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SANDIA REPORT SAND85—1605 • Unlimited Release • UC—70
Printed February 1986

Ground Motion Produced at Yucca Mountain From Pahute Mesa Underground Nuclear Explosions

Luke J. Vortman

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
under Contract DE-AC04-76DP00789

SF2900Q(8-81)

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes
Printed copy: A12
Microfiche copy: A01

SAND85-1605
Unlimited Distribution

GROUND MOTION PRODUCED AT YUCCA MOUNTAIN FROM PAHUTE MESA UNDERGROUND NUCLEAR EXPLOSIONS

by

Luke J. Vortman
Ground Motion & Seismic Division
Sandia National Laboratories
Albuquerque, New Mexico 87185

Abstract

Prediction equations were developed for peak vector acceleration, velocity, and displacement from underground nuclear explosions at Pahute Mesa. Separate equations were developed using data from stations on rock and alluvium, rock only, and alluvium only. Equations were further subdivided into three groups: all data, deletion of data with known site anomalies, and additional deletion of Yucca Mountain data. Differences in the prediction equations for the three groups using rock and alluvium and rock only were small. Alluvium only data were too sparse for valid equations. Data were normalized to remove the effects of source-energy coupling, and prediction equations recalculated.

Anomalously high accelerations had been observed previously at Engine Test Stand 1 in the Nuclear Rocket Development Station area. These new data show peak vector accelerations 4 to 10 times predictions from events in Area 20 and smaller enhancements from events in Area 19. The area receiving the greater accelerations is concentrated at Engine Test Stand 1 and diminishes within about 4 km east and west of that station. Examination of velocity from event location to the point of measurement suggests transmission paths with a high velocity layer at a shallower depth on the path from Area 19 than from Area 20.

Measurements made at Yucca Mountain indicate that qualitatively similar large accelerations exist at Yucca Mountain but with the largest observed to date only 4.19 times prediction. Since the data set for Yucca Mountain is relatively small, the possibility exists for even greater enhancements for underground nuclear explosions in locations other than those included in the data set.

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PREFACE

The Nevada Nuclear Waste Storage Investigations (NNWSI) Project, managed by the Nevada Operations Office of the U.S. Department of Energy, is examining the feasibility of siting a repository for commercial high-level nuclear wastes at Yucca Mountain on and adjacent to the Nevada Test Site (NTS). This work, intended to extend our understanding of the ground motion at Yucca Mountain resulting from testing of nuclear weapons on the NTS, was funded jointly by the NNWSI Project and the Military Applications Weapons Test Program. This report is a summary of the weapons test seismic investigation through FY84 and provides the interpretation of the data necessary to support the conceptual design.

The prediction equations in this report supersede those in SAND79-1002 and SAND80-1020/1.

ACKNOWLEDGMENTS

J. G. Lee was responsible for data acquisition, L. S. Converse for digitizing of the data, and J. D. Pearcey for its processing. T. L. P. Butler provided algorithms used in the analysis, and J. W. Long assisted in the analysis.

A NOTE ABOUT CLASSIFICATION

In order to publish the results of this investigation in an unclassified report, the data on which the prediction equations are based has been omitted. For those who have access to classified reports, the data are contained in SAND84-2296.

In the text, figures, and tables a letter-number designation has been used in place of event names. The following table relates the letter-number designation to the name and date of the Pahute Mesa events used in this data set.

KEY TO LETTER-NUMBER CODE AND EVENT NAMES

A01	Boxcar	04/26/68
A02	Camembert	06/26/75
A03	Colby	03/14/76
A04	Fontina	02/12/78
A05	Handley	03/26/70
A06	Jorum	09/16/69
A07	Kasseri	10/28/75
A08	Muenster	01/03/76
B01	Almendro	06/06/73
B02	Backbeach	04/11/78
B04	Cheshire	02/14/76
B05	Estuary	03/09/76
B07	Fondutta	04/11/78
B08	Halfbeak	06/30/66
B09	Inlet	11/20/75
B11	Mast	06/19/75
B13	Panir	08/31/78
B14	Pool	03/17/76
B15	Scotch	05/23/67
B16	Tybo	05/14/75
B17	Pepato	06/11/79
B18	Sheepshead	09/26/79
B19	Colwick	04/26/80
B20	Kash	06/12/80
B21	Tafi	07/25/80
B22	Serpa	12/17/80
B23	Harzer	06/06/81
B24	Molbo	02/12/82
B25	Hosta	02/12/82
B26	Gibne	04/25/82
B27	Nebbiolo	06/24/82
B28	Farm	12/16/78
B29	Cabra	03/26/83
B30	Chancellor	09/01/83
B31	Kappeli	07/25/84

CHAPTER 1. INTRODUCTION

Background

The amplitude of ground motion observed at a specific point is a function of how effectively the explosion energy is coupled to the medium at the source, of the geologic structure between the source and the receptor (which makes up the transmission path), and the geology in the vicinity of the receptor. Variations in the characteristics of any or all three, result in differences in amplitude from one receptor location to another. It is the purpose of this report to examine variations at a number of locations from Underground Nuclear Explosions (UNEs) on Pahute Mesa at the Nevada Test Site (NTS), and, in particular, to examine the data for larger than expected motions at Yucca Mountain.

Whether amplitudes are larger or smaller than expected is judged against a prediction equation which is essentially an average value obtained from a large number of measurements. It is important at the outset to understand the data set used and why it was chosen.

Since March, 1976, under the provisions of the Threshold Test Ban Treaty, data have been available only for yields no greater than 150 kilotons. But in case that treaty is abrogated, for whatever reason, the option of conducting weapons tests in the range of 1 megaton or slightly more, must not be limited by the existence on the NTS of structures which would be damaged by the resulting ground motion. Conversely, any structures built must be designed to resist motions from the larger yields. Therefore, the data set consists of measurements from underground nuclear explosions before and after March, 1976. There were 17 UNEs in the earlier set with yields ranging from 155 to 1400 kt.

The number of three-component stations operated on each event varied from 4 to 22, for a total of 164 three-component stations. (Some surface

ground zero stations containing a vertical component only, have been included.) As shown in Table I there were scientific stations and stations operated by the U. S. Geological Survey (USGS). The former were for the purpose of understanding close-in ground shock phenomenology and ranged from surface zero to about 10 km with a single exception at 22.5 km. The USGS data were obtained to assess off-site safety and measurements were made from on-site to as far as the California coast, with emphasis on Las Vegas[1]. Where available, USGS data from on-site to no farther than Beatty off-site were added to the data set. This allowed data for many events to include both close-in data and data from more distant stations to about 70 km. No more distant data were used, since the purpose is to describe ground motion experienced by on-site facilities rather than to define off-site safety considerations. This portion of the data was obtained from the mid-1960's to the mid-1970's with equipment which was state-of-the-art at the time. The data must be used, however, in estimation of ground motion from larger yields, because it is all that exists. The earlier data set had station locations unrelated to the interests of NNWSI Project--e.g., there were no stations at Yucca Mountain, and no measurements taken except on the surface.

The later data are from 18 UNEs with yields ranging from 80 to 147 kt. The number of three-component stations operated on each event was from 10 to 20, with a total of 305. No data from events with yields smaller than 80 kt have been included to avoid biasing the data set toward small yields when the interest is in ground motion from larger yields. These later data have the advantage of including data from

Table I. Purpose and Number of Stations In Data Set

Early Set				Later Set			
Event Name	Scientific	USGS	Total	Event Name	Scientific & PNE	NNWSI	Total
Almendro	5	17	22	Backbeach	2	8	10
Boxcar	8	6	14	Colwick		18	18
Camembert	6	1	7	Farm	4	16	20
Cheshire	8	1	9	Fondutta	5	8	13
Colby	9		9	Gibne		18	18
Estuary	4	1	5	Harzer		19	19
Fontina	7	1	8	Hosta		18	18
Halfbeak	6	4	10	Kash		18	18
Handley	7	2	9	Molbo		20	20
Inlet	7	1	8	Nebbiolo		20	20
Jorum	6	7	13	Panir	5	9	14
Kasseri	7	1	8	Pepato	4	16	20
Mast	7	1	8	Serpa		15	15
Muenster	6	1	7	Sheepshead	2	17	19
Scotch	3	1	4	Tafi		19	19
Pool	10	3	13	Cabra		19	19*
Tybo	10		10	Chancellor		14	14*
				Kappeli		11	11*
TOTALS	116	48	164		22	283	305

*Used in Chapter 4 only.

locations of interest to the NNWSI Project. Table II shows the locations of stations in the NNWSI Weapons Test Seismic Investigations. No data from downhole stations have been used in this report. Data from 22 scientific and Peaceful Nuclear Explosion Program (PNE) stations have been included to provide data from stations closer than the locations of the NNWSI Project stations.

Stations were located on alluvium and rock. Following the practice established by Environmental Research Corporation (ERC), we have considered the rock and alluvium stations together, and then separately.

This report summarizes the weapons test seismic data recorded through FY84 and provides the interpretation of the data necessary to support the conceptual design.

TABLE II

Station Locations for Weapons Test Seismic Investigations

Stations	Location	Hole No.	Depth (m)	Medium	Date Installed
W-1	Area 16	None		Eleana Shale	8/77 (Removed 11/77)
W-2	Syncline Ridge	None		Limestone over Eleana	8/77 (Removed 6/78)
W-3	Piledriver	Ue-15.01	417	Granite	9/77 (Removed 5/83)
W-4	Area 6	Ue-6b	130	Alluvium	4/77 (Removed 5/78)
W-5	Skull Mountain	None		Tuff	10/77 (Moved 5/81) (Removed 10/83)
W-6	ETS-2	None		Alluvium	10/77
W-7	Calico Hills	None		Eleana SHale	10/77
W-8	Yacht Hole	Ue-1L	679 570(a)	Alluvium over Eleana Shale	3/78 (Removed 8/78)
W-9	Rainier Mesa	U-12g. 08 CH No. 1	432	Tuff	12/77 (Removed 4/84)
W-10	Well J-11	J-11	356(b) 343	Alluvium over Tuff	3/78 4/78
W-10′	200	J-11′	61	Alluvium	3/78 (Removed 7/81)
W-11	Area 4	Ue-4aa	346	Alluvium over Limestone	3/78 (Removed 4/84)
W-12	Yucca Mountain	USW-GU3	352	Tuff	3/83
W-13	Area 18	Ue-18r	762	Tuff over Welded Tuff	6/78 8/78 (Removed 4/84)
W-14	Yucca Mountain	None		Tuff	10/78
W-15	Dome Mountain	None		Lava	10/78 (Removed 8/82)
W-16	Forty-mile Canyon	None		Rholite	10/78 (Removed 8/82)
W-17	North Timber Mountain	None		Tuff	7/78 (Removed 8/82)
W-18	South Timber Mountain	None		Tuff	7/78 (Removed 8/82)
W-19	Mine Mountain	None		Limestone	2/79 (Removed 9/80)
W-20	Yucca Mountain	None		Tuff	7/80 (Moved to UGW-G1 4/82)
W-21	Yucca Mountain, SW	None		Tuff	7/80
W-22	Yucca Mountain, NW	None		Tuff	7/80
W-23	Yucca Mountain, NE	None		Tuff	7/80
W-24	Yucca Mountain	USW-G1	564	Tuff	3/82
W-25	Yucca Mountain	USW-G1	358	Tuff	8/83

(a) After 4/78 (b) Before 12/78

Philosophy of Ground Motion Prediction Equations

It is in order to discuss the philosophy of ground motion prediction equations, especially since the approach to ground motion criteria which will be adopted by NRC is not clear.

We will be dealing with prediction equations of the form

$$a,\ u,\ d = k\ W^{n}\ R^{-m}$$

where a, u, and d are peak vector amplitudes of acceleration in g's, velocity in cm/s, or displacement in cm, W is the yield in kilotons, and R the range in kilometers. The deviation of amplitude for a given range is commonly called the "standard error of estimate," since it measures the error involved in using the regression value to estimate amplitude, and is referred to herein as σ.

Using the entire data set results in the largest values of σ, which would be used where causes of large variations cannot be identified. Three causes of variation have been identified in these data. The first is associated with coupling of explosion energy, the second with transmission path, and the third is related to the geology at the station location. Later an effort will be made to isolate the effects of the first and third.

Illustrating the first, Figure 1 is a portion of acceleration fits for individual UNEs, scaled to a common yield using a regression equation of the next section. (The dashed line is the regression fit for data from all UNEs in the data set.) At 10 km the largest acceleration produced is about 5 times the smallest. The lines are, with some exceptions, roughly parallel, representing about the same attenuation with distance. The difference in the roughly parallel lines is due to the energy coupling at the source. An argument can be made that, for the purposes of evaluating

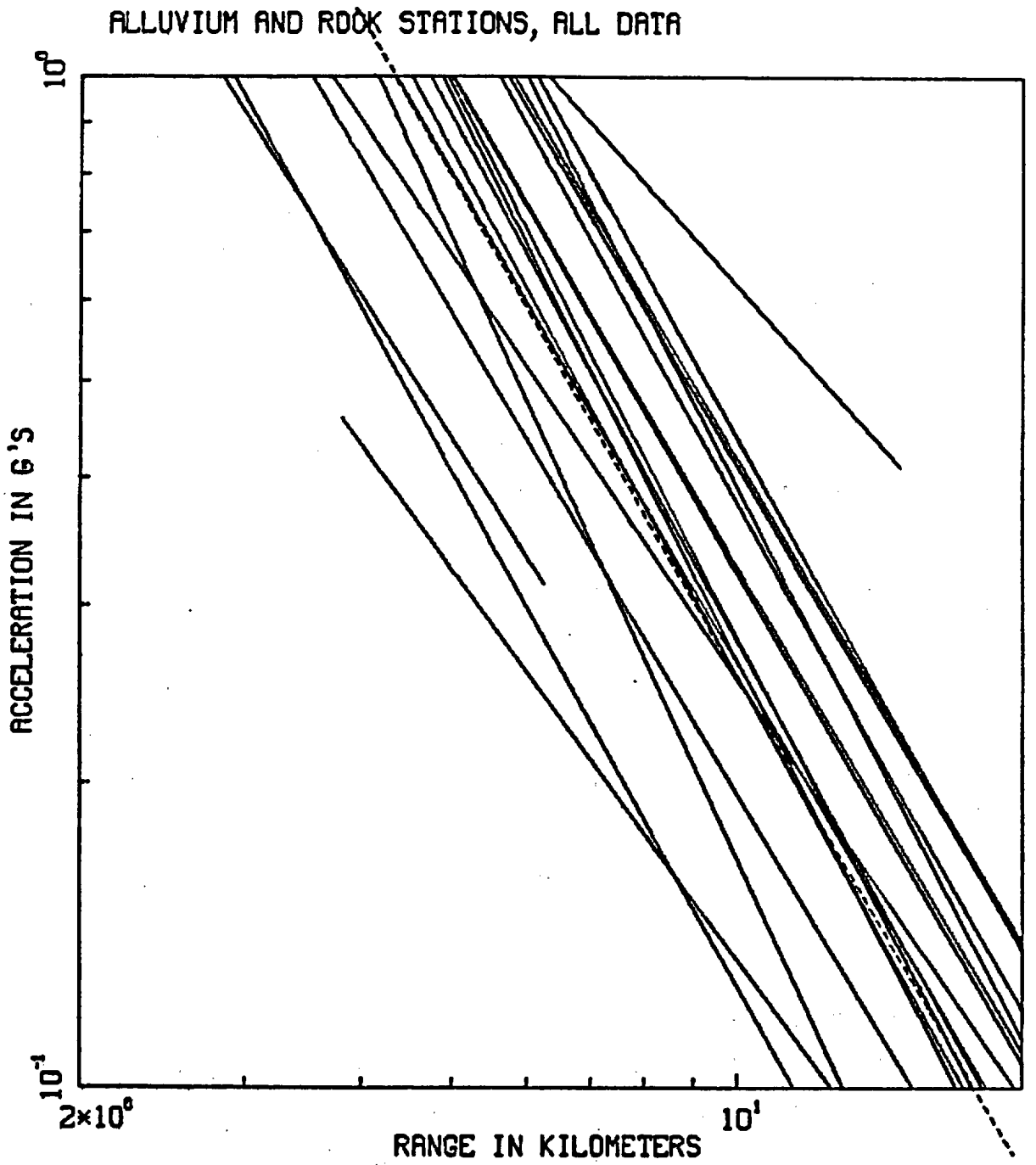

Figure 1. Fits to data from individual UNEs scaled to a common yield.

the ground motion parameters for design of a waste facility at Yucca Mountain, it is the strongly coupled UNEs that are of concern, not those weakly coupled. If, for example, half of the events on the lower side of the distribution were disregarded, the use of the remaining ones would cause the fit to predict higher acceleration with a smaller standard error of estimate. The ultimate extension of this argument is that the motion predicted by the best-coupled event could be used to establish design parameters.

The third cause of variation in the data is related to the geology at the station. One example is Station W-3 located on the Climax granite. There, peak vector velocity and displacement are usually low compared to data at other stations because the mass of granite resists motion. Peak vector acceleration is sometimes low, sometimes not. This station has data only in the later data set. Another example is Station W-6 in the later data set, at about the same location as ETS-1 and ETS-2 in the earlier data set. There, peak vector acceleration shows much greater amplitudes relative to other stations. It was observed to be eight times predicted acceleration on the Purse event. (Data from the Purse event was not included in the data set.) Peak vector velocity is greater by a lesser amount than for acceleration, and peak vector displacement is usually comparable to that from other stations. Stations A, B, C, and D in the later data set are near Station W-6 at separations of about 1800 m along a line perpendicular to the radius from the event through Calico Hills. They show varying degrees of enhanced acceleration. Still another example is Station W-9 on Rainier Mesa and Station W-15 on Dome Mountain. Both have shown evidence of topographic effects by having motion, particularly displacement, that is large relative

to other stations[2]. Figures 2 and 3 illustrate how acceleration and displacement for these particular stations are relative to other stations. It has been customary, where data from a given station is consistently above or below prediction, to apply a multiplication factor to data from that station to improve the agreement with prediction[1]. This has not been done in this report.

Where a station has a systematic deviation with respect to other stations, the inclusion of data from one or more such stations biases the regression fit and increases σ. Two philosophical arguments can be made. One, the deviant data should be retained, because in making predictions, other locations may have comparable deviations. Two, the deviant data should be removed, because, in the case of Yucca Mountain, measurements are being made to determine if there are greater than predicted motions at that location.

The question remains, if Yucca Mountain shows greater than predicted motion, should those data be included? This question will be addressed later by showing the effect on prediction equations of retaining or deleting those data.

The data were analyzed in three groups:

Group I - All of the data.

Group II - Data deleted from Stations W-3, W-6, W-9, W-15, ETS-1, ETS-2, A, B, C, and D.

Group III - As in Group II, but with deletion of data from the Yucca Mountain stations (W-14, W-20, W-21, W-22, W-23, and W-24).

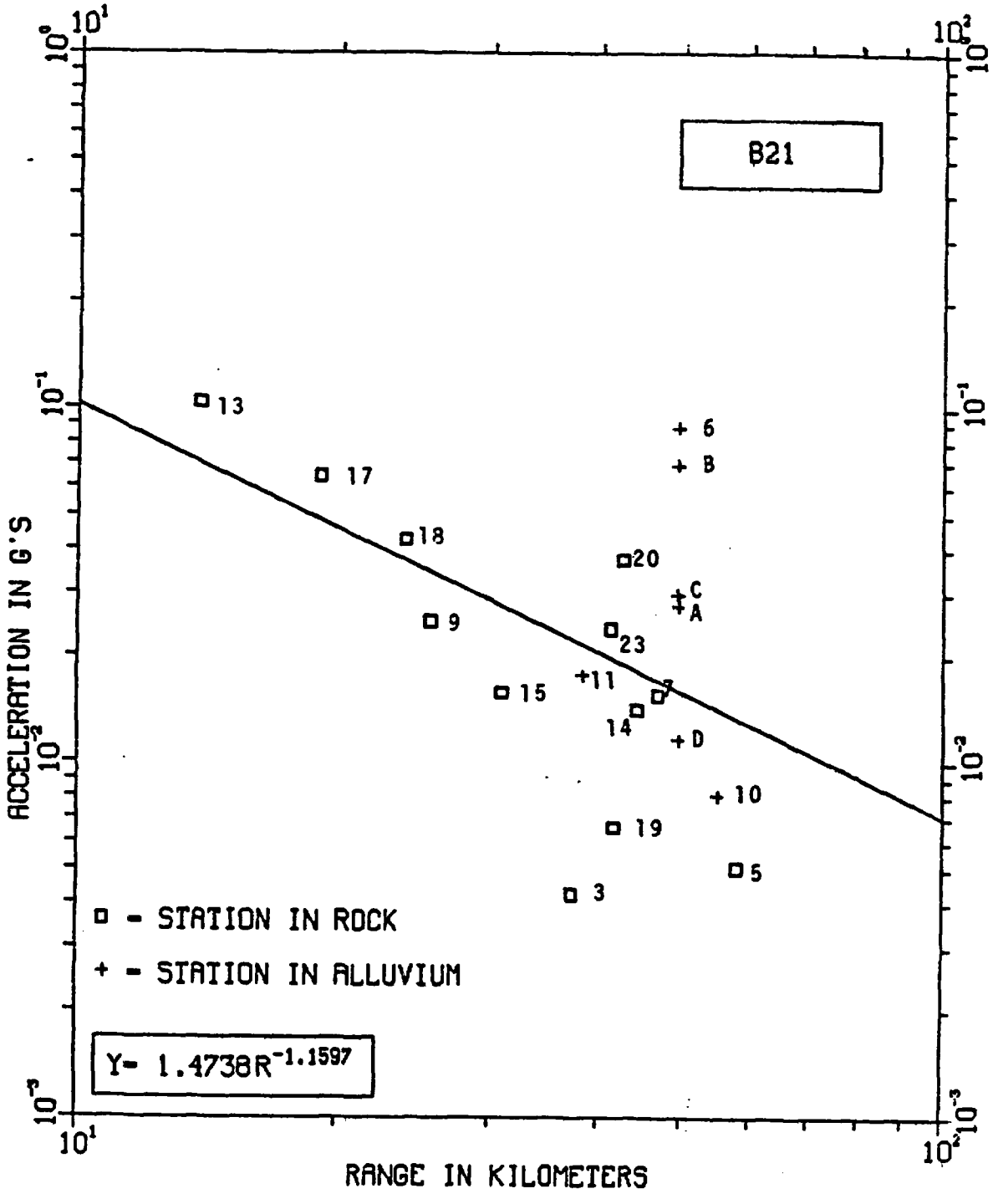

Figure 2. Relative peak vector acceleration for stations in the data set.

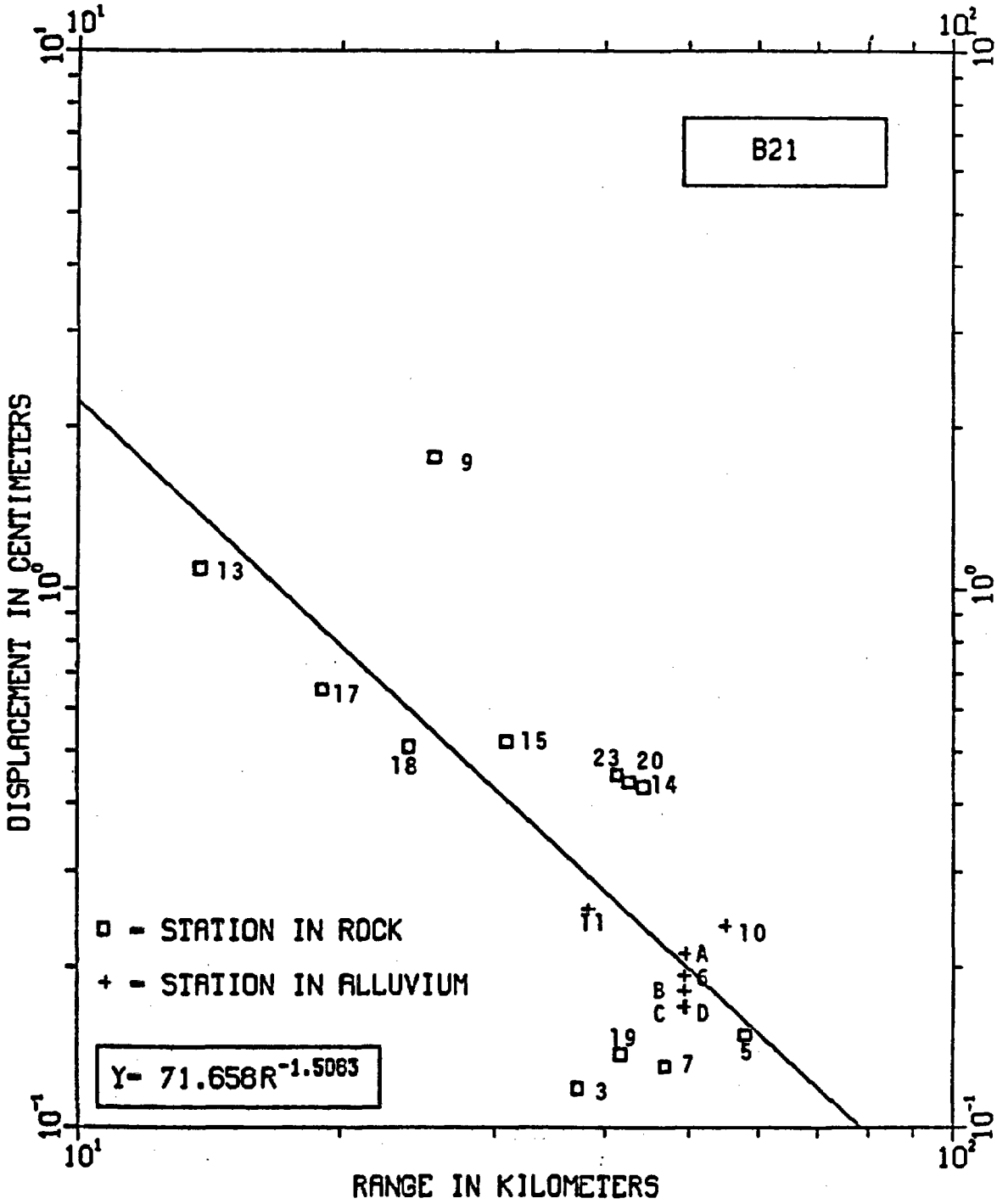

Figure 3. Relative peak vector displacement for stations in the data set.

For each group the single regression was performed to determine the effect the deletion of stations had on the regression fits. The regression fits are of the form $Y = c\ R^{-\beta}$, where Y is peak vector acceleration, velocity, or displacement.

Of the 32 events, 15 involved none of the stations from which data were deleted in Groups II and III, so values of c and β are the same for the three groups. Five of the remaining 17 had no Yucca Mountain stations and the values are the same for Groups II and III. For acceleration, the deletion of stations to form Group II caused an increase in both c and β, and the deletion of stations to form Group III caused a further increase. The same was true for velocity except for four cases (B02, B26, and B13) where there was a decrease in β. For displacement there were 8 cases where both c and β decreased, and one case where β alone decreased. All other changes were increases going from Group I to Group II, and from Group II to Group III.

Figure 4 shows the data and regression fit for Group I for a typical event. Note the position of data for Stations 3, 6, 9, 15, A, B, and C. Figure 5 shows the result for Group II with data from these stations deleted. Now note the position of the data from the Yucca Mountain stations 14, 21, 22, 23, and 24. Figure 6 shows the results for Group III with the Yucca Mountain stations deleted. With each deletion there was an increase in both c and β.

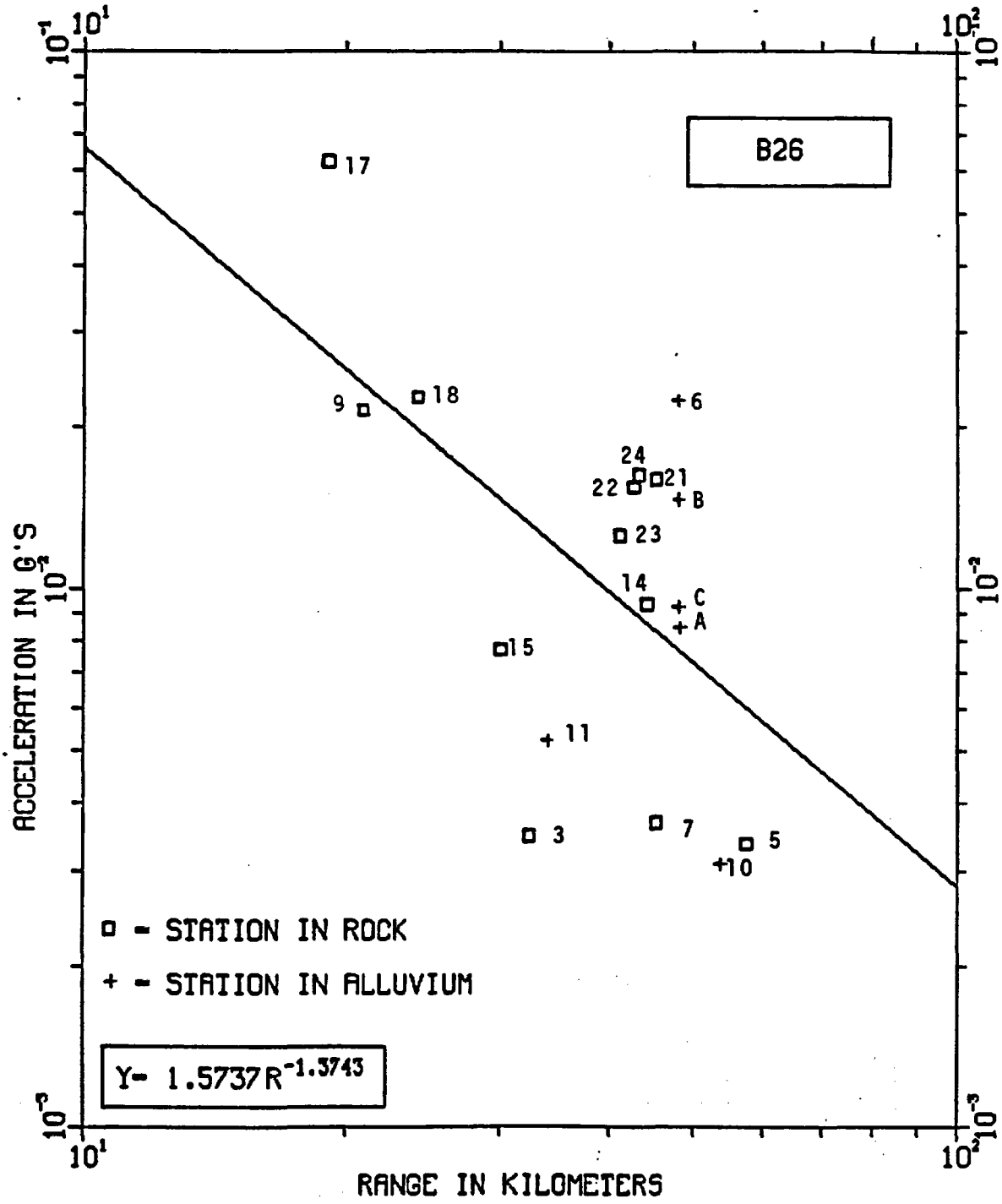

Figure 4. Data and regression fit for Group I.

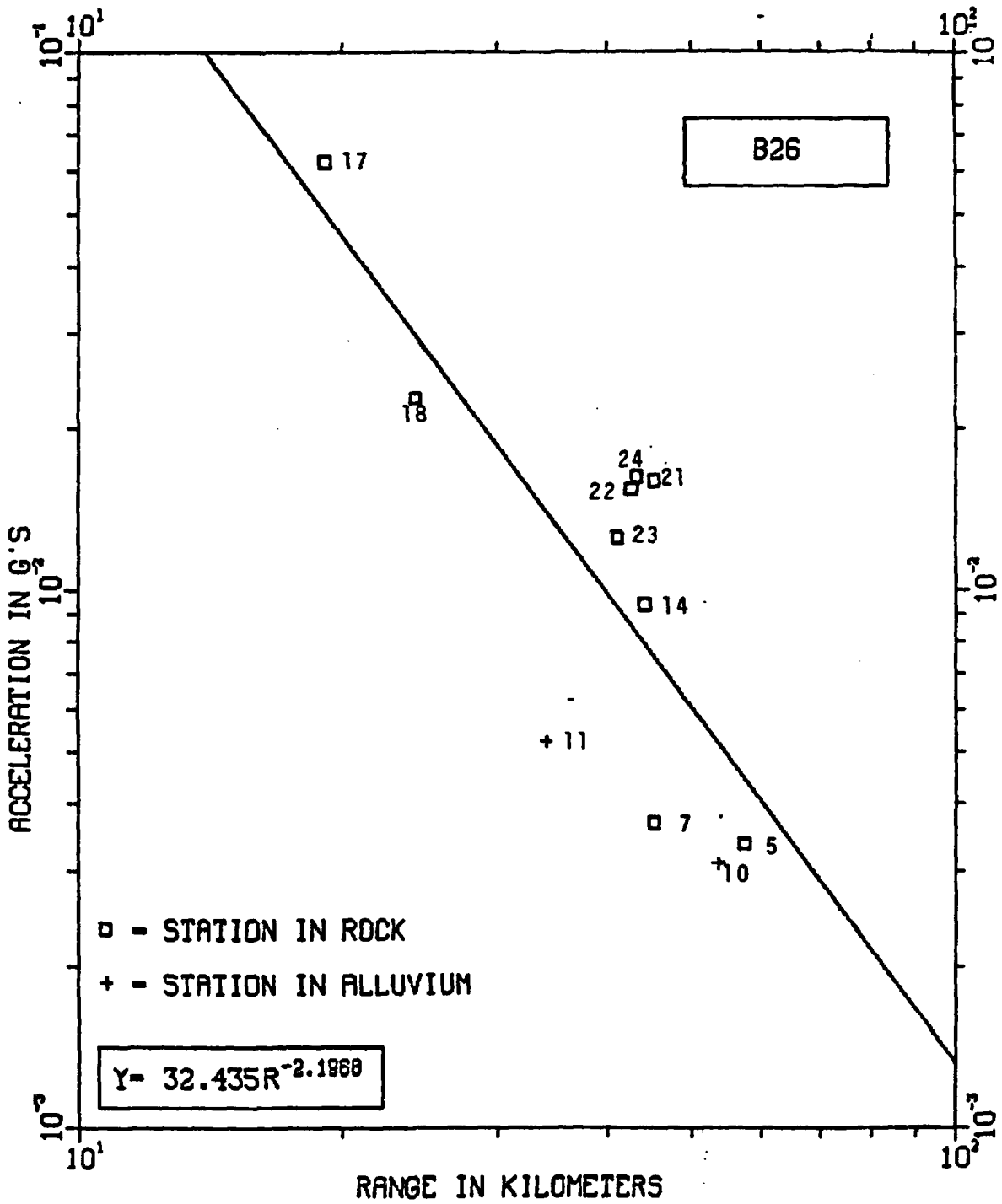

Figure 5. Data and regression fit for Group II.

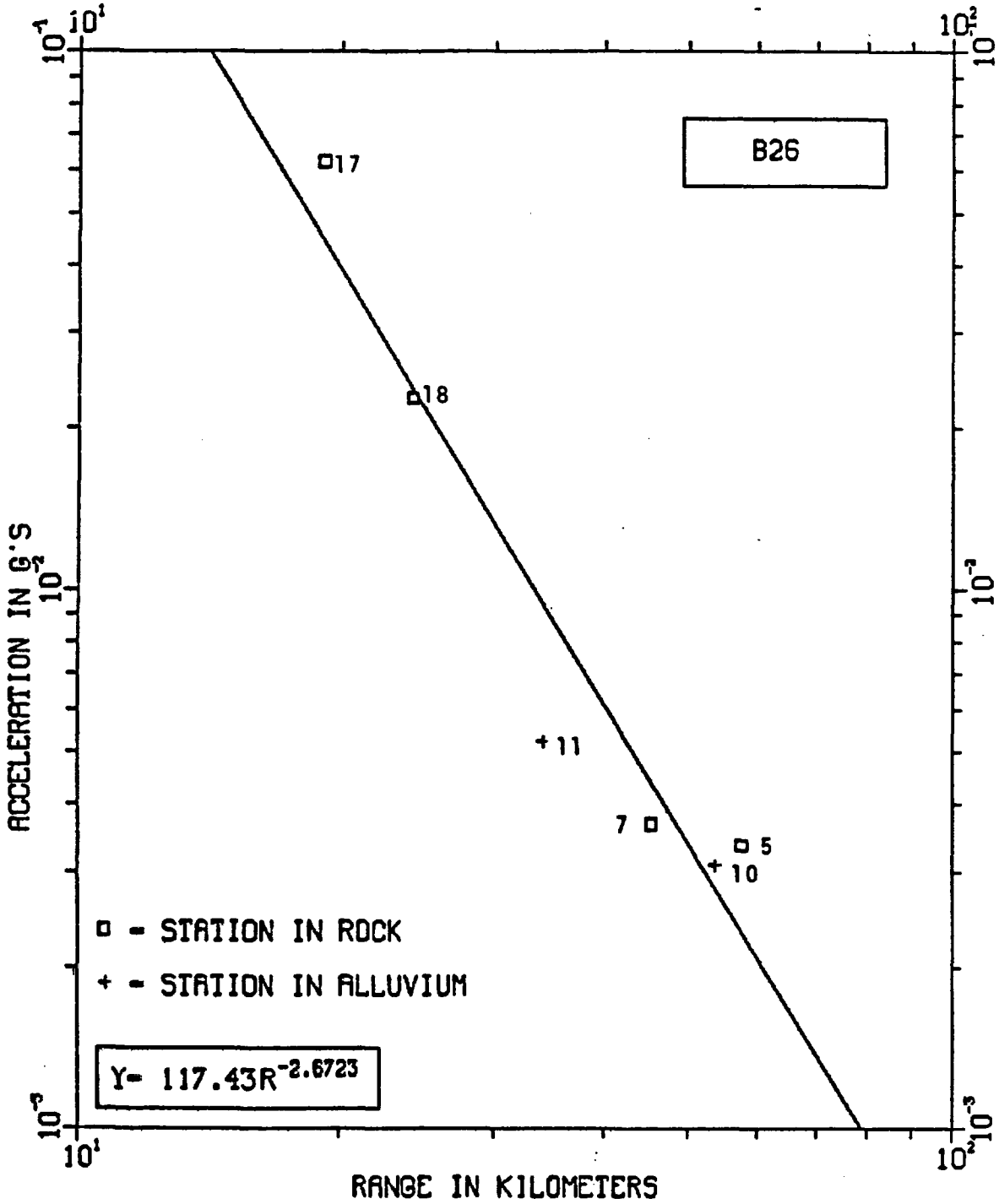

Figure 6. Data and regression fit for Group III.

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CHAPTER 2. PREDICTION EQUATIONS

The following prediction equations were obtained from Pahute Mesa events with yields from 80 to 1400 kilotons. Accordingly, they should be used for similar geology and over a comparable range of yields.

For each group the data regressions were done separately for (1) stations on alluvium and rock, (2) stations on rock only, and (3) stations on alluvium only. There are separate equations for peak vector acceleration, velocity, and displacement.

Group I - Stations on Alluvium and Rock

For acceleration:

$$a = 0.436\ W^{0.490}\ R^{-1.624},\ N = 415,\ \sigma_a = 2.063,\ \sigma_R = 1.562, \qquad \text{(Eq. 1)}$$

where a is peak vector acceleration in g's, W is yield in kilotons, R is the slant range in kilometers, N is the number of data points, and σ is the standard error of the estimate on acceleration or range.

For velocity:

$$u = 11.11\ W^{0.629}\ R^{-1.522},\ N = 421,\ \sigma_u = 1.732,\ \sigma_R = 1.435 \qquad \text{(Eq. 2)}$$

where u is peak vector velocity in cm/s.

For displacement:

$$d = 2.633\ W^{0.665}\ R^{-1.556},\ N = 418,\ \sigma_d = 1.789,\ \sigma_R = 1.453. \qquad \text{(Eq. 3)}$$

where d is peak vector displacement in cm.

Group I - Stations on Rock

For acceleration:

$$a = 0.435\ W^{0.502}\ R^{-1.685},\ N = 303,\ \sigma_a = 1.965,\ \sigma_R = 1.493. \qquad \text{(Eq. 4)}$$

For velocity:

$$u = 12.13\ W^{0.621}\ R^{-1.561},\ N = 309,\ \sigma_u = 1.744,\ \sigma_R = 1.428. \qquad \text{(Eq. 5)}$$

For displacement:

$$d = 2.884\ W^{0.656}\ R^{-1.593},\ N = 306,\ \sigma_d = 1.819,\ \sigma_R = 1.456. \qquad \text{(Eq. 6)}$$

The differences between this set and the previous one for both alluvium and rock are small and are consistent with the fact that about three-quarters of the data are from stations in rock.

Group I - Stations on Alluvium

For acceleration:

$$a = 0.198\ W^{0.276}\ R^{-1.075},\ N = 112,\ \sigma_a = 2.153,\ \sigma_R = 2.041. \qquad \text{(Eq. 7)}$$

For velocity:

$$u = 12.44\ W^{0.566}\ R^{-1.434},\ N = 112,\ \sigma_u = 1.653,\ \sigma_R = 1.420. \qquad \text{(Eq. 8)}$$

For displacement:

$$d = 2.882\ W^{0.606}\ R^{-1.468},\ N = 112,\ \sigma_d = 1.671,\ \sigma_R = 1.419. \qquad \text{(Eq. 9)}$$

Note that the exponents of both W and R for acceleration are smaller than those for velocity and displacement. The reason for the low exponent of R is that Stations W-6, A, B, C, and D which have enhanced acceleration on some of the events and which are at the larger distances, are causing the slope to be less than for velocity and displacement. The cause of the low value of the exponent on W is unclear.

Group II - Stations on Alluvium and Rock

For acceleration:

$$a = 0.549\ W^{0.466},\ R^{-1.687},\ N = 320,\ \sigma_a = 1.909,\ \sigma_R = 1.467 \qquad \text{(Eq. 10)}$$

For velocity:

$$u = 13.12\ W^{0.607}\ R^{-1.549},\ N = 326,\ \sigma_u = 1.582,\ \sigma_R = 1.345 \qquad \text{(Eq. 11)}$$

For displacement:

$$d = 3.230\ W^{0.636}\ R^{-1.581},\ N = 323,\ \sigma_d = 1.712,\ \sigma_R = 1.405 \qquad \text{(Eq. 12)}$$

Group II - Stations on Rock

For acceleration:

$$a = 0.581\ W^{0.456}\ R^{-1.678},\ N = 266,\ \sigma_a = 1.944,\ \sigma_R = 1.486 \qquad \text{(Eq. 13)}$$

For velocity:

$$u = 13.25\ W^{0.606}\ R^{-1.547},\ N = 272,\ \sigma_u = 1.579,\ \sigma_R = 1.343 \qquad \text{(Eq. 14)}$$

For displacement:

$$d = 2.964\ W^{0.650}\ R^{-1.584},\ N = 269,\ \sigma_d = 1.677,\ \sigma_R = 1.386 \qquad \text{(Eq. 15)}$$

Group II - Stations on Alluvium

For acceleration:

$$a = 0.0687\ W^{0.504}\ R^{-1.233},\ N = 54,\ \sigma_a = 1.694,\ \sigma_R = 1.533 \qquad \text{(Eq. 16)}$$

For velocity:

$$u = 9.777\ W^{0.619}\ R^{-1.494},\ N = 54,\ \sigma_u = 1.617,\ \sigma_R = 1.379 \qquad \text{(Eq. 17)}$$

For displacement:

$$d = 4.484\ W^{0.532}\ R^{-1.503},\ N = 54,\ \sigma_d = 1.888,\ \sigma_R = 1.526 \qquad \text{(Eq. 18)}$$

Group III - Stations on Alluvium and Rock

For acceleration:

$$a = 0.450\ W^{0.501}\ R^{-1.709},\ N = 285,\ \sigma_a = 1.897,\ \sigma_R = 1.454 \qquad \text{(Eq. 19)}$$

For velocity:

$$u = 11.14\ W^{0.638}\ R^{-1.574},\ N = 291,\ \sigma_u = 1.556,\ \sigma_R = 1.324 \qquad \text{(Eq. 20)}$$

For displacement:

$$d = 2.732\ W^{0.667}\ R^{-1.609},\ N = 288,\ \sigma_d = 1.693,\ \sigma_R = 1.387 \qquad \text{(Eq. 21)}$$

Group III - Stations on Rock

For acceleration:

$$a = 0.511\ W^{0.482}\ R^{-1.717},\ N = 231,\ \sigma_a = 1.941,\ \sigma_R = 1.471 \qquad \text{(Eq. 22)}$$

For velocity:

$$u = 12.04\ W^{0.628}\ R^{-1.593},\ N = 237,\ \sigma_u = 1.543,\ \sigma_R = 1.313 \qquad \text{(Eq. 23)}$$

For displacement:

$$d = 2.683\ W^{0.675}\ R^{-1.640},\ N = 234,\ \sigma_d = 1.632,\ \sigma_R = 1.348 \qquad \text{(Eq. 24)}$$

Group III - Stations on Alluvium

For acceleration, velocity, and displacement, the equations are the same as for Group II because none of the Yucca Mountain stations were on alluvium, therefore none were deleted in going from Group II to Group III.

Tables III, IV, and V summarize the foregoing equations and permit ready comparisons of the changes in k, n, m, σ_a, σ_u, σ_d, and σ_R in going from Group I to Group II, and from Group II to Group III. Most significant is that each of the deletions of data improved σ in all cases except displacement for the alluvium only set, where there was an increase. Values

Table III. Summary of Prediction Equations for Peak Vector Acceleration

	k	n	m	σ_a	σ_R	Motion from 700 kt at 22.8 km				
						Data	Mean (mg's)	+1σ (mg's)	+2σ (mg's)	
Alluvium & Rock										
Group I	0.436	0.490	1.624	2.063	1.562	415	67.3	138.9	286.6	Eq. 1
II	0.549	0.466	1.687	1.909	1.467	320	59.5	113.6	216.9	Eq. 10
III	0.450	0.501	1.709	1.897	1.454	285	57.3	108.6	206.1	Eq. 19
ERC*	0.249	0.464	1.340	2.30	1.862	401	78.8	181.3	417.0	
Reference 3	1.042	0.397	1.731	1.741	1.371	215	60.7	105.1	181.9	
Rock Only										
Group I	0.435	0.502	1.685	1.965	1.493	303	60.1	118.0	231.9	Eq. 4
II	0.581	0.456	1.678	1.944	1.486	266	60.7	117.9	229.3	Eq. 13
III	0.511	0.482	1.717	1.941	1.471	231	56.0	108.7	211.0	Eq. 22
Alluvium Only										
Group I	0.198	0.276	1.075	2.153	2.041	112	41.9	90.2	194.2	Eq. 7
II	0.0687	0.504	1.233	1.694	1.533	54	39.5	66.9	113.3	Eq. 16
III	0.0687	0.504	1.233	1.694	1.533	54	39.5	66.9	113.3	Eq. 16

* Environmental Research Corporation (Ref. 1)

Table IV. Summary of Prediction Equations for Peak Vector Velocity

	k	n	m	σ_u	σ_R	Motion from 700 kt at 22.8 km				
						Data	Mean (cm/s)	+1σ (cm/s)	+2σ (cm/s)	
Alluvium & Rock										
Group I	11.11	0.629	1.522	1.732	1.435	421	5.87	10.16	17.60	Eq. 2
II	13.12	0.607	1.549	1.582	1.345	326	5.51	8.72	13.80	Eq. 11
III	11.14	0.638	1.574	1.556	1.324	291	5.30	8.25	12.84	Eq. 20
ERC*	6.64	0.622	1.340	1.950	1.646	221	5.92	11.54	22.50	
Rock Only										
Group I	12.13	0.621	1.561	1.744	1.428	309	5.38	9.39	16.37	Eq. 5
II	13.25	0.606	1.547	1.579	1.343	272	5.57	8.79	13.88	Eq. 14
III	12.04	0.628	1.593	1.543	1.313	237	5.06	7.81	12.05	Eq. 23
Alluvium Only										
Group I	12.44	0.566	1.434	1.653	1.420	112	5.73	9.47	15.65	Eq. 8
II	9.777	0.619	1.494	1.617	1.379	54	5.28	8.54	13.80	Eq. 17
III	9.777	0.619	1.494	1.617	1.379	54	5.28	8.54	13.80	Eq. 17

* Environmental Research Corporation (Ref. 1)

Table V. Summary of Prediction Equations for Peak Vector Displacement

	k	n	m	σ_a	σ_R	Motion from 700 kt at 22.8 km				
						Data	Mean (cm)	+1σ (cm)	+2σ (cm)	
Alluvium & Rock										
Group I	2.633	0.666	1.556	1.789	1.453	418	1.59	2.85	5.10	Eq. 3
II	3.230	0.636	1.581	1.712	1.405	323	1.49	2.54	4.35	Eq. 12
III	2.732	0.667	1.609	1.693	1.387	288	1.41	2.39	4.04	Eq. 21
ERC*	0.441	0.775	1.170	2.120	1.901	380	1.82	3.86	8.19	
Rock Only										
Group I	2.884	0.656	1.593	1.819	1.456	306	1.46	2.65	4.82	Eq. 6
II	2.964	0.650	1.584	1.677	1.386	269	1.48	2.48	4.16	Eq. 15
III	2.683	0.675	1.640	1.632	1.348	234	1.32	2.16	3.53	Eq. 24
Alluvium Only										
Group I	2.882	0.606	1.468	1.671	1.419	112	1.55	2.59	4.33	Eq. 9
II	4.484	0.532	1.503	1.888	1.526	54	1.33	2.51	4.75	Eq. 18
III	4.484	0.532	1.503	1.888	1.526	54	1.33	2.51	4.75	Eq. 18

* Environmental Research Corporation (Ref. 1)

of k increased going from Group I to Group II and decreased going from Group II to Group III for alluvium plus rock and for rock only. This was true for all three motion parameters. For alluvium only, k decreased going from Group I to Group II except for displacement where there was an increase. The changes in n were exactly opposite those for k. For the alluvium plus rock data set there was an increase in m going from Group I to Group II and a further increase going from Group II to Group III. For the rock only set there was a decrease going from Group I to Group II and an increase going from Group II to Group III. For the alluvium only set there was an increase in m going from Group I to Group II. The comments on changes in n and m apply to all three motion parameters.

Perhaps it is easier to appreciate the differences in the equations in terms of the differences in the motions they predict. The motion predicted by each equation at 22.8 km from a 700 kt event has been added to Tables III, IV, and V. This example was chosen as representative of the largest yield suitable for the point in the Buckboard Area closest to Yucca Mountain. In all cases the smallest motion is predicted by the Group III data set.

The prediction equations of Environmental Research Corporation[1] have been added to Tables III, IV, and V for comparison with Groups I, II, and III using the alluvium plus rock data set. In each case σ is larger as a result of a larger range of yields and the inclusion of off-site data. Their equations result in larger predicted motions for acceleration, velocity, and displacement. An earlier prediction equation (Ref. 3) for on-site motion but with a smaller number of events has been added to Table III. That equation predicts acceleration comparable to the Group III equation.

It was noted earlier that elimination of data from poorly coupled UNEs would result in slightly larger predicted motion and a smaller σ. Nine events were chosen (A03, A05, A06, B01, B07, B08, B16, B22, and B28) for deletion, the first because of poor data, and the remainder as weakly coupled. The alluvium plus rock and Group I data set was used, and resulted in the following equations:

For acceleration:

$$a = 0.702\ W^{0.472}\ R^{-1.697},\ N = 294,\ \sigma_a = 1.909,\ \sigma_R = 1.464, \qquad \text{(Eq. 25)}$$

For velocity:

$$u = 12.79\ W^{0.613}\ R^{-1.524},\ N = 300,\ \sigma_a = 1.696\ \sigma_R = 1.414, \qquad \text{(Eq. 26)}$$

For displacement:

$$d = 2.389\ W^{0.664}\ R^{-1.512},\ N = 299,\ \sigma_a = 1.709,\ \sigma_R = 1.425. \qquad \text{(Eq. 27)}$$

The mean and 1 and 2σ values for 700 kt at 22.8 km were 76.7, 146.5, and 279.8 mg's; 6.05, 10.25, and 17.39 cm/s; and 1.64, 2.80, and 4.78 cm. Comparison of these results with those of Equations 1, 2, and 3 in Tables III, IV, and V shows that the differences are very small. The σs are less, but by a small amount. This suggests that the inclusion of data from stations deleted in Groups II and III caused deviations that dominated the effect of weak coupling.

To test that suggestion data from the same nine events were deleted using the Group III data set for alluvium and rock, with the following results:

For acceleration:

$$a = 0.703\ W^{0.491}\ R^{-1.778},\ N = 185,\ \sigma_a = 1.686,\ \sigma_R = 1.342, \qquad \text{(Eq. 28)}$$

For velocity:

$$u = 11.87\ W^{0.635}\ R^{-1.566},\ N = 191,\ \sigma_u = 1.507,\ \sigma_R = 1.299, \qquad \text{(Eq. 29)}$$

For displacement:

$$d = 2.317\ W^{0.677}\ R^{-1.556},\ N = 190,\ \sigma_d = 1.606,\ \sigma_R = 1.356. \qquad \text{(Eq. 30)}$$

For 700 kt at 22.8 km the mean and 1 and 2σ values were 67.5, 113.9, and 192.0 mg's; 5.68, 8.56, and 12.91 cm/s; and 1.51, 2.42, and 3.89 cm. When these results are compared with those of Equations 19, 20, and 21 of Tables III, IV, and V, σ is smaller for Equations 28, 29, and 30, but the difference was appreciable only for acceleration. As expected the mean values predicted are larger, whereas the 2σ values are smaller for acceleration and displacement, and about the same for velocity.

For predicting ground motion it is concluded that Equations 28, 29, and 30 have little advantage over Equations 19, 20, and 21, and use of the latter or Equations 22, 23, and 24 for stations in rock is recommended.

The relative differences in the predictions of Equations 1 through 24 are shown in Table VI for 700 kt at 22.8 km. The peak vector values are ordered from largest to smallest. Values for the ERC equations are also shown, and they always predict the largest motion. For acceleration the values predicted for stations on alluvium are noticeably less than for stations on rock or rock and alluvium combined.

This is better illustrated by Figure 7 which shows that the alluvium values (Equations 7 and 16) are even smaller relative to the other equations

Table VI. Relative Differences in Predictions of Equations 1-24 for 700 kt at 22.8 km

Acceleration				Velocity				Displacement			
Group	Medium	Eq.	g's	Group	Medium	Eq.	cm/s	Group	Medium	Eq.	cm
		ERC	0.0788			ERC	5.92			ERC	1.82
I	A&R	1	0.0673	I	A&R	2	5.87	I	A&R	3	1.59
II	R	13	0.0607	I	A	8	5.73	I	A	9	1.55
I	R	4	0.0601	II	R	14	5.57	II	A&R	12	1.49
II	A&R	10	0.0595	II	A&R	11	5.51	II	R	15	1.48
III	A&R	19	0.0573*	III	A&R	20	5.30*	III	A&R	21	1.41*
III	R	22	0.0560*	I	R	5	5.38	I	R	6	1.46
I	A	7	0.0419	II&III	A	17	5.28	II&III	A	18	1.33
II&III	A	16	0.0395	III	R	23	5.06*	III	R	24	1.32*

*Recommended for use.

A&R Alluvium and Rock
R Rock only
A Alluvium only

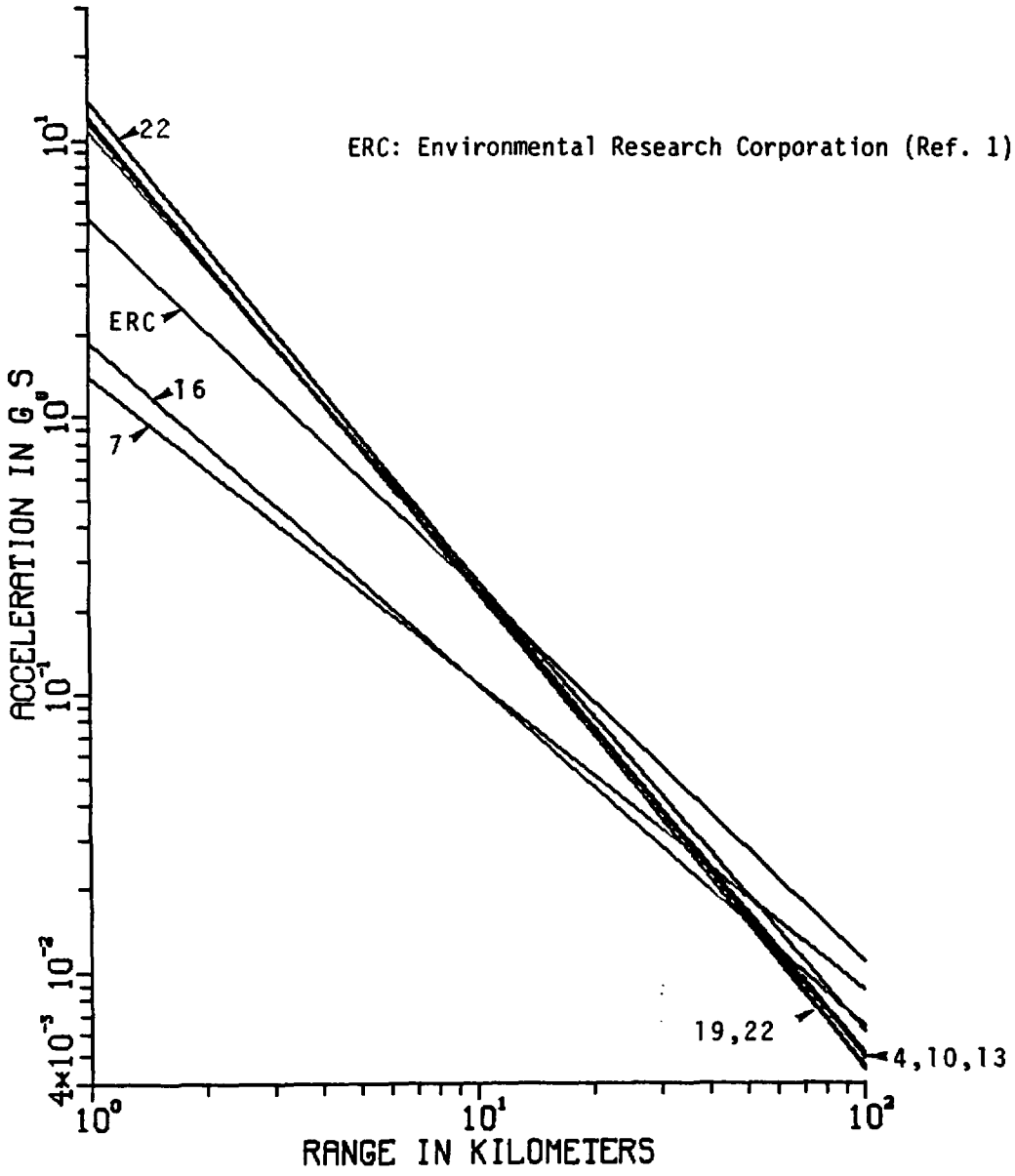

Figure 7. Comparison of regression equations.

at the closer distances. They become larger at the greater distances. This is attributed to a small alluvium sample over a relatively short distance range. The ERC equation predicts much larger values at the greater distances and smaller values at the closer distances. Note that there is very little difference between the Group III values for rock (Equation 22) and those for rock and alluvium (Equation 19) throughout the entire range. Although no similar plot is shown for velocity, the differences between the eight equations are only about ±10 percent at 22.8 km with greater divergence at larger and smaller distances.

If a displacement plot was shown it would reveal that at the closest distances all equations have about the same values except for alluvium (Equations 9 and 18) which has lower values and the ERC equation which has values that are lower still. At 15 km the differences between all equations is only about ±10 percent. The predicted values diverge slightly at the greater distances except for the ERC equation which predicts significantly greater values.

In view of the differences in the various equations, and the data on which they are based, it is a judgment that Equations 22, 23, and 24 should be used for stations on rock for acceleration, velocity, and displacement, respectively. Further, Equations 19, 20, and 21 should be used for stations on alluvium, rather than Equations 16, 17, and 18, because of the small sample and the small range of distances represented in the alluvium data set.

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CHAPTER 3. ANOMALOUS GROUND MOTION AT NRDS

Ground motion that was unexpectedly high has been observed at specific locations, particularly from certain Pahute Mesa tests.[4]

"Ground motion recorded at station Engine Test Stand (ETS), on the Nuclear Rocket Development Station (NRDS), from certain underground nuclear explosions at Nevada Test Site exhibits levels which are significantly greater than the level of response expected on the basis of average Nevada Test Site experience. The anomalous response, with respect to the average NTS response, is greatest at ETS and decreases in all directions from it. Characteristics of the anomaly include a spectrum unusually enriched in high (3-5 Hz) frequency components and velocity and acceleration seismograms having pulse-like first arrivals with a peak vector amplitude considerably greater than typically observed at that distance. Analysis of observed data leads to the conclusion that the anomaly is related to physical parameters of the travel path rather than solely to parameters of the source or receiving station environments. The particular travel path between Pahute Mesa and ETS appears to have a general bearing of N-18°-W from ETS. The specific cause of the anomalous response is presently not clear."[4]

Figure 8 (from Reference 4) shows the pattern of iso-acceleration contours about ETS for the Purse event. The peak values at ETS were about eight times those at E-MAD to the south.

One of the characteristics of the anomaly is the pronounced difference in the waveforms. Figure 9 shows the vertical acceleration, velocity, and displacement at Station W-6 for Event B21 which had the anomalous motion and, at the bottom, the same for Event B23, which did not. The two events had similar yields, but different azimuths. B21 was at 49.37 km and B23 at 52.3 km. B21 has maximum acceleration, velocity, and displacement at the beginning of the record, whereas B23 has more emergent waveforms with maxima occurring later in the wavetrain. Note the differences in scale. After 15 seconds the amplitudes for both events are comparable. Amplitudes for the B21 displacements are not significantly enhanced over those of B23. Figures 10 and 11 show the radial and tangential waveforms, respectively, and these exhibit similar characteristics.

On both events signal arrival was delayed about 150 to 290 milliseconds relative to arrival at nearby stations W-7 and W-10. A similar delay has been observed at W-6 on a number of other events.

Spectral differences between the two events are shown in the PSRVs of Figures 12, 13, and 14 for vertical, radial, and tangential components, respectively. The signals from B21 are rich in high frequencies relative to those of B23. There is relatively little difference below 0.3 Hz. Dominant frequencies for B21 are from 3 to 5 Hz for all components, whereas for B23 they are from 0.4 to 0.6 Hz.

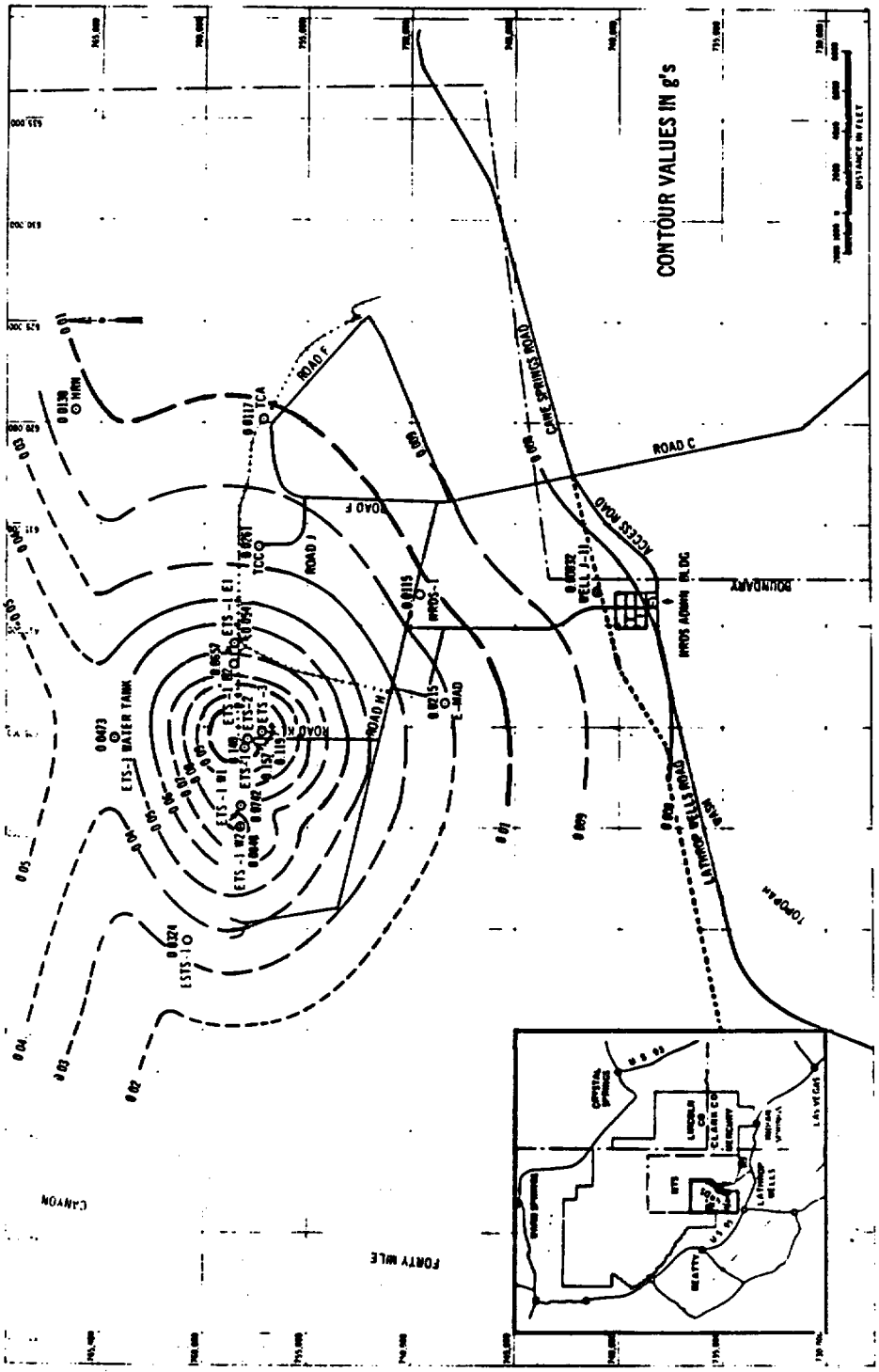


Figure 8. Schematic Contour Map of Peak Particle Accelerations Observed at NRDS Stations, Purse Detonation.

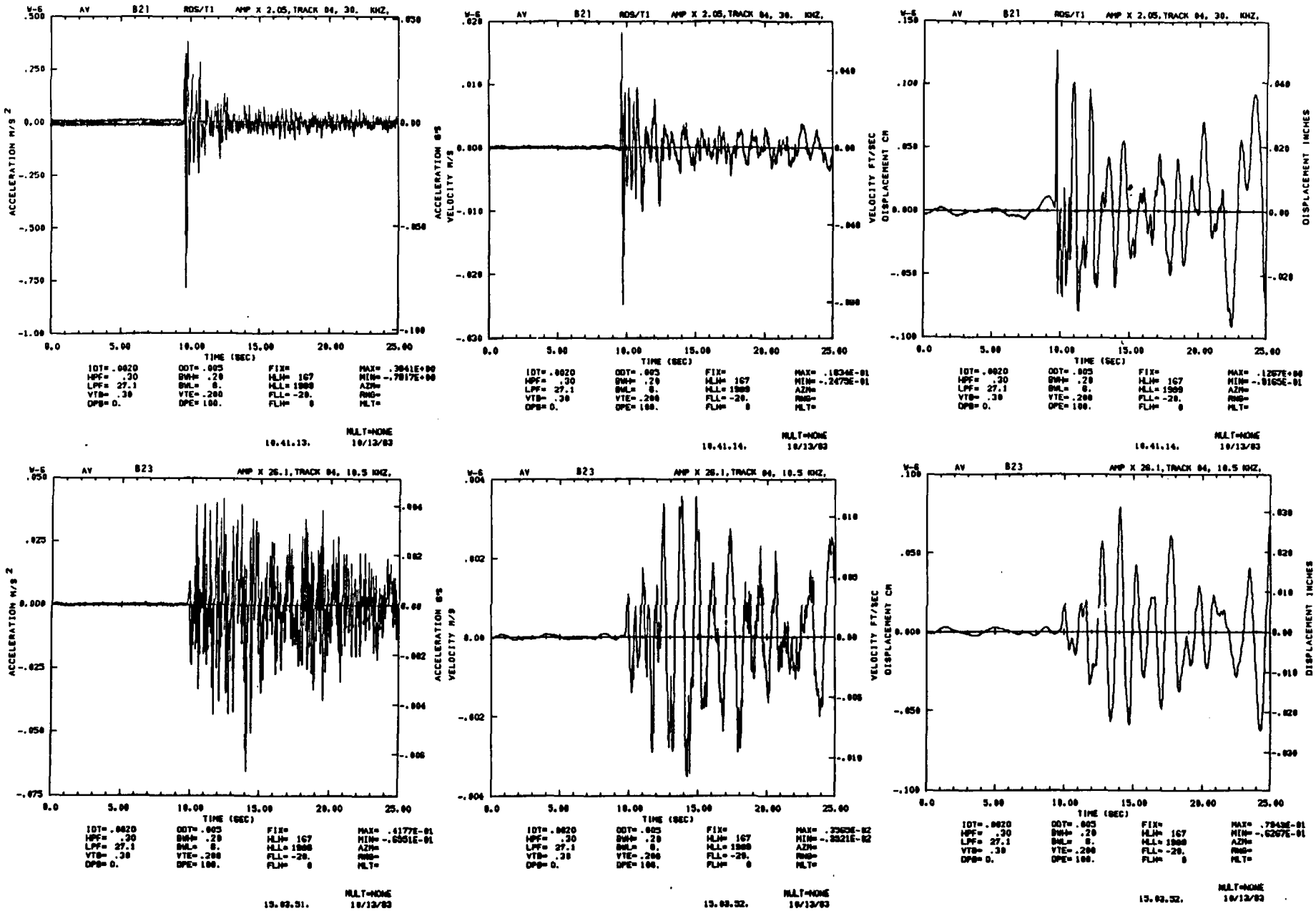


Figure 9. Vertical waveforms for anomalous and ordinary motion.

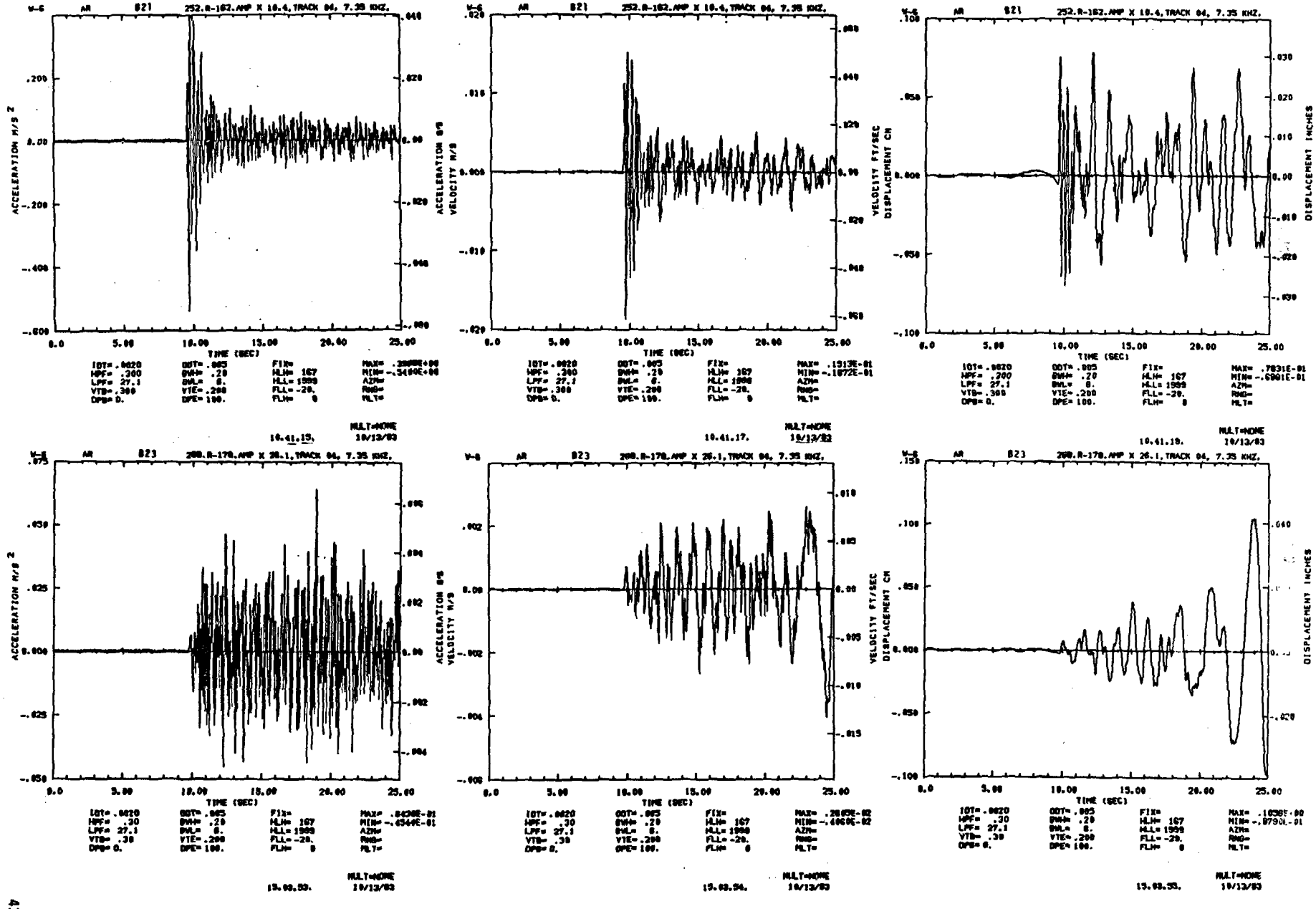


Figure 10. Radial waveforms for anomalous and ordinary motion.

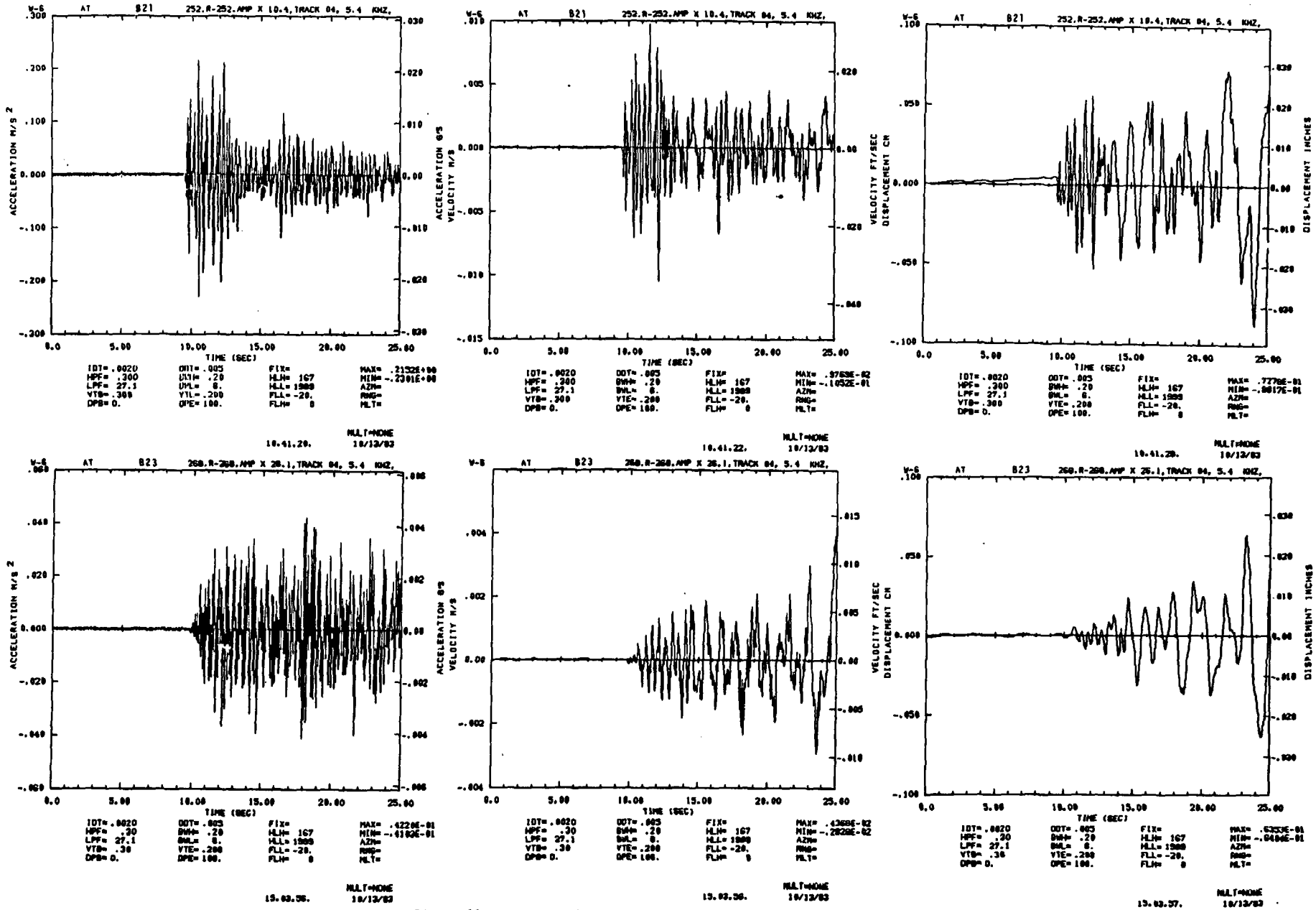


Figure 11. Tangential waveforms for anomalous and ordinary motion.

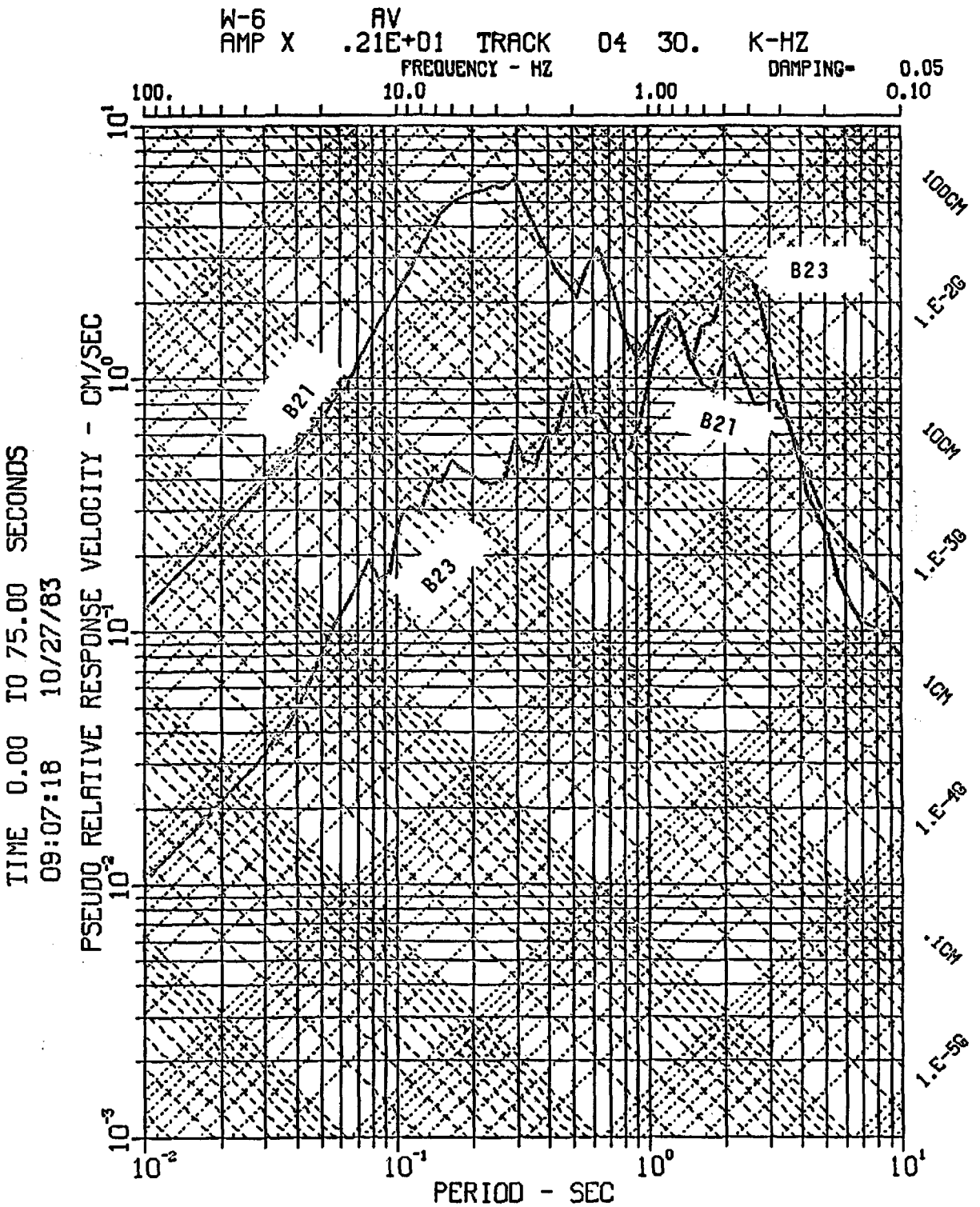


Figure 12. Vertical Pseudo Relative Velocity (PSRVs) for anomalous (B21) and ordinary (B23) ground motion.

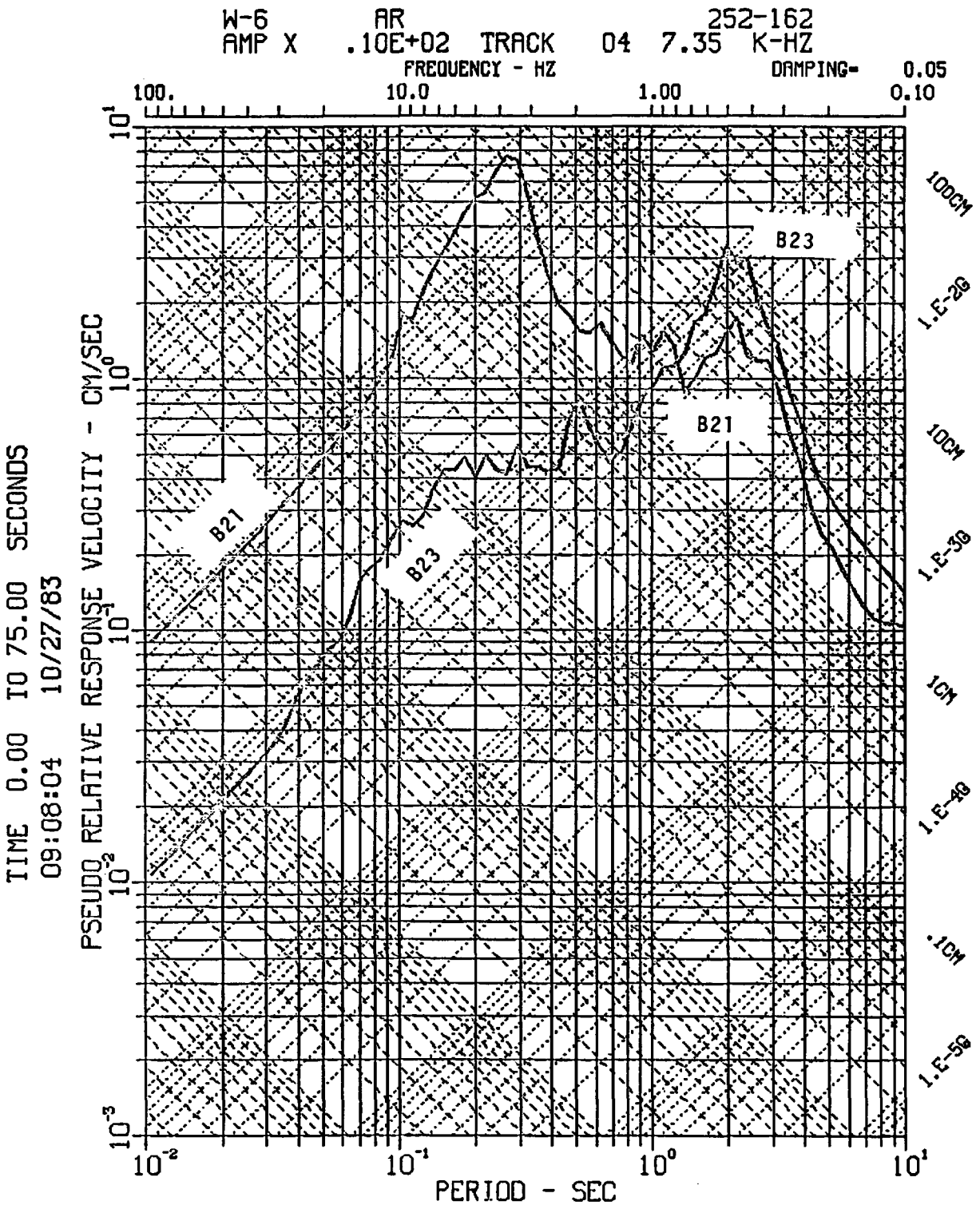


Figure 13. Radial Pseudo Relative Velocity (PSRVs) for anomalous (B21) and ordinary (B23) ground motion.

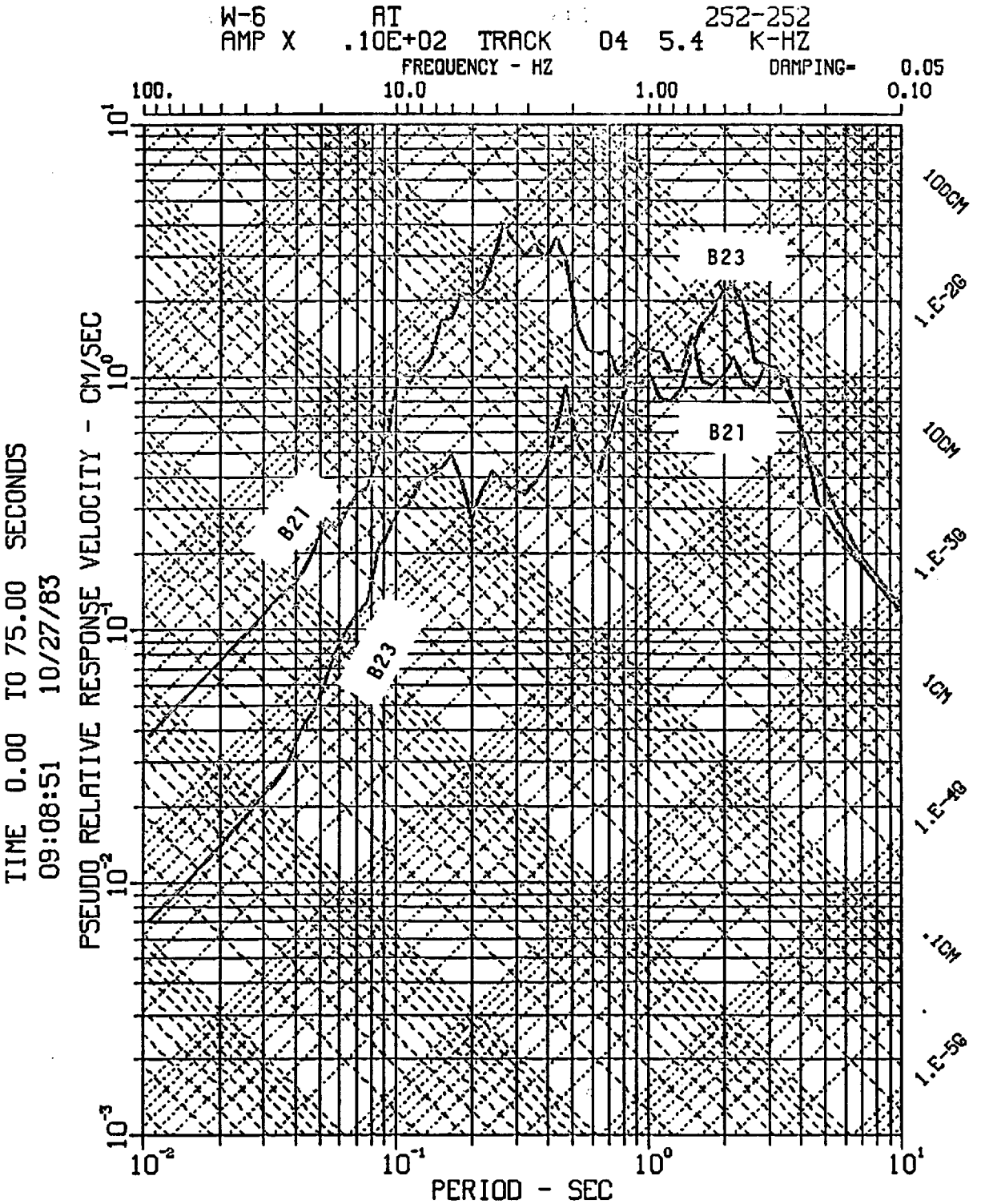


Figure 14. Tangential Pseudo Relative Velocity (PSRVs) for anomalous (B21) and ordinary (B23) ground motion.

In this chapter the ETS anomaly is examined further before examining Yucca Mountain data for similar phenomena. The reference above to average Nevada Test Site experience means an average obtained from a prediction equation of the type described in Chapter 2, where the data are obtained from many representative stations.

The approach used here is to determine a ground motion ratio, r, where

$$r = \frac{\text{Measured Peak Vector Motion}}{\text{Motion from Prediction Equation}} .$$

Values of r were obtained for each of the peak vector accelerations, velocities, and displacements by dividing them by a predicted value from the appropriate choice of Equations 1 through 24. Table VII tabulates the ratios for rock and alluvium for Groups I, II, and III, using the appropriate equation numbers listed at the top of each column. Table VIII shows the same for rock only, and Table IX for alluvium only.

Next, for stations with fixed locations the ratios for all tests at that station were compared. (For the early data set there were a number of stations with the same identity, e.g., SZ, S-1, etc., which were actually at different locations on different events, and these have been omitted in the comparison. Stations A, B, C, and D were not at

Table VII. Ratios for Stations on Rock and Alluvium

		Group I Appendix A			Group II Appendix B			Group III Appendix C		
Station	Event	a Eq. 1	u Eq. 2	d Eq. 3	a Eq. 10	u Eq. 11	d Eq. 12	a Eq. 19	u Eq. 20	d Eq. 21
BAL	B01	0.51	1.10	1.02	0.60	1.18	1.10	0.64	1.27	1.19
	B08	1.06	0.86	0.93	1.26	0.92	1.00	1.36	1.01	1.10
BHR	B01	0.34	0.64	1.00	0.40	0.69	1.08	0.43	0.74	1.17
	B08	0.68	0.44	0.78	0.81	0.47	0.84	0.88	0.51	0.93
BTY	B05	1.35	0.85	1.03	1.59	0.90	1.09	1.74	0.99	1.21
	B04	1.26	0.84	0.56	1.48	0.89	0.60	1.59	0.97	0.65
	A02	1.50	1.26	0.96	1.79	1.37	1.04	1.90	1.46	1.12
	A04	1.23	1.09	1.29	1.47	1.19	1.42	1.53	1.25	1.49
	B09	1.40	1.35	0.52	1.63	1.44	0.55	1.78	1.57	0.60
	B14	0.90	0.71	0.70	1.05	0.76	0.74	1.15	0.83	0.82
	A08	1.11	0.81	0.77	1.35	0.88	0.85	1.41	0.93	0.91
	B11	1.85	1.30	0.81	2.21	1.40	0.87	2.40	1.53	0.96
	A07	0.88	0.90	1.31	1.07	0.98	1.44	1.11	1.03	1.53
CP1	A05	0.28	0.17	0.15	0.34	0.19	0.17	0.35	0.20	0.18
	A06	0.39	0.53	0.97	0.48	0.59	1.07	0.50	0.62	1.13
EMD	A06	1.34	1.88	2.57	1.62	2.06	2.85	1.69	2.17	3.02
	B15	0.71	0.84	1.47	0.82	0.88	1.53	0.92	0.98	1.72
ET1	B01	1.25	2.17	2.21	1.47	2.33	2.38	1.57	2.50	2.57
	A06	6.27	3.99	4.55	7.60	4.37	5.02	7.92	4.60	5.33
PE1	B13	1.78	1.67	1.33	1.82	1.67	1.32	1.98	1.80	1.43
	B07	0.54	1.17	0.95	0.54	1.14	0.92	0.58	1.23	0.99
PE2	B07	1.11	1.09	0.81	1.14	1.09	0.80	1.26	1.19	0.88
	B13	2.47	1.83	1.66	2.61	1.84	1.67	2.86	2.01	1.83
PE7	B13	1.10	1.73	1.97	1.14	1.73	1.95	1.23	1.86	2.12
	B07	0.49	0.97	0.86	0.51	0.97	0.85	0.56	1.06	0.93
PE9	B07	0.43	0.65	0.61	0.48	0.67	0.62	0.54	0.76	0.70
	B28	0.77	1.31	1.68	0.86	1.36	1.72	0.96	1.51	1.94
	B13	0.73	1.06	0.91	0.82	1.10	0.93	0.91	1.22	1.05
	B17	1.03	1.74	2.16	1.16	1.81	2.22	1.30	2.02	2.51
Q25	B01	0.29	0.56	0.86	0.34	0.61	0.93	0.37	0.66	1.02
	A01	0.50	0.45	0.37	0.62	0.50	0.41	0.65	0.53	0.44
	A05	0.58	0.26	0.13	0.72	0.29	0.15	0.75	0.31	0.16
	B08	1.23	0.68	0.34	1.48	0.74	0.37	1.62	0.81	0.41
	A06	0.82	0.38	0.32	1.01	0.42	0.35	1.07	0.44	0.38
SZ	A02	1.59	1.42	1.58	1.51	1.40	1.56	1.47	1.36	1.52
	A04	1.05	1.06	—	1.00	1.05	—	0.96	1.01	—
	B09	1.80	0.99	1.40	1.62	0.94	1.34	1.61	0.93	1.31
	B09	2.26	1.40	2.13	2.03	1.33	2.04	2.02	1.31	2.00
	A07	1.36	0.94	1.44	1.30	0.93	1.44	1.24	0.89	1.38
	A07	3.00	0.65	1.06	2.86	0.64	1.07	2.74	0.62	1.02
	B11	2.12	0.64	0.85	1.93	0.62	0.82	1.91	0.61	0.80
	A08	2.06	1.06	1.60	1.98	1.05	1.61	1.91	1.02	1.54
	B16	0.52	1.35	3.94	0.47	1.28	3.76	0.46	1.27	3.69
	B16	0.51	1.45	3.75	0.46	1.38	3.58	0.45	1.36	3.51
W-10	B22	0.30	0.58	0.71	0.34	0.60	0.72	0.39	0.69	0.84
	B17	1.08	1.29	1.39	1.24	1.35	1.44	1.41	1.52	1.65
	B13	0.86	1.56	2.49	0.99	1.63	2.58	1.11	1.83	2.93
	B24	1.20	0.91	1.36	1.36	0.94	1.39	1.55	1.07	1.60
	B27	0.76	1.55	2.33	0.87	1.62	2.42	0.97	1.81	2.73
	B21	1.12	1.25	1.76	1.28	1.32	1.83	1.44	1.47	2.07
	B18	0.65	1.18	1.86	0.75	1.23	1.93	0.83	1.38	2.18

Table VII. Ratios for Stations on Rock and Alluvium (Cont'd)

		Group I Appendix A			Group II Appendix B			Group III Appendix C		
Station	Event	a Eq. 1	u Eq. 2	d Eq. 3	a Eq. 10	u Eq. 11	d Eq. 12	a Eq. 19	u Eq. 20	d Eq. 21
	B26	0.53	0.77	0.97	0.60	0.80	0.99	0.69	0.91	1.14
	B07	0.61	1.12	1.47	0.70	1.16	1.51	0.79	1.32	1.74
	B23	0.56	1.22	1.67	0.64	1.28	1.74	0.72	1.44	1.98
	B20	0.88	1.50	1.67	1.01	1.57	1.73	1.14	1.77	1.96
	B25	0.75	0.82	0.95	0.87	0.86	1.00	0.97	0.96	1.13
	B28	0.92	1.18	2.03	1.06	1.24	2.10	1.20	1.39	2.39
	B19	0.71	1.04	1.35	0.81	1.09	1.39	0.92	1.23	1.58
	B02	0.79	1.53	2.41	0.91	1.60	2.49	1.02	1.79	2.82
W-11	B19	0.81	0.73	0.74	0.90	0.75	0.76	1.00	0.83	0.85
	B28	1.04	1.02	1.15	1.16	0.96	1.17	1.29	1.07	1.32
	B25	1.54	0.67	0.68	1.72	0.69	0.69	1.91	0.77	0.78
	B20	0.79	0.95	1.12	0.88	0.98	1.15	0.99	1.10	1.30
	B23	0.51	0.64	0.78	0.56	0.66	0.80	0.62	0.73	0.89
	*B26	0.43	0.62	0.59	0.47	0.63	0.60	0.53	0.71	0.68
	B18	0.67	0.55	0.69	0.74	0.57	0.70	0.82	0.62	0.78
	B21	1.35	1.07	1.07	1.52	1.11	1.11	1.69	1.24	1.24
	B27	0.79	0.58	0.59	0.88	0.60	0.60	0.97	0.66	0.67
	B24	0.89	0.59	0.75	0.98	0.60	0.76	1.11	0.68	0.86
	B17	0.82	1.07	1.52	0.92	1.10	1.56	1.04	1.23	1.76
	B22	0.29	0.34	0.36	0.32	0.34	0.37	0.36	0.38	0.41
W-13	B22	0.79	1.10	0.75	0.85	1.12	0.76	0.96	1.24	0.85
	B17	1.50	1.59	1.30	1.60	1.61	1.30	1.76	1.76	1.43
	B24	1.45	1.43	0.99	1.48	1.42	0.97	1.63	1.54	1.06
	B27	1.34	1.81	1.22	1.41	1.83	1.22	1.53	1.98	1.33
	B21	1.50	1.24	0.93	1.59	1.25	0.94	1.73	1.36	1.02
	B18	1.92	1.72	0.96	2.02	1.74	0.97	2.18	1.87	1.05
	B23	1.30	1.54	1.11	1.41	1.57	1.12	1.55	1.72	1.24
	B20	1.21	1.56	1.28	1.29	1.58	1.29	1.42	1.73	1.42
	B25	1.27	1.97	1.18	1.40	2.02	1.21	1.55	2.22	1.34
	B28	1.02	1.22	1.13	1.08	1.23	1.13	1.19	1.34	1.24
	B19	1.27	1.38	1.20	1.33	1.39	1.19	1.45	1.51	1.30
W-14	B19	1.46	1.55	1.86	1.65	1.61	1.91	1.84	1.80	2.16
	B28	1.16	1.56	1.86	1.32	1.63	1.92	1.48	1.82	2.17
	B25	0.78	1.41	1.88	0.90	1.48	1.95	1.01	1.66	2.21
	B23	0.80	1.62	1.84	0.92	1.70	1.91	1.03	1.90	2.16
	B20	1.75	1.63	2.59	1.99	1.70	2.67	2.24	1.90	3.03
	B26	1.17	1.16	1.49	1.31	1.19	1.52	1.49	1.35	1.74
	B18	1.23	1.28	1.16	1.39	1.34	1.20	1.54	1.48	1.34
	B21	1.37	1.60	2.26	1.56	1.67	2.34	1.74	1.86	2.63
	B27	1.29	1.50	1.67	1.47	1.56	1.72	1.64	1.74	1.93
	B24	0.99	1.07	1.18	1.11	1.10	1.20	1.26	1.24	1.37
	B17	2.23	1.99	2.45	2.54	2.07	2.52	2.86	2.32	2.86
	B22	0.68	1.19	1.26	0.77	1.23	1.29	0.88	1.40	1.48
W-15	B17	0.84	1.22	1.79	0.94	1.26	1.83	1.05	1.40	2.05
	B27	0.81	1.29	1.34	0.89	1.32	1.37	0.98	1.46	1.52
	B24	0.29	0.70	1.04	0.32	0.72	1.04	0.36	0.80	1.18
	B21	0.85	1.43	1.57	0.94	1.48	1.61	1.05	1.63	1.79
	B26	0.52	0.91	1.22	0.57	0.93	1.23	0.64	1.04	1.40
	B20	0.82	1.51	2.12	0.91	1.55	2.16	1.01	1.73	2.43
	B23	0.51	1.10	1.31	0.57	1.14	1.34	0.64	1.26	1.50
	B28	2.57	2.40	2.46	2.84	2.48	2.51	3.17	2.75	2.82
	B19	0.84	1.64	2.00	0.92	1.69	2.04	1.03	1.87	2.28

Table VII. Ratios for Stations on Rock and Alluvium (Cont'd)

		Group I Appendix A			Group II Appendix B			Group III Appendix C		
Station	Event	a Eq. 1	u Eq. 2	d Eq. 3	a Eq. 10	u Eq. 11	d Eq. 12	a Eq. 19	u Eq. 20	d Eq. 21
W-16	B19	0.75	0.68	0.86	0.83	0.70	0.88	0.92	0.78	0.98
	B28	0.83	0.62	0.67	0.93	0.64	0.69	1.03	0.71	0.77
	B23	0.28	0.66	0.89	0.31	0.68	0.91	0.34	0.76	1.02
	B25	0.27	0.54	0.79	0.30	0.56	0.82	0.33	0.63	0.92
	B20	0.72	0.85	1.19	0.80	0.88	1.22	0.89	0.98	1.37
	B18	0.39	0.47	0.42	0.43	0.48	0.43	0.48	0.53	0.47
	B24	0.97	0.58	0.57	1.06	0.59	0.57	1.19	0.66	0.64
	B27	0.57	0.50	0.54	0.63	0.51	0.55	0.69	0.57	0.61
	B17	0.97	0.72	0.89	1.08	0.74	0.91	1.20	0.83	1.02
	B22	0.12	0.27	0.33	0.14	0.28	0.34	0.15	0.31	0.39
W-17	B17	0.97	0.98	0.84	1.06	1.00	0.85	1.17	1.10	0.94
	B13	3.49	1.70	1.00	3.78	1.73	1.01	3.02	1.35	1.30
	B27	2.57	1.23	1.17	2.76	1.25	1.18	4.18	1.91	1.12
	B24	1.44	0.75	0.61	1.51	0.75	0.61	1.68	0.83	0.68
	B18	2.09	1.16	0.67	2.24	1.18	0.68	2.45	1.29	0.74
	B22	0.33	0.54	0.43	0.36	0.55	0.43	0.41	0.61	0.49
	B21	1.58	1.10	0.92	1.70	1.13	0.93	1.86	1.23	1.03
	B20	1.20	0.94	0.99	1.30	0.96	1.00	1.44	1.05	1.11
	B25	0.42	0.61	0.68	0.46	0.63	0.70	0.51	0.69	0.78
	B23	0.76	0.89	0.86	0.84	0.91	0.88	0.92	1.01	0.98
	B26	1.99	0.95	0.75	2.12	0.96	0.75	2.37	1.06	0.84
	B28	0.85	0.92	0.82	0.92	0.94	0.82	1.02	1.03	0.91
	B19	2.09	0.98	1.06	2.24	1.00	1.06	2.46	1.09	1.17
W-18	B19	1.06	0.99	1.24	1.15	1.01	1.25	1.27	1.11	1.39
	B28	0.71	0.87	1.02	0.78	0.89	1.03	0.87	0.98	1.15
	B26	1.07	0.80	0.79	1.15	0.81	0.79	1.29	0.90	0.89
	B23	0.84	0.93	0.87	0.94	0.96	0.89	1.04	1.06	0.99
	B25	0.56	0.67	0.73	0.63	0.69	0.75	0.70	0.77	0.84
	B20	1.01	1.16	0.93	1.10	1.19	0.95	1.22	1.31	1.06
	B21	1.51	1.20	1.03	1.65	1.23	1.05	1.82	1.35	1.16
	B22	0.39	0.60	0.54	0.43	0.61	0.54	0.49	0.69	0.62
	B18	1.55	0.72	0.68	1.69	0.74	0.69	1.85	0.81	0.76
	B24	0.78	0.86	0.61	0.84	0.87	0.61	0.94	0.96	0.68
	B27	2.47	1.10	1.14	2.69	1.13	1.16	2.96	1.24	1.29
	B13	3.93	1.45	0.98	4.31	1.49	1.00	4.79	1.65	1.12
	B17	1.07	0.92	1.02	1.18	0.95	1.04	1.31	1.05	1.16
W-19	B18	0.83	0.57	0.39	0.93	0.59	0.40	1.03	0.65	0.45
	B21	0.58	0.50	0.66	0.66	0.53	0.68	0.73	0.58	0.76
	B20	0.53	0.59	0.81	0.60	0.62	0.83	0.67	0.69	0.94
	B19	0.57	0.50	0.49	0.64	0.51	0.50	0.71	0.57	0.57
W-20	B23	1.86	1.90	1.98	2.12	1.99	2.05	2.38	2.22	2.31
	B21	3.40	2.25	2.18	3.85	2.35	2.25	4.30	2.61	2.53
	B22	0.89	1.33	0.94	1.01	1.38	0.96	1.15	1.57	1.10
	B24	2.10	1.58	1.31	2.34	1.62	1.33	2.65	1.83	1.52
W-21	B24	1.50	1.02	1.33	1.67	1.05	1.35	1.90	1.18	1.54
	B27	2.15	1.61	1.92	2.44	1.68	1.98	2.72	1.87	2.23
	B22	0.34	0.80	1.17	0.39	0.83	1.19	0.44	0.94	1.38
	B23	1.04	1.32	1.96	1.19	1.38	2.04	1.33	1.55	2.31
	B25	0.87	1.80	2.72	1.01	1.89	2.82	1.13	2.11	3.20
	B26	2.07	1.54	1.51	2.32	1.59	1.54	2.65	1.80	1.77
W-22	B26	1.82	1.00	1.05	2.04	1.03	1.07	2.31	1.16	1.22
	B25	0.87	1.17	1.46	1.00	1.22	1.51	1.13	1.37	1.71
	B23	1.25	1.15	1.52	1.43	1.20	1.57	1.60	1.35	1.78

Table VII. Ratios for Stations on Rock and Alluvium (Cont'd)

		Group I Appendix A			Group II Appendix B			Group III Appendix C		
Station	Event	a Eq. 1	u Eq. 2	d Eq. 3	a Eq. 10	u Eq. 11	d Eq. 12	a Eq. 19	u Eq. 20	d Eq. 21
	B27	4.49	1.99	1.17	5.08	2.07	1.20	5.66	2.30	1.35
	B24	1.38	1.18	1.06	1.54	1.21	1.08	1.74	1.37	1.23
W-23	B24	1.47	2.09	1.31	1.64	2.14	1.33	1.85	2.41	1.51
	B27	2.53	2.96	1.86	2.85	3.08	1.92	3.17	3.42	2.15
	B22	0.75	1.26	0.94	0.85	1.31	0.97	0.97	1.48	1.11
	B21	2.06	2.55	2.13	2.33	2.66	2.20	2.60	2.96	2.47
	B23	1.74	2.22	2.26	1.98	2.32	2.34	2.22	2.59	2.64
	B25	1.18	2.23	2.15	1.35	2.34	2.23	1.52	2.61	2.53
	B26	1.40	0.85	0.85	1.56	0.88	0.86	1.77	0.99	0.98
W-3	B23	0.32	0.21	0.29	0.35	0.22	0.29	0.38	0.24	0.32
	B26	0.26	0.20	0.25	0.29	0.20	0.25	0.33	0.22	0.28
	B25	0.67	0.28	0.22	0.73	0.29	0.23	0.81	0.32	0.25
	B20	0.58	0.35	0.53	0.64	0.37	0.54	0.72	0.41	0.61
	B28	1.23	0.47	0.21	1.36	0.48	0.22	1.51	0.54	0.24
	B07	0.22	0.17	0.25	0.24	0.17	0.25	0.27	0.19	0.28
	B19	0.28	0.25	0.37	0.31	0.26	0.37	0.35	0.29	0.42
	B02	0.42	0.20	0.13	0.47	0.20	0.13	0.52	0.22	0.15
	B18	0.35	0.22	0.20	0.39	0.22	0.21	0.43	0.25	0.23
	B21	0.31	0.28	0.48	0.35	0.29	0.49	0.39	0.32	0.55
	B27	0.35	0.20	0.22	0.39	0.21	0.22	0.43	0.23	0.24
	B24	0.41	0.22	0.36	0.45	0.23	0.37	0.51	0.26	0.42
	B17	0.36	0.30	0.41	0.41	0.31	0.42	0.45	0.35	0.47
	B13	0.59	0.32	0.46	0.64	0.33	0.47	0.71	0.36	0.53
	B22	0.13	0.11	0.14	0.14	0.11	0.14	0.16	0.13	0.16
W-4	B02	0.66	0.82	0.65	0.74	0.85	0.67	0.83	0.95	0.75
	B07	0.48	1.12	1.01	0.54	1.16	1.03	0.61	1.30	1.18
W-5	B28	0.81	0.74	0.90	0.93	0.77	0.93	1.05	0.87	1.06
	B19	0.59	0.79	1.23	0.68	0.82	1.28	0.76	0.93	1.45
	B02	0.45	0.43	0.36	0.51	0.44	0.38	0.57	0.50	0.43
	B20	0.73	0.91	1.59	0.85	0.95	1.65	0.96	1.07	1.88
	B25	0.79	0.64	0.49	0.92	0.67	0.51	1.03	0.75	0.58
	B26	0.64	0.90	1.20	0.73	0.93	1.23	0.84	1.06	1.41
	B07	0.57	0.47	0.25	0.65	0.49	0.26	0.74	0.55	0.29
	B23	0.66	0.67	0.71	0.77	0.71	0.73	0.86	0.79	0.83
	B22	0.21	0.20	0.17	0.24	0.21	0.18	0.27	0.24	0.21
	B17	0.71	0.87	0.69	0.82	0.91	0.72	0.93	1.02	0.82
	B24	0.96	1.05	1.48	1.09	1.09	1.51	1.25	1.24	1.74
	B27	1.33	1.33	1.01	1.53	1.39	1.05	1.71	1.56	1.19
	B21	0.76	0.74	1.19	0.88	0.78	1.24	0.98	0.87	1.40
	B18	0.59	0.48	0.46	0.67	0.51	0.48	0.75	0.56	0.54
W-6	B18	1.66	0.97	1.34	1.89	1.02	1.39	2.10	1.13	1.56
	B21	10.20	4.56	1.19	11.60	4.77	1.24	13.00	5.33	1.40
	B27	1.82	1.27	1.37	2.07	1.32	1.43	2.32	1.47	1.60
	B24	10.20	5.27	0.78	11.50	5.45	0.79	13.01	6.16	0.91
	B17	3.69	2.16	1.16	4.22	2.25	1.20	4.76	2.53	1.37
	B13	1.99	1.31	1.18	2.27	1.36	1.21	2.56	1.53	1.38
	B22	0.53	0.60	0.71	0.60	0.63	0.72	0.69	0.71	0.83
	B23	0.96	1.34	1.77	1.10	1.41	1.84	1.23	1.57	2.08
	B07	0.94	1.19	1.60	1.07	1.24	1.64	1.22	1.40	1.88
	B26	3.19	1.54	0.85	3.60	1.59	0.86	4.10	1.80	0.99
	B25	1.26	1.08	1.39	1.45	1.14	1.45	1.63	1.27	1.64
	B20	3.86	2.12	1.36	4.41	2.21	1.40	4.96	2.48	1.59
	B02	1.41	1.08	0.90	1.59	1.12	0.93	1.79	1.26	1.05

Table VII. Ratios for Stations on Rock and Alluvium (Cont'd)

		Group I Appendix A			Group II Appendix B			Group III Appendix C		
Station	Event	a Eq. 1	u Eq. 2	d Eq. 3	a Eq. 10	u Eq. 11	d Eq. 12	a Eq. 19	u Eq. 20	d Eq. 21
	B19	5.01	2.48	0.99	5.70	2.58	1.02	6.40	2.89	1.15
	B28	5.46	2.70	1.04	6.23	2.82	1.08	7.01	3.16	1.22
W-7	B28	1.44	0.76	0.66	1.63	0.79	0.68	1.83	0.88	0.78
	B19	0.72	0.61	0.76	0.81	0.64	0.78	0.91	0.71	0.89
	B02	0.44	0.47	0.36	0.50	0.49	0.37	0.56	0.55	0.42
	B20	0.73	0.62	0.88	0.83	0.64	0.91	0.93	0.72	1.03
	B25	0.49	0.46	0.64	0.57	0.48	0.66	0.63	0.54	0.75
	B26	0.48	0.45	0.58	0.54	0.47	0.59	0.61	0.53	0.67
	B07	0.31	0.55	0.73	0.36	0.57	0.75	0.40	0.64	0.86
	B23	0.36	0.67	0.90	0.41	0.70	0.93	0.46	0.78	1.05
	B22	0.24	0.30	0.38	0.27	0.32	0.39	0.31	0.36	0.44
	B13	0.66	0.95	1.31	0.75	0.99	1.34	0.85	1.11	1.52
	B17	0.74	0.67	0.93	0.84	0.70	0.95	0.95	0.78	1.08
	B24	1.08	0.79	0.54	1.21	0.82	0.55	1.37	0.92	0.63
	B27	0.56	0.70	0.91	0.63	0.73	0.94	0.70	0.81	1.06
	B21	1.65	0.91	0.75	1.88	0.95	0.77	2.10	1.06	0.87
	B18	0.50	0.60	0.72	0.57	0.62	0.75	0.63	0.69	0.84
W-8	B07	0.39	0.55	0.67	0.43	0.56	0.68	0.49	0.63	0.77
	B02	0.54	0.78	0.57	0.60	0.81	0.58	0.67	0.89	0.65
W-9	B02	0.51	1.00	0.77	0.54	1.01	0.77	0.59	1.10	0.85
	B19	1.11	2.16	2.40	1.20	2.20	2.43	1.32	2.41	2.68
	B28	0.92	1.67	1.37	0.99	1.70	1.39	1.09	1.86	1.54
	B07	0.56	1.99	2.47	0.60	2.00	2.46	0.66	2.21	2.74
	B26	0.80	1.51	1.58	0.86	1.52	1.58	0.96	1.69	1.77
	B23	0.63	2.29	2.69	0.67	2.32	2.72	0.74	2.53	2.99
	B20	0.83	3.11	3.17	0.91	3.18	3.22	1.00	3.51	3.58
	B21	0.99	3.40	3.91	1.08	3.49	3.99	1.20	3.84	4.42
	B27	0.58	1.26	1.08	0.62	1.28	1.08	0.68	1.39	1.19
	B24	2.14	1.74	1.96	2.30	1.76	1.96	2.58	1.96	2.20
	B17	1.29	2.36	2.85	1.41	2.41	2.89	1.56	2.66	3.23
	B13	0.68	1.77	1.86	0.72	1.80	1.87	0.79	1.97	2.06
	B22	0.40	1.03	1.17	0.43	1.04	1.17	0.48	1.16	1.31
A	B19	2.37	1.25	1.29	2.70	1.30	1.33	3.03	1.46	1.51
	B28	2.81	1.72	1.80	3.20	1.79	1.86	3.61	2.01	2.11
	B23	0.81	1.05	1.65	0.93	1.10	1.71	1.05	1.23	1.94
	B25	0.50	1.07	1.51	0.58	1.12	1.57	0.65	1.26	1.78
	B26	1.22	0.84	1.19	1.37	0.87	1.22	1.57	0.99	1.40
	B27	1.89	1.29	0.96	2.15	1.34	1.00	2.40	1.49	1.12
	B24	2.39	1.23	0.77	2.69	1.28	0.79	3.05	1.44	0.90
	B20	2.59	1.50	1.86	2.96	1.57	1.93	3.33	1.76	2.19
	B17	2.72	1.40	1.50	3.11	1.46	1.55	3.51	1.64	1.76
	B18	1.94	1.16	0.64	2.20	1.22	0.67	2.46	1.35	0.75
	B21	3.20	2.17	1.32	3.67	2.27	1.37	4.10	2.53	1.54
B	B21	8.01	2.76	1.12	9.16	2.89	1.16	10.20	3.23	1.31
	B18	1.49	0.69	0.95	1.69	0.73	0.99	1.88	0.81	1.11
	B27	1.53	0.91	1.17	1.74	0.95	1.21	1.94	1.06	1.36
	B20	3.02	1.33	1.49	3.45	1.39	1.54	3.88	1.56	1.74
	B24	5.30	2.40	0.79	5.96	2.48	0.81	6.77	2.80	0.93
	B26	2.10	0.94	1.14	2.36	0.97	1.16	2.69	1.10	1.33
	B25	1.36	0.94	1.29	1.57	0.99	1.34	1.76	1.10	1.52

Table VII. Ratios for Sations on Rock and Alluvium (Cont'd)

		Group I Appendix A			Group II Appendix B			Group III Appendix C		
Station	Event	a Eq. 1	u Eq. 2	d Eq. 3	a Eq. 10	u Eq. 11	d Eq. 12	a Eq. 19	u Eq. 20	d Eq. 21
	B28	2.28	1.35	1.13	2.60	1.41	1.17	2.93	1.59	1.32
	B19	3.11	1.49	1.25	3.53	1.55	1.29	3.97	1.74	1.46
C	B19	2.03	1.15	1.15	2.31	1.20	1.18	2.59	1.34	1.34
	B25	0.88	0.63	0.87	1.01	0.66	0.90	1.14	0.74	1.02
	B23	0.89	1.20	1.69	1.01	1.26	1.75	1.14	1.41	1.99
	B26	1.32	0.78	0.76	1.49	0.80	0.78	1.70	0.91	0.89
	B24	2.88	1.74	0.83	3.24	1.80	0.85	3.68	2.03	0.97
	B20	1.29	1.22	1.38	1.48	1.28	1.42	1.66	1.43	1.62
	B27	2.55	1.18	1.24	2.89	1.23	1.28	3.23	1.38	1.44
	B13	1.46	1.34	1.51	1.66	1.39	1.56	1.87	1.57	1.77
	B17	1.54	1.36	1.36	1.76	1.42	1.40	1.99	1.60	1.59
	B18	2.27	1.06	1.22	2.59	1.11	1.26	2.88	1.23	1.42
	B21	3.45	1.76	1.05	3.94	1.84	1.09	4.41	2.06	1.23
D	B21	1.35	1.19	1.05	1.54	1.25	1.09	1.72	1.39	1.23
	B18	1.08	1.02	1.55	1.23	1.06	1.61	1.37	1.18	1.81
	B13	0.69	1.18	1.93	0.78	1.23	1.99	0.88	1.38	2.26
	B27	1.58	1.62	2.01	1.80	1.70	2.08	2.01	1.89	2.34
	B17	1.70	1.12	1.36	1.94	1.17	1.40	2.19	1.31	1.60
	B20	1.02	1.15	1.42	1.17	1.20	1.46	1.31	1.35	1.66
	B25	0.59	0.65	0.79	0.68	0.68	0.82	0.77	0.77	0.93
	B19	4.49	2.21	1.85	5.11	2.30	1.91	5.73	2.58	2.16
	B28	3.10	1.37	1.40	3.53	1.43	1.44	3.97	1.60	1.64

Table VIII. Ratios for Stations on Rock Only

		Group I Appendix D			Group II Appendix E			Group III Appendix F		
Station	Event	a Eq. 4	u Eq. 5	d Eq. 6	a Eq. 13	u Eq. 14	d Eq. 15	a Eq. 22	u Eq. 23	d Eq. 24
BHR	B01	0.40	0.72	1.12	0.39	0.69	1.09	0.44	0.79	1.28
	B08	0.83	0.49	0.88	0.78	0.47	0.85	0.90	0.54	1.02
CP1	A05	0.33	0.20	0.17	0.33	0.19	0.17	0.37	0.22	0.19
	A06	0.46	0.60	1.09	0.46	0.58	1.07	0.51	0.66	1.24
PE1	B13	1.94	1.73	1.38	1.77	1.66	1.35	1.94	1.82	1.50
	B07	0.58	1.19	0.96	0.52	1.14	0.95	0.57	1.23	1.03
PE2	B07	1.22	1.14	0.84	1.10	1.08	0.82	1.23	1.20	0.93
	B13	2.77	1.93	1.75	2.53	1.83	1.71	2.82	2.05	1.96
PE7	B13	1.21	1.80	2.04	1.10	1.72	2.00	1.21	1.89	2.23
	B07	0.54	1.01	0.89	0.49	0.96	0.87	0.55	1.07	0.99
PE9	B07	0.52	0.71	0.66	0.46	0.67	0.64	0.54	0.78	0.77
	B28	0.91	1.44	1.83	0.83	1.35	1.77	0.96	1.57	2.13
	B13	0.87	1.16	0.99	0.78	1.09	0.96	0.91	1.27	1.15
	B17	1.23	1.92	2.37	1.11	1.79	2.29	1.29	2.11	2.77
SZ	A02	1.51	1.39	1.54	1.51	1.40	1.55	1.47	1.35	1.48
	A04	0.98	1.03	--	1.01	1.05	—	0.96	1.00	—
	B09	1.67	0.94	1.33	1.62	0.94	1.34	1.57	0.91	1.27
	B09	2.09	1.33	2.03	2.03	1.33	2.04	1.97	1.28	1.94
	A08	1.95	1.04	1.57	1.99	1.05	1.58	1.92	1.01	1.51
	B11	1.97	0.61	0.81	1.96	0.62	0.82	1.87	0.59	0.78
	A07	1.27	0.92	1.40	1.31	0.94	1.42	1.25	0.89	1.34
	A07	2.81	0.63	1.04	2.88	0.65	1.05	2.76	0.62	0.99
	B16	0.48	1.28	3.74	0.47	1.29	3.77	0.45	1.23	3.57
	B16	0.47	1.37	3.55	0.46	1.38	3.59	0.44	1.32	3.40
W-13	B22	0.92	1.18	0.81	0.82	1.11	0.78	0.94	1.28	0.92
	B17	1.70	1.68	1.37	1.54	1.60	1.33	1.73	1.80	1.53
	B21	1.67	1.31	0.98	1.54	1.25	0.96	1.70	1.39	1.09
	B18	2.12	1.81	1.01	1.96	1.73	0.99	2.15	1.91	1.11
	B28	1.15	1.29	1.19	1.05	1.22	1.16	1.17	1.37	1.33
	B19	1.41	1.45	1.25	1.29	1.38	1.22	1.42	1.53	1.38
	B23	1.49	1.65	1.18	1.36	1.56	1.15	1.53	1.77	1.34
	B25	1.48	2.13	1.27	1.35	2.01	1.24	1.53	2.30	1.45
	B20	1.37	1.66	1.35	1.25	1.57	1.32	1.39	1.77	1.52
	B24	1.59	1.48	1.02	1.43	1.41	1.00	1.59	1.56	1.13
	B27	1.49	1.91	1.27	1.37	1.82	1.25	1.51	2.01	1.41
W-14	B27	1.54	1.65	1.82	1.41	1.55	1.77	1.63	1.81	2.13
	B24	1.19	1.17	1.29	1.06	1.09	1.24	1.24	1.29	1.51
	B20	2.11	1.80	2.85	1.91	1.68	2.75	2.22	1.98	3.35
	B25	0.95	1.57	2.08	0.86	1.47	2.01	1.00	1.74	2.46
	B23	0.97	1.80	2.03	0.88	1.69	1.96	1.02	1.99	2.39
	B19	1.74	1.71	2.04	1.58	1.60	1.97	1.83	1.87	2.38
	B28	1.40	1.73	2.05	1.26	1.61	1.98	1.47	1.90	2.40
	B26	1.41	1.27	1.63	1.25	1.18	1.58	1.47	1.40	1.93
	B18	1.46	1.41	1.27	1.33	1.33	1.23	1.54	1.55	1.48
	B21	1.64	1.77	2.48	1.49	1.66	2.40	1.73	1.90	2.90
	B17	2.69	2.20	2.69	2.43	2.05	2.60	2.82	2.42	3.17
	B22	0.83	1.31	1.38	0.74	1.22	1.33	0.87	1.45	1.65
W-15	B17	0.99	1.33	1.94	0.90	1.25	1.88	1.04	1.45	2.25
	B21	1.00	1.56	1.70	0.91	1.47	1.65	1.04	1.69	1.95
	B26	0.61	0.99	1.32	0.54	0.92	1.27	0.63	1.07	1.53
	B28	3.01	2.62	2.66	2.73	2.46	2.58	3.14	2.85	3.08
	B19	0.98	1.78	2.16	0.89	1.68	2.10	1.01	1.93	2.48

Table VIII. Ratios for Stations on Rock Only (Cont'd)

		Group I Appendix D			Group II Appendix E			Group III Appendix F		
Station	Event	a Eq. 4	u Eq. 5	d Eq. 6	a Eq. 13	u Eq. 14	d Eq. 15	a Eq. 22	u Eq. 23	d Eq. 24
	B23	0.60	1.20	1.42	0.55	1.13	1.38	0.63	1.31	1.65
	B20	0.96	1.64	2.30	0.87	1.54	2.23	1.00	1.79	2.66
	B24	0.34	0.76	1.11	0.31	1.71	1.08	0.35	0.82	1.28
	B27	0.94	1.39	1.44	0.86	1.32	1.40	0.98	1.51	1.65
W-16	B27	0.66	0.54	0.58	0.60	0.51	0.56	0.69	0.58	0.66
	B24	1.13	0.63	0.61	1.01	0.59	0.59	1.16	0.68	0.70
	B20	0.85	0.93	1.29	0.77	0.87	1.25	0.88	1.01	1.50
	B25	0.32	0.60	0.87	0.29	0.56	0.84	0.33	0.65	1.01
	B23	0.33	0.72	0.97	0.30	0.68	0.94	0.34	0.79	1.12
	B19	0.88	0.74	0.93	0.80	0.70	0.91	0.92	0.81	1.07
	B28	0.98	0.68	0.73	0.89	0.63	0.71	1.02	0.74	0.84
	B18	0.46	0.51	0.45	0.42	0.48	0.44	0.48	0.55	0.52
	B17	1.14	0.78	0.97	1.03	0.74	0.94	1.19	0.86	1.12
	B22	0.15	0.30	0.36	0.13	0.28	0.35	0.15	0.32	0.42
W-17	B22	0.39	0.58	0.46	0.35	0.54	0.45	0.40	0.63	0.53
	B17	1.12	1.05	0.90	1.02	0.99	0.87	1.15	1.13	1.02
	B18	2.36	1.24	0.71	2.17	1.18	0.70	2.42	1.32	0.80
	B21	1.79	1.18	0.98	1.64	1.12	0.96	1.84	1.26	1.10
	B28	0.98	0.98	0.87	0.89	0.93	0.85	1.00	1.06	0.98
	B19	2.37	1.04	1.12	2.16	0.99	1.09	2.43	1.12	1.26
	B26	2.28	1.01	0.80	2.04	0.95	0.77	2.32	1.08	0.90
	B23	0.88	0.96	0.93	0.81	0.91	0.90	0.92	1.04	1.06
	B25	0.49	0.66	0.74	0.45	0.62	0.71	0.51	0.72	0.85
	B24	1.63	0.79	0.64	1.46	0.75	0.63	1.64	0.84	0.72
	B20	1.38	1.01	1.06	1.26	0.95	1.03	1.42	1.08	1.20
	B27	2.91	1.31	1.24	2.67	1.24	1.21	2.98	1.40	1.39
	B13	4.01	1.82	1.06	3.64	1.72	1.04	4.13	1.96	1.21
W-18	B13	4.57	1.57	1.06	4.15	1.48	1.03	4.74	1.70	1.22
	B27	2.84	1.19	1.23	2.59	1.12	1.19	2.93	1.28	1.39
	B20	1.17	1.25	1.00	1.06	1.18	0.97	1.21	1.36	1.15
	B24	0.90	0.92	0.65	0.81	0.86	0.63	0.92	0.99	0.74
	B25	0.67	0.73	0.79	0.61	0.69	0.77	0.70	0.80	0.90
	B23	0.99	1.02	0.94	0.90	0.96	0.91	1.03	1.10	1.08
	B26	1.24	0.86	0.85	1.10	0.80	0.82	1.27	0.93	0.97
	B19	1.22	1.06	1.32	1.11	1.00	1.29	1.25	1.15	1.51
	B28	0.83	0.94	1.09	0.75	0.88	1.06	0.86	1.01	1.25
	B21	1.74	1.29	1.10	1.60	1.22	1.07	1.80	1.39	1.25
	B18	1.77	0.78	0.72	1.63	0.74	0.71	1.84	0.83	0.82
	B22	0.46	0.65	0.58	0.41	0.61	0.56	0.48	0.71	0.68
	B17	1.25	1.00	1.10	1.13	0.94	1.07	1.30	1.08	1.26
W-19	B18	0.98	0.62	0.43	0.89	0.59	0.41	1.02	0.68	0.49
	B21	0.69	0.56	0.72	0.63	0.52	0.70	0.73	0.61	0.84
	B19	0.67	0.54	0.53	0.61	0.51	0.52	0.71	0.59	0.62
	B20	0.63	0.65	0.89	0.57	0.61	0.86	0.67	0.72	1.04
W-20	B24	2.51	1.73	1.43	2.24	1.61	1.38	2.62	1.90	1.67
	B23	2.24	2.11	2.18	2.03	1.97	2.10	2.36	2.32	2.56
	B21	4.06	2.48	2.39	3.70	2.33	2.32	4.28	2.72	2.79
	B22	1.08	1.47	1.03	0.96	1.37	0.99	1.14	1.63	1.23
W-21	B22	0.41	0.89	1.29	0.37	0.82	1.24	0.44	0.98	1.53
	B23	1.25	1.47	2.17	1.14	1.37	2.10	1.33	1.62	2.56
	B25	1.06	2.00	3.01	0.96	1.87	2.91	1.13	2.22	2.56
	B24	1.79	1.12	1.45	1.60	1.04	1.40	1.87	1.23	1.70
	B27	2.56	1.78	2.10	2.34	1.66	2.03	2.71	1.95	2.46

Table VIII. Ratios for Stations on Rock Only (Cont'd)

		Group I Appendix D			Group II Appendix E			Group III Appendix F		
Station	Event	a Eq. 4	u Eq. 5	d Eq. 6	a Eq. 13	u Eq. 14	d Eq. 15	a Eq. 22	u Eq. 23	d Eq. 24
	B26	2.50	1.69	1.66	2.22	1.57	1.60	2.61	1.86	1.96
W-22	B26	2.19	1.10	1.15	1.94	1.02	1.11	2.28	1.21	1.35
	B27	5.35	2.19	1.28	4.87	2.05	1.24	5.63	2.40	1.49
	B24	1.65	1.29	1.16	1.47	1.20	1.12	1.71	1.41	1.36
	B25	1.06	1.30	1.61	0.96	1.21	1.56	1.12	1.44	1.90
	B23	1.51	1.28	1.67	1.37	1.20	1.62	1.60	1.41	1.97
W-23	B23	2.09	2.46	2.49	1.90	2.30	2.41	2.21	2.71	2.92
	B25	1.43	2.48	2.38	1.30	2.32	2.30	1.51	2.74	2.80
	B24	1.75	2.28	1.42	1.56	2.13	1.38	1.82	2.50	1.67
	B27	3.00	3.26	2.03	2.73	3.06	1.97	3.15	3.56	2.36
	B26	1.67	0.93	0.92	1.49	0.87	0.89	1.74	1.03	1.09
	B22	0.91	1.39	1.04	0.81	1.29	1.00	0.95	1.54	1.23
	B21	2.46	2.81	2.34	2.24	2.64	2.26	2.58	3.08	2.72
W-3	B25	0.77	0.30	0.24	0.71	0.28	0.23	0.80	0.33	0.28
	B23	0.37	0.23	0.31	0.34	0.21	0.30	0.38	0.24	0.35
	B20	0.68	0.39	0.58	0.62	0.36	0.56	0.71	0.42	0.67
	B13	0.68	0.35	0.50	0.62	0.33	0.48	0.71	0.38	0.57
	B17	0.43	0.33	0.45	0.39	0.31	0.43	0.45	0.36	0.52
	B27	0.41	0.22	0.23	0.38	0.20	0.23	0.43	0.23	0.27
	B24	0.49	0.24	0.39	0.44	0.23	0.38	0.51	0.26	0.46
	B26	0.31	0.21	0.27	0.28	0.20	0.26	0.32	0.23	0.31
	B07	0.25	0.18	0.27	0.23	0.17	0.26	0.26	0.20	0.31
	B28	1.44	0.51	0.23	1.30	0.48	0.22	1.50	0.56	0.26
	B19	0.33	0.27	0.40	0.30	0.26	0.38	0.34	0.30	0.46
	B02	0.49	0.21	0.14	0.45	0.20	0.13	0.51	0.23	0.16
	B18	0.41	0.24	0.22	0.38	0.22	0.21	0.43	0.25	0.25
	B21	0.37	0.31	0.52	0.34	0.29	0.50	0.39	0.34	0.60
	B22	0.15	0.12	0.15	0.14	0.11	0.15	0.16	0.13	0.18
W-5	B02	0.54	0.47	0.40	0.49	0.44	0.39	0.57	0.52	0.47
	B19	0.72	0.88	1.36	0.65	0.82	1.32	0.76	0.97	1.61
	B28	0.99	0.82	1.00	0.89	0.76	0.96	1.04	0.91	1.18
	B07	0.69	0.52	0.28	0.62	0.48	0.27	0.73	0.58	0.33
	B26	0.79	1.00	1.32	0.70	0.92	1.27	0.83	1.11	1.58
	B24	1.17	1.16	1.63	1.04	1.08	1.57	1.23	1.29	1.94
	B27	1.61	1.48	1.11	1.46	1.38	1.08	1.70	1.63	1.34
	B17	0.87	0.97	0.77	0.78	0.90	0.74	0.92	1.07	0.92
	B20	0.90	1.01	1.76	0.81	0.94	1.70	0.95	1.12	2.10
	B23	0.81	0.75	0.78	0.73	0.70	0.76	0.86	0.83	0.93
	B25	0.97	0.71	0.54	0.88	0.66	0.52	1.03	0.79	0.64
	B22	0.25	0.22	0.19	0.23	0.21	0.18	0.27	0.25	0.23
	B18	0.71	0.54	0.51	0.65	0.50	0.49	0.75	0.59	0.60
	B21	0.92	0.83	1.32	0.84	0.77	1.27	0.98	0.92	1.56
W-7	B21	1.98	1.01	0.82	1.80	0.94	0.79	2.09	1.11	0.96
	B18	0.60	0.66	0.79	0.55	0.62	0.77	0.63	0.72	0.92
	B22	0.29	0.34	0.42	0.26	0.31	0.40	0.31	0.37	0.49
	B23	0.43	0.74	0.99	0.39	0.70	0.95	0.46	0.82	1.16
	B20	0.87	0.68	0.97	0.79	0.64	0.94	0.92	0.75	1.14
	B25	0.60	0.51	0.70	0.54	0.48	0.68	0.63	0.56	0.83
	B17	0.89	0.74	1.02	0.80	0.69	0.98	0.94	0.82	1.20
	B13	0.80	1.05	1.43	0.72	0.98	1.39	0.84	1.16	1.69
	B27	0.66	0.77	1.00	0.60	0.72	0.97	0.70	0.84	1.17
	B24	1.30	0.87	0.59	1.16	0.81	0.57	1.35	0.96	0.69
	B26	0.58	0.50	0.63	0.51	0.46	0.61	0.60	0.55	0.75

Table VIII. Ratios for Stations on Rock Only (Cont'd)

		Group I Appendix D			Group II Appendix E			Group III Appendix F		
Station	Event	a Eq. 4	u Eq. 5	d Eq. 6	a Eq. 13	u Eq. 14	d Eq. 15	a Eq. 22	u Eq. 23	d Eq. 24
	B07	0.38	0.61	0.80	0.34	0.57	0.78	0.40	0.67	0.95
	B28	1.73	0.84	0.73	1.56	0.78	0.70	1.82	0.92	0.86
	B19	0.86	0.67	0.83	0.78	0.63	0.81	0.90	0.74	0.98
	B02	0.52	0.52	0.39	0.48	0.49	0.38	0.55	0.57	0.46
W-8	B02	0.63	0.85	0.61	0.58	0.80	0.60	0.66	0.92	0.70
	B07	0.46	0.60	0.73	0.41	0.56	0.71	0.48	0.65	0.85
W-9	B07	0.64	2.11	2.61	0.58	1.99	2.54	0.65	2.25	2.94
	B26	0.92	1.61	1.68	0.82	1.51	1.63	0.94	1.73	1.91
	B19	1.27	2.31	2.56	1.15	2.18	2.49	1.30	2.48	2.89
	B28	1.05	1.78	1.46	0.95	1.69	1.42	1.08	1.92	1.66
	B02	0.57	1.06	0.81	0.52	1.00	0.79	0.58	1.12	0.91
	B24	2.47	1.86	2.09	2.21	1.75	2.03	2.53	2.01	2.39
	B27	0.66	1.33	1.14	0.60	1.27	1.11	0.67	1.42	1.27
	B13	0.77	1.88	1.97	0.70	1.78	1.92	0.78	2.01	2.21
	B17	1.49	2.54	3.06	1.35	2.39	2.98	1.54	2.75	3.50
	B20	0.96	3.35	3.40	0.87	3.16	3.31	0.99	3.62	3.89
	B23	0.71	2.43	2.85	0.65	2.31	2.79	0.73	2.60	3.20
	B22	0.46	1.10	1.24	0.41	1.04	1.21	0.47	1.18	1.41
	B21	1.14	3.67	4.21	1.05	3.47	4.09	1.19	3.96	4.79

Table IX. Ratios for Stations on Alluvium Only

		Group I Appendix G			Group II Appendix H			Group III Appendix H		
Station	Event	a Eq. 7	u Eq. 8	d Eq. 9	a Eq. 16	u Eq. 17	d Eq. 18	a Eq. 16	u Eq. 17	d Eq. 18
BAL	B01	0.48	1.02	0.95	0.63	1.19	1.11	0.63	1.19	1.11
	B08	0.87	0.77	0.84	1.24	0.92	0.96	1.24	0.92	0.96
BTY	A04	1.46	1.07	1.27	1.56	1.19	1.56	1.56	1.19	1.56
	B05	1.09	0.75	0.92	1.63	0.91	1.03	1.63	0.91	1.03
	A02	1.50	1.19	0.91	1.82	1.37	1.08	1.82	1.37	1.08
	B04	1.20	0.77	0.52	1.62	0.91	0.59	1.62	0.91	0.59
	B14	0.73	0.64	0.63	1.10	0.77	0.70	1.10	0.77	0.70
	A08	1.16	0.77	0.75	1.31	0.88	0.91	1.31	0.88	0.91
	B11	1.47	1.17	0.73	2.13	1.40	0.84	2.13	1.40	0.84
	A07	0.99	0.87	1.28	1.08	0.98	1.57	1.08	0.98	1.57
	B09	1.22	1.22	0.47	1.78	1.46	0.52	1.78	1.46	0.52
EMD	A06	1.42	1.89	2.49	1.57	2.04	3.08	1.57	2.04	3.08
	B15	0.53	0.72	1.28	0.90	0.90	1.36	0.90	0.96	1.38
ET1	A06	6.87	3.88	4.43	7.52	4.35	5.46	7.52	4.35	5.46
	B01	1.28	2.05	2.09	1.63	2.37	2.42	1.63	2.37	2.42
Q25	A06	0.71	0.35	0.30	0.83	0.41	0.37	0.83	0.41	0.37
	B01	0.23	0.51	0.78	0.13	0.61	0.92	0.31	0.61	0.92
	A01	0.46	0.43	0.35	0.51	0.49	0.44	0.51	0.49	0.44
	A05	0.52	0.25	0.12	0.58	0.28	0.16	0.58	0.28	0.16
	B08	0.88	0.60	0.30	1.31	0.73	0.35	1.31	0.73	0.35
W-10	B23	0.38	1.04	1.43	0.68	1.30	1.51	0.68	1.30	1.51
	B25	0.49	0.69	0.81	0.88	0.87	0.86	0.88	0.87	0.86
	B28	0.62	1.00	1.73	1.14	1.26	1.81	1.14	1.26	1.81
	B07	0.38	0.93	1.23	0.75	1.19	1.27	0.75	1.19	1.27
	B26	0.34	0.64	0.81	0.67	0.82	0.82	0.67	0.82	0.82
	B02	0.57	1.31	2.08	1.02	1.64	2.18	1.02	1.64	2.18
	B19	0.50	0.89	1.16	0.89	1.12	1.21	0.89	1.12	1.21
	B20	0.59	1.26	1.42	1.07	1.60	1.49	1.07	1.60	1.49
	B27	0.56	1.33	2.02	0.97	1.66	2.13	0.97	1.66	2.13
	B24	0.79	0.76	1.15	1.53	0.97	1.17	1.53	0.97	1.17
	B13	0.58	1.32	2.12	1.07	1.66	2.22	1.07	1.66	2.22
	B22	0.18	0.48	0.58	0.36	0.61	0.60	0.36	0.61	0.60
	B18	0.49	1.02	1.62	0.84	1.26	1.72	0.84	1.26	1.72
	B17	0.71	1.08	1.18	1.31	1.37	1.24	1.31	1.37	1.24
	B21	0.78	1.07	1.51	1.38	1.34	1.60	1.38	1.34	1.60
W-11	B21	1.16	0.95	0.95	1.92	1.16	1.00	1.92	1.16	1.00
	B17	0.68	0.93	1.34	1.17	1.15	1.38	1.17	1.15	1.38
	B18	0.69	0.50	0.63	1.07	0.60	0.65	1.07	0.60	0.65
	B22	0.25	0.29	0.32	0.45	0.36	0.32	0.45	0.36	0.32
	B27	0.79	0.52	0.54	1.26	0.63	0.55	1.26	0.63	0.55
	B24	0.71	0.51	0.65	1.31	0.63	0.66	1.31	0.63	0.66
	B20	0.66	0.83	0.99	1.12	1.02	1.03	1.12	1.02	1.03
	B19	0.72	0.64	0.66	1.21	0.79	0.68	1.21	0.79	0.68
	B26	0.35	0.53	0.51	0.64	0.66	0.52	0.64	0.66	0.52
	B28	0.91	0.82	1.02	1.55	1.00	1.05	1.55	1.00	1.05
	B25	1.40	0.60	0.61	2.30	0.73	0.63	2.30	0.73	0.63
	B23	0.48	0.58	0.70	0.78	0.70	0.73	0.78	0.70	0.73
W-4	B02	0.54	0.72	0.57	0.93	0.89	0.60	0.93	0.89	0.60
	B07	0.35	0.95	0.87	0.65	1.20	0.88	0.65	1.20	0.88
W-6	B28	3.91	2.30	0.90	7.04	2.89	0.93	7.04	2.89	0.93
	B07	0.63	1.00	1.35	1.20	1.27	1.38	1.20	1.27	1.38
	B26	2.15	1.28	0.72	4.19	1.64	0.73	4.19	1.64	0.73
	B23	0.68	1.15	1.53	1.21	1.44	1.61	1.21	1.44	1.61

Table IX. Ratios for Stations on Alluvium Only (Cont'd)

		Group I Appendix G			Group II Appendix H			Group III Appendix H		
Station	Event	a Eq. 7	u Eq. 8	d Eq. 9	a Eq. 16	u Eq. 17	d Eq. 18	a Eq. 16	u Eq. 17	d Eq. 18
	B25	0.86	0.92	1.19	1.53	1.15	1.26	1.53	1.15	1.26
	B19	3.72	2.13	0.85	6.59	2.66	0.89	6.59	2.66	0.89
	B02	1.08	0.93	0.78	1.89	1.16	0.82	1.89	1.16	0.82
	B20	2.72	1.80	1.17	4.91	2.27	1.22	4.91	2.27	1.22
	B27	1.42	1.10	1.20	2.44	1.36	1.26	2.44	1.36	1.26
	B24	7.17	4.44	0.66	13.70	5.64	0.67	13.70	5.64	0.67
	B13	1.43	1.11	1.01	2.58	1.40	1.05	2.58	1.40	1.05
	B18	1.33	0.85	1.19	2.23	1.05	1.25	2.23	1.05	1.25
	B22	0.33	0.50	0.59	0.66	0.64	0.60	0.66	0.64	0.60
	B17	2.56	1.83	1.00	4.66	2.31	1.04	4.66	2.31	1.04
	B21	7.58	3.93	1.04	13.10	4.89	1.10	13.10	4.89	1.10
A	B21	2.38	1.87	1.15	4.13	2.32	1.21	4.13	2.32	1.21
	B18	1.55	1.02	0.57	2.60	1.25	0.60	2.60	1.25	0.60
	B17	1.88	1.19	1.28	3.44	1.50	1.34	3.44	1.50	1.34
	B27	1.47	1.11	0.84	2.52	1.38	0.89	2.52	1.38	0.89
	B20	1.83	1.28	1.60	3.29	1.61	1.67	3.29	1.61	1.67
	B24	1.67	1.04	0.66	3.19	1.32	0.67	3.19	1.32	0.67
	B19	1.76	1.07	1.12	3.11	1.34	1.17	3.11	1.34	1.17
	B25	0.34	0.91	1.29	0.61	1.14	1.37	0.61	1.14	1.37
	B23	0.58	0.90	1.42	1.02	1.12	1.50	1.02	1.12	1.50
	B26	0.82	0.70	1.01	1.60	0.90	1.02	1.60	0.90	1.02
	B28	2.01	1.46	1.55	3.62	1.84	1.61	3.62	1.84	1.61
B	B28	1.63	1.15	0.97	2.94	1.45	1.01	2.94	1.45	1.01
	B26	1.41	0.78	0.96	2.75	1.00	0.97	2.75	1.00	0.97
	B25	0.93	0.80	1.11	1.65	1.00	1.17	1.65	1.00	1.17
	B19	2.30	1.28	1.09	4.08	1.60	1.13	4.08	1.60	1.13
	B20	2.13	1.13	1.28	3.84	1.42	1.34	3.84	1.42	1.34
	B27	1.19	0.79	1.02	2.04	0.98	1.07	2.04	0.98	1.07
	B24	3.71	2.02	0.68	7.09	2.57	0.69	7.09	2.57	0.69
	B18	1.19	0.61	0.84	2.00	0.75	0.89	2.00	0.75	0.89
	B21	5.96	2.38	0.98	10.30	2.96	1.03	10.30	2.96	1.03
C	B21	2.57	1.52	0.91	4.45	1.89	0.96	4.45	1.89	0.96
	B18	1.82	0.93	1.07	3.05	1.14	1.13	3.05	1.14	1.13
	B17	1.07	1.15	1.16	1.95	1.45	1.21	1.95	1.45	1.21
	B24	2.02	1.46	0.71	3.85	1.86	0.72	3.85	1.86	0.72
	B27	1.98	1.03	1.09	3.40	1.27	1.14	3.40	1.27	1.14
	B13	1.04	1.13	1.30	1.88	1.43	1.35	1.88	1.43	1.35
	B20	0.91	1.04	1.18	1.65	1.31	1.24	1.65	1.31	1.24
	B19	1.51	0.99	0.99	2.67	1.23	1.04	2.67	1.23	1.04
	B25	0.60	0.54	0.74	1.07	0.67	0.79	1.07	0.67	0.79
	B23	0.63	1.02	1.46	1.11	1.28	1.54	1.11	1.28	1.54
	B26	0.89	0.65	0.65	1.74	0.83	0.65	1.74	0.83	0.65
D	B25	0.41	0.55	0.68	0.72	0.70	0.72	0.72	0.70	0.72
	B28	2.21	1.16	1.20	3.99	1.46	1.25	3.99	1.46	1.25
	B19	3.33	1.90	1.60	5.89	2.37	1.67	5.89	2.37	1.67
	B20	0.78	0.98	1.22	1.30	1.23	1.27	1.30	1.23	1.27
	B27	1.23	1.41	1.76	2.11	1.75	1.84	2.11	1.75	1.84
	B17	1.18	0.95	1.16	2.15	1.20	1.21	2.15	1.20	1.21
	B13	0.49	1.00	1.66	0.89	1.26	1.73	0.89	1.26	1.73
	B18	0.87	0.89	1.37	1.45	1.10	1.45	1.45	1.10	1.45
	B21	1.00	1.03	0.91	1.74	1.28	0.96	1.74	1.28	0.96

precisely the same locations on all shots, but, as will be shown later, the differences from one event to another were relatively small and within the same area. They have been included in the treatment here.) Where the ratio is 1, the measured value equals the predicted one.

In Figure 15 the acceleration ratios at Station W-3 in the Piledriver Climax granite are shown for 15 events from Group II, Equation 10 of Table VII. Velocity and displacement ratios are shown in Figures 16 and 17, respectively. The dashed lines in the three figures are the log average of all 15 ratios.

Several observations can be made from these three figures. First, log averages for all three parameters are much less than one, reflecting the resistance of the granite mass to motion. Second, there is considerable scatter representing differences in coupling and transmission path, since station geology is the same. Third, certain events such as B22 have very small ratios in all three figures, suggesting that this was a weakly coupled explosion. An examination of the working point geology shows it to be an unusually porous medium with low compressional velocity. Fourth, the acceleration and velocity ratios suggest that Event B28 may have been strongly coupled.

Rock and alluvium ratios for Group I and all stations are plotted in Appendix A; those for Group II in Appendix B; and those for Group III in Appendix C. Similar ratio comparisons for rock only are in Appendices D, E, and F, and those for alluvium only, are in Appendices G and H.

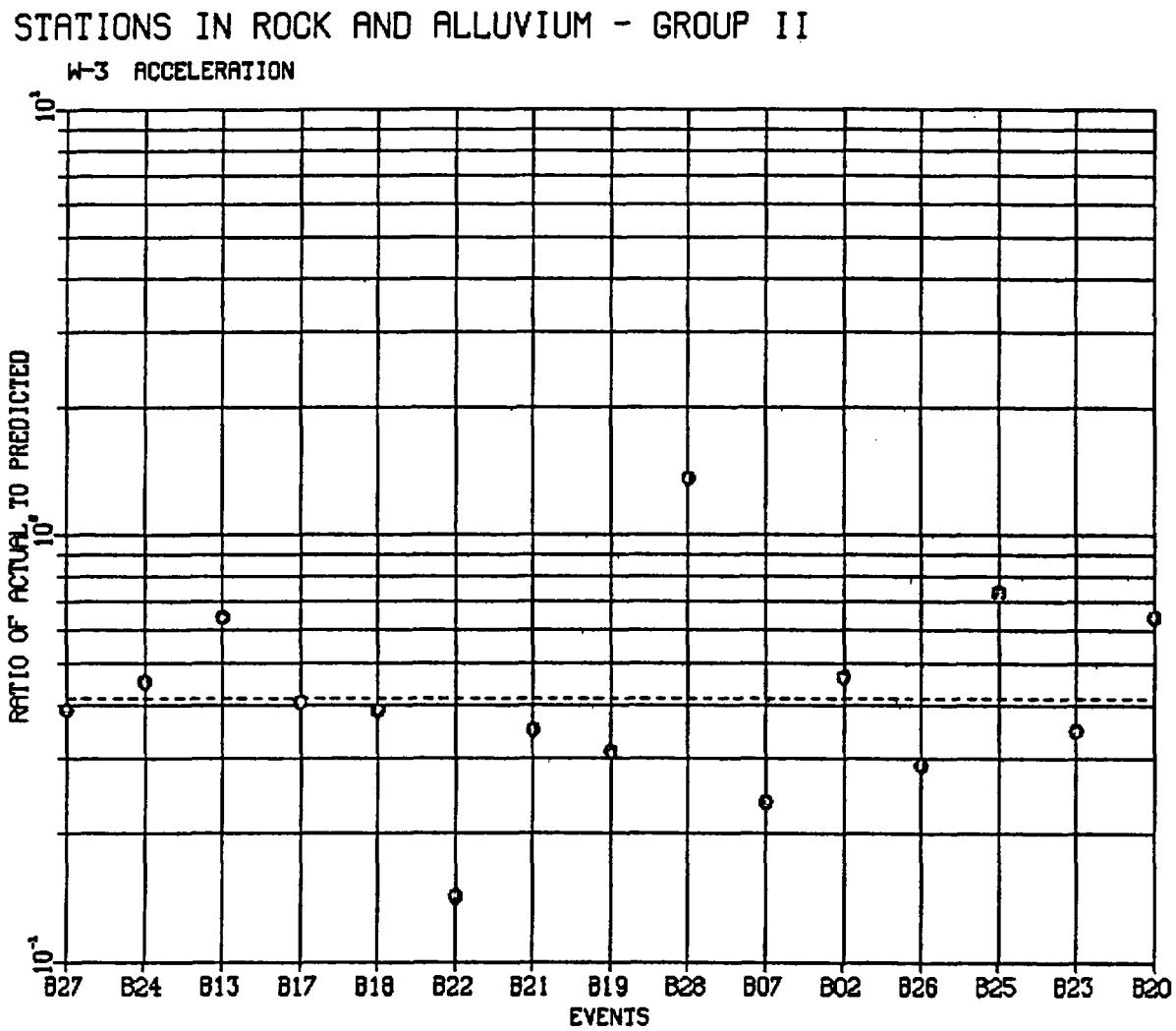


Figure 15. Acceleration ratios for stations in rock and alluvium - Group II.

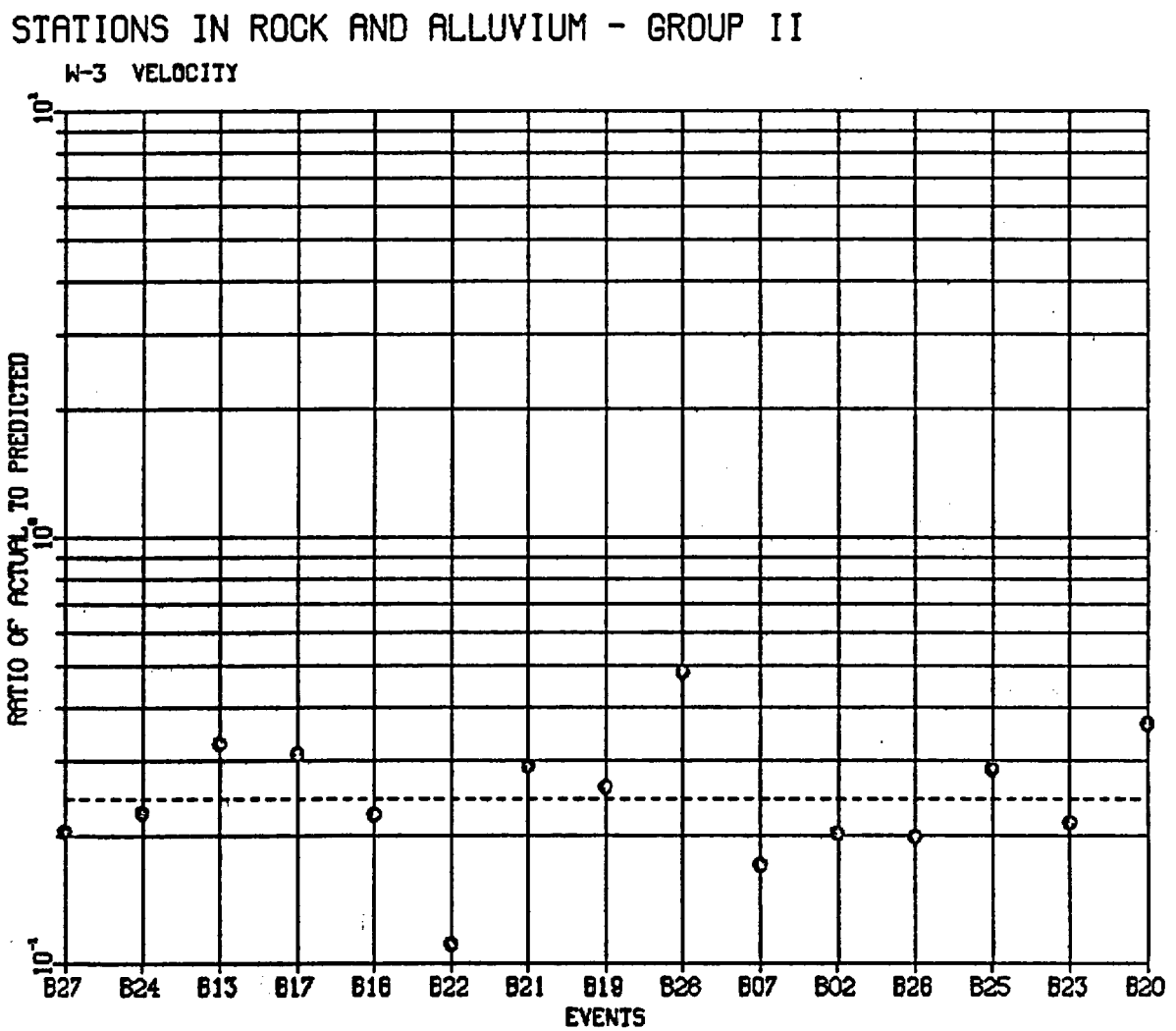


Figure 16. Velocity ratios for stations in rock and alluvium - Group II.

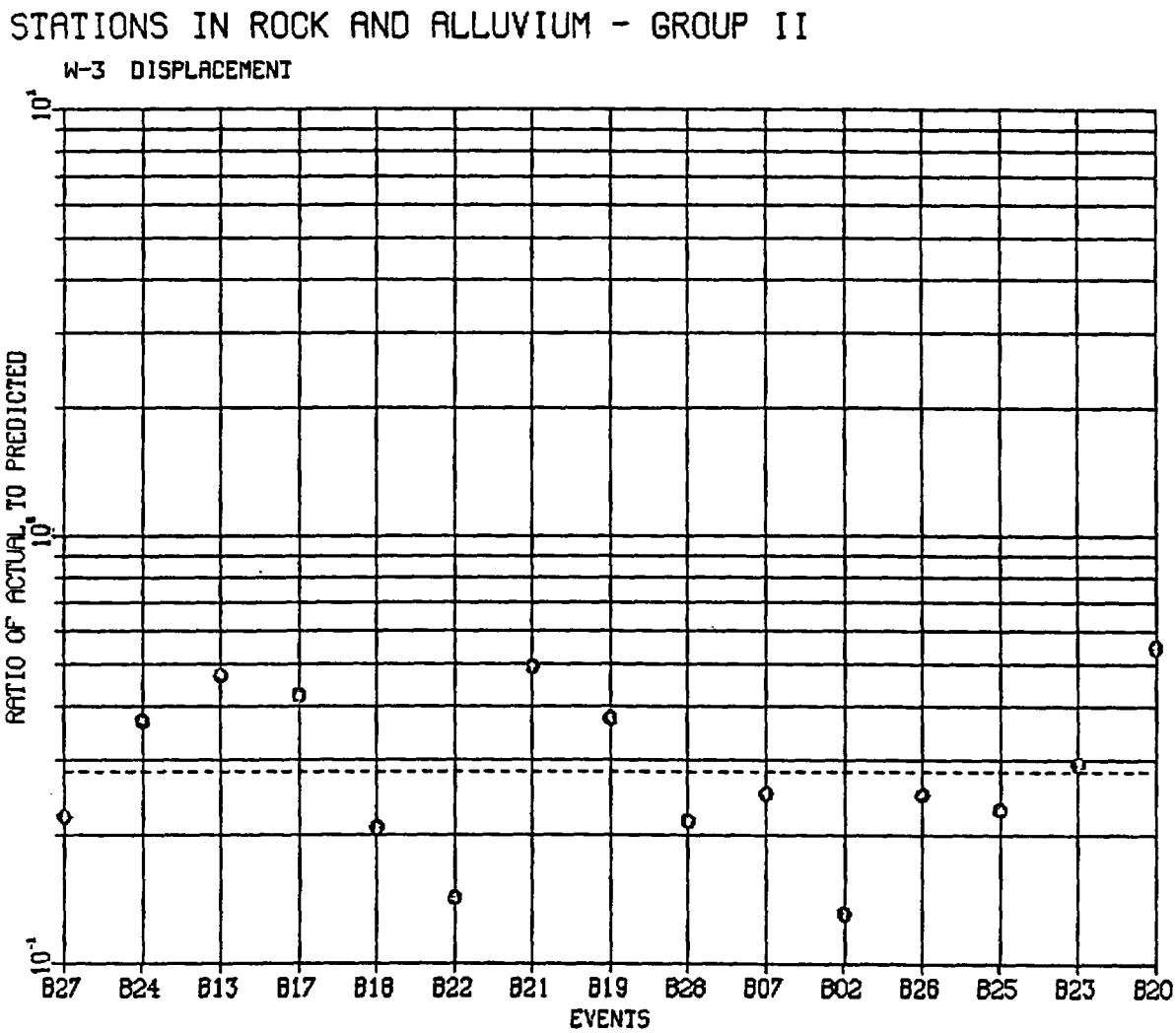


Figure 17. Displacement ratios for stations in rock and alluvium - Group II.

Table X compares the log average ratios for each station on rock and alluvium for the three groups. For each station there is a notation of the medium and the number of events for which measurements were made at the station. There are 9 stations for which all average ratios are less than 1. Two (Q25 and W-11) are on alluvium, and the rest (CP1, W-16, W-19, W-3, W-5, W-7 and W-8) are on rock. There are 13 stations for which the average ratios are consistently greater than 1. Six (ET1, W-6, A, B, C, and D) are on alluvium and are in the vicinity of the Engine Test Stand. Seven (PE2, W-13, W-14, W-20, W-21, W-22, and W-23) are on rock; five of the seven are at Yucca Mountain.

Table XI compares the log average ratios for the stations on rock only. The same seven stations on rock listed above have average ratios of less than 1, and the same seven have average ratios greater than 1.

Table XII makes the same comparison for stations on alluvium only. Here only Q25 has values consistently less than 1, and only ET1, A, and D have values which are all greater than 1.

There are 36 stations listed in Table X. The log average ratios can be divided into four sets:

Set 1	$r_a < r_u < r_d$
Set 2	$r_a < r_u > r_d$
Set 3	$r_a > r_u > r_d$
Set 4	$r_a > r_u < r_d$

Table X. Log Average Ratios for Stations on Rock and Alluvium

			Group I Appendix A			Group II Appendix B			Group III Appendix C		
Station	Medium	No. of Events	a Eq. 1	u Eq. 2	d Eq. 3	a Eq. 10	u Eq. 11	d Eq. 12	a Eq. 19	u Eq. 20	d Eq. 21
BAL	A	2	0.73	0.97	0.97	0.87	1.04	1.04	0.94	1.13	1.14
BHR	R	2	0.48	0.53	0.88	0.57	0.57	0.95	0.62	0.62	1.04
BTY	A	9	1.24	0.99	0.84	1.48	1.06	0.91	1.58	1.14	0.99
CP1	R	2	0.33	0.30	0.38	0.40	0.34	0.42	0.42	0.35	0.45
EMD	A	2	0.98	1.25	1.94	1.16	1.35	2.09	1.25	1.46	2.28
ET1	A	2	2.80	2.94	3.17						
PE1	R	2	0.98	1.40	1.12	0.99	1.38	1.10	1.07	1.48	1.19
PE2	R	2	1.65	1.41	1.16	1.73	1.42	1.15	1.90	1.54	1.27
PE7	R	2	0.74	1.29	1.30	0.76	1.29	1.29	0.83	1.40	1.40
PE9	R	4	0.71	1.12	1.19	0.79	1.16	1.22	0.89	1.30	1.37
Q25	A	5	0.61	0.44	0.34	0.75	0.49	0.37	0.79	0.52	0.40
SZ	R	10	1.41	1.05	1.74	1.31	1.02	1.70	1.28	1.00	1.65
W-10	A	15	0.74	1.13	1.54	0.85	1.18	1.59	0.96	1.32	1.81
W-11	A	12	0.75	0.69	0.78	0.84	0.71	0.80	0.94	0.79	0.90
W-13	R	11	1.30	1.48	1.08	1.38	1.50	1.09	1.51	1.64	1.19
W-14	R	12	1.18	1.44	1.73	1.34	1.50	1.78			
W-15	R	9	0.75	1.28	1.59						
W-16	R	10	0.49	0.57	0.67	0.55	0.58	0.68	0.61	0.65	0.77
W-17	R	13	1.25	0.94	0.80	1.35	0.96	0.81	1.50	1.05	0.90
W-18	R	13	1.08	0.92	0.87	1.19	0.94	0.88	1.32	1.04	0.98
W-19	R	4	0.62	0.54	0.57	0.69	0.56	0.58	0.77	0.62	0.65
W-20	R	4	1.86	1.73	1.52	2.10	1.80	1.56			
W-21	R	6	1.13	1.30	1.70	1.28	1.35	1.75			
W-22	R	5	1.65	1.26	1.24	1.87	1.31	1.27			
W-23	R	7	1.49	1.88	1.54	1.68	1.95	1.58			
W-3	R	15	0.38	0.24	0.28						
W-4	A	2	0.56	0.96	0.81	0.63	0.99	0.83	0.71	1.11	0.94
W-5	R	14	0.65	0.67	0.70	0.75	0.70	0.72	0.85	0.79	0.82
W-6	A	15	2.44	1.66	1.14						
W-7	R	15	0.60	0.61	0.70	0.68	0.63	0.72	0.77	0.71	0.82
W-8	R	2	0.46	0.66	0.62	0.51	0.67	0.63	0.57	0.75	0.71
W-9	R	13	0.80	1.82	1.90						
A	A	11	1.80	1.29	1.25						
B	A	9	2.62	1.29	1.13						
C	A	11	1.70	1.17	1.15						
D	A	9	1.41	1.22	1.43						

Table XI. Log Average Ratios for Stations on Rock Only

		Group I Appendix D			Group II Appendix E			Group III Appendix F		
Station	No. of Events	a Eq. 4	u Eq. 5	d Eq. 6	a Eq. 13	u Eq. 14	d Eq. 15	a Eq. 22	u Eq. 23	d Eq. 24
BHR	2	0.58	0.60	0.99	0.55	0.57	0.96	0.63	0.65	1.15
CP1	2	0.39	0.35	0.43	0.39	0.33	0.42	0.43	0.38	0.49
PE1	2	1.06	1.43	1.15	0.96	1.37	1.13	1.05	1.49	1.25
PE2	2	1.84	1.48	1.21	1.67	1.41	1.18	1.86	1.57	1.35
PE7	2	0.81	1.35	1.35	0.74	1.28	1.32	0.81	1.42	1.49
PE9	4	0.84	1.23	1.29	0.76	1.15	1.25	0.88	1.35	1.51
SZ	10	1.32	1.02	1.67	1.31	1.03	1.69	1.27	0.98	1.60
W-13	11	1.46	1.57	1.14	1.33	1.49	1.11	1.49	1.67	1.28
W-14	12	1.42	1.59	1.90	1.28	1.49	1.84			
W-15	9	0.88	1.39	1.72						
W-16	10	0.58	0.62	0.73	0.53	0.58	0.70	0.60	0.67	0.84
W-17	13	1.44	1.01	0.86	1.30	0.95	0.84	1.47	1.08	0.97
W-18	13	1.26	0.99	0.93	1.14	0.93	0.90	1.30	1.07	1.07
W-19	4	0.73	0.59	0.62	0.67	0.56	0.60	0.77	0.65	0.72
W-20	4	2.23	1.91	1.66	2.01	1.78	1.61			
W-21	6	1.36	1.44	1.87	1.22	1.34	1.80			
W-22	5	1.98	1.39	1.35	1.79	1.30	1.31			
W-23	7	1.79	2.08	1.68	1.61	1.94	1.63			
W-3	15	0.44	0.26	0.30						
W-5	14	0.79	0.74	0.77	0.72	0.69	0.74	0.84	0.82	0.92
W-7	15	0.72	0.67	0.77	0.66	0.63	0.74	0.76	0.74	0.90
W-8	2	0.54	0.71	0.67	0.49	0.67	0.65	0.56	0.77	0.77
W-9	13	0.91	1.95	2.02						

Table XII. Log Average Ratios for Stations on Alluvium Only

		Group I Appendix G			Group II Appendix H			Group III Appendix H		
Station	No. of Events	a Eq. 7	u Eq. 8	d Eq. 9	a Eq. 16	u Eq. 17	d Eq. 18	a Eq. 16	u Eq. 17	d Eq. 18
BAL	2	0.65	0.89	0.89	0.88	1.05	1.03	0.88	1.05	1.03
BTY	9	1.18	0.92	0.79	1.52	1.07	0.92	1.52	1.07	0.92
EMD	2	0.86	1.14	1.78	1.18	1.35	2.05	1.18	1.35	2.05
ET1	2	2.97	2.82	3.04						
Q25	5	0.51	0.41	0.31	0.63	0.48	0.38	0.63	0.48	0.38
W-10	15	0.50	0.95	1.31	0.92	1.20	1.37	0.92	1.20	1.37
W-11	12	0.67	0.61	0.70	1.13	0.75	0.72	1.13	0.75	0.72
W-4	2	0.43	0.83	0.70	0.78	1.03	0.73	0.78	1.03	0.73
W-6	15	1.74	1.42	0.98						
A	11	1.30	1.10	1.08						
B	9	1.90	1.10	0.98						
C	11	1.23	1.00	0.99						
D	9	1.03	1.04	1.24						

For Group I, Set 1 contains BHR, EMD, ET1, PE9, W-10, W-14, W-15, W-16, W-21, W-5, W-9, and W-7. Set 2 includes BAL, PE1, PE7, W-13, W-23, W-4, and W-8. Set 3 includes BTY, PE2, Q25, W-17, W-18, W-20, W-22, W-6, A, B, and C. Set 4 has CP1, SZ, W-11, W-19, W-3, and D. The 13 alluvium stations fall into three sets, nearly half of them, into Set 3. The two stations with known topographic effects (W-9 and W-15) fall into Set 1. Of six stations in the vicinity of the Engine Test Stand, four (W-6, A, B, and C) are in Set 3. There is one (ET1) in Set 1, and one (D) in Set 4. Neither of the two events for which there are data at ET1 were within the azimuthal window where the anomaly has been observed. Station D had only one event within the window, and its location was at the eastern edge of where the anomaly has been observed.

These trends are consistent with observation. For topographic effects, displacements are large, relative to predictions, and velocity and acceleration are closer to predictions. For the anomaly, the accelerations are larger than predicted, the velocity less so, and the displacement close to prediction. For Groups II and III in Table X Stations W-5 and W-7 move from Set 1 to Set 4; the change is caused by small differences in ratios.

Of five stations at Yucca Mountain, W-14 and W-21 were in Set 1, W-23 in Set 2, and W-20 and W-22 in Set 3. All were on ridges where topographic effects might be expected. There is a correlation with location, however. Stations W-14 and W-21 are at the southern edge of the repository "block," W-20 and W-22 in the middle, and W-23 at the northern edge.

The log average ratios of Tables X, XI, and XII include the effects of coupling, transmission, and station geology. Determination of a coupling factor for each event was attempted by using stations on rock and alluvium for Group III and determining log averages of ratios for all Group I stations on each shot. An example is shown in Table XIII. Table XIV lists the log averages of acceleration, velocity, and displacement ratios for 32 events. The number of stations available for each event is also shown. The right-hand column is the log average of the acceleration, velocity, and displacement columns. At the bottom are the log averages of each column. The value of 1.006 suggests a very small departure from the prediction equation when all three parameters are considered.

A ratio above one represents the degree of coupling greater than average, and that less than one, the degree of coupling less than average, where average coupling is determined from Equations 19, 20, and 21. At the bottom of the table the $\pm 1\sigma$ values from the equations are listed. Only Event B22 is less than -1σ for all three parameters. Event B16 is less for acceleration only and A05 is less for acceleration and velocity. Only velocity for Events B13 and B14 is greater than $+1\sigma$.

A comparison of ratios with yield showed that there was no trend with yield, indicating that yield effects were adequately accommodated by the prediction equations. Plotting ratios according to location within Silent Canyon Caldera shows no particular pattern.

If these ratios, referred to as coupling factors, are a true measure of coupling, they should bear some reasonable relationship to geophysical

Table XIII. An Example of Average Ratios Calculated for All Stations on a Single Event

Stations in Rock and Alluvium - Group III

Event A01

Station	Acceleration Ratio	Velocity Ratio	Displacement Ratio
SSB2	.363E+01	.163E+01	.130E+01
SSB1	.261E+01	.144E+01	.147E+01
025	.655E+00	.541E+00	.473E+00
603	.121E+01	.939E+00	.937E+00
602	.779E+00	.718E+00	.586E+00
601	.826E+00	.698E+00	.582E+00
S74	.931E+00	.137E+01	.139E+01
S34	.188E+01	.214E+01	.251E+01
S24	.115E+01	.111E+01	.748E+00
S16	.212E+01	.143E+01	.103E+01
S12	.121E+01	.112E+01	.104E+01
S-8	.528E+00	.112E+01	.722E+00
S-3	.523E+00	.682E+00	.713E+00
S-1	.635E+00	.849E+00	.173E+01

Log Average	=	.111E+01	.105E+01	.977E+00
Simple Average	=	.133E+01	.113E+01	.109E+01

Table XIV. Log Average Ratios (Coupling Factors) for Thirty-two Events, Group III Rock and Alluvium (Appendix C), Equations 19, 20, and 21

Event	Number of Stations	a	u	d	a+u+d / 3
A01	14	1.096	1.036	0.939	1.022
A02	7	1.808	1.448	1.248	1.484
A03	9	1.294	1.170	1.163	1.208
A04	8	1.181	1.041	0.898	1.034
A05	9	0.534	0.574	0.649	0.583
A06	11	0.762	1.039	1.114	0.959
A07	8	1.318	0.877	1.127	1.092
A08	6	1.329	0.912	0.872	1.018
B01	21	0.590	1.068	1.056	0.873
B02	7	0.840	0.832	0.670	0.777
B04	8	1.426	0.921	0.765	1.001
B05	5	1.366	1.237	1.277	1.292
B07	10	0.644	0.935	0.852	0.801
B08	10	0.860	0.730	0.932	0.836
B09	8	1.231	0.926	0.707	0.931
B11	8	1.506	0.950	0.882	1.081
B13	9	1.808	1.595	1.469	1.618
B14	12	1.915	1.588	1.469	1.647
B15	4	1.468	1.276	1.079	1.264
B16	10	0.462	1.005	1.323	0.850
B17	12	1.243	1.227	1.267	1.246
B18	10	1.069	0.882	0.760	0.895
B19	9	1.073	0.935	1.083	1.028
B20	9	1.045	1.102	1.299	1.143
B21	8	1.468	1.104	1.142	1.228
B22	8	0.371	0.496	0.486	0.447
B23	8	0.741	0.989	1.082	0.925
B24	8	1.315	0.952	0.911	1.045
B25	8	0.831	0.828	0.861	0.840
B26	6	0.912	0.838	0.905	0.884
B27	8	1.346	1.139	1.152	1.209
B28	12	0.906	0.905	1.110	0.969
Log Average		1.041	0.989	0.988	1.006
Equation		19	20	21	
σ		1.897	1.556	1.693	1.710
$+1\sigma$		1.975	1.539	1.673	1.720
-1σ		0.549	0.636	0.584	0.589

properties of the medium in the vicinity of the working point. There was no significant trend of the coupling factors with acceleration, velocity, or displacement, or their log averages with either density or sonic velocity.

The lack of correlation could mean that (1) the coupling factor is not a good index of coupling, or (2) the geophysical data did not reflect a true picture of the medium in the vicinity of the working point. To check the latter, the density was plotted against the velocity at the working point (Figure 18). There was considerable scatter about the mean which is shown as the solid line. The arrows at the left and right margins indicate the standard errors of the estimate. When the data from shots in tuff (t in the figure) were separated from those in rhyolite (r), the scatter was not appreciably different. The scatter results from two primary causes.[5] First, both density and velocity of tuff and rhyolite overlap, although the largest values of both are in rhyolite and the smallest in tuff. Second, differences in measurement techniques before 1977 and those in 1977 and later, cause the velocity measurements of the earlier events to be higher; no comparable differences are seen in density. Whether the working point was above or below the water table seemed to make relatively little difference. The dashed line curving downward at the left is a density-velocity relationship reported by Farmer[6] based on work by Judd and Huber.[7] The latter was based on a number of rock types. The mean of the Pahute Mesa data falls well below that of Judd and Huber. The fine lines are the ±5% error in density and ±20% error in velocity reported by Howard[8] for measurements at Pahute Mesa.

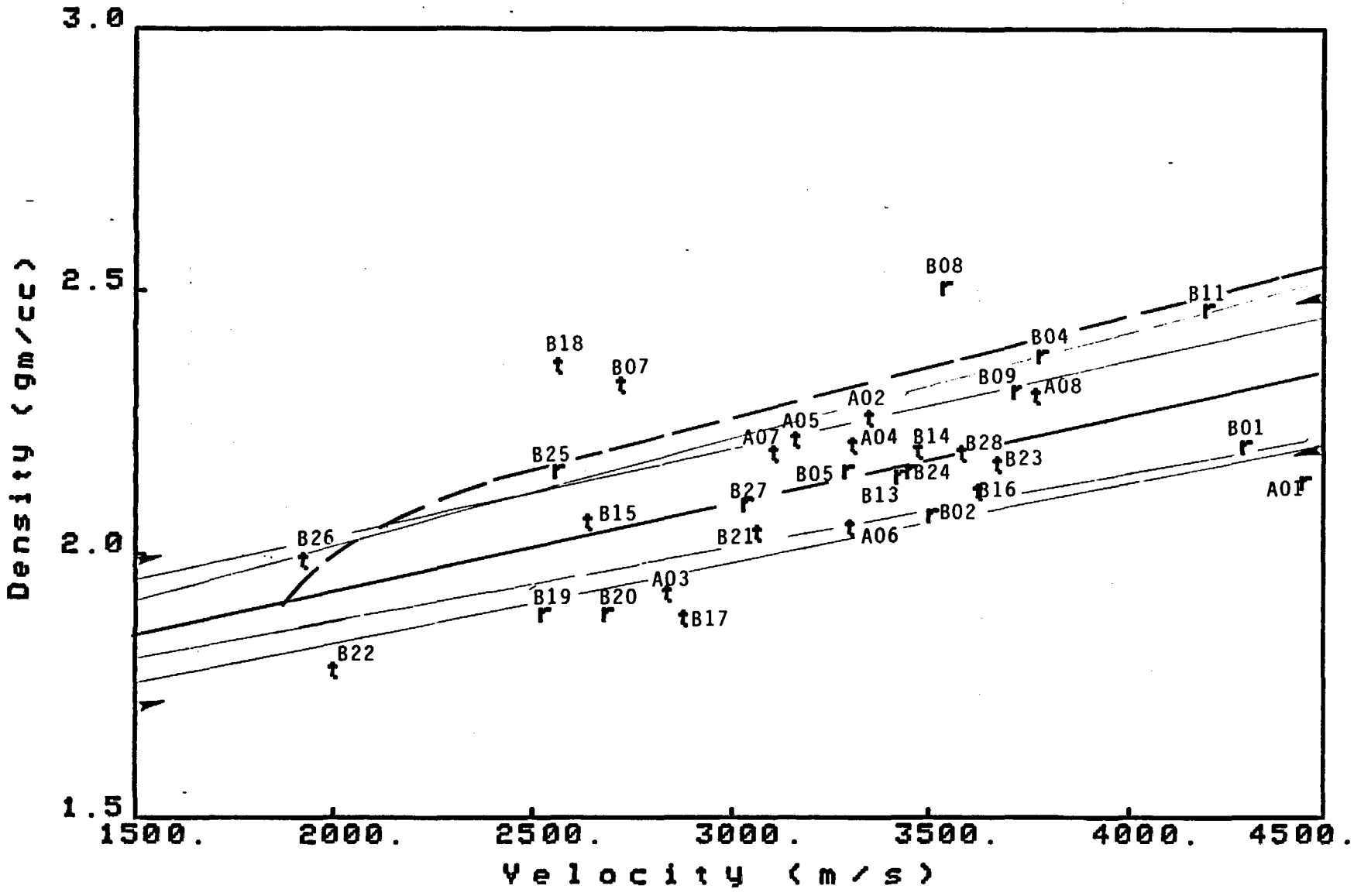


Figure 18. Density versus velocity at the working point for events in tuff (t) and rhyolite (r).

From the foregoing it is concluded that the reason for lack of correlation between coupling factors and working point velocity and density is the scatter in measurement of those two parameters.

Assuming that the coupling factors are a valid index of coupling, the next step was to divide the peak vector acceleration, velocity, and displacement data for each event by the factors of Table XIV to arrive at values of acceleration, velocity, and displacement as if all shots coupled in the same way.

Regressions using the modified data gave the following results.

Group I

For acceleration:

$$a = 0.422\ W^{0.492}\ R^{-1.614},\ N = 415,\ \sigma_a = 1.858,\ \sigma_R = 1.468, \qquad \text{(Eq. 31)}$$

For velocity:

$$u = 12.26\ W^{0.612}\ R^{-1.519},\ N = 421,\ \sigma_u = 1.666,\ \sigma_R = 1.399, \qquad \text{(Eq. 32)}$$

For displacement:

$$d = 2.870\ W^{0.651}\ R^{-1.560},\ N = 418,\ \sigma_d = 1.706,\ \sigma_R = 1.408, \qquad \text{(Eq. 33)}$$

When the above equations are compared with Equations 1, 2, and 3, respectively, it is seen that removing the effects of coupling changes the equations by only small amounts. This is because the events for which coupling increased motion was closely offset by those for which coupling decreased it relative to the average. Note that removing the effects of coupling has decreased σ in all cases.

Group II

For acceleration:

$$a = 0.518\ W^{0.470}\ R^{-1.672},\ N = 319,\ \sigma_a = 1.659,\ \sigma_R = 1.354, \qquad \text{(Eq. 34)}$$

For velocity:

$$u = 13.56\ W^{0.600}\ R^{-1.542},\ N = 325,\ \sigma_u = 1.500,\ \sigma_R = 1.301, \qquad \text{(Eq. 35)}$$

For displacement:

$$d = 3.508\ W^{0.623}\ R^{-1.583},\ N = 322,\ \sigma_d = 1.638,\ \sigma_R = 1.366. \qquad \text{(Eq. 36)}$$

These equations can be compared with Equations 10, 11, and 12. The changes were in the same direction as noted above for Group I.

Group III

For acceleration:

$$a = 0.403\ W^{0.514}\ R^{-1.697},\ N = 284,\ \sigma_a = 1.621,\ \sigma_R = 1.329, \qquad \text{(Eq. 37)}$$

For velocity:

$$u = 10.69\ W^{0.643}\ R^{-1.570},\ N = 290,\ \sigma_u = 1.441,\ \sigma_R = 1.262, \qquad \text{(Eq. 38)}$$

For displacement:

$$d = 2.786\ W^{0.665}\ R^{-1.612},\ N = 287,\ \sigma_d = 1.602,\ \sigma_R = 1.340. \qquad \text{(Eq. 39)}$$

The Group III equations can be compared with Equations 19, 20, and 21. Again, the differences are small, and σ decreased in each case.

With the effects of coupling removed, the station ratios may now be recalculated for the three groups using the above equations. The results are tabulated in

Table XV. That table can be compared with Table X. In Table XV ratios are given for stations in Groups II and III even though those stations were not used in determining the equations on which the ratios were based.

Table XVI lists the ratios for the stations in the NRDS area for each event on which measurements were made at the stations. The ratios indicate the extent to which ground motion amplitudes exceed that given by Equations 37, 38, and 39. The table also shows the azimuth (from north) from the station to the event. The events are listed in order of the azimuth from the station to the event. Generally, as the azimuths increase, the ratios decrease.

If a line is drawn from the Purse event to Station W-6 (the same location as ETS-2), the line crosses the aeromagnetic high at a location about N234514, E183059, which is about 3650 m from W-6. For the events listed in Table XVI a line was extended from the location of the event through the above coordinates as a pivot point and extended 3650 m, at which location a perpendicular was drawn. Along this perpendicular, four stations A, B, C, and D, were located at a spacing of about 1830 m between them and Station W-6. This was done to explore the lateral extent of the anomaly.

Figure 19 is an aeromagnetic map[9] of a portion of the NRDS area. The map shows the location of each station. The acceleration ratios of Table XVI are shown as vectors the length of which is proportional to the ratio. Each vector is pointed toward the underground nuclear explosion which caused it.

Table XV. Log Average Ratios for Stations in Rock and Alluvium (Coupling Removed)

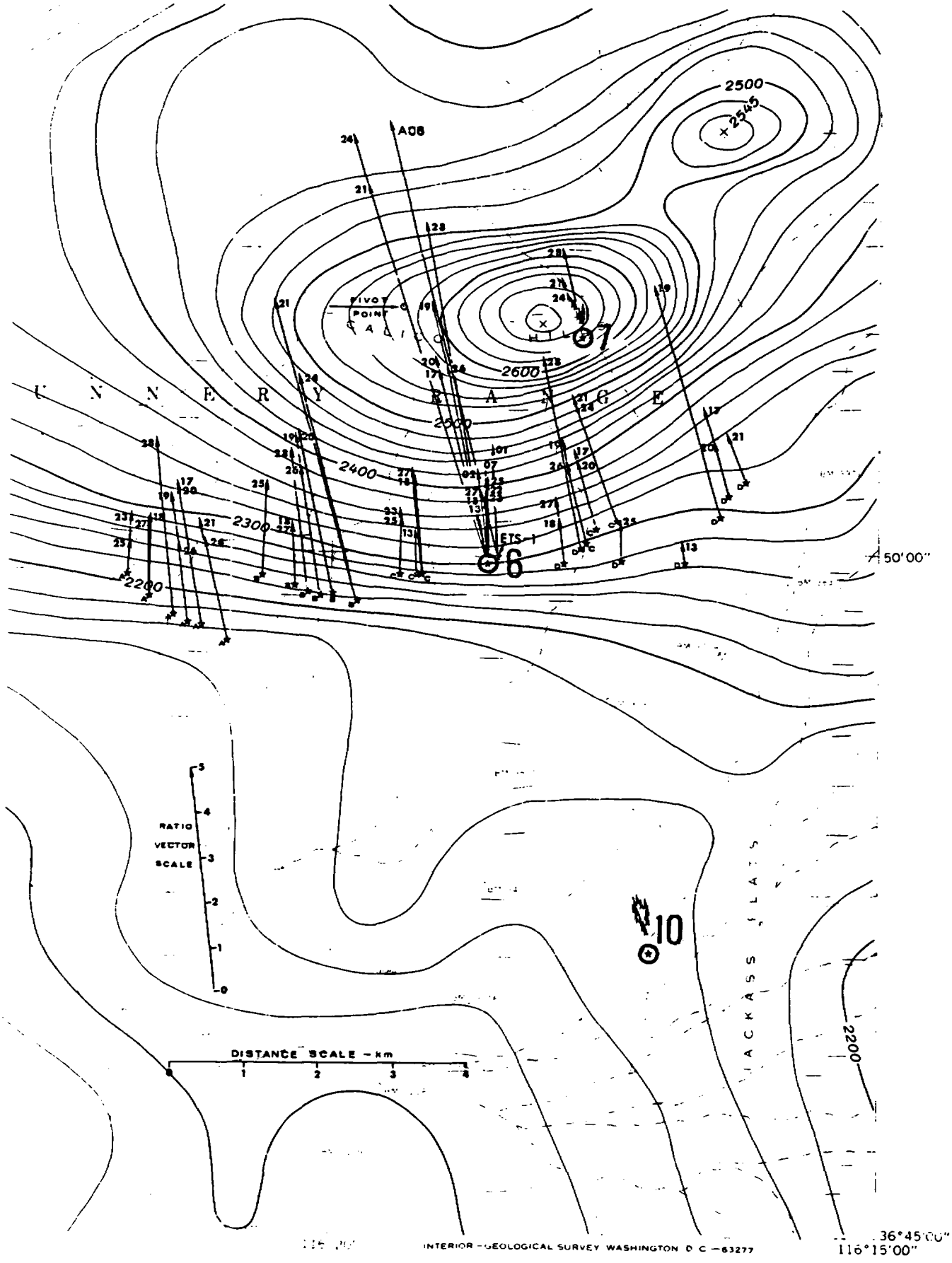
			Group I			Group II			Group III		
Station	Medium	No. of Events	a Eq. 31	u Eq. 32	d Eq. 33	a Eq. 34	u Eq. 35	d Eq. 36	a Eq. 37	u Eq. 38	d Eq. 39
BAL	A	2	1.01	1.09	0.99	1.18	1.16	1.06	1.29	1.27	1.16
BHR	R	2	0.67	0.59	0.90	0.78	0.64	0.96	0.85	0.70	1.05
BTY	A	9	0.85	0.91	0.85	1.00	0.98	0.91	1.08	1.06	0.99
CP1	R	2	0.51	0.40	0.46	0.61	0.43	0.51	0.63	0.45	0.53
EMD	A	2	0.91	1.08	1.79	1.06	1.15	1.91	1.16	1.26	2.10
ET1	A	2	4.11	2.80	2.98	4.84	3.00	3.22	5.11	3.19	3.41
PE1	R	2	0.92	1.12	0.99	0.93	1.12	0.97	1.02	1.23	1.06
PE2	R	3	1.53	1.13	1.02	1.60	1.14	1.01	1.78	1.28	1.13
PE7	R	2	0.68	1.03	1.14	0.71	1.04	1.12	0.78	1.16	1.25
PE9	R	4	0.68	0.96	1.02	0.76	1.00	1.04	0.86	1.15	1.19
Q25	A	5	0.80	0.56	0.37	0.97	0.56	0.41	1.03	0.60	0.44
SZ	R	10	1.32	1.08	1.72	1.24	1.05	1.68	1.20	1.02	1.63
W-10	A	15	0.75	1.14	1.58	0.85	1.20	1.62	0.98	1.39	1.88
W-11	A	12	0.77	0.72	0.80	0.85	0.75	0.81	0.96	0.86	0.93
W-13	R	11	1.32	1.54	1.09	1.39	1.58	1.09	1.55	1.76	1.22
W-14	R	12	1.19	1.51	1.77	1.34	1.58	1.81	1.54	1.82	2.08
W-15	R	9	0.70	1.23	1.44	0.77	1.27	1.45	0.87	1.45	1.66
W-16	R	10	0.52	0.60	0.69	0.57	0.62	0.70	0.65	0.71	0.80
W-17	R	13	1.22	0.95	0.79	1.31	0.97	0.80	1.47	1.10	0.90
W-18	R	13	1.05	0.92	0.85	1.15	0.95	0.86	1.30	1.08	0.98
W-19	R	4	0.51	0.53	0.54	0.56	0.55	0.55	0.64	0.63	0.62
W-20	R	4	2.15	1.98	1.75	2.41	2.07	1.79	2.78	2.39	2.07
W-21	R	6	1.31	1.49	1.94	1.48	1.55	1.98	1.71	1.80	2.30
W-22	R	5	1.64	1.29	1.26	1.84	1.35	1.29	2.11	1.56	1.48
W-23	R	7	1.61	2.08	1.69	1.81	2.17	1.72	2.07	2.50	1.99
W-3	R	15	0.38	0.24	0.28	0.42	0.25	0.29	0.48	0.29	0.33
W-4	A	2	0.75	1.06	1.06	0.84	1.10	1.08	0.97	1.27	1.25
W-5	R	14	0.69	0.70	0.74	0.78	0.74	0.76	0.90	0.86	0.88
W-6	A	15	2.46	1.69	1.17	2.78	1.77	1.19	3.19	2.04	1.38
W-7	R	15	0.61	0.62	0.72	0.68	0.65	0.73	0.79	0.75	0.85
W-8	R	2	0.62	0.72	0.81	0.68	0.75	0.82	0.78	0.85	0.94
W-9	R	13	0.82	1.82	1.89	0.87	1.87	1.90	0.98	2.11	2.14
A	A	11	1.67	1.28	1.20	1.89	1.34	1.23	2.16	1.55	1.42
B	A	9	2.33	1.31	1.11	2.63	1.37	1.14	3.02	1.58	1.32
C	A	11	1.48	1.10	1.08	1.67	1.15	1.10	1.92	1.33	1.27
D	A	9	1.19	1.12	1.28	1.35	1.17	1.32	1.54	1.35	1.52

Table XVI. Ratios for Stations in NRDS Area

Station	Event	Azimuth (°) Toward Event	Group III a Eq. 37	u Eq. 38	d Eq. 39
ET1	A06	345.63	10.00	4.39	4.86
	B01	356.64	2.60	2.33	2.44
W-6	B21	342.24	8.84	4.86	1.23
	B24	342.45	10.00	6.50	1.00
	B20	345.40	4.77	2.26	1.23
	B17	345.51	4.45	2.07	1.08
	B19	347.56	5.97	3.10	1.07
	B26	347.77	4.53	2.16	1.09
	B28	349.45	7.74	3.50	1.10
	B27	352.95	1.71	1.30	1.40
	B02	353.09	2.13	1.52	1.57
	B18	353.52	1.60	1.28	2.07
	B13	354.87	1.41	0.96	0.94
	B07	358.11	1.90	1.50	2.21
	B23	358.23	1.66	1.60	1.94
	B25	359.21	1.95	1.54	1.91
	B22	359.27	1.86	1.44	1.72
W-7	B21	339.61	1.42	0.97	0.77
	B24	339.61	1.06	0.98	0.69
	B20	343.05	0.89	0.66	0.80
	B17	343.21	0.88	0.64	0.85
	B19	345.11	0.85	0.76	0.82
	B26	345.38	0.68	0.63	0.75
	B28	347.24	2.03	0.98	0.70
	B27	350.73	0.52	0.71	0.93
	B02	350.87	0.66	0.66	0.62
	B18	351.30	0.48	0.79	1.11
	B13	352.97	0.47	0.70	1.04
	B07	356.51	0.63	0.69	1.01
	B23	356.65	0.62	0.80	0.98
	B25	357.82	0.76	0.65	0.88
	B22	357.82	0.85	0.73	0.92
W-10	B21	341.69	0.98	1.34	1.82
	B24	341.84	1.18	1.13	1.76
	B20	344.56	1.09	1.61	1.52
	B17	344.68	1.31	1.24	1.30
	B26	345.38	0.76	1.09	1.26
	B19	346.42	0.85	1.31	1.48
	B28	348.17	1.32	1.54	2.16
	B27	351.17	0.72	1.60	2.39
	B02	351.29	1.21	2.15	4.23
	B18	351.65	0.63	1.56	2.88
	B13	353.04	0.61	1.16	2.00
	B07	356.05	1.23	1.43	2.05
	B23	356.17	0.97	1.46	1.84
	B22	357.20	1.06	1.39	1.73
	B25	357.82	0.85	0.73	0.92

Table XVI. Ratios for Stations in NRDS Area (Cont'd)

Station	Event	Azimuth (°) Toward Event	Group III a Eq. 37	u Eq. 38	d Eq. 39
A	B21	346.49	2.79	2.30	1.36
	B24	347.01	2.34	1.52	1.00
	B20	349.79	3.21	1.61	1.69
	B17	349.83	3.27	1.34	1.40
	B19	352.54	2.83	1.56	1.40
	B26	352.67	1.72	1.18	1.55
	B28	354.38	3.98	2.23	1.91
	B27	358.74	1.78	1.32	0.98
	B18	359.42	1.86	1.54	0.99
	B23	3.53	1.41	1.25	1.80
	B25	4.04	0.78	1.52	2.09
B	B21	344.37	6.96	2.95	1.16
	B24	344.76	5.20	2.97	1.02
	B20	347.76	3.73	1.42	1.35
	B19	350.34	3.70	1.87	1.36
	B26	350.50	2.96	1.32	1.46
	B28	352.25	3.23	1.76	1.20
	B27	356.25	1.44	0.93	1.19
	B18	356.88	1.44	0.92	1.47
	B25	2.22	2.12	1.34	1.78
C	B21	340.13	3.00	1.88	1.08
	B24	340.17	2.82	2.14	1.07
	B20	343.69	1.60	1.31	1.25
	B17	343.83	1.86	1.30	1.26
	B19	345.91	2.41	1.44	1.25
	B26	346.15	1.87	1.09	0.99
	B27	354.08	2.40	1.21	1.26
	B18	354.67	2.20	1.40	1.87
	B13	355.97	1.03	0.99	1.21
	B23	359.50	1.53	1.43	1.85
	B25	0.37	1.36	0.90	1.20
D	B21	338.01	1.17	1.27	1.08
	B20	341.65	1.26	1.23	1.28
	B17	341.82	2.05	1.07	1.27
	B19	343.70	5.35	2.77	2.00
	B28	347.99	4.38	1.78	1.48
	B27	351.66	1.49	1.66	2.04
	B13	351.82	0.49	0.87	1.55
	B18	352.20	1.05	1.35	2.39
	B25	357.39	0.92	0.93	1.09



Aeromagnetic survey flown at 8000 feet barometric elevation, 1961

Figure 19. Aeromagnetic map of NRDS area showing peak vector acceleration ratio vectors.

At Station W-10 the ratios are close to 1. Those at Station 7 are less than 1 with the exceptions of Events 24, 21, and 28, which were 1.06, 1.42 and 2.03, respectively. Events 21 and 24 had ratios of 8.84 and 10 at Station W-6, 6.96 and 5.20 at Station B, 3.00 and 2.82 at Station C, and 2.79 and 2.34 at Station A. Only Event 21 had a measurement at Station D where it was close to 1. The ratio for Event A06 (all other numbers are preceded with a B to match data in the Appendices--the letter has been omitted in the figure to reduce clutter) is as large as that for Event 24; A06 was measured only at Station ETS-1. Event 28 produced ratios of 7.74, 4.38, 3.98, and 3.23 at Stations W-6, D, A, and B, respectively. Event 19 had ratios of 5.97, 5.35, 3.70, 2.83, and 2.41 at Stations W-6, D, B, A, and C, respectively. Whereas Event 21 and 24 ratios were greatest at Station 6 and reduced uniformly on either side, those for events 19 and 28 were reduced, but not uniformly.

The following observations can be made from Table XVI and Figure 19:

a. The enhanced acceleration is greatest at azimuths of 342.24, 342.45, 345.63, and 349.45 degrees from Stations W-6 and ETS-1.

b. At those Stations all events in Area 20 produced accelerations greater than predicted by a factor of more than four. Events in Area 19 had ratios of less than 2 with the exception of Event B02 which had a ratio of 2.13, and B01 at ET1 with 2.60.

c. The area of enhanced acceleration is limited to an east-west dimension of about 4 km on either side of Station W-6.

d. The north-south dimension has not been defined, but there is no enhancement at Station W-10 and none at Station W-7 except for the B28 event.

Figure 20 is a map of Pahute Mesa showing the location of the events used in this analysis relative to the boundary of the Silent Canyon Caldera. Figure 21 shows the ratios from Table XVI for those events for which measurements were made at Stations W-6 and ET1. There is nothing in the pattern of the ratios to suggest that location relative to the Silent Canyon Caldera is a factor in the amount of acceleration amplification observed at the two stations.

Table XVII lists the arrival time and relative velocity for stations in the NRDS area. The term relative velocity has been used because it is calculated on the basis of a straight line slant range between the working point of the detonation and the surface station. No account has been taken of the fact that the transmission paths are at depth and involve refraction at unknown interfaces.

Using the data of Table XVII, Figure 22 shows the velocities for each of the Pahute Mesa events for which measurements were made at Station W-6. There is a definite trend showing the lowest velocity in the SW portion of the Silent Canyon Caldera and the largest values in the NE portion. Figure 23 is a plot of these velocities as a function of the slant distance. Data shown as open circles are data for which arrival times have been confirmed. Those designated as solid circles are data for which there remains an uncertainty in arrival time because of the absence of a zero-time fiducial. Relative times are correct, so any error in absolute time would show similar differences on this and subsequent figures.

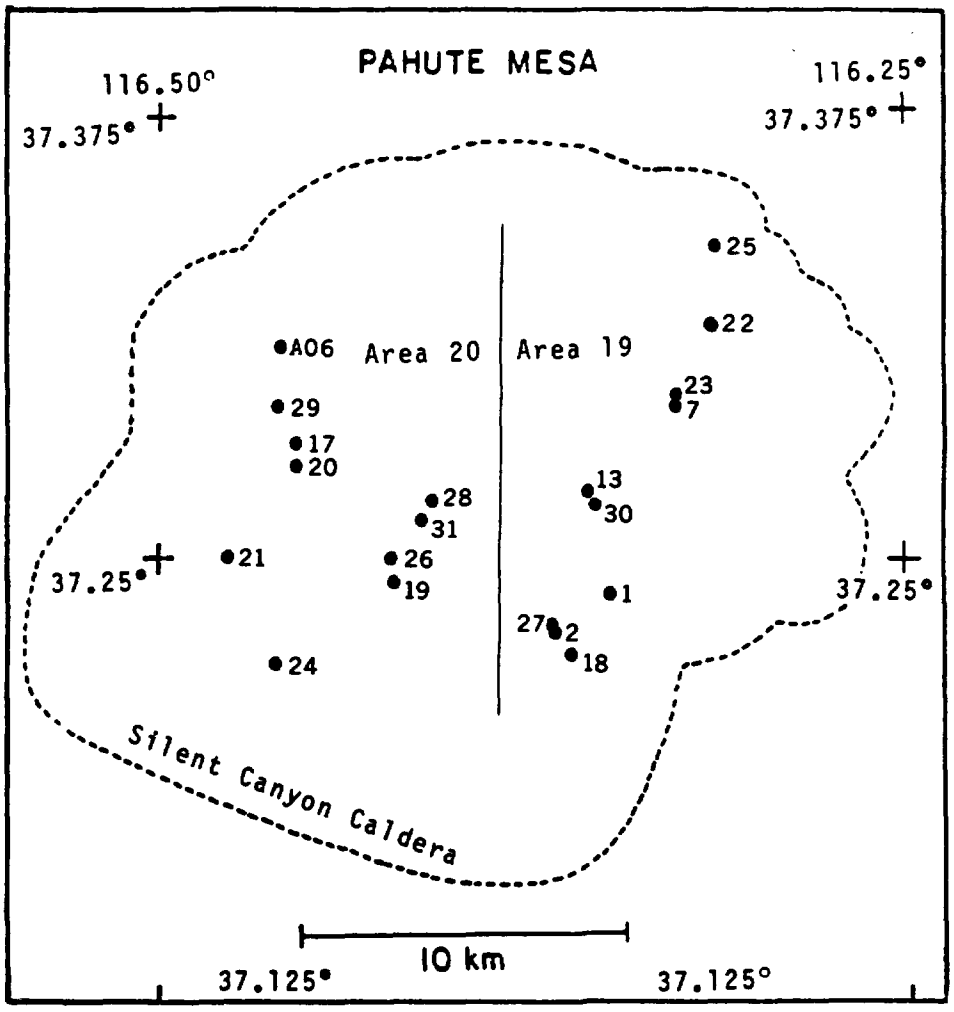


Figure 20. Map of Pahute Mesa showing the locations of the events used in this analysis.

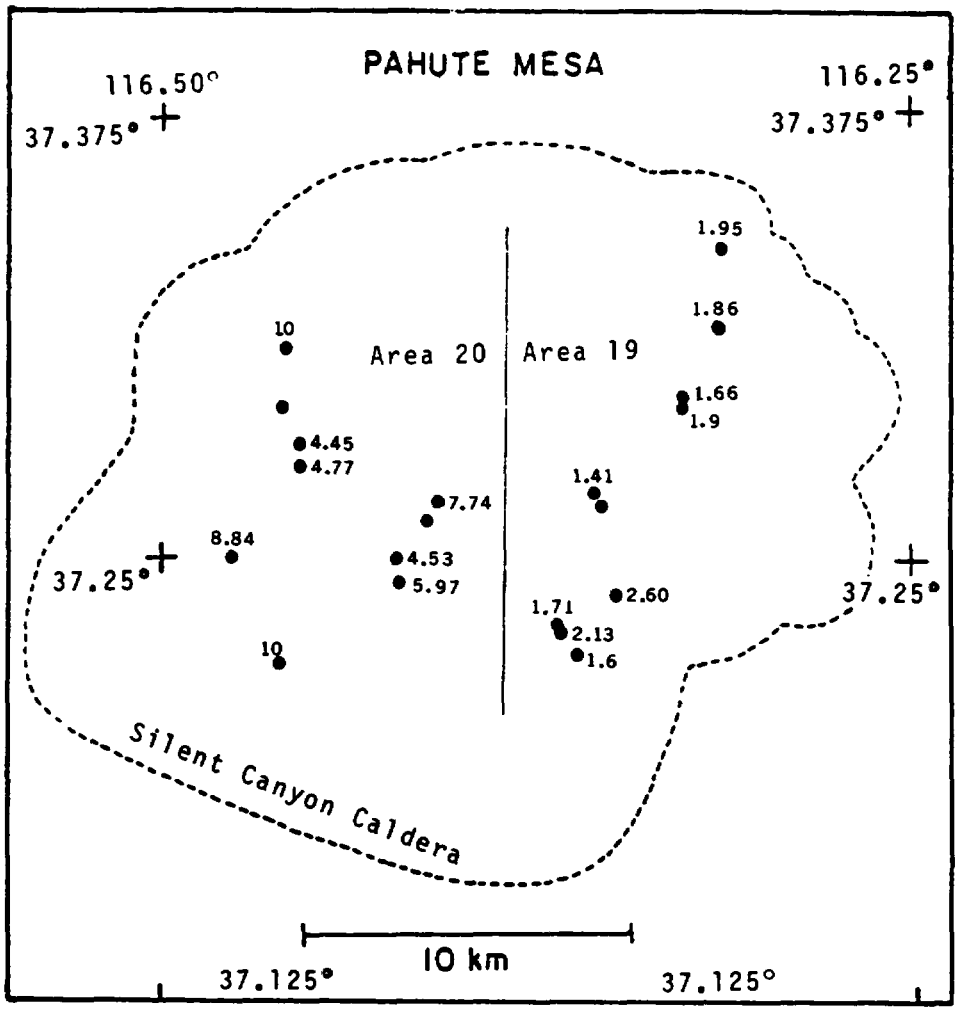


Figure 21. Map of Pahute Mesa showing the ratios for events for which measurements were made at Stations W-6 and ET-1.

Table XVII. Arrival Time and Relative Velocity at NRDS

Station	Event	Azimuth (°) Toward Event	Slant Range (km)	Time of Arrival (sec)	Relative Velocity (km/s)
W-6	B21	342.24	49.372	9.500	5.197
	B24	342.45	45.592	8.891	5.128
	B20	345.40	51.496	9.827	5.240
	B29	345.41	53.678	10.180	5.273
	B17	345.51	52.391	10.000	5.239
	B19	347.56	47.263	9.076	5.207
	B26	347.77	48.067	9.227	5.209
	B31	349.29	49.161	9.414	5.222
	B28	349.45	49.772	9.443	5.271
	B27	352.95	45.153	8.532	5.292
	B02	353.09	44.835	8.317	5.391
	B18	353.52	44.303	8.402	5.273
	B13	354.87	49.420	8.836	5.593
	B30	355.07	49.053	9.127	5.374
	B07	358.11	51.890	9.427	5.504
	B23	358.23	52.305	9.672	5.408
	B25	359.21	57.235	10.518	5.442
	B22	359.27	54.662	10.044	5.442
W-7	B21	339.61	46.868	8.864	5.287
	B24	339.61	43.084	8.257	5.218
	B20	343.05	48.869	9.182	5.322
	B29	343.15	51.049	9.537	5.353
	B17	343.21	49.759	9.346	5.324
	B19	345.11	44.562	8.404	5.302
	B26	345.38	45.357	8.555	5.302
	B31	347.03	46.398	8.789	5.279
	B28	347.24	47.002	8.775	5.356
	B27	350.73	42.276	7.884	5.362
	B02	350.87	41.954	7.556	5.552
	B18	351.30	41.409	7.716	5.367
	B13	352.97	46.484	8.192	5.674
	B30	353.17	46.110	8.454	5.454
	B07	356.51	48.865	8.768	5.573
	B23	356.65	49.277	8.982	5.486
	B25	357.82	54.181	9.832	5.511
	B22	357.82	51.607	9.374	5.505
W-10	B21	341.69	55.071	10.280	5.357
	B24	341.84	51.290	9.683	5.297
	B20	344.56	57.161	10.607	5.389
	B29	344.59	59.344	11.002	5.394
	B17	344.68	58.054	10.723	5.414

Table XVII. Arrival Time and Relative Velocity at NRDS (Cont'd)

Station	Event	Azimuth (°) Toward Event	Slant Range (km)	Time of Arrival (sec)	Relative Velocity (km/s)
	B26	345.38	53.697	9.972	5.385
	B19	346.42	52.897	9.832	5.380
	B31	348.01	54.764	10.086	5.430
	B28	348.17	55.372	10.188	5.435
	B27	351.17	50.678	9.283	5.459
	B02	351.29	50.357	9.087	5.542
	B18	351.65	49.814	9.054	5.501
	B13	353.04	54.893	9.536	5.756
	B30	353.21	54.520	9.845	5.538
	B07	356.05	57.264	10.179	5.626
	B23	356.17	57.675	10.397	5.547
	B22	357.20	59.995	10.754	5.579
	B25	357.82	62.569	11.227	5.573
A	B21	346.49	49.507	9.500	5.211
	B24	347.01	45.752	8.847	5.171
	B31	349.40	47.812	9.161	5.219
	B29	349.61	53.721	10.189	5.272
	B20	349.79	51.545	9.832	5.243
	B17	349.83	52.445	10.000	5.245
	B19	352.54	47.429	9.065	5.232
	B26	352.67	48.245	9.200	5.244
	B28	354.38	49.944	9.476	5.271
	B27	358.74	45.349	8.700	5.213
	B18	359.42	44.548	8.535	5.219
	B13	0.13	49.670	9.036	5.497
	B30	0.39	49.398	9.311	5.305
	B23	3.53	52.611	9.813	5.361
	B25	4.04	57.604	10.736	5.365
B	B21	344.37	49.405	9.500	5.201
	B24	344.76	45.635	8.855	5.154
	B29	347.66	53.632	10.148	5.285
	B20	347.76	51.452	9.829	5.235
	B31	350.20	45.945	8.706	5.277
	B19	350.34	47.323	9.065	5.220
	B26	350.50	48.134	9.235	5.212
	B28	352.25	49.844	9.443	5.278
	B27	356.25	45.258	8.585	5.272
	B18	356.88	44.435	8.416	5.280
	B30	358.10	49.248	9.195	5.356
	B23	1.53	52.514	9.782	5.368
	B25	2.22	57.489	10.695	5.375
C	B21	340.13	49.405	9.385	5.264
	B24	340.17	45.621	8.809	5.179

Table XVII. Arrival Time and Relative Velocity at NRDS (Cont'd)

Station	Event	Azimuth (°) Toward Event	Slant Range (km)	Time of Arrival (sec)	Relative Velocity (km/s)
	B20	343.69	51.460	9.837	5.231
	B29	343.76	53.642	10.111	5.305
	B17	343.83	52.351	9.910	5.283
	B19	345.91	47.323	8.972	5.275
	B26	346.15	48.121	9.182	5.241
	B31	349.54	44.000	8.243	5.338
	B27	354.08	45.239	8.627	5.244
	B18	354.67	44.397	8.437	5.262
	B13	355.97	49.535	8.936	5.544
	B23	359.50	52.481	9.792	5.360
	B25	0.37	57.430	10.375	5.535
D	B24	337.88	45.724	8.800	5.196
	B21	338.01	49.506	9.400	5.267
	B20	341.65	51.533	9.807	5.255
	B29	341.80	53.711	10.108	5.314
	B17	341.82	52.419	9.890	5.300
	B19	343.70	47.429	8.972	5.286
	B28	347.99	49.853	9.357	5.328
	B31	350.03	41.401	7.961	5.200
	B27	351.66	45.308	8.568	5.288
	B13	351.82	49.738	8.841	5.626
	B18	352.20	44.447	8.348	5.324
	B30	353.88	49.168	9.167	5.364
	B25	357.39	57.276	10.314	5.553

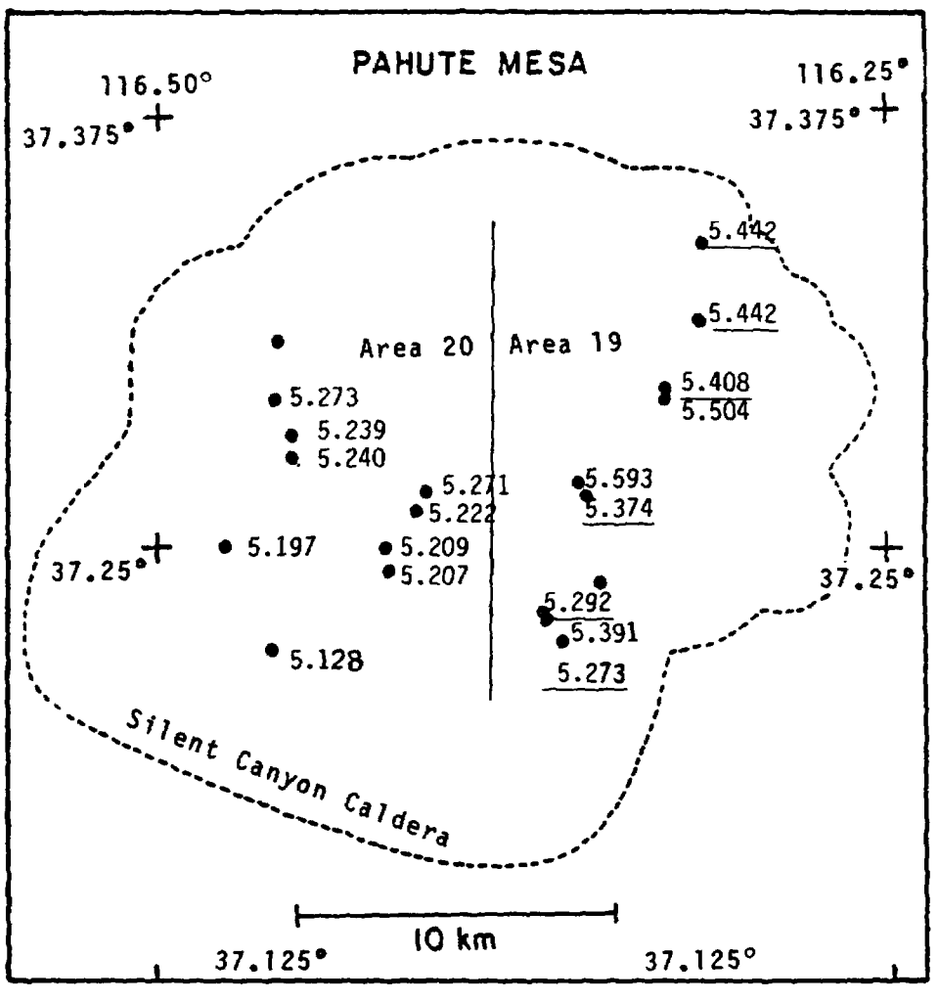
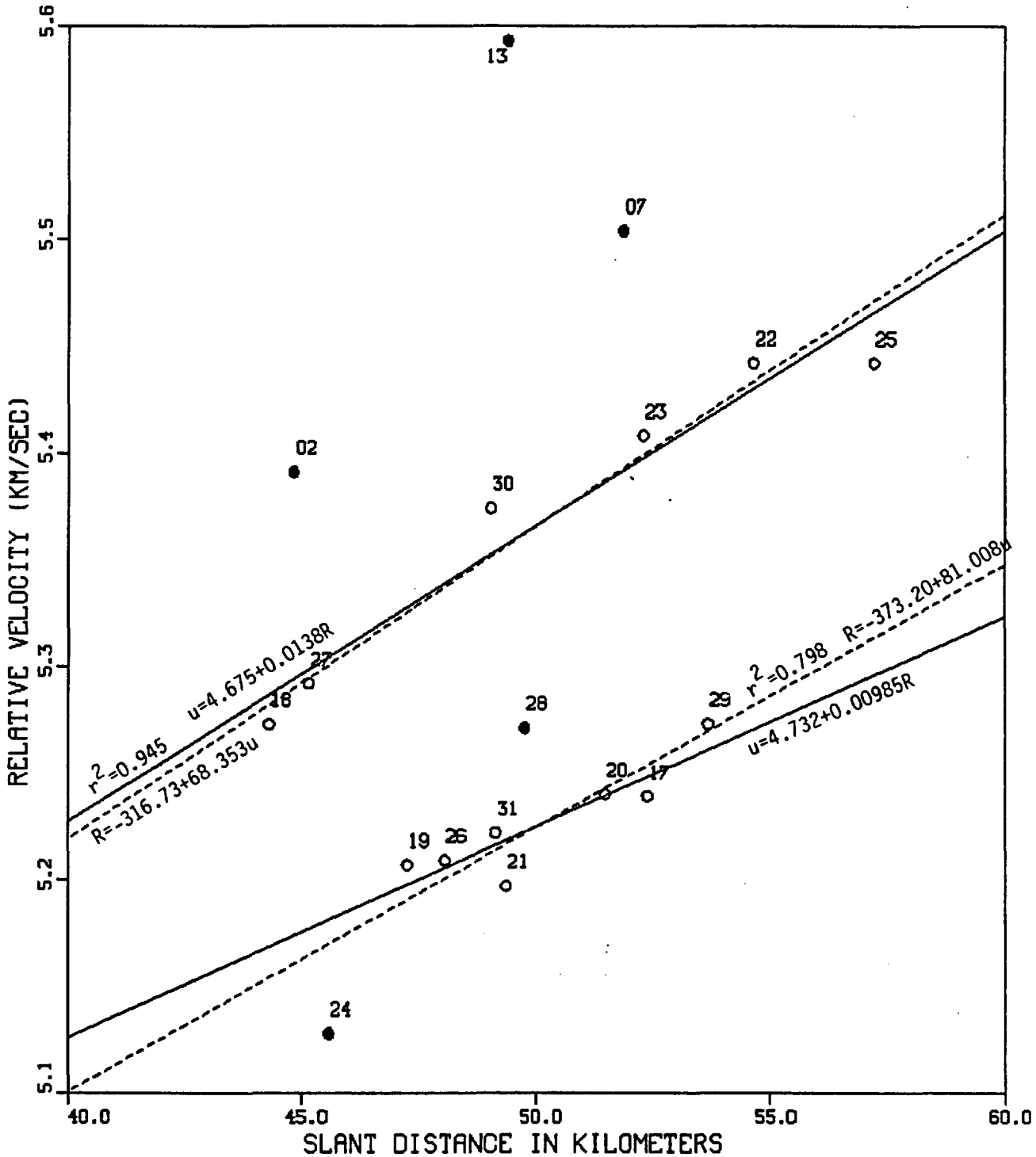


Figure 22. Map of Pahute Mesa showing velocities for events for which measurements were made at Station W-6.

FIGURE 23

STATION W-6

RELATIVE VELOCITY VS. SLANT DISTANCE



The distribution of velocities in Figure 23 shows two different groupings with a spread of about 100 meters per second. In Figure 22 the velocities in the upper set have been underlined except for those for which arrival times are not confirmed. All of the data in the upper data set are in Area 19 and all in the lower data set were in Area 20. Both sets show an expected increase with distance, suggesting that the signals reaching the farther stations travel through deeper and hence higher-velocity media. Although the data have been fit with a linear regression, they suggest that a second order fit would perhaps be a better one.

In Figure 24 the same velocities have been plotted as a function of azimuth about the station. There is a clear trend of increasing velocity with increasing azimuth.

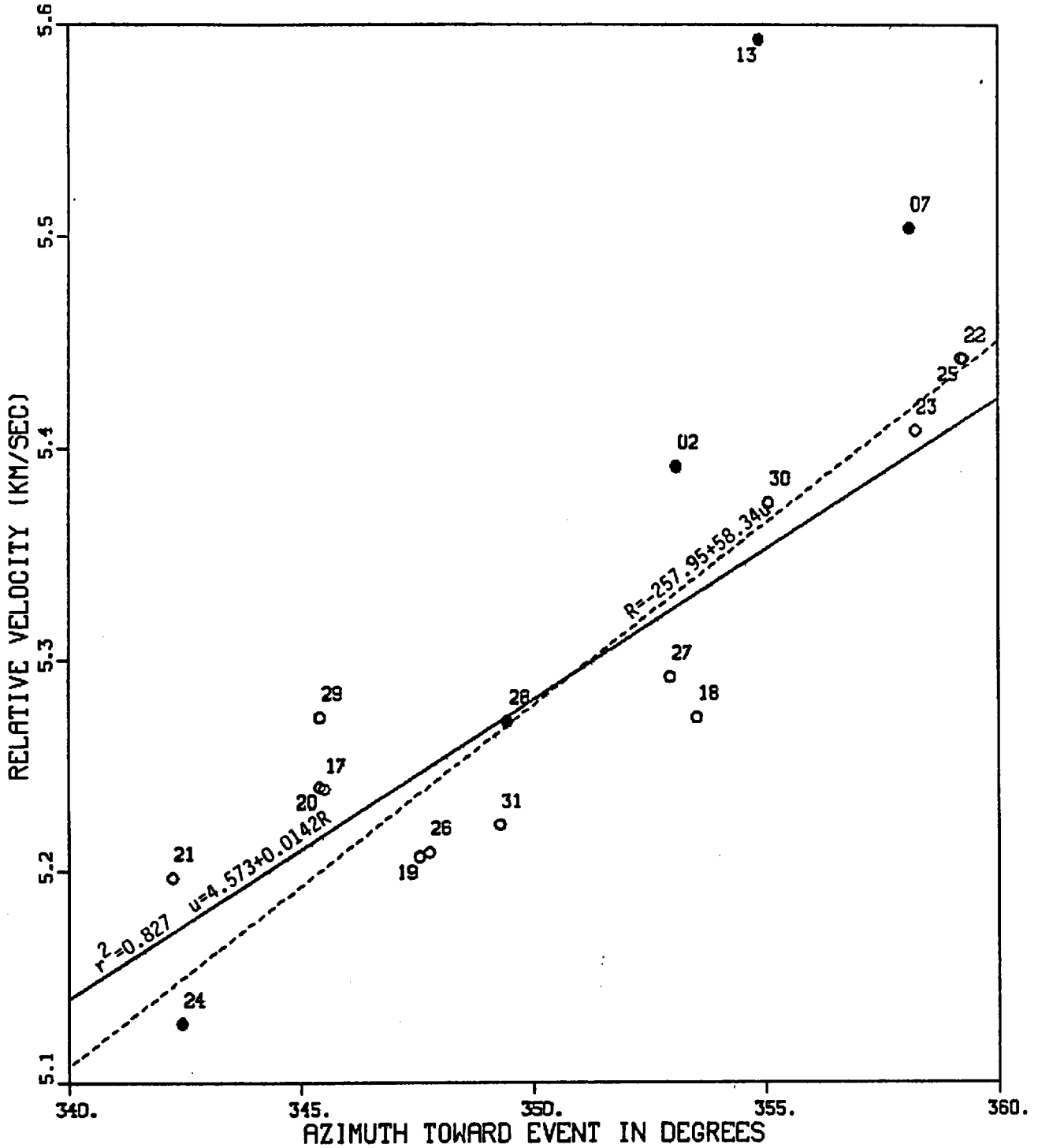
Figure 25 shows the same velocity distribution for Pahute Mesa and Station W-7. Again, the velocities in the upper data set have been underlined and fall in Area 19. Figure 26 shows a distribution for W-7 comparable to that in Figure 23 for W-6. Again, as shown in Figure 27, there is a relatively linear increase in velocity with increasing azimuth.

Figure 28 shows a similar distribution and velocity for Station W-10. Here, too, the data fall into sets of higher and lower velocities as shown in Figure 29. This is in spite of the fact that at Station W-10 the accelerations show no significant enhancement. Figure 30 shows a relatively uniform increase in velocity with increasing azimuth.

FIGURE 24

STATION W-6

RELATIVE VELOCITY VS. AZIMUTH TOWARD EVENT



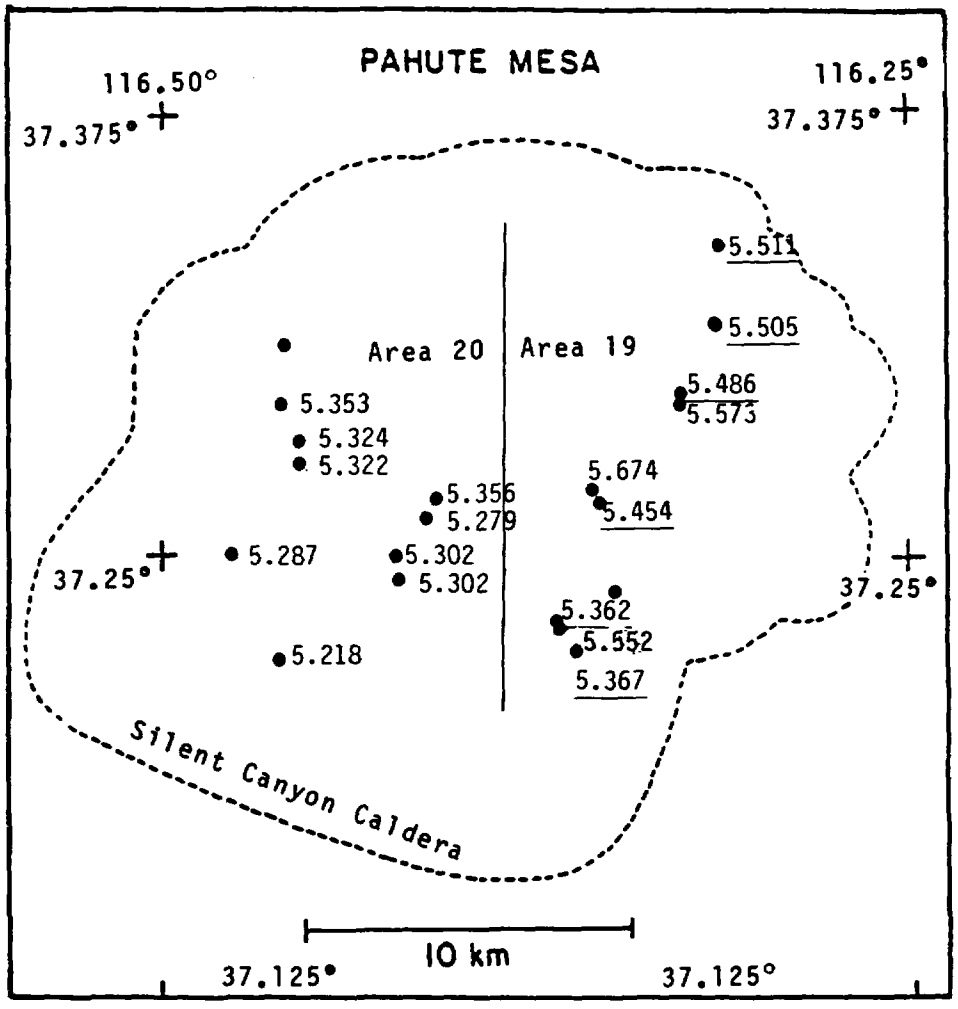


Figure 25. Map of Pahute Mesa showing velocities for events for which measurements were made at Station W-7.

FIGURE 26

STATION W-7

RELATIVE VELOCITY VS. SLANT DISTANCE

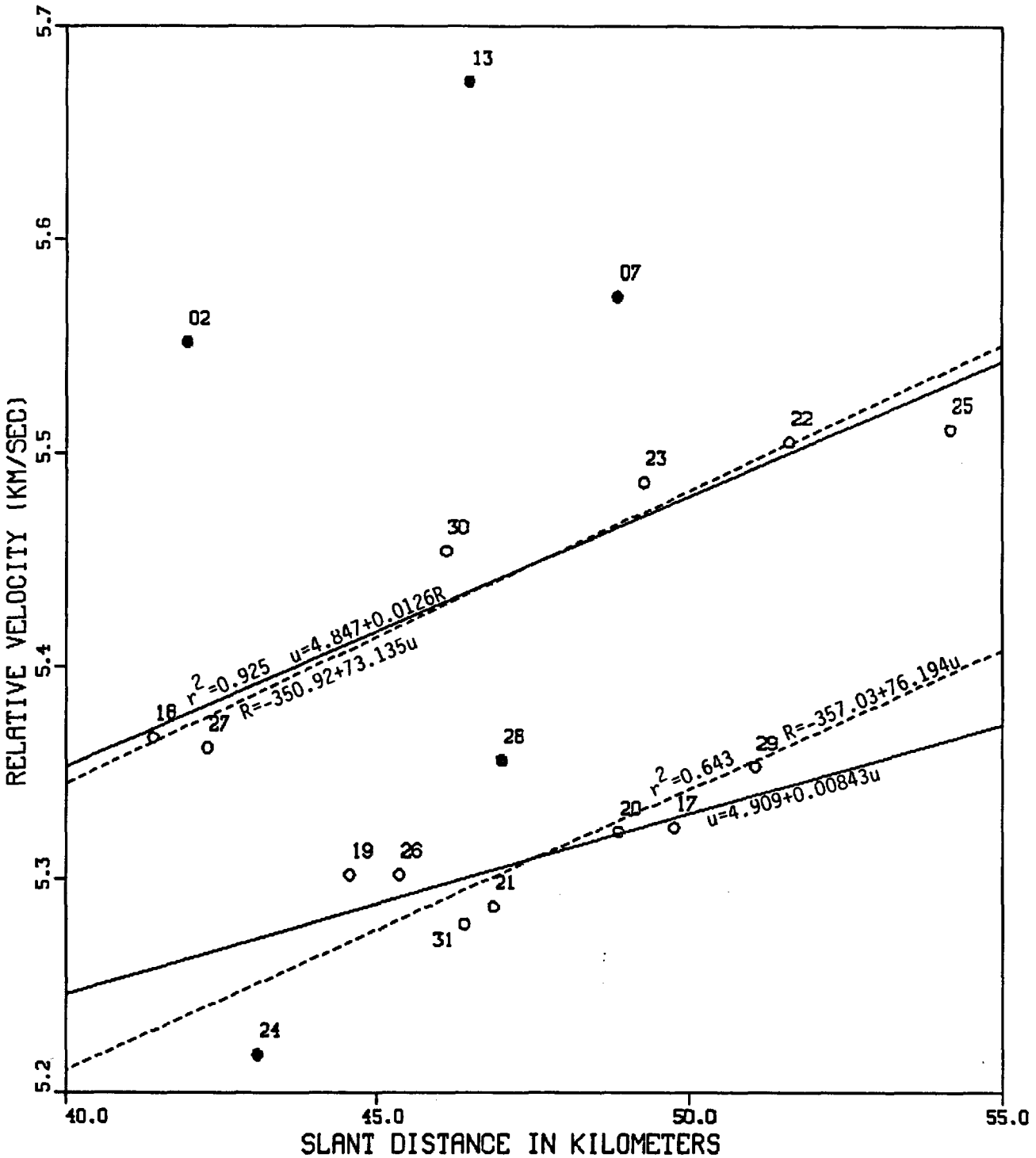
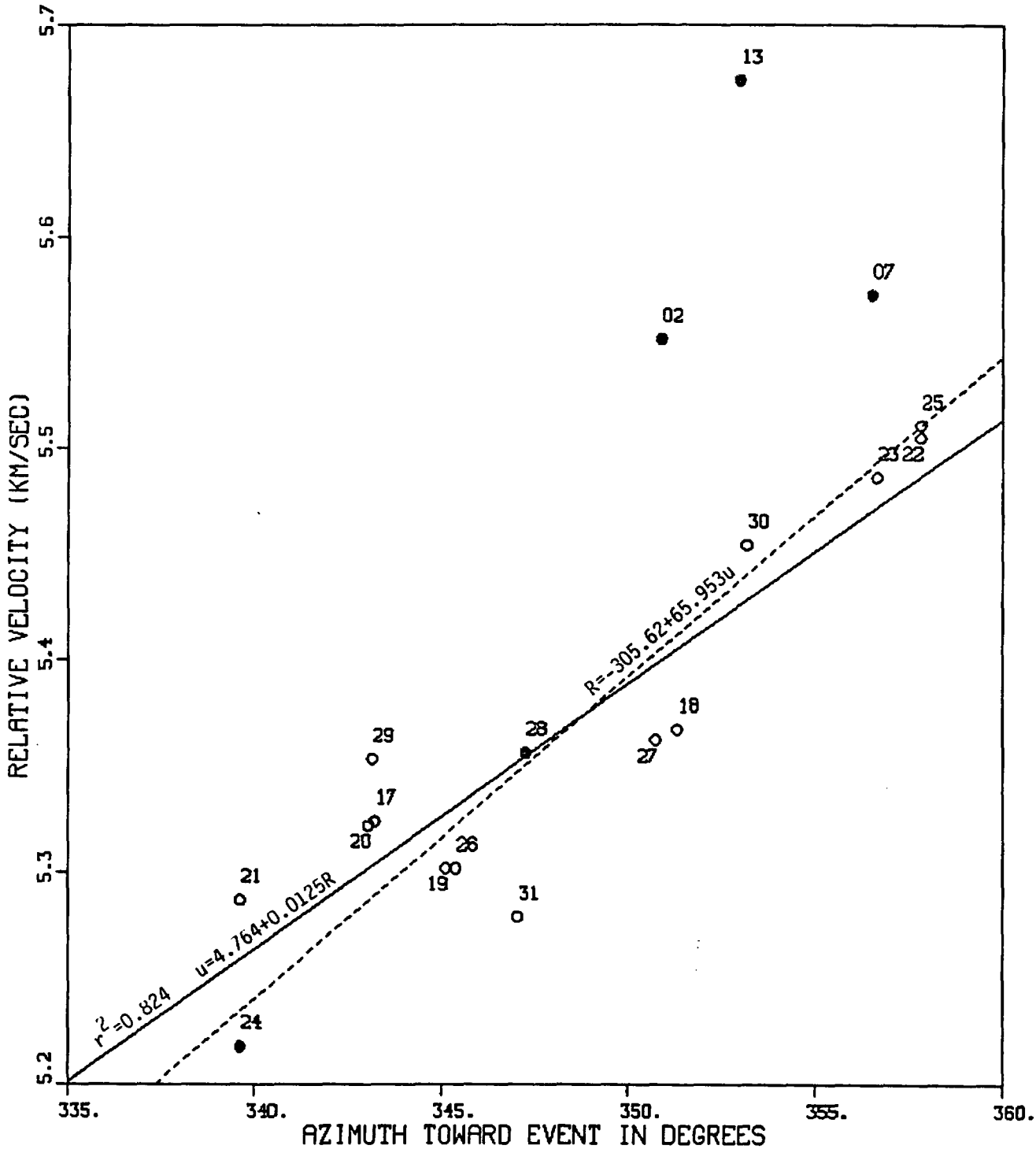


FIGURE 27

STATION W-7

RELATIVE VELOCITY VS. AZIMUTH TOWARD EVENT



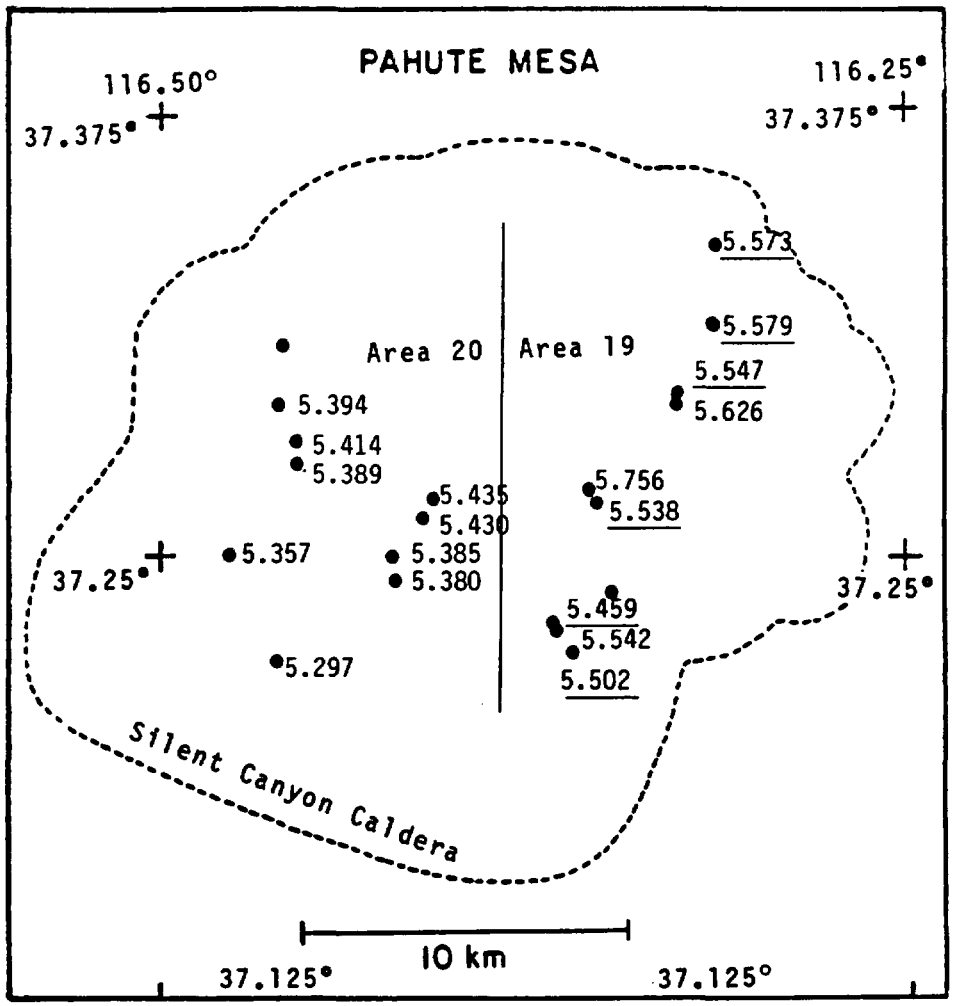


Figure 28. Map of Pahute Mesa showing velocities for events for which measurements were made at Station W-10.

FIGURE 29

STATION W-10

RELATIVE VELOCITY VS. SLANT DISTANCE

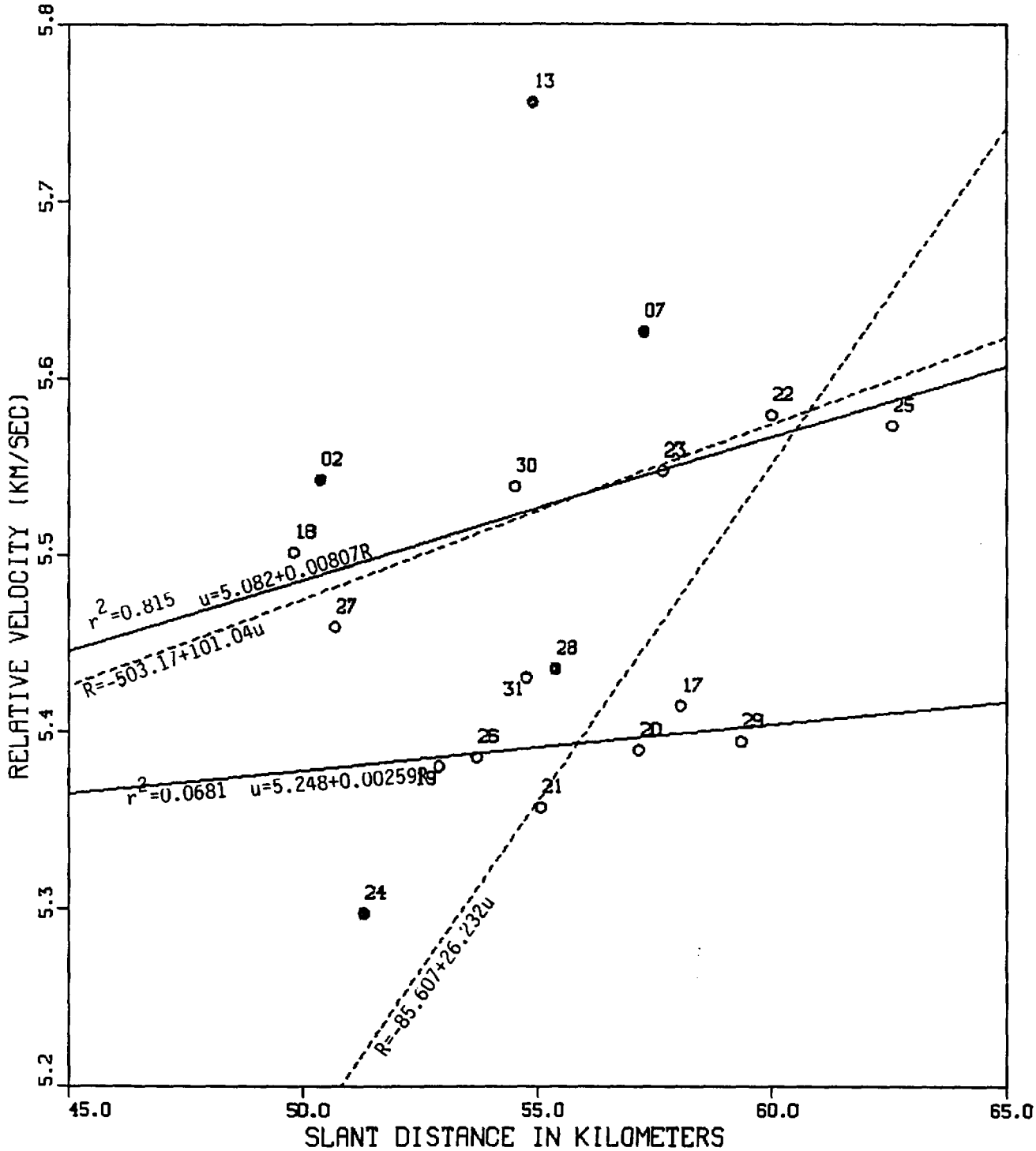
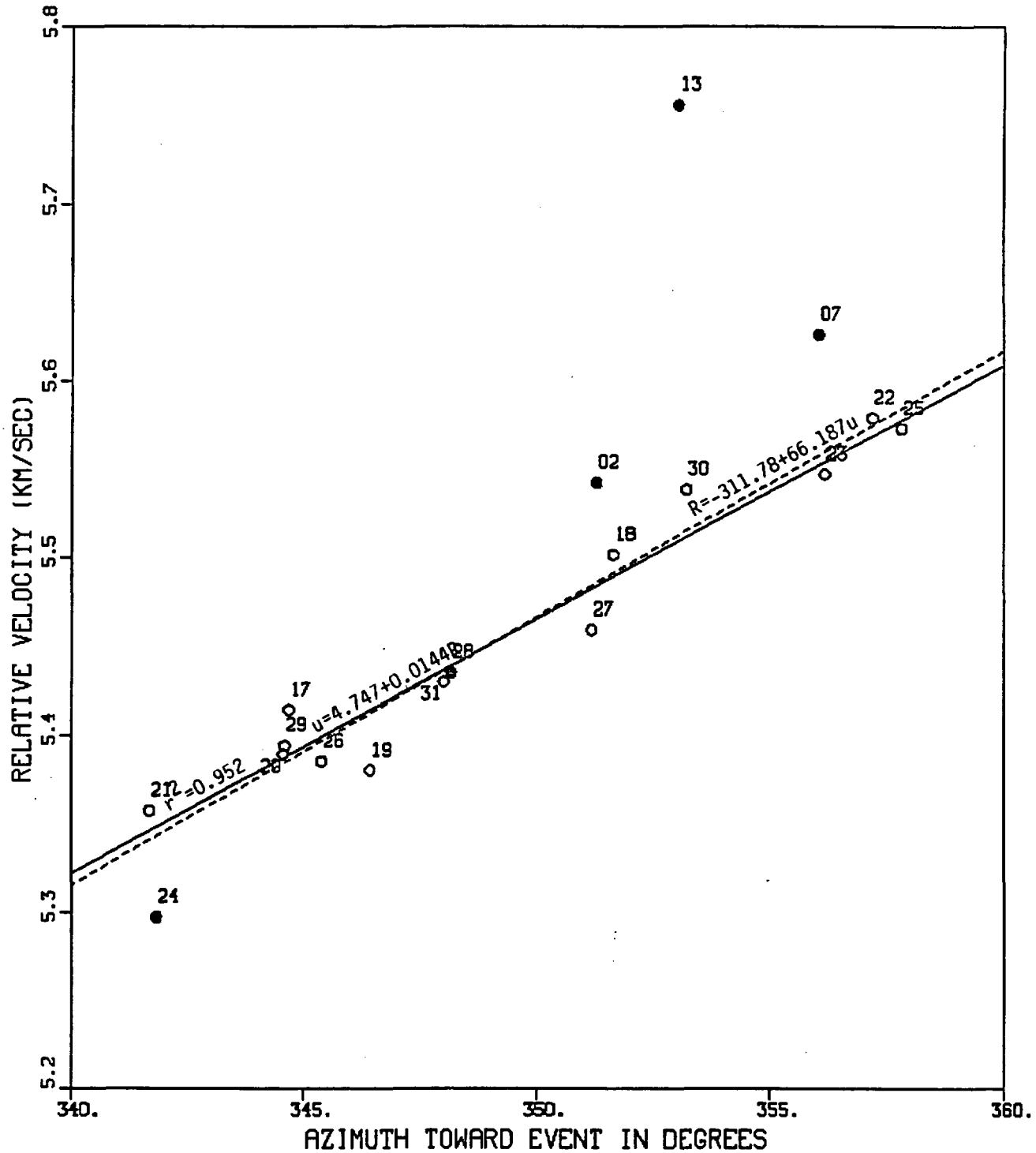


FIGURE 30

STATION W-10

RELATIVE VELOCITY VS. AZIMUTH TOWARD EVENT



Although Stations A, B, C, and D were not at fixed locations (see Figure 19) the location of each station varied over only about 1.3 to 3.0 kilometers. Hence, in the following they are treated as though they were located each at a single location.

The velocities for Station A are shown in Figure 31 and plotted as a function of distance in Figure 32. There is only a slight hint of higher and lower velocity sets. As shown in Figure 33, the trend of increasing velocity with increasing azimuth is much less than seen in the previous figures.

Corresponding information for Station B is shown in Figures 34, 35, and 36. Figure 35 shows a greater separation of a high velocity data set from a low velocity data set than was seen at Station W-6.

Similar data for Station C is shown in Figures 37, 38, and 39. Here there is no clearcut separation into two separate data sets in spite of the fact that locations span across the W-6 location. The velocity for event B-25 appears high, relative to the other verified data; however, this data point has been carefully checked and the arrival time and distance ascertained. Nevertheless, the data are believed to be valid and no explanation exists for this larger velocity.

Similar information is shown for Station D in Figures 40, 41, and 42. Again, event B-25 shows a high velocity but the remaining events show relatively little trend of increasing velocity with distance making the set quite different from nearby Stations W-6 and W-7. Trends with azimuth also are smaller than seen before, except for Station C.

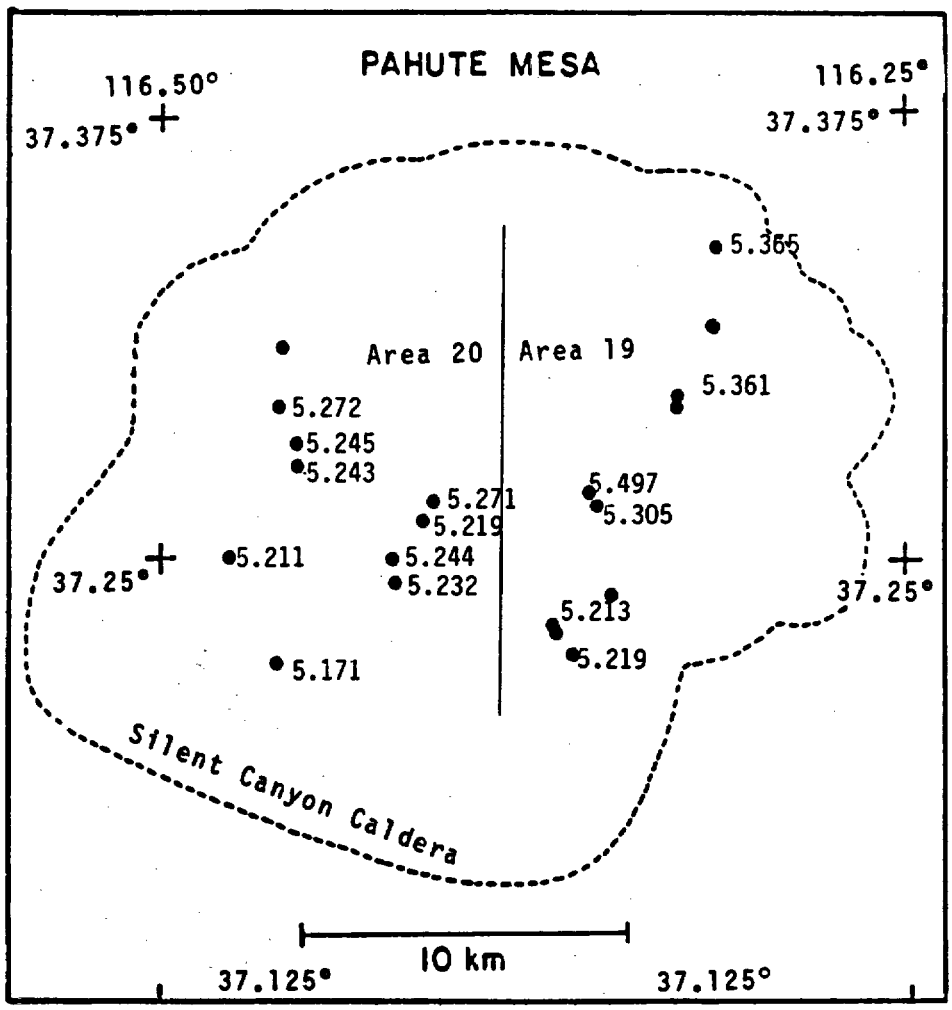


Figure 31. Map of Pahute Mesa showing velocities for events for which measurements were made at Station A.

FIGURE 32

STATION A

RELATIVE VELOCITY VS. SLANT DISTANCE

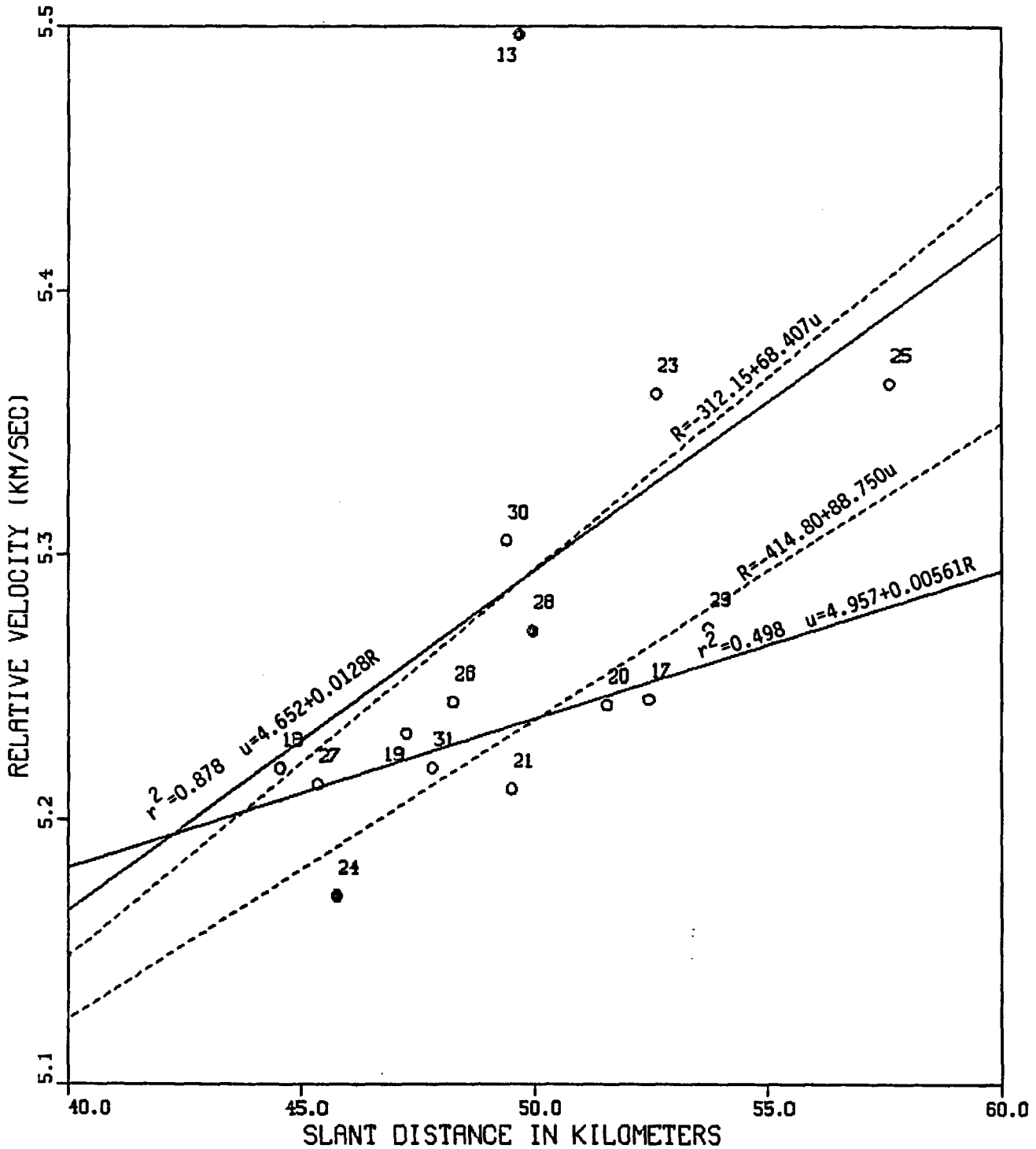
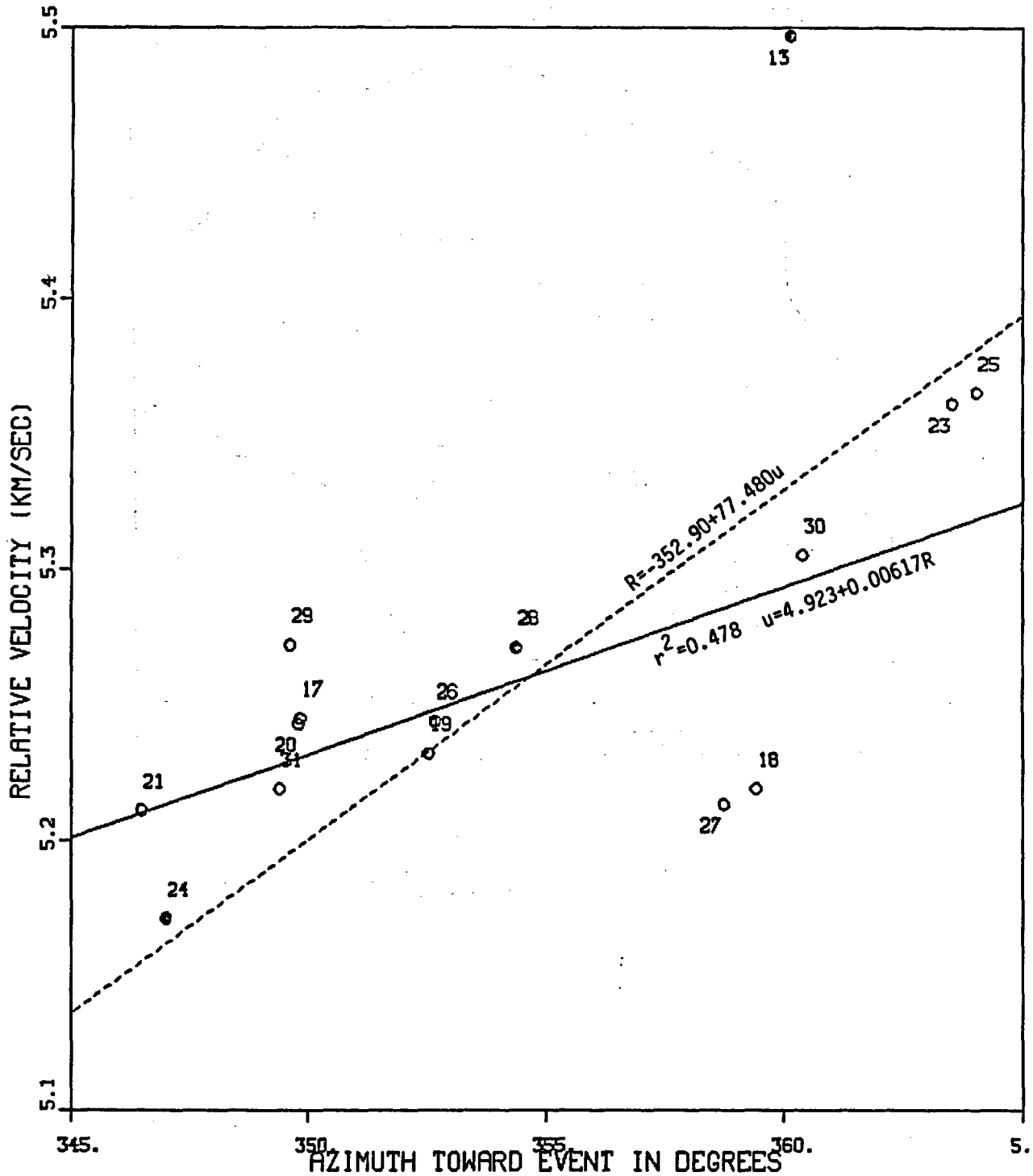


FIGURE 33

STATION A

RELATIVE VELOCITY VS. AZIMUTH TOWARD EVENT



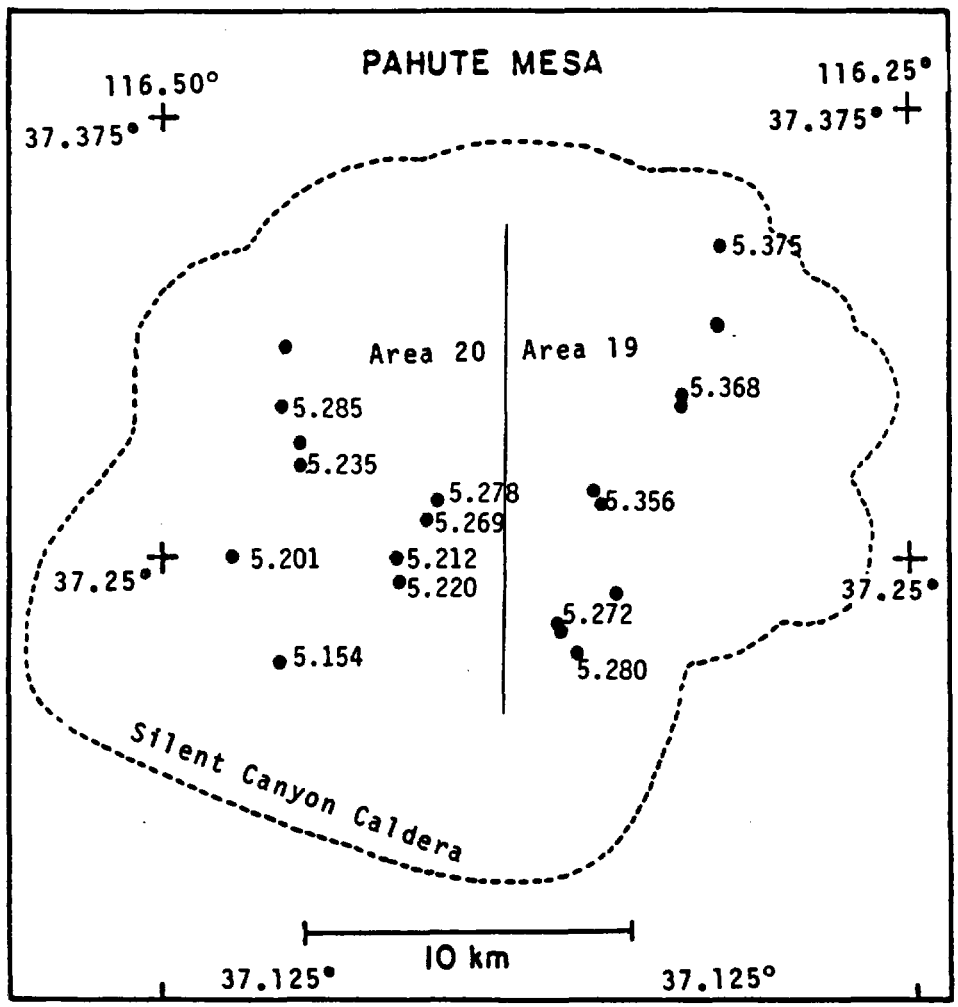


Figure 34. Map of Pahute Mesa showing velocities for events for which measurements were made at Station B.

FIGURE 35

STATION B

RELATIVE VELOCITY VS. SLANT DISTANCE

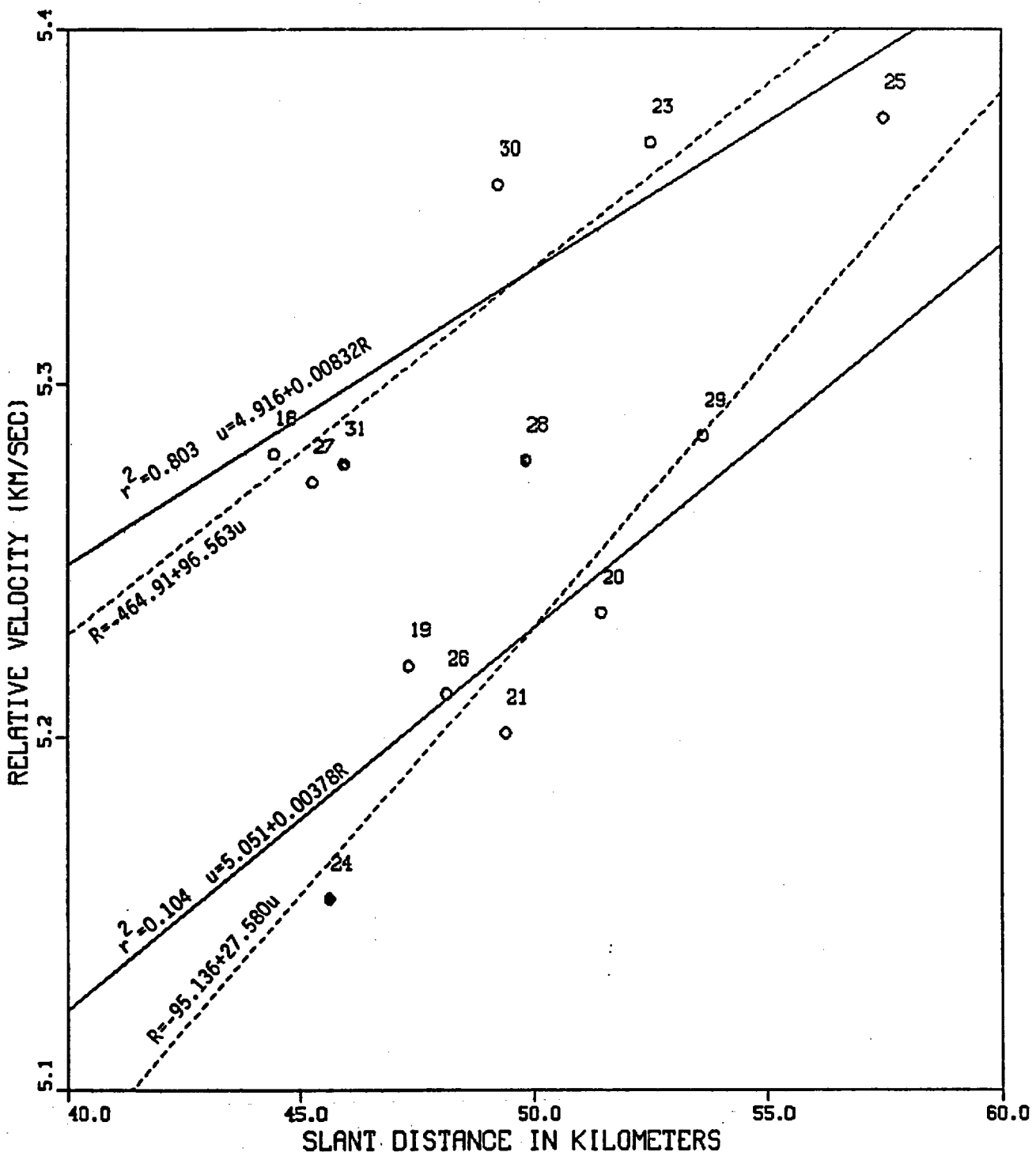
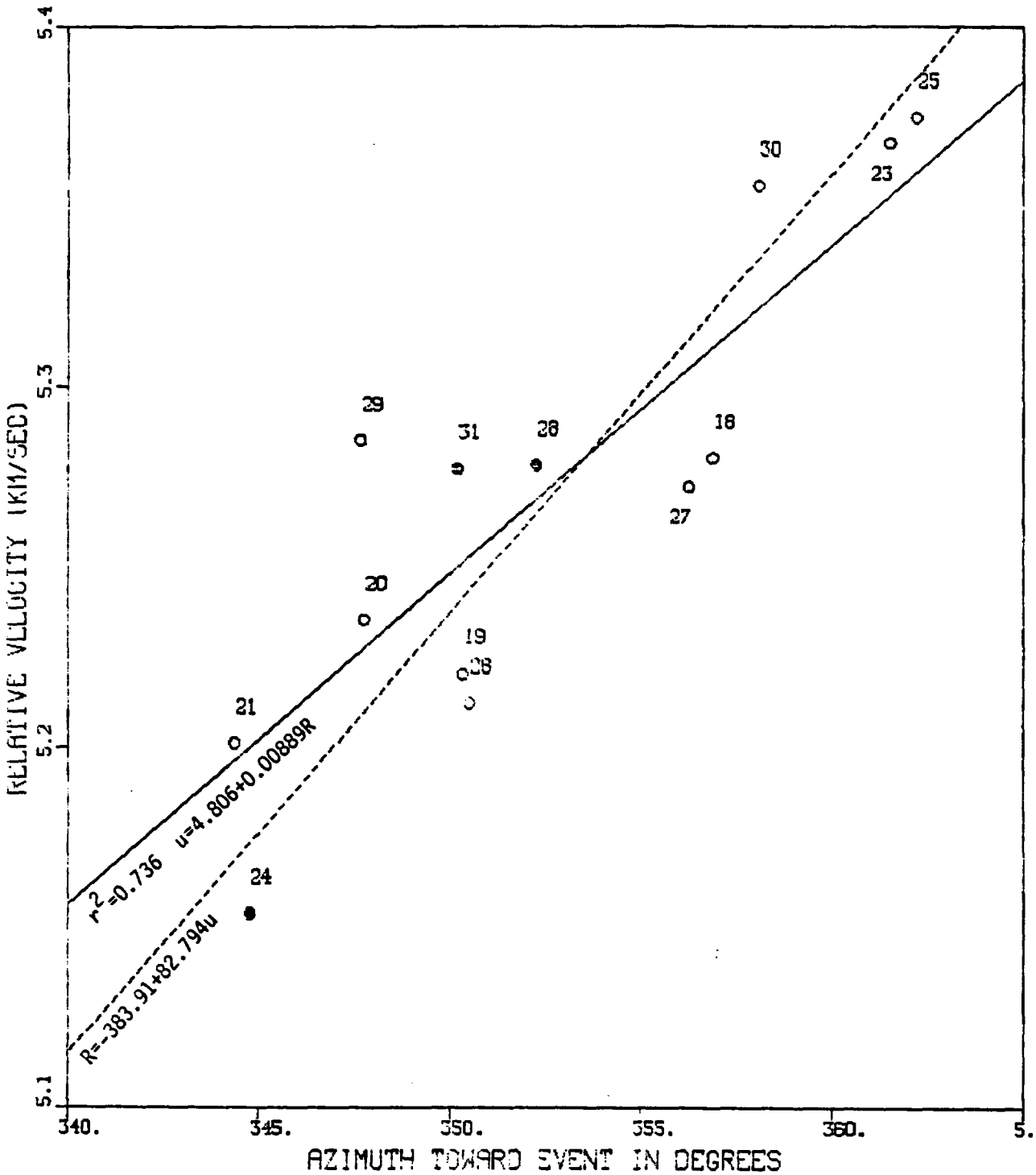


FIGURE 36

STATION B

RELATIVE VELOCITY VS. AZIMUTH TOWARD EVENT



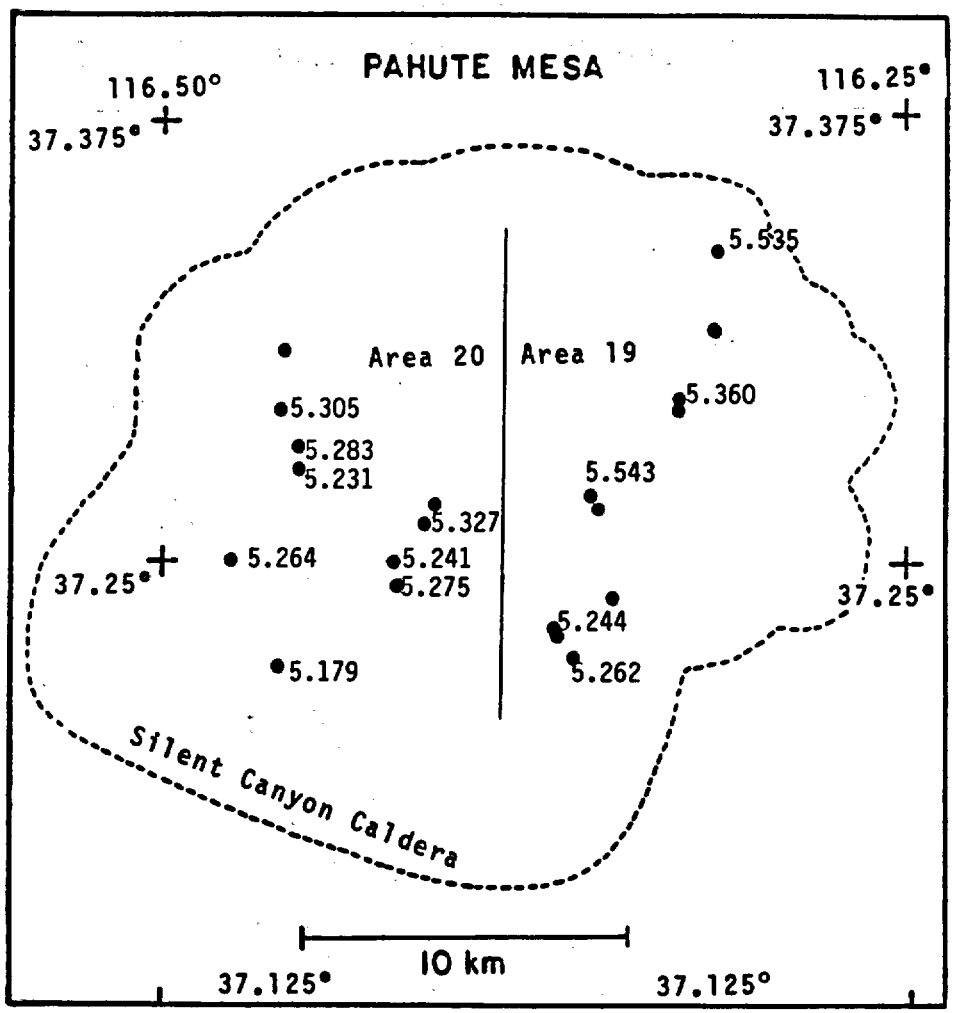


Figure 37. Map of Pahute Mesa showing velocities for events for which measurements were made at Station C.

FIGURE 38

STATION C

RELATIVE VELOCITY VS. SLANT DISTANCE

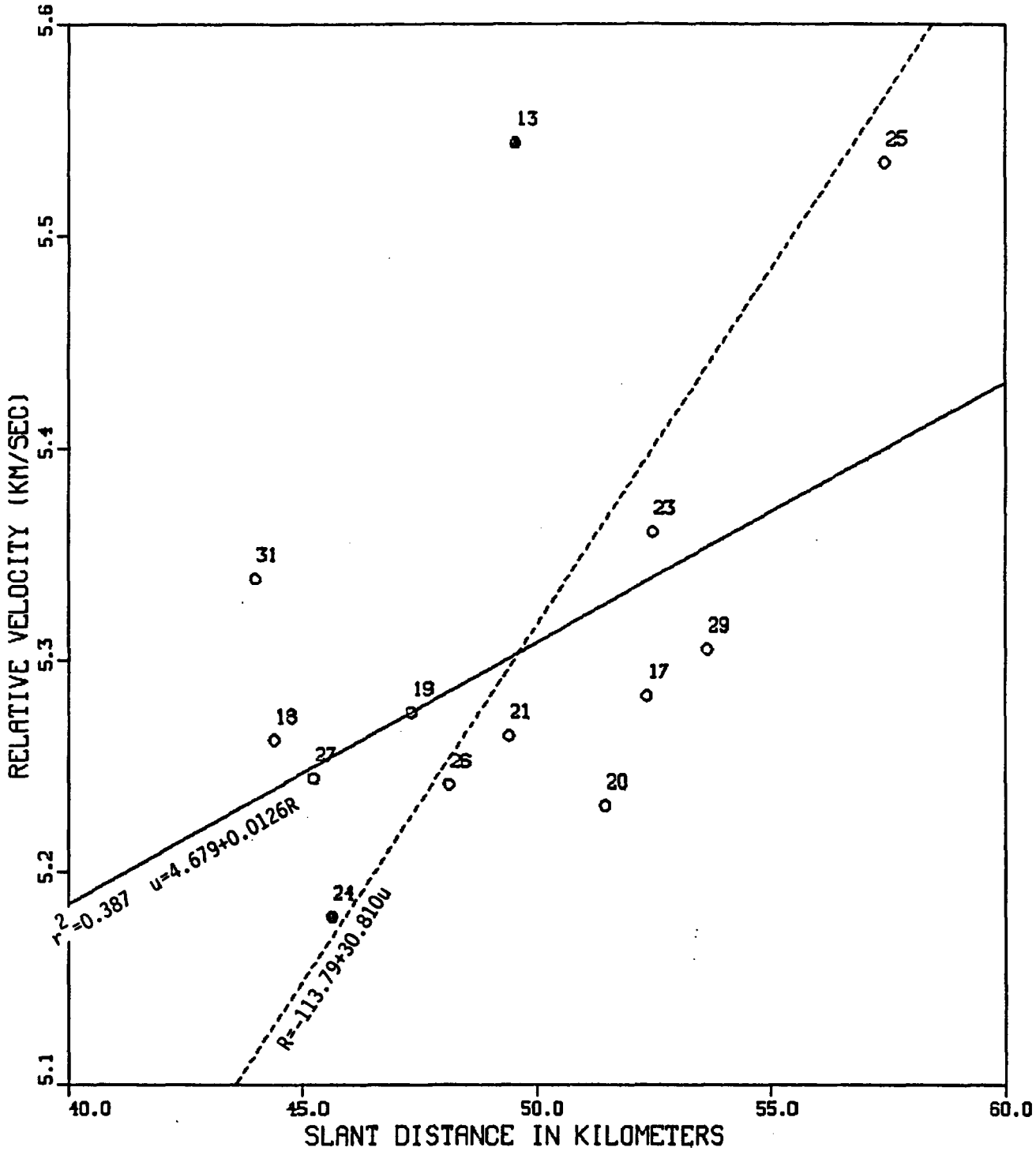
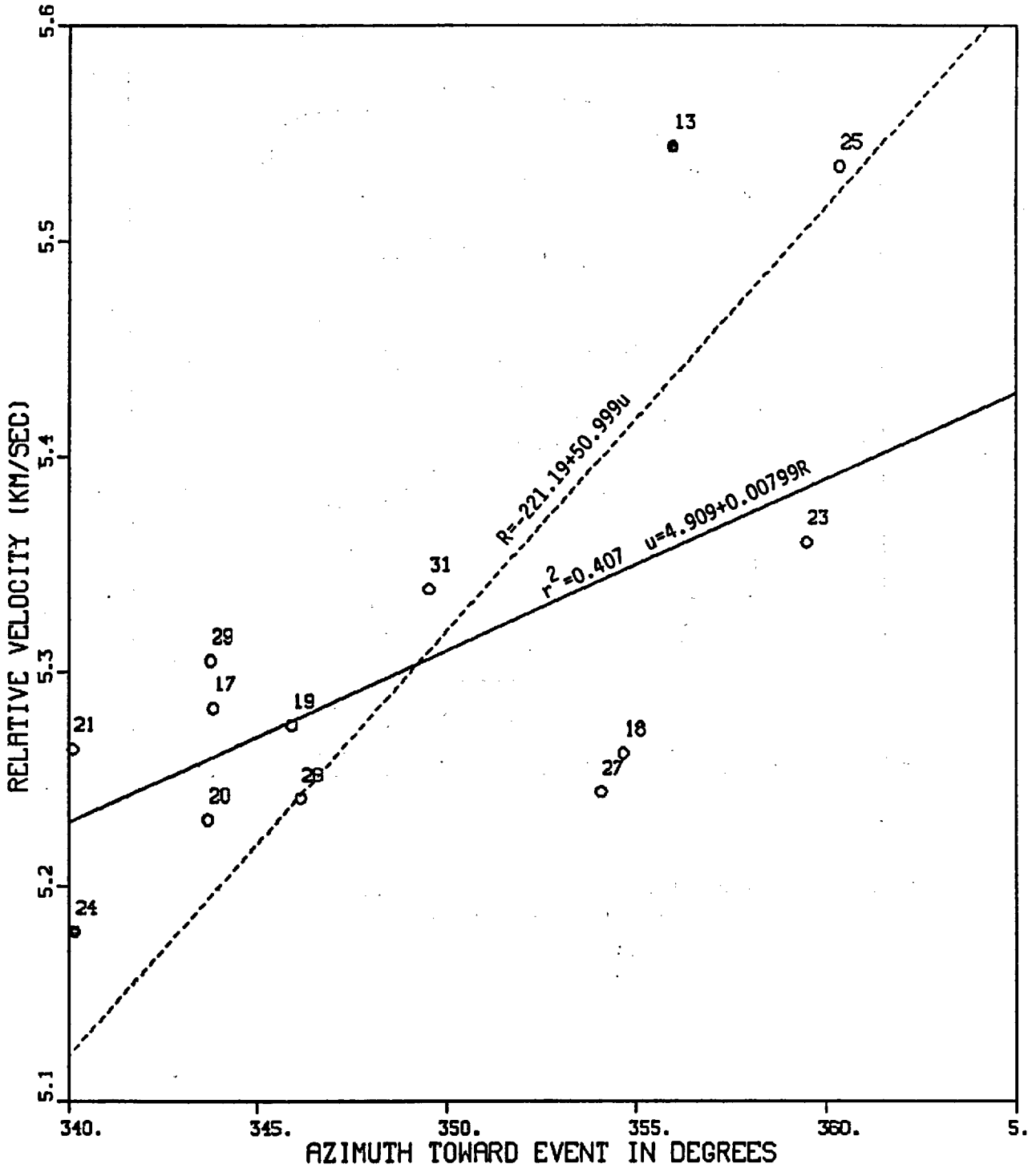


FIGURE 39

STATION C

RELATIVE VELOCITY VS. AZIMUTH TOWARD EVENT



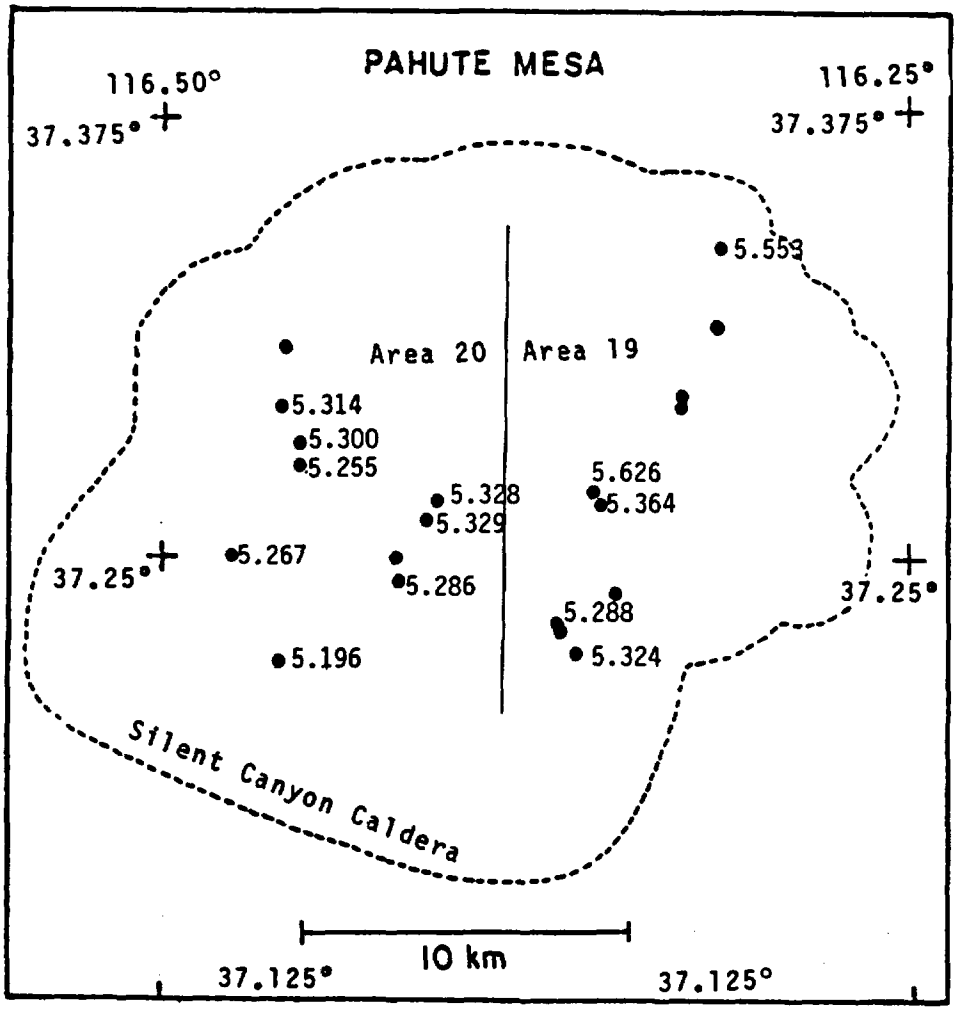


Figure 40. Map of Pahute Mesa showing velocities for events for which measurements were made at Station D.

FIGURE 41

STATION D

RELATIVE VELOCITY VS. SLANT DISTANCE

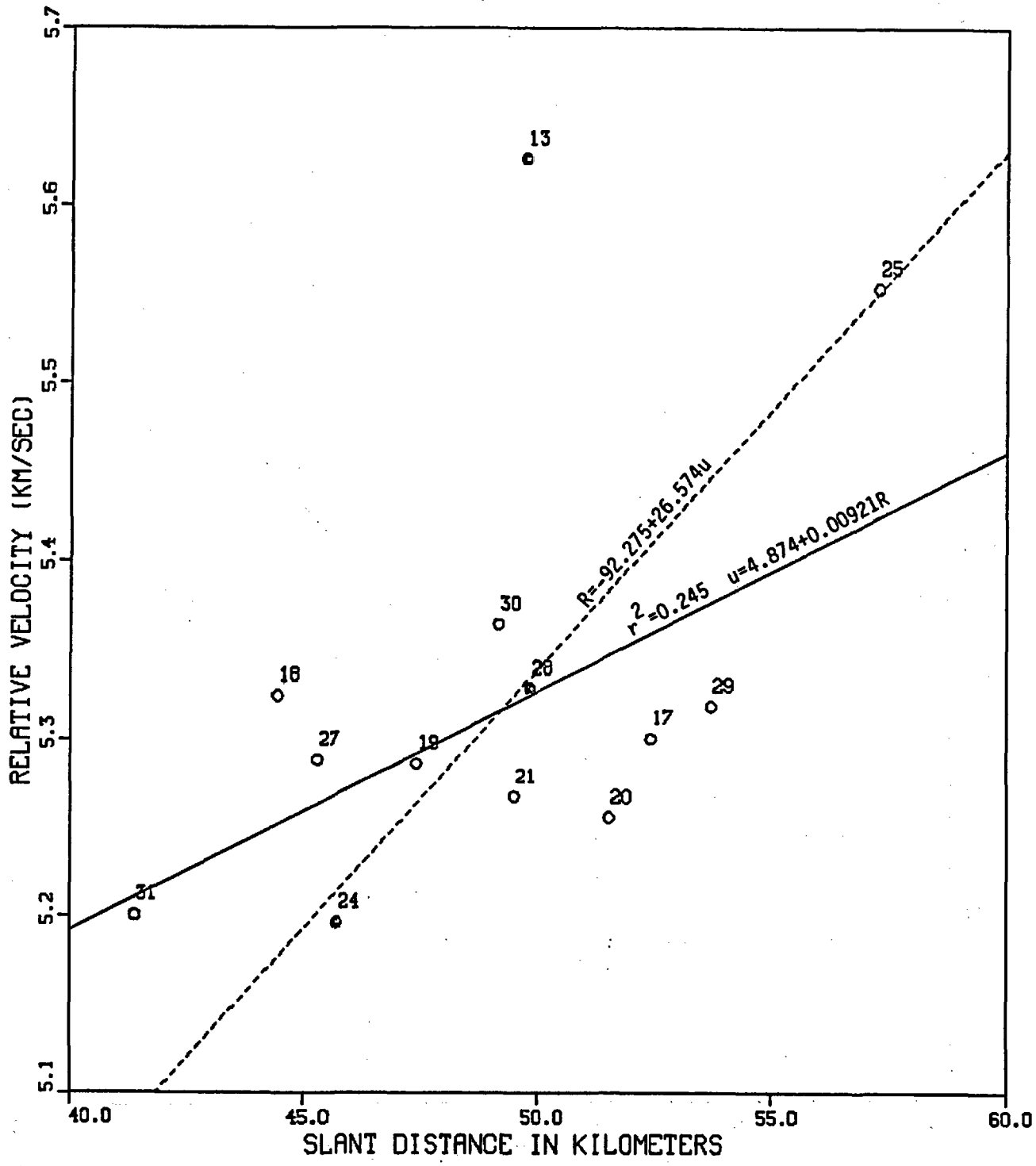
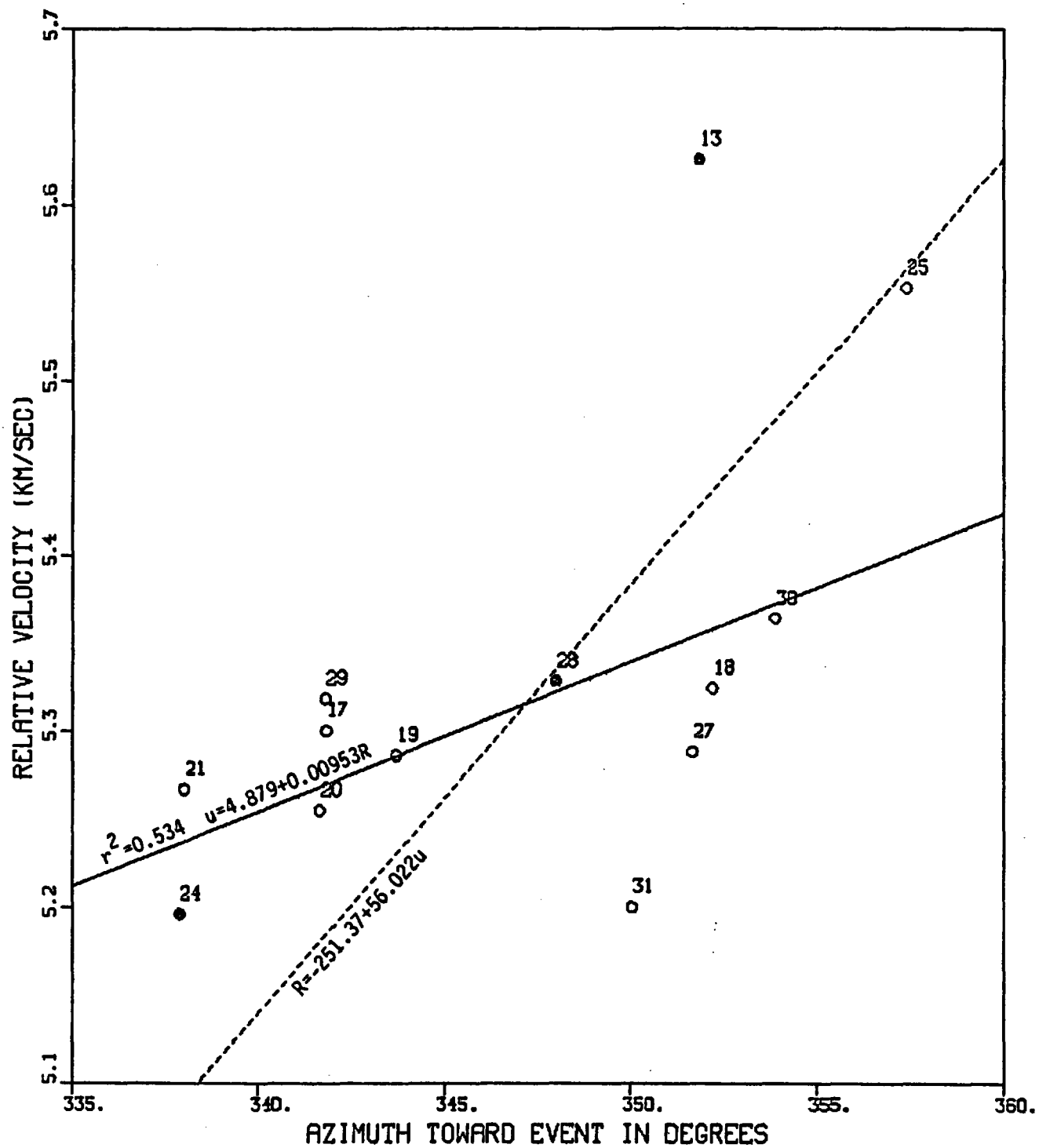


FIGURE 42

STATION D

RELATIVE VELOCITY VS. AZIMUTH TOWARD EVENT



In view of the foregoing, it should be clear that highest acceleration ratios were seen for Area 20 in the region where the lowest velocities were observed and the reverse was true for Area 19. All shots occurred within the Silent Canyon Caldera for which Healey[10] shows a pronounced gravity low within the boundaries of the caldera with a strong gravity gradient at the caldera boundary. His gravity map suggests relatively little difference between the Area 19 and 20 portions of the caldera.

All transmission paths from the Silent Canyon Caldera to the stations at NRDS must pass through the Timber Mountain Caldera. Healey shows no particular gravity departure with respect to the Timber Mountain Caldera. Carr and Quinlivan[11] say "Gravity profiles prepared by D. L. Healey and C. H. Miller (written commun., 1965), using reliable density data for the Cat Canyon, allow for a body of granite about 10,000 ft below the top of Timber Mountain (about 3,000 ft below sea level)."

The difference in velocity between events in Area 19 and Area 20 are consistent with transmission paths through a high-velocity layer such as granite occurring at a shallower depth along the transmission paths from Area 19 than along those from Area 20. Said another way, the deeper depths for transmissions from Area 20 may allow first arrivals to be delayed and allowed to coincide with later-arriving pulses following shallower paths, thus providing the large acceleration ratios observed for Area 20 events.

Figure 19 shows that the increase in acceleration ratio vectors is relatively narrow in an east-west direction. It is possible that this narrow distribution is accounted for by local geology in near proximity

to the north of Station W-6 in addition to the observed differences seen in the foregoing in velocities from the events within the Silent Canyon Caldera. This leaves a possibility that this narrow distribution of ratio vectors could be related to the aeromagnetic high at Calico Hills. Thus, both the Timber Mountain Caldera and Calico Hills geology may be contributing to the observed anomalies at NRDS.

CHAPTER 4. ANOMALOUS GROUND MOTION AT YUCCA MOUNTAIN

Having addressed the matter of anomalous ground motion in the NRDS area it is in order to ask whether or not similar anomalously high accelerations exist at Yucca Mountain.

Table XVIII lists the ratios with coupling removed for peak vector acceleration, velocity, and displacement for stations at Yucca Mountain. Ratios are for Group III data. Again, the events are listed in order of increasing azimuth. Three recent events, B29, B30, and B31, have been included in the table even though data from those three events were not included in the data set from which Equations 37, 38, and 39 were derived.

Figure 43 is an aeromagnetic map[9] of the Yucca Mountain area showing a pronounced low at the north end of Yucca Mountain with a sharp gradient on its north side to a high. There is another major high in the vicinity of Dome Mountain. Again, the peak vector acceleration ratios are shown as vectors for each of the measurements made. Because of the tight clusters of vectors, no effort has been made to identify the events from which each ratio was derived. This can best be done by comparing Figure 43 with Table XVIII. Ratio vectors are shown for Stations 26 and 27 for one event. These stations were not listed in Table II, having been installed after the table was prepared. Several things can be noted from the figure and table:

a. There are 17 ratios greater than 2, with the largest being 4.19 at Station W-22 from event B27.

Table XVIII. Ratios for Stations at Yucca Mountain

Station	Event	Azimuth (°) Toward Event	Group III a Eq. 37	u Eq. 38	d Eq. 39
W-12	B29	0.52	0.46	1.24	1.68
	B31	5.58	0.70	1.47	2.44
	B30	10.99	0.78	1.27	1.72
W-14	B21	355.41	1.18	1.70	2.32
	B24	356.86	0.97	1.31	1.51
	B17	358.09	2.67	1.90	2.27
	B20	358.21	2.15	1.73	2.34
	B26	1.72	1.65	1.62	1.93
	B19	1.75	1.72	1.93	2.01
	B31	2.95	1.12	1.42	1.94
	B28	2.97	1.64	2.03	1.97
	B27	8.08	1.21	1.53	1.69
	B18	8.97	1.18	1.69	1.78
	B25	11.13	1.21	2.01	2.58
	B23	11.30	1.39	1.92	2.00
	B22	11.77	2.38	2.83	3.05
W-20	B21	357.76	2.92	2.37	2.23
	B24	359.48	2.04	1.93	1.67
	B23	13.80	3.20	2.25	2.15
	B22	14.15	3.12	3.19	2.28
W-21	B24	0.21	1.46	1.25	1.70
	B29	0.42	0.93	1.22	1.67
	B26	4.71	2.91	2.16	1.96
	B31	5.84	1.20	1.42	2.51
	B27	11.00	2.01	1.65	1.95
	B30	11.63	1.06	0.99	1.28
	B25	13.31	1.35	2.56	3.74
	B23	13.68	1.79	1.57	2.15
	B22	14.02	1.19	1.91	2.85
W-22	B24	2.38	1.34	1.44	1.36
	B26	6.97	2.55	1.40	1.36
	B27	13.72	4.19	2.02	1.18
	B25	15.47	1.35	1.66	2.00
	B23	16.08	2.16	1.37	1.66
W-23	B21	355.75	1.77	2.69	2.18
	B24	357.35	1.42	2.56	1.67
	B29	358.10	0.86	1.40	1.24
	B26	2.96	1.95	1.19	1.09
	B27	9.40	2.35	3.01	1.88
	B30	10.25	1.17	1.83	1.10
	B25	12.29	1.82	3.17	2.95
	B23	12.59	3.00	2.64	2.46
	B22	13.02	2.61	3.00	2.29
W-24	B29	359.67	0.70	0.82	1.03
	B26	4.08	2.75	1.42	1.26

Table XVIII. Ratios for Stations at Yucca Mountain (Cont'd)

Station	Event	Azimuth (°) Toward Event	Group III a Eq. 37	Group III u Eq. 38	Group III d Eq. 39
W-25	B31	5.28	1.96	1.04	1.52
	B30	11.54	1.97	0.99	0.89
W-26	B31	1.17	1.10	1.12	1.38
W-27	B31	1.34	0.96	0.99	1.42
W-15	B21	346.14	0.71	1.49	1.62
	B24	347.04	0.28	0.85	1.29
	B29	350.45	0.43	0.91	1.13
	B20	350.79	0.98	1.58	1.87
	B17	350.87	0.98	1.14	1.62
	B19	355.04	0.97	2.01	2.12
	B26	355.18	0.71	1.26	1.54
	B28	357.37	3.51	3.06	2.55
	B27	4.33	0.73	1.29	1.33
	B23	9.70	0.86	1.28	1.40
W-16	B24	343.15	0.91	0.70	0.71
	B20	347.47	0.86	0.89	1.05
	B17	348.11	1.13	0.68	0.81
	B19	351.16	0.87	0.84	0.92
	B28	354.22	1.14	0.79	0.70
	B27	0.03	0.52	0.50	0.53
	B18	1.55	0.37	0.60	0.63
	B23	6.28	0.46	0.77	0.95
	B25	6.67	0.40	0.76	1.07
	B22	7.25	0.42	0.64	0.80

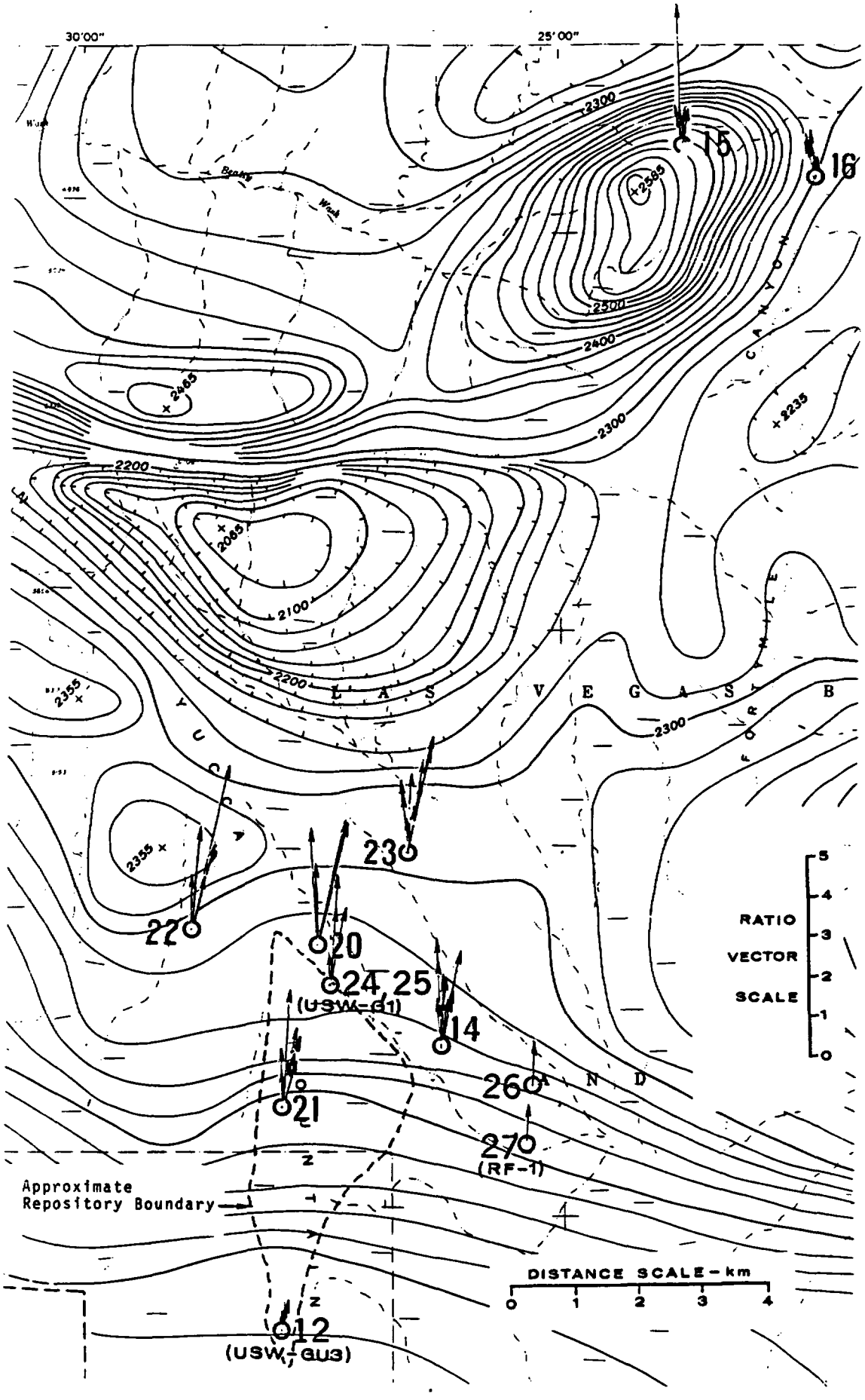


Figure 43. Aeromagnetic map of the Yucca Mountain area showing peak vector acceleration ratios.

b. None of the ratios are as large as the largest seen at the NRDS area.

c. All four of the ratios at Station 20 are greater than 2.

d. Nine events produced the 17 ratios greater than 2. Three of the events were in Area 19 and six in Area 20. The three events in Area 19 produced four of the five largest ratios. This is in contrast to the NRDS pattern where the 19 largest ratios (3 and above) were from Area 20 events.

Figure 44 is a map of Pahute Mesa showing the ratios for events for which measurements were made at the various stations at Yucca Mountain. The map shows ratios larger than 2 where they exist. For events with no ratio larger than 2 the largest from that event is shown. The numbers in parentheses are the stations at which each ratio was observed. There are five events for which no ratio is shown. These are events which occurred before any stations were installed at Yucca Mountain. Again, no relation between the ratios and their location with respect to the boundary of the Silent Canyon Caldera can be seen.

The pattern of the largest ratios is quite different from that shown in Figure 21 for measurements made at Station 6 in the NRDS area.

The data base on which the recommended prediction equations were based (Group III) had excluded data from areas of known anomalies and from Yucca Mountain. (See Chapter 1.) For example, Equation 37 predicts 58 mg as a mean value for 700 kt at a distance of 22.8 km. This was predicated on

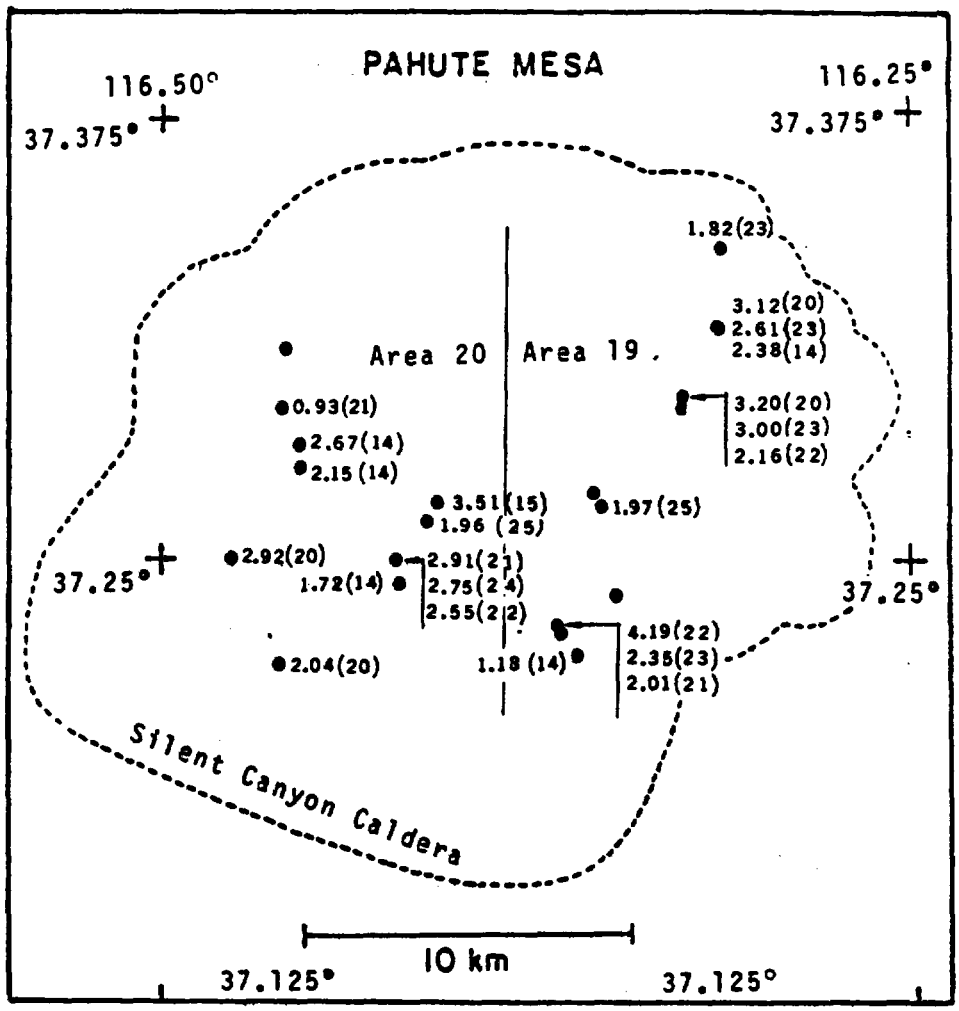


Figure 44. Map of Pahute Mesa showing the ratios for events for which measurements were made at the various stations at Yucca Mountain.

a test being conducted in the Buckboard Area at the point closest to the repository shaft. If the Buckboard Area generated anomalies comparable to those observed for Pahute Mesa events, the largest amplification would be 4.19 (Figure 44). Thus, an anomalous value of 243 mg would have to be expected. This, then is the enhanced acceleration. Since these values were not included in deriving the prediction equation, the standard error of the estimate must be added as though 243 mg were the mean. Thus, the 1σ value from Equation 37 would be 0.39 g, and the 2σ value 0.64 g.

Figure 45 shows the velocities (from Table XIX) for the events for which measurements were made at Station W-14. Here again velocities show a general increase smallest in the southwest portion of the Caldera to largest in the northeast portion. A plot of velocity vs slant distance (Figure 46) shows a relatively uniform increase in velocity with distance. Figure 47 shows the increase in velocity with increasing azimuth which is not as large as was seen for some of the stations in the NRDS area.

No plots are shown for Stations 12, and 20-28, because the number of events was too small for a pattern of velocity distribution to be developed.

In Figure 43 the vectors for Station W-15 are shown to be small except for that from Event B28. The distribution of velocities for that Station are shown in Figure 48. Again the smaller velocities tended to be in the southwestern portion and the larger values in the northeastern portion. There is quite a strong trend (Figure 49) of increasing velocity with

Table XIX. Arrival Time and Relative Velocity at Yucca Mountain

Station	Event	Azimuth (°) Toward Event	Slant Range (km)	Time of Arrival (sec)	Relative Velocity (km/s)
W-12	B29	0.52	53.596	10.270	5.219
	B31	5.58	50.181	9.668	5.190
	B30	10.99	51.455	9.841	5.229
W-14	B21	355.41	44.390	8.672	5.119
	B24	356.86	40.761	8.041	5.069
	B29	357.64	49.215	9.521	5.169
	B17	358.09	47.981	9.355	5.129
	B20	358.21	47.086	9.200	5.118
	B26	1.72	44.225	8.614	5.134
	B19	1.75	43.403	8.446	5.139
	B31	2.95	45.593	8.855	5.149
	B28	2.97	46.221	8.887	5.201
	B27	8.08	42.462	8.300	5.116
	B18	8.97	41.760	8.148	5.125
	B25	11.13	55.504	10.463	5.305
	B23	11.30	50.488	9.638	5.238
	B22	11.77	53.001	10.028	5.285
W-20	B21	357.76	42.729	8.536	5.006
	B24	359.48	39.150	7.590	5.158
	B25	13.39	54.386	10.458	5.200
	B23	13.80	49.381	9.749	5.065
	B22	14.15	51.909	10.032	5.174
W-21	B24	0.21	41.671	8.358	4.986
	B29	0.42	50.145	9.838	5.097
	B26	4.71	45.329	8.732	5.191
	B31	5.84	46.774	9.214	5.076
	B27	11.00	43.815	8.663	5.058
	B30	11.63	48.057	9.381	5.123
	B25	13.31	56.958	10.846	5.252
	B23	13.68	51.953	9.992	5.199
	B22	14.02	54.480	10.400	5.238
W-22	B24	2.38	38.923	7.856	4.955
	B26	6.97	42.710	9.500	4.496
	B27	13.72	41.410	8.291	4.995
	B25	15.47	54.627	10.517	5.194
	B23	16.08	49.639	9.709	5.113
	B22	16.32	52.178	10.105	5.164
W-23	B21	355.75	41.343	8.295	4.984
	B24	357.35	37.722	7.600	4.963
	B29	358.10	46.181	9.076	5.088
	B31	3.85	42.609	8.465	5.039
	B27	9.40	39.553	7.918	4.995

Table XIX. Arrival Time and Relative Velocity at Yucca Mountain (Cont'd)

Station	Event	Azimuth (°) Toward Event	Slant Range (km)	Time of Arrival (sec)	Relative Velocity (km/s)
	B30	10.25	43.780	8.632	5.072
	B25	12.29	52.647	10.119	5.203
	B23	12.59	47.636	9.292	5.127
W-24	B29	359.67	48.166	9.415	5.116
	B26	4.08	43.307	8.586	5.044
W-25	B31	5.28	44.713	8.814	5.073
	B30	11.54	45.990	8.978	5.123
W-26	B31	1.17	46.143	8.832	5.225
W-27	B31	1.34	47.063	8.793	5.352
W-28	B31	5.80	42.195	8.394	5.027
W-15	B21	346.14	30.943	6.420	4.820
	B24	341.04	27.186	5.656	4.807
	B29	350.45	35.455	7.150	4.959
	B20	350.79	33.285	6.904	4.821
	B17	350.87	34.185	7.027	4.865
	B19	355.04	29.284	6.081	4.816
	B26	355.18	30.103	6.218	4.841
	B28	357.37	31.976	6.501	4.919
	B27	4.33	27.911	5.837	4.782
	B25	9.67	40.829	7.977	5.118
	B23	9.70	35.811	7.153	5.006
	B22	10.45	38.311	7.650	5.008
W-16	B21	342.73	32.109	6.463	4.968
	B24	343.15	28.241	5.800	4.869
	B20	347.47	34.206	6.962	4.913
	B17	348.11	35.104	7.100	4.944
	B26	351.39	30.881	6.300	4.902
	B19	351.71	30.068	6.144	4.894
	B28	354.22	32.682	6.531	5.004
	B27	0.03	28.369	5.776	4.912
	B18	1.55	27.583	5.620	4.908
	B23	6.28	36.054	6.982	5.164
	B25	6.67	41.065	7.855	5.228
	B22	7.25	38.523	7.446	5.174

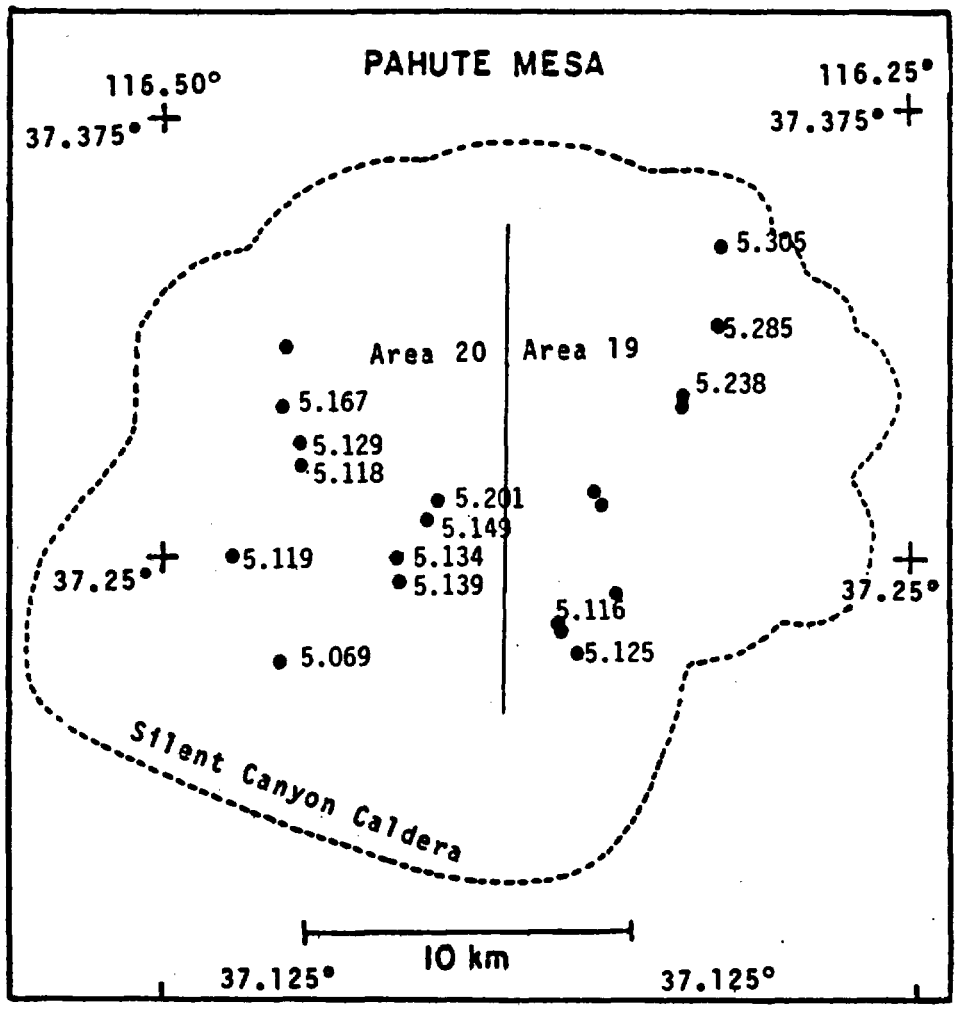


Figure 45. Map of Pahute Mesa showing velocities for events for which measurements were made at Station W-14.

FIGURE 46

STATION W-14

RELATIVE VELOCITY VS. SLANT DISTANCE

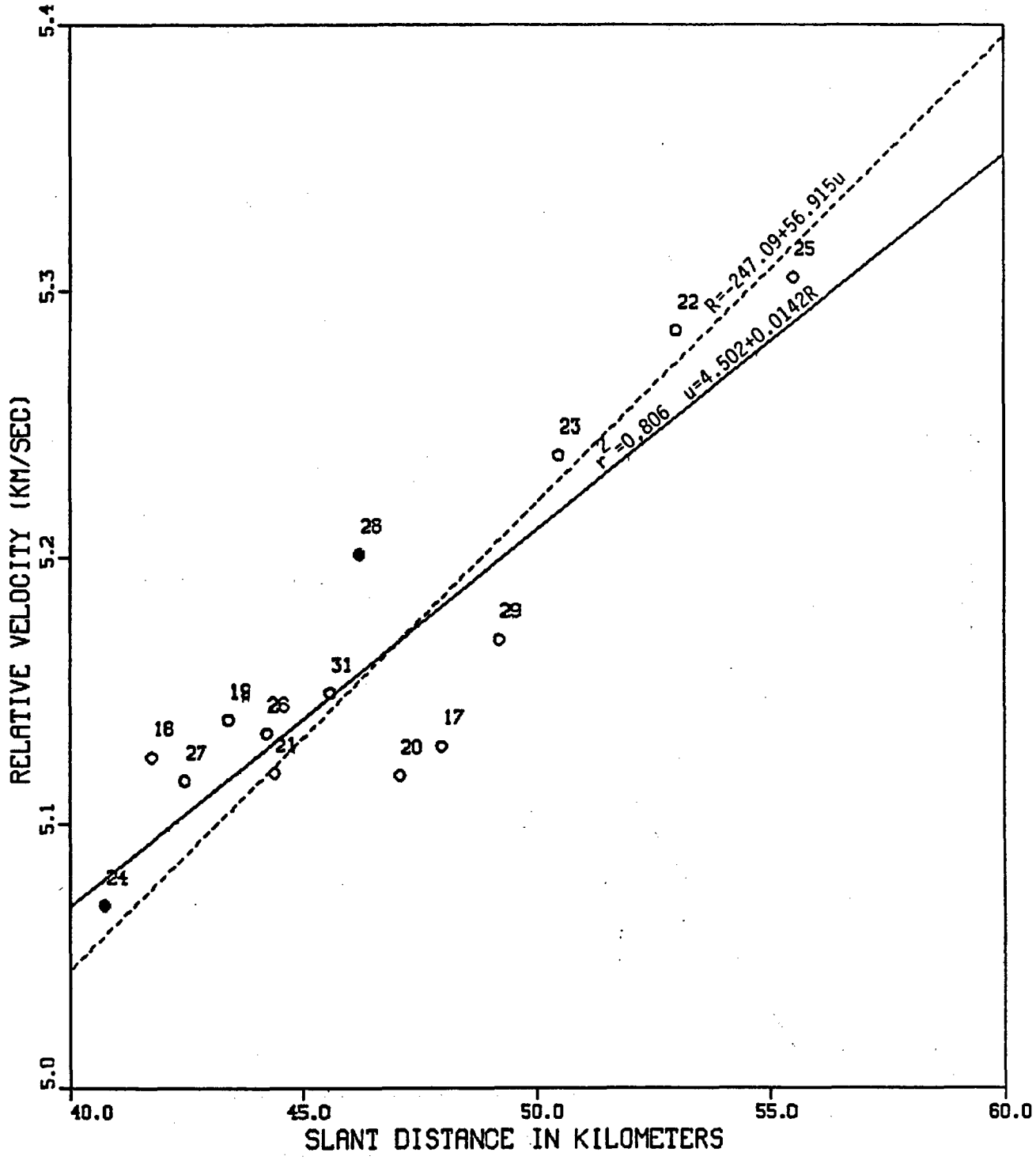
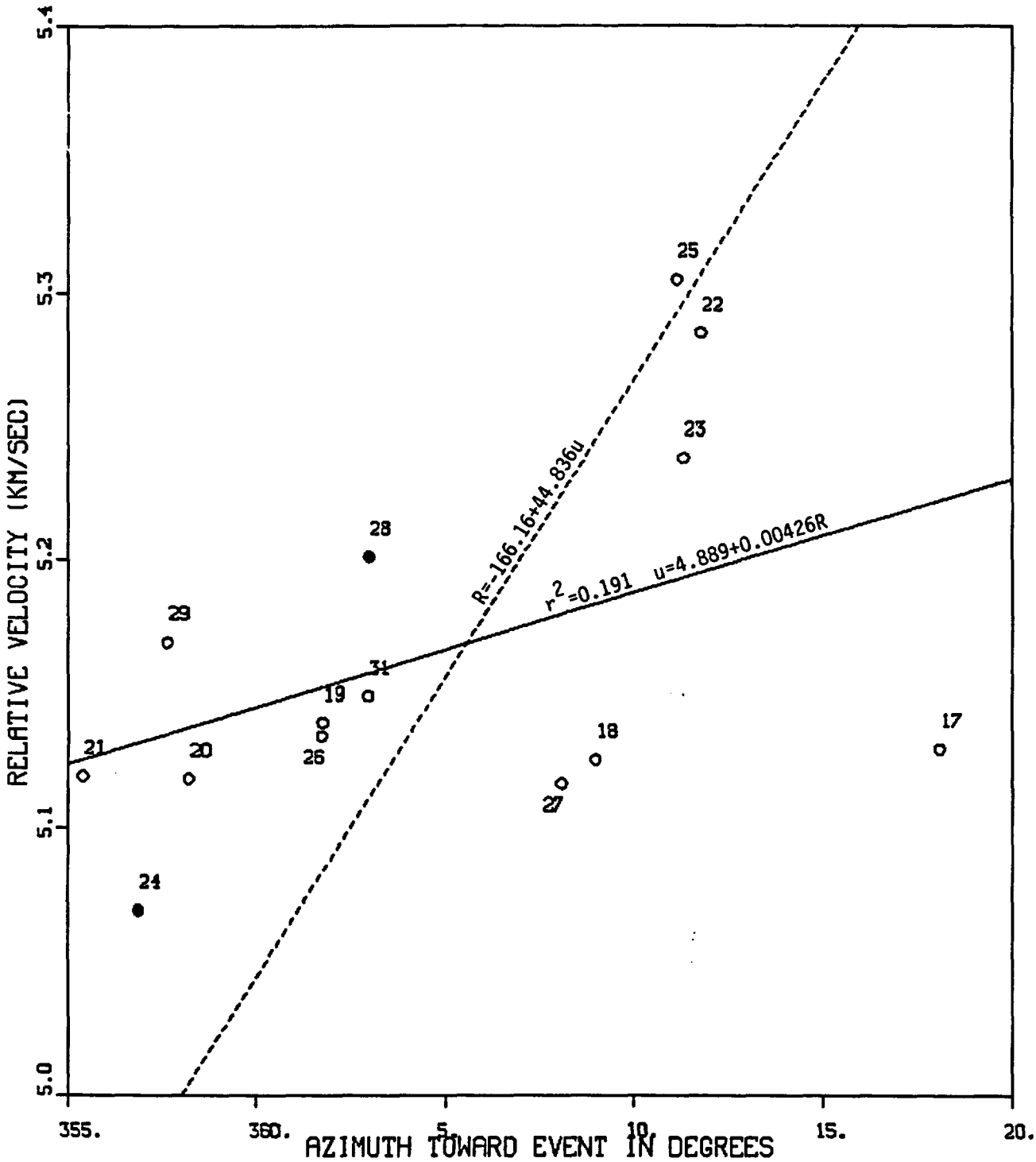


FIGURE 47

STATION W-14

RELATIVE VELOCITY VS. AZIMUTH TOWARD EVENT



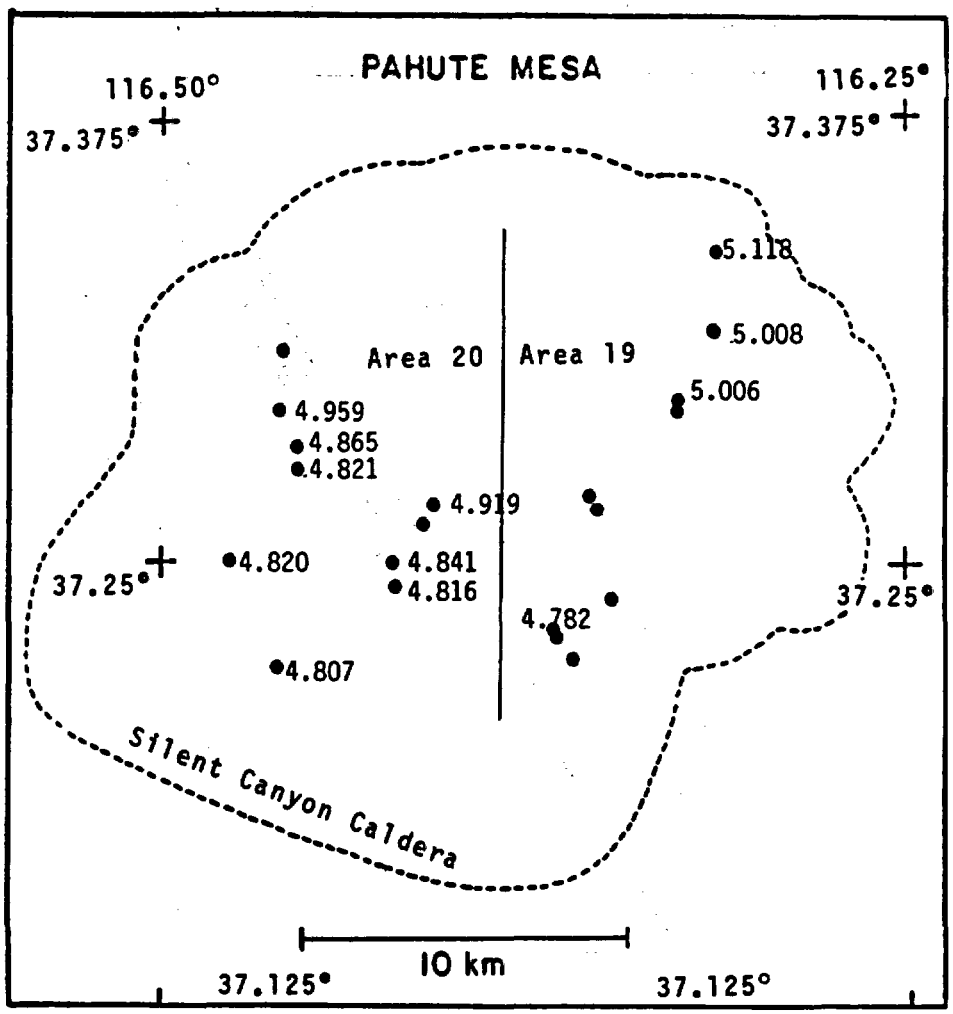


Figure 48. Map of Pahute Mesa showing velocities for events for which measurements were made at Station W-15.

FIGURE 49

STATION W-15

RELATIVE VELOCITY VS. SLANT DISTANCE

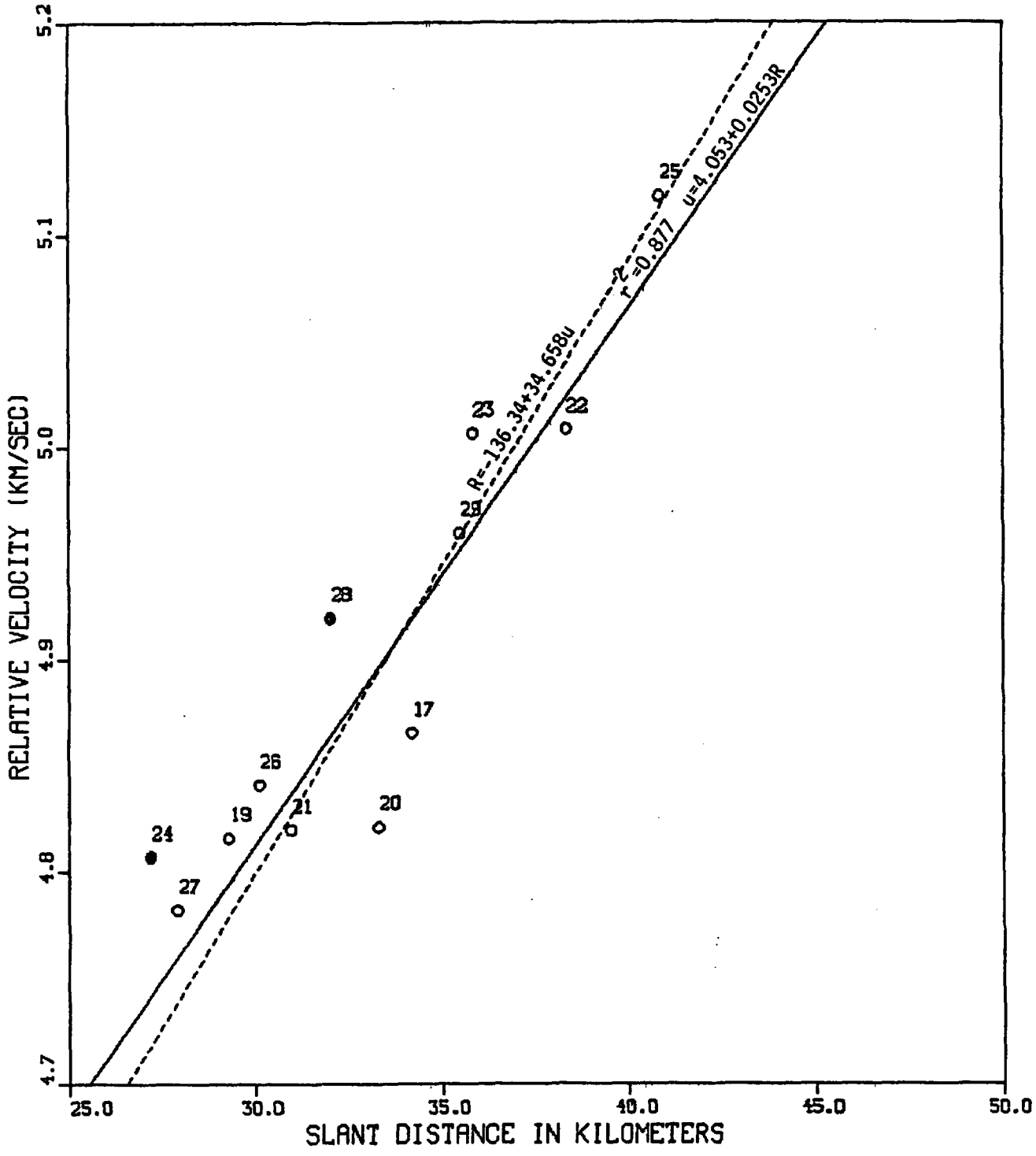
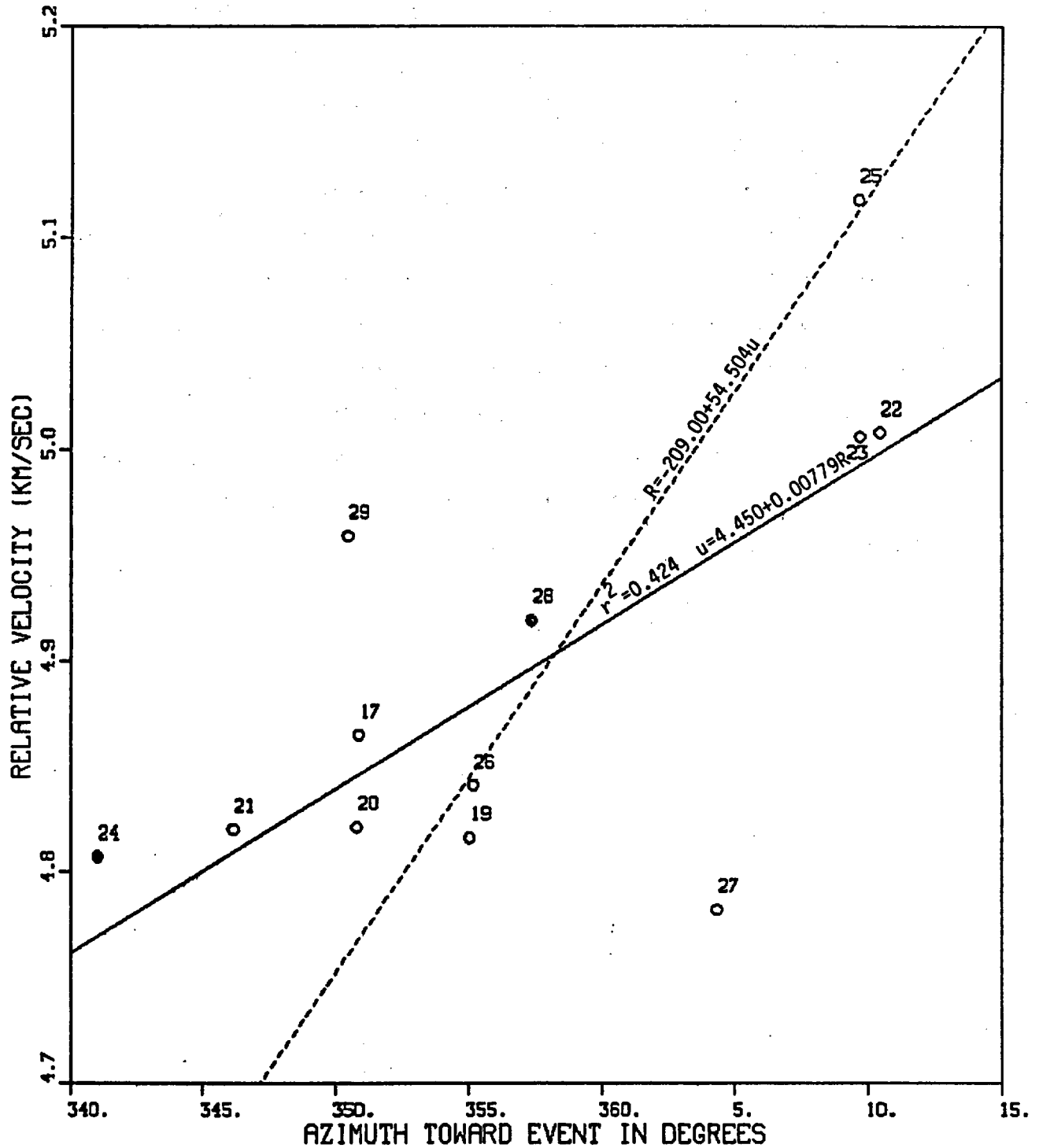


FIGURE 50

STATION W-15

RELATIVE VELOCITY VS. AZIMUTH TOWARD EVENT



increasing slant distance. Note that these velocities are lower than those shown for Station W-14 because the distance is less and the transmission paths are relatively shallower. There is only a small increase in velocity with increasing azimuth (Figure 50).

The velocity distribution for Station W-16 is shown in Figure 51. The same distribution pattern as seen for the other events is seen here also. However, the differences between highest and lowest velocity is greater than that seen for Station W-15. The increase of velocity with increasing slant range parallels that for Station W-15 although the values for Station W-16 are about 0.1 kilometers per second higher than for Station W-15. The plot of velocity versus increasing azimuth (Figure 53) shows no trend at all were it not for Stations W-22, W-23, and W-25 which have values considerably higher than stations at smaller azimuths.

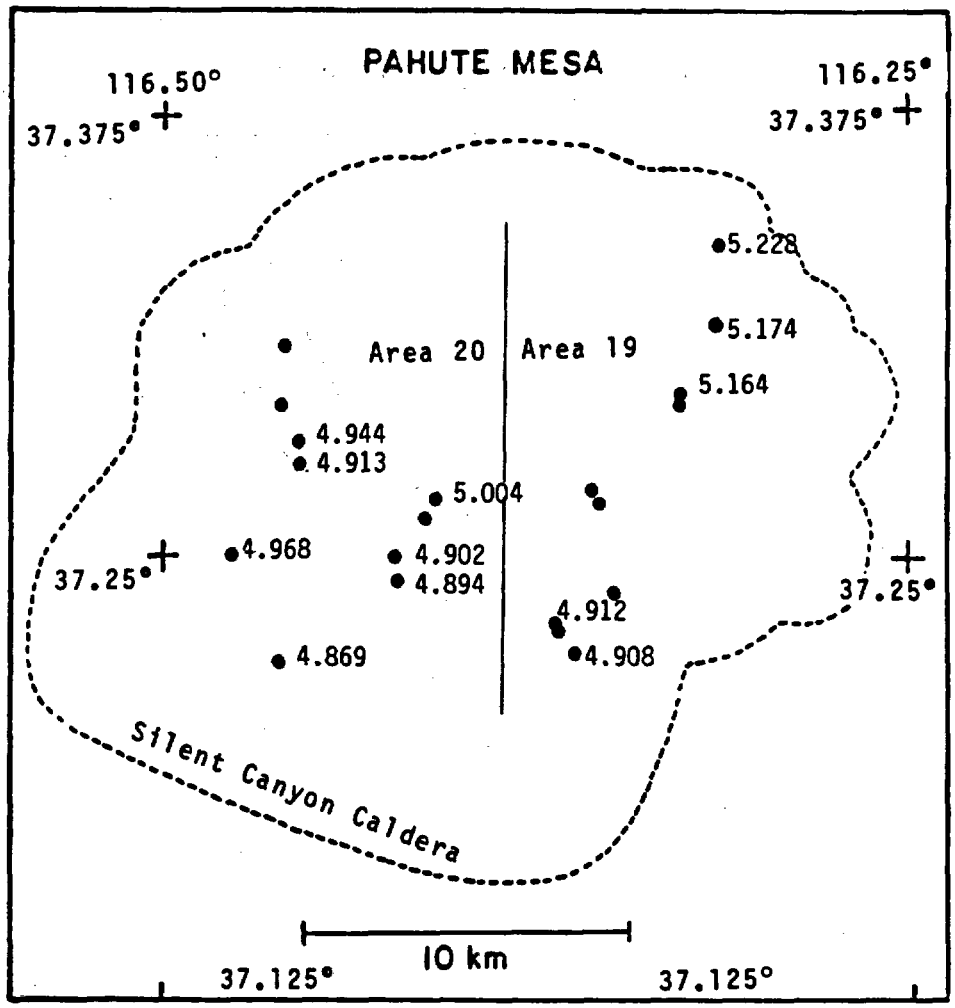


Figure 51. Map of Pahute Mesa showing velocities for events for which measurements were made at Station W-16.

FIGURE 52

STATION W-16

RELATIVE VELOCITY VS. SLANT DISTANCE

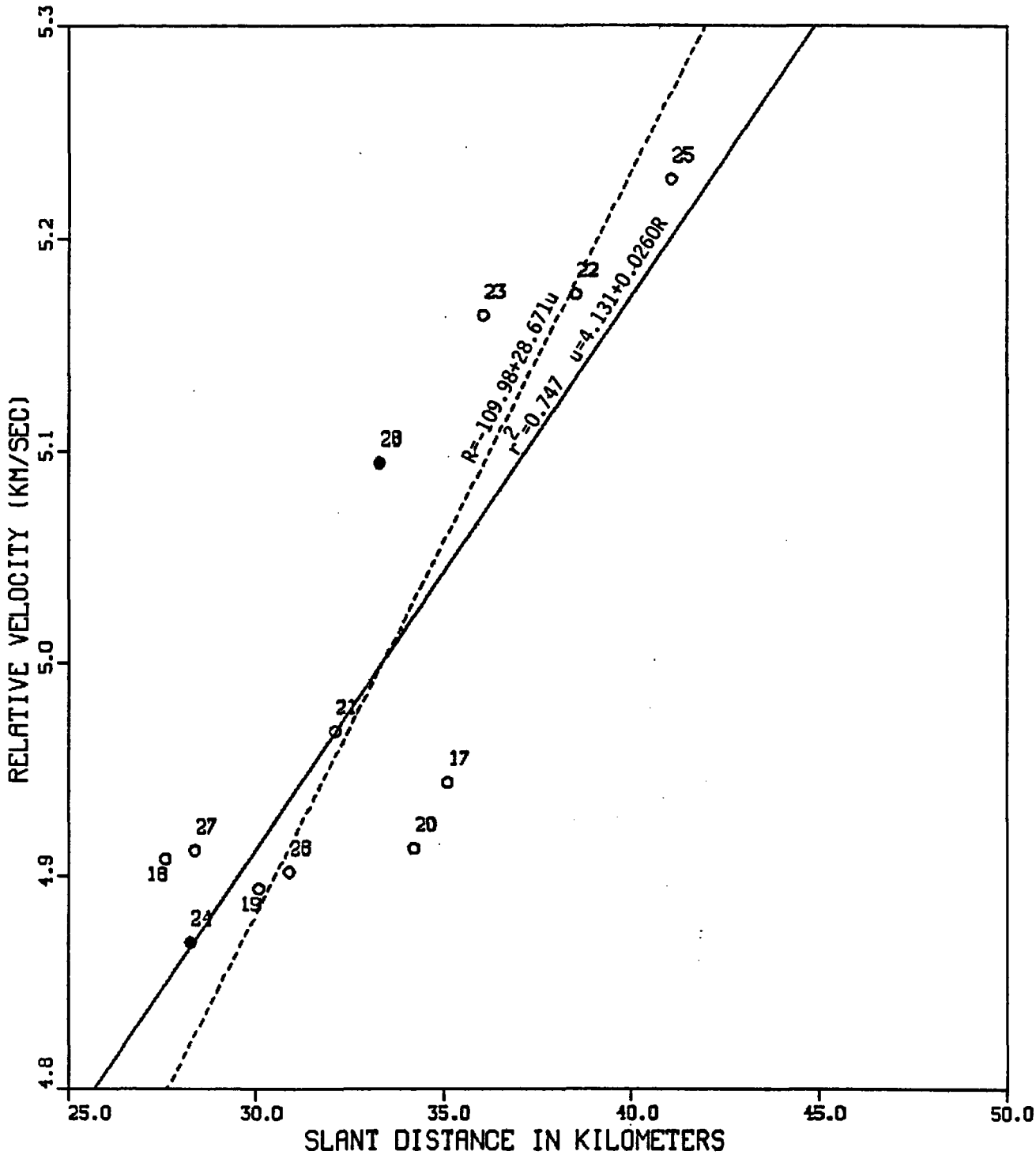
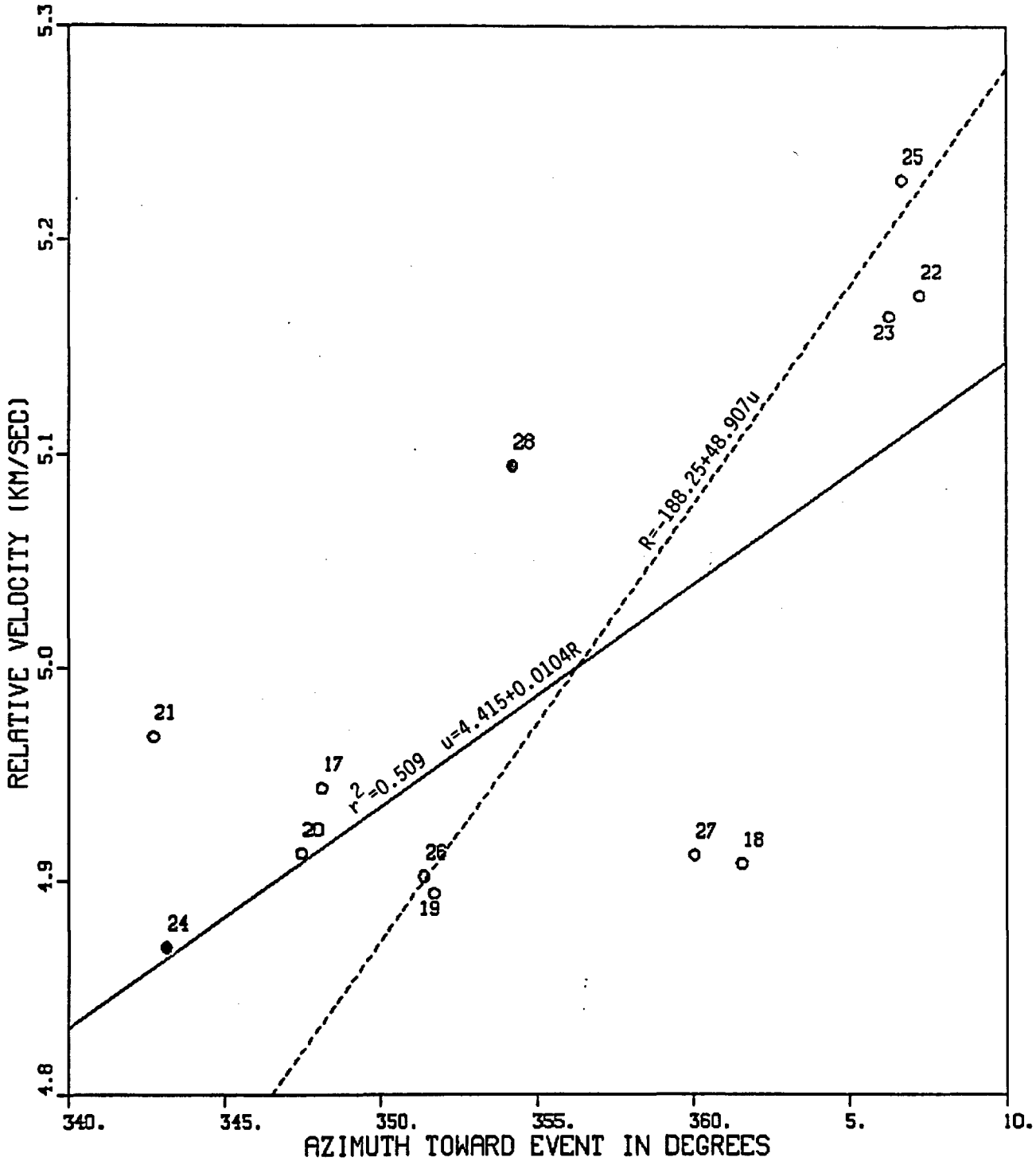


FIGURE 53

STATION W-16

RELATIVE VELOCITY VS. AZIMUTH TOWARD EVENT



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CHAPTER 5. DISCUSSION AND CONCLUSIONS

Prior to the work reported here, the seismic anomaly at Engine Test Stand 1 at NRDS was thought to be associated with events along an azimuth of N 18° W of ETS-1. Observations had been made on Chateaugay, Benham, and Purse, where the azimuths were 18.73°, 18.38°, and 18.91°, respectively. This work has shown that the azimuthal window for the larger ratios is essentially the region of the Area 20 events, or about 10°, although ratios from 1.4 to 2.1 are observed for Area 19 events.

The corresponding azimuthal window for the Yucca Mountain stations includes both Area 19 and 20, and is about 15°. The ratios there are not as great as those in the NRDS area.

Earlier it was noted that the anomalously high acceleration observed at ETS-1 was probably due to a combination of the effects of coupling, transmission path, and local geology at the point of measurement. With coupling effects removed from the data of Tables XVI and XVII, the other two effects remain as possible contributors. The transmission paths within the 10° and 15° azimuthal windows noted above pass from the Silent Canyon Caldera into and through the Timber Mountain Caldera. The data here suggest that some feature within the Timber Mountain Caldera and within the two azimuthal windows may be affecting transmission paths to both the Yucca Mountain and NRDS areas. If a high velocity medium such as a granite intrusive exists within the azimuthal window from Area 19 to Station W-6, but outside and

to the east of the window from Area 19 to Yucca Mountain, the higher velocities at Station W-6 than at Station W-14 would be accounted for. Microgranite porphyry has been observed[12] in the southwest quadrant of the Timber Mountain Caldera in about the location which would be consistent with the above explanation. Local geology nearer ETS-1 may be increasing acceleration there over and above the increase attributed to the Timber Mountain Caldera.

Ground motion prediction equations have been provided for three groups of data each separated according to whether stations were on rock or alluvium, and rock and alluvium together. It is concluded that where effects of coupling are unknown that Equations 19, 20, and 21 are appropriate for predicting peak vector accelerations, velocities, and displacements, respectively. Where coupling effects are known or can be estimated from working point geophysical properties similar to an earlier event, it is recommended that Equations 37, 38, and 39 be used.

The NRDS seismic anomaly has been examined, and it was concluded that larger amplifications of acceleration result from events in Area 20 than in Area 19, and that p-wave velocities are lower between Area 20 and NRDS than between Area 19 and NRDS. These observations are consistent with a geologic structure where a high velocity medium is closer to the surface on the path between Area 19 and NRDS than on the path between Area 20 and NRDS.

The data relating to the possibility of similar anomalous motion at Yucca Mountain is considerably smaller than what is available from the NRDS

area. There is enough to present the following tentative conclusions:

1. Peak vector accelerations in the vicinity of the Yucca Mountain repository "block" are greater than at the southern end (Station W-12) and at the northern end (Stations W-15 and W-16).
2. The enhanced acceleration observed in the vicinity of the repository "block" is less than that seen at NRDS. The largest enhancement seen at Yucca Mountain is about 4 compared with 10 observed at NRDS.
3. Since the data set for Yucca Mountain is relatively small, the possibility exists for even greater enhancements for UNEs in locations other than those included in the data set.
4. Since these enhanced effects have been removed from the data base on which Equations 19-27 and 37-39 were based, allowance must be made for these larger departures from predictions obtained from those equations.

Prediction equation 37 gives a mean value of 58 mg for a distance of 22.8 km from 700 kt. Because of anomalously high motion observed at Yucca Mountain this could be increased to 243 mg. The corresponding 1σ and 2σ values would be 0.39 and 0.64 g.

This work has concentrated on data from the Pahute Mesa events. No corresponding analysis has been done for Yucca Flat events. Since transmission paths from Yucca Flat to Yucca Mountain pass north of Calico Hills with its

site-dependent contribution to high acceleration and south of the portion of the Timber Mountain Caldera that appears to offer transmission-dependent contribution, it would be prudent to examine the effect of Yucca Flat events on enhanced acceleration at Yucca Mountain.

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Appendix A

Ratios for Rock and Alluvium for Group I

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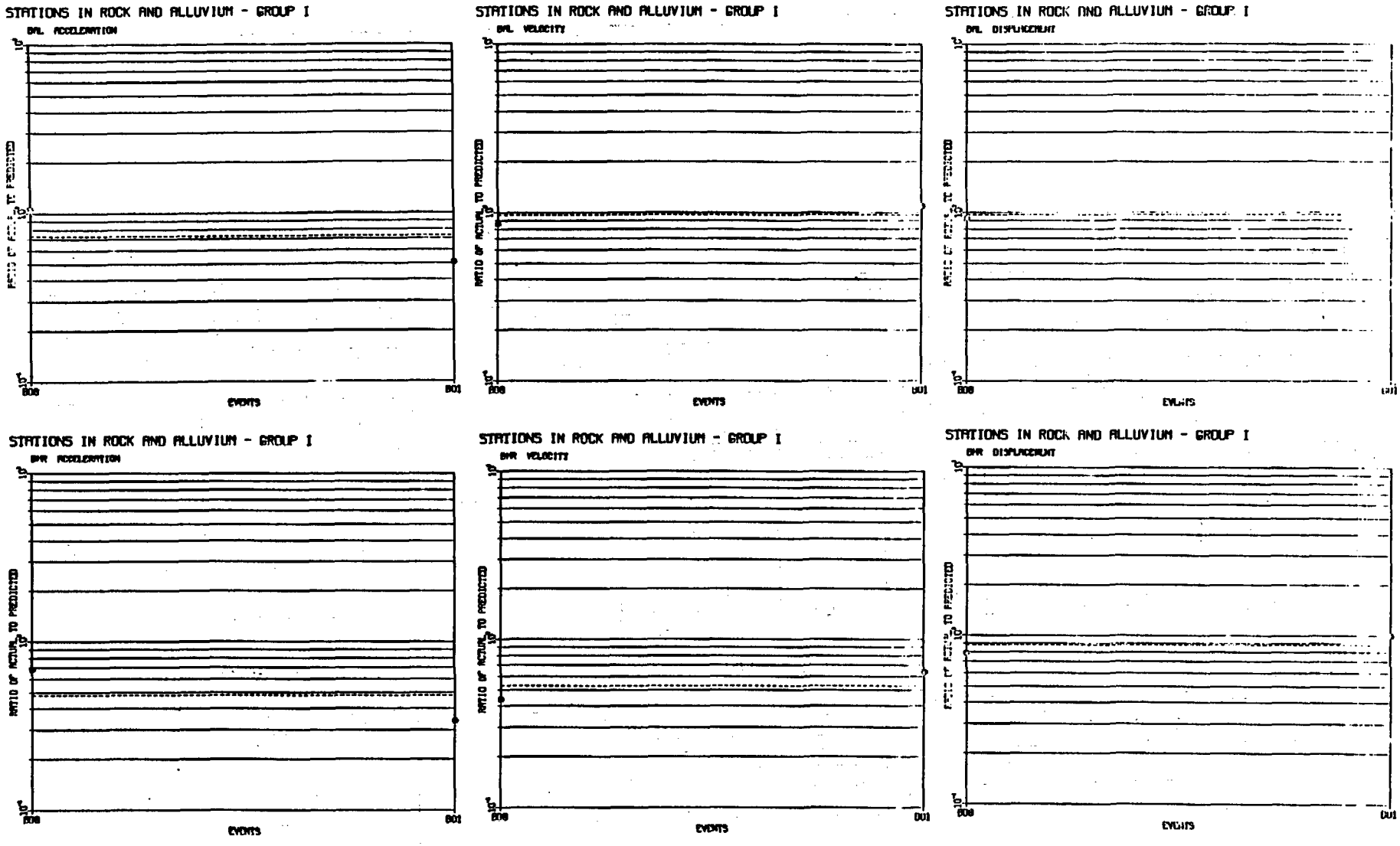
STATIONS IN ROCK AND ALLUVIUM - GROUP I
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STATIONS IN ROCK AND ALLUVIUM - GROUP I
BAL VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP I
BAL DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP I
BAR ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP I
BAR VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP I
BAR DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
B08
B01

Figure A-1

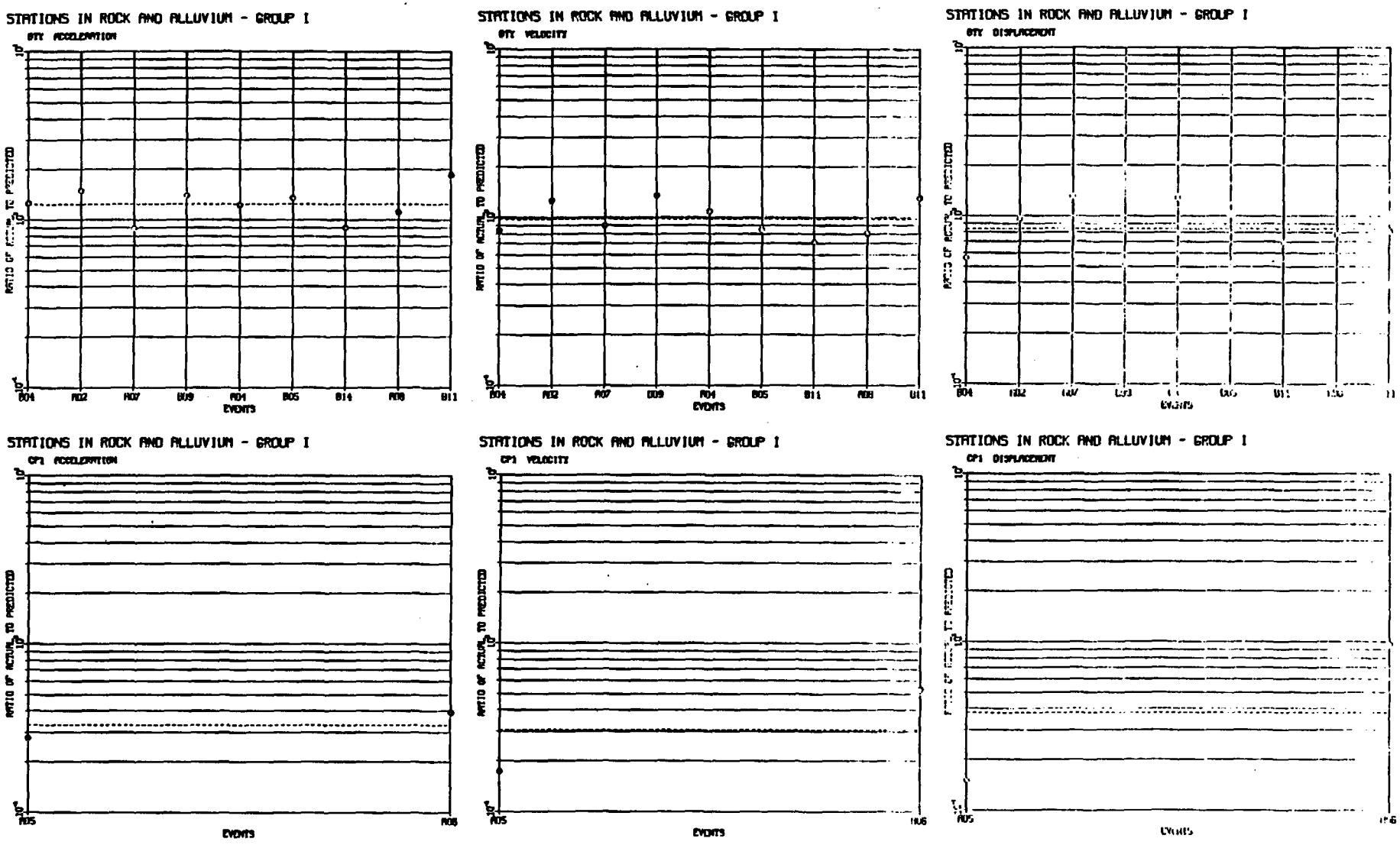

STATIONS IN ROCK AND ALLUVIUM - GROUP I
BTY ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP I
BTY VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP I
BTY DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP I
CP1 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP I
CP1 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP I
CP1 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure A-2

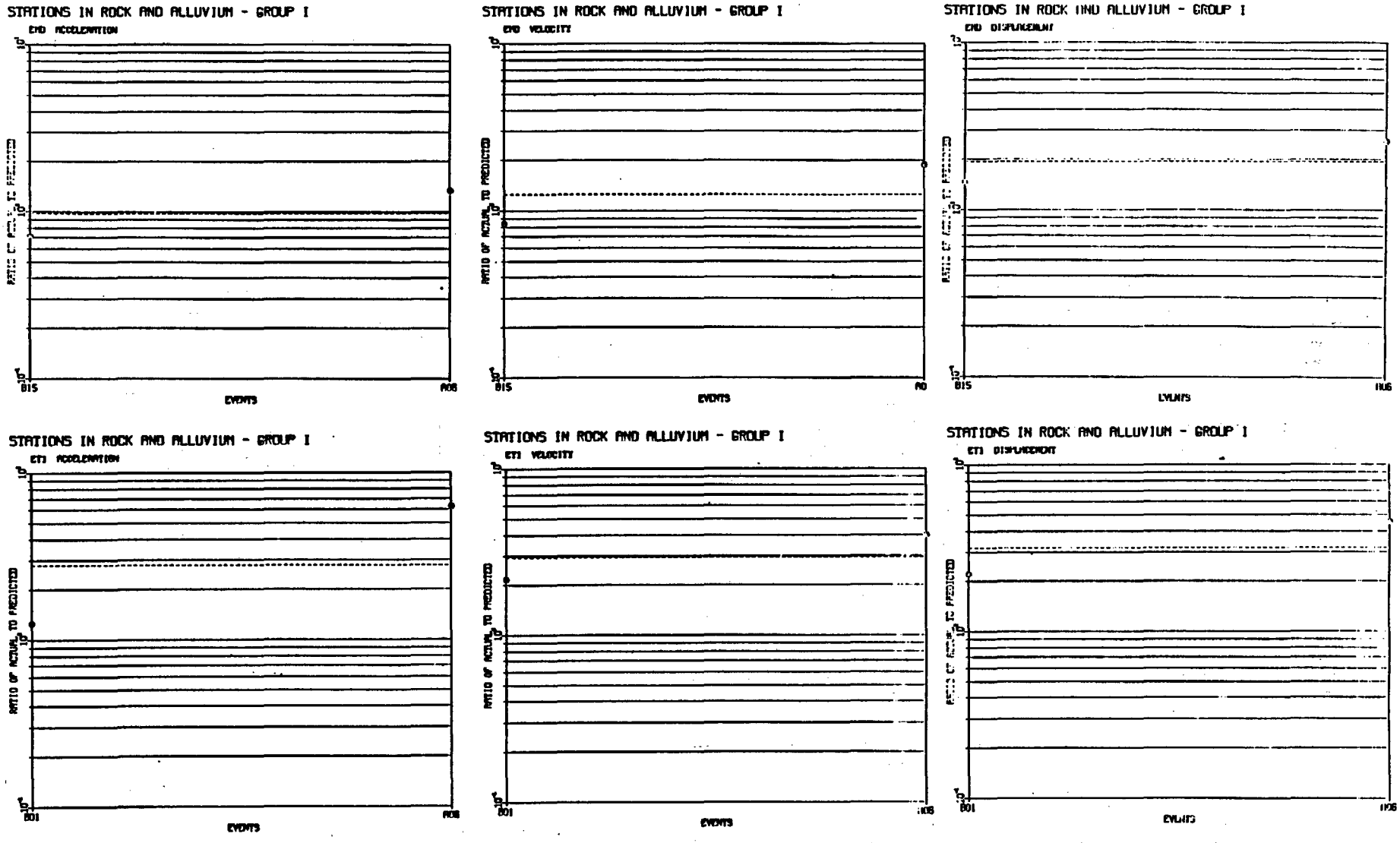

STATIONS IN ROCK AND ALLUVIUM - GROUP I
END ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
END VELOCITY
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
END DISPLACEMENT
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
ETI ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
ETI VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
ETI DISPLACEMENT
EVENTS

Figure A-3

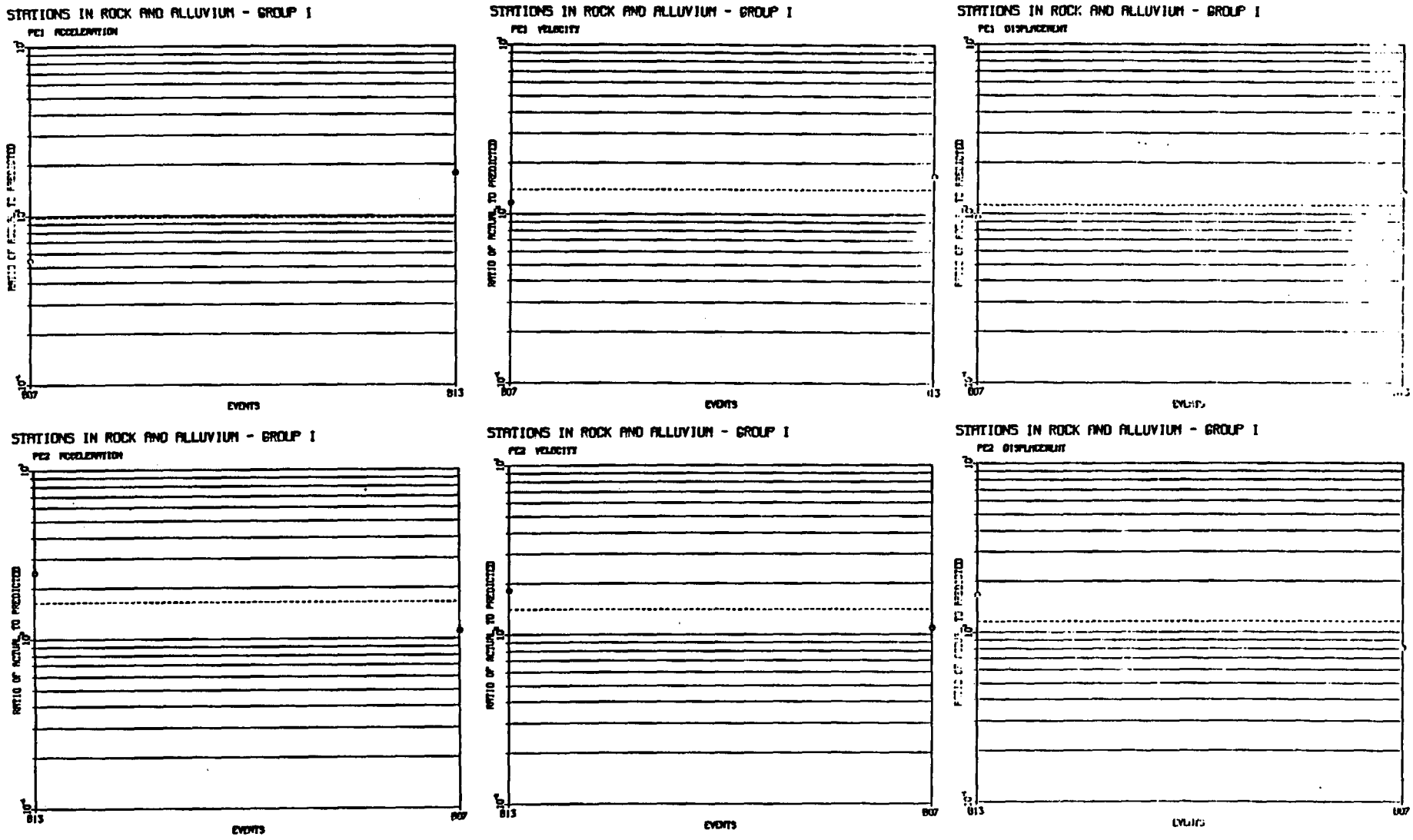

STATIONS IN ROCK AND ALLUVIUM - GROUP I
PC1 ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
PC1 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
PC1 DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP I
PC2 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
PC2 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
PC2 DISPLACEMENT

Figure A-4

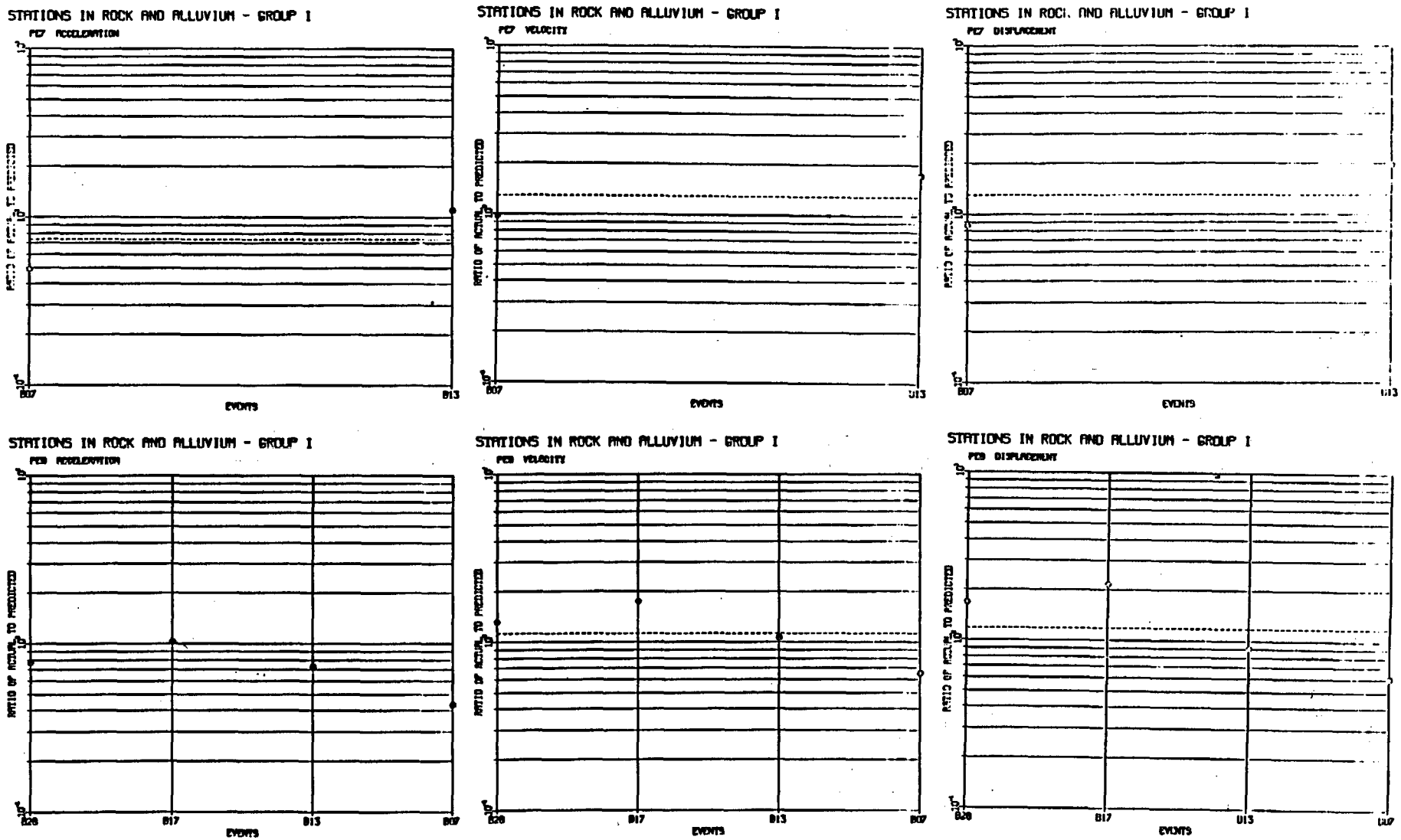
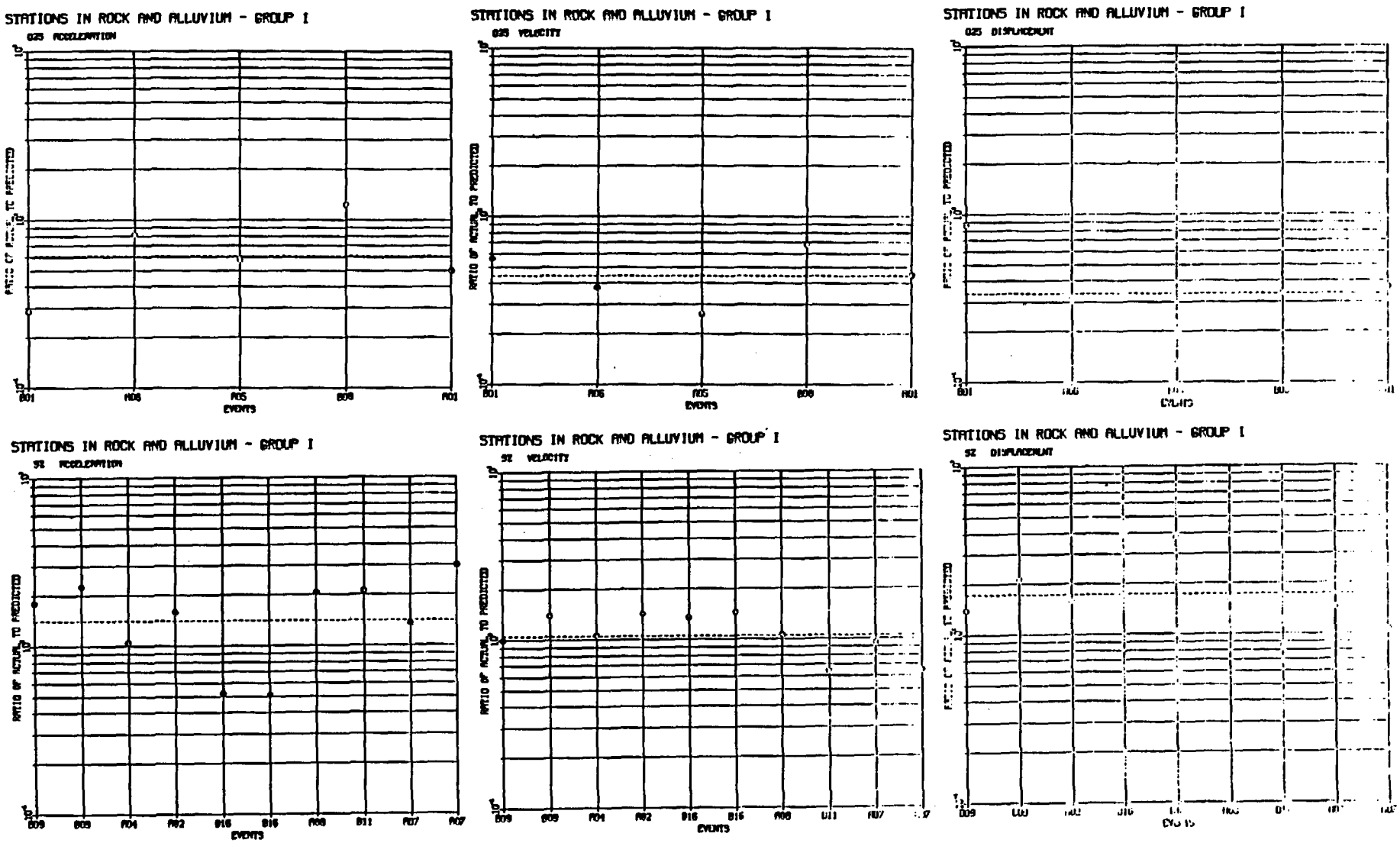

STATIONS IN ROCK AND ALLUVIUM - GROUP I
PGA ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP I
PGV VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP I
PGD DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP I
PGA ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP I
PGV VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP I
PGD DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
B07
B13
B17
B20

Figure A-5


STATIONS IN ROCK AND ALLUVIUM - GROUP I
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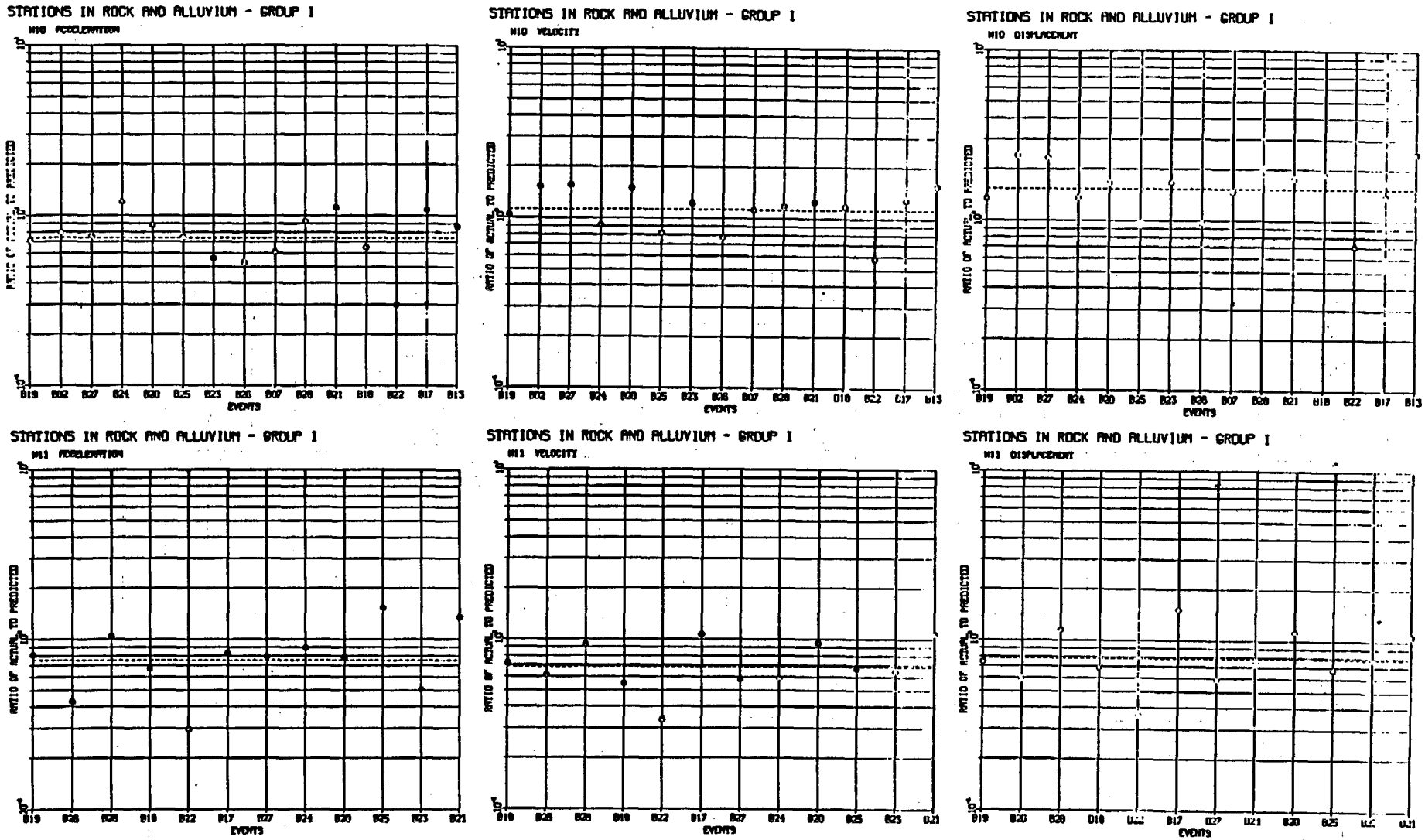
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
025 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
025 DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP I
SZ ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
SZ VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
SZ DISPLACEMENT

Figure A-6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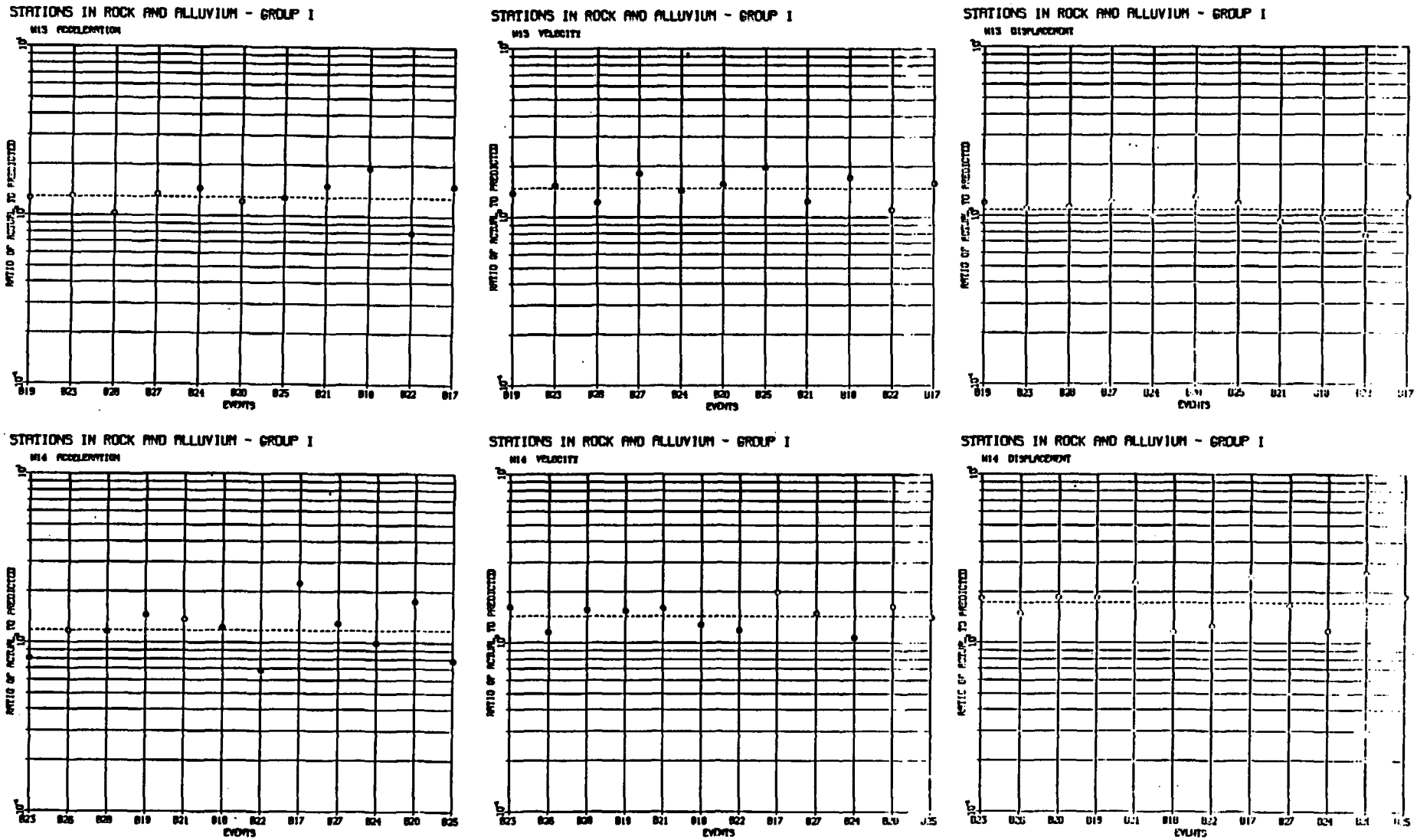
H10 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H10 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H10 DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H11 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H11 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H11 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure A-7


STATIONS IN ROCK AND ALLUVIUM - GROUP I
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H13 VELOCITY
H13 DISPLACEMENT
H14 ACCELERATION
H14 VELOCITY
H14 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure A-8

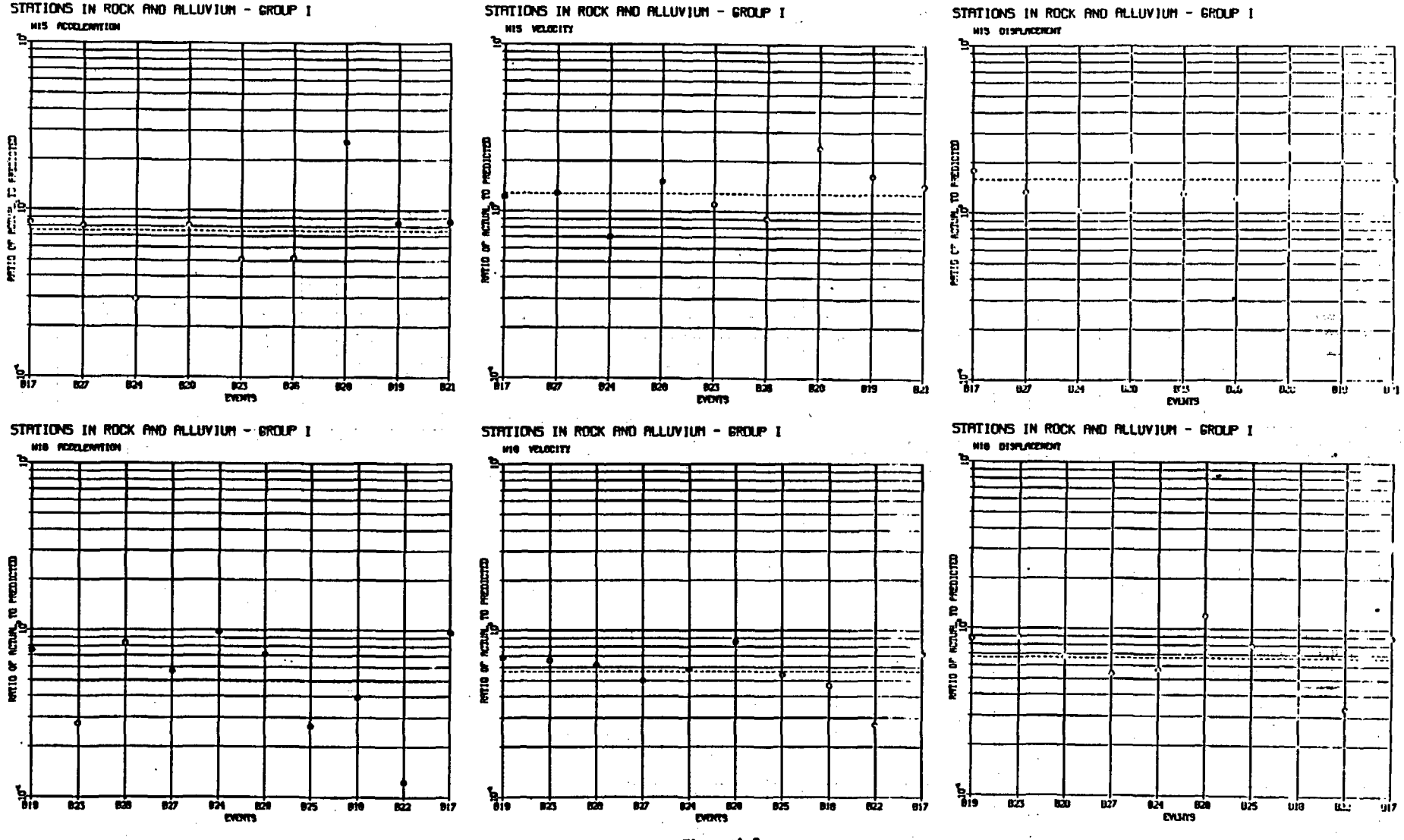

STATIONS IN ROCK AND ALLUVIUM - GROUP I
H15 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H15 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H15 DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H10 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H10 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H10 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure A-9

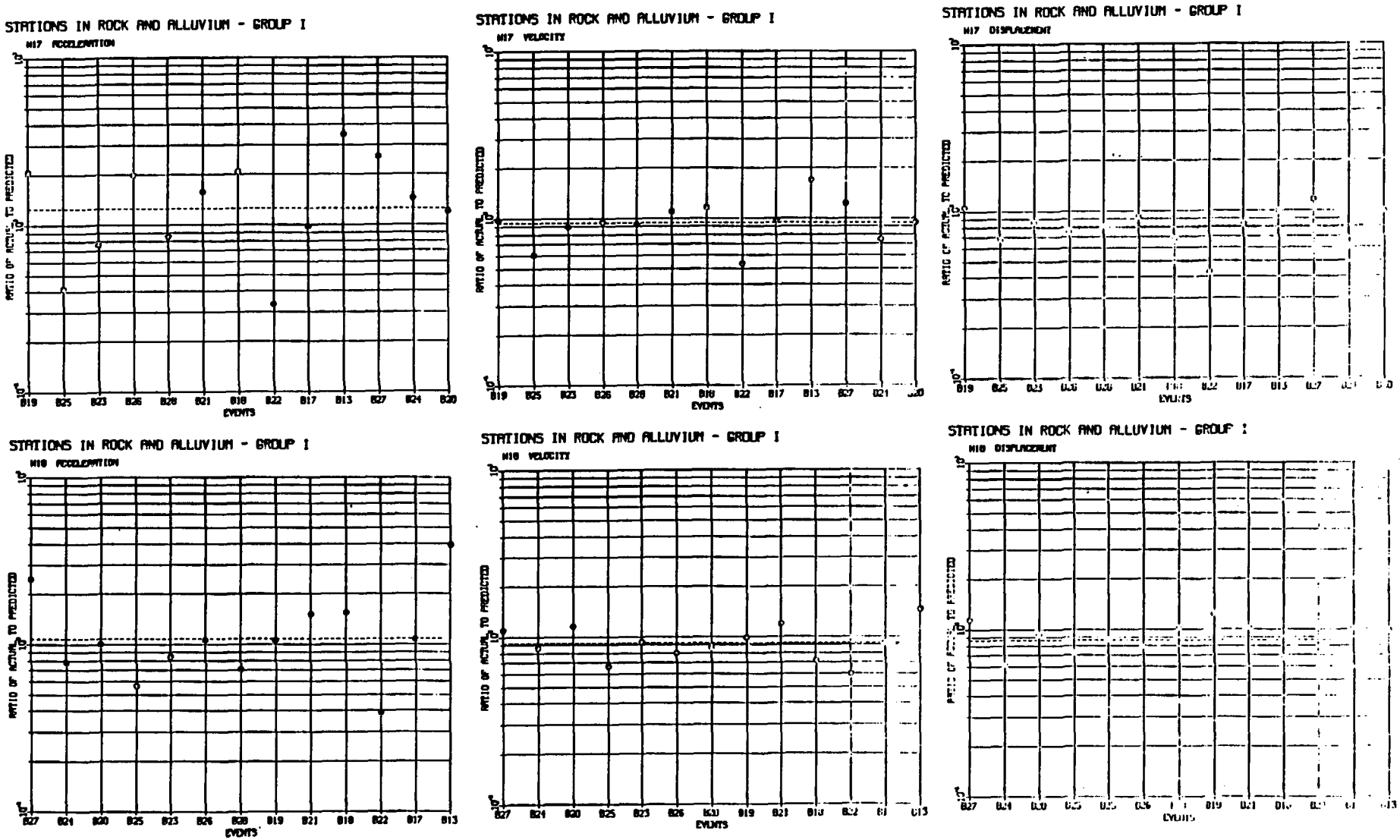

STATIONS IN ROCK AND ALLUVIUM - GROUP I
H17 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H17 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H17 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H10 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H10 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H10 DISPLACEMENT
EVENTS

Figure A-10

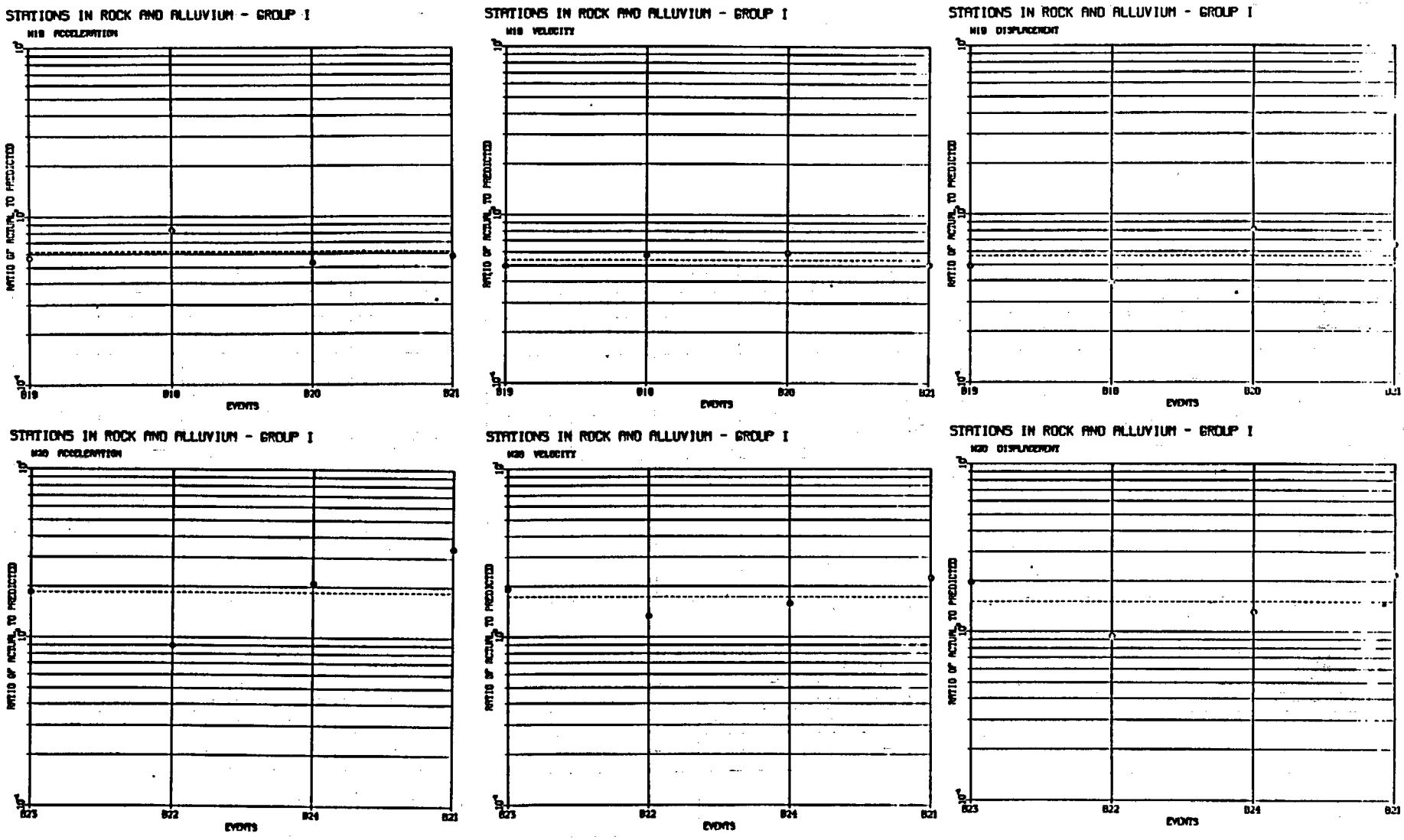
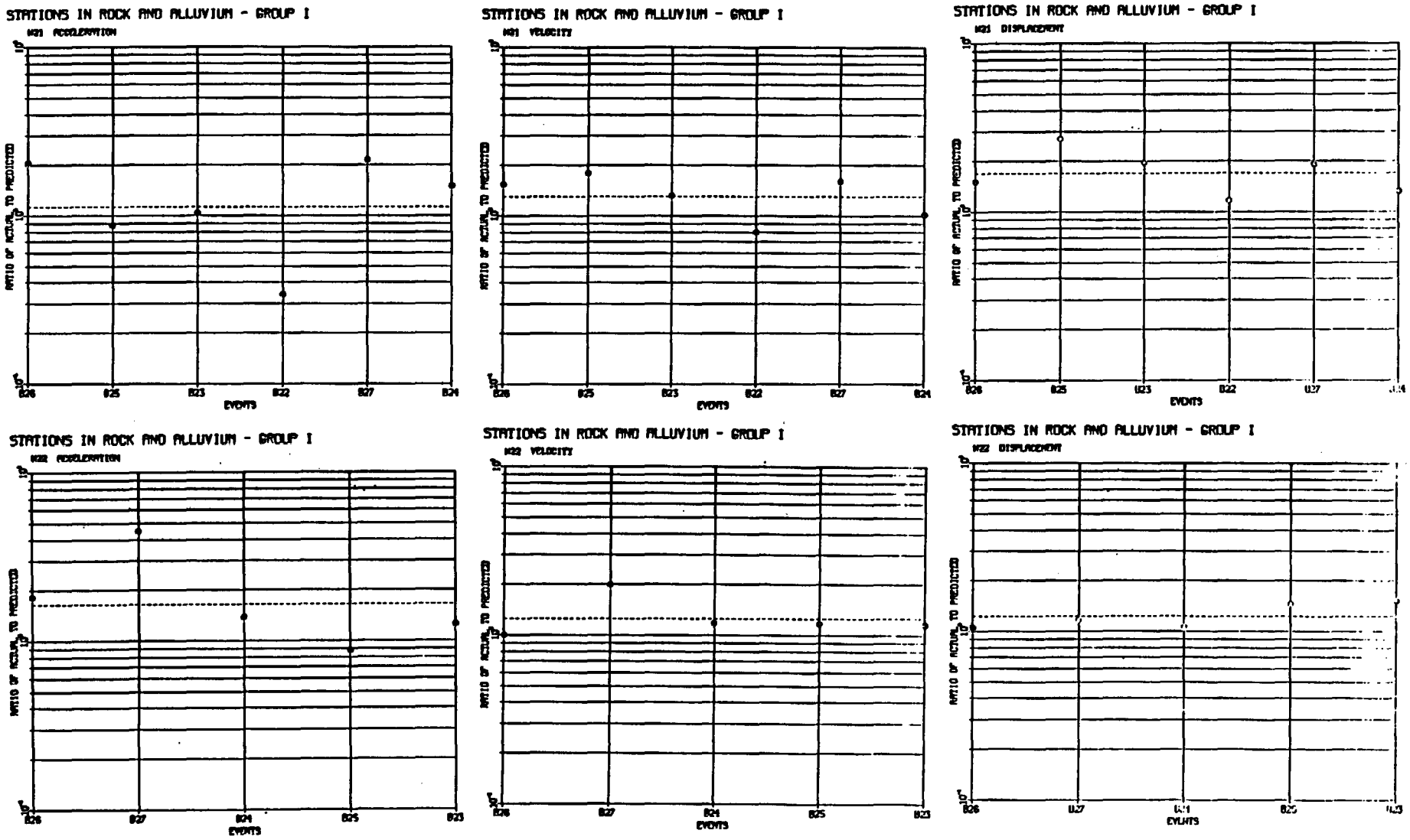

STATIONS IN ROCK AND ALLUVIUM - GROUP I
H19 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H19 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H19 DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H20 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H20 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP I
H20 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
B19
B18
B20
B21
B23
B22
B24

Figure A-11


STATIONS IN ROCK AND ALLUVIUM - GROUP I
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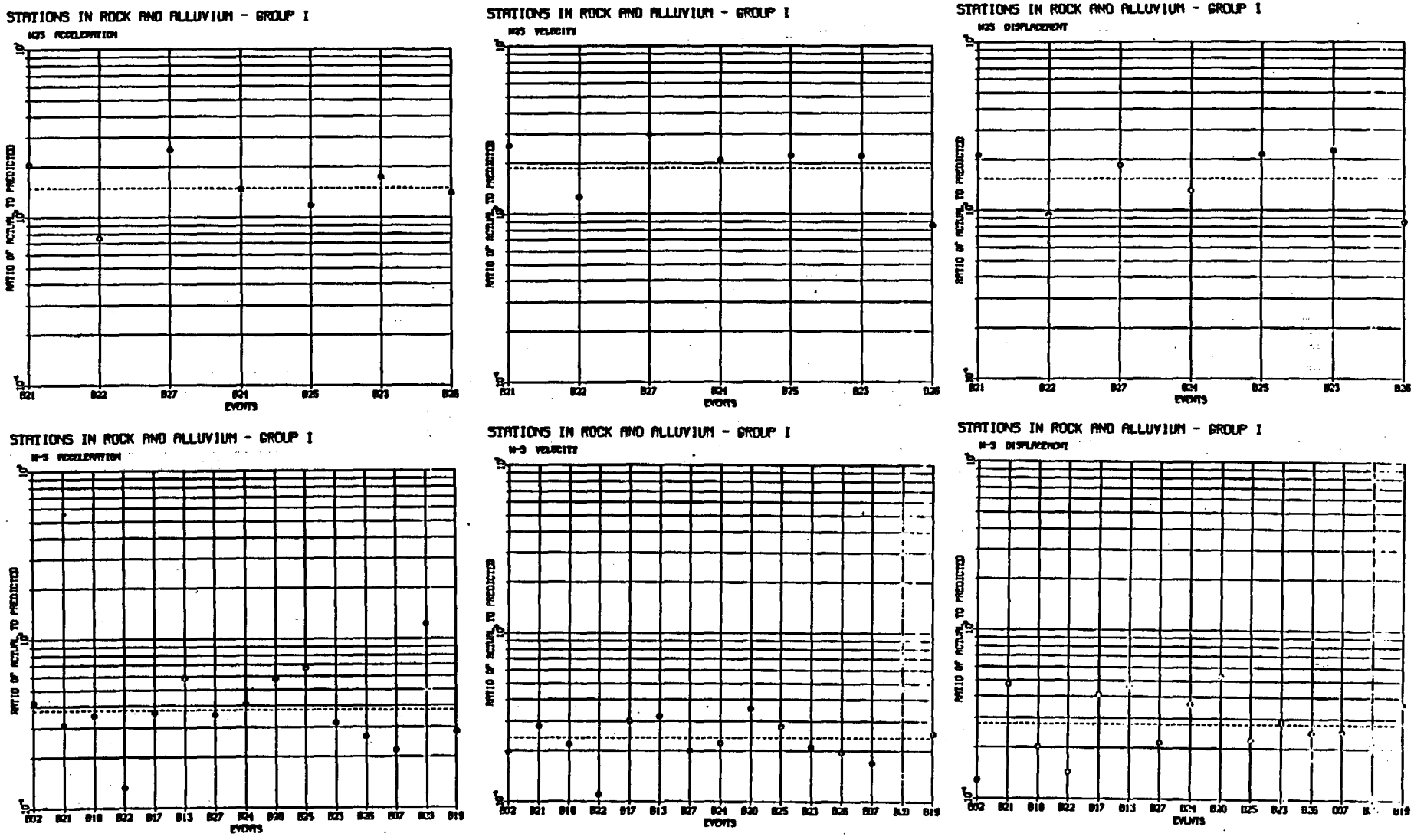
H21 VELOCITY
H21 DISPLACEMENT
H22 ACCELERATION
H22 VELOCITY
H22 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure A-12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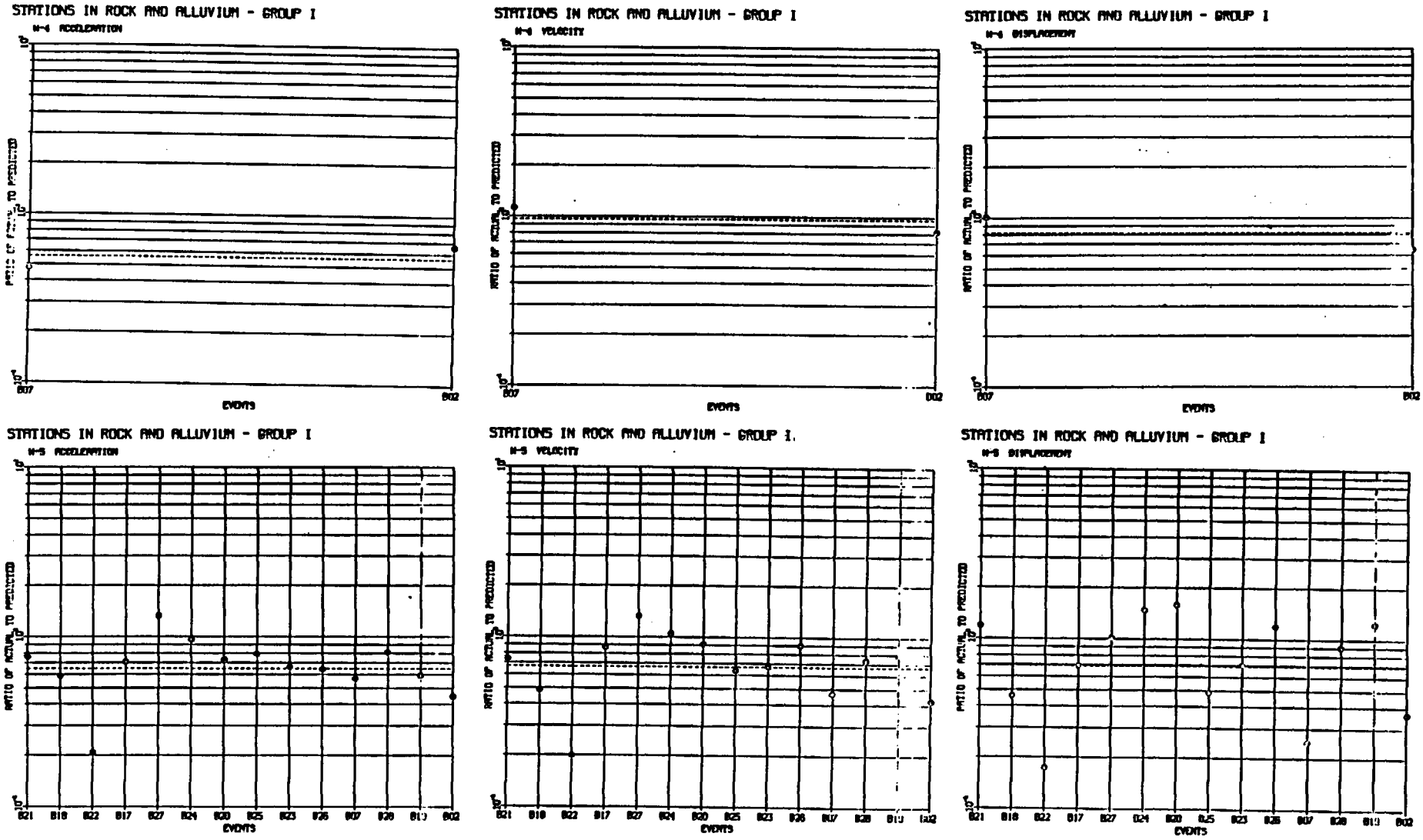
N25 ACCELERATION
N25 VELOCITY
N25 DISPLACEMENT
N-S ACCELERATION
N-S VELOCITY
N-S DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure A-13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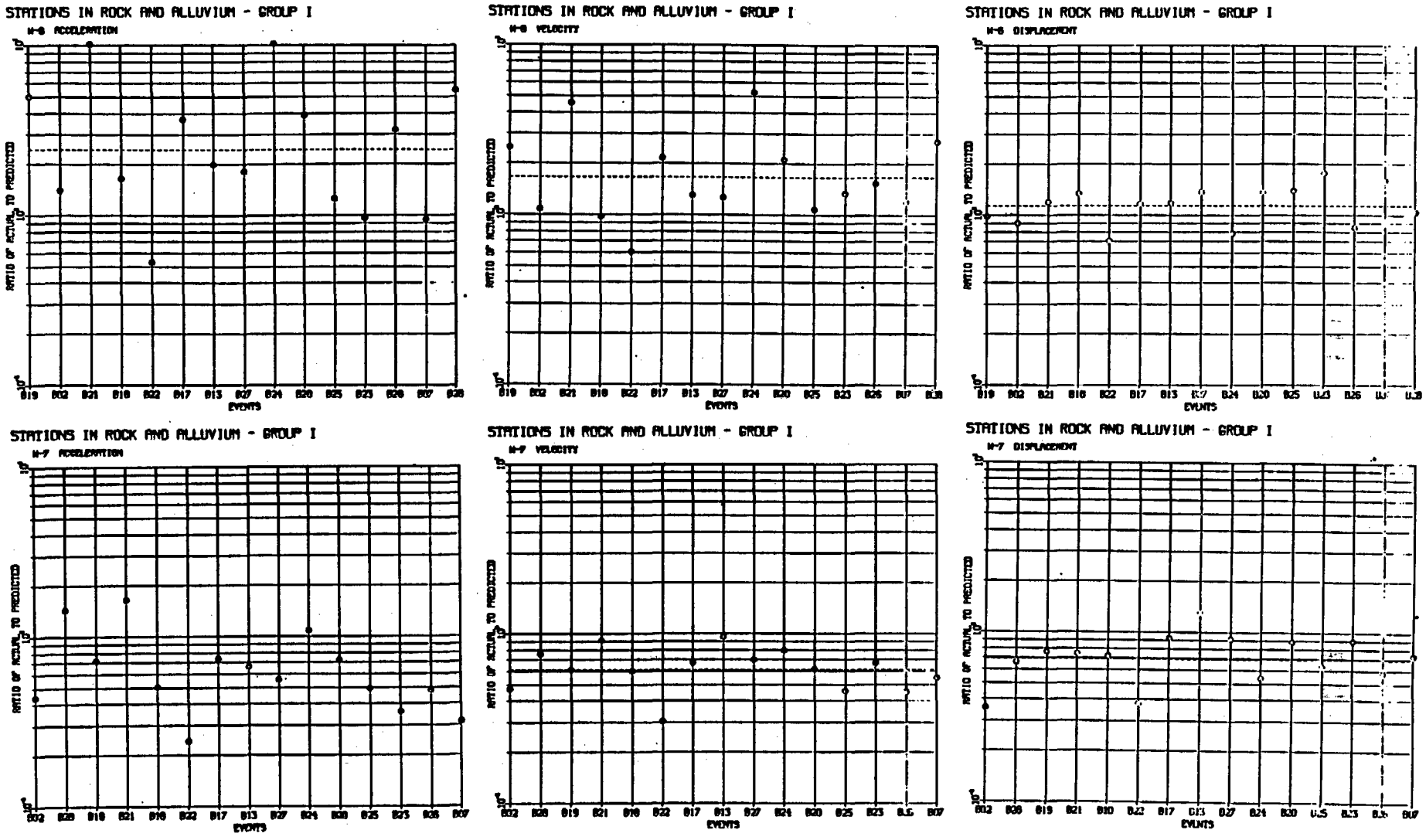
N-4 ACCELERATION
N-4 VELOCITY
N-4 DISPLACEMENT
N-5 ACCELERATION
N-5 VELOCITY
N-5 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
B07
B02
B21 B10 B22 B17 B27 B24 B20 B25 B23 B26 B07 B28 B13 B02

Figure A-14


STATIONS IN ROCK AND ALLUVIUM - GROUP I
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H-6 VELOCITY
H-6 DISPLACEMENT
H-7 ACCELERATION
H-7 VELOCITY
H-7 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure A-15

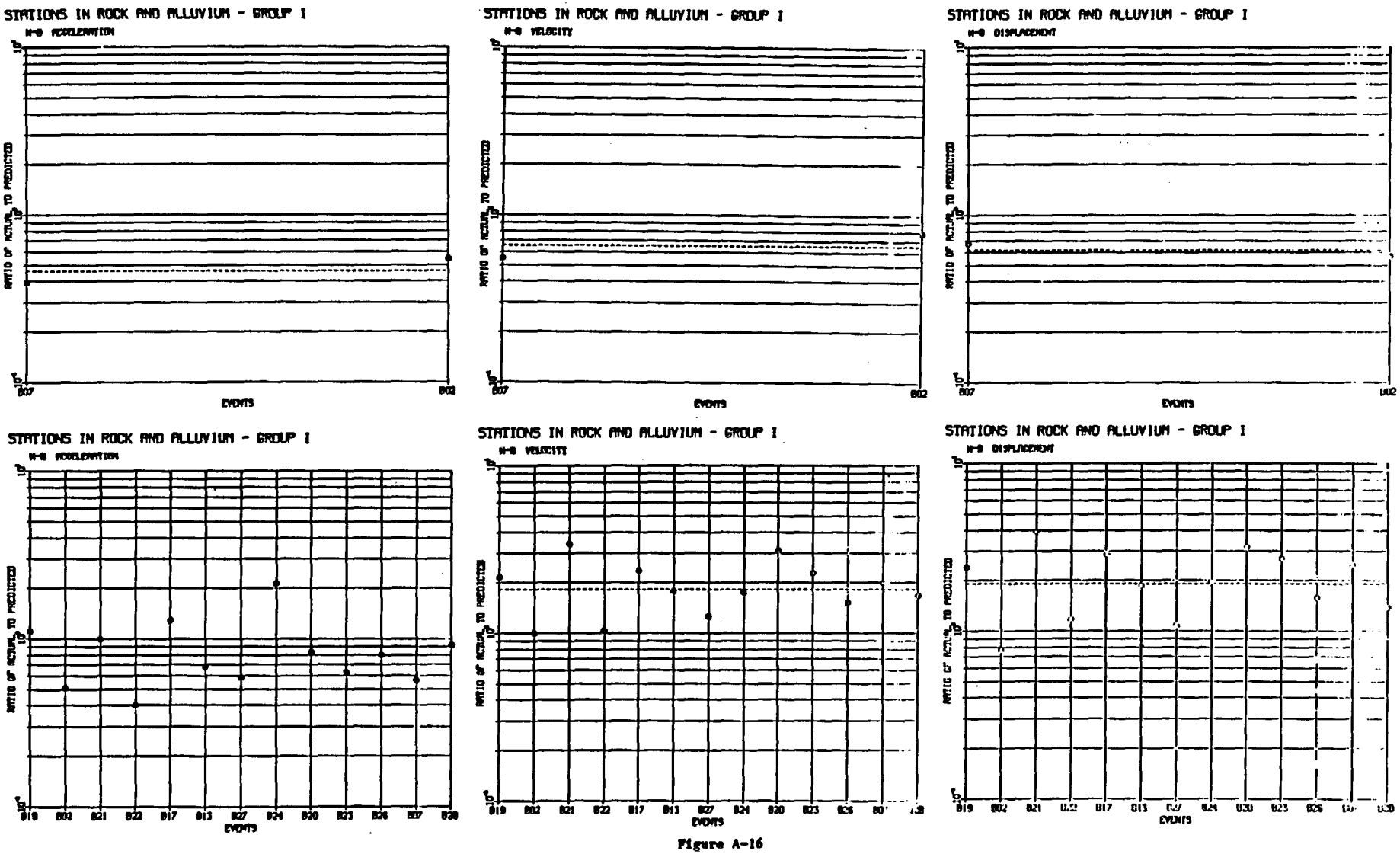
STATIONS IN ROCK AND ALLUVIUM - GROUP I
N-S ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
N-S VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
N-S DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
N-S ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
N-S VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP I
N-S DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure A-16

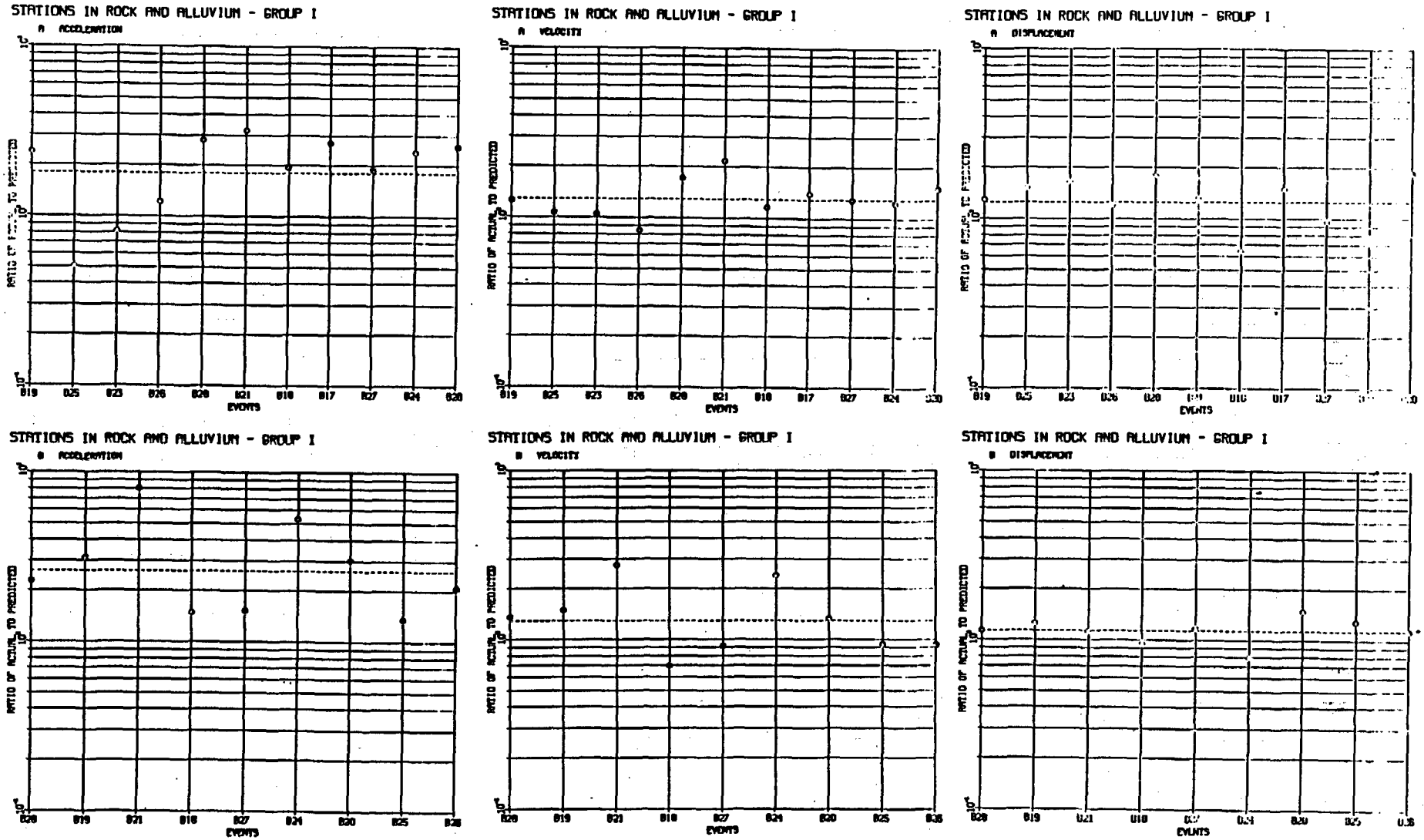
STATIONS IN ROCK AND ALLUVIUM - GROUP I
A ACCELERATION
A VELOCITY
A DISPLACEMENT
B ACCELERATION
B VELOCITY
B DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure A-17

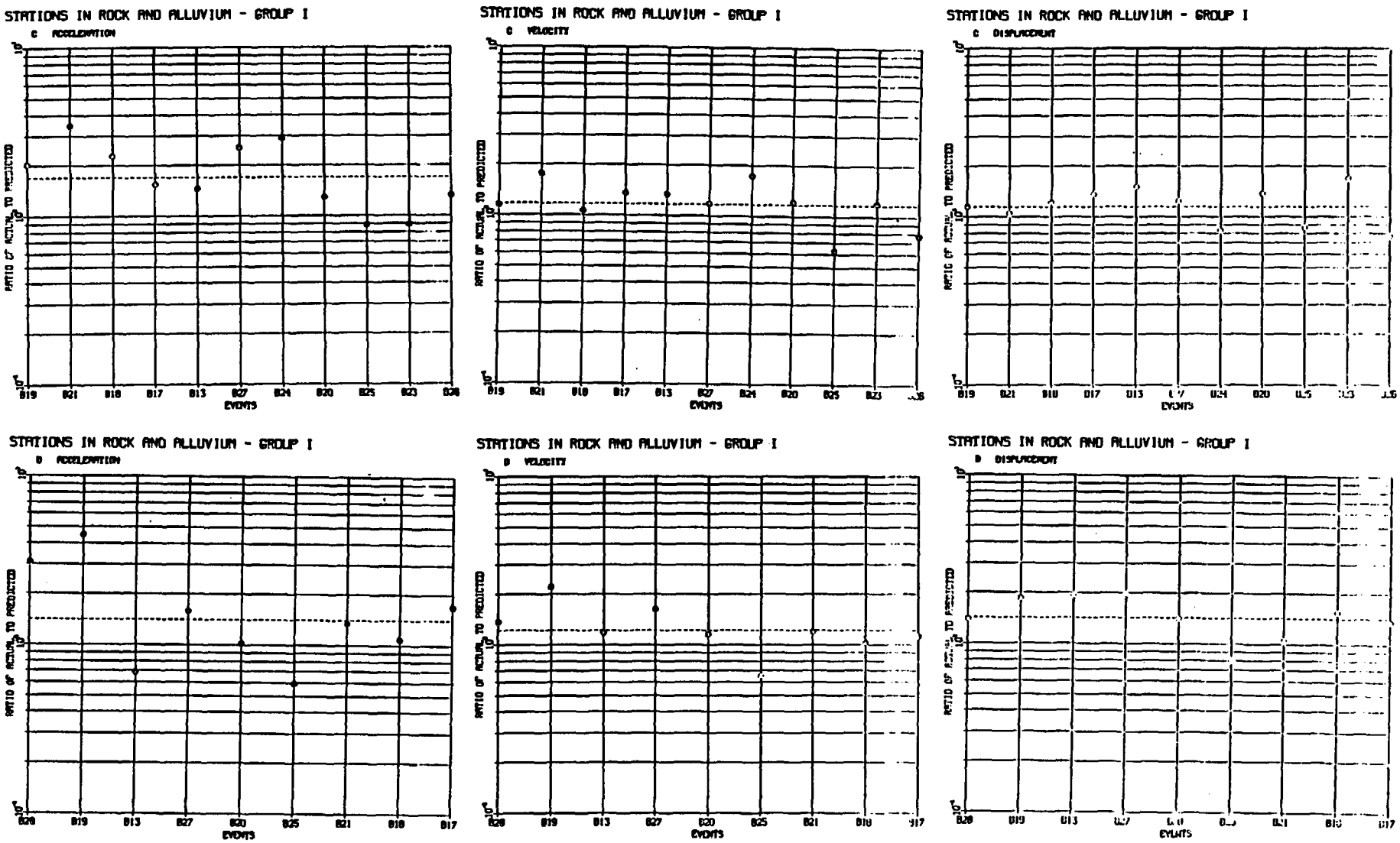
STATIONS IN ROCK AND ALLUVIUM - GROUP I
C ACCELERATION
C VELOCITY
C DISPLACEMENT
D ACCELERATION
D VELOCITY
D DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure A-18

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Appendix B

Ratios for Rock and Alluvium for Group II

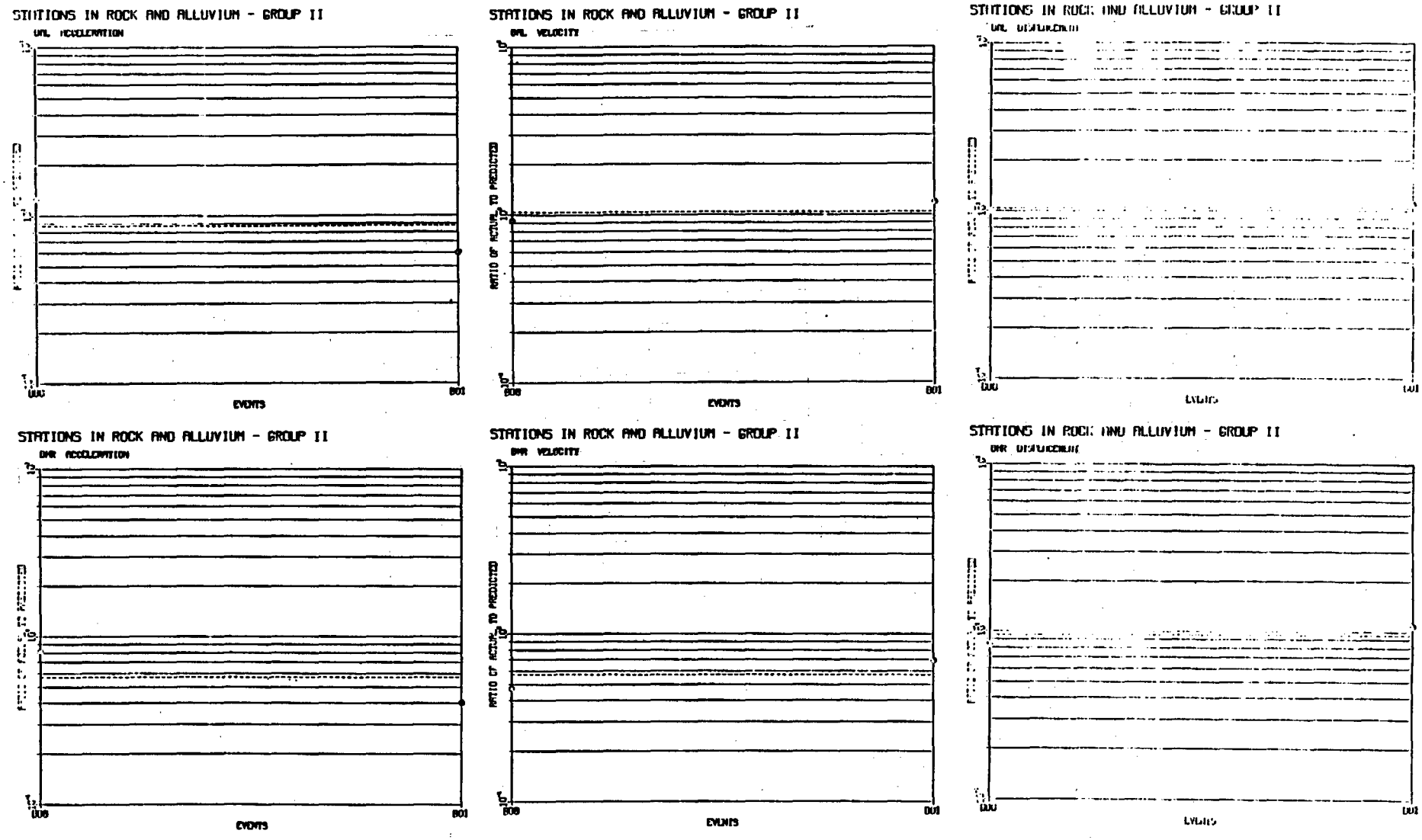

STATIONS IN ROCK AND ALLUVIUM - GROUP II
VAL ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
VAL VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
VAL DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP II
DAR ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
DAR VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
DAR DISPLACEMENT

Figure B-1

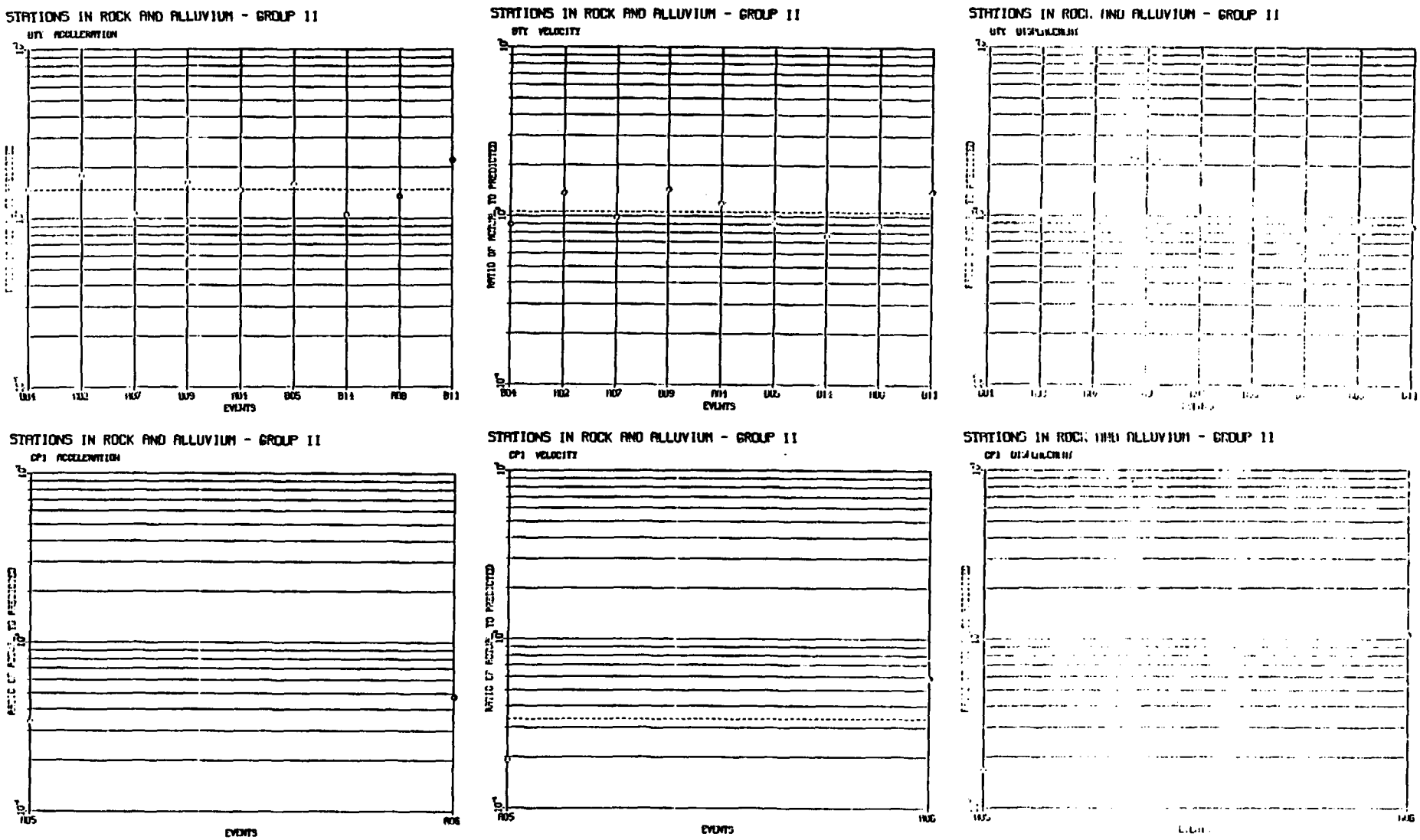

STATIONS IN ROCK AND ALLUVIUM - GROUP II
UTY ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
UTY VELOCITY
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
STATIONS IN ROCK AND ALLUVIUM - GROUP II
CP1 ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
CP1 VELOCITY
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II

Figure B-2

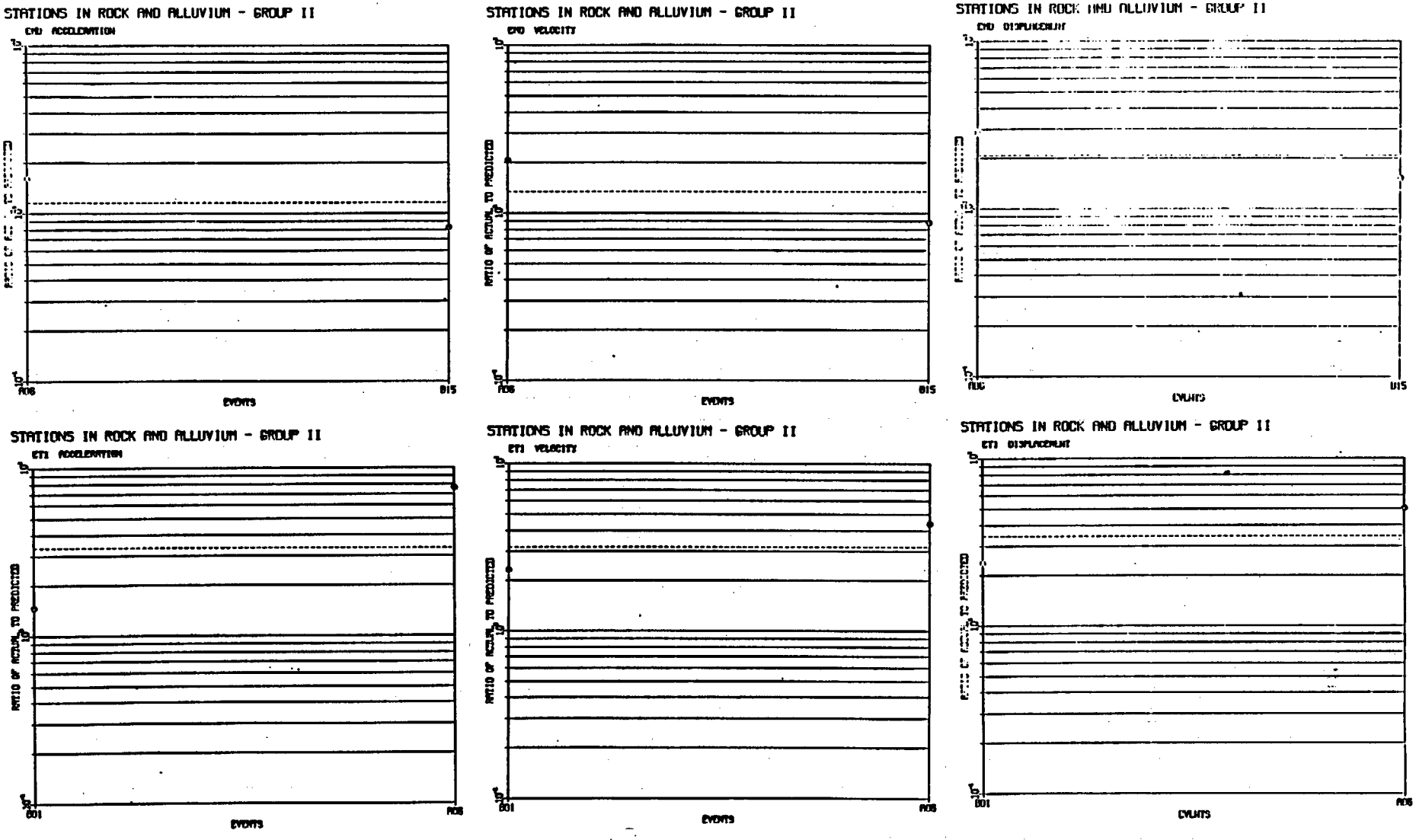

STATIONS IN ROCK AND ALLUVIUM - GROUP II
CHO ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
CHO VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
CHO DISPLACEMENT
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
ETI ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
ETI VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
ETI DISPLACEMENT
EVENTS

Figure B-3

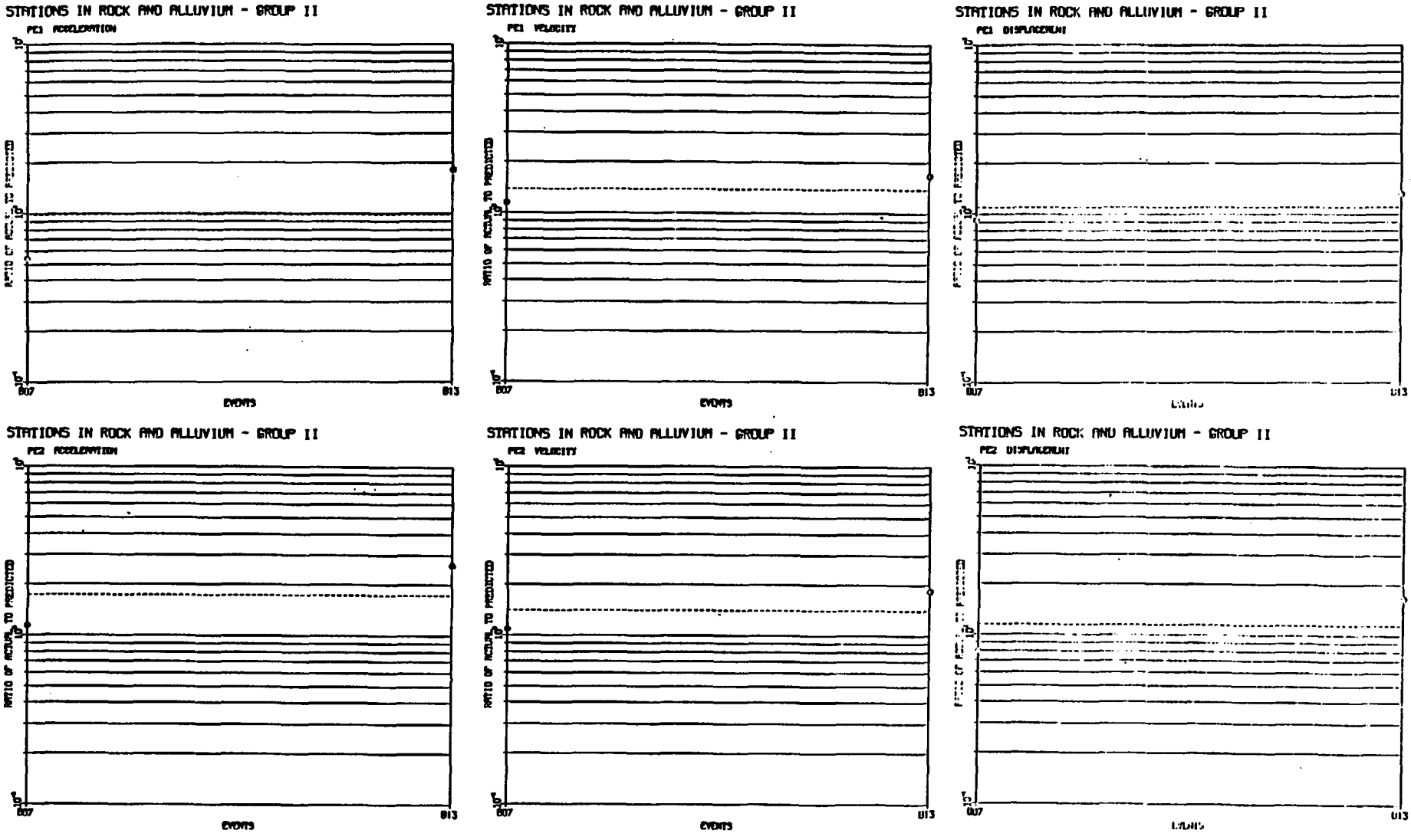

STATIONS IN ROCK AND ALLUVIUM - GROUP II
PC1 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP II
PC1 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP II
PC1 DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP II
PC2 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP II
PC2 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP II
PC2 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
007
013

Figure B-4

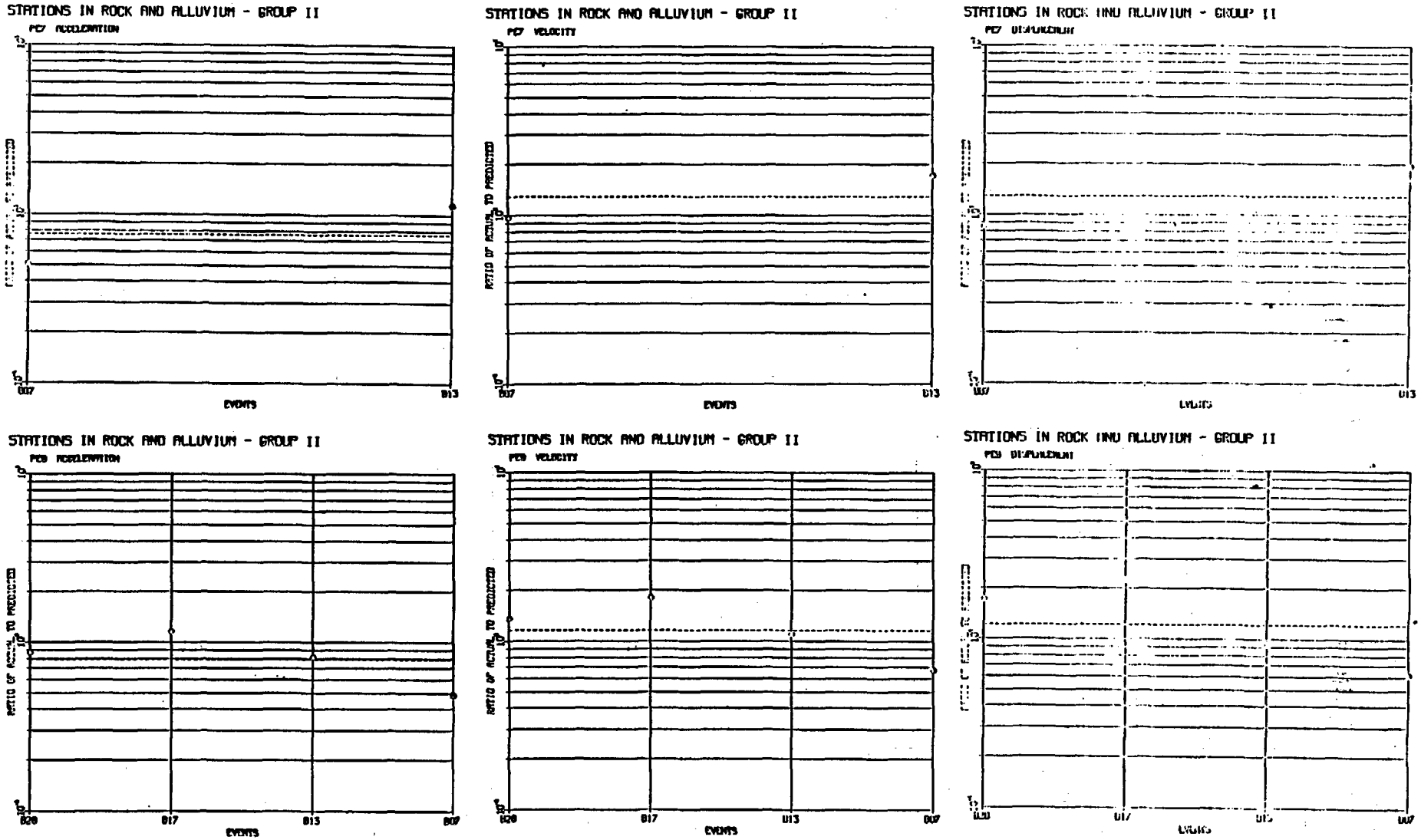

STATIONS IN ROCK AND ALLUVIUM - GROUP II
PC7 ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
PC7 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
PC7 DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP II
PC9 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
PC9 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
PC9 DISPLACEMENT

Figure B-5

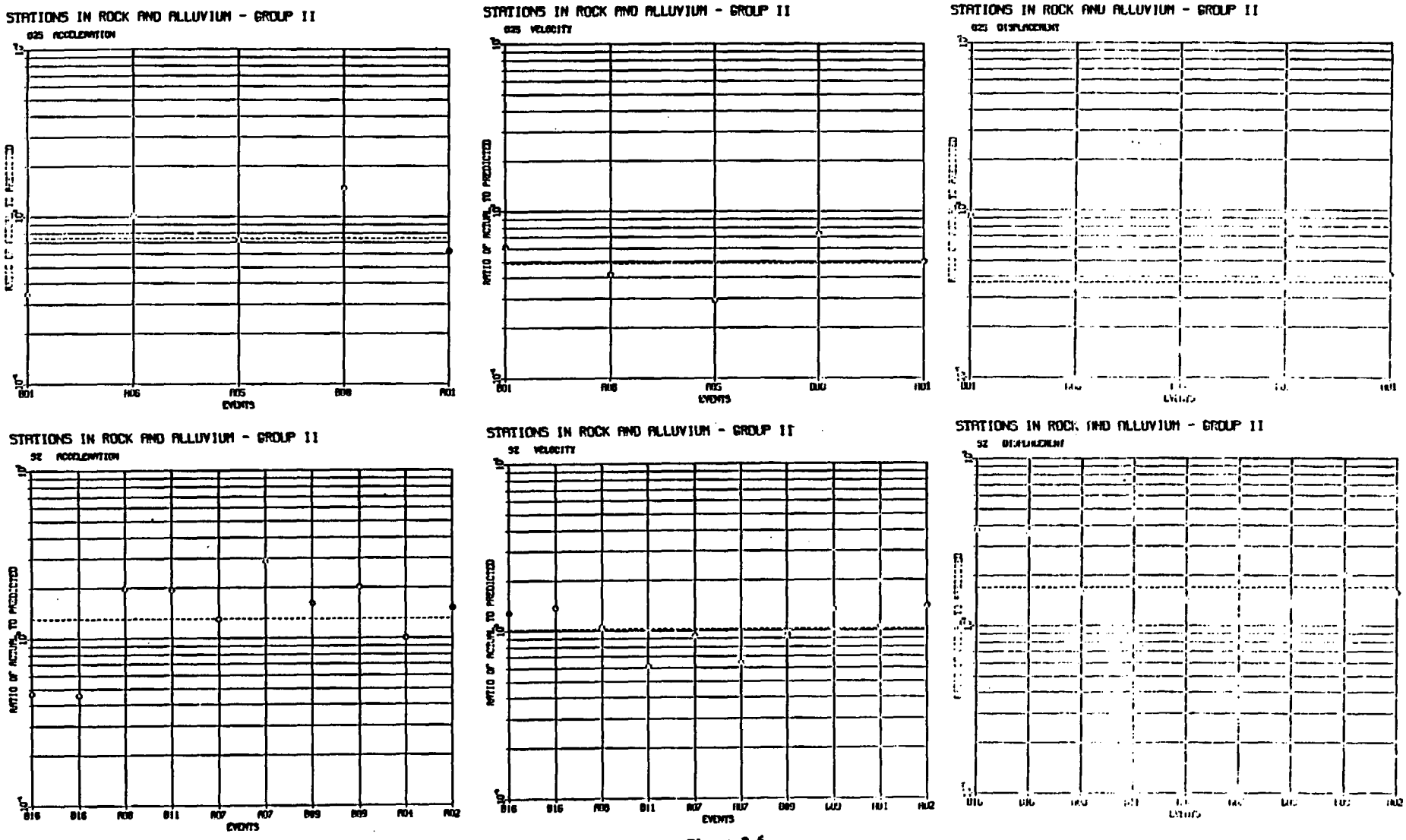
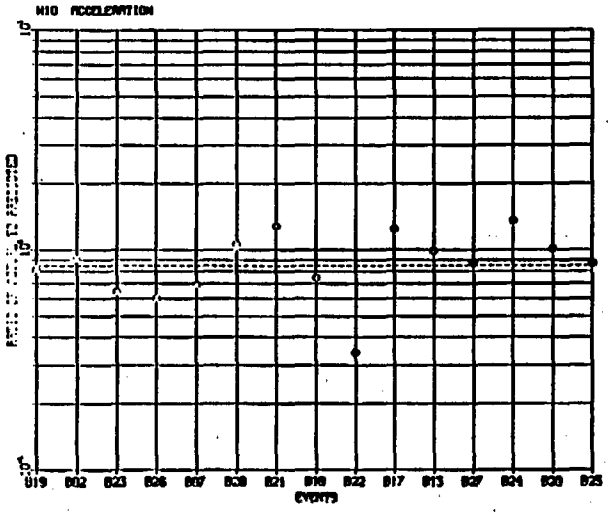
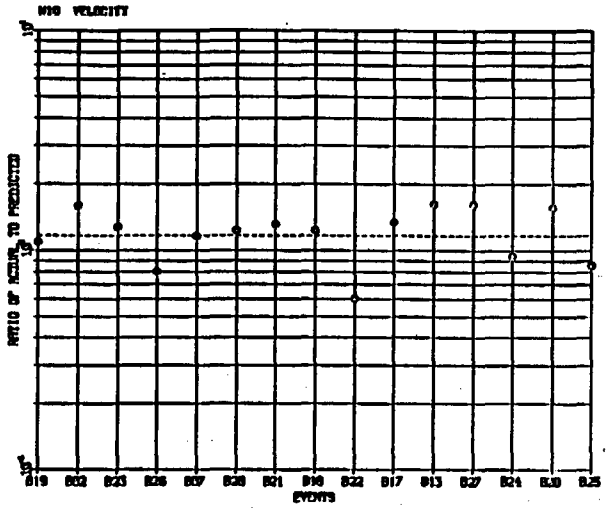

STATIONS IN ROCK AND ALLUVIUM - GROUP II
025 ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
025 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
025 DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP II
92 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
92 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
92 DISPLACEMENT

Figure B-6

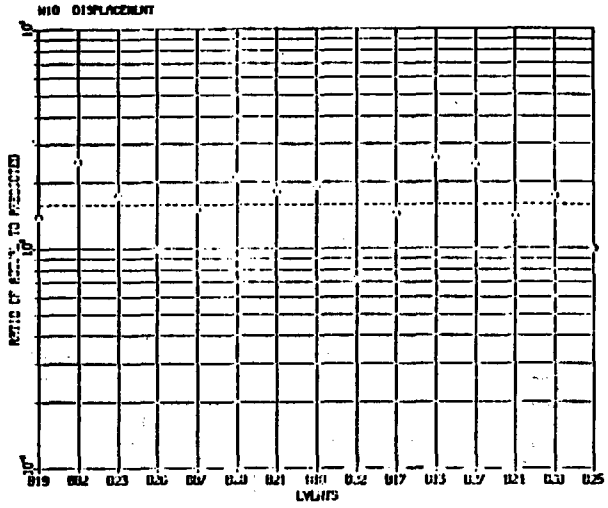
STATIONS IN ROCK AND ALLUVIUM - GROUP II



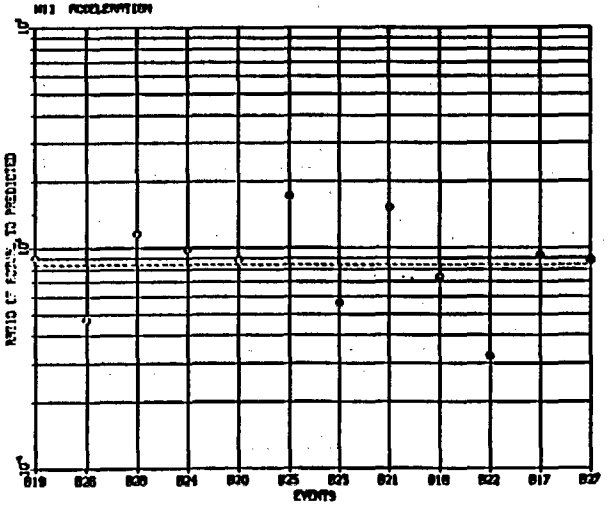
STATIONS IN ROCK AND ALLUVIUM - GROUP II



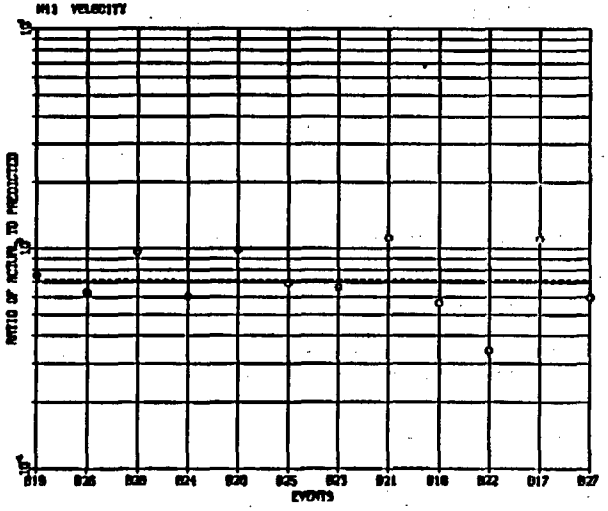
STATIONS IN ROCK AND ALLUVIUM - GROUP II



STATIONS IN ROCK AND ALLUVIUM - GROUP II



STATIONS IN ROCK AND ALLUVIUM - GROUP II



STATIONS IN ROCK AND ALLUVIUM - GROUP II

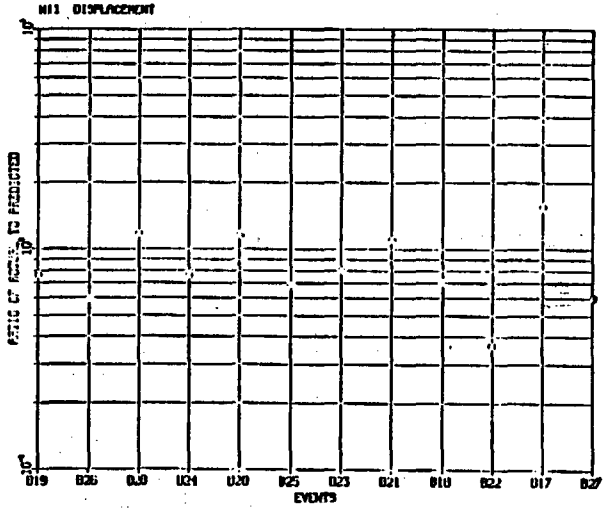
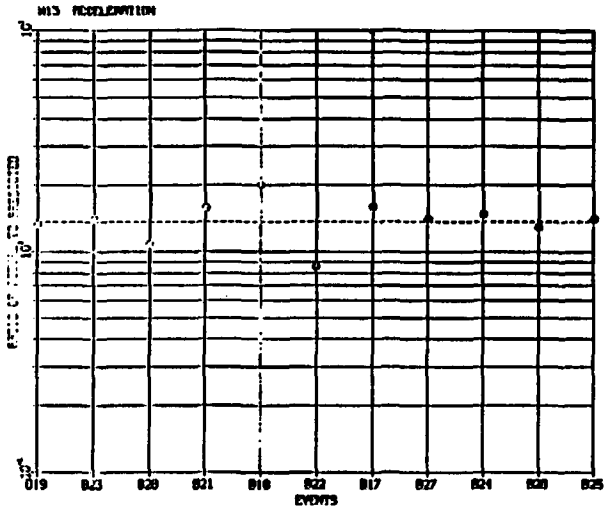
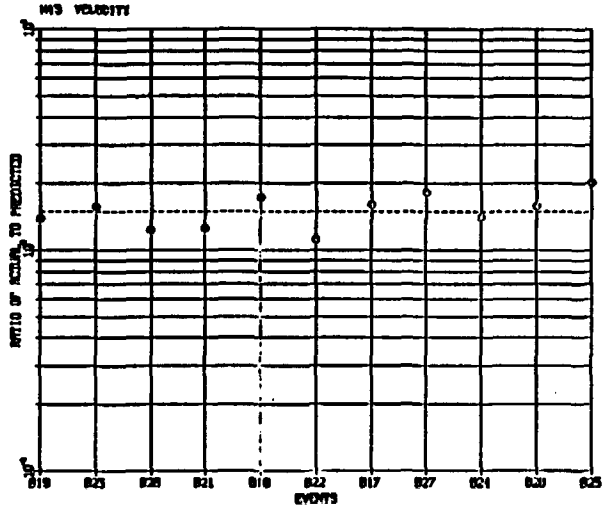


Figure B-7

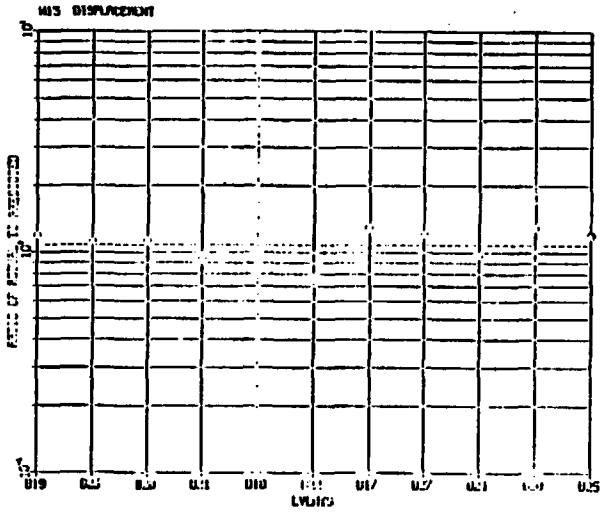
STATIONS IN ROCK AND ALLUVIUM - GROUP II



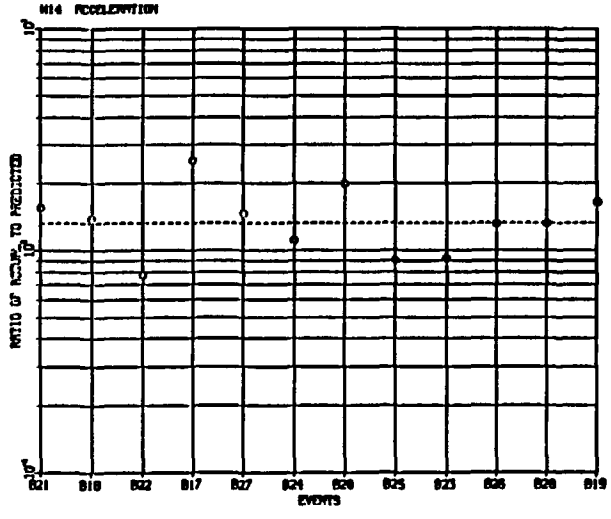
STATIONS IN ROCK AND ALLUVIUM - GROUP II



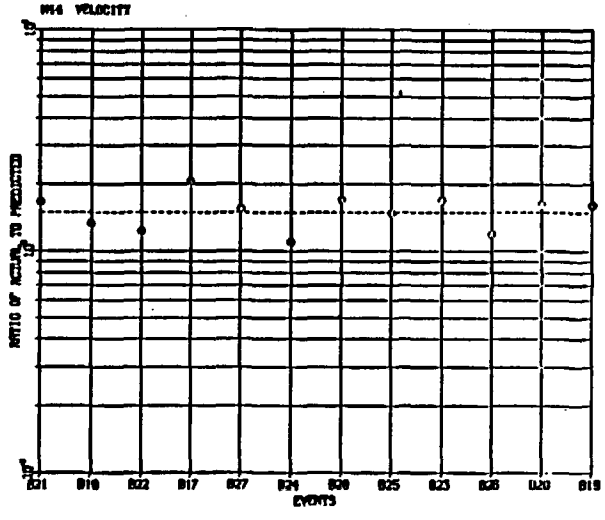
STATIONS IN ROCK AND ALLUVIUM - GROUP II



STATIONS IN ROCK AND ALLUVIUM - GROUP II



STATIONS IN ROCK AND ALLUVIUM - GROUP II



STATIONS IN ROCK AND ALLUVIUM - GROUP II

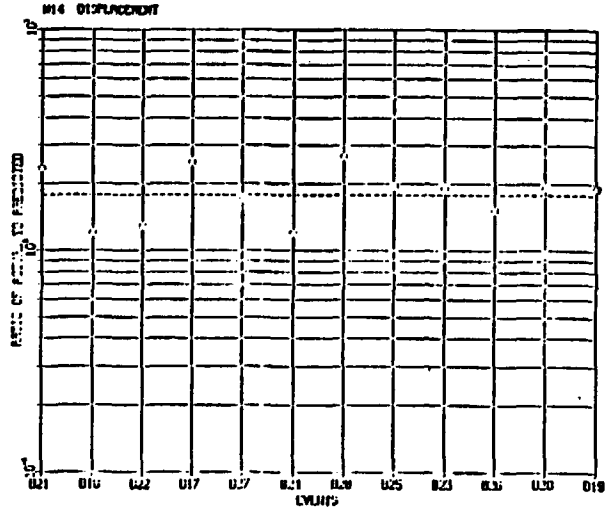


Figure B-8

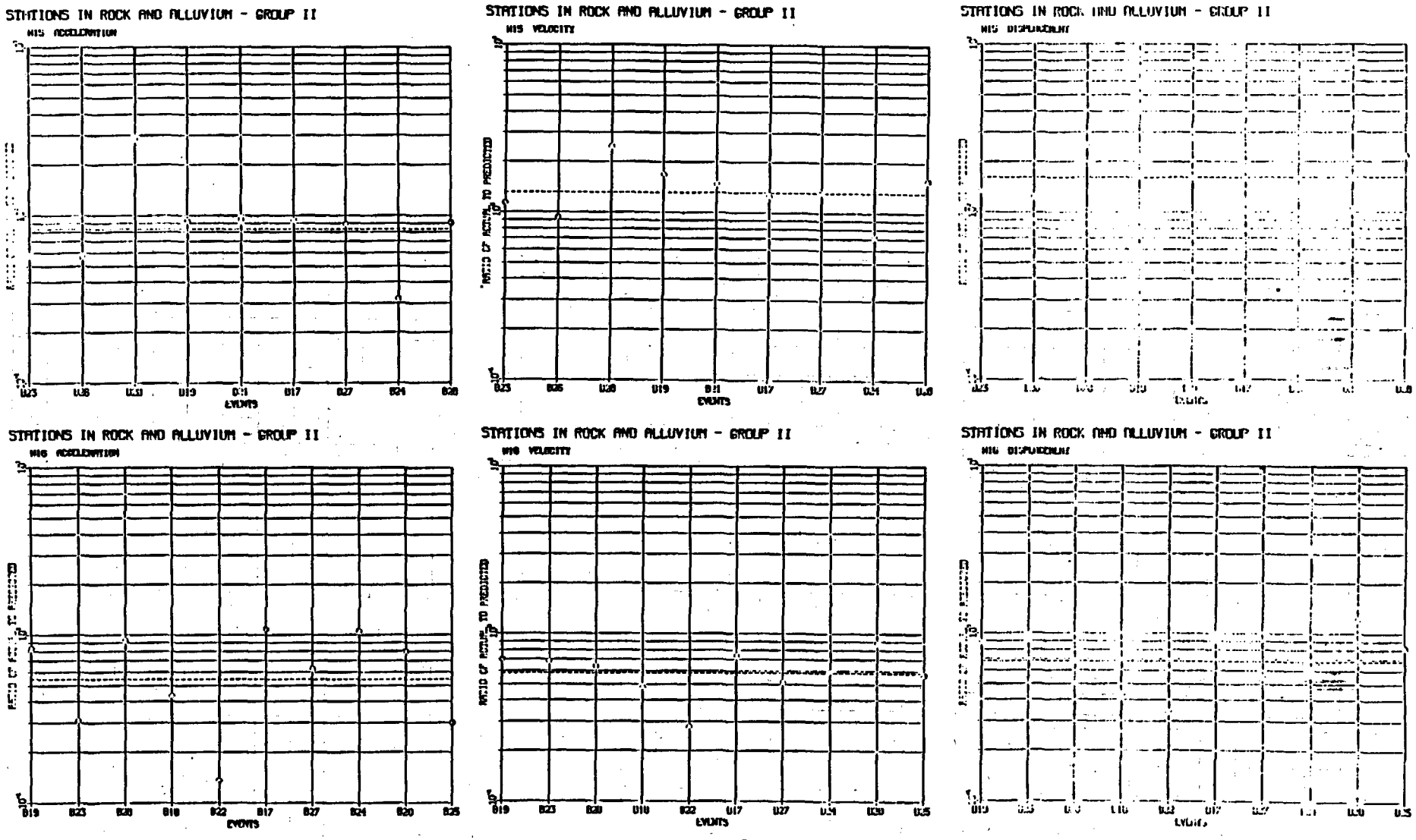

STATIONS IN ROCK AND ALLUVIUM - GROUP II
H15 ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
H15 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
H16 ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
H16 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure B-9

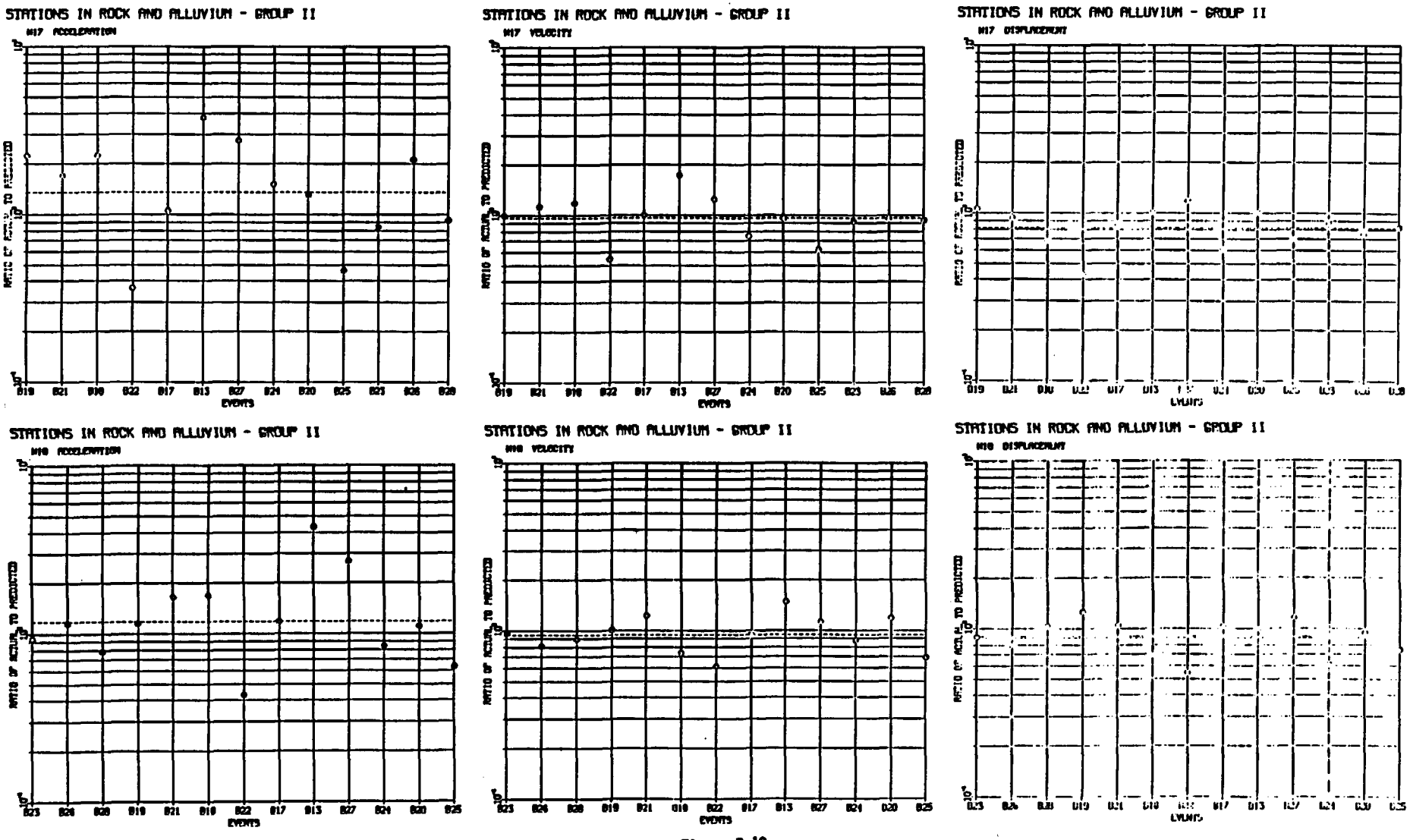
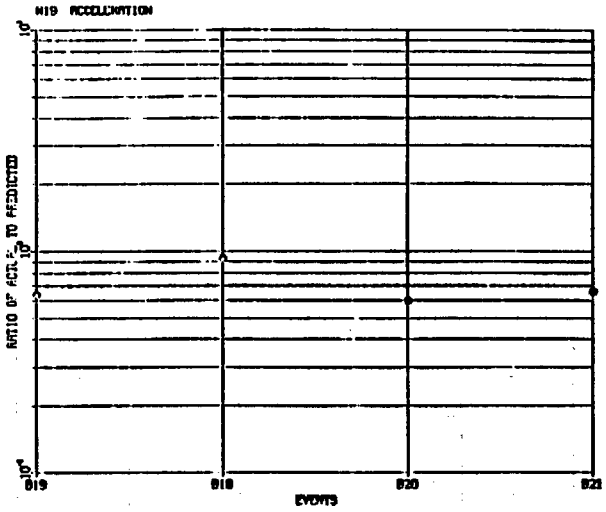
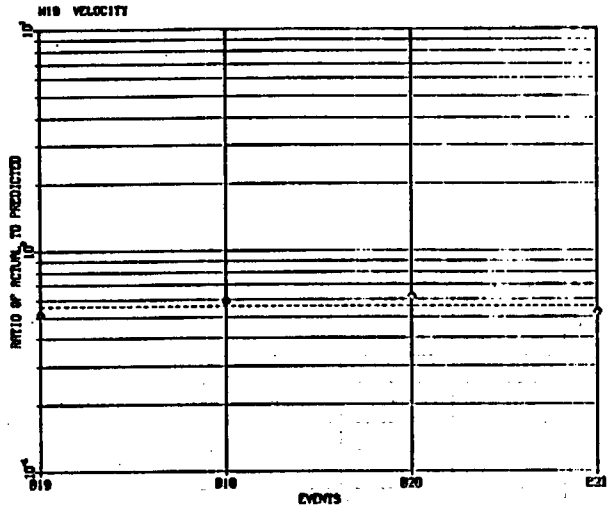

STATIONS IN ROCK AND ALLUVIUM - GROUP II
H17 ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
H17 VELOCITY
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
H17 DISPLACEMENT
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
H10 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
H10 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
H10 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure B-10

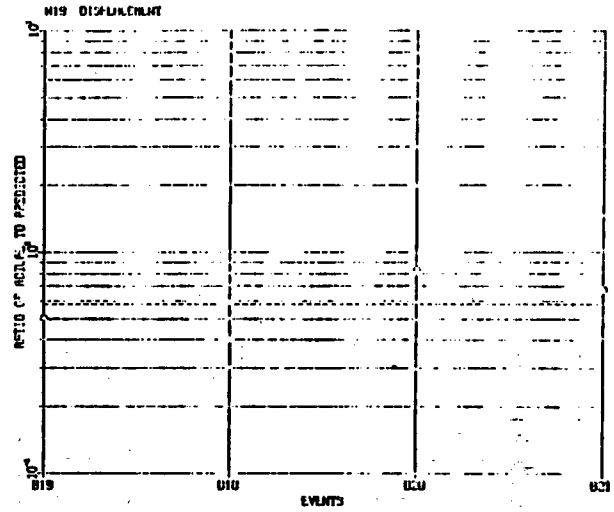
STATIONS IN ROCK AND ALLUVIUM - GROUP II



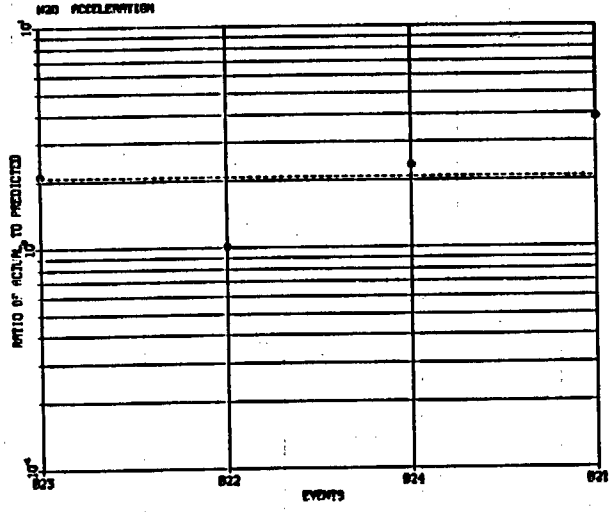
STATIONS IN ROCK AND ALLUVIUM - GROUP II



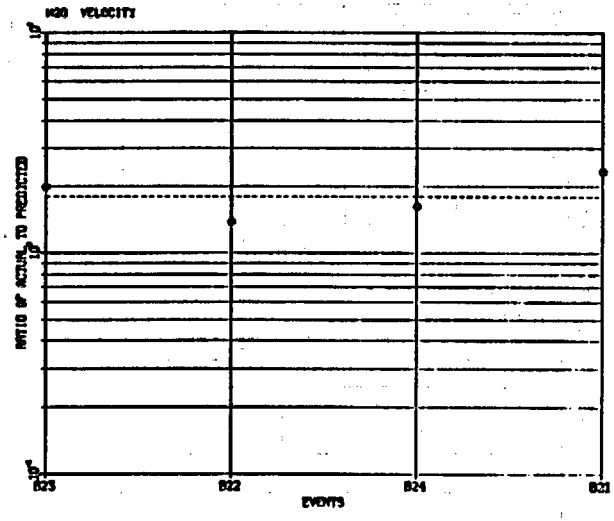
STATIONS IN ROCK AND ALLUVIUM - GROUP II



STATIONS IN ROCK AND ALLUVIUM - GROUP II



STATIONS IN ROCK AND ALLUVIUM - GROUP II



STATIONS IN ROCK AND ALLUVIUM - GROUP II

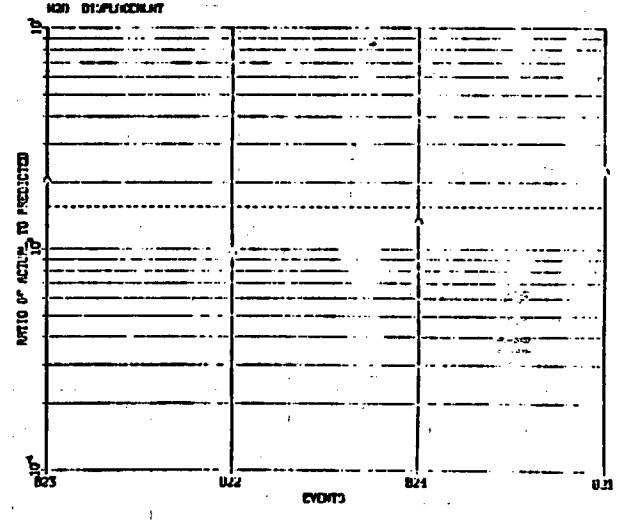


Figure B-11

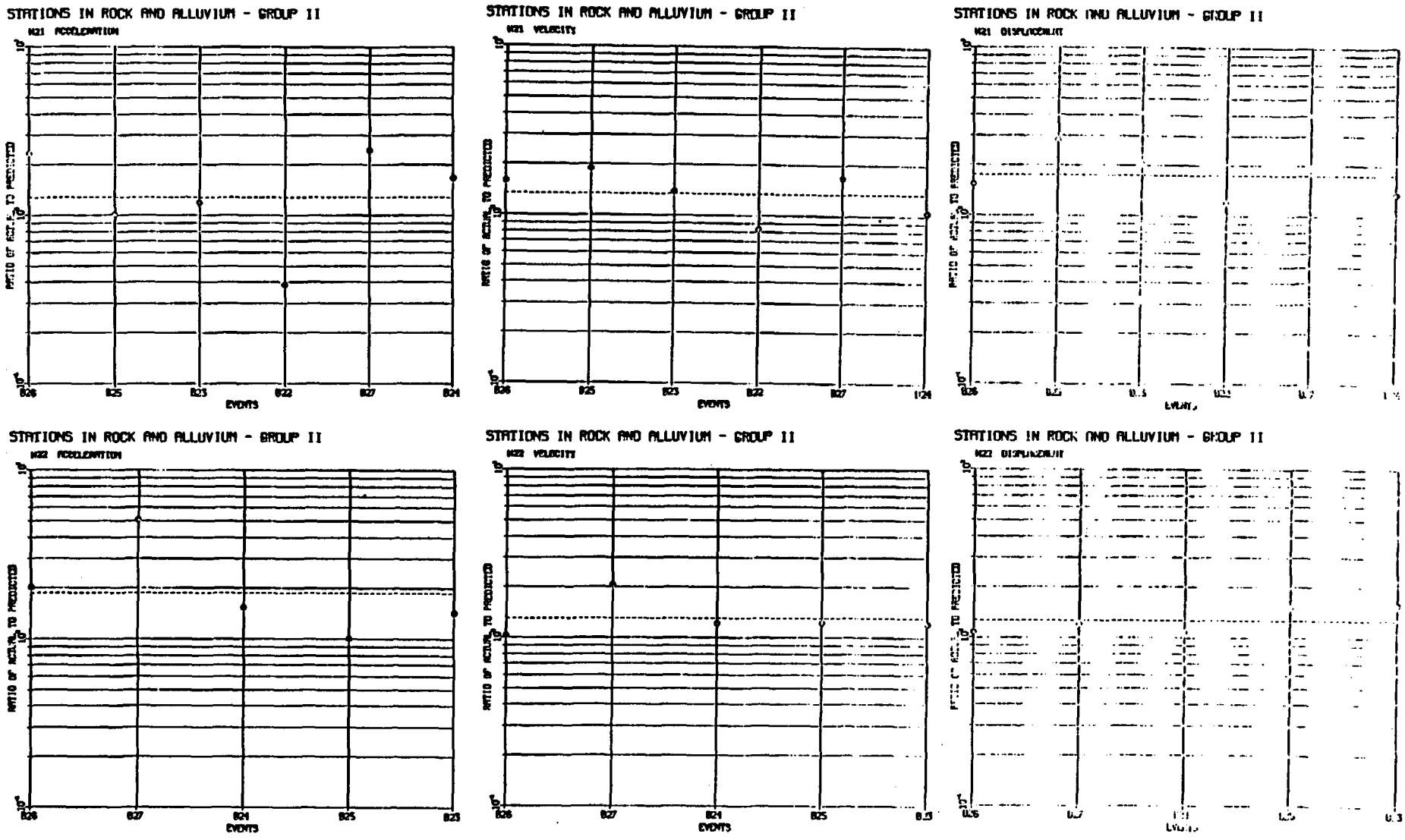
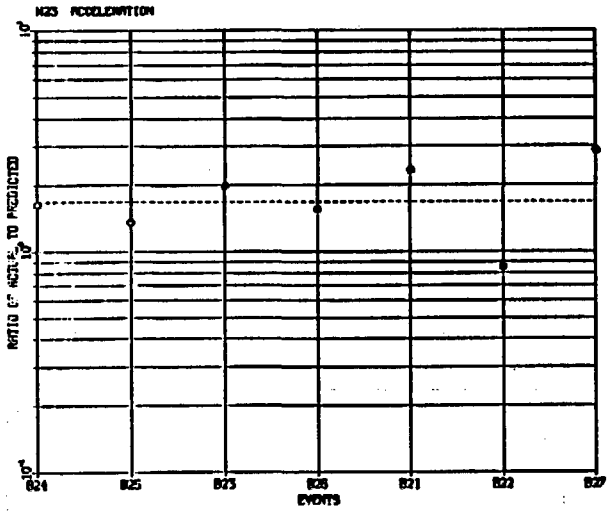
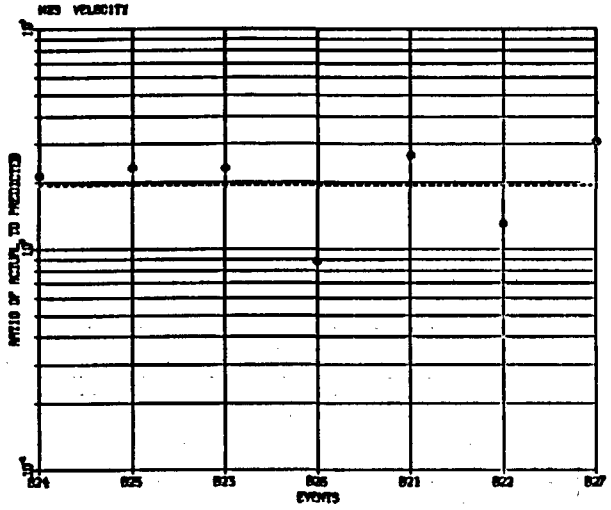

STATIONS IN ROCK AND ALLUVIUM - GROUP II
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
STATIONS IN ROCK AND ALLUVIUM - GROUP II
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II

Figure B-12

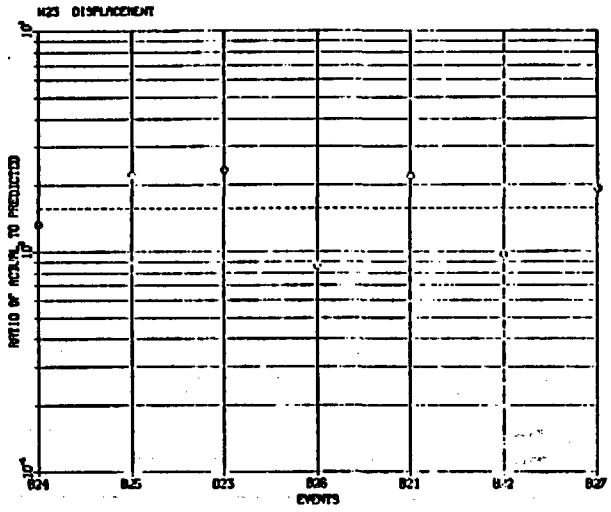
STATIONS IN ROCK AND ALLUVIUM - GROUP II



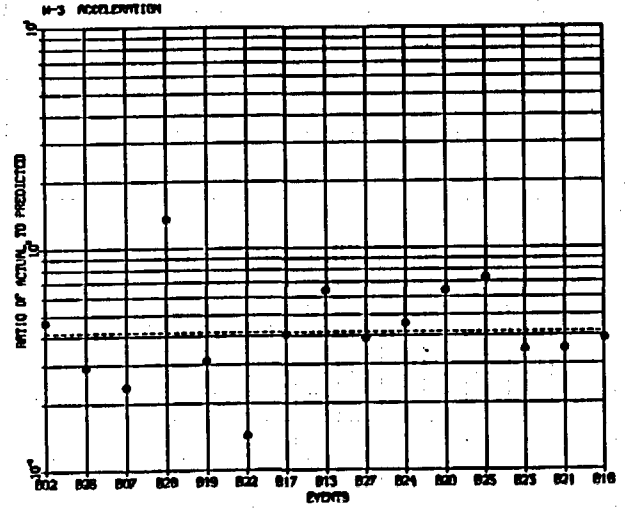
STATIONS IN ROCK AND ALLUVIUM - GROUP II



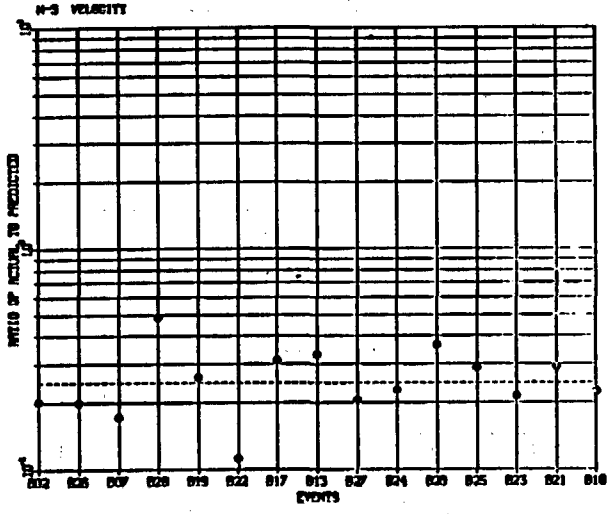
STATIONS IN ROCK AND ALLUVIUM - GROUP II



STATIONS IN ROCK AND ALLUVIUM - GROUP II



STATIONS IN ROCK AND ALLUVIUM - GROUP II



STATIONS IN ROCK AND ALLUVIUM - GROUP II

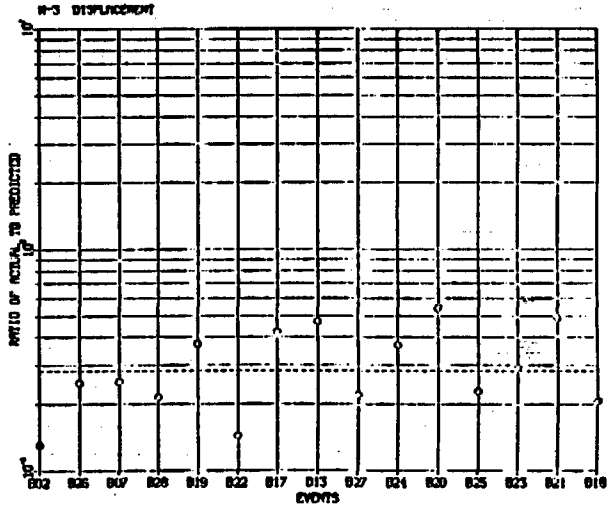


Figure B-13

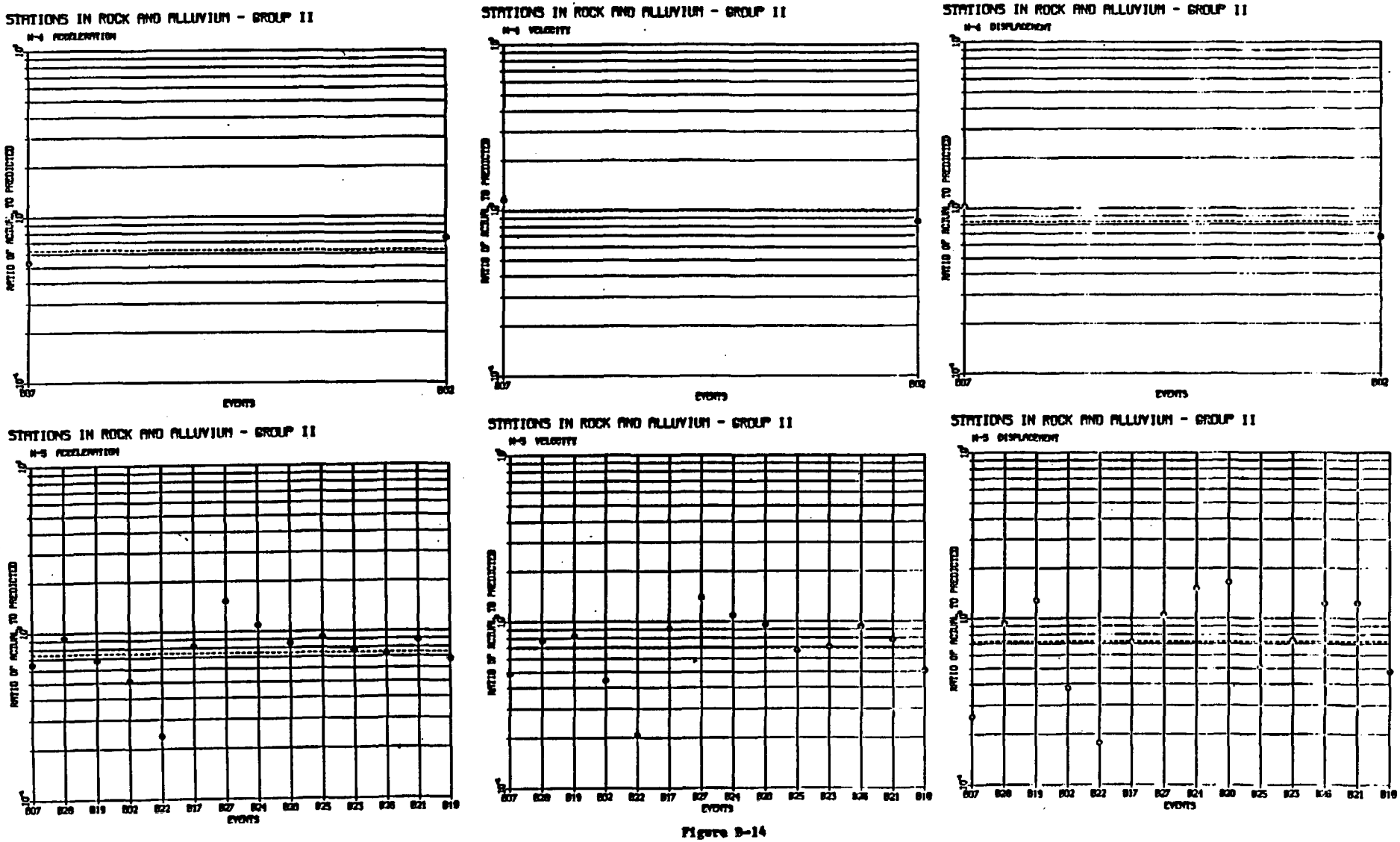

STATIONS IN ROCK AND ALLUVIUM - GROUP II
N-4 ACCELERATION
N-4 VELOCITY
N-4 DISPLACEMENT
N-5 ACCELERATION
N-5 VELOCITY
N-5 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
B07
B20
B19
B02
B22
B17
B27
B24
B20
B25
B23
B26
B21
B10

Figure B-14

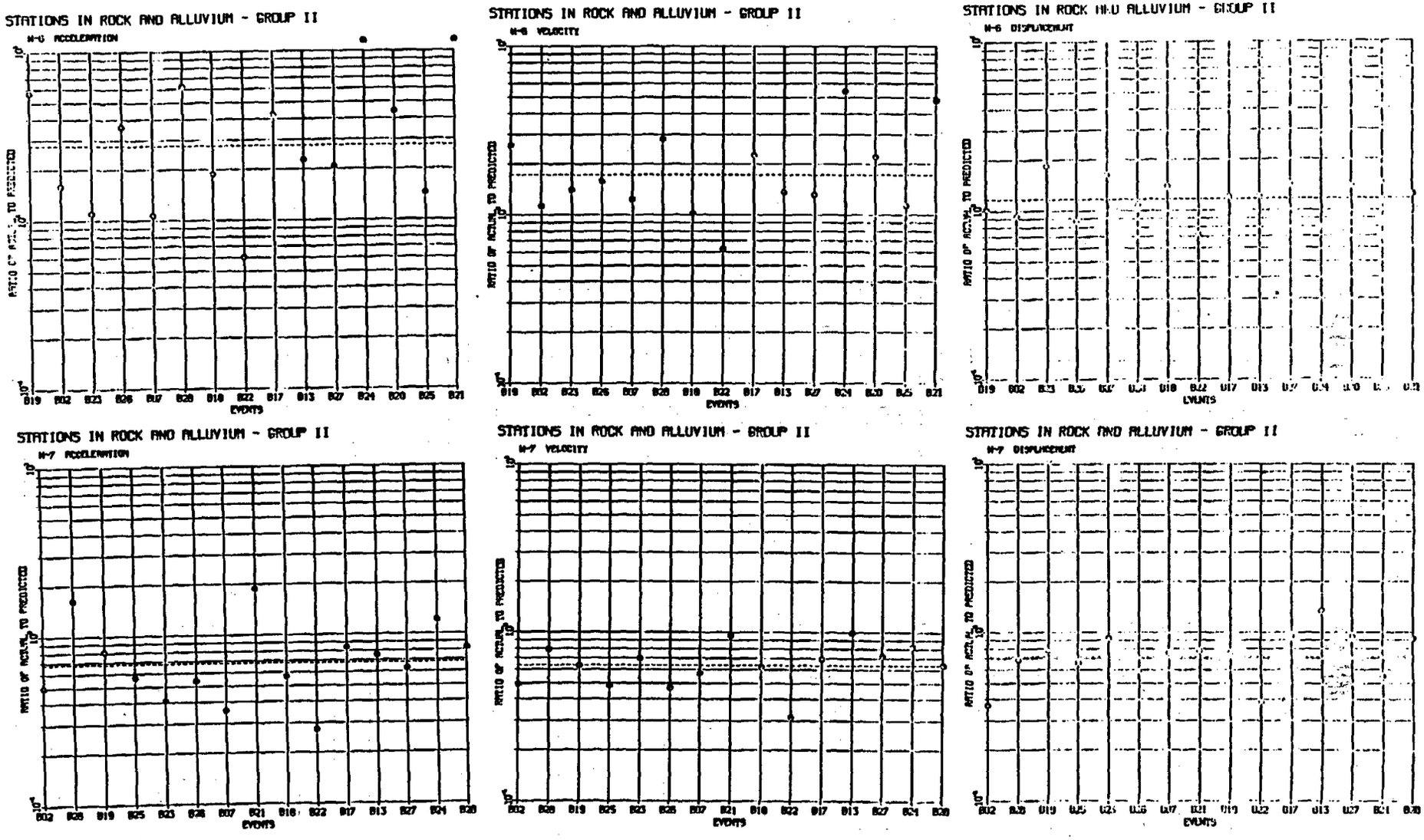

STATIONS IN ROCK AND ALLUVIUM - GROUP II
N-6 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP II
N-6 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP II
N-6 DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP II
N-7 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP II
N-7 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP II
N-7 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure B-15

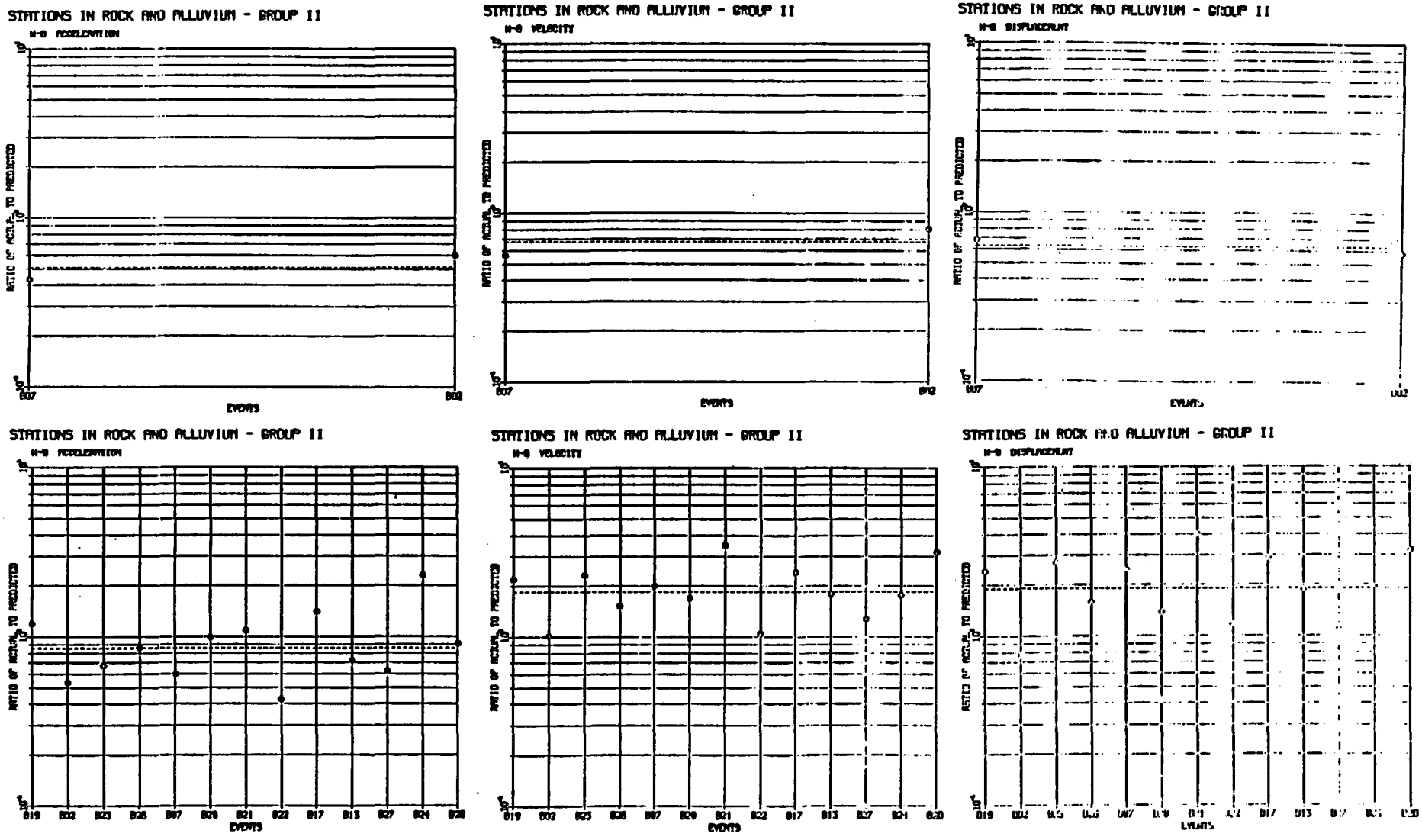

STATIONS IN ROCK AND ALLUVIUM - GROUP II
N-S ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP II
N-S VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP II
N-S DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP II
N-S ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP II
N-S VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP II
N-S DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure B-16

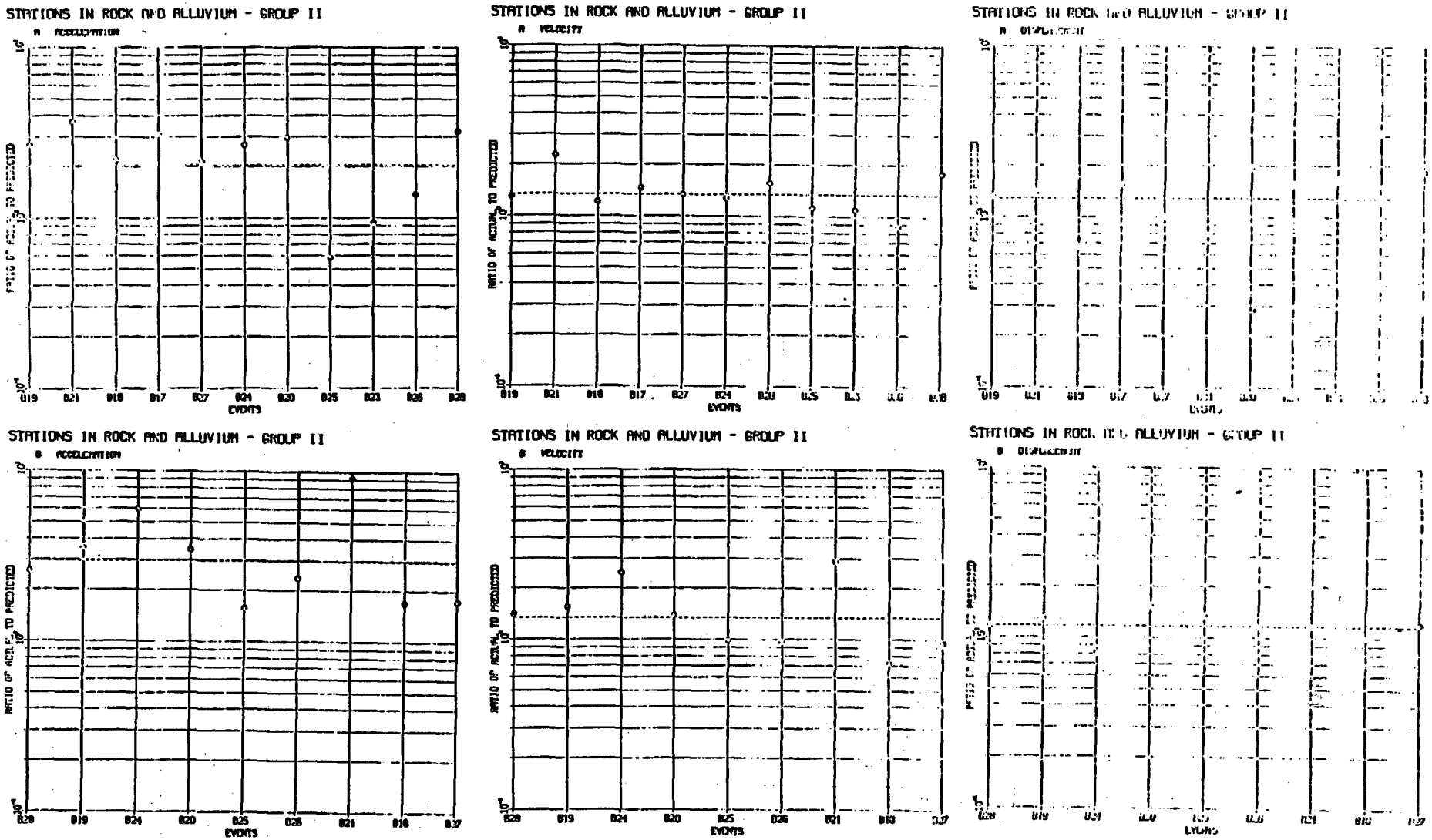

STATIONS IN ROCK AND ALLUVIUM - GROUP II
A ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP II
A VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP II
STATIONS IN ROCK AND ALLUVIUM - GROUP II
B ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP II
B VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP II
B DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure B-17

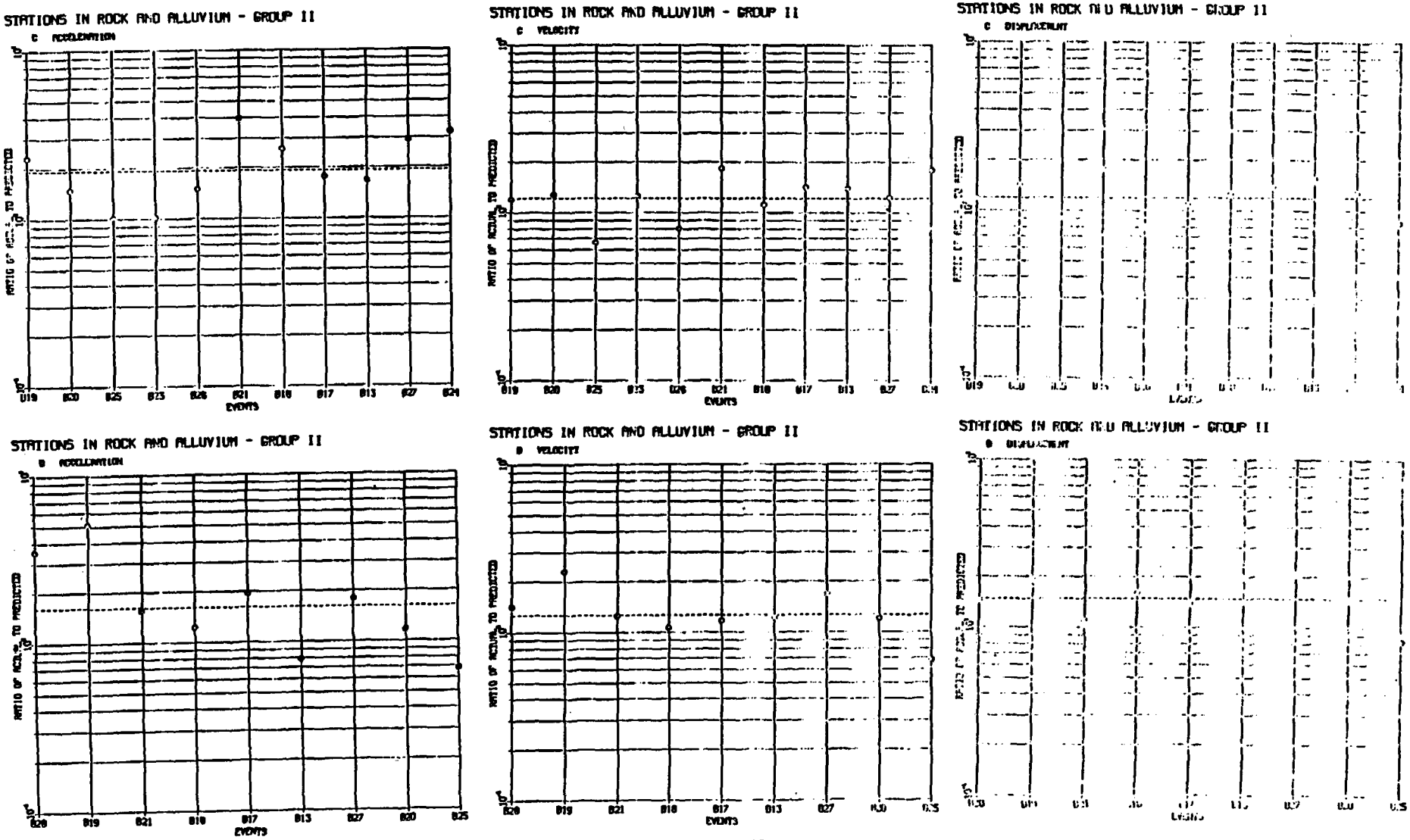

STATIONS IN ROCK AND ALLUVIUM - GROUP II
C ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
C VELOCITY
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
C DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP II
B ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
B VELOCITY
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP II
B DISPLACEMENT

Figure B-18

Appendix C

Ratios for Rock and Alluvium for Group II

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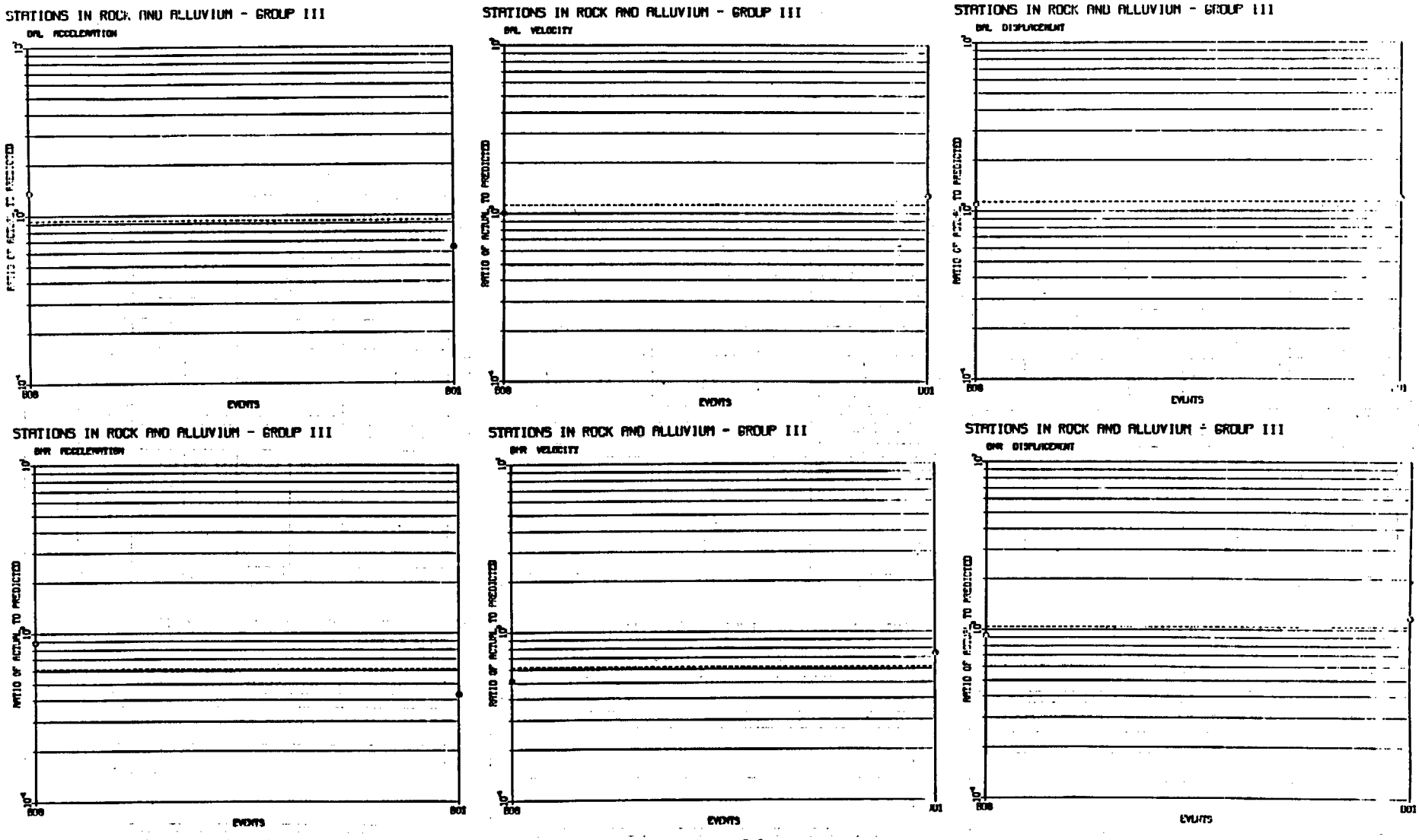

STATIONS IN ROCK AND ALLUVIUM - GROUP III
BAL ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP III
BAL VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP III
BAL DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP III
BAR ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP III
BAR VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP III
BAR DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
B08
B01
D01
A01

Figure C-1

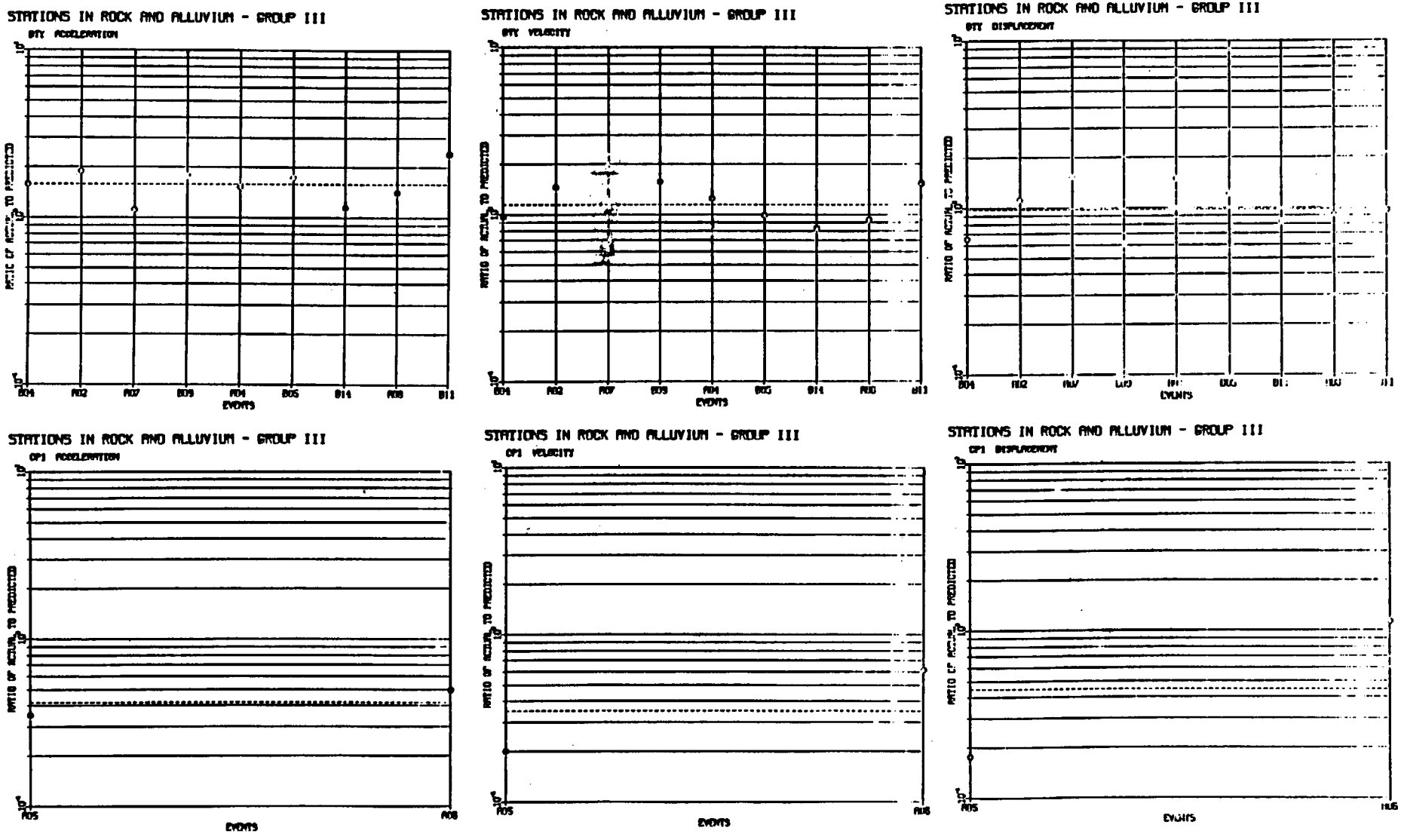

STATIONS IN ROCK AND ALLUVIUM - GROUP III
BTY ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP III
BTY VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP III
BTY DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP III
CP1 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP III
CP1 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP III
CP1 DISPLACEMENT
EVENTS

Figure C-2

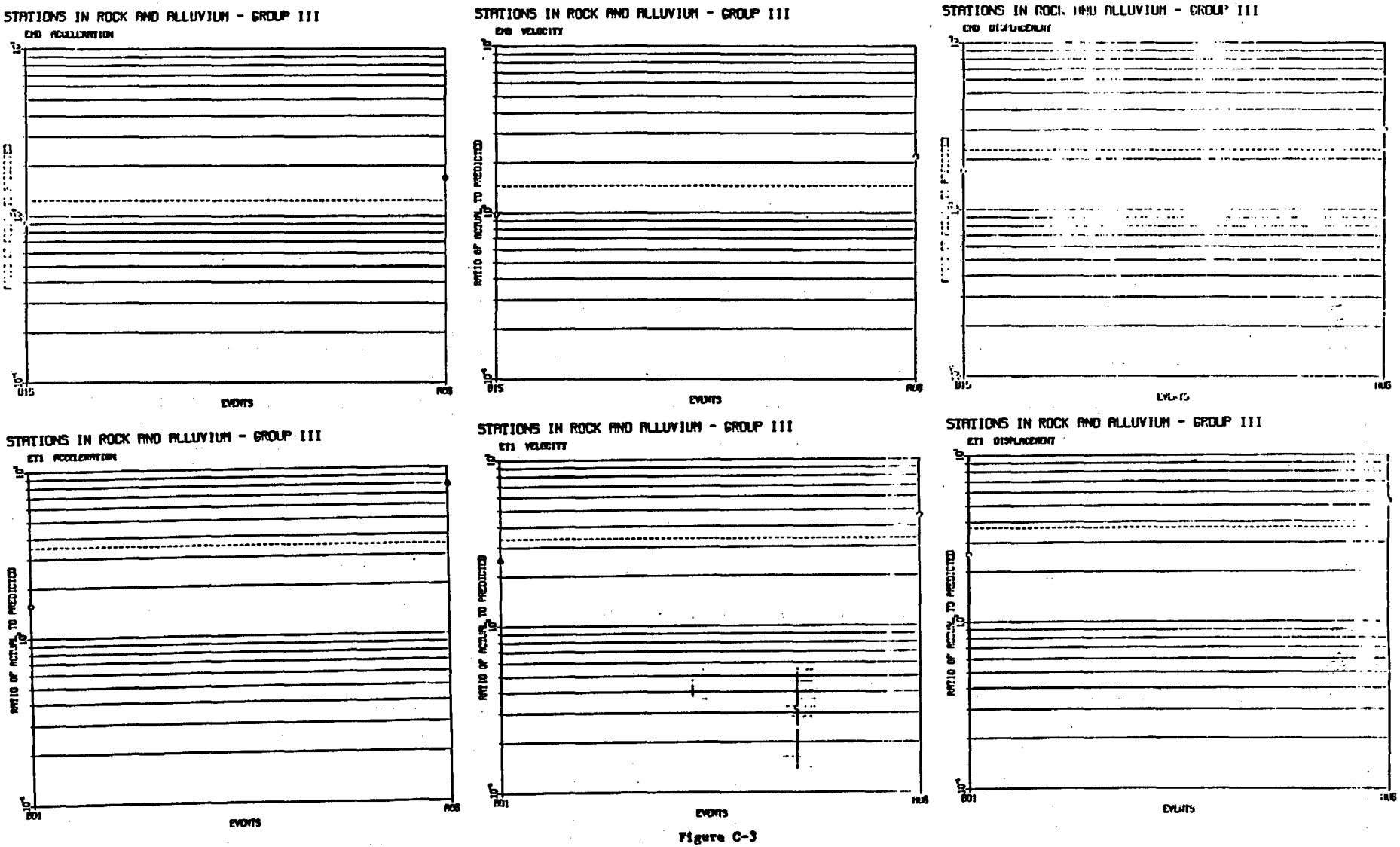

STATIONS IN ROCK AND ALLUVIUM - GROUP III
END ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
END VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
END DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP III
ET1 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
ET1 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
ET1 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure C-3

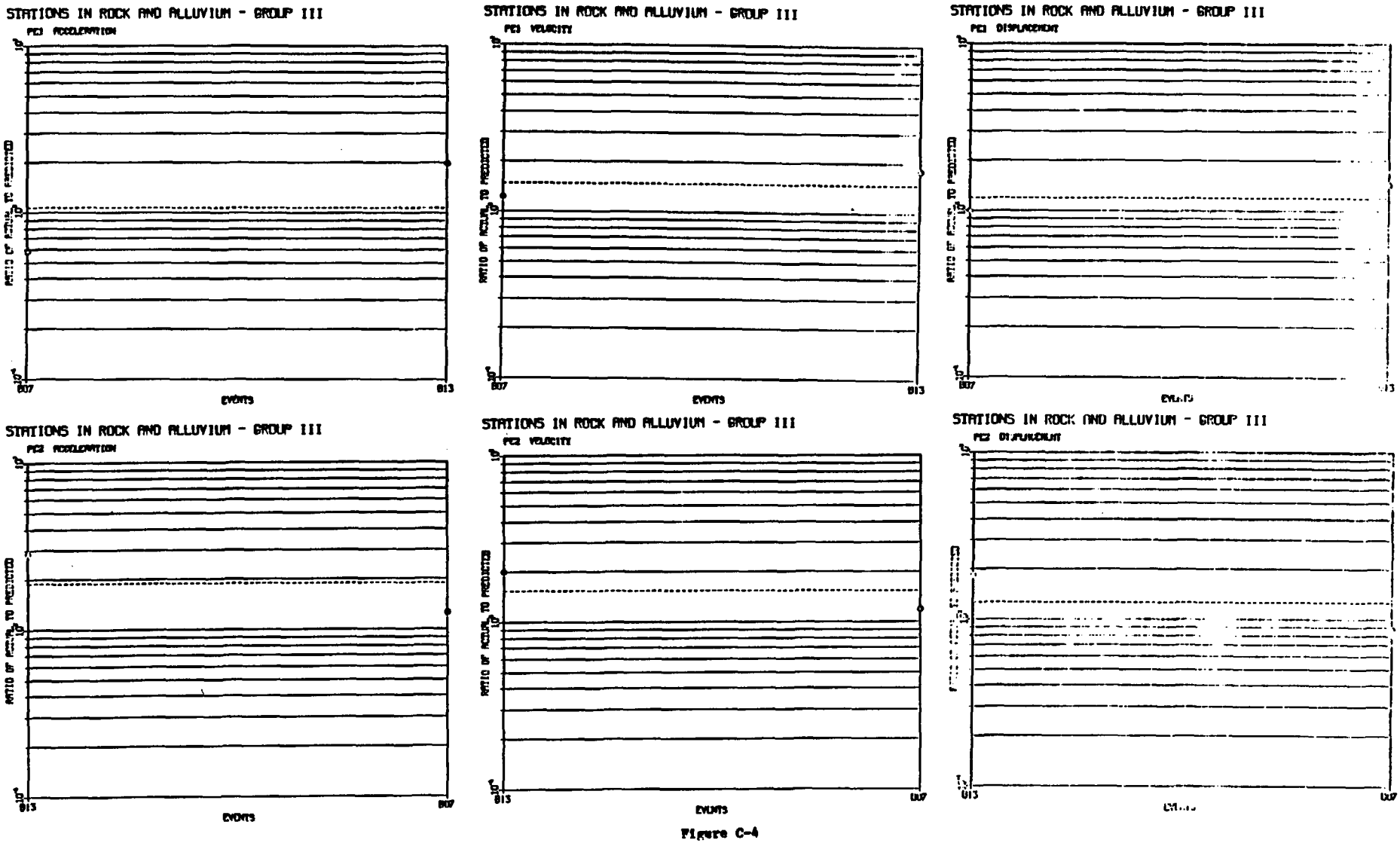

STATIONS IN ROCK AND ALLUVIUM - GROUP III
PC1 ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
PC1 VELOCITY
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
PC1 DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP III
PC2 ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
PC2 VELOCITY
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
PC2 DISPLACEMENT

Figure C-4

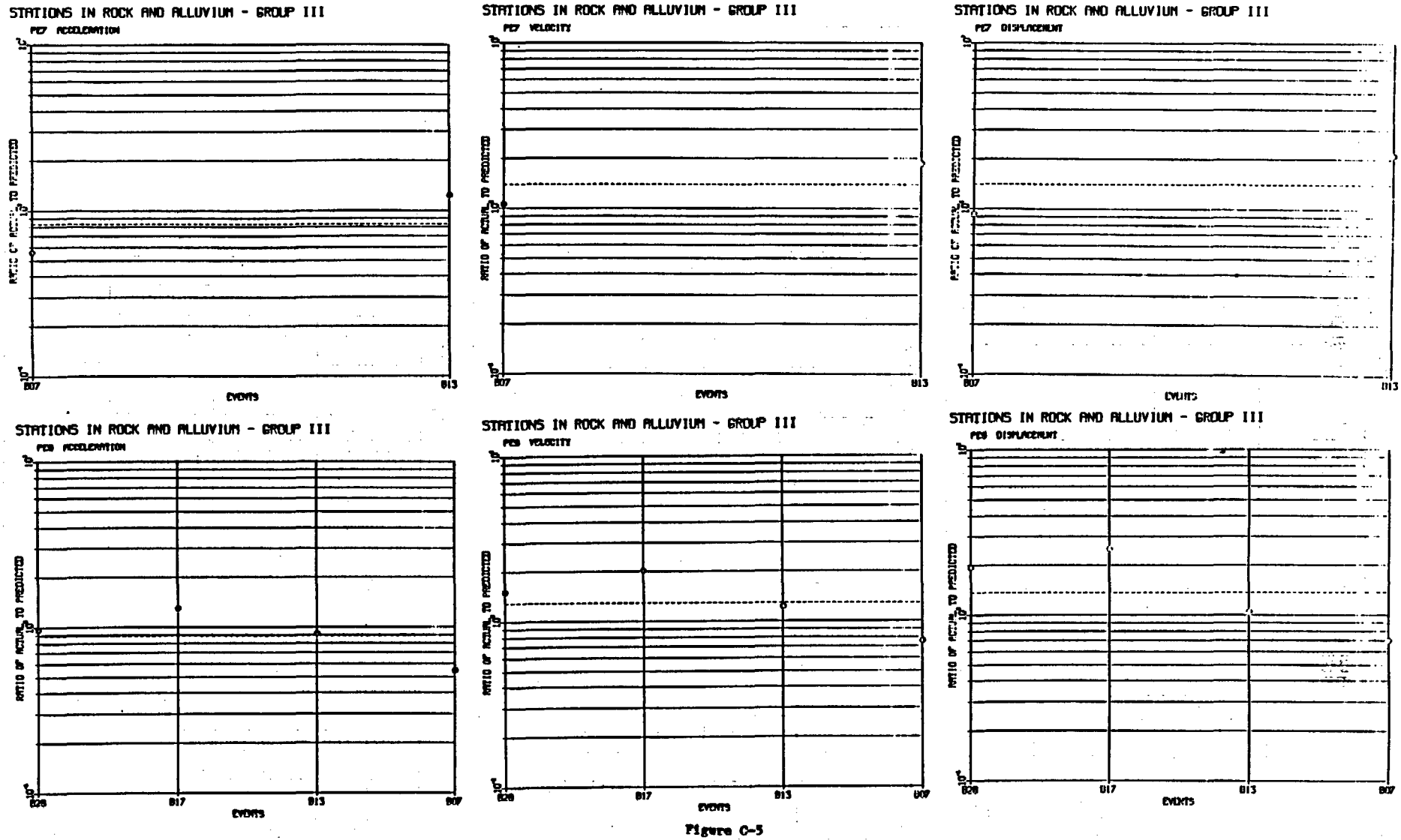

STATIONS IN ROCK AND ALLUVIUM - GROUP III
PC7 ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
PC7 VELOCITY
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
PC7 DISPLACEMENT
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
PC8 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
PC8 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
PC8 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure C-5

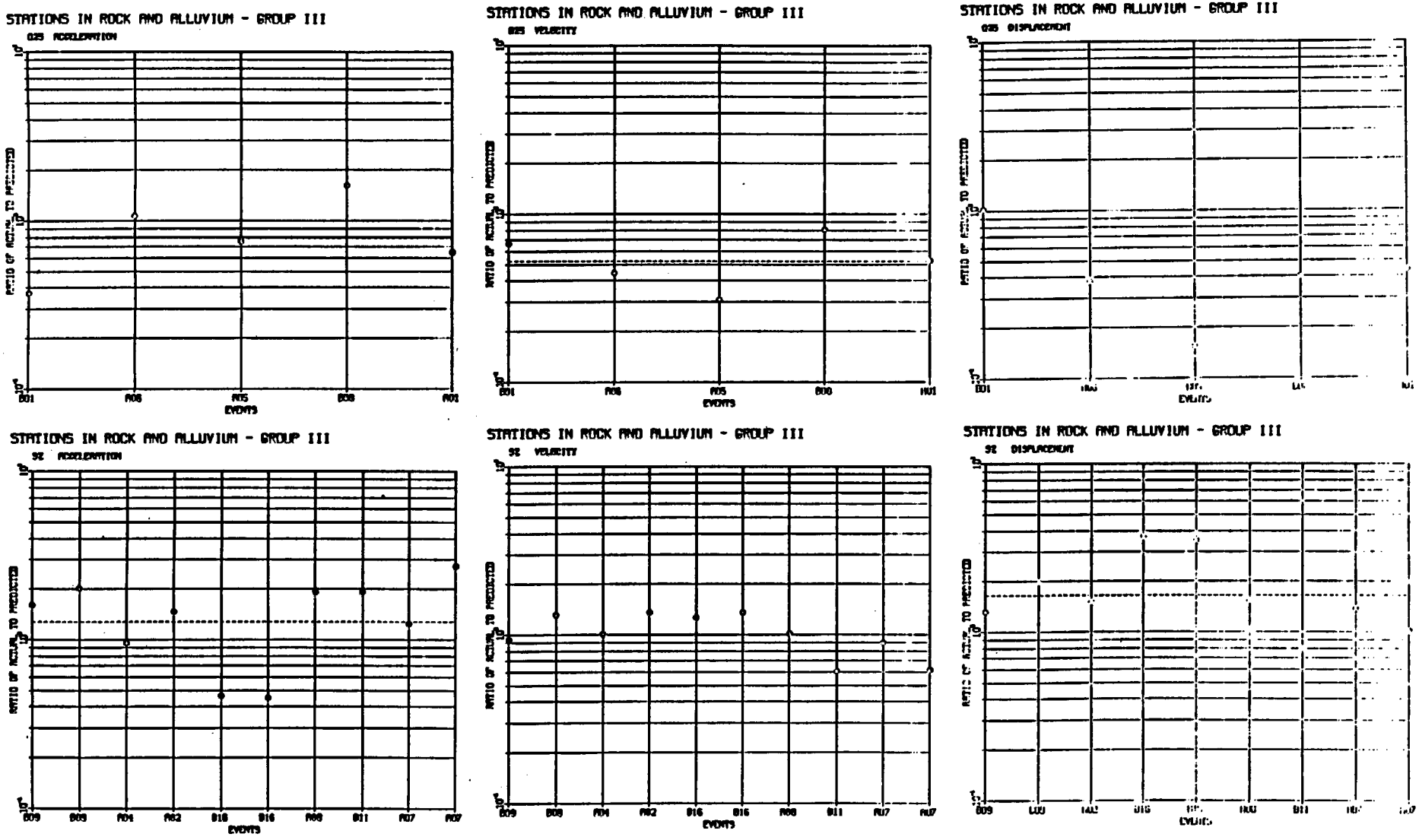

STATIONS IN ROCK AND ALLUVIUM - GROUP III
025 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
025 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
025 DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP III
92 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
92 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
92 DISPLACEMENT

Figure C-6

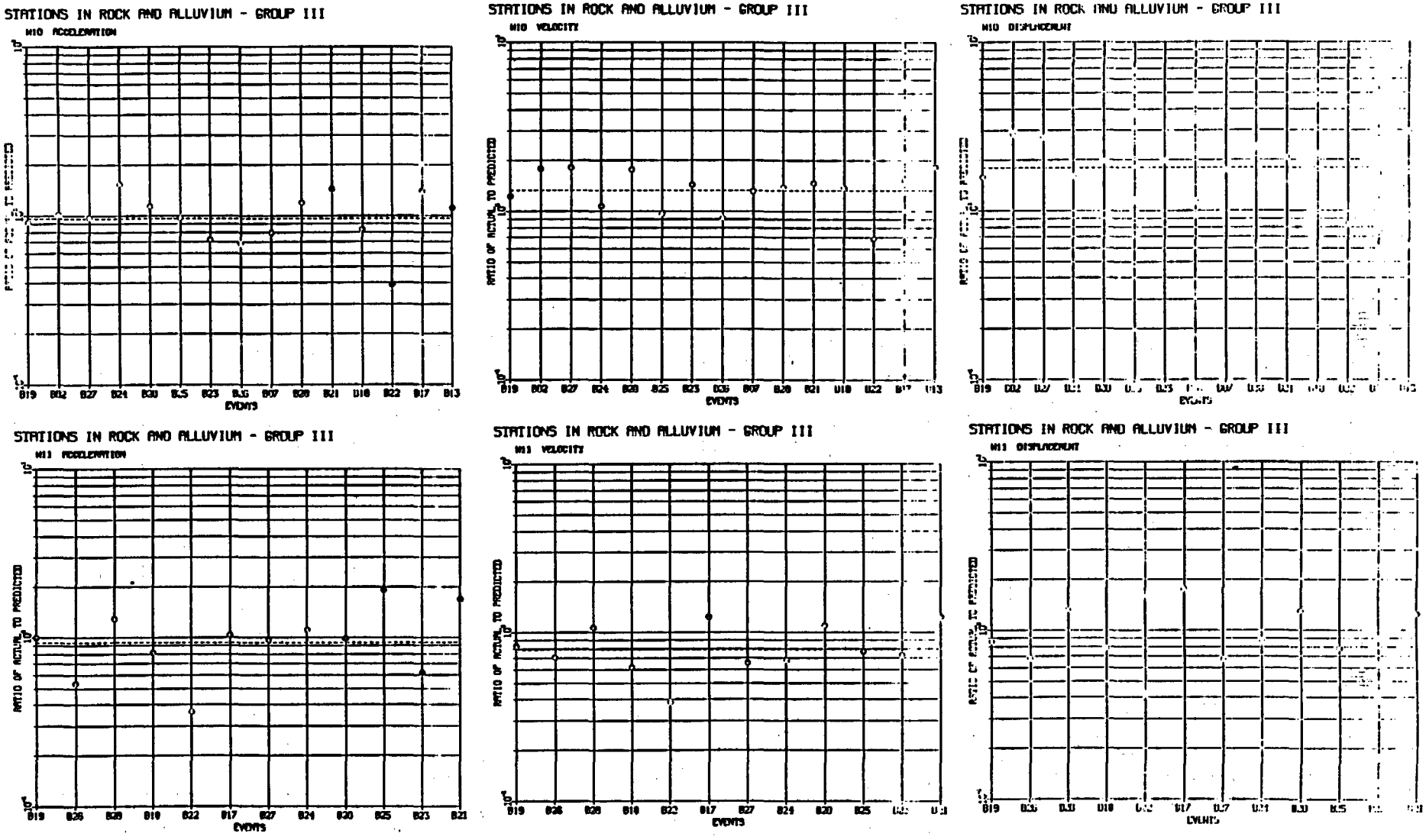
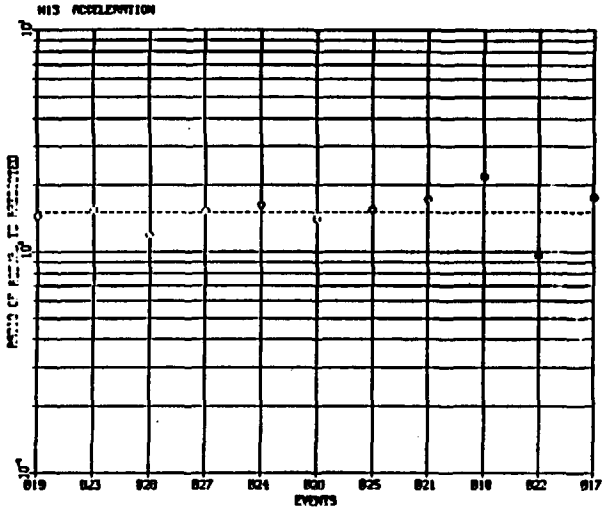
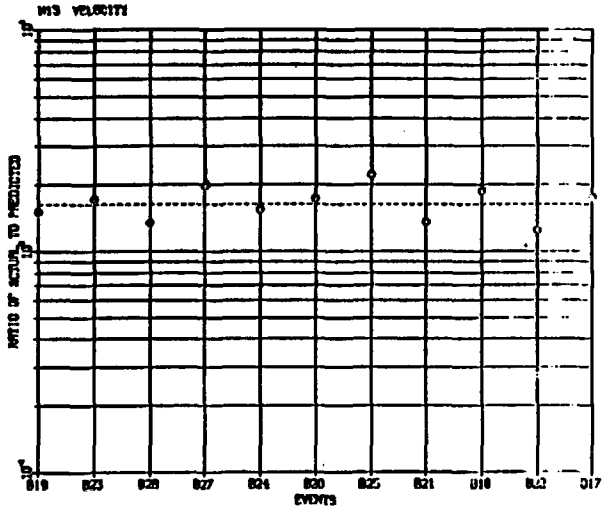

STATIONS IN ROCK AND ALLUVIUM - GROUP III
M10 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP III
M10 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP III
M10 DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP III
M11 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP III
M11 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP III
M11 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure C-7

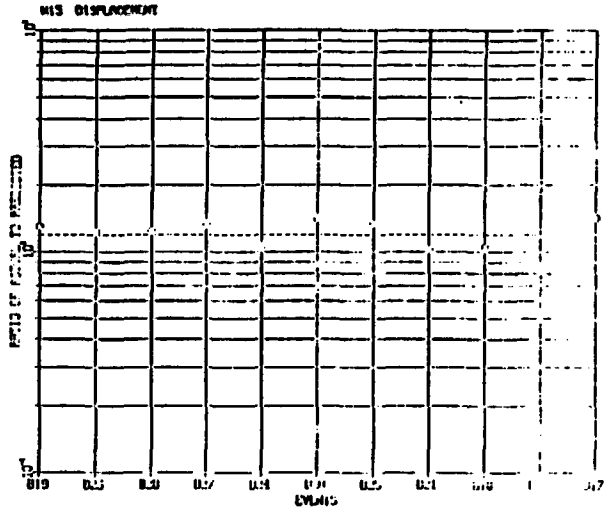
STATIONS IN ROCK AND ALLUVIUM - GROUP III



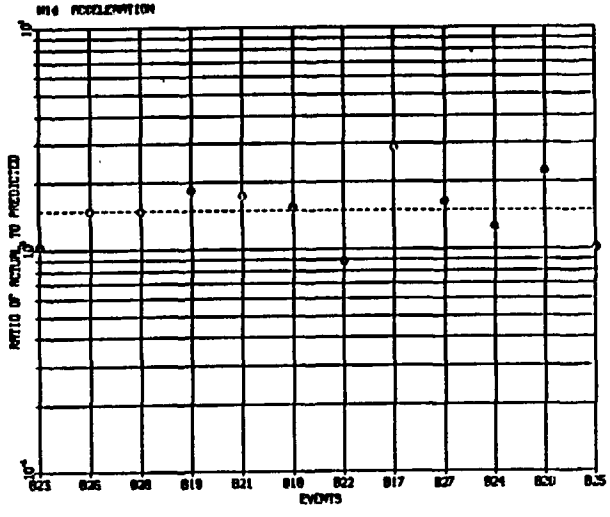
STATIONS IN ROCK AND ALLUVIUM - GROUP III



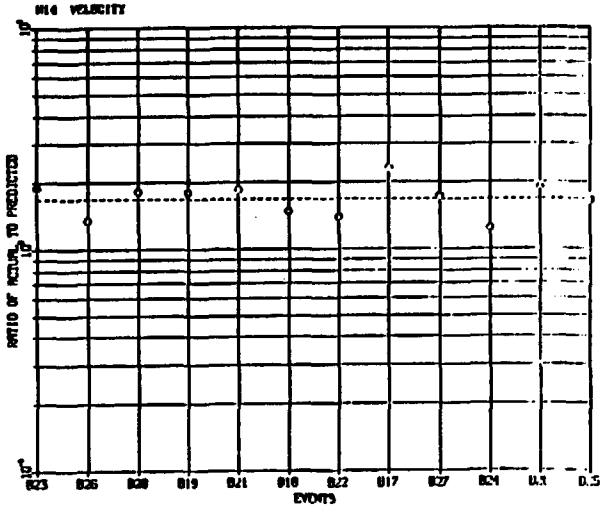
STATIONS IN ROCK AND ALLUVIUM - GROUP III



STATIONS IN ROCK AND ALLUVIUM - GROUP III



STATIONS IN ROCK AND ALLUVIUM - GROUP III



STATIONS IN ROCK AND ALLUVIUM - GROUP III

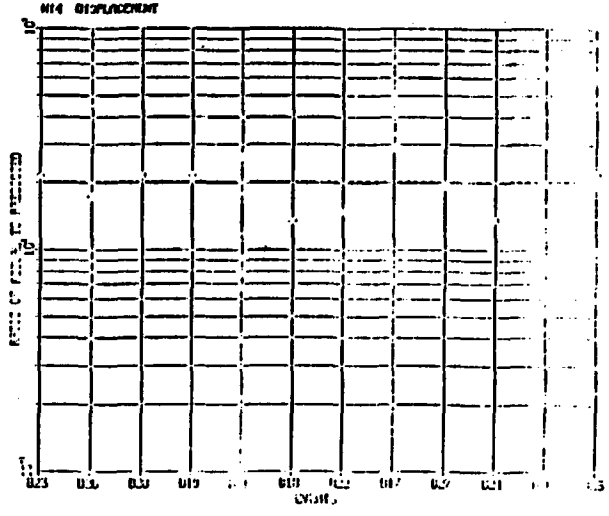
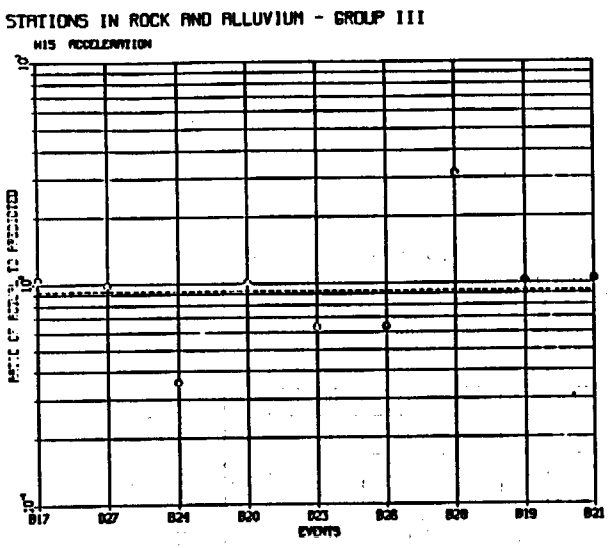
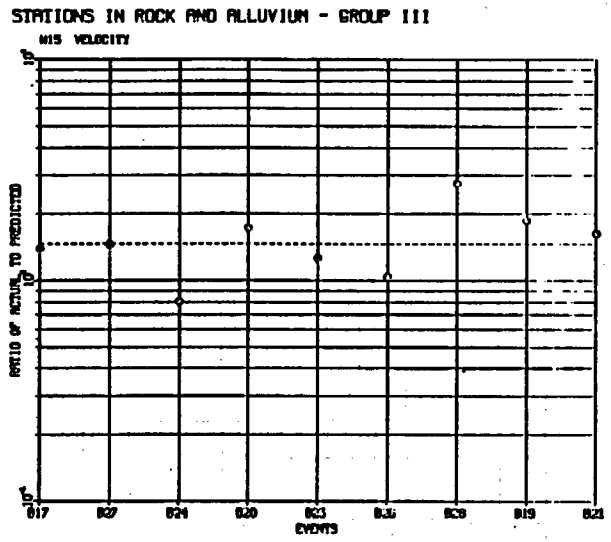
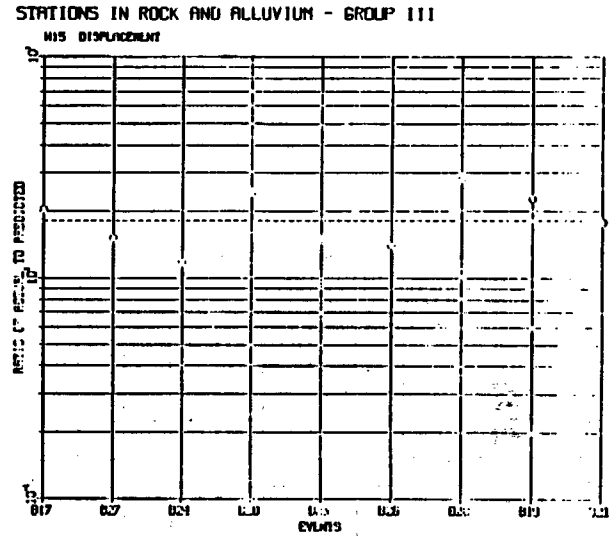
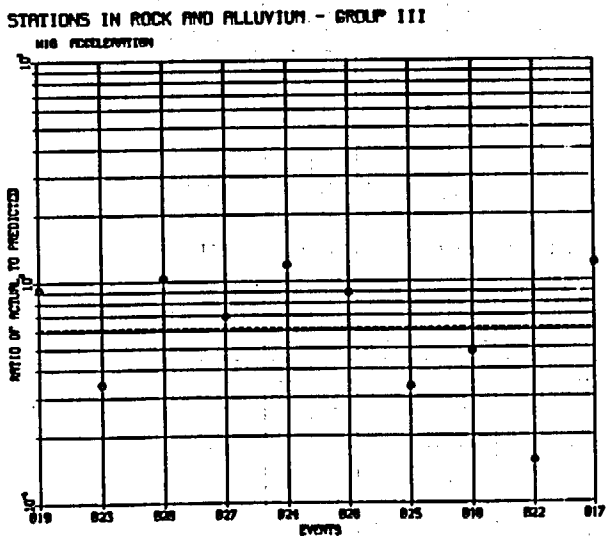


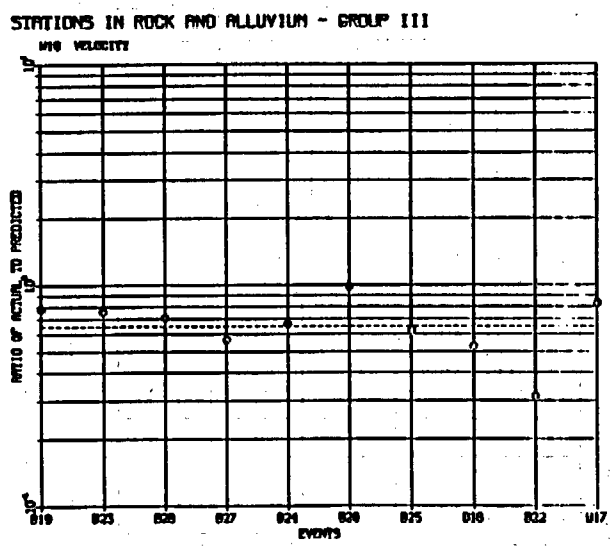
Figure C-8


STATIONS IN ROCK AND ALLUVIUM - GROUP III
H15 ACCELERATION
EVENTS


STATIONS IN ROCK AND ALLUVIUM - GROUP III
H15 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS


STATIONS IN ROCK AND ALLUVIUM - GROUP III
H15 DISPLACEMENT
EVENTS


STATIONS IN ROCK AND ALLUVIUM - GROUP III
H16 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS


STATIONS IN ROCK AND ALLUVIUM - GROUP III
H16 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS

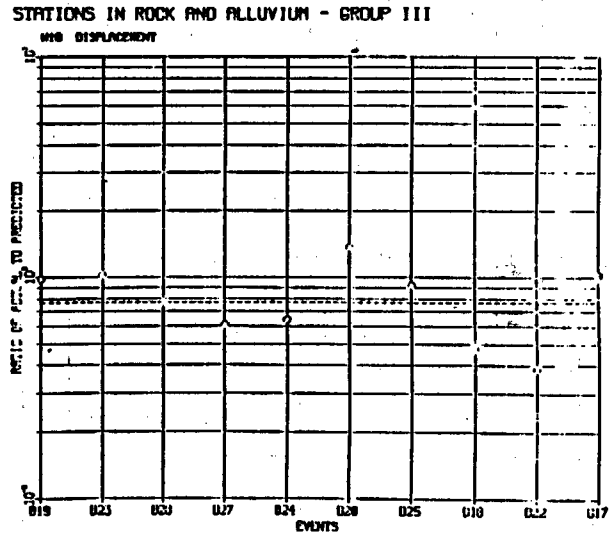

STATIONS IN ROCK AND ALLUVIUM - GROUP III
H16 DISPLACEMENT
EVENTS

Figure C-9

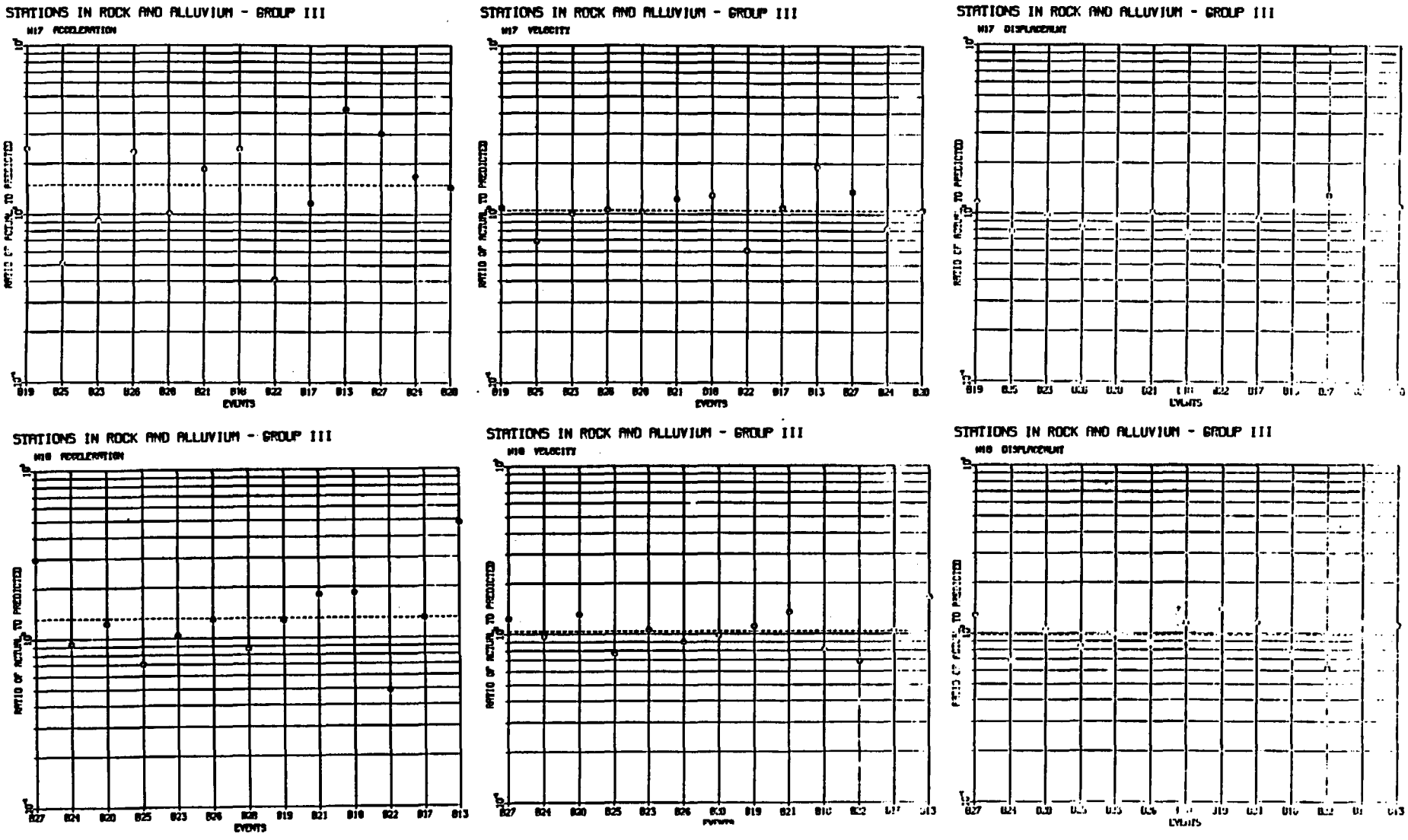

STATIONS IN ROCK AND ALLUVIUM - GROUP III
M17 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP III
M17 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP III
M17 DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP III
M18 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP III
M18 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP III
M18 DISPLACEMENT
EVENTS

Figure C-10

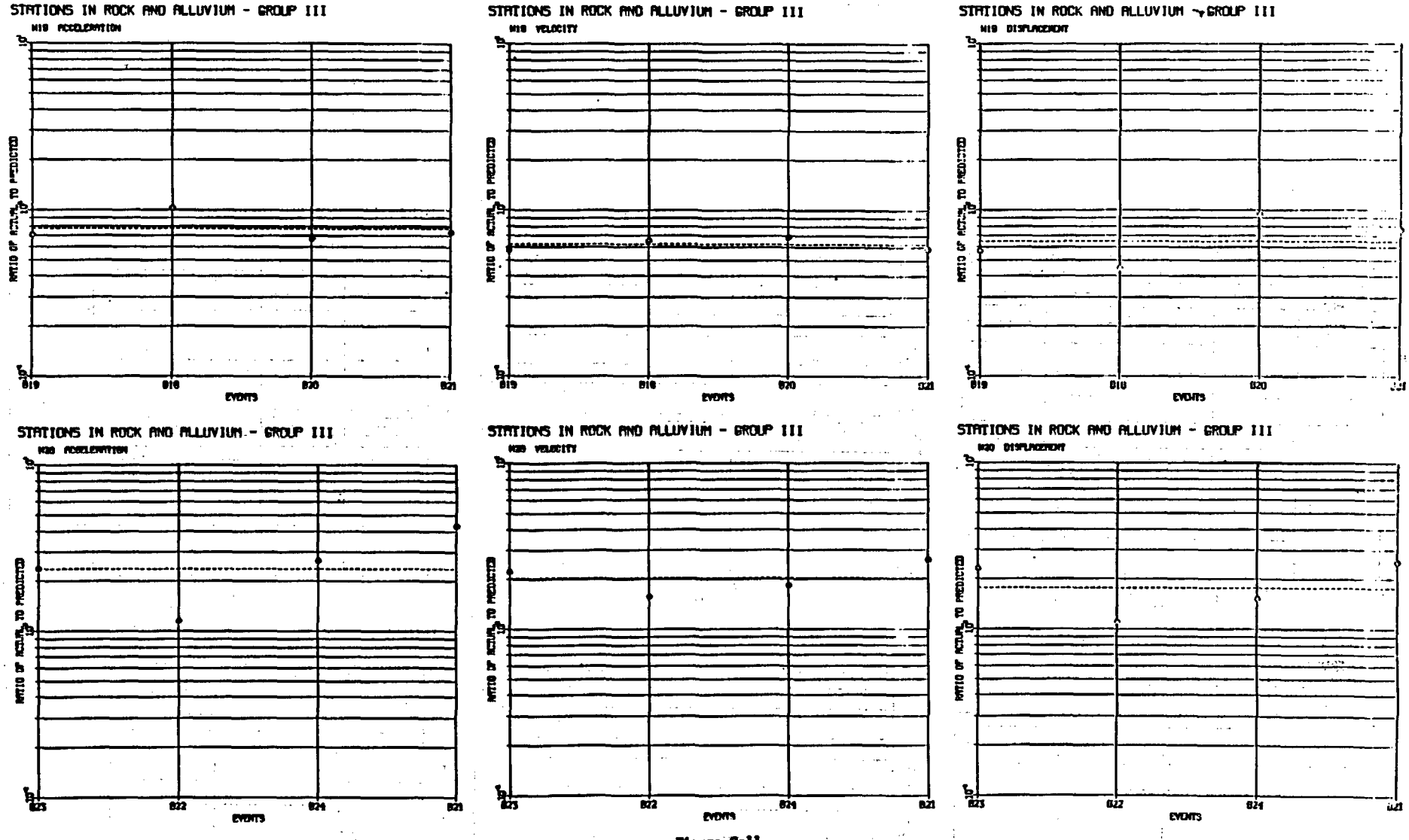

STATIONS IN ROCK AND ALLUVIUM - GROUP III
H19 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP III
H19 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP III
H19 DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP III
H20 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP III
H20 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP III
H20 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
B19
B18
B20
B21
B23
B22
B24

Figure C-11

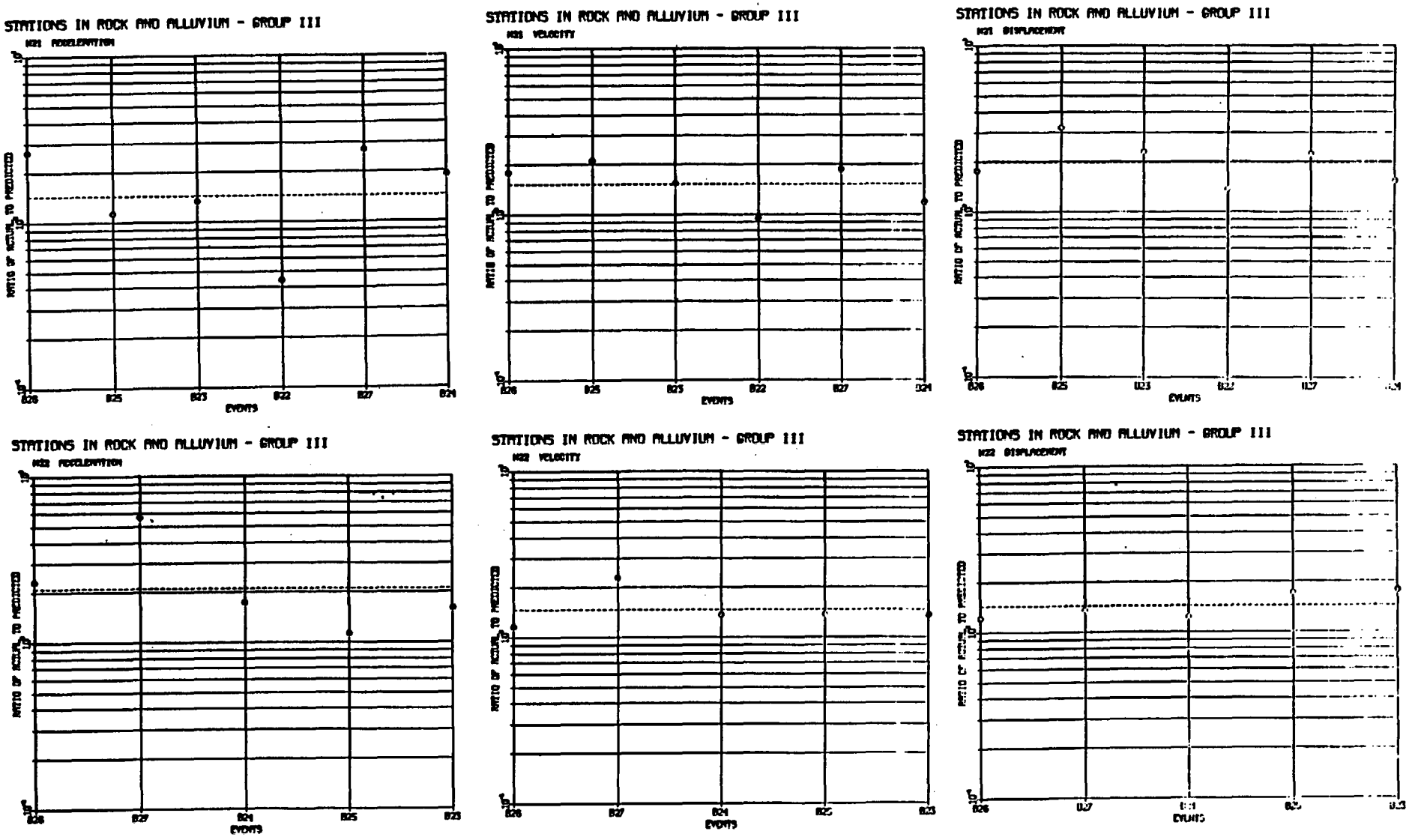

STATIONS IN ROCK AND ALLUVIUM - GROUP III
N21 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP III
N21 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP III
N21 DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP III
N22 ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP III
N22 VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP III
N22 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure C-12

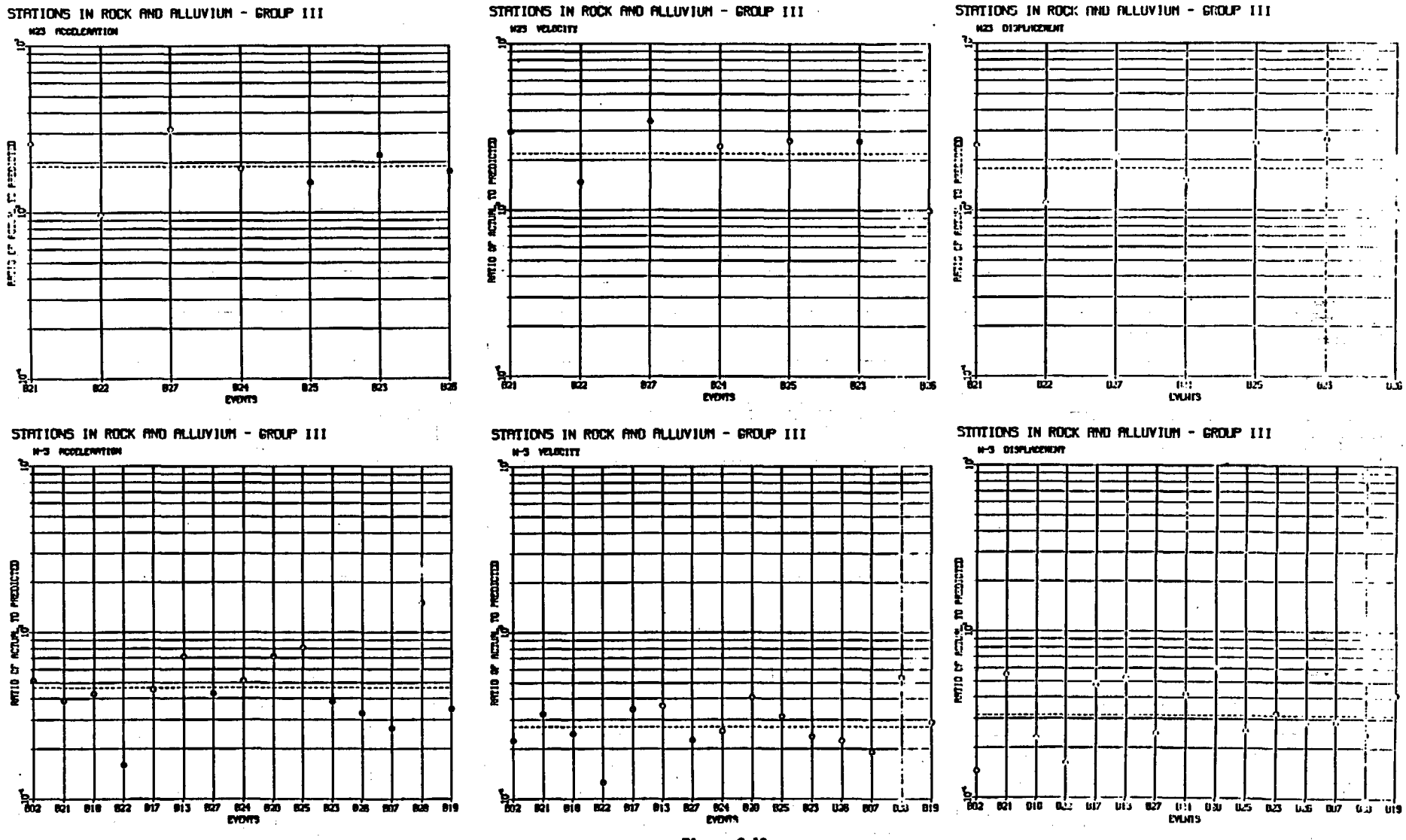

STATIONS IN ROCK AND ALLUVIUM - GROUP III
N23 ACCELERATION
N23 VELOCITY
N23 DISPLACEMENT
N-S ACCELERATION
N-S VELOCITY
N-S DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure C-13

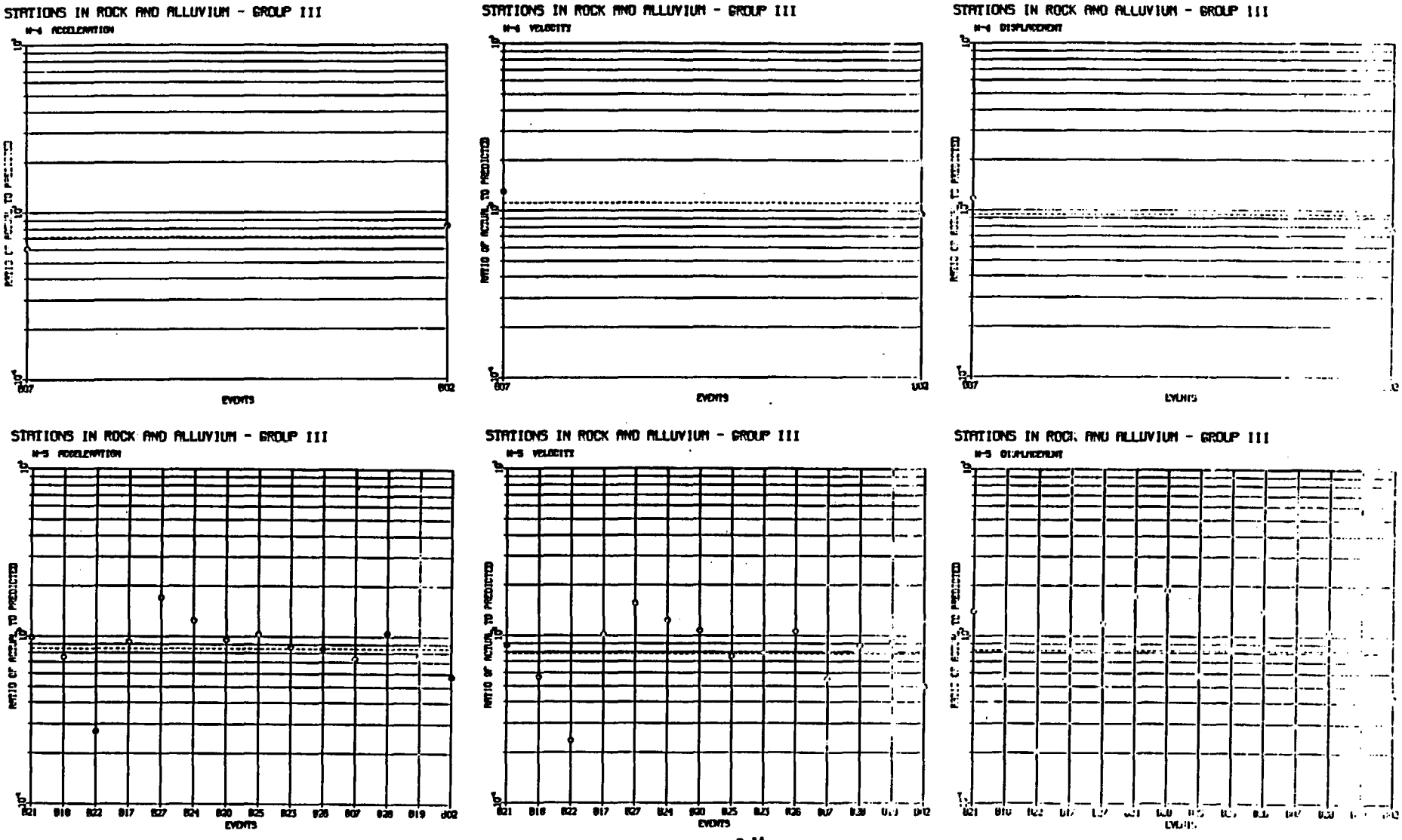

STATIONS IN ROCK AND ALLUVIUM - GROUP III
N-4 ACCELERATION
N-4 VELOCITY
N-4 DISPLACEMENT
N-5 ACCELERATION
N-5 VELOCITY
N-5 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
B07
B02
B21
B10
B22
B17
B27
B24
B20
B25
B23
B26
B19

Figure C-14

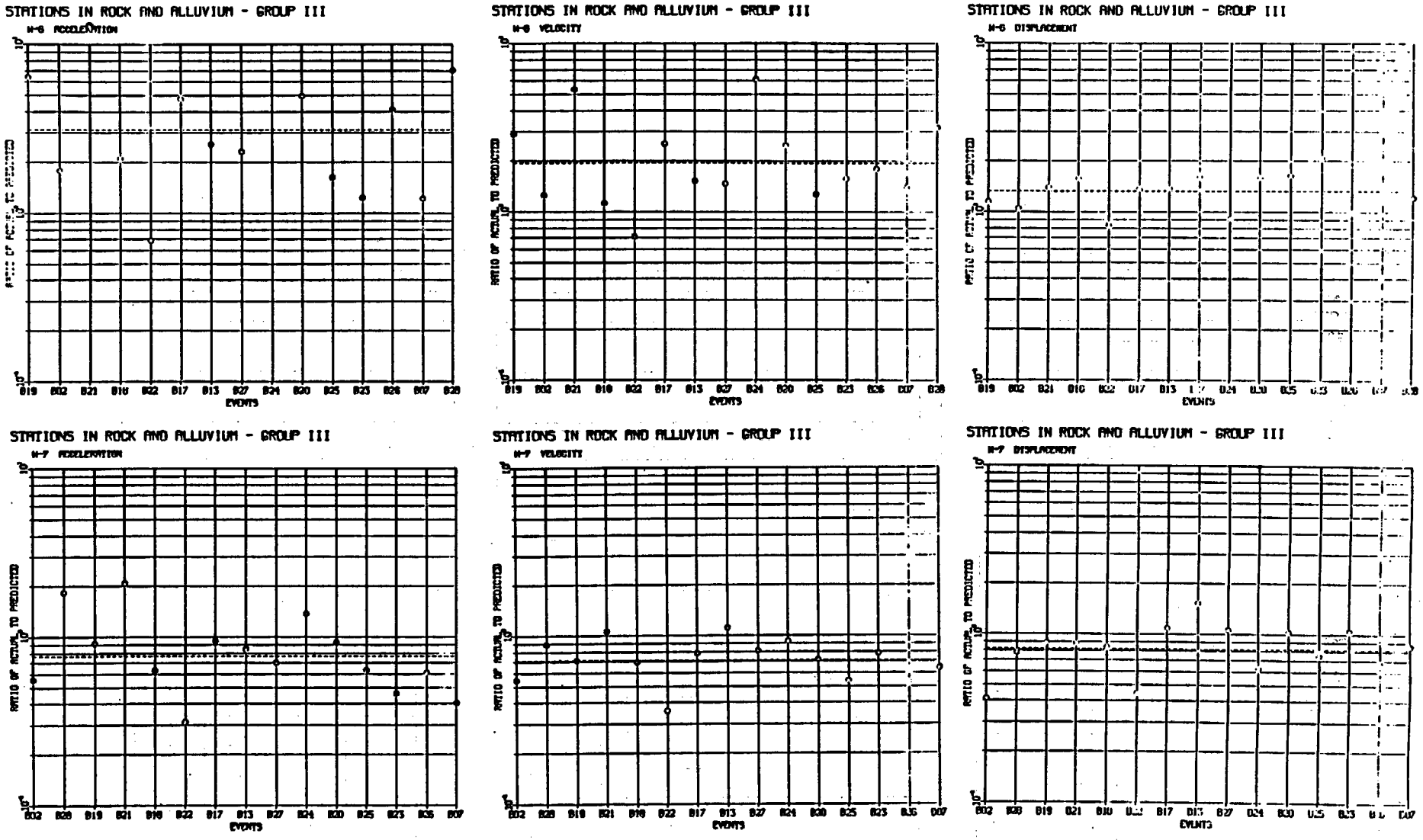

STATIONS IN ROCK AND ALLUVIUM - GROUP III
H-6 ACCELERATION
H-6 VELOCITY
H-6 DISPLACEMENT
H-7 ACCELERATION
H-7 VELOCITY
H-7 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure C-15

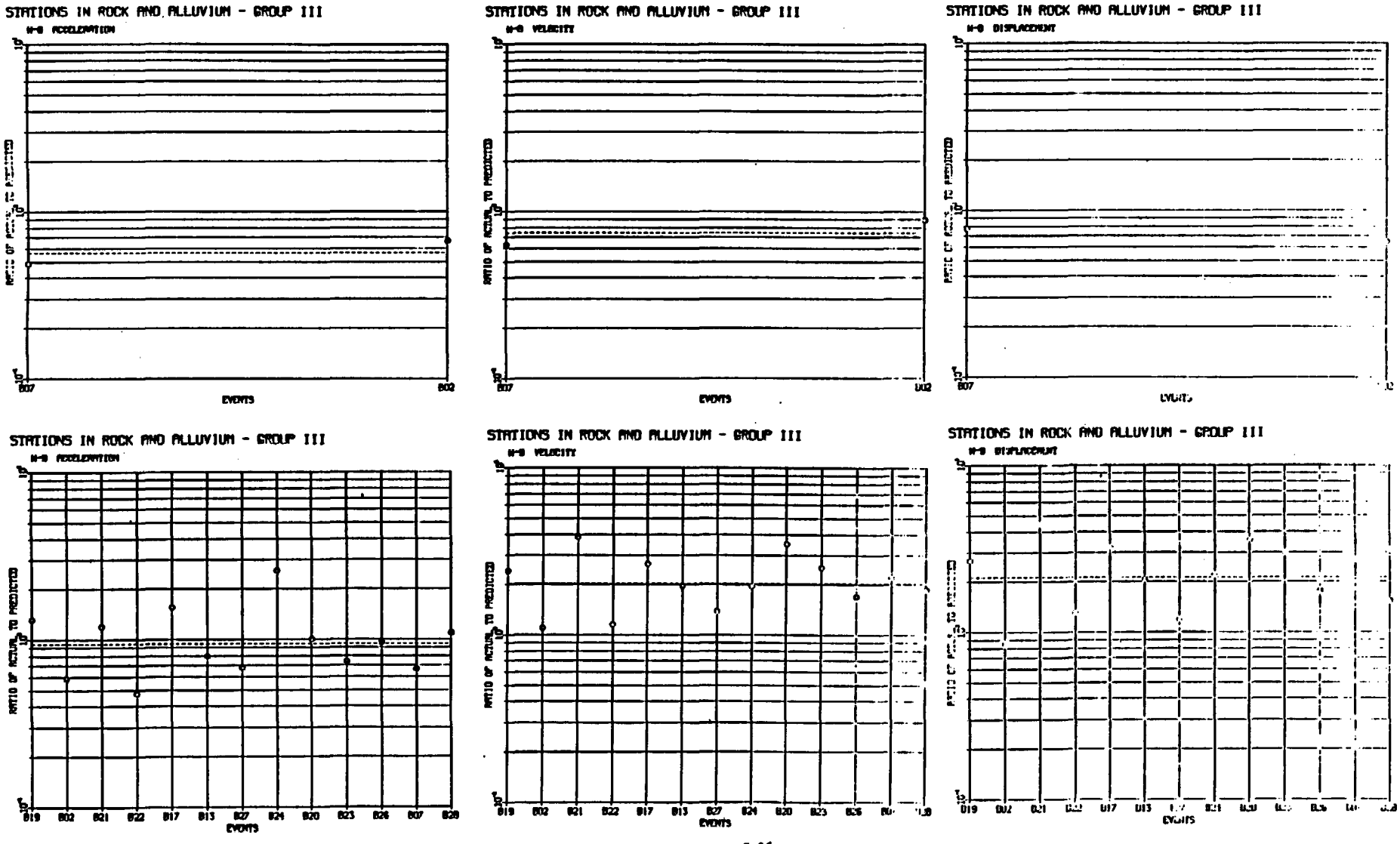

STATIONS IN ROCK AND ALLUVIUM - GROUP III
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
STATIONS IN ROCK AND ALLUVIUM - GROUP III
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
EVENTS

Figure C-16

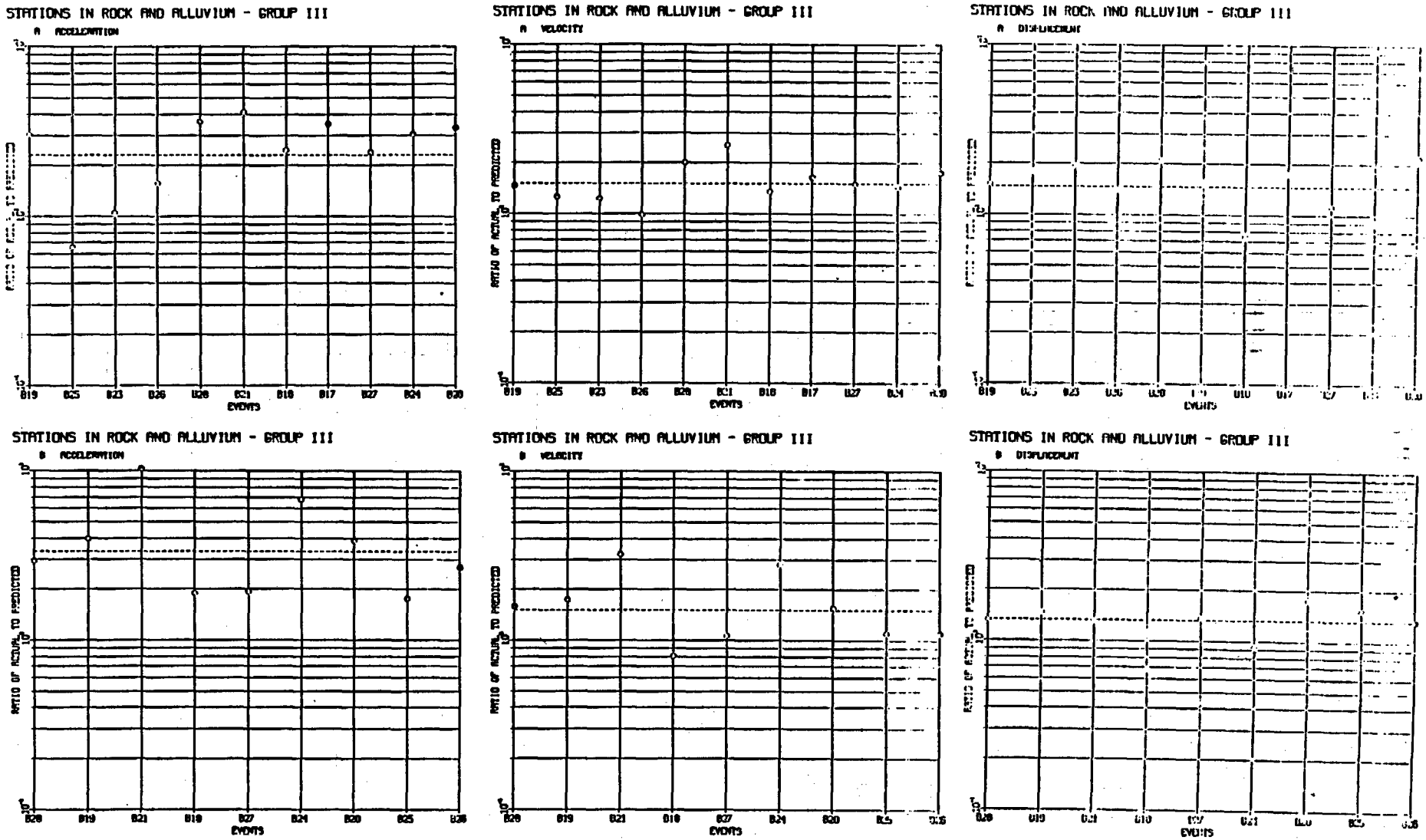

STATIONS IN ROCK AND ALLUVIUM - GROUP III
A ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP III
A VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP III
A DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP III
B ACCELERATION
STATIONS IN ROCK AND ALLUVIUM - GROUP III
B VELOCITY
STATIONS IN ROCK AND ALLUVIUM - GROUP III
B DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure C-17

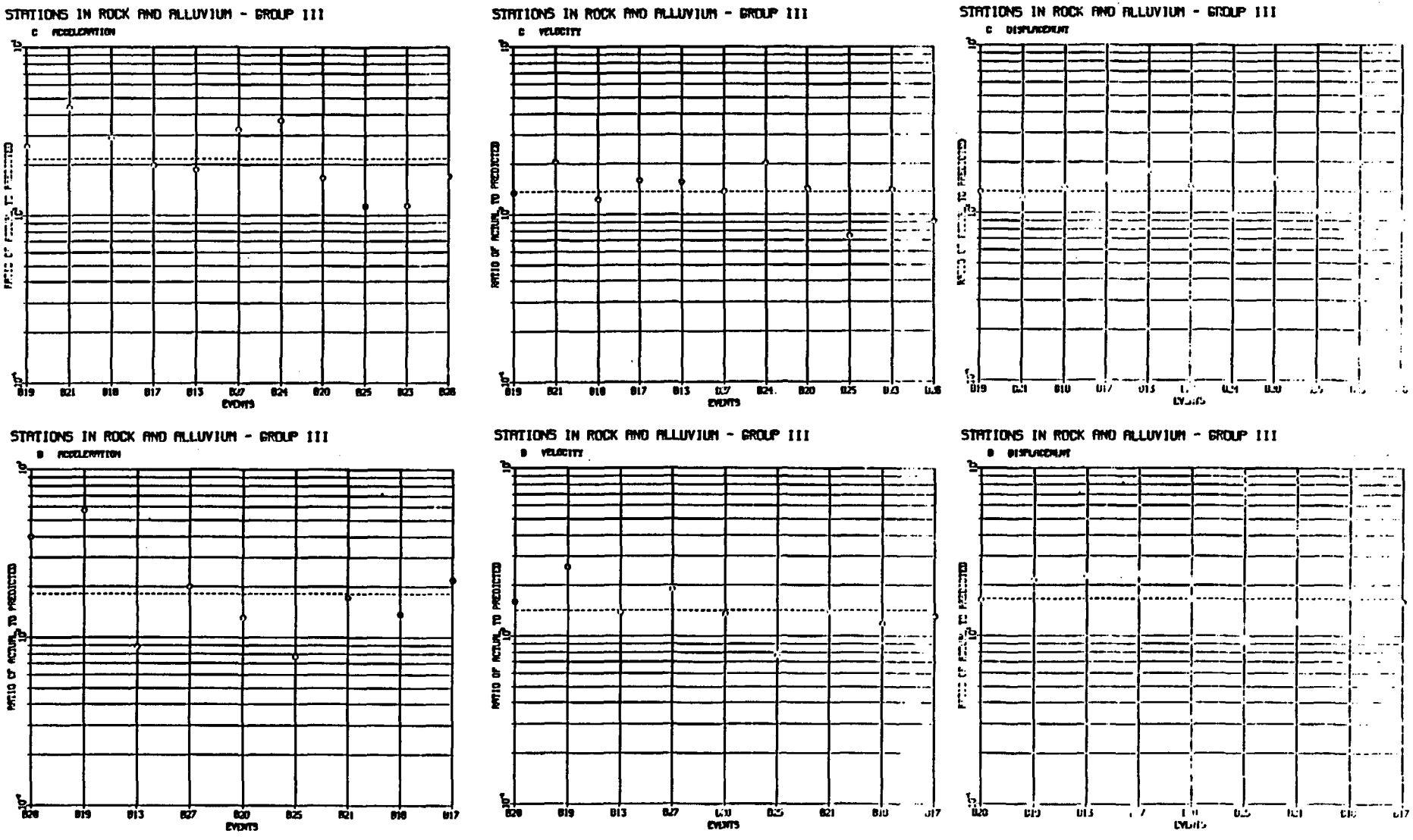

STATIONS IN ROCK AND ALLUVIUM - GROUP III
C ACCELERATION
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
C VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
C DISPLACEMENT
STATIONS IN ROCK AND ALLUVIUM - GROUP III
B ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
B VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK AND ALLUVIUM - GROUP III
B DISPLACEMENT

Figure C-18

Appendix D

Ratios for Rock for Group I

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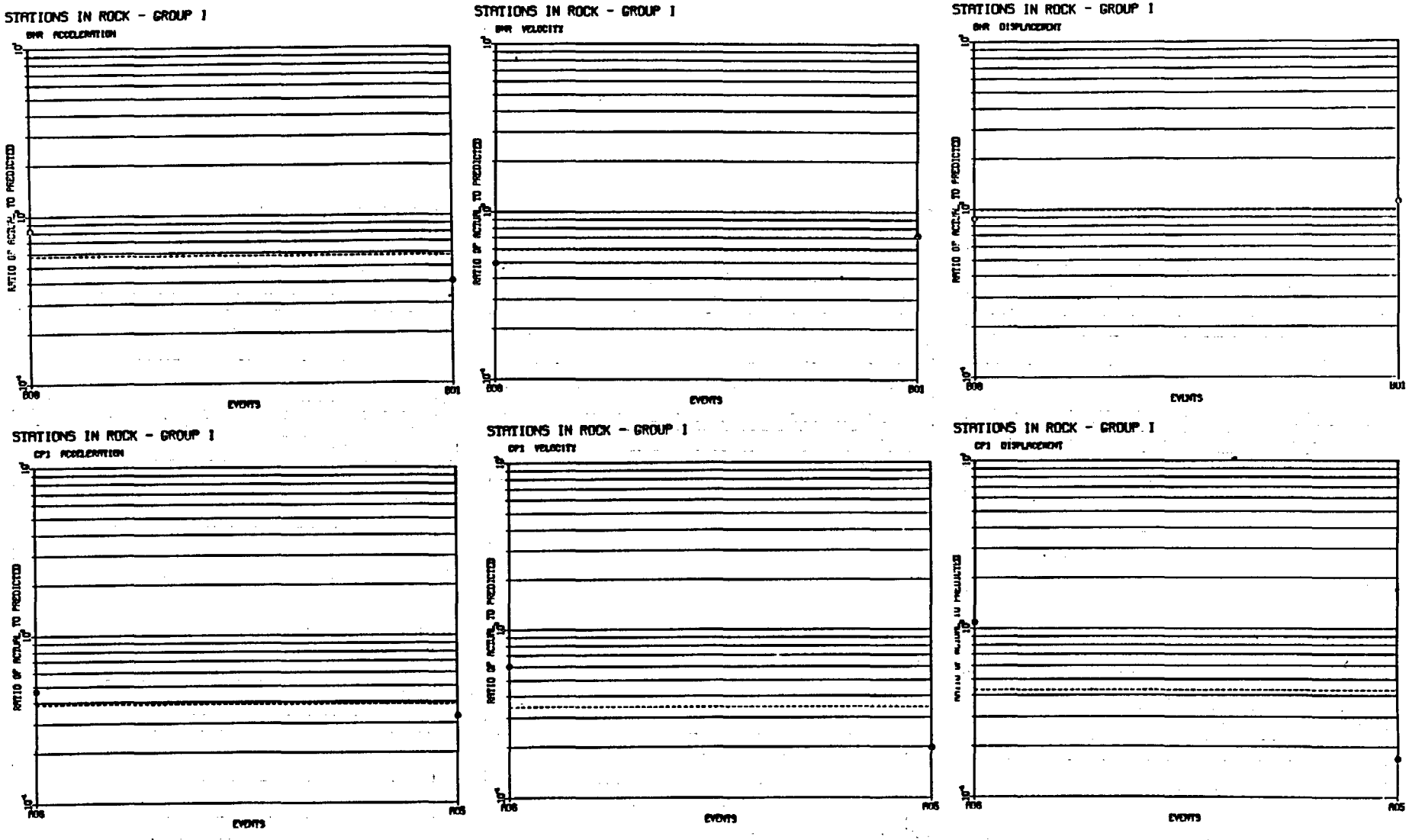

STATIONS IN ROCK - GROUP I
BHR ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP I
BHR VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP I
BHR DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP I
CP1 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP I
CP1 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP I
CP1 DISPLACEMENT
EVENTS

Figure D-1

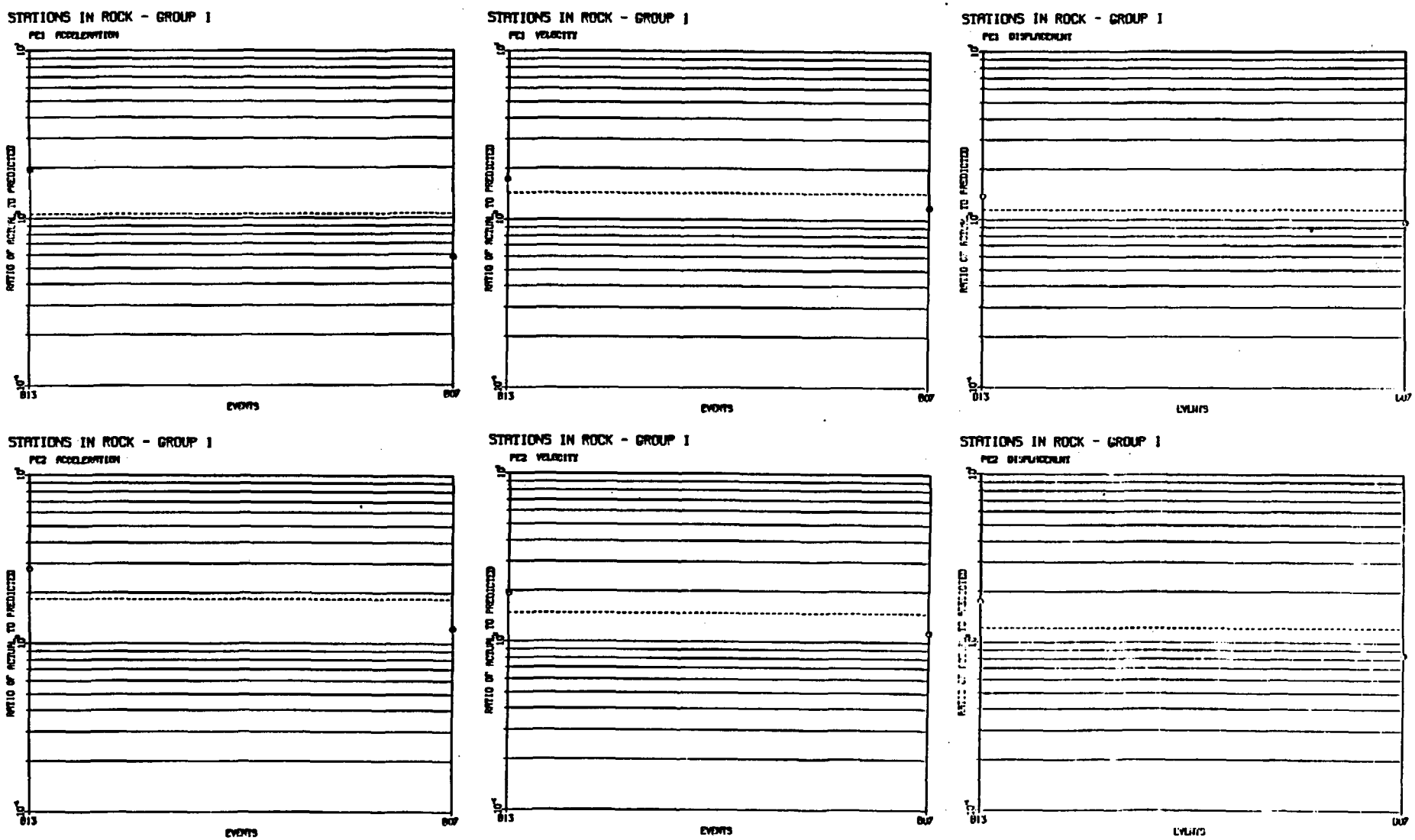

STATIONS IN ROCK - GROUP I
PC1 ACCELERATION
STATIONS IN ROCK - GROUP I
PC1 VELOCITY
STATIONS IN ROCK - GROUP I
PC1 DISPLACEMENT
STATIONS IN ROCK - GROUP I
PC2 ACCELERATION
STATIONS IN ROCK - GROUP I
PC2 VELOCITY
STATIONS IN ROCK - GROUP I
PC2 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
B13
B07

Figure D-2

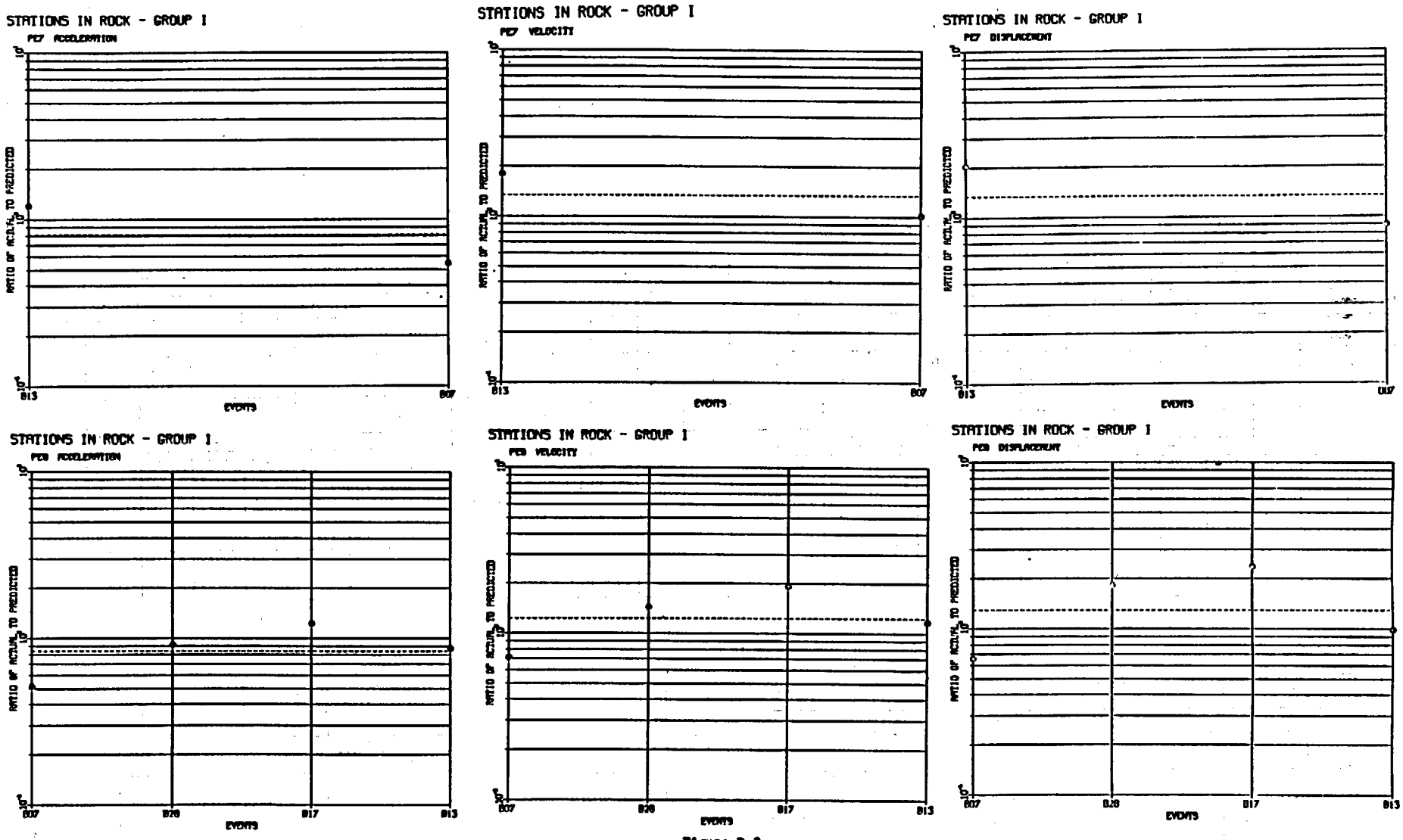

STATIONS IN ROCK - GROUP I
PE7 ACCELERATION
STATIONS IN ROCK - GROUP I
PE7 VELOCITY
STATIONS IN ROCK - GROUP I
PE7 DISPLACEMENT
STATIONS IN ROCK - GROUP I
PE8 ACCELERATION
STATIONS IN ROCK - GROUP I
PE8 VELOCITY
STATIONS IN ROCK - GROUP I
PE8 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
B13
B07
B20
B17

Figure D-3

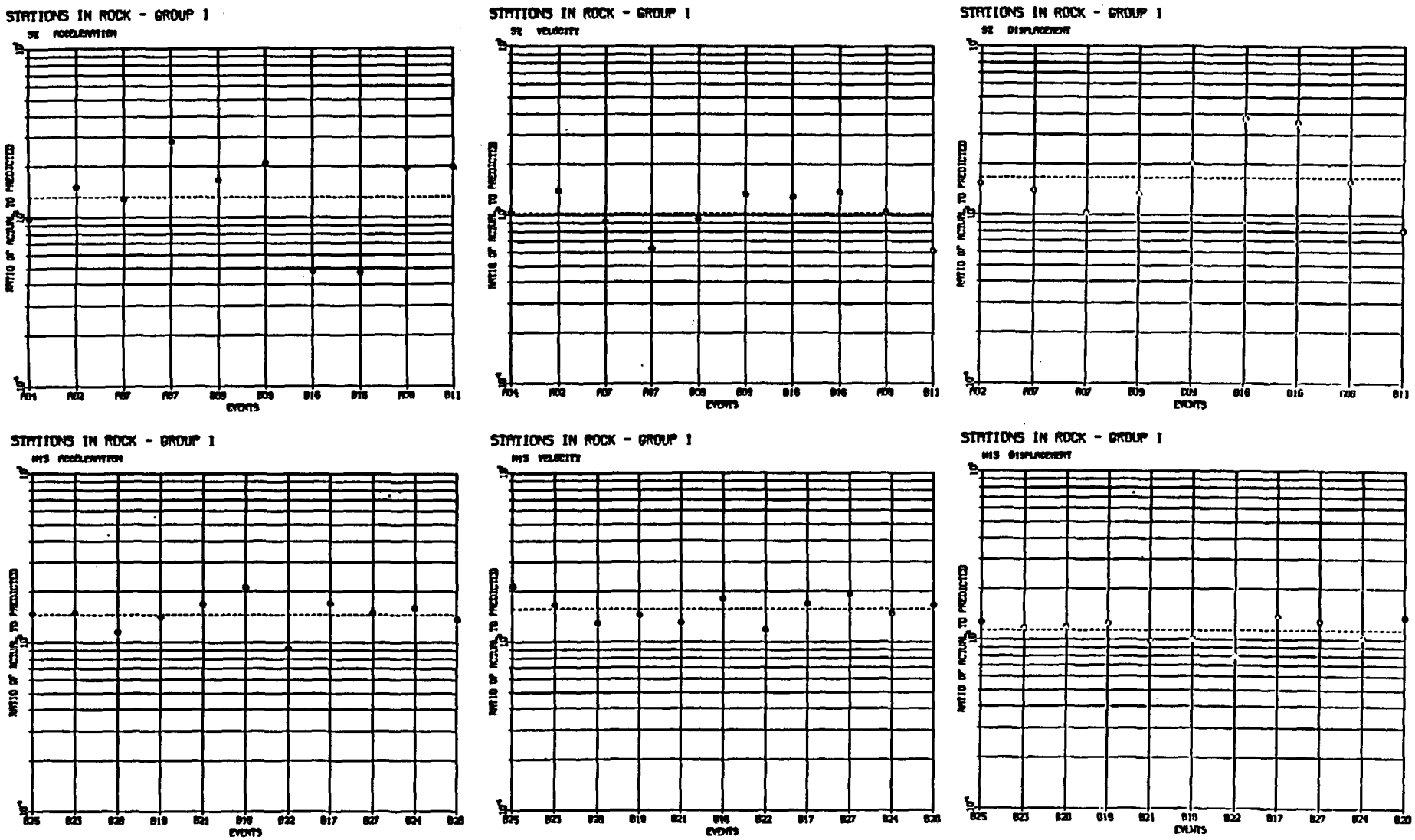

STATIONS IN ROCK - GROUP 1
SE ACCELERATION
SE VELOCITY
SE DISPLACEMENT
HHS ACCELERATION
HHS VELOCITY
HHS DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure D-4

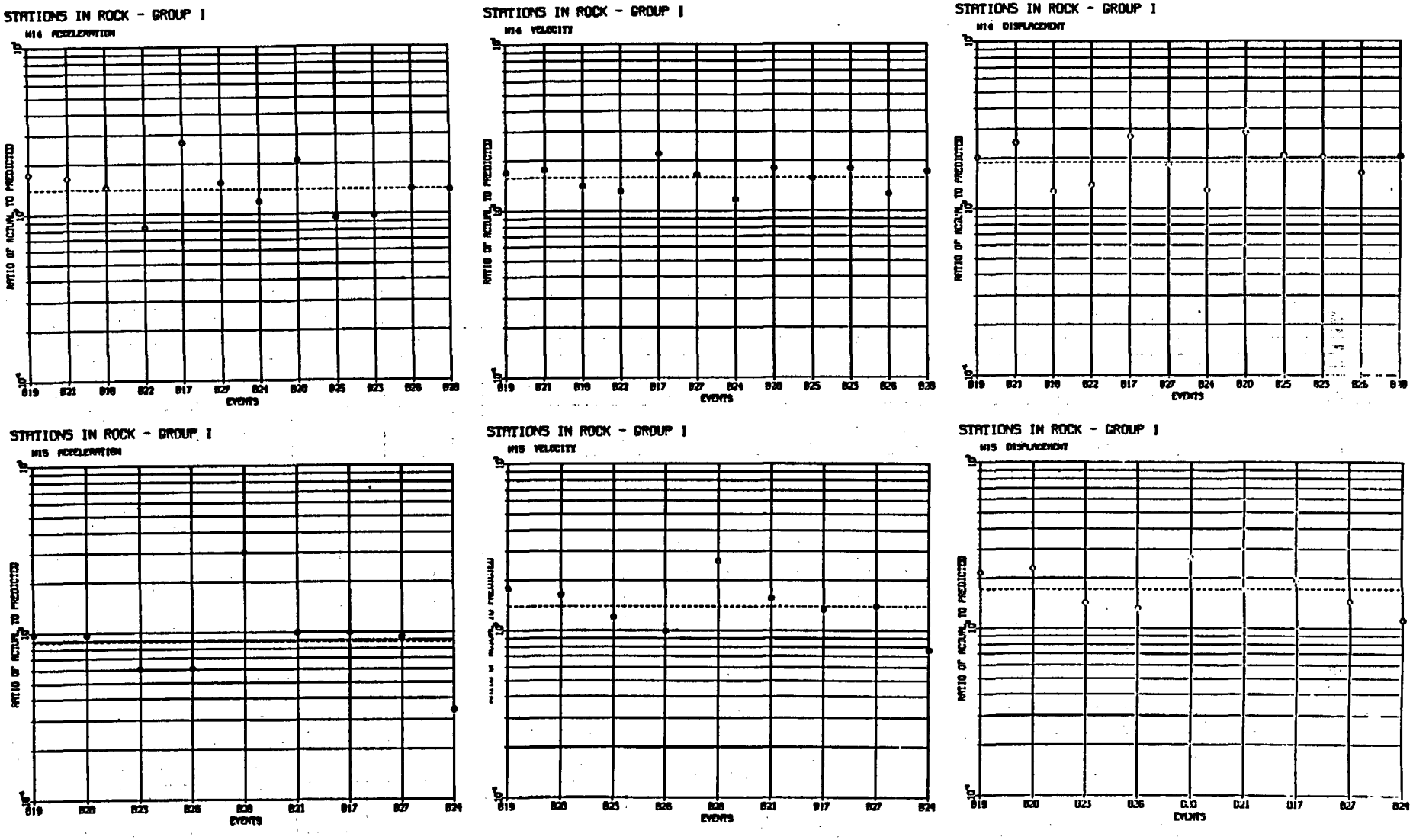

STATIONS IN ROCK - GROUP I
N14 ACCELERATION
STATIONS IN ROCK - GROUP I
N14 VELOCITY
STATIONS IN ROCK - GROUP I
N14 DISPLACEMENT
STATIONS IN ROCK - GROUP I
N15 ACCELERATION
STATIONS IN ROCK - GROUP I
N15 VELOCITY
STATIONS IN ROCK - GROUP I
N15 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure D-5

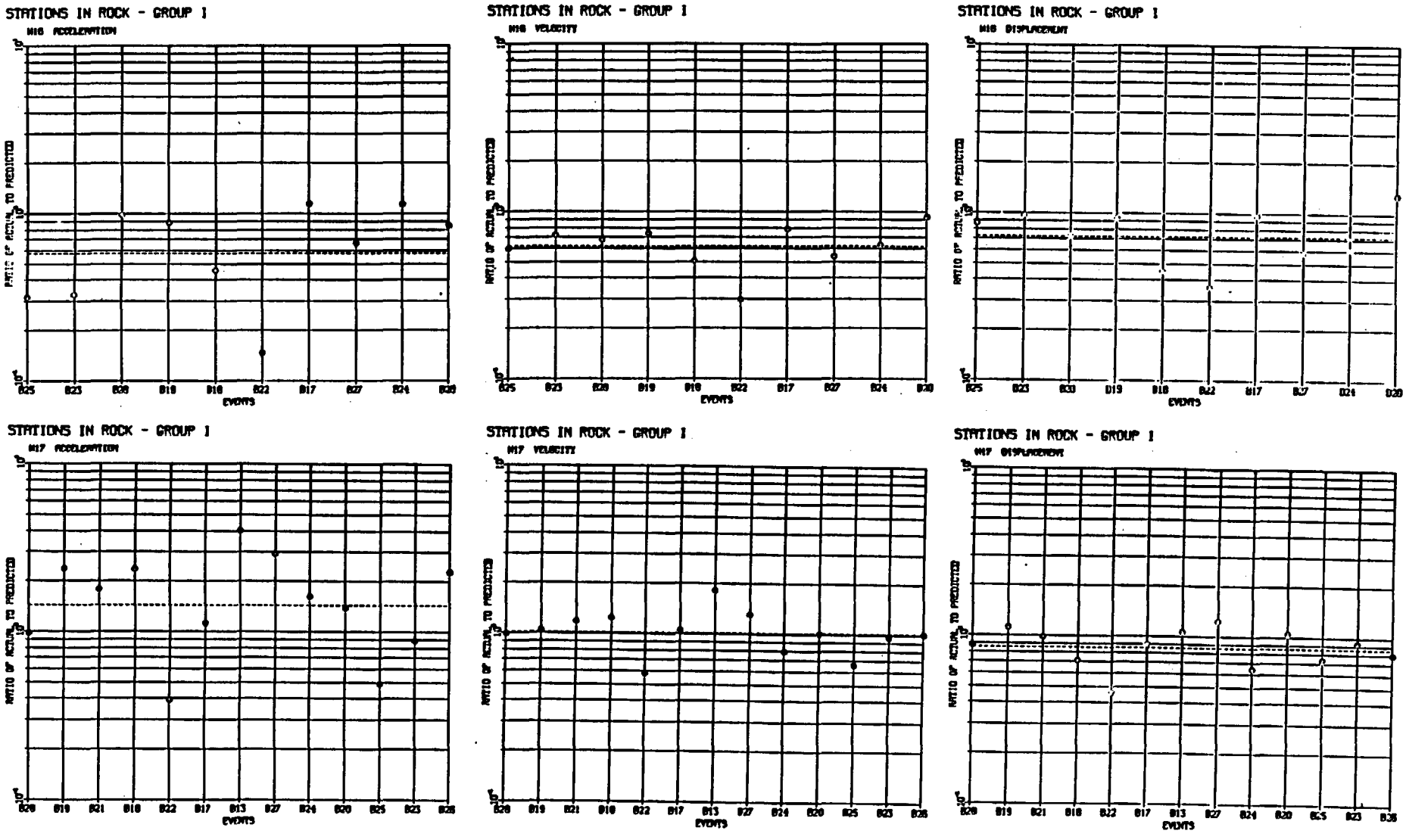

STATIONS IN ROCK - GROUP I
H16 ACCELERATION
STATIONS IN ROCK - GROUP I
H16 VELOCITY
STATIONS IN ROCK - GROUP I
H16 DISPLACEMENT
STATIONS IN ROCK - GROUP I
H17 ACCELERATION
STATIONS IN ROCK - GROUP I
H17 VELOCITY
STATIONS IN ROCK - GROUP I
H17 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure D-6

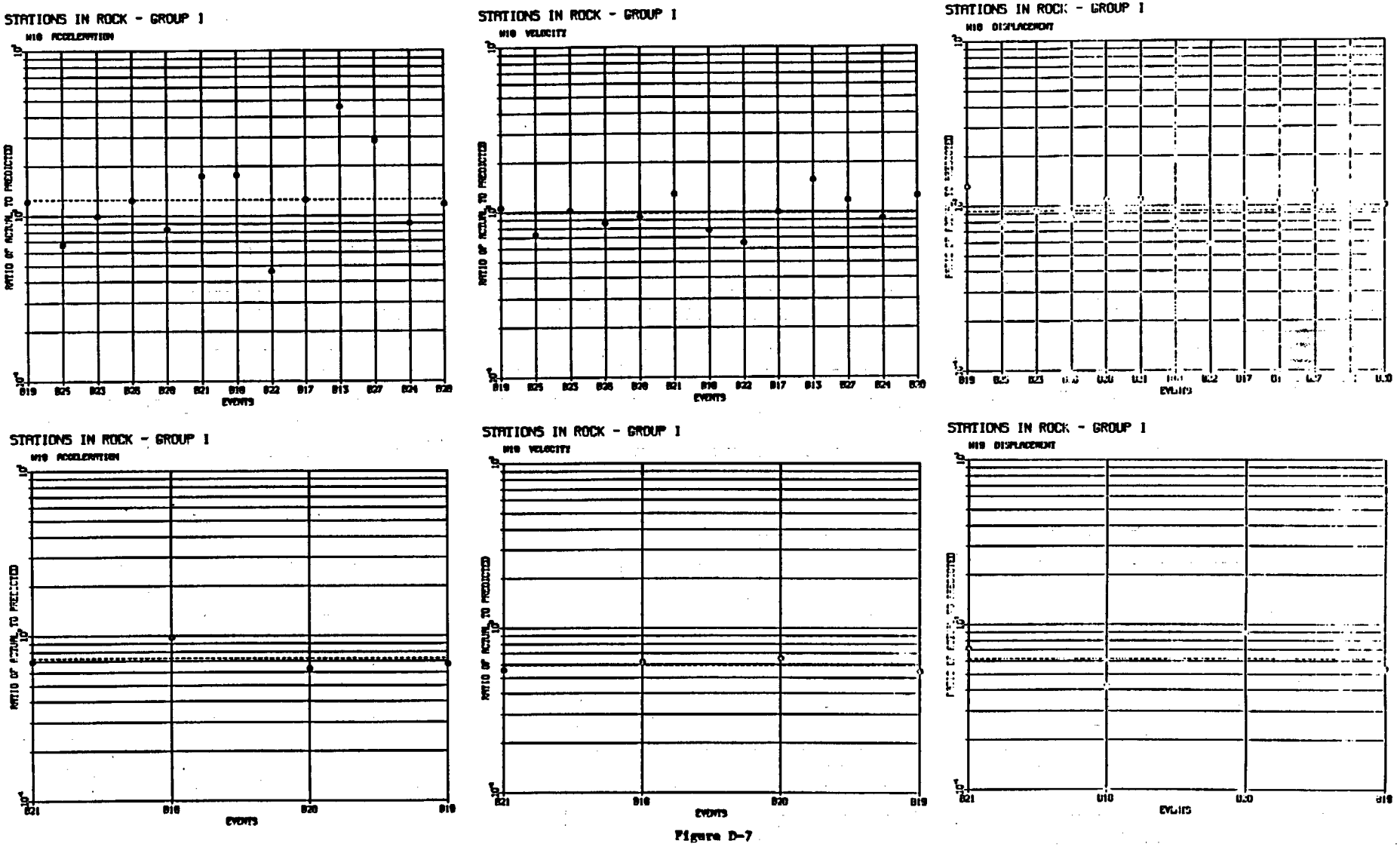

STATIONS IN ROCK - GROUP I
H10 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP I
H10 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP I
H10 DISPLACEMENT
STATIONS IN ROCK - GROUP I
H10 ACCELERATION
STATIONS IN ROCK - GROUP I
H10 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP I
H10 DISPLACEMENT

Figure D-7

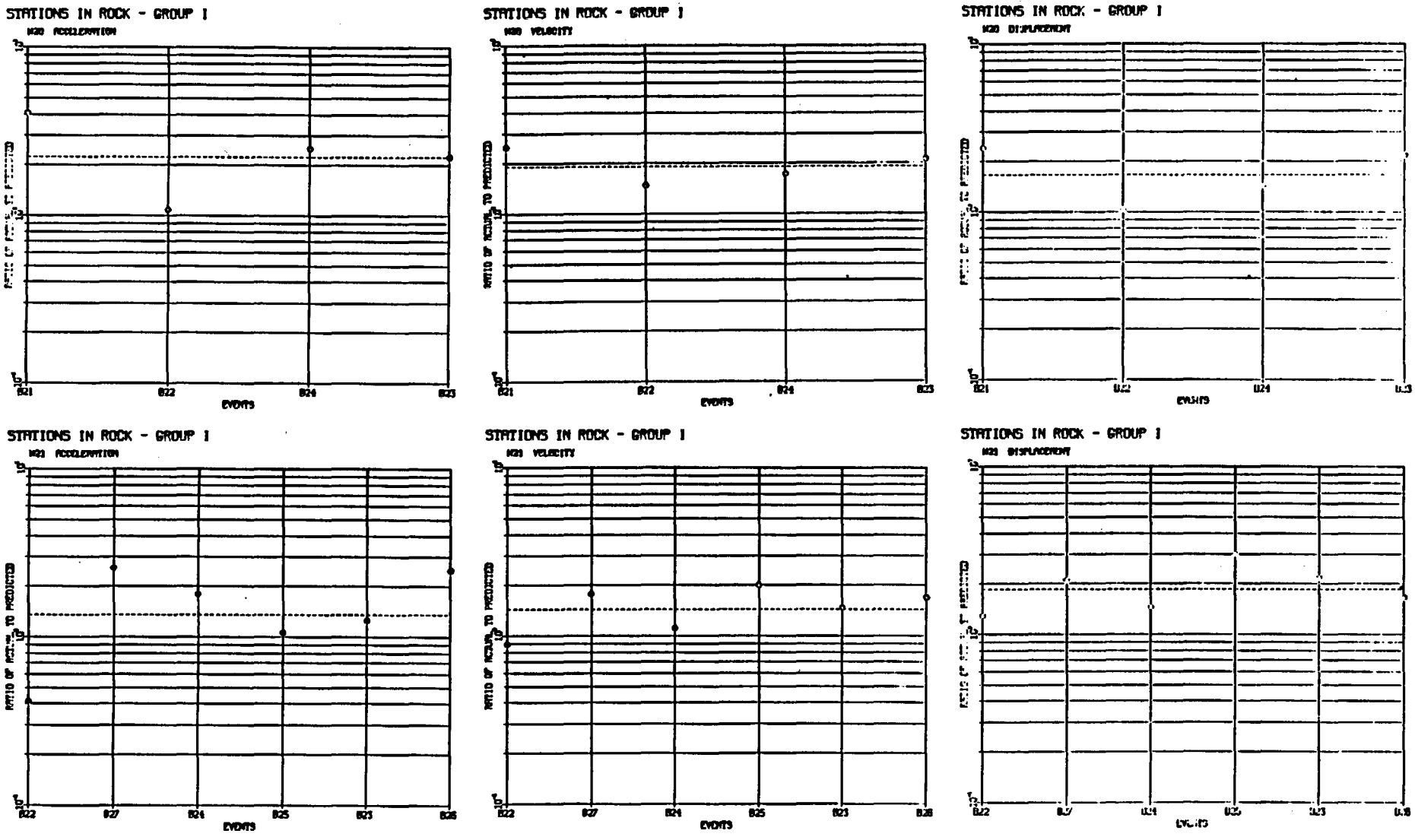

STATIONS IN ROCK - GROUP I
EVENTS
STATIONS IN ROCK - GROUP I
EVENTS
STATIONS IN ROCK - GROUP I
EVENTS
STATIONS IN ROCK - GROUP I
EVENTS
STATIONS IN ROCK - GROUP I
EVENTS
STATIONS IN ROCK - GROUP I

Figure D-8

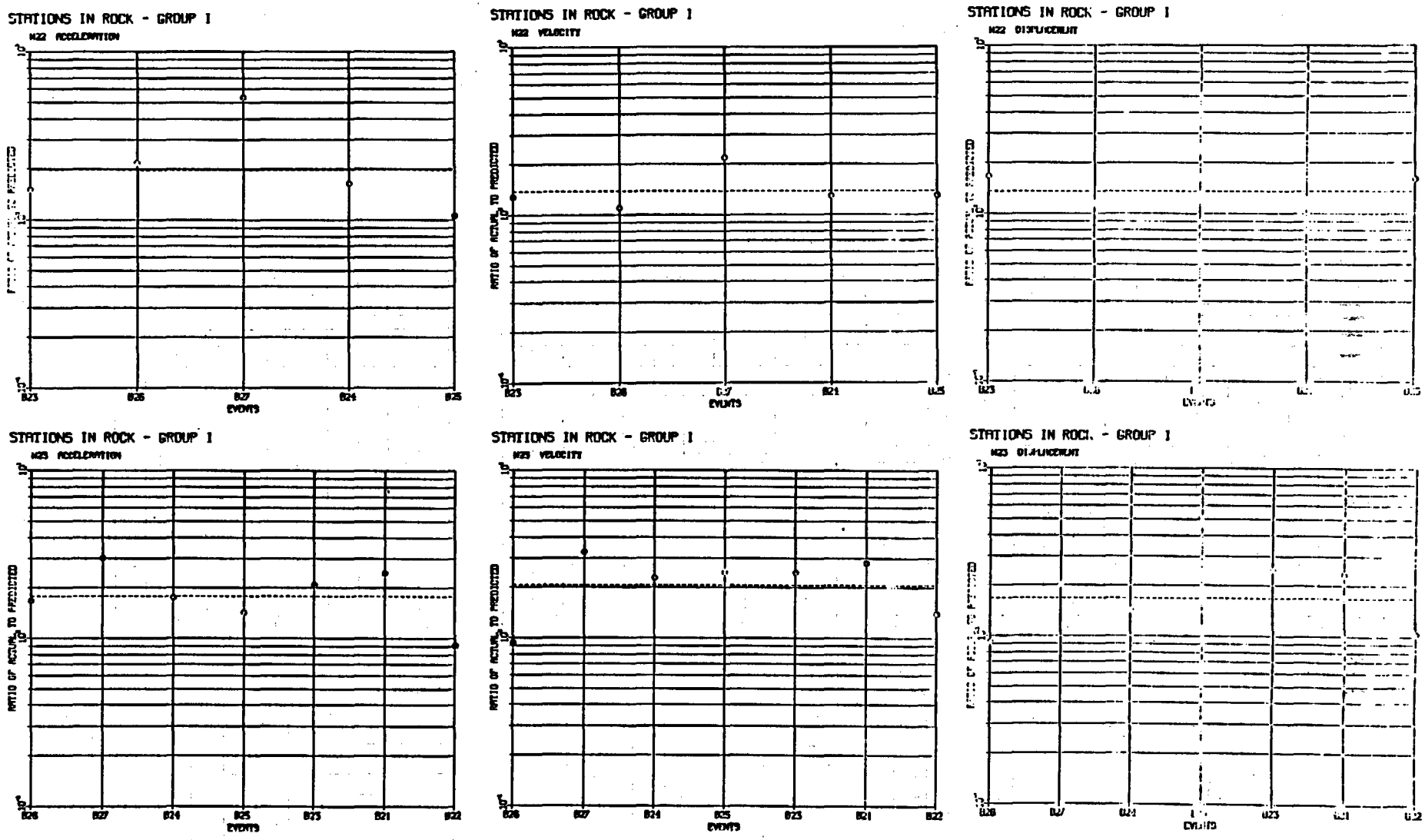

STATIONS IN ROCK - GROUP I
N22 ACCELERATION
N22 VELOCITY
N22 DISPLACEMENT
N23 ACCELERATION
N23 VELOCITY
N23 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure D-9

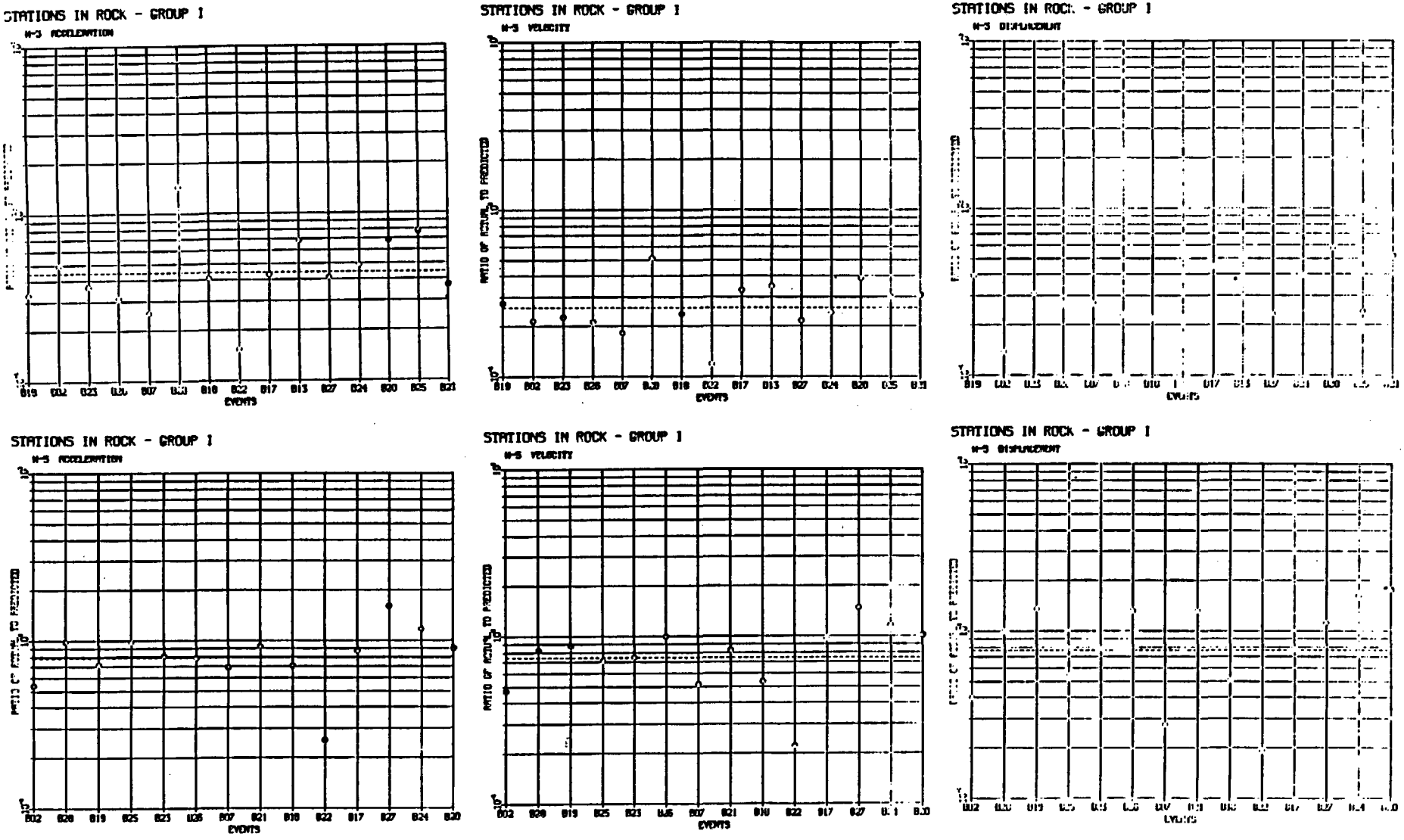

STATIONS IN ROCK - GROUP I
N-S ACCELERATION
EVENTS
STATIONS IN ROCK - GROUP I
N-S VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP I
N-S DISPLACEMENT
EVENTS
STATIONS IN ROCK - GROUP I
N-S ACCELERATION
EVENTS
STATIONS IN ROCK - GROUP I
N-S VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP I
N-S DISPLACEMENT

Figure D-10

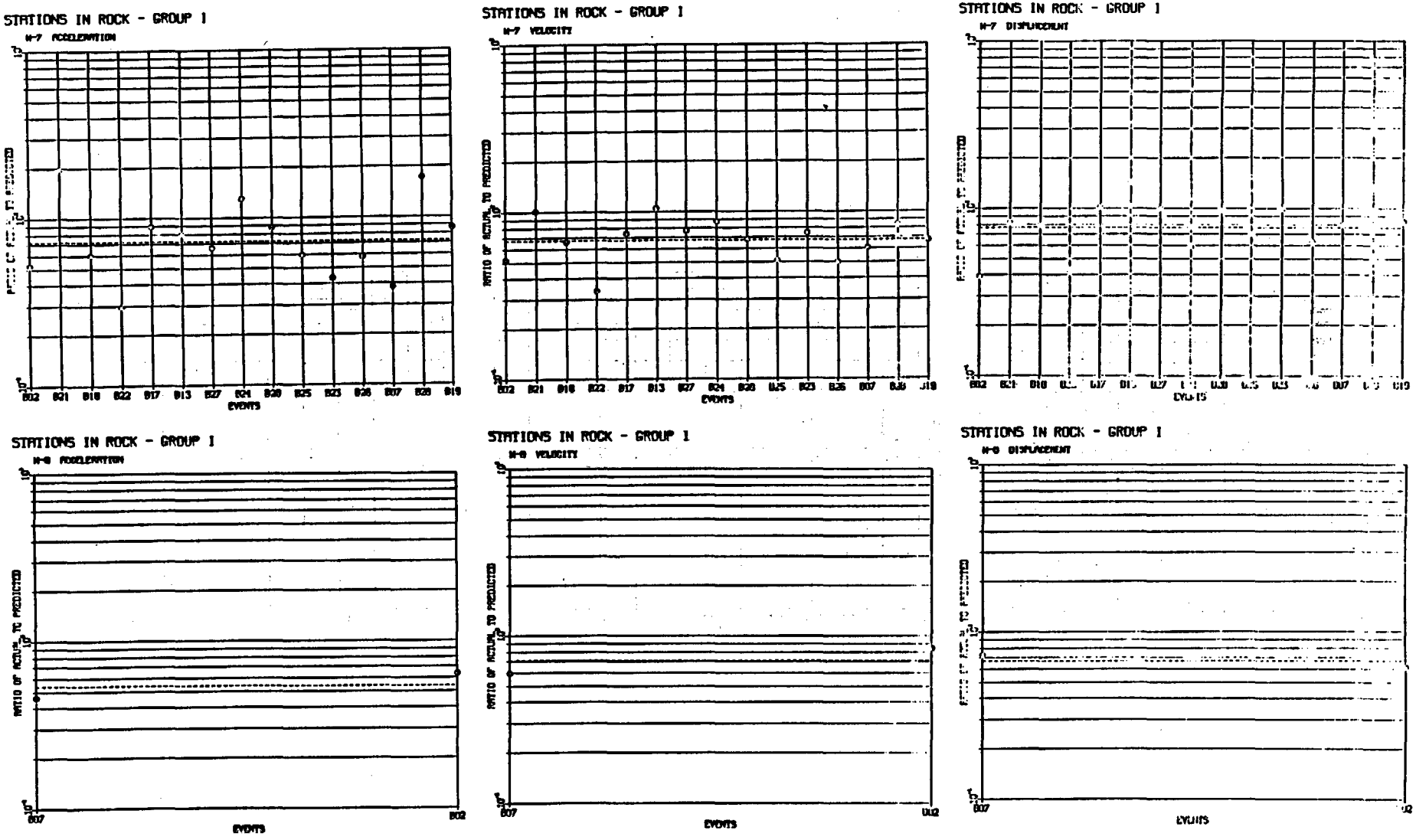
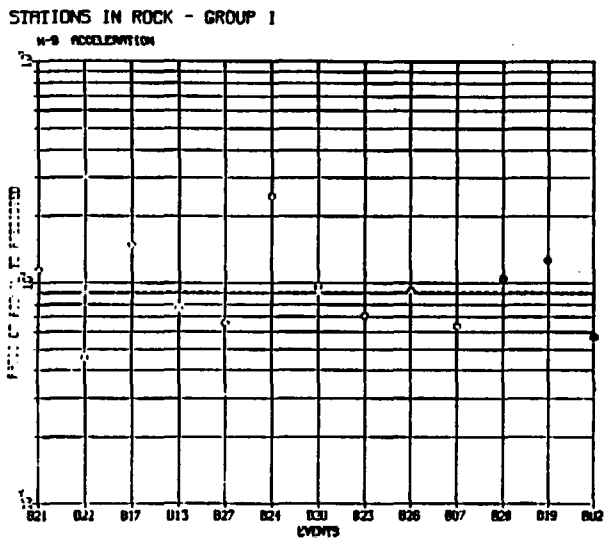
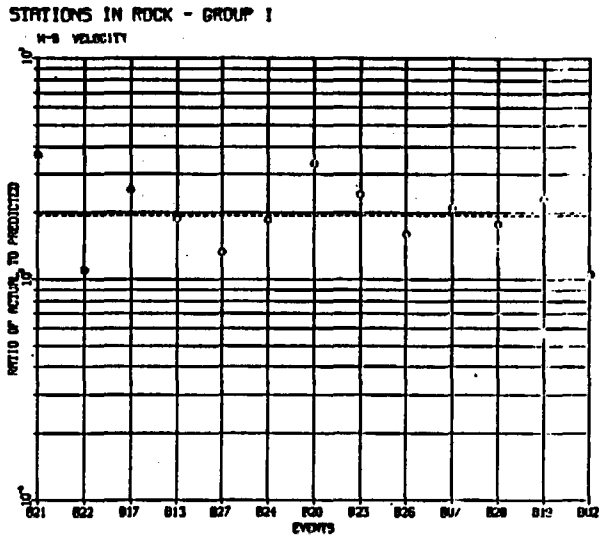

STATIONS IN ROCK - GROUP I
H-7 ACCELERATION
EVENTS
STATIONS IN ROCK - GROUP I
H-7 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP I
H-7 DISPLACEMENT
STATIONS IN ROCK - GROUP I
H-8 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP I
H-8 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP I
H-8 DISPLACEMENT

Figure D-11


STATIONS IN ROCK - GROUP I
H-S ACCELERATION
B21 B22 B17 B13 B27 B24 B30 B23 B26 B07 B28 B19 B02
EVENTS


STATIONS IN ROCK - GROUP I
H-S VELOCITY
B21 B22 B17 B13 B27 B24 B30 B23 B26 B07 B28 B12 B02
EVENTS

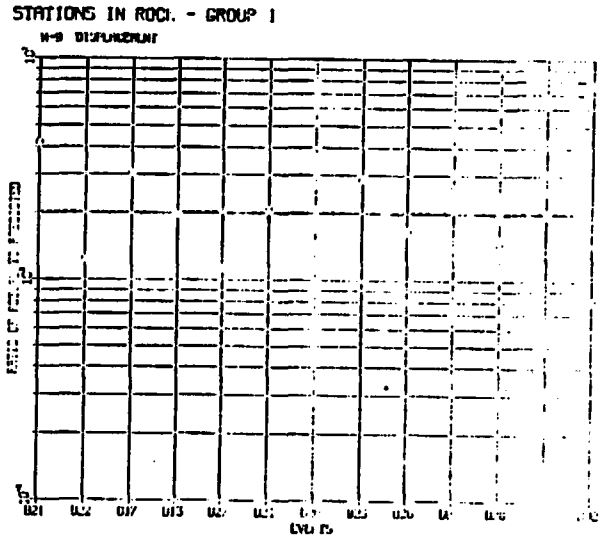

STATIONS IN ROCK - GROUP I
H-S DISPLACEMENT

Figure D-12

Appendix E

Ratios for Rock for Group II

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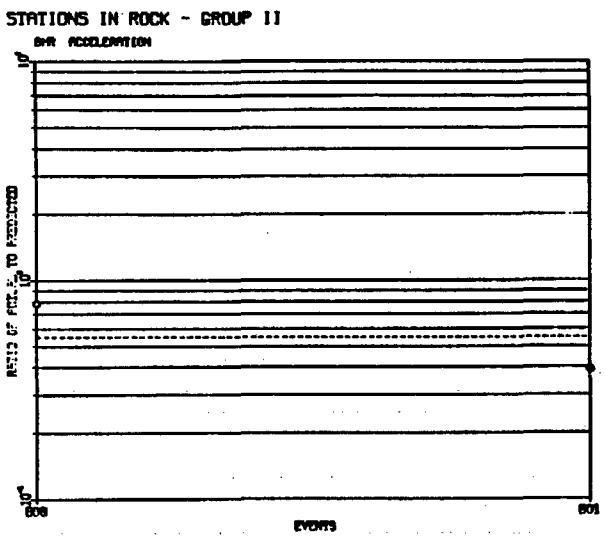
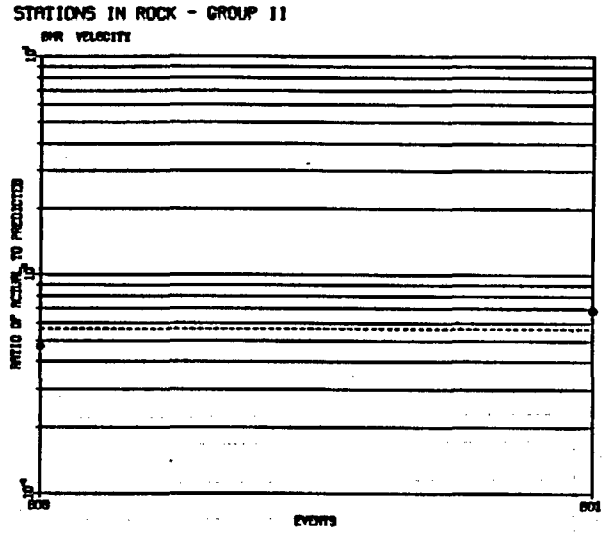
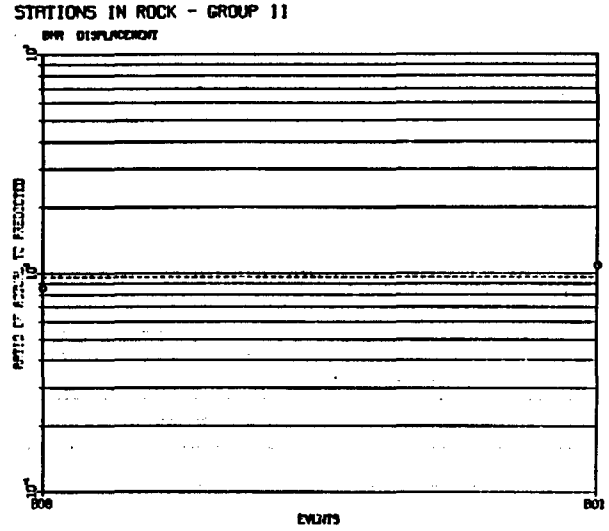
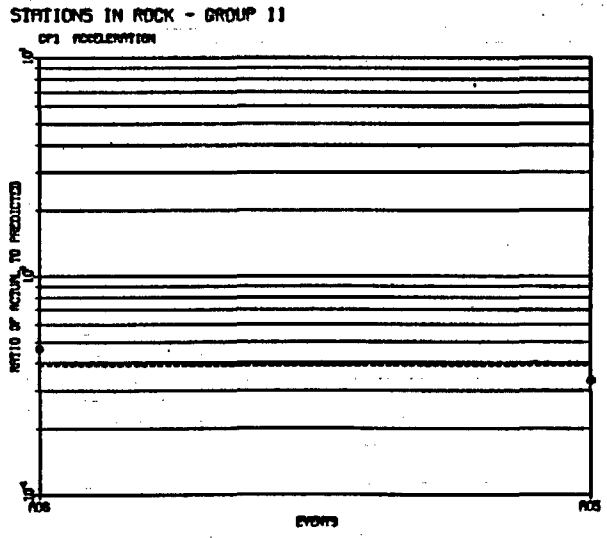
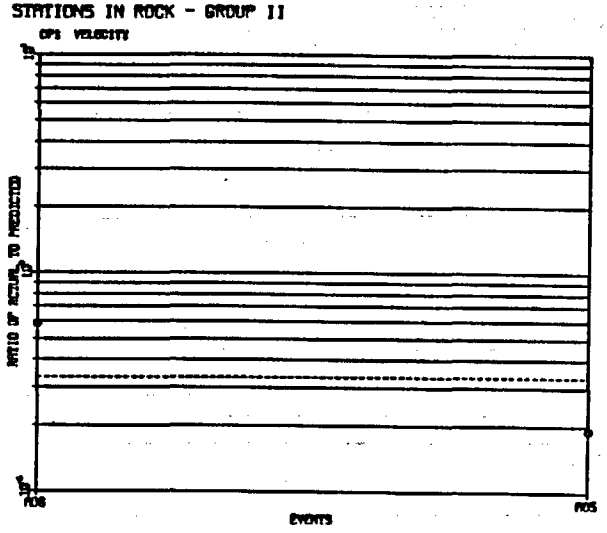

STATIONS IN ROCK - GROUP II
BHR ACCELERATION
EVENTS


STATIONS IN ROCK - GROUP II
BHR VELOCITY
EVENTS


STATIONS IN ROCK - GROUP II
BHR DISPLACEMENT
EVENTS


STATIONS IN ROCK - GROUP II
CP1 ACCELERATION
EVENTS


STATIONS IN ROCK - GROUP II
CP1 VELOCITY
EVENTS

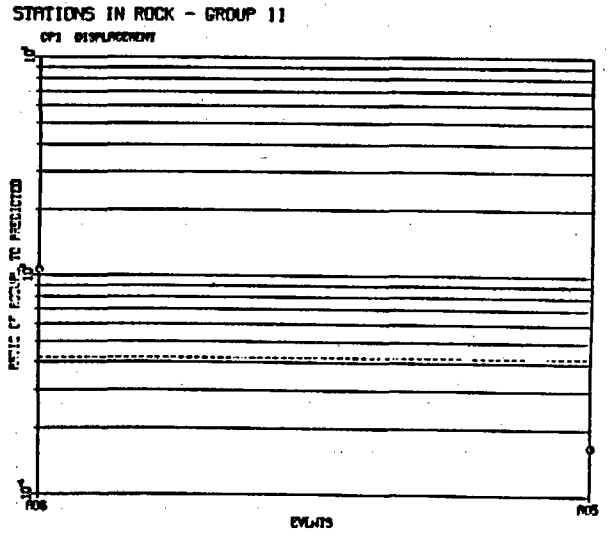

STATIONS IN ROCK - GROUP II
CP1 DISPLACEMENT
EVENTS

Figure E-1

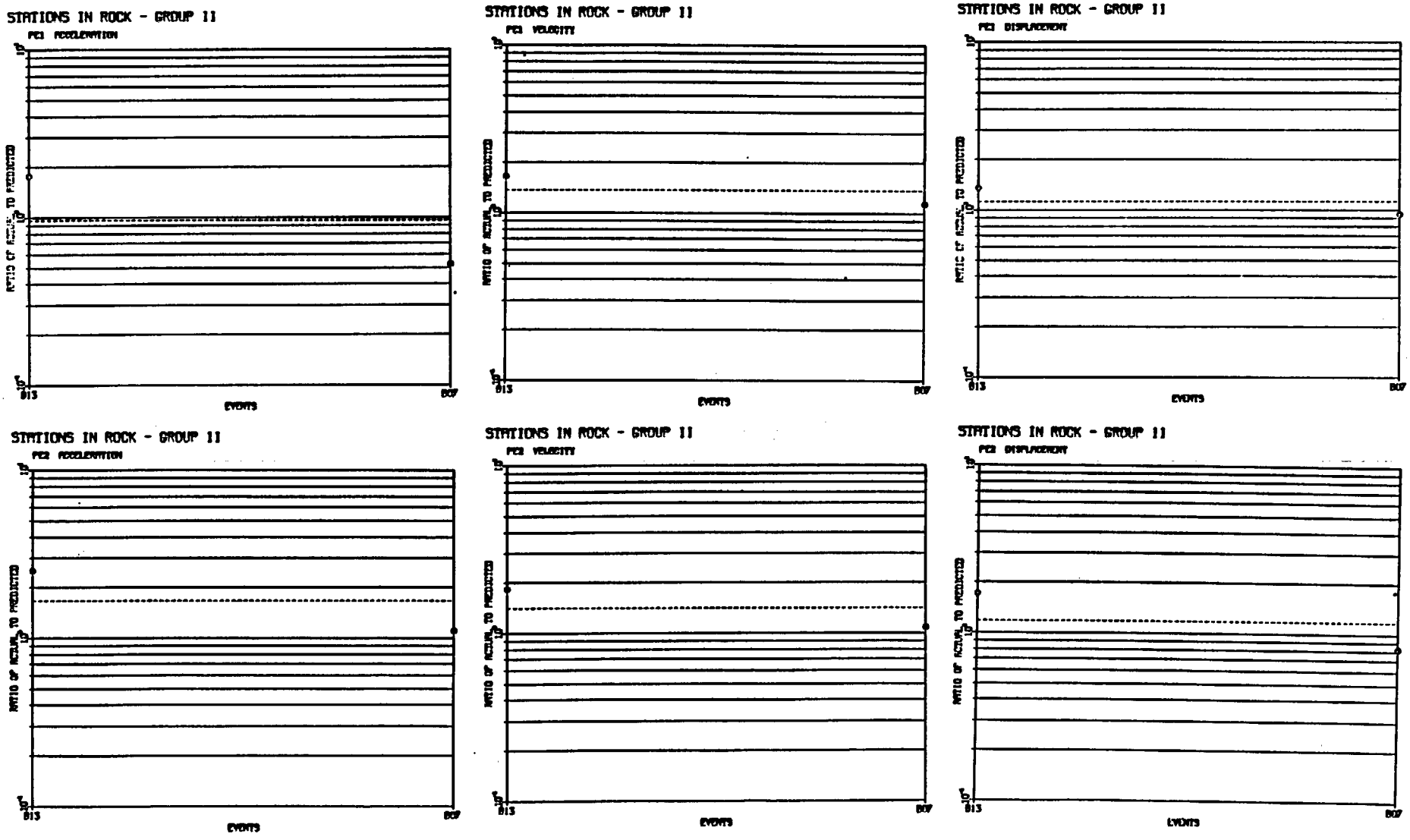

STATIONS IN ROCK - GROUP II
PC1 ACCELERATION
STATIONS IN ROCK - GROUP II
PC1 VELOCITY
STATIONS IN ROCK - GROUP II
PC1 DISPLACEMENT
STATIONS IN ROCK - GROUP II
PC2 ACCELERATION
STATIONS IN ROCK - GROUP II
PC2 VELOCITY
STATIONS IN ROCK - GROUP II
PC2 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
B13
B07

Figure E-2

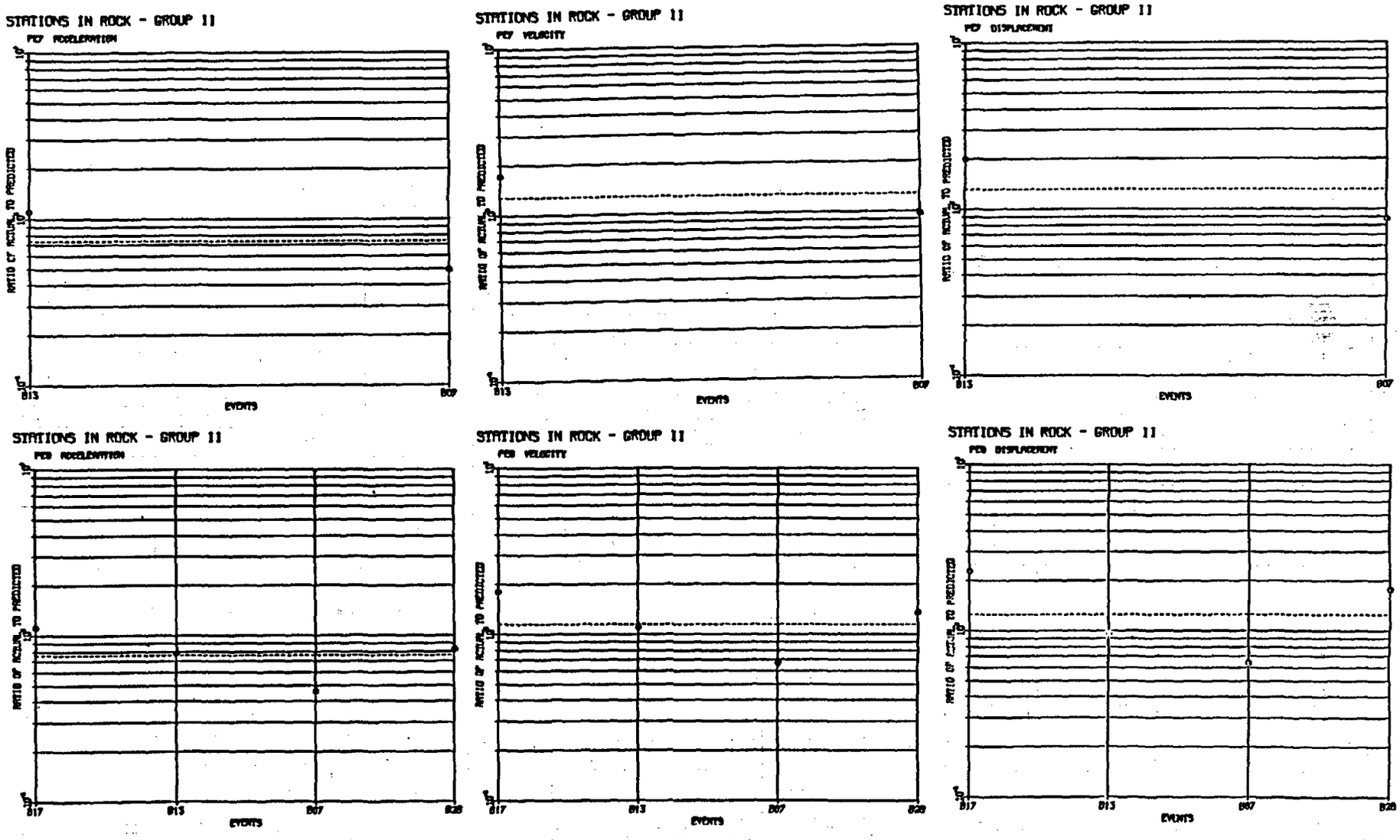

STATIONS IN ROCK - GROUP II
PEF ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP II
PEF VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP II
PEF DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP II
PEB ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP II
PEB VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP II
PEB DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure E-3

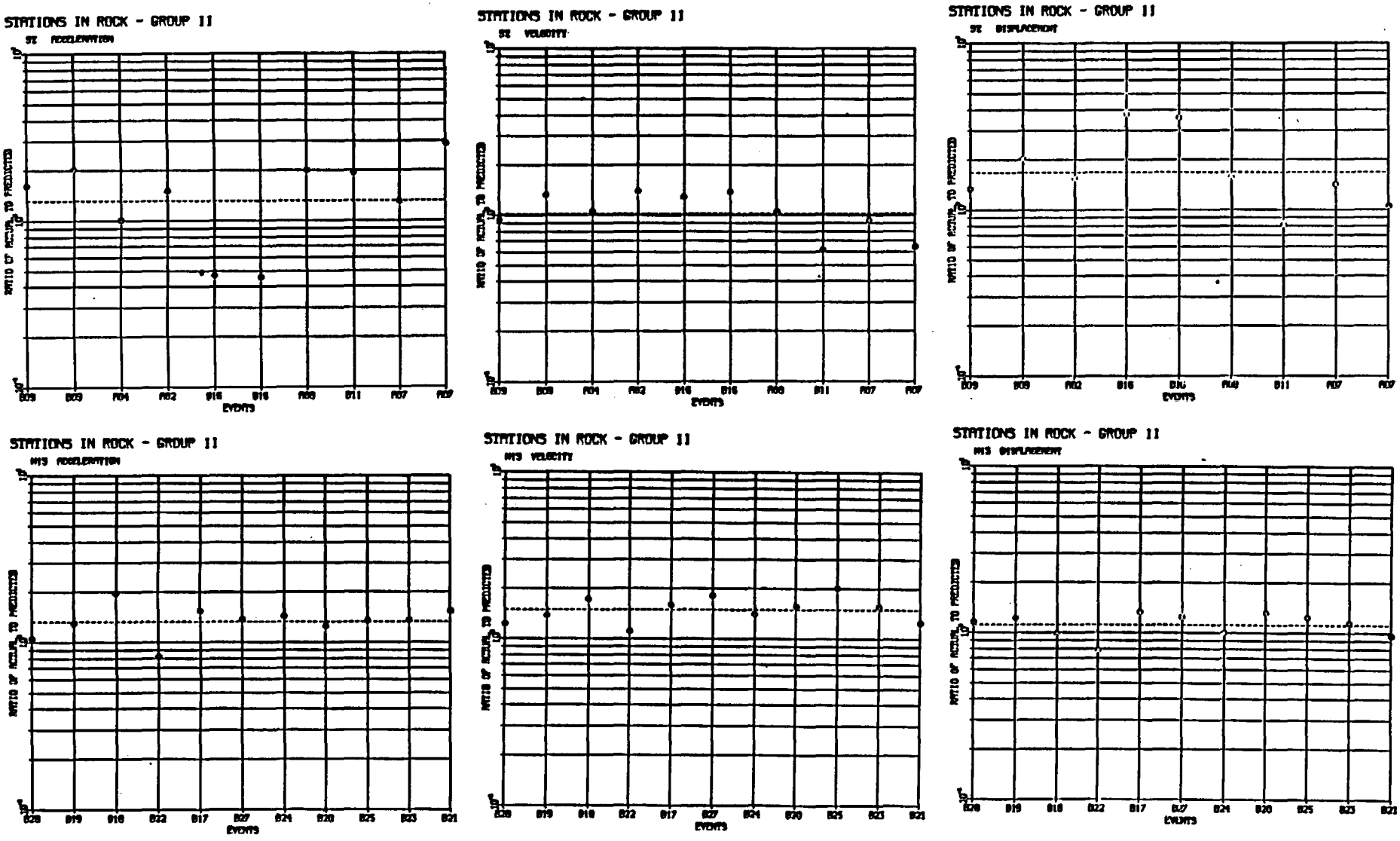

STATIONS IN ROCK - GROUP II
SZ ACCELERATION
STATIONS IN ROCK - GROUP II
SZ VELOCITY
STATIONS IN ROCK - GROUP II
SZ DISPLACEMENT
STATIONS IN ROCK - GROUP II
M13 ACCELERATION
STATIONS IN ROCK - GROUP II
M13 VELOCITY
STATIONS IN ROCK - GROUP II
M13 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure E-4

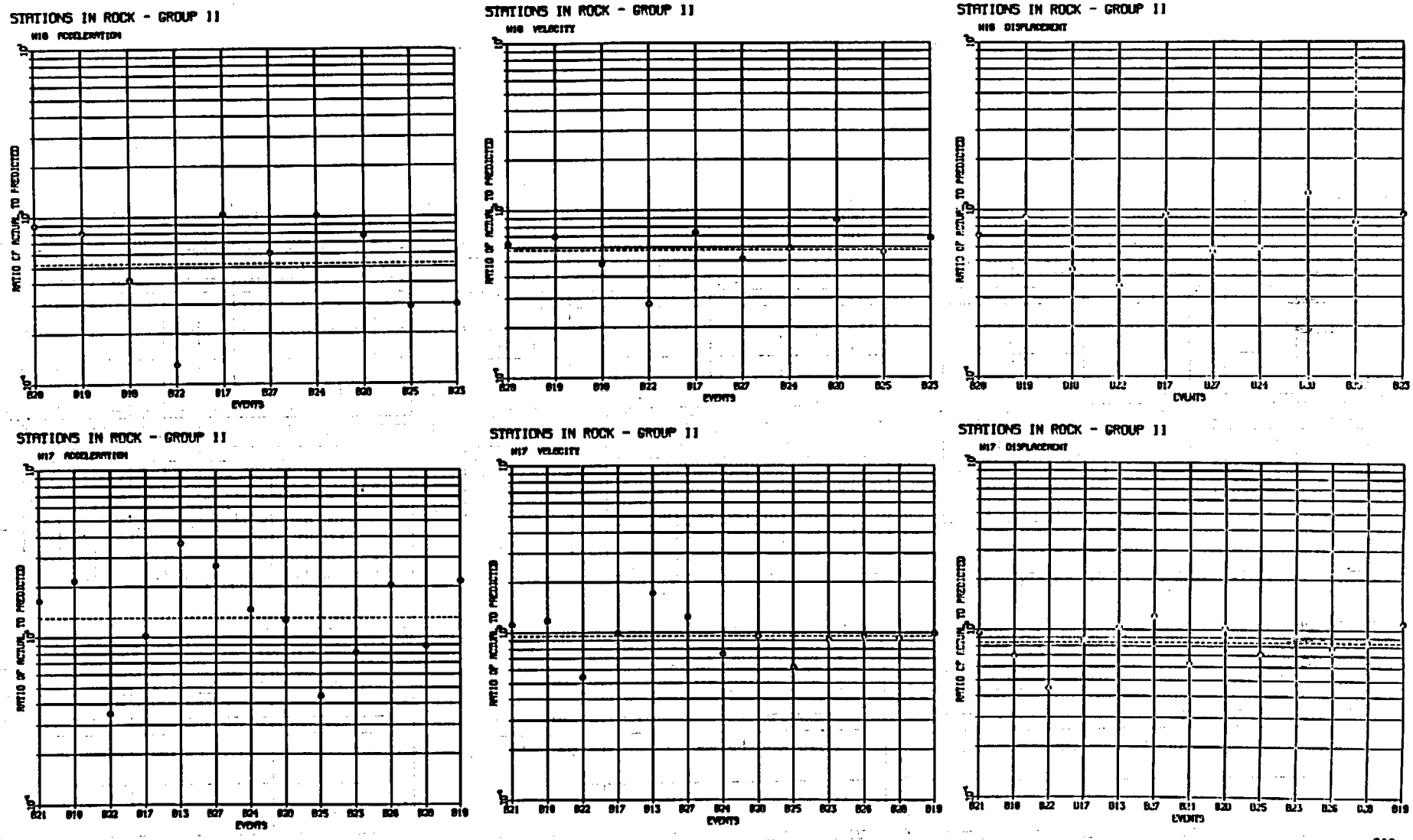

STATIONS IN ROCK - GROUP II
H16 ACCELERATION
STATIONS IN ROCK - GROUP II
H16 VELOCITY
STATIONS IN ROCK - GROUP II
H16 DISPLACEMENT
STATIONS IN ROCK - GROUP II
H17 ACCELERATION
STATIONS IN ROCK - GROUP II
H17 VELOCITY
STATIONS IN ROCK - GROUP II
H17 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure E-5

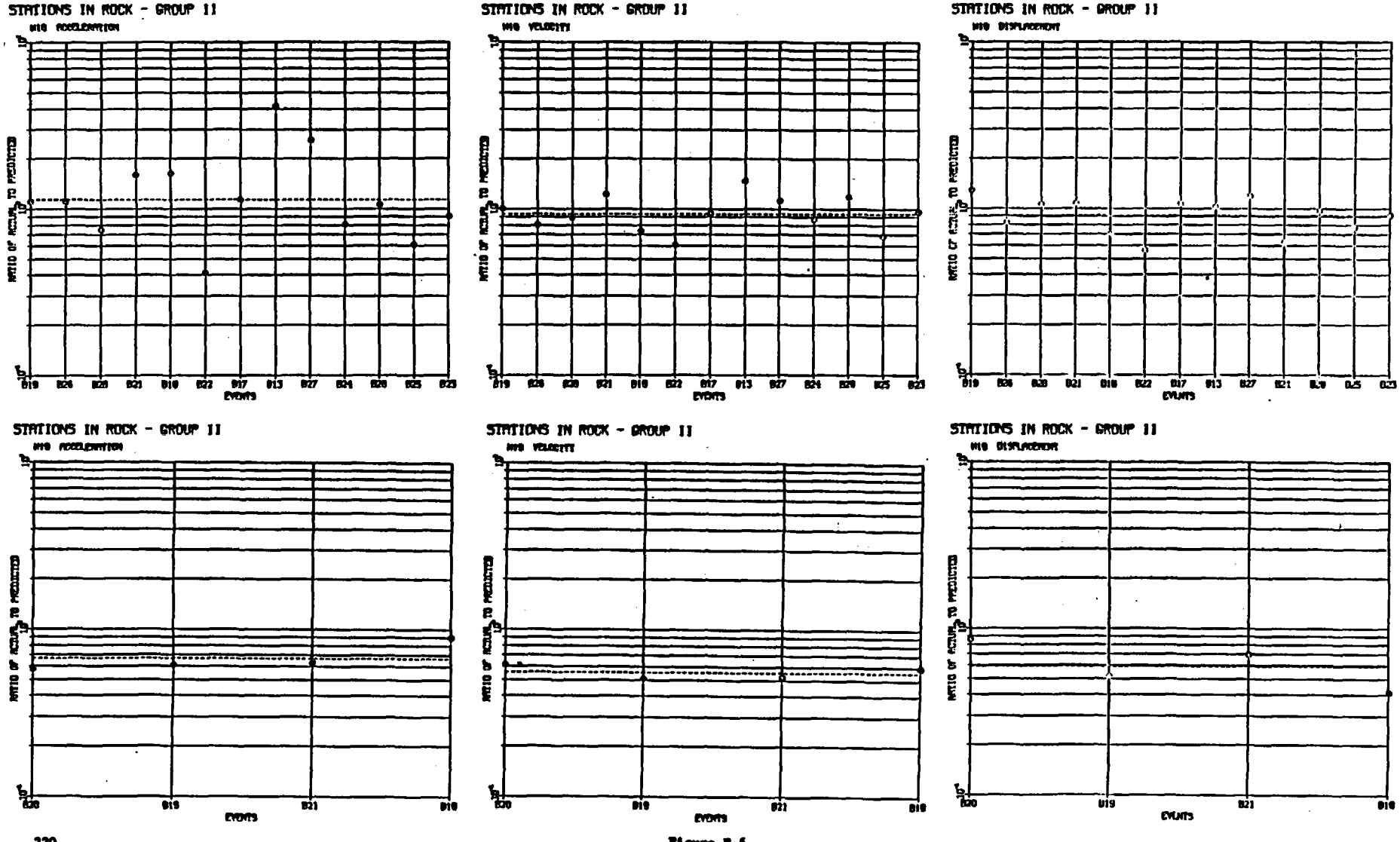

STATIONS IN ROCK - GROUP II
STATIONS IN ROCK - GROUP II
STATIONS IN ROCK - GROUP II
STATIONS IN ROCK - GROUP II
STATIONS IN ROCK - GROUP II
STATIONS IN ROCK - GROUP II
EVENTS

Figure E-6

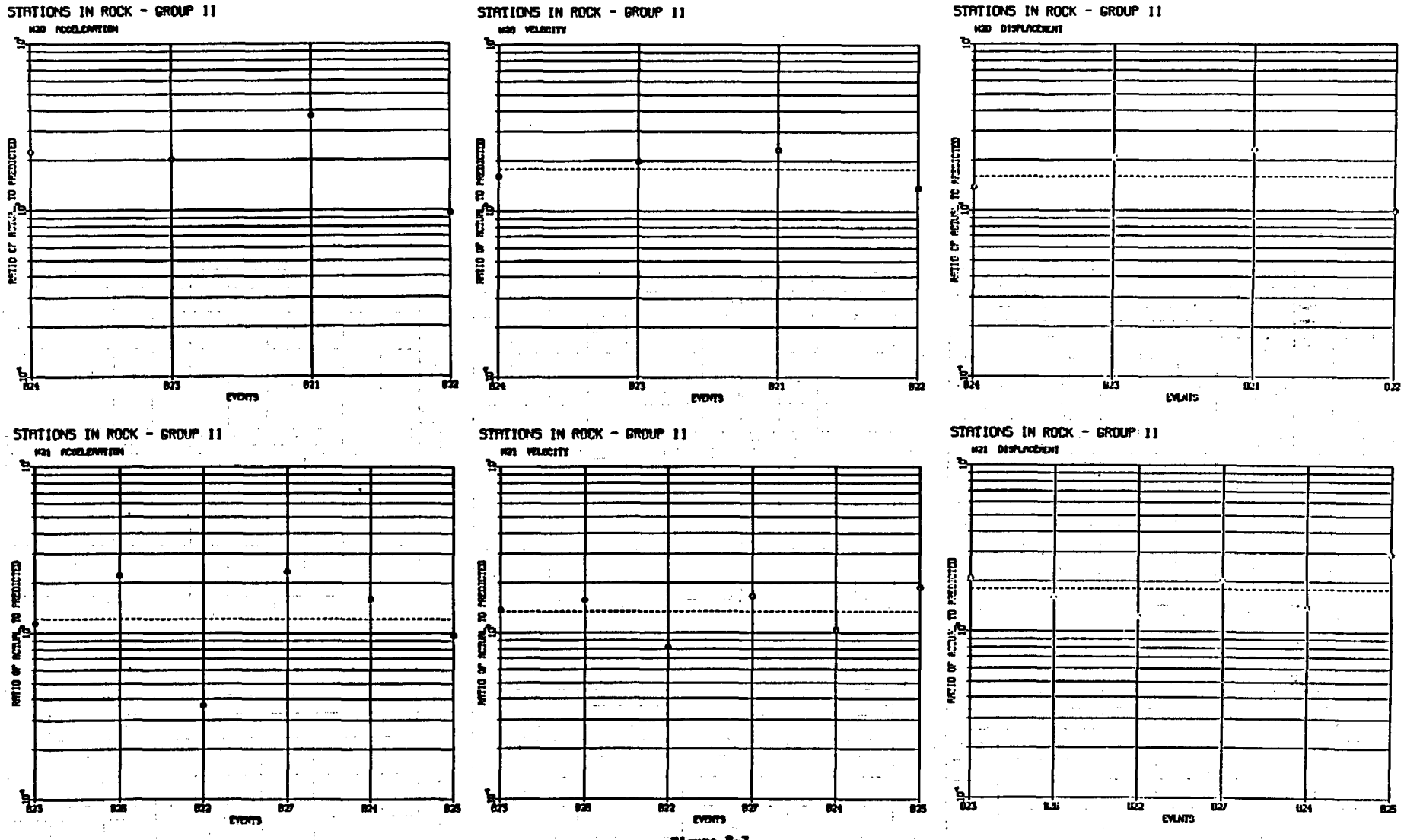

STATIONS IN ROCK - GROUP II
H20 ACCELERATION
H20 VELOCITY
H20 DISPLACEMENT
H21 ACCELERATION
H21 VELOCITY
H21 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure E-7

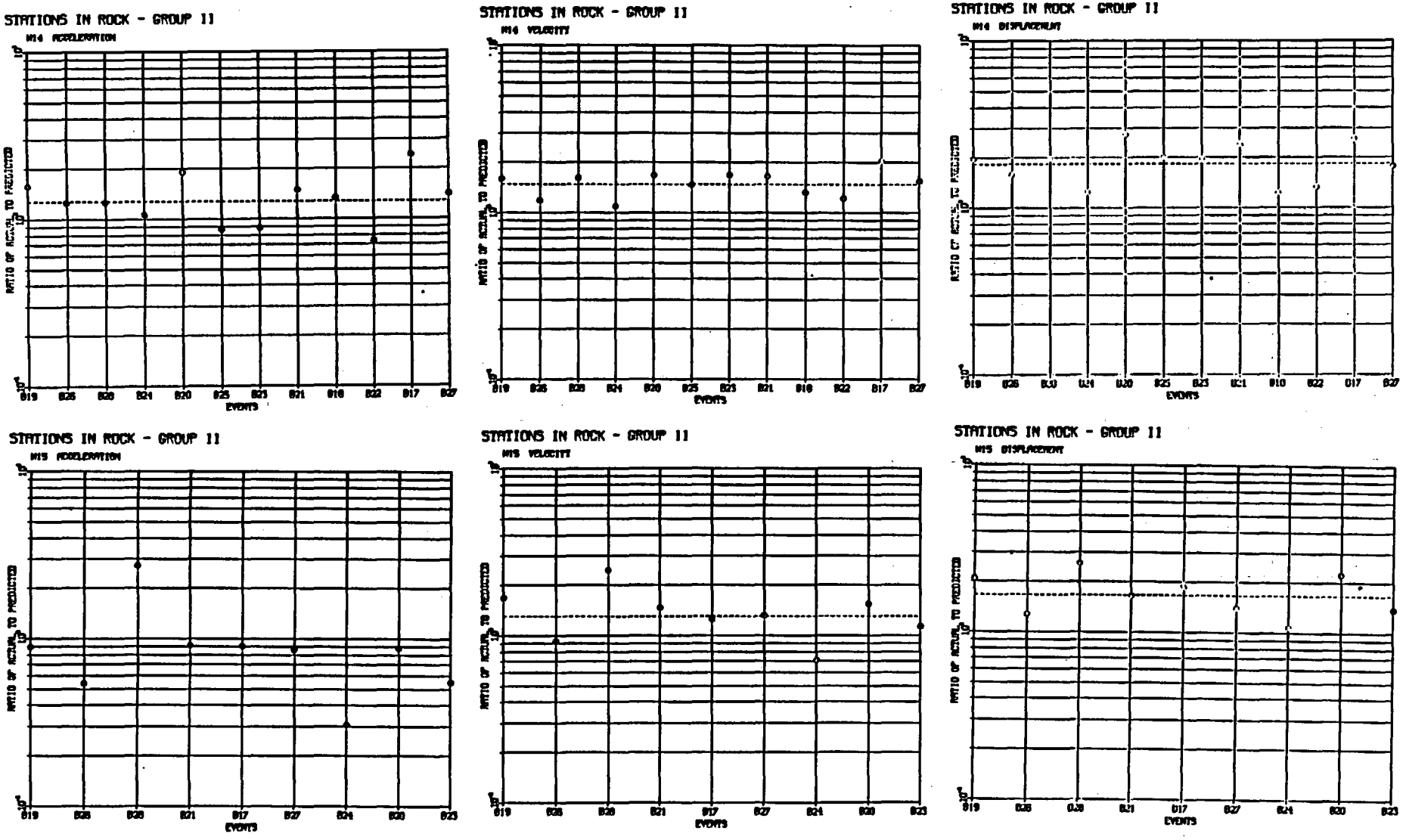

STATIONS IN ROCK - GROUP II
M14 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP II
M14 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP II
M14 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP II
M15 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP II
M15 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP II
M15 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure E-8

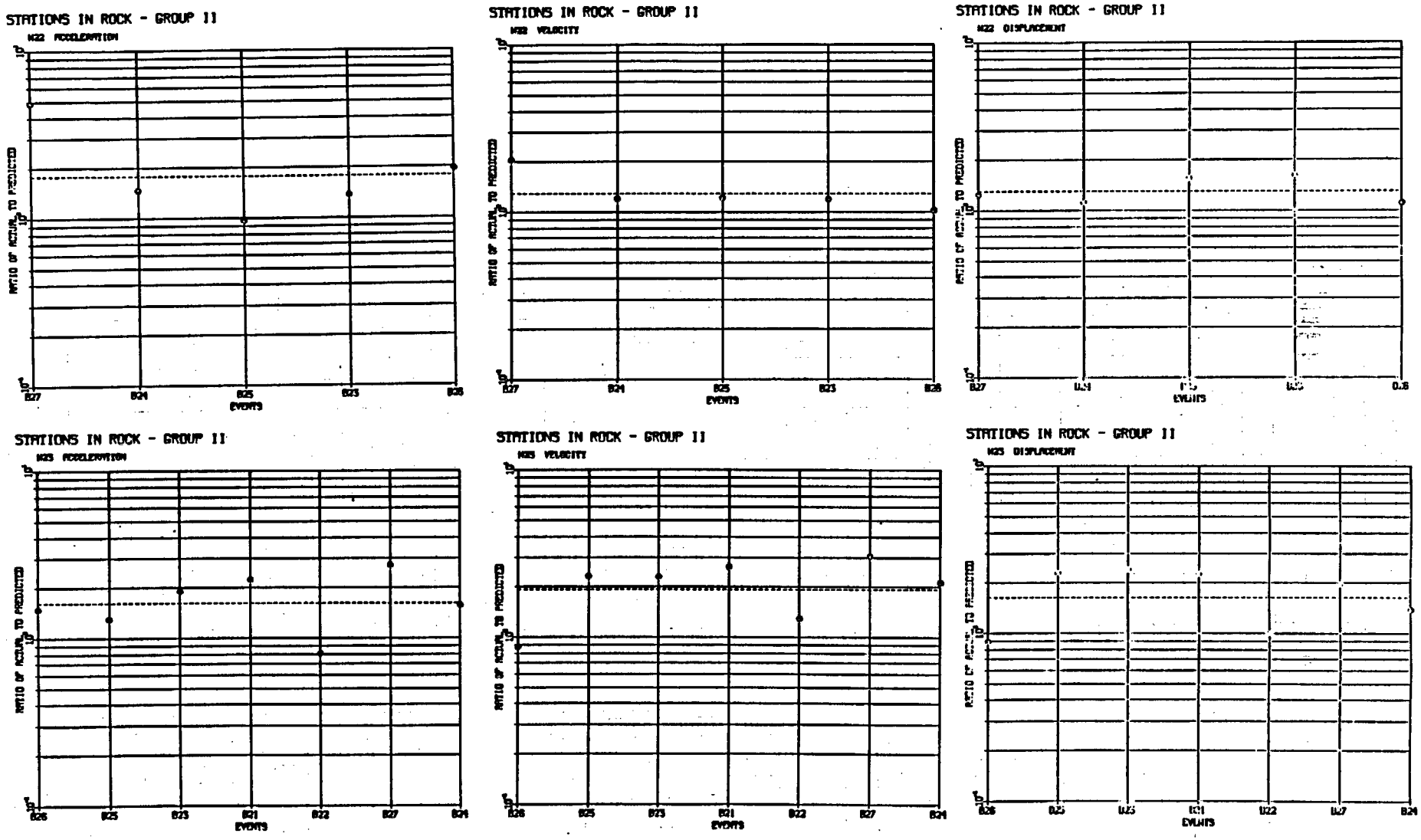

STATIONS IN ROCK - GROUP II
N22 ACCELERATION
N22 VELOCITY
N22 DISPLACEMENT
N23 ACCELERATION
N23 VELOCITY
N23 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure E-9

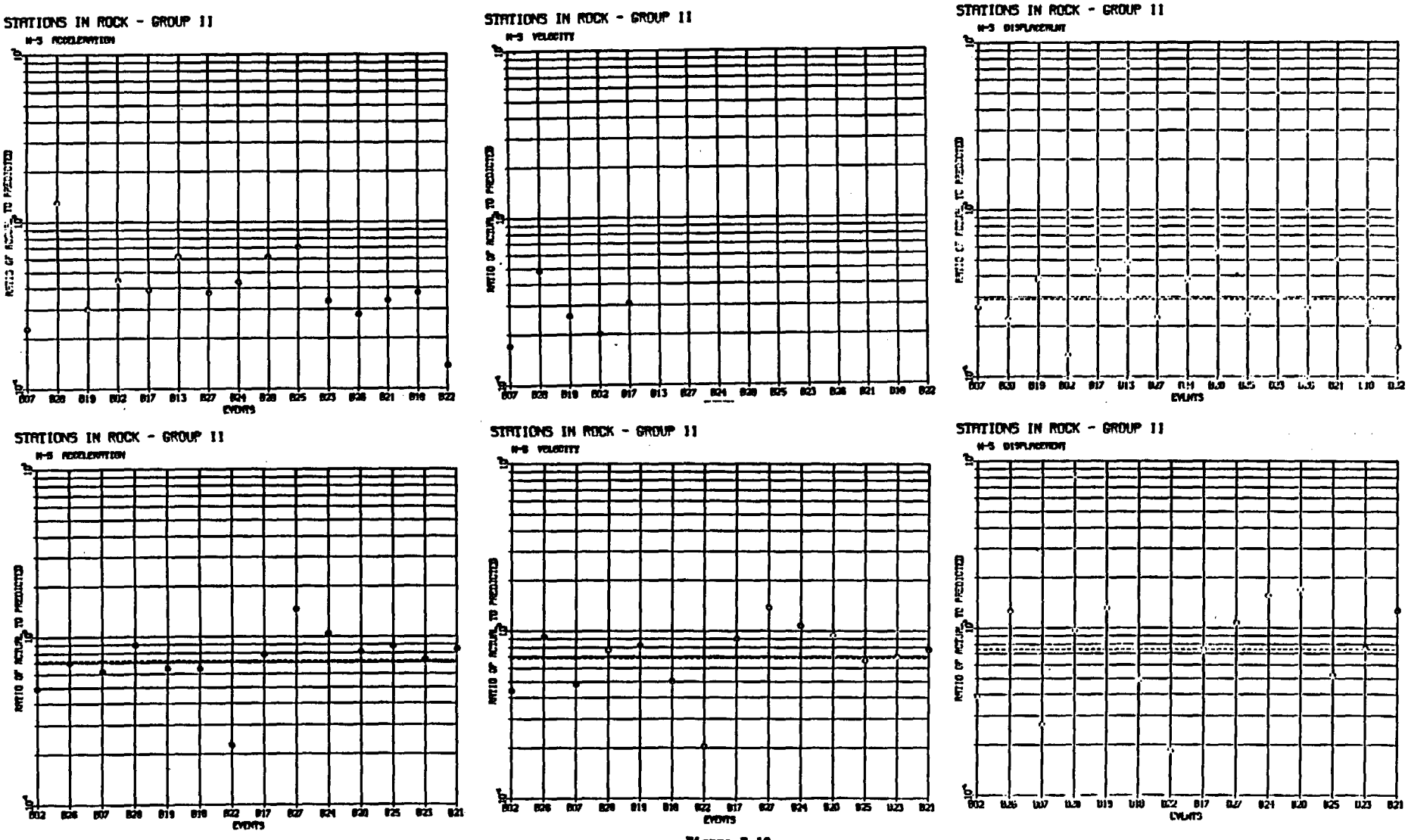

STATIONS IN ROCK - GROUP II
N-S ACCELERATION
EVENTS
STATIONS IN ROCK - GROUP II
N-S VELOCITY
EVENTS
STATIONS IN ROCK - GROUP II
N-S DISPLACEMENT
EVENTS
STATIONS IN ROCK - GROUP II
N-S ACCELERATION
EVENTS
STATIONS IN ROCK - GROUP II
N-S VELOCITY
EVENTS
STATIONS IN ROCK - GROUP II
N-S DISPLACEMENT
EVENTS

Figure E-10

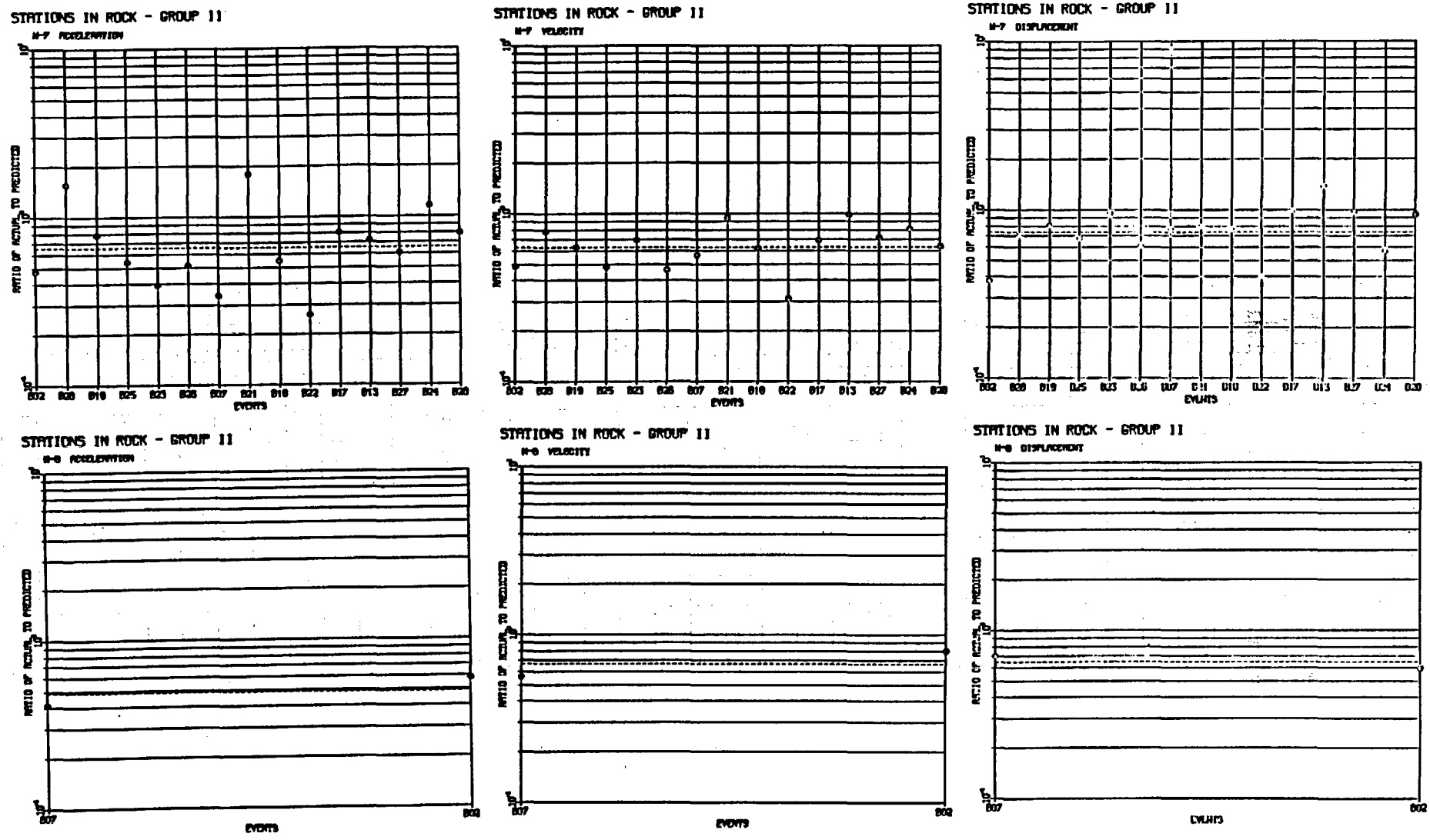

STATIONS IN ROCK - GROUP II
N-7 ACCELERATION
N-7 VELOCITY
N-7 DISPLACEMENT
N-8 ACCELERATION
N-8 VELOCITY
N-8 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure E-11

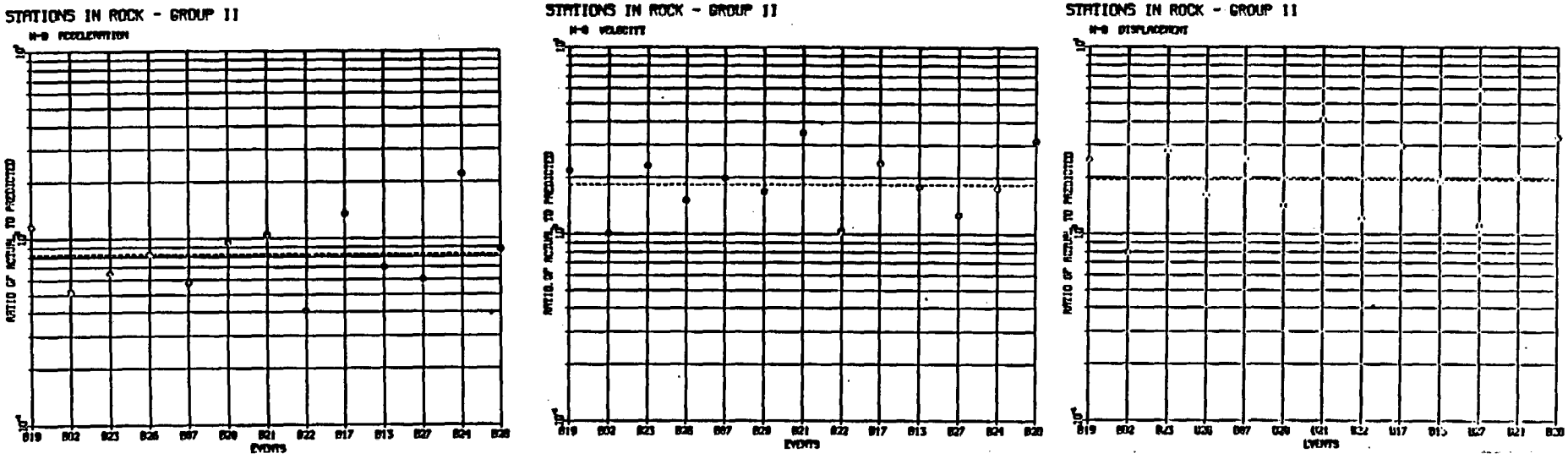

STATIONS IN ROCK - GROUP II
N-S ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP II
N-S VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP II
N-S DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure E-12

Appendix F

Ratios for Rock for Group III

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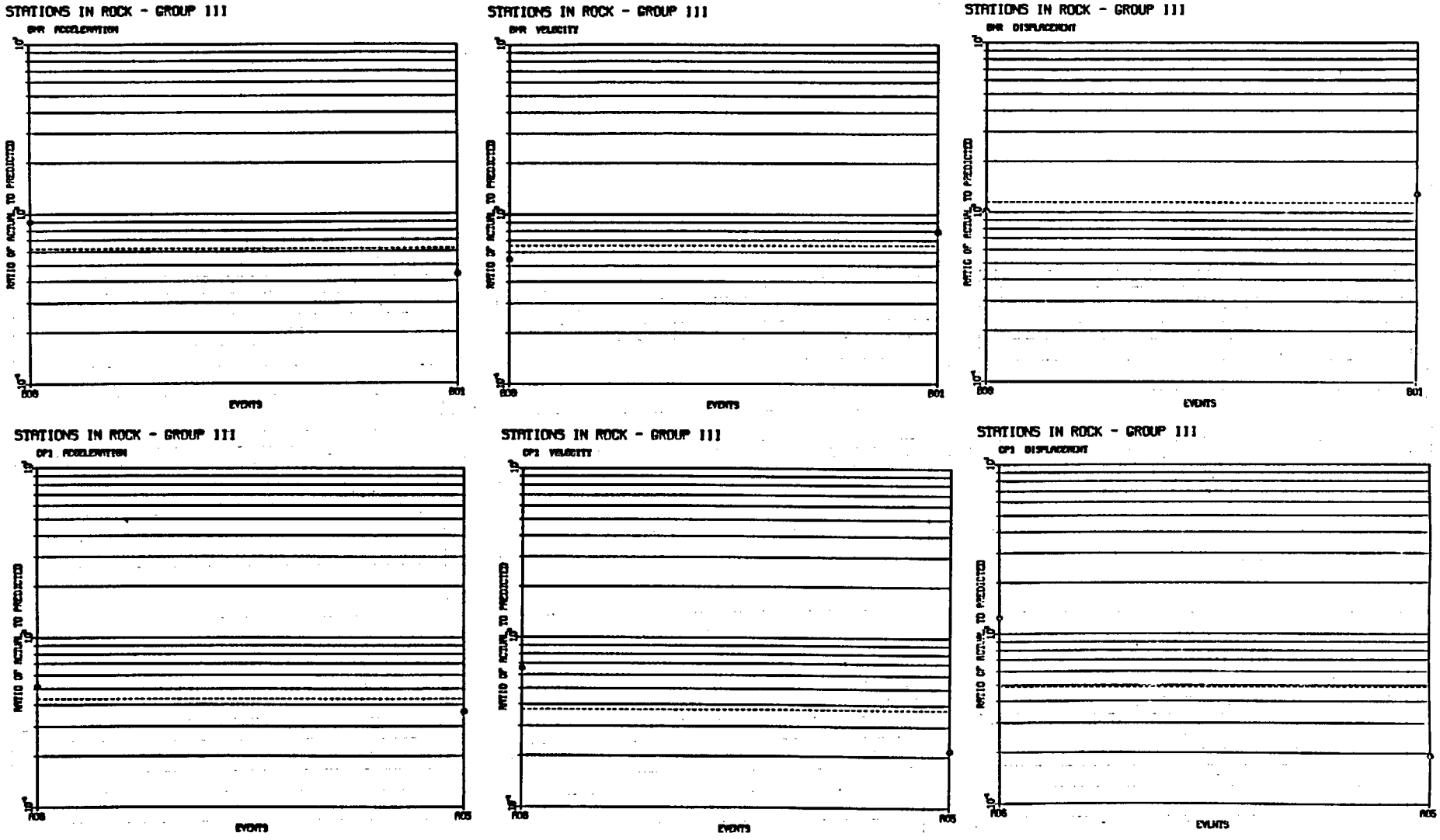

STATIONS IN ROCK - GROUP III
BHR ACCELERATION
STATIONS IN ROCK - GROUP III
BHR VELOCITY
STATIONS IN ROCK - GROUP III
BHR DISPLACEMENT
STATIONS IN ROCK - GROUP III
CP1 ACCELERATION
STATIONS IN ROCK - GROUP III
CP1 VELOCITY
STATIONS IN ROCK - GROUP III
CP1 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
R08
R05

Figure F-1

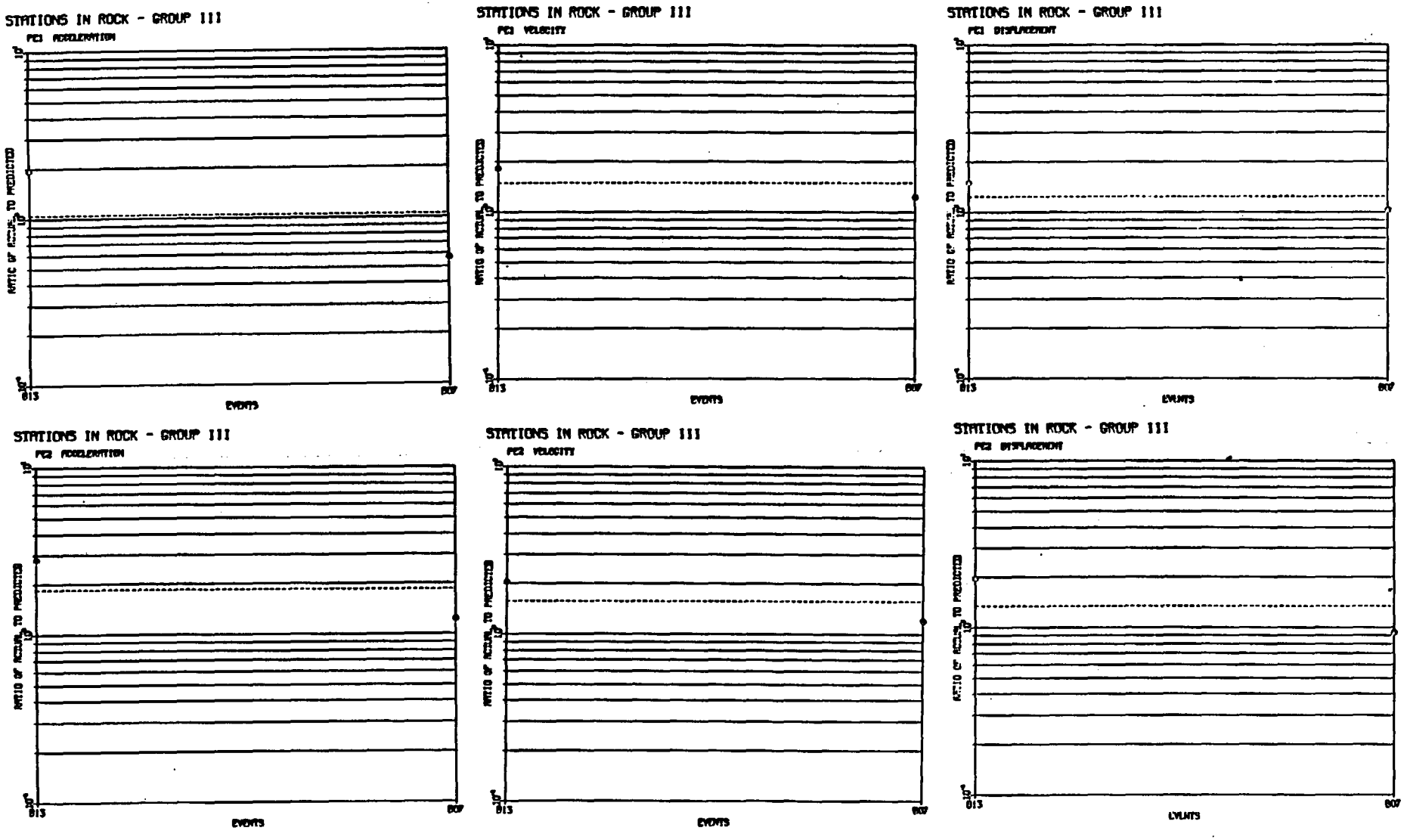

STATIONS IN ROCK - GROUP III
PC1 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
PC1 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
PC1 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
PC2 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
PC2 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
PC2 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure F-2

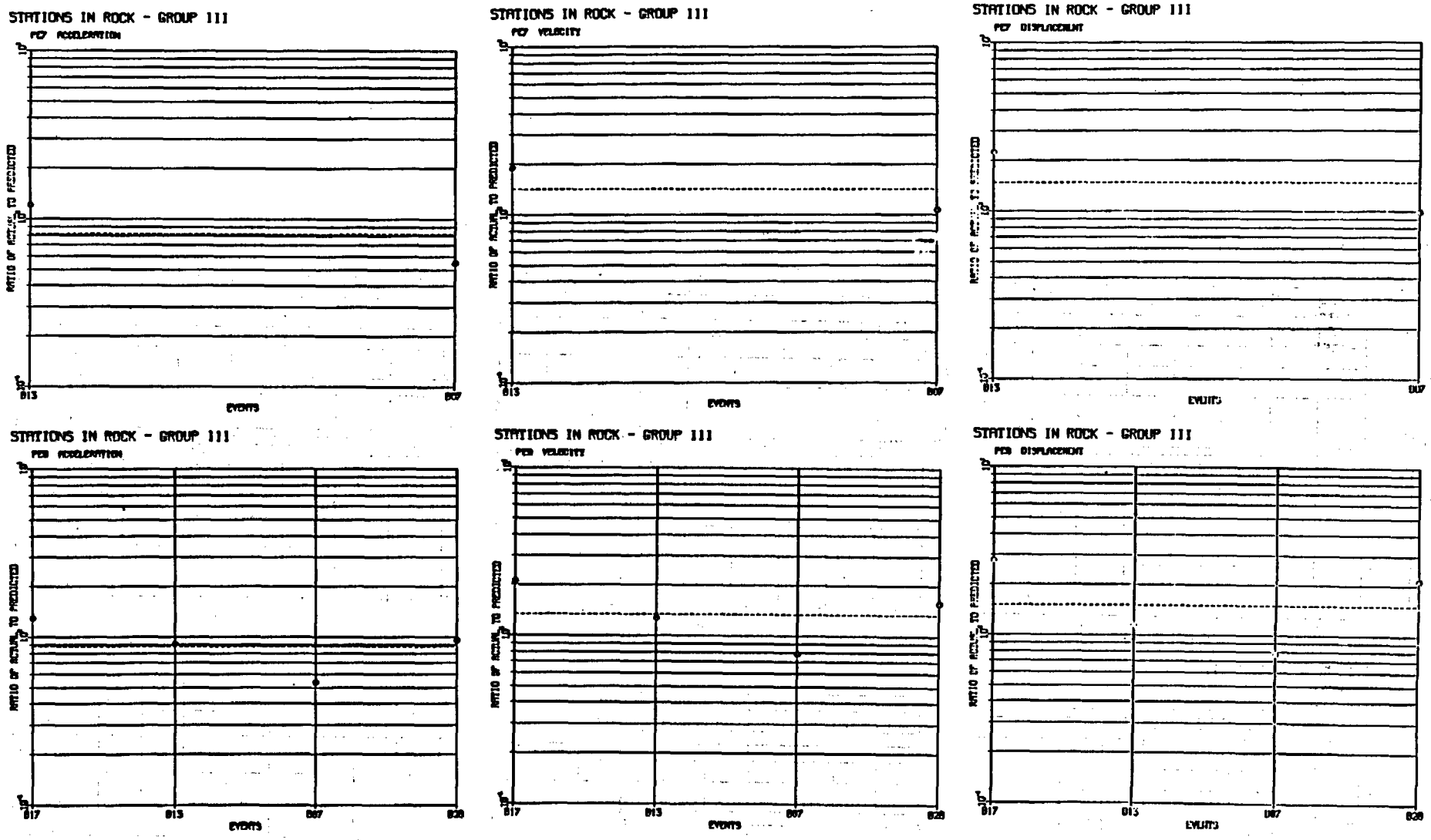

STATIONS IN ROCK - GROUP III
PGA ACCELERATION
STATIONS IN ROCK - GROUP III
PGA VELOCITY
STATIONS IN ROCK - GROUP III
PGA DISPLACEMENT
STATIONS IN ROCK - GROUP III
PGD ACCELERATION
STATIONS IN ROCK - GROUP III
PGD VELOCITY
STATIONS IN ROCK - GROUP III
PGD DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
013
007
017
020

Figure P-3

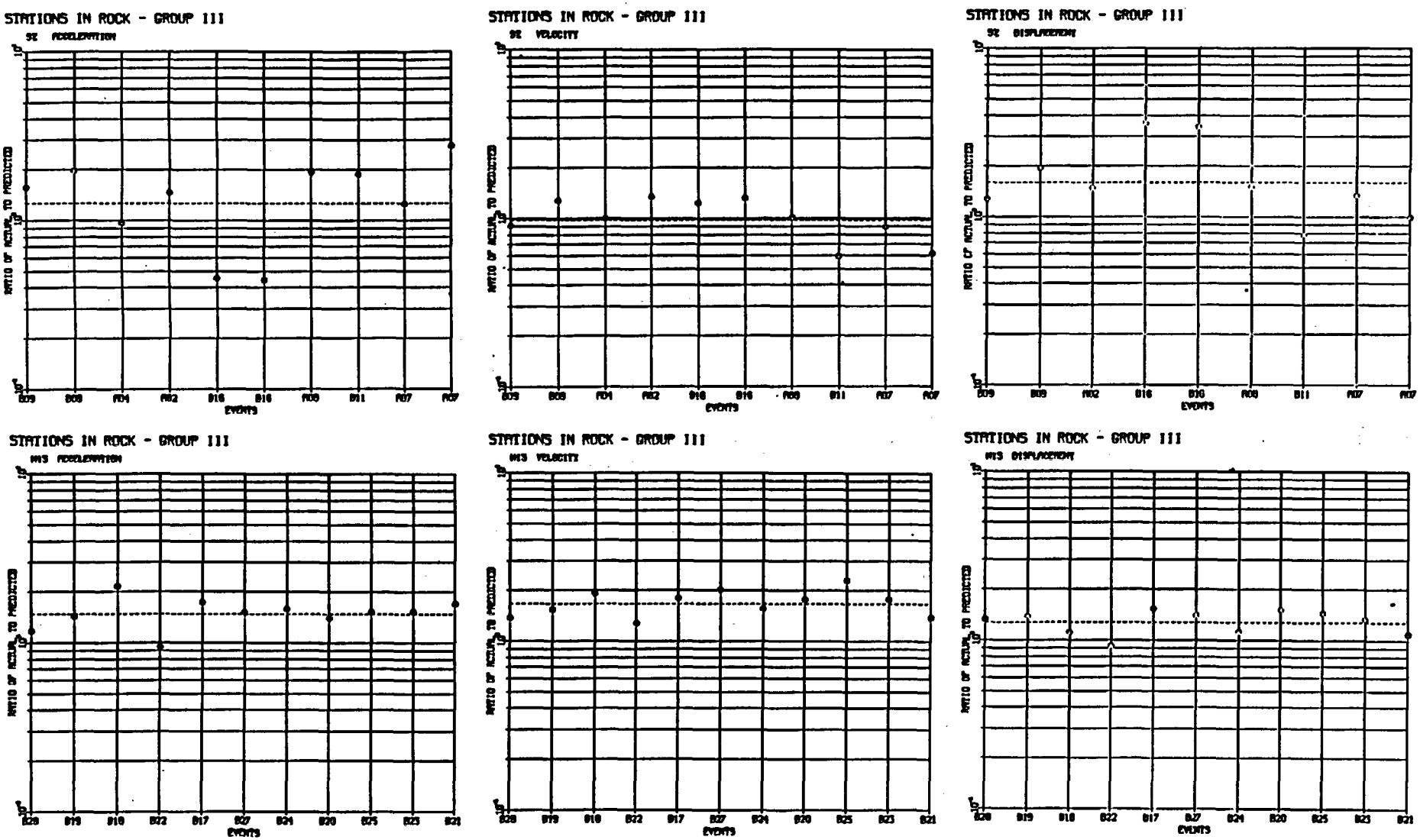

STATIONS IN ROCK - GROUP III
9Z ACCELERATION
9Z VELOCITY
9Z DISPLACEMENT
HNS ACCELERATION
HNS VELOCITY
HNS DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure P-4

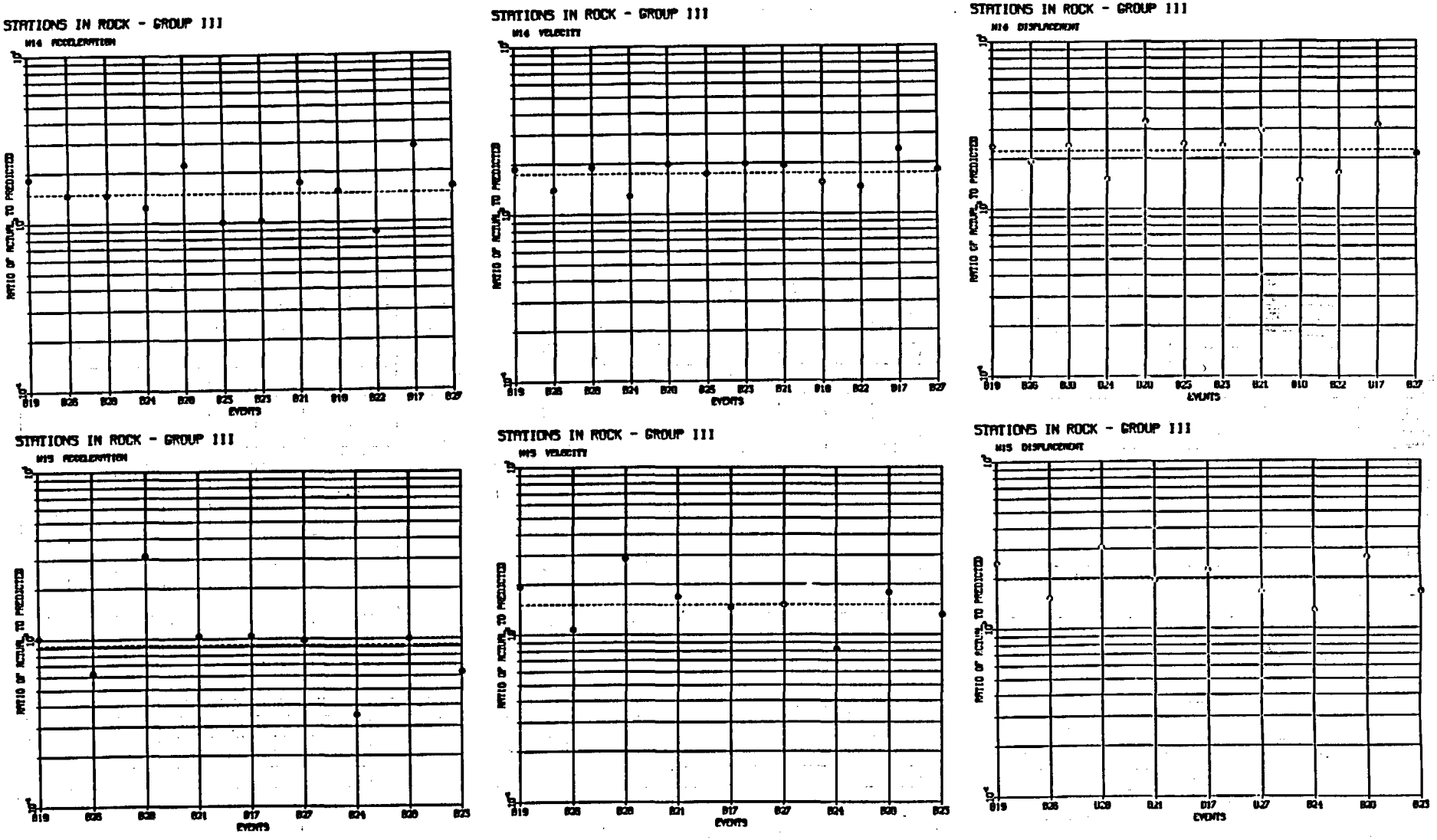
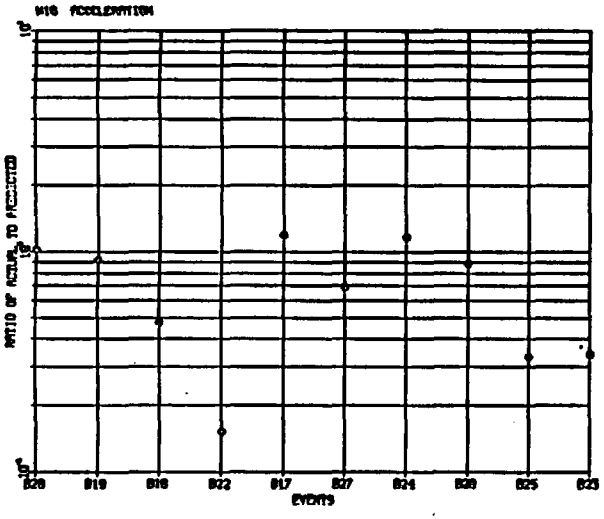
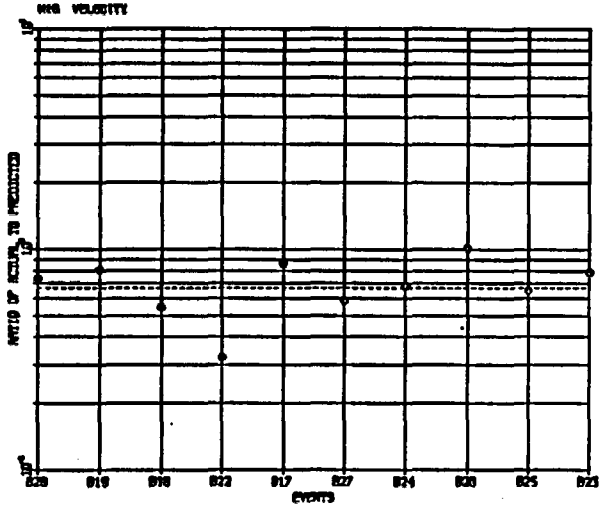

STATIONS IN ROCK - GROUP III
N14 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
N14 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
N14 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
N15 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
N15 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
N15 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure F-5

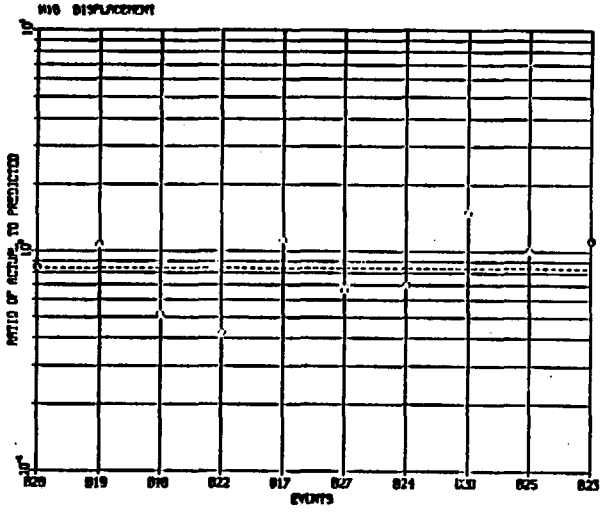
STATIONS IN ROCK - GROUP III



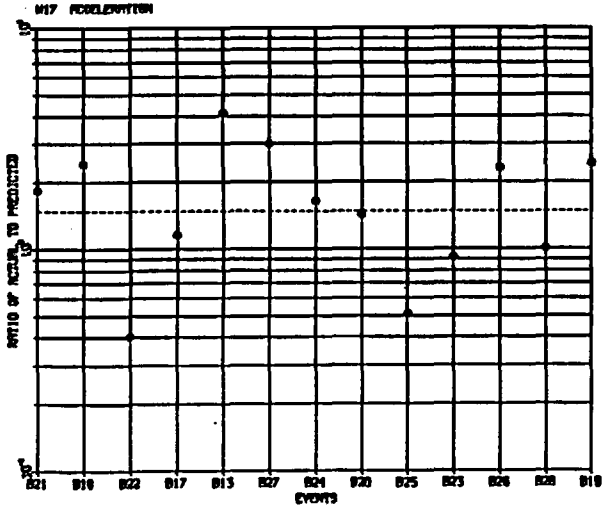
STATIONS IN ROCK - GROUP III



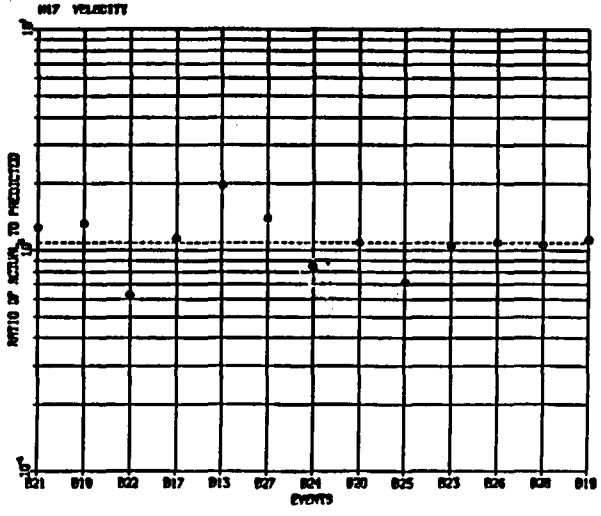
STATIONS IN ROCK - GROUP III



STATIONS IN ROCK - GROUP III



STATIONS IN ROCK - GROUP III



STATIONS IN ROCK - GROUP III

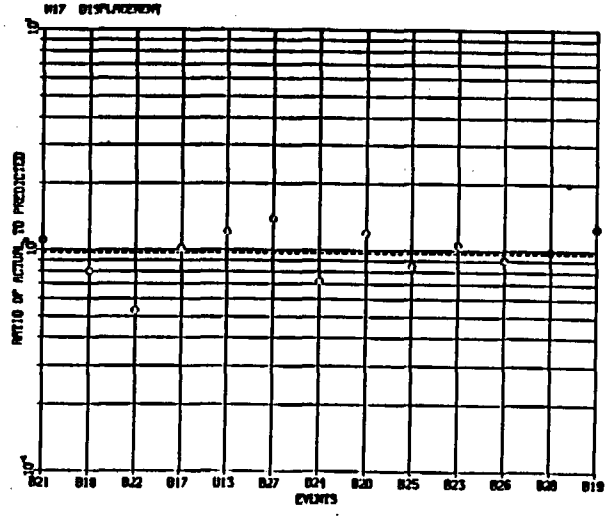


Figure F-6

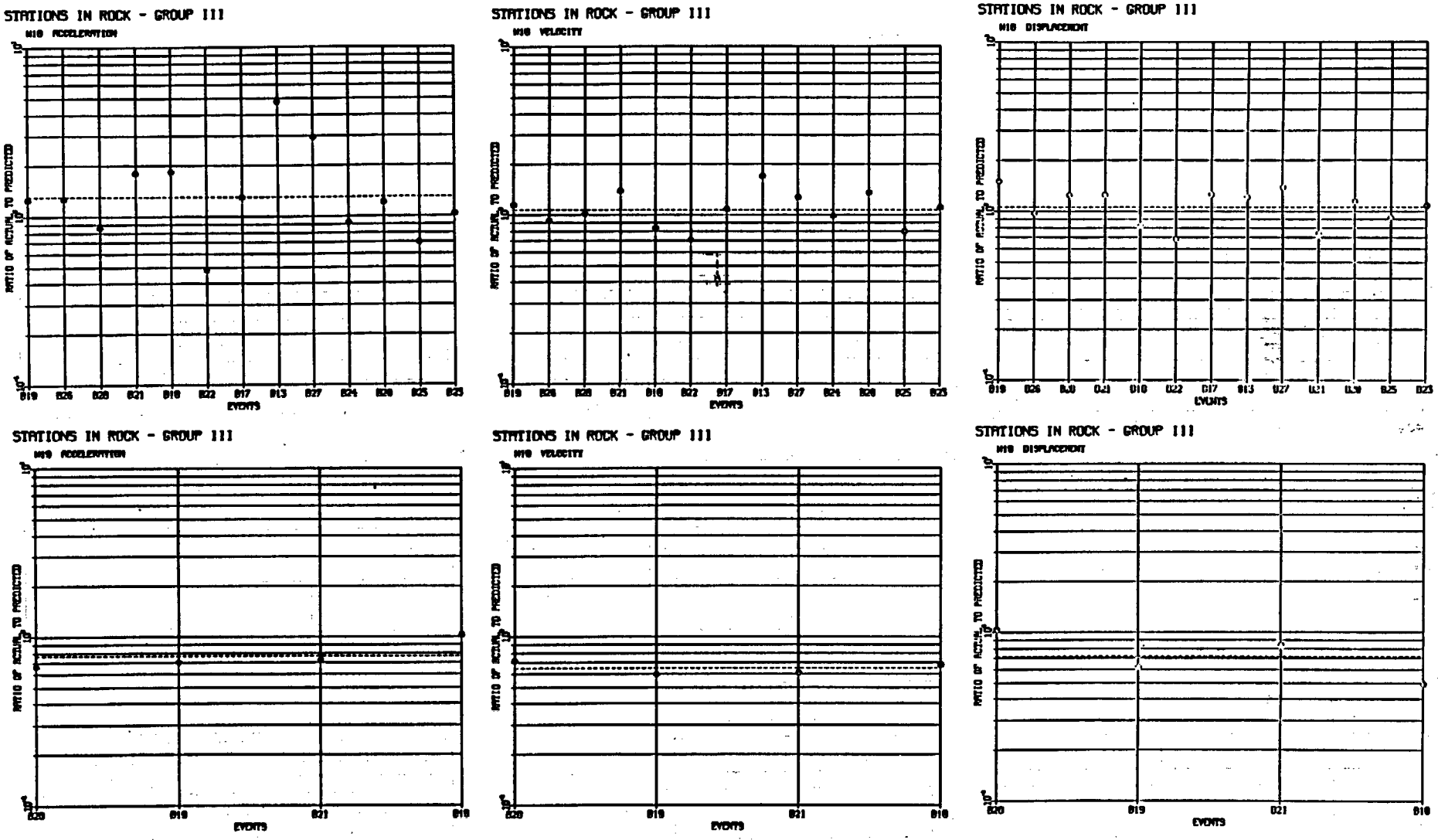

STATIONS IN ROCK - GROUP III
H10 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
H10 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
H10 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
H10 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
H10 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
H10 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure F-7

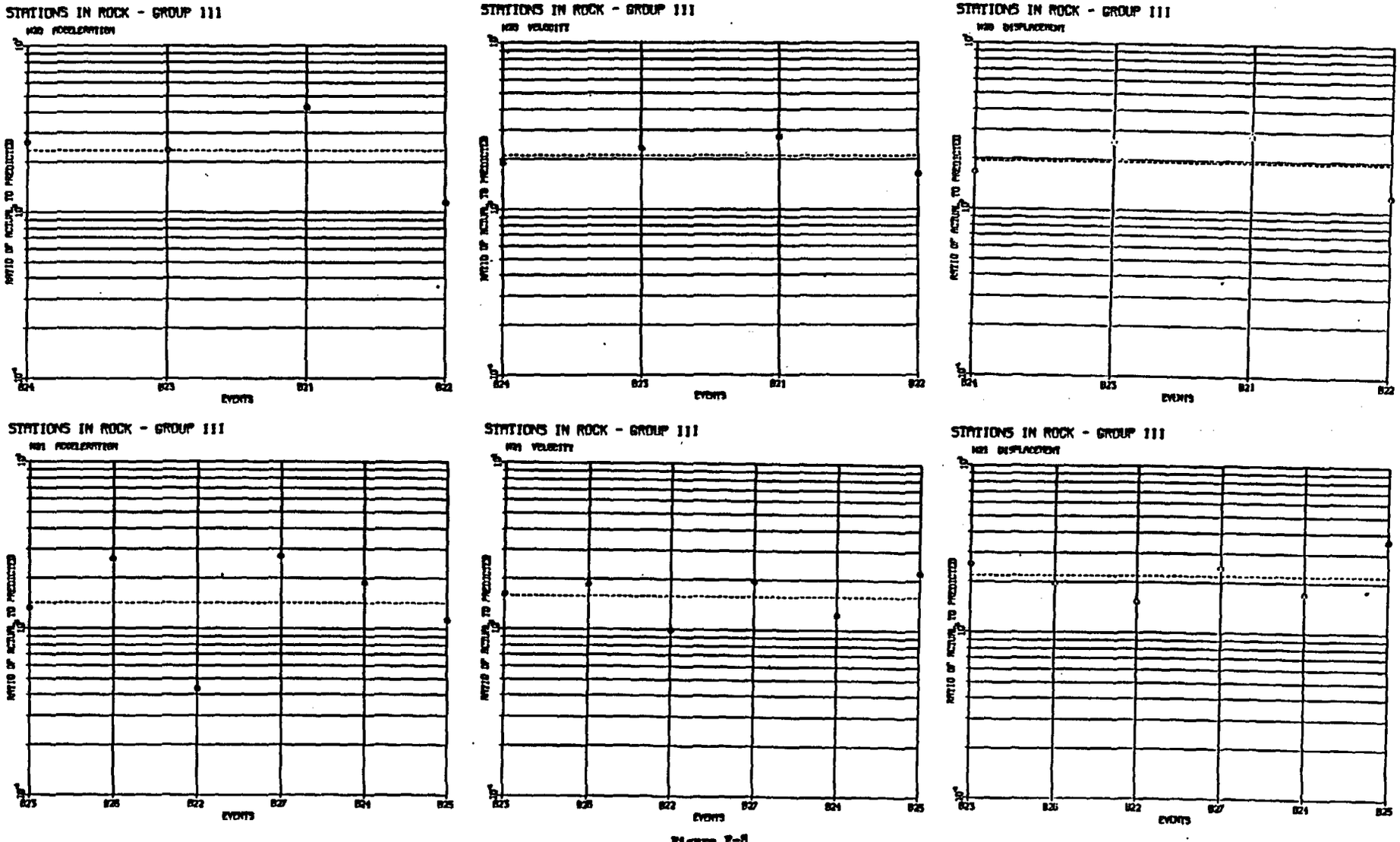

STATIONS IN ROCK - GROUP III
H20 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
H20 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
H20 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
H21 ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
H21 VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ROCK - GROUP III
H21 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure F-8

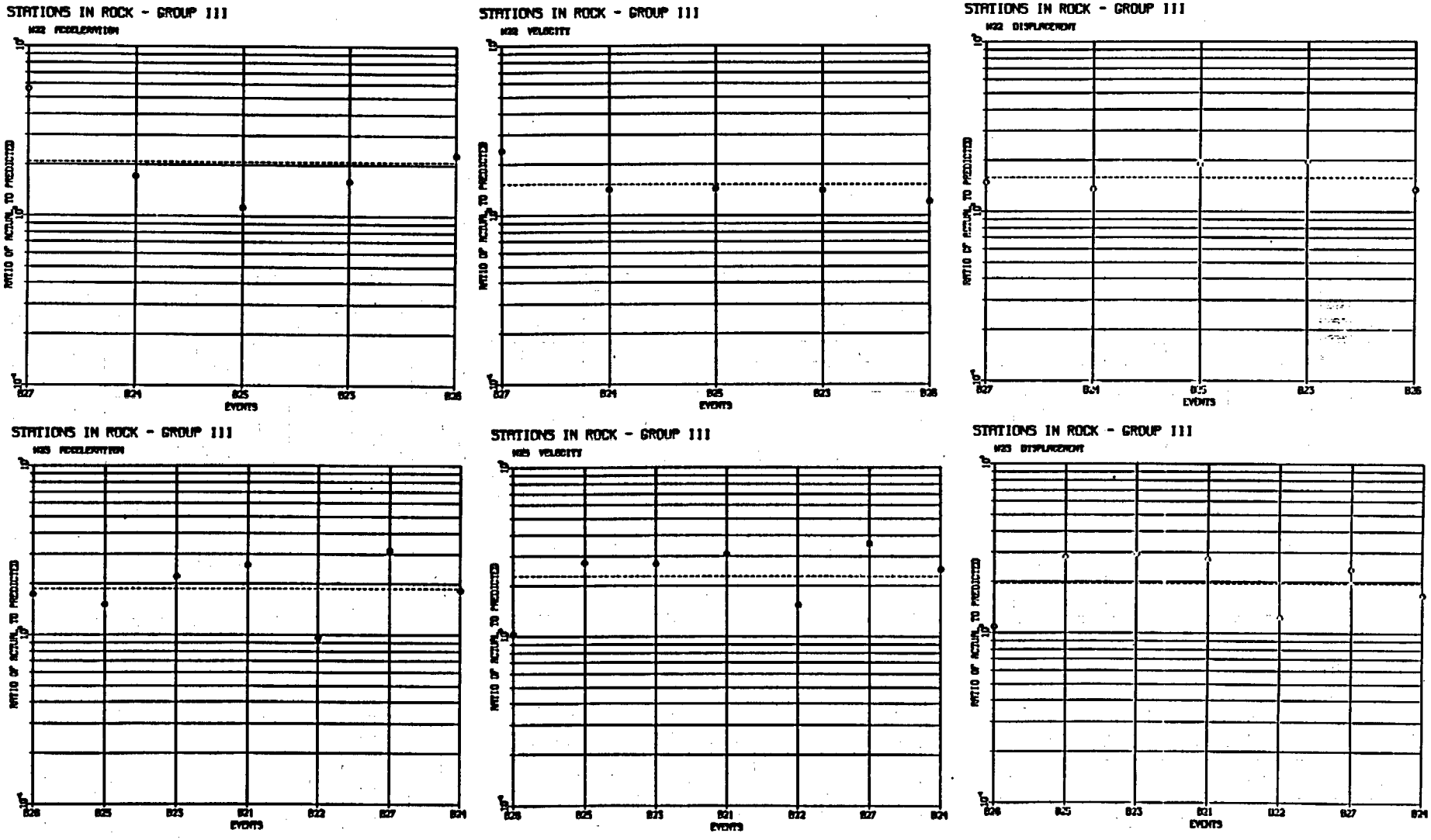

STATIONS IN ROCK - GROUP III
N22 ACCELERATION
N22 VELOCITY
N22 DISPLACEMENT
N25 ACCELERATION
N25 VELOCITY
N25 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure F-9

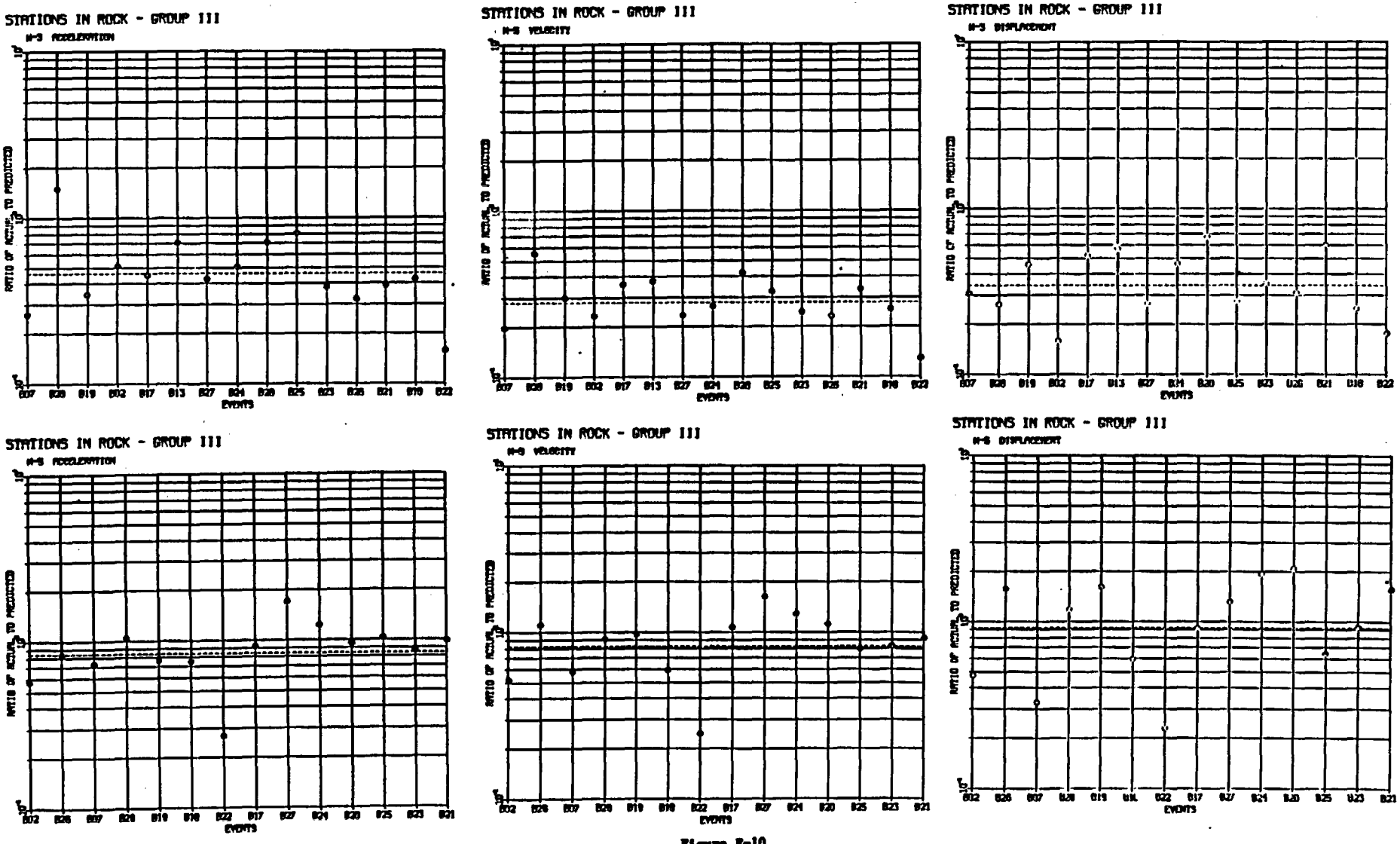

STATIONS IN ROCK - GROUP III
N-S ACCELERATION
STATIONS IN ROCK - GROUP III
N-S VELOCITY
STATIONS IN ROCK - GROUP III
N-S DISPLACEMENT
STATIONS IN ROCK - GROUP III
N-S ACCELERATION
STATIONS IN ROCK - GROUP III
N-S VELOCITY
STATIONS IN ROCK - GROUP III
N-S DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure F-10

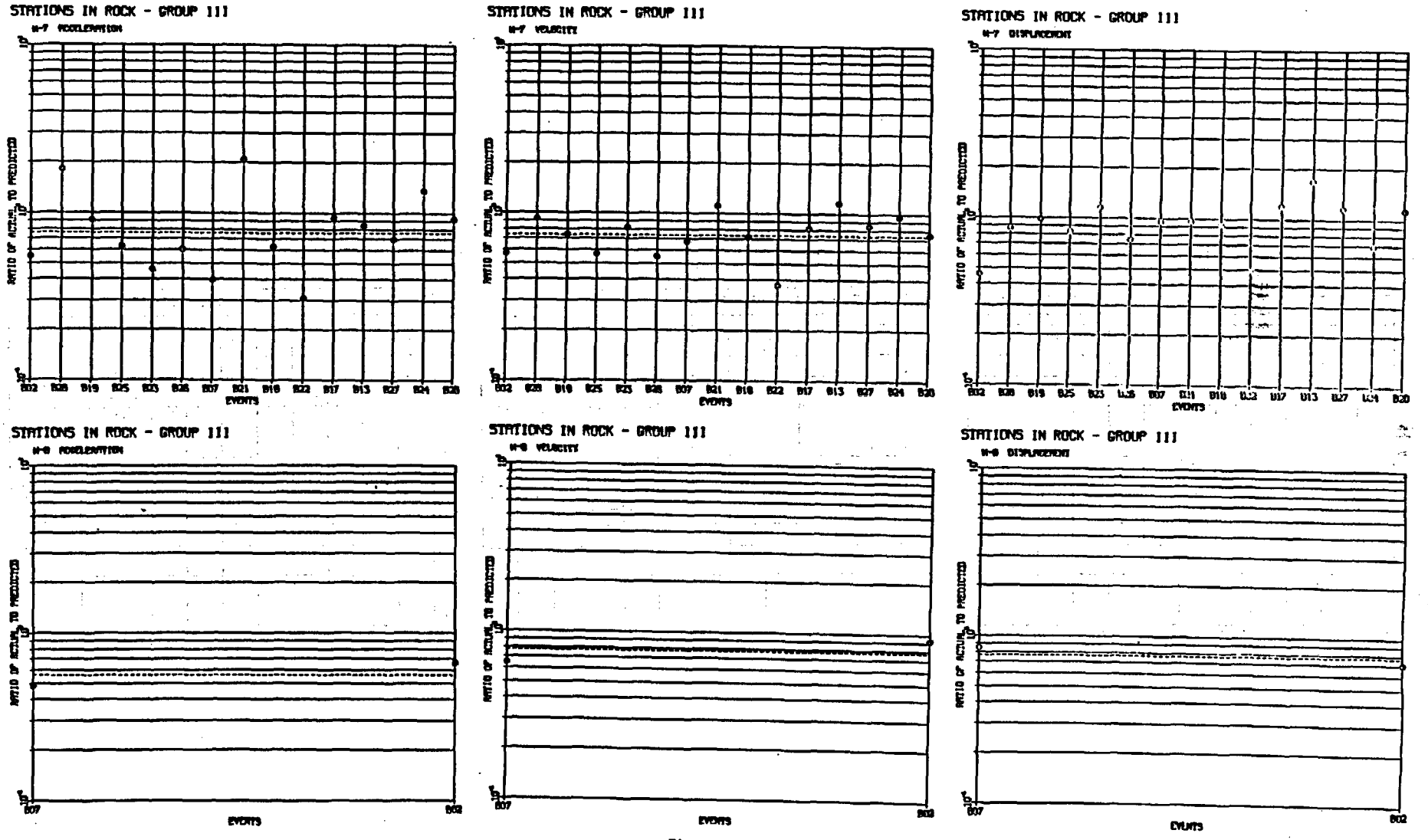
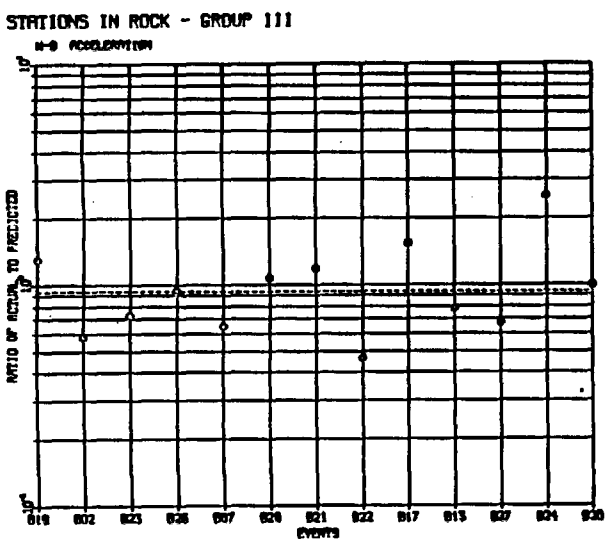
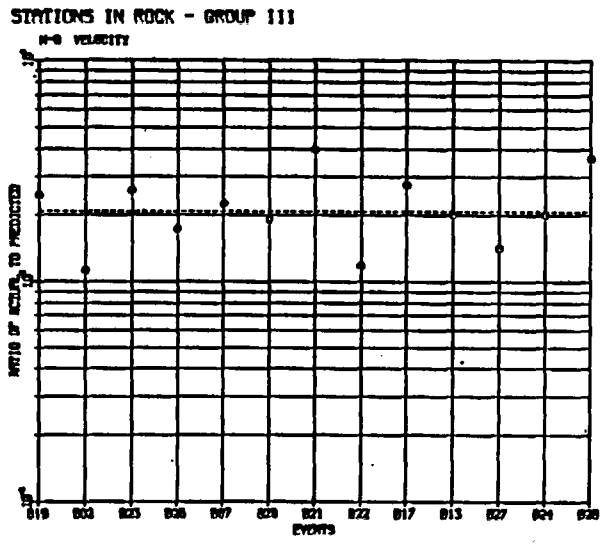

STATIONS IN ROCK - GROUP III
N-7 ACCELERATION
STATIONS IN ROCK - GROUP III
N-7 VELOCITY
STATIONS IN ROCK - GROUP III
N-7 DISPLACEMENT
STATIONS IN ROCK - GROUP III
N-8 ACCELERATION
STATIONS IN ROCK - GROUP III
N-8 VELOCITY
STATIONS IN ROCK - GROUP III
N-8 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure F-11


STATIONS IN ROCK - GROUP III
N-S ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS


STATIONS IN ROCK - GROUP III
N-S VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS

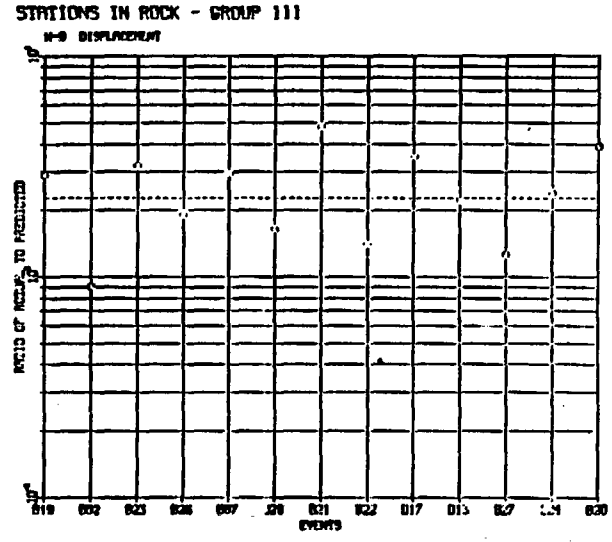

STATIONS IN ROCK - GROUP III
N-S DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure F-12

Appendix G

Ratios for Alluvium for Group I

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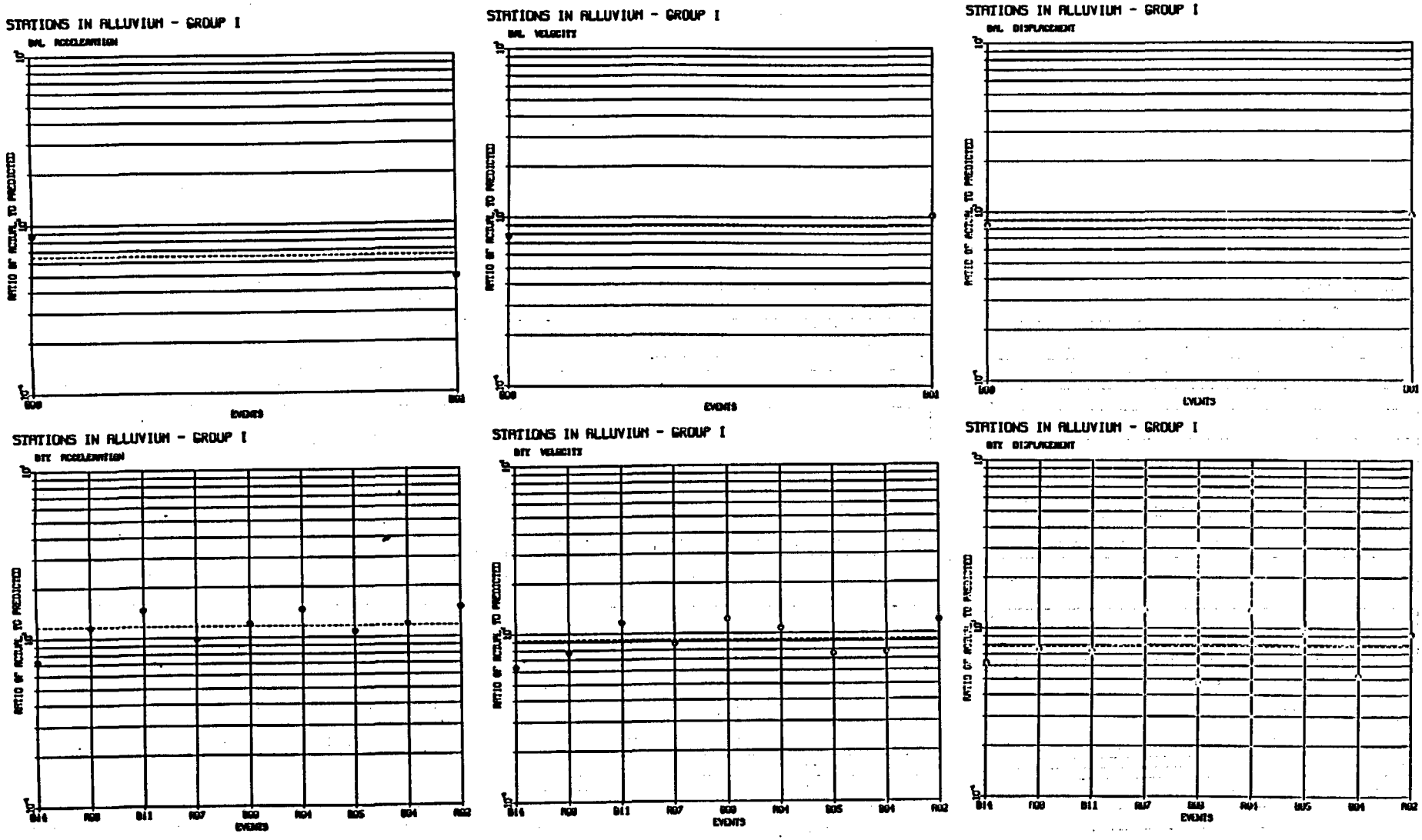
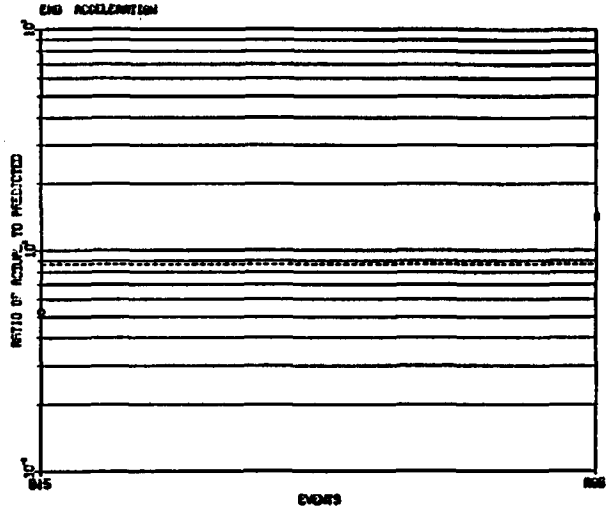
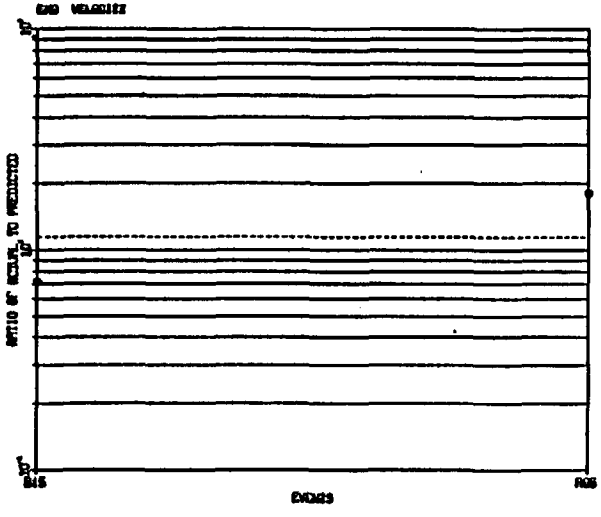

STATIONS IN ALLUVIUM - GROUP I
BAL ACCELERATION
STATIONS IN ALLUVIUM - GROUP I
BAL VELOCITY
STATIONS IN ALLUVIUM - GROUP I
BAL DISPLACEMENT
STATIONS IN ALLUVIUM - GROUP I
BIT ACCELERATION
STATIONS IN ALLUVIUM - GROUP I
BIT VELOCITY
STATIONS IN ALLUVIUM - GROUP I
BIT DISPLACEMENT
EVENTS

Figure G-1

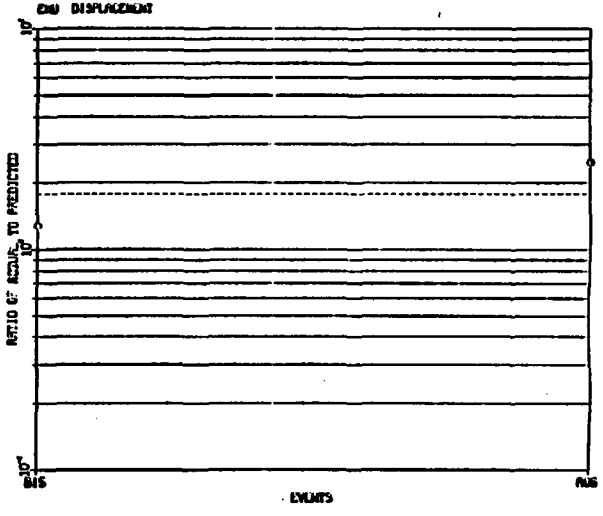
STATIONS IN ALLUVIUM - GROUP I



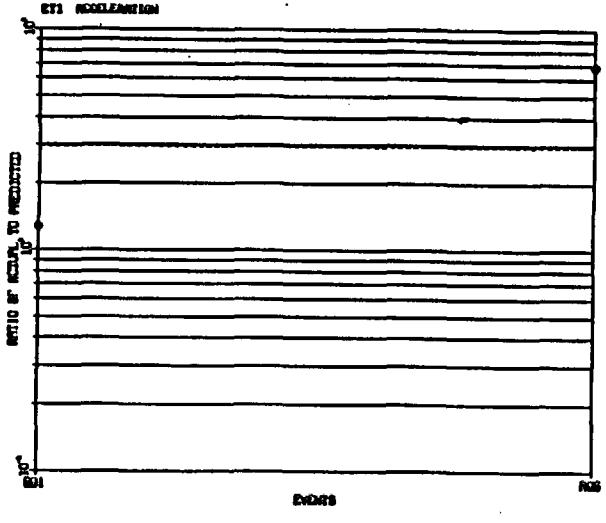
STATIONS IN ALLUVIUM - GROUP I



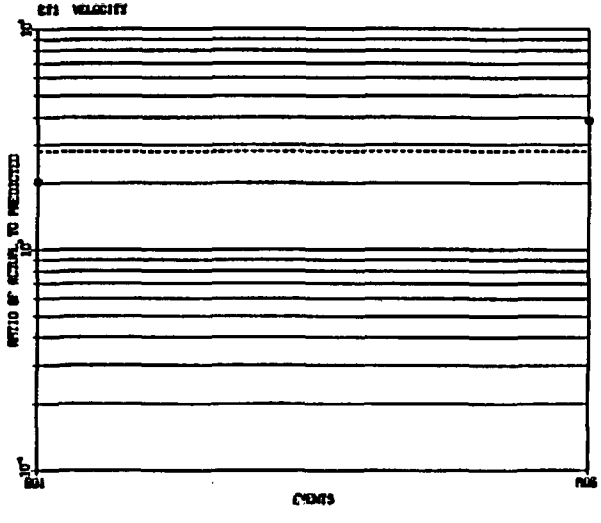
STATIONS IN ALLUVIUM - GROUP I



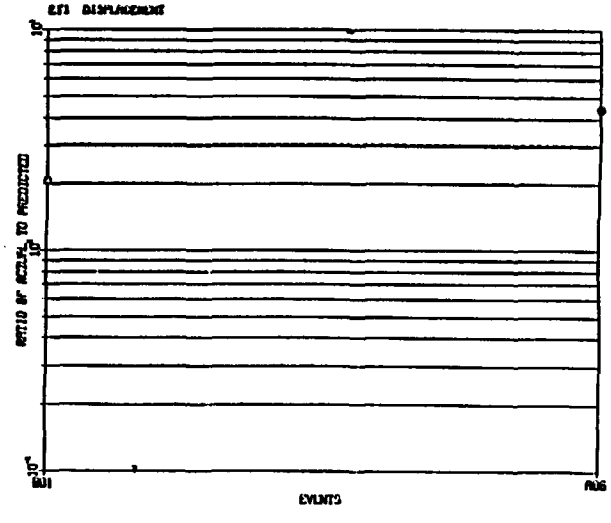
STATIONS IN ALLUVIUM - GROUP I



STATIONS IN ALLUVIUM - GROUP I



STATIONS IN ALLUVIUM - GROUP I



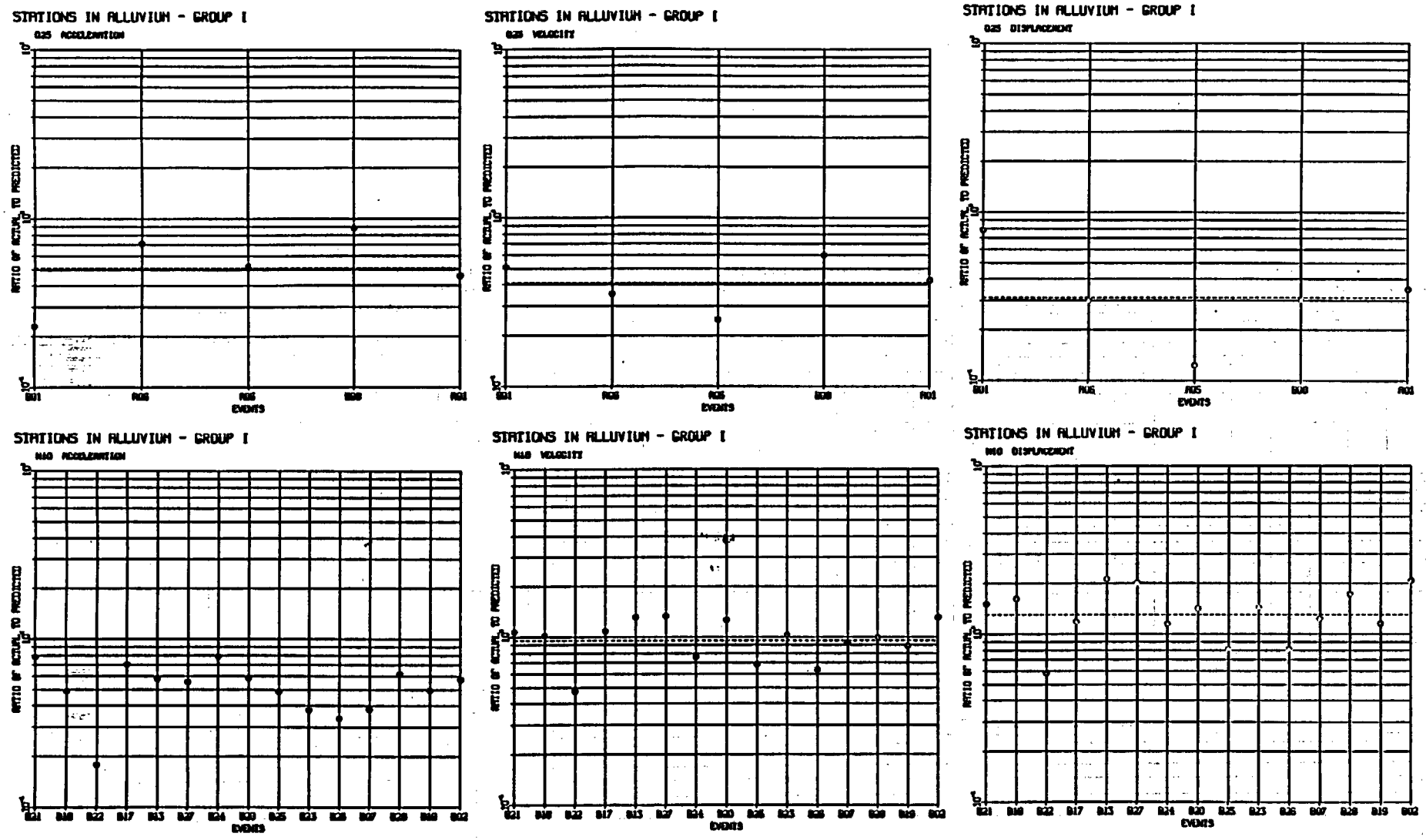

STATIONS IN ALLUVIUM - GROUP I
025 ACCELERATION
STATIONS IN ALLUVIUM - GROUP I
025 VELOCITY
STATIONS IN ALLUVIUM - GROUP I
025 DISPLACEMENT
STATIONS IN ALLUVIUM - GROUP I
NAO ACCELERATION
STATIONS IN ALLUVIUM - GROUP I
NAO VELOCITY
STATIONS IN ALLUVIUM - GROUP I
NAO DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure C-3

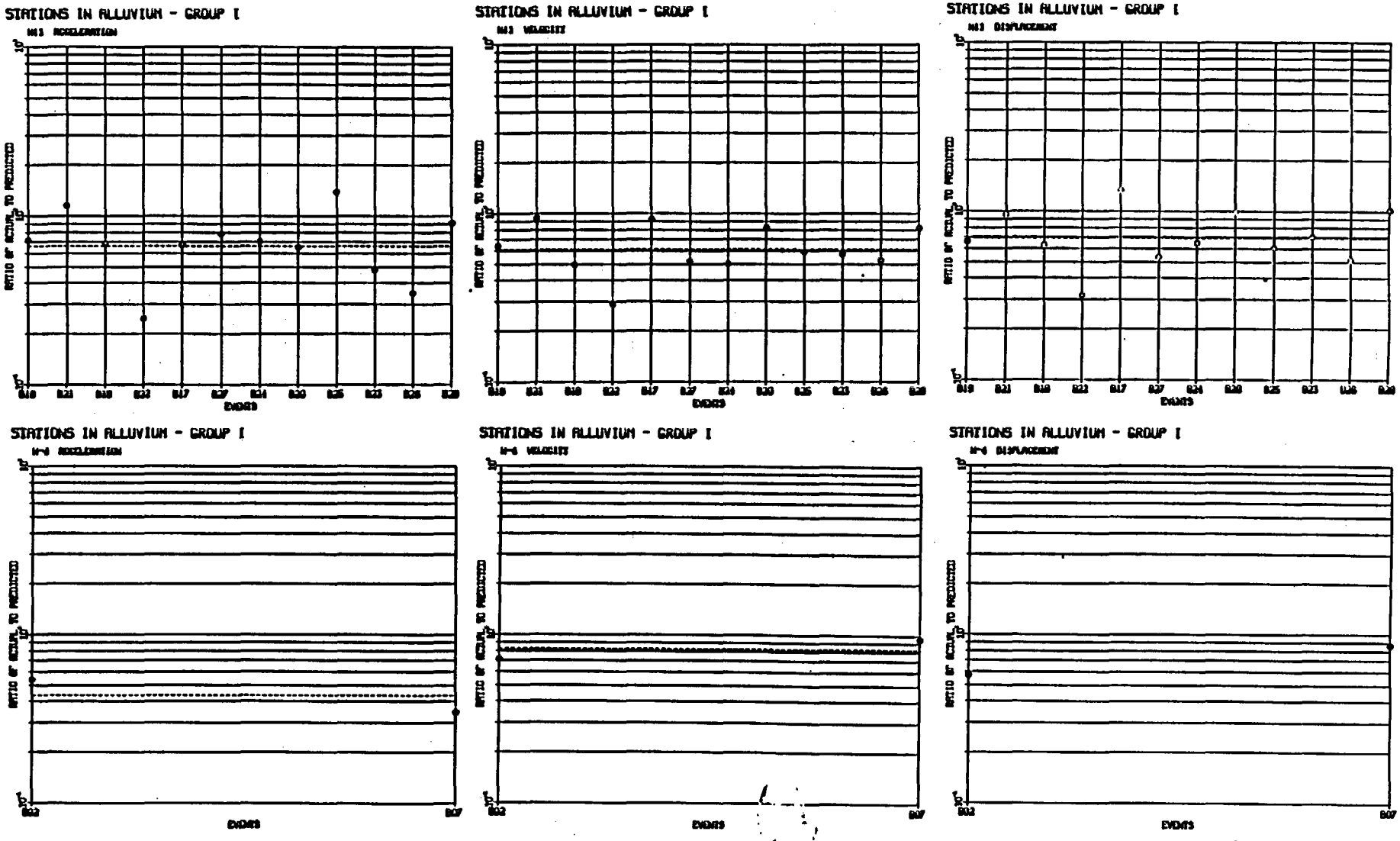

STATIONS IN ALLUVIUM - GROUP I
STATIONS IN ALLUVIUM - GROUP I
STATIONS IN ALLUVIUM - GROUP I
STATIONS IN ALLUVIUM - GROUP I
STATIONS IN ALLUVIUM - GROUP I
STATIONS IN ALLUVIUM - GROUP I

Figure G-4

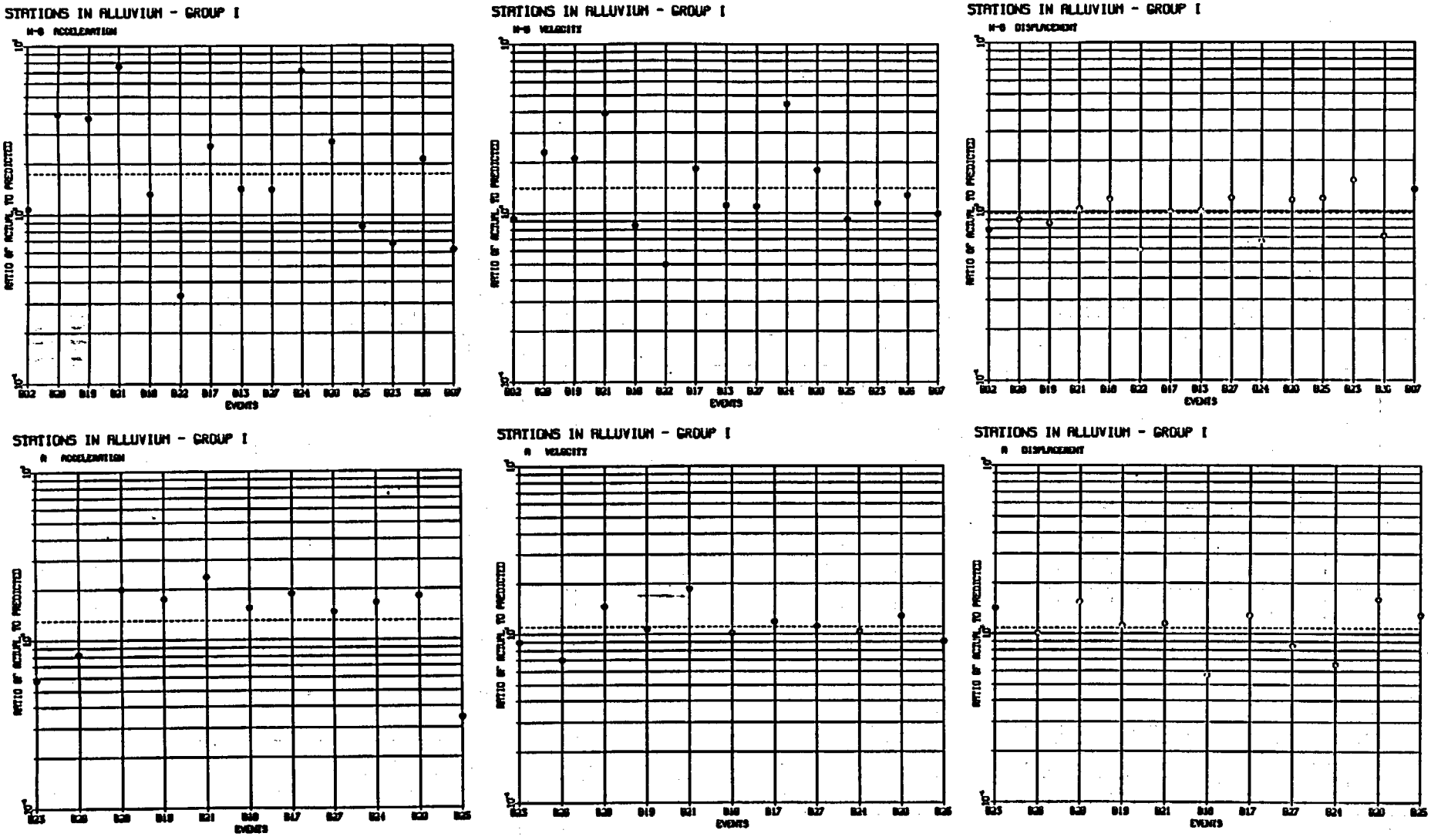

STATIONS IN ALLUVIUM - GROUP I
N-S ACCELERATION
STATIONS IN ALLUVIUM - GROUP I
N-S VELOCITY
STATIONS IN ALLUVIUM - GROUP I
N-S DISPLACEMENT
STATIONS IN ALLUVIUM - GROUP I
A ACCELERATION
STATIONS IN ALLUVIUM - GROUP I
A VELOCITY
STATIONS IN ALLUVIUM - GROUP I
A DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure C-5

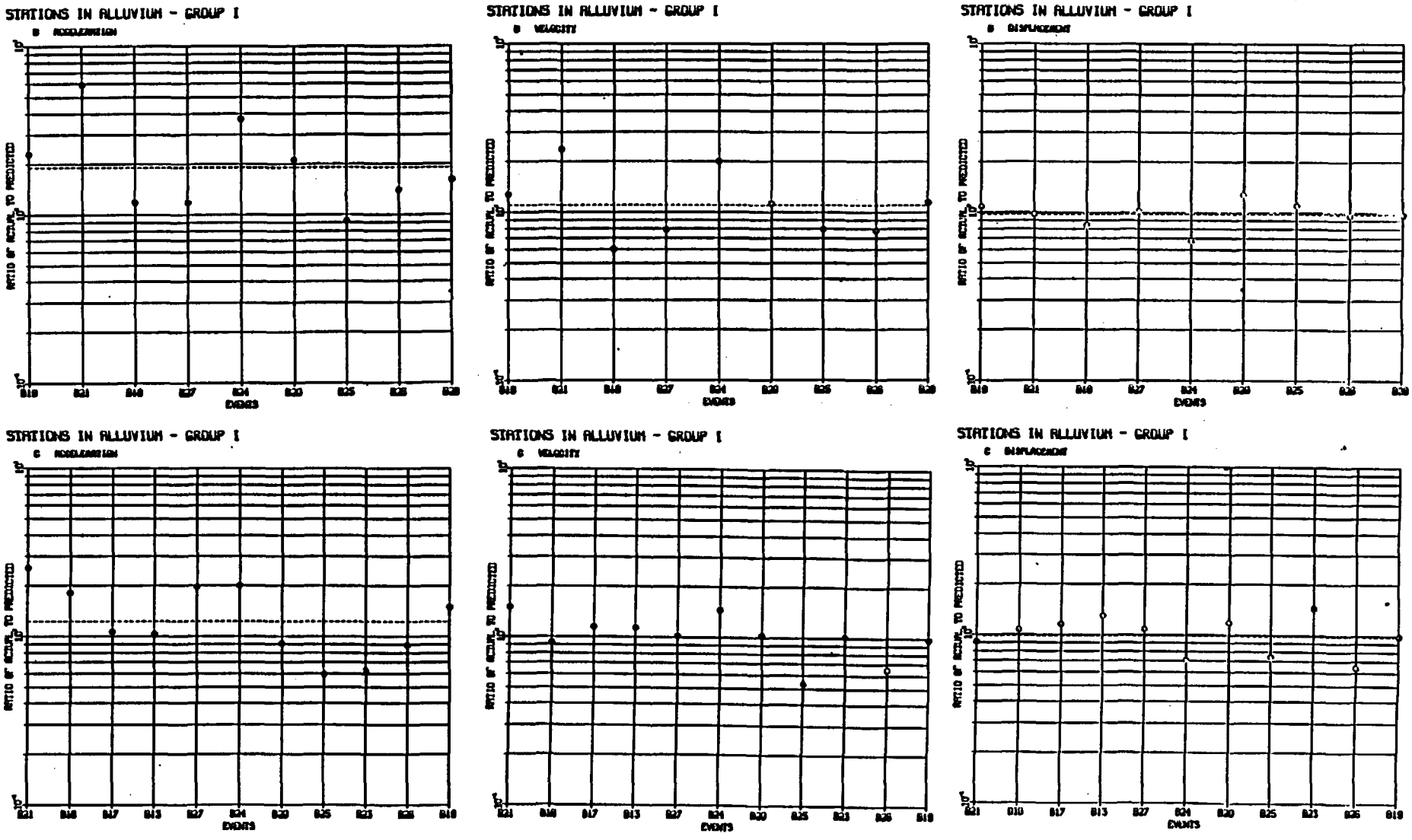
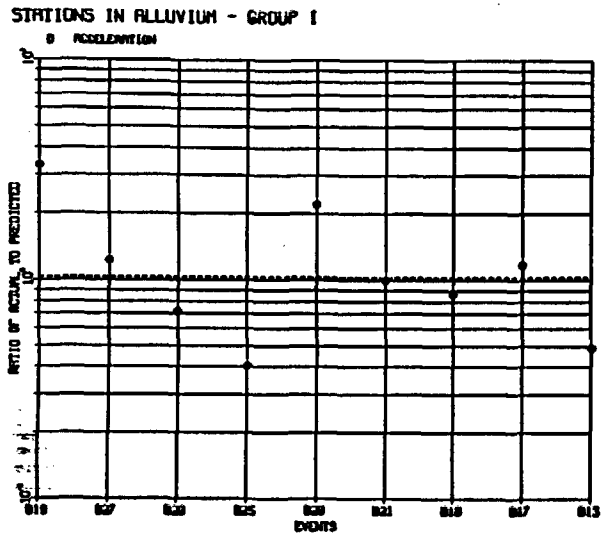
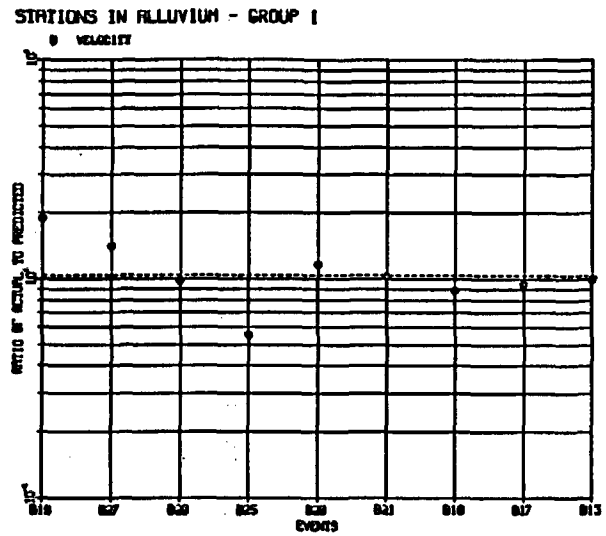

STATIONS IN ALLUVIUM - GROUP I
B ACCELERATION
STATIONS IN ALLUVIUM - GROUP I
B VELOCITY
STATIONS IN ALLUVIUM - GROUP I
B DISPLACEMENT
STATIONS IN ALLUVIUM - GROUP I
C ACCELERATION
STATIONS IN ALLUVIUM - GROUP I
C VELOCITY
STATIONS IN ALLUVIUM - GROUP I
C DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure G-6


STATIONS IN ALLUVIUM - GROUP I
ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS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VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS

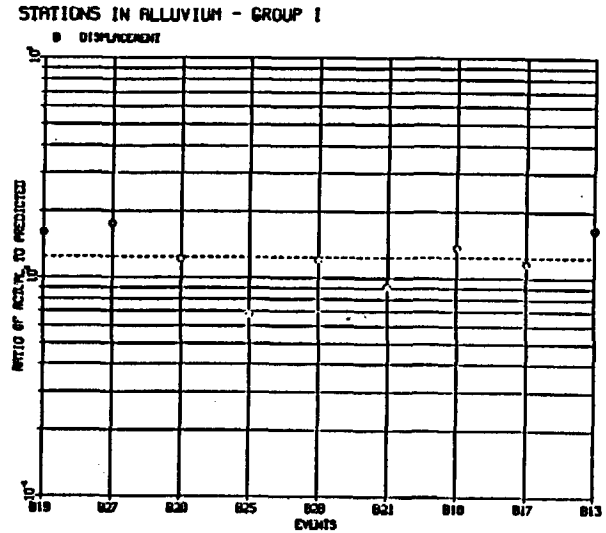
STATIONS IN ALLUVIUM - GROUP I
DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure G-7

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Appendix H

Ratios for Alluvium for Groups II and III

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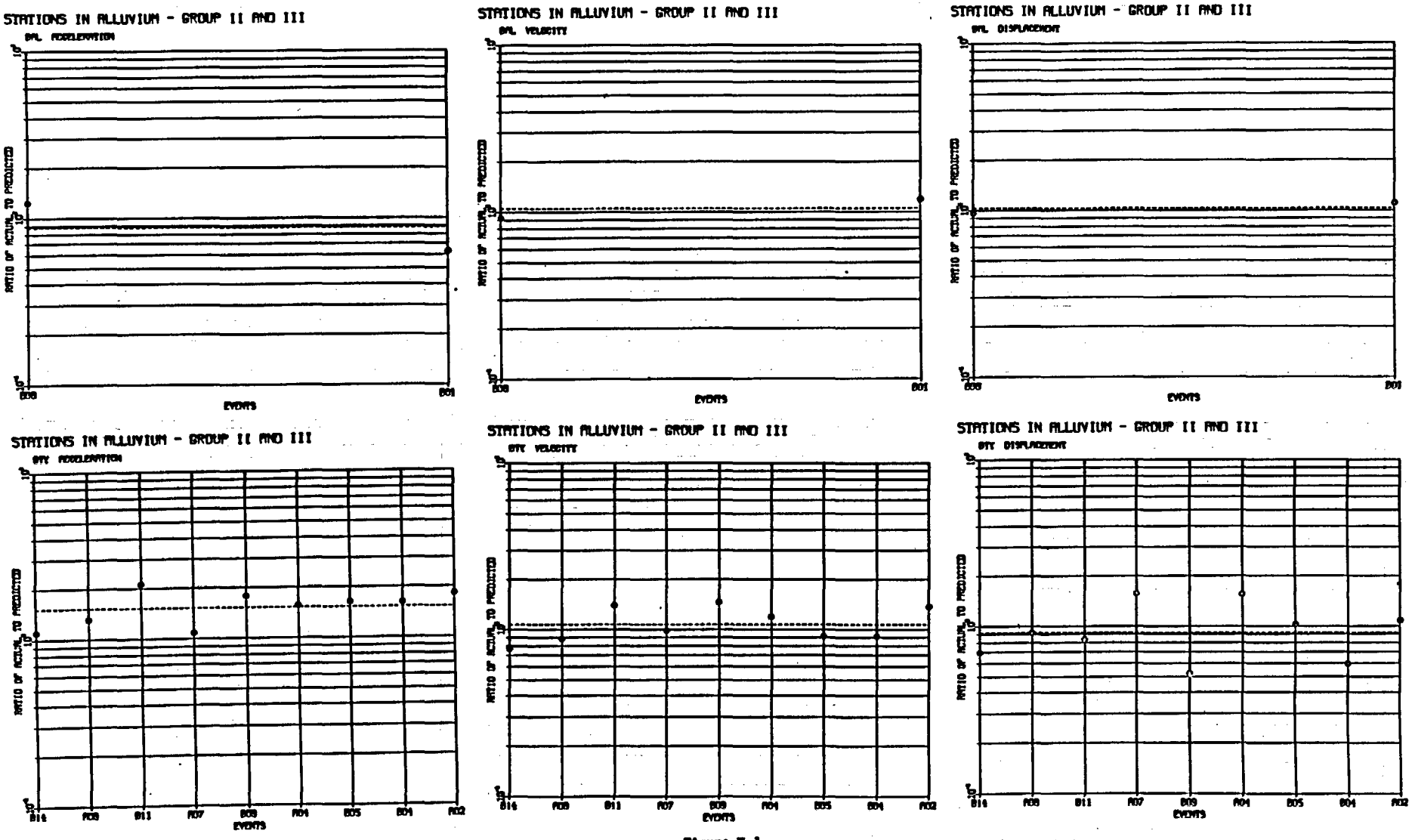
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BAL ACCELERATION
BAL VELOCITY
BAL DISPLACEMENT
BTY ACCELERATION
BTY VELOCITY
BTY DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
B08
B01
B14
A08
B11
A07
B09
A04
B05
B04
A02

Figure H-1

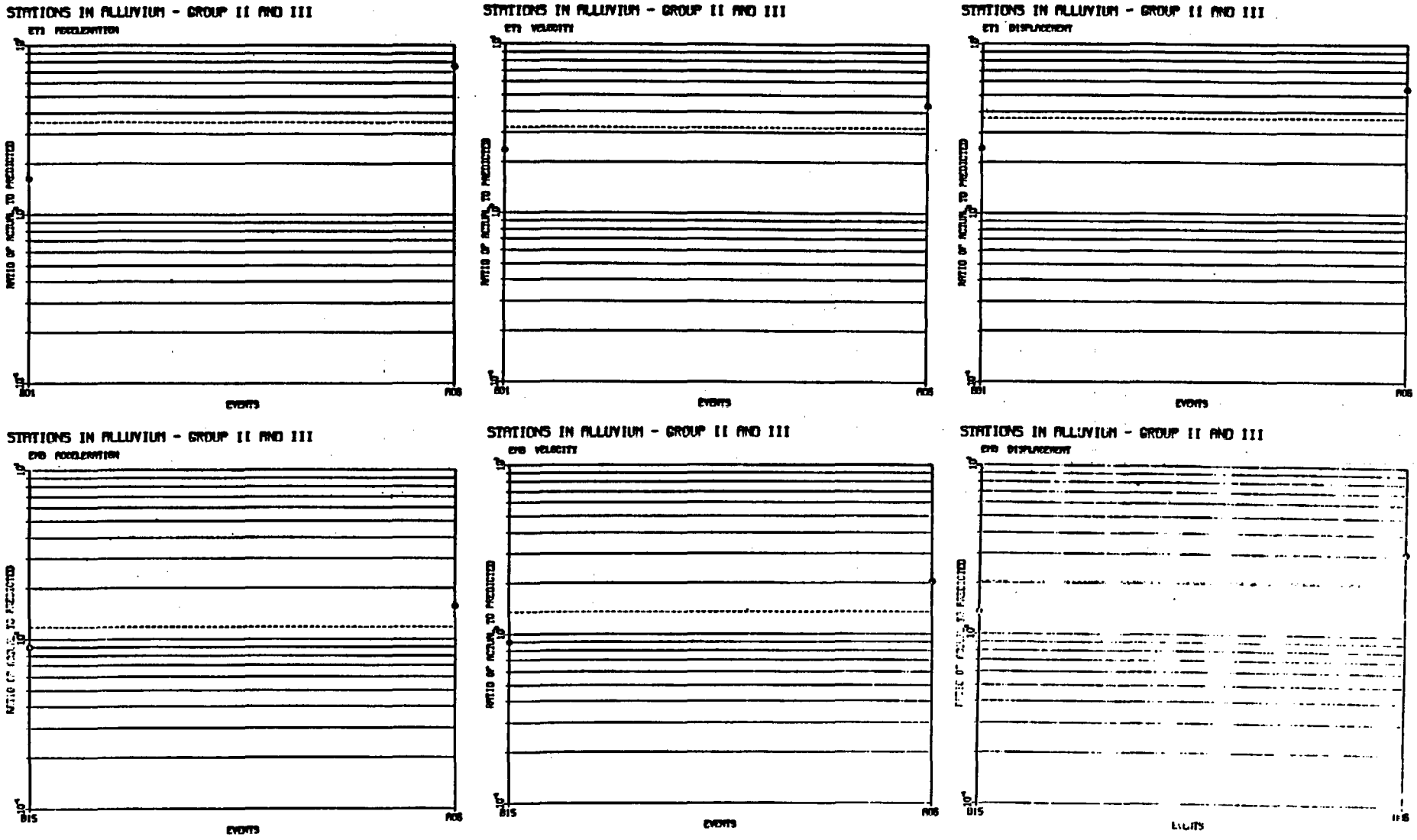

STATIONS IN ALLUVIUM - GROUP II AND III
ETI ACCELERATION
STATIONS IN ALLUVIUM - GROUP II AND III
ETI VELOCITY
STATIONS IN ALLUVIUM - GROUP II AND III
ETI DISPLACEMENT
STATIONS IN ALLUVIUM - GROUP II AND III
EYB ACCELERATION
STATIONS IN ALLUVIUM - GROUP II AND III
EYB VELOCITY
STATIONS IN ALLUVIUM - GROUP II AND III
EYB DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
B01
A06
B15

Figure H-2

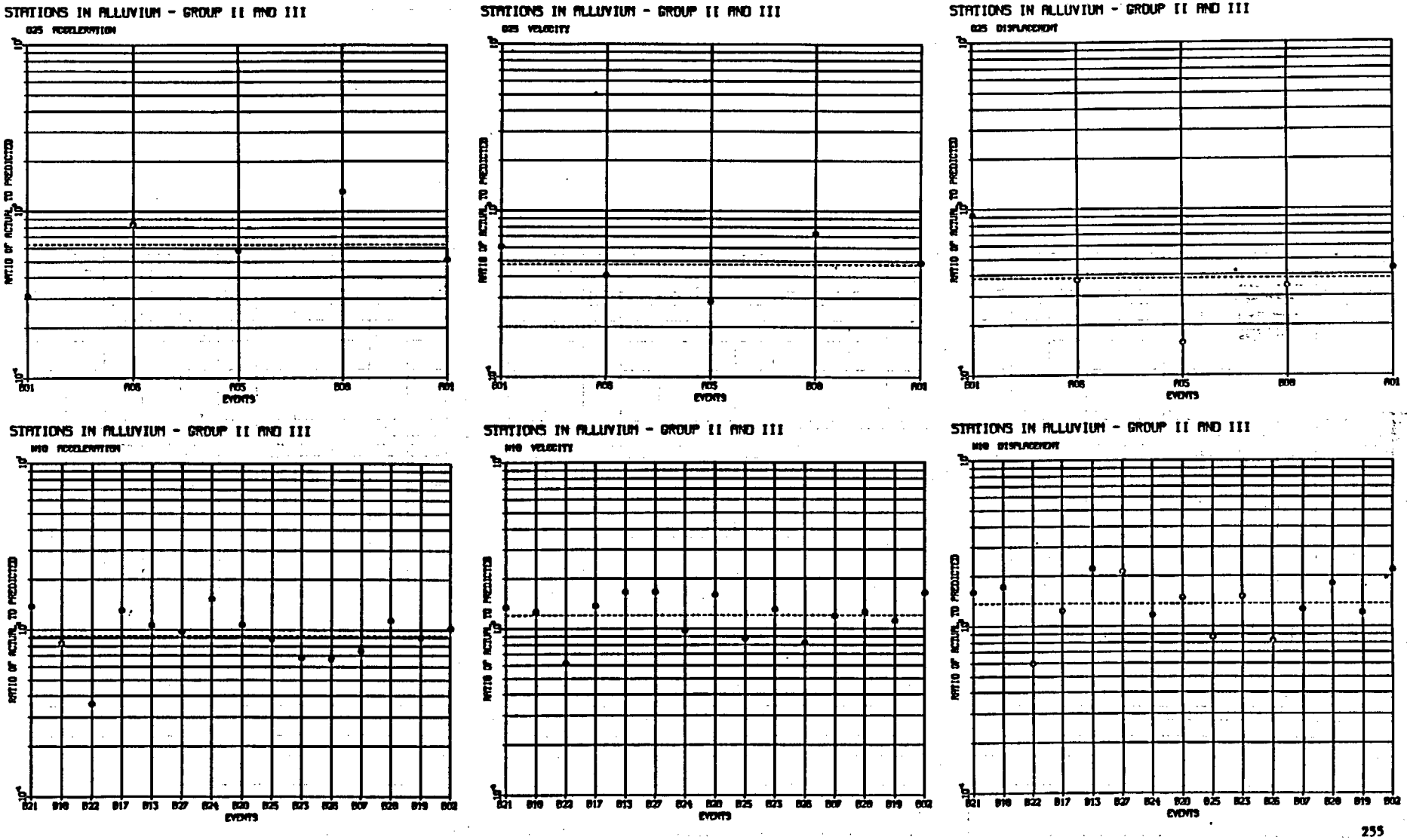

STATIONS IN ALLUVIUM - GROUP II AND III
025 ACCELERATION
025 VELOCITY
025 DISPLACEMENT
M10 ACCELERATION
M10 VELOCITY
M10 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
B01 A06 A05 B08 A01
B21 B10 B22 B17 B13 B27 B24 B20 B25 B23 B26 B07 B28 B19 B02

Figure A-3

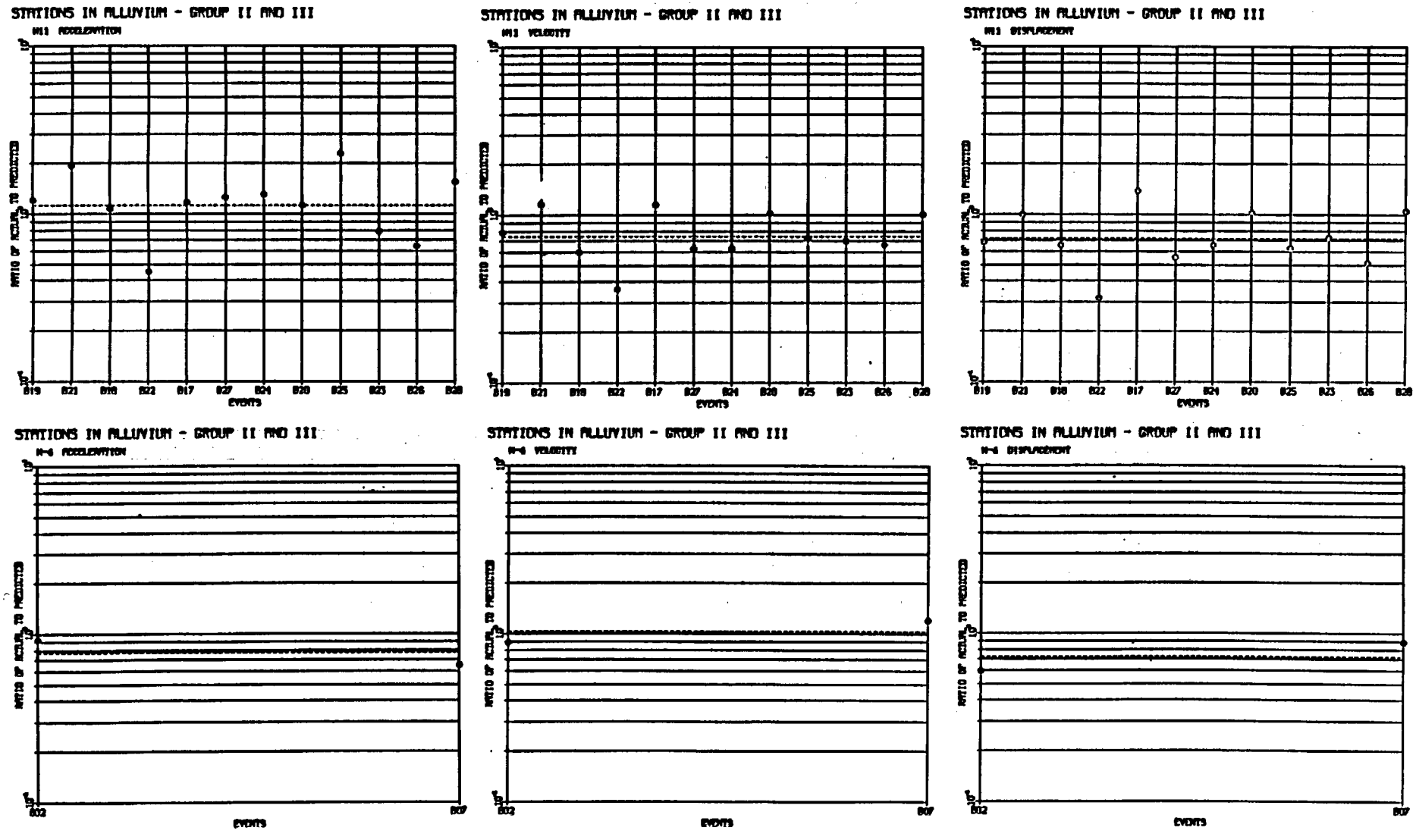

STATIONS IN ALLUVIUM - GROUP II AND III
M1 ACCELERATION
M1 VELOCITY
M1 DISPLACEMENT
M-4 ACCELERATION
M-4 VELOCITY
M-4 DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
B19 B21 B18 B22 B17 B27 B24 B20 B25 B23 B26 B28
B02 B07

Figure A-4

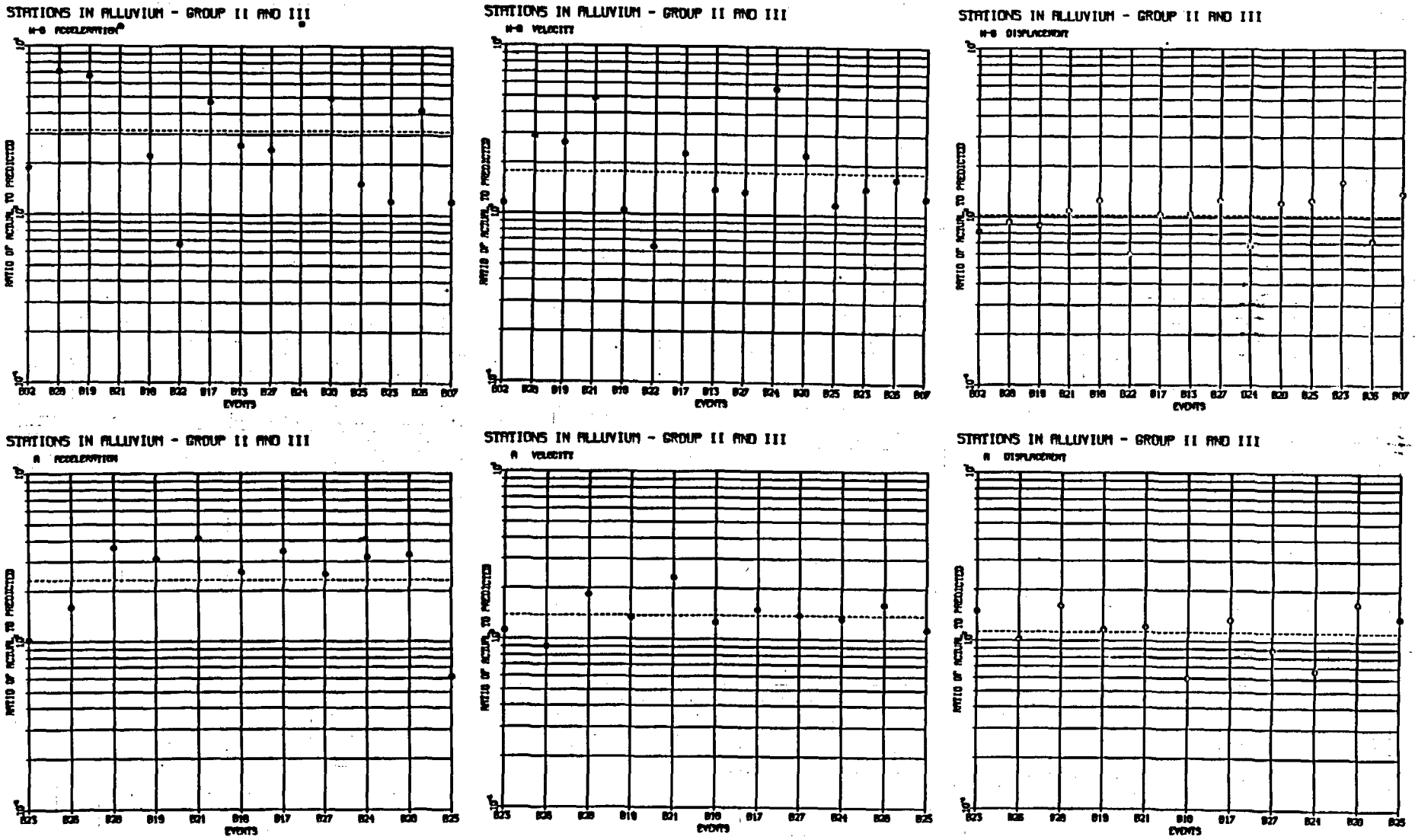

STATIONS IN ALLUVIUM - GROUP II AND III
H-G ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ALLUVIUM - GROUP II AND III
H-G VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ALLUVIUM - GROUP II AND III
H-G DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ALLUVIUM - GROUP II AND III
A ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ALLUVIUM - GROUP II AND III
A VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
STATIONS IN ALLUVIUM - GROUP II AND III
A DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure A-5

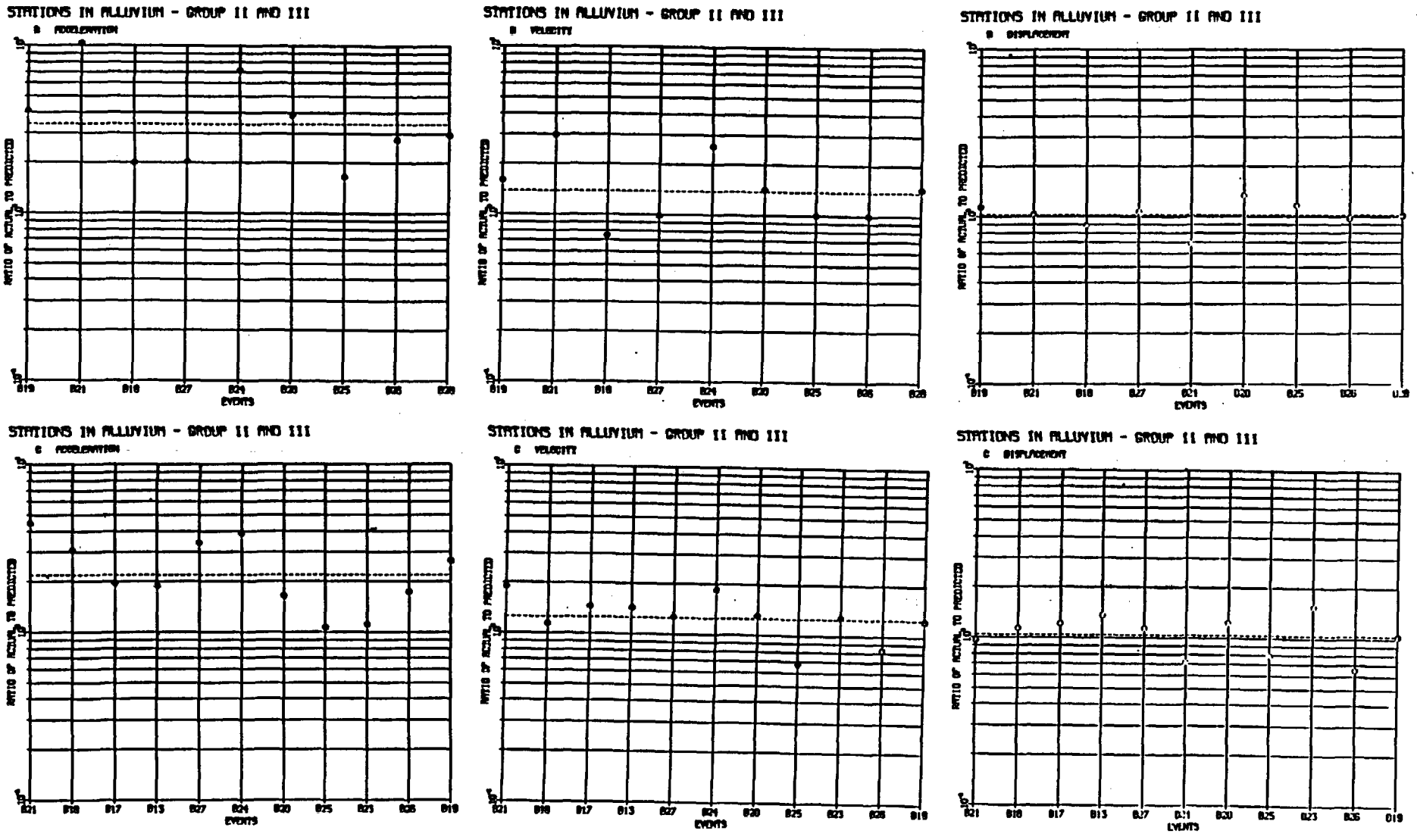
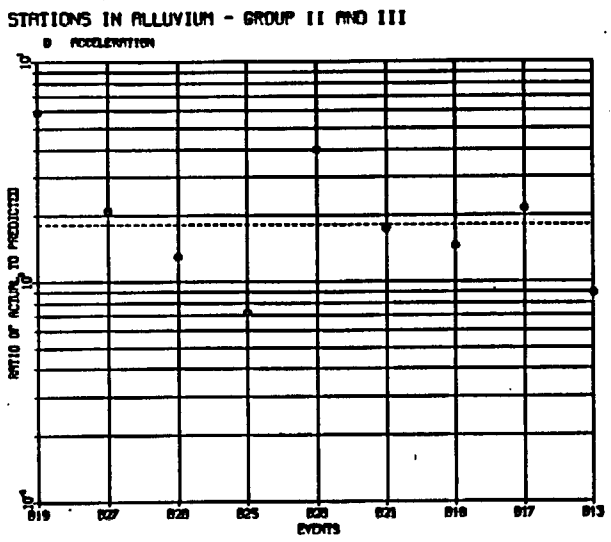
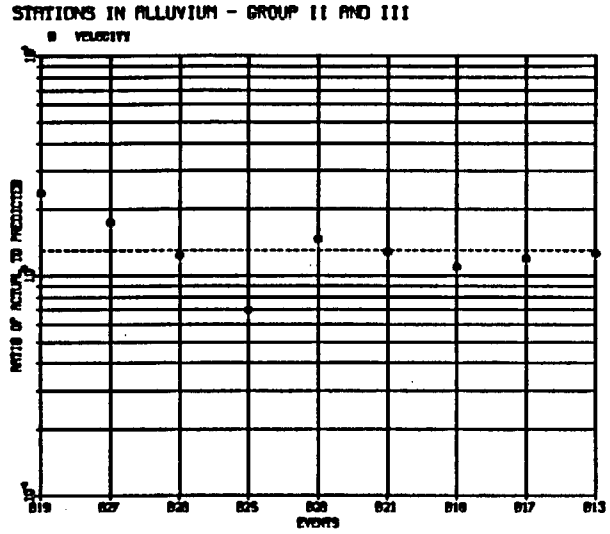

STATIONS IN ALLUVIUM - GROUP II AND III
B ACCELERATION
B VELOCITY
B DISPLACEMENT
C ACCELERATION
C VELOCITY
C DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS

Figure A-6


STATIONS IN ALLUVIUM - GROUP II AND III
ACCELERATION
RATIO OF ACTUAL TO PREDICTED
EVENTS
B19
B27
B20
B25
B28
B21
B10
B17
B13


STATIONS IN ALLUVIUM - GROUP II AND III
VELOCITY
RATIO OF ACTUAL TO PREDICTED
EVENTS
B19
B27
B20
B25
B28
B21
B10
B17
B13

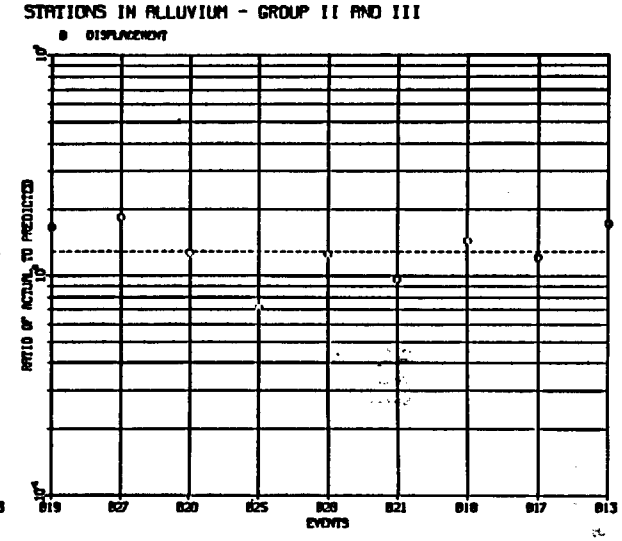

STATIONS IN ALLUVIUM - GROUP II AND III
DISPLACEMENT
RATIO OF ACTUAL TO PREDICTED
EVENTS
B19
B27
B20
B25
B28
B21
B10
B17
B13

Figure R-7

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