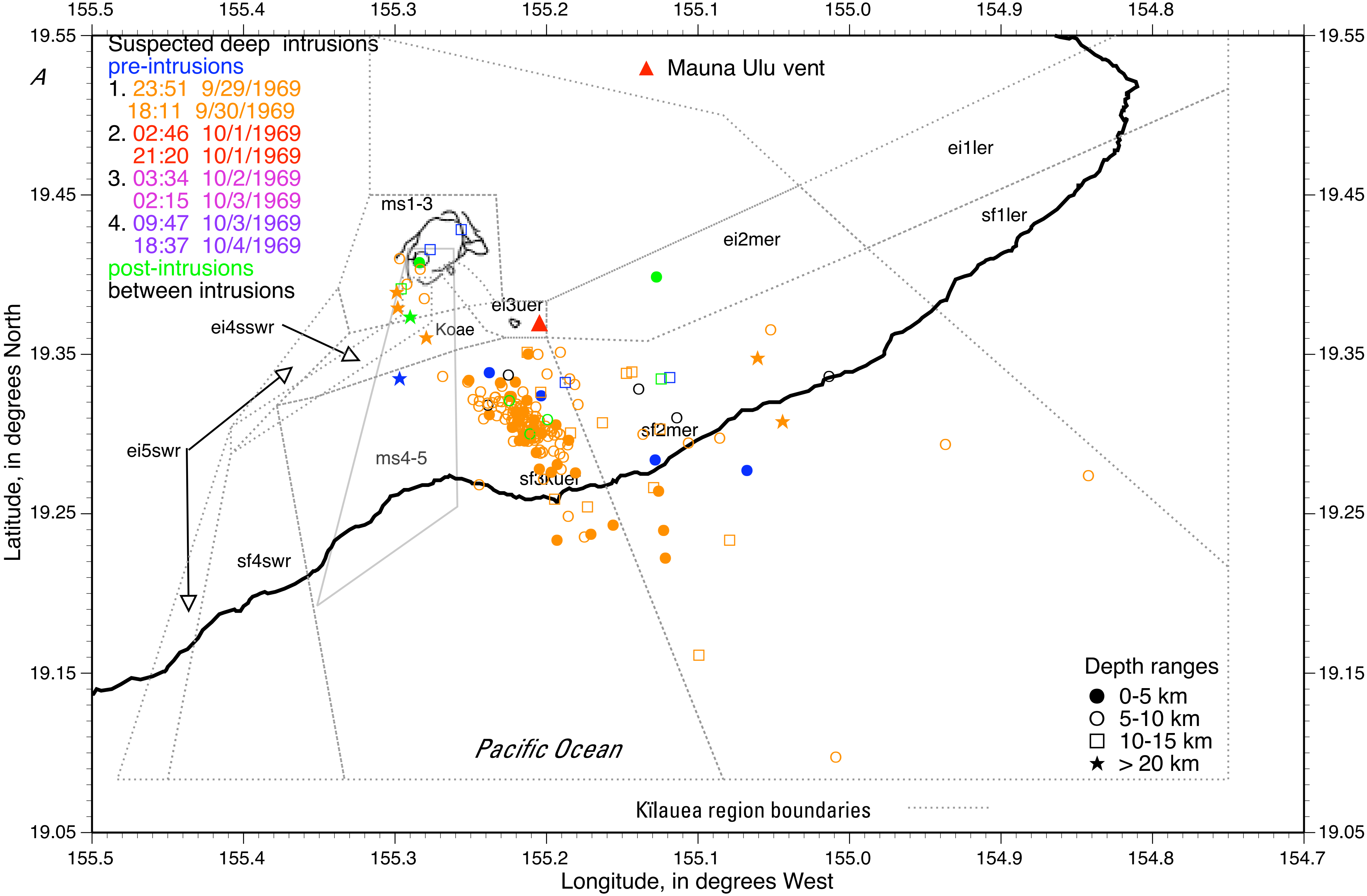
Appendix Figure E16

Mauna Ulu IA episodes 6-7: data from 8/1-7/1969



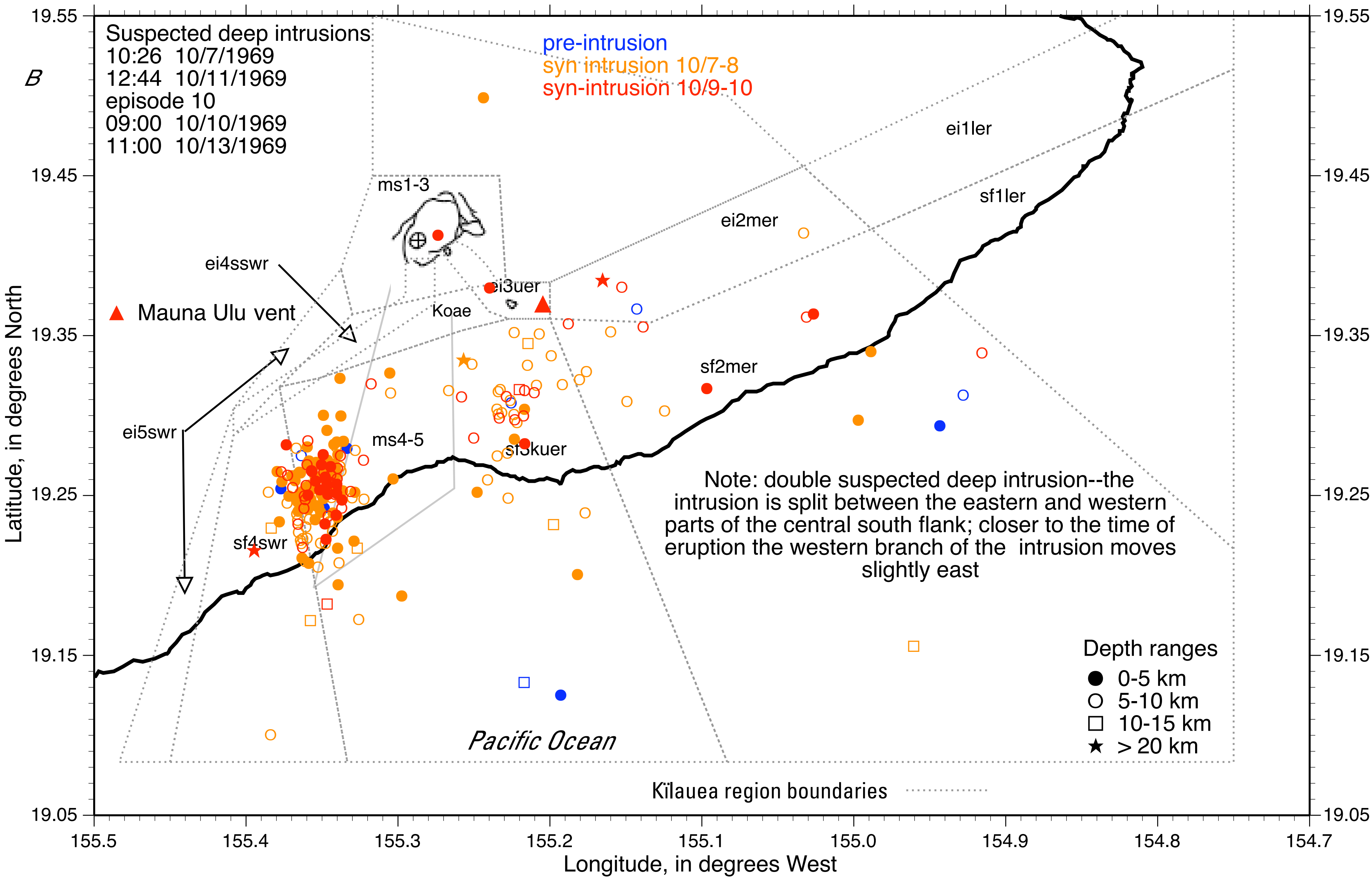
Appendix Figure E17a

Mauna Ulu IA Suspected deep intrusions 10/1969: data from 9/28-10/5/1969



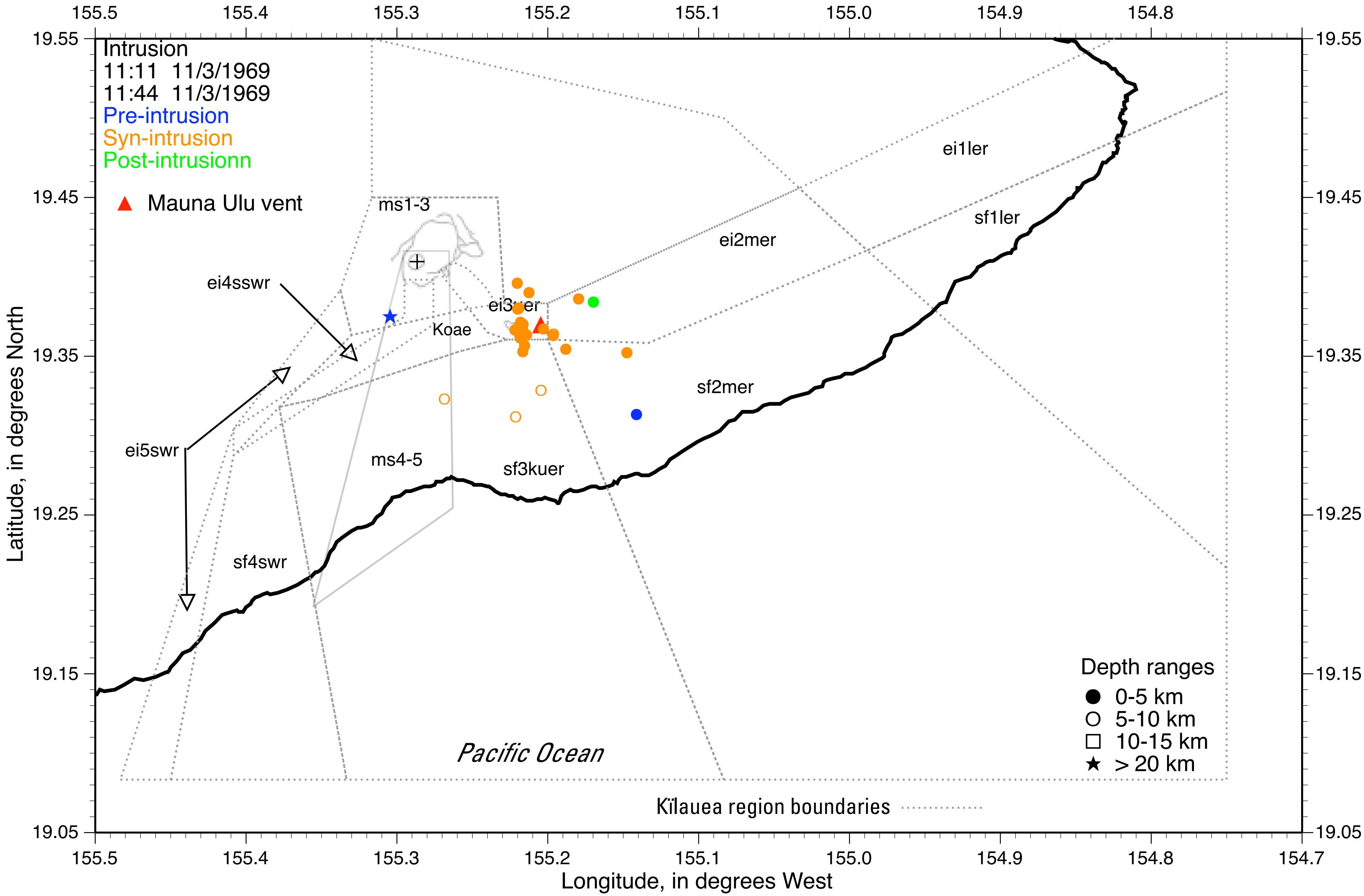
Appendix Figure E17b

Mauna Ulu IA Suspected deep intrusion/pre-episode 10 by date: data from 10/6-10/1969



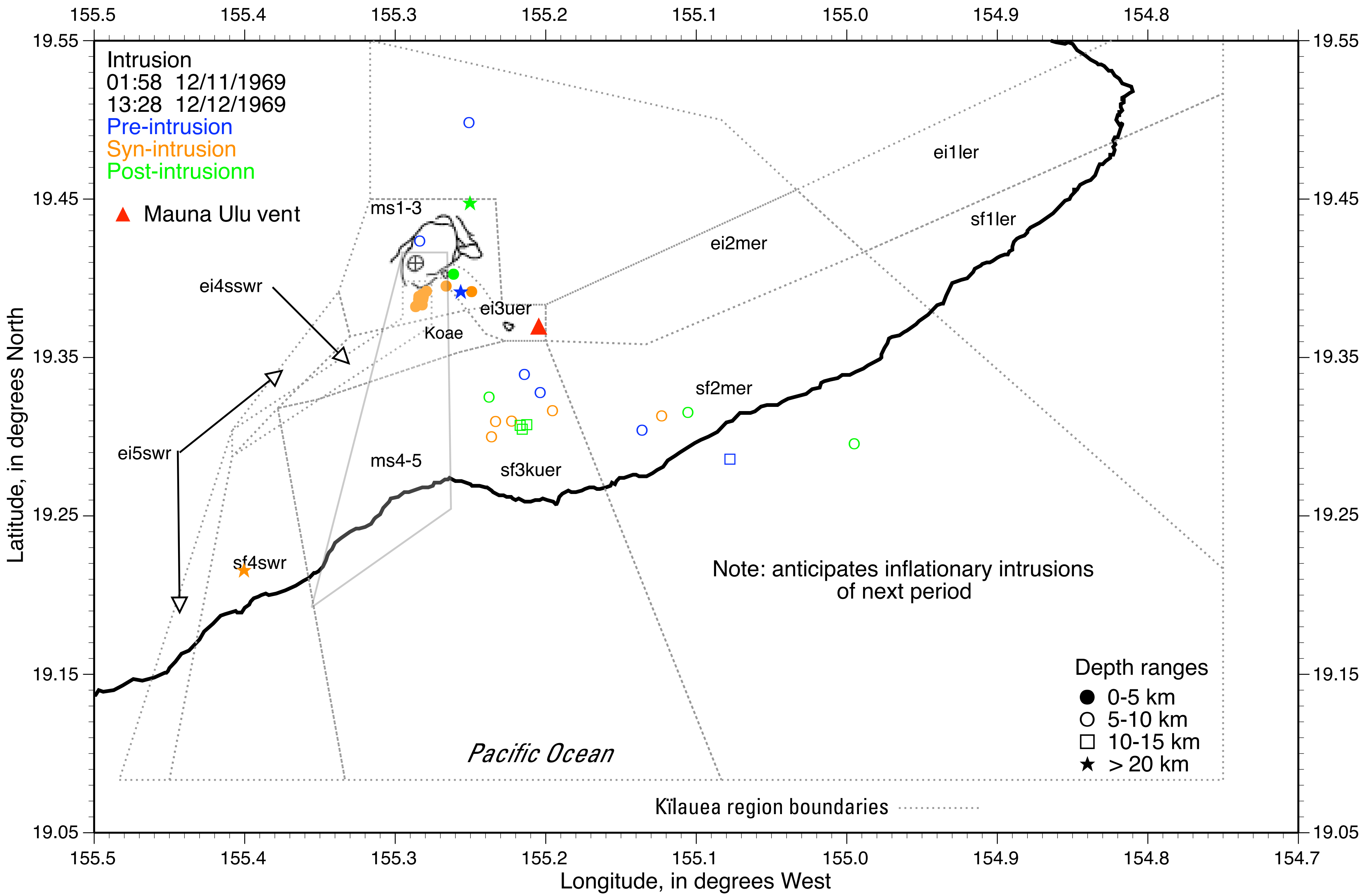
Appendix Figure E18

Mauna Ulu IA Intrusion 11/3-4/1969: data from 10/27-11/6/1969



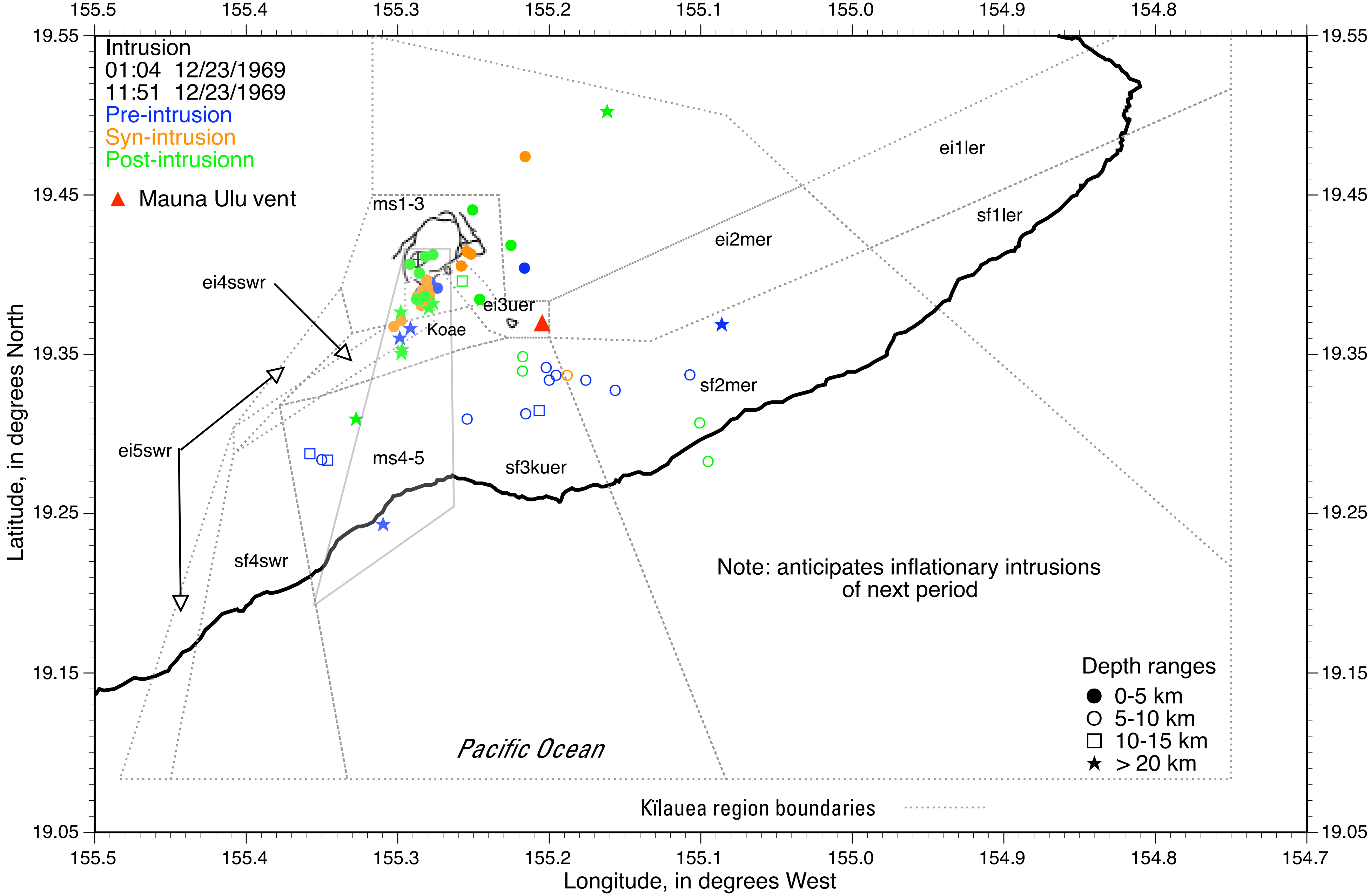
Appendix Figure E19

Seismic precursors to end of Mauna Ulu IA: data from 12/10-13/1969



Appendix Figure E20

Seismic precursors to end of Mauna Ulu IA: data from 12/20-251969



Appendix Figure E21

Seismic precursors to end of Mauna Ulu IA. Suspected deep intrusion: data from 12/26-29/1969

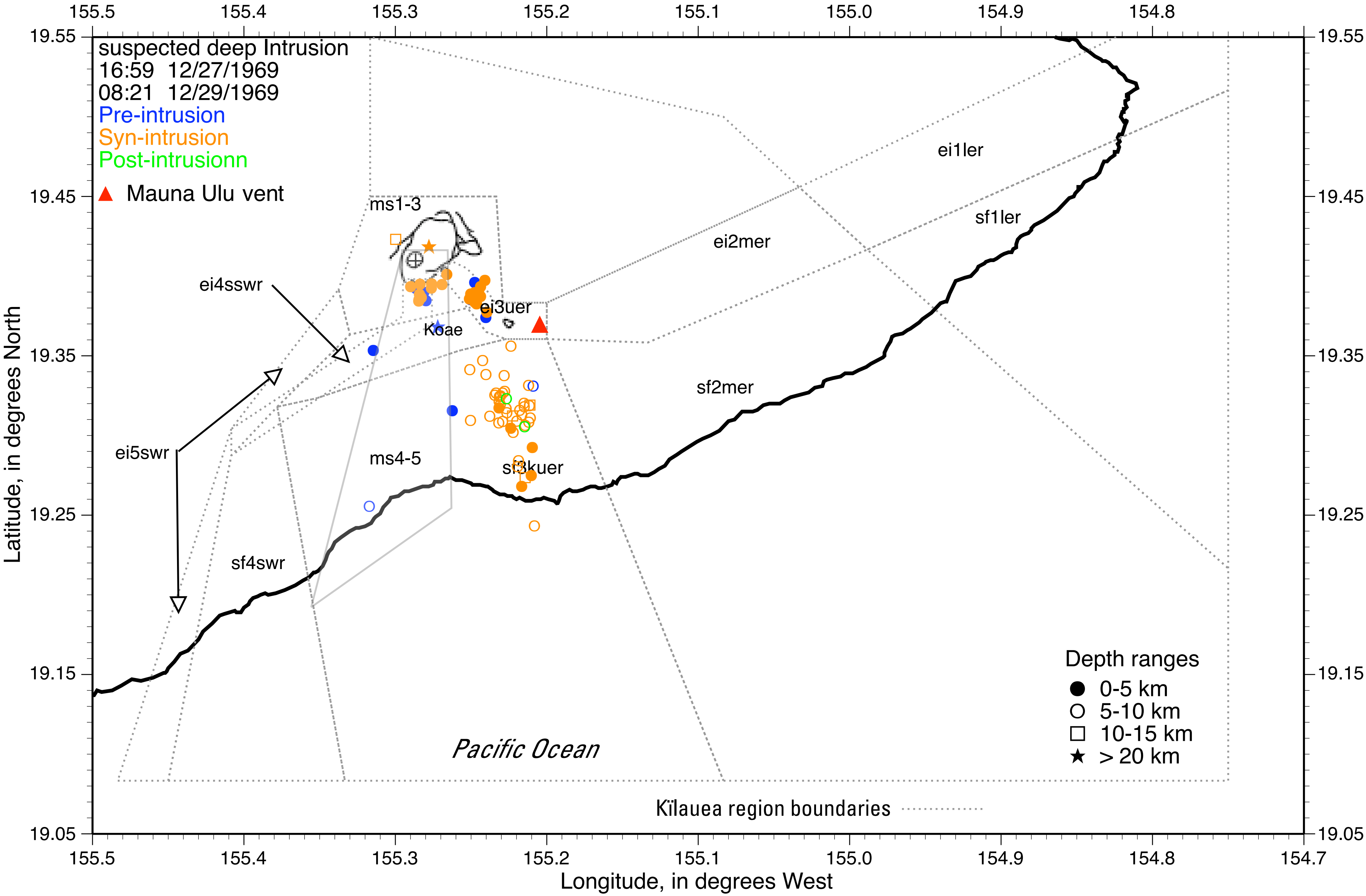
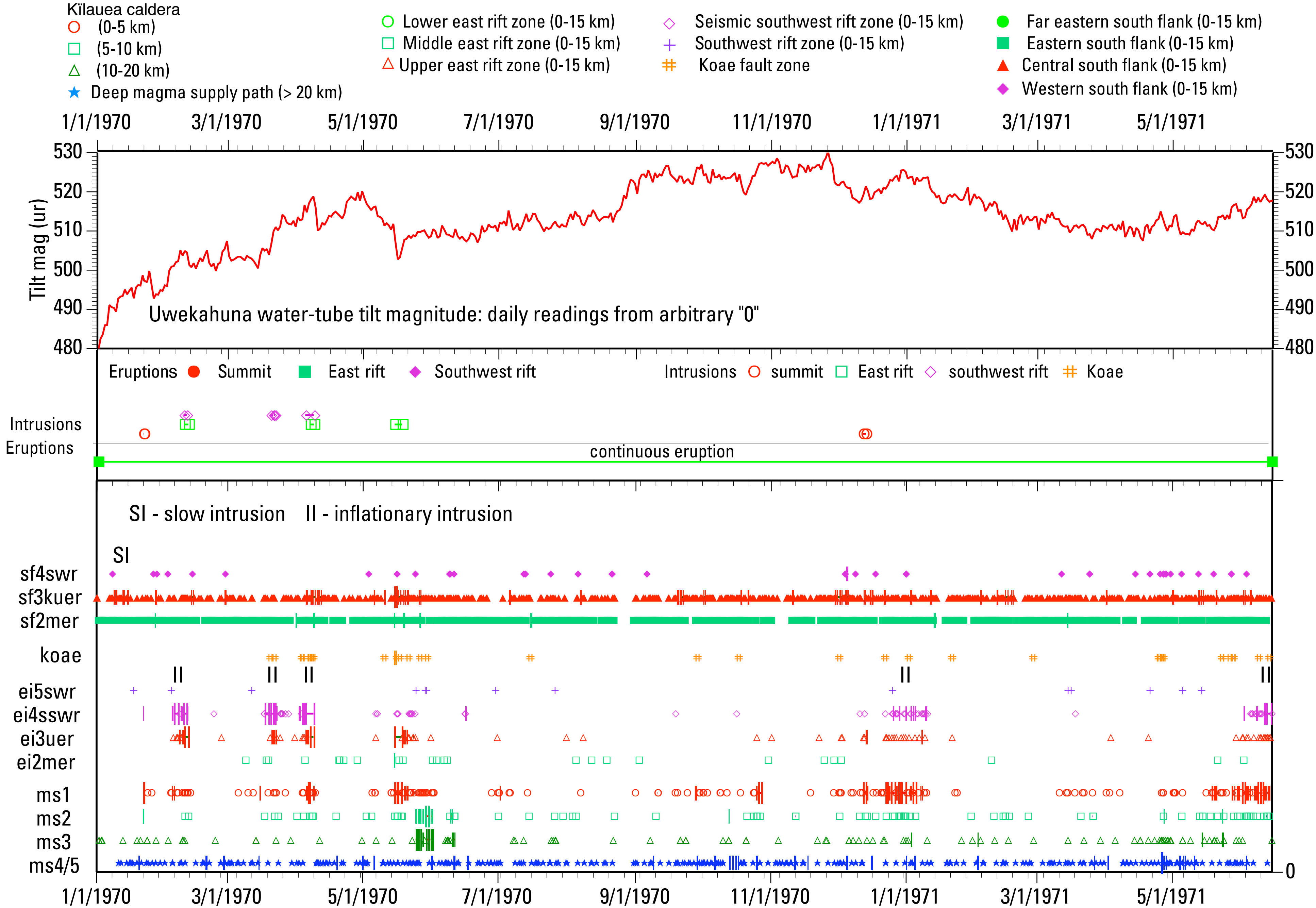
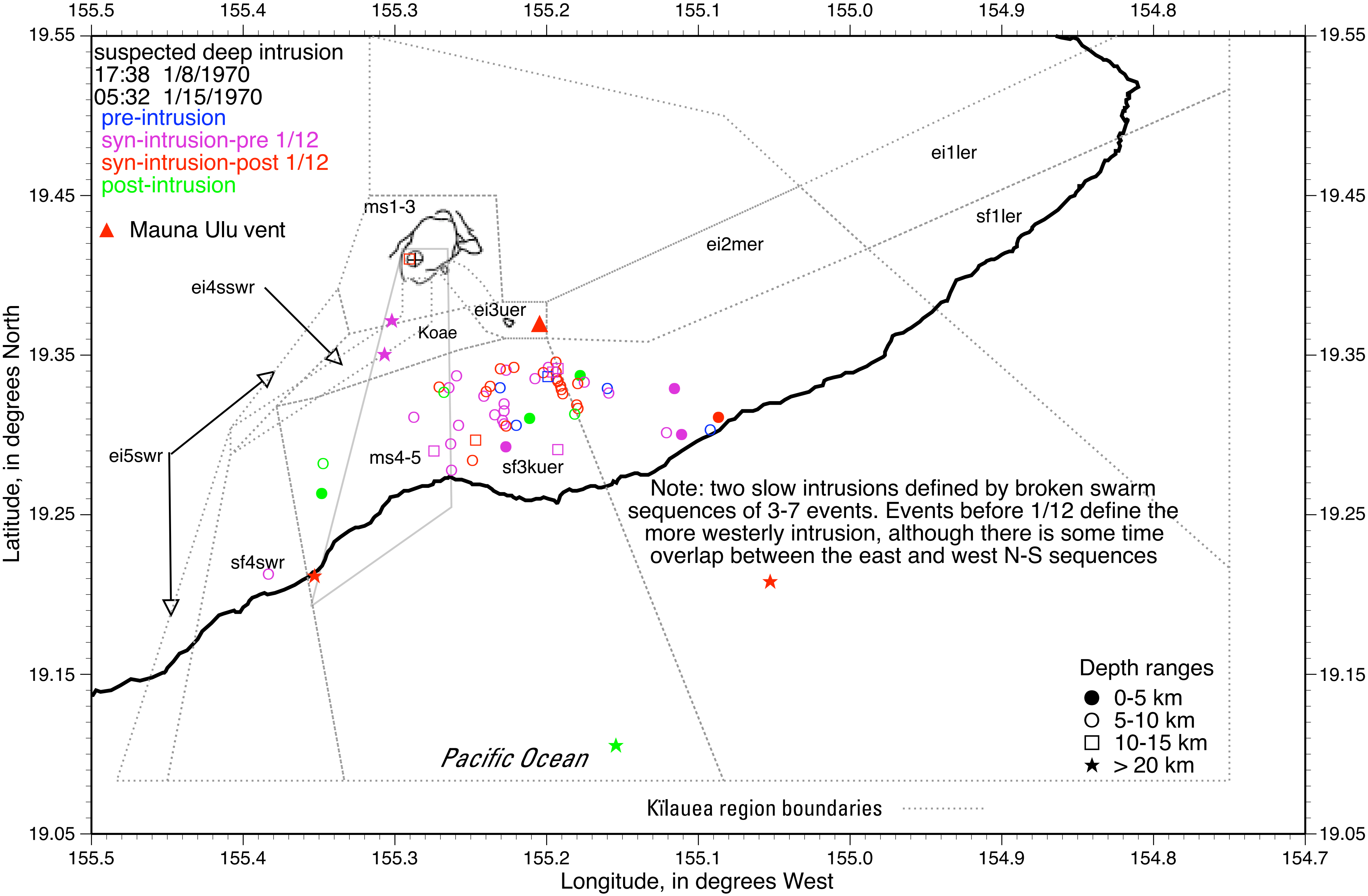


Figure E22. Mauna Ulu IB earthquake swarms and tilt



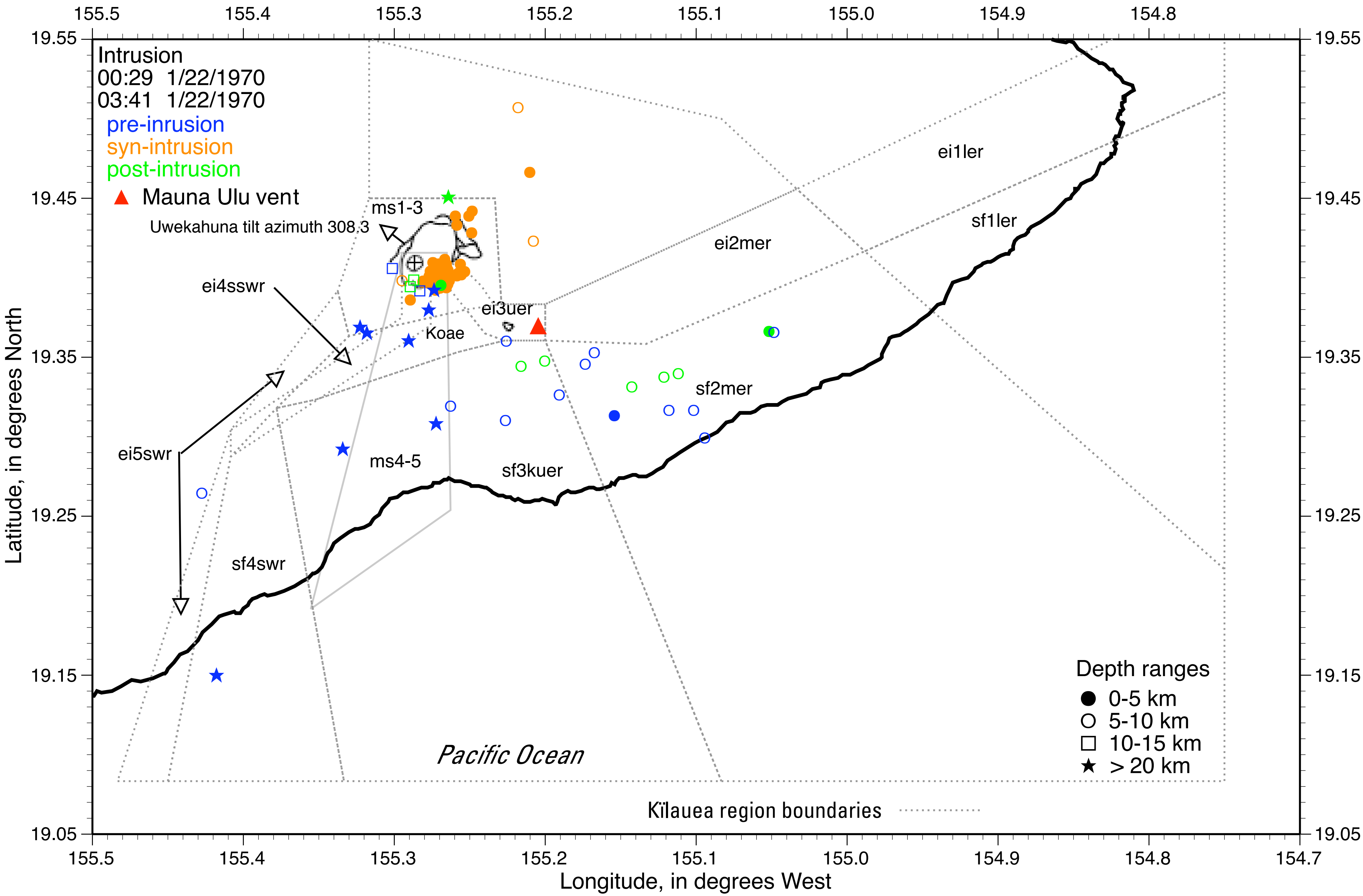
Appendix Figure E23

Mauna Ulu IB 1/1970 suspected deep intrusion: data from 1/7-15/1970



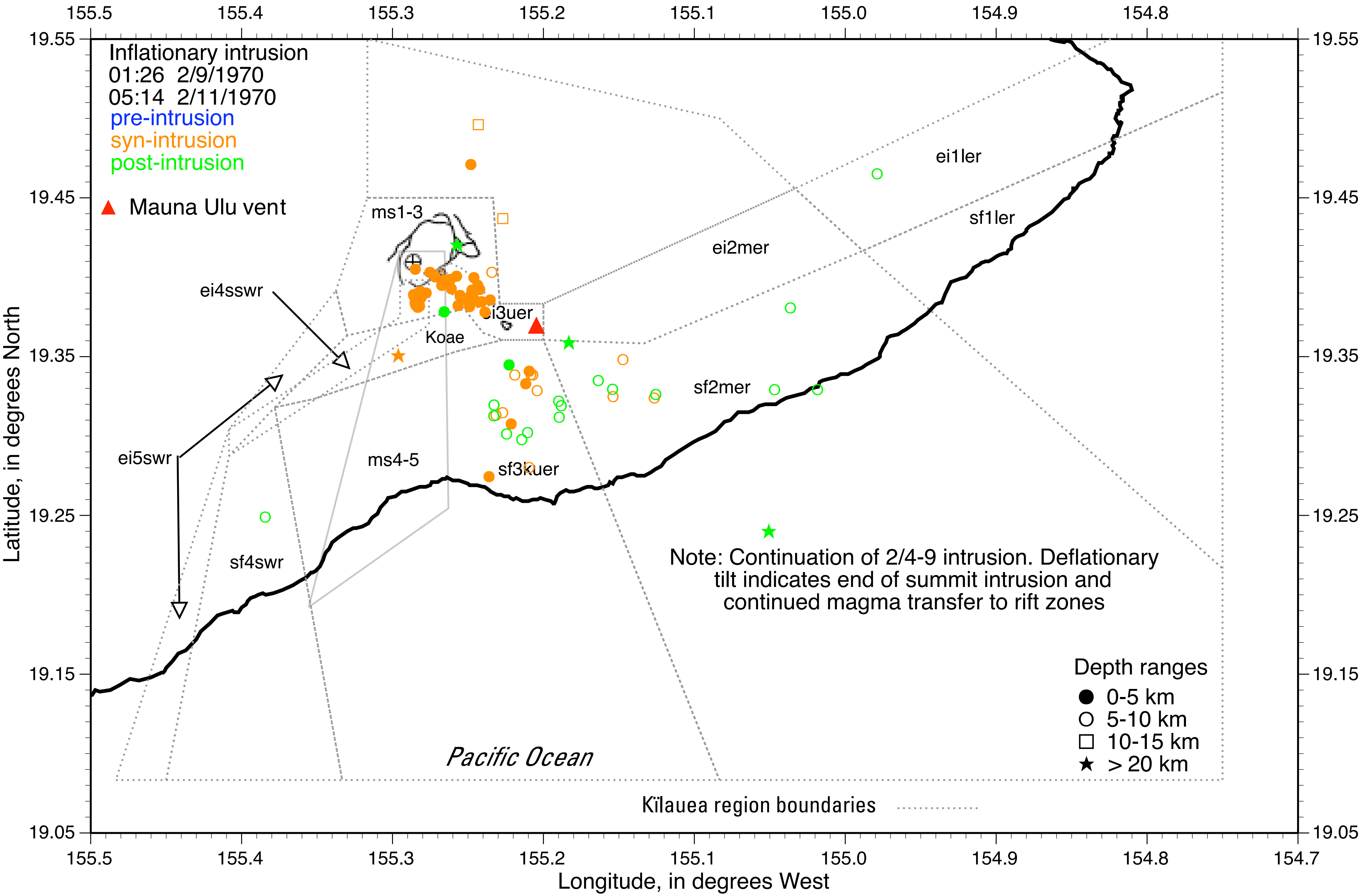
Appendix Figure E24

Mauna Ulu IB 1/1970 intrusion: data from 1/16-23/1970



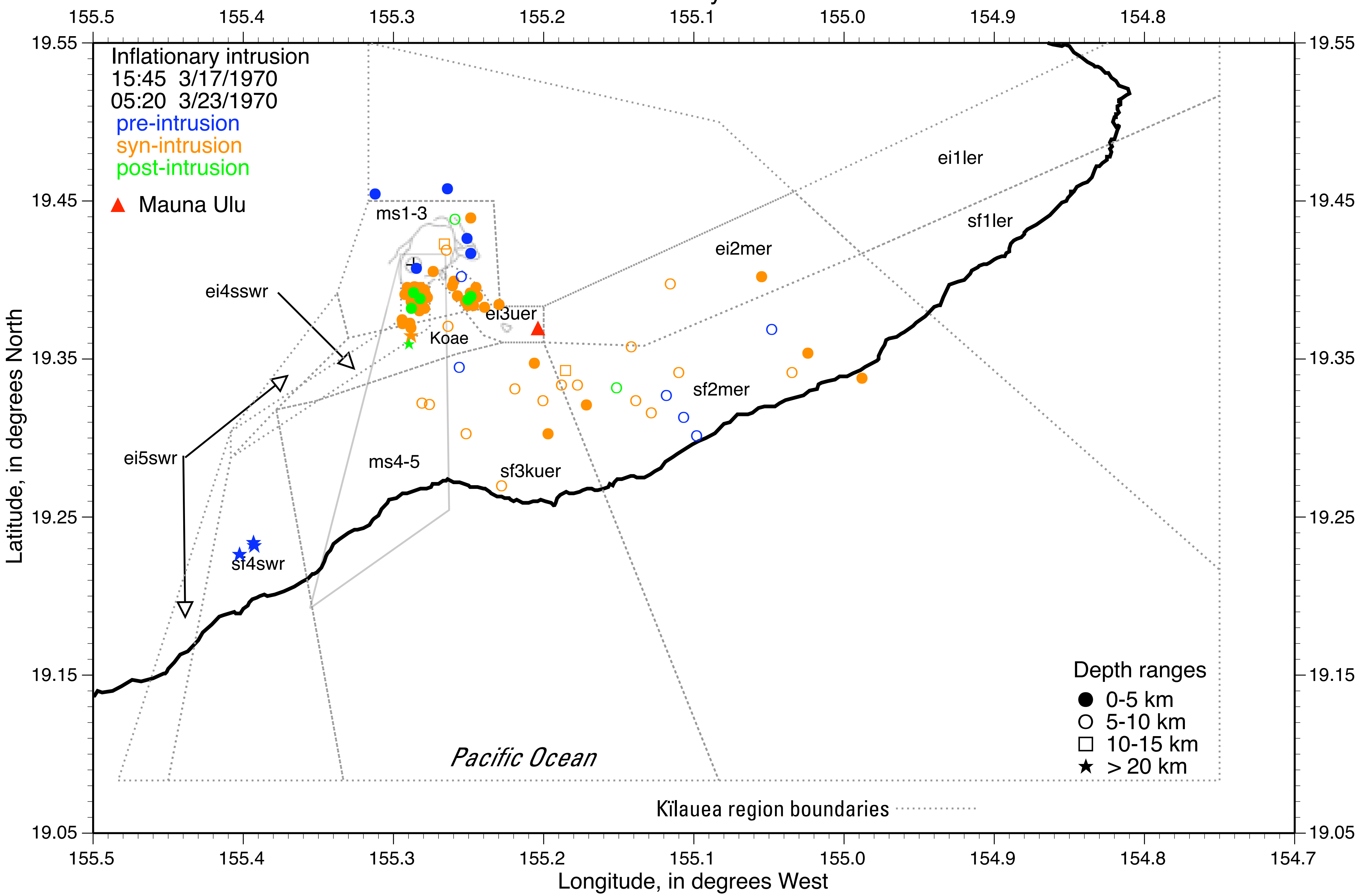
Appendix Figure E25

Mauna Ulu IB 2/1970 inflationary intrusion: data from 2/9-15/1970



Appendix Figure E26

Mauna Ulu IB 3/1970 inflationary intrusion: data from3/15-24/1970



Appendix Figure E27

Mauna Ulu IB 4/1970 inflationary intrusion: data from 4/2-11/1970

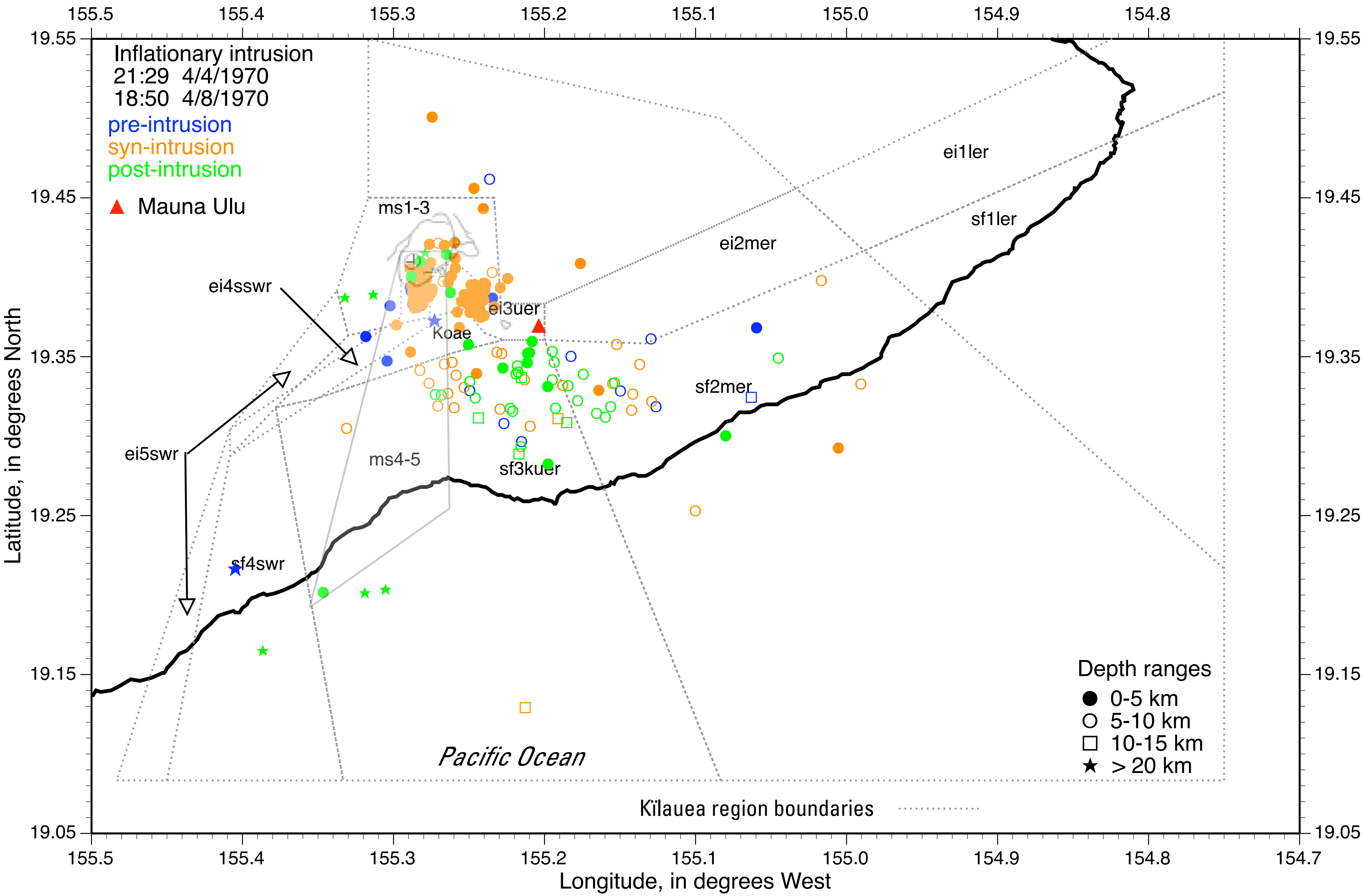
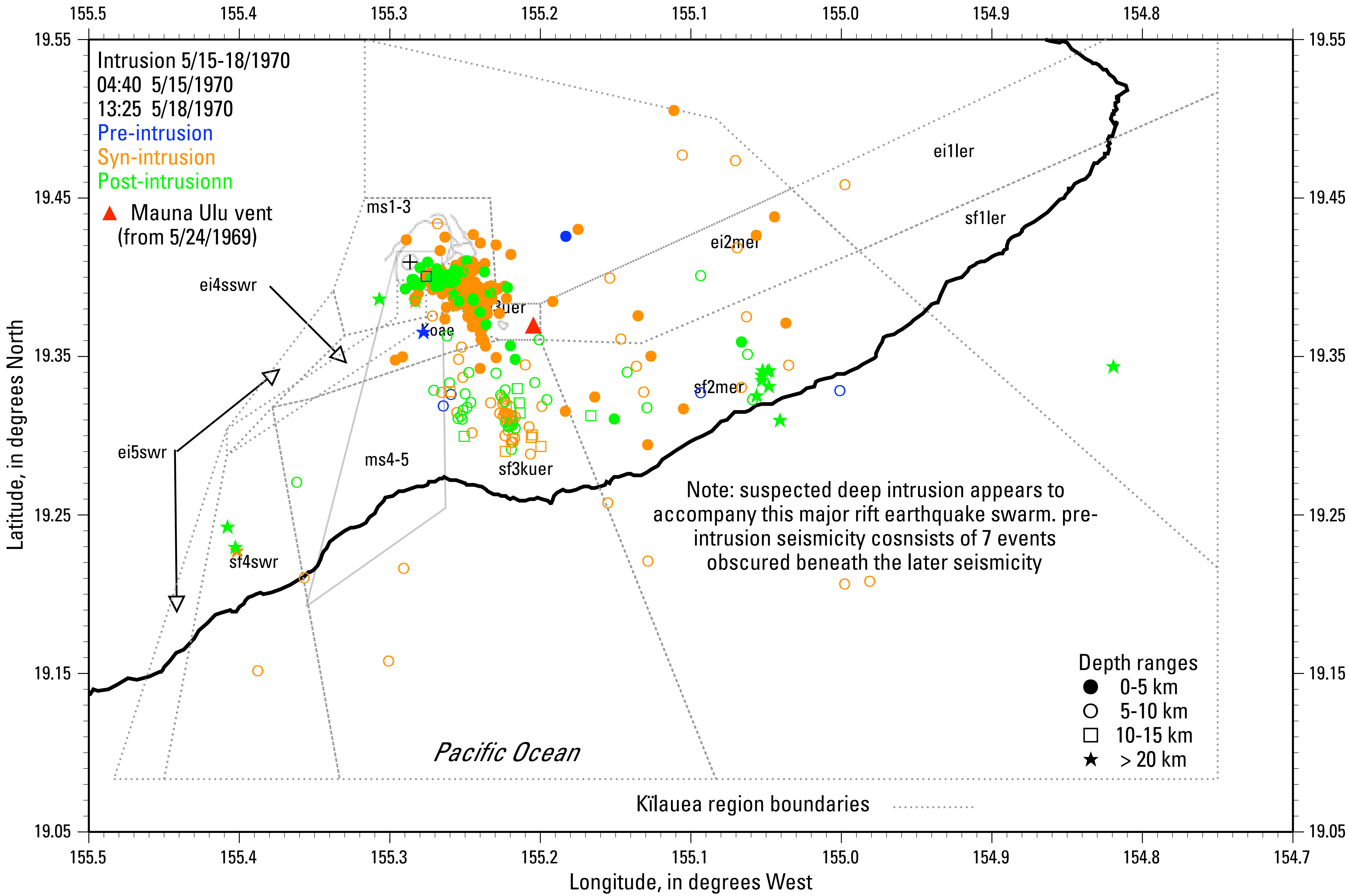


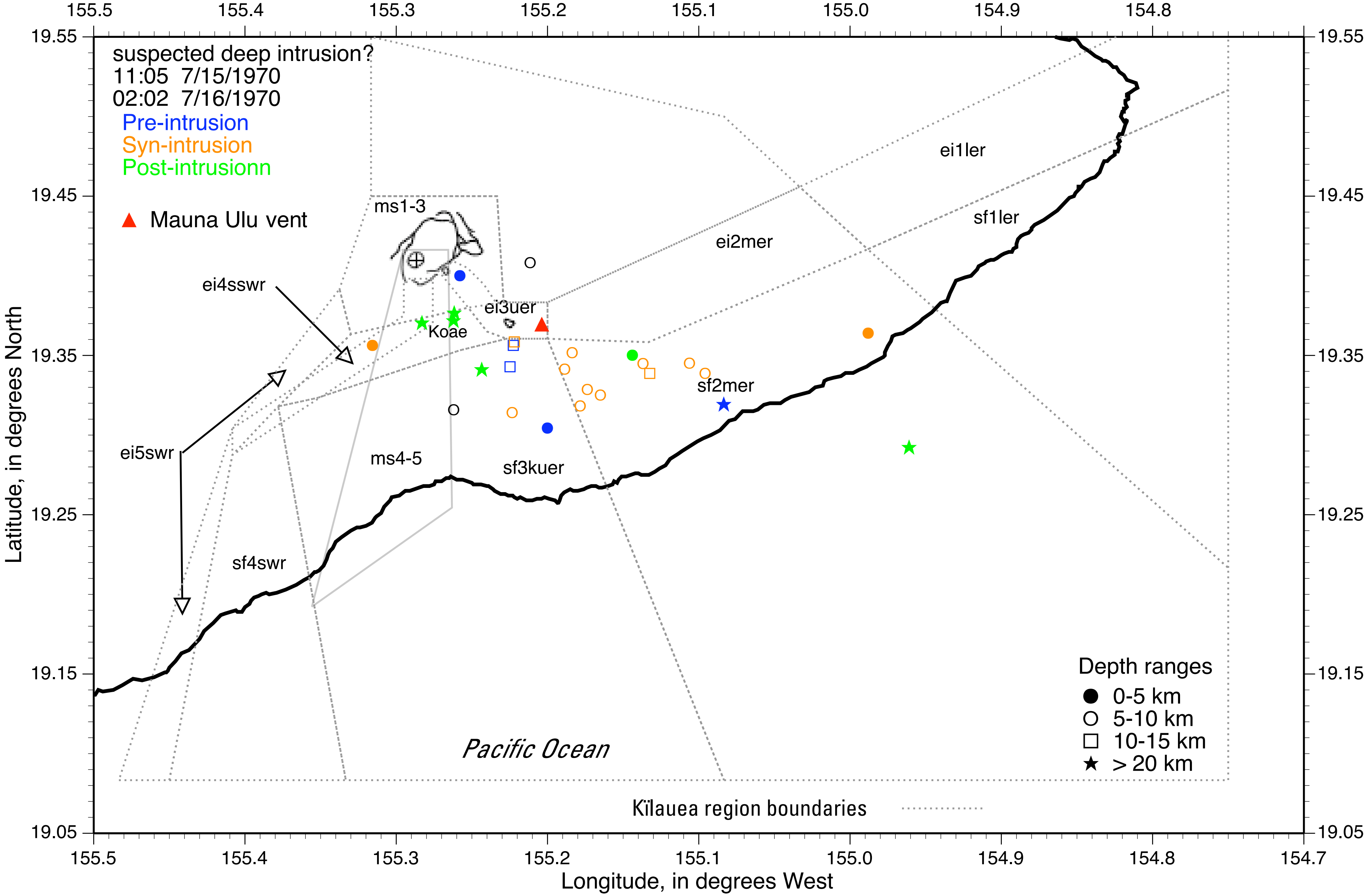
Figure E28

Mauna Ulu IB May 1970 intrusion: data from 5/14-22/1970



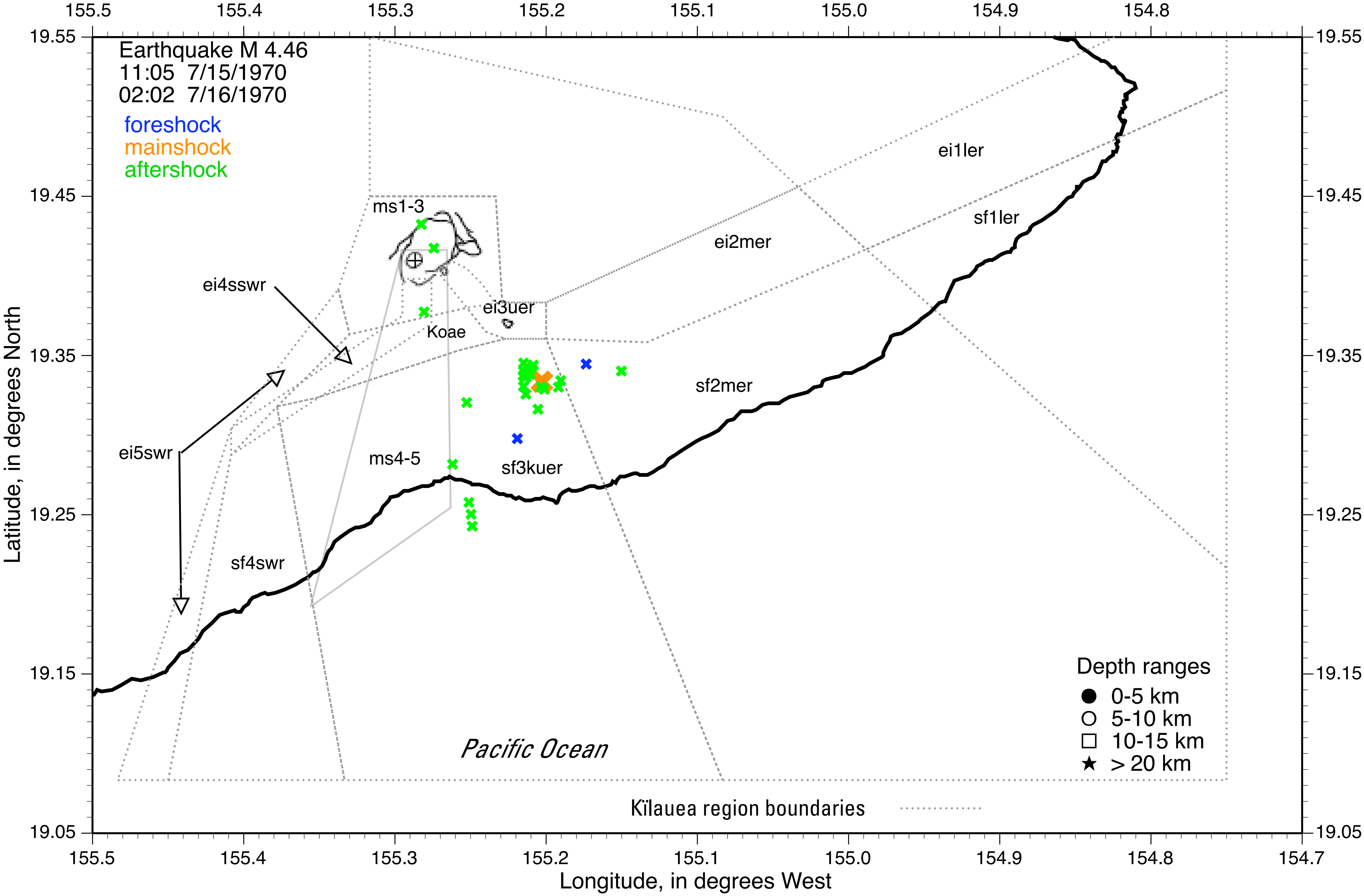
Appendix Figure E29

Mauna Ulu IB suspected deep intrusion?: data from 7/8-15/1970



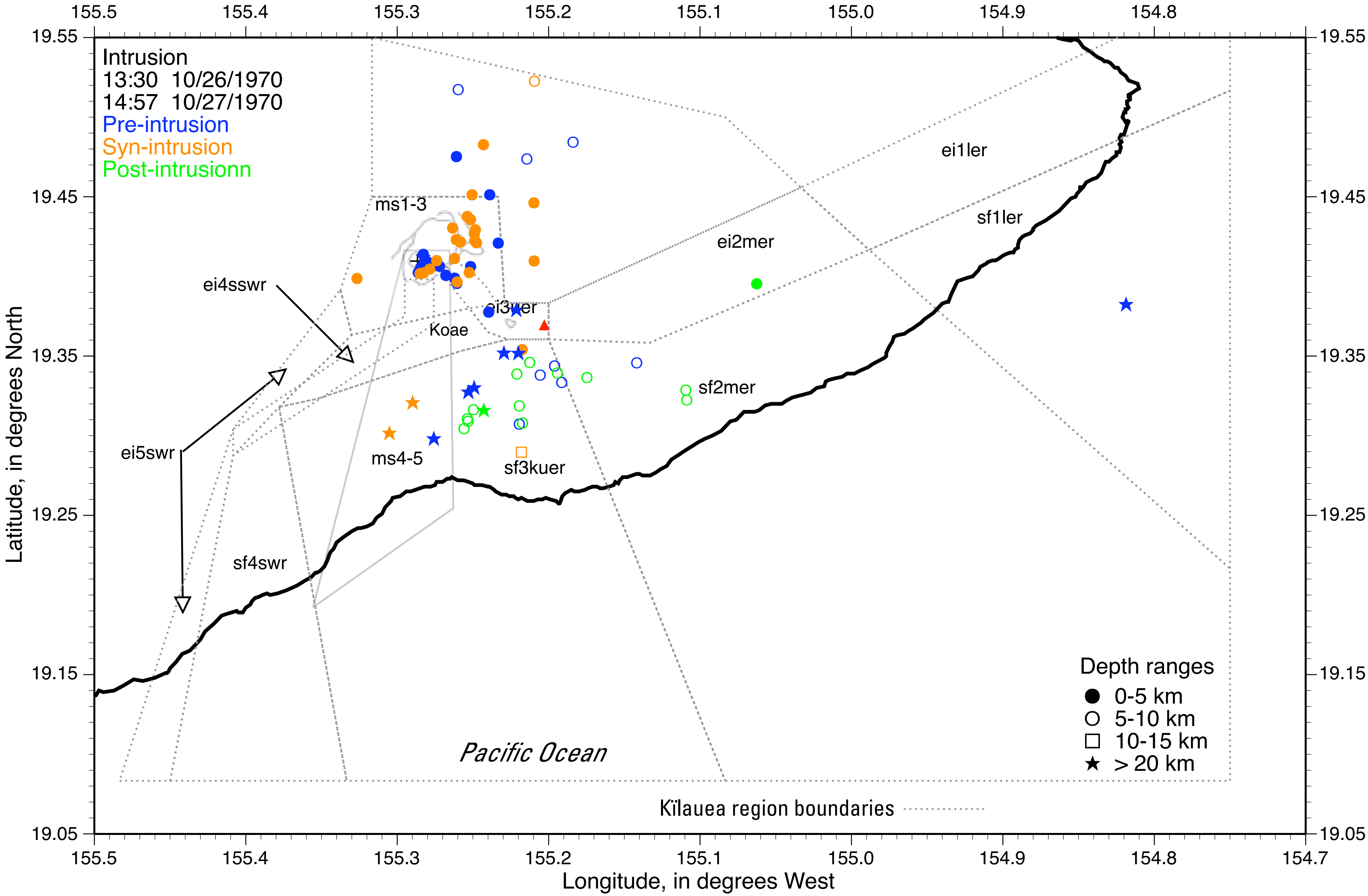
Appendix Figure E30

Mauna Ulu IB South flank earthquake: data from 9/20-22/1970



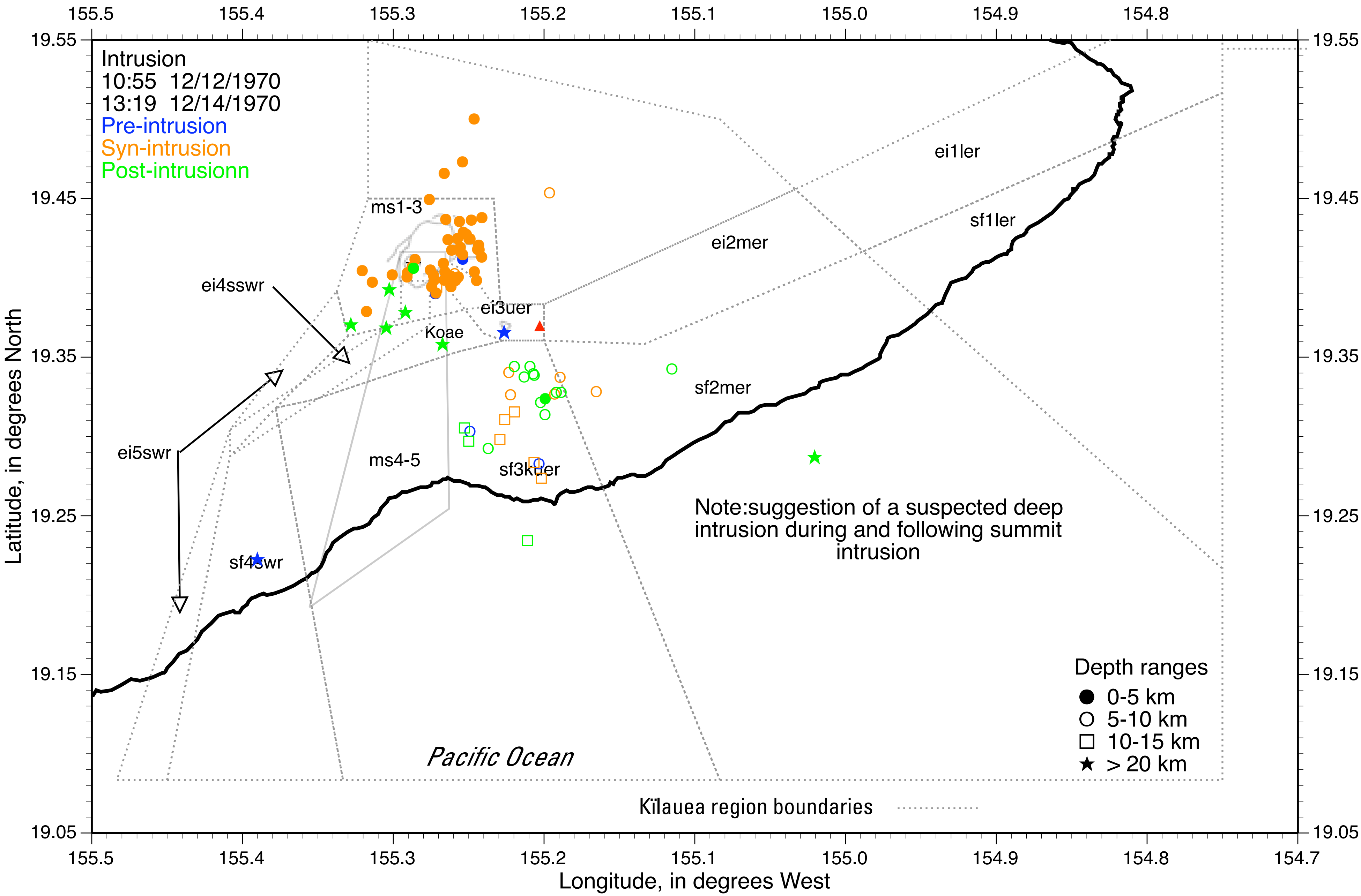
Appendix Figure E31

Mauna Ulu IB October 1970 intrusion: data from 10/23-31/1970



Appendix Figure E32

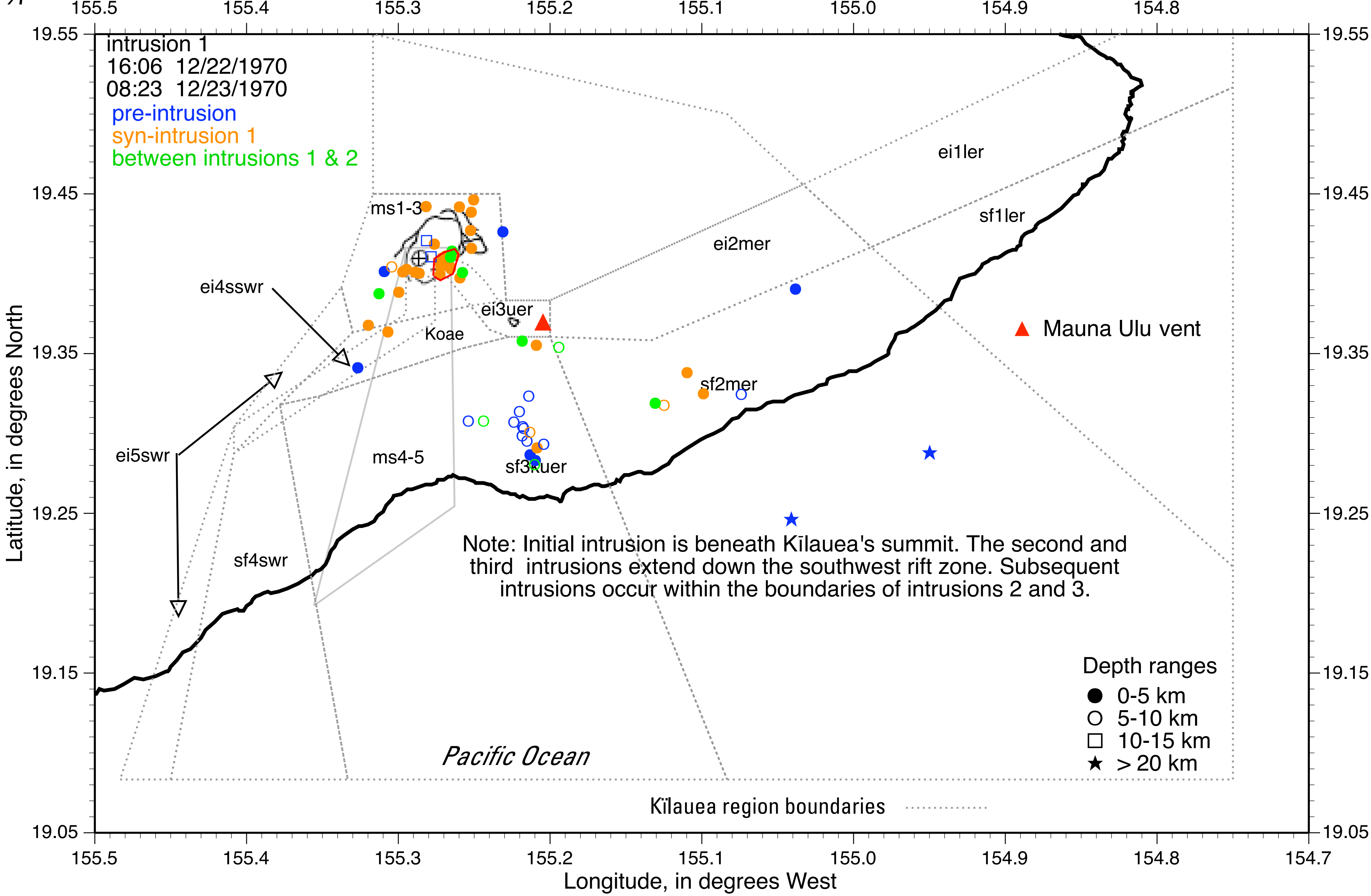
Mauna Ulu IB December 1970 intrusion: data from 12/11-16/1970



Appendix Figure E33a

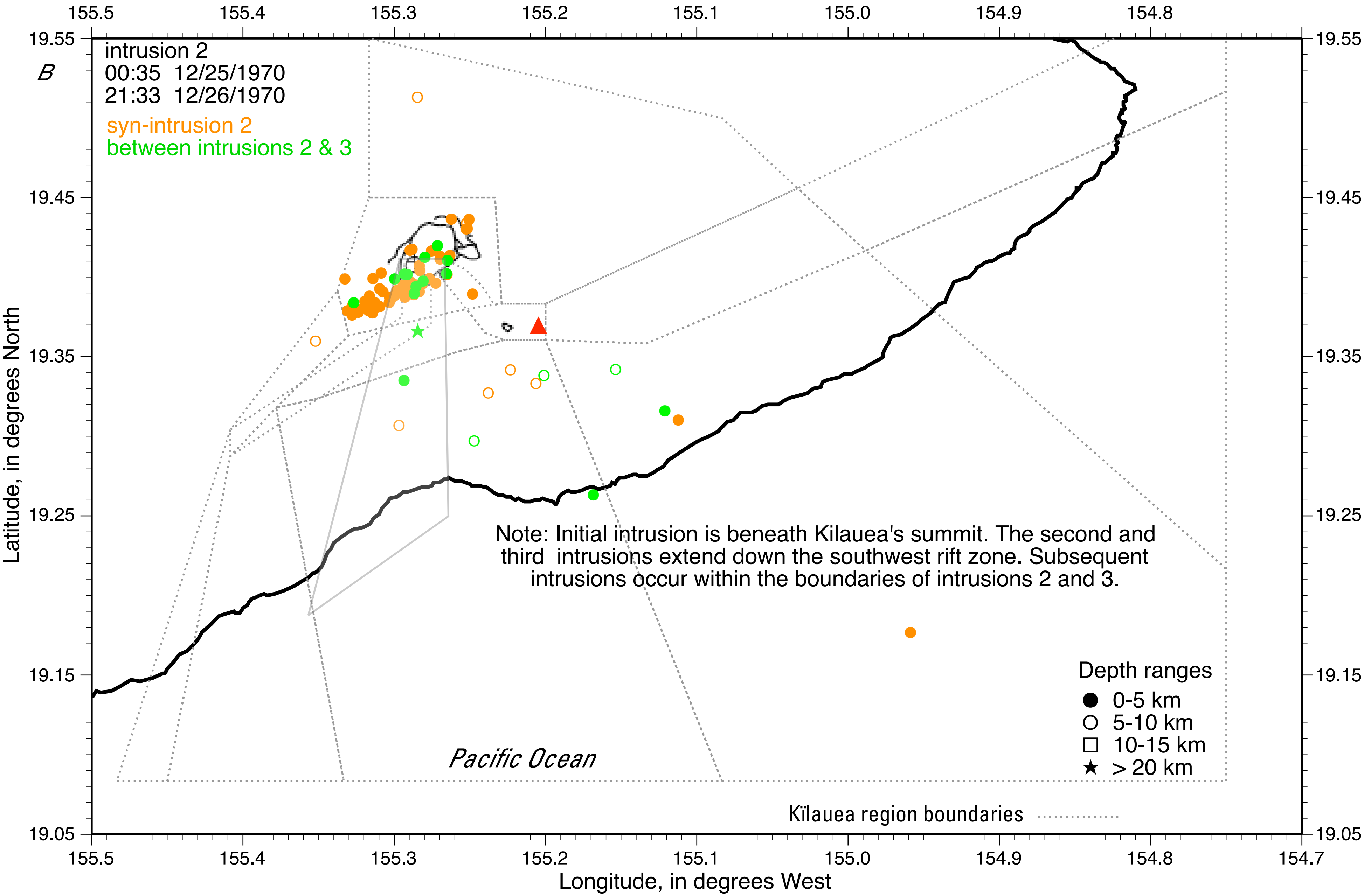
Mauna Ulu IB 12/1970-1/1971 inflationary intrusions: data from 12/21-23/1970

A



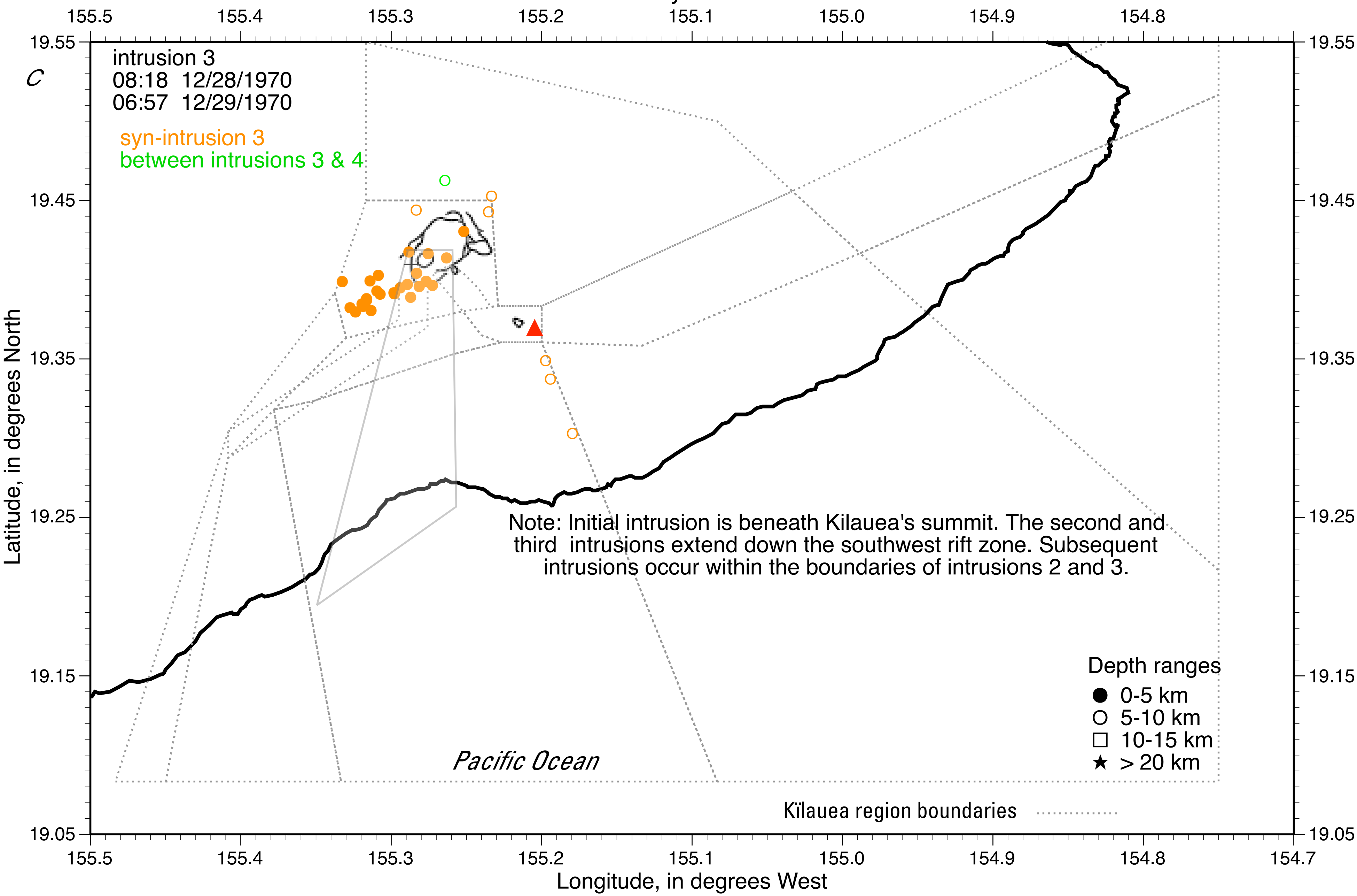
Appendix Figure E33b

Mauna Ulu IB 12/1970-1/1971 inflationary intrusions: data from 12/25-26/1970



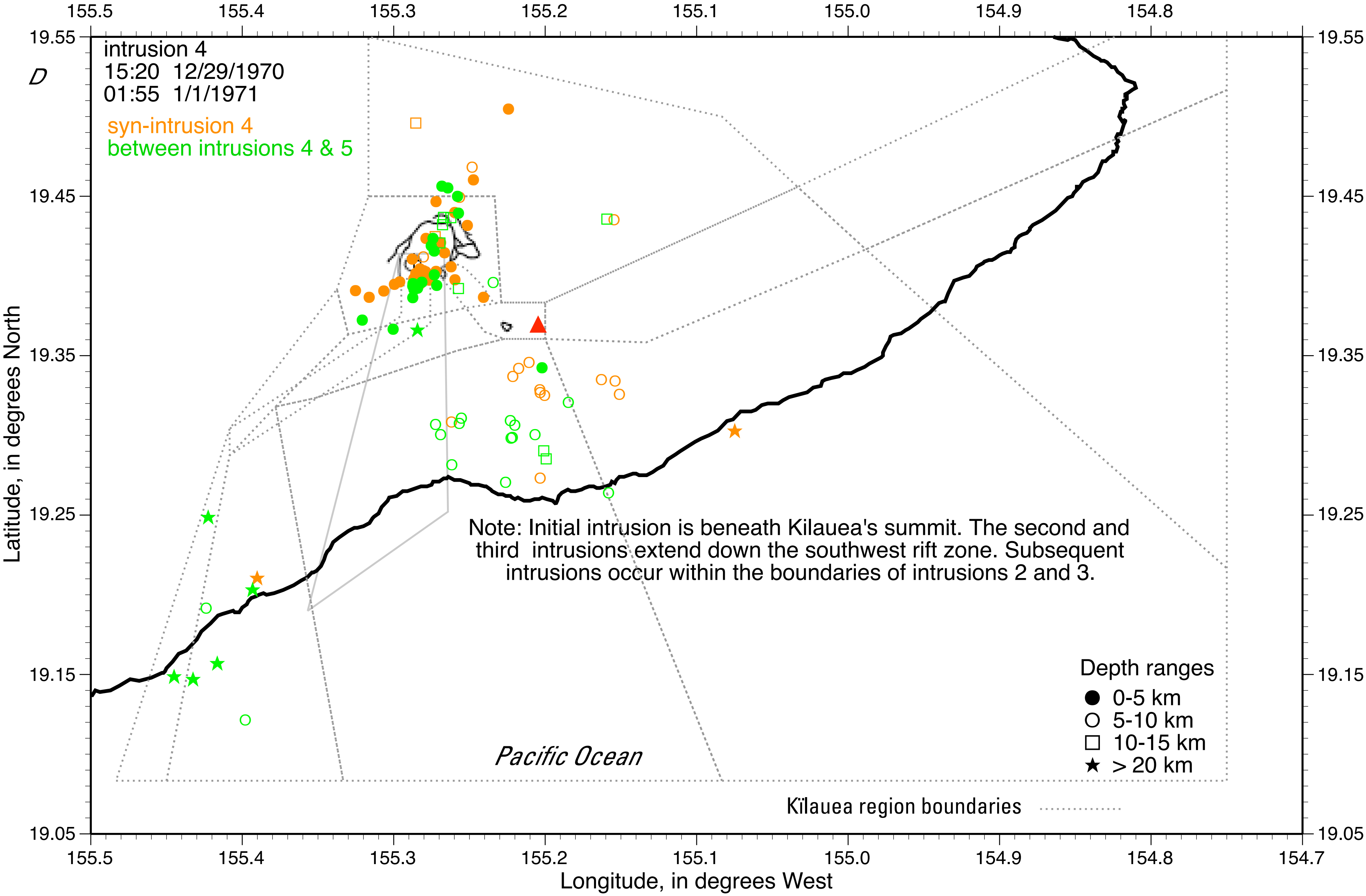
Appendix Figure E33c

Mauna Ulu IB 12/1970-1/1971 inflationary intrusions: data from 12/28-29/1970



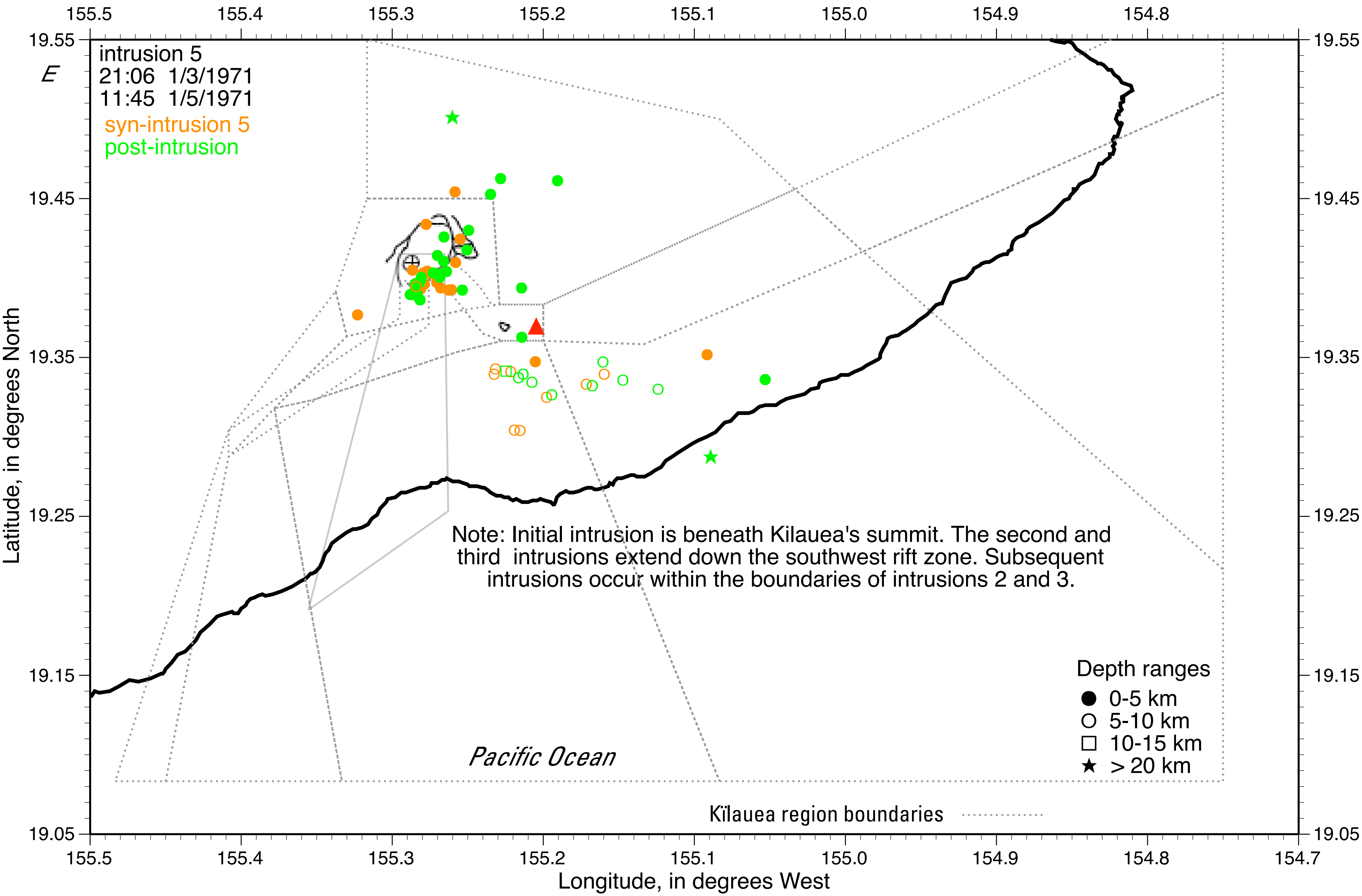
Appendix Figure E33d

Mauna Ulu IB 12/1970-1/1971 inflationary intrusions: data from 12/29/1970-1/1/1971



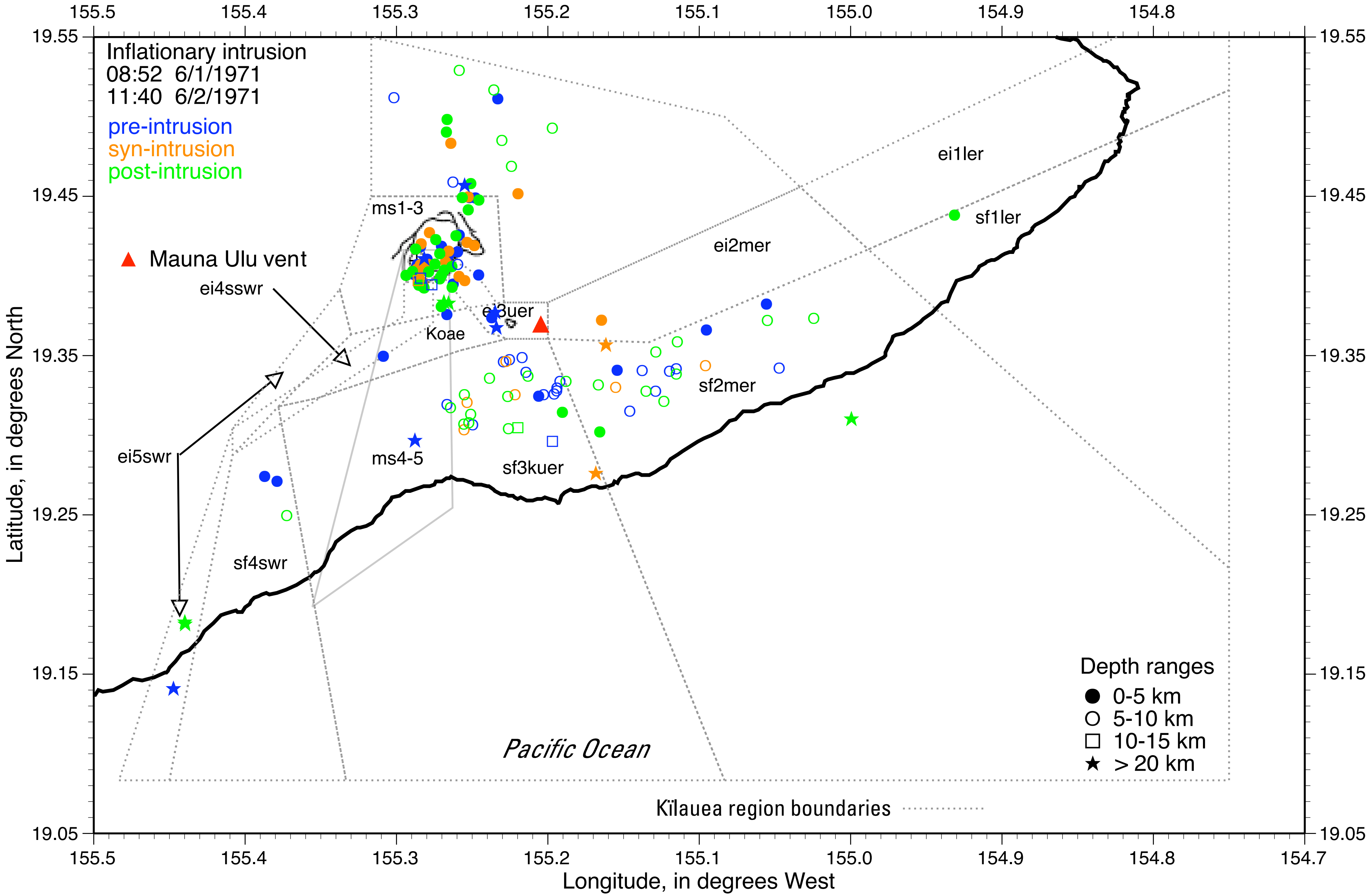
Appendix Figure E33e

Mauna Ulu IB 12/1970-1/1971 inflationary intrusions: data from 1/3/1970-1/6/1971



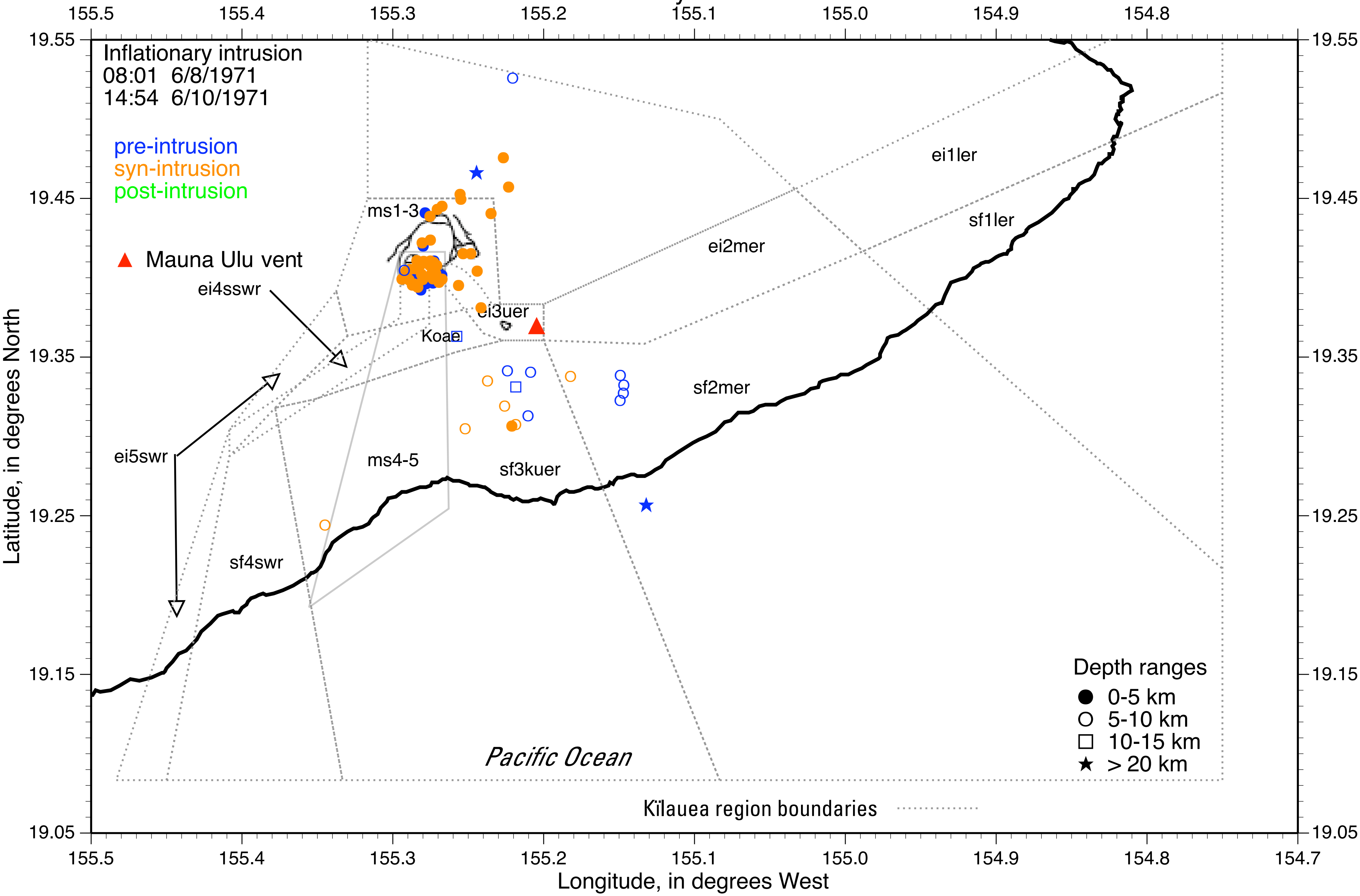
Appendix Figure E34

Mauna Ulu IB 6/1971 inflationary intrusion: data from 5/27-6/5/1971



Appendix Figure E35

Mauna Ulu IB 6/1971 inflationary intrusion: data from 6/6-10/1971



Appendix Figure E36

Mauna Ulu IB 6/1971 inflationary intrusion: data from 6/11-16/1971

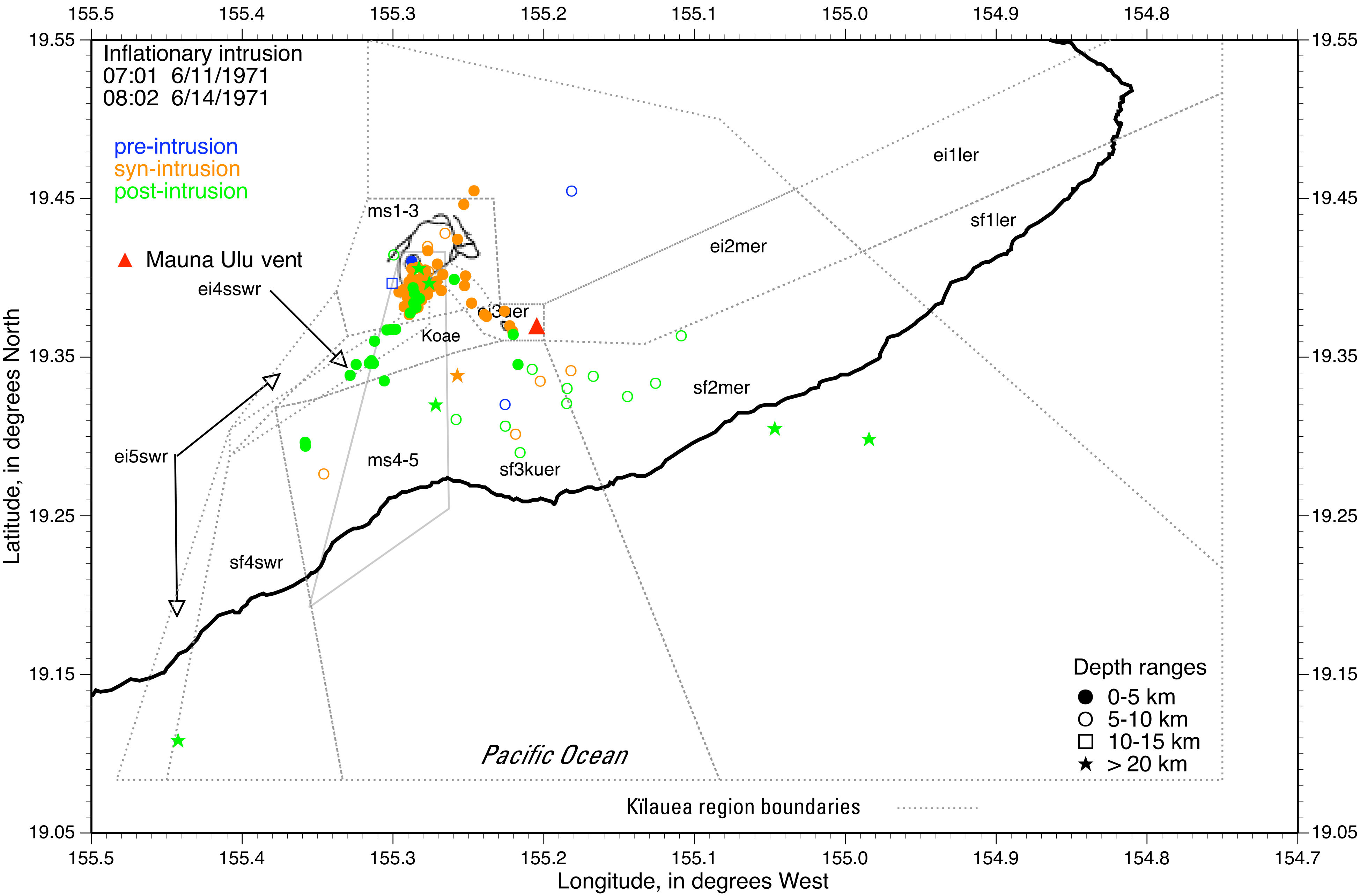
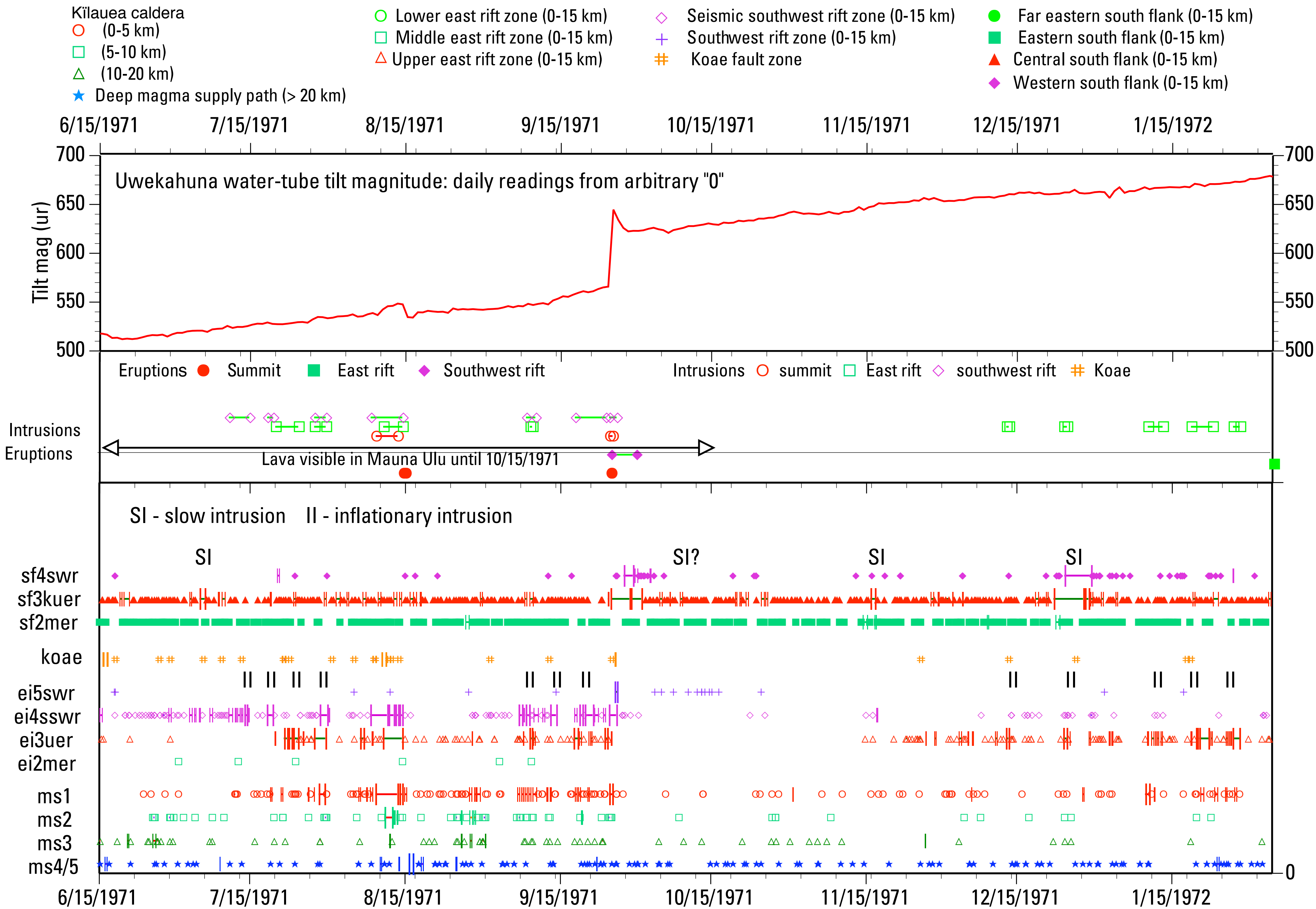
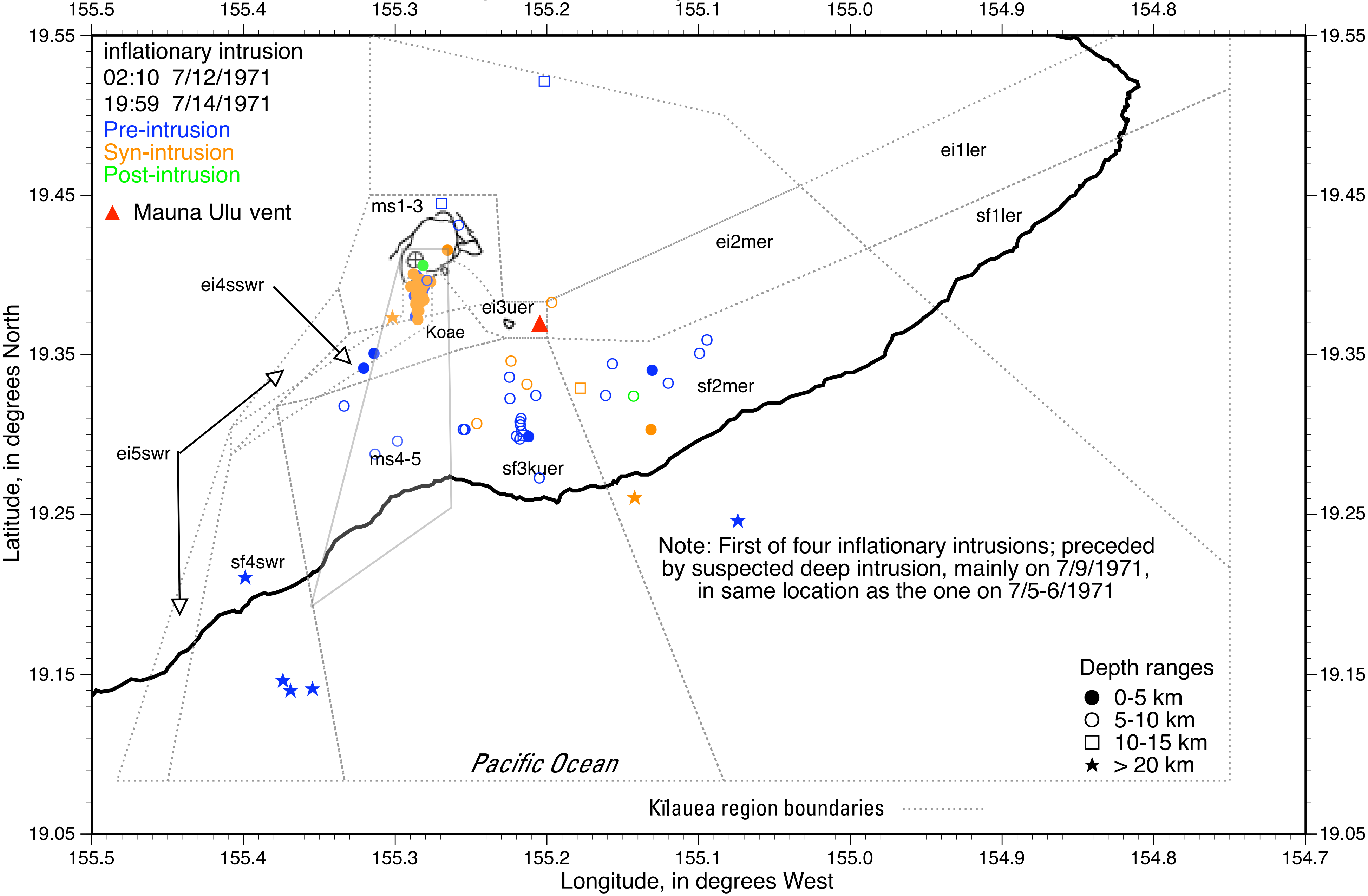


Figure E37. Mauna Ulu pause: earthquake swarms and tilt



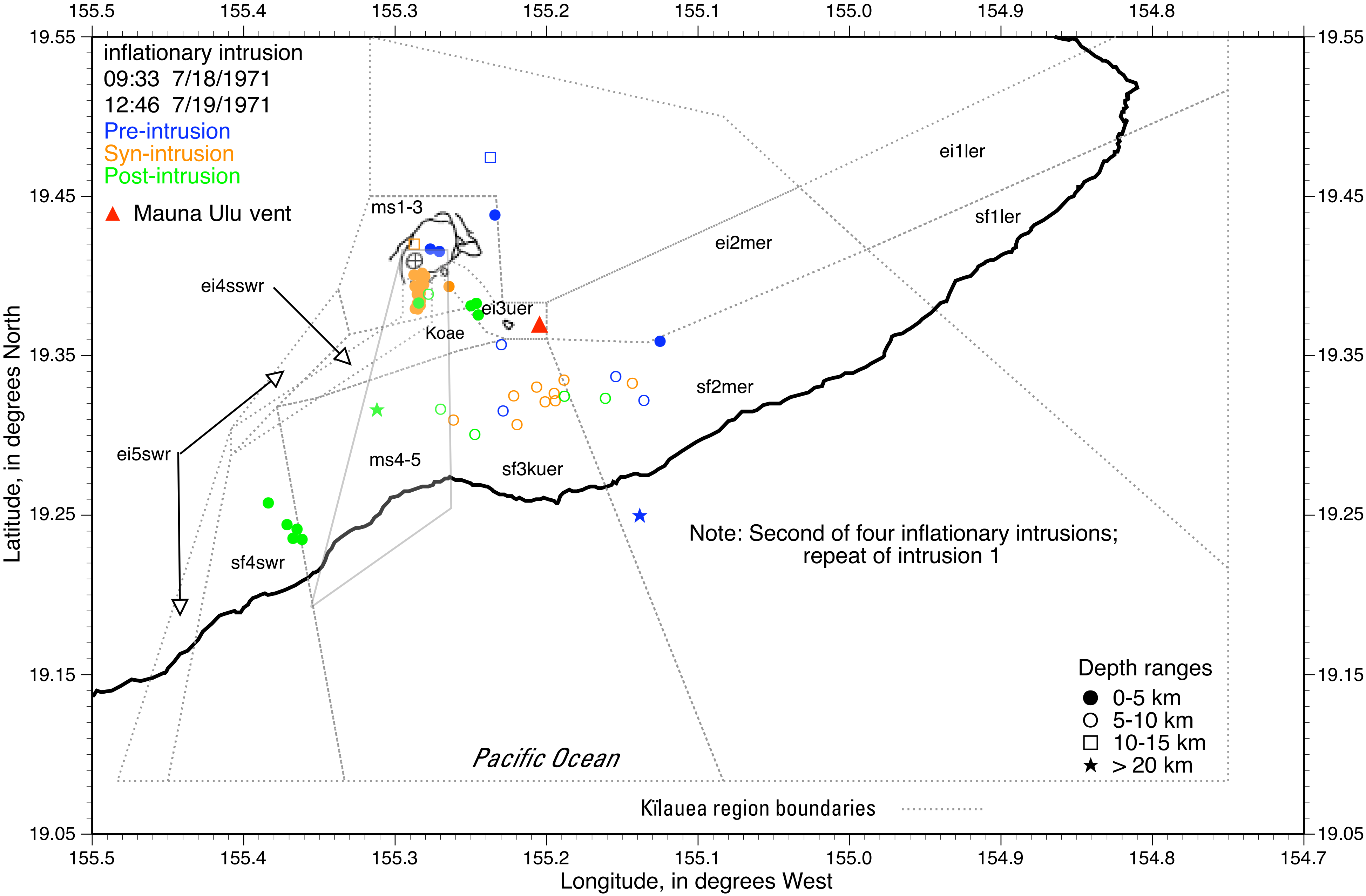
Appendix Figure E38

Mauna Ulu pause inflationary intrusions: data from 7/7-15/1971



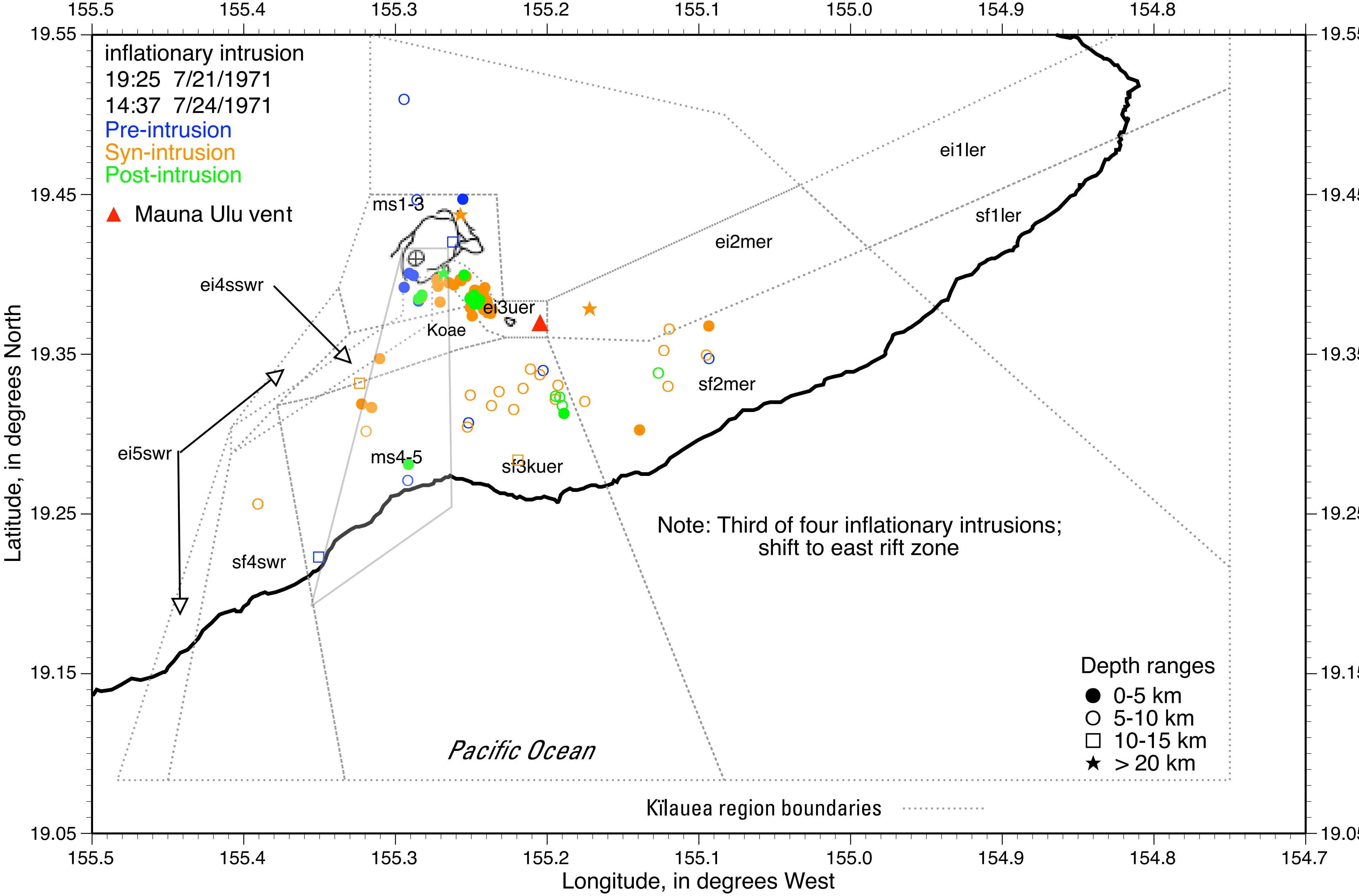
Appendix Figure E39

Mauna Ulu pause inflationary intrusions: data from 7/16-20/1971



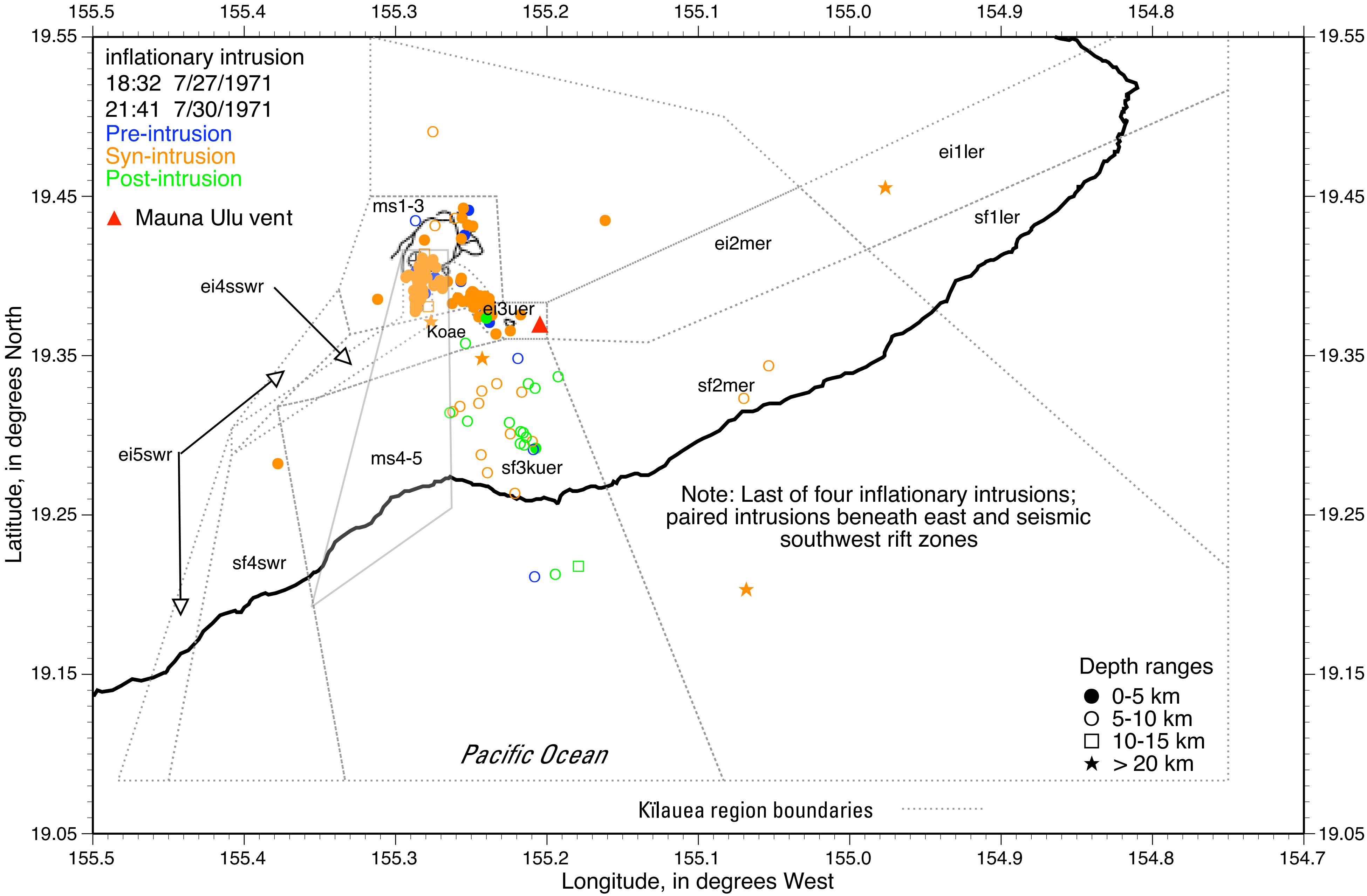
Appendix Figure E40

Mauna Ulu pause inflationary intrusions: data from 7/20-25/1971



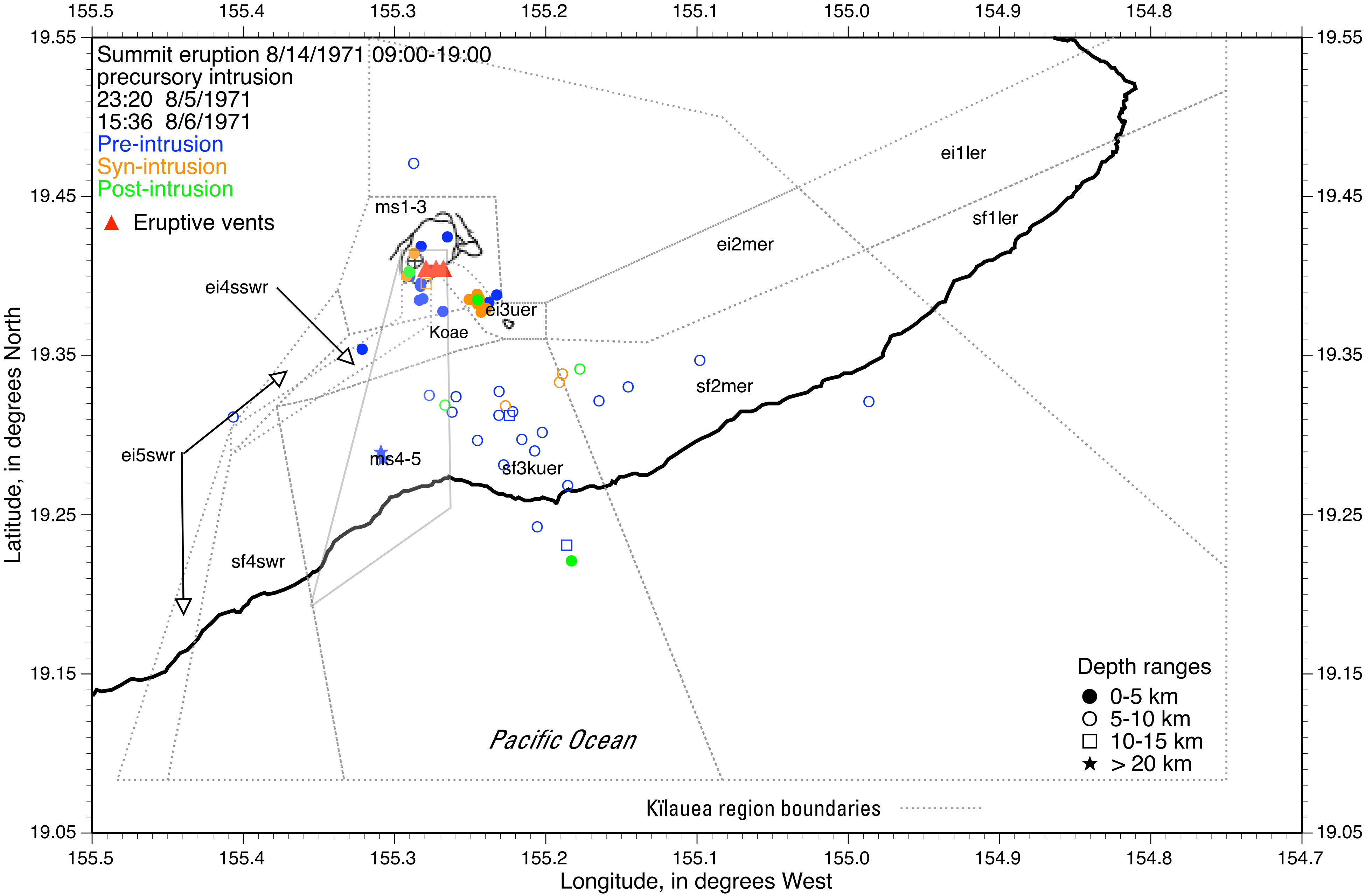
Appendix Figure E41

Mauna Ulu pause inflationary intrusions: data from 7/26-8/1/1971



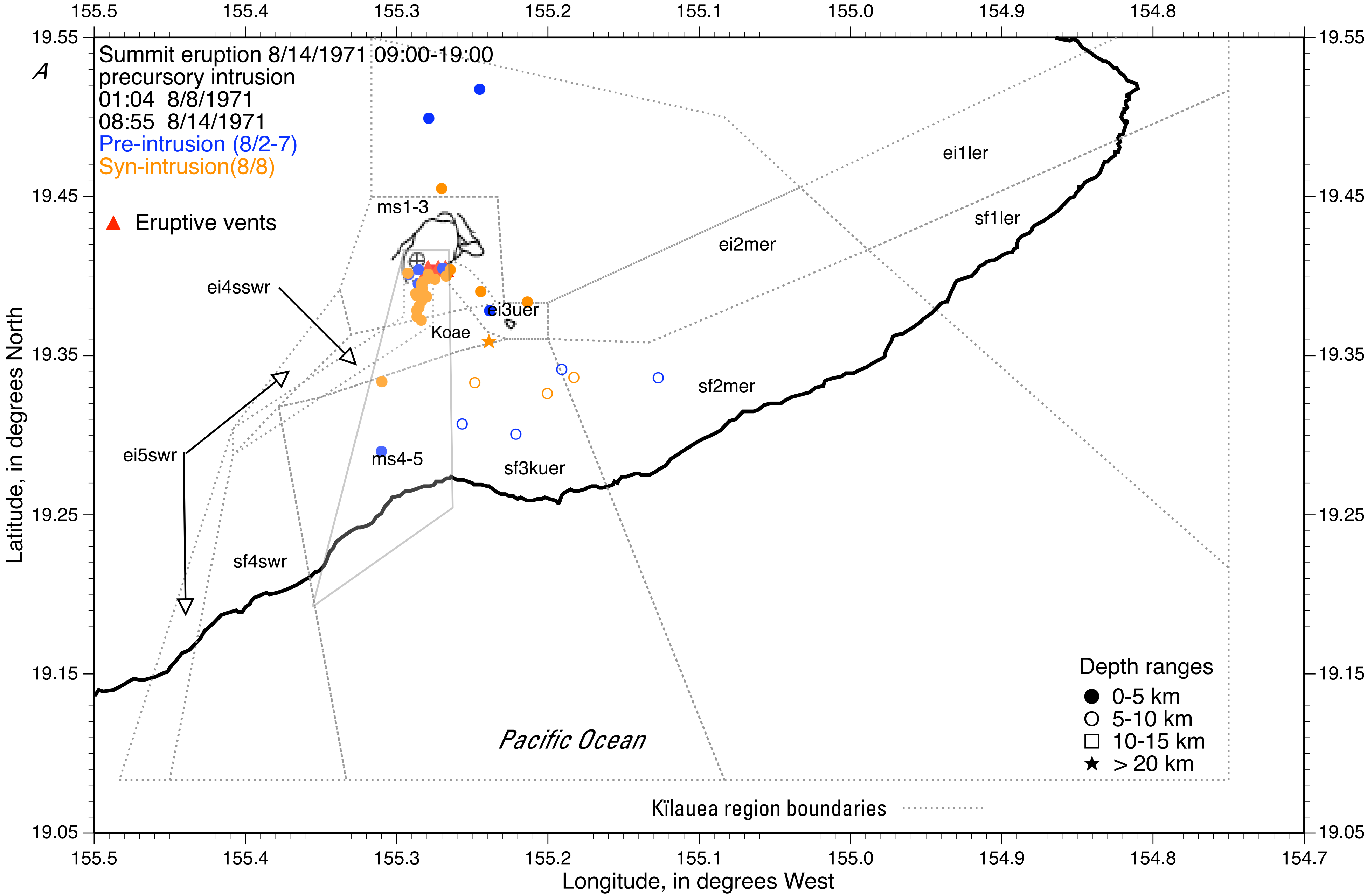
Appendix Figure E42

Mauna Ulu pause 8/14/1971 eruption precursory intrusion: data from 8/2-8/1971



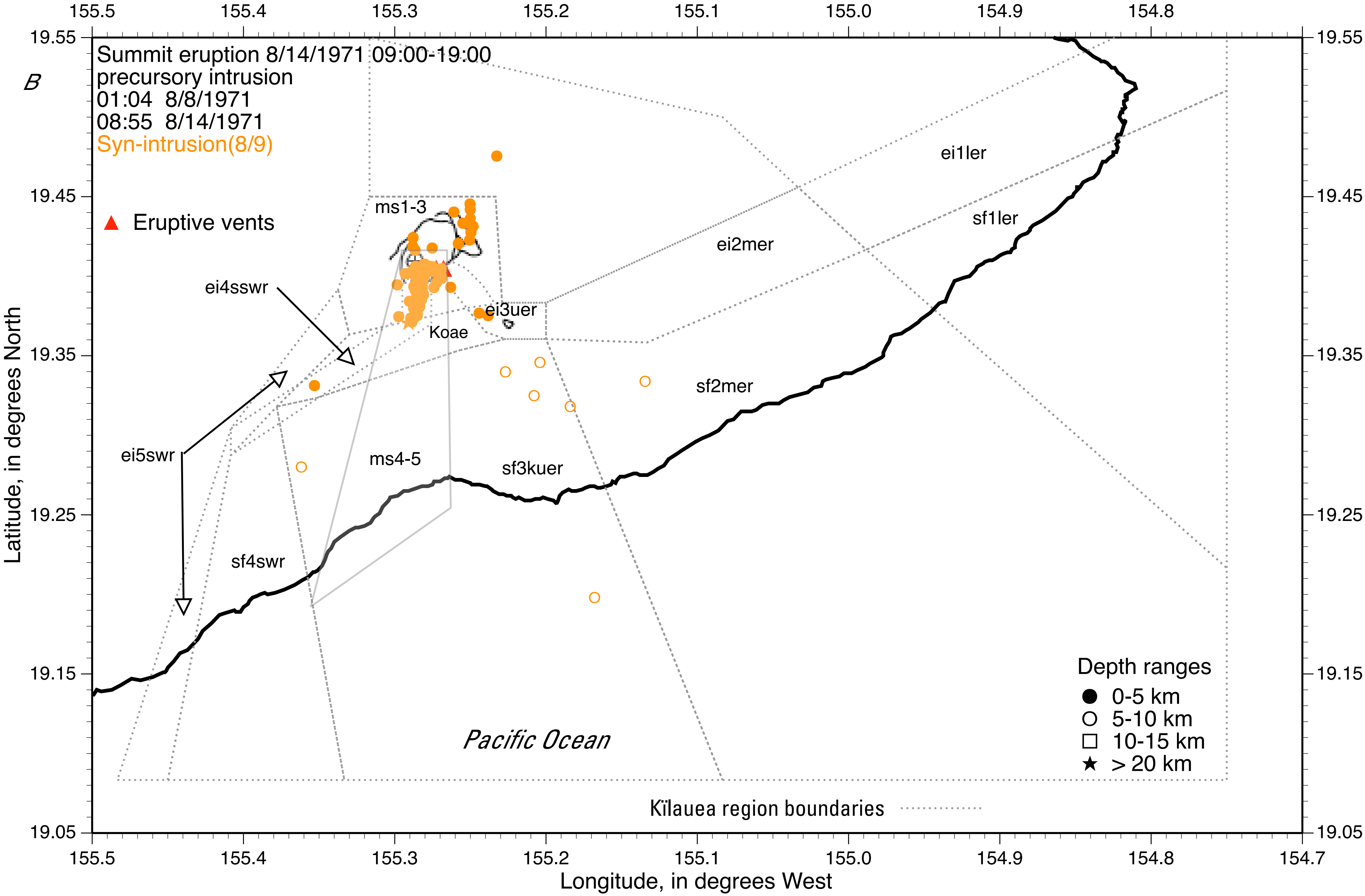
Appendix Figure E43a

Mauna Ulu pause 8/14/1971 eruption precursory seismicity by date: data for 8/8/1971



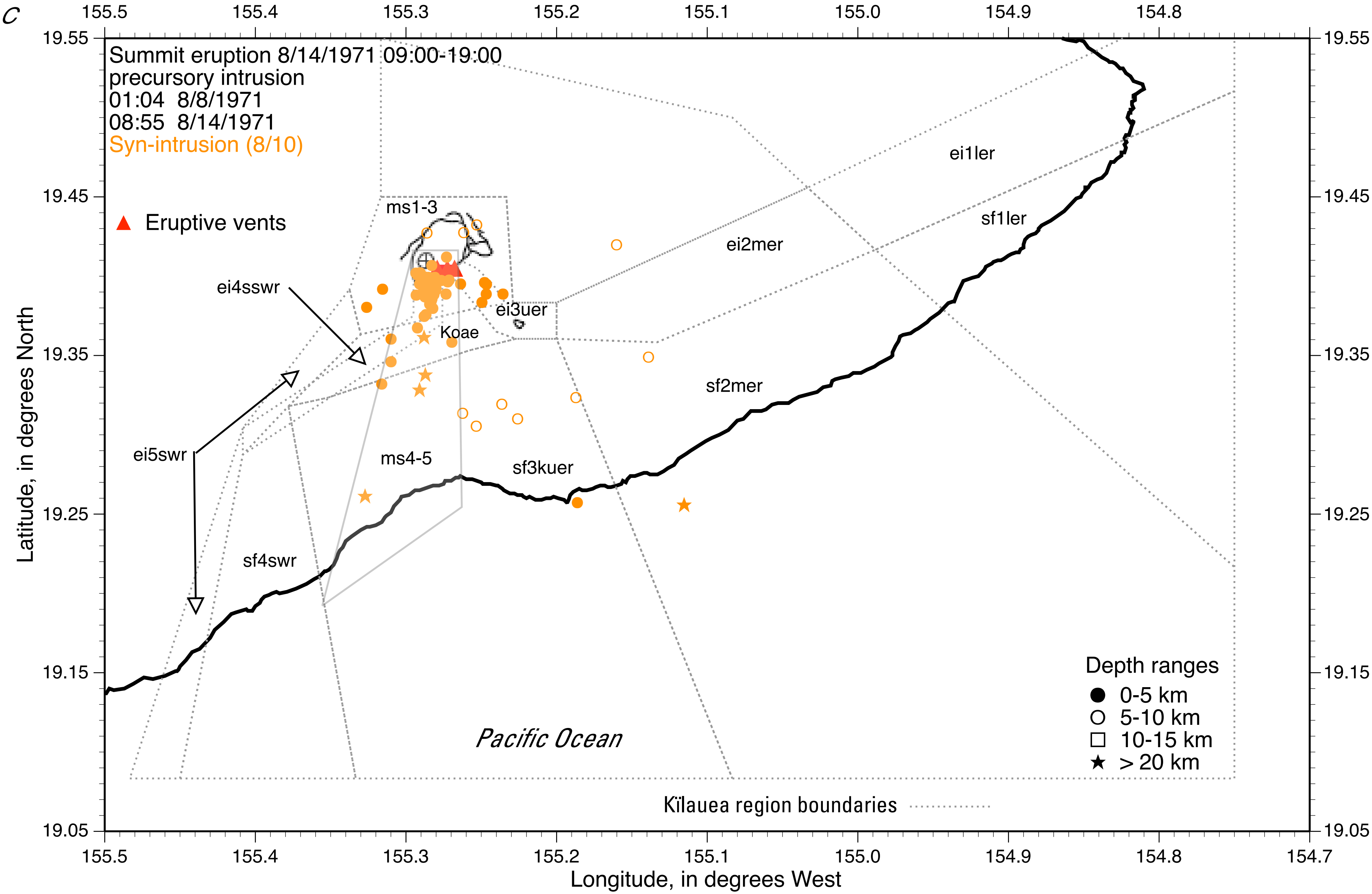
Appendix Figure E43b

Mauna Ulu pause 8/14/1971 eruption precursory seismicity by date: data for 8/9/1971



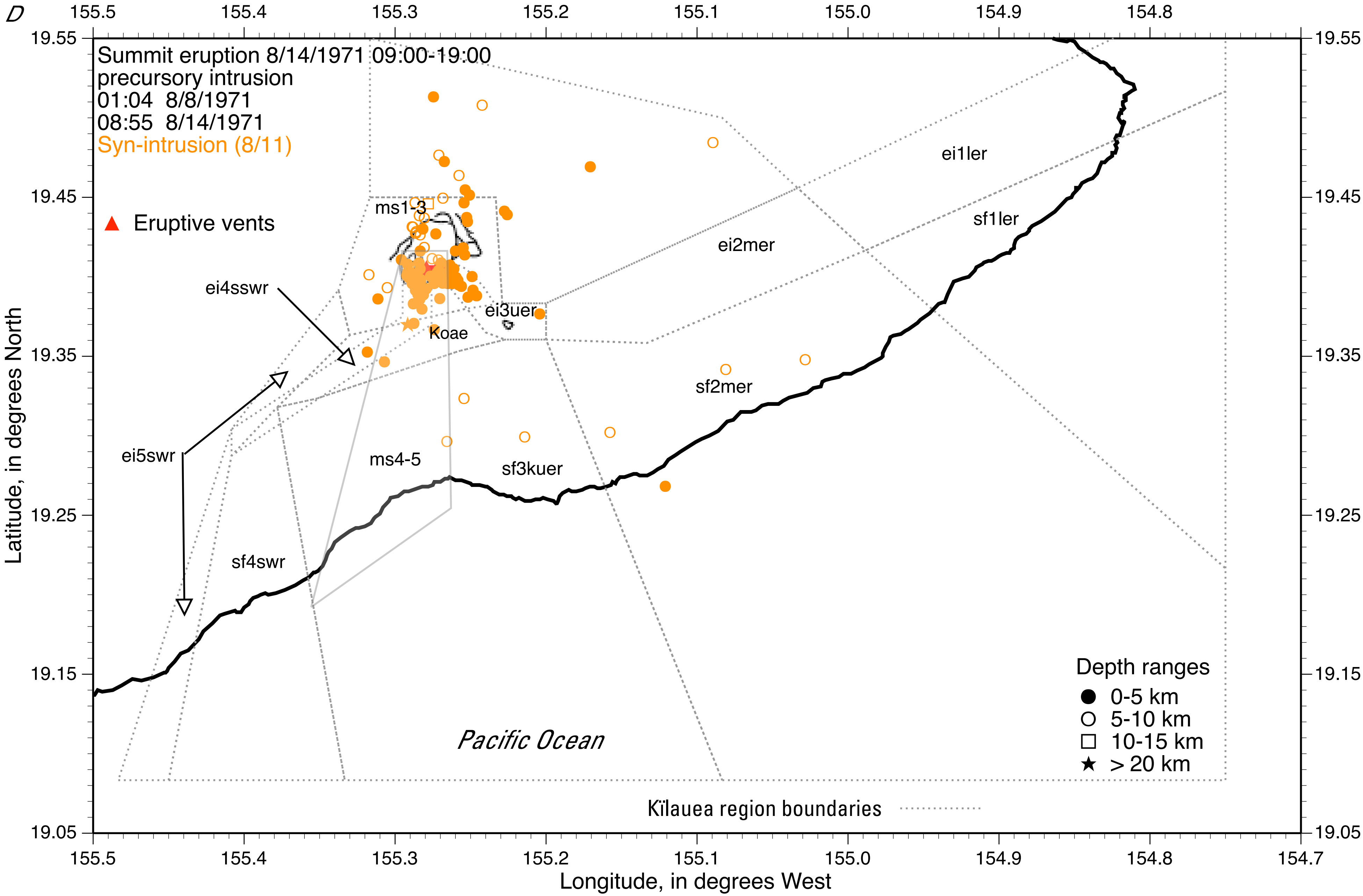
Appendix Figure E43c

Mauna Ulu pause 8/14/1971 eruption precursory seismicity by date: data for 8/10/1971



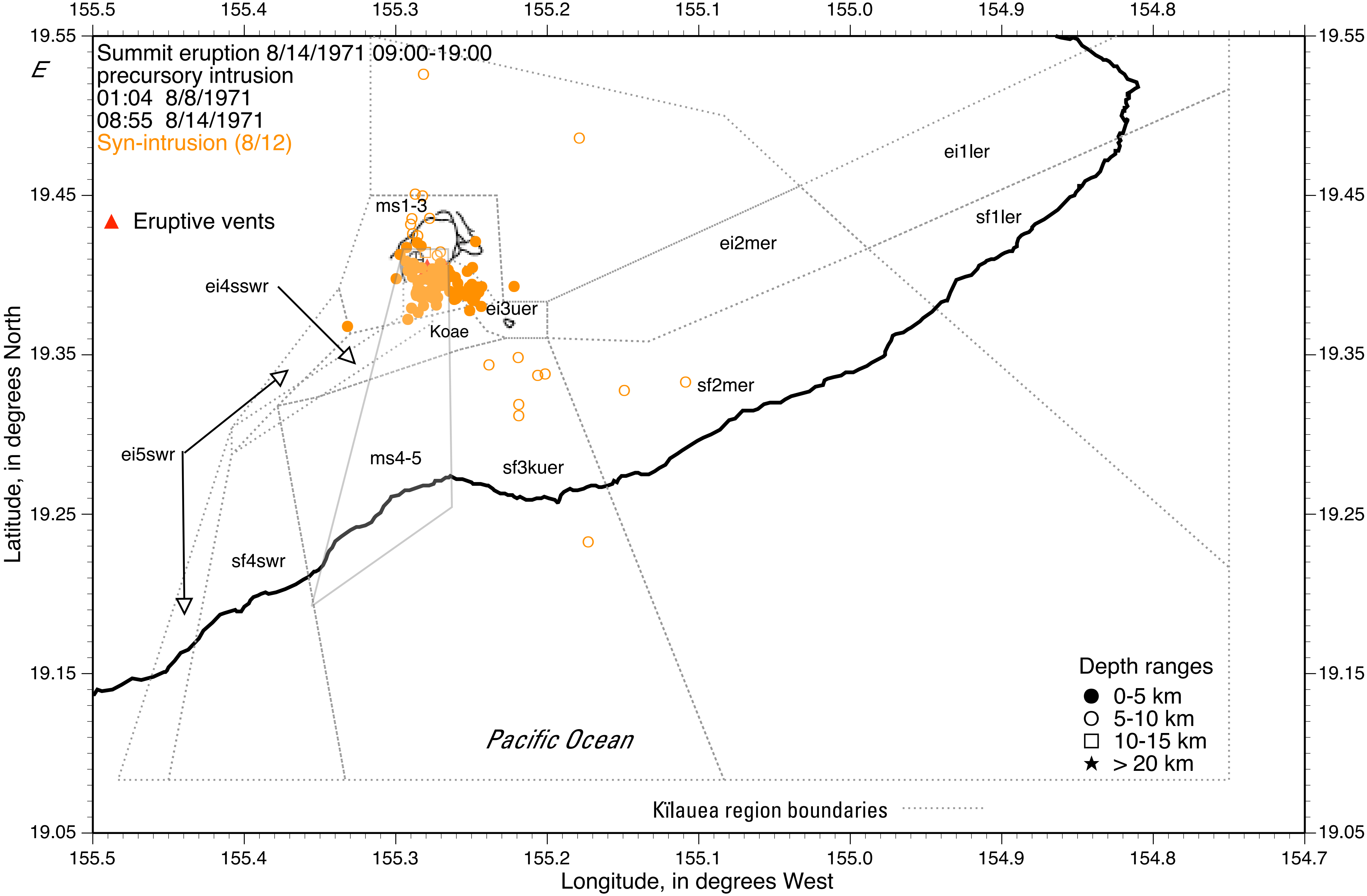
Appendix Figure E43d

Mauna Ulu pause 8/14/1971 eruption precursory seismicity by date: data for 8/11/1971



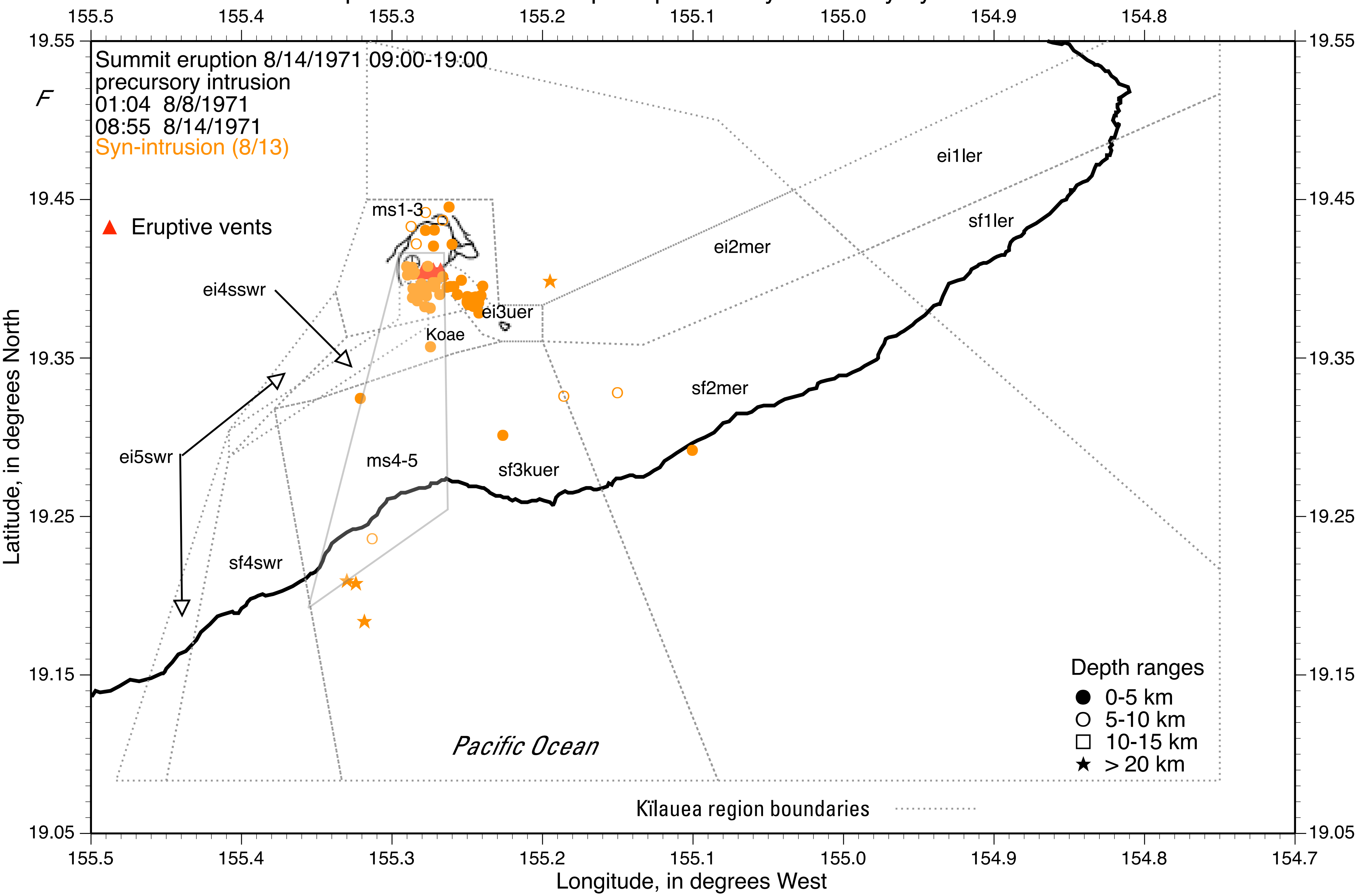
Appendix Figure E43e

Mauna Ulu pause 8/14/1971 eruption precursory seismicity by date: data for 8/12/1971



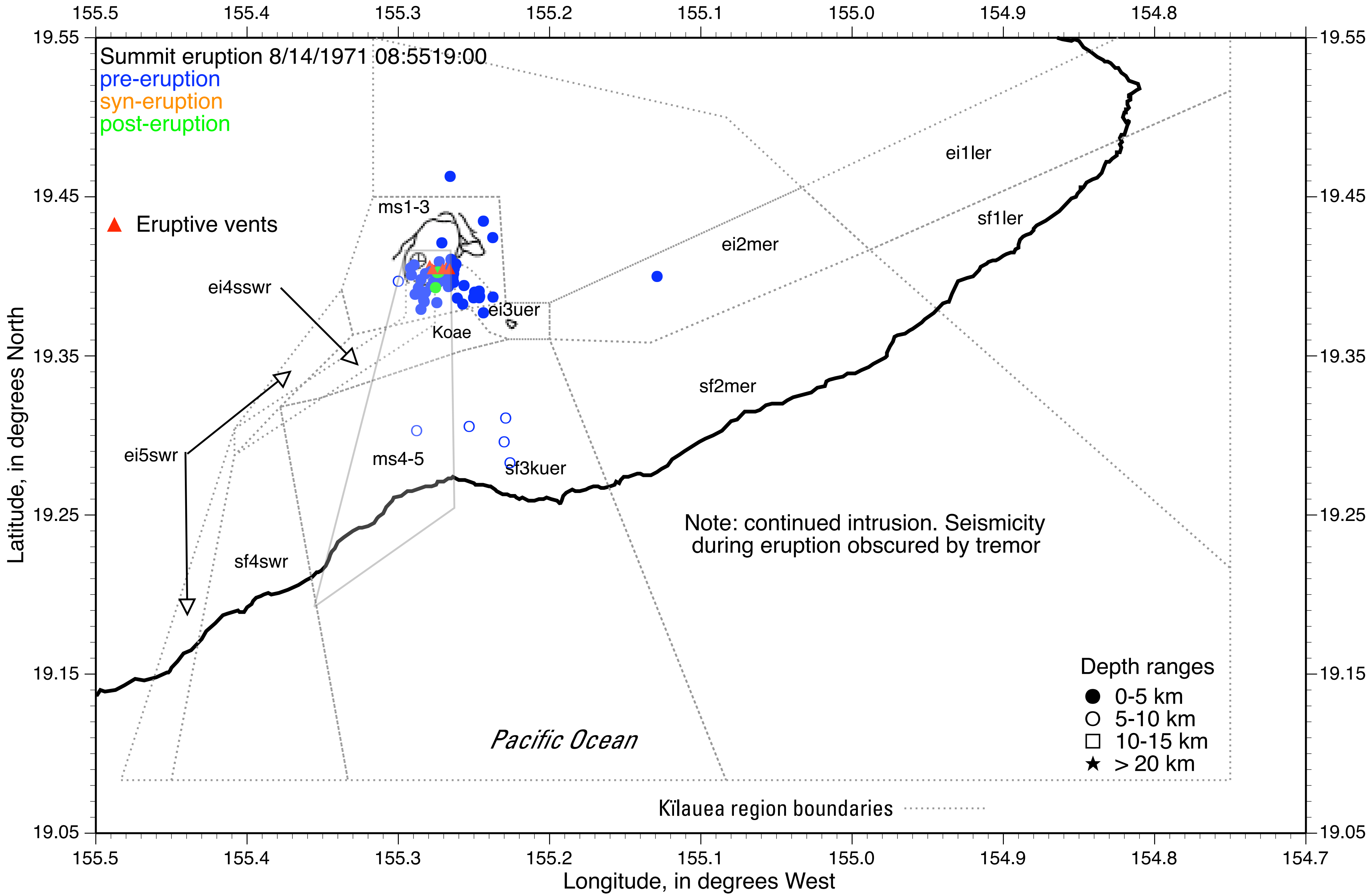
Appendix Figure E43f

Mauna Ulu pause 8/14/1971 eruption precursory seismicity by date: data for 8/13/1971



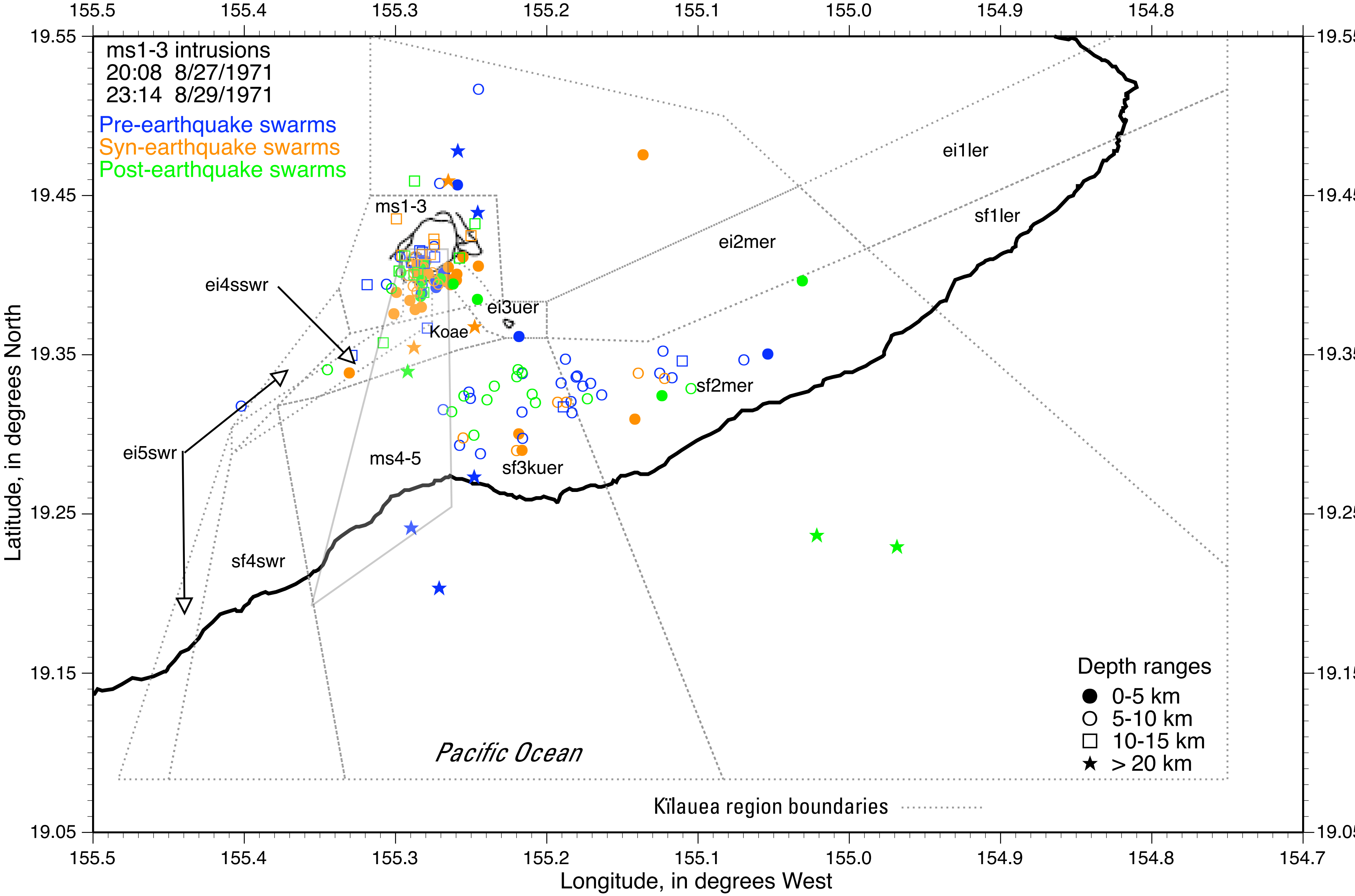
Appendix Figure E44

Mauna Ulu pause 8/14/1971 eruption precursory seismicity by date: data for 8/14/1971



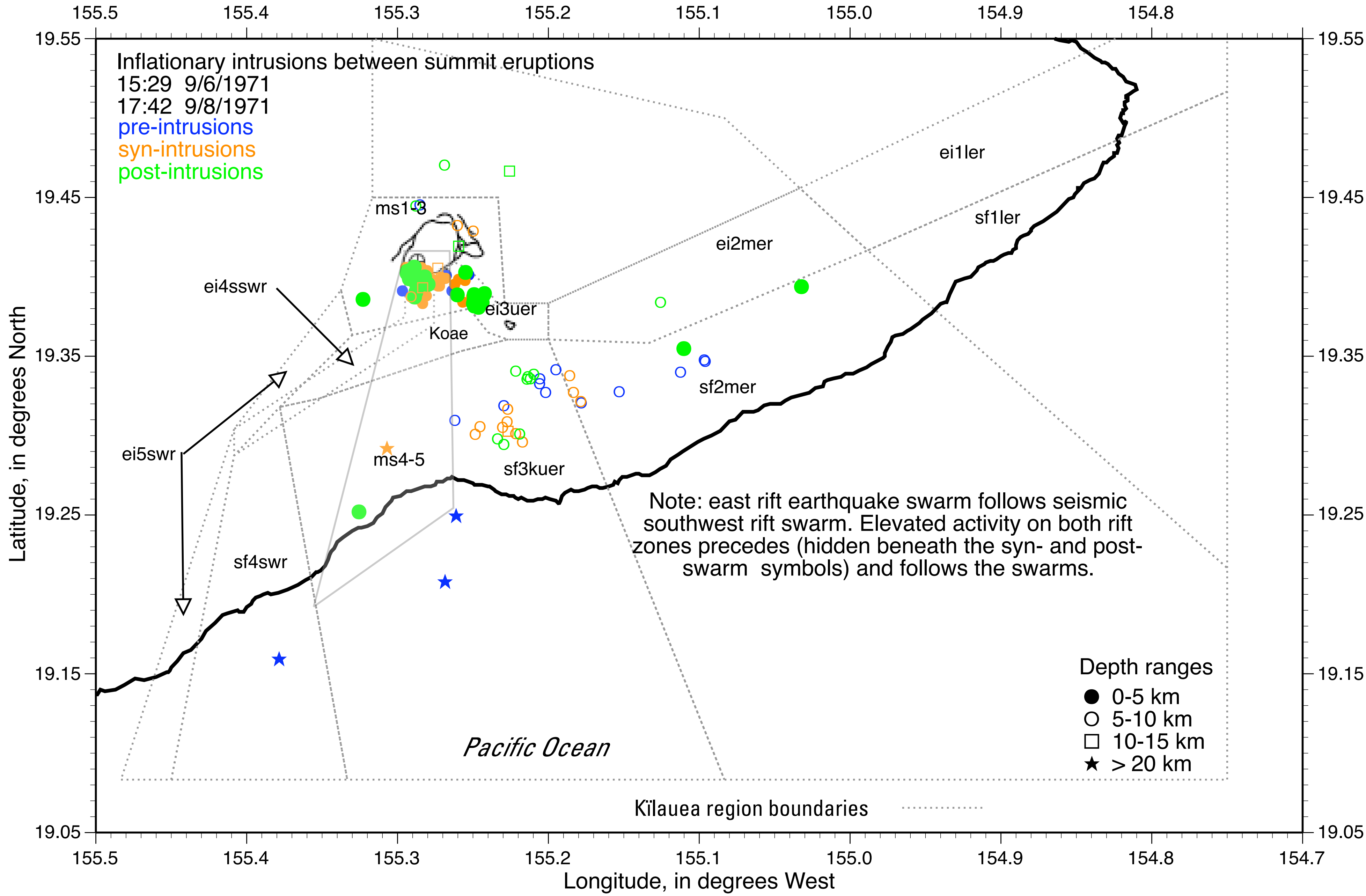
Appendix Figure E45

Mauna Ulu pause seismicity between eruptions: data from 8/25-9/1/1971

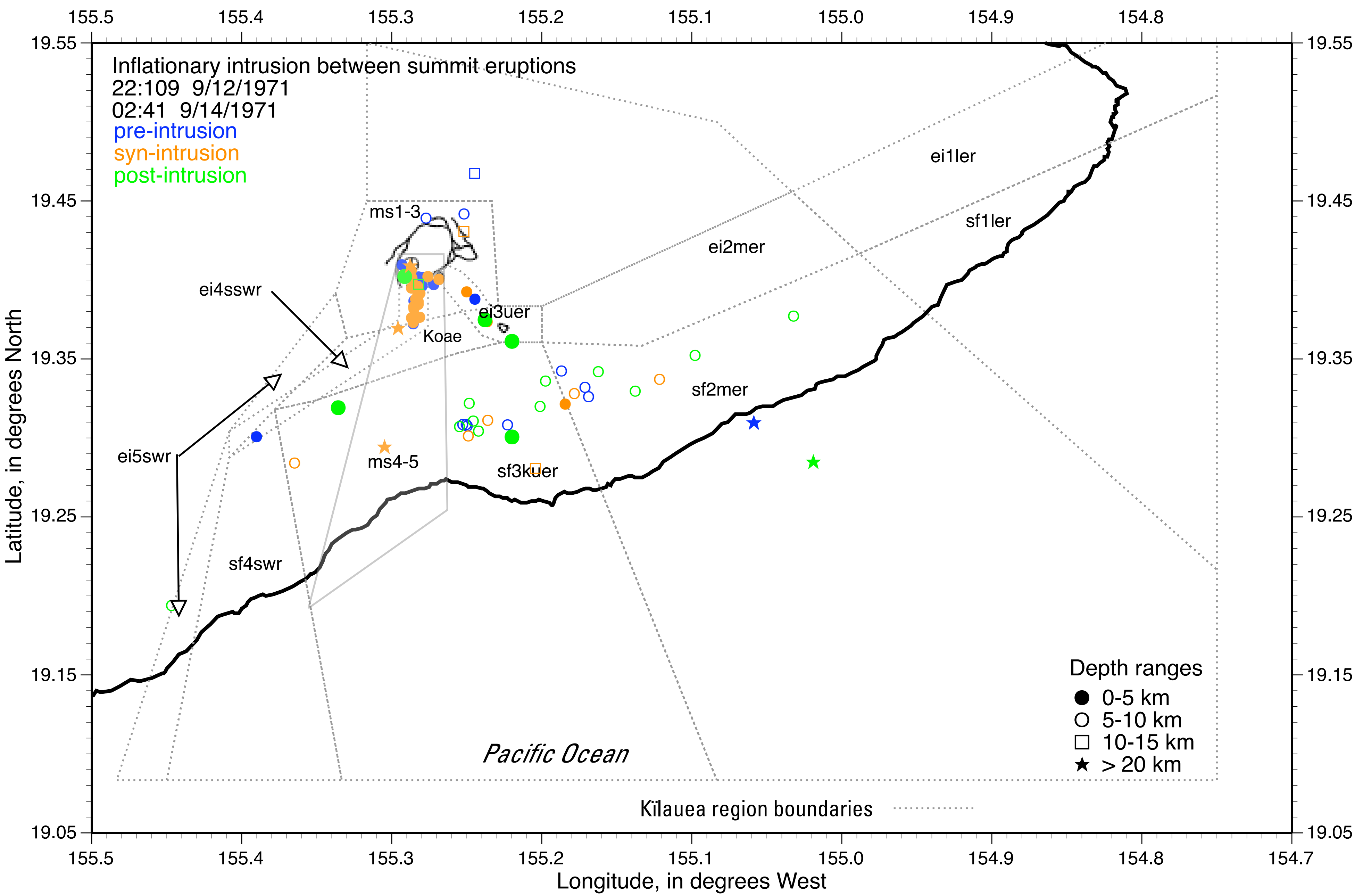


Appendix Figure E46

Mauna Ulu pause inflationary intrusions: data from 9/4-10/1971

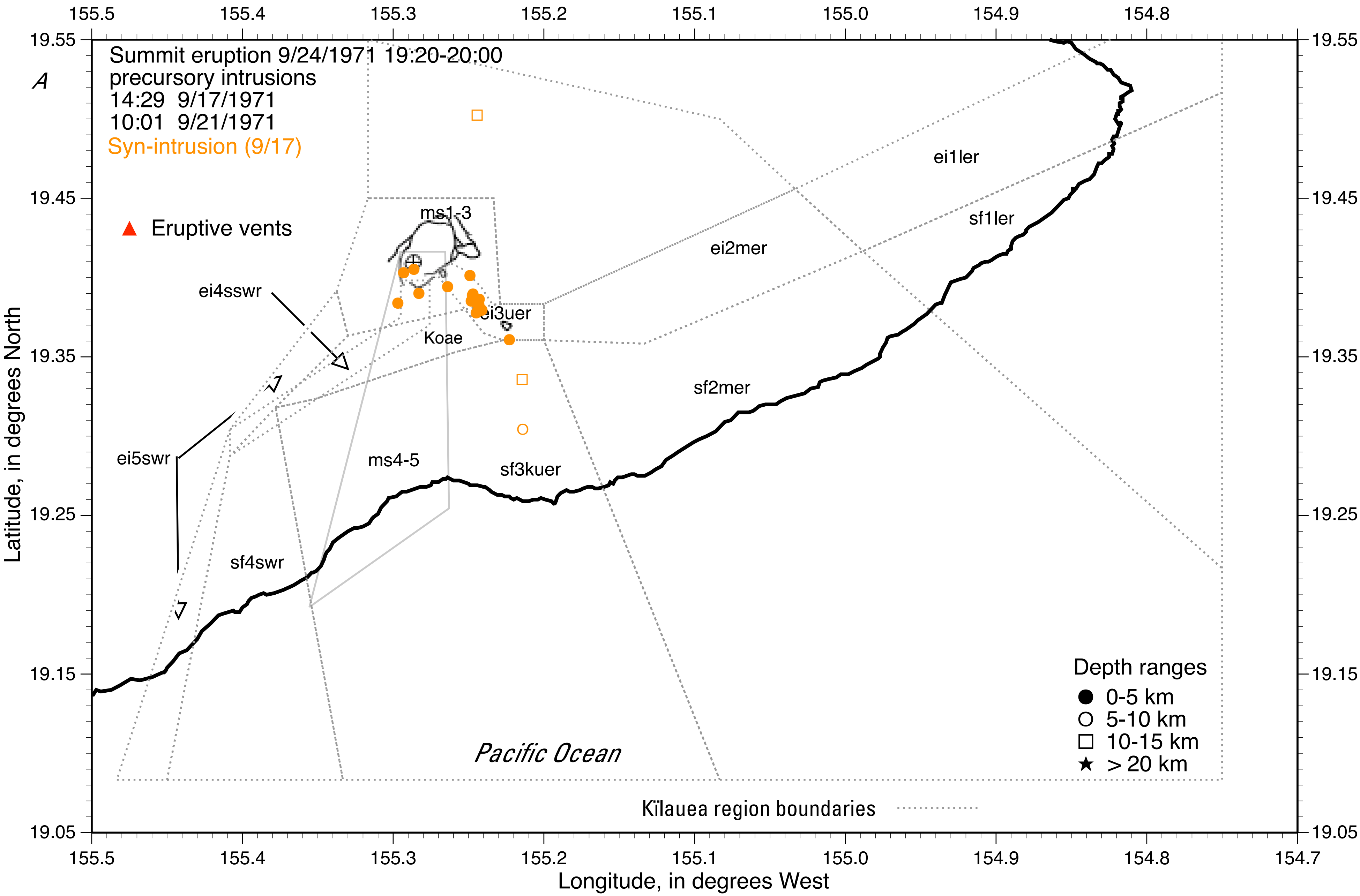


Appendix Figure E47
Mauna Ulu pause inflationary intrusions: data from 9/11-16/1971



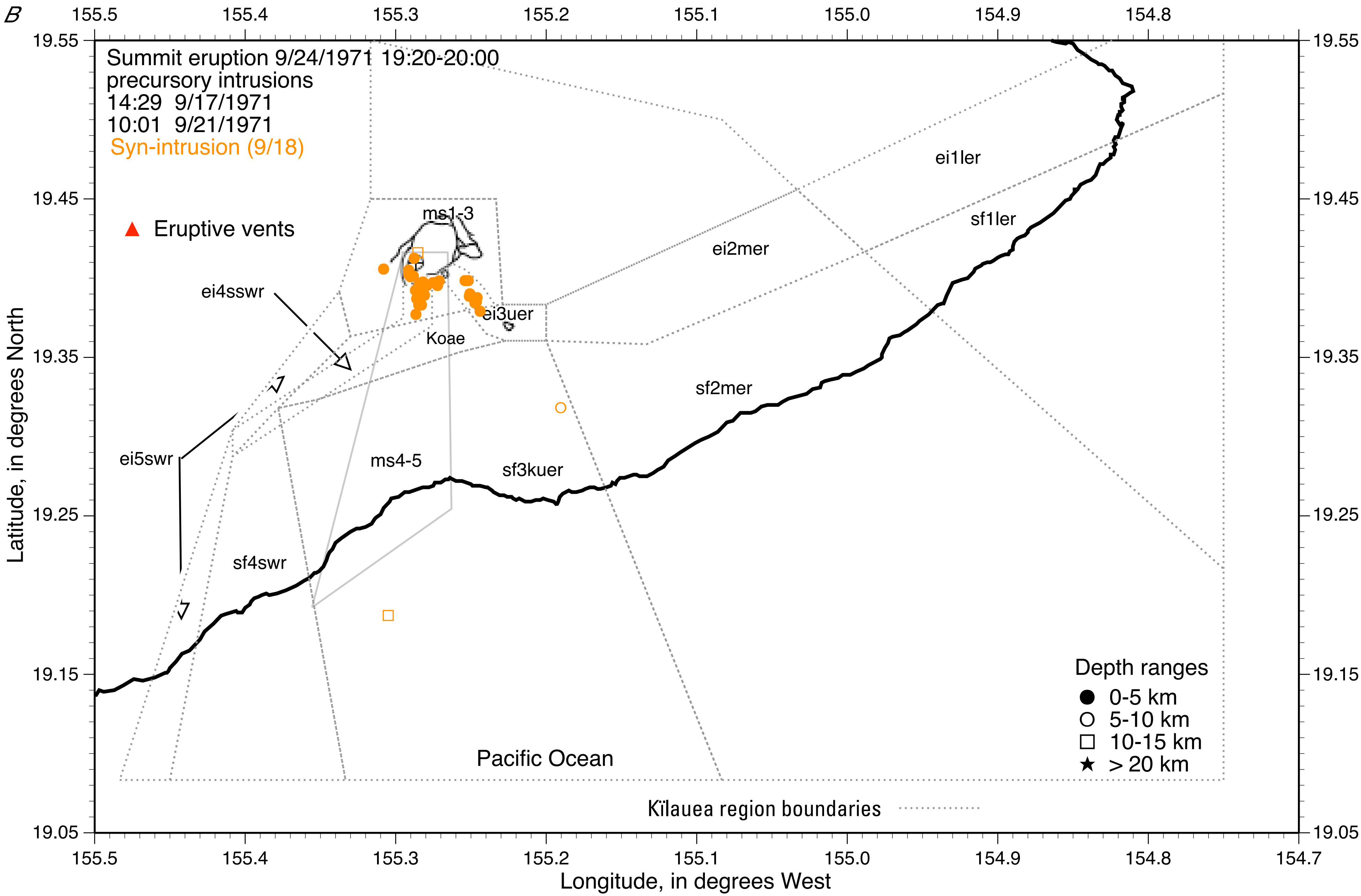
Appendix Figure E48a

Mauna Ulu pause 9/24/1971 eruption--pre-eruption seismicity by date: data from 9/17/1971



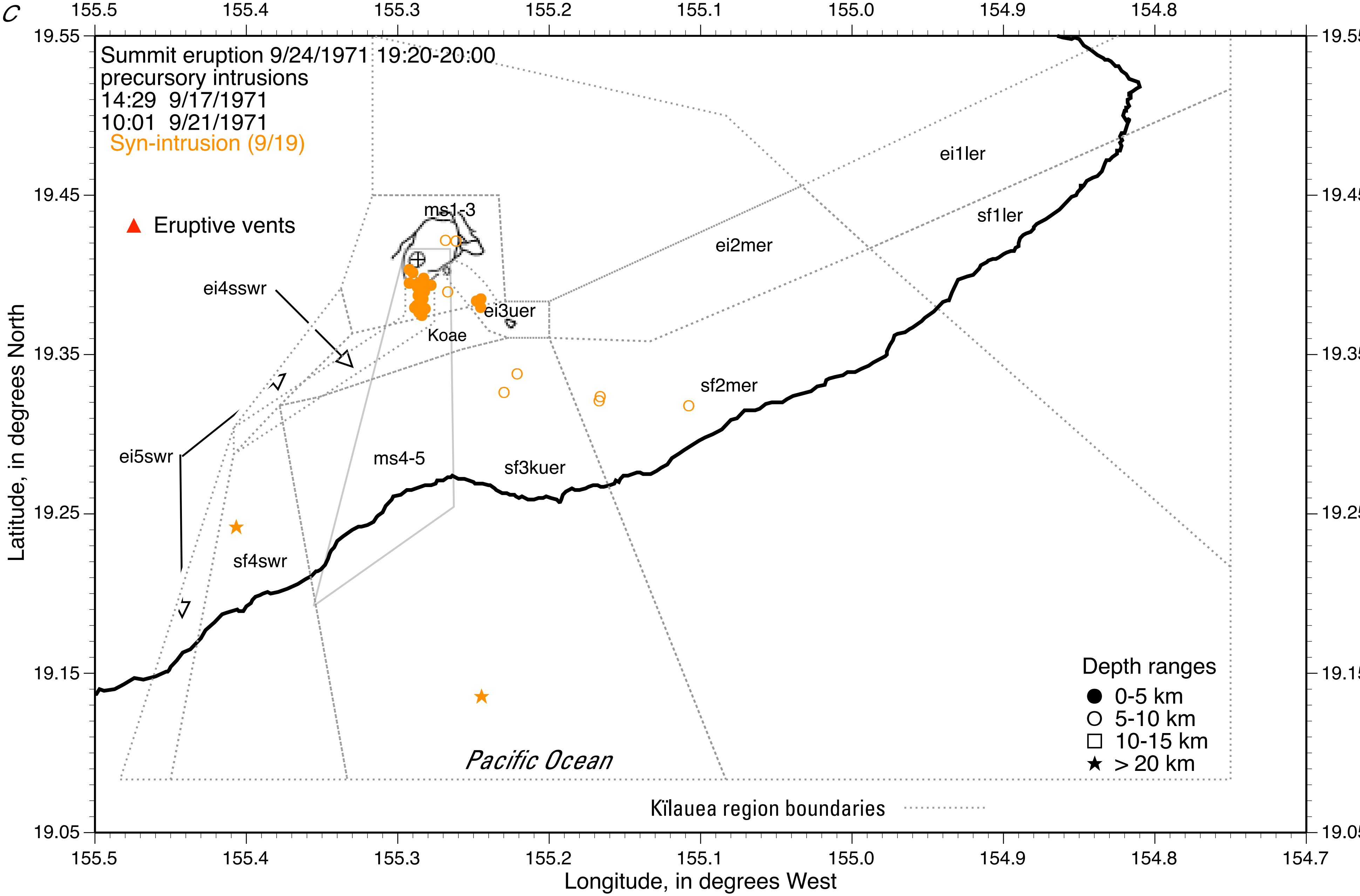
Appendix Figure E48b

Mauna Ulu pause 9/24/1971 eruption--pre-eruption seismicity by date: data from 9/18/1971



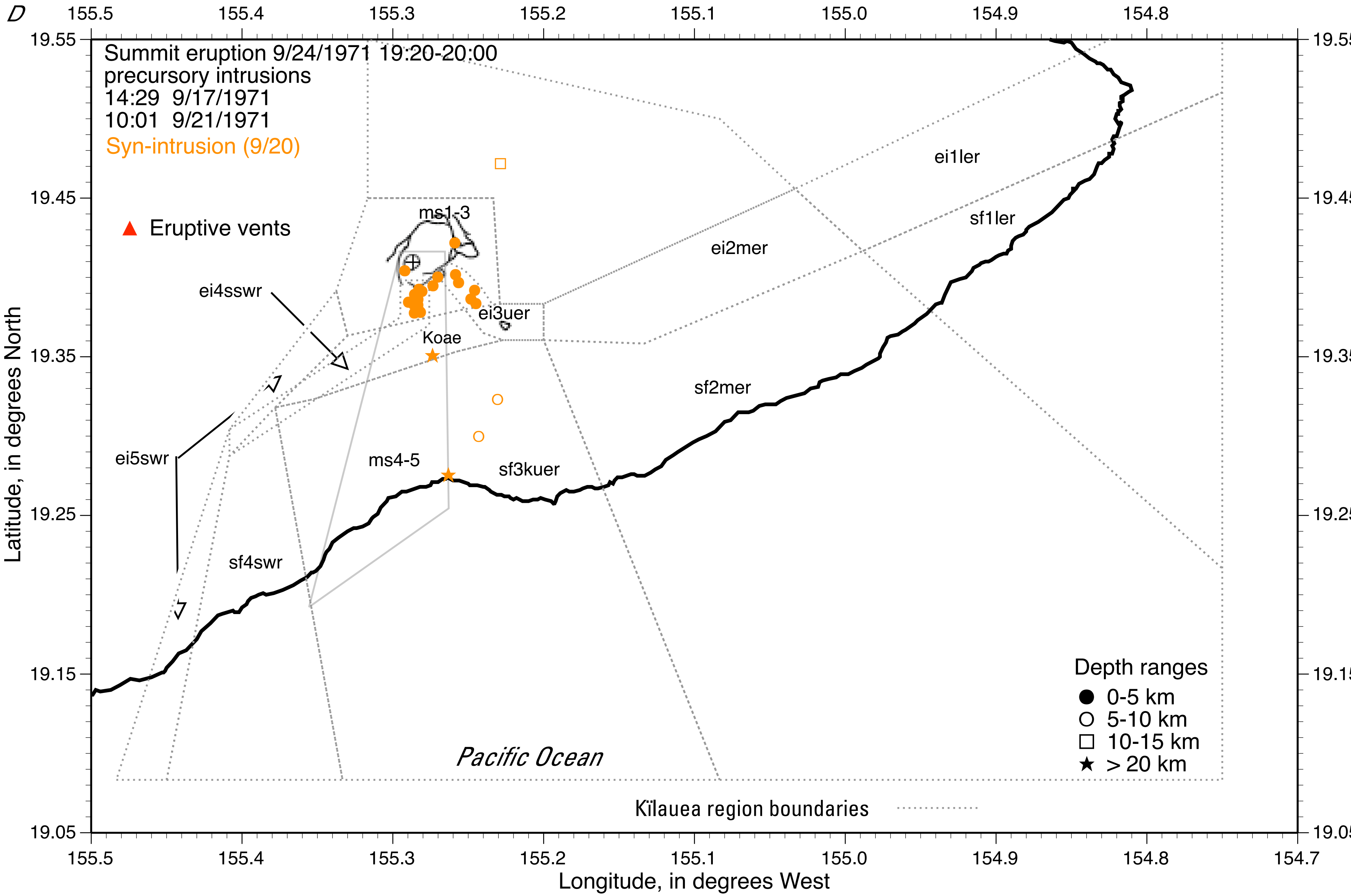
Appendix Figure E48c

Mauna Ulu pause 9/24/1971 eruption--pre-eruption seismicity by date: data from 9//19/1971



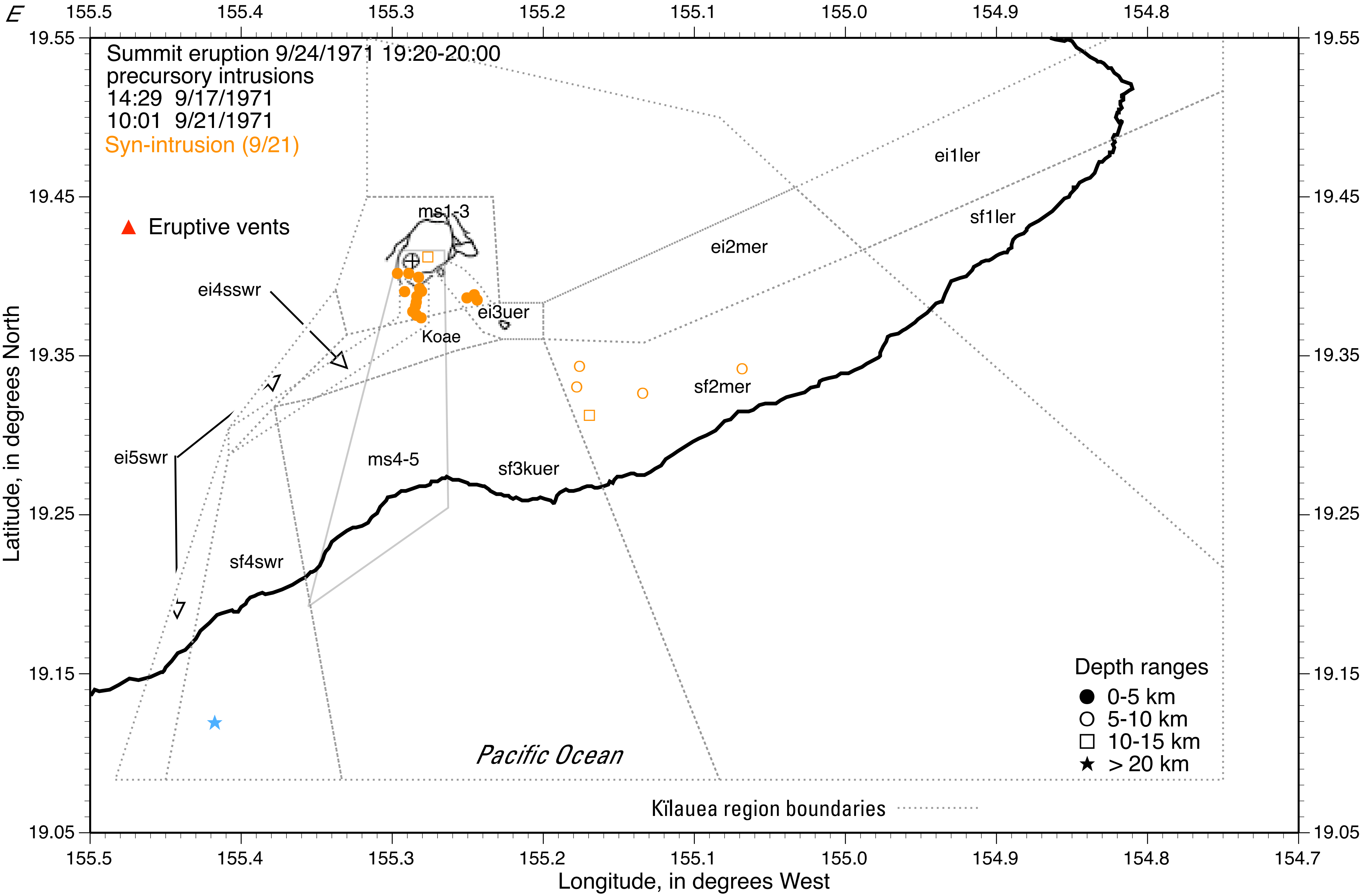
Appendix Figure E48d

Mauna Ulu pause 9/24/1971 eruption--pre-eruption seismicity by date: data from 9/20/1971



Appendix Figure E48e

Mauna Ulu pause 9/24/1971 eruption--pre-eruption seismicity by date: data from 9/21/1971



Appendix Figure E48f

Mauna Ulu pause 9/24/1971 eruption--pre-eruption seismicity--deep magma supply event 9/22/1971

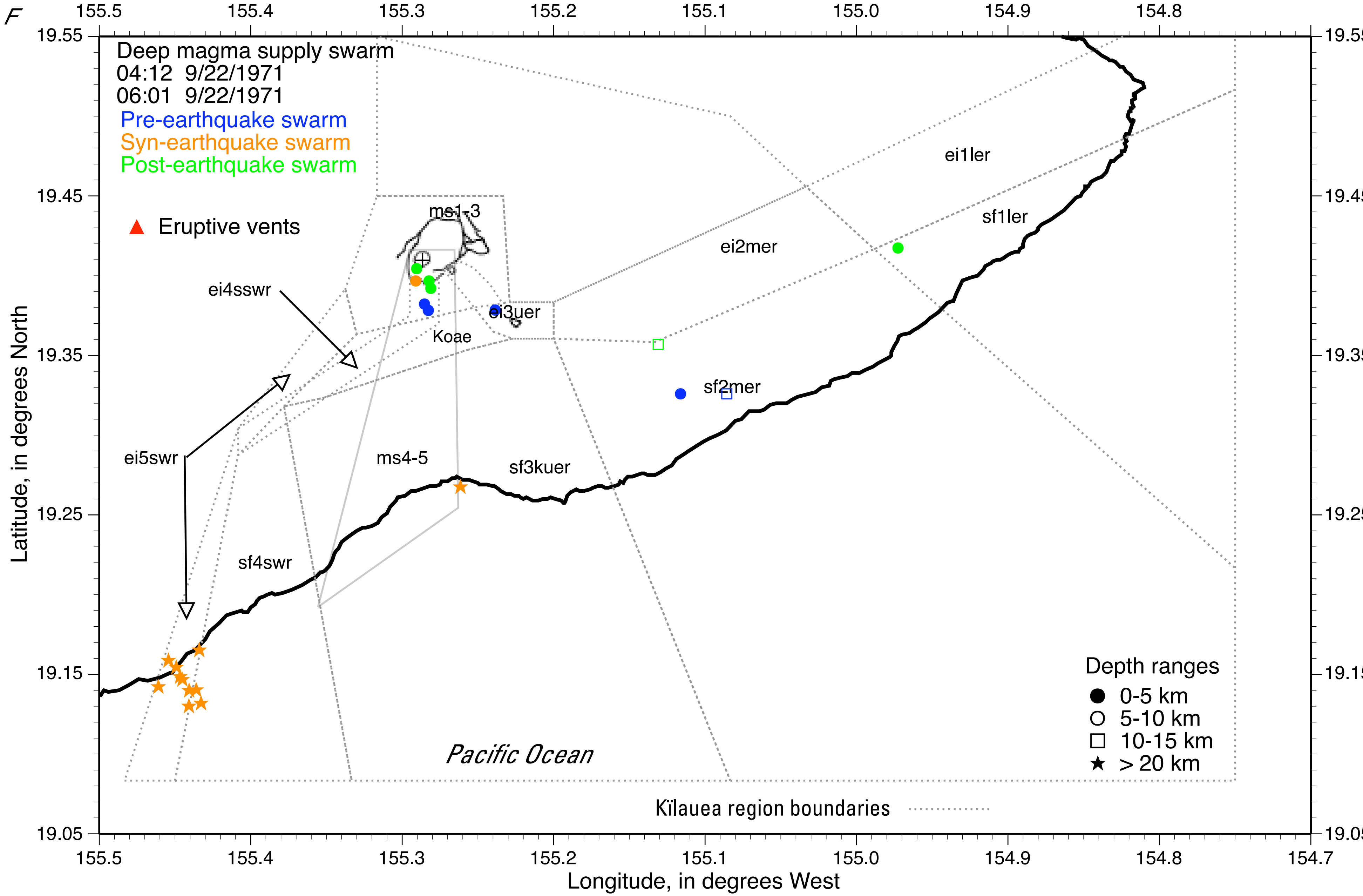
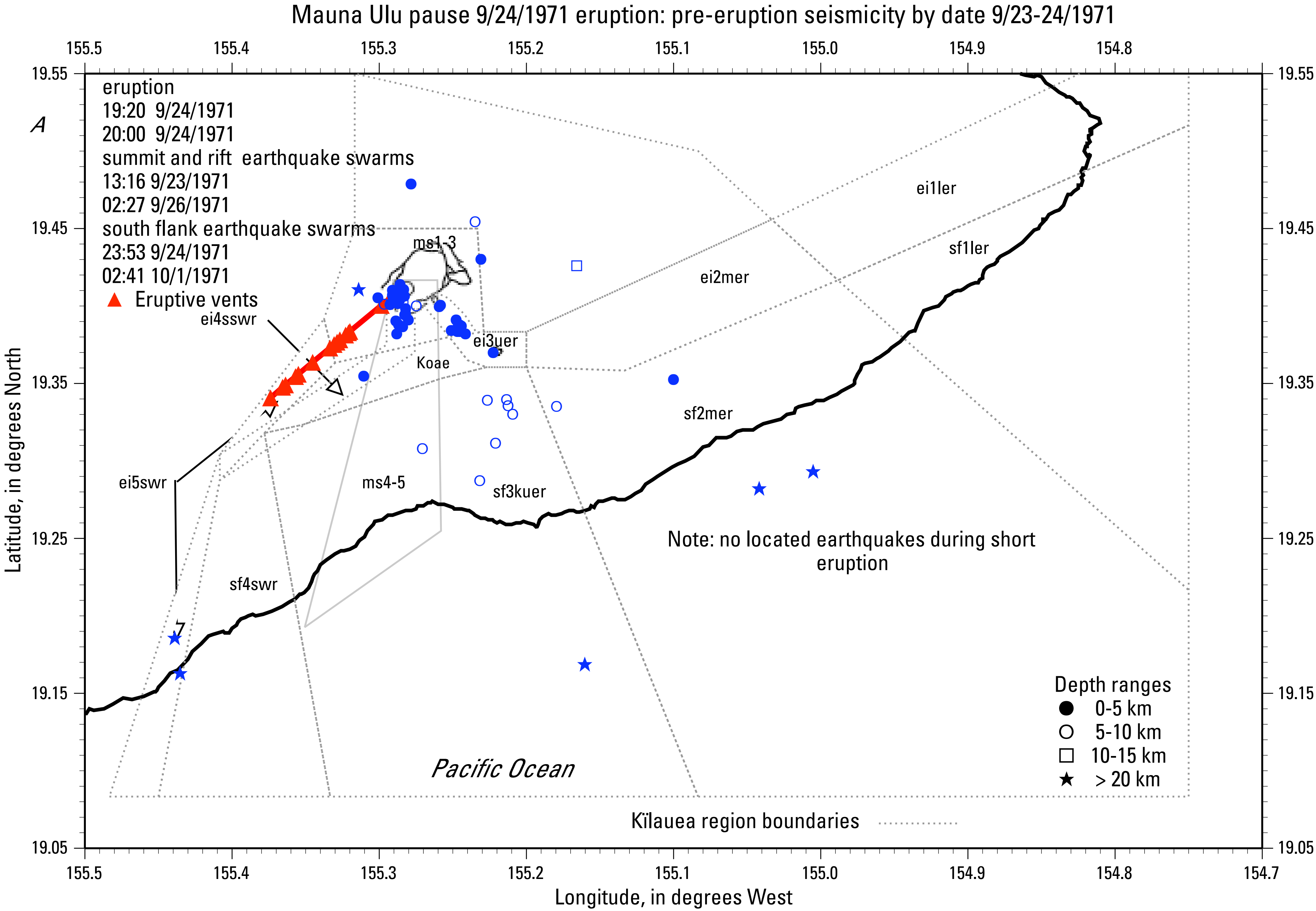


Figure E49a



Mauna Ulu pause 9/24/1971 eruption: pre-eruption seismicity by date 9/23-24/1971
eruption
19:20 9/24/1971
20:00 9/24/1971
summit and rift earthquake swarms
13:16 9/23/1971
02:27 9/26/1971
south flank earthquake swarms
23:53 9/24/1971
02:41 10/1/1971
Eruptive vents
A
ms1-3
ei4sswr
ei3uer
Koae
ei1ler
sf1ler
ei2mer
sf2mer
ei5swr
ms4-5
sf3kuer
sf4swr
Note: no located earthquakes during short eruption
Pacific Ocean
Depth ranges
0-5 km
5-10 km
10-15 km
> 20 km
Kīlauea region boundaries
Latitude, in degrees North
Longitude, in degrees West
155.5
155.4
155.3
155.2
155.1
155.0
154.9
154.8
154.7
19.55
19.45
19.35
19.25
19.15
19.05

Figure E49b

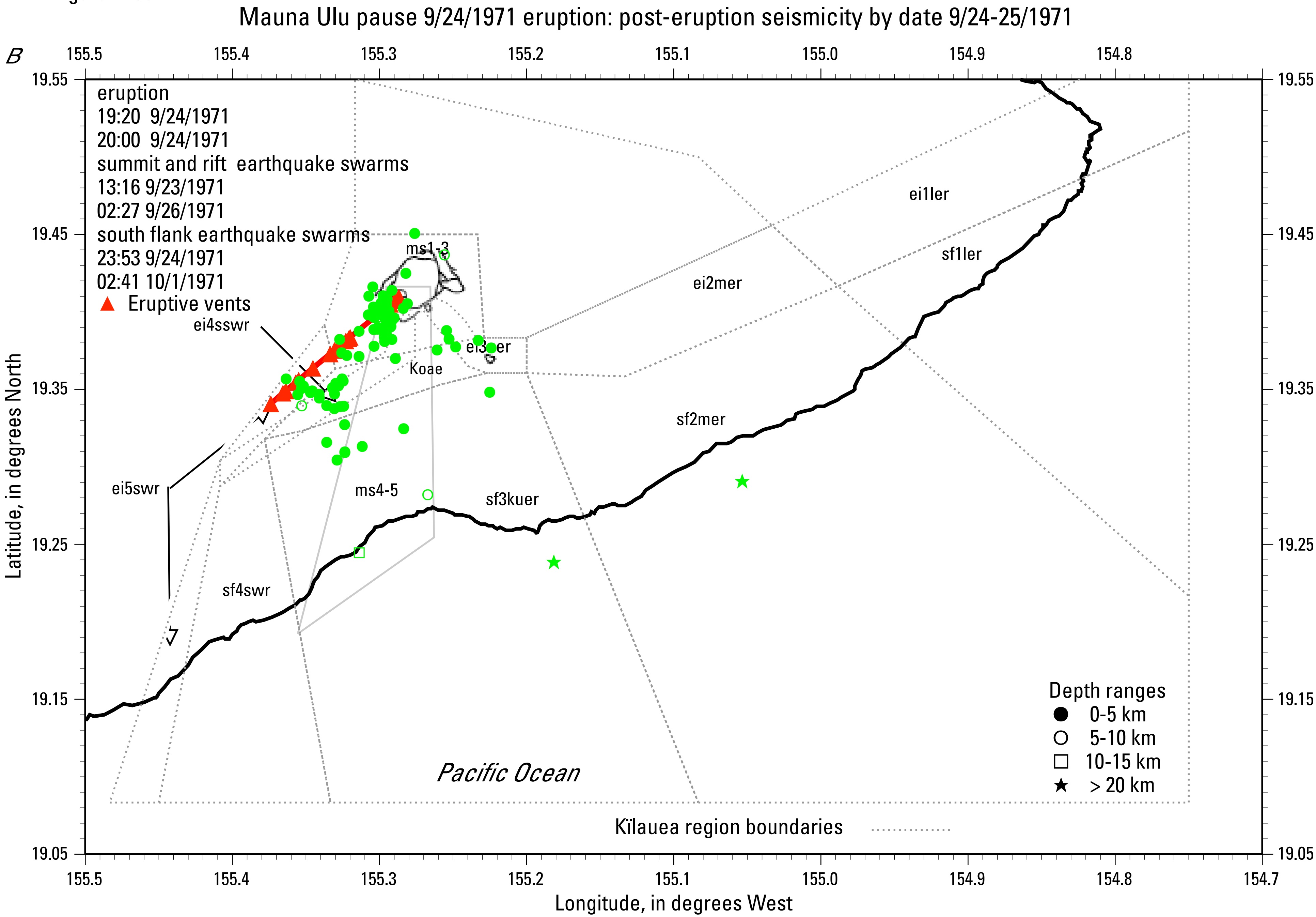
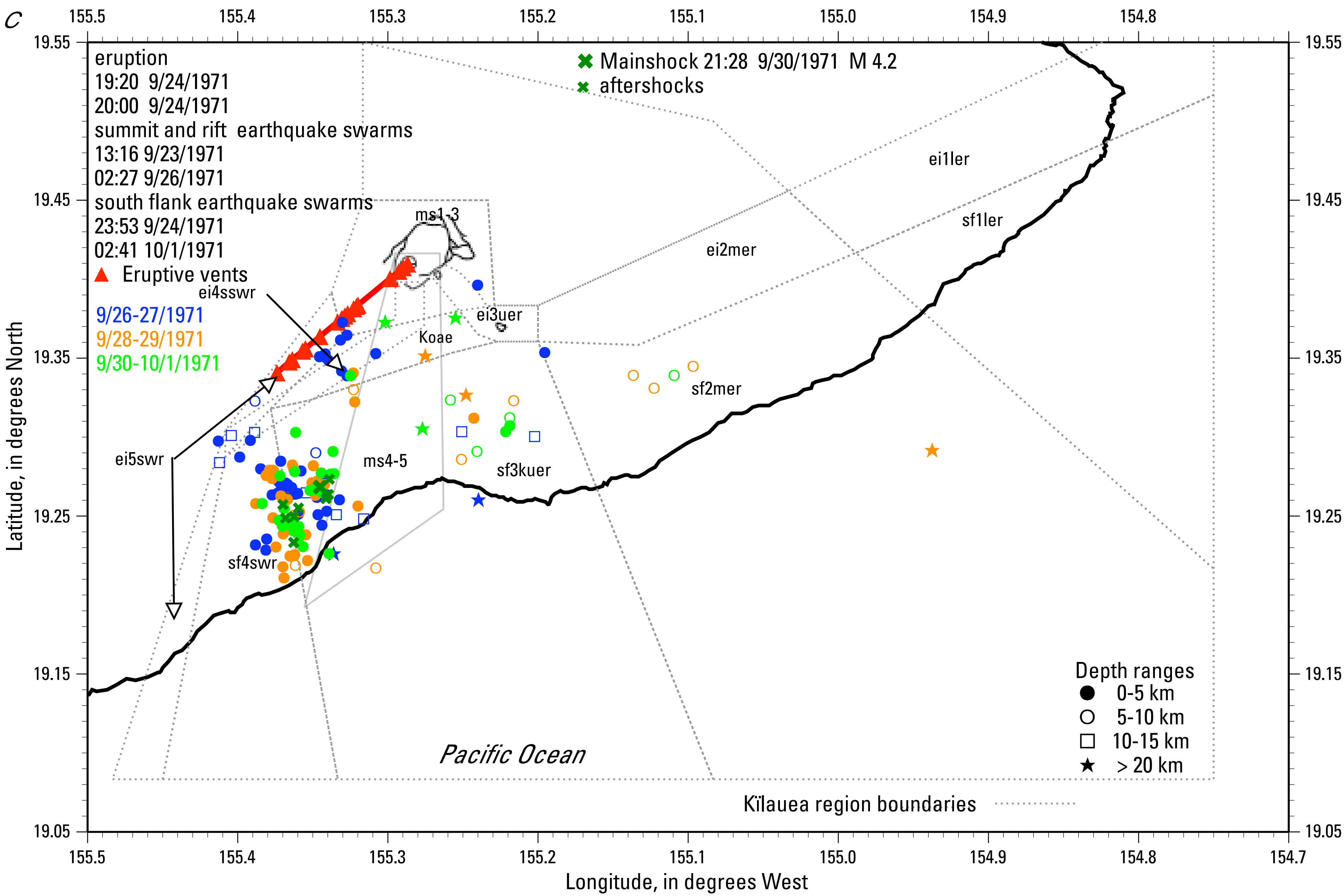

Mauna Ulu pause 9/24/1971 eruption: post-eruption seismicity by date 9/24-25/1971
B
155.5
155.4
155.3
155.2
155.1
155.0
154.9
154.8
154.7
19.55
19.45
19.35
19.25
19.15
19.05
eruption
19:20 9/24/1971
20:00 9/24/1971
summit and rift earthquake swarms
13:16 9/23/1971
02:27 9/26/1971
south flank earthquake swarms
23:53 9/24/1971
02:41 10/1/1971
Eruptive vents
ei4sswr
ei5swr
sf4swr
ms1-3
ms4-5
Koae
ei3mer
ei1ler
sf1ler
ei2mer
sf2mer
sf3kuer
Pacific Ocean
Depth ranges
0-5 km
5-10 km
10-15 km
> 20 km
Kīlauea region boundaries
Latitude, in degrees North
Longitude, in degrees West

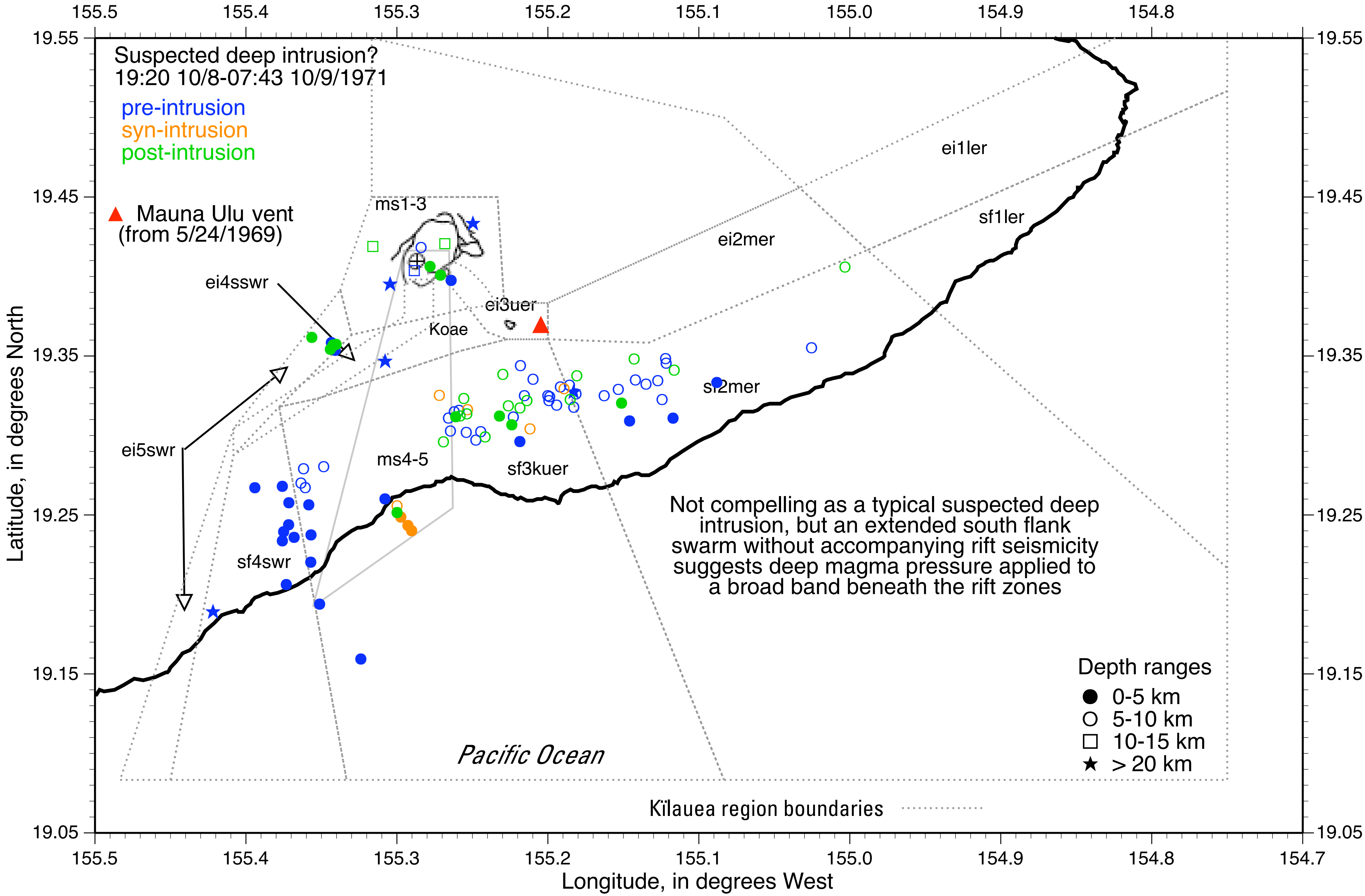
Figure E49c

Mauna Ulu pause 9/24/1971 eruption: post-eruption seismicity by date 9/26-10/1/1971



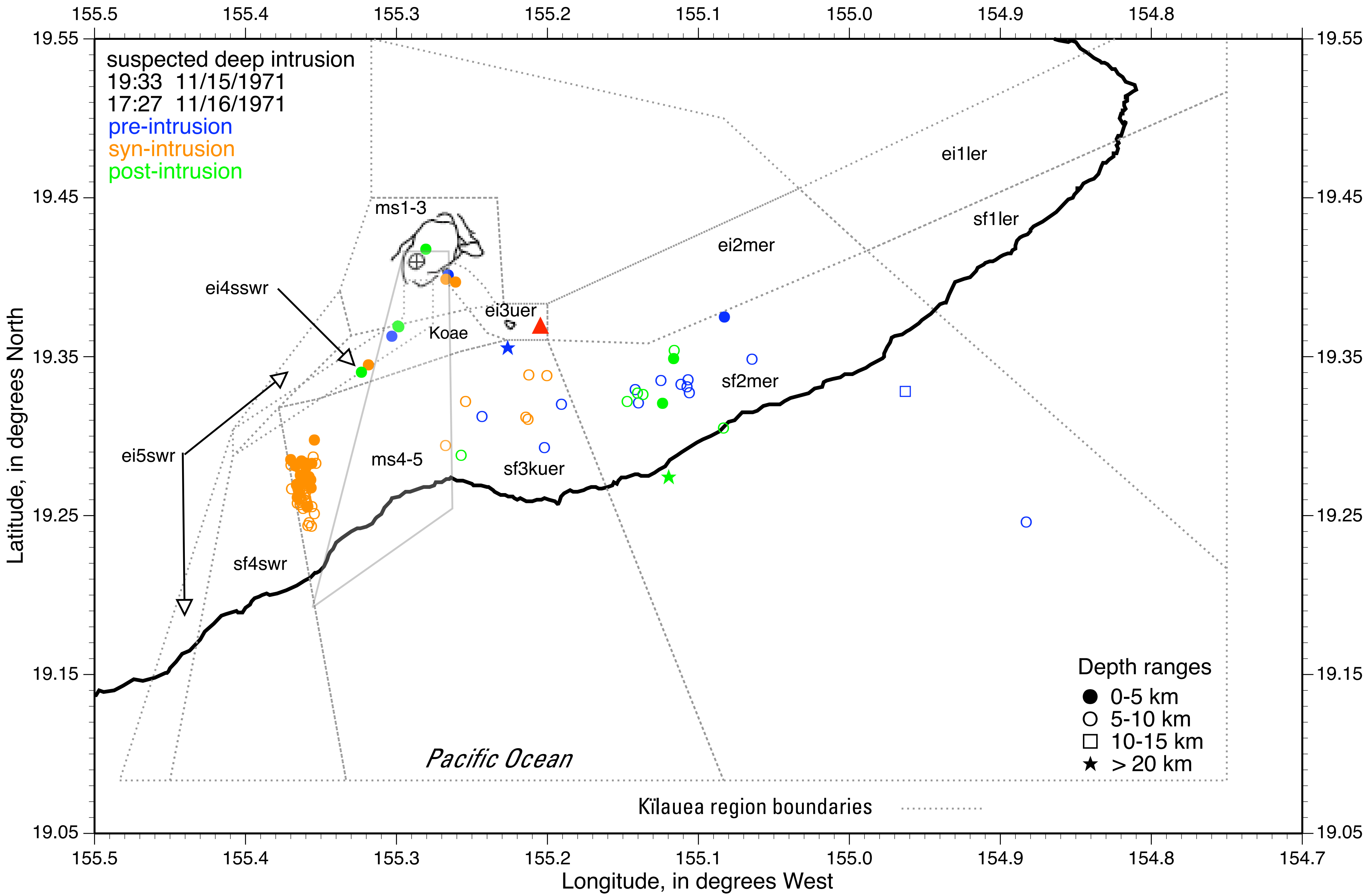
Appendix Figure E50

Mauna Ulu pause Suspected deep intrusion?: data from 10/2-13/1971



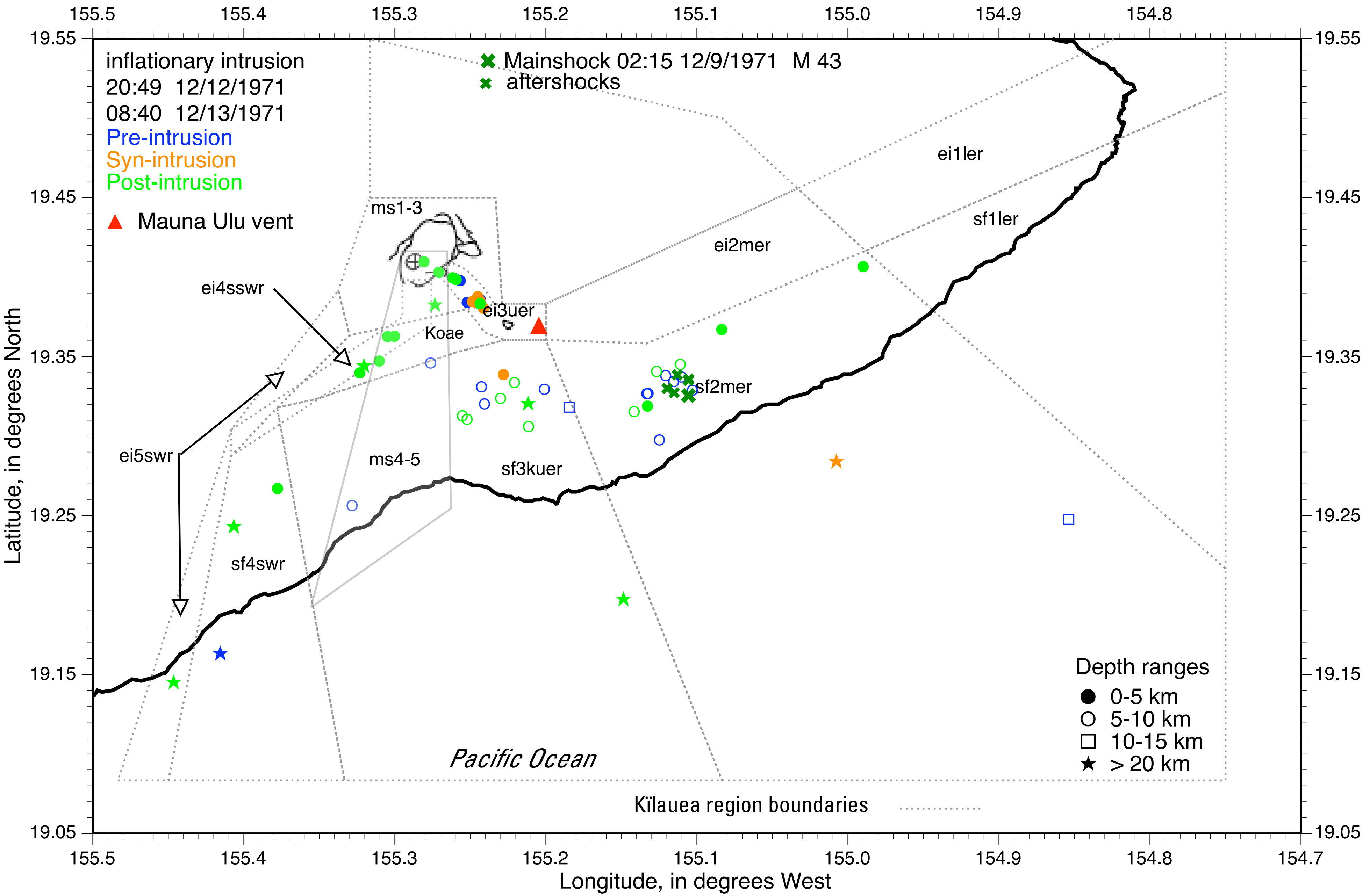
Appendix Figure E51

Mauna Ulu pause 11/1971 suspected deep intrusion: data from 11/14-16/1971



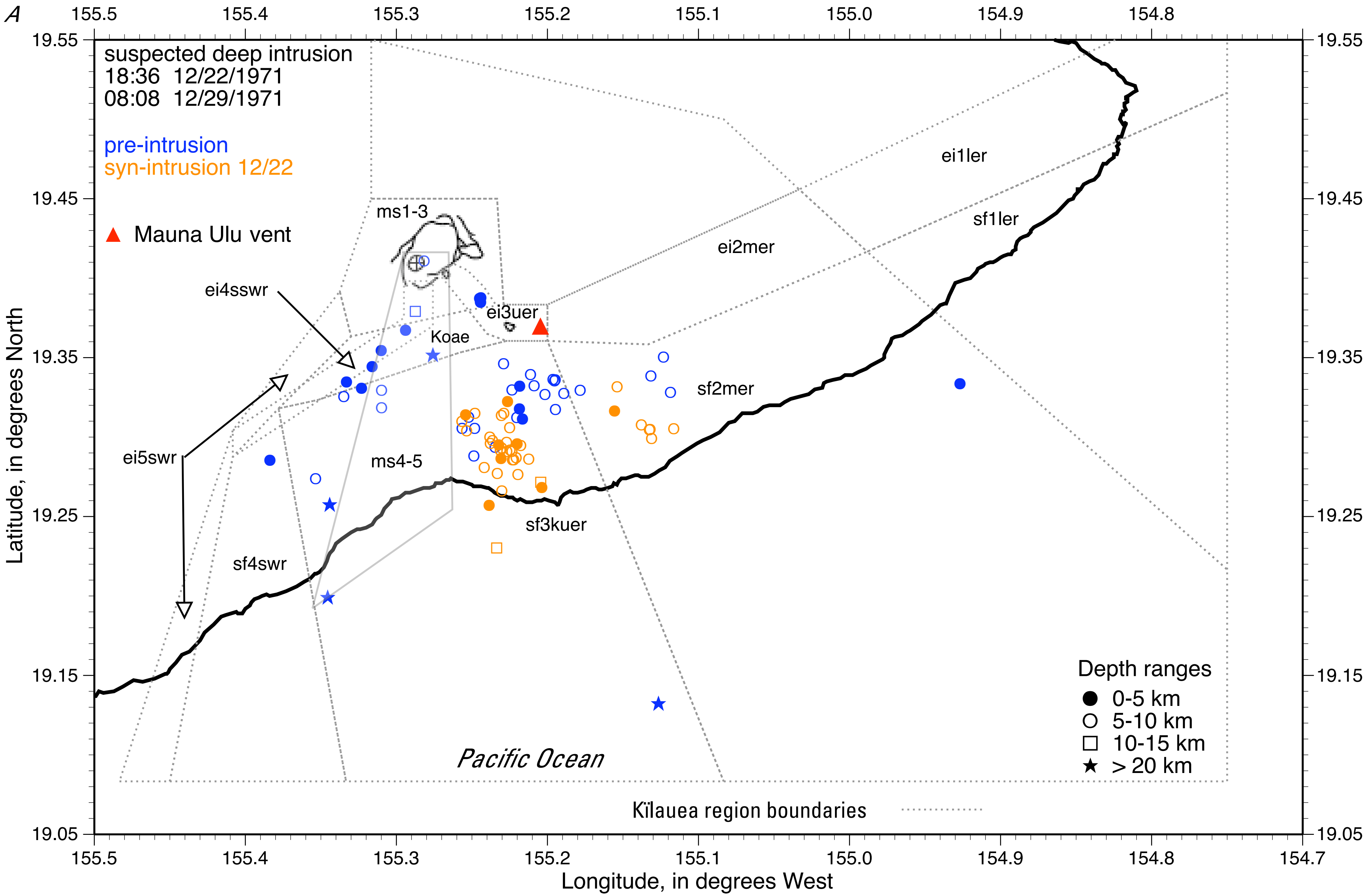
Appendix Figure E52

Mauna Ulu pause inflationary intrusion: data from 12/9-16/1971

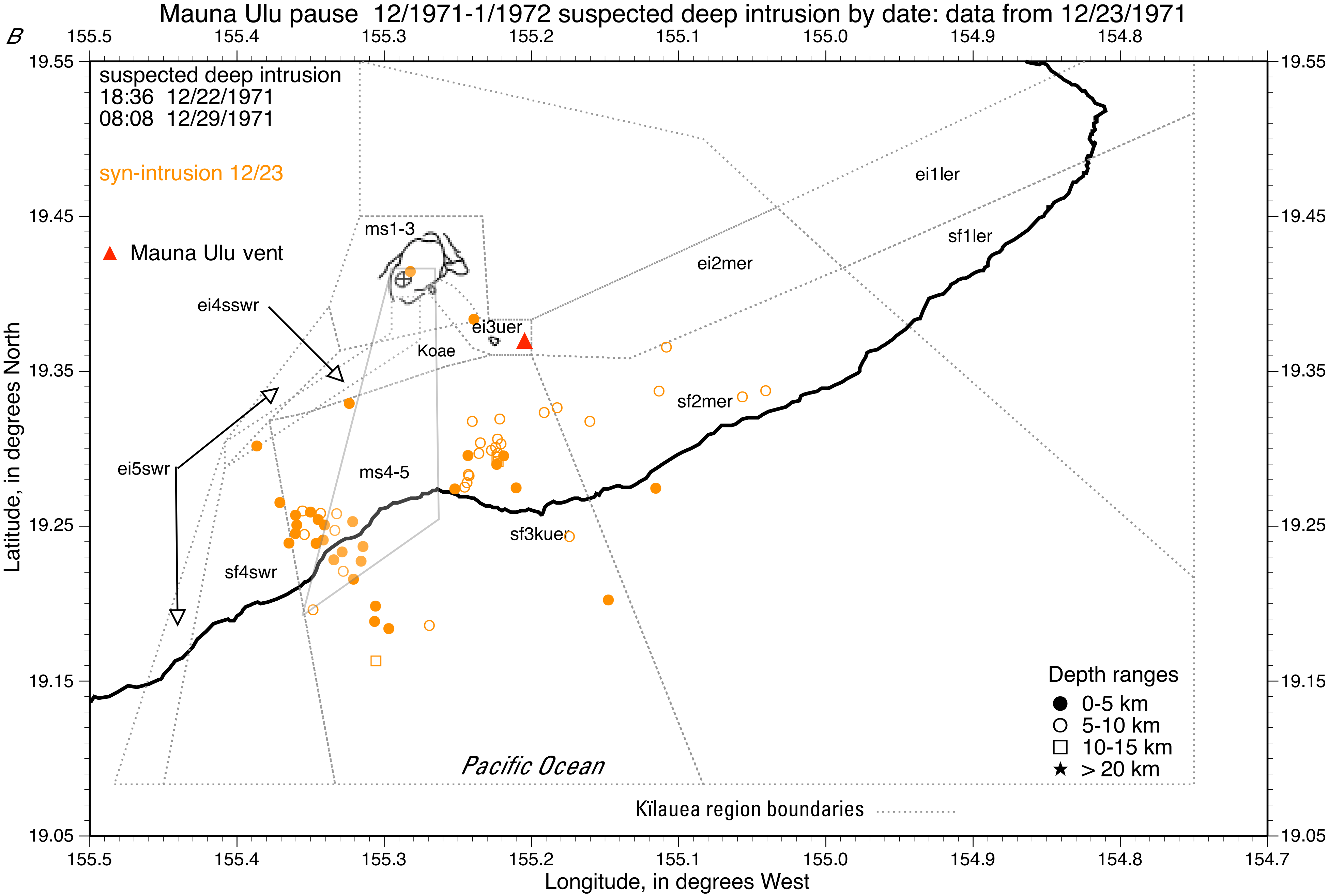


Appendix Figure E53a

Mauna Ulu pause 12/1971-1/1972 suspected deep intrusion by date: data from 12/22/1971

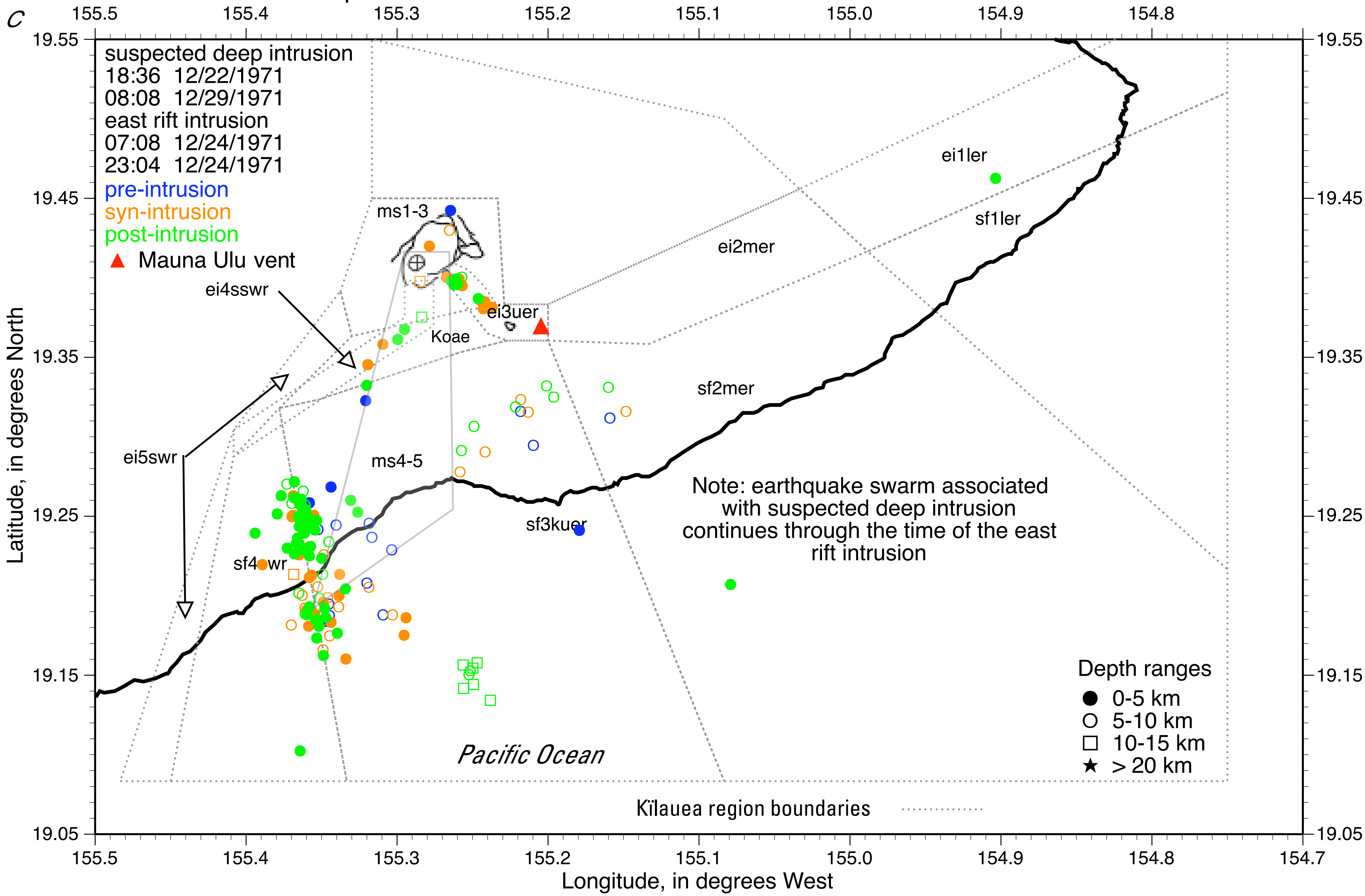


Appendix Figure E53b



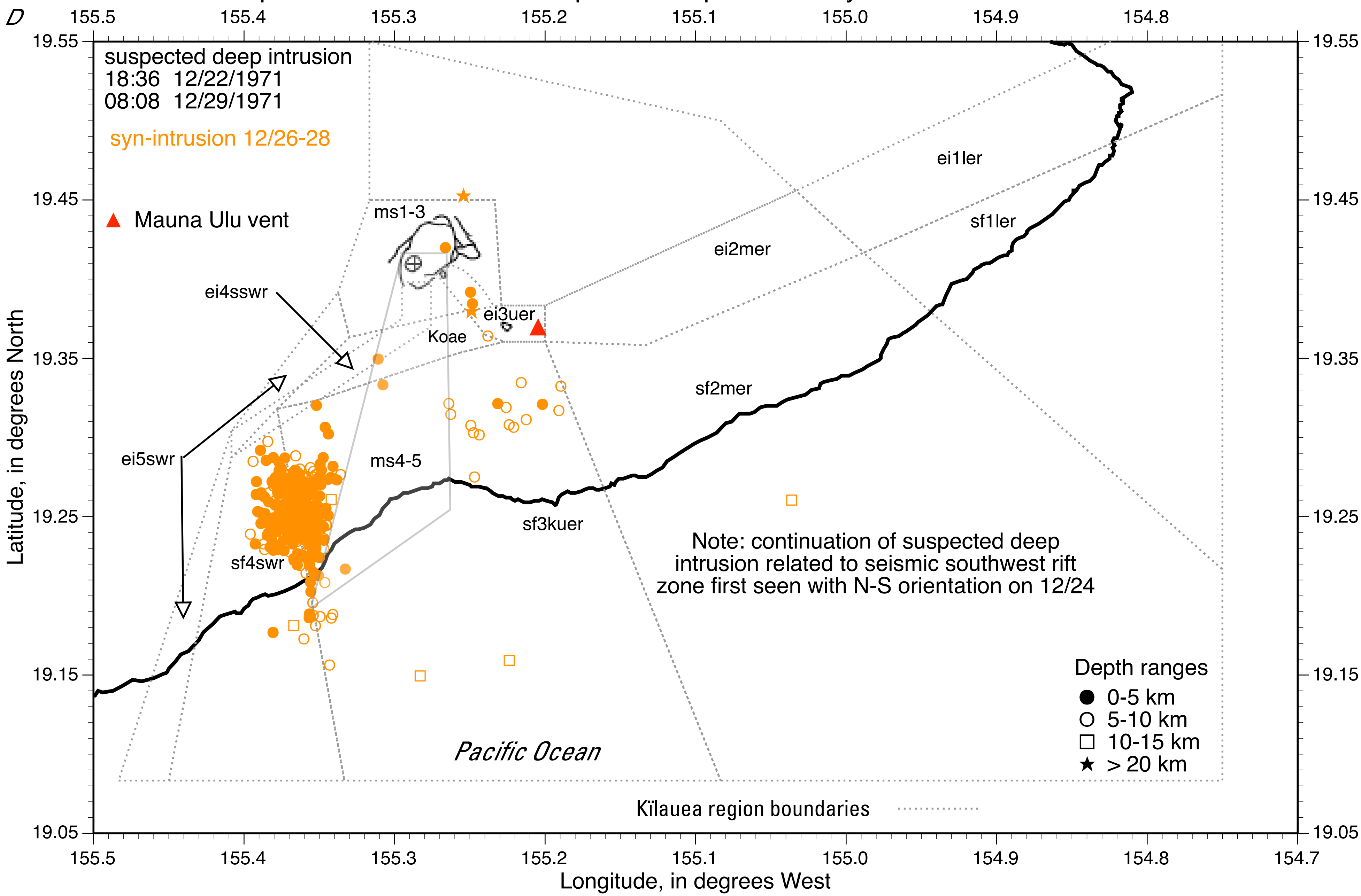
Appendix Figure E53c

Mauna Ulu pause 12/1971-1/1972 east rift intrusion: data from 12/24-25/1971



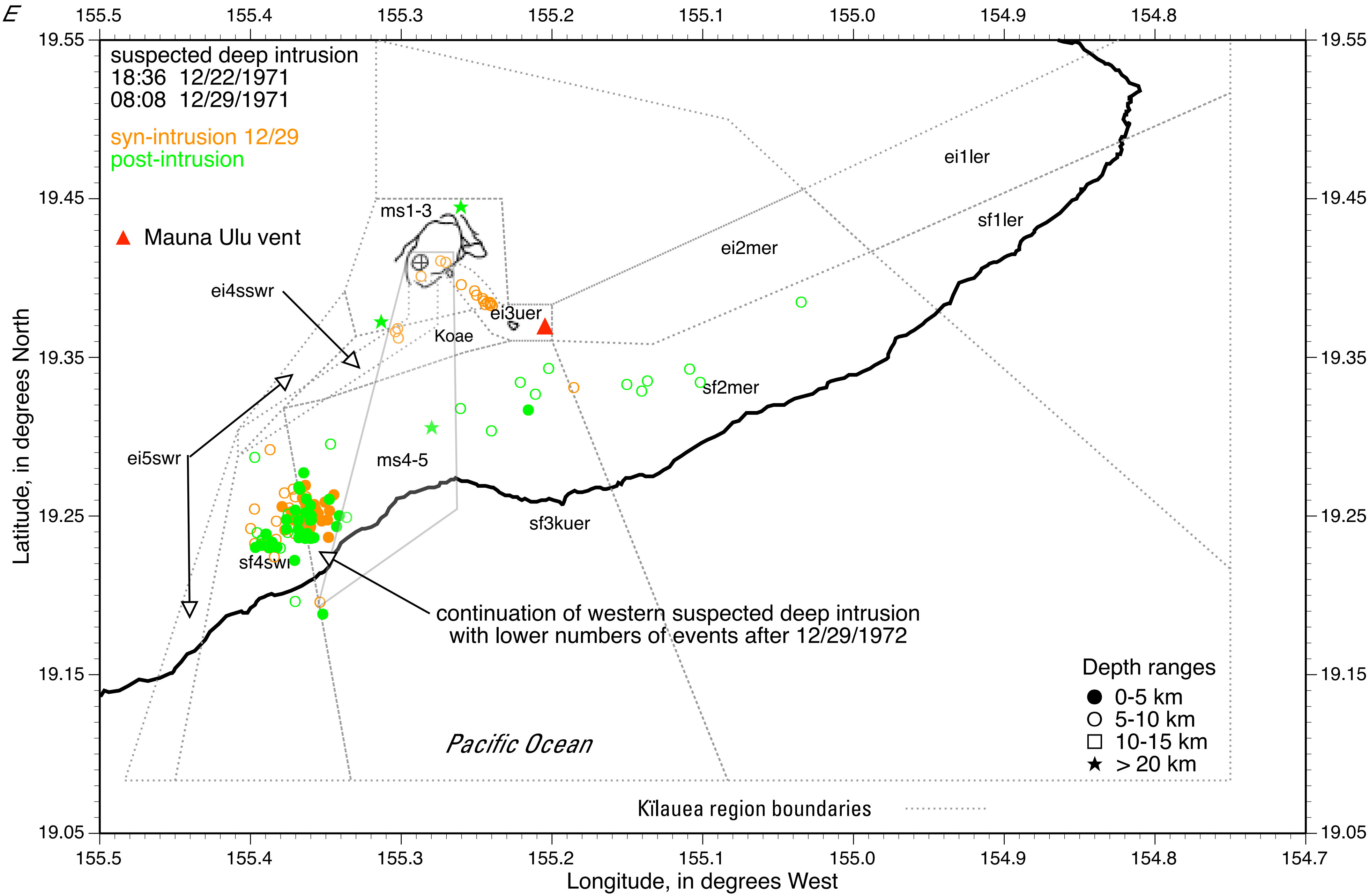
Appendix Figure E53d

Mauna Ulu pause 12/1971-1/1972 suspected deep intrusion by date: data from 12/26-281971



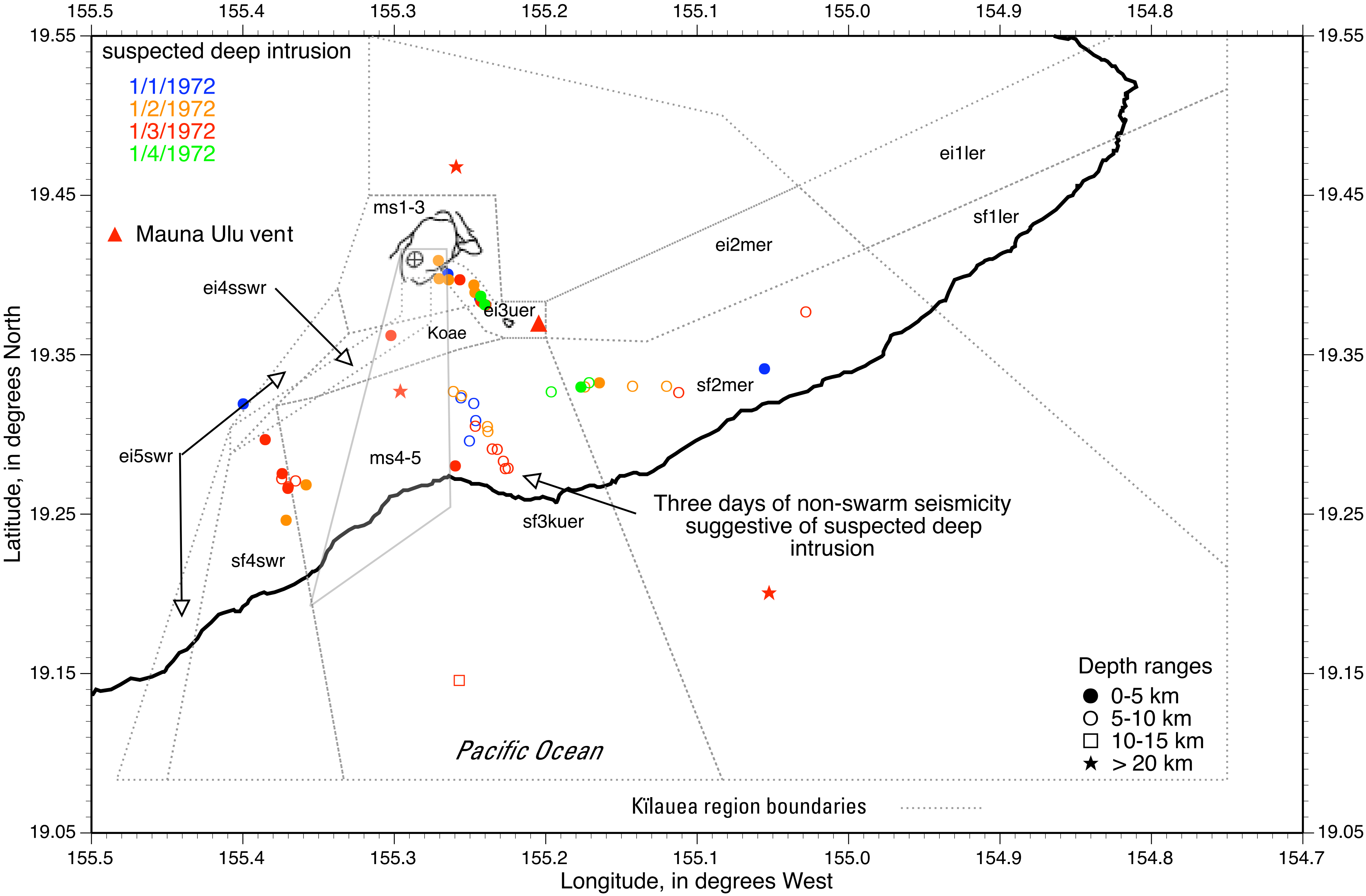
Appendix Figure E53e

Mauna Ulu pause 12/1971-1/1972 suspected deep intrusion: data from 12/29-31/1971



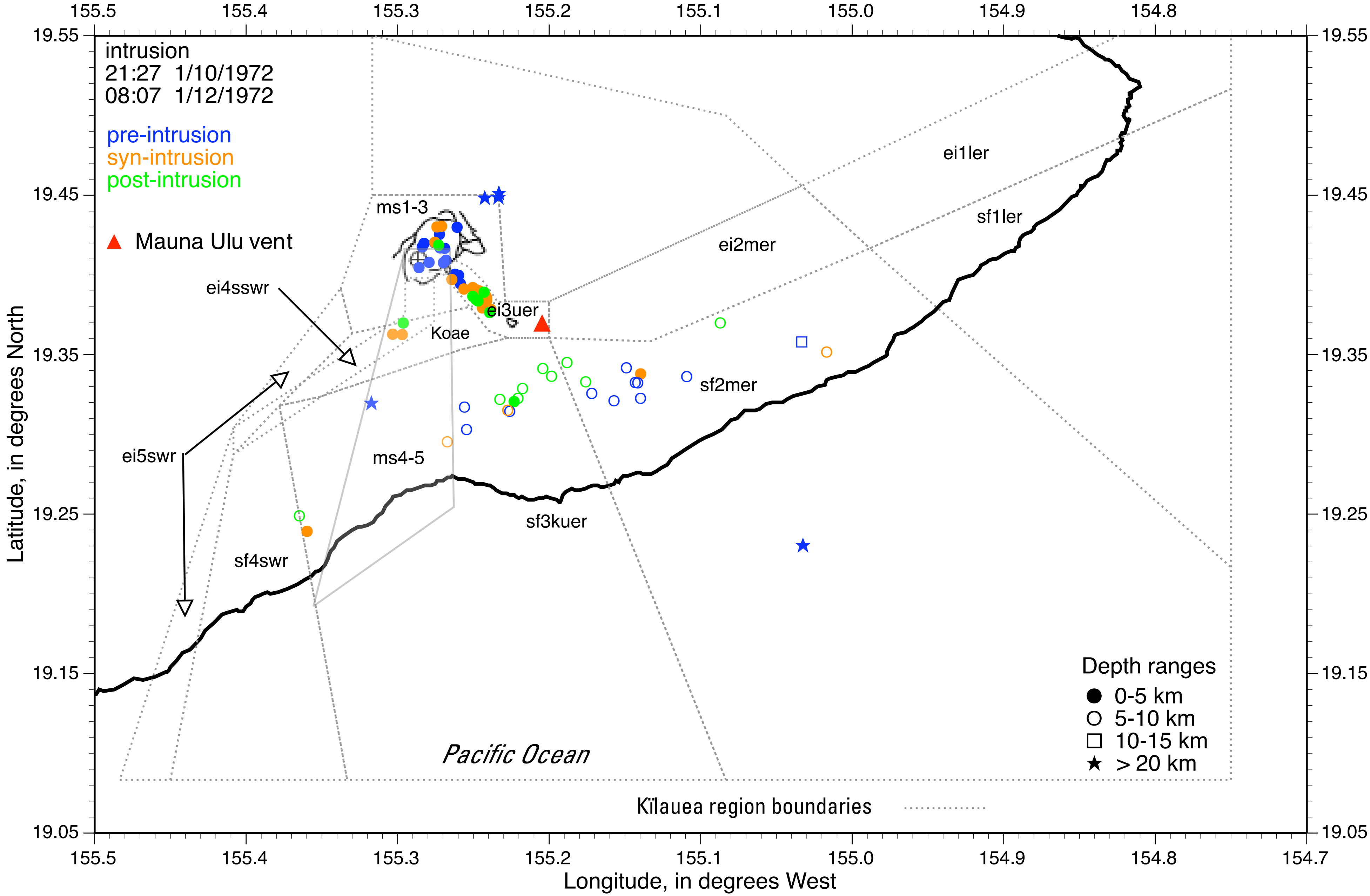
Appendix Figure E54

Mauna Ulu pause Post-intrusion by date: data from 1/1-4/1972



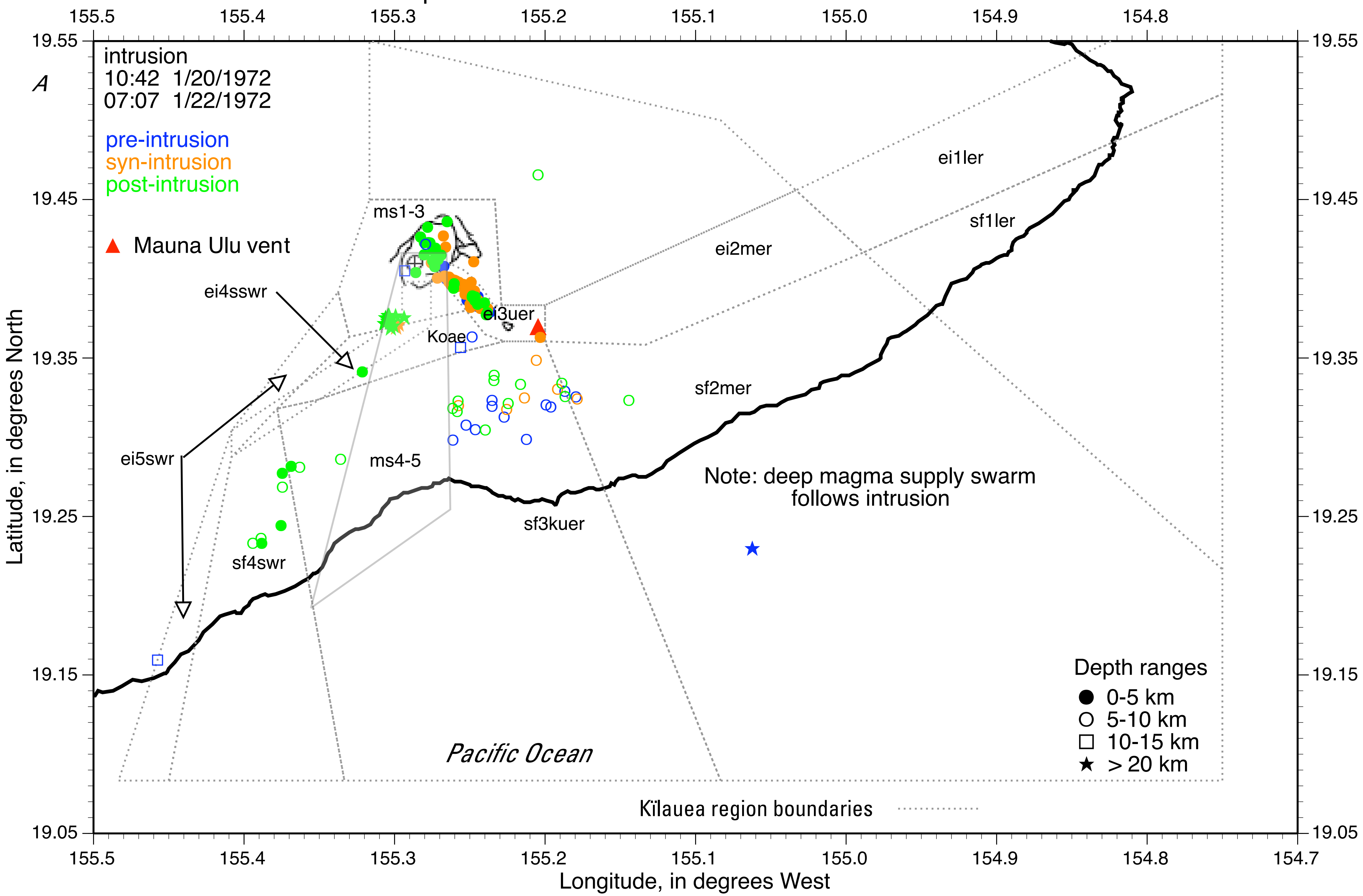
Appendix Figure E55

Mauna Ulu pause 11/1972 intrusion: data from 1/8-13/1972



Appendix Figure E56 a

Mauna Ulu pause 1/20-22/1972 intrusion: data from 1/18-25/1972



Appendix Figure E56 b

Mauna Ulu pause 1/26-28/1972 intrusion: data from 1/26-2/1/1972

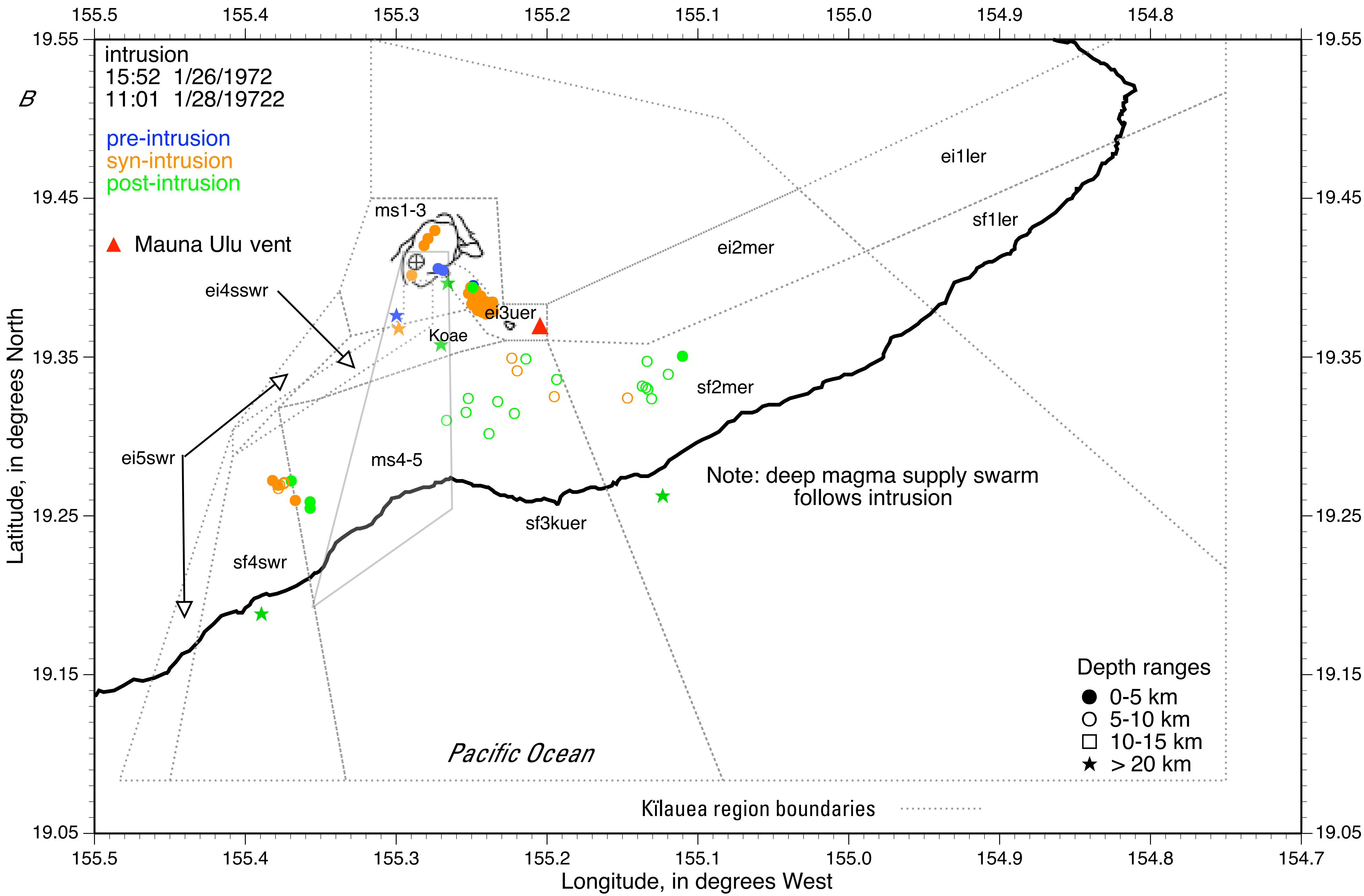


Figure E57 Mauna ULU II: earthquake swarms and tilt

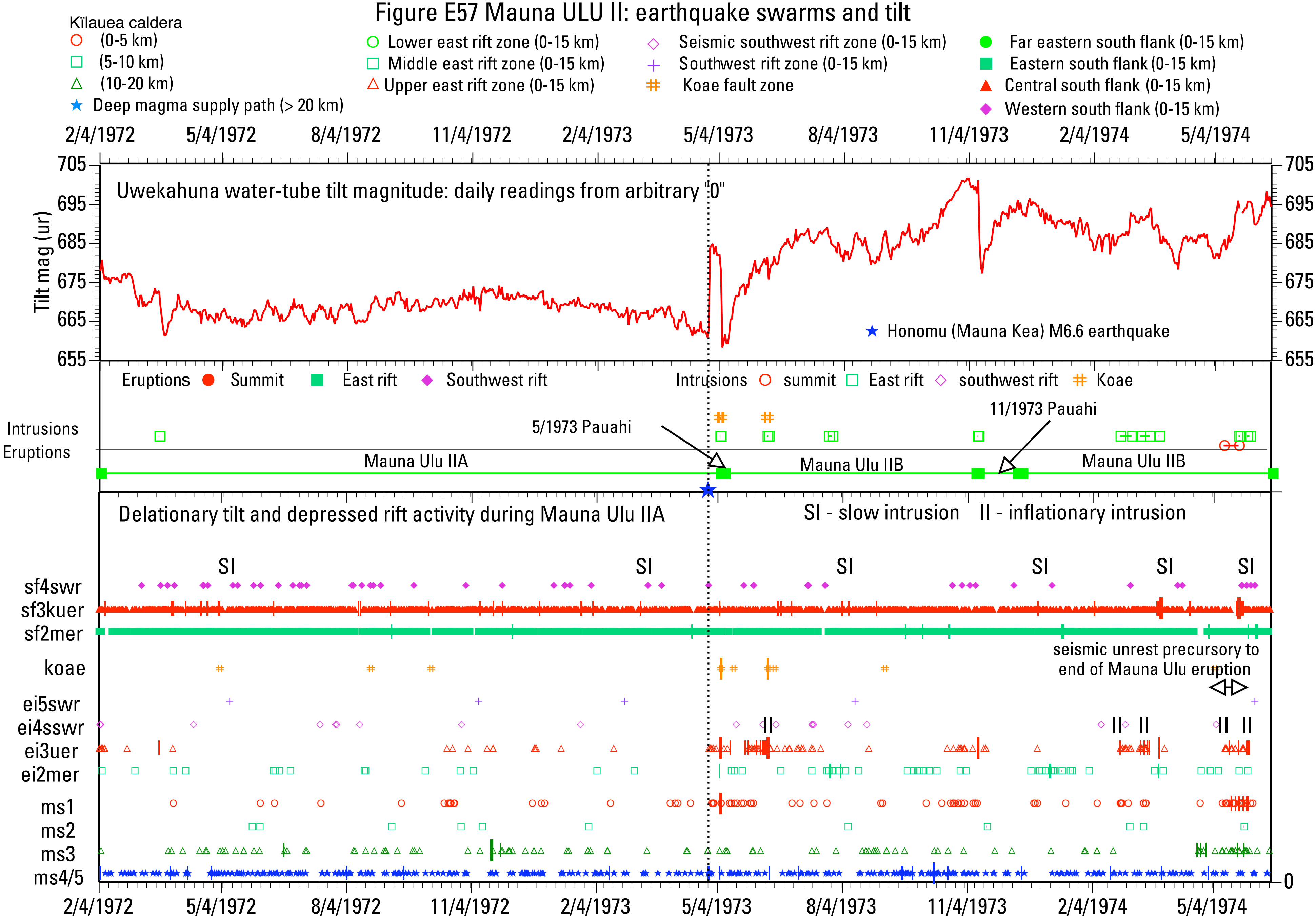
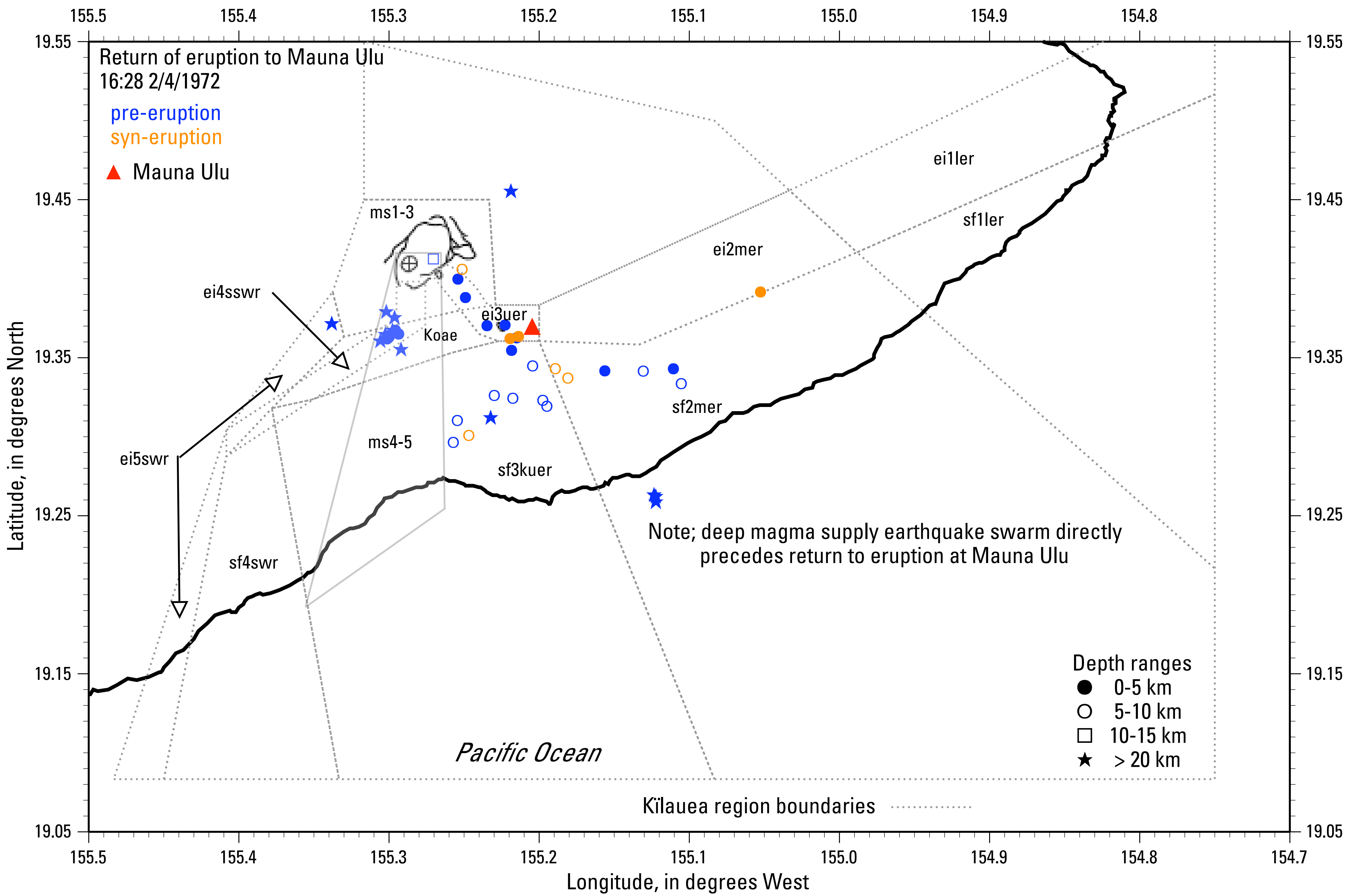


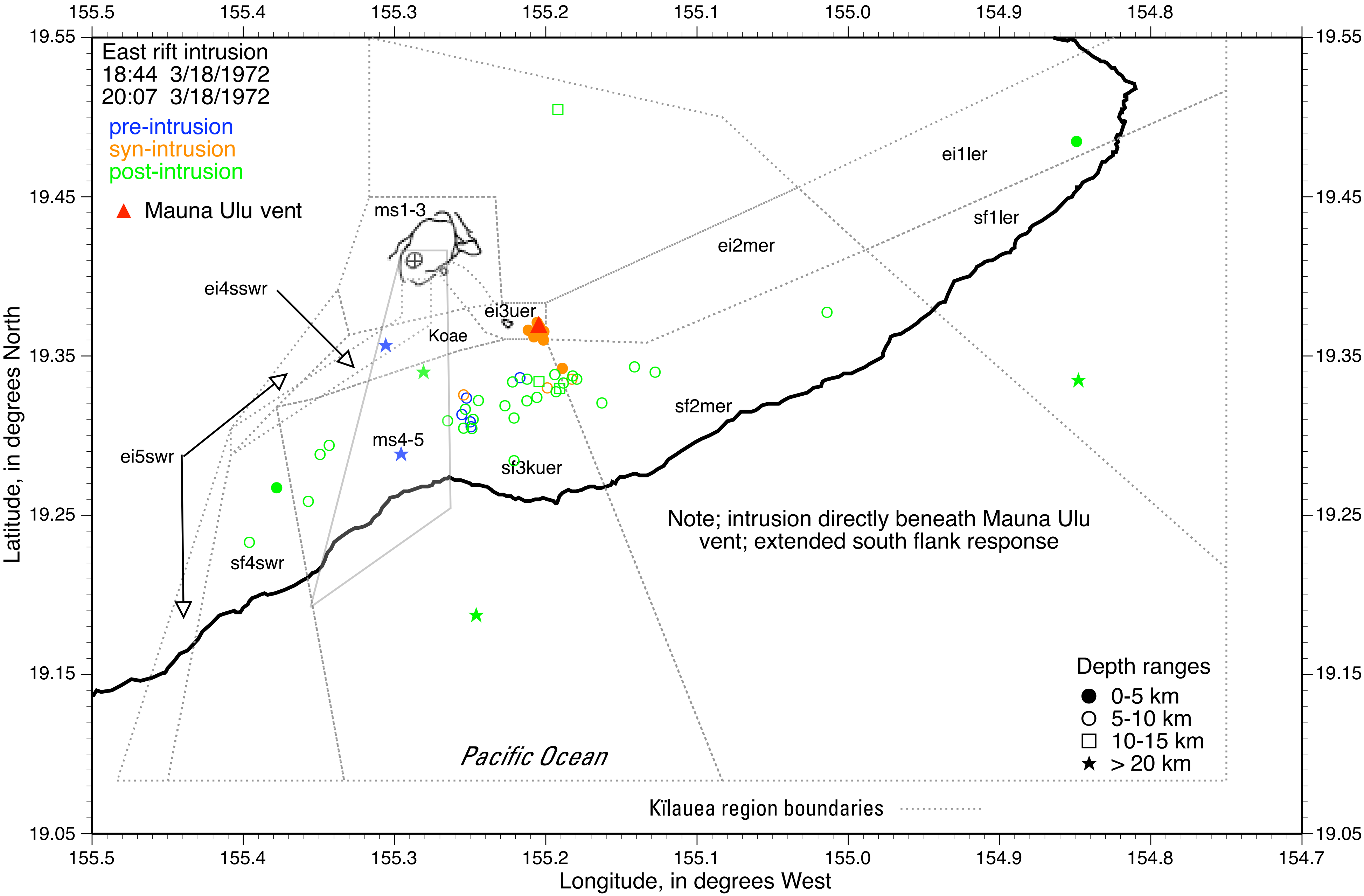
Figure E58

Mauna Ulu IIA 3/1972 Precursory seismicity to Mauna Ulu II: data from 2/2-5/1972



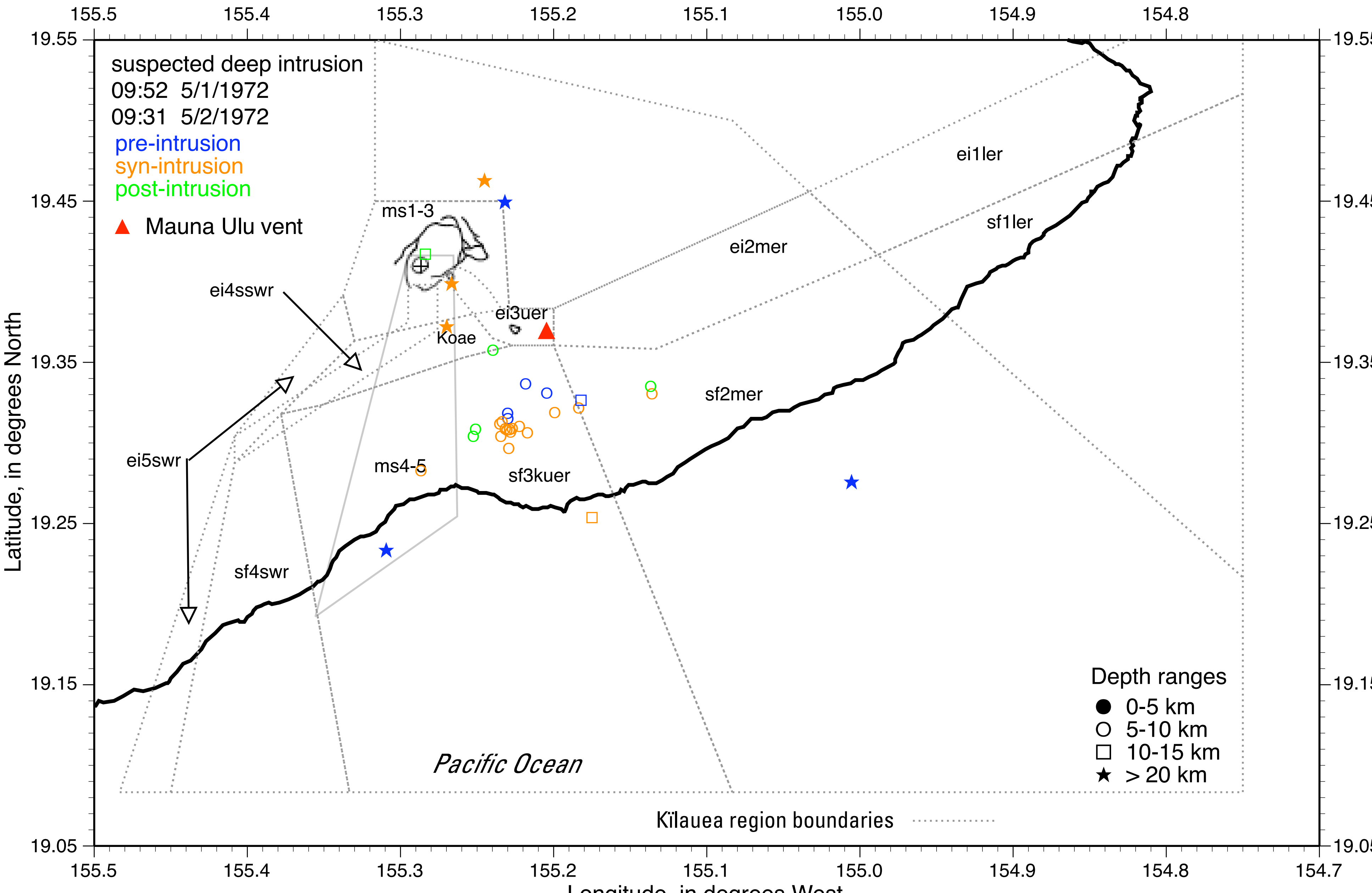
Appendix figure E59

Mauna Ulu IIA 3/1972 intrusion: data from 3/15-251972



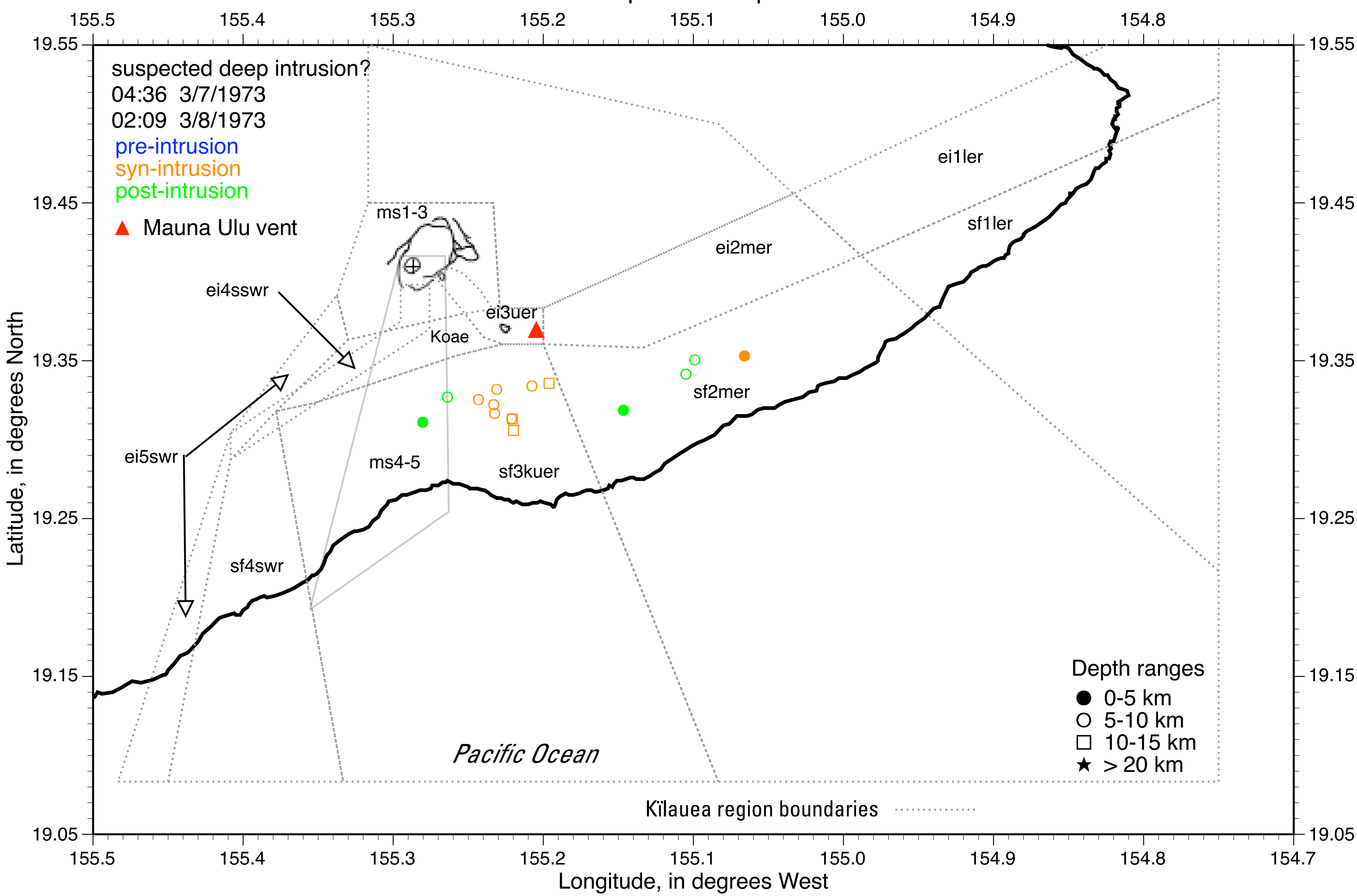
Appendix figure E60

Mauna Ulu IIA--May 1972 suspected deep intrusion: data from 4/30-5/3/1972



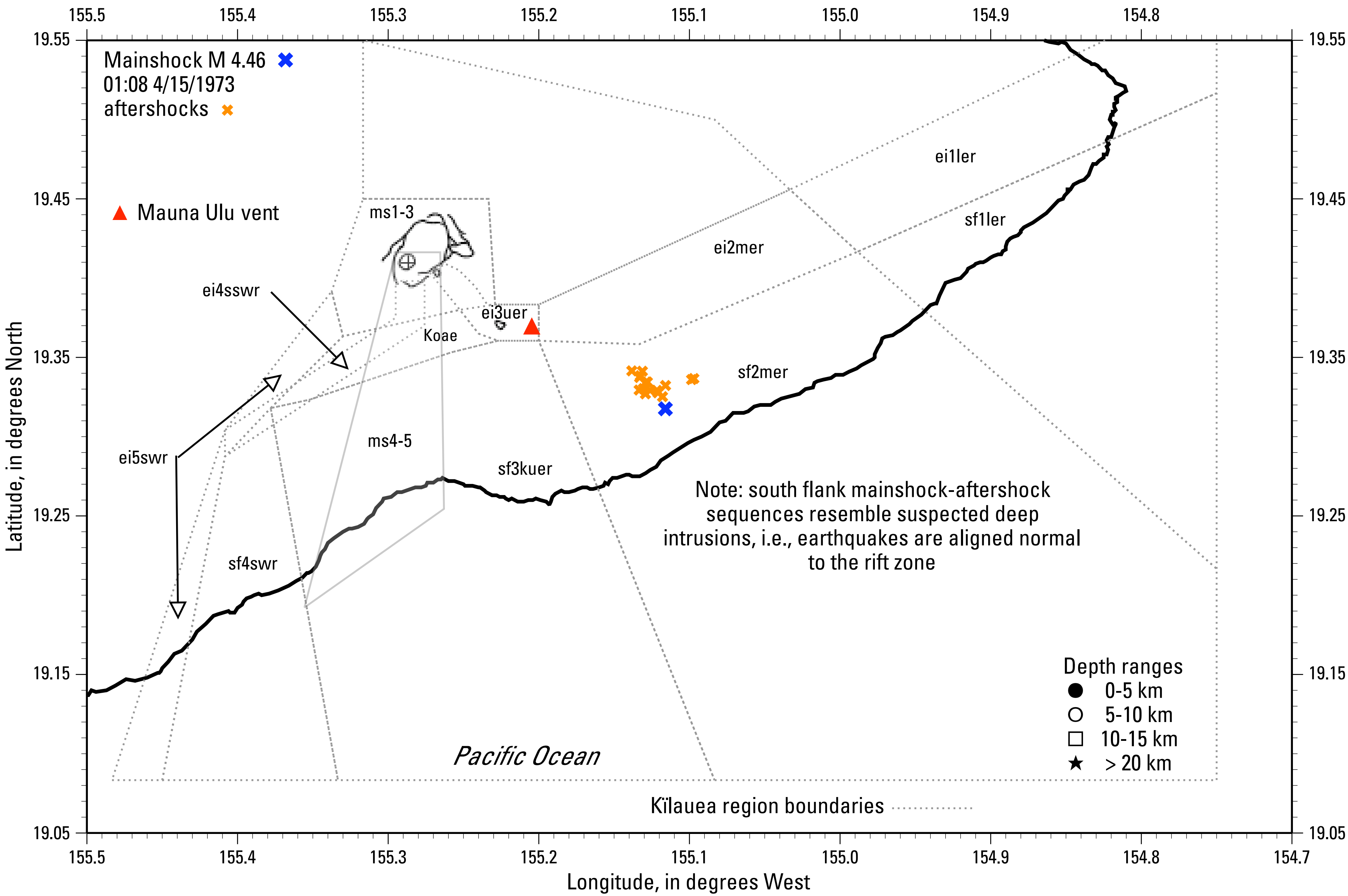
Appendix figure E61

Mauna Ulu IIA--March 1973 suspected deep intrusion?: data from 3/7-8/1973



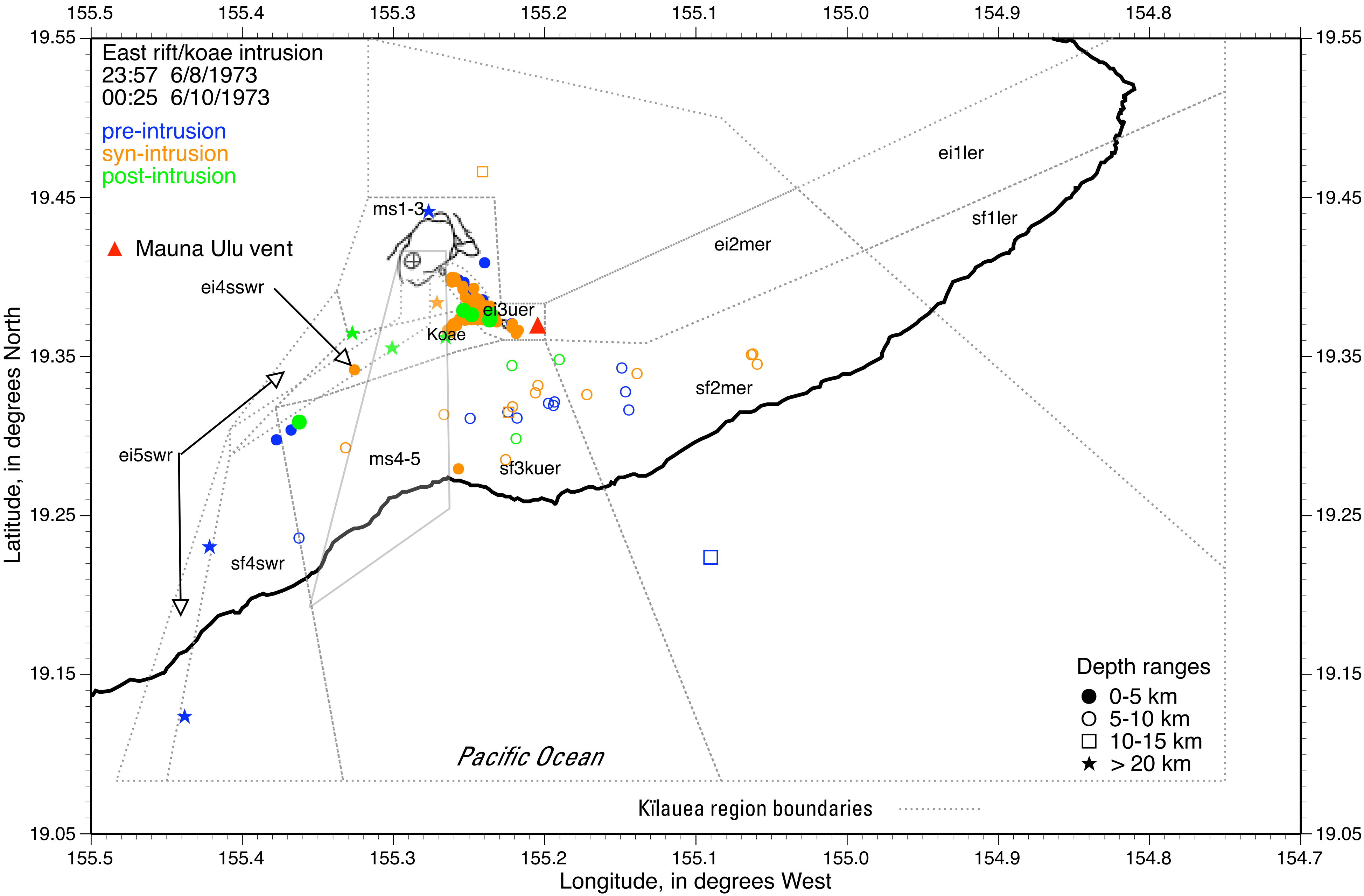
Appendix figure E62

Mauna Ulu IIA April 1973 earthquake and aftershocks: data from 4/15-16/1973



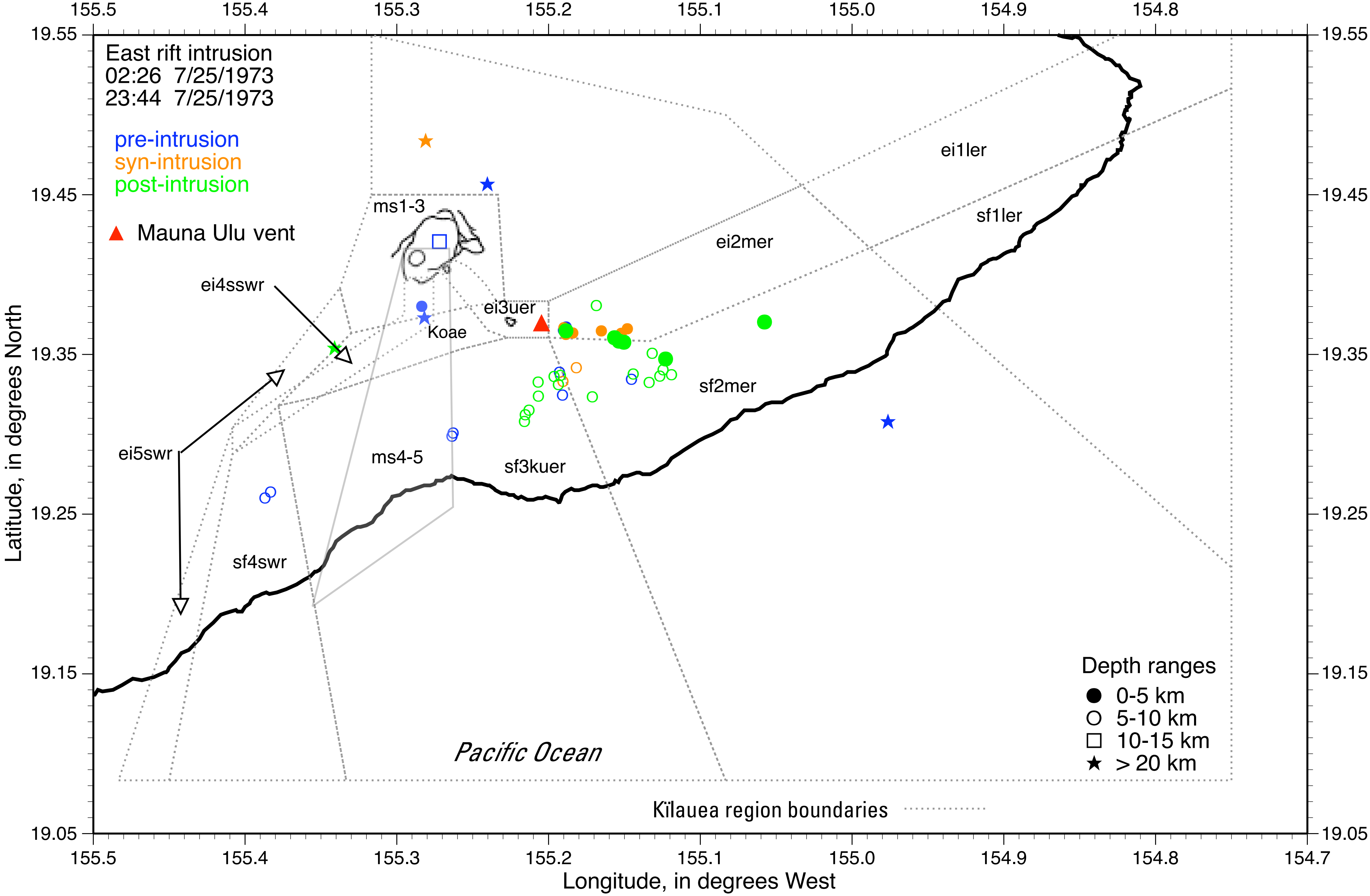
Appendix figure E63

Mauna Ulu IIB June 1973 intrusion: data from 5/30-6/12/1973



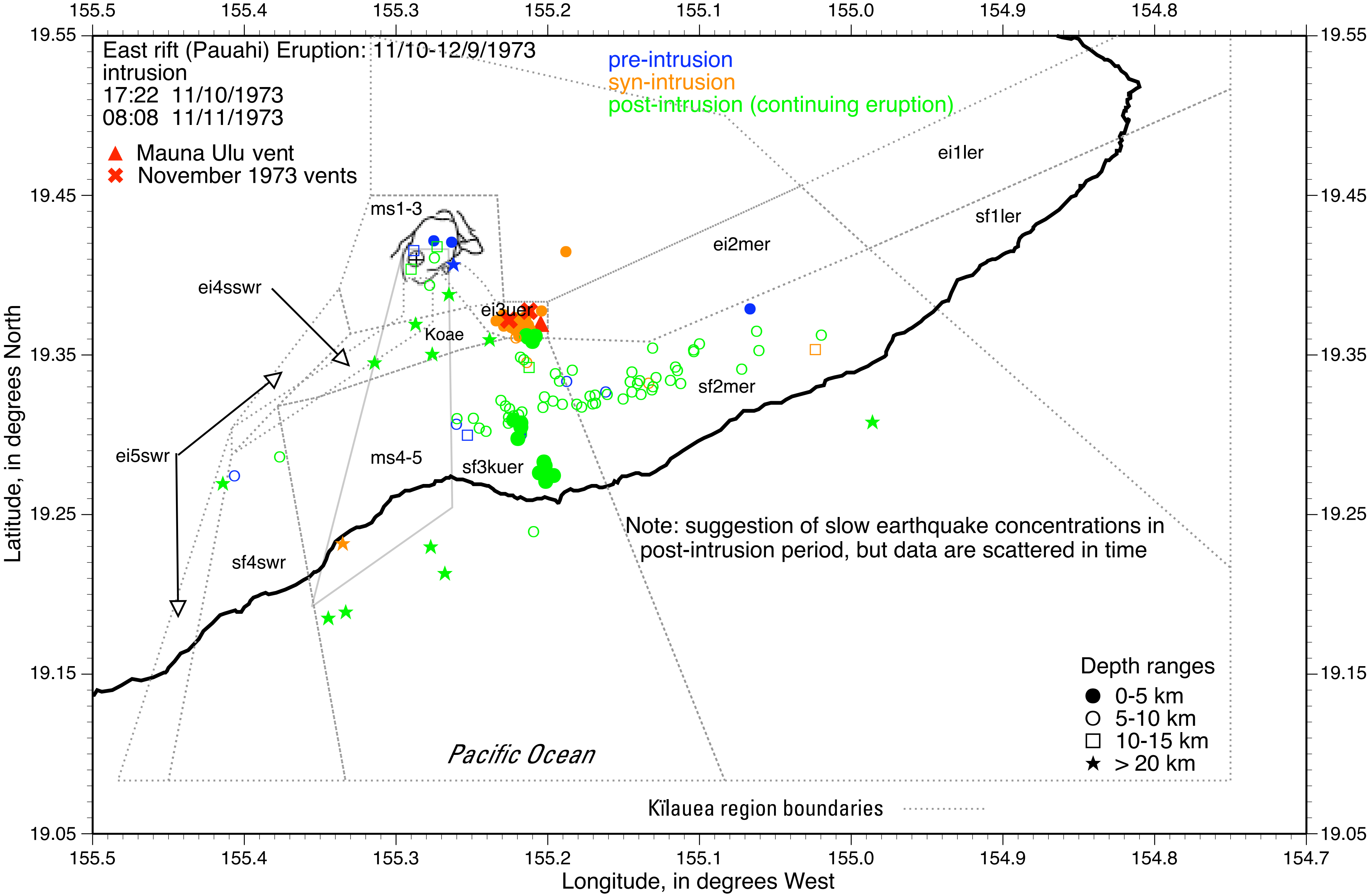
Appendix figure E64

Mauna Ulu IIB 7/1973 intrusion: data from7/21-30/1973



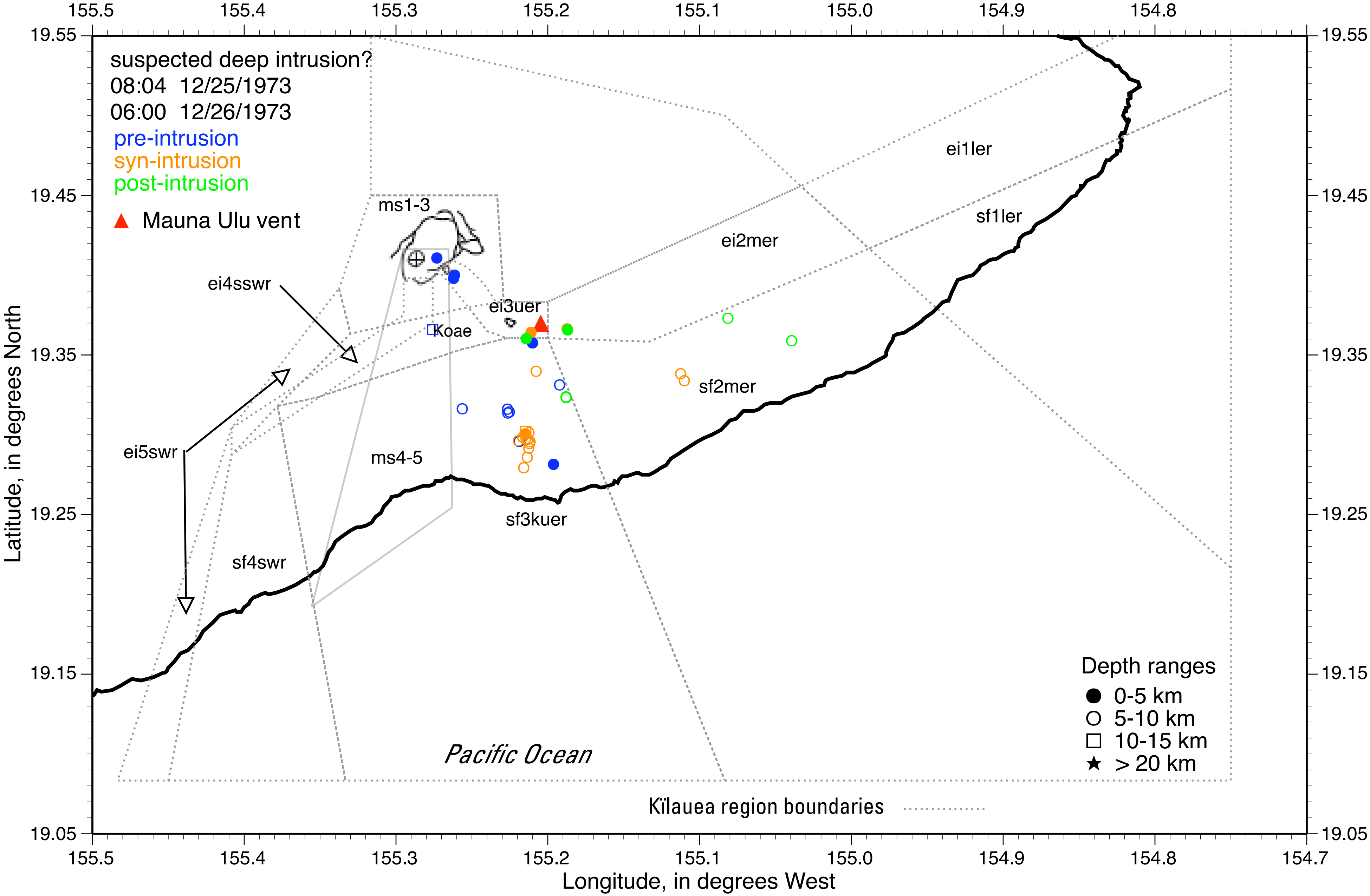
Appendix figure E65

Mauna Ulu IIB 11/1973 eruption and intrusion: data from 11/9-12/12/1973



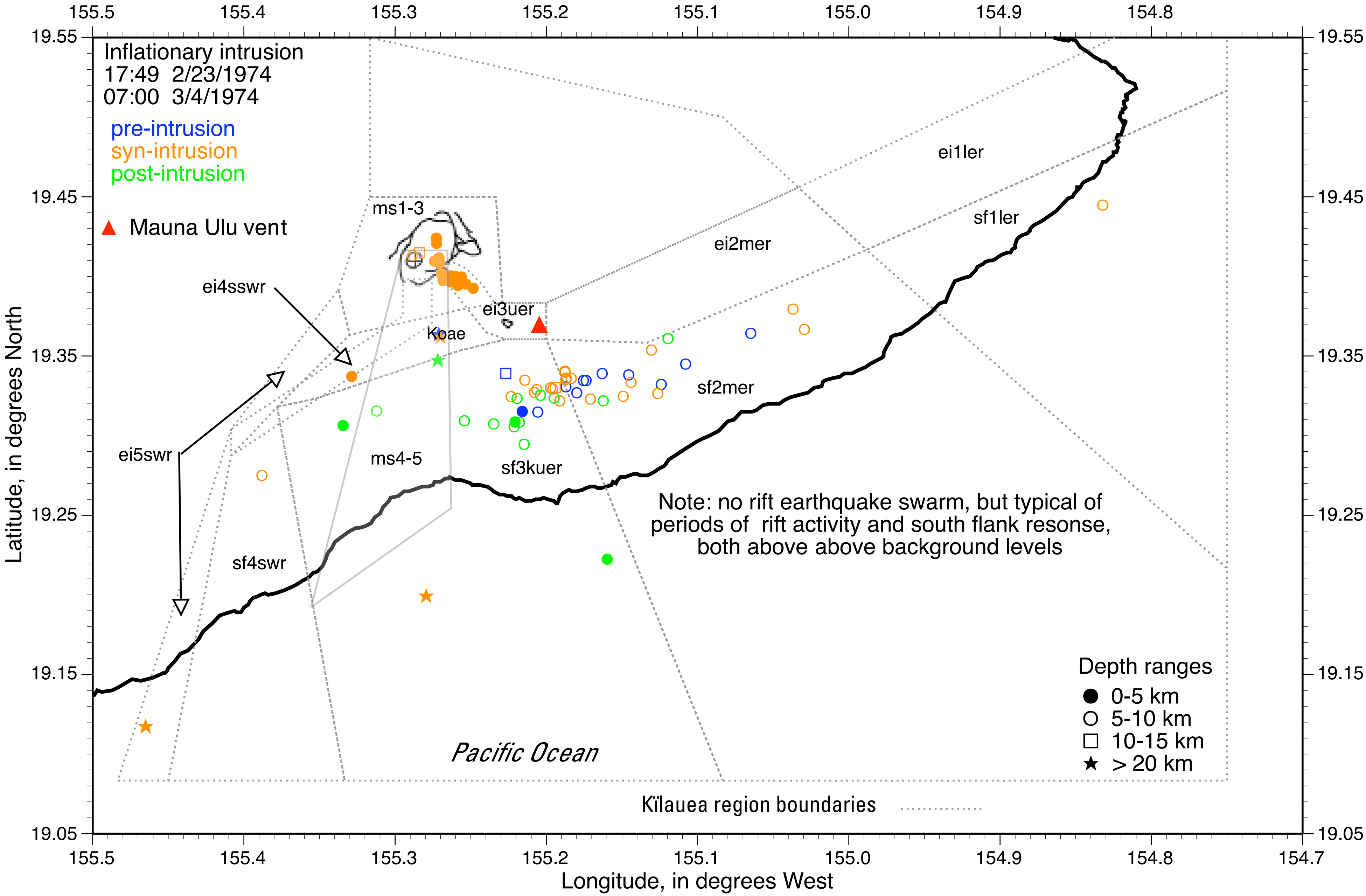
Appendix figure E66

Mauna Ulu IIB--December 1973 suspected deep intrusion?: data from 12/22-27/1973



Appendix figure E67

Mauna Ulu IIB 2, 3/1974 inflationary intrusion: data from 2/21-3/7/1974



Appendix figure E68

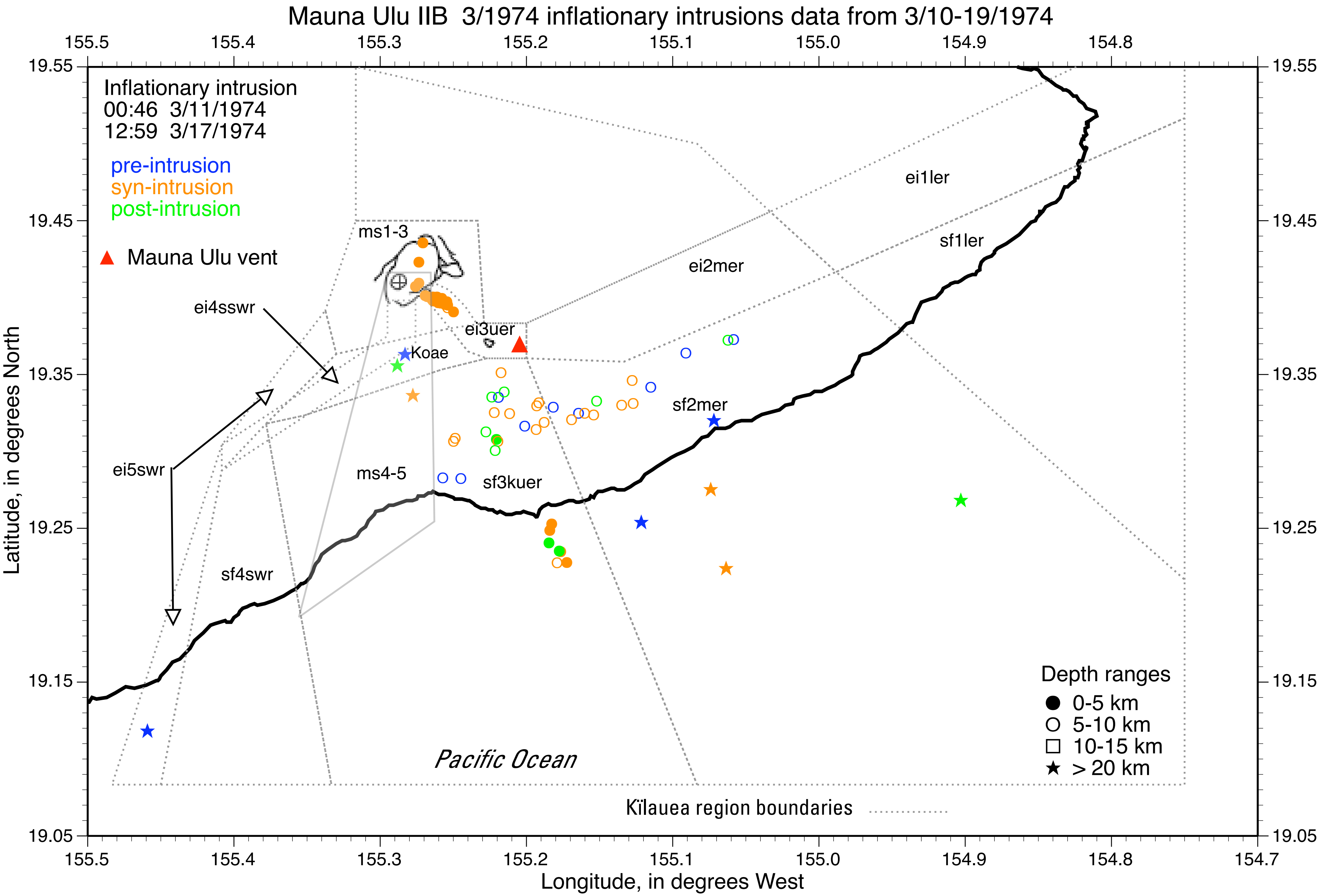
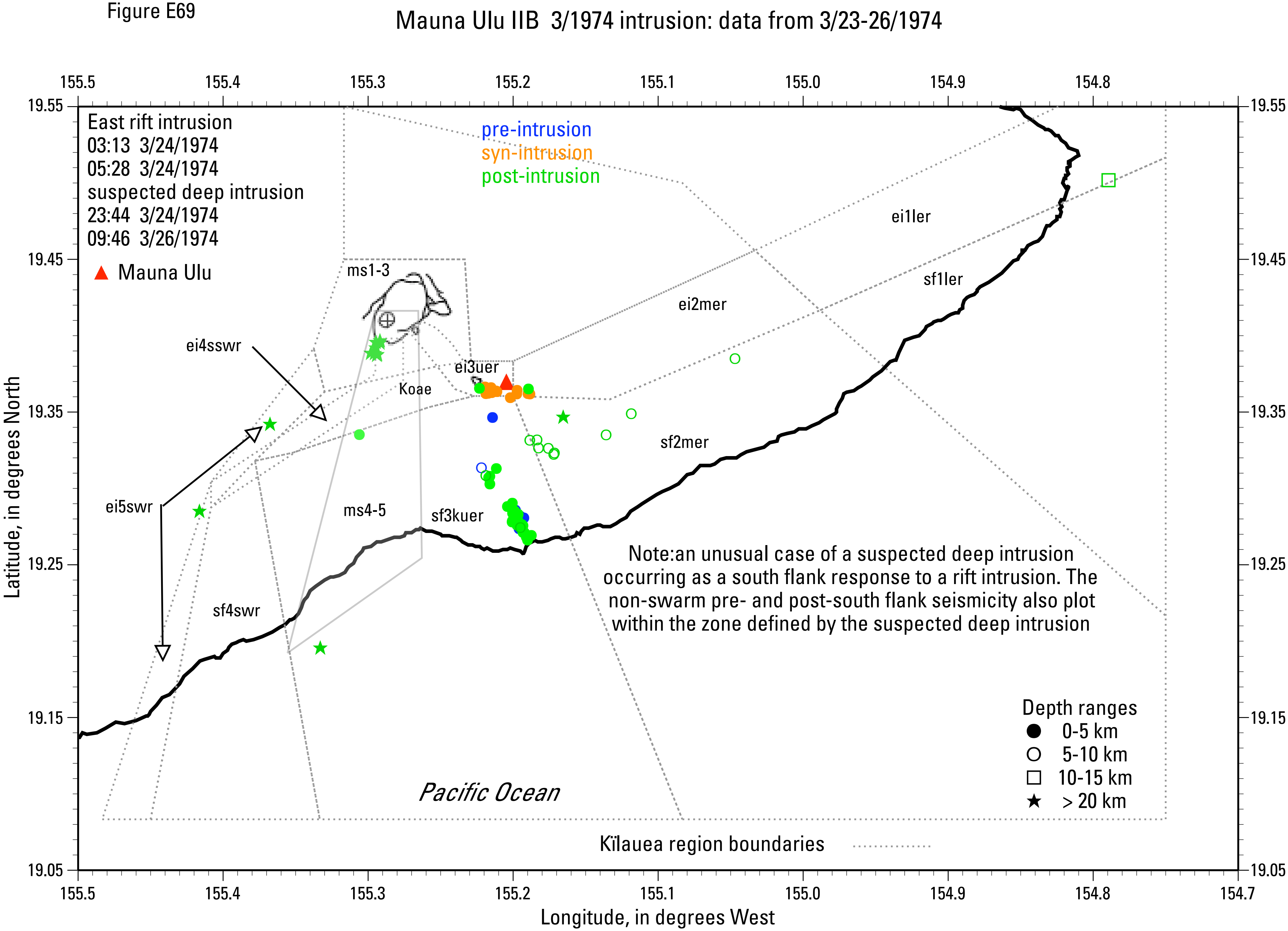


Figure E69


Mauna Ulu IIB 3/1974 intrusion: data from 3/23-26/1974
East rift intrusion
03:13 3/24/1974
05:28 3/24/1974
suspected deep intrusion
23:44 3/24/1974
09:46 3/26/1974
Mauna Ulu
pre-intrusion
syn-intrusion
post-intrusion
ms1-3
ei4sswr
ei3uer
Koae
ei5swr
ms4-5
sf3kuer
sf4swr
ei1ler
sf1ler
ei2mer
sf2mer
Note:an unusual case of a suspected deep intrusion occurring as a south flank response to a rift intrusion. The non-swarm pre- and post-south flank seismicity also plot within the zone defined by the suspected deep intrusion
Pacific Ocean
Depth ranges
0-5 km
5-10 km
10-15 km
> 20 km
Kīlauea region boundaries
Latitude, in degrees North
Longitude, in degrees West
155.5
155.4
155.3
155.2
155.1
155.0
154.9
154.8
154.7
19.55
19.45
19.35
19.25
19.15
19.05

Appendix figure E70a

Mauna Ulu IIB Precursors to end of Mauna Ulu eruption: data from 5/12-23/1974

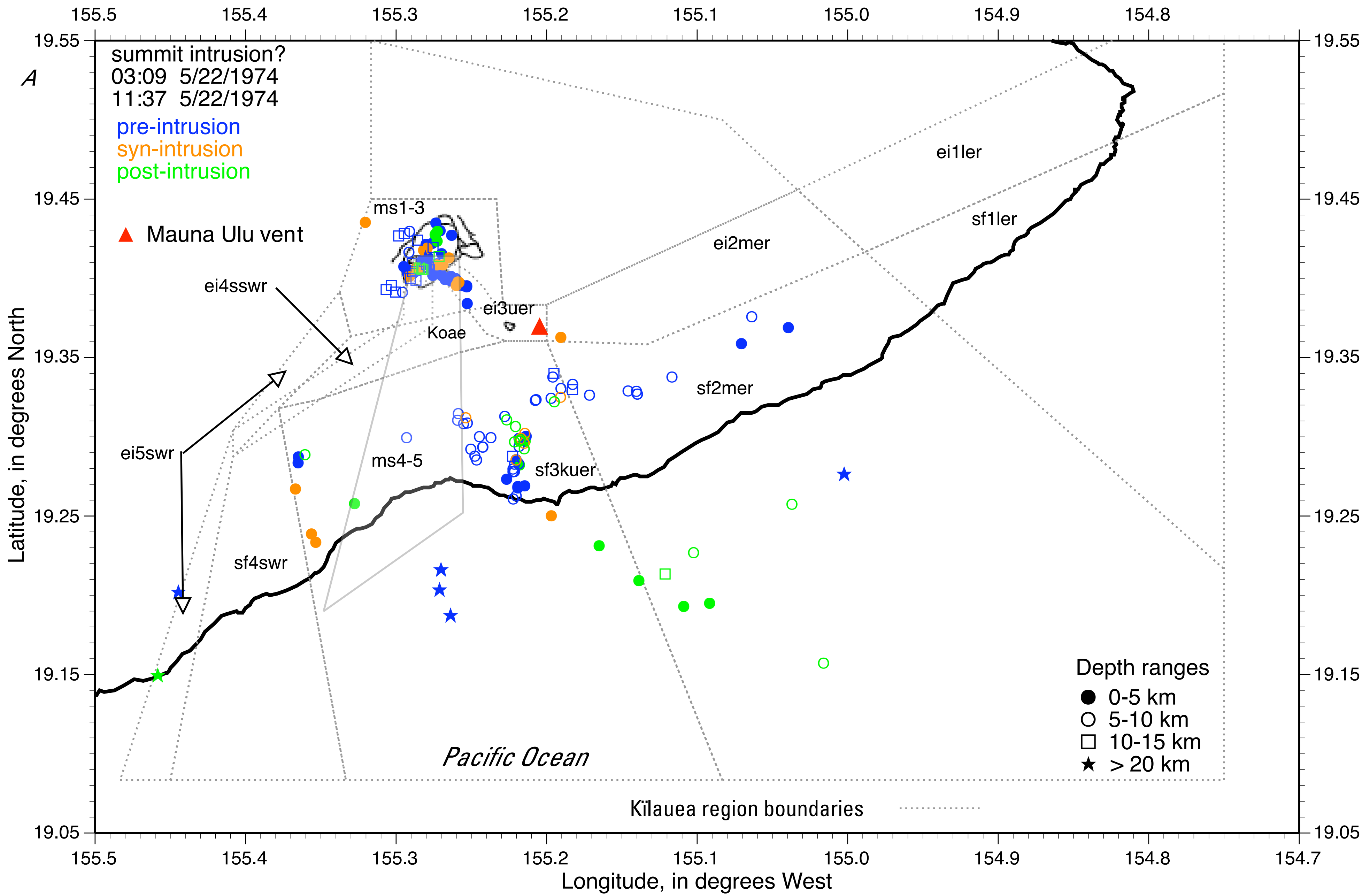


Figure E670b

Mauna Ulu IIB Precursors to end of Mauna Ulu eruption: data from 5/24-26/1974

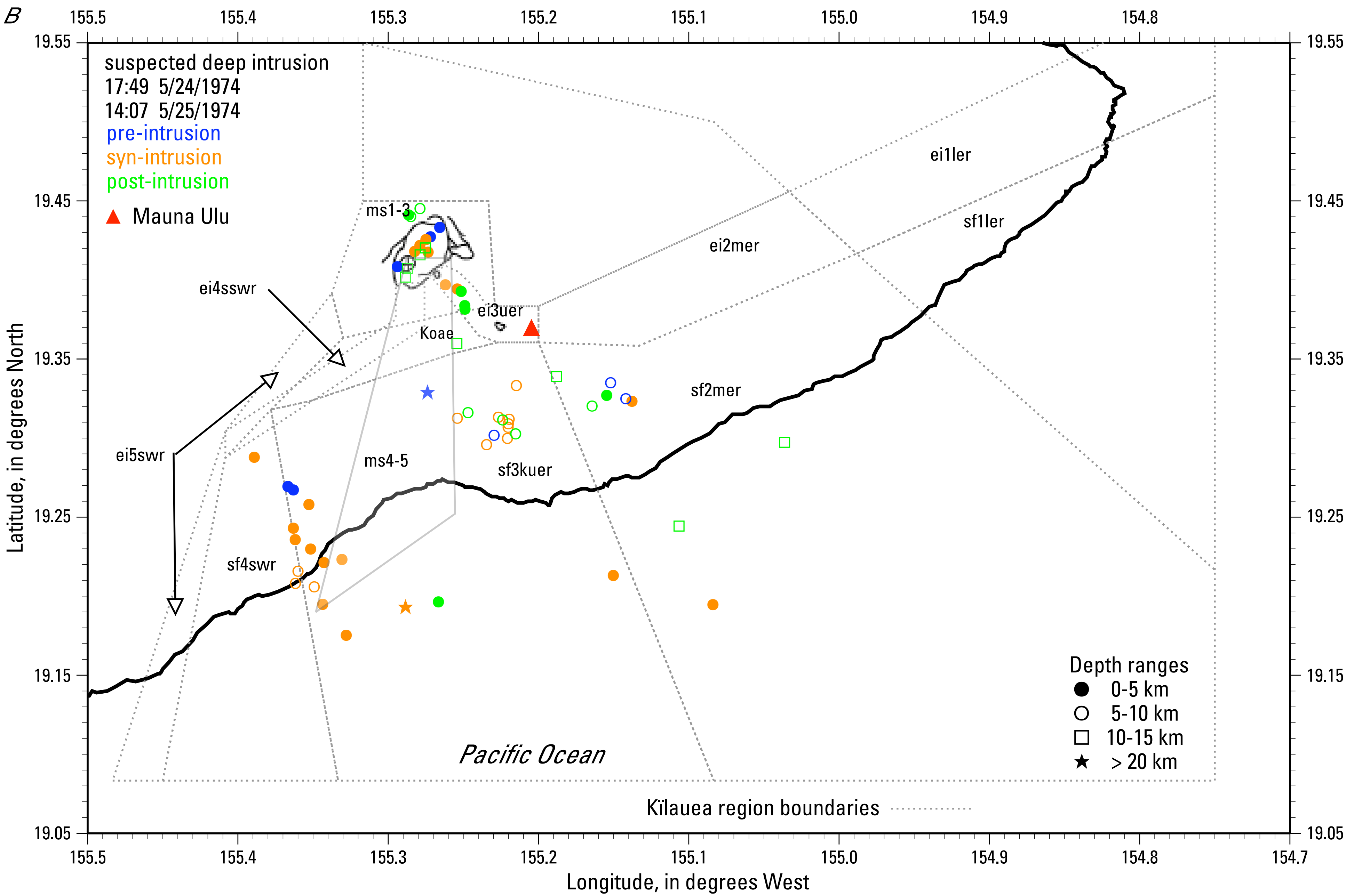


Figure E70c

Mauna Ulu IIB Precursors to end of Mauna Ulu eruption: data from 5/27-6/3/1974

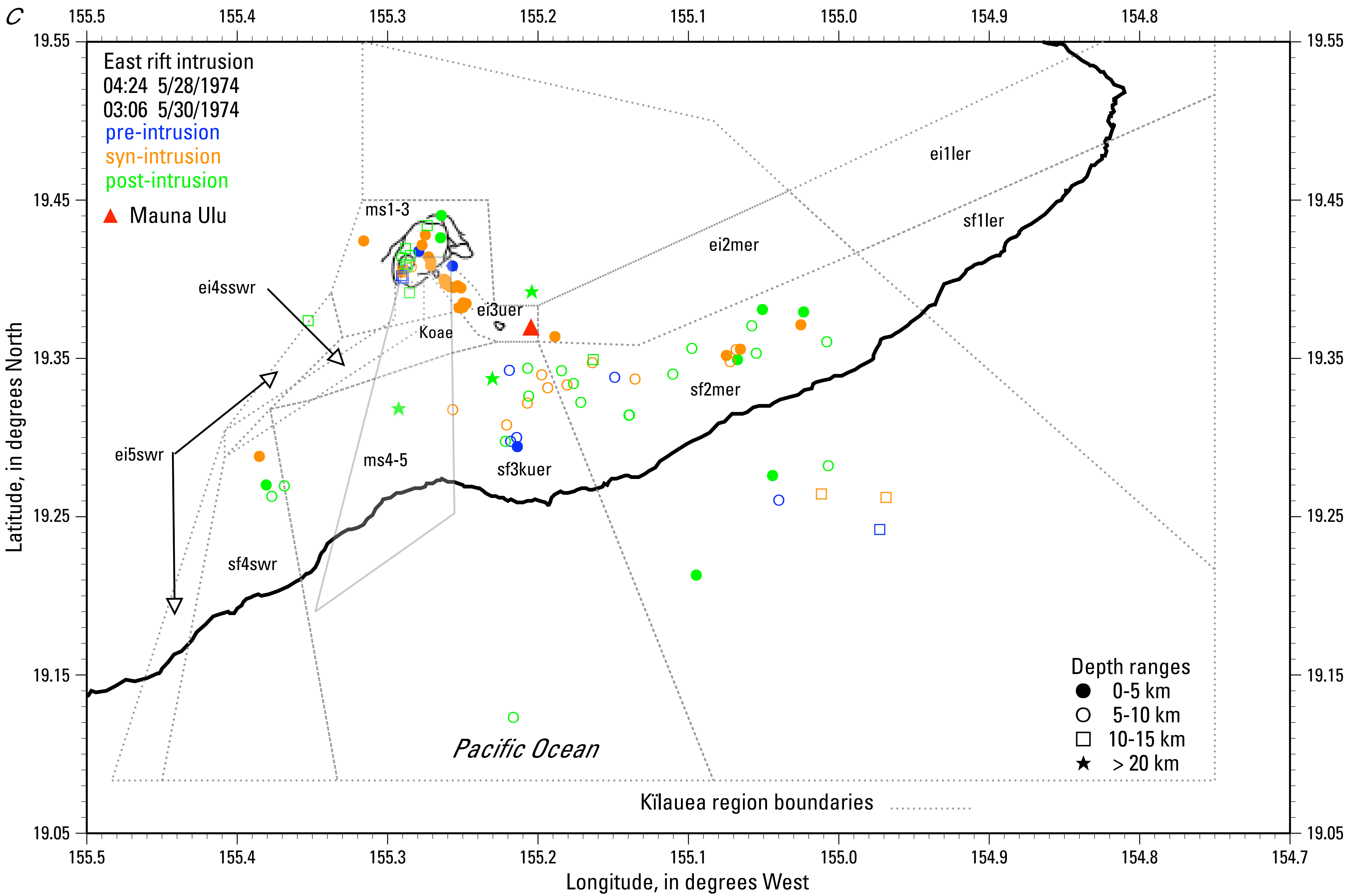
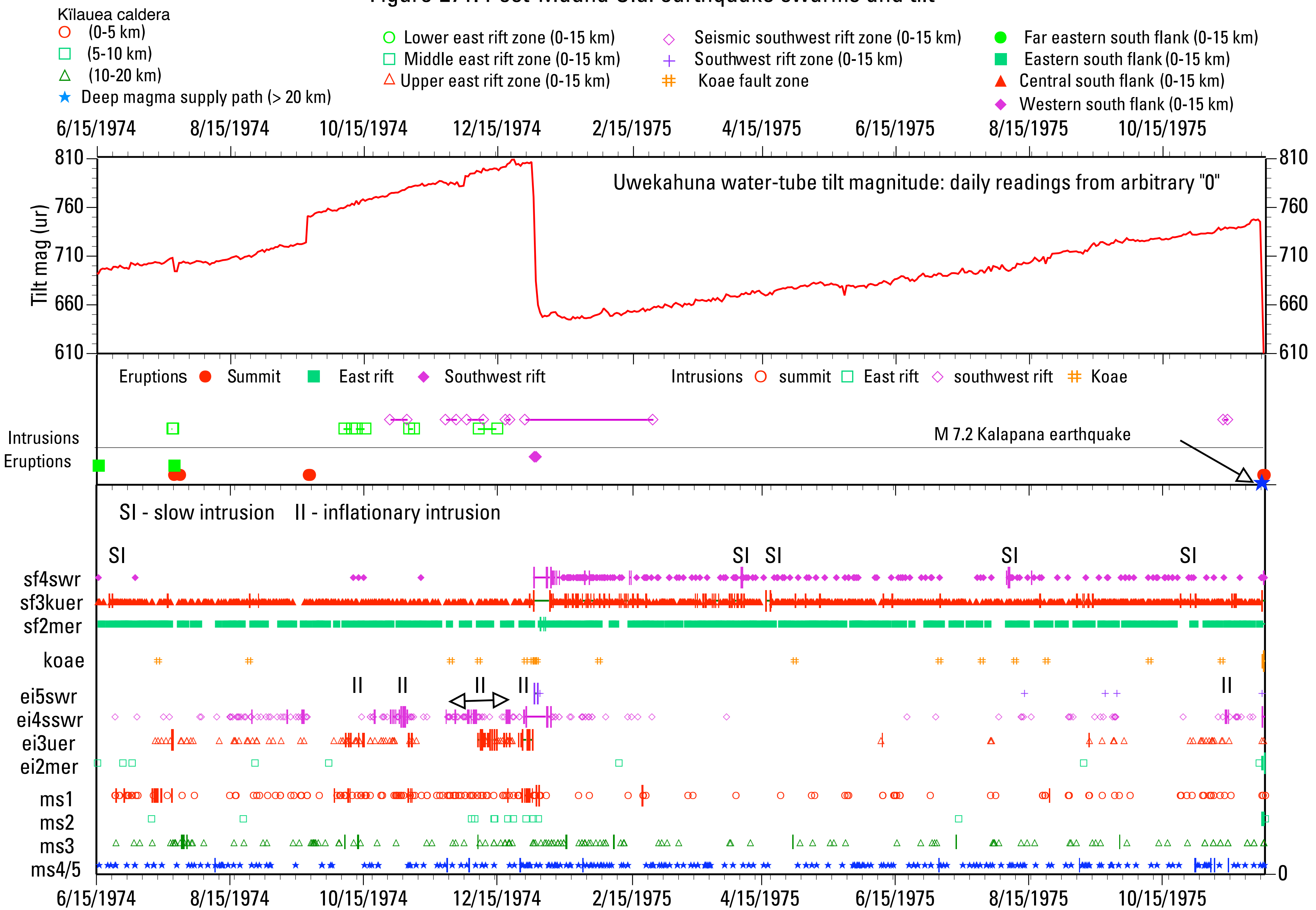
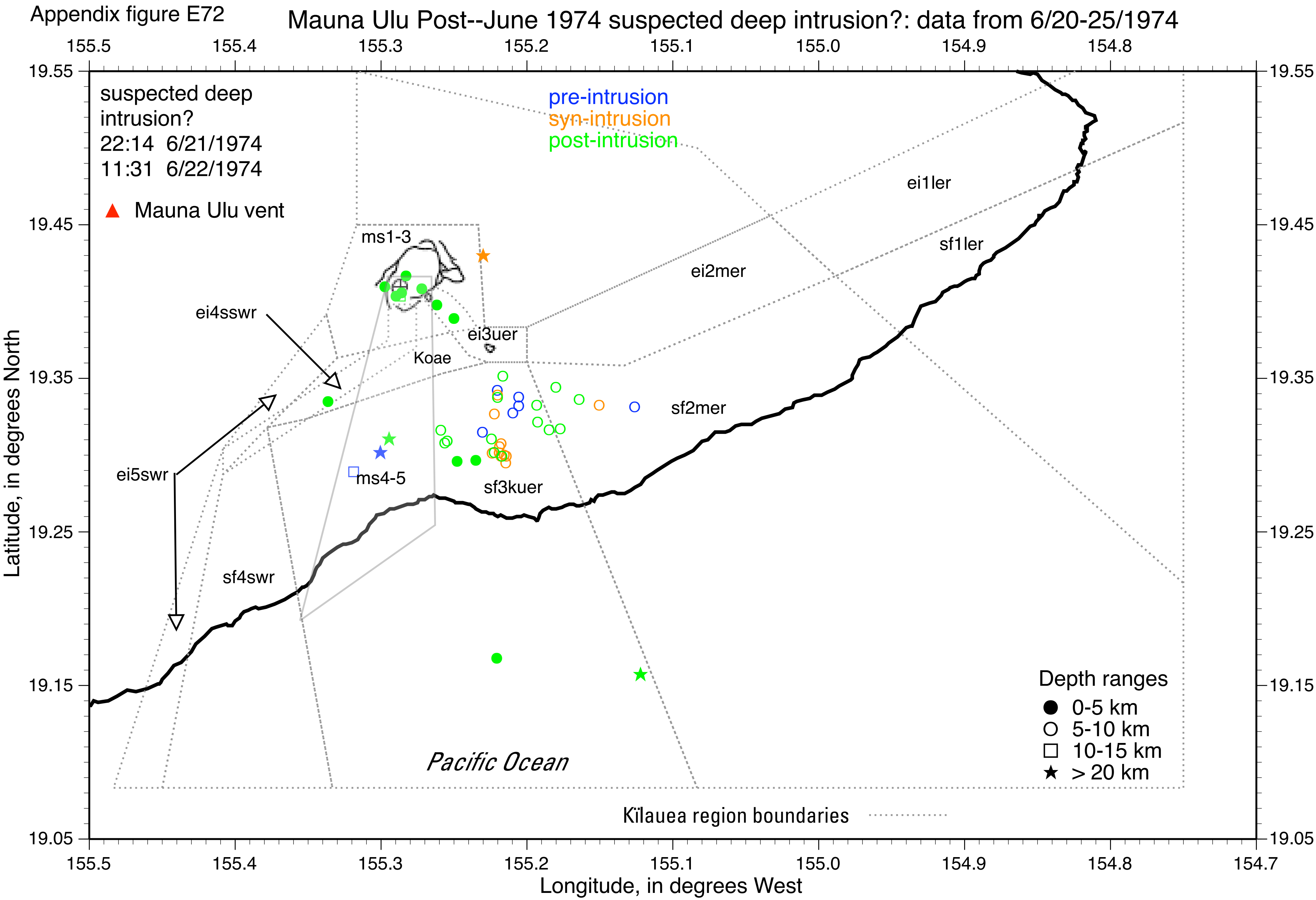


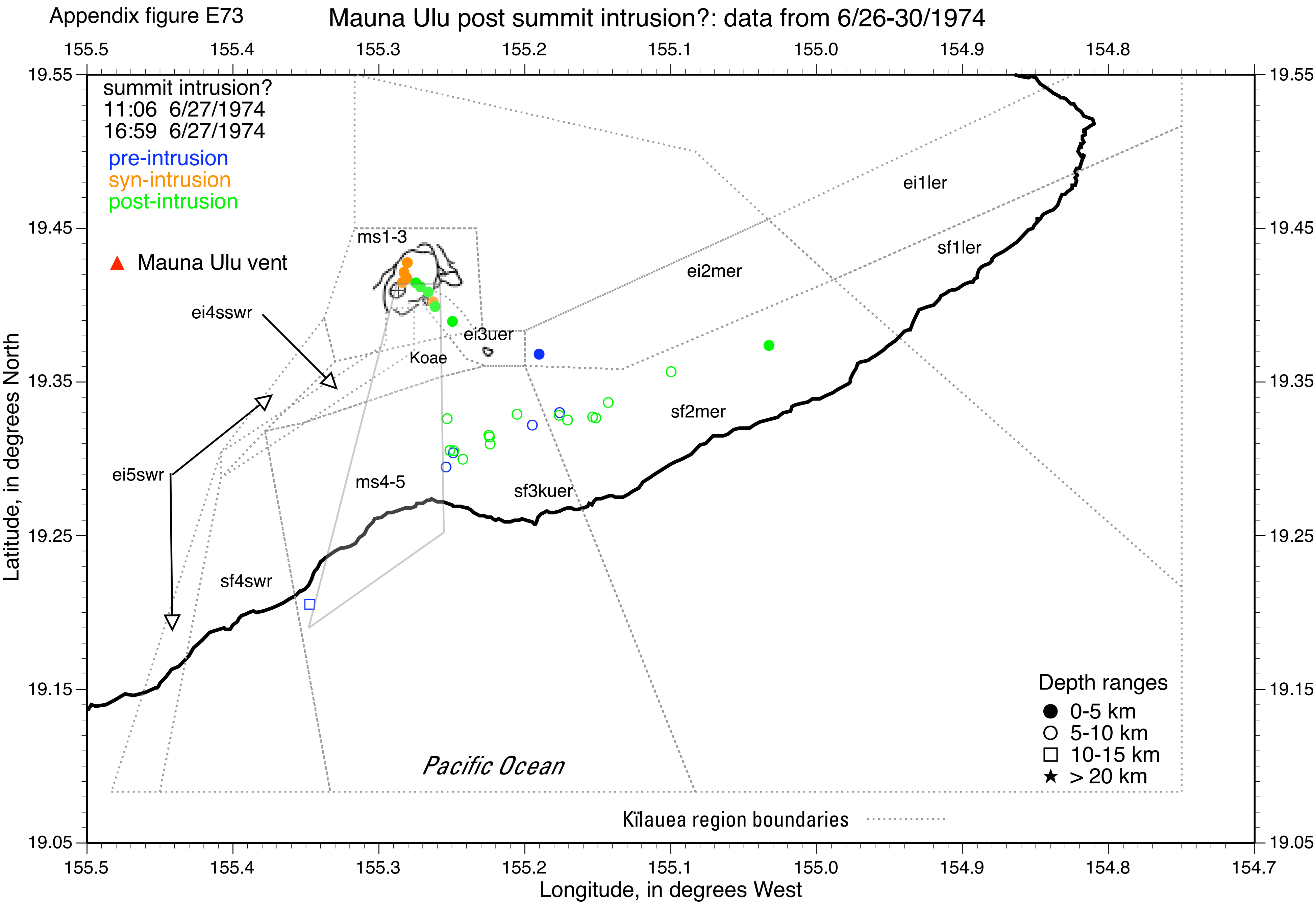
Figure E71. Post-Mauna Ulu: earthquake swarms and tilt



Appendix figure E72

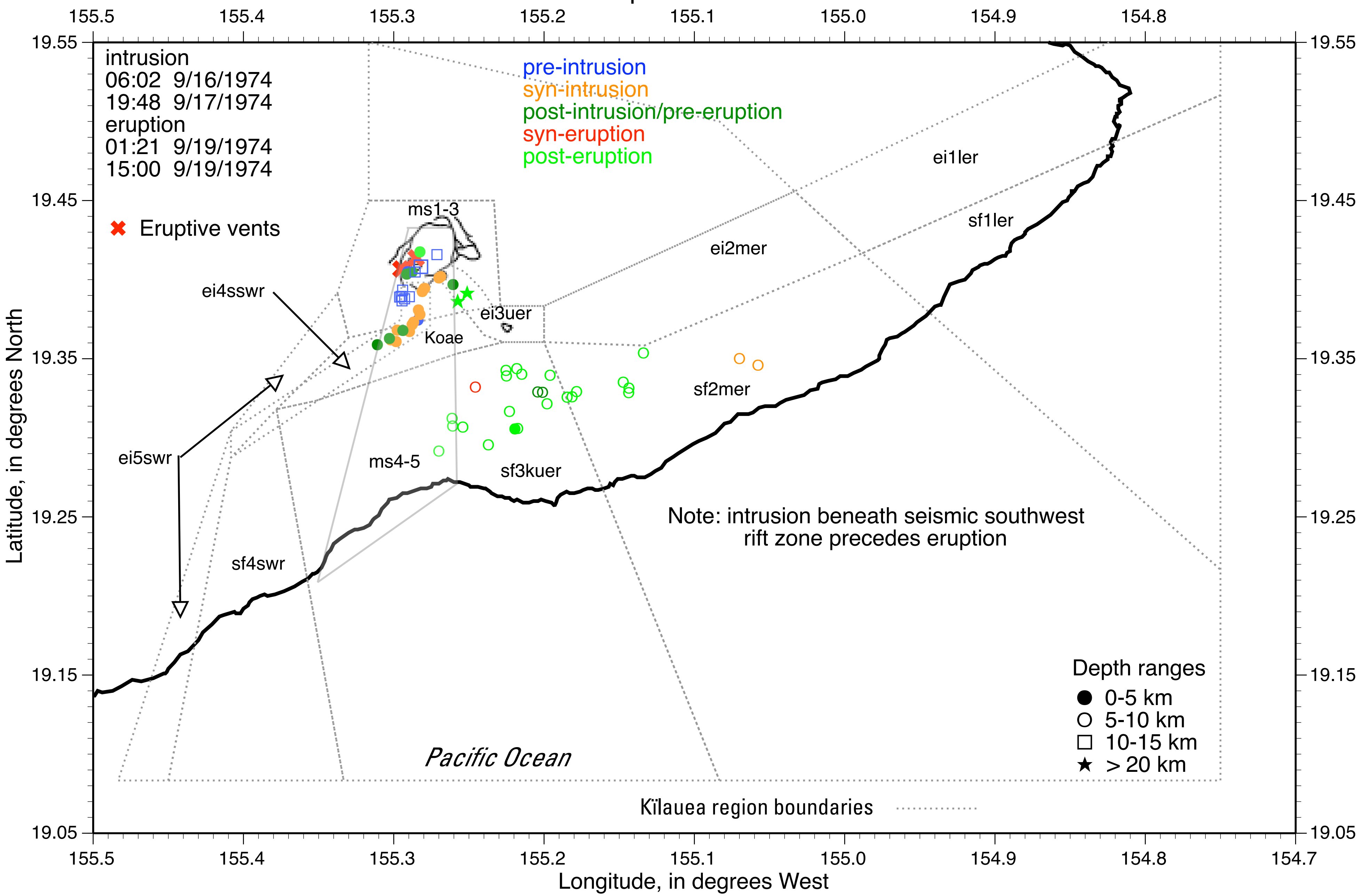


Appendix figure E73



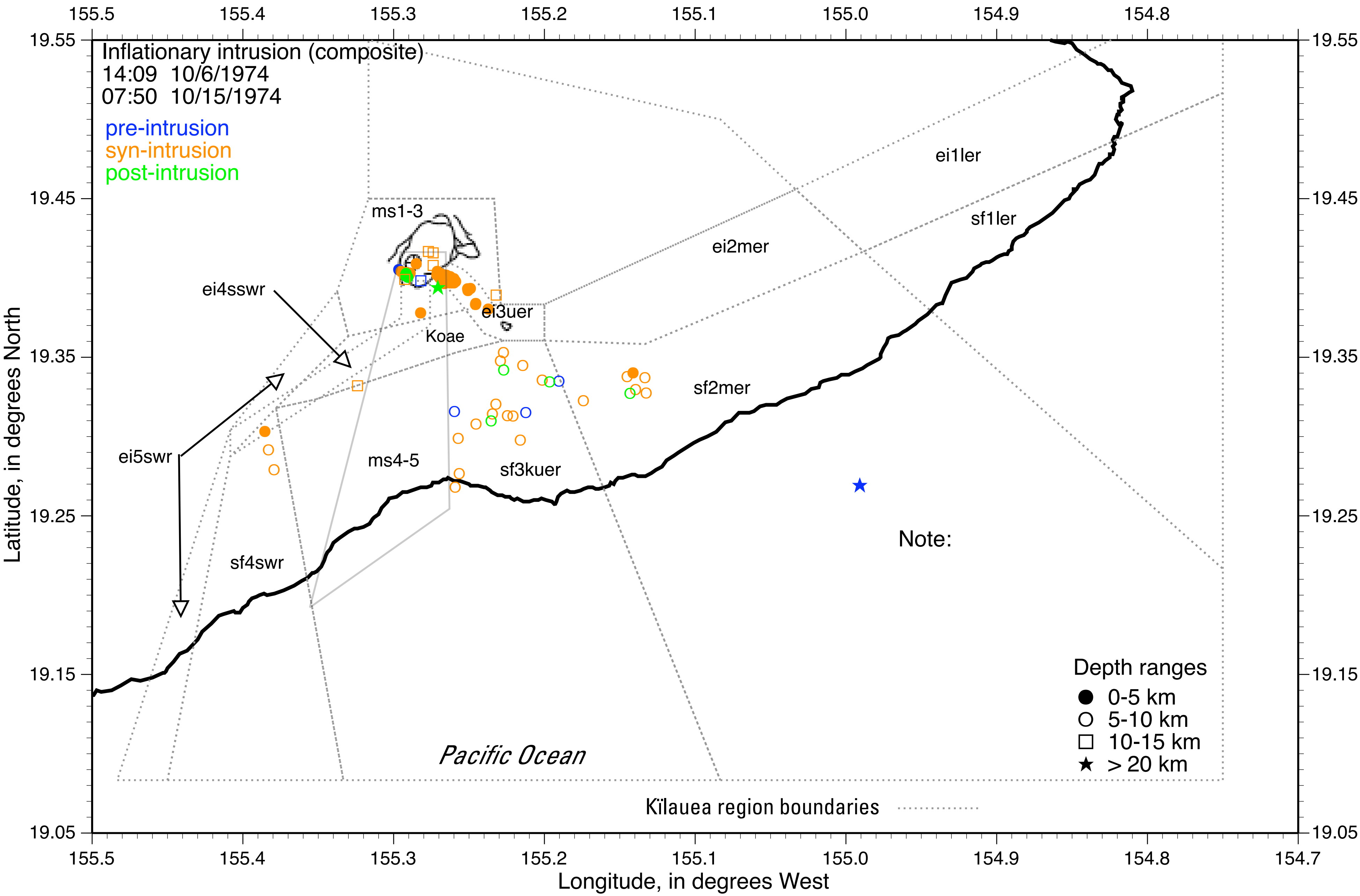
Appendix figure E74

Post-Mauna Ulu 9/19/1974 eruption/intrusion: data from 9/15-26/1974



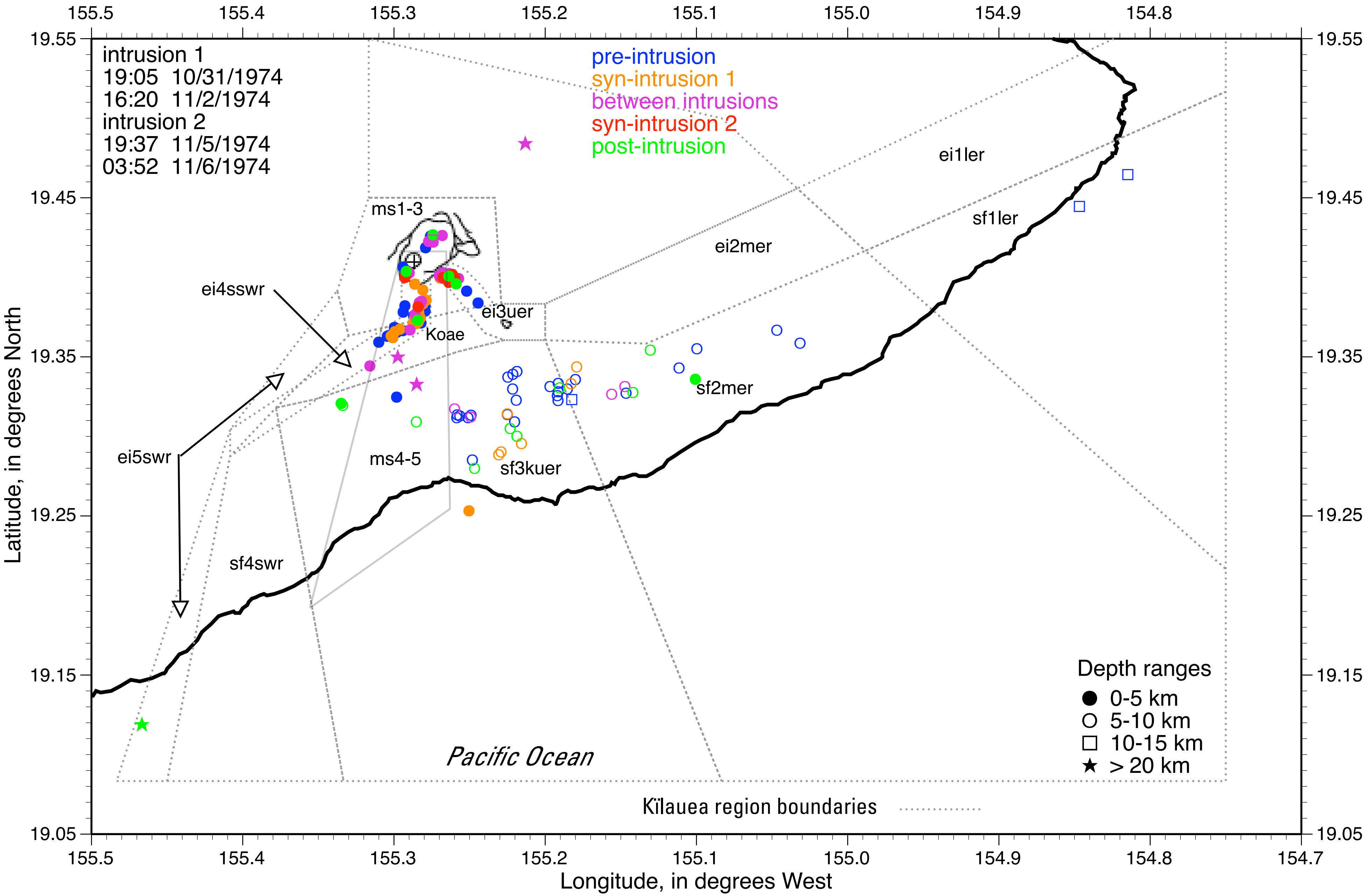
Appendix figure E75

Post-Mauna Ulu inflationary intrusions: data from 10/4-16/1974

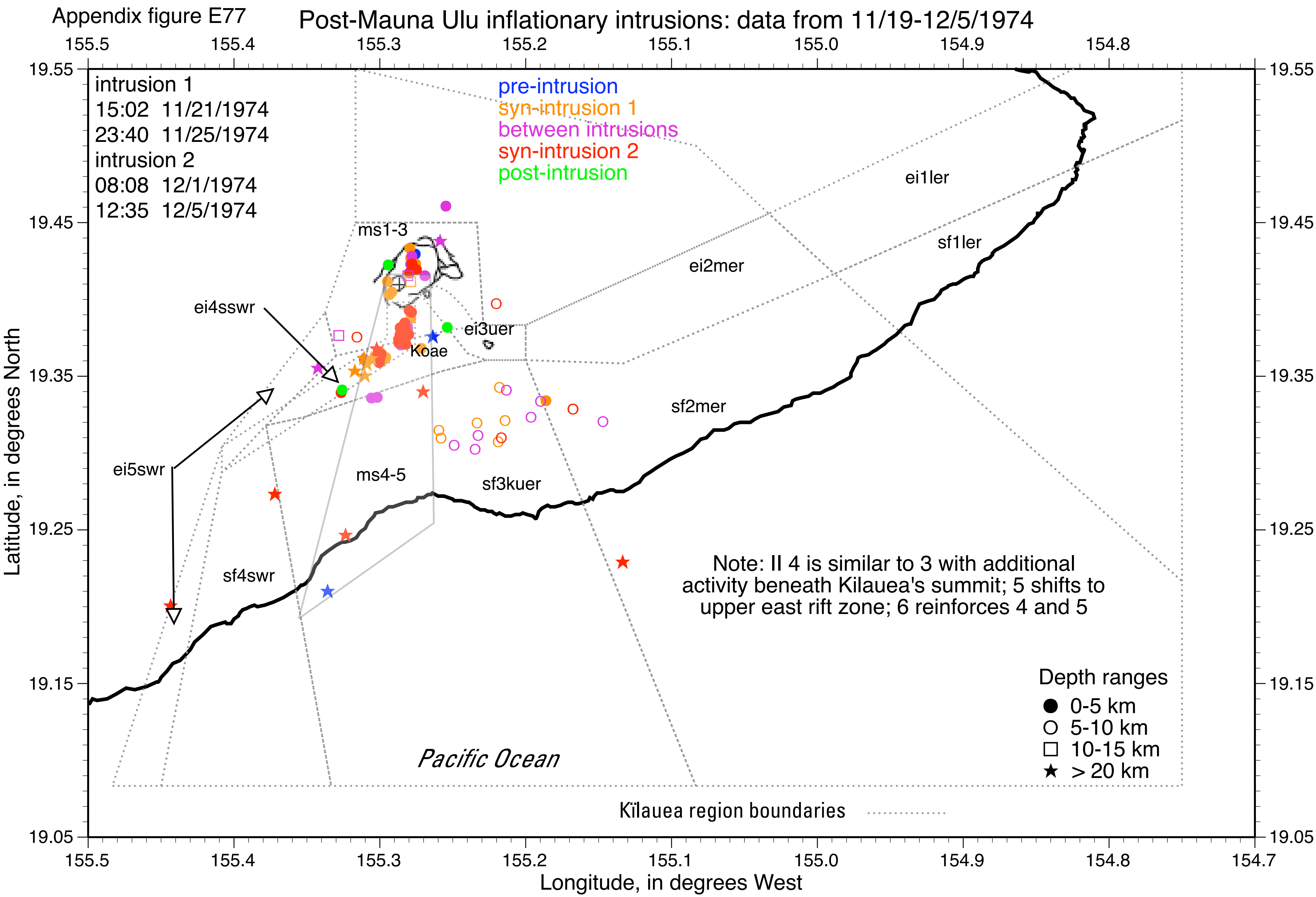


Appendix figure E76

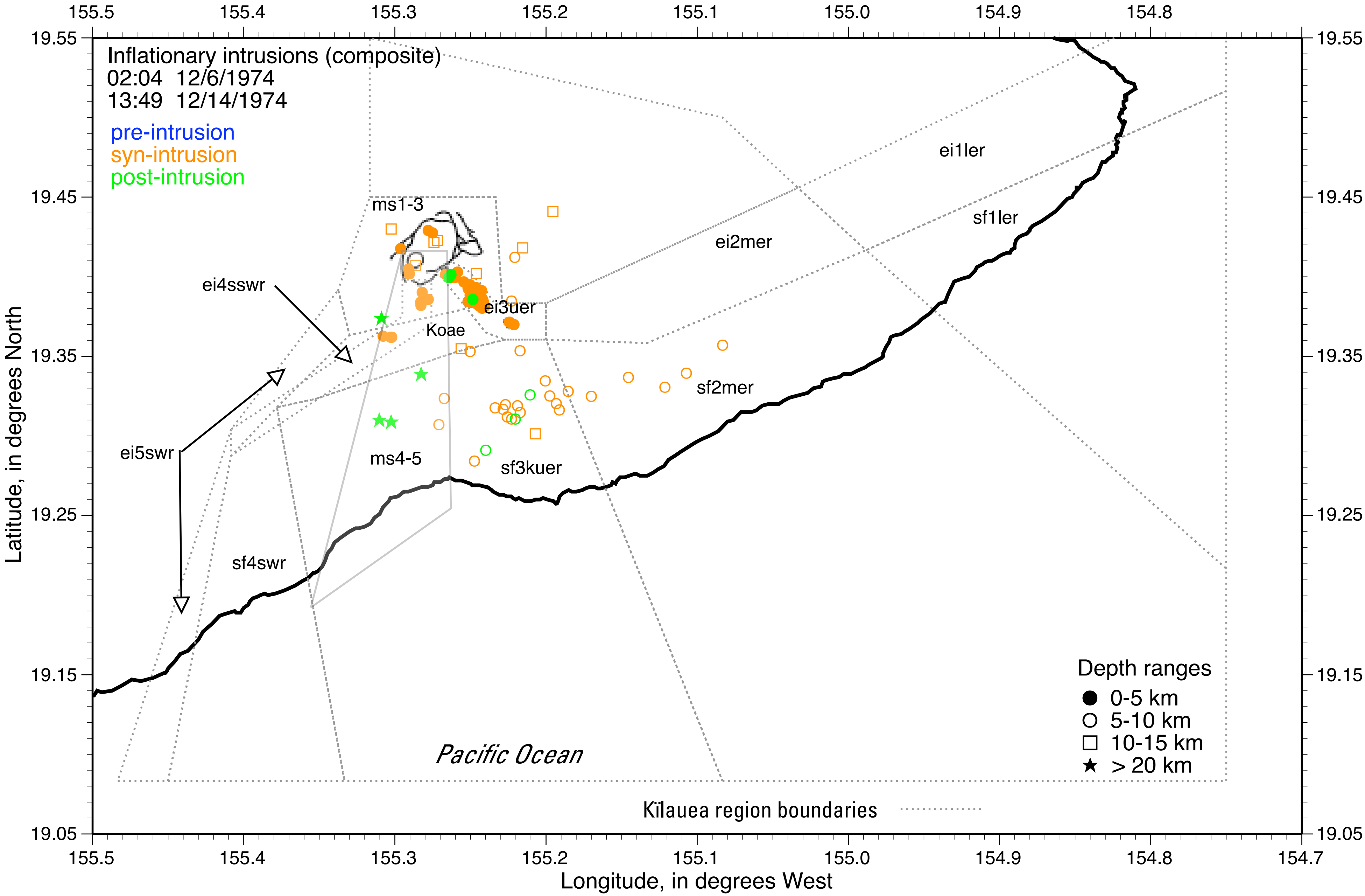
Post-Mauna Ulu inflationary intrusions: data from 10/27-11/9/1974



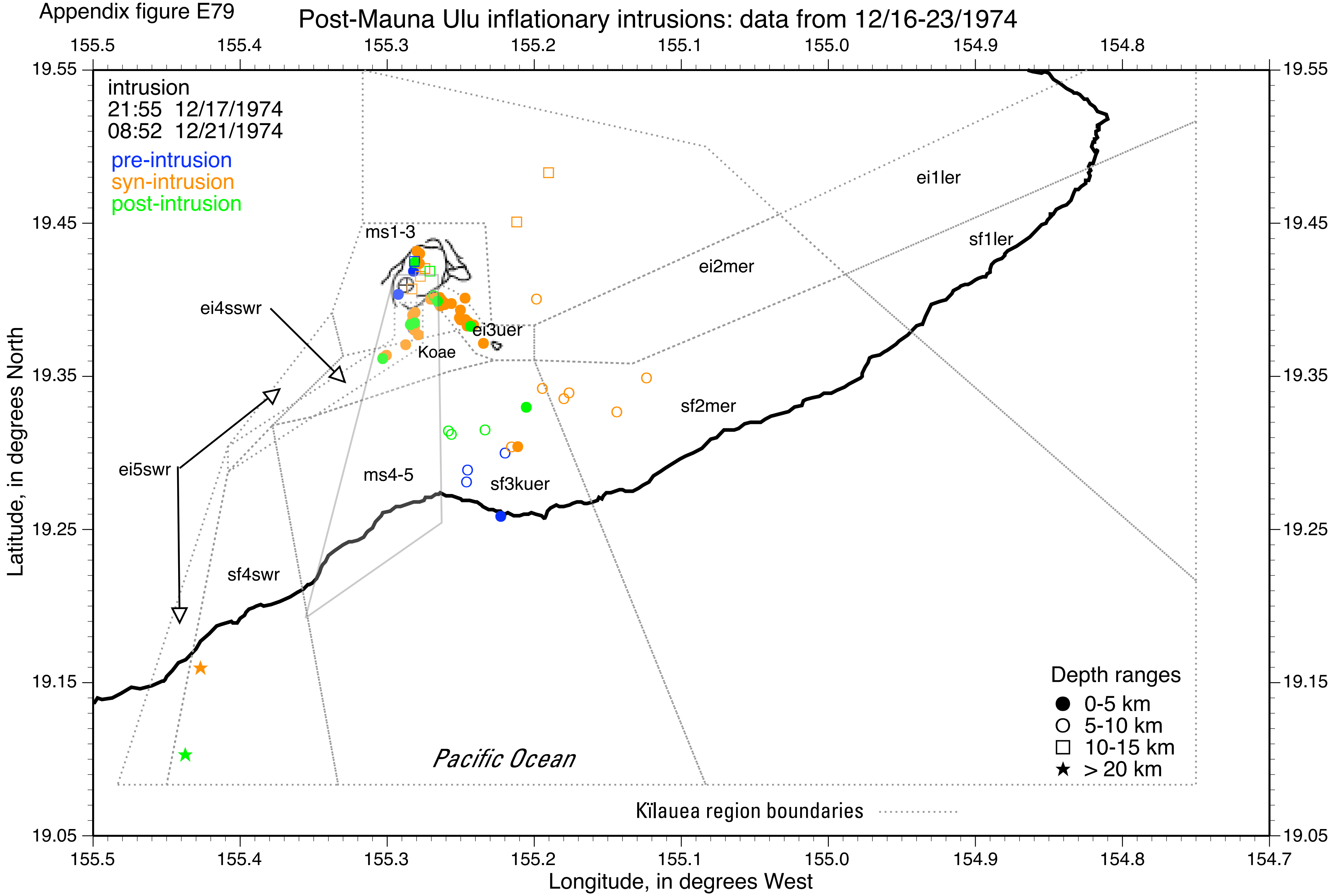
Appendix figure E77



Appendix figure E78 Post-Mauna Ulu inflationary intrusions: data from 12/6-15/1974

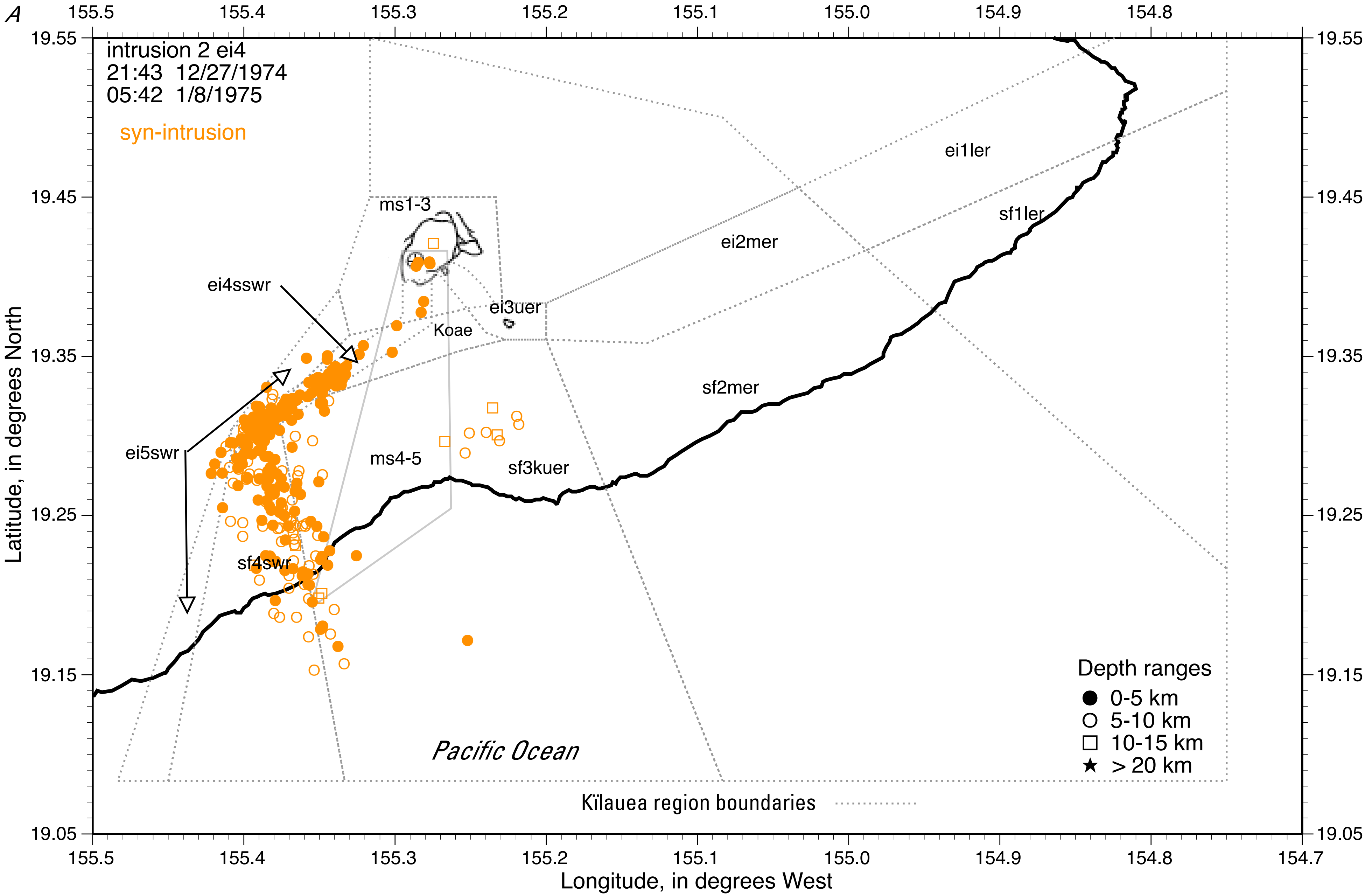


Appendix figure E79

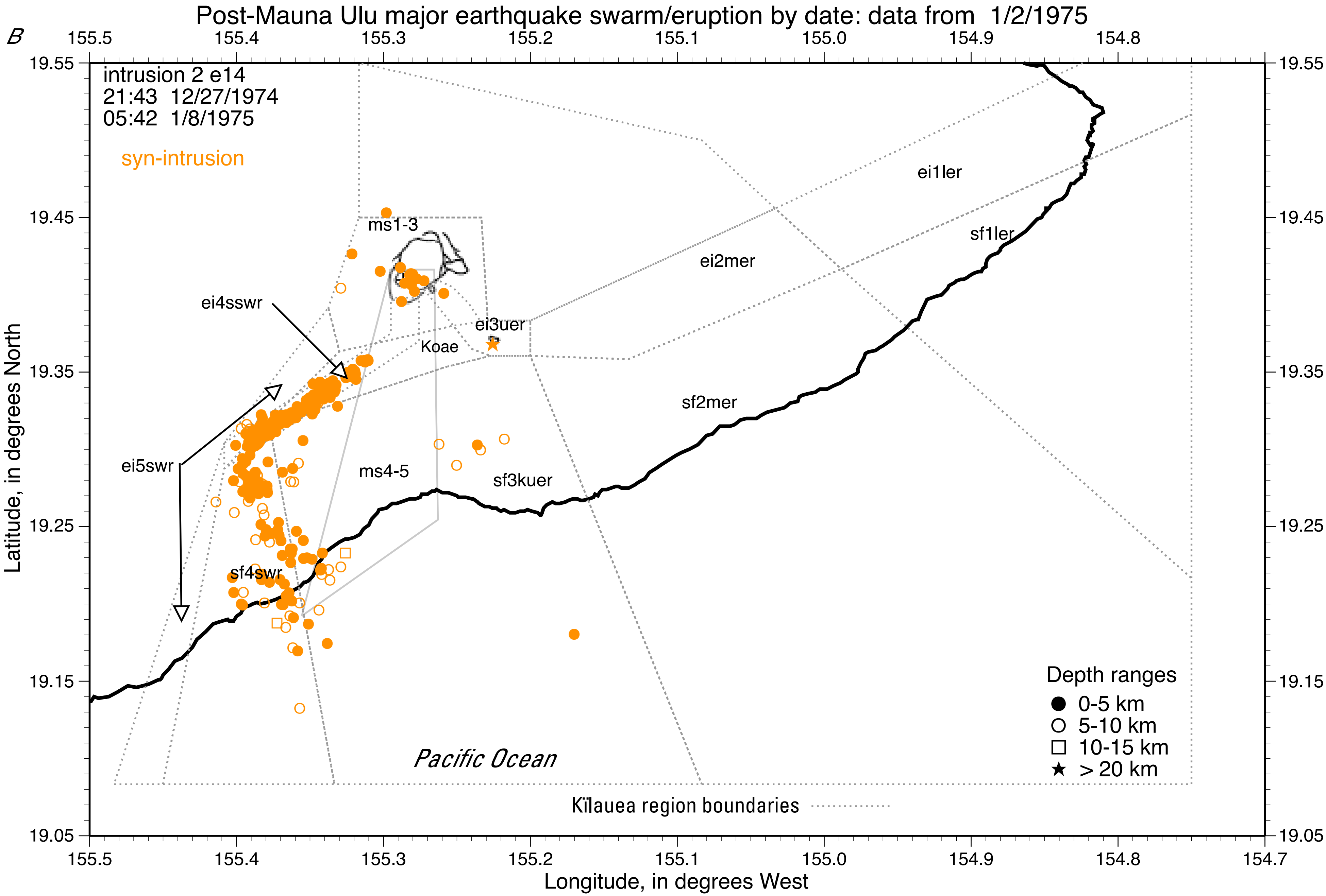


Appendix figure E80a

Post-Mauna Ulu major earthquake swarm/eruption by date: data from 1/1/1975

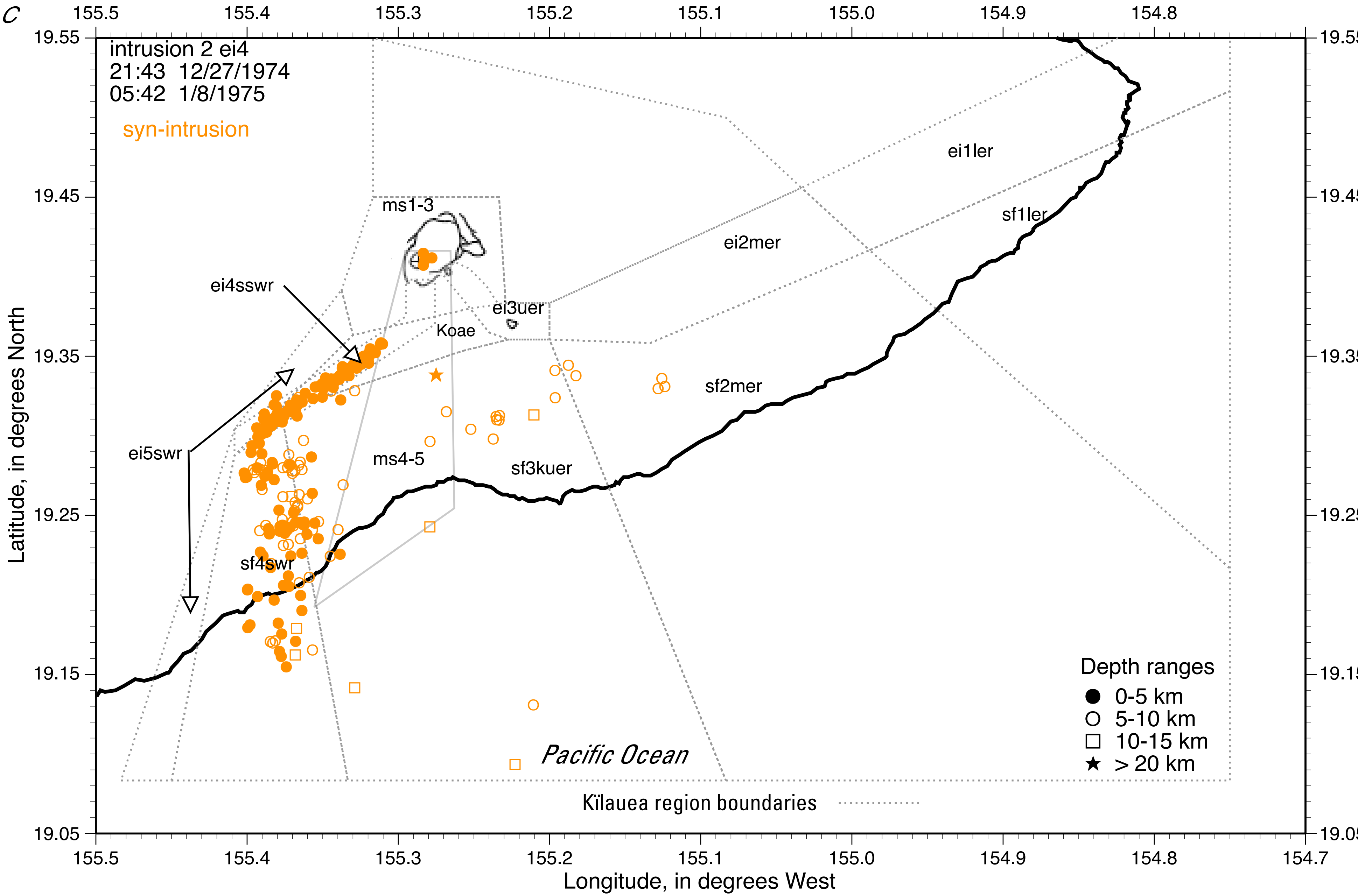


Appendix figure E80b



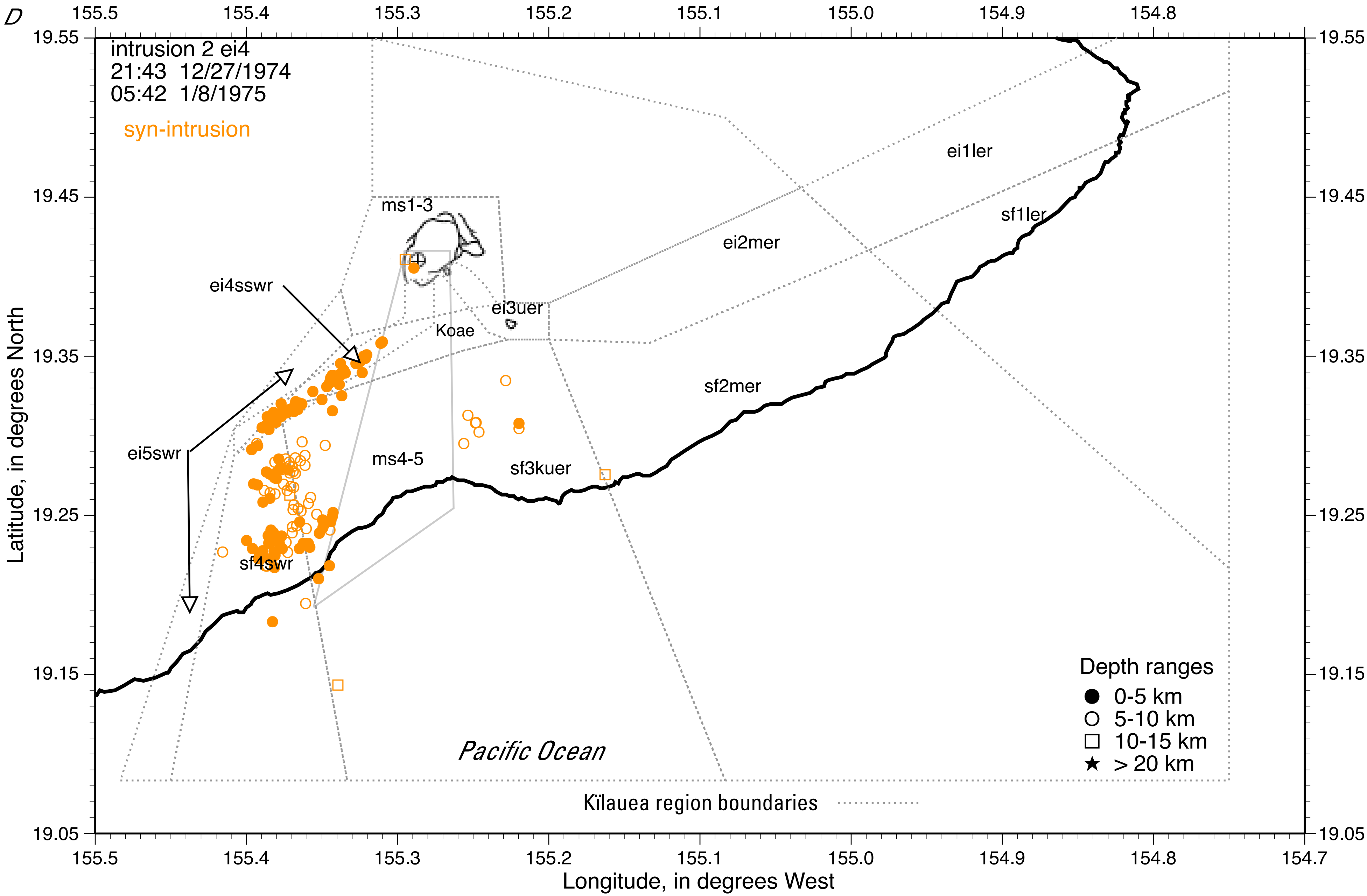
Appendix figure E80c

Post-Mauna Ulu major earthquake swarm/eruption by date: data from 1/3/1975



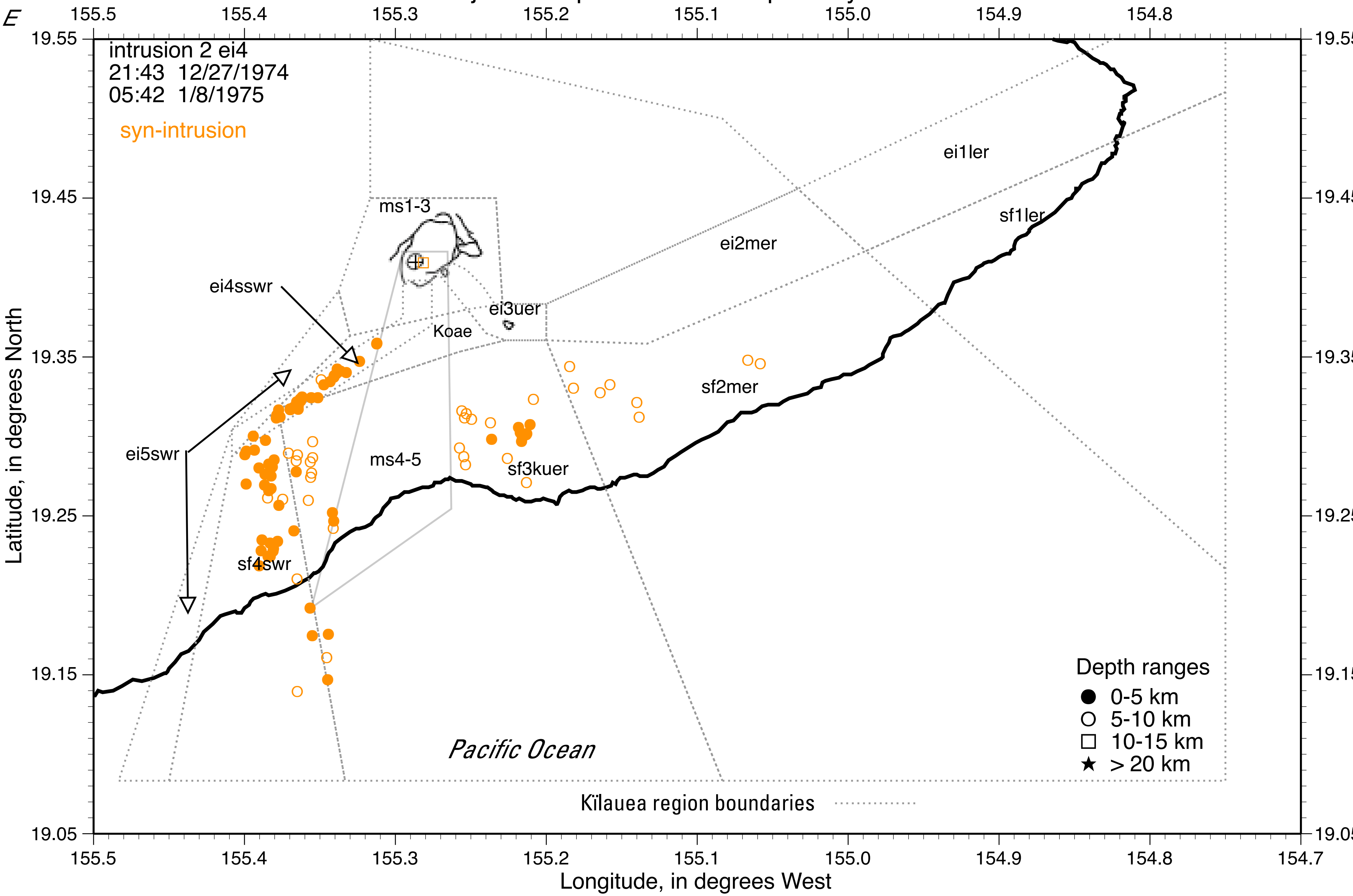
Appendix figure E80d

Post-Mauna Ulu major earthquake swarm/eruption by date: data from 1/4/1975



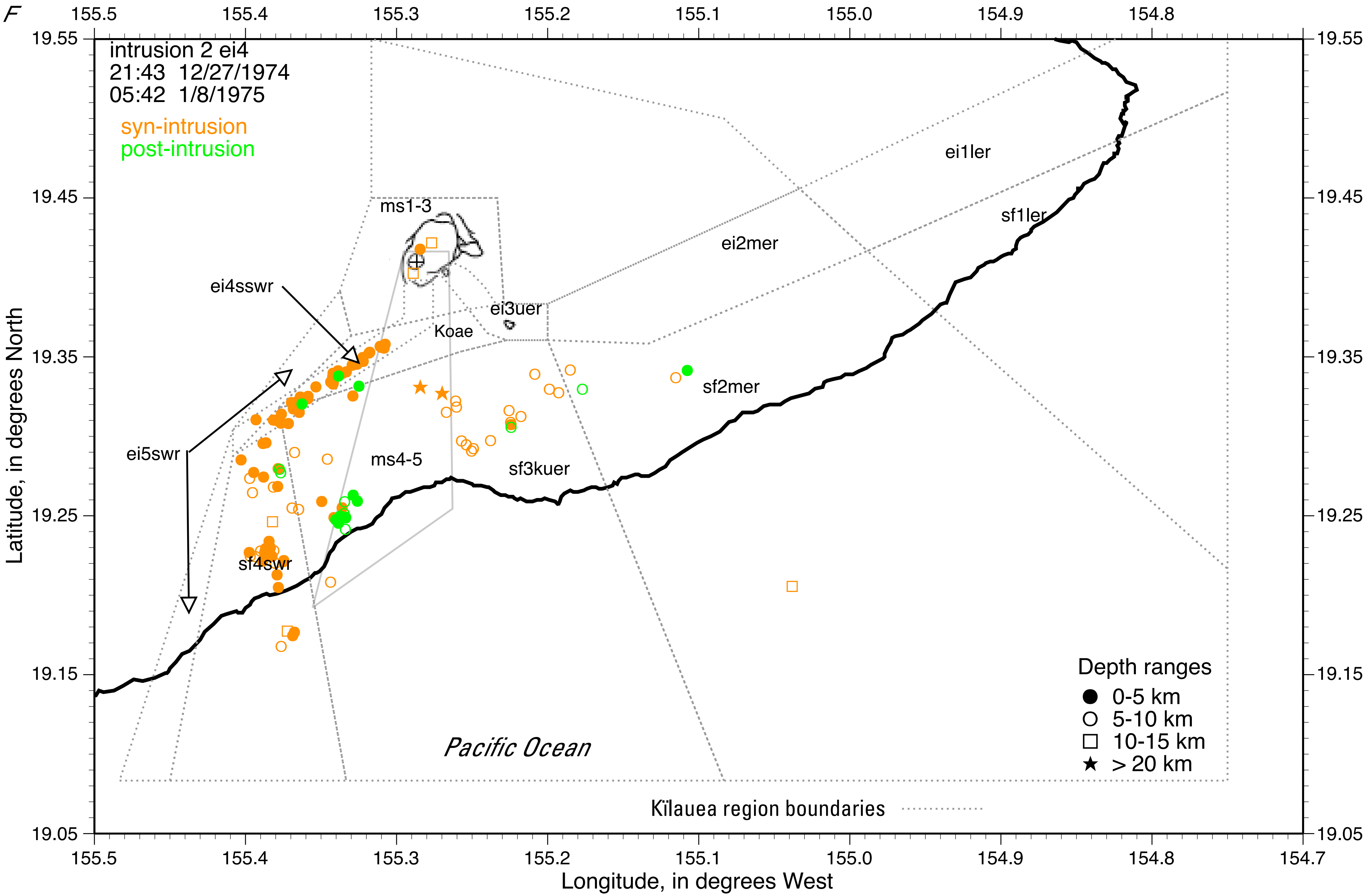
Appendix figure E80e

Post-Mauna Ulu major earthquake swarm/eruption by date: data from 1/5/1975

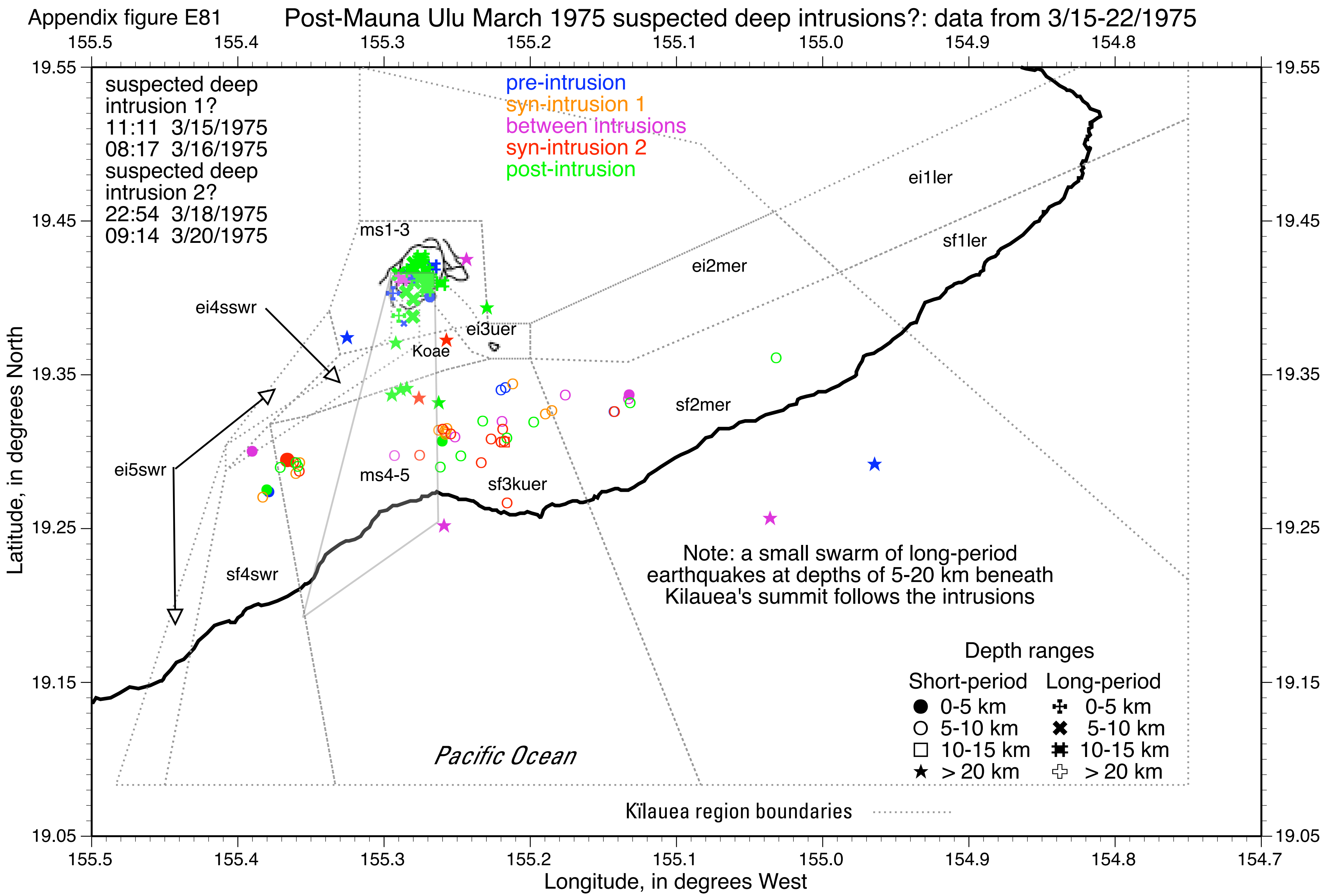


Appendix figure E80f

Post-Mauna Ulu major earthquake swarm/eruption by date: data from 1/6-8/1975

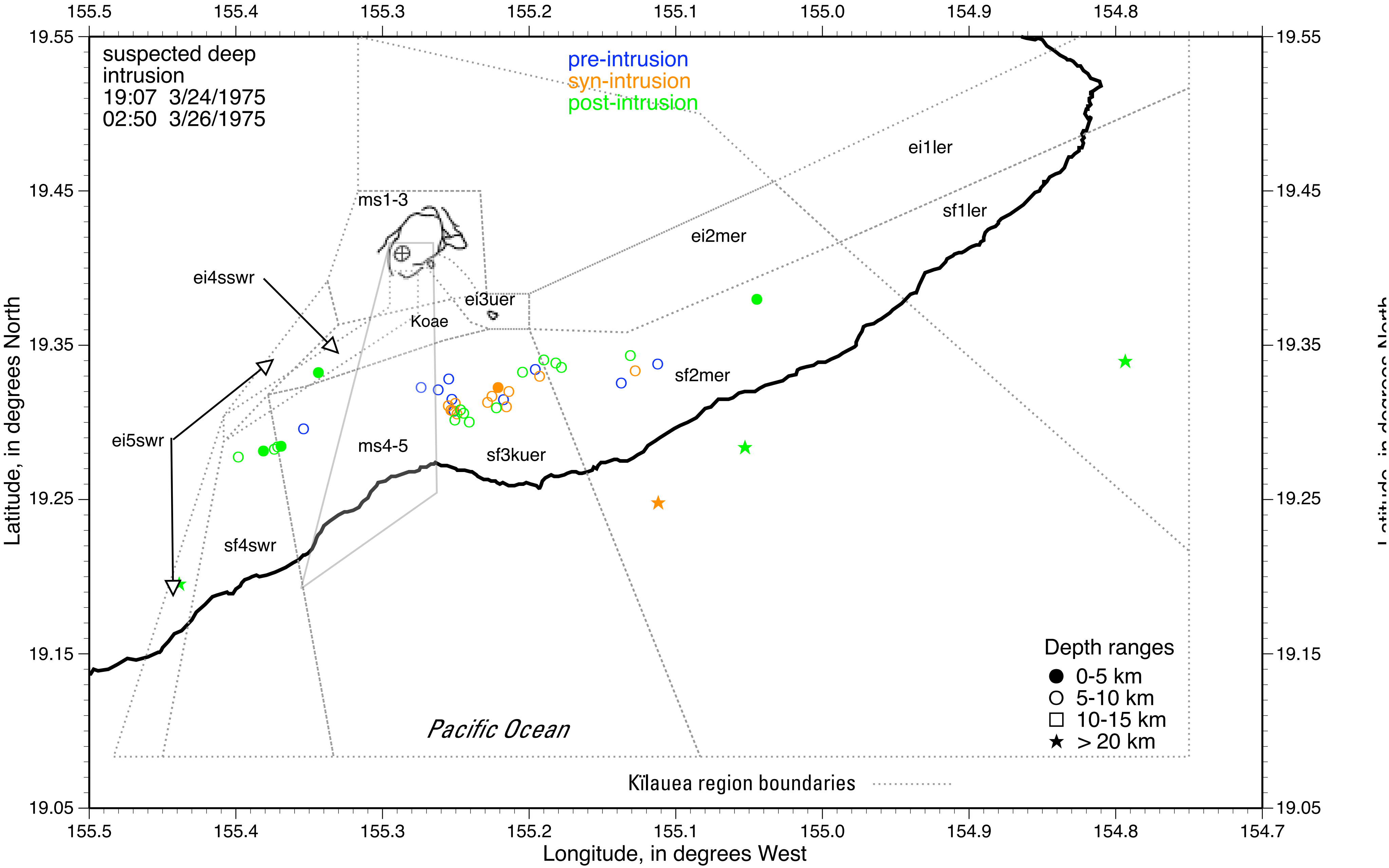


Appendix figure E81

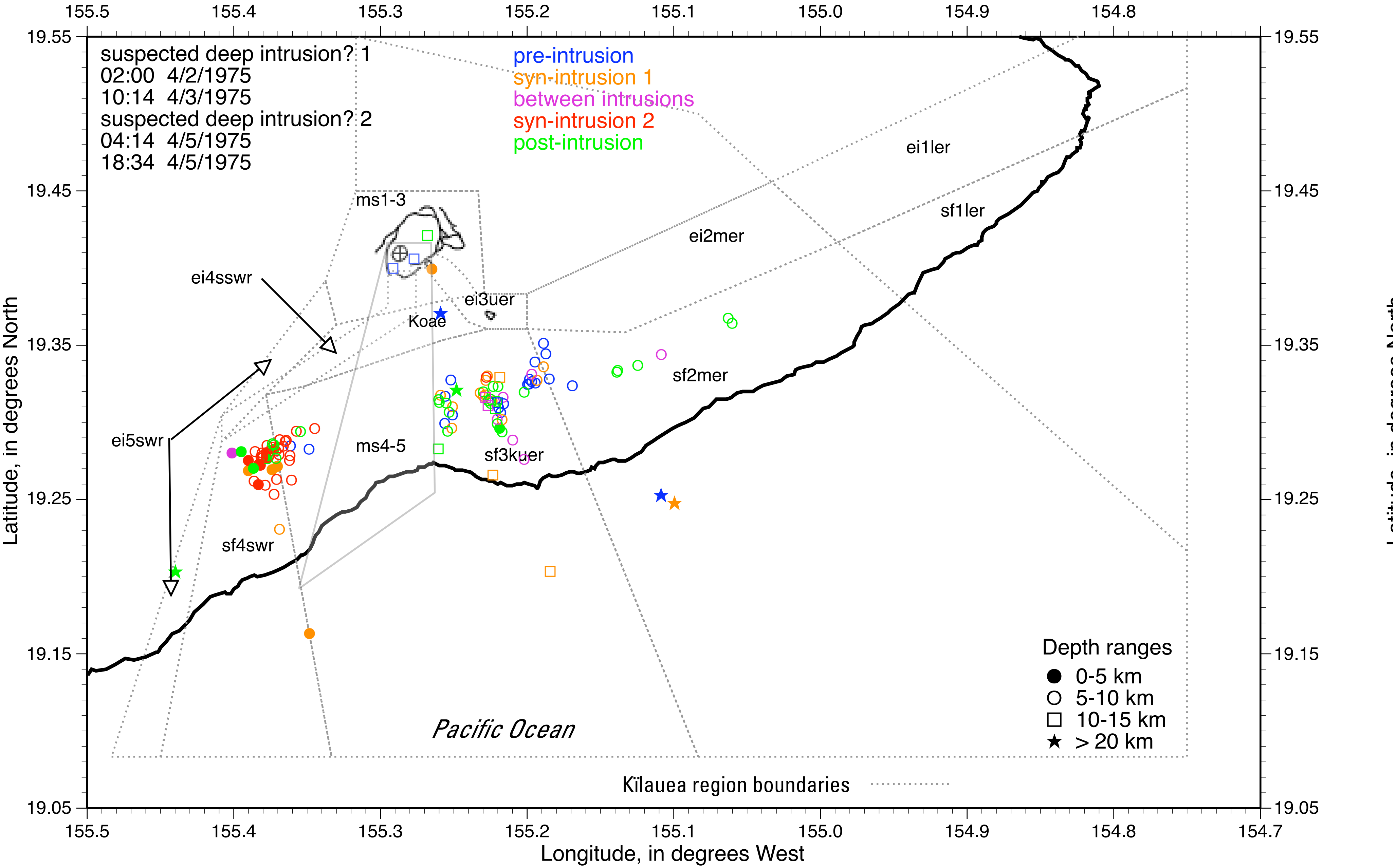


Appendix figure E82

Post-Mauna Ulu March 1975 suspected deep intrusions: data from 3/23-29/1975

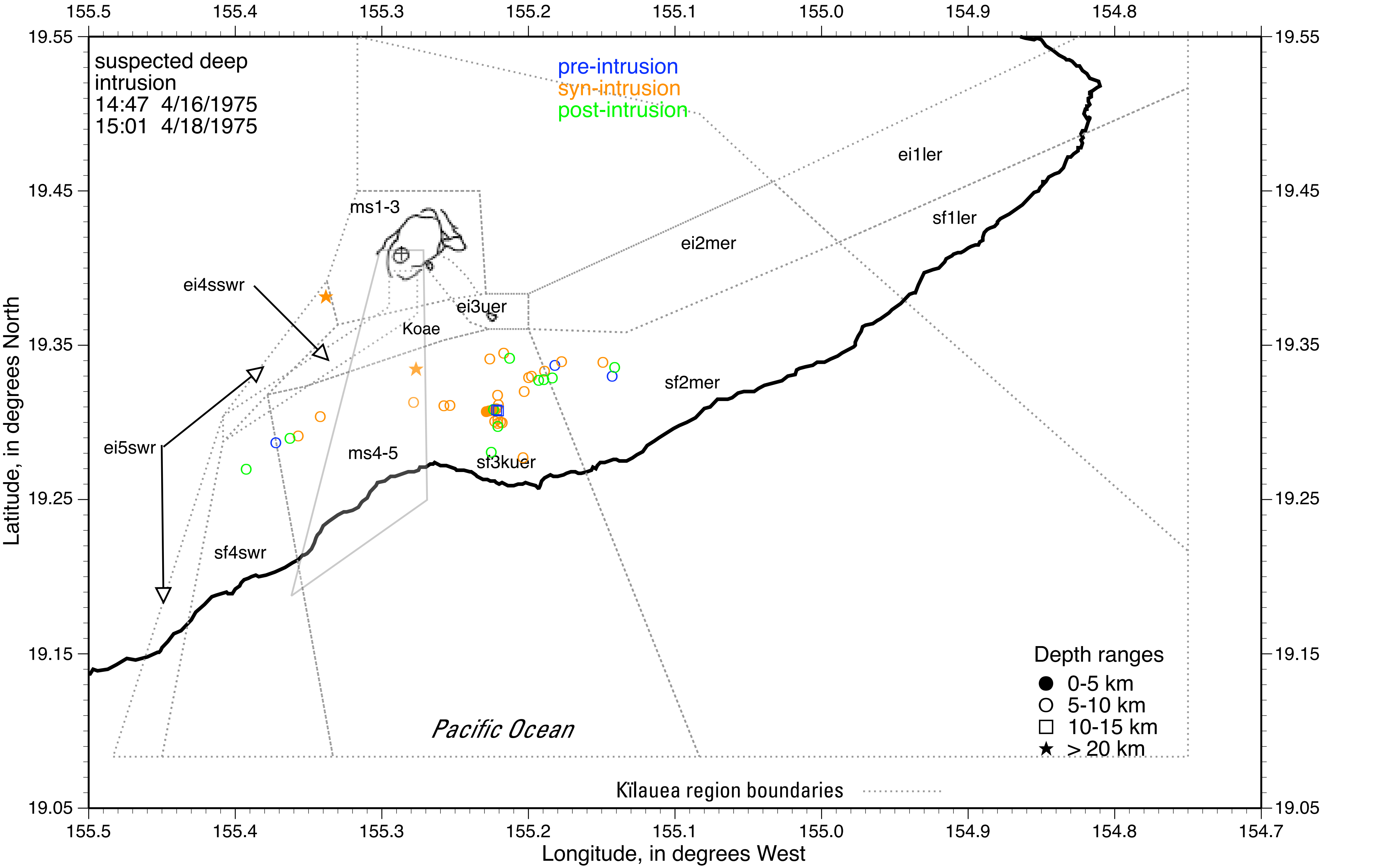


Appendix figure E83 Post-Mauna Ulu April 1975 suspected deep intrusions: data from 3/30-4/9/1975



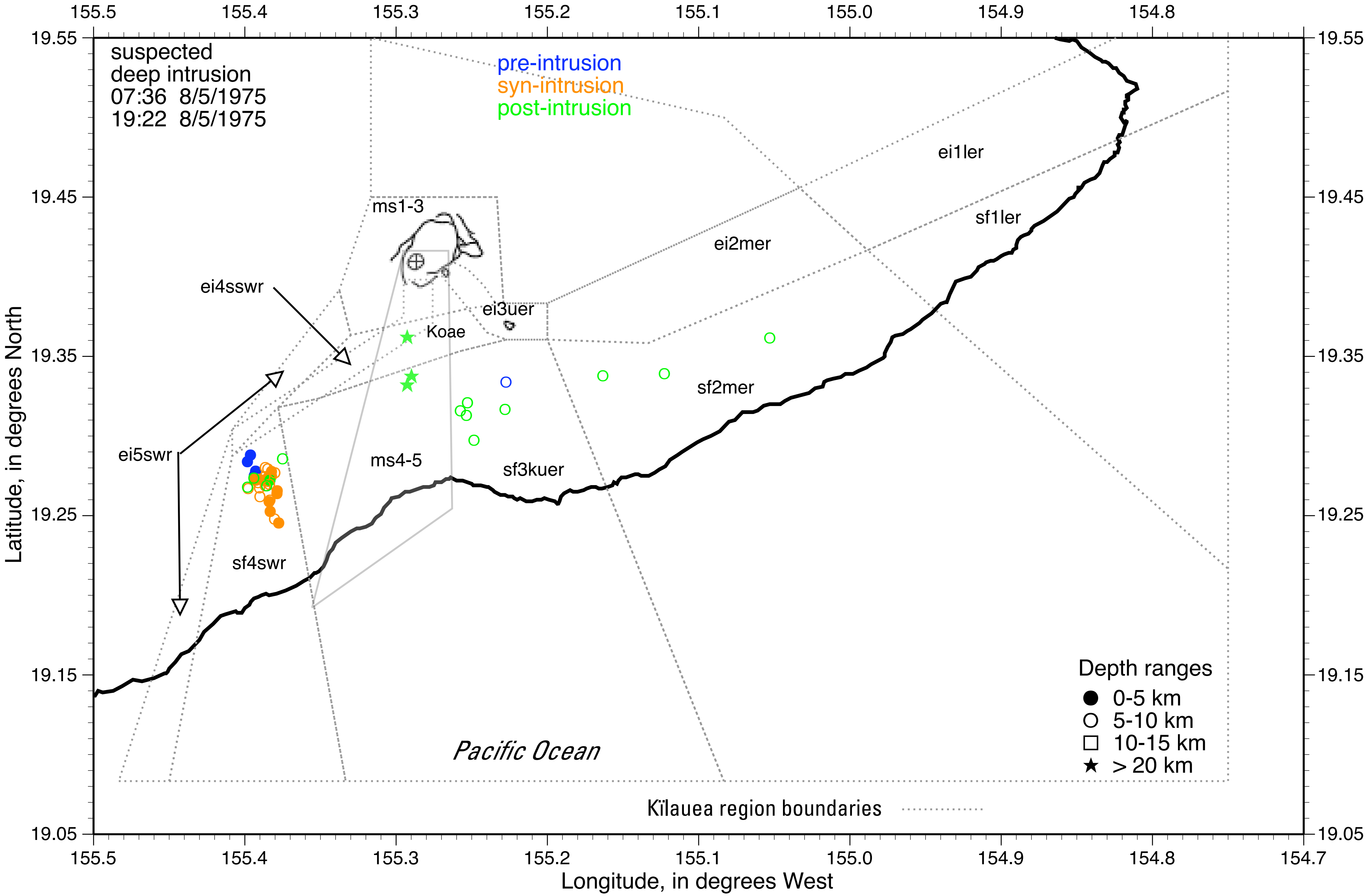
Appendix figure E84

Post-Mauna Ulu April 1975 suspected deep intrusions: data from 4/15-20/1975



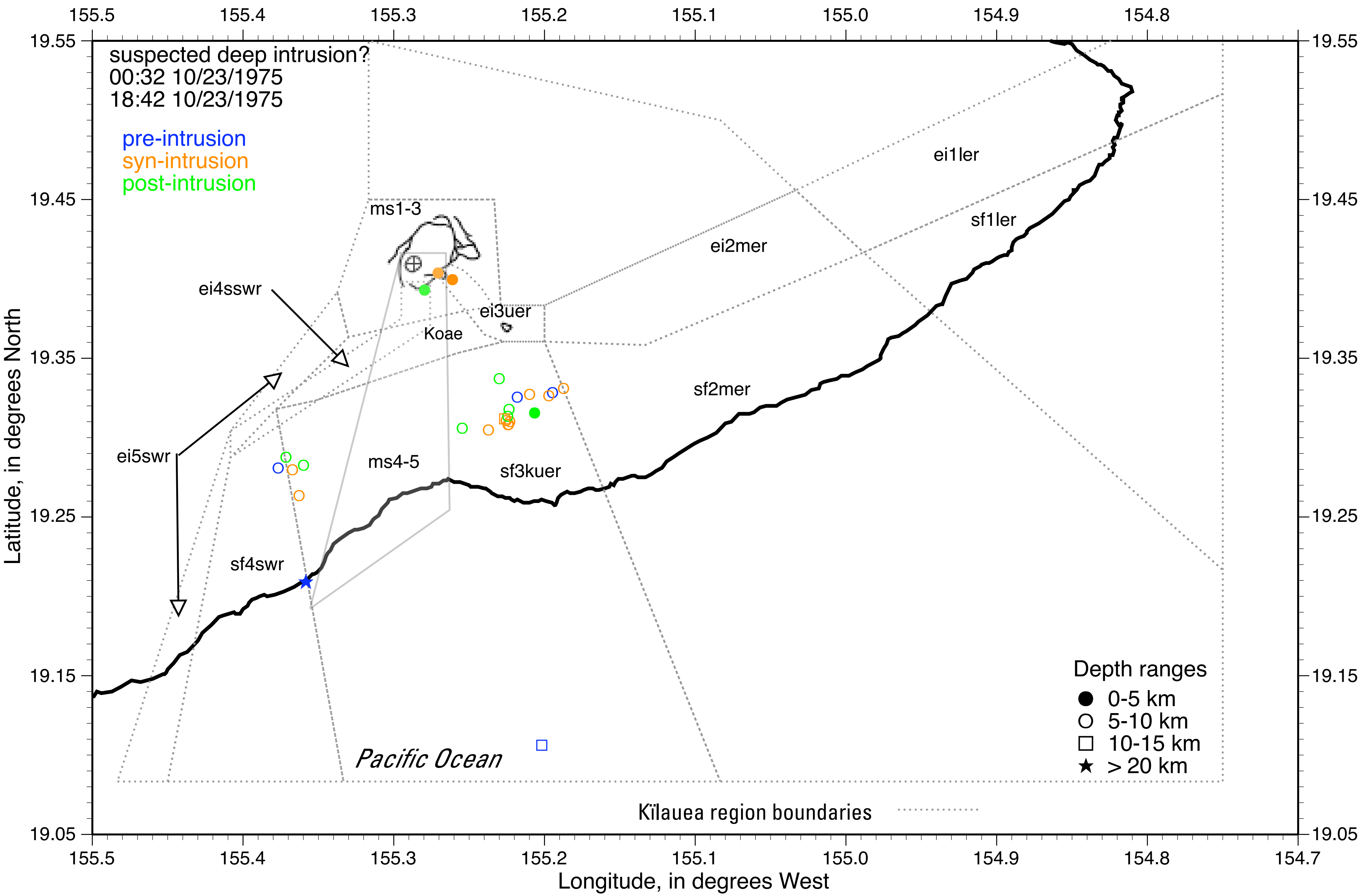
Appendix figure E85

Post-Mauna Ulu suspected deep intrusion: data from 8/4-7/1975

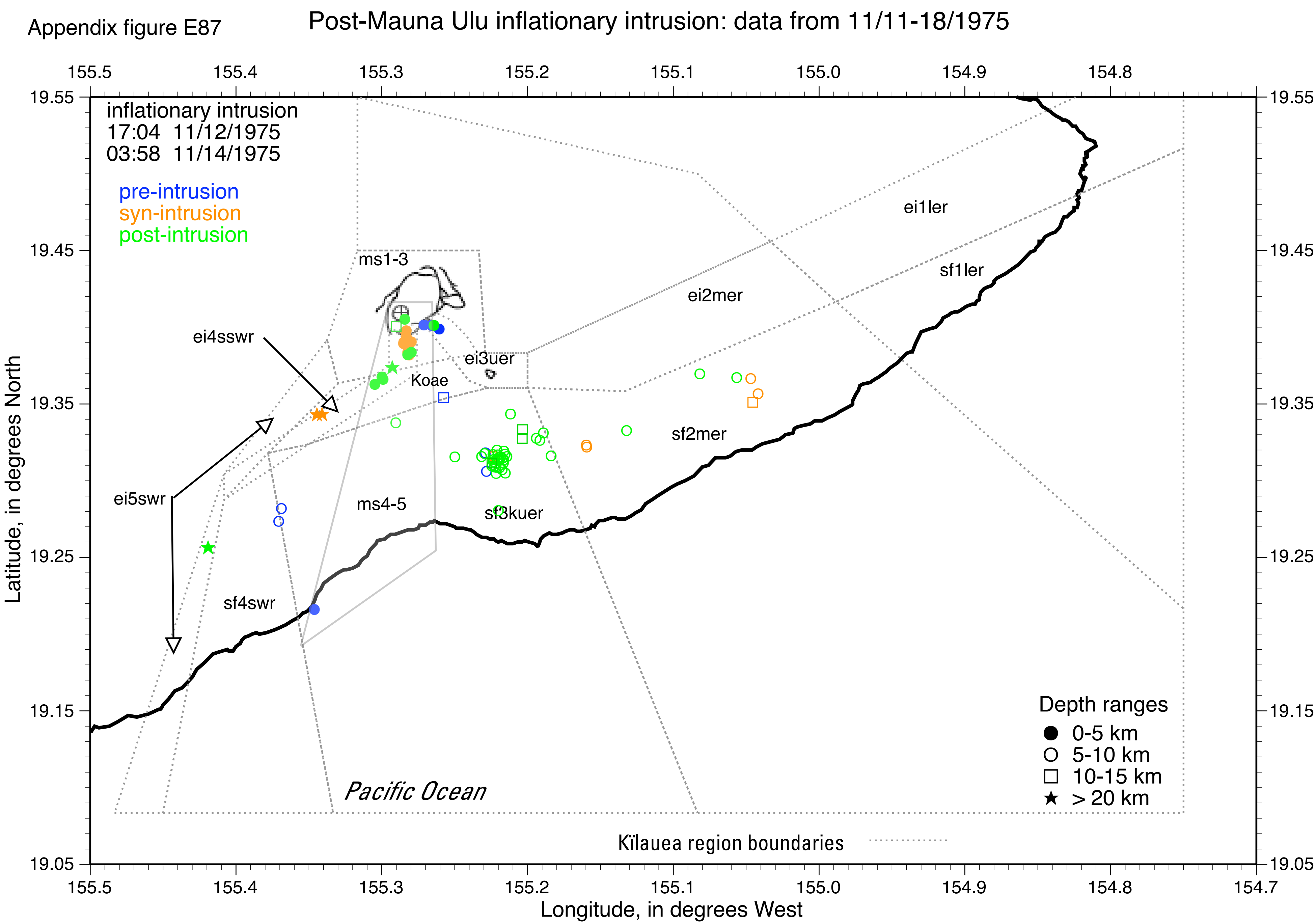


Appendix figure E86

Post-Mauna Ulu suspected deep intrusion: data from 10/22-25/1975



Appendix figure E87



Appendix F. Supplementary Material to Support Chapter 6

Table F1 presents tilt volume, eruption efficiency, and magma supply rate for the period 1975–1983.

Figure F1 shows short- and long-period earthquake swarms for all regions.

Figures F2*A–H* show short-period earthquake counts and earthquakes of M>4 at 1-year intervals from 1 February 1975 to 1 February 1983.

Figure F2*I–P* show long-period earthquake counts and earthquakes of M>4 at 1-year intervals from 1 February 1975-1 February 1983.

Figure F3 shows time series plots at 1-year intervals for 1975–1983.

Figure F4 presents the M7.2 south flank earthquake of 29 November 1975. Aftershocks are shown through 5 December 1975.

Figures F5–F38 show locations of earthquakes for eruptions and intrusions between June 1976 and December 1982.

Table F1. Tilt volume, eruption efficiency and magma supply rate 1975-1983

Cycle	Event[1]	begin date	End date	Δt (yrs)	T_{mag}[2]	T_{az}	T_{vol}[3]	E_{vol}[4]	E_{eff}[5]	Msr[6]	Comment
1975-1983	net	11/27/1975	1/1/1983	7.0965							deflation
		11/27/1975	11/28/1975		2.7	108.4	0.0012				
		11/28/1975	11/30/1975		178.2	133. 9	0.0801				
		11/30/1975	12/10/1975		56.9	154.2	0.0256				
		12/10/1975	3/5/1976		39.2	198.4	0.0176				
	sum						0.1225				
		6/20/1976	6/22/1976		4.8	119.5	0.0034				
		7/14/1976	7/15/1976		6.6	107.7	0.0030				
	ks I	1/20/1977	1/24/1977		5.3	299.4	0.0024				
		2/7/1977	2/11/1977		6.6	107.7	0.0030				
		9/11/1977	9/13/1977		43.7	107.2	0.0197				
		9/13/1977	9/14/1977		26.3	122.5	0.0118				
		9/14/1967	9/16/1967		30.8	130.8	0.0139				
		9/16/1967	9/22/1977		12.9	163.2	0.0058				
		9/26/1977	10/9/1977		14.4	144.7	0.0065				
	sum						0.0577				
	erz E	9/13/1977	10/1/1977				0.0000	0.0263	0.46		
							0.0000				
		5/28/1979	5/30/1979		4.3	133.3	0.0019				
		8/11/1979	8/13/1979		3.5	99.5	0.0016				
		11/15/1979	11/16/1979		8.2	100.1	0.0037				
	erz E	11/16/1979	11/17/1979				0.0000	0.0005	0.13		
		3/1/1980	3/3/1980		2.7	122.0	0.0012				
		3/10/1980	3/11/1980		13.0	112.0	0.0059				
	erz E	3/11/1980	3/11/1980				0.0000				
		8/26/1980	8/27/1980		9.7	112.8	0.0044				
		10/20/1980	10/22/1980		9.0	135.0	0.0040				
		11/2/1980	11/3/1980		8.5	122.6	0.0038				
		1/20/1981	1/21/1981		2.7	147.4	0.0012				
		2/9/1981	2/10/1981		2.9	126.9	0.0013				
	ks I	2/12/1981	2/18/1981		13.4	104.4	0.0060				
	ks I	6/23/1981	6/29/1981		13.8	301.4	0.0062				
		8/1/1981	8/7/1981		7.0	289.2	0.0032				
		8/10/1981			28.9	86.0	0.0130				
		8/10/1981			22.2	117.9	0.0100				
		8/10/1981			46.6	127.7	0.0210				
		8/11/1981	8/14/1981		20.3	157.4	0.0091				
	ks I	3/22/1982	3/25/1982		8.3	313.6	0.0037				
		4/30/1982	5/2/1982		10.1	323.1	0.0045				
	ks E	4/30/1982	5/1/1982					0.0004	0.09		
	ks I	6/8/1982	6/9/1982		8.6	340.4	0.0039				
		6/21/1982	6/23/1982		21.0	120.4	0.0095				
		6/23/1982	6/24/1982		32.8	141.4	0.0147				
		6/24/1982	6/30/1982		9.6	134.4	0.0043				
	ks I	9/23/1982	9/25/1982		23.3	329.6	0.0105				
	ks I	9/25/1982			10.1	319.9	0.0046				
	sum							0.0150			
	ks E	9/25/1982	9/26/1982				0.0000	0.0024	0.16		
	ks I	9/27/1982	10/3/1982		6.0	334.7	0.0027				
		12/9/1982	12/11/1982		4.4	148.4	0.0020				
	total	11/27/1975	1/1/1983	7.0965			0.3518	0.0028		0.050	without 1975 eq dilation
1975 eq dil							0.7200			0.151	Owen, 2006

[1]inf=inflation; def=deflation; trans=transfer; I=intrusion; E=eruption; ks=Kīlauea's summit; erz=East rift zone; swr=Southwest rift zone; kfz=Koaʻe fault zone
[2]Uwekahuna tilt magnitude in microradians
[3]Tilt volume in cubic kilometers=Uwēkahuna tilt magnitude*.00045 (see text for explanation)
[4]Values are equivalent magma volume obtained by multiplying published volumes by 0.8 to account for vesiculation
[5]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.
[6]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. The true magma supply rate includes the volume of rift dilation during the 1975 earthquake . These values are not known because of limitations imposed by the early ground deformation network.

Cross references, chapter 6 tables and appendix F 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 intusions (green), and suspected deep intrusions (magneta)]

Chap. 6 page	Chap. 6 table	Row in table	App. F figure
119	6.1	1	F4
do	do	3	F5A
do	do	4	F5B
do	do	5	F6
do	do	6	F7
do	do	16	F8
do	do	17	F9
do	do	20	F10
do	do	21	F11
do	do	23	F12
do	do	24, 27-29	F13
do	do	30	F14
do	do	31	F15
do	do	33	F16
120	6.1 cont	1	F17
do	do	6	F18
do	do	7	F19
do	do	9	F20
do	do	11	F21
do	do	12	F22A
do	do	14	F22B
do	do	16	F23
do	do	24	F24
do	do	25	F25

Chap. 6 page	Chap. 6 table	Row in table	App. F figure
do	do	28	F26
do	do	31	F27
do	do	33	F28
do	do	36	F29
121	8.1 cont	1	F30
do	do	2	F31
do	do	3	F32
do	do	4	F33
do	do	5	F34
do	do	8	F35
do	do	9	F36
do	do	16	F37
do	do	20	F38

Figure F1. Graphs showing Kīlauea short- and long-period earthquake swarms for all regions of the volcano from 1 November 1975 to 1 February 1983 (through episode 1 of the Puʻu ʻŌʻo-Kupaianaha eruption). Dates on figure in mm/dd/yyyy format.

Figure F2. Graphs showing Kīlauea activity from 1 February 1975 to 1 February 1983. Dates on figure in mm/dd/yyyy format. *A–H*, Short-period earthquake counts and earthquakes of M>4 at 1-year intervals. *J–P*, Long-period earthquake counts and earthquakes of M>4 at 1-year intervals.

Figure F3. 1975–1983. *A–H*, Time series plots at 1-year intervals for 1975–1983. Shown are Uwēkahuna tilt, times of eruption and intrusion, occurrence of earthquakes by region.

Figure F4. Map showing Kīlauea activity around the *M*7.2 south flank earthquake on 29 November 1975. Aftershocks are shown through 5 December 1975. Black polygons show zones of earthquakes defining slow intrusions defined in chapter 5 (fig. 5.2). These are parallel or coincident with preferred concentrations of aftershocks, indicating a similarity in south flank stress regime for slow intrusions and large earthquakes. Dates on figure in mm/dd/yyyy format.

Figure F5. Maps showing Kīlauea activity around the June 1976 and July 1976 traditional east rift intrusions. Dates on figure in mm/dd/yyyy format. *A*, Data from 17–26 June. *B*, Data from 9–19 July.

Figure F6. Map showing Kīlauea activity around the January 1977 traditional east rift intrusion. South flank seismicity extends to south of the vents for the September 1977 eruption. Dates on figure in mm/dd/yyyy format.

Figure F7. Map showing Kīlauea activity around the February 1977 traditional east rift intrusion. South flank seismicity extends to south of the vents for the September 1977 eruption. Dates on figure in mm/dd/yyyy format.

Figure F8. Map showing activity around September 1977 east rift eruption. Data from 13 September to 4 October 1977. Dates on figure in mm/dd/yyyy format.

Figure F9. Map showing activity around May 1979 traditional east rift intrusion that extends to the east of the vents for the later November 1979 eruption and even east of the seismicity associated with that eruption. Data from 28 May to 1 June. Dates on figure in mm/dd/yyyy format.

Figure F10. Map showing activity around August 1979 traditional upper east rift intrusion with almost no south flank accompaniment. Data from 7–16 August. Dates on figure in mm/dd/yyyy format.

Figure F11. Map showing activity during 21–24 September 1979. An intense south flank earthquake swarm is accompanied by a long-period earthquake swarm. Dates on figure in mm/dd/yyyy format.

Figure F12. Map showing activity during 1–14 October 1979, including paired upper east rift/upper seismic southwest rift intrusion. Intense south flank activity both precedes and follows the intrusion. Dates on figure in mm/dd/yyyy format.

Figure F13 .Map showing activity around November 1979 eruption. Data from 14–19 November. Overlapping intrusions precede, accompany, and follow the eruption at short distances uprift and downrift from the erupting vents. No long-period seismicity accompanied this eruption. Dates on figure in mm/dd/yyyy format.

Figure F14. Map showing activity around January 1980 traditional east rift intrusion. Data from 13–24 January. Symbols are covered by continued posteruption seismicity. Dates on figure in mm/dd/yyyy format.

Figure F15. Map showing activity around February 1980 traditional east rift intrusion. Data from 31 January to 5 February. Symbols are covered by continued post eruption seismicity. Dates on figure in mm/dd/yyyy format.

Figure F16. Map showing activity around March 1980 traditional east rift intrusion. Data from 1–4 March. Dates on figure in mm/dd/yyyy format.

Figure F17. Map showing activity around March 1980 eruption. A small eruption is accompanied by a large intrusion. Data from 8–14 March. Dates on figure in mm/dd/yyyy format.

Figure F18. Map showing activity around July 1980 traditional east rift intrusion. South flank seismicity occurs before and after the intrusion. Data from 28 July to 7 August. Dates on figure in mm/dd/yyyy format.

Figure F19. Map showing activity around August 1980 traditional east rift intrusion. Data from 26–30 August. Dates on figure in mm/dd/yyyy format.

Figure F20. Map showing activity around October 1980 traditional east rift intrusion. The earthquake swarm extends from upper to lower east rift zone. Data from 20–28 October. Dates on figure in mm/dd/yyyy format.

Figure F21. Map showing activity around November 1980 traditional east rift intrusion. Data from 30 October to 6 November. Dates on figure in mm/dd/yyyy format.

Figure F22. Maps showing activity around January 1981 seismic southwest rift zone intrusion. Dates on figure in mm/dd/yyyy format. *A*, Data from 17–22 January. Intrusive activity shifts to the west. *B*, Data from 23–31 January. Two intrusions during 24–28 January. South flank response remains south of the east rift.

Figure F23. Map showing activity around January-February 1981 seismic southwest rift zone intrusions. Data from 17 January to 18 February. Central and eastern south flank seismicity precedes, accompanies, and follows three closely spaced intrusions within nearly continuous intrusive activity. Intrusion is at the southwest end of the seismic southwest rift zone, overlapped by both pre- and postintrusion seismicity. February intrusion has progressed farther downrift from the location of the January intrusions. Dates on figure in mm/dd/yyyy format.

Figure F24. Map showing activity around April 1981 seismic southwest rift zone suspected slow intrusion. Data from 24–28 April. Dates on figure in mm/dd/yyyy format.

Figure F25. Map showing activity around June 1981 summit intrusion. Data from 23–28 June. Ideal-Arrowsmith tiltmeter shows a sharp inflationary tilt step between 14:00 and 16:00 on 25 June and a more gradual inflation between 17:00 and 24:00 on 26 June. These times do not correspond to specific concentrations of summit earthquakes. Dates on figure in mm/dd/yyyy format.

Figure F26. Map showing activity around July 1981 seismic southwest rift zone intrusion. Data from 17–24 July. Symbols are partly covered by continued post eruption seismicity. Dates on figure in mm/dd/yyyy format.

Figure F27. Map showing activity around the beginning of a migrating sequence of seismic southwest rift zone intrusions during 1–7 August 1981. Data from 31 July to 7 August. South flank seismicity is sparse and located beneath the east rift. Dates on figure in mm/dd/yyyy format.

Figure F28. Map showing activity around 9–15 August 1981 seismic southwest rift zone intrusion. Dates on figure in mm/dd/yyyy format. *A*, Earthquakes from 8–23 August are colored by date and indicate a complex pattern of migration within the seismic southwest rift zone. South flank seismicity occurs adjacent to the rift seismicity. *B*, Earthquakes subdivided by day from 9–15 August. A major intrusion beneath the seismic southwest rift zone that resembles the intrusion following the eruption of 31 December 1974.

Figure F29. Map showing activity around January 1982 seismic southwest rift zone intrusion. Data from 14–17 January. This the first of five intrusions within nearly continuous intrusive activity preceding the April 1982 summit eruption. Dates on figure in mm/dd/yyyy format.

Figure F30. Map showing activity around February 1982 seismic southwest rift zone intrusion. Data from 24 Feburary to 1 March. Dates on figure in mm/dd/yyyy format.

Figure F31. Map showing activity around 3 March 1982 seismic southwest rift zone intrusion. Data from 2–5 March. Dates on figure in mm/dd/yyyy format.

Figure F32. Map showing activity around 9 March 1982 seismic southweast rift zone intrusion. Data from 6–12 March. Dates on figure in mm/dd/yyyy format.

Figure F33. Map showing activity around the 23 March 1982 seismic southwest rift zone intrusion. Data from 21–27 March. This intrusion was the last on the seismic southwest rift zone preceding the April 1982 eruption. Dates on figure in mm/dd/yyyy format.

Figure F34. Map showing activity around April 1982 summit eruption/intrusion. Data from 25 April to 11 May. Following the eruption a small paired intrusion propagates south and southeast. Dates on figure in mm/dd/yyyy format.

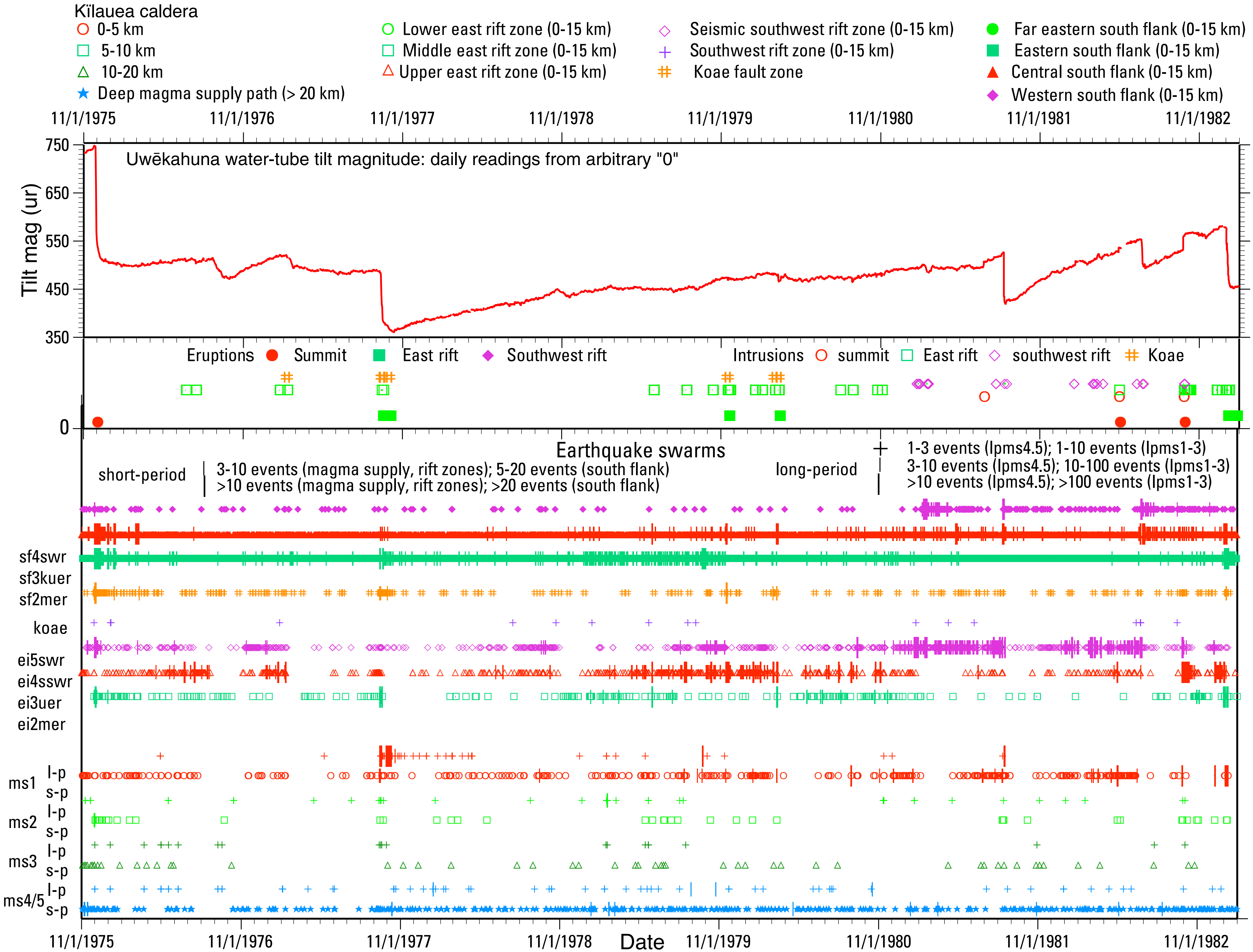
Figure F35. Map showing activity around 8–9 June 1982 seismic southwest rift zone intrusion. Data from 4–14 June. This the first of two large intrusions within nearly continuous intrusive activity between the two 1982 summit eruptions. Pre-, syn- and postintrusion data overlap with the postintrusion earthquakes extending farther downrift. Dates on figure in mm/dd/yyyy format.

Figure F36. Map showing activity around 22–24 June 1982 seismic southwest rift zone intrusion. Data from 18–28 June. This is the second of two large intrusions within nearly continuous intrusive activity between the two 1982 summit eruptions. This and the preceding intrusion resemble the seismic sequence of August 1981. Dates on figure in mm/dd/yyyy format.

Figure F37. Map showing activity around September 1982 summit eruption/intrusion. Data from 23 September to 8 October. Intrusion precedes eruption and continues beyond the period of eruption. A second small intrusion (30 September-1 October) extends to the south and southeast within the posteruption period. Seismicity beneath the western south flank may indicate a continuation of the June intrusion. Dates on figure in mm/dd/yyyy format.

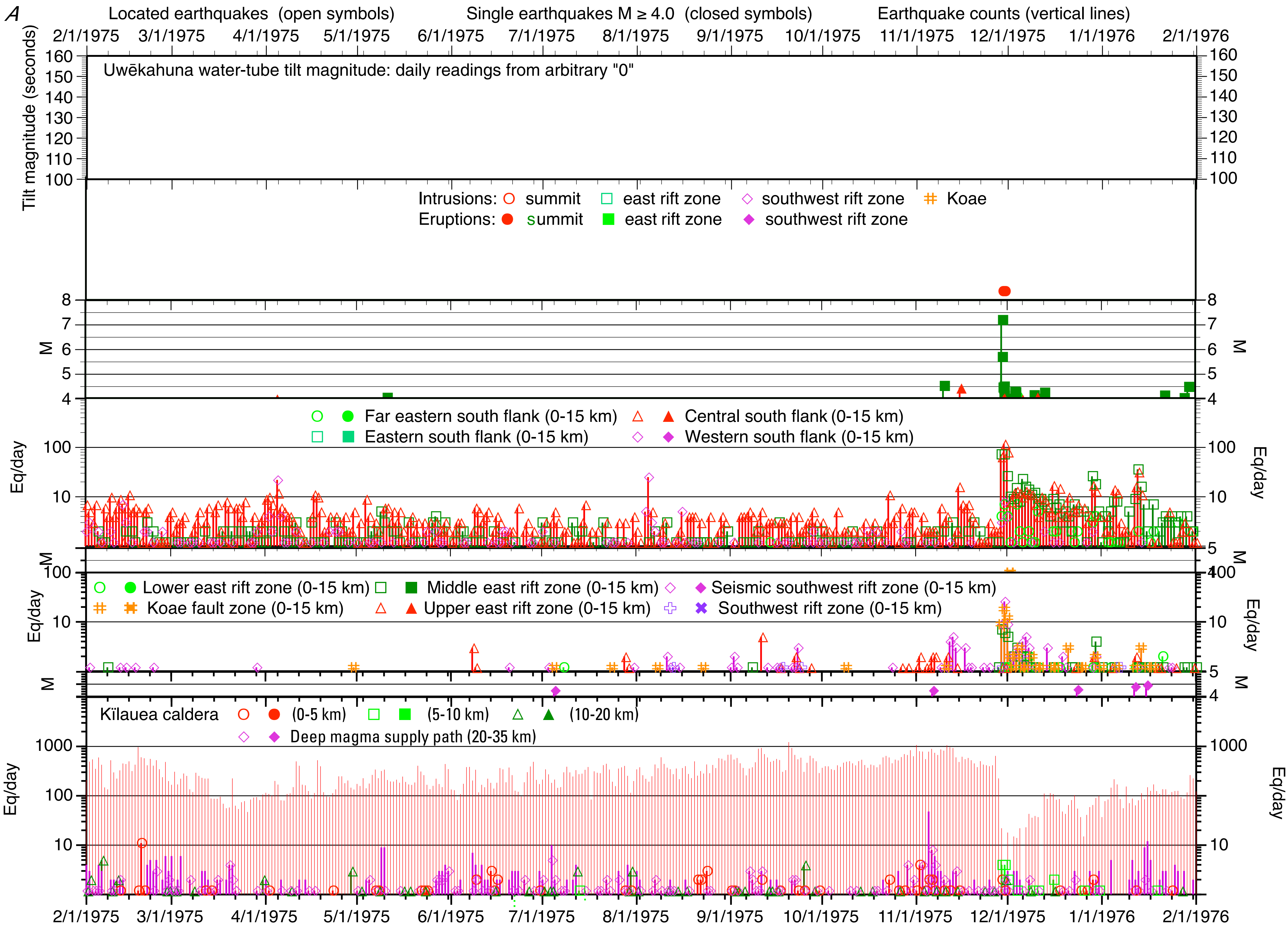
Figure F38. Map shwoing activity around October 1982 east rift zone intrusions. Data from 1–15 October. Four intrusions, mostly beneath the uppermost east rift zone. Seismicity beneath the western south flank may indicate a continuation of the June intrusion. Dates on figure in mm/dd/yyyy format.

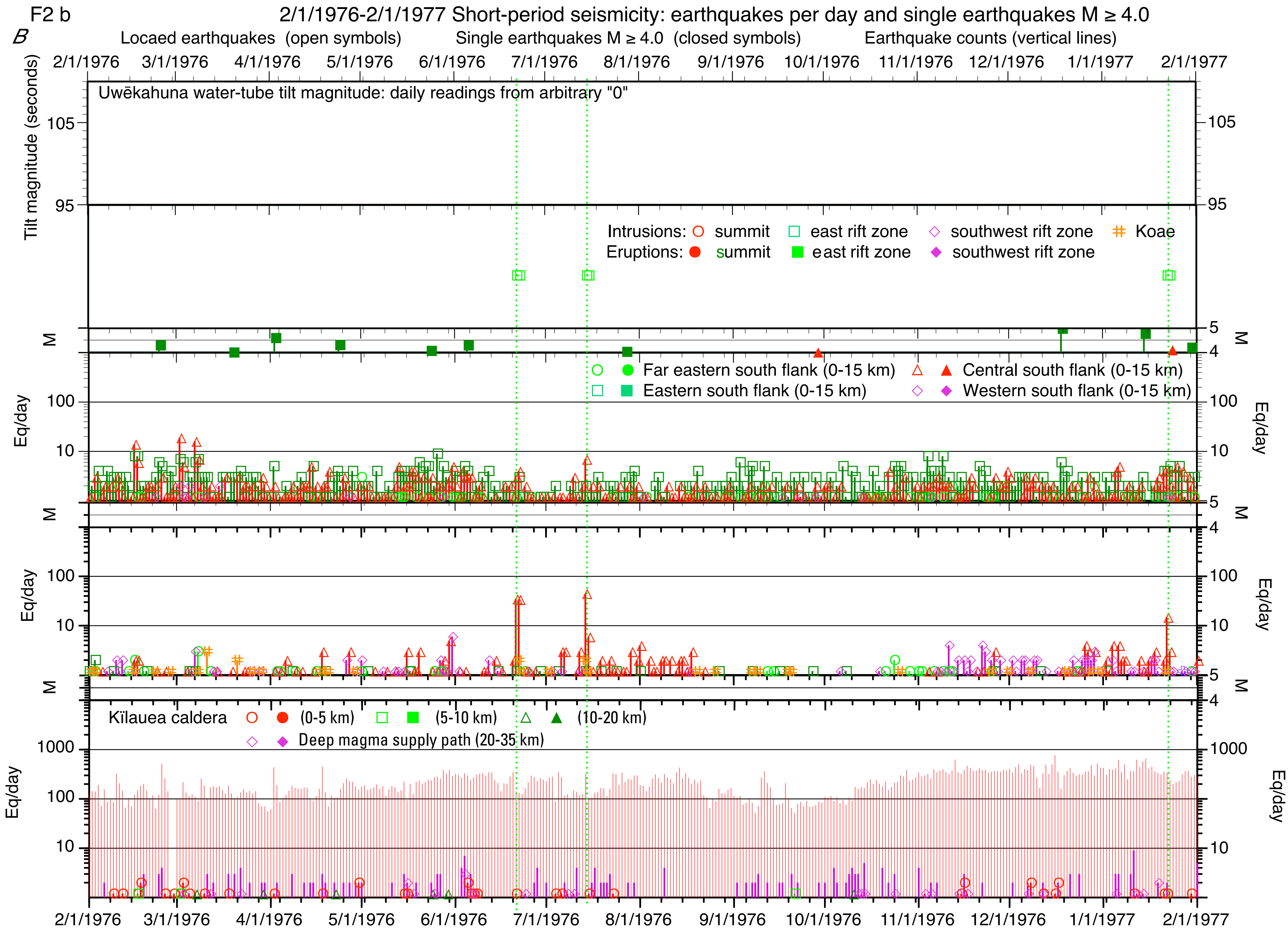
Figure F1. 11/29/1975 earthquake through episode 1 of the Pu'u 'O'o-Kupaianaha eruption



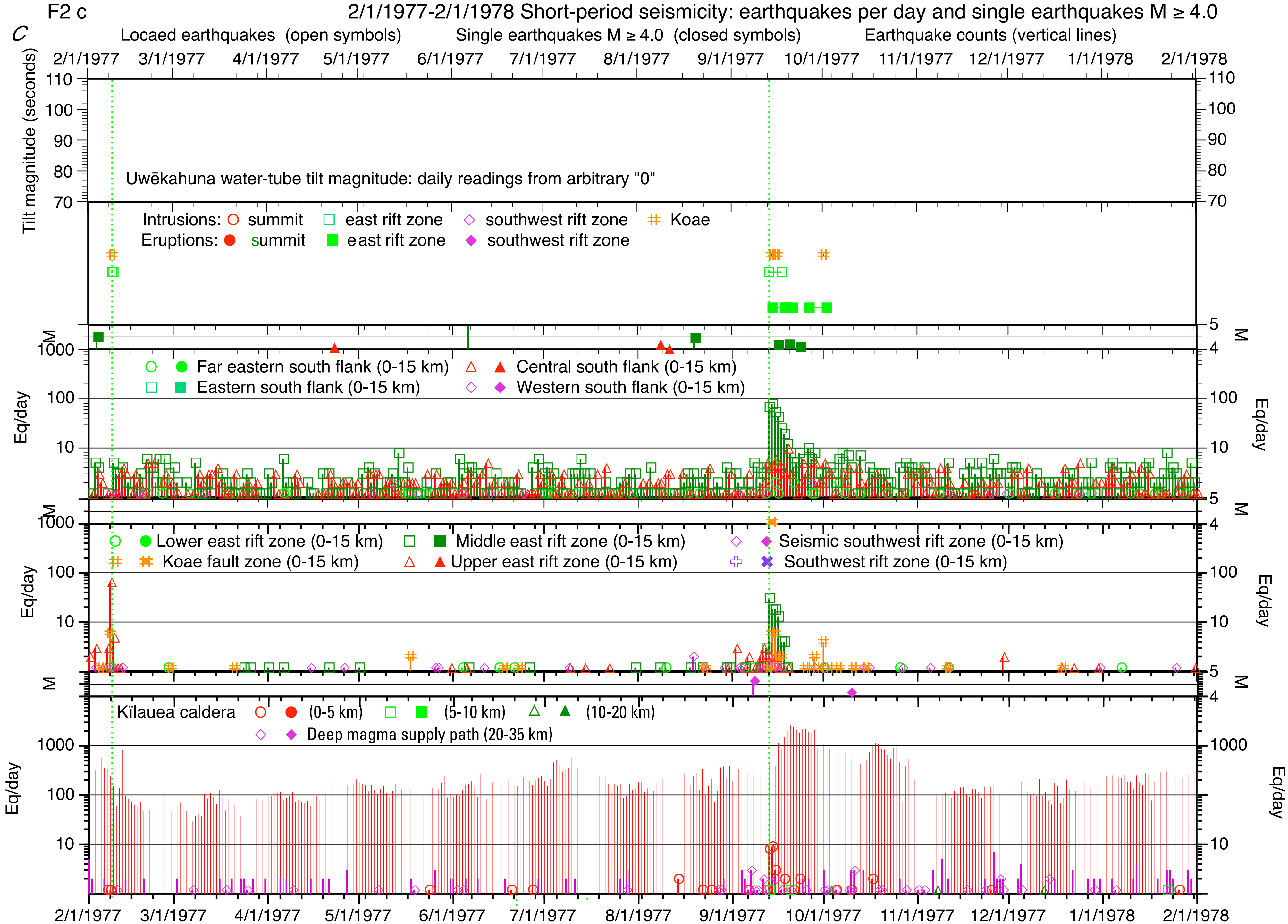
F2 a

2/1/1975-2/1/1976 Short-period seismicity: earthquakes per day and single earthquakes M ≥ 4.0



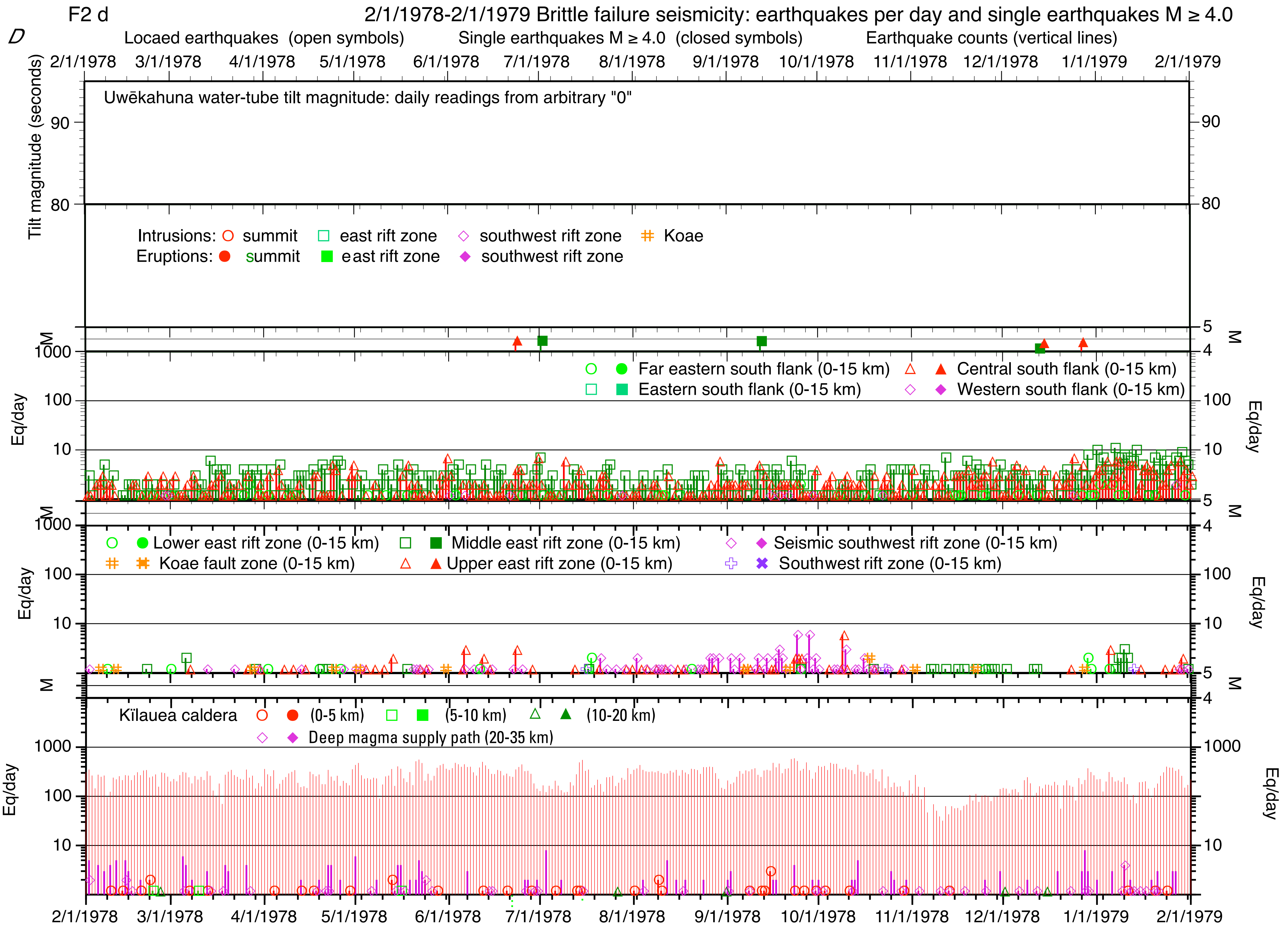

F2 b
2/1/1976-2/1/1977 Short-period seismicity: earthquakes per day and single earthquakes M ≥ 4.0
B
Locaed earthquakes (open symbols)
Single earthquakes M ≥ 4.0 (closed symbols)
Earthquake counts (vertical lines)
2/1/1976 3/1/1976 4/1/1976 5/1/1976 6/1/1976 7/1/1976 8/1/1976 9/1/1976 10/1/1976 11/1/1976 12/1/1976 1/1/1977 2/1/1977
Uwēkahuna water-tube tilt magnitude: daily readings from arbitrary "0"
Tilt magnitude (seconds)
105
95
Intrusions: summit east rift zone southwest rift zone Koae
Eruptions: summit east rift zone southwest rift zone
M
5
4
Far eastern south flank (0-15 km)
Central south flank (0-15 km)
Eastern south flank (0-15 km)
Western south flank (0-15 km)
Eq/day
100
10
Kīlauea caldera (0-5 km) (5-10 km) (10-20 km)
Deep magma supply path (20-35 km)
1000

F2 c

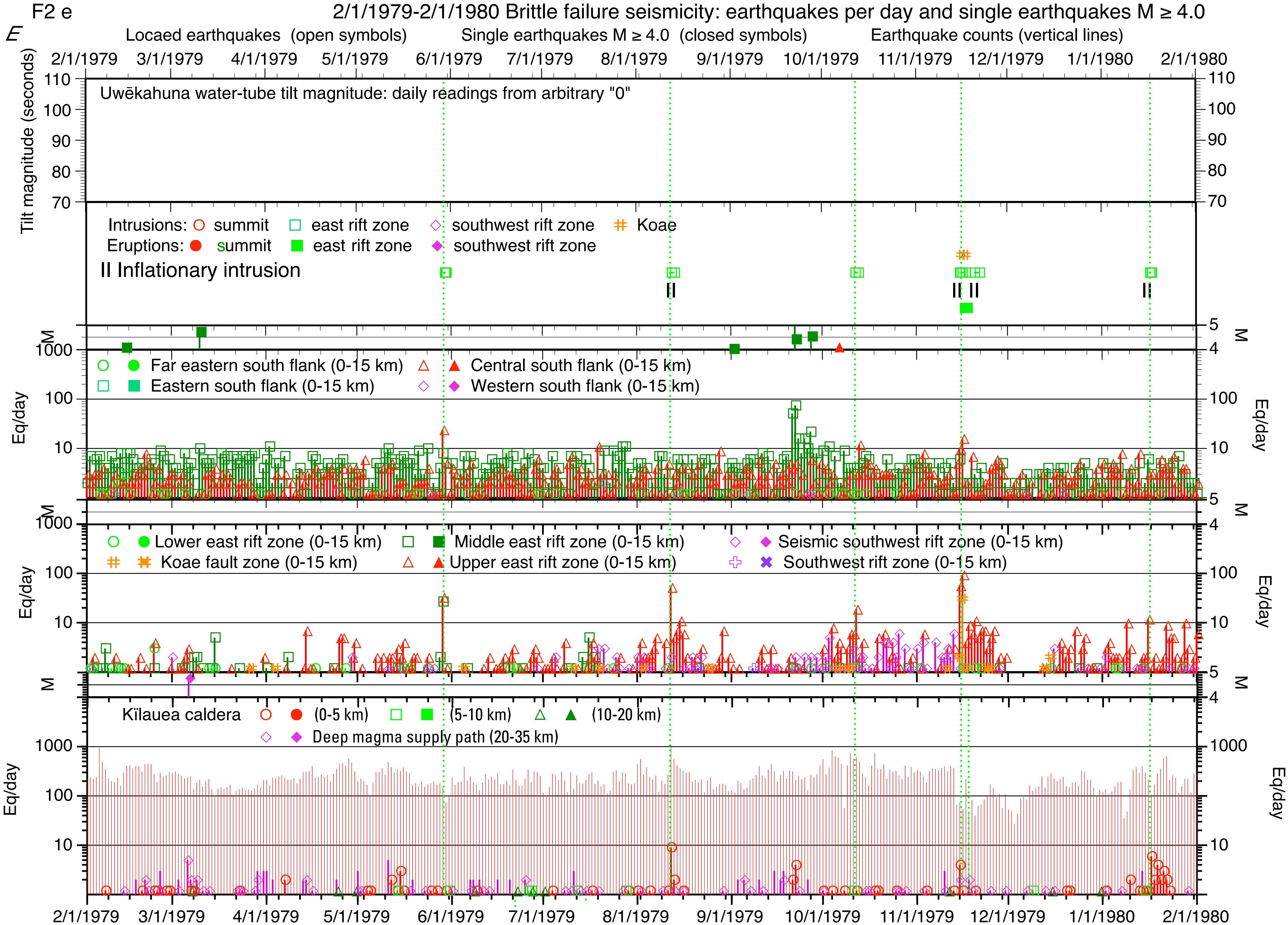


2/1/1977-2/1/1978 Short-period seismicity: earthquakes per day and single earthquakes M ≥ 4.0
Locaed earthquakes (open symbols)
Single earthquakes M ≥ 4.0 (closed symbols)
Earthquake counts (vertical lines)
2/1/1977 3/1/1977 4/1/1977 5/1/1977 6/1/1977 7/1/1977 8/1/1977 9/1/1977 10/1/1977 11/1/1977 12/1/1977 1/1/1978 2/1/1978
Tilt magnitude (seconds)
Uwēkahuna water-tube tilt magnitude: daily readings from arbitrary "0"
Intrusions: summit east rift zone southwest rift zone Koae
Eruptions: summit east rift zone southwest rift zone
M
Eq/day
Far eastern south flank (0-15 km)
Central south flank (0-15 km)
Eastern south flank (0-15 km)
Western south flank (0-15 km)
Lower east rift zone (0-15 km)
Middle east rift zone (0-15 km)
Seismic southwest rift zone (0-15 km)
Koae fault zone (0-15 km)
Upper east rift zone (0-15 km)
Southwest rift zone (0-15 km)
Kīlauea caldera (0-5 km) (5-10 km) (10-20 km)
Deep magma supply path (20-35 km)

F2 d


D
2/1/1978-2/1/1979 Brittle failure seismicity: earthquakes per day and single earthquakes M ≥ 4.0
Locaed earthquakes (open symbols)
Single earthquakes M ≥ 4.0 (closed symbols)
Earthquake counts (vertical lines)
2/1/1978
3/1/1978
4/1/1978
5/1/1978
6/1/1978
7/1/1978
8/1/1978
9/1/1978
10/1/1978
11/1/1978
12/1/1978
1/1/1979
2/1/1979
Tilt magnitude (seconds)
Uwēkahuna water-tube tilt magnitude: daily readings from arbitrary "0"
90
80
Intrusions: summit
east rift zone
southwest rift zone
Koae
Eruptions: summit
east rift zone
southwest rift zone
M
5
4
1000
100
10
Eq/day
Far eastern south flank (0-15 km)
Central south flank (0-15 km)
Eastern south flank (0-15 km)
Western south flank (0-15 km)
Lower east rift zone (0-15 km)
Middle east rift zone (0-15 km)
Seismic southwest rift zone (0-15 km)
Koae fault zone (0-15 km)
Upper east rift zone (0-15 km)
Southwest rift zone (0-15 km)
Kīlauea caldera
(0-5 km)
(5-10 km)
(10-20 km)
Deep magma supply path (20-35 km)

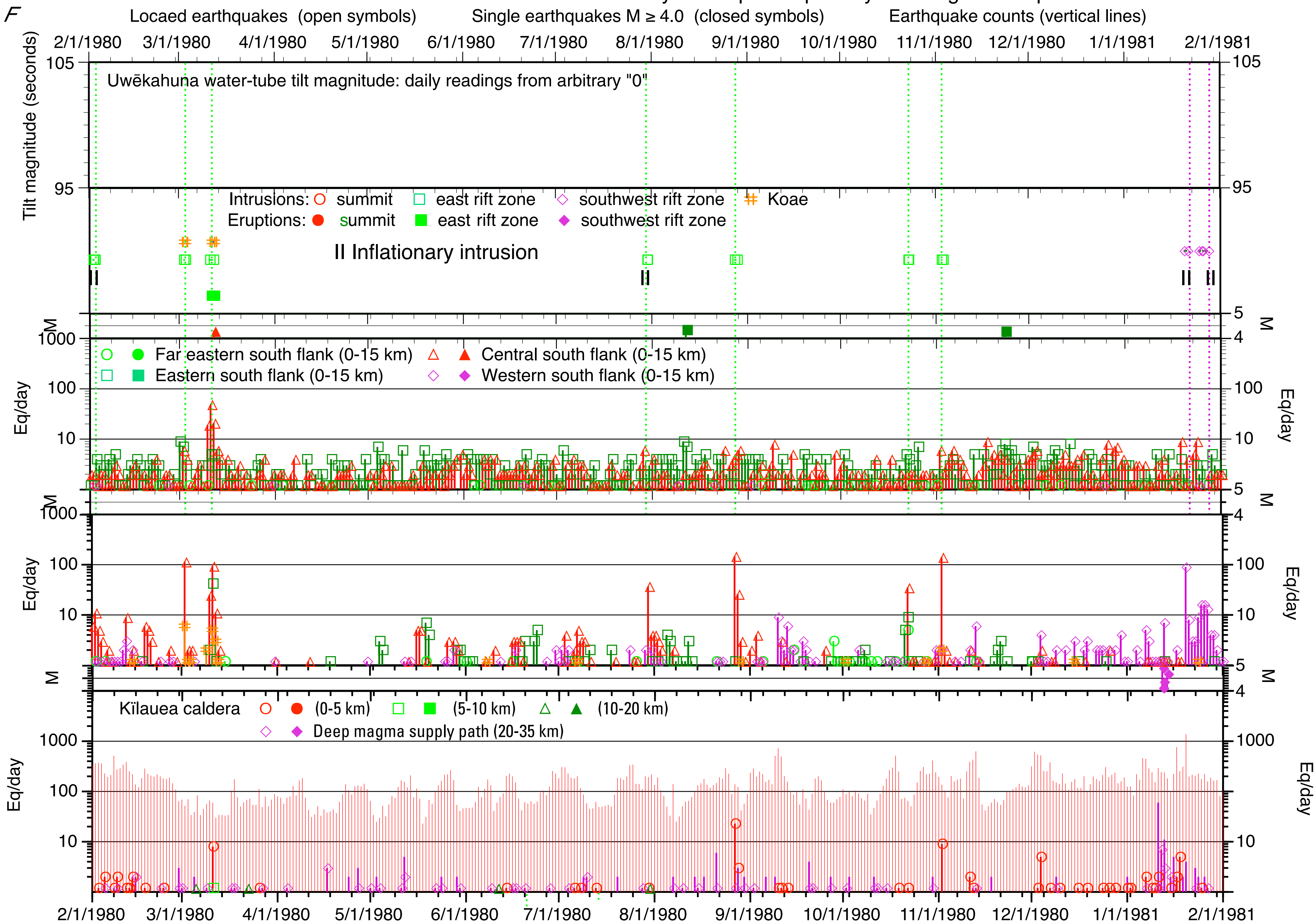
F2 e

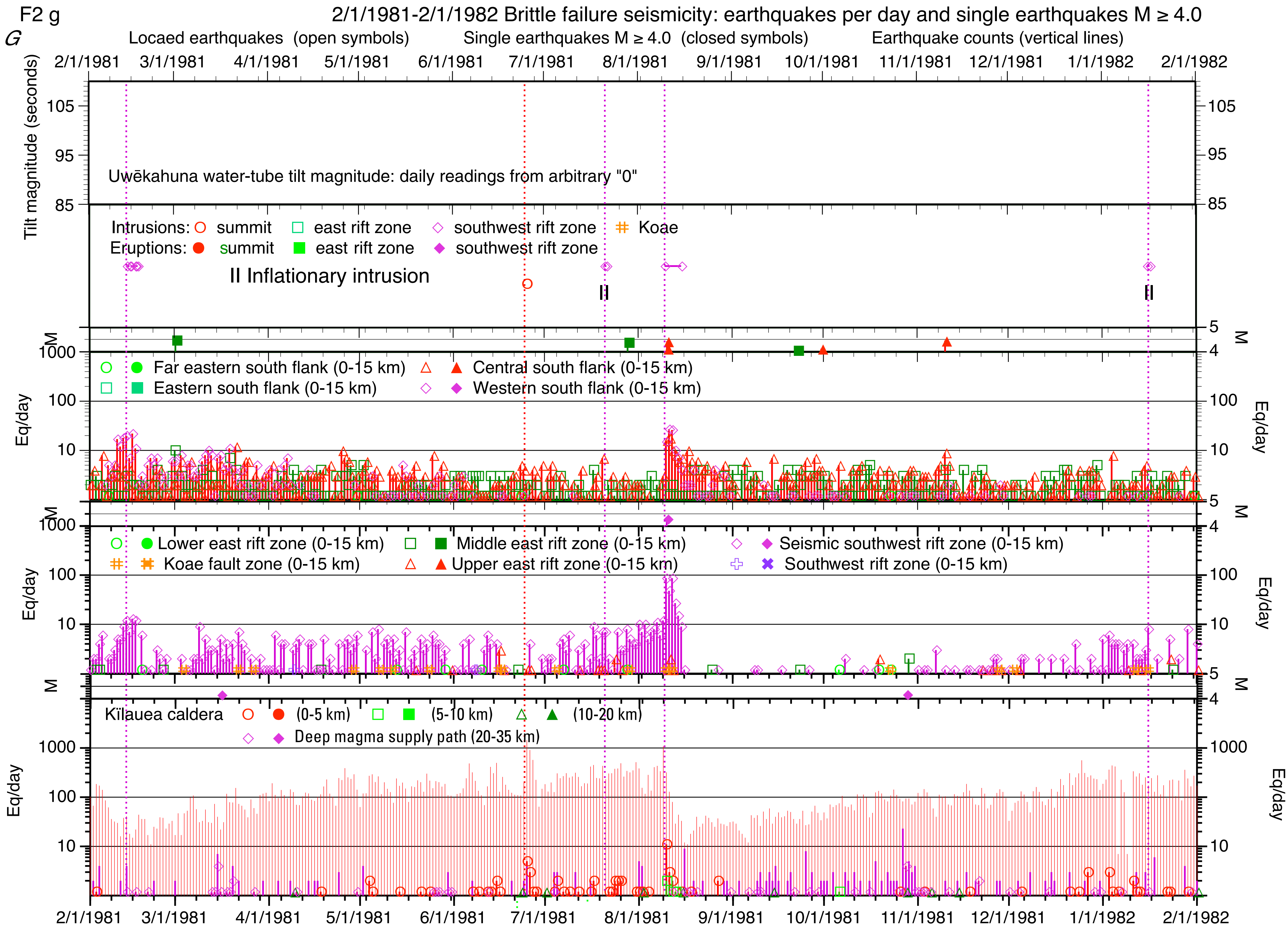


2/1/1979-2/1/1980 Brittle failure seismicity: earthquakes per day and single earthquakes M ≥ 4.0
E
Locaed earthquakes (open symbols)
Single earthquakes M ≥ 4.0 (closed symbols)
Earthquake counts (vertical lines)
Uwēkahuna water-tube tilt magnitude: daily readings from arbitrary "0"
Tilt magnitude (seconds)
Intrusions: summit east rift zone southwest rift zone Koae
Eruptions: summit east rift zone southwest rift zone
II Inflationary intrusion
Far eastern south flank (0-15 km)
Central south flank (0-15 km)
Eastern south flank (0-15 km)
Western south flank (0-15 km)
Lower east rift zone (0-15 km)
Middle east rift zone (0-15 km)
Seismic southwest rift zone (0-15 km)
Koae fault zone (0-15 km)
Upper east rift zone (0-15 km)
Southwest rift zone (0-15 km)
Kīlauea caldera (0-5 km) (5-10 km) (10-20 km)
Deep magma supply path (20-35 km)
Eq/day
M
2/1/1979 3/1/1979 4/1/1979 5/1/1979 6/1/1979 7/1/1979 8/1/1979 9/1/1979 10/1/1979 11/1/1979 12/1/1979 1/1/1980 2/1/1980

F2 f

2/1/1980-2/1/1981 Brittle failure seismicity: earthquakes per day and single earthquakes M ≥ 4.0




F2 g
2/1/1981-2/1/1982 Brittle failure seismicity: earthquakes per day and single earthquakes M ≥ 4.0
G
Locaed earthquakes (open symbols)
Single earthquakes M ≥ 4.0 (closed symbols)
Earthquake counts (vertical lines)
2/1/1981
3/1/1981
4/1/1981
5/1/1981
6/1/1981
7/1/1981
8/1/1981
9/1/1981
10/1/1981
11/1/1981
12/1/1981
1/1/1982
2/1/1982
Tilt magnitude (seconds)
105
95
85
Uwēkahuna water-tube tilt magnitude: daily readings from arbitrary "0"
Intrusions: summit
east rift zone
southwest rift zone
Koae
Eruptions: summit
east rift zone
southwest rift zone
II Inflationary intrusion
M
5
4
1000
100
10
Eq/day
Far eastern south flank (0-15 km)
Central south flank (0-15 km)
Eastern south flank (0-15 km)
Western south flank (0-15 km)
Lower east rift zone (0-15 km)
Middle east rift zone (0-15 km)
Seismic southwest rift zone (0-15 km)
Koae fault zone (0-15 km)
Upper east rift zone (0-15 km)
Southwest rift zone (0-15 km)
Kīlauea caldera
(0-5 km)
(5-10 km)
(10-20 km)
Deep magma supply path (20-35 km)

F2 h

2/1/1982-2/1/1983 Brittle failure seismicity: earthquakes per day and single earthquakes M ≥ 4.0

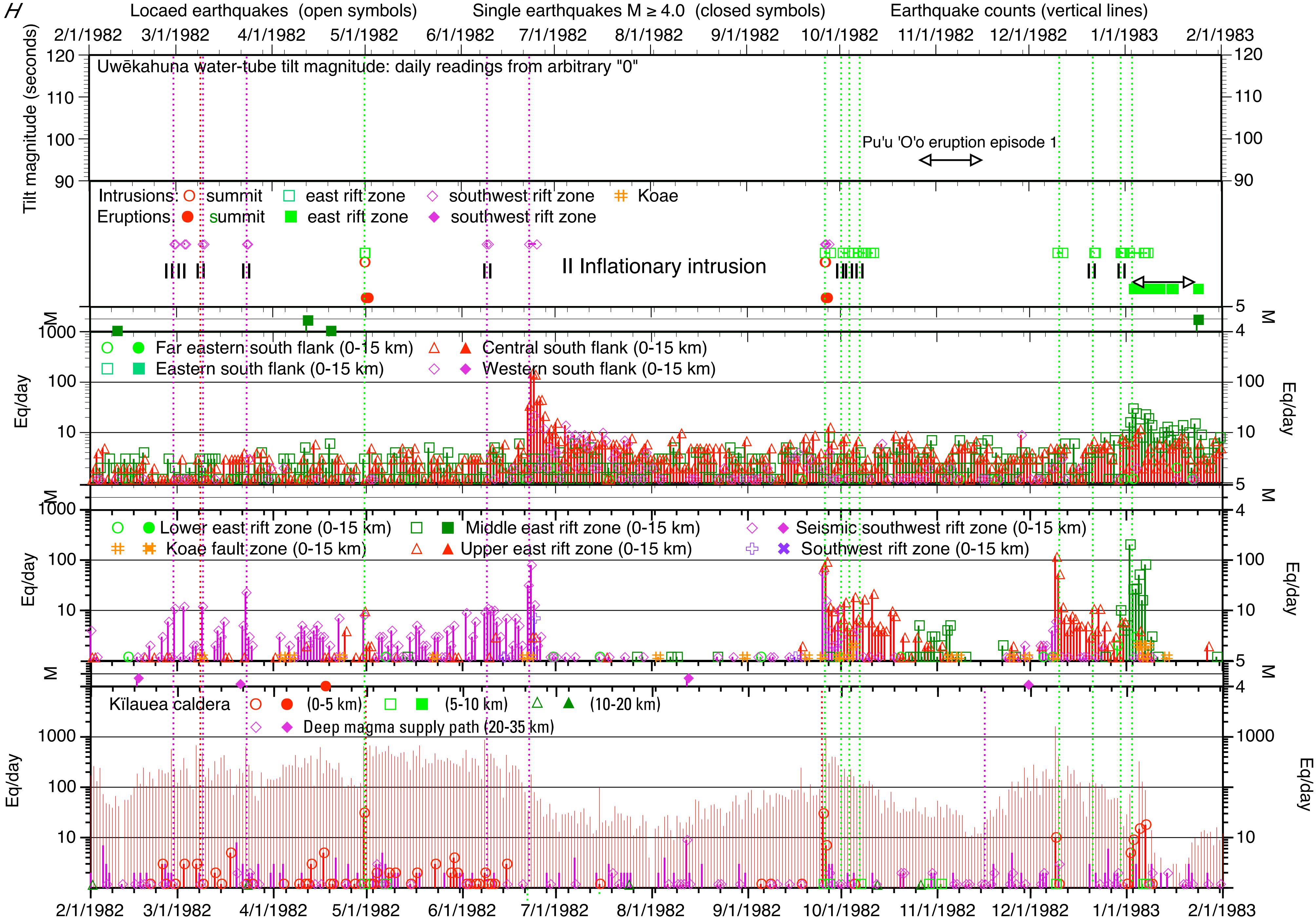
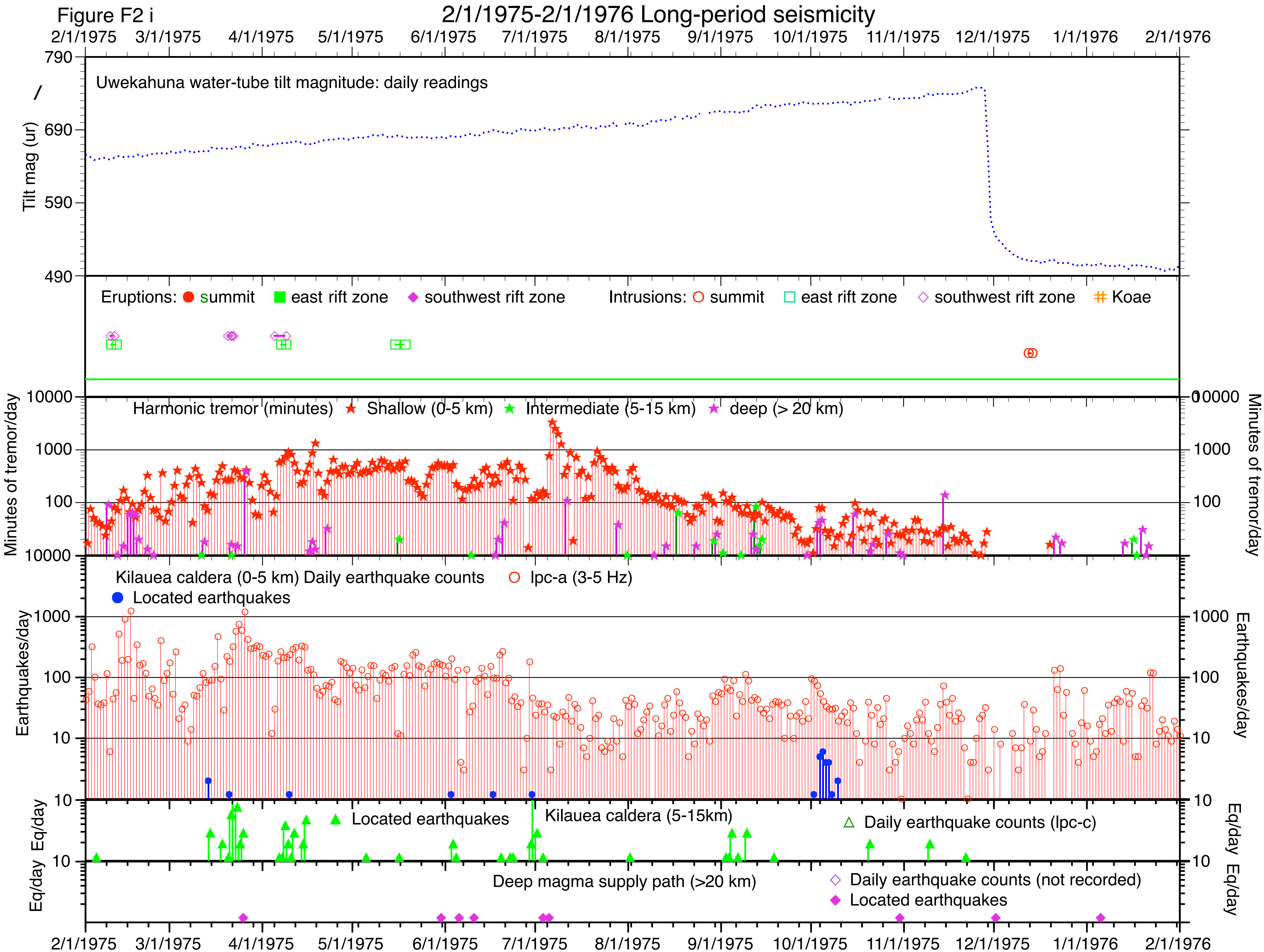


Figure F2 i



2/1/1975-2/1/1976 Long-period seismicity
2/1/1975
3/1/1975
4/1/1975
5/1/1975
6/1/1975
7/1/1975
8/1/1975
9/1/1975
10/1/1975
11/1/1975
12/1/1975
1/1/1976
2/1/1976
Uwekahuna water-tube tilt magnitude: daily readings
Tilt mag (ur)
790
690
590
490
Eruptions: summit
east rift zone
southwest rift zone
Intrusions: summit
east rift zone
southwest rift zone
Koae
Harmonic tremor (minutes)
Shallow (0-5 km)
Intermediate (5-15 km)
deep (> 20 km)
Minutes of tremor/day
10000
1000
100
Kilauea caldera (0-5 km) Daily earthquake counts
lpc-a (3-5 Hz)
Located earthquakes
Earthquakes/day
10
Located earthquakes
Kilauea caldera (5-15km)
Daily earthquake counts (lpc-c)
Eq/day
Deep magma supply path (>20 km)
Daily earthquake counts (not recorded)
Located earthquakes

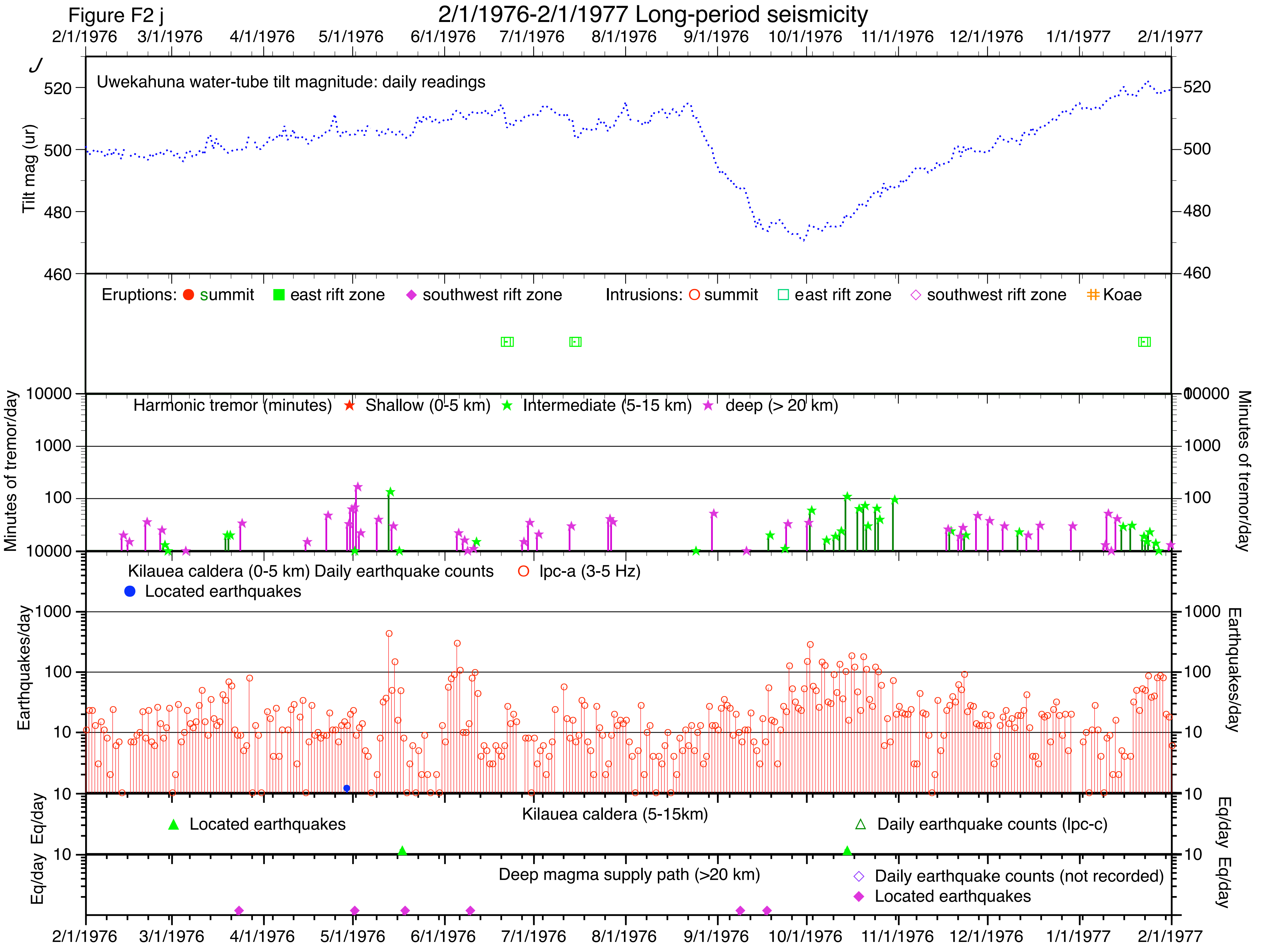


Figure F2 j
2/1/1976-2/1/1977 Long-period seismicity
Uwekahuna water-tube tilt magnitude: daily readings
Tilt mag (ur)
Eruptions: summit
east rift zone
southwest rift zone
Intrusions: summit
east rift zone
southwest rift zone
Koae
Harmonic tremor (minutes)
Shallow (0-5 km)
Intermediate (5-15 km)
deep (> 20 km)
Minutes of tremor/day
Kilauea caldera (0-5 km) Daily earthquake counts
lpc-a (3-5 Hz)
Located earthquakes
Earthquakes/day
Kilauea caldera (5-15km)
Located earthquakes
Daily earthquake counts (lpc-c)
Eq/day
Deep magma supply path (>20 km)
Daily earthquake counts (not recorded)
Located earthquakes
2/1/1976
3/1/1976
4/1/1976
5/1/1976
6/1/1976
7/1/1976
8/1/1976
9/1/1976
10/1/1976
11/1/1976
12/1/1976
1/1/1977
2/1/1977

Figure F2 k

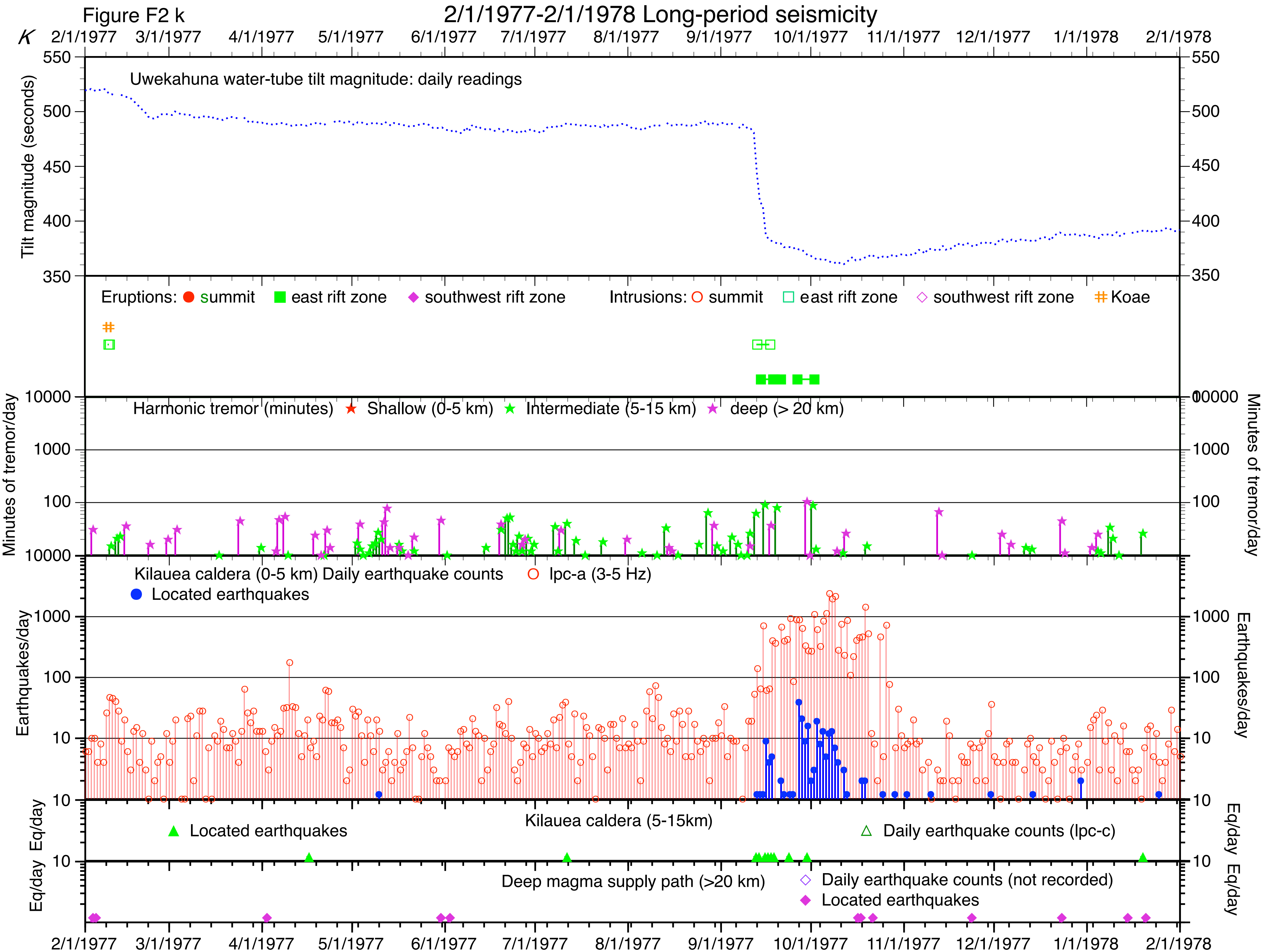

2/1/1977-2/1/1978 Long-period seismicity
K
2/1/1977 3/1/1977 4/1/1977 5/1/1977 6/1/1977 7/1/1977 8/1/1977 9/1/1977 10/1/1977 11/1/1977 12/1/1977 1/1/1978 2/1/1978
Uwekahuna water-tube tilt magnitude: daily readings
Tilt magnitude (seconds)
550 500 450 400 350
Eruptions: summit east rift zone southwest rift zone
Intrusions: summit east rift zone southwest rift zone Koae
Harmonic tremor (minutes) Shallow (0-5 km) Intermediate (5-15 km) deep (> 20 km)
Minutes of tremor/day
10000 1000 100
Kilauea caldera (0-5 km) Daily earthquake counts lpc-a (3-5 Hz)
Located earthquakes
Earthquakes/day
1000 100 10
Kilauea caldera (5-15km)
Located earthquakes
Daily earthquake counts (lpc-c)
Eq/day
10
Deep magma supply path (>20 km)
Daily earthquake counts (not recorded)
Located earthquakes
Eq/day

Figure F2 l

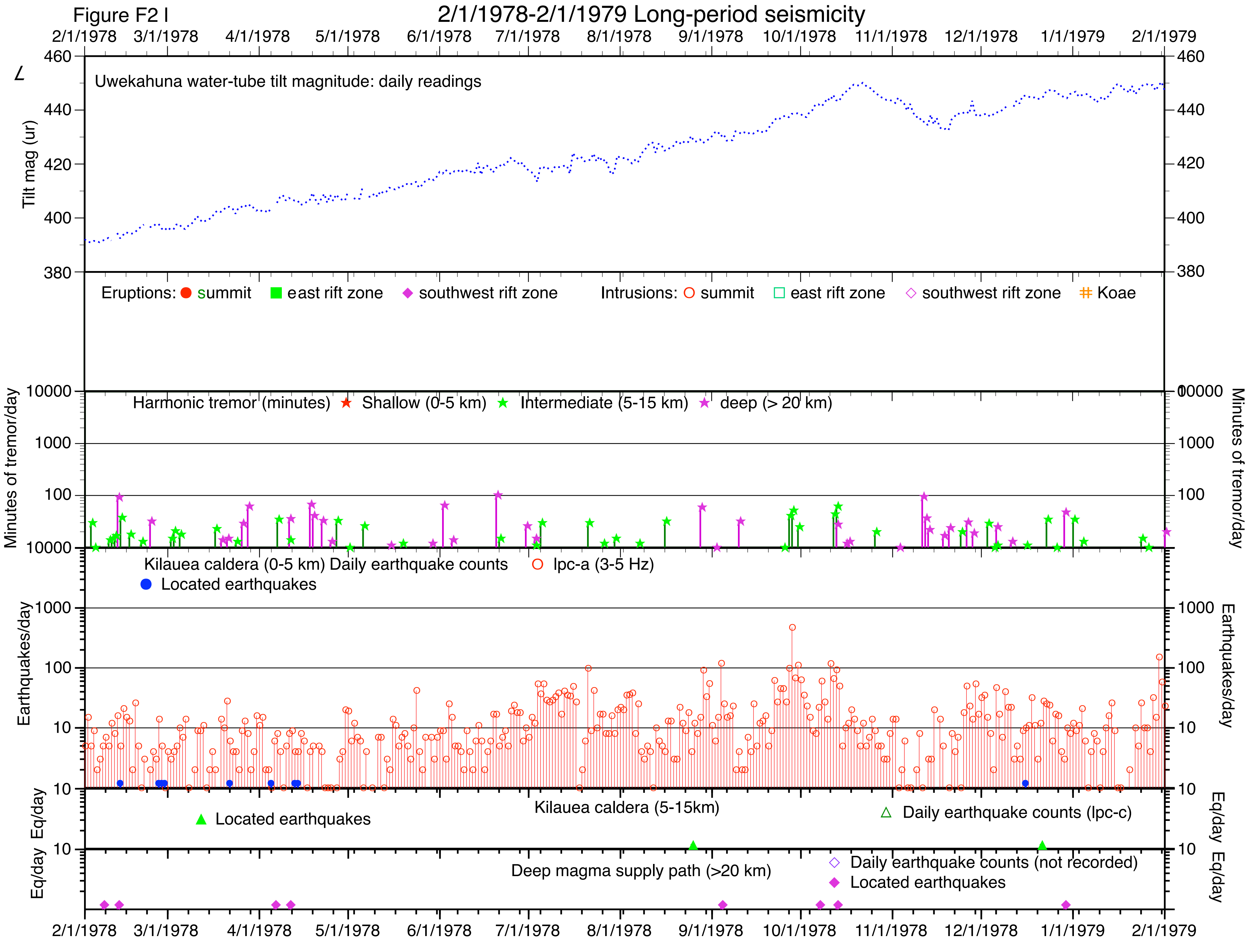

2/1/1978-2/1/1979 Long-period seismicity
Uwekahuna water-tube tilt magnitude: daily readings
Tilt mag (ur)
Eruptions: summit east rift zone southwest rift zone Intrusions: summit east rift zone southwest rift zone Koae
Harmonic tremor (minutes) Shallow (0-5 km) Intermediate (5-15 km) deep (> 20 km)
Minutes of tremor/day
Kilauea caldera (0-5 km) Daily earthquake counts lpc-a (3-5 Hz)
Located earthquakes
Earthquakes/day
Kilauea caldera (5-15km)
Located earthquakes
Daily earthquake counts (lpc-c)
Eq/day
Deep magma supply path (>20 km)
Daily earthquake counts (not recorded)
Located earthquakes
2/1/1978
3/1/1978
4/1/1978
5/1/1978
6/1/1978
7/1/1978
8/1/1978
9/1/1978
10/1/1978
11/1/1978
12/1/1978
1/1/1979
2/1/1979

Figure F2 m

2/1/1979-2/1/1980 Long-period seismicity

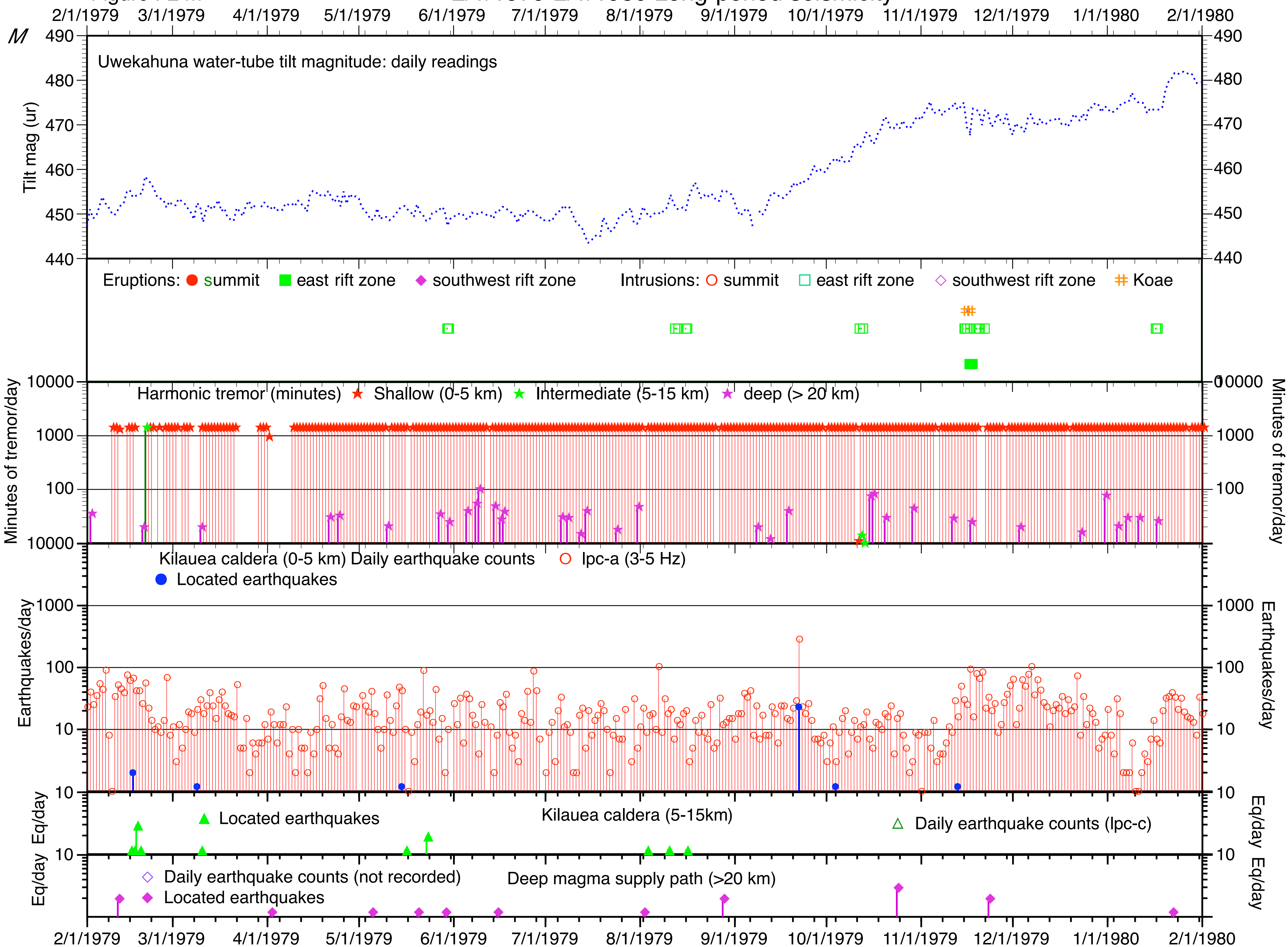
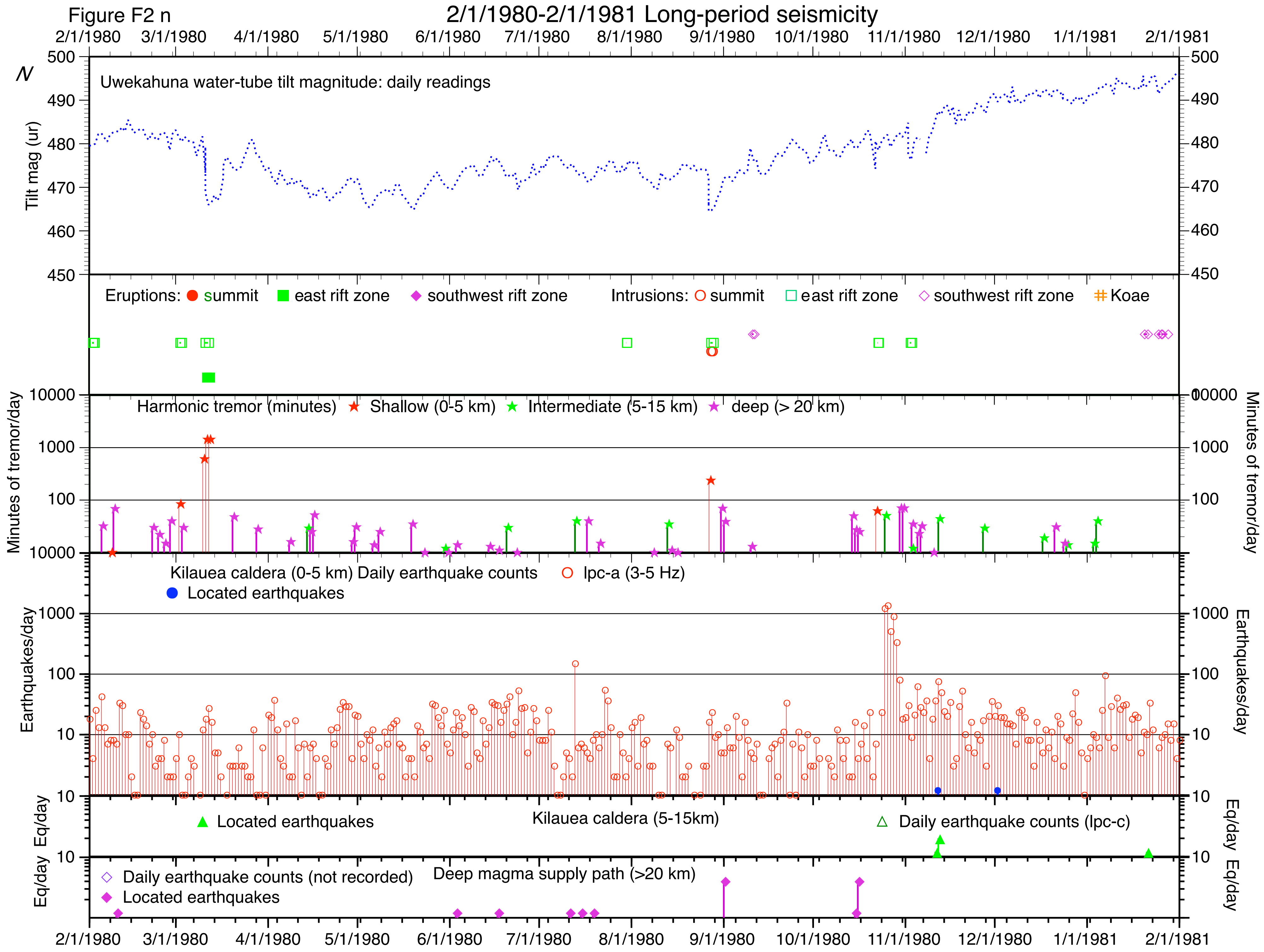


Figure F2 n



2/1/1980-2/1/1981 Long-period seismicity
2/1/1980 3/1/1980 4/1/1980 5/1/1980 6/1/1980 7/1/1980 8/1/1980 9/1/1980 10/1/1980 11/1/1980 12/1/1980 1/1/1981 2/1/1981
N
Uwekahuna water-tube tilt magnitude: daily readings
Tilt mag (ur)
500 490 480 470 460 450
Eruptions: summit east rift zone southwest rift zone Intrusions: summit east rift zone southwest rift zone Koae
Harmonic tremor (minutes) Shallow (0-5 km) Intermediate (5-15 km) deep (> 20 km)
Minutes of tremor/day
10000 1000 100
Kilauea caldera (0-5 km) Daily earthquake counts lpc-a (3-5 Hz)
Located earthquakes
Earthquakes/day
1000 100 10
Eq/day
Located earthquakes
Kilauea caldera (5-15km)
Daily earthquake counts (lpc-c)
Daily earthquake counts (not recorded)
Located earthquakes
Deep magma supply path (>20 km)

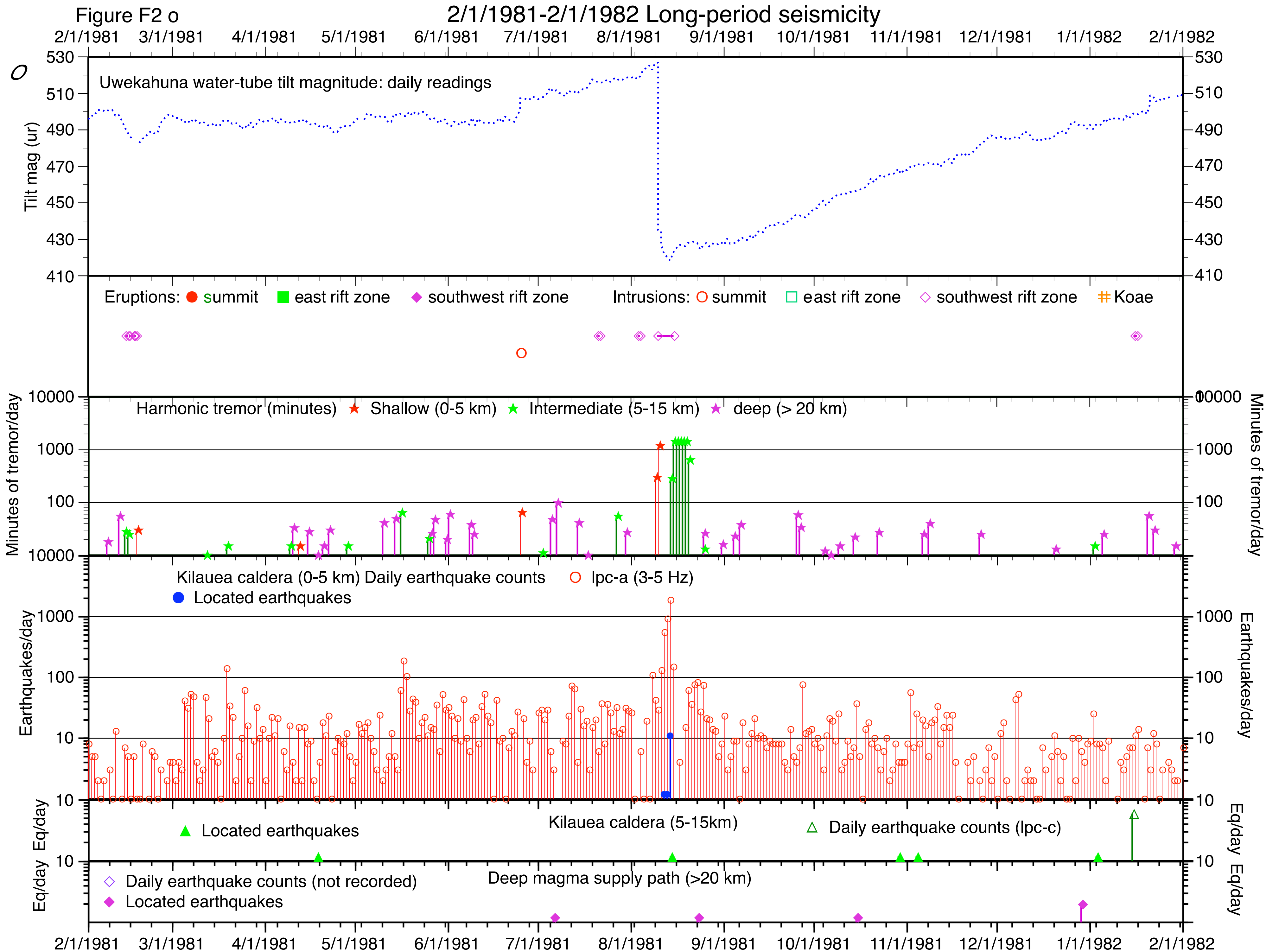
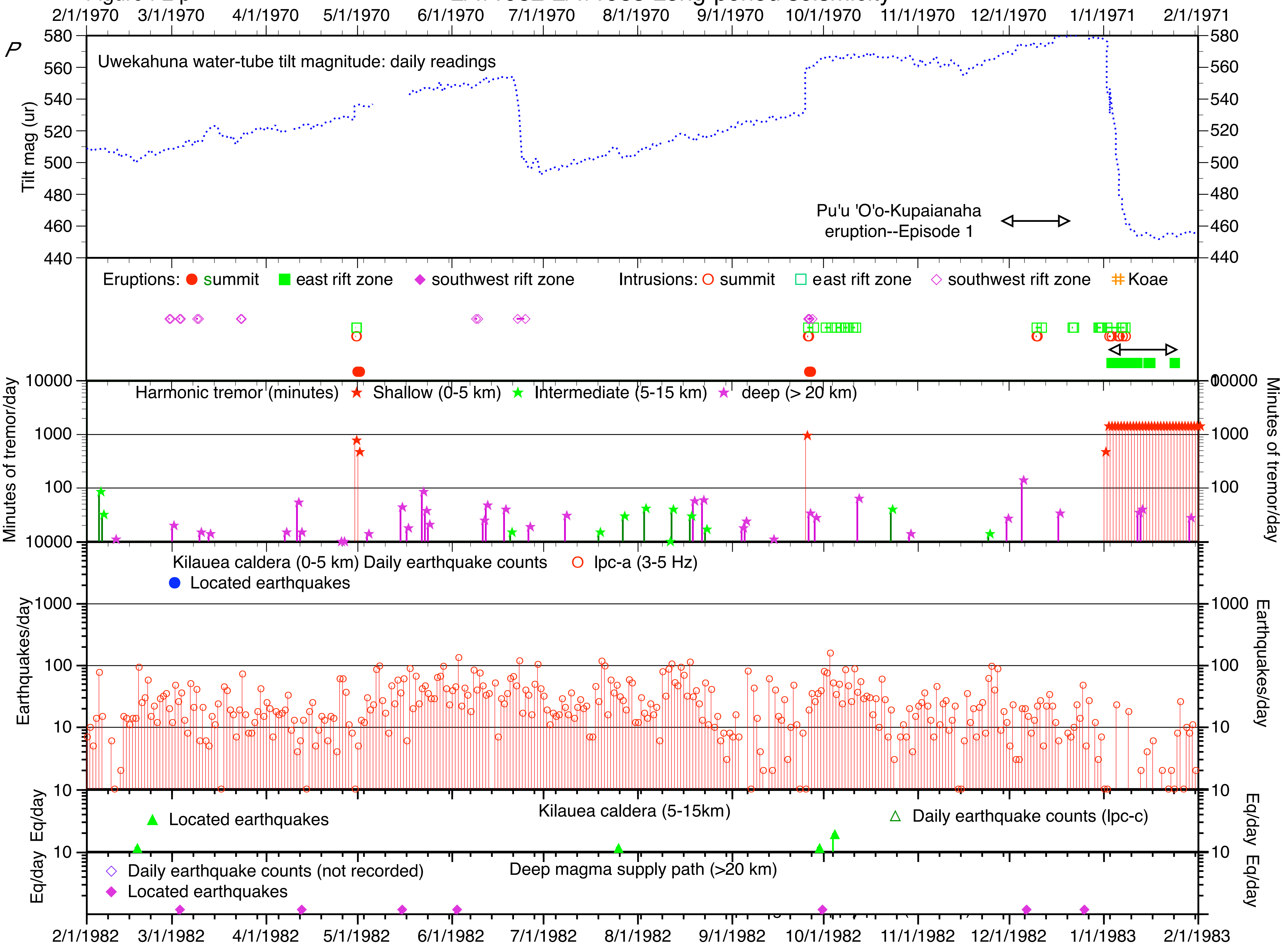


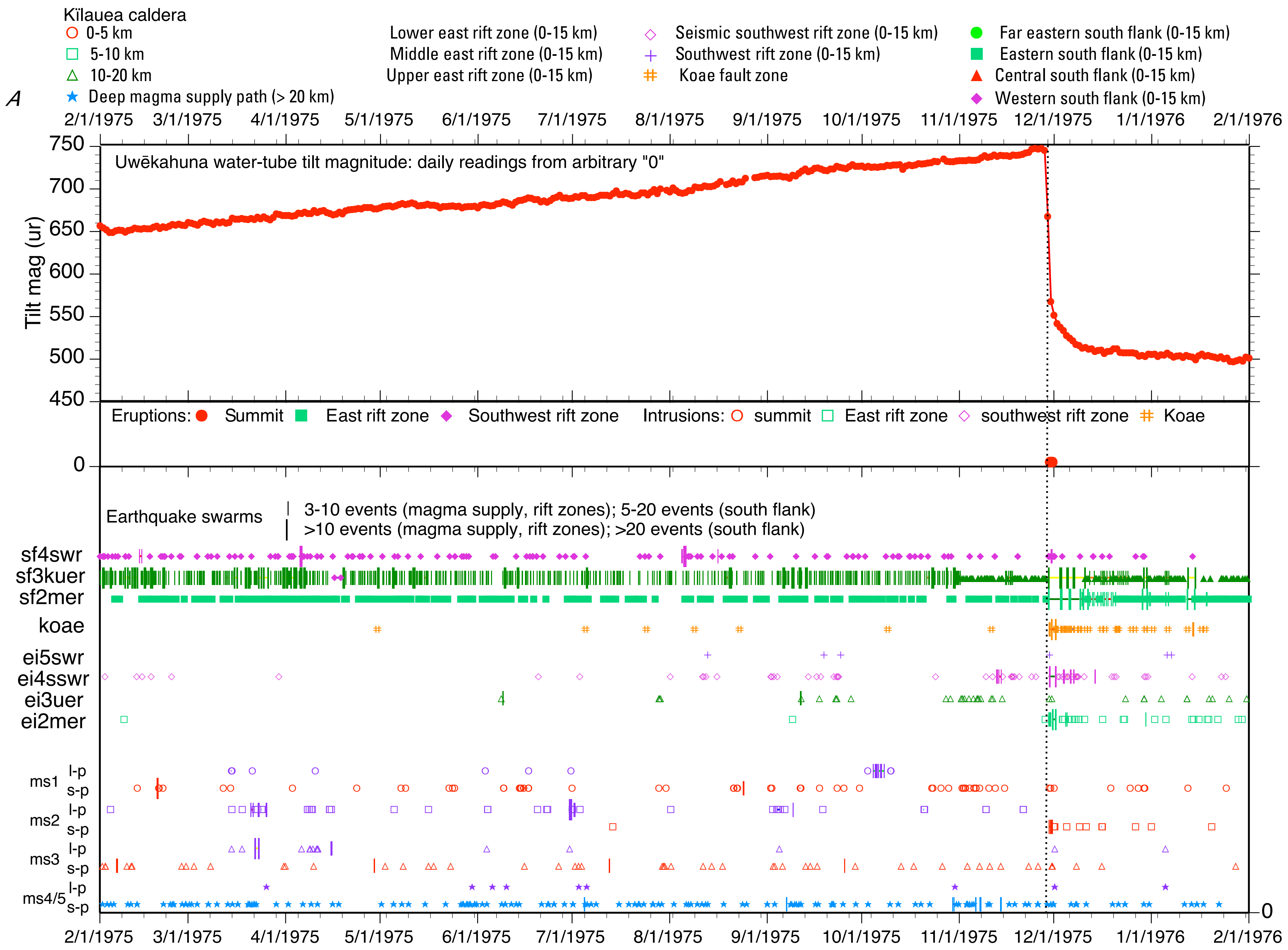
Figure F2 o
2/1/1981-2/1/1982 Long-period seismicity
Uwekahuna water-tube tilt magnitude: daily readings
Tilt mag (ur)
Eruptions: summit east rift zone southwest rift zone
Intrusions: summit east rift zone southwest rift zone Koae
Harmonic tremor (minutes) Shallow (0-5 km) Intermediate (5-15 km) deep (> 20 km)
Minutes of tremor/day
Kilauea caldera (0-5 km) Daily earthquake counts lpc-a (3-5 Hz)
Located earthquakes
Earthquakes/day
Located earthquakes
Kilauea caldera (5-15km)
Daily earthquake counts (lpc-c)
Eq/day
Daily earthquake counts (not recorded)
Located earthquakes
Deep magma supply path (>20 km)
2/1/1981 3/1/1981 4/1/1981 5/1/1981 6/1/1981 7/1/1981 8/1/1981 9/1/1981 10/1/1981 11/1/1981 12/1/1981 1/1/1982 2/1/1982

Figure F2 p

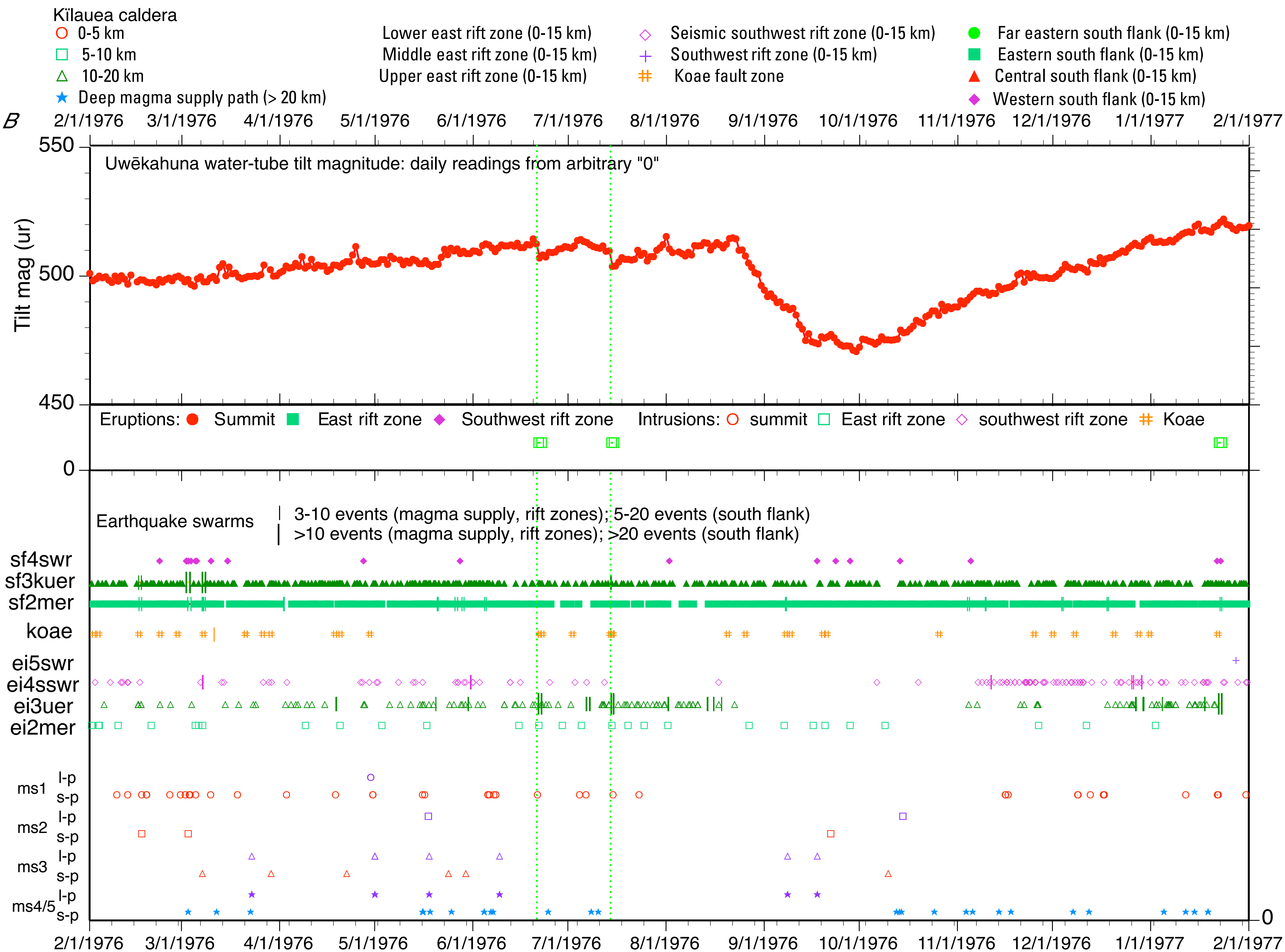
2/1/1982-2/1/1983 Long-period seismicity



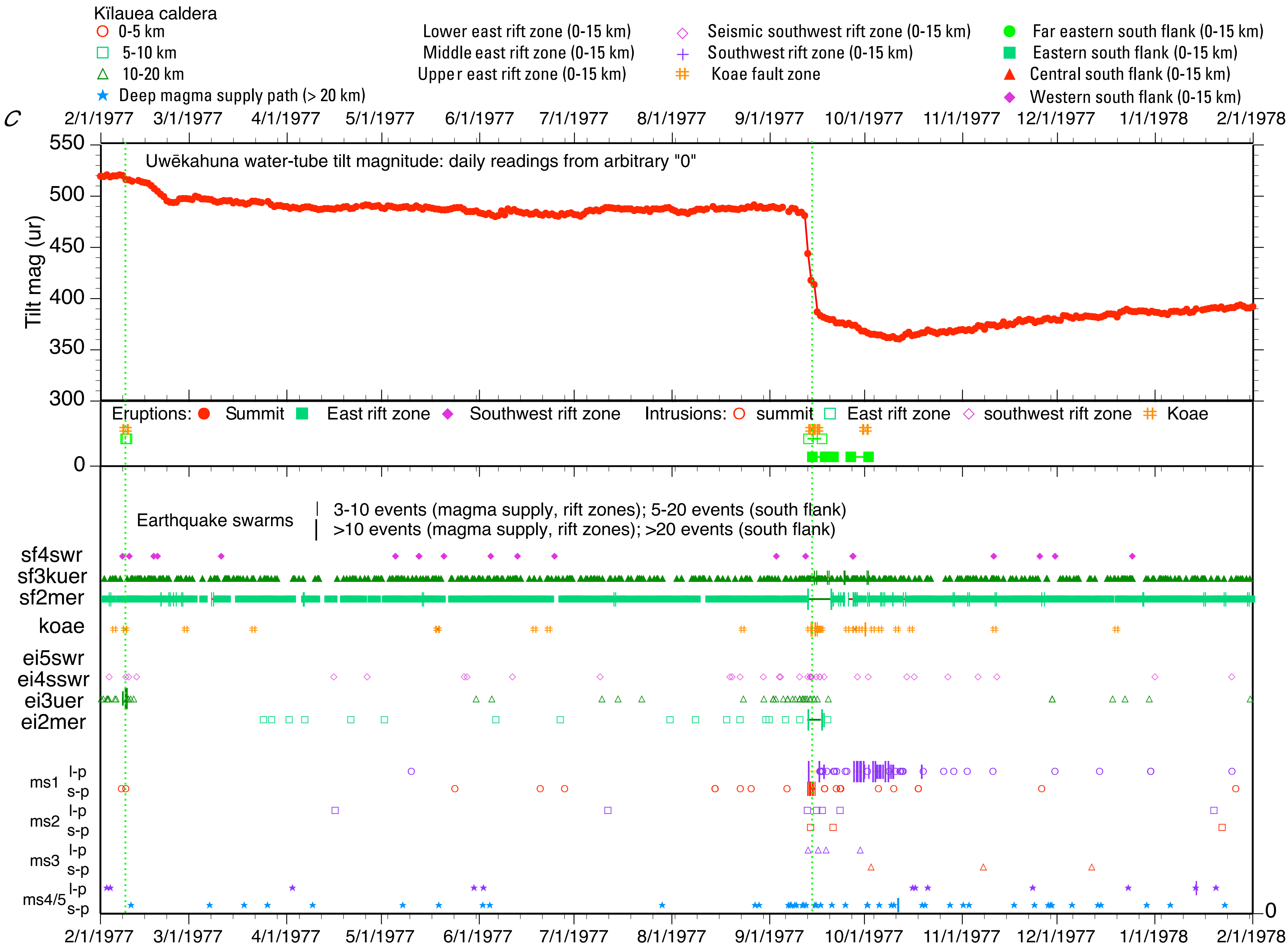
Appendix figure F3 a



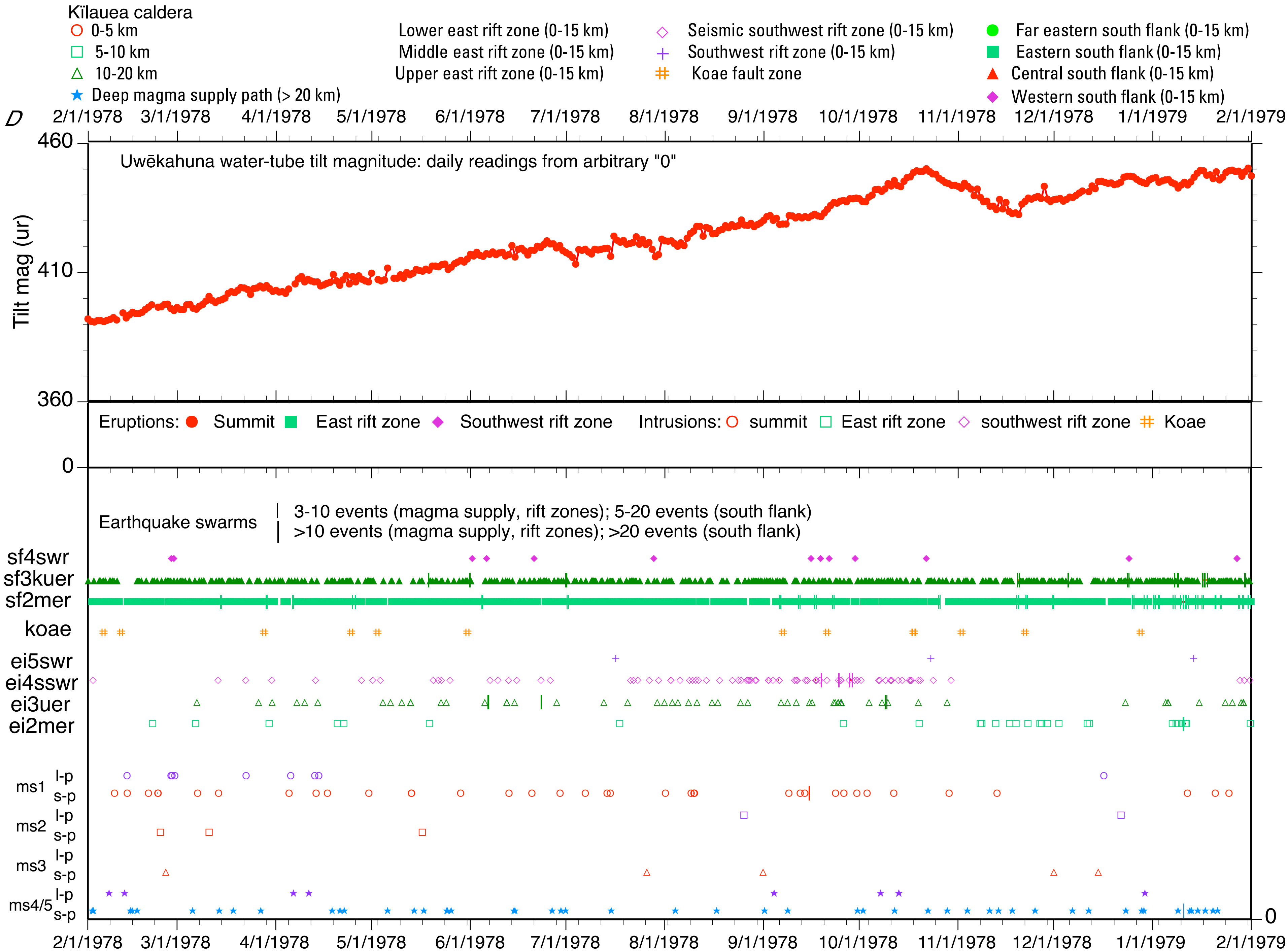
Appendix figure F3 b



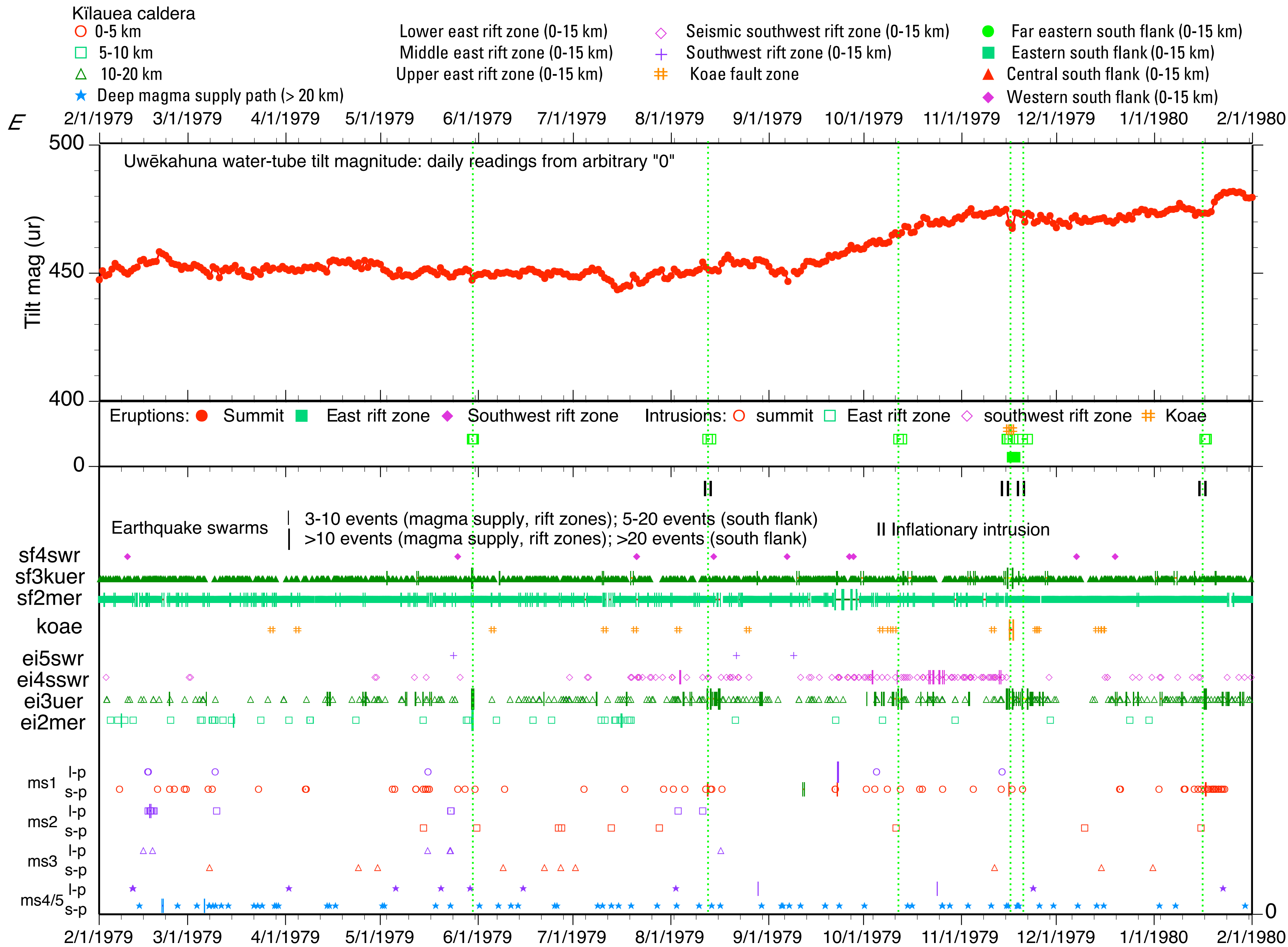
Appendix figure F3 c



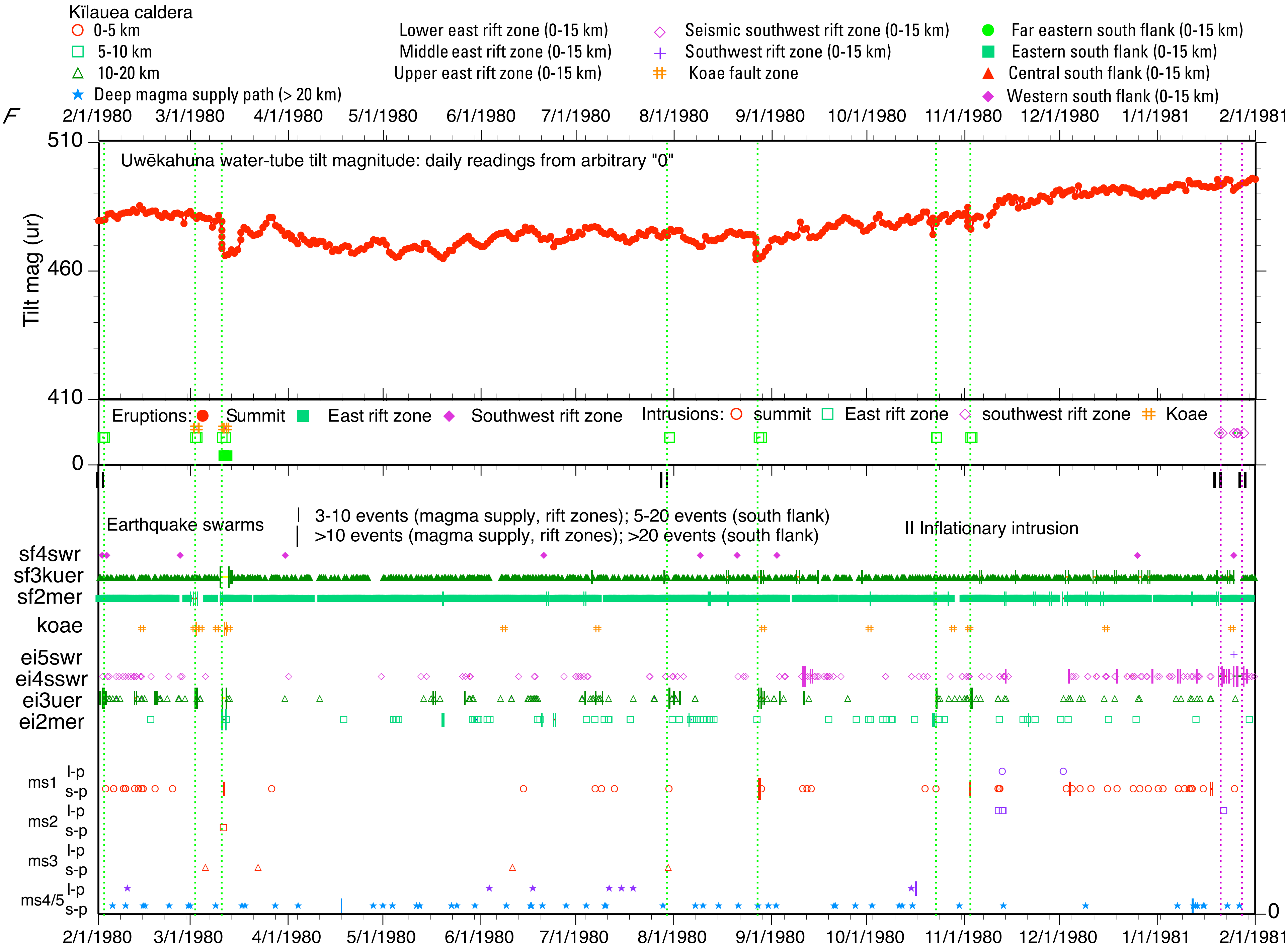
Appendix figure F3 d



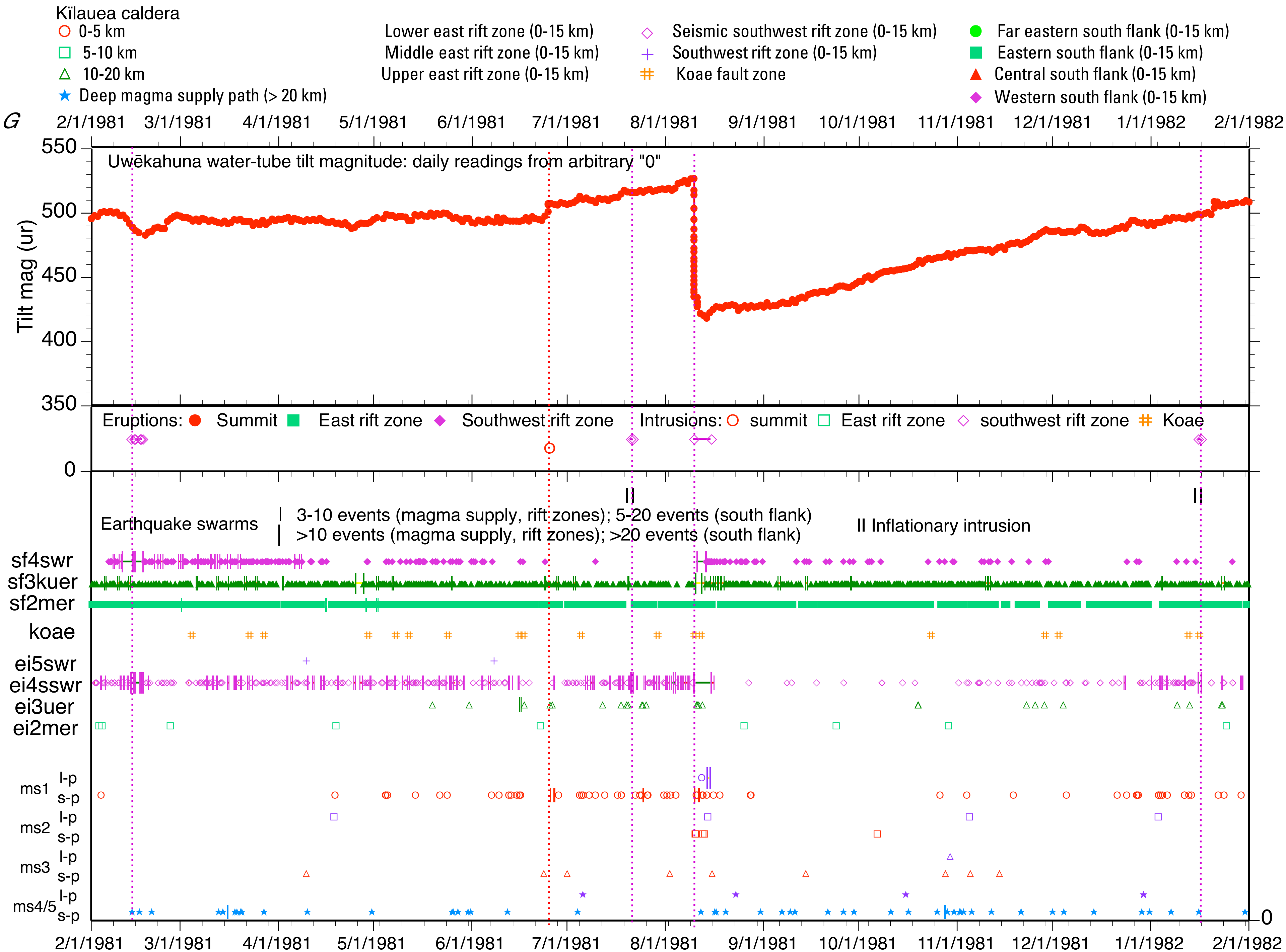
Appendix figure F3 e



Appendix figure F3 f



Appendix figure F3 g



Appendix figure F3 h

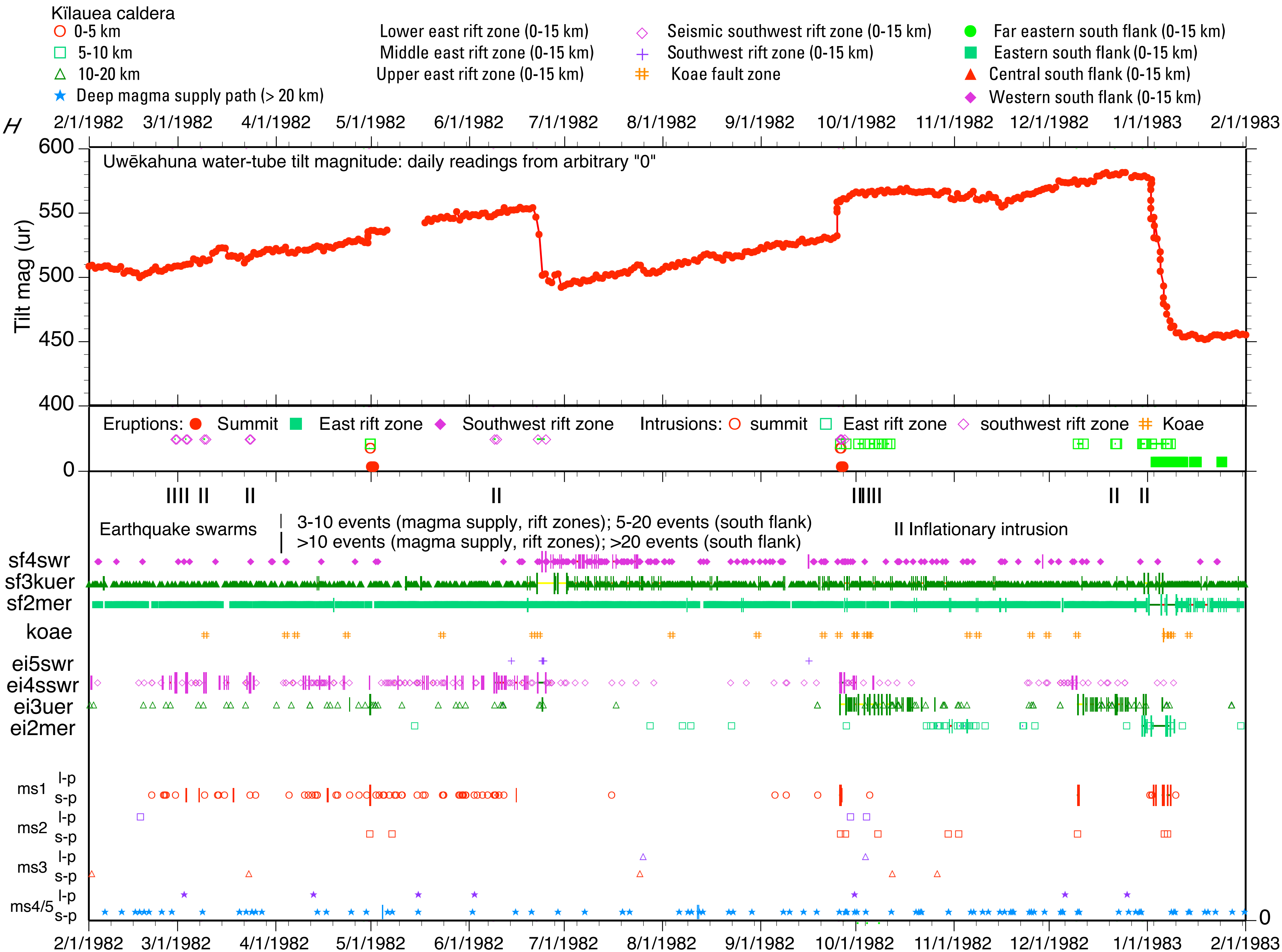
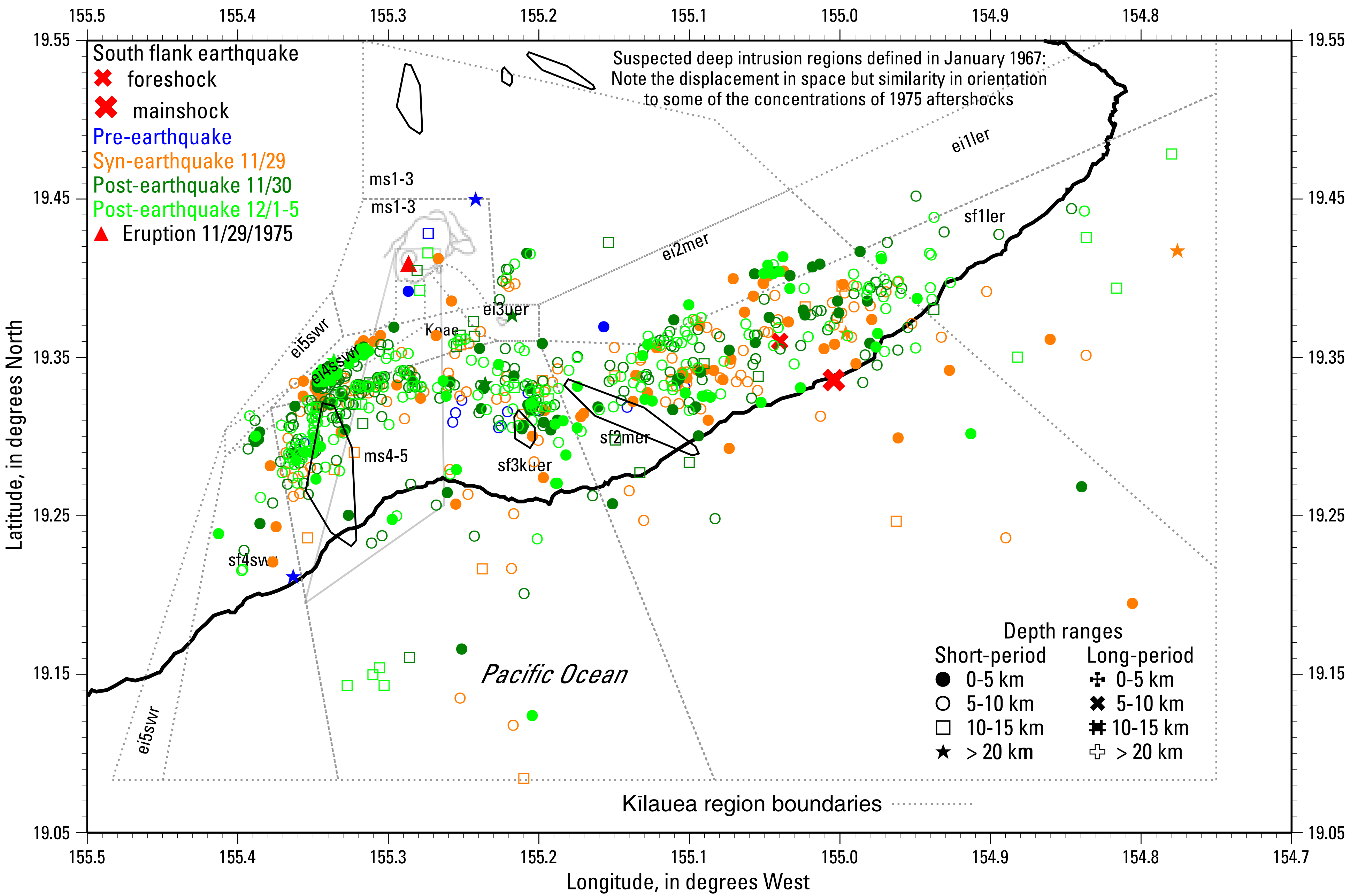
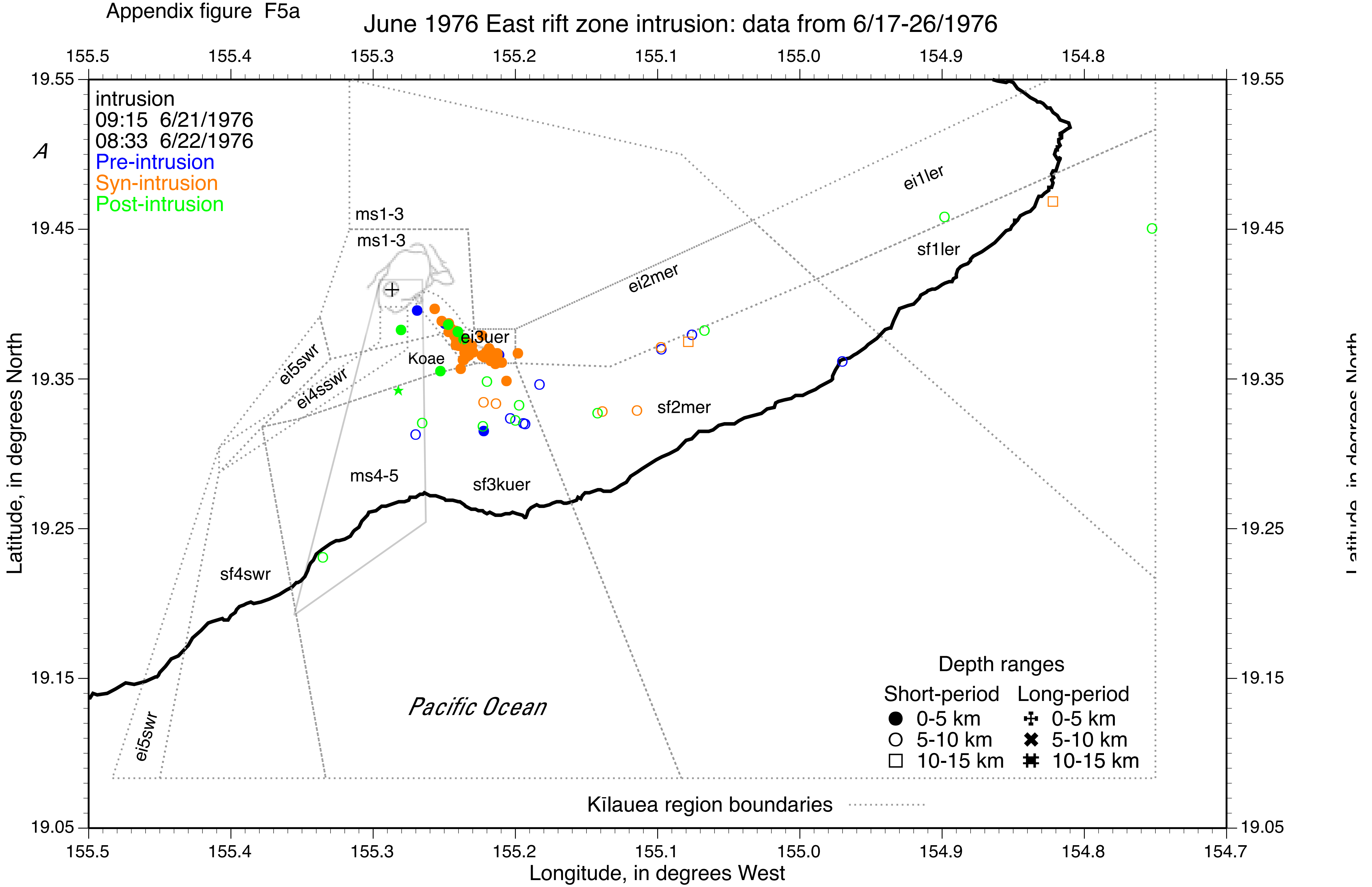


Figure F4

11/29/1975 south flank earthquake and aftershocks; data from 11/26-12/5/1975

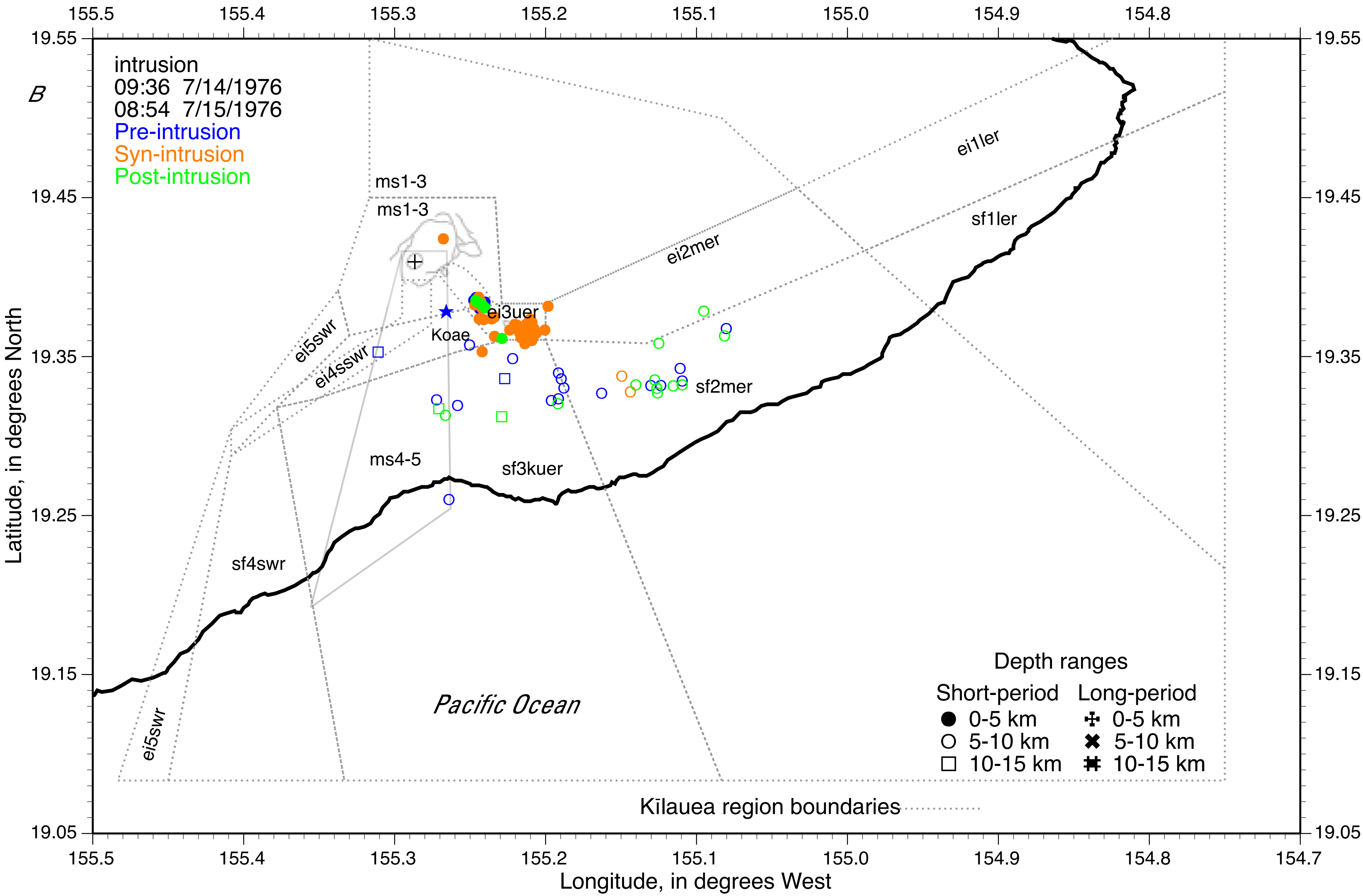


Appendix figure F5a

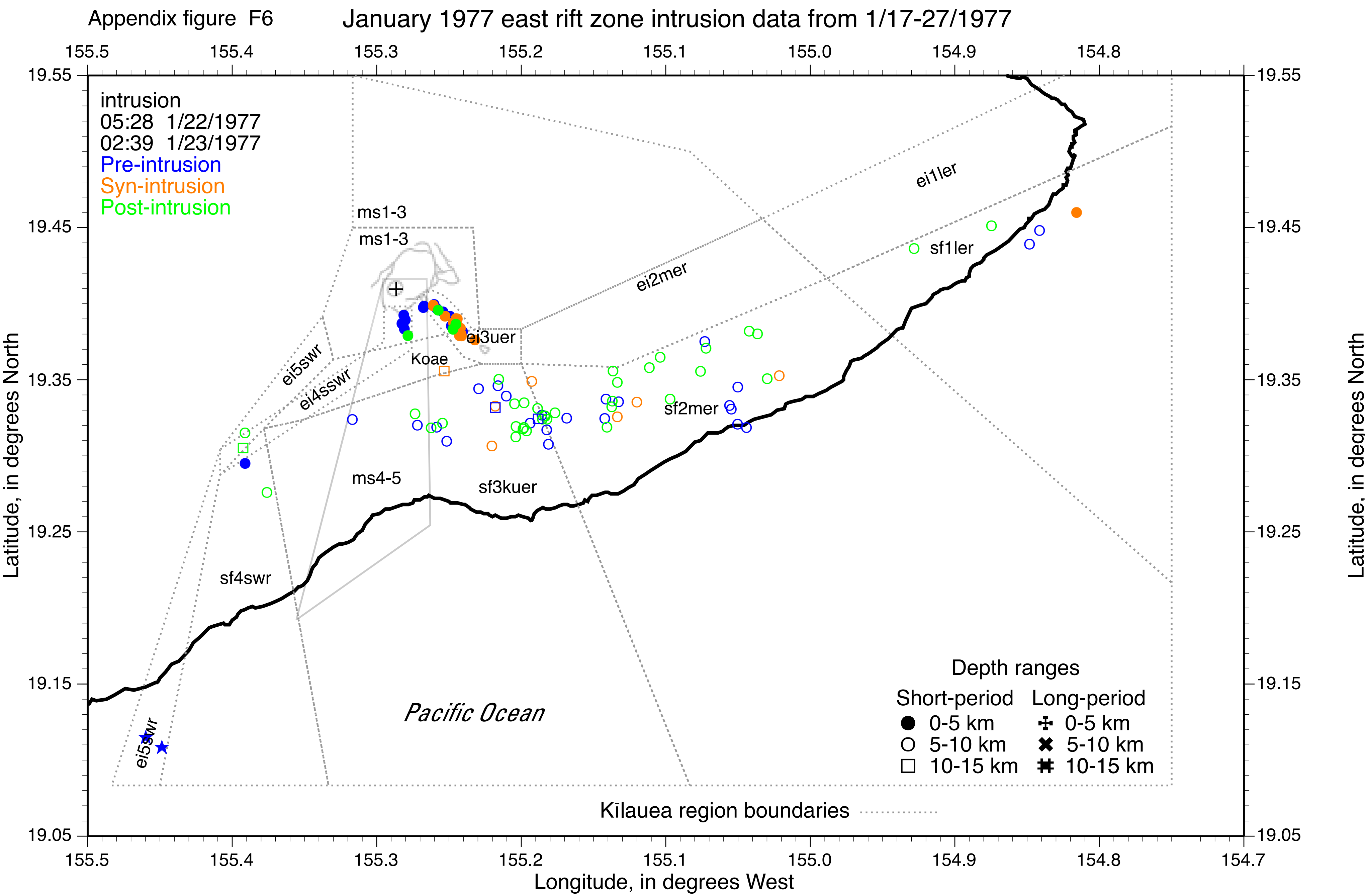


Appendix figure F5b

July 1976 east rift zone intrusion: data from 7/9-19/1976

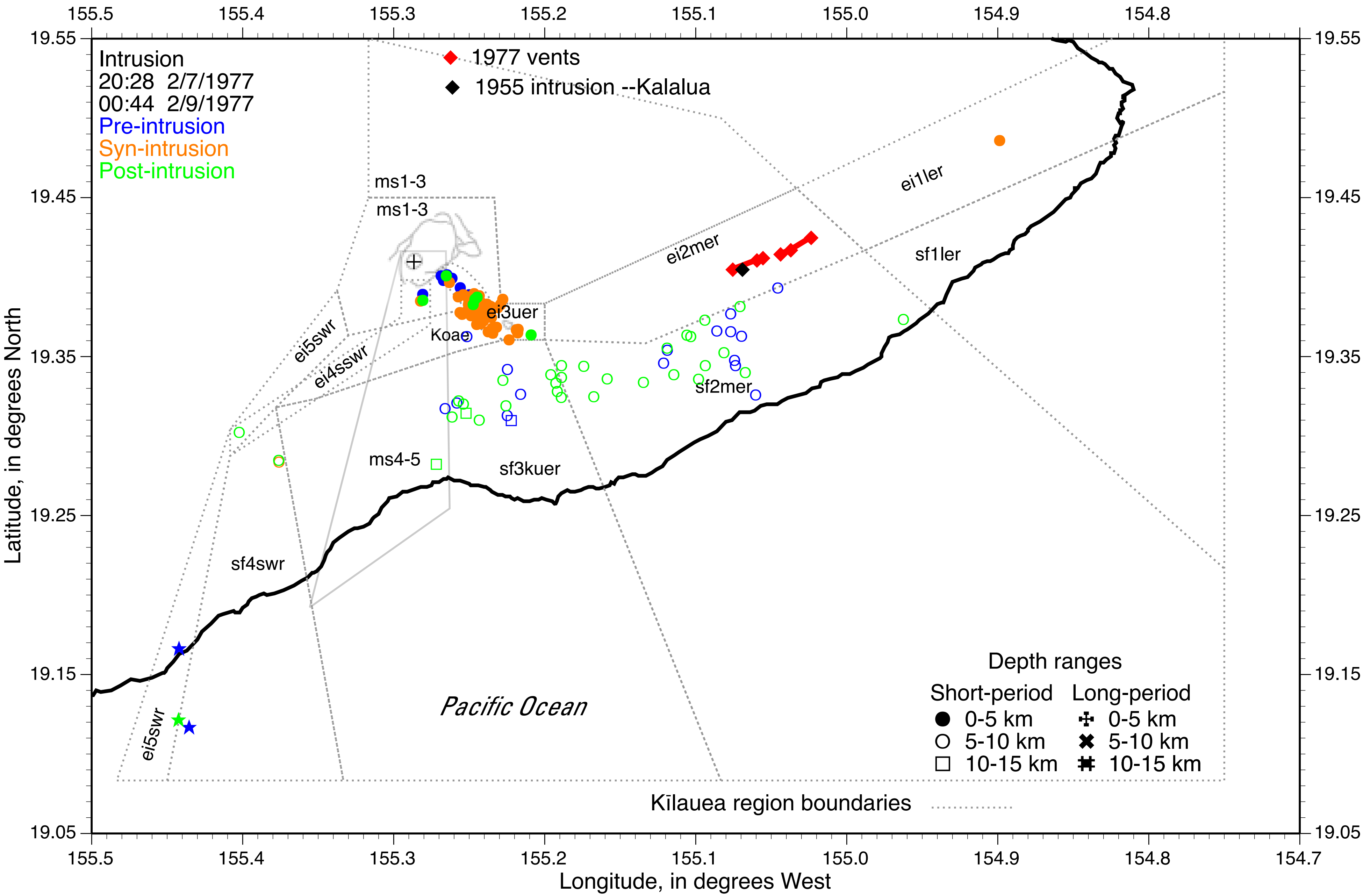


Appendix figure F6



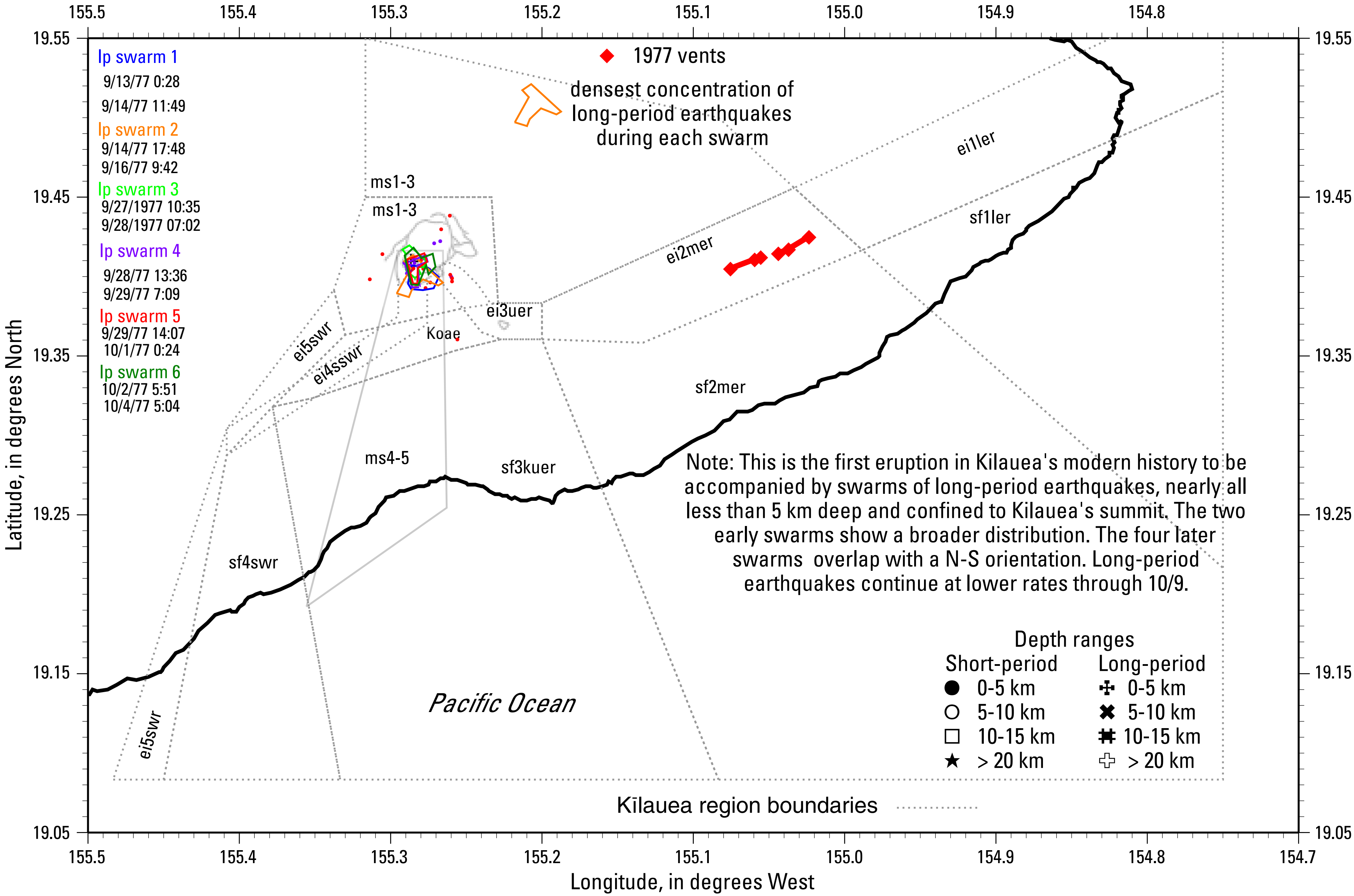
Appendix figure F7

February 1977 east rift intrusion: data from 2/3-13/1977



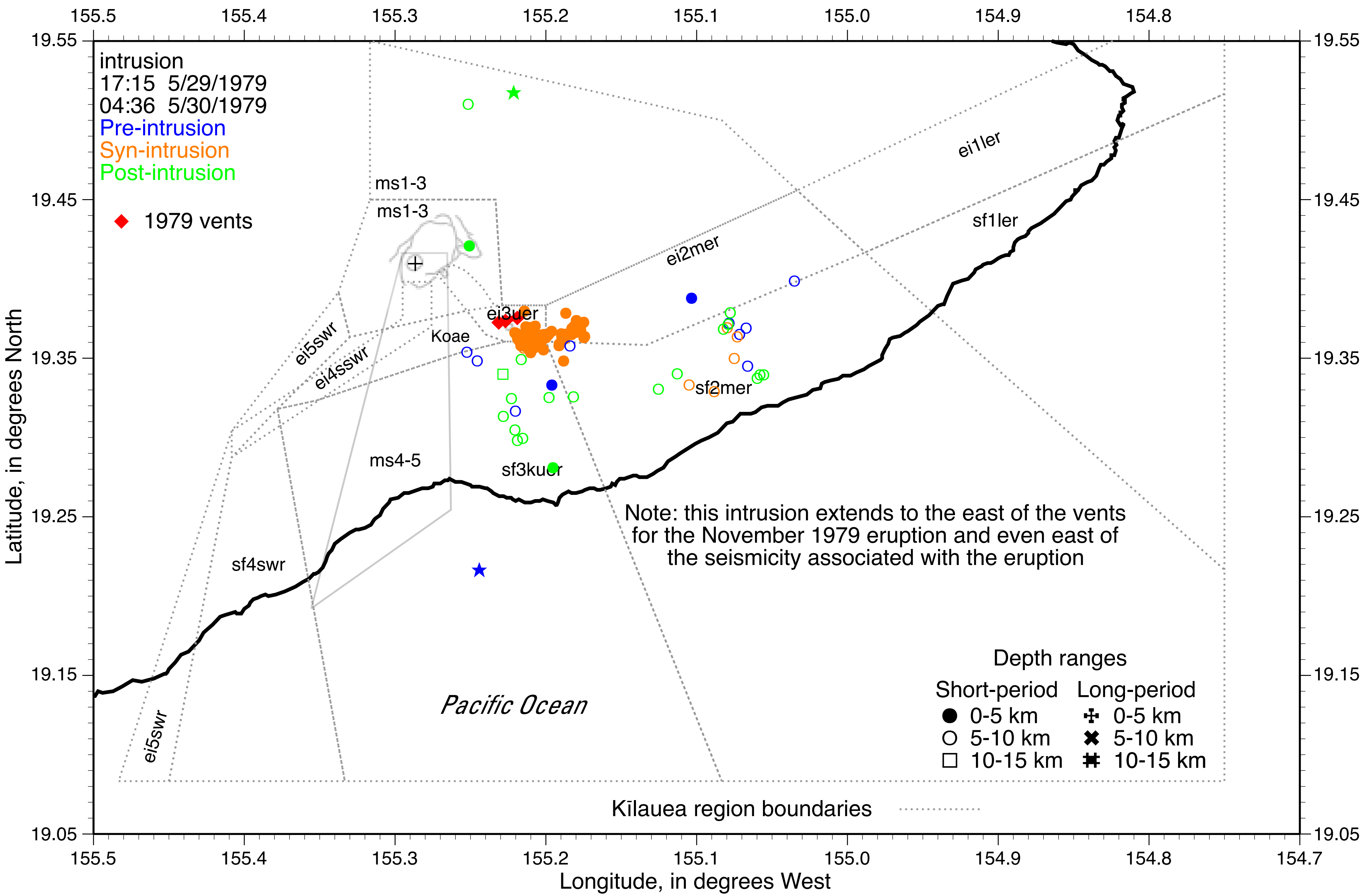
Kīlauea region boundaries

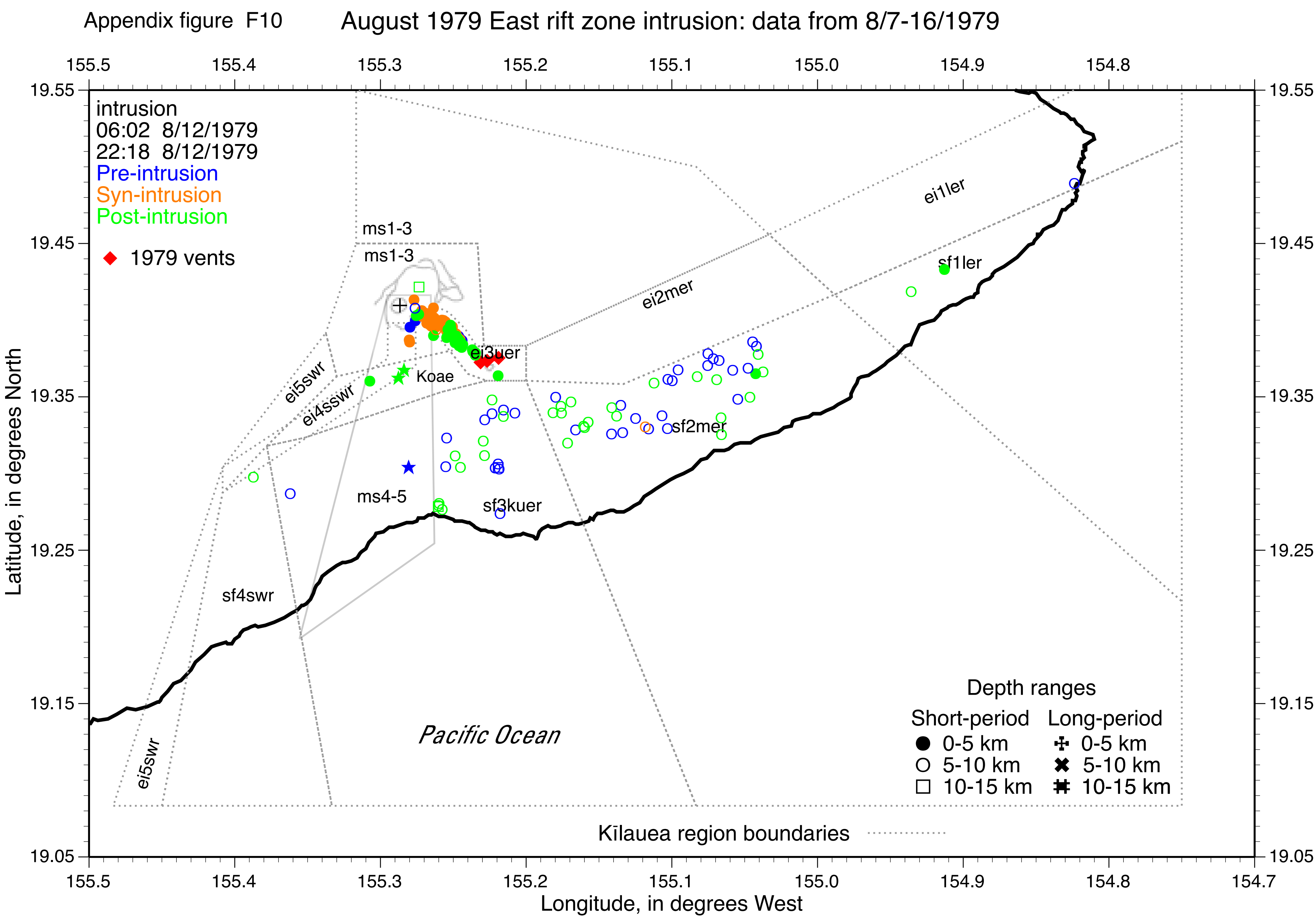
Figure F8 September 1977 east rift eruption: Long-period seismicity--data from 9/13-10/4/1977



Appendix figure F9

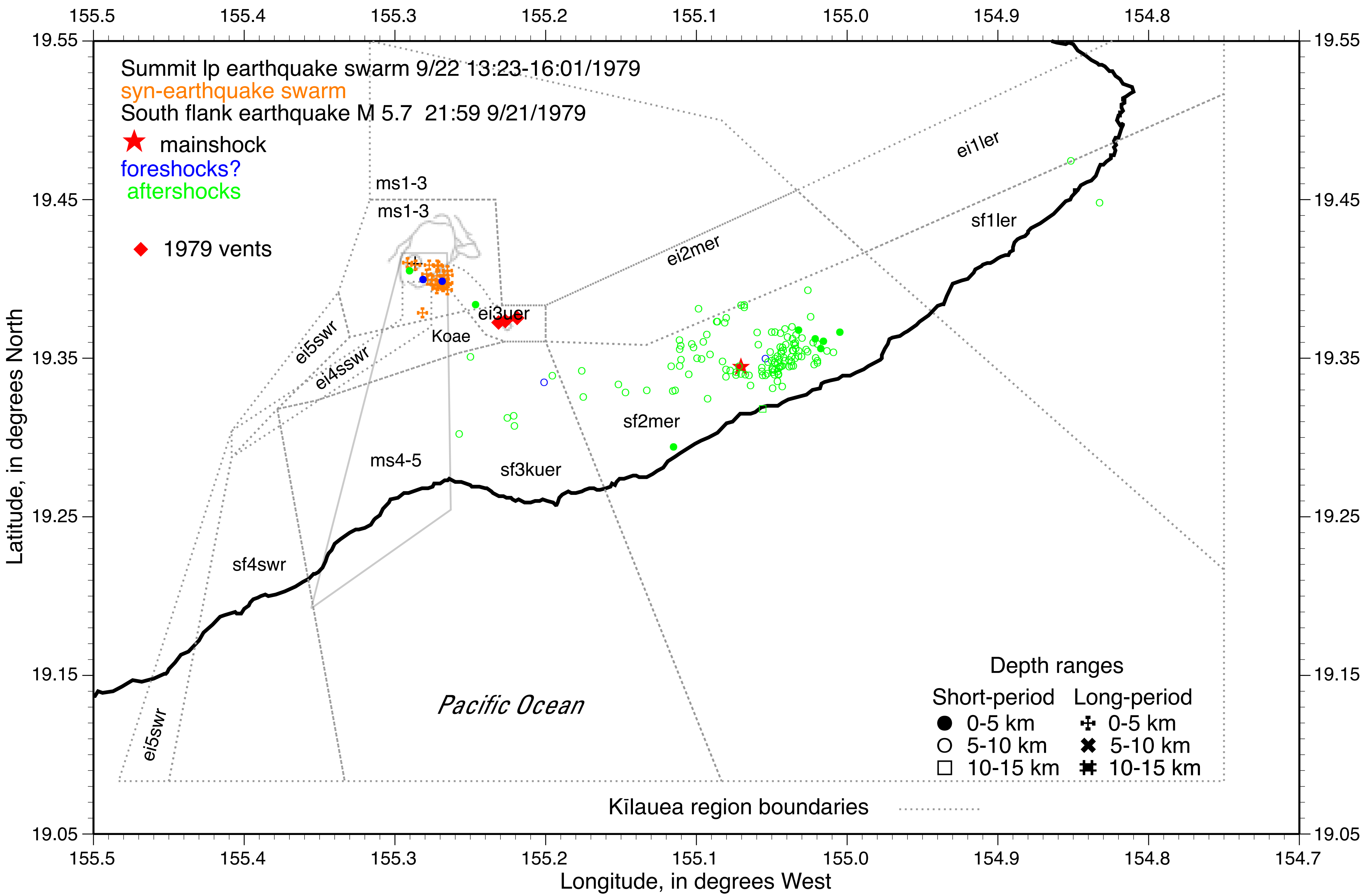
May 1979 East rift zone intrusion: data from 5/28-6/1/1979

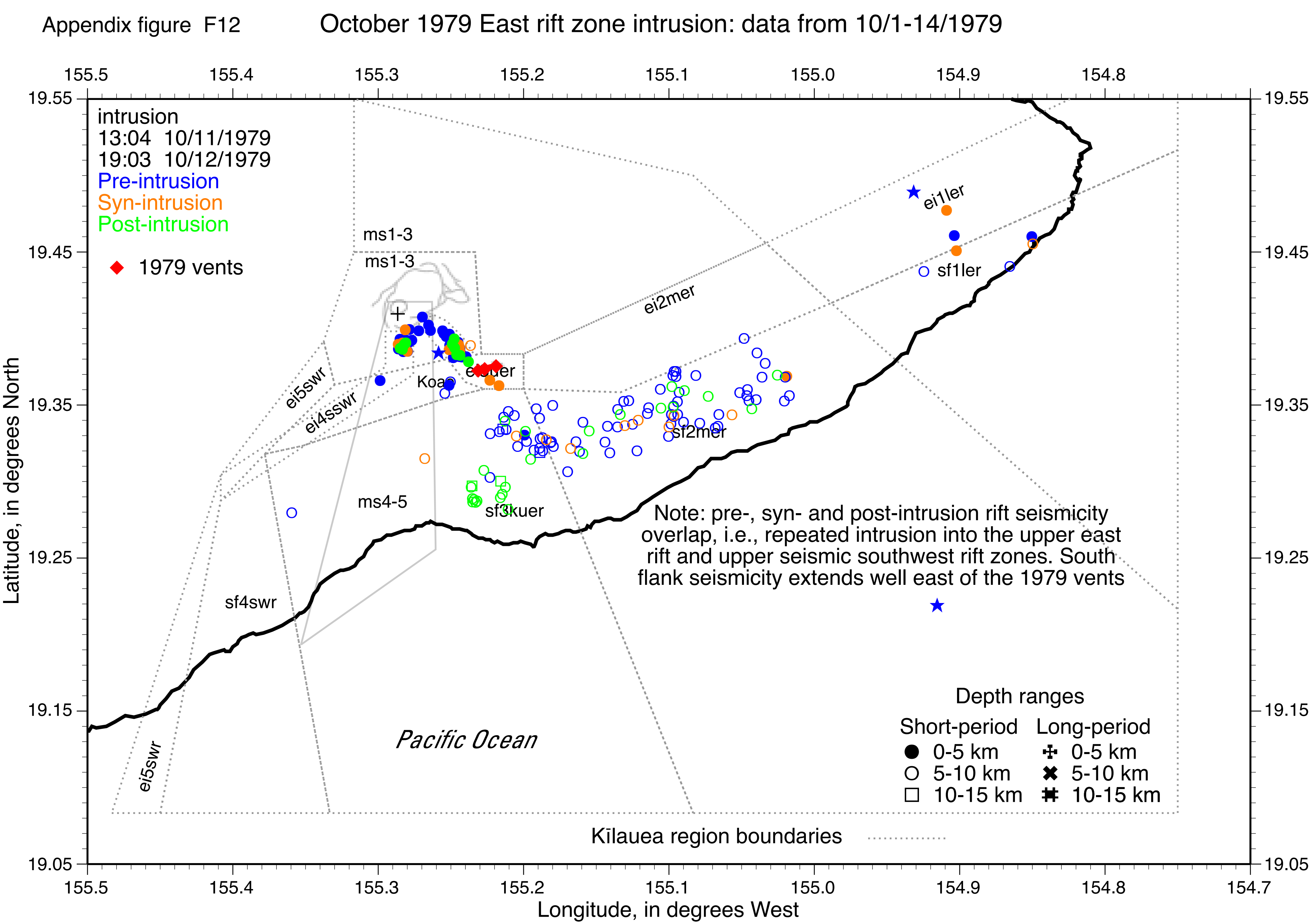




Appendix figure F10
August 1979 East rift zone intrusion: data from 8/7-16/1979
intrusion
06:02 8/12/1979
22:18 8/12/1979
Pre-intrusion
Syn-intrusion
Post-intrusion
1979 vents
ms1-3
ei5swr
ei4sswr
Koae
ei3uer
ei2mer
ei1ler
sf1ler
sf2mer
sf3kuer
ms4-5
sf4swr
Pacific Ocean
Depth ranges
Short-period
Long-period
0-5 km
5-10 km
10-15 km
Kīlauea region boundaries
Latitude, in degrees North
Longitude, in degrees West
155.5
155.4
155.3
155.2
155.1
155.0
154.9
154.8
154.7
19.55
19.45
19.35
19.25
19.15
19.05

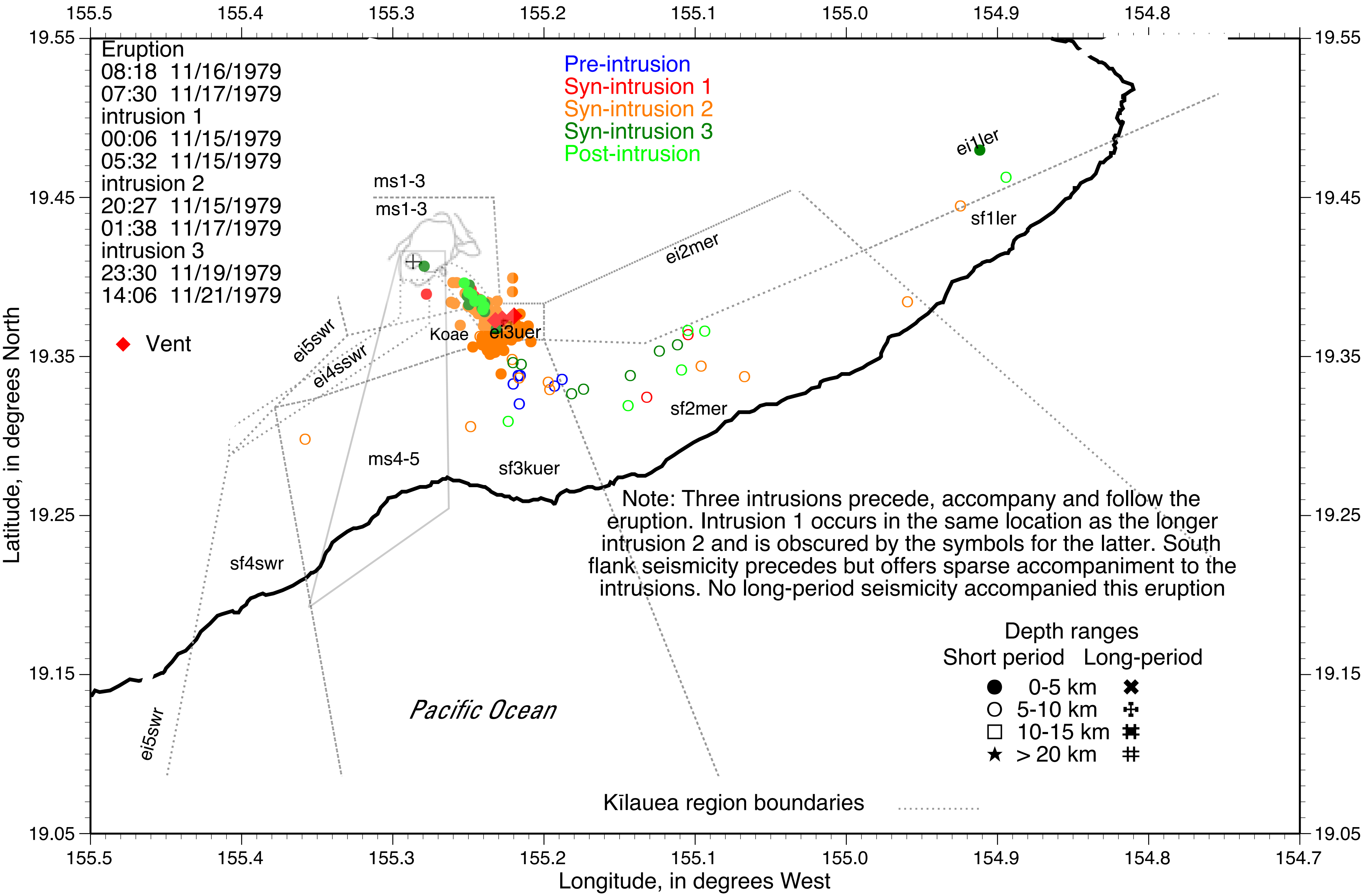
Appendix figure F11 September 1979 south flank swarm/lp swarm: data from 9/21-24/1979



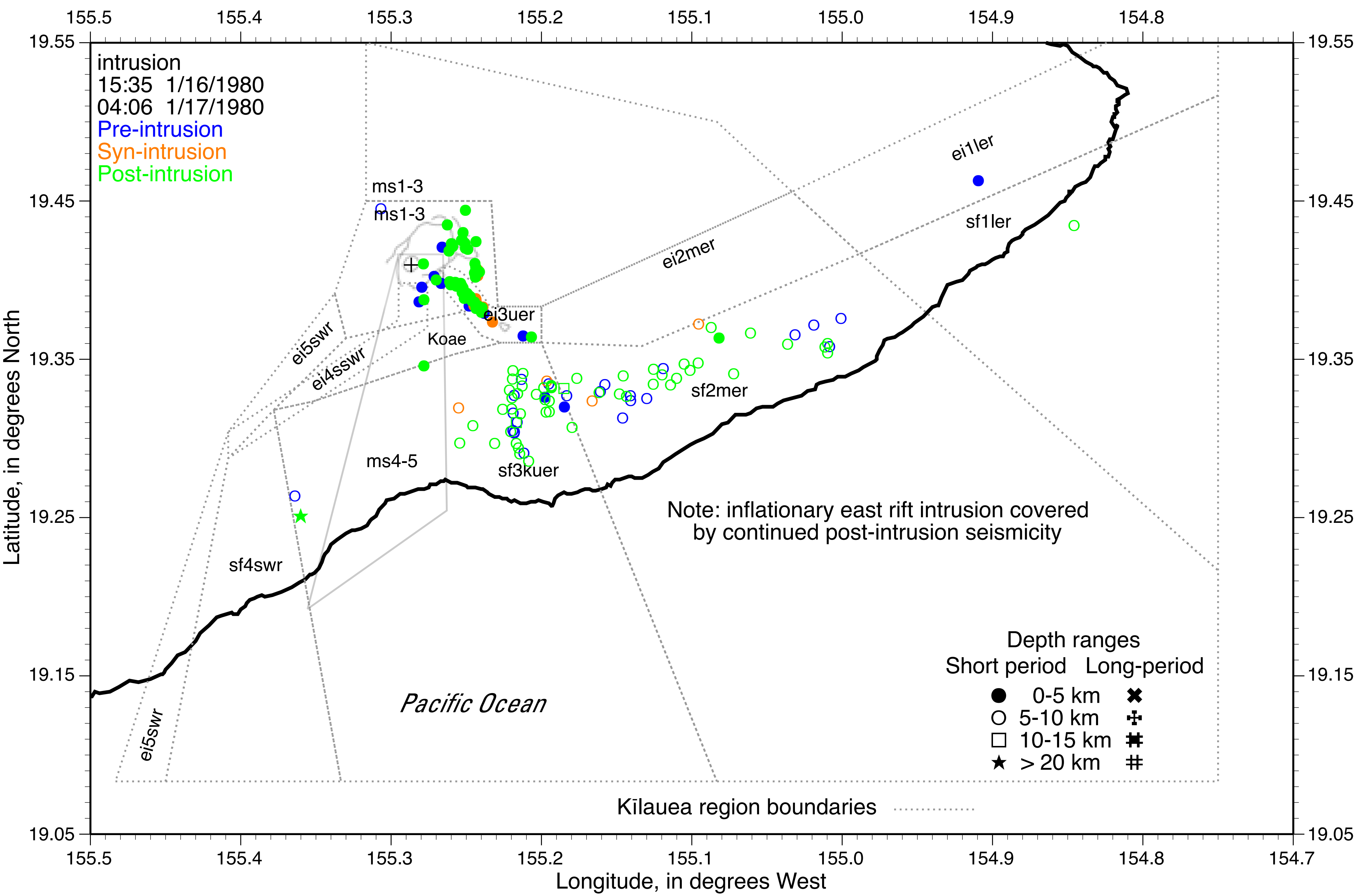

Appendix figure F12
October 1979 East rift zone intrusion: data from 10/1-14/1979
intrusion
13:04 10/11/1979
19:03 10/12/1979
Pre-intrusion
Syn-intrusion
Post-intrusion
1979 vents
ms1-3
ms1-3
ei2mer
ei1ler
sf1ler
ei5swr
ei4sswr
Koa
sf2mer
ms4-5
sf3kuer
sf4swr
ei5swr
Note: pre-, syn- and post-intrusion rift seismicity overlap, i.e., repeated intrusion into the upper east rift and upper seismic southwest rift zones. South flank seismicity extends well east of the 1979 vents
Pacific Ocean
Depth ranges
Short-period
Long-period
0-5 km
5-10 km
10-15 km
0-5 km
5-10 km
10-15 km
Kīlauea region boundaries
Latitude, in degrees North
Longitude, in degrees West
155.5
155.4
155.3
155.2
155.1
155.0
154.9
154.8
154.7
19.55
19.45
19.35
19.25
19.15
19.05

Appendix figure F13

November 1979 east rift eruption: data from 11/14-19/1979

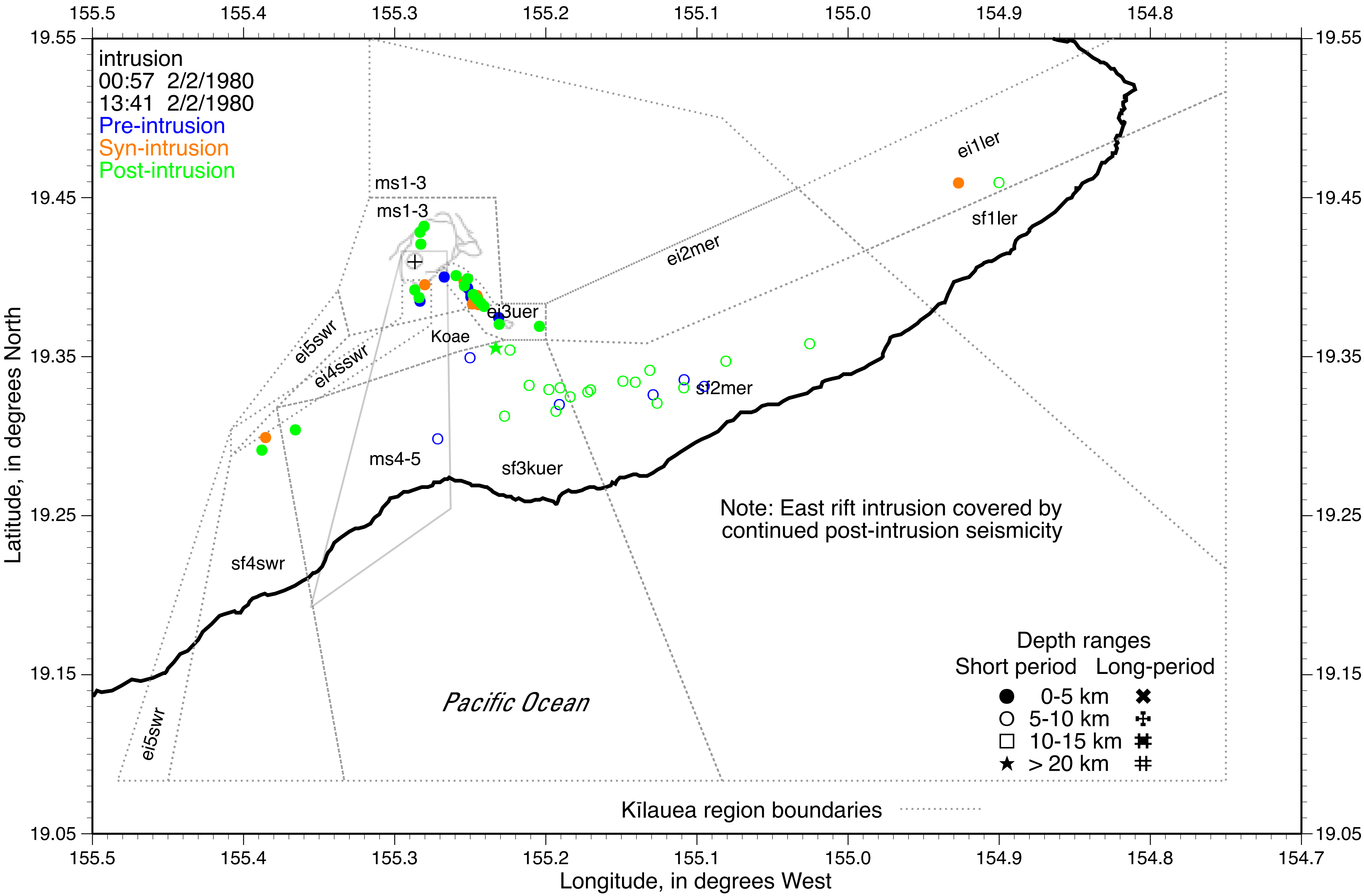


Appendix figure F14 January 1980 East rift zone intrusion: data from 1/13-24/1980

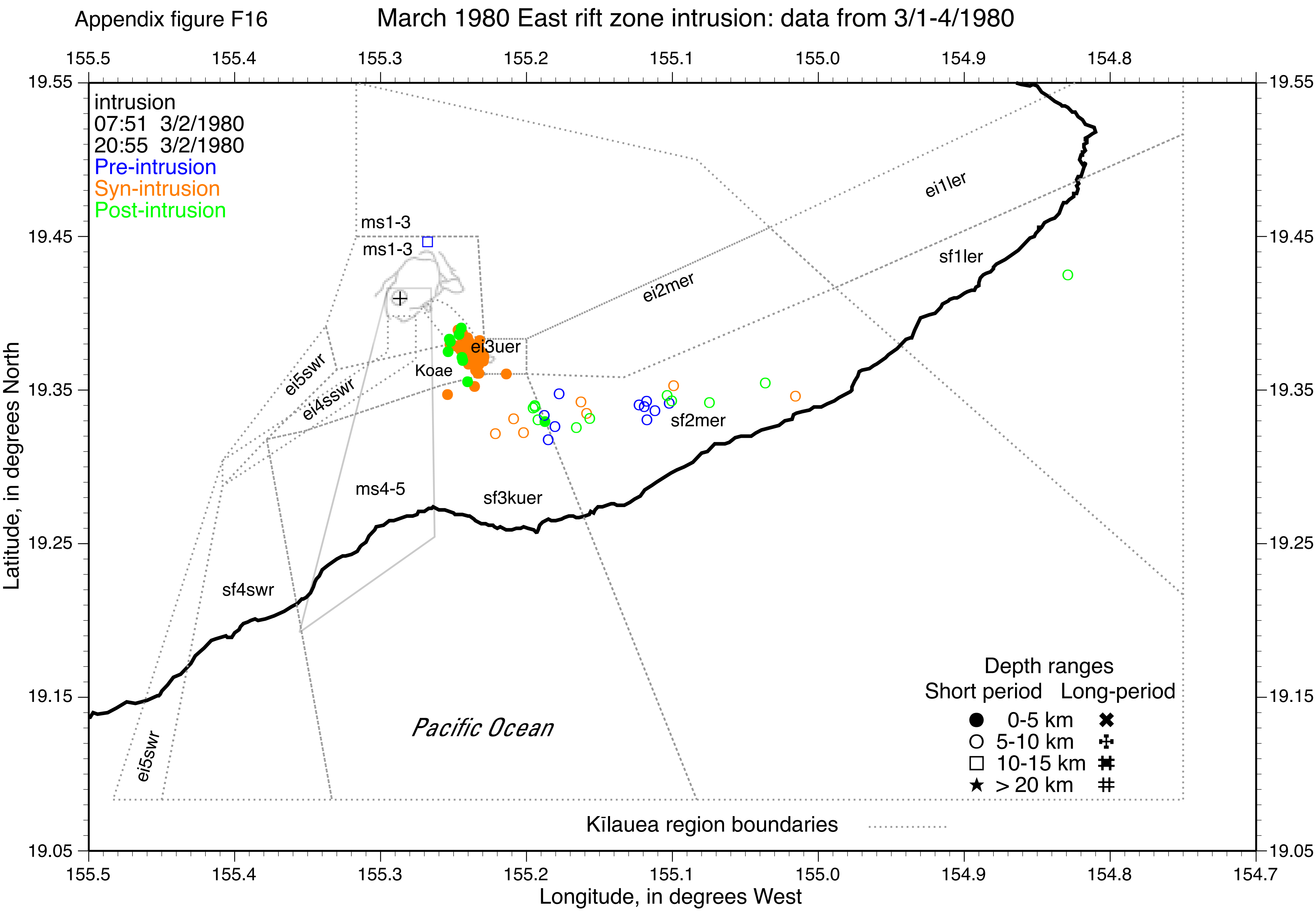


Appendix figure F15

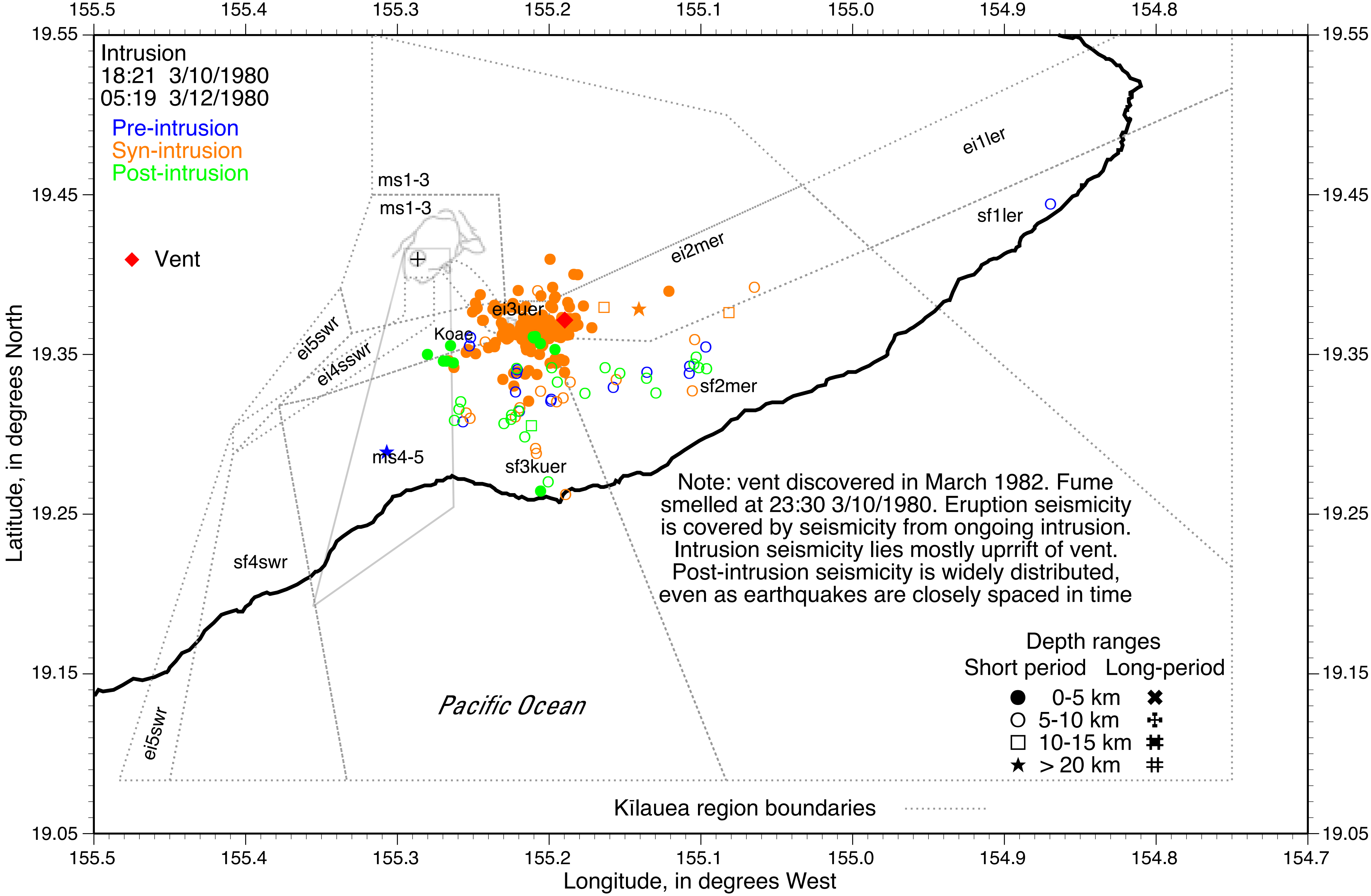
February 1980 East rift zone intrusion: data from 1/31-2/51980



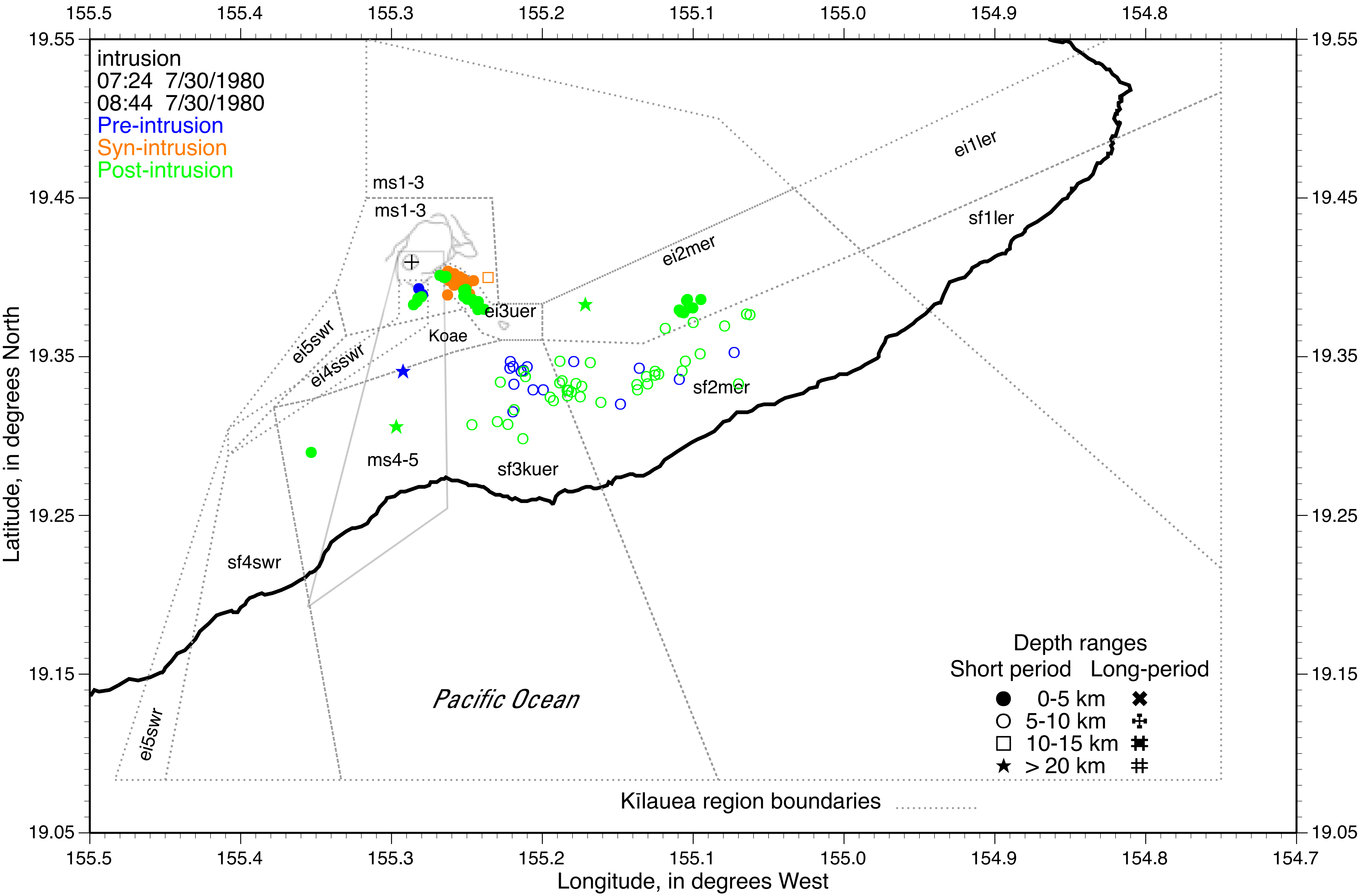
Appendix figure F16



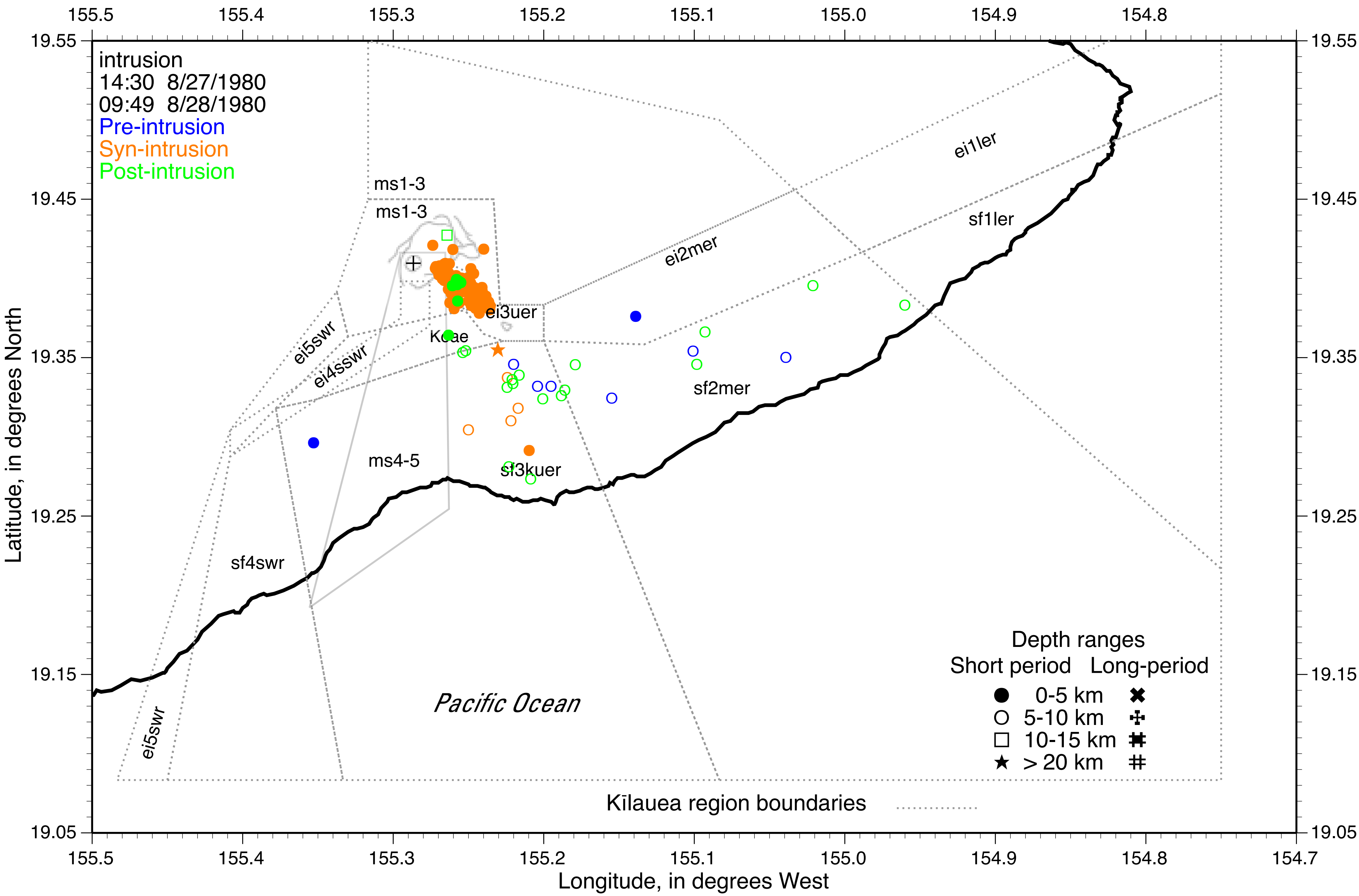
Appendix figure F17 March 1980 east rift eruption: data from 3/8-14/1980



Appendix figure F18 July 1980 East rift zone intrusion: data from 7/28-8/7/1980

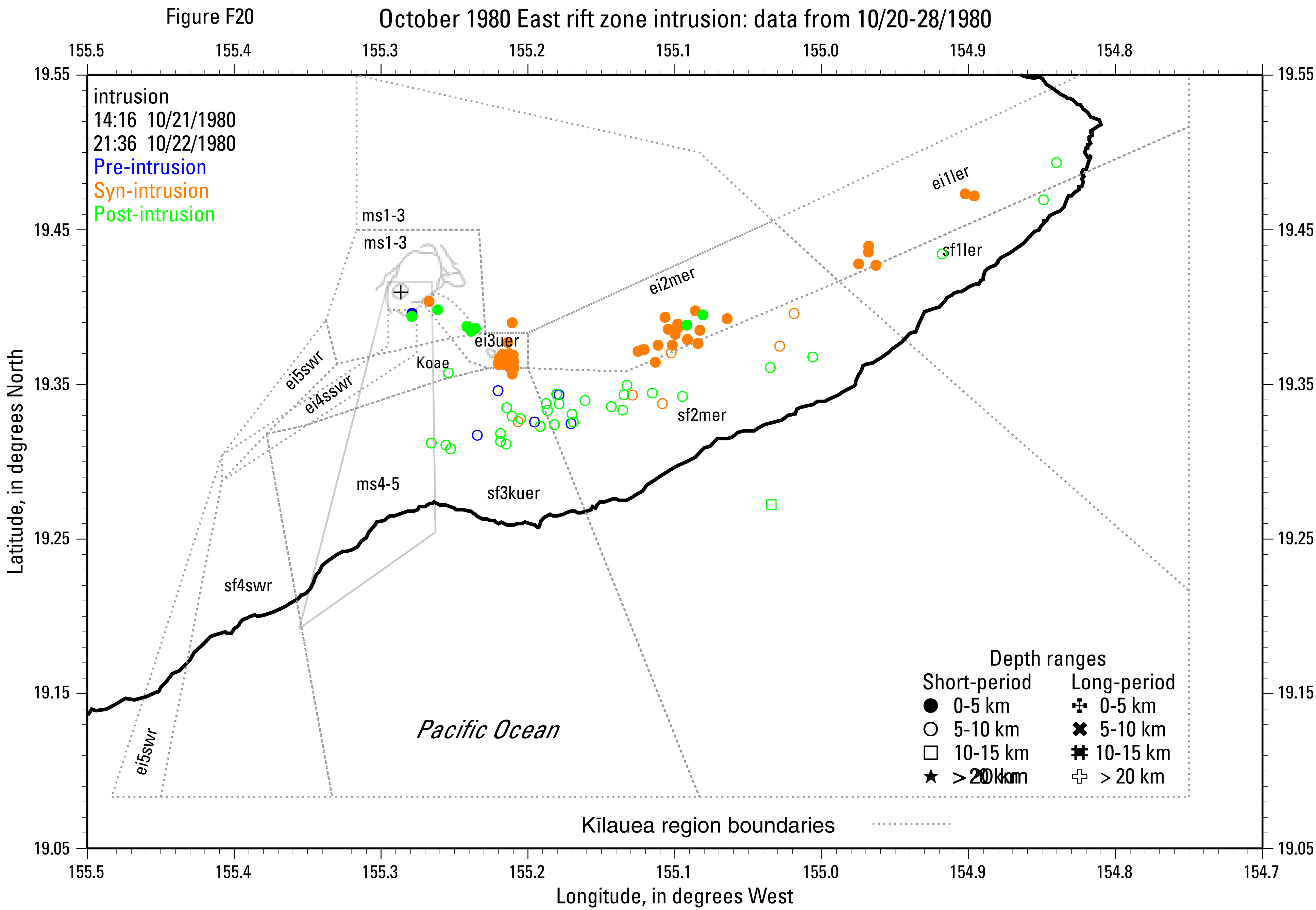


Appendix figure F19 August 1980 East rift zone intrusion: data from 8/26-30/1980

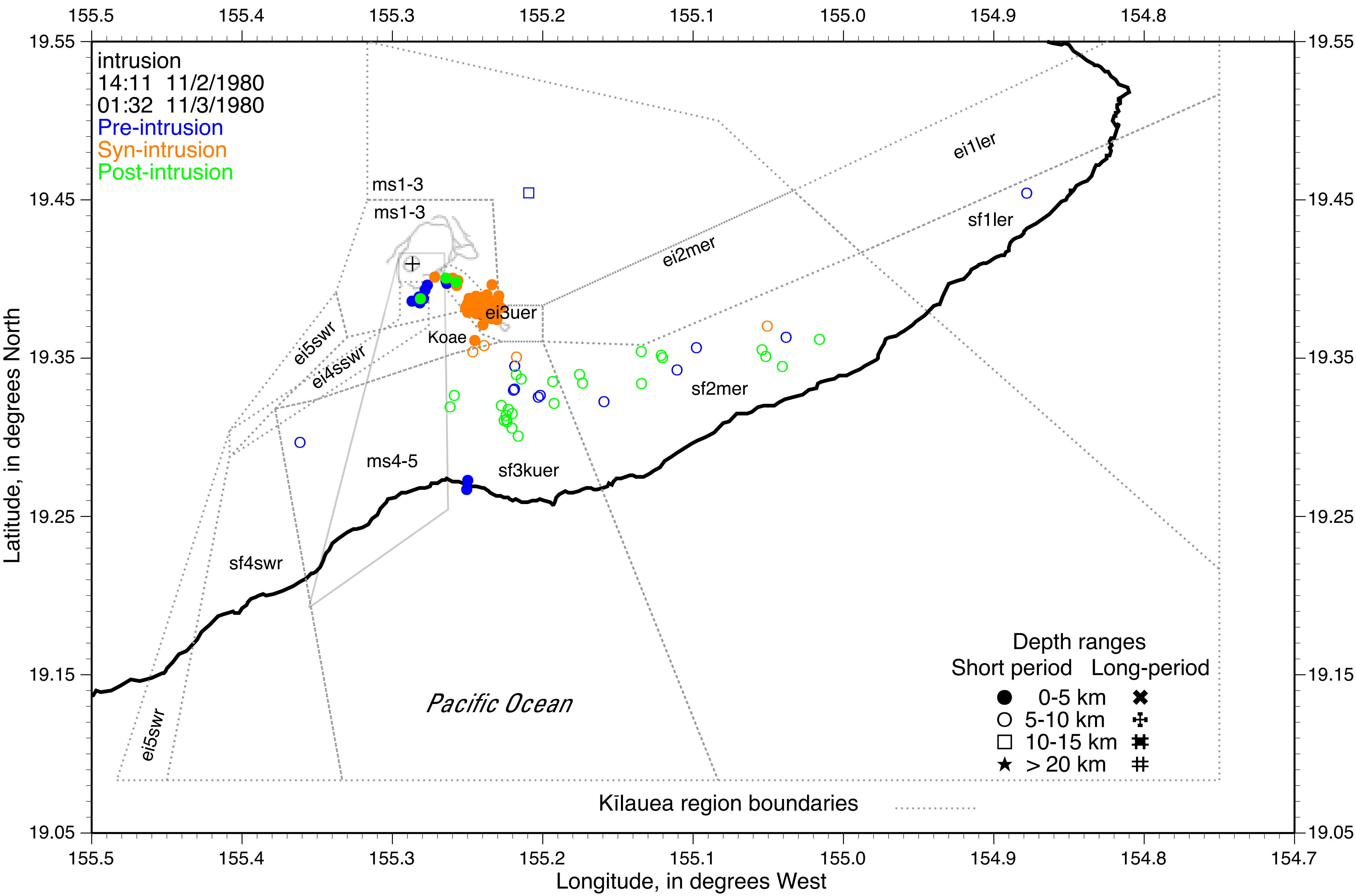


Kīlauea region boundaries

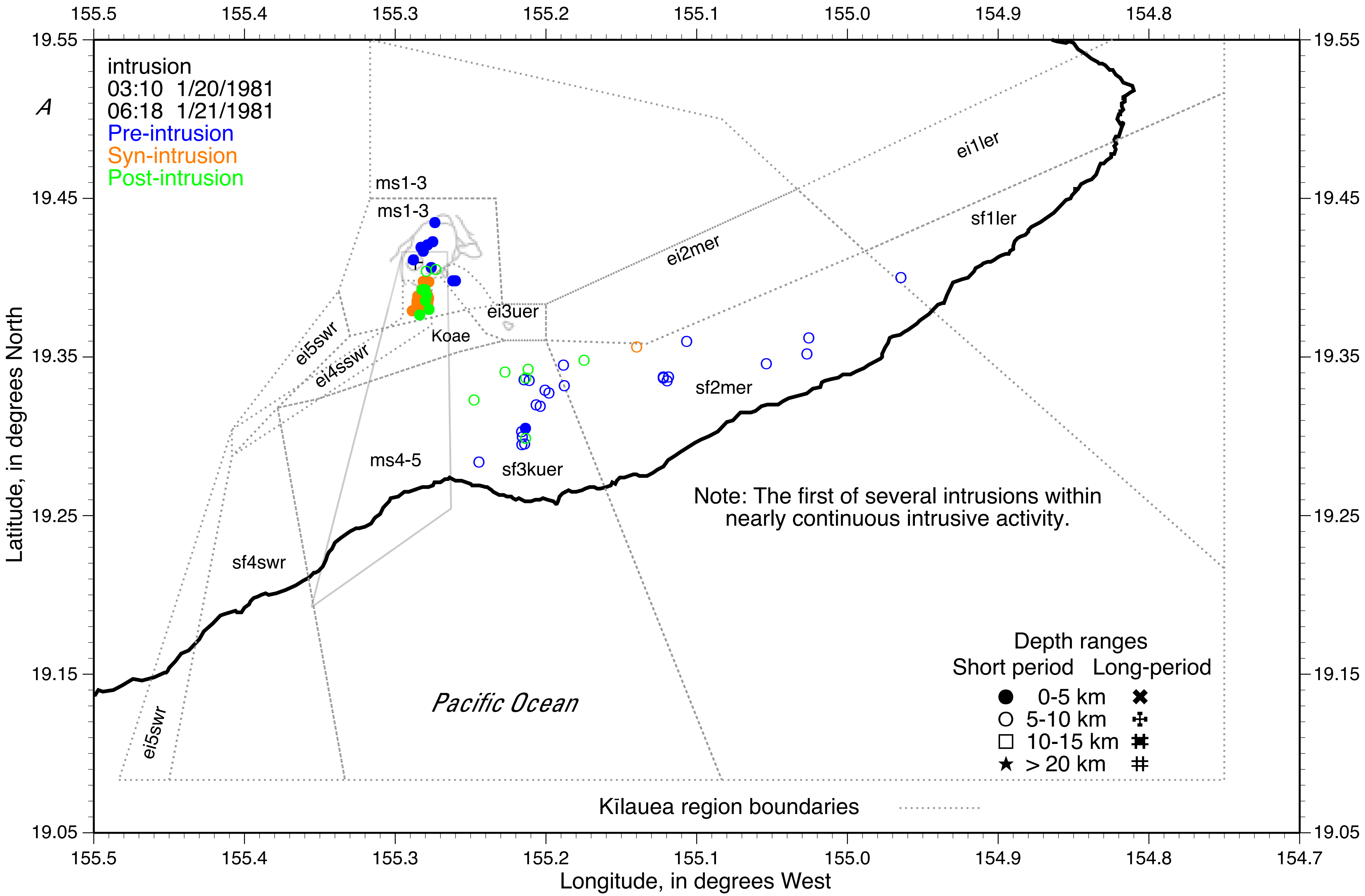
Figure F20



Appendix figure F21 November 1980 East rift zone intrusion: data from 10/30-11/6/1980

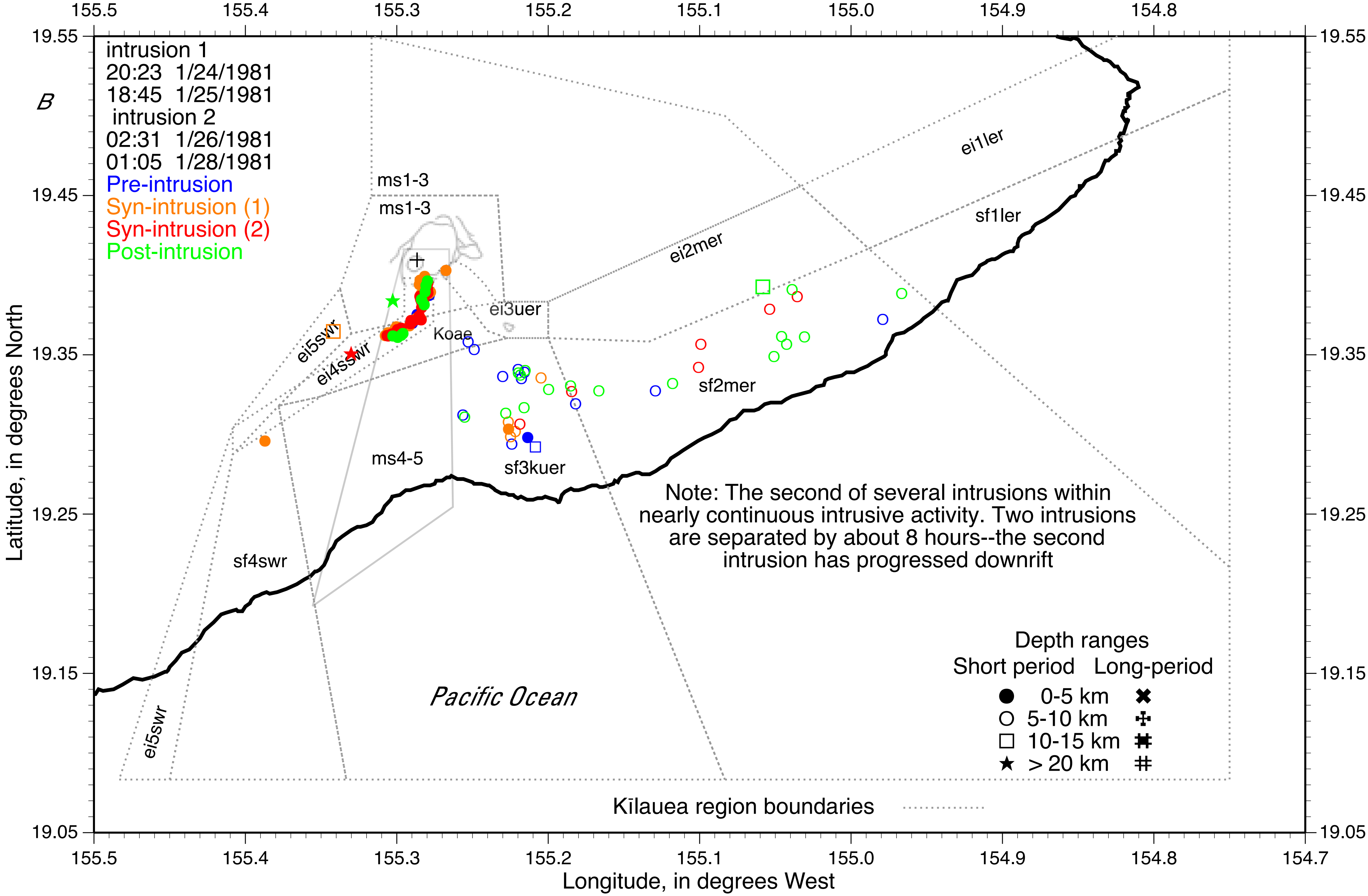


Appendix figure F22a January 1981 seismic southwest rift zone rift zone intrusion data from1/17-22/1981

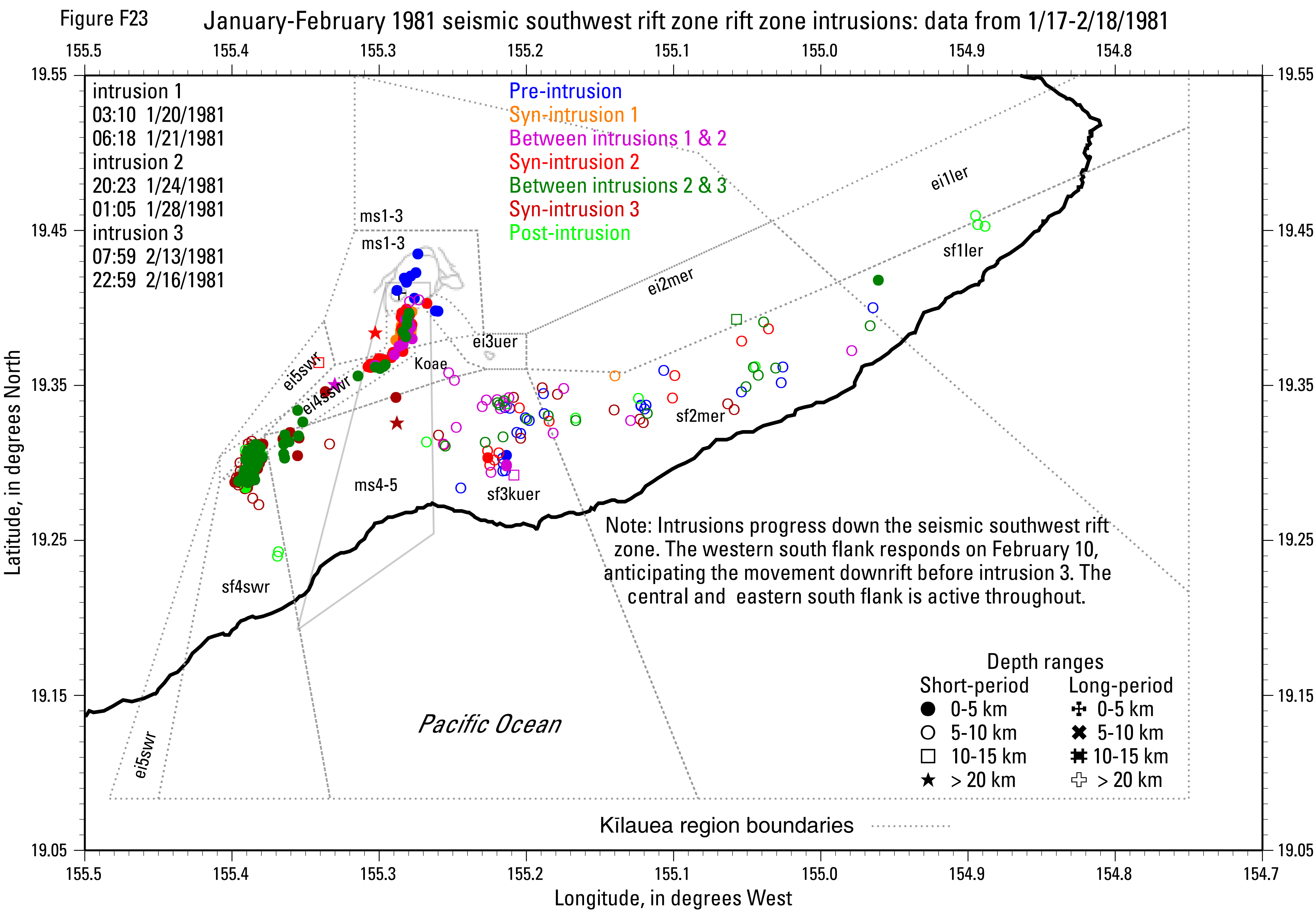


Appendix figure F22b

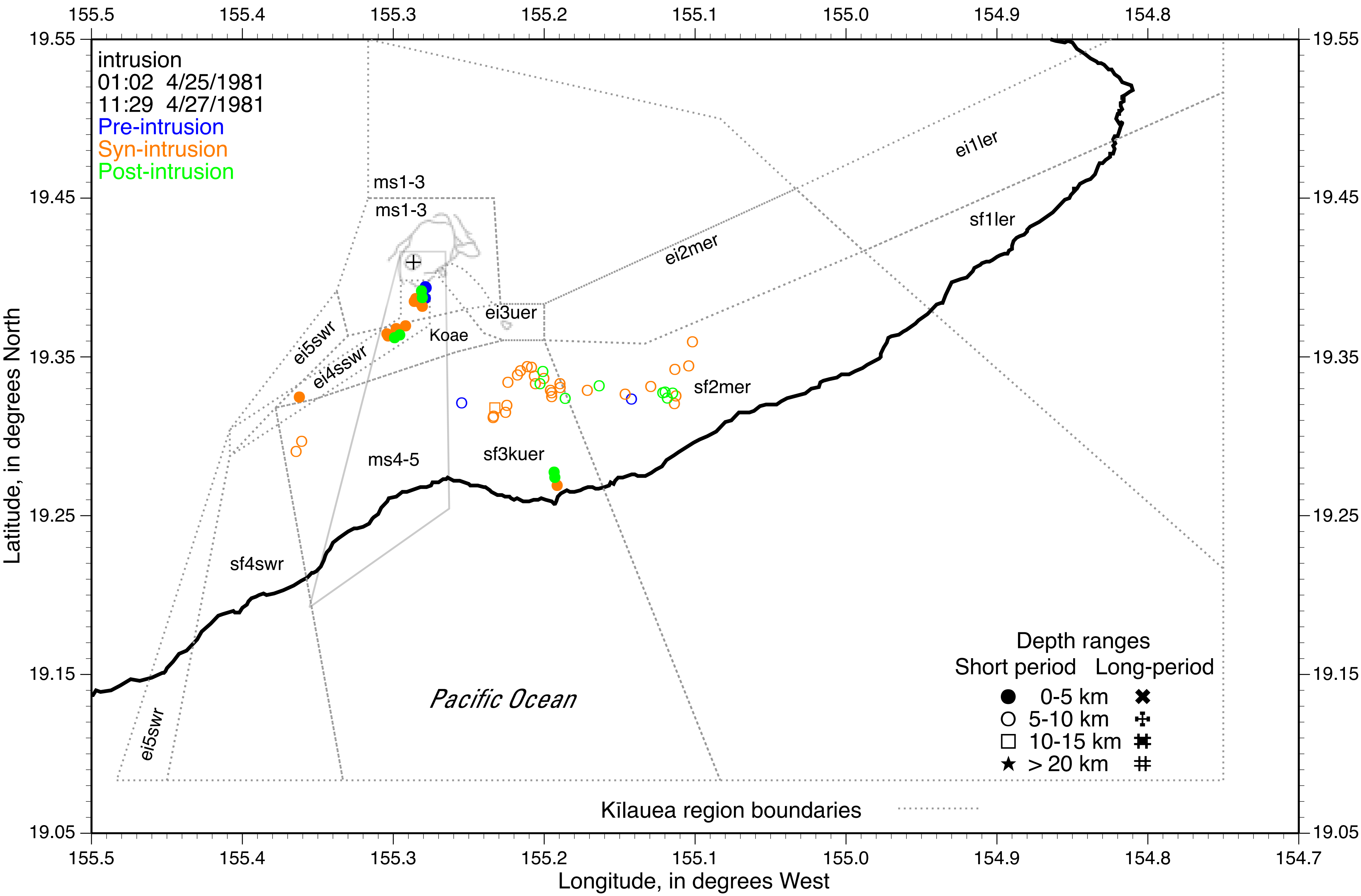
January 1981 seismic southwest rift zone rift zone intrusion data from 1/23-31/1981

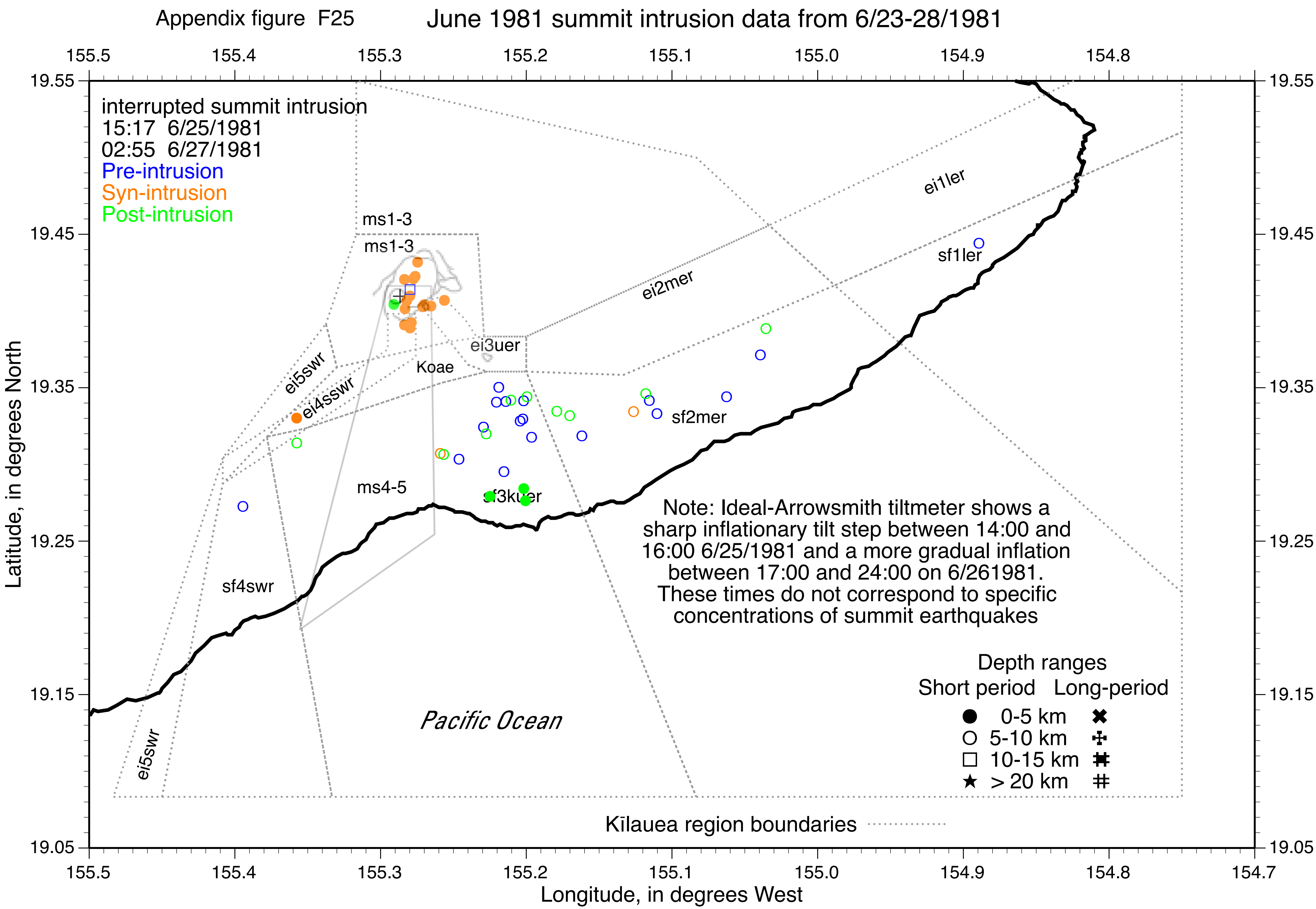


Kīlauea region boundaries



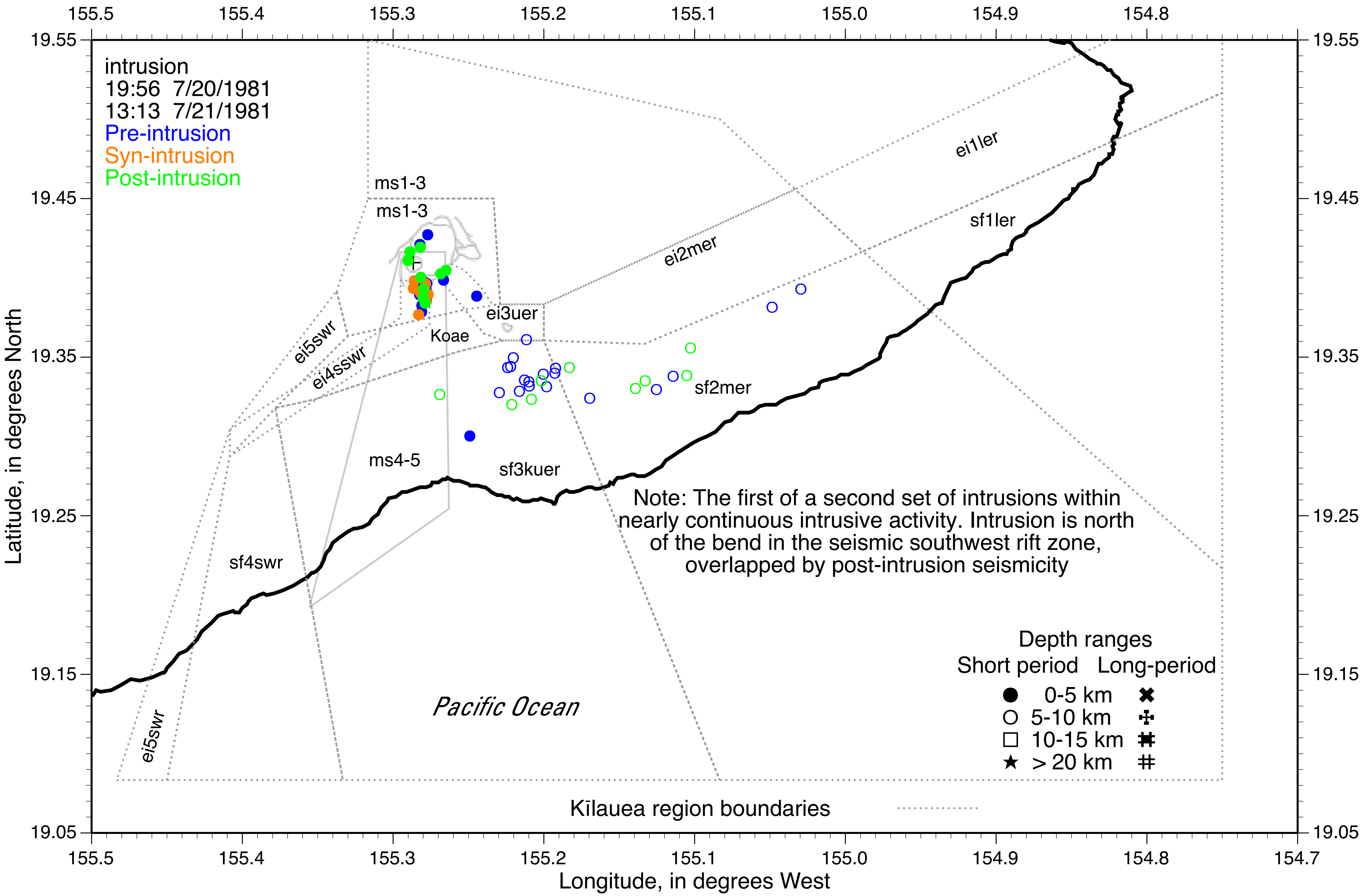
Appendix figure F24 April 1981 slow intrusion?: data from 4/24-28/1981



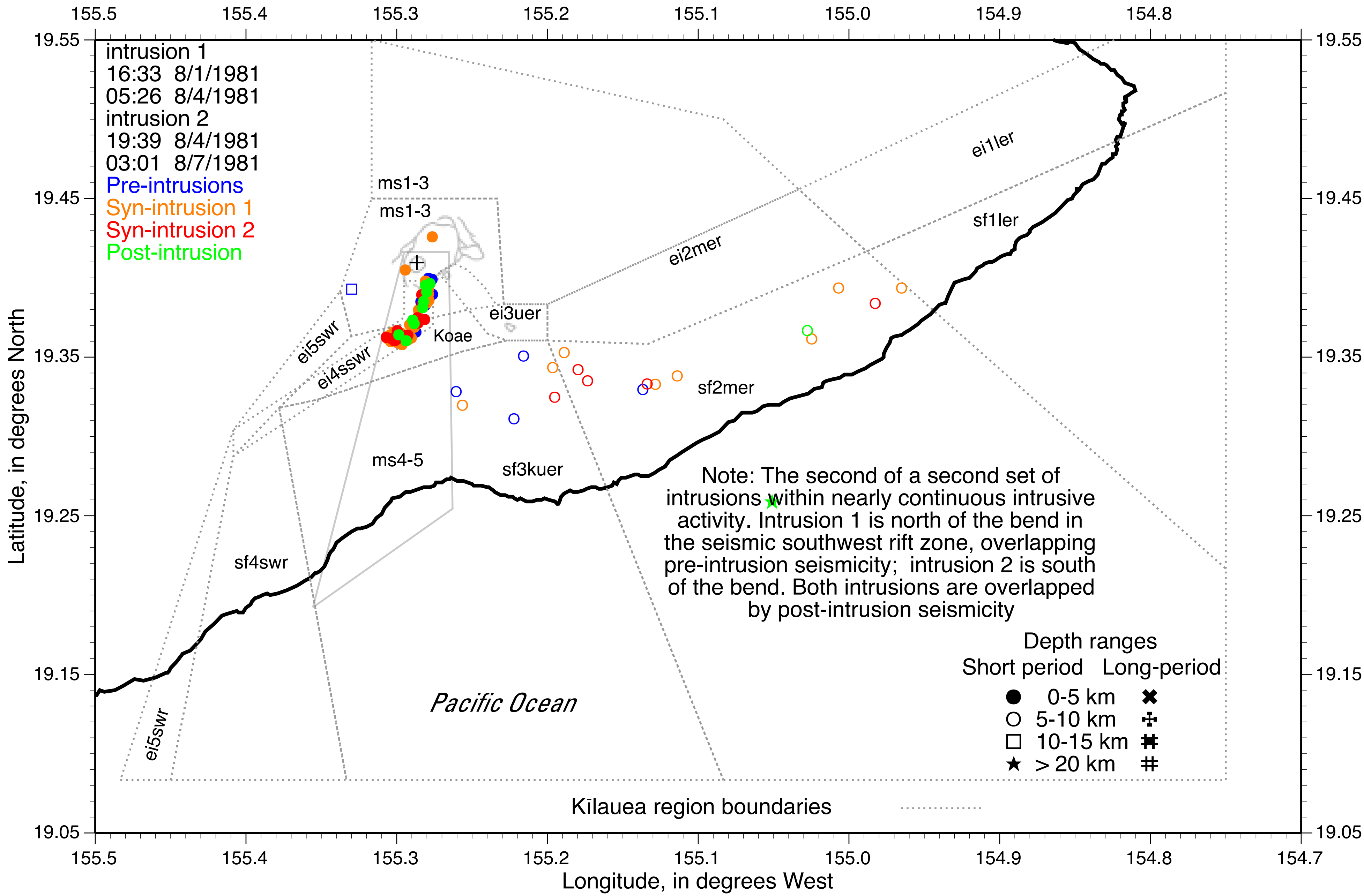


Appendix figure F25
June 1981 summit intrusion data from 6/23-28/1981
interrupted summit intrusion
15:17 6/25/1981
02:55 6/27/1981
Pre-intrusion
Syn-intrusion
Post-intrusion
ms1-3
ms1-3
ei3uer
Koae
ei5swr
ei4sswr
ei2mer
ei1ler
sf1ler
sf2mer
sf3kuer
ms4-5
sf4swr
ei5swr
Pacific Ocean
Note: Ideal-Arrowsmith tiltmeter shows a sharp inflationary tilt step between 14:00 and 16:00 6/25/1981 and a more gradual inflation between 17:00 and 24:00 on 6/261981. These times do not correspond to specific concentrations of summit earthquakes
Depth ranges
Short period
Long-period
0-5 km
5-10 km
10-15 km
> 20 km
Kīlauea region boundaries
Latitude, in degrees North
Longitude, in degrees West
155.5
155.4
155.3
155.2
155.1
155.0
154.9
154.8
154.7
19.55
19.45
19.35
19.25
19.15
19.05

Appendix figure F26 July 1981 seismic southwest rift zone rift zone intrusion data from 7/17-24/1981



Appendix figure F27 August 1981 seismic southwest rift zone rift zone intrusion data from 7/31-8/7/1981



Appendix figure F28a August 1981 seismic southwest rift zone rift zone intrusion data from 8/8-23/1981

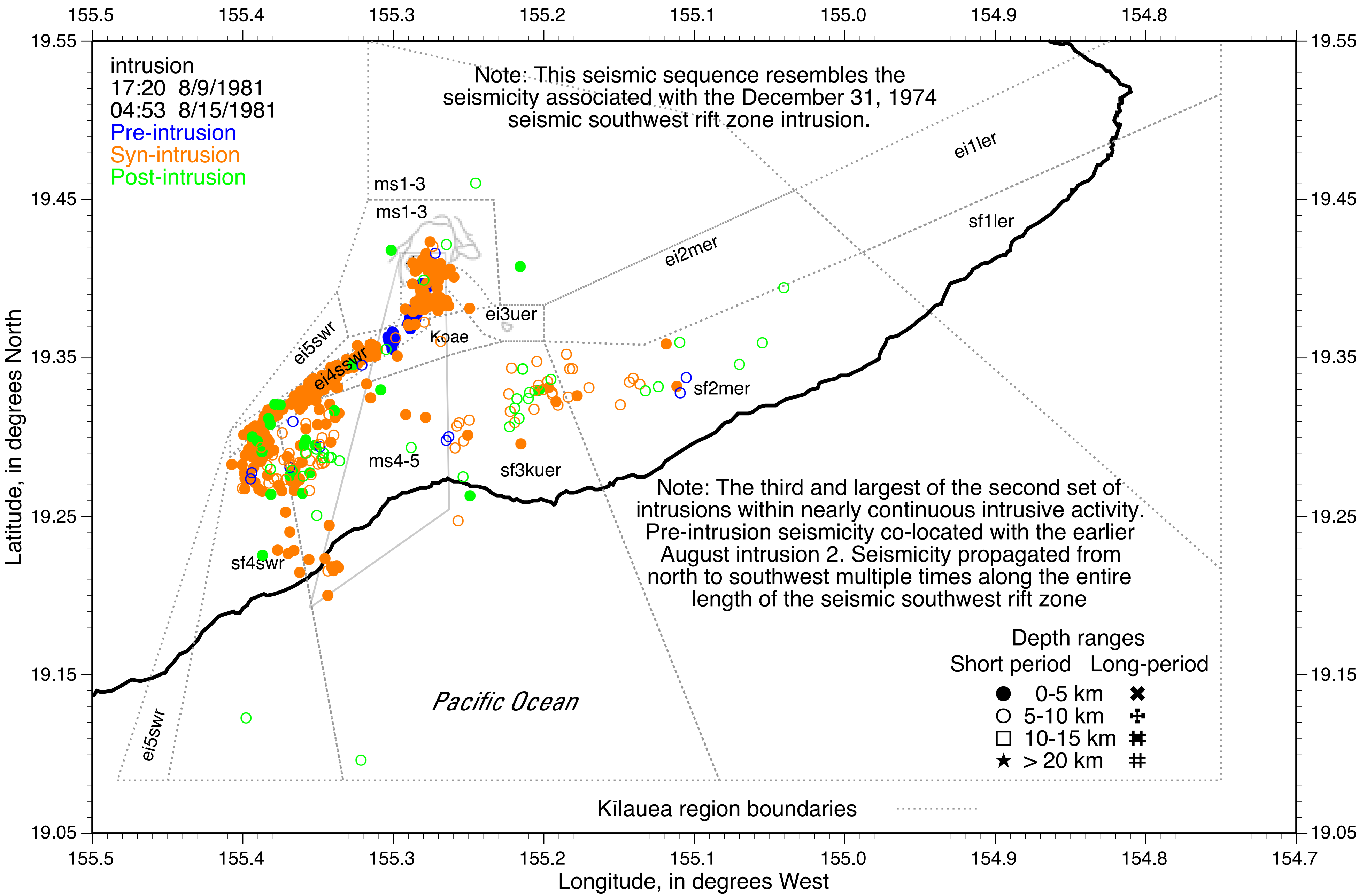
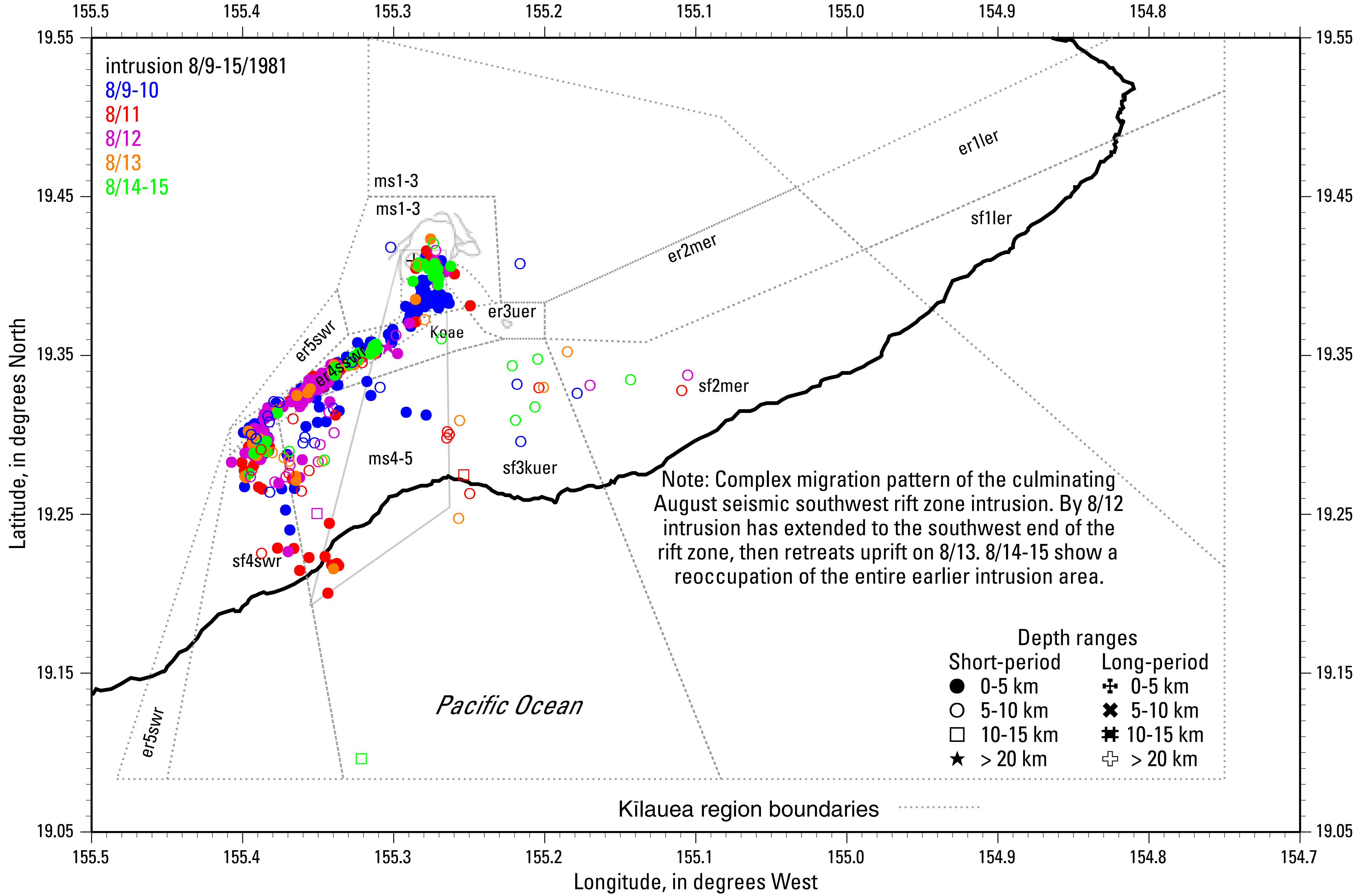
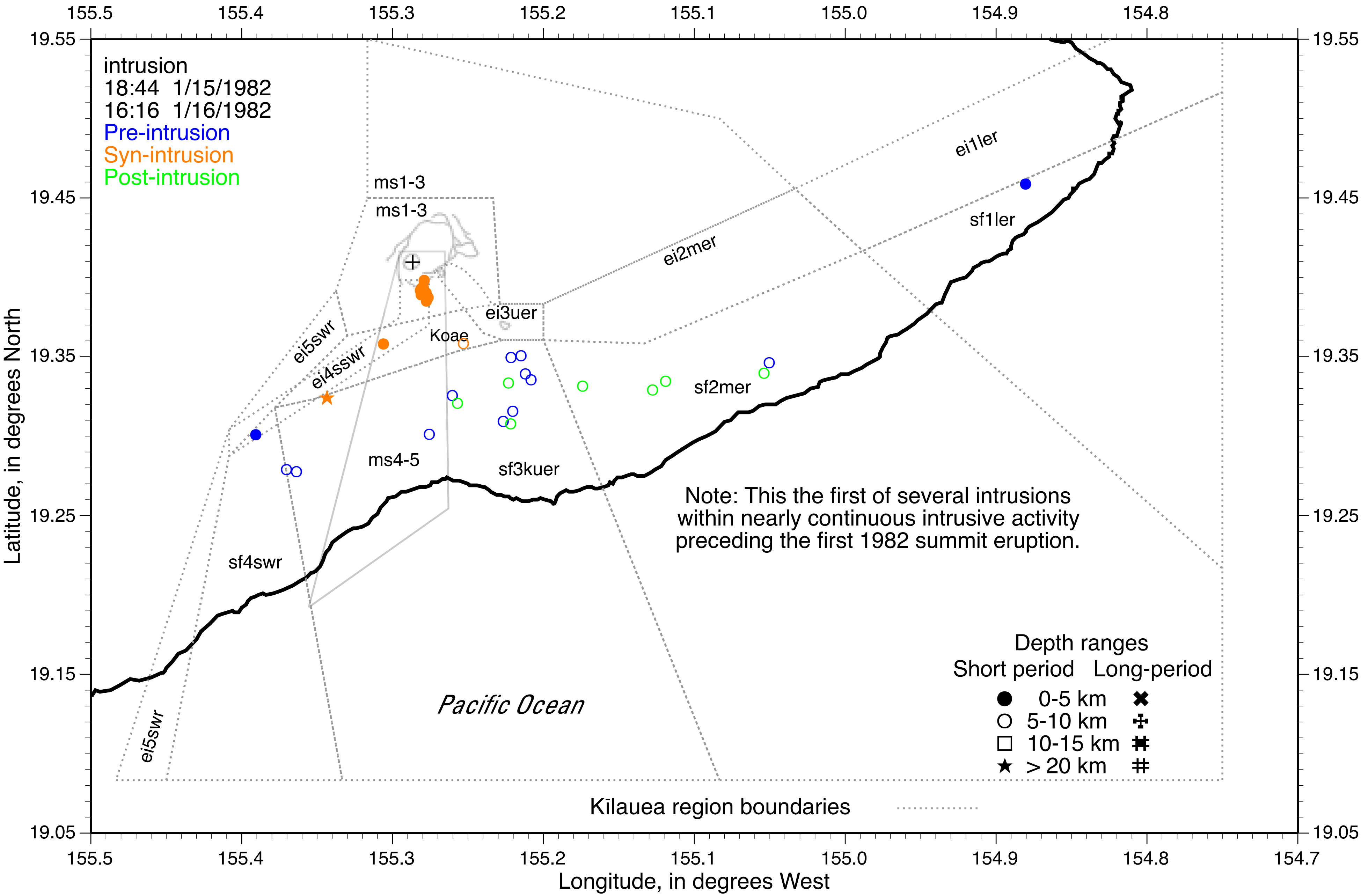


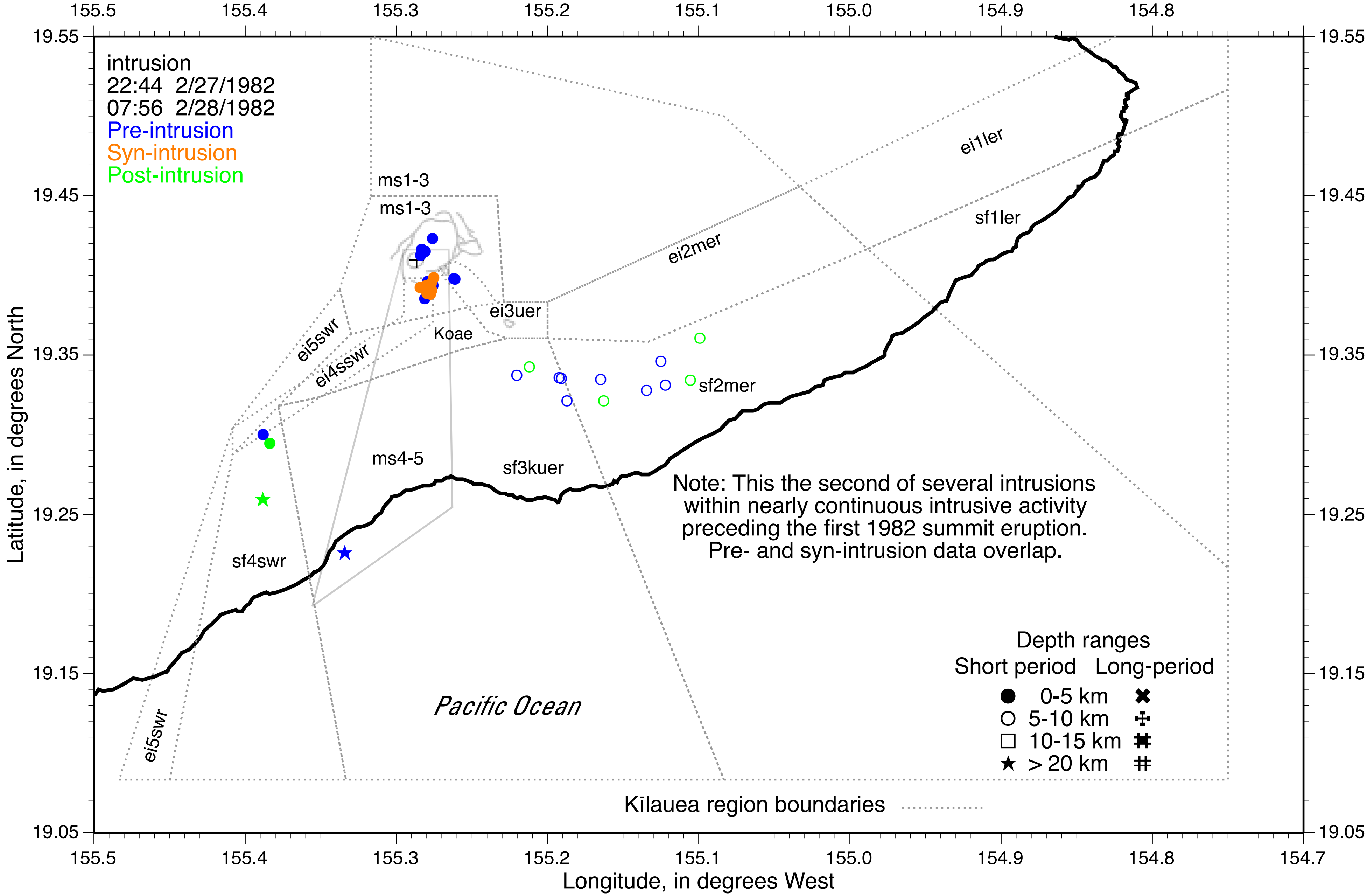
Figure F28b August 1981 seismic southwest rift zone rift zone intrusion: Subdivided by day 8/9-15/1981



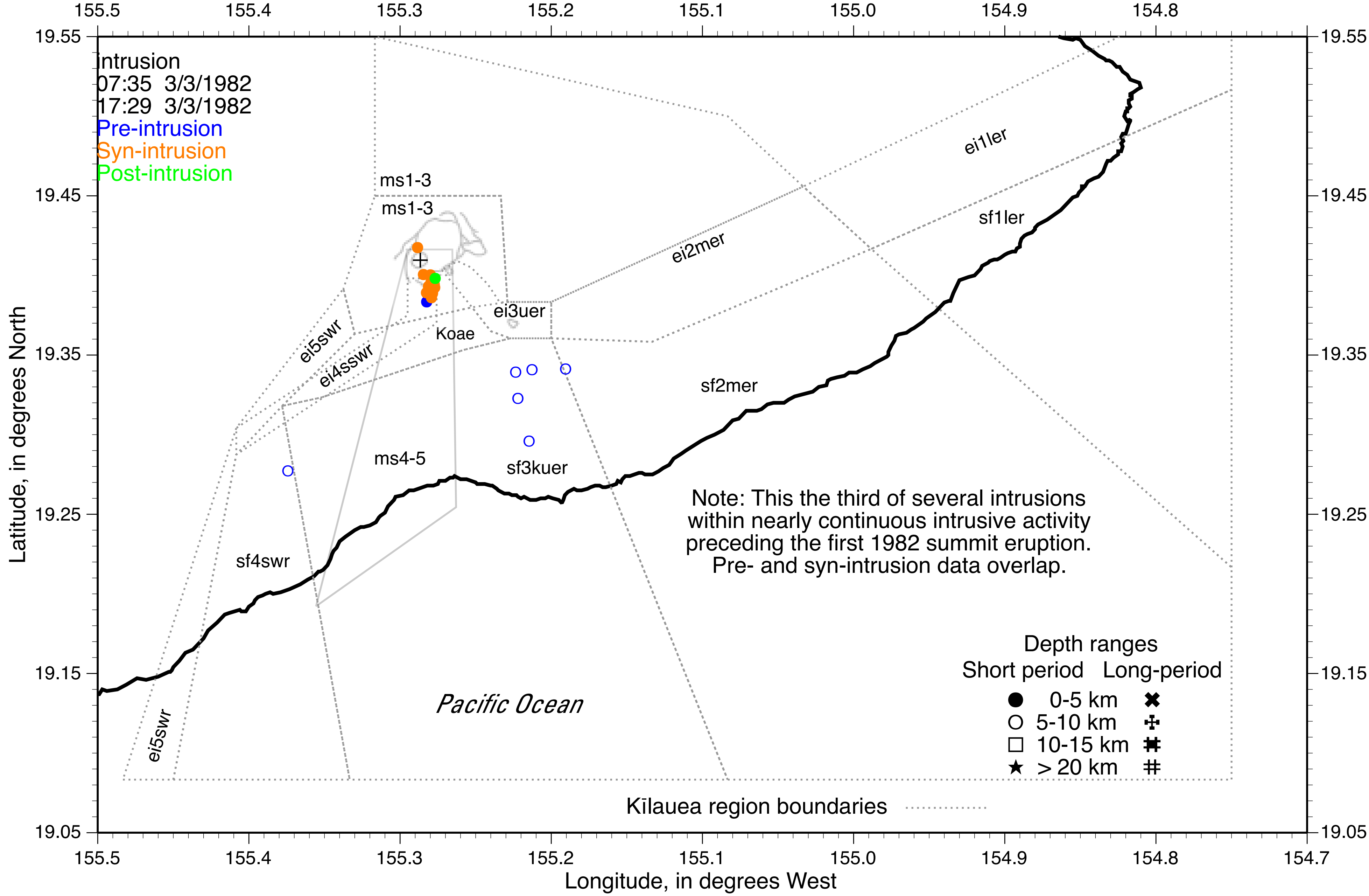
Appendix figure F29 Janruary 1982 seismic southwest rift zone rift zone intrusion: data from 1/14-17/1982



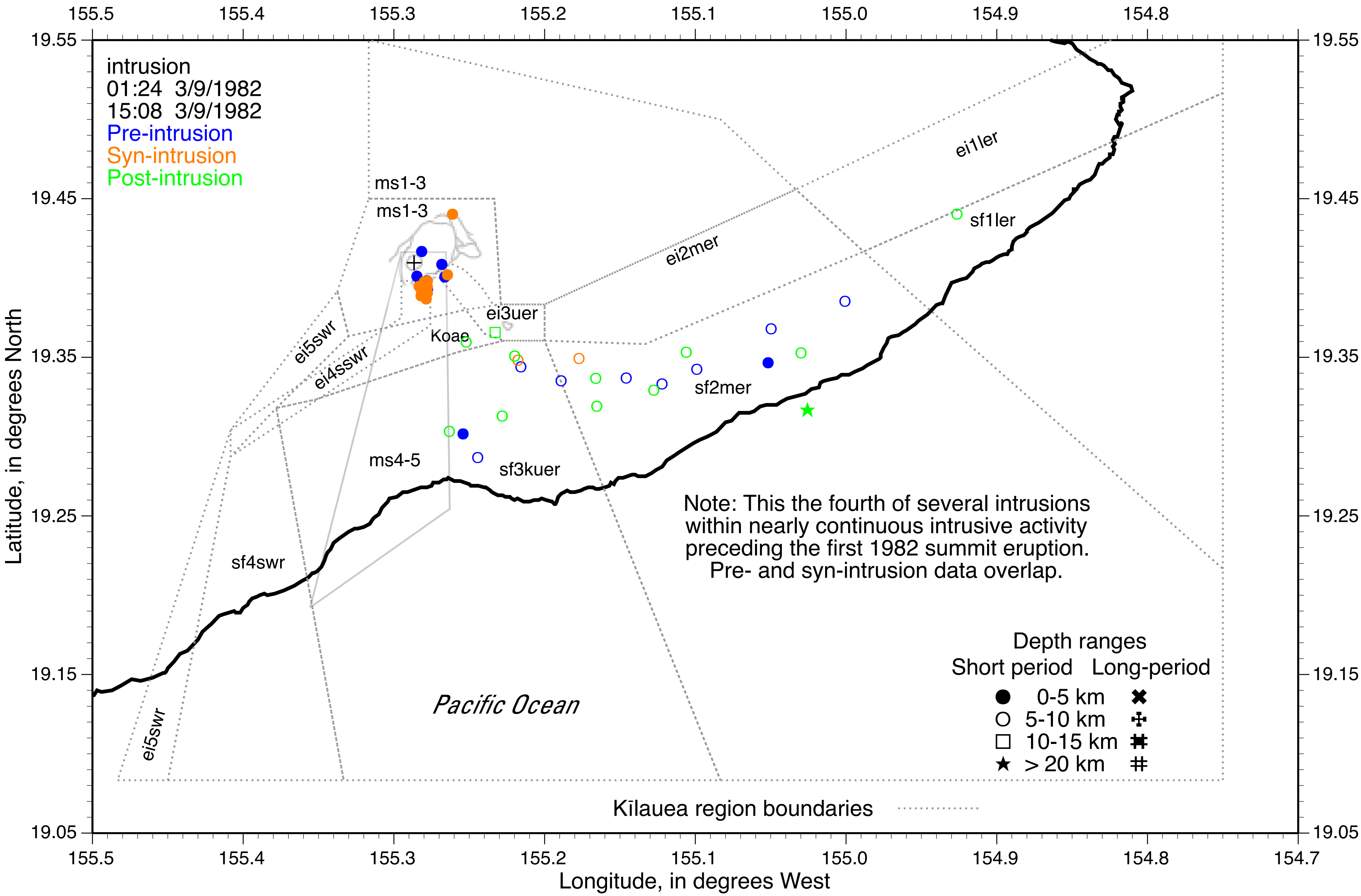
Appendix figure F30 February 1982 seismic southwest rift zone rift zone intrusion data from 2/24-3/1/1982



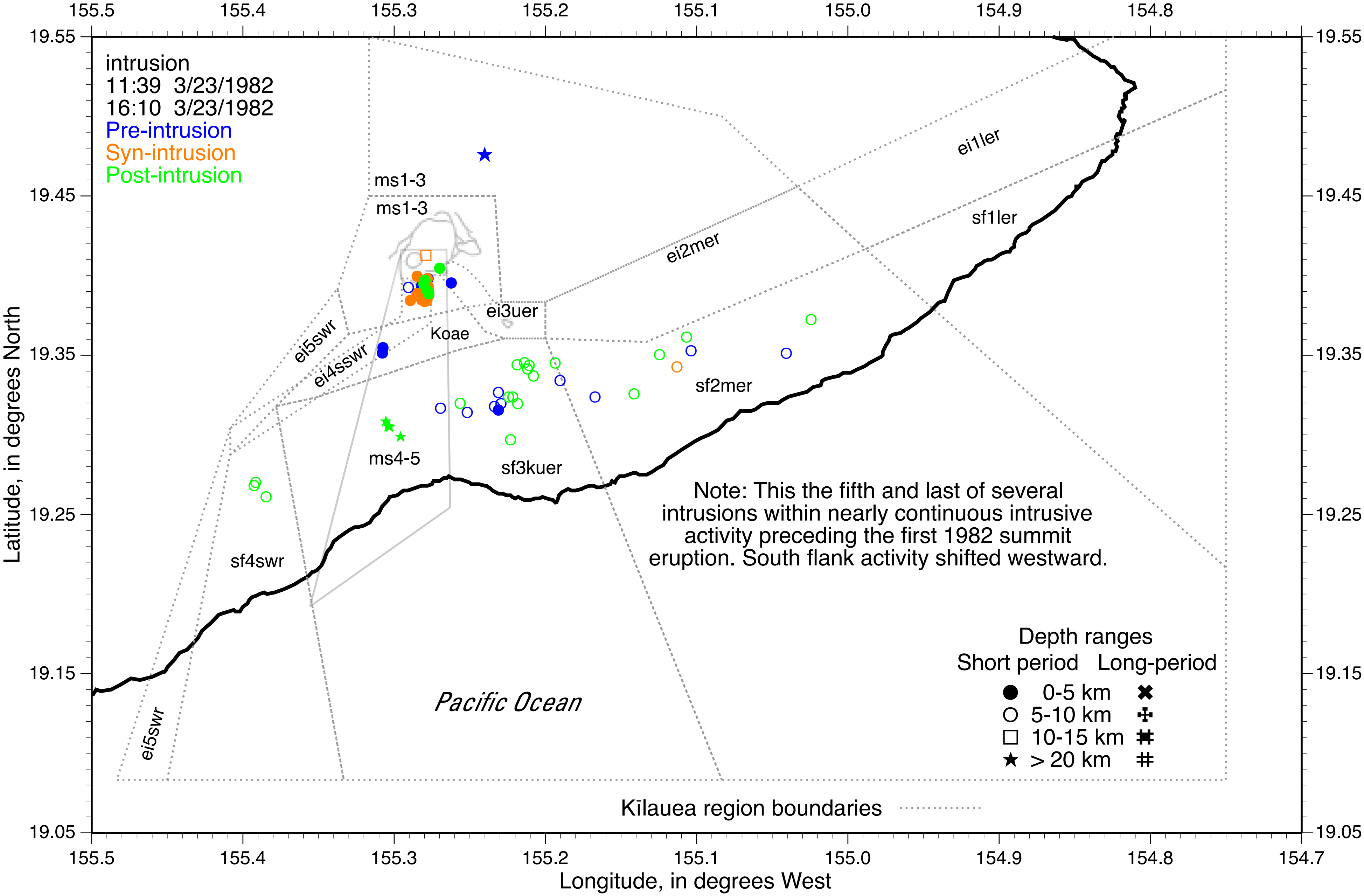
Appendix figure F31 March 1982 seismic southwest rift zone rift zone intrusion data from 3/2-5/1982



Appendix figure F32 March 1982 seismic southwest rift zone rift zone intrusion data from 3/6-12/1982

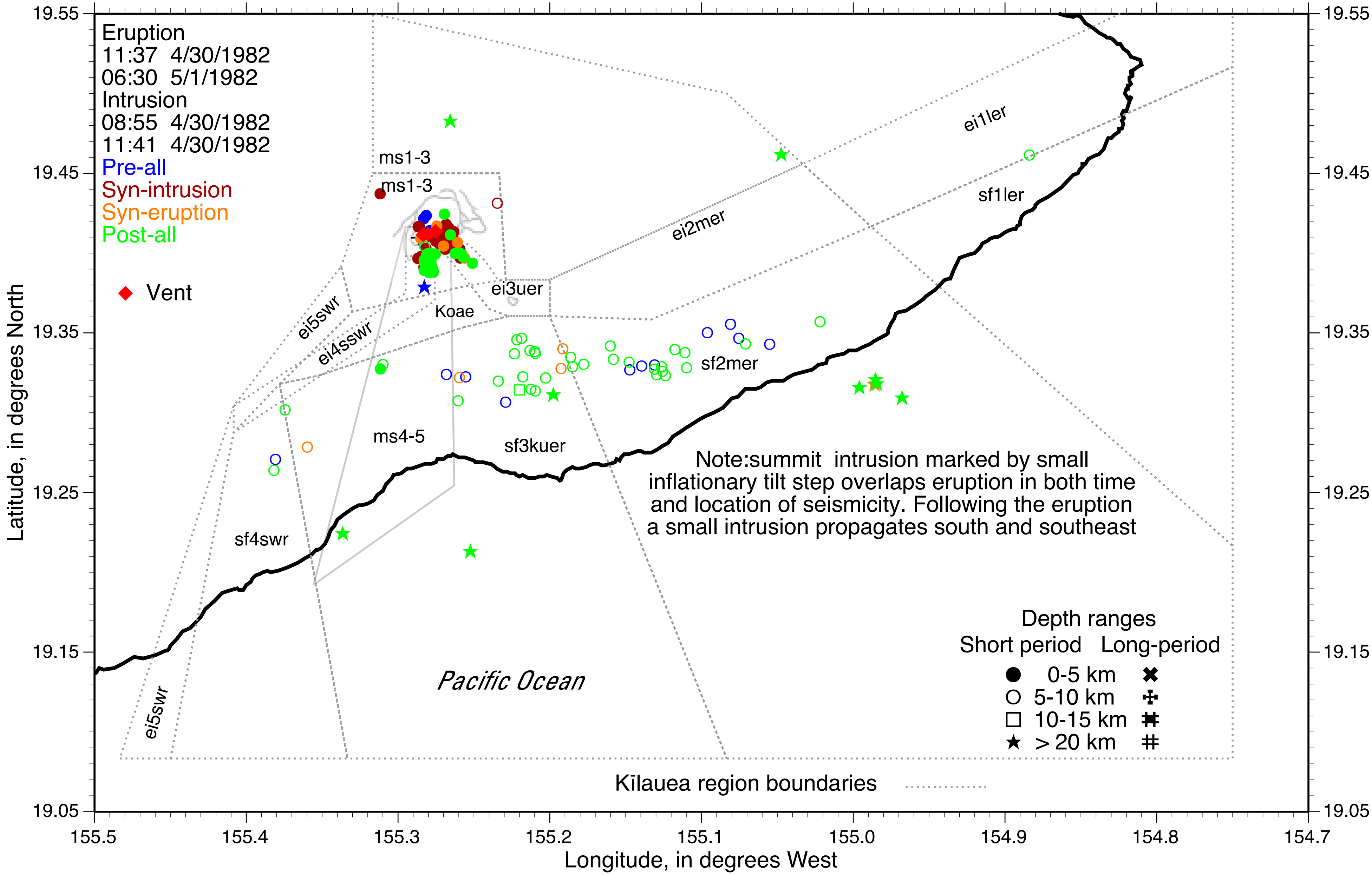


Appendix figure F33 March 1982 seismic southwest rift zone rift zone intrusion data from 3/21-27/1982



Appendix figure F34

April 1982 summit eruption and intrusion: data from 4/25-5/11/1982



Appendix figure F35 june 1982 seismic southwest rift zone rift zone intrusion data from 6/4-14/1982

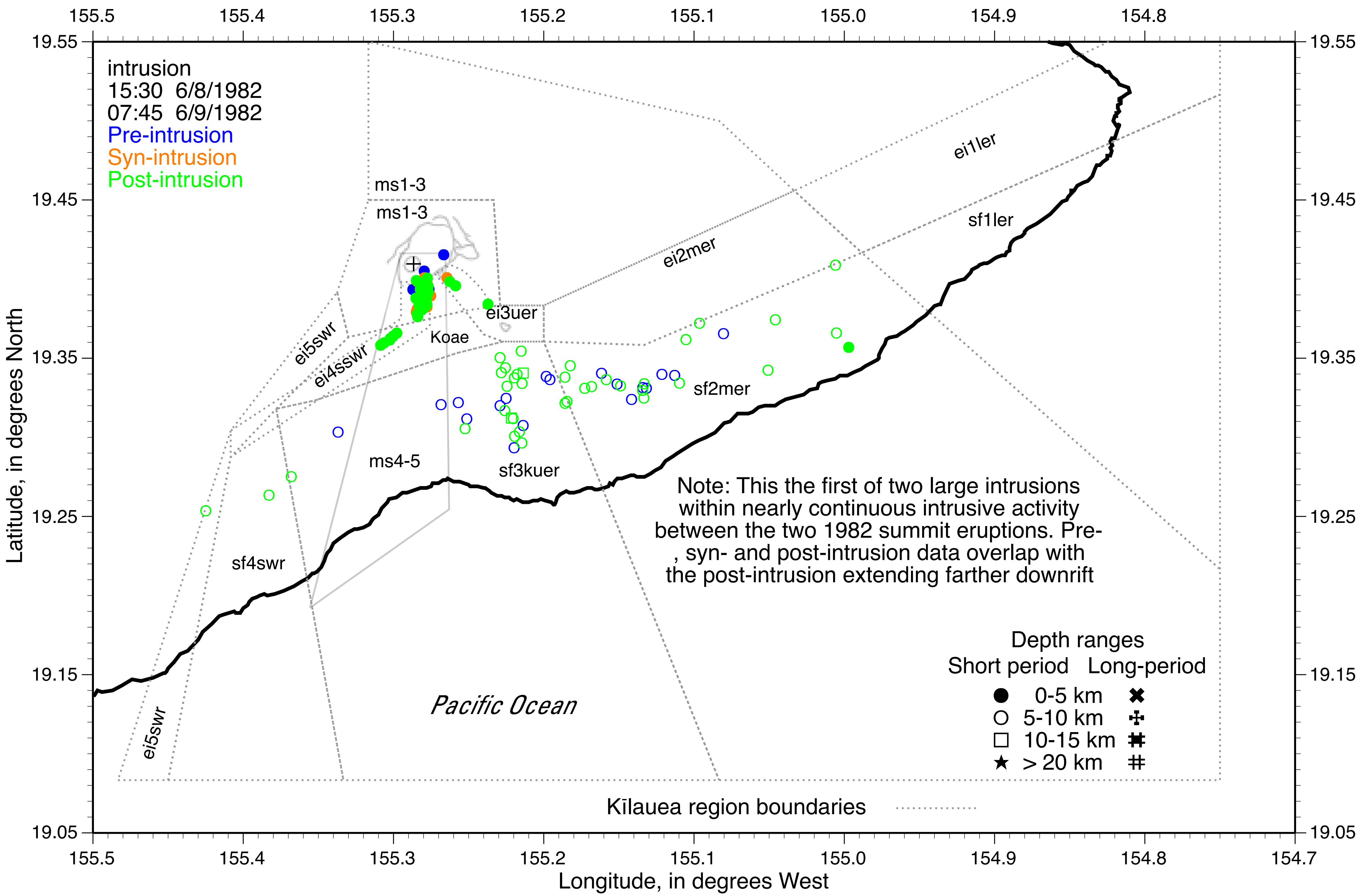
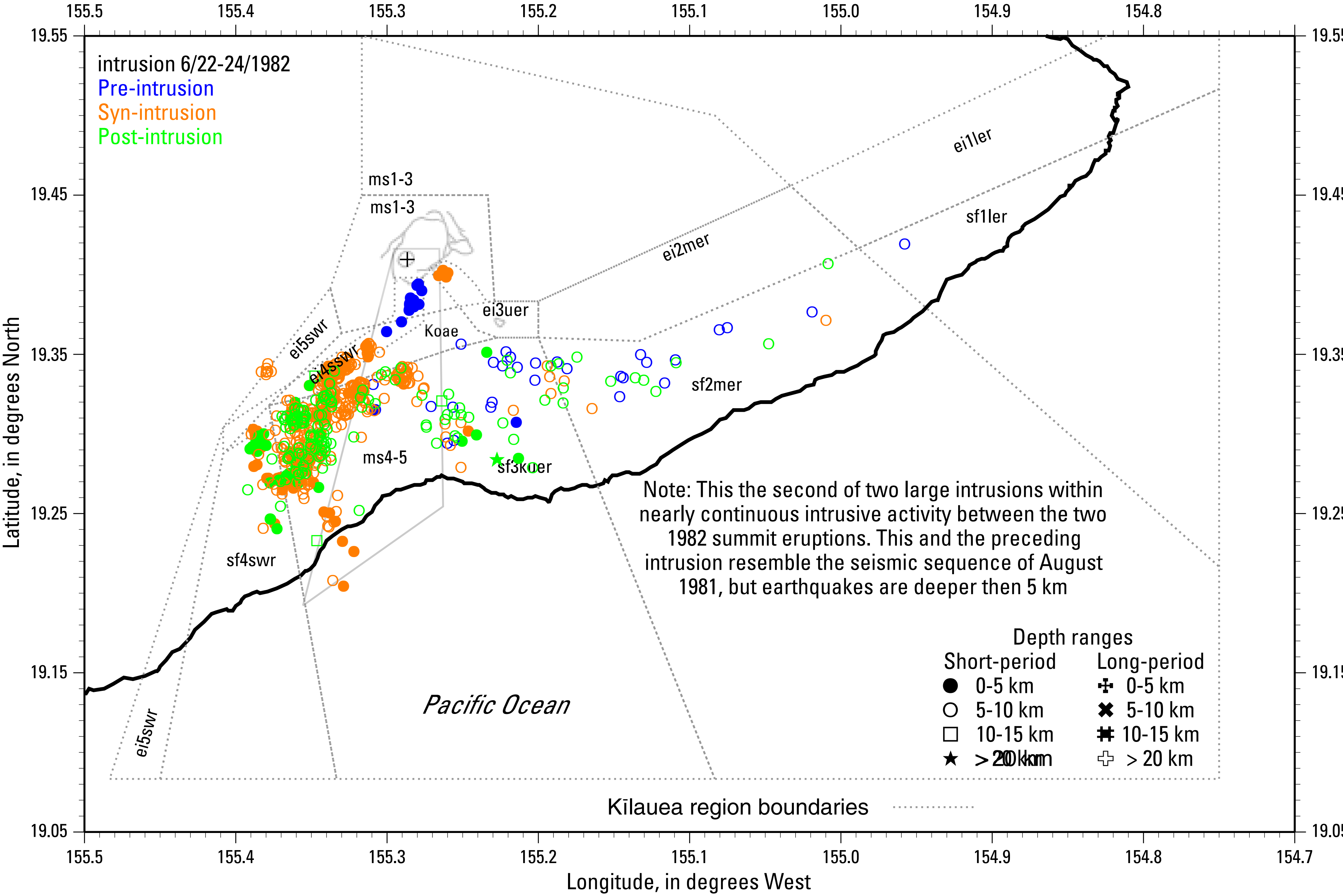
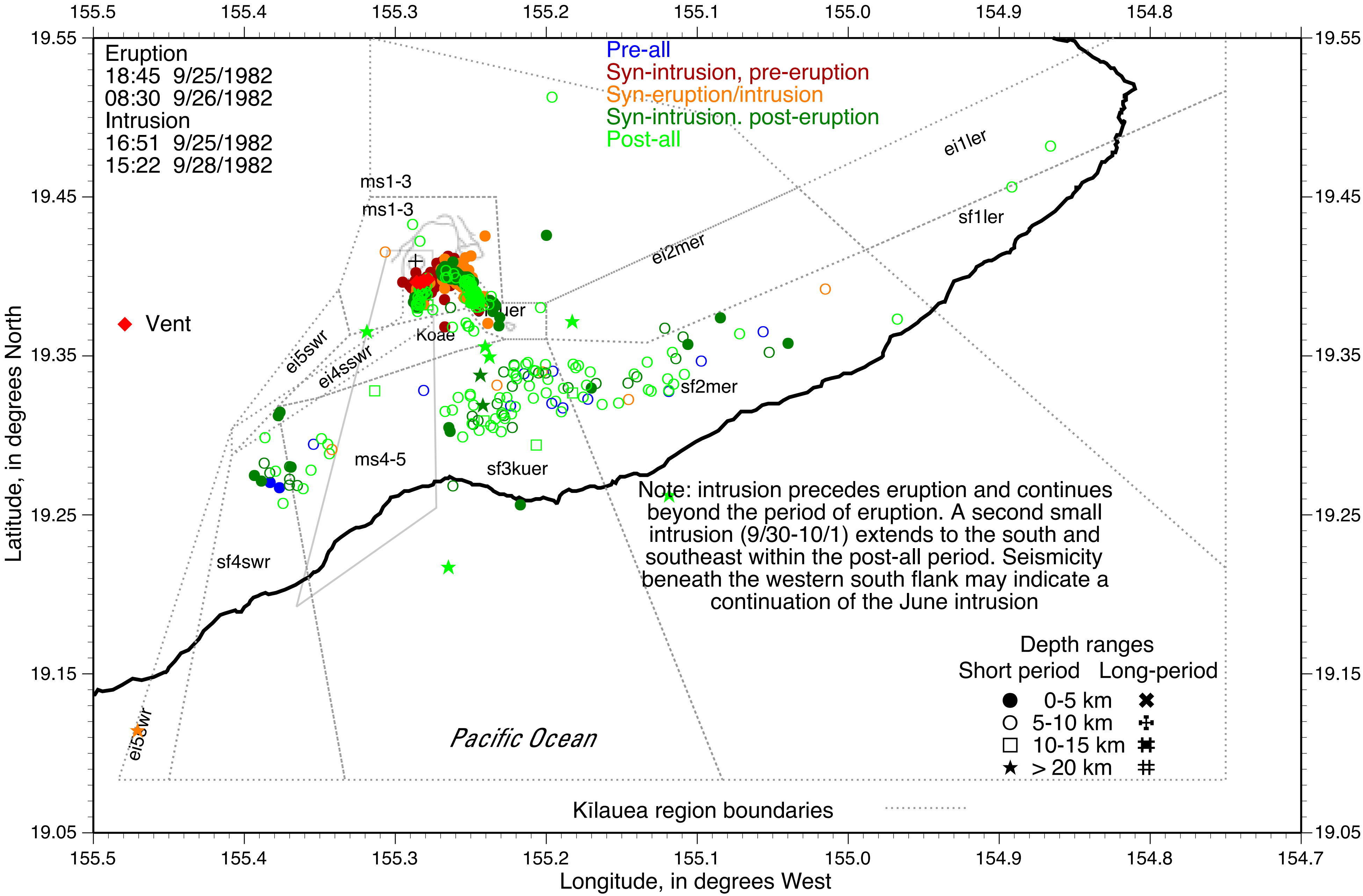


Figure F36

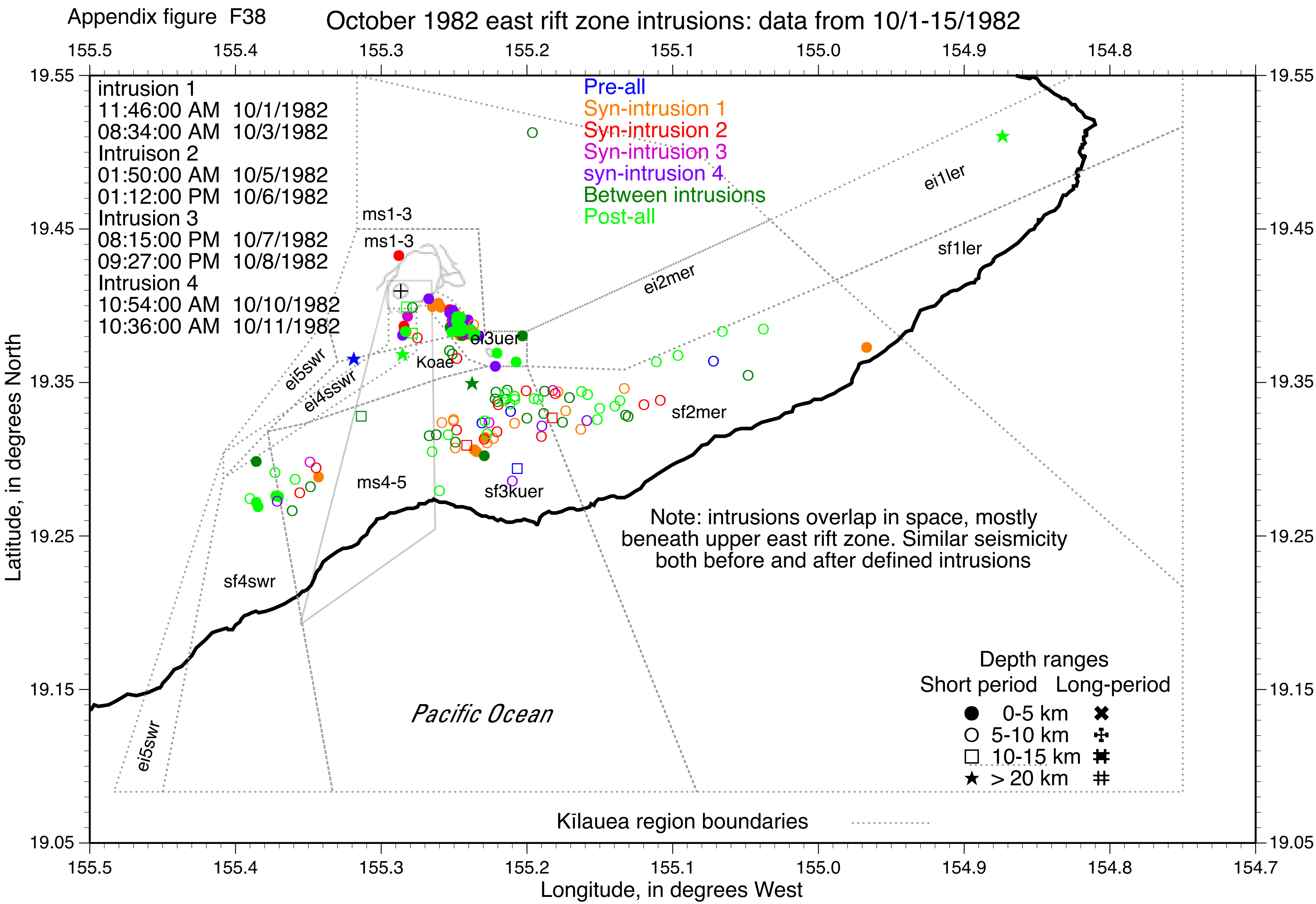
June 1982 seismic southwest rift zone intrusion: data from 6/18-28/1982



Appendix figure F37 September 1982 summit eruption and intrusion: data from 9/23-10/8/1982



Appendix figure F38



Appendix G. Supplementary Material to Support Chapter 7

Table G1 presents tilt volume, eruption efficiency, and magma supply rate from 1983 to 2008.

Figures G1–G3 present 1-year time series plots between 1 February 1982 and 1 February 2008 showing details of numbers of both short- and long-period earthquakes shown in text figures.

Figures G4–G7 present time series plot of earthquake swarms and plots of earthquake locations for the events of Stage IA.

Figures G8–G15 present time series plots of earthquake swarms and plots of earthquake locations for the events of Stage IB.

Figures G16–G24 present time series plot of earthquake swarms and plots of earthquake locations for the events of Stage IIA.

Figures G25–G49 present time series plot of earthquake swarms and plots of earthquake locations for the events of Stage IIB.

Figures G50–G82 present time series plot of earthquake swarms and plots of earthquake locations for the events of Stage III.

Appendix table G1. Tilt volume, eruption efficiency and magma supply rate 1983-2008

Cycle	Event[1]	beg date	end date	Dt (yr)	T_{mag}[2]	T_{az}	T_{vol}[3]	E_{vol}[4]	E_{eff}[5]	msr[6]	Comment
Stage IA											Pu‘u ‘Ō‘o
Pu‘u ‘Ō‘o	def	1/2/1983	1/14/1983		45.6	118.67	0.0205				def rotates cw
		1/3/1983	1/8/1983		86.2	133.78	0.0387				
		1/9/1983	1/14/1983		8.8	160.97	0.0040				
	sum						0.0632				
Episode 1	E	1/3/1983	1/23/1983					0.0112	0.177		
		2/24/1983	3/3/1983		13.9	117.1	0.0063				
Episode 2	E	2/10/1983	2/25/1983					0.0112	1.790		
		3/27/1983	4/9/1983		33.7	124.91	0.0152				
Episode 3	E	3/21/1983	3/28/1983					0.0304	2.006		
		6/12/1983	6/17/1983		16.2	112.93	0.0073				
Episode 4	E	6/13/1983	6/17/1983					0.0088	1.205		
		6/30/1983	7/3/1983		9.3	119.74	0.0042				
Episode 5		6/29/1983	7/3/1983					0.0104	2.485		
		7/22/1983	7/25/1983		16.7	116.57	0.0075				
Episode 6		7/22/1983	7/25/1983					0.0072	0.957		
		8/15/1983	8/18/1983		19.7	116.94	0.0089				
Episode 7		8/15/1983	8/17/1983					0.0112	1.265		
		9/5/1983	9/7/1983		14.8	116.57	0.0067				
Episode 8		9/6/1983	9/7/1983					0.0064	0.959		
		9/15/1983	9/17/1983		16.2	115.2	0.0073				
Episode 9		9/15/1983	9/17/1983					0.0064	0.876		
		10/5/1983	10/7/1983		16.9	107.82	0.0076				
Episode 10		10/5/1983	10/7/1983					0.0112	1.472		
		11/5/1983	11/8/1983		21.1	109.92	0.0095				
Episode 11		11/5/1983	11/7/1983					0.0096	1.010		
		11/30/1983	12/2/1983		24.6	110.56	0.0111				
Episode 12		11/30/1983	12/1/1983					0.0064	0.578		
		1/19/1984	1/23/1984		13.9	110.7	0.0062				
Episode 13		1/20/1984	1/22/1984					0.0080	1.283		
		1/29/1984	2/1/1984		12.1	112.31	0.0055				
Episode 14		1/30/1984	1/31/1984					0.0048	0.881		
		2/12/1984	2/17/1984		15.7	110.43	0.0070				
Episode 15		2/14/1984	2/15/1984					0.0064	0.909		
		3/3/1984	3/5/1984		18.2	104.7	0.0082				
Episode 16		3/3/1984	3/4/1984					0.0096	1.174		
		3/30/1984	3/31/1984		14.6	109.6	0.0066				
Episode 17		3/30/1984	3/31/1984					0.0080	1.219		
		4/18/1984	4/22/1984		30.1	111.9	0.0135				
Episode 18		4/18/1984	4/21/1984					0.0192	1.418		
		5/14/1984	5/18/1984		8.6	126.87	0.0039				
Episode 19		5/16/1984	5/18/1984					0.0016	0.412		
		6/6/1984	6/11/1984		21.6	124.11	0.0097				

Cycle	Event[1]	beg date	end date	Dt (yr)	T_{mag}[2]	T_{az}	T_{vol}[3]	E_{vol}[4]	E_{eff}[5]	msr[6]	Comment
Episode 20		6/7/1984	6/8/1984					0.0032	0.330		
		6/30/1984	7/1/1984		12.7	107.2	0.0057				
Episode 21		6/30/1984	6/30/1984					0.0046	0.801		
		7/7/1984	7/10/1984		11.3	117.22	0.0051				
Episode 22		7/8/1984	7/9/1984					0.0063	1.227		
		7/28/1984	7/29/1984		16.2	112.93	0.0073				
Episode 23		7/28/1984	7/29/1984					0.0076	1.041		
		8/19/1984	8/21/1984		12.0	117.18	0.0054				
Episode 24		8/19/1984	8/20/1984					0.0093	1.723		
		9/19/1984	9/20/1984		20.9	114.44	0.0094				
Episode 25		9/19/1984	9/20/1984					0.0089	0.945		
		11/2/1984	11/4/1984		9.9	112.11	0.0045				
Episode 26		11/2/1984	11/2/1984					0.0053	1.181		
		11/19/1984	11/20/1984		10.5	105.95	0.0047				
Episode 27		11/20/1984	11/20/1984					0.0067	1.427		
		12/3/1984	12/4/1984		10.4	123.69	0.0047				
Episode 28		12/3/1984	12/4/1984					0.0099	2.126		
		1/2/1985	1/7/1985		16.5	112.54	0.0074				
Episode 29		1/3/1985	1/5/1985					0.0104	1.399		
		2/3/1985	2/5/1985		31.1	107.76	0.0140				
Episode 30		2/4/1985	2/5/1985					0.0113	0.806		
		3/11/1985	3/14/1985		30.9	116.57	0.0139				
Episode 31		3/13/1985	3/14/1985					0.0155	1.116		
		4/21/1985	4/23/1985		21.4	113.81	0.0096				
Episode 32		4/21/1985	4/22/1985					0.0130	1.353		
		6/12/1985	6/14/1985		7.7	109.8	0.0034				
Episode 33		6/13/1985	6/13/1985					0.0063	1.835		
		7/6/1985	7/8/1985		18.3	118.18	0.0082				
Episode 34		7/6/1985	7/7/1985					0.0085	1.032		
		7/25/1985	7/26/1985		13.1	118.81	0.0059				
Episode 35		7/26/1985	7/26/1985					0.0132	2.234		
Episode 35a		7/27/1985	8/12/1985					0.0132		0.3013	
		9/2/1985	9/3/1985		14.4	109.89	0.0065				
Episode 36		9/2/1985	9/2/1985					0.0092	1.421		
		9/24/1985	9/25/1985		14.3	104.04	0.0064				
Episode 37		9/24/1985	9/25/1985					0.0118	1.835		
		10/20/1985	10/22/1985		17.2	112.69	0.0077				

Cycle	Event[1]	beg date	end date	Dt (yr)	T_{mag}[2]	T_{az}	T_{vol}[3]	E_{vol}[4]	E_{eff}[5]	msr[6]	Comment
Episode 38		10/21/1985	10/21/1985					0.0118	1.534		
		11/13/1985	11/15/1985		16.0	110.07	0.0072				
Episode 39		11/13/1985	11/15/1985					0.0110	1.528		
		1/1/1986	1/2/1986		14.5	114.54	0.0065				
Episode 40		1/1/1986	1/2/1986					0.0093	1.419		
		1/27/1986	1/28/1986		30.9	111.8	0.0063				
Episode 41		1/27/1986	1/28/1986					0.0110	1.746		
		2/22/1986	2/23/1986		21.4	114.9	0.0080				
Episode 42		2/22/1986	2/23/1986					0.0097	1.210		
		3/21/1986	3/23/1986		7.7	107.2	0.0057				
Episode 43		3/22/1986	3/22/1986					0.0082	1.448		
		4/11/1986	4/14/1986		18.3	102.24	0.0110				
Episode 44		4/13/1986	4/14/1986					0.0092	0.836		
		5/7/1986	5/8/1986		13.1	113.05	0.0066				
Episode 45		5/7/1986	5/8/1986					0.0075	1.138		
		6/1/1986	6/2/1986		14.4	104.86	0.0066				
Episode 46		6/2/1986	6/2/1986					0.0078	1.195		
		6/25/1986	6/29/1986		14.3	116.03	0.0062				
Episode 47		6/26/1986	6/26/1986					0.0070	1.137		
		7/18/1986	7/19/1986		17.2	105.82	0.0081				erz dil rate =.0459
ep 48 fissure		7/18/1986	7/19/1986					0.0058	0.714		Owen, 2000. JGR
stage IA	sum	1/2/1983	7/19/1986	3.5428			0.4304	0.4604	1.070	0.1215	msr using tilt vol
	mean az					113.07				0.1300	msr using E vol
	std dev					5.5794				0.1760	add erz dil rate
Stage IB		7/20/1986	11/8/1991	5.3032							net def
	ks I	12/3/1990	12/4/1990		9.2	302.2	0.0041				
		1/7/1991	1/15/1991		8.8	101.31	0.0040				
	ks I	8/20/1991	8/24/1991		4.9	290.56	0.0022				
	sum						0.0103	0.7743		0.1479	E vol, (Sutton and others, 2003)
	add dil						0.0459			0.1938	
Stage IIA		11/8/1991	4/1/1997	5.3963							
		11/7/1991	11/15/1991		15.5	116.57	0.0070				
episode 49		11/8/1991	11/26/1991					0.0110			vol = .011 (mr)[7]
		2/17/1992	2/22/1992		18.0	102.93	0.0081				
episode 50		2/17/1992	3/3/1992	0.0411				0.0061			vol = .0032 (mr)[7]

Cycle	Event[1]	beg date	end date	Dt (yr)	T_{mag}[2]	T_{az}	T_{vol}[3]	E_{vol}[4]	E_{eff}[5]	msr[6]	Comment
		3/3/1992	3/4/1992		3.9	131.99	0.0017				
episode 51		3/7/1992	9/27/1992	0.5585				0.0826			vol = .024 (mr)[7]
		10/4/1992	10/6/1992		7.1	121.76	0.0032				
episode 52		10/3/1992	2/20/1993	0.3833				0.0567			vol = .0002 (mr)[7]
		2/7/1993	2/9/1993		5.1	128.16	0.0023				
		2/23/1993	3/2/1993		7.6	120.3	0.0034				
episode 53		2/20/1993	1/29/1997	3.9398				0.5824			vol = .535 (mr)
	ks inf	1/31/1996	2/1/1996		18. 5	307.41	0.0083				ep 54 dike vol
		10/25/1996	10/28/1996		4.5	116.57	0.0020				(Owen and others, 2000; Thornber and others, 1996)
		1/27/1997	1/30/1997		26.8	118.22	0.0121				1.3km*2.4 km*0.3m
episode 54		1/30/1997	1/31/1997					0.0003			vol = .00000936 km^3; (Desmarais and Segall, 2007)
episode 55		2/24/1997	4/1/1997	0.0986				0.0146			
	sum			5.3963			0.0481	0.7537		0.1486	vol =.00023km^3
	add dil						0.0459			0.1945	ep 55 vol from xt[8] total=.0159
stage IIB		4/1/1997	12/1/2003	6.6667							def
episode 55		4/1/1997	12/1/2003					0.9860			(Sutton and others, 2003)
		1/13/1998	1/15/1998		8.0	128.99	0.0036				ep 55 vol from xt[8] total=1.073
		9/11/1993	9/13/1993		7.1	158.63	0.0032				
		2/20/2000	2/22/2000		8.5	147.3	0.0038				
		12/20/2001	12/21/2001		4.1	129.29	0.0018				
		11/17/2003	11/18/2003		6.4	116.57	0.0029				
	sum						0.0154	0.9860		0.1502	
	add dil						0.0459			0.1961	msr before co_2 increase
Stage IIIA	total uplift	12/1/2003	5/18/2007	3.4606	57.8	316.21	0.0260				inf
episode 55		12/1/2003	5/18/2007					0.5570			ep 55 vol from xt[8] total=0.557
	def	12/4/2003	12/5/2003		5.9	140.91	0.0027				
		3/4/2004	3/5/2004		6.7	109.98	0.0030				co_2 began increase (3x) in 2004
		5/12/2004	5/14/2004		6.4	116.57	0.0029				
		6/3/2004	6/9/2004		8.0	115.64	0.0036				

Cycle	Event[1]	beg date	end date	Dt (yr)	T_{mag}[2]	T_{az}	T_{vol}[3]	E_{vol}[4]	E_{eff}[5]	msr[6]	Comment
		7/8/2004	7/11/2004		6.9	135	0.0031				
		7/27/2004	7/30/2004		9.8	130.29	0.0044				
		12/23/2004	12/27/2004		3.1	131.19	0.0014				
		1/27/2006	2/3/2006		5.5	128.66	0.0025				
		3/3/2006	3/8/2006		8.8	128.37	0.0040				
		3/10/2006	3/13/2006		9.3	111.8	0.0042				
Cycle	Event[1]	beg date	end date	Dt (yr)	T_{mag}[2]	T_{az}	T_{vol}[3]	E_{vol}[4]	E_{eff}[5]	msr[6]	Comment
		3/20/2006	3/22/2006		5.9	129.09	0.0027				
	sum						0.0604	0.5570		0.1784	
	add dil						0.0459			0.2243	
episode 55	total	2/24/1997	6/17/2007	10.3080				1.6600		0.1610	xt[8] mr[7]
stage IIIB		5/18/2007	3/19/2008	0.8378							def
		5/22/2007	5/29/2007		7.6	130.56	0.0034				
		6/15/2007	6/20/2007		34.8	122.51	0.0157				
episode 56	E	6/19/2007	6/19/2007					0.0000			Father's Day **E**; (Poland and others, 2008)
		7/6/2007	7/16/2007		4.7	132.56	0.0021				
episode 57	E	7/2/2007	7/20/2007					0.0007			
episode 58	E	7/21/2007	3/19/2008	0.6626				0.0913			volume from xt[8] mr[7] estimate
		7/21/2007	1/1/2009	1.4511							
	sum						0.0212	0.0913		0.1343	
	add dil						0.0459			0.1802	

[1] Abbreviations: inf=inf; def=def; ; vol=volume; dil=dilation; cw=clockwise; trans=transfer; I=intrusion; E=**E**; ks=Kīlauea's summit; erz=East rift zone; swr=Southwest rift zone; kfz=Koaʻe fault zone

[2] Uwēkahuna tilt magnitude in microradians

[3] Tilt volume in cubic kilometers=Uwēkahuna tilt magnitude*.00045 (see text for explanation)

[4] Values are equivalent magma volume obtained by multiplying published volumes by 0.8 to account for vesiculation

[5] 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.

[6] Minimum magma supply rate calculated as described in text. The volume equivalent for pre-**E** inf is added to the sum of volume equivalents for subsequent defs 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.

[7] mr = HVO monthly report

[8] xt = Christinal Heliker volume estimate (see Heliker and Mattox, 2003, table 1)

Cross references, chapter 7 tables and appendix G 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 intusions (green), and suspected deep intrusions (magneta)]

Chap. 7 page	Chap. 7 table	Row in table	App. G figure
140	7.1	13	G5
do	do	28	G6
141	7.1 cont	14	G7
148	7.2	3	G9
do	do	10	G10
do	do	12	G11
do	do	13	G12
149	7.2 cont	6,7	G13
do	do	10,11	G14
do	do	13,14	G15
156	7.3	1	G17
do	do	2	G18
do	do	3,5	G19
do	do	6	G20
do	do	24	G21
do	do	28	G22
do	do	32	G23A
157	7.3 cont	7,8	G23B
do	do	10-12	G23C
do	do	15	G24
158	7.4	6	G26
do	do	17,18	G27A
do	do	19	G27B

Chap. 7 page	Chap. 7 table	Row in table	App. G figure
do	do	20	G28
do	do	23	G29
do	do	24,26	G30
do	do	29	G31
do	do	31	G32
do	do	33	G33
159	7.4 cont	3	G34A
do	do	5	G34B
do	do	13	G35
do	do	15	G36
do	do	18	G37
do	do	21	G38
do	do	22	G39
do	do	24	G40
do	do	28	G41
do	do	29	G42
do	do	30	G43
160	7.4 cont	1,2	G44
do	do	3	G45
do	do	4	G46
do	do	6	G47
do	do	9	G48
do	do	13	G49
166	7.5	5	G51
do	do	11	G52
do	do	12	G53
do	do	15	G54
do	do	17	G55
do	do	18	G56
do	do	20,21	G57

Chap. 7 page	Chap. 7 table	Row in table	App. G figure
do	do	23.25	G58
do	do	30	G59
do	do	31-33	G60
167	7.5 cont	2	G60
do	do	5	G61
do	do	6	G62
do	do	7	G63
do	do	8	G64A
do	do	9	G64B
do	do	10	G64C
do	do	11	G64D
do	do	13-15	G65
do	do	16-17	G66
do	do	18-19	G67
do	do	20-21	G68
do	do	22	G69
do	do	23	G70
do	do	24	G71
do	do	26	G72
do	do	27	G73
do	do	28	G74
do	do	30	G75
do	do	31	G76
176	7.6	1	G77
do	do	3	G78
31	7.6 cont	1	G79
do	do	7	G80
do	do	8	G81
do	do	9	G82

Figure G1. Graphs showing Kīlauea short-period eathquakes per day and those of magnitude >4, 1982 to February 2008. *A–Z*, Data at 1-year intervals. Dates on figures in mm/dd/yyyy format.

Figure G2. Graphs showing Kīlauea long-period eathquakes per day and those of magnitude >4, 1982 to February 2008. *A–Z*, Data at 1-year intervals. Dates on figures in mm/dd/yyyy format.

Figure G3. Graphs showing Kīlauea earthquake swarms (long- and short-period), from 1982 to February 2007. *A–Z*, Data at 1-year intervals. Dates on figures in mm/dd/yyyy format.

Figure G4. Graphs showing Kīlauea activity from 1 January 1983–20 July 1986 (Puʻu ʻŌʻo-Kupaianaha eruption Stage IA**)**. Time series shows short- and long-period earthquake swarms for all regions as short vertical lines. Dates on figure in mm/dd/yyyy format. See text figure 7.1 and table 7.1 for event details.

Figure G5. Map showing activity around suspected deep intrusion on 23 December 1984. Data from 22–24 December. Dates on figure in mm/dd/yyyy format.

Figure G6. Map showing activity around suspected deep intrusion on 5–6 October 1985 beneath site SDI 2 (chap. 5, fig. 5.2). Data from 4–8 October.. Dates on figure in mm/dd/yyyy format.

Figure G7. Map showing activity around episode 48 fissure eruption on 18–19 July 1986 associated with migration of eruption from Puʻu ʻŌʻo to Kupaianaha. Data from 14–24 July. Dates on figure in mm/dd/yyyy format.

Figure G8. Graphs showing Kīlauea activity during Puʻu ʻŌʻo-Kupaianaha eruption Stage IB from 20 July 1986 to 8 November 1991. Time series shows short- and long-period earthquake.swarms for all regions. See text figure 7.5 and table 7.2 for event details. Dates on figure in mm/dd/yyyy format.

Figure G9. Map showing activity around Nāmakanipaio earthquake swarm of 13 September 1986. Data from 13–14 September. This sequence not associated with an east rift intrusion. Dates on figure in mm/dd/yyyy format.

Figure G10. Map showing activity around Nāmakanipaio earthquake swarm of 11–12 July 1988. This sequence not associated with an east rift intrusion. Dates on figure in mm/dd/yyyy format.

Figure G11. Map showing activity around upper east rift intrusion on 17 September 1988. Data from 12–21 September. Dates on figure in mm/dd/yyyy format.

Figure G12. Map showing *M*6.2 sourth flank earthquake on 25 June 1989, mainshock and aftershocks to 30 June. Dates on figure in mm/dd/yyyy format.

Figure G13. Map showing activity around summit intrusion on 4 December 1990. Data from 11 November to 6 December. Intrusion indicated by inflationary tilt begins near the shallow magma chamber (small open cross) imaged in 1996 by long-period seismic array. Intrusion then extends downrift to south and southeast. The intrusion was accompanied by a few long-period earthquakes. It is possible that this intrusion marks the advent of a second summit magma reservoir at ~1 km depth. This is the first of several intrusions to be preceded within a month or so by a Nāmakanipaio sequence (Okubo and Nakata, 2003). Dates on figure in mm/dd/yyyy format.

Figure G14. Map showing activity around upper east rift intrusion on 26 March 1991. Data from 25–30 March, with a precursory Nāmakanipaio sequence on 13 March. Dates on figure in mm/dd/yyyy format.

Figure G15. Map showing activity around upper east rift intrusion on 21 August 1991. Data from 17–25 August, with a precursory Nāmakanipaio sequence on 10 August. Dates on figure in mm/dd/yyyy format.

Figure G16. Graphs showing Kīlauea activity from 8 November 1991 to 1 January 1997 (Puʻu ʻŌʻo -Kupaianaha eruption Stage IIA**)**. Time series shows short- and long-period earthquake swarms for all regions as vertical lines connected across the time of intrusion. See text figure 7.7 and table 7.3 for event details. Dates on figure in mm/dd/yyyy format.

Figure G17. Map showing activity around eruption of 8–26 November 1991 (episode 49 to 26 November. Eruption returns to Puʻu ʻŌʻo accompanied by very few earthquakes. Dates on figure in mm/dd/yyyy format.

Figure G18. Map showing activity around upper east rift intrusion on 28–29 January 1992. Data from 25–31 January. Dates on figure in mm/dd/yyyy format.

Figure G19. Map showing activity around eruption of 17 February-3 March 1992 (episode 50 to 3 March). Data from 9–19 February. Eruption is preceded by a Nāmakanipaio sequence on 4 February 1992 and an east rift intrusion on 11–13 February. Dates on figure in mm/dd/yyyy format.

Figure G20. Map showing activity around upper east rift intrusion on 3–4 March 1992. Data from 1–5 March. Intrusion precedes episode 51 on 7 March. Dates on figure in mm/dd/yyyy format.

Figure G21. Map showing activity around suspected deep intrusion on 11–12 September 1993 beneath site SDI 2 (chap. 5, fig. 5.2). Data from 9–14 September. Dates on figure in mm/dd/yyyy format.

Figure G22. Map showing activity around deep magma-supply earthquake 1 February 1994. Data from 26 January to 4 February. *M*5.2 mainshock is located just offshore in the central south flank. Aftershocks trace a major part of the deep magma supply path (Wright and Klein, 2006). Possible foreshocks are located a considerable distance to the west and north. Dates on figure in mm/dd/yyyy format.

Figure G23. Maps showing: *A*, Activity around a suspected deep intrusion on 25–26 October 1994. Data from 23 to 27 October. *B*–*C*, Activity around a paired inflationary intrusion on 1–2 February 1996, within which an eruption “surge” occurs about 3 hours after the beginning of intrusion—(*B*) short-period seismicity and (*C*) long-period seismicity. Data from 27 January to 11 February. Dates on figure in mm/dd/yyyy format.

Figure G24. Map showing activity around a suspected deep intrusion on 25–26 October 1996 beneath site SDI 2 (see chap. 5, fig. 5.2). Data from 23–30 October. Dates on figure in mm/dd/yyyy format.

Figure G25. Graphs showing Kīlauea activity from 1 January 1997–1 December 2003 (Puʻu ʻŌʻo-Kupaianaha eruption Stage IIB). Time series shows short- and long-period earthquake swarms for all regions as vertical lines. See text figure 7.10 and table 7.4 for event details. Dates on figure in mm/dd/yyyy format.

Figure G26. Map showing earthquake locations for a Nāmakanipaio sequence on 2–3 June 1997 not associated with an east rift intrusion. Data from 30 May to 10 June. Dates on figure in mm/dd/yyyy format.

Figure G27. Map showing activity around a small summit and upper east rift intrusion accompanied by a "surge" on 14 January 1988. Dates on figure in mm/dd/yyyy format. *A*, Short-period seismicity. *B*, Long-period seismicity.

Figure G28. Map showing activity around a Nāmakanipaio sequence on 27–28 January 1998 not associated with an east rift intrusion. Data from 26–28 January. Dates on figure in mm/dd/yyyy format.

Figure G29. Map showing activity around a silent earthquake (Montgomery-Brown and others, 2009) on 19 September 1998. Data from 18–20 September. The earthquake pattern resembles that of suspected deep intrusions beneath zone SDI 2. Dates on figure in mm/dd/yyyy format.

Figure G30. Map showing Kīlauea activity on 27–28 September 1998. Data from 27–30 September. Two mainshocks: *M*4.6 (27 September) located northeast of Kīlauea Caldera, and *M*4.8 (28 September) located in the eastern south flank, the latter with aftershocks. Dates on figure in mm/dd/yyyy format.

Figure G31. Map showing activity around *M*5.2 Hilea (Mauna Loa) earthquake on 16 April 1999 and aftershocks. Data from 16–23 April. Seismicity beneath the Kīlauea lower southwest rift zone was triggered beginning 1 hour after the mainshock and continuing for nearly 15 hours. Dates on figure in mm/dd/yyyy format.

Figure G32 Map showing activity around 26 May 1999 Nāmakanipaio mainshock *M*4.3 with aftershocks. Data from 25–30 May. Dates on figure in mm/dd/yyyy format.

Figure G33. Map showing activity around upper east rift intrusion on 12 September 1999. Data from 10–16 September. Dates on figure in mm/dd/yyyy format.

Figure G34. Map showing activity around upper east rift intrusion on 23–24 February 2000, preceded by a swarm of deep magma-supply earthquakes. Data from 17–29 February. *A*, Short-period seismicity. *B*, Long-period seismicity.

Figure G35. Map showing activity around an eruptive surge on 24 September 2000. Data from 20–28 September. Dates on figure in mm/dd/yyyy format.

Figure G36. Map showing activity around a silent earthquake (Montgomery-Brown and others, 2009) on 8–9 November 2000 preceding a broader south flank earthquake swarm. Data from 8–18 November. Dates on figure in mm/dd/yyyy format.

Figure G37. Map showing activity around an eruptive surge on 20 May 2001. Data from 16–24 May. Dates on figure in mm/dd/yyyy format.

Figure G38. Map showing activity around suspected deep intrusion on 23–24 June 2001 beneath site SDI 2 (chap. 5, fig. 5.2). Data from 22–30 June. Dates on figure in mm/dd/yyyy format.

Figure G39. Map showing activity around a silent earthquake (Montgomery-Brown and others, 2009) on 19 September 2001. Data from 17–22 September. Dates on figure in mm/dd/yyyy format.

Figure G40. Map showing activity around an eruptive surge on 9 December 2001 preceding a small summit intrusion. Data from 8–15 December. Dates on figure in mm/dd/yyyy format.

Figure G41. Map showing activity around a small upper east rift intrusion on 19 December 2001. Data from 17–23 December. Dates on figure in mm/dd/yyyy format.

Figure G42. Map showing activity around suspected deep intrusion on 12 February 2002 beneath site SDI 2 (chap. 5, fig. 5.2). Data from 10–16 February. Dates on figure in mm/dd/yyyy format.

Figure G43. Map showing acivity around an eruptive surge on 5 April 2002. Data from 2–8 April. No earthquakes occurred during the surge. Dates on figure in mm/dd/yyyy format.

Figure G44. Map showing activity around two suspected deep intrusions on 21 August and 28–29 August 2002 beneath site SDI 2 (chap. 5, fig. 5.2). Data from 20–31 August. Dates on figure in mm/dd/yyyy format.

Figure G45. Map showing activity around a silent earthquake (Montgomery-Brown and others, 2009) on 17 December 2002. Data from 11–18 December. Dates on figure in mm/dd/yyyy format.

Figure G46. Map showing activity around an eruptive surge on 21 January 2003. Data from 8–28 January. No earthquakes during the surge. Dates on figure in mm/dd/yyyy format.

Figure G47. Map showing activity around a Nāmakanipaio sequence on 6–7 April 3003, preceded and followed by deep magma supply earthquakes. Data from 31 March-14 April. Dates on figure in mm/dd/yyyy format.

Figure G48. Map showing activity around a silent earthquake (Montgomery-Brown and others, 2009) on 3 July 2003 preceded by a suspected deep intrusion near site SDI 3 (chap. 5, fig. 5.2) on 1–2 July. Data from 28 June-5 July. Dates on figure in mm/dd/yyyy format.

Figure G49. Map showing activity around an eruptive surge on 8 August 2003, with both short-period and long-period summit seismicity before and after. Data from 6–10 August. Dates on figure in mm/dd/yyyy format.

Figure G50. Graphs showing Kīlauea activity from 1 December 2003 to 19 March 2008 (Puʻu ʻŌʻo-Kupaianaha eruption Stage III). Time series shows short- and long-period earthquake swarms for all regions as vertical lines connected across the times of intrusion. Dates on figure in mm/dd/yyyy format. See text fig. 7.13 and tables 7.5 and 7.6 for event details.

Figure G51. Map showing activity around a suspected deep intrusion on 22 December 2003 beneath site SDI 2 (see chap. 5, fig. 5.2). Data from 18–26 December 2003. Dates on figure in mm/dd/yyyy format.

Figure G52. Map showing activity around an upper east rift intrusion on 4 March 2004 accompanying a surge. Data from 2–8 March 2004. Dates on figure in mm/dd/yyyy format.

Figure G53. Map showing seismic activity preceding and following an eruptive surge on 20 March 2004. Data from 18–26 March 2004. Dates on figure in mm/dd/yyyy format.

Figure G54. Map showing activity around an uppermost east rift intrusion on 12–13 May 2004, preceding an eruptive surge on 15 May. Data from 8–18 May. Dates on figure in mm/dd/yyyy format.

Figure G55. Map showing activity around a small upper east rift intrusion 4 June 2004. Data from 3–9 June. Dates on figure in mm/dd/yyyy format.

Figure G56. Map showing activity around a double east rift intrusion on 9–10 July 2004 showing downrift migration of epicenters. Data from 1–14 July. Pre- and posteruption south flank earthquakes extend well east of the rift intrusion site. Dates on figure in mm/dd/yyyy format.

Figure G57. Map showing activity around an upper east rift intrusion on 27 July 2004 accompanying a surge. Data from 25 July-2 August. Earthquakes after the surge occur near the upper middle east rift boundary. Dates on figure in mm/dd/yyyy format.

Figure G58. Map showing activity around a Nāmakanipaio sequence on 2 November 2004. Data from 29 October-9 November. Dates on figure in mm/dd/yyyy format.

Figure G59. Map showing activity around an upper east rift intrusion on 22–23 December 2004. Data from 19–29 December. Dates on figure in mm/dd/yyyy format.

Figure G60. Map showing activity around a silent earthquake (Montgomery-Brown and others, 2009) on 25–27 January 2005, preceded on 24-25 January by an upper east rift intrusion and followed on 27-29 January by a Nāmakanipaio sequence. Dates on figure in mm/dd/yyyy format.

Figure G61. Map showing activity around an upper-middle east rift intrusion on 29–30 December 2005, preceded by deep magma-supply earthquakes. Data from 25 December 2005 to 2 January 2006. Dates on figure in mm/dd/yyyy format.

Figure G62. Map showing activity around the beginning of paired intrusions on the uppermost seismic southwest rift zone and the uppermost east rift zone on 15–16 January 2006. Data from 14–19 January. The first intrusion is on the upper east rift. Dates on figure in mm/dd/yyyy format.

Figure G63. Map showing activity around a Nāmakanipaio sequence on 22–23 January 2006. Data from 20–23 January. Dates on figure in mm/dd/yyyy format.

Figure G64. Maps showing activity around a series of nearly continuous paired intrusions into the upper east rift zone and the uppermost seismic southwest rift zone in January-February 2006. Dates on figure in mm/dd/yyyy format. *A*, 25–26 January 2006: An intrusion into the uppermost east rift zone. Data from 24–28 January. *B*, 29–31 January 2006: Two intrusions beneath the upper east rift zone separated by about 10 hours. The preintrusion east rift seismicity is colocated with the syneruption seismicity. Data from 29–31 January. *C*, 1–8 February 2006: A large paired intrusion into the upper east rift zone and upper seismic southwest rift zone accompanied by several deep magma-supply earthquakes. Data from 1–9 February. *D*, 9–18 February 2006: A continuation of of nearly continuous intrusions into the upper east rift zone and the uppermost seismic southwest rift zone, consisting of successive swarms of 40, 38, 10, 12, and 48 rift events. Data from 9–20 February.

Figure G65. Map showing activity around two intrusions overlapping in time on 22–24 February 2006, which are the last of a 1-month sequence of paired intrusions on the uppermost east rift zone and uppermost seismic southwest rift zone. Data from 21–25

February. The intrusions were preceded by a Nāmakanipaio sequence that began on 22 February. Dates on figure in mm/dd/yyyy format.

Figure G66. Map showing activity during waning of nearly continuous intrusion into the upper east rift zone and the uppermost seismic southwest rift zone on 27 February to 1 March 2006. Data from 26 February to 2 March. Dates on figure in mm/dd/yyyy format.

Figure G67. Map showing activity around Nāmakanipaio sequence on 1–4 March 2006, directly preceding a small upper seismic southwest rift intrusion. Data from 1–5 March. Dates on figure in mm/dd/yyyy format.

Figure G68. Map showing activity around Nāmakanipaio sequence on 6 March 2006, overlapping with a small upper seismic southwest rift intrusion on 6–7 March. Data from 5–7 March. Dates on figure in mm/dd/yyyy format.

Figure G69. Map showing activity around Nāmakanipaio sequence on 11 March 2006 accompanying a small intrusion into the uppermost seismic southwest rift zone. Data from 10–12 March. Dates on figure in mm/dd/yyyy format.

Figure G70. Map showing activity around a suspected deep intrusion on 16 March 2006 beneath site SDI 2 (chap. 5, fig. 5.2). Data from 15–17 March. Dates on figure in mm/dd/yyyy format.

Figure G71. Map showing activity around a small upper east rift intrusion on 22–23 March 2006, followed by paired (nonswarm) activity beneath the upper east rift zone and upper seismic southwest rift zone. Data from 19–29 March. Dates on figure in mm/dd/yyyy format.

Figure G72. Map showing activity around a small upper-middle east rift intrusion on 9–10 May 2006, preceded by paired (nonswarm) activity beneath the upper east rift zone and upper seismic southwest rift zone and a possible suspected deep intrusion beneath the central south flank. Data from 4–12 May. Dates on figure in mm/dd/yyyy format.

Figure G73. Map showing activity around an intrusion on 29–30 July 2006 beneath the upper seismic southwest rift zone. Data from 28–31 July. Dates on figure in mm/dd/yyyy format.

Figure G74. Map showing activity around an upper east rift intrusion on 3–4 August 2006, followed by paired (nonswarm) activity beneath the upper east rift zone and upper seismic southwest rift zone. Data from 1–8 August. Dates on figure in mm/dd/yyyy format.

Figure G75. Map showing activity around a suspected deep intrusion on 3–5 April 2007 beneath the central south flank. Continuous GPS measurement did not record a spreading step. Data from 1–10 April. Dates on figure in mm/dd/yyyy format.

Figure G76. Map showing activity around a silent earthquake (Montgomery-Brown and others, 2010) on 16 April 2007 associated with very low seismicity. Data from 15–18 April. Dates on figure in mm/dd/yyyy format.

Figure G77. Map showing activity around two intrusions on 24–27 May 2007 beneath the upper east rift zone separated by about 9 hours. Data from 22–29 May. Dates on figure in mm/dd/yyyy format.

Figure G78. Map showing activity around intrusion on 31 May-1 June 2007 beneath the uppermost seismic southwest rift zone. Data from 30 May-2 June. Dates on figure in mm/dd/yyyy format.

Figure G79. Map showing activity around silent earthquake (Montgomery-Brown and others, 2009) on 17–18 June 2007 that overlaps in time with the intrusion accompanying the Father's Day eruption (see text fig. 7.14). Data from 17–18 June. Dates on figure in mm/dd/yyyy format.

Figure G80. Map showing activity around a small upper east rift intrusion on 3–4 July 2007. Data from 2–4 July. Dates on figure in mm/dd/yyyy format.

Figure G81. Map showing activity around a small middle east rift intrusion on 5–6 July 2007, anticipating the east rift eruption of 21 July (vents shown). Data from 5–11 July. Dates on figure in mm/dd/yyyy format.

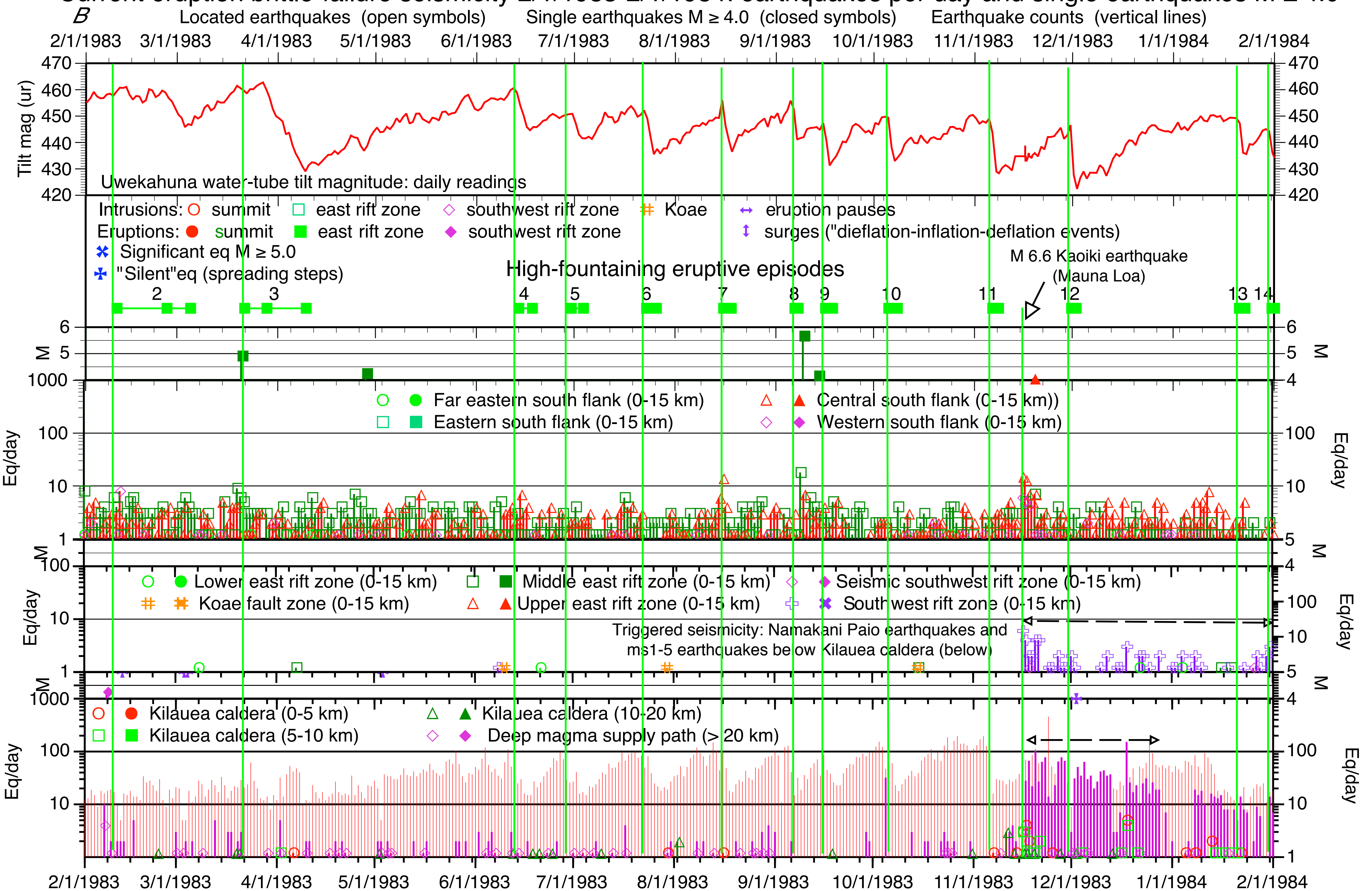
Figure G82. Map showing activity around an upper east rift intrusion on 16–17 July 2007, precursory to the eruption on 21 July (vents shown). Data from 12–21 July. South flank seismicity occurs only before and after the intrusion and extends to a region south of the eruption vents. Dates on figure in mm/dd/yyyy format.

Appendix figure G1 a

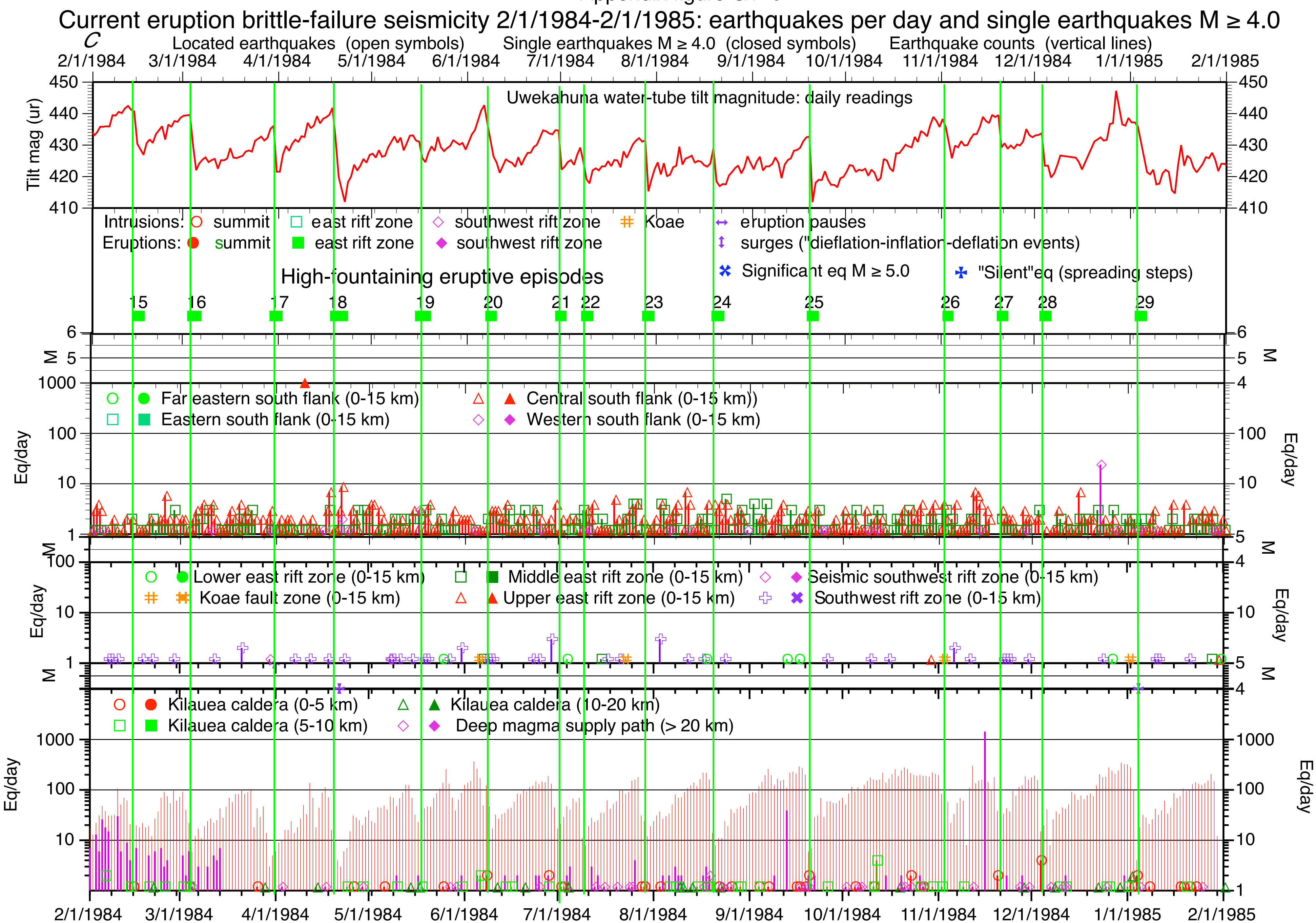
Current eruption brittle-failure seismicity 2/1/1982-2/1/1983: earthquake swarms and single earthquakes M ≥ 4.0

Appendix figure G1 b

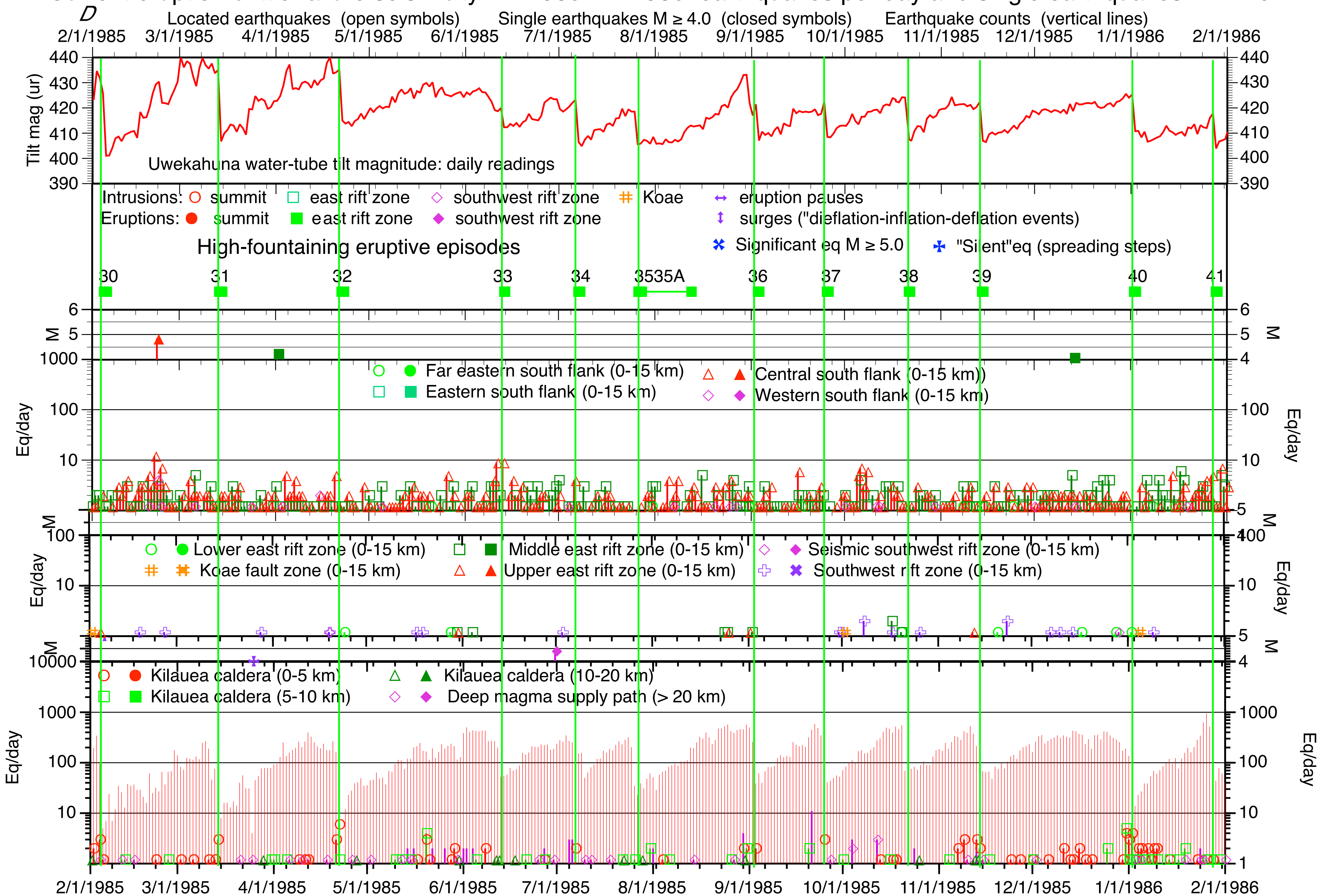
Current eruption brittle-failure seismicity 2/1/1983-2/1/1984: earthquakes per day and single earthquakes M ≥ 4.0



Appendix figure G1 c

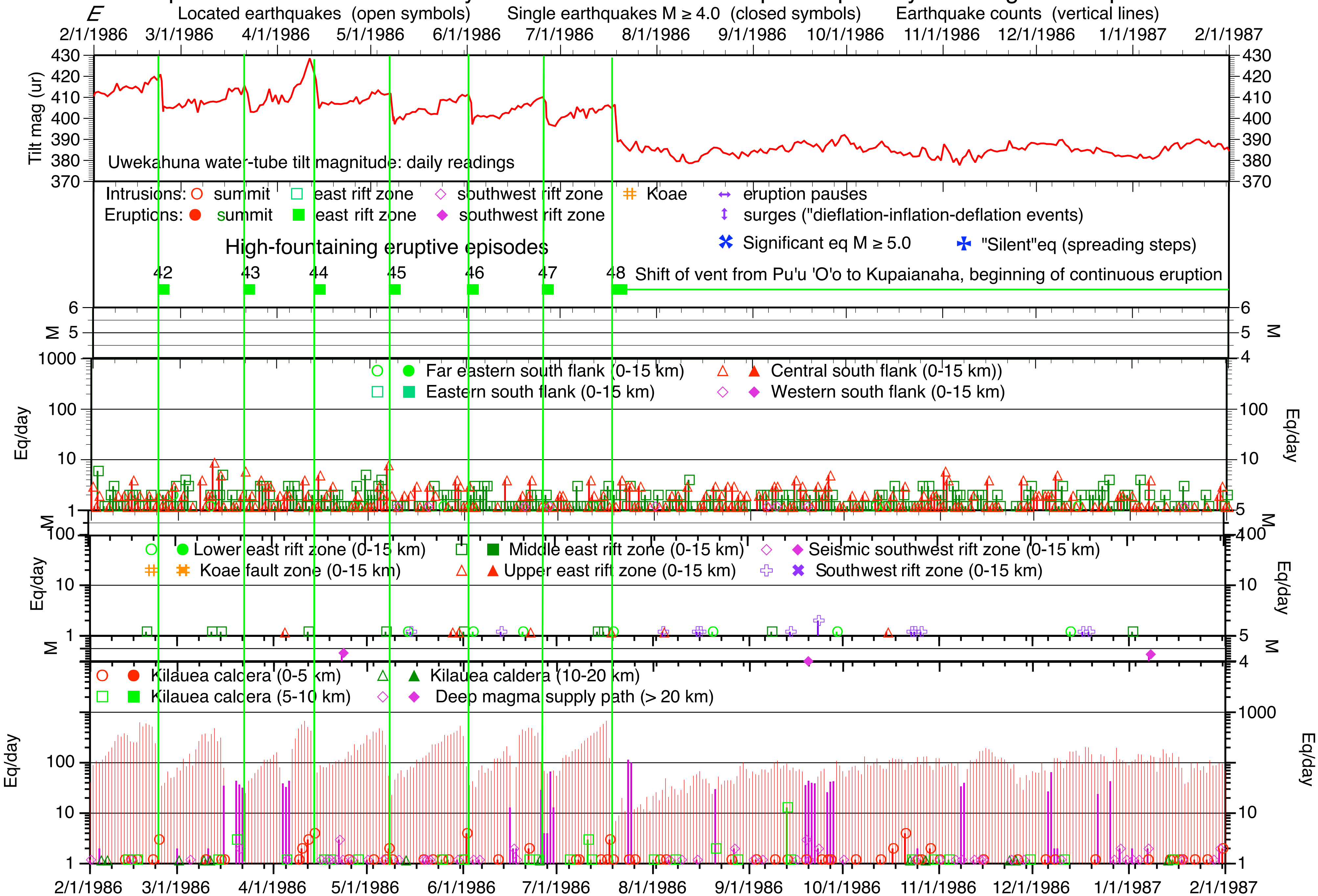


Appendix figure G1 d



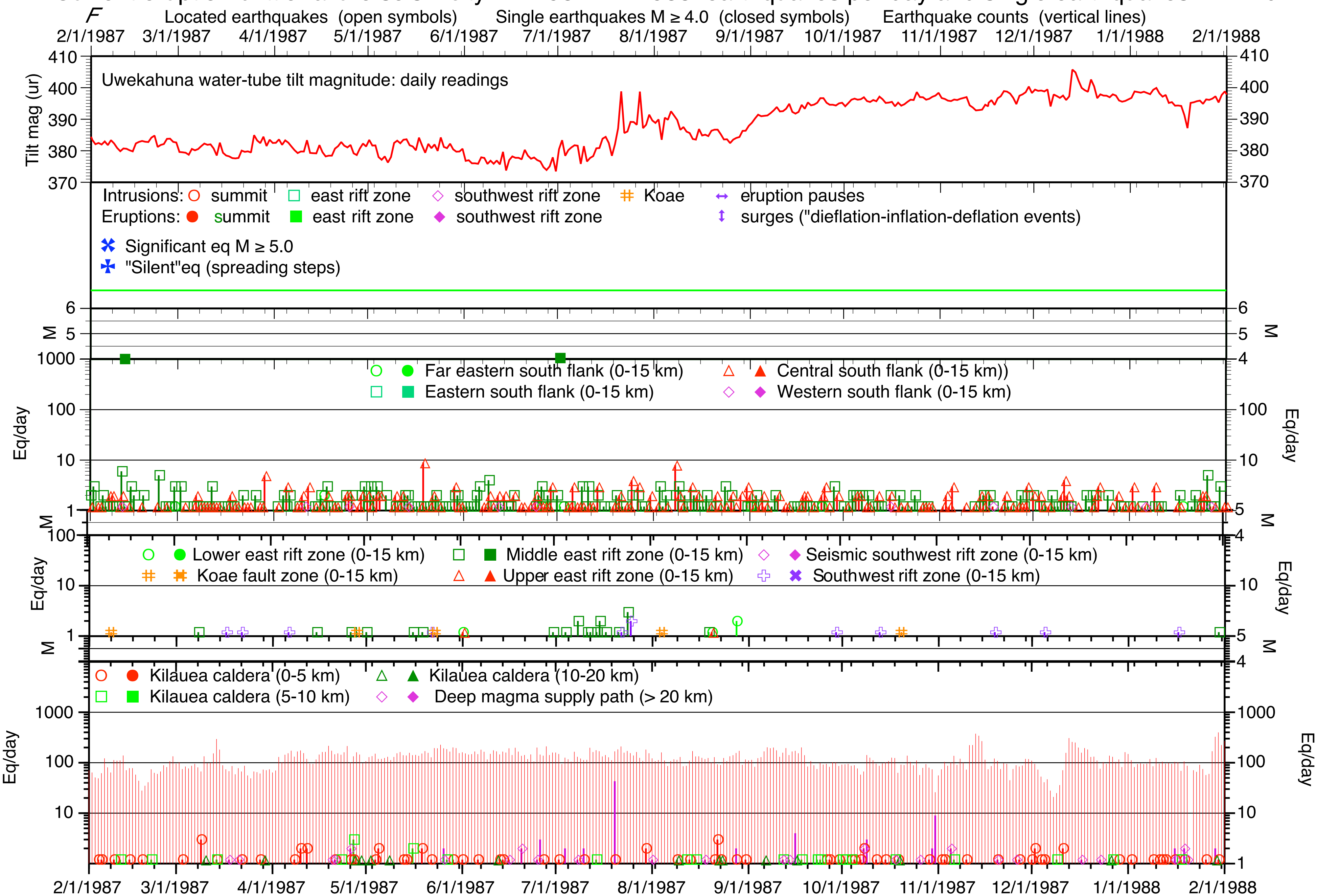
Appendix figure G1 e

Current eruption brittle-failure seismicity 2/1/1986-2/1/1987: earthquakes per day and single earthquakes M ≥ 4.0

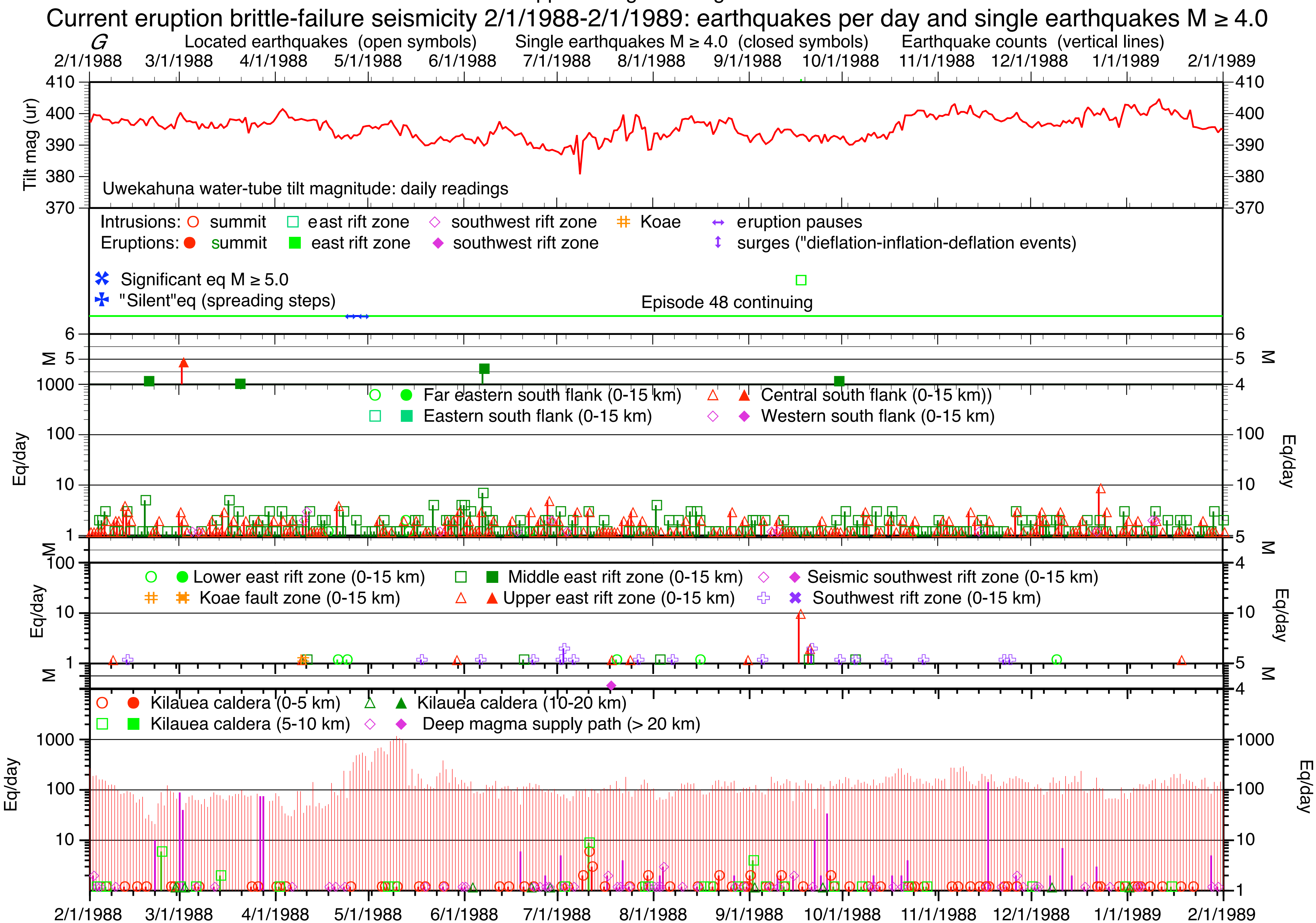


Appendix figure G1 f

Current eruption brittle-failure seismicity 2/1/1987-2/1/1988: earthquakes per day and single earthquakes M ≥ 4.0

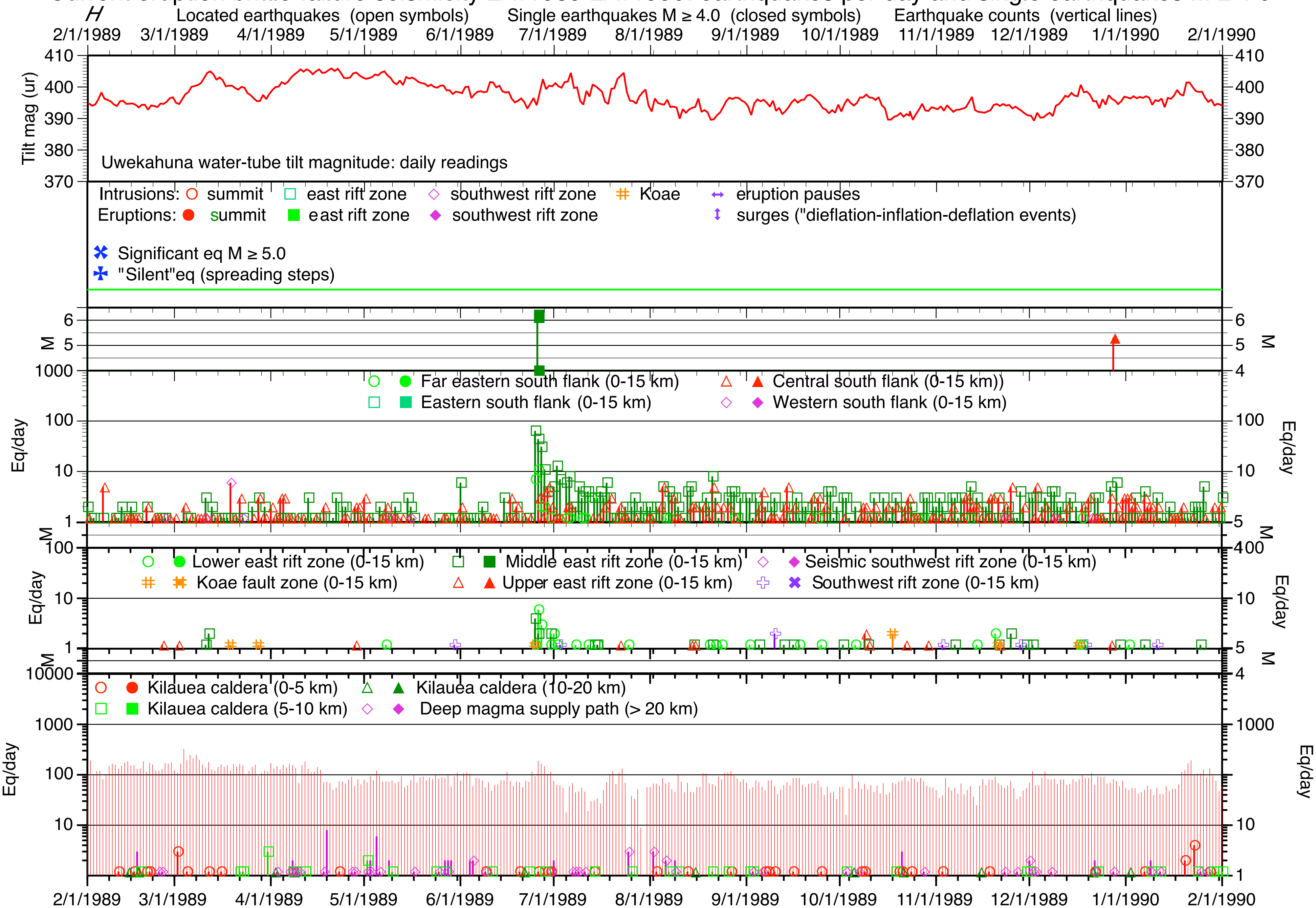


Appendix figure G1 g



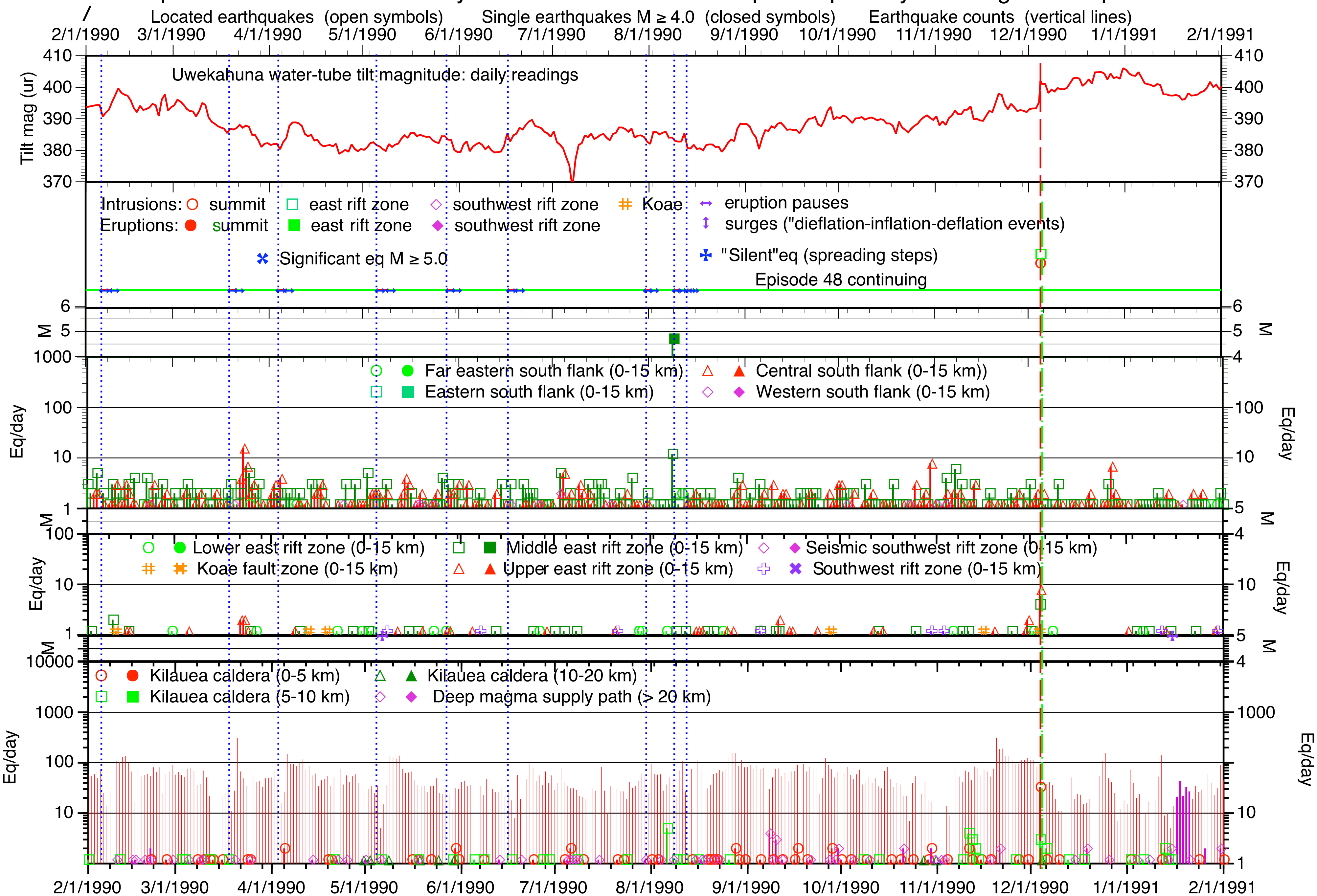
Appendix figure G1 h

Current eruption brittle-failure seismicity 2/1/1989-2/1/1990: earthquakes per day and single earthquakes M ≥ 4.0



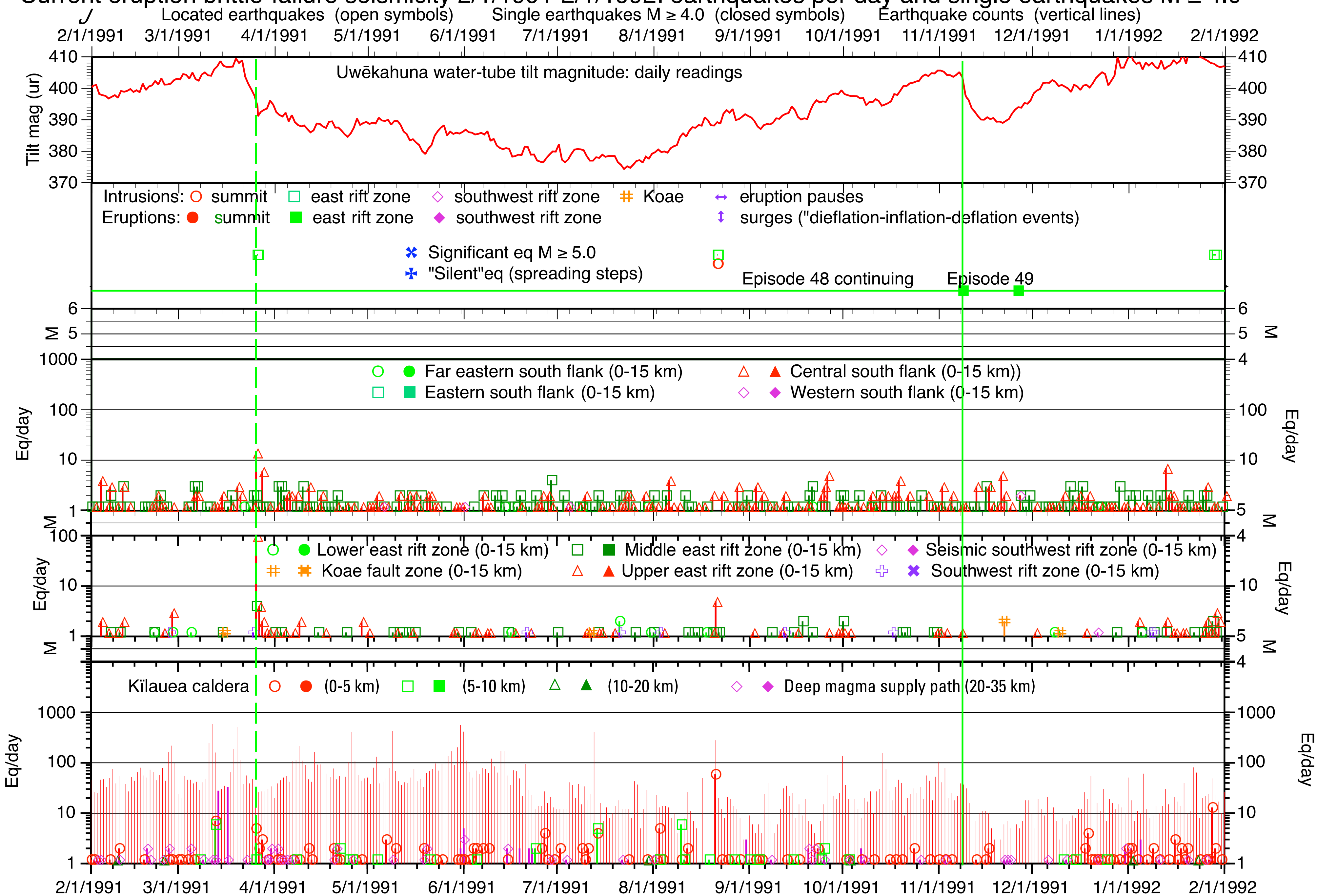
Appendix figure G1 i

Current eruption brittle-failure seismicity 2/1/1990-2/1/1991: earthquakes per day and single earthquakes M ≥ 4.0



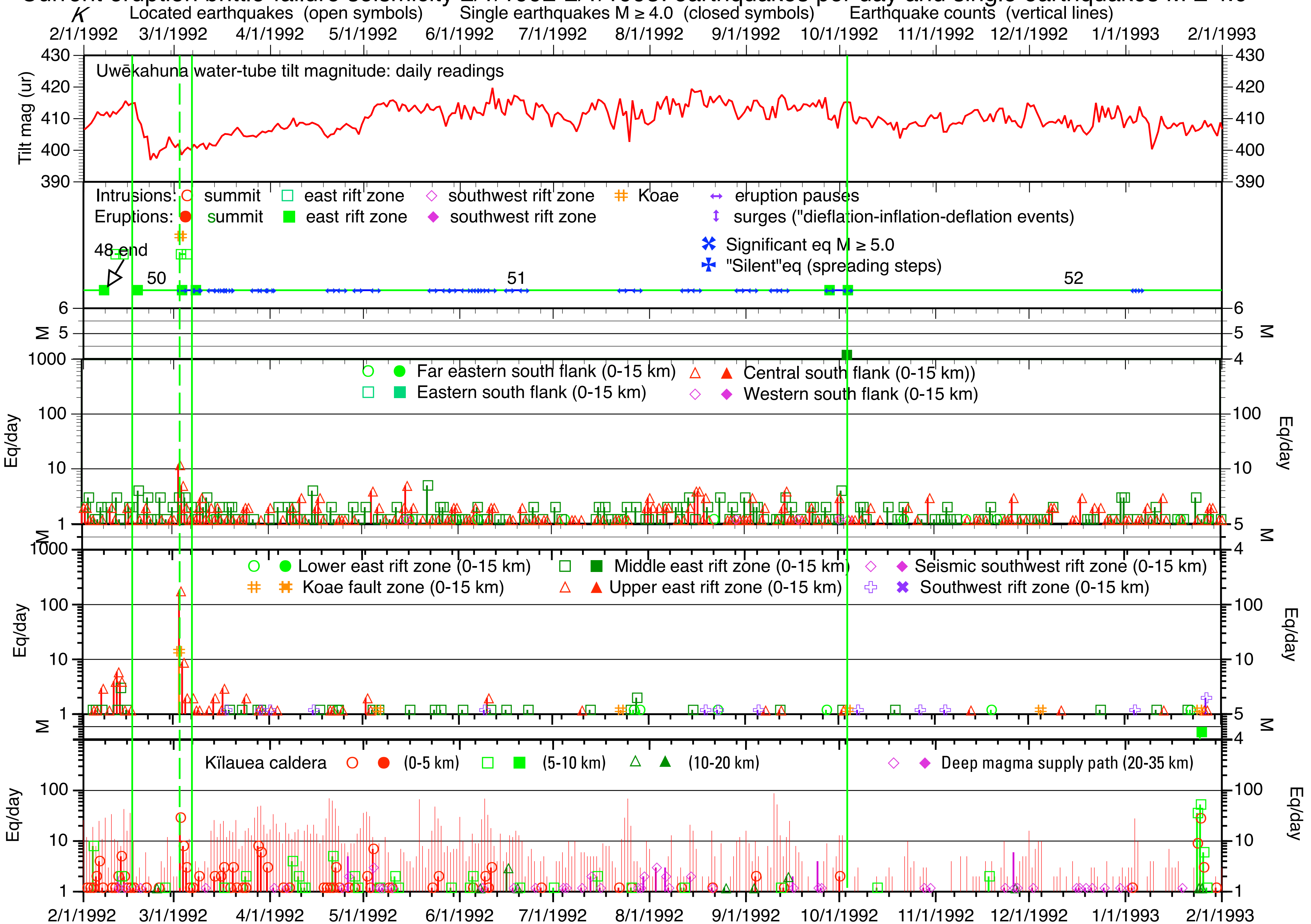
Appendix figure G1 j

Current eruption brittle-failure seismicity 2/1/1991-2/1/1992: earthquakes per day and single earthquakes M ≥ 4.0



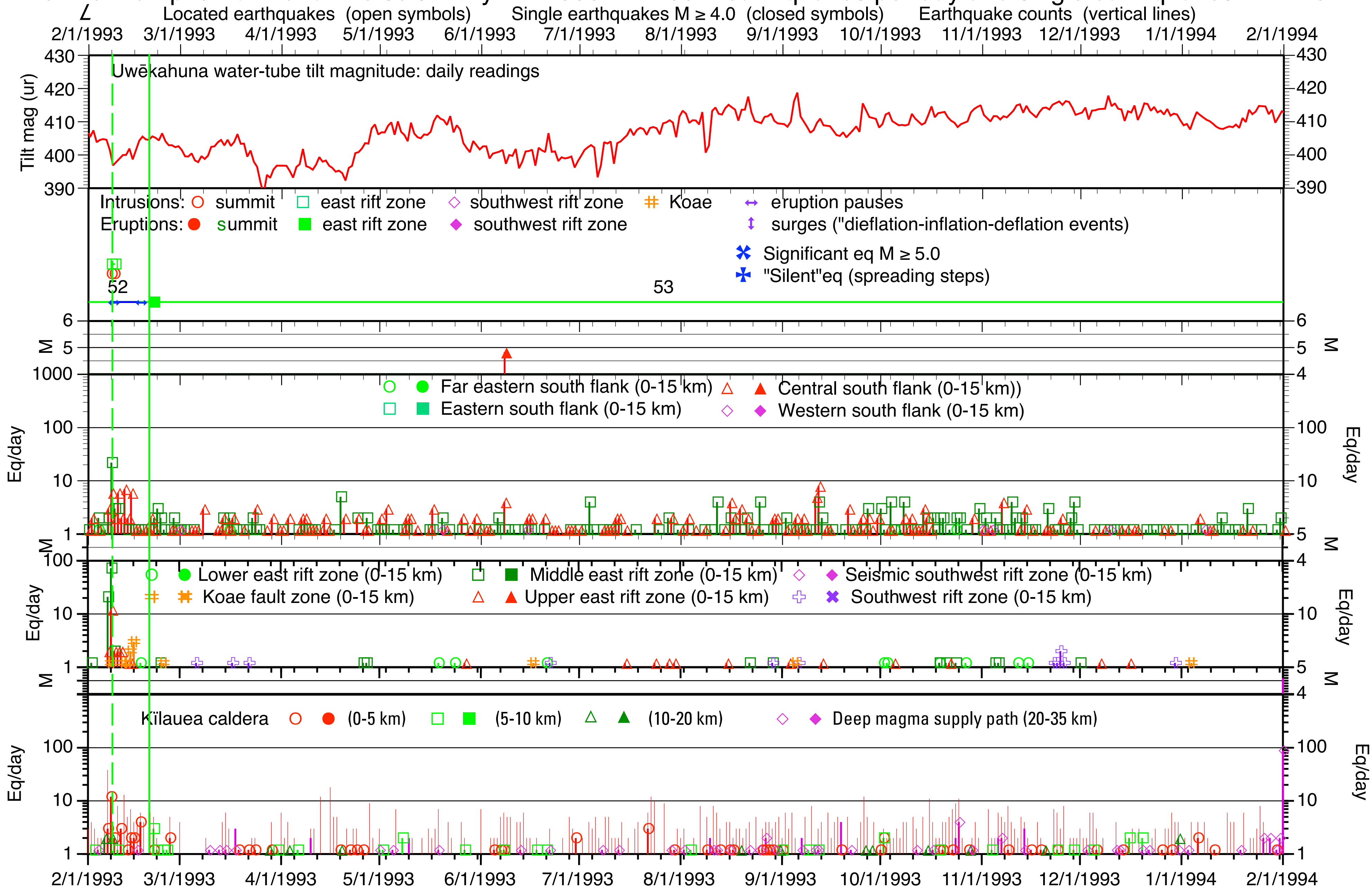
Appendix figure G1 k

Current eruption brittle-failure seismicity 2/1/1992-2/1/1993: earthquakes per day and single earthquakes M ≥ 4.0



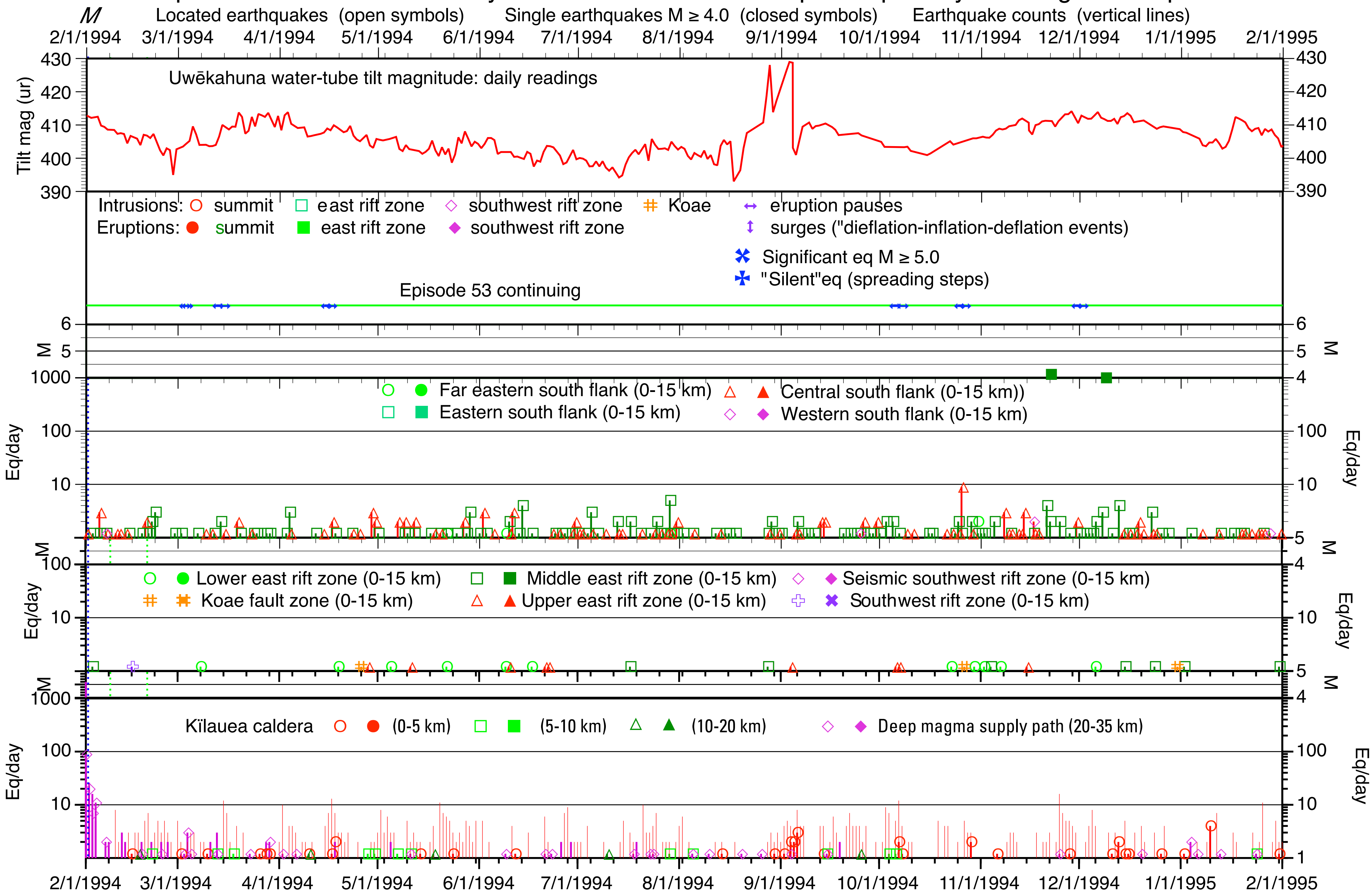
Appendix figure G1 l

Current eruption brittle-failure seismicity 2/1/1993-2/1/1994: earthquakes per day and single earthquakes M ≥ 4.0



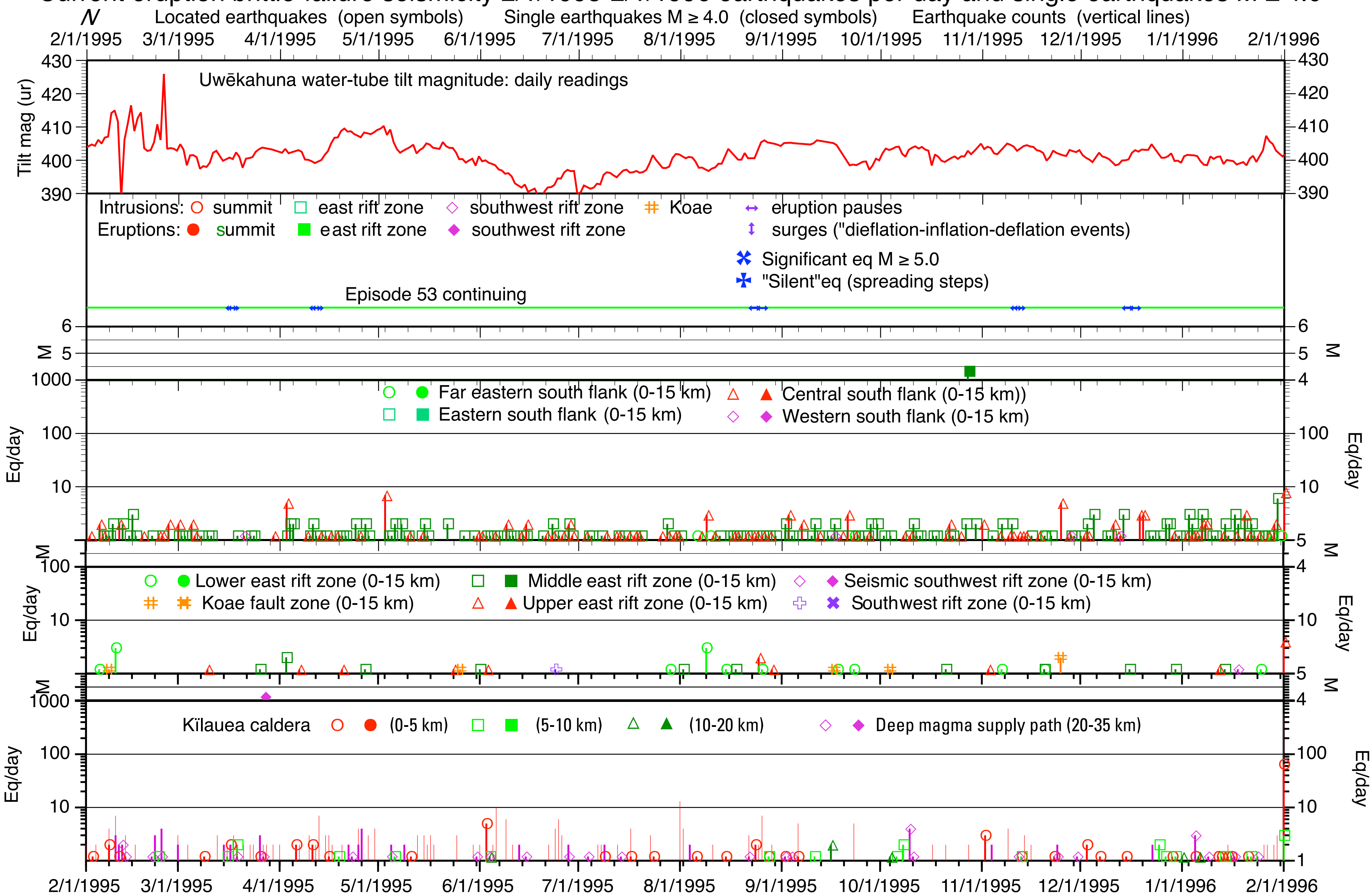
Appendix figure G1 m

Current eruption brittle-failure seismicity 2/1/1994-2/1/1995: earthquakes per day and single earthquakes M ≥ 4.0



Appendix figure G1 n

Current eruption brittle-failure seismicity 2/1/1995-2/1/1996 earthquakes per day and single earthquakes M ≥ 4.0

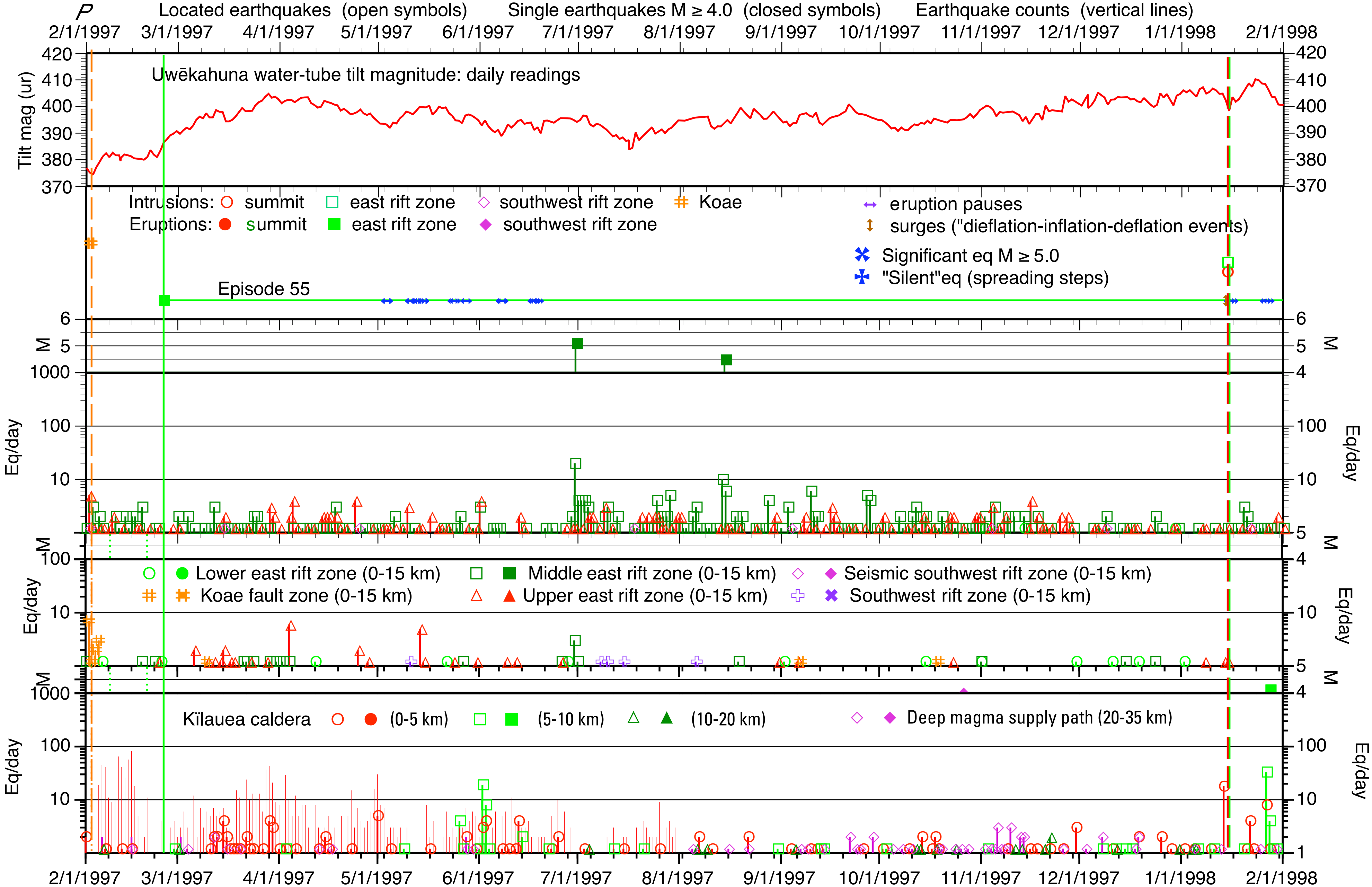


Appendix figure G1 o

Current eruption brittle-failure seismicity 2/1/1996-2/1/1997: earthquakes per day and single earthquakes M ≥ 4.0

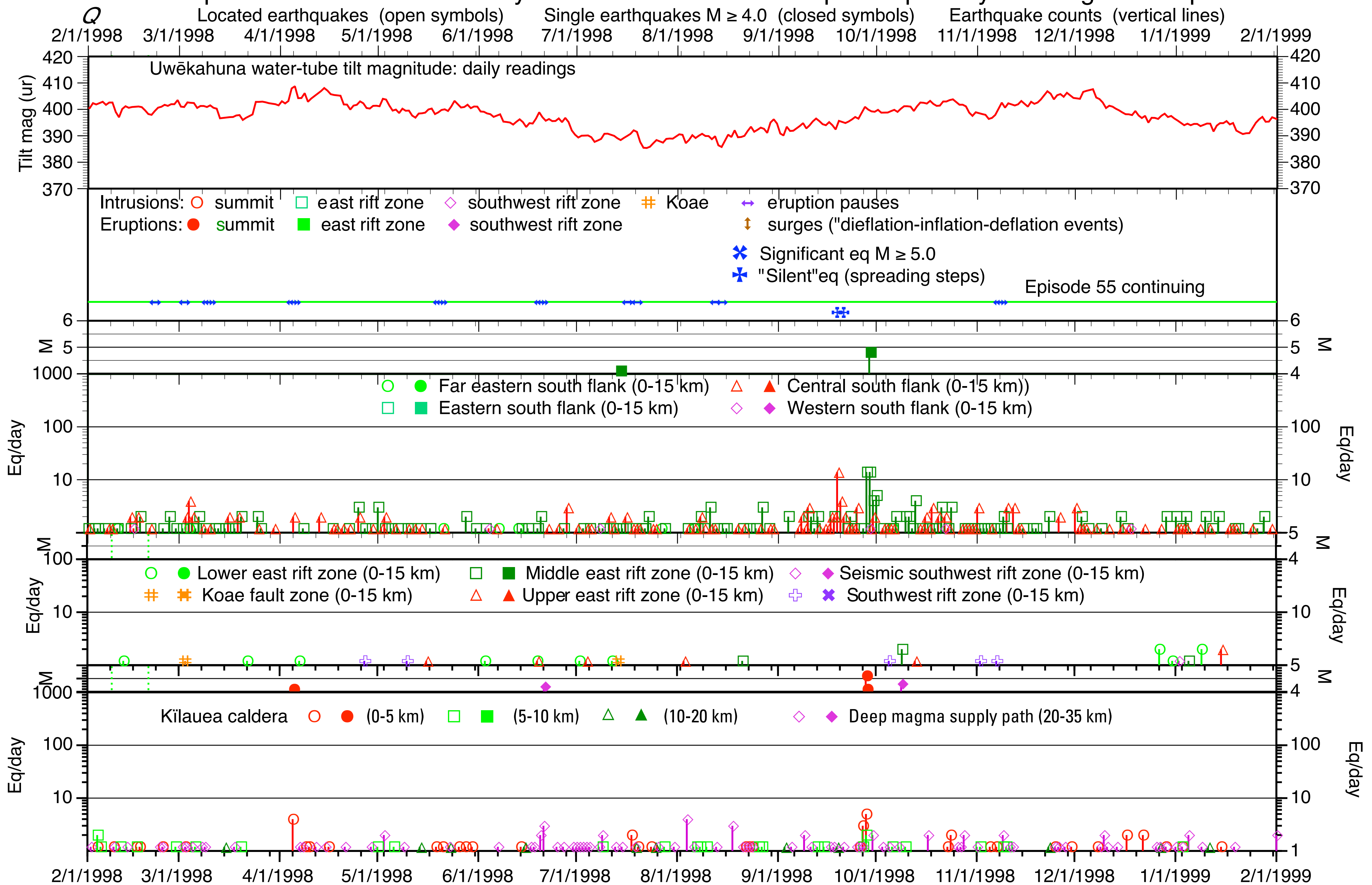
Appendix figure G1 p

Current eruption brittle-failure seismicity 2/1/1997-2/1/1998 earthquakes per day and single earthquakes M ≥ 4.0



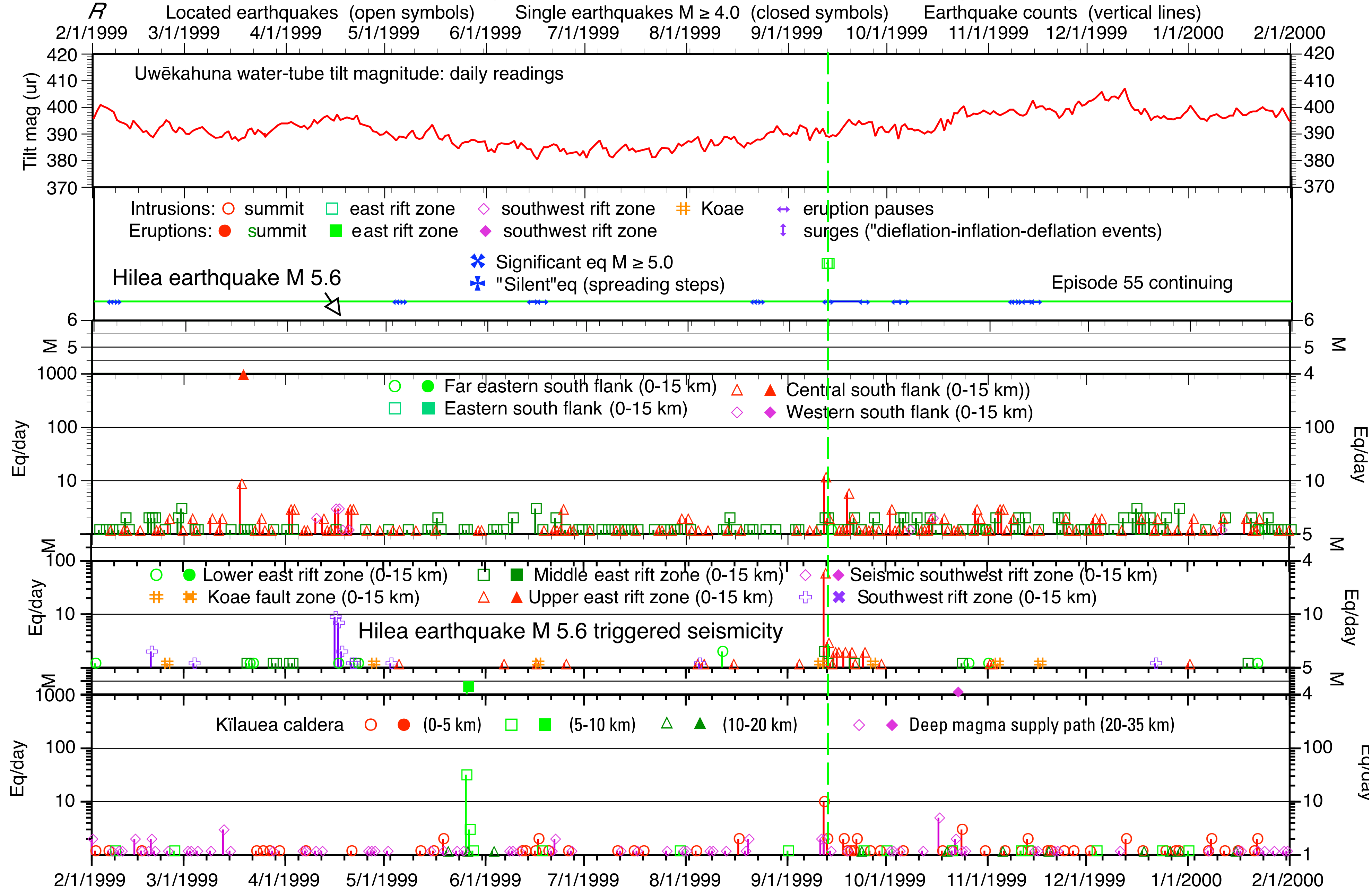
Appendix figure G1 q

Current eruption brittle-failure seismicity 2/1/1998-2/1/1999: earthquakes per day and single earthquakes M ≥ 4.0



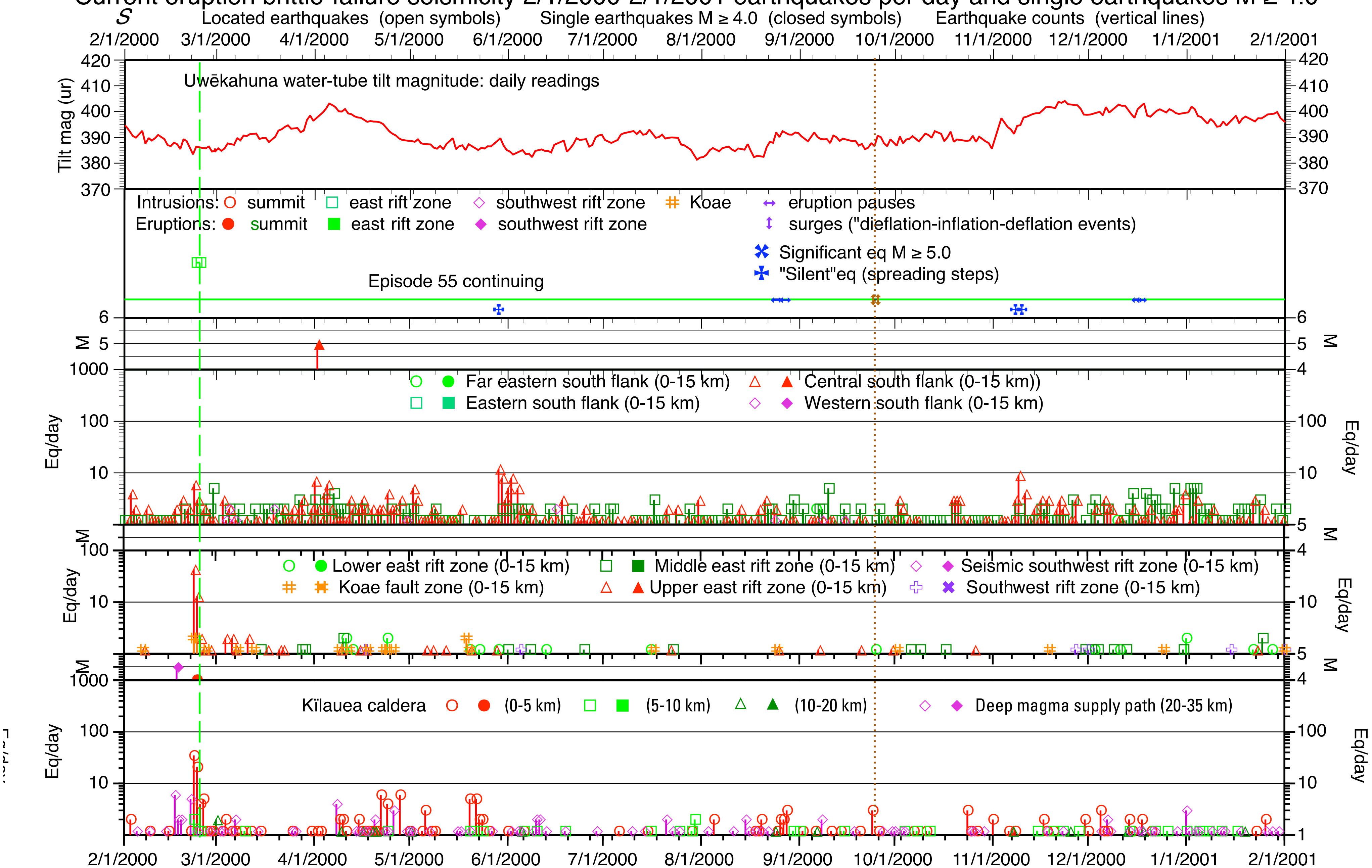
Appendix figure G1 r

Current eruption brittle-failure seismicity 2/1/1993-2/1/1994: earthquakes per day and single earthquakes M ≥ 4.0



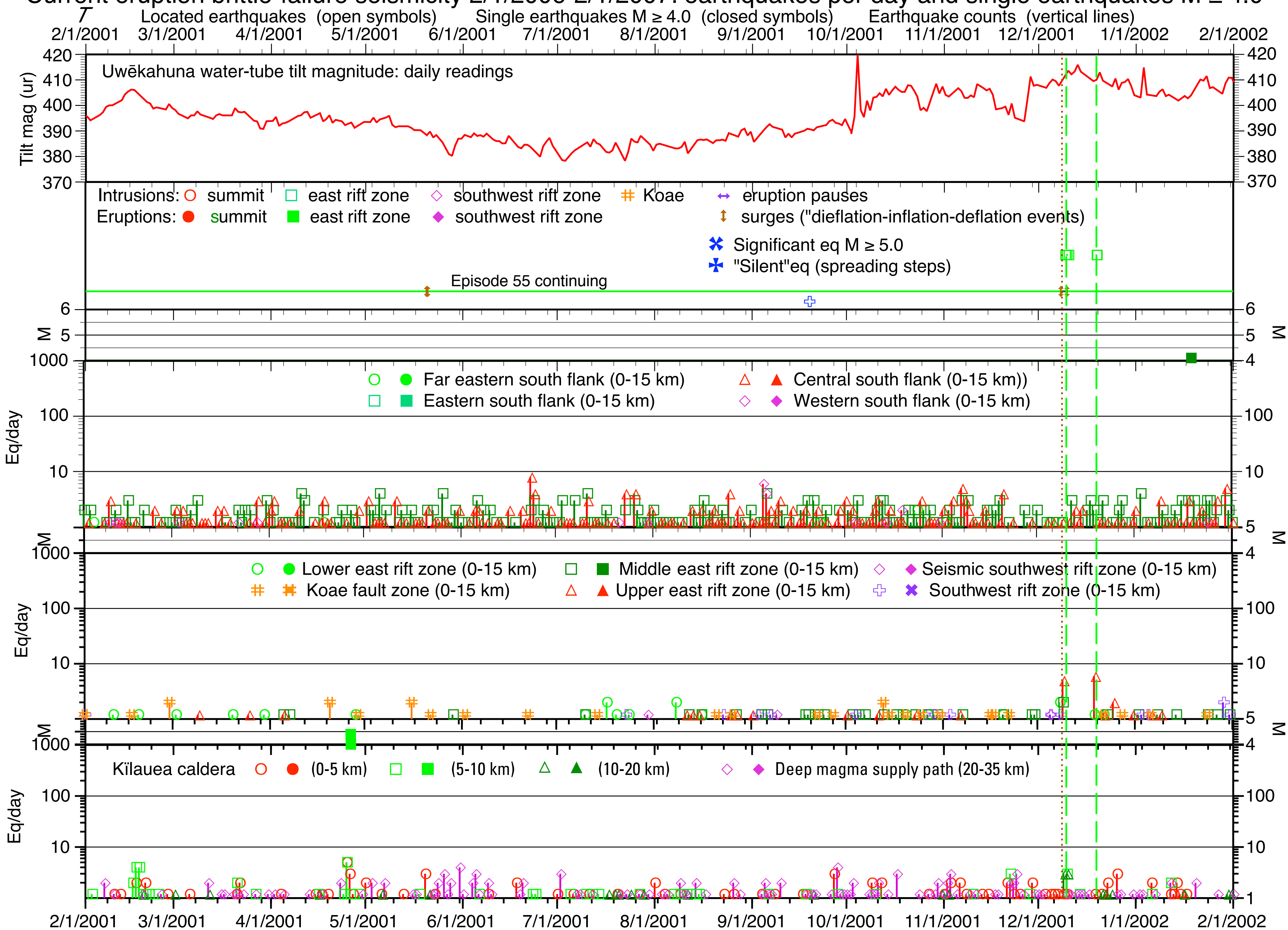
Appendix figure G1 s

Current eruption brittle-failure seismicity 2/1/2000-2/1/2001 earthquakes per day and single earthquakes M ≥ 4.0



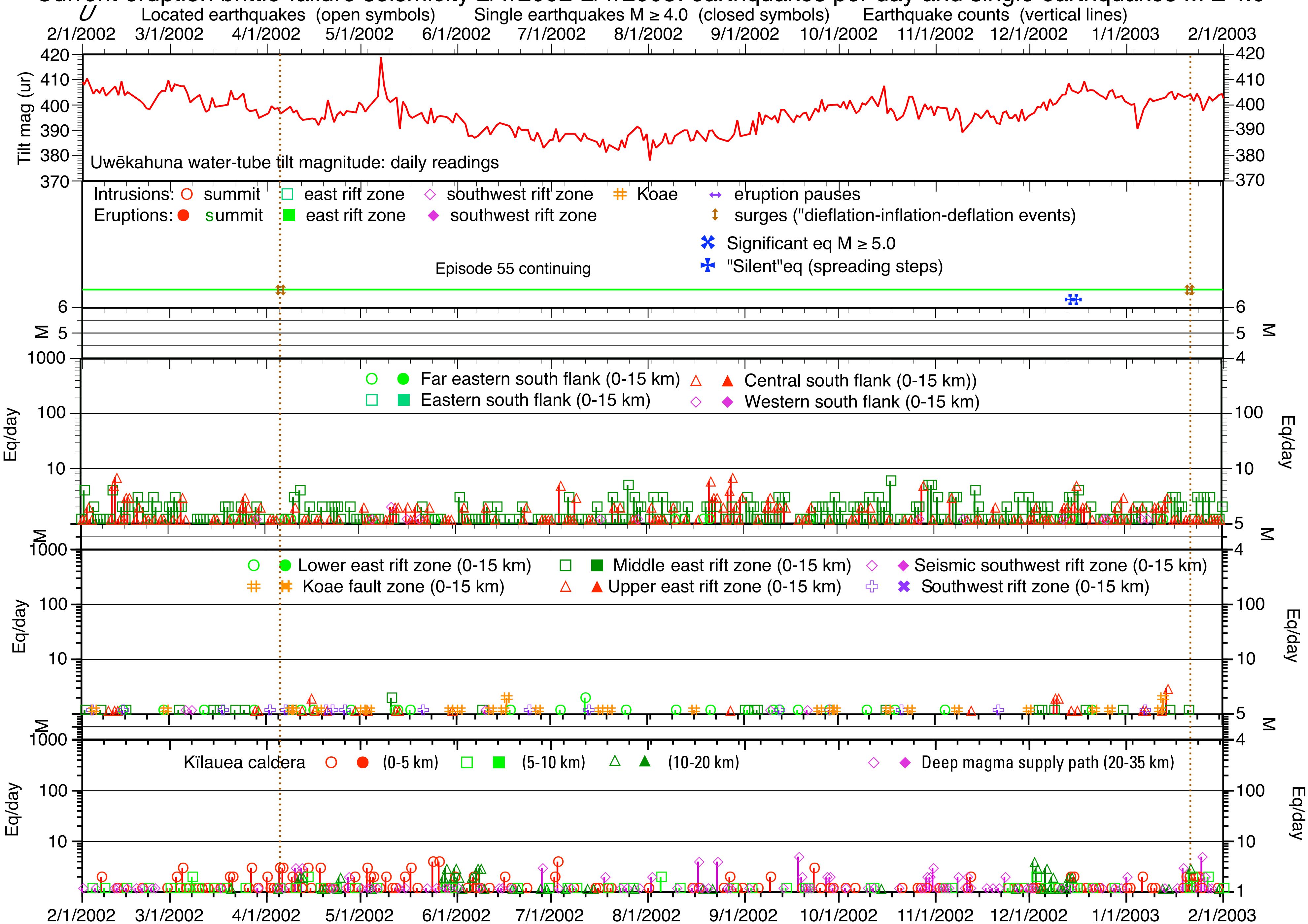
Appendix figure G1 t

Current eruption brittle-failure seismicity 2/1/2006-2/1/2007: earthquakes per day and single earthquakes M ≥ 4.0



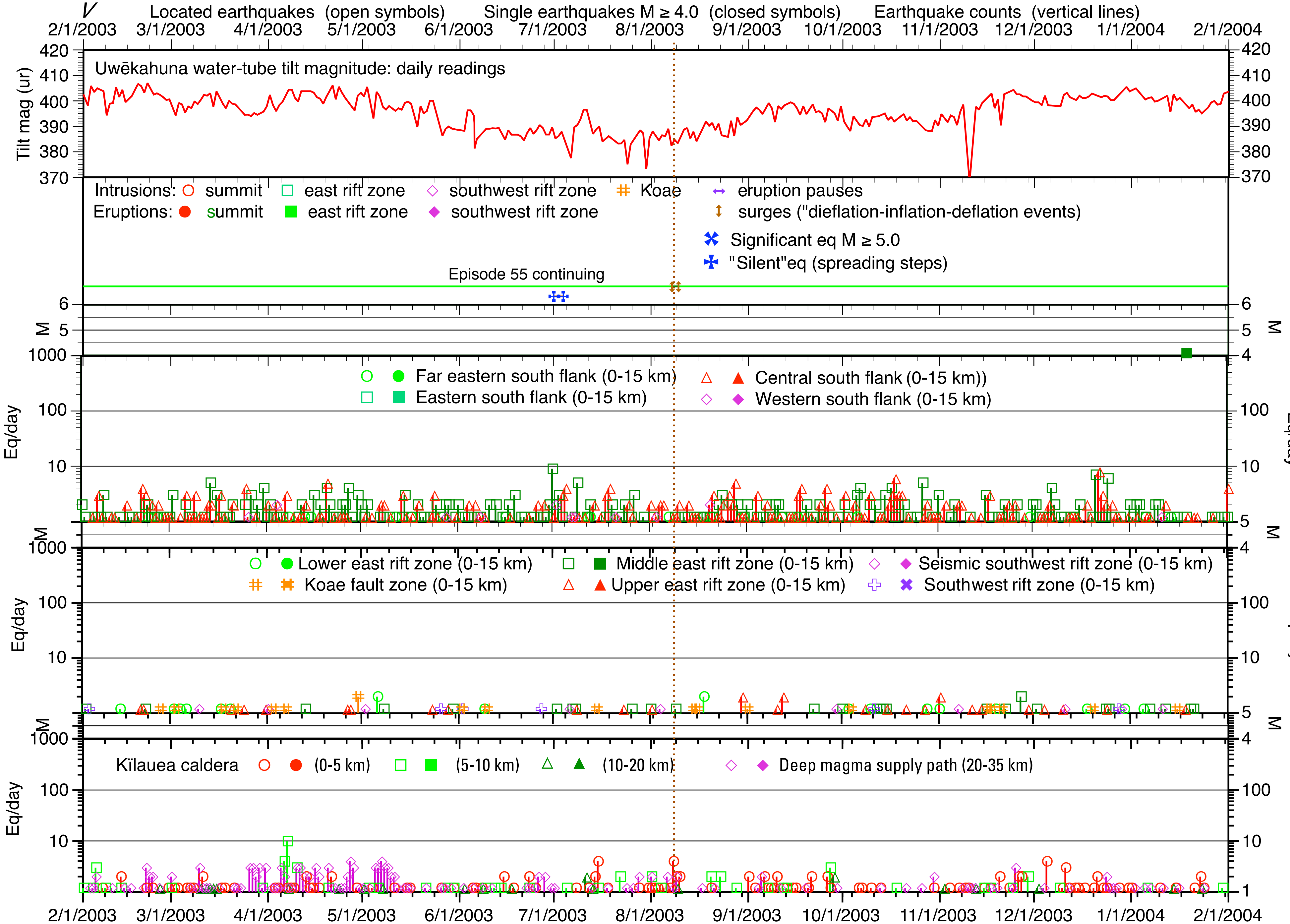
Appendix figure G1 u

Current eruption brittle-failure seismicity 2/1/2002-2/1/2003: earthquakes per day and single earthquakes M ≥ 4.0



Appendix figure G1 v

Current eruption brittle-failure seismicity 2/1/2003-2/1/2004: earthquakes per day and single earthquakes M ≥ 4.0

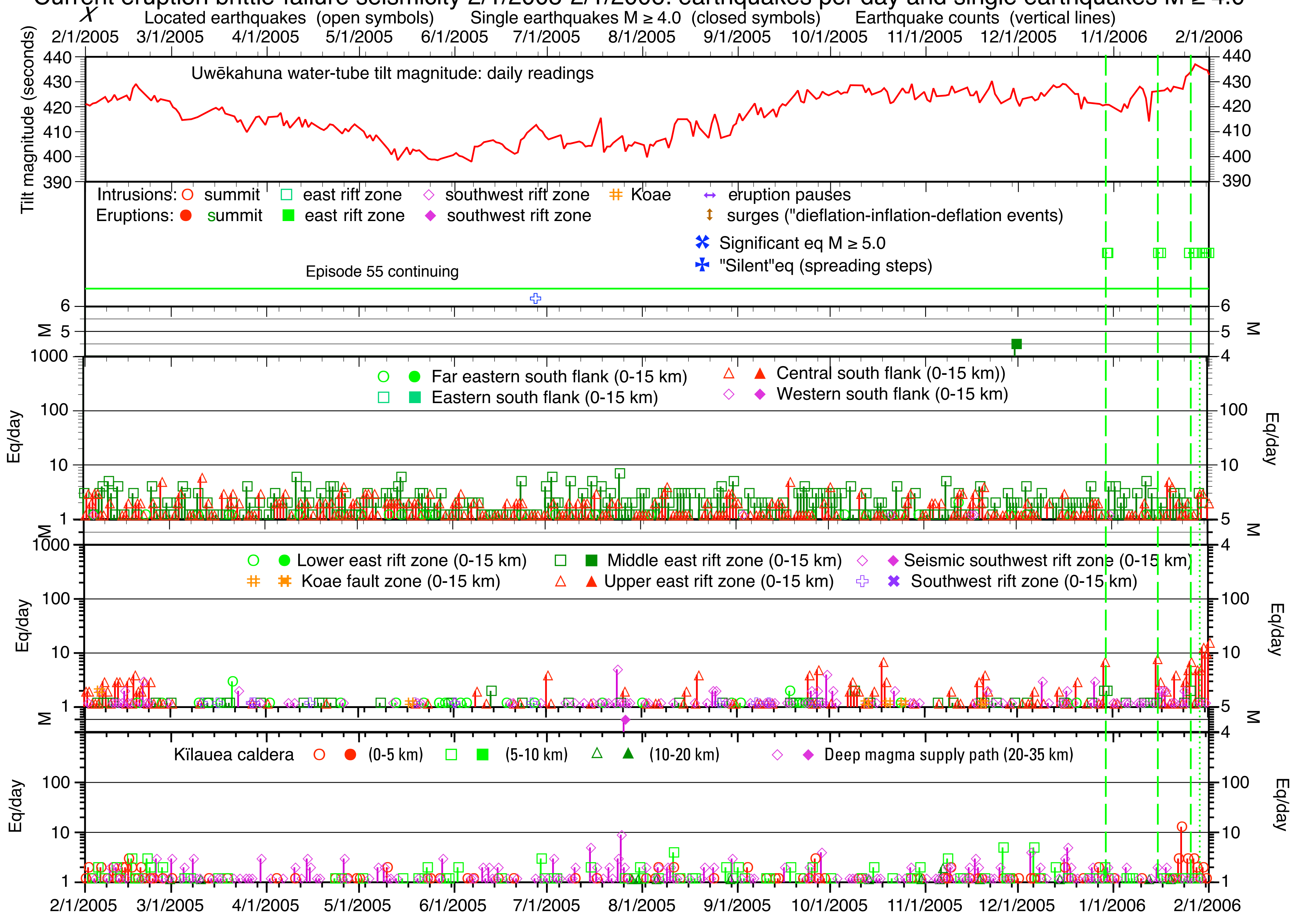


Appendix figure G1 w

Current eruption brittle-failure seismicity 2/1/2004-2/1/2005: earthquakes per day and single earthquakes M ≥ 4.0

Appendix figure G1 x

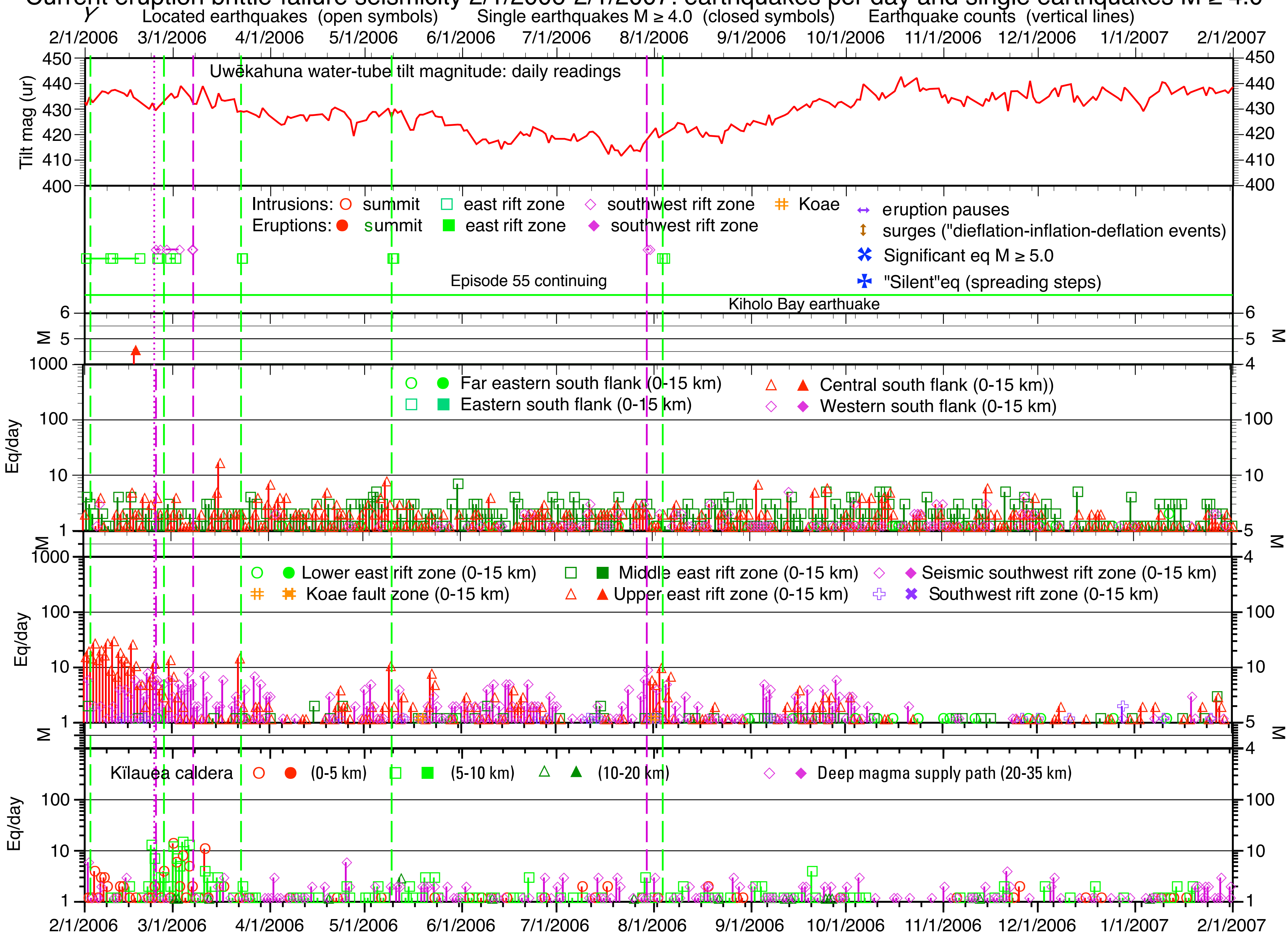
Current eruption brittle-failure seismicity 2/1/2005-2/1/2006: earthquakes per day and single earthquakes M ≥ 4.0



Appendix figure G1 y

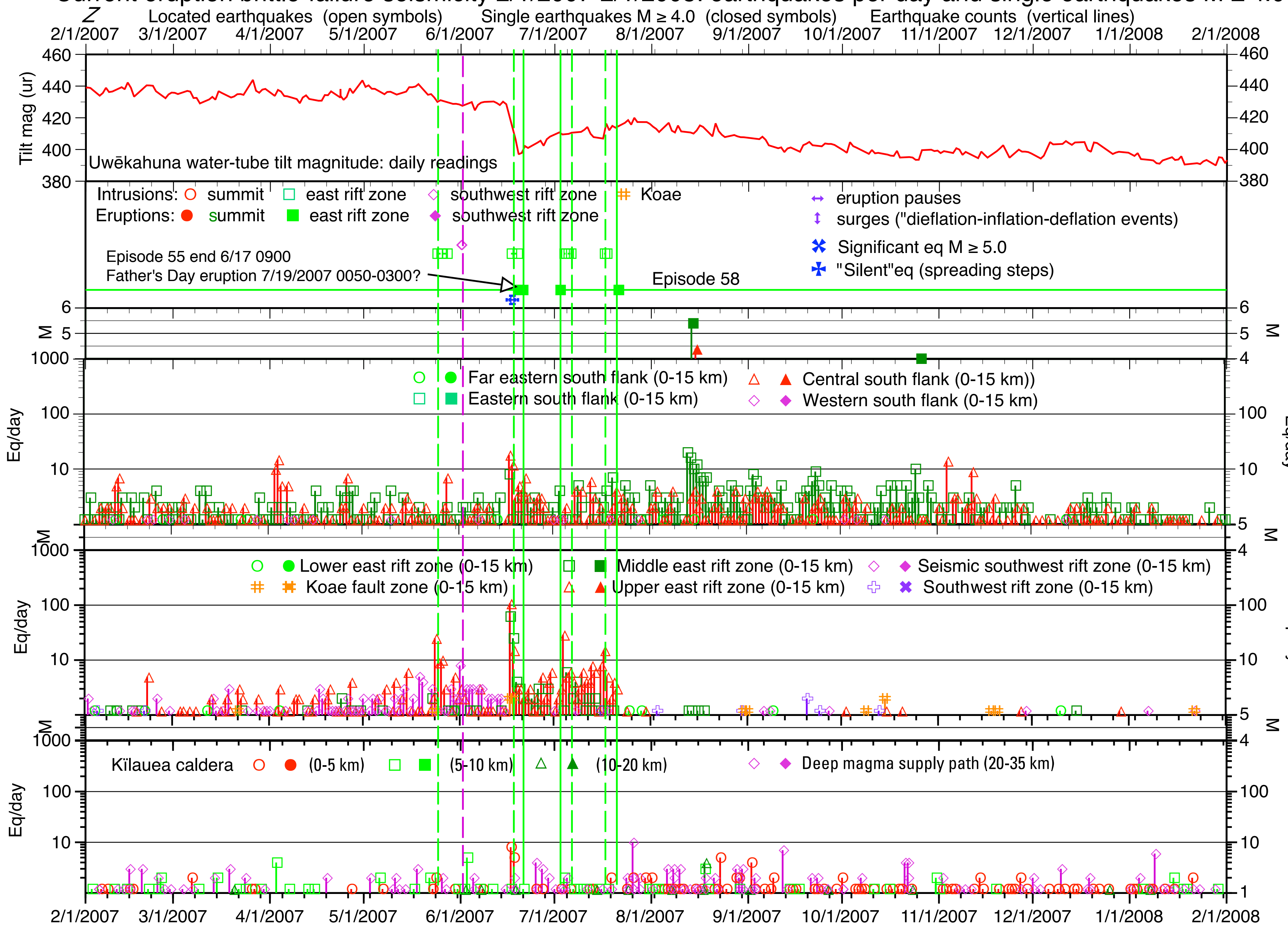
Current eruption brittle-failure seismicity 2/1/2006-2/1/2007: earthquakes per day and single earthquakes M ≥ 4.0

Located earthquakes (open symbols) Single earthquakes M ≥ 4.0 (closed symbols) Earthquake counts (vertical lines)



Appendix figure G1 z

Current eruption brittle-failure seismicity 2/1/2007-2/1/2008: earthquakes per day and single earthquakes M ≥ 4.0

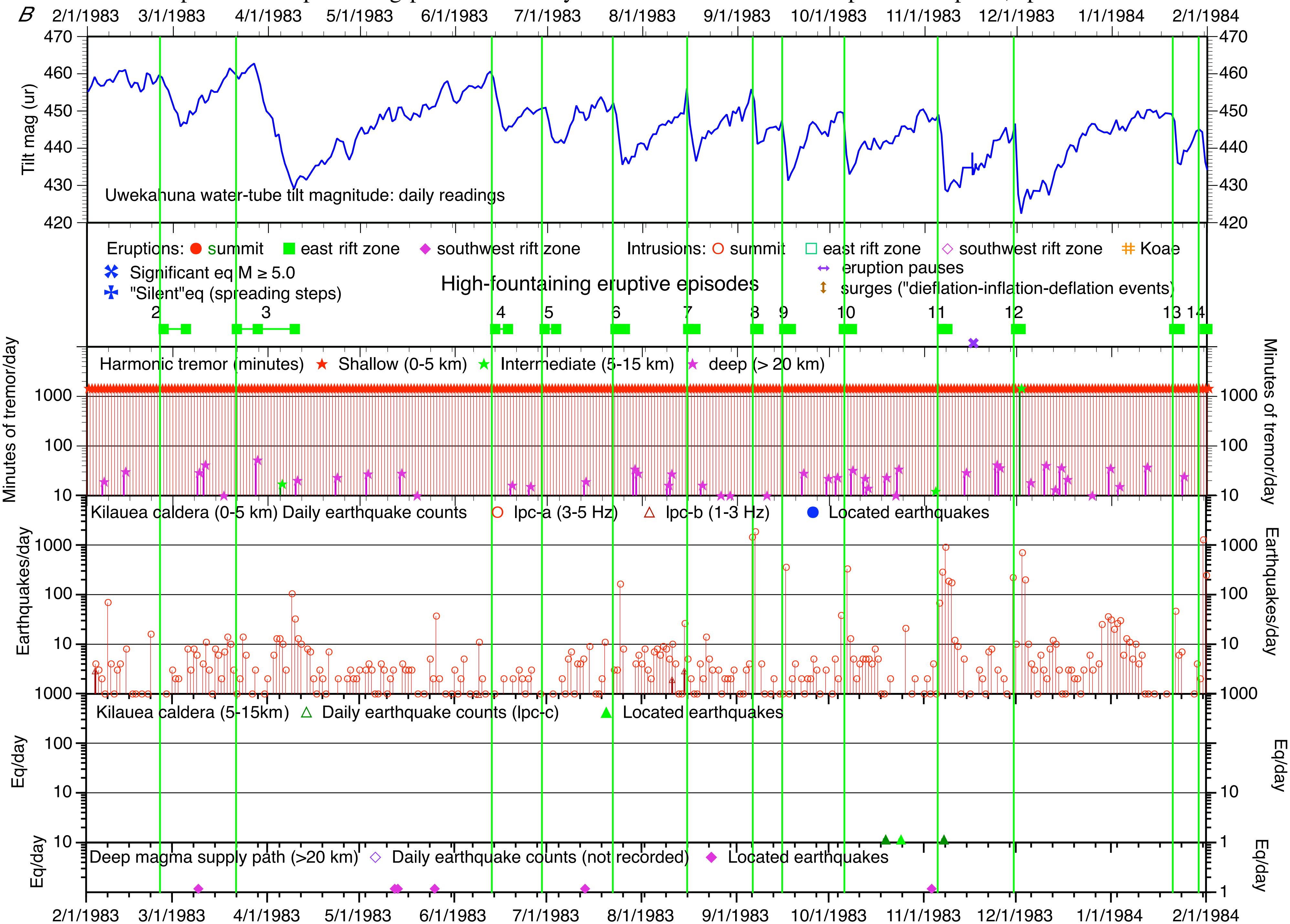


Appendix figure G2 a

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 2/1/1982-2/1/1983: precursors to episodic eruption, episode 1

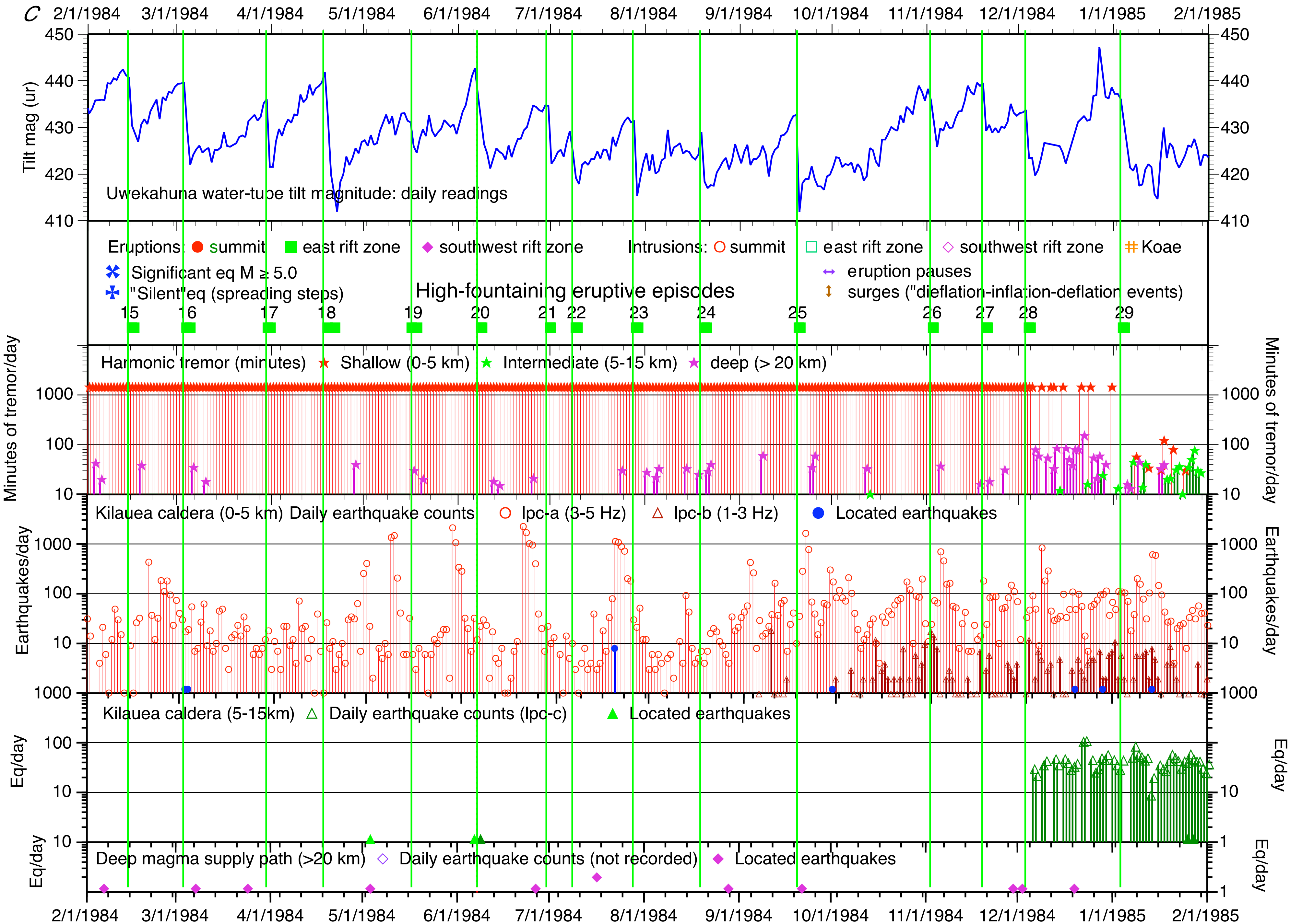
Appendix figure G2 b

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 2/1/1983-2/1/1984: Initial episodic eruption, episodes 2-14



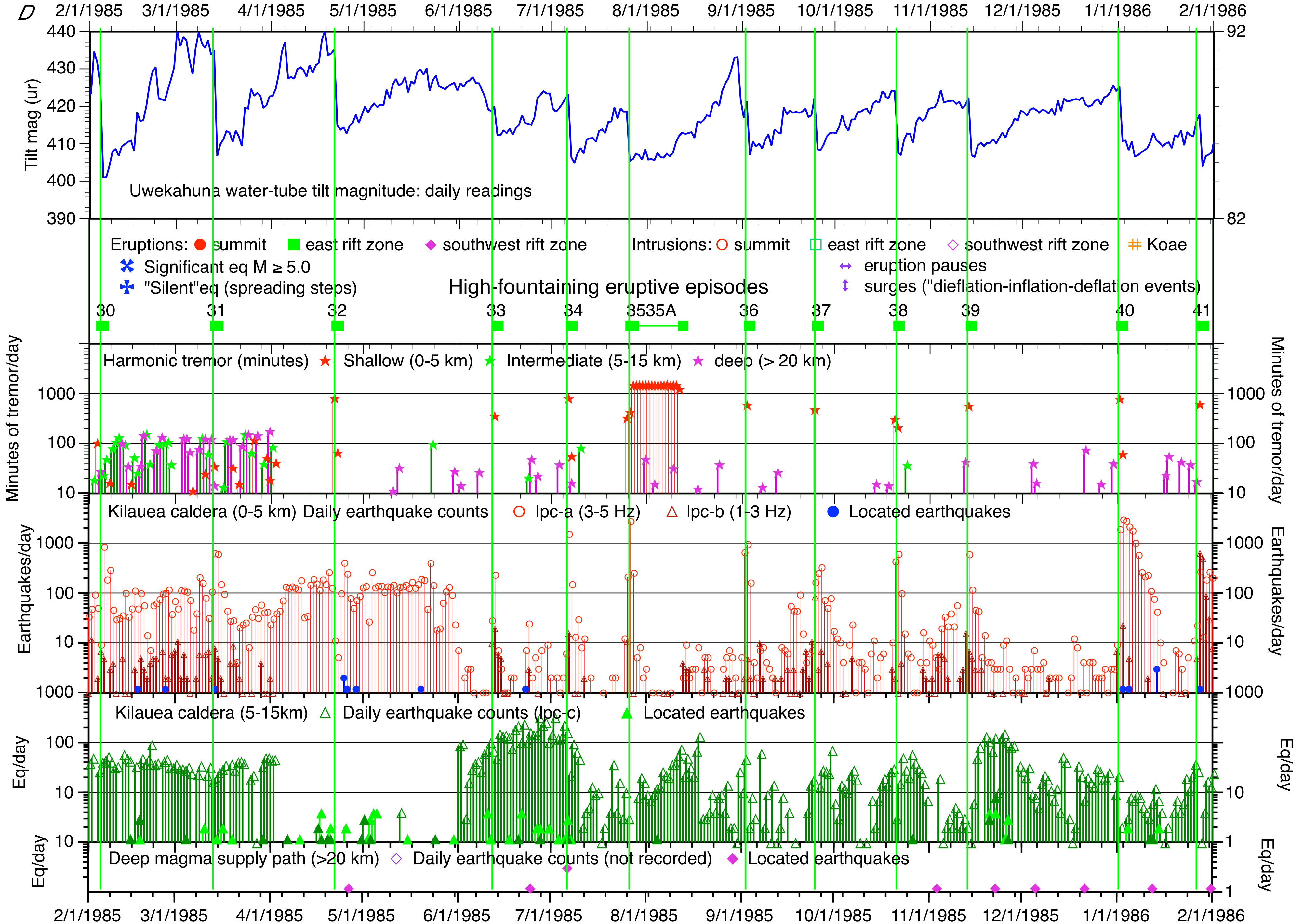
Appendix figure G2 c

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 2/1/1984-2/1/1985: Initial episodic eruption, episodes 20-29



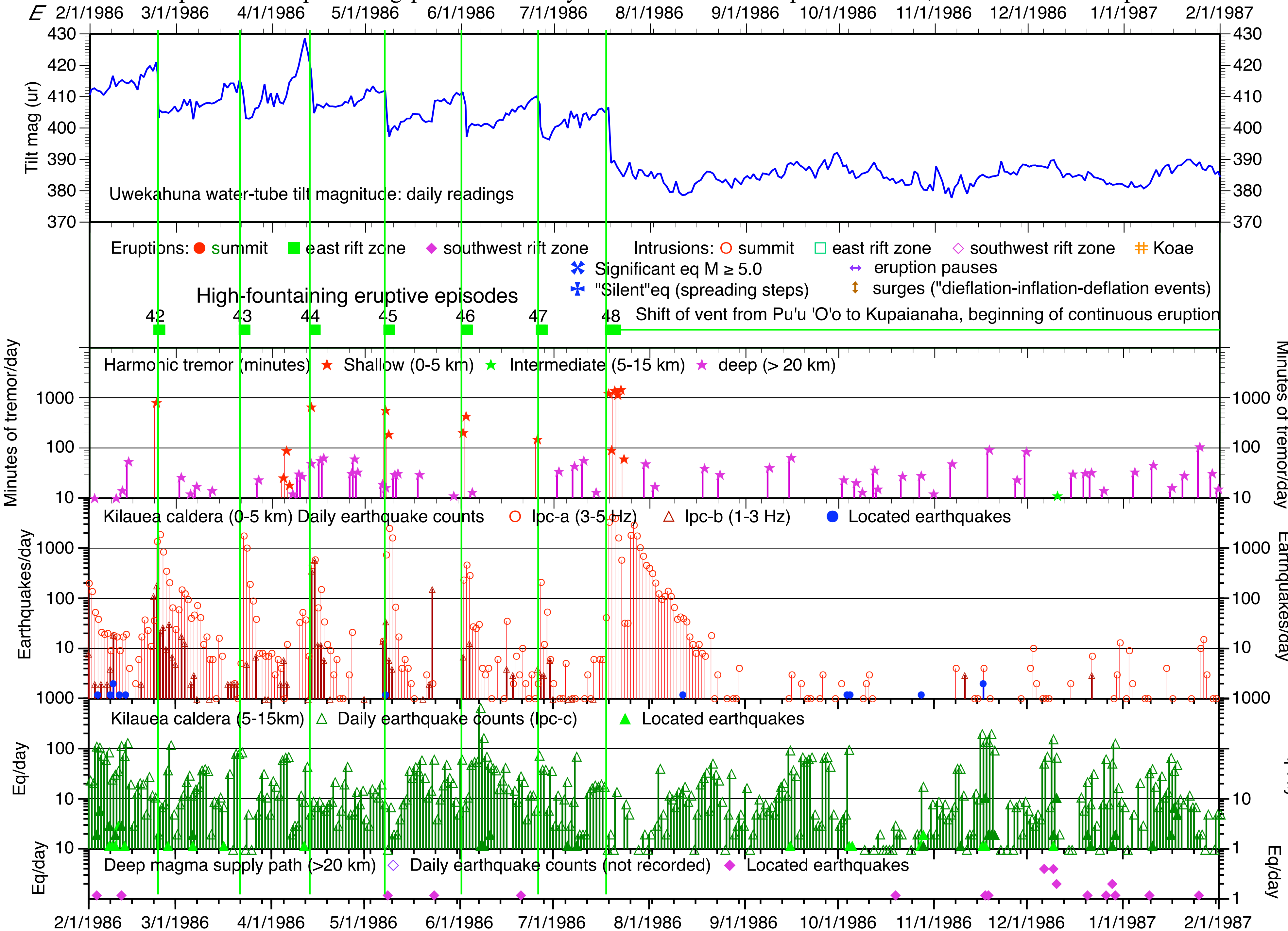
Appendix figure G2 d

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 2/1/1985-2/1/1986: Initial episodic eruption, episodes 30-41



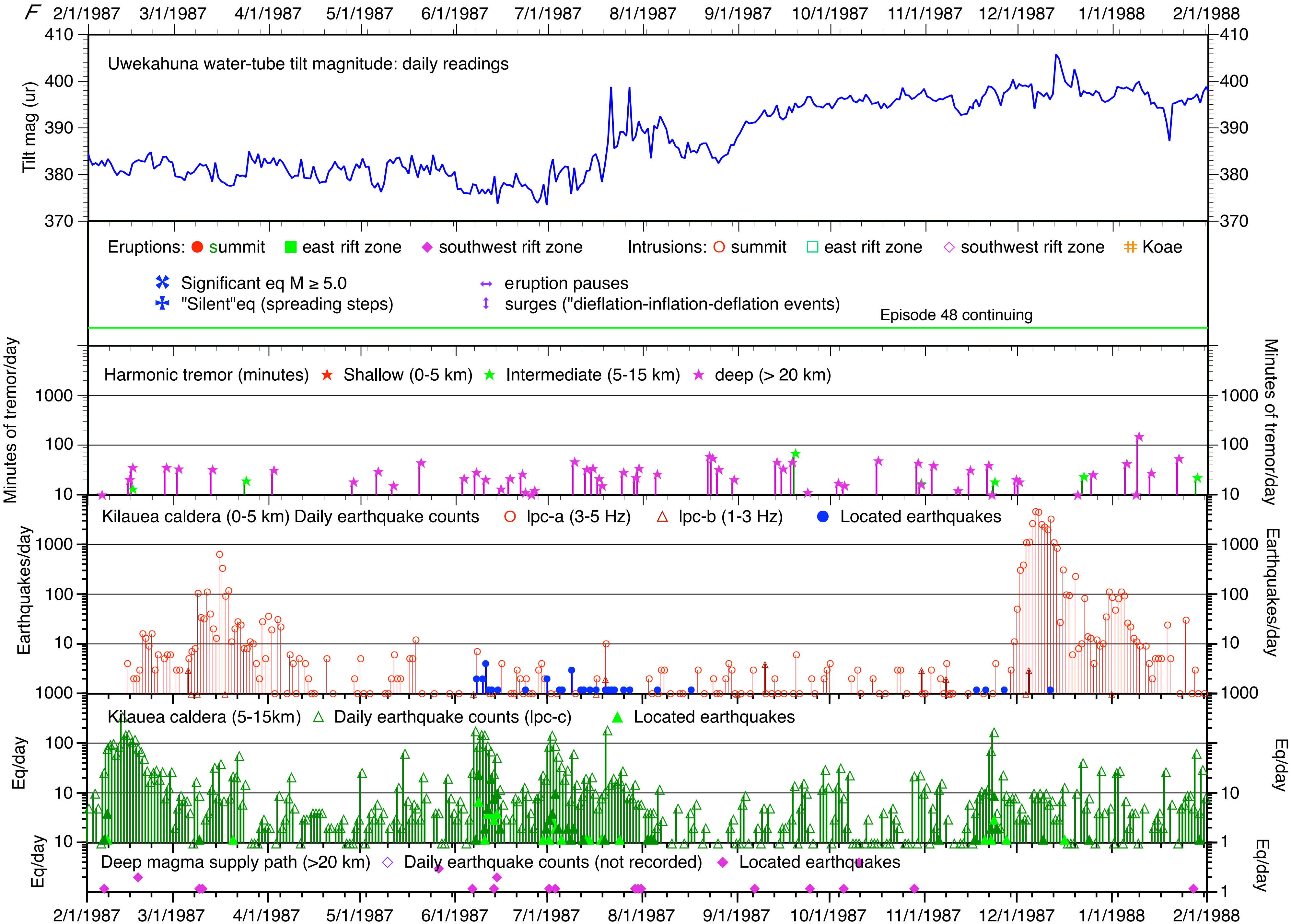
Appendix figure G2 e

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 2/1/1986-2/1/1987: episodes 42-47; 48--continuous eruption



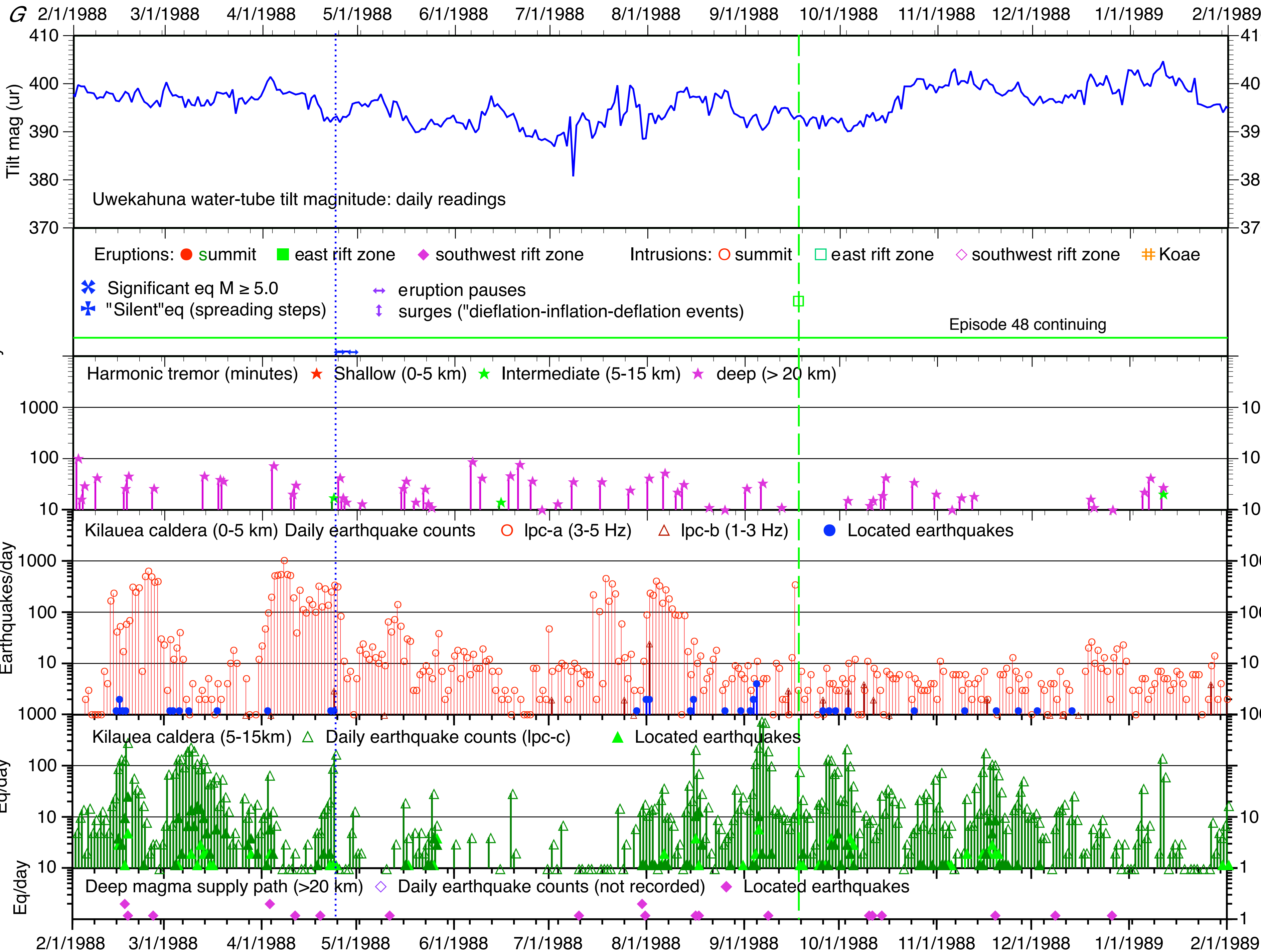
Appendix figure G2 f

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 2/1/1987-2/1/1988: Kupaianaha



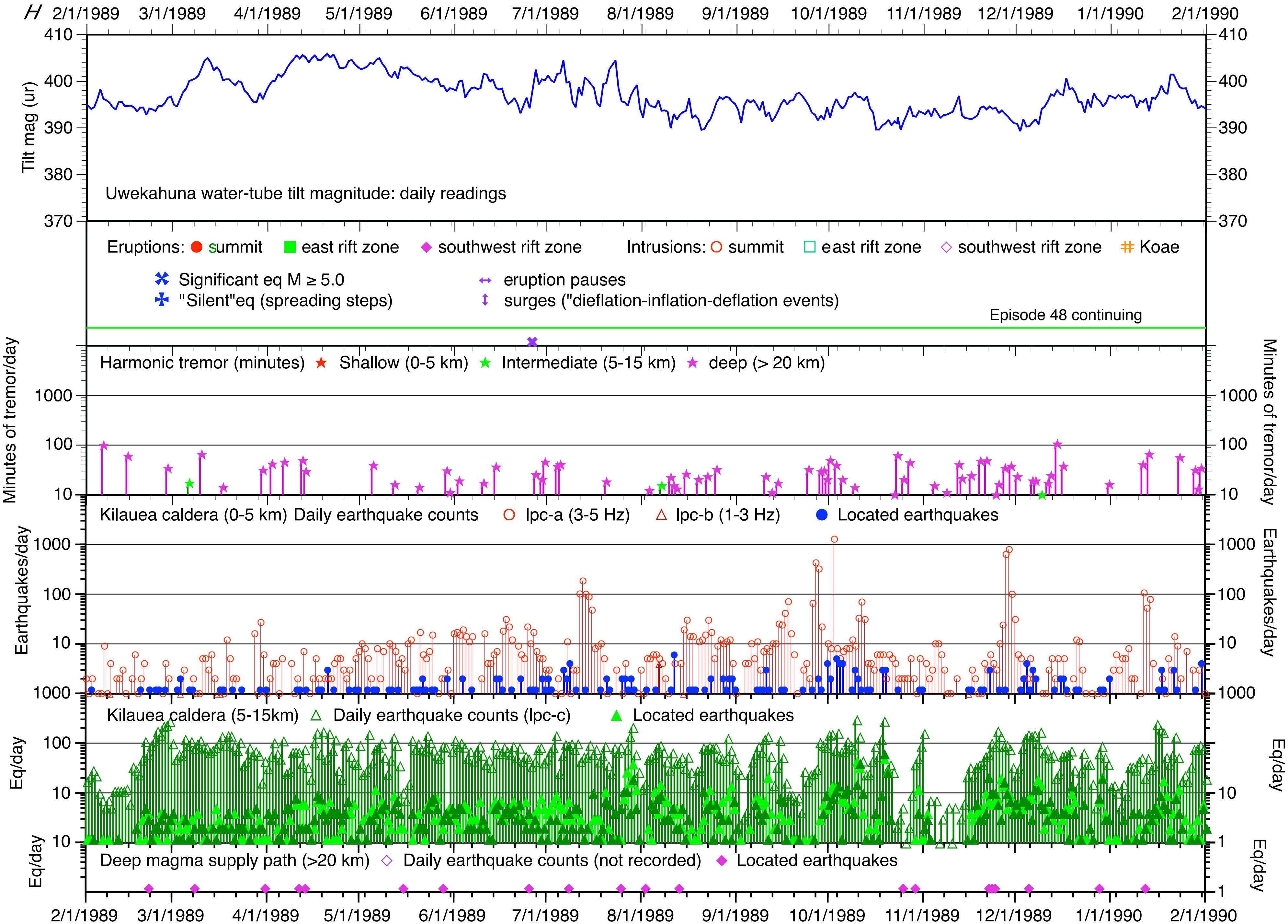
Appendix figure G2 g

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 2/1/1988-2/1/1989: Kupaianaha



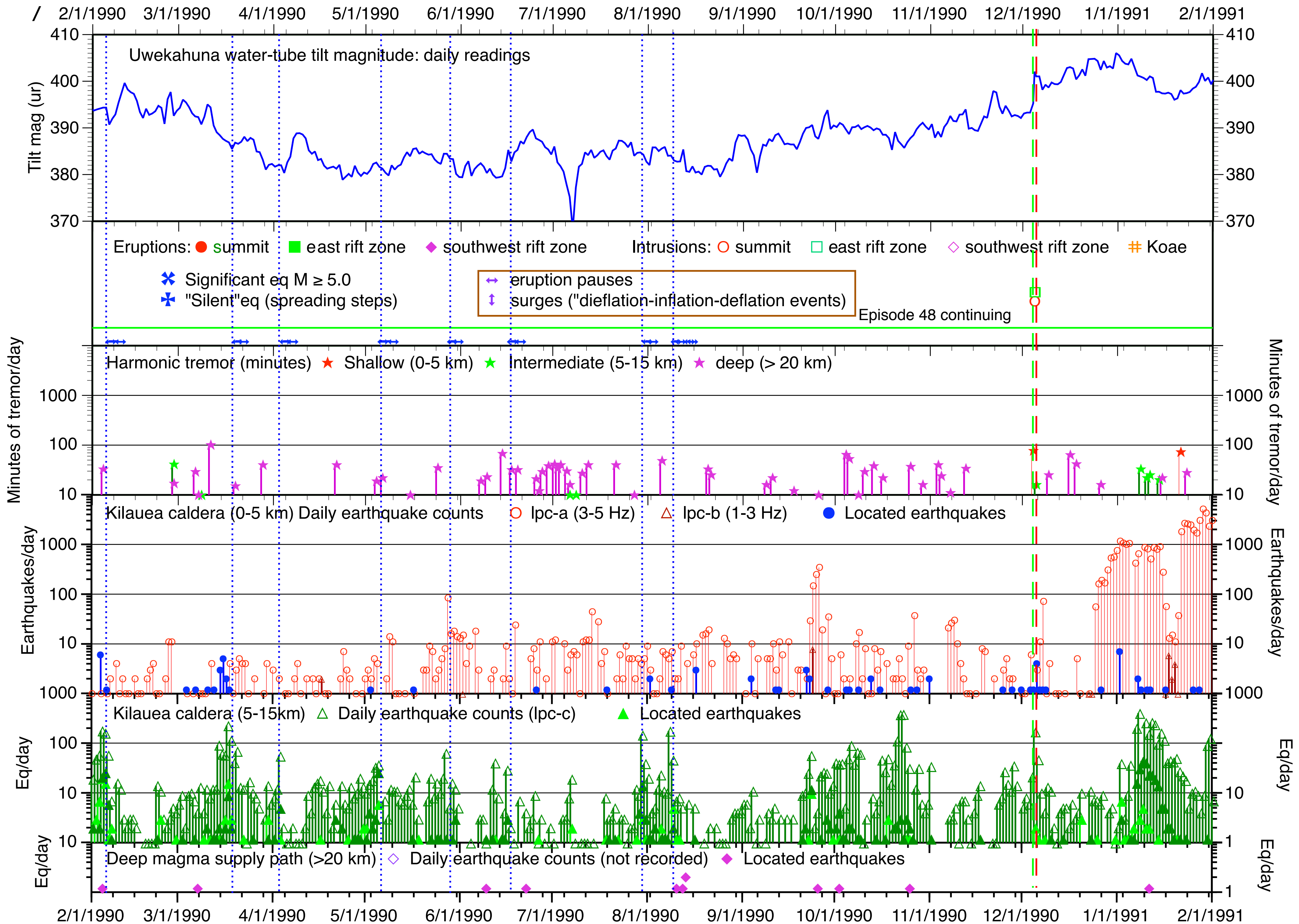
Appendix figure G2 h

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 2/1/1989-2/1/1990: Kupaianaha



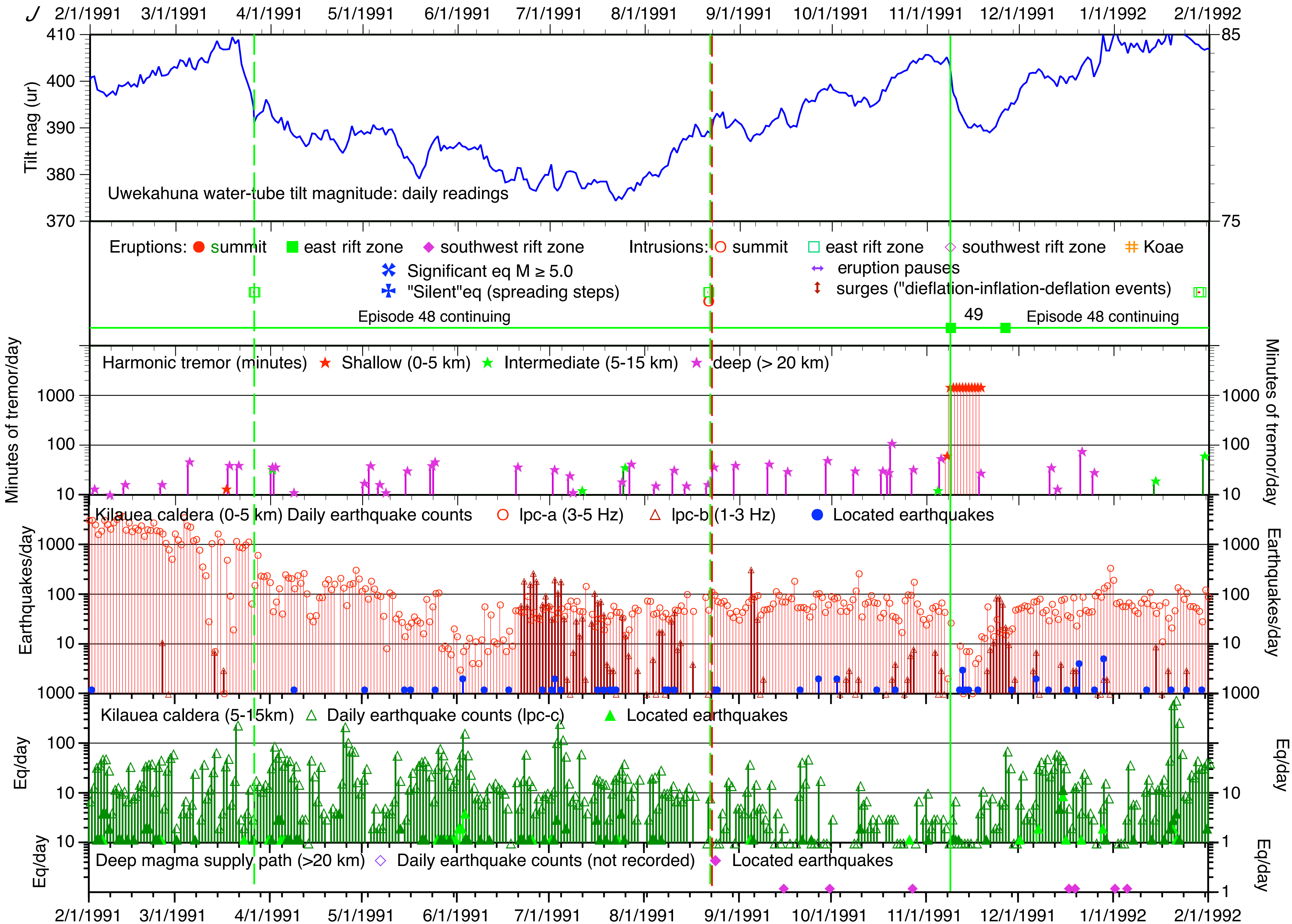
Appendix figure G2 i

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 2/1/1990-2/1/1991: Kupaianaha



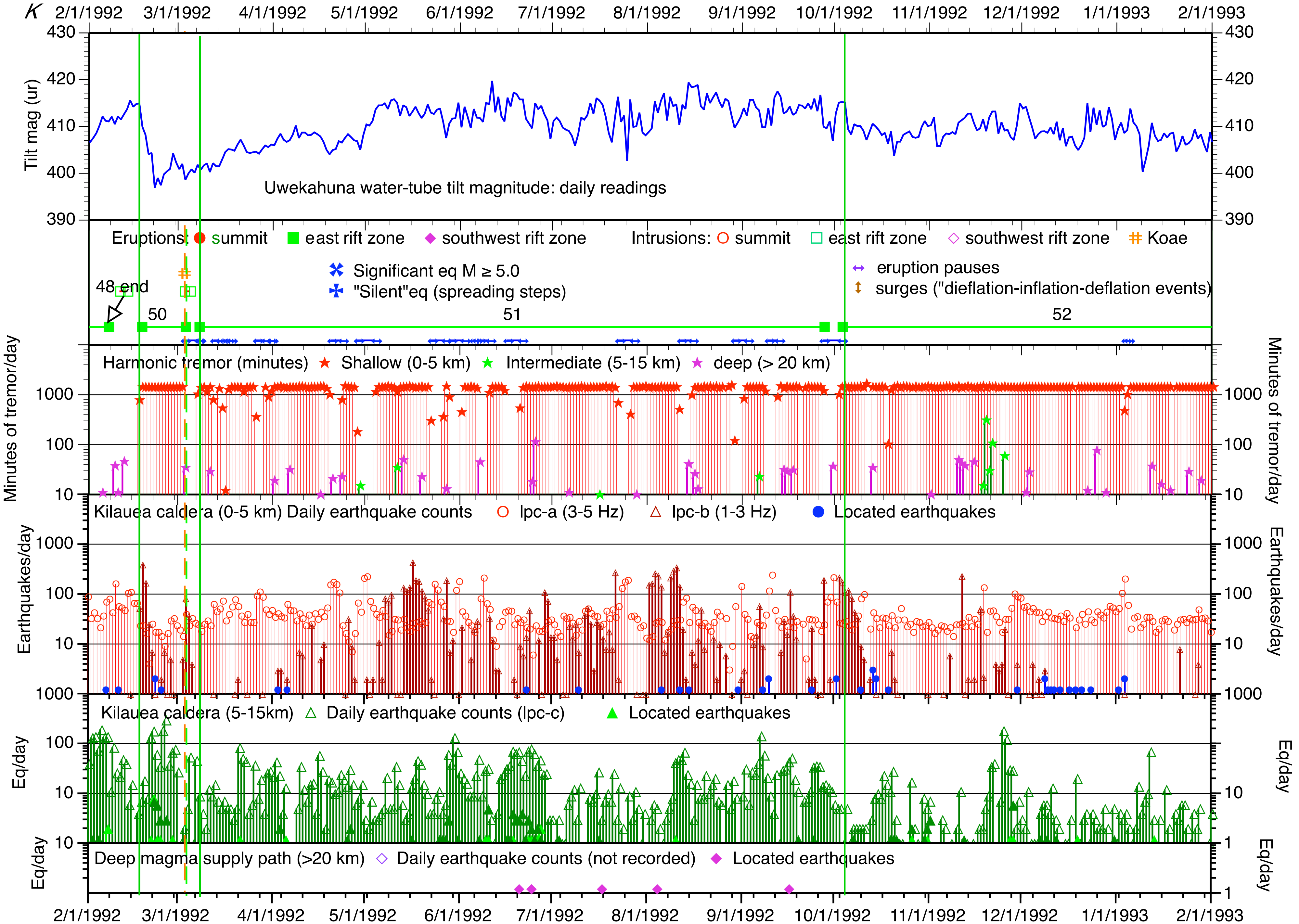
Appendix figure G2 j

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 2/1/1991-2/1/1992 Kupaianaha--episode 49 (return to Pu'u 'O'o)



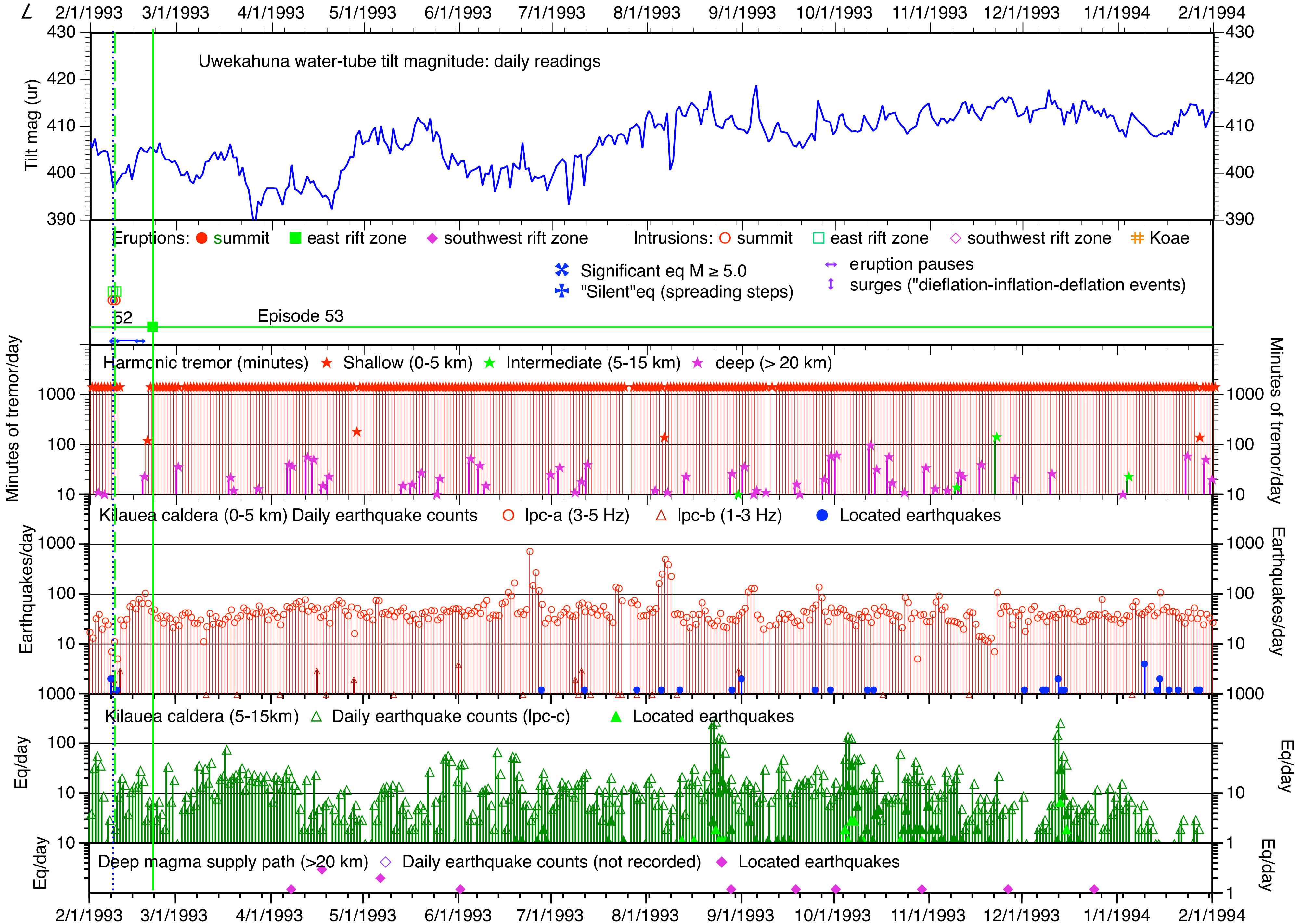
Appendix figure G2 k

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 2/1/1992-2/1/1993 post-Kupaianaha--episodes 50-52



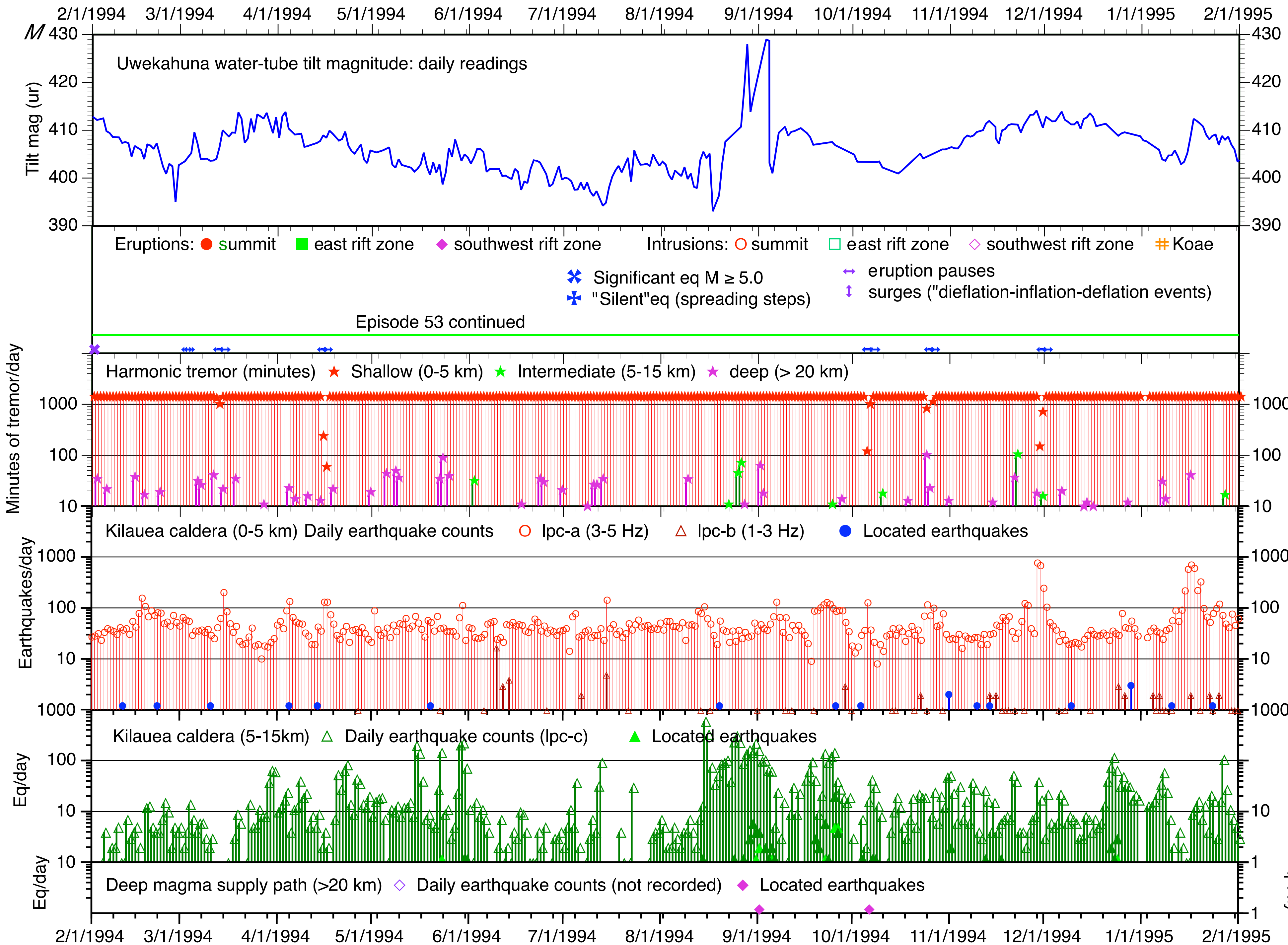
Appendix figure G2 l

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 2/1/1993-2/1/1994: post-Kupaianaha--episode 53



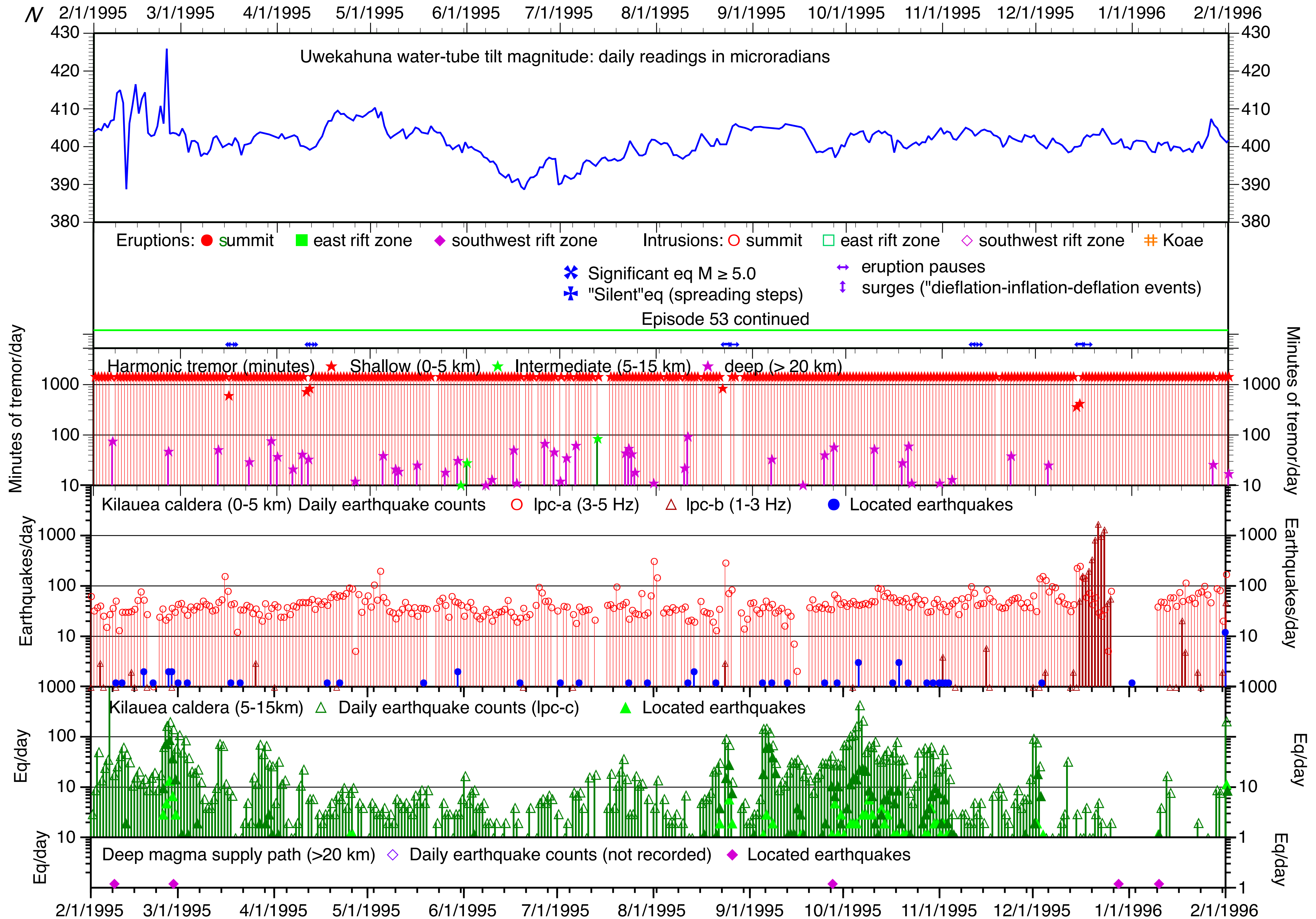
Appendix figure G2 m

Pu'u 'O'o-Kupaianaha eruption long-period seismicity 2/1/1994-2/1/1995 post-Kupaianaha--episode 53



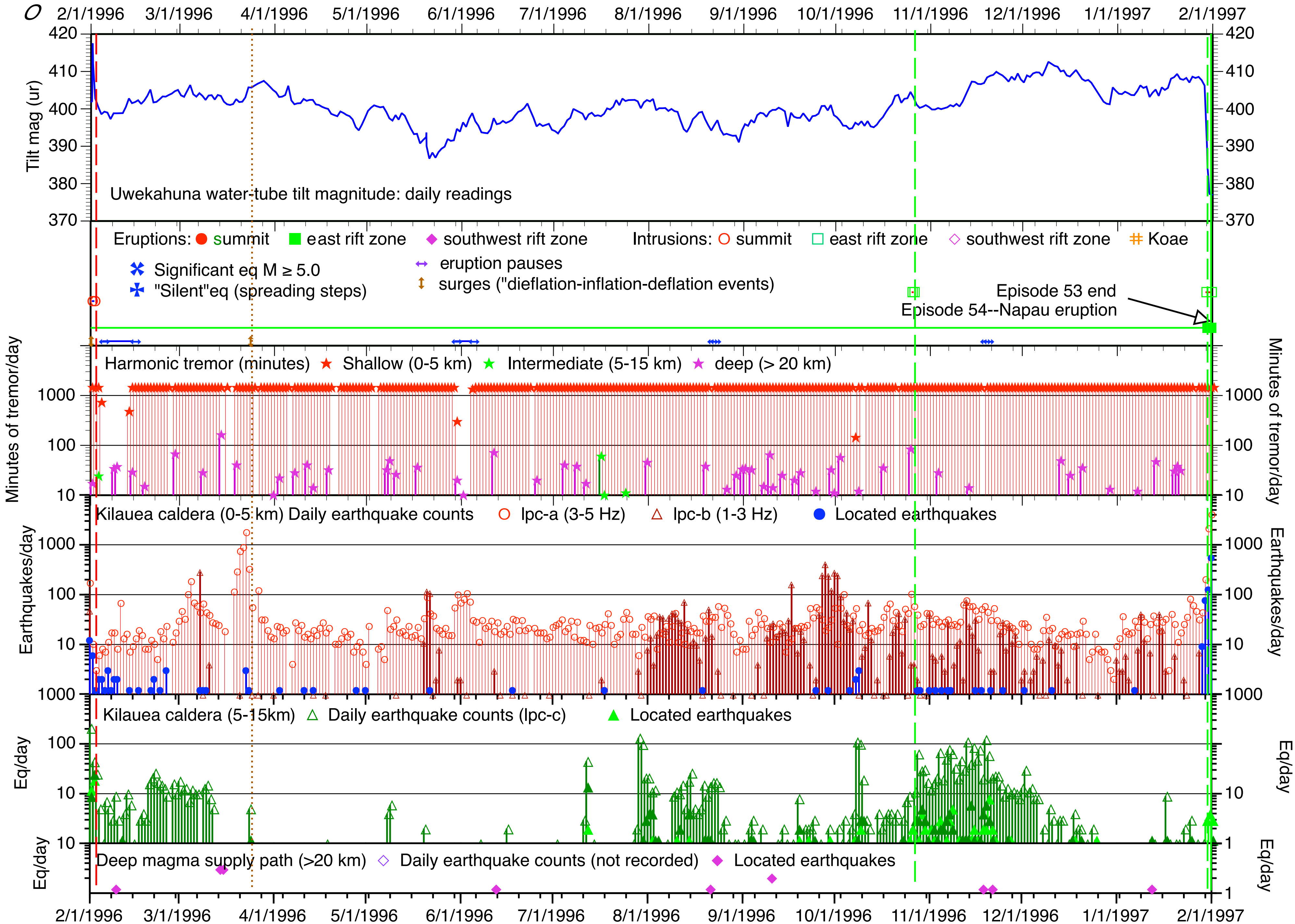
Appendix figure G2 n

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 2/1/1995-2/1/1996 post-Kupaianaha--episode 53



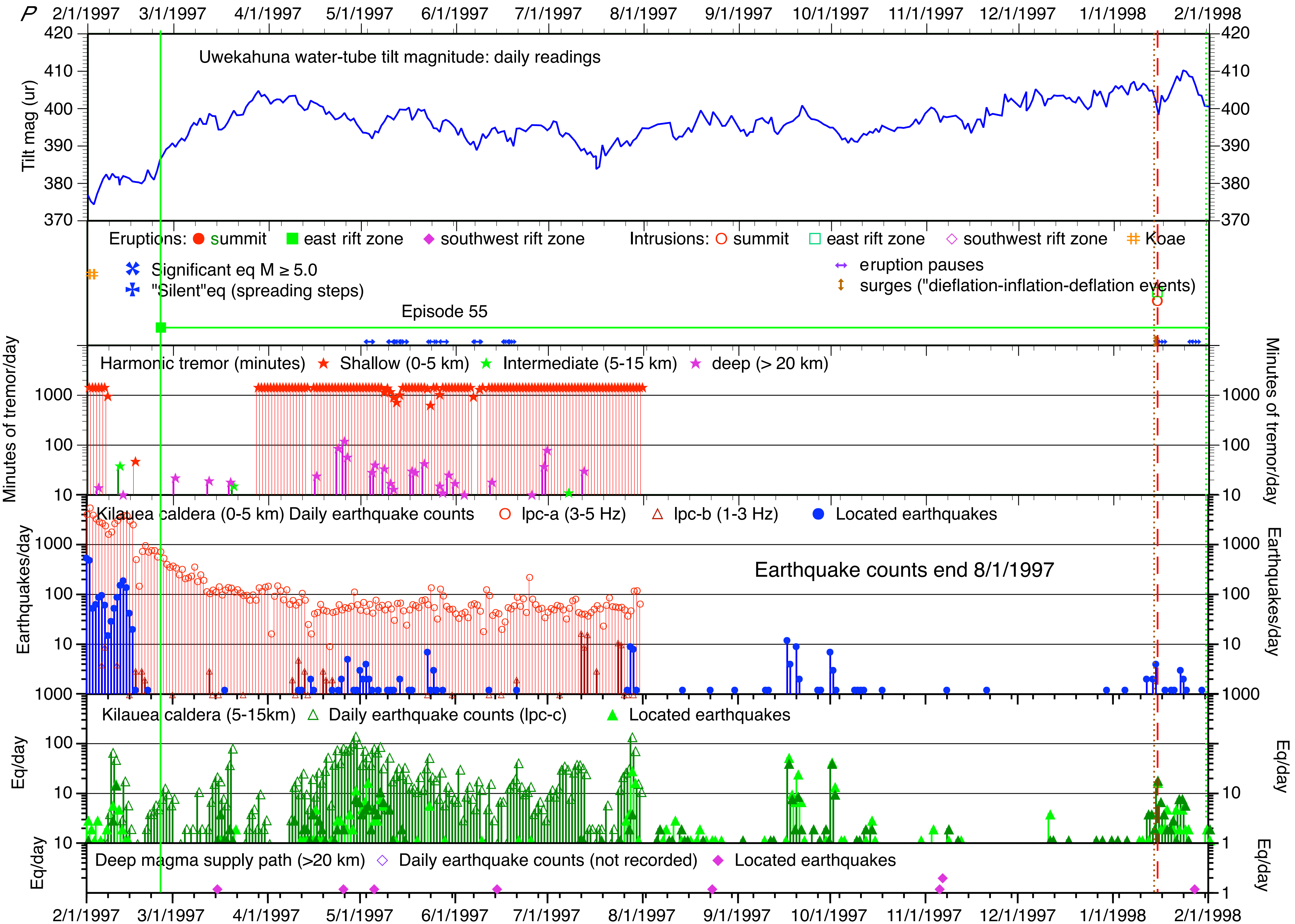
Appendix figure G2 o

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 21/1996-2/1/1997: post-Kupaianaha--episode 53-54



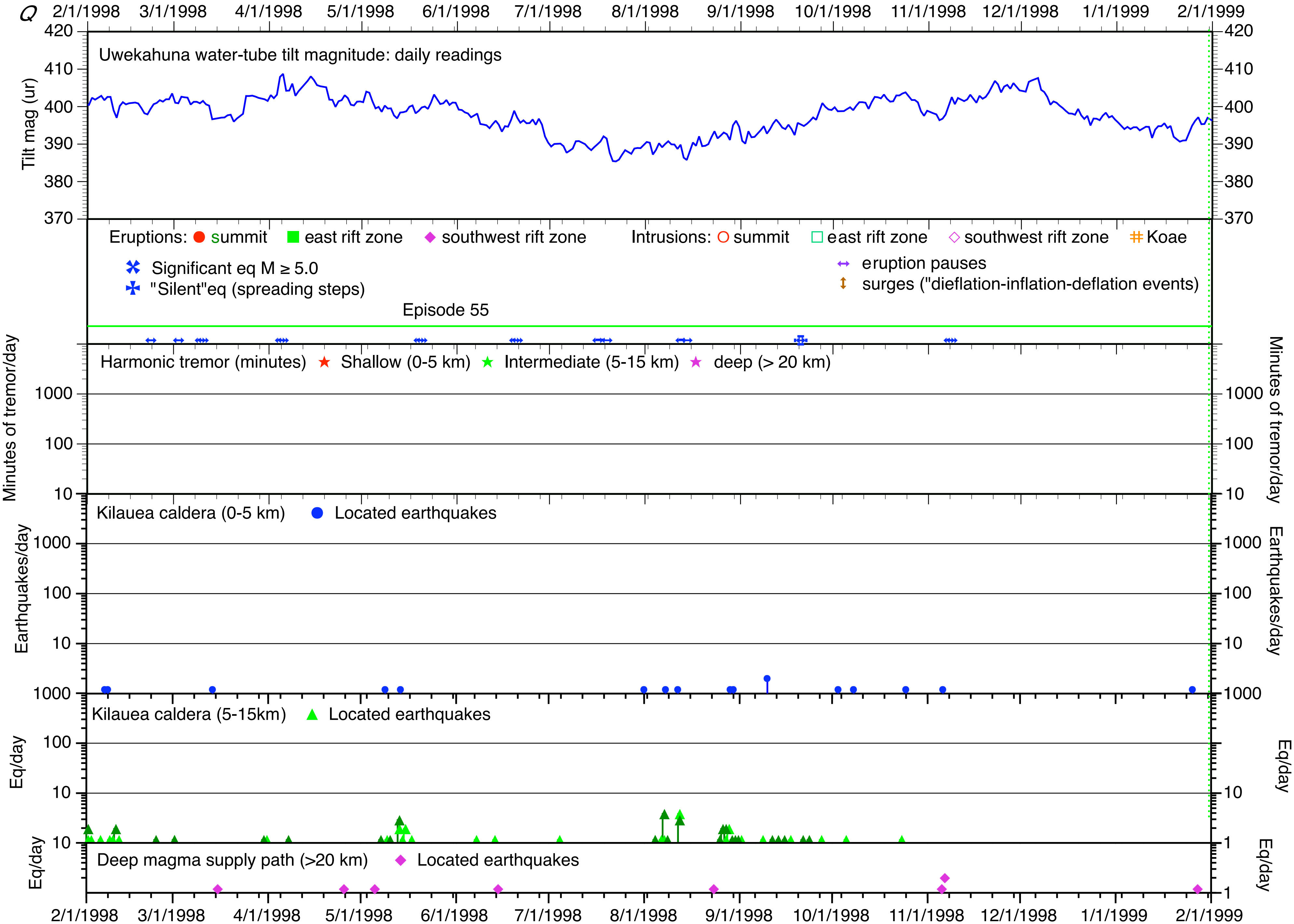
Appendix figure G2 p

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 21/1997-2/1/1998 post-Kupaianaha--episode 54-55



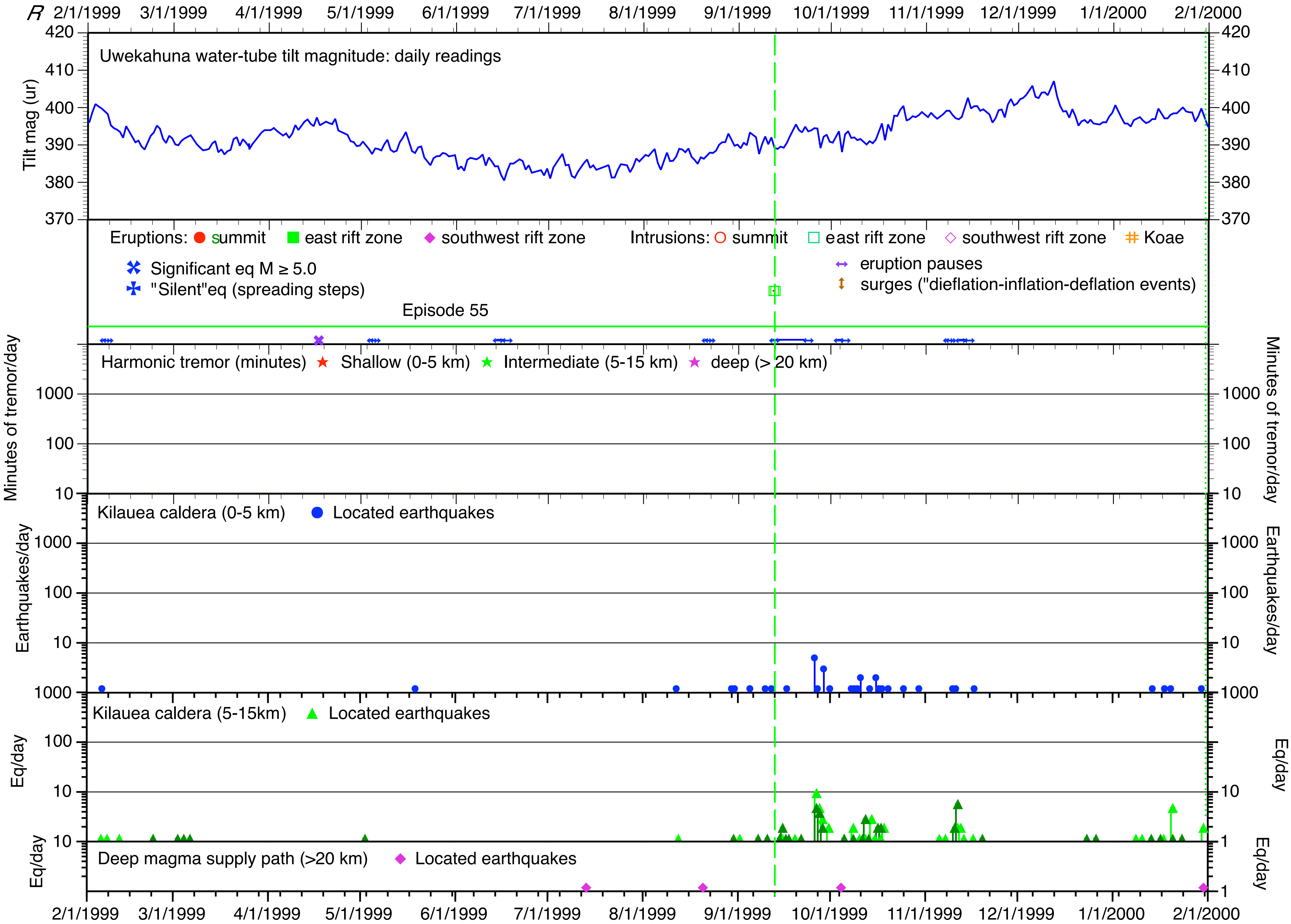
Appendix figure G2 q

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 21/1998-2/1/1999 post-Kupaianaha--episode 55



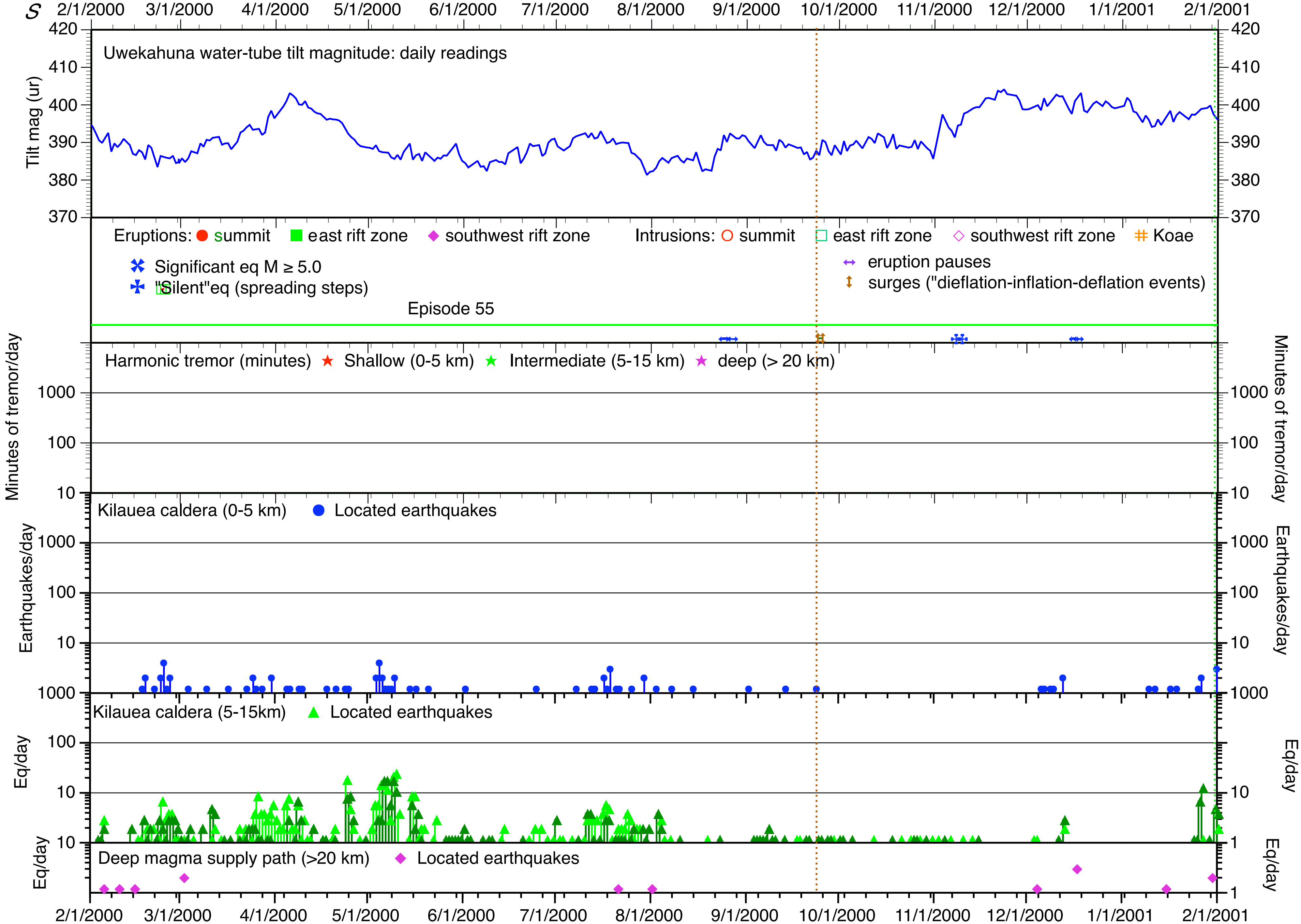
Appendix figure G2 r

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 21/1999-2/1/2000 post-Kupaianaha--episode 55



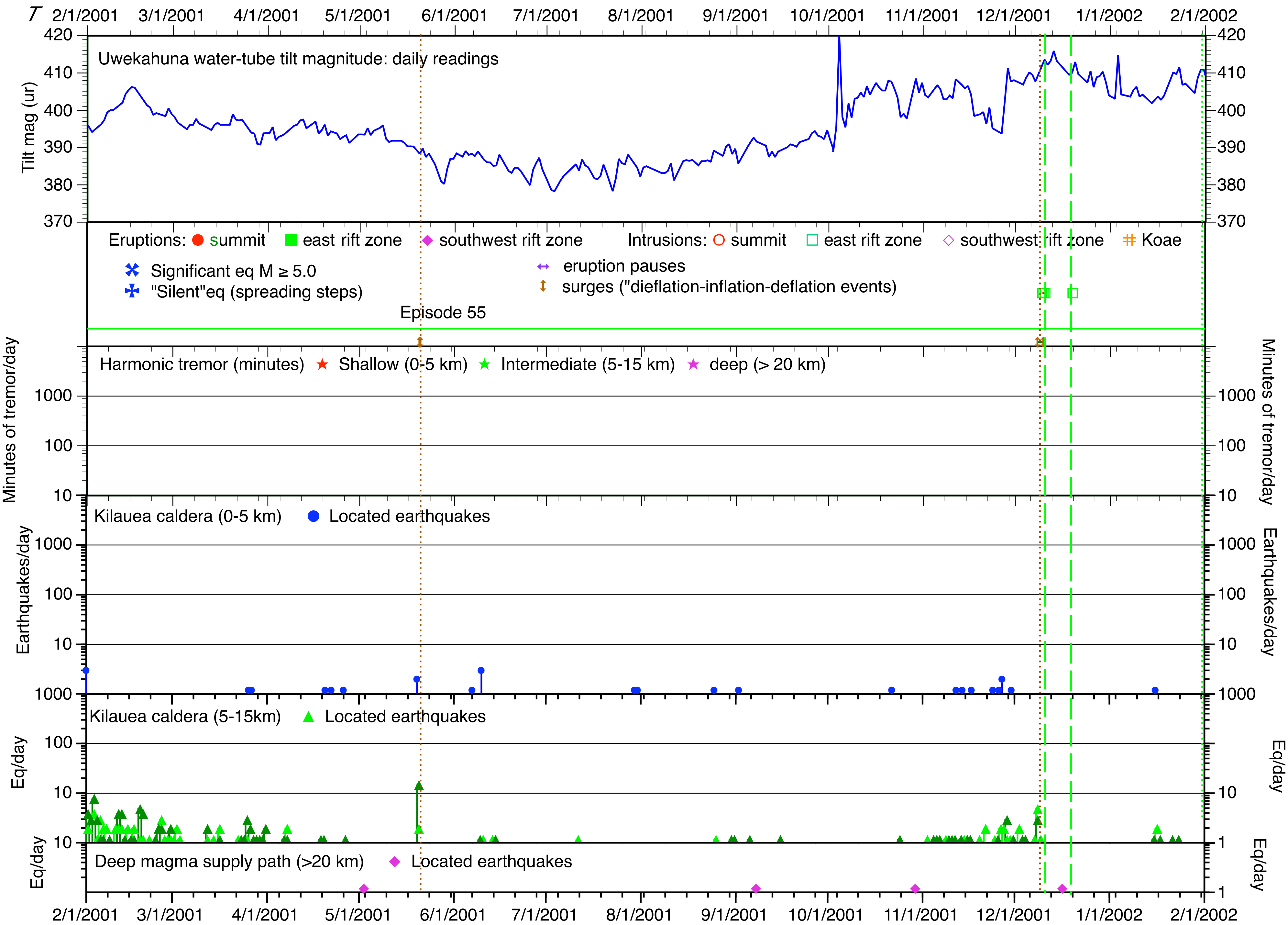
Appendix figure G2 s

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 21/2000-2/1/2001 post-Kupaianaha--episode 55



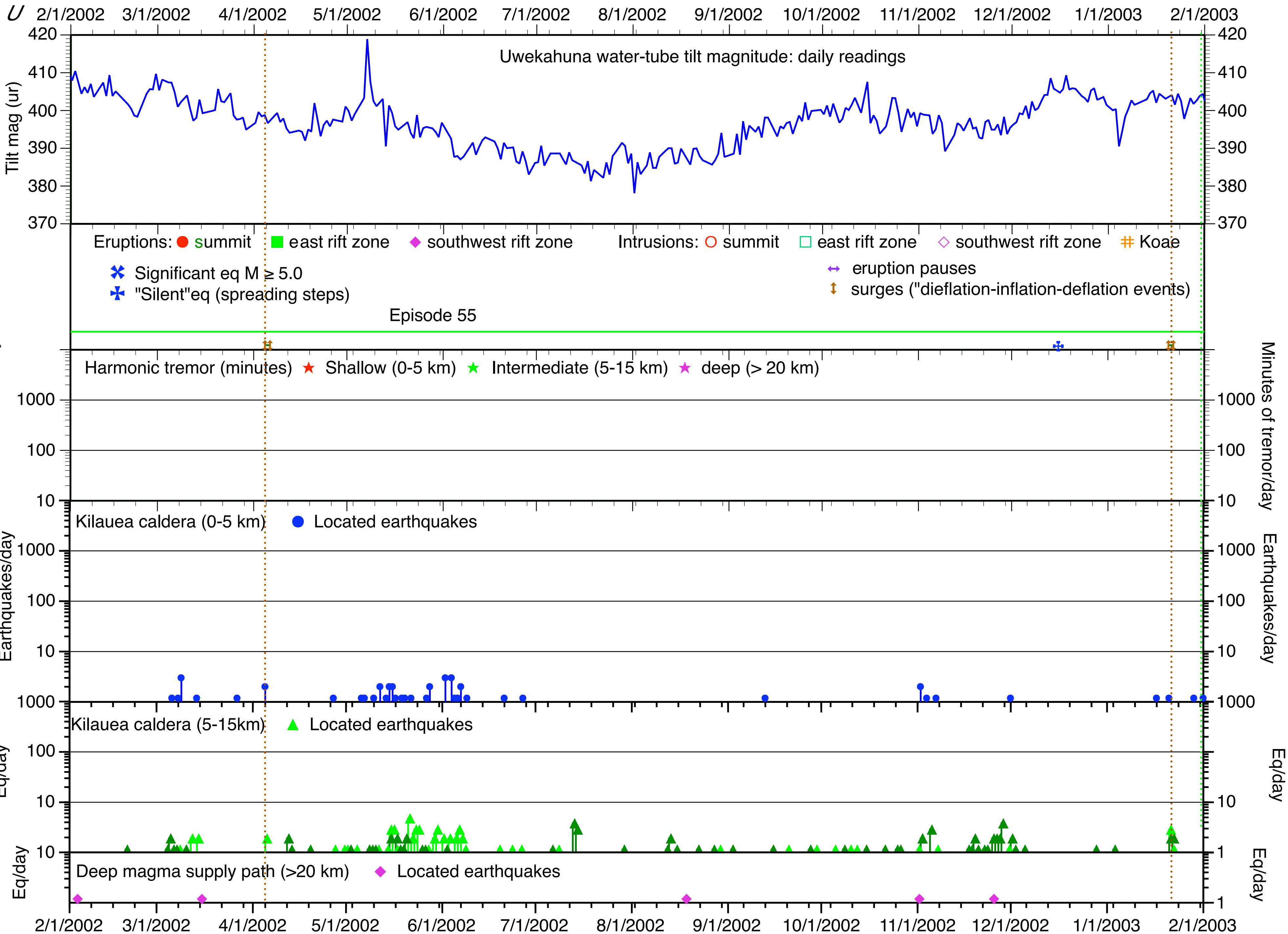
Appendix figure G2 t

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 21/2001-2/1/2002 post-Kupaianaha--episode 55



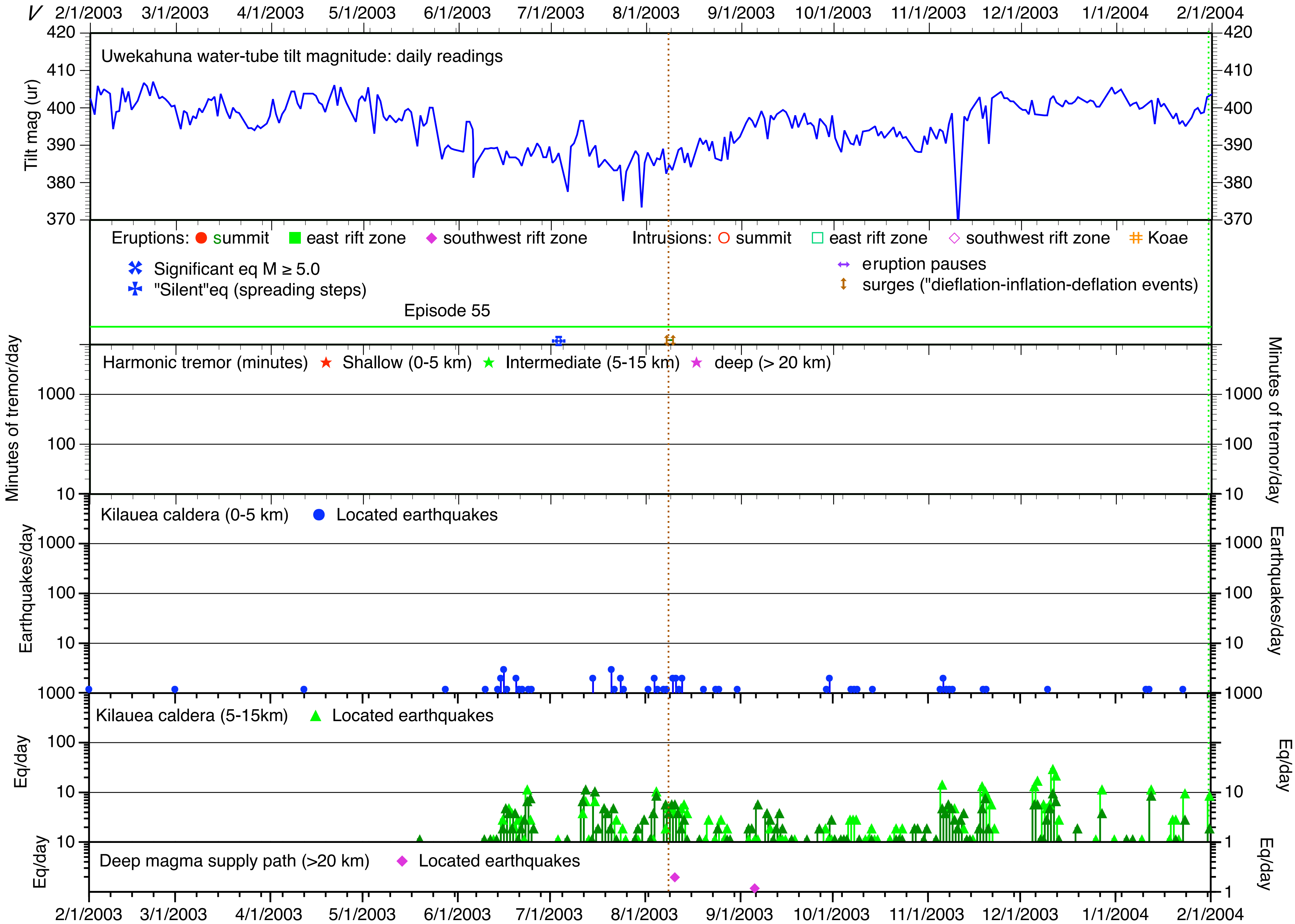
Appendix figure G2 u

Puʻu ʻŌʻo-Kupaianaha eruption long-period seismicity 21/2002-2/1/2003 post-Kupaianaha--episode 55



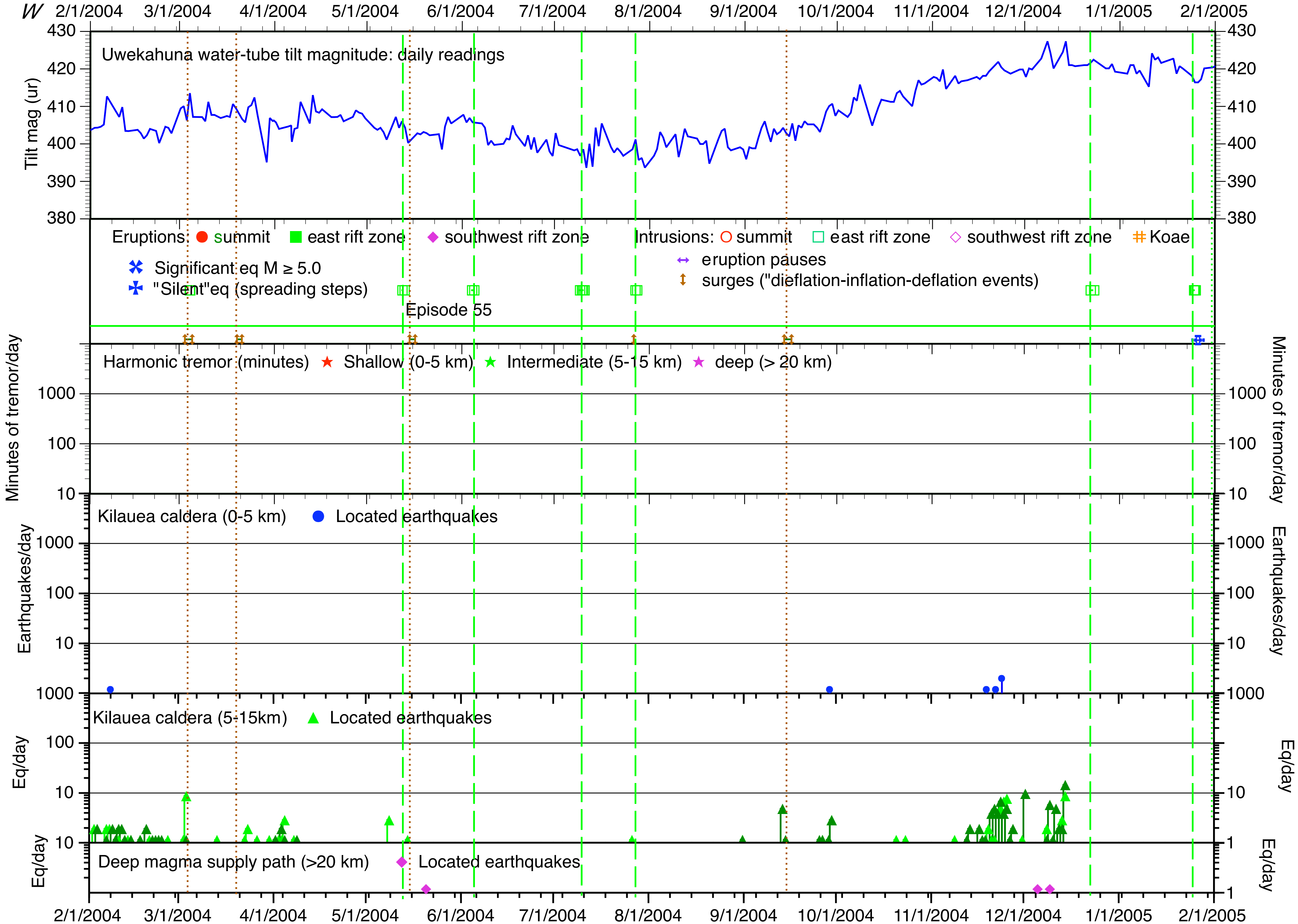
Appendix figure G2 v

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 21/2003-2/1/2004 post-Kupaianaha--episode 55



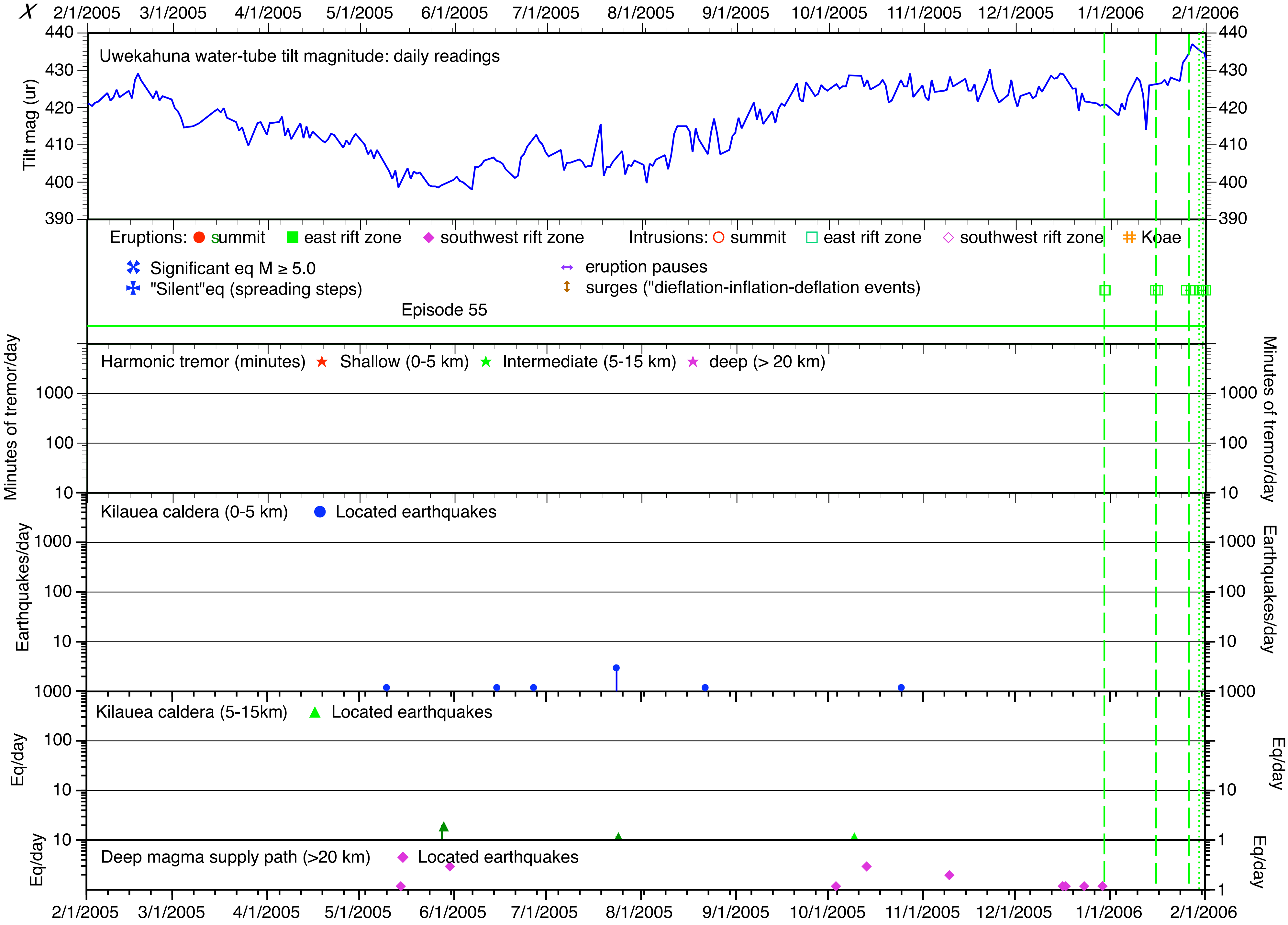
Appendix figure G2 w

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 21/2004-2/1/2005 post-Kupaianaha--episode 55



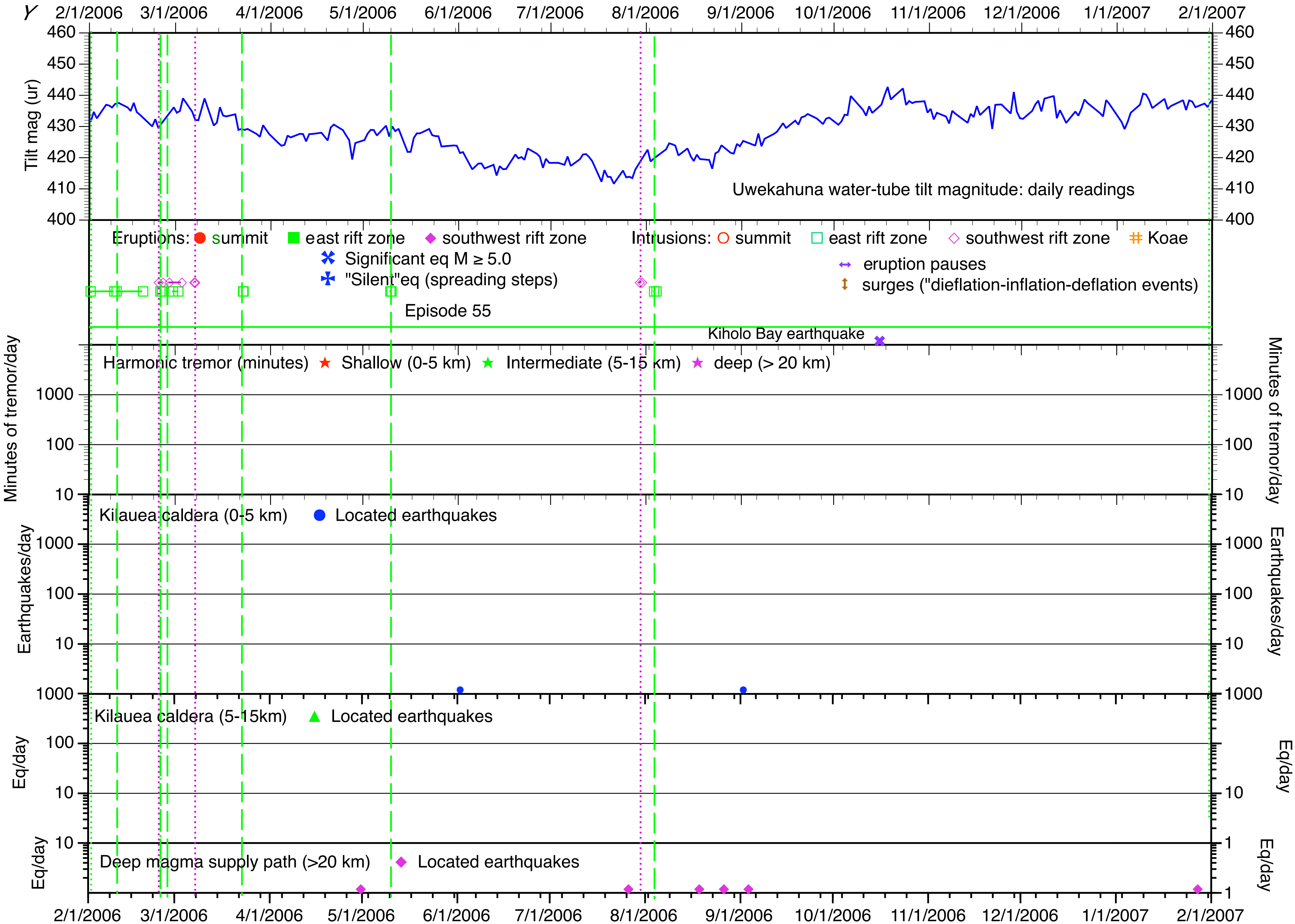
Appendix figure G2 x

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 21/2005-2/1/2006 post-Kupaianaha--episode 55



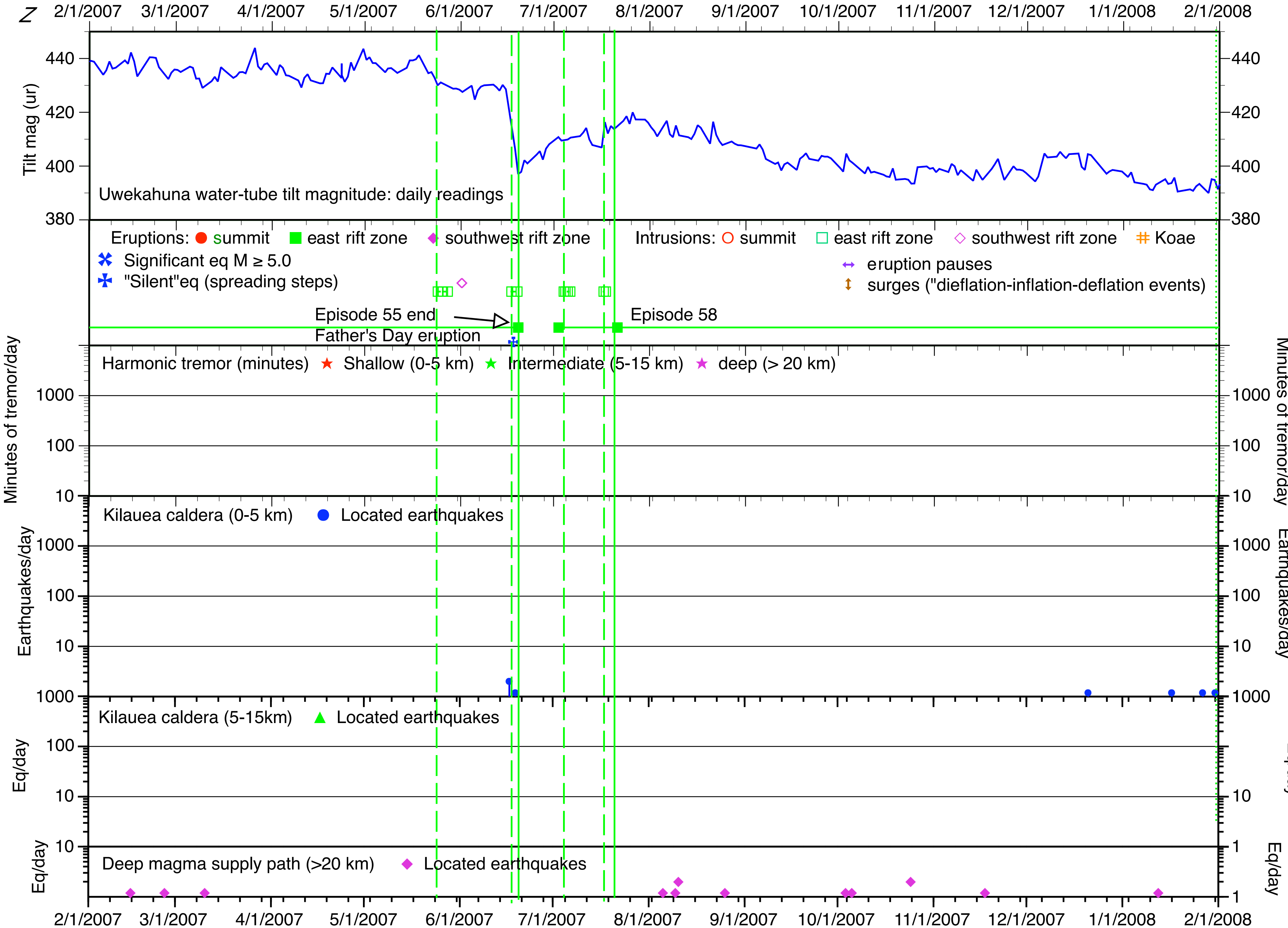
Appendix figure G2 y

Pu‘u ‘Ō‘o-Kupaianaha eruption long-period seismicity 21/2006-2/1/2007 post-Kupaianaha--episode 55

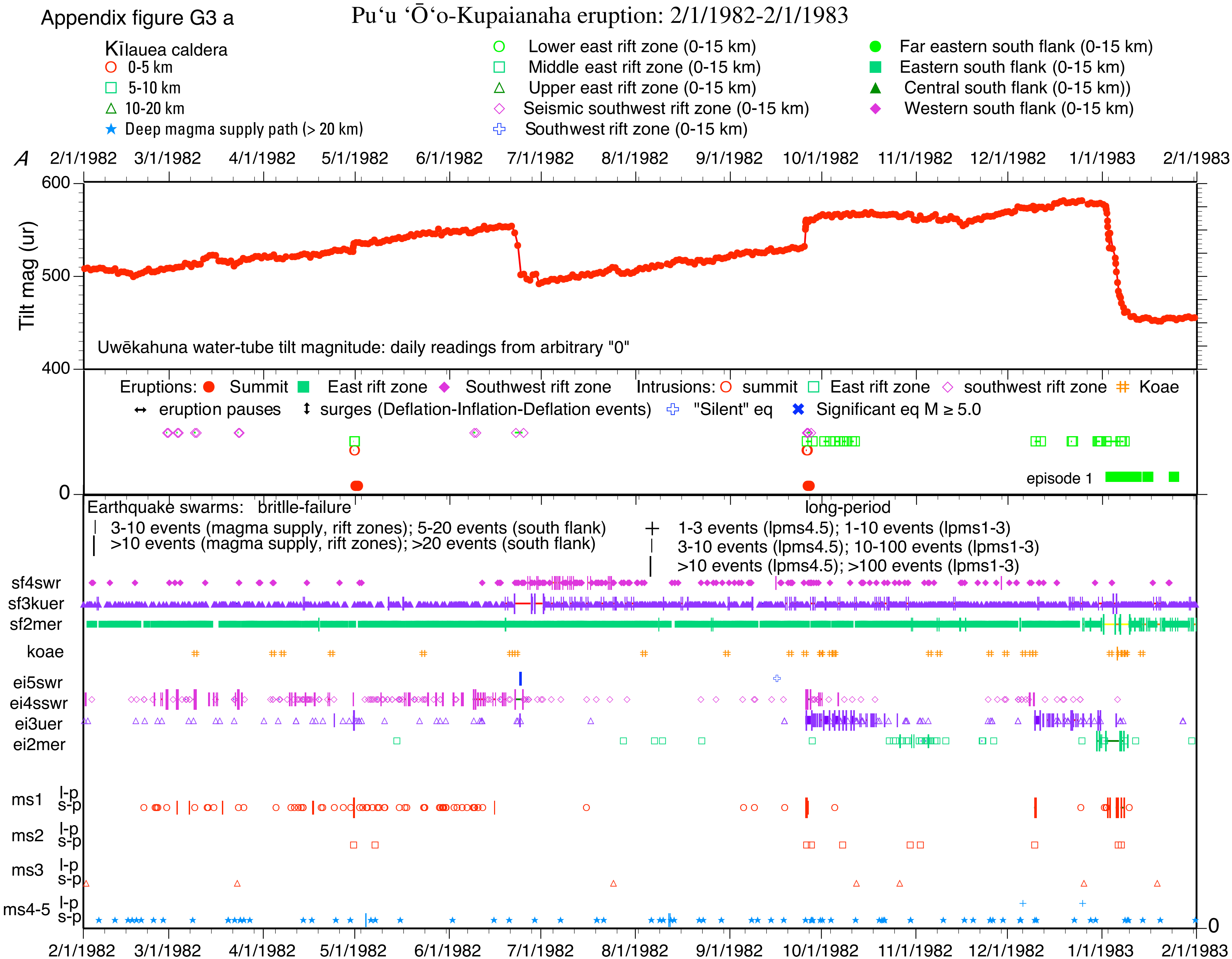


Appendix figure G2 z

Pu‘u ‘Ō‘o-Kupaianaha eruptionn long-period seismicity 21/2007-2/1/2008 post-Kupaianaha--episode 55-58

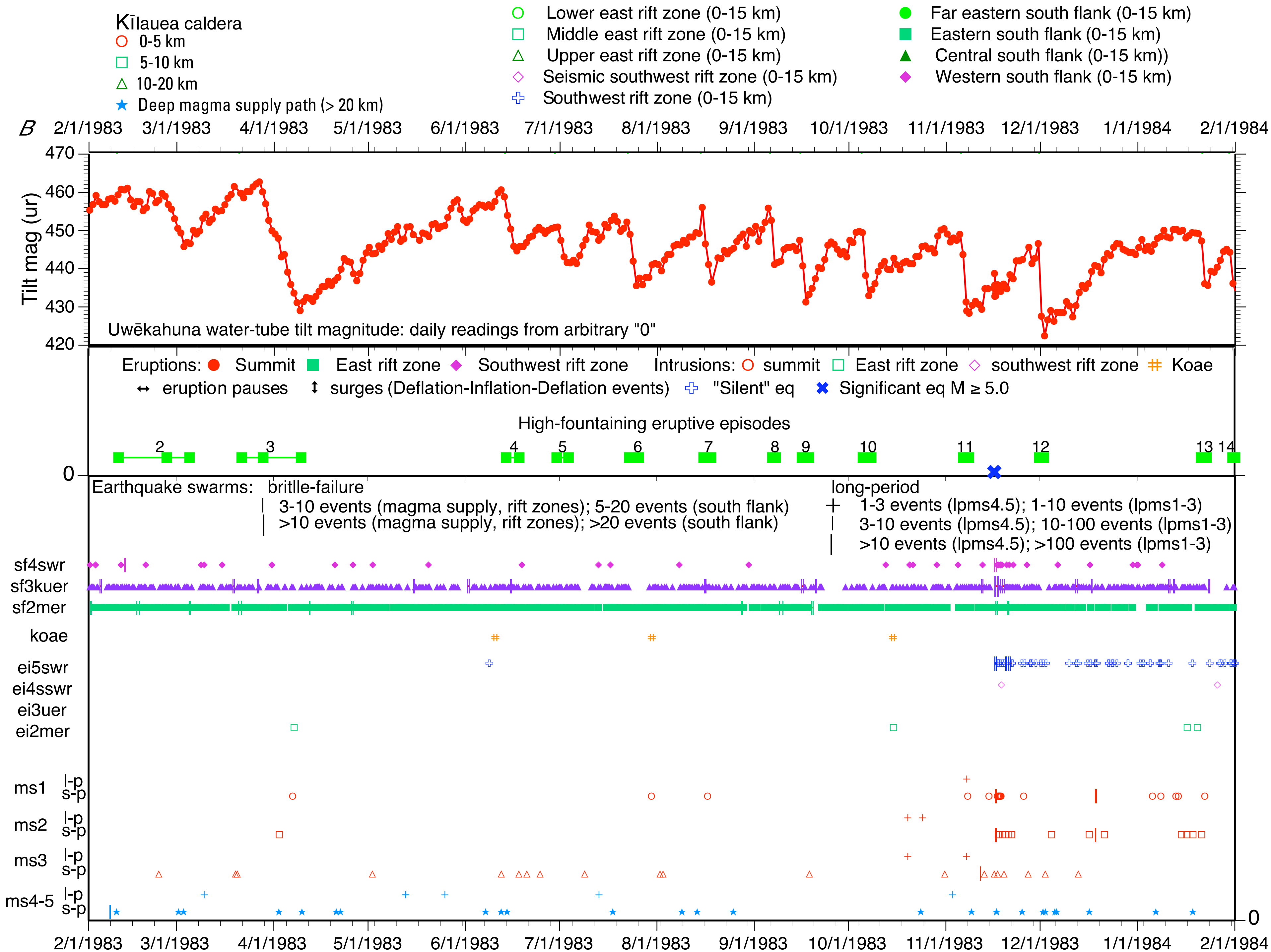


Appendix figure G3 a



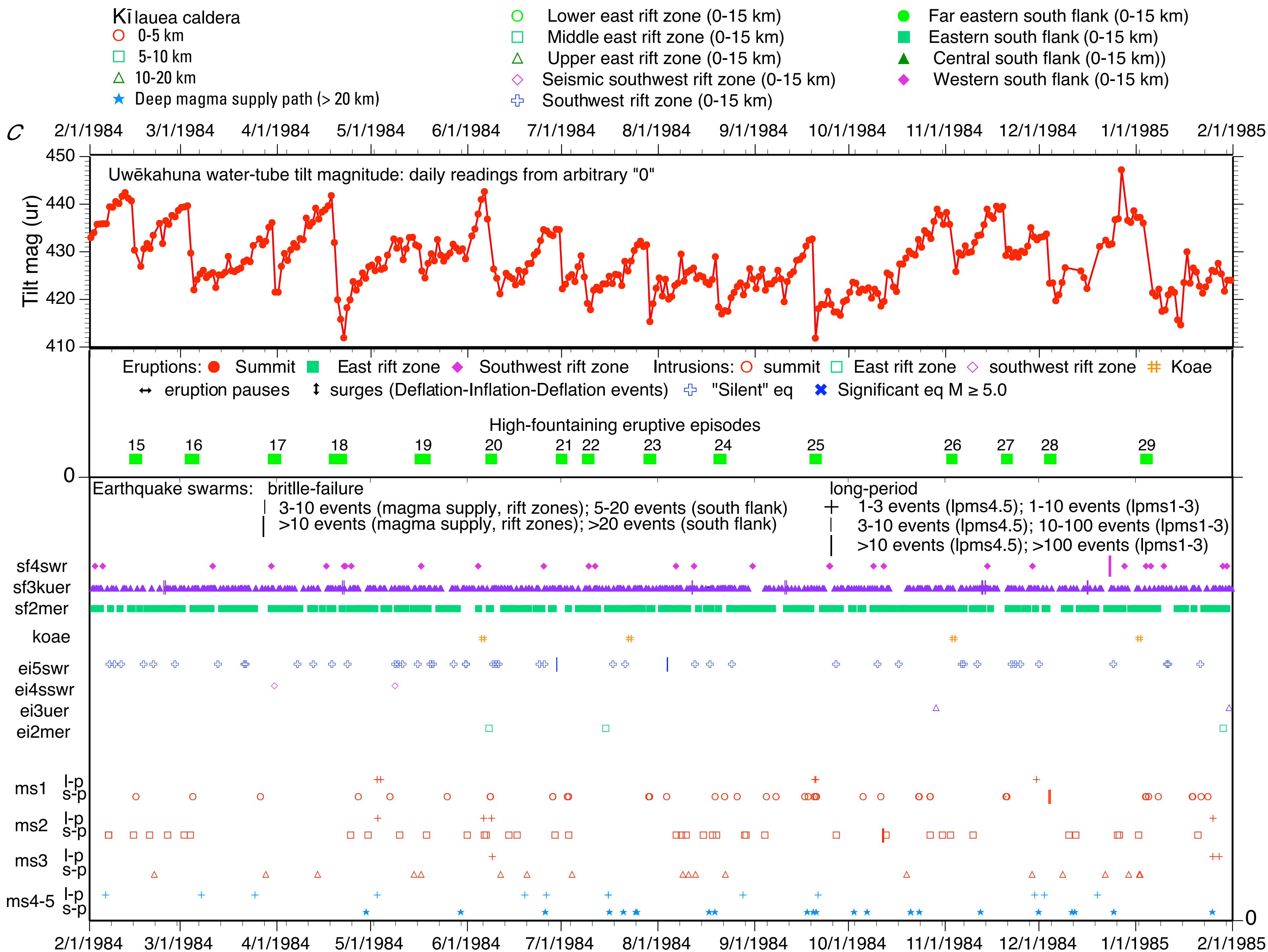
Appendix figure G3 b

Pu‘u ‘Ō‘o-Kupaianaha eruption: 2/1/1983-2/1/1984

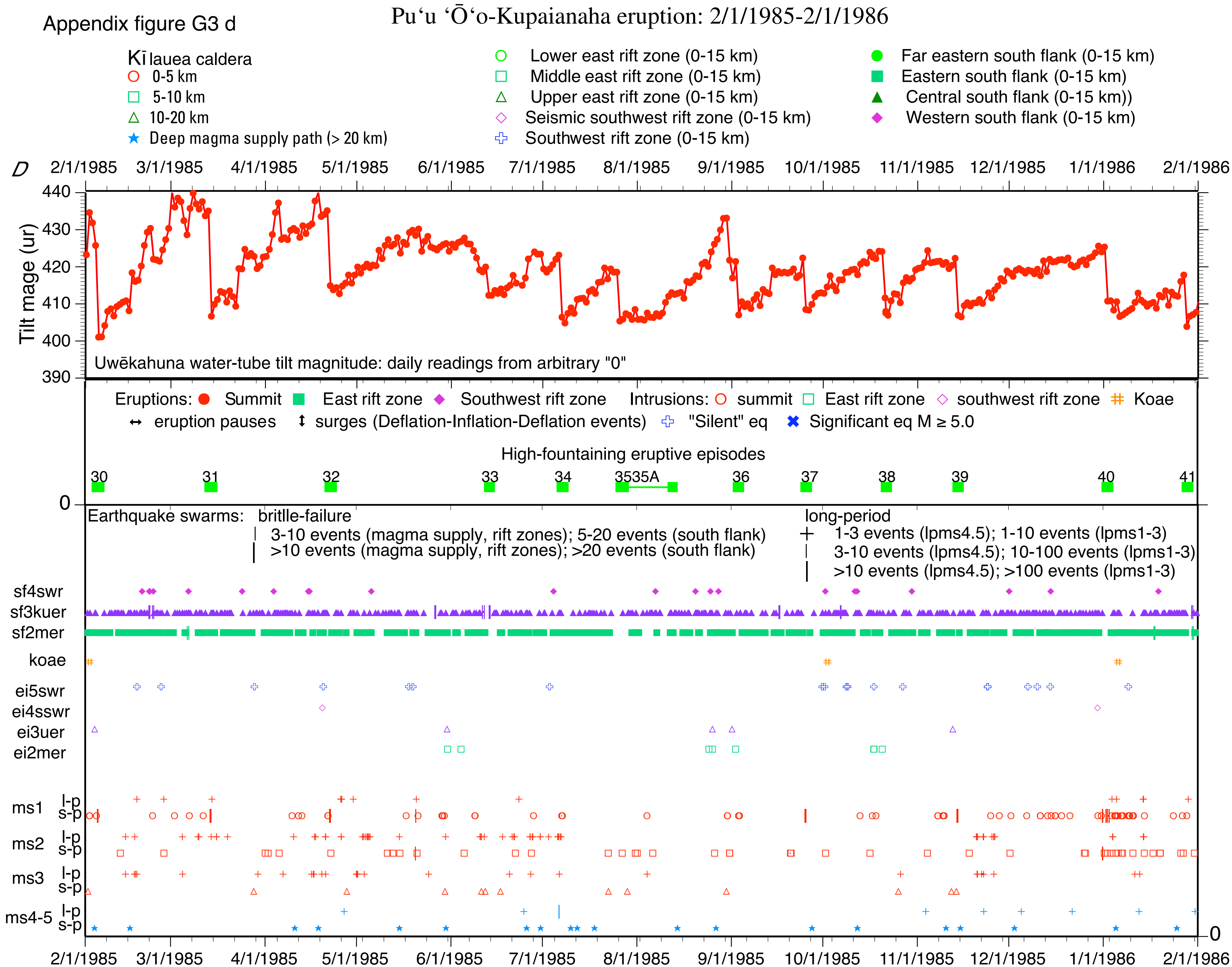


Appendix figure G3 c

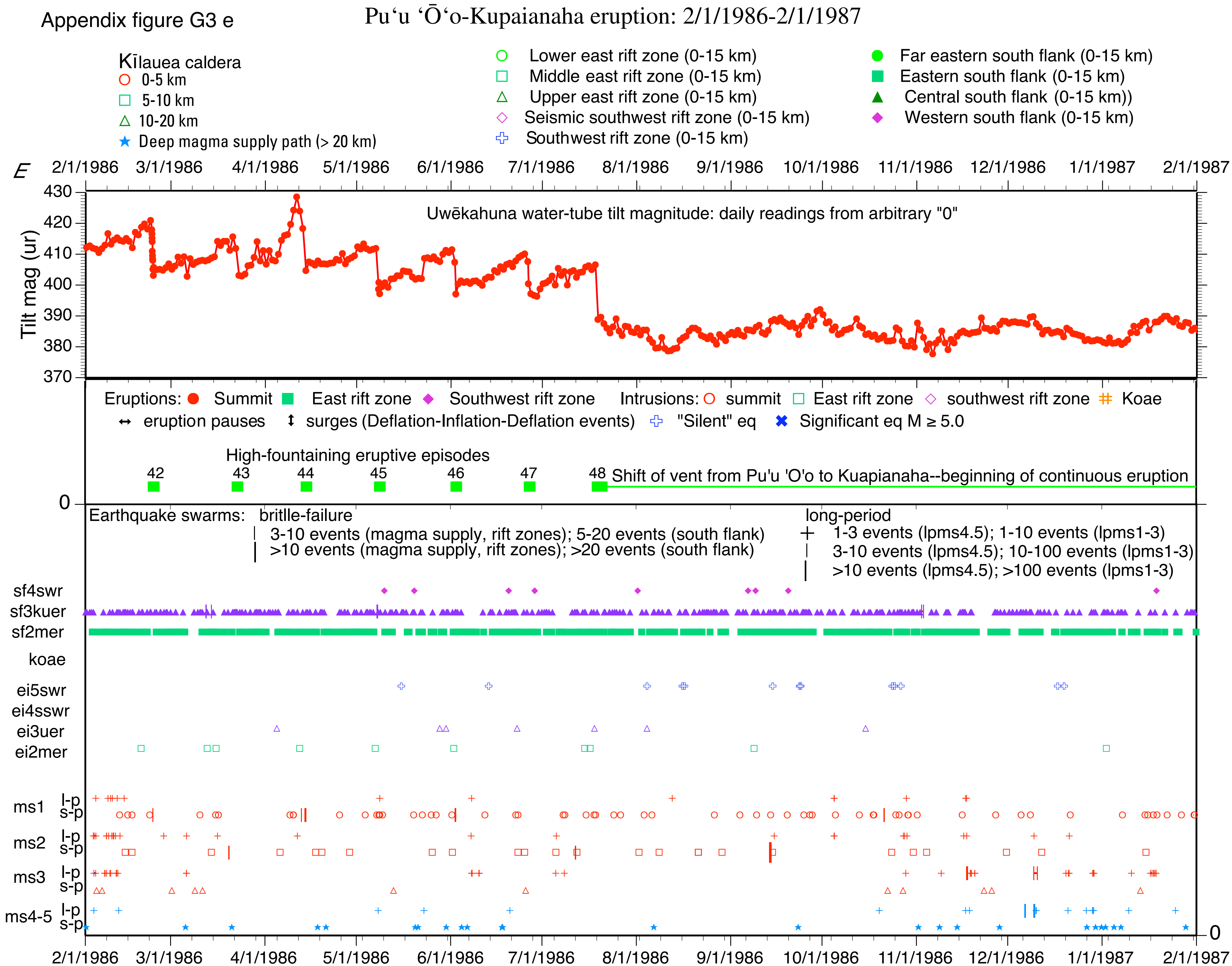
Pu‘u ‘Ō‘o-Kupaianaha eruption: 2/1/1984-2/1/1985



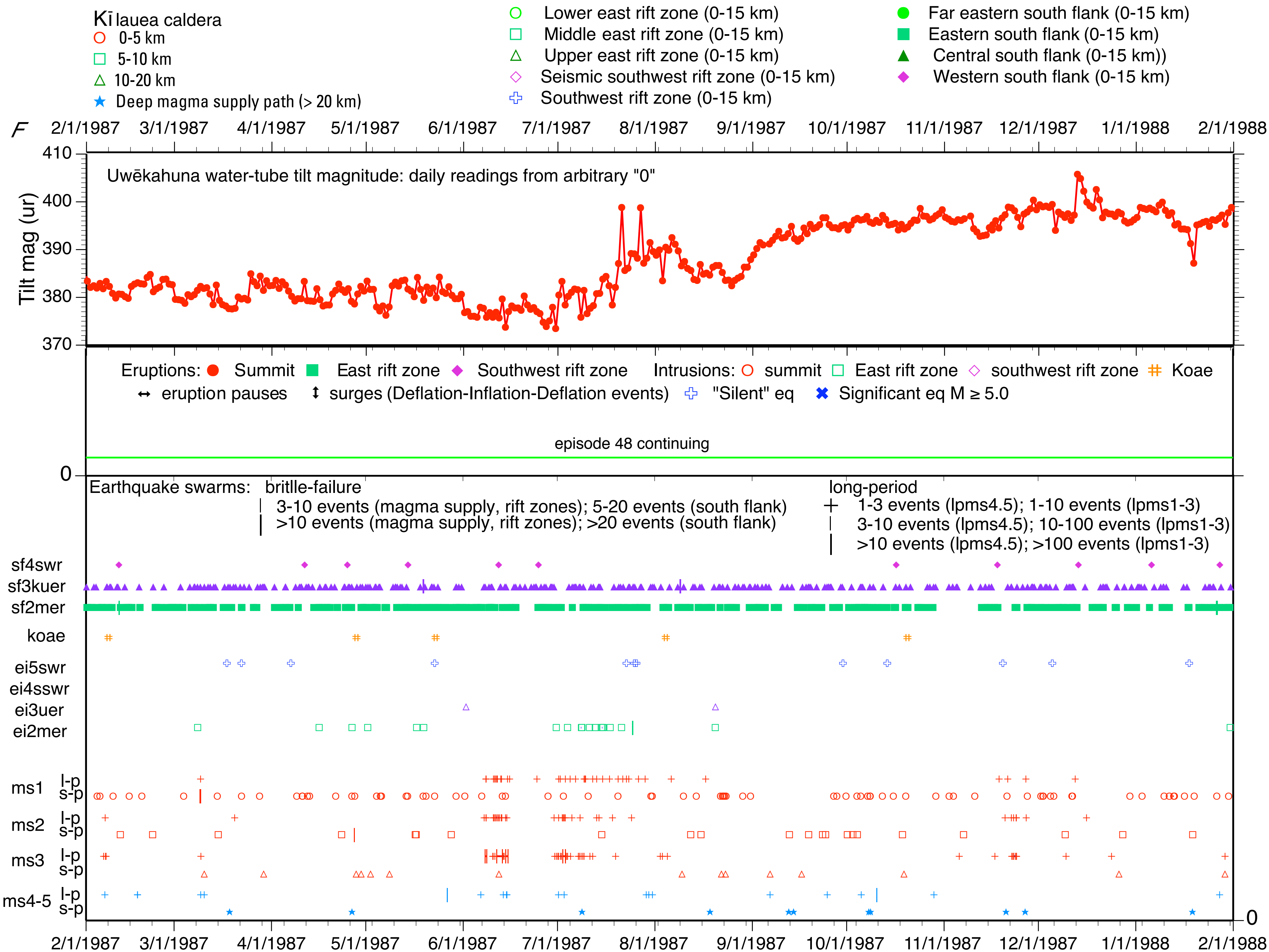
Appendix figure G3 d



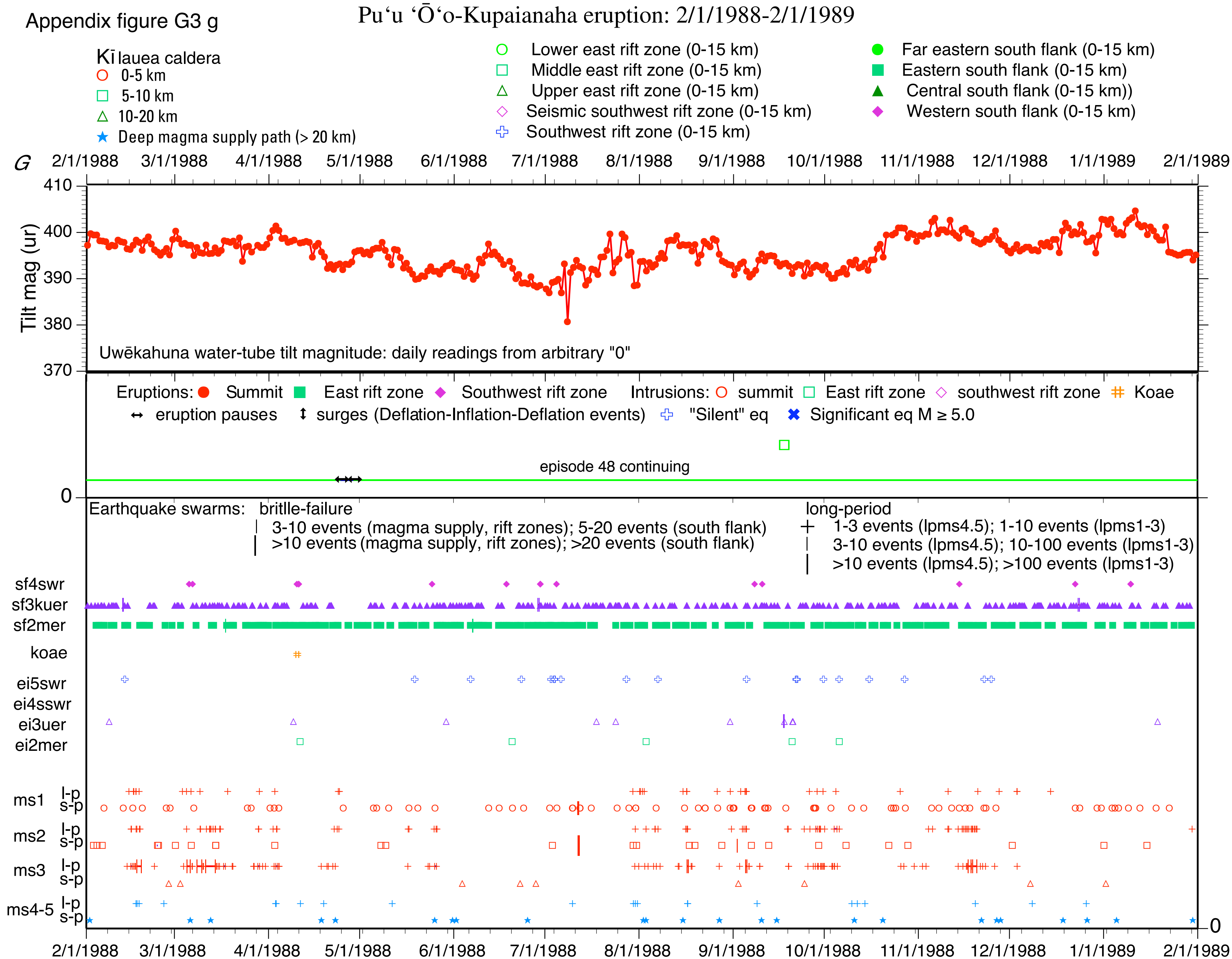
Appendix figure G3 e

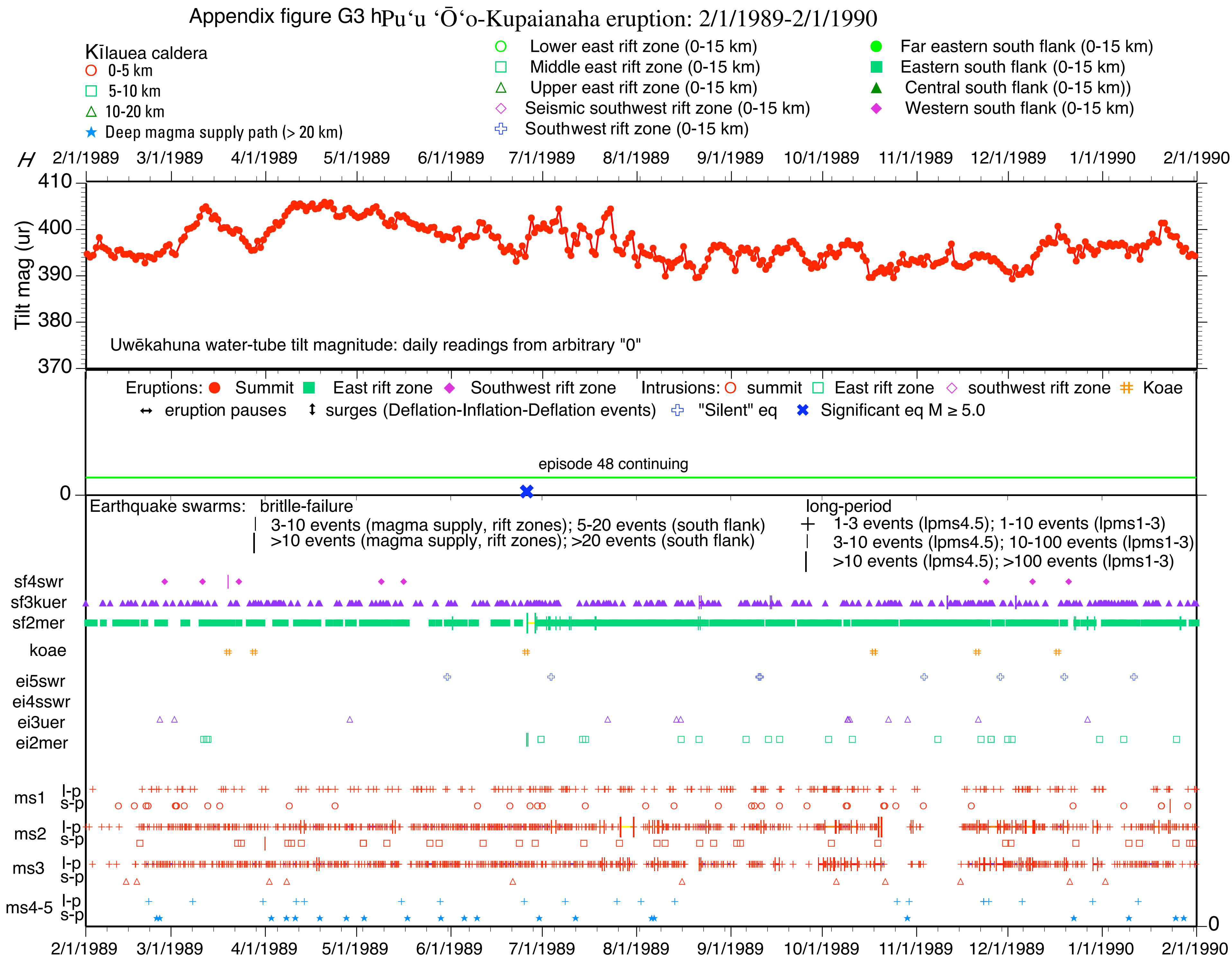


Appendix figure G3 f Puʻu ʻŌʻo-Kupaianaha eruption: 2/1/1987-2/1/1988



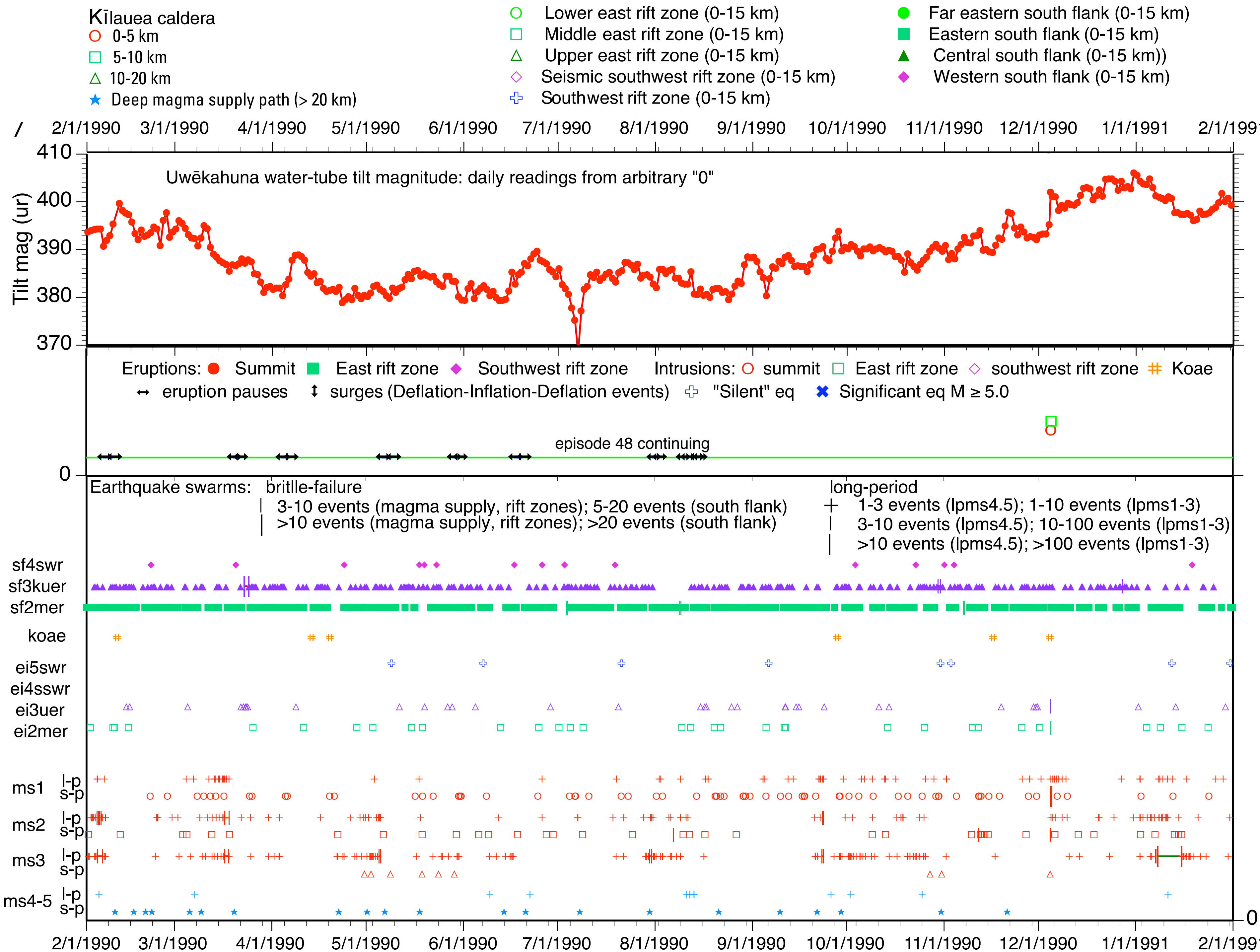
Appendix figure G3 g



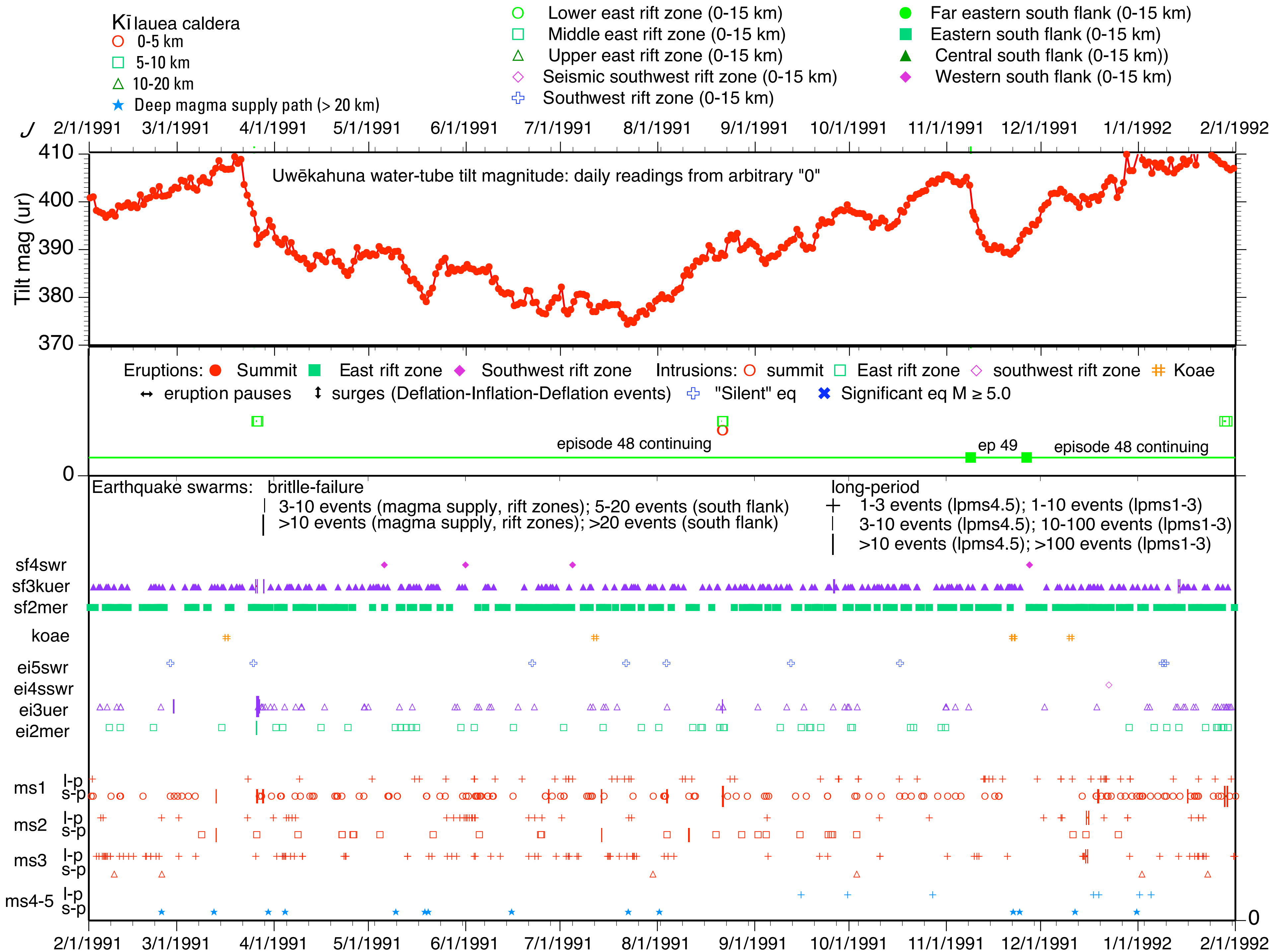


Appendix figure G3 h Puʻu ʻŌʻo-Kupaianaha eruption: 2/1/1989-2/1/1990
Kīlauea caldera
0-5 km
5-10 km
10-20 km
Deep magma supply path (> 20 km)
Lower east rift zone (0-15 km)
Middle east rift zone (0-15 km)
Upper east rift zone (0-15 km)
Seismic southwest rift zone (0-15 km)
Southwest rift zone (0-15 km)
Far eastern south flank (0-15 km)
Eastern south flank (0-15 km)
Central south flank (0-15 km))
Western south flank (0-15 km)
H
2/1/1989 3/1/1989 4/1/1989 5/1/1989 6/1/1989 7/1/1989 8/1/1989 9/1/1989 10/1/1989 11/1/1989 12/1/1989 1/1/1990 2/1/1990
Tilt mag (ur)
410 400 390 380 370
Uwēkahuna water-tube tilt magnitude: daily readings from arbitrary "0"
Eruptions: Summit East rift zone Southwest rift zone Intrusions: summit East rift zone southwest rift zone Koae
eruption pauses surges (Deflation-Inflation-Deflation events) "Silent" eq Significant eq M ≥ 5.0
episode 48 continuing
0
Earthquake swarms: brittle-failure
3-10 events (magma supply, rift zones); 5-20 events (south flank)
>10 events (magma supply, rift zones); >20 events (south flank)
long-period
1-3 events (lpms4.5); 1-10 events (lpms1-3)
3-10 events (lpms4.5); 10-100 events (lpms1-3)
>10 events (lpms4.5); >100 events (lpms1-3)
sf4swr
sf3kuer
sf2mer
koae
ei5swr
ei4sswr
ei3uer
ei2mer
ms1 l-p s-p
ms2 l-p s-p
ms3 l-p s-p
ms4-5 l-p s-p
0
2/1/1989 3/1/1989 4/1/1989 5/1/1989 6/1/1989 7/1/1989 8/1/1989 9/1/1989 10/1/1989 11/1/1989 12/1/1989 1/1/1990 2/1/1990

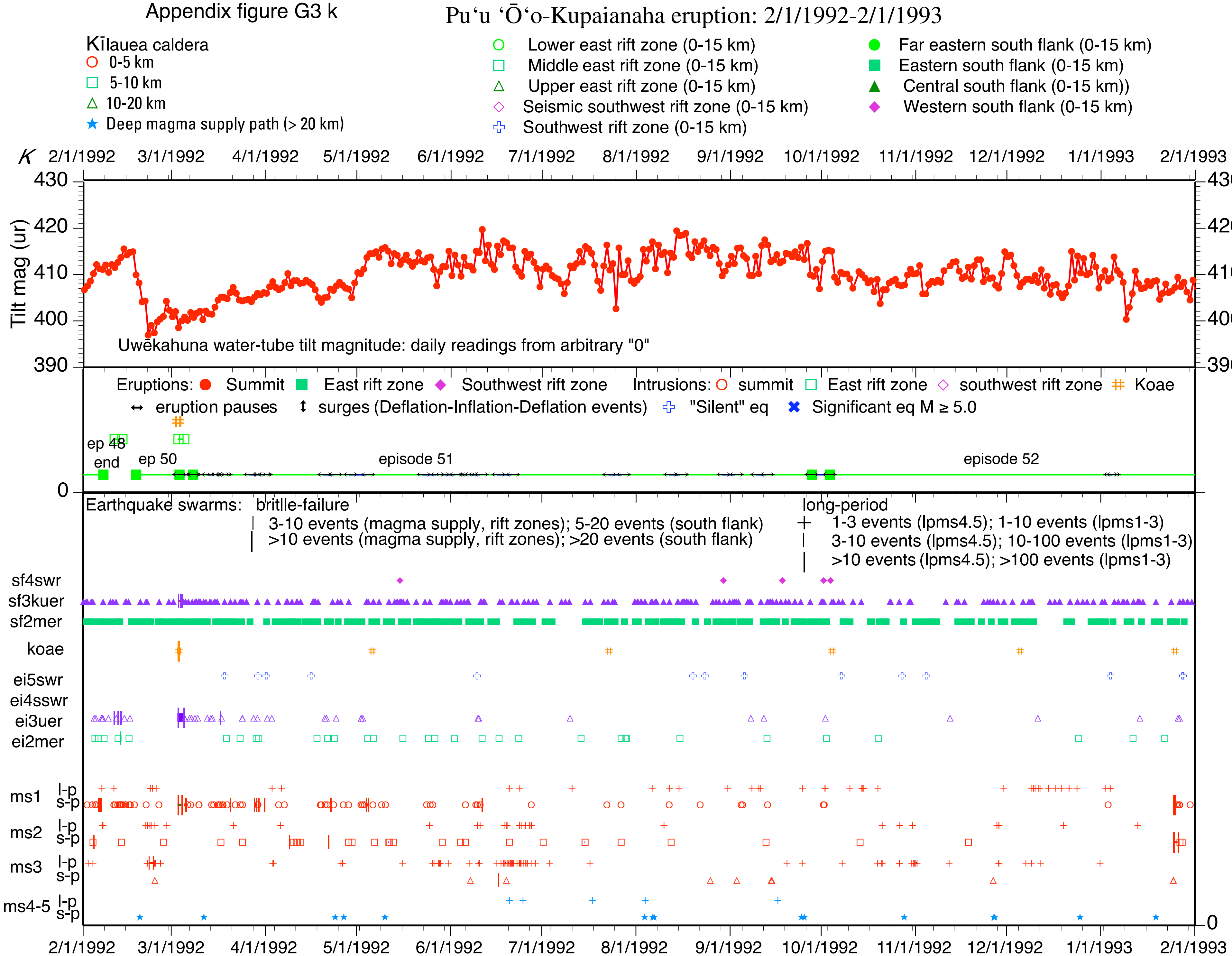
Appendix figure G3 ¡ Puʻu ʻŌʻo-Kupaianaha eruption: 2/1/1990-2/1/1991



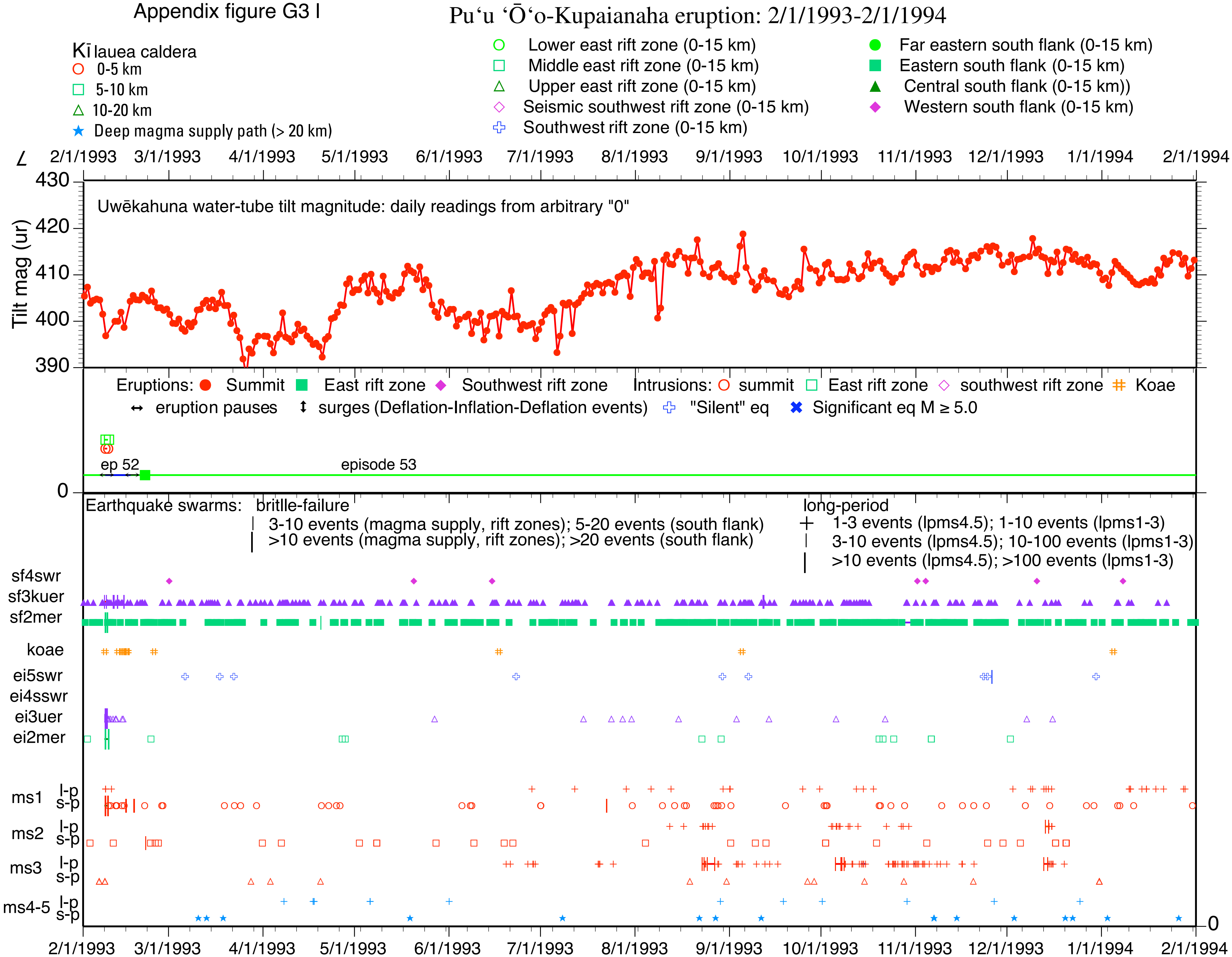
Appendix figure G3 j Puʻu ʻŌʻo-Kupaianaha eruption: 2/1/1991-2/1/1992



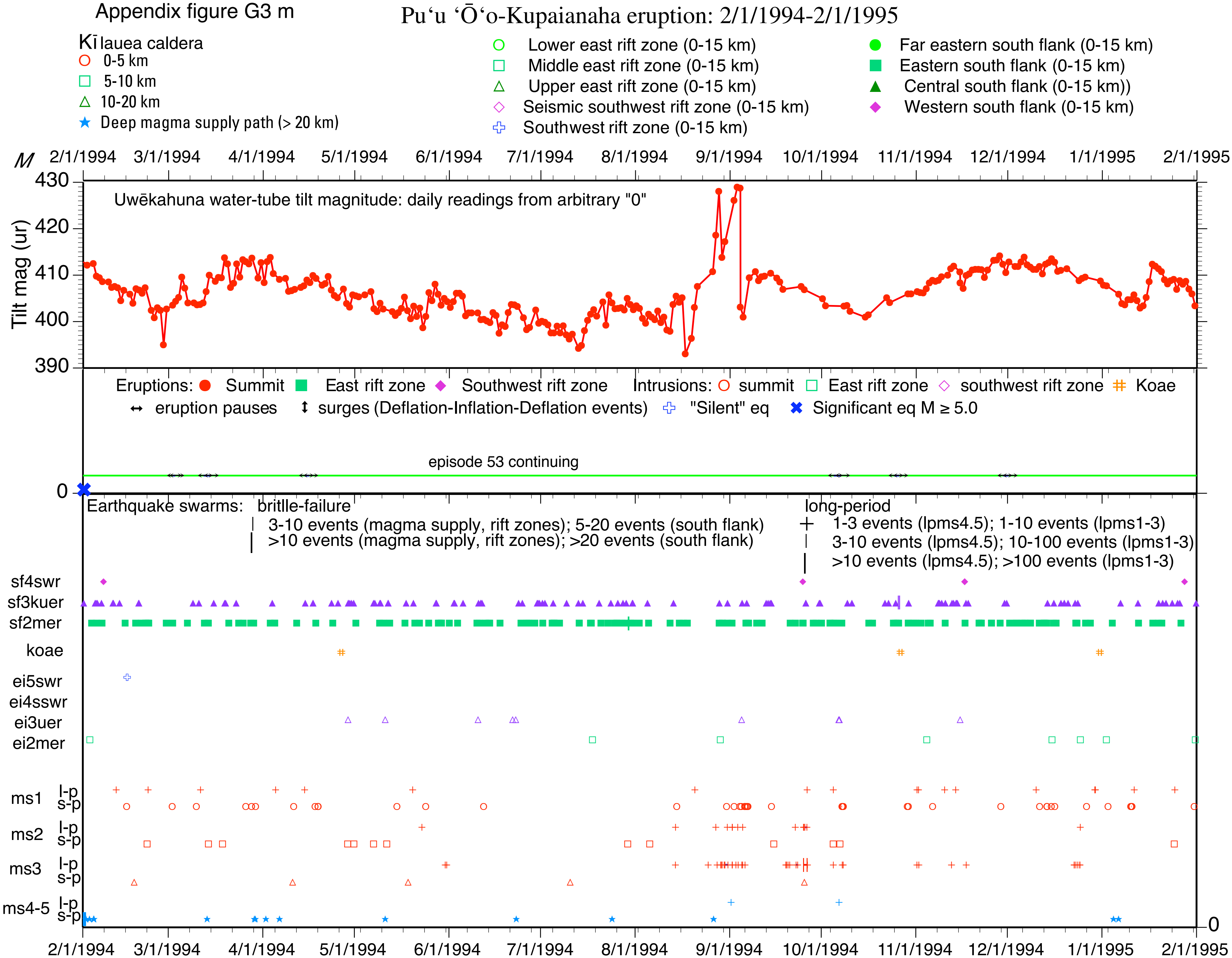
Appendix figure G3 k



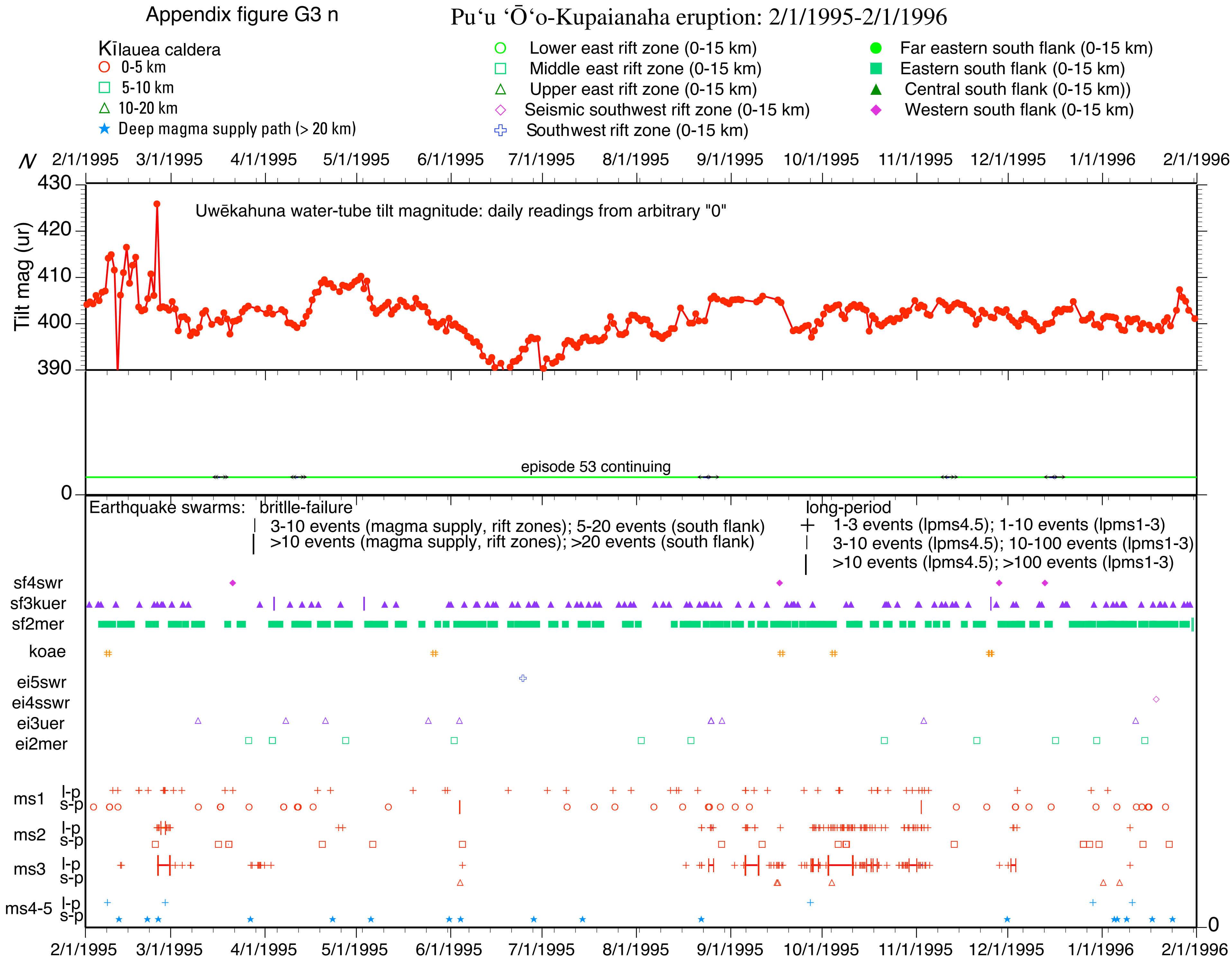
Appendix figure G3 l



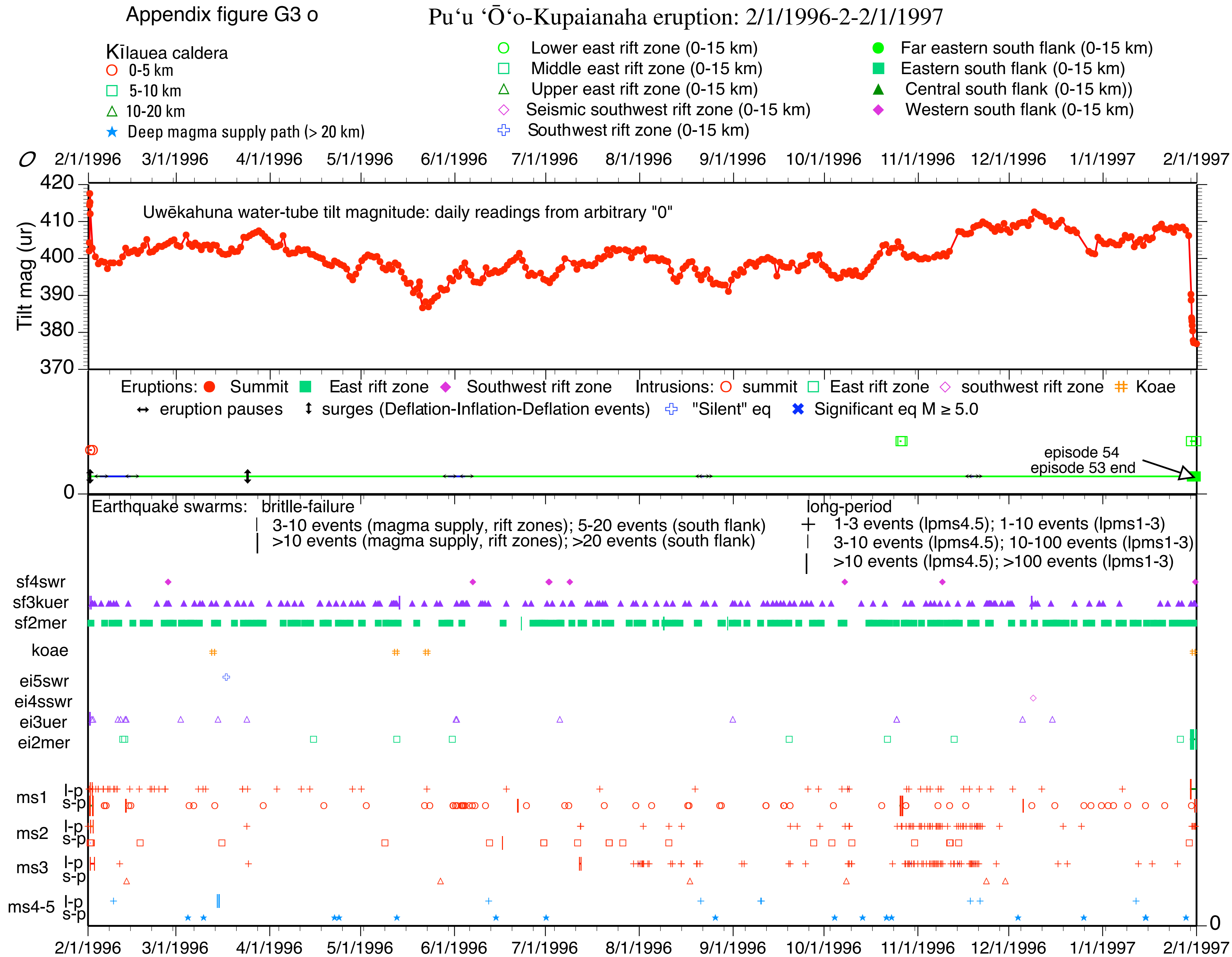
Appendix figure G3 m



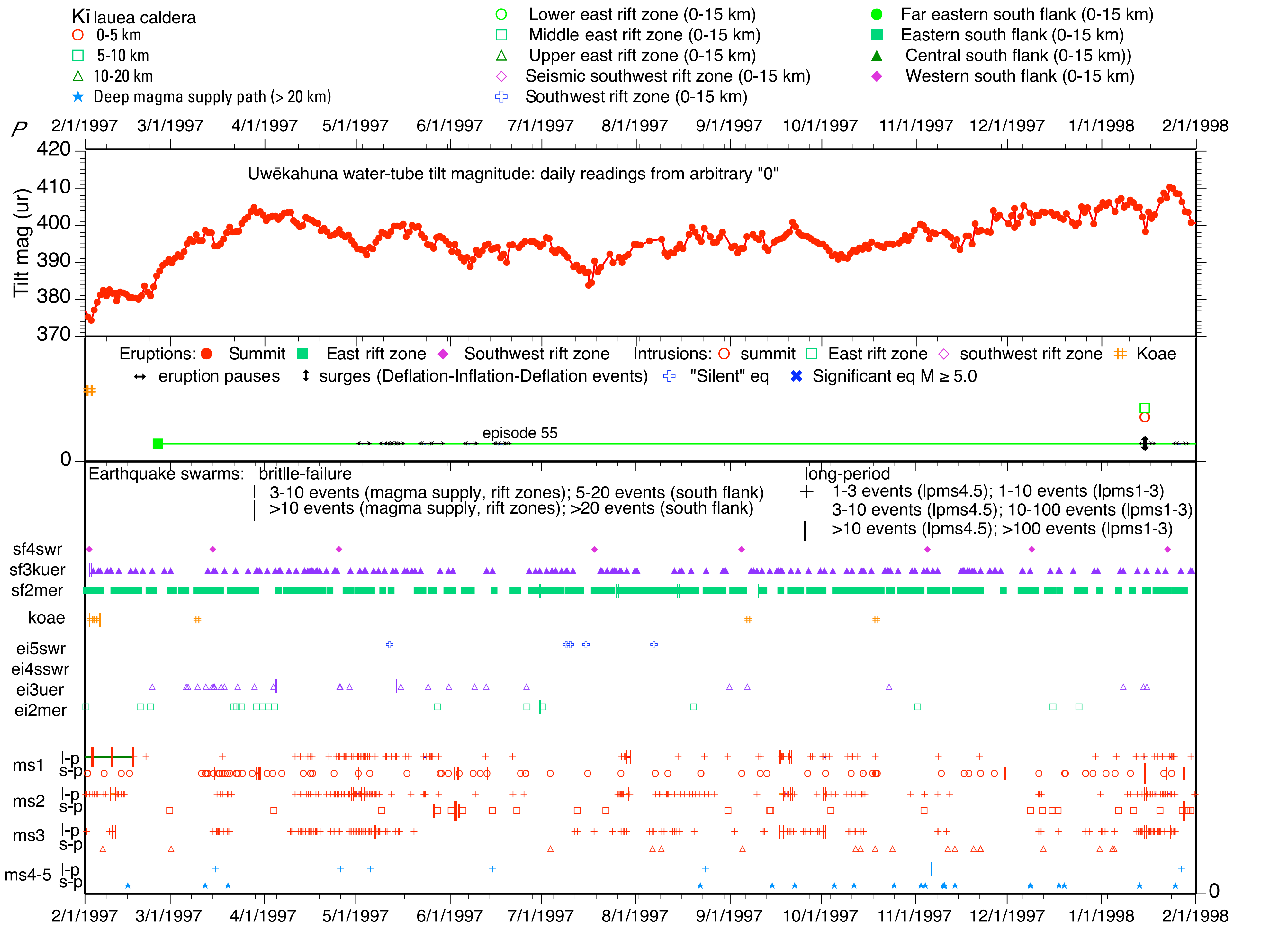
Appendix figure G3 n

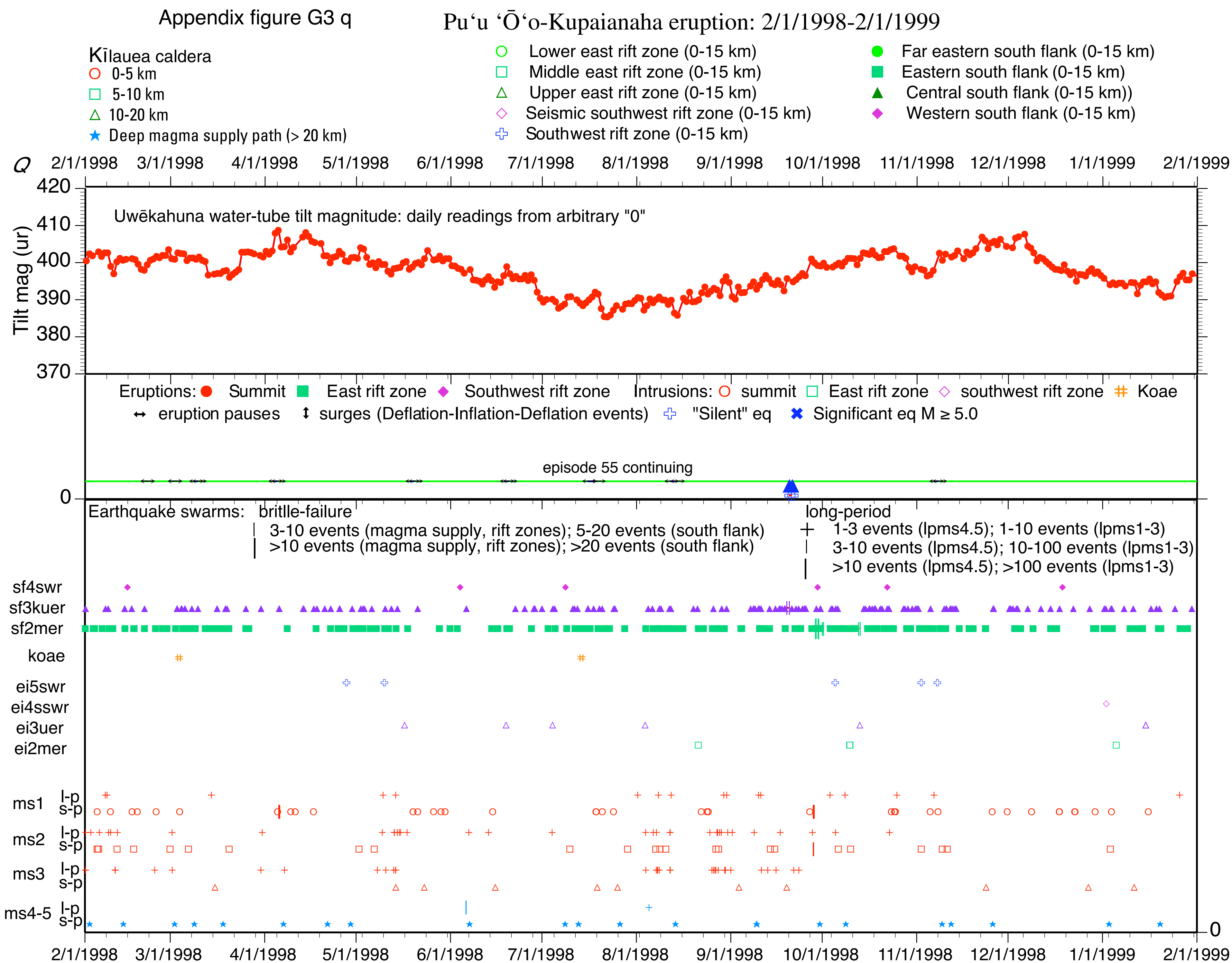


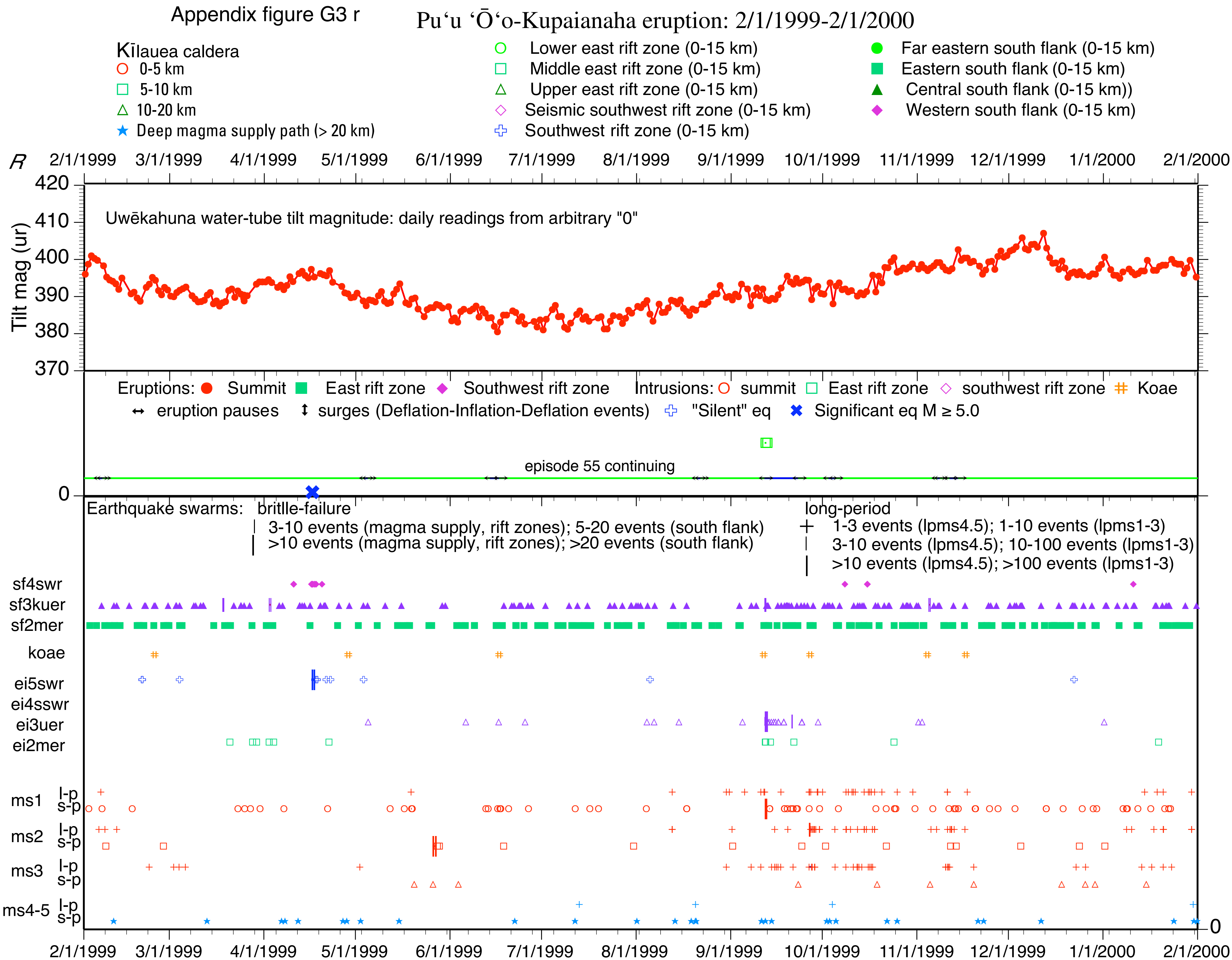
Appendix figure G3 o



Appendix figure G3 p Puʻu ʻŌʻo-Kupaianaha eruption: 2/1/1997-2/1/1998



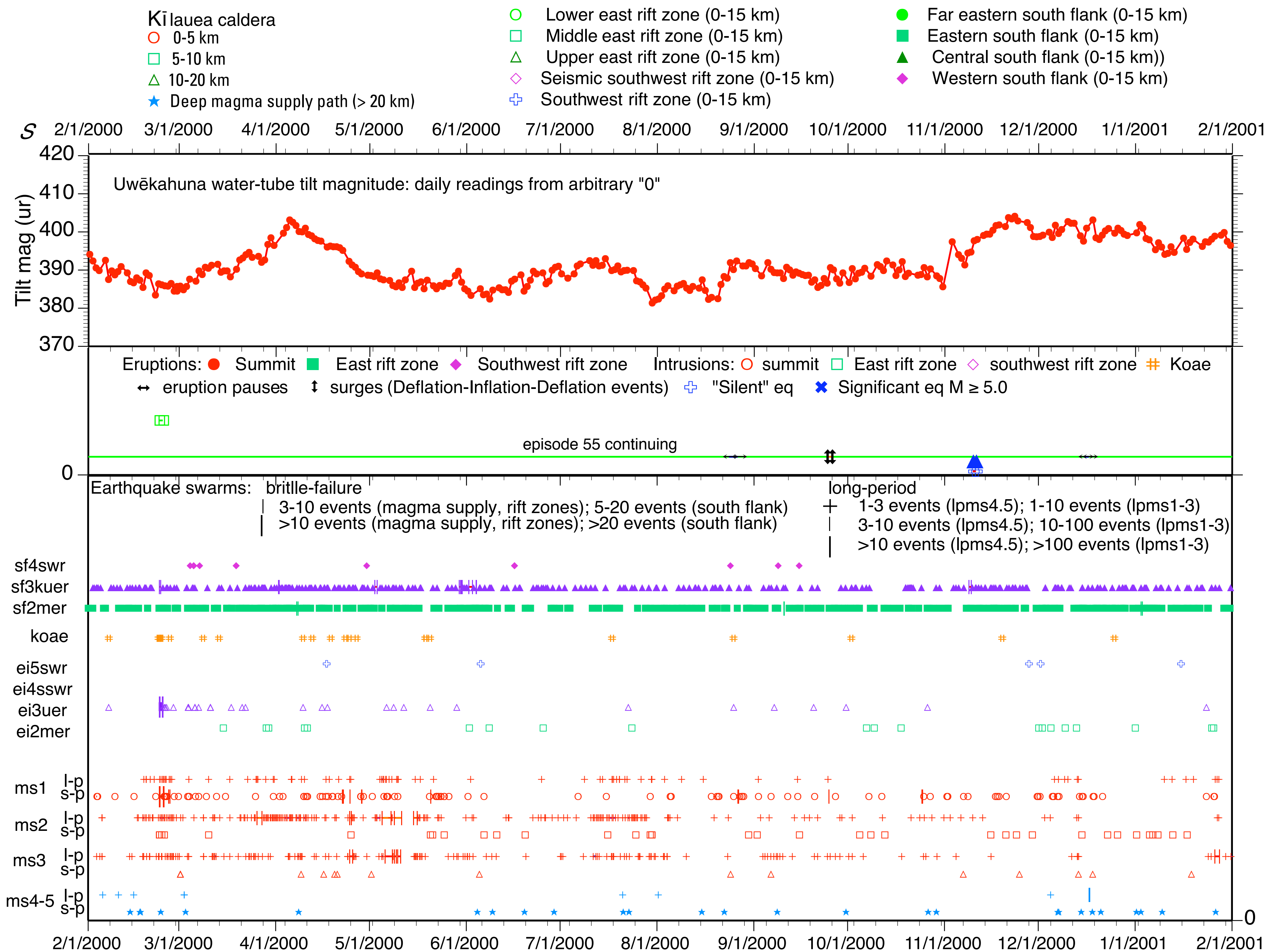

Appendix figure G3 q
Pu'u 'Ō'o-Kupaianaha eruption: 2/1/1998-2/1/1999
Kīlauea caldera
0-5 km
5-10 km
10-20 km
Deep magma supply path (> 20 km)
Lower east rift zone (0-15 km)
Middle east rift zone (0-15 km)
Upper east rift zone (0-15 km)
Seismic southwest rift zone (0-15 km)
Southwest rift zone (0-15 km)
Far eastern south flank (0-15 km)
Eastern south flank (0-15 km)
Central south flank (0-15 km))
Western south flank (0-15 km)
Q
2/1/1998 3/1/1998 4/1/1998 5/1/1998 6/1/1998 7/1/1998 8/1/1998 9/1/1998 10/1/1998 11/1/1998 12/1/1998 1/1/1999 2/1/1999
Tilt mag (ur)
420 410 400 390 380 370
Uwēkahuna water-tube tilt magnitude: daily readings from arbitrary "0"
Eruptions: Summit East rift zone Southwest rift zone Intrusions: summit East rift zone southwest rift zone Koae
eruption pauses surges (Deflation-Inflation-Deflation events) "Silent" eq Significant eq M ≥ 5.0
episode 55 continuing
0
Earthquake swarms: britlle-failure
3-10 events (magma supply, rift zones); 5-20 events (south flank)
>10 events (magma supply, rift zones); >20 events (south flank)
long-period
1-3 events (lpms4.5); 1-10 events (lpms1-3)
3-10 events (lpms4.5); 10-100 events (lpms1-3)
>10 events (lpms4.5); >100 events (lpms1-3)
sf4swr
sf3kuer
sf2mer
koae
ei5swr
ei4sswr
ei3uer
ei2mer
ms1 l-p s-p
ms2 l-p s-p
ms3 l-p s-p
ms4-5 l-p s-p
0
2/1/1998 3/1/1998 4/1/1998 5/1/1998 6/1/1998 7/1/1998 8/1/1998 9/1/1998 10/1/1998 11/1/1998 12/1/1998 1/1/1999 2/1/1999



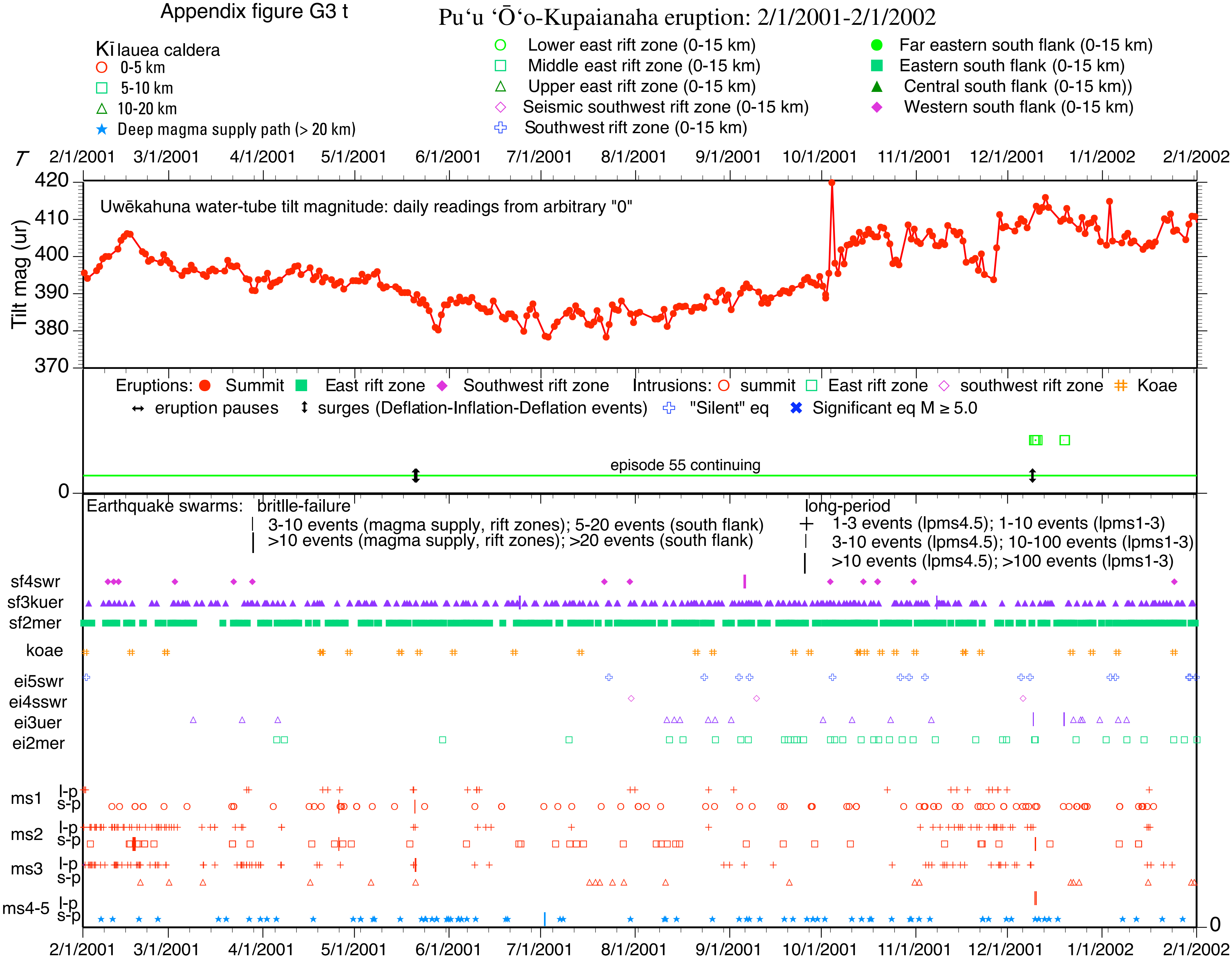
Appendix figure G3 r
Pu‘u ‘Ō‘o-Kupaianaha eruption: 2/1/1999-2/1/2000
Kīlauea caldera
0-5 km
5-10 km
10-20 km
Deep magma supply path (> 20 km)
Lower east rift zone (0-15 km)
Middle east rift zone (0-15 km)
Upper east rift zone (0-15 km)
Seismic southwest rift zone (0-15 km)
Southwest rift zone (0-15 km)
Far eastern south flank (0-15 km)
Eastern south flank (0-15 km)
Central south flank (0-15 km))
Western south flank (0-15 km)
R
2/1/1999 3/1/1999 4/1/1999 5/1/1999 6/1/1999 7/1/1999 8/1/1999 9/1/1999 10/1/1999 11/1/1999 12/1/1999 1/1/2000 2/1/2000
Tilt mag (ur)
420 410 400 390 380 370
Uwēkahuna water-tube tilt magnitude: daily readings from arbitrary "0"
Eruptions: Summit East rift zone Southwest rift zone
Intrusions: summit East rift zone southwest rift zone Koae
eruption pauses
surges (Deflation-Inflation-Deflation events)
"Silent" eq
Significant eq M ≥ 5.0
episode 55 continuing
0
Earthquake swarms: britlle-failure
3-10 events (magma supply, rift zones); 5-20 events (south flank)
>10 events (magma supply, rift zones); >20 events (south flank)
long-period
1-3 events (lpms4.5); 1-10 events (lpms1-3)
3-10 events (lpms4.5); 10-100 events (lpms1-3)
>10 events (lpms4.5); >100 events (lpms1-3)
sf4swr
sf3kuer
sf2mer
koae
ei5swr
ei4sswr
ei3uer
ei2mer
ms1 l-p s-p
ms2 l-p s-p
ms3 l-p s-p
ms4-5 l-p s-p
0
2/1/1999 3/1/1999 4/1/1999 5/1/1999 6/1/1999 7/1/1999 8/1/1999 9/1/1999 10/1/1999 11/1/1999 12/1/1999 1/1/2000 2/1/2000

Appendix figure G3 s

Pu‘u ‘Ō‘o-Kupaianaha eruption: 2/1/2000-2/1/2001

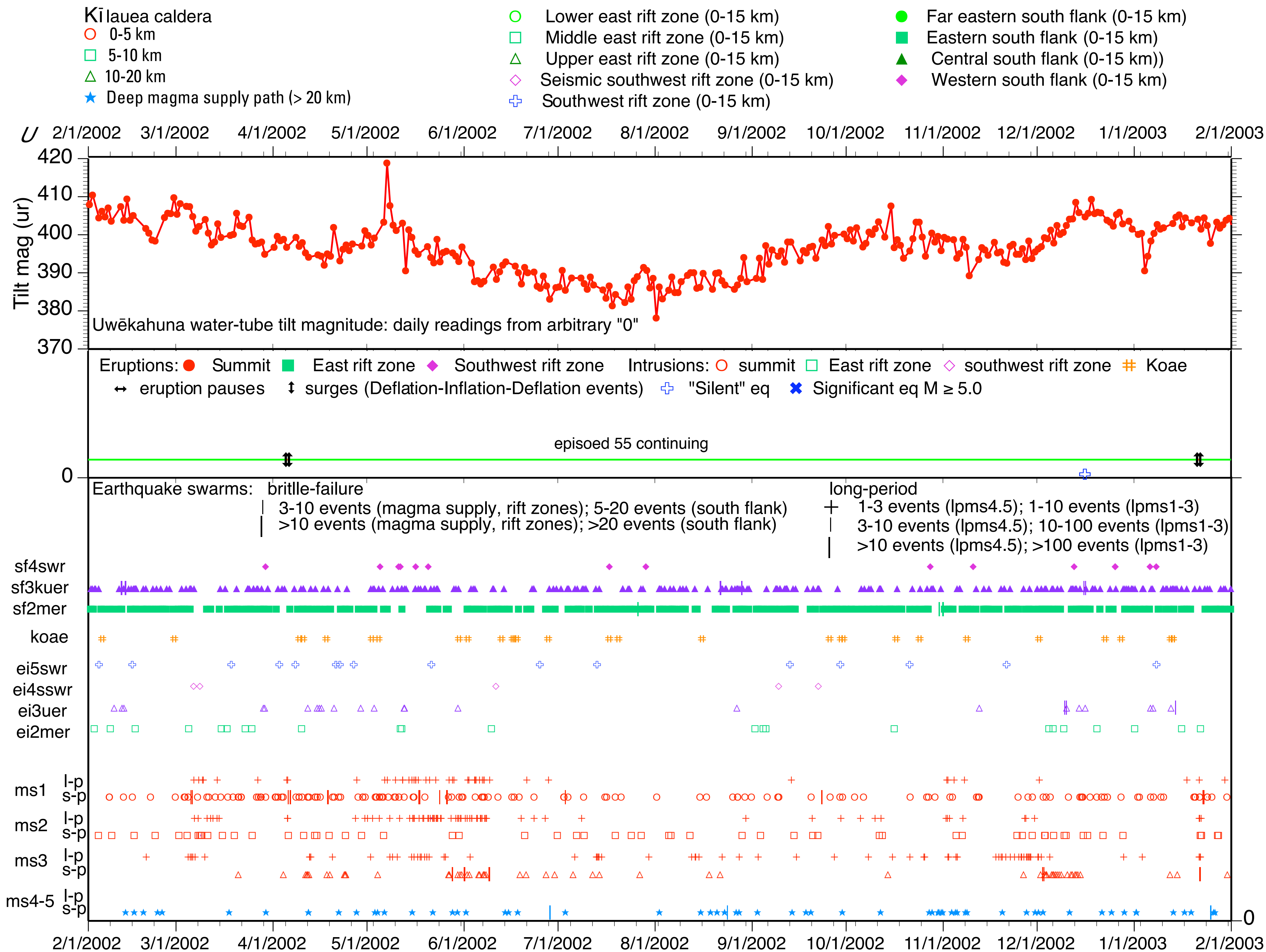


Appendix figure G3 t



Appendix figure G3 u

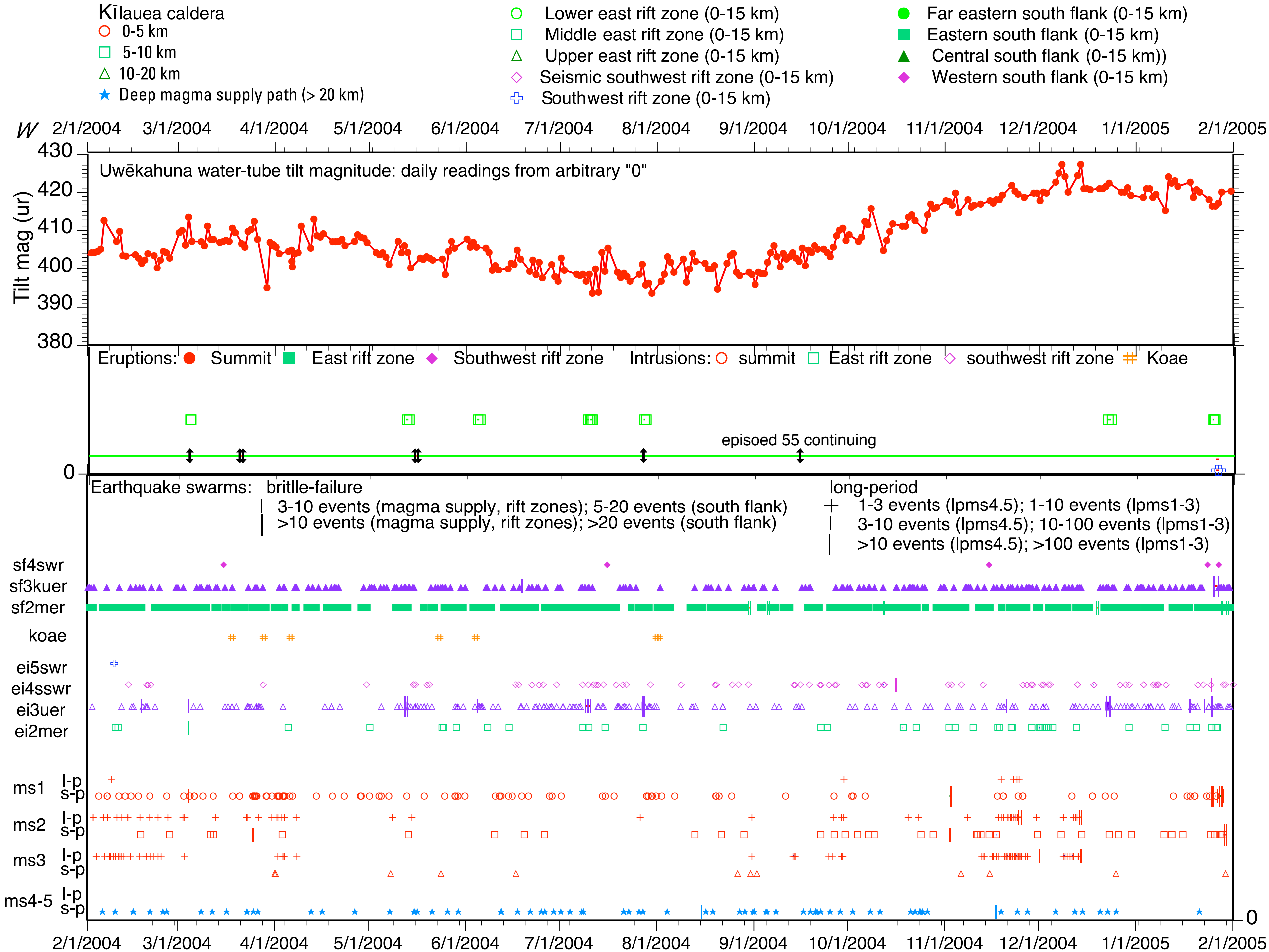
Pu‘u ‘Ō‘o-Kupaianaha eruption: 2/1/2002-2/1/2003



Appendix figure G3 v

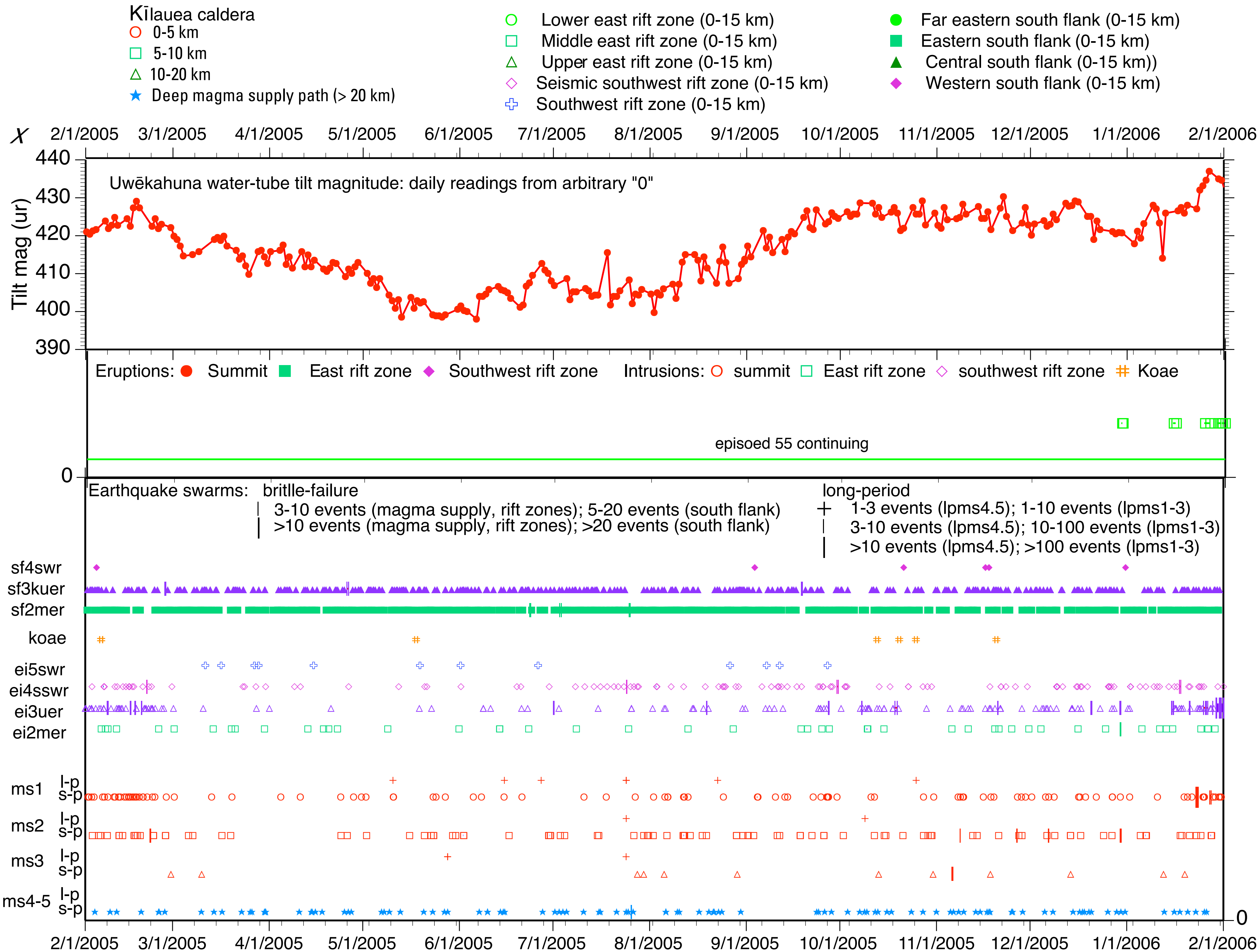
Appendix figure G3 w

Puʻu ʻŌʻo-Kupaianaha eruption: 2/1/2004-2/1//2005



Appendix figure G3 x

Pu‘u ‘Ō‘o-Kupaianaha eruption: 2/1/2005-2/1//2006



Appendix figure G3 y

Puʻu ʻŌʻo-Kupaianaha eruption: 2/1/2006-2/1//2007

Appendix figure G3 z

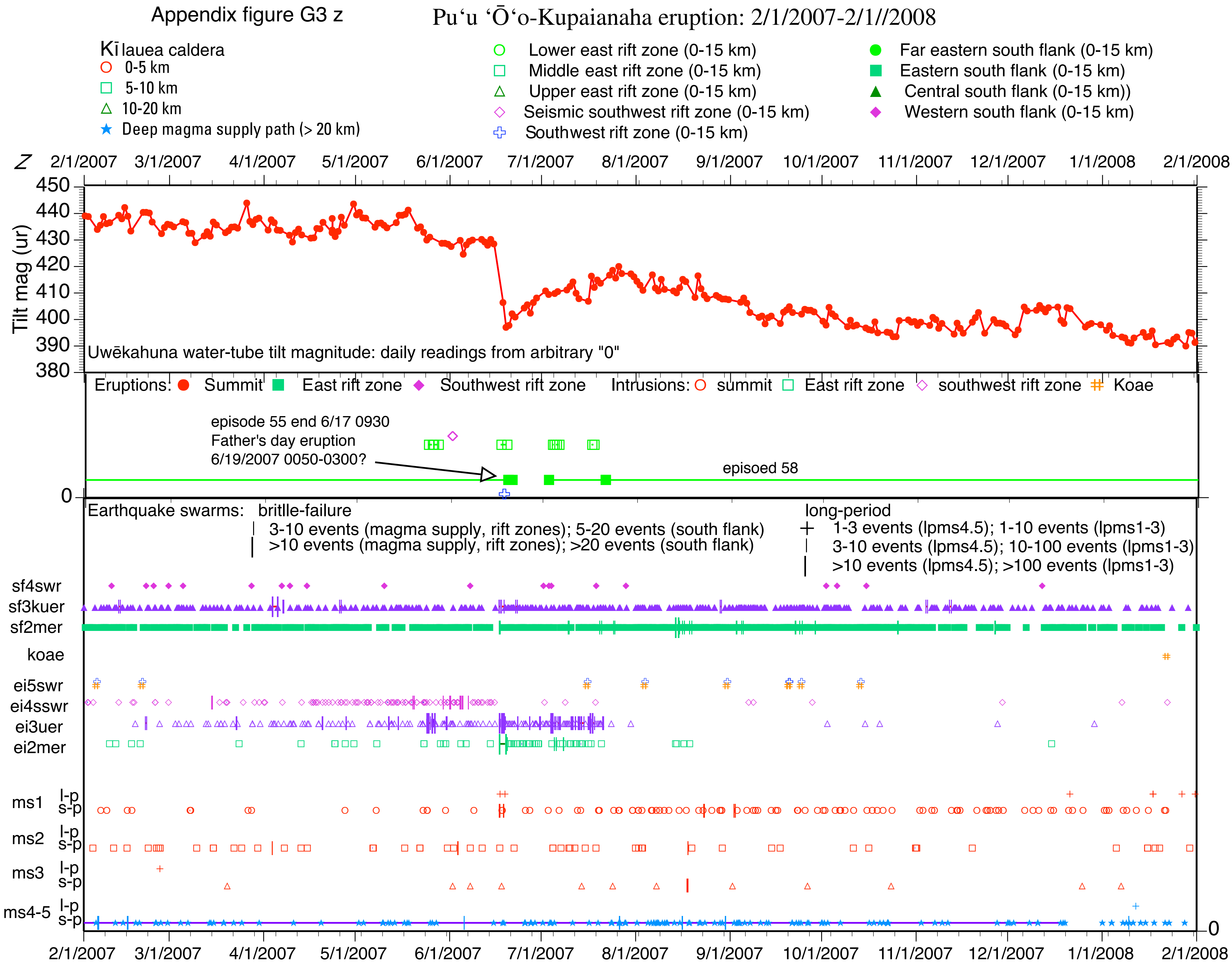
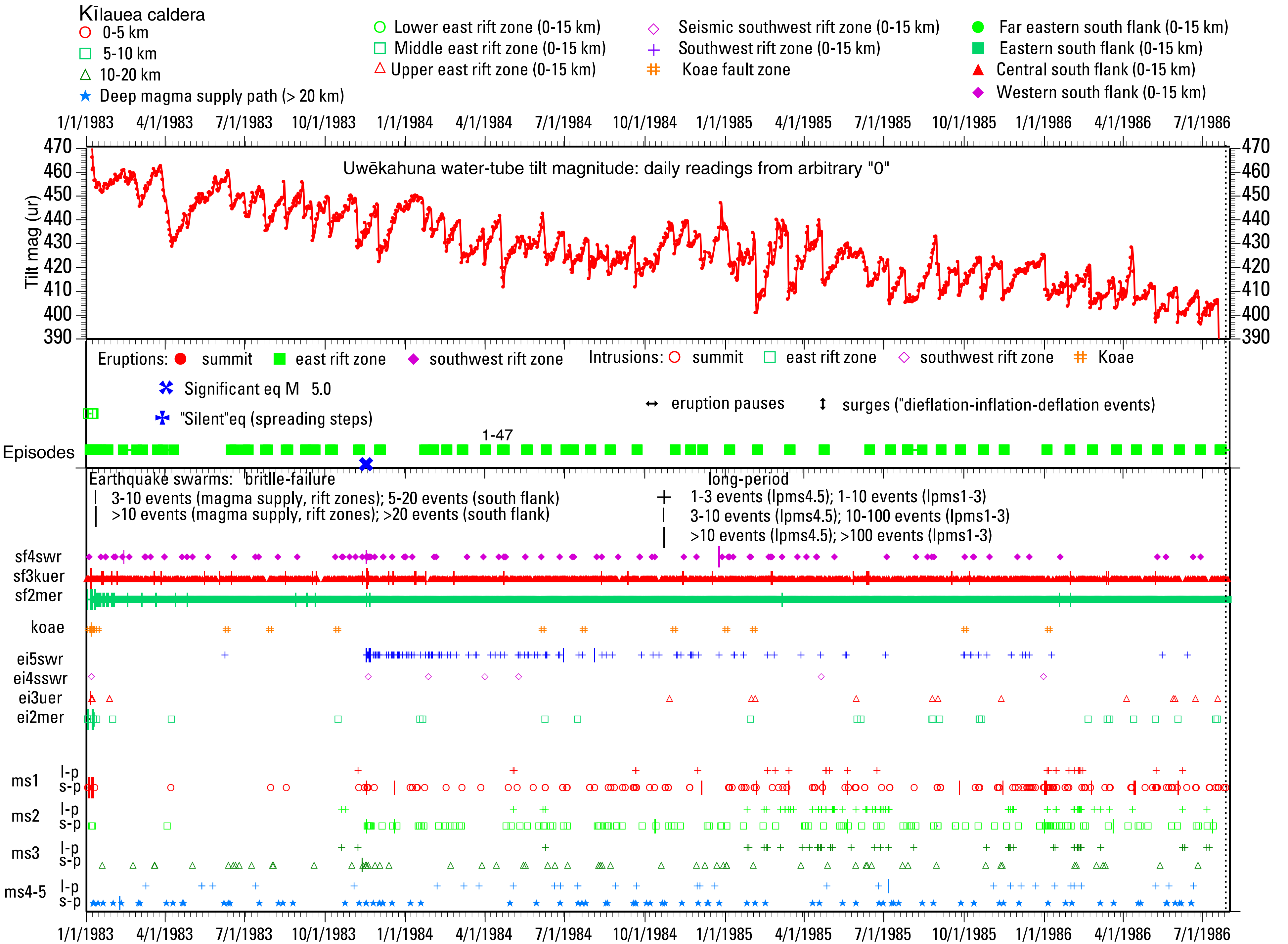


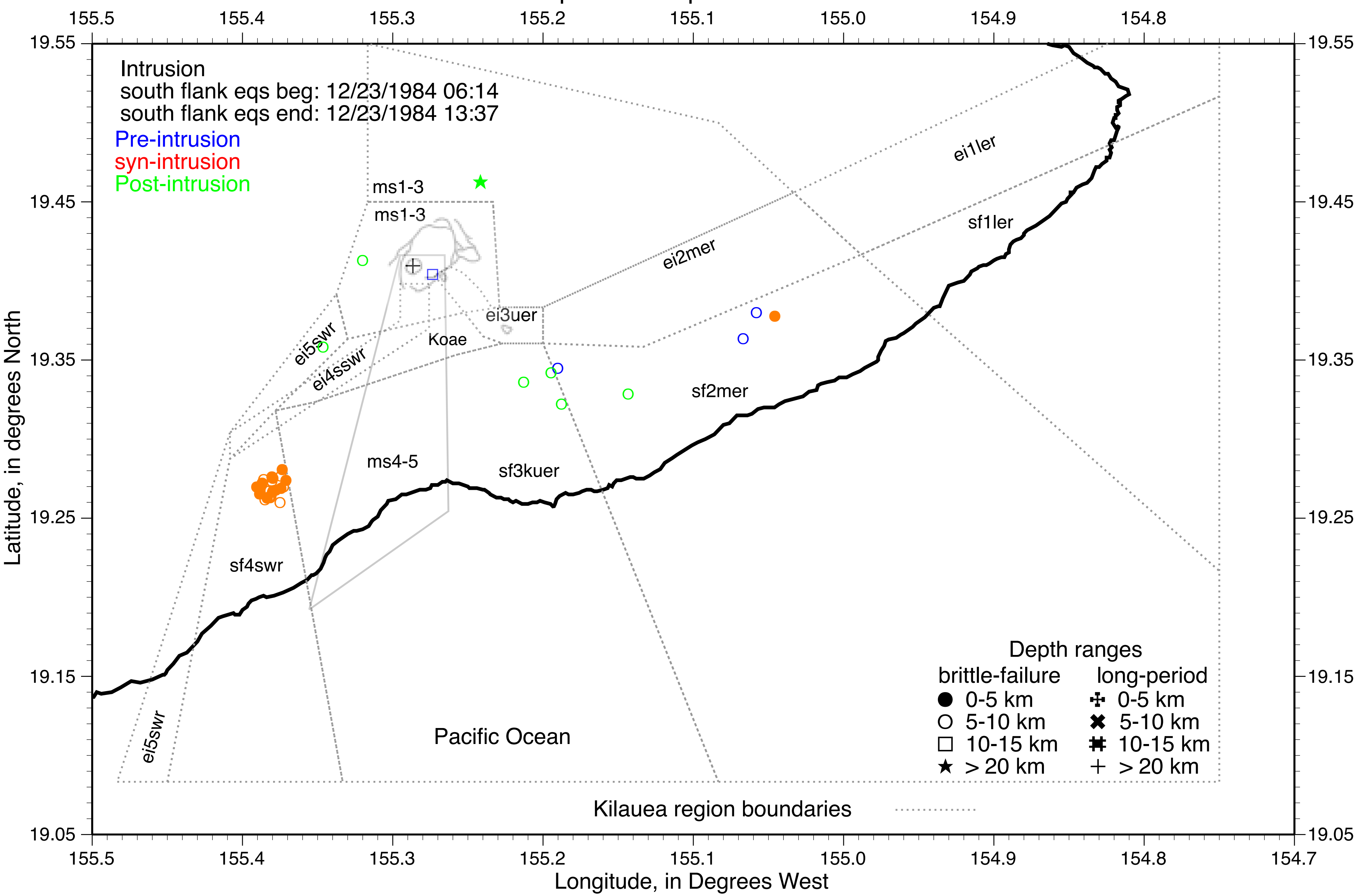
Figure G4

Pu‘u ‘Ō‘o-Kupaianaha eruption: Stage IA, episodes 1-47

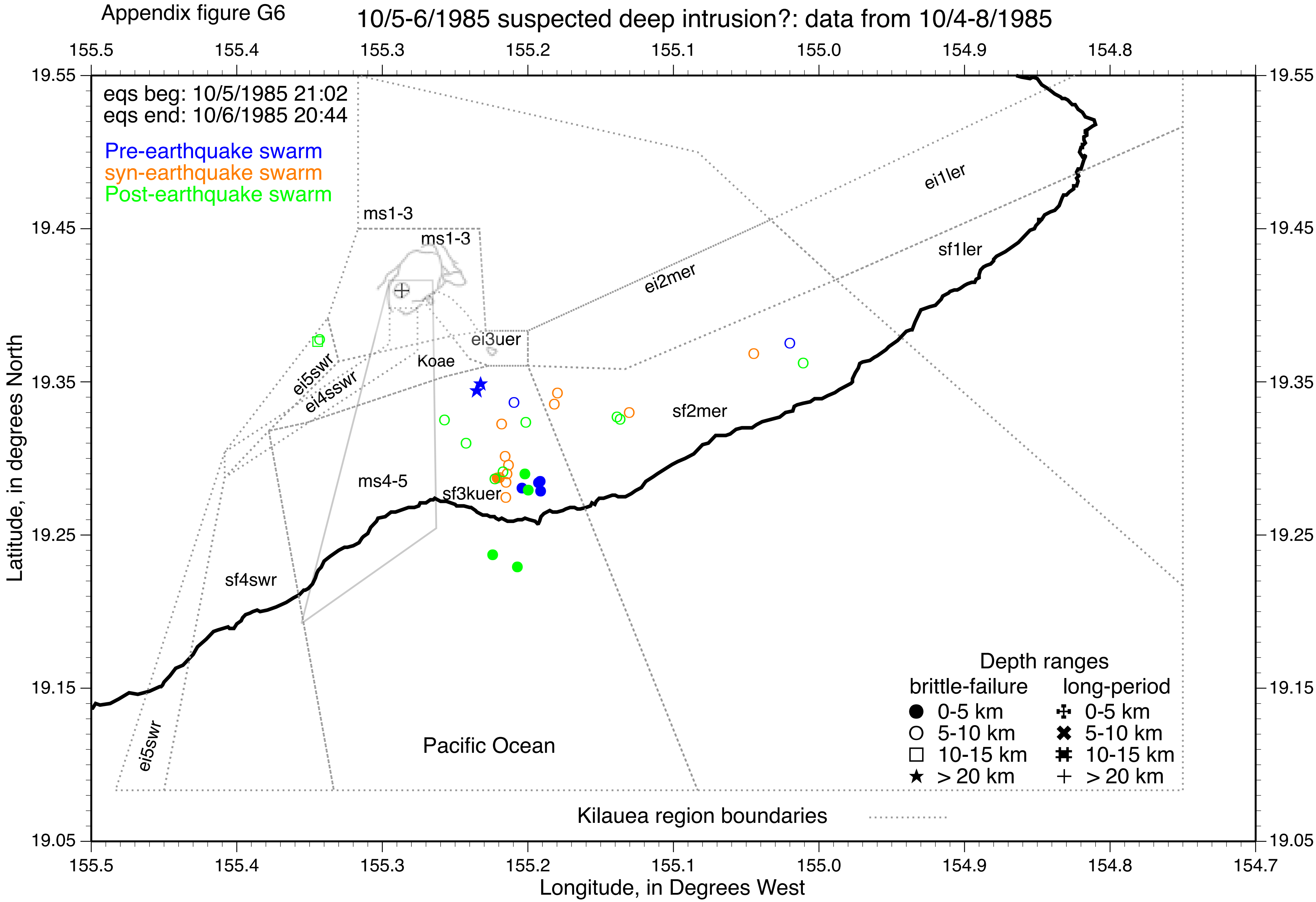


Appendix figure G5

12/23/1984 suspected deep intrusion data from 12/22-241984



Appendix figure G6



Appendix figure G7 Episode 48 fissure eruption leading to continuous eruption: data from 7/14-24/1986

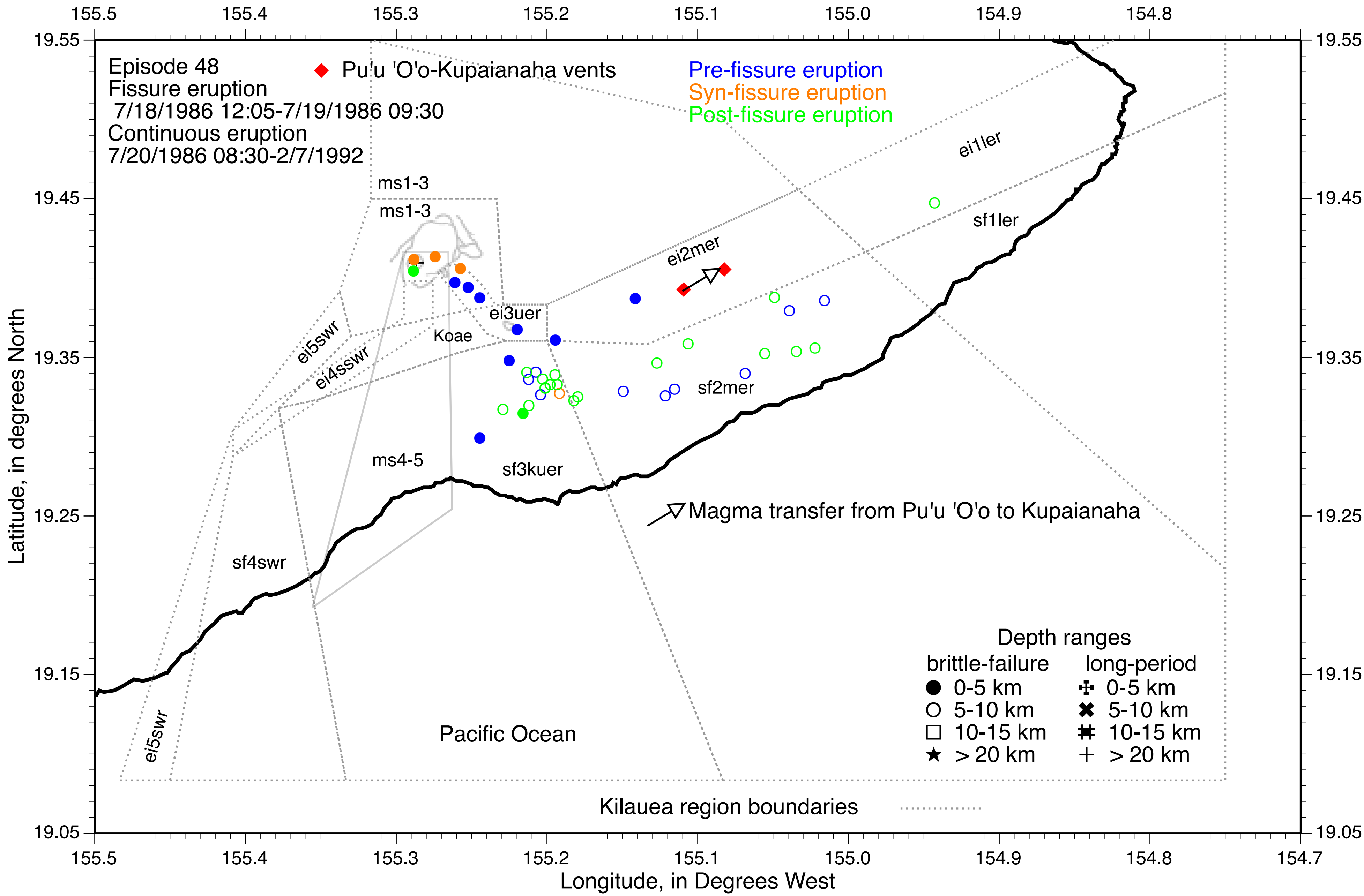
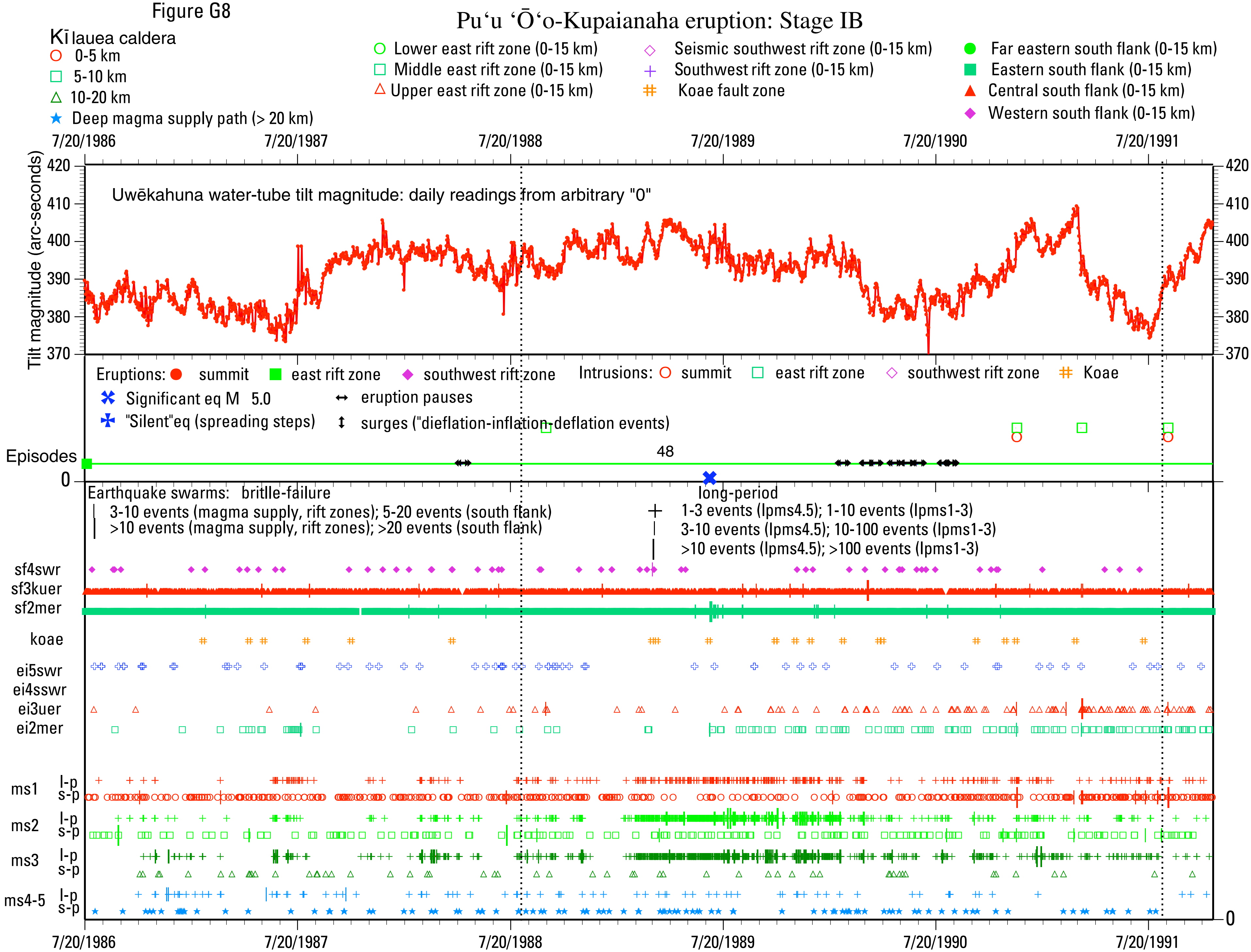
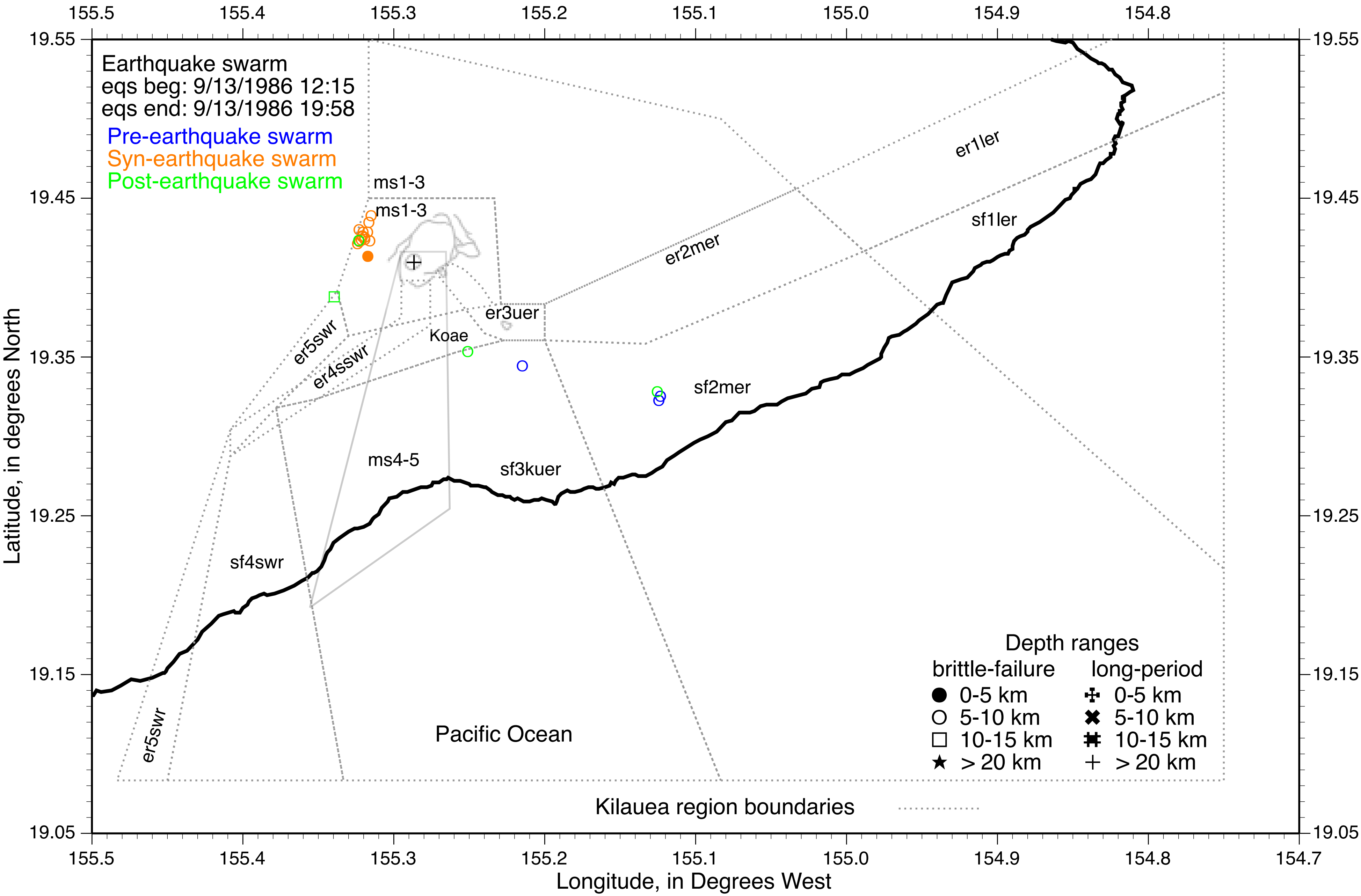


Figure G8

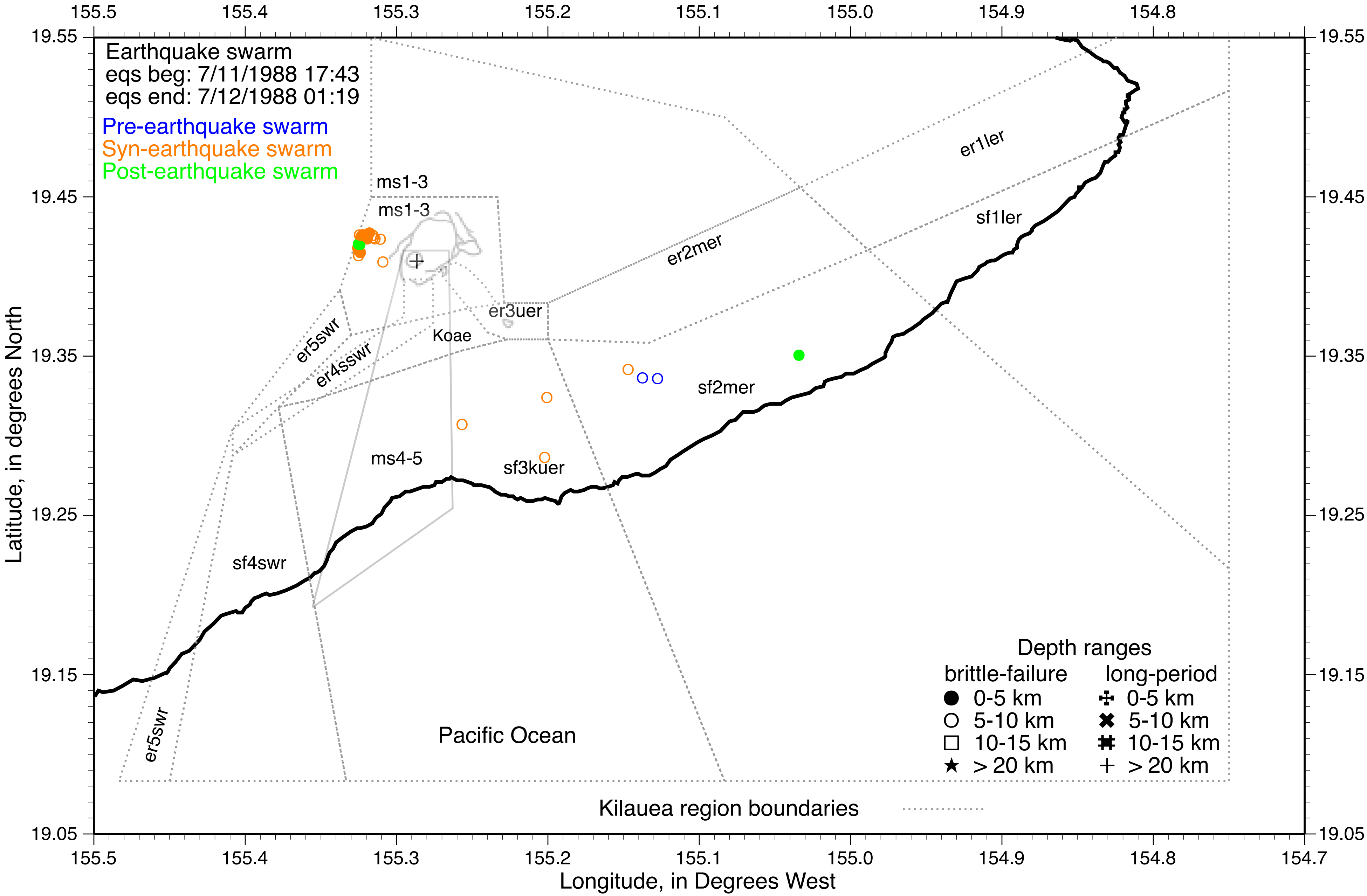

Pu‘u ‘Ō‘o-Kupaianaha eruption: Stage IB
Kīlauea caldera
0-5 km
5-10 km
10-20 km
Deep magma supply path (> 20 km)
Lower east rift zone (0-15 km)
Middle east rift zone (0-15 km)
Upper east rift zone (0-15 km)
Seismic southwest rift zone (0-15 km)
Southwest rift zone (0-15 km)
Koae fault zone
Far eastern south flank (0-15 km)
Eastern south flank (0-15 km)
Central south flank (0-15 km)
Western south flank (0-15 km)
7/20/1986
7/20/1987
7/20/1988
7/20/1989
7/20/1990
7/20/1991
Tilt magnitude (arc-seconds)
Uwēkahuna water-tube tilt magnitude: daily readings from arbitrary "0"
Eruptions: summit
east rift zone
southwest rift zone
Intrusions: summit
east rift zone
southwest rift zone
Koae
Significant eq M 5.0
"Silent"eq (spreading steps)
eruption pauses
surges ("dieflation-inflation-deflation events)
Episodes
48
Earthquake swarms: britlle-failure
3-10 events (magma supply, rift zones); 5-20 events (south flank)
>10 events (magma supply, rift zones); >20 events (south flank)
long-period
1-3 events (lpms4.5); 1-10 events (lpms1-3)
3-10 events (lpms4.5); 10-100 events (lpms1-3)
>10 events (lpms4.5); >100 events (lpms1-3)
sf4swr
sf3kuer
sf2mer
koae
ei5swr
ei4sswr
ei3uer
ei2mer
ms1
ms2
ms3
ms4-5
l-p
s-p

Appendix figure G9

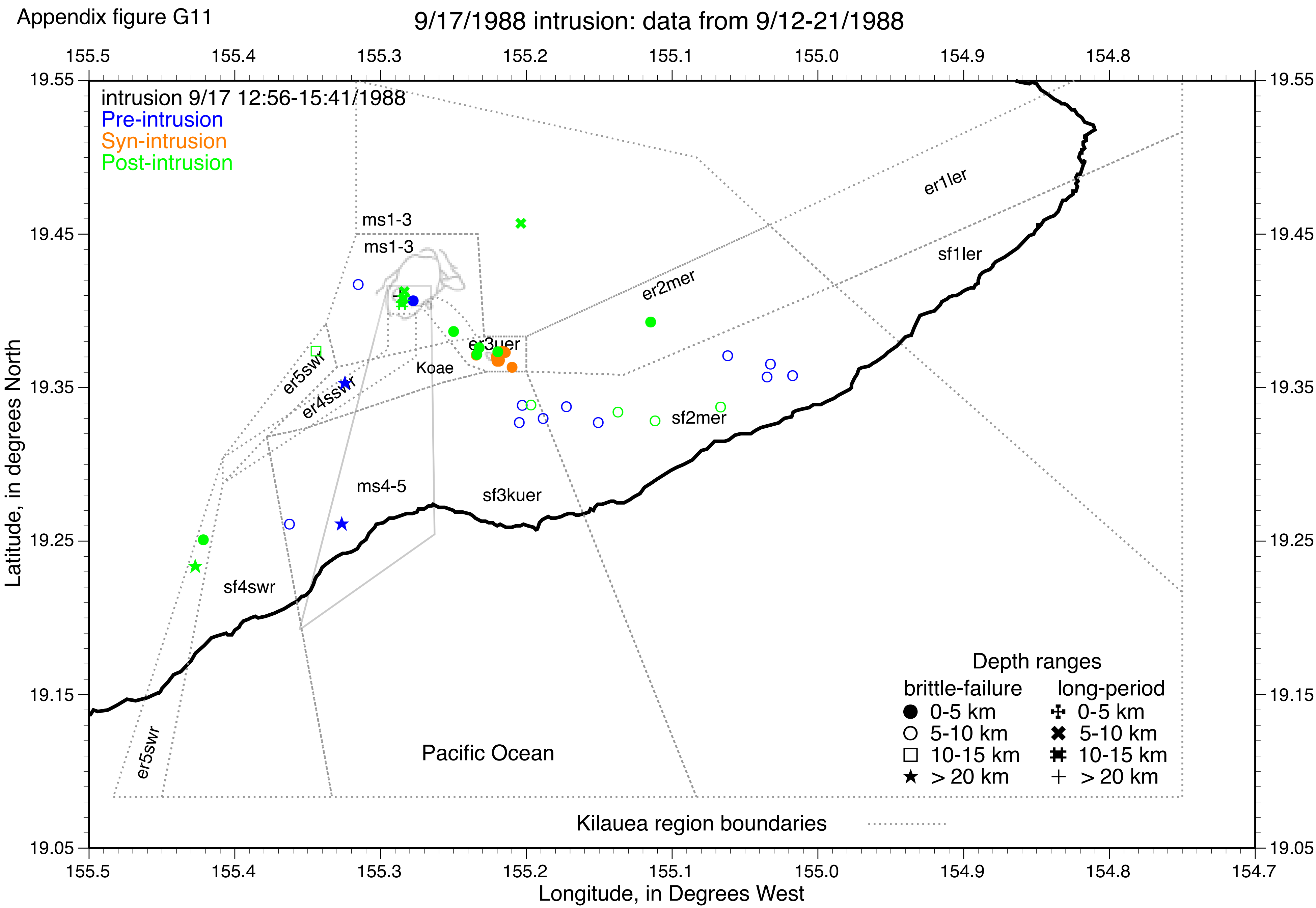
9/13/1986 Namakani Paio sequence: data from 9/13-14/1986



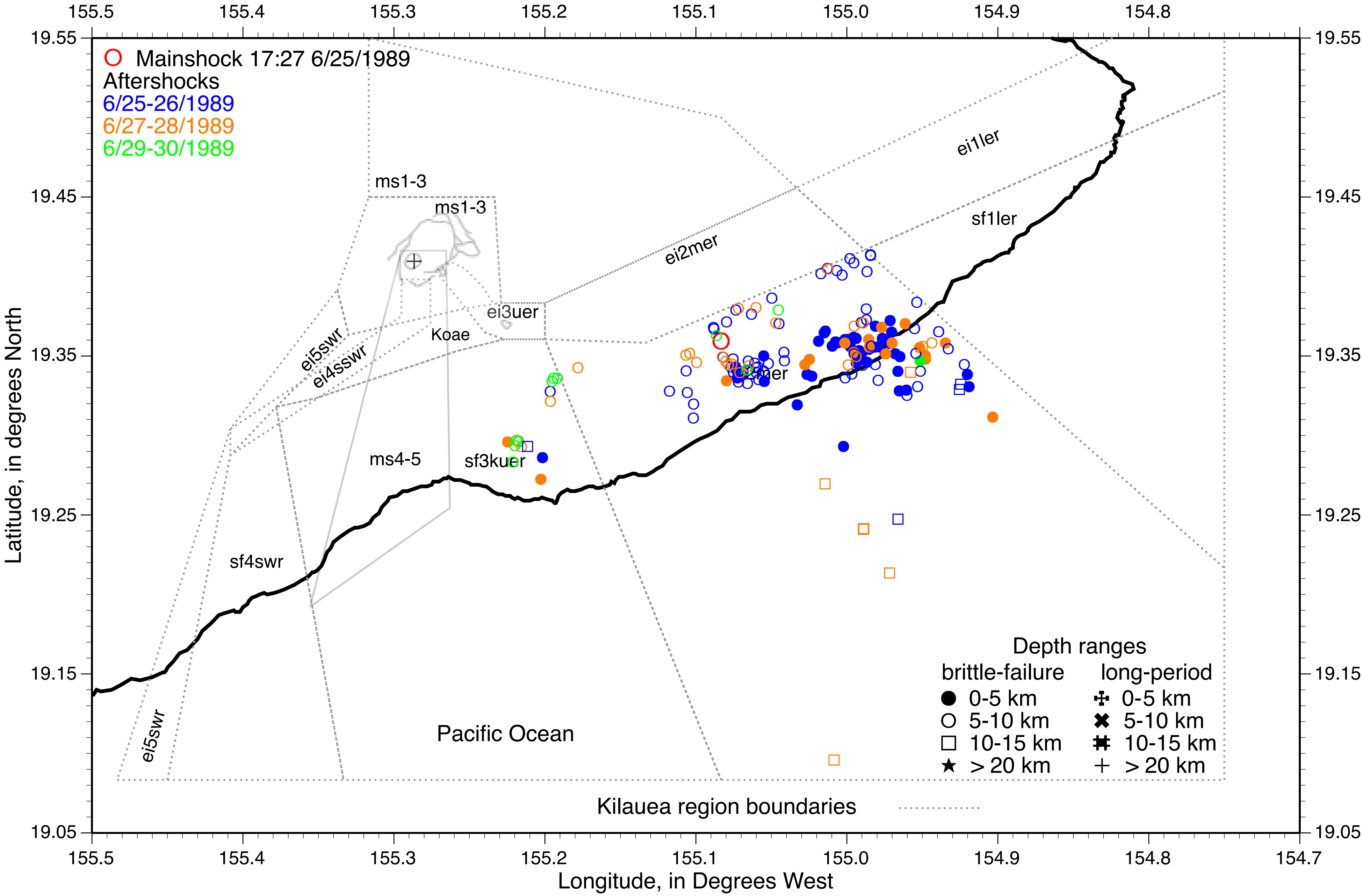
Appendix figure G10 7/11-12/1988 Namakani Paio sequence: data from 7/11-12/1988



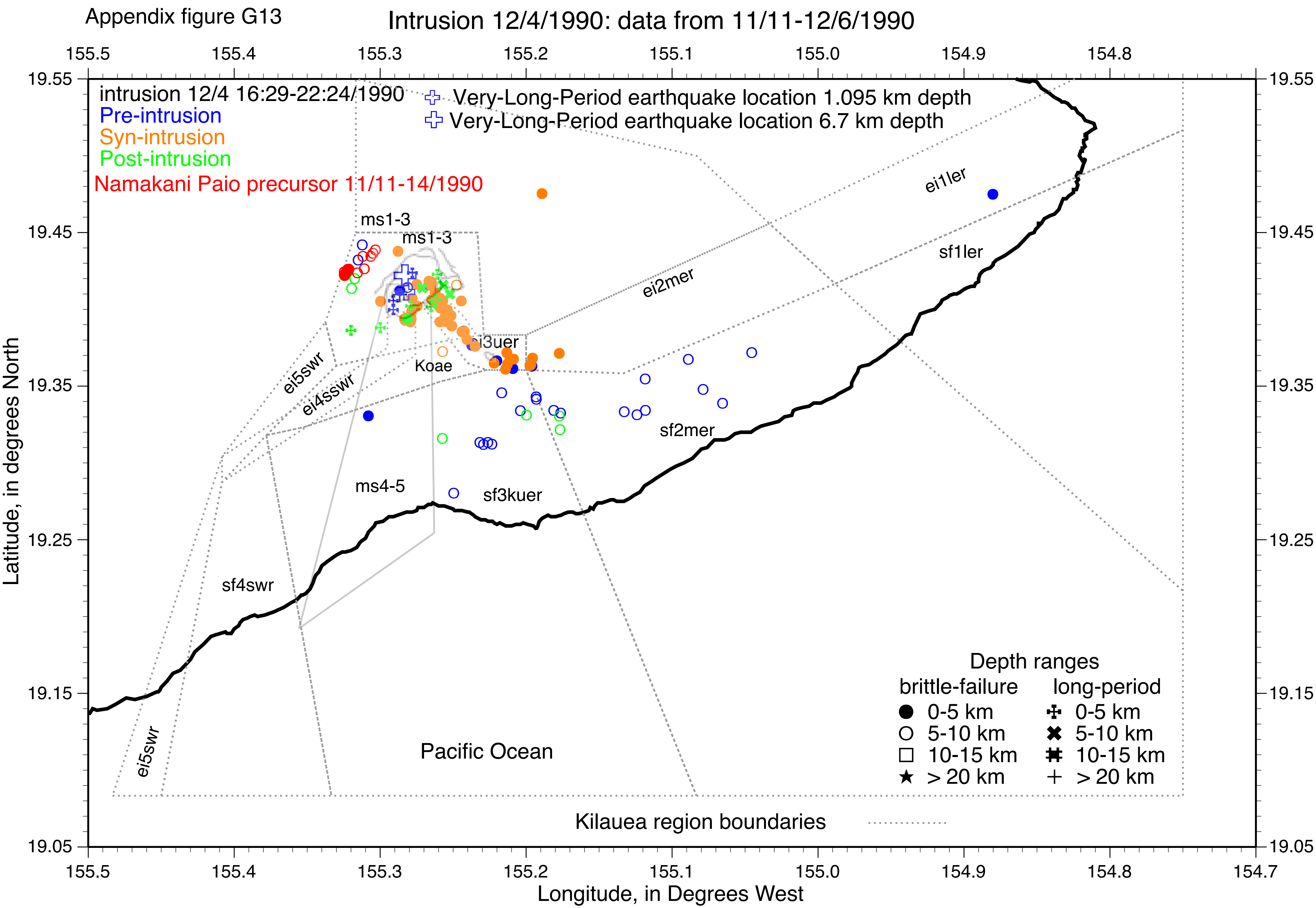
Appendix figure G11



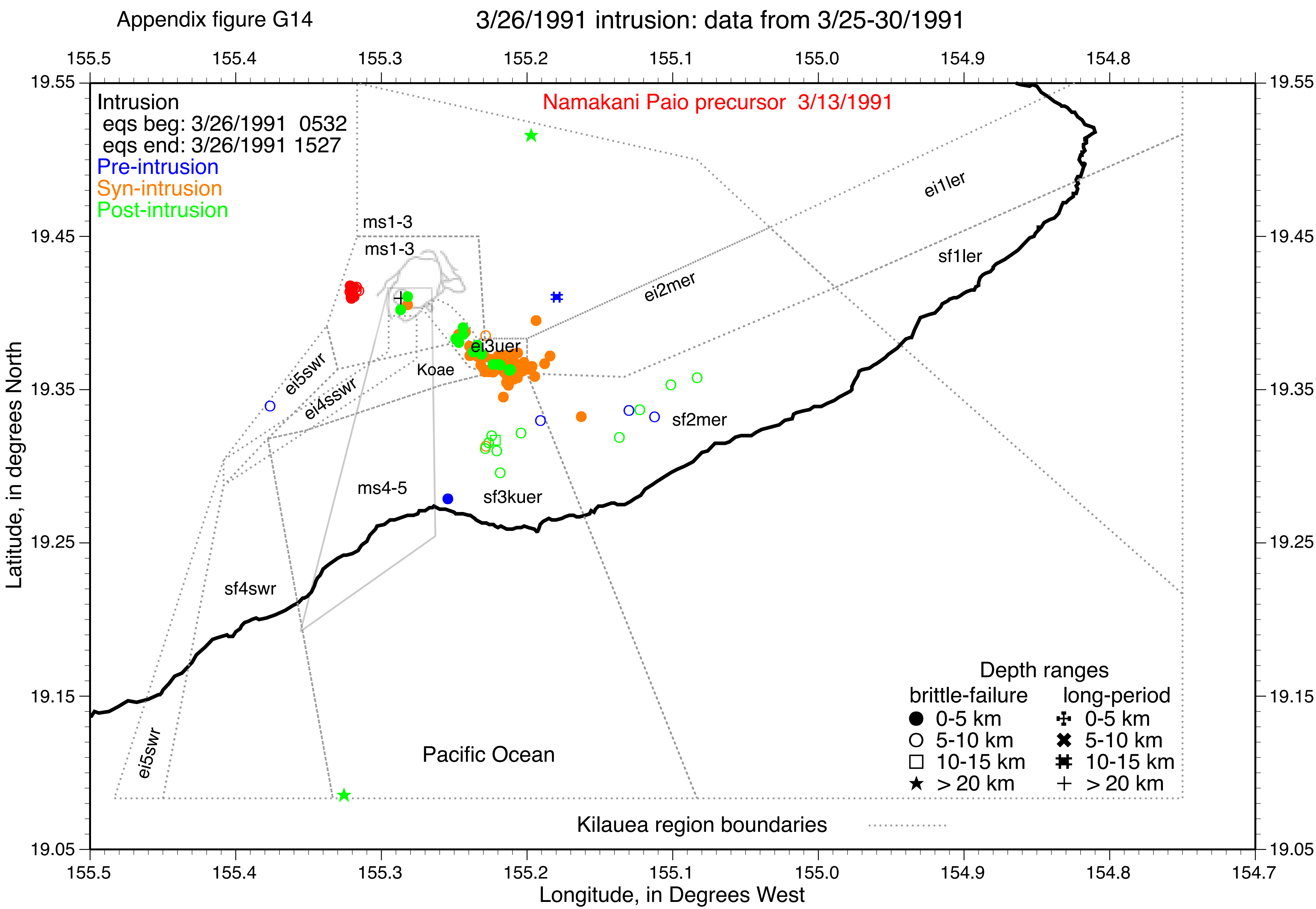
Appendix figure G12 6/25/1989 M 6.2 south flank earthquake: data from 6/25-30/1989



Appendix figure G13



Appendix figure G14



Appendix figure G15

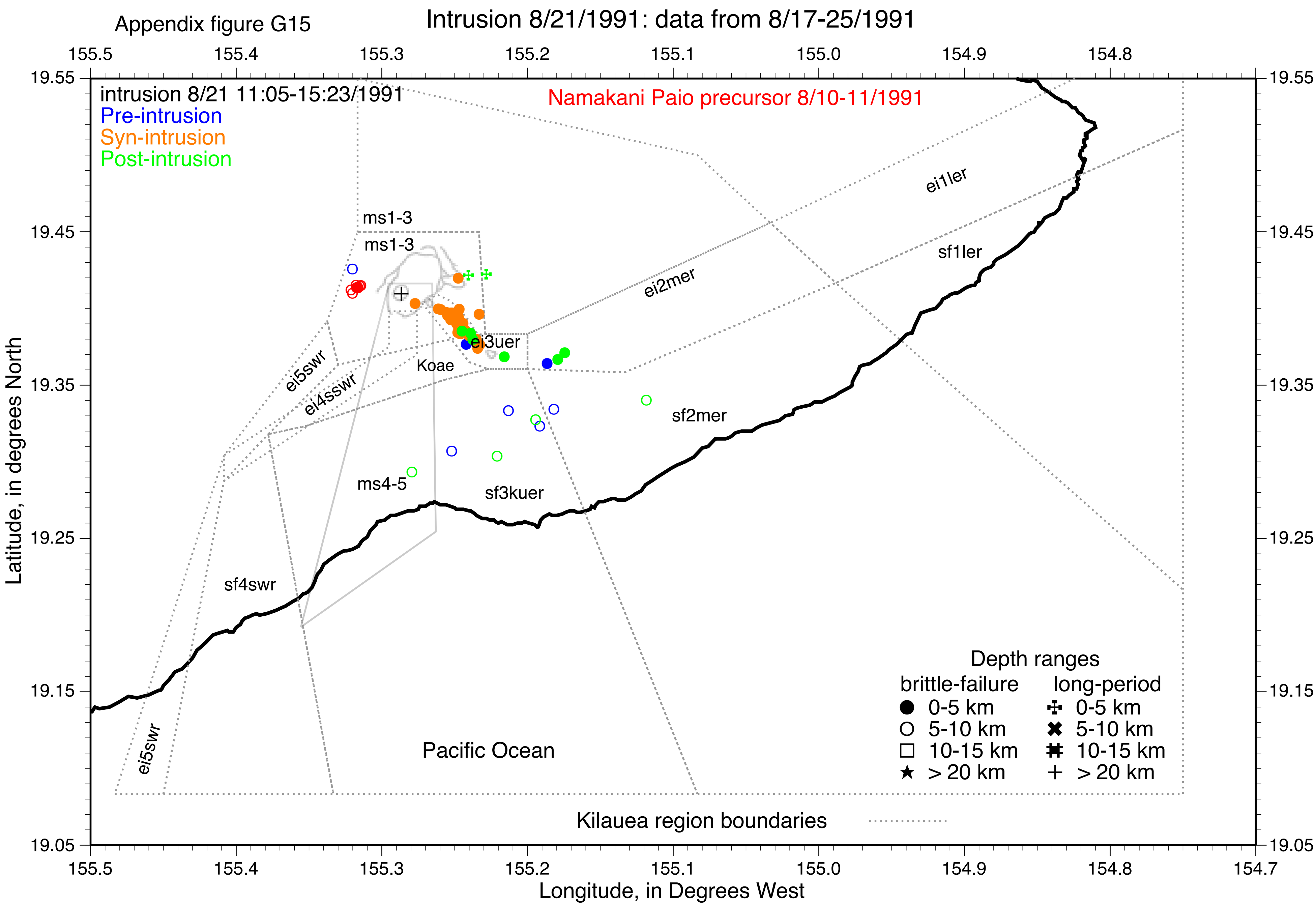
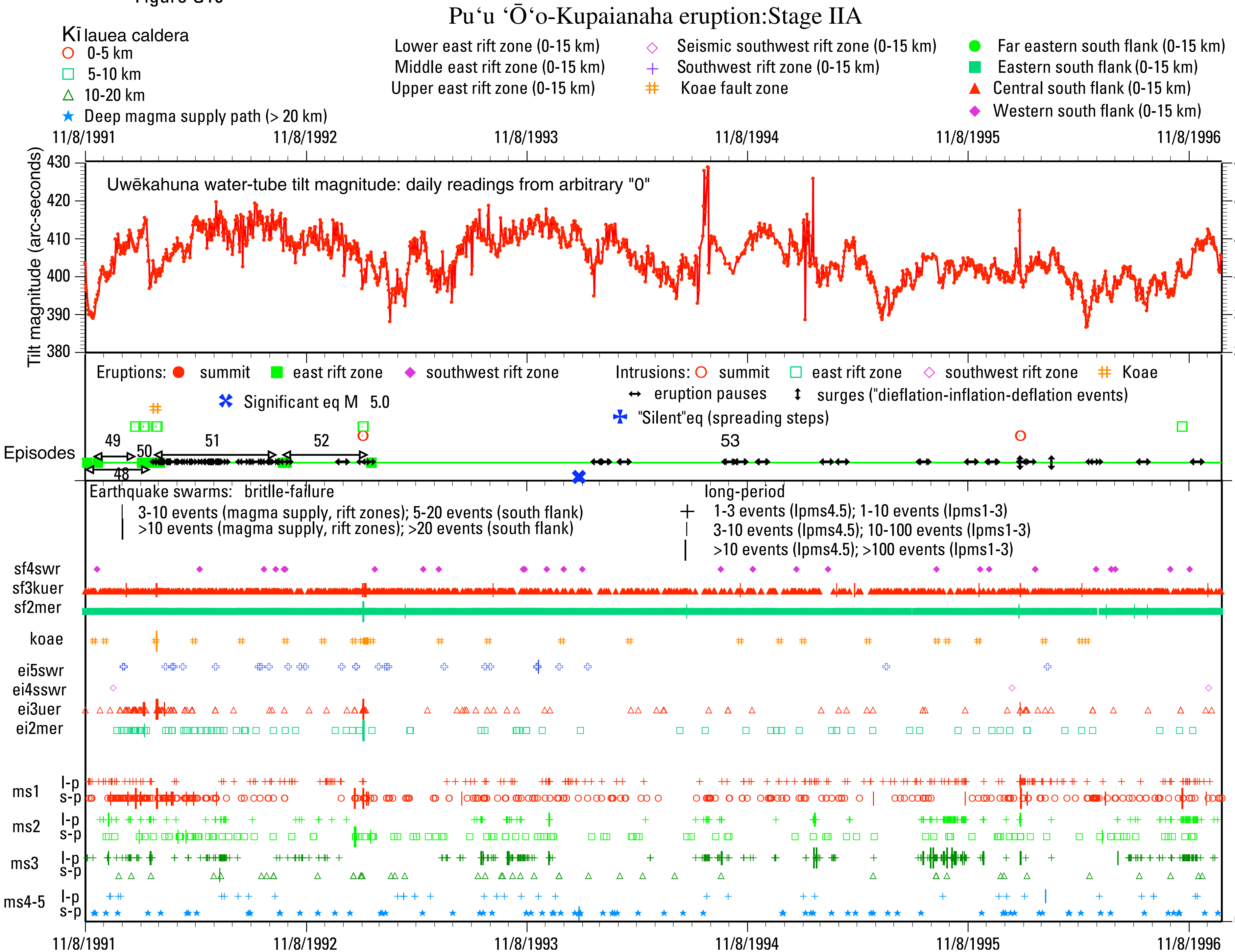
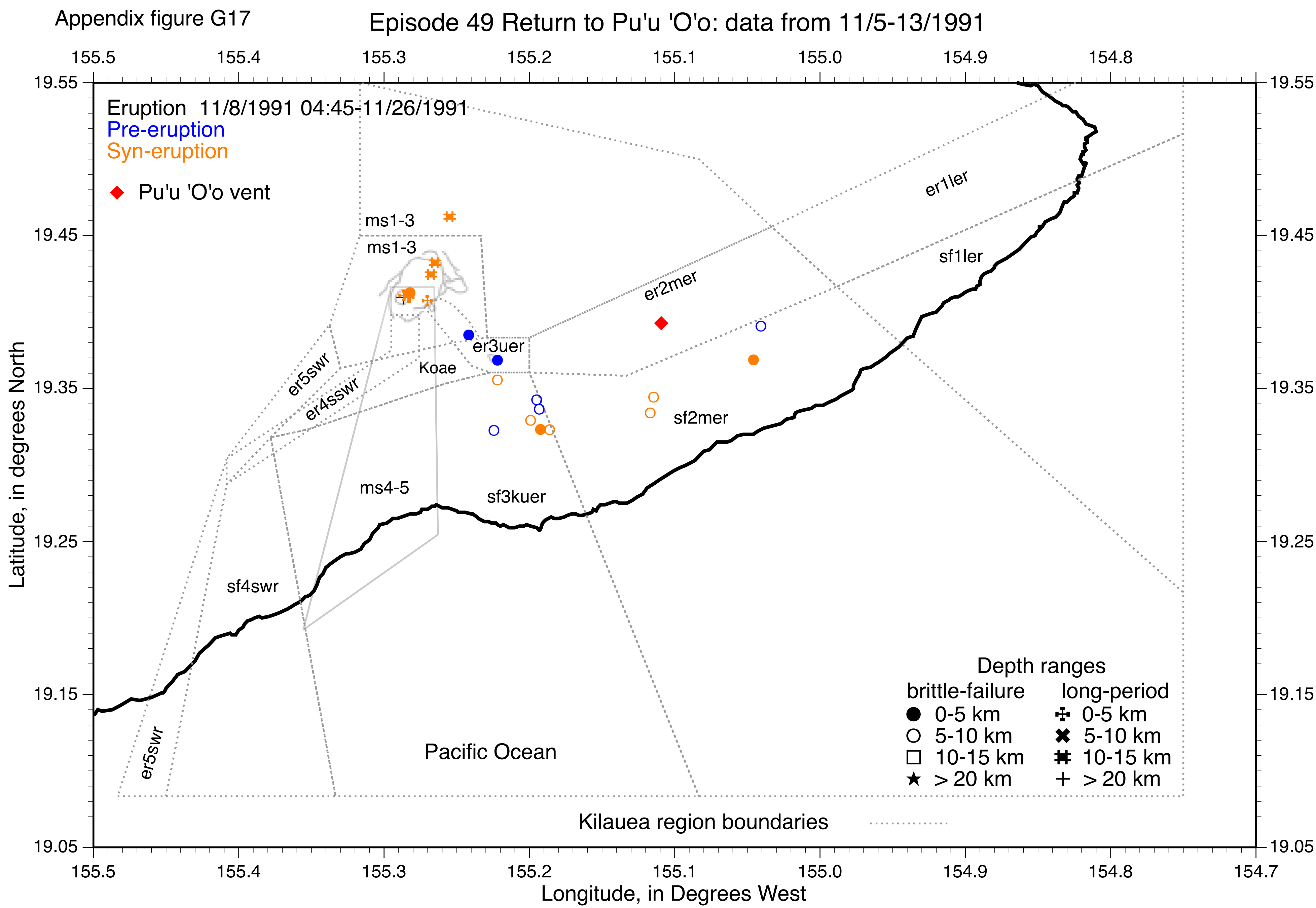


Figure G16



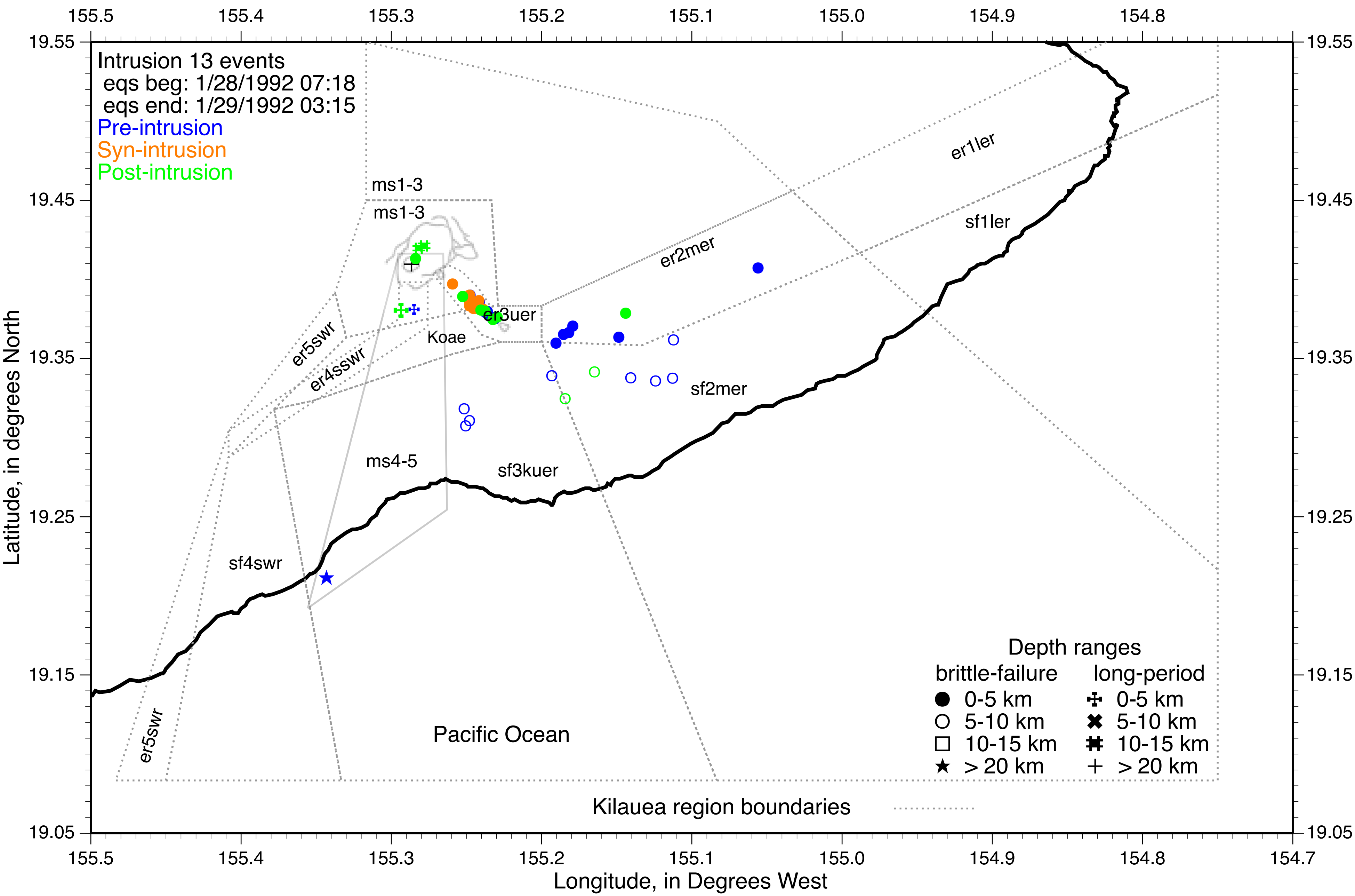
Pu‘u ‘Ō‘o-Kupaianaha eruption:Stage IIA
Kīlauea caldera
0-5 km
5-10 km
10-20 km
Deep magma supply path (> 20 km)
Lower east rift zone (0-15 km)
Middle east rift zone (0-15 km)
Upper east rift zone (0-15 km)
Seismic southwest rift zone (0-15 km)
Southwest rift zone (0-15 km)
Koae fault zone
Far eastern south flank (0-15 km)
Eastern south flank (0-15 km)
Central south flank (0-15 km)
Western south flank (0-15 km)
11/8/1991
11/8/1992
11/8/1993
11/8/1994
11/8/1995
11/8/1996
Tilt magnitude (arc-seconds)
Uwēkahuna water-tube tilt magnitude: daily readings from arbitrary "0"
430
420
410
400
390
380
Eruptions: summit
east rift zone
southwest rift zone
Intrusions: summit
east rift zone
southwest rift zone
Koae
Significant eq M 5.0
eruption pauses
surges ("dieflation-inflation-deflation events)
"Silent"eq (spreading steps)
Episodes
48
49
50
51
52
53
Earthquake swarms: britlle-failure
3-10 events (magma supply, rift zones); 5-20 events (south flank)
>10 events (magma supply, rift zones); >20 events (south flank)
long-period
1-3 events (lpms4.5); 1-10 events (lpms1-3)
3-10 events (lpms4.5); 10-100 events (lpms1-3)
>10 events (lpms4.5); >100 events (lpms1-3)
sf4swr
sf3kuer
sf2mer
koae
ei5swr
ei4sswr
ei3uer
ei2mer
ms1
ms2
ms3
ms4-5
l-p
s-p
0

Appendix figure G17

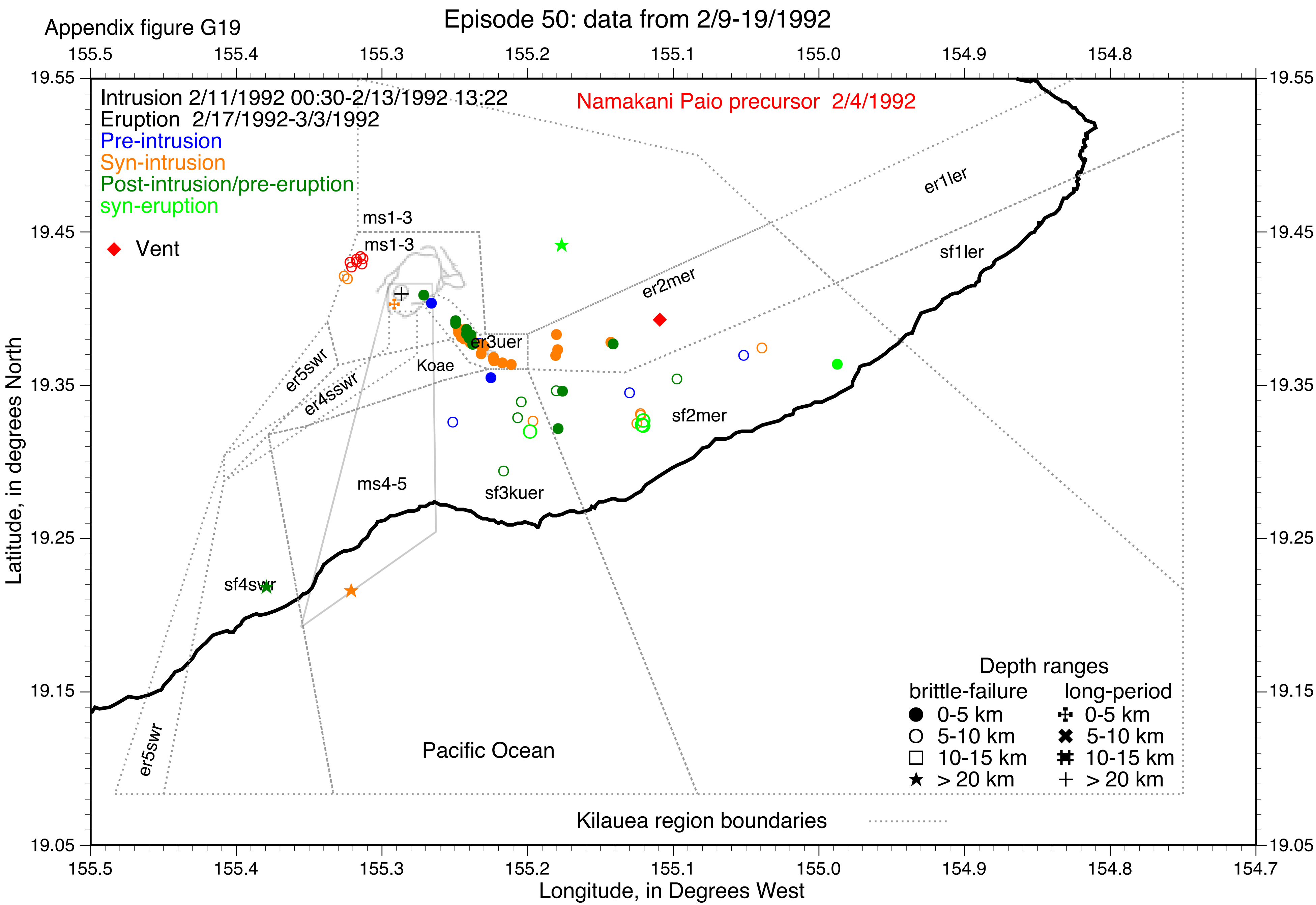


Appendix figure G18

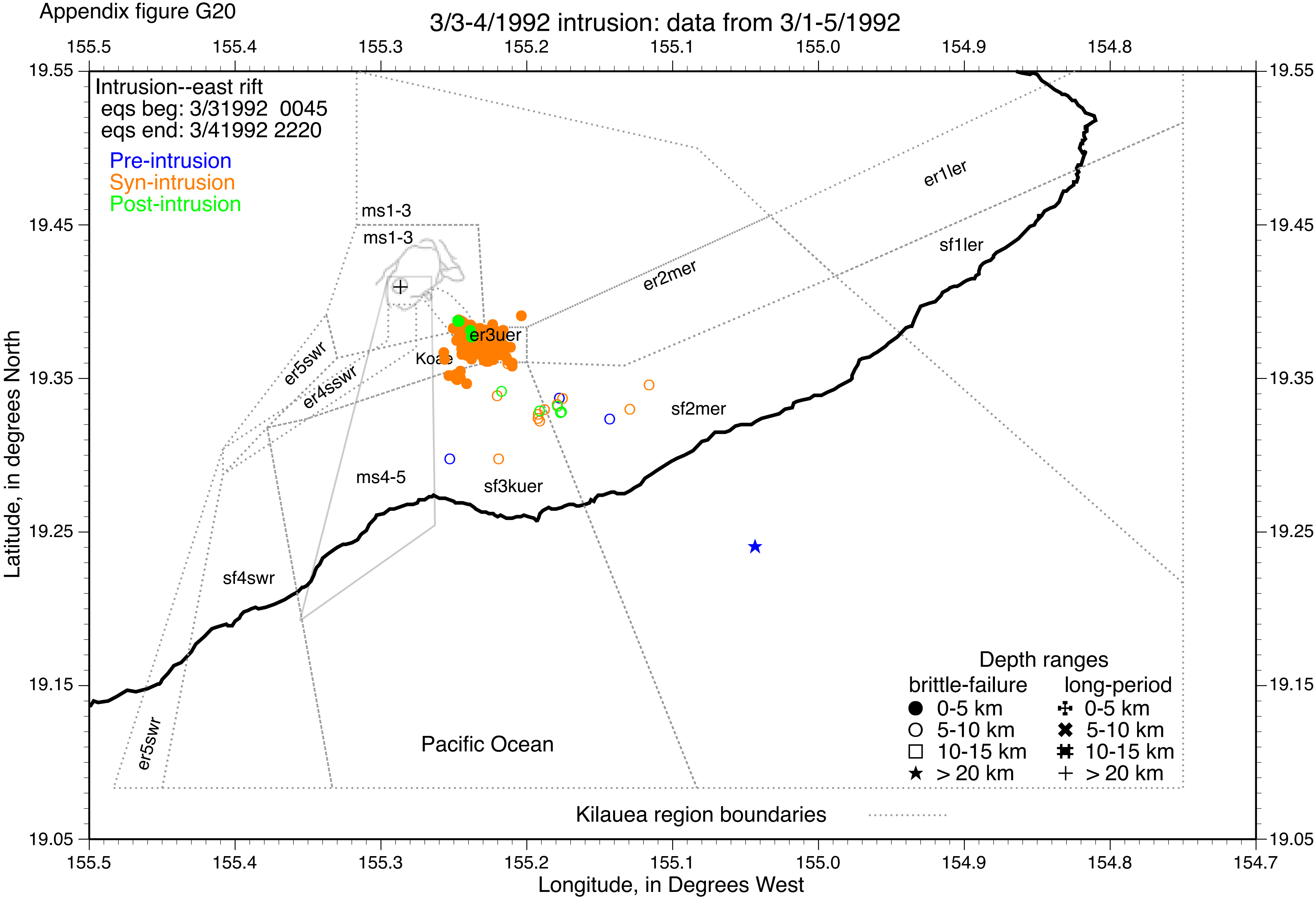
1/28-29/1992 intrusion: data from 1/25-31/1992



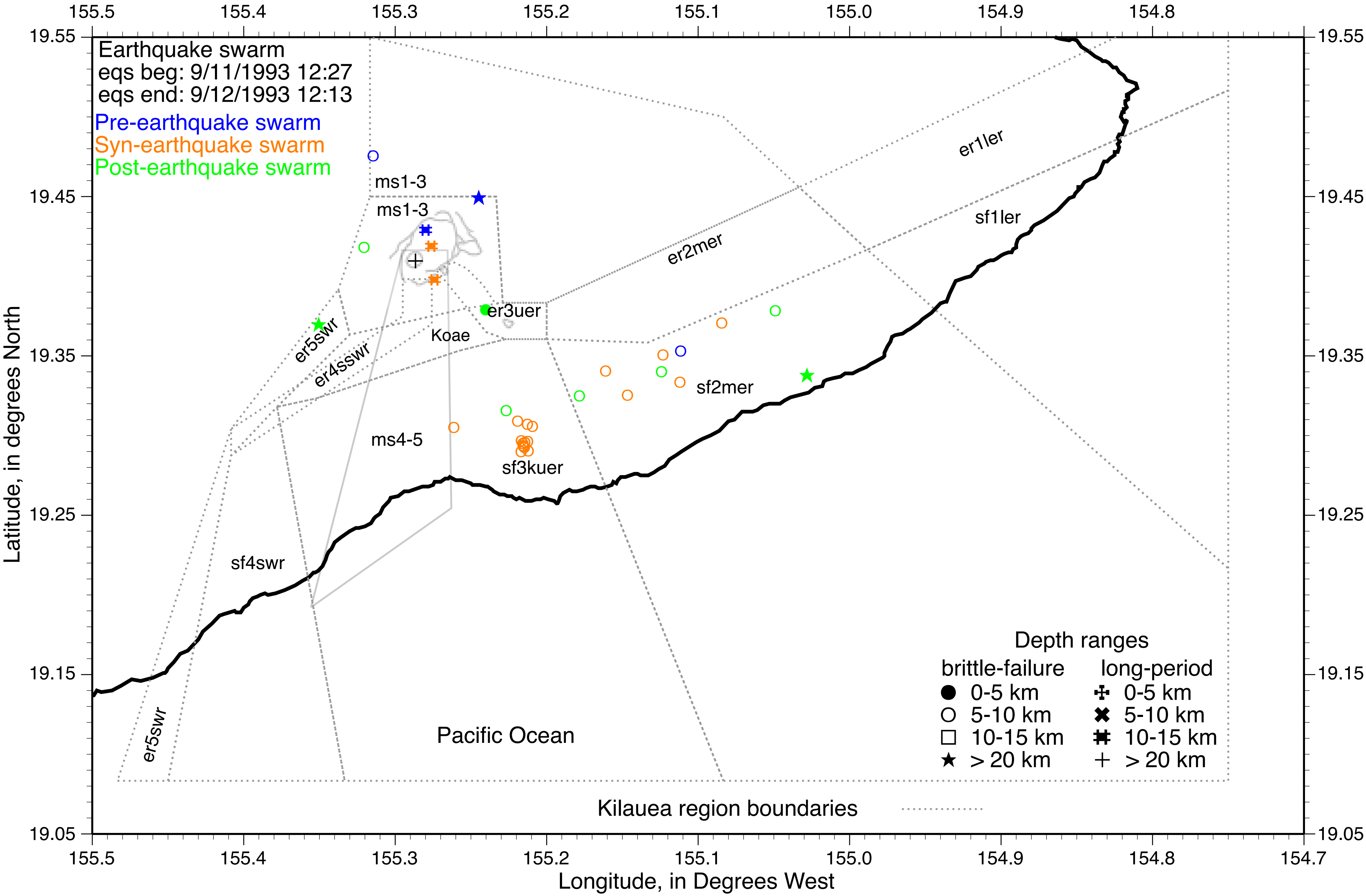
Appendix figure G19



Appendix figure G20

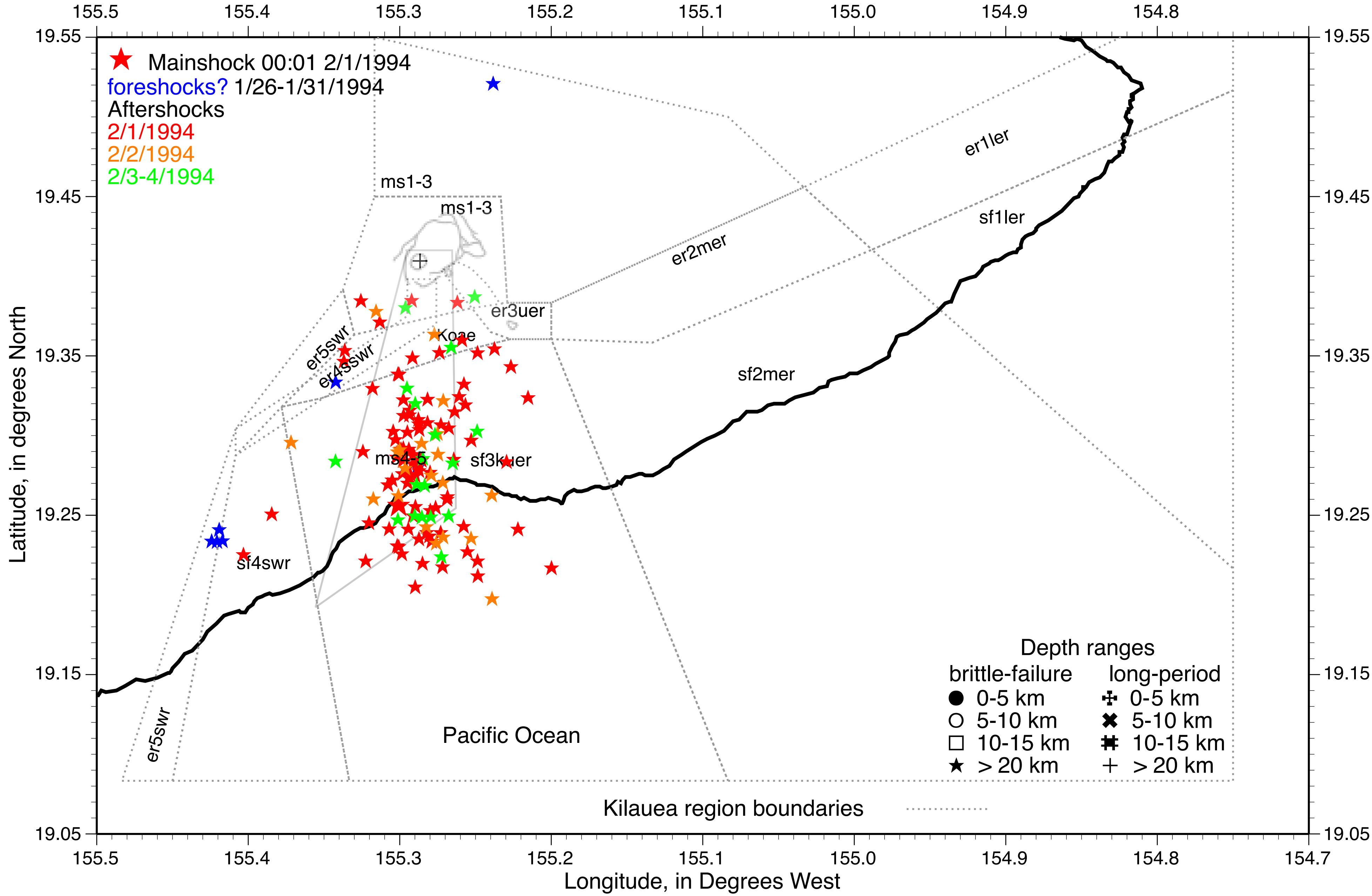


Appendix figure G21 9/11-12/1993 suspected deep intrusion?: Data from 9/9-14/1993



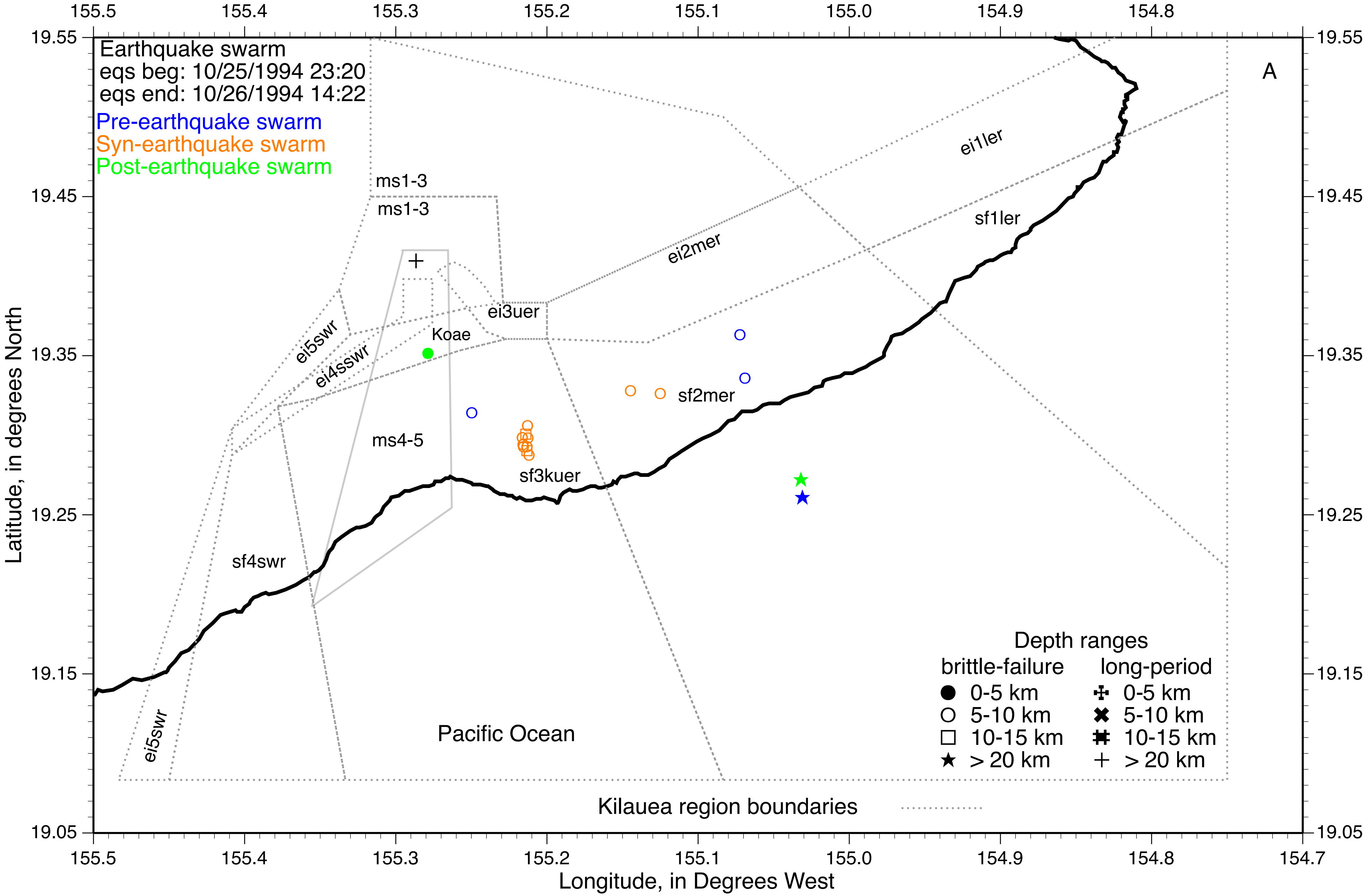
Appendix figure G22

2/1/1994 M 5.2 deep magma supply earthquake: data from 1/26-2/4/1994

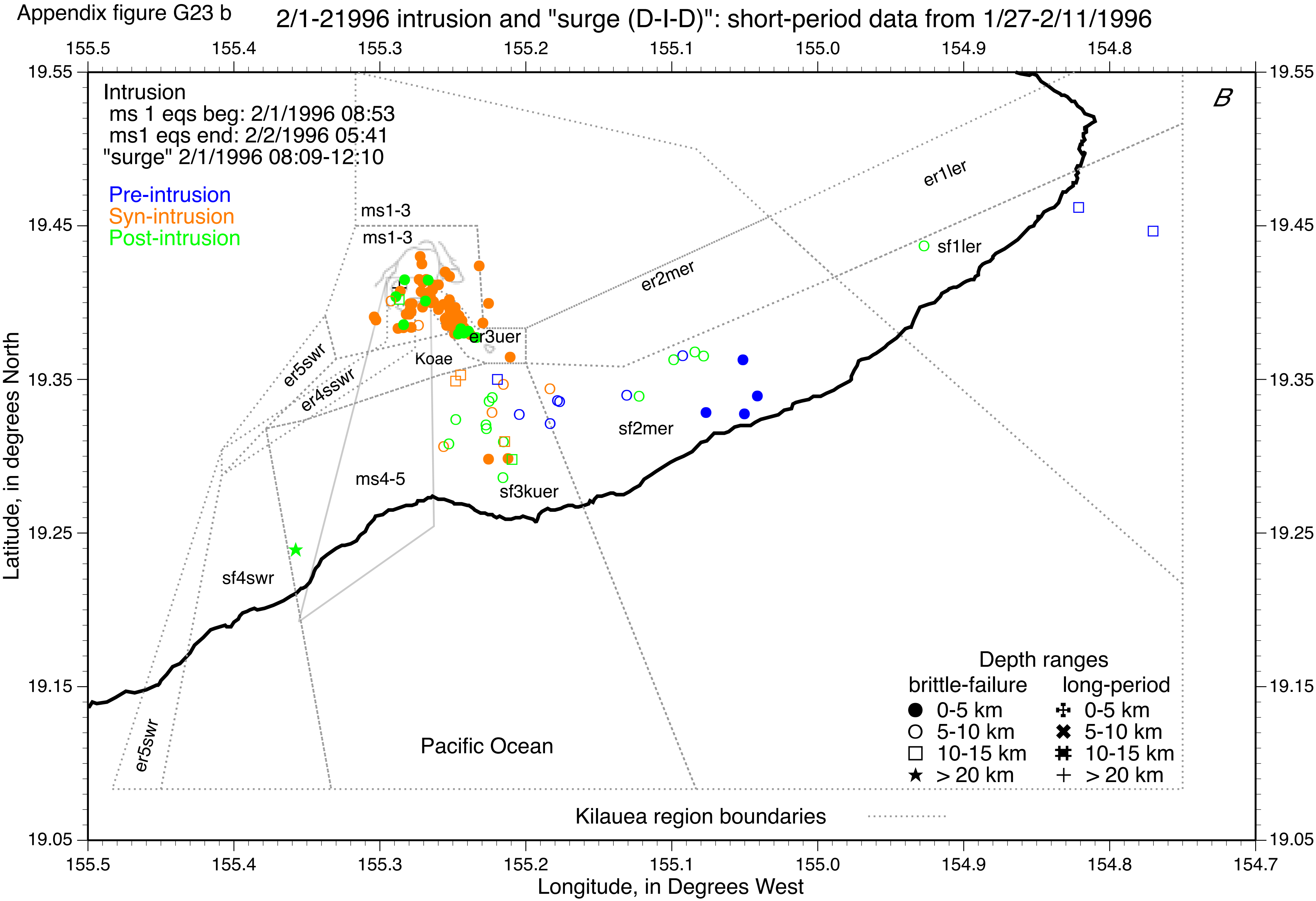


Appendix figure G23 a

10/25-26/1994 suspected deep intrusion: Data from10/23-27/1994

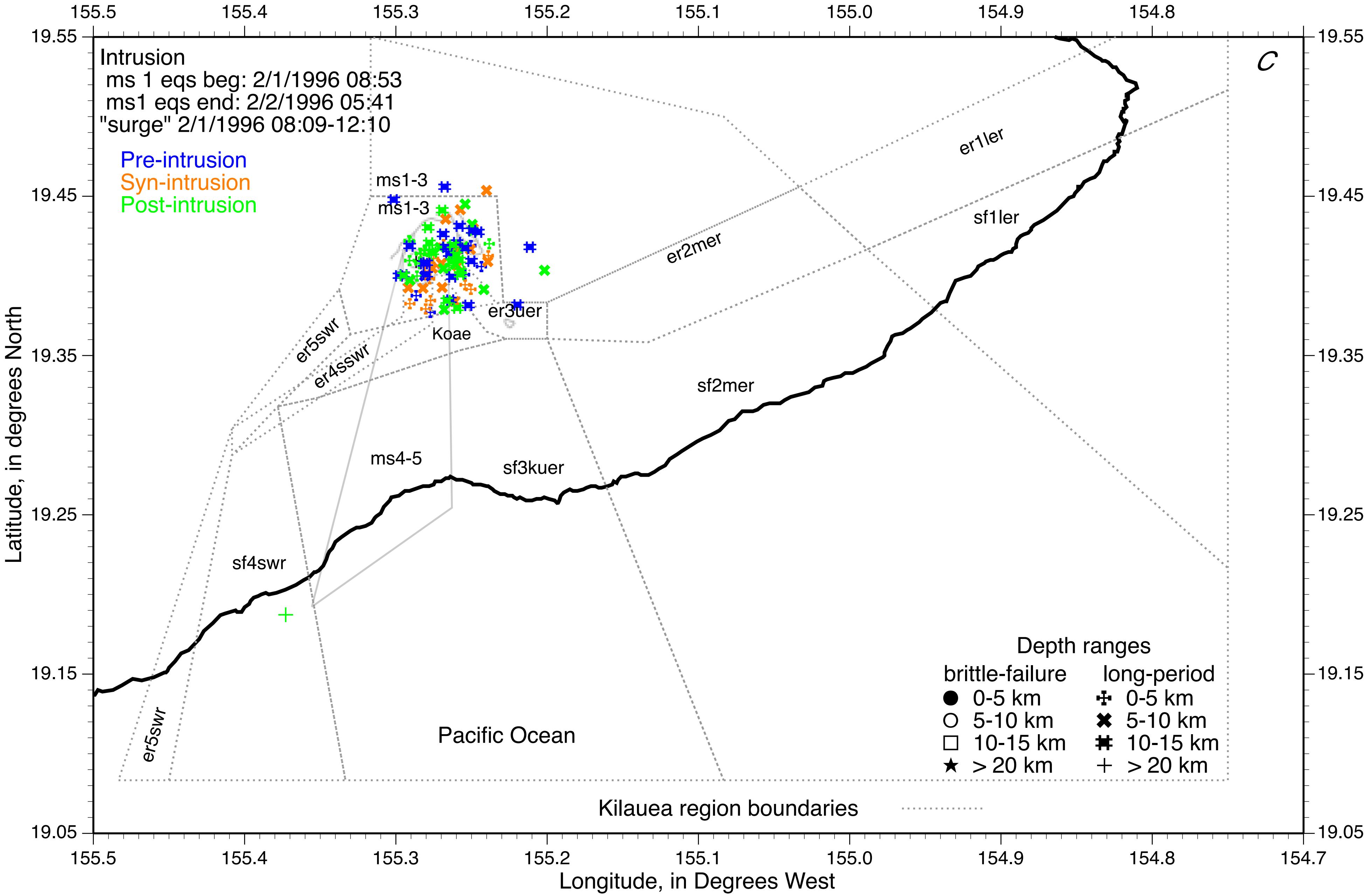


Appendix figure G23 b



Appendix figure G23 c

2/1/1996 "surge (D-I-D)": Long-period data from 1/27-2/11/1996



Appendix figure G24

10/25-26/1996 Upper east rift intrusion: data from 10/23-30/1996

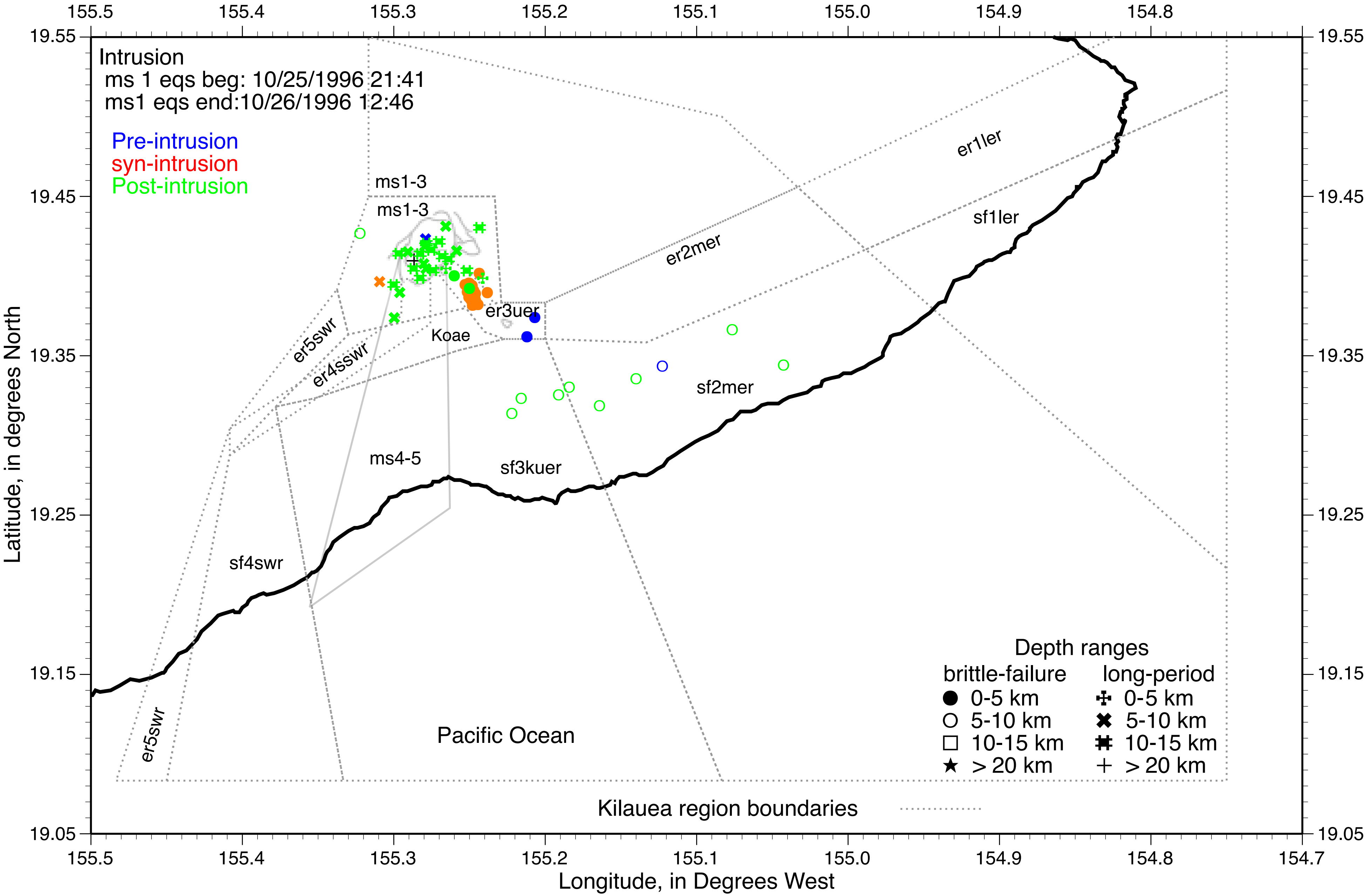
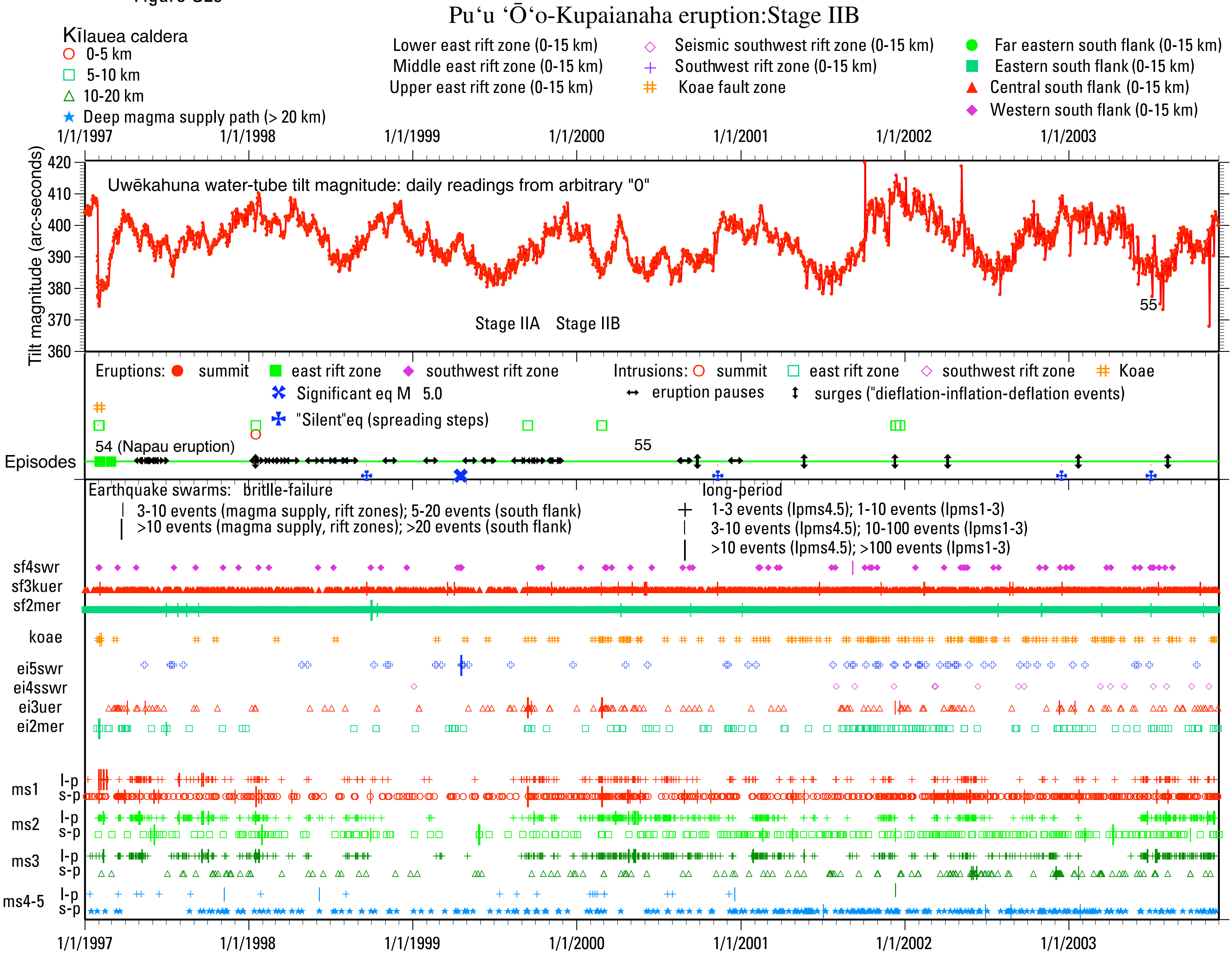
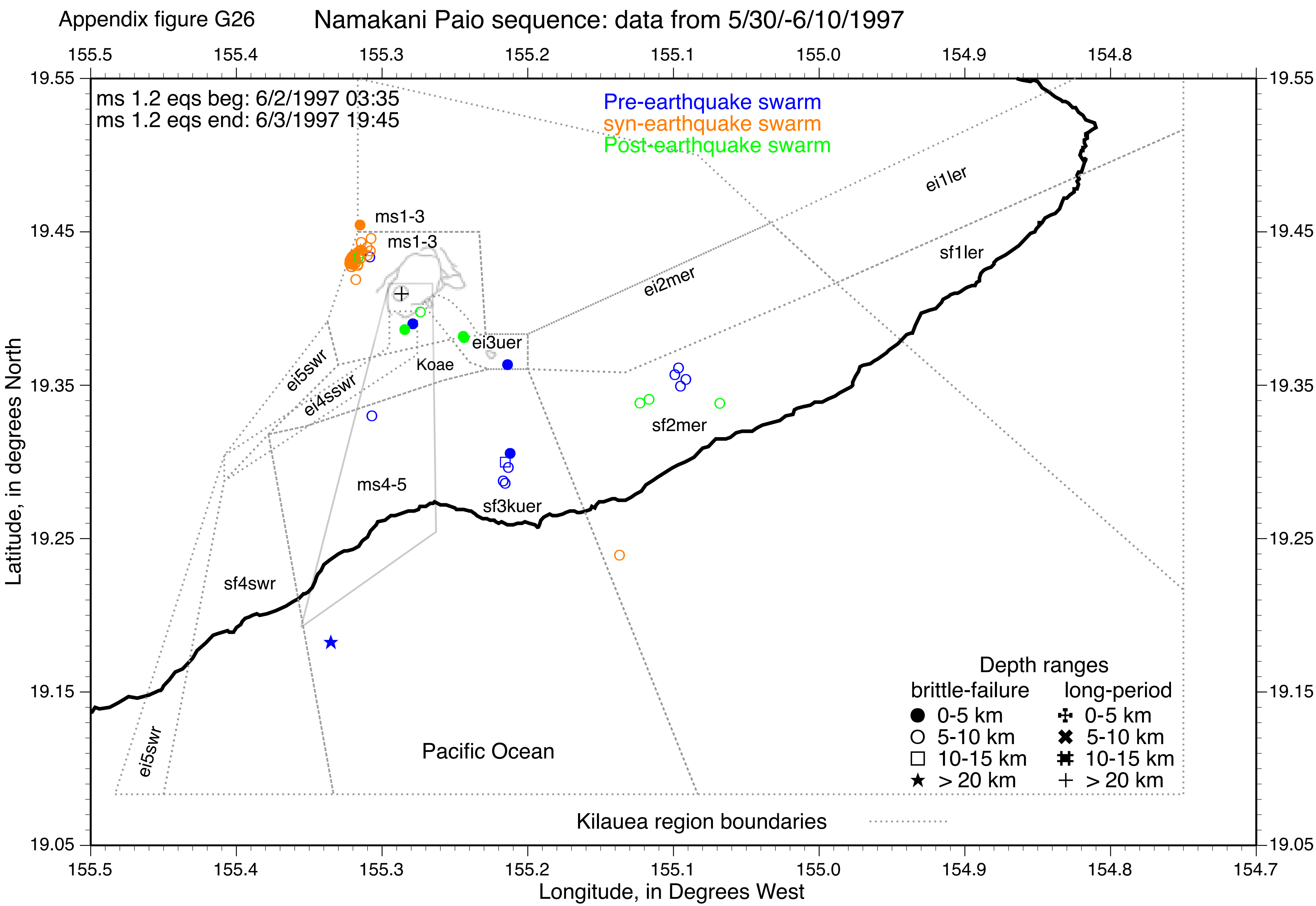


Figure G25

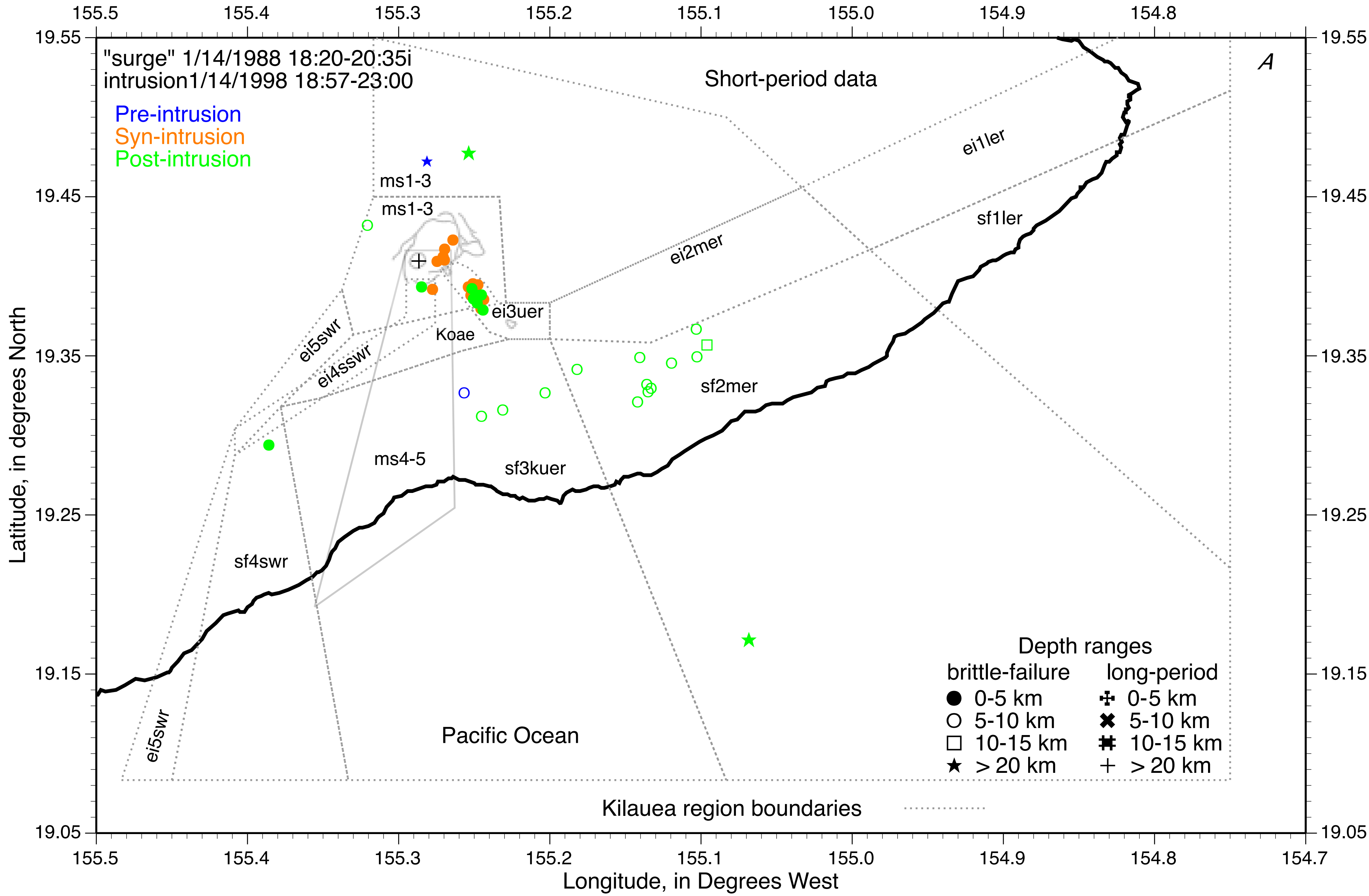


Pu‘u ‘Ō‘o-Kupaianaha eruption:Stage IIB
Kīlauea caldera
0-5 km
5-10 km
10-20 km
Deep magma supply path (> 20 km)
Lower east rift zone (0-15 km)
Middle east rift zone (0-15 km)
Upper east rift zone (0-15 km)
Seismic southwest rift zone (0-15 km)
Southwest rift zone (0-15 km)
Koae fault zone
Far eastern south flank (0-15 km)
Eastern south flank (0-15 km)
Central south flank (0-15 km)
Western south flank (0-15 km)
1/1/1997
1/1/1998
1/1/1999
1/1/2000
1/1/2001
1/1/2002
1/1/2003
Tilt magnitude (arc-seconds)
420
410
400
390
380
370
360
Uwēkahuna water-tube tilt magnitude: daily readings from arbitrary "0"
55
Stage IIA
Stage IIB
Eruptions: summit
east rift zone
southwest rift zone
Intrusions: summit
east rift zone
southwest rift zone
Koae
Significant eq M 5.0
eruption pauses
surges ("dieflation-inflation-deflation events)
"Silent"eq (spreading steps)
54 (Napau eruption)
55
Episodes
Earthquake swarms: britlle-failure
3-10 events (magma supply, rift zones); 5-20 events (south flank)
>10 events (magma supply, rift zones); >20 events (south flank)
long-period
1-3 events (lpms4.5); 1-10 events (lpms1-3)
3-10 events (lpms4.5); 10-100 events (lpms1-3)
>10 events (lpms4.5); >100 events (lpms1-3)
sf4swr
sf3kuer
sf2mer
koae
ei5swr
ei4sswr
ei3uer
ei2mer
ms1
ms2
ms3
ms4-5
l-p
s-p
0

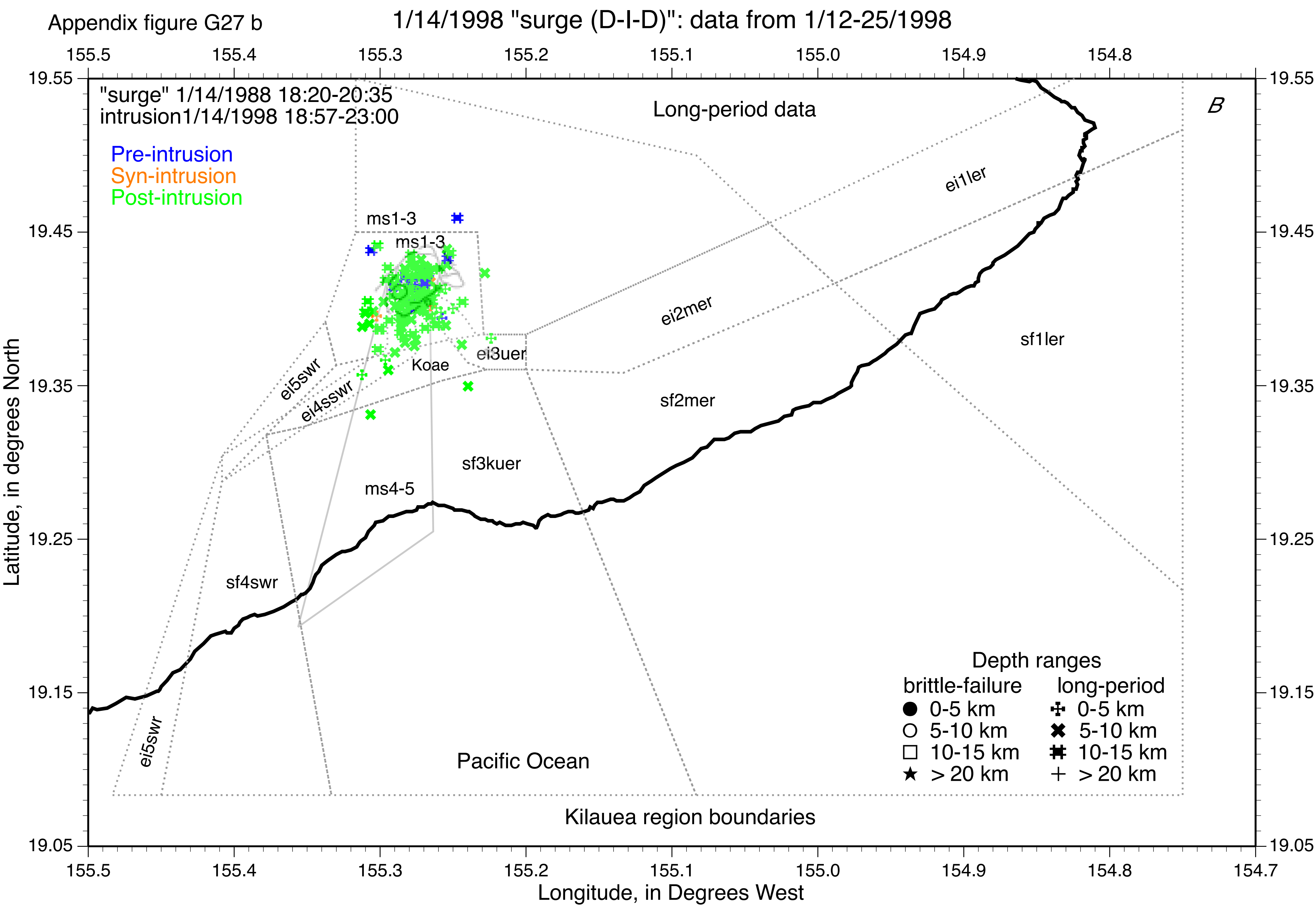
Appendix figure G26



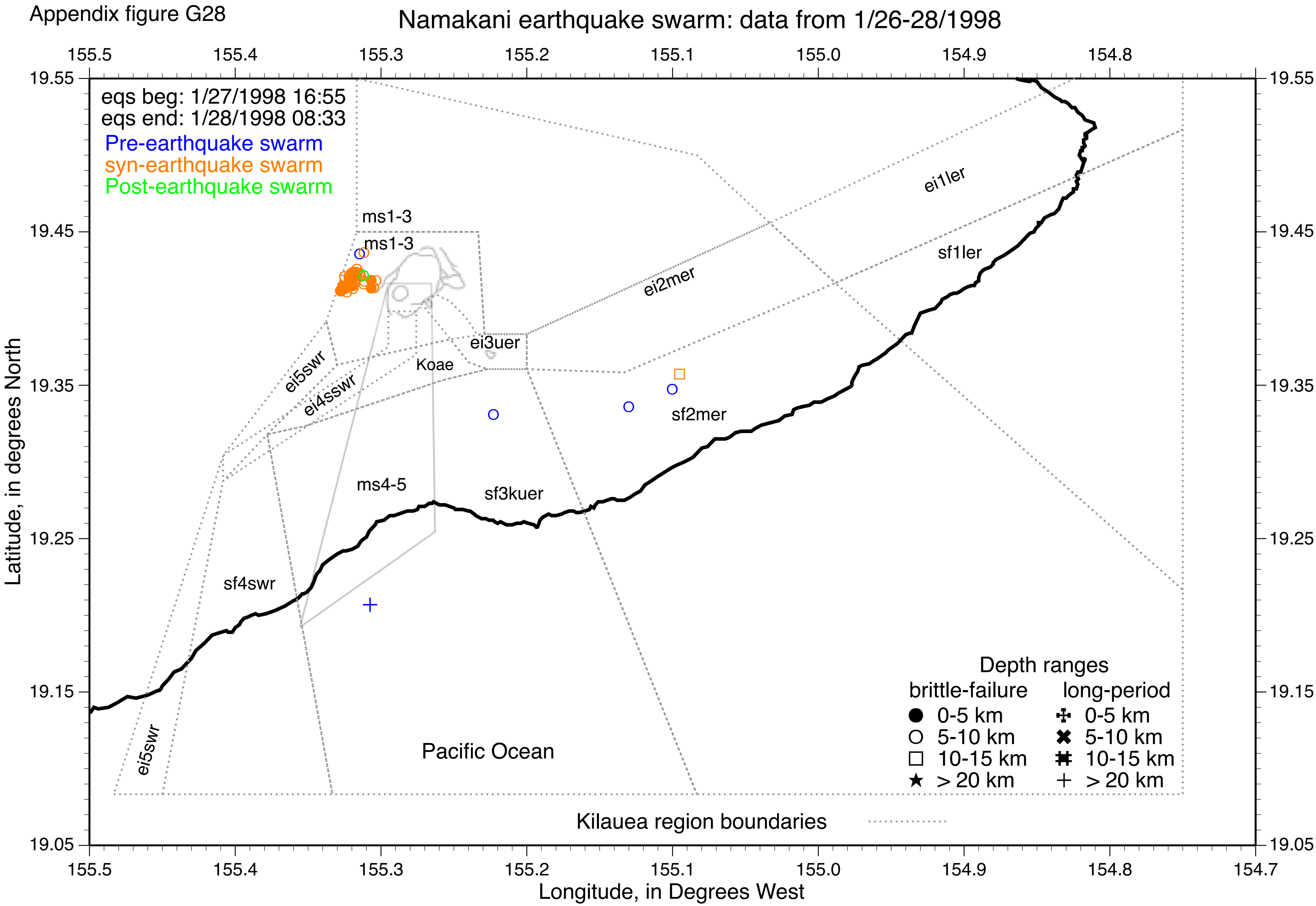
Appendix figure G27 a 1/14/1998 intrusion and "surge (D-I-D)": data from 1/12-25/1998



Appendix figure G27 b

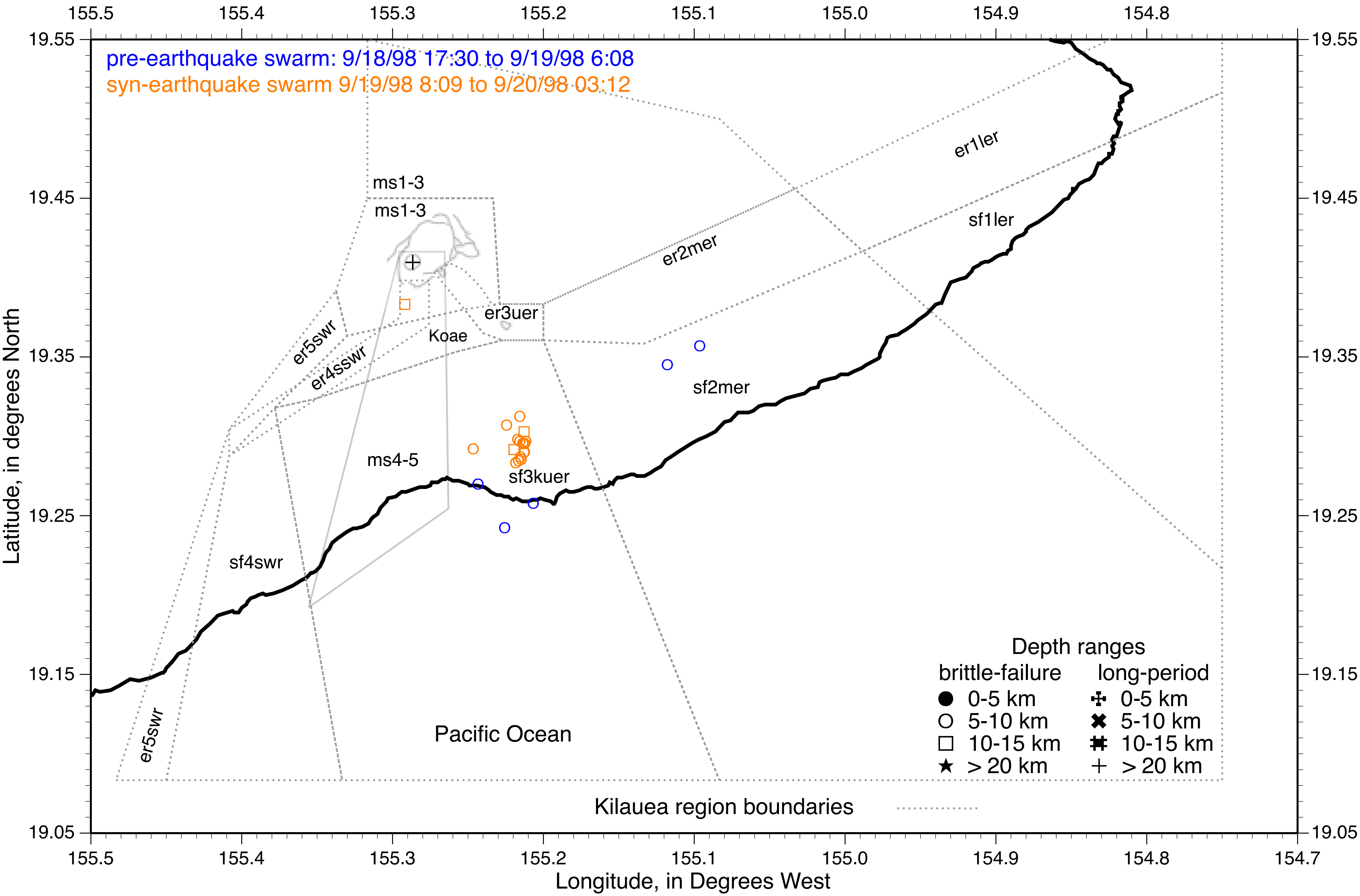


Appendix figure G28

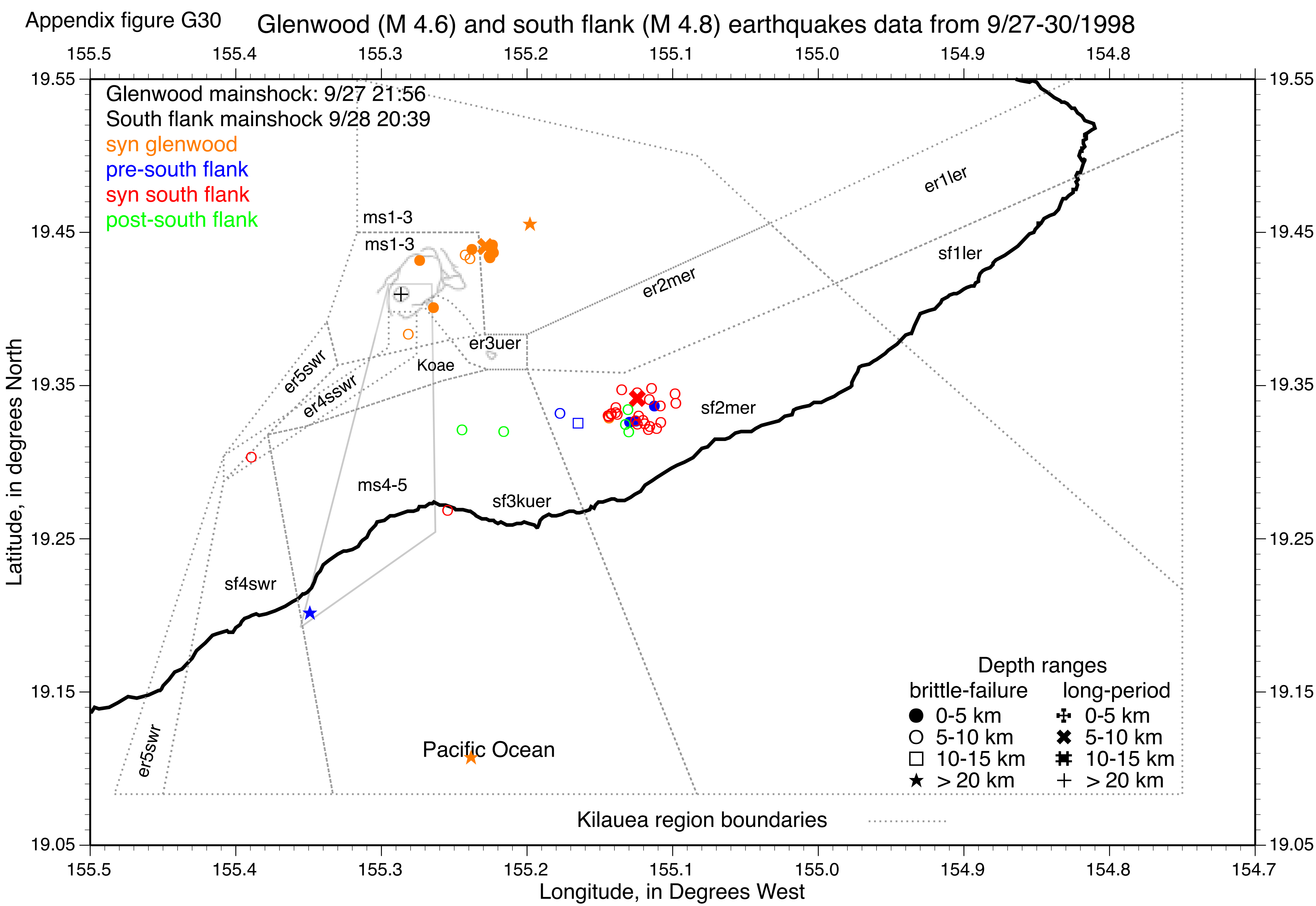


Appendix figure G29

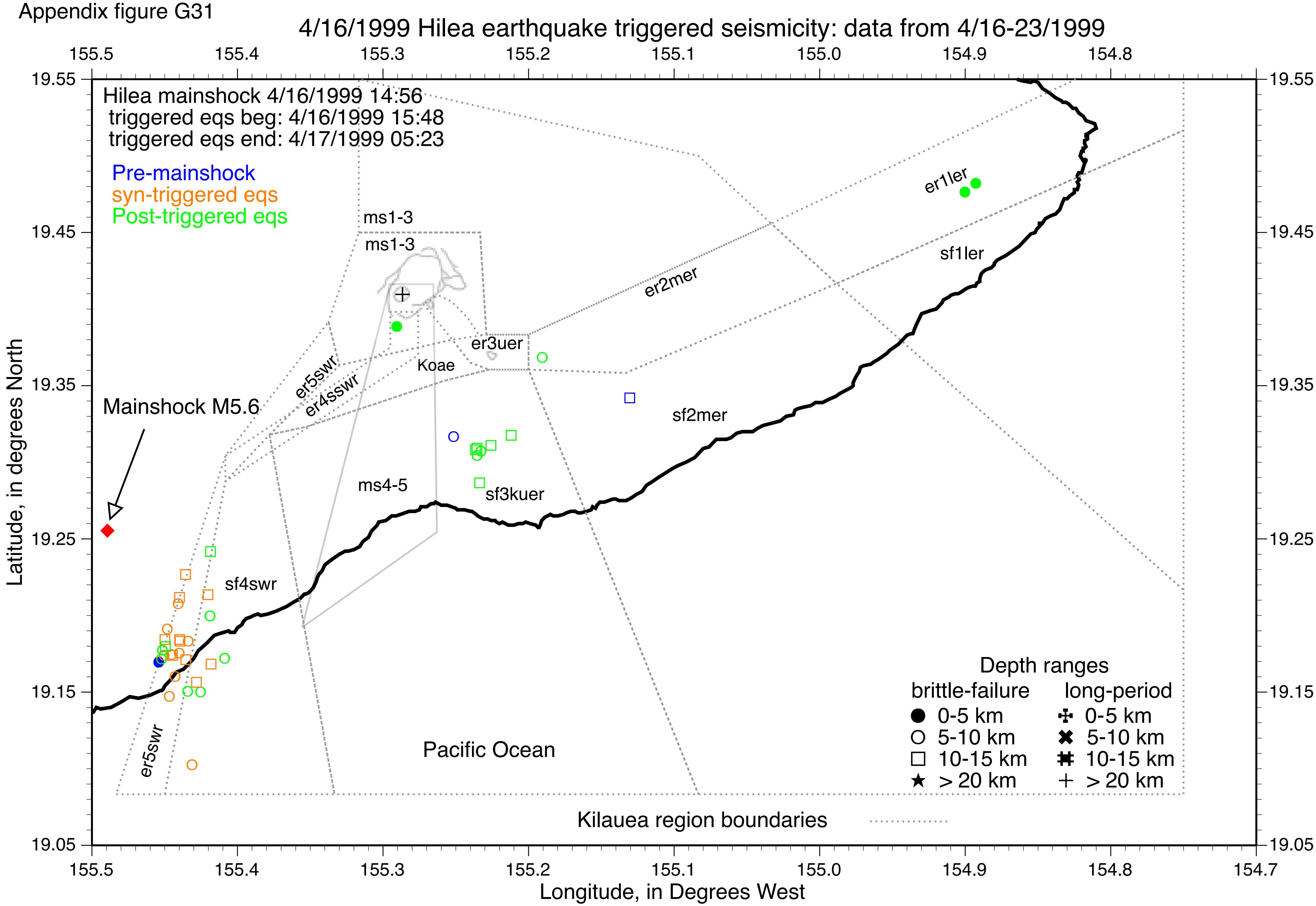
9/19/1998 silent earthquake: data from 9/18-20/1998



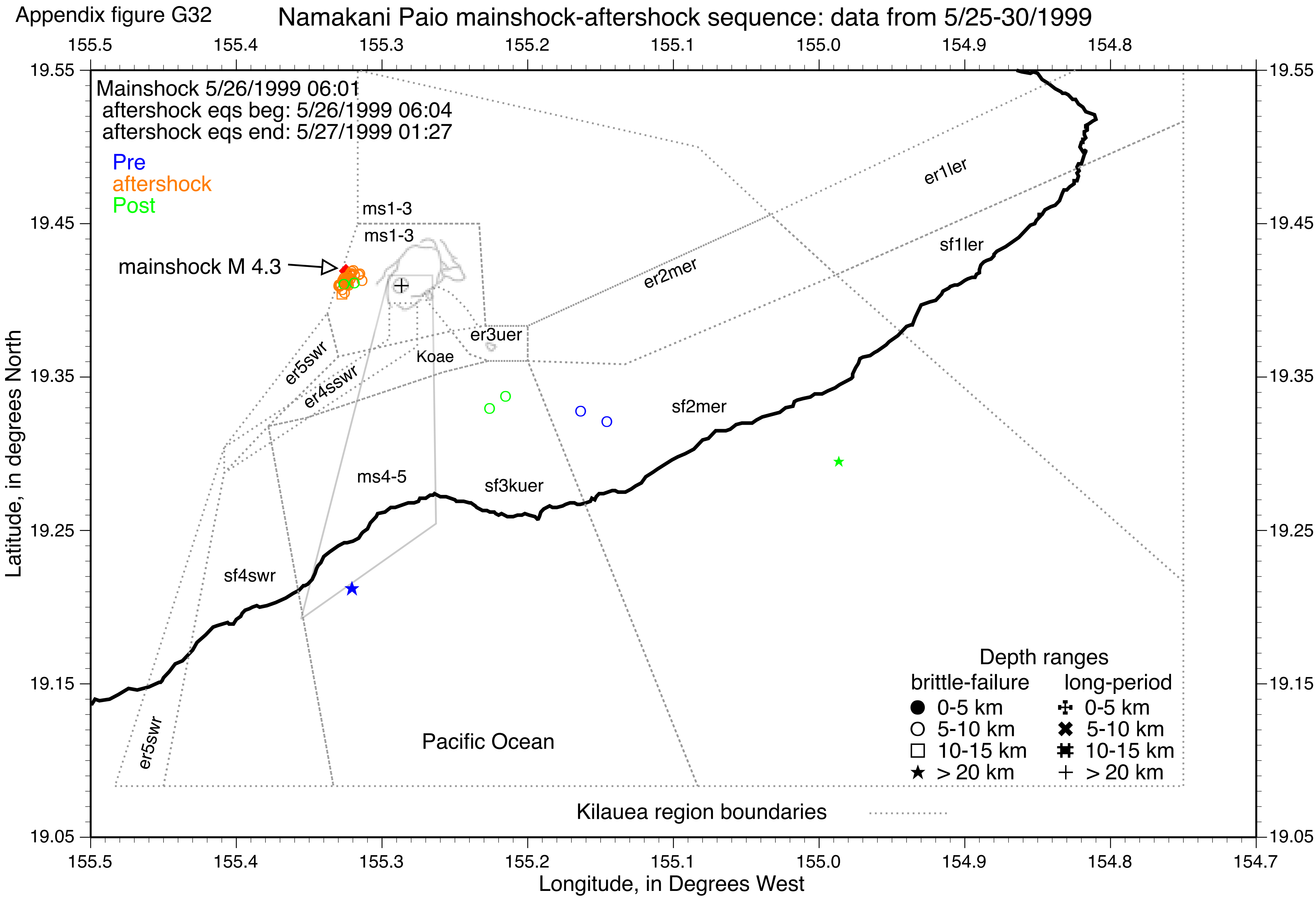
Appendix figure G30



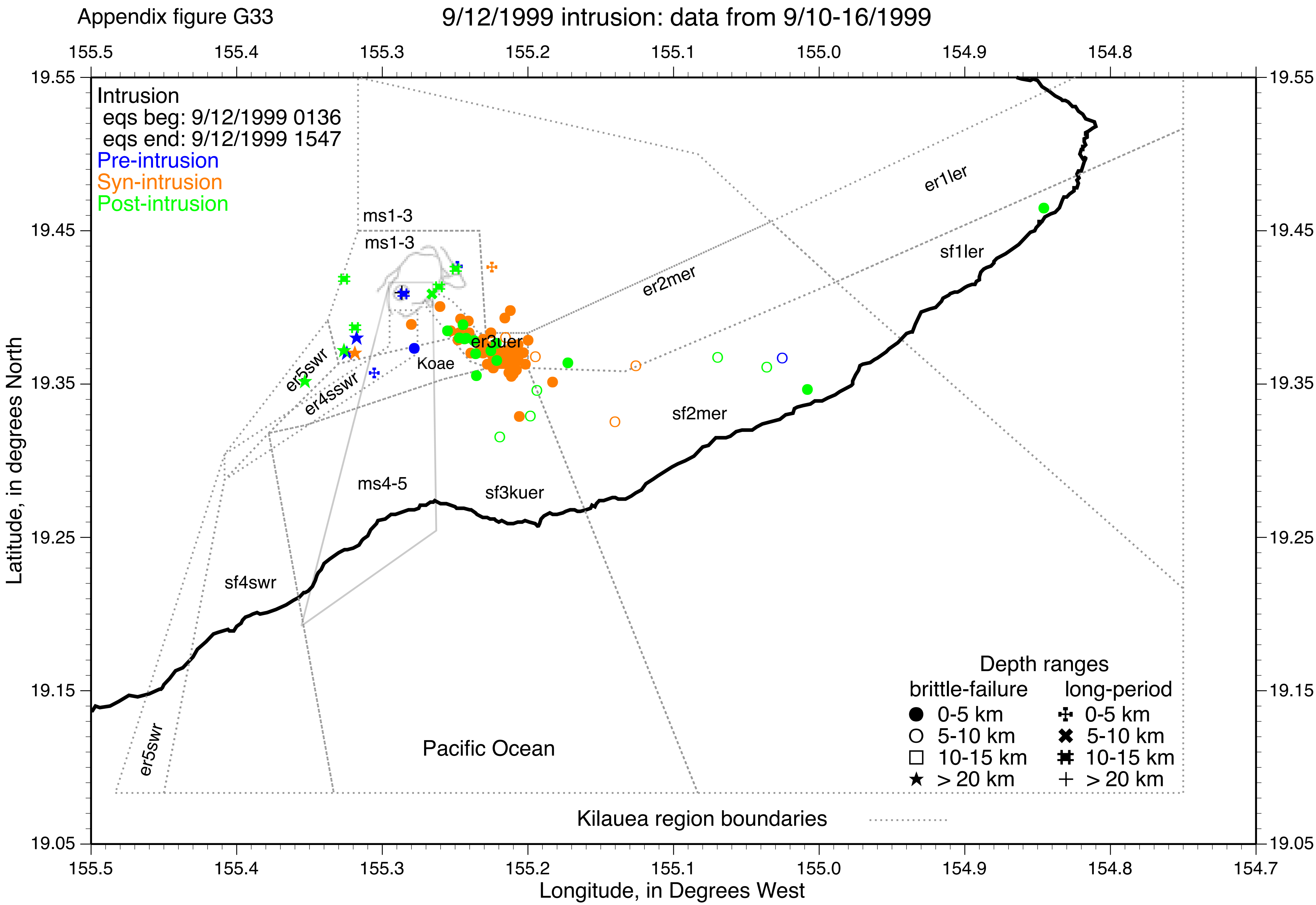
Appendix figure G31



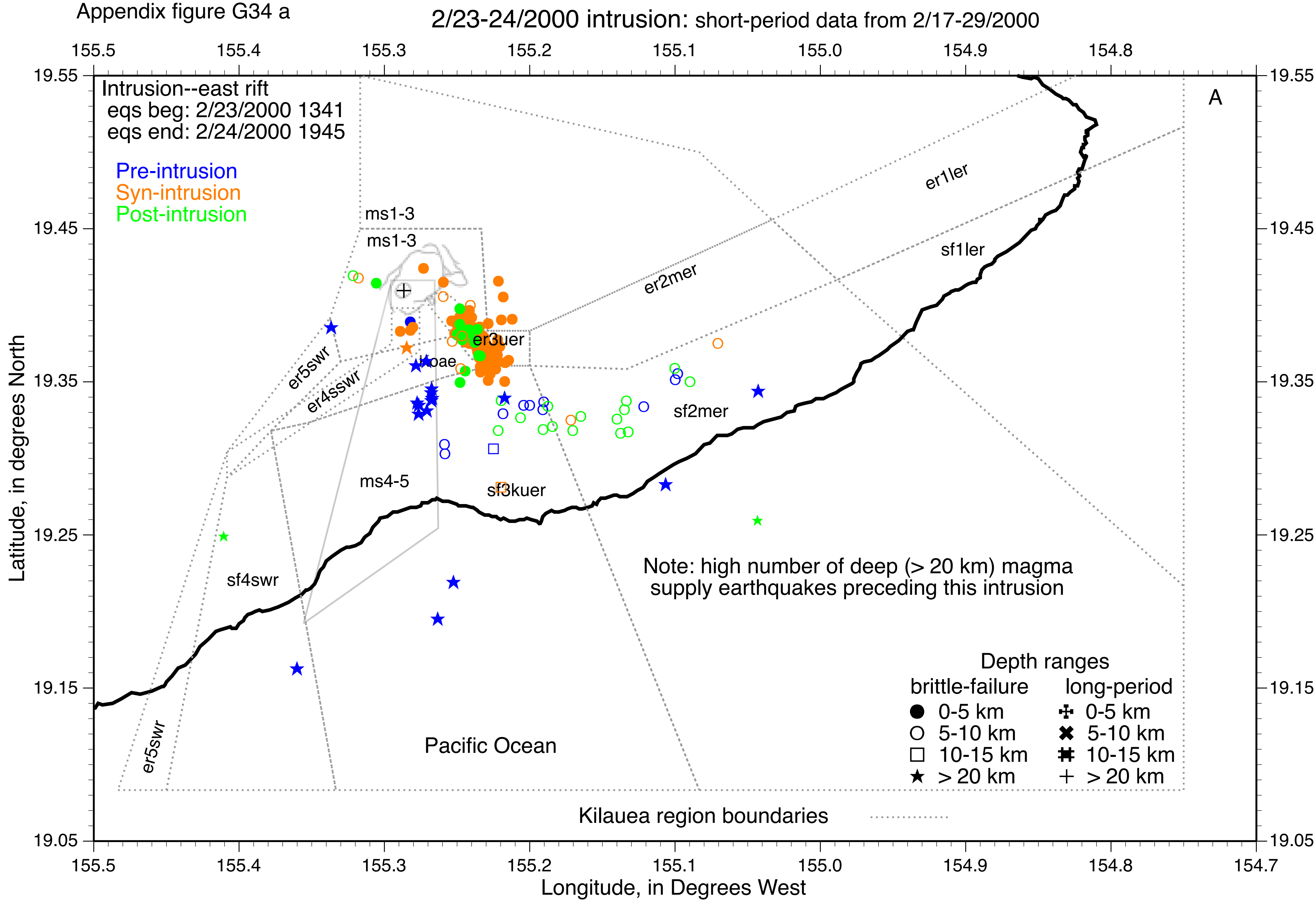
Appendix figure G32



Appendix figure G33

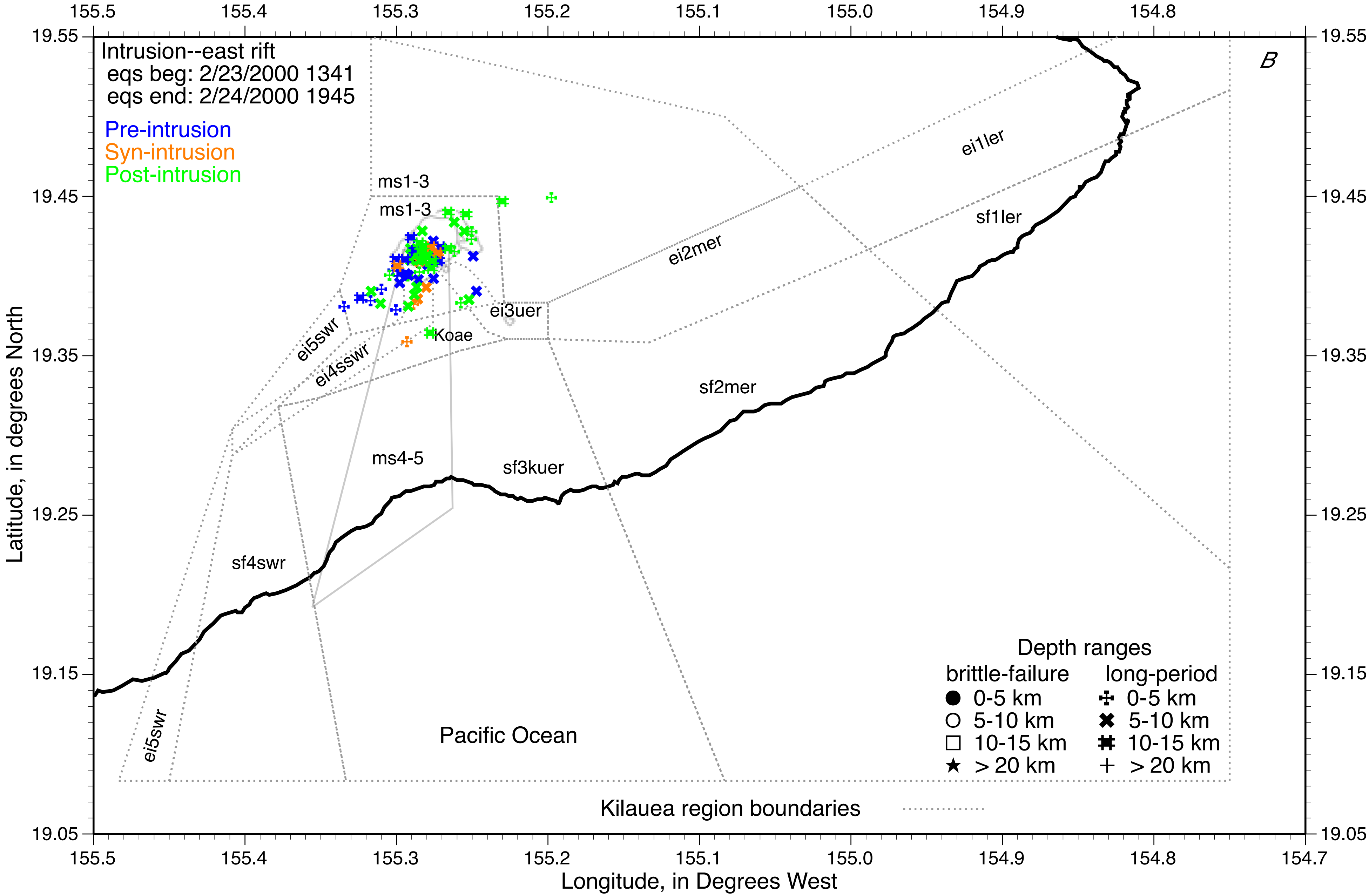


Appendix figure G34 a

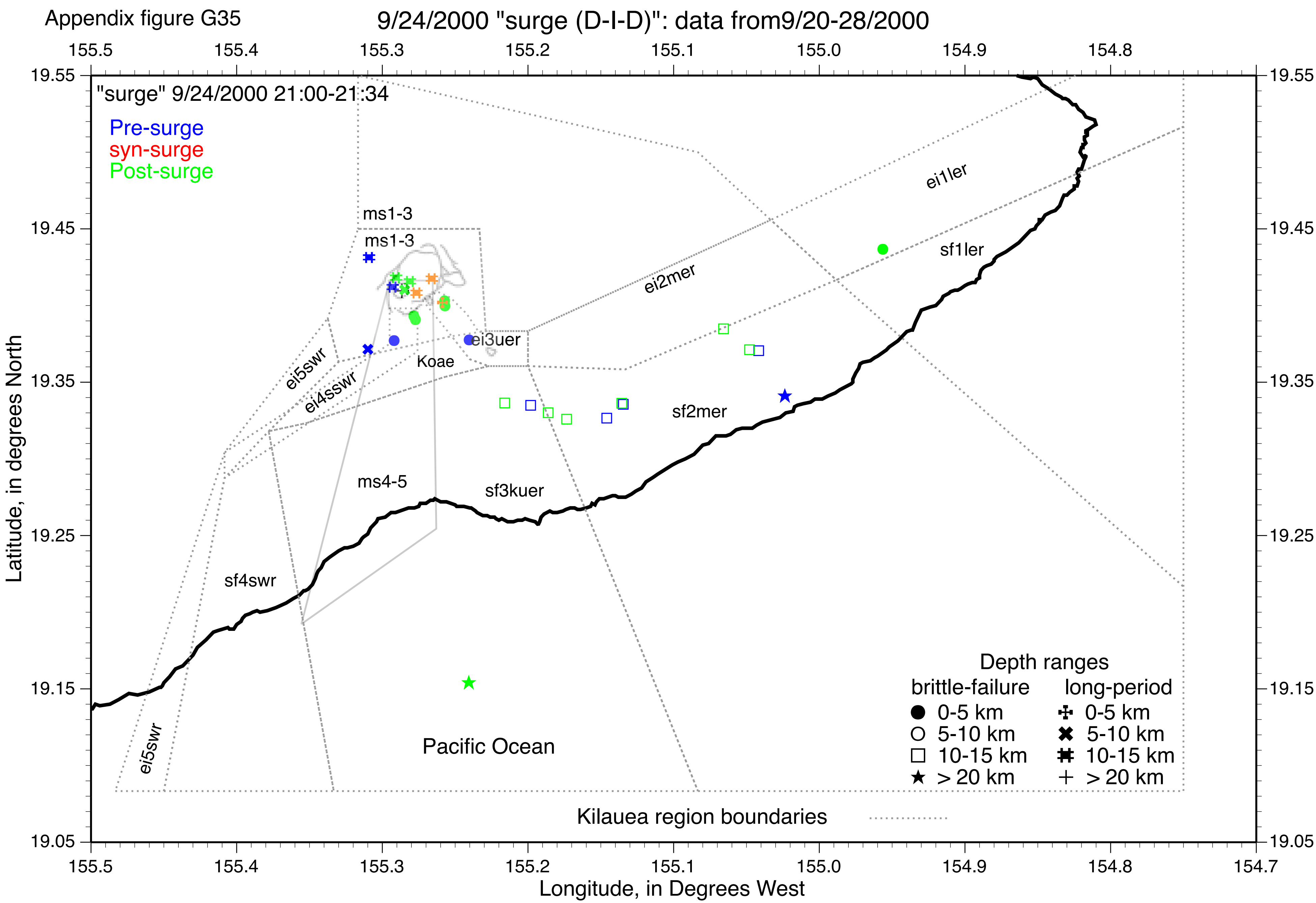


Appendix figure G34 b

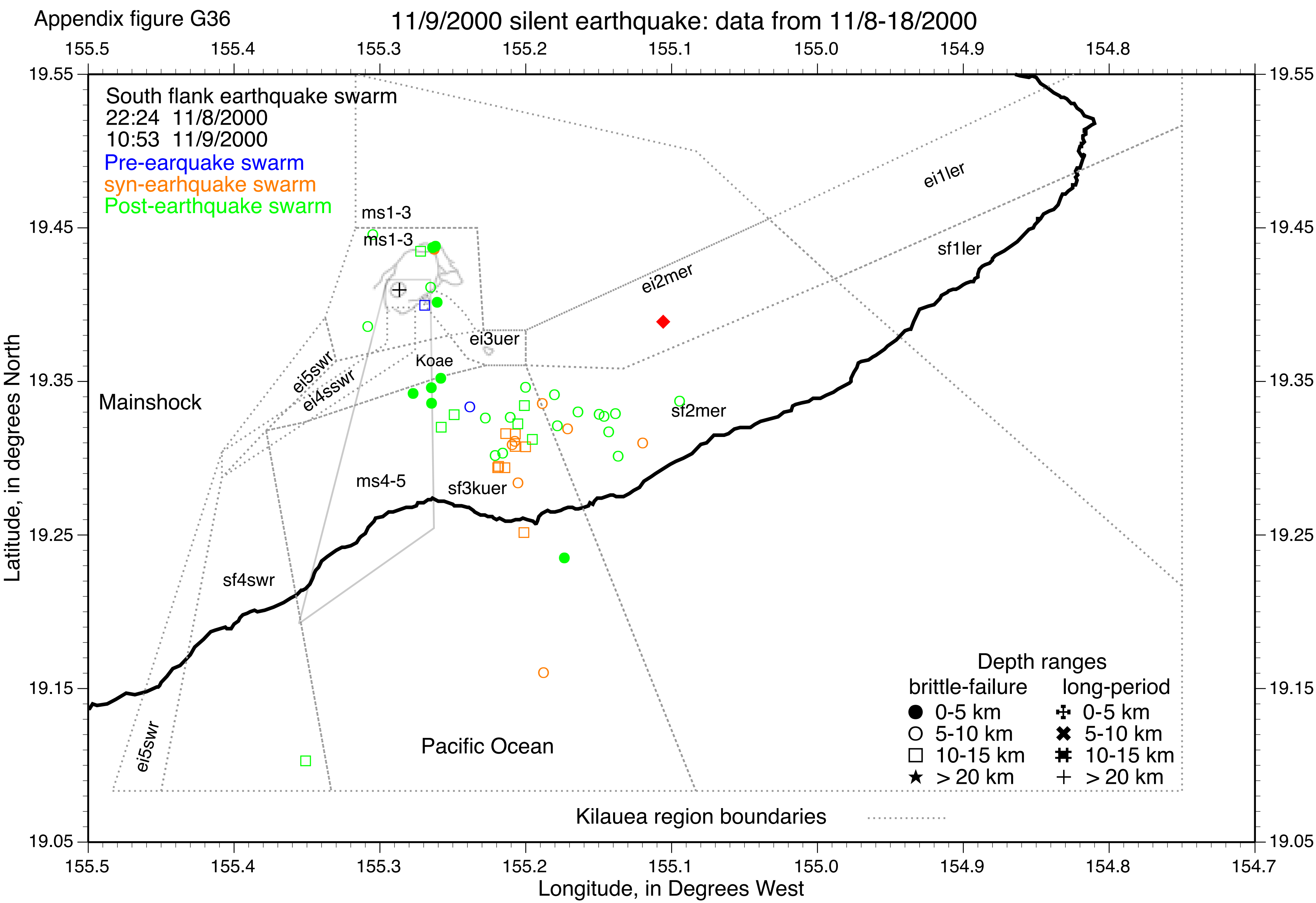
2/23-24/2000 intrusion: long-period data from 2/17-29/2000



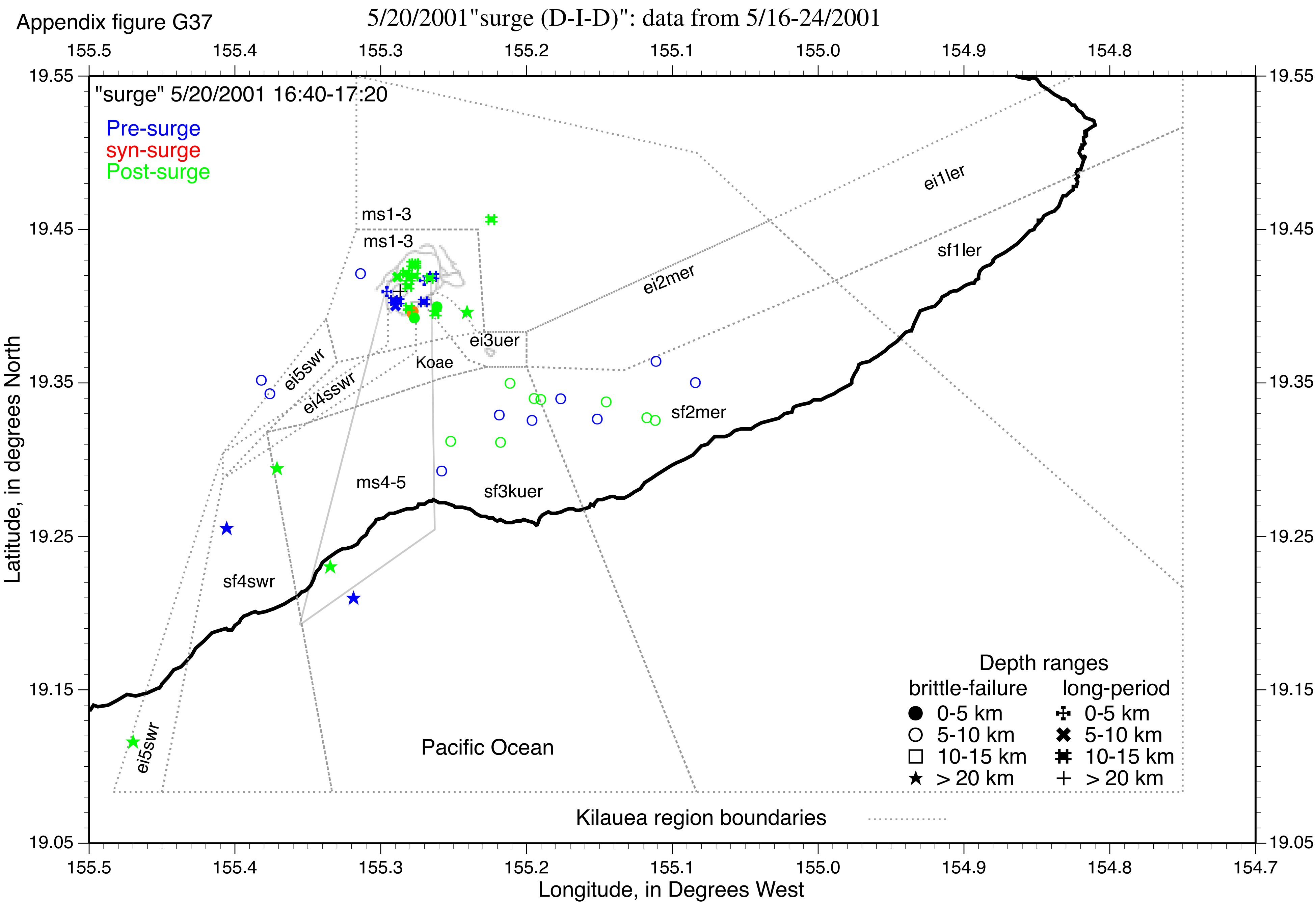
Appendix figure G35



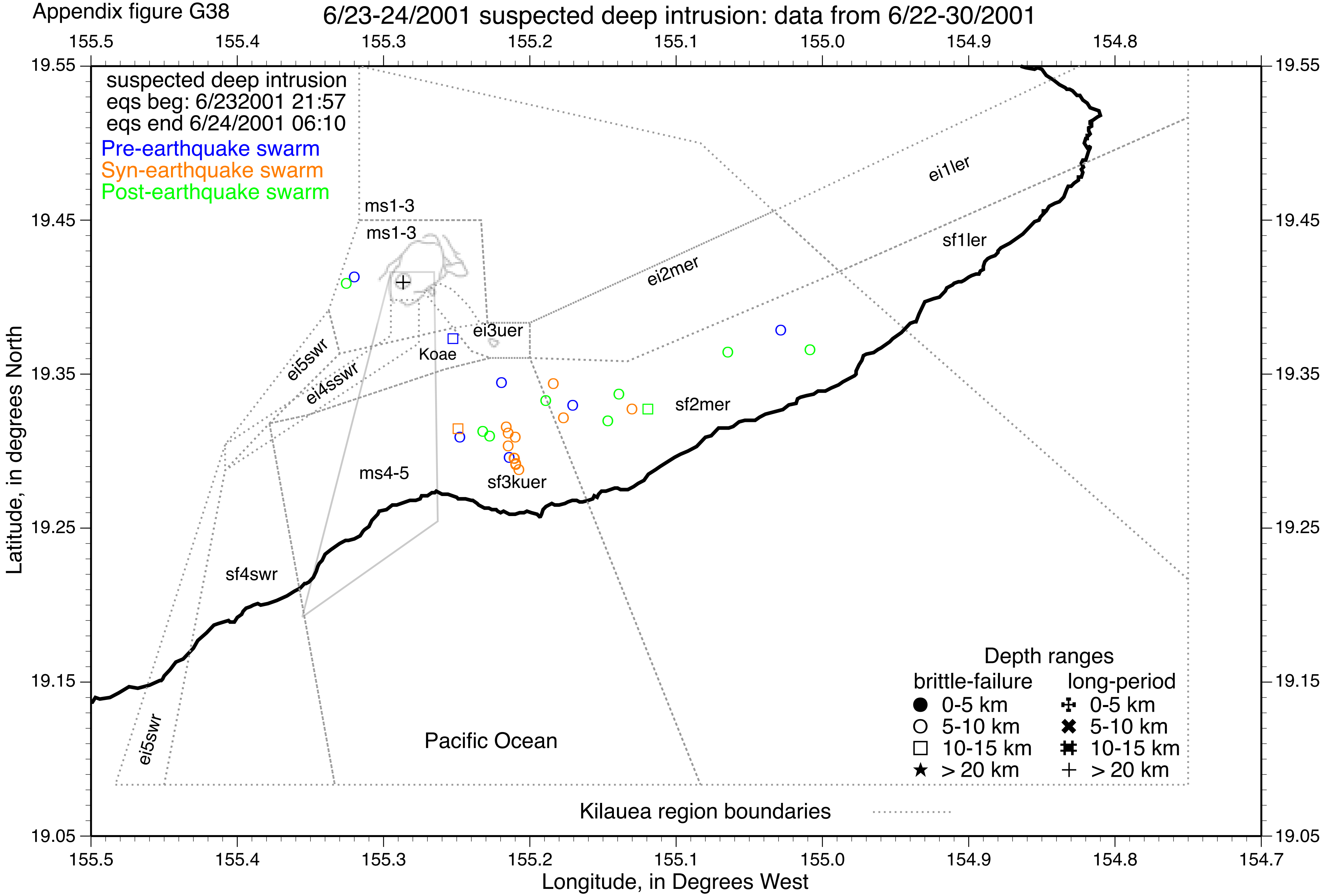
Appendix figure G36



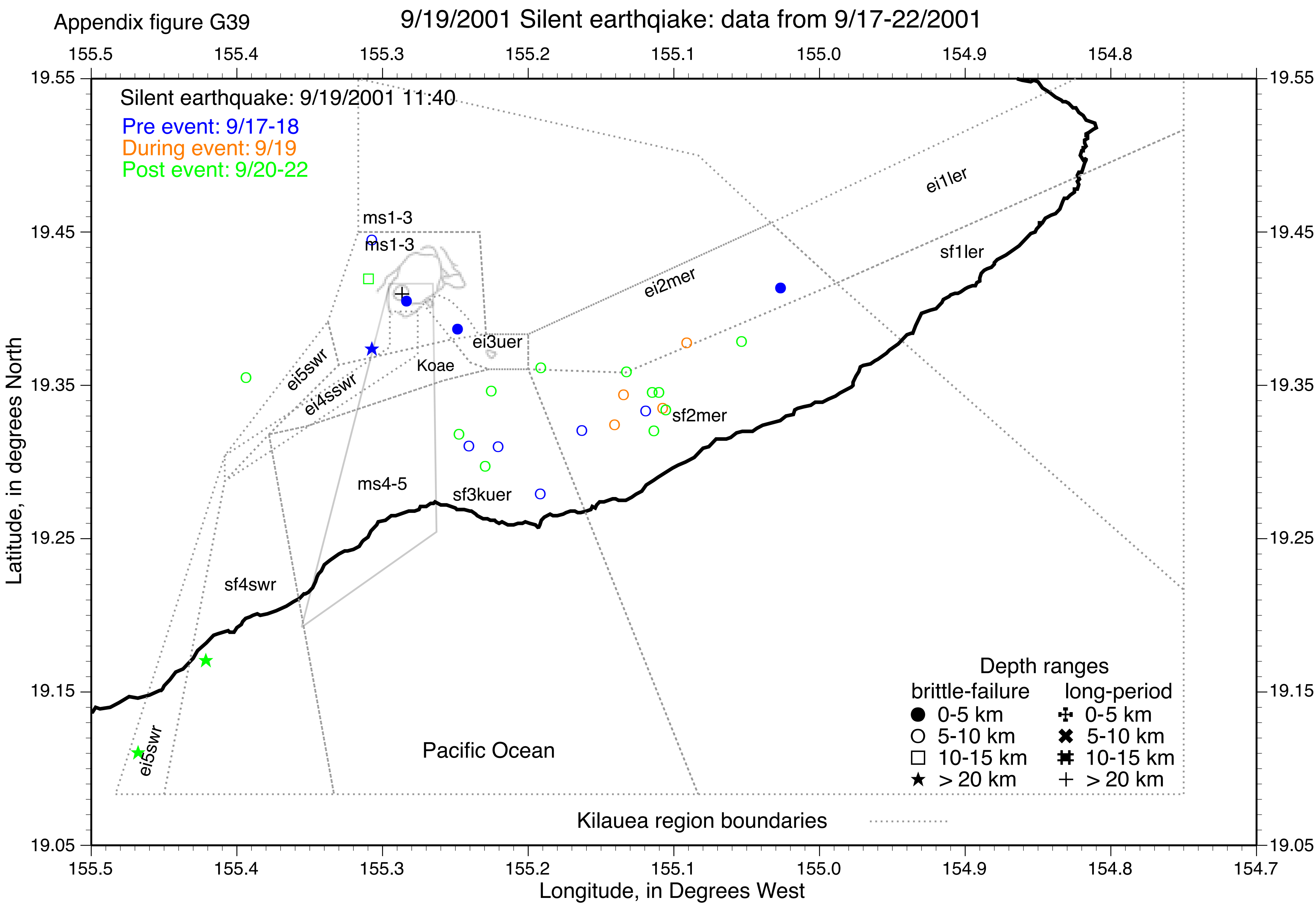
Appendix figure G37



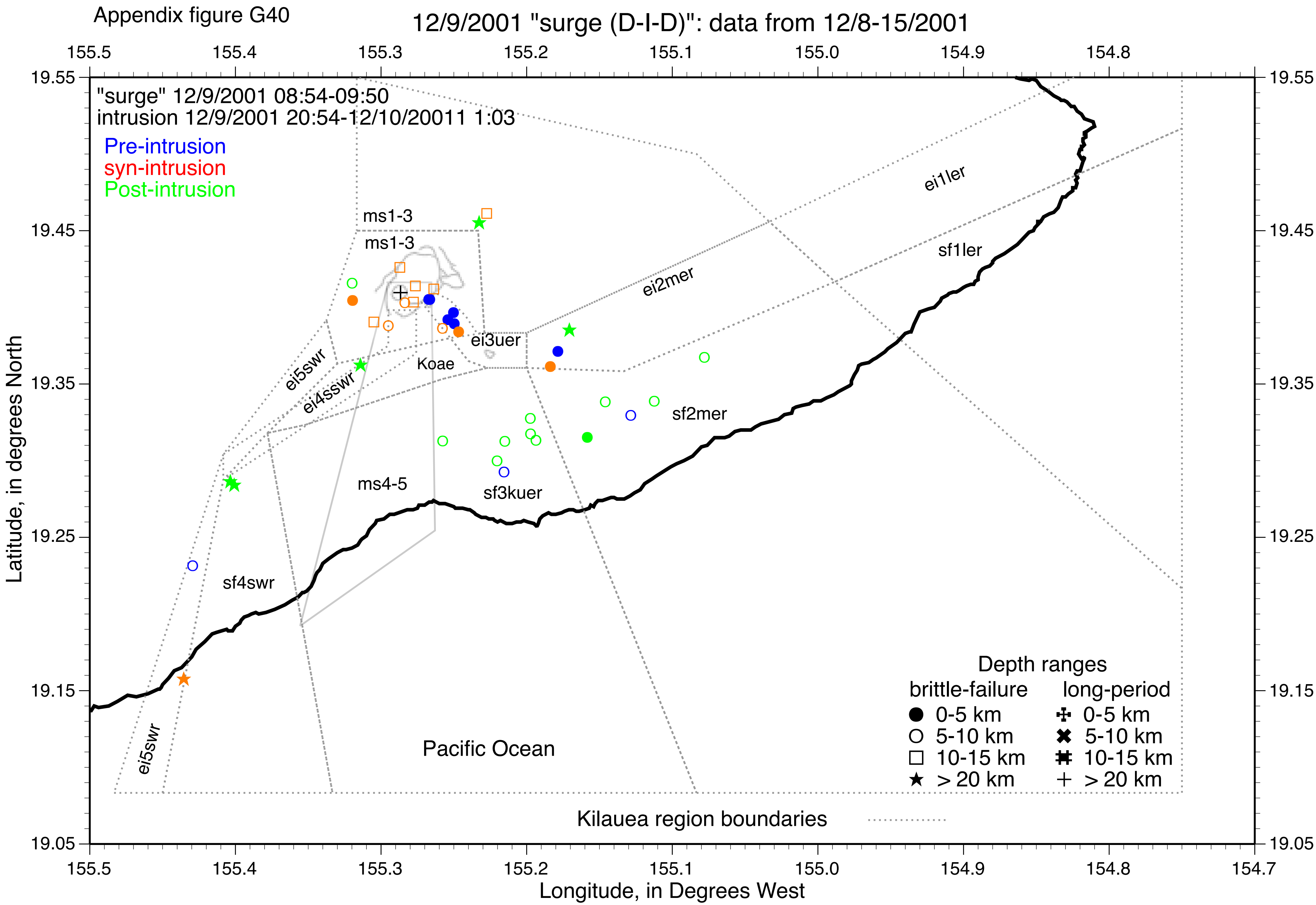
Appendix figure G38



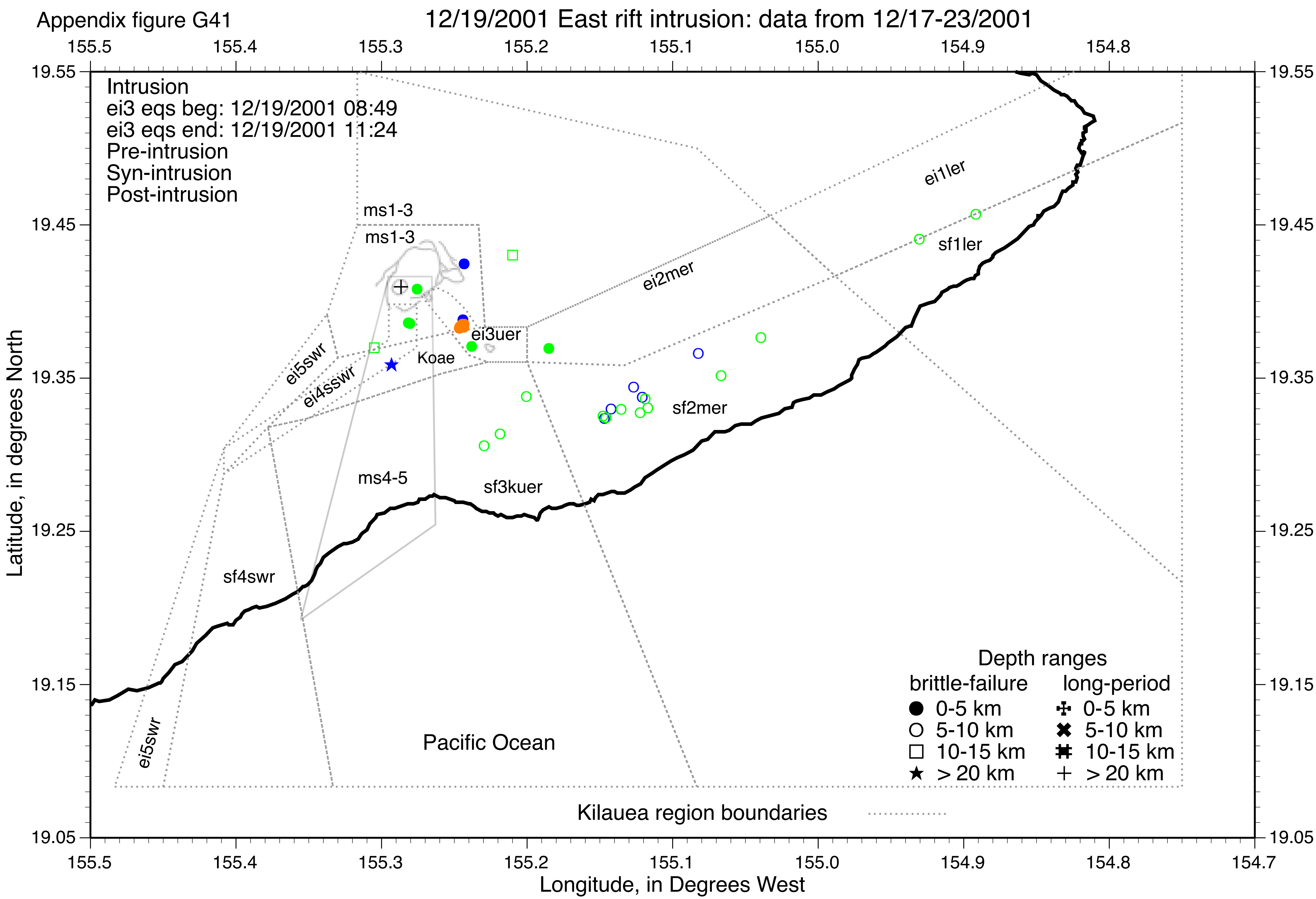
Appendix figure G39



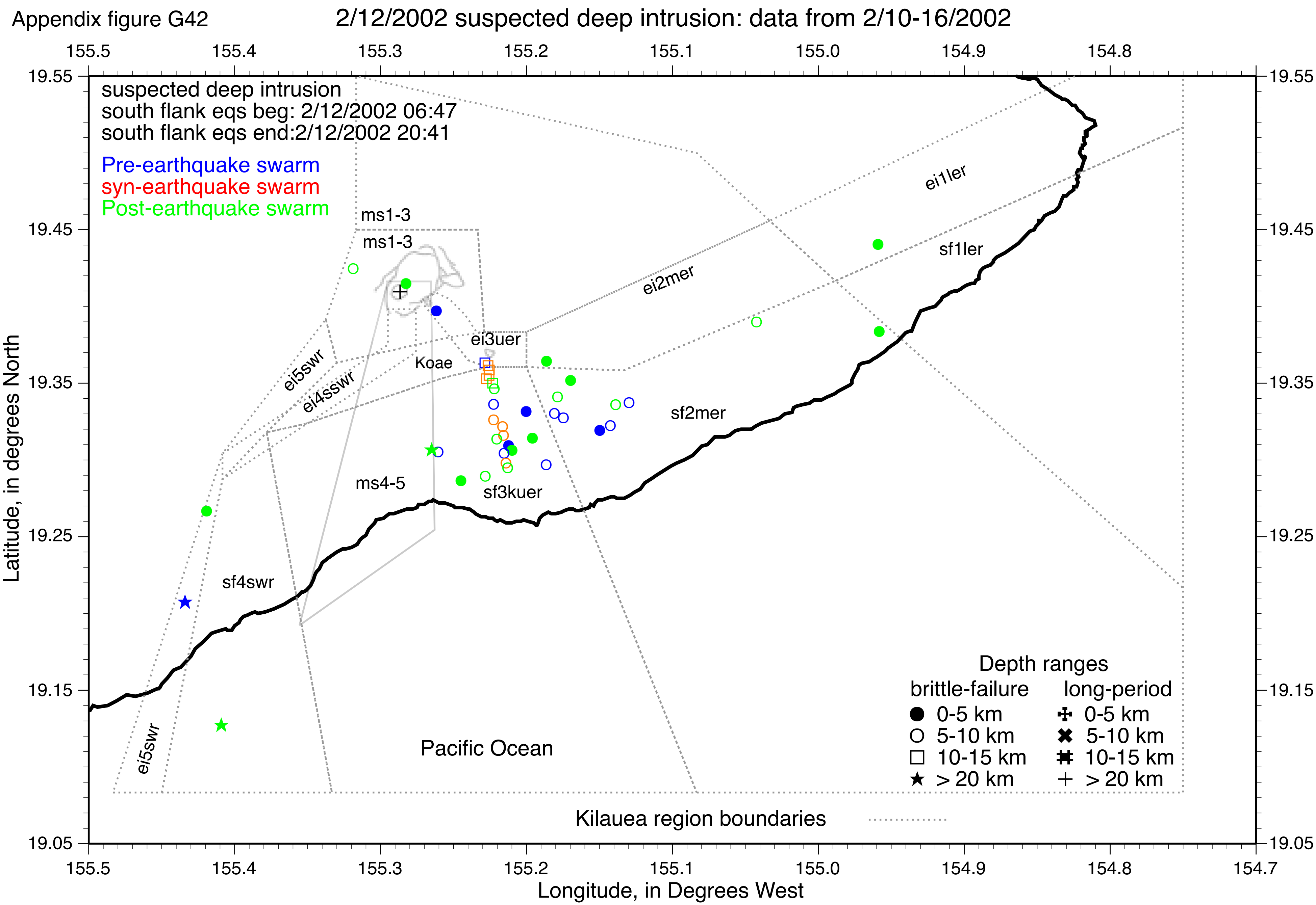
Appendix figure G40



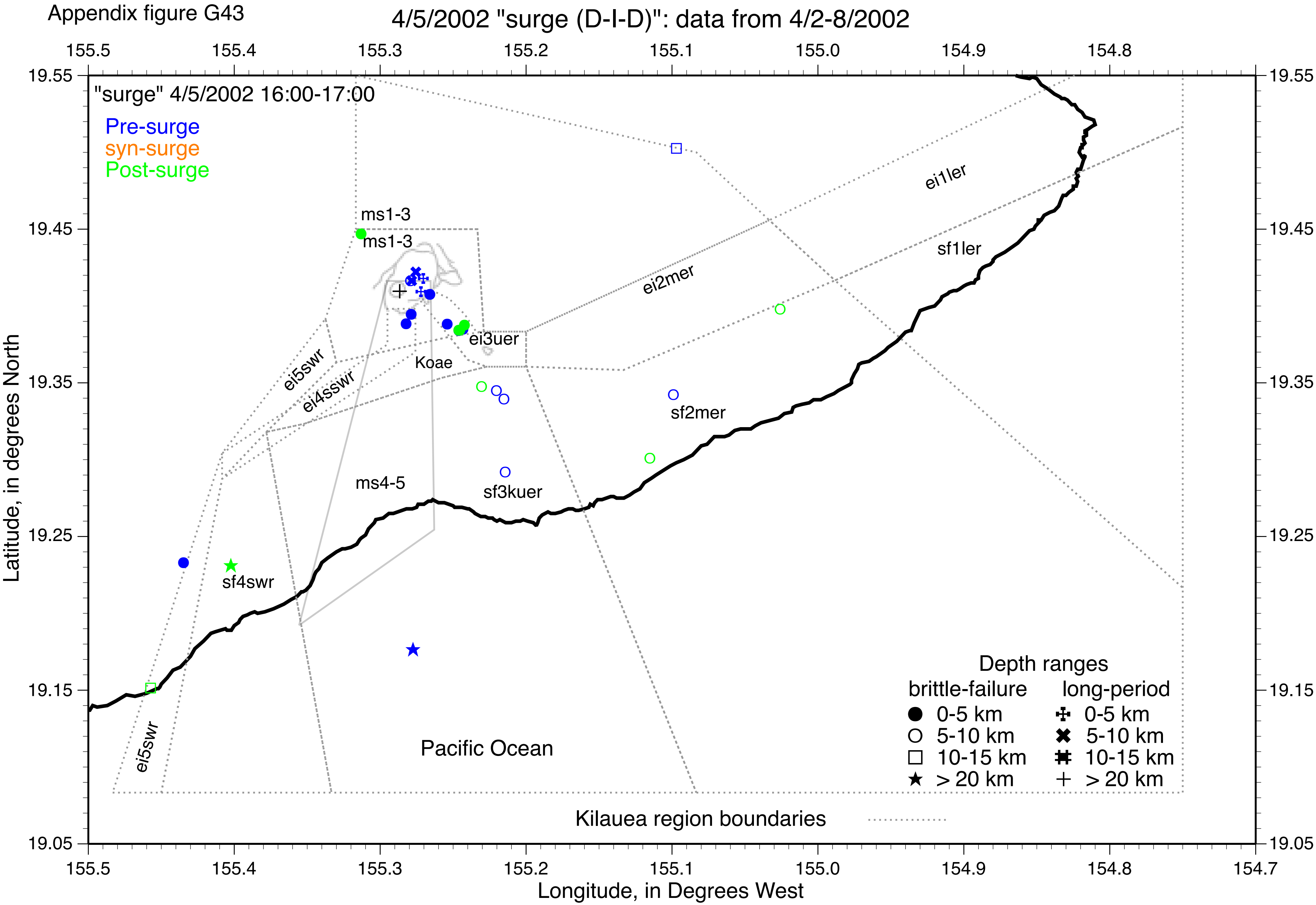
Appendix figure G41



Appendix figure G42

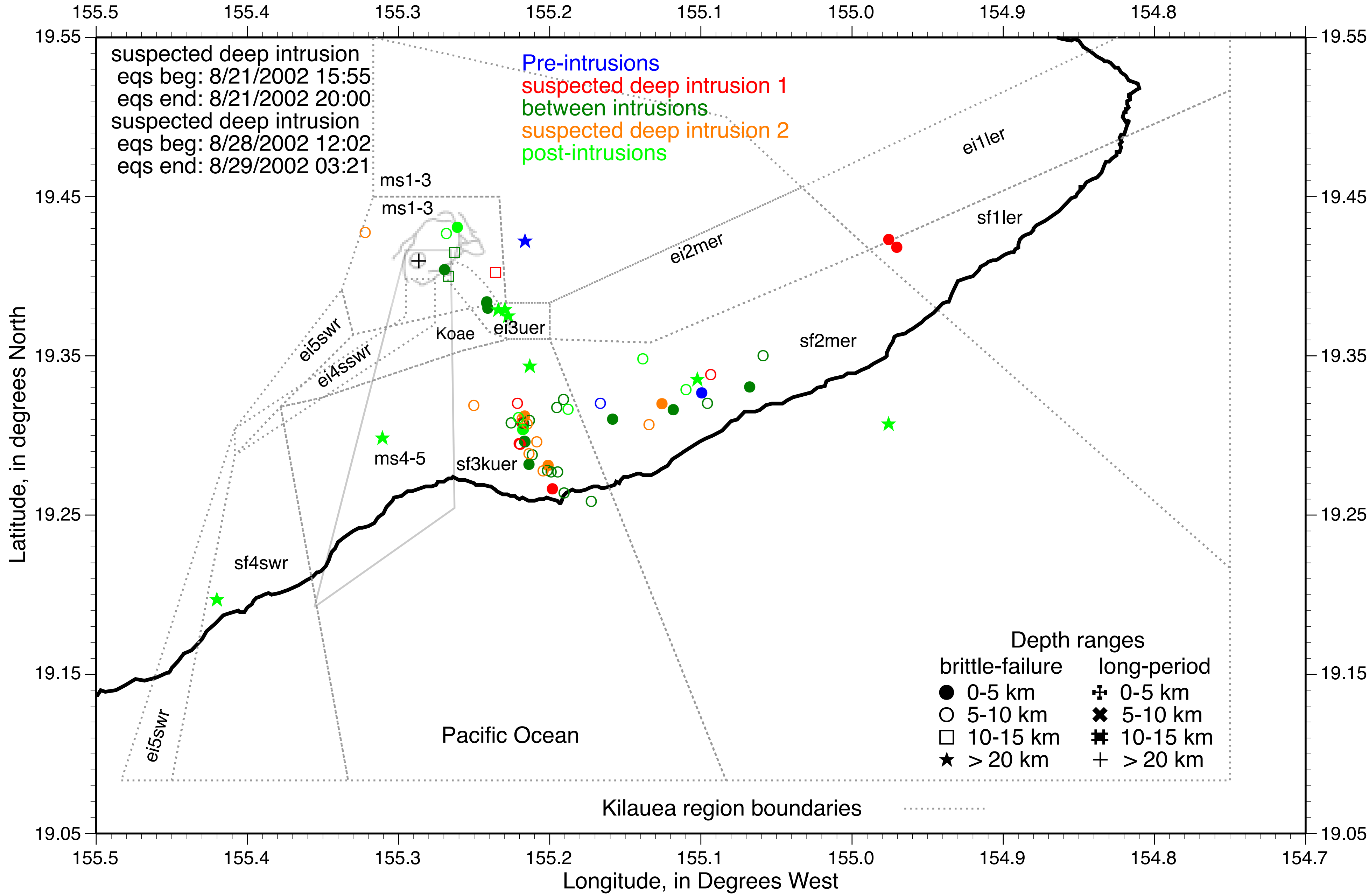


Appendix figure G43

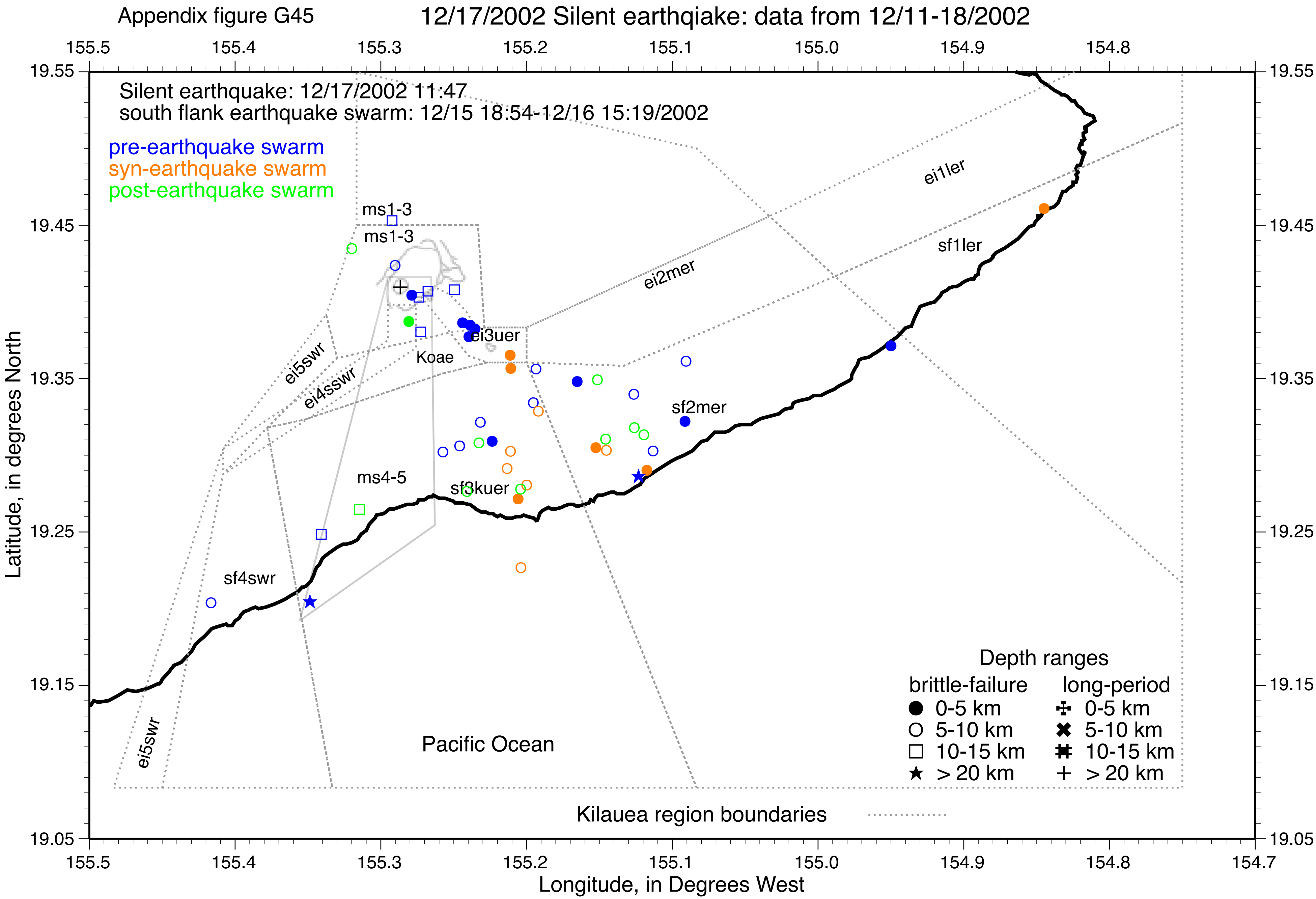


Appendix figure G44

8/21-22, 28-29/2002 suspected deep intrusions data from 8/20-31/2002

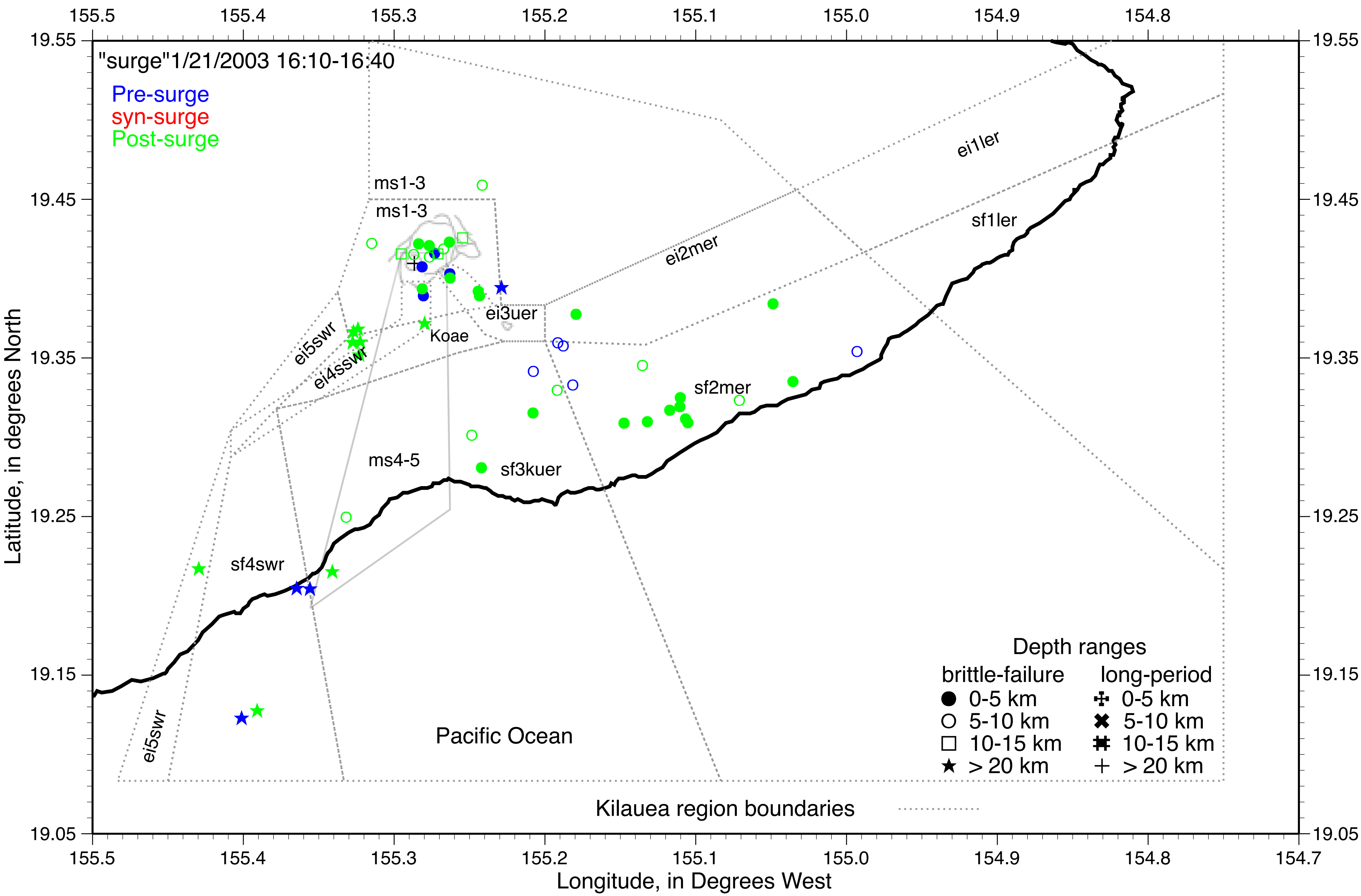


Appendix figure G45

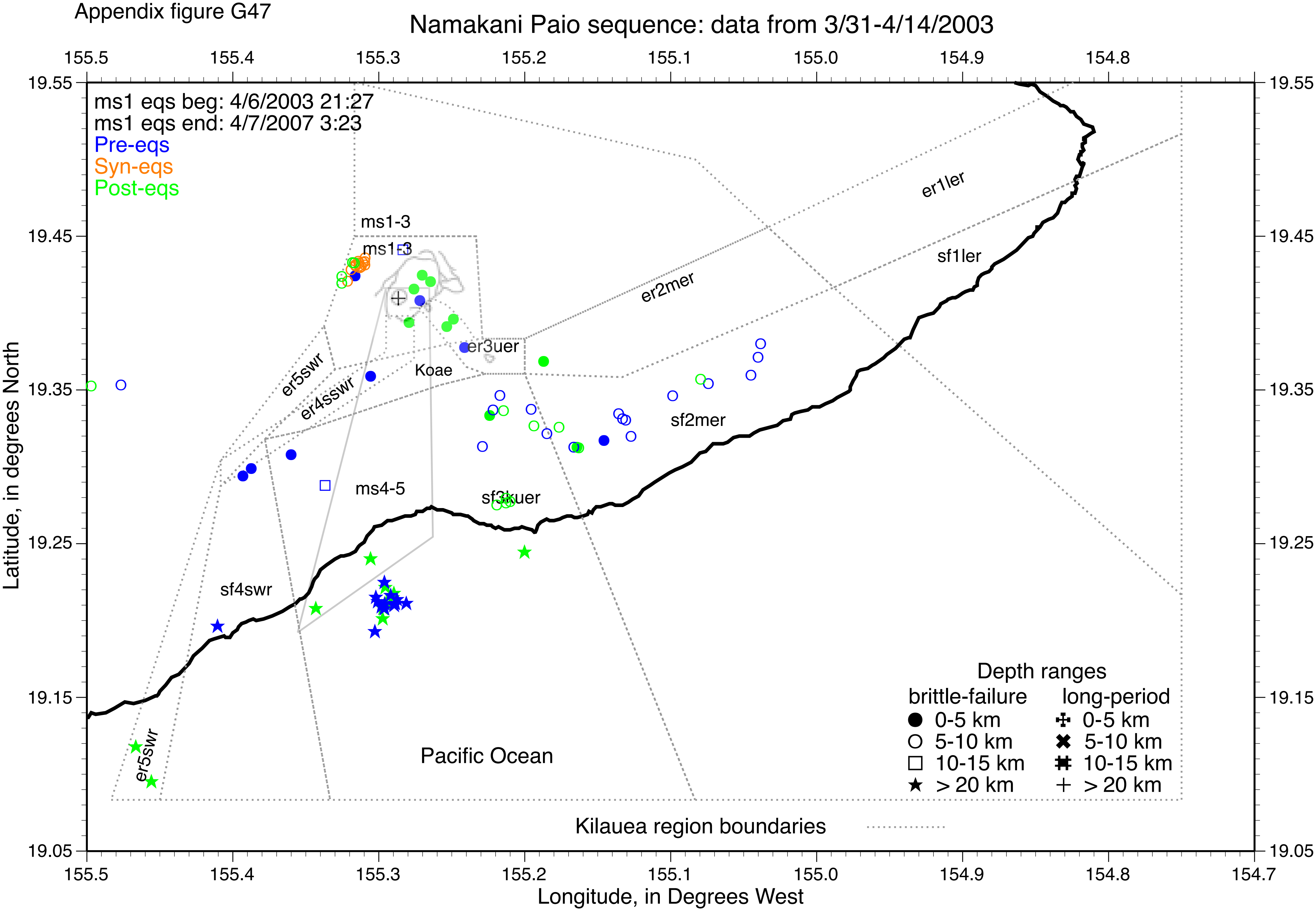


Appendix figure G46

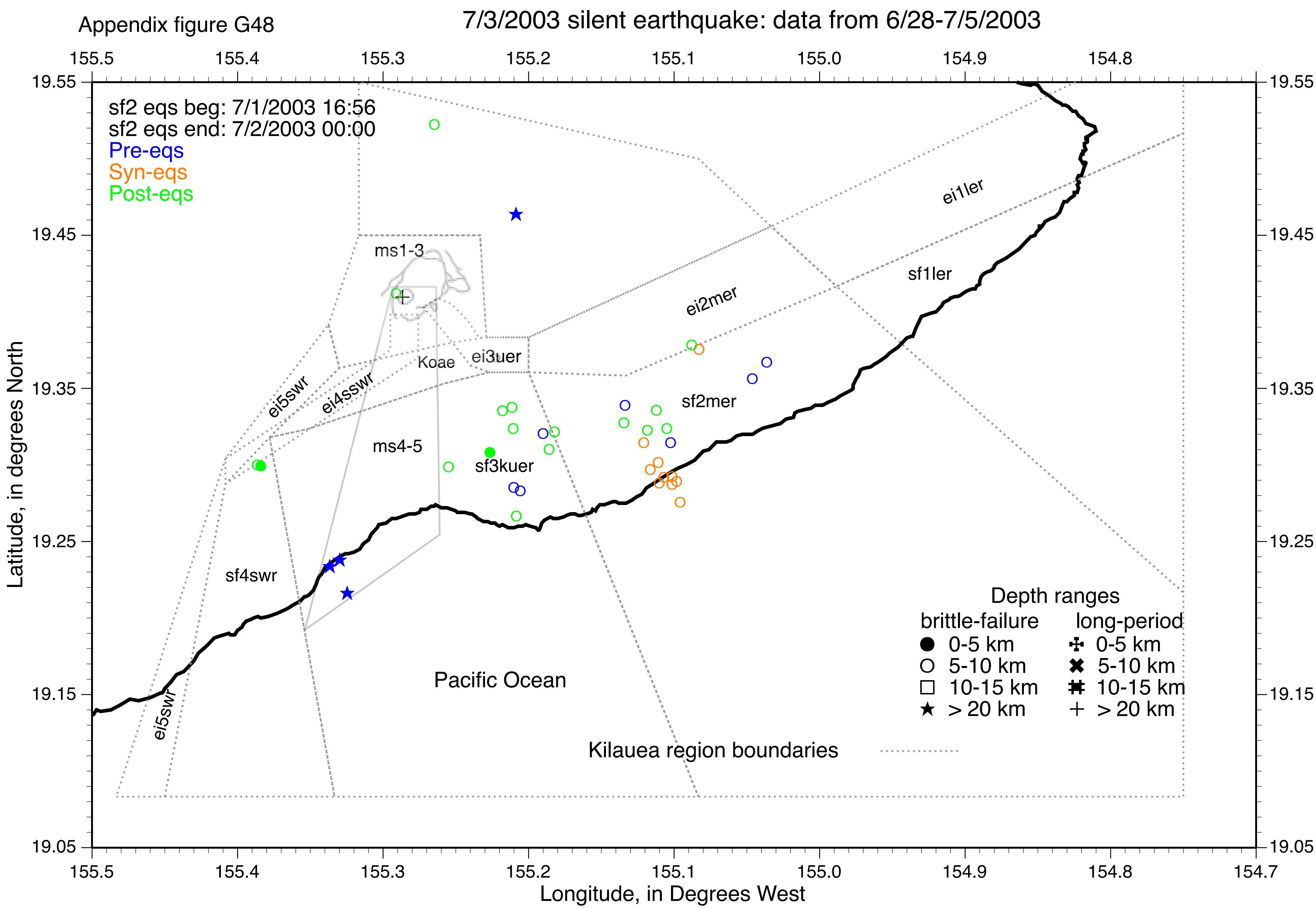
Pu'u 'O'o-Kupaianaha eruption 1/21/2003 "surge (D-I-D)": data from1/8-28/2003



Appendix figure G47



Appendix figure G48



Appendix figure G49

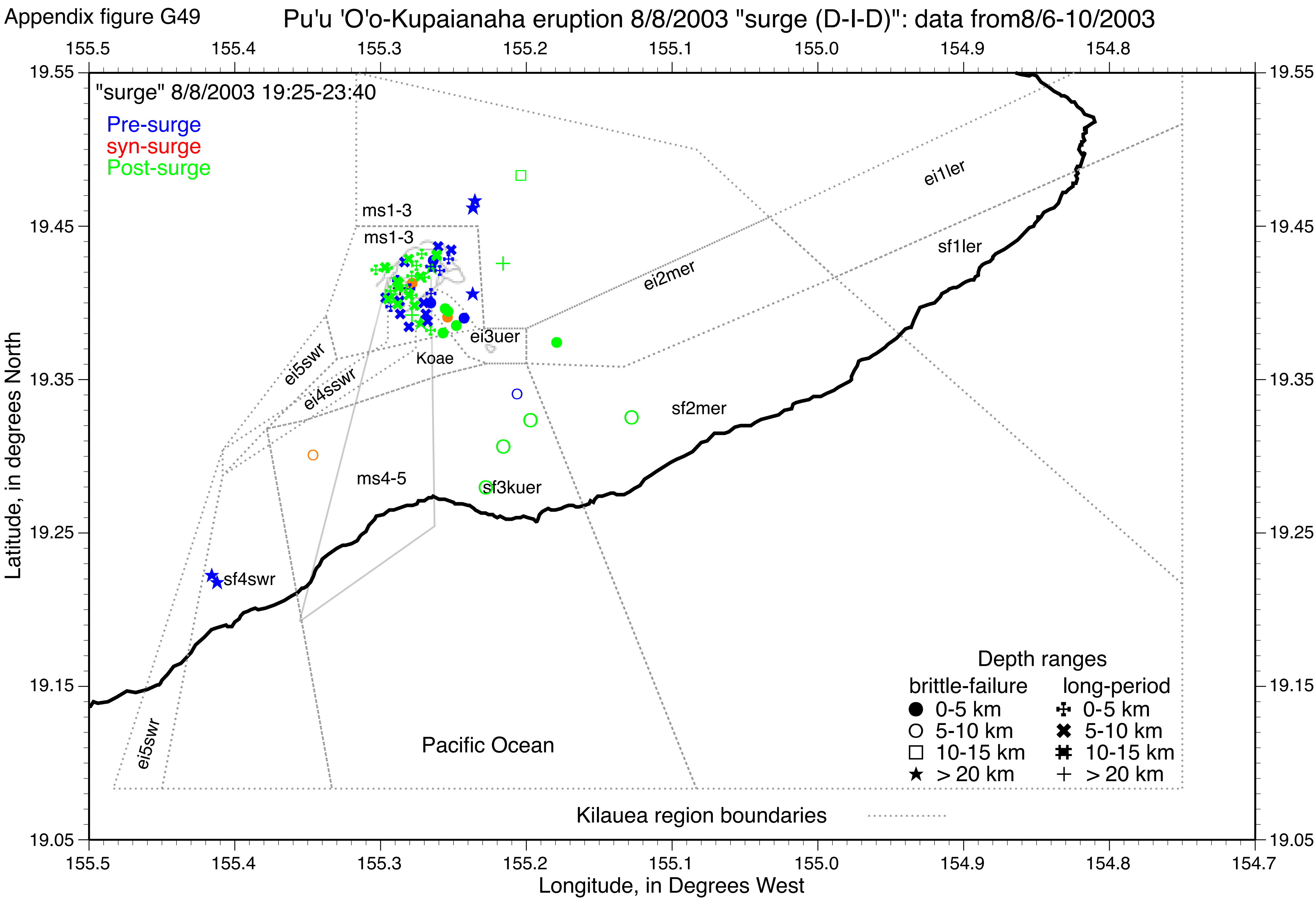
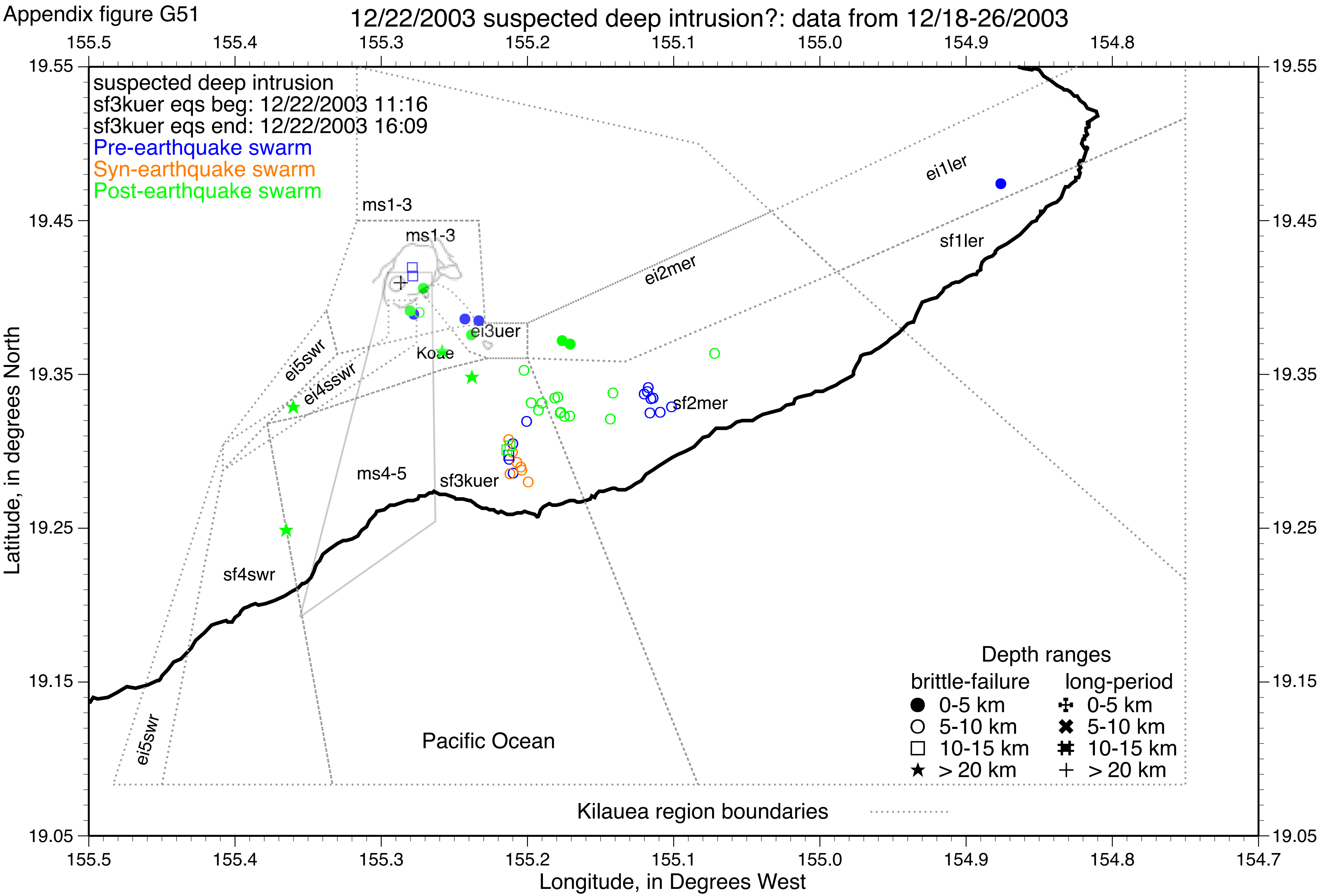


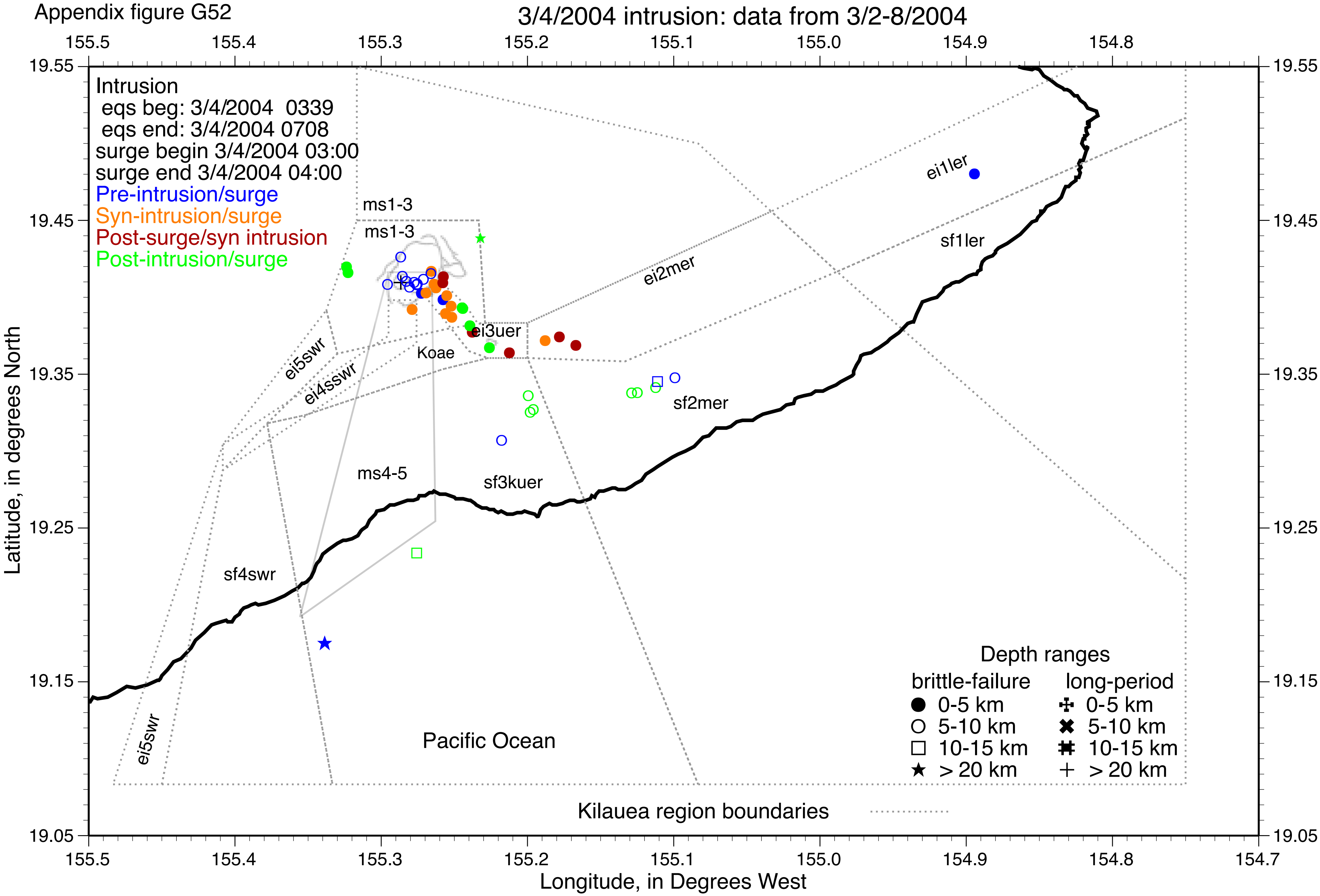
Figure G50

Pu‘u ‘Ō‘o-Kupaianaha eruption: Stage III

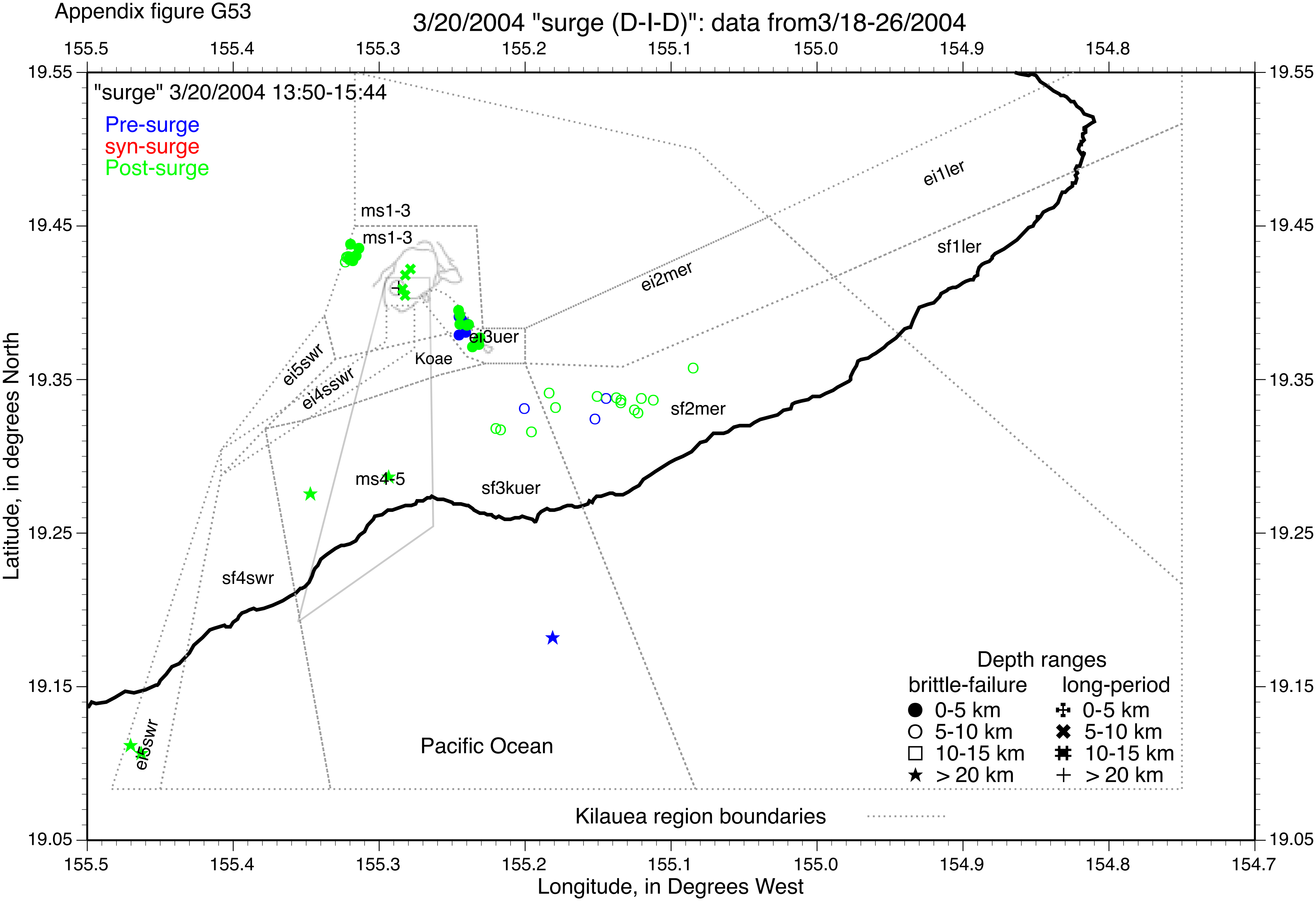
Appendix figure G51



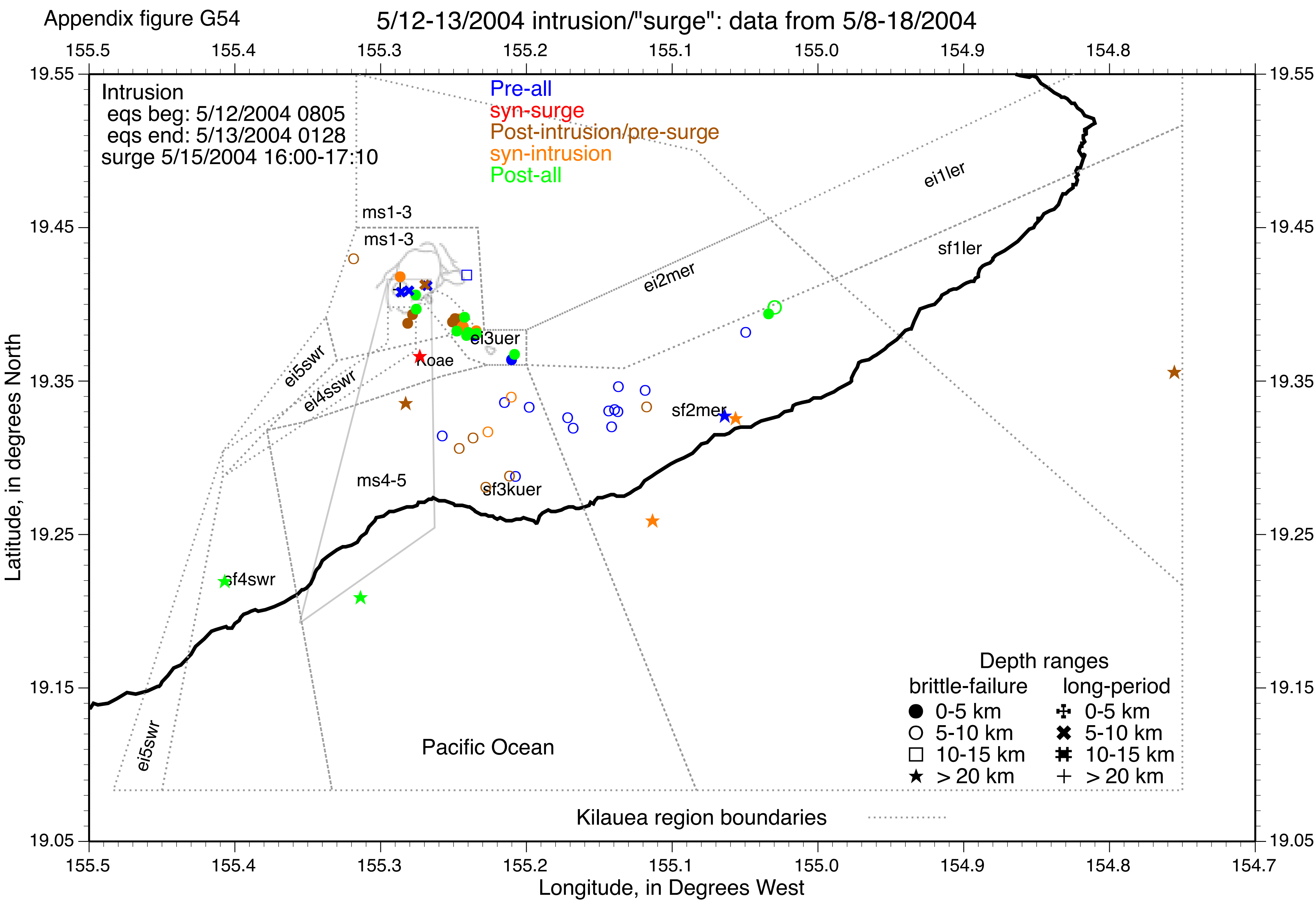
Appendix figure G52

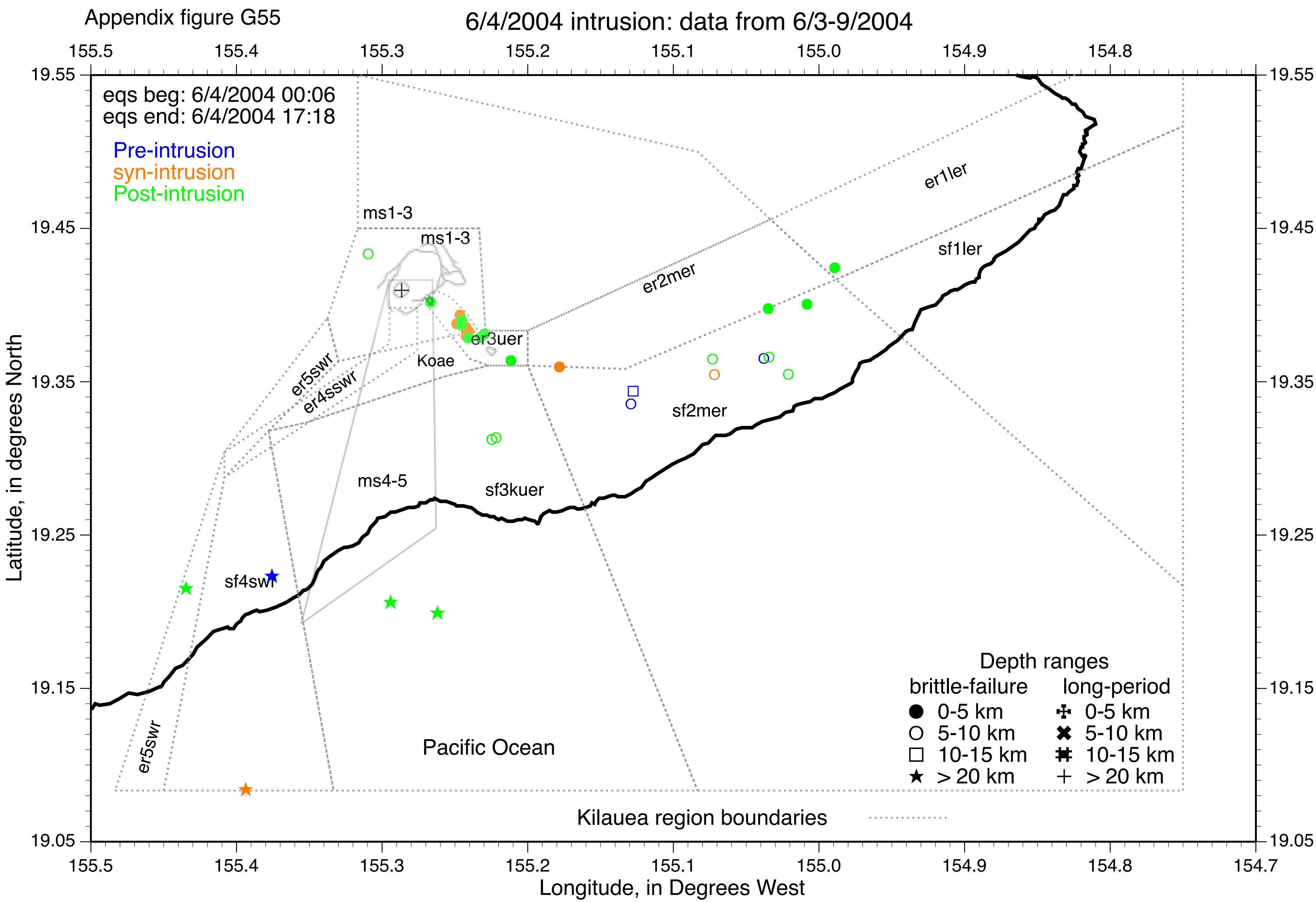


Appendix figure G53



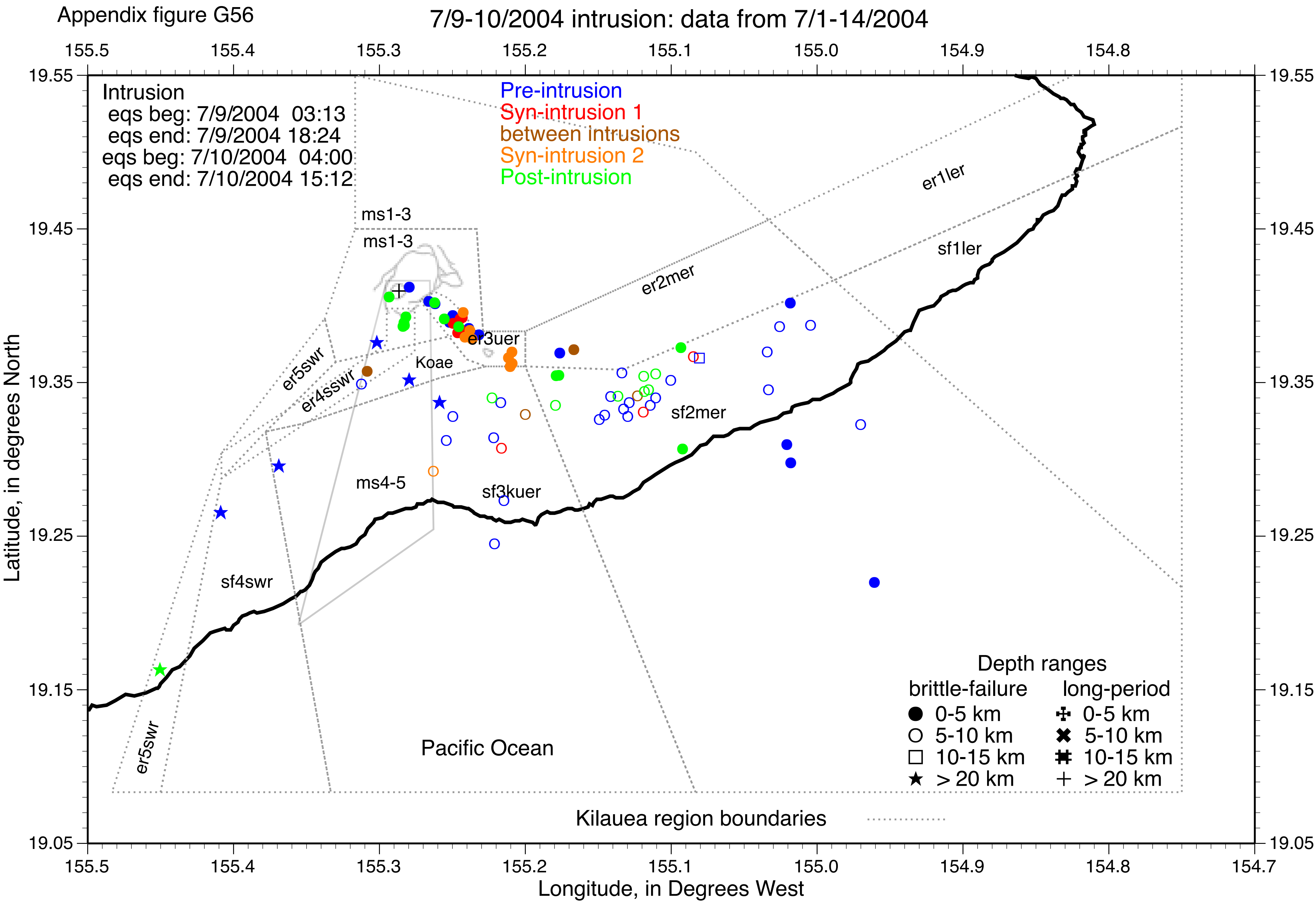
Appendix figure G54



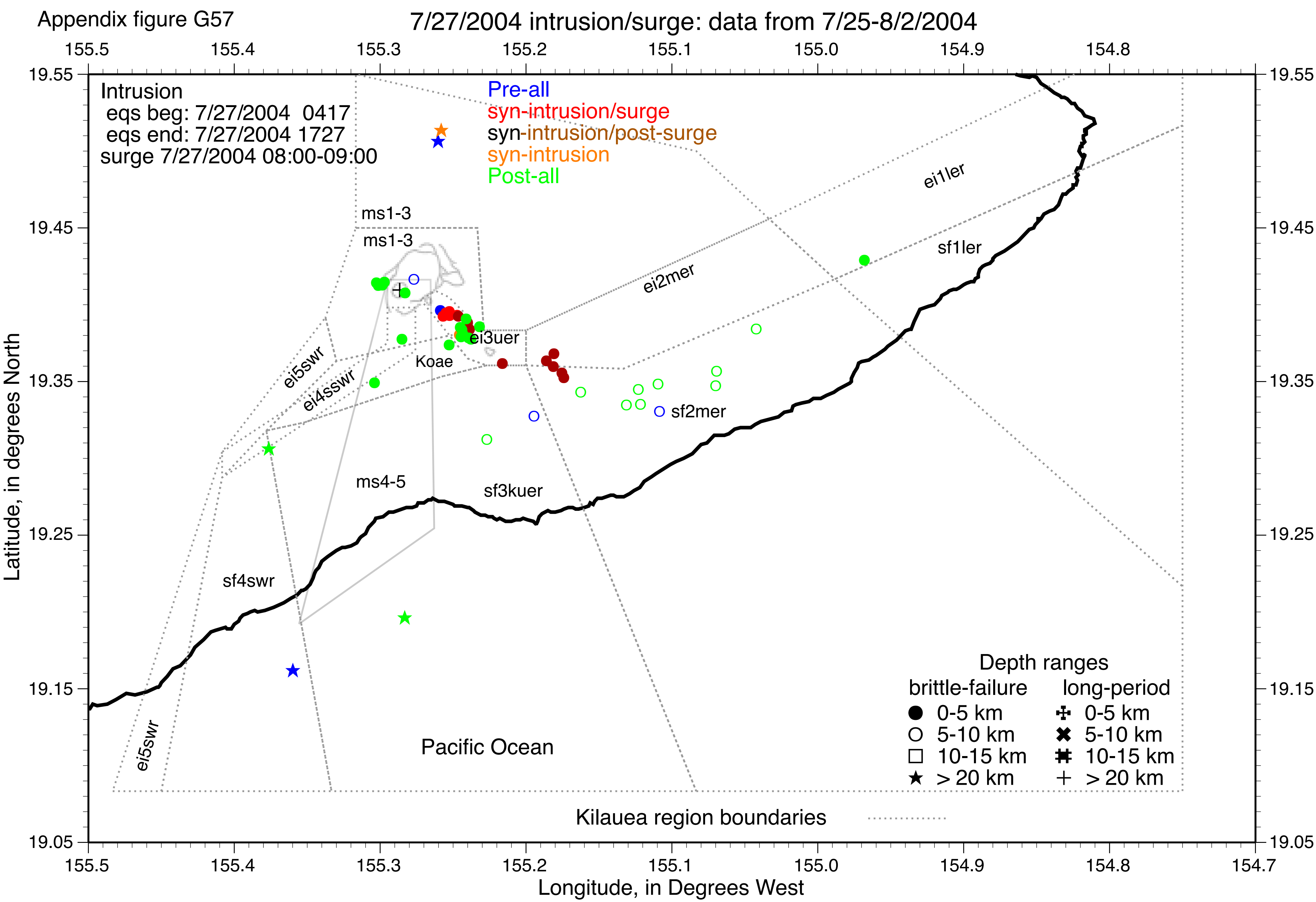


Appendix figure G55
6/4/2004 intrusion: data from 6/3-9/2004
eqs beg: 6/4/2004 00:06
eqs end: 6/4/2004 17:18
Pre-intrusion
syn-intrusion
Post-intrusion
155.5
155.4
155.3
155.2
155.1
155.0
154.9
154.8
154.7
19.55
19.45
19.35
19.25
19.15
19.05
ms1-3
ms1-3
er1ler
sf1ler
er2mer
er3uer
Koae
er5swr
er4sswr
sf2mer
ms4-5
sf3kuer
sf4swr
er5swr
Pacific Ocean
Depth ranges
brittle-failure
long-period
0-5 km
5-10 km
10-15 km
> 20 km
0-5 km
5-10 km
10-15 km
> 20 km
Kilauea region boundaries
Latitude, in degrees North
Longitude, in Degrees West

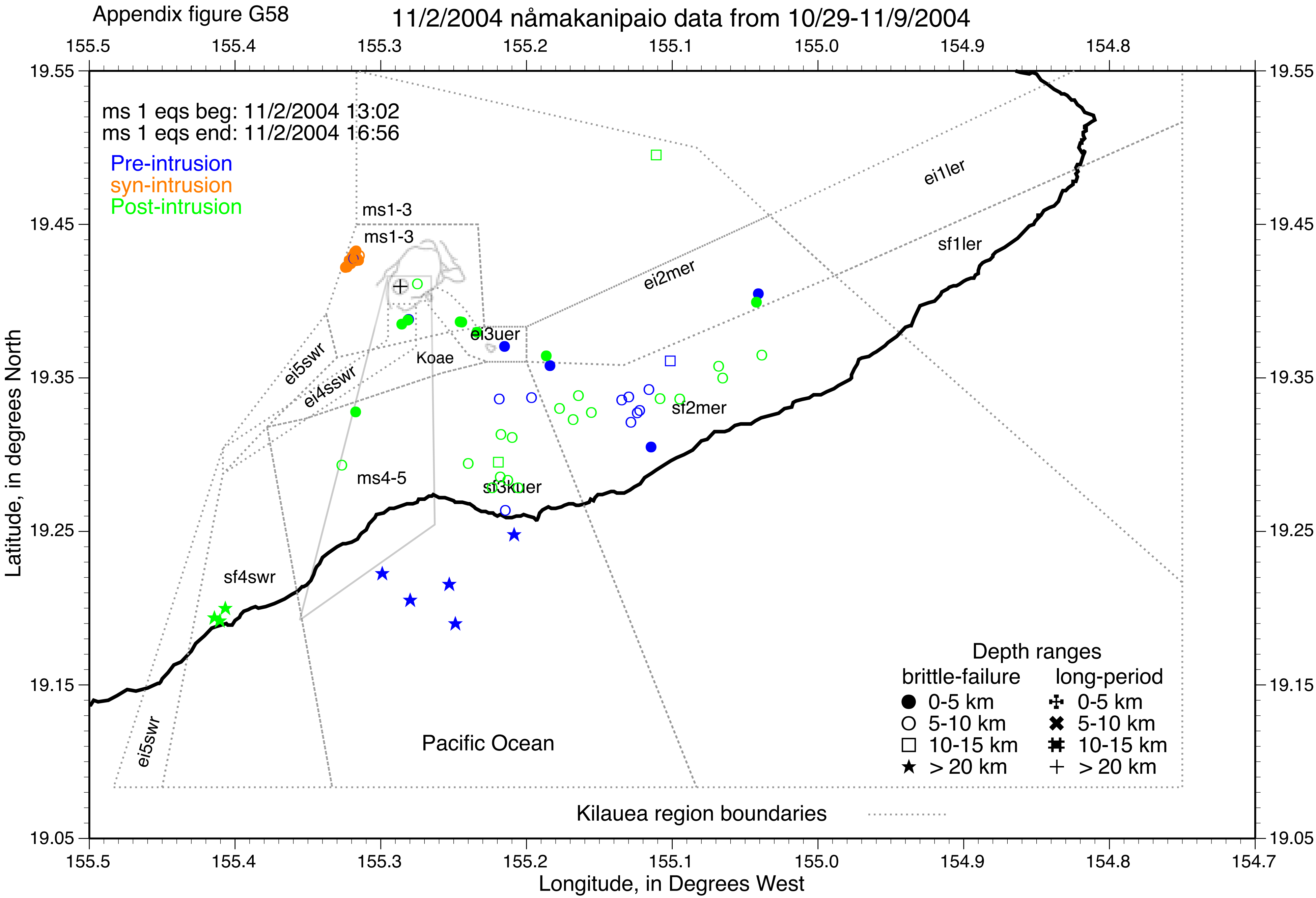
Appendix figure G56



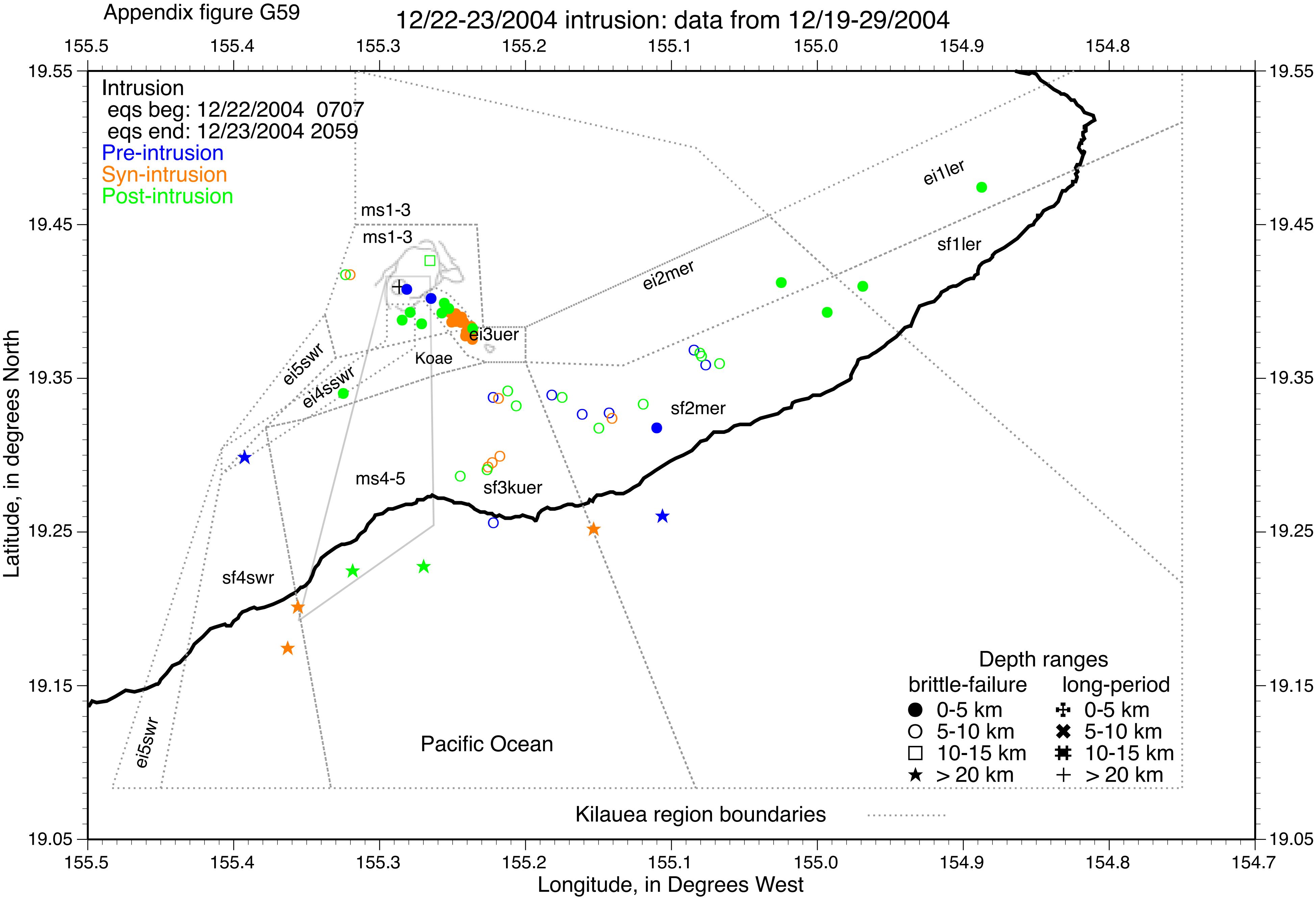
Appendix figure G57



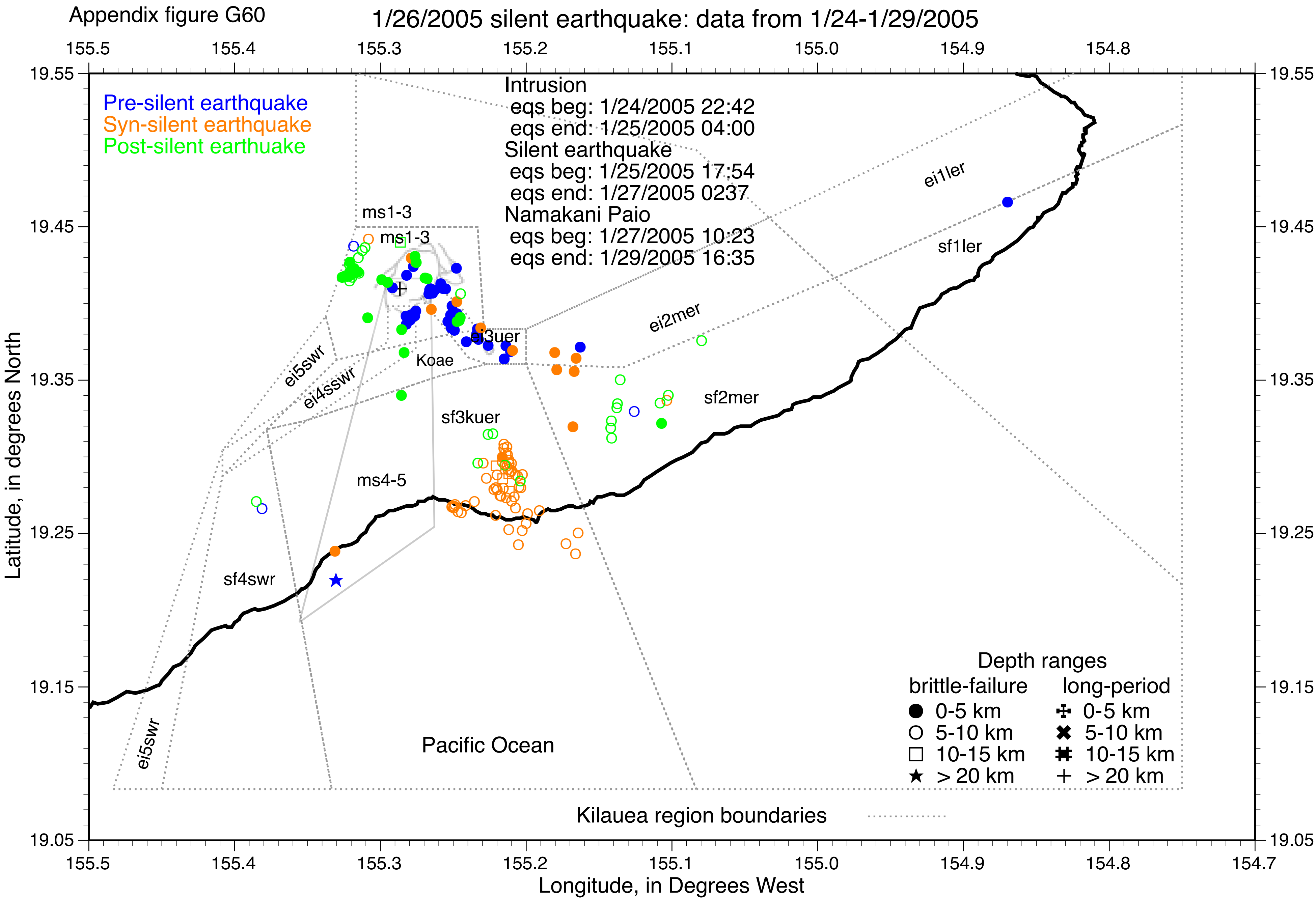
Appendix figure G58



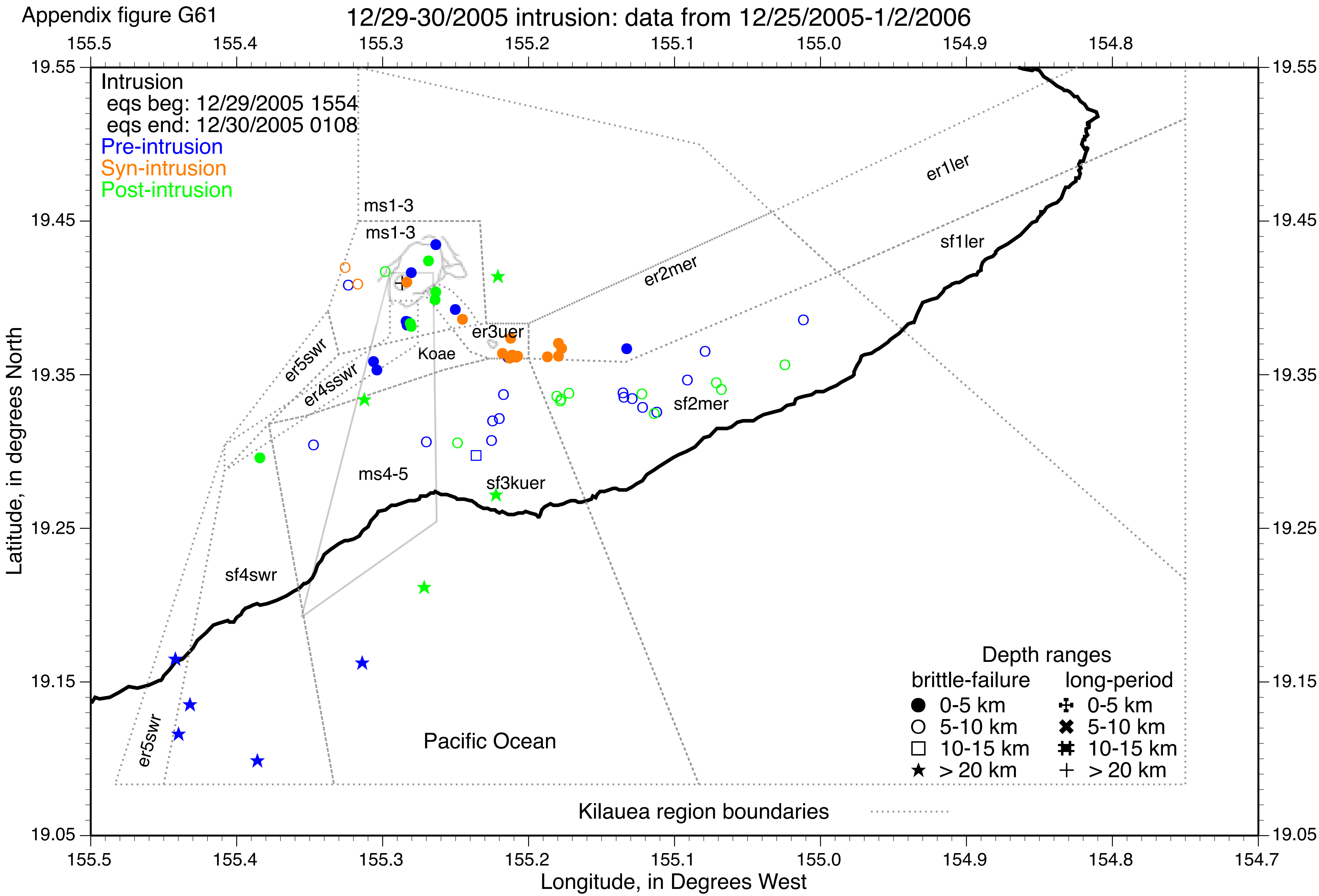
Appendix figure G59



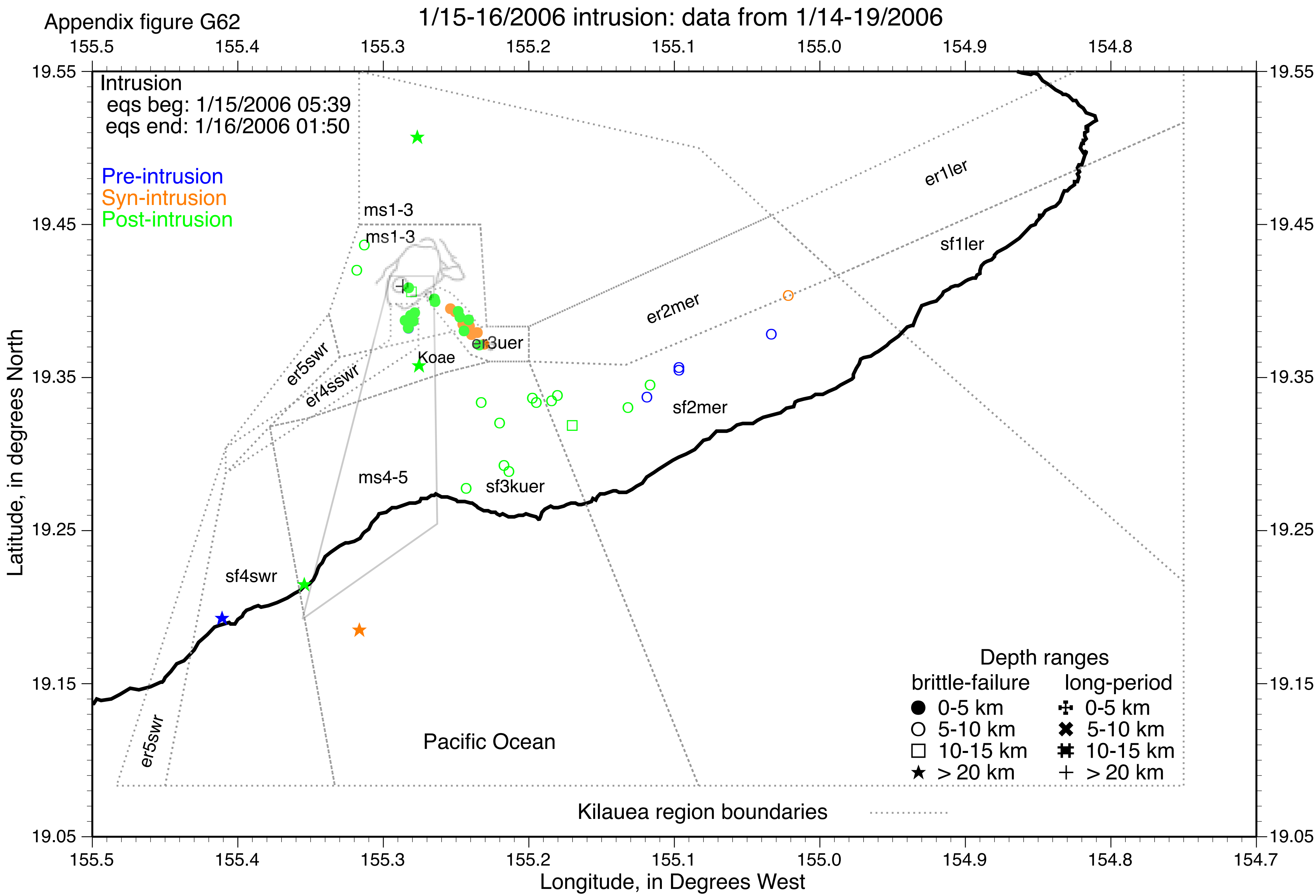
Appendix figure G60



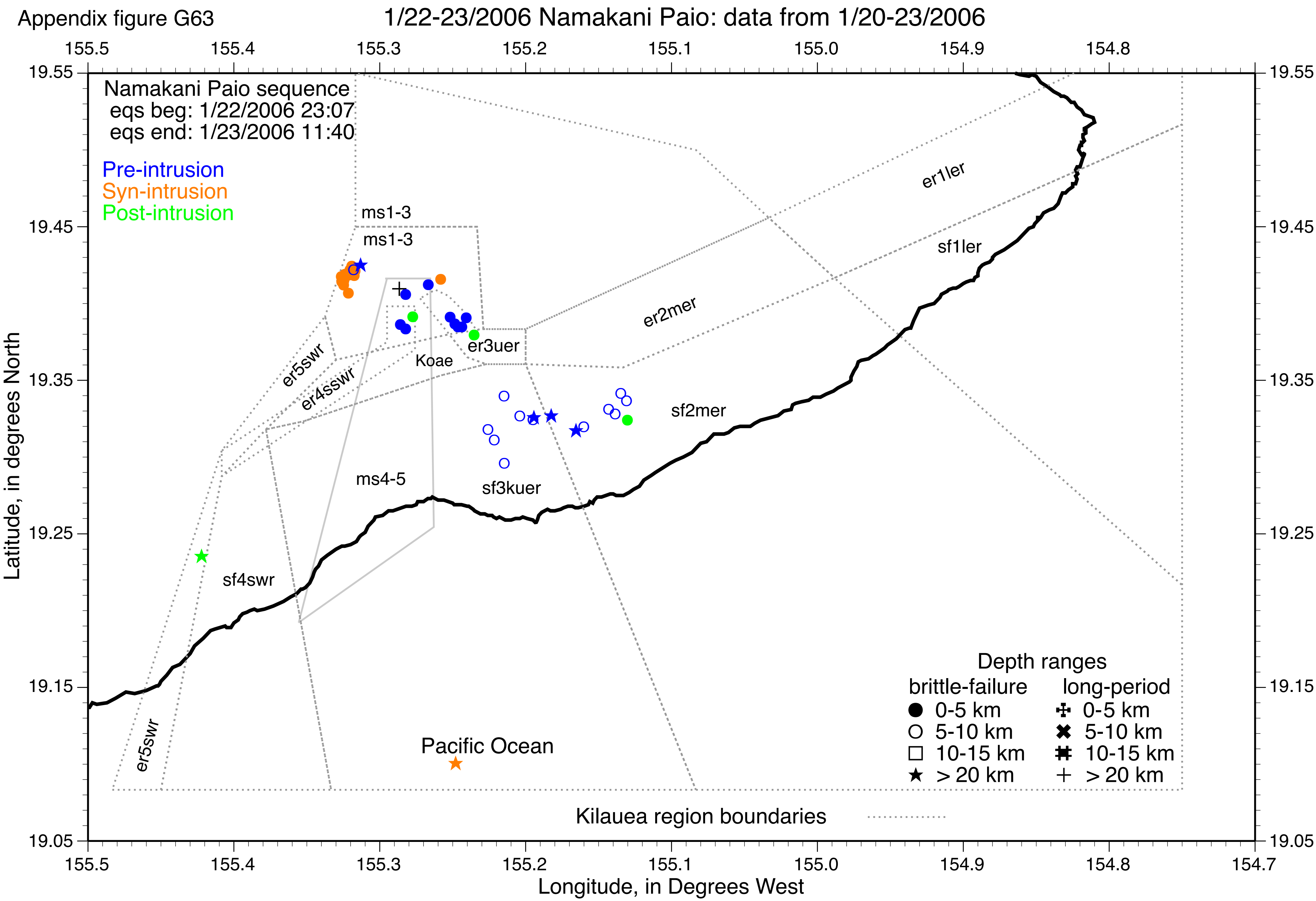
Appendix figure G61



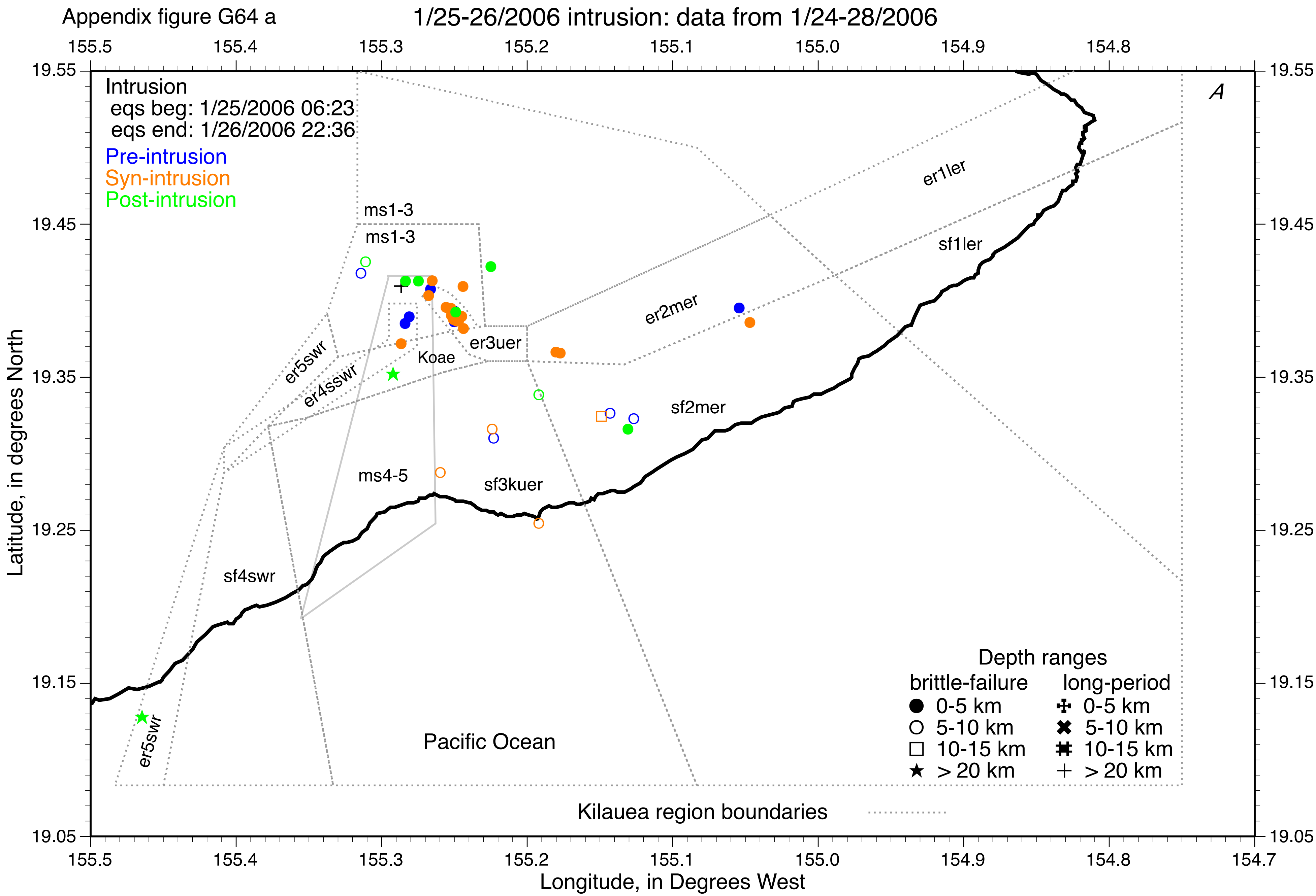
Appendix figure G62



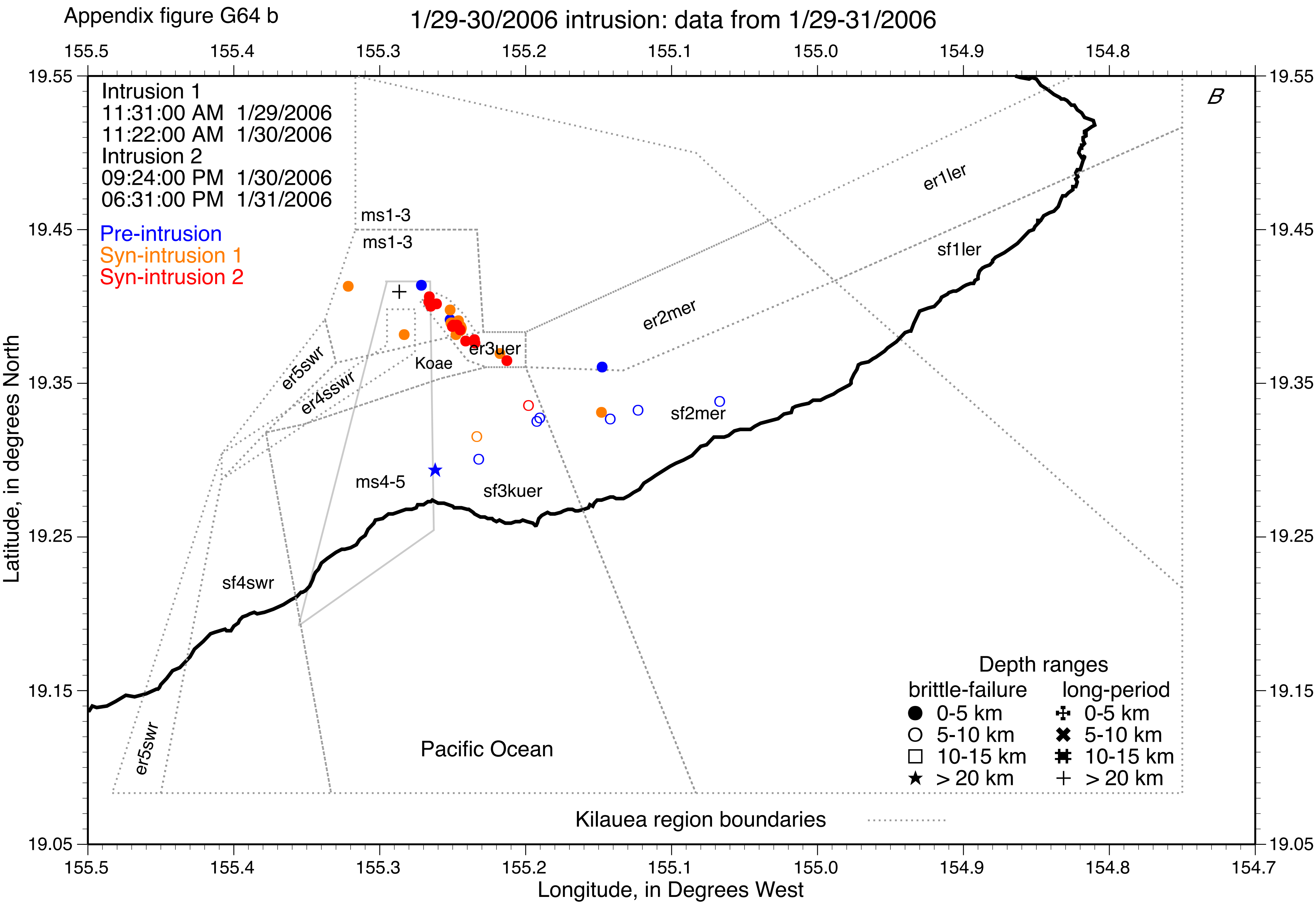
Appendix figure G63



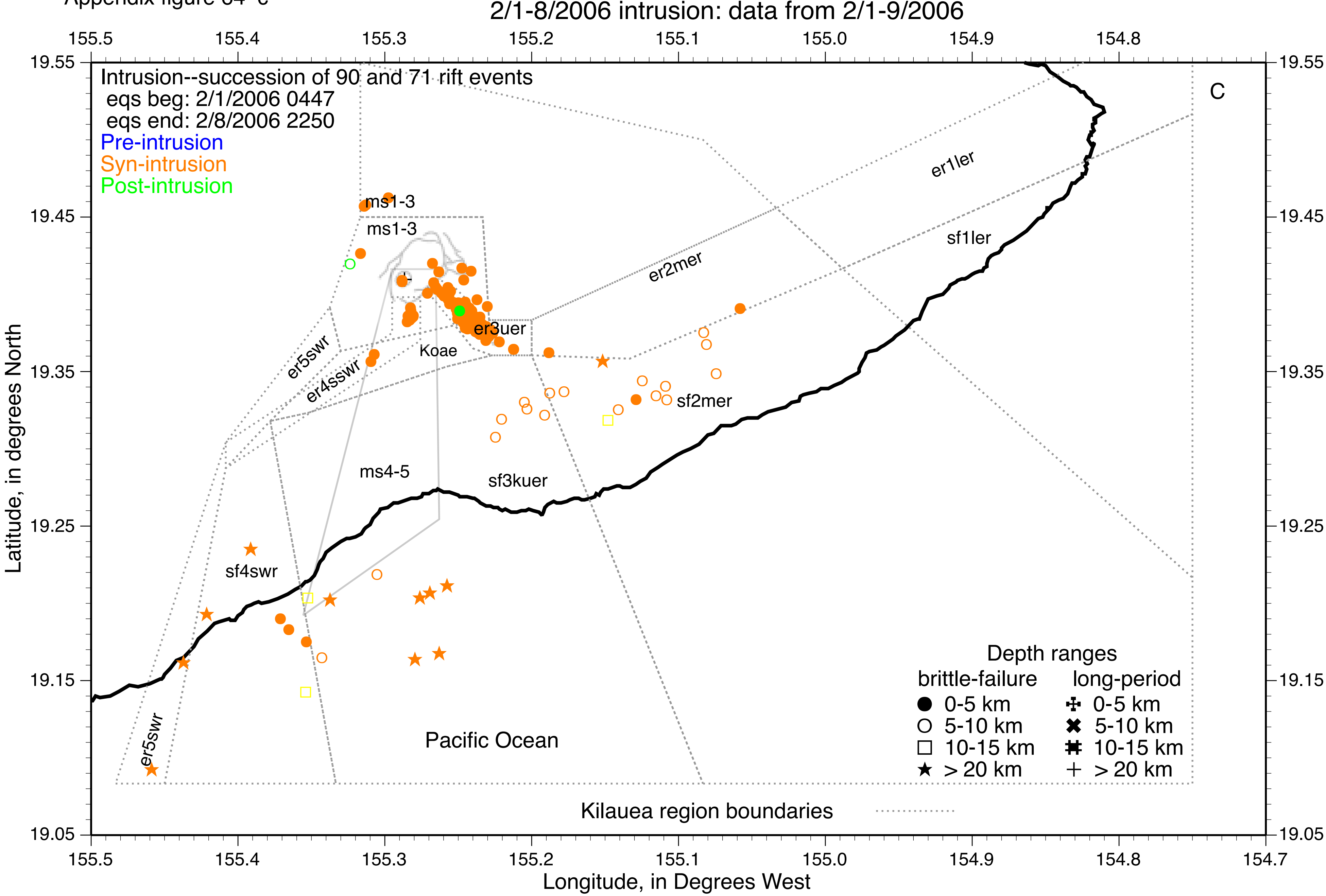
Appendix figure G64 a

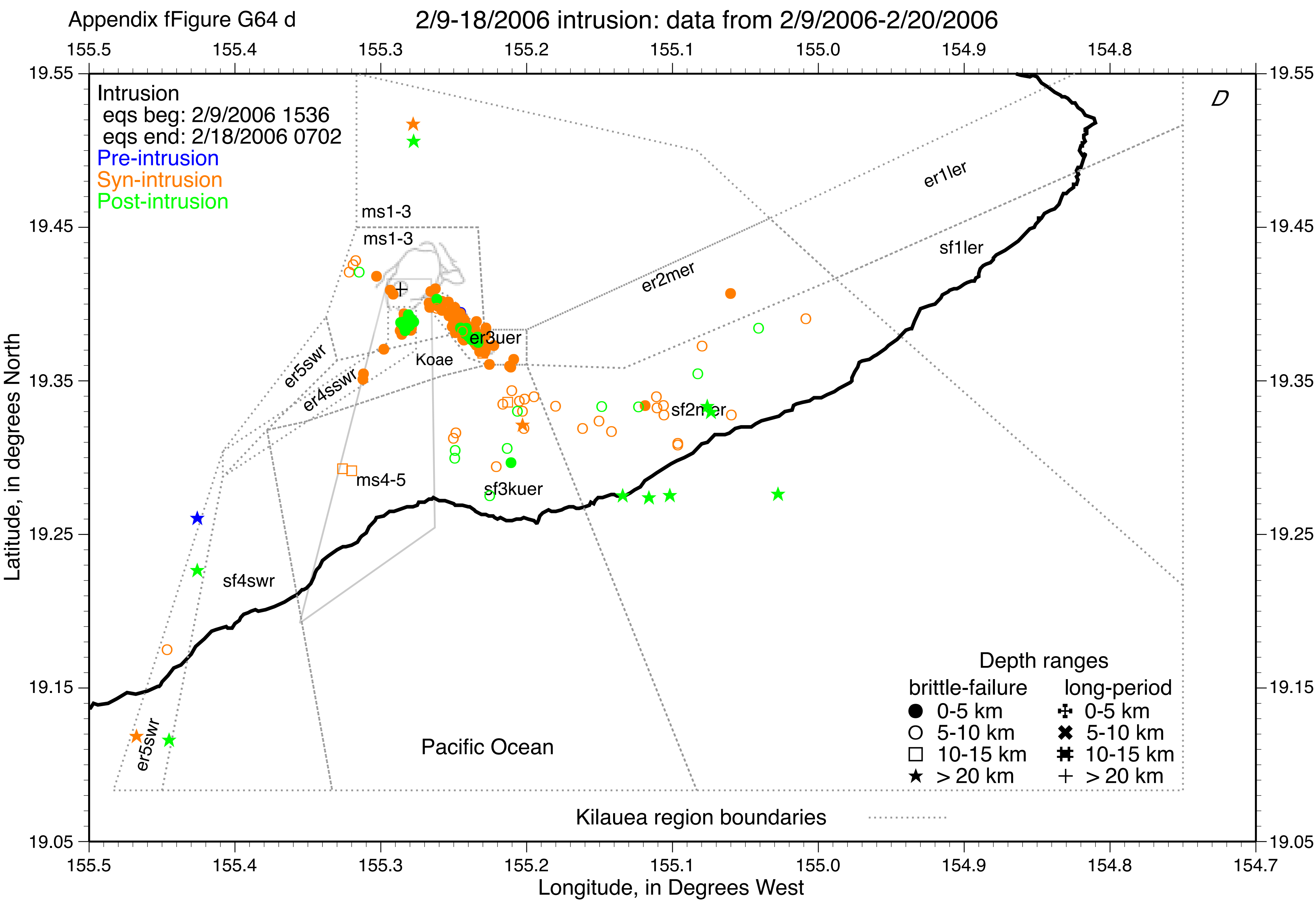


Appendix figure G64 b



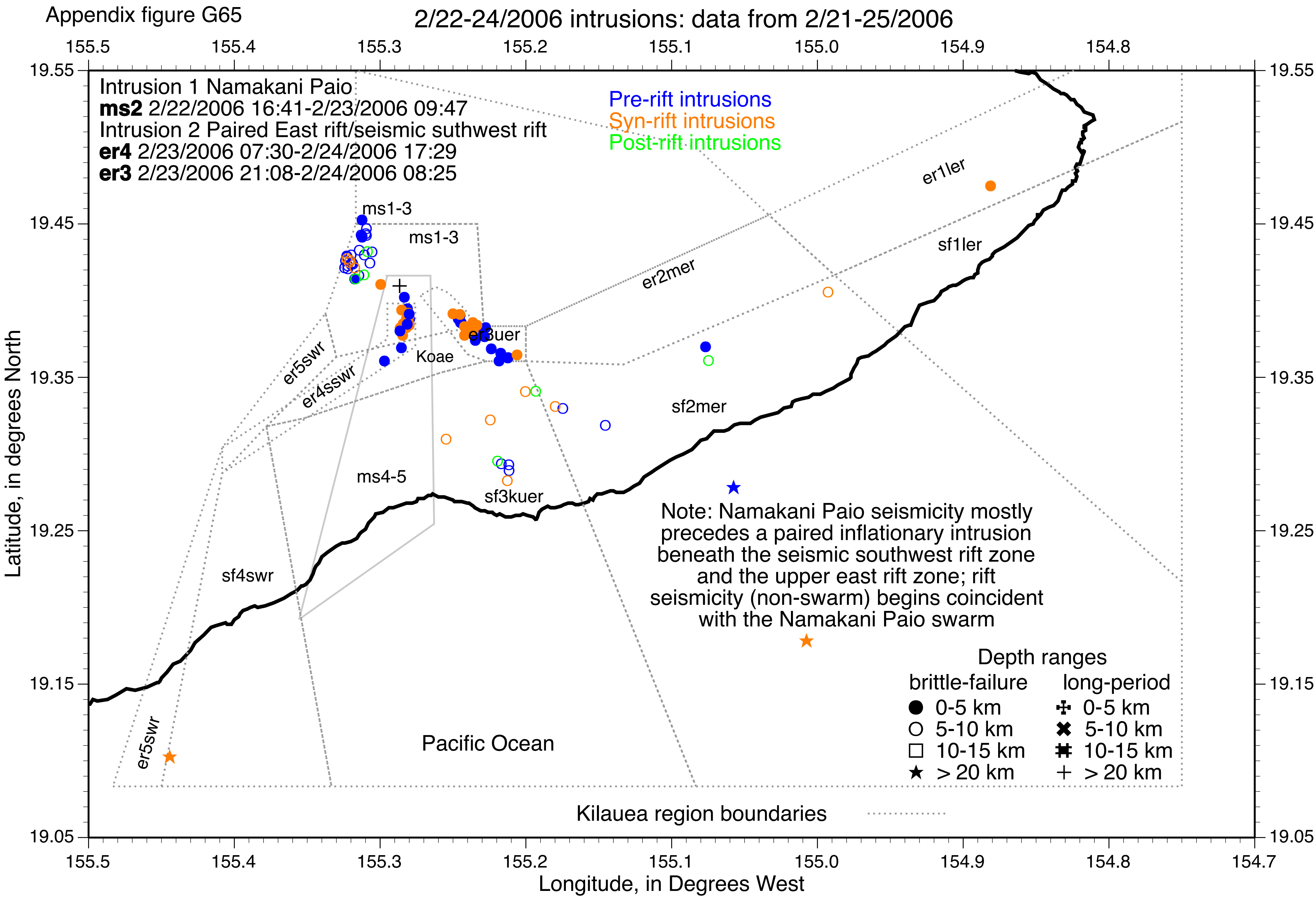
Appendix figure 64 c



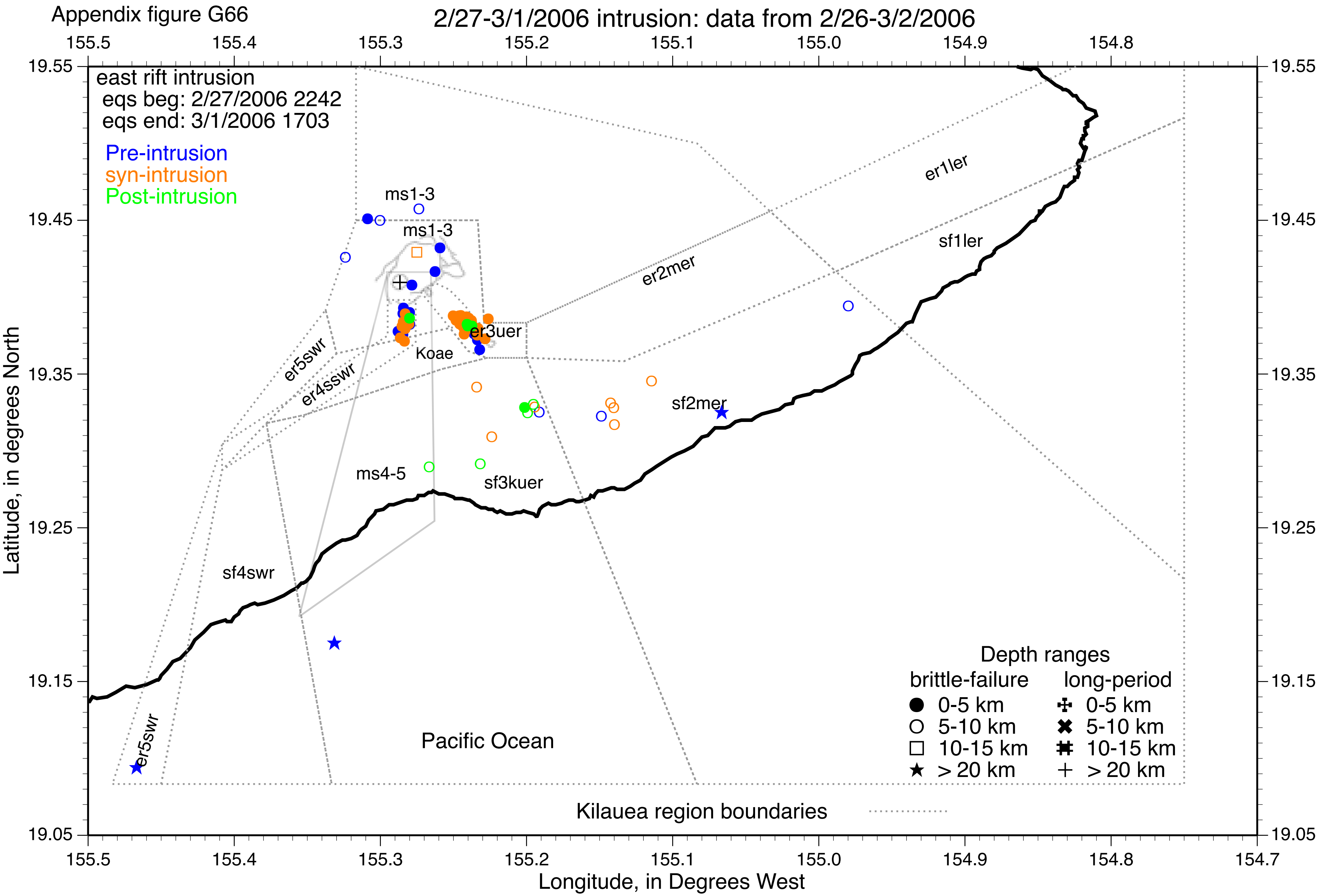


Appendix fFigure G64 d
2/9-18/2006 intrusion: data from 2/9/2006-2/20/2006
Intrusion
eqs beg: 2/9/2006 1536
eqs end: 2/18/2006 0702
Pre-intrusion
Syn-intrusion
Post-intrusion
D
155.5
155.4
155.3
155.2
155.1
155.0
154.9
154.8
154.7
19.55
19.45
19.35
19.25
19.15
19.05
ms1-3
ms1-3
er1ler
sf1ler
er2mer
er3uer
Koae
er5swr
er4sswr
sf2mer
ms4-5
sf3kuer
sf4swr
er5swr
Pacific Ocean
Depth ranges
brittle-failure
long-period
0-5 km
5-10 km
10-15 km
> 20 km
0-5 km
5-10 km
10-15 km
> 20 km
Kilauea region boundaries
Latitude, in degrees North
Longitude, in Degrees West

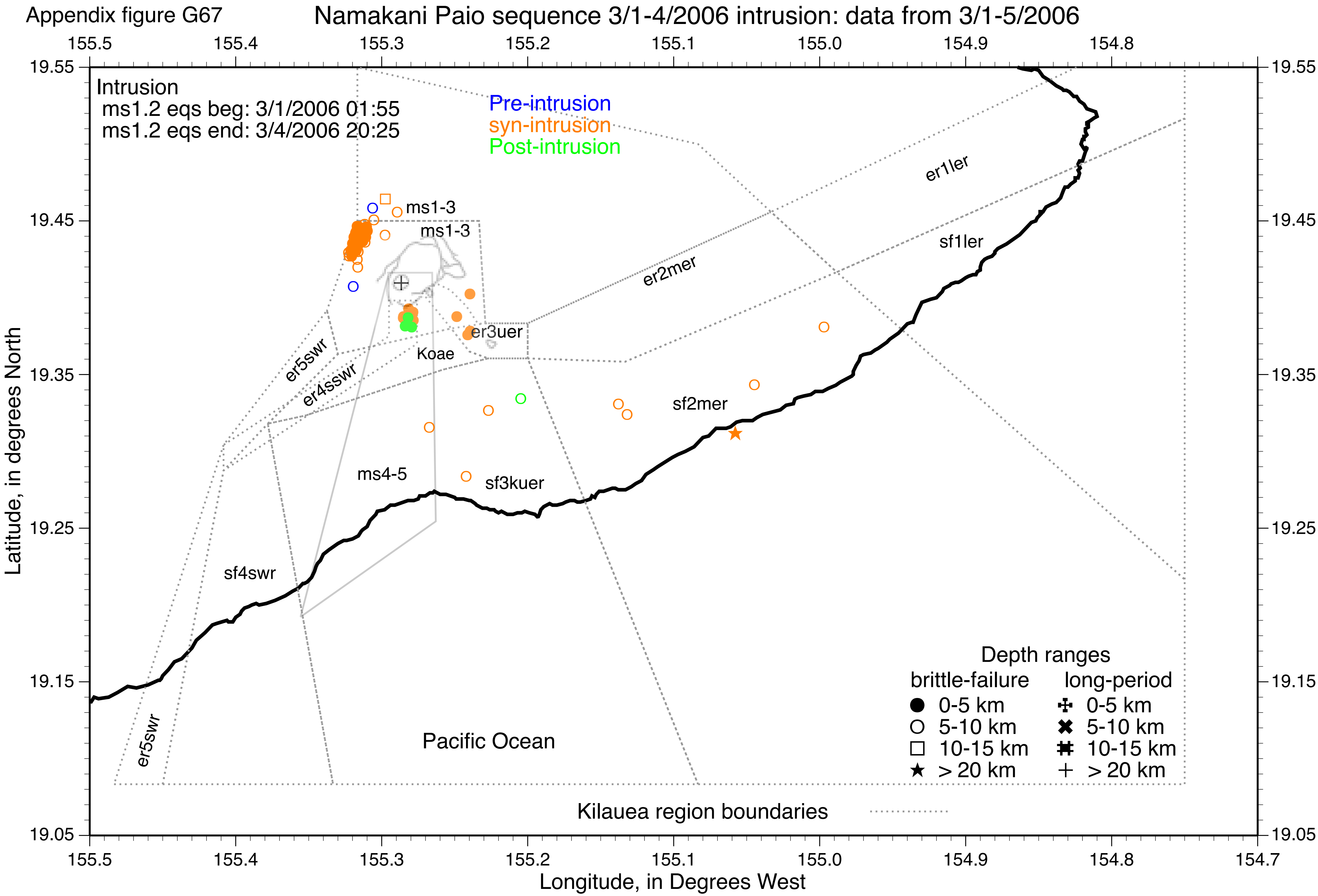
Appendix figure G65



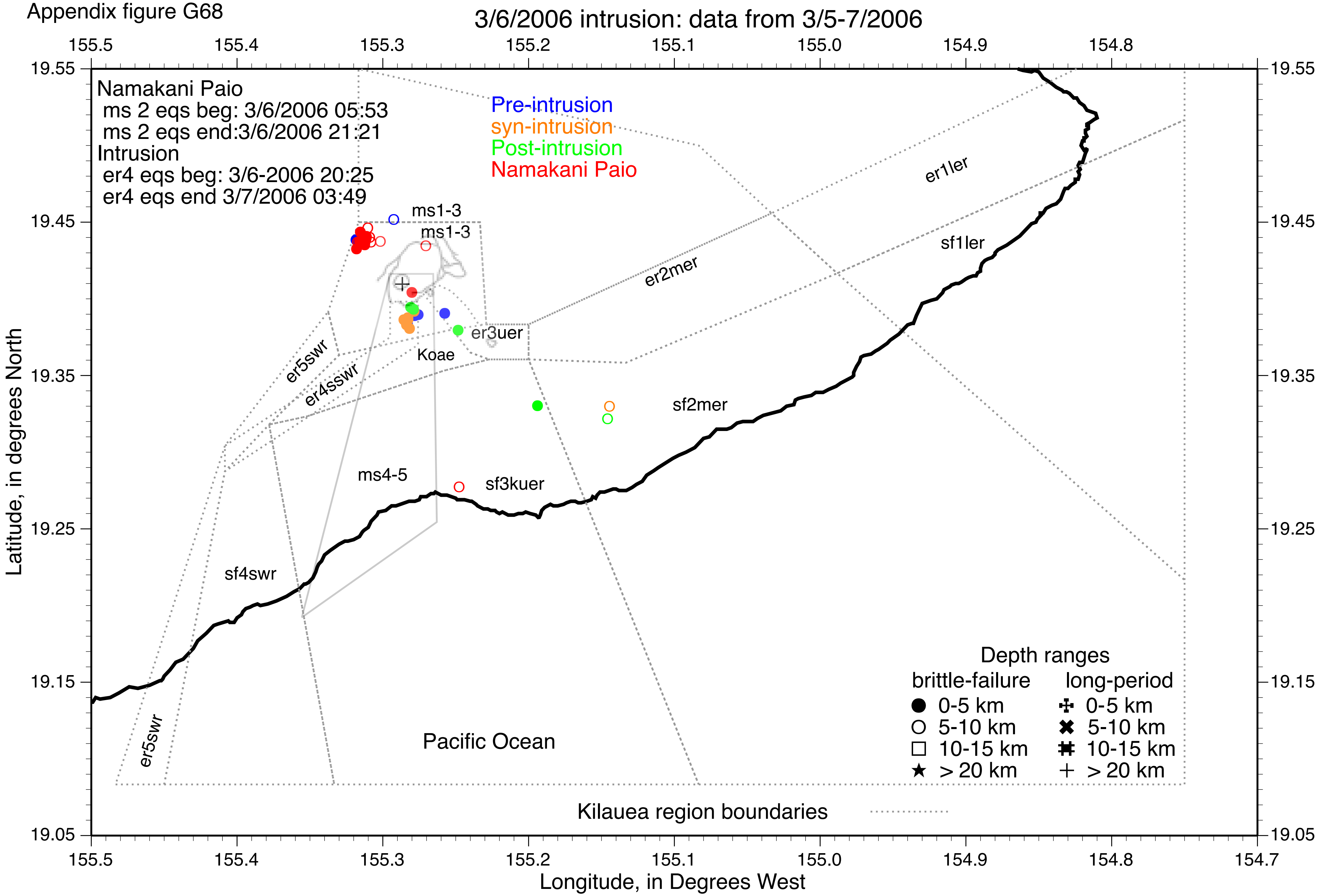
Appendix figure G66



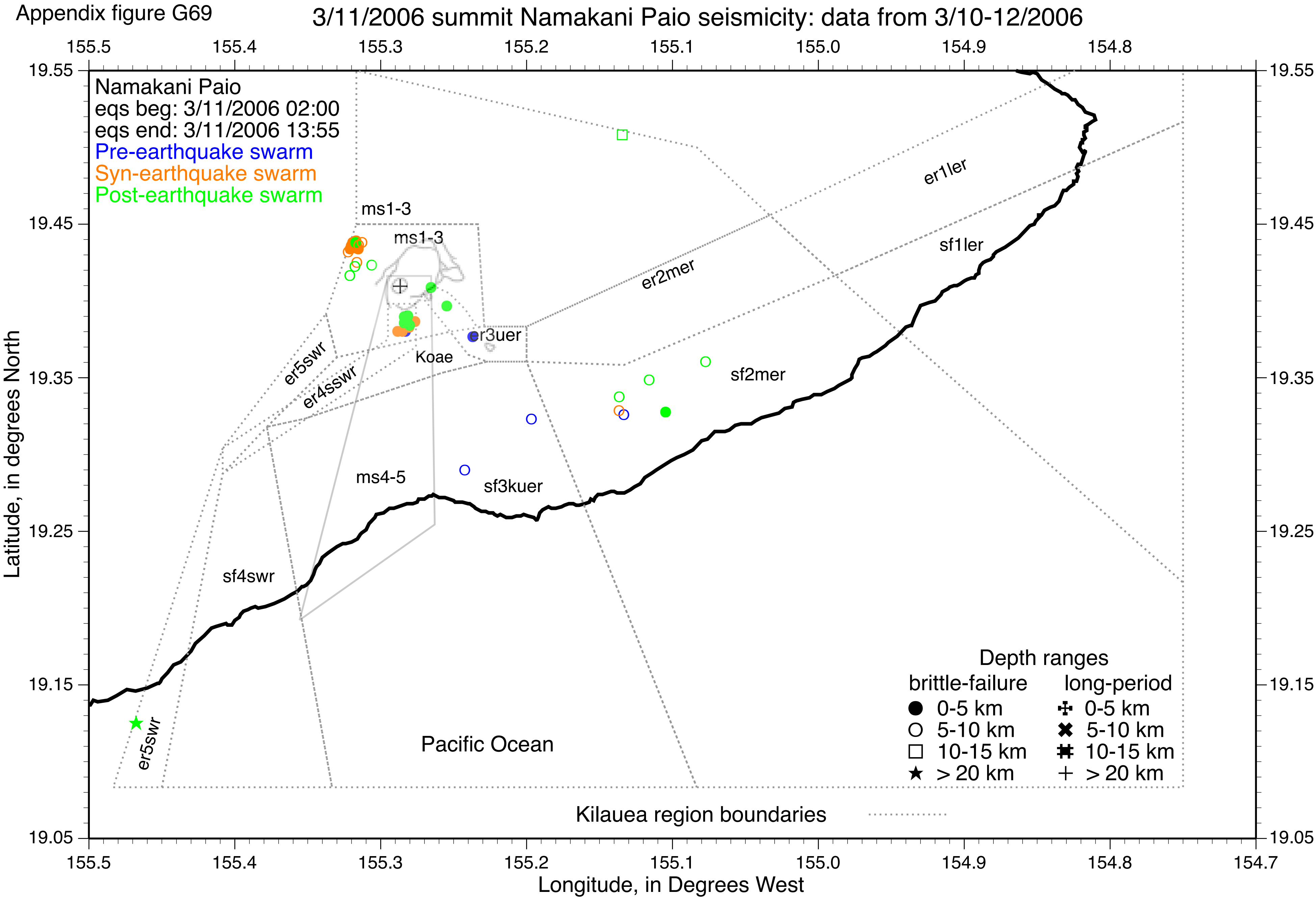
Appendix figure G67

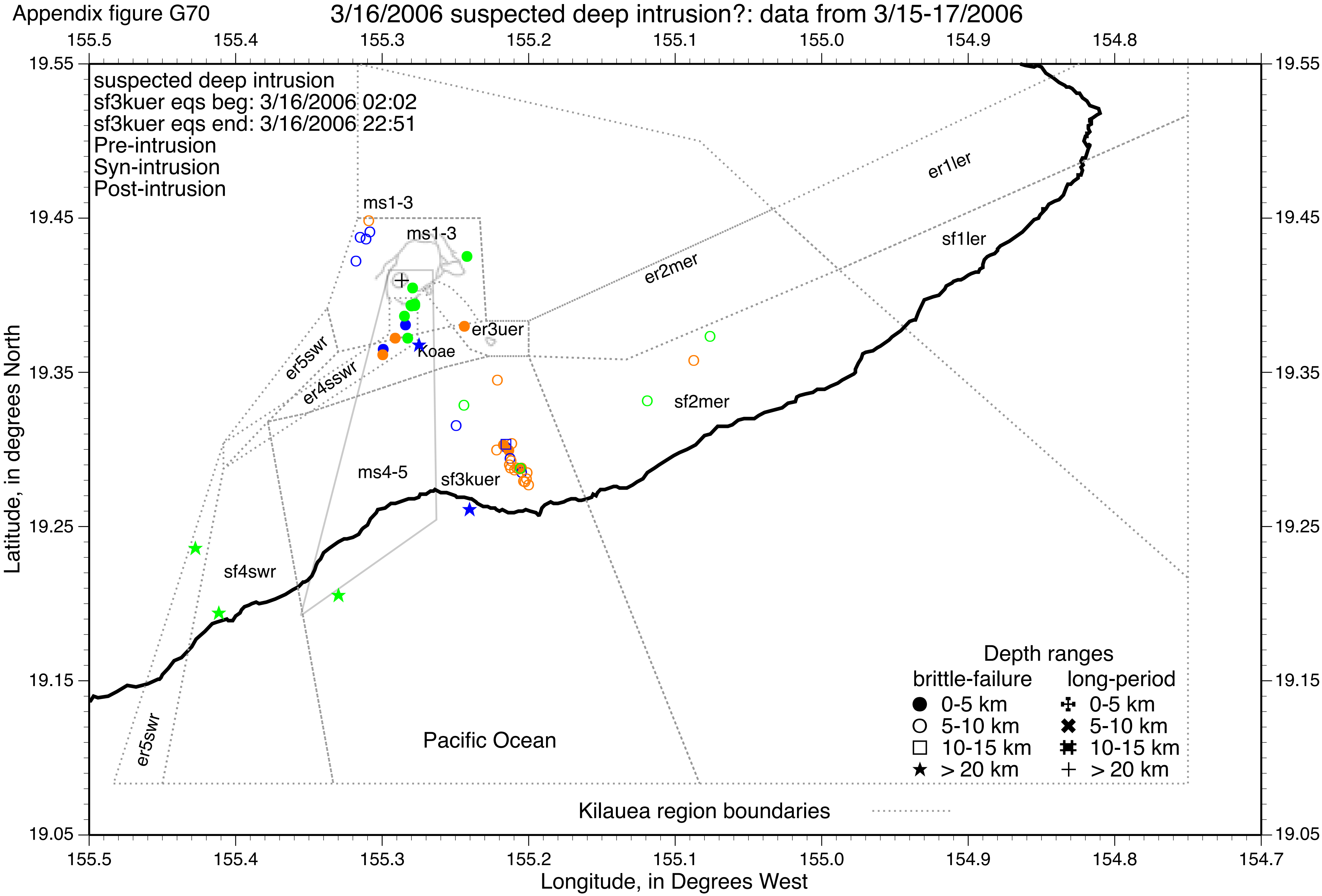


Appendix figure G68

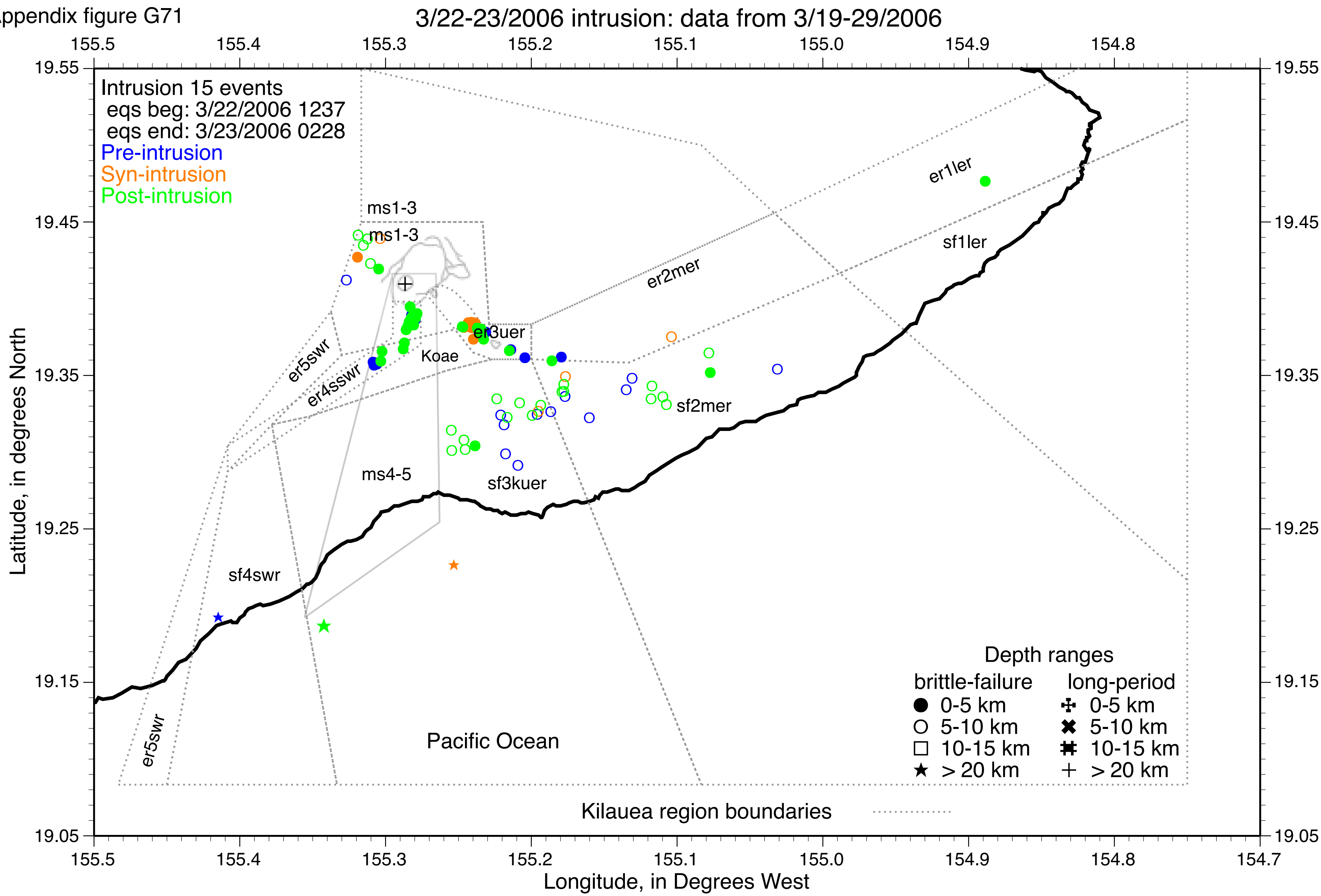


Appendix figure G69



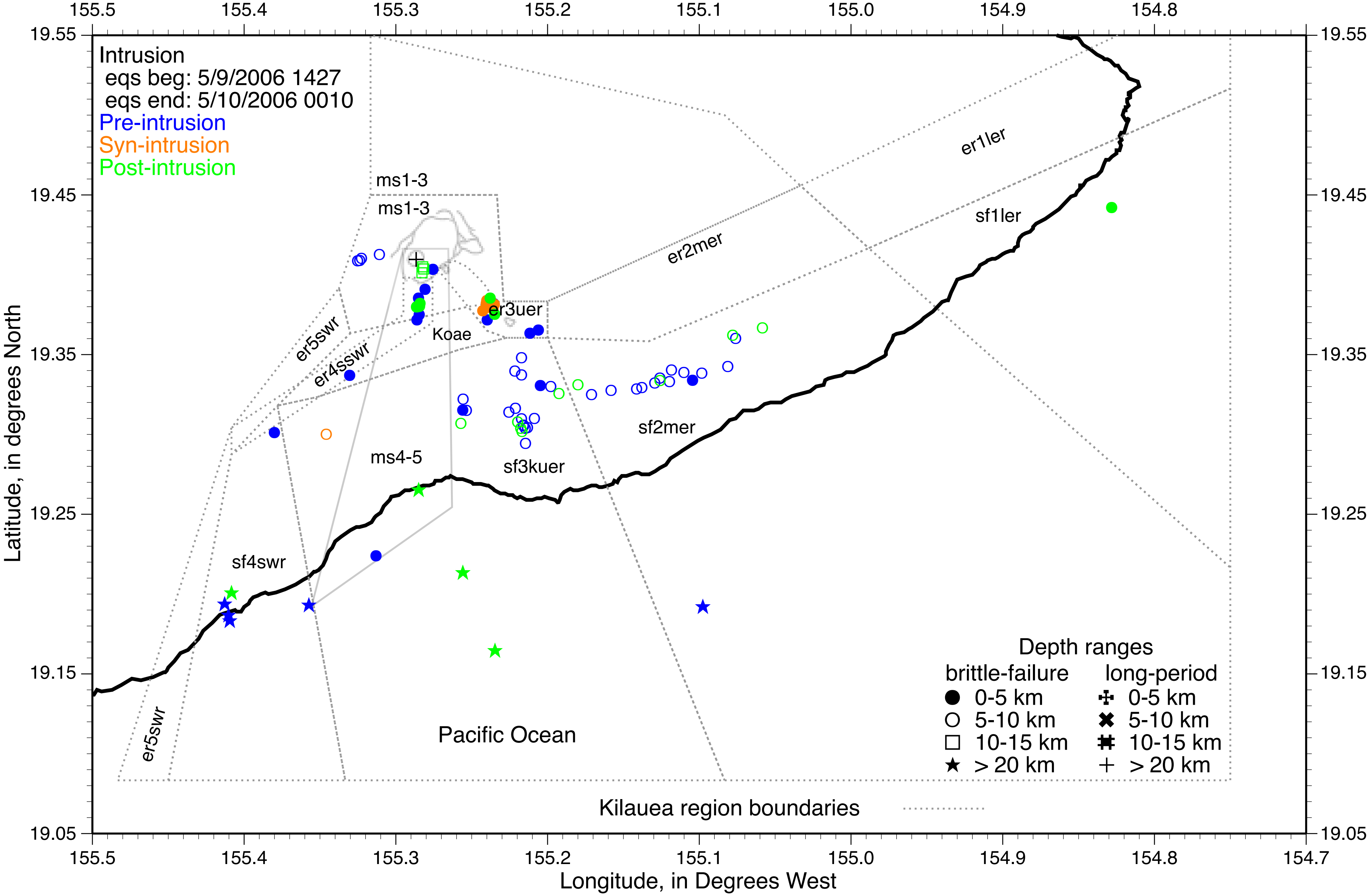

Appendix figure G70
3/16/2006 suspected deep intrusion?: data from 3/15-17/2006
suspected deep intrusion
sf3kuer eqs beg: 3/16/2006 02:02
sf3kuer eqs end: 3/16/2006 22:51
Pre-intrusion
Syn-intrusion
Post-intrusion
ms1-3
ms1-3
er1ler
sf1ler
er2mer
er3uer
Koae
er5swr
er4sswr
sf2mer
ms4-5
sf3kuer
sf4swr
er5swr
Pacific Ocean
Depth ranges
brittle-failure
long-period
0-5 km
5-10 km
10-15 km
> 20 km
0-5 km
5-10 km
10-15 km
> 20 km
Kilauea region boundaries
Latitude, in degrees North
Longitude, in Degrees West
155.5
155.4
155.3
155.2
155.1
155.0
154.9
154.8
154.7
19.55
19.45
19.35
19.25
19.15
19.05

Appendix figure G71

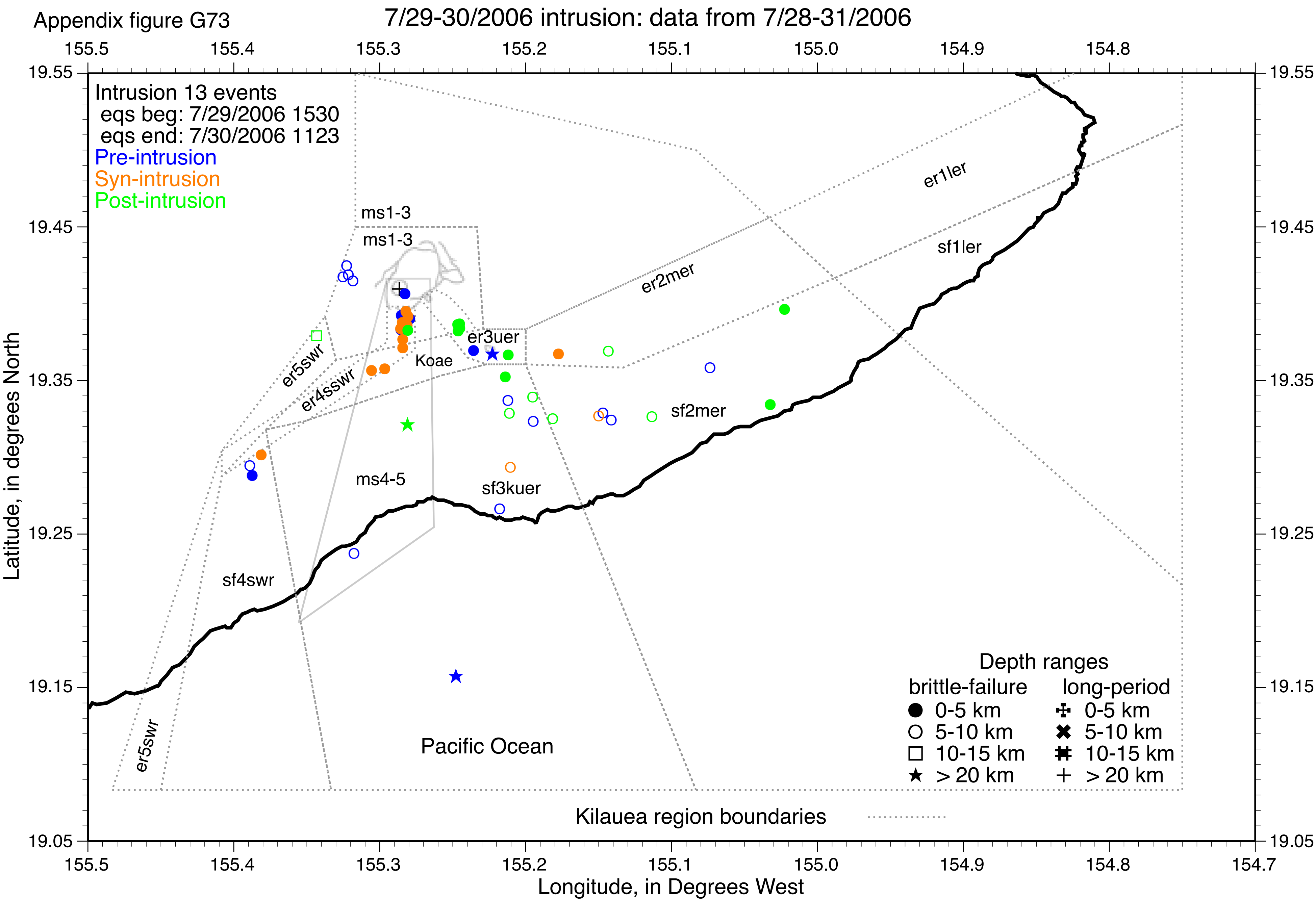


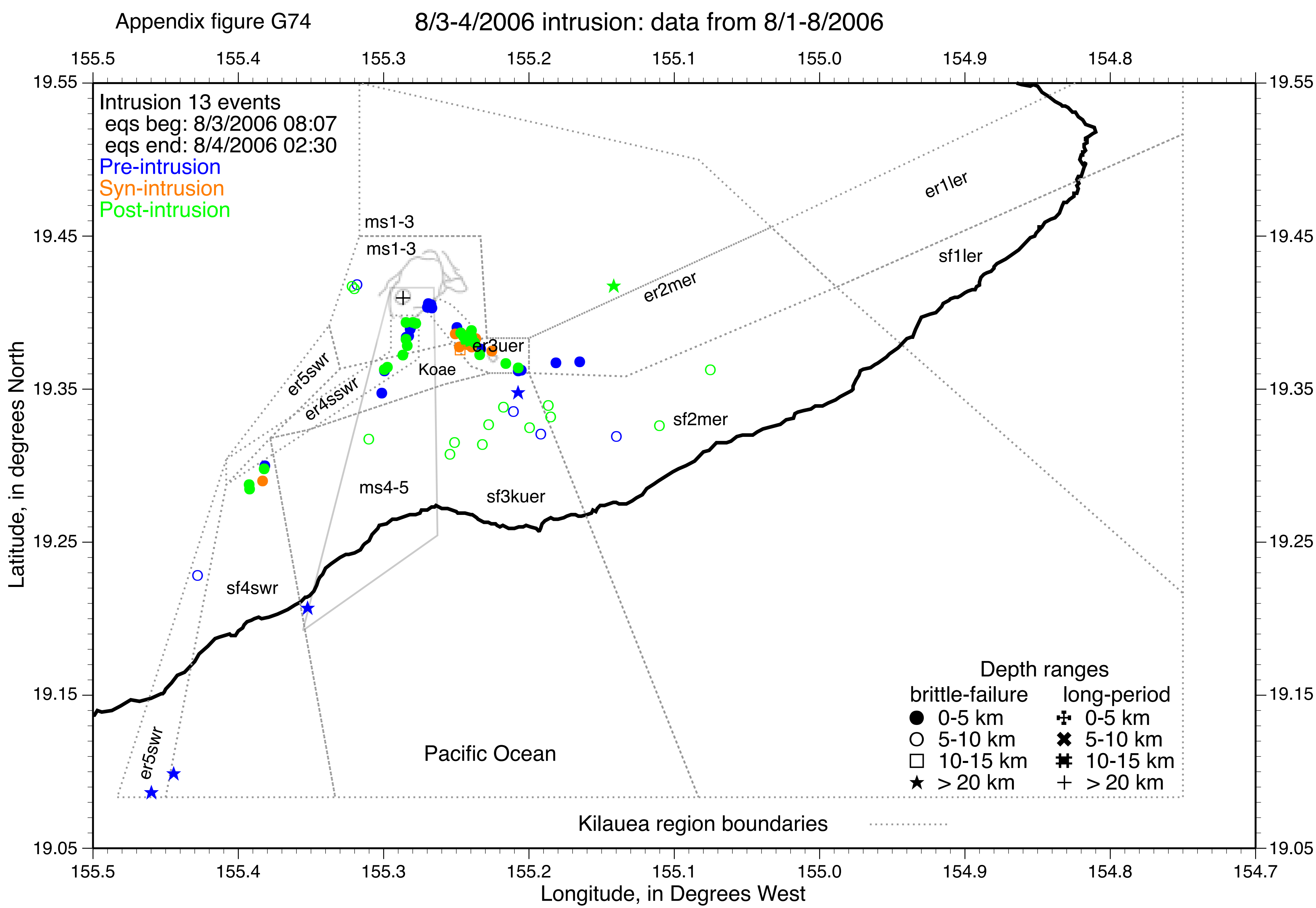
Appendix figure G72

5/9-10/2006 intrusion: data from 5/4-12/2006



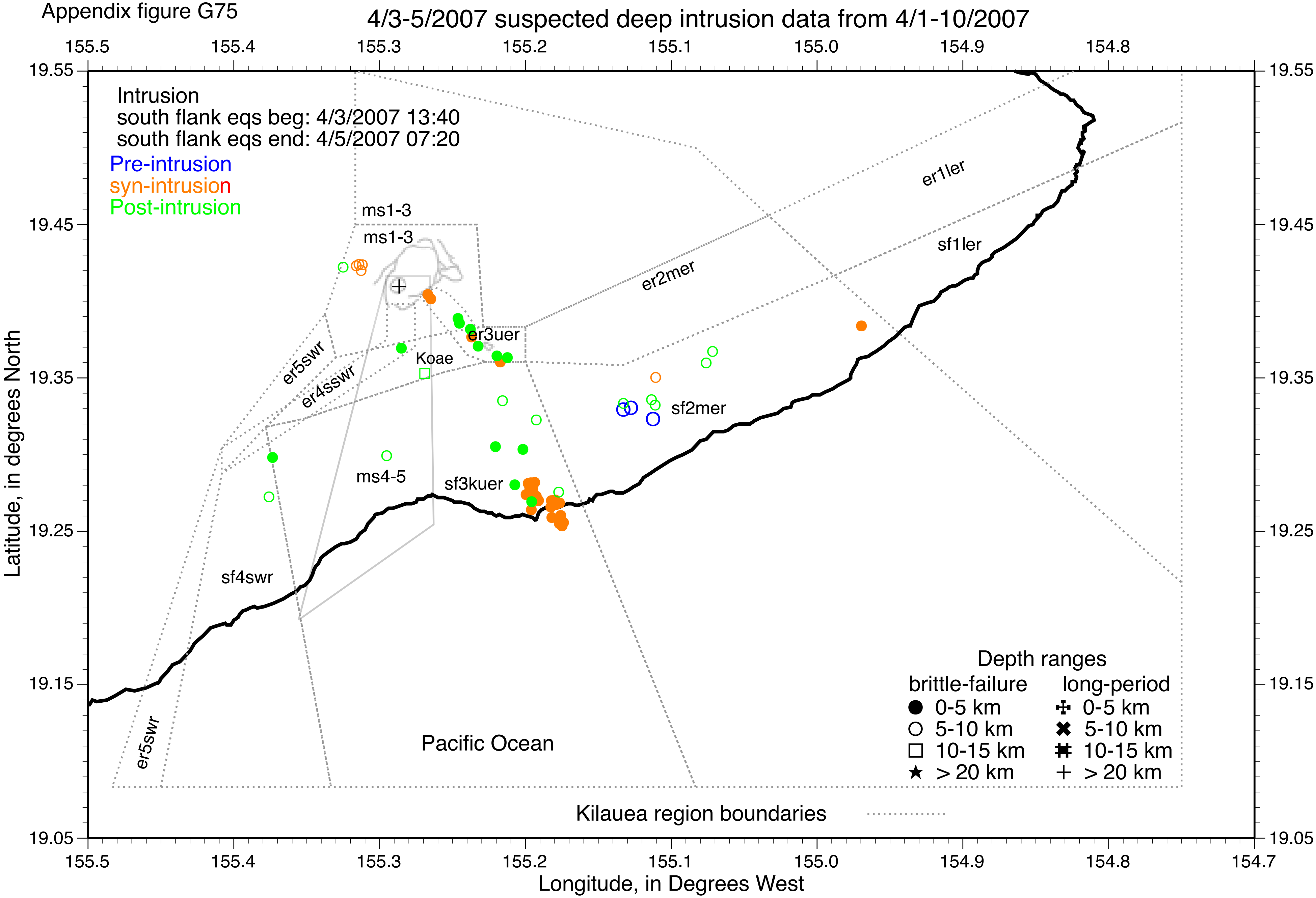
Appendix figure G73

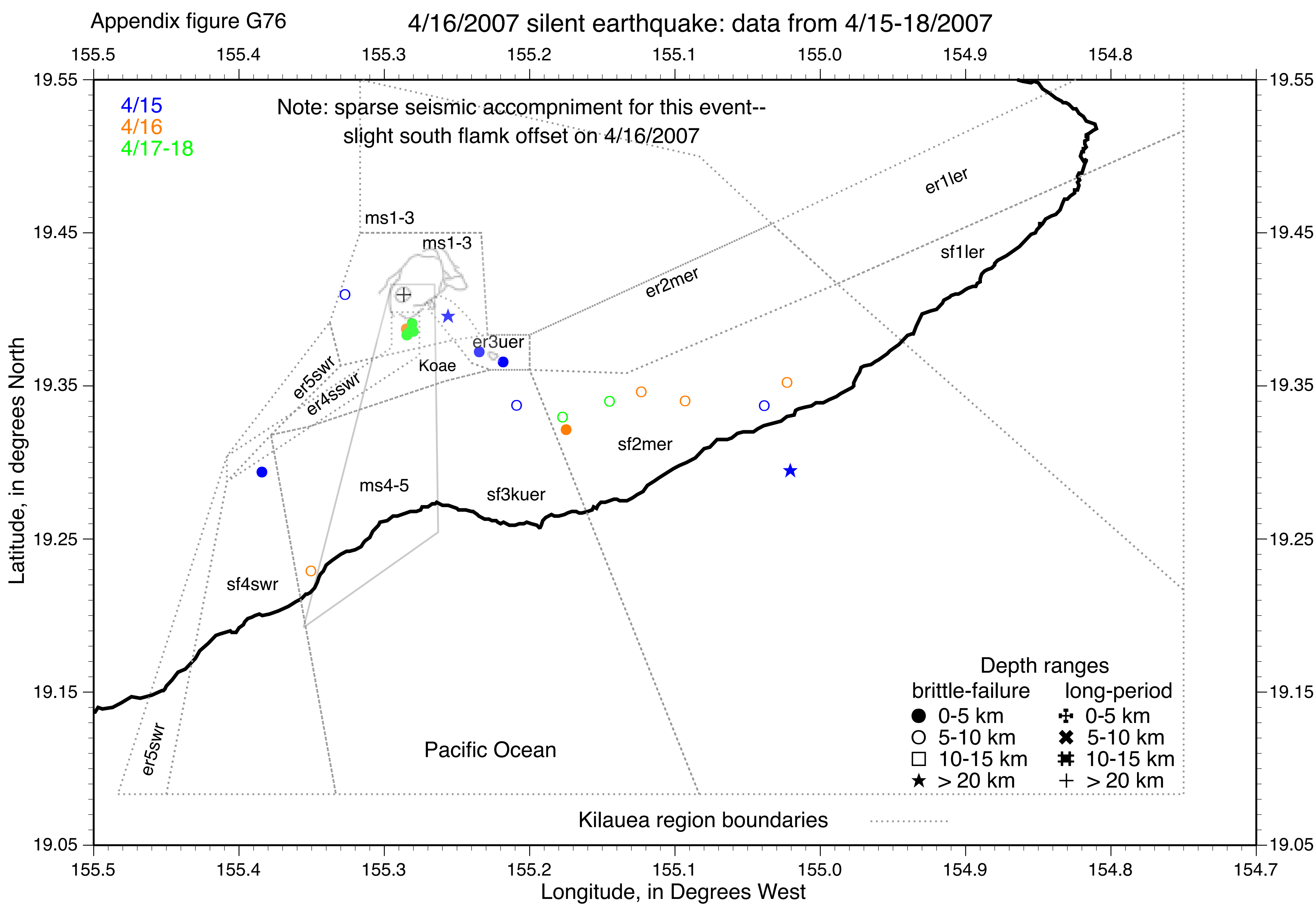




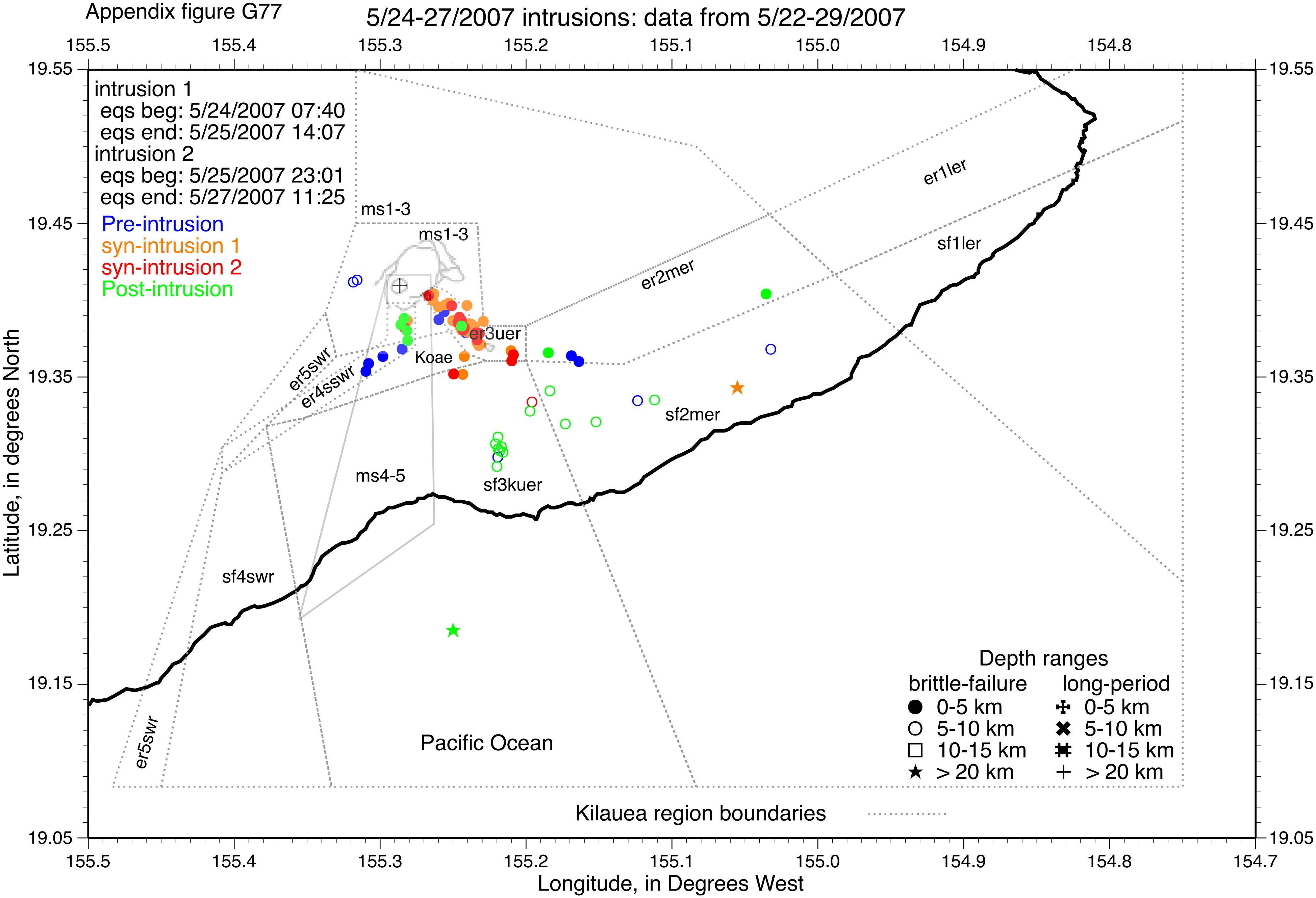
Appendix figure G74
8/3-4/2006 intrusion: data from 8/1-8/2006
Intrusion 13 events
eqs beg: 8/3/2006 08:07
eqs end: 8/4/2006 02:30
Pre-intrusion
Syn-intrusion
Post-intrusion
ms1-3
ms1-3
er1ler
sf1ler
er2mer
er3uer
Koae
er5swr
er4sswr
sf2mer
ms4-5
sf3kuer
sf4swr
er5swr
Pacific Ocean
Depth ranges
brittle-failure
0-5 km
5-10 km
10-15 km
> 20 km
long-period
0-5 km
5-10 km
10-15 km
> 20 km
Kilauea region boundaries
Latitude, in degrees North
Longitude, in Degrees West
155.5
155.4
155.3
155.2
155.1
155.0
154.9
154.8
154.7
19.55
19.45
19.35
19.25
19.15
19.05

Appendix figure G75

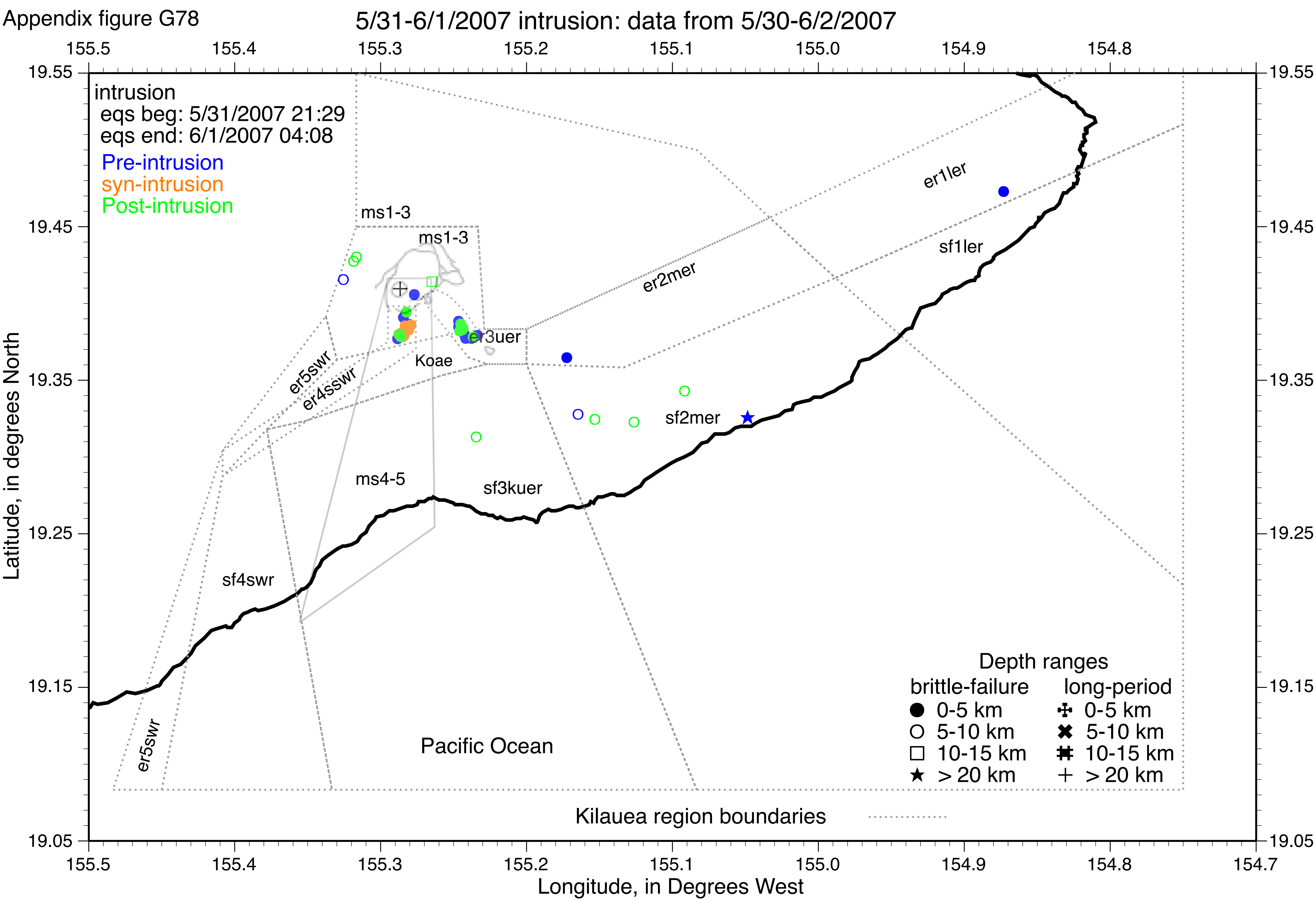



Appendix figure G76
4/16/2007 silent earthquake: data from 4/15-18/2007
4/15
4/16
4/17-18
Note: sparse seismic accompniment for this event--
slight south flamk offset on 4/16/2007
155.5
155.4
155.3
155.2
155.1
155.0
154.9
154.8
154.7
19.55
19.45
19.35
19.25
19.15
19.05
ms1-3
ms1-3
er3uer
Koae
er5swr
er4sswr
er2mer
er1ler
sf1ler
sf2mer
ms4-5
sf3kuer
sf4swr
er5swr
Pacific Ocean
Depth ranges
brittle-failure
long-period
0-5 km
5-10 km
10-15 km
> 20 km
0-5 km
5-10 km
10-15 km
> 20 km
Kilauea region boundaries
Latitude, in degrees North
Longitude, in Degrees West

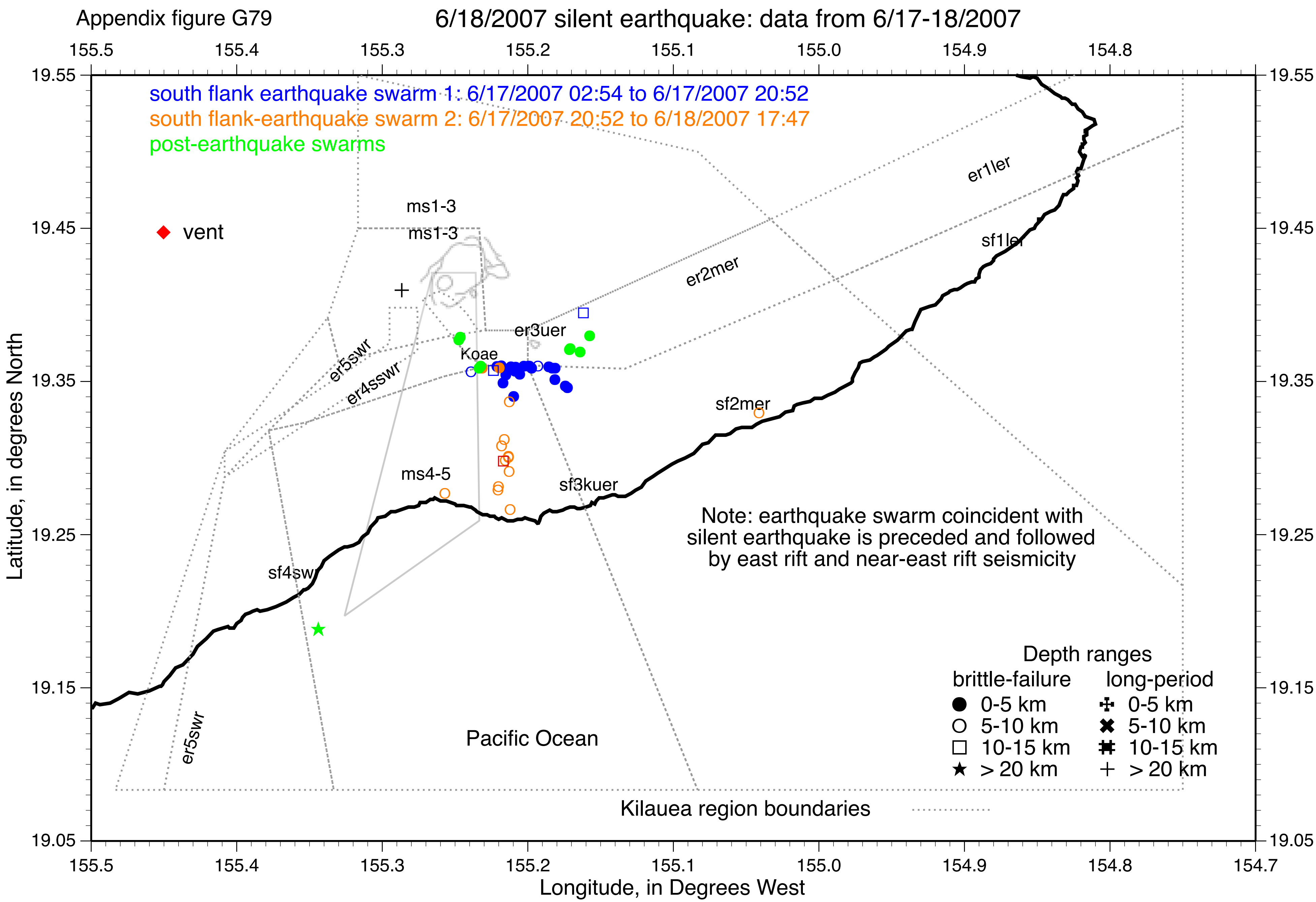
Appendix figure G77



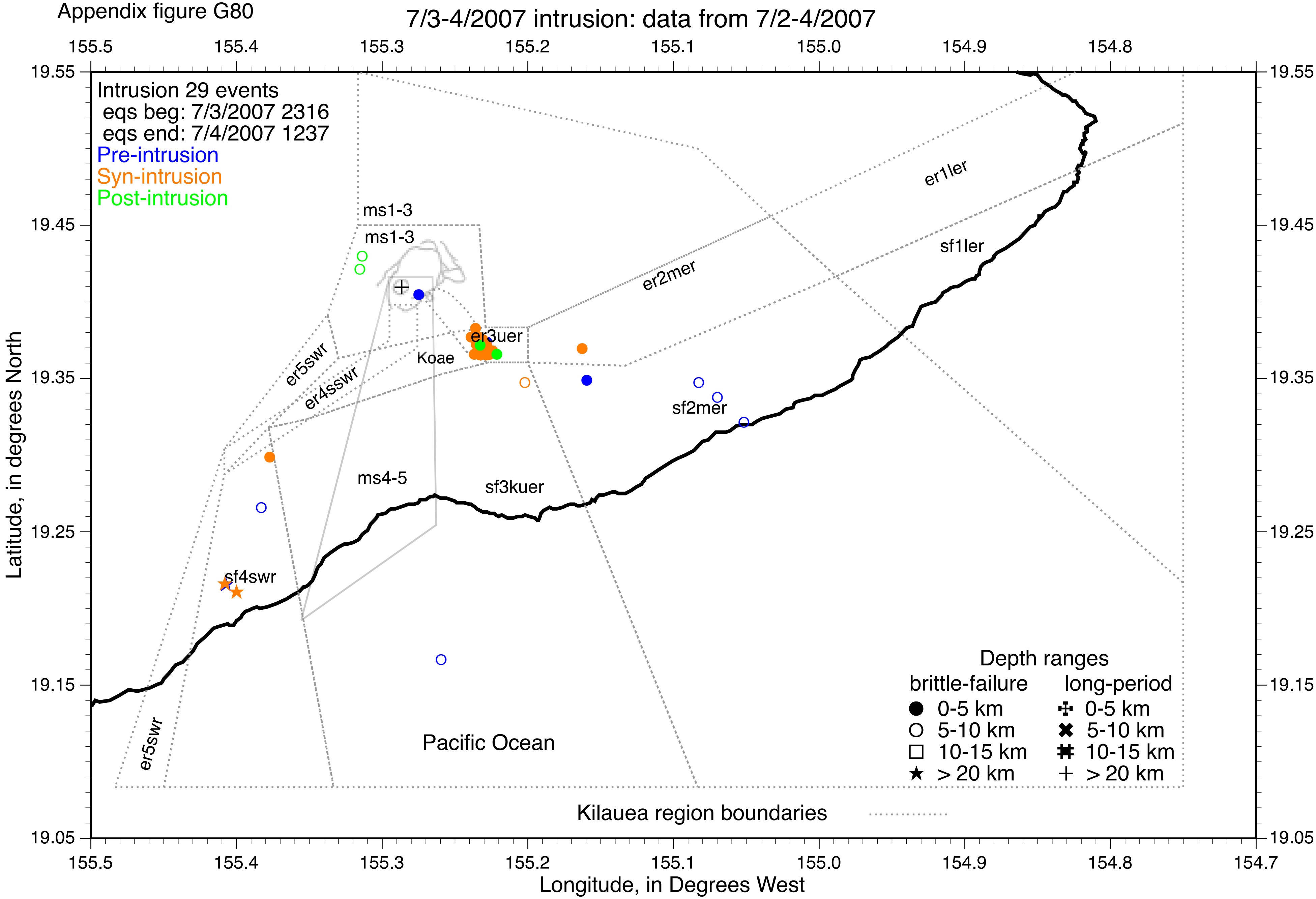
Appendix figure G78



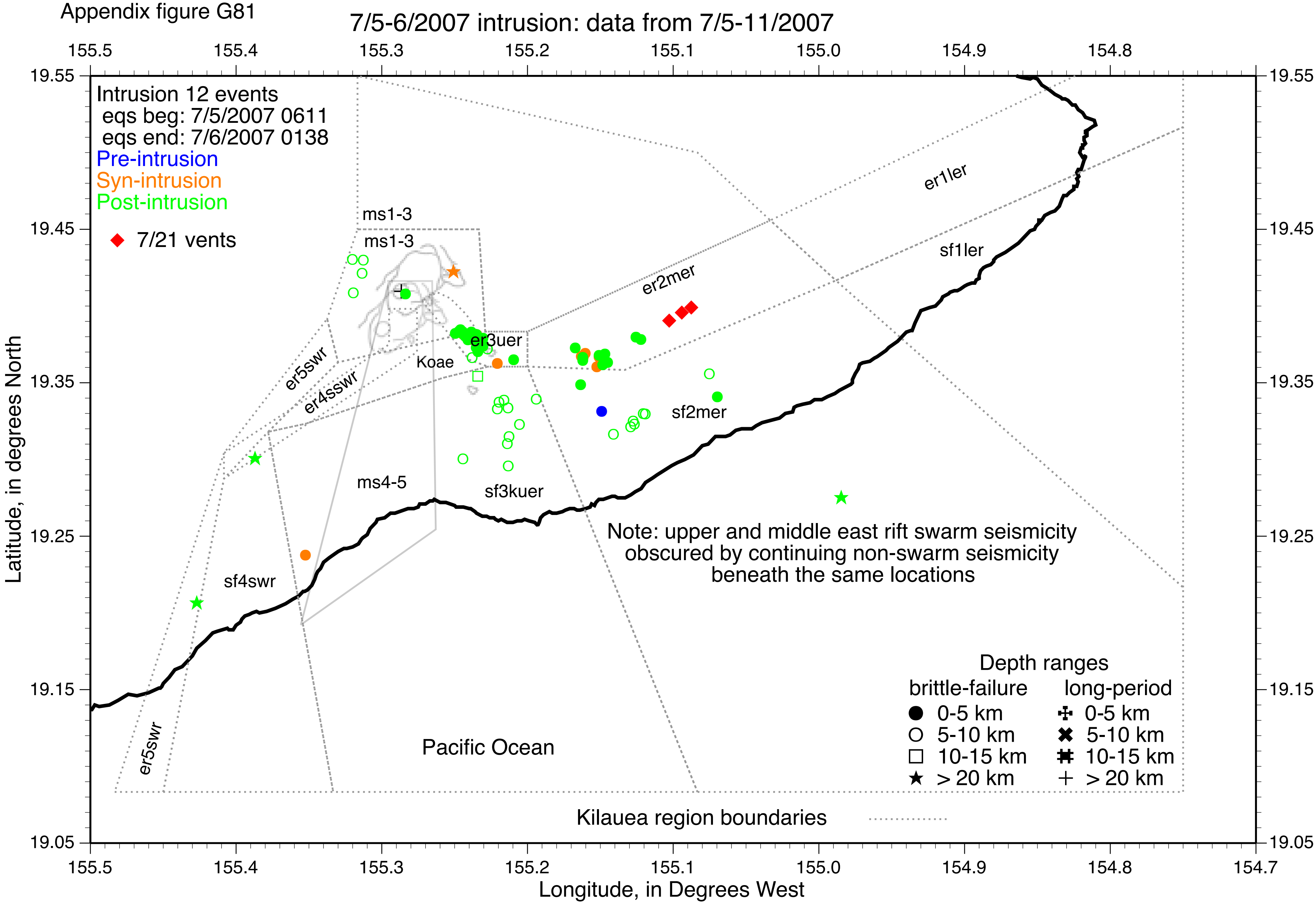
Appendix figure G79



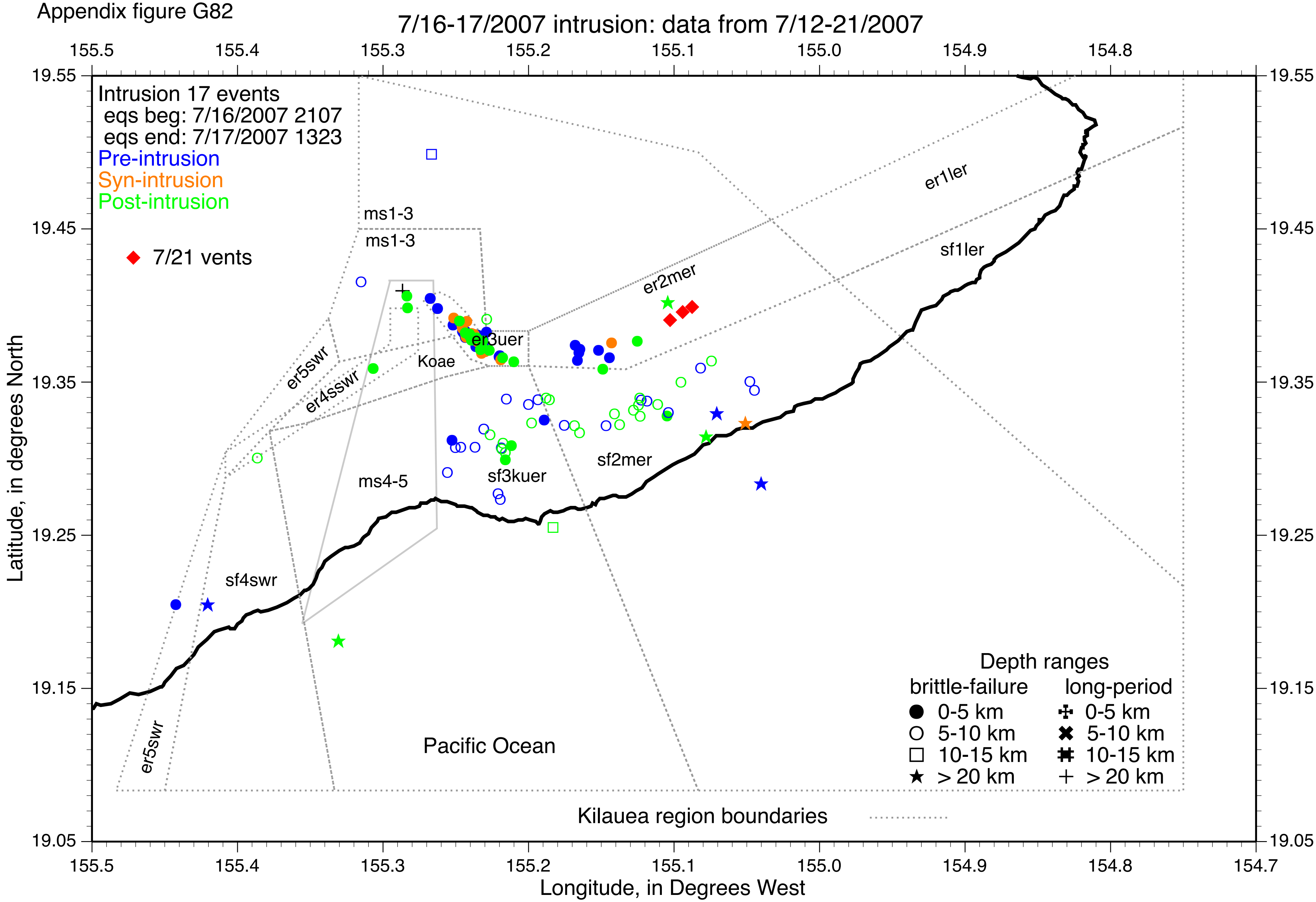
Appendix figure G80



Appendix figure G81



Appendix figure G82



Appendix H. Supplementary Material to Support Chapter 8

Tables H1–H3 contain accumulated earthquake counts and moment for all regions plotted in figures 8.11 and 8.12.

Table H4a gives volumes of the three magma batches erupted at Halema‘uma‘u in 1952, 1961, and 1967-68 that are identified in eruptions between 1952 and the beginning of the Mauna Ulu eruption in May 1969. Table H4b gives additional volumes inferred for intrusions over the same period of time. See text for interpretations using these quantities.

Figure H1 shows the location of edm and Global Positioning System (GPS) stations used in constructing figures 8.8 and 8.9.

Appendix table H1. Accumulated counts and moment release from 1/1/1950 to 11/29/1975

Stage	Region[i]	cum cts	Cts/yr	Cum mom	Mom/yr	Acc adj mom[ii]	Comment
pre-1952	**ms1**	53	21.30	1.489	0.599		Period of inflation from March 5 1950 to the beginning of the 1952 Halema‘uma‘u eruption on June 27, 1952
1/1/1950	**ms2.3**	7	2.82	7.469	3.005		
6/27/1952	**ms4.5**	21	8.45	361.24	145.31		
908 days	**ms5gln**	1	0.4	0.0281	0.0113		40-60 km deep earthquakes north of Kīlauea caldera; precursors to the 1959 eruption in Kīlauea Iki 11/14/-12/20/1959
2.486 years	**er1**	0	0	0	0		
	er2.3	36	14.5	13.673	5.500		
	er4.5	8	3.22	2.333	0.938		
	koae	27	10.9	10.4143	4.1892		Koa‘e crisis of December 8-12/1950; deep magma supply earthquakes and shallow events associated with cracking across the Koa‘e fault zone
	sf1	1	0.4	0.2214	0.0891		
	sf2.3	73	29.4	1193.919	480.26		
	sf4	7	2.82	95.7915	38.533		Offshore south flank crisis affecting all regions with many earthquakes recorded on Oahu
1952-1961	**ms1**	743	85.8	34.343	3.965		Period from the beginning of the 1952 Halema‘uma‘u eruption to the beginning of the 1961 Halema‘uma‘u eruptions
6/27/1952	**ms2.3**	118	13.6	13.688	1.580		
2/24/1961	**ms4.5**	153	17.7	155.892	17.996		
3164 days	**ms5gln**	378	43.6	39.662	4.579		Buildup to eruption in Kīlauea Iki on November 14, 1959
8.663 years	**er1**	147	17.0	20.495	2.366		Buildup to eruption on lower east rift zone on February 28, 1955
	er2.3	88	10.2	35.965	4.152		
	er4.5	55	6.35	4.389	0.507		
	koae	29	3.35	3.564	0.412		
	sf1	40	4.62	6.225	0.719		
	sf2.3	160	18.5	760.457	87.787		M 6.2, 6.6 earthquakes on March 30, 1954
	sf4	8	0.92	0.979	0.113		
1961-1967	**ms1**	59	8.81	3.074	0.459		Period from the beginning of the 1961 Halema‘uma‘u eruptions to the beginning of the 1967-68 Halema‘uma‘u eruption
2/24/1961	**ms2.3**	51	7.62	3.673	0.549		
11/5/1967	**ms4.5**	717	107.0	56.137	8.386		Beginning in 1960 20-35 km deep earthquake swarms beneath Kīlauea caldera supplant the 40-60 km deep earthquakes north of the caldera
2445 days	**ms5gln**	0	0	0	0		
6.694 years	**er1**	24	3.59	0.922	0.138		
	er2.3	117	17.5	9.988	1.492		
	er4.5	56	8.37	1.369	0.205		
	koae	256	38.2	6.900	1.031		
	sf1	63	9.41	5.273	0.788		
	sf2.3	1383	207.0	98.653	14.738		
	sf4	50	7.47	3.331	0.498		

Appendix table 8.1 cont. Accumulated counts and moment release from 1/1/1950 to 11/29/1975

Stage	**Region**[i]	cum cts	cts/yr	cum mom	mom/yr	cum adj mom[ii]	Comment
1967-1969	**ms1**	193	125.0	3.086	1.991		1967-68 Halema'uma'u eruption and the buildup to the east rift Mauna Ulu eruption
11/5/1967	**ms2.3**	84	54.2	2.751	1.775		
5/24/1969	**ms4.5**	233	150.0	10.902	7.035		
566 days	**ms5gln**	0	0	0	0		
1.550 years	**er1**	4	2.58	0.0377	0.0243		
	er2.3	230	148.0	1.320	0.852		
	er4.5	55	35.5	0.5956	0.3844		
	koae	24	15.5	0.631	0.407		
	sf1	14	9.03	0.257	0.166		
	sf2.3	1058	683	26.230	16.927		
	sf4	13	8.39	0.178	0.115		
1969-1974	**ms1**	1454	287.0	6.700	1.324		Mauna Ulu eruption
5/24/1969	**ms2.3**	802	159.0	4.826	0.954		
6/15/1974	**ms4.5**	1272	251.0	55.343	10.938		
1848 days	**ms5gln**	0	0	0	0		
5.060 years	**er1**	38	7.51	0.589	0.116		
	er2.3	1776	351.0	8.999	1.779		
	er4.5	1228	243	6.358	1.257		
	koae	360	71.2	6.392	1.263		
	sf1	47	9.29	0.676	0.134		
	sf2.3	7031	1390	135.256	26.733		
	sf4	654	129	33.835	6.687		
Pre-1975 eq	**ms1**	273	187	3.104	2.131		End of Mauna Ulu eruption to the M 7.2 south flank earthquake
6/15/1974	**ms2.3**	185	127	3.408	2.340		
11/29/1975	**ms4.5**	273	187	25.994	10.981		
532days	**ms5gln**	0	0	0	0		
1.457 years	**er1**	1	0.69	0.0067	0.0046		
	er2.3	516	354	2.675	1.837		
	er4.5	933	641	11.831	8.123		
	koae	19	13	0.562	0.386		
	sf1	4	2.75	0.05	0.0343		
	sf2.3	2085	1431	124.090	85.195		
	sf4	827	568	75.386	51.757		

[i] Regions shown in chapter 1, figure 1.3
[ii] Moment of earthquakes of M≥6.0 is counted as "0" and shown on plots with a symbol (↑) accompanied by date, magnitude and true moment

Appendix table H2. Accumulated counts and moment release from 1/1/1976 to 1/1/1982[1]

Stage	Region[2]	cum cts	Cts/yr	Cum mom	Mom/yr	Acc adj mom[3]	Comment
1976-1982 short-period seiimicity	**ms1**	393	65.50	11.26	1.88		No earthquakes exceed M 6.0 in any region during this period
	ms2.3	63	10.50	1.37	0.23		
	ms4.5	337	56.17	6.02	1.00		
	ms5gln	0	0	0	0		
	er1	146	24.33	1.700	0.28		
	er2.3	2518	419.67	53.63	8.94		
	er4.5	1647	274.50	34.29	5.72		
	koae	199	33.17	12.44	2.07		
	sf1	293	48.83	6.21	1.04		
	sf2.3	9904	1650.6	447.38	74.56		
	sf4.5	600	100.00	6.06	1.01		
1976-1982 long-period seismicity	**lpms1**	335	55.83	2.77	0.46		
	lpms2.3	50	8.33	0.54	0.09		
	lpms4.5	69	11.50	0.80	0.13		

[11] Counts and moment in all regions include continuing aftershocks associated with the M 7.2 earthquake of 11/29/1975
[2] Regions shown in appendix figure
[3] Moment of earthquakes of M ≥ 6.0 is counted as "0" and shown on plots with a symbol (↑) accompanied by date, magnitude and true moment

Appendix table H3a. Accumulated short-period counts and moment release for the Pu‘u ‘Ō‘o-Kupaianaha eruption

Stage	Region[i]	cum cts	Cts/yr	Cum mom	Mom/yr	Comment
pre-1983	**ms1**	222	204.76	4.0042	3.6932	
1/1/1982	**ms2.3**	16	14.76	0.974	0.0899	
2/1//1983	**ms4.5**	106	97.77	9.4114	8.6805	
396 days	**msnp**	1	0.92	0.0146	0.0135	
1.084 years	**er1**	14	12.91	0.0583	0.0538	
	er2.3	1202	1108.7	8.5729	7.9072	
	er4	670	617.97	9.4014	8.6714	
	er5	0	0	0	0	
	er4.5	670	617.97	9.4014	8.6713	
	koae	35	32.28	1.2856	1.1858	
	sf1	23	21.21	0.1086	0.1002	
	sf2.3	2636	2431.3	38.6581	35.6563	
	sf4	317	292.38	2.2003	2.0295	
Stage IA	**ms1**	160	46.27	0.8994	0.2601	
2/1/1983	**ms2.3**	75	21.69	1.6677	0.4823	
7/18/1986	**ms4.5**	149	43.09	10.2827	2.9737	
1263 days	**msnp**	177	51.18	2.1586	0.6243	High count from earthquakes triggered by the 11/16/1983 Ka‘ōiki earthquake
3.458 years	**er1**	21	6.07	0.1581	0.0457	
	er2.3	34	9.83	0.1470	0.0425	
	er4	6	1.74	0.0139	0.0040	
	er5	138	39.91	0.8542	0.2470	High count from earthquakes triggered by the 11/16/1983 Ka‘ōiki earthquake
	er4.5	6	1.74	0.8681	0.2510	Calculated without triggered earthquakes
	koae	10	2.89	0.2063	0.0597	
	sf1	50	14.46	0.4272	0.1236	
	sf2.3	3507	1014.2	133.4378	38.5996	Dominated by earthquakes on 3/20/1983 (M 4.9) and 9/9/1983 (M 5.7)
	sf4	142	40.07	1.0154	0.2937	
Stage IB	**ms1**	501	94.37	3.0731	0.5789	
7/18/1986	**ms2.3**	78	14.69	1.0273	0.1935	
11/8/1991	**ms4.5**	299	56.32	9.3593	1.7630	
1939 days	**msnp**	230	43.33	2.4952	0.4700	
5.309 years	**er1**	69	13.00	0.4150	0.0782	
	er2.3	374	70.45	1.9064	0.3591	
	er4	0	0	0	0	
	er5	65	12.24	0.2490	0.0469	Probably continuing effects of Ka‘ōiki earthquake
	er4.5	65	12.24	0.2490	0.0469	Probably continuing effects of Ka‘ōiki earthquake
	koae	21	3.96	0.1479	0.0279	
	sf1	78	14.69	0.6671	0.1257	
	sf2.3	3691	695.27	365.40	68.8300	Dominated by M 6.2 earthquake on June 25, 1989
	sf4	69	13.00	0.5976	0.1107	

Appendix table 8.3a cont.

Stage	Region[i]	cum cts	cts/yr	cum mom	mom/yr	Comment
Stage IIA	**ms1**	483	93.79	4.1961	0.8148	
11/8/1991	**ms2.3**	69	13.40	0.4773	0.0927	
1/1/1997	**ms4.5**	342	66.41	33.3721	6.4802	Dominated by M 5.2 earthquake on February 1, 1994
1881 days	**msnp**	268	52.04	3.7726	0.7326	
5.150 years	**er1**	49	9.51	0.2160	0.0419	
	er2.3	555	107.77	2.7631	0.5365	
	er4	3	0.58	0.0030	0.0006	
	er5	31	6.02	0.0992	0.0193	
	er4.5	34	6.60	0.1022	0.0198	
	koae	46	8.93	1.5474	0.3005	
	sf1	35	6.800	0.5078	0.0986	
	sf2.3	2168	420.98	36.509	7.0893	
	sf4	32	6.21	.0963	0.0187	
Stage IIB	**ms1**	804	116.30	16.4008	2.3724	
1/1/1997	**ms2.3**	219	31.68	1.1227	0.1624	
12/1/2003	**ms4.5**	812	117.46	18.1447	2.6258	
2525 days	**msnp**	389	56.27	14.7828	2.1384	
6.913 years	**er1**	114	16.49	2.2650	0.3276	
	er2.3	489	70.74	4.1389	0.5987	
	er4	16	2.31	0.0710	0.0103	
	er5	78	11.28	0.3074	0.0465	
	er4.5	94	13.60	0.3785	0.0548	
	koae	125	18.08	0.5333	0.0771	
	sf1	71	10.27	1.0831	0.1567	
	sf2.3	3796	549.10	86.0533	12.5926	
	sf4	93	13.45	0.6252	0.0904	
Stage IIIA	**ms1**	302	87.27	1.1262	0.3254	
12/1/2003	**ms2.3**	87	25.14	0.4026	0.1163	
5/18/2007	**ms4.5**	668	193.03	7.5018	2.1677	
1264 days	**msnp**	508	146.79	2.1303	0.6156	
3.461years	**er1**	65	18.78	0.5059	0.1462	
	er2.3	1382	399.35	5.9478	1.7187	
	er4	696	201.12	2.3368	0.6753	
	er5	34	9.82	0.0599	0.0173	
	er4.5	730	210.92	2.3968	0.6925	
	koae	19	5.49	0.0254	0.0073	
	sf1	92	26.58	0.5784	0.1671	
	sf2.3	2986	862.85	24.1275	6.9720	
	sf4	157	45.37	0.3303	0.0954	

Appendix table 8.3a cont.

Stage	**Region**[i]	cum cts	cts/yr	cum mom	mom/yr	Comment
Stage IIIB	**ms1**	114	136.07	0.3346	0.3993	
5/18/2007	**ms2.3**	25	29.84	0.0928	0.1108	
3/19/2008	**ms4.5**	150	179.04	1.9009	2.2690	
306 days	**msnp**	46	54.89	0.1203	0.1436	
0.838 years	**er1**	6	7.16	0.0609	0.0727	
	er2.3	508	606.36	12.3767	14.7732	
	er4	70	83.55	0.3627	0.4329	
	er5	8	9.55	0.0098	0.0116	
	er4.5	78	93.08	0.3725	0.4445	
	koae	16	19.10	0.0578	0.0690	
	sf1	7	8.36	0.0442	0.0527	
	sf2.3	958	1143.5	42.4646	50.6869	
	sf4	16	19.09	0.0778	0.0929	

Appendix table 8.3b. Accumulated long-period counts and moment release for Pu‘u ‘Ō‘o-Kupaianaha eruption

Stage	Region[i]	cum cts	Cts/yr	Cum mom	Mom/yr	Comment
pre-1983	**lpms1**	0	0	0	0	
1/1/1982	**lpms2**	5	4.61	0.0287	0.0265	
2/1//1983	**lpms3**	1	0.92	0.0065	0.0060	
396 days	**lpms2.3**	6	5.53	0.0352	0.0325	
1.084 years	**lpms4.5**	7	6.46	0.0170	0.0425	
Stage IA	**lpms1**	35	10.12	0.1154	0.0334	
2/1/1983	**lpms2**	101	29.21	0.3801	0.1099	
7/18/1986	**lpms3**	66	19.09	0.2946	0.0852	
1263 days	**lpms2.3**	167	48.29	0.6747	0.1951	
3.458 years	**lpms4.5**	35	10.12	0.2191	0.0634	
Stage IB	**lpms1**	422	79.49	2.3469	0.4421	
7/18/1986	**lpms2**	1900	357.90	15.4470	2.9098	
11/8/1991	**lpms3**	2296	432.50	21.8393	4.1139	
1939 days	**lpms2.3**	4196	790.40	37.2863	7.0237	
5.309 years	**lpms4.5**	103	19.40	1.2769	0.2405	
Stage IIA	**lpms1**	250	48.54	0.8941	0.1736	
11/8/1991	**lpms2**	342	66.41	1.1611	0.2255	
1/1/1997	**lpms3**	1446	280.78	4.9944	0.9698	
1881 days	**lpms2.3**	1788	347.19	6.1555	1.1953	
5.150 years	**lpms4.5**	42	8.16	0.4309	0.0837	
Stage IIB	**lpms1**	2751	397.94	13.1825	1.9069	
1/1/1997	**lpms2**	1396	201.94	15.0146	2.1719	
12/1/2003	**lpms3**	1193	172.57	15.0221	2.1730	
2525 days	**lpms2.3**	2589	374.51	30.0367	4.3449	
6.913 years	**lpms4.5**	44	6.36	0.2085	0.0302	
Stage IIIA	**lpms1**	21	6.07	0.059	0.0153	
12/1/2003	**lpms2**	261	75.42	1.0458	0.3022	
5/18/2007	**lpms3**	185	53.46	0.8311	0.2478	
1264 days	**lpms2.3**	446	128.88	1.8769	0.5500	
3.461years	**lpms4.5**	28	8.09	0.2228	0.0644	
Stage IIIB	**lpms1**	82	97.88	0.4217	0.5033	
5/18/2007	**lpms2**	0	0	0	0	
3/19/2008	**lpms3**	0	0	0	0	
306 days	**lpms2.3**	0	0	0	0	Need explanation for dramatic decrease in long-period counts
0.838 years	**lpms4.5**	11	13.13	0.1105	0.1319	

[i] Regions shown in figure 1.3

Appendix table H4. Volumes of magma batches entering Kīlauea plumbing

a. Magma erupted in homogeneous summit eruption or mixed in hybrid eruptions

Magma name	date begin	date end	V (km^3)	Comment	Reference[1]
1952	6/27/1952	11/9/1952	.0870	Halemaʻumaʻu eruption	4
	3/20/1955	5/26/1965	.0333	Latter part of 1955 eruption; mixing percentage 41.9	9, 1
	1/26/1960	1/29/1960	.0035	Middle part of 1960 eruption; mixing percentage35.7	9, 2
Total			.1335		
1954	5/31/1954	6/3/1954	.0050	Kīlauea caldera eruption	8
	11/14/1959	11/21/1959	.0042	1959 eruption episode 1: mixing percentage 45.5	5; 3
	11/22/1959	12/20/1959	.0027	1959 eruption episodes 2-17: mixing percentage 13.2	5, 3
Total			.0119		
1961	3/5/1955	3/6/1955	.0418	Kalalua intrusion--calculated as parent for 1977 eruption	9,
	1/30/1960	2/4/1960	.0086	middle part of 1960 eruption; mixing percentage 58.2	5, 2
	2/24/1961	7/17/1961	.0103	Halemaʻumaʻu eruptions (3)	6
	9/22/1961	9/25/1961	.0390	East rift eruption: assume 1961 and 1967 transferred in equal volume	6, 15
	12/7/1962	12/9/1962	.0049	12/1962 East rift eruption	14, 15
	8/21/1963	8/23/1963	.0022	8/1963 East rift eruption	10, 15
	10/5/1963	10/6/1963	.0155	10/1963 east rift eruption	11, 15
	3/5/1965	3/15/1965	.0033	3/1965 east rift eruption	12, 15
	12/24/1965	12/25/1965	.0036	12/1965 east rift eruption	13, 15
Total			.1292		
1967-68	2/12/1960	2/18/1960	.0043	later part of 1960 eruption: mixing percentage 24.8	5, 2
	9/22/1961	9/25/1961	.0390	East rift eruption: assume 1961 and 1967 transferred in equal volume	6, 15
	12/7/1962	12/9/1962	.0064	12/1962 East rift eruption	14, 15
	8/21/1963	8/23/1963	.0016	8/1963 East rift eruption	10, 15
	10/5/1963	10/6/1963	.0250	10/1963 east rift eruption	11, 15
	3/5/1965	3/15/1965	.0381	3/1965 east rift eruption	12, 15
	12/24/1965	12/25/1965	.0177	12/1965 east rift eruption	13, 15
	11/5/1967	7/14/1968	.0744	Halemaʻumaʻu eruption	7
	8/22/1968	8/28/1968	.0024	8/1968 east rift eruption	16, 18
	10/7/1968	10/22/1968	.0234	10/1968 east rift eruption	16, 18
	2/22/1969	2/28/1969	.0061	2/1969 east rift eruption	17, 18
Total			.2384		
Grand total			.5130	Total amount of unfractionated magma identified; add .01 km^3/year for rift dilation during spreading; lifetime of magma batches ~ 10 years	

[1] 1. (Helz and Wright, 1992); 2. (Wright and Helz, 1996); 3. (Wright, 1973); 4. (Macdonald, 1952); 5. (Richter and others, 1970); 6. (Richter and others, 1964); 7. (Kinoshita and others, 1969); 8. (Macdonald and Eaton, 1954); 9. (Macdonald and Eaton, 1964); 10. (Peck and Kinoshita, 1976); 11. (Moore and Koyanagi, 1969); 12. (Wright and others, 1968); 13. (Fiske and Koyanagi, 1968); 14. (Moore and Krivoy, 1964); 15. (Wright and Fiske, 1971); 16. (Jackson and others, 1975); 17. (Swanson and others, 1976); 18. (Wright and others, 1975)

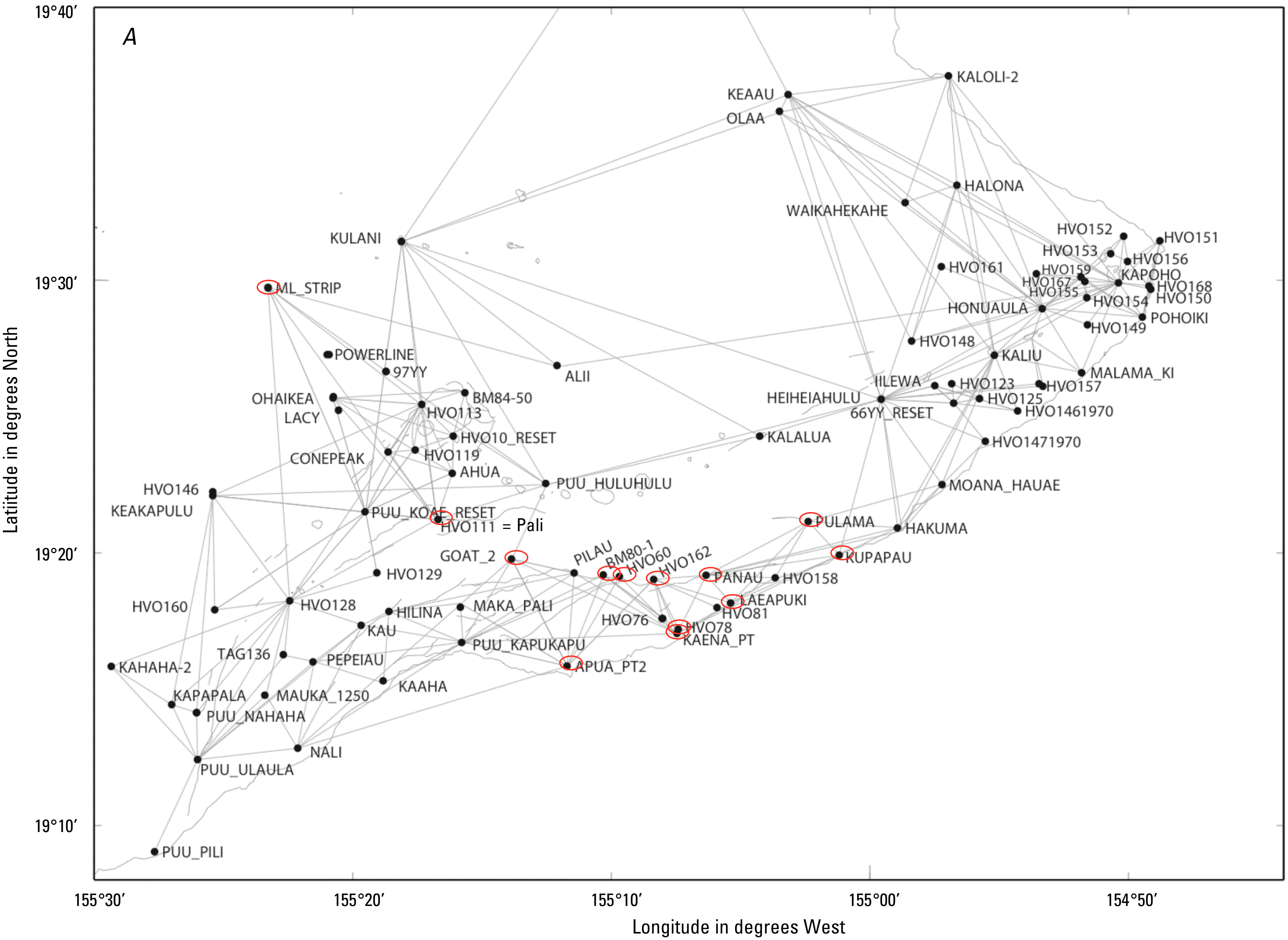
b. Additional magma transfer to east rift zone: Deflation volumes not associated with eruption[i]

date begin	date end	V (km^3)	Comment
9/15/1950 12/8/1950	12/8/1950 12/16/1950	.0088 .0507	Assumed to be magma batch of 1952 chemistry do.
Subtotal		.0595	Minimum volume1952 magma intruded into the rift zone.
6/26/1952	10/2/1952	.0323	Assumed to be magma batch of 1961 chemistry
3/10/1954	3/24/1954	.0082	do
12/13/1954	1/17/1955	.0114	do
2/19/1955	12/29/1955	.1494	do
8/31/1959	11/14/1959	.0011	do
Subtotal		.2024	Volume of 1961 magma intruded into the east rift zone
11/15/1959	11/23/1959	.0213	Assumed to be magma batch of 1967-68 chemistry[ii]
12/23/1959	1/17/1960	.0103	do
1/17/1960	10/21/1960	.1405	do
9/21/1961	9/30/1961	.0779	do
10/28/1961	11/4/1961	.0046	do
12/6/1962	12/9/1962	.0092	do
5/8/1963	5/12/1963	.0157	do
6/28/1963	7/2/1963	.0085	do
8/21/1963	8/22/1963	.0036	do
10/4/1963	10/10/1963	.0362	do
11/11/1964	12/1/1964	.0022	do
3/5/1965	3/9/1965	.0395	do
12/23/1965	12/29/1965	.0213	do
10/1/1966	10/7/1966	.0044	do
8/9/1967	8/18/1967	.0038	do
Subtotal		.399	Maximum additional volume of 1967-68 chemistry. May include a percentage of 1961 chemistry
Total		.6609	

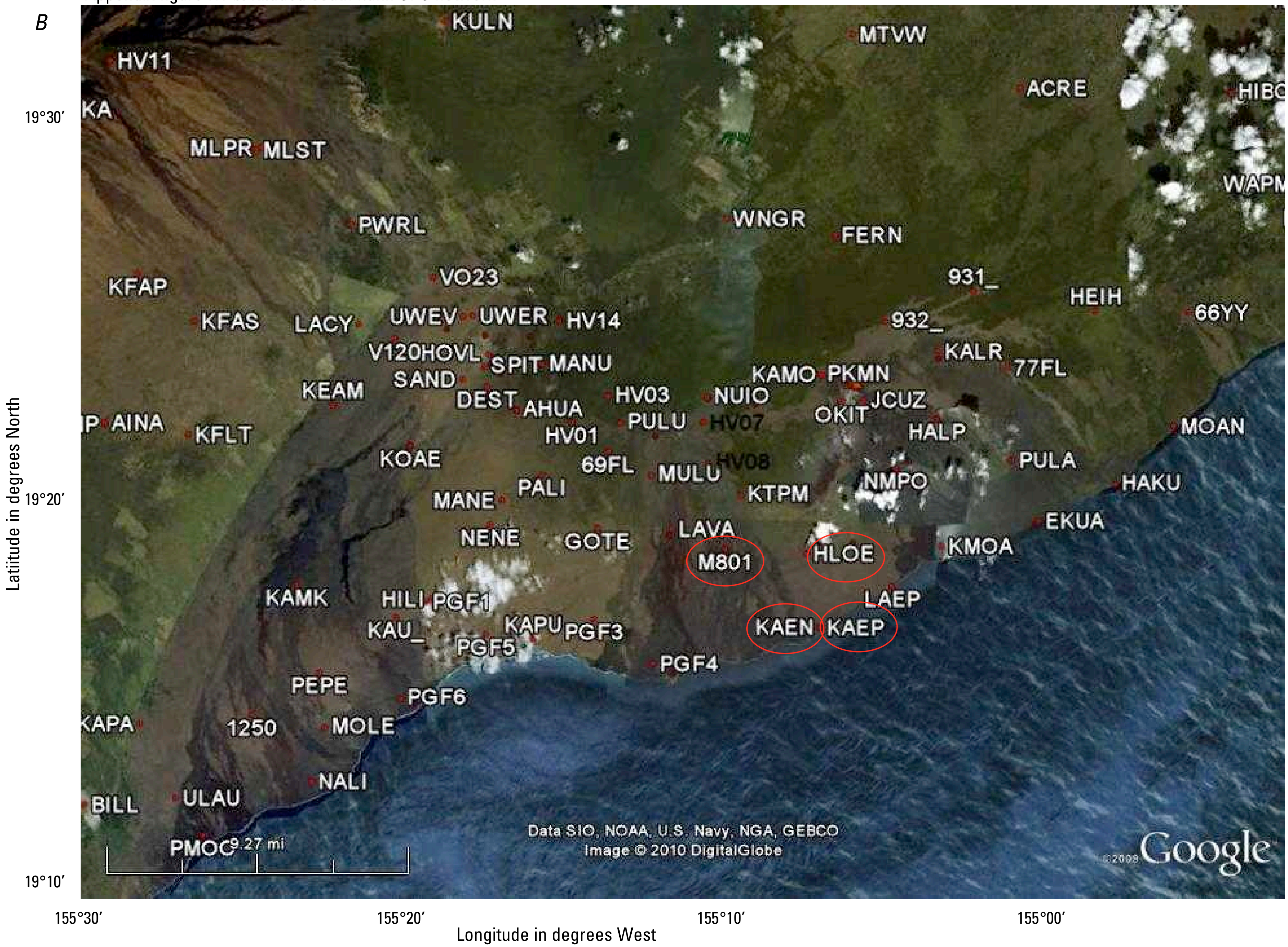
[i] Volumes calculated from deflation
[ii] Latest time that magma can enter east rift zone for mixing with the latter part of the 1960 eruption

Figure H1. Maps showing locations of stations shown in text figures 8.9 and 8.10. *A*, Stations in the Hawaiian Volcano Observatory edm network. Stations used in the plots in this report are circled in red. *B*, Stations in the Hawaiian Volcano Observatory Global Positioning System (GPS) network. Stations used in the plots in this report are circled in red.

Appendix figure H1 a. Kilauea south flank edm network



Appendix figure H1 b. Kilauea south flank GPS network



Appendix I. Summit tilt calculations and Mogi inflation centers

Modeling of tilt changes

The simplest and most useful way to model the buried inflation and deflation source at Kīlauea is the point Mogi pressure source in an elastic half-space (Mogi, 1958). We state here the theoretical elevation, tilt and total volume relations historically used to model contour maps of elevation changes from leveling surveys, and maps of tilt vectors from tiltmeter arrays. Here d is the horizontal distance from the source center, f is the depth of the source, a is the radius of the source sphere, P is the pressure inside the buried sphere and μ is the rigidity measured in the same units as the pressure. The elevation change when pressure is applied is (Eaton, 1962; Mogi, 1958):

$$\Delta h = \frac{3a^3 P}{4\mu}\left[\frac{f}{(f^2+d^2)^{3/2}}\right] \qquad (1)$$

We abbreviate the expression $3a^3P/4\mu$ with the letter K (expressed in units of km^3), which is (1) constant for a given episode, (2) determined empirically by the data, and (3) a measure of the strength of the source. The change at the center of inflation (d=0) is $\Delta h_0 = K/f^2$. The integrated volume of the uplift or collapse is $\Delta V = \Delta h_0 2\pi f^2$ (Eaton, 1962). Thus:

$$\Delta V = 2\pi K \qquad (2)$$

and depends only on the strength of the source and not directly on its depth f. This ΔV is the volume of the elastic source but must allow for magma compression before equating to magma volume. The radial tilt change τ around the Mogi source is also a function of distance d and depth f (Eaton, 1962; Jackson and others, 1975):

$$\tau = \frac{K3d/f}{f^3(1+d^2/f^2)^{5/2}} \qquad (3)$$

The maximum tilt τ_m occurs at d=f/2 and is $\tau_m = 0.86K/f^3$. A useful relation is:

$$\frac{\tau}{\tau_m} = 3.5\frac{d/f}{(1+d^2/f^2)^{5/2}} \qquad (4)$$

The volume change is $\Delta V = 2.32\pi f^3 \tau_m$ (Dzurisin et al, 1984). Thus $\Delta V = 2\pi K$, the same relation as derived from elevation. K (and thus ΔV) can be determined from elevation changes, tilt, or both. It is useful to estimate volume change from a single tiltmeter like Uwēkahuna or Whitney when it is the only record of a single deflation event. Combining equations 2 and 3 yields:

$$\Delta V = \frac{\tau 2\pi\left(1 + d^2 / f^2\right)^{5/2}}{3d / f} = D\tau \qquad (5)$$

The volume factor D can be calculated for each tiltmeter's response to a single source, and may not change much during several inflation/deflation episodes.

The elevation change Δh and tilt τ have different dependencies on the source depth f. The maximum height Δh_0 scales with $\sim f^{-2}$: moving a source deeper rapidly reduces the height of the bulge, but broadens it so that the volume depends only on the strength of the Mogi source. For distances d large compared to the source depth f, $\Delta h \sim Kf/d^3$, for d>>f. The height has a weak dependence on source depth but very rapidly falls off with distance. The maximum tilt τ_m scales with $\sim f^{-3}$, thus tilt diminishes rapidly with increasing source depth, and has a stronger dependence on source depth than the elevation function Δh. For distances d large compared to the source depth f, $\tau \sim 3Kf/d^4$, for d>>f. The tilt on the flanks of the bulge also has a weak dependence on source depth, but falls off very strongly with distance.

At Kīlauea, we estimate the volume change ΔV (essentially the factor K) from a single tilt change τ. The tilt scales linearly with K, once the distance and source depth are known. The tilt has a weak dependence on source depth f, and varies essentially as f to the first power. Tilt has a strong dependence on distance d, however, starting at 0 at d=0, reaching a sharp maximum, and falling off as d to the fourth power. For the d>>f case, $\tau \sim 3Kf/d^4$. A source depth change from 2.5 to 3.5 km produces only a 30% change in tilt, but changing d by 20% changes tilt by 100%. The volume change ΔV does not depend only on the source depth: the source depth (even an approximate one) is needed to calculate the shape of the elevation or tilt curve, but the volume scales with the amplitude of the curve, not its width. It is therefore very important to determine the inflation source location fairly well before scaling ΔV from τ, and to calibrate the ΔV to τ relation for a time period with well-determined source location but not necessarily well-determined source depth. In other words, for a Mogi source of a given strength, changing the lateral position of the source by 1 km can have a much bigger effect on tilt than changing the depth by 1 km.

The location and depth of the Mogi source, or more complicated source approximated with concentric contours, can be determined from a map of level contours or a map of tilt vectors. The level contours are concentric on the source location and their average radii yield a set of distance versus Δh points. A spreadsheet programmed with equation (1) can calculate the elevation profile, and the source depth and intensity K can be determined interactively.

For any two stations, 1 and 2, the depth f of the deformation source can be determined from measuring the tilt magnitude τ and the known distance from each station to the source location and then calculating depth directly from the tilts τ_1 and τ_2, and their source distances d_1 and d_2. Taking the ratio of the tilt equations and solving for f yields

$$f^2=(Cd_1^2-d_2^2)/(1-C) \text{ where } C=(\tau_1 d_2/\tau_2 d_1)^{2/5} \qquad (6)$$

A graphic solution may be found for the source location from the average intersection of tilt vectors. The source depth and the constant K (or volume) may then be determined iteratively by fitting tilts (or elevations) and distances with a spreadsheet. Errors of the source determination may be empirically estimated from the fitting or mismatch of elevation contours and the uncircularity of contours. Alternatively, a least-squares solution for the source depth and location can be obtained for measurements from a network of stations using a computer program. This can yield average values for different time periods, but the progression of inflation or deflation centers is best estimated from changes of tilt azimuth over short periods of time.

Examples of fitting a Mogi source

We next examine an example elevation and tilt profile for the 1966–1967 summit inflation (figure I1). This example covers a time when both the leveling and tilt measurements span approximately the same period, and there are adequate measurements to determine the Mogi source. The example also illustrates some problems with using only tilt data. The inflation height contour radii were measured from the October 1967 leveling survey differenced from the January 1966 survey (Fiske and Kinoshita 1969, their figure 4A). The deformation location is near 155º 16.8' west, 19º 23.7' north. The iteratively determined source depth from both elevation and tilt is at 3.3 km. The wet tilt measurements fit the Mogi profile fairly well, except for measurements like Ke'āmoku, which typically shows tilt magnitudes much larger than the model fit to other stations, and may have some amplification due to local ground effects. Because there are only 5 independent and un-corrupted tilt stations, and because the tilt curve fit is poorer than the level curve, water tube tilt by itself does not yield a good Mogi solution. The Uwēkahuna long-base tiltmeter is a few hundred meters from the vault housing the short-base tiltmeter, but the two measurements agree fairly well. The calculated volume change from tilt and leveling is 0.056 km^3. The volume factor D estimated for Uwēkahuna from this 1966–1967 episode is about 0.00050 km^3/microradian.

We next plot elevation and tilt profiles for the 1959 inflation and 1960 summit deflation (figure I2). This is not as clean a time period as the 1967 example because the episode includes both inflation and deflation with possible migration of the deformation center, and because the elevation and tilt surveys include overlapping but not identical time periods. The tilt history at Uwēkahuna and Whitney is plotted vs. time in figure A1, showing the amount and timing of pre-eruption inflation and the big January 1960 collapse. The deflation height contour radii (figure I2a) were measured from the May 1960 leveling survey differenced from the January 1958 survey (figure I3; Eaton, unpublished). The deformation location is the same as 1966-67 and is near 155º 16.8' west, 19º 23.7' north. The iteratively determined source depth from elevation contours is at 2.53 +/- 0.05 km, the volume change is 0.070 km^3 (K=0.011 km^3), and the Mogi fit is good over all radii. We estimate a minimum error of 0.05 km based on multiple fit attempts and the scatter of data points within model curves. The lateral error is larger, about 0.2 km based on visual examination of contours and the original leveling points. The Mogi model curves are fit to an average radius of the level contours, and lack of circularity or concentricity of the contours is another source of error. A rigorous statistical inversion of level data and errors is beyond the scope of this paper and is unnecessary for the volcanic conclusions we draw. The tilt solution (addendum figure 3b) uses the water tube tilt changes between January 12, 1959 and July 7, 1960 (HVO tilt file, Asta Miklius, personal communication, 2009). This interval is as close as possible to the leveling interval, but includes the pre-eruption inflation in 1958–59, the November 1959 eruption, and most of the 1960 deflation. The tilt values (figure I2b), even when the Keʻāmoku site is excluded, do not define a smooth Mogi curve. The Mogi source at the depth of 2.53 km (determined from the 1/58-5/60 leveling survey) can't be determined from the noisy and sparse 1/59–7/60 tilt data, and a tilt-based source at 3.0 km depth is equally likely. The volume changes are 0.107 and 0.125 km^3, respectively. Even though the two 1959-60 volumes derived from tilt are very uncertain, they agree within 20–30% of each other, and are larger than the 0.07 km^3 volume determined from leveling because they exclude a year of prior inflation and include two additional months of deflation.

The 1/20/60 – 4/1/60 tilt survey (figure I4), started just after the great deflation had begun, is a large event and is fit as well by a Mogi solution as any Kīlauea an water tube tilt survey can be. We show alternative Mogi solutions at 2.5, 3.0, and 3.5 source depths. We exclude the errant Keʻāmoku station. The best fit is between the 3.0 km and 3.5 km source depths, where only the first two stations discriminate between those depths. The 2.5 km source depth, found for the 1/58–5/60 leveling survey, which includes the 1/60–4/60 tilt survey and two years of prior inflation, is a poorer fit to the water tube data. This suggests the pre-1960 inflation was centered shallower than 2.5 km, and the 1960 deflation was between 3.0 and 3.5 km.

The tilt results suggest that a well-placed tilt station (like Uwēkahuna or Whitney on the flank of a tilt bulge) can estimate the magnitude of an inflation or deflation to about 20%, once the location and depth of the center is known. The comparisons also suggest that level surveys are much better than tilt surveys to locate inflation centers: even a tilt survey made over the optimum 1/60-4/60 period where the changes are very large can only resolve depths to about a kilometer, but level surveys can resolve Mogi depths to about 0.2 km or better with smaller changes. Water tube tilt was measured more easily by a survey crew over a shorter time period than a level survey, and tilt provides a crude approximation to a level survey. We only use level surveys to estimate inflation/deflation centers (table I1).

The leveling and tilt data suggest the inflation in 1958–1959 was at a shallower 2–2.5 km Mogi center depth than the subsequent 1960 collapse, which was deeper, perhaps between 3.0 and 3.5 km, but this is not well-determined. Figure I2a demonstrates 2.53 km is a good average depth for the 150 microradian inflation and 350 microradian deflation (net 200 microradian deflation) of the whole 1958–60 episode. The 3.0 to 3.5 km source depth of the 1/20/60 – 4/1/60 tilt collapse (figure I4) suggests that the deflation occurred at a depth greater than the average. Thus the inflation (about half of the later deflation) must have been shallower than 2.53 km. We interpret this result to mean that the top of the magma reservoir expands in response to inflation and magma addition, but that deflations, particularly large ones, are centered deeper in the reservoir.

Both source depths and volumes are subject to errors in determination. Note that the source depth f can be fairly well determined by fitting the elevation profile (figure I2a). Estimating the source depth from a tilt profile as equal to twice the distance at which the maximum tilt occurs (figures I1b, I2b) can be more difficult, however: tilt varies widely near its maximum radius and near the source because tilt is very sensitive to non-Mogi irregularities of the source near the surface. Also there is more depth error if only sparse tilt data are available. Both the elevation and tilt curves scale linearly with the volume change ΔV. Thus the volume determination is generally well determined from a profile of height or tilt measurements, and is less sensitive to irregularities in the tilt curve. Choosing a short time period spanning a single but large inflation or deflation episode may yield a better fit from a simple Mogi source. The tilt data and multiple Mogi curves of figure I2b show that even if source depth and location are well known, volume estimates made from a single tilt measurement can easily be in error by about 20–40%, and more if the location is poorly known.

Multiple inflation and deflation centers and reservoir volume relations

We determined a Mogi inflation/deflation source for a large set of published level surveys, and can infer some characteristics of the magma reservoir source. We determined the deformation center locations, depth and volumes from contoured level survey maps using the same methods as in the sample cases above. The Mogi center locations and depths are in appendix figures A2 and I5 along with those of Fiske and Kinoshita (1969). The level profiles with model fits are in figures I6 and I7, and the events and parameters are listed in the table I1.

Most of the Mogi centers strongly cluster in the south caldera, with another smaller cluster in the central caldera. Two centers lie outside the main cluster (10/76–3/77 and 3/77–8/77), one to the south and one to the SW (appendix figure A2). The level surveys for these two centers involve a rift zone contribution and are not a bulls-eye pattern. Both the centers determined in this paper and the Fiske and Kinoshita (1969) centers define the two south and central caldera areas active during this period. The Fiske and Kinoshita centers may scatter a bit more in the east-west direction, but the apparent east-west lineation is not visible in the larger data set and two irregular clusters without an east-west lineation is a better representation of the active area.

We interpret the scatter of different deformation centers as both a shifting locus of magma accumulation and depletion, and the expression of a source that is irregular in shape and definitely not a point source as represented in the Mogi model. The 2 km extent of the sources is larger than the error associated with any one source, and individual error does not contribute much to the extent of sources. Detailed inversions of source shapes are possible using tilt, level and displacement data (eg. Dieterich and Decker, 1975), but we will only generalize that the deforming part of the caldera is an irregular shape about 2 km in diameter in the south caldera.

1924 subsidence

We determined three alternative Mogi models to the 1921–1927 survey which includes the large 1924 eruption and caldera collapse (Wilson, 1935). This was the largest eruption observed geodetically and the maximum deflation was more than twice that in the large January 1960 eruption. The models are for 1, 2 and 3 Mogi sources all centered below Halemaʻumaʻu . The first 1-source model with a deflation center at 1.65 km depth does not fit the level data very well (figure I6a). Adding a shallow deflation source 800 m below Halemaʻumaʻu to a source at a typical 3.8 km depth greatly improves the fit to level contours out to 6 km from the center (figure I6b). Subsidence did not stop at the caldera boundary 6 km from Halemaʻumaʻu, however, and the level line continued through Keaau (39 km from Halemaʻumaʻu) to Hilo. The line to Keaau is almost radial to caldera, but we do not model the dog-leg extension from Keaau to Hilo. A third deflation source at about 30 km depth is required to subside the flank of Kīlauea out to 40 km. We kept the shallow 800m source and moved the 3.8 km source to a depth of 3.5 km to get the best fit (figure I6c). The exact depth and volume of the 30 km source is definitely not well determined because it comes only from fitting the four points along the Volcano highway to Keaau. This is only one radial line and not a concentric set of confirming level curves as would be desired.

There is no geodetic record elsewhere in the past 200 years for a deforming magma source below the base of the crust. And yet Wilson’s leveling suggests a source on the order of 30 km distant from the documented sources within the crust beneath Halemaʻumaʻu. We suggest in the text for chapter 3 that the anomalous source is not a deep Mogi source beneath Halemaʻumaʻu, but rather as an eccentric and unlocated source that we postulate as representing the loss of a deep magma system beneath the east rift zone, a loss that extended beyond the documented intrusion near the end of the onshore east rift zone.

Filling and draining of magma reservoirs

The depths of the Mogi inflation/deflation centers illuminate the portions of the magma reservoir that fill between eruptions and drain during different size deflations. Refer to figure I8 showing the distribution of Mogi depths for centers listed in table I1 by the volume change of the event. Most inflation and deflation centers are between 3 and 4 km deep, and this is the most active part of the reservoir. All but one of the centers between 2.0 and 2.9 km are small inflation centers. This means the top of the active reservoir is just above 2 km depth. The exception to the small inflation in the upper reservoir rule is the 1/58–5/60 period, which includes two years of inflation followed by a larger deflation, with a net average depth of 2.5 km. Of course the upper reservoir can participate in other events, which also include volume changes in other parts of the reservoir and have deeper average Mogi centers. We exclude the 10/76–3/77 event as a special case: it is south of the caldera and is separated from the other centers laterally and is much deeper at 6.0 km. This center occurred during the recovery after the *M*7.2 Kalapana earthquake in which the south flank moved laterally south up to 6 m, and probably represents filling of the deeper voids in the Koae fault zone created by the earthquake as well as filling the shallow magma reservoir.

The largest volume reservoir events (>0.06 km^3) are different in distribution from the smaller events (figure I8). On average, the smaller events (<0.06 km^3) tend to inflate at a shallow center between 2.0 and 3.6 km, but small rapid deflation events are between 3.0 and 3.8 km. The four largest deflationary points include collapses from the 1924 eruption, the Nov. 1975 earthquake, and the Jan–Feb 1960 eruption (which is included in two survey periods). These four deflationary points have a linear trend where the larger the volume change, the deeper the deflation center. This means the draining must tap deeper parts of the reservoir to gain more magma volume change, and the deflation center moves downward as more of the deeper reservoir is tapped. The depths of different sized inflation and deflation sources means the reservoir tends to add magma at its top (like filling a pail) and to subtract magma lower down (like opening a valve on the side of a pail).

The linear relation of volume change of the largest deflations to the Mogi depth, and the observation that all volume changes lie below this line (figure I8), suggest that there is a geometric relation between the change of liquid magma and the total reservoir volume. The line defined by the four large deflations is $\Delta V = 0.089(f-1.75)$ where ΔV is the magma volume change in km^3, and f is the depth of the Mogi center. The intercept of this linear relation (1.75 km) and the shallowest observed Mogi depth (2.0 km) suggest that we assume the top of the reservoir is at 1.75 km. Let us also assume for modeling purposes that the active reservoir is a sphere centered at depth f. The deepening of this active reservoir with magma volume change also means the size of the active reservoir increases with depth. If we model the top of the reservoir at a depth of 1.75 km, its radius is f-1.75 and its volume V is $4\pi/3\ (f-1.75)^3$. The volume fraction of inflating/deflating magma is $\Delta V/V$, which in our model depends on f. For Mogi depths of 2.5, 3.0 and 3.5, the liquid to total volume fractions are 3.7%, 1.3% and 0.68%. Wright and Klein (AGU 2010) noted that erupted/intruded magma batches in mid-20th century Kīlauea eruptions had volumes of about 0.2 km^3, which for a reservoir diameter of 3 km, yields a liquid fraction of 1.4%, the same as our middle value. The hypothesized relation between liquid fraction and depth means that larger, deeper deflations have smaller liquid magma fractions by volume, and small shallow events have more liquid. Note that the observed volume changes in figure I8 are all below this maximum line because many volume changes occur within a spherical volume that does not reach the top of the reservoir at 1.75 km. Thus the top of the reservoir is mostly liquid and the bottom is mostly solid, which agrees with the lower density of magma compared to rock. Of course this reasoning is based on a simplified point model and is qualitative in nature.

Whitney tilt volume calculations

In an effort to determine magma center volume changes from a single tiltmeter, we examine the simpler period of January 20 to April 1, 1960, during which Kīlauea summit underwent a massive deflation associated with the East rift eruption of 1/13–2/19/1960. Unfortunately there is no level survey for this interval, but the deflation is included in a longer interval from 1/58 to 5/60 for which a level survey exists (table I1, event 1). We can use this 1960 deflation as an example of estimating source depth from two tiltmeters and volume change from a single tiltmeter. The tilts are 275 and 199 microradians and the source distances are 3.2 and 3.8 km for the short-base water tubes at Uwēkahuna and Whitney, respectively. Equation (6) thus yields a source depth of 3.0 km. Comparison of measured portable water-tube tilts and a calculated Mogi source at 3.0 km depth (figure I4) confirm the 3.0 km depth and a volume of

0.107 km^3 as a good fit to the tilt data, excluding Keʻāmoku as an amplified site. Note that (figure I5) the location of the two tiltmeters on the flank of the tilt bulge does not give a good resolution of the source depth but does measure the height of the tilt curve. The tradeoff between volume and source depth of the three curves of figure I4 means that for variation of +/- 0.5 km from its average source depth of 3.0 km, the magma volumes vary by +/- 20%. The volume error will be more than these interdependence variances. These tiltmeters gives similar volume estimates. From appendix table A2, the ratio of Whitney to Uwēkahuna tilt for a depth of 3 km is 1.38. We apply this ratio to the Dvorak factor for Uwēkahuna of 0.00045 km^3/micro-radian to yield 0.00062 km^3/micro-radian for the conversion of Whitney tilt magnitude to volume. We use this factor for the volume calculations during periods before 1960 when the only measurements were tilt made at the Whitney vault.

Given the good fit of a Mogi source to the water-tube tilts of the 1960 deflation, what volume changes do the continuous tiltmeters at Uwēkahuna and Whitney imply? We can both calculate theoretical volume factors from the 3.0 km source using equation (5), and determine empirical factors from the 0.107 km^3 source volume determined from all 7 tiltmeters. Equation (5) applied to Uwēkahuna yields a theoretical volume factor of D_{UT}=0.00035 km^3/microradian. The empirical volume factor using 275 microradians of deflation and a 0.107 km^3 source determined by the Mogi curve fit imply that D_{UE}=0.00039 km^3/microradian for Uwēkahuna. The empirical value is probably a better one to use because it uses volumes calculated by an array of tiltmeters and includes a tiltmeter site correction. The 0.107 km^3 source volume was determined by fitting a curve to an array of 7 tiltmeters, not just the tiltmeter whose volume factor we are determining. Increasing the theoretical volume factors calculated from equation (5) by 10% should empirically correct other sources measured at Uwēkahuna. Note that the Uwēkahuna short-base tilt in the 1966–67 inflation (figure I1b) similarly requires a positive 20% correction to match the Mogi source determined by the tiltmeter array. The empirical volume factor is similar to the summit volume factor value of 0.00045 km^3/microradian used by Dvorak and Okamura (1985) and Dvorak and Dzurisin (1993). Each tiltmeter will have its own volume factor D because it depends on the distance and depth to the source.

The theoretical volume factor for the Whitney tiltmeter and the 1960 deflation source is D_{WT}=0.00049 km^3/microradian, which is somewhat larger than the Uwēkahuna factor because Whitney is farther from the source. The empirical factor for Whitney is D_{WE}=0.00054 km^3/microradian. The theoretical volume factors for Whitney also require a 10% correction. Using equation (5) and typical deformation centers (table I1), we can calculate a table of tiltmeter volume factors for various Mogi locations and depths, and apply the 10% empirical correction (see table I2). The Dvorak factor for Uwēkahuna that we use (0.00045 km^3/micro-radian) corresponds to a source depth of ~ 3.8 km in appendix table A1. The tilt factor applied to the Puʻu ʻŌʻo -Kupaianaha (PK) eruption gave an eruption efficiency of 1.01 for deflation azimuths near Fiske-Kinoshita center 1. The dike volume estimated for the dike associated with episode 1 of the PK eruption is higher by a factor of 1.5 than the volume estimated by the tilt deflation (Hall Wallace and Delaney, 1995). If this volume is used in the summation of text table 7.8, the eruption efficiency is close to or slightly less than 1.

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Appendix table I1: Inflation/deflation centers derived from leveling contour maps.

seq.	start	end	Inf /def	lat d	lat m	lon d	lon m	F km	K(km^3)	Offset (m)	dV (km^3)	reference	geologic events	comments
0a	1921	1927	def	19	24.8	155	17.2	1.65	0.0091	-1.1	0.0571	Wilson 1935	1924 Halem. eruption	Two depth sources are required to fit levelling curve. (a) is single source
0b	ditto	ditto	ditto		ditto		ditto	0.8, 3.8	0.0016, 0.03	-0.6	0.010, 0.1884	ditto	ditto	(b) is two sources at 0.8 and 3.8 km depth which fits better & is good geologically
0c	ditto	ditto	ditto		ditto		ditto	0.8, 3.5, 30	0.0016, 0.024, 0.73	0.09	0.010, 0.15, 4.6	ditto	ditto	(c) is three sources which fits the caldera very well and the Volcano-Keaau level line toward Hilo. A spherical Mogi source at 30 km gives too large a volume, but deep or tectonic movement is required.
1	Jan-58	May-60	def	19	24.68	155	16.60	2.53	0.0112	0	0.0703	Eaton unpub	major ERZ eruption	Includes eruption deflations in 11/59 and 1-2/60 & prior inflations. +/-0.05 depth error
	1/20/1960	4/1/1960	Def		ditto		ditto	3.0-3.5	-	-	0.107-0.132	HVO water tube tilt files	ditto	Water tube tilt result, less precise than leveling, last part of above period.
2	7/1/1960	4/1/1963	inf	19	23.91	155	16.84	3.2	0.012	0.07	0.0754	Moore & Krivoy 1964 fig 4	summit & ERZ erupns.	NE transect
3	3/9/1965	7/15/1965	inf	19	24.84	155	16.53	3.3	0.001	0.023	0.0063	Wright et al 1968 fig 6		Map only shows contours, not benchmarks. Inflation after 3/5/65 eruption.
4	Jan-66	Jul-66	inf	19	24.26	155	16.64	2.95	0.001	0.012	0.0063	Fiske & Kinoshita 1969 fig 4b		Fiske & Kinoshita center 1.
5	Jul-66	Sep-66	inf	19	24.92	155	16.60	3.5	0.0013	0.025	0.0082	Fiske & Kinoshita 1969 fig 4c		Possible additional small shallow source. Fiske & Kinoshita center 2.
6	Jan-66	Oct-67	inf	19	23.86	155	16.74	3.3	0.009	0.095	0.0565	Fiske & Kinoshita 1969 fig 4a		
FK3	Oct 1966	Jan 1967		19	23.76	155	16.44							Fiske & Kinoshita center 3.
7	1/12/1967	2/27/1967	inf	19	23.70	155	17.20	2.9	0.0012	0.025	0.0075	Dieterich & Decker 1975 fig 11		North transcect. Fiske & Kinoshita center 4.
FK5	Feb 1967	Feb 1967		19	23.76	155	17.64							Fiske & Kinoshita center 5.
FK6	Feb 1967	May 1967		19	23.52	155	16.86							Fiske & Kinoshita center 6.
FK7	May 1967	June 1967		19	23.52	155	16.68							Fiske & Kinoshita center 7.
FK8	June 1967	July 1967		19	23.82	155	17.10							Fiske & Kinoshita center 8.
FK9	July 1967	Sept 1967		19	23.82	155	16.14							Fiske & Kinoshita center 9.
8	Sep-67	10/31/1967	inf	19	23.60	155	16.89	3.4	0.00145	0.017	0.0091	Kinoshita et al, Phys Volc fig 11		Map only shows contours, not benchmarks. Transect to N. 2x error in scale on map. Inflation before 1967-68 summit eruption. Fiske & Kinoshita center 10.
9	10/31/1967	11/10/1967	def	19	23.46	155	16.73	3.8	0.001	0.023	0.0063	Kinoshita & Koyanagi 1969 fig	11/5/67 caldera erupt	Average of NW & NE transects; "-1.5" cm contour approximate.
9a	11/10/1967	7/15/1968	Inf /def									Kinoshita & Koyanagi 1969 fig		Not Mogi source: Halemaumau deflates, Keanakakoi inflates.
10	7/15/1968	8/28/1968	def	19	23.86	155	16.61	3.0	0.0025	0.025	0.0157	Jackson et al 1975 fig 13	8/68 ERZ eruption	Contours elongate to NW-SE, N transect.
11	8/28/1968	10/10/1968	def	19	23.78	155	16.66	3.7	0.0028	0.026	0.0176	Jackson et al 1975 fig 32	10/68 ERZ eruption	Contours elongate to NS, innermost contour offset to south, NW transect.

12	7/15/1968	10/10/1968	def	19	23.94	155	16.64	3.2	0.0045	0.055	0.0283	Jackson et al 1975 fig 35	two ERZ eruptions	Includes two previous periods.
13	2/5/1969	3/5/1969	def	19	24.18	155	16.92	3.7	0.0018	0.012	0.0113	Swanson et al 1976 fig 20	2/69 ERZ eruption	N-S kidney shaped contours.
14	2/9/1970	5/20/1970	inf	19	23.47	155	16.63	2.5	0.0012	0.012	0.0075	Duffield et al 1976 fig 7		Shallow deflation source 2 km NE of inflation center; elongate source.
15	6/8/1971	8/25/1971	inf	19	24.24	155	16.55	2.3	0.0012	0	0.0075	Duffield et al 1982 fig 4	8/14/71 caldera erupt	Kidney shaped contours; average of E and W transects; possible deep ~30 km source may improve curve fit.
16	8/25/1971	9/30/1971	inf	19	24.13	155	17.46	2.0	0.0019	0.02	0.0119*	Duffield et al 1982 fig 9	9/24/71 SWR eruption	Intrusion made an inflation signal, not deflation. Elongated contours follow SW rift; volume thus underestimed; NW transect from uprift end of source.
17	9/30/1971	1/20/1972	inf	19	23.98	155	16.98	3.6	0.0042	0.04	0.0264	Duffield et al 1982 fig 10b		Includes deflation after 9/24/71 SWR eruption plus subsequent inflation.
18	11/30/1971	1/20/1972	inf	19	23.76	155	16.80	3.5	0.0023	0.025	0.0144	Tilling et al 1987 fig 16.38		Subset of previous period, primarily with inflation and no deflation.
19	6/12/1972	12/13/1972	def	19	23.87	155	17.40	4.6	0.017	0.15	0.1068	Ryan et al subsidence mech fig 15		average of NW and SE transects
20	12/4/1972	5/12/1973	def	19	23.82	155	16.64	3.7	0.00154	0.022	0.0097	Ryan et al subsidence mech fig 18	5/5/73 ERZ eruption	East rift has a non-Mogi dike intrusion deformation, but caldera has Mogi src.
21	11/13/1973	4/5/1974	inf	19	24.68	155	16.65	2.6	0.00048	0.05	0.0030	Lockwood et al 1999 fig 17a		Complex pattern in S & E caldera; inner contour not fit by model and may require a very shallow sourcel; SW transect
22	4/4/1974	7/31/1974	inf	19	24.40	155	16.42	3.0	0.0019	0.004	0.0119	Lockwood et al 1999 fig 17b		SSE transect, contours elongate to NE.
23	7/26/1974	10/1/1974	inf	19	24.16	155	17.24	2.9	0.0021	0.014	0.0132	Lockwood et al 1999 fig 17c		East transect; contours elongate to NE.
24	9/30/1974	1/13/1975	def	19	24.10	155	16.94	3.0	0.007	0.06	0.0440	Lockwood et al 1999 fig 17d	SWR eruption	Average of NW & NE transects; inner contour poorly fit.
25	Jan-75	Sep-75	inf	19	23.68	155	16.74	3.3	0.0064	0.05	0.0402	Lipman et al 1985 fig. 17b		
26	Sep-75	Jan-76	def	19	23.72*	155	16.84*	3.4	0.022	0.4	0.1382*	Lipman et al 1985 fig. 17c	M7.2 earthquake	Elongate dike-like bulge along SWR and diminished central bulge relative to Mogi model. Mogi volume is thus overestimated for summit, but total volume including SW extension may be underestimated by Mogi model.
27	Jan-76	Sep-76	def	19	23.74	155	16.71	3.5	0.0041	0.107	0.0257	Lipman et al 1985 fig. 17d		Post earthquake deflation; ERZ deflation from intrusions.
28	Oct-76	Mar-77	inf	19	23.19	155	16.42	6.0	0.0049	0.03	0.0308	Lipman et al 1985 fig. 17e		Southerly, deep deflation center; one ERZ intrusion.
29	Mar-77	Aug-77	def	19	22.85*	155	18.30*	3.1	0.00068	0.01	0.0043*	Lipman et al 1985 fig. 17f		Mogi fit to west end of elongate depression across south caldera with small bump in middle. Actual source is maybe 2x larger and more irregular than Mogi.
30	8/25/1977	9/23/1977	def	19	23.92	155	16.74	3.5	0.0059	0.05	0.0371	Lipman et al 1985 fig. 17g	ERZ eruption	West transect. Excellent Mogi fit.
31	Dec-83	Nov-91	def	19	23.45	155	16.94	3.7	0.00118	-0.003	0.0074	Delaney et al 1993 fig 5	ERZ eruption	Steady deflation sustained Puu Oo eruption. Total from 8 yr average.
32	1996	2002	Def	19	23.40	155	16.43	3.2	0.004	-0.025	0.025	Cervelli and Miklius 2003 fig 5	ERZ eruption	Steady deflation sustained Puu Oo eruption. Total from 6 yr average.

(*) Irregular source shape, Mogi elevation contours not a good fit, but source depth may be OK.

Contours roughly circular unless noted otherwise. Mogi a good fit unless noted with *. Transect through contours taken to give "average" radii to the NW or N unless noted otherwise. Zero contour assumed to be arbitrary and chosen at an outer benchmark within deformation zone, thus the offset factor adjusts the data to a baseline to fit the Mogi curve.

Appendix table I2. Long-base water-tube tilt vectors 1960-1965

Cycle	Begin	End	Lon.	Lat.	Mag.	Az.	Comment	Reference
1960	12/28-31/1959 12/29/1959 1/13/1960 1/18/1960	9/22-24/1960 9/24/1960 2/21/1960 7/24/1960	155.278	19.404	 72.82 77.03	 122.69 124.01	[i]TM; U; K[ii]; SS[iii] A[iv]; deflation Match water-tube[v] **Eruption—lower east rift zone** 1960 deflation[vi]	
1960-1961	9/16/–24/1960 9/19/1960 7/24/1960 9/21/1961 7/21–25/1961 7/22/1961 9/21/1961	7/21–25/1961 7/23/1961 9/21/1961 9/25/1961 10/6–11/1961 10/7/1961 9/30/1961	155.279 155.280	19.399 19.399	 54.22 67.98 25.00 35.73	 306.14 305.69 135.87 135.82	TM; U; K; SS; A; inflation Match water-tube 1960-1961 inflation **Eruption—middle east rift zone** TM; U; K; SS; A; deflation Match water-tube 1961 deflation	
1961-1962	10/6–11/1961 10/7/1962 9/30/1961 12/7/1962 10/26–11/1/1962 12/6/1962	10/26–11/1/1962 10/29/1962 12/6/1962 12/9–12/1962 12/10–12/1962 12/12/1962	155.2815 155.282	19.399 19.399	 21.19 25.13 1.98 4.85	 302.75 301.36 147.26 133.47	TM; U; K; SS; A; inflation Match water-tube 1961-1962 inflation **Eruption—upper east rift zone** TM; U; K; SS; A; deflation Match water-tube 1962 deflation	1 2 13; 14 2
1962-1963	12/10–12/1962 12/12/1962 5/8/1963 5/8/1963 3/18–21/1963 3/20/1963 7/2/1963 6/27/1963 5/10–14/1963 5/13/1963 7/3–6/1963 7/5/1963 8/21/1963 8/20/1963	3/18–21/1963 3/20/1963 5/12/1963 5/12/1963 5/10–14/1963 5/13/1963 7/4/1963 7/2/1963 7/3–6/1963 7/5/1963 8/5–12/1963 8/7/1963 8/23/1963 8/22/1963	155.280 [vii] 155.283	19.400 19.397	7.05 7.22 5.64 4.91 2.55 2.67 2.37	325.64 126.27 91.21 119.64 332.24 290.85 112.07	TM; U; K; SS; A; inflation Match water-tube **Intrusion-Koae fault zone** deflation TM; U; K; SS; A; mixed Match water-tube **Intrusion-Koae fault zone** deflation TM; U; K; SS; A[viii]; mixed Match water-tube TM; U; K; SS; A; inflation[ix] Match water-tube **Eruption—upper east rift zone** deflation	3 4 5 6

Appendix table I2 cont.

Cycle	Begin	End	Lon.	Lat.	Mag.	Az.	Comment	Reference
	8/5–12/1963	8/22-23/1963	nd	nd			TM; A; south of FK centers	7
	8/22/1963	10/4/1963			5.61	282.67	inflation	
	10/5/1963	10/6/1963					**Eruption—middle east rift zone**	
	10/4/1963	10/10/1963			16.62	124.36	deflation	
	8/5–12/1963	10/7-11/1963	155.278	19.395			TM; U; K; SS; A[x] deflation	8
	8/7/1963	10/9/1963			12.46	131.52	Match water-tube--deflation	
1963-1965	10/7-11/1963	1/17-19/1965	155.280	19.400			TM; U; K; SS; A—inflation	9
	10/9/1963	1/18/1965			17.84	300.41	Match water-tube—inflation	
	10/10/1963	3/5/1965			21.46	302.13	Inflation—entire period	
	1/17-19/1965	3/6-8/1965	155.277	19.399			TM; U; K; SS; A--deflation	10
	1/18/1965	3/7/1965			14.40	126.44	Match water-tube--deflation	
	3/5/1965	3/15/1965					**Eruption—middle east rift zone**	
	3/5/1965	3/9/1965			18.10	128.36	Syn-eruption deflation	
	3/6-8/1965	8/30-9/7/1965	155.275	19.406			TM; U; K; SS; A--inflation	11
	3/9/1965	9/5/1965			5.84	287.10	Match water-tube--inflation	
	3/9/1965	12/23/1965			11.21	281.58	Inflation—entire period	
	12/25/1965	12/25/1965					**Eruption—upper east rift zone**	
	12/23/1965	12/28/1965			9.85	98.33	deflation[xi]	
	8/30-9/7/1965	12/27-30/1965	15.275	19.399			TM; U; K; SS; A--deflation	12
	9/5/1965	12/28/1965			4.43	101.61	Match water-tube--deflation	

References

1(Koyanagi and others, 1963; Krivoy and others, 1963; Krivoy and others, 1964); 2 (Krivoy and others, 1964); 3 (Koyanagi and others, 1964); 4 (Krivoy and others, 1965); 5 (Koyanagi and others, 1964); 6 (Koyanagi and others, 1964); 7 (Koyanagi and others, 1964); 8 (Okamura and others, 1964?); 9 (Kinoshita and others, 1965?; Koyanagi and others, 1965; Koyanagi and others, 1965; Okamura and others, 1965; Okamura and others, 1966); 10 (Okamura and others, 1966); 11 (Koyanagi and others, 1966; Powers and others, 1966); 12 (Koyanagi and others, 1969); 13 (Okamura and others, 1963); 14 (Okamura and others, 1964)

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[i] Long-base water-tube tilt stations in use: Tree Molds; Uwekauna; Keaumoku; Sand Spit; Ahua (figure 18). One additional station (Kalihipaa) lies to the south of the network on the map. Magnitudes are small and azimuths from this station are not used.

[ii] The Keaumoku station vector is consistently ~10 degrees more southerly than the intersection of the other vectors

[iii] Sand Spit lies very close to the centers of inflation/deflation and its azimuth determines the direction to the center

[iv] The Ahua station vector is consistently ~10 degrees more westerly than the intersection of the other vectors

[v] Results from the daily readings in Uwekahuna vault measured over the same time interval as the long-base network

[vi] Results from the daily readings in Uwekahuna vault measured over the entire period of inflation or deflation

[vii] Inconsistent tilt intersection. Ahua (southernmost station) shows deflation toward Koae fault zone—other stations mixed

[viii] Ahua shows inflation toward Koae—still recording recovery from Koae intrusions

[ix] Ahua shows deflation toward the Koae-still showing effects of Koae intrusions

[x] Anomalous deflation toward east rift zone associated with Koae deformation and intrusion

[xi] Ahua shows deflation toward Koae; Uwekahuna, Tree Molds and Sand spit show deflation toward east rift zone

Figure I1. Comparison of leveling contour radii (*A*) and water-tube tilt surveys (*B*) around Kīlauea Caldera for the nearly identical time periods of the two survey types (March 1966–November 1967 for tilt, January 1966–October 1967 for leveling). Leveling data from Fiske and Kinoshita (1969); water-tube tilt data from the files of the Hawaiian Volcano Obsrvatory. The same Mogi model is compared to both data sets—source depth of 3.3 km; source volume of 0.056 km^3. The Mogi fit was to the level data, which is much better at determining the location and depth of the Mogi center. The tilt data confirms that a Mogi source fit can only approximate the tilt data. Tilt data, particularly from a short-base tiltmeters in a vault, has the advantage of frequency of measurement. The tilt at the Uwēkahuna Vault closely matches the Mogi model and thus is a good measure of source volume, assuming the source is about 3 km distant. For locations of the long-base water-tube tiltmeters, see figure I5.

Figure I2. Comparison of leveling contour radii (*A*) and water-tube tilt surveys (*B*) around Kīlauea Caldera for the overlapping but nonidentical time period including the major 1960 collapse. The source depth of 2.53 km is well determined for the January 1958–May 1960 leveling interval. A depth error of about +/-0.05 km is a minimum error because it only considers misfit of the average radii data points to the Mogi model and not other error sources (see text). The same source depth (with an adjustment for a slightly larger volume change) adequately fits the tilt data for the shorter January 1959–July 1960 period. A deeper Mogi source at 3.0 km (blue curve in *B*) improves the tilt fit for the shorter time interval, however. For locations of the long-base water-tube tiltmeters, see figure I5.

Figure I3. Elevation changes in the Kïlauea summit region, from 1958 to July 1960. Contour interval in feet. The primary zone of subsidence is centered on Halemaÿumaÿu Crater. A secondary zone of subsidence is defined near Makaopuhi Crater on Kïlauea's east rift zone. This is an area of secondary magma storage and intrusion that has also been active during subsequent eruption cycles (Jackson and others, 1975, figure 32; Moore and Krivoy, 1964, figure 4; Swanson and others, 1976b, figure 4). Finally, the changes along the Hilina Pali road, traversing the Koaÿe Fault Zone between the east rift and south flank, show seaward tilting in the Koaÿe, and relative uplift of the south flank across the Kalanaokuaiki Pali. This uplift is consistent with movement of magma from the upper parts of Kïlauea's east rift zone combined with seaward movement of Kïlauea's south flank. This is also in agreement with the south-southeast azimuths of Whitney tilt vectors shown in text figure 4.3 during this period. (Contour map produced by the Topographic Division of the U.S. Geological Survey at the request of Jerry Eaton. Based on unpublished data of Jerry Eaton).

Figure I4. Tilt values from the water-tube tilt array for the major caldera collapse from 20 January to 1 April 1960. Also plotted are Mogi model curves for three different source depths. The large size of the tilt values relative to background noise mean this is the best data in the Kīlauea water-tube tilt record to constrain a Mogi source, yet there is still uncertainty with regard to the source depth. A depth of 3.0–3.5 km fits better than the shallow 2.53-km depth for the longer period that includes both inflation and deflation (figure I2). Fortunately, the Uwēkahuna Vault is well placed to record the the source amplitude (for volume calculations) and is relatively insentive to source depth because the model curves intersect near the 3-km distance of Uwēkahuna for this source location. For locations of the long-base water-tube tiltmeters, see figure I5.

Figure I5. Location of inflation-deflation centers. Using Mogi models: Tiltmeter locations are shown as green triangles, and locations of inflation and deflation centers as red circles. The green stars are centers from the mid 1960s identified by Fiske and Kinoshita (1969). The blue symbols are locations of the long-base water-tube tilt network. Red x's are geographic features. The blue symbols (keyed to depth) in appendix A figure A2 (not shown here) are inflation and deflation centers determined in this study and listed in appendix table I1. Using long-base water-tube network: Tilt vectors are tabulated and plotted in Hawaiian Volcano Observatory seismic summaries. As the tilt vectors do not intersect in a point, the location is estimated by eye from the various plots. The Sand Spit and Outlet stations lie very close to the centers of inflation/deflation located south-southeast of Halemaʻumaʻu. The locations plotted use The Sand Spit tilt vector to place the deformation epicenter, even though intersections from other pairs of stations, for example Tree Molds and Uwēkahuna, may lie on the opposite side of Sand Spit from that indicated by the vector at Sand Spit. The centers of inflation and deflation all lie within the Fiske-Kinoshita array within an area of 1 km^2 marked by black oval and are approximately equidistant from Uwēkahuna. Time periods covered by inflation (+) and deflation (-) centers are labeled as follows:

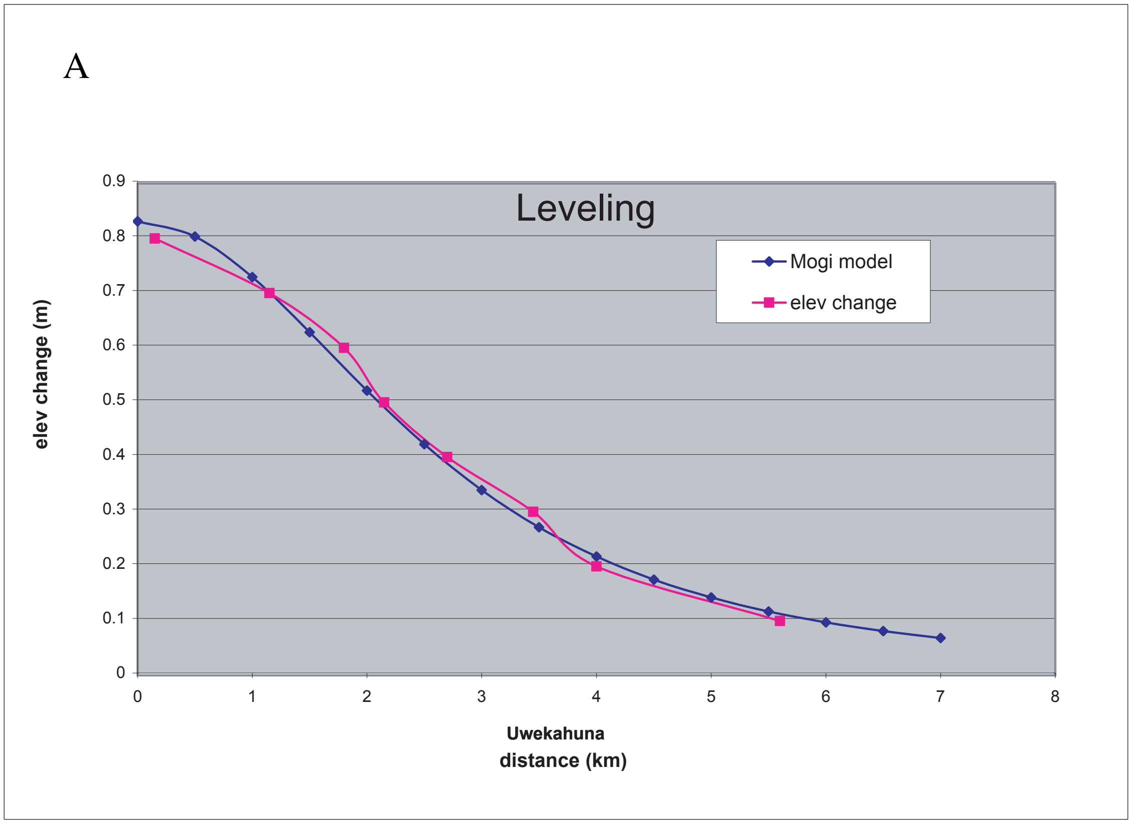
Centers of inflation			Centers of deflation		
Label	Begin date	End date	Label	Begin date	End date
i1	9/23/1960	7/23/1961	d1	12/30/1959	9/23/1960
i2	10/9/1961	10/30/1962	d2	10/30/1961	12/11/1962
i3	12/11/1962	3/20/1963	d3	7/23/1961	10/9/1961
i4	7/5/1963	8/10/1963	d4	8/10/1963	10/9/1963
i5	10/9/1963	1/18/1965	d5	1/18/1965	3/7/1965
i6	3/7/1965	9/3/1965	d6	9/3/1965	12/29/1965

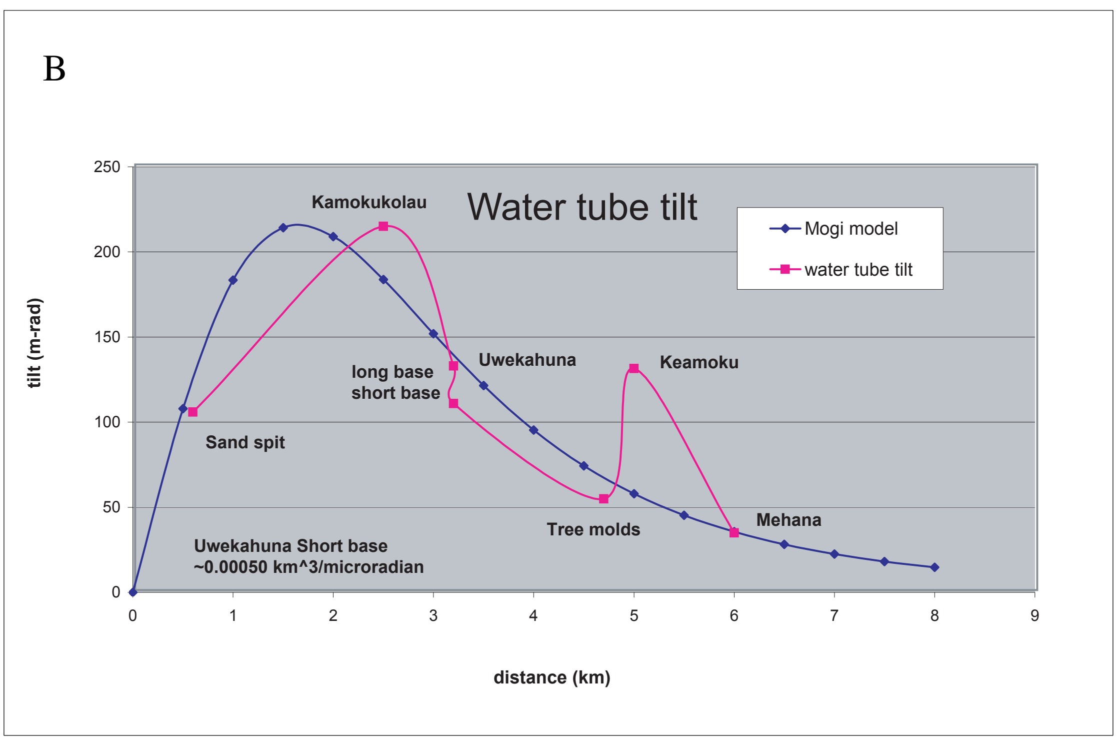
Figure I6. Elevation profiles vs. radius from the Mogi inflation/deflation center, determined for the 1924 subsidence measured between 1921 and 1927, assuming a single source (*A*), two sources (*B*) or three surces (*C*). See table I1 for the Mogi sources.

Figure I7. Elevation profiles vs. radius from the Mogi inflation/deflation center, determined for the set of 32 survey time periods after 1924 that are listed in table I1. The elevation vs. distance data are for the average radius from all published elevation contour maps the authors could locate in the literature. The iteratively determined Mogi fits are also plotted. The sub-figure numbers (01 to 32) are keyed to survey numbers in table I1.

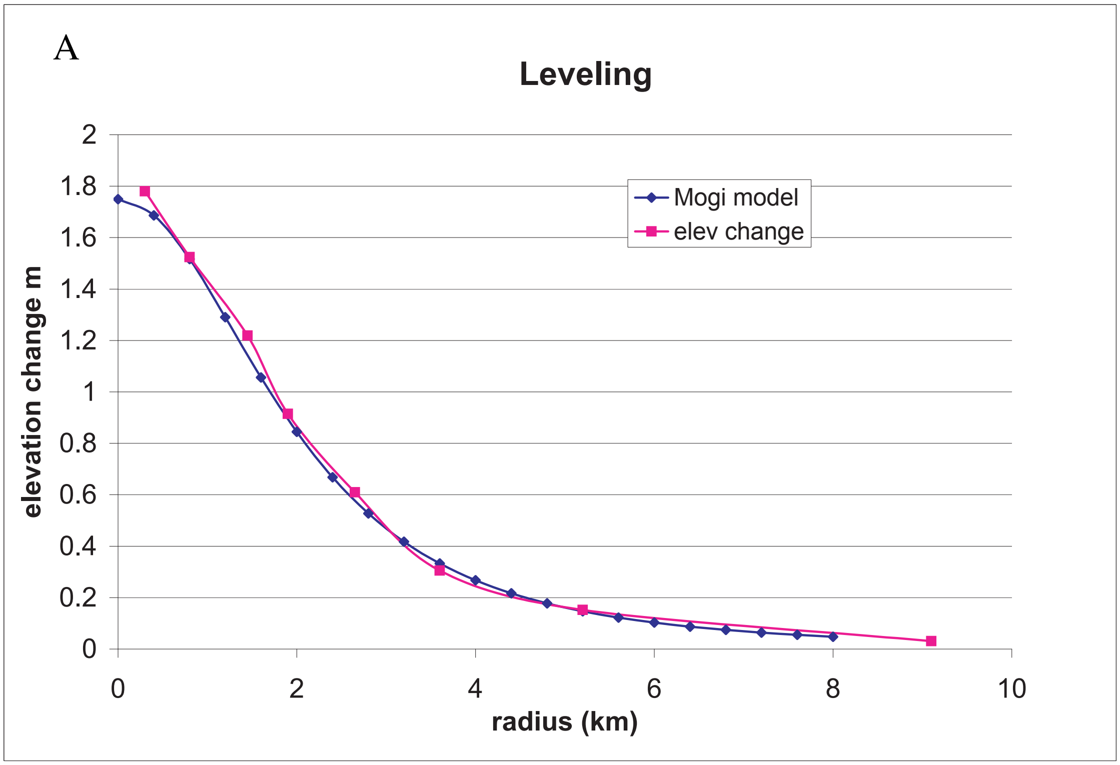
Figure I8. Mogi volume changes vs. Mogi source depths for the set of time periods listed in table I1. The inflation center depths (squares), which are almost exclusively in the range from 2.0 to 3.5 km, average less than the deflation depths (diamonds), which are concentrated in the range of 3.0 to 3.8 km. This means the reservoir tends to expand near its top, but deflate from lower down near 3–4 km. The four largest volume deflations nearly form a line which is an empirical limit to the size of the maximum deflation, with larger deflations limited to Mogi centers lower in the reservoir. This linear relation of volume to depth, when combined with the assumption that the top of the reservoir is at about 1.75 km depth, predicts that the percentage of the active fraction of magma increases with shallower depths. Thus the top of the reservoir is mostly liquid and the bottom is mostly solid.

Appendix fig I1. Leveling data 1/66-10/67 (Fiske and Kinoshita 1969)
Water tube tilt data 3/16/66 - 11/7/67 (HVO files)
Mogi model for both: 3.3 km source depth, 0.056 km^3 source volume

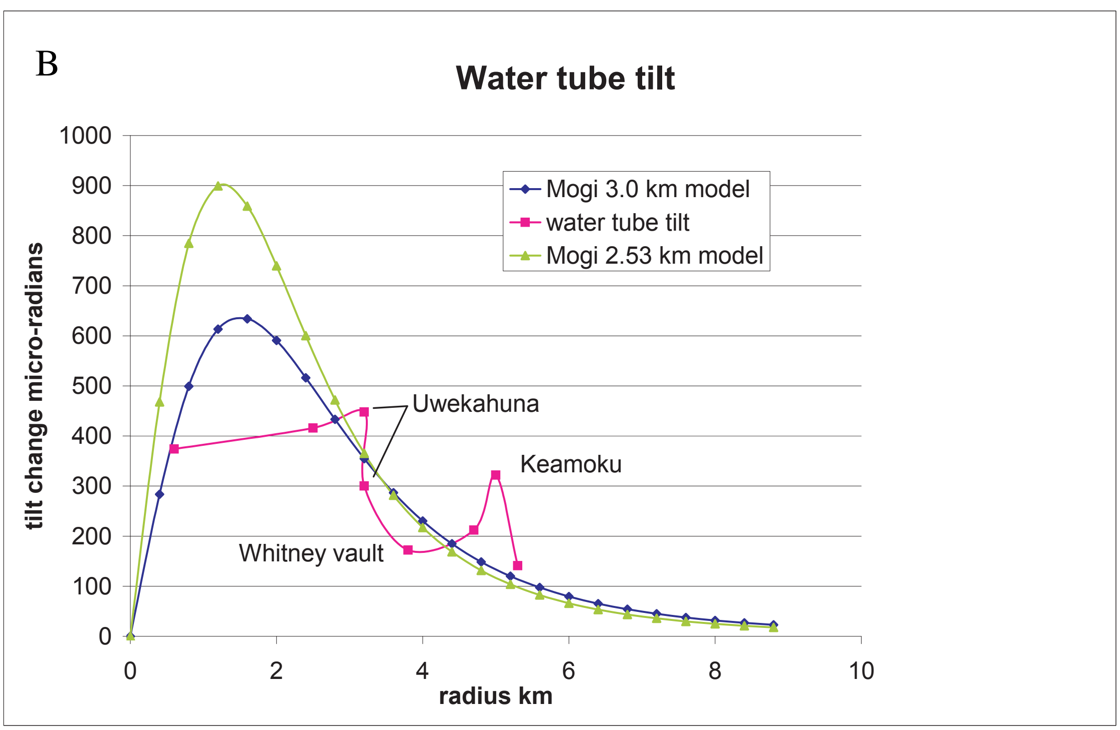




Appendix fig I2.



a. 1/58-5/60 inflation & collapse. 2.53 km deep source, deflation volume 0.07 km^3.



b. 1/12/59-7/7/60 inflation & collapse. 3.0 km deep source, deflation volume 0.125 km^3. Alternative 2.53 km deep source, deflation volume 0.107 km^3

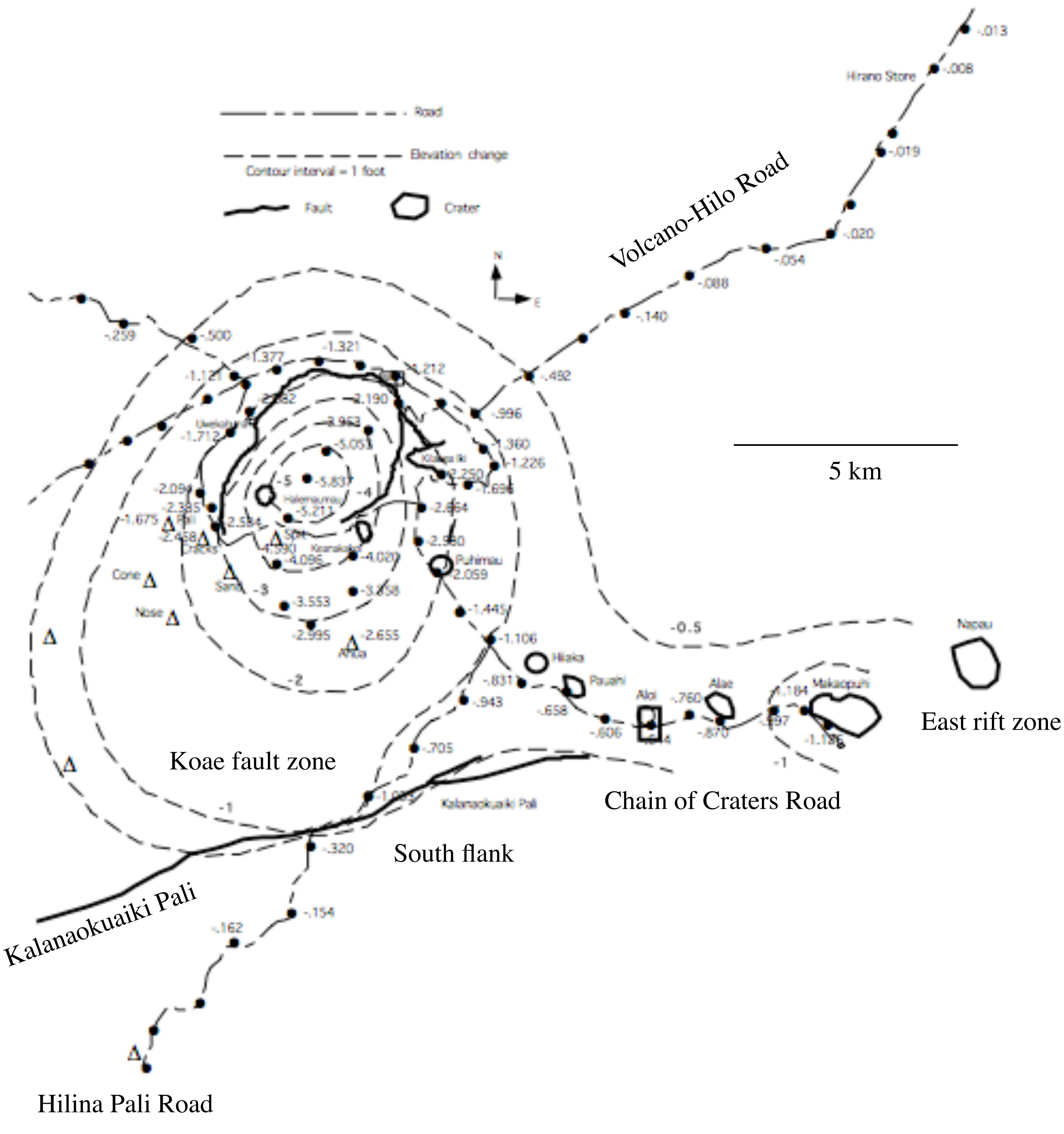
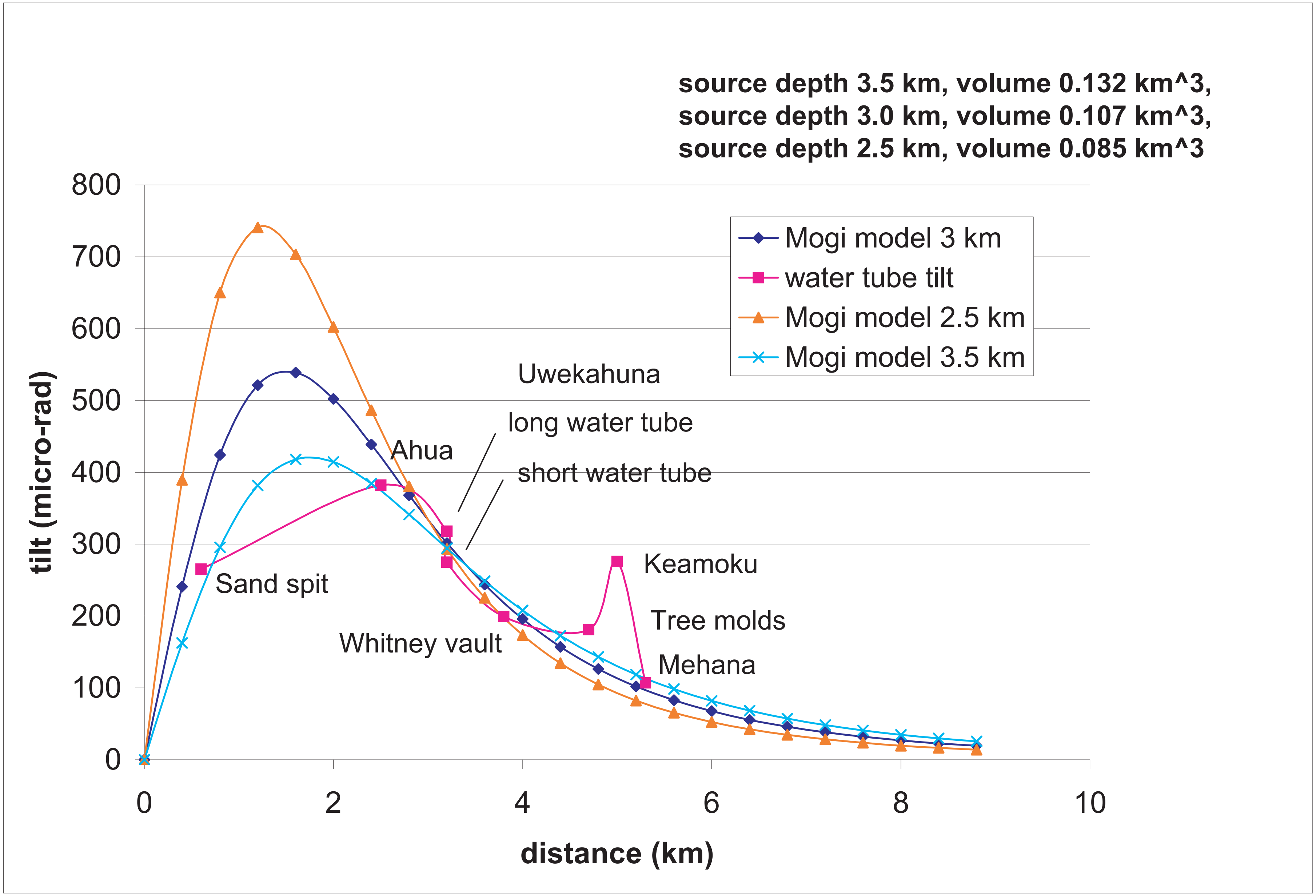
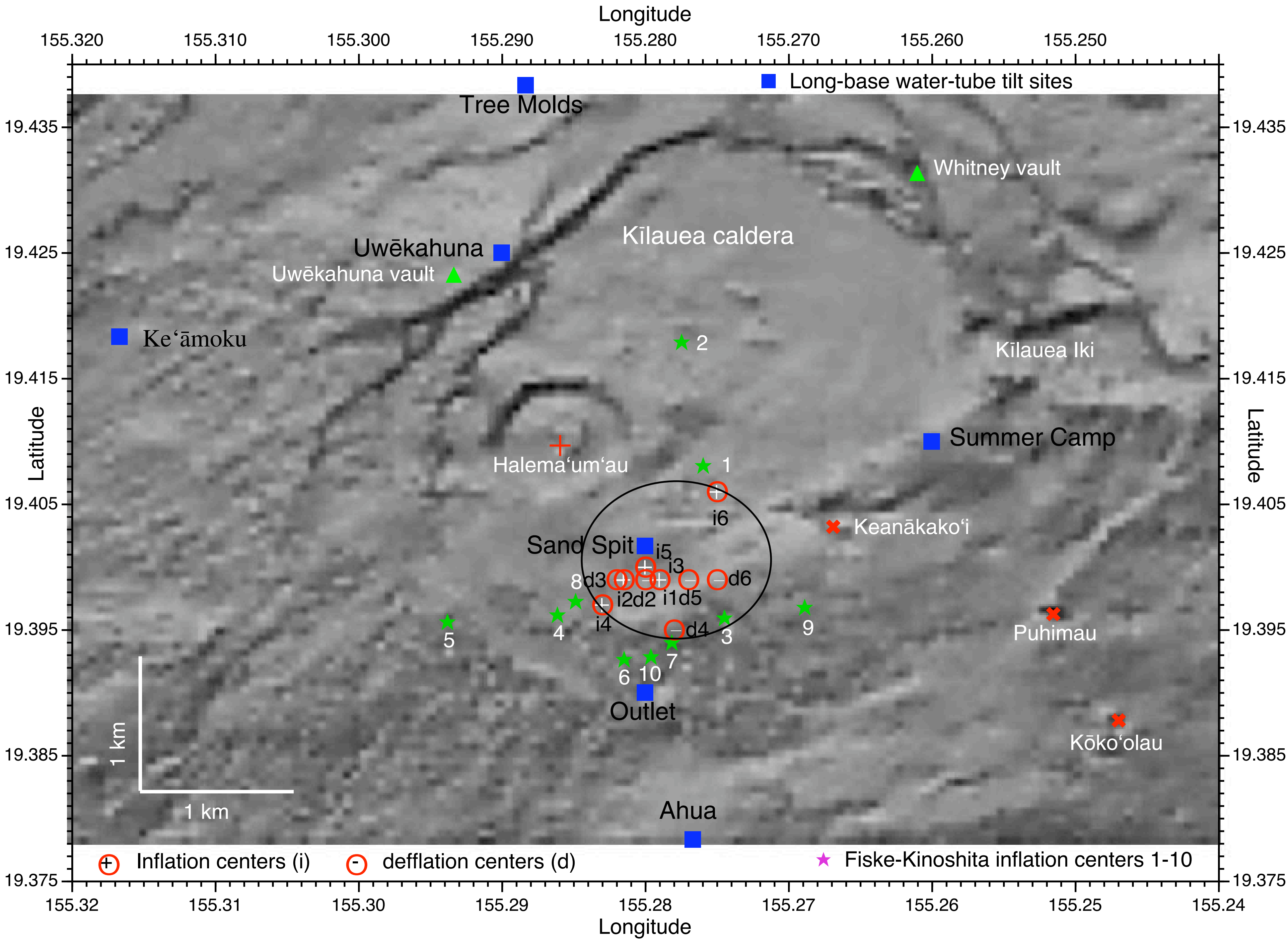


Figure I3. Elevation changes, 1958-July 1960 [Run by the Topographic Division of the U.S. Geological Survey at the request of Jerry Eaton; unpublished data courtesy of Jerry Eaton]

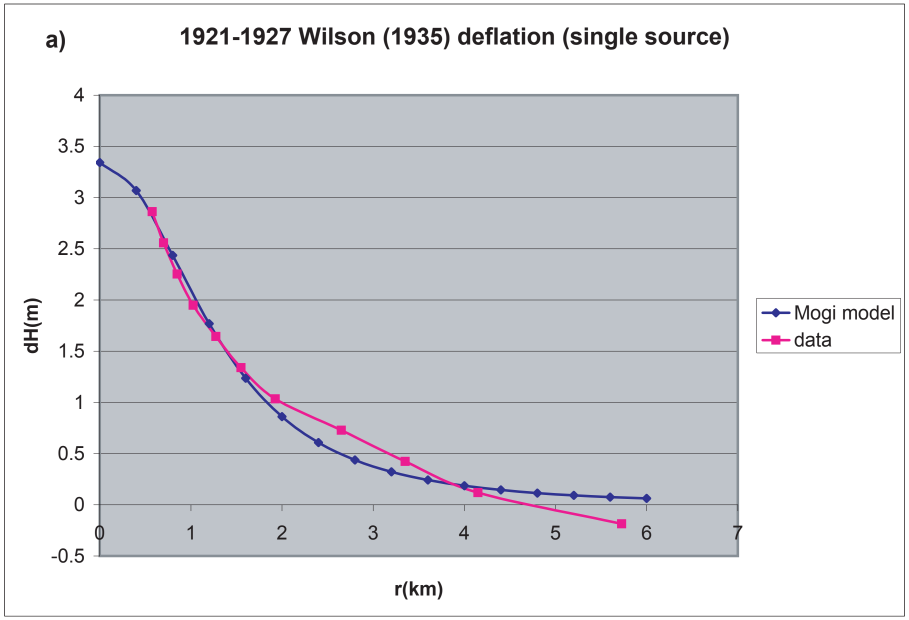
Appendix fig I4. 1/20/60 - 4/1/60 collapse, water tube tilt

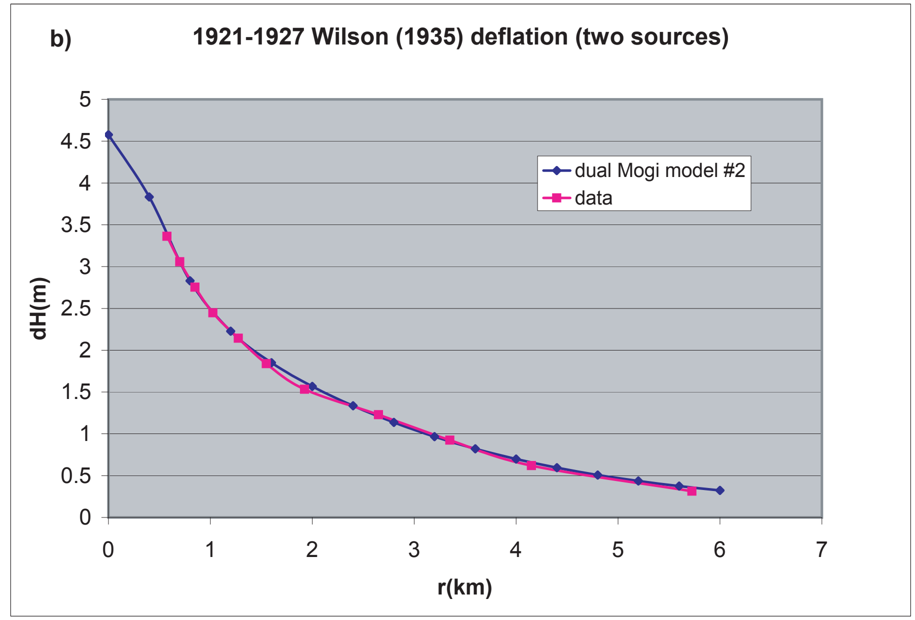


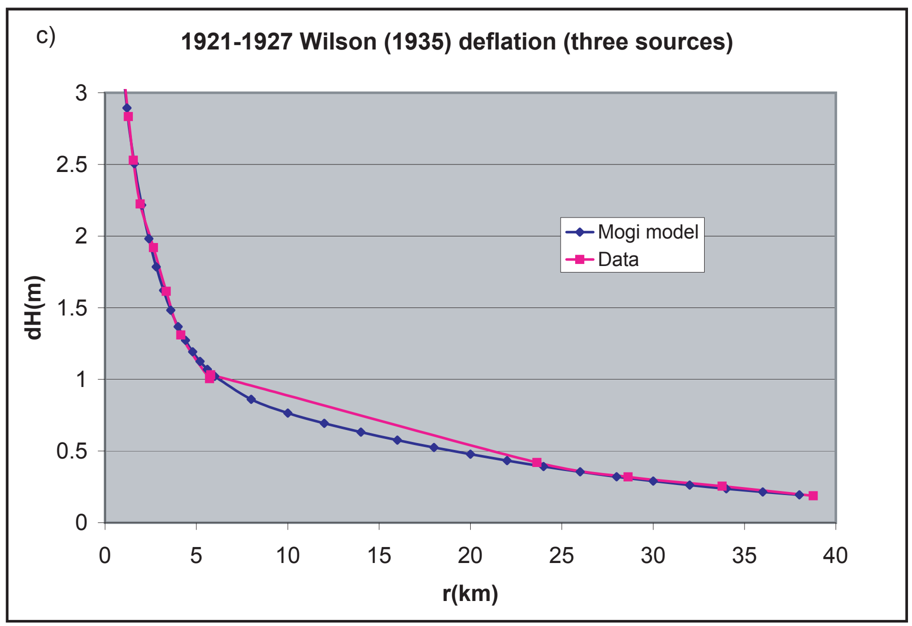
Appendix I. Figure I5 Inflation/deflation centers determine from the long-base water tube network



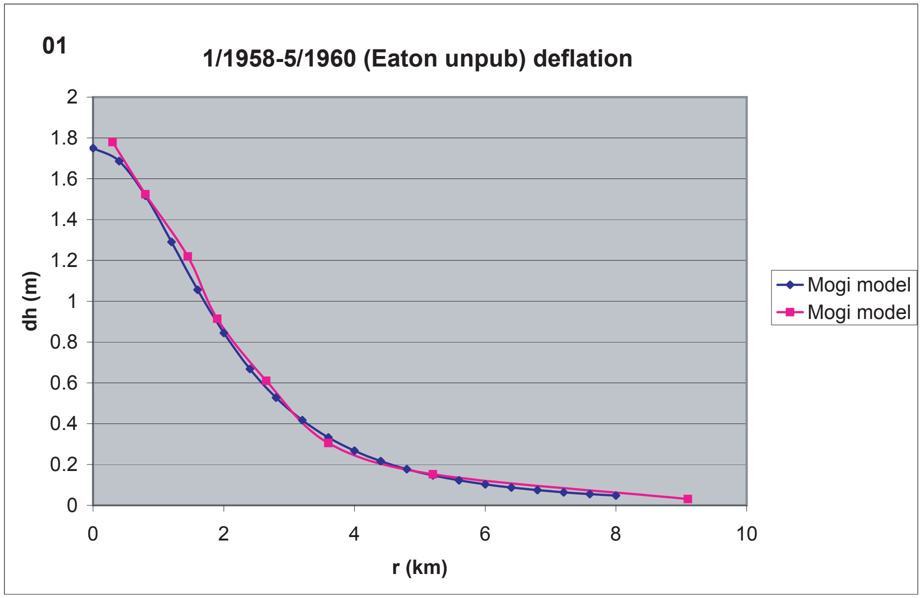
Appendix fig. I6. Mogi model fits to contoured levelling data. See addendum table I1 for Mogi source data.

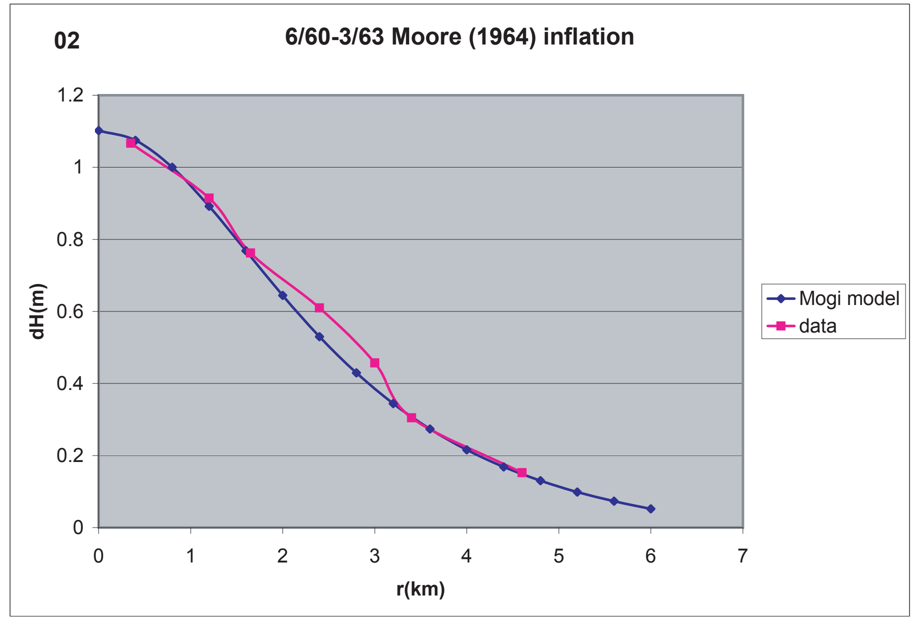


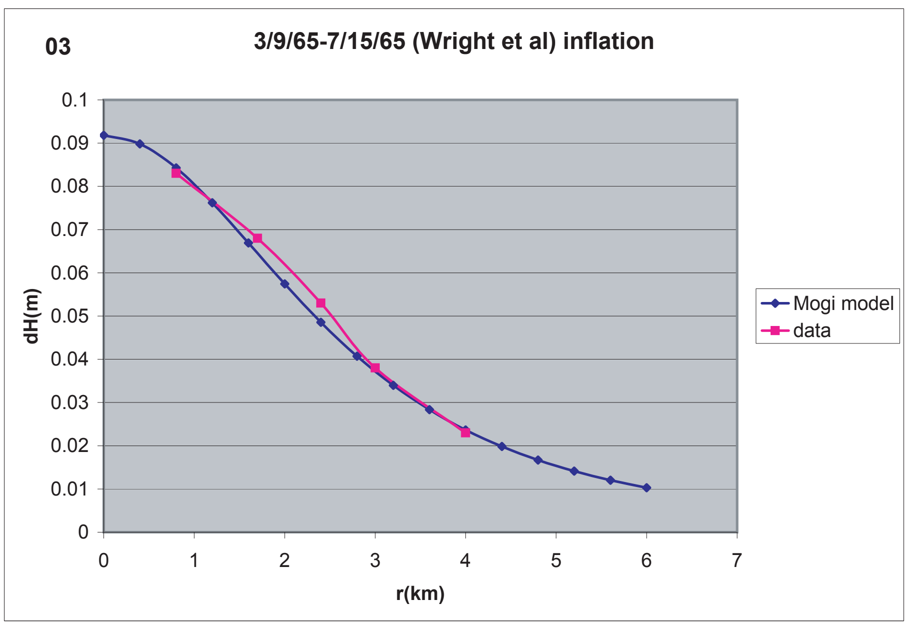


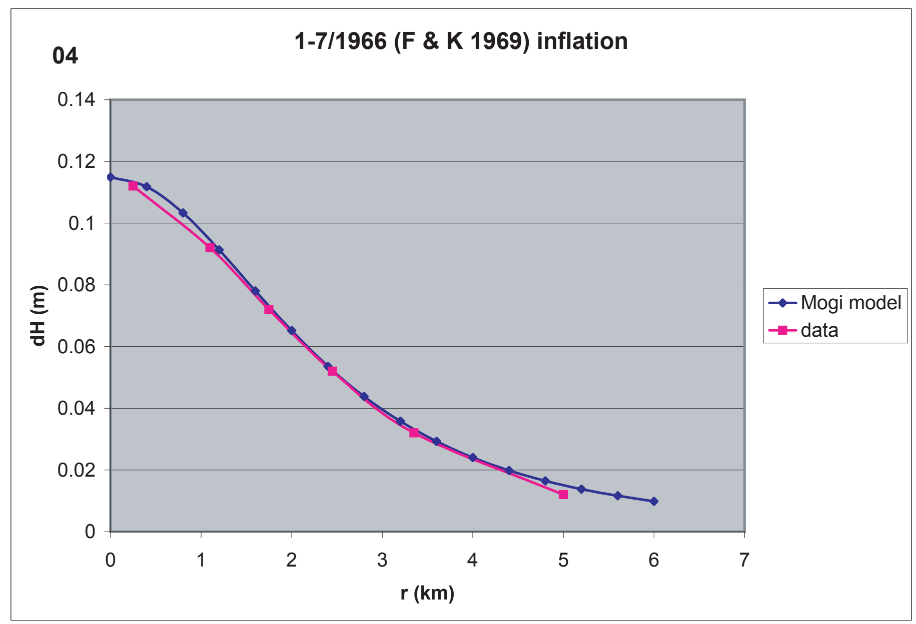


Appendix fig. I7.01-04. Mogi model fits to contoured levelling data. See table I1 for Mogi source data.

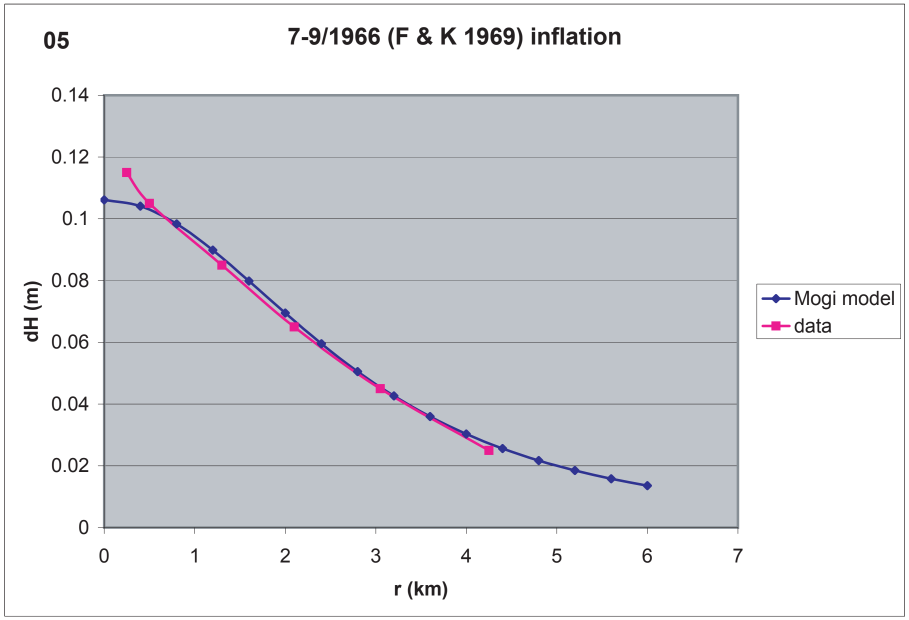


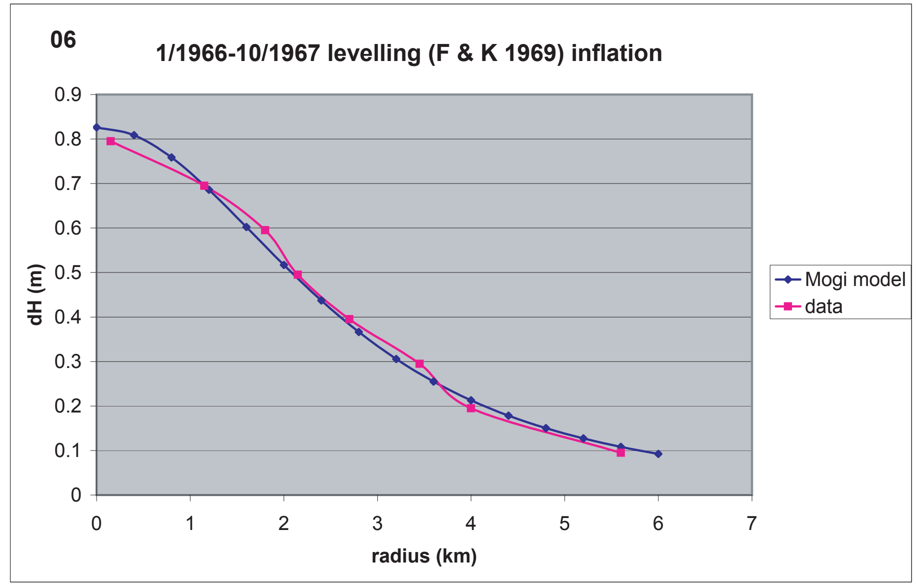


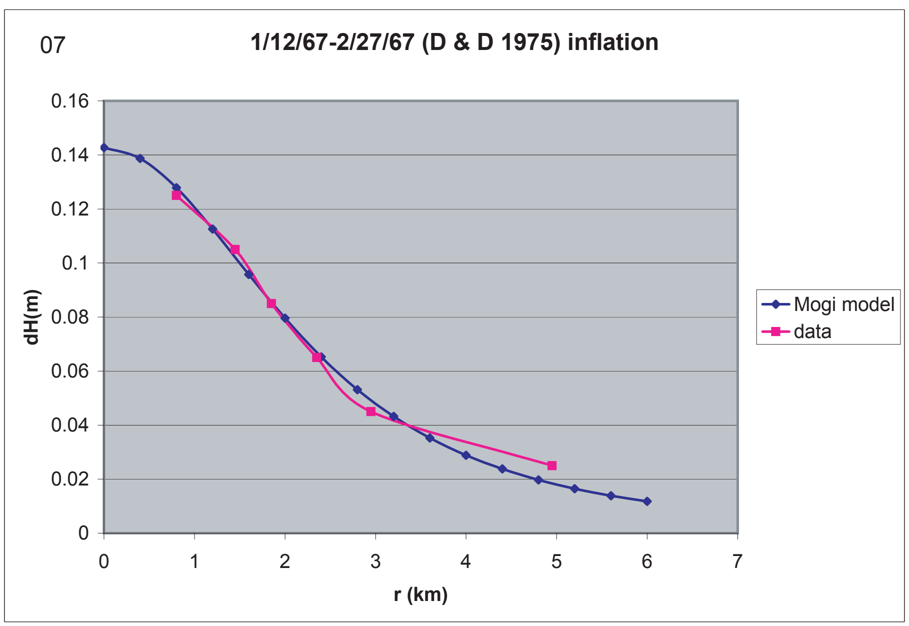


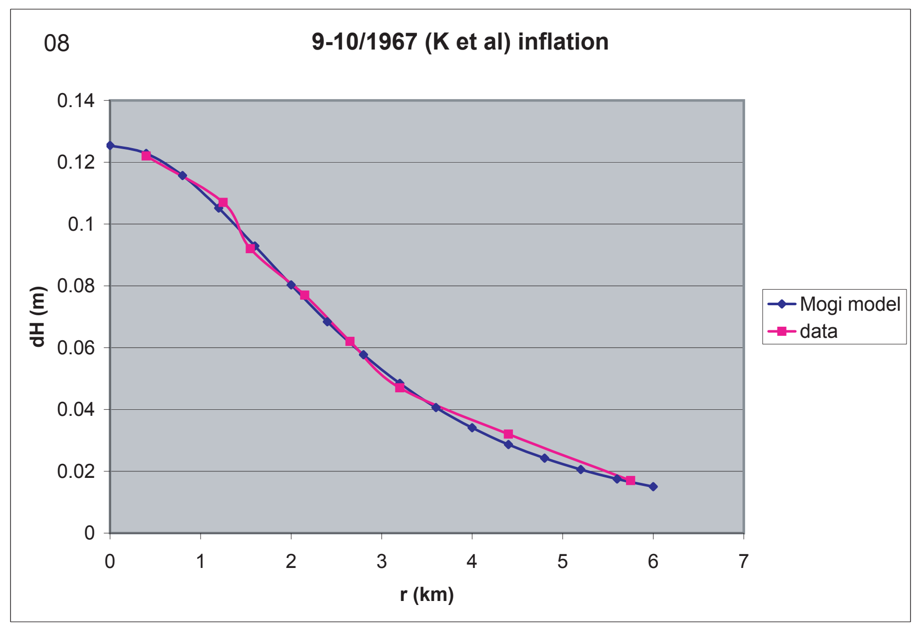


Appendix fig. I7.05-08. Mogi model fits to contoured levelling data. See table I1 for Mogi source data.

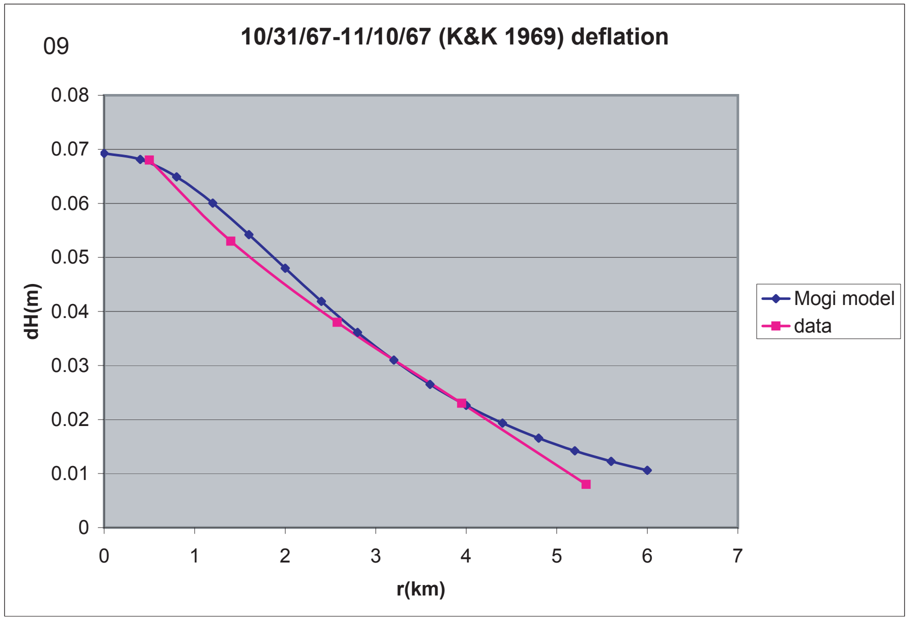


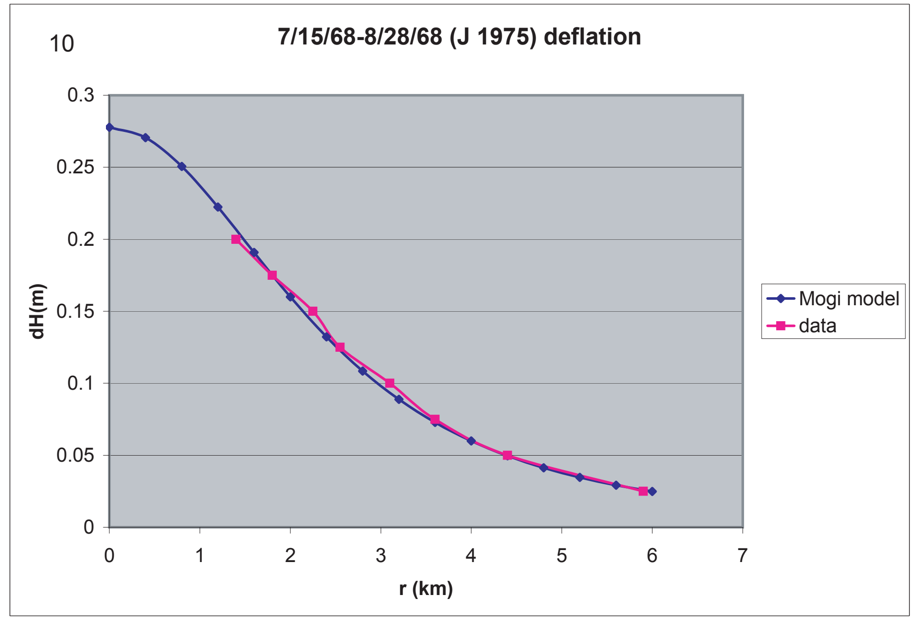


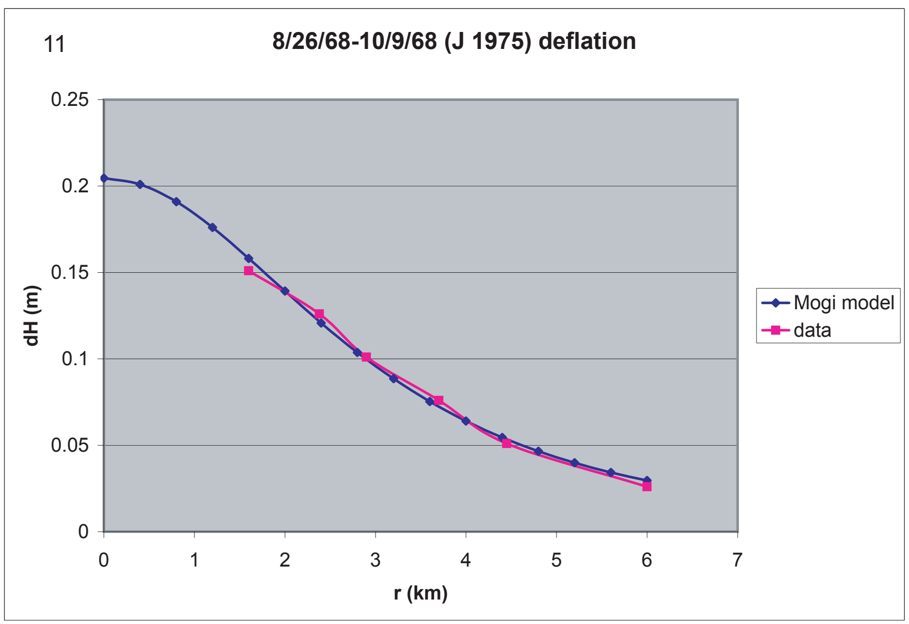


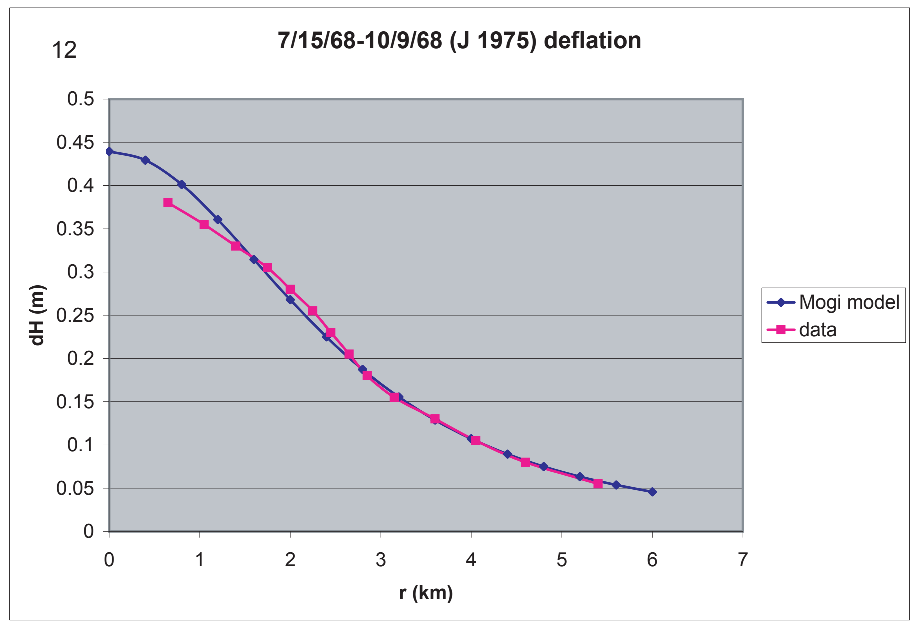


Appendix fig. I7.09-12. Mogi model fits to contoured levelling data. See table I1 for Mogi source data.

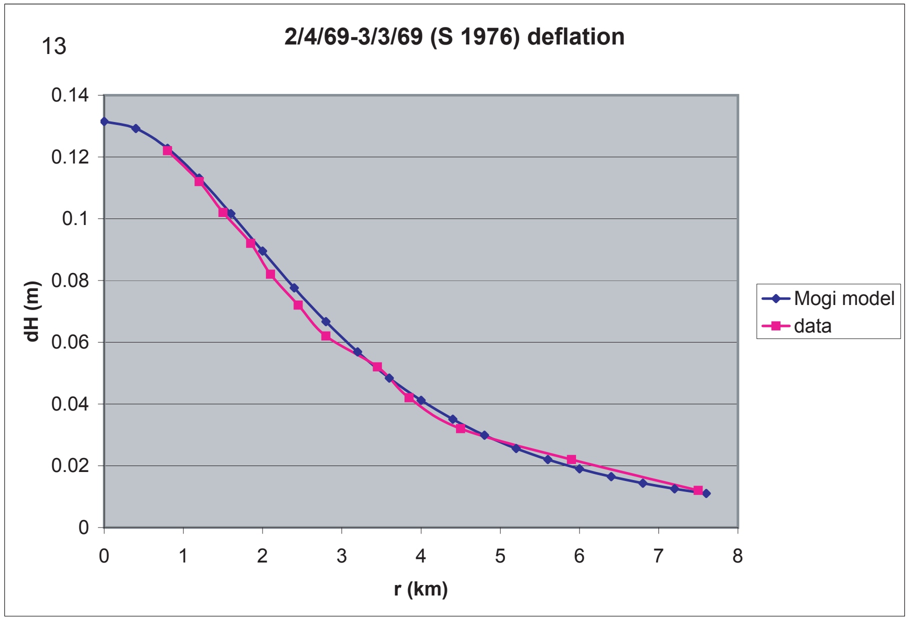


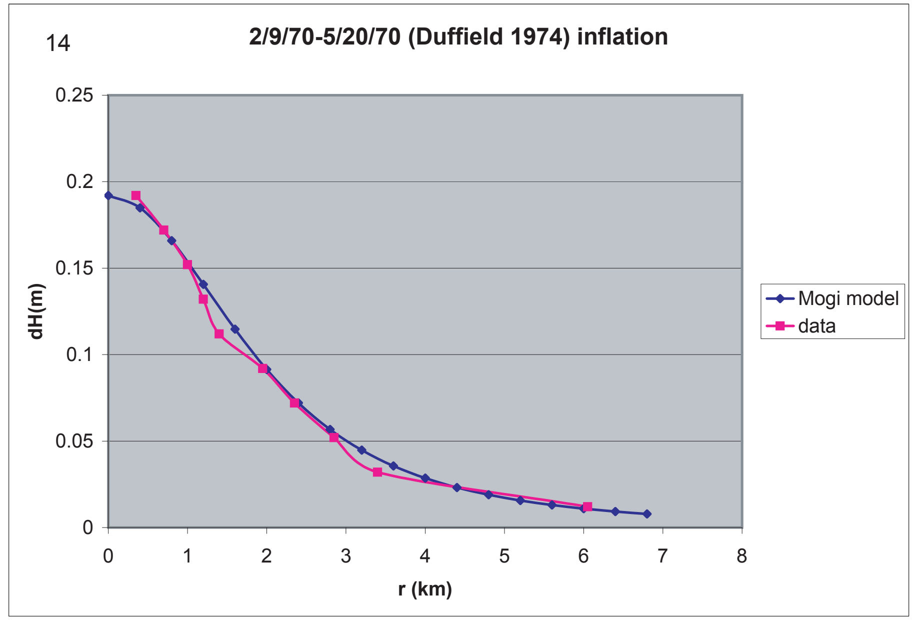


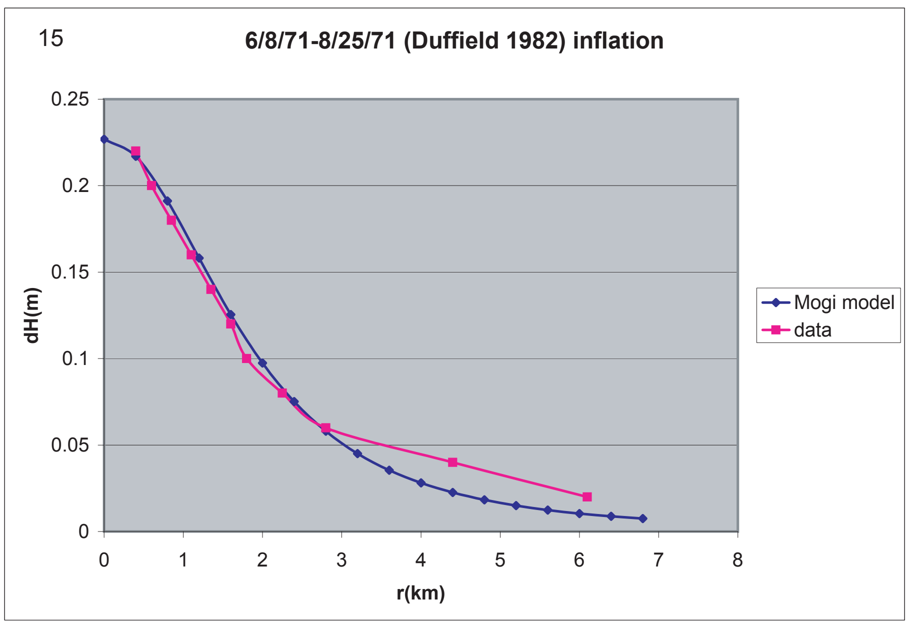


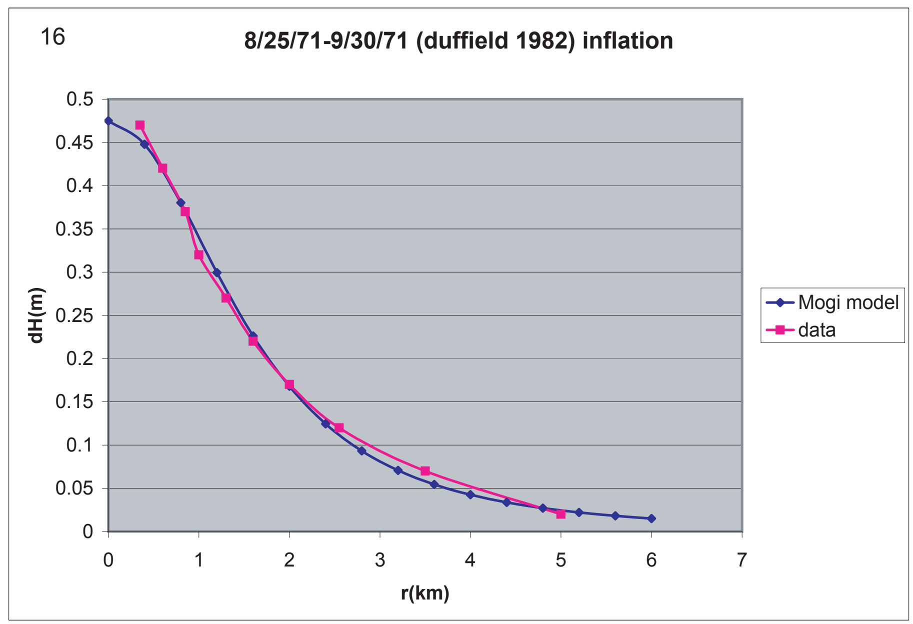


Appendix fig. I7.13-16. Mogi model fits to contoured levelling data. See table I1 for Mogi source data.

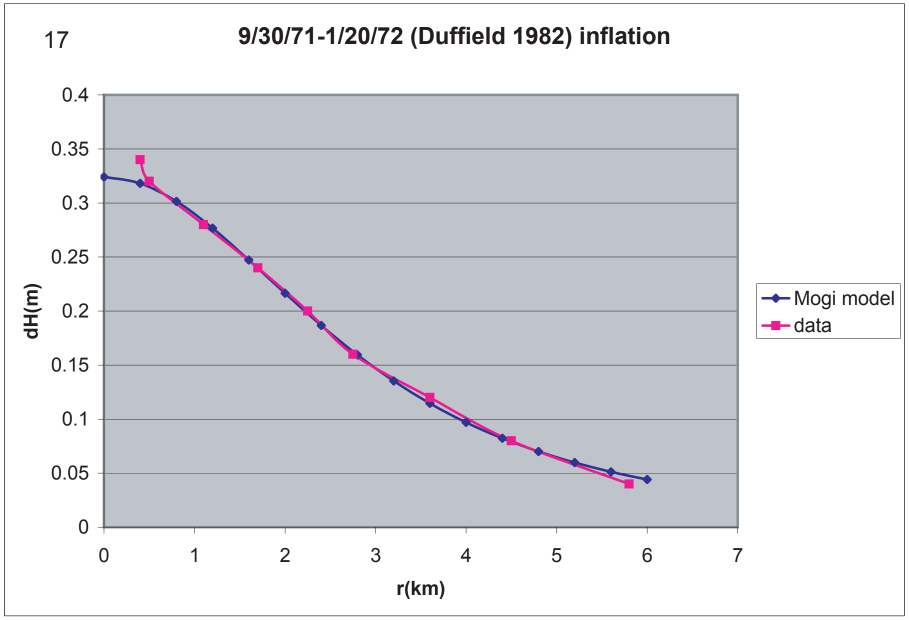


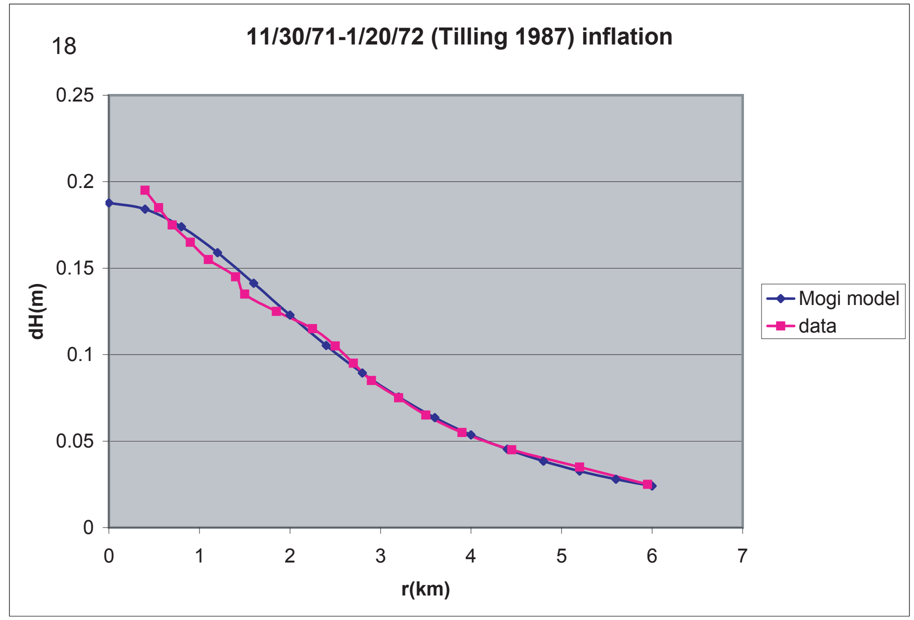


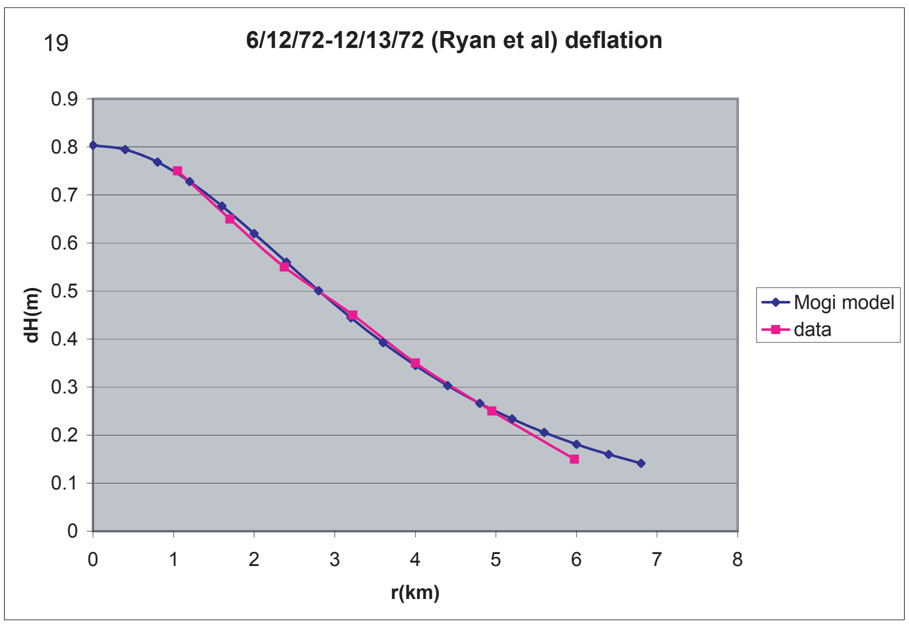


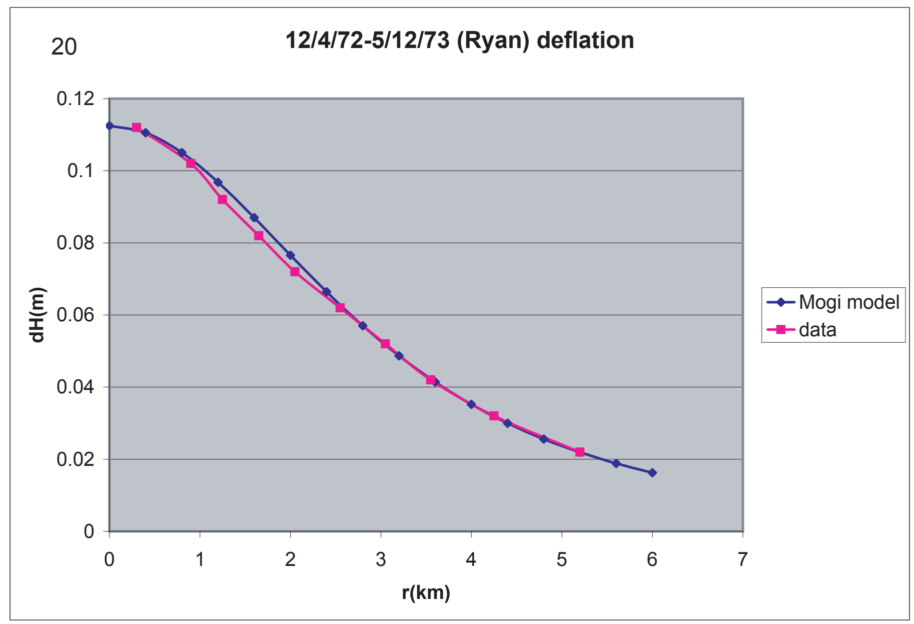


Appendix fig. I7.17-20. Mogi model fits to contoured levelling data. See table I1 for Mogi source data.

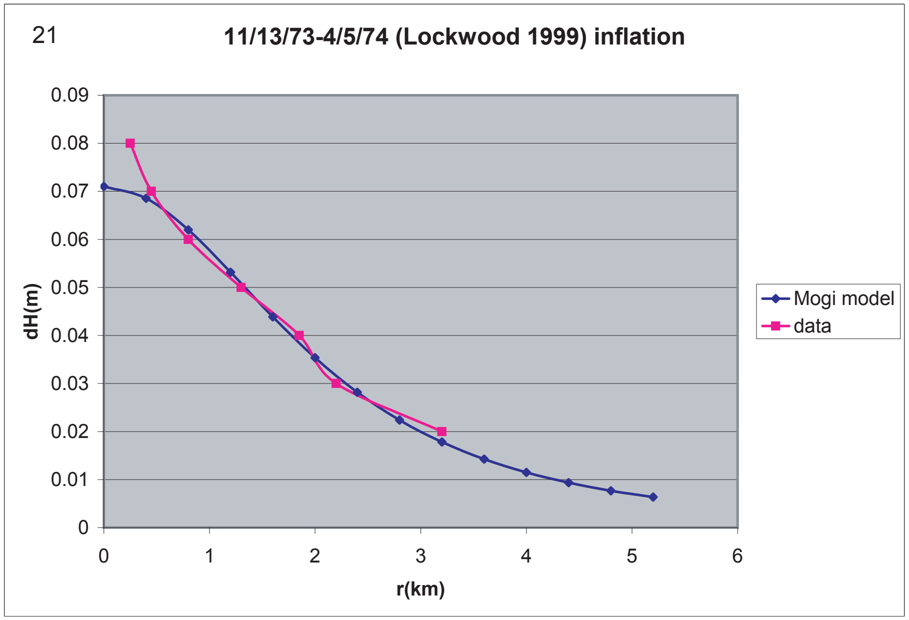


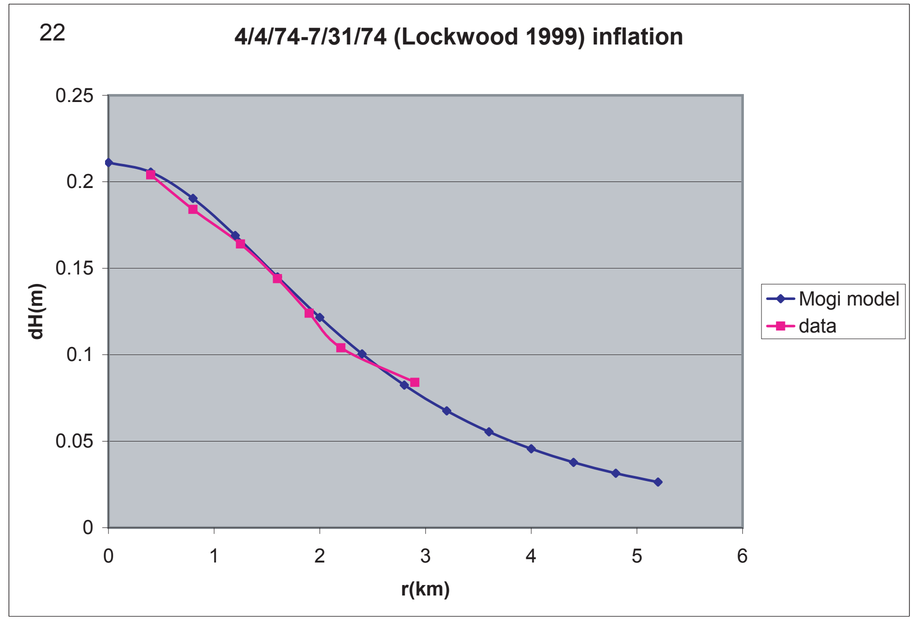


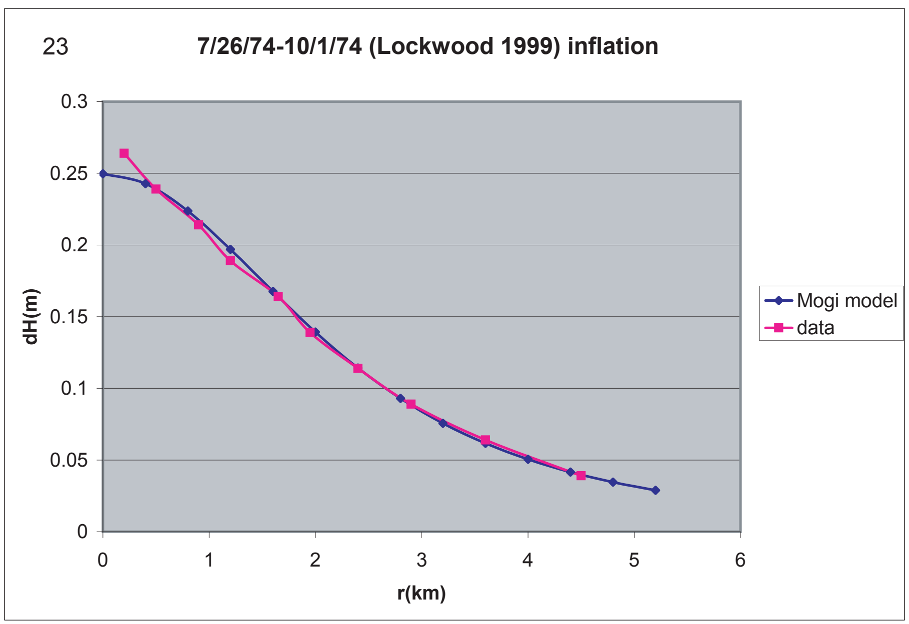


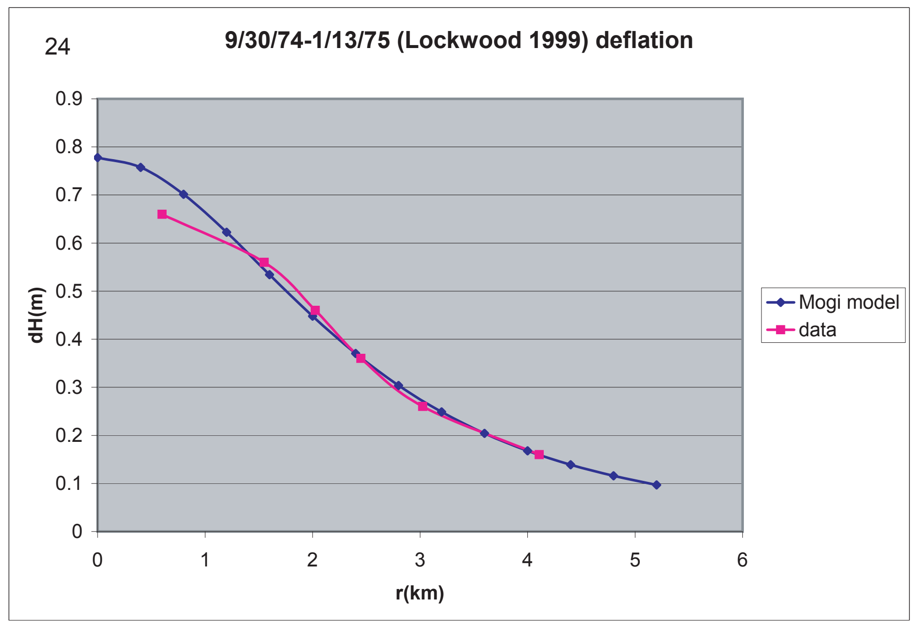


Appendix fig. I7.21-24. Mogi model fits to contoured levelling data. See table I1 for Mogi source data.

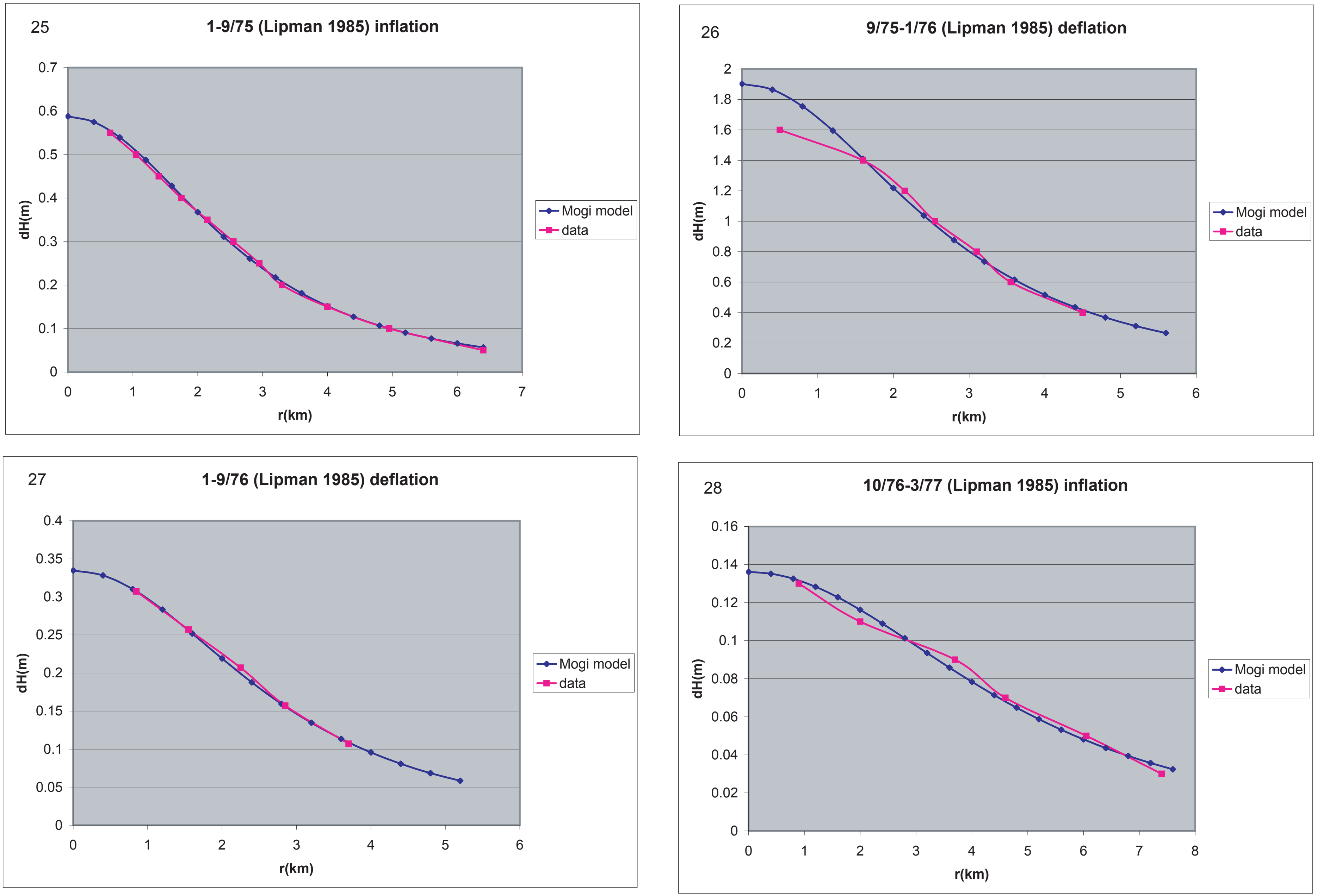




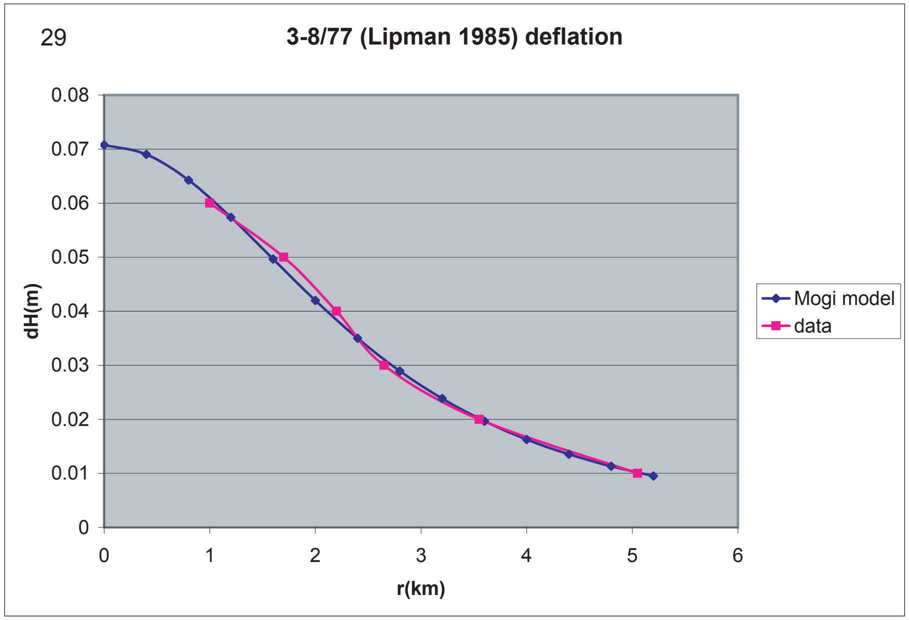


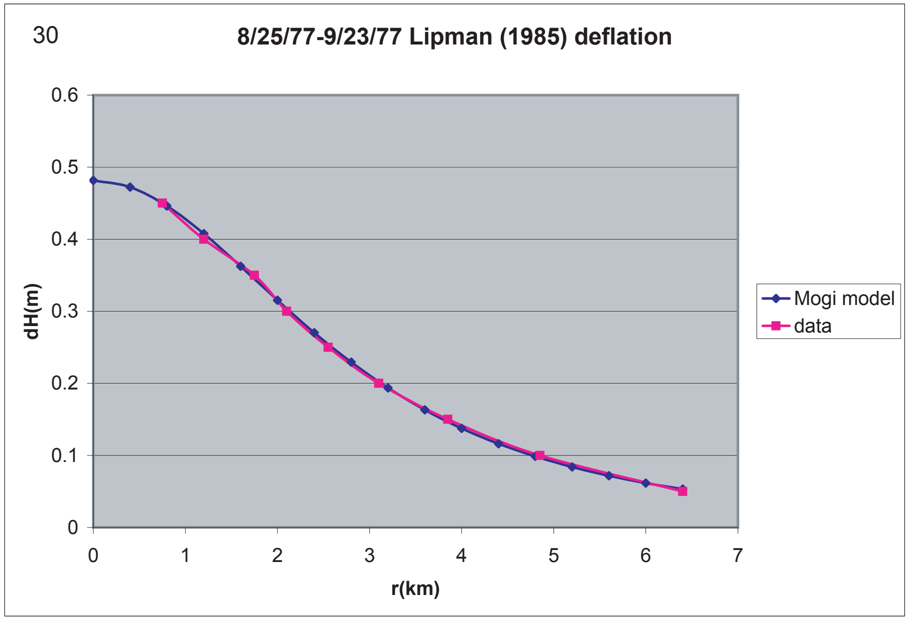


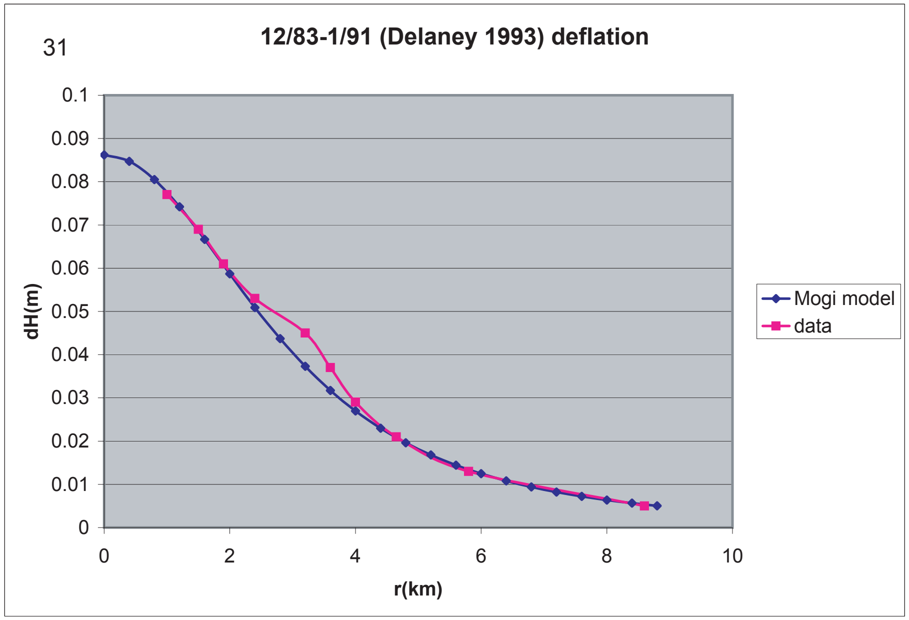
Appendix fig. I7.25-28. Mogi model fits to contoured levelling data. See table I1 for Mogi source data.

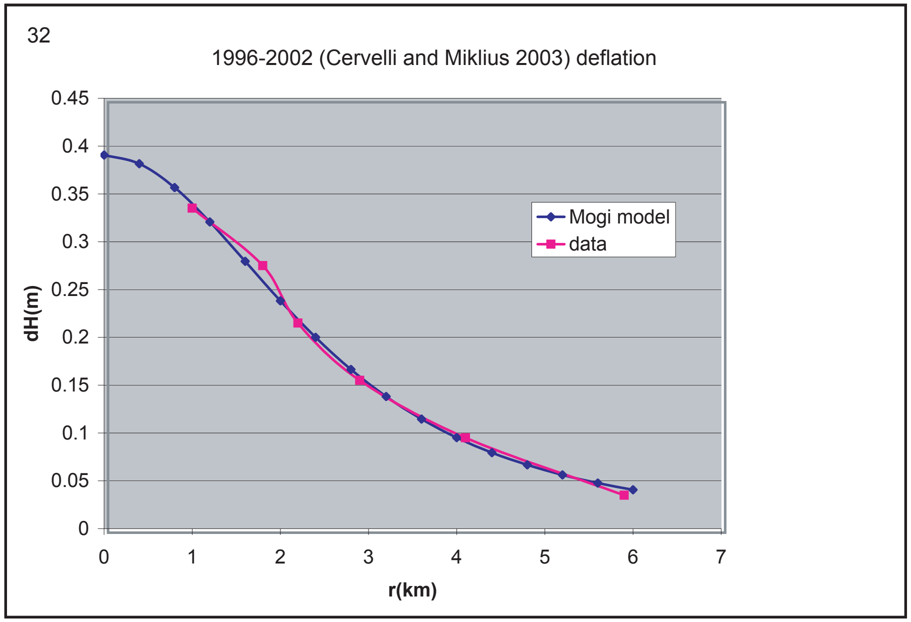


Appendix fig. I7.29-32. Mogi model fits to contoured levelling data. See table I1 for Mogi source data.









Appendix figure I8. Mogi volume changes vs. Mogi center depths for a set of level surveys.