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Determinations of the depth to the surfaces of active lava lakes at Mauna Ulu and Alae, Kilauea Volcano, Hawaii

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ABSTRACT

Many measurements of the depth to the surfaces of the active lava lakes at Mauna Ulu and Alae were made during the 1972-1974 Mauna Ulu eruption of Kilauea Volcano, Hawaii. These measurements significantly increased the body of data for similar measurements at Mauna Ulu during 1969-1971. The measurement method is simple and requires only the use of a Brunton compass and optical rangefinder. Tests of measurement reproducibility, involving experienced and inexperienced observers and two different rangefinders, indicate an overall uncertainty of no more than about 10 % for depth-to-surface determinations $\geqslant$ 100 m, and 5 % or less for depth-to-surface determinations $\leqslant$ 50 m.

INTRODUCTION

Throughout the 1972-74 Mauna Ulu eruption (Tilling and others, in press), frequent determinations were made of the depth to the surfaces of the active lava lakes contained in summit craters of Mauna Ulu and Alae volcanic shields (Table 1). We use the term "depth to surface" to refer to the vertical distance from the point of measurement, almost always the crater rim, to the surface of the actively circulating lava lake. If the lake surface is crusted over (i.e., no molten lava is visible, no circulation), the "depth to surface" is equivalent to the depth to the apparent solid floor of the summit crater. The true floor of the crater, of course, only can be seen with complete draining of the lava lake.

The visible active surface area of the lava lake can occupy the entire crater, or can be restricted to one or more smaller areas that occur as openings in the solidified crust or as perched lava pools confined by levees and surrounding moat. In the latter case, the lake surface can be highly irregular, variable in the measured "depth to surface", depending upon which point(s) is (are) used for depth determination.

ACKNOWLEDGMENTS

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MEASUREMENT TECHNIQUE

The depth-to-surface measurements were made by a simple method illustrated by Swanson and others (1979, Figure 49): an optical rangefinder measured the slope distance to one or more distinctive points on the lake surface, and the corresponding vertical angles to the point(s) were measured

by the clinometer of a Brunton compass. The depth to lake surface (or apparent crater floor) is the product of the sine of the angle and range finder distance.

MEASUREMENT REPRODUCIBILITY AND UNCERTAINTY

Our measurements indicated that each observer could generally obtain reproducible angle measurements to within + 0.5 degree using the Brunton clinometer, thus yielding a maximum uncertainty of about 1 percent for the sines of the range of angles measured. However, the reproducibility of rangefinder measurements among different observers was considerably less satisfactory, and we conducted tests of precision, accuracy, and possible operator error. During the course of the eruption, two different rangefinders were used for distance measurements, and tests were conducted for each (Tables 2 and 3).

In the test of instrument # 1 (November 1972), involving eight observers, it was possible to assess possible operator bias as well as precision and accuracy; five were regular users (observers 1-5, Table 2), and three (observers 6-8) had little or no experience. Not surprisingly, the inexperienced users obtained the most discrepant readings, in terms of both precision and accuracy, especially for distances greater than 80 m (Table 2). The results suggest that the measurements obtained by experienced users have a precision of about 5 % or less for distances up to about 110 m and about 10 % for distances approaching 200 m; accuracy worsens for measurements of distances over 100 m.

In the test of instrument # 2 (June 1973), only experienced users were involved (Table 3). This instrument yielded somewhat more precise results than instrument # 1, as suggested by differences in standard deviations (cf. Tables 2 and 3). In both tests, for distances greater than 100 m, the rangefinders give significantly smaller distances than the taped distances (Fig. 1). At these long distances, the under-measurment by the rangefinders is in part instrumental and possibly in part due to the tendency of the stretched steel tape to drape around minor irregularities of the ground surface between the two points measured. Therefore, the differences between rangefinder readings and actual distances could be somewhat smaller than those indicated by the tests of the rangefinders. We estimate the total uncertainty--rangefinder and clinometer readings as well as operator variations--to be no more than about 10 % for the deeper lava-lake stands ($>$ 100 m) and 5% or less for higher stands ($<$ 50 m).

SIGNIFICANCE OF THE MEASUREMENTS

The measurements made during the 1972-1974 eruptive activity significantly increased the body of data for similar measurements at Mauna Ulu during its 1969-1971 eruption (Swanson and others, 1979, Fig. 7). Through mid-1973 of the 1972-1974 Mauna Ulu eruption, at times the measured depth(s) to the surface for Mauna Ulu lava lake varied sympathetically with those for Alae lava lake, as well as showed positive correlation with Kilauea summit tilt.

This observation led Tilling and others (in press) to suggest that a delicate hydrostatic balance existed between the Kilauea summit reservoir, the Mauna Ulu holding tank, and the Mauna Ulu-fed vent at Alae.

REFERENCES CITED

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Table 1. Measurements of depth to surfaces of active lava lakes and related observations at Mauna Ulu and Alae, Kilauea Volcano, Hawaii during 1971-1974. N.D., not determinable; N.O., no observation. Time given is Hawaiian Standard Time. Depth to lake surface is given in meters below the crater rim (ground surface).

	MAUNA ULU				ALAE		
DATE	TIME	DEPTH (m)	GENERAL CIRCULATION PATTERN	REMARKS	TIME	DEPTH (m)	REMARKS
10/15/71		145		Surface at end of 1969-71 eruption (Swanson & others, 1979)			
2/5/72	0900-1000	<78	No pattern	Discovered crater about "half full"			
	1300-1600	78	No pattern				
2/6/72	1400-1500	38	Outward from Vent "A"				
2/7/72	1030-1800	25	W -> E	Spilling over notch and flowing down trench			At 1225 first flows from inlet tube into subsidence bowl
2/8/72	0900-1000	<25	W -> E	Notch engulfed			About 1/4 of bowl covered
	1400-1730	17	W -> E				About 3/4 of bowl covered
2/11/72	0930-1200	16	W -> E				Floor entirely covered; level rising
2/12/72	1000-1500	N.D.	N.D.				Brim full; few short-duration spills
2/13/72	p.m.	N.D.	N.D.				Major overflow to ESE begins
2/14/72	p.m.	21	N.D.				Brim full; overflow continues
2/15/72	a.m.	<21	N.D.				Brim full; overflow continues
2/16/72	0900-1600	27	E -> W				Overflow stop; crusted surface subsides 1-2 m and no lava enters Alae
2/17/72		>27	E -> W	Cascade from trench into lake			
2/18/72	0900-1100	35		Entire lake crusted over			
2/19/72		38		Entire lake crusted over			
2/22/72		N.D.		All surface activity stopped			
2/24/72		N.D.		New lake appears			
2/25/72		-		Brim full; overflows south and north sides of trench			
2/26/72-3/1/72				Near brim full; fluctuating			
3/5/72		>30	E -> W	Cascade over notch into lake			
3/9/72		>40	E -> W				
3/11/72		-	N.D.	Surface higher than on 3/9/72			

Table 1. Continued

3/14/72		5-15	N.D.	Brim full; overflows followed by drain backs to 5-15 m below rim		N.O.
3/18/72	1800	N.D. 30-40?	N.D. N.D.	New fissure opens on west flank of shield; surface dropped "several tens of meters" and overflow ceased		Perched lake formed; levees around former Alae rim and small overflows
3/19/72		30-40?	N.D.	Surface "remained low"		Decline in vigor of vents "C" and "D"; level in vents dropped a bit
4/3/72		>30	E -> W	Surface "risen somewhat"; a new vent opened between "B" and west end of trench; Cascades into lake from trench		Some overflows from lake
4/20/72		30	E -> W	Occasional spills over septum into western crater; surface in trench and crater about equal, implying a connection through septum		N.O.
4/21-6/20/72		20-30	E -> W	Fluctuating mainly between 22-26 m		Vent "C" very active; numerous overflows into lake. Lake surface mostly high; direct overflows from lake as well as through tubes. Alae lake separated into two compartments; overflows and major shield growth. Tube-fed lava from lake into Makaopuhi Crater
6/20-7/14/72		30-45	E -> W			Vent "C" still actively feeding lava into two-compartment lake, whose level is generally brim full.
					1-10	Periodic overflows and shield growth; surface 1-10 m below levees
7/15/72		33	E -> W			Brim full; local spillovers
7/16/72		N.D.	E -> W			Brim full; many overflows
7/24/72		N.D.	N.D.		3-5	
7/31/72		34			N.D.	
8/1/72		38-39			3-5	
8/3/72		38			-	
8/4/72		36			3-5	
8/10/72		36			4-6	
8/12/72		36			N.D.	Surface below rim
8/14/72		40				
8/17/72		38			8-9	

Table 1. Continued

8/21/72		40				8-9	
8/22/72		39				>8	
8/23/72		37				N.O.	
8/24/72		38				N.O.	
8/27/72	1215	38				N.O.	
	1410	40				N.O.	
8/29/72	1010	39?					Some overflows
	1530	38					Some overflows
9/1/72	1845	35	W -> E				Some overflows
	1940	33	E -> W				Some overflows
	1950		W -> E				Some overflows
9/3/72		24					Some overflows
9/4/72	1015	34				8-9	
9/5/72	0930	38	W -> E	Surfaces variable from place	1100	16	
		44		to place			
		53					
	1400	36			1500	16	
9/7/72	0800	34	E -> W		0825		Brim full; evidence of overflows during the night
	0930		W -> E		1800		Brim fill; two overflows
	1930		W -> E				
9/9/72	1000	35	E -> W		1100-1200		Brim full; no overflows in progress
9/11/72	a.m.	37	W -> E				Brim full; no overflow
	p.m.	47					
9/15/72	1400	37	W -> E			15	
			& E -> W				
9/19/72	0820	41	E -> W		0850	5-6	
	1800	46	W -> E				
9/20/72	1110	>46	W -> E	Too fumy to measure, but surface is lower than on 9/19/72	1130	20	
9/22/72	a.m.	>46	?	Too fumy to measure		6-7	
9/26/72	1400	43-46	E -> W	Fumy, poor measurements	1445		Brim full
9/28/72		42	Stagnant			10	
9/30/72	1528	44	W -> E			11	N.O.
10/3/72	0810	43	W -> E			8-10	
10/5/72	1000	38	E -> W			2-4	Evidence of overflows between observations 10/3/72 and 10/5/72
	1140		W -> E				

Table 1. Continued

10/6/72	0920	56	E -> W		0940		Brim full
	1615	47	E -> W		1600	1-2	
10/10/72	1240	40	E -> W		1130	15	
10/11/72	1900	43	W -> E				
10/13/72	0825	47	E -> W & W -> E		0925	16	
10/16/72	1445-1600	44	E -> W & W -> E		1525	>16	Flow to north; no visible flow into lake
10/17/72	0810	47	W -> E		0925	10-12	
10/20/72	1400	40	W -> E	Flow very sluggish	1445	2	
10/24/72	0855	47	E -> W		0945	3-4	Active flows to N and NW
10/25/72	0810	34	"		0840		
11/3/72	0815	36	"		0855		
11/3/72	0930	33	"				Active fountain at vent; flow N and NE
11/6/72	0920	35	"		0935		
11/7/72	0900	35	"				Much lava added to E side of shield; "northeast lake" formed
11/10/72	0915	34	"		0930		
11/11/72	1155	30	"				
11/13/72	1105	30	(weak, variable)		1130		Overflows from northeast lake
11/14/72	1100	30	W -> E		1100		
11/20/72	0925	25	E -> W		1040		Northeast lake not visible, but SW compartment of Alae lake brim full
11/22/72	1435	33	N.D.		1445		SW compartment of Alae lake crusted over
11/26/72	1100-1145	34	Variable, local around several fountains	Strong degassing bursts from trench area at 1155-1230	1145-1215		No visible lava at vent "C," sruface down at northeast lake; large flows in broad area south of Alae
11/28/72		N.D.	Variable, local around several fountains	Partial collapse in trench			Vent "C" fuming copiously; lava being fed to area S of Alae shield
11/29/72	1000	30	E -> W	Degassing periods			Lava visible in channel feeding NE lake

Table 1. Continued

21/1/72	1140	34	E -> W	degassing periods			Lava flowing into Alae lake
12/4/72	1130	29	"		1200		Vent "C" feeding two subterranean streams
12/6/72	1030-1155		W -> E random				Vent "C" level dropped 1 m but still feeding the two streams; large flows to S and SE
12/10/72	1100	30	W -> E				New cone at vent "C" active lava "too low to see"
12/12/72	1500-1730	<30	"				Flames from cone at vent "C;" flows spreading south of Alae
12/13/72	1355	22	Random				
12/14/72	1255	27	"				Copious flows in general areas SE and S of Alae
12/17/72	1140	31	"				Many flows from secondary sources S of vent "C"
12/20/72	1000	31	"				
12/24/72	1300	27	E -> W				Large flows to S and SE
12/26/72	2030	24	Random				Vent "C" and new vent 100 m to E feeding flows to N and NE
12/28/72	2400	26	W -> E				Vent "C" and new vent stopped
1/1/73	1050	28	"				Active flow to west
1/10/73	1330	42	Random			4	Circular hole at vent "C;" flames visible even in daylight
1/12/73	0940	<42	"				
1/13/73	1300-1400	32	W -> E			10	Lava visible at south end of vent "C"
1/15/73	1430	32	"			8	Sluggish bubbling lava; no visible surface flows, but heat waves suggest tube transport toward Makaopuhi
1/16/73	1545	31	Random?			12	
1/19/73	0925	31	Poor visibility			10	
1/23/73	1410	30	E -> W				
1/28/73	0920	31	N.D.				
1/30/73	1735	32	N.D.			>5	Lava not visible in vent
2/1/73	1530	34	N.D.				

Table 1. Continued

2/2/73	0920	<34	N.D.		10-12	
2/7/73	1200	34	N.D.		8	
2/10/73	2000	30	N.D.			Brief degassing bursts at vent "C"
2/13/73	1645	32	local to degassing sites			
2/14/73	1130	25-30	N.D.	Conditions too fumy for precise measurement		
2/16/73	1035	28-34	E -> W	Conditions too fumy for precise measurement		
2/18/73	1240	30	Random			Gas-piston action at vent "C;" 8-15 in
2/20/73	1435	30	N.D.		8-15	Gas-piston action at vent "C;" 8-15 in fluctuation in column
2/22/73	1105	32	Random			
2/26/73	1435	33				
3/2/73	0940	25				
3/8/73	0945	24	W -> E			
3/12/73	1425	31	"			Some overflows from openings near vent "C"
3/14/73	1000	31	"		15-20	Overflows ceased; gas-piston action; openings at vent "C" coalesce into larger (25x20 m) opening
3/18/73						Overflows to SW & SWW
3/20/73	1435	31	Random			Overflows to N
3/22/73		34				Overflows from vent "C"
4/2/73	1040	38	E -> W		24	
4/3/73	0930	30	"		24	
4/5/73	1030	31	"		18	
4/9/73	1015	31	"			N.O.
4/13/73	0940	>31	"	Too fumy for rangefinder measurement		N.O.
4/18/73	p.m.	>31	N.D.	Too fumy for rangefinder measurement		N.O.
4/26/73	0915	41	N.D.			N.O.
4/27/73	1000	37	N.D.			N.O.

Table 1. Continued

4/28/73	1300	39	N.D.			26	N.O.
4/30/73	1435	33	Random			26	
5/1/73	1020	30	"		1350	7	Active overflows from depression SE of vent "C"
5/2/73	1030	40-41	"				
5/3/73	1420	38	"				
5/5/73				Completely drained - but bottom of crater not visible because of dust			Completely drained; vent "C" collapsed
5/6/73		198-202					Rubble-choked bottom at "C"
5/8/73	1115	153-156		Measurement to eastern part			
5/9/73		126?					
5/10/73	1410	145		Measurement to eastern part; but a high lava mark at 126 m			N.O.
	1430	149-156		Measurement to western part			N.O.
		144		Eastern part			N.O.
	1625	144		Measurement to eastern and western parts			N.O.
5/14/73	1245	114-120		Eastern part, variable			N.O.
		124-126		Crusted over western part			N.O.
	1330	133		Active area of western part			N.O.
		114		Eastern part			N.O.
5/15/73	1100	99		Eastern part overflowing into western part			N.O.
5/18/73	0925	116		Eastern part overflowing into western part in 20 m cascade			No live lava; rubble choked bottom
5/21/73	1000	102-106		Eastern pit; lava ledge between the two pits			N.O.
		97					
		111		Western pit			N.O.
	1155	101		Eastern pit			N.O.
		120		Western pit			N.O.
5/25/73	1215	49		The two pits now one lake			N.O.
	1550	52					
5/30/73	0930	40					
		34		Depth to part containing island of semi-solid lava		34	Live lava visible, but not moving
6/3/73	0645	30-34					
6/5/73	1630	18	E -> W	Well-defined circulation pattern discernible again (first time since 4/13/73)		4-9	Surface variable, depending on position in lake
6/7/73	0845	21-23	"		0945	3-4	No live lava, but crust indicated high rise since 6/5/73
		18		Surface near island			

Table 1. Continued

6/9/73	1110	112		Sudden partial draining between 0000-0300	N.O.
6/10/73	1140	88	E -> W		N.O.
6/11/73	0955	75	"		No live lava seen at vent "C"
6/12/73	1245	71	"		N.O.
6/14/73	1030	65	"		N.O.
		58		Top of levee	N.O.
	1245	61			N.O.
6/15/73	1030	61-65	"	Surface variable from active part of lake, levee, and moat	N.O.
6/19/73	1345-1537	49-52	"	Sluggish lava motion	N.O.
6/20/73	0930	45-51	"	Levee is 1-2 m above moat	N.O.
6/21/73	1123	45-52	N.D.		Vent "C" rubble choked issuing hot air only
	1245	49			
6/23/73	0930	42-48 (45 avg)	E -> W		No visible lava; depth to deepest point of rubble-choked pit is 23 m
6/24/73	p.m.	48-50	"		N.O.
6/26/73	1515	39-40	N.D.	Island is 6 m above lake surface	N.O.
6/27/73	1000	39-48	N.D.		N.O.
6/28/73	1230-1345	33-35	N.D.		No lava visible at vent "C"
7/3/73	1100	24-26	N.D.	Measurement to eastern part of lake, western part crusted over and fragmented	No lava visible at vent "C;" depth to pit bottom is 20 m, reflecting filling by rockfalls
	1230		N.D.	High lava mark, tops of semi-solid islands	N.O.
7/5/73	1345	26		Western end crusted over	N.O.
		19-21		Active part of lake	N.O.
7/6/73	1140	7-17	N.D.	Tops of islands	N.O.
		20-26	N.D.	Moat areas	N.O.
		18-20	N.D.	Active lake	N.O.
7/7/73	1515	18-19	E -> W	Lake, western end	N.O.
		8		Top of island	N.O.
7/8/73	0900-1015	22-23		Lava surface	N.O.
		9-10		Top of island	N.O.
7/12/73	1430	16-18	N.D.	Eastern end of lake	N.O.

Table 1. Continued

7/13/73	0925	17-20	N.D.	Range of measurements by three different observers	N.O.
	1020	15-17	N.D.	Range of measurements by three different observers	N.O.
7/16/73	0900	17-23	W -> E		N.O.
7/20/73	1130	11		Surface in 10 m diameter circular pit	N.O.
		15		Surface in 15 m diameter circular pit; visible lava restricted to these two pits	
7/24/73	1025	26	E -> W	Ponding area	N.O.
		35		Another ponding area west of the one above	N.O.
		15		Crusted surface at vent	N.O.
7/25/73	1115	50		Crusted surface, deepest part of western end	N.O.
		34		Crusted surface of vent, eastern end	N.O.
7/28/73	1050	71		Deepest end of western end	Bottom of vent "C" 25 m; no visible lava
7/31/73	1100	73		" " " " "	N.O.
8/6/73	1000	71		" " " " "	N.O.
8/10/73	1400	77		" " " " "	N.O.
8/15/73	1330	77		" " " " "	N.O.
8/16/73	1345	81		" " " " "	N.O.
9/4/73	1300	62	E -> W	Active lava reappears; circulation sluggish	N.O.
9/5/73	0945	69	"	Sluggish movement	No change in configuration of 7/28/73
9/13/73	1000	69	-	Lake crusted completely; no live lava, no glow	N.O.
9/25/73				No activity; heavy fume	All quiet; heat at cracks
9/26/73	1535	67		Low fountaining at eastern end; flow advances from 5 m high cone	N.O.
9/27/73		61		Crater floor entirely covered by lava	N.O.
9/29/73	1000	50		Cone still feeds flows	N.O.
9/30/73	1545	63		No visible lava; partially collapsed floor	N.O.
10/1/73	1500	63		About same as one 9/30/73	N.O.
10/4/73	1330	56		Degassing bursts; hissing sounds; cone has glowing holes, but no visible lava	N.O.

Table 1. Continued

10/6/73	1115	N.D.	Lake occupies 1/2 - 3/4 of crater floor; spatter cone 10-12 m high	N.O.
10/10/73	0955	43	Western end (fed from east)	N.O.
		32	Eastern end (active area)	
10/14/73	1030	39	Western end	N.O.
		25-27	Eastern end	N.O.
10/19/73		37	Western floor	N.O.
10/20/73		25-27	Western end	N.O.
		15	Eastern end (active)	N.O.
10/22/73		25	Active lake	N.O.
		32	Western floor	N.O.
		15	Eastern floor	N.O.
10/26/73		24	Active lake	N.O.
		37	Western floor	N.O.
10/29/73		24	Active lakes; 6 m below levee	N.O.
		35	Western floor	N.O.
11/4/73-11/8/73			Brim full; major overflow preceeding collapse and November 10 outbreak at Pauahi Crater	N.O.
12/13/73	1800?	N.D.	Lava reappears in crater; vent near south rim	N.O.
12/14/73		27	Crusted surface of new lava largely crusted surface; weak bubbling at vent	N.O.
12/18/73		N.D.	Degassing bursts; new cone at vent new cove 5-6 m high	N.O.
12/23/73	1130	23	Measurement to base of active cone	N.O.
12/24/73	1200-1500	6	Highest level before dropping to about 12 m	N.O.
12/27/73		16	Sample collected from lava lake mark	N.O.
12/30/73	1740	6	High stand of surface	N.O.
	1820	>6	Following drainback	N.O.
12/31/73		2	Measurement to top of active cone	N.O.
		13	Lowest point, western floor	N.O.
1/2/74		6	Lava back to stand of 12/30/73	N.O.
1/4/73		6-12	Localized collapse along center of crater; barely a glow at cone	N.O.
1/7/74			Continual collapse of crater, cone as well	N.O.
1/8/74			Configuration basically same as on 1/7/74; weak spatter activity at vent; orange flame visible at cone	N.O.

Table 2. Test of rangefinder measurements (in meters) obtained with instrument #1 (November 22, 1972) Observers 1-5 are experienced users, observers 6-8 inexperienced.

Observer	Distances, m			
	A	B	C	D
1	43	88	110	175
2	42.7	80	111	170
3	44	84	115	205
4	41.7	85	108	210
5	45	78	105	174
6	47.3	75.5	110	158
7	45.8	94	100	220
8	45.5	95	120	239
Average (1-8)	44.4	84.9	109.9	193.9
Range	41.7-47.3	75.5-95	105-120	158-239
Standard deviation (%)	1.9 (4.3)	7.1 (8.4)	6.0 (5.4)	28.6 (14.7)
Average (6-8)	46.2	88.2	110.0	205.7
Range	45.4-47.3	75.5-95	100-120	158-239
Standard deviation (%)	1.0 (2.2)	11.0 (12.5)	10 (9.1)	42.4 (20.6)
Average (1-5)	43.3	83.3	109.8	186.8
Range	41.7-45	78-88	105-115	174-210
Standard deviation (%)	1.3 (3.0)	4.0 (4.8)	3.7 (3.4)	19.1 (10.2)
DISTANCE (measured by steel tape)	43.6	82.0	110.0	189.6

Table 3. Test of rangefinder measurements with instrument #2 (June 18, 1973). All observers are experienced users. Instrument readings in "feet" and converted to "meters."

Observer	Distances, m						
	A	B	C	D	E	F	G
1	12.3	22.7	45.8	75.0	122.0	177.0	289.8
2	12.5	22.7	45.1	74.1	115.9	167.8	289.8
3	12.8	23.2	46.0	75.0	117.4	183.0	259.2
4	12.5	23.2	45.8	76.2	122.0	166.8	266.9
5	12.4	23.0	44.2	76.2	109.8	180.0	289.8
Average	12.5	23.0	45.4	75.3	117.4	174.9	279.1
Range	12.3-12.8	22.7-23.2	44.2-46.0	74.1-76.2	109.8-122.0	166.8-183.0	259.2-289.8
Standard deviation	0.2	0.2	0.7	0.9	5.1	7.3	14.9
(%)	1.6	1.0	1.5	1.2	4.3	4.2	5.3
DISTANCE (measured by steel tape)	12.2	22.9	45.8	76.2	122.0	183.0	294.0

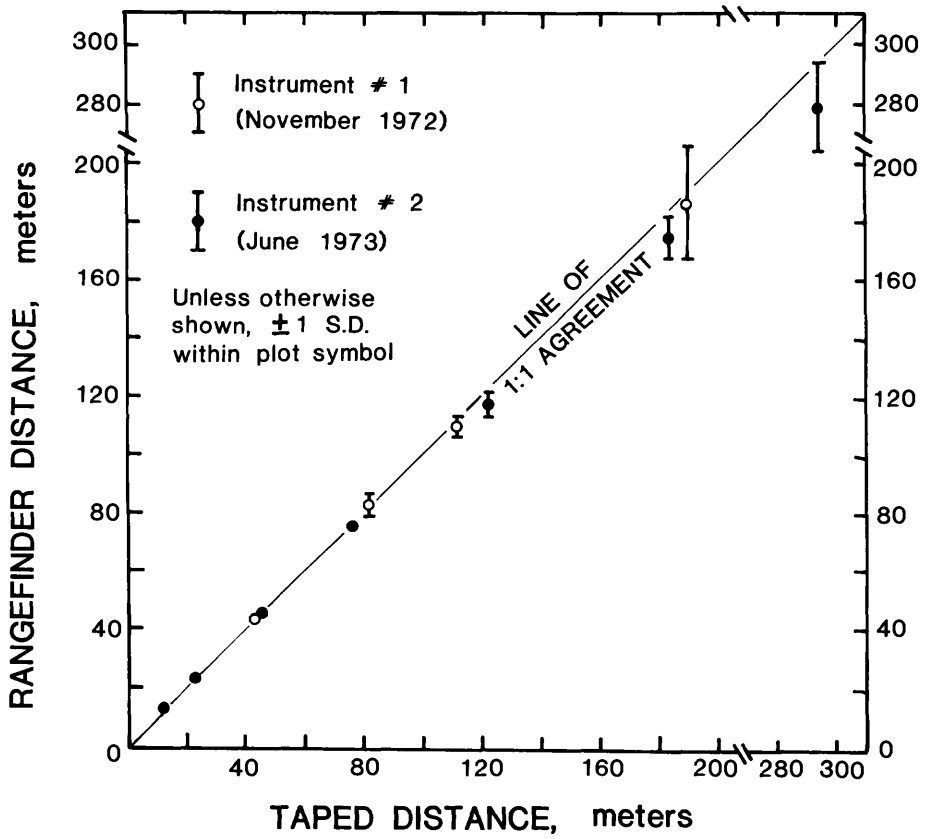

Figure 1. Comparison of rangefinder distance and the actual distance measured by steel tape for two tests of rangefinder measurements (data of Tables 2 and 3).