UNITED STATES DEPARTMENT OF INTERIOR

GEOLOGICAL SURVEY

Maps and Preliminary Interpretation of Linear Features South of 40° N., Utah

by

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INTRODUCTION

This report presents linear-feature data mapped from computer-enhanced Landsat images and a preliminary lineament interpretation of the State of Utah south of 40° N. The purpose of this report is primarily a data release. Plate 1 shows the location of the study area and the linear features mapped. The procedures and terminology used in this report are discussed in detail by Sawatzky and Raines (in press, 1980). The term "linear feature" is used to mean a rectilinear or curvilinear feature on an image or photograph that is selected and mapped by a skilled photogeologic interpreter (Sawatzky and Raines, in press, 1980) and generally represents a rectilinear or curvilinear aspect of the topography of the area, such as, for example, a stream valley or an alignment of depressions. "Lineament" is used in this report to refer to an interpreted, linear geologic entity that is defined by linear concentrations of linear features. Therefore, the lines on plate 1 are linear features, plates 2-6 show selected examples of linear-feature maps, plates 7-11 are linear-feature concentration maps from which lineaments are intepreted, and the lines on plate 12 are the lineaments that have been interpreted.

METHODS

This section briefly describes the methods used; the reader is referred to Sawatzky and Raines (in press, 1980) for complete discussions. The digital data for these Landsat scenes were processed to enhance tonal gradients (linear features), and the enhanced images were interpreted at a scale of 1:800,000. Black and white images of all four spectral bands were used. A total of 8,730 linear features were observed with a total ground length of 27,276 km. The linear-feature data were then digitized and statistically analyzed for preferred orientation using the procedures discussed in Sawatzky and Raines (in press, 1980). The statistics for the full data set are shown in appendix 1 and summarized in figure 1. Six intervals, where direction is measured from north in a clockwise direction from 0 to 350 degrees, are statistically significant at a 90 percent significance value, 349 (11° W.), 353-359 (7° W.-1° W.), 1-3, 6-15, 17-66, and 68-70. This orientation analysis shows which directions are statistically significant in the area considered as a whole. However, due to the large area including many diverse tectonic subelements and the nature of the statistic used to define preferred orientations, other geologically important trends or locally important trends in the data set may not have been defined.

In order to address this fact, the linear-feature data were subset according to the tectonic elements defined by Kelley and Clinton (1960) and each subelement was statistically analyzed for preferred orientation. The subareas are outlined and named on plate 1 and the statistics for each are summarized in figure 1; the full direction histograms are in appendix 2.

From this orientation analysis of subareas, several additional trends were defined as statistically significant in many of the subareas. Combining these results with those from the full data set and from inspection of linear-feature plots, such as shown on plates 2-6, five intervals were selected as having significance for this regional analysis. These intervals are as follows: (1) 18-66, (2) 351-15, (3) 330-350, (4) 300-330, and (5) 270-295 and 85-90. Intervals 3, 4, and 5 come exclusively from the subarea statistics. The spatial concentration of linear features in these five intervals was then

Figure 1.--Statistical summaries of the trends for the whole data set, various tectonic subelements, including various basins and uplift groups. The intervals shown are only those that were statistically significant at a 90% significance value for the length-weighted analysis. The length-weighted analysis was selected because it generally includes all of the trends from the unweighted analysis plus a few additional trends, and it can group trends that are separate in the unweighted analysis. The geographic extent of each subelement is as defined by Kelly and Clinton (1960) and is shown on plate 1. The uplifts consist of a group defined by those subelements with both east-west and northwest trends and include the Uncompahgre Uplift, Monument Upwarp, Capitol Reef Fold Belt, and the San Rafael Swell. Basins A includes the following basins and transitions: White Canyon Slope, Blanding Basin, Piute Fold Belt, Kaibito Saddle, Henry Basin, and Circle Cliffs Uplift. Basins B includes those basins without east-west trends and with northwest and northeast trends: Paradox Fold-Fault Belt, Piute Fold Belt, and Kaiparowits Basin. Basins C includes those remaining basins with east-west trends: Blanding Basin, Henry Basin, and Capitol Reef.

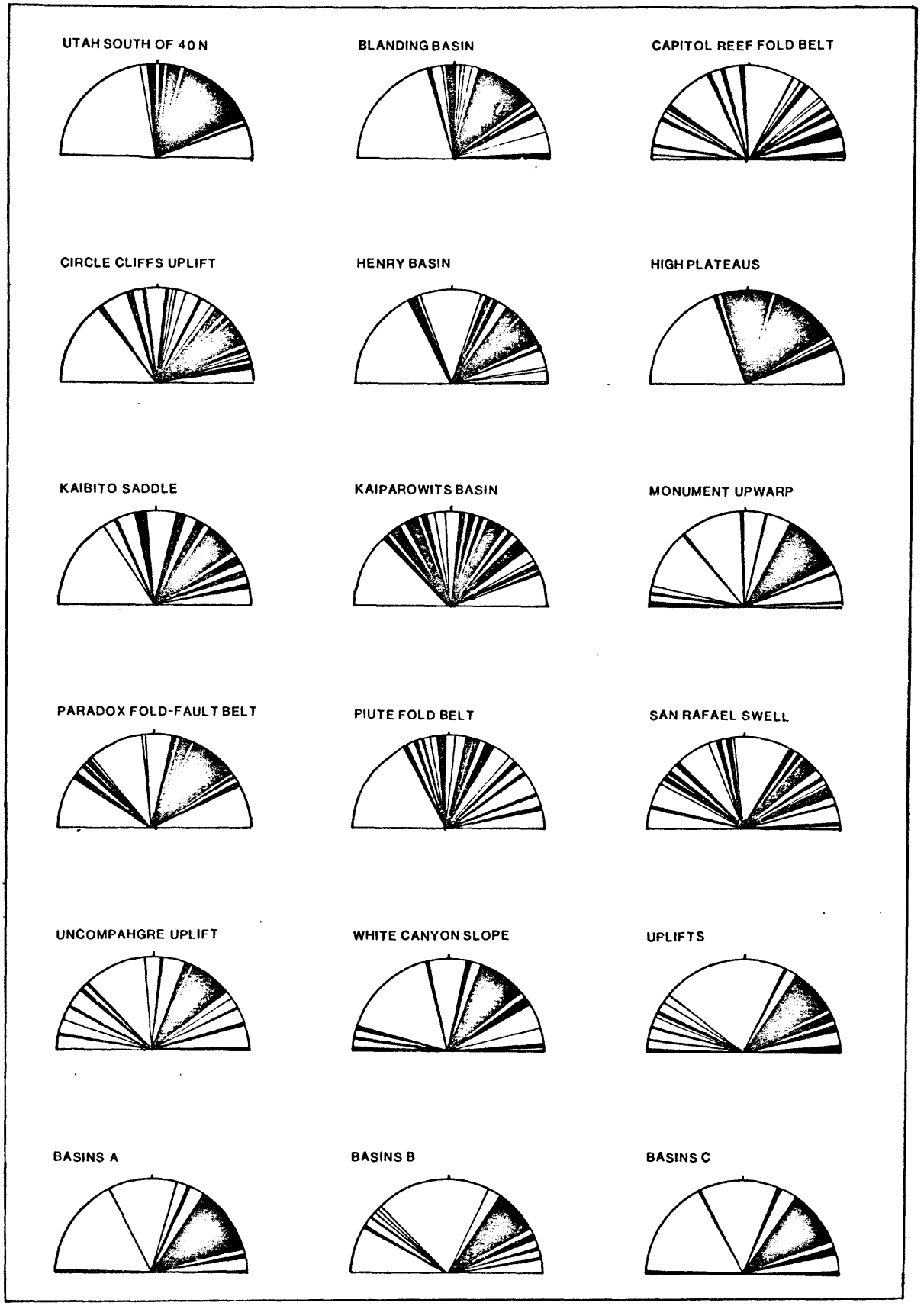

Figure 1.--Statistical summaries of the tends for the whole data set, various tectonic subelements, including various basins and uplift groups.

computer-contoured to prepare plates 7-11. The spatial concentration is the length of selected linear features per 3.5 km unit cell.

From inspection of plates 7-11, linear spatial concentrations of linear features are apparent. It is important to realize that the numbers contoured are relative concentrations; therefore, the highs and lows, not the magnitude, are considered important. These linear spatial concentrations of linear features are here defined to be the representation of lineaments, and plate 12 shows the interpreted lineaments. The lineaments in plate 12 are generally drawn down the centers of the highs in plates 7-11; these lineaments represent the linear concentrations in a simplified fashion. The lineaments shown as solid lines are well expressed, and those shown as dashed lines are suggested but poorly expressed by these data. We should also point out in this analysis technique that, for example, northeast-trending lineaments were only defined by northeast-trending linear concentrations of northeast-trending linear features.

One final aspect of the data is from the orientation analysis of the subareas; certain groupings of subareas on the basis of sets of trends were observed. The statistics for these groups are shown in figure 1 as uplifts, basins A, basins B, and basins C. If the subelements are grouped on the basis of (1) those containing northwest and east-west trends, and (2) those without this pair, the following subelements are selected: the Uplifts Group, Uncompahgre Uplift, Monument Uplift, Capitol Reef Fold Belt, and the San Rafael Swell, the Basins A and B group. Transitional areas between basins and uplifts are arbitrarily excluded. The High Plateau-Basin and Range area is also arbitrarily excluded because it is not fully included in the data set, and it is so large a subarea that it is statistically like all of southern Utah. Accepting these two arbitrary exclusions, this classification essentially subdivided the study area into two classes: the uplifts with northeast, north-northwest, and east-west statistically significant trends of linear features, and the basins with northeast statistically significant trends but without the northwest-east-west combination. Only the Circle Cliffs Uplift and the Capitol Fold Belt Reef are misclassified by this classification scheme.

Basins B and C are other groups that were observed. Basins B consists of the Paradox Fold-Fault Belt, the Piute Fold Belt, and the Kaiparowits Basin, all of which have northwest and northeast trends without east-west trends. Basins C consists of the Blanding Basin, Henry Basin, and Capitol Reef Fold Belt, all of which are basins with east-west trends, and not in the Basins B group. Other groups could, of course, be found.

PRELIMINARY INTERPRETATION

The purpose of this section is to present some observations concerning the lineaments of plate 12 and the orientation statistics in figure 1 with regards to geologic structures in this region. These observations are considered to be preliminary, but a possible starting point for a geologic analysis of these interpreted lineaments.

Considering the statistical orientation analysis of the full data set, north- and northeast-trending linear features form the only statistically significant intervals. In all of the subareas, northeast trends are statistically significant and north-south trends are significant in most. Thus, these two trends are so strong that they overwhelm the other possible trends when

the whole data set is analyzed. For subelements, however, northwest- to north-northwest trends are almost always statistically significant and east-west trends frequently occur. Spatially, the linear features of the northwest interval are insignificant in the southeast corner of the area and form the strongest trends in the northern half of the area. The linear features of the north-northwest trends are best developed in the southwestern part of the area. The linear features of the east-west trends occur most frequently between 37° to 39° N. latitude.

The north-trending lineaments occur primarily in the eastern half of the area and are not understood at present. However, they may be related to the Toroweap and Oak Creek fault systems described by Shoemaker, Squires, and Abrams (1978).

The east-west lineaments appear to be continuations of the east-trending structural lineaments of central Nevada described by Ekren and others (1976). Ekren and others (1976) show that these lineaments in Nevada are of pre-Oligocene origin, are associated with lithologic boundaries, range and valley termini, caldera boundaries, and strong magnetic interruptions, and probably involve deep-seated crustal control. On the east, east-west lineaments may be related to the Maysville fault zone that forms the southern termination of the north-trending upper Arkansas River graben (Van Alstine, 1968; Knepper, 1974). The latest movement (Pleistocene) on the Maysville fault is down to the north.

The north-northeast-trending lineaments west of 111°30′ longitude are spatially associated with the Wasatch-Sevier-Hurricane fault zones and are part of the Basin and Range Province (Eardley, 1968). These lineaments have the same general spacing, however with a more north-northeast trend, as those with a northeast trend in eastern Utah. Are these two groups of lineaments related?

The northeast-trending lineaments in eastern Utah are continuous with the Bright Angel and Mesa Butte fault systems described by Shoemaker, Squires, and Abrams (1978) and probably also the Sinyala fault system. They state that these three fault systems are zones of faulting about 10 mi wide, seem to control Cenozoic volcanism, are associated with recent earthquake epicenters, had experienced repeated movement of various types from the Precambrian to the Holocene, and owe their origin to major Precambrian fault zones similar to the Shylock and Chaparral fault zones in central Arizona as described by Anderson aand Creasey (1967).

The northeast-trending lineaments occur within the Colorado Lineament of Warner (1978) that includes the Colorado Mineral Belt shear zones of Tweto and Sims (1963) and the Mullen Creek-Nash Fork Shear Zone of Houston and McCallum (1961). Warner (1978) presents data that suggest that his Colorado Lineament extends to the Great Lakes area. A northeastward continuity of the various lineaments involved is supported by the work of Raines (1979) in South Dakota and by the work of Shurr (1979; personal commun., 1978) in the Williston Basin and into Wisconsin. However, the lineaments defined in this study, results of similar studies in Mexico (Raines, 1978; Raines and others, 1978) and central New Mexico (Knepper, 1978), and work in progress in Arizona and the Powder River Basin by Raines and in the San Juan Basin by Knepper (personal commun., 1980), contradict Warner's conclusion that these northeast-trending lineaments are restricted to a Precambrian wrench fault system that formed along a continental plate margin. Simply stated, the tectonic pattern of northeast-trending lineaments, probably related to shear zones that Warner attributed to

his Colorado Lineament seem to occur systematically from Hermosillo, Mexico, at 29° N. latitude, across Arizona, New Mexico, and Utah, and into the Powder River Basin at least as far north as 46° N. latitude. This pattern seems too wide for a simple wrench fault system; it must represent a more complex regional tectonic phenomena of which Warner's Colorado Lineament is a part.

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APPENDIX 1

Statistical data for area south of 40° N., Utah

ABSOLUTE STRIKE FREQUENCY ANALYSIS.

Utah lin. s. 40deg unweighted .97

10 LEVELS OF FREQUENCY AT 12 PER LEVEL.

NO. OF DATA = 8730

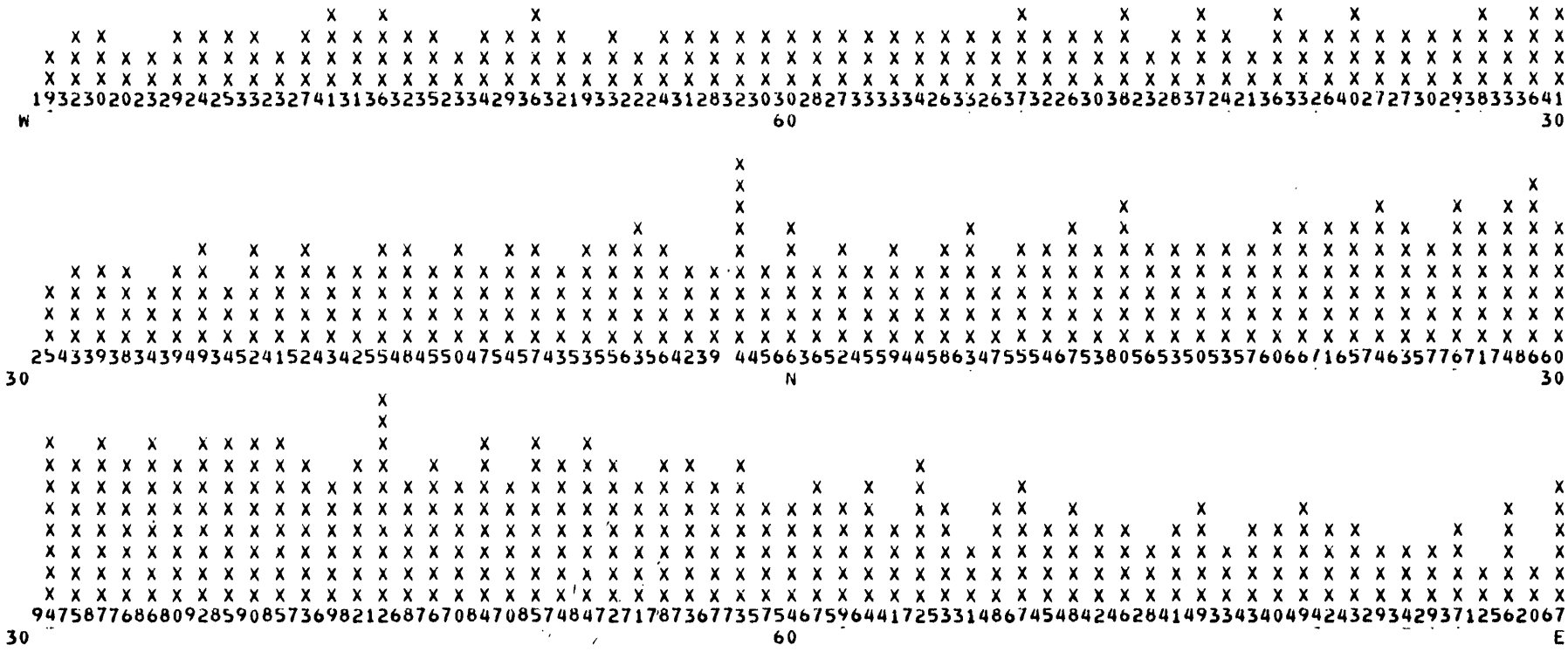


TABLE OF AZIMUTH VS FREQUENCY FOR PRECEDING STRIKE FREQUENCY PLOT

AZIM	BRNG	FREQ	AZIM	BRNG	FREQ	AZIM	BRNG	FREQ	AZIM	BRNG	FREQ
271	-89	19	316	-44	37	1	1	56	46	46	76
272	-88	32	317	-43	24	2	2	52	47	47	70
273	-87	30	318	-42	21	3	3	45	48	48	84
274	-86	20	319	-41	36	4	4	59	49	49	70
275	-85	23	320	-40	33	5	5	44	50	50	85
276	-84	29	321	-39	26	6	6	58	51	51	74
277	-83	24	322	-38	40	7	7	63	52	52	84
278	-82	25	323	-37	27	8	8	47	53	53	72
279	-81	33	324	-36	27	9	9	55	54	54	71
280	-80	23	325	-35	30	10	10	54	55	55	78
281	-79	27	326	-34	29	11	11	67	56	56	73
282	-78	41	327	-33	38	12	12	53	57	57	67
283	-77	31	328	-32	33	13	13	80	58	58	73
284	-76	36	329	-31	36	14	14	56	59	59	57
285	-75	32	330	-30	41	15	15	53	60	60	54
286	-74	35	331	-29	25	16	16	50	61	61	67
287	-73	23	332	-28	43	17	17	53	62	62	59
288	-72	34	333	-27	39	18	18	57	63	63	64
289	-71	29	334	-26	38	19	19	60	64	64	41
290	-70	36	335	-25	34	20	20	66	65	65	72
291	-69	32	336	-24	39	21	21	71	66	66	53
292	-68	19	337	-23	49	22	22	65	67	67	31
293	-67	33	338	-22	34	23	23	74	68	68	48
294	-66	22	339	-21	52	24	24	63	69	69	67
295	-65	24	340	-20	41	25	25	57	70	70	45
296	-64	31	341	-19	52	26	26	76	71	71	48
297	-63	28	342	-18	43	27	27	71	72	72	42
298	-62	32	343	-17	42	28	28	74	73	73	46
299	-61	30	344	-16	55	29	29	86	74	74	28
300	-60	30	345	-15	48	30	30	60	75	75	41
301	-59	28	346	-14	45	31	31	94	76	76	49
302	-58	27	347	-13	50	32	32	75	77	77	33
303	-57	33	348	-12	47	33	33	87	78	78	43
304	-56	33	349	-11	54	34	34	76	79	79	40
305	-55	34	350	-10	57	35	35	86	80	80	49
306	-54	26	351	-9	43	36	36	80	81	81	42
307	-53	33	352	-8	53	37	37	92	82	82	43
308	-52	26	353	-7	55	38	38	85	83	83	29
309	-51	37	354	-6	63	39	39	90	84	84	34
310	-50	32	355	-5	56	40	40	85	85	85	29
311	-49	26	356	-4	42	41	41	73	86	86	37
312	-48	30	357	-3	39	42	42	69	87	87	12
313	-47	38	358	-2	104	43	43	82	88	88	56
314	-46	23	359	-1	45	44	44	112	89	89	20
315	-45	28	360	0	66	45	45	68	90	90	67

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

Utah lin. s. 40deg unweighted .97

10 LEVELS OF FREQUENCY AT 27 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 8730

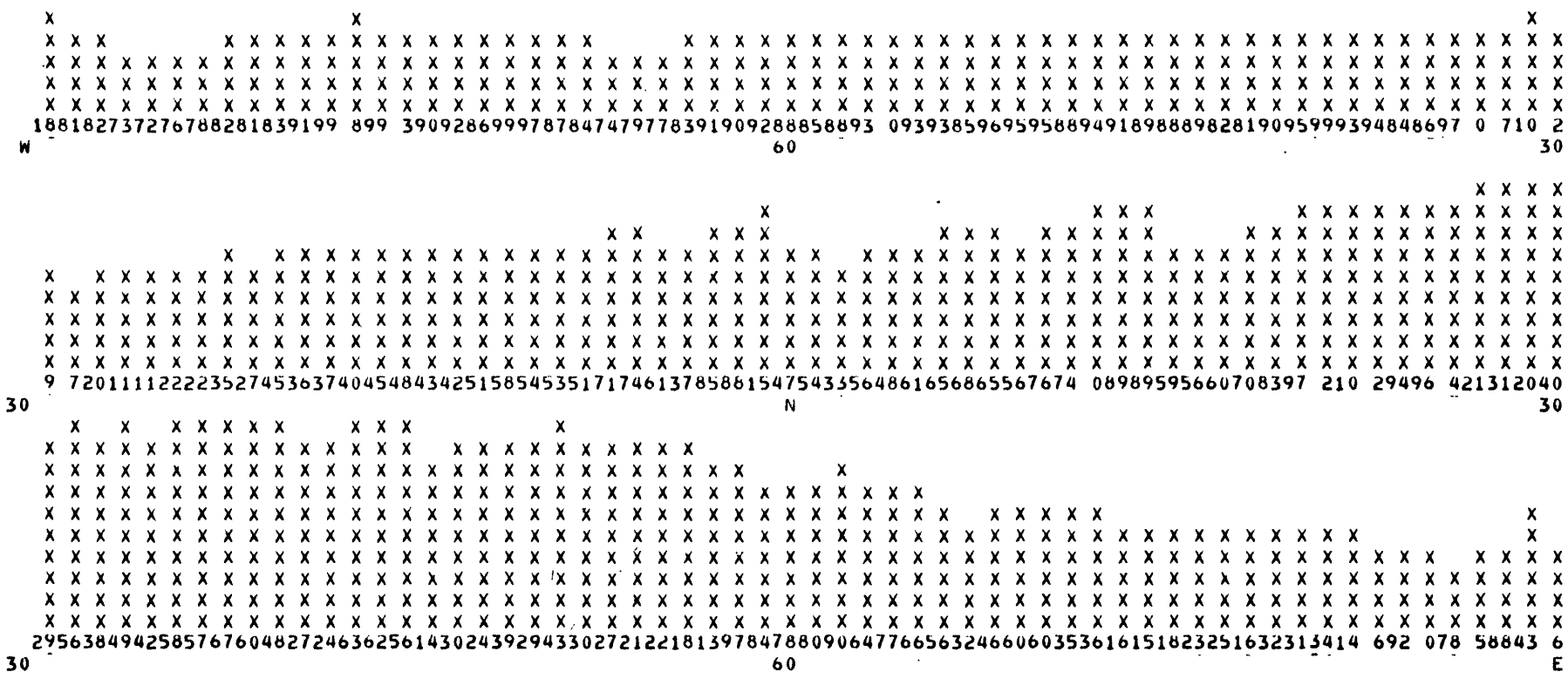


TABLE OF AZIMUTH VS FREQUENCY FOR PRECEDING STRIKE FREQUENCY PLOT

AZIM	BRNG	FREQ	AZIM	BRNG	FREQ	AZIM	BRNG	FREQ	AZIM	BRNG	FREQ
271	-89	118	316	-44	89	1	1	154	46	46	214
272	-88	81	317	-43	82	2	2	133	47	47	230
273	-87	82	318	-42	81	3	3	156	48	48	224
274	-86	73	319	-41	90	4	4	148	49	49	239
275	-85	72	320	-40	95	5	5	161	50	50	229
276	-84	76	321	-39	99	6	6	165	51	51	243
277	-83	78	322	-38	93	7	7	168	52	52	230
278	-82	82	323	-37	94	8	8	165	53	53	227
279	-81	81	324	-36	84	9	9	156	54	54	221
280	-80	83	325	-35	86	10	10	176	55	55	222
281	-79	91	326	-34	97	11	11	174	56	56	218
282	-78	99	327	-33	100	12	12	200	57	57	213
283	-77	108	328	-32	107	13	13	189	58	58	197
284	-76	99	329	-31	110	14	14	189	59	59	184
285	-75	103	330	-30	102	15	15	159	60	60	178
286	-74	90	331	-29	109	16	16	156	61	61	180
287	-73	92	332	-28	107	17	17	160	62	62	190
288	-72	86	333	-27	120	18	18	170	63	63	164
289	-71	99	334	-26	111	19	19	183	64	64	177
290	-70	97	335	-25	111	20	20	197	65	65	166
291	-69	87	336	-24	122	21	21	202	66	66	156
292	-68	84	337	-23	122	22	22	210	67	67	132
293	-67	74	338	-22	135	23	23	202	68	68	146
294	-66	79	339	-21	127	24	24	194	69	69	160
295	-65	77	340	-20	145	25	25	196	70	70	160
296	-64	83	341	-19	136	26	26	204	71	71	135
297	-63	91	342	-18	137	27	27	221	72	72	136
298	-62	90	343	-17	140	28	28	231	73	73	116
299	-61	92	344	-16	145	29	29	220	74	74	115
300	-60	88	345	-15	148	30	30	240	75	75	118
301	-59	85	346	-14	143	31	31	229	76	76	123
302	-58	88	347	-13	142	32	32	256	77	77	125
303	-57	93	348	-12	151	33	33	238	78	78	116
304	-56	100	349	-11	158	34	34	249	79	79	132
305	-55	93	350	-10	154	35	35	242	80	80	131
306	-54	93	351	-9	153	36	36	258	81	81	134
307	-53	85	352	-8	151	37	37	257	82	82	114
308	-52	96	353	-7	171	38	38	267	83	83	106
309	-51	95	354	-6	174	39	39	260	84	84	92
310	-50	95	355	-5	161	40	40	248	85	85	100
311	-49	88	356	-4	137	41	41	227	86	86	78
312	-48	94	357	-3	185	42	42	224	87	87	105
313	-47	91	358	-2	188	43	43	263	88	88	88
314	-46	89	359	-1	215	44	44	262	89	89	143
315	-45	88	360	0	147	45	45	256	90	90	106

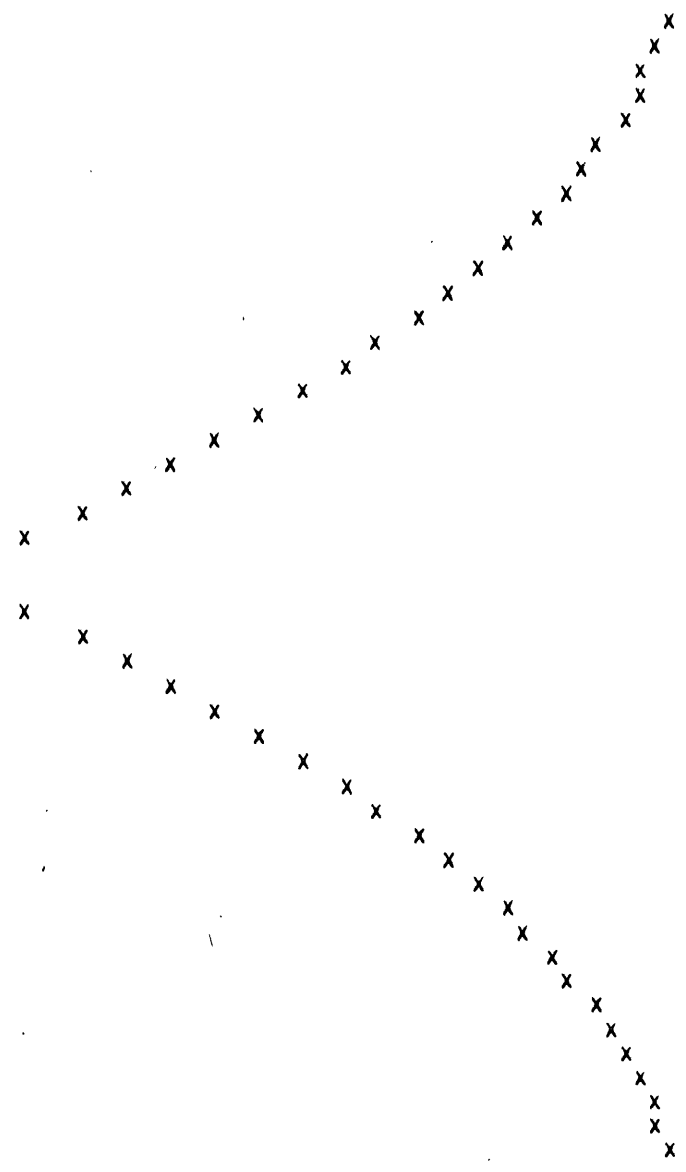
Utah lin. s. 40deg unweighted .97

FREQUENCY PROBABILITY DATA

NO. OF DATA = 8730 EVENT PROB. = 0.017 PROB. LIMIT = 0.970

FREQUENCY MEAN = 145.5

EMP. FREQ.	REL. FREQ.	FREQ. PROB.	SIGNIF VALUE	SIGNIFICANCE 0 .2 .4 .6 .8 1.0
123	1.9	0.006	93.8	
124	1.9	0.007	92.4	
125	1.9	0.008	90.9	
126	1.9	0.009	89.1	
127	2.0	0.010	87.1	
128	2.0	0.012	84.7	
129	2.0	0.013	82.1	
130	2.0	0.015	79.2	
131	2.0	0.016	75.9	
132	2.0	0.018	72.3	
133	2.0	0.020	68.4	
134	2.0	0.022	64.1	
135	2.0	0.023	59.5	
136	2.1	0.025	54.6	
137	2.1	0.026	49.3	
138	2.1	0.028	43.8	
139	2.1	0.029	38.1	
140	2.1	0.030	32.1	
141	2.1	0.031	25.9	
142	2.1	0.032	19.5	
143	2.1	0.033	13.1	
144	2.1	0.033	6.5	
145	2.2	0.033	0.0	
146	2.2	0.033	-0.0	
147	2.2	0.033	6.7	
148	2.2	0.032	13.3	
149	2.2	0.031	19.8	
150	2.2	0.030	26.1	
151	2.2	0.029	32.2	
152	2.2	0.028	38.2	
153	2.3	0.027	43.8	
154	2.3	0.025	49.2	
155	2.3	0.024	54.3	
156	2.3	0.022	59.1	
157	2.3	0.020	63.5	
158	2.3	0.019	67.7	
159	2.3	0.017	71.5	
160	2.3	0.016	75.0	
161	2.3	0.014	78.1	
162	2.4	0.013	81.0	
163	2.4	0.011	83.6	
164	2.4	0.010	85.9	
165	2.4	0.009	87.9	
166	2.4	0.008	89.7	
167	2.4	0.007	91.3	
168	2.4	0.006	92.6	
169	2.4	0.005	93.8	



LOCATION OF MAXIMA AND THEIR SIGNIFICANCE VALUES.

AZIMUTH	EMP. FREQ.	SIG. VALUE
345	148	13.3
349	158	67.7
354	174	99.9
359	215	99.9
1	154	49.2
3	156	59.1
7	168	92.6
10	176	99.9
12	200	99.9
22	210	99.9
28	231	99.9
30	240	99.9
32	256	99.9
34	249	99.9
36	258	99.9
38	267	99.9
43	263	99.9
47	230	99.9
49	239	99.9
51	243	99.9
55	222	99.9
62	190	99.9
64	177	99.9
69	160	75.0

69 160 75.0

ABSOLUTE STRIKE FREQUENCY ANALYSIS.

Utah lin. s. 40deg length-weighted .97

10 LEVELS OF FREQUENCY AT 150 PER LEVEL.

NO. OF DATA = 134232

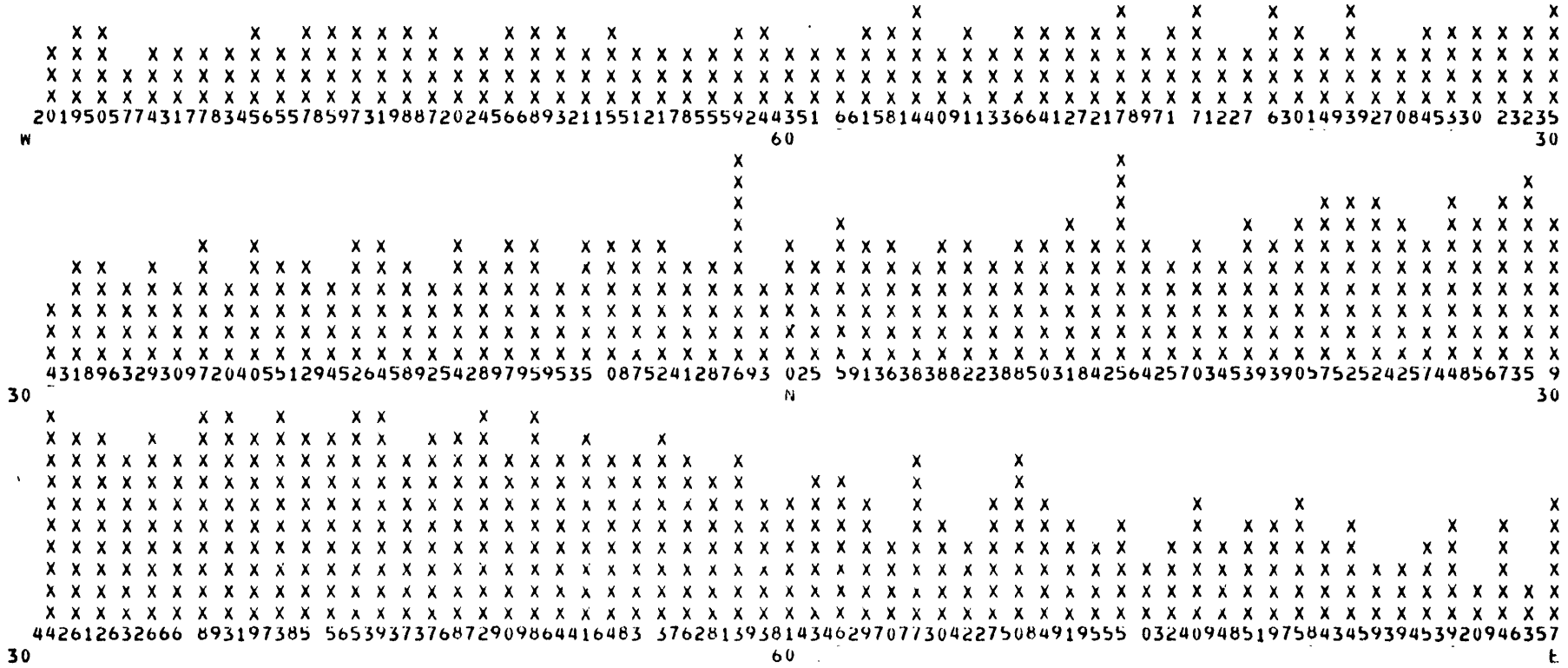


TABLE OF AZIMUTH VS FREQUENCY FOR PRECEDING STRIKE FREQUENCY PLOT

AZIM	BRNG	FREQ	AZIM	BRNG	FREQ	AZIM	BRNG	FREQ	AZIM	BRNG	FREQ
271	-89	320	316	-44	707	1	1	725	46	46	1237
272	-88	519	317	-43	412	2	2	905	47	47	1268
273	-87	450	318	-42	327	3	3	791	48	48	1372
274	-86	257	319	-41	706	4	4	836	49	49	1090
275	-85	374	320	-40	530	5	5	638	50	50	1398
276	-84	431	321	-39	414	6	6	838	51	51	1064
277	-83	377	322	-38	693	7	7	882	52	52	1241
278	-82	383	323	-37	392	8	8	723	53	53	1164
279	-81	545	324	-36	370	9	9	888	54	54	1083
280	-80	365	325	-35	484	10	10	850	55	55	1203
281	-79	457	326	-34	453	11	11	931	56	56	1076
282	-78	585	327	-33	530	12	12	784	57	57	928
283	-77	497	328	-32	502	13	13	1425	58	58	1113
284	-76	531	329	-31	532	14	14	864	59	59	893
285	-75	498	330	-30	635	15	15	725	60	60	781
286	-74	587	331	-29	404	16	16	770	61	61	943
287	-73	320	332	-28	631	17	17	734	62	62	946
288	-72	424	333	-27	689	18	18	953	63	63	829
289	-71	456	334	-26	563	19	19	893	64	64	570
290	-70	468	335	-25	629	20	20	990	65	65	1077
291	-69	493	336	-24	530	21	21	1157	66	66	730
292	-68	321	337	-23	797	22	22	1052	67	67	542
293	-67	515	338	-22	520	23	23	1052	68	68	827
294	-66	351	339	-21	840	24	24	1042	69	69	1150
295	-65	421	340	-20	655	25	25	857	70	70	784
296	-64	378	341	-19	712	26	26	1144	71	71	691
297	-63	355	342	-18	594	27	27	985	72	72	595
298	-62	459	343	-17	752	28	28	1067	73	73	655
299	-61	524	344	-16	864	29	29	1335	74	74	400
300	-60	443	345	-15	658	30	30	909	75	75	532
301	-59	351	346	-14	592	31	31	1444	76	76	840
302	-58	406	347	-13	754	32	32	1226	77	77	494
303	-57	561	348	-12	728	33	33	1212	78	78	685
304	-56	558	349	-11	797	34	34	1163	79	79	719
305	-55	614	350	-10	795	35	35	1326	80	80	775
306	-54	440	351	-9	595	36	36	1166	81	81	584
307	-53	591	352	-8	835	37	37	1408	82	82	634
308	-52	413	353	-7	800	38	38	1493	83	83	359
309	-51	556	354	-6	887	39	39	1319	84	84	439
310	-50	464	355	-5	852	40	40	1373	85	85	545
311	-49	512	356	-4	741	41	41	1285	86	86	639
312	-48	572	357	-3	728	42	42	1205	87	87	220
313	-47	617	358	-2	1376	43	43	1365	88	88	694
314	-46	389	359	-1	593	44	44	1439	89	89	263
315	-45	471	360	0	800	45	45	1137	90	90	857

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

Utah lin. s. 40deg length-weighted .97

10 LEVELS OF FREQUENCY AT 423 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 134232

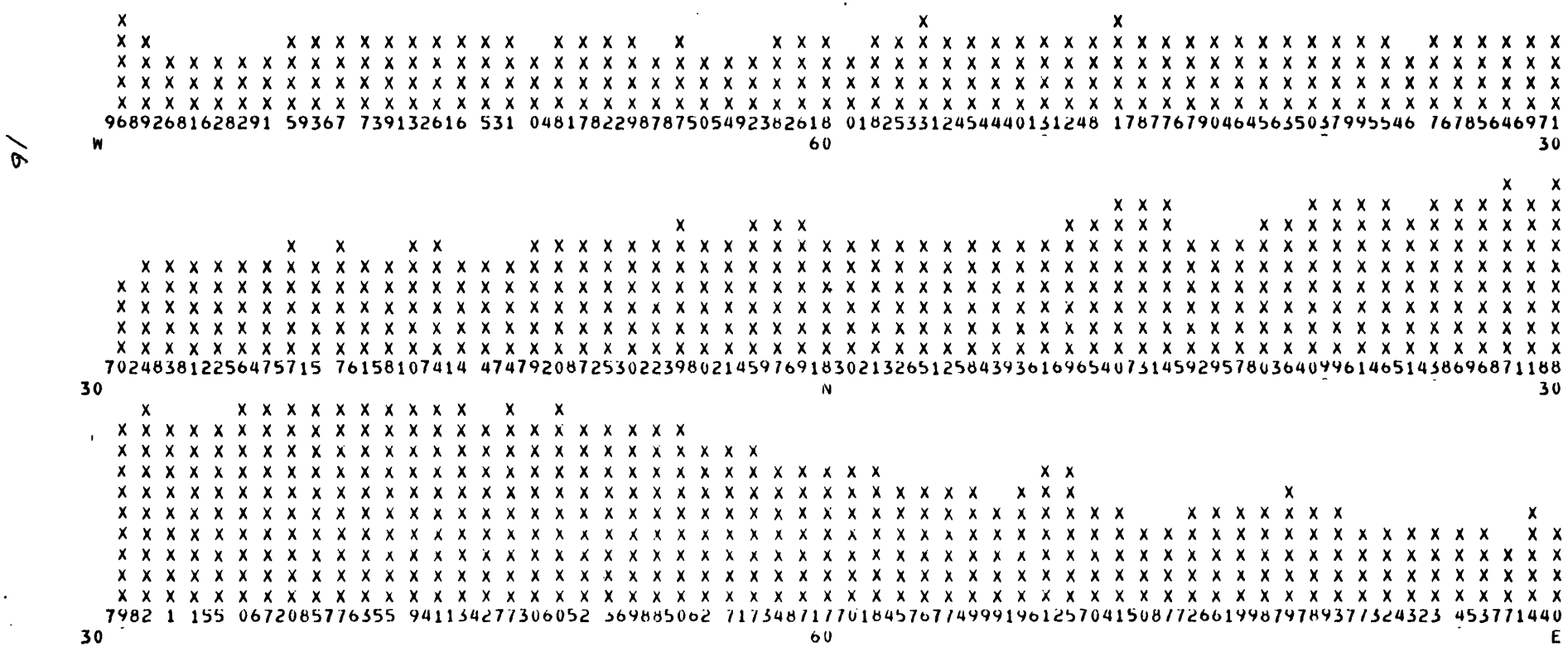


TABLE OF AZIMUTH VS FREQUENCY FOR PRECEDING STRIKE FREQUENCY PLOT

AZIM	BRNG	FREQ	AZIM	BRNG	FREQ	AZIM	BRNG	FREQ	AZIM	BRNG	FREQ
271	-89	1696	316	-44	1590	1	1	2430	46	46	3642
272	-88	1289	317	-43	1446	2	2	2421	47	47	3877
273	-87	1226	318	-42	1445	3	3	2532	48	48	3730
274	-86	1081	319	-41	1563	4	4	2265	49	49	3860
275	-85	1062	320	-40	1650	5	5	2312	50	50	3552
276	-84	1182	321	-39	1637	6	6	2358	51	51	3703
277	-83	1191	322	-38	1499	7	7	2443	52	52	3469
278	-82	1305	323	-37	1455	8	8	2493	53	53	3488
279	-81	1293	324	-36	1246	9	9	2461	54	54	3450
280	-80	1367	325	-35	1307	10	10	2669	55	55	3362
281	-79	1407	326	-34	1467	11	11	2565	56	56	3207
282	-78	1539	327	-33	1465	12	12	3140	57	57	3117
283	-77	1613	328	-32	1564	13	13	3073	58	58	2934
284	-76	1526	329	-31	1669	14	14	3014	59	59	2787
285	-75	1616	330	-30	1571	15	15	2359	60	60	2617
286	-74	1405	331	-29	1670	16	16	2229	61	61	2670
287	-73	1331	332	-28	1724	17	17	2457	62	62	2718
288	-72	1200	333	-27	1883	18	18	2580	63	63	2345
289	-71	1348	334	-26	1881	19	19	2836	64	64	2476
290	-70	1417	335	-25	1722	20	20	3040	65	65	2377
291	-69	1282	336	-24	1956	21	21	3199	66	66	2349
292	-68	1329	337	-23	1847	22	22	3261	67	67	2099
293	-67	1187	338	-22	2157	23	23	3146	68	68	2519
294	-66	1287	339	-21	2015	24	24	2951	69	69	2761
295	-65	1150	340	-20	2207	25	25	3043	70	70	2625
296	-64	1154	341	-19	1961	26	26	2986	71	71	2070
297	-63	1192	342	-18	2058	27	27	3196	72	72	1941
298	-62	1338	343	-17	2210	28	28	3387	73	73	1650
299	-61	1426	344	-16	2274	29	29	3311	74	74	1587
300	-60	1318	345	-15	2114	30	30	3688	75	75	1772
301	-59	1200	346	-14	2004	31	31	3579	76	76	1866
302	-58	1318	347	-13	2074	32	32	3882	77	77	2019
303	-57	1525	348	-12	2279	33	33	3601	78	78	1898
304	-56	1733	349	-11	2320	34	34	3701	79	79	2179
305	-55	1612	350	-10	2187	35	35	3655	80	80	2078
306	-54	1645	351	-9	2225	36	36	3900	81	81	1993
307	-53	1444	352	-8	2230	37	37	4067	82	82	1577
308	-52	1540	353	-7	2522	38	38	4220	83	83	1432
309	-51	1413	354	-6	2539	39	39	4185	84	84	1343
310	-50	1512	355	-5	2480	40	40	3977	85	85	1623
311	-49	1548	356	-4	2321	41	41	3863	86	86	1404
312	-48	1701	357	-3	2845	42	42	3855	87	87	1553
313	-47	1578	358	-2	2697	43	43	4009	88	88	1177
314	-46	1477	359	-1	2769	44	44	3941	89	89	1814
315	-45	1567	360	0	2118	45	45	3813	90	90	1440

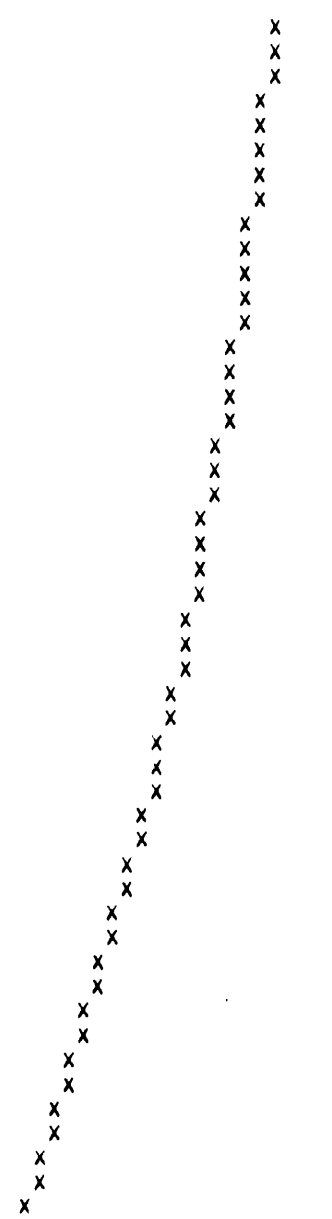
Utah lin. s. 40deg length-weighted .97

FREQUENCY PROBABILITY DATA

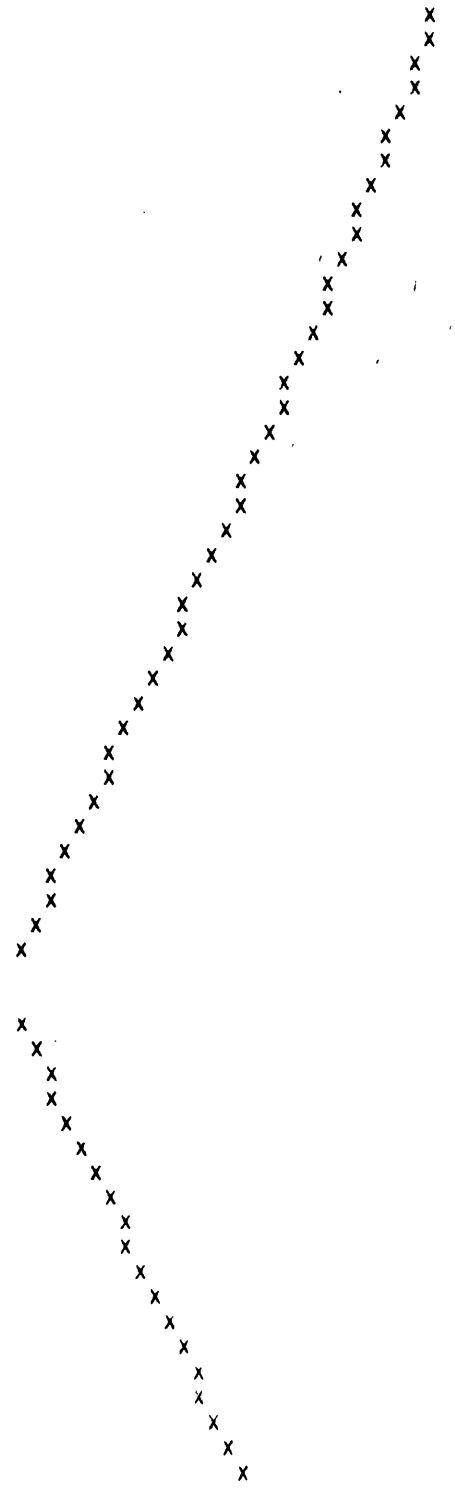
NO. OF DATA =134232 EVENT PROB. = 0.017 PROB. LIMIT = 0.970

FREQUENCY MEAN = 2237.2

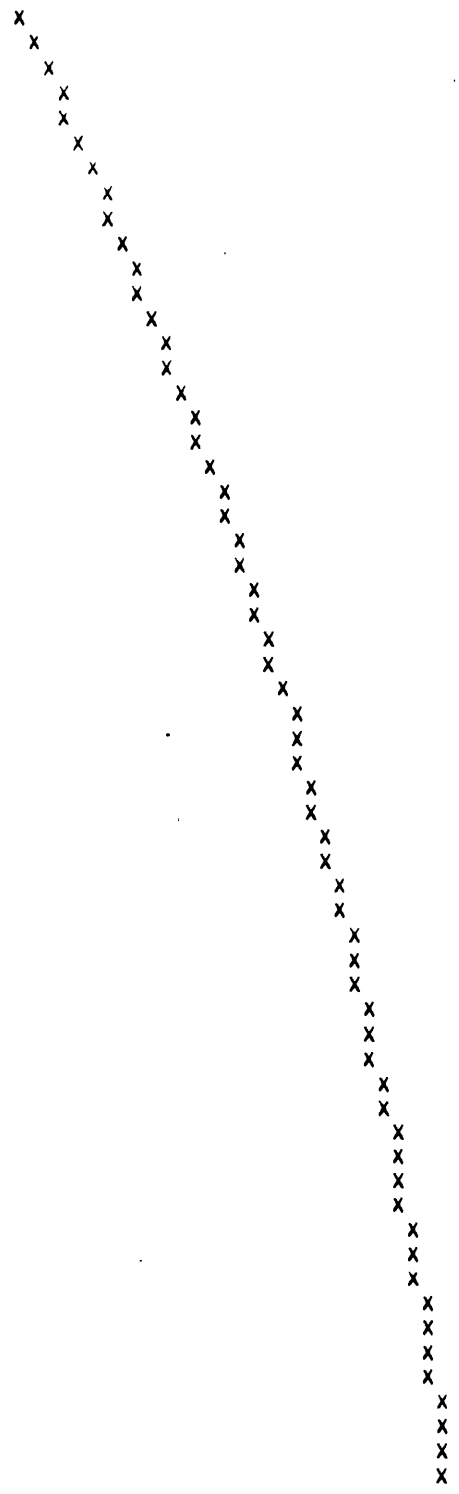
EMP. FREQ.	REL. FREQ.	FREQ. PROB.	SIGNIF VALUE
2149	2.1	0.001	93.8
2150	2.1	0.002	93.5
2151	2.1	0.002	93.2
2152	2.1	0.002	92.8
2153	2.1	0.002	92.5
2154	2.1	0.002	92.2
2155	2.1	0.002	91.8
2156	2.1	0.002	91.4
2157	2.1	0.002	91.0
2158	2.1	0.002	90.6
2159	2.1	0.002	90.2
2160	2.1	0.002	89.7
2161	2.1	0.002	89.3
2162	2.1	0.002	88.8
2163	2.1	0.002	88.3
2164	2.1	0.003	87.8
2165	2.1	0.003	87.3
2166	2.1	0.003	86.7
2167	2.1	0.003	86.2
2168	2.1	0.003	85.6
2169	2.1	0.003	85.0
2170	2.1	0.003	84.4
2171	2.1	0.003	83.7
2172	2.1	0.003	83.1
2173	2.1	0.003	82.4
2174	2.1	0.003	81.7
2175	2.1	0.004	81.0
2176	2.1	0.004	80.3
2177	2.1	0.004	79.5
2178	2.1	0.004	78.8
2179	2.1	0.004	78.0
2180	2.1	0.004	77.2
2181	2.1	0.004	76.3
2182	2.1	0.004	75.5
2183	2.1	0.004	74.6
2184	2.1	0.005	73.7
2185	2.1	0.005	72.8
2186	2.1	0.005	71.9
2187	2.1	0.005	70.9
2188	2.1	0.005	69.9
2189	2.1	0.005	68.9
2190	2.1	0.005	67.9
2191	2.1	0.005	66.9
2192	2.1	0.005	65.8
2193	2.1	0.005	64.7
2194	2.1	0.006	63.6
2195	2.1	0.006	62.5
2196	2.1	0.006	61.3
2197	2.1	0.006	60.1



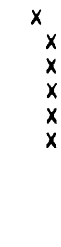
2198	2.1	0.006	58.9
2199	2.1	0.006	57.7
2200	2.1	0.006	56.5
2201	2.1	0.006	55.2
2202	2.1	0.006	53.9
2203	2.1	0.007	52.6
2204	2.1	0.007	51.3
2205	2.1	0.007	50.0
2206	2.1	0.007	48.6
2207	2.1	0.007	47.3
2208	2.1	0.007	45.9
2209	2.1	0.007	44.5
2210	2.1	0.007	43.0
2211	2.1	0.007	41.6
2212	2.1	0.007	40.1
2213	2.1	0.007	38.7
2214	2.1	0.008	37.2
2215	2.2	0.008	35.7
2216	2.2	0.008	34.1
2217	2.2	0.008	32.6
2218	2.2	0.008	31.1
2219	2.2	0.008	29.5
2220	2.2	0.008	27.9
2221	2.2	0.008	26.3
2222	2.2	0.008	24.8
2223	2.2	0.008	23.1
2224	2.2	0.008	21.5
2225	2.2	0.008	19.9
2226	2.2	0.008	18.3
2227	2.2	0.008	16.6
2228	2.2	0.008	15.0
2229	2.2	0.008	13.3
2230	2.2	0.008	11.7
2231	2.2	0.008	10.0
2232	2.2	0.008	8.4
2233	2.2	0.008	6.7
2234	2.2	0.008	5.0
2235	2.2	0.008	3.3
2236	2.2	0.008	1.7
2237	2.2	0.008	0.0
2238	2.2	0.008	0.0
2239	2.2	0.008	1.7
2240	2.2	0.008	3.4
2241	2.2	0.008	5.1
2242	2.2	0.008	6.8
2243	2.2	0.008	8.5
2244	2.2	0.008	10.2
2245	2.2	0.008	11.8
2246	2.2	0.008	13.5
2247	2.2	0.008	15.2
2248	2.2	0.008	16.6
2249	2.2	0.008	18.5
2250	2.2	0.008	20.1
2251	2.2	0.008	21.8
2252	2.2	0.008	23.4
2253	2.2	0.008	25.0
2254	2.2	0.008	26.6
2255	2.2	0.008	28.2
2256	2.2	0.008	29.8
2257	2.2	0.008	31.4



2258	2.2	0.008	32.9
2259	2.2	0.008	34.4
2260	2.2	0.007	36.0
2261	2.2	0.007	37.5
2262	2.2	0.007	39.0
2263	2.2	0.007	40.4
2264	2.2	0.007	41.9
2265	2.2	0.007	43.3
2266	2.2	0.007	44.8
2267	2.2	0.007	46.2
2268	2.2	0.007	47.5
2269	2.2	0.007	48.9
2270	2.2	0.007	50.3
2271	2.2	0.006	51.6
2272	2.2	0.006	52.9
2273	2.2	0.006	54.2
2274	2.2	0.006	55.5
2275	2.2	0.006	56.7
2276	2.2	0.006	57.9
2277	2.2	0.006	59.1
2278	2.2	0.006	60.3
2279	2.2	0.006	61.5
2280	2.2	0.006	62.6
2281	2.2	0.005	63.7
2282	2.2	0.005	64.8
2283	2.2	0.005	65.9
2284	2.2	0.005	67.0
2285	2.2	0.005	68.0
2286	2.2	0.005	69.0
2287	2.2	0.005	70.0
2288	2.2	0.005	71.0
2289	2.2	0.005	71.9
2290	2.2	0.004	72.9
2291	2.2	0.004	73.8
2292	2.2	0.004	74.7
2293	2.2	0.004	75.5
2294	2.2	0.004	76.4
2295	2.2	0.004	77.2
2296	2.2	0.004	78.0
2297	2.2	0.004	78.8
2298	2.2	0.004	79.5
2299	2.2	0.004	80.3
2300	2.2	0.003	81.0
2301	2.2	0.003	81.7
2302	2.2	0.003	82.4
2303	2.2	0.003	83.0
2304	2.2	0.003	83.7
2305	2.2	0.003	84.3
2306	2.2	0.003	84.9
2307	2.2	0.003	85.5
2308	2.2	0.003	86.1
2309	2.2	0.003	86.6
2310	2.2	0.003	87.1
2311	2.2	0.002	87.7
2312	2.2	0.002	88.2
2313	2.2	0.002	88.7
2314	2.2	0.002	89.1
2315	2.2	0.002	89.6
2316	2.2	0.002	90.0
2317	2.2	0.002	90.4



2318	2.2	0.002	90.8
2319	2.2	0.002	91.2
2320	2.2	0.002	91.6
2321	2.2	0.002	92.0
2322	2.2	0.002	92.3
2323	2.2	0.002	92.7
2324	2.2	0.002	93.0
2325	2.2	0.002	93.3
2326	2.2	0.001	93.6
2327	2.2	0.001	93.9



LOCATION OF MAXIMA AND THEIR SIGNIFICANCE VALUES

AZIMUTH	EMP. FREQ.	SIG. VALUE
344	2274	55.5
349	2320	91.6
354	2539	99.9
357	2845	99.9
359	2769	99.9
1	2430	99.9
3	2532	99.9
8	2493	99.9
10	2669	99.9
12	3140	99.9
22	3261	99.9
25	3043	99.9
28	3387	99.9
30	3688	99.9
32	3882	99.9
34	3701	99.9
38	4220	99.9
43	4009	99.9
47	3877	99.9
49	3860	99.9
51	3703	99.9
53	3488	99.9
62	2718	99.9
64	2476	99.9
69	2761	99.9

APPENDIX 2

Directional histograms for subelements

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

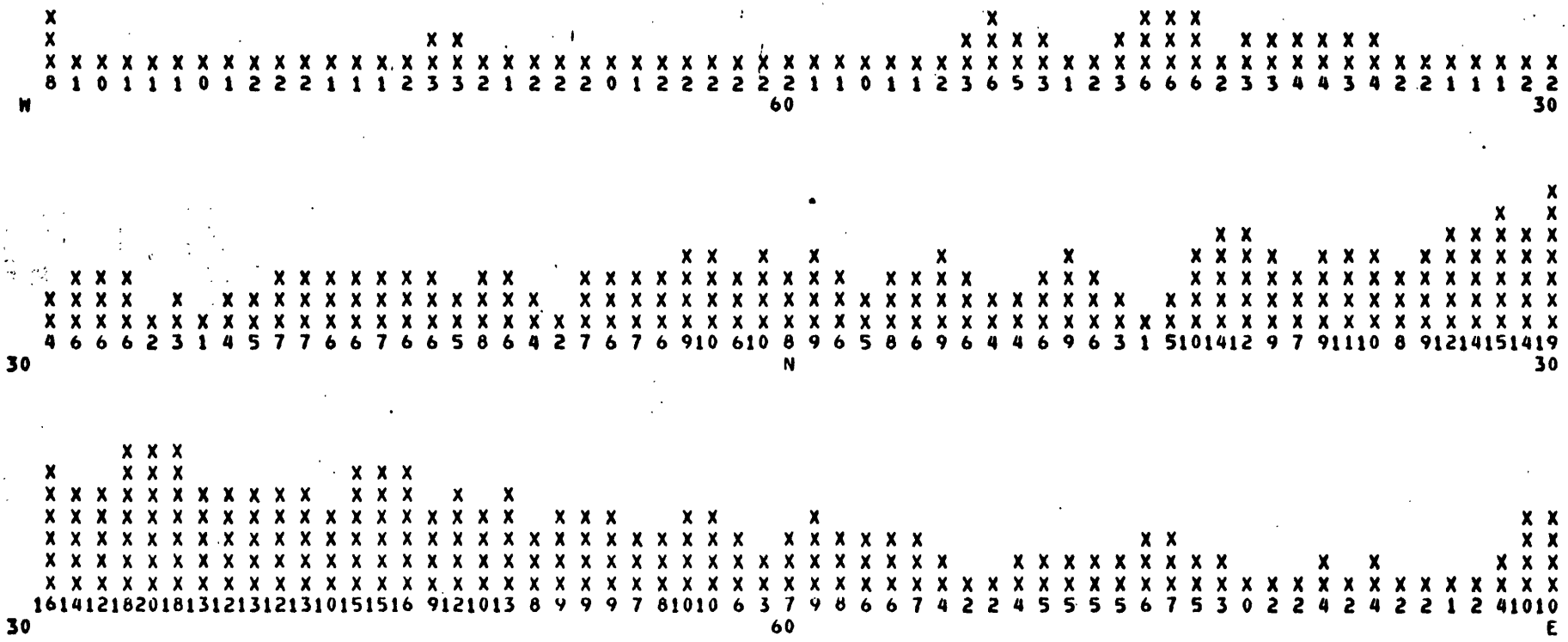
Utah Blanding basin unweighted .97

10 LEVELS OF FREQUENCY AT 3 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 350

90 % significance value ≥ 11



24

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

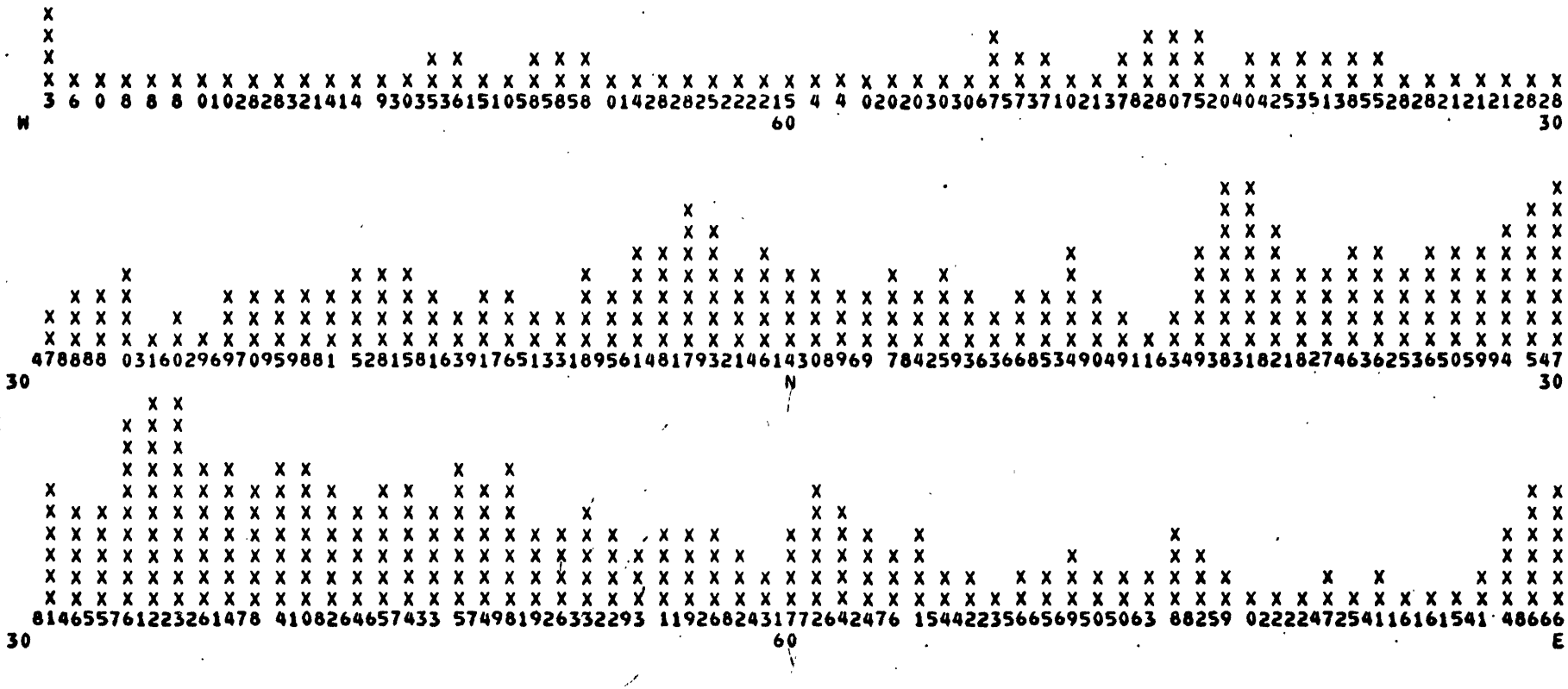
Utah Blanding basin length weighted .97

10 LEVELS OF FREQUENCY AT 33 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 5181

90% significance value ≥ 103



25

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

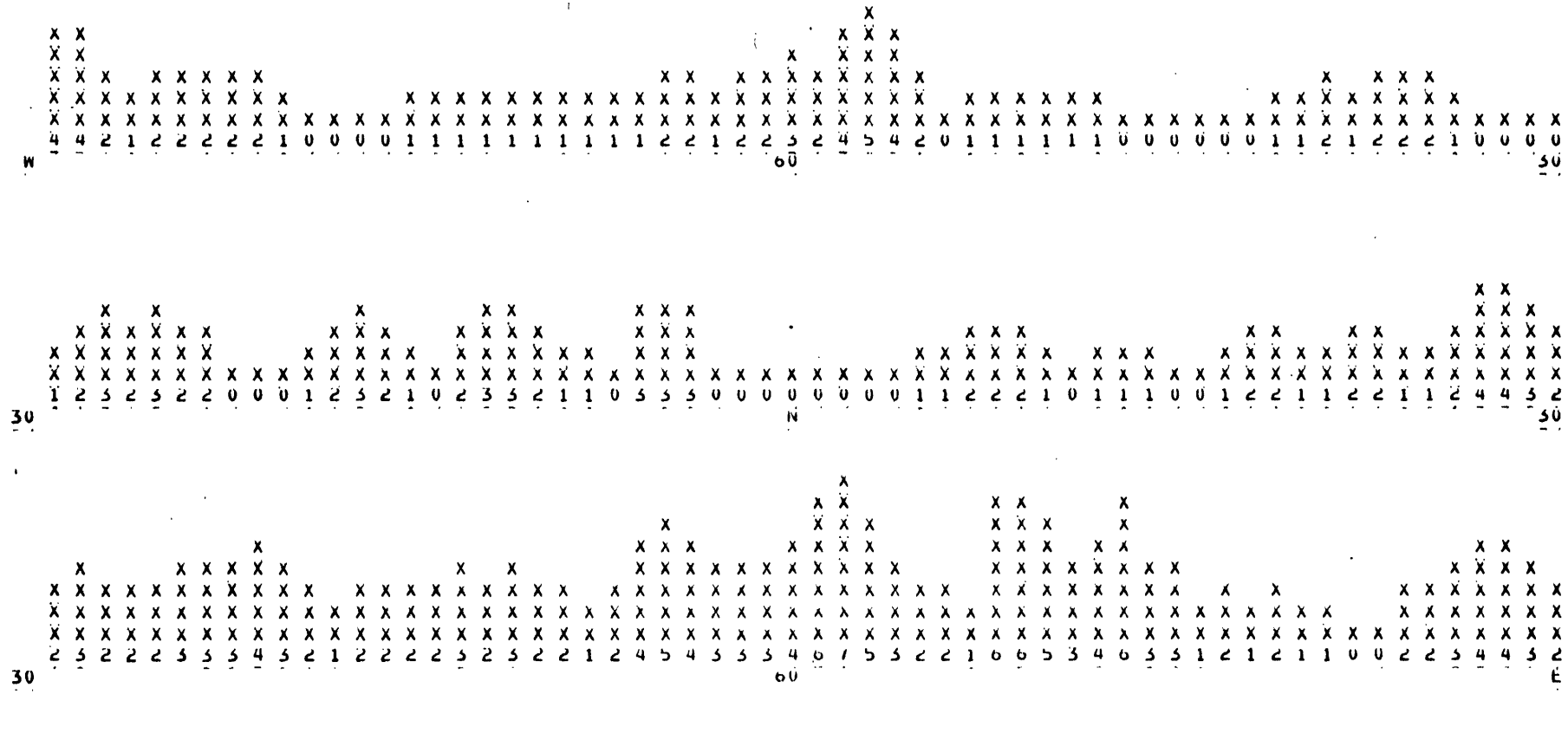
Utah Capital Reef fold belt unweighted .97

10 LEVELS OF FREQUENCY AT 1 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 3.89

NO. OF DATA = 111

90 % significance value ≥ 9



EMPIRICAL STRIKE FREQUENCY ANALYSIS.

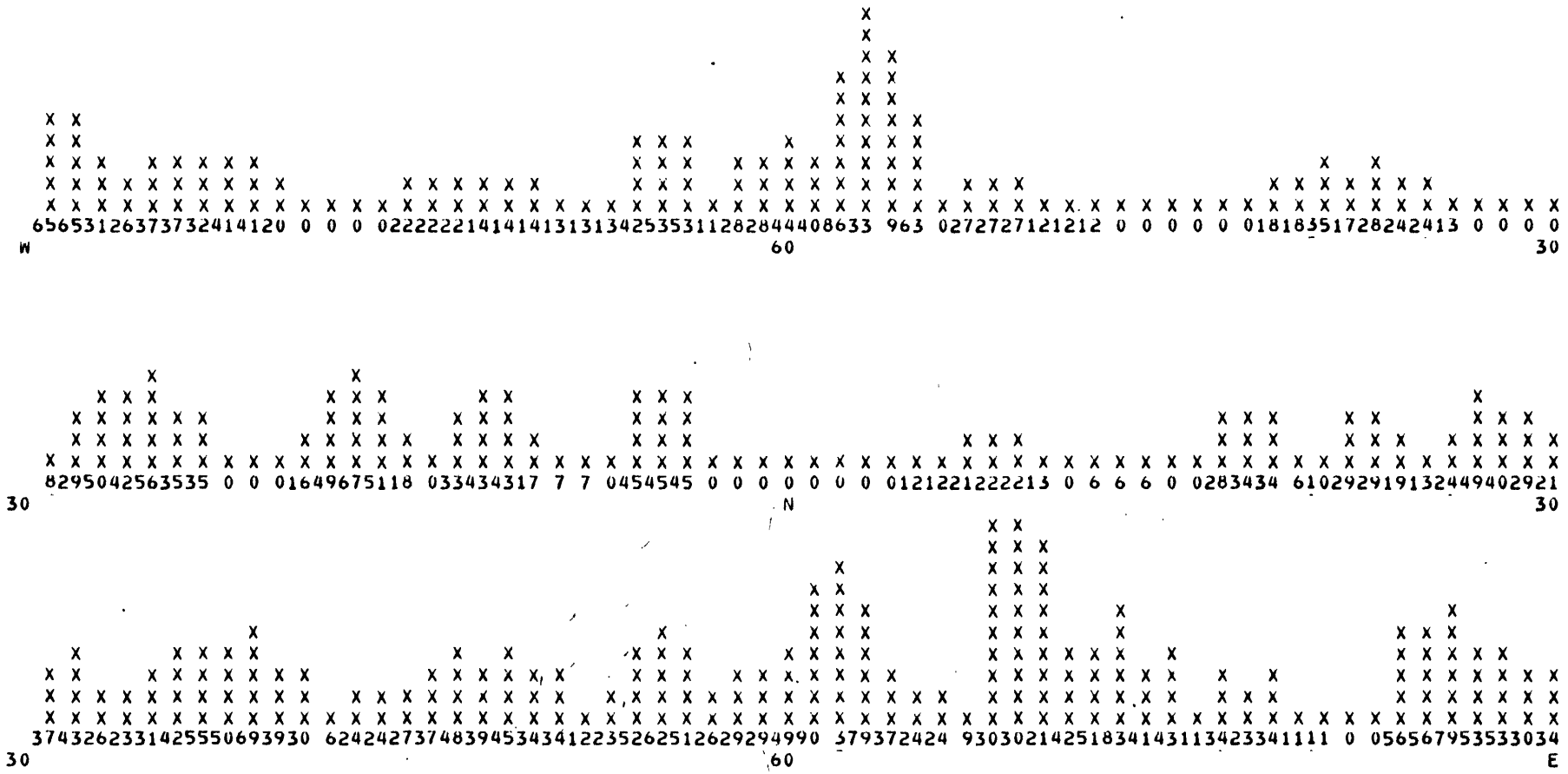
Utah Capital Reef fold belt weighted .97

10 LEVELS OF FREQUENCY AT 14 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 1780

90 % significance value ≥ 40



EMPIRICAL STRIKE FREQUENCY ANALYSIS.

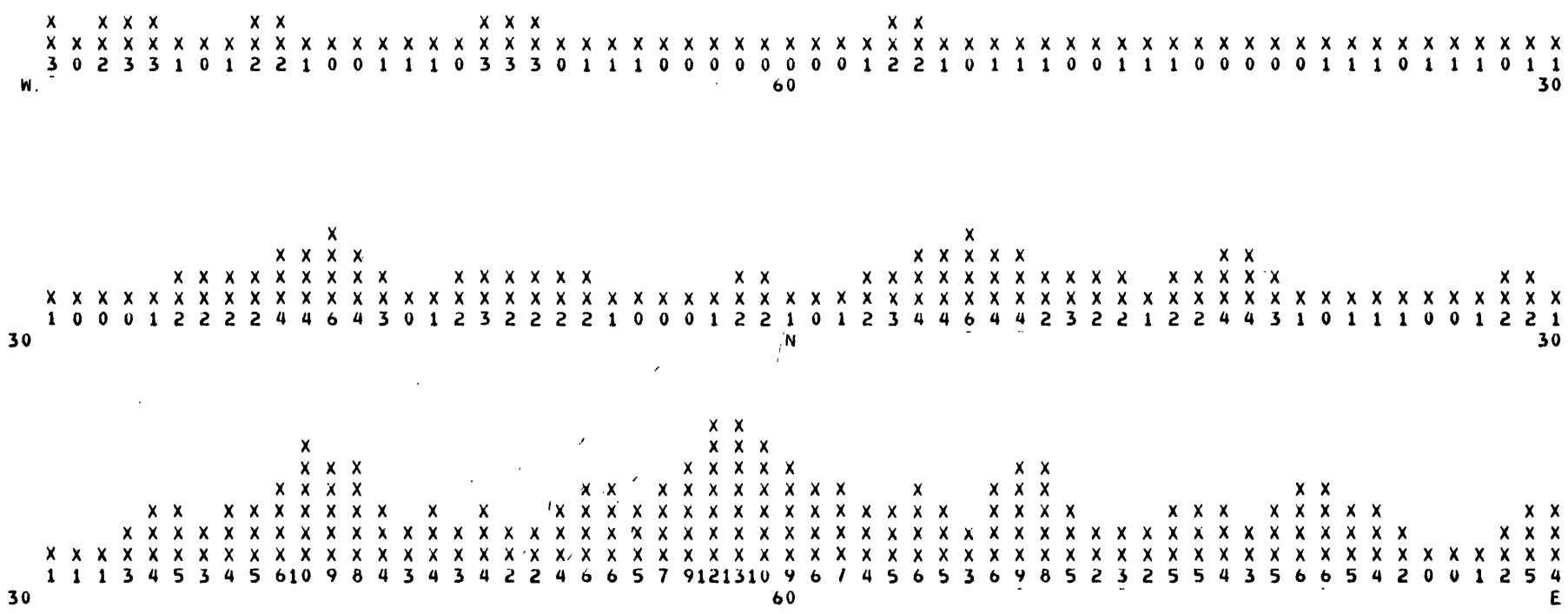
Circle Cliffs uplift Utah unweighted .97

10 LEVELS OF FREQUENCY AT 2 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 2.78

NO. OF DATA = 153

90 % significance value > 8



EMPIRICAL STRIKE FREQUENCY ANALYSIS.

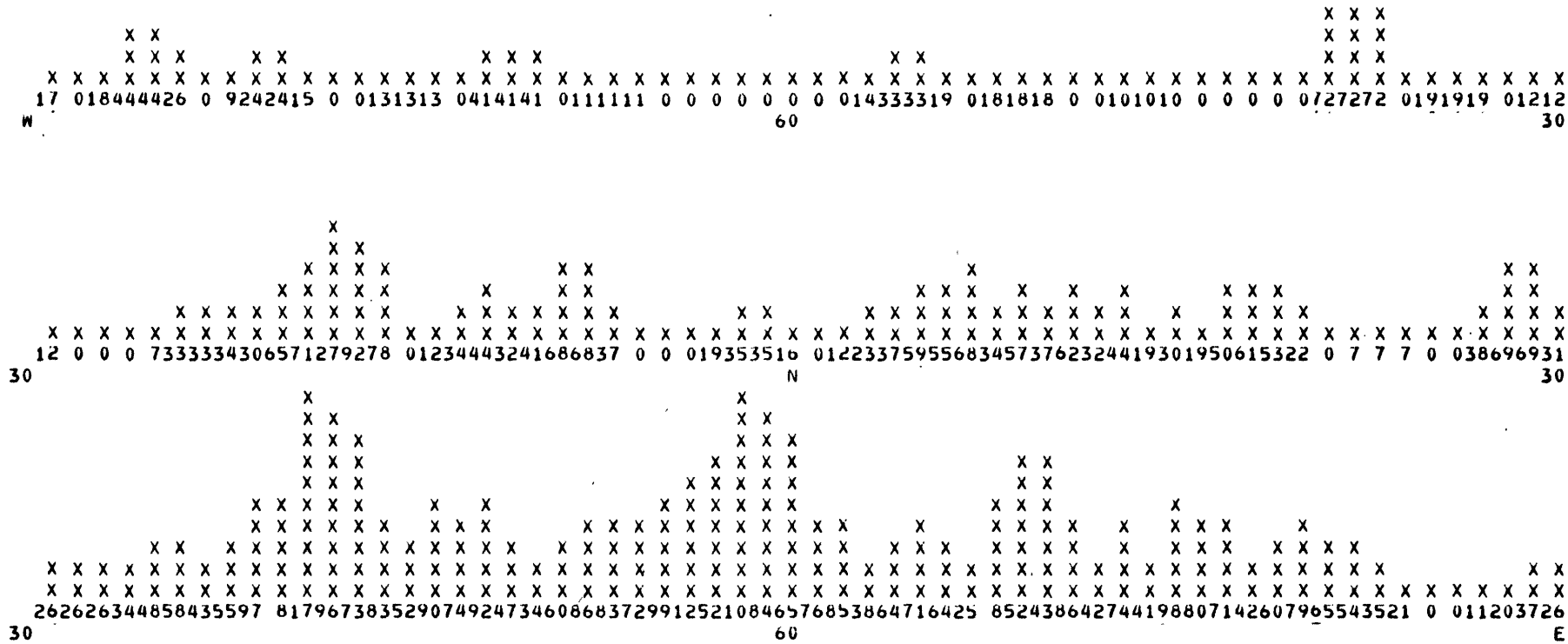
Circle Cliffs uplift Utah length weighted .97

90 % significance value ≥ 54

10 LEVELS OF FREQUENCY AT 22 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 2497



Henry Basin

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

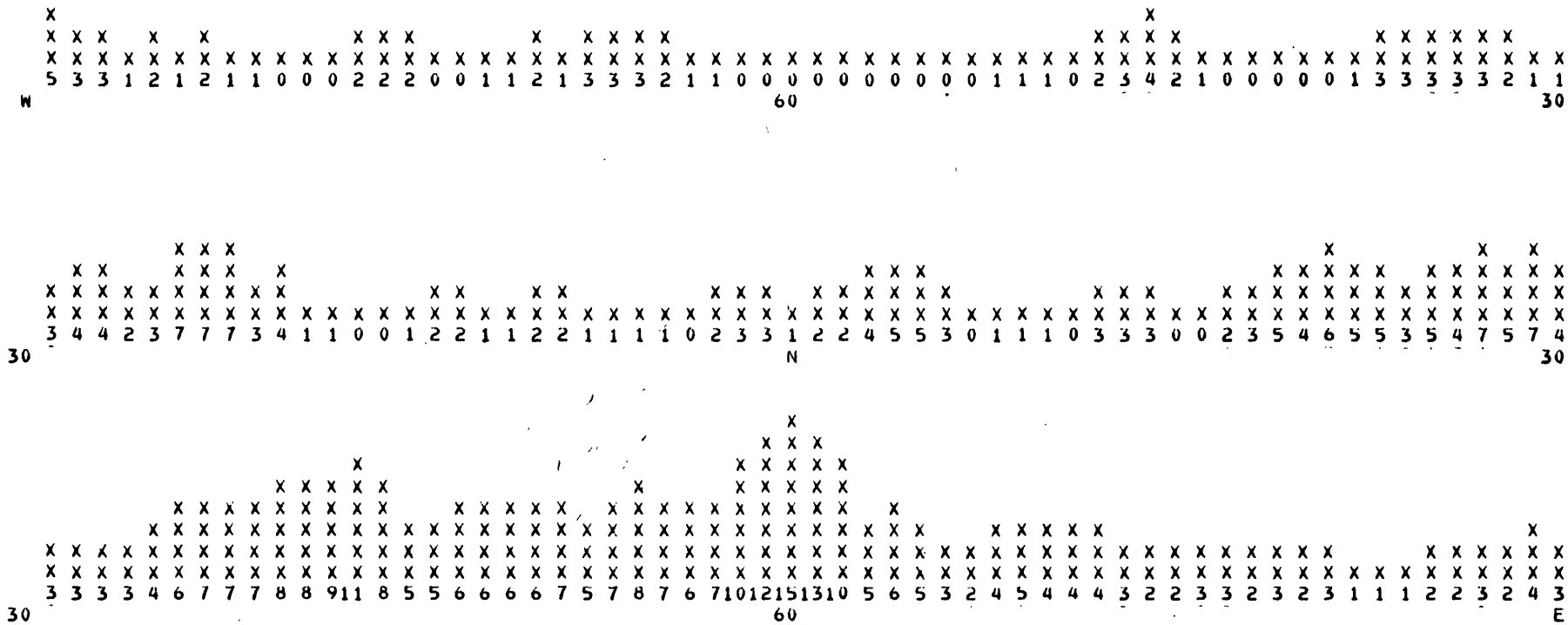
90 % significance value ≥10

Henry Basin + centers Utah unweighted .97

10 LEVELS OF FREQUENCY AT 2 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 2.78

NO. OF DATA = 186



Henry Basin

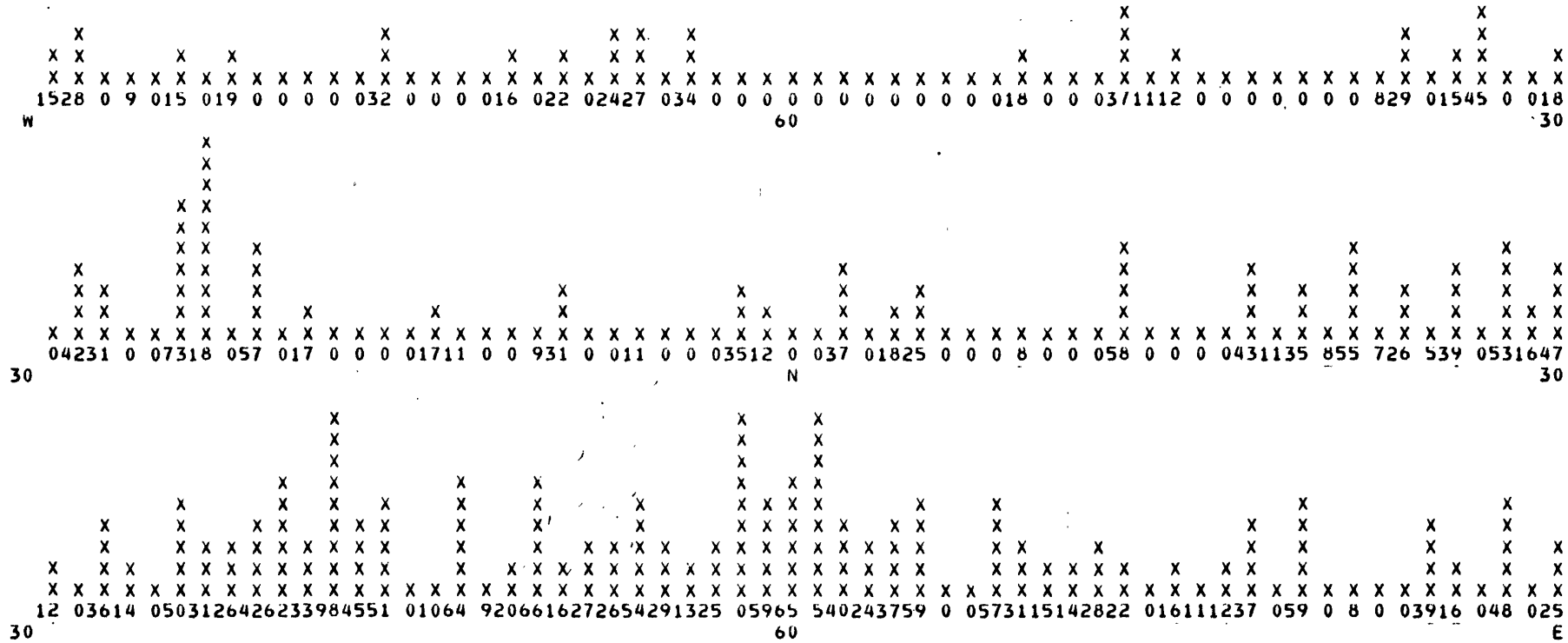
ABSOLUTE STRIKE FREQUENCY ANALYSIS.

90 % significance value = 66

Henry Basin + centers Utah length weighted .97

10 LEVELS OF FREQUENCY AT 12 PER LEVEL.

NO. OF DATA = 3175



High Plateaus

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

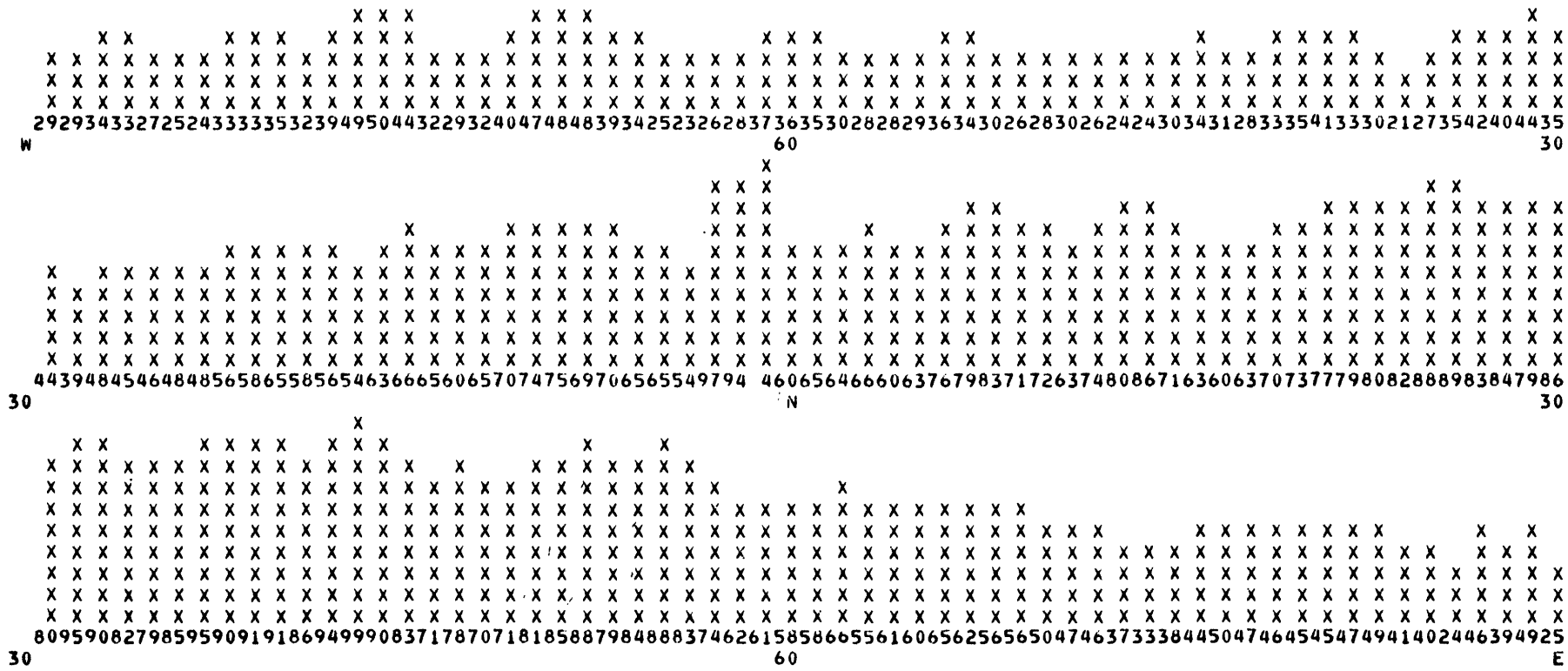
90 % significance value ≥ 69

Utah plateau area to west unweighted .97

10 LEVELS OF FREQUENCY AT 11 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 3329



High Plateaus

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

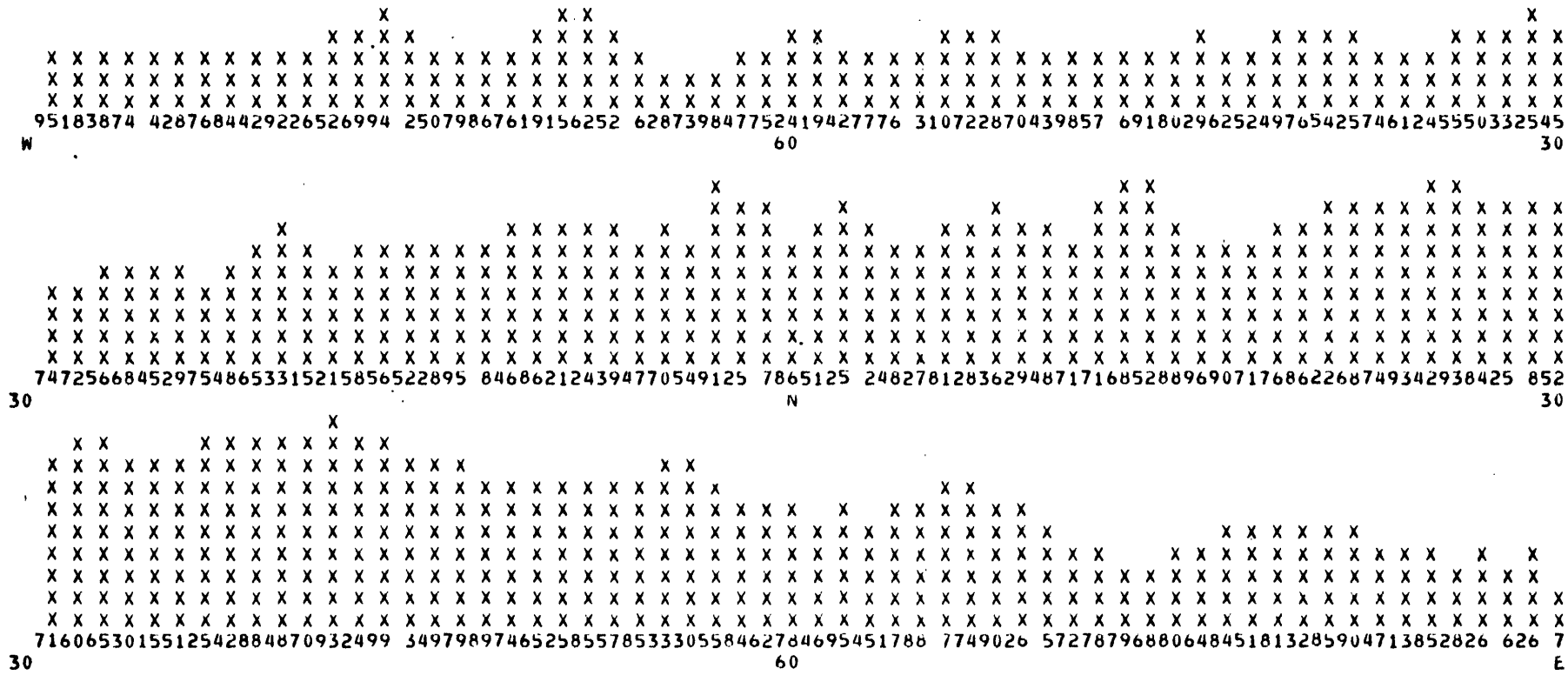
90 % significance value ≥ 895

Utah plateau area to west leng weighted .97

10 LEVELS OF FREQUENCY AT 170 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 50766



33

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

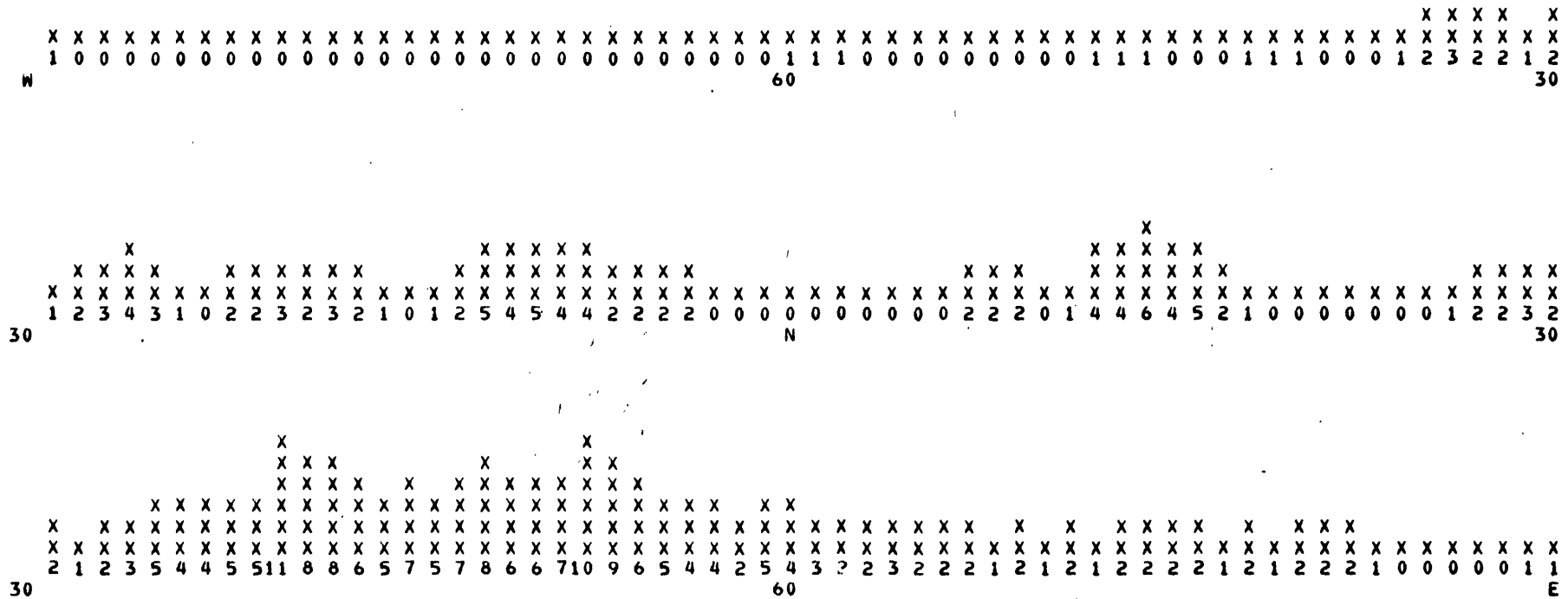
90 % significance value ≥ 9

Utah lineaments Kaibito saddle unweighted .97

10 LEVELS OF FREQUENCY AT 2 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 3.89

NO. OF DATA = 112



90 % significance value ≥ 45

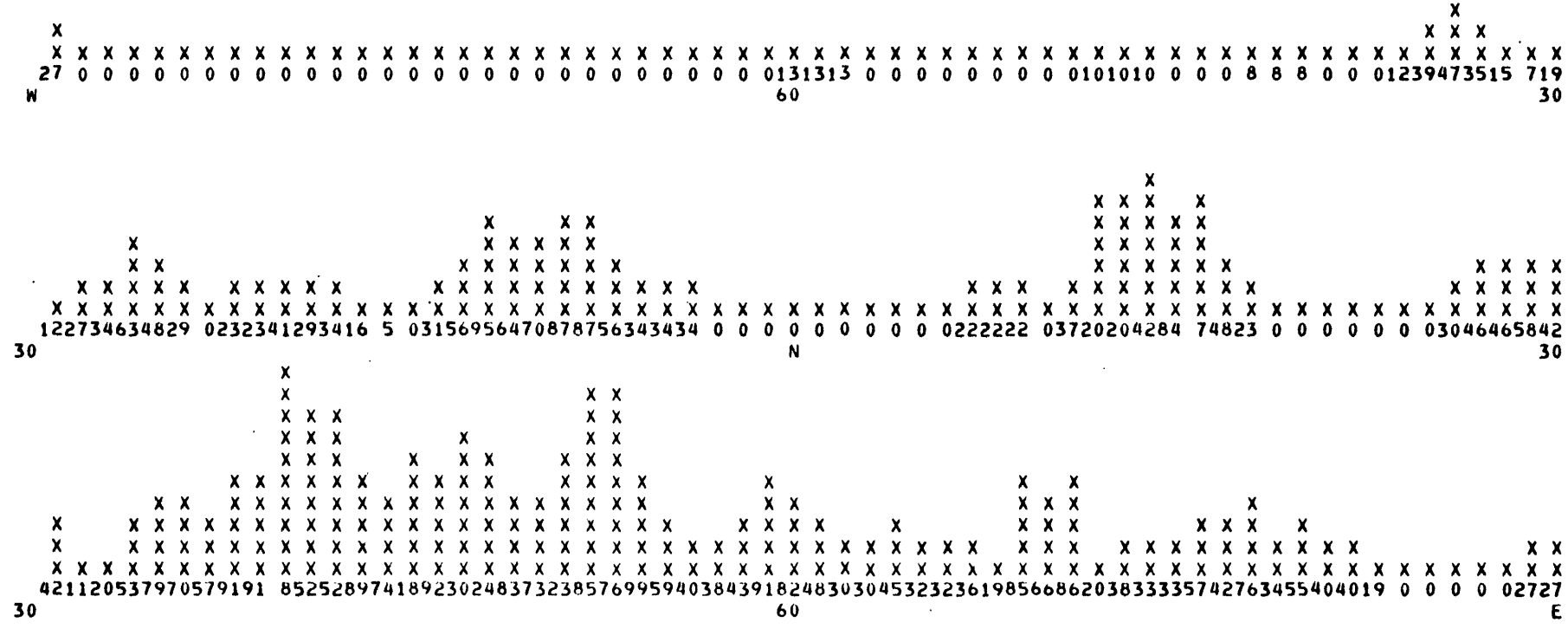
EMPIRICAL STRIKE FREQUENCY ANALYSIS.

Utah lineaments Kaibito saddle leng. weighted .97

10 LEVELS OF FREQUENCY AT 21 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 2030



EMPIRICAL STRIKE FREQUENCY ANALYSIS.

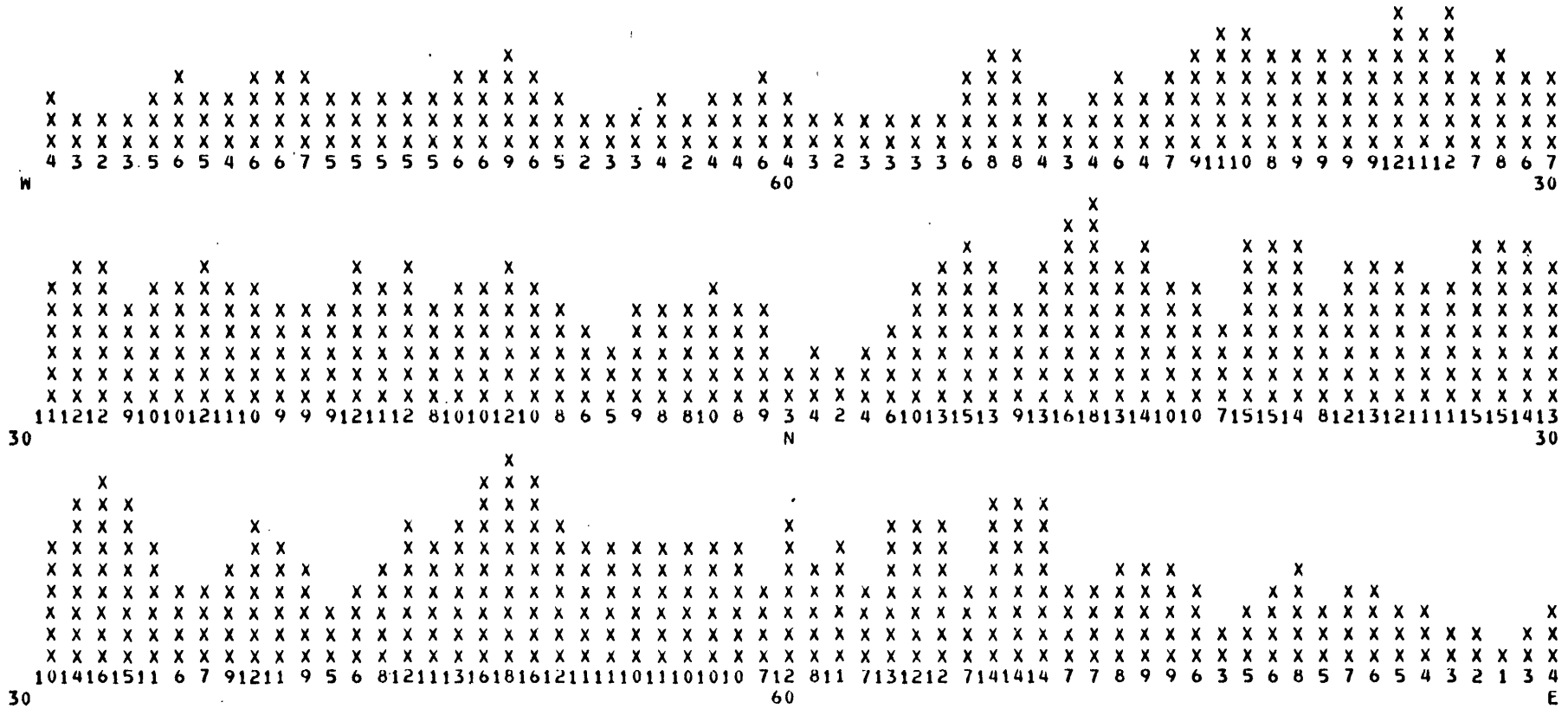
Utah lin.Kaiparowits basin unweighted .97

10 LEVELS OF FREQUENCY AT 2 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 507

90 % significance value ≥ 14



EMPIRICAL STRIKE FREQUENCY ANALYSIS.

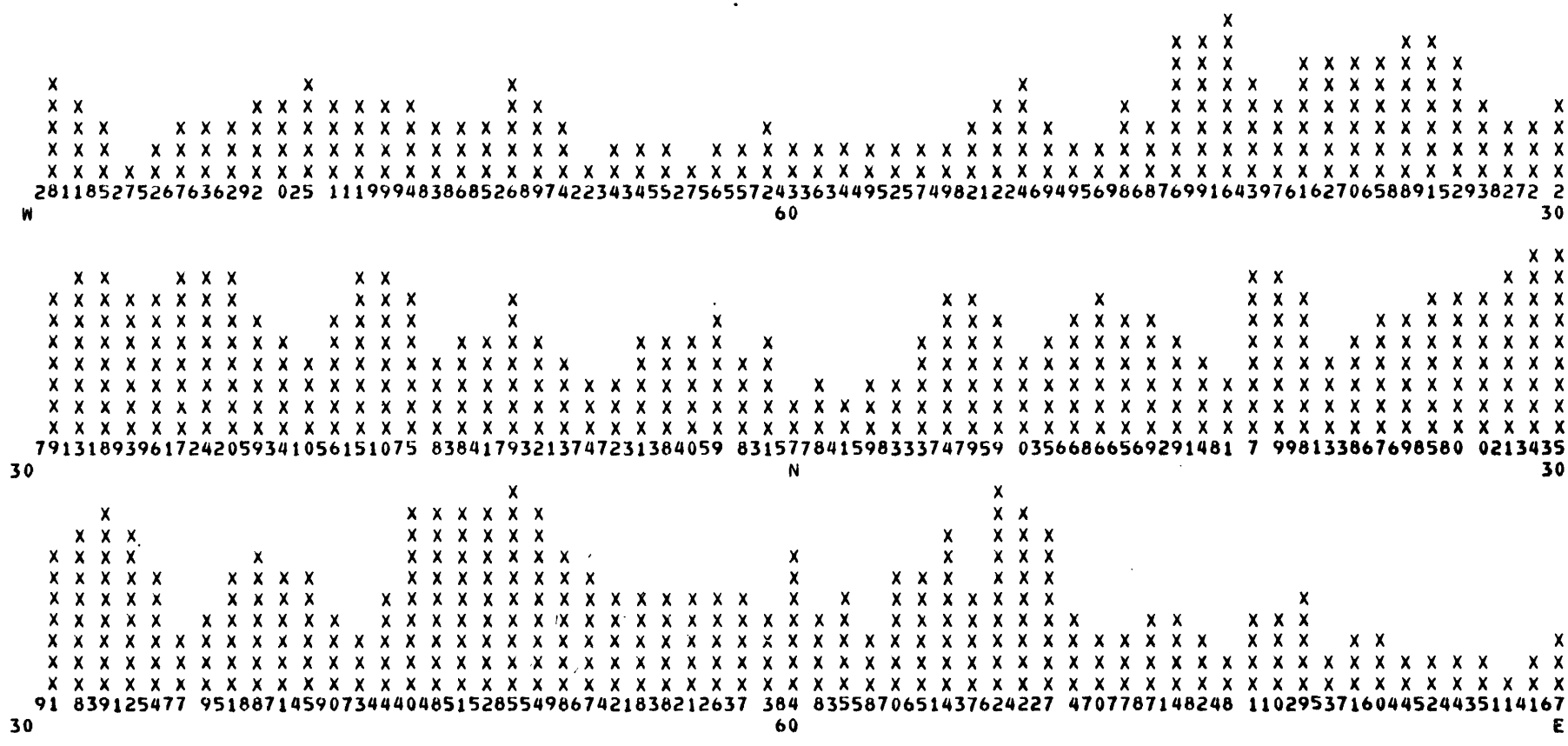
90 % significance value ≥ 148

Utah lin. Kaiparowits basin length weighted .97

10 LEVELS OF FREQUENCY AT 29 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 7681



37

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

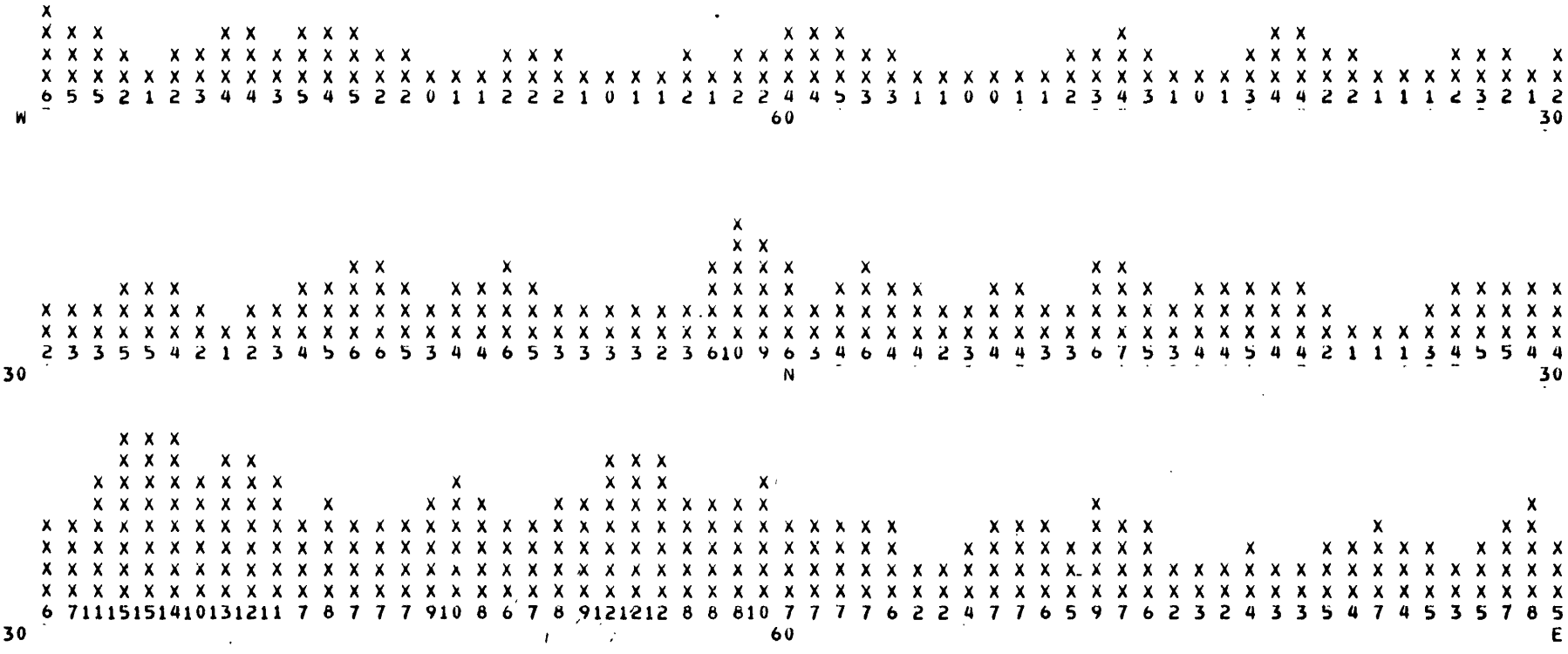
Utah Monument Upwarp unweighted .97

10 LEVELS OF FREQUENCY AT 2 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 270

90 % significance value ≥ 9



EMPIRICAL STRIKE FREQUENCY ANALYSIS.

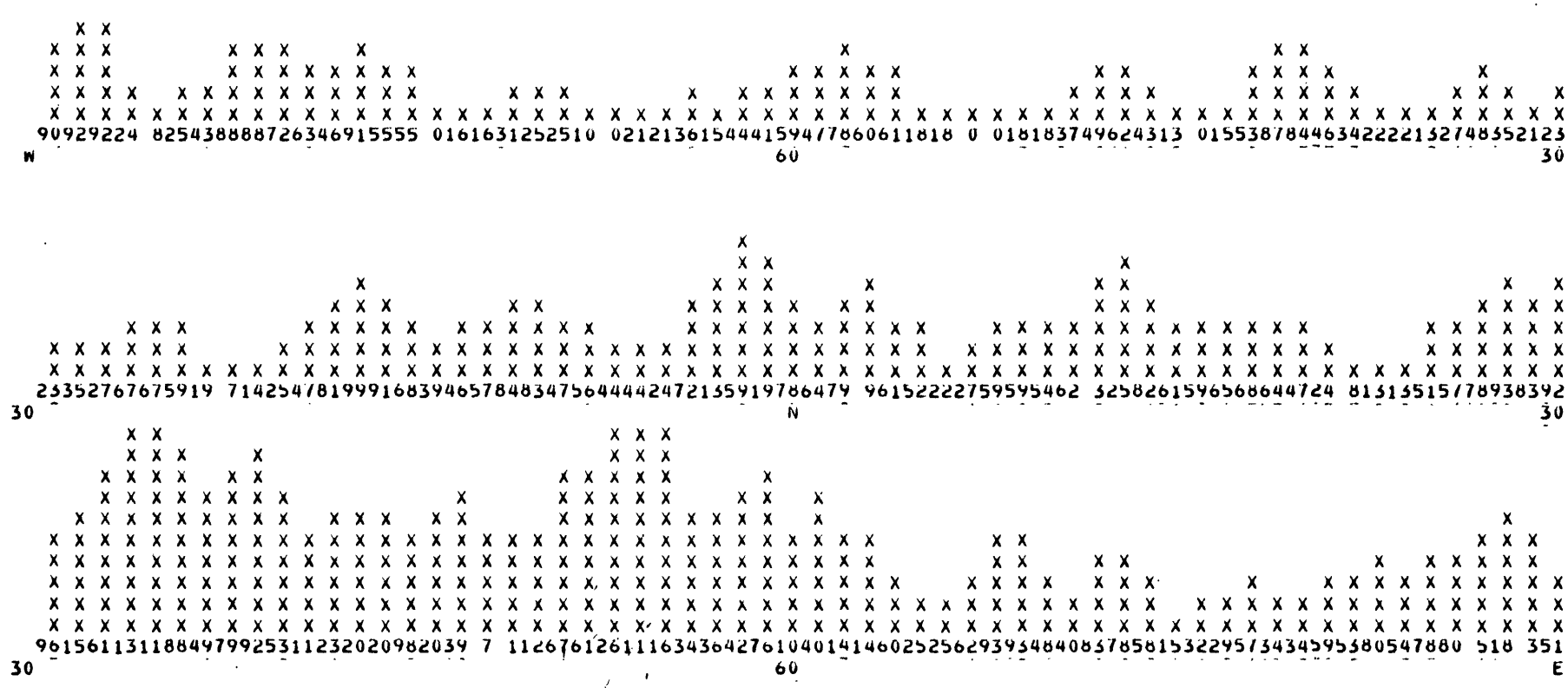
Utah Monument Upwarp length weighted .97

10 LEVELS OF FREQUENCY AT 23 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 4158

90 % significance value ≥ 84



EMPIRICAL STRIKE FREQUENCY ANALYSIS.

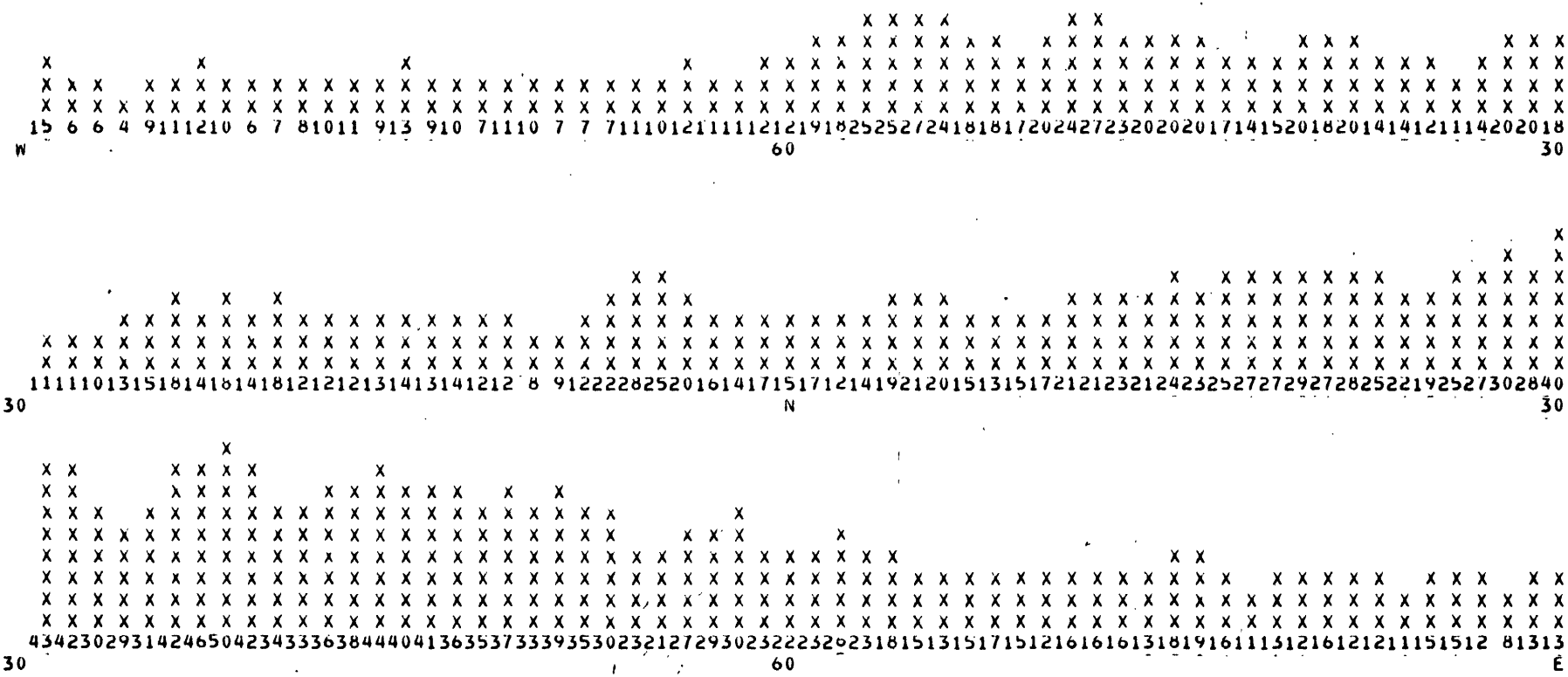
90 % significance value ≥ 28

Paradox fold-fault belt Utah unweighted .97

10 LEVELS OF FREQUENCY AT 6 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 1156



EMPIRICAL STRIKE FREQUENCY ANALYSIS.

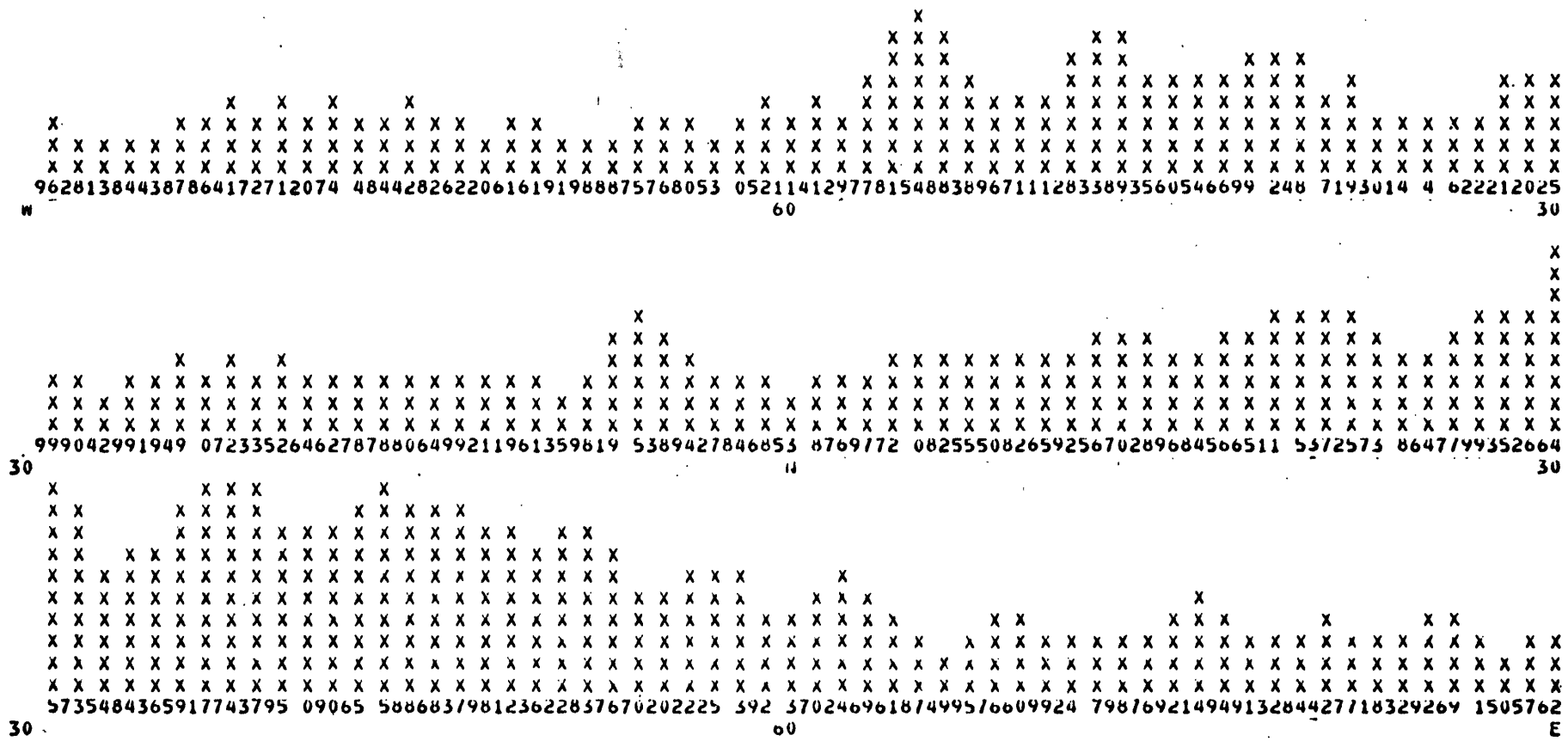
90 % significance value = 342

Paradox fold-fault belt Utah leng.weighted .97

10 LEVELS OF FREQUENCY AT 78 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 18678



EMPIRICAL STRIKE FREQUENCY ANALYSIS.

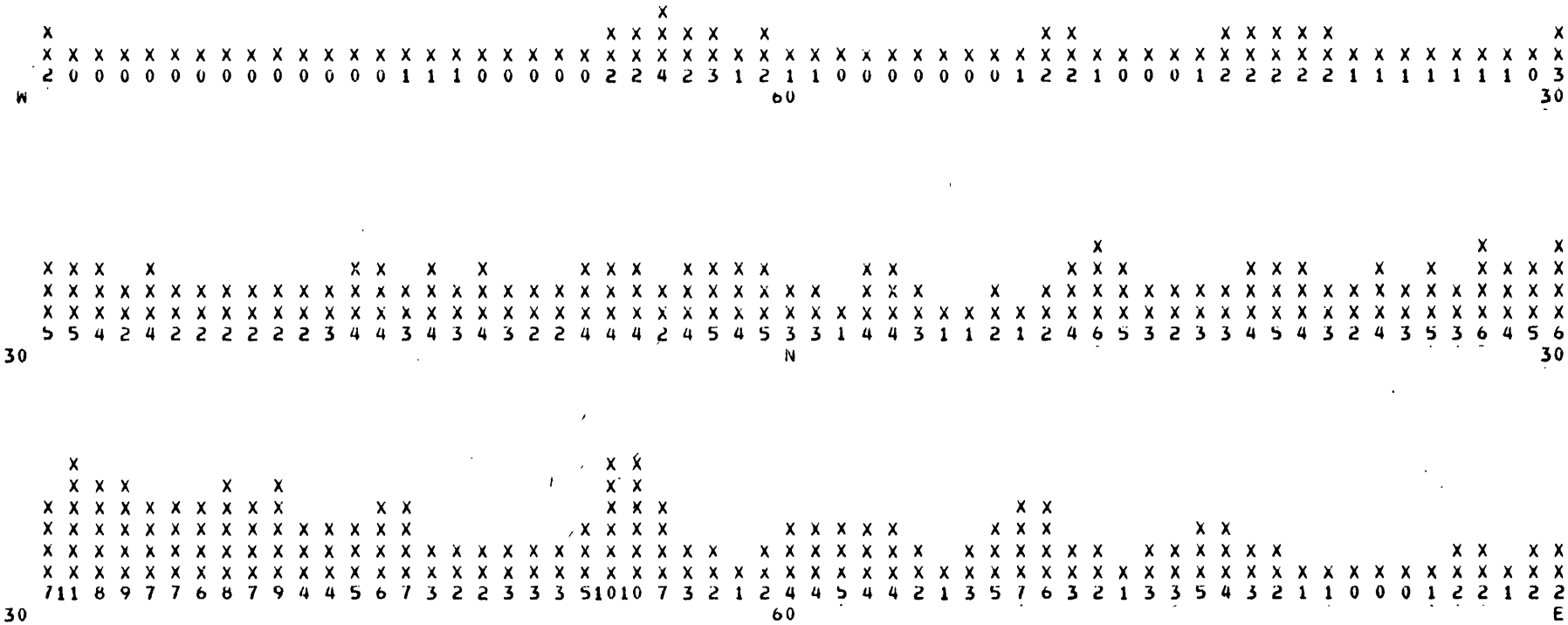
90 % significance value ≥ 9

Piute fold belt Utah unweighted .97

10 LEVELS OF FREQUENCY AT 2 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 2.78

NO. OF DATA = 165



42

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

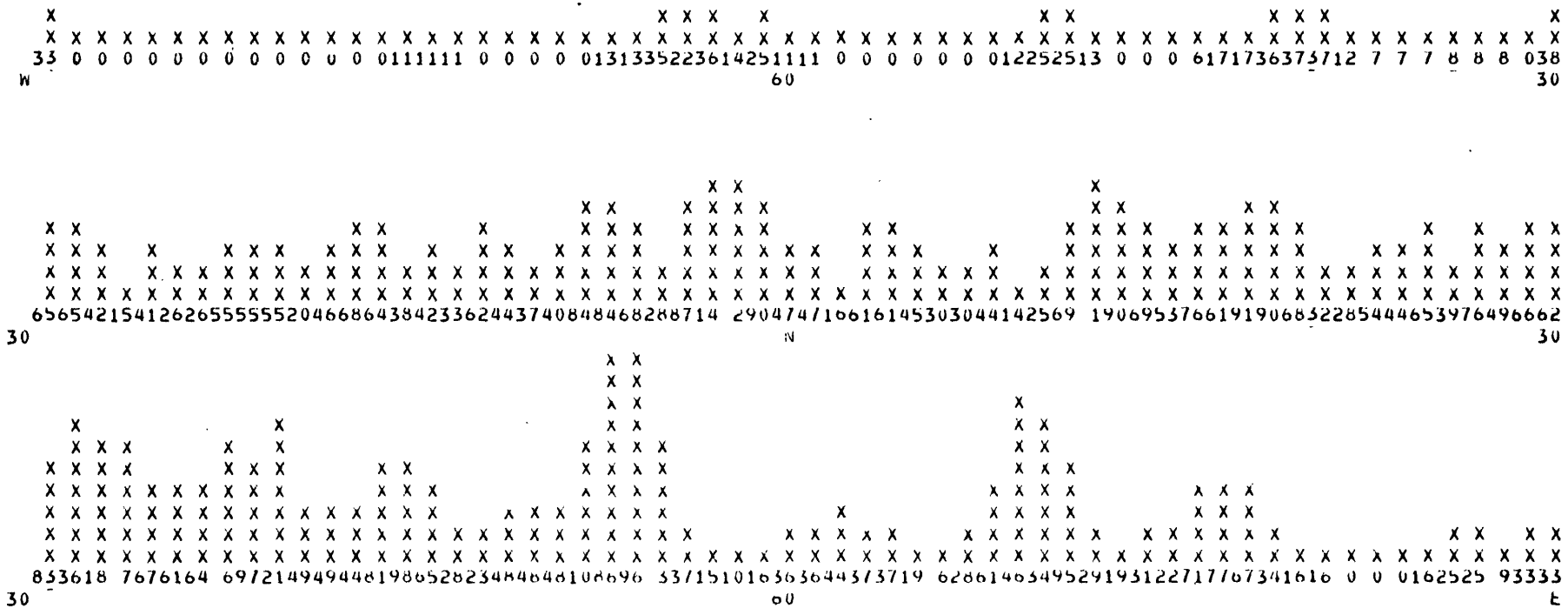
Piute fold belt Utah weighted .97

10 LEVELS OF FREQUENCY AT 20 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 2427

90 % significance value = 52



EMPIRICAL STRIKE FREQUENCY ANALYSIS.

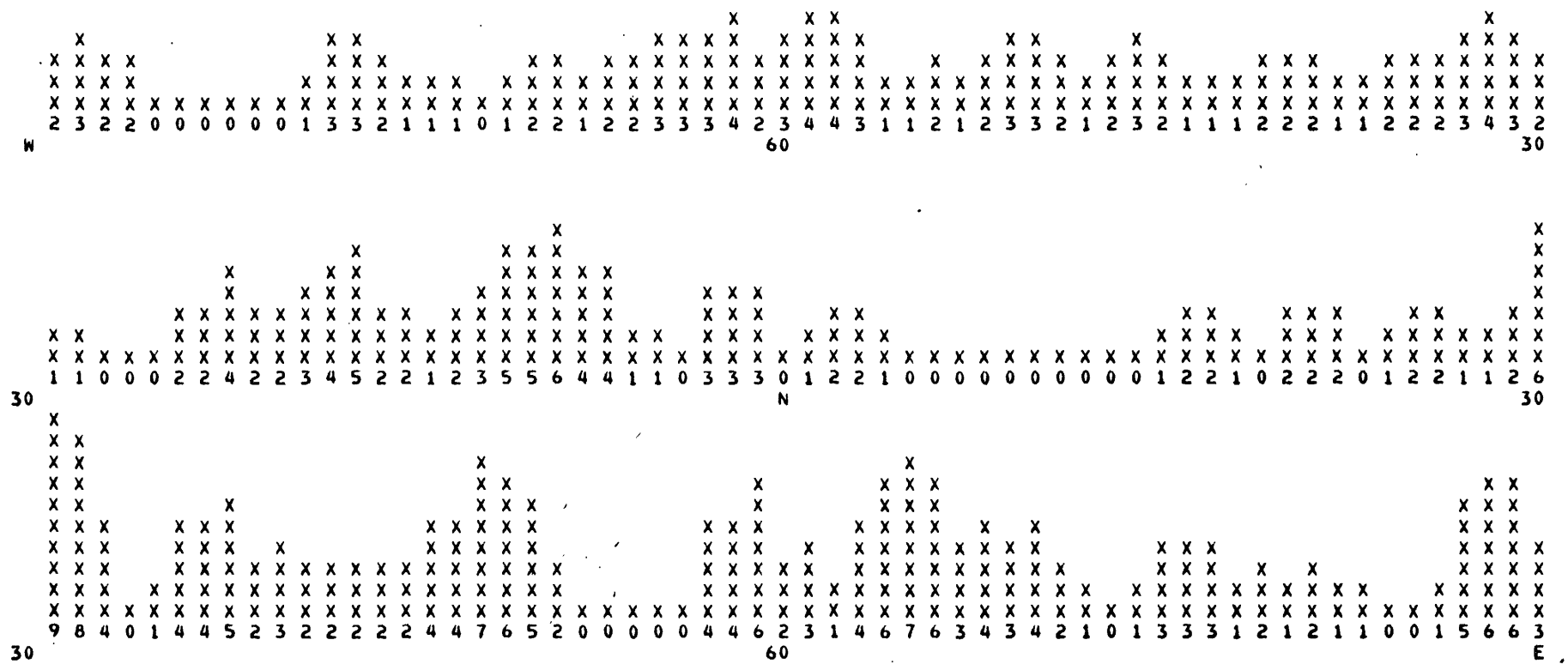
San Rafael Swell unweighted .97

90 % significance value ≥ 8

10 LEVELS OF FREQUENCY AT 1 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 2.78

NO. OF DATA = 131



47

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

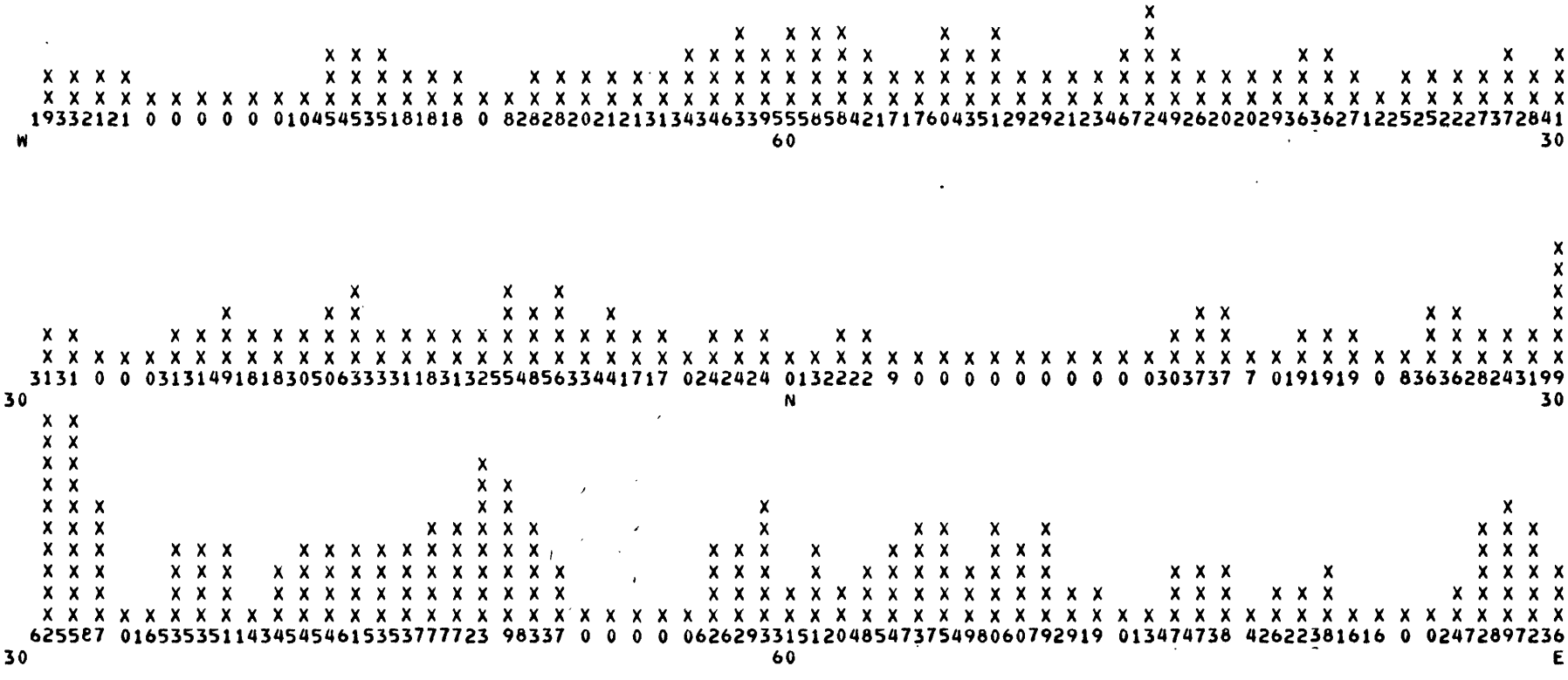
San Rafael Swell length weighted .97

10 LEVELS OF FREQUENCY AT 17 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 1959

90 % significance value = 43



45

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

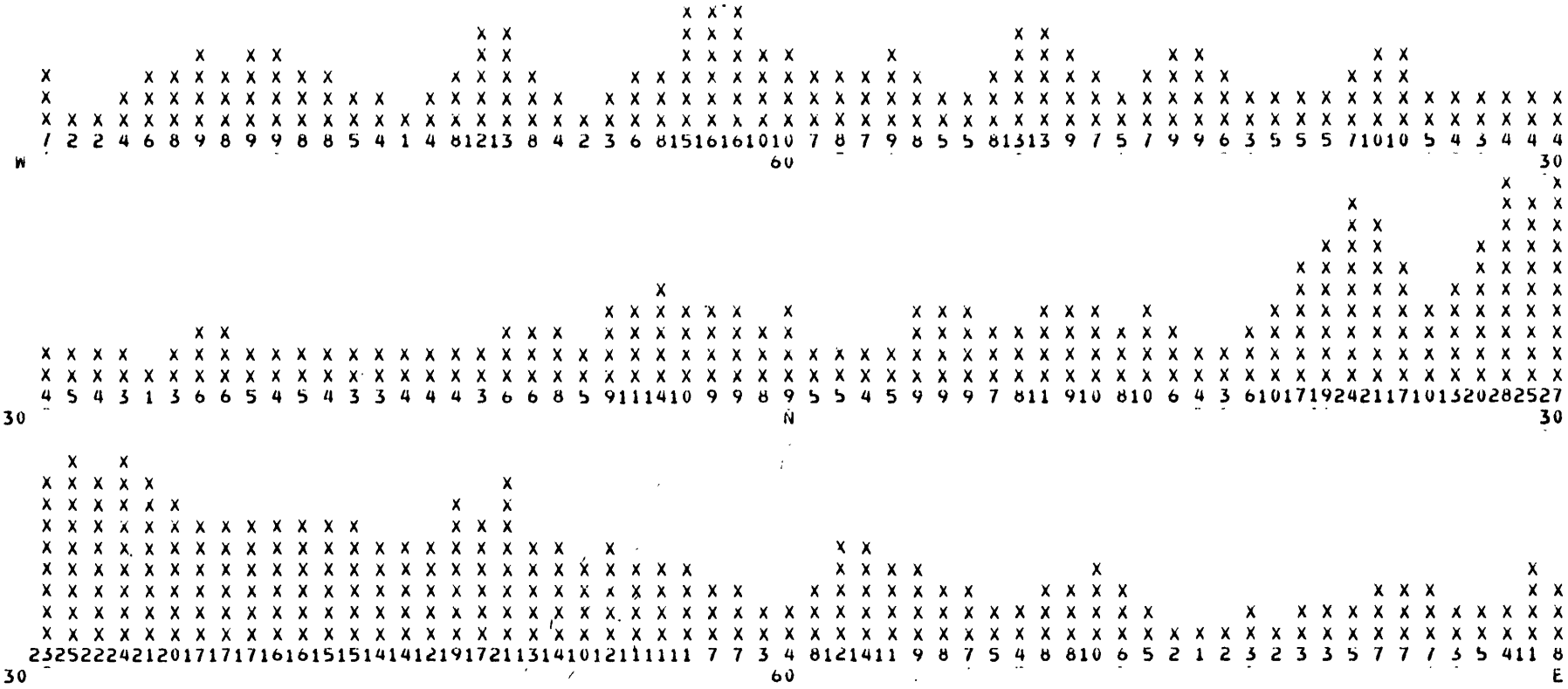
90 % significance value 215

Utah Uncompahgre uplift unweighted .97

10 LEVELS OF FREQUENCY AT 3 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 535



EMPIRICAL STRIKE FREQUENCY ANALYSIS.

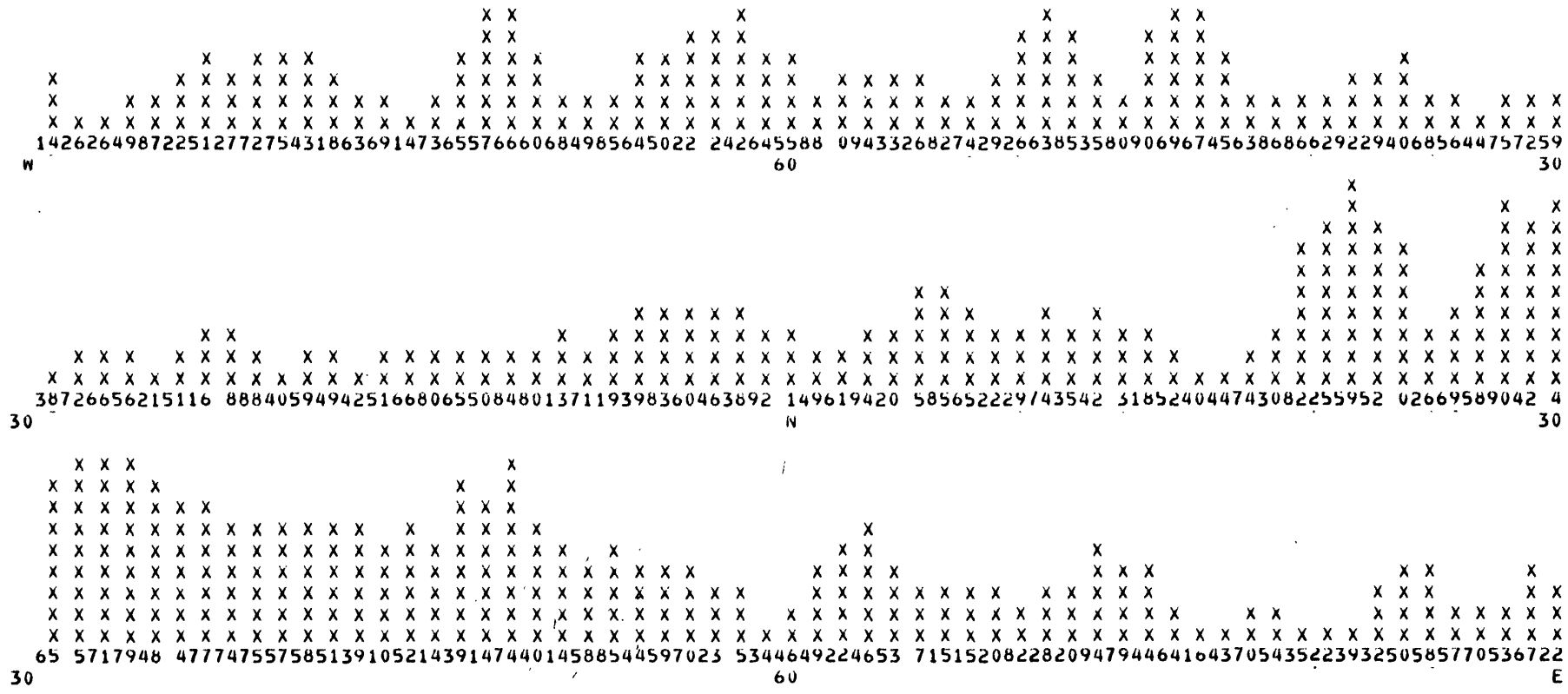
Utah Uncompahgre uplift weighted .9/

10 LEVELS OF FREQUENCY AT 46 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.6/

NO. OF DATA = 8733

90 % significance value ≥ 167



47

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

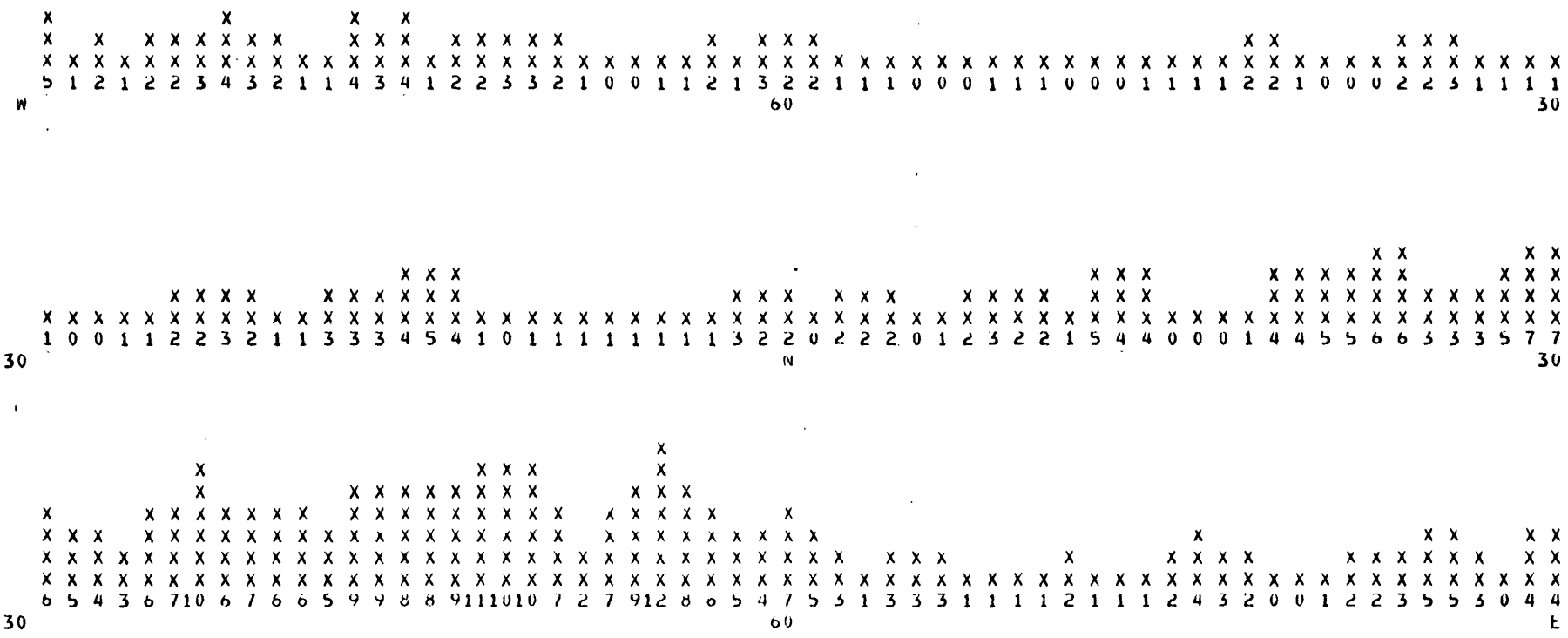
White Canyon slope unweighted .97

10 LEVELS OF FREQUENCY AT 2 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 2.78

NO. OF DATA = 170

90 % significance value >9



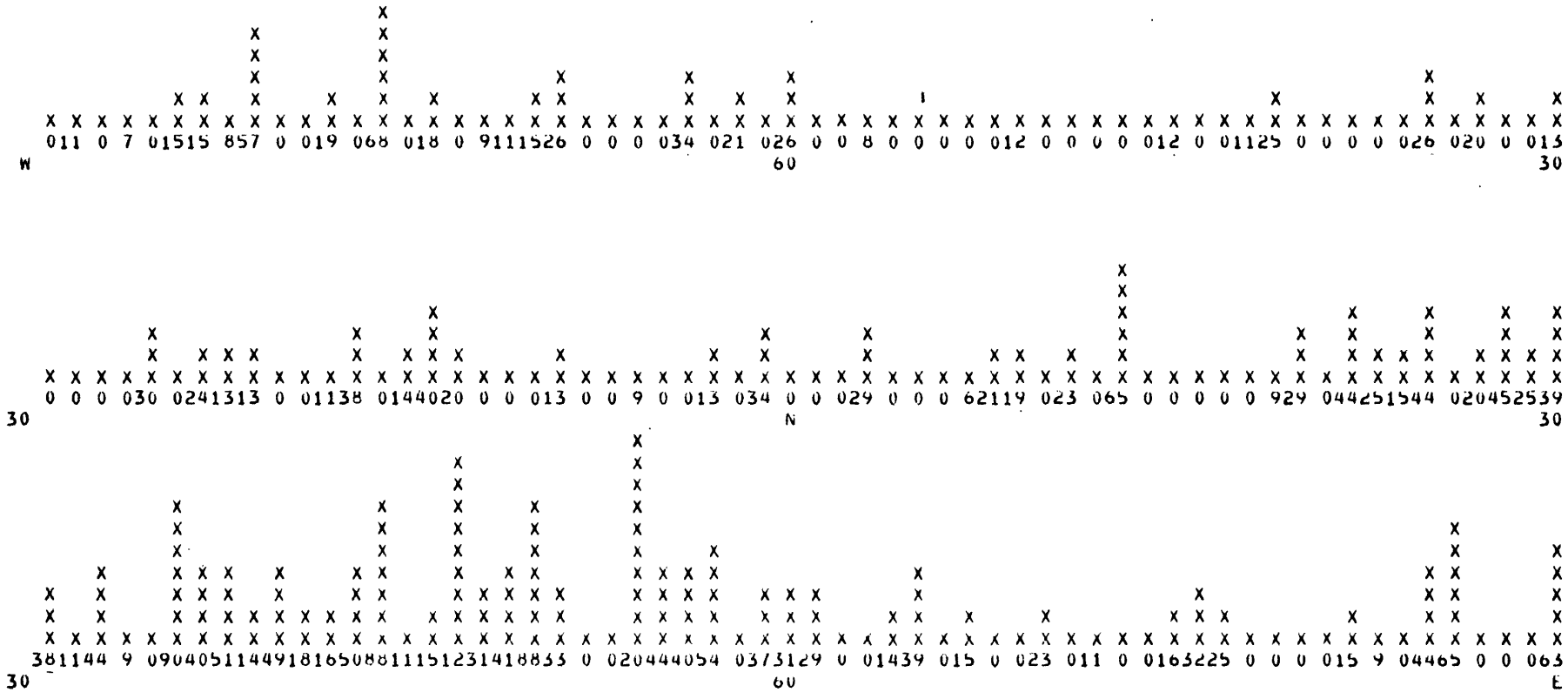
ABSOLUTE STRIKE FREQUENCY ANALYSIS.

90 % significance value = 59

White Canyon slope length weighted Utah .97

10 LEVELS OF FREQUENCY AT 13 PER LEVEL.

NO. OF DATA = 2792



64

Uplifts

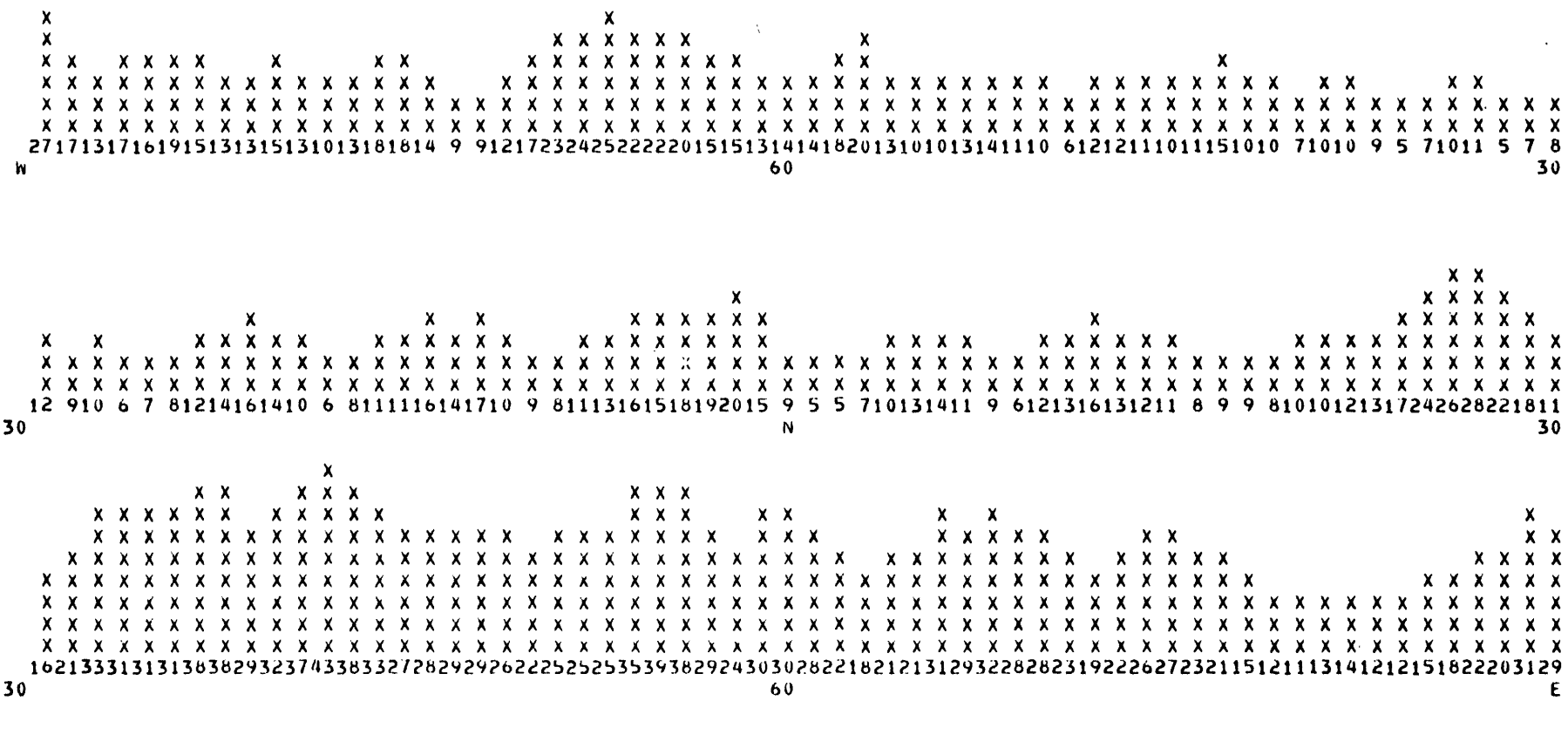
EMPIRICAL STRIKE FREQUENCY ANALYSIS. 90 % significance value 725

Gp1- Uncom,San_r, Cap_r Mon- unweight .97

10 LEVELS OF FREQUENCY AT 5 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 1037



Uplifts

90 % significance value ≥ 81

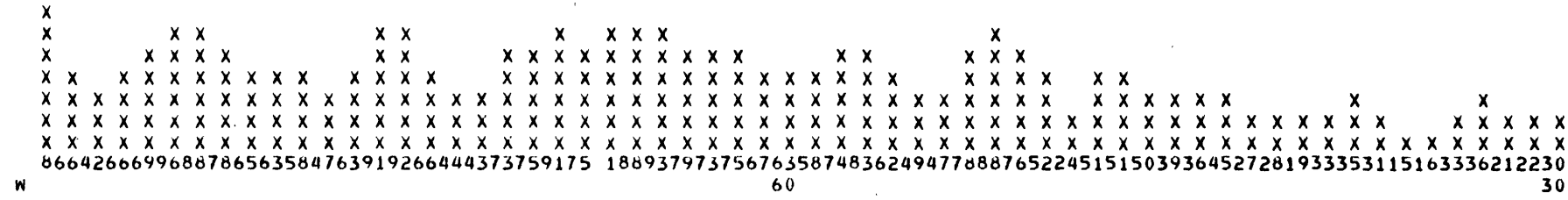
EMPIRICAL STRIKE FREQUENCY ANALYSIS.

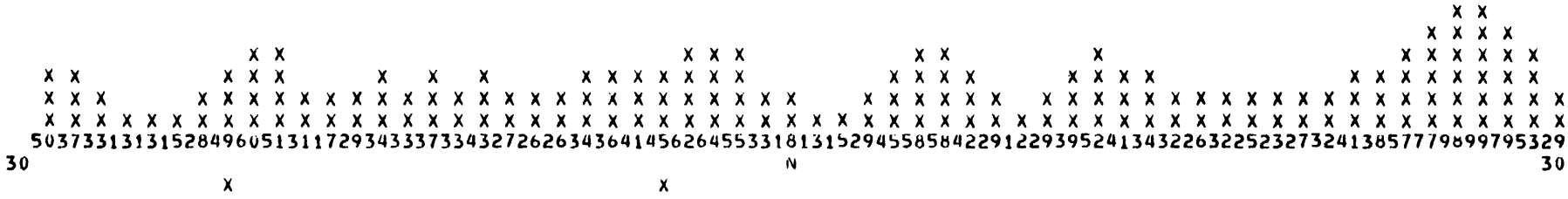
Gp1 (Uncom San_r Cap_r Mon) leng. weight .97

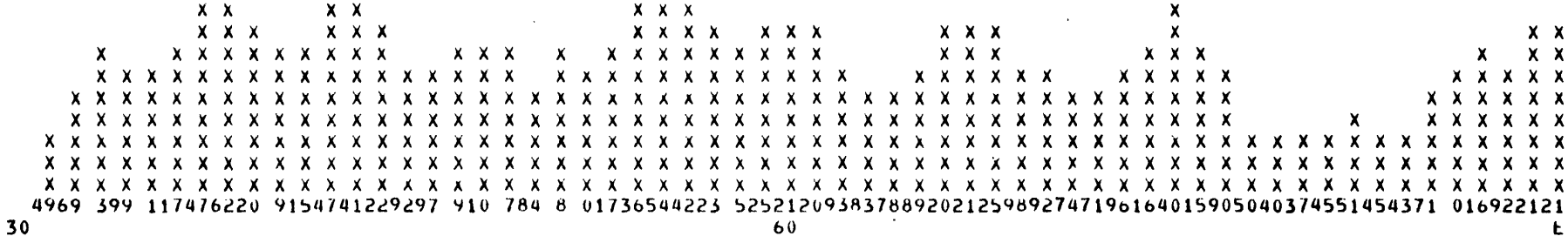
10 LEVELS OF FREQUENCY AT 17 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 3976







Basins A

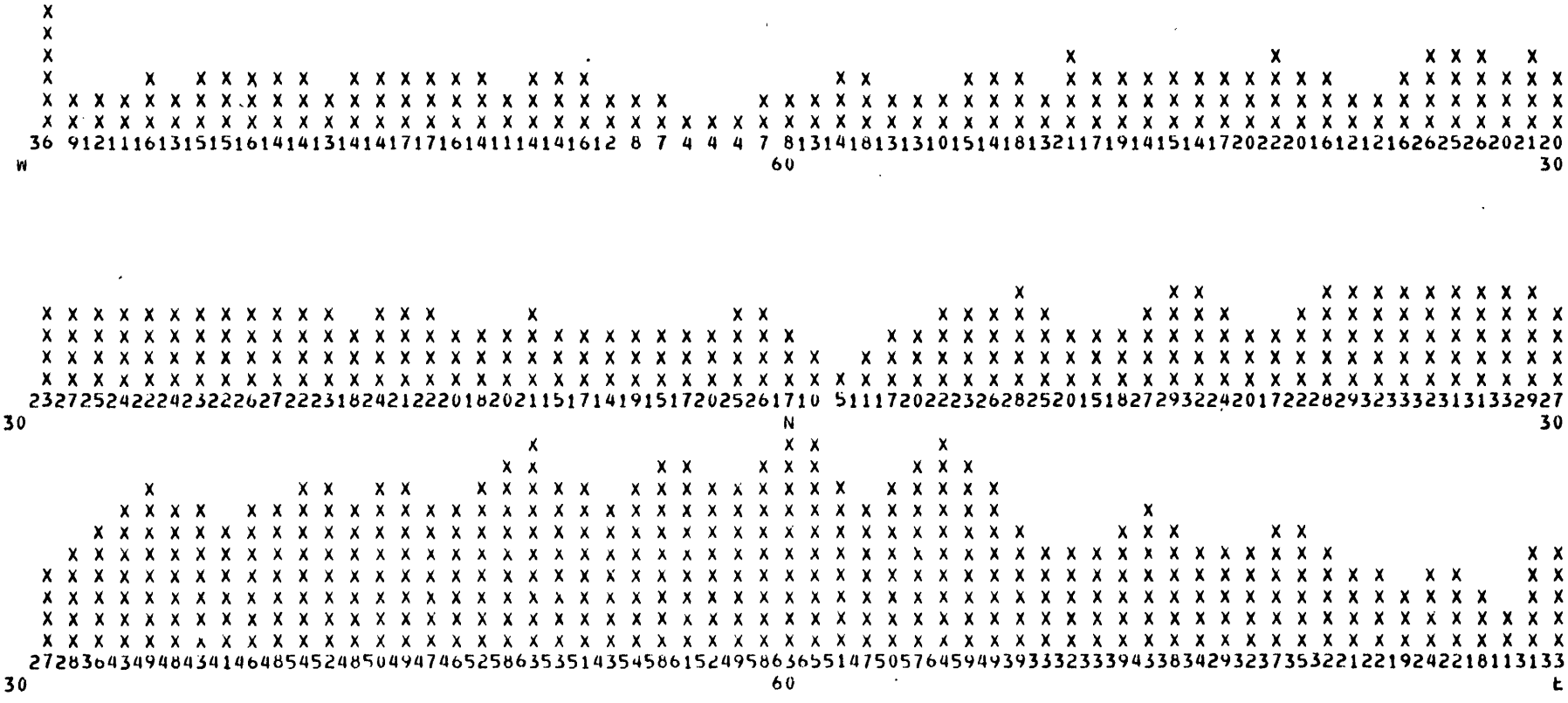
EMPIRICAL STRIKE FREQUENCY ANALYSIS. 90 % significance value ≥ 36

Gp2 (Kaip Piut Blan Whit Hen Cir Kabit) unweight .97

10 LEVELS OF FREQUENCY AT 7 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 1607



52

Basins A

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

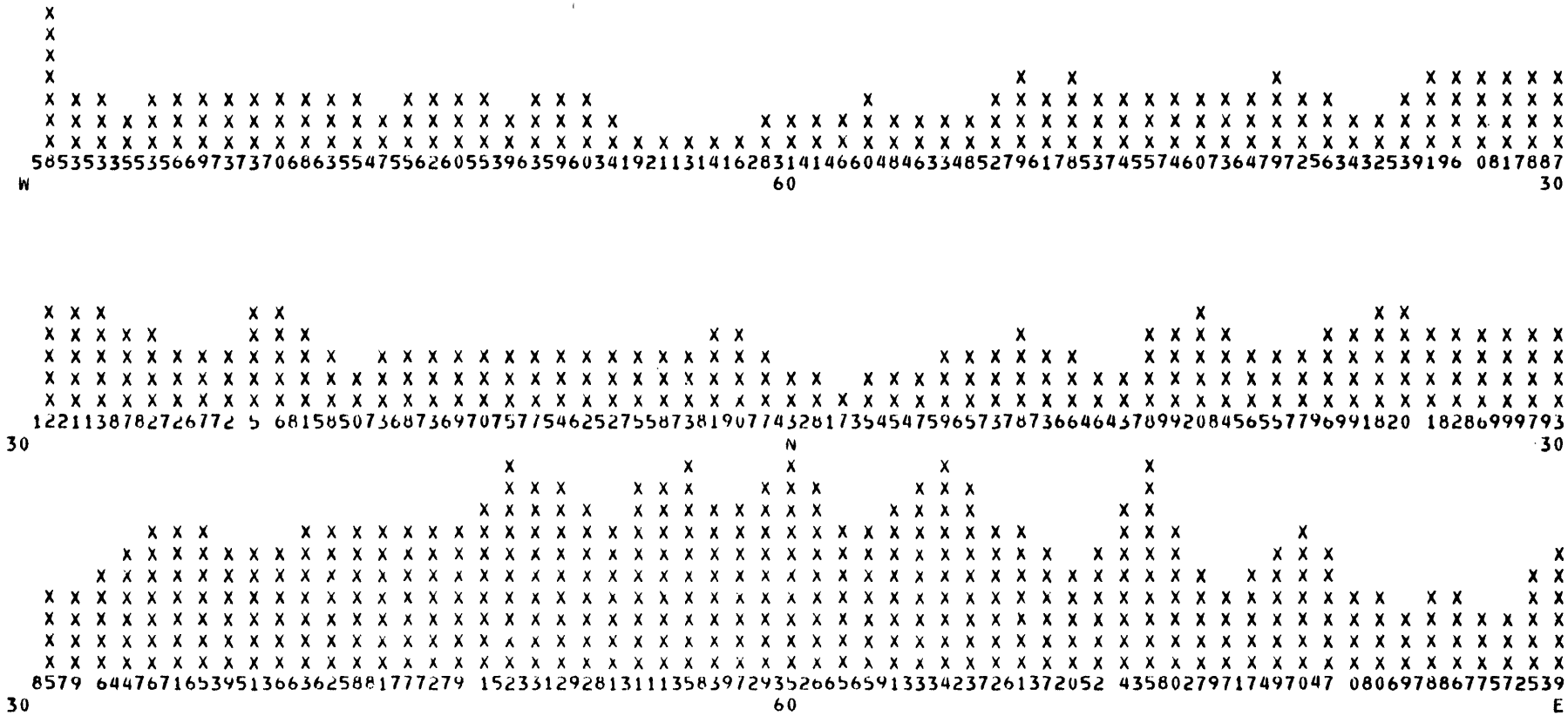
90 % significance value ≥ 116

Gp2 (Kaip Piut Blan Whit Hen Cir Kabit) leng. weight .97

10 LEVELS OF FREQUENCY AT 26 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 5914



Basins B

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

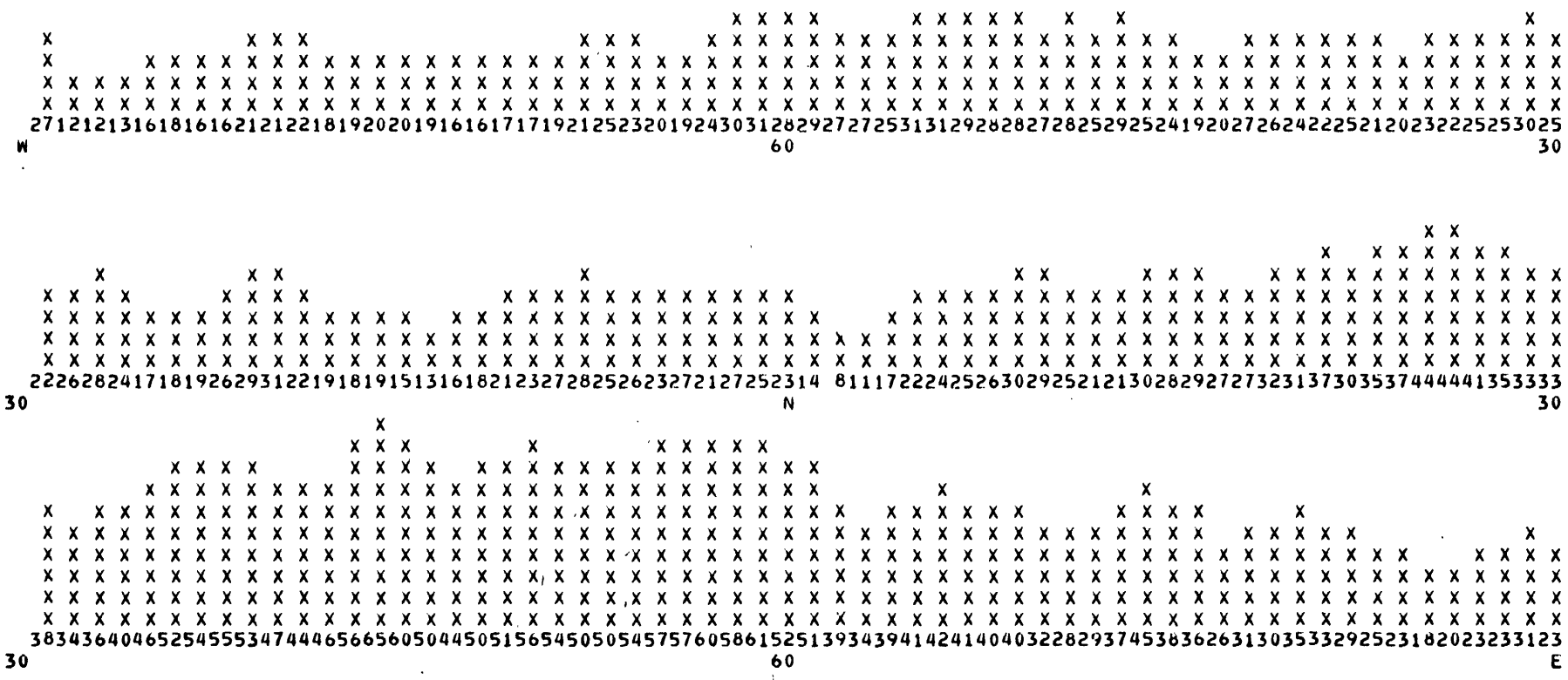
90 % significance value ≥ 40

Utah tectonic areas (Pardx Piut Kaip) unweighted .97

10 LEVELS OF FREQUENCY AT 7 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 1799



54

Basins B

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

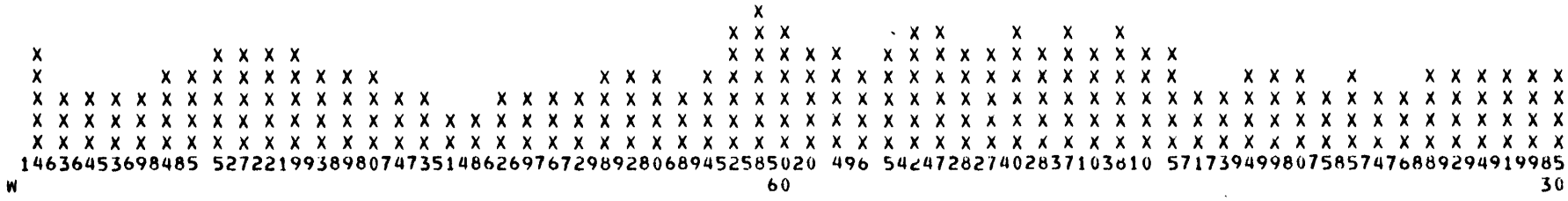
90 % significance value = 129

Utah tectonic Gp3 (Pardx Piut Kaip) length weighted .97

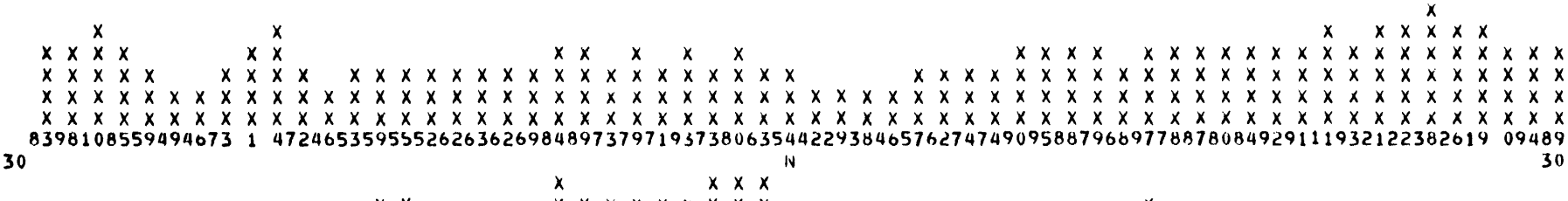
10 LEVELS OF FREQUENCY AT 26 PER LEVEL.

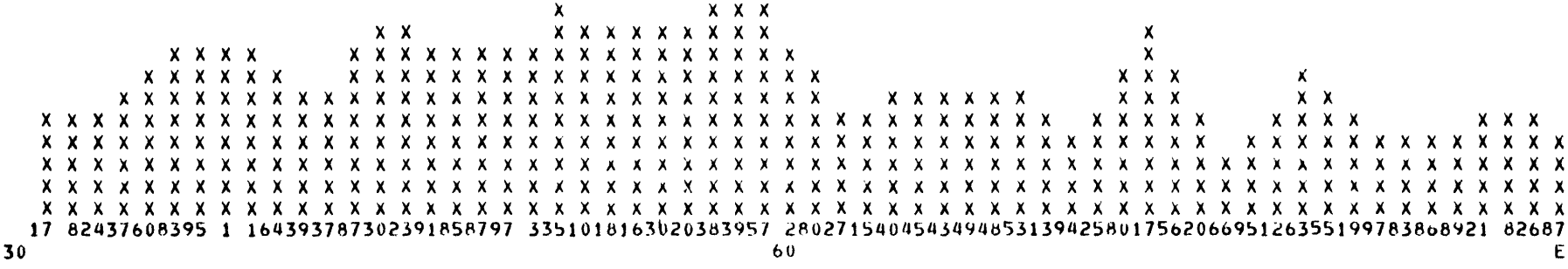
PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 6689



55





Basins C

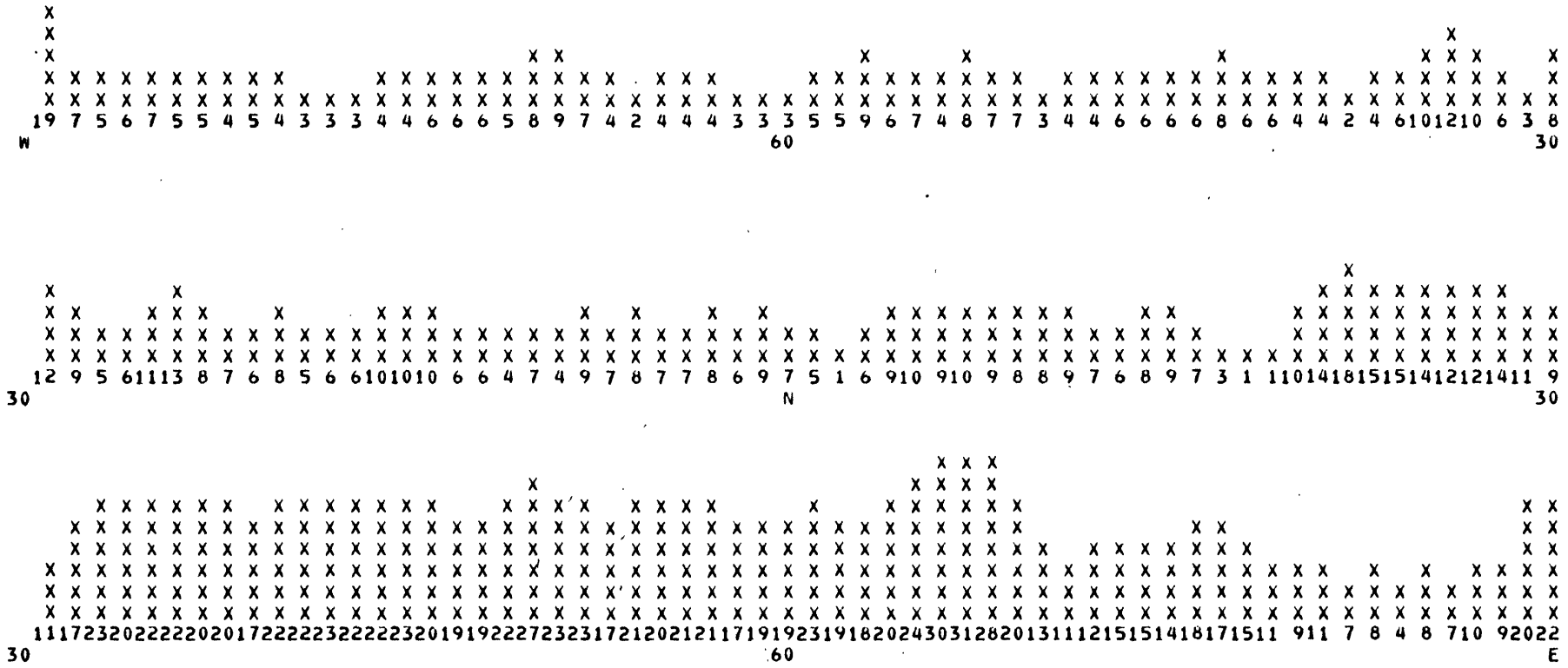
EMPIRICAL STRIKE FREQUENCY ANALYSIS. 90 % significance value ≥17

Utah tectonic Gp4 (Hen Blan Cap_r) unweighted .97

10 LEVELS OF FREQUENCY AT 4 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 640



95

Basins C

EMPIRICAL STRIKE FREQUENCY ANALYSIS.

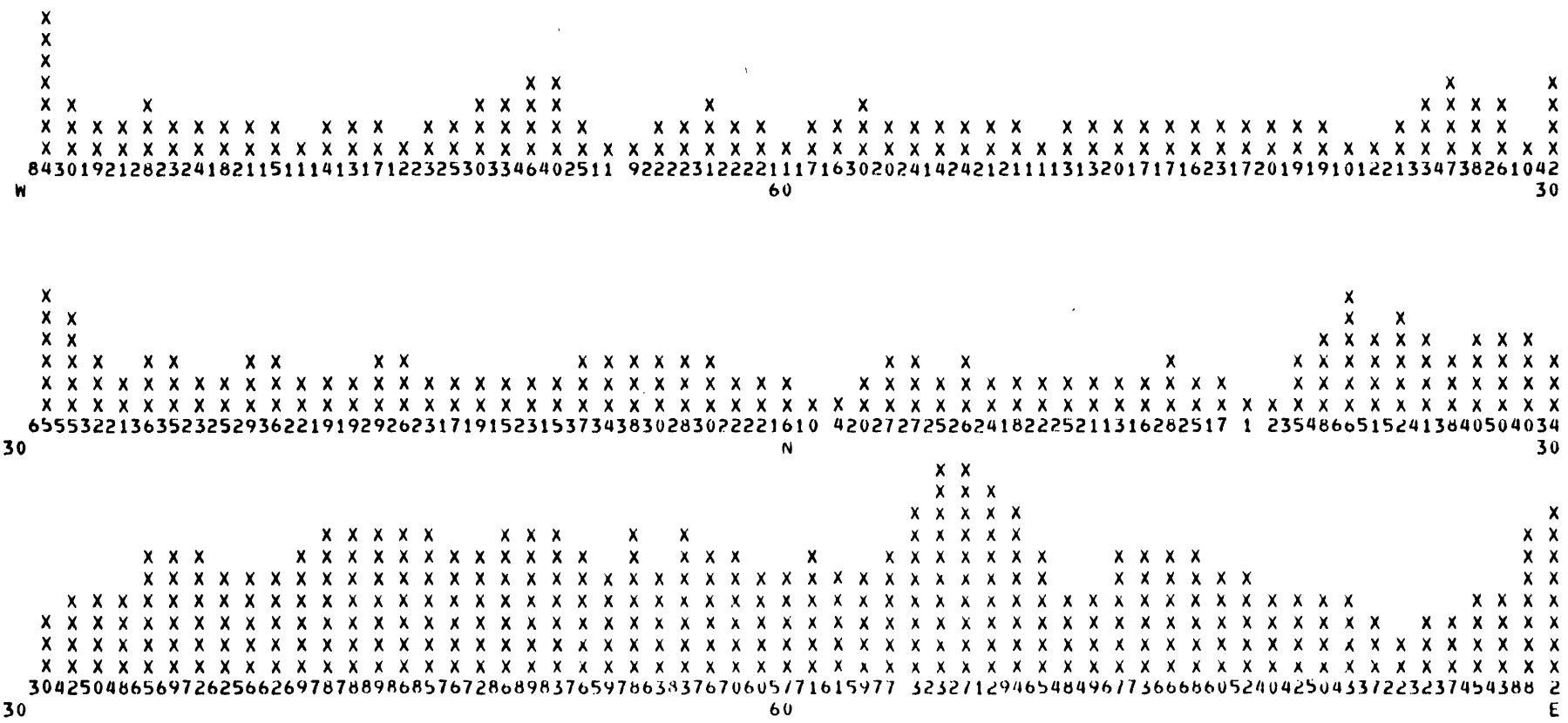
90 % significance value ≥ 51

Utah tectonic Gp4 (Hen Blan Cap_r) leng weighted .97

10 LEVELS OF FREQUENCY AT 13 PER LEVEL.

PERCENT AZIMUTH FOR SMOOTHING = 1.67

NO. OF DATA = 2355



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